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ENCYCLOPEDIA OF EXPLOSIVES
AND
RELATED ITEMS

PATR 2700
VOLUME 1

BY
BASIL T. FEDOROFF
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ASSISTED BY
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U.S. ARMY RESEARCH AND DEVELOPMENT COMMAND
TACOM, ARDEC
WARHEADS, ENERGETICS AND COMBAT SUPPORT CENTER
PICATINNY ARSENAL
NEW JERSEY, USA
1960
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PREFACE

The widespread interest in explosives during and since World War II has resulted in the need for a comprehensive coverage of the field of explosives and related items. In 1941-1944, Dr B. T. Fedoroff in collaboration with G. D. Clift had published a "Laboratory Manual of Explosives" in four small volumes (Lefax Co), for which there were numerous requests. Since the printed editions had been exhausted and the plates were no longer available, Dr Fedoroff decided to write a revised edition. As the work progressed, it became evident that additional help would be needed, not only because of the tremendous expansion of the literature, but also because it was decided to broaden the scope of the work.

This Encyclopedia is intended to cover the following items: a) Military and industrial explosives, explosive compositions, propellants and pyrotechnic compositions b) Explosives and explosive compositions which have not been used for military or industrial purposes c) Analytical procedures for the more common explosives, propellants and pyrotechnic compositions d) Compounds which deflagrate or may possibly explode because of the presence of plosophoric groups e) Ammunition items, such as projectiles, bombs, grenades, detonators, fuzes, etc f) Calibers of weapons and projectiles used in the US and foreign countries g) Brief definitions of ordnance terms h) Names of scientists who made important contributions in the fields of explosives, ammunition and weapons

Over the years a number of works, including dictionaries, have been published in the field of explosives, propellants, etc, which are of general or limited scope. None of these has attempted to include in one work a comprehensive coverage of the broad field of items listed above.

The authors hope that this Encyclopedia will be of value not only in saving many hours of library work but also in reducing the need for much laboratory work in order to obtain information already available. It is hoped that some of the data and even lack of data may stimulate additional work in the fields covered.

In compiling this work, the authors have freely consulted with, and had the cooperation of so many individuals that a listing would be impractical. Any attempt to do so would surely result in some embarrassing omissions. We therefore take this opportunity to thank all those who have been consulted or who have helped in other ways in the preparation of this work. Throughout the Encyclopedia information received from individuals is acknowledged in the text. Picatinny Arsenal Technical Information (Library) reference works, such as journals, periodicals, books and unclassified reports, were made available through the cooperation of all Library personnel. The complete copy of this manuscript was Vari-typed by Miss Margaret Dee, Mrs Sylvia Griffin and Mrs Bertha Kelly with the cooperation of Mr Joseph Farkas & Mr John Noonan, whom we consulted freely (all of the Technical Publications Unit, Feltman Research and Engineering Laboratories). Special acknowledgement is due to the officials (both military and civilian) of Picatinny Arsenal for encouraging this work and for obtaining its financial support.

Although considerable effort has been made to present this information as accurately as possible, mistakes and errors in transcription do occur. The interpretations of data and opinions expressed are the responsibility of the authors and are not necessarily those of the Department of the Army or of Picatinny Arsenal. This report has been prepared for information purposes only and the Department of the Army or Picatinny Arsenal shall not be responsible for any events or decisions arising from the use of this information.
INTRODUCTION

The user of this Encyclopedia is urged to read this Introduction to obtain an understanding of the authors' way of treating and covering the subject matter. Because of the broad scope of the work and the vast amount of material available, discussions of most items are brief. Theoretical and physico-chemical aspects, except for a few constants, are usually covered by the references. Items of distinct military or commercial importance are discussed in more detail. References to all sources of data, as well as references for broader coverage, are given following each item. No claim is made to complete coverage, but the authors believe that, in general, few pertinent references have been omitted.

No attempt has been made to cover the large volume of material included in classified reports and no information from such reports has been used. However, for the benefit of those who have the right of access to classified information, some references to these sources may be given. Army regulations declassifying most of the classified reports originating before January 1, 1946, were not issued in time to permit review of the large number of these reports for information which would have been included under the letter A and covered in this first volume. Subsequent volumes may include subject matter from these declassified reports. In some cases, reports listed here as classified, may subsequently have been declassified.

As was mentioned in the preface we have listed not only compounds which have been reported as explosive, but also compounds which have been or may be prepared and which, because of the presence of plosophoric groups, may possibly be explosive. This has been done because, unfortunately, many workers who have prepared compounds which may be explosive, have not made tests for explosibility. Many substances ordinarily not considered explosive, have exploded accidentally or been caused to explode experimentally.

Because of the potential hazard from compounds containing plosophoric groups we have included compounds which, in our opinion, contain a sufficient percentage of such groups to make them dangerous under certain conditions. Such compounds may possibly find use as components of explosive mixtures, fuse compositions, etc. In the case of nitro compounds, this percentage was arbitrarily set at about 14% NO₂ and/or NO nitrogen, although some compounds with lower nitrogen content have been exploded. High nitrogen compounds on combustion yield large volumes of gas which may contribute to the ballistic potential of a propellant composition containing such compounds. If these compounds are not in themselves exothermic, their endothermicity may be of value in reducing the flash of propellent compositions. We have, therefore, decided to include compounds which contain about 40% or more nitrogen.

In addition to a given explosive compound, we have included references to what may be considered as the parent compound of azido, nitro or nitroso derivatives. This is done because some information concerning the parent is usually needed for the preparation of explosive derivatives. References (mostly Beilstein) to intermediate non-explosive derivatives are included for the same reason. For example, naphthalene and its various mononitro and dinitroderivatives, which are not explosive are listed and references given.
In order to make the Encyclopedia as compact as possible we used abbreviations, many of which are the same as used in Chemical Abstracts except that periods after abbreviations are omitted. A list of abbreviations symbols, code letters and special designations of items connected with explosives, propellants, pyrotechnics, ammunition and weapons is included in this work. This list is placed immediately before the Encyclopedia proper (see Abbreviations, pp Abbr 1-59) and also includes abbreviations and code letters for various Ordnance establishments, industrial installations and scientific institutions, both US and foreign. Some additional abbreviations are given in a supplementary list (see Abbreviations, pp Abbr 59-65). Wherever we have been able to do so and are permitted by security regulations, the meaning of code letters on ammunition, weapons and other military items is briefly explained.

Following the above lists, the journals, books, and other reference sources most frequently used are given, together with our abbreviations for them (See pp Abbr 66-76). Journal abbreviations, not included in our list, are the same as given in the "List of Periodicals Abstracted by Chemical Abstracts," Ohio University, Columbus 10, Ohio (1956), except that we do not use periods and leave no space between abbreviated words. Although the French, Italian, Spanish and Portuguese books and journals do not capitalize the words in titles (except the first word) we use captials, as is the practice in abbreviating US and British journals.

Nomenclature

Since most organic compounds can be designated by several names, it was necessary in each case to decide under which name to list a particular compound. Not only are different names used by different writers, but frequently the Abstractor for Chemical Abstracts used another name and in the Chemical Abstracts Indexes the compound is often indexed under a still different name. In general, the Chemical Abstracts Index name is here given preference. However, when a trivial name or an older name is used, the compound may be listed under one of these names. In every case where more than one name has been used to designate a compound, the others are also listed. In addition, alternative names are or will be listed and the various names cross-indexed. The reader will thus usually have little difficulty in locating the desired item under which the compound is discussed in this book. In most cases, when a compound is described in the German literature, the German name is also given. This should be of help to those who seek information on the compound in the German literature, particularly Beilstein and Gmelin.

Azido, nitramino, nitro and nitroso derivatives are listed under what may be considered as the parent compound. Thus all the mono-, di-, and trinitrotoluenes will be discussed under toluene. For example, nitraminotetrazoles are discussed under aminotetrazole. With this system the various azido, nitro, etc derivatives included above are kept together and are not scattered throughout the Encyclopedia. Since these derivatives of a given parent compound are usually of some related interest from the point of view of properties, preparation and references, we believe that this arrangement is the most convenient.

While most azido, nitroso, and nitro derivatives are listed under their parent compounds, the amino, azo, azoxy, etc derivatives are listed as parent compounds, themselves, either individually or as a group. Similarly, alkyl, phenyl and other
derivatives are listed under their corresponding alkyl, aryl, etc names, eg amyl derivatives under amyl, etc. Bis- compounds in general will be listed under B, and tris- compounds under T. Halogen containing compounds will be found under the appropriate halogen; eg chlorobenzene under C etc. Salts, peroxides, hydroperoxides, etc of organic compounds are listed under the corresponding organic parent compound, while metallic salts are discussed under the appropriate acids, such as chloric, nitric, perchloric, etc. An exception is Ammonium Nitrate which is discussed separately in this volume and not under Nitric Acid. Normal, iso-, tertiary-, etc, isomers of alkyl compounds are listed under the corresponding alkyl group. Thus isobutylperoxide will be found under butylperoxides.

When the position of a substituent group has not been established or is in doubt, the doubtful position may be indicated by x or followed by (?). In some cases the probable positions are given in parentheses, eg 4( or 7)-aminobenzotriazole. Where two ways are commonly used to indicate the position of groups or elements in a molecule, one of the alternative ways is usually placed in parentheses directly after the letter or symbol designating the position, eg 2(or o), and a (or 1H). This is done to avoid repeating the whole name.

The nomenclature, particularly of complex compounds, is not always satisfactory in spite of the good work of the nomenclature commissions of the International Union of Pure and Applied Chemistry. Occasionally, a competent chemist would not be able to write the correct structure based on a given name. This is particularly noticeable in the naming of open chain and cyclic polynitrogen compounds and especially when the molecule contains both types of structures. As a result of our work in this field we have evolved a system which we have been using and which has some advantage in reducing ambiguity. Where it has seemed advisable, an additional name has been added, based on the system described below. This system was worked out in collaboration with Drs H. Matsuguma and H. Walter of Picatinny Arsenal and is essentially a combination of those systems used in Beilsteins Handbuch der Organischen Chemie and Chemical Abstracts.

The open chain polynitrogen groups include:

- Diazene $\text{-HN=N<}$
- Triazene $\text{-N:N:N<}$
- Tetrazene(1) $\text{>N-NH-N:N-}$ [called herein \textit{isotetrazene} as has been done by F.L. Scott et al., \textit{JACS} \textbf{75}, 5310(1953)]
- Tetrazene(2) $\text{>N-N:N<N}$ (which herein will be called simply \textit{tetrazene})
- Pentazadiene $\text{-N:N-NH-N:N-}$
- Hexazadiene $\text{-N:N-NH-NH-N:N-}$, etc

In these groups Beilstein designates the nitrogen at one end of the chain as N and the one at the other end as N', but there is no provision for naming the compound if some organic radical is attached to one of the nitrogens not at an end of the chain. The system used in US Chemical Abstracts consists of designating the nitrogens by the numerals 1,2,3,4 etc but there is no provision for differentiating these numerals from those used in the ring structures (such as benzene, pyridine, triazole, tetrazole etc) which may be attached to one of the nitrogens of the open chain compounds. None of the above systems provides a ready, unequivocal indication of the position (in the ring) to which the nitrogen of the open chain compound is attached.
In the system we have adopted the nitrogens of open chain compounds are designated as \( N^1, N^2, N^3, N^4, N^5, N^6 \), etc. For instance, the compound \( C_2H_5 \cdot N \cdot N \cdot NH \cdot NH \cdot C_6H_5 \) would be called \((N^1\text{-ethyl, } N^5\text{-phenyl})\text{-isotetrazene}\) and the compound

\[
\begin{array}{c}
C_2H_5 \cdot N \cdot N \cdot \left( N\left( NH_2 \right) \right) \cdot N \\
\end{array}
\]

would be called \((N^1\text{-ethyl, } N^3\text{-amino, } N^4\text{-methyl, } N^5\text{-phenyl})\text{-isotetrazene}\). Slightly more difficult would be the naming of a compound in which one (or several) hydrogens in an attached ring or in the straight nitrogen chain is substituted by one (or several) radicals, such as \( NH_2, NO_2, C_6H_5, \) etc.

Let us name, according to our system, the compound:

\[
\begin{array}{c}
\text{NO}_2 \\
\text{H}_2C-\text{CH} \\
\text{\( \cdot \)} \\
\text{C_2H_5} \\
\end{array}
\]

a ring attached to the left \( N \) of the open chain nitrogen compound has the ring atoms designated \( 1', 2', 3', 4' \), etc arranged \textit{counterclockwise} and the atoms of the ring attached to the right \( N \) of the open chain nitrogen compound numbered \( 1, 2, 3, 4 \), etc arranged \textit{clockwise}, then the name of the compound would be \([N^1\text{-}(2', 6'\text{-dinitrotoluene-4')}, N^4\text{-amino-\( \alpha \text{-tetrazole-5'})\text{-isotetrazene}]}\). Here, \(-4')\) indicates that \( N^1 \) is attached to position \( 4' \) in the \( 2', 6'\text{-dinitrotoluene} \) ring. The \(-5)\) indicates that \( N^4 \) is attached to position \( 5 \) in the tetrazole ring. The \( \alpha \) indicates the type of tetrazole to distinguish it from the \( \beta \) tetrazole. In the \( \alpha \) compound the hydrogen atoms are in positions 1 and 5, whereas in the \( \beta \) compound they are in the 2 and 5 positions. Currently Chemical Abstracts uses the designations 1H and 2H to indicate the ring atom to which a hydrogen is attached in the parent tetrazole ring. Since the \( NH_2 \) group is in an \( \alpha \)-tetrazole it can only be attached to the \( N \) in the 1-position and it is therefore unnecessary to indicate the position.

In rare cases in which a third ring compound is attached to one of the intermediate \( N \) atoms of an open chain nitrogen compound, its substituents would be numbered \textit{clockwise} using double primes, as \( 1'', 2'', 3'' \), etc. In some cases the groups \( NH_2, NO_2, \) etc may be attached to intermediate \( N \) atoms of the open \( N \) chain.

Following is the formula of a complicated hypothetical compound:

\[
\begin{array}{c}
\text{NO}_2 \\
\text{H}_2C-\text{CH} \\
\text{\( \cdot \)} \\
\text{C_2H_5} \\
\end{array}
\]

According to our system its name would be: \([N^1\text{-}(2', 6'\text{-dinitrotoluene-4')}, N^4\text{-amino-\( \beta \text{-tetrazole-5'})}, N^6\text{-amino, } N^4\text{-}(1\text{-amino-\( \alpha \text{-tetrazole-5'})\text{-isotetrazene}]}\)

By adopting the proposed system it would be easier to arrive at a name corresponding to a given formula or to write a formula corresponding to a given name.
than by using the systems described in Beilstein, Chemical Abstracts or British literature.

As another example may be cited the compound

\[
\begin{array}{c}
N\cdot NH\cdot C\cdot N\cdot N\cdot NH\cdot NH\cdot N\cdot N\cdot C\cdot NH\cdot N \\
\| \quad \| \\
N \quad N \\
\| \quad \| \\
N \quad N
\end{array}
\]

which we would name \([N^a,N^b\text{-bis(a-tetrazolyl-5)}]-\text{hexazadiene.}\) Let us now find a simple unequivocal name for the compound:

\[
\begin{array}{c}
\text{CH} \\
\text{CH} \\
\text{CH} \\
\text{N} \\
\text{CH} \\
\text{CH}
\end{array}
\]

which has been variously named: a)pyrido-[2,1-c]-s-triazole b)triazolo-pyridine c)2,3-diazopyrrocoline d)benztriazole and e)1,2,3-benzisotriazole. Of these, only the 1st name would allow writing the correct structural formula once one learns the significance of the letter c. This system, however, not only uses numerals for indicating the position of atoms but also uses letters, a,b,c,d,e, etc for each side of a ring compound. On examining the above formula it is evident that the compound is a pyrido-s-triazole, but since there may be several such compounds, it is necessary to indicate the position at which the pyridine is connected to the s-triazole. If we adopt the system of numbering each ring separately, and if the group on the right side of the formula has the numerals 1,2,3, etc starting from \(\text{NH}\) and counting clockwise, while the group on the left side has the numerals 1',2',3', etc starting from \(N\) and counting counterclockwise, then the formula numbering would be

\[
\begin{array}{c}
\text{CH} \\
\text{CH} \\
\text{CH} \\
\text{N} \\
\text{CH} \\
\text{CH}
\end{array}
\]

and the proposed name is \((\text{pyrido-1',2'}-s\text{-triazole-4,5}).\)

If this compound had an amino group in position 4' of the pyridine ring and a methyl group in position 1 of the triazole ring, then the name would be \((4'-\text{aminopyridine-1',2'})-(1\text{-methyl-s-triazole-4,5}).\)

In the case of \textit{tetrazoles} we use the Chemical Abstract system of numeration, but the compd

\[
\begin{array}{c}
\text{HC} \\
\text{N} \\
\text{N}
\end{array}
\]

known as \(1\text{-h-tetrazole}\) we call \(\alpha\text{-tetrazole}\) and the compd \(\text{HC}=\text{N}-\text{NH},\)

\[
\begin{array}{c}
\text{N} \\
\| \\
\text{N}
\end{array}
\]

known as \(2\text{-h-tetrazole}\) we call \(\beta\text{-tetrazole}.\) We retain the name \(\text{isotetrazole}\) for the compound \(\text{H}_2\text{C}=\text{N}=\text{N}\)

\[
\begin{array}{c}
\text{N} \\
\| \\
\text{N}
\end{array}
\]

In the case of \textit{tetrazines}, the compd \(\text{HC}=\text{N}-\text{N}\) is called by us \(s\text{(or sym-)}\)

\[
\begin{array}{c}
\text{N} \\
\| \\
\text{N}
\end{array}
\]

tetrazine and the compd \(\text{HC}=\text{N}-\text{N}\), \(v\text{(or vic-)}\)-tetrazine. The \(s\text{-tetrazine}\) is not known

\[
\begin{array}{c}
\text{HC} \\
\text{N}
\end{array}
\]
In the case of triazines, the compound $\text{HC}^1\text{N}^2\text{N}$ is called by us as-triazine, $\text{HC}^1\text{N}^2\text{N}$, the compound $\text{HC}^1\text{N}^2\text{N}$, $\nu(\text{or} \ \text{vic})$-triazine and the compound $\text{HC}^1\text{N}^2\text{N}$, $\sigma(\text{or} \ \text{sym})$-triazine. If H is in position 1, we add $\alpha$- in front of $\sigma$- or of $\nu$- and if H is in position 2, the letter $\beta$- is used and in the case of the compound $\text{HC}^1\text{N}^2\text{N}$, our name is $\gamma$-s-triazole.

In the case of triazoles, the compound $\text{HC}^3\text{N}^4\text{N}$ is called $\nu(\text{or} \ \text{vic})$-triazole and the compound $\text{HC}^3\text{N}^4\text{N}$, $\sigma(\text{or} \ \text{sym})$-triazole. If H is in position 1, we add $\alpha$- in front of $\sigma$- or of $\nu$- and if H is in position 2, the letter $\beta$- is used and in the case of the compound $\text{HC}^3\text{N}^4\text{N}$, our name is $\gamma$-s-triazole.

In the case of isotriazoles, the compound $\text{HG}^1\text{N}^2\text{N}$ is called by us $\nu(\text{or} \ \text{vic})$-isotriazole, and the compound $\text{HG}^1\text{N}^2\text{N}$, $\sigma(\text{or} \ \text{sym})$-isotriazole. If H is in position 1, we add $\alpha$- in front of $\sigma$- or of $\nu$- and if H is in position 2, the letter $\beta$- is used and in the case of the compound $\text{HG}^1\text{N}^2\text{N}$, our name is $\gamma$-s-triazole.

In order to avoid the use of rings (which have to be drawn by hand) as much as possible, we adopted a system similar to that used in Beilstein for such compounds as benzene, pyridine, tetrazole, etc. For example, benzene is written as $\text{HC}^5\text{N}^6\text{N}$, and $\alpha$-tetrazole as $\text{HC}^6\text{N}^1\text{N}^2$. It should be noted that in these formulas, as written, position 1 is always in the middle of the upper line.
PHYSICAL TESTS FOR DETERMINING EXPLOSIVE AND OTHER PROPERTIES
OF ITEMS DESCRIBED IN THIS WORK*

Abel's Test (Essai du Abel, in Fr.) A brief description is given on pA2 of this volume. The test is also described in TM 9-1910(1955),57-60

Ability to Propagate Detonation; Transmission of Detonation or Extent of Propagation of Explosion. The property of an expl to conduct detonation, which has been started by an initiator, to neighboring layers is dependent on the props of the expl mainly velocity of deton and on some other factors(such as confinement, thickness of layer, diam of charge, density of packing, and temp) (Ref 1,3,4,5 & 6). In some substa(such as AN), the deton wave might easily die out(or dampen) if the optimum conditions for propagation are not fulfilled.

Munroe(Ref 2) described several tests for detn of propagation of deton in AN. For these experiments, use was made of a wooden trough, appr 5/4' square in cross-section and 10' long, which rested on the ground. Such a trough held ca 125 lbs of AN. Use was made of both warm nitrate(52°) and of cold nitrate(27°). The warm nitrate was used to insure deton and was placed at the initiating end of the train. The effect was detd by the size and extent of the crater produced beneath the box. As the initiation of AN could not be produced by detonators(such as electric tetryl detonator), it was necessary to use sticks of blasting gelatin. With this initiation complete detonation of AN could be obtained, except in cases when AN was 1" or smaller in diam.

Warm AN deton easily, faster than cold AN

The propagation test may also be conducted similarly to the pin method described by Cook(Ref 6) Refs: 1)Colver(1918),639 2)E.Munroe, ChemMetEng 28, 541(1922) 3)J.L.Shepuck, ArOrdn 24, 329 & 395(1924) 4)G.W.Jones, ArOrdn 5, 599(1924) 5)D.B.Gawthrop, ArOrdn 6, 47(1925) 6)Cook(1958),29-31

Absorption of Moisture by Explosives, Propellants and Pyrotechnic Compositions. See Hygroscopicity

Action of Light on Explosives, etc. See Light, Action on Explosives, etc

Aptitude à l'Inflammation, Essai. Same as Capability to Inflame Test

Armor Plate Impact Test (Shell Impact Test). This test was developed during WW II to provide an additional sensitivity test for HE's commonly used and to supplement data obtained by impact and rifle-bullet tests. The test is supposed to duplicate the conditions which take place when a HE projectile hits a hard surface.

For this test a modified 60 mm Mortar Shell is loaded with the test expl, drilled about ½ inch, and closed with a steel plug screwed into the shell to give a close fit between the plug base and the charge. The igniter and propelling charges are loaded into the "gun", through a simple breech plug. The loaded shell is fired from a 5 foot length of Shelby steel tubing against rigidly-mounted mild steel plates. Velocities of the niter and propelling charges are loaded into the "gun" through a simple breech plug. The loaded shell is fired from a 5 foot length of Shelby steel tubing against rigidly-mounted mild steel plates. Velocities of the shells are measured electronically and whether or not flash occurs on impact is determined by observation. The value reported is the velocity in ft/sec at which the expl is unaffected in 50% of the trials. Refs: 1)OSRD 5146(1945),2-3 & 11 2)PATR 1740, Rev 1(1958)

Available Energy. Same as Maximum Available Work Potential

Ballistic Mortar Test (Ballistische Mrser, Probe in Ger) (Essai au mortier épreuve, in Fr) is a measure of power. It is used in the US in preference to the Trauzl Test which is standard in some European countries. The Ballistic Mortar Test consists of firing various charges of test explosive in a heavy steel mortar, attached to a pendulum bar and suspended on knife edges, and comparing the degrees of swings produced with that obtained on detonation of 10 g samples of TNT. From the values for TNT and from the weights of charges of sample producing nearly the same deflections as 10 g of TNT, the amnt of sample producing exactly the same deflection as 10 g of TNT is calculated. Then the Ballistic Mortar Value is derived from the formula:

\[
BM \text{ Value} = \frac{10 \times 100}{\text{Sample Weight}} \% \text{ of TNT}
\]


Ballistic Pendulum Test (Essai au pendule balistique, in Fr) (Ballistische Pendel Probe, in Ger). This is the Official Test for the power of coal mine explosives, both in the US and the British. The pendulum used at the US BurMines Testing Station, Bruceton, Pa consists of a mortar(12.2" diam and weighing 31600 lbs), attached to a pendulum, as described in Ref 3, p 43. The test expl is loaded (8 oz) in a borehole(2½" ID & 2½" deep) of a steel cannon(24" OD x 36" long) and the charge is stemmed(tamped) with 2 lb of clay. The cannon is then moved on a track to within 1/4 of the mortar and after adjusting the bore exactly opposite the mortar-muzzle the charge is fired by means of an electric detonator. The impact of products shooting from the cannon against the mortar causes deflection(swing) of the pendulum. The swing is measured and compared with that produced by the same amnt(8 oz) of 40 per cent straight Dynamite(NG 40, NaN03, 44 woodpulp 15 & CaCO3 1%), which is designated as PTSS(Pittsburgh Testing Station Standard) Dynamite. Its swing is 2.7 to 3.1"

* For meaning of abbreviations, see pp Abbr 1 to Abbr 76, which follow
By means of trial and failure the weight of the sample(W) that gives approximately the same swing as 8 oz of the standard is then detd, and three shots are fired with this wt. The exact swing of the sample(Sx) is calcd from the formula:

\[ S_x = \frac{W \times Sp}{8} \]

where Sp is swing given by 8 oz of the standard (Refs 1,2,3 & 4)

The pendulum in use at the British testing station at Rotherham weighs 5 tons and is suspended by steel rods from an overhead axle having roller bearings. The bore-hole of the cannon (gun) is 30" long and 1 1/8" diam. The charge consists of 4 oz of expl well-rammed with 2 lbs dry clay as stemming. The cannon is moved to within 2" of the mortar-muzzle and the charge is fired by an electric detonator. The swing is read and compared with 3,27" which is the swing produced by 4 oz of 60% Gelignite (NG 60, CC 4, KNO₃ 28 & woodmeal 8%) (Ref 2, p 183-4)

The ballistic pendulum test is also used in GB for determining performance of military explosives. For this a 10 g sample of expl is detonated in a loose condition under light confinement at the center of a heavy hollow cylinder, closed at one end, and suspended so as to form a pendulum. The swing is compared with that produced by 10 g of picric acid. The results are expressed as percentages of the performance of picric acid (Ref 5) (Refs: 1)Marshall 2(1917),473 2)Barnett(1919),182-4 3)US BurMines Bull 346 (1931),40-6 3a)Vennin, Birlot & Leforce(1932),269 4)Stettbacher(1933),368 5)Blatt,OSRD 1914(1944) Behavior Towards Heat Tests. See Sensitivity to Flame, Heat, Sparks, Electrostatic Discharges, etc Tests, as well as Burning Tests, Combustion Tests and Index of Inflammability Tests

Bergmann-Junk Test has been used widely in Europe and to some extent in the US for testing the stability of NC. In this method NC is heated at 132° for 2 hours which action causes the evoln of some nitrogen oxide fumes. The fumes are absorbed in water giving a soin of nitrous and nitric acid. The nitrogen content of the soin is detd by the Schulze-Tiemann method. More detailed description will be given in Vol II, under B.

**References:**
1)E.Bergmann & A.Junk, ZAngChem 17,982,1018 & 1074(1904) 2)Reilly(1938)83-5 3)Kast-Metz (1944),218-20 & 312 4)PATR 1401,Rev 1(1950),19-25

**Bichel Bomb or Bichel Pressure Gage** is a device for measuring the press of an expln and for collecting and examining the gaseous, liq., and solid products formed. The apparatus consists of two stout cast steel horizontal cylinders, one of 15 1/2 and the other 20 1 capacity. Each cylinder can be closed with heavy lids provided with lead gaskets and secured in place by heavy stud bolts and an iron yoke. Three or more small diam holes are drilled through the upper part of cylinders: the 1st hole is connected to the tube of a vacuum pump, the 2nd accommodates an insulated plug that provides a means for conducting the electric current to the electric detonator inside the bomb and the 3rd is connected to a press gage provided with a registering drum.

For examination of an expl a charge (usually 50 to 300 g) is placed inside the bomb, and, after closing the lid, the air is evacuated by means of a vacuum pump. Then the chge is fired electrically and the pressure diagram is obtained. Method of computation of results is given in Ref 2. The result thus obtained is termed the "maximum pressure of the explosive in its own volume"

This apparatus also affords a means for collecting and examining the products formed on expln. The method of sampling is described in Ref 2, pp 92-3. (Refs: 1)C.E.Bichel, "New Methods of Testing Explosives," Griffin, London(1905) 2)US BurMines Bull 346(1931),84-95 3)Vivas, Feigen span & Ladreda, v 4(1944),98-104(Under the name "Medidor de presion de la casa Carbonic")


**Blasting Caps and Detonators, Initiating Efficiency.** See under Initiating Efficiency of Primary Explosives, Blasting Caps and Detonators

**Bomb Drop Tests** (Bomb Functioning Test) are usually conducted using bombs assembled in the conventional manner, as for service usage, but provided with either inert or simulated fuzes. The target is usually reinforced concrete. (Refs: 1)Ordnance Proof Manual, Aberdeen Proving Ground, Nos 9-11(1949) & Nos 10-80(1957) 2)PATR 1401,Rev 1(1958)

**Booster Sensitivity Test** involves measuring the relative sensitivities of various expl to an arbitrary graded series of boosters. This test was designed to classify expl on the basis of their ease of deton by boosters. The source of the shock pellets of varying weights which may be degraded by wax spacers of Acrawax B. The booster charge is initiated by a No 8 detonator. The weight of tetryl reported as a final value is the min wt which will produce 50% detonations through the thickness of wax in inches, as indicated

This test is considered as one of the Detonation by Influence(Sympathetic Detonation) Tests. (See also Gap Test, Halved Cartridge Gap Test and Wax Gap Test). (Refs: 1)OSRD Rept 5746(1945) 2)PATR 1740, Rev 1(1958)

**Brisance or Shattering Effect** (Brisance, in Fr) (Brisanz, in Ger) (Poder rompedor or Brisancia, in Span) (Poterie dirompente, in Ital) can be approximately measured by the following methods: a) Compression Tests
Calorimetric Tests for Explosives, Propellants and Pyrotechnic Compositions. These tests include determinations of heat of combustion, etc. Tests of burning rate, index of inflammability test, and sensitivity to flame, heat, sparks, electrostatic discharges, etc. Tests. As a surplus expls are usually destroyed by burning, it is desirable to know their burning characteristics before proceeding to burn them on a large scale. A number of different methods have been designed at the US BurMines. One of the tests, designated as V-466 is as follows: Paper is placed on the ground, the cartridge, the wt of which should not exceed 2 lbs, are opened and the contents spread in a thin layer on the paper. After saturating the expl with kerosene, a charge (ca 25 g) of black blasting pdr is placed on the edge of the layer and an igniter, connected to a firing machine placed at a distance of not less than 60 ft, is placed in contact with the pdr. The duration of burning of the expl is recorded. (See also Combustion Tests, Index of inflammability Test and under Sensitivity to Flame, Heat, Spark, Electrostatic Discharges, etc. Tests). Ref: US BurMines Bull 346 (1931), 31

Colorimetric Tests for Explosives, Propellants and Pyrotechnic Compositions. These tests include determinations of heat of combustion (designated as Qc), heat of explosion (Qe), heat of formation (Qf), heat of fusion (Qfus), heat of sublimation (Qsubl) and heat of vaporization (Qvapz).


Capability to Ignite Tests (Épreuves de l'aptitude de l'inflammation or Épreuves de combustion, in Fr). See Combustion Tests, Index of inflammability Test and also under Sensitivity to Flame, Heat, Sparks, Electrostatic Discharges, etc. Tests.

Cavity Charge Performance. See Shaped (or Hollow) Charge Efficiency in this section.

Chisel Test permits simultaneous detn of the brisance and potential. It is discussed by Pepin Léhalleu (1935), 64

Characteristic Product of Berthelot (Produit caractéristique de Berthelot, in Fr) will be discussed in Vol II, under C. Ref: Marshall 2 (1917), 417

Closed Vessel Test (Essai en vase clos or Épreuve à la bombe, in Fr) will be described in Vol II, under C. Refs: 1) H. Muraour, "Poudres et Explosifs," Presses Universitaires de France, Paris (1947), 73-4 2) H. Muraour et al, MAF 22, 517-93 (1948)

Coefficient d'Utilisation prototypique (CUP or cup) (Épreuve de travail spécifique). It is a modification of Trauzl Test (qv) designed by Dauriche and used as an official French test. Briefly the test consists of packing the cavity (25 mm dia & 125 mm deep) of Trauzl lead block (200 mm dia & 200 mm high) with 15 g of crystaline PA (picric acid) in such a manner that the height of charge is exactly 38 mm. In an identical block is placed such an amount of expl to test, that it would produce an expansion of cavity as close as possible to that produced by 15 g of PA. After slightly compressing the charge and inserting a perforated cork with a No
detonator, the cavity is filled to the top with dry sand and the same is done with the charge of PA. After firing the charges, the expansions of cavities are noted and compared. If $\text{expansion (V'' cc)}$ produced by C' g of sample is not exactly identical with the expansion (Vcc) produced by 15 g PA, but does not differ much, the exact wt of expl (C g) necessary to produce expansion Vcc can be found from the equation $$\frac{C'}{C} = \frac{V'}{V}.$$ Then the value of CUP is obtained from the formula $$\frac{50 \times 100}{C},$$ where C is wt of expl necessary to produce the same expansion as produced by 15 g of PA (Ref 6). It has been claimed that this method gives more reliable results than the regular Trauzl test. 

**References:**

Combustion Tests (Epreuves de combustion ou de l'Aptitude à l'inflammation, in Fr.). French official combustion tests for expls and propellants include: a) Combustion en gouttière de 20 mm (Combustion in a trough of 20 mm), known also as Epreuve de propagation dans une gouttière de 20 mm (Propagation test in a trough of 20 mm) and b) Combustion en tas conique (Combustion in a conical pile), known also as Epreuve de sensibilité à l'inflammation (Sensitivity to ignition test) are described by L. Méard, MP 33, 329–30 (1951).

**Combustion Tests**, such as Copper Cylinder Compression or Crusher Test (Brisance Meter of Kast Test), Lead Block Compression or Crusher Test (Hess Apparatus Test) and Compression with Small Lead Blocks will be discussed in Vol II, under C. 

**Concrete Test** will be discussed in Vol II, under C. Ref: Marshall 2, (1917), 273


Cup Test or Cup Test, same as Brisance Meter of Kast Test will be discussed in Vol II, under B.


Crawshaw-Jones Apparatus for testing coal mine explosives for permissible will be discussed in Vol II, under C. Ref: US BurMines Bull 346, (1931), 95

Copper Cylinder Compression (or Crushing) Test. Same as Brisance Meter of Kast Test will be discussed in Vol II, under B.


Crawshaw-Jones Apparatus for testing coal mine explosives for permissible will be discussed in Vol II, under C. Ref: US BurMines Bull 346, (1931), 95

Cup Test (Brisance Meter of Kast Test), Lead Block Crushing (Compression) Test are used for estimation of the brisance of explosives CUP or cup Test. See Coefficient d'utilisation praktique in this section

Dautriche Method for Determination of Velocity of Detonation will be discussed in Vol II, under D, as one of the Detonation Velocity Tests

Deflagration Test or Deflagration Temperature Test. See Ignition Temperature Test in this section

Dilatometry Test. See Hygroscopicity Test in this section

Density Determinations will be discussed in Vol II, under D.

Detonation by Influence or Sympathetic Detonation Tests (Transmission of Detonation at a Distance Test) (Aptitude à transmettre la détonation à distance, Essai or Coefficient de self-excitation, Essai, in Fr) (Detonationstransfer Probe or Schlagweite Probe, in Ger) (Determinación de la sensibilidad a la iniciación por simpatia, in Span) (Distanza di esplosione per simpatia, Prova, in Ital) include the following methods:

a) Booster Sensitivity Test (qv) b) Four-Cartridge Test (See BATR 2510 (PB 1612) (1958), p Ger 52)


Detonation Pressure is, according to Cook (Ref), a property of great importance in detonation technology. Its direct measurement cannot be made due to its transient nature and its exceedingly high magnitudes, at least in condensed explosives. The detonation pressure is, however, accurately defined by the hydrodynamic equation given on p 32 of the Ref. Note: The "detonation pressure" must not be confused with "Pressure of Gases Developed on Detonation" (qv). Ref: Cook (1958), 32

Detonators and Blasting Caps, Initiating Efficiency. See under Initiating Efficiency of Primary Explosives, Blasting Caps and Detonators

Distribution of Shell Fragment Masses was studied at ERL, Bruceton, Pa by firing shells in a Fragmentation Pit filled with sawdust. The fragments were recovered by a magnetic separator. Details of procedure are given in OSRD Rept 5607(1945). See also OSRD Repts 5606 and 5608

Drop Test. Same as Impact Sensitivity Test

Earth Cratering Test. See Cratering Effect Test in Vol II, under C

Erosion of Gun Barrel(s) (Erosion (ou usure) des bouches à feu, in Fr) (Erosion der Gewehrläufe; Bohrhubnung, in Ger) Test will be discussed in Vol III, under E. Refs: 1) Marshall 2 (1917), 315

Esop's Test for Efficiency of Detonators, devised by K. Esop of Austria, in 1889, consisted of the following operations: A 50 g sample of uniform grain PA (picric acid), was made into a cartridge and, after inserting a test detonator, it was placed on a steel plate covering two small lead cylinders (crushers), set vertically on a steel base. After the chge was fired, the compression of the cylinders was measured and this served as a std value indicating complete detonation. This same type of detonator was then tested in mixts of PA with varying ams of cotton seed oil and the max ams of oil still permitting complete deton was detd. The larger this ams, the more efficient was the detonator (Ref 1)

This test was investigated in Europe after WWI and found to be more reliable than other tests, especially the sand test (Refs 1 & 2). In a modification of the test devised at the Chemisch-Technische Reichsanstalt, in Berlin (Refs 3 & 4) mixts of TNT with paraffin wax and later of TNT with talc compressed into pellets, served as inert exph for testing detonators. Completeness of deton was judged by firing the pellet with the test detonator in a small lead block (Trauzl test) and measuring the enlargement of cavity (Compare with Grotta's Test and Miniature Cartridge Test). Refs: 1) Marshall 2 (1917), 532 2) H. Kast & A. Haid, SS 18, 166 (1924)
3) Jäherber CTR V, 112 (1926) & VI, 121 (1927) 4) Marshall 3 (1932), 163-4

Explosion by Influence (or Sympathetic Detonation) Test. See Detonation by Influence Tests

Explosion (or Ignition) Temperature Test. See Ignition (or Explosion) Temperature Test, in this section

Extent of Propagation of Explosion. See Ability to Propagate Detonation in this section

Exudation Tests (Exudation Essais, in Fr) (Ausschwitzungsproben, in Ger). The purpose of the exudation test is to determine whether expls, such as dynamites, DNT, TNT, etc would release any liq in storage, especially in hot climates

Following tests are described in Ref 1, pp 25-7: a) Centrifuge Test b) Forty-Degree Test and c) British Test. Of these the centrifuge test was adopted by the Burmines as being best suited for ascertaining the liability of dynamites to exude

The French test, called exudation par étuvage, is conducted as follows:

Weigh to the nearest mg a tall Kraft paper container 30 mm in diam and 0.2 mm thick. Pack the container with the sample (100 g) and reweigh. Take to the nearest mg a piece of porous cardboard 5 x 5 cm square and 2 mm thick. Place the container on the cardboard and insert the ensemble in an oven, thermostatically maintained at 40 ± 1°C or 50 ± 1°C. After 21 days, reweigh the cardboard, the sample + container, and the empty container

If the loss in wt of sample is P, increase in wt of container p and increase in wt of cardboard is p', then (p + p') is the wt of exudate and P - (p + p') the loss in volatiles. Multiply the wts by 100 to express in percentage (Ref 5)

Another French method is described in Ref 3a

A German method for det of exudation is described in Ref 7

Some tests have been investigated at Picatinny Arsenal, but exudation has been observed or induced in loaded items of ammunition by subjecting them either to alternate periods of heating and cooling or to continuous heating at 160°C (71°C). There is no record of TNT exudation from US shell smaller in caliber than 105 mm or from Composition B loaded shells stored at ambient temp. However, most TNT and TNT-contg expls can be caused to exude by storing the loaded components at 160°F (71°C) or in temps which fluctuate sharply.

In one series of tests to induce exudation and to obtain exudate samples for analysis and examination of properties, unfuzed shell were placed in an inverted position in temps up to 160°F (71°C) and the exudate was collected in a tared vessel. A summary of the pertinent results from exudation studies conducted at PA has been prepared by Skel (Ref 6). Refs: 1) Marshall 2 (1917), 419-22 2) Barnett (1919), 215 3) US Burmines Bull 346 (1931), 25-7 3a) Pepin Lehalleur (1935), 61 4) Reilly (1938), 65 5) L. Médard, MP 33, 328 (1951) 6) PATR 2493 (1958) 7) PATR 2510 (PB 161270) (1958), Ger 45

Falling Weight Test. Same as Impact Sensitivity Test
FI Test (Figure of Insensitiveness Test). The degree of sensitiveness exhibited by an expl detonated on mechanical shock is important because sensitiveness largely determines the precautions necessary in manufacturing, handling, and applications of the explosive. The difficulties sometimes attributed to determining sensitiveness by impact or drop-weight machines were reportedly overcome by an apparatus designed by Dr Rotter of the Research Dept, Woolwich, England. By this procedure reproducible accurate results were obtained, not by personal observation of sound or flash produced, but by a quantitative measurement of the gas produced at different heights of fall when the falling weight delivered sufficient energy to cause decompa of the expl.

The results are compared to a standard expl, such as picric acid, gunpowder or mercury fulminate, and expressed as a ratio known as figure of insensitiveness. This ratio represents the relative energies of the impact required to produce explosions of equal degrees of completeness from initial decomposition to complete detonation. Picric Acid is taken as 100, and explosives giving higher numbers are less sensitive while those giving lower numbers are more sensitive than picric acid. Ref: R. Robertson, JCS 119 1,15(1921)

Fire Resistance or Fire Tests are described under Sensitivity to Flame, Heat, Sparks, Electrostatic Discharges, etc

Flame Test (Length and Duration of Flame Determination) (Grösse und Dauer von Sprengstoff-Flammen Probe, in Ger) (Medición de la longitud y la duración de la llama, in Span). The test is based upon the belief that the greater the length of the flame an explosive emits and the longer the time during which that flame endures, the greater are the chances that such a flame when shot into the atmosphere of a coal mine will ignite inflammable or expl mixts of mine gas and air; of coal dust and air; or of mine gas, coal dust, and air.

The flame test apparatus used at the US BurMines Explosives Experiment Station at Bruceton, Pa consists essentially of a cannon in which an explosive is fired or detonated. The cannon, identical with that employed for the ballistic pendulum, is mounted vertically on a concrete foundation located in a dark building. By means of a photographic pendulum equipped with suitable devices to cut off all extraneous light rays, the flame is continuously observed such that its apex is in the field of view. The flame is recorded on a sensitized film wrapped around a drum that revolves at a predetermined rate of speed. The length of each flame is indicated by its height in the photograph, and the duration by the length of photograph. When testing detonating expls, cartridges 1/4" in diam are used, the wt of charge being 100 ± 0.5 g, including the wrapper. When testing black blasting powder or other burning expls, the charge is tampered in the borehole and the igniter is imbedded centrally in the top of the charge. Refs: 1) US BurMines Bull 346, (1931),67 2) Stettbacher(1933),65-8 3) Reilly(1938),69 4) Vivas, Feigenpan & Ladreda 4 (1944),108-11 5) Pérez Ara (1945),125

Flash Point Test. See Ignition(or Explosion) Temperature Test, described in this section

Flash Test for Cops. See Optical Method for Testing Caps

Forty-Degree Test. See under Exudation Tests

Four-Cartridge Test is the Ger detonation by influence test. It is described in PATR 2510(PB 161270) (1958), p Ger 52

Fragmentation Test (Splitterprobe, in Ger). The fragmentation test consists of static functioning of the expl filler of a projectile, rocket, bomb or mine for the purpose of determining the number and weight grouping of the recovered fragments. The test gives a measure of the brisance and efficiency of an expl as well as the sensitivity of the test item.

Tests used abroad are briefly discussed in Refs 1,3,4, & 9, while the tests used in the US are described in Refs 2, 5, 6, 7, 8, 9

There are four general types of fragmentation tests used by US Ord Dept: a) Closed Chamber or Pit Test, b) Open Pit Test, c) Panel Test, and d) Velocity Measurement Test. The Closed Chamber Test, as conducted at Picatinny Arsenal, is described in detail in Ref 7. The other three tests, as conducted at Aberdeen Proving Ground, are described in Ref 6. More information on fragmentation will be given in Vol III, under F Refs: 1) Stettbacher(1933),50-1 & 218-19 2) L.V. Clark, JEC 25, 1389-90(1933) 3) A.Majrich & F. Sorm, SS 30, 298-9(1935) 4) A. Stettbacher, Protar B, 90(1942) 5) Hart(1946),33 & 213 6) Ordnance Proof Manual OPM 40-23(1947) 7) PicArsen Testing Manual 5-1(1950) 8) TM 9-19(1955),63-4 9) PATR 1740, Rev 1 (1958) 10) PATR 2510(PB 161270) (1958), p Ger 52

Fragment Density-, Fragment Concentration- or Density of Splinters Test (Splitterdichteprobe) is described in PATR 2510(1958), p Ger 52

Fragment Gun was originally developed by the British as a convenient instrument for imparting high velocity to controlled fragments in order to study their performance. The "gun" consists merely of a steel tube into which is inserted a flat slug, of any desired shape, cast in a wood's metal matrix. A cylindrical charge of expl is inserted into the other end of the tube so that it fits smoothly against the disc of slug and wood's metal surround. The charge is then detonated, from the end opposite to the slug, using a tetryl booster and suitable detonator. With a given type of tube and slug, the velocity imparted to the slug is a measure of a property of the expl closely related to brisance. The velocity is determined by sending the slug through three wire screens and determining the time intervals by means of a Mettegang recorder or other suitable device. Refs: 1) OSRD Rept 805(1942),27-8 2) OSRD Rept 804(1942),27-8
Fragment Velocity Measurement of statically detonated projectiles provides data for analysis of the effectiveness of projectile fillers and shell design. Evaluation of the lethality of fragments also depends upon the degree of fragment velocity.

The basic technique for detg fragment velocity consists of firing a model shell (such as 3") filled with a test HE against a mild steel panel (such as 1/4" and 1/8" thick) and photographing the fragments with a motion picture camera which also records elapsed time. By comparing the time with the distance traveled, an av velocity is obtained (Ref 2). In tests conducted at ERL, Bruceton, Pa, 10 expls were investigated using the "Bruceton Fragment Retardation Apparatus." Damage to steel panels was also detd. Refs: 1)OSRD Rept 5622(1946) 2)Ordnance Proof Manual OPN 80-16(1957)

Freecing Tests(for Dynamites). The freezing of expls, such as dynamites, leads as a rule to an increase in the rigidity and brittleness of the cartridges, as evidenced by cracks in the sample. The extent of the rigidity has been measured at the US BurMines by means of an apparatus called the "Crusher Board." This consists of a wooden base with a superimposed aluminum plate provided with a hole at each of its four corners by which it may be made to slide up or down on vertical brass guide rods which are attached to the corners of the wooden base. The sample of expl to be tested (a section of a cartridge, previously frozen at desired temp, 10 cm long cut from the center minus wrapper) is placed on its side in the central position of the wooden base and the aluminum plate is slipped over the guide rods so as to rest on the sample. Both ends of the cartridge are observed for cracks if any appears in either end in 10 secs a 100 g weight is added to the center of the Al plate and if no cracks appear in 10 secs an addnl 100 g wt is added. These operations are continued until the first crack is seen on either end of the sample. The total wt on top of the plate plus the wt of the plate(911 g) is taken as a measure of the compressive strength.

Explosives that do not freeze when exposed to temps as low as $35.0^\circ F(1.67^\circ 0)$ are called LF(low-freezing), those not freezing at $0^\circ F(-17.8^\circ C)$ are ELF(extra low-freezing) and those not freezing at lower temps are NF(non-freezing). Ref: US BureauMines Bull 346, (1931), 27-29

Frictional Impact Sensitivity Test. See under Friction Sensitivity Test

Friction Pendulum Test. See under Friction Sensitivity Tests

FRICITION SENSITIVITY TESTS (Reibungsempfindlichkeit Proben) in (Ger) (Essais à la friction, in Fr) (Pruebas al sensibilidad al rozamiento, in Span). The tests may be divided into qualitative and quantitative types.

A. Qualitative Friction Tests: a)French Test No 1. Place a gram of explo in a porcelain mortar and rub with a pestle. Report if it detonates or deflagrates(Refs 7 & 10) b)French Test No 2. Place a small sample on a tile or on an anvil and strike a glancing blow by means of a wooden hammer. Report the results(Refs 6 & 8) Note: Explosives sensitive to these tests are considered as dangerous to handle and if used in mining should not be tampered even with a wooden tamper c)German Test of Imperial Railway Commission consisted of rubbing a small quantity of explo in a small unglazed mortar with an unglazed porcelain pestle(Refs 1, 2 & 6) d)British Tests of Dupré are glancing blow tests. They are described in Ref 6, p 79

B. Quantitative Friction Tests. a)Rathsburg Test uses an apparatus which consists of two steel discs about 1/2" in diam with polished surfaces. The lower disc is stationary, while the upper rotates at 80 rpm. Loads ranging from 1 to 20 kg can be placed on the upper disc, thus maintaining it at various pressures. The explosive to be tested is mixed with finely pulverized sand and then a small portion is placed on the lower disc. A 20 kg load is placed on the upper disc, the disc is lowered to touch the sample and the rotation is started. If the sample does not explode after 20 revolutions, it is removed from the apparatus and a new portion is tested in the same manner. If no detonations occur after 6 trials, the expl is considered insensitive to friction. If any detonations are observed with a 20 kg load, the tests are repeated using successively smaller loads until the wt is reached with which no explo takes place. The av number of revolutions required to detonate an explo when tested 6 times with the mininum pressure is then recorded(Refs 5 & 11)

b)US Bureau of Mines Pendulum Friction Apparatus was devised in 1911 by C. E. Munroe, C.Hall & S.P. Howell and three models of different sizes were built at that time. The apparatus consists of a pendulum to the lower end of which is attached a 20 kg shoe, with an interchangeable face of steel or fiber. It is also possible to use other types of shoes, such as a wooden one with or without carborundum cloth attached to its striking surface. The shoe is permitted to fall from a height of 1 m and to sweep back and forth on a steel anvil, the polished face of which is provided with three grooves ca 1/8" deep cut at right angles to the line of swing. The grooves are designed to prevent the sample of explo, spread upon the anvil for testing, from being brushed off the anvil by movement of the shoe across it. The pendulum is adjusted, before placing the sample on the anvil, to swing 18 + 1 times before coming to rest.

With a steel shoe raised to the height of 1 m, spread a 7 g sample of the explosive evenly in and about the grooved portion of the anvil, and allow the shoe to strike the sample with glancing blows until it comes to rest. Clean the anvil and shoe, place another portion of the same explo and continue the test. Repeat test a total of 10 times and report the number of snaps, cracklings, ignitions, and/or explosions. If the sample detonates after 1 or 2 trials, discontinue the test in order to prevent damage to the apparatus. Such an explosive is considered as not passing the permeability test. If the expl remains unaffected in 10 trials with the
steel shoe, it is considered to pass the test. If some trials with the steel shoe produce burnings or cracklings, repeat the test using the hard fiber shoe. If in 10 trials with this shoe there is no more unfavorable result than an almost undistinguishable local cracking, the expl is considered as passing the test for permisibility (Refs 3, 6, 8, 12, 13, 14 & 15). c) Laboratory Model of Pendulum Friction Apparatus. As the regular Burdine's apparatus is expensive and requires large samples of expla. Taylor & Rinkenbach used a smaller model (ca ¾ the size of the B of M app.). The shoe weighed 74 g and samples 0.005 to 0.05 g. One of these models is at the B of M Testing Station and another at PicArsn. This small model is considered particularly suitable for testing initiating expls (Ref 4). d) Impact-Friction Pendulum, used by the Spencer Chemical Co (Ref 16) consists of a hammer with a 9 ft handle and a 400 lb head. The hammer delivers energy to a sample of explosive by falling a specified distance before striking the sample. Variation in energy delivered is achieved by adjusting the height from which the hammer is released. The hammer is drawn to this height in an arc, by an electric winch and released from a distance by a lanyard connected to a trigger.


Gap Test is one of the detonation by influence (sympathetic detonation) tests. The purpose of this test is to determine the sensitivity of a charge of expl to initiation by another charge located a certain distance from the 1st chge. The larger the distance, the more sensitive is the expl.

In the test used in France, two cartridges 30 mm diam, each weighing 50 g, are placed upon two vertical steel cylinders. The cartridges are placed a known distance apart with axis coinciding (in line), and then one of the cartridges is detonated. After finding the max distance at which there are 3 successive detonations by influence of the 2nd cartridge, the min distance is detd at which there are 3 successive failures. The mean of the two distances is designated as CSE (coefficient de self-excitation) (Refs 1, 3 & 4)

The US Burdines uses the following test, known as the Halved-Cartridge Gap Method: By means of a wooden device (such as a skewer), punch a cavity in the center of one end of a 1¼" diam cartridge to receive a No 6 electric detonator, which will be inserted when the operator is ready to fire. Cut the cartridge at right angles to its axis so that the column of expl at the end of the cartridge in which the cavity has been punched is 4" long. If the expl runs freely, place over the cuts small pieces of thin paper and fasten them in place with rubber bands. With the two cut ends facing each other, space the two halves of the cartridge the required distance apart by rolling them on a flat surface in a piece of manila paper 0.005 to 0.0055" thick, cut to such a length that each gap mark is 4" from the end of the paper and to such a width that it will wrap exactly 3 times around the cartridges. Hold the tube thus formed in place by means of carpet tacks and bring the temp of sample to 22 ± 5° C. Insert the detonator and fire it.

The greatest distance between the halves at which both of them detonate in four shots is termed the "sensitivity" and is expressed in cms; the min distance at which no explosion occurs in four trials is also detd. Finally, by four trials at each intermediate distance, the number of "explosions" and "no explosions" that occur is noted and recorded.

In the gap test described in Ref 5, p 68, cylindrical cartridges of expl 8" in length and 1.25" in diam are prep by pressing or casting equal wts of the expl into paper shells. Two of these are suspended vertically so that there is an air space between them and their axial lines are coincident. The space between the faces of cartridges is always a multiple of 1". A detonator is embedded axially in the lower end of the lower cartridge and used to initiate detonation in this cartridge. By repeated tests with varying air spaces, there is detd the max distance at which the upper cartridge can be detonated by the lower. This will be 1" less than the min distance at which three successive tests fail to detonate the upper cartridge.

The interposition of solid barriers such as wood or concrete decreases the max distance for sympathetic deton and this effect is very significant when small charges are involved (Ref 5).

Application of the gap test to detn of efficiency of detonators is described by Clark as one of the "Propagation Tests" (Ref 2a). For this test a 0.50 g chge of DADNPb (diazodinitrophenol) is placed in a No 8 detonator shell and pressed under a reinforcing capsule at 3400 psi. In a similar manner detonators contg 0.50 and 1.00 g chges of MF (mercuric fulminate) are prep. The test detonator is placed centrally in a cylindrical oaken shield, with its long axis parallel to and coinciding with the long axis of the shield.
and with its base flush with the end of the shield. A cartridge of 40% straight dynamite with its cut end facing the detonator across an air gap of known length, is wrapped together with the detonator in three turns of heavy paper. The max gap over which detonation can be transferred with certainty from the detonator to cartridge of dynamite is deter by four trials. (See also Booster Sensitivity Test and Wax-Gap Test). Refs: 1)E.Builot, MAF 9, 799(1930) 2)US Bur Mines Bull 346 (1931), 59 2a)L.V.Clarke, IEC 25, 668 (1933) 3) M.Dutour, MP 31, 74 (1949) 4)L.Médard, MP 33, 342-4 (1951) 5)TM 9-1910 (1955), 67-8

120° German Test (Erhitzungsprüfung bei 120° in Ge). This test, originally designed to be conducted at 135° to determine the stability of NC and propellants, was used to a considerable extent in Germany and in other countries. A 2.5g sample of NC or of smokeless propellant is placed in a test tube 350 mm long, 16 mm ID and 19 mm OD. A strip of blue litmus paper is inserted so that it is 25 mm above the expl. The tube is loosely closed with a cork, and inserted in one of the orifices in the cover of the bath contg boiling xylene and provided with a reflux condenser. The orifices are in the form of tubes 11 cm long, closed at the bottom and contg glycerin. The time of heating required to turn the litmus paper red is taken as an indication of stability. Then heating is continued until the appearance of brown fumes and may be further continued until explosion occurs. Refs: 1)R.F.Hunt (1938), 82 2)Kast-Metz (1944), 233-4

Granulation Test. The purpose of this test is to determine particle-size distribution. For this superimpose the required number and sizes of US Standard Sieves as required by the specification, in the order of decreasing size, placing the largest mesh on top and a receiving pan at the bottom. Place a 50 g portion of the sample on the top sieve, cover it, and shake mechanically (at 300-15 gyrations and 150-10 taps) or by hand, for 5 mins. Weigh the material retained on each sieve and calculate the percentage of the sample through each sieve and, if required, that retained on any sieve. Ref: Spec MIL-STD-286 (1956), Method No 506.1

Grotto's Test for Detonators, described by B.Grotta, IEC 17, 134-8(1925) consisted of firing the charges of an insensitive expl (such as a mix of TNT 92 with iron oxide 8%), placed on a lead plate 1.5 x 1.5" and 0.25" thick, with various strength detonators and observing the damage caused to the plate. It was found that the so-called "Reinforced Booster Type Detonators" (compd detonators contg MF,HgN₂+TNT) produced complete detonations in 100% of tests, while simple detonators (contg only MF) gave 90% of misfires (Compare with Esop's Test and Miniature Cartridge Test)

Halved Cartridge Gap Test. See under Gap Test

Heat of Combustion (Qc), Heat of Explosion (Qe) and Heat of Formation (Qf) will be discussed under Calorimetric Tests in Vol II.

Heat Tests (Thermal Stability Tests) include among others the following: 1)Abels' or KI Test (qv) 2)American Test at 65.0°C or 80°C (See Ref 2 p 80 and under Surveillance Tests in this section) 3)Angeli's Test (See Ref 2, p 90 and p 4403 of this volume) 4)Bergmann-Junk Test (qv) 5)Brane's Test (Ref 2, p 88) 6)Brunswig's Test (Ref 2, p 86) 7)Chiaraviglio & Corbino's (Ref 2, p 88) 8)Conductivity Method (Ref 2, p 91) 9)Continuous Stability Test (Ref 2, p 70) 10)Dehansoux Test (Ref 2, p 90) 11)Dupré's Vacuum Test (Ref 2, p 87) 12)Dutch Test (Ref 2, p 85) 13)German 135° Test (qv) 14)Guttmann's Test (Ref 2, p 78) 15)Haid, Becker & Dittmar's Test (Ref 2, p 92) 16)Heat Tests at 100°, 120° and 134.5° (qv) (Compare with German 135° Test) 17)Hess' Test (Ref 2, p 78) 18)Hoitsema's Test (Ref 2, p 78) 19)Horn-Seifert's Test (Ref 2, p 79) 20)International 75° Test (qv) 21)Jensen's Test (Ref 2, p 80) 22)Marquayrol's Test (Ref 2, p 90) 23)Meerscheide-Hüllessem's Tests (Ref 2, pp 85 & 89) 24)Methyl Violet Test (Ref 2, p 79) 25)Mitrasch's Method (Ref 2, p 87) 26)Mölt's Test (Ref 1, p 224) 27)Obermüller's Method (Ref 2, p 87) 28)pH Measurements (Acidity Measurements) are made on a 5g sample of expl after heating from 75° to 132° according to the nature of the expl, and the change in pH is noted. 29)Pollard's Test (Ref 2, p 80) 30)Resistance to Heat Test (qv) 31)Silvered Vessel Test (qv) 32)Simon Thomas' Test (Waltham Abbey Test) (Ref 1, p 225 & Ref 2, p 80) 33)Spica's Test (Ref 2, p 78) 34)Surveillance Tests at 65° or 80°C (qv) 35)Sy's Test (Ref 2, p 85) 36)Talliani's Test (qv) 37)Taylor's Test (Ref 2, p 82) 38)Tomonari's Test (Ref 2, p 91) 39)Vacuum Stability Tests (qv) 40)Vielle's Test (Ref 1, p 224 & Ref 2, p 78) 41)Warming-lademethode 75° (Ref 2, p 81) 42)Will's Test (Ref 1, p 225 & Ref 2, p 86) 43)Zinc Iodide Test (Ref 2, p 77) Refs: 1)Barnett (1919), 217-225 2)Reilly (1938), 70-93 3)PATR 1401, Rev 1 (1950), 12-18

100° Heat Test is one of the US standard stability tests. Transfer four weighed 0.60g portions of sample of known moisture content to each of four test tubes, 75 mm long and 10 mm diam, two of which have been tared. Place all tubes in an oven maintained at 100±1°. After 48 hrs remove two tared tubes, cool in a desiccator and weigh each tube. Replace the tubes in the oven and heat for the 2nd 48 hr period. Cool in a desiccator and weigh. Calculate the percentage loss in wt during each 48-hr period of heating and subtract the known percentage of moisture from wt lost during the 1st 48 hr period. Allow the untared test tubes to remain in the oven for 100 hrs of continuous heating and note if ignition or expln takes place. Refs: 1)PATR 1401, Rev 1 (1950), 13 2)TM 9-1910 (1955), 55-6

120° and 134.5° Heat Tests. The 120° test is used for testing the stability of HE's & double-base propellants, while the 134.5° test is used for single-base propellants and for nitrocellulose. In either case, weigh five 2.5g portions of the sample and place each in a heavy Pyrex test tube, 15 mm ID, 18 mm OD and 290 mm long. Insert a piece of std, normal methyl violet paper 70 mm long and 20 mm wide, vertically in each tube so that
the lower edge of paper is 25 mm above the sample. Stopper each tube with a cork through which a hole 4 mm in diam has been bored to prevent build-up of pressure inside the tube. Place the tubes in the appropriate const temp bath at 120.0±0.5° or 134.5±0.5°, which is so designed that no more than 7 mm of the tube projects above the cover. The bath is in the form of a cylindrical tube, provided with a perforated cover and reflux condenser. The bath is filled with aq glycerin d ca 1.21 for 120° and d 1.24 for 134.5° bath. Examine at 5 mins intervals each tube by lifting one-half of its length and replacing quickly. Record the time at which the test paper in any of the 5 tubes changes to a pink salmon color. Continue heating until any of the tubes explodes. Refs: 1)PATR 1401, Rev 1 (1950), 16-17 2)TM 9-1910 (1955), 243 & 245

Hemispherical Iron-Dish Test is one of the Fire Resistance Tests described under Sensitivity to Flame, Heat, Sparks, etc Tests

Hess' Brisance Test. See under Brisance (Shattering Effect) in Vol II

High Speed Optical Devices Used for Measuring Detonation Rates are mentioned under Detonation Rate Determination. Ref: Cook (1958), 22-35

High-Speed Radiography may be subdivided into: 1)Flash Radiography and 2)Continuous (or Streak) Radiography. The 1st has been very useful in studying the behavior of the collapsing liner and the jets from shaped charges, while the 2nd has been used in the study of solid explosives. Ref: Cook (1958), 35-6

Hollow Charge Efficiency Test. See Shaped Charge Efficiency Test

Hopkinson's Pressure Bar Test. The quantitative measurement of the press developed by expls over small intervals of time, which is a measure of expl violence, was made possible by application of the method conceived by Prof B. Hopkinson. The application of Hopkinson's principle to a wide field of research; such as initiation of deton, properties of the deton wave, and the design of detonators & fuses; and the design of a variety of instruments were carried out by physicists of the Res Dept, Woolwich, England

The principle on which the determination of press is based depends on the fact that when a charge is fired against the end of a cylindrical steel bar ballistically suspended, a wave of compression travels along the bar and is reflected at the far end as a tension wave. In order to investigate the properties of the wave, a short length of the bar farthest from the charge is cut off, the ends are surfaced, and the pieces are joined by a film of vaseline. The compression wave travels unchanged through the joint into the short bar (known as the time-piece), but the film is unable to transmit the tension wave. Hence, when the amplitude of the reflected tension wave reaching the joint becomes greater than that of the original compression wave, the time-piece is projected with a momentum which depends on the expl press developed and the time to traverse the short bar. By the use of time-pieces of different lengths, it is possible to approximate the maximum pressure developed, and to calculate mean pressure values over various time intervals. In order to protect the instrument it is necessary to interpose a pellet of standardized material between the test expl and the pressure bar. Refs: 1)B. Hopkinson, PhilTrans 213A, 437(1914) 2)R. Robertson, JCS 119 I, 19-24(1921) 3)J. L. Sherrick, ArOrds 24, 330(1924) 4)Marshall 3 (1932), 155-7

Humidity Test. See Hygroscopicity Test

Hygroscopicity (or Humidity) Test (Absorption of Moisture Test) (Reprise d'humidité, Essai, in Fr) (Hygroskopizität- or Feuchtigkeit Probe, in Ger). The hygr nature or property of a material to absorb moisture from its environment must be known if an expl is to be considered for military or commercial use. Absorption of moisture can have an adverse effect on the sensitivity, stability, or reactivity of expls. This property should be negligible to very low absorption for most expls

In one test procedure a weighed sample of known granulation, if solid, is exposed to predetermined conditions of temp and humidity until equilibrium is attained. In cases where either the rate of absorption is very low, or large amounts of water are picked up, the sample is exposed for a stated time, for example, 24 hrs. The exposed sample is then reweighed and the moisture absorbed is expressed as % hygroscopicity

French hygroscopicity tests, known as: a)Reprise d'humidité de l'explosif en vrac (Taking up moisture by an explosive in bulk) and b)Reprise d'humidité en atmosphère saturée d'eau des explosifs encartouchés (Taking up moisture by cartridged explosives in atmosphere saturated with water) are described in Ref 4 Refs: 1)Marshall 2 (1917), 416-9 2)Barnett (1919), 214 3)Davis (1943), 313 4)A. M. Lavergne, MP 33, 325-7 (1951) 5)TM 9-1910(1955), 10-2 6)PATR 1740, Rev 1(1958)

Ignition (or Explosion)Temperature Test; Ignition Point Test (De/lagration Temperature or Flash Point Test) (Entzündungstemperatur; Explosionstemperatur or Entzündungspunkt Probe, in Ger); (Essai de déflagration, in Fr). Heat causes the decomp of all expls at a rate which varies with the temp. Almost all expls have a critical temperature below which the rate of decomp is small to negligible. One measure of the relative sensitivity of expls to heat is detd by means of the ignition or explosion temperature test

The procedure, in one test, is to immerse a fixed depth in a bath of Woods' metal, a metal blasting cap containing 0.02 g expl sample. The molten bath is maintained at a controlled temp by means of an electric furnace. A number of tests is made with the bath at various temps so as to produce flashes or explosions over a range of 2 to 10 seconds. The data so obtained are plotted as a time-temp curve and from this curve is found the temp to cause ignition or explosion in 5 seconds (Refs 5,7,8,9,10&11)
Another method is to place an expl sample directly on the molten Wood's metal bath or other metal surface heated at a controlled temp. The temp of the metal surface is increased until a value of 0.1 sec for ignition or explosion is estimated by the observer as an almost instantaneous interval of time (Refs 9, 10 & 11). Other methods are described in Refs 1, 2, 3a & 4). Refs: 1)Marshall 2, (1917),435-7 2)Barnett (1919),213 3)M.M.Kostevitch, SS 23, 156(1928) 3a)Venin, Burlot & Lécorce(1932),211 4)Stettbacher (1933),373 5)L.V.Clark, IEC 25, 668 & 1389(1933) 6)Reilly(1938),66 & 83 7)Davis(1943),21 8)OSRD Rept No 1966(1943) 9)PATR 1401, Rev 1(1950), 10)TM 9-1910(1955),50 11)PATR 1740, Rev 1(1958) Ignition(or Explosion) Time Tests(at Constant Temperatures). In some cases the explosion is maintained at constant temp and the time to explosion is measured. Same type of apparatus can be used for Ignition Temperature Test. Patterson(Refs 18 & 3) det the relationship between time to ignition and temp and showed that the lower the temp the longer was the time reqd for ign of propellant s. Wiggam & Goodyear(Ref 2) have made a critical study of the explosion-time test. Refs: 1)G.W.Patterson, SS 5, 49(1910) 2)D.R. Wiggam & E.S.Goodyear, IEC,AnalEd 4, 77(1932) 3)Reilly(1938),83 Impact-Friction Pendulum Test is briefly described, p A354, Note d), under Ammonium Nitrate Ref: Spencer Chemical Co, "Safety Data," Kansas City, Mo(1960)
Impact Sensitivity or Shock Sensitivity Test(Drop Weight or Falling Weight Test) (Sensibilité au choc du mouton, in Fr) (Stossempfindlichkeit or Fallhammer-Prob, in Ger) (Prueba al choque or Prueba de la caída de un peso, in Span) (Determination della sensibilità all' urto o Saggio alla Berta, in Ital). This test was designed to determine the sensitivity(resistance) of expls to shock(impact). The information obtained by this test is considered most valuable, as it gives assurance of safety of handling, transportation and use.
Essentially, the test consists of placing a small amt of expl on a surface of a stationary steel block( anvil) and then striking the sample by allowing a certain load(called hammer) to drop on it from a designated height. The max height that a substance can withstand without exploding or deflagrating is considered the impact value. The greater the fall of the hammer of the same wt, the less sensitive to impact is the expl.
It seems that one of the first successful impact machines was constructed in Germany by F. Lenze, who described it in Ref 1. This apparatus is also briefly discussed by Marshall(Ref 2), Stettbacher(Ref 8) & P372 gives a brief description of the apparatus called Fallhammer nach Kas(Hsee also Ref 11)
The US Bureau of Mines constructed several models, small and large(Refs 5, 13 & 15), which seem to be similar to the German machines. With the Bureau of Mines Small Impact Apparatus, tests are conducted as described in Refs 5, 13 & 16. One of such machines is installed at Picatinny Arsenal. The max wt of the hammer is 2 kg and the maximum height is 100 cm. This app uses unconfined samples of expl, each weighing 0.02 g. This machine gives consistent results for fairly sensitive expls, but for expls such as TNT, the results are not very reliable. Note: Considerable efforts were made during WWII to place impact testing on a more fundamental basis both from the suitability of the apparatus used to give reproducibility and the reliability and mathematical interpretation of results(See Refs 10, 13 & 17)
More consistent results than some obtained with the B of M machines are obt with an apparatus used for many years at Picatinny Arsenal(Refs 4, 13, 15 & 16). With this machine, known as Picatinny Arsenal Impact Apparatus, samples are tested under confinement and results are reported in inches. The usual weight hammer is 2 kg for HE's and smaller wts of 1 lb or 8 oz for initiating expls. For a description of apparatus and procedure, see Refs 13, 15 & 16
Both the US B of M and PA Impact Machines have been used at Picatinny Arsenal for the testing of liquid expls, with a modification in sample handling required only in the case of the BM apparatus(Refs 12a & 16)
Dr Rotter of the Research Dept, Woolwich, England, designed an apparatus and a method of testing(Refs 3 & 6), which is claimed to be more accurate than other known methods. This is now an official British test and the value obtained is known as FI(Figure of Insensitiveness) (qv)
Index of inflammability. This is a measure of the likelihood that a bare charge will catch fire when exposed to flames. The test is made by bringing an oxyhydrogen flame in contact with the sample. The max time of exposure which gives no ignition is 10 trials and the minimum exposure which gives ignition in each of 10 trials are determined. The index of inflammability is 100 divided by the mean of the two times in seconds. The most inflammable substances have high indices, such as 2.50. (See also Sensitivity to Flame, Heat, Sparks, etc Tests) Ref: PATR 1740, Rev 1(1958)
Inflammability Test. See Index of Inflammability Test and under Sensitivity to Flame, Heat, Sparks, Electrostatic Discharges, etc.

Influence Tests. See Detonation by Influence Tests

Initial Velocity (Muzzle Velocity) Determination. See under Ballistics, External in Vol II

Initiating Efficiency (or Strength) of Detonators by the Miniature Cartridge Test. This test developed at the US BurMines consists of loading, at a constant packing density, a 5 g charge of an insensitive expl (such as a homogeneous TNT-Iron Oxide Mixture) into a paper cartridge ½" ID and 2½" long. After inserting the detonator to test into the cartridge, the ensemble is fired in the center of 1000 g of Ottawa sand placed in a steel bomb of 3" ID. The crushed sand which passes through a No 30 US Std Sieve (see Table 1, p 6474) is weighed and from this is subtracted the value for detonator alone (blank), which is obtained by similarly firing a miniature cartridge containing 5 g of pure iron oxide and the same type of detonator. The difference in crushed sand thus derived represents the initiating efficiency of the detonator. Ref: US BurMinesTechPaper 677(1945)

INITIATING EFFICIENCY (INITIATING VALUE OR STRENGTH) OF INITIATING EXPLOSIVES, BLASTING CAPS AND DETONATORS, DETERMINATIONS (Essais des amorces, in Fr) (Grenzinizialen, in Ger). Initiating efficiency (strength or value) can be expressed in terms of min wt of primary (or initiating) expl or in smallest No of blasting cap or detonator required to cause max detonation of a HE. This can be deter by one of the following methods: a) Esop's Test (qv) b) Gap Test (qv) c) Grotta's Test (qv) d) Lead Plate Test (see under Plate Tests) e) Miniature Cartridge Test (see previous item) f) Nail Test (qv) g) Optical Method (qv) h) Sand Test (see next item) i) Small Lead Block Compression Test (see Esop's Test) j) Small Lead Block Expansion Test (see under Trauzl Tests) k) Sound Test (qv) (Compare with Sensitivity to Initiation by Initiating Explosives, Detonators and Boosters Tests). Refs: 1) Marshall 2, (1917), 530-2 2) H. Kast & A. Haid, SS 19, 146 & 160(1924) 3) L. Wöhler, SS 20, 145 & 165(1925); SS 21, 1, 35, 55, 97 & 121(1926) 4) W. Friederich & P. Vervoort, SS 21, 51(1926) 5) L. Wöhler et al, SS 22, 95(1927) 6) B. Cserneczky, SS 24, 169-72(1929) 7) A. Haid & H. Koenen, SS 25, 393, 433 & 463(1930) 8) Marshall 3, (1932), 163-4 9) Steettbacher(1933), 361 10) Reilly(1938), 69-70 11) Perez Aza(1945), 121-3 12) PATR 1401, Rev 1(1950), 12 13) TM 1910(1955), 64 (Initiating Value)

Initiating Efficiency (or Strength) of Primary Explosives by Sand Test. Using 0.400 g charges of tetryl and 0.400 g of the initiating explosive under test, det the wts of sand crushed by initiator alone and by initiator + tetryl. Subtract from the last value, the amt crushed by 0.400 g of initiator and record this as the value crushed by the tetryl. Repeat the test with initiator + tetryl a total of 5 times and compare the results. If the values for tetryl do not vary by more than 3.0 g and the av of these is within 2.0 g of the av value for tetryl obtained with 0.300 g of LA as an initiator, consider it as the maximum. Repeat the test using smaller amts (0.350 g, 0.300 g etc) of initiator (and always 0.400 g of tetryl) until the minimum is reached. (Compare with Sensitivity to Initiation by Detonators, etc). Refs: 1) L. V. Clark, IEC 25, 666(1933) 2) PATR 1401, Rev 1(1950), 12

Initiating Power. Same as Initiating Efficiency

Initiating Strength. Same as Initiating Efficiency

Initiating Value. Same as Initiating Efficiency

Initiation Sensitivity by Electrostatic Discharges or by Sparks. See under Sensitivity to Flame, Heat, Sparks and Electrostatic Discharges

International 75° Test is one of the common stability tests for expls. Place two samples of 10 g each in tared weighing bottles 35 mm diam and 50 mm high, cover them and weigh. Heat the loosely covered bottles for 2 hrs at 75°C in a desiccator and weigh. Calculate the loss of wt as % of volatility of sample. Note if the material undergoes decomposition or is markedly volatile as indicated by discoloration, the appearance of brownish fumes, etc. Refs: 1) Reilly(1938), 80 2) PATR 1401, Rev 1(1950), 13 3) TM 9-1910(1955), 55 Iron Oxide-TNT Test for Detonators. See Grotta's Test and the Initiating Efficiency of Detonators by the Miniature Cartridge Test

Kast Brisance Meter is an apparatus for measuring the brisance by compression (crushing) of a copper cylinder. It will be discussed in Vol II, under Brisance Meter of Kast

Kast Value or Brisance Value of Kast Test will be discussed in Vol II, under Brisance Value of Kast

KI-Heat Tests or KI-Storch Tests. See Abel Test, p A2 of this volume

Kraftszahl (KZ) Probe (Strength Number Test) is a German modification of Trauzl Test. Ref: PATR 2510 (PB 161270)(1958) p Ger 102

Lead Block (or Cylinder) Compression (or Crushing) Test (Lead Block Test or Hess Test) (Stauchprobe nach Hess, in Ger) (Épreuve au block de plomb, in Fr) is one of the German tests for brisance, also called percussive force. It will be described in Vol II, under Compression Tests

Lead Block Expansion Test. See Trauzl Test

Lead Plate Test. See under Plate Tests

Length and Duration of Flame Test (Größe und Dauer von Sprengstoff-Flammen Probe, in Ger). See Flame Test
Maximum Available Work Potential is discussed in Cook(1958), 36-7
Maximum Potential Work is the same as Brisance Value of Hoyt
Maximum Pressure of Explosion (Maximum Pressure of Gases Developed on Explosion) (Maximale Explosions-
druck or Gasdruck, in Ger). See under Pressure of Explosion
Mechanical Shock may be of two types: shock due to friction and shock due to impact. These tests are de-
scribed under Friction Tests and under Impact Tests. Ref: Barnett (1919), 208
Miniature Cartridge Test. See Initiating Efficiency of Detonators by the Miniature Cartridge Test
Miniature Charge Techniques for detn of detonation velocity is briefly discussed in Cook (1958), 41-2

B. Mortar Test (Épreuve de tir au mortier or Essai au mortier éprouvette, in Fr) (Mörserprobe, in Ger). A device used both in England and France essentially consists of a large cast-iron, solid cylindrical block securely fixed on a concrete foundation and set with its axis at elevation of 45°. The upper face of the block contains a cylindrical bore, 125 mm diam and 85 mm deep, and on the bottom of this bore is a smaller bore serving as a receptacle for 10 g charge of expl to test. A 15 kg cylindrical cast-iron shot 123 mm diam and 125 mm high, perforated in the center to allow the passage of fuse, is inserted in the bore above the charge of expl and the fuse is ignited. Instead of a fuse an elec detonator with wires passing through the perforation in the shot can be used. The distance that the shot is thrown is measured and compared with that obtained with 10 g of a std expl of the same nature. With this device blasting gelatine gave 240 meters, gelatine dynamite 188 and Brit permitted expts 80 to 120 m (Ref 1)

Same method as in France has been used in Spain and the device is called mortero probeta (Refs 3 & 4). According to Ref 3, the test with mortar permits calculation of the travail utile de l'explosif (useful work of the explosive). This is called in Ref 4 medida del potencial o efecto útil de un explosivo


Munroe-Neumann Effect Test. See Shaped Charge Efficiency Test
Muzzle Velocity (Mündungsgeschwindigkeit, in Ger) or Initial Velocity Determination will be discussed in Vol II under Ballistics, External

Neill Test (Essai al clou, in Fr) (Nadel Probe, in Ger) (Prueba de la puntilla, in Span). A simple, cheap, and accurate test to determine the relative efficiency of detonators and one suitable for use in the field is called the nail test. In this test a wire nail is fastened to the side of a detonator suspended horizontally in the air and the detonator is fired. The angle to which the nail is bent is measured to the nearest 0.25° and the average of five tests is the computed result. Four-inch wire finishing nails of approximately the same length, gage and weight are used in the test. Refs: 1) US BurMines Bull 59, (1913), 25 2) US BurMines Bull 346, (1931), 113 3) Stetthachez (1933), 354 4) Davis (1943), 421 5) Pérez Ara (1945), 123

Normal (or Specific) Volume. See under Volume of Gases Evolved on Detonation (or Explosion)
Optical Method for Testing Cans consists in photographing the flashes produced on explosion. (Compare with Flame Test). Refs: 1) H.E. Brownson, JSCI 24, 381 (1905) 2) W.D. Borland, JSCI 25, 241 (1906) 3) Reilly (1938), 70

Pendulum Friction Device Test. See under Friction Sensitivity Tests

Percussive Force of an Explosive can be defined as the capacity of an explosive to produce compression or disruption when it explodes under atmospheric confinement only. Percussive force is manifest only in HE's and can be measured by detonating unconfined expls on top of a steel plate covering a small lead block. The compression of block is approx proportional to propulsive force (Ref 1). According to Refs 2 & 3, the 'relative percussive force' is identical with 'relative brisance.' Refs: 1) US BurMines Bull 346, (1931), 106-7 2) Vennin, BurMines Bull 346, (1931), 190 3) L.V. Clark, IEC 25, 1389 (1933)

Permissibility Tests in Galleries are described in Refs listed under Galleries For Testing Permissible Explosives. The US BurMines Tests are described in Bull 346, (1931), 49-59 and other publications of the B of M

Plate Denting Tests, although not actually involving shattering by expls, are used as measures of brisance. In these tests the effect of a cylinder of expl when detonated in contact with a steel plate, is detd under such conditions that the more powerful expls depress and dent but never puncture or shatter the plate, while less powerful expls merely dent or bend it

Plate denting tests used at ERL, Bruceton, Pa have been conducted by two methods:

Method A. A 20 g charge of expl is cast or pressed in a copper cylinder of ¾" ID and ¾" wall. The loaded tube is placed vertically on a 4" square piece of cold-rolled steel plate, ¾" thick, supported by a short length of heavy steel tubing, placed in a vertical position. The expl charge is boostered by a 5 g pellet of tetryl which in turn is initiated by a No 8 detonator (Refs 1,3 & 4)

Method B. A modification of Method A involves firing a 1¾" diam by 5" long uncased charge of expl on a lightly greased 1¾" thick, 5" square cold-rolled steel plate, with one or more of similar plates used as backing. The charge is initiated with a No 8 detonator and two 1¾" diam, 30 g tetryl pellets as boosters (Refs 2 & 4)
The depth of dent in both test methods is measured within 0.001 to 0.002" and a measure of the relative brisance or plate denting value, X, is calculated from the formula

\[ X = \frac{\text{Test Sample Dent Depth}}{\text{Dent Depth for TNT}} \times 100 \]

Data obt'd by Method A are summarized in Refs 1, 2, 3 & 4 and data obt'd by Method B are given in Refs 2 & 4. Refs: 1) OSRD Rept 804 (1942), 29-31 2) OSRD Rept 5746 (1945), 20-2 3) TM 9-1910 (1955), 61-2 4) PATR 1740, Rev 1 (1958)

Plate Tests include Plate Cutting and Plate Denting Tests (Plattenproben or Durchschlags- und Strahlungs- Proben, in Ger) and use brass, copper, iron, lead and steel as materials for plates. The tests are used either for dent of brisance of expl or for dent of efficiency of detonators. Essentially the tests consist of detonating a test item in the center of a plate supported at both ends. This may either dent the plate or cut it (puncture), and these damages serve as criteria of brisance or efficiency. When testing a detonator on a lead plate the strength is judged not only from the size of dent or hole made, but even more from the number and depth of the striations on the surface of the lead made by the minute particles of metal (such as copper) from the capsule of detonator (Ref 1a) (See also Refs 2a & 6)

The Steel Plate Denting Tests used in the US are described above, while other plate tests are discussed in the following references: Refs: 1) Marshall 2, (1917), 501 (French method involving detonation of a charge 100 to 200 g of expl in the middle of a soft steel plate 500×500×25 mm thick, resting on two supports 400 mm apart, and measuring the depth of dent produced) 1a) Marshall 2, (1917), 530 (Testing of detonators by lead plate test) 2) B. Grotta, Chem Met Eng 25, 1126-32 (1922) (The lead plate test as applied to commercial detonators) 2a) H. Kast & A. Haid, SS 14, 166 (1924) 3) A. V. Clark, IEC 25, 1366-7 (1933) (Same lead plate test as in Ref 2) 4) Stebbach (1933), 361 (Brief discussion on uses of iron, brass, and copper plates) 5) Vivas, Feigenspan & Ladreda 4, (1944) (Lead plate tests called by them in Spain "Pruebas sobre las planchas de plomo") 6) P. A. Perez Ara (1945), 121-4 (Lead plate test called by him in Spain, "Prueba de la placa de plomo," described in detail) 7) Stebbach (1948), 89 (Plate test using 10 mm thick iron plate) 8) Stebbach (1952), 115 & 141 9) Belgrano (1952), 51-2 (Steel plate test, called in Italy, "Prova della piastra di acciaio")

Potential (Potentiel or Effet utile, in Fr). According to definition given in Refs 1 & 2 it is equal to Q×425 kg/m, where Q is heat of expln in Kcal/kg and 425 is mechanical equivalent of heat. This unit is identical with the maximum quantity of work that can possibly be done by a unit weight of the explosive.

A slightly different definition is given by Mursou (Ref 3): the potentiel de l' explosif is equal to Q×428, where Q is the heat evolved on decomposition of 1 kg of explosive and 428 is the mech equiv of heat.


Power of Explosive is defined by Barnett (Ref 2) as "its capacity for doing useful work." Power may also be defined as energy x time. The value called in France rendement pratique or effet utile corresponds approx to "power." The Fr value can be calculated as has been done in France either as potentiel (potential) or as produit caracteristique de Berthelot (characteristic product of Berthelot)

Power is usually defined in terms of one or several of the following experimental methods: a) Ballistic Mortar Test (q.v.) b) Ballistic Pendulum Test (q.v) c) Cratering Effect Test (q.v) d) Mortar Test (q.v) e) Quinan Test (q.v) f) Trausl or Lead Block Expansion Test (q.v), and its modifications CUP and Kraftzahl.


Pressure-Boat Apparatus of Hopkinson. See Hopkinson Pressure-Boat Apparatus

Pressure of Gases Developed on Combustion of Propellants or Explosives can be detd either by calc or by combustion in a closed vessel (combustion en vase clos, in Fr), as described by H. Muraour, "Poudres et Explosifs," Paris (1947), 73-4

Pressure of Gases Developed on Explosion or Detonation is an important factor because it serves as a measure of the capacity of an expl to do work, although the character of the work is detd by the rate at which this pressure is built up

Pressure of gases can be either calc or approx detd experimentally by detonating a sample in one of the following devices: Bichel Bomb, Krupp Bomb, Noble and Abel Recording Pressure Gage, Petavel Recording Manometer, Piezoelectric Gages, etc. (See also Bichel Bomb and Detonation Pressure). Refs: 1) Marshall 2, (1917), 444-7 2) US Bull Mines Bull 346, (1931), 84 3) Marshall 3, (1932), 133 4) Vennin, Buriot & Lecorce, (1932), 50-3 & 72-86 5) Stebbach (1933), 69 6) Vivas, Feigenspan & Ladreda 4, (1944), 20-29, 85-6 & 98-104 Primary Explosives, Initiating Efficiency. See under Initiating Efficiency of Primary Explosives, Blasting Caps and Detonators

Produit Characteristique (Fr). See Characteristic Product

Propagation of Detonation. See Ability to Propagate Detonation, in this section
Propagation Test. Under this name is described by L.V. Clark, IEC 25, 668 & 1389 (1933) an application of the gap test (y) for testing the efficiency of detonators.

Propulsive Force. According to L.V. Clark, IEC 25, 1388 (1933), the relative propulsive force can be deducted either by ballistic pendulum test or by Trauzl test, the usual tests for definition of power of explosives.

Quickness (Vivacité, in Fr) of Burning of Propellants, Determination is described by H. Muraour, "Poudres et Explosifs," Presses Universitaires de France, Paris (1947), 90-92, as well as in his other papers published in MP and MAF.

Quinon Test permits determination simultaneously the brisance and the work performed on detonation of an expl. This value is called in Fr ‘‘potential’’ and may be considered as being approx proportional to power. The apparatus consists of two cylindrical steel blocks placed one on top of the other and guided vertically by four steel rods imbedded in the base. The top of the lower block is provided with a central cavity to hold 1-2 g of expl and a small electric detonator. The upper block is perforated in the center to allow the passage of electric wires and it is also provided with a device (such as a ratchet) permitting the block to be held in any position, but not interfering with its movement upwards. A steel plate is placed on top of the base and a small solid lead cylinder (crusher) is inserted between the plate and the bottom of the lower steel block. After inserting the charge with detonator, the upper steel block is lowered on top of the lower block and the charge is fired. The pressure of expl will push the lower block down compressing the lead cylinder located underneath and will lift simultaneously the upper block to some position in which it will be held by the ratchet. The diminution in height of lead cylinder is taken as a measure of brisance and the height to which the upper block is lifted as a measure of potential or work, which is practically the same as power.Refs: 1) Vennin, Burlot & Lecorch (1932), 192-3 2) Pepin Lehalleur (1935), 63 3) Pérez Ara (1945), 118

Red Iron Test is one of the Red (Epreuve du premier rouge). Place in each of five test tubes, near the bottom, a rolled strip of blue litmus paper, followed by a clean test tube, a rolled strip of blue litmus paper, followed by a small solid lead cylinder (crusher) is inserted between the plate and the bottom of the lower steel block. After inserting the charge with detonator, the upper steel block is lowered on top of the lower block and the charge is fired. The pressure of expl will push the lower block down compressing the lead cylinder located underneath and will lift simultaneously the upper block to some position in which it will be held by the ratchet. The diminution in height of lead cylinder is taken as a measure of brisance and the height to which the upper block is lifted as a measure of potential or work, which is practically the same as power.

Relative Propulsive Force of an Explosive. See Propulsive Force of an Explosive.

Relative Percussive Force of an Explosive. See Percussive Force of an Explosive.

Relative Propulsive Force of an Explosive. See Propulsive Force of an Explosive.

Reprise d'humidité, Essai (Fr). See under Hygroscopicity Tests.

Resistance to Heat Test (Epreuve de la résistance à la chaleur). This Fr ‘‘Official’’ test for determination of stability of NC or of smokeless propellants is conducted in a thermostatically controlled oven, ‘‘type d’Arsenal,’’ NC is tested at 108.5° and propellants at 108.5° and 109°, both with std blue litmus paper. The test is conducted in the following two stages: a) Test to the First Red (Epreuve du premier rouge). Place in each of five clean test tubes, near the bottom, a rolled strip of blue litmus paper, followed by a 10 g sample of propellant in small grains. Stopper the tubes and place them in the oven. Note the time of beginning change of color of paper to red. Cool the sample and save it until next day. b) Test for Total Resistance (Epreuve à la résistance totalisée). Replace the blue litmus paper with a new strip and continue heating in the oven until the change in color to red. Record the time and leave the sample at RT for at least 2 hrs (preferably overnight). Change the paper and heat the sample as above, etc. During these tests, one will observe that the intervals between beginning of heating and appearance of red color become shorter and shorter. As soon as this becomes one hour or less, stop the test and discard the sample. Count the total time of heating required to arrive at this point and this gives RT. Do not count the time between heatings. Ref: Book of Instructions issued by the Commission des Substances Explosives,' Chapitre III, Articles 95-107 and Chapitre IV, Articles 230-1.

Rifle Bullet Test (Beschussprobe, in Ger). See Bullet Impact Sensitivity Test.

Rotter Impact Test. See FI (Figure of Insensitivity) and also under Impact Tests.

Sand Test or Sand Crushing Test (Sandprobe, in Ger) (Essai au sabre, in Fr) (Prueba de la arena, in Span). This test, devised by W.O. Snelling in 1910 and studied extensively by C.G. Storm & W.C. Cope (Ref 1), is considered to measure the shattering (disruptive) power of an expl called brisance.* This characteristic is important because it determines the effectiveness with which an expl can fragment a shell, bomb casing, grenade or warhead of a rocket.

The sand test consists essentially in detg the amt of standard sand (supplied by the Ottawa Silica Co, Ottawa, Ill), crushed by a std wt (usually 0.400 g) of expl. The original sand passes through No 20-mesh sieve (US Std) and contains no particles smaller than No 30-mesh. The test is conducted in a cylindrical steel bomb, 3/4" in diam, 8 1/2" with cylindrical cavity 1/2" diam and 6" deep. Procedure: Transfer an accurately weighed 0.400 g portion of test expl, of such granulation as to pass through a No 100 sieve, to each of five empty No 6 commercial blasting cap shells (of Cu, Al or gilding metal) held during transfer in loading block. Insert in each shell a reinforcing cap provided with a small hole in the center and by means of a plunger subject the charge (previously placing it behind a barricade) to a pressure of 3000 psi for 3 mins. With a pin, prick the powder train in one end of a piece of miner's black powder fuse 8-9" long and crimp to the pricked end one of the above loaded No 6 caps, taking care that the fuse is held firmly against the

*According to W.R. Tomlinson, Jr, formerly of PicArsn, sand test det "energy'' rather than brisance.


If the expl chge cannot be initiated by flame, it is pressed without insertion of the reinforcing cap. Then a 0.300 g chge of LA is placed on top of the expl, followed by the reinforcing cap and another compression at 3000 psi. Then the fuse is inserted and the chge initiated as above. After detg the amt of sand crushed by these caps, subtract the wt of sand crushed by 0.300 g LA, when loaded alone in No 6 caps.

A modification of this test applicable to liquid expls is described in Ref 9, pp 9 & 11. The sand test may also be applied to detg the amt of LA and/or tetryl, that must be used as initiator or booster to insure that the sample crushes the max net wt of sand. This is designated as sensitivity to initiation test. (See also Initiating Efficiency of Primary Explosives by Sand Test.) Refs: 1)US BurMines TechPaper 125(1916) 2)US BurMines RI 2558(1923) 2a)H.Kast & A.Haid, SS 18, 166(1924) 3)US BurMines RI 3039(1930) 4)US BurMines Bull 346, (1931),109-13 5)L.V.Clark, IEC 25, 664 & 1387(1933) 6)ORSRD Repts 803 & 804 (1942),24-7 7)Davis(1943),422-3 8)Pérez Ara(1945),124 9)PATR 1401, Rev 1(1950),7-12 9)TM 9-1910 (1955),60-10 10)PATR 1740, Rev 1(1958)

SAND TEST for Detonators: See Initiating Efficiency of Detonators by Miniature Cartridge Test and also under Initiating Efficiency of Primary Explosives by Sand Test

Sensitivity to Detonation by Initiating Agents. See Sensitivity to Initiation by Detonators and Boosters


SENSITIVITY TO FLAME, HEAT, SPARKS, ELECTROSTATIC DISCHARGES, ETC. These tests may be found listed in the literature under titles Burning Tests, Combustion, Fire Resistance Tests, Fire Tests, Index of Inflammability Test, Inflammability Tests and other names.

US Bur of Mines(Ref 3) describes the following tests, under general title Fire Resistance Tests:

a)Fuse Test. Insert an 8' long piece of squarely cut burning fuse into a test tube 3/4" x 7' (clamped on a stand) with spit end against 3 g of the expl. Ignite the projecting end of the fuse and observe the behavior of the EXPL. 20-30 MESH

DETONATOR

FUZE

BLACK PWD

RUBBER TUBE

120 Gr STD

OTTAWA SAND

20-30 MESH

60 Gr STD

OTTAWA SAND

20-30 MESH

charge in the cap. Pour into the bomb 80.0 ± 0.1 g of std sand and level it by striking the bomb with a hammer. Lower the cap into the bomb so that the cap is centered at the axis of the bomb and just touches the sand. Pour 120 ± 0.1 g of sand being careful not to disturb the position of the cap. Pass the upper end of the fuse through a tightly fitting rubber tubing which is then inserted in the hole of the bomb cover. Lower the cover into position and fasten it securely by means of two bolts with nuts. Ignite the fuse and after expln of chge, remove the cover. Transfer the contents of the bomb to a piece of glazed paper, cleaning the bomb and cover thoroughly. After removing pieces of cap and burnt fuse, transfer the sand to a No 30 sieve fitted with a bottom pan and a cover and shake for 3 mins on a mechanical shaker. Weigh to 0.1 g the sand which passed through the sieve and record the average of all five values. This wt is the sand test value or brisance value.
explosion behind a safety glass. b) Hemispherical Iron-Dish Test. After heating an iron dish of hemispherical form; 4" in diam with a bottom 0.033" 0.007" thick, to a red heat, drop (by means of a mechanical charging device operated behind a safety glass) on the bottom of the disk a charge of expl, not more than 0.5 g. If the last charge does not detonate, increase the quantity by 0.5 g increments up to 5 g. The point of "no explosion" is detd by trials in which no expn occurs with "a point of expln" occurring for a sample 0.5 g higher in weight. c) Red Hot Iron Test. Heat to cherry-red (ca 900°) an iron bar 15 mm in diam over 10 cm of its length and bring it in contact with a small quantity expl placed on an asbestos board. If the expl burns without detonation, repeat the test using a 100 g charge placed on an asbestos board. A permissible exp is considered to pass the test when it burns without deton and extinguishes itself when the source of heat is withdrawn. The iron bar should be brought in contact with the expl by a mechanical device while the operator is protected by a safety glass (Ref 3).

Similar tests are listed by Barnett (Ref 2) as Fire Tests.


Sensitivity to Initiation by Primary (or Initiating) Explosives, Detonators and Boosters, Tests (Sensitiveness to Detonation by Initiating Agents) (Sensibilité à l'amorce Essais, in Fr) [Zünd-(Initiier)-Vermogen Proben, in Ger] (Eficencia como agente iniciador, Pruebas, in Sp) (Sensibilità all' innescamento, Saggi, in Ita). Sensitivity to initiation of a HE can be expressed as the min weight of an initiating explosive required for complete detonation. It can also be expressed in the smallest No of a detonator required for complete detonation. If initiation of a HE cannot be achieved by a detonator alone and a booster is required, the min wt of booster expl and its name must be indicated.

The tests are essentially the same as listed under Initiating Efficiency of Initiating Explosives, etc.

In the US the sensitivity to initiation is conducted by the sand test using diminishing wts of an initiator, such as LA (lead azide), until there is obtained the min wt which will cause complete detonation of 0.40 g of powdered HE's when pressed in a blasting cap shell under a pressure of 3000 psi. When a HE (such as ammonium picrate) cannot be detonated by LA (or by other initiating expls) alone, the test is repeated by detonating 0.40 g of HE with a composite detonator consisting of 0.200 g LA and tetryl as a base charge. By repeating the tests with diminishing wts of tetryl, the min wt required to detonate the HE is detd (Refs 1 & 3).

In the Fr test, called "sensibilité à l'amorce," described in detail by Mérard (Ref 2) a 50 g sample of expl HE contained in a Kraft paper cartridge, 30 mm diam and provided at one end with a mercury fulminate detonator and picric acid booster is laid horizontally on a lead plate 12×15 cm and 15 mm thick, resting on a steel plate at least 1 cm thick. After firing the cartridge, the appearance of the lead plate is observed. If the detonation is complete, the impression in the part of the plate farthest from the detonator would be somewhat deeper. In this case it is required to repeat the test using either a smaller detonator or a smaller booster. If the detonator is too small to achieve complete detonation, a larger size should be tried until detonation is complete. Refs: 1) PATR 1401, Rev 1 (1950), 7-11 2) L. Mérard, MP 33, 339-42 (1951) 3) TM 9-1910 (1955), 52-3 (See also Refs under Initiating Efficiency of Initiating Explosives, etc)

Setting Point Determination is described under Sodium Azide, Plant Analytical Procedures, p A613

Shaped Charge or Hollow Charge Efficiency (Cavity Charge Performance of Munroe-Neumann Effect). This term is applied to explosive charges with lined or unlined cavities formed in the charge opposite to the end of initiation. The lined or unlined hollow charge effect is sometimes referred to as simply cavity effect. A flat end explosive of high brisance produces a dent in a hard steel plate; the same explosive using the unlined cavity effect of Munroe-Neumann, erodes the target forming a smooth shallow crater; and a lined cavity in the same explosive and charge size produces a deep, narrow V-shaped hole in the steel plate. The application of this phenomenon represents one of the major advances in the use of explosives during WWII.

The penetration action of a shaped charge is dependent upon a number of factors, such as a) the explosive used, b) type of liner material and its thickness, c) cone angle and other shape of cavity and d) stand-off distance or distance between the base of cavity and target. These factors must be determined experimentally for each explosive and for each type of shaped charge design.

This test is conducted by placing the assembly vertically, at a known stand-off distance, above several layers of 0.5 inch thick armor-plate steel and detonating the charge. After detonation, the depth of hole, its average diameter at the top, and its volume are determined. Refs: 1) TM 9-1910 (1955), 78-85 2) PATR 1740, Rev 1 (1958) 3) Cook (1958), 226-64
Shell Impact Sensitivity Test. See Armor Plate Impact Test, in this section.

Silvered Vessel Test or Woltham Abbey Silvered Vessel Test (Silbergefässprobe, in Ger), designed for testing cordeite, but suitable for testing other propellants and NC, is conducted as follows: A 50 g sample of cordeite, cut into pieces 1/4" long, is placed into a vacuum-jacketed round-bottom flask ("silvered vessel"), provided with a piece of tubing fused at the lower part of the neck and sealed at the other end. This tube serves as a means for observing color of gases evolved during heating of cordeite. After closing the flask with a perforated cork and inserting a precision thermometer in the middle of the sample, the flask is placed in a thermostatically controlled air-bath at 80 ± 0.1°C. Reading of thermometer and the color of gases in the lateral tube are observed at regular intervals and the time of appearance of red fumes is recorded. A few hours after this, the temp of cordeite begins to rise and as soon as the rise reaches 2°C, the test is considered completed. A good "service" cordeite will stand this test for 500-600 hrs. *Refs: 1) F.L. Nathan, JSCI 28, 443-4 (1909) 2) Marshall 2, (1917), 663-4 3) Reilly (1938), 81 4) Kast-Hetz (1944), 318

Small Lead Block Compression Test for Detonators. See under Explosives and Propellants, in this section.

Steel Plate Denting Test or Steel Test. See under Volume of Gases Evolved on Detonation (or Explosion).

Specific or Normal Volume. See under Volume of Gases Evolved on Detonation (or Explosion).

Strength of Explosives, Test. According to Marshall 2, (1917), 469 "Trauzl's lead block test affords a ready means of ascertaining the approximate relative strength of explosives." As power of explosives is also detd by the same test, it seems that there is no difference between strength and power.

65°C and 80°C Surveillance Tests are standard US stability tests for propellants. Transfer a 45 g sample to a dry 8 oz flint-glass bottle provided with an air-tight ground-glass stopper. Place the bottle in an oven or a special chamber (such as is represented by Fig 81, p 244, *Ref 2*) maintained at 65.5 ± 1°C. After heating for 24 hrs, reseat the stopper and continue heating. Observe the bottle every 24 hrs and note the number of days required to cause the evolution of red fumes (oxides of nitrogen). Test values of 20 days or less indicate a condition of hazardous instability calling for immediate disposal of the sample. Values of 90 days or less indicate insufficient stability.

The test can be conducted at 80°C when anticipatory data are required quicker than by the 65°C test. *Refs: 1) PATR 1401, Rev 1 (1950), 15-16 2) TM 9-1910 (1955), 243-4

70°C Surveillance Test, described by D.R. Wiggam & E.S. Goodyear, IEC, Anal Ed 4, 73 (1932), is similar to the above tests, except the temperature of heating is different.

Sympathetic Detonation Test. See Detonation by Influence Test.

Talians Test for detg the thermal stability of NG, NC, and NG propellants was first described in 1921 (*Ref 1*). The app consists of a glass tube, in which 1.3 g of sample is placed, closed with a ground-glass top and connected with a paraffin trap, the top of which is connected to a Hg manometer. The entire app, except the manometer, is heated in a specially constructed oven at 120°C for NG or NG contg propellants, and at 135°C for NC. After 30 min of heating the sample, the stopcocks on the sample tube and on the manometer are closed to keep the sample in contact with its decompo products. The pressure developed is measured at suitable intervals and the index of stability adopted is the time in minutes necessary to attain a press of 100 or 300 mm Hg.

As first described the Talian test was considered a good quantitative test of thermal stability but it was tedious and time consuming. Numerous investigators have subsequently modified the initial procedure. Goujon (*Ref 2*) heated NC, previously dried at 100°C for 2 hrs, in a const vol at 135°C in the presence of its decompo products and noted the time necessary to develop a press of 100 mm Hg. This time characterized the stability of the sample and the test was completed in 2 hrs. Wiggam & Goodyear (*Ref 3*) made modifications in the Taliani app and conducted the test on double-base powders at 120°C. Haed et al (*Ref 4*) studied the time-press relationships of NC and HE's at 75°C. Tonegutti (*Ref 5*) conducted this test at 120, 125 & 130°C on NC, NG, NGu and other expls. Berl et al (*Ref 6*) used the "glass-feather" manometer, at 135°C or higher.
TALIANI APPARATUS

For research purposes a small scale micro-Taliani app has been constructed and applied to the study of HE's (Refs 8, 9 & 10). A description of this app and the procedure for its use will be prepd in a PA rept of std lab procedure. Refs: 1) M. Taliani, Gazz 51 1,184-93(1921) & CA 16, 342(1922) 2) J. Goujon, MAF 8, 837-902(1929); SS 26, 217, 261, 289, 330, 361 & 400(1931) & CA 26, 1444(1932) 3) D. R. Wiggam & E. S. Goodyear, IEC, Anal Ed 4, 73(1932) & CA 26, 1444(1932) 4) A. Haid et al, SS 30, 66-8 & 105-8(1935) & CA 29, 4585(1935) 5) M. Tonegutti, Industria Chimica 9, 1334-42(1934) & CA 29, 6061(1935); Chim e Ind 17, 517-21(1935) & CA 30, 1562(1936); and SS 33, 185-6(1936) & CA 32, 8145(1938) 6) E. Berl et al, IEC, Anal Ed 10, 220(1938) & CA 32, 4338(1938) 7) Reilly(1938), 88 8) NOL Memo Rept 10288(1950) (Conf) 9) NAVORD Rept 2782(1953) (Conf) 10) PA Memo Rept MR-55(1954) (Conf)

Temperature Developed on Detonation (or Explosion) can be detd experimentally with a fair degree of accuracy by optical methods and can also be estimated by calcn as discussed in the following: Refs: 1) E. Sarrau, "Théorie des Explosifs," Gauthier-Villars, Paris(1895), 16-17 2) Marshall 2, (1917), 453 & 459-60 3) Barnett(1919), 200 4) Vennin, Birlot & Lécorche(1932), 36-50 5) Stettbacher(1933), 85 6) H. Muraour, "Poudres et Explosifs," Paris(1947), 71-3 7) Stettbacher(1948), 14 8) Stettbacher(1952), 17

Testing Galleries. See Galleries for Testing Permissible Explosives

Thermal Stability Tests. See Heat Tests

Time of Ignition(or Explosion) Test. See Ignition(or Explosion) Test

Transmission of Detonation Through Air. See Detonation by Influence(Sympathetic Detonation)

Transmission of Detonation Through Explosive Charge(Extent of Propagation of Explosion). See Ability to Propagate Detonation, in this section

Trazul Test; Trazul Lead Block Test or Lead Block Expansion Test(Cavité au bloc de Trazul ou Épreuve au bloc de plomb de Trazul, in Fr) (Trazulsche Probe or Bleiblockausbachung Methode, in Ger) (Prueba Trazul o Prueba del bloque de plomo, in Span) (Metodo del Trazul o Metodo del blocco di piombo, in Ital). According to Ref 5, this test measures the "comparative disruptive power" of an expl through enlargement of a cavity in a cylindrical lead block under carefully standardized conditions. Std conditions for conducting this test were defined by a Comm of the Fifth International Congress of Applied Chemistry(Ref 1). Although one of the oldest tests known for detg power, it is still widely used today but more common in Europe than in the USA

Procedure. A sample of the test expl(approx 10 g) is detonated in a cavity or borehole, 25 mm in diam and 125 mm deep, in a std lead block 200 mm in diam and 200 mm in height. The borehole is made centrally in the upper face of each block, previously cast in a mold from desilvered lead of the best quality. An electric blasting cap is placed centrally in the chge. After the chge and detonator are placed in the borehole, 40 cc of Ottawa sand are added and tamped lightly. An addnl 10 cc of sand are added and tamped more thoroughly. The volume of the hole made due to the press exerted by the exploding chge is then detd; and the distension(expansion) is calcd by subtracting from this value, the vol of the borehole before the chge is detonated. Three such tests are made and the results averaged. Expansions for equivalent wts of expls are calcd, and the test value is expressed in % of the expansion of an equivalent wt of TNT

The Trazul test in France is somewhat different in procedure although dimensions of the lead block are the same(See Coefficient d’utilisation pratique, in this section).

Initiating efficiency(strength) of primary expls can be approx detd by firing a small chge(such as 1.0 g) in the cavity of a small lead block, such as 100 mm in height and 100 mm in diam. For testing detonators in such block, a hole is bored in the block of the exact diam of the detonator and of such a depth that the top of the detonator is flush with the top of the block(Ref 5, p 106 & Ref 5a, p 666)
**Vacuum Stability Test** was designed in 1923 by Vivas, Feigenspan, and in 1943 by Marshall. It is used to test the stability of explosives and propellants in an environment of reduced pressure. In this test, the thermal decomposition of a sample is followed by observing the rise in pressure of the gases given off in vacuum. The test can be conducted at temps ranging from 80°C to 100°C (Ref 1), but in the US, the temps are 90°C for propellants and 100°C or 120°C for HE.

**VACUUM STABILITY APPARATUS**

![Apparatus Diagram]

Procedure: Transfer 5 g of thoroughly dried propellant or HE (use 1 g in case of initiating expls) to a glass heating tube (A) so designed that the ground neck (B) can be sealed with mercury after a calibrated capillary tube (C) with a ground stopper end has been connected. Place in the cup (D), attached to the lower end of the capillary, ca 7 ml Hg and insert a rubber stopper with a tube connected to a vacuum pump. Tilt the app forward to free of Hg the capillary opening of the cup (D) and evacuate the apparatus until the press is reduced to ca 5 mm. This will force the Hg to rise in (C), nearly to the top. Disconnect the pump, add ca 1 ml of Hg to (D) and measure the total vertical height of the column in (C). Measure and subtract the vertical height of the column of Hg in (D). Note the RT and atm press. Insert the tube (A) in a bath maintained at desired temp ±0.5°C and heat for 40 hrs unless an excessive amt of gas (11 ml) will be evolved in less time. Remove the app, cool RT and observe the atm press. Measure the total vertical height of the column of Hg in the capillary (C) and subtract the vertical height of the column in the cup (D). Calculate the vol of liberated gas from the difference between the initial and final levels, as well as the vol of the capillary per unit length, the vol of tube (A), and the atm press and temp conditions at the beginning and end of the test. The formula for this calcn is given in Ref 3, p 14. **Refs:**


Vapor Pressure of Explosives and Related Substances gives an idea as to their volatility and in some cases to their stability. Methods for measuring vapor pressure may be divided into static and dynamic. Their description can be found in the following: **Refs:**


**Velocity of Detonation Tests.** See Detonation Rate Tests

Vitesse de détonation. Fr for Detonation Rate

**Vivacité, Determination de la.** Fr for Quickness of Burning of Propellants, Determination

**Volatility of Explosives and Related Substances** may be expressed by the loss of wt per unit of its exposed surface at a given temp and in unit time. Two of the volatility tests used in the US are: 100°C Heat Test (qv) and 75°C International Test (qv).

R. Colson, MP 30, 55(1948) describes a French volatility test conducted by leaving a weighed sample in a container of a known surface in dry air at atm press and at a desired temp (such as 60°C) for several hours or days and then reweighing. The loss of wt in milligrams per square decimeter and per one hour is known as *volatilité*

**Volume of Gases Evolved on Explosion or Detonation** may be either calc'd or detd experimentally by exploding material in one of the bombs, such as Bichel Bomb (qv), and then collecting and measuring the volume. The volume (in liters) evolved by 1 kg of expl, measured at NTP, is called *specific volume or normal volume* (Vol). **Refs:**


**Waltham Abbey Silvered Vessel Test.** See Silvered Vessel Test

**Wax Gap Test** is one of the Detonation by Influence tests (qv) and is similar to the Booster Sensitivity test (qv). The Wax Gap Test is described briefly under Ammonium Nitrate, p 1354, Note c and in more detail in Spencer Chemical Company, "Safety Data," Kansas City, Mo (1960).
# LIST OF ABBREVIATIONS, CODE NAMES AND SYMBOLS USED IN THIS WORK AND IN MILITARY ORGANIZATIONS OF THE USA AND OF VARIOUS OTHER COUNTRIES

(Items not listed here are given in the text. For German abbreviations see PATR 2510)
(See also Supplement, pages Abbr 59ff)

<p>| A or Abstr | abstract | AASM | Association of American Steel Manufacturers |
| A or Abstr | acid (as MA, mixed acid) | AATCC | American Association of Textile Chemists and Colorists |
| A | aniline | AAWC | Australian Advisory War Council |
| A | argon | AB | Aktiebolaget (Swed)(same as Ger A-G) |
| A | Army | AB | aviobamba(Rus)(aerial bomb) |
| A | atomic | ABBG | Aktiebolaget Bofors–Gullspång (Swed) |
| A | after an Ordn term, indicates a | ABBN | Aktiebolaget Bofors–Nobelkrut (Swed) |
| A(gomma) | Ital gelatin type expl contg NG | abbrev | Atomic Bomb Casualty Commission |
| A | absolute temperature | ABCM | Association of British Chemical Manufacturers |
| A₁ | first class; excellent | see Abel's Expl | see Picric Powder |
| A₁(Monobel; A₁(Roundkol); A₂(Monobel) | British explosives | ABL | Allegany Ballistics Laboratory |
| A/₄₀ | Rus 40/60 amatol | ABMA | Army Ballistic Missile Agency, Redstone Arsenal, Huntsville, Ala(see also OML) |
| A/₈₀ | Rus 80/20 amatol | ABNP | Aktiebolaget Norma Projektillfabrik(Swed) |
| A₁ | Augusta Arsenal, Agusta, Ga | ABNT | Aktiebolaget Nota Tandrofsfabrik(Swed) |
| AAA | antiaircraft artillery | ABSAV | Aktiebolaget Svensak Automat Vapen(Swed) |
| AAAAW | antiaircraft artillery automatic weapons | ABSKF | Aktiebolaget Svenska Krutfaktorierna, Landskrona(Swed) |
| AAC | antiaircraft cannon | absol or abs | absolute |
| AADL | Artillery Ammunition Development Laboratory, PicArsn, Dover, NJ (now AARDL) | abspn | absorption |
| AAE | American Association of Engineers | abstr or A | abstract |
| AAE | Aeroplane and Armament Establishment (Brit) | abt | about |
| AAF | Army Air Forces | AC | Allied Chemicals, New York |
| AAFCE | Allied Air Forces, Central Europe | AC | symbol for hydrogen |
| AAG | antiaircraft gun | Ac | cyanide (CWA) |
| AAM | air-to-air missile | Ac | acetyl(CH₃CO-, not CH₃COO-) |
| AAMG | antiaircraft machine gun | AC | acid |
| AARDL | Artillery Ammunition Rocket Development Laboratory, PicArsn, Dover, NJ (formerly AADL) | AC | adjusted charge (Brit) |</p>
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<td>AWRE</td>
<td>Atomic Weapons Research Establishment (Brit)</td>
</tr>
<tr>
<td>az</td>
<td>azimuth</td>
</tr>
<tr>
<td>Az</td>
<td>azote (French for nitrogen)</td>
</tr>
<tr>
<td>azx</td>
<td>azoxy</td>
</tr>
</tbody>
</table>

**B**

B base (of a bomb)

B battery

B benzene

B blind or dud (Brit)

B bomb (er)

B boron

B brisance calcld by Kast formula (see the text)

B broneprobivnoy (Rus) (armor-piercing)

B used after an Ordn term, denotes a standardized item for use by both Army and Navy

B(gomma) Ital gelatin type expd contg NG

B(salt) one of Amer designations for ethylenediamine dinitrate

B₄ Jap incendiary expl (see text)

B(poudre) Fr propellant named in honor of Gen Boulanger; formerly called V(poudre) because it was invented by Vieille
Abbr 7

BD base detonating
BD bomb disposal
BD Fr propellant contg DPhA
B/D bulldozer
BDS Bomb Disposal Squad, now called EODT
BDSA Business and Defense Service Administration (Commerce Dept, Washington 25, DC)
BDU bomb disposal unit
BE base ejection (chemical shell)
Bé Baumé
Be beryllium
BEAIRA British Electrical and Allied Industries Research Association
Belg Belgium, Belgian
Bellites older Swed expls
benz benzene
Berger(explosifs) Fr expls (see the text)
BESA British Engineering Standards Association
BESS base ejection smoke shell
Bess Bessemer
BethStCorp Bethlehem Steel Corp
betw between
BF barrage fire
BF before firing (Brit)
BF poudre B fusil (Fr NC propel-lant for military rifle
BFF Beretta Francese e Figli (Italfirm)
BFNL, Fr military rifle propellants
BFP, BFP₁ (see the text)
BG Birmingham gauge, for wire
BG, BG₄ & BGC Fr propellants (see the text)
BG or BIG blasting gelatin
BGOD Blue Grass Ordnance Depot, Richmond, Ky
BGR bombing and gunnery range
BH Brinell hardness
BHC benzene hexachloride
BHOD Black Hills Ordnance Depot, (gloo, SDak
BHP British horse-power
BHRA British Hydromechanics Research Association
BI base initiating; base ignition
Bi bismuth
BI Board of Investigation
BIB baby incendiary bomb
bibl bibliography
BICERA British Internal Combustion Engine Research Association
bioch biochemical
bili biological
BIOS British Intelligence Objectives Subcommittee
BIPM Bureau International des Poids et Mesures (Fr) (International Bureau of Weights and Measures)
BISC British Intelligence Sub-Committee
Bisoflex 102 Brit for triethyleneglycol dicaprylate
BISRA British Iron and Steel Research Association
BJ brass jacket
BJM British Joint Services Mission, Washington 6, DC
bk or blk black
BkPdr black powder
BKhV boyevoye khimicheskoye veshchestvo (Rus) (CWA)
BL base-loaded (shell)
BL breech loading (separate loading ammo with bagged propelling charge)
BL Burnside Laboratory, E.I. DuPont de Nemours & Co, Penns Grove, NJ
BL blue
Blastin Swed expl (see the text)
BLC base-loaded capped (shell)
BLDG building
blk see bk
BMT British Leather Manufacturers Research Association
BFL Fr military rifle propellants
BMU Bureau of Mines, Pittsburg, Pa
BM(poudres) Fr Navy (marine) propellant
BMRC British Manufacturing Research Co
BMG Browning machine gun
BMI Battelle Memorial Institute
bmr bomber
BN poudre nouvelle (Fr modified propellant)
BNM ETA see BurMines TS
BNL Brookhaven National Laboratory, Upton, NY
BNO British Naval Officer
<table>
<thead>
<tr>
<th>Abbr</th>
<th>Description</th>
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<tbody>
<tr>
<td>BNP</td>
<td>Bureau of Naval Personnel</td>
</tr>
<tr>
<td>BOAC</td>
<td>British Ordnance Ammunition Corps</td>
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<tr>
<td>BOAC</td>
<td>British Overseas Airways Company</td>
</tr>
<tr>
<td>BO</td>
<td>blown out (Brit)</td>
</tr>
<tr>
<td>BOD</td>
<td>Base Ordnance Depot</td>
</tr>
<tr>
<td>BOD</td>
<td>biochemical (biological) oxygen demand (capacity of water to absorb oxygen)</td>
</tr>
<tr>
<td>BOD</td>
<td>Birmingham Ordnance District, Birmingham, Ala</td>
</tr>
<tr>
<td>BOD</td>
<td>Boston Ordnance District, Boston 10, Mass</td>
</tr>
<tr>
<td>Bol</td>
<td>Bolivia</td>
</tr>
<tr>
<td>Bolvon</td>
<td>Austr liq expl (HNO₃ + m-DNB)</td>
</tr>
<tr>
<td>Bonit</td>
<td>Swed for expl cong RDX &amp; TNT</td>
</tr>
<tr>
<td>BOP</td>
<td>Burlington Ordnance Plant, Burlington, NJ</td>
</tr>
<tr>
<td>Boronites</td>
<td>expl mixts of amatols with boron salts (suitable for press-loading of ammo) (see PATR 1292 and the text)</td>
</tr>
<tr>
<td>BOV</td>
<td>boyevoye (travliayouschcheiy veshchestvo (Rus) (War poison substance) (poison gas) (CWA)</td>
</tr>
<tr>
<td>BOV</td>
<td>brown oil of vitriol (tech sulfuric acid)</td>
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<tr>
<td>BOW</td>
<td>Badger Ordnance Works, Baraboo, Wisc</td>
</tr>
<tr>
<td>BOW</td>
<td>Base Ordnance Workshop</td>
</tr>
<tr>
<td>BP</td>
<td>base point</td>
</tr>
<tr>
<td>BP</td>
<td>boiling point</td>
</tr>
<tr>
<td>BP</td>
<td>Bolta Products, Lawrence, Mass</td>
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<tr>
<td>BP</td>
<td>boyevyiye priapcy (Rus) (ammonition)</td>
</tr>
<tr>
<td>BP</td>
<td>British Patent (see BritP)</td>
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<tr>
<td>BP</td>
<td>bronprozhigayushchii (Rus) (burn through armor) (shaped charge)</td>
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<tr>
<td>B-P</td>
<td>bullet-proof</td>
</tr>
<tr>
<td>BP-152</td>
<td>brown powder used by Italians in cannons prior to invention of smokeless propellant</td>
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<tr>
<td>BPB</td>
<td>black pow or bag</td>
</tr>
<tr>
<td>BPCVMRA</td>
<td>British Paint, Colour &amp; Varnish Manufacturers Association</td>
</tr>
<tr>
<td>BPD(polvere)</td>
<td>Ital sporting propellant</td>
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<tr>
<td>BPP</td>
<td>black powder pellet</td>
</tr>
<tr>
<td>BPZ</td>
<td>bronprozhigayushchii-zazhigayushchii (Rus) (shaped charge, incendiary)</td>
</tr>
<tr>
<td>Br or Brit</td>
<td>British</td>
</tr>
<tr>
<td>Br</td>
<td>bromine</td>
</tr>
<tr>
<td>Br431(polvere)</td>
<td>brown powder used in Ital Navy prior to the invention of smokeless propellant</td>
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Abbr 9

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>Btry</td>
<td>battery (4 guns)</td>
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<tr>
<td>BTS</td>
<td>Bellini-Tosi System (of radio direction)</td>
</tr>
<tr>
<td>BTTN or BuTTN</td>
<td>butanetriol trinitrate</td>
</tr>
<tr>
<td>BTU</td>
<td>Board of Trade Unit (kilowatt/hour)</td>
</tr>
<tr>
<td>BTU</td>
<td>British Thermal Unit(s)</td>
</tr>
<tr>
<td>Bu or Bur</td>
<td>Bureau</td>
</tr>
<tr>
<td>Bu or but</td>
<td>butyl(normal)</td>
</tr>
<tr>
<td>BuA</td>
<td>Bureau of Aeronautics, Washington 25, DC</td>
</tr>
<tr>
<td>Bucks</td>
<td>Buckinghamshire(Brit)</td>
</tr>
<tr>
<td>BuGDN</td>
<td>butyleneglycolnitrate</td>
</tr>
<tr>
<td>Bulg</td>
<td>Bulgaria</td>
</tr>
<tr>
<td>Bull</td>
<td>bulletin</td>
</tr>
<tr>
<td>Buna</td>
<td>Butadiene-Natrium (synthetic rubber)</td>
</tr>
<tr>
<td>BuOrd or BUORD</td>
<td>Bureau of Ordnance</td>
</tr>
<tr>
<td>BurMines</td>
<td>Bureau of Mines, Pittsburg, PA</td>
</tr>
<tr>
<td>BurMinesTS</td>
<td>Bureau of Mines Test Station, Bruceton, PA</td>
</tr>
<tr>
<td>BMTS</td>
<td>Bureau of Ships</td>
</tr>
<tr>
<td>BuShips</td>
<td>Bureau of Ships</td>
</tr>
<tr>
<td>but alc</td>
<td>butyl alcohol</td>
</tr>
<tr>
<td>BW</td>
<td>Biological Warfare</td>
</tr>
<tr>
<td>BW(poudre)</td>
<td>Fr propellant (see the text)</td>
</tr>
<tr>
<td>BWC</td>
<td>board wood cellulose (Brit)</td>
</tr>
<tr>
<td>BWG</td>
<td>Birmingham Wire Gauge</td>
</tr>
<tr>
<td>BWRA</td>
<td>British Welding Research Association</td>
</tr>
<tr>
<td>BWW</td>
<td>Biological Warfare Weapons</td>
</tr>
<tr>
<td>Bz</td>
<td>benzoyl, C₆H₄CO-</td>
</tr>
<tr>
<td>BzH</td>
<td>benzaldehyde, C₆H₅COH</td>
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<tr>
<td>Bzl</td>
<td>benzy1, C₆H₅CH-</td>
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<tr>
<td>BzOH</td>
<td>benzoic acid, C₆H₅COOH</td>
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<td>°C</td>
<td>degree centigrade</td>
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<td>C</td>
<td>capacitance</td>
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<tr>
<td>C</td>
<td>capped</td>
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<tr>
<td>C</td>
<td>carbamite (Brit for centralite)</td>
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<tr>
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<td>carbon</td>
</tr>
<tr>
<td>C</td>
<td>cellulose</td>
</tr>
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<td>C</td>
<td>centigrade</td>
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<td>Commanding</td>
</tr>
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<td>Conf</td>
<td>confidential</td>
</tr>
<tr>
<td>C</td>
<td>constant</td>
</tr>
<tr>
<td>C(explosif)</td>
<td>Fr explosive (see the text)</td>
</tr>
<tr>
<td>C-2(polvere)</td>
<td>Ital propellant similar to Brit cordite MD</td>
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<tr>
<td>C-7</td>
<td>Ital sporting propellant</td>
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<tr>
<td>Ca</td>
<td>calcium</td>
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<td>ca</td>
<td>cathode</td>
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C

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<tr>
<td>CA</td>
<td>Chemical Abstracts</td>
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<tr>
<td>ca</td>
<td>circa (about, approximately)</td>
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<tr>
<td>CA</td>
<td>Coast Artillery</td>
</tr>
<tr>
<td>CA</td>
<td>Contra-aereo (Ital) (antiaircraft)</td>
</tr>
<tr>
<td>C/A</td>
<td>counter-attack</td>
</tr>
<tr>
<td>CA₃;CA₂</td>
<td>coton azotique 1 et 2 (Fr)(NC contg ca 12%N)(see the text)</td>
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<td>CAA</td>
<td>Civil Aeronautics Admin</td>
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<td>Coast Artillery Corps</td>
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<tr>
<td>CAD</td>
<td>Central Ammunition Depot</td>
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<td>CADO</td>
<td>Central Air Documents Office, now ASTIA</td>
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<tr>
<td>Cal</td>
<td>Caliber (inside diameter of a weapon)</td>
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<tr>
<td>cal</td>
<td>length of a cannon in calibers</td>
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<tr>
<td>Cal</td>
<td>see Calif</td>
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<td>cal</td>
<td>gram-calorie</td>
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<tr>
<td>Cal</td>
<td>kg-calorie (see kcal)</td>
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<td>Cornell Aeronautical Laboratory</td>
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<td>calc</td>
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<td>calculated</td>
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<td>calc'g</td>
<td>calculating</td>
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<td>calc'n</td>
<td>calculation</td>
</tr>
<tr>
<td>Calif</td>
<td>California</td>
</tr>
<tr>
<td>CalTech,</td>
<td>California Institute of Technology, Pasadena, Calif</td>
</tr>
<tr>
<td>Caltech, or CIT</td>
<td>(see also CIT)</td>
</tr>
<tr>
<td>CAM</td>
<td>Centro Armamento Marinha</td>
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<tr>
<td>Cambs</td>
<td>Cambridgeshire, Engl</td>
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<tr>
<td>camf</td>
<td>camouflage</td>
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<tr>
<td>Can</td>
<td>Canada, Canadian</td>
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<tr>
<td>can</td>
<td>canister</td>
</tr>
<tr>
<td>cap</td>
<td>capital letter</td>
</tr>
<tr>
<td>Carib</td>
<td>Brit for centralite</td>
</tr>
<tr>
<td>Carlsonites</td>
<td>Canadian Armament Research and Development Establishment (formerly ARDEC)</td>
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<tr>
<td>cas</td>
<td>Caribbean</td>
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<tr>
<td>cec</td>
<td>older Swed expls</td>
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<tr>
<td>cart</td>
<td>cartridge</td>
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<td>CAS</td>
<td>Canadian Army Staff, Washington 8, DC</td>
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<td>CASEE</td>
<td>Canadian Army Signals</td>
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<td>Cavvy</td>
<td>Engineering Establishment</td>
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<td>Cb</td>
<td>cavalry</td>
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<tr>
<td>CB</td>
<td>columbium</td>
</tr>
<tr>
<td>CB</td>
<td>Construction Battalion (its members, during WW II were called “Seabees”)</td>
</tr>
<tr>
<td>CBR</td>
<td>chemical, biological and radiological (warfare)</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>CC</td>
<td>Collodion cotton</td>
</tr>
<tr>
<td>cc</td>
<td>Cubic centimeters</td>
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<tr>
<td>CCA</td>
<td>Celanese Corp of America, New York 6, NY</td>
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<tr>
<td>CCAE</td>
<td>(Joint) Congressional Committee of Atomic Energy</td>
</tr>
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<td>CCL</td>
<td>Chemists Club Library, 50E 41st St, New York 6, NY</td>
</tr>
<tr>
<td>CCLI</td>
<td>Charlotte Chemical Laboratories, Inc, Charlotte, NC</td>
</tr>
<tr>
<td>Cd</td>
<td>Cadmium</td>
</tr>
<tr>
<td>CDB</td>
<td>Companhia Dinamitos do Brasil (Rio de Janeiro, Brazil)</td>
</tr>
<tr>
<td>CDEE</td>
<td>Chemical Defence Experimental Establishment (Brit)</td>
</tr>
<tr>
<td>CDRD</td>
<td>Chemical Defence Research Department</td>
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<tr>
<td>Ce</td>
<td>Cerium</td>
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<tr>
<td>CF</td>
<td>Corps of Engineers</td>
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<tr>
<td>CE</td>
<td>&quot;Composition Exploding&quot; (Brit for tetryl)</td>
</tr>
<tr>
<td>CEC</td>
<td>Companhia Explosivos Cheddite (Brazil)</td>
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<tr>
<td>CEF</td>
<td>Canadian Expeditionary Force (in France)</td>
</tr>
<tr>
<td>CEG</td>
<td>Chemical Engineering Group, London</td>
</tr>
<tr>
<td>CEI</td>
<td>Commissariat à l'Énergie Atomique (Fr Atomic Energy Commission)</td>
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<tr>
<td>Cellamite</td>
<td>Fr expl contg AN, NG, CC and cellulose</td>
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<tr>
<td>cemf</td>
<td>Counter electromotive force</td>
</tr>
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<td>CENCO</td>
<td>Central Scientific Co, Chicago 13, Ill</td>
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<tr>
<td>centf</td>
<td>Centrifugal</td>
</tr>
<tr>
<td>Centr</td>
<td>Centralite (US); carbamite (Brit)</td>
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<tr>
<td>Centralite TA</td>
<td>Belg AN expl (see the text)</td>
</tr>
<tr>
<td>CEPE</td>
<td>Central Experimental &amp; Proving Establishment (Canada)</td>
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<tr>
<td>CERN</td>
<td>European Council for Nuclear Research</td>
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<tr>
<td>CETME</td>
<td>Centro de Estudios Tecnicos de Materiales Especiales (Span)</td>
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<tr>
<td>cf</td>
<td>Compare with; refer to</td>
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<td>CFA</td>
<td>Canadian Field Artillery</td>
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<td>cf ante</td>
<td>Compare above</td>
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<td>CFE</td>
<td>Central Fighter Establishment (Brit)</td>
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<tr>
<td>cfh</td>
<td>Cubic feet per hour</td>
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<td>cfm</td>
<td>Cubic feet per minute</td>
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<td>cf post</td>
<td>Compare after</td>
</tr>
<tr>
<td>cfs</td>
<td>Cubic feet per second</td>
</tr>
<tr>
<td>cg</td>
<td>Centigram</td>
</tr>
<tr>
<td>CG</td>
<td>Commanding General</td>
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<tr>
<td>CG-13,CG-14</td>
<td>Ital double base propellants (see the text)</td>
</tr>
<tr>
<td>CGS</td>
<td>Centimeter-gram-second</td>
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<tr>
<td>CGS</td>
<td>Central Gunnery School</td>
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<tr>
<td>CGS</td>
<td>Chief of the General Staff</td>
</tr>
<tr>
<td>CGS</td>
<td>Coast Guard Station</td>
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<tr>
<td>CGWI</td>
<td>Corning Glass Works, Inc, Corning, NY</td>
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<tr>
<td>CH</td>
<td>Case-hardened</td>
</tr>
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<td>Ch</td>
<td>Chapter</td>
</tr>
<tr>
<td>char</td>
<td>Character, characteristic</td>
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<tr>
<td>Ch D'Aff</td>
<td>Chargé d'Affaires</td>
</tr>
<tr>
<td>Chakatsuyaku</td>
<td>Jap for TNT (Sanskho-teruoru)</td>
</tr>
<tr>
<td>Chanayaku</td>
<td>Jap expl (see the text)</td>
</tr>
<tr>
<td>Chaoyaku</td>
<td>Jap expl (see the text)</td>
</tr>
<tr>
<td>Chauyaku</td>
<td>Jap for cyclotol</td>
</tr>
<tr>
<td>Cheddites</td>
<td>Fr, Ital &amp; Swiss chlorate expls chemical</td>
</tr>
<tr>
<td>Chemico</td>
<td>Chemical Construction Corp, New York 1, NY</td>
</tr>
<tr>
<td>ChemWarf</td>
<td>See CW</td>
</tr>
<tr>
<td>chemy</td>
<td>Chemistry</td>
</tr>
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<td>chge</td>
<td>Charge</td>
</tr>
<tr>
<td>Chikkaen</td>
<td>Jap for lead azide</td>
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<td>Chin</td>
<td>Chinese</td>
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<td>Chishoki-anin</td>
<td>Jap expl (see the text)</td>
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<td>chif</td>
<td>Chloroform</td>
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<tr>
<td>Chuju-kayaku</td>
<td>Jap for cordite</td>
</tr>
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<td>CI</td>
<td>Cast iron</td>
</tr>
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<td>CI</td>
<td>Chemical Inspectorate (Brit)</td>
</tr>
<tr>
<td>CI</td>
<td>Colour Index (Society of Dyers and Colourists (Brit)</td>
</tr>
<tr>
<td>CIA</td>
<td>Central Intelligence Agency</td>
</tr>
<tr>
<td>CIBA</td>
<td>Chemische Industries Basel (Swiss)</td>
</tr>
<tr>
<td>CIGM</td>
<td>Chief Inspector for Gun Mounting (Brit)</td>
</tr>
<tr>
<td>CIL</td>
<td>Canadian Industries Ltd, Montreal, Canada</td>
</tr>
<tr>
<td>CINCAF</td>
<td>Commander in Chief of Allied Forces</td>
</tr>
<tr>
<td>CINCEUR</td>
<td>Commander in Chief (of the US Forces) in Europe</td>
</tr>
<tr>
<td>CIOS</td>
<td>Combined Intelligence Objectives Subcommittee</td>
</tr>
<tr>
<td>CIOS</td>
<td>Comité International de l'Organisation Scientifique (Fr) (International Committee of Scientific Organization)</td>
</tr>
</tbody>
</table>
Abbr 11

CIT  See CalTech
    Carnegie Institute of
    Technology, Pittsburgh, Pa
CIT  Cal
    Carnegie Institute of
    Technology, Pittsburgh, Pa
CIT/GAL  Cal
    California Institute of
    Technology/Guggenheim
    Aeronautical Laboratory
CIT/JPL  Cal
    California Institute of
    Technology/Jet Propulsion
    Laboratory

civ  civil
CK  code name for cyanogen
chloride gas (CWA)
cl  centiliter
Cl  chlorine
CLR  Chemical Laboratory
    Report (Pic Arsn)

cm  centimeter
CM  chemical mortar
CM  court martial
CMA  Canadian Manufacturers
    Association
CMLC  Chemical Corps
CNES  Companhia Nacional Explosivos
      Segurança(Brazil)
CNQB  Companhia Nitro Quimica
      Brasileira(São Miguel, Brazil)
CNR  Canadian National Railways
CNRS  Centre National de la Recherche
      Scientifique(Fr)

CNS  design for chloroacetophenone
      + chloropicrin in chlf (CWA)
CNTB  choking, nose, tear and
      blister gases(CWS)
c/o  care of
Co  cobalt
CO  Commanding Officer
Co  Company
Co-bomb  cobalt bomb
COC  Combat Operations Center
COD  cash on delivery, collect on
      delivery
COD  Charleston Ordnance Depot,
      N Charleston, SC
COD  Chicago Ordnance District,
      Chicago 6, Ill
COD  Cincinnati Ordnance District,
      Cincinnati 2, Ohio
COD  Cleveland Ordnance District,
      Cleveland 14, Ohio
coef  coefficient

COFORD  or
C of ORD  Chief of Ordnance

C of R  center of rotation
Col  colonel
coll  colorless
Fr expl (see the text)
coll  collective
collab  collaborator(s)
colecn  collection
Colo  Colorado
combd  combined
combin  combination
combstn  combustion
Combat Zone
commanding
commander, commodore
commandant
commercial
commission, committee
communication
composite

Comp A-1  Amer explosive compositions
Comp A-2  based on RDX (see the text)
Comp A-3  binding agent and desensitizer
Comp B  contg paraffin, NC & lecithin
Comp B-2  compound
Comp C  complete
Comp C-2  composition
Comp C-3  component
Comp C-4  compression
Comp D-2  compartment
compar  cash on delivery
compd  connect
compl  Continental Army Command,
      Fort Monroe, Va
compn  concentrate(verb)
comprsn  concentrated
compt  concentrating
CON  conclusion
con  concentration
CONARC  conductor
  conductory
conf or C  confidential
cong  congress
conj  conjugate
conn  connect(verb)
Conn  Connecticut
cons  consult
Abbr 12

consg  consulting
const  constant'
constg  consisting
constrn  construction
cont  contain, continue, containing
contd  contained, continued
contg  containing
contl  continental
contn  continuation
contr  contract, contractor
contrg  contracting
CONUS  Continental United States
conv  convenient
Convn  Convention
Co-op  cooperation
Coopalite  Belg expl contg AN, TNT, NG & wood flour (see the text)
COORDBDB  Co-ordinating Board
coordn  coordination
Co-P  copilot
COP  Cornhusker Ordnance Plant, Grand Island, Neb
cor  corrected
Cordites  Brit propellants
CORG  Combat Operations Research Group, Fort Monroe, Va
Cornw  Cornwall, Engl
Coronit  Swed for PA
Corp  corporation
corr  correspond
corn  corrosion
cos  cosine
cosc  cosecant
COSSAC  Chief of Staff to Supreme Allied Commander
cot  cotangent (see also ctn)
COW  Cactus Ordnance Works, Dumas, Tex
COW  Cherokee Ordnance Works, Danville, Pa
COW  Coventry Ordnance Works (Brit)
Cox  coxswain
COXE  Combined Operations Experimental Establishment
CP  candle power
CP  chamber pressure, chemically pure
CP  common pointed (solid pointed shell having low armor penetration performance) (Brit)
C/P or CP  concrete-piercing
C_p  constant pressure
cot  cotangent (see also ctn)
CP  coton poudre (Fr) (nitrocellulose)
CP_1  Fr NC (12.96 to 13.4% N)
CP_2  Fr NC (11.7 to 12.2% N)
CP_3  Fr NC (11.5% N) (old designation)
C_p100  carbon pourcent (Fr) (% of C)
CPC  common pointed capped (shell) (Brit)
CPC  Coors Porcelain Co, Golden, Colo
Cpl  corporal
CPO  Chief Petty Officer
CPPA  Canadian Pulp and Paper Association
CR  complete round
CRA  center of resistance or drag
C of R  commencement of rifling
C of R  commencement of rifling
Cresylite  code name of 2,4,6-trinitro-m-cresol
CrFol  crown folio (size of a book 9.5" x 15")
crgc  carriage
CRH  caliber-radius-head (radius of curvature of the ogival part of a shell expressed in calibers)
crit  critical
crkc  crankcase
CRL  Chemical Research Laboratory (Brit)
CRS  Canadian Rocket Society
Crs  cresol
CrsBl  Cresol Blue
CRST  cold-rolled steel
cruc  crucible
cryst(s)  crystal(s); crystalline
crystd  crystallized
crystg  crystallizing
crystn  crystallization
Cs  cesium
CS  Chemical Society (Brit)
C/S  Chief of Staff
CS  Civil Service
CSC  cartridge short case
CSC  Central Scientific Co, Chicago 13, Ill
CSC  Civil Service Commission
CSE  Commercial Solvents Corp, Terre Haute, Ind and New York 16, NY
CSE  coefficient de self-excitation (Fr) (transmission of detonation by influence)
Abbr 13

CSE
Commission des Substances Explosives(Fr)

CSE(exposifs) explosives developed or approved by the CSE(eg 55-CSE-1948)(see the text)

CSG Combat Service Group

CSIR Council for Scientific and Industrial Research

CSIRO Commonwealth Scientific and Industrial Research Organization(Australia)

CSP cast steel plate

CSS cast semi-steel central standard time

CSUSA Chief of Staff, US Army

CSUSAf Chief of Staff, US Air Force

C/T controlled target

CTA cyanuric triazide

CTC carbon tetrachloride

CTF Commander Task Force

tgte cartridge

CTMTN cyclotrimethylenetrintritramine (RDX)

ctn cotangent(see also cot)

CTR Chemisch-technische Reichsanstalt, Berlin

CTRA Coal Tar Research Association(Brit)

CU Chicago University, Chicago 37, Ill

cu cu cm cubic centimeter

Cu cuprum(copper)

CUA Catholic University of America, Washington 17, DC

CuCTez copper chlorotetrazole

cu ft cubic foot

cu in cubic inch

cu m cubic meter

cum cumulative

cuw cubic micron

Cumb Cumberland, Engl

cu mm cubic millimeter

CUP coefficient d’utilisation pratique(Fr for modified Trauzl test value, relative to PA taken as 100%)

curr current

cu yd cubic yard

cv calorific value

$C_v$ constant volume

c veh combat vehicle

CW chemical warfare

CWA chemical warfare agent

Curtiss-Wright Corp, Woodridge, NJ

CWA Chemical Warfare Royal Engineers(Brit)

Chemical Warfare Service

Chemical Warfare Service Army

CWS Chemical Warfare Royal

CWSA hundredweight(used to designate different guns of the same caliber by indicating their weight)

cwty cy cyan

cycl cyclic

Cyclonite same as cyclotrimethylene-trinitramine (RDX)

Cyclotol cyclonite + TNT
cyl cylinder

CyOx symbol for tetrahydro-3,5-dinitro-1,3,5,2H-oxdiazine

Canal Zone(Panama)

Combat Zone

Czecho-Slovakia

D density(g/cc)
dextrorotatory
differential

when added to the designation of a Fr propellant, means that DPhA is used as stabilizer (eg BD, BFD, etc)

Dunnite, Explosive D or ammonium picrate

"desensitizer 2" (see Comp D-2)
decommitating agent
delay(ed) action

Department of the Army(formerly part of War Dept)

Detroit Arsenal, Centerline, Mich
direction action(point detonating fuze) (Brit)

Divisional Artillery
delayed action bomb

Divisional ammunition dump
diazodinitrophenol

Dept of Aeronautical Engineering Research (Brit)
delayed action fuze

Dept of the Air Force (formerly part of War Dept)
direct action impact(fuze)

Dakota
DAM delayed action mine
deg degree; °
Dan Danish
diethyleneglycol
DANC decontaminating agent, DEGDN or deg or decomp
diethyleneglycoldinitrate
degnon-corrosive.
DanP Danish Patent
diethyleneglycolmononitrate
DART Code name of an Amer missile
dehydrate(d)
DAS Defense Atomic Support
dehydration
Agency (formerly AFSWP)
Del Delaware
del delayed
DATNB 1,3-diamino-2,4,6-trinitrobenzene
delq deliquescent
DAV Disabled American Veterans
delvd delivered
DB depth bomb
demo demolition
DB dive bomber
defensively equipped merchant ship
DB double barreled
denb Denbigshire, Wales
DB driving band(rotating band)
delq delayed
DBP or DBuPh dibutylphthalate
delq delayed
DBT Rus expl contg DNB & TNT
delq delayed
DBX depth bomb explosive(contains
DEGDN DEGMN diethyleneglycoldinitrate
AN, RDX, TNT & Al)(see also
DEG
denex Delaware
Minex)
DC depth charge
Dep depot
dem Department
DC or dc direct current
Dep depart
DC District of Columbia
departmental
DCA défense contre avion(Fr)(anti-
depy deputy
aircraft defense)
ssee deriv
DCC Dow Chemical Co, Midland, Mich
tDer Destroyer Escort Radar (vessel)
DCDA dicyandiamide
derbs Derbyshire, Engl
depth
DCDRD Director of Chemical Defence
deriv derivative
Research & Development(Brit)
derivn derivation
DCT depth charge thrower
descript description
depth
DD Design Dept(Brit)
designation
DD Fr expls contg PA & DNPh
desic desiccator
design
(see also MBT)
designolle French expls(see the
det(d) determine(d)
description
det(d) determine(d)
DD 60/40 Fr expl contg 60/40-PA/DNPh
determination
det(d) determine(d)
designolle French expls(see the
detonation; detonates
det(d) determine(d)
DPBSA Dupont do Brasil Sociedade
detoned
detonation; detonates
detn detonation
(Anônima Industrias Químicas
detonated
detonation velocity
(Duperiol)
detnd detonating
detonation velocity
D-day Beginning of the action day
detng detonating
detonation velocity
DDNP see DADNPh(diazodinitrophenol)
detop detachment
DEA diethanolamine
detric detachment
DEA diethanolamine
DEUCE digital electronic universal
decomposition
detn detonation
development
DEUT digital electronic universal
dec composition
detn detonation
dev device
decomposition
devsolve detachments
decomposition
devs development
decompose
deviation
Dec December
devolved Devon
DEHEMA
devon Devonshire, Engl
Chemisches Apparatewesen, 
dextrated
devrots dextrorotatory
Frankfurt a/Main, Germany
dex dextrinated
devrol dextrorotatory
decom
DEUT digital electronic universal
chemists digital electronic universal
DECHEMA.
DEUT digital electronic universal
compting engine
devol developmental
Dec or decomp decompose
devol development
Dechema or decomp decompose
devol development
Dechema or decompose decomposed
devol development
Dec or decomp decompose decomposed
devol development
decom decomposing decomposed
devol development
decompg decomposing decomposed
devol development
decompa decomposition decomposing
devol development
decontn decontamination decomposing
devol development
def def defence
devn Devon
defguard deflagrates
devon Devonshire, Engl
defguard deflagrating dem
devor Devonshire, Engl
defgguard deflagrating devor Devonshire, Engl
defgrn deflagration
<table>
<thead>
<tr>
<th>Abbr</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGGM</td>
<td>Director General of Guided Missiles (Brit)</td>
</tr>
<tr>
<td>dgnl</td>
<td>diagonal</td>
</tr>
<tr>
<td>D/H</td>
<td>direct hit</td>
</tr>
<tr>
<td>DGOF</td>
<td>Director, General of Ordnance Factories (Brit)</td>
</tr>
<tr>
<td>DGWRD</td>
<td>Director of Guided Weapons Research &amp; Development (Brit)</td>
</tr>
<tr>
<td>DI</td>
<td>degradation increase (of cellulose)</td>
</tr>
<tr>
<td>Di</td>
<td>Ger &amp; Swiss design of DNT</td>
</tr>
<tr>
<td>diag</td>
<td>diagonal</td>
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<tr>
<td>diam</td>
<td>diameter</td>
</tr>
<tr>
<td>Diamin</td>
<td>Ger for ethylenediamine-dinitrate (EDD)</td>
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<tr>
<td>dibas</td>
<td>dibasic</td>
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<td>dicta</td>
<td>dictaphone</td>
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<td>dictation</td>
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<td>dicty</td>
<td>dictionary</td>
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<tr>
<td>Didi</td>
<td>Ger &amp; Swiss design of DEGDN</td>
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<td>diffc</td>
<td>difficult (ly)</td>
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<td>diffr</td>
<td>difference</td>
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<td>dig</td>
<td>digest</td>
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<td>dilute</td>
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<td>diln</td>
<td>dilution</td>
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<td>dimin</td>
<td>diminution</td>
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<tr>
<td>dimn</td>
<td>dimension</td>
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<tr>
<td>Dimple</td>
<td>Deuterium Moderated Pile, Low Energy, Harwell, Engl</td>
</tr>
<tr>
<td>DIN</td>
<td>Deutsche Industrie Normen (German Industry Standards)</td>
</tr>
<tr>
<td>Dina</td>
<td>Ger for dinitronapthalene</td>
</tr>
<tr>
<td>DNA</td>
<td>diethanolnitramine dinitrate</td>
</tr>
<tr>
<td>Dinamaito</td>
<td>Jap for dynamite</td>
</tr>
<tr>
<td>Dinitryl</td>
<td>code name for glycerol-α-2,4-dinitrophenylether dinitrate</td>
</tr>
<tr>
<td>Dinol</td>
<td>designation for diazodinitrophenol</td>
</tr>
<tr>
<td>dir(d)</td>
<td>direct (ed)</td>
</tr>
<tr>
<td>DPrGeDN</td>
<td>dipropylene glycol dinitrate</td>
</tr>
<tr>
<td>Dir</td>
<td>Director</td>
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<tr>
<td>dirn</td>
<td>direction</td>
</tr>
<tr>
<td>dis</td>
<td>dissolve(s)</td>
</tr>
<tr>
<td>Di-salt</td>
<td>dimethyl ammonium nitrate (see PATR 2510, p Ger 37)</td>
</tr>
<tr>
<td>disc</td>
<td>discount</td>
</tr>
<tr>
<td>discon</td>
<td>disconnect</td>
</tr>
<tr>
<td>discord</td>
<td>disconnected</td>
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<tr>
<td>discont (d)</td>
<td>discontinue (d)</td>
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<tr>
<td>disd</td>
<td>dissolved</td>
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<tr>
<td>Disol</td>
<td>Ger &amp; Swiss design of DNAns dispersed</td>
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<tr>
<td>disp</td>
<td>displacement</td>
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<tr>
<td>disp1</td>
<td>dissociate(s)</td>
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<tr>
<td>dissoc</td>
<td>dissociated</td>
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<tr>
<td>dissoed</td>
<td>dissociation</td>
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<tr>
<td>dissocn</td>
<td>distance</td>
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<tr>
<td>dist</td>
<td>distilled</td>
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<td>distg</td>
<td>distillation</td>
</tr>
<tr>
<td>distn</td>
<td>district</td>
</tr>
<tr>
<td>Distr</td>
<td>code names for N,N′-ethylenedinitramine</td>
</tr>
<tr>
<td>Ditetyl or</td>
<td>Octyl</td>
</tr>
<tr>
<td>Dithekite 13</td>
<td>code name for liq expl contg NB &amp; nitric acid divided</td>
</tr>
<tr>
<td>div</td>
<td>Division</td>
</tr>
<tr>
<td>Divn</td>
<td>division</td>
</tr>
<tr>
<td>dk or drk</td>
<td>dark</td>
</tr>
<tr>
<td>dk1</td>
<td>dekagram</td>
</tr>
<tr>
<td>dkm</td>
<td>dekameter</td>
</tr>
<tr>
<td>DL</td>
<td>dead load</td>
</tr>
<tr>
<td>dlvd</td>
<td>delivered</td>
</tr>
<tr>
<td>dm</td>
<td>decimeter</td>
</tr>
<tr>
<td>DMWD</td>
<td>Dept of Miscellaneous Weapons Development (Brit)</td>
</tr>
<tr>
<td>DMXRD</td>
<td>Director of Materials &amp; Explosives Research &amp; Development (Brit)</td>
</tr>
<tr>
<td>DN</td>
<td>dinitro-</td>
</tr>
<tr>
<td>DN or Dn</td>
<td>Fr for DNN (dinitronaphthalene)</td>
</tr>
<tr>
<td>DNA</td>
<td>dinitroaniline</td>
</tr>
<tr>
<td>DNAcet</td>
<td>dinitroacetone</td>
</tr>
<tr>
<td>DNAns</td>
<td>dinitroanisole</td>
</tr>
<tr>
<td>DNB</td>
<td>dinitrobenzene</td>
</tr>
<tr>
<td>DNBA</td>
<td>dinitrobenzaldehyde</td>
</tr>
<tr>
<td>DNBAc</td>
<td>dinitrobenzoic acid</td>
</tr>
<tr>
<td>DNC</td>
<td>Dept of Naval Construction</td>
</tr>
<tr>
<td>DNCrS or DNC</td>
<td>dinitrochlorobenzene</td>
</tr>
<tr>
<td>DNDAPh or</td>
<td>dinitrochlorohydrin</td>
</tr>
<tr>
<td>DNBC</td>
<td>dinitroresol</td>
</tr>
<tr>
<td>DNCph or</td>
<td>Dept of National Defence (Canada)</td>
</tr>
<tr>
<td>DNCH</td>
<td>dinitrodiazophenol</td>
</tr>
<tr>
<td>DNCrs or DNC</td>
<td>dinitrodiazoxamide</td>
</tr>
<tr>
<td>DNDAP</td>
<td>(see also AfNO)</td>
</tr>
</tbody>
</table>
DNDMSA or DNDMeSA: dinitrodimethylsulfamide
DNDPhA: dinitrodiphenylamine
DNEU or DNEteU: dinitroethyleneurea
DNF: dinitorufurane
DNG: diglycerindinitrate
DNGcU: dinitroglycoluril
DNM or DNMe: dinitromethane
DNMeA or DNMA: dinitromethylaniline
DNN: dinitoraphthalene
DNO: Directorate of Naval Ordnance
DNPF: bis(dinitropropyl)-fumarate
DNPh: dinitorphenol
DNPN: bis(dinitropropyl)-nitramine
DNPS: dinitorpropylsuccinate
DNPT: dinitropropyl-trinitrobutyrate
DNPTB: (see the text)
DO: Defence Order
doc: document
DOD: Detroit Ordnance District, Detroit 31, Mich
DOFL: Diamond Ordnance Fuze Laboratory, Washington 25, DC
dom: domestic
Dom: Dominion
Donarit: expl contg AN, TNT, NG, CC & vegetable meal (see the text)
Dors: Dorsetshire, Engl
DOS: Dept of State
DOS: Director of Ordnance Services(Brit)
DOT: direct oxidation test
DOV: distilled oil of vitriol (96%H2SO4)
DOVAP: Dopppler Velocity and Position (see also EXRADOP; KOTAR and UDOP)
doz: dozen
DP: deck-piercing
DP: displaced person
DP: degree of polymerization
DP: distribution point (for supplies)
DPA: see DPhA(diphenylamine)

DPB: dipentaerythritol
DPE: dipentaerythritolhexanitrate
DPEHN: Dugway Proving Ground, Utah
diphénylamine
DPT or DNPT: dinitropentamethylene nitramine; 2,6-dinitro(bicyclo)pentamethylene-2,4,6,8-tetramine or 3,7-dinitro-1,3,5,7-tetraza-bicyclo[3,3,1]nonane
Dr: Doctor
dr ap: dram apothecaries (0.0355 deciliter)
dr av: dram avoirdupois (1.7718 gram)
DRB: Defence Research Board (Canada)
DRBC: Defence Research Board of Canada
DRCL: Defence Research Chemical Laboratories (Canada)
DRD: Design Research Division
DRD: Directorate of Research and Development (US Air Force)
DRF: Deutsche Rezeptformeln (German Pharmacopeia)
DRI: Denver Research Institute, Univ of Denver, Denver 10, Colo
drk: dark
DRKL: Defence Research Kingston Laboratory (Canada)
DRML: Defence Research Medical Laboratories (Canada)
DRNL: Defence Research Northern Laboratory (Canada)
dtr: discarding sabot
duration of sustained injection (Rocketry)
DS: DSIR/ TIDU: Dept of Scientific and Industrial Research (Brit)
DSIR: Dept of Scientific and Industrial Research (Brit)
DSIS: Defence Scientific Information Service (Canada)
DSP: Direction du Service des Poudres (Fr)
DSR: Director of Scientific Research & Experiments Dept (Naval)
DSWV: daylight saving time
double set trigger
Directorate of Special Weapons and Vehicles (Brit)
DTM: Director of Torpedoes and Mines (Brit)
Dualines: older Swed expls (see the text)
ductile
"Duck": (amphibian vehicle)
DUKW: Dumb
Dumbarton, Scotland
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dumf</td>
<td>Dumfried, Scotland</td>
</tr>
<tr>
<td>Dunnite</td>
<td>Amm picrate or Expl D</td>
</tr>
<tr>
<td>dupl</td>
<td>duplicate</td>
</tr>
<tr>
<td>duPont</td>
<td>E.L.duPont de Nemours &amp; Co, Wilmington, Del</td>
</tr>
<tr>
<td>DV</td>
<td>dyumoobrazuyushcheiyve veshchestvo(Rus)(smoke agent)</td>
</tr>
<tr>
<td>DVA</td>
<td>Department of Veterans Affairs</td>
</tr>
<tr>
<td>DVV</td>
<td>drobiashchevy vzyryvchatoye veshchestvo(Rus) (brisan explosive)</td>
</tr>
<tr>
<td>D-wave</td>
<td>detonation wave</td>
</tr>
<tr>
<td>DWE</td>
<td>Director of Weapons and Equipment(Brit)</td>
</tr>
<tr>
<td>DWR(D)</td>
<td>Director of Weapons Research (Defence)(Brit)</td>
</tr>
<tr>
<td>dwt</td>
<td>pennyweight (1.55 gram)</td>
</tr>
<tr>
<td>Dy</td>
<td>dysprosium</td>
</tr>
<tr>
<td>dyn</td>
<td>dynamite</td>
</tr>
<tr>
<td>Dynamit F</td>
<td>Swiss dynamite with 65%NG</td>
</tr>
<tr>
<td>Dz</td>
<td>diazole</td>
</tr>
<tr>
<td>DZ</td>
<td>dropping zone</td>
</tr>
</tbody>
</table>

**E**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>East</td>
</tr>
<tr>
<td>E</td>
<td>electromotive force</td>
</tr>
<tr>
<td>(suffix) denotes an experimental variation of an ordnance item</td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>electron or its charge</td>
</tr>
<tr>
<td>E</td>
<td>energy</td>
</tr>
<tr>
<td>e</td>
<td>erg</td>
</tr>
<tr>
<td>E</td>
<td>Jap &amp; Swiss explosives (see the text and PATR 907)</td>
</tr>
<tr>
<td>E</td>
<td>Young's modulus</td>
</tr>
<tr>
<td>ea</td>
<td>each</td>
</tr>
<tr>
<td>EA</td>
<td>Edgewood Arsenal, Md (see also ACC)</td>
</tr>
<tr>
<td>EAON</td>
<td>except as otherwise noted</td>
</tr>
<tr>
<td>EB</td>
<td>Encyclopedia Britannica</td>
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<tr>
<td>E-boat</td>
<td>enemy boat (torpedo)</td>
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<tr>
<td>EC</td>
<td>&quot;Explosive Company&quot; (Brit propellant invented in 1880)(see the text)</td>
</tr>
<tr>
<td>propellant contg GC, Ba &amp; K nitrate, starch, DPhA and Aurine)</td>
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<tr>
<td>EC(Blank Fire)</td>
<td>expandable cluster aircraft rocket launcher</td>
</tr>
<tr>
<td>ECARL</td>
<td>expandable cluster aircraft rocket launcher</td>
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**Echos or**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escho</td>
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<tr>
<td>ECNR</td>
<td>European Council for Nuclear Research</td>
</tr>
<tr>
<td>ECPI</td>
<td>Eastman Chemical Products, Inc, Kingsport, Tenn</td>
</tr>
<tr>
<td>ECS</td>
<td>Electrochemical Society</td>
</tr>
<tr>
<td>Ecrasite</td>
<td></td>
</tr>
<tr>
<td>EDD</td>
<td>ethylenediamininitrate</td>
</tr>
<tr>
<td>FDF</td>
<td>European Defence Force</td>
</tr>
<tr>
<td>edn</td>
<td>edn</td>
</tr>
<tr>
<td>EDNA</td>
<td>ethylenedinitramine(same as Haleite)</td>
</tr>
<tr>
<td>EDNATOL</td>
<td>EDNA+TNT</td>
</tr>
<tr>
<td>EDTA</td>
<td>ethyleneglycoldinitrate</td>
</tr>
<tr>
<td>EDVAC</td>
<td>electronic discrete variable automatic calculator</td>
</tr>
<tr>
<td>EEI</td>
<td>Edison Electric Institute</td>
</tr>
<tr>
<td>EES</td>
<td>Engineering Experiment Station, Annapolis, Md</td>
</tr>
<tr>
<td>EF</td>
<td>Expeditionary Forces</td>
</tr>
<tr>
<td>EF</td>
<td>Fr propellant for blank fire</td>
</tr>
<tr>
<td>EFC</td>
<td>(number of firings with full charges; a Brit term used to assess the life of a gun)</td>
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<tr>
<td>efl</td>
<td>efflorescence</td>
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<td>effy</td>
<td>efficiency</td>
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<tr>
<td>EFM</td>
<td>Engineering Field Manual</td>
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<td>EGDN</td>
<td>ethyleneglycoldinitrate</td>
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<tr>
<td>EHP or ehp</td>
<td>effective horsepower</td>
</tr>
<tr>
<td>EI</td>
<td>end of injection (Rocketry)</td>
</tr>
<tr>
<td>eject</td>
<td>ejce</td>
</tr>
<tr>
<td>EKC</td>
<td>EKCN</td>
</tr>
<tr>
<td>Ekrasit</td>
<td>Ger for Amm trinitrocresylate</td>
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<td>EL</td>
<td>Eastern Laboratory, Gibbstown, NJ (DuPont Co)</td>
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<tr>
<td>Eastern Laboratory, Gibbstown, NJ (DuPont Co)</td>
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</tr>
<tr>
<td>elec or electr</td>
<td>electric(al)</td>
</tr>
<tr>
<td>elem(s)</td>
<td>element(s)</td>
</tr>
<tr>
<td>elevn</td>
<td>elevation</td>
</tr>
<tr>
<td>EIP</td>
<td>electric primer</td>
</tr>
<tr>
<td>eman</td>
<td>emanation</td>
</tr>
<tr>
<td>emf</td>
<td>electromotive force</td>
</tr>
<tr>
<td>EMFWK</td>
<td>Eidgenossische Munitionsfabrik und Waffenkontrolle, Aitdor (Swiss Govt Munition Plant and Arms Inspection)</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Meaning</td>
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<td>--------------</td>
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<tr>
<td>emgcy</td>
<td>emergency</td>
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<tr>
<td>EMMET</td>
<td>ethyltrimethylolmethane trinitrate or 1,1,1-trimethylolpropane trinitrate</td>
</tr>
<tr>
<td>Emp</td>
<td>Emperor, Empire</td>
</tr>
<tr>
<td>en</td>
<td>ethylenediamine (used in formulas only)</td>
</tr>
<tr>
<td>Encyc</td>
<td>encyclopedia</td>
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<tr>
<td>Energa</td>
<td>Belg A/T rifle grenade engine</td>
</tr>
<tr>
<td>Engl</td>
<td>England engineer</td>
</tr>
<tr>
<td>Engr</td>
<td>engineering</td>
</tr>
<tr>
<td>Engrs</td>
<td>Engineers (troops)</td>
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<tr>
<td>ENIAC</td>
<td>electronic numerical integrator and computer</td>
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<tr>
<td>Enl</td>
<td>enlisted</td>
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<tr>
<td>Ennayaku</td>
<td>Jap expl (see the text)</td>
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<td>Ens</td>
<td>ensign</td>
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<tr>
<td>EO</td>
<td>&quot;explosion only&quot; (Brit) (a very inferior explosion insufficient to be classed as a low order detonation)</td>
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<tr>
<td>EOC</td>
<td>Elswick Ordnance Co, Subsidiary of Armstrong, Elswick, Engl</td>
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<tr>
<td>EOCD</td>
<td>Eastman Organic Chemicals Dept, Rochester 3, NY</td>
</tr>
<tr>
<td>EOD</td>
<td>Erie Ordnance Depot, Port Clinton, Ohio</td>
</tr>
<tr>
<td>EODT</td>
<td>Explosives Ordnance Disposal Team, formerly BDS</td>
</tr>
<tr>
<td>EOR</td>
<td>Explosives Ordnance Reconnaissance</td>
</tr>
<tr>
<td>EP</td>
<td>English Patent (see BrP)</td>
</tr>
<tr>
<td>EP</td>
<td>Ital initiator for shaped chge projs (original type)</td>
</tr>
<tr>
<td>EPA</td>
<td>European Producing Agency</td>
</tr>
<tr>
<td>EPF</td>
<td>electrical percussion fuze</td>
</tr>
<tr>
<td>EPFW</td>
<td>Eidgenössische Pulverfabrik in Wimmis (Bern) (Swiss Govt Powder Plant)</td>
</tr>
<tr>
<td>EPS</td>
<td>Explosions per minute</td>
</tr>
<tr>
<td>eq</td>
<td>equal</td>
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<tr>
<td>eqn(s)</td>
<td>equation(s)</td>
</tr>
<tr>
<td>EqS</td>
<td>equivalent to sheathed (explosives)</td>
</tr>
<tr>
<td>equil</td>
<td>equimolecular</td>
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<tr>
<td>equim</td>
<td>equivalent</td>
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<td>equiv</td>
<td>equivalent</td>
</tr>
<tr>
<td>Er</td>
<td>erbium</td>
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<tr>
<td>ERA</td>
<td>Evans Research &amp; Development Corp, New York 17, NY</td>
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<tr>
<td>ERAMA</td>
<td></td>
</tr>
<tr>
<td>ERDC</td>
<td></td>
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<tr>
<td>ERDE</td>
<td>Explosives Research &amp; Development Establishment, Ministry of Supply, Waltham Abbey, Ess, Engl</td>
</tr>
<tr>
<td>ERDL</td>
<td>Engineering Research &amp; Development Laboratory, Fort Belvoir, Va.</td>
</tr>
<tr>
<td>EREC</td>
<td>Esso Research &amp; Engineering Co, Linden, NJ</td>
</tr>
<tr>
<td>ERETS</td>
<td>Experimental Rocket Engine Test Station</td>
</tr>
<tr>
<td>ERG</td>
<td>Explosives Research Group, Utah Univ</td>
</tr>
<tr>
<td>ERI</td>
<td>Engineering Research Institute, Univ of Michigan, Ann Arbor, Mich</td>
</tr>
<tr>
<td>ERL</td>
<td>Explosives Research Laboratory, Brucketon, Pa (existed during WW II)</td>
</tr>
<tr>
<td>ERRL</td>
<td>Eastern Regional Research Laboratory</td>
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<tr>
<td>ErTeN</td>
<td>erythritol tetranitrate</td>
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<tr>
<td>ESA</td>
<td>Explosivos Sociedad Anónima (Lurin, Peru)</td>
</tr>
<tr>
<td>Escho</td>
<td>same as Echo</td>
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<tr>
<td>ESP</td>
<td>end of sustained pressure (Rocketry)</td>
</tr>
<tr>
<td>esp</td>
<td>especially</td>
</tr>
<tr>
<td>Ess</td>
<td>Essex, Engl</td>
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<tr>
<td>EST</td>
<td>Eastern standard time estimate (verb)</td>
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<tr>
<td>est</td>
<td>establish (ed)</td>
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<td>estd</td>
<td>estimated</td>
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<td>estg</td>
<td>estimating</td>
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<td>estn</td>
<td>estimation</td>
</tr>
<tr>
<td>esu</td>
<td>electrostatic unit</td>
</tr>
<tr>
<td>Et or et</td>
<td>ethane</td>
</tr>
<tr>
<td>Et or et</td>
<td>ethyl (C\textsubscript{2}H\textsubscript{6})</td>
</tr>
<tr>
<td>et al</td>
<td>et alii (Lat) (and others)</td>
</tr>
<tr>
<td>et acet</td>
<td>ethyl acetate</td>
</tr>
<tr>
<td>et alc</td>
<td>ethyl alcohol</td>
</tr>
<tr>
<td>ete or et</td>
<td>ethylene</td>
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<tr>
<td>eth</td>
<td>ether</td>
</tr>
<tr>
<td>Ethyltetryl</td>
<td>N,2,4,6-tetranitroethylaniline</td>
</tr>
<tr>
<td>etl</td>
<td>ethanol</td>
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<tr>
<td>ETOUSA</td>
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</tbody>
</table>
et passim "and here and there"
Ets Établissement (Fr) (Firm)
et seq et sequentia (Lat) (and the following)
ETT Explosion Temperature Test
EU effect utile, also called travail pratique (see the text) (Fr)
Eu europium
Eur Europe
ev electron volt(s)
evap(d) evaporated(d)
evapg evaporating
evapn evaporation
evoln evolution
EWD Economic Warfare Division
EWT Eastern winter time
ex(s) example(s)
Ex a Greek prefix meaning "out of"
exam(d) examine(d)
examg examining
examn examination
Exc Excellence
exc excellent
exch exchange
excl exclusive
excld excluded
Exogene Ital for cyclonite
exp exponent
expl explode(s)
expl(s) explosive(s)
expld exploded
Expl D ammonium picrate
explg exploding
expln explosion
expr exploder
expt experiment
exptl experimental
ext external
extr extract
EXTRADOP Extra Döppler (cf DOVAP)
exrd extracted
extrg extracting
extrm extraction
°F degree Fahrenheit
F Farad
f fathom(182.5cm)
F February
F fellow; member of an association
f female
F field
F fleet
fluorine
foot
force
force spécifique (Fr) (specific force)
frequency
fugacity
fugasnyi (Rus) (of great heaving effect)
Fuzr Field Artillery
fighter aircraft
fixed ammunition
Frankford Arsenal, Phila, Pa
fuel-air (ratio)
Federal Atomic Commission
Field Ammunition Depot
First Aid and Decontamination Center
Fleet Admiral
Field Artillery Field Manual
Fabbrica Automobili Isotta-Fraschini (Ital)
fast air mine
first aid nurse
First Aid Post
forward ammunition point
forward area sight
final average sustained pressure (Rocketry)
fathom (182.5cm)
Favier (explosifs) Belg & Fr expls (see the text)
fighter bomber
flying boat
fragmentation bomb
Ital solventless propellants
free balloon barrage (Brit)
Federal Bureau of Investigation
final boiling point
Fort Custer, Mich
Ital solventless propellant
Federal Communications Commission
FCDA Federal Civil Defence Administration
firing control order
Fellow of Chemical Society (Brit)
forecast
factory
Field Depot
Fire Department
FD fuze delay
FDC firing data computer
fdg fading
f dr fluid drachm(0.00355 l)
F-drive front drive
Fdry foundry
FE Fábrica de Estrela(Vila Inhomero, Brazil)
FE Far East
Fe ferrum(Lat) (iron)
FE Fleet Engineer
Fe, Fe 2, Fe 3, Fe 4 Ital double base propellants
Feb February
Fed or Fedl Federal
FEMW Field Engineering and Mine Warfare(Brit)
FF flying fortress
ff and the following pages
FG field gun
FGAN fertilizer grade ammonium nitrate
FH foghorn
FHA Federal Housing Administration
Fi, fi fighter
FI Figure of Insensitiveness (Brit) (see the text)
fi for instance
FI Franklin Institute, Phila3, Pa
FI fuze, instantaneous
FIAT Field Information Agency, Technical
FIAT Fabbrica Italiana Automobili, Torino(Italy)
FID fuze, instantaneous detonating
fig(s) figure(s)
flt filter
filt filtrate
filtn filtration
FIMC Fabbrica Italiana Micce di Casale(Ital)
fin finance
fisc fiscal
FIU Fighter Interception Unit
Fivolite code name for tetramethylol-cyclopentanol pentanitrate or nitropentanol
Fivonite code name for tetramethylol-cyclopentanonone tetranitrate or nitropentanone
fl fluid
Fl fluorine
FLA First Lord of the Admiralty(Brit)
Fla Florida
Flak or FLAK Flugabwehrkanone(Ger)(AA cannon)
flam flammable
Flammivore Belg safety expl (see the text)
flex flexible
Flg Flagship
flge flange
floc flocculent
fl oz fluid ounce(0.02957 1) in USA and 0.02841 1 in GtBrit)
FLP Fábrica Lusitania de Pólvora (Portugal)
fl p flash point
flshls flashless
fwg following
FM Field Manual
FM Field Marshall
FM force-majeure(Fr) (disaster)
FM frequency modulation
FM fulminate of mercury(see MF)
FM symbol for titanium tetrachloride(CWA)
FMP full metal patched(bullet)
FN flat-nosed
FN(fusil) current Belg cal .30 rifle (see the text)
FNA fuming nitric acid
FNAG Fabrique Nationale d'Armes de Guerre, Herstal, Liége, Belgium
fnd found
fnp foundation
FNEA Fábrica Naval de Explosivos, Azul (Argentina)
FNH flashless, non hygroscopic (propellant)
FNMAL Fábrica Nacional de Munições de Armas Ligeiras(Portugal)
fn p fusion point
FPN Itot expl contg AN, PETN & wax
FNP Fábrica Nacional de Pólvora, near Mexico City
FNRL Fixed Nitrogen Research Laboratory
FNV Fábrica Nacional de Valla dolid(Span)
FO Foreign Office(Brit)
FOD Field Ordnance Depot
folw follow
folwg following
Forcites Belg & Swed expls(see the text)
Forg(s) forging(s)
Formit mixt of MAN-salt, AN & Tri-salt (see PATR 2510, p Ger 52)
formn formation
fort fort, fortification
<table>
<thead>
<tr>
<th>Abbr</th>
<th>Definition/Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort</td>
<td>fortress</td>
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<tr>
<td>Fortex</td>
<td>older Fr AN expls (see the text)</td>
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<tr>
<td>FOSDIC</td>
<td>film optical sensing device for input to computers</td>
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<tr>
<td>FP</td>
<td>firing point</td>
</tr>
<tr>
<td>FP or Fp</td>
<td>fission product</td>
</tr>
<tr>
<td>FPEG</td>
<td>Fábrica de Pólvoras y Explosivos de Granada (Span)</td>
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<td>FPL</td>
<td>Forest Products Laboratory</td>
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<td>FPM</td>
<td>Fábrica de Pólvoras de Murcia (Span)</td>
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<td>fpm</td>
<td>feet per minute</td>
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<td>FPRL</td>
<td>Forest Products Research Laboratory (Brit)</td>
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<td>fps</td>
<td>feet per second</td>
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<td>FPV</td>
<td>Fábrica Presidente Vargas (Piquette, Brazil)</td>
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<td>fr</td>
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<td>Fr</td>
<td>France; French</td>
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<td>Fractorites</td>
<td>Belg expls (see the text)</td>
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<td>frag</td>
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<td>fragment</td>
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<td>fragn</td>
<td>fragmentation</td>
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<td>FRB</td>
<td>Fire Research Board (Brit)</td>
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<td>FREL</td>
<td>Feltman Research &amp; Engineering Laboratories, Pic-Arsn, Dover, NJ</td>
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<tr>
<td>freqy</td>
<td>frequency</td>
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<td>Fri</td>
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<td>fricn</td>
<td>friction</td>
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<td>FRITALUX</td>
<td>France, Italy and Benelux Countries</td>
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<td>FrP</td>
<td>French Patent</td>
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<td>fr p</td>
<td>freezing point</td>
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<td>FRS</td>
<td>Federal Reserve System</td>
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<td>FrT</td>
<td>Fragmentation Test</td>
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<td>FrV</td>
<td>fragment velocity</td>
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<td>fs</td>
<td>feet per second</td>
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<td>FS</td>
<td>Faraday Society (Brit)</td>
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<td>FS</td>
<td>Field Service (Brit)</td>
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<td>FS</td>
<td>fin-stabilized</td>
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<tr>
<td>FS</td>
<td>fog siren</td>
</tr>
<tr>
<td>FS</td>
<td>US design for smoke-producing liq mixt of SO₃ &amp; SO₂HCl (CWA)</td>
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<td>FSB</td>
<td>Federal Specification Board</td>
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<td>FSB</td>
<td>Field Selection Board</td>
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<td>FSC</td>
<td>Fisher Scientific Co, Pittsburgh 19, PA</td>
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<td>FSD</td>
<td>Field Supply Depot</td>
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<td>FSL</td>
<td>First Sea Lord (Brit)</td>
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<td>FT</td>
<td>firing tables</td>
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<td>flame temperature</td>
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<td>FT</td>
<td>flame thrower</td>
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<td>ft</td>
<td>foot; feet</td>
</tr>
<tr>
<td>FTB</td>
<td>fleet torpedo bomber</td>
</tr>
<tr>
<td>FTC</td>
<td>Federal Trade Commission</td>
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<tr>
<td>FtD</td>
<td>foot candle</td>
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<tr>
<td>FTB</td>
<td>Fort Dix, New Jersey</td>
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<tr>
<td>FTC</td>
<td>fuze time difference</td>
</tr>
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<td>FtKn</td>
<td>Fort Knox, Ky</td>
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<tr>
<td>ft-lb</td>
<td>feet pounds</td>
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<td>ft-lb/min</td>
<td>feet pounds per minute</td>
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<td>ft-lb/sec</td>
<td>feet pounds per second</td>
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<tr>
<td>ft/min</td>
<td>feet per minute</td>
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<td>FtSam</td>
<td>Fort Sam Houston, Tex</td>
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<td>ft/sec</td>
<td>feet per second</td>
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<td>FtTh</td>
<td>Fort Thomas, Ky</td>
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<td>fusing</td>
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<td>Fus</td>
<td>fusilage</td>
</tr>
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<td>fusn</td>
<td>fusion</td>
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<tr>
<td>FUSAG</td>
<td>First United States Army Group</td>
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<tr>
<td>FVRDE</td>
<td>Fighting Vehicles Research &amp; Development Establishment (Brit)</td>
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<tr>
<td>fut</td>
<td>future</td>
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<tr>
<td>FW</td>
<td>fog whistle</td>
</tr>
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<td>FYr</td>
<td>fiscal year</td>
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<td>fuze</td>
<td>fuze</td>
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**Abbreviations**

<table>
<thead>
<tr>
<th>Abbr</th>
<th>Definition/Explanation</th>
</tr>
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<tbody>
<tr>
<td>GAFC</td>
<td>Goodyear Aircraft Corp, Akron 15, Ohio</td>
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<tr>
<td>GAFC</td>
<td>General Aniline &amp; Film Corp, New York 14, NY</td>
</tr>
<tr>
<td>GAC</td>
<td>Guggenheim Aeronautical Laboratory of the California Institute of Technology, Pasadena, Calif</td>
</tr>
<tr>
<td>Abbr</td>
<td>Meaning</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
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<tr>
<td>GAM</td>
<td>guided air missile</td>
</tr>
<tr>
<td>Gamsit</td>
<td>Swiss expl (see the text)</td>
</tr>
<tr>
<td>GAP</td>
<td>gun aiming point</td>
</tr>
<tr>
<td>GAP</td>
<td>gun aiming post</td>
</tr>
<tr>
<td>GAPA</td>
<td>ground-to-air-pilotless aircraft</td>
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<td>GaR</td>
<td>Garand rifle</td>
</tr>
<tr>
<td>GAR</td>
<td>guided air rocket</td>
</tr>
<tr>
<td>Garr</td>
<td>garrison (Brit)</td>
</tr>
<tr>
<td>gas</td>
<td>gasoline</td>
</tr>
<tr>
<td>Gaub</td>
<td>gaubitsa (Russ) (howitzer)</td>
</tr>
<tr>
<td>Gaz</td>
<td>Gazette (Brit Govt publication)</td>
</tr>
<tr>
<td>Gazz</td>
<td>Gazzetta (Ital)</td>
</tr>
<tr>
<td>GB</td>
<td>glider bomb</td>
</tr>
<tr>
<td>GB</td>
<td>See Gt Brit (Great Britain)</td>
</tr>
<tr>
<td>GB</td>
<td>gunboat</td>
</tr>
<tr>
<td>GBC</td>
<td>green bag charge (used in Amer separate-loading ammunition)</td>
</tr>
<tr>
<td>Gc</td>
<td>glycol</td>
</tr>
<tr>
<td>GC</td>
<td>gun control</td>
</tr>
<tr>
<td>GC</td>
<td>guncotton</td>
</tr>
<tr>
<td>GCA</td>
<td>Geneva Convention Act</td>
</tr>
<tr>
<td>g-cal</td>
<td>gram-calorie</td>
</tr>
<tr>
<td>GCB</td>
<td>ground contamination bomb</td>
</tr>
<tr>
<td>GCC</td>
<td>Goodrich Chemical Co, Avon Lake, Ohio</td>
</tr>
<tr>
<td>g/cc</td>
<td>grams per cubic centimeter</td>
</tr>
<tr>
<td>GcDN</td>
<td>glycol dinitrate</td>
</tr>
<tr>
<td>GCL</td>
<td>Gibbs Chemical Lab, Harvard Univ, Cambridge, Mass</td>
</tr>
<tr>
<td>GCM</td>
<td>General Court Martial</td>
</tr>
<tr>
<td>GCRC</td>
<td>Goodrich Research Center, Brecksville, Ohio</td>
</tr>
<tr>
<td>GCT</td>
<td>General Classification Test</td>
</tr>
<tr>
<td>GeTNB</td>
<td>glycol trinitrobutyrate</td>
</tr>
<tr>
<td>Gd</td>
<td>gadolinium</td>
</tr>
<tr>
<td>GD</td>
<td>gelatin dynamite</td>
</tr>
<tr>
<td>GD</td>
<td>General Depot</td>
</tr>
<tr>
<td>GD</td>
<td>grenade discharger</td>
</tr>
<tr>
<td>GD</td>
<td>ground defense</td>
</tr>
<tr>
<td>GD1; GD2; GDII</td>
<td>Ital gelatin blasting expls contg NG</td>
</tr>
<tr>
<td>GDIM</td>
<td>same as above</td>
</tr>
<tr>
<td>GDN</td>
<td>see GcDN or NGc</td>
</tr>
<tr>
<td>GE</td>
<td>gas ejection</td>
</tr>
<tr>
<td>GE</td>
<td>General Electric Co</td>
</tr>
<tr>
<td>Ge</td>
<td>germanium</td>
</tr>
<tr>
<td>gelat</td>
<td>gelatinous</td>
</tr>
<tr>
<td>Gelatine-</td>
<td>Swiss expl (see the text)</td>
</tr>
<tr>
<td>Aldorfit</td>
<td>} Swiss chlorate expl (see the text)</td>
</tr>
<tr>
<td>Gelatin-Cheddite</td>
<td>Swiss chlorate expl (see the text)</td>
</tr>
<tr>
<td>gen</td>
<td>general</td>
</tr>
<tr>
<td>Gen</td>
<td>General</td>
</tr>
<tr>
<td>GEO</td>
<td>Ital gelatin blasting expl contg NG</td>
</tr>
<tr>
<td>geol</td>
<td>geological</td>
</tr>
<tr>
<td>GEOM</td>
<td>Ital same type of expl as GEO</td>
</tr>
<tr>
<td>Ger</td>
<td>German; Germany</td>
</tr>
<tr>
<td>g-g or GG</td>
<td>green-green (double star rocket) (AC sig</td>
</tr>
<tr>
<td>g gr</td>
<td>great gross (12 gross; 1728)</td>
</tr>
<tr>
<td>gH</td>
<td>gun howitzer</td>
</tr>
<tr>
<td>GHQ</td>
<td>General Headquarters</td>
</tr>
<tr>
<td>GI</td>
<td>Government issue (also nickname for an Amer soldier)</td>
</tr>
<tr>
<td>g/l</td>
<td>gram/liter</td>
</tr>
<tr>
<td>GL</td>
<td>grenade launcher</td>
</tr>
<tr>
<td>GL</td>
<td>gun limber</td>
</tr>
<tr>
<td>glac</td>
<td>glacial</td>
</tr>
<tr>
<td>GLEEP</td>
<td>Graphite Low Energy Experimental Pile</td>
</tr>
<tr>
<td>GLMC</td>
<td>Glen L. Martin Co, Baltimore, Md</td>
</tr>
<tr>
<td>Glos</td>
<td>Gloucestershire, Engl</td>
</tr>
<tr>
<td>GLR</td>
<td>General Laboratory Report (PicArsn)</td>
</tr>
<tr>
<td>GLTN</td>
<td>glycerin lactate trinitrate</td>
</tr>
<tr>
<td>glyc</td>
<td>glycerol</td>
</tr>
<tr>
<td>GM</td>
<td>guided missile</td>
</tr>
<tr>
<td>GM</td>
<td>gun metal</td>
</tr>
<tr>
<td>G-Man</td>
<td>Govt man (FBI agent)</td>
</tr>
<tr>
<td>GMJ</td>
<td>gilding metal jacket (of a bullet)</td>
</tr>
<tr>
<td>GMLTeN</td>
<td>glycerin monolactate tetranitrate</td>
</tr>
<tr>
<td>g-mol</td>
<td>gram-molecule</td>
</tr>
<tr>
<td>gmv</td>
<td>gram molecular volume</td>
</tr>
<tr>
<td>gnd</td>
<td>ground</td>
</tr>
<tr>
<td>gnde</td>
<td>grenade</td>
</tr>
<tr>
<td>Gnr</td>
<td>gunner</td>
</tr>
<tr>
<td>GOC</td>
<td>General Officer, Commanding</td>
</tr>
<tr>
<td>Gomme</td>
<td>Fr gelatin dynamites</td>
</tr>
<tr>
<td>GOP</td>
<td>Gulf Ordnance Plant, Aberdeen, Miss</td>
</tr>
<tr>
<td>Gov</td>
<td>Governor</td>
</tr>
<tr>
<td>gov</td>
<td>governor (mechanical)</td>
</tr>
<tr>
<td>Govt</td>
<td>Government</td>
</tr>
<tr>
<td>GovtPrtgOff</td>
<td>Government Printing Office, Washington, DC</td>
</tr>
<tr>
<td>or GPO</td>
<td>general purpose</td>
</tr>
<tr>
<td>GP</td>
<td>Ital sporting propellant</td>
</tr>
<tr>
<td>GPA</td>
<td>Glycerine Producers</td>
</tr>
<tr>
<td>GPB</td>
<td>general purpose bomb</td>
</tr>
<tr>
<td>GPH</td>
<td>gallons per hour</td>
</tr>
<tr>
<td>GPO</td>
<td>General Post Office</td>
</tr>
<tr>
<td>GPO</td>
<td>See GovtPrtgOff</td>
</tr>
<tr>
<td>gr</td>
<td>grain(s) (0.0648 gram)</td>
</tr>
<tr>
<td>GR</td>
<td>gunnery range</td>
</tr>
<tr>
<td>GRakrult</td>
<td>older Swed propellant (see the text)</td>
</tr>
</tbody>
</table>
gran granular
GRE ground radar equipment
GrF grazing fire
Grf 88 Ger for PA
Grison(dynamites) Fr permissible dynamites
Grisonites; Fr & Belg permissible explosives (see text)
Grisoutites; Grisonites explosives (see text)
grn ground
grnd ground
Gs gauss
GS general service(Brit)
GS General Staff
GS gun sight
G-salt nitroguanidine (see NGu)
GSC green star, cluster
GSP green star, parachute
G-suit gravity suit
Gt Great(as GtBrit)
GT gun turret
GT’NB symbol for ethyleneglycol-dinitrobutyrate(classified)
Gu guanidine
Guar guarantee
Guate Guatemala
Guer Guernsey
GW guided weapon
GWVA Great War Veterans Association (of Canada)
Gy gunnery
gyro gyroscope

HA Halstead Arsenal, Fort Halstead, Kent, Engl
HA heavy artillery
ha hectare
HA high angle(for antiaircraft)
HAA heavy antiaircraft artillery
HAB high altitude bombing
HAC Hague Arbitration Convention
HAC Hughes Aircraft Co, Colver City, Calif
HACSIR Honorary Advisory Council for Scientific and Industrial Research (Canada)
HADN Holloman Air Development Center hexamine dinitrate
HBR same as Comp C-4
Hb harbor
HBr hardness, Brinell
HBRA Howitzer Battery Royal Artillery (Brit)
HBX high blast explosives(torpex type expls)
HC hexachloroethane (smoke)
HC high capacity(bomb)
HCC Harshaw Chemical Co(see UCCC)
Hd hoghead(238 1 in USA and 286.4 1 in GtBrit)
HD Home Defence(Brit)
HD horse-drawn
HD symbol for Mustard Gas, distilled(blister gas) (CWA)
Hdbk handbook
He helium
HE high explosive
HEAP high-explosive, armor-piercing
HEAT high-explosive, antitank
HEBD high-explosive, base detonating
HEC Halstead Exploiting Centre (Brit)
HEDA high-explosive delayed action
HEF high-explosive, fragmentation (bomb)
HEH high-explosive, heavy(projectile)
HEI high-explosive, incendiary
HEIA high-explosive immediate action
HEI-Kongo Jap expl known also as H-6 Amer expl (classified)
HEI-T Jap for trinitrophenetole
HEI high-explosive, incendiary with tracer
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HELC</td>
<td>high-explosive, long case</td>
</tr>
<tr>
<td>Helv</td>
<td>Helvetica (Swiss)</td>
</tr>
<tr>
<td>HEP</td>
<td>high-explosive, plastic (corresponds to Brit HE/SH)</td>
</tr>
<tr>
<td>HEPL</td>
<td>High Energy Physics Laboratory</td>
</tr>
<tr>
<td>HEP-T</td>
<td>high-explosive, plastic with tracer</td>
</tr>
<tr>
<td>Heptyl</td>
<td>code name for 2,4,6-trinitrophenyl-trimethylolmethylnitramine trinitrate</td>
</tr>
<tr>
<td>Herf</td>
<td>Herefordshire, Engl</td>
</tr>
<tr>
<td>Herts</td>
<td>Hertfordshire, Engl</td>
</tr>
<tr>
<td>HES</td>
<td>Hercules Experiment Station, Woodale, Del</td>
</tr>
<tr>
<td>HE/SH</td>
<td>high-explosive shell</td>
</tr>
<tr>
<td>HE/S</td>
<td>high-explosive squashhead (Brit) (corresponds to Amer HEP)</td>
</tr>
<tr>
<td>HE-T</td>
<td>high-explosive with tracer</td>
</tr>
<tr>
<td>hex</td>
<td>hexagonal</td>
</tr>
<tr>
<td>HEX</td>
<td>high energy expls (US)</td>
</tr>
<tr>
<td>Hexa, Hexamine</td>
<td>code names for hexanitrodiphenylamine (HNDPhA)</td>
</tr>
<tr>
<td>Hexyl Urotropine</td>
<td></td>
</tr>
<tr>
<td>Hexa</td>
<td>Ger for hexanitrodiphenylamine</td>
</tr>
<tr>
<td>Hexamit or</td>
<td>Ger &amp; Swiss expl contg TNT &amp; HNDPhA (similar to Novit)</td>
</tr>
<tr>
<td>Hexanit</td>
<td>Swiss expl (see the text)</td>
</tr>
<tr>
<td>Hexatonal</td>
<td>Ger &amp; Swiss for cyclonite (RDX)</td>
</tr>
<tr>
<td>Hexogen</td>
<td>Span for cyclonite (RDX)</td>
</tr>
<tr>
<td>Hexogeno</td>
<td>Swiss expls contg RDX, NG &amp; CC</td>
</tr>
<tr>
<td>Hexonite</td>
<td></td>
</tr>
<tr>
<td>Hf</td>
<td>hafnium</td>
</tr>
<tr>
<td>HF</td>
<td>harassing fire</td>
</tr>
<tr>
<td>HF</td>
<td>high frequency (3 to 30 megacycles/sec)</td>
</tr>
<tr>
<td>HFA</td>
<td>high frequency amplifier</td>
</tr>
<tr>
<td>HFC</td>
<td>high frequency current</td>
</tr>
<tr>
<td>HF/DF</td>
<td>high frequency direction finder</td>
</tr>
<tr>
<td>HFI</td>
<td>height finding instrument</td>
</tr>
<tr>
<td>HG</td>
<td>Hotchkiss gun (MG)</td>
</tr>
<tr>
<td>Hg</td>
<td>hydrargyrum (Lat) (mercury)</td>
</tr>
<tr>
<td>HH</td>
<td>heavy hydrogen</td>
</tr>
<tr>
<td>H-hour</td>
<td>the time at which a planned operation is to begin (US); same as Brit Z-hour</td>
</tr>
<tr>
<td>HiC</td>
<td>high capacity</td>
</tr>
<tr>
<td>HiFi</td>
<td>high fidelity</td>
</tr>
<tr>
<td>H-ion</td>
<td>hydrogen ion</td>
</tr>
<tr>
<td>hist</td>
<td>historical</td>
</tr>
<tr>
<td>hi-volt</td>
<td>high voltage</td>
</tr>
<tr>
<td>H₂-Kongo</td>
<td>Jap expl (H₂ Mixture) (see the text)</td>
</tr>
<tr>
<td>HIM</td>
<td>Hollandsche Industrie und Hande Maatschappij (Dutch)</td>
</tr>
<tr>
<td>hl</td>
<td>hectaritre</td>
</tr>
<tr>
<td>HM</td>
<td>His (or Her) Majesty’s (Brit)</td>
</tr>
<tr>
<td>HM</td>
<td>hydrazine mononitrate</td>
</tr>
<tr>
<td>HMAC</td>
<td>House Military Affairs Committee</td>
</tr>
<tr>
<td>hmd</td>
<td>humid</td>
</tr>
<tr>
<td>HMF</td>
<td>His (or Her) Majesty’s Force (Brit)</td>
</tr>
<tr>
<td>HMG</td>
<td>heavy machine gun</td>
</tr>
<tr>
<td>HMG</td>
<td>His (or Her) Majesty’s Government (Brit)</td>
</tr>
<tr>
<td>HNS</td>
<td>His (or Her) Majesty’s Service (Brit)</td>
</tr>
<tr>
<td>HNSO</td>
<td>His (or Her) Majesty’s Ship (Brit)</td>
</tr>
<tr>
<td>HMT</td>
<td>see HMTeA</td>
</tr>
<tr>
<td>HMTD</td>
<td>see HMPaA</td>
</tr>
<tr>
<td>HMTeA</td>
<td>hexamethylenetetramine</td>
</tr>
<tr>
<td>HMTeA</td>
<td>hexamethylenetriperoxide-diamine</td>
</tr>
<tr>
<td>HMX</td>
<td>His Majesty’s Explosive (High Melting Explosive) (cyclo-tetramethylene-tetranitramine)</td>
</tr>
<tr>
<td>HN</td>
<td>“hotter than no flash” (Brit propellant)</td>
</tr>
<tr>
<td>HNAB</td>
<td>hexanitroazobenzene</td>
</tr>
<tr>
<td>HNG</td>
<td>hydren-nitroglycerin (NG contg NSug as an antifreeze)</td>
</tr>
<tr>
<td>HNH</td>
<td>hexanitroanisole</td>
</tr>
<tr>
<td>HNCbl</td>
<td>hexanitrocarbanilide</td>
</tr>
<tr>
<td>HNDPh</td>
<td>hexanitrophenyl</td>
</tr>
<tr>
<td>HNDPhA</td>
<td>hexanitrophenylamine</td>
</tr>
<tr>
<td>HNDPhAEN</td>
<td>hexanitrophenylaminooxynitrate</td>
</tr>
<tr>
<td>HNDPhBzI</td>
<td>hexanitrophenylbenzyl</td>
</tr>
<tr>
<td>HNDPhGu</td>
<td>hexanitrophenylguanidine</td>
</tr>
<tr>
<td>HNDPhSfi</td>
<td>hexanitrophenylsulfide</td>
</tr>
<tr>
<td>HNDPhSo</td>
<td>hexanitrophenylsulfone</td>
</tr>
<tr>
<td>HNDPhU</td>
<td>hexanitrophenylurea</td>
</tr>
<tr>
<td>HNEn</td>
<td>hexanitroethene</td>
</tr>
<tr>
<td>HNMat</td>
<td>hexanitromannitol</td>
</tr>
<tr>
<td>HN0 or HNOx</td>
<td>hexanitrosoxanilide</td>
</tr>
<tr>
<td>Ho</td>
<td>holmium</td>
</tr>
<tr>
<td>HoC</td>
<td>Home Office (Brit)</td>
</tr>
<tr>
<td>HOCL</td>
<td>hollow charge (same as SC)</td>
</tr>
<tr>
<td>Hot</td>
<td>Hotchkiss Ordnance Co, Ltd, England</td>
</tr>
<tr>
<td>Holl</td>
<td>Holland</td>
</tr>
<tr>
<td>Holter</td>
<td>Span expl comparable to PBX Mil expl developed by Hispano-Suiza, Genève, Switz (its compn was not published)</td>
</tr>
</tbody>
</table>
Homocyclonite: same as HMX
code name for 3,7-dinitro-1,5-endooethylene-1,3,5,7-tetrazacyclooctane

Hon: honorary
Horiz: horizontal
Hosp: hospital
HOW: Holston Ordnance Works, Kingsport, Tenn
How or H: howitzer
H-P or h-press: high pressure
HP: hollow point (bullet)
HP or hp: horse power
HPAB: Hanssons Pyrotekniska Aktiebolaget (Swed)
HPC: Hercules Powder Co, Wilmington 99, Del
HPCC: Hellenic Powder Cartridge Company at Daphni near Athens
hp-hr: horsepower-hour(s)
HQ: Headquarters
hr(s): hour(s)
HR: humidity, relative
HRRL: Human Resources Research Laboratory
HS: US design for Mustard Gas and for chloracetophenone & chloropicrin in chloroform (CWA's)
high speed
HSC: hotter than "solventless carbamite propellant" (Brit)
HSL: high speed launch (Brit)
HSMS: high speed mine-sweeper (Brit)
HSS: high speed steel
HSSAB: Hispano-Suiza Sociedad Anónima, Barcelona (Span)
HSSAG: Hispano-Suiza Société Anonyme, Genève (Switz)
HT: half-tracked
HT: high tension
HTA: Amer expls (classified)
HTP: high-test peroxide
HU: Harvard University, Cambridge, Mass
Hung: Hungary
Hunts: Huntingdonshire, Engl
hv: heavy
HV: high velocity or hyper-velocity
hv: high voltage
HV$_2$: Fr for polyvinyl acetate

HVAG: Holzverzuckerungs Aktiengesellschaft Domat-Ems (Swiss)
HVAP: hypervelocity, armor-piercing
HVAR: hypervelocity aircraft rocket
HVAT: hypervelocity, anti-tank
HVG: hypervelocity gun
HVT: hypervelocity, target practice
HW: heavy weapon
hw: hectowatt
hwt: hundredweight (45.36 kg in USA and 50.8 kg in GB Brit)
Hwy: highway
Hx: hydroxy
hyd: hydrated, hydrolysis
hydr: hydraulics
hyrd: hydrodynamics
hydres: hydrostatics
hydrx: hydroxide
hyg: hygiene
hygr: hygroscopic
hygr: hygroscopicity
Hyman: code name for N-nitro-
HYPO: High Power Output Reactor
Hz: herz
Hz: hydrazo

I: impulse
I or Inc: incendiary
I: infantry
I or Inst: instantaneous
I: intensity of electric current
flow
I: iodine
I or i: iso- (as applied to a type of organic compound)
IA: Italy
IA: Indiana Arsenal, Charlestown, Ind
IA: Iowa
IAW&D: Inspector of Antiaircraft Weapons and Devices ( Brit)
IAG: Industria ArmiGalesi (Ital)
IAR: Institute for Atomic Research
IASP: initial average sustained pressure (Rocketry)
IATM: International Association for Testing Materials
IAWR: Institute for Air Weapons Research
<table>
<thead>
<tr>
<th>Code</th>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB</td>
<td>incendiary bomb</td>
<td>incendiary bomb</td>
</tr>
<tr>
<td>IB</td>
<td>information bulletin</td>
<td>information bulletin</td>
</tr>
<tr>
<td>IBEN</td>
<td>incendiary bomb with explosive nose</td>
<td>incendiary bomb with explosive nose</td>
</tr>
<tr>
<td>IBHP</td>
<td>Institut Beige des Hautes Pressions, Bruxelles, Belg</td>
<td>Institut Beige des Hautes Pressions, Bruxelles, Belg</td>
</tr>
<tr>
<td>ibid</td>
<td>ibidem(Lat)</td>
<td>ibidem(Lat)</td>
</tr>
<tr>
<td>bpl</td>
<td>initial boiling point</td>
<td>initial boiling point</td>
</tr>
<tr>
<td>ICBM or IBM</td>
<td>intercontinental ballistic missile</td>
<td>intercontinental ballistic missile</td>
</tr>
<tr>
<td>ICC</td>
<td>Interstate Commerce Commission</td>
<td>Interstate Commerce Commission</td>
</tr>
<tr>
<td>ICI</td>
<td>Imperial Chemical Industries (Ltd) formerly Nobel Co(Brit)</td>
<td>Imperial Chemical Industries (Ltd) formerly Nobel Co(Brit)</td>
</tr>
<tr>
<td>ICIANZ</td>
<td>Imperial Chemical Industries of Australia &amp; New Zealand</td>
<td>Imperial Chemical Industries of Australia &amp; New Zealand</td>
</tr>
<tr>
<td>ICIL, Nobel Div</td>
<td>Imperial Chemical Industries, Ltd, Nobel Div, Stevenston, Ayrshire, Scotland</td>
<td>Imperial Chemical Industries, Ltd, Nobel Div, Stevenston, Ayrshire, Scotland</td>
</tr>
<tr>
<td>ICSU</td>
<td>International Council of Scientific Unions</td>
<td>International Council of Scientific Unions</td>
</tr>
<tr>
<td>ID or id</td>
<td>internal (inside) diameter</td>
<td>internal (inside) diameter</td>
</tr>
<tr>
<td>Ida</td>
<td>Idaho</td>
<td>Idaho</td>
</tr>
<tr>
<td>IDR</td>
<td>Intelligence Division Report</td>
<td>Intelligence Division Report</td>
</tr>
<tr>
<td>IE(balistita)</td>
<td>Span propellant</td>
<td>Span propellant</td>
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<td>IEME</td>
<td>Inspectorate of Electrical and Mechanical Equipment(Brit)</td>
<td>Inspectorate of Electrical and Mechanical Equipment(Brit)</td>
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<tr>
<td>IED</td>
<td>Industrial Engineering Division</td>
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<tr>
<td>IIT</td>
<td>Index of Inflammability Test(Brit)</td>
<td>Index of Inflammability Test(Brit)</td>
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<td>IM</td>
<td>interceptor missile</td>
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<tr>
<td>IMk</td>
<td>identification mark</td>
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<td>immediately</td>
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<td>impulse</td>
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<tr>
<td>IMP</td>
<td>Industrial Mobilization Plan</td>
<td>Industrial Mobilization Plan</td>
</tr>
<tr>
<td>IMP</td>
<td>initial maximum pressure</td>
<td>initial maximum pressure</td>
</tr>
<tr>
<td>imp gal</td>
<td>imperial gallon(4.54 l)</td>
<td>imperial gallon(4.54 l)</td>
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<td>impr</td>
<td>improved</td>
<td>improved</td>
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<td>impregnate(d)</td>
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<tr>
<td>imprt</td>
<td>important</td>
<td>important</td>
</tr>
<tr>
<td>IMR</td>
<td>improved military rifle(Pdr)(Brit)</td>
<td>improved military rifle(Pdr)(Brit)</td>
</tr>
<tr>
<td>in or &quot;</td>
<td>inch</td>
<td>inch</td>
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<tr>
<td>In</td>
<td>indium</td>
<td>indium</td>
</tr>
<tr>
<td>inact</td>
<td>inactive</td>
<td>inactive</td>
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</table>

**Notes:**
- Lat prefix meaning "below" as in infrared of the invisible spectrum.
- inches of mercury
- inject
- injection
- inch-pound(s)
- inorganic
- iodine number and saponification number
- inches per second
- insoluble
- insolvency
- Inspector
- inspection
- instantaneous
- Institute
- instantaneous fuze(Brit)(a percussion fuze with no delay action)
- Institution
- instruction
- instrument
- internal
- interchangeable
- international
- insoluble nitrogen to total nitrogen introduction
- Iowa
- Iowa Ordnance Plant, Burlington, Iowa
- initial point
- Ingersoll Products Div of Borg-Warner Corp, Kalamazoo, Mich
- inches per minute
- infrared
- iridium
- intermediate range ballistic missile
- initial rate of climb
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>IRE</td>
<td>Institute of Radio Engineers</td>
</tr>
<tr>
<td>irreg</td>
<td>irregular</td>
</tr>
<tr>
<td>IS</td>
<td>impact sensitiveness</td>
</tr>
<tr>
<td>ISA</td>
<td>Ignifera Societa Anonima in Locarno-Minusio(Swiss) (see also ZSF)</td>
</tr>
<tr>
<td>ISC</td>
<td>Iowa State College</td>
</tr>
<tr>
<td>iso-Bu</td>
<td>iso-butyl</td>
</tr>
<tr>
<td>isom</td>
<td>isomeric</td>
</tr>
<tr>
<td>iso-Pr</td>
<td>iso-propyl</td>
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<tr>
<td>isoth</td>
<td>isothermal</td>
</tr>
<tr>
<td>Isp</td>
<td>specific impulse</td>
</tr>
<tr>
<td>ISTM</td>
<td>International Society for Testing Materials</td>
</tr>
<tr>
<td>ISWG</td>
<td>Imperial Standard Wire Gauge (Brit)</td>
</tr>
<tr>
<td>IT</td>
<td>infantry tank</td>
</tr>
<tr>
<td>ITB</td>
<td>infantry training bomb</td>
</tr>
<tr>
<td>Ital</td>
<td>Italian</td>
</tr>
<tr>
<td>Ital P</td>
<td>Italian Patent</td>
</tr>
<tr>
<td>IUPAC</td>
<td>International Union of Pure and Applied Chemistry</td>
</tr>
<tr>
<td>J</td>
<td>Ger symbol for iodine</td>
</tr>
<tr>
<td>J or j</td>
<td>journal</td>
</tr>
<tr>
<td>J</td>
<td>Fr sporting propellant</td>
</tr>
<tr>
<td>JA</td>
<td>Joliet Arsenal, Joliet, Ill</td>
</tr>
<tr>
<td>JAAF</td>
<td>Joint Army-Air Force</td>
</tr>
<tr>
<td>Jan</td>
<td>January</td>
</tr>
<tr>
<td>JAN</td>
<td>Joint Army-Navy</td>
</tr>
<tr>
<td>JANAF</td>
<td>Joint Army-Navy-Air Force</td>
</tr>
<tr>
<td>Jap</td>
<td>Japanese</td>
</tr>
<tr>
<td>JapP</td>
<td>Japanese Patent</td>
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<tr>
<td>JATO</td>
<td>jet assisted take off, also called RATO or &quot;booster rocket&quot;</td>
</tr>
<tr>
<td>JF</td>
<td>jet fighter</td>
</tr>
<tr>
<td>JHU</td>
<td>Johns Hopkins University, Baltimore, Md</td>
</tr>
<tr>
<td>JHU/APL</td>
<td>Johns Hopkins Univ, Applied Physics Laboratory, Silver Springs, Md</td>
</tr>
<tr>
<td>JHU/ORO</td>
<td>Johns Hopkins Univ, Operations Research Office</td>
</tr>
<tr>
<td>JOP</td>
<td>Joint Operations Center</td>
</tr>
<tr>
<td>JP</td>
<td>jet propelled</td>
</tr>
<tr>
<td>JP-1, JP-2, etc</td>
<td>jet fuels(see the text)</td>
</tr>
<tr>
<td>JPC</td>
<td>Jet Propulsion Center</td>
</tr>
<tr>
<td>JPG</td>
<td>Jefferson Proving Ground Madison, Ind</td>
</tr>
<tr>
<td>JPL</td>
<td>Jet Propulsion Laboratory Pasadena 3, Calif</td>
</tr>
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<td>JPRS</td>
<td>Joint Publications Research Service</td>
</tr>
<tr>
<td>Jr</td>
<td>junior</td>
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<tr>
<td>JRDB</td>
<td>Joint Research and Development Board(U.S. Army &amp; Navy)</td>
</tr>
<tr>
<td>JS&amp;TIC</td>
<td>Joint Scientific and Technical Intelligence Committee (Brit)</td>
</tr>
<tr>
<td>Jugo</td>
<td>See Yugo</td>
</tr>
<tr>
<td>Junite</td>
<td>Fr code name for ethylene-bisurethane junction</td>
</tr>
<tr>
<td>JUSMAPG</td>
<td>Joint United States Military Advisory &amp; Planning Group</td>
</tr>
<tr>
<td>JUSMG</td>
<td>Joint United States Military Group</td>
</tr>
<tr>
<td>just</td>
<td>justice</td>
</tr>
<tr>
<td>juv</td>
<td>juvenile</td>
</tr>
<tr>
<td>K</td>
<td>degree Kelvin</td>
</tr>
<tr>
<td>K</td>
<td>kalium(Lat) (potassium)</td>
</tr>
<tr>
<td>k</td>
<td>constant</td>
</tr>
<tr>
<td>k</td>
<td>Jap expl(see the text)</td>
</tr>
<tr>
<td>K</td>
<td>kilo = 10^3</td>
</tr>
<tr>
<td>K</td>
<td>knot</td>
</tr>
<tr>
<td>K-1 &amp; K-2</td>
<td>Rus expls contg TNT &amp; DNB</td>
</tr>
<tr>
<td>Kaipinites</td>
<td>Fr expls contg Amm perchlorate, Na nitrate and TNT or TNN</td>
</tr>
<tr>
<td>Kan</td>
<td>Kansas</td>
</tr>
<tr>
<td>KAPL</td>
<td>Knolls Atomic Power Laboratory</td>
</tr>
<tr>
<td>Karioo</td>
<td>Jap black powder(see the text)</td>
</tr>
<tr>
<td>Kasshokuyaku</td>
<td>Jap brown powder(see the text)</td>
</tr>
<tr>
<td>KC</td>
<td>Kellog Company, Jersey City, NJ</td>
</tr>
<tr>
<td>kc</td>
<td>kilocycle(s)</td>
</tr>
<tr>
<td>kcal or Cal</td>
<td>kilocalorie(s)</td>
</tr>
<tr>
<td>KDNBF</td>
<td>potassium dinitrobenzofuroxan</td>
</tr>
<tr>
<td>Keyneyakuro</td>
<td>Jap for trinitrophenetole</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram(s)</td>
</tr>
<tr>
<td>kg/cu m</td>
<td>kilograms per cubic meter</td>
</tr>
<tr>
<td>Kg-m</td>
<td>kilogram-meter</td>
</tr>
<tr>
<td>kg/m/s</td>
<td>kilogram-meter per second</td>
</tr>
<tr>
<td>kg/sq m</td>
<td>kilograms per square meter</td>
</tr>
<tr>
<td>KGC</td>
<td>Kontes Glass Co, Vineland, NJ</td>
</tr>
<tr>
<td>KhF</td>
<td>kimicheskii fugass(Rus) (chem land mine)</td>
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<tr>
<td>Kibakuyaku</td>
<td>Jap initiating expl(see the text)</td>
</tr>
<tr>
<td>Kibakuzai</td>
<td>Jap primer or percussion charge</td>
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<tr>
<td>kj</td>
<td>kilojoule</td>
</tr>
<tr>
<td>kl</td>
<td>kiloliter</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>-------------</td>
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<tr>
<td>KLG</td>
<td>Kimble Laboratory Glassware, Toledo, Ohio</td>
</tr>
<tr>
<td>km</td>
<td>kilometer</td>
</tr>
<tr>
<td>kMc/s</td>
<td>kilomegacycles per second (*1000 megahertz)</td>
</tr>
<tr>
<td>km/hr</td>
<td>kilometers per hour</td>
</tr>
<tr>
<td>KMOP</td>
<td>Kings Mills Ordnance Plant, Kings Mills, Ohio</td>
</tr>
<tr>
<td>km/s</td>
<td>kilometers per second</td>
</tr>
<tr>
<td>KNSFNV</td>
<td>Koninklijke Nederlandsche Springstoffenfabrieken Naamloze Venootschap</td>
</tr>
<tr>
<td>Ko</td>
<td>Jap Amm perchlorate type expl contg ferrosilicon</td>
</tr>
<tr>
<td>Kokoshokuyaku</td>
<td>Jap black powder type expl</td>
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<tr>
<td>KOP</td>
<td>Kansas Ordnance Plant, Parsons, Kan</td>
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<tr>
<td>KOP</td>
<td>Kingsbury Ordnance Plant, LaPorte, Ind</td>
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<td>Koshitsu</td>
<td>Jap expls (see also Shouyaku-koshitsu)</td>
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<td>KOTAR</td>
<td>Correlated Tracking &amp; Ranging (cf DOVAP &amp; UDOP)</td>
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<td>KOW</td>
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<td>KOW</td>
<td>Keystone Ordnance Works, Meadville, Pa</td>
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<tr>
<td>KR</td>
<td>Kings Regulations(Brit)</td>
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<tr>
<td>Kr</td>
<td>krypton</td>
</tr>
<tr>
<td>KV</td>
<td>kapciul'-vosplamenitel' (Rus) (igniter cap)</td>
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<tr>
<td>kv</td>
<td>kilovolt(s)</td>
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<td>kva</td>
<td>kilovolt-ampere</td>
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<tr>
<td>kw</td>
<td>kilowatt(s)</td>
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<td>kilowatt-hour</td>
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<td>Ky</td>
<td>Kentucky</td>
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<td>Kraftzahl(see the text)</td>
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<td>I</td>
<td>liter(s)</td>
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<td>latun'(Rus)(brass) for Land Service (Brit)</td>
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<td>lanthana for Belg propellants (see the text)</td>
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<tr>
<td>La</td>
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<td>LA</td>
<td>lead azide</td>
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<tr>
<td>LA</td>
<td>Light Artillery</td>
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<td>Los Angeles (Calif)</td>
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<td>LAA</td>
<td>light antiaircraft artillery</td>
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<td>laboratory</td>
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<td>Iachrymator</td>
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<td>Lact ON</td>
<td>lactose octanitrate</td>
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<td>LAG</td>
<td>light automatic gun</td>
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<td>lang</td>
<td>older Swed propellant language</td>
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<td>LAOD</td>
<td>Los Angeles Ordnance District, Pasadena, Calif</td>
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<tr>
<td>LASL</td>
<td>Los Alamos Scientific Laboratory, Los Alamos, NM</td>
</tr>
<tr>
<td>Lat</td>
<td>Latin</td>
</tr>
<tr>
<td>lat ht</td>
<td>latent heat</td>
</tr>
<tr>
<td>LB</td>
<td>light bomb</td>
</tr>
<tr>
<td>lb</td>
<td>pound(s)</td>
</tr>
<tr>
<td>lb ap</td>
<td>pound apothecary, see lb tr</td>
</tr>
<tr>
<td>lb av</td>
<td>pound avoirdupois(453.59g)</td>
</tr>
<tr>
<td>lb/cu ft</td>
<td>pounds per cubic foot</td>
</tr>
<tr>
<td>lb-ft</td>
<td>pound-foot(foot)</td>
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<td>lb/HP</td>
<td>pound(s) per horsepower</td>
</tr>
<tr>
<td>lb-in</td>
<td>pound-inch(es)</td>
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<td>LBM</td>
<td>lever of breech mechanism</td>
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<tr>
<td>lb/mol</td>
<td>pound molecule</td>
</tr>
<tr>
<td>lb/sq in</td>
<td>pound per square inch</td>
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<tr>
<td>lb tr</td>
<td>pound troy(373.2418g)</td>
</tr>
<tr>
<td>lb/yd</td>
<td>pound(s) per yard</td>
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<td>landing craft</td>
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<tr>
<td>LC</td>
<td>Library of Congress, Wash 25, Pa</td>
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<tr>
<td>LC</td>
<td>light case (chemical)</td>
</tr>
<tr>
<td>LC</td>
<td>long case</td>
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<td>LCA</td>
<td>Lake City Arsenal, Independence Mo</td>
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<tr>
<td>LMA</td>
<td>landing craft assault(ship)</td>
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<tr>
<td>LCB</td>
<td>light case (chemical) bomb(Brit)</td>
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<tr>
<td>LCG</td>
<td>landing craft, gun</td>
</tr>
<tr>
<td>LCG(M)</td>
<td>landing craft gun (medium)</td>
</tr>
<tr>
<td>LCR</td>
<td>landing craft, rocket</td>
</tr>
<tr>
<td>LCT</td>
<td>landing craft, tank</td>
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<tr>
<td>LCTR(R)</td>
<td>landing craft, tank(rocket)</td>
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<td>LCSE</td>
<td>Laboratorie de la Commission des substances Explosives(Fr)</td>
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<tr>
<td>LCV</td>
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</tr>
<tr>
<td>ld</td>
<td>laev-o-and dextro-rotatory</td>
</tr>
<tr>
<td>LD</td>
<td>lethal dose</td>
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<td>LD</td>
<td>long delay</td>
</tr>
<tr>
<td>LD</td>
<td>long distance</td>
</tr>
<tr>
<td>LD50</td>
<td>killing 50% of subjects under in 30 days</td>
</tr>
<tr>
<td>LD50/30</td>
<td>killing 50% of subjects under in indicated time</td>
</tr>
<tr>
<td>LD50 time</td>
<td>killing 50% of personnel</td>
</tr>
<tr>
<td>LDNR</td>
<td>lead dinitroresorcinol</td>
</tr>
<tr>
<td>LDWTI</td>
<td>Lucidol Division, Wallace &amp; Tiernan Inc, Buffalo 5, NY</td>
</tr>
<tr>
<td>LTD</td>
<td>long distance telephone</td>
</tr>
<tr>
<td>Abbr</td>
<td>Meaning</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>LE</td>
<td>Lee-Enfield(rifle) (Brit)</td>
</tr>
<tr>
<td>LE</td>
<td>low explosive</td>
</tr>
<tr>
<td>LEC</td>
<td>Laboratory Equipment Corp, St Joseph, Mich</td>
</tr>
<tr>
<td>Leics</td>
<td>Leicestershire, Engl</td>
</tr>
<tr>
<td>LEWCF</td>
<td>Lanza Elektrizitätswerke und Chemische Fabriken Aktiengesellschaft (Basel)</td>
</tr>
<tr>
<td>LF</td>
<td>land forces</td>
</tr>
<tr>
<td>LF</td>
<td>low frequency (30 to 3000 kilocycles per second)</td>
</tr>
<tr>
<td>lft(s)</td>
<td>leaflet(s)</td>
</tr>
<tr>
<td>LG</td>
<td>Lewis gun (Brit)</td>
</tr>
<tr>
<td>lg</td>
<td>logarithm</td>
</tr>
<tr>
<td>lg t</td>
<td>long ton (Brit) (1016.05 kg or 2240 lb)</td>
</tr>
<tr>
<td>lgth</td>
<td>length</td>
</tr>
<tr>
<td>l/hr</td>
<td>liter(s) per hour</td>
</tr>
<tr>
<td>l-hr</td>
<td>lumen-hour(s)</td>
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<tr>
<td>LI</td>
<td>Lefax Inc, Phila 7, Pa</td>
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<tr>
<td>LIAB</td>
<td>light infantry</td>
</tr>
<tr>
<td>Li</td>
<td>lithium</td>
</tr>
<tr>
<td>Lieut or Lt</td>
<td>Lieutenant</td>
</tr>
<tr>
<td>ligr</td>
<td>ligroin</td>
</tr>
<tr>
<td>liq</td>
<td>liquid</td>
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<tr>
<td>Lithofracteurs; { } older Belg expls (see the text) Lithotrite</td>
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</tr>
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<td>LLA</td>
<td>Lend-Lease Administration</td>
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<td>LLA</td>
<td>low level attack</td>
</tr>
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<td>LM</td>
<td>land mine</td>
</tr>
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<td>lm</td>
<td>lumen</td>
</tr>
<tr>
<td>LG</td>
<td>light machine-gun</td>
</tr>
<tr>
<td>lmt</td>
<td>limit</td>
</tr>
<tr>
<td>LN</td>
<td>liquid nitrogen</td>
</tr>
<tr>
<td>LN</td>
<td>long nose</td>
</tr>
<tr>
<td>In</td>
<td>logarithm, natural (also ( \log_e ))</td>
</tr>
<tr>
<td>loc cit</td>
<td>loco citato (Lat) (in the place cited) used when several footnotes intervene between two citations not only to the same work, but also to the same place in that work</td>
</tr>
<tr>
<td>LOD</td>
<td>Letterkenny Ordnance Depot, Chambersburg, Pa</td>
</tr>
<tr>
<td>LOD</td>
<td>Lima Ordnance Depot, Lima, Ohio</td>
</tr>
<tr>
<td>LOD</td>
<td>low order detonation</td>
</tr>
<tr>
<td>LOF</td>
<td>line of fire</td>
</tr>
<tr>
<td>log</td>
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<tr>
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<td>see In</td>
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<tr>
<td>Logs</td>
<td>logistics</td>
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<tr>
<td>LOMC</td>
<td>Lenape Ordnance Modification Center, Newark, Del</td>
</tr>
<tr>
<td>Lond</td>
<td>London</td>
</tr>
<tr>
<td>LOP</td>
<td>Louisiana Ordnance Plant, Shreveport, La</td>
</tr>
<tr>
<td>LORAC</td>
<td>long range accuracy (system of radio navigation)</td>
</tr>
<tr>
<td>LOW</td>
<td>Longhorn Ordnance Works, Marshall, Tex</td>
</tr>
<tr>
<td>LOX</td>
<td>liquid oxygen explosives (oxyliquits)</td>
</tr>
<tr>
<td>LP</td>
<td>liquid propellant (Rocketry)</td>
</tr>
<tr>
<td>Lyddite</td>
<td>Lyddite</td>
</tr>
<tr>
<td>LP(poudre)</td>
<td>Belg propellant (see the text)</td>
</tr>
<tr>
<td>LPC</td>
<td>Liberty Powder Co, Mt Braddock, Pa (Olin Industries)</td>
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<tr>
<td>LPIA</td>
<td>Liquid Propellants Information Agency</td>
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<tr>
<td>lpw</td>
<td>lumens per watt</td>
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<tr>
<td>LR</td>
<td>long range</td>
</tr>
<tr>
<td>LRB</td>
<td>long range bomb</td>
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<tr>
<td>LRG</td>
<td>long range gun</td>
</tr>
<tr>
<td>LRL</td>
<td>Livermore Research Lab</td>
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<tr>
<td>LRPG</td>
<td>Long Range Proving Ground</td>
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<tr>
<td>LRWE</td>
<td>Long Range Weapons Establishment (Brit)</td>
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<td>LSOP</td>
<td>Lone Star Ordnance Plant, Texarkana, Tex</td>
</tr>
<tr>
<td>LST</td>
<td>landing ship tanks</td>
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<tr>
<td>LSt</td>
<td>lead styphnate</td>
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<td>Lt</td>
<td>See Lieut</td>
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<tr>
<td>Lt,tlt</td>
<td>light</td>
</tr>
<tr>
<td>LtAA</td>
<td>light antiaircraft artillery</td>
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<tr>
<td>Ltd</td>
<td>Limited</td>
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<tr>
<td>LTk</td>
<td>light tank</td>
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<td>LTRS</td>
<td>Low Temperature Research Station (Brit)</td>
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<td>Lu</td>
<td>lutetium</td>
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<td>lubr</td>
<td>lubricant, lubrication</td>
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<td>Lux</td>
<td>Luxemburg</td>
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<td>LVD</td>
<td>low velocity dynamite</td>
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<td>LVT</td>
<td>landing vehicle tracked</td>
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<tr>
<td>l/w</td>
<td>lumens per watt</td>
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<tr>
<td>Lyddite</td>
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<td>LZ</td>
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<td>M</td>
<td>Mach number</td>
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<tr>
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<td>Manual</td>
</tr>
<tr>
<td>Mark(model)</td>
<td>Mark(model)</td>
</tr>
<tr>
<td>Abbr 30</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>followed by a number (as M2) signifies a standardized Ordn item (Roman numerals as MII are used by the Brit)</td>
</tr>
<tr>
<td>m-</td>
<td>M</td>
</tr>
<tr>
<td>M</td>
<td>symbol for a metal (M II means a divalent metal, etc)</td>
</tr>
<tr>
<td>m</td>
<td>meter(s)</td>
</tr>
<tr>
<td>m</td>
<td>mile</td>
</tr>
<tr>
<td>m</td>
<td>milli (1/1000)</td>
</tr>
<tr>
<td>M</td>
<td>mine</td>
</tr>
<tr>
<td>M</td>
<td>minomët (Rus) (mine thrower)</td>
</tr>
<tr>
<td>M</td>
<td>molar (as applied to concentration) (not molal)</td>
</tr>
<tr>
<td>M</td>
<td>Mono-</td>
</tr>
<tr>
<td>M</td>
<td>mortar</td>
</tr>
<tr>
<td>M</td>
<td>mortira (Rus) (mortar)</td>
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<td>μ</td>
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<td>M</td>
<td>micron</td>
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<td>M, M₄, M₆,</td>
<td>M₈, &amp; M₁₀</td>
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<tr>
<td>M₄,</td>
<td>&amp;</td>
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<td>Ma</td>
<td>masurium</td>
</tr>
<tr>
<td>MA</td>
<td>medium artillery</td>
</tr>
<tr>
<td>MA</td>
<td>Milan Arsenal, Milan, Tenn</td>
</tr>
<tr>
<td>ma</td>
<td>milliamperes (s)</td>
</tr>
<tr>
<td>mÅ</td>
<td>milliangström</td>
</tr>
<tr>
<td>MA</td>
<td>Military Attaché</td>
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<tr>
<td>MA</td>
<td>Ministry of Aviation (Brit)</td>
</tr>
<tr>
<td>MA</td>
<td>mountain artillery</td>
</tr>
<tr>
<td>MABT</td>
<td>Fr &amp; Ital expl contg PA, TNT &amp; DNN</td>
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<tr>
<td>macarite</td>
<td>Belg expl (see the text)</td>
</tr>
<tr>
<td>mach</td>
<td>machine</td>
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<td>machinery</td>
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<tr>
<td>Macmillan</td>
<td>The Macmillan Co, NY</td>
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<tr>
<td>MADAEC</td>
<td>Military Application Division of the Atomic Energy Commission</td>
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<tr>
<td>MAEE</td>
<td>Marine Aircraft Experimental Establishment (Brit)</td>
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<td>mag</td>
<td>magazine</td>
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<td>magnet</td>
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<td>Major</td>
</tr>
<tr>
<td>Maj-Gen</td>
<td>Major-General</td>
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<td>Man</td>
<td>Manitoba, Canada</td>
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<tr>
<td>Man-Salt</td>
<td>methylamine nitrate (see PATR 2510, p Ger 108)</td>
</tr>
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<td>manuf</td>
<td>manufacture</td>
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<tr>
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<td>manufactured</td>
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<td>manufacturing</td>
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<td>MAP</td>
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<tr>
<td>MAS</td>
<td>Military Agency for Standardization</td>
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<tr>
<td>MASB</td>
<td>motor anti-submarine boat</td>
</tr>
<tr>
<td>masc</td>
<td>masculine</td>
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<tr>
<td>Mass</td>
<td>Massachusetts</td>
</tr>
<tr>
<td>MAT</td>
<td>Fr, Ital &amp; Jap expl contg PA &amp; TNT</td>
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<tr>
<td>mat</td>
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<tr>
<td>Matagnites</td>
<td>Belg expls (see the text)</td>
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<tr>
<td>math</td>
<td>mathematical</td>
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<tr>
<td>maths'</td>
<td>mathematics</td>
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<tr>
<td>Matsu</td>
<td>Jap for blasting gelatin</td>
</tr>
<tr>
<td>max</td>
<td>maximum</td>
</tr>
<tr>
<td>max</td>
<td>metal and explosive (mixture giving maximum performance for each metal and explosive system)</td>
</tr>
<tr>
<td>max cap</td>
<td>maximum capacity</td>
</tr>
<tr>
<td>MB</td>
<td>medium Besa (Brit machine gun)</td>
</tr>
<tr>
<td>MB</td>
<td>medium bomber</td>
</tr>
<tr>
<td>mb</td>
<td>millibar</td>
</tr>
<tr>
<td>mbl</td>
<td>monoblock</td>
</tr>
<tr>
<td>MBT</td>
<td>motor boat</td>
</tr>
<tr>
<td>MB</td>
<td>mountain battery</td>
</tr>
<tr>
<td>MB</td>
<td>Fr &amp; Ital sporting propellant</td>
</tr>
<tr>
<td>mobile</td>
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<tr>
<td>mc</td>
<td>millicurie</td>
</tr>
<tr>
<td>mC</td>
<td>motor car</td>
</tr>
<tr>
<td>MCA</td>
<td>modified cordite contg cracked mineral jelly (Brit)</td>
</tr>
<tr>
<td>MCB</td>
<td>Manufacturing Chemists' Association, Washington 5, DC</td>
</tr>
<tr>
<td>MCB</td>
<td>Matheson, Coleman &amp; Bell, Norwood, Ohio</td>
</tr>
<tr>
<td>MCC</td>
<td>medium capacity bomb</td>
</tr>
<tr>
<td>MCD</td>
<td>Monsanto Chemical Co, St Louis, Mo</td>
</tr>
<tr>
<td>MCI</td>
<td>McGraw-Hill Book Co, Inc, NY</td>
</tr>
<tr>
<td>Md</td>
<td>Merck &amp; Co, Inc, Rahway, NJ</td>
</tr>
<tr>
<td>MD</td>
<td>Maryland</td>
</tr>
<tr>
<td>MD</td>
<td>mean deviation</td>
</tr>
<tr>
<td>MD</td>
<td>Medical Doctor</td>
</tr>
<tr>
<td>MD</td>
<td>military district</td>
</tr>
<tr>
<td>MD</td>
<td>mine depot, mine detector</td>
</tr>
<tr>
<td>MD(Cordite)</td>
<td>modified cordite (Brit)</td>
</tr>
<tr>
<td>MDN or MDn</td>
<td>mélinité-dinitronaphthaline (Fr expl contg PA &amp; DNN)</td>
</tr>
<tr>
<td>MDPC</td>
<td>mélinité-dinitrophénolep-crésylite (Fr expl contg PA, DNN &amp; TNCrs)</td>
</tr>
<tr>
<td>Abbr</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>MDW</td>
<td>Military District, Washington, DC</td>
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<tr>
<td>Me or me</td>
<td>methyl</td>
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<tr>
<td>ME</td>
<td>military engineer(ing)</td>
</tr>
<tr>
<td>me</td>
<td>milliequivalent</td>
</tr>
<tr>
<td>ME</td>
<td>muzzle energy</td>
</tr>
<tr>
<td>MeAN</td>
<td>methyamine nitrate</td>
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<tr>
<td>MEC</td>
<td>Metalab Equipment Co, Hicksville, LI, NY</td>
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<tr>
<td>mech</td>
<td>mechanical</td>
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<tr>
<td>Med</td>
<td>medicine, medical</td>
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<tr>
<td>Med</td>
<td>medium</td>
</tr>
<tr>
<td>MedArty</td>
<td>Medium Artillery</td>
</tr>
<tr>
<td>MEDINA</td>
<td>methylenedinitramine</td>
</tr>
<tr>
<td>MeEDNA</td>
<td>N-methylenedinitramine</td>
</tr>
<tr>
<td>Mégadyne</td>
<td>Belg expl(see the text)</td>
</tr>
<tr>
<td>Meiyaku</td>
<td>Jap for tetrtyl</td>
</tr>
<tr>
<td>Mel</td>
<td>melamine</td>
</tr>
<tr>
<td>Mélanite</td>
<td>Belg expl(see the text)</td>
</tr>
<tr>
<td>Melinit</td>
<td>Ger &amp; Rus for PA</td>
</tr>
<tr>
<td>Mélinite</td>
<td>Fr for PA</td>
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<tr>
<td>Mem</td>
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<td>Mems</td>
<td>Memoirs</td>
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<tr>
<td>MeN</td>
<td>methyl nitrate</td>
</tr>
<tr>
<td>MeNENA</td>
<td>1-nitroxytrimethylene-3-nitramine</td>
</tr>
<tr>
<td>Menkayaku</td>
<td>Jap for NC(shokamen)</td>
</tr>
<tr>
<td>Menyaku</td>
<td>Jap for guncotton</td>
</tr>
<tr>
<td>MeOr</td>
<td>methyl orange</td>
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<tr>
<td>mep</td>
<td>mean effective pressure</td>
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<td>meq</td>
<td>milliequivalent</td>
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<td>MeR</td>
<td>methyl-red</td>
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<tr>
<td>Meri</td>
<td>Merionetshire, Wales</td>
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<tr>
<td>MERL</td>
<td>Mechanical Engineering Research Laboratory(Brit)</td>
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<td>Mes</td>
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<td>Messrs</td>
<td>Messieurs(Fr)</td>
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<tr>
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<tr>
<td>methanol</td>
<td>methyl alcohol</td>
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<tr>
<td>Metilites</td>
<td>liquid expls used in mine clearing</td>
</tr>
<tr>
<td>metlrg</td>
<td>metallurgical</td>
</tr>
<tr>
<td>M et R</td>
<td>Fr sporting propellant</td>
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<tr>
<td>Metr</td>
<td>metriol</td>
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<tr>
<td>MetrTN or MTN</td>
<td>metriol trinitrate</td>
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<tr>
<td>mev</td>
<td>million electron volts</td>
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<tr>
<td>MEXE</td>
<td>Military Engineering and Experimental Establishment(Brit)</td>
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<tr>
<td>MF</td>
<td>medium frequency(300 to 3000 kilocycles per second)</td>
</tr>
<tr>
<td>MF</td>
<td>mercuric fulminate</td>
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<tr>
<td>mf</td>
<td>millifarad</td>
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<td>μf</td>
<td>microfarad</td>
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<tr>
<td>MFA</td>
<td>Manual of Field Artillery manufactured</td>
</tr>
<tr>
<td>mfd or manufd</td>
<td>Fr expl contg PA &amp; DNN manufacturing</td>
</tr>
<tr>
<td>MFDN</td>
<td>mobile floating unit</td>
</tr>
<tr>
<td>MEG</td>
<td>machine gun</td>
</tr>
<tr>
<td>Mg</td>
<td>magnesium</td>
</tr>
<tr>
<td>mg</td>
<td>milligram(s)</td>
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<tr>
<td>M-gas</td>
<td>motor gasoline</td>
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<td>MGB</td>
<td>motor gunboat</td>
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<td>millihenry</td>
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<td>mile</td>
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<td>MI</td>
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<td>Middlesex, Engl</td>
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<tr>
<td>mi/hr</td>
<td>miles per hour</td>
</tr>
<tr>
<td>MIIR</td>
<td>Mellon Institute of Industrial Research</td>
</tr>
<tr>
<td>MIL or Mil</td>
<td>military</td>
</tr>
<tr>
<td>min or minim</td>
<td>minimum</td>
</tr>
<tr>
<td>min(s)</td>
<td>minute(s)</td>
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<tr>
<td>Minérite</td>
<td>Belg expl(see the text)</td>
</tr>
<tr>
<td>Minex</td>
<td>expl contg Amm carbonate RDX, TNT &amp; Al</td>
</tr>
<tr>
<td>Minite</td>
<td>Belg expl(see the text)</td>
</tr>
<tr>
<td>Minn</td>
<td>Minnesota</td>
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<tr>
<td>Minol</td>
<td>expl contg AN, TNT &amp; Al</td>
</tr>
<tr>
<td>Minolex</td>
<td>expl contg AN, RDX, TNT &amp; Al</td>
</tr>
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<td>Ministry</td>
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<td>miscible</td>
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<td>Miss</td>
<td>Mississippi</td>
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<td>MIT</td>
<td>Massachusetts Institute of Technology</td>
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<tr>
<td>mixt</td>
<td>mixture</td>
</tr>
<tr>
<td>MJ</td>
<td>metal jacketed(bullet)</td>
</tr>
<tr>
<td>mineral jelly(Brit for vaseline)</td>
<td></td>
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<tr>
<td>Mk</td>
<td>Mark(used by the Brit with a Roman numeral to designate a model as MkI) Amer practice is to use an Arabic numeral</td>
</tr>
<tr>
<td>Mk1</td>
<td>original Brit cordite(see the text under Cordite)</td>
</tr>
<tr>
<td>Mk2</td>
<td>Jap expl(same as Nigotanyaku Mk2)</td>
</tr>
<tr>
<td>m-kg</td>
<td>meter-kilogram(s)</td>
</tr>
<tr>
<td>ml</td>
<td>milliliter(s)</td>
</tr>
<tr>
<td>ML</td>
<td>motor launch</td>
</tr>
<tr>
<td><strong>Abbr</strong></td>
<td><strong>Text</strong></td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>ML</td>
<td>muzzle loader, muzzle loading (in mortars)</td>
</tr>
<tr>
<td>Mlt</td>
<td>maltose</td>
</tr>
<tr>
<td>MltON</td>
<td>maltose octanitrate</td>
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<tr>
<td>mm</td>
<td>millimeter(s)</td>
</tr>
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<td>μm</td>
<td>millimicron</td>
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<td>mM</td>
<td>millimole</td>
</tr>
<tr>
<td>m/min</td>
<td>meters per minute</td>
</tr>
<tr>
<td>MMMC</td>
<td>Minnesota Mining &amp; Manufacturing Co, St Paul, Minn</td>
</tr>
<tr>
<td>MMN or MMn</td>
<td>mélinite-mononitronaphthaline (Fr expl contg PA &amp; MNN)</td>
</tr>
<tr>
<td>Mn</td>
<td>manganese</td>
</tr>
<tr>
<td>MN or Mn</td>
<td>Fr for MN</td>
</tr>
<tr>
<td>MNA</td>
<td>mononitroaniline</td>
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<td>mononitrobenzene</td>
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<td>mononitrobenzoic acid</td>
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<td>mononitrocresol</td>
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<tr>
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<td>Fr &amp; Ital expl contg AN, DNN &amp; TNT (same as Siperite)</td>
</tr>
<tr>
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<td>mononitromethane</td>
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<td>mononitromethylaniline</td>
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<td>MN or Mn</td>
<td>Fr for MN(mononitronaphthalene)</td>
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<td>mannose</td>
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<tr>
<td>MnnHN</td>
<td>mannose hexanitrate</td>
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<tr>
<td>MNO</td>
<td>symbol for N,N’-dinitrodimethyl-oxamide (DNDMOxm)</td>
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<td>metriol trinitrate</td>
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<td>MTrk</td>
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<td>MTS</td>
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<td>MTSQ</td>
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<td>modernizirovannyi uproschchennyi vzryvatel’ (Rus) (modern simplified pull fuze)</td>
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<td>meena zamedlennago deystviya (Rus) (delayed action mine)</td>
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| N | nautical |
| N | Naval, Navy |</p>
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<td>not wg</td>
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<td>Nov</td>
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<td>Novit</td>
<td>Swedish underwater explosive containing TNT &amp; HNDPhA (similar to Hexamit)</td>
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<td>Nitropenta (same as PETN)</td>
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<td>No-flash/containing potassium sulfate (Bril propellant)</td>
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<td>Solution of NC, China wood oil &amp; rosins in methyl acetate used in loading of ammo</td>
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<td>National Reactor Test Station, Arco, Idaho</td>
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<td>New series; new system</td>
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<td>Nitrate of sodium (Brit)</td>
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<td>NSug</td>
<td>Nitrosugar</td>
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<tr>
<td>NSX</td>
<td>Amer demolition explosive containing NS, Ba nitrate, MNN, p-MNA, and oil</td>
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<td>NT</td>
<td>Nitron, now termed Rn</td>
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<td>Nitrate-trotyl (Fr explosive containing AN &amp; TNT such as amatol)</td>
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<td>NT</td>
<td>normal temperature</td>
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<td>Fr expl contg AN &amp; TNN</td>
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<tr>
<td>NZTN</td>
<td>Fr expl contg AN, Na nitrate &amp; TNN</td>
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<td>NTP</td>
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<td>n wt</td>
<td>net weight</td>
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<tr>
<td>NX</td>
<td>Fr expl contg AN &amp; TNX</td>
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<td>NYOD</td>
<td>New York Ordnance District, New York 14, NY (includes ROD)</td>
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<tr>
<td>Nyperite</td>
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<tr>
<td>NZAOC</td>
<td>New Zealand Army Ordnance Corps</td>
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<p>| O    | Octa- |
| O    | office |
| O    | Officer |
| O    | Ohio |
| O    | order |
| O    | Ordnance |
| o-   | ortho |
| O    | orúdiyiye(Rus) (gun or cannon) |
| O    | oskolochnyi (Rus) (fragmentation) (adj) |
| O    | oxygen |
| O    | Fr explosive (see the text) |
| OA   | Ordnance artificer |
| OAC  | Ordnance Ammunition Command Joliet, Ill |
| OAPC | Office of Alien Property Custodian |
| OB   | observation balloon |
| OB   | see OBd |
| OB   | oxygen balance (OB to CO₂ or OB to CO expressed in %) |
| OBA  | oxygen breathing apparatus |
| OBD  | Ordnance Base Depot |
| OBd  | Ordnance Board |
| Obr  | Obrazets (Rus) (Model) |
| obsn | observation |</p>
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<tr>
<th>Abbr</th>
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<td>OLCr</td>
<td>Ordnance Lieutenant-Commander (Navy)</td>
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<td>Office of Military Government of the United States</td>
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<td>Onayaku</td>
<td>Jap for trimonite</td>
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<td>or or orn</td>
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<td>OV</td>
<td>otravliayushcheiye veshchestvo (Rus)(toxic substance)(war gas)</td>
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<td>ounce fluid(29.5737 cc) (US)</td>
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<td>ounce troy(31.1035 g)</td>
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<td>P(salt)</td>
<td>symbol for pipercine dinitrate</td>
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<td>symbol for (methyleneoxy)-dimethanol dinitrate</td>
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<td>Pa or Penna</td>
<td>Pennylavania</td>
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<td>Picatinny Arsenal</td>
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<td>protactinium</td>
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<td>Panzerabwehrkanone (Ger) (antitank gun)</td>
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<td>PAMETRADA</td>
<td>Turbine Research &amp; Development Association(Brit)</td>
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Abbr 39

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<td>Pan-American(World) Airways</td>
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<td>Panclastites</td>
<td>Fr &amp; Brit liq expls contg liq N₂O₄ and liq fuels</td>
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<td>platoon anti-tank</td>
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<td>Pan-American Union</td>
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<td>PB</td>
<td>pilotless bomber</td>
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<tr>
<td>Pb</td>
<td>plumbum(lead)</td>
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<td>PB</td>
<td>Publication Board of Office of Technical Services(US)</td>
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<td>PB₁; PB₂; PB₃</td>
<td>prismatic brown powders</td>
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<td>PB₄(poudres)</td>
<td>used in Fr Naval guns prior to the invention of smokeless propellant</td>
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<td>Publication Board L</td>
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<td>patrol bomber Martin(flying boat)</td>
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<td>PBOW</td>
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<td>PB-RDX</td>
<td>Amer expl(classified)</td>
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<td>PBRept</td>
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<td>phenylbenzylurethane(Brit gelatinizer for NC)</td>
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<td>plastic bonded explosive (US)(composition is classified)</td>
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<tr>
<td>pc</td>
<td>per centum, %</td>
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<td>Polverifico Comocini di Como (Ital)</td>
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<td>precipitation symbol for 3,5-dinitro-3,5-diazapiperidinium nitrate</td>
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<td>point detonating fuze</td>
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<td>propylene-1,2-dinitramine</td>
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<td>pounder(eg 18 Pdr; used to designate a gun firing a projectile weighing 18 lb) (Brit)</td>
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<td>plastic explosive</td>
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<tr>
<td>Penna or Pa</td>
<td>Pennsylvania</td>
</tr>
<tr>
<td>Pent</td>
<td>Pentagon Building, Washington, DC</td>
</tr>
<tr>
<td>penta</td>
<td>pentagonal</td>
</tr>
<tr>
<td>Pent</td>
<td>pentolite</td>
</tr>
<tr>
<td>Pentastit</td>
<td>Swiss expl contg PETN &amp; pentaerythritol tetrastearate(PETS)</td>
</tr>
<tr>
<td>Penthrite</td>
<td>Brit for PETN</td>
</tr>
<tr>
<td>Pentolite</td>
<td>mixts of PETN &amp; TNT</td>
</tr>
<tr>
<td>Pentoriru</td>
<td>Jap for pentolite</td>
</tr>
<tr>
<td>Pentalita</td>
<td>Span expl (see the text)</td>
</tr>
<tr>
<td>Pentrinit</td>
<td>Swiss expl contg PETN &amp; NG</td>
</tr>
<tr>
<td>Pentro</td>
<td>see Pentryl (Swiss)</td>
</tr>
<tr>
<td>Pentrol</td>
<td>Italy expl contg PETN &amp; TNT</td>
</tr>
<tr>
<td>Pentryl</td>
<td>β(2,4,6-trinitrophenyl-nitramino) ethyl nitrate</td>
</tr>
<tr>
<td>Pentryl(Swiss)</td>
<td>expl mixt of PETN, TNT &amp; Al</td>
</tr>
<tr>
<td>or Pentro</td>
<td>manufd by a special process</td>
</tr>
<tr>
<td>Pentryl</td>
<td>Same as PETN</td>
</tr>
<tr>
<td>PEP</td>
<td>explos contg PETN &amp; Gult Crown E oil</td>
</tr>
<tr>
<td>per</td>
<td>period; periodical</td>
</tr>
<tr>
<td>PERA</td>
<td>Production Engineering Research Association</td>
</tr>
<tr>
<td>Perammon</td>
<td>Fr Amm perchlorate expl</td>
</tr>
<tr>
<td>percn</td>
<td>percussion</td>
</tr>
<tr>
<td>perfn</td>
<td>perforation</td>
</tr>
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<td>perm</td>
<td>permanent</td>
</tr>
<tr>
<td>permn</td>
<td>permission</td>
</tr>
<tr>
<td>Pemonite</td>
<td>Belg expl (see the text)</td>
</tr>
<tr>
<td>pers</td>
<td>personnel</td>
</tr>
<tr>
<td>PERSPEX</td>
<td>acrylic resin; may be used as a binding or coating agent, in explos &amp; propellants</td>
</tr>
<tr>
<td>pertg</td>
<td>pertaining</td>
</tr>
<tr>
<td>Pertite</td>
<td>Ital for PA</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>PETA</td>
<td>pentaerythritol tetracetate</td>
</tr>
<tr>
<td>PETN</td>
<td>pentaerythritol tetranitrate</td>
</tr>
<tr>
<td>petr</td>
<td>petrol; petroleum</td>
</tr>
<tr>
<td>petr eth</td>
<td>petroleum ether</td>
</tr>
<tr>
<td>Petrin</td>
<td>pentaerythritol trinitrate</td>
</tr>
<tr>
<td>Petrin Acr</td>
<td>Petrin acrylate (classified)</td>
</tr>
<tr>
<td>PETS</td>
<td>pentaerythritol tetrastearate (component of Pentastit)</td>
</tr>
<tr>
<td>PETX</td>
<td>symbol for tetra-(nitraminomethyl)-methane</td>
</tr>
<tr>
<td>PI</td>
<td>Philippine Islands point initiating</td>
</tr>
<tr>
<td>PIAT</td>
<td>projector infantry anti-tank</td>
</tr>
<tr>
<td>PIB</td>
<td>Polytechnic Institute of Brooklyn, N</td>
</tr>
<tr>
<td>PIC</td>
<td>Parr Instrument Company, Moline, Ill</td>
</tr>
<tr>
<td>Pic Arsn</td>
<td>Picatiny Arsenal, Dover, NJ</td>
</tr>
<tr>
<td>Picramide</td>
<td>same as TNA</td>
</tr>
<tr>
<td>Picratol</td>
<td>mixt of Amm P &amp; TNT (US)</td>
</tr>
<tr>
<td>Picric Powder</td>
<td>Brit expl contg Amm P, Al, sawdust &amp; crude petroleum</td>
</tr>
<tr>
<td>Explosive</td>
<td>Span for picric acid</td>
</tr>
<tr>
<td>Picrinita</td>
<td>Brit for nitroguanidine</td>
</tr>
<tr>
<td>Picrite</td>
<td>Jap for PA(Oshokuyaku)</td>
</tr>
<tr>
<td>Picurinsan</td>
<td>Jap for ammonium picrate</td>
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<tr>
<td>Picurinsan-ammonia</td>
<td>Swiss blasting expl(see the text)</td>
</tr>
<tr>
<td>Picric</td>
<td>Percentage Initiation by Grit (Brit)</td>
</tr>
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<td>Picrinita</td>
<td>Ital mil expl of WWI (see the text)</td>
</tr>
<tr>
<td>Picrite</td>
<td>Amer expl contg PETN &amp; Gulf Crown E oil pack artillery</td>
</tr>
<tr>
<td>Pl</td>
<td>plural</td>
</tr>
<tr>
<td>Plancastita</td>
<td>Span expl(see the text) plastic</td>
</tr>
<tr>
<td>Plast</td>
<td>Swiss expl</td>
</tr>
<tr>
<td>Plastita</td>
<td>Span expl</td>
</tr>
<tr>
<td>Plastil</td>
<td>Swiss expl</td>
</tr>
<tr>
<td>Plat</td>
<td>Platoon</td>
</tr>
<tr>
<td>Plomoplastrita</td>
<td>Amer expl contg Pb nitrate &amp; TNT reconnaissance &amp; rescue plane, ground based</td>
</tr>
<tr>
<td>Plumbatol</td>
<td>Pressurized Light Water (Reactor)</td>
</tr>
<tr>
<td>Pluto</td>
<td>Picatinny liquid explosives (nitromethane ethylene-diamine) parachute mine</td>
</tr>
<tr>
<td>PM</td>
<td>Post meridiem (Lat) afternoon</td>
</tr>
<tr>
<td>PM</td>
<td>powder metallurgy</td>
</tr>
<tr>
<td>PM</td>
<td>Prime Minister (Brit)</td>
</tr>
<tr>
<td>PM</td>
<td>Provost Marshall</td>
</tr>
<tr>
<td>PN</td>
<td>performance number</td>
</tr>
<tr>
<td>PNA</td>
<td>pentanitroaniline</td>
</tr>
<tr>
<td>PNDPhEth</td>
<td>pentanitrodiphenylether</td>
</tr>
<tr>
<td>PNDPhEtI</td>
<td>pentanitrodiphenylethanol</td>
</tr>
<tr>
<td>PNDPhSfo</td>
<td>pentanitrodiphenylsulfone</td>
</tr>
<tr>
<td>PNG</td>
<td>persona non grata (Lat) undesirable person</td>
</tr>
<tr>
<td>PNP</td>
<td>Ital expl contg PETN, AN &amp; Wax polonium</td>
</tr>
<tr>
<td>Po</td>
<td>Philadelphia Ordnance District, Phila 2, Pa</td>
</tr>
<tr>
<td>POD</td>
<td>Pittsburgh Ordnance District, Ptgh 22, Pa</td>
</tr>
<tr>
<td><strong>Abbr</strong></td>
<td><strong>POD</strong></td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td><strong>POD</strong></td>
<td>Pueblo Ordnance Depot, Pueblo, Colo</td>
</tr>
<tr>
<td><strong>polym</strong></td>
<td>polymer</td>
</tr>
<tr>
<td><strong>POP</strong></td>
<td>Pantex Ordnance Plant, Amarillo, Tex</td>
</tr>
<tr>
<td><strong>pos</strong></td>
<td>positive (as an adjective)</td>
</tr>
<tr>
<td><strong>poss</strong></td>
<td>possible</td>
</tr>
<tr>
<td><strong>pot</strong></td>
<td>potential</td>
</tr>
<tr>
<td><strong>Potentite</strong></td>
<td>Belgrade, same as tonite</td>
</tr>
<tr>
<td><strong>Potentites</strong></td>
<td>mixtures of NC &amp; K nitrate used in Fr as propellants and as demolition explosives</td>
</tr>
<tr>
<td><strong>Poudre B</strong></td>
<td>see B(poudre)</td>
</tr>
<tr>
<td><strong>Poudre NB</strong></td>
<td>see NB(poudre)</td>
</tr>
<tr>
<td><strong>Poudre NB JK</strong></td>
<td>see NB JK(poudre)</td>
</tr>
<tr>
<td><strong>POW</strong></td>
<td>prisoner of war</td>
</tr>
<tr>
<td><strong>powd</strong></td>
<td>powder (ed)</td>
</tr>
<tr>
<td><strong>pp</strong></td>
<td>pages</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>percussion primer</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>percussion powder</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>pistol-pulemèt (Rus)</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>pilotless plane</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>Polverifico Piemontese (Ital)</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>power plant</td>
</tr>
<tr>
<td><strong>PP</strong></td>
<td>proof paper (firing report) (Brit)</td>
</tr>
<tr>
<td><strong>PPP</strong></td>
<td>paper (firing report) (Brit)</td>
</tr>
<tr>
<td><strong>PPB’s</strong></td>
<td>proof paper (firing report) (Brit)</td>
</tr>
<tr>
<td><strong>PPC(B)</strong></td>
<td>Phillips Petroleum Co, Bartlesville, Okla</td>
</tr>
<tr>
<td><strong>PPC(McG)</strong></td>
<td>Phillips Petroleum Co, McGregor, Tex</td>
</tr>
<tr>
<td><strong>PPD</strong></td>
<td>pistol-pulemèt Degtiarêva (Rus)</td>
</tr>
<tr>
<td><strong>ppm</strong></td>
<td>parts per million</td>
</tr>
<tr>
<td><strong>PPP</strong></td>
<td>plastic protective plate (Brit)</td>
</tr>
<tr>
<td><strong>PPRI(Can)</strong></td>
<td>Pulp &amp; Paper Research Institute of Canada</td>
</tr>
<tr>
<td><strong>PPSh</strong></td>
<td>pistol-pulemèt Shpagna (Rus)</td>
</tr>
<tr>
<td><strong>ppt</strong></td>
<td>precipitate</td>
</tr>
<tr>
<td><strong>pp</strong></td>
<td>precipitated</td>
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<tr>
<td><strong>pp</strong></td>
<td>precipitating</td>
</tr>
<tr>
<td><strong>pptn</strong></td>
<td>precipitation</td>
</tr>
<tr>
<td><strong>PQ</strong></td>
<td>Province of Quebec, Canada</td>
</tr>
<tr>
<td><strong>pr</strong></td>
<td>pair</td>
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<tr>
<td><strong>Pr</strong></td>
<td>praseodymium</td>
</tr>
<tr>
<td><strong>Pr</strong></td>
<td>Proceedings</td>
</tr>
<tr>
<td><strong>Pr or pr</strong></td>
<td>propyl(normal)</td>
</tr>
<tr>
<td><strong>PR</strong></td>
<td>public relations</td>
</tr>
<tr>
<td><strong>PR</strong></td>
<td>Puerto Rico</td>
</tr>
<tr>
<td><strong>Pr 4/5 &amp; Pr 20/24</strong></td>
<td>Ital propellants (see the text)</td>
</tr>
<tr>
<td><strong>prac</strong></td>
<td>practice</td>
</tr>
<tr>
<td><strong>pract</strong></td>
<td>practical</td>
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<tr>
<td>Abbr</td>
<td>Meaning</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>Pt</td>
<td>point(s)</td>
</tr>
<tr>
<td>Pt</td>
<td>port</td>
</tr>
<tr>
<td>PT</td>
<td>primary target (Arty)</td>
</tr>
<tr>
<td>PT-boat</td>
<td>patrol torpedo-boat</td>
</tr>
<tr>
<td>PTC</td>
<td>patrol torpedo-craft</td>
</tr>
<tr>
<td>PT-Div</td>
<td>patrol torpedo-boat division</td>
</tr>
<tr>
<td>Pte</td>
<td>private(soldier)</td>
</tr>
<tr>
<td>pte</td>
<td>private</td>
</tr>
<tr>
<td>PTRD</td>
<td>protivotankovoye ruzhiö</td>
</tr>
<tr>
<td>PTRS</td>
<td>A/T rifle of Semënov (Rus)</td>
</tr>
<tr>
<td>PTX1 &amp; PTX2</td>
<td>Picatinny ternary expls (RDX, tetryl &amp; TNT or RDX, PETN &amp; TNT)</td>
</tr>
<tr>
<td>pty</td>
<td>party</td>
</tr>
<tr>
<td>Pu</td>
<td>plutonium</td>
</tr>
<tr>
<td>PU</td>
<td>Princeton University, Princeton, NJ</td>
</tr>
<tr>
<td>PU</td>
<td>Purdue University, Lafayette, Ind</td>
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<tr>
<td>Publ</td>
<td>Publication</td>
</tr>
<tr>
<td>publ(d)</td>
<td>publish(ed)</td>
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<tr>
<td>publg</td>
<td>publishing</td>
</tr>
<tr>
<td>publn(s)</td>
<td>publication(s)</td>
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<tr>
<td>pulv(d)</td>
<td>pulverize(d)</td>
</tr>
<tr>
<td>pulvn</td>
<td>pulverization</td>
</tr>
<tr>
<td>PUNS</td>
<td>permanently unfit for Naval service</td>
</tr>
<tr>
<td>PV</td>
<td>patrol vessel</td>
</tr>
<tr>
<td>PVA</td>
<td>polyvinyl acetate</td>
</tr>
<tr>
<td>PVA-4</td>
<td>Amer expl contg polyvinyl acetate, RDX &amp; DBuPh</td>
</tr>
<tr>
<td>PVAIc</td>
<td>polyvinyl alcohol</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinylchloride</td>
</tr>
<tr>
<td>Pvt</td>
<td>private</td>
</tr>
<tr>
<td>PW</td>
<td>powder weight (in a charge)</td>
</tr>
<tr>
<td>PW</td>
<td>prisoner of war</td>
</tr>
<tr>
<td>PWA</td>
<td>Public Works Administration</td>
</tr>
<tr>
<td>PWC</td>
<td>Brit for &quot;paper wood cellulose&quot; (contg 85% of a-cellulose)</td>
</tr>
<tr>
<td>PWD</td>
<td>Petroleum Warfare Development (Brit)</td>
</tr>
<tr>
<td>PWP</td>
<td>plasticized white phosphorus</td>
</tr>
<tr>
<td>PWT</td>
<td>propulsion wind tunnel</td>
</tr>
<tr>
<td>PX</td>
<td>Post Exchange; Army Exchange</td>
</tr>
<tr>
<td>Py or py</td>
<td>pyridine or pyridyl</td>
</tr>
<tr>
<td>pyc</td>
<td>pycnometer</td>
</tr>
<tr>
<td>py</td>
<td>pyrometer</td>
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<tr>
<td>Pyro</td>
<td>pyrocellulose, pyrocotton</td>
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<tr>
<td>pyro or pyrot</td>
<td>pyrotechnics</td>
</tr>
<tr>
<td>Pyrolithes; Pyronomes</td>
<td>Belg black powder type</td>
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<tr>
<td>pz</td>
<td>piezo</td>
</tr>
<tr>
<td>Q</td>
<td>gunner’s quadrant (Arty)</td>
</tr>
<tr>
<td>Q</td>
<td>quantity of electricity, Coulombs</td>
</tr>
<tr>
<td>Q</td>
<td>quantity of heat</td>
</tr>
<tr>
<td>Q</td>
<td>quebrachitol</td>
</tr>
<tr>
<td>Q</td>
<td>quartermaster</td>
</tr>
<tr>
<td>Q</td>
<td>vessel for trapping boats</td>
</tr>
<tr>
<td>Q</td>
<td>heat of combustion</td>
</tr>
<tr>
<td>Qc</td>
<td>heat of combustion at constant pressure</td>
</tr>
<tr>
<td>Qc</td>
<td>heat of combustion at constant volume</td>
</tr>
<tr>
<td>QF</td>
<td>clearance for classified atomic information; issued by AEC</td>
</tr>
<tr>
<td>QE</td>
<td>quadrant elevation (angle of elevn of a gun above horizon) (Brit)</td>
</tr>
<tr>
<td>Qf</td>
<td>heat of explosion</td>
</tr>
<tr>
<td>Qe</td>
<td>heat of formation</td>
</tr>
<tr>
<td>Qf</td>
<td>heat of formation at constant pressure</td>
</tr>
<tr>
<td>QFA</td>
<td>heat of formation at constant volume</td>
</tr>
<tr>
<td>QFG</td>
<td>quick firing (of guns using fixed or semi-fixed cartridge cases) (Brit); rapid firing (US)</td>
</tr>
<tr>
<td>QF</td>
<td>quick firing ammunition</td>
</tr>
<tr>
<td>QFA</td>
<td>quick-firing gun (Brit)</td>
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<td>QFD</td>
<td>qualified</td>
</tr>
<tr>
<td>QMC</td>
<td>Quartermaster Corps</td>
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<tr>
<td>QMG</td>
<td>Quartermaster General (Can)</td>
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<tr>
<td>QOC</td>
<td>Quaker Oats Co, Chicago 54, Ill</td>
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<tr>
<td>QPN</td>
<td>quebrachitol pentanitrate</td>
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<tr>
<td>QFA</td>
<td>Queen’s Regulations (Brit)</td>
</tr>
<tr>
<td>QFA</td>
<td>same as Q-boat</td>
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<tr>
<td>QF</td>
<td>quar(s) (for liquids 0.946 1 in the US and 1.136 1 in GtBrit)</td>
</tr>
<tr>
<td>QF</td>
<td>qual</td>
</tr>
<tr>
<td>QF</td>
<td>qualitatively</td>
</tr>
<tr>
<td>QF</td>
<td>qualitative; quality</td>
</tr>
<tr>
<td>QF</td>
<td>quant</td>
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<tr>
<td>QF</td>
<td>quantitatively</td>
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<td>QF</td>
<td>quot vide (Lat) (which see)</td>
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<td>QF</td>
<td>quarry</td>
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<tr>
<td>R</td>
<td>degrees Rankine</td>
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<td>R</td>
<td>radical (organic)</td>
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<tr>
<td>R</td>
<td>radius</td>
</tr>
<tr>
<td>R</td>
<td>range</td>
</tr>
<tr>
<td>R</td>
<td>gas constant (1.9885 cal/degree)</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>°R</td>
<td>degrees Réaumur (80°R = 100°C)</td>
</tr>
<tr>
<td>R</td>
<td>recoilless</td>
</tr>
<tr>
<td>R or Rept</td>
<td>report</td>
</tr>
<tr>
<td>R or Rus</td>
<td>Russia(n)</td>
</tr>
<tr>
<td>R or V</td>
<td>ruzhiô or vintovka(Rus)(riple)</td>
</tr>
<tr>
<td>R(poudre)</td>
<td>symbol for Fivonite</td>
</tr>
<tr>
<td>RA</td>
<td>Radford Arsenal, Radford, Va</td>
</tr>
<tr>
<td>RA</td>
<td>Raritan Arsenal, Metuchen, NJ</td>
</tr>
<tr>
<td>RA or RSA</td>
<td>Redstone Arsenal, Huntsville, Alabama</td>
</tr>
<tr>
<td>RA</td>
<td>Royal Arsenal(Brit)</td>
</tr>
<tr>
<td>RA</td>
<td>Royal Artillery</td>
</tr>
<tr>
<td>RABRM</td>
<td>Research Association of British Rubber Manufacturers</td>
</tr>
<tr>
<td>rac</td>
<td>racemic</td>
</tr>
<tr>
<td>RAC</td>
<td>Royal Armoured Corps(Brit)</td>
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<td>rad</td>
<td>radio</td>
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<tr>
<td>RADAR</td>
<td>Radio Detection and Ranging</td>
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<tr>
<td>RADC</td>
<td>Rome Air Development Center(US)</td>
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<tr>
<td>RAE</td>
<td>Royal Aircraft Establishment (Brit)</td>
</tr>
<tr>
<td>RAF</td>
<td>Royal Air Force(Brit)</td>
</tr>
<tr>
<td>Raibun</td>
<td>Jap primary expl(see the text)</td>
</tr>
<tr>
<td>Raiko</td>
<td>Jap for MF</td>
</tr>
<tr>
<td>RAOC</td>
<td>Royal Army Ordnance Corps (Brit)</td>
</tr>
<tr>
<td>RAOD</td>
<td>Royal Army Ordnance Depot(Brit)</td>
</tr>
<tr>
<td>RArty</td>
<td>Royal Artillery(Brit)</td>
</tr>
<tr>
<td>Ra-Th</td>
<td>radium-thorium</td>
</tr>
<tr>
<td>RATO</td>
<td>rocket assisted take off, called also &quot;booster rocket&quot;; more common name is JATO</td>
</tr>
<tr>
<td>RB</td>
<td>rifle bomber</td>
</tr>
<tr>
<td>Rb</td>
<td>rubidium</td>
</tr>
<tr>
<td>RBT</td>
<td>Rifle Bullet Test</td>
</tr>
<tr>
<td>RC</td>
<td>Rand Corp, Santa Monica, Calif</td>
</tr>
<tr>
<td>RCA</td>
<td>Radio Corp of America</td>
</tr>
<tr>
<td>RCAF</td>
<td>Royal Canadian Air Force</td>
</tr>
<tr>
<td>RCAT</td>
<td>radio controlled airplane target</td>
</tr>
<tr>
<td>RCh</td>
<td>reduced charge</td>
</tr>
<tr>
<td>RCL</td>
<td>Radiation Counter Laboratories, Chicago, Ill</td>
</tr>
<tr>
<td>RCOC</td>
<td>Royal Canadian Ordnance Corps Research Department</td>
</tr>
<tr>
<td>RD</td>
<td>Research &amp; Development road</td>
</tr>
<tr>
<td>Rd</td>
<td>round(s) (of Ammo)</td>
</tr>
<tr>
<td>Rd(s)</td>
<td>rural delivery</td>
</tr>
<tr>
<td>RD</td>
<td>Research Department &quot;B&quot; (Brit propellant used during WWI)</td>
</tr>
<tr>
<td>RDB</td>
<td>rifle double-base(propellant)</td>
</tr>
<tr>
<td>rds/m</td>
<td>rounds per minute</td>
</tr>
<tr>
<td>RDX</td>
<td>Research Department Explosive (cyclonite, hexogen or cyclo-trimethylenetrinitramine)</td>
</tr>
<tr>
<td>Ré</td>
<td>Réaumur</td>
</tr>
<tr>
<td>Re</td>
<td>rhenium</td>
</tr>
<tr>
<td>RE</td>
<td>Royal Engineers(Brit) receive(d)</td>
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<tr>
<td>rec(d)</td>
<td>recognition</td>
</tr>
<tr>
<td>recogn</td>
<td>recrystallize(d)</td>
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<td>recry(D)</td>
<td>recrystallization</td>
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<td>recrystn</td>
<td>reduction</td>
</tr>
<tr>
<td>redn</td>
<td>reduction and oxidation</td>
</tr>
<tr>
<td>redoX</td>
<td>Reference(s) refrigerating</td>
</tr>
<tr>
<td>ref(s)</td>
<td>refrigeration</td>
</tr>
<tr>
<td>refl</td>
<td>reflux</td>
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<tr>
<td>Reg</td>
<td>regiment</td>
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<tr>
<td>Regl</td>
<td>regimental</td>
</tr>
<tr>
<td>reinfd</td>
<td>reinforced</td>
</tr>
<tr>
<td>Reinhold</td>
<td>Reinhold Publishing Corp, New York 22, NY</td>
</tr>
<tr>
<td>Reintri rel</td>
<td>Ger &amp; Swiss for purified TNT relative</td>
</tr>
<tr>
<td>reln</td>
<td>relation</td>
</tr>
<tr>
<td>Rep</td>
<td>Republic</td>
</tr>
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<td>req(d)</td>
<td>require(d)</td>
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<tr>
<td>res</td>
<td>reserve</td>
</tr>
<tr>
<td>RES</td>
<td>Reynolds Experimental Station, of Atlas Powder Co, Tamaqua, Pa</td>
</tr>
<tr>
<td>RESB</td>
<td>Royal Engineers Standards Board (Brit)</td>
</tr>
<tr>
<td>resp</td>
<td>respectively</td>
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<td>restr</td>
<td>restricted</td>
</tr>
<tr>
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<td>returned</td>
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<tr>
<td>RETMA</td>
<td>Radio-Electronics-Television Manufacturers Association</td>
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<td>Rev(s)</td>
<td>Review(s)</td>
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<tr>
<td>revn</td>
<td>revolution</td>
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<tr>
<td>Abbr</td>
<td>Meaning</td>
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<tr>
<td>------</td>
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</tr>
<tr>
<td>RF</td>
<td>rapid firing; rimfire</td>
</tr>
<tr>
<td>rf</td>
<td>rifle</td>
</tr>
<tr>
<td>RFA</td>
<td>Royal Field Artillery (Brit)</td>
</tr>
<tr>
<td>RFAmmo</td>
<td>rimfire ammunition</td>
</tr>
<tr>
<td>RFC</td>
<td>Reconstruction Finance Corp</td>
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<tr>
<td>RFF</td>
<td>Royal Firearms Factory, England</td>
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<tr>
<td>RFG</td>
<td>rifle fine grain (propellant) (Brit)</td>
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<tr>
<td>RFN</td>
<td>red fuming nitric</td>
</tr>
<tr>
<td>RFNA</td>
<td>red fuming nitric acid</td>
</tr>
<tr>
<td>Rg</td>
<td>range</td>
</tr>
<tr>
<td>RG</td>
<td>rifle grenade</td>
</tr>
<tr>
<td>RG</td>
<td>ruchnaya granata (Rus) (hand grenade)</td>
</tr>
<tr>
<td>RGb</td>
<td>river gunboat</td>
</tr>
<tr>
<td>RGF</td>
<td>Royal Gun Factory (Brit)</td>
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<tr>
<td>RGM</td>
<td>rounds per gun per minute</td>
</tr>
<tr>
<td>RGn</td>
<td>recoilless gun</td>
</tr>
<tr>
<td>RH</td>
<td>relative humidity</td>
</tr>
<tr>
<td>Rh</td>
<td>rhodium</td>
</tr>
<tr>
<td>RHB</td>
<td>radar homing beacon</td>
</tr>
<tr>
<td>RHC(H)</td>
<td>Rohm &amp; Haas Co, Huntsville, Ala</td>
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<tr>
<td>RHC(Ph)</td>
<td>Rohm &amp; Haas Co, Phila 5, Pa</td>
</tr>
<tr>
<td>rheo</td>
<td>rheostat</td>
</tr>
<tr>
<td>rhmb</td>
<td>rhombic</td>
</tr>
<tr>
<td>RN</td>
<td>round nose</td>
</tr>
<tr>
<td>RNZArty</td>
<td>Royal New Zealand Army Artillery</td>
</tr>
<tr>
<td>RNZNA</td>
<td>Royal New Zealand Army</td>
</tr>
<tr>
<td>RNZN</td>
<td>Royal New Zealand Navy</td>
</tr>
<tr>
<td>RO</td>
<td>radar operator</td>
</tr>
<tr>
<td>ROC</td>
<td>Rochester Ordnance District, Rochester, NY (See NYOD)</td>
</tr>
<tr>
<td>ROF</td>
<td>Royal Ordnance Factory (Brit)</td>
</tr>
<tr>
<td>Rohtri</td>
<td>Ger &amp; Swiss for crude TNT</td>
</tr>
<tr>
<td>Rom</td>
<td>Roman</td>
</tr>
<tr>
<td>Romite</td>
<td>Ital cheddite type expl</td>
</tr>
<tr>
<td>ROD</td>
<td>Ridgewood Ordnance Plant, Cincinnati, Ohio</td>
</tr>
<tr>
<td>RONZArty</td>
<td>Royal New Zealand Artillery</td>
</tr>
<tr>
<td>ROP</td>
<td>Rocky Ordnance Plant (Brit)</td>
</tr>
<tr>
<td>ROP</td>
<td>Rockford Ordnance Plant, Rockford, Ill</td>
</tr>
<tr>
<td>ROR</td>
<td>rocket on rotor</td>
</tr>
<tr>
<td>Rossite</td>
<td>code name for guanylnitrourea</td>
</tr>
<tr>
<td>RORC</td>
<td>(nitrodicyandiamidine)</td>
</tr>
<tr>
<td>ROTS</td>
<td>Reserve Officers Training Corps</td>
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<tr>
<td>ROW</td>
<td>Radford Ordnance Works, Radford, Va</td>
</tr>
<tr>
<td>Roy</td>
<td>Royal</td>
</tr>
<tr>
<td>RP</td>
<td>rocket projectile</td>
</tr>
<tr>
<td>RP</td>
<td>rocket propellant</td>
</tr>
<tr>
<td>R/P</td>
<td>rocket projector</td>
</tr>
<tr>
<td>RPD</td>
<td>Rocket Propulsion Department</td>
</tr>
<tr>
<td>rpgd</td>
<td>rounds per gun per diem</td>
</tr>
<tr>
<td>rgpm</td>
<td>rounds per gun per minute</td>
</tr>
<tr>
<td>rpm</td>
<td>revolutions per minute</td>
</tr>
<tr>
<td>rps</td>
<td>rounds per minute</td>
</tr>
<tr>
<td>rpr</td>
<td>revolutions per second</td>
</tr>
<tr>
<td>RQ</td>
<td>railroad</td>
</tr>
<tr>
<td>RR</td>
<td>Red River Arsenal, Texarkana, Tex</td>
</tr>
<tr>
<td>RRA</td>
<td>Rolls-Royce Co, England</td>
</tr>
<tr>
<td>RRC</td>
<td>Radar Research Establishment (Brit)</td>
</tr>
<tr>
<td>RRI</td>
<td>Rocket Research Institute</td>
</tr>
<tr>
<td>RRL</td>
<td>Reynolds Research Laboratory, Tamaqua, Penna (Atlas PC)</td>
</tr>
<tr>
<td>RRL</td>
<td>Road Research Laboratory (Brit)</td>
</tr>
<tr>
<td>RRS</td>
<td>Reaction Research Society, Glendale, Calif</td>
</tr>
<tr>
<td>RS</td>
<td>rolled steel</td>
</tr>
</tbody>
</table>

This list includes various abbreviations along with their meanings, encompassing fields such as military, engineering, and science. Each abbreviation is paired with a description to provide a comprehensive understanding of its context.
Abbr 45

R-salt cyclotrimethylenetrinitrosamine
RSigG rocket, signal, green
RSigR rocket, signal, red
RSL Royal Society, London
RSM rocket sea-marker
RSOP reconnaissance, selection and organization of artillery positions
RSVP répondez s'il vous plaît(Fr) (please answer)
R/T radio telegraphy or radio telephony(Brit)
rt rate
RT room temperature
RTCC Reilly Tar & Chemical Corp, Indianapolis 4, Ind
Ru ruthenium
Rum Rumania; Rumanian
Rupturita Braz expl manufd by SAER Council(Brit)
Rus Russia; Russian
RV remaining velocity
Ry(s) railway(s)
RyBn Railway Battalion
RyJn railway junction

s second
s- secondary(as applied to a type of organic compound)
s series
s service
s single
S slotted tubular propellant (Brit)
S solventless propellant(Brit)
S south; southern
S staff
S sulfur
S or sym- symmetrical
S Fr & Ital expls (see the text)
S Fr sporting propellant
S1; S2 etc Ger & Ital expls used in underwater ammo(see PATR 2510, pp 170 & 212)
Sa samarium
SA samokhodnaya artilleriya(Rus) (self-propelled artillery)
Sa Saturday
SA Secretary of the Army
SA semi-automatic
SA small arms

SA Sociedad Anónima(Span)
SA Società Anonima(Ital)
SA Société Anonyme(Fr)
SA Sociedade Anónima(Port)
SA (Joint Stock Company)
SA South America
SA Space Agency(US)
SA Springfield Armory,
Springfield 1, Mass
SA SA152 Ital propellant(obsolete)
SA SAA small arms ammunition
SA Société Anonyme d‘Arendonck(Belg)
SA SAA Standards Association of Austalia
SA Sabulites Belg & Ital expls of various comps
SA SAC Scientific Advisor to the Army Council(Brit)
SA SAC Strategic Air Command
SA SAC Supreme Allied Commander
SA SACN Società ACNA(Ital)
SA SAD Sociedade Anónima de la Dinamita(Portug)
SA SADN Società Anonima Dinamite
SA SAEF Nobel Avigliana(Ital)
SA SAFA Société Anonyme des Explosifs Favier (Belg)
SA SAB Société Anonyme des Explosifs d‘Havré(Fr)
SA SAEH Società Anonima di Esplovidenti e Prodotti Chimiche(Villafranca)(Ital)
SA SAEPC Société Anonyme d‘Explosifs et de Produits Chimiques
SA SAEPCM Società Anonima di Esplovidenti e Prodotti Chimiche, Monte-
catini(Ital)
SA SAER Sociedade Anonima Explosivos Rupturita(Brazil)
SA SAFA Società Anonima Fabbrica Armi(Ital)
SA SAFAT Società Anonima Fabbrica Armi Torino(Ital)
SA SAICE Società Anonima Consomatori Esplosivi(Orbetello)(Ital)
<table>
<thead>
<tr>
<th>Abbr</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAIM</td>
<td>Società Anonima Italina Micce (Ponte Stazzemese) (Ital)</td>
</tr>
<tr>
<td>Sakumadainamaito</td>
<td>Jap for gelignite</td>
</tr>
<tr>
<td>Sakura-dainamaito</td>
<td>Jap dynamite (see the text)</td>
</tr>
<tr>
<td>salv</td>
<td>salvage</td>
</tr>
<tr>
<td>SAM</td>
<td>surface-to-air missile</td>
</tr>
<tr>
<td>SAMCM</td>
<td>Società Anonima Munizione e Cartuccheria Martignoni (Ital)</td>
</tr>
<tr>
<td>SAME</td>
<td>Society of American Military Engineers</td>
</tr>
<tr>
<td>SANACC</td>
<td>State Army-Navy-Air Coordinating Committee</td>
</tr>
<tr>
<td>Sanshoki mechiru nitoruamintororu</td>
<td>Jap for tetryl (same as Meiyakaku)</td>
</tr>
<tr>
<td>SAP</td>
<td>semi-armor-piercing</td>
</tr>
<tr>
<td>sapon</td>
<td>saponification, saponify</td>
</tr>
<tr>
<td>saponed</td>
<td>saponified</td>
</tr>
<tr>
<td>saponging</td>
<td>saponifying</td>
</tr>
<tr>
<td>sap val</td>
<td>saponification value</td>
</tr>
<tr>
<td>SAR</td>
<td>semi-automatic rifle</td>
</tr>
<tr>
<td>Sask</td>
<td>Saskatchewan, Can</td>
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<tr>
<td>sat</td>
<td>saturate</td>
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<td>saturated</td>
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<td>satisf</td>
<td>satisfactory</td>
</tr>
<tr>
<td>satn</td>
<td>saturation</td>
</tr>
<tr>
<td>SB</td>
<td>Selection Board</td>
</tr>
<tr>
<td>SB</td>
<td>shell bullet (explosive bulleted)</td>
</tr>
<tr>
<td>SB</td>
<td>Siege Battery</td>
</tr>
<tr>
<td>SB</td>
<td>smooth-bore</td>
</tr>
<tr>
<td>Sb</td>
<td>stibium (Lat) (antimony)</td>
</tr>
<tr>
<td>SB</td>
<td>submarine boat</td>
</tr>
<tr>
<td>SBAS</td>
<td>standard beam approach system</td>
</tr>
<tr>
<td>SBCP</td>
<td>slow burning cocoa powder (see the text)</td>
</tr>
<tr>
<td>Sc</td>
<td>scandium</td>
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<tr>
<td>S &amp; C</td>
<td>Schaar &amp; Co, Chicago 7, Ill</td>
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<tr>
<td>Sc or Sci</td>
<td>science</td>
</tr>
<tr>
<td>SC</td>
<td>shaped charge</td>
</tr>
<tr>
<td>Sc or Sch</td>
<td>Schneiderite (Fr, Ital &amp; Rus expl)</td>
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<tr>
<td>SC</td>
<td>short case</td>
</tr>
<tr>
<td>SC</td>
<td>solventless, carbamite (Brit propellant cong centralite)</td>
</tr>
<tr>
<td>SC</td>
<td>South Carolina</td>
</tr>
<tr>
<td>SCA</td>
<td>Seacoast Artillery</td>
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<tr>
<td>ScD</td>
<td>Scientiae Doctor (Lat); Doctor of Science</td>
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<tr>
<td>SCC</td>
<td>schedule; school</td>
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<td>Sch</td>
<td>Schneiderite (Fr, Ital &amp; Rus expl)</td>
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<tr>
<td>Schiesswolle</td>
<td>HNPDPA, TNT &amp; Al (see PATR 2510, p 172)</td>
</tr>
<tr>
<td>Sci or Sc</td>
<td>science</td>
</tr>
<tr>
<td>SCI</td>
<td>Society of Chemical Industry</td>
</tr>
<tr>
<td>sclt</td>
<td>scarlet</td>
</tr>
<tr>
<td>ScM</td>
<td>Master of Science</td>
</tr>
<tr>
<td>SC/RDL</td>
<td>Signal Corps, Research and Development Laboratories</td>
</tr>
<tr>
<td>scrng</td>
<td>screening</td>
</tr>
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<td>Scy</td>
<td>Secretary</td>
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<tr>
<td>SD</td>
<td>Salvage Depot</td>
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<tr>
<td>SD</td>
<td>sans dissolvant (Fr) (solventless)</td>
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<tr>
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<td>sawdust</td>
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<td>SD</td>
<td>self-destroying</td>
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<td>SD</td>
<td>Service Depot</td>
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<td>shell dressing</td>
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<td>SD</td>
<td>Signal Department (Brit Navy)</td>
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<td>SD or SDak</td>
<td>South Dakota</td>
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<tr>
<td>SD</td>
<td>straight dynamite</td>
</tr>
<tr>
<td>SD</td>
<td>Submarine Department</td>
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<td>SDC</td>
<td>Shell Development Company</td>
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<tr>
<td>SDC</td>
<td>Special Devices Center</td>
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<tr>
<td>SD NÉO</td>
<td>Fr solventless propellant based on DEGDN</td>
</tr>
<tr>
<td>SD Ngl</td>
<td>Fr solventless propellant based on NG</td>
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<tr>
<td>SDO</td>
<td>synthetic drying oils (used in some incendiaries)</td>
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<td>SDVM</td>
<td>Société Dinamite Villafranca-Mulazzo (Ital)</td>
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<td>Se</td>
<td>selenium</td>
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<td>SE</td>
<td>Society of Engineers</td>
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<td>south-east</td>
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<td>Sébomites</td>
<td>Fr chlorate expls of pre WWI</td>
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<td>second(s)</td>
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<td>Sec or Secry</td>
<td>Secretary</td>
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<td>SECI</td>
<td>Société d'Études Chimiques pour l'Industrie (Fr)</td>
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<td>segment</td>
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<td>Braz safety expls manufd by CNES</td>
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<td>Seigara</td>
<td>Jap expl (see the text)</td>
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<td>SEM</td>
<td>Società Esplodenti e Munizione (Roma, Italy)</td>
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<tr>
<td>Sen</td>
<td>Senator</td>
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<td>Sen</td>
<td>Senior</td>
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<td>Sengite</td>
<td>Belg expl (see the text)</td>
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<td>sensitive</td>
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<td>sensy</td>
<td>sensibility, sensitivity</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>SEPC</td>
<td>Società Esplodenti et Prodotti Chimiche (Torino) (Ital)</td>
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<td>separating</td>
</tr>
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<td>sepn</td>
<td>separation</td>
</tr>
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<td>SEPR</td>
<td>Société d’Étude de la Propulsion par Réaction (Fr) (Society for the Study of Propulsion by Reaction Technique)</td>
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<td>Sept</td>
<td>September</td>
</tr>
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<td>seq</td>
<td>sequence</td>
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<tr>
<td>ser</td>
<td>series</td>
</tr>
<tr>
<td>Seranin</td>
<td>older Swed AN dynamite</td>
</tr>
<tr>
<td>Serg</td>
<td>Sergeant</td>
</tr>
<tr>
<td>Serj Maj</td>
<td>Sergeant-Major (Brit)</td>
</tr>
<tr>
<td>SERL</td>
<td>Signals Engineering Research Laboratory</td>
</tr>
<tr>
<td>Serv</td>
<td>Service</td>
</tr>
<tr>
<td>SES</td>
<td>Suffield Experimental Station (Can)</td>
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<tr>
<td>SET</td>
<td>Société d’Explosifs Titanite</td>
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<tr>
<td>Sévranites</td>
<td>Fr plastic expls contg PETN and Amm perchlorate</td>
</tr>
<tr>
<td>SEX</td>
<td>symbol for 1-acyclocta-hydro-3,5,7-trinitro-1,3,5,7-tetrazocine</td>
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<tr>
<td>SF</td>
<td>safety fuze</td>
</tr>
<tr>
<td>SF</td>
<td>San Francisco</td>
</tr>
<tr>
<td>SF</td>
<td>sans flammes (Fr) (flashless)</td>
</tr>
<tr>
<td>SF</td>
<td>sans fumée (Fr) (smokeless)</td>
</tr>
<tr>
<td>SF</td>
<td>Santa Fe</td>
</tr>
<tr>
<td>sf</td>
<td>self-feeding</td>
</tr>
<tr>
<td>SF</td>
<td>semi-fixed</td>
</tr>
<tr>
<td>SF</td>
<td>signal flare</td>
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<tr>
<td>SF</td>
<td>supersonic frequency</td>
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<td>SFE</td>
<td>Société Française des Explosifs</td>
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<td>SFHEPC</td>
<td>Société Franco-Hellénique d’Explosifs et Produits Chimiques (Ktripito, Greece)</td>
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<td>Sf</td>
<td>sulfide</td>
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<td>SFIEC</td>
<td>Société Franco-Italienne d’Explosifs Cheddite</td>
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<tr>
<td>SFMCTG</td>
<td>Société Française des Munitions de Chasse, de Tir et de Guerre (Fr)</td>
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<tr>
<td>Sfo</td>
<td>sulfone</td>
</tr>
<tr>
<td>SFOD</td>
<td>San Francisco Ordnance District, Oakland, Calif</td>
</tr>
<tr>
<td>SG</td>
<td>smoke generator</td>
</tr>
<tr>
<td>SG</td>
<td>specialist in gunnery</td>
</tr>
<tr>
<td>SGACI</td>
<td>Scientific Glass Apparatus Co, Inc, Bloomfield, NJ</td>
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<td>SGD</td>
<td>straight gelatin dynamite</td>
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<tr>
<td>SGEC</td>
<td>Société Générale d’Explosifs Cheddite</td>
</tr>
<tr>
<td>SGEM</td>
<td>Società Generale di Esplosivi e Munizione (Ital)</td>
</tr>
<tr>
<td>SGIMC</td>
<td>Società Generale per l’Industria Mineraria e Chimica (Ital) (see also SAPCM)</td>
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<tr>
<td>SGM</td>
<td>ship-to-ground missile</td>
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<tr>
<td>SGP</td>
<td>Sécurité-Grison-Poussière (Belg expls safe to use in gaseous and dusty coal mines)</td>
</tr>
<tr>
<td>SGR</td>
<td>sodium graphite reactor</td>
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<tr>
<td>Sh</td>
<td>shrapnel’ (Rus) (shrapnel)</td>
</tr>
<tr>
<td>SH</td>
<td>Squashhead (Brit) (see also HE/SH and HEP)</td>
</tr>
<tr>
<td>ShCh or SC</td>
<td>shaped charge</td>
</tr>
<tr>
<td>SHAEF</td>
<td>Supreme Headquarters, Allied Expeditionary Forces</td>
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<tr>
<td>SET</td>
<td>Jap for thermite</td>
</tr>
<tr>
<td>SET</td>
<td>SHAPE</td>
</tr>
<tr>
<td>SET</td>
<td>Supreme Headquarters of Atlantic Powers in Europe</td>
</tr>
<tr>
<td>SET</td>
<td>shell</td>
</tr>
<tr>
<td>SET</td>
<td>hollow projectile filled with expl or other material</td>
</tr>
<tr>
<td>SET</td>
<td>Shellite</td>
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<tr>
<td>SF</td>
<td>Shellite</td>
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<tr>
<td>SF</td>
<td>Brit expl contg PA 70 &amp; DNPh 30% (See also Tridite)</td>
</tr>
<tr>
<td>SF</td>
<td>SHF</td>
</tr>
<tr>
<td>SF</td>
<td>super high frequency (3000 to 30000 megacycles per second)</td>
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<tr>
<td>SF</td>
<td>Jap cast PA prep by a special method</td>
</tr>
<tr>
<td>SF</td>
<td>Jap AN expl</td>
</tr>
<tr>
<td>SF</td>
<td>Jap coal mining expls</td>
</tr>
<tr>
<td>SF</td>
<td>Jap expls (see the text)</td>
</tr>
<tr>
<td>SF</td>
<td>Jap for PETN</td>
</tr>
<tr>
<td>SF</td>
<td>Jap for NC (Menkayaku)</td>
</tr>
<tr>
<td>SF</td>
<td>Jap propellant</td>
</tr>
<tr>
<td>SF</td>
<td>Jap expl</td>
</tr>
<tr>
<td>SF</td>
<td>Jap for cyclonite and some of its expls (see also Tanayaku)</td>
</tr>
<tr>
<td>SF</td>
<td>SHQEA</td>
</tr>
<tr>
<td>SF</td>
<td>Supreme Headquarters of the European Army</td>
</tr>
<tr>
<td>SF</td>
<td>Jap AN expl</td>
</tr>
<tr>
<td>SF</td>
<td>Jap coal mining expls</td>
</tr>
<tr>
<td>SF</td>
<td>Jap expls (see the text)</td>
</tr>
<tr>
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<td>Jap for NC (Menkayaku)</td>
</tr>
<tr>
<td>SF</td>
<td>Jap propellant</td>
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<td>Jap expl</td>
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<td>Jap for cyclonite and some of its expls (see also Tanayaku)</td>
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<tr>
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<td>SHQEA</td>
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<td>SF</td>
<td>Supreme Headquarters of the European Army</td>
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<tr>
<td>SF</td>
<td>Jap AN expl</td>
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<tr>
<td>SF</td>
<td>Jap coal mining expls</td>
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<td>SF</td>
<td>Jap expls (see the text)</td>
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<tr>
<td>SF</td>
<td>Jap for PETN</td>
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<tr>
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<td>Jap for NC (Menkayaku)</td>
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<tr>
<td>SF</td>
<td>Jap propellant</td>
</tr>
<tr>
<td>SF</td>
<td>Jap expl</td>
</tr>
<tr>
<td>SF</td>
<td>Jap for cyclonite and some of its expls (see also Tanayaku)</td>
</tr>
<tr>
<td>SI</td>
<td>specific impulse</td>
</tr>
<tr>
<td>SI</td>
<td>start of ignition (of liq propellants in rockets)</td>
</tr>
<tr>
<td>Abbr</td>
<td>English</td>
</tr>
<tr>
<td>-------</td>
<td>---------</td>
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</tbody>
</table>
| SIA   | Società Italiana Ansaldi (Ital) | SMG | Smith Inst
| Sib   | Siberia | SM | submarine gun
| SIB   | Special Intelligence Bureau | smk sh | Smithsonian Institute, Washington, DC
| SIBD  | Società Italiana Davy Bickford at Taino (Ital) | smk sig | smoke shell
| SIEB  | Società Italiana Ernesto Breda (Ital) | SMLE | Smith Inst
| Siem  | Ital sporting propellant | smls | smoke signal
| SIEP  | Società Italiana dell'Esplosivo Prometeus | smpl | Smithsonian Institute, Washington, DC
| SIG   | Schweizerische Industrie-gesellschaft (Neuhausen) (Swiss) | sample | Safety in Mines Research Establishment (Brit)
| sig   | Signal Corps | SMRE | seamless
| SigC  | Signal Corps | sample | sample
| sign  | signature; signify | SMLE | sample
| Silites | older types Fr & Ital cannon propellants | SN | sodium nitrate
| Simplonit | Swiss expl(see the text) | SIB | stannum (Lat), tin
| sin   | sine | SNF | situation normal, all fouled up (Amer slang)
| sing  | singular | SNL | Société d'Aviation (Fr)
| SIPE  | Società Italiana Prodotti Espolenti (Milano) | SNM | Société Nobel Française
| Sipe  | Ital sporting propellant | SNSE | Society of Nuclear Medicine
| Siperite | same as MNDT | SO | Society of Nuclear Scientists and Engineers
| SIPRE | Snow, Ice and Permafrost Research Establishment | SOA | Stationery Office (Brit) (see HMSO)
| sit   | situate | SOC | School of Artillery
| SIT   | spontaneous ignition temperature | SOC | Shell Oil Co, San Francisco, Calif
| sitd  | situated | SOCONY | Standard Oil Co, Whiting, Ind
| sitn  | situation | Sociy | Standard Oil Co of New York
| Sixolite | code name for tetramethylol-cyclohexanolpentanitrate | SOD | Society
| Sixonite | code name for tetramethylol-cyclohexanonetetranitrate | SOD | Savanna Ordnance Depot, Savanna, Ill
| SJ    | steel jacket | SOD | Seneca Ordnance Depot, Romulus, NY
| SJOD  | San Jacinto Ordnance Depot, Channelview, Tex | SOD | Sierra Ordnance Depot, Herlong, Calif
| SL    | separate-loading | SOD | Sioux Ordnance Depot, Sidney, Neb
| sl    | slight(ly) | SODC | Springfield Ordnance District, Springfield 1, Mass
| S/L   | streamlined | SOFAR | Standard Oil Development Company
| SLEEP | Swedish Low-Energy Experimental Pile | Sofranex A | sound fixing and ranging
| SLOD  | San Louis Ordnance District, St Louis 1, Mo | sol | Fr plastic expl contg NG, CC, AN, Al & liq DNT
| S/Lt  | Second Lieutenant | Solenita | soluble
| sl sol | slightly soluble | soln | Ital rifle propellant
| sly   | slowly | solv | solution
| Sm    | samarium | soly | solvent(s)
| SM    | strategic missile | solys | solubility
| S/M   | submarine | Soms | solubilities
| SMAC  | Senate Military Affairs Committee | Son | Somersetshire, Engl
| SMC   | Sten machine carbine (Brit) | SONAR | Sonora, Mexico
|     |         | SOP | Submarine Sound Operation, Navigation and Ranging
|     |         |     | Scranton Ordnance Plant, Scranton, Pa
<table>
<thead>
<tr>
<th>Abbr</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>SOS</td>
<td>smoke obscuring screen</td>
</tr>
<tr>
<td>SOS</td>
<td>sniping, observation and scouting distress</td>
</tr>
<tr>
<td>SOS</td>
<td>international distress signal</td>
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<tr>
<td>SOW</td>
<td>Sunflower Ordnance Works, Lawrence, Kan</td>
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<tr>
<td>SP</td>
<td>self-propelled</td>
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<tr>
<td>SP</td>
<td>Service des Poudres(Fr)</td>
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<tr>
<td>SP</td>
<td>single-perforated(propellant)</td>
</tr>
<tr>
<td>SP</td>
<td>smokeless propellant</td>
</tr>
<tr>
<td>sp</td>
<td>solidification or setting point</td>
</tr>
<tr>
<td>SP</td>
<td>solid propellants(Rocketry)</td>
</tr>
<tr>
<td>sp</td>
<td>specific</td>
</tr>
<tr>
<td>SP</td>
<td>Supply Post</td>
</tr>
<tr>
<td>SP₁; SP₂; SP₃</td>
<td>black powders used by the French in cannons prior to invention of smokeless propellants</td>
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<tr>
<td>SPAR</td>
<td>Super Precision Approach Radar</td>
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<tr>
<td>SPAT</td>
<td>self-propelled antitank</td>
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<tr>
<td>SPCEBC</td>
<td>Société des Produits Chimiques et d'Explosifs Bergès, Corbin et Companie(Grenoble)(Fr)</td>
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<tr>
<td>SPRGM</td>
<td>self-propelled caterpillar gun-mount</td>
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<tr>
<td>SPE</td>
<td>Society of Plastics Engineers</td>
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<tr>
<td>Spec(s)</td>
<td>Specification(s)</td>
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<tr>
<td>SPG</td>
<td>self-propelled gun</td>
</tr>
<tr>
<td>sp gr</td>
<td>specific gravity</td>
</tr>
<tr>
<td>sp ht</td>
<td>specific heat</td>
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<tr>
<td>SPI</td>
<td>Society of the Plastics Industry</td>
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<tr>
<td>SPIA</td>
<td>Solid Propellants Information Agency, Johns Hopkins University, Silver Spring, Md</td>
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<tr>
<td>splty</td>
<td>specialty</td>
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<td>SM</td>
<td>self-propelled mount</td>
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<tr>
<td>sp</td>
<td>spontaneous</td>
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<tr>
<td>spr</td>
<td>sapper</td>
</tr>
<tr>
<td>sp vol</td>
<td>specific volume</td>
</tr>
<tr>
<td>SpW</td>
<td>Special Weapon</td>
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<tr>
<td>SPXECC</td>
<td>Special Executive</td>
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<tr>
<td>spzd</td>
<td>specialized</td>
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<tr>
<td>Sq</td>
<td>Squadron</td>
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<td>sq</td>
<td>square</td>
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<tr>
<td>SQ</td>
<td>superquick(Brit)</td>
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<tr>
<td>SQC</td>
<td>Soldier's Qualification</td>
</tr>
<tr>
<td>sq cm or cm²</td>
<td>square centimeter(s)</td>
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<tr>
<td>Sq(D)</td>
<td>dive squadron</td>
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<tr>
<td>sq ft</td>
<td>square foot(feet)</td>
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<tr>
<td>sq in or in²</td>
<td>square inch(es)</td>
</tr>
<tr>
<td>sq km</td>
<td>square kilometer(s)</td>
</tr>
<tr>
<td>sq m or m²</td>
<td>square meter(s)</td>
</tr>
<tr>
<td>sq mi</td>
<td>square mile(s)</td>
</tr>
<tr>
<td>sq mm</td>
<td>square millimeter(s)</td>
</tr>
<tr>
<td>sq yd</td>
<td>square yard(s)</td>
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<tr>
<td>Sr</td>
<td>short rifle</td>
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<tr>
<td>SR</td>
<td>sound ranging</td>
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<td>SR</td>
<td>Special Regulation(s)</td>
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<tr>
<td>Sr</td>
<td>strontium</td>
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<tr>
<td>SRDE</td>
<td>synthetic rubber</td>
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<tr>
<td>SRED</td>
<td>Signals Research and Development Establishment</td>
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<tr>
<td>SRI</td>
<td>Scientific Research and Experiments Department(Naval)</td>
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<tr>
<td>SRI</td>
<td>Southwest Research Institute, San Antonio, Tex</td>
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<tr>
<td>SRI</td>
<td>Stanford Research Institute, Stanford, Calif</td>
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<tr>
<td>SPAR</td>
<td>short rifle military, Lee-Enfield(Brit)</td>
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<tr>
<td>SPAT</td>
<td>single shot(firearm)</td>
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<tr>
<td>SPC</td>
<td>star shell</td>
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<td>SPC</td>
<td>steamship</td>
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<tr>
<td>SPS</td>
<td>supersensitive</td>
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<tr>
<td>SRED</td>
<td>Selective Service Act</td>
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<td>SRE</td>
<td>Social Security Administration</td>
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<td>SPIE</td>
<td>Schweizer Sprengstoff</td>
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<td>SPA</td>
<td>Aktiengesellschaft Cheddit &amp; Dynamit (Liestal &amp; Isleton, Switzerland)</td>
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<tr>
<td>SPIAG</td>
<td>Société Suisse des Explosifs, Gamsen-Briége</td>
</tr>
<tr>
<td>SPIA</td>
<td>Schweizerische Sprengstoff Fabrik, AG, Dottikon, Switzerland</td>
</tr>
<tr>
<td>SPAG</td>
<td>submarine guided missile</td>
</tr>
<tr>
<td>SPE</td>
<td>Sargent Scientific Laboratory Instruments, Chicago 30, Ill</td>
</tr>
<tr>
<td>SPF</td>
<td>ship-to-ship missile</td>
</tr>
<tr>
<td>SPE</td>
<td>surface-to-surface missile</td>
</tr>
<tr>
<td>STRE</td>
<td>Società Sarda Materie Esplodenti (Caglieri, Sardinia) (Ital)</td>
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<tr>
<td>SSPF</td>
<td>symbol for nuclear powdered submarine</td>
</tr>
<tr>
<td>SSPF</td>
<td>Specification Serial Number</td>
</tr>
<tr>
<td>SSPF</td>
<td>start of sustained pressure (Rocketry)</td>
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<tr>
<td>SPA</td>
<td>Staatliche Schwarzpulverfabriken (Aubonne &amp; Chur) (Switz)</td>
</tr>
<tr>
<td>SPA</td>
<td>symbol for radar picket submarine</td>
</tr>
<tr>
<td>SSPF</td>
<td>starting time</td>
</tr>
<tr>
<td>STAB</td>
<td>Station</td>
</tr>
<tr>
<td>STAB</td>
<td>stabilizer</td>
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</table>
Abbr 50

STAF  Strategic Air Force Staffs, Staffordshire, Engl
(staf)* after Mark as MkV* denotes a minor design modification in Ordn items (Brit)
std     standard
stdz    standardize
stdzn   standardization
Sst     Société (Fr) (Society)
Systy   Société Anonyme (Fr) (Joint Stock Company)
stl     stilbene
STP     standard temperature and pressure
strg    strength, strong
STR     Submarine Thermal Reactor (as in the Nautilus)
SU      "solventless, urethane" (Brit propellant)
Sub     Subaltern (Brit)
sub     submarine
sub or subm submarine
subway  subway
sub-cal  sub-caliber
subd    subdivision
subj    subject
subl    sublimes (s)
subln   sublimation
subm or sub submarine
subs    subsidiary
subseq  subsequent
subs    substance, substitute
Suc     sucrose
succr   successor
SucON   sucrose octanitrate
SUE     Société Universelle des Explosifs
suff    sufficient
Suff    Suffolk, Engl
Sug     sugar
SUM     surface-to-underwater (guided) missile
Sund    Sunday
Superforcite Belg gelatin dynamite
supers  supersaturated
SupHgs  Supreme Headquarters
SUPO    Super Power Water Boiler (Reactor)
suppl   supplement
supra   Lat for "above" - used to refer to earlier parts of the book
Supt    Superintendent
SuptDoc  Superintendent of Documents
surf    surface
Surr    Surrey, Engl

suspd   suspended
suspn   suspension
Suss    Sussex, Engl
SUV     Saybolt Universal Viscosity
SV      saponification value
SV      striking velocity (Brit)
SVB     Società Vulcania di Brescia (Ital)
SW      short waves
SW      South Wales
SW      South-west
SWE     Special Weapons Center
Swed    Sweden, Swedish
SwedP   Swedish Patent
SG      Standard Wire Gauge (Brit)
SwissP  Swiss Patent
Switz   Switzerland
sym     symmetrical
symb    symbol
syn     synonym
Synd    syndicate
synth   synthetic
syr     syrup
syty    syrupy
syst    system

T       tank
T       target angle
T       technical
T       temperature
t or T  tertiary (as applied to type of organic compound
T       time
t       toluene (Fr & Ital)
t       ton, short (US) = 2000 lb = 907.18 kg = 0.8929 t
Ton     ton, long (Brit) = 2240 lb = 1016.05 kg
1.1023t=0.9842 t
SUM     metric ton = 1000 kg = 2204.62 lb =
T       torpedo
T       tracer
T       with tracer (Brit)
T       tri
T       tritium
T       trotil or tol (Rus) (TNT)
T       Troy (weight) (1 lb = 373.2418 g)
T       tubular propellant (Brit)
T       followed by a number (e.g., T28)
T       signifies an experimental unstandardized item
T       Fr sporting propellant
/T     with tracer (Brit)
T1 Fr & Ital for MNT
T2 Fr & Ital for DNT
T3 Fr & Ital for TNT
T4 Fr & Ital for RDX
Ta tantalum
TA triacetin
TAC Tables Annuelles Internationales de Constantes et Données Numériques (See in Abbreviations for Books and Journals)
TAC Technical Assistance Committee
TACAN Tactical Air Navigation Committee
TACC Tactical Air Control Center
TAM/DNLC Titanium Alloy Mfd., Div of National Lead Co.
Tan tangent
Tanayaku Jap RDX expls(see also Shouyaku)
Tanoyaku Jap expl countg RDX, TNT & tetryl
TAP time and percussion (fuze)
TAPPI Technical Association of the Pulp and Paper Industry
TATNB triaminotrinitrobenzene (classified)
TAX symbol for 1-acetylhexahydro-3,5-dinitro-s-triazine
TB Technical Bulletin
Tb terbium
TB tracer bullet
TBD torpedo-boat destroyer
Tbis Fr pistol propellant
TC Tennessee Corp, Atlanta, Ga
TC tracer composition
TCA Twin Cities Arsenal, Minneapolis, Minn.
TCC Thiokol Chemical Corp., Trenton, NJ and Elkton, Md (see also RMD/TCC)
TD tank destroyer
TD torpedo detonating
T-Day Termination of War Day
TDE Technical Development Establishment (India)
Te tellurium
tetra tetraazylazide
techn tech technical
Tech Technician(a specialist rating)

TEE Torpedo Experimental Establishment
TEG triethylene glycol
TEGDN or TEGN triethylene glycol dinitrate
TEGMN triethylene glycol mononitrate
tela tetraethyllead
telegram telephone
Sv Swiss dynamic
temp tetramethylammonium nitrate
temperature
Rus designation for PETN
tetranitroaniline
Tetrabenzyl tetrabenzylether
TETRAN tetrapropylthallium
TETN tetranitromethane
TETNMB tetranitromethylaniline
TETNT tetranitrotoluene
TETNTMB or 3, 5, 3', 5'-tetranitro-4, 4'-tetramethylamino diphenyl (see also Swed plastic perchlorate type, see the text)
tertiary
TETTeA tetraethyllead
TETTet tetraethyl
Tetracene guanin tetroxidogenometra
tetramethylammonium nitrate
Span for tetryl
tetramethyl ammonium nitrate
Tetra-4-tetryl tetra(2,4,6-trinitro)-phenyl-nitraminomethyl) methane
<table>
<thead>
<tr>
<th>Abbr 52</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tétréthyl</td>
</tr>
<tr>
<td>tetrg</td>
</tr>
<tr>
<td>tetrh</td>
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<tr>
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<td>unrotating projectiles (former Brit name for rockets)</td>
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| V     | "poudre V," original name of smokeless propellant invented by Vieille; the name was changed to "poudre B" in honor of Gen Boulanger, then Minister of War Veterans Administration Vickers-Armstrong (Brit concern manufg arms, ordnance and ships)
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<td>vinylacetylene polymer</td>
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<td>Volunteer Air Reserve</td>
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<td>vaseline (See also PG)</td>
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<td>variable bomb (guided bomb)</td>
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<td>code name for a fighting bomber plane of the Naval Air Service</td>
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<td>vapor density</td>
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<td>velocity of detonation</td>
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<td>Victory Day</td>
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<td>VDI</td>
<td>Verein Deutscher Ingenieure (Association of German Engineers)</td>
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<td>VDT</td>
<td>variable density tunnel (aerodynamics)</td>
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<td>volume in cc occupied by 1 kg of an expl at a given density (Fr)</td>
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<td>Fr ballistite (see the text)</td>
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<td>Vickers gun (automatic) (Brit)</td>
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<td>vintovochnaya granata (Rus) (rifle grenade)</td>
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<td>very high frequency (130 to 300 megacycles per second)</td>
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<td>Vincennite</td>
<td>poisonous mix used during WWI</td>
</tr>
<tr>
<td>viol</td>
<td>violet</td>
</tr>
<tr>
<td>VIP</td>
<td>very important person (eg, Vice President)</td>
</tr>
<tr>
<td>Vir or Va</td>
<td>Virginia</td>
</tr>
<tr>
<td>Viritie</td>
<td>Ital black powder type expl</td>
</tr>
<tr>
<td>visc</td>
<td>viscosity</td>
</tr>
<tr>
<td>Vixorite</td>
<td>Span expl (Resina explosiva)</td>
</tr>
<tr>
<td>viz</td>
<td>videlicet (Lat) (namely)</td>
</tr>
<tr>
<td>VLF</td>
<td>very low frequency (10 to 30 kilocycles per second)</td>
</tr>
<tr>
<td>V/m</td>
<td>volts per meter</td>
</tr>
<tr>
<td>VM</td>
<td>code name for the Marine Corps Aviation</td>
</tr>
<tr>
<td>VMG</td>
<td>Vickers machine gun</td>
</tr>
<tr>
<td>VNP</td>
<td>vinyl nitrate polymer</td>
</tr>
<tr>
<td>Vo</td>
<td>initial velocity</td>
</tr>
<tr>
<td>Vo</td>
<td>initial volume</td>
</tr>
<tr>
<td>VOA</td>
<td>Voice of America</td>
</tr>
<tr>
<td>VOC</td>
<td>Vickers Ordnance Co, England</td>
</tr>
<tr>
<td>Voc</td>
<td>vocabulary</td>
</tr>
<tr>
<td>volat</td>
<td>volume</td>
</tr>
<tr>
<td>volat</td>
<td>volatile, volatiles</td>
</tr>
<tr>
<td>volary</td>
<td>volatility</td>
</tr>
<tr>
<td>VOLS CAN</td>
<td>volume scanning (Radio system)</td>
</tr>
<tr>
<td>VOM</td>
<td>voltmeter</td>
</tr>
<tr>
<td>VOW</td>
<td>Volunteer Ordnance Works, Chattanooga, Tenn</td>
</tr>
<tr>
<td>VOP</td>
<td>Vice President</td>
</tr>
<tr>
<td>VP</td>
<td>Véry pistol ammunition</td>
</tr>
<tr>
<td>VPA</td>
<td>code name for the Navy Patrol bomber</td>
</tr>
<tr>
<td>VPB</td>
<td>Vickers plate hardness</td>
</tr>
<tr>
<td>VPH</td>
<td>Virginia Polytechnic Institute, Blacksburg, Va</td>
</tr>
<tr>
<td>VPI</td>
<td>code name for the patrol torpedo plane of the Naval Air Service versus</td>
</tr>
<tr>
<td>VPT</td>
<td>Vickers Sons &amp; Maxim Ltd, England</td>
</tr>
<tr>
<td>VS &amp; ML</td>
<td>very short waves</td>
</tr>
<tr>
<td>VSW</td>
<td>vacuum tube (radio)</td>
</tr>
<tr>
<td>VT</td>
<td>Vermont</td>
</tr>
</tbody>
</table>
Abbr 57

VTF variable time fuze(proximity fuze)WBNS Water Boiler Neutron Source (Reactor)
vv vice versa WC War Cabinet(Brit)
VV vzryvchatoiye veshchestvo(Rus) WC War College
VV(vexpl subst) w/c watt per candle
VX code name of an experimental WCC weapon carrier
plane of the Naval Air Service WC War Claims Commission
WCC War Crimes Commission
WC World Council of Churches
WCC Wyandotte Chemical Corp,
WC Wyandotte, Mich
WC War Cabinet Scientific Advisory
WC War College Committee(Brit)
W(Water Boiler Neutron Source) WC War Cabinet Science Committee
(War Committee)
WA War Department (now DA & DAF)
WA War College Western Defence Command
WAAC Western Electric
WAC or Wac Women's Army Corps(USA)
WADC Wright(Patterson)Air Development Center, Patterson
WAASC Women's Army Auxiliary
WAAF Women's Auxiliary Air Force
(WAAC) WhH White House, Washington,DC
W(AAF) WHOI Woods Hole Oceanographic
W(AASC) Institution,Mass
WAAC Women's Army Auxiliary WhP or WP white phosphorus
Service Corps(Brit) whr watt-hour(s)
WAAF Women's Auxiliary Air Force wh West Indies
(WAAS) wrg wrought iron
WAASC Women's Army Auxiliary WI Wash,V.A.
WAC Women's Army Corps(USA) WI Wash,Wisc
WADC Wright(Patterson) Air Development Center, Patterson WIT Washington Institute of
WAAS Women's Army Auxiliary Sciences
WACS Women's Army Auxiliary WhP or WP white phosphorus
WAC or Wac Women's Army Corps(USA) whr watt-hour(s)
WADC Wright(Patterson)Air Development Center, Patterson WI West Indies
WAF Women's Auxiliary Air Force(WAAS) wrg wrought iron
WADC Wright(Patterson) Air Development Center, Patterson WI Wash,Wisc
WADF Western Air Defence Force WIT Washington Institute of
WA Western Air Defence Force Technology
WAL Watertown Arsenal Laboratory Ger for synthetic toluene
Wallonites older Belg mining expls work
WAPD Westinghouse Atomic Power weekly
Division wk work
War Warws Warwickshire,Engl wkly weekly
WAS Washington Academy of Sciences
W Wash Washington
Wash, DC Washington, District of Columbia
Waves Women Accepted for Volunteer Emergency Service
Waves Women Accepted for Volunteer Emergency Service
WAC Women's Army Corps(USA) work
WADC Wright(Patterson) Air Development Center, Patterson working
WAF Women's Auxiliary Air Force weekly
W ADC Wright(Patterson) Air Development Center, Patterson wood meal
WAF Women's Auxiliary Air Force modified propellant mfd at
WADC Wright(Patterson) Air Development Center, Patterson Waltham
WAF Women's Auxiliary Air Force Werkzeugmaschinenfabrik
Waves Women Accepted for Volunteer Emergency Service Bührle & Co, Oerlikon-Zürich
(Waves Women Accepted for Volunteer Emergency Service (Switz)
Waves Women Accepted for Volunteer Emergency Service J.Wiley & Sons, New York 17
Waves Women Accepted for Volunteer Emergency Service Wisconsin
Waves Women Accepted for Volunteer Emergency Service Washington Institute of Technology
Waves Women Accepted for Volunteer Emergency Service Ger for synthetic toluene
Waves Women Accepted for Volunteer Emergency Service work
Waves Women Accepted for Volunteer Emergency Service working
Waves Women Accepted for Volunteer Emergency Service weekly
Waves Women Accepted for Volunteer Emergency Service wood meal
Waves Women Accepted for Volunteer Emergency Service modified propellant mfd at
Waves Women Accepted for Volunteer Emergency Service Waltham
Waves Women Accepted for Volunteer Emergency Service Werkzeugmaschinenfabrik
| Abbr 58 |
|-----------------|-------------------|------------------|-------------------|
| WO              | Warrant Officer   | WWI              | World War I       |
| wo              | without           | WWII             | World War II      |
| WOAS            | when on active service | Wyo             | Wyoming           |
| WOD             | Wingate Ordnance Depot, Gallup, NM | WyoUniv        | University of Wyoming, Laramie, Wyo |
| Worcs           | Worcestershire, Engl | wo               | without          |
| w or wo         | with or without   | WWII             | World War II      |
| WO/W            | without weapon    | WOAS when on active service | Wyo         |
| WP              | West Point (US Military Academy) | WOAS when on active service | Wyo         |
| WP or WhP       | white phosphorus  | WOAS when on active service | Wyo         |
| WP              | wood pulp         | WOAS when on active service | Wyo         |
| WP              | Würfelpulver(Ger cube or die shape propellant) | WOAS when on active service | Wyo         |
| WPAFB           | Wright-Patterson Air Force Base, Ohio | WOAS when on active service | Wyo         |
| WPB             | War Production Board | XB               | experimental      |
| WPC             | War Problems Committee | Xe               | explosive(such as RDX) |
| wpc             | watt per candle   | Xlil             | xenon             |
| wpfg            | waterproofing     | Xmas             | code name for the beginning of action(see also H-hour and Z-hour) |
| wpn(s)          | weapon(s)         | Xylite           | Jap unknown name expls(see the text) |
| WRAC            | Women's Royal Army Corps(Brit) | Y                | experimental bomber |
| WRAMA           | Warner-Robins Air Matériel Area | Y                | Xenon             |
| WRC             | War Resources Council | Y                | Rus for TNX       |
| WRD/ES          | Woolwich Research Dept/ Explosives Section, England | Y                | Fr for TNX        |
| WRE             | Weapons Research Establishment(Australia) | Y                |                  |
| WRNS            | Women's Royal Naval Service (Brit) | Y                |                  |
| WROW            | Wabash River Ordnance Works, Newport, Ind | Y                |                  |
| WS              | Wireless Station  | Yld              |                  |
| WSEG            | Weapons System Evaluation Group | YMCA            |                  |
| WSMR            | White Sands Missile Range, Las Cruces, NM (formerly WSPG) | Yb               |                  |
| WSOW            | Weldon Springs Ordnance Works, Mo | Yd               |                  |
| WSPG            | White Sands Proving Ground, Las Cruces, NM (now WSMR) | Yel              |                  |
| WSS             | War Savings Stamp  | Y- gun           |                  |
| WT              | War tax           | Y-intercept      |                  |
| WT              | weapon training   | Y-y or YY        |                  |
| wt              | weight            |                  |                  |
| WT Inc          | Wallace & Tiernan Inc, Buffalo, NY (See also LDWTI) | Z                |                  |
| WU              | Western Union     | Z                |                  |
| WUDO            | Western Union Defence Organization | Z                |                  |
| WUTC            | Western Union Telegraph Co | ZA               |                  |
| WV              | Women's Volunteers | ZAB              |                  |
| WVa or WV       | West Virginia     | Zac              |                  |
| WVOW            | West Virginia Ordnance Works, Pt Pleasant, WVa | Zar              |                  |
| W/W             | with weapons      |                  |                  |
SUPPLEMENT TO ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>atomic, bacteriological, chemical (warfare)</td>
</tr>
<tr>
<td>ack-ack</td>
<td>antiaircraft (originated among Brit signalmen)</td>
</tr>
<tr>
<td>Acrolein</td>
<td>Fr CWA of WWI, desgn Papite</td>
</tr>
<tr>
<td>Adamsite</td>
<td>Brit design for diphenylaminochloroarsine (CWA)</td>
</tr>
<tr>
<td>ADCC</td>
<td>Air Defence Control Center</td>
</tr>
<tr>
<td>ADF</td>
<td>auxiliary detonating fuze</td>
</tr>
<tr>
<td>ADGB</td>
<td>Air Defence of Great Britain</td>
</tr>
<tr>
<td>ADRDE</td>
<td>Air Defence Research and Development Establishment (Brit)</td>
</tr>
<tr>
<td>AFF</td>
<td>Army Field Forces</td>
</tr>
<tr>
<td>AFR</td>
<td>after flame ratio</td>
</tr>
<tr>
<td>AFSC</td>
<td>Armed Forces Staff College, Norfolk, Va.</td>
</tr>
<tr>
<td>AIR</td>
<td>air-arming impact rocket</td>
</tr>
<tr>
<td>Ala</td>
<td>Alabama</td>
</tr>
<tr>
<td>Alas</td>
<td>Alaska</td>
</tr>
<tr>
<td>ALBM</td>
<td>air-launched ballistic missile</td>
</tr>
<tr>
<td>AMSCE</td>
<td>Army Map Service, Corps of Engineers, Washington, DC</td>
</tr>
<tr>
<td>ANPD/GE</td>
<td>Aircraft Nuclear Propulsion Department, General Electric</td>
</tr>
<tr>
<td>AOMC</td>
<td>Army Ordnance Missile Command</td>
</tr>
<tr>
<td>AOTS</td>
<td>Aviation Ordnance Test Station, Chincoteague, Va.</td>
</tr>
<tr>
<td>APC-BT</td>
<td>armor-piercing capped, ballistic cap</td>
</tr>
<tr>
<td>APCC</td>
<td>Americal Potash &amp; Chemical Corporation</td>
</tr>
<tr>
<td>AR</td>
<td>Atomic Products Division</td>
</tr>
<tr>
<td>APD</td>
<td>armor-piercing, discarding sabot</td>
</tr>
<tr>
<td>APDS</td>
<td>Fr desgn for chloropicrin (CWA)</td>
</tr>
<tr>
<td>Aquate</td>
<td>aircraft rocket</td>
</tr>
<tr>
<td>ARDC/BMD</td>
<td>Air Research and Development Command, Ballistic Missile Division, Palo Alto, Calif</td>
</tr>
<tr>
<td>ARL</td>
<td>aircraft rocket launcher</td>
</tr>
<tr>
<td>ARPA</td>
<td>Advanced Research Projects Agency</td>
</tr>
<tr>
<td>ART</td>
<td>Army Research Task</td>
</tr>
<tr>
<td>ART</td>
<td>automatic range tracking</td>
</tr>
<tr>
<td>ARTS</td>
<td>Army Research Task Summary</td>
</tr>
<tr>
<td>ASAES</td>
<td>Army Small Arms Experimental Station</td>
</tr>
<tr>
<td>A-Stoff</td>
<td>Ger desgn for chloroacetone (CWA)</td>
</tr>
<tr>
<td>ATAR</td>
<td>antitank aircraft rocket</td>
</tr>
<tr>
<td>ATTRAN</td>
<td>automatic terrain recognition and navigation (system)</td>
</tr>
<tr>
<td>AUW</td>
<td>air-to-underwater</td>
</tr>
<tr>
<td>AW</td>
<td>above water (Brit)</td>
</tr>
</tbody>
</table>

References:
1) British Standards Institution, "Chemical Symbols and British Standard No 813," London (1938)  
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10) Ditto, SR No 320-5-5 (1953)  
11) Ditto, SR No 320-80-1 (1953)  
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18) V. M. Businov & V. P. Savelov, "Anglo-Russki Artilleriiskii Slovar', Voyenizdat, Moscow (1959)  
20) Henry Voos, & H. M. Nechi, PicArsn; private communication (1960)
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<tr>
<th>Abbr 60</th>
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</thead>
<tbody>
<tr>
<td><strong>BA</strong></td>
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<tr>
<td><strong>BAR</strong></td>
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<tr>
<td><strong>BASF</strong></td>
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<tr>
<td><strong>BDF</strong></td>
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<tr>
<td><strong>BENELUX or</strong></td>
</tr>
<tr>
<td>Benelux</td>
</tr>
<tr>
<td><strong>BER</strong></td>
</tr>
<tr>
<td><strong>Berthollite</strong></td>
</tr>
<tr>
<td><strong>BFP</strong></td>
</tr>
<tr>
<td><strong>Bibi</strong></td>
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<tr>
<td><strong>Blaukreuz</strong></td>
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<tr>
<td><strong>BLC</strong></td>
</tr>
<tr>
<td><strong>BLC</strong></td>
</tr>
<tr>
<td><strong>BL&amp;P</strong></td>
</tr>
<tr>
<td><strong>BL&amp;T</strong></td>
</tr>
<tr>
<td><strong>Bn</strong></td>
</tr>
<tr>
<td><strong>BNW or BuWeps</strong></td>
</tr>
<tr>
<td><strong>Bretonite</strong></td>
</tr>
<tr>
<td><strong>BRLI</strong></td>
</tr>
<tr>
<td><strong>B-Stoff</strong></td>
</tr>
<tr>
<td><strong>BuAer</strong></td>
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<tr>
<td><strong>Buntkreuz-schiessen</strong></td>
</tr>
<tr>
<td><strong>BuOrd</strong></td>
</tr>
<tr>
<td><strong>Burrowite</strong></td>
</tr>
<tr>
<td><strong>BuWeps</strong></td>
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</tbody>
</table>

**C**

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<tbody>
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<td></td>
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<tr>
<td><strong>CA</strong></td>
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<tr>
<td><strong>Camite</strong></td>
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<tr>
<td><strong>Campiellite</strong></td>
</tr>
<tr>
<td><strong>CB</strong></td>
</tr>
<tr>
<td><strong>CCIA</strong></td>
</tr>
<tr>
<td><strong>CDA</strong></td>
</tr>
</tbody>
</table>

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**Acronyms**

- **CERCHAR**: Centre d'Études et de Recherches des Charbonnages, Verneuil, France
- **CF**: center fire (Brit)
- **CGM**: Committee on Guided Missiles (US)
- **CIC**: Combat Information Center
- **Cici**: Fr design for dichloromethylether (CWA)
- **CK**: symbol for cyanogen chloride (CWA)
- **Clark I**: Ger design for biphenylchloroarsine (CWA)
- **Clark II**: Ger design for biphenylylcyanoarsine (CWA)
- **CN**: US design for chloroacetophenone (tear gas) (CWA)
- **CNC**: symbol for chloroacetophenone in chloroform
- **Collongite**: Fr design for phosgene and diphosgene (CWA)
- **COMP**: Charlotte Ordnance Missile Plant, Charlotte, NC
- **C-Stoff**: Ger CWA of WWI, dimethylsulfate 75 & methylchlorosulfonate 25%
- **CWLR**: Chemical Warfare Laboratories Reports
- **Cyclite**: Ger design for mixt of tech methyl- & ethylcyanoformates with ca 10% of esters of chloroformic acid (CWA)
- **DA**: US design for biphenylylchloroarsine (CWA)
- **DAG**: Dynamit Aktiengesellschaft, Germany
- **DC**: symbol for biphenylylcyanoarsine (CWA)
- **DEFA**: Direction et Études des Fabrications d’Armement (Fr)
- **DI**: dark ignition
- **Dick**: Ger design for ethyldichloroarsine (CWA)
- **Diphosgene**: symbol for perchloromethylformate (CWA)
Abbr 61

dk
deka = 10

DM
US design for Adamsite (diphenylaminochloroarsine) (CWA)

DME/RD
Directorate of Materials and Explosives, Research and Development (Brit)

DMIC
Defense Metals Information Center, Battelle Memorial Institute, Columbus, Ohio

DN
Department of the Navy

DO
dissolved oxygen

DOD
Department of Defense (US)

DP
symbol for diphosgene (trichloromethylchloroformate) (CWA)

DR
direction ranging

DR
distant range

DRE
Defense Research and Engineering

DRL
Defense Research Laboratory

DSFS
discarding sabot fin stabilized (projectile)

D-Stoff
German design for phosgene and diphosgene (CWA)

DT
day tracer (Brit)

DWM
Deutche Waffen- und Munitionsfabriken, Germany

ED
US design for Ger CWA "Dick" (ethyldichloroarsine)

EDS
Explosives Development Section, PicArsn, Dover, NJ

EI
Experiments Incorporated (US)

elec
electricity

EOD
Explosive Ordnance Disposal

EODS-NPP
Explosive Ordnance Disposal Service - Naval Propellant Plant

Erlen fl
Erlenmeyer flask

E-Stoff
German design for cyanogen bromide (CWA)

EW
Electronic Warfare

FFAR
folding fin aircraft rocket

FG
fine grain (Brit)

FM
fulminate of mercury (see MF)

FOCOL
field of fire, observation cover & concealment, obstacles, lines of communication

Forestite or Vincennite
Fr designs for hydrocyanic acid (CWA)

FOURA
forward observation unit, Royal Artillery (Brit)

FP
flashless propellant

FPC
Fire Prevention Code

FQ
quick fuze

FR
flash ranging

Fraissite
fr design for benzylidioide (CWA)

FS
flash spotting

FS
forged steel (Brit)

F-Stoff
Ger design for TiCl4, smoke-producing agent of WWI

G
giga = 10^9

gsymbol for ethylyphosphorodimethylamidocyanate or Tabun (see PATR 2510, p Ger 204, under Trilons) (CWA)

See KUD-1

guided air-to-surface missile

green star, blinker, parachute (US)

symbol for isopropylmethylphosphonofluoridate or Soman (see PATR 2510, p Ger 204, under Trilons) (CWA)

glide bomb (see the text)

symbol for pinacolylmethylphosphonofluoridate or Soman (see PATR 2510, p Ger 204, under Trilons) (CWA)

Gun design for Mustard Gas and for some other CWA's (see Yellow Cross Ammunition in the text)

gunfire

Gardner-Gatling (Brit)

gyro gunsight

10^9

guided missile countermeasure

Government owned, contractor operated

Government owned, government operated

code name for air-to-air missile with turbojet engine

Gopher Ordnance Works, Rosemont, Minnesota

Ger design for some CWA's (See Green Cross Ammunition in the text)

green-yellow, double star (US)

H
hecto = 10^2
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HA</td>
<td>high angle (Brit)</td>
</tr>
<tr>
<td>HAPO</td>
<td>Hanford Atomic Products Operation</td>
</tr>
<tr>
<td>HC</td>
<td>US design for smoke-producing agent of WWI: ( \text{Zn} + \text{ZnCl}_2 + \text{ZnO} )</td>
</tr>
<tr>
<td>HEF</td>
<td>high energy fuel</td>
</tr>
<tr>
<td>HEL</td>
<td>high-explosive, light (shell)</td>
</tr>
<tr>
<td>HEL</td>
<td>Human Engineering Laboratory, Aberdeen PG, MD</td>
</tr>
<tr>
<td>HES</td>
<td>high-explosive, smoke (shell) design for Mustard Gas-Lewisite mixt (CWA)</td>
</tr>
<tr>
<td>HN</td>
<td>design for nitrogen Mustard Gas (CWA) Homomartonite</td>
</tr>
<tr>
<td>HOP</td>
<td>Hoosier Ordnance Plant, Indiana Arsenal, Charleston, Ind</td>
</tr>
<tr>
<td>HT</td>
<td>symbol for &quot;Mustard Gas-Agent T&quot; (CWA)</td>
</tr>
<tr>
<td>HumRRO</td>
<td>Human Resources Research Office</td>
</tr>
<tr>
<td>HVAPDSFS</td>
<td>hypervelocity armor-piercing, discarding sabot, fin stabilized (projectile)</td>
</tr>
<tr>
<td>HVTP-T</td>
<td>hypervelocity, target practice, tracer warhead contg a nuclear fusion device</td>
</tr>
<tr>
<td>I</td>
<td></td>
</tr>
<tr>
<td>IED</td>
<td>Industrial Engineering Division (changed to IMED), PicArsn, Dover, NJ</td>
</tr>
<tr>
<td>IGFarbenind</td>
<td>Interessengemeinschaft Farbenindustries, Germany</td>
</tr>
<tr>
<td>IM</td>
<td>insoluble matter</td>
</tr>
<tr>
<td>IMED</td>
<td>Industrial Maintenance and Engineering Division, PicArsn, Dover, NJ</td>
</tr>
<tr>
<td>INS</td>
<td>International Notational System</td>
</tr>
<tr>
<td>invest</td>
<td>to investigate</td>
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<td>investd</td>
<td>investigated</td>
</tr>
<tr>
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<td>investigating</td>
</tr>
<tr>
<td>investn</td>
<td>investigation</td>
</tr>
<tr>
<td>IRFNA</td>
<td>inhibited red fuming nitric acid</td>
</tr>
<tr>
<td>IV</td>
<td>initial velocity</td>
</tr>
<tr>
<td>J</td>
<td></td>
</tr>
<tr>
<td>JANMB</td>
<td>Joint Army-Navy Munition Board</td>
</tr>
<tr>
<td>JB-2</td>
<td>an Amer version of the Ger V-1 (see PATR 2510, p 213) (called also Loon)</td>
</tr>
<tr>
<td>JCS</td>
<td>Joint Chiefs of Staff</td>
</tr>
<tr>
<td>K</td>
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</tr>
<tr>
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</tr>
<tr>
<td>L</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Lewisite (CWA)</td>
</tr>
<tr>
<td>LA</td>
<td>light artillery</td>
</tr>
<tr>
<td>Lacritite</td>
<td>Fr design for thiophosgene (CWA) launcher</td>
</tr>
<tr>
<td>Lchr</td>
<td>low energy detonating cord</td>
</tr>
<tr>
<td>LEDC</td>
<td>lower explosion limit</td>
</tr>
<tr>
<td>LEL</td>
<td>US design for vinylchloroarsine</td>
</tr>
<tr>
<td>Lewisite</td>
<td>large grain (Brit)</td>
</tr>
<tr>
<td>LG</td>
<td>Lee-Metford (Rifle) (Brit)</td>
</tr>
<tr>
<td>LM</td>
<td>lead mononitroresorcinate</td>
</tr>
<tr>
<td>LMR</td>
<td>light machine rifle</td>
</tr>
<tr>
<td>Loon</td>
<td>see JB-2</td>
</tr>
<tr>
<td>Loss or</td>
<td>Ger designs for Mustard Gas (CWA) Gelbkreuz</td>
</tr>
<tr>
<td>IMED</td>
<td>Industrial Maintenance and Engineering Division, PicArsn, Dover, NJ</td>
</tr>
<tr>
<td>INS</td>
<td>International Notational System</td>
</tr>
<tr>
<td>invest</td>
<td>to investigate</td>
</tr>
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<td>investd</td>
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<td>investn</td>
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</tr>
<tr>
<td>IRFNA</td>
<td>inhibited red fuming nitric acid</td>
</tr>
<tr>
<td>IV</td>
<td>initial velocity</td>
</tr>
<tr>
<td>J</td>
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<td>JANMB</td>
<td>Joint Army-Navy Munition Board</td>
</tr>
<tr>
<td>JB-2</td>
<td>an Amer version of the Ger V-1 (see PATR 2510, p 213) (called also Loon)</td>
</tr>
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<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>M-day</td>
<td>the day on which mobilization shall begin</td>
</tr>
<tr>
<td>MDF</td>
<td>mild detonating fuze</td>
</tr>
<tr>
<td>MDS</td>
<td>modified strip cordite</td>
</tr>
<tr>
<td>MDT</td>
<td>modified tubular cordite</td>
</tr>
<tr>
<td>ME</td>
<td>Martini-Enfield (rifle) (Brit)</td>
</tr>
<tr>
<td>MED</td>
<td>Materials Explosives Division (Brit)</td>
</tr>
<tr>
<td>NPGS</td>
<td>Naval Post Graduate School, Monterey, Calif</td>
</tr>
<tr>
<td>NQ</td>
<td>nitroguanidine flashless (propellant) (Brit)</td>
</tr>
<tr>
<td>Nr</td>
<td>Ger abbreviation for Nummer (number)</td>
</tr>
<tr>
<td>NS</td>
<td>Naval Service (Brit) (see also /N)</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>NT</td>
<td>night tracer (Brit)</td>
</tr>
<tr>
<td>NTM</td>
<td>Naval Torpedo Station, Newport, RI</td>
</tr>
<tr>
<td>NWL</td>
<td>Naval Weapons Laboratory, Dahlgren, Va</td>
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<tr>
<td>M</td>
<td>Martini-Enfield (rifle) (Brit)</td>
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<tr>
<td>m</td>
<td>measurement</td>
</tr>
<tr>
<td>MD</td>
<td>modified strip cordite (propellant) (Brit)</td>
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<tr>
<td>MN</td>
<td>modified tubular cordite</td>
</tr>
<tr>
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<td>modified strip cordite</td>
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<tbody>
<tr>
<td>MISUM</td>
<td>Monthly Intelligence Summary</td>
</tr>
<tr>
<td>ML</td>
<td>metal lined (Brit)</td>
</tr>
<tr>
<td>MLD</td>
<td>minimum lethal dose (toxicity)</td>
</tr>
<tr>
<td>MLE</td>
<td>magazine Lee-Enfield (rifle) (Brit)</td>
</tr>
<tr>
<td>MLE</td>
<td>Modèle (Fr for Model)</td>
</tr>
<tr>
<td>MLM</td>
<td>magazine Lee-Metford (rifle) (Brit)</td>
</tr>
<tr>
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<tr>
<td>MRLG</td>
<td>muzzle-loading rifled gun</td>
</tr>
<tr>
<td>MRC</td>
<td>Mathematics Research Center, US Army, Univ of Wisconsin</td>
</tr>
<tr>
<td>MTF</td>
<td>mechanical time fuze</td>
</tr>
<tr>
<td>Mustard Gas</td>
<td>Brit design for dichlorodicycloarsine (CWA) (See also Yperite)</td>
</tr>
<tr>
<td>MWDD</td>
<td>Miscellaneous Weapons Development Department (Brit)</td>
</tr>
<tr>
<td>MLRG</td>
<td>muzzle-loading rifled gun</td>
</tr>
<tr>
<td>MRC</td>
<td>Mathematics Research Center, US Army, Univ of Wisconsin</td>
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<td>MTF</td>
<td>mechanical time fuze</td>
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<tr>
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<tr>
<td>OARP</td>
<td>Office of Advanced Research Programs, Washington, DC</td>
</tr>
<tr>
<td>OASD</td>
<td>Office of Assistant Secretary of Defense</td>
</tr>
<tr>
<td>T</td>
<td>Office of Aeronautical and Space Research (now OARP)</td>
</tr>
<tr>
<td>OC</td>
<td>Ordnance Corps</td>
</tr>
<tr>
<td>OEHO</td>
<td>Ordnance Engineering Handbook Office, Duke Univ, Durham, NC</td>
</tr>
<tr>
<td>OMRO</td>
<td>Ordnance Material Research Office</td>
</tr>
<tr>
<td>OMTF</td>
<td>Ordnance Missile Test Facility, White Sands, NM</td>
</tr>
<tr>
<td>ONI</td>
<td>Office of Naval Intelligence</td>
</tr>
<tr>
<td>Opacite</td>
<td>Fr design for SnCl₄, smoke-producing agent of WWI</td>
</tr>
<tr>
<td>ORD</td>
<td>Ordnance Technical Committee Minutes</td>
</tr>
<tr>
<td>OSFD</td>
<td>Office of Space Flight Development (now OSFP)</td>
</tr>
<tr>
<td>OSFP</td>
<td>Office of Space Flight Programs, Washington, DC (superseding OSFD)</td>
</tr>
<tr>
<td>OT</td>
<td>ordinary temperature</td>
</tr>
<tr>
<td>OTCM</td>
<td>Ordnance Technical Committee Minutes</td>
</tr>
<tr>
<td>OTIO</td>
<td>Ordnance Technical Intelligence Office</td>
</tr>
<tr>
<td>OTIS</td>
<td>Ordnance Technical Intelligence Service (Aberdeen Proving Ground, Md)</td>
</tr>
<tr>
<td>OvF</td>
<td>Overhead fire</td>
</tr>
<tr>
<td>OZTC(HA)</td>
<td>Organization and Training Center (Heavy Artillery) (US)</td>
</tr>
<tr>
<td>P</td>
<td>pilotless aircraft</td>
</tr>
<tr>
<td>PANAGRA</td>
<td>Pan-American-Grace Airways</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>Papite</td>
<td>Fr design for acrolein used in WWI as a lachrymator</td>
</tr>
<tr>
<td>PBAA</td>
<td>polybutadiene acrylic acid (used in some Thiokol propellants)</td>
</tr>
<tr>
<td>PD</td>
<td>symbol for phenyldichloroarsine (CWA)</td>
</tr>
<tr>
<td>Per</td>
<td>Ger design for trichloromethyl-chloroformate (CWA)</td>
</tr>
<tr>
<td>Phosgene</td>
<td>design for carbonyl chloride, COCl₂ (CWA)</td>
</tr>
<tr>
<td>pico</td>
<td>10⁻¹² meter = micromicron</td>
</tr>
<tr>
<td>PIR</td>
<td>pressure-arming impact rocket pack howitzer</td>
</tr>
<tr>
<td>Pkt How</td>
<td>platelets</td>
</tr>
<tr>
<td>pts</td>
<td>a mixture of pebble and fine grain propellants (Brit)</td>
</tr>
<tr>
<td>P(Mixture)</td>
<td>percussion nose</td>
</tr>
<tr>
<td>posn</td>
<td>percussion tube (Brit)</td>
</tr>
<tr>
<td>PPCo</td>
<td>Pacific Powder Company, Tenino, Wash</td>
</tr>
<tr>
<td>prpnt or proplnt</td>
<td>propellant</td>
</tr>
<tr>
<td>PS</td>
<td>US design for chloropicrin (CWA)</td>
</tr>
<tr>
<td>PT</td>
<td>Percussion tube (Brit)</td>
</tr>
<tr>
<td>Q</td>
<td>chemical agent of specialized application</td>
</tr>
<tr>
<td>QB or qb</td>
<td>quick burning (propellant)</td>
</tr>
<tr>
<td>QFC</td>
<td>quick firing converted (Brit)</td>
</tr>
<tr>
<td>RAD</td>
<td>radiation absorbed dose (a unit of absorbed dose of ionizing radiation)</td>
</tr>
<tr>
<td>RAT</td>
<td>rocket-assisted torpedo</td>
</tr>
<tr>
<td>Rationite</td>
<td>Fr design for smoke-producing mixt of WWI: chlorosulfonic acid &amp; dimethylsulfate</td>
</tr>
<tr>
<td>RBLG</td>
<td>rifled breech-loading gun</td>
</tr>
<tr>
<td>RC</td>
<td>reduced charge (ammunition)</td>
</tr>
<tr>
<td>RD 38</td>
<td>a system of interior ballistics used by the Brit</td>
</tr>
<tr>
<td>RDF</td>
<td>radio direction finder requirement</td>
</tr>
<tr>
<td>reqt</td>
<td>rye flour</td>
</tr>
<tr>
<td>RF</td>
<td>Royal Gun Factory (Brit)</td>
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<tr>
<td>RGF</td>
<td>Royal Gunpowder Factory (Brit)</td>
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<tr>
<td>RGPLF</td>
<td>Royal Laboratory (Brit)</td>
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<tr>
<td>RITF</td>
<td>Royal Navy Torpedo Factory (Brit)</td>
</tr>
<tr>
<td>ROD</td>
<td>Rochester Ordnance District is now absorbed into NYOD</td>
</tr>
<tr>
<td>ROD</td>
<td>Rossford Ordnance Depot, Toledo, Ohio</td>
</tr>
<tr>
<td>RPE</td>
<td>Rocket Propulsion Establishment (Brit)</td>
</tr>
<tr>
<td>RR</td>
<td>recoiless rifle</td>
</tr>
<tr>
<td>RSAF</td>
<td>Royal Small Arms Factory</td>
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<tr>
<td>S</td>
<td>Brit smoke-producing agent of WWI: K nitrate 45, pitch 30, sulfur 12, borax 9 &amp; glue 4%</td>
</tr>
<tr>
<td>S20</td>
<td>an Ital expl (see the text)</td>
</tr>
<tr>
<td>SAE</td>
<td>Society of Automotive Engineer</td>
</tr>
<tr>
<td>S&amp;W</td>
<td>Smith &amp; Wesson (revolver)</td>
</tr>
<tr>
<td>SC</td>
<td>solid case (Brit)</td>
</tr>
<tr>
<td>SCAR</td>
<td>solventless cordite (Brit)</td>
</tr>
<tr>
<td>SCEL</td>
<td>subcaliber aircraft rocket Signal Corps Engineering Laboratory</td>
</tr>
<tr>
<td>SD</td>
<td>short delay</td>
</tr>
<tr>
<td>SDT</td>
<td>self-destroying tracer</td>
</tr>
<tr>
<td>SEM</td>
<td>Station d'Essais de Montluçon (Fr)</td>
</tr>
<tr>
<td>SFG</td>
<td>sulfurless fine grain (powder) (Brit)</td>
</tr>
<tr>
<td>SID</td>
<td>Scientific Intelligence Digest</td>
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<tr>
<td>SK</td>
<td>Brit &amp; US design for ethyliodoacetate (CWA)</td>
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<tr>
<td>SLOP</td>
<td>St Louis Ordnance Plant, St Louis, Mo smokeless</td>
</tr>
<tr>
<td>smkls</td>
<td>short model Lee-Enfield (rifle) (Brit)</td>
</tr>
<tr>
<td>SMLE</td>
<td>School of Mine Warfare, Yorktown, Va</td>
</tr>
<tr>
<td>SMW</td>
<td>self-propelled caterpillar gun mount</td>
</tr>
<tr>
<td>SSR</td>
<td>spin-stabilized rocket</td>
</tr>
<tr>
<td>STRAC</td>
<td>Strategic Army Corps</td>
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<td>Sulvanite</td>
<td>Fr design for ethylchlorosulfonate and for bromine (CWA)</td>
</tr>
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<td>Surpalite</td>
<td>Fr design for trichloromethylchloroformate (CWA)</td>
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<td>SWAC</td>
<td>Special Weapons Ammunition Command</td>
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<td>Special Weapons Center</td>
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<tr>
<td><strong>Abbr</strong> 65</td>
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<td>Tera = (10^{12})</td>
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</tr>
<tr>
<td>TA</td>
<td>tractor-drawn artillery</td>
</tr>
<tr>
<td>TCBM</td>
<td>transcontinental ballistic missile</td>
</tr>
<tr>
<td>Thera</td>
<td>symbol for incendiary CWA &quot;thermate&quot;</td>
</tr>
<tr>
<td>TH1</td>
<td>symbol for specific composition of CWA &quot;thermate&quot;</td>
</tr>
<tr>
<td>TH2</td>
<td>symbol for specific component of CWA &quot;thermate&quot;</td>
</tr>
<tr>
<td>TH3</td>
<td>specific component of chemical agent &quot;thermate&quot;</td>
</tr>
<tr>
<td>TJ</td>
<td>turbojet</td>
</tr>
<tr>
<td>TML</td>
<td>tetramethyl lead</td>
</tr>
<tr>
<td>TNTBP</td>
<td>mix of TNT with black powder</td>
</tr>
<tr>
<td>Tonite</td>
<td>Fr design for chloroacetone (CWA)</td>
</tr>
<tr>
<td>TOP</td>
<td>total obscuring power (area in sq ft covered by the smoke produced by 1 lb of material)</td>
</tr>
<tr>
<td>T-Stoff</td>
<td>Ger design for xylylbromide (CWA)</td>
</tr>
<tr>
<td><strong>U</strong></td>
<td></td>
</tr>
<tr>
<td>UERD</td>
<td>Underwater Explosions Research Division, Norfolk Naval Shipyard</td>
</tr>
<tr>
<td>UOS</td>
<td>Underwater Ordnance Station, Newport, RI</td>
</tr>
<tr>
<td>USAOMC</td>
<td>United States Army Ordnance Missile Command, Redstone Arsenal, Alabama</td>
</tr>
<tr>
<td><strong>Note:</strong> Subordinate units included ABMA, ARGMA and WSMR</td>
<td></td>
</tr>
<tr>
<td><strong>V</strong></td>
<td></td>
</tr>
<tr>
<td>VAR</td>
<td>vertical aircraft rocket</td>
</tr>
<tr>
<td>VGFAG</td>
<td>Vereinigte Glanzstoff-Fabriken Aktiengesellschaft</td>
</tr>
<tr>
<td><strong>W</strong></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>chemical agent</td>
</tr>
<tr>
<td>WAAC</td>
<td>Woolwich Arsenal</td>
</tr>
<tr>
<td>WASAG</td>
<td>Westfälisch-Anhaltische Sprengstoff Aktiengesellschaft, Germany</td>
</tr>
<tr>
<td>WB</td>
<td>white star, blinker, parachute</td>
</tr>
<tr>
<td>WF</td>
<td>wheat flour</td>
</tr>
<tr>
<td>WhF</td>
<td>white star cluster</td>
</tr>
<tr>
<td>WSC</td>
<td>white star-parachute</td>
</tr>
<tr>
<td><strong>Y</strong></td>
<td></td>
</tr>
<tr>
<td>Yperite</td>
<td>Fr design for dichlorodiethyl-sulfide (CWA); Brit design Mustard Gas; US design HS and Ger designs Lost or Gelbkreuz</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS FOR BOOKS AND PERIODICALS USED AS REFERENCES IN THIS WORK

(Abbreviations not included in this list are the same as used by the American Chemical Society in Chemical Abstracts) (See also supplement to this list, pp 75-6)

**Note:** When the name of a journal was changed, the words, "changed to," "formerly," "now," etc are followed here not by the full name of the journal but by the abbreviation used in this dictionary. This is done because the journals are arranged alphabetically according to their abbreviations and not according to the full names of the journals.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFChJ</td>
<td>Armed Forces Chemical Journal (Washington, DC)</td>
</tr>
<tr>
<td>AHThCatalog</td>
<td>Arthur H. Thomas' Catalog of Apparatus and Reagents, Philadelphia (1950)</td>
</tr>
<tr>
<td>AIChE</td>
<td>American Institute of Chemical Engineers (Journal published beginning 1955)</td>
</tr>
<tr>
<td>All&amp;EnExpls(1946)</td>
<td>APG, &quot;Allied and Enemy Explosives,&quot; Aberdeen, Md (1946)</td>
</tr>
<tr>
<td>AmChemJ</td>
<td>American Chemical Journal (discontinued in 1913)</td>
</tr>
<tr>
<td>AmJPhys</td>
<td>American Journal of Physics</td>
</tr>
<tr>
<td>Anal</td>
<td>Analyst (Cambridge, England)</td>
</tr>
<tr>
<td>AnalChem</td>
<td>Analytical Chemistry (formerly IEC, Anal Ed)</td>
</tr>
<tr>
<td>AnalChimActa</td>
<td>Analytica Chimica Acta (Amsterdam)</td>
</tr>
<tr>
<td>AngChem</td>
<td>Angewandte Chemie, formerly Zeitschrift für Angewandte Chemie (Berlin)</td>
</tr>
<tr>
<td>Ann</td>
<td>Annalen der Chemie (Justus Liebig's)</td>
</tr>
<tr>
<td>AnnActas</td>
<td>Annales de l'Association Canadienne-Française pour l'Avancement des Sciences (Montreal)</td>
</tr>
<tr>
<td>AnnChim(Rome)</td>
<td>Annali di Chimica (Rome), formerly AnnChimAppl</td>
</tr>
<tr>
<td>AnnChimAnal</td>
<td>Annales de Chimie Analytique, Paris</td>
</tr>
<tr>
<td>AnnChimAppl</td>
<td>Annali di Chimica Applicata (Rome), now AnnChim(Rome)</td>
</tr>
<tr>
<td>AnnChimPhys</td>
<td>Annales de Chimie et de Physique (Paris), now AnnChim</td>
</tr>
<tr>
<td>AnnPhys</td>
<td>Annales de Physique, Paris</td>
</tr>
<tr>
<td>AnnPhysik</td>
<td>Annalen der Physik, Leipzig</td>
</tr>
<tr>
<td>APG</td>
<td>Aberdeen Proving Ground, Maryland</td>
</tr>
<tr>
<td>ArchParm</td>
<td>Archiv der Pharmazie (Berlin) (suspended in 1944 and resumed in 1950)</td>
</tr>
</tbody>
</table>
Abbr 68

C&EN  Chemical and Engineering News
Chem  Chemist (New York)
ChemAge  Chemical Age (London)
ChemAnal  Chemist Analyst (Phillipsburg, New Jersey)
ChemBer  Chemische Berichte (supersedes Ber)
ChemEngrg  Chemical Engineering, formerly Chem & MetEngrg
ChemEngrgProgr  Chemical Engineering Progress (New York)
Chem&Ind  Chemistry and Industry (London), published together with JSCI, but is now separated
ChemInd  Chemical Industries, changed to ChemIndWeek, on Jan 20, 1951
ChemIndWeek  Chemical Industries Week, changed to ChemWeek on June 2, 1951
ChemMetEngrg  Chemical and Metallurgical Engineering, now ChemEngrg
ChemN  Chemical News and Journal of Industrial Science
ChemObzor  Chemiky Obzor (Chemical Review, Prague) (now ChemPrumysl)
ChemPrumysl  Chemicky Prumysl (Prague)
ChemRevs  Chemical Reviews (Baltimore, Md)
ChemRubHdb  Chemical Rubber Publishing Co, Handbook of Chemistry & Physics, Cleveland, Ohio, 38th ed (1956-7)
ChemWbl  Chemisch Weekblad (Amsterdam)
ChemWeek  Chemical Week (formerly ChemIndWeek)
ChemZtg  Chemiker Zeitung (Kothen, Anhalt). In Jan 1951 the name was changed to "Chemiker Zeitung ehemals Kothen" (Stuttgart) and in Jan 1954 to "Chemiker Zeitung mit Chemische Apparatur und Chemie-Börse" (Heidelberg)
ChemZtr  Chemisches Zentralblatt (Berlin)
Chim&Ind(Paris)  Chimie et Industrie (Paris)
Chim e Ind(Milan)  Chimica e l'Industria (Milan)
C IOS Rept  Combined Intelligence Objectives Sub-Committee Report
Colver(1918)  E. de W. Colver, "High Explosives," Van Nostrand, NY (1918)
Conf or C  Confidential
CR  Comptes Rendues de l'Academie des Sciences (Paris)
Cundill(1889)  J. P. Cundill, "A Dictionary of Explosives," London (1889). The French translation was published in MP 5,235-354(1892) and 6,7-132(1893)
Davis(1943)  T. L. Davis, "The Chemistry of Powder and Explosives," Wiley, NY (1943)
DoklAkadN  Doklady Akademii Nauk (Proceedings of Academy of Science, Russia)
DRP  Deutsches Reichs Patent (German State Patent)
Erikson, Wiley J.G.Erikson, P.F.Wiley & V.P.Wystrach, "The 1,2,3- and 1,2,4-Triazines, Tetrazines and Pentazines," Interscience, NY(1956)
Escales, NG & D(1908) R.Escales, "Nitroglyzerin und Dynamit," Veit & Co, Leipzig(1908)
Escales, Chloratspr(1910) R.Escales, "Chloratsprengstoffe," Veit,Leipzig(1910)
Escales, Schwarzpulver(1914) R.Escales, "Schwarzpulver und Sprengsalpeter," Veit, Leipzig (1914)
Escales, Nitrospr(1915) R.Escales, "Nitrosprengstoffe," Veit,Leipzig(1915)
Escales, Initialspr(1917) R.Escales, "Initialsprengstoffe," Veit,Leipzig(1917)
Explosivst ExplsEngr The Explosives Engineer, Hercules Powder Co, Wilmington, Del
Feodos'ev & Siniarev(1956) V.J.Feodos'ev & G.B.Siniarev, "Introduction to Rocket Techniques, Oborongiz, Moscow(1956)
FIAT Field Information Agency, Technical
FM Field Manual
FrP French Patent
Gazz Gazzetta Chimica Italiana(Rome)
GerP German Patent
Gmelin(Syst Nr & year) Gmelin-Krauts Handbuch der Anorganischen Chemie, Verlag Chemie, Berlin, 8th ed(1928-1958)
Gody(1907) L.Gody, 'Traité des Matières Explosives;'Wesmael-Charlier,Namur(1907)
GornyZh Gorny Zhurnal(Mining Journal, Russia)
Hackh's(1944) Hackh's Chemical Dictionary,' Blackston, Philadelphia(1944)
HACSIR Honorary Advisory Council for Scientific and Industrial Research(Canada)
Helv Helvetica Chimica Acta(Basel, Switzerland)
Heuser(1944) E.Heuser; 'The Chemistry of Cellulose;'Wiley, NY(1944)
IA Iron Age
IEC Industrial and Engineering Chemistry
IGFarbenind Interessengemeinschaft Farbenindustrie
IndChem Industrial Chemist(London)
<table>
<thead>
<tr>
<th>Journal/Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbr 70</td>
<td></td>
</tr>
<tr>
<td>Instr</td>
<td>Instruments (Pittsburgh)</td>
</tr>
<tr>
<td>Instrn</td>
<td>Instrumentation (Philadelphia)</td>
</tr>
<tr>
<td>IzvestAkadN</td>
<td>Izvestiya Akademii Nauk (Bulletin of Academy of Science, Russia)</td>
</tr>
<tr>
<td>J ACS</td>
<td>Journal of the American Chemical Society</td>
</tr>
<tr>
<td>JAgriFChem</td>
<td>Journal of Agricultural and Food Chemistry</td>
</tr>
<tr>
<td>JapP</td>
<td>Japanese Patent</td>
</tr>
<tr>
<td>JApplChem (London)</td>
<td>Journal of Applied Chemistry (London), called J SCI prior to 1951</td>
</tr>
<tr>
<td>JApplPhys</td>
<td>Journal of Applied Physics, formerly called Physics</td>
</tr>
<tr>
<td>JahresberCTR</td>
<td>Jahresbericht der Chemisch-Technischen Reichsanstalt</td>
</tr>
<tr>
<td>JAOAC</td>
<td>Journal of the Association of Official Agricultural Chemists</td>
</tr>
<tr>
<td>JARS</td>
<td>Journal of the American Rocket Society (changed to JetPropn and then to ARSJ)</td>
</tr>
<tr>
<td>JChemEduc</td>
<td>Journal of Chemical Education</td>
</tr>
<tr>
<td>JChemPhys</td>
<td>Journal of Chemical Physics</td>
</tr>
<tr>
<td>JChimPhys</td>
<td>Journal de Chimie Physique (Paris)</td>
</tr>
<tr>
<td>JCS</td>
<td>Journal of the Chemical Society (London)</td>
</tr>
<tr>
<td>JetPropn</td>
<td>Jet/Propulsion (formerly JARS, now ARSJ)</td>
</tr>
<tr>
<td>JFranklnInst</td>
<td>Journal of the Franklin Institute</td>
</tr>
<tr>
<td>JIEC</td>
<td>Journal of Industrial Engineering Chemistry, changed in 1923 to IEC</td>
</tr>
<tr>
<td>JOC</td>
<td>Journal of Organic Chemistry</td>
</tr>
<tr>
<td>JOil &amp; Col</td>
<td>Journal of the Oil and Color Chemists Association (London)</td>
</tr>
<tr>
<td>JOptSocAm</td>
<td>Journal of the Optical Society of America</td>
</tr>
<tr>
<td>JPhChem</td>
<td>Journal of Physical Chemistry, except the years 1947-1951 when it was called JPhCollChem</td>
</tr>
<tr>
<td>JPhCollChem</td>
<td>Journal of Physical and Colloid Chemistry (See JPhChem)</td>
</tr>
<tr>
<td>JPraktChem</td>
<td>Journal für Praktische Chemie, discontinued in May 1943. Continued as J MakrChem, then as MakrChem. Resumed as a separate journal since March 1956</td>
</tr>
<tr>
<td>JRNBS</td>
<td>Journal of Research of the National Bureau of Standards</td>
</tr>
<tr>
<td>JRussPhChemSoc</td>
<td>See ZhrusFiz-KhimObshch</td>
</tr>
<tr>
<td>JSCI</td>
<td>Journal of the Society of Chemical Industry, called JApplChem since 1951</td>
</tr>
<tr>
<td>JScInst</td>
<td>Journal of Scientific Instruments</td>
</tr>
<tr>
<td>Kast (1921)</td>
<td>H. Kast, &quot;Spreng- und Zündstoffe,&quot; Braunschweig (1921)</td>
</tr>
<tr>
<td>KhimReferatZh</td>
<td>Khimicheski Referativnyi Zhurnal, now called ReferatZhKhim</td>
</tr>
<tr>
<td>Khimstroi</td>
<td>Journal for Projecting and Construction of the Chemical Industry (discontinued in 1935)</td>
</tr>
</tbody>
</table>
Abbr 72


P or Pat Patent

PA or PicArsn Picatinny Arsenal, Dover, NJ

PACLR Picatinny Arsenal Chemical Laboratory Report

PAGLR Picatinny Arsenal General Laboratory Report

PACT Prévention des Accidents - Contrôles Techniques (Bruxelles)

PAMR or PicArsnMemRept Picatinny Arsenal Memorandum Report


Pascal (1930) P. Pascal, "Explosifs, Poudres, Gaz de Combat," Hermann, Paris (1930)

PATR or PicArsnTechRept Picatinny Arsenal Technical Report, Dover, New Jersey


PATR 2510(1958) B.T. Fedoroff et al, Picatinny Arsenal Technical Report No. 2510 (1958), "Dictionary of Explosives, Ammunition and Weapons" (German Section)

PB Rept Publication Board's Report (of the US Office of Technical Services)

PBL Rept Ditto, Library of Congress


PhilMag Philosophical Magazine (London)

PhilTr Philosophical Transactions of the Royal Society of London

PHS Rept Public Health Service Report (USA)

PhysRevs Physical Reviews

PhysZSow Physikalische Zeitschrift der Sowjetunion (Leipzig) (discontinued in 1938)

PicArsn See PA

PrChSoc Proceedings of the Chemical Society (London)

PromOrgKhim Promyshlennost' Organicheskoy Khimii (Organic Chemical Industry, Russia)

Protar Protar (Solothurn, Switzerland)


PrzChem Przemysl Chemiczny (Warsaw)

QuartRevs Quarterly Reviews (London)

Quim y Ind Quimica y Industria (Barcelona) (discontinued in 1941)

R or Rept Report


Rec Recueil de Travaux Chimiques des Pays Bas (Amsterdam)

ReferatZhKhim Referativnyi Zhurnal, Khimiya (Abstract Journal, Chemistry) (Russia)


Rept or R Report

Rept Invn or RI Report of Investigation

Res(London) Research (London)

RevChInd Review of Scientific Instruments

RI or ReptInv Report of Investigation


RoczChem Roczniki Chemii (Chemical Annual, Poland) (formerly Chemik Polski and Chemji)
Abbr 74

Ullmann (Vol & year) F. Ullmann; Enzyklopädie der Technischen Chemie, "Urban & Schwarzenberg, Berlin, 2nd ed, vol 4 (1926) and 3rd ed, vol 1 (1951) and following volumes

USNIP United States Naval Institute Proceedings

UspKhim Uspekhi Khimi (Progress in Chemistry, Russia)


Vestnik Moskov Univ Vestnik Moskovskago Universiteta (Bulletin of University of Moscow)


Weaver (1917) E. M. Weaver, "Military Explosives," Wiley (1917)


ZAnalChem Zeitschrift für Analytische Chemie, Fresenius (München)

ZAngChem Zeitschrift für Angewandte Chemie, called AngChem since 1932

ZAnorgChem Zeitschrift für Anorganische und Allgemeine Chemie (Leipzig)

ZavodLab Zavodskaya Laboratoriya (Factory Laboratory Journal, Russia)

ZElektrochem Zeitschrift für Elektrochemie (Berlin)

ZhAnalKhim Zhurnal Analiticheskoy Khimii (Journal of Analytical Chemistry, Russia)

ZhFizKhim Zhurnal Fizicheskoy Khimii (Journal of Physical Chemistry, Russia)

ZhKimProm Zhurnal Khimicheskoy Promyshlennosti (Journal of Chemical Industry, Russia)

ZhNeorgKhim Zhurnal Neorganicheskoy Khimii (Journal of Inorganic Chemistry, Russia)

ZhObshchKhim Zhurnal ObshcheKhimii (Journal of General Chemistry, Russia)

ZhPrikKhim Zhurnal Prikladnoy Khimii (Journal of Applied Chemistry, Russia)

ZhRusFiz-KhimObsch Zhurnal Russkago Fiziko-Khimicheskago Obschestva (Journal of the Russian Physico-Chemical Society, discontinued in 1930)

ZhTekhnFiz Zhurnal Tekhnicheskoy Fiziki (Journal of Technical Physics, Russia)

ZKrist Zeitschrift für Kristallographie (Frankfurt a/M)

ZPhysChem (Frankfurt) Zeitschrift für Physikalische Chemie (Frankfurt a/M)

ZPhysChem (Leipzig) Zeitschrift für Physikalische Chemie (Leipzig)

ZPhysiolChem Zeitschrift für Physiologische Chemie (Berlin)

[See also "List of Periodicals Abstracted by Chemical Abstracts", The Chemical Abstracts Service, The Ohio State University, Columbus 10, Ohio (1956)]
### SUPPLEMENT TO THE LIST OF ABBREVIATIONS FOR BOOKS AND PERIODICALS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLR</td>
<td>Chemical Laboratory Report (Picatinny Arsenal)</td>
</tr>
<tr>
<td>Compt Rend Acad Sci (USSR)</td>
<td>See Dokl Acad N</td>
</tr>
<tr>
<td>Dokl Acad N</td>
<td>See p Abbr 63 [listed sometimes in CA and in some papers as Compt Rend Acad Sci (USSR)]</td>
</tr>
<tr>
<td>GLR</td>
<td>General Laboratory Report (Picatinny Arsenal)</td>
</tr>
<tr>
<td>Gorst (1957)</td>
<td>A.G. Gorst, &quot;Porokha i Vzryvchatyiye Veshchestva&quot; (Propellants and Explosives), Gosizdatoboronprom, Moscow (1957)</td>
</tr>
<tr>
<td>Shidlovskii (1954)</td>
<td>A.A. Shidlovskii, &quot;Osnovy Pirotekhniki&quot; (Fundamentals of Pyrotechnics), Gosizdatoboronprom, Moscow (1954)</td>
</tr>
</tbody>
</table>


Stettbacher (1952)  A. Stettbacher, "Pólvoras y Explosivos," G. Gili, Buenos Aires (1952)


Webster's Unabridged Dictionary (1951)  See Merriam-Webster's (1951)

Yaremenko & Svetlov (1957)  N. E. Yaremenko & B. Ya. Svetlov, "Teoriya i Tekhnologuiya Promyshlennykh Vzryvcharykh Veshchestv" (Theory & Technology of Industrial Explosives), Promstroyizdat, Moscow (1957)

ZhEkspTeoretFiz  Zhurnal Experimental'noi i Teoreticheskoi Fiziki (Journal of Experimental & Theoretical Physics) (Russia)

ZPhysChem or ZPhysChemLeipzig (See also p Abbr 74)  Zeitschrift für physikalische Chemie, published in Leipzig (must not be confused with the journal published in Frankfurt since about 1953)

ZPhysChem (Frankfurt)  Zeitschrift für physikalische Chemie (Frankfurt a/M)
ENCYCLOPEDIA OF EXPLOSIVES
AND RELATED ITEMS

"106'". Code designation for 1,9-Dinitroxy
-2,4,6,8-tetranitro-2,4,6,8-tetrazanonane
described under Dihydroxytetrazanonane

"121'". See Firing or Igniter Composition in PATR 2510(1958), p Ger 49

A(explosif). A Fr expl prep'd by mixing Amm perchlorate 94 & CC(collodion cotton), in the form of jelly 6%
Ref: Commission des Substances Explosives, MP 12, 18(1903-4)

A(series). Ger rockets, A(Raketen) (see PATR 2510, p Ger 1)

A1(Monobel). Brit permitted expl: AN 60, NG 10, WM 9, K chloride 20 & moisture 1%; max charge 28 oz and Bal Pend Swing 2.78"
Ref: Barnett(1919), 134

A1(Roundkol). A current, granular Brit permitted coal mining expl: AN 53.6-56.5, Na nitrate 9-11, Mg & NGc 9-11, vegetable fibers 11-13, Na chloride 11-13, Amm phosphate(dibasic) 0-0.5; resin 0-0.5 & moisture 2%. Power 61% of BG and d 0.70
Ref: Cundill's Dictionary, MP 5, 279(1892)

A-4(Rocket). Same as V-2 described in PATR 2510(1958), p Ger 213

A6(Fuseheads). See PATR 2510(1958), p Ger 1

A-9/A-10(Guided Missile). See PATR 2510 (1958), p Ger 1

Abbcites. Brit permitted expls: a)AN78-82, NG 9-11, WM(dried at 100°) 8-10 & moisture 0.5-2.5%(Ref 1) b)AN 58, NG 8, DNT 2, WM 9 & Na chloride 23%
Ref: Escales, "Ammonsprengstoffe"(1909), 187

Abbreviations of Ordnance and other terms are
given at the beginning of the volume.
Abbreviations of German Ordnance terms are
given in PATR 2510(1958), pp Ger 309-45

Abel, Sir Frederick Augustus(1827-1902),
was a leading Brit scientist in the fields of propellants and explosives. Introduced the practice of beating nitrocellulose to effect stabilization, devised a stability test for explosives which is named after him, and was the author of numerous patents and publications on explosives
Ref: 1)J.Spiller, JCS 87, 565-70(1905)
2)T.Urbański, MAF 13, 835-6(1934)
3)Pérez Ara(1945), 362 4)Giua, Dizionario, v1(1948), p 1

Abel & Dewar Smokeless Propellant, invented
in 1889, consisted of high nitrogen NC gelatinized by acetone or ethyl acetate & NG
Ref: Cundill's Dictionary, MP 5, 279(1892)

Abel Powder or Picric Powder. A mixt for priming PA(picric acid) invented in 1869 by Sir F.A.Abel: Amm picrate 40 & K nitrate 60% (Ref 1). French used a similar compn called Brugère(poudre). In Ref 2, the compn of picric powder is given as Amm picrate 43 & K nitrate 57%; yel solid,dec without melting; brisance — less than TNT; ballistic strength ca 75% TNT; deton rate ca 3500 m/s vs 6900 for TNT; sensitivity to impact, rifle bullet and initiation — comparable to tetryl; stability and compatibility with metals — comparable to Amm picrate. Was used during WWII by the British as a booster in AP projectiles filled with Shellite(qv)
Ref: 1)Thorpe 4(1940), 483 2)All&En

Abbcites. Brit permitted expls: a)AN78-82,
Abel's Researches on Guncotton are described in JCS 20, 310–357 & 505–576(1867)

Abel Smokeless Propellant, invented in 1886, consisted of a mixt of AN & NC coated with petroleum w or w/o camphor

Ref: Cundill’s Dictionary, MP 5, 279(1892)

Abel's Test or KI-Starch Test was designed by Sir F.A.Abel to determine the stability of propellants and explosives. It involved heating a small sample of an expl in a test tube closed with a stopper provided with a hook on which is suspended a strip of KI-Starch paper, moistened at the upper half with 50% glycerin in water. The tube is heated in a constant temp bath and the time necessary to produce a slight brownish (or other) coloration at the border between the moistened and dry areas of the indicator paper is observed. The longer the time required the greater the stability of substance under test. The test is usually conducted either at 65.5° or 82.2°, but other temps may also be used. More detailed descriptions of the test are given under propellants and under some expls, such as TNT

Notes: a)Although this test is one of the oldest in existence, it is still used very extensively b)In this test, nitrogen dioxide, which starts to evolve at the moment of decompn of a propellant or an expl, forms, on contact with wetted portion of the test paper, a mixture of nitrous and nitric acid. The acids attack KI and the liberated iodine colors the starch paper c)Koehler & Marquerol(Ref 2) do not recommend the use of Abel's test for NC propellants contg Ca carbonate - Bergmann-Junk test(qv) gives more reliable results


Abellite. A type of Brit dynamite patented by Sir F.A.Abel: NG 65.5, GC(gun cotton) (finely divided) 30.0, Na nitrate 3.5 & Na carbonate 1.0%

Refs: 1)Daniel, Dictionnaire (1902), p 1 2)Perez Ara(1945), 330

Abellite No. 1. A type of Brit "permitted" expl: AN 68, TNT 6.7, DNB(dinitrobenzene) 7.0, Na chloride 17.5, moisture 0.5 & unac 0.3%

Ref: Barnett(1919), 132

Abelli, Modesto(1859–1911). Ital scientist who specialized in expls. Was director for a number of years of the Nobel Dynamite Plant at Avigliana

Ref: L.Cesaris, SS 6, 381–2(1911)

Abelli Propellant: NC 30–45, NG 45–30 & NGu 20–25%

Ref: M.Abelli, USP 899,855(1908) & CA 3, 377(1909)

Note: It seems that incorporation of NGu in propellants as a cooling agent was not originally a German idea but that of Abelli [See PATR 2510(1958), p Ger 81(Gudolpulver) and Ger 121(Nitroguanidin or Nigu)]

Aberdeen Chronograph. See under Chronographs

Aberdeen Proving Ground is the US Ordnance Proving Ground located in Maryland, near Baltimore. Its mission is outlined in Ordnance Corps Order 4-57, 11 Feb 1957 and in Change 1, 25 July 1957, Dept of the Army, Chief of Ordnance, Washington 25, DC

Abietates. See under Abietic Acid and Derivatives

ABIETIC ACID AND DERIVATIVES

Abietic Acid or Sylvic Acid (1,2,3,4,4a,4b,5, 6,10,10a-Decahydro-7-isopropyl-1,4a-dimethyl-1-phenanthrene-carboxylic Acid), C$_9$H$_{11}$COOH,
A3

MW 302.44. Leaflets, mp 174–5°, bp 200° at 1mm, d 1.132 at 25°, nD 1.514, [α]D 115.6°. Insol in w, very sol in alc & eth. May be obtained from the resin of pine species (colophony) or by other methods (Refs 1, 2 & 5). A lab method of prep is described in Ref 6. Its toxicology, fire hazard, storage and handling are discussed in Ref 7. It was claimed (Ref 3) that the ignition sensitivity be improved when a metallic acetylide (or other metallic acetylide) was added.

**Abietic, Azido Derivative**, N3C19H28·COOH – not found in Beil or CA through 1956

**Abietic Acid, Diazido Derivative**, (N3)2C19H27·COOH – not found in Beil or CA through 1956

**Mononitroabietic Acid**, (O2N)C19H28·COOH – not found in Beil

**Dinitroabietic Acids.** The dinitro compd of the formula (O2N)2C19H26·COOH, mp 178–184°, reported to be obtained by Johansson on nitrating abietic acid (Refs 1 & 2) could not be identified as dinitroabietic acid by later investigators. Goldblatt et al (Refs 3 & 4) reported that by nitrating abietic acid with nitric acid (d 1.42) in AcOH or in boiling alc, they obtained white crystals, mp 171.2–171.4°, corresponding to the formula, (O2N)2C19H28·COOH. Fieser & Campbell (Refs 5 & 6) prepd the compd (O2N)2C19H26·COOH, ndls decomposng at 178–185°, by nitrating dehydroabietic acid, C19H27·COOH, with fuming nitric or mixed nitric-sulfuric acid. This compd was identified as 6,8-dinitrodehydroabi etic or pyroabietic acid and had the same props as comp reported by Johansson as dinitroabi etic acid.

**Trinitroabietic Acid**, (O2N)3C19H26·COOH. This compd, crysts, mp 177–8°, claimed to be prepd by Dubourg (Refs 1 & 2) proved to be identical with 6,8-dinitrodehydroabietic acid, (O2N)2C19H28·COOH prepd by Fieser & Campbell (Ref 3).

**Polynitro Derivative of Abietic Acid** (no formula given), yel amorphous solid which exploded on heating and gave bright red Na, K & Amm salts, sol in w. It was prepd by dissolving abietic acid in fuming nitric acid (heated, if necessary) and pouring the soln into a large amt of ice cold water.

**Abietic Acid, Organic Derivatives (Abietates):** It has been claimed that the incorporation of 5–10% of an aliphatic or aromatic abietate (eg ethyl, methyl, phenyl or benzyl abietates) in single- or double-base propellants reduced the temp of burning and eliminated the muzzle flash.

**Benzyl Abietate**, C19H27·CO2·C6H5. Semi-liqui, bp 294–297° at 4mm, d 1.036 at 15/4° and nD 1.551. Used as a plasticizer and was recommended as a flash reducer in smokeless propellants.

Ethy Abietate, C19H29·CO2·C6H5. Yel oil.
freezing at \(-45^\circ\), bp 204–207° at 4mm, d 1.032 at 15/4°, n_D 1.5265. Used in lacquers and recommended as a flash reducer in smokeless propellants.


*Ethyl Abietate, Nitratio* with HNO_3 (d 1.42) in alcoholic soln produced a solid, mp 157.5–157.8°, corresponding to the formula C_{19}H_{36}N_6O_6 with N=6.90%. The same compd was obtained by refluxing an alcoholic suspension of the Na salt of C_{19}H_{36}N_6O_6 with diethyl sulfate.

*Refs:* 1)Beil 9, not found 2)L.A. Goldblatt et al, JACS 52,2135(1930)

*Methyl Abietate, C_{19}H_{36}CO_2CH_3*. Liq, bp 225–6° at 16mm, d 1.050 at 15/4° and n_D 1.3344. Recommended as a plasticizer for NC

*Refs:* 1)Beil 9, [430] 2)C.C. Kesler et al, JACS 49,2902(1927)

*Phenyl Abietate, C_{19}H_{36}CO_2C_6H_5*. Semi-solid, distilled at 330–333° at 4mm giving a dark-colored gum which did not become lighter in color on redistilling: d 1.056 at 15/4° and n_D 1.5354. Recommended as a flash reducer in propellants.

*Refs:* 1)Beil 9, [431] 2)C.C. Kesler et al, JACS 49,2901(1927)

*Ablation*. According to Nicholls et al (Ref 1), there is considerable contemporary interest in the phenomenon of ablation, or mass loss from solids as a result of their immersion in an environment from which there is a large rate of energy transfer.

The study of ablation in shock tubes conducted in Canada is briefly described in open literature (Ref 1), whereas the studies of ablation conducted in the USA are classified (Ref 2).


**Abnormal Temperature Testing of Propellants** is discussed in the US Ordnance Proof Manual No 40–32(1949). The purpose of these tests is to determine the effect of extreme temps (as low as \(-70^\circ\)F and as high as \(160^\circ\)F) on ballistic uniformity of a propellant and the adequacy of the ignition system. In these tests, the projectiles are fired at various temps to determine the relationship of velocity/temperature and pressure/temperature.

**Abonachit 2.** A Ger expl used during WWII for filling grenades. See Filler No 57 in PATR 2510(1958), p Ger 47

**Abrasive.** Any grinding or polishing material, such as emery, ground glass, carborundum, infusorial earth, pumice etc. Some of these materials are used in priming compositions in order to increase the sensitivity of other components (such as MF, KClO_4 etc) to friction or impact. Crystalline Sb_2S_3 used in priming comps functions not only as a fuel but also as an abrasive (See under Primers).

*Refs:* 1)Kirk & Othmer 1(1947), 1–12(12 refs) 2)Riegel, Industrial Chemistry(1949), 334–41

**Absolute Method of Measurement of Power of Explosives.** See under Power of Explosives, Measurements

**Absolute Rate Theory** (also known as Transition State or Activated Complex Theory). A theory of reaction rates based on the postulate that molecules form, before undergoing reaction, an activated complex which is in equilibrium with the reactants. The rate of reaction is controlled by the concn of the complex present at any instant. In general, the complex is unstable and has a very brief existence (See also Collision Theory of Reaction).

Absorbent Materials from Potatoes. A fibrous material, obtained by washing potatoes until the remaining fibers contain 15% or less starch and then drying and comminuting the fibers, was proposed as an absorbent for liquid explosives (such as NG), etc (Ref 1). In another patent by the same firm, the absorbent is prepared by evaporating the liquid used in washing potato starch, followed by drying and pulverizing the residual fibrous mass, which contains but little starch (Ref 2).

Absorbent Materials for Liquid Explosives. See under Liquid Explosives (Absorbate) only. The application of sorbent is prepared by evaporating the liquid used in washing potato starch, followed by drying and pulverizing the residual fibrous mass, which contains but little starch (Ref 2).

Absorsberent Materials to Control Exudation. Absorptions may be classed principally as physical, chemical, thermal (radiation), electrical and physiological. Only the first two are treated here.

Absorption Spectroscope. Colored solutions which absorb light rays of different wave lengths than the color of the absorbent. (See also Absorption and Adsorption)

Absorbent Materials in Dynamites. See Dopes

Absorbent Materials for Liquid Explosives. See under Liquid Explosives (Oxyliquids)

Absorbent Materials for Nitrogen Oxides. A saturated solution of potassium dichromate or 0.02M Kpermanganate in concd sulfuric acid can be advantageously used to replace PbO₂ in analytical organic combustions for the determination of C, H and N.


Absorbent Materials from Potatoes. A fibrous material, obtained by washing potatoes until the remaining fibers contain 15% or less starch and then drying and comminuting the fibers, was proposed as an absorbent for liquid explosives (such as NG), etc (Ref 1).

Absorbent Materials for Liquid Explosives. See under Liquid Explosives (Absorbate) only. The application of sorbent is prepared by evaporating the liquid used in washing potato starch, followed by drying and pulverizing the residual fibrous mass, which contains but little starch (Ref 2).

Absorptions are processes of taking up (incorporating) gases, liquids or solids inside a liquid or solid substance which may be called the "absorbent." Absorptions may be classed principally as physical, chemical, thermal (radiation), electrical and physiological. Only the first two are treated here.

In physical absorption no chemical reactions take place and the absorbed material (absorbate) is held by the absorbing material (absorbent) only by the forces of cohesion or capillary action in the pores of the solid. Physical absorption is a reversible process. As examples may be cited the absorption of gases such as nitrogen or oxygen in water, and absorption by soda lime or KOH of carbon dioxide.

In chemical absorption definite chemical bonds are produced between the atoms and molecules inside the "absorbents" and the atoms and molecules of the "absorbates."
This is usually accompanied by considerable evolution of heat and the reaction is very difficult to reverse. For instance, when cold platinum sponge is held in the vapors of alcohol absorption proceeds with enormous evolution of heat - the sponge becomes red hot and ignites the alcohol. This property has been used in some "lighters".

From the point of view of industry, the book of Brown on Unit Operations (Ref 4, p32) defines absorption as "an operation in which significant or desired transfer of material is from the vapor phase to the liquid phase". Absorption usually, but not always, designates an operation in which the liquid is supplied as a separate stream independent of the vapor being treated.


Absorption Coefficient. See Coefficient of Absorption

Absorption, Electronic. See under Absorption Spectroscopy

Absorption Spectroscopy is the technique devoted to the study of radiations absorbed on passing through matter of various forms. Essentially, the method consists in placing a transparent solid or liq material or soln in quartz containers, called cells, between the source of light (visible, ultraviolet etc) and a spectrometer, and observing which lengths of radiation are absorbed. Absorption spectroscopy is used in analysis of expls and propellants.

The technique which determines the relationship between the wave length (frequency) of radiation and its attenuation by absorption upon passage through a particular medium, is called absorption spectrophotometry.

Absorption Towers or Columns are tall cylindrical structures designed for absorption (qv) of gases by liquids. There are several types of towers, such as:

b) Plate tower: The simplest type consists of a closed vertical cylinder the inside of which is partitioned by a set of horizontal trays installed one above the other. Each tray has two openings, one in the center for a bubble cap, the other on the side for an overflow tube. The liquid moves from the top to the bottom of the tower while the gas passes counter current. The liquid flows across the first tray and then falls to the second tray. It flows in this tray in the opposite direction and falls to the third tray, thus following a twisting path down the column.

b) Packed tower consists of a closed cylinder filled with different solids such as pieces of stone, brick, glass, coke, Raschig rings, Berl saddles, Lessing rings, Nielson propeller packing, Hechenbleikner blocks, Stedmann packing, Bregeat multiple spirals etc. Here, as in the case of plate towers, the liquid flows from the top of the tower and the gas enters at the bottom.

c) Spray towers contain fine-spray nozzles through which the liquid is forced under pressure against the incoming gas to be absorbed. Another method of "atomizing" the liquid consists of impinging the liquid against a disk rotated at very high speed. In the so-called "cyclone-spray scrubber" the gas enters tangentially and is forced into a spiral path by a system of deflector plates, while the absorbing liquid (such as water) enters a perforated tube located in the center of the column and is sprayed against the particles of gas. This method is very suitable for removing dust, fumes, etc from the air. Plate and packed towers are also used in the fractional distillation of liquids.


Acacia. See Gum Arabic

AcAn. Code name for 1,9-Diacetoxy-2,4,6,8-tetranitro-2,4,6,8-tetrazanonane, described under Diacetoxytetrazanonane. It is also called 1,9-Diacetoxypentamethylene-2,4,6,8-tetranitramine and 2,4,6,8-Tetranitro-2,4,6,8-tetrazanonane-1,9-diol-diacetate

Acapnia. An Ita sporting propellant (polvere da caccia), similar to Schultze Propellants (qv, formerly manufd by the Societe Italiennne pour la Fabrication de l'Acapnia

Ref/s: 1) Daniel, Dictionnaire(1902),2 2) Belgrano(1952),292

ACARDITE OR AKARDIT

Acardites are comds developed in Germany as stabilizers-gelatinizers for NC in smokeless propellants. There are three acardites of which Acardite I was developed first.

Acardite I (asym-Diphenylurea or N,N-Diphenylurea) (Akardit I or Stabilit in Ger), (C₆H₅)₂N-CO-NH₂, mw 212.24, N 13.20%, OB to CO₂ - 233.7%, OB to CO - 135.7%. Col ndls, mp 189°, d 1.276. Can be prep by one of the methods mentioned in Refs 1 or 2 by the method used in Germany during WWII and communicated to us by Dr Hans Walter (Ref 9). The manuf in Germany was conducted in two stages: a) Treatment in the cold of diphenylamine with phosgene in the presence of soda ash in an autoclave under atmospheric pressure: (C₆H₅)₂N-H + Cl-CO-CI + 1/2 Na₂CO₃ → (C₆H₅)₂N-CO-CI + NaCl + CO₂

b) Treatment of the resulting diphenylcarbamyl chloride with ammonia gas, in the presence of soda ash, conducted in the same autoclave but under pressure and at a temp of about 100°: (C₆H₅)₂N-CO-CI + NH₃ + 1/2 Na₂CO₃ → (C₆H₅)₂N-CO-NH₂ + NaCl + CO₂

Following are some props of Acardite I:

solubilities (appr) at RT, g/100 ml of solvent (Ref 6a & other sources): acet 1.50, benz 0.306, carbon disulfide 0.24, chl 5.80, alc (95%) 0.94, ethylene chloride 2.31, eth 0.209, methanol 2.93, toluene 0.105, & petr eth 0.17;
nearly insol in w; heats of combustn 1605.4 kcal/mol at C\textsubscript{v}, 18\degree C, 18\% H\textsubscript{2}O liq (Refs 7 & 8) or 1606.2 at C\textsubscript{p} (Ref 7); heat of formn 28.3 kcal/mol at C\textsubscript{v} or 32.6 at C\textsubscript{p} (Ref 7)

Acardite I was used in Germany as a stabilizer-gelatinizer and as a muzzle flash reducer in NC smokeless propellants. When used in small quantities (say 0.8%), acardites served as stabilizers, while in larger quantities they acted as moderators of burning rate and as flash reducers. Acardite I was considered inferior in all respects to acardites II and III (Ref 6). According to Ref 5, Acardite I does not exert any gelatinizing action on NC, especially if NC is of high nitrogen content.

Reudler (Ref 3), studied the nitration of Acardite I and obtained asym-dinitrodiphenylureas and asym-tetranitrodiphenylurea.

Analytical procedures for acardites are briefly described following Acardite III:


Acardite III or Ethylacardite (N'-Ethyl-N,N-diphenylurea) (Acardite III, in Ger), C\textsubscript{12}H\textsubscript{14}N\textsubscript{2}CO-N(C\textsubscript{6}H\textsubscript{5})\textsubscript{2}, mw 240.29, N 11.66\%, OB to CO\textsubscript{2} -246.4\%, OB to CO -146.5\%. White crysts, mp 72.3\°C for a tech sample and 73.1\°C for samples recryst from ethanol or chlfs (Ref 4). It was prepd in Germany by treating equimolar quantities of ethylamine and diphenylamine in the presence of limestone. This was followed by fractional distillation. The following reaction took place:

\[
\text{CH}_3\text{NH}_2 + \text{COCl}_2 + \text{NH}(\text{C}_6\text{H}_5)_2 + \text{CaCO}_3 \rightarrow \text{CH}_3\text{NH}-\text{CO}-\text{N}(\text{C}_6\text{H}_5)_2 + \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O} \quad \text{(Ref 2)}
\]

Heat of combustn 1771.5 kcal/mol at C\textsubscript{v}, 18\degree C, 18\% H\textsubscript{2}O liq or 1772.6 at C\textsubscript{p} (Refs 4 & 5); heat of formn 24.1 kcal/mol at C\textsubscript{v} or 29.1 at C\textsubscript{p} (Refs 4 & 5).

Acardite II was proposed in Germany as a stabilizer-gelatinizer in NC smokeless propellants. As a stabilizer, it was considered superior to Acardites III & I and as a gelatinizer inferior to Acardite III but superior to Acardite I (Ref 3).

Acardites, Analytical Procedures. Following methods are based on Refs 1, 2, 3 & 5:

Method 1 (when only acardite I is present and no urethanes, DPhA or centralites): a) Extract with chloroform or methylene chloride (5-10g) a finely divided propellant using a Soxhlet or other extractor (ca 15 hrs for complete extraction). Evaporate chlf under reduced pressure and weigh the dry residue (wt 1), which is equal to centralite & acardite I.

b) Treat the residue with aq AcOH at pH ca 4. This will hydrolize the centralite, leaving acardite I intact.

c) Wash the residue with chloroform or methylene chloride (5-10g) a large sample (ca 10g) of finely ground propellant using a Soxhlet ca 1890, no further analysis is necessary.

d) Determin the mp and if it is close to 1890, no further analysis is necessary.

e) If mp is not 1890, determine the amount of acardite I, and weigh (wt 2). Wt 2 is equal to acardite I and wt 1.

Method 2 (when acardite I and a centralite are present): a) Extract the finely ground sample of propellant, as in Method 1, evaporate the solvent and weigh the dry residue (wt 1), which is equal to centralite & acardite b) Treat the residue with aq AcOH at pH ca 4. This will hydrolize the centralite, leaving acardite I intact.

c) Wash the residue with w, dry, and weigh (wt 2). Wt 2 is equal to acardite I and wt 1 - wt 2 is equal to centralite.

d) Determine the mp of acardite I and if it is 1890, no further analysis is necessary.

e) If mp is not 1890, determine the amount of centralite I, and filter through sintered glass crucible, under vacuo. Rinse the residue with few cc of w, dry, and weigh (wt 2). Wt 2 is equal to acardite I and wt 1 - wt 2 is equal to urethanes such as diphenylurethane, ethylphenylurethane, etc.

Method 3 (when acardite I and substituted urethanes are present in propellants not contg NG or DEGDN): a) Extract with chlf or methylene chloride a large sample (ca 10g) of finely ground propellant, evaporate the solvent and weigh (wt 1). This is equal to acardite I & urethanes.
b) Stir the residue with 50cc of toluene, previously saturated with acardite I, and filter through sintered glass crucible, under vacuo. Rinse the residue with few cc of w, dry, and weigh (wt 2). Wt 2 is equal to acardite I and wt 1 - wt 2 is equal to urethanes such as diphenylurethane, ethylphenylurethane, etc.

d) Determine the amount of unreacted bromine by adding KI to the solution: Br2 + 2KI = KBr + I2, and titrating the liberated iodine with N/5 Na thiosulfate solution in presence of starch. Calculate the amount of acardite I, knowing that 1cc of N/5 thiosulfate = 0.0106 g of acardite I (wt 2).

If the wt 2 is smaller than wt 1, some impurity is present (Refs 2 & 5).

Note: According to Dalbert & Tranchant (Ref 3), the above direct bromination of acardite I is not as convenient as their method, which consists essentially of: a) Saponification of acardite I (extracted from propellant) by boiling with 3N NaOH solution for 2 hrs: H2N-CO-N(C6H4)3 + H2O = C6H5-NH-C6H4 + CO2 + NH3.
b) Bromination of the resulting di-phenylamine with bromide-bromate (1/2 hr): C6H5-NH-C6H4 + 2Br2 = BrC6H5-NH-C6H4Br + 2HBr.
c) Determination of unreacted bromine by adding to the solution KI and titrating the liberated iodine with N/10 thiosulfate in presence of starch. Calculate the amount of acardite I, knowing that 1cc of N/10 thiosulfate corresponds to 0.0021g DPhA or 0.0053g acardite I.

Method 4 (when acardite II alone is present as stabilizer and gelatinizer): a) Extract the finely divided sample of propellant (ca 10g) with methylene chloride or chlf and evaporate the solvent.
b) Dry at 110° and weigh (wt 1) (acardite II is not volatile at 110°).
c) Determine the mp and if it is ca 170.5°, the identity of acardite II is established. If mp differs from 170.5°, boil the residue with ethanol and sulfuric acid to split the acardite II:

CH3-NH-CO-N(C6H4)3 + H2O = CO2 + C6H5-NH-C6H4 + C6H5-NH-C6H4 + CH3-NH3.
d) Distill off quantitatively methylene into a flask contg AcOH and save the residue contg DPhA.

e) Treat.
the soln of methylamine with aq Na nitrite: 
\[
\text{CH}_3\text{NH}_2 + \text{NaNO}_2 + \text{CH}_3\text{COOH} \rightarrow \text{N}_2 + \text{CH}_3\text{COONa} + \text{CH}_3\text{OH} + \text{H}_2\text{O},
\]
and collect the liberated nitrogen into a gas burette. Calc from the amt of N, the amt of acardite II (wt 2). If wt 2 is smaller than wt 1, then something else than acardite II is present.

f) In order to establish that the sample contains acardite II and not acardite III, treat the soln(after removal of N gas) with chronic acid mixt(K$_2$Cr$_2$O$_7$ + H$_2$SO$_4$) to oxidize the methanol to formaldehyde. The pungent odor of formaldehyde indicates the presence of acardite II in propellants. More definite results are obtained by treating the oxidized soln with fuchsin, previously discolored by treatment with SO$_2$ gas. Bluish-red coloration indicates the absence of formaldehyde, which would form in the presence of acardite II. Procs g) & h)— same as in Method 4

Method 7(when acardite III and centralites are present): Procs a) & b)— same as in Method 5; c), d) & e) — same as in Method 4; f), g) & h) — same as Method 6

Method 8(when acardite II and diphenylamine are present): a) Extract ca 10g of finely divided propellant with methylene chloride or with chlf, evap the solvent and dry and weigh the extracted residue (P = x + y, where x is the wt of acardite II and y is the wt of DPhA in propellant) b) Dissolve the extracted material in 50cc chlf, add 300cc water and an excess of K bromide-bromate soln of known concn c) After brominating for 4 hrs at RT, add aq soln of KI and titrate the liberated iodine with N/10 Na thiosulfate d) If the calcd wt of DPhA is equal to 452, the P' = 169x/452 + y, then

\[
\text{Eg: If P = 2.5000 g and P' = 1.8000 g, then } x + y = 2.5000 	ext{ and } 0.374x + y = 1.8000, \text{ then } x = 1.119 \text{ g and } y = 1.381 \text{ g (Ref 3, p 342)}
\]

Method 9(when acardite III and DPhA are present)— same as in Method 8 except the formula in proced(d) shall be

\[
P_1 = 169x/480 + y = 0.352x + y
\]

Note: In Ref 4 are given colorimetric reactions with aq K nitrate—sulfuric acid for acardite I(color of ring brn-red & violet and color after mixing grn-brn turning into yel-brn) and for acardite III(color of ring blue-grn, and color after mixing blue-grn turning into violet)

PicArsn; private communication(1959)

**Accelerographs, Accelerometers** and other devices for experimental study of movement of projectiles in guns are described by P. Libessart, MAF 11,1077–1117(1932)

**Accessibility** is the ratio between the portion of a cellulose sample which is accessible to a given reagent (such as $\text{Ac}_2\text{O}$, $\text{Ac}_2\text{O} + \text{HNO}_3$, $\text{AcONO}_2$ etc) and the portion which is not accessible.

It has been claimed that the crystalline (or ordered) regions of cellulose resist the penetration of reagents while the amorphous regions are more reactive. This definition is only approximate.


**Acceptable Explosives** belong to the group of "Dangerous Chemicals" (qv), as defined by the ICC (Interstate Commerce Commission), which may be safely transported by railroads, motor vehicles and steamships subject to certain regulations.

Acceptable explosives may be divided into three classes:

**Class A**: dangerous explosives (detonating or otherwise) of maximum hazard. Their distinguishing characteristic is the susceptibility to deton by a blasting cap. Typical examples are: dynamite, PA, TNT, NC, NG and AN and chlorate expls. Black powder is also included in this group although it cannot be detonated by a commercial blasting cap (ICC Sec 73.53)

**Class B**: less dangerous explosives than A. In general they function by rapid combustion rather than by deton. Typical examples: some smokeless propellants, some pyrotechnic powders (flash powders) and signal devices (ICC Sec 73.88)

**Class C**: relatively safe expls (minimum hazard). They are defined as certain types of manufd articles which contain class A or class B expls, or both, as components but in restricted quantities. E.g: small arms ammunition and certain types of fireworks (ICC Sec 53.100)(See also Forbidden Explosives)


**Accidental Explosions in Process Industry Plants.** Causes of such explosions may sometimes be determined by a study of resulting missiles as well as of any corpses

Ref: C. Field, ChEng 54,102–4(Jan 1947); 126–8(Feb 1947); 118–20(March 1947)

**Accidental Scientific Discoveries.** Title of a booklet by B.E. Schaar, published in 1955 by Schaar & Co, 754 W. Lexington St, Chicago 7, Ill. Among many interesting items in the booklet, mention is made of the accidental discoveries of dynamite, acetylene, the benzene ring, iodine, oxygen, petroleum jelly, plastics, radioactivity, and X-rays. All these substances and phenomena are of importance in the expls industry

Ref: C. Field, ChEng 54,102–4(Jan 1947); 126–8(Feb 1947); 118–20(March 1947)

**Accidents in Industry (Laws, Prevention, Statistics, etc).** See the following publications:

1)G. C. Whalen, ChemView 54,852–3(1944)


3)J. C. Daubney, Metallurgy 33,31–4(1945)

4)"Accident Investigations" 4)US Army, Corps of Engineers Safety and Accident Prevention Div, Safety Requirements, Pamphlet, US Govt
ACENAPHTHENE AND DERIVATIVES

Acenaphthene (Ethylene naphthalene or 7,8-Dihydroacenaphthylene), C_{14}H_{10},

\[ \text{CH}_3 \]

\[ \text{CH}_2 \]

mw 154.1, col ndls, mp 95°, bp 227°, d 1.0678. It is one of the products of coal tar distillation; insol in w and sol in hot alc; used in org synth in the manuf of dyes (Ref 3). Its prep & props are discussed in Beil (Ref 1). A qualitative test for acenaphthene (by nitration it to 5-nitrocacenaphthene) is given in Ref 3


Note: M. Berthelot, CR 65,508(1867), tried to obtain an explosive by nitration of acenaphthene but the highest product of nitration was a non-explosive dinitro compd which melted with decomp at 206°. The same product was later prepd by F. Sachs and G. Mosenbach, Ber 44,2860(1911) and identified as 5,6-dinitrocacenaphthene (see below)

Acenaphthene, Azido Derivative, N_4C_{12}H_{22}, mw 195.22, N 21.53% – not found in Beil, but one isomer, 4-Trisazoacenaphthene, col crysts, mp 66°–8°, is described by G.T. Morgan & H.A. Harrison, JSCI 49,415T(1930). Its expl props were not examined

Acenaphthene, Diazido Derivative, (N_4)_2C_{12}H_{24}, not found in Beil or CA through 1956

Acenaphthene-4-diazonium Chloroaurate,

C_{14}H_3N_2Cl_4Au, pale yel ppt decomp violently on heating


Mononitrocacenaphthene, O_2N-C_{12}H_9 – not found in Beil, but two isomers 2- and 4-nitrocacenaphthenes are described by G.T. Morgan & H.A. Harrison, JSCI 49,415T & 419T(1930). Another isomer 5-nitrocacenaphthene is described by T.Ishii & Y.Yamazaki, Memor Faculty Technol, Tokyo MetropolUniv, No 1,21–9(1951) & CA 47,2159(1953)
Dinitroacenaphthene, \((O_N)_2C_4H_8\), mw 244.20, N 11.47%. Following isomers are described in the literature:

2,5-Dinitroacenaphthene, yel ndls(from AcOH), mp dec 205-6\(^\circ\)C (Ref 2,p 419T).

2,7-Dinitroacenaphthene, brn-yel ndls (from AcOH), mp 155-6\(^\circ\)C (Ref 2, p 419T).

5,6-Dinitroacenaphthene, crysts, sinter intermediate in the manuf of chemicals used ca 2100 and melt at 220-4\(^\circ\)C (Refs 1 & 3).

Trinitroacenaphthene, \((O_N)_3C_4H_8\), mw 289.20, N 14.53% - not found in Beil or CA through 1956.

Acenaphthene Picrate, \(C_{12}H_{10} + C_6H_4N_3O_7\), mw 383.31, N 10.96%. Orange-red prisms, mp 161-162.5\(^\circ\)C (Refs 1,2,3 & 5), expl at 418\(^\circ\)C (Ref 4). Can be prepd by mixing equimolecular quantities of acenaphthene and picric acid in hot alc, followed by cooling.


Acetal or Acetaldehyde-diethyl acetol (Acetol, Ethylidene Diethyl Ether or 1,1-Diethoxy-ethane), \(CH_3CH(OC_2H_5)_2\), mw 118.17, OB to CO\(_2\) -230.2\%, OB to CO -148.9\%. Col liq at 1.3819, d 0.825 at 20\(^\circ\)C; sl sol in w, sol in eth, miscible with alc (See also Ref 8). Heat of combstn at 298 kJ/mol or ca 930.5 at C\(_p\); spec heat 0.51 cal/g/\(^\circ\)C.

Can be prepd by treating acetaldehyde with ethanol in the presence of anhyd Ca chloride (Ref 2) or by other methods (Ref 1).

Acetal is stable under neutral or sl alkaline conditions, but hydrolyzes in the presence of acids to form acetaldehyde.

It has been used as a solvent and as an intermediate in the manuf of chemicals used in the expl industry and of synthetic rubber (Ref 4). During WWII, acetal (as well as acetaldehyde) was used in Germany as hypergolic fuel in liquid rocket propellants in conjunction with red or white fuming nitric acid which served as an oxidizer. Acetal was later replaced by catechol (Benzcathechin or Benzol in Ger) (Ref 10).

Acetal is dangerous when exposed to heat or flame and it can react vigorously with oxidizing materials. Its toxicity, toxicology and fire hazards are discussed in Ref 7.

Acetal is a poor solvent for NC but its admixture with anhydrous alcohol (see Acetel Solvent) greatly increases its solvent power (Ref 8).

Revs: 1)Beil 1,603, (326) & (671-2) 2)Org-Synth, CollVol 1 (1941), 1-2 3)W. J. Huff, US BurMinesReptInvest 3669 (1942) & CA 37, 1869-70 (1943) (The lower limit of inflammability of acetal at atm pressure and at 25\(^\circ\) is 1.65\% by vol and the ignition temp at 0\(^\circ\) is 230\(^\circ\) in air and 174\(^\circ\) in oxygen) 4)Ullmann 3 (1953), 13-17 5)P. Dugleux & P. Laffitte, CR 221, 661-3 (1945) & CA 40, 3951 (1946) (Studies of spontaneous inflammation of mixtures of acetal with air) 6)Kirk & Othmer 1 (1947), 40-5 7) Sax (1957), 228 8)Durrans (1957), 116 9) Carbid & Carbon Corp, Bulletin "The Physical Properties of Synthetic Organic Chemicals" 10) Dr. Hans Walter, PicArsn, Dover, NJ; private communication.

Acetal Solvent consists of a mix of acetal and abs alc. The 90% mix has d 0.82, boiling range 75–85° and bp 38°. Acetal solvent gelatinizes NC much better than straight acetal and also dissolves many resins

Ref: Durrans(1957),116

Acetal Compounds of Pentaerythritol are described by A.Scrabal & S.Kalpshanow,Ber 61B,55–78(1928) & CA 22,1328(1928). (See also under Pentaerythritol)

ACETALDEHYDE AND DERIVATIVES

Acetaldehyde or Aldehyde (Ethylaldehyde, Ethyldene Oxide or Ethanal), CH₃CHO, mw 44.05, OB to CO₂ – 181.6%. Col liq, freezing ca –123.5°, bp 20.8°, d 0.7833 at 18/4°, nD 1.3316, Q₂ 281.9 and Q₅ 47.9 kcal/mol

(Ref 1a). It is miscible w, alc and eth (See also Ref 7). Various methods of prep are given in Refs 1,3 & 9. In Ref 2 is described the catalytic production of acetaldehyde from acetylene and steam over activated carbon and promoted by phosphoric acid. Yields of 85–90% of theor were reported. The reaction of acetaldehyde with sulfuric acid is exothermic and when uncontrolled proceeds with almost expl violence. Mixts of acetaldehyde vapor with air(4 to 57% acetaldehyde by vol) are highly inflammable and expl. Uses and applications of acetaldehyde are listed in Ref 3,pp 32 & 39. It was used extensively during WWI as an intermediate for making acetic acid, which was transformed to aceton

Acetaldehyde (as well as acetal) was used during WWII in Germany as a hypergolic fuel in liquid rocket propellants in conjunction with oxidizers, red or white concd nitric acids. These fuels were later replaced by catechol(Brenzcatechol or Brenzöl, in Ger) (Ref 5). Acetaldehyde, (together with formaldehyde and hydrated lime) has been used for the prep of pentaerythritol (Ref 4)

Toxicity, toxicology and fire and expl hazards are discussed in Refs 7 & 8. Its expl hazard is severe when exposed to flame.

Expl range in air is 4.0 to 57% of acetaldehyde (Ref 8)

Typical US specifications for a technical grade acetaldehyde are: color–water white; acetaldehyde (minim) 99%; acidity as AcOH 0.5%(max), sp gr 0.770 to 0.790 at 20°

Acetaldehyde shows a great tendency to polymerize. A few drops of concd H₂SO₄ added to anhydrous acetaldehyde causes it to polymerize to:

Paraldehyde or 2,4,6-Trimethyl-1,3,5-trioxane (CH₂CHO)₃, mw 132.16, OB to CO₂ -181.6%. Col liq with pleasant odor, fr p ca 12.5°, bp 124°, d 0.9943 at 20°, nD 1.4049, fr p 42°,

Acetoldehyde or Aldehyde(Ethylaldehyde) (CH₃CHO), mw 30.05, OB to CO₂ -181.6%. Col liq, freez- abs visc at 150° 0.1359, sp heat 0.459 cal/g/°C

ing ca -123.5°, bp 20.80, d 0.7833 at 18/40, and heat of fusion 25.2 gcal/g. Sol in w n° 1.3316, QP 281.9 and q~ 47.9 kcal/mol (13.3% at 8.50 and 5.8% at 750); sol in eth, alc & chlf(Ref 3,p 42). It is used as a solvent (See also Ref 7).

Various methods of prep for cellulose derivatives, fats, oils, waxes, gums, etc as well as for many other purposes (Refs 6 & 7)

At a lower temp and with a smaller quant of sulfuric acid a solid polymer Metaldehyde is formed. It is used as the solid fuel "Meta" (See also Ref 4a)


Additional References on Acetaldehyde: a)W.J. Huff, USBurMinesReptInvest 3669(1942) & CA 37,1871(1943)(Ignition temp of acetaldehyde at 0° in air is 165° and in oxygen 159°) b) Saburo Yagi, RevPhysChemJapan 19,106–30 (1945) & CA 44,2346–7(1950)(Oxidation reactions of acetaldehyde and explosion of AcH mixtures with oxygen c) P.Gray & A.D.Yoffe,
Acetaldehyde, Analytical Procedures are discussed in the following references: 1) Beil 1,601,(326) & [668-70] 2)H.A.Iddles & C.E.Jackson, AnalChem 6,454-6(1936) (Precipitation of acetaldehyde as hydrazone using 2,4-dinitrophenylhydrazine as a reagent) 3)Kirk & Othmer 1(1947),38(Quantitative and quantitative methods of determining acetaldehyde) 4)Jacobs(1949),476-8(Quantitative and quantitative methods of detn) 5)Ullmann 3 (1953),11

Acetaldehyde-Nitrogen Dioxide Mixtures, with a large prop of dioxide, expl vigorously when heated to 350-400°. The expln may be considered to be the result of a chain-thermal process
Ref: P.Gray & A.Yoffe, JCS 1950,3184

Acetaldehyde, Azido Derivative(Azidoacetaldehyde or Triazoacetaldehyde), N2.CH2.CHO, very unstable oil, expl mildly on heating. Was prepd in impure state from chloroacetaldehyde hydrate and Na azide. Dec by KOH with violent evln of ammonia & nitrogen
Refs: 1)Beil 1,627 2)M.O.Forster & H.E. Fierz, JCS 93,1870-1(1908)

Mononitroacetaldehyde, (O2N)CH2.CHO, was prepd according to Beil 1, [684], in aq soln but not isolated

Dinitroacetaldehyde, (O2N)2 CH-CHO - not found in Beil or CA through 1956

Acetaldehydepicrylhydrazone or Ethyldene-[2,4,6-trinitrophenylhydrazine, (O2N)2 CH2: NH-N: CH·CH3, mw 269.18, N 26.02%. Brn lfts, mp 119-20°; v sl sol in w, sl sol in eth, fairly sol in alc & AcOH. Was prepd by heating 2,4,6-trinitrophenylhydrazine with acetaldehyde

Ref: 1)Beil 15,495 2)A.Purgotti, Gazz 24 J, 575(1894) & JCS 68 1,28(1895)

Acetaldehyde Superoxide. See Diethylidene Dioxide

ACETALDOXIME AND DERIVATIVES

Acetaldol or β-Hydroxybutyraldehyde also called Aldol, CH3.CH(OH)CH2.CHO, mw 88.10. Col liq when freshly distilled at reduced press, bp 72° at 12mm, d 1.103 and sp heat 0.737 cal/g/°C. May be prepd by the aldol condensation reaction(qv) of two acetaldehyde molecules in the presence of a small amt of an alkali. Other methods of prepn and props are given in Refs 1,2,3 & 4. Aldol is used in solvent mixts

During WWII aldol was used in Germany for the prepn of 1,3-butyleneglycol (by hydrogenation) which was either dehydrated to form butadiene or nitrated to the expl 1,3-butyleneglycol dinitrate

On standing aldol changes to a viscous dimer from which paraldol, [CH3.CH(OH)CH2.CHO], separates. Wh triclinic cryst, d 1.345 at 15.6/4°, mp 95-97°. It boils in vacuo, under which condition part of it is reconverted to aldol. Sol in w or alc, sl sol in eth. Unlike paraldehyde it shows some props of the aldehydes. Used as a raw material for making resins for plastics and synth coatings(Ref 4). Acetaldehyde may be hydrogenated to form 1,3-butyleneglycol from which the expl 1,3-butyleneglycol dinitrate may be prepd.(See also Aldol and Aldol Condensation)


Acetaldol, Analytical Procedures are briefly discussed under Aldol in Ullmann 3(1953),172

ACETALDOXIME AND DERIVATIVES

Acetaldoxime or Aldoxime(Acetaldehyd oxime
or Ethanaloxime), \( \text{CH}_3\text{CH}(\text{NOH}) \), mw 59.07, N 23.71\%, Nds, mp 47°, bp 114–5°, d 0.965 at 20/4°, \( \text{n}_D^2 \), 1.4278, \( \text{Q}_D \), 340.6 kcal/mol, \( \text{Q}_\text{v} \) 12.8; sol in \( \text{H}_2\text{O} \), misc with alc, sol in eth, acet and sl sol in gasoline. Was discovered in 1882 by V. Meyer, described by Petraczek (Ref 2) and then by Franchimont (Ref 3). Can be prepd from acetalddehyde, hydroxylamine hydrochloride and \( \text{Na}_2\text{CO}_3 \) in aq soln or by other methods. Some of its props were detd by Landrieu (Ref 4).

**Refs:** 1) Beil 1,608 2) Petraczek, Ber 15,2783(1892) 3) A. Franchimont, Rec 10, 236(1891) 4) P. Landrieu, CR 140,867(1905) 5) Kirk & Othmer 5(1953),692(under Oximes) 6) Mercr(1952), p 5


**Acetaldoxime, Azido Derivative, \( \text{N}_3\text{CH}_2\text{CH}(\text{NOH}) \) – not found in Beil or in CA through 1956

**Mononitroacetaldoxime or Methazonic Acid, \( \text{(O}_2\text{N})\text{CH}_2\text{CH}(\text{NOH}) \), mw 104.07, N 26.92\%, crysts, mp 79–80°; sol in w, alc, eth, acet and warm benz or chl. Can be prepd by treating nitromethane in aq NaOH or by other methods (Refs 1 & 4). Its ammonium salt, \( \text{C}_3\text{H}_7\text{N}_2\text{O}_3\text{NH}_4 \) obtained by the action of ammonia on nitromethane, dec on heating with evol of poisonous hydrogen cyanide (Ref 3). Its \( \text{K} \) salt \( \text{C}_2\text{H}_3\text{N}_2\text{O}_3\text{K} \), yel ppt expl on heating with evol of it blue flame (Ref 2) and its Ag salt, \( \text{C}_3\text{H}_7\text{N}_2\text{O}_3\text{Ag} \), pale yel ppt, expl ca 100° (Ref 3).

**Refs:** 1) Beil 1,627 2) O. Schulz, Ber 29, 2289(1896) 3) W.R. Dunstan & E. Goulding, Ber 42, 2030–1(1909)

**Nitroacetaldoxime, Anhydride, \( \text{C}_4\text{H}_7\text{N}_2\text{O}_4 \), mw 172.10, N 32.56\%. Two isomers, \( \alpha^* \), mp 168–72° (dec)<\( \beta^* \), mp 121–2° are described in the literature. Ag & Na salts of \( \alpha^* \)-isomer were reported to be mild expls

**Refs:** 1) Beil 2,332 & [684] 2) W. Steinkopf, JPkr Chem 81, 228(1910) 3) H. Wieland, Ann 444, 15(1925)

**ACETAMIDE AND DERIVATIVES**

**Acetamide, Amide or Ethanamide** (Acetic Acid Amide), \( \text{CH}_3\text{CO NH}_2 \) (abbreviated to AcNH\(_2\) ) mw 59.0, OB to CO\(_2\) -149.2\%, OB to CO -94.91\%. Hygr cryst mp 81°, bp 221.2°, d 1.159/20/20°, \( \text{n}_D^2 \), 1.4274 and vapor pres at 105° 10.0 mm Hg. Sol in w, alc and other solvents. Solys of several subst in acetamide were investigated by Stafford (Ref 2). Various methods of prepn are listed in Refs 1 & 4. The method from \( \text{Amm acetate} \) is described in Ref 2. When heated to decompn it emits highly toxic fumes of cyanides (Ref 6).

Numerous uses of acetamide are discussed in Refs 4 & 5. According to Ref 4, p 47, the neutral and amphoteric characteristics of acetonamide make it valuable as an anti-acid in expl compns


**Acetamide, Analytical Procedures** are discussed in Kirk & Othmer 1(1947), 47 and in Organic Analysis, Interscience, 3(1956), 188 & 192

**Acetamide, Azido Derivative** (Azidoacetamide or Triazoacetamide) \( \text{N}_3\text{CH}_4\text{CO NH}_2 \) mw 100.08 N55.99\%. Col ndls(from benz), mp 58° expl on further heating; easily sol in alc & w, diff sol in benz & petr eth. Can be prepd by shaking azidoacetic ester with aq ammonia

**Refs:** 1) Beil 2,229 2) M.O. Forster & H.E. Fierz, JCS 93,80-1(1908)

**Mononitroacetamide** \( \text{O}_2\text{NCH}_4\text{CO NH}_2 \), mw 104.07, N26.92% crysts, mp 102–3°. Was prepd by introducing ammonia into an ethereal soln.
of nitroacetyl chloride (Ref 4). It forms salts, some of which are expl.

Distillation of Amm nitroacetamide with concd KOH gives a tribasic acid, \( C_6H_5N_3O_4 \) and the Amm salt of this acid gives with Ag nitrate a yel solid which is expl. Another nitroacetamide deriv, \( C_6H_5N_2O_5 \), gives with Ag nitrate a wh cryst compd, \( AgC_6H_5N_2O_5 \), which expl violently on heating.

Refs: 1) Beil 2, 226 & (100) 2) F. Ratz, Monatsh 25, 716 & 739(1894) 3) W. Steinkopf, J Prakt Chem 81, 207, Anm 210(1910) 4) W. Steinkopf & M. Kühnel, Ber 75, 1328(1942) & CA 37, 4687(1943)

Dinitroacetamide, \((O_2N)C_6H_5.CO.NH\), mw 149.07, N28.19% - not found in Beil or CA through 1956

Note: However, this compd is listed in ADL Punch Cards and Reports as Compound No 351 and also in the following confidential reports: 1) J. Farago NOrd 9951(1950) 2) N.D. Mason, NavOrd 1589, NOL(1950) 3) J. Farago et al, NavOrd 483, BuOrd(1952)

Trinitroacetamide, \((O_2N)C_6H_5.CO.NH\) - not found in Beil or CA through 1956

Acetamidoanisole, Diazido Derivative, \( C_6H_4N_3O_5 \) - not found in Beil or in CA through 1956

Mononitroacetamidoanisole, \( CH_3.CO.NH \): \( C_6H_5(NO_2)O \). O. CH₃. Several isomers are listed in Beil 13, 388, 389, 390, 422, 521, 522, (136, 137, 186) & [192, 193, 194, 195, 216, 287]

Dinitroacetamidoanisole, \( CH_3.CO.NH.C_6H_2(NO_2)_2 \). O. CH₃. Several isomers are listed in Beil 13, 393, 394, 425, 526, 527, 528, 530, (123, 137, 138, 139) & [290, 292]

Trinitroacetamidoanisole or Trinitroacetamino-anisole, \( C_6H_2N_3O_5 \), mw 300.19, N 18.67%. Following isomers are listed in Beil:

2,3,5-Trinitro-4-acetamidoanisole or 2,3,5-Trinitro-4-acetaminophenolmethylether.

\[ O.CH_3 \]

\[ HC-C=NO_2, \text{ wh ndls} \]

\[ O_2N.C-C=NO_2 \]

\[ NH.CO.CH_3 \]

(called by Lorang 4-Methoxy-2,3,6-trinitro-1-acetylamino-benzene), mp 242° from dil AcOH or aq alc (Ref 2), mp 246° fromalc (Ref 3). Was first prepd by Reverdin (Ref 2) from 2,3,5-trinitro-4-amidoanisole and acetic anhydride in the presence of a little concd sulfuric acid. Lorang (Ref 3) prepd it by nitrating 2,3-dinitro-4-acetamidoanisole with mixed nitric-sulfuric acids. Its expl props were not examined


2,3,6-Trinitro-4-acetamidoanisole or 2,3,6-trinitro-4-acetaminophenol-methylether

\[ O.CH_3 \]

\[ O_2N.C-C=NO_2 \]

\[ HC-C=NO_2 \]

\[ NH.CO.CH_3 \]
explon (Ref 2). Its perchlorate is also known but its expl props have not been investigated [Ref 1, p (372)]. Its acetate and chloride are unstable and slowly evolve N₂ at 100°

Ref: 1)Beil 16,603-4,(372) & (307) 2)W.H.Gray, JCS 1926,3180-1

**ACETAMIDODIPHENYLEThER AND DERIVATIVES**

**Acetamidodiphenylether**, CH₃.CO.NH·C₆H₄·O · C₆H₄ is described in Beil 13,414,(161) & [172,245]

Acetamidodiphenylether, Azido Derivative, N₃·C₆H₁₂NO₂—not found in Beil or CA through 1956

Acetamidodiphenylether, Diazido Derivative, (N₃)₂·C₆H₁₂NO₂—not found in Beil or CA through 1956

Mononitroacetamidodiphenylether,

C₆H₁₂N₂O₄. Two isomers are described in Beil 13,[285,287]

Dinitroacetamidodiphenylether, C₆H₁₂N₂O₄. One isomer 2',4'-Dinitro-4-acetamido-

diphenylether, CH₃·CO·NH·C₆H₄·O·C₆H₄ is described in Beil 13,463

Trinitroacetamidodiphenylether, C₆H₁₆N₃O₆—not found in Beil or CA through 1956

Tetranitroacetamidodiphenylether,C₆H₂₄N₅O₁₆, mw 407.25, N 17.20%, OB to CO₂ -88.4%, Following isomer is listed in Beil:

3,5,2',4'-Tetranitro-4-acetamidodiphenylether or 3,5-Dinitro-4-acetamidophenol-

[2',4'-dinitrophenyl]-ether, CH₃·CO·NH·C₆H₂(NO₂)₂·O·C₆H₄(NO₂)₂, wh ndls(from glas AcOH). Can be prep by warming 3,5,2',4'-tetranitroamidodiphenylether with acetic an-hydride and some concd sulfuric acid. Its expl props were not examined

Refs: 1)Beil 13,530 2)F. Reverdin & A Dresel, Ber 38,1595(1905)

Pentanitroacetamidodiphenylether,
Acetamido-2-nitroguanidine, CH₃.CO.NH.NH.CH₃.CO.NH.NH₂ + HNO₃, mw 179.14, N 39.09%. Cryst (from abs alc), mp 145.5-146.5° (Ref 2), 142-3° (Ref 1). Sol in w and alc. Can be prepd by heating aminoguanidine, AcOH and a trace of nitric acid on a water bath (Ref 1). Qf 471.5 kcal/mol and Qf 118.04 (Ref 2)

Ref: 1)Beil-not found 2)M.M.Williams et al, JPhChem 61, 264 & 266(1957)

N-Acetamido-N'-nitroguanidine or 1-Acetamido-3-nitroguanidine (called in Ref 3, p 264, 1-Acetamido-2-nitroguanidine), CH₃.CO.NH .NH₂ + HNO₃, mw 161.13, N 43.46%, OB to CO -34.8%. Crysts (from w), mp 194-5°. Can be prepd either from nitroaminoguanidine, AcOH and Ac₂O or from acetyldrazide and methyl nitrosoguanidine (Ref 2). Qf ca 475 kcal/mol and Qf 46.3 (Ref 3). May be suitable as an ingredient of propellants


1-Acetimidomethylhexamine Nitrate, C₄H₆N₂O₄, mw 274.28, N 30.64%, crystals, mp 183-4°. One of the compds obtained by Bachmann et al in the course of investigation of the action of acetic anhydride on hexamine mononitrate, under a contract recommended by NDRC

Ref: W.E.Bachmann, E.L. Jenner & L.B. Scott JACS 73, 2775-7(1951)

Acetamidoguanidine Nitrate,
CH₃.CO.NH.NH.C(:NH).NH₂ + HNO₃, mw 179.14, N 39.09%. Cryst (from abs alc), mp 145.5-146.5° (Ref 2), 142-3° (Ref 1). Sol in w and alc. Can be prepd by heating aminoguanidine, AcOH and a trace of nitric acid on a water bath (Ref 1). Qf 471.55 kcal/mol and Qf 118.04 (Ref 2)
Mononitroacetamidonaphthalene,
\((O_2N)C_{12}H_{18}NO\). Several isomers are described in Beil 12,1258,1260,1261,1313, 1315,(530,544) & [704,705,731,732,733]

Dinitroacetamidonaphthalenes,
\((O_2N)C_{12}H_{18}NO\). Several isomers are described in Beil 12,1263,1264,1316,(532) & [704,705,731,732,733]

Trinitroacetamidonaphthalenes,
\((O_2N)C_{12}H_{18}NO\). Several isomers are described in Beil 12,1263,1264,1316,(532) & [709, 735]

Ref s: 1)Beil 12, [709] 2)W.H.Talen, Rec 47,356(1928)

2,4,8-Trinitro-1-acetamidonaphthalene, creamy plates, mp 207°. Was prepd by treating 2,4,5-trinitro-1-aminonaphthalene with acetic anhydride & concd sulfuric acid

Ref s: 1)Beil—not found 2)E.R.Ward & L. A.Day, JCS 1951, 785 & CA 45,9014(1951)

1,6,8-Trinitro-2-acetamidonaphthalene, yellow crystals, mp 239-40°. Was prepd by treating 1,6,8-trinitro-2-aminonaphthalene with acetic anhydride & concd sulfuric acid

Ref s: 1)Beil 12, [739] 2)E.J.van der Kam, Rec 45,729(1926)

Tetranitro-, Pentanitro- and Hexanitro-acetamidonaphthalenes—are not found in Beil or in CA through 1956

ACETAMIDOPHENETOLE AND DERIVATIVES

Acetamidophenetole, Ethoxyacetanilide or Acetaminophenolethylether, 
\(\text{CH}_3\cdot\text{CO} \cdot \text{NH} \cdot \text{CH}_3\cdot\text{O} \cdot \text{C}_2\text{H}_4\). All isomers are listed in Beil 13,371,416,461,(113,133, 160) & [172,244]

Acetamidophenetole, Azido Derivative, 
\(N_3 \cdot C_{10}H_{18}NO\)—not found in Beil or in CA through 1956

Acetamidophenetole, Diazido Derivative, 
\((N_2)C_{10}H_{18}NO\)—not found in Beil or in CA through 1956

Mononitroacetamidophenetole, \(\text{CH}_3\cdot\text{CO} \cdot \text{NH} \cdot \text{C}_6\text{H}_4\cdot\text{NO}\) & [193,194,195]

Dinitroacetamidophenetole, \(\text{CH}_3\cdot\text{CO} \cdot \text{NH} \cdot \text{C}_6\text{H}_4\cdot(\text{NO}_2)_2\cdot \text{O} \cdot \text{C}_2\text{H}_4\). Several isomers are described in Beil 13,388,389,391,522,(136,137) & [290, 292]

Trinitroacetamidophenetole, \(\text{CH}_3\cdot\text{CO} \cdot \text{NH} \cdot \text{C}_6\text{H}_4\cdot(\text{NO}_2)_3\cdot \text{O} \cdot \text{C}_2\text{H}_4\). All existing isomers are listed in Beil 13,394,526,(139,193) & [290, 292]

Ref s: 1)Beil—[704] 2)J. van der Kam, Rec 46, 644(1927)

Tetranitroacetamidophenetole, \(C_{10}H_{24}N_3O_10\)—not found in Beil or in CA through 1956

ACETAMIDOPHENOL AND DERIVATIVES

Acetamidophenol or Acetaminophenol
\(\text{CH}_3\cdot\text{CO} \cdot \text{HN} \cdot \text{C}_6\text{H}_4\cdot\text{OH}\), mw 151.16, N9.27%. All existing isomers are described in Beil 13,370,415,460,(113,132,159) & [171,213, 243]

Acetamidophenol, Azido Derivative, 
\(N_3 \cdot C_{6}H_{4}NO\)—not found in Beil or in CA through 1956

Acetamidophenol, Diazido Derivative,
(N$_3$)$_2$C$_8$H$_4$NO$_2$—not found in Beil or CA through 1956

3-Azido-2,6-dinitro-4-acetamidophenol (called in Ref 2 2,5-Dinitro-4-acetylamo-3-triazophenol) CH$_3$.CO.NH.C$_6$H(N$_3$)(NO$_2$)$_2$.OH, mw 282.18, N 29.79%. Ocher-colored ndls or golden yet scales (from alc), mp 167-8°. Can be prep by treating 2,3,6-trinitro-acetanhydride with Na azide in warm w. Its expl props were not examined

Refs: 1)Beil 13,(198) 2)R. Meldola & H. Kuntzen, JCS 99,43(1911)

Mononitroacetamidophenol, C$_6$H$_4$N$_2$O$_6$, mw 196.16, N 14.28%. All possible isomers are described in Beil 13, 422-3, 520-1, (136-7) & [191,193-4,285,287]

Dinitroacetamidophenol, C$_6$H$_4$N$_2$O$_6$, mw 241.16, N 17.43%. All possible isomers are listed in Beil 13, 396,425,528,530,(193-4) & [197,216, 290,292]

Trinitroacetamidophenol, C$_6$H$_4$N$_2$O$_6$, mw 286.16, N 19.58%. The following isomers are described in the literature:

2,3,5-Trinitro-4-acetamidophenol, CH$_3$.CO-NH.C$_6$H(N$_3$)(NO$_2$)$_2$.OH, It bn scales (from AcOH), mp 191-2°(dec), easily sol in alc & AcOH. Can be prep by treating 3,5-dinitro-4-acetamidophenol with fuming nitric acid at 0° or by other methods. Its explosive props were not examined

Refs: 1)Beil 13,(195) 2)F. Reverdin & R. Meldola, JPrChem 88, 798(1913) & JCS 102, 1493(1913)

2,3,6-Trinitro-4-acetamidophenol, CH$_3$.CO-NH.C$_6$H(N$_3$)(NO$_2$)$_2$.OH, yel ndls (from AcOH), mp 178-9°(dec); sol in AcOH and hot alc; diff sol in hot w. Can be prep by treating 3-nitro-4-acetamidophenol with fuming nitric acid (Ref 2) or by other methods (Ref 1,4 & 5). Forms numerous salts of which the cobalt, nickel, and silver salts are mild explosives (Ref 3)


3,5,6-Trinitro-2-acetamidophenol, 2-Acetamido-3,5,6-trinitrophenol or 2-Hydroxy-3,4,6-trinitroacetanilide, It yel leaflets mp 1510. Was prep by adding 2-acetamido-5-nitrophenol to nitric acid


Mononitroacetamidophenol, C$_6$H$_4$N$_2$O$_6$, mw 196.16,N 14.28%. All possible isomers are described in Beil 13, 533,(191) & [296]

Tetranitroacetamidophenol, C$_8$H,N,0, mw 331.16, N 21.15%—not found in Beil or CA through 1956

ACETAMIDOTETRAZOLE AND DERIVATIVES

5-Acetamido-1H-tetrazole, called by Thiele & Ingle Acetyl-[5-amino-tetrazol] and in Beil

Tetrazolon-(5-anil, CH$_3$.CO.NH.C—NH-N

or CH$_3$.CO.N:C—NH-N

HN—N, mw 127.11, N 55.10%. Wh leaflets (from w or alc) or prisms(from acetanhydride), mp 269°(dec)(Refs 1,2 & 3), mp 271°(Ref 4); easily sol in alc, acetanhydride & hot w, nearly insol in ether. Can be prep by heating 5-amino-tetrazole with an excess of acetanhydride or acetylchloride. Its X-ray diffraction pattern is given in Ref 5


Acetamidotetrazole, Azido Derivatives—not found in Beil or CA through 1956
Acetamidotetrazole, Nitro- and Dinitro-Derivatives—not found in Beil or CA through 1956

ACETAMIDOTOLUENE AND DERIVATIVES

Acetamidotoluene, Methylacetanilide or Acetoluidide, C₇H₈NO. The three isomers are described in Beil 12, 792, 860, 920, (379, 400, 420), [439, 468, 501]

Acetamidotoluene, Azido Derivative, N₃, C₇H₈N₃O—not found in Beil or in CA through 1956

Acetamidotoluene, Diazido Derivative, (N₃)₄C₇H₈N₃O—not found in Beil or in CA through 1956

4-Acetamidotoluene-4-diazoniumhydroxide or 4-Acetamido-2-diazoniumhydroxide-toluene (N-Acetyl-4-methyl-3-diazoisoamidobenzene, or 2-Methyl-5-acetamino-benzediazoniumhydroxide), CH₃CO-N₂H₂

N₂OH

Known only in the form of its salts some of which are stable and a few expl. For instance, the bromide, CH₃CO.N₂H₂.Br, prepd by Wallach from 2-amino-4-acetanilideminozotoluene (Ref 3) and designated by him as "acetparatoluidine-o-diazobromide" (Refs 1 & 2), is a yel solid which explodes on rapid heating. The chloride, designated as "acetparatoluidine-o-diazochloride" and prepd from 4-acetanilideto-diazopiperidine (Ref 4), also explodes on heating.

Refs: 1)Beil 16, 608 2)O. Wallach, Ann 235, 249 (1886) 3)Beil 13, 133 (41) & (62) 4)Beil 20, 91

Mononitroacetamidotoluene, C₇H₈N₂O₃. Several isomers are described in Beil 12, 843, 845, 847, 849, 876, 877, 998, 1002, (392, 393, 394, 408, 440) & [458, 459, 460, 476, 477, 534, 536]

Dinitroacetamidotoluene, C₇H₈N₂O₄. Several isomers are described in Beil 12, 851, 1010, (396, 409, 442) & [462, 463, 479, 480, 481, 482, 538]

Trinitroacetamidotoluene, C₇H₈N₃O₄, mw 284.19, N19.72%, OB to CO₂-80.9%. One isomer is listed in Beil

2.4,6- Trinitro-3-acetamidotoluene,

(O₃N)₃C₆H₃-\(\text{NH} \cdot \text{CO} \cdot \text{C₇H₈} \text{OH}_{-} \text{CH₃}\), microscopic

ndis(from alc), mp 249°(dec). Was prepd by warming 2,4,6-trinitro-3-acetamidotoluene with acetic anhydride and some concd sulfuric acid. Its expl props were not discussed

Refs: 1)Beil 12, 482 2)J.W. Cook & O.L. Brady, JCS 117, 752 (1920)

Tetranitroacetamidotoluene, C₇H₈N₄O₆—was not found in Beil or in CA through 1956

ACETAMIDOTRIAZOLES AND DERIVATIVES

4-Acetamido-asym-triazole, called by H & S "Acetyl-hydrotetrazin," HC=NH—N

CH₃.COH-NH.N—CH₃

126.12, N44.43%, apparently cryt compd, known only in the very sol in w & alc and insol in eth, ligroin & chlf. Was prepd by heating 4-amino-asym-triazole with acetyl chloride

Refs: 1)Beil 26, 19 2)A. Hantzsch & O. Silberräd, Ber 33, 84 (1900)

1-Acetamido-asym-triazole, called in CA 12, 4-Triazole-1-acetamide, NH-C(CH₃CO)₂-N, shiny plates, mp 185-

N

6°. Was obtained from ethyl-1,2,4-triazoile-1-acetate in methanol satd with ammonia at RT

Reps: 1)Beil—not found 2)C. Ainsworth & R. Jones, JACS 77, 622 (1955) & CA 50, 1785 (1956)

Acetamidotriazole, Azido-Derivative—not found in Beil or CA through 1956

Acetamidotriazole, Nitro- and Dinitro-Derivatives—not found in Beil or CA through 1956

ACETANILIDE AND DERIVATIVES

Acetanilide, Acetamidobenzene or Acetyl-aniline (N-Phenylacetamide, Antifebrin or Acetanil), C₆H₅.NH.COH CH₃ mw 135.16, OB to CO₂-231%, OB to CO -136.1%. Col crystals, mp 114.2°, bp 303.8°, d 1.21 at 4/4°, Q° 1014.4 kcal/mol, heat of
vaporization at 154° 136 cal/g, mean heat capacity (from 0° to 99.6°) 0.339 cal/g°C, sol in w, alc & eth. Can be prep’d by heating aniline with AcOH or by other methods. A lab prep from aniline and (CH₂CO)₂O is described in Ref 2. Its fire hazard is small when exposed to flame (Ref 6)

Various uses of acetanilide, among them as a stabilizer for hydrogen peroxide and for cellulose, are listed in Refs 4 & 5. According to Ref 4, p 52, a considerable quantity of acetanilide was used during W W I I for the manuf of acetylsulfonyl chloride

Note: According to one of the Hercules Co Laboratory manuals, acetanilide was used as one of the ingredients of smokeless propellants. Some nitrat ed acetanilide derivatives are explosive


Acetanilide, Analytical Procedures are discussed in Refs: 1)Kirk & Othmer I(1947), 52 and 2)Organic Analysis, Inter science, NY, 2(1954), 44,133,142,162, & 2(1956),186, 188,190

Acetanilide, Azido Derivatives, C₆H₄N,N,O, mw 176.18, N 31.80%. Following isomers are described in the literature:

Azidoacetanilide or Triazoacetanilide, C₆H₅ . NH . CO . CH₂ . N₃; ndls, mp 83-83.5°. Was prep’d by treating aniline with azidoacetamide

Refs: 1)Beil 12, 245 2)M.O.Forster & R.Müller, JCS 95,201(1909)

4-Azidoacetanilide, Acet-(4-azido)-aniline or Acetyl-p-aminotriazobenzene, N₂ . C₆H₅ . NH . CO . CH₂ crystals, mp 122.5-124°. Was prep’d by treating p-acetamido-benzeneidiazoniumperbromide with ammonia

Refs: 1)Beil 12,772 2)H.Rupe & K.von Majewski, Ber 33,3406(1900) 3)O.Silberrad & B.J.Smart, JCS 89,170(1906)

Acetanilide, Diazido Derivative, N₂ . C₆H₅ . NH . CO . CH₂ . N₃—not found in Beil or CA through 1956

Mononitroacetanilides (MNAAn), C₆H₄N₂O₃.
All isomers are described in Beil 12,245,691, 703,719,(193,342,347,351) & [371,380,389].
A new method of prep of p-MNAAn is given in USP 2,406,578(1948), by E.H.Bart,CA 41, 153(1947)

Note: nitration of acetanilide has been discussed in the following refs:

Acetanilide, Analytical Procedures are discussed in Refs: 1)Kirk & Othmer I(1947), 52 and 2)Organic Analysis, Interscience, NY, 2(1954), 44,133,142,162, & 2(1956),186, 188,190

Acetanilide, Azido Derivatives, C₆H₄N,N,O, mw 176.18, N 31.80%. Following isomers are described in the literature:

Azidoacetanilide or Triazoacetanilide, C₆H₅ . NH . CO . CH₂ . N₃; ndls, mp 83-83.5°. Was prep’d by treating aniline with azidoacetamide

Refs: 1)Beil 12, 245 2)M.O.Forster & R.Müller, JCS 95,201(1909)

4-Azidoacetanilide, Acet-(4-azido)-aniline or Acetyl-p-aminotriazobenzene, N₂ . C₆H₅ . NH . CO . CH₂ crystals, mp 122.5-124°. Was prep’d by treating p-acetamido-benzeneidiazoniumperbromide with ammonia

Refs: 1)Beil 12,772 2)H.Rupe & K.von Majewski, Ber 33,3406(1900) 3)O.Silberrad & B.J.Smart, JCS 89,170(1906)

Acetanilide, Diazido Derivative, N₂ . C₆H₅ . NH . CO . CH₂ . N₃—not found in Beil or CA through 1956

Mononitroacetanilides (MNAAn), C₆H₄N₂O₃.
All isomers are described in Beil 12,245,691, 703,719,(193,342,347,351) & [371,380,389].
A new method of prep of p-MNAAn is given in USP 2,406,578(1948), by E.H.Bart,CA 41, 153(1947)

Note: nitration of acetanilide has been discussed in the following refs:

Nitronitrosoacetanilides, C₆H₄N,O₃. Several isomers were prep’d by H. France et al,JCS 1940,370 & CA 34,3700(1940)

Dinitroacetanilides (DNAAc), C₆H₅N₂O₃, mw 225.16, N 18.66%. Several isomers are listed in Beil 12,447,754,758,759,(362) & [405,410, 414]

Note: B.B.Dey et al, JSciIndianResearch 10B,140-4(1951) & CA 47,3257(1953) discuss the prep of 3,4-DNAAc, mp 145-6° and of 2,3-DNAAc, mp 186-7°

2,4-Dinitro-N-nitrosoacetanilide, (O₃N)₂C₆H₅ . N(NO). CO . CH₃, mw 254.16, N 22.05%, oil, prep’d by treating 2,4-dinitroacetanilide with nitrosyl chloride in the presence of K acetate. Its expl props were not investigated

Refs: 1)Beil—not found 2)H.France et al, JCS 1940,3 70-1 & CA 34,3700(1940)

Dinitro-N-nitroacetanilide, (O₃N)₂C₆H₅ . N(NO). CO . CH₃, mw 270.16 N 20.74% -not found
in Beil or in CA through 1956

**Trinitroacetanilides**, C₆H₅N₂O₃, mw 270.16, N₂O.74, OB to CO₂ -71.1%, OB to CO₂ -23.7%. Following isomers are described in the literature:

2,3,5-Trinitroacetanilide or N-Acetyl-2,3,5-trinitroaniline and 3,4,5-Trinitroacetanilide or N-Acetyl-3,4,5-Trinitroaniline, (O₂N)₃C₆H₅.NH.CO.CH₃, were prepd by acetylation of corresponding trinitroanilines (TNA’s)

**Refs:** 1)Beil—not found 2)E.Macciotta, AnnChimAppl(Rome) 36, 212(1946) & CA 41, 1115(1947)

2,4,6-Trinitroacetanilide or N-Acetyl-2,4,6-Trinitroaniline, solid, mp 235° (with decomp). Was prepd by treating 2,4,6-trinitroaniline with acetic acid and a little concd sulfuric acid. Its expl props are not mentioned in Refs 1,2 & 3. For absorption spectra see Ref 4


**Trinitro-N-nitrosoacetanilide**, (O₂N)₃C₆H₅.NH.CO.CH₃—not found in Beil or in CA through 1956

**Trinitro-N-nitroacetanilide**, (O₂N)₃C₆H₅.N(O₂)₂.C₂H₅.NH.CO.CH₃—not found in Beil or in CA through 1956

2,3,4,6-Tetranitroacetanilide or N-Acetyl-2,3,4,6-Tetranitro-aniline, (O₂N)₄C₆H₅.NH.CO.CH₃, mw 315.16, N 22.22%, OB to CO₂ -48.2%, OB to CO₂ -7.6%. Yel ndls (from radical, HN:N) through benz +AcOH), mp 169-70° (with decomp). Was prepd by heating 2,3,4,6-tetranitroaniline with acetic anhydride and a little concd sulfuric acid. TeNAAn is an expl and was proposed by Flürscheim(Ref 2) as an ingredient of expl comps. It is rather unstable, even at low temp and sensitive to shock (Ref 3)


**Tetranitro-N-nitrosoacetanilide**, (O₂N)₄C₆H₅:N(O₂)₂, N 42.4% -not found in Beil or in CA through 1956

2,3,4,6-Tetranitro-N-nitroacetanilide or N₂,N₂,O₂,Pentanitroacetanilide, (O₂N)₅C₆H₅.N(NO₂)₂, CO.CH₃, mw 360.16, N 23.34%. Yel solid, unstable; decomp slowly in air and in boiling w. Was prepd by treating 2,3,4,6-tetranitrophenylnitramine with acetyl chloride

**Refs:** 1)Beil—not found 2)E.Macciotta & Z.Orani, Gazz 60, 408(1930) & CA 24, 4280 (1930)

**Acetaniside.** Same as Acetamidoanisole

**Acetates.** See under Acetic Acid and Derivatives

**Acetatopentamminecobalt(III)nitrate**, [CO(NH)₂C₂H₃O₂(NO₂)₂], crysts. Its lab props are not mentioned in Refs 1,2 & 3. For absorption spectra see Ref 4


**Acetazidine, Azidine or Acethydrazidine.** Beil 2, p 4 gives its formula as:

HN·N·C·CH₃, but its prepn is not given

H₂N·N·C·CH₃

According to Beil 16, pp 4-5, the hypothetical radical, HN:N, is called formazyl and the hypothetical compound, H₃N·N·C·CH₃ is called formazan or formazylhydride (Formazylwasserstoff). This means that acetazidine may be called C-methylformazan.

**Acethydarzidine or Azetazidine.** See Formazans and Formazyls
ACETIC ACID AND DERIVATIVES

Acetic Acid (Ethanoic or Acetonecarboxylic Acid) (AcOH) (Essigsäure, in Ger), CH₃COOH, mw 60.05, OB to CO₂, -106.6%. Col liq., mp 16.7°, bp 118.1°, d 1.049 at 20°/4°, flp +104°E, Qₚ 208.5 kcal/mol (Ref 4). Miscible with w, alc & eth; insol in CS₂. It is found in the products of distn of wood and for this reason is called "pyroligneous acid". Can be prepd by the oxidation of acetaldehyde, by the action of CO on methanol or by other methods (Refs 1, 5 & 7). Dangerous at high temps in contact with oxidizing agents, such as nitric or chromic acids. Its vapors can produce in air a moderately severe exfn above 112°F(44.4°C) (Ref 3a). Toxicology and fire & expl hazards of acetic acid are discussed in Ref 9. Freezing points of mixts AcOH/H₂O and AcOH/Ag₂O are given in Refs 2 & 3. More information on chemical and physical props of AcOH is given in Refs 5 & 7.

Various uses of acetic acid are discussed in Refs 5 & 7. Its principal use in explosives industry is the manuf of cyclonite (RDX) by the Bachmann process. It can also be used for the prepn of high-nitrogen (ca 14%N) nitrocellulose. US specification JAN-A-465, covers the requirements for acetic acid used in Ordnance (see Acetic Acid, Analytical Procedures).

Recovery of acetic acid used in the production of cyclonite and of other nitramines is discussed in Ref 6.


Additional References on Acetic Acid:
a) M. Usanovich & S. Abidov, Zhur Obsh Khim 10,223-6(1940) & CA 34, 7285(1940) (Nitration of toluene in the presence of acetic acid and nitrobenzene) b) J. Chédin & S. Féneant, MSCE 32, 92-100(1945) (Molecular composition of HONO₂-AcOH mixtures; studies by Raman spectroscopy) c) J. Chédin et al, MSCE 34, 289-90(1948) (Mixtures of HONO₂, AcOH, H₂O and metallic nitrates) d) M. Kirsch & C. A. Winkler, CanJRes 28B, 715-19(1950) (Nitrolysis of hexamine in acetic acid) e) E. D. Hughes et al, JCS 1950, 2406-09 (Mechanism of aromatic nitrations in the presence of AcOH) f) S. Féneant-Eymard, MSCE 37, 297-346(1952) (Physico-chemical studies of AcOH) g) A. V. Titov, Zh Obsh Khim 24, 77-9(in Eng); 78-81(in RusX1954); CA 49, 7338(1955) (Formation of slightly stable compd CH₂COOH.HNO₃)

Acetic Acid, Analytical Procedures. Acetic acid intended for use in the manuf of expls must comply with the following chemical and physical requirements of Purchase Description PA-PD-572 (superseding Spec JAN-A-465):

a) Acetic Acid Content—minim 99.8%, as detd by immersing a glass-stoppered weighing bottle contg 5 ± 0.0002 g sample in 250 ml w (previously neutralized to phenol-phthalein by adding few drops of 0.1N NaOH soln) and titrating to a pink end point with 0.1N NaOH

\[ \% \text{AcOH} = \frac{6.005 \times V \times N}{W} \]

where V = vol of NaOH used in titrating sample, N = normality of NaOH soln and W = grams of sample.

b) Acetic Anhydride Content—max 0.03%, as detd by treating a 10 ml sample (measured by a pipette), dissolved in 50 ml w (contained in a 250 ml iodine flask with 10.00 ml of an approx 1.25% Na bisulfite soln) and titrating (after allowing the mixt to stand for 15 mins) the excess of bisulfite with 0.1N std iodine soln, using starch as an indicator

\[ \% \text{Ac}_2\text{O in AcOH} = \frac{(A - B) \times N \times 0.220}{W} \]

where A = ml of iodine soln used to titrate
10.00 ml of Na bisulfite soln treated as above but without the sample (blank); B = ml of iodine soln used for bisulfite soln contg sample and N = normality of iodine soln

c) Formic Acid Content—max 0.15%, as detd by treating a 10 ml sample (measured by a pipette), dissolved in 100 ml w (contained in a 250 ml iodine flask) with 10 ml of 20% Na acetate soln and 25.00 ml of 0.01 N Na hypobromite soln. After allowing the mixt to stand 15 mins at RT and adding 5 ml of 25% KI soln and 10 ml of concd HCl, the liberated iodine shall be titrated with 0.1N std Na thiosulfate soln

\[ \%HCOOH \text{ in } AcOH = \frac{A - B}{N} \times 0.230 \]

where \( A \) = ml of Na thiosulfate soln used to titrate 25 ml of Na hypobromite soln treated as above but without using the sample (blank); \( B \) = ml of thiosulfate soln used to titrate the mixt contg the sample and N-normality of iodine soln

d) Freezing Point—min 16.2°, as detd by means of 0° to 50° mercury thermometer graduated to 0.1° and standardized against one having the Bureau of Standards calibration. The test is conducted in 100 ml cylinder immersed in an ice-water bath. After supercooling the sample to ca 1° below the assumed fr p, the cylinder is removed from ice water and its inner side scratched and the contents stirred by means of the thermometer until the supercooled liquid partly solidifies. Then the outside of the cylinder is wiped dry and the thermometer watched very closely. The temp rises quickly and then remains constant for about 30 secs.

This temp is taken as the fr p of sample

e) Lead Content—max 10 ppm, as detd by evaporating a 5 ml sample on a steam bath, dissolving the residue in 2 ml of 0.1N HCl soln, transferring the soln quantitatively (by rinsing with w) into a 25 ml Nessler tube and filling the tube to the mark with w. A second Nessler tube shall be filled to 25 ml mark with the standard soln (which was previously prepd by dissolving 3.2 mg of lead nitrate and 5 ml of pure AcOH in 1 l of w) and 10 ml of satd hydrogen sulfide water added to the contents of each Nessler tube. After allowing the tubes to stand for 10 mins, the color in the 1st tube shall not be darker than that in the 2nd tube

f) Iron Content—max 10 ppm, as detd in the manner described for lead detn, except that soln of the residue in 2 ml of 0.1N HCl soln shall be made alkaline by Amm hydroxide soln before pouring it into the 1st Nessler tube and that the standard soln for the 2nd Nessler tube shall be prepd by dissolving 0.43g of Fe(NH₄)₂(SO₄)₂ . 12H₂O and 5 ml of AcOH in 1 l of w. Same reagent, hydrogen sulfide water, as above is used in both tubes

g) Chlorides Content—max 0.001%, as detd by comparing the turbidity produced on mixing in a 50 ml Nessler tube a 10 ml sample, 35 ml w, 3 ml concd nitric acid and 1 ml of 0.1N silver nitrate soln with that produced by 10 ml of standard soln (prepd by dissolving 15 mg of NaCl in 1 l w) with 35 ml w, 3 ml concd nitric acid and 1 ml of 0.1N silver nitrate soln. The turbidity produced in the 1st tube shall be not greater than that in the 2nd one

h) Sulfates Content—max 0.001%, as detd by evaporating to dryness a 50 ml sample contg 10 mg of Na carbonate on a steam bath, dissolving the residue in 5 ml of w, filtering into a 10 ml Nessler tube and diluting to the mark with w. A 2nd 10 ml tube shall contain 10 ml of standard soln, previously prepd by dissolving 82 mg of K sulfate in 1 l of w. After adding to each tube 1 ml of 1:20 hydrochloric acid & 1 ml barium chloride soln and allowing to stand for 10 min, the turbidity produced in the 1st tube shall be not greater than that in the 2nd tube

i) Sulfurous Acid Content—max 0.001%, as detd by titrating 300 ml of w contg some starch indicator with 0.01N iodine soln to
end point, adding 50 ml of sample and continuing titration to the same end point

\[ \% \text{Sulfurous acid} = V \times N \times 0.082, \]

where \( V \) = total ml of iodine soln minus ml used to titrate \( w \) and \( N \) = normality of iodine soln

Slightly more rigid requirements are for the reagent grade acetic acid (see Ref 2)

For more information on analysis of acetic acid see Refs 1 & 3


(Various methods are described. Detn of \( \text{AcOH} \) in anhydride is in v 3, p 24)

**Acetic Acid, Azido Derivative (Azidoacetic Acid or Triazoacetic Acid), \( N_3 \cdot CH_2 \cdot CO_2H \), \( mw \) 101.07, N 41.58%. Col hygrosc plates, mp ca 160\(^\circ\), bp 95\(^\circ\) at 3 mm, d 1.354 at 33\(^\circ\). Detonates violently on heating in a capillary tube; expl mildly with evoln of flame on heating on a hot plate. Can be prep'd by shaking ethylester of azidoacetic acid with aq 20% KOH soln

Its silver salt, \( C_2H_2O_2N_4Ag \), N 20.2%, ndls, deflagrates on heating


4)J.H.Boyer & J.Hamer, JACS 77,953(1955) & CA 50,1826(1956)

**Acetic Acid, Diazo Derivative (Azidacetic Acid Azido or Triazoacetic Acid), \( N_3 \cdot CH_2 \cdot CO_2N \), \( mw \) 126.08, N66.66%. Col oil with unpleasant smell; mp explodes; insol in w. Was prep'd by treating azidoo-acetic acid dihydratehydrochloride with Na nitrite in cold aq soln

Ref's: 1)Beil 2,230 & (101) 2)T.Curtius, et al, Ber 41, 354 & 1036(1908)

**Nitroacetic Acid** (Nitroäthansäure or Nitroessigsäure, in Ger), \( O_2N \cdot CH_2 \cdot COOH \), \( mw \) 105.05, N 13.33%. Ndls, expl on heating; sol in chlf, benz & toluene; insol in petr eth; decomp by w; yields nitromethane when heated with w. Was prep'd from the dipotassium salt (see below) and dry HCl in ether (Refs 1 & 3)

Its dipotassium salt, \( C_2HK_2NO_4 \), ndls, sol in w and insol in edhyl & methyl alcs, can expl on contact with w(Ref 2). Can best be prep'd by treating nitromethane with KOH (1:1)(Ref 6). Other methods of prepn are given in Refs 1 & 2. It is a powerful expl(Ref 5)

The aq soln of the salt yields with Pb acetate a white ppt and with Ag nitrate and mercurous chloride yel ppts. These salts deflagrate in a flame (the Ag salt the strongest) (Ref 3)


4)J.H.Boyer & J.Hamer, JACS 77, 953(1955) & CA 50, 1826(1956)

**Acetic Acid—Perchloric Acid Mixture.** See perchloric acid—acetic acid mixture

**ACETATES**

**Ammonium Acetate (Normal), \( CH_3COO \cdot NH_4 \), \( mw \) 77.08

Wh deliq crysts, mp 114\(^\circ\), bp decomp, d 1.171 at 25\(^\circ\)/4\(^\circ\)(see Note). Sol in w & alc, sl sol in acet. Can be prep'd by neutralizing acetic acid with ammonia or Amm carbonate. The commercial salt contains some acid salt (see below). The pure salt is used as a lab reagent, etc
Note: According to most chemical handbooks the density of Amm acetate is equal to 1.073. This seems to be impossible if the densities of aqueous solns, as given in Ref 2, p 810, are 1.077 for 40% soln and 1.092 for 50% soln at 16\(^\circ\)C. The d = 1.171, cited here, was detd by Bilz & Balz (see Ref 1, p 113).


**Ammonium Acetate(Acid),** \(\text{CH}_3\text{COONH}_4\text{CH}_3\text{COOH}\). Long deliq ndls, mp ca 66\(^\circ\). Sol in \(\text{w}\) & alc. Can be prep by distn of the normal salt in acetic acid.

Refs: 1)Kirk & Othmer 1(1947),811 2)Ullmann 6(1955),791

**Calcium Acetate(Acetate of Lime),** \((\text{CH}_4\text{COO})_2\text{Ca}\), mw 158.17. Cryst from \(\text{w}\) as col ndls contg 2 mols of water of crystn. The transition of the di- to the monohydrate(89.77% of anhyd salt) takes place at 84\(^\circ\). The normal commercial salt contains 82-85% of anhyd salt. The anhyd salt decomp when heated at moderate temp. It is sol in \(\text{w}\) & alc. Can be prep by neutralizing the pyroligneous liquors from hardwood distn with Ca carbonate followed by evapn, drying and purification. Until about 1932 it was the only important source for prep of acetone and acetic acid but the development of the Weizmann fermentation process (yielding acetone and synthetic acetic acid), as well as direct acetic acid processes have relegated the salt to a place of minor industrial importance.

**Monohydrate of Ca acetate** is used as analytical reagent and its requirements when used in military installations are listed in US Spec MIL-C-14000


**Cellulose Triacetate.** See under Acetyl Celluloses.

**Dipotassium Nitroacetate.** See p A27

**Lead Acetate (Sugar of Lead or Plumbous Acetate)(Bleiazetar or Bleizucker in Ger),** \(\text{Pb(CH}_3\text{COO)}_2\cdot 3\text{H}_2\text{O}\), mw 379.35. Wh monocrys, d 2.55, mp loses 3\(\text{H}_2\text{O}\) at 75\(^\circ\); for the anhyd salt, \(\text{Pb(CH}_3\text{COO)}_2\), mw 325.35 mp ca 280\(^\circ\). Sol in \(\text{w}\) and glycerin; sl sol in alc, chlf, \(\text{CCl}_4\) & benz. Can be prep by dissolving litharge in hot concd \(\text{AcOH}\) or by treating a mixt of lead and \(\text{AcOH}\) with air under press. Its lab method of prepn from red salt in acetic acid lead oxide \((\text{PbO}),\text{AcOH}\) and chlorine is described in Ref 2.


**Lead Acetates (Basic) are obtained by dissolving lead oxide in \(\text{aq}\) solns of sugar of lead.** White solids, very sol in \(\text{w}\). Ullmann (Ref 2) gives their formulae as, \([\text{Pb}_3(\text{OH)}_4][\text{CH}_3\text{COO})_3\] and \([\text{Pb}(\text{OH})_{4/5}][\text{CH}_3\text{COO})_3\].

Refs: 1)Kirk & Othmer 8(1952),268 2)Ullmann 6(1955),791
Lead Sub-acetate, CH₃COOPb and (CH₃COO)₂Pb₂, H₂O. Wh powd, sol in w.
Can be prep'd by reaction of lead suboxide and acetic anhydride in atm of nitrogen. Its aq soln is used in lab for pptg colloidal subs from solns.

Refs: 1)Beil 2, (50) 2)H.G.Denham, JCS 115,109-111(1919)

Lead Tetraacetate, Pb(CH₃COO)₄, mw 443.39.
Col monocn dls, mp 175⁰, d 2.228; decomp or Acetyl Oxide (abbreviated to PbO₂.
Can be prep'd by adding Ac₂O, (CICO)₂O, MW 102.09, 08 to C₂H₂O, cool to 10, b to dcooling(Ref 1).

It is used as an oxidizer in -125.4, col liq, fr p -73.10, bp 139.50, d 1.0838 at 200/200, n D 1.3904, sp ht 0.434 cal/g/0, Q vapzn 66.1 cal/g, fl p 1240 F

Refs: 1)Kirk & Othmer 8(1952),268 2) (closed cup), Qc 431.9 and Qf 130.8 kcal/mol

ACETIC ANHYDRIDE AND DERIVATIVES

Acetic Anhydride, Ethanoic Anhydride or Acetyl Oxide (abbreviated to Ac₂O), (CH₃CO)₂O, mw 102.09, OB to CO₂ -125.4, col liq, fr p -73.10, bp 139.50, d 1.0838 at 200/200, n D 1.3904, sp ht 0.434 cal/g/0, Q vapzn 66.1 cal/g, fl p 1240 F

Refs: 1)Kirk & Othmer 8(1952),268 2) (closed cup), Qc 431.9 and Qf 130.8 kcal/mol

US Spec (C₁₀₂₃),3H₂O, plates, expl violently on AcOH, in the prepn of high nitrogen content heating Beil 2,

Lead Aceto-Bromate, Pb₃(CH₃COO)₂(BrO₃)₂, plates, expl when heated to ca 165⁰ or on impact [Beil 2,[121]]

Lead Aceto-Chlorate, Pb₃(CH₃COO)₂(OH)⁻·(ClO₄)₂·2½H₂O, scales, expl violently on heating [Beil 2, [121]]

Lead Aceto-Perchlorate, Pb₃(CH₃COO)₂·(OH)⁻·(ClO₄)₂·H₂O, plates, expl violently on heating or on impact [Beil 2,[121]]

Lead Aceto-Sodium Perchlorate, Pb(CH₃COO)₂·NaClO₄, prisms, explode on heating [Beil 2, [121]]

Sodium Acetate, CH₃COO·Na, mw 82.04.
Wh deliq monocn crystals, d 1.528, mp 324⁰, at 200 1.464. Sol in w, sl sol in alc. Can be prep'd by neutralizing acetic acid with Na₂CO₃ or with NaOH and heating the resulting trihydrate to remove water of crystn (Refs 1 & 2). Can also be obtained from wood sulfite liquor and NaOH or Ca(OH)₂(Ref 2). Its uses are listed in Refs 2,5 & 6. According to Violette (Ref 3) mixts of equal parts of Na acetate with K saltpeter explode violently when heated. The same applies to mixts of Na acetate and saltpeter (Ref 4)


Acetic Anhydride, Ethanoic Anhydride or Acetyl Oxide (abbreviated to Ac₂O), (CH₃CO)₂O, mw 102.09, OB to CO₂ -125.4, col liq, fr p -73.10, bp 139.50, d 1.0838 at 200/200, n D 1.3904, sp ht 0.434 cal/g/0, Q vapzn 66.1 cal/g, fl p 1240 F
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deton or one with HClO₄ of d less than 1.50 g/cc has no expl props (Ref 9).

The safe use of Ac₂O-HClO₄ as electrolytic polishing bath has been investigated by Hikita & Asaba (Ref 12) and by Médard & Sartorius (Ref 10) resulting in a 3 phase diagram to show the dangerous zones.


Acetic Anhydride, Analytical Procedures.

Material intended for use in the USA for the manuf of expls(such as cyclonite) shall comply with the requirement of Spec JAN-A-459, as determined by the following tests:

a) Color. Prepare 500 ppm of platinum standard by dissolving 1.245 g K₂PtCl₆ and 1.000 g COCl₂-H₂O in aq HCl(1:5) contained in 11 volumetric flask and dilute to the mark. Pipette 1 ml of this soln into a 50 ml Nessler tube and dilute with w to the mark. Fill a 2nd Nessler tube with the sample and compare the color of solns in both tubes. The intensity of color of the sample shall be no greater than that of the standard.

Save the sample for procedure (b)

b) Suspended Matter–none. Observe the sample in the 2nd Nessler tube of proc (a)– there shall be no suspended matter.

c) Acetic Anhydride Content (Purity)–minim 97.07%. Have two dry glass-stoppered Erlenmeyer flasks, the first 500 ml and the 2nd 250 ml. Pipette 50 ml of approx 0.5N carbonate-free NaOH into first flask and 20 ml of freshly distilled aniline into 2nd flask. Stopper both flasks. By means of Lunge weighing bottle weigh to ±0.0002 g, 0.9 to 1.0 g sample into 1st flask and 1.6 to 1.7 g into the 2nd one. The samples shall be added dropwise and the flasks swirled to prevent local overheating.

Refer to:

%Ac₂O = 10.21 \left( \frac{V_1N_1 - V_2N_2}{W_1} - \frac{V_3N_3 - V_4N_4}{W_2} \right) \%,

where

\[ V_1 = \text{ml NaOH added to 1st flask} \]
\[ V_2 = \text{ml HCl used in back titration of contents in the 1st flask} \]
\[ V_4 = \text{ml NaOH used in titrating 2nd flask} \]
\[ N_1 = \text{normality of NaOH added to 1st flask and used in titrating contents of 2nd flask} \]
\[ N_4 = \text{normality of HCl used in back titration of 1st flask} \]
\[ N_3 = \text{normality of NaOH used in blank} \]

\[ W_1 = \text{g of sample in 1st flask} \]
\[ W_2 = \text{g of sample in 2nd flask} \]

d) Chlorides–none. Dissolve 2 ml sample in 20 ml chloride-free w, add 1 ml concd nitric acid, shake and add a few drops of 1N Ag nitrate soln. No turbidity or opalescence shall be observed.

e) Sulfates–none. Dissolve 2 ml sample in
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20 ml sulfate-free w, add 1 ml concd HCl, shake and add a few drops of 10% Ba chloride soln. No turbidity shall be observed.

f) Heavy Metals—none. Dissolve 10 ml sample in 100 ml w and 5 ml concd HCl. Saturate the soln with hydrogen sulfide gas and note the appearance of a ppt, which is indicative of the presence of Sb, As, Bi, Cd, Cu, Pb, Hg or Sn. Dissolve another 10 ml sample in 100 ml w, neutralize with NH$_4$OH (using litmus paper indicator) and add 5 ml in excess. Cool the soln, saturate with H$_2$S gas and note the appearance of a ppt, which is indicative of the presence of Co, Mn, Ni or Zn.

Acetic anhydride intended for use as a reagent shall comply with the requirements listed in Ref 3.

Analysis of acetic anhydride is also discussed in Refs 1, 3 & 4.


Acetic Anhydride, Azido Derivative (Azidoacetic Anhydride or Triazoacetic Anhydride, H$_3$C.O.C.H$_2$.N$_3$—not found in Beil or CA through 1956

Acetic Anhydride, Diazido Derivative or Diazidoacetic Anhydride, N$_2$.H$_3$.C.O.C.OC. CH$_2$.N$_3$—not found in Beil

Ref: 1) Beil—not found  2) K. Freudenberg et al, Ber 65, 1191(1932)

Acetic Anhydride—Perchloric Acid Mixtures. See under Perchloric Acid

Acetic Ether (Essig-ether, in Ger). See Ethyl Acetate

ACETINS AND DERIVATIVES

Acetins are esters obtained by reactions of glycerin with acetic acid. There are mono-, di- and tri-acetins.

Monacetin or Glyceryl Monoacetate, C$_3$H$_4$(OH)$_3$.O$_2$.C.CH$_3$, mw 134.13, OB to CO$_2$ -71.6%, Mixt of two isomers is a col liq, d 1.206, at 20/4°, bp 130° at 3 mm, N D 1.4499 Q$_c$ 595.6 kcal and Q$_f$ 214.5 (Ref 6); very sol in w or alc; sol in chlf; sl sol in eth or petr eth and insol benz. Can be prepd by heating at 170°, equimolar quantities of anhyd glycerol and glacial acetic acids in the presence of H$_3$PO$_4$ or P$_2$O$_5$ (Refs 1 & 3). Vender (Ref 2) proposed using water sol acetins as gelatinizing agents for NC in the prepn of smokeless propellents. Acetins were also used in manuf of some dynamites (see also Refs 4 & 5)


Diacetin or Glyceryl Diacetate, C$_3$H$_4$(OH)$_2$.O$_2$.C.CH$_3$, mw 176.17, OB to CO$_2$ -136.2% OB to CO -72.7%. Mixt of two isomers is a col liq, d 1.177 at 20/20°, bp 175-60 at 40 mm, n$_D^{20}$ 1.371, Q$_c$ 801.8 kcal/mol and Q$_f$ 264.8 (Ref 6); sol in w or alc; al sol in eth; very sol in benz. Can be prepd in mixt with other compds by heating at 110°, anhyd glycerol with glacial acetic acid and concd sulfuric acid (Refs 1 & 3). Vender (Ref 2), proposed its use as gelatinizer for NC. According to Refs 4 & 5, diacetin has been used as a solvent, plasticizer and softening agent


Triacetin (TA) or Glyceryl Triacetate, C$_3$H$_4$(O$_2$.C.CH$_3$)$_3$, mw 218.20, OB to CO$_2$, -139.3%, OB to CO -73.3%. Col liq, fr p ca -78°, bp 258-60°, d 1.163 at 20/20°, N$_D^{20}$
1.4307, QV \text{1008.6 kcal/mol} \text{and} Q_3 \text{314.5 kcal/mol}

and triacetin are described in Ref 1. An infrared method for detg triacetin is described in Refs 2 & 3.

Triacetin intended for use in the manuf of US smokeless propellants shall comply with the requirements of Spec JAN-T-301, as ded by the following tests:

a) Color Prepare the standard by adding 0.5 ml of 0.1N iodine soln & 100 ml w and visually compare the color in 25 ml Nessler tube with that of sample. The color of sample shall be no darker than that of standard.

b) Specific Gravity—1.153 ±0.003 at 25/40, as ded by pycnometer or Westphal balance.

c) Acidity as AcOH—max. 0.005%. Neutralize about 400 ml of 95% ethanol, with 0.1N NaOH soln to faint pink coloration, using 1 to 2 drops phpt indicator, and transfer about half to a 500 ml Erlenmeyer flask contg 100 ml sample. Mix thoroughly and titrate rapidly with 0.1N NaOH to faint pink coloration. Disregard gradual fading of this color.

\[ \%\text{AcOH} = \frac{6.0 \times V \times N}{W} \]

where V ml of NaOH soln required for titration; N-normality of NaOH soln; W-g of sample (vol x gravity).

d) Asb—max. 0.002%. Weigh a portion of ca 10 g in an accurately tared small porcelain and evap to near dryness over a low flame or on a hot plate. Ignite the residue to const wt at a red heat, cool in a desiccator and weigh.

e) Ester Content as TA—min 98.0%. Take two 250 ml flasks which can be fitted by means of ground joints to reflux condensers. Accurately, weigh by means of a Lunge pipette, 1.8 ±0.2g sample into the 1st flask, add 100 ml of N/3 NaOH soln and connect to the 1st reflux condenser. Add to the 2nd flask (blank) only 100 ml N/3 NaOH soln and connect to the 2nd reflux condenser. Boil gently each flask for ca 1 hr with occasional swirling (saponification takes place in the
1st flask). Wash down the sides of each condenser and the ground joints, with about 25 ml w, cool the flasks rapidly to RT and titrate their contents with N/3 sulfuric acid

\[
\% \text{TA} = \frac{7.27 \times (V - v) \times N}{w}
\]

where \(V\) ml of acid used to titrate blank; \(v\) ml of sulfuric acid used to titrate excess of NaOH after saponification and N-normality of sulfuric acid

**Refs:**
1) P. Fuchs, Z. Anal. Chem. 121, 305 (1941) & CA 35, 6205 (1941)
2) A. H. Castelli et al, PATR 2021 (1954) (C)
3) A. H. Castelli et al, PATR 2222 (1956) (C)

**Note:** Above classified references 2 and 3 were not used in this description of analytical procedures

**Mononitroacetic acid or Glycerylmonoacetate Nitrate**, \(C_3H_5(OH)(ONO_2)(O_2C-CH_3)\)—not found in Beil

**Dinitroacetic acid, Glycerylmonodinitrate or Glyceraldinitroacetate**, called in Beil Glycerin-acetat-dinitrat, \(C_3H_5(ONO_2)(O_2C-CH_3)\), mw 224.13, N 12.50% OB to \(CO_2\), 42.8% Lt yel oil d 1.45 at 15° (Ref 2) d 1.42 at 15° (Ref 3) fr p < -20°, bp 147° at 15 mm (dec); insol in w, benz & 

**Nitrate,\(C_3H_5(ONO_2)(O_2C-CH_3)\)—not found in Beil**, was prep'd by acetylation or by nitrating and as a solv for NC (Ref 6)

**Loss of wt in 24 hrs at 75° was 1.4% (Ref 3)**

It was proposed as an antifreeze addition to NG in dynamites (Ref 2)

**Note:** According to Naoum (Ref 3) the sample of Vender (Ref 2) probably contained NG

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**Mononitroacetic acid, Glyceryldiacetate Nitrate or Diacetin Nitrate**, called in Beil, Glycerin-\(a,\beta\)-di-acetat-\(\gamma\)-nitrat, \(C_3H_5(ONO_2)(O_2C-CH_3)\), mw 245.19, N 5.71%. Crysts, mp 18-20°, insol in w. Was prep'd by acetylatimg glycerine-\(\alpha\)-mononitrate. It is not mentioned as an expl

**Nitrate,\(C_3H_5(ONO_2)(O_2C-CH_3)\)—not found in Beil**, was prep'd by acetylation or by nitrating and as a solv for NC (Ref 6)

**Acetone and Derivatives**

**Acetone or Dimethylketone** (abbreviated to acet)(2-Propanone, Propanol, Acetocarbinol or Pyruvic Alcohol) (\(\alpha\)-Oxy-\(\beta\)-oxopropan, Oxy-aceton, Acetoxyalkohol or Brenztraubenalkohol in Ger), \(CH_3-CO-CH_3\), mw 58.08, OB to \(CO_2\) -220.4%, OB to CO -137.7%. Col, mobile, flamm liq, frp ca -94.6°, bp 56.5°, d 0.7898 at 20°/4°, \(n_D^2\) 1.3591, vap pres 180.3 mm Hg at 20°, sp heat 0.5176 cal/g at 20°, visc 0.00337 cgs units at 15°, \(Q_e^2\) 435.3 (Ref 17)
Miscible in all props with w, alc, eth, methanol, esters and other org solvs. It is a good solvt for NC. Cellulose acetate, nitrocompds etc. First obtained in 1595 by Libavius by the dry distn of sugar of lead and in 1805 by Trommsdorff, who distilled Na and K acetates. The correct compn was estbd in 1832 by Liebig & Dumas (Ref 17, p 881).

There are many methods for the prepn of acet of which the dry distn of Ca acetate was the most common until, a few years after WWI, the carbohydrate fermentation method of C. Weizmann was introduced (Refs 31 & 48). By far the largest prdn of acet in the USA is from petroleum-derived propylene by way of isopropanol (Refs 31 & 48). Another method is to pass acetylene and steam over FeO-ZnO catalyst at elevated temps (Ref 48). In Germany acet was produced in 95% yield from AcOH by a vapor-phase catalytic process using a cerium oxide catalyst at 400°C (Ref 31). There are also other methods of prepn (Refs 1, 2, 3, 4, 10, 14, 31, 33, 42, 47, & 48).

Acetone is very flammable and should not be exposed to heat or flame. Mixts of acet vapor with air are expl if the acet content is 2.55 to 12.8% at RT. The ignition temp of acet vapor in air at 0°C is 567°C and in oxygen 485°C (Ref 20). The expl props and hazards of acet-air mixts and precautions against their propagation to expln are discussed in Refs 5, 6, 7, 8, 9, 19, 27 & 28. The expl deton of weak shocks in liqs, such as acet, ethanol and ether is discussed in Ref 45. Brooke (Ref 40) detmnd the flash points of acet-water mixts and has shown that they are ignitable even when the acet content is as low as 2%. The fl p of a 2% acet-water mixt is 44.4°C and of an 18% soln is 7.1°C. The fl p decreases rapidly with an increase in the acet content. In pouring acet down the drain, it is advisable to add enough water to make the acet concn less than 2%.

The toxicity and toxicology of acet are discussed in Refs 17, 28, 31, 42 & 46. In general there seems to be no indication that acet produces any toxic effects in workers who use it in well ventilated buildings.

Osmotic press data for solns of NC in acet have been obtained by Huggins (Ref 21), vapor tensions of gels by Schultz (Ref 15) and by Calvet (Ref 22), sedimentation rates by Moisimann et al (Refs 24 & 25), viscosity vs NC concn by Wissler (Ref 36), thermodynamic props by Munster (Ref 41), and various other props of NC-acet solns are discussed in Refs 13, 23, 26, 29, 32, 34, 35, 38, 39 & 44. The absorption spectra of acet are recorded by Pauling (Ref 30) and the reaction with 1,3,5-TNB, in the presence of an alkali, to give a black solid complex has been noted by Kimura (Ref 43).
ACETONE, ANALYTICAL PROCEDURES

Detection of Acetone. The presence of acetone may be detected by the iodoform test, which depends on the fact that when acet is treated with iodine and Na hydroxide, iodoform and Na acetate are formed:

\[
\text{CH}_3\text{CO}_2\text{H} + 3\text{I}_2 + 4\text{NaOH} \rightarrow \text{CH}_3\text{I} + \text{CH}_3\text{COONa} + 3\text{NaI} + 3\text{H}_2\text{O}
\]

The presence of iodoform is detected by its characteristic odor or by formation of crystals. Other ketones, as well as aldehydes and alcohol interfere and should be detected separately. Description of qualitative test is given in Ref 16, p 619

Other qualitative tests for acetone include:

a) Dénigès mercuric sulfate test, described in Refs 2 & 19  
b) Dinitrophenylhydrazine test, described in Refs 10 & 19 and  
c) The Faught sodium nitroprusside test, described in Ref 16, p 685 (see also Ref 12)

Quantitative Determinations of Acetone. The oldest and still widely used method is the "Messing test", based on the iodoform reaction described above. This test originally described in 1888 (Ref 1) was also described in detail by Goodwin (Ref 5), Friedmann (Ref 6) and Bonner (Ref 13). Jacobs (Ref 16, pp 685-6) describes the test and its modifications and gives some additional refs. The modification of Baer (Ref 17) described below under "Determination of Acetone in Smokeless Propellants Also Containing Alcohol" was successfully used at PicArsn.

The quantitative test, known as the hydroxylamine hydrochloride test (Refs 8 & 16) or as the oximation method (Refs 15 & 20) is based on the following equation:

\[
\text{CH}_3\text{CO}_2\text{H} + 2\text{H}_2\text{O} + \text{NH}_2\text{OH} \rightarrow \text{CH}_3\text{NH}_2\text{OH} + \text{CO}_2 + \text{H}_2\text{O}
\]
(CH₃)₂ CO + NH₂OH · HCl → (CH₃)₂ C:- NOH + HCl + H₂O

In aq soln this reaction goes (in cold) to 95% completion and the same applies to some other lower ketones. For higher ketones it is necessary to heat the mixt to complete the reaction and this might decom the hydroxylamine hydrochloride.

Procedure:

a) Weigh a sample containing acetone into 250 ml vol flask and dil with w to the mark (conc of acet after diln shall be ca 1%)

b) Take a 10 ml aliquot in a 125 ml Erlenmeyer flask, add few drops of bromphenol-blue indicator (0.1% soln in 30% alc) and neutralize any alkalinity with 0.1N HCl soln

c) Weigh out approx 0.5g cp hydroxylamine hydrochloride, dissolve it in 5 ml w, add a few drops of bromphenol indicator and neutralize any free acidity with 0.1N NaOH soln

d) Add the hydroxylamine hydrochloride soln to the above acetone soln in 125 ml flask, stopper it and allow to stand for 45 mins. e) Titrate the liberated HCl (see the above equation) with 0.1N NaOH and calc the amt of acet, as follows:

\[
\text{% Acetone} = \frac{A \times N \times 0.05808 \times 100}{W \times 0.95}
\]

Where: A=ml of approx 0.1N NaOH used to neutralize the aliquot; N=normality of NaOH soln and W=total wt of sample

Quantitative tests other than Messinger and oximation methods are described in Refs 7, 10 & 11. Detns of acet in propellants are described in Refs 3, 4, 6, 7, 13 & 17. The proc of Ref 17 is given below under Determination of Acetone in Smokeless Propellants Containing also Alcohol.

Specification Requirements for Acetone Used in Ordnance. Acetone intended for use as a solvent in prep of propellants and pentolite shall comply with the requirements of US Spec JAN-A-489 and shall be tested according to the procedures outlined below:

a) Appearance. Acetone shall be colorless, transparent and show no turbidity when mixed with distilled water in any proportion. This test is conducted in a test tube or cylinder.

b) Distillation Range. Acetone shall distil completely (reach the dry point) within a range of 1°C. The temp 56.1°C shall be included within the distillation range at 760 mm Hg. The method in sect 100.1 of Federal Spec VV-L-791 shall be used.

c) Nonvolatile Matter — max 0.002 per 100 ml sample, is detd by evapg a 100 ml sample in a platinum dish on a steam bath, followed by drying the dish to const wt at 105-110°C.

d) Permanganate Reduction. The pink color shall persist for at least 30 mins when 0.5 ml of 0.1N K permanganate soln is added to a 100 ml graduate contg the sample. The graduate is stoppered and the soln is thoroughly mixed before it is allowed to stand at 15°C.

Note: According to Mr G.D. Clift, the following precautions shall be observed during this test:

1. Only glass stoppers shall be used for the sample bottles and the graduate.
2. The graduate shall be rinsed with HCl, distilled w and a portion of sample just before the test.
3. Only freshly prep'd soln of K permanganate shall be used as the lower oxides present in old solns catalyze the reaction and discolor the permanganate.
4. Sample shall not be placed in the sunlight.
5. There shall be no oxides of nitrogen or sulfur dioxide present.

e) Specific Gravity shall be 0.7915 to 0.7935 at 20/20°C when detd by a Westphal balance, chainomatic balance, sp gr bottle or pycnometer.

f) Alkalinity as NaOH — max 0.001%, when detd by titrating a 50 ml sample dissolved in 100 ml water with N/10 standard acid, using methyl red as an indicator.

g) Acidity as AcOH — max 0.001%, when detd by titrating with N/10 NaOH soln a 300 ml sample (previously reduced by vigorously boiling to 100 ml) dissolved in 300 ml distilled water neutral to ph ph.

h) Aldehydes — max trace, when detd by shaking a mixt of 10 ml acetone and 10 ml w
with 1 cc of the test solution (see below), allowing to stand for 1 hr and filtering the mixt. The filtrate tested with 1 ml of a 10% NaCl soln shall not give more than a trace of turbidity.

Note 1: The "test solution" is prep'd by mixing 1 ml of NaOH soln (9 g in 100 ml w) with 1 ml of Ag nitrate soln (9 g in 100 ml w), followed by adding dropwise enough Amm hydroxide (d 0.90) to just dissolve the ppt completely.

Note 2: Acetone used in manuf of pentolite may contain, according to G.D.Clift, the following amts of impurities: CO₂-up to 0.05%, mesityl oxide 100,000 ppm, formaldehyde 18500 ppm and tar (such as produced by the action of alkalies on TNT) 1,000 ppm.

Acetone Intended for Use as a Reagent shall comply with the requirements and undergo the tests described in Reagent Chemicals (1950), 24-5 (Ref 18).

Determination of Acetone in Smokeless Propellants Containing Also Alcohol. This method developed by M.Baer of PicArsn is described in Ref 17. Propellant used for this detm contd NC (13.2% N) 54.6 NG 35.5, Et Centr 0.9, carbon black 1.2, K chlorate (contg 0.5% Mg stearate & 0.5% Mg oxide) 7.6, and volatiles 0.2%. After investigating several existing methods of detn of acetone and finding most of them unsuitable for analysis of the above propellant, Baer decided that the most suitable would be Messinger's method (see Refs 1 & 5), and for alcohol - quantitative oxidation to acetic acid with an excess of K₂Cr₂O₇ in H₂SO₄ and titrating the iodine liberated by the excess of dichromate when it is allowed to react with KI.

Following is the procedure:

a) Assemble the digestion apparatus, which shall consist of two condensers vertically placed and connected at their tops by an inverted U tube. To the lower end of the 1st condenser is attached a 1500 ml flat bottom flask and the tip of the lower end of 2nd condenser is extended to the bottom of a 250 ml flat bottom flask. All connections shall consist of std ground glass joints.

b) Cut the sample into ca 1/4" in diam and 1/2" in length as rapidly as possible, weigh in a stoppered bottle (5 g in case of finished propellant and 25 g in case of green one) and transfer to the 1500 ml flask of the digestion apparatus. Add 500 ml w, 100 ml of 30% NaOH soln, several pieces of porcelain to prevent bumping and a small piece of paraffin to prevent frothing.

c) To the 250 ml flask of the digestion apparatus (which is marked to indicate vol of 150 ml), add enough w to cover the bottom with a 1/4" layer. Connect the digestion app. Immerse this flask in ice-water and let tap w run through the 2nd condenser, but keeping the 1st condenser just full but the w not running.

d) Heat the 1500 ml flask slowly so that 3-4 hrs will be required to collect 150 ml of distillate. At the end of this period propellant should be completely disintegrated, and if not continue the distillation.

e) Disconnect the 250 ml flask (receiver) from the 2nd condenser and add 10-15 g of anhyd Na sulfate. Continue to keep the distillate in the ice-bath for 15-20 mins longer and then filter by means of a No 41 Whatman (or equivalent) catching the filtrate in a 250 ml volumetric flask. Rinse the receiver flask and filter paper with two 25 ml portions of w catching the washings in the above vol flask.

f) Allow the flask and contents to come to RT and fill the flask to the 250 ml mark with w.

Estimation of Acetone: g) Pipette 25 ml aliquot to a 250 ml iodine flask contg 50 ml of N/1 NaOH soln, stopper and allow to stand 5 mins.

h) Add from a burette about 25% excess of 0.1N iodine soln while continually and vigorously swirling the flask. Stopper the flask and allow to stand at least 10 mins (20 mins in cold weather).

Note: If the flask is not swirled vigorously while adding iodine soln and if iodine is not added in 25% excess, the reaction will not go to completion and much iodine remains uncombined. This will require 3 times as much thiosulfate on back titration of
iodine. The excess of iodine may be either
calcld or detd by preliminary titration  

i) Neutralize the NaOH by adding 25 ml of 2N
sulfuric acid and then 0.3–0.4 ml in excess.

Note: If a larger excess of acid is added,
more thiosulfate will be required to titrate
the excess of iodine than necessary. The
exact amt of acid necessary for neutraliza-
tion of caustic may be established by pre-
liminary titration of 50 ml N/1 caustic with
2N acid in presence of phpt indicator

j) Add from a burette, while swirling the
flask, 0.05N Na thiosulfate soln until the
yel color just remains visible; then add
some freshly prepd starch soln and continue
titration to the appearance of a bluish color

k) Run a blank using the same vol of iodine
soln but no sample

\[
\% \text{ Acetone} = \frac{(A-B) \times N \times 0.96747}{W}
\]

where \( A = \text{ml of Na thiosulfate soln used}
\) to titrate a blank, \( B = \text{ml of Na thiosulfate}
soln to titrate the sample, \( N = \text{normality of thiosulfate}
\) soln and \( W = \text{g of sample represented}
\) by aliquot portion

Note: Analysis of alcohol is included here
because it can be run simultaneously with
acetone, using the same distillate

**Estimation of Alcohol:**

\( g^{1} \) Pipette 25 ml
aliquot of procedure (f) to a 250 ml flat bot-
tom flask contg 25 ml \( w \), cool the flask for
15 min in an ice-water bath, add ca 0.20 g
of \( K_2Cr_2O_7 \) (accurately weighed) and 6 ml
concd \( H_2SO_4 \)  

\( h^{1} \) Attach to the flask (by
means of a ground glass joint) a reflux con-
denser. Bring the contents to a boil in 10–
15 mins and allow it to boil for 5 mins.

\( i^{1} \) Disconnect the flask from the condenser
and cool to \( RT \). Dilute the contents to
c\( 100 \text{ ml with } w \), and add 3–4 g \( \text{KI} \)

\( j^{1} \) Stopper immediately, agitate by swirling and,
after allowing to stand 3 mins, titrate the
liberated iodine with std 0.1N Na thiosulfate
soln in the manner described in proc (j)

\[
\% \text{ Alcohol} = \left[ \frac{A - (0.049 \times B \times N)}{W} \right] \times 23.44
\]

where \( A = \text{g of } K_2Cr_2O_7 \text{ used}; \ B = \text{ml of}
Na thiosulfate soln used to titrate the sam-
ple; \( N = \text{normality of thiosulfate and } W = \text{g}
\) of sample represented by aliquot taken

Ref(s) (Acetone, Analytical):

1) A. Messinger, Ber 21, 2366 (1888) & J SCI 18, 138 (1889)
2) G. Dénigès, J PharmChim 9, 7 (1899) & Analyst 24, 92 (1899) (Detn of small quantities of
acet, such as in air, by treating the sample
with a large excess of acidic mercuric sul-
fate and heating to 100°. An insol compd
\( (2HgSO_4 \cdot 3HgO)_6 (C_8H_4O)_2 \) is deposited.
This method is also described in Ref 19)
3) A. Pieroni, Atti Accad Lin 27, II, 52–7 (1918)
JSCI 37, 749A (1918) & CA 13, 789 (1919)
4) C. F. van Duin et al, Rec 38, 163–9 (1919)
& CA 13, 2596–7 (1919)
5) L. F. Goodwin, JACS 42, 39–45 (1920) (Analysis of acet by the
Messinger method was found to be accurate)
6) F. Friedmann, SS 16, 121–3 (1921) & CA 16, 343 (1922) (Detn of acet in NG propellants
conducted by passing a slow current of
\( CO_2 \) or \( N_2 \) through a U tube filled with fine shav-
ings of sample and immersed in a water bath
at 75°. The acet of sample is volatilized
and passed into buret filled with 23% KOH
soln, where it is absorbed. The soln of KOH
diluted to 100 ml and a 20 ml aliquot is
placed in iodine flask where acet is detd by
the Messinger method)
7) M. Marqueyrol & P. Loriette, MP 19, 362 (1922) & CA 17, 1717
(1923) (Detn of acet based on the addn to a
soln contg sample \( K \) iodide and Na hypochlo-
rite in the presence of alkali, until the 1st
appearance of free iodine, which may be de-
tected by starch-bicarbonate indicator)
8) M. Morasco, JEC 18, 701 (1920) (The air contg
acet is drawn through bubblers contg 0.2%
hydroxylamine hydrochloride soln and the
amt of acet is estimated by titrating HCl
liberated through the formation of acetoxime,
with std NaOH in the presence of methyl
orange indicator) (see also Refs 15 & 16)
9) C. A. Adams & J. R. Nicholls, Analyst 54,
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5–9(1929)(Analysis of mixts contg acetone, ethanol & isopropanol) 10)H.A.Iddle & C.E. Jackson, AnalChem 6,454–6(1934)(Acet, as well as other carbonyl compds, reacts quantitatively with 2,4-dinitrophenylhydrazine with formation of solid hydrazide. This procedure seems to be only approximate) 11)E.K.Nikitin, ZhPrikKim 9,1543–6(1936)(in Fr) & CA 31,2126(1937)(Rapid detn of acetone in w conducted by mixing 1 ml of soln to test azoacetone, Azidopropanone or Acetonylazidone with 1 ml of 0.2% furfural and 1 ml KOH soln. nmp 99.09, N42.41%. Treat in a similar manner 1 ml w contg 0.05% Col, very refractive 'oil bp 33...50 at 1 mm and 1 ml w contg 0.025% serving as standards. Compare the rates of pptn of sample with those of standards and calc concn of acet from the formula given in paper. The accuracy of the method is ±5%) 12)Kirk & Othmer, l(1947),92(Analytical procedures and specs for acet) 13)T.G.Bonner, Analyst 72,434–39 (1947) 14)W.B.Huckabay et al, AnalChem 19, 838–41(1947)(21 refs)(Optimum conditions for titrimetric detn of acet in liquefied gases) 15)R.Dalbert & J.Tranchant, MP30,343–51(1948)(Dent of acet & ethyl acetate in propellants)(36 refs)(After briefly describing and criticizing the principal methods of detg acet in propellants, such as those of Messinger, Marqueyrol & Loriette and Bonner, D & T give, on p 349, their modification of the oximation method described in Refs 8 & 16. D & T claim that their modification gives accurate results and that alcohol and ethyl acetate do not interfere) 16)Jacobs(1949), 619 & 685–7 (Estimation of acetone by the iodoform method, by the Messinger method and by the Morasco method, called by Dalbert & Tranchant the oximation method)(See also Refs 1,5,8 & 15) 17)M.Baer,ChemLabRept 130,159; PicArsn,Dover,NJ(1950) 18)Reagent Chemicals(1950),24–5 19)A.Boulègue, MSCE 36,257–8(1951)(Micro dent of acet in air by the method of Déniges, described in Ref 2 and by the method dinitrophenylhydrazine) 20)J.-P.Pillet,MP 36,267–75(1954) (Analysis of mixts contg acet, ethyl acetate and alc employed for prepn of some Fr propellants and for recovery of some discarded propellants. In the method of Pillet, first the density of mixt is detd at 18°, then acetone by oximation(see Ref 15), ethyl acetate by saponification and alc by difference)

Acetoneallylozonide. See Allylacetoneozonide

Acetoneallylperoxide. See Allylacetonelperoxide

Acetone, Azido Derivative(Azidoacetone, Triazocetone, Azidopropanone or Acetonylazido-mide), N3-CH3·CO·CH3, mw 99.09, N42.41%. Col, very refractive 'oil bp 33...50 at 1 mm d 1.1132 at 25/4°C, nD 1.4515(Refs 1 & 2); bp 42–3° at 2 mm (Ref 4),bp 30° at 1 mm (Ref 5); sol in w. Detonates on heating and decomp in storage. Can be prepd by shaking chloroacetone with concd aq soln of Na azide and a small amt of AcOH


Acetone, Diazido Derivative or 1,3-Diazido-2-propanone, N3·CH3·CO·CH3·N3, mw 140.11, N50.99% – not found in Beil or CA through 1956

Acetone-Azidoacetylhydrazide, called in Ger Acetyl-[azidoacet]-hydrazid or Isopropyliden-[azidoacetyl]-hydrazine(CH2)3C·N·NH·CO·CH3·N3, mw 155.16, N45.14%. Wh ndls (from acet), mp 114°. Was prepd from azidooacetic anhydride and acetone. No info on expl props

Refs: 1)Beil 2,(101) 2)Th.Curtius & A.Bock- mühn, Ber 45,1033(1912)

Acetone-[4-bromphenylhydrazone]-peroxide (Peroxyd des Aceton-p-bromphenylhydrazons, in Ger), (CH3)2C-N-NH-C6H5Br, mw 259.16, \[O2\]

N10.81%, OB to CO2 –132.7%, OB to CO –77.1%. YeI,unstable prisms from ligroin, mp 45–47° with decomp; expl on heating. Sol in most org solvents. Can be prepd by passing air through cold, agitated acetone-[4-bromphenylhydrazone], suspended in ligroin(Ref 2)
Acetone Compound, C₂H₂N₈O₄, (No structural formula given), mw 658.56, N₃8.29%, bright yellow lifts. Was prepared by pouring acet into ice cold nitric acid (d 1.5), cooling and adding to the resulting oil an excess of ammonia. Its trinitro derivative, C₂H₁₅N₁₈O₁₂, (No structural formula given), mw 793.59, N 37.07%, yellow needles, mp 193-5°, was prepared by dissolving compound C₂H₁₂N₈O₄ in nitric acid (d 1.5) and pouring immediately into water. No expl props of either compound were mentioned.

Acetone Compounds of Pentaerythritol are described by L.Orthner, Ber 61B,116-18(1928). None of them is an explosive.

Acetonediperoxide. See Acetoneperoxide, Dimeric

Acetoneditetrazyl Azide. See under Acetylnitroazides

5-Acetonehydrazone-a(1H)-tetrazole, called Acetone 5-tetrazolylhydrazone by Benson,

\[ (CH₃)₂C:N-NH-C-NH₂, \text{ mw } 140.15, \]

N 59.97%, OB to CO₂-137.0%. Cryst, mp 181.5°. Sol in w; sol in acet, alc and Et acet. Was prepared from 5-hydrazinotetrazole hydrochloride and acetone in the presence of Na acetate. Its expl props were not examined.

Acetone Insoluble Test is one of the standard tests for detecting the purity of expls and propellants. It is conducted by dissolving a weighed amt of sample(W) in measured vol of acet at RT and filtering the soln through a tared sintered glass crucible(W). After rinsing the residue with acet and drying the crucible in an oven to const wt, it is reweighed(W₂).

\[ \% \text{ Acetone Insoluble} = \left( \frac{W_2 - W_1}{W} \right) \times 100 \]

(See also under individual compounds)

Acetonemonotetrazylazide. See under Acetylnitroazides

Acetone, Nitration. Krauz & Stepanek (Ref 1) attempted to prepare tetranitromethane by nitration of acetone, but failed. Instead, they obtained (after treating the resulting product with a silver salt) a very expl solid claimed to be Ag salt of "acetylmethylnitrolic acid," also called a-nitro-a-isonitroso-acetone.

Hass & Hudgin (Ref 3) nitrated acetone, using a vapor-phase nitration technique described in Ref 2. The high-boiling fraction from the nitration gave an odor of acetic acid, an acidic reaction inaq soln, a red color with ferric chloride and a yellow salt with Ag nitrate soln, which was water sol and partially decompd on distil. Attempts at its further purification and prep of other derivs were unsuccessful, primarily due to instability of the compd. The paper (Ref 3) does not give the compn of high boiling fraction of nitration and does not state whether the substance was solid or liquid.

(See also Nitroacetone, described below)
very sol in benz. It was prep'd in 1899 by Lucas (Ref 4) from iodoacetone and Ag nitrate in ethereal soln at 0°. This is an indirect method of prep'n as were the methods of Harries (Ref 5) and Wieland & Block (Ref 6). It was claimed by Henry (Ref 2) that O. de Battice prep'd nitroacetone in 1895 in Belgium by oxidation of nitroisopropanol with chromic mixture. Henry described the compd as a col, mobile liq with a sharp odor, d 1.070 at 14°, bp 152° at 767 mm and insol in w.

Lucas claimed (Ref 3) that the compd described by Henry was not nitroacetone, but this statement was disputed by Henry (Ref 4). Harries also claimed (Ref 5) that the compd described by Henry is not nitroacetone.

More recently, Hass & Hudgin (Ref 7) claimed that they had isolated some nitroacetone from the high-boiling fraction of the vapor-phase nitration of acetone but it is not clear from their paper whether the substance was liq or solid. Hurd & Nilson (Ref 8) prep'd nitroacetone as pale-green crysts, mp 47°, by oxidizing 1-nitro-2-propanol with sodium peroxide (Baker's Analyzed) and cooled to 0° in an ice bath. Then 3 ml of dil sulfuric acid (4:1) was added at such a rate to keep the temp below 50° but was not allowed to exceed 60°(by temporarily cooling the mixt in an ice bath). The material separated as an oily liq which tended to float on the watery layer. It was purified by dissolving it in ether, washing the ethereal soln three times with w and finally evaporating on a steam bath with a slow current of air. The resulting white solid was dried for

**ACETONE PEROXIDES**

Two peroxides are known, dimeric and trimeric

**Acetoneperoxide, Dimeric or Diacetone Di-peroxide** (Acetonediperoxide, Dimeric Aceton peroxide, Acetonedimer Peroxide, Cyclo diacetone Peroxide or Dicycloacetone Peroxide) (Was called in Ger Dimolekulares-aceton-superoxyd, Polymeres-acetonsuperoxid or 3, 3, 6, 6-Tetramethyl-1, 2, 4, 5-tetraoxan),

\[
\text{OO} \quad \begin{array}{c}
\text{(CH}_3\text{)}_2\text{C} \\
\text{C} \\
\text{(CH}_3\text{)}_2 \\
\text{CO}_3 \text{, mw 148.16, OB to CO} \\
\text{-151.2%, OB to CO}_3 \text{ -86.4}. \text{ Col prisms(from Et acet), mp 131.5-133°, very volat. Insol in w and dil acids & alkalies, unaffected by boiling in w for 6 hrs. Was prep'd by Baeyer & Villiger (Ref 2) by treating a cooled ethereal soln of acet with Caro's reagent prep'd by rubbing K persulfate with concd sulfuric acid and then adding K sulfate). Pastereau(Ref 3) prep'd the peroxide by treating acetone with 2% hydrogen peroxide in sulfuric acid soln. Other methods of prep'n(including ozonization of acet) are given in Refs 4,5,7,8 and in some of the addnl refs.}
\]

Phillips (Ref 6) attempted to prepare the dimeric acet peroxide by the method of Ref 2 but obtained the trimeric form instead. However, he succeeded in preparing the dimeric form by using the following method: 5 ml of acetone was mixed with 2 ml of 30% hydrogen peroxide (Baker's Analyzed) and cooled to 5° in an ice bath. Then 3 ml of dil sulfuric acid (4:1), was added at such a rate that the temp rose to 50° but was not allowed to exceed 60°(by temporarily cooling the mixt in an ice bath). The material separated as an oily liq which tended to float on the watery layer. It was purified by dissolving it in ether, washing the ethereal soln three times with w and finally evaporating on a steam bath with a slow current of air. The resulting white solid was dried for

**Acetone Oxime. See Acetoxime**

**Acetone, Ozonization.** According to Schroeter (Ref 1) a product contg active O was prep'd by treating acetone with ozonized O or air. No compn was given. Briner & Meier (Ref 2) attempted to ozonize acet in a gaseous form, but instead of prep'n an acet ozonide, they obt'd CO₂, HCOOH & HCHO. Doevre (Ref 3) conducted ozonization of acet in solns. Schroeter (Ref 4) conducted ozonization of acet in the presence of org catalysts, particularly ether. No compns of resulting products were given.

2 hrs and bottled. It explodes violently on heating, impact or friction.

Following props (Ref 6) of dimeric acetone peroxide were detd at PicArsn: action with match flame - a slight puff; brisance by sand test - 30.1 g sand crushed when 0.4 g of peroxide was initiated with 0.2 g MF, vs 48.0 g sand crushed by 0.4 g TNT; impact sensitivity, BurMinesApp with 2 kg wt - 7 cm, vs 60+ for TNT; minimum detonating charge in sand test - 0.19 g MF; volatility - 66.4% loss of wt at RT after 14 days and complete volatilization without residue after 3 hrs at 75°.

Its toxicity is unknown and fire & expln hazards are moderate (Ref 11).

Rohrlich & Sauermilch (Ref 6a) say that high sensitivity and extreme volatility of dimeric peroxide exclude it from practical consideration. It was recommended, by Nahsen (Addnl Ref a) for use in fuzes, detonators and caps and by Thiemann (Addnl Ref c) as an additive to Diesel fuels.


Addnl Refs on Dimeric Acetone Peroxide:
a) Sprengwerke Dr R. Nahsen, Ger P 423, 176(1925) & BritCA, Sect B(1926), p 613 (Use of acetone peroxides in fuzes, detonators and caps in lieu of MF)  b) N. V. de Bataafse Petroleum Maatschappij, Brit P 444, 544(1936) & CA 30, 5588(1936); Ger P 671, 012(1939) & CA 33, 3399(1939)

Acetone peroxide, Trimeric or Triacetone Triperoxide (Acetonetriperoxide, Trimeric Acetone Peroxide, Acetonetriperoxide, Cycloacetonetriperoxide, or Tricycloacetone Peroxide) (Called by Wolfenstein Tricycloacetone-superoxyd and by Rohrlich and Sauermilch Tricycloacetoneperoxyd),

$$\text{O} - \text{C} \left(\text{CH}_3\right)_2 - \text{O}$$

$$\text{O} \quad \text{O}$$

$$\text{O} \quad \text{O}$$

$$\left(\text{CH}_3\right)_2 \text{C} - \text{O} - \text{O} - \text{C} \left(\text{CH}_3\right)_2,$$

mw 222.23, OB to CO, O5 - 151.2%, OB to CO - 86.4%. Col volat crysts (from eth), mp 94-5°.
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(Ref 3); ndls, mp 96.5° (Ref 1, p 714) or crysts, mp 98.5°(Ref 9); d 1.2 (Ref 4); volat with w vapor; non-hygroscopic. Insol in w, acids & alkalies and unaffected by boiling in w for 6 hrs; decmpd by hot dil sulfuric acid. It is diff sol in methanol, glycerin & isoamyl alc. Its soly in some org solvents at 17° is as follows: absol alc 0.15, ether 5.5, acet 9.15, C disulfide 9.97, C tetrachloride 24.8, trichloroethylene 22.7, benz 18.0, pyridine 15.4, chlf 42.5 & petr eth 7.35%(Ref 13)

Trimeric acetone triperoxide was first prepd by Wolfenstein (Ref 2) from acet, 50% hydrogen peroxide and a small amt of phosphoric acid. This method required 4 weeks. Much simpler and more rapid was the method of Baeyer & Villiger (Ref 3), which consisted of adding (with cooling) concd HCl to a mixt contg equal amts of acet and 50% hydrogen peroxide. More recent methods of prepn are given in Refs 7,9,10,11,13,14 and in some of the additional references. The method of prepn used at PicArsn is described in Ref 10. In this, 5 ml of acet were mixed with 2 ml of 30% hydrogen peroxide (Baker’s Analyzed) and cooled to 5° in an ice bath. Then 3 ml of dil sulfuric acid (4:1) was added dropwise, the temp not being allowed to rise above 10°. The white flocculent ppt which formed instantly was shaken out with ether and the ethereal soln was washed 3 times in a separatory funnel with cold w. The ether was evapd on a steam bath using a slow current of air and the crysts of peroxide were air dried for 3 hours.

The proced used by Ficherouille & Kovache (Ref 13) consisted of adding in small portions a total of 5 cc of concd sulfuric acid to a small flask contg 16 g of acet (wellcooled in ice w). The flask was shaken vigorously after each addn and the temp was not allowed to rise above 25°. A total of 32 g of 45% hydrogen peroxide was added in small portions while the flask was kept in ice-w and then the mixt was allowed to stand overnight. The crysts were then separated by filtration and, after rinsing them with a large amt of ice w, were dried in a desiccator over anhyd Ca chloride.

Trimeric acetone peroxide expld violently on heating, impact or friction. It is highly brisant and very sensitive. It may be deton under water or when it contains up to 25% of moisture (Ref 15)

Its expl and some other props were determined in Germany (Refs 4 & 11), France (Refs 7 & 13), USA (Ref 10) and Russia (Refs 12 & 15)

Following are some properties:

*Action of flame*, burned violently and sometimes detond

*Action of heat*, as detd by Patry (Ref 7) by placing small samples of ca 0.005g on a "block Maquenne," the sample melted at 97° and then up to 245° it vaporized without decom; between 245 & 250°, it either decom without flame, burned with smoky flame, or deton; between 250 & 285° it deton vigorously; between 285 & 305° it behaved in a manner similar to that described for the 245-250° range; over 305° it ignited with a smoky flame without deton

*Brisance* by the Lead Plate Test was detd by Rohrlch and Sauermilch (Ref 11) with caps contg as top charge: 0.05, 0.1, 0.2 or 0.3 g trimeric peroxide (compressed to 250 kg/cm²), an intermediate charge of 0.3 g PETN (compressed to 250 kg/cm²) and a base charge of 0.5 g PETN (compressed to 500 kg/cm²). The holes punched by these caps were comparable to those produced by No 8 caps

*Brisance* by the Sand Test was detd by Phillips (Ref 10) using 0.4 g sample initiated with 0.2 g MF. The amt of sand crushed was 34.1 g (TNT 48.0 g)

*Burning rate* at 1 atm of a highly compressed cylinder of peroxide – 0.95 cm/sec (Ref 12)
Compatibility with explosives. Equal wt of peroxide with PA, TNT, RDX, PETN, tetryl, KCIO₃, AN, or Sb₂S₃, stored for 40 days at 50°, registered loss of wt equal to about 50% due to complete volatilization of the peroxide; there was no decompo of PA, TNT, etc (Ref 13)

Compatibility with metals. Strips of metals (Cu, Al, Zn, Sn, brass or Fe) stored with peroxide for 15 days showed no signs of corrosion: a slight corrosion was observed with lead (Ref 13)

Detonation velocity -5290 m/sec as dened in column 6.3 mm diam and d 1.2 (Ref 4); 3065 m/sec, as dened in a column 15 mm diam and with d 0.68 (Ref 11); 3750 at d 0.92 and 5300 at d 1.18 (Ref 5a)

Friction sensitivity. Extremely sensitive (Ref 4a)

Impact sensitivity with Bur of Mines App and 500 g wt, 10 cm (Ref 10)

Impact sensitivity with the French app called “petit mouton” using 50 g wt, 15 cm for 50% detonations (Ref 13)

Note: Results of impact sensitivity tests show that acetone triperoxide is one of the most sensitive explosives known

Initiation test. A 0.05 g charge of peroxide, compressed at 250 kg/cm², caused PETN to detonate. When compression of the peroxide was increased to 500 kg/cm² partial failures resulted (Ref 11); min chge of peroxide to detonate TNT at d 1.35 in Cu tube 0.16 g (Ref 5a)

Power by the Trauzl Test. A 10 g sample gave expansion of 250 cc vs 285 cc for TNT (Ref 11)

Minimum detonating charge of MF in the sand test 0.19 g (Ref 10)

Toxicity, Fire & Explosion Hazards are discussed in Ref 18

Volatility. Sublimes even at ord temp (14-18°), losing about 6.5% of its wt in 24 hrs (Ref 11); loses 68.6% of its wt in 14 days at room temp (Ref 10); loses 1.5% in 2 hrs at 50° (Ref 11), loses 100% in 3 hrs (Ref 10). At 100° it volatilizes very rapidly, depositing fine needles on the cover (Ref 11)

Uses. It has been recommended for use in primers, detonators, etc (Refs 13, 14 & a), but due to its high volatly and high sensitivty it does not seem very desirable for military use

Refs on Trimeric Acetone Peroxide:

Addnl Refs on Trimeric Acetone Peroxide:
a) Sprengstoffwerke Dr Nahnse, Ger P 423, 176 (1925) & Brit CA, Sect B, 1926, 613 (Use of acet peroxide in detonators, caps and fuezes in lieu of MF) b) A. E. Thiemann, ChZtr 1942II, 275-8 (Acet peroxides are claimed to be effective ignition promoters when added to Diesel fuels) c) R. Acree & H. L. Haller,
JACS65,1652–3(1943) (Small quantities of the trimer are claimed to be present in isopropyl alcohol left standing for several years. This peroxide might be a cause of explosions of stored isopropyl alcohol, occasionally reported in literature) d)Gévelot & Gaupiat, FrP 893,941(1944) & CA 47,8374(1953) (Trimeric acet peroxide combined with PA and RDX gave explosives of high power and velocity of detonation. Such mixtures were less sensitive to shock than ordinary primary explosives. A still higher vel of detn may be achieved by replacing the metallic(Cu or brass) container for explosives (eg NC + black powder) e)F.I.Berezovskaya et al, ZhurFizKhim18,321–8(1944) & CA 39,2024(1945) (Effect of catalytic addition on the decomp of acet peroxide is discussed) f)M.Kolobielski, CR 237,1717-18(1935) & CA 49,1696(1955) [Mixt of trimeric and dimeric peroxides may be obtained by total ozonization of 2,2,3,5-tetramethyl-2-(β,β-dimethylvinyl)-2,3-dihydrofuran] Acetonepiperonylhydrozone or Acetone-(2,4,6-trinitrophenylhydrozone)\((\text{CH}_3)_2\text{C}:\text{N}:\text{NH}^+\text{C}_6\text{H}_4(\text{NO}_2)_3^-, \text{mw} 283.20, \text{N}24.73\%\), Yel or brn ndls, mp ca 125°, dec ca 130°. Was prepd by heating picryl hydrazine with acetone in alc et al, Ber 65B, 1188(1932) & CA 26,5071(1932) or AcOH so In. No info on expl props


Acetonetetrazyl Azide. See under Acetonyl-tetrazoles and Derivatives

Acetonetriperoxide. See Acetone Peroxide, Trimeric

ACETONITRILE AND DERIVATIVES

Acetonitrile, Cyanomethane or Methyl Cyanide (Ethanimonitrile or Methanocarbonitrile), \text{CH}_2\text{CN}, \text{mw} 41.05, \text{N}34.12\%\), OB to CO\(_2\) –214.4\%, OB to CO –136.4\%. Col liq, fr p –41° to –44°, bp ca 82\°, d 0.7828 at 20\°/4\°, n 16.51.3496, vap press 100 mm at 27\°,

1 p(Cleveland open cup) 55°F, \(Q^P_{\text{c}}\) 304 kcal/mol, \(Q^-\) –16 kcal/mol (Refs 2 & 3) \(Q^V\) detd at PicArsn, 1324 cal/g with w liq (Ref 3a). Miscible with w, alc & eth. Can be prepd by dehydration of acetamide or by other methods. Used as a solvent for many org compds(among them RDX, HMX, etc) and as a starting material for the prepn of some org compds. Its toxicity and fire hazard are discussed in Ref 6. The expl hazard is great when acetonitrile is exposed to heat, flame or chem reactions with oxidizers. It forms an azeotrope with water


Mononitroacetonitrile, Nitrocyanomethane or Nitromethylcyanide (Nitroethanenitrile), \text{N}_2\text{·CH}_2\text{·CN}, \text{mw} 82.07, \text{N}68.28\%. Col liq, bp 53\° at 12 mm, vinyl)-2.3-dihydrofuran\] deflagrates when dropped on hot plate. Was prepd from chloroacetonitrile and Na azide in trinitrophenylhydrazone) (\text{CH}_3\text{)}, C:N*NH--\text{aq} c,51-

\text{NO}_2' \text{mw} 283.20, \text{N}24.73\%\), Yel or \bn Rf:1Bi o on )ruebr ndls, mp ca 1250, dec ca 1300. Was prepd by heating picryl hydrazine with acetone in alc et al, Ber 65B, 1188(1932) & CA 26,5071(1932) or AcOH so In. No info on expl prp (no other refs in CA through 1956)

Refs: 1)Beil – not found 2)K.Freudenberg et al, Ber 65B,1188(1932) & CA 26,5071(1932) (no other refs in CA through 1956)
Ref:s: 1)Beil 2,227 & (100) 2)W. Steinkopf et al Ber41, 1048-9 (1908) & 42, 619(1909) 3)A.H. Blatt et al, OSRD 2014 (1944)

Dinitroacetonitrile or Dinitrocyanomethane (Dinitroethanenitrile), \((O_2N)_2CHCN\), mw 131.05, N 32.07%, OB to CO \(-6.1\%\), OB to CO +18.3%. Solid, expl on heating or impact. It was prepared in impure state in 1861 by Schischkoff on heating its Amm salt with aq sulfuric acid and extracting with ether. The Amm salt was obtained by treating triacetonitrile (qv) with hydrogen sulfide: \(O\) to \(CO\), +210\%., \(O\) to \(CO\) -126.2%. \(CN(\text{NO}_2)\), +4HS \(\rightarrow\) C\(_2\)N(\text{NO}_2)\(_2\) (\(\text{NH}_4\))\(_4\) +4S + Col liq, d 0.9737 at 20°/40°, mp ca -9°, bp 194° at 754 mm, vap press 0.43 mm at 86°.

Dinitroacetonitrile forms salts, some of which are explosive, e.g., silver salt, Ag\(_2\)CN\(_3\)O\(_4\), expl violently on impact.

Treatment of dinitroacetonitrile or its Amm salt with fuming nitric acid gave the nitroacetonitrile described below.

Ref:s: 1)Beil 2,228-9 2)L. Schischkoff, Ann 119, 249-50 (1861) (not in CA through 1956)

Trinitroacetonitrile or Trinitrocyanomethane (Trinitroethanenitrile), \((O_2N)_3C\cdot CN\), mw 176.05, N 31.83%, OB to CO +18.2%, OB to CO +36.4%. Yellow volatile crystals with pungent odor, mp 41.5° and expl on rapid heating ca 220° (Ref 1 & 2); sol in eth, decomposed by w or alc. Was first obtained in 1857 by Schischkoff on treating Na fulminurate with mixed fuming nitric-sulfuric acid in the cold (Ref 3). The same investigator obtained it in 1861 from dinitroacetonitrile and its Amm salt (Ref 3).

According to Blatt (Ref 4) its lead block expansion value is 182% of PA and FI (figure of insensitivity) 6% PA.

Following props were detd at PicArsn and given in unclassified reports (Ref 5 & 6):

- \(Q_v\) 1324 cal/g with w liq and 982 cal/g with w vapor; impact sensitivity, BurMines app with 2 kg wt 15 cm or less.
- Trinitroacetonitrile is a very powerful expl., and may be suitable for use in primers and detonators.


Acetonylaceton, Azido- and Diazido-Derivatives – not found in Beil or CA through 1956

Mononitroacetonylacetone and Dinitroacetonil-acetone – not found in Beil or CA through 1956

ACETONYLTETRAZOLEs AND DERIVATIVES

5-Acetylnyl-\(\alpha(1H)\)-tetrazole (C-Acetylnyl-tetrazol or Acetessig-tetrazotsäure, in Ger), \(CH_3\cdot CO\cdot CH_2\cdot C\cdot NH\cdot N\), mw 126.12, N44.43%, || NO || N

OB to CO -126.9%. Crystals, mp 114°, easily sol in w or alc. Can be prepared by heating 1,3-dioxotetramethylene-1,2-carboxamide
with w, eliminating 2 molecules of CO₂ (Ref 2)

Refs: 1) Beil — not found  2) G. Schroeter & E. Finck, Ber 71, 683–84 (1938) 3) F. R. Benson, Chem Revs 41, 6 (1947)

Acetonilazidotetrazole or Azidoacetonyltetrazole, called by Friederich Acetonenomonotetrazylxazide, C₆H₅NO·O·N₃ (no structural formula given in CA), mw 167.14, N 58.67%, OB to CO₂ -90.9%, OB to CO -52.7%. Solid, explodes on heating. Can be prep by interaction of monochloroacetone with tetrazylazide

It was claimed by Friederich & Dynamit A–G to be a powerful expl, which can be used either alone or in combination with other exps, such as RDX, PETN & tetryl, or as a primary compd in detonators. Usual constituents of primary mixes such as tetracene, Ca silicide, glass powder, Sb sulfide, Pb dioxide, Ba nitrate, etc may be admixed with acetonilazidotetrazole

Refs: 1) W. Friederich, USP 2, 170, 943 (1939) & CA 34, 265 (1940) 2) Dynamit A–G, FrP 841, 768 (1939) & CA 34, 4574 (1940) 3) Dynamit A–G, BrP 510, 992 (1939) & CA 34, 5664 (1940) 4) W. Friederich, GerP 695, 254 (1940) & CA 35, 5318 (1941)

Acetonilazidotetrazole, called by Friederich Acetoninatedtetrazylxazide, (N₅CN₃)·H₄·C·CO·CH₃·(N₅CN₃), mw 276.19 N 71.01%, OB to CO₂ -63.7%, OB to CO -34.8%. Solid, expl on heating. Was prep by interaction of sym-dichloroacetone, Cl·H₄·C·CO·CH₃·Cl with 2 mols of tetrazyl azide

It was patented by Friederich & Dynamit A–G for the same purposes as acetonilazidotetrazole

Refs: — same as above

Aceto-Perchloric Acid Mixtures. See Perchloric Acid—Acetic Anhydride—Water Mixtures

ACETOPHENONE AND DERIVATIVES

Acetophenone or Methylphenylketone (Acetylbenzene or Hypnone)(AcPh or MeCOPh), CH₃·CO·C₆H₅, mw 120.14, OB to CO₂ -253.0%, OB to CO -146.5%. Col crysts, mp 20.5°, bp 202° (83.5° at 12 mm), d 1.0266 at 25/25°, n D 1.5337, fl p 221°F (140.5°) (Ref 5). Insol in w but miscible with all common org solvents. According to Kirk & Othmer (Ref 2), it was first prepd in 1857 by Friedel by distn of a mixt of Ca benzoate and Ca acetate. Commercially, acetophenone is prepd by the Friedel–Crafts reaction using benz,Al chloride and acetic anhydride.

It is an excellent solvent for NC (Ref 3), as well as for other cellulose esters & ethers (Ref 2). Its toxicity is unknown and its fire hazard is slight when exposed to heat or flame. It can react with oxidizing materials


Acetophenone, Azido Derivatives, C₆H₅N₃O, mw 161.16, N 26.07%. Two isomers are described in the literature: ω–Azidoacetophenone, Triazoacetophenone, Phenacyl Azide, Benzoylazidomethane, N·C₆H₅·CO·C₆H₅ plates (from eth + petr eth), mp 17°. Reacts very explosively with concd sulfuric acid. Was prepd by prolonged shaking of ω-bromoacetophenone with Na azide in aq alc, with cooling

Refs: 1) Beil 7, (154) 2) M. O. Forster & R. Müller, JCS 97, 140 (1910) & CA 4, 1606–7 (1910) 3) J. H. Boyer, JACS 74, 4507 (1952)

2–Azidoacetophenone or 1–Acetyl–2-azidobenzene, CH₃·CO·C₆H₄·N₃, crysts (from ligroin), mp 22–22.5°. Can be prepd by treating (2-acetyl-benzenediazo)–hydroxyiamide CH₃·CO·C₆H₄·N·N·OH with dil sulfuric acid. No ref to its expl props

Diazidocetophenone, C₇H₇ON₃, mw 202.18, N41.57%. One isomer, called o-azidophenacylazide, N₆·CH₂·CO·C₆H₄·N₃, wh ndls, mp 37–8°C prep by Beil & Straw by treating a dil acid soln of diazotized o-amino-phenacylazide with a sl molar excess of Na azide. Analysis was not attempted because the compd immediately showed signs of decompn

References: 1) Beil 7,225] 2) A. Sonn & W. Bülow, Ber56,1697(1925) & CA20,376(1926)

Tetranitroacetophenone, C₇H₆N₄O₄ was not found in Beil or CA through 1956

Acetophenone-(4-bromophenylhydrazone)-peroxide, called in Ger Peroxyd des Aceto-phenon-p-bromphenyl-hydrason, N₆·CH₂·CO·C₆H₄·Br, mw 321.18, N₁₀.26%, OB to CO₂ –162.0%. Yel unstable ndls or prisms, mp 48–9°C, expl on heating or standing; sol in most org solvents. Can be prep by passing air through cold, agitated acetophenone-(4-bromophenylhydrazone) suspended in petr eth. No refs to its expl props

References: 1) Beil15,437 & 118] 2) P.C. Freer, Ber30,737(1897) 3) M. Busch & W. Dietz, Ber47,3290-1(1914)

5-Acetophenonehydrazone-α(1H)-tetrazole or 5-[(Methylphenylmethylene)-hydrazone]-α(1H)-tetrazole, called in Ger Tetrazolon-α-phenylidenhydrazon or β-α-Phenäthyldenhydrazinotetrazol, N₁₃.33%.


Acetophenoneperoxide Dimeric, or Diacetophenone Diperoxide, CH₃·O₂·CH₃
A49

m w 272.29, OB to CO₂ -211.5%. Col crystals, mp 185-6³(Ref 3), 182-3³(Refs 2 & 4), 181-2³ (Ref 5). Was first prep'd by heating 1-methyl-1-phenylazozone in AcOH (Ref 2). Other methods of prep'n are given in Refs 3, 4, & 5.

No refs to its expl props


ACETOPHENOXYNE OXIME AND DERIVATIVES

Acetophenoneoxime or Methylphenylketoxime, CH₃C(=NOH), C₆H₅,ndls, mp 58.5-59', is described in Beil 7, 278-9,(150) & [216]

Acetophenoneoxime, Azido Derivative (Azido acetophenoneoxime or Triazoacetophenoneoxime), N₃, CH₃C(=NOH). C₆H₅, mw 176.18, N 31.80%. Pale yel oil which could not be crystallized. Was prep'd from azidoacetophenone and hydroxylamine as described in Ref 2. No refs to its expl props

Refs: 1) Beil 7, (154) 2)M.O. Forster & R. Müller, JCS 97, 141-2(1910) & CA 4, 1607(1910)

Acetophenoneoxime, Diazo Derivative, C₆H₅N₂O—not found in Beil or CA through 1956

Mononitro acetophenoneoximes, C₆H₅N₃O₂, mw 180.16, N 15.55%. Several isomers are listed in Beil 7, 288, 289,(153) & [221]

Dinitroacetophenoneoximes, C₆H₅N₄O₄, mw 225.16,N 18.66%. Several isomers are listed in Beil 7, 290, 291 & (154)

Trinitroacetophenoneoximes, C₆H₅N₅O₅, mw 270.16, N 20.74%. Not found in Beil or CA through 1956

Acetophenylamine. See Aminoacetophenone

Acetophenynitramine. See Nitraminoacetophenone

ACETOTETRAZACYCLOOCTANE OR ACETYLOCTAHYDROTETRAZINE AND DERIVATIVES

1-Aceto-1,3,5,7-tetrazacyclooctane or 1-Acetyl-1,3,5,7-tetrazacyclooctane,

H₃C.C₂O, N \CH₃.NH.C₂H₅.NH, mw \CH₃.NH.C₂H₅

158.20, N 35.42%. May be considered as the parent compd of derivs which follow

Refs—not found in Beil or CA through 1956

1-Aceto-3,7-dinitro-5-nitroso-1,3,5,7-tetrazacyclooctane or 1-Acetyl-3,7-dinitro-5-nitroso-1,3,5,7-tetrazacyclooctane,

H₃C.CO, N \CH₃.N(NO₂).CH₂N(NO₂)

described in Beil 7, 278-9, (150) & 12161

Acetophenoneoxime, Azido Derivative (Azido acetophenoneoxime or Triazoacetophenoneoxime), N₃, CH₃C(=NOH). C₆H₅, mw 176.18, N 31.80%. Pale yel oil which could not be crystallized. Was prep'd from azidoacetophenone and hydroxylamine as described in Ref 2. No refs to its expl props

Refs: 1) Beil—not found 2)W. E. Bachmann & N. C. Deno, JACS 73, 2778(1951)

1-Aceto-3,5,7-trinitro-1,3,5,7-tetrazacyclooctane or 1-Acetyl-3,5,7-trinitro-1,3,5,7-tetrazacyclooctane,

H₃C.CO, N \CH₃.N(NO₂).CH₂N(NO₂)

designated as SEY and QDX and also called 1-Acetyl-3,5,7-trinitrooctahydro-s-tetrazine, 1-Acetyl octahydro-3,5,7-trinitro-1,3,5,7-tetrazocine, or Octahydro-1-acetyl-3,5,7-trinitro-s-tetrazocine, mw 293.20, N 33.44%. OB to CO₂ -57.3%, OB to CO -24.6%. Crysts mp 224.2-224.7° with frothing; can be detond
by a hammer blow (Ref 4). Si sol in pyridine, acet & nitromethane; nearly insol in alc, benz, AcOH & eth. It is usually formed during nitrolysis of hexamine (Refs 3 & 4), but can also be prepared by other methods, such as oxidation of 1-aceto-3,7-dinitro-5-nitroso-1,3,5,7-tetrazacyclooctane, either with absol nitric acid at 40° or with a mixt of absol nitric with hydrogen peroxide (30% strength) (Ref 6).

Goes over (25%) to HMX on treatment with 98% nitric acid at 5° (Refs 3 & 4). X-ray diffraction spectra of SEX are given in Ref 2, UV absorption spectra in Refs 5 & 7 and analytical procedures in Ref 8.


Acetotetrazanonanediol acetate and Derivatives. See Acetyl diacet oxytetrazanonanone and Derivatives

Acetotoluide or Acetotoluclidine. See Acetamidotoluene and Derivatives

**ACETOTRIAZACYCLOHEXANE OR ACETYLHEXADIOHYDROTRIAZINE AND DERIVATIVES**

1-Aceto-1,3,5-triazacyclohexane or 1-Acetyl-1,3,5-triazacyclohexane,

\[ \text{H}_2\text{C} \cdot \text{CO} \cdot \text{N} \backslash \begin{array}{c} \text{CH}_2-\text{NH} \\ \text{CH}_2-\text{NH} \end{array} \text{CH}_2 \]

mw 129.16, N32.54%. May be considered as the parent compd of the dinitro-deriv which follows

Refs: not found in Beil or CA through 1956

1-Aceto-3,5-dinitro-1,3,5-triazacyclohexane; 1-Acetyl-3,5-dinitro-s-triazine; 1-Acetyl-3,5-dinitro-1,3,5-triazacyclohexane or 1,5-Dinitro-3-acetyl-1,3,5-triazine; designated as TAX,

\[ \text{H}_2\text{C} \cdot \text{CO} \cdot \text{N} \backslash \begin{array}{c} \text{CH}_2-\text{N} (\text{NO}_2) \\ \text{CH}_2 \end{array} \]

mw 219.16, N 31.9% OB to CO$_2$ -69.4%, OB to CO -32.9%. Crysts, mp 156-8°, sol in acet, alc and acet-alc mixts. It is one of the products of nitrolysis of hexamine and was first prep'd in Canada. It also can be prep'd from 3,5-dinitro-3,5-diazapiperidinium nitrate and by other methods described in Refs 4&6. Cyclonite in 38% yield may be obtained by treating TAX with nitric acid as described in Ref 3. Its UV absorption spectra are given in Refs 5&7 and analytical procedures in Ref 8.


Acetotrinitrotetrazacycloctane. See under Acetotetrazacycloctane and Derivatives

**ACETOXIME AND DERIVATIVES**

Acetoxime or Acetone Oxime(2-Propanone Oxime or Dimethyl Ketonoxime), mw 73.00, N 19.16%, OB to CO$_2$ -164.2%, Col crysts, mp 61°, bp 136.6°, d 0.97 at 20°/20°, (D$_c$ 490.5 kcal/mol, Qf 12.6 kcal/mol; sol in w, alc, eth & pet eth. Can be prep'd by shaking an aq soln of hydroxylamine with acet and extracting acetoxime with ether (Ref 3). The product cannot be obtained in a perfectly dry condition without considerable loss by volatilization (Ref 2). It can be used as a solvent for cellulose ethers; as an intermediate
in org synthesis and as a primer for Diesel fuels

Acetoxime is the simplest ketoxime. It occurs in two isomeric forms:
\[ R' - C - R(anti) \text{ and } R' - C - R(syn), \]
\[ \text{NOH} \quad \text{HON} \]

where \( R' \) is a radical of greater weight than \( R \)


Acetoxime, Azido Derivative (Azidoacetoxime, Triazooacetoxime or 1-Azido-2-propanoate), \( C_4 H_4 N_2 O_3 \), \( \text{NO, mw} 118.09, \text{N} 23.72\% \) not listed in Beil or CA through 1956

Acetoxime, Diazido Derivative, \( C_4 H_4 N_2 O_2 \), \( \text{NO, mw} 118.09, \text{N} 23.72\% \) not listed in Beil or CA through 1956

\[ \text{Mononitroacetoxamidine, } C_4 H_{12} N_2 O_4 \text{– not found in Beil or CA through 1956} \]

\[ \text{Dinitroacetoxamidine, } C_4 H_{11} N_2 O_6 \text{. Several isomers are listed in Beil 13, 366 & 446} \]

\[ \text{Trinitroacetoxamidine, } C_4 H_9 N_2 O_8 \text{. Sev-} \]

\[ \text{eral isomers are described in Beil 13, 366 & 446, none of them explosive} \]

\[ \text{Refs:} 1) \text{Beil 1, 661} 2) \text{M.O. Forster & H.E. Fierz, JCS 93, 83 (1908) } \]

Acetoxime, Diazido Derivative, \( C_4 H_4 N_2 O_2 \), \( \text{NO, mw} 118.09, \text{N} 23.72\% \) not listed in Beil or CA through 1956

\[ \text{Mononitroacetoxamidine, } C_4 H_{12} N_2 O_4 \text{– not found in Beil or CA through 1956} \]

\[ \text{Dinitroacetoxamidine, } C_4 H_{11} N_2 O_6 \text{. Several isomers are listed in Beil 13, 366 & 446} \]

\[ \text{Trinitroacetoxamidine, } C_4 H_9 N_2 O_8 \text{. Sev-} \]

\[ \text{eral isomers are described in Beil 13, 366 & 446, none of them explosive} \]

\[ \text{Tetranitroacetoxamidine, } C_4 H_8 N_2 O_{10} \text{, mw} 407.25, \text{N} 17.20\%. Following isomer listed in Beil} \]

\[ x, x, 2', 4' - \text{Tetranitro-4-acetoxydiphenylamine, } \]

\[ \text{CH}_3 \cdot \text{COO} \cdot \text{C}_6 \text{H}_3 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{O} \cdot \text{C}_2 \text{H}_5 \text{, may be considered as the parent compd of the trinitro- deriv described below} \]

\[ \text{Ref:} 1) \text{Beil 13, 532} 2) \text{F. Reverdin & E. Delettra, Ber 37, 1731 (1904)} \]

\[ \text{Note: No higher nitrated compds are listed in Beil or CA through 1956} \]

\[ \text{ACETOXYETHOXYTRIAZAH PENTANE AND DERIVATIVES} \]

\[ \text{1-Acetoxy-7-ethoxy-2, 4, 6-triazahoxane, } \]

\[ \text{CH}_3 \cdot \text{COO} \cdot \text{C}_6 \text{H}_3 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{O} \cdot \text{C}_2 \text{H}_5 \text{, may be considered as the parent compd of the trinitro- deriv described below} \]

\[ \text{Ref:} \text{not found in Beil or CA through 1956} \]

\[ \text{1- Acetoxy-7-ethoxy-2, 4, 6-trinitro-2, 4, 6- triazahoxane, } \]

\[ \text{CH}_3 \cdot \text{COO} \cdot \text{C}_6 \text{H}_3 \cdot \text{N} \cdot \text{NO}_2 \cdot \text{CH}_2 \cdot \text{N} \cdot \text{NO}_2 \cdot \text{CH}_2 \cdot \text{O} \cdot \text{C}_2 \text{H}_5 \cdot \text{mw} 340.26, \text{N} 24.70\%, \text{OB to CO}_2 \cdot 70.5\%, \text{OB to CO} \cdot 32.9\%. \text{Crysts, mp 106'-7°. Was obtained by Chute et al as one of the products of nitrolysis of hexamine. No refs to its expl props} \]

\[ \text{Ref:} 1) \text{Beil—not found} 2) \text{W. J. Chute et al, CanJRes 27B, 504 & 513 (1949); CA 43, 9074 (1949)} \]
ACETOXYMETHYL TETRAZACYCLO-
OCTANE AND DERIVATIVES

1-Acetoxymethyl-1,3,5,7-tetrazacyclooctane, 
H₂C-N(CH₃.OOC.CH₃)-CH₂ may be 
HN — CH₂ — NH — CH₂ — NH

considered as the parent compd of trinitro-
deriv described below

Refs: not found in Beil or CA through 1956

1-Acetoxymethyl-3,5,7-trinitro-1,3,5,7-
tetrazacyclooctane

H₂C-N(CH₃.OOC.CH₃)-CH₂
O₂N.N—CH₂ -N NO₂,

mw 323.23, N 30.34%, OB to CO₂ -61.9%, OB 
to CO -27.2%. Crysts, mp 152.0 (when heated 
rapidly). No suitable solvent for its recrystn 
has been found. It was obtained on nitrolysis 
and acetylation of DPT (1,5-methylene-3,7-
dinitro-1,3,5,7-tetrazacyclooctane)

Acetoxymethyltrinitrotetrazacyclooctane reacts with a mixt of 
HNO₃ and Ac₂O to give a linear tetranitramine, 1,9-diace- 
toxy-2,4,6,8-tetranitro-2,4,6,8-tetrazanone(qv) (scission of 
the 8-membered ring takes place). When AN was present in the 
HNO₃-Ac₂O mixt, the ring remained intact and the cyclic 
tetranitramine, HMX(1,3,5,7-tetranitro-1,3,5,7-tetrazacyclo-
öctane) was formed in good yield

Refs: 1)Beil—not found 2)W.E. Bachmann 
& E.Jenner, JACS 73, 2773-4(1951) & CA 46, 
2085(1952) 3)W.E. Bachmann & N.Deno, 
JACS 73, 2778(1951) & CA 46, 2085(1952)

ACETOXYMETHYL TRIAZACYCLO-
HEXANE AND DERIVATIVES

1-Acetoxymethyl-1,3,5-triazacyclohexane,

H₂C-N(CH₃.OOC.CH₃)-CH₂
HN — CH₂ — NH

may be considered as the parent compd of 
dinitro- deriv described below

Refs: not found in Beil or CA through 1956

1-Acetoxymethyl-3,5-dinitro-1,3,5-triaza-
cyclohexane,

H₂C-N(CH₃.OOC.CH₃)-CH₂
O₂N.N—CH₂ — N NO₂,

mw 249.19, N 28.11%, OB to CO₂ -73.8%, 
OB to CO -35.3%. Crysts, mp 143.7-144.7; 
sol in acet, insol in w or petr eth. Was ob-
tained by Chute et al as one of the products of 
nitrolysis of hexamine. No refs to its expl props

Refs: 1)Beil—not found 2)W.J.Chute et 
al, CanJRes 27B, 506 & 517-18(1949); CA 
43,9074(1949)

ACETOXYNAPHTHALENE

Acetoxyphthalene or Naphthylacetate, 
called in Beil Essigsäure -naphtylester,
CH₃COO. C₆H₅. Two isomers α- and β- are 
described in Beil 6, 608, 644, (307, 313) 
& [580, 600]

Acetoxyphthalene, Azido Derivative, 
CH₃, COO.C₆H₅, N₃ and Diazido Derivative 
CH₃, COO. C₆H₅(N₃)₂—not found in Beil 
or CA through 1956

Mononitroacetoxyphthalene, C₆H₅NO₄.
Four isomers: 2-nitro-1-acetoxy-, 5-nitro-1-
acetoxy-, 1-nitro-2-acetoxy- and, 8-nitro-2-
the 8-membered ring takes place). When 
AcO was present in the 
AcO mixt, the ring 
remained intact and the cyclic 
tetranitramine, 
HMX(1,3,5,7-tetranitro-1,3,5,7-tetrazacyclo-
öctane) was formed in good yield

Refs: 1)Beil—not found 2)W.E. Bachmann 
& E.Jenner, JACS 73, 2773-4(1951) & CA 46, 
2085(1952) 3)W.E. Bachmann & N.Deno, 
JACS 73, 2778(1951) & CA 46, 2085(1952)

ACETOXYMETHYL TETRAZACYCLO-
OCTANE AND DERIVATIVES

1-Acetoxymethyl-1,3,5,7-tetrazacyclooctane, 
H₂C-N(CH₃.OOC.CH₃)-CH₂
O₂N.N—CH₂ — N NO₂,

mw 249.19, N 28.11%, OB to CO₂ -73.8%, 
OB to CO -35.3%. Crysts, mp 143.7-144.7; 
sol in acet, insol in w or petr eth. Was ob-
tained by Chute et al as one of the products of 
nitrolysis of hexamine. No refs to its expl props

Refs: 1)Beil—not found 2)W.J.Chute et 
al, CanJRes 27B, 506 & 517-18(1949); CA 
43,9074(1949)
Note: No higher nitrated derivs were found in Beil or CA through 1956

ACETOXYTRIAZAHEPTANE

1-Acetoxy-2,4,6-triazahexane,
\[(\text{CH}_3\text{COO})\text{CH}_2\cdot \text{NH} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{NH} \cdot \text{CH}_2\],
may be considered as the parent compd of its trinitro-deriv described below
Refs—not found in Beil or CA through 1956

1-Acetoxy-2,4,6-trinitro-2,4,6-triazahexane; N,, N', N''-Trinitro(acetoxymethylaminomethyl)
-(methylaminomethyl)amine; 2,4,6-Triaza-2,4,6-trinitro-heptan-1-ol or MSX, (\text{H}_3\text{C}-\text{OOC}) -
\text{CH}_2\cdot \text{N(NO}_2\cdot \text{CH}_2\cdot \text{N(NO}_2\cdot \text{CH}_3\cdot \text{N(NO}_2\cdot \text{CH}_3, 
\text{mw} 296.20, N 28.38%. Col rosettes or prisms; mp 153-4°. Was prep'd from 1,5-dinitro-
3-methyl-hexahydro-1,3,5-triazine,
\[\text{H}_2\text{C} \cdot \text{N(NO}_2\cdot \text{CH}_2 \cdot 
\text{O}_2\text{N.N} \cdot \text{CH}_2 \rightarrow \text{N.C}_3\] 
added along with a soln of AN in 98% nitric acid to AcOH + Ac_2O, stirring and adding w
(Ref 2).No ref to its expl props. Ultraviolet absorption spectra are given in Ref 3

This compd was examined in connection with a study of the reaction leading to the production of cyclonite

Acetozone. See Acetylbenzoylperoxide

ACETYLACETONE

ACETYLACETONE AND DERIVATIVES

Acetylacetonc, 2,4-Pentandione or Di-acetyl methane, \text{CH}_3\text{CO} \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_3, 
\text{mw} 101.11. col liq. d 0.9721 at 25/4° fp -23.2°, bp 137-140°, n_D^o 1.4513. Can be prep'd from acetone, ethyl acetate and Na ethylate or by other methods. It is an excellent gelatinizer for NC
Refs: 1)Beil 1,777,(401) & [831]

2)L.Claissen & E.Ehrhardt, Ber 22, 1010 (1889) and many other later refs listed in Beil and in CA

Chromium Salt of Acetylacetone or Chromyl-acetylacetone, \text{Cr(C}_3\text{H}_2\text{O}_4\cdot \text{H}_2\text{O}, \text{red-viol crysts, d 1.34, mp 214°, bp 340° (without decomp). Was prep'd by Urbain & Debièrne by treating chromic nitrate with acetylacetone (Refs 1 & 2). Its UV absorption spectra are given in Ref 3 and crystallographic structure by X-rays in Ref 4

Maisner (Ref 5) claims that incorporation of up to 3% Cr acetylacetonate in rocket propellants prep'd by gelling nitroparaffins (such as nitromethane) with NC, renders them easier to ignite. These mixts can vary from syrupy to solid gels, depending on the amt of NC used. When gels are solid (large amts of NC), they are suitable for use as regular propellants. Same mixts can be used as expls, especially when an org amine (such as methyl-amine) is incorporated to serve as a sensitizer. All these mixts can be prep'd at RT


Acetylacetone, Azido Derivative, \text{N}_3 \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_2 \cdot \text{CO} \cdot \text{CH}_3, and Acetyl-
acetone, Diazido Derivative, \text{N}_3 \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_2 \cdot \text{CO} \cdot \text{CH}_3 \cdot \text{N}_3, not found in Beil

Mononitroacetylacetone, (\text{O}_2\text{N}) \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_3 and Dinitroacetylacetone
\text{O}_2\text{N} \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_3 \cdot \text{CO} \cdot \text{CH}_2\cdot \text{NO}_2, not found in Beil

Acetylacetone Peroxide, Polymer, (\text{C}_3\text{H}_2\text{O}_4)_x, 
\text{mw} (134.13)_x, OB to CO_2 -131.2%, OB to CO -71.5%. Glassy syrup, not volatile with steam; very expl. Was prep'd by Pastureau from acetyl acetone and hydrogen peroxide in sulfuric acid soln

Refs: 1) Beil 1, 785 2) J. Pastureau,
ACETYLALANINE AND DERIVATIVES

Acetyl-d/-alanine or Acetamidopropionic Acid, \( \text{CH}_3 \cdot \text{CO} \cdot \text{NH} \cdot \text{CH} \left( \text{CH}_3 \right) \cdot \text{COOH} \), plates or ndls, mp 138-139.5\(^\circ\). Can be prepd by treating d,l-alanine with acetic anhydride or by other methods.

Refs: 1) Beil 4,394,(495) & [811] 2) A. de Jong, Rec 19,282(1900) and several other refs in Beil and in CA.

Azidoacetyl-d/-alanine, \( \text{CH}_3 \cdot \text{CO} \cdot \text{N} \left( \text{N}_3 \right) \cdot \text{CH} \left( \text{CH}_3 \right) \cdot \text{COOH} \), mw 172.15, N 32.55%. Long fine ndls, mp 1010. Was prepd by Freudenberg & Keller from dl-alanin by a procedure described in Ref 2. In the course of prep of this compd an intermediate, Azidoacetyl-d/-alanine chloride was obtained. This chloride could not be purified because it decompd explosively at ca 30\(^\circ\).

Refs: 1) Beil—not found 2) K. Freudenberg & R. Keller, Ber 71B, 334(1938) & CA 29, 9075(1938)

Note: No nitrated derivs of acetyl-d/-alanine were found in Beil or CA through 1956.

Acetyloniline. See Acetanilide.

ACETYL BENZOYLPEROXIDE AND DERIVATIVES

Acetylbenzoylperoxide; Benzoylacetylperoxide; Acetozone or Benzozone (formerly called Acetylbenzoyl-superoxyd in Ger).

\( \text{CH}_3 \cdot \text{CO} \cdot \text{O}_2 \cdot \text{CO} \cdot \text{C}_6 \text{H}_5 \), mw 180.15. Wh crysts mp 37-41\(^\circ\), bp 130\(^\circ\) at 19 mm (might explode); expl violently at 85-100\(^\circ\) and also by friction or compression; stable, when dry at RT, but decomp in the presence of moisture, org matter or traces of alc, eth or acids; sl sol in \( w(0.064 \text{ g in } 100 \text{ ml at } 25\(^\circ\)) \) alc & mineral acids; sol in \( \text{CCl}_4 \), chl, eth & oils. Was first prepd by Nef(Ref 2) from benzaldehyde and acetic anhydride. Other methods of prep are listed in Ref 1.
Caruthers (Ref 5) patented a method of prep in which benzaldehyde and acetaldehyde are caused to react at ca 35° with an O-contg gas in the presence of dibenzoylperoxide.

Thermal decompn of acetylbenzoylperoxide is discussed in Ref 3 and the decompn by UV light in Ref 4. Its fire & expln hazard, toxicity and shipping regulations are discussed in Refs 6 & 7.

Acetylbenzoylperoxide is used in lab and industry as an oxidation and polymerization catalyst in a number of reactions.


Acetylbenzoylperoxide, Azido Derivative, N₃ · C₆H₅O₄ — not found in Beil or CA through 1956

Acetyl-(3-nitrobenzoyl)-peroxide or m-Nitrobenzoylacetylperoxide (called by Nef m-nitrobenzoylacetylhydroperoxyd), CH₃ · CO · O₂ · CO · C₆H₄ · NO₂, mw 225.15, N6.22%. Col ndls (from hot methanol), mp 68°; expl at higher temps; sol in most org solvents; diff sol in cold methanol & ligroin. Was prepd by treating acetylbenzoylperoxide with fuming nitric acid in the cold.

Refs: 1) Beil 9, 381 2) J. U. Nef, Ann 298, 286(1897)

Note: No later refs were found in CA through 1956

Acetyl-(dinitrobenzoyl)-peroxide, CH₃ · CO · O₂ · CO · C₆H₃(NO₂)₂ — not found in Beil or CA through 1956

Acetylbenzoylperoxide; Benzylacetylperoxide; Benzylperacetate or Peracetic Acid Benzyl ester, CH₃ · CO · O₂ · CH₂ · C₆H₅; powder. It was patented in 1927 by Carbide & Carbon Chemicals Co (Ref 2) for use as a catalyst in polymerizing vinyl compds particularly vinyl chloride and acetate. Sax (Ref 4) lists this compd without giving its formula or method of prep but states that it is a powerful oxidizing agent; its toxicity—details unknown, fire hazard—moderate by spontaneous chemical reaction, expln hazard—moderate when shocked or exposed to heat and disaster control—dangerous; shock will cause deton with evoln of toxic fumes; will react with w and steam to produce heat; can react vigorously with reducing materials.

Refs: 1) Beil—not found 2) Carbide & Carbon Chemicals Co, FrP 748,972(1933) & CA 27, 5755(1933) 3) Tobolsky & Mersobian (1954)—not found 4) Sax (1957), 236

Acetyl Bromide or Ethanoyl Bromide, CH₃COBr, mw 122.96, OB to CO₂ -58.6%, OB to CO -45.5%. Col liq fuming strongly in the air; d 1.663 at 16° mp -96.5, bp 76° at 750 mm, nD 1.4537 at 15.8°. Miscible with eth, benz & chlf, decomp violently by w and alc. Can be prepd from acetyl chloride and an excess of HBr or by other methods. Its toxicity, fire & explosion hazards are discussed in Ref 3.

Ref: 1)Beil 2,174,(79) & [176] 2) H. Staudinger & E. Anthes, Ber 46, 1421(1913) 3) Sax (1957), 236

ACETYL CELLULOSE AND DERIVATIVES

Acetyl Celluloses (AC) (Acetates of Cellulose or Cellulose Acetates). According to Dorée (Ref 3) the action of AC₂O on cellulose (called acetylation) should theoretically yield the triacetate [C₆H₅O₃(OOC · CH₃)₃]ln. Actually, the products of acetylation are a mixture of tri-, di- and mono-acetate. A characteristic property of the lower acetylated acetates is their sol in acetone, whereas the triacetate can absorb acetone only to the extent of causing swelling.

Lab and industrial methods of prep of AC are described in Refs 2, 3, 4 & 6. AC is used in the manuf of rayon, films, unbreakable
windows (Ref 4), as a component and an inhibitor coating of rocket propellants (Refs 5 & 7). The Italians claim that AC has the property of slowing down the rate of burning of a propellant and rendering the combustion more uniform.

Following are Italian military specification requirements for AC: ash ≤ 0.15%, free acid none, foreign matter <0.1, ether <0.15, insol in acet ≤1.0 and acidity (caled as AcOH) ≤0.15%, detd by 132° Heat Test using a Bergmann-Junk tube.


Nitroacetylcelluloses (NAC) (Cellulose Acetate Nitrates). Oddo (Ref 2), being dissatisfied with the chem stability of NC’s decided to det whether acetylated NC’s would be any better. He took 10g of NC (11.66%N), dried it at 90° and gradually introduced 300g of acetic anhydride free of AcOH. After 12 hrs at RT the mixt was heated on a sand bath, under reduced pressure and under a reflux condenser (sealed with a sulfuric acid valve), until about two-thirds of the acetic anhydride was distilled. The residual liq was filtered and poured into a large amt of w. The resulting light yellow product was dried, dissolved in AcOH, filtered and repptd by pouring the soln dropwise with agitation into a large amt of cold w. The dried purified product was white and could be easily pulverized. Its mw was (290.5)_n and N ca 9.65%, which corresponds approx to C<sub>6</sub>H<sub>4</sub>O<sub>2</sub>(ONO<sub>2</sub>)<sub>2</sub>(OAc), calcd mw (294.1)_n. It decomposes at ca 185.5° with the evoln of gas. The product was easily sol in et acet, AcOH & pyridine and could be gelatinized by 1:1-ether/alc.

Dorée (Ref 3) prep’d several NAC’s (some of them with a N content as high as 13.8% and an AcOH content 32.3%) by gradually adding cellulose to an ice-cooled bath contg a mixt of acetic anhydride and fuming nitric acid. Krüger (Ref 4) studied the nitration-acetylation of cellulose with mixts of acetic anhydride-nitric acid-acetic acid. Werner (Ref 5) studied a method of prep of NAC by nitration of fibrous cellulose triacetate with nitric acid contg less than 9% w. He also studied prep of NAC by acetylation of NC. A brief description of NAC is also given in Ref 6.

NAC with N ca 11.5% has been used in Italy as an ingredient of DEGDN propellants (polveri al nitroglicerol). Following are Italian military specification requirements (Ref 7): nitrogen content 11.20-11.70%, fineness ≤ 90, acetyl content ≥ 1.50% ash ≤ 1%, lime calcld as CaO ≤ 0.30%, stability by 80° Abel test > 25 min, by 135° Ger test 50 min and by 131° Bergmann-Junk test ≤ 1.75 cc of NO.


**ACETYL CHLORIDE AND DERIVATIVES**

Acetyl Chloride or Ethanoyl Chloride, CH<sub>3</sub>CO·Cl, mw 78.50, OB to CO₂ -91.7%, OB to CO -71.3%. Col liq which fumes in air. It is flm, d 1.1051 at 20°, mp -112°, bp 51-2°, N 20° 1.3898. Miscible with eth, benz, chlf, glacial AcOH & petr eth. Decomp violently by w or alc. Extremely irritating to the eyes. Can be prep’d from glacial AcOH and phosphorus trichloride (see also Ref 6) or by other methods listed in Ref 1. Used as an acetylation agent and for the detn of w in organic liquids. Its toxicity, fire and explosion hazards are discussed in Refs 4 & 5.

Its nitrocompound is described below.
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Azidoacetyl chloride or Triazoaocetyl chloride, N₂.CH₂.CO.Cl, mw 119.52, N 35.16%. Col

Nitroacetyl Chloride, O₂N.CH₂.CO.Cl, mw 123.50, N 11.33%, OB to CO₂ -25.9%, OB to CO 30%. Liq, fr -35⁰, bp 68⁰ at 12 mm; slow distn is accompanied by an expln. Was prepd in poor yield by nitrination of ketene in Acetyldinitroglycerin. See Glycerin Acetate ether, cooled in solid CO₂ + alcohol.(Ref 2)

Dinitroacetyl chloride, (O₂N)₂CH₂.CO.Cl - not found in Beil or CA through 1956

Acetyldiacetoxytetrazan nonane and derivatives

2-(4)-Acetyl-1,9-diacetoxy-2,4,6,8-tetrazan nonane or 2-(4)-Aceto-2,4,6,8-tetrazan nonane-1,9-diol-diacetate,

CH₃.CO-O.CH₂-NCH₂-NH-CH₂-NH-CH₂-NH-CH₂-O.CO.CH₃
Q_v 9.64 kcal/mol. Isomers in which acetyl group is attached to the ring, *anilinoacetophenones*, are not described in Beil, although their nitro-, dinitro- and trinitro- derivs are listed in vol 14. One of the anilinoacetophenones was prep'd recently by S.G.P.Plant & C.R.Worthing, JCS 1955,1279 & CA 50, 2457(1956) and listed as 4-acetyldiphenylamine.

**Azidoacetyldiphenylamine**, N$_2$C$_{14}$H$_{12}$NO, mw 252.27, N 22.21%. Following isomer is known:

CH$_3$.CO - N$\rightleftharpoons$C$_6$H$_4$.N$_3$

pale yel crs, mp 99-99.5°, decomp thermally to gums. Was prep'd by diazotizing o-amino-N-acetyl-diphenylamine in aq HCl and treating the product with Na azide.

*Refs:* 1) Beil - not found 2) P.A.S.Smith et al, JACS 75,6336(1953) & CA 49,7571 (1955)

**Diazidoacetyldiphenylamine,**

(N$_2$)$_2$C$_{14}$H$_{11}$NO - not found in Beil or CA through 1956

**Mononitroacetyldiphenylamine**, C$_{14}$H$_{13}$O$_2$N$_2$. Its N-acetyl-derivs are listed in Beil 12, [372,391], while the isomers with acetyl on one of the rings are given in Beil 14, [29,30]. The latter isomers may also be called nitroanilinoacetophenones.

**Dinitroacetyldiphenylamine**, C$_{14}$H$_{11}$N$_2$O$_4$. Three N-acetyl-isomers are described in Beil 12, 720,754 & [391,410], while one isomer with acetyl on one of the rings is given in Beil 14, [32].

**Trinitroacetyldiphenylamine**, C$_{14}$H$_{10}$N$_4$O$_7$, mw 346.25, N 16.18%. No N-acetyl-isomers are listed in Beil 12, but two isomers with acetyl on one of the rings are given in Beil 14, [42 & 47].

**Tetranitroacetyldiphenylamine**, C$_{14}$H$_{9}$N$_5$O$_8$, mw 391.25, N 17.90%. Following isomer is described in the literature 2,4,2',4' - Tetranitro-N-acetyl-diphenylamine, called in Ger Essigsäure-bis[2,4-dinitrophenyl]-amid,

(ONO)$_2$C$_6$H$_4$.N.CO.CH$_3$,

(ONO)$_2$C$_6$H$_4$.N.CO.CH$_3$,

crys, mp 197°. Was obtained by Pictet on treating N-acetyldiphenylamine with diacetylorthonitric acid, (HO)$_3$N(O,OC.CH)$_2$.

*Refs:* 1) Beil 12,754 2) A. Pictet, Arch-SciencPhysNat, Genève,[IV] 16,201(1903) & ChemZtr 1903 II, 1109

**Pentanitroacetyldiphenylamine**, C$_{14}$H$_{11}$N$_4$O$_11$, not found in Beil or CA through 1956

**Hexanitroacetyldiphenylamine**, C$_{14}$H$_{11}$N$_4$O$_{13}$, mw 481.25, N 20.38%. Following isomer is described in the literature:

2,4,6,2',4',6' - Hexanitro-N-acetyl-diphenylamine, called in Ger Essigsäure-bis[2,4,6-trinitrophenyl]-amid,

(ONO)$_2$C$_6$H$_4$.N.CO.CH$_3$,

(ONO)$_2$C$_6$H$_4$.N.CO.CH$_3$,

Lt yel crs, mp 240° with decompn; starts to blacken ca 200°; sol in ben & acet; insol in ligroin. Was prep'd by treating silver salt on one of the rings are given in Beil 14, 26.04. OB to CO$_2$ -307.2%, OB to CO -184.3°. Col gas with garlic odor, fr p -85° at 895 mm, subl p -84° at 760 mm, d 0.91 (air =1.0), Q_f -54.9 kcal/mol. Bnuni(Ref 19c) gives bp -23°, crit temp +35.4° and temp of triple point -83.6°. Soly in w 1.7 vols per 1 vol of w at RT; soly in acct over the temp range of 0° to 40° and at a partial press of C$_2$H$_4$.
of 1 atm can be calcd from the equation \( S = 13000/(T-185.3) \) -81.3 derived by Brameld, & W. Examination of the material prep'd by M & Clark (Ref 7). Soly at higher press is much greater.

Acetylene gas burns in air with a very hot luminous flame. When burned in oxygen (as in an oxyacetylene flame) temps of the order of 6000°F(3315°C) can be attained. According to Reppe (Ref 20g), acetylene tends to decompose explosively into its elements even at a press of the order of 1 atm, evolving appreciable quantities of heat. Compressing acetylene is a dangerous operation unless a special technique is used (as in loading containers for oxyacetylene welding). For purposes of safe storage, acetylene can be dissolved in acet and kept indefinitely.

Mixts of gaseous acetylene and air are extremely expl. In dry air at atm press the expl limits are 2.6 to 77%(or even 80%) of acetylene by vol.

Numerous explosions have occurred (see CA from 1907 to present) which were attributed to acetylene or to acetylene liberated from Ca carbide.

According to Sax (Ref 23) acetylene is not toxic and its fire hazard is great when exposed to heat or flame. Its expl hazard is moderate when exposed to heat or flame or when it undergoes spontaneous chem reactions. At high press it may decomp explosively even at moderate temps. It can react vigorously with oxidizing materials and it forms expl compds on contact with Cu or Ag (see Acetylides).

The discovery of acetylene in 1836(or 1837) is attributed to Edmond Davy, but it was not until 1860 that Berthelot definitely identified and named it(Ref 9, p 101 & Ref 16, p 469). The compd obtained by Bertholot from cuprous acetylide was not pure because it contained some vinyl chloride. Acetylene was not produced commercially until Ca carbide was produced in the lab in 1899 by Morehead & Willson, by heating a mixt of lime and coke in an electric furnace. They expected to prepare metallic calcium but obtained the carbide instead.

Examination of the material prep'd by M & W showed that when it was brought into contact with water, a large amt of gas, identified as \( C_2H_2 \), evolved. This gave impetus to the comb production of CaC₂ for use in acetylene generators. At first \( C_2H_2 \) was used for increasing the illuminating power and heating value of water gas, but since 1906 it has been utilized for welding and cutting steel. The chemical utilization of \( C_2H_2 \) began in Germany in 1910, then in Canada in 1914 and finally in this country. Research in the field of acetylene chem was greatly expanded during WW I & II and the use of \( C_2H_2 \) increased tremendously (Ref 9). The industrial prep of acetylene from Ca carbide is described in Ref 9, pp 102-7 and Ref 24, pp 34-41.

Many other methods for the manuf of acetylene have been developed, especially during and after WW II in Germany, such as from hydrocarbons by the Hils arc-cracking process (Ref 9, pp 107-10), from hydrocarbons by the Wulff thermal cracking process (Ref 9, pp 110-11) and from methane by its partial combustion (Ref 9, pp 111-12).

In addn to the above mentioned processes for the production of acetylene, several others were developed, of which the Tennessee Eastman process (Ref 22) and the Société Belge de l'Azoite (SBA)--Kellogg process (Ref 27) are the most recent.

Purification of crude acetylene for lab purposes is described in InorgSynth v 2(1946), 76.

Uses: In addition to the extensive use of acetylene in oxyacetylene welding it is used as a starting material for the manuf of inorg and org acetylides as well as many other compds. Some of them such as acetone, acetaldehyde, acetic acid, acetic anhydride, etc are indispensable in the manuf and testing of expls and ammo. Acetylene was also used to manufacture tetranitromethane by the method described in PATR 2510 (1958), p Ger 195, under Tetan.
Straight acetylene can be used as an explosive when in liquefied or solidified form (see Acetylene as an Explosive) (See also Acetylene Condensation or Polymerization Products, Acetylene Derivatives, Acetylene Hydroperoxides & Peroxides, Acetylene-Nitric Acid Reactions, Acetylene Reactions, Acetylenic Compounds, Acetylenides, Cuprene and Halogenated Acetylenes)

which is capable of withstanding temps up to 2500°C. The process is different from any previously used. A paper reported in the 6th Symposium on Combustion, Reinhold, NY(1957), 247-54(22 refs) 26)H.H.Nelson, "The Effect of Pipe Diameter on the Thermal Decomposition of Acetylenes." A paper reported in the 6th Symp on Combustn, Reinhold NY(1957),823-27(17 refs) 27)SBA-Kellogg Way to Acetylene, C&EN 36,15(Jan 13, 1958) [Brief description of the manuf of C2H2 from natural gas or naphtha by the process patented by the Société Belge de l' Azote(SBA) using a special burner. This process was adopted in USA by the M.W.Kellogg Co, NY. Ethylene can also be produced by this method] 28) Many papers on acetylene and acetylene chemistry are listed in Chemical Abstracts, especially starting about 1940. There are listed above only the more important papers

Acetylene-Air Mixtures. Various C2H2-air mixtures were detonated in rubber balloons by means of central elec detonators. Photographs of spherical explosions thus produced were made with a rotating-drum camera and with a 6000-frame-per-sec movie camera. Deton vels measured by this method agreed with values obtained from measurements in tubes by std techniques. For instance, the mixts contg 12.5% C2H2 developed a deton vel of 1920 m/sec and multiple reflected waves were clearly observed (See also Acetylene-Oxygen Mixtures) 29)H.Freiwald & H.Ude, CR 236, 1741-3(1953) & CA 47,9617(1953) & CA 49, 860(1955)

Acetylene, Analysis. See Acetylene and Derivatives Analysis, listed after Acetylene Derivatives

Acetylene as an Explosive. When acetylene is liquefied it becomes an expl which can be detonated by a blow, spark or a detonator. The same applies to acetylene in the solid state. According to Rimarski & Metz (Ref 3), solid acetylene is an expl of considerable power as detnd by the Trauzl lead block test, although less powerful than common HE's. Its brisance and deton vel (2270 m/sec at d 0.503) are also inferior to the common HE's. Sensitivity to heat, friction, shock and spark are slight. By using solid C2H2 with liq air or oxygen, a very brisant expl is obtained. The disadvantages of using solid C2H2 lie in the difficulties in storage and transportation

Acetylene may also be used as an expl when in the gaseous state, but for this use it must be previously mixed with some oxygen-contg gas, such as air to create an expl mixt. For instance, gaseous acetylene is used as a blasting expl in cases where materials are desired to be reduced to large pieces (Ref 1). In one application a lead pipe was separated into 3 sections by two light, easily broken partitions. The first sectn (next to the tamping) was charged with CaC2 in small grams, the second sectn contained water and the third an electric exploder. After inserting the pipe into a borehole and tamping, the first partition was broken from outside by an iron bar thus allowing an influx of air and causing the CaC2 and H2O to form acetylene. The resulting pres broke the 2nd partition bringing the C2H2-air mixt in contact with the exploder which, after a suitable time had elapsed caused the mixt to detonate

According to British regulations issued during WWI, acetylene when liq or when subject to a certain degree of compression, or when in admixture with atm air or oxygen, was deemed an expl (Ref 2)

Stettbacher (Ref 4) gives the following expl props for 74.75/24.55 mixts of liq O2 with solid C2H2: maxim d less than 1, normal gas vol 634 l/kg, heat of expln 2760 kcal/kg, deton vel 6000 m/sec, maxim temp of expl (calcd) 7280° and sensitivity to impact 5 cm with 2 kg wt
The expl decompn of acetylene is discussed in Ref 5 and the effect of mixing with hydrocarbons and other gases upon the explosibility of C₂H₂ in Ref 6 (For more information on explosions of acetylene and its homologs, consult CA under Acetylenes)

Refs: 1) Anon, Sprengstoffe, Waffen und Munition 9, 41(1914) & CA 9, 1115(1915)
2) British Statutory Rules and Orders 1919, No 809, “Acetylene as an Explosive” & CA 14, 468(1920) 3) W. Rimarski & L. Metz, Autogen Metallarbeiten, 26, 341(1933); Chem Ztr 1934 I, 803-4 & CA 29, 4942(1935)
4) A. Stertbacher, Protar 8, 91(1942) & CA 37, 1603(1943) 5) E. A. Blyumberg & D. A. Frank-Kamenetskii, Zh.Fiz.Khim 20, 1301-17(1946) & CA 41, 2059(1947)

Acetylene Black. See under Carbon Blacks.

Acetylene Chloride or Chloroethyne. See under Halogenated Acetylenes.

Acetylene Condensation and Polymerization Products may be obtained by subjecting acetylene to the action of heat, light, electrons, alpha-rays, elec discharge, etc with or without catalysts (Ref 1, 189-2-3[1]). One such products is cuprene (qv), which is a condensation product of acetylene and not a polymer as it is usually called. The real polymerization product of acetylene is C₆H₆, which was obtained (together with other compounds) in 1866 by Berthelot by heating acetylene in retorts of glass softening at 400-500°Ref 1, p 232). The same investigator, prepd by silent electrical discharge in acetylene some unidentified products of high mol wt which decomp explosively during their distn (Ref 1, p 232)

Wohl (Ref 2) proposed to use the condensation products obtained from C₆H₆ (either by the action of heat or by the silent discharge in the presence of Cu₂O) as com-burents for various blasting expls, such as those based on black powder, NG, AN, Amm perchlorate, liq oxygen, etc.

Systematic studies of acetylene polymerization were conducted in the laboratories of the du Pont Co and the results are described in numerous papers (see Ref 3). Studies of acetylenic polymers from the point of view of their utilization in solid rocket propellants has been conducted by Reaction Motors (see Ref 10). Polymerization under press is described in Ref 4 and some industrial products obtained by polymerizing acetylene are listed in Ref 5

Shimizu & Kimura (Ref 6) proposed a smoke-producing mixt contg as the principal ingredient a product obtained by treating C₂H₂ polymer (consisting mainly of divinyl-acetylene) with 5-6 atoms of chlorine at 60-70°. Other ingredients of the smoke mixt are Al, KC₁₀, and kieselguhr.

According to Saito (Ref 7), the acetylene trimers obtained as byproducts in the prepn of CH₂:CH. Cl. CH by condensation of acetylene are expl. They can be stabilized by hydrochlorination in the presence of a complex salt of CuCl and NH₄Cl to yield additive compds contg 1 or 2 mols of HCl, from which they are separated by distn. Nakagawa (Ref 8) reviews the chemistry of polyacetylenes and gives 25 references. Polymerization of acetylene is also discussed in Ref 9 (See also Cuprene)

Acetylene, Acetylenic Compounds and Acetylenes; Analytical Procedures.

Hydrogen atoms adjacent to the triple bond of an acetylenic compd are easily replaced by silver, cuprous or mercurous atoms and the resulting metallic derivs are usually insol in w.

Following methods are described by Siggia (Ref 7a, pp 48-58)

A) Ammonical silver nitrate method, in which the excess silver is detd volumetrically by 0.1N NH₄CNS soln. Ppt of AgC:CR which forms during this reaction is expl and should be destroyed as described under Silver Acetylide

B) Alcoholic silver nitrate method in which the following reaction takes place:

\[ 2\text{AgNO}_3 + \text{HC:C}_2\text{R} \rightarrow \text{AgC}_2\text{R}_2 + 2\text{HNO}_3 \]

The liberated HNO₃ is titrated by std alkali.

This method is especially useful for H₂O-insol samples but it can also be used for H₂O-sol samples

C) Ammoniacal silver nitrate method which is applicable to samples contg aldehydes; aldehydes are serious interferences in methods A & B because they reduce the silver ions present

D) Cuprous method, described in Ref 7a, pp 57-8, involves reaction of cuprous chloride with the acetylenic compd in a pyridine soln, according to the equation: Cu₂Cl₂ + 2HC:C₂R → 2CuC₂R₂ + 2HCl. The liberated HCl is titrated with std alkali. This method is not as accurate as silver methods, but it is applicable to samples with which silver cannot be used because of interfering reactions

Piganiol (Ref 8) also describes silver nitrate and cuprous chloride methods, as well as the following additional methods:

E) Potassium iodo-mercurate reagent, prep'd by dissolving 66 g HgCl₂ and 163 g KI in 160 ml w and adding 125 ml of 10% NaOH soln. Acetylenes give, in alc, ppts (RC:C)₂Hg whose mp's are characteristic. For instance, (CH₃:C:C)₄Hg has mp 203-4°, whereas (C₄H₅:C:C)₄Hg has mp 162-3°. This method permits detn in some cases of the structure of pptd compd, as does the Raman spectra method.
Raman spectra method is the only physical method used at present to detect an acetylene compd in a complex mixt. The method is not as rapid as chemical methods, but it gives more valuable info about the entire structure of the molecule (Ref 8)

For detn of acetylene in air or other gases the following procedures can be used:

a) For small concn of acetylenes (up to ca 2%), the measured vol of gas is passed through a cuprous chloride or silver nitrate reagent until an appreciable amt of ppt forms. An apparatus of the Orsat type can be used (Ref 8)

b) For high concns of acetylenes, the gas can be passed through concd H2SO4 using the Orsat apparatus. Olefins are also absorbed. If silver nitrate soln is used for absorption of gas, olefins do not interfere but ammonia and carbon disulfide do (Ref 8)

c) Fractionation methods in columns of Podbielniak or McMillan type, operating at slightly above atm press to eliminate the freezing of acetylene in the column (Ref 4 & 7)

In detn of disubstituted acetylenic compds, formation of ppts is observed only when using mercuric salts (chloride, sulfate or nitrate), but this reaction is not specific because some ethylenic compds and compds contg certain oxygen and nitrogen groups also give ppts. This method, however, can be used in conjunction with the Raman spectra method (Ref 8)

According to Piganiol (Ref 8), the problem of detection of various acetylenic compds in a mixt is fairly complicated and must be solved individually for each particular case. Sometimes several methods must be tried before the problem is solved

Following methods may be tried for solvng each problem:

a) Detn of carbon and hydrogen atoms by combustion
b) Absorption of C2H2 contg gas by 80% sulfuric acid
c) Measurement of d of mixt
d) Use of mercuric cyanide for absorption of

Some ingredients of mixt, such as divinyl acetylene and tetramers and detn of the amt of carbon in residue

Analysis of acetylenes for impurities is briefly discussed in Kirk & Othmer (Ref 7)

Refs:
1) Beil 1, 237-8, (103-4), [216-17] & [908-9]
4) H. P. McKoon & H. D. Eddy, IEC, Anal Ed 18, 133 (1946) (Detn of traces of acetylene)
5) C. D. Wagner et al, Ibid 19, 10X (1947) (Detn of mono- and dialkylacetylenes)
6) T. A. Geisman et al, Ibid 19, 919-21 (1947) (Detn of traces of acetylene in air)
7) Kirk & Othmer 1, (1947) 114-16
9) J. Marszak & M. Koulkes MSCE 36, 421-6 (1951) (Detg the true C2H2 functioning group by using Ag benzoate)
10) M. Koulkes & I. Marszak, Bull Fr [V]. 19, 556-7 (1952) & CA 46, 10050 (1952) (Detg the true C2H2 functioning group by using the AgNO3-C2H4 diamine complex)

Acetylenedicarboxamide. See under acetylenedicarboxylic Acid and Derivatives
Acetylenedicarboxanilide. See Bis(carboxanilidemacrocyne, also called Di(N-phenylcarboxamido)-acetylene

ACETYLENEDICARBOXYLIC ACID AND DERIVATIVES

Acetylenedicarboxylic Acid (Acetylenedicarbonsäure or Butindisäure, in Ger; Acide Acetylenedicarboxylique, in Fr), HO2C-C:C-CO2H, mw 114.06, OB to CO2 -70.1%, OB to CO -14.0%. Plates, mp 178-80° (decomp). Very sol in w, alc and eth;
cryts from solns as a dihydrate. May be prepd by the method of Baeuer from a, a'-
dibromosuccinic acid and alc KOH (Ref 3). A modified version of the prep is given in
Refts 4 & 5. Gilman & Haubein (Ref 6) prep'd it by stirring vinyl bromide and n-butyl-
lithium in ether for 15 mins and carbonating the resulting milky mixt with dry ice

Its silver salt detonates violently from heat or shock as was found by Bandrowski
(Ref 2). This property is not mentioned in Beil, although the salt is listed (Ref 1, 2, 802)

Refts: 1)Beil 2,801,(317) & [670] 2)E. Band-
rowski, Ber 10,844(1877) 3)A. Baeuer, Ber
18,677-8(1885) 4)H.J. Backer & J.M. Van
der Zanden, Rec 47,778(1928) 5)OrgSynth,
CollVol 2(1943), 10 6)H.Gilman & A.H.
Haubein, JACS 67,1421(1945)

Acetylenedicarboxamide or Bis(carboxamide)-
acetylene; H2N.OC.CiC.CO.NH2, mw
120.09, N24.99%. Microcrystallinic powder,
mp-dec at 294°; sparingly sol in w, alc, eth.
chlf & AcOH. Was prep'd by treating dimethyl-
acetylenedicarboxylate with ammonia at
10°

Refts: 1)Beil 2,(317) 2)Ch.Moureau & J.
Bongrand, AnnChim(Paris), [9], 14,12(1920)

Mononitroacetylenedicarboxamide, (O2N)-
HN: CO. C: C. CO . NH2—not found in Beil
or CA through 1956

Dinitroacetylenedicarboxamide,
(O2N). HN. CO. C: C. CO . NH2(NO2)—not
found in Beil or CA through 1956

Acetylenedicloride. See under Halogenated
Acetylenes

ACETYLENEDIUREIN OR
GLYCOLURIL AND DERIVATIVES

Acetylenediurein, Glycoluril or Tetrahydro-
imidazo[|]imidazo-2,5(1H,3H)-dione (Acetyl-
enediureide; Glyoxaldehydeimido(2,5-
dione)hexahydroimidazo[|]imidazo-
urée, in Fr) (Acetylenediurein, Glyoxalurine;
a. /3; a. /3-Diurenylen-lathan; Dioxo-hex-
hydro-[imidazo-4',5':4,5-imidazo]- Gly-
koluril or Acetylenharnstoff, in Gerl.

\[ \text{OC} \quad \text{NH-CH-NH} \]
\[ \text{CO} \quad \text{CO} \quad \text{NH-CH-NH} \]

mw 142.12, N39.43%, OB to CO2 =101.3%.
OB to CO =56.3%. Wh ndls, mp 297° without
melting. It was obtained by treating 1 part of acetylene diureine with
5 parts of abs nitric acid. The structure of this compd was not definitely established.
It decompd on heating with w but was not attacked by aq ammonia (Refs 1 & 3)

Another dinitro-compd, called by Fran- chimont & Klobbie isodinitroglycolurilite, wh microscop crysts, insol in ordinary org solvents and sol in concd nitric acid was also obtained from acetylenediurein and absol nitric acid. It was distinguished from the first isomer by the fact that the latter was not decmp on heating with w but was decompd by aq ammonia at RT (Refs 1 & 3)

Refs: 1)Beil 26, 443 2)A.Frangimont & E.Klobbie, Rec 7, 18-19 & 246(1888) 3)Ibid, 8, 290-1(1889)

Note: No later refs were found in CA through 1956

Trinitroacetylenediurein, C₆H₃N₃O₃ and Tetranitroacetylenediurein, C₆H₃N₃O₆--were not found in Beil or CA through 1956

Acetylene, Halogenated. See Halogenated Acetylene

ACETYLENE HYDROPEROXIDES AND PEROXIDES

A series of compds which contain both acetylene bonds and peroxide groups, was synthesized by Milas et al by using a modification of the sulfuric acid-hydrogen peroxide method originally described in Refs 1 & 2. The procedure consists essentially in allowing an acetylenecarbinol, R₁R₂C(OH)-C:CCH₂ or glycol R₁R₂C(OH).C:C(OH).R₁R₂, in which R₁ & R₂ are various hydrocarbon radicals, to react at low temp with hydrogen peroxide in the presence of sulfuric acid of suitable strength

Following types of compds were prep'd:

A) Acetylene hydroperoxides, R₁R₂C:C=CH₂

such as 1,1-dimethyl-2-propynylhydroperoxide or 3-methyl-3-hydroperoxy-1-butyne, (CH₃)₂C(OOH).C:CCH₂, oxygen 16.0%. Liq, bp 42 to 52.2° at 17 mm, d 0.9540 at 25° and nD²⁵ 1.4295; 1,1-diethyl-2-propynylhydroperoxide or 3-methyl-3-hydroperoxy-1-pentyne, (C₂H₅)₂C(OOH).C:CCH₂, oxygen 14.0%. Liq, bp 38-40° at 5 mm, d 0.9547 at 25°/4°, nD²⁵ 1.4369

B) Acetylene dihydroperoxides,

\[
\begin{align*}
&\text{H}_2\text{C} \\
&\text{CH}_2=\text{CH}_2 \\
&\text{CH}_2=\text{CH}_2 \\
&\text{O}_2
\end{align*}
\]

such as 1,1,4,4-tetramethyl-2-butylnylendihydroperoxide or 2,5-dimethyl-2,5-dihydroperoxy-3-hexyne, (CH₃)₂C(OOH).C:C(OOH).C:C(CH₃)₂, oxygen 18.4%. Solid, mp 107-9° (decomp); 1,1'-dihydroperoxy-1,1'-dicyclohexyl-acetylene,

\[
\begin{align*}
&\text{H}_2\text{C} \\
&\text{CH}_2=\text{CH}_2 \\
&\text{CH}_2=\text{CH}_2 \\
&\text{O}_2
\end{align*}
\]

oxygen 12.6%; solid, mp 95° (decomp)

2,5-dimethyl-2,5-di-(t-butylperoxy)-3-hexyne,

\[
\begin{align*}
&\text{(CH₃)₂C:O} \\
&\text{CH₃} \\
&\text{CH₃} \\
&\text{C(OOH).C:CH₃}
\end{align*}
\]

C) Dialkynyl peroxides,

\[
\begin{align*}
&\text{R}_1\text{R}_2\text{C}-\text{O}-\text{C}-\text{R}_1\text{R}_2 \\
&\text{H:C} \\
&\text{C:C}
\end{align*}
\]

such as bis(1,1-dimethyl-2-propynyl)-peroxide or di-(3-methylbutynyl)-3-peroxide,

\[
\begin{align*}
&\text{(CH₃)₄C:O} \\
&\text{CH₃} \\
&\text{CH₃} \\
&\text{C:C(CH₃)₄}
\end{align*}
\]

Liq, bp 65-7° at 2 mm, d 0.881 at 25°, nD²⁵ 1.4219

\[
\begin{align*}
&\text{R}_1\text{R}_2\text{C}-\text{O} \text{OO}_2 \text{C}-\text{R}_1\text{R}_2 \\
&\text{H:C} \\
&\text{C:C}
\end{align*}
\]

such as bis(1,1-methyl-1-ethyl-2-propynyl)peroxide or di-(3-methyl-pentynyl)-3-peroxide,

\[
\begin{align*}
&\text{(CH₃)₃C(H₅)C:O} \\
&\text{CH₃} \\
&\text{C:C(CH₃)₃}
\end{align*}
\]

Liq, bp 53-55° at 2 mm, d 0.9030 at 25°/4° and nD²⁵ 1.4390

These peroxides are stable but they can be detonated by means of a blasting cap

Refs: 1) N.A.Milas, USP 2,22307(1940) & CA 35, 1802(1941) 2) N.A.Milas & D.M. Surgenor, JACS 68, 206-7(1946) 3) N.A.Milas
Acetylene, Manufacture of Tetranitromethane, From. See PATR 2510 (1958), p Ger 195, unde Tetan

Acetylene-Nitric Acid Reactions Studies. Reactions between acetylene and nitric acid were studied in Italy as early as 1901 by Baschieri (Gazz 31 II, 462), in 1902 by Testoni & Mascalini and in 1903 by Mascarelli & A. Quilico, M. Frei and other investigators found that the earlier work was incomplete and questionable and for this reason they repeated some of the earlier work and published a series of papers in Gazz, beginning in 1929 (vol 59). The products which they examined, many of them explosive, were prep by bubbling a slow current of purified acetylene through fuming nitric acid. Following is a selected list of papers and the names of the expl comds prep by Q & F:

a) Gazz 59, 930-41 (1929) & CA 24, 3484 (1930) (An expl compd presumably 5-isoxazolecarboxylic acid. This compd was reexamined in 1942 and the results were published in Ref m)

b) Gazz 60, 721-44 (1930) & CA 25, 1247 (1931) (An expl compd, C₄H₂N₂O₂, which was not identified) (See Ref h)

c) Gazz 61, 484-500 (1931) & CA 26, 454 (1932) (The constitution of an expl compd, C₄H₂N₂O₂, was partially established). There was also prep an expl oil heavier than water, C₄H₂NO₂, bp 147° at 155 mm

d) Gazz 61, 759-72 (1931) & CA 26, 1606 (1932) (The structure of a previously prep expl oil, C₄H₂NO₂, was partly established)

e) Gazz 61, 970-6 (1931) & CA 26, 2978 (1932) (Prepn and some props of a-isoxazolamine hydrochloride and diazoaminoisoxazole)

f) Gazz 62, 436-44 (1932) & CA 26, 5561 (1932) (Mono substituted derivs of a-isoxazolocarboxylic acid, etc)

g) M. Frei, Gazz 62, 457-63 (1932) & CA 26, 5952 (1932) (Some expl derivs of a-isoxazolocarboxylic acids and of a-methyl-isoxazolecarboxylic acid)

h) Gazz 62, 503-18 (1932) & CA 62, 5953-4 (1932) (The structure of a previously prep expl compd, C₄H₂N₂O₂, was established as ON:CH:CH:CN:N.C(NO)₂. The compd was named α-isoxazoleazotrinilmethane. Benzeneazotrinilmethane and its nitrocompd p-nitrobenzeneazotrinilmethane were also prep)

i) Gazz 62, 912-27 (1932) & CA 27, 1348 (1933) (More info on benzeneazotrinilmethane, p-nitrobenzeneazotrinilmethane. Prepn an props of other expl comds are given, such a β-naphthylazotrinilmethane and p,p'-biphenylenebisazotrinilmethane)

j) Gazz 65, 1203-13 (1935) & CA 30, 5219-21 (1936) (Prepn and establishment of structure of eulite. It decomp explosively when heated above its mp, 102.8°)

k) Gazz 66, 278-99 (1936) & CA 31, 1805 (1937) (Prepn of the mercuric salt of eulite, which exploded violently on heating)

l) Gazz 71, 327-42 (1941) & CA 36, 771 (1942) (Nitro, amino and diazo derivs of isoxazole m) Gazz 72, 458-74 (1942) & CA 39, 2753-4 (1945) (By means of a synthesis of isoxazole derivs with fulminic acid, it was establish, that the structure of the acid reported in Ref a is incorrect. It should be 3-isoxazole carboxylic acid)

n) Gazz 76, 3-29 (1946) & CA 41, 380-2 (1947) (Further investg of the compd described in Refs a and m. Prepn of some derivs of furazan. Silver salts of 4-(3-isoxazolyl)-3-furazonocarboxylic acid and of 3-furazanocarboxylic acid are explosive)

o) Gazz 76, 30-43, 87-107, 195-9 (1946) & CA 41, 382-6 (1947) (Further work on eulite)

Acetylenenitrile. See Cyanocetylene

Acetylene-Oxygen and Acetylene-Air Mixts were examined in Japan and the results are reported in the following refs:

1) R. Kiama et al, Rev PhysChem Japan 23, 43-8 (1953) & CA 48, 8544 (1954) (A mixt of 54% C₂H₂ and 46% O₂, initially at 270° and 10.9 atm, exploded on being compressed
rapidly (0.7 sec) to 56.1 atm. No expln was observed with mixts of C₂H₂-air treated under similar conditions.) 2) H. Kiyama et al., Rev Phys Chem Japan 24, 41-8 (1954) & CA 49, 1200 (1955) (Mixts of C₂H₂ and O or air at 10 kg/cm² were rapidly introduced into a heated vessel and the occurrence or nonoccurrence of an expln was noted. The min expln temp for C₂H₂-O mixts was 220-30° and for C₂H₂-air mixts ca. 390°. Addn of a small amt of CCl₄ elevated the temp of expln about 25°, while addn of H₂O vapor elevated the temp even more. In both cases the resulting explns were more severe than without the addns.) 3) H. Teranishi, Rev Phys Chem Japan 25, 58-63 (1955) & CA 50, 8207 (1956) (Previous work on the expln of mixts of C₂H₄ with O and air at 10 kg/cm² press was continued. Explns of C₂H₂-O air mixts were less violent than corresponding C₂H₂-O mixts. The addn of small amts of H₂O to C₂H₂ mixts increased the temp of expln while addn of small amts of methanol increased the temp only for a C₂H₂/O ratio greater than 2. N retarded the propagation of expln and an increase in the press of either the air or the O mixts decreased the temp required for spontaneous expln)

Acetylene Ozonide. Briner & Wunenburger (Ref 1) reported that the action of ozone on acetylene carried out in a gaseous phase, resulted in expln, but few crysts of ozonide were obtained when reaction was carried out in soln and at low temps. These crysts could not be properly investigated because they exploded violently a short time after their prepn. Hurd & Christ (Ref 2) conducted ozonization of some acetylene derivs with 5-10% solns of ozone in chl. Jacobs (Ref 3) conducted ozonization of some substi-
tuted acetylenes. Dallwigk et al (Ref 4) detd infrared spectra of ozonides of some acetylene derivs


Acetylene Peroxides. See Acetylene Hydroperoxides and Peroxides

Acetylene Reactions are described in the following references:

Acetylene Tetrachloride. A misnomer for 1,1,2,2-Tetrachloroethane

Acetylene Tetraurethane. See Ethane Tetraurethane

Acetylenic Compounds are organic compounds contg at least one triple bond -C≡C-. They may be hydrocarbons, alcohols, acids, aldehydes, etc. The acetylenic hydrocar-
bons include, in addition to acetylene (qv), the higher members, such as allylene or propyne H₃C.C:CH, crotonylene or butyne -2 H₃C.C:CH₂, valerylone or pentyne -2 H₄C₂.C:CH₂, etc

Considerable research on acetylenic compds was conducted before and during WW II in Germany, especially by W. Reppe et al. In more recent years, research on acetylenic compds was conducted by a group of investigators in Gt Britain: K. Bowden, E.R. Jones, Sir Ian Helbron,
E. J. Haynes, B. C. Weedon, E. A. Braude, F. Sondheimer, M. C. Whiting, H. B. Henbest, T. Y. Shen, E. M. Fowler, G. Eglington, etc. Results of their work were described in numerous papers published in JCS, beginning in 1946. Many acetylenic compounds are described in refs listed under Acetylene and Acetylenes.

Following are some additional references on acetylenic compounds which might be of interest as explosives:

1) C. L. Leese & R. A. Raphael, JCS 1950, 2729, & CA 45, 3324 (1951) (In the course of synthesizing long-chain aliphatic acids from acetylenic compounds, some expl substances were obtained, eg, methylmethylthiuronium picrate, C6H5N2O2S, N 15.7%, mp > 300°, detonated violently on rapid heating) 2) J. B. Armitage et al., CA 41, 1574 (1953) (In the prepn of monosubstituted derivs of di-acetylene, a small quantity of an expl product corresponding to the formula:

\[ H_2C=CH_2 \cdot C: C \cdot C: CH \]

was obtained. It was a liquid, bp 42° at 150 mm, nD^20 1.4038 3) T. Herbertz, Ber 85, 475-82 (1952) & CA 47, 1574 (1953) (In the syntheses of acetylenic compds, starting with diacetylene, some expl substances were obtained, eg, CIC6H5C:CHCl, liq, bp 110° at 5-6 mm, expl decompn ca 120°

Acetylenic Derivatives. See Acetylene Derivatives


Acetylglycine, Azide (Azidoacetylglycine or Triazooacetylglycine), CH3, CO.N(N3), CH3, COOH, mw 158.12, N35.44%. Explosive, undistillable oil. Was prep'd from glycine and azidoacetic acid

Refs: 1) Beil-not found 2) K. Freudenberg & R. Keller, Ber 71B, 334 (1938) & CA 32, 2905 (1938)

1-Acetylhexahydro-3,5-dinitro-s-triazine.

See 1-Aceto-3,5-dinitro-triazacyclohexane under Acetotriazacyclohexane and Derivatives

N-Acetylhexahydrodiphenylamine. See N-Cyclohexylacetanilide

Acetylhexahydrotetrazine. See Acetotriazacyclohexane

ACETYLHYDRAZOBENZENE AND DERIVATIVES

N-Acetylhydrazobenzene or N-Acetyl-N,N'-diphenylhydrazine (Acetic 1,2-diphenylhydrazide),

\[ CO \cdot CH_2 \cdot C_6H_5 \cdot N \cdot NH \cdot C_6H_5, \]

mw 226.27, N 12.38%, OB to CO2—240.4%. Ndl's (from hot alc), mp 159°, Qc 1792.9 kcal/mol (Ref 3); insol in w & alkalies, sol in alc & eth. Was prep'd from hydrazobenzene and acetic anhydride (Ref 2)

Refs: 1) Beil 15, 244, (64) & (93) 2) D. Stern, Ber 17, 380 (1884) 3) A. Pongratz, et al., Ber 77, 651-4 (1944) & CA 40, 6068 (1946)

Azido-Diazido- and Nitrated Acetylhydrazobenzenes—were not found in Beil or CA through 1956

ACETYLIDES AND CARBIDES (INORGANIC)

Acetylides (Acetylene Derivatives, Inorganic) (Acetylenide or Carbide, in Ger). Acetylides are compds obtained by replacement of one or two hydrogen atoms of acetylene or its homologs or derivatives by a metal. Their structure may be as follows: HC=CM', M'=C=CM or RC=CM', where M' stands for a monovalent metal and R for an organic radical, eg LiC=CH, AgC=CAg, CuC=Cu.

With divalent metals the formulae would be

\[ C\cdot C\cdot M'' \]

Certain carbides (but not all) may be regarded as acetylides, eg calcium carbide, CaC2.

Note: Kirk & Othmer (Ref 4) list the acetylides
of Ca and of some other metals under carbides

A general method for the prep of acetylides

is to pass C₂H₂ through ammoniacal solns of the corresponding salts (such as nitrates) or of oxides. For the prep of alkali metal acetylides, the metal (such as Na or K) is dissolved in liq NH₃ and the C₂H₂ is passed through

Most acetylides of the heavy metals are very sensitive to mechanical action. Only one of the acetylides (cuprous acetylide) has found application in industry as an ingredient of electric detonators. Some acetylides, as for instance, that of silver, are probably suitable for use in primers and detonators. They also may be incorporated in LA-based compositions for expl rivets in order to reduce their ignition point (Ref 6).

According to Sax (Ref 6) the toxicity of acetylides is unknown, but their expl hazards are considered to be the same as those of fulminates and azides. The acetylides must be handled with extreme care and in storage they must be kept cool and wet. Metal powders, such as finely divided Cu or Ag, should be excluded. Shipping regulations are the same as for other primary and initiating explosives


The following acetylides and carbides may be of interest

Aluminum Acetylide, Al₃(C₂)₃, wh solid, prep’d by direct action of acetylene on Al pdr at 450-500°. It is a true acetylide because on hydrolysis it gives C₂H₂

Reps: 1) Beil 1, 220 2) J. F. Durand, Bull Fr [4] 35, 1141 (1924); JCS 126, 1, 1278 (1924) & CA 19, 633 (1925)

Aluminum Carbide, Al₃C, pale yel hexag crys, mp 2200°, subliming in vacuo at 1800°, reacts with H₂ giving methane together with less than 10% hydrogen. This reaction was used in Germany for producing the gas employed in galleries for testing expls in regard to their safety for use in gaseous and dusty coal mines (Ref 4). Al₃C₃

was first prep’d in 1894 by Moissan (Reps 1, 2 & 3) by heating an intimate mixt of alumina (Al₂O₃) with carbon in an electric arc furnace. Other methods of prep are also known


Arsenical Carbide, As₄C₆, b m amorph ppt, which expl on warming or gentle rubbing. Was prep’d by treating acetylene-bis-magnesium iodide, MgI₂C₂, with carbon in an electric arc furnace.

Reps: 1) Beil 1, 221 2) E. deMahler, Bull Fr [4] 29, 1072 (1921) & JCS 122, 1, 101 (1922)

Aurous Acetylide. See Gold Acetylide

Barium Carbide, also called Barium Carbide, BaC₂, greyish solid d 3.75. Was first prep’d by Maquenne by treating Ba amalgam with carbon in a stream of hydrogen (Reps 1 & 2). Moissan (Ref 2a) prep’d it by heating BaO, or BaCO₃, with methane. Vaughn et al (Ref 4) obtained an unstable product, corresponding to an approx formula between BaC₂ and Ba(C₂H₂) by adding a soln of Ba in liq NH₃ to C₂H₂ in liq NH₃. Masdupuy & Gallais (Ref 5) prep’d BaC₂ by heating to 120° Ba (H₂O₂, 4NH₃), which was obtained by treating Ba in liq NH₃ with acetylene


Beryllium Acetylide, BeC₂, wh solid, prep’d
by passing pure dry \( \text{C}_2\text{H}_2 \) over Be pdr at ca 450 \( ^\circ \)

Refs: 1) Beil 1,(218) 2) J. F. Durand, Bull Fr [4] 35, 1145(1924); JCS 126 1,1278 (1924) & CA 19, 632(1925)

Beryllium Carbide, \( \text{Be}_2\text{C} \), yel or brn-yel crystals, d 1.9 at 15 \( ^\circ \). Was first prep by heat-ing beryllium oxide with carbon in an electric furnace (Ref 2). Other methods of prepn are listed in Ref 1. Henry (Ref 3) established its formula as \( \text{Be}_2\text{C} \).

Refs: 1) Beil 1,(7 & 127) 2) P. Lebeau, CR 121, 466(1895) & JCS 70 II, 169(1896)

Boron Carbide, \( \text{B}_4\text{C} \), coml prod called "Nor-die," mp ca 2375 \( ^\circ \), d 2.52 is prep by heating anhyd boric oxide \( \text{B}_2\text{O}_3 \) with carbon in graphite resistance furnace at ca 2500 \( ^\circ \). Its special interest is due to its remarkable hardness which lies on the Moh's scale betw that of silicon carbide and diamond. Used as an abrasive. Detailed description of this compd is given in Kirk & Othmer 2(1948), 830-4(21 refs)

Cadmium Acetylide, \( \text{CdC}_2 \) (formula is not definitely established). It was prep by passing pure dry \( \text{C}_2\text{H}_2 \) over pulverized \( \text{Cd} \) at ca 500 \( ^\circ \) (Refs 1 & 2 ). Gebauer (Ref 3) prep'd two derivs, \( \text{CdC}_2 \), \( \text{CdH}_4 \), \( \text{Cd}_2 \) and \( \text{CdC}_2 \). \( \text{CdH}_4 \), both of which partially de-compd by hot w but were stable in the air even at 200 \( ^\circ \).

Refs: 1) Beil 1,(220) 2) J. F. Durand, Bull Fr 35, 1142(1924) & CA 19, 632(1925)

Calcium Acetylide, \( \text{CaC}_2 \) (formula is not definitely established). It was prep by passing pure dry \( \text{C}_2\text{H}_2 \) over pulverized \( \text{Cd} \) at ca 500 \( ^\circ \) (Refs 1 & 2 ). Gebauer (Ref 3) prep'd two derivs, \( \text{CaC}_2 \), \( \text{CaH}_2 \), \( \text{Ca}_2 \) and \( \text{CaC}_2 \). \( \text{CaH}_2 \), both of which partially de-compd by hot w but were stable in the air even at 200 \( ^\circ \).

Refs: 1) Beil 1,(220) 2) J. F. Durand, Bull Fr 35, 1142(1924) & CA 19, 632(1925)

Calcium-2-acetylide, called in Beil Calciumcarbido-Acetylen, \( \text{Ca}(\text{C}_2\text{H})_2 \), wh solid which decompd in 5 hrs. Was first prep'd either by passing \( \text{C}_2\text{H}_2 \) into soin of \( \text{Ca} \) in liq \( \text{NH}_2 \) or by adding \( \text{Ca-NH}_2 \) soln to \( \text{C}_2\text{H}_2-\text{NH}_2 \) soln


Calcium Acetylide or Calcium Carbide, \( \text{CaC}_2 \), mw 64.10, OB to \( \text{CO}_2 \) and \( \text{CaO} -75.0 \%. The pure prod is a wh solid, mp 2300 \( ^\circ \), d 2.155, sp heat (0 to 2000 \( ^\circ \))0.28 cal/g, whereas the carbide ranges in color from steel-grey to red-bm. It exists in four crystn forms of which the tetragonal predominates. It reacts vigorously with w producing acetylene and \( \text{Ca} \) hydroxide. If only a small amt of w is used, the carbide becomes incandescent and causes an expln of acetylene-air mixt formed on contact of w with \( \text{CaC}_2 \). Small quantities of \( \text{CO}_2 \) and \( \text{CaO} \) may form in \( \text{CaC}_2 \) drums during storage, and the opening of such drums is a dangerous operation. Many methods of prepn are known and listed in Beil. The earliest method is that of Wöhler (Ref 2), who prep'd \( \text{CaC}_2 \) by heating Zn-Ca alloy(previously prep'd by Caron) with carbon at very high temp. Invention of an industrial method of prepn--heating quick-lime and carbon in an elect arc furnace at 2500-3000 \( ^\circ \) is generally attributed to Willson, who in collaboration with Lord Kelvin prep'd \( \text{CaC}_2 \) in 1892(Ref 3). Slightly later (1894-5) and independently, Moissan prep'd \( \text{CaC}_2 \) by essentially the same process as Willson. Böhm (Ref 4) claimed that he invented a similar process earlier than Willson and applied for patent in 1891, but the patent was not issued until 1895. The electric arc furnace method invented in 1892 is essentially the same as the current method of manuf of \( \text{CaC}_2 \). Detailed description of the method is given in Refs 5,6,7 & 8. The coml prod contains \( \text{CaO} \), graphite and some other impurities.

For the lab prepn of pure \( \text{CaC}_2 \), a small quantity of pure \( \text{Ca} \) cyanamide is heated in the presence of carbon:

\[ \text{CaCN}_2 + \text{C} \rightarrow \text{CaC}_2 + \text{N}_2 \] (see also Ref 5a)

Toxicity, fire & expln hazards, storage & handling and shipping regulations are discussed in Ref 9
CaC$_2$ is used extensively for the manuf of acetylene, and Ca cyanamide (by fixation of atmospheric nitrogen), as the starting material for making the melamine family of resins, for the manuf of acetylene black and many other purposes.


**Calcium Carbide-Ammonia-Acetylene**

(called in Ger "Calciumcarbidammoniak-acetylen") CaC$_2$ + H$_2$C$_2$ + 4NH$_3$, wh prism crystals, which become incandescent in contact with w, Cl, CO$_2$ & SO$_2$ and yield exists in both cuprous, Cu$_2$C$_2$, and cupric, CuC$_2$, forms.

**Cuprous Acetylide or Dicopper Acetylide** (Acetylene Copper or Copper Carbide) [Dicopper(1)-acetylenid, in Ger], Cu-C

mw 151.10

Brick-red amor pdr which expl violently when dry, on heating to ca 120$^\circ$ and also by friction.

Note: According to Ref 5, Cu$_2$C$_2$ flashes at ca 150$^\circ$. Klement & Köddemann-Gros (Ref 8, p 213-15) gave for 95% pure prod an expln temp of 170$^\circ$ in air and 265$^\circ$ in a high vac.

Cu$_2$C$_2$ is sl sol in w and sol in alkalies and aq KCN. The usual method of prep is to pass dry C$_2$H$_2$ into an ammoniacal soln of a cuprous salt in the absence of air. It has been claimed until recently that monohydrate, Cu$_2$C$_2$.H$_2$O is first obtained and this goes on gentle heating, into the anhyd salt (Ref 4a). Klement & Köddemann-Gros, (Ref 8) prep C$_2$H$_2$ of 95% purity and studied its oxidation products.
Morita (Ref 11) prepd cuprous acetylide from a 5% soln of CuCl, and claimed that its ignition temp was 260-70°. This temp was lowered to 100° after the acetylide was oxidized by air. At the same time the color changed to black and the compd became very sensitive to impact. On further oxidn the ign temp rose to 200. It is presumed that oxidn transformed cuprous acetylide into the cupric compd. Schlubach & Wolf (Ref 9b) in attempting to prepd CuC=CH by treating a satd soln of C\textsubscript{2}H\textsubscript{2} in w at 0° with an aq soln of CuSO\textsubscript{4} + NH\textsubscript{4}OH + NO, NH\textsubscript{3}, HCl obtained instead the Cu\textsubscript{2}C\textsubscript{2}.

Vestin (Ref 10) claimed that there is no hydrate of Cu\textsubscript{2}C\textsubscript{2} and previously to this Dolgopol' ski claimed that the monohydrate is actually di(cuprocacetaldehyde), Cu\textsubscript{2}CH : CHO. For its prepn D recommends passing pure C\textsubscript{2}H\textsubscript{2}(with exclusion of air) into a soln of CuCl until all the CuCl has reacted. The liq is decanted and the residue washed with abs alc and eth, previously saturated with C\textsubscript{2}H\textsubscript{2}. The ppt is dried by passing over it dry C\textsubscript{2}H\textsubscript{2} at 50° until const wt is obtained. The resulting subst obtained by D was a red-brn powd which expld on heating or on exposure to mech action. When tested on an impact sensitivity apparatus with an 8 kg wt, the subst deton at 30 cm, compared with 15 cm for a coml anhyd prod prepd by passing a mixt of tech gases from a low-temp polymerization of C\textsubscript{2}H\textsubscript{2} through the CuCl soln. The latter compd flashed with a bright flame when lightly touched with a glass rod. Its structure was not detd.

Cuprous acetylide forms whenever acetylene gas comes in contact with copper, its alloys or some of its salts. As the illuminating gas, made by distn of coal usually contains some acetylene, it should not be conducted through pipes contg Cu. If such pipes are used, great care and caution should be observed in cleaning the pipes inside (Ref 2).

Mixts of Cu\textsubscript{2}C\textsubscript{2} with PbCl\textsubscript{2} are extremely sensitive to friction (Ref 2) and Cu\textsubscript{2}C\textsubscript{2} expl on contact with nitric acid, permanganates, sulfuric acid, bromine or chlorine, etc (Ref 8).

Toxicity, fire & expln hazards and shipping regulations are discussed by Sax (Ref 13).

Cuprous acetylide is the only acetylide found application in the expl industry. It is used in ign compns for coml elec detonators (Ref 5a).

Chambionnat (Ref 9) in the course of investigation of the possible use of Cu\textsubscript{2}C\textsubscript{2} as a fungicide, prepd mixts of Cu\textsubscript{2}C\textsubscript{2} with inert subst, such as talcum pdr, and detd their expl props. The tests showed that mixts of talc with as little as 16% Cu\textsubscript{2}C\textsubscript{2} can be initiated by an elec spark, but it requires a minimum of 25% Cu\textsubscript{2}C\textsubscript{2} for initiation by heat, such as a hot plate. Mixts with as little as 35% Cu\textsubscript{2}C\textsubscript{2} can be initiated by rubbing in mortar at temp 55-60°, whereas at RT a minimum of 65-70% of Cu\textsubscript{2}C\textsubscript{2} is required.

Cuprous acetylide has been used also for prepn of industrial catalysts (See Cuprous Acetylide Catalyst, which follows).

separation equipment for coke-oven gas)
12) Sh. Morita JSocHighPressureGasInd 19, 167-7(1955) & CA 50, 6047(1956) 13) Sax (1957), 518

Cuprous Acetylide Catalysts. \( \text{Cu}_2 \text{C} \) supported on silica gel, kieselguhr etc can be used as a catalyst in some org reactions

Cuprous Acetylide-Chloride, \( \text{Cu}_2 \text{C} \text{CuCl} + \text{H}_2\text{O} \), dk violet pdr, deflagrates very weakly on heating in an open flame. Was prep by passing acetylene through \( \text{CuCl} \) in 0.2N HCl
Refs: 1) Beil 1(104) 2) W. Manchot & J. C. Withers, Ann 387 270-2(1912)

Note: Some other cuprous acetylide-chloride compds (none of them seem to be expl) were described in Beil 1,910 and in the following Scandinavian papers:

Cuprous Hydrogen Acetylide (Monokupfer-acetylenid, in Ger), \( \text{Cu} \) CH. Attempt to prepare this compd by adding with stirring satd soln of \( \text{CuH}_2 \) in \( \text{H}_2 \text{O} \) to an aq soln of \( \text{CuSO}_4 \) + \( \text{NH}_2\text{OH} + \text{H}_2\text{O} \). \( \text{H}_2\text{N} \cdot \text{HCl} \) was unsuccessful. Instead of this, the dicopper acetylide, \( \text{Cu}_2 \text{C} \) was obtained.
Refs: 1) Beil-not found 2) H. Schlubach & V. Wolf, Ann 568, 152(1950) & CA 44, 8313 (1950)

Cupric Acetylide [Kupfer (II)-acetylenid, in Ger], \( \text{CuC}_2 \), mw 87.56, OB & \( \text{CO}_2 \) 73.1% Black amors ppt, which expl violently on heating, impact or friction. According to Morita (Ref 5) its ignition temp is 100-120° and it explodes on slight impact even under w

It was first prepd by Söderbaum (Ref 2), on passing acetylene through an ammoniacal soln of a cupric salt at ca 5°. The compn of the resulting black pdr was 12 \( \text{CuC}_2 + \text{H}_2\text{O} \). Durand (Ref 3) prepd \( \text{CuC}_2 \) by the action of \( \text{CaC}_2 \) on an aq soln of \( \text{CuCl}_2 \) and purified the resulting ppt with dil AcOH. Nast & Pfab (Ref 6) prepd \( \text{CuC}_2 \) by treating \( \text{KCl} \) in \( \text{NH}_3 \) with \( [\text{Cu(NH}_3)_4](\text{NO}_3)_2 \) in \( \text{NH}_3 \).

Brameld et al (Ref 4) investigated the formation of copper acetylides from aq solns of various cupric salts and acetylene. The resulting compds appear to fall into two types: a) black amors ppts and b) lustrous, metallic appearing plates

The type a) expl sometimes with a report, sparks and flashes to form black Cu. It could be fired by a drop of HNO₃. The explosibility of this type of acetylide is greater than that of cuprous acetylide. This type includes most acetylides, formed from the more common cupric salts, such as the chloride, sulfate and nitrate, and those formed from copper org salts made alkaline with alkalies other than ammonia, or also with ammonia, provided insufficient amonia is present to retain all the Cu as a complex salt

The type b) cupric acetylides expl on gentle tapping (sometimes even when touched under soln) with a bright flash and report to form metallic Cu. It could be obtained as a reaction of \( \text{CuSO}_4 \) and \( \text{CuCl}_2 \) in an aq solution. According to Beil (Ref 2), it was obtained as a reaction of \( \text{CuCl}_2 \) and \( \text{CuSO}_4 \) in an aq solution.
to Dr Hans Walter of PicArsn, the following procedure was developed by the Lindé Co of München:

A) Determination of acetylene:

a) Assemble an apparatus as represented on the drawing

b) Weigh a sample ($W_1 = ca 0.5g$)

Place it in the flask containing a small amount of O-free w.

c) Stopper the flask and pass a current of O-free CO$_2$ or N$_2$ to remove air.

d) Continuing to pass CO$_2$, add slowly from a separatory funnel O-free concd (20-30%) HCl until the disappearance of amber color.

e) Collect the liberated C$_2$H$_2$ in the test tube containing O-free 5% aq soln of gelatin (used as a protective colloid) with some NH$_4$Cl and Cu$_2$Cl$_2$ (free of CuCl$_2$).

f) Boil the soln in the flask to expel residual C$_2$H$_2$ and collect it also in the test tube.

g) Acetylene reacts with Cu$_2$Cl$_2$ in the test tube giving Cu$_2$C$_2$, which imparts an intense red coloration to the contents of the tube. Determine the amount of Cu$_2$C$_2$ in the tube by comparing the color with known standards or by using a colorimeter and calculate the corresponding amount of C$_2$H$_2$ ($W_2$).

B) Determination of total copper:

a) Oxidize the cuprous copper soln in the flask to cupric state by adding KClO$_3$ in slight deficiency to the HCl present.

b) Boil the soln to drive out chlorine, cool, transfer to a volumetric flask and make up with water.

c) Take an aliquot, add an excess of KI and titrate the resulting bromine soln with Na thiosulfate in presence of starch indicator.

d) Calculate copper content ($W_3$) taking into consideration the following equations:

$2CuCl_2 + 4KI = 2CuI + I_2 + 4KCl$ and $I_2 + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$.

C) Estimation of Cu(I) and Cu(II) in copper acetylide can be accomplished by the indirect method, which involves solving the following equations:

$x + y + z = W_1$

$127.14x + 63.57 y = 63.57 W_1$

$26.04 x + 26.04 y = W_2$

$151.16 - 87.59$

where $W_1$ is the wt of sample, $x$ is the wt of Cu$_2$C$_2$, $y$ the wt of Cu$_2$Cl$_2$, $z$ the wt of impurities, $W_2$ total wt of Cu(procedure B) and $W_3$ total amt of C$_2$H$_2$(procedure A).

In the method described by Klement & Ködermann-Gros (Ref 4) total Cu is detd by dissolving a sample in HCl, oxidizing Cu(I) to Cu(II) with HNO$_3$, boiling with H$_2$SO$_4$ (until the disappearance of NO$_2$ fumes), cooling, diluting with water and estimating Cu content electrolytically. For detn of Cu(I) content a 50 mg sample is placed in the flask of the apparatus described on p 204 of Ref 4 and (after removing all air by passing a stream of O-free CO$_2$) it is treated with 10 ml of O-free concd HCl. After evoln of C$_2$H$_2$ ceases, 70-80 ml of water is added and the soln titrated with 0.1N KBrO$_3$ soln as described by Zintl & Wattenberg (Ref 1). The acetylene content is detd gas-volumetrically in a special apparatus (described on p 205, Ref 4) by treating a sample with 20% KCN soln; Cu$_2$Cl$_2$ 8KCN + 2H$_2$O + Cu$_2$H$_2$ + 2K$_2$[Cu(CN)$_6$] + 2KOH.

The water content is detd by heating a sample in a high vacuo to 140° in the presence of P$_2$O$_5$.

In the method of Voronkov (Ref 3), Cu(II) is reduced to Cu(I) with NH$_2$OH, the obtained Cu$_2$C$_2$ is decomposed with HNO$_3$ and Cu detd...
volumetrically. The acetylene content is detd by a rather complicated method which is not described here because its brief description is given in CA 43, 2972(1949).

Dolgopol'skii et al (Ref 2) proposed two methods of detg copper in Cu₂C₄:

a)The dichromate methods involves soln in 15-18% HCl, soln in boiling HNO₃, adding concd alkali(to ppt Cu as hydroxide), soln of the ppt, add of Seignette salt (turning the color from greenish to violet), of boiling soln with Ca(OH)₂, dissolving a 25 ml concd HNO₃, and titrating with K₂Cr₂O₇ in the presence (C₅H₅)₂NH.H₂SO₄, as an indicator.
b)The iodometric method involves dissolving a 0.1-0.2 g sample in 15-20% HCl, evaporating the soln to 2-3ml, treating it with ca 25 ml concd HNO₃, and titrating with complete oxidation (color turning from grn to blue); this followed by boiling the soln with concd H₂SO₄ until disappearance of NO₃, cooling, adding ammonia in excess, boiling to remove excess NH₃, cooling, adding H₂SO₄, adding 40-50ml 10% KI and titrating the soln with 0.25N Na₂S₂O₃ using starch indicator. These methods of analysis are also applicable to copper derivs of vinyl-acetylene and of acetylenedivinyl.

Siggia (Ref 5) gives some general methods of analysis of acetylene and acetylenides. 

Caution: Copper acetylenides are very expl when dry and should be destroyed, after experiments, in the same manner as described by Siggia for silver acetylide (Ref 5). For this, rinse all pieces of used apparatus with dil nitric acid, dissolve all solid deposits in the same acid and pour the solns into a sink. Dolgopol'skii (Ref 2) advises destroying Cu derivs of acetylene, etc, as well as the technical gas mixts from acetylene polymerization, by treating them in the cold for about 1 hr with a 15% HCl or by heating them to 80-85° for about 1 hr with 10% HCl.

Refs: 1)E. Zintl & H. Wattenberg, Ber 55, 3366(1922) 2)J.L. Dolgopol'skii et al, Zh-PriklKhim 19, 1281-90(1946) & CA 41, 6721-

Gold Acetylide or Gold Carbide (Aurous Acetylide), Au₂C₇, mw 418.42. Yel ppt, mp expl on rapid heating(various temps are reported ranging from 83° to 157°). Very sol in w, insol in alc. Can be prep'd by passing acetylene through an ammoniacal soln of sodium aurothio sulfate Na₂Au(S₂O₃)₂, which had been previously prep'd by mixing aq solns of AuCl₃ and Na₂S₂O₃.

When thoroughly dried, aurous acetylide readily expl, not only on rapid heating(see above) but also on impact, friction or even when touched with a camel’s hair brush. Several explns have occurred during its prepn in various labs. When expld, it produces a flame and leaves a black, powdered residue of gold. Reppe et al (Ref 3) found Au₂C₇ as a suitable catalyst in prepn of some org compds.


Halogen Substituted Products of Acetylene. See Halogenated Acetylenes under H’s.

Iron Acetylide (Ferrous Acetylide) [Eisen (II)-acetylenid, in Ger], FeC₆; solid, stable in the air or w at RT; decompd by HCl with evoln of C₆H₆. Was prep'd by Durand on treating CaC₆ with ferrous chloride.

Refs: 1)Beil 1,(220) 2)J.F. Durand, CR 177, 693 (1923) & CA 18,657(1924)

Iron Carbide Fe₃C; brilliant wh crysts, ignites when heated, d 7.07 at 16°, not attacked by w even at 150°. Was prep'd by Moissan on heating pure iron with sugar-charcoal in an elec furnace.


Lead Acetylide, PbC₆(probably), mw 231.21. Lt grey powd, stable toward H₂O. Stated to be prep'd by adding CaC₂ to an aq soln.
of Pb acetate and washing the resulting ppt with dil AcOH (Ref 2)

Montignie (Ref 3) reported unsuccessful attempts to prep PbC₂ by calcining some org salts but he prep'd a mixt of PbC₂ with several other compds by dropping a methanolic soln of Pb acetate on CaC₂. He reported that his prod was stable in air but hydrolyzed by acid or alk solns


Lithium Carbide or Monolithium Acetylide, LiC₂, wh crys, d 1.65 at 18°C was prep'd by Moissan on heating Li carbonate with 6 mols of sugar-charcoal in an elec furnace: Li₂CO₃ + 6C → 2LiC₂ + 3CO (Ref 2). It is a powerful reducing agent and reacts with w in cold to produce pure C₂H₂ and the reaction becomes violent at ca 100°C (see also Dilithium Acetylide listed below)

Refs: 1) Beil 1, 238 2) H. Moissan, CR 122, 362-3 (1896) & JCS 70 I, 419 (1896)

Monolithium Hydroacetylide or Monolithium Acetylide-Acetylene, LiH₂C₂ or Li₂C₂ + C₂H₂. It is claimed in Beil 1, p 238 that this compd was prep'd by Moissan (Ref 2). There is some misunderstanding because the compd LiH₂C₂ is not listed in Ref 2, but there is described by Moissan, among other acetylides, the complex, Li₂C₂ + C₂H₂ + 4NH₃, called lithium carbide-ammonia-acetylene (see below) which gave on heating Li₂C₂.

Campbell et al, (Ref 3) prep'd LiH₂C₂ in soln by adding small pieces of Li to liq NH₃ while passing C₂H₂ gas into the mixt until the final soln changed from blue to col. LiH₂C₂ appears to undergo spont decomp during its isolation from liq NH₃, with an approx equimol mixt of LiH₂C₂ and LiC₂ being formed with some occlusion of NH₃ vapor. Masdupuy & Gallais (Ref 4) claimed to have prep'd LiH₂C₂ from Li, NH₃ and C₂H₂ but Beil 1 (1909) states that it exists only in soln

Refs: 1) Beil 1, 238 & 1909 2) H. Moissan, CR 127, 911(1898) & JCS 76 I, 241(1899)

Dilithium Acetylide or Lithium Carbide, Li₂C₂, wh crys. Was first prep'd by Guntz on heating Li to redness in a vac with carbon or in a current of CO or CO₂ (Ref 2). Moissan (Ref 3) prep'd it by heating lithium carbide-ammonia-acetylene. Tucker & Moody (Ref 4) prep'd it by heating Li carbonate and carbon in three types of elec furnaces to produce the reaction: Li₂CO₃ + 4C → Li₂C₂ + 3CO. The granular carbon type of furnace gave the best results. Other methods of prepns are given in Refs 5 & 6


Magnesium Acetylide or Magnesium Carbide, MgC₂, tetragonal crys, which are decomp'd by w into C₂H₂ and Mg(OH)₂. Was first prep'd in 1866 by Berthelot (Ref 2) by heating Mg pdr in stream of C₂H₂. Many other methods are listed in Beil, but it seems that heating of Mg pdr to ca 450° in a stream of acetylene is the simplest method (Ref 3). It was claimed that MgC₂ was converted to Mg₂C at ca 500°

Refs: 1) Beil 1, 421,(105) & 1911 2) M. Berthelot, Ann 139, 161(1866) 3) H. Franck et al, ZAnorgChem 232, 110(1937)
Manganous Acetylide [Mangan (II)-acetylenid, in Ger], MnCl₂. Solid, stable at RT in air or w. Was prep'd by treating CaC₂ with MnCl₂ at 450-500°C.

Refs: 1) Beil 1, [220] 2) J. F. Durand, CR 177, 694 (1923) & CA 18, 657 (1924)

Manganese Carbide, Mn₃C : solid, d 6.89 at 17°C; was first prep'd by Troost & Hautefeuille. Moissan prep'd it by heating in an elec furnace a mixt of Mn₃O₄ with sugar-carbon. Other methods of prep'n are given in Refs 1 & 3.


Nickel Carbide, Ni₃C; solid, stable up to 380-400°C; decomd by dil acids or by super-heated steam to methane & other products. Was prep'd by interaction of Ni pdr with CO at 200-300°C.

Refs: 1) Beil 1, [228] 2) H. A. Bahr & Th. Bahr, Ber 61, 2178-8 (1928) & 63, 99 (1930)

Phosphorus Carbide, P₃C₈, amorphous, which spontaneously ignites when gently warmed. Was prep'd by treating an ethereal soln of acetylene-bis-magnesium iodide, Mg₃C₂, with phosphorus trichloride.

Refs: 1) Beil 1, [221] 2) E. deMahler, Bull Fr 4, 29, 107 (1921) & JCS 122, 1, 101 (1922)
Monopotassium Acetylide or Potassium Hydrogen Acetylide (Ethynylpotassium), KHC$_2$, mw 64.13. Wh crysts, viol dec on contact with w; ignites & burns with incandescence in atm of Cl$_2$ or SO$_2$ in the cold. Was first prepd by Berthelot (Ref 2) on heating potassium in acetylene. Moissan (Ref 3) obtained it by passing C$_2$H$_4$ through K liquefied by NH$_3$ at -40 to -80$^\circ$C. Vaughn et al (Ref 4) by adding a soln of K in liq NH$_3$ to C$_2$H$_2$ in liq NH$_3$. Other methods of prepn are listed in Ref 1

Refs: 1)Beil 1, 239[217] & {909} 2)M. Berthelot, AnnChimPhys [419], 385(1866) 3)H.Moissan, CR 127, 911(1898) & JCS 76 I, 241(1899) 4)T.H.Vaughan et al, JOC 2, 3-4(1937) & CA 31, 575(I1937)

Dipotassium Acetylide or Potassium Carbide, K$_2$C$_2$, mw 102.2. Wh crysts, dec vigorously on contact w. Was obtained in small quant by Moissan on heating monopotassium acetylide: 2KHC$_2$ $\rightarrow$ K$_2$C$_2$ + H$_2$C$_2$. Other methods of prepn are listed in Ref 1

Refs: 1)Beil 1, 239 2)H.Moissan, CR 127, 917(1898) & JCS 76 I, 241(1899)

Monorubidium Acetylide or Rubidium Hydrogen Acetylide, RbHC$_2$ or Rb$_2$C$_2$ + C$_2$H$_2$. Wh hygr crysts, mp ca 300$^\circ$ with sl decomp; stable in dry atm; reacts explosively when heated to 350$^\circ$ in presence of PbO$_2$. Was obtained by Moissan by passing C$_2$H$_4$ through a soln of Rb in liq NH$_3$. Other methods of prepn are listed in Ref 1

Refs: 1)Beil 1, 239 2)H.Moissan, CR 136, 1217(1903) & JCS 84 I, 545(1903)

Dirubidium Acetylide or Rubidium Carbide Rb$_2$C$_2$, wh solid; reacts violently with halogens, liq S and sl heated P with evoln of flame. Was prepd by Moissan on heating RbHC$_2$ in a vacuum

Refs: 1)Beil 1, 239 2)H.Moissan, CR 136, 1221(1903) & JCS 84 I, 546(1903)

Silicon Carbide, SiC, mw 40.10; crysts from pale gm to blk, mp-starts to dec ca 2500$^\circ$ and dec completely ca 2700$^\circ$; d 3.15-3.20

Was first prepd in 1891 by Acheson by heating SiO$_2$ with C and essentially the same method is used now. It is an abrasive, which only boron carbide and diamond surpass in hardness. A detailed description of SiC is given in Kirk & Othmer 2(1948), 854-66(49 refs)

Silver Acetylide; Disilver Acetylide or Silver Carbide (Azetylenesilber; Disilberacetylenid or Silberacetylenid, in Ger), Ag$_2$C$_2$, mw 239.78. Wh solid expl at 120-140$^\circ$C (Ref 2, p 3); 225$^\circ$ (Ref 6, p 304) for Ag$_2$C$_2$ prepd from neutral soln. Was first prepd in 1858 by Quet and in the same year by Vogel & Reischauer (see Ref 2, p 1) by passing a stream of acetylene through an ammoniacal soln of silver nitrate. Stettbacher (Refs 2 & 6a) and other investigators (Refs 3-6) studied props of Ag$_2$C$_2$ and compared methods of prepn using ammoniacal silver nitrate solns with those using neutral or slightly acidic solns [see also Disilver Acetylide-Silver Nitrate (Complex)]

A method of prepn recently described (Ref 7) consists of passing a rapid stream of acetylene through an aq N/10 soln of silver perchlorate contg 10% ammonia

Following are some props of silver acetylide which was prepd from ammoniacal solns of silver nitrate: deton vel 1880 m/sec at d (not given); power by Trauzl test 132 cm$^3$ at d 1.67(Ref 6, pp 304-5); minimum initiating charge for 0.8g tetryl, 0.07g Ag$_2$C$_2$ compared to 0.02g for LA (Ref 2, p 4); beat of expln 400 cal/g

Taylor & Rinkenbach (Ref 4) investigated four samples of silver acetylide prepd by various methods. The sample B, prepd from an ammoniacal soln of AgNO$_3$, gave an impact sensitivity with 0.5kg wt 15 cm(LA 43 cm); expln temp 177$^\circ$ (LA 383$^\circ$) and pendulum friction values, fall 33 cm and number of swings 4(for LA 37.5 cm and 12 swings)

Ag$_2$C$_2$ is considered to be inferior in expl props to silver acetylide-silver nitrate, which is described below. Ag$_2$C$_2$ is more sensitive to shock

Muraour (Ref 5) investigated the action of
the shock of electrons on Ag$_3$C$_2$


Monosilver Acetylide + Silver Chloride (Complex), AgHC$_2$. AgCl or Ag$_2$HC$_2$Cl, weakly expl ppt. Can be prep by treating an ammoniacal soln of AgCl with an excess of C$_2$H$_4$.

Refs: 1) Beil 1, 241 2) C. Willgerodt, Ber 28, 2111 (1895)

Note: According to R. Vestin & E. Ralf, Acta Chem Scandinavica 10, 261 (1949) & Beil 1, 910; this complex does not exist.

Monosilver Acetylide + Silver Nitrate (Complex), AgHC$_2$. AgNO$_3$, or AgHC$_2$NO$_3$. Solid, expl violently ca 30°. Can be prep from C$_2$H$_4$ and an aq soln of silver nitrate, as described in Ref 2.

Refs: 1) Beil 1, 241 2) C. Willgerodt, Ber 28, 2108 (1895)

Note: According to R. Vestin & E. Ralf, Acta Chem Scandinavica 10, 261 (1949) & Beil 1, 910; this complex does not exist.

Disilver Acetylide + Silver Chloride (Complex), Ag$_2$C$_2$. AgCl or [Ag$_2$C$_2$]Cl; weak expl ppt. Can be prep by passing C$_2$H$_4$ through an ammoniacal soln of freshly ppted AgCl until about two-thirds of the AgCl is consumed.

Refs: 1) Beil 1, 241 2) M. Berthelot & M. Delépine, CR 129, 370 (1899) & JCS 76, 1, 942 (1899)

Disilver Acetylide + Silver Nitrate (Complex) (Silver Acetylide-Silver Nitrate), Ag$_2$C$_2$. AgNO$_3$, or Ag$_2$C$_2$NO$_3$, mw 409.67, N 3.42%. Wh pdt d 5.38 (Ref 5); mp-detox ca 212° (Ref 6).

It is insol in w, alc & eth. Was prep by passing pure C$_2$H$_4$ through a soln of 10 g AgNO$_3$ in 40 ml H$_2$O and 6 ml HNO$_3$(d 1.4). After cooling, the wh ppt was filtered from the soln and purified by washing with alc and acet. The yield was 7 to 7.95 g compared with the theoretical 8.04 g (Ref 2). Another method of prep is to pass C$_2$H$_4$ through an aq soln of AgNO$_3$, not stronger than 10% (Refs 3 & 6).

This compd is more powerful and less sensitive than Ag$_3$C$_2$. Its rate of deton is higher than that of Ag$_3$C$_2$, but the brisance is almost the same. It is extremely sensitive to flame, less sensitive to impact than MF and less sensitive to friction than LA. It detonates according to the equation:

$$\text{Ag}_2\text{C}_2 + \text{AgNO}_3 \rightarrow 3\text{Ag}\text{(vapor)} + \text{CO}_2 + \text{CO} + 0.5\text{N}_2 + 185 \text{cal}$$

Following is additional data on the expl props of this complex: brisance (brisanzwert, calcd by the Kast formula) 9.4 (millions), compared with 107 for LA; deton vel 3460 m/sec at d 3.96 (LA 5300 at d 4.6); expln temp 217° & 265° (LA 315°); heat of expln 451 cal/g (LA 268); impact sensitivity with a 2 kg wt 3.4 cm (LA 3.2 cm); initiating ability-comparable to MF and LA; power (by Trauzl test) 145 cm$^3$ for a 10 g sample (LA 181 cm$^3$); spec vol 200 1/kg (LA 310); stability in storage at 90° satisfactory. It is unaffected by moisture, light and CO; temp of expln (calcd by Kast formula given in Ref 3, p 338) 5740° (LA 3450°).

According to Shaw & Fisher (Ref 6a), this complex can be used as a means of dtrg C$_2$H$_4$ in gas mixtures.


Note: W. Venier, Brit P 6705 (1906) proposed to use Ag$_3$C$_2$ as an ingredient of primer compns, such as MF 41.4, KClO$_3$ 41.4, Ag$_3$C$_2$ 6.9, K picrate 6.9 & Al 3.4%.
complex was obtained, together with non-explosive Ag₂C₂ + 6AgNO₃, during removal of acetylene from coke-oven gases by absorption in an aq soln of AgNO₃

**Disilver Acetylide + Six Silver Nitrates**

(Complex), Ag₂C₂ + 6AgNO₃ or C₂Ag₈N₄O₁₈, crysts, mp when heated to 308-327°C it melts and then suddenly decomposes with evoln of red fumes. Can be prep'd by passing C₂H₂ through a 30% soln of AgNO₃ in H₂O or N/1 HNO₃. It is not expl

Refs: 1) Beil 1, 1911 2) J. A. Shaw & E. Fisher, JACS 68, 2749 (1946); USP 2,474,869 (1949) & CA 43, 7670 (1949)

**Disilver Acetylide + Silver Iodide**

(Complex), Ag₂C₂ + AgI or [Ag₂C₂]I; gm very expl ppt. Can be prep'd from C₂H₂ and an ammoniacal soln of freshly prep'd AgI, taken in excess. It is not expl

Refs: 1) Beil 1, 1911 2) M. Berthelot & R. Delépine, CR 129, 361 (1899) & JCS 76 I, 842 (1899)

**Disilver Acetylide + Two Silver Iodides**

(Complex), Ag₂C₂ + 2AgI or Ag₆C₂I₃; yel ppt which mildly deton when heated in a flame. Can be prep'd by reacting C₂H₂ with AgI soln in aq KI in the presence of a small amt of KOH

Refs: 1) Beil 1, 1911 2) M. Berthelot & R. Delépine, CR 129, 361 (1899) & JCS 76 I, 842 (1899)

**Disilver Acetylide + Two Silver Perchlorates**

(Complex), Ag₂C₂ + 2AgClO₄ + 2H₂O; wh crystals, expl on heating. Can be prep'd by treating Ag₆C₂ with concd Ag perchlorate soln


**Disilver Acetylide + Disilver Sulfate**

Complex, (Ag₆C₂). Ag₂SO₄ or (Ag₆C₂)Ag₂SO₄, wh ppt, deton weakly in vacuo. Can be prep'd by treating C₂H₂ with an excess of silver sulfate in soln

Refs: 1) Beil 1, 1911 2) M. Berthelot & R. Delépine, CR 129, 361 (1899) & JCS 76 I, 842 (1899)

**Disilver Oxide + Acetylene + Disilver Chromate**

(Complex), Ag₂O + C₂H₂ + Ag₂CrO₄. Or-red crysts, expl ca 157°C. Can be prep'd from acetylene and a boiling soln of silver bi-chromate

Refs: 1) Beil 1, 241 2) M. Berthelot & R. Delépine, CR 129, 361 (1899) & JCS 76 I, 842 (1899)

Note: According to R. Vestin & E. Ralf, Acta Chem. Scandinavica 3, 104 (1949) & Beil 1, 1911 the existence of this compd is questionable

**Two Disilver Acetylides + Silver Chloride**

(Complex), (Ag₆C₂). AgCl or Ag₆C₂ + AgCl; yel ppt which expl violently. Can be prep'd by treating ammoniacal AgCl soln with HCl and C₂H₂

Refs: 1) Beil 1, 241 2) M. Berthelot & R. Delépine, CR 129, 361 (1899) & JCS 76 I, 842 (1899)

**Silver Acetylide, Analytical.** The acetylene content can be detd by the same method as described under Copper Acetylides, Analytical, procedure A, except that the sample shall not be exposed to direct light. The silver content can be detd by transferring quantitatively the residue of AgCl in the flask into a tared sintered glass crucible, rinsing it with w and then alcohol, drying it and weighing

R. Stadler, SS 33, 269-72, 302-5 & 334-38 (1938), briefly outlines analyses of pure and tech silver acetylides and describes methods of detg the expln temp, heat of expln, gases developed on expln, vel of deton, lead block expansion, sensitivity to initiation, friction sensitivity, impact sensitivity, stability in storage and brisance by Kast formula

**Silver Acetylide, Destruction** can be accomplished by dissolving it in dil nitric acid and pouring the soln into a sink. Another method is to make ammoniacal the mixture
contg solid acetylide and then dissolve the ppt (under hood) in 5% KCN soln. The resulting liq is poured into 5% ferrous sulfate (to destroy the excess cyanide) and then into a sink.


Monosodium Acetylide or Sodium Hydrogen Acetylide (Ethynylsodium) NaHC₂, mw 48.02; wh to yel friable solid, d 1.33; mp expl ca 150° with evoln of gases that catch fire in the air leaving a blk residue which is still very reactive; decomp explosively on contact with w or alc and burns with flame in atm of Cl or Br at RT; it is sol in liq NH₃ and insol in eth & benz. Was first prepd by Berthelot (Ref 2) by heating Na with C₂H₂ and then by Moissan (Ref 3) from Na and C₂H₂ at RT but under pressure. Many other methods of prepn are given in the literature. Its prepn from Na & C₂H₂ in liq NH₃ and from sodamide and C₂H₂ in liq NH₃ are described in Refs 4 - 7


Disodium Acetylide or Sodium Carbide, Na₂C₂, mw 70.00; wh pdr, d 1.575 at 15°, mp decomp ca 400°, insol in common org solvents. It reacts explosively on contact with w and forms expl mixts with oxidizers, phosphorus, some metals, chlorides and iodides. Was first prepd by Berthelot (Ref 2) from C₂H₂ and molten Na. Matignon (Ref 3) prepd it by heating monosodium acetylide to 210-220°. Guernsey & Sherman (Ref 4) describe in detail apparatus and procedure by bubbling acetylene through molten Na.

Ylla-Conte (Ref 5) patented in Germany an industrial method of prepn by the action of Na vapors on carbon at high temps produced by an elec arc betn C electrodes in atm of H in a closed chamber. Some other methods are listed in Ref 1, p 909

Refs: 1) Beil 1, 239, [217] & 1909 2) M. Berthelot, AnnChim [4], 9, 40 (1866) 3) Matignon, CR 124, 776 (1897) 4) E. W. Guernsey & M. S. Sherman, JACS 48, 141 (1926) 5) J. Ylla-Conte, GerP 526, 627 (1930) & CA 4808 (1931)

Strontium Acetylide or Strontium Carbide, SrC₂; greyish solid, d 3.19; reacts with w and is still very reactive; decomp explosively with evin of acetylene. Was first on contact with w or alc and burns with prepd by Moissan (Ref 2) on heating Sr or SrO with CO at 1050° & 2000°. Cryst structure Na with C₂H₂ and then by Moissan (Ref 3) is discussed in Ref 4 from Na and C₂H₂ in liq NH₃, and from sodamide and C₂H₂ in liq NH₃ are described in Refs 4 - 7


Thorium Dicarbide, ThC₂, solid, d 8.96 at 18°. Was prepd by Moissan & Étard on heating in an electric furnace a mixt of powdered thorium oxide and sugar-charcoal made into a paste with turpentine. Other methods of prepn are given in Ref 3

Refs: 1) Beil 1, 914 & 1914 2) H. Moissan & A. Étard, CR 122, 573 (1896) & CA 70 II, 423 (1896) 3) Gmelin, Syst No 55, "Thorium" (1955), 298

Titanium Carbide, TiC; solid mp ca 3140° d 4.97. Can be prepd by heating an intimate mixt of TiO₂ (or Ti metal) with carbon in vacuo or in atm of hydrogen. It is used as an abrasive, being slightly softer than WC

Ref: Kirk & Othmer 2 (1948), 848-9

Tungsten Carbide (Wolfram Carbide) WC; cryssts, mp 2867, d 15.7. Was first obtained in 1893 by Moissan. Can be prepd by heating W-metal pdr and carbon black to cu 2000° in a pure graphite crucible. It is the most important abrasive for general use

Ref: Kirk & Othmer 2 (1948), 846-8 (13 refs)
Uranium Carbides. Moissan prepd in 1896 a gmn cryst compd d 11.28 at 18° to which he assigned the formula $U_2C$. This method of prepn consisted of heating a mixt of $U_3O_8$ with sugar-charcoal in an elec furnace. Later investigators obtained on using Moissan’s method $U_2C$. As none of the compds prepd by Moissan’s method was pure, Litz et al (Ref 3) designed a new method of prepn and succeeded in preparing pure UC and UC$_2$. Both compds are crystalline. UC goes at temp ca 2400° to UC$_2$.

**Acetyl Laurin (Acetyl Coconut Oil).** A compd patented by Woodbridge (Ref 1) for use(in combination with DNT etc) as an ingredient of smokeless propellants. The formula and methods of prepn are not given in the original patent but, according to C.I. Johnson (Ref 2), the product designated as acetyl laurin apparently consisted of a mixture of monoacetyl dilaurin, $C_{12}H_{22}(CH_2CO)(C_9H_2O_2)$ and diacetyl monolaurin, $C_{12}H_{22}(CH_2CO)(CH_2CO)(C_9H_2O_2)$ in which the term laurin was used to mean coconut oil. This material is a good plasticizer for NC and a satisfactory propellant was made using it. It also acts as a flash reducer.

According to F.R. Schwartz (Ref 3), the compd may be prepd as follows: a) Heat mixture consisting of 639 g coconut oil (1 mol), 188 g high gravity glycerol (2 mol) and 0.3-0.5 g CaO (catalyst) at 250° (480°F) with agitation and in an atm of CO$_2$. b) Periodically, withdraw a small amt of the reaction mixture and test it for miscibility with 90/10-methanol/water soln. As soon as one part of the reaction mixture becomes miscible with 4 parts of the 90/10 methanol-water solvent, stop heating c) Filter while still hot using a filter of Columbia activated carbon and 8 g of Decalite (diatomaceous earth) to remove the CaO catalyst d) Add 150 g of AcOH + 2 g $H_2SO_4$ to the filtrate and heat under reflux until the acid number is less than 5. This takes 2 to 5 hours e) Distill off the excess AcOH, using a stream of CO$_2$, neutralize with Na$_2$CO$_3$ and filter.

**Note:** Method of prepn of acetyl laurin is described in detail because it is not found in the literature.

Another method of prepn of acetyl laurin is to treat triacetin (see under Acetins), in the presence of an alkaline catalyst with lauric acid to replace one of the acetyl groups. The AcOH produced by the reaction can be removed by azeotropic distn using sufficient hydrocarbon solvent to maintain the distn temp at ca 200°
Acetylmethylglucoside. See Methylglucosideacetate

AcetylmethylNitrolic Acid; Pyruvonitrolic Acid or α-Nitro-α-isonitrosoacetone [1-Nitropropano-(2)oxim-(1), in Ger], CH₃.CO.C:N, mw 126.11, N22.22%. Following isomers are listed in the literature: 4-Acetyl-5-methyl-1,2,3-oxydiazole;Acetaldione-diazonhydride or Diazaoctacyclacetoneanhydride,

CH₃-C.O-N

It yel oil, does not solidify at -17°; dec ca 90° when distd at 13 mm press and explodes when distd at 760 mm; sol in w, alc & eth. Was prepd by diazotization of the prod obtd on redn of isonitrosoacetonylacetone with Zn in dil H₂SO₄.


4-Acetyl-3-methyl-1,2,5-oxydiazole or 4-Acetyl-3-methyl-furazan,

N-O-N

CH₃.CO.C═C.CH₃

liq, bp 154.5° at 743 mm; volat with steam; diff sol in w. Can be prepd by heating α-acetyl-α-methyl-glyoxime diacetate with w

Refs: 1)Beil 27,692 2)G.Ponzio & G.Ruggeri, Gazz 53,301(1923) & CA 17,3974 (1923)

3-Acetyl-5-methyl-1,2,4-oxydiazole,

CH₃.C-O-N

Acetyl Nitrate or Acyl Nitrate (Nitroacetic anhydride), CH₃.CO.O.N₂O₃, mw 105.05, N13.33, OB to CO₂ 22.8% Col, hyg, strongly fuming (in air) liq, d 1.24 at 15°, bp 22° at 70 mm; dec ca 60° to oxides of N, TeNM & a yel oil; expl violently on rapid heating or on contact with active oxides such as HgO; dec by w into AcOH & HNO₃. Can be prepd by the action of N₂O₃ on Ac₂O in the cold or by adding anhyd HNO₃ to a slight excess of Ac₂O, followed by distn in vacuo (Refs 1,2,3 & 5). Another method involves treating ketene with anhyd HNO₃ in the presence of inert diluents (such as CCl₄, CH₂Cl₂, etc) in cold (-10 to -40°)(Ref 12). Its solns are prepd by mixing fuming HNO₃ with AcOH & Ac₂O, in the cold. Wibaut (Ref 4) reported an expn of crude acetyl nitrate during its distn in vacuo and König(Ref 15) reported two expls attributed to acetyl nitrate

Acetyl nitrate is a very powerful nitrating agent and can be used for the prepn of anhyd inorg nitrates (Ref 5) as well as nitric esters of alcohols, PE and cellulose (Ref 10). Dis-
cussion on nitrating action of acetyl nitrate is given in Ref 8. With aromatic compds, acetyl nitrate shows a strong tendency to give ortho-substituted products. Thus toluene nitrated with acetyl nitrate gives 88% ortho-Cl. CO. -NO mw 89.05, N 15.73%. Yel. liq., dec by direct light, its vapors expl violently. Can be prep'd by the action of nitrosylchloride on AgOAg under strong cooling (Ref 2) or by the action of dry AgNO₃ on acetyl chloride at -30 to -40°.


1. Acetylocta-hydro-3,5,7-trinitro-1,3,5,7-tetrazocene. See 1-Aceto-3,5,7-trinitro-1,3,5,7-tetrazacyclooctane, under Aceto-tetrazacyclooctane

Acetylperchlorate or Acetylumperchlorate, CH₃CO·ClO₄. This compd was usually prep'd by treating perchloric acid with an excess of acetic anhydride: HClO₄ + Ac₂O + AcClO₄ + AcOH. This compd was usually prepd from acetyl chloride at -10°, as well as some other props. Mal'kova (Refs 13 & 14) investigated the systems Ac₂O-HNO₃ by methods of physico-chemical analysis.


Acetyl Nitrite (Nitrosoacetic Anhydride), CH₃·CO·O·NO mw 89.05, N 15.73%. Yel. liq., dec by direct light, its vapors expl violently. Can be prep'd by the action of nitrosylchloride on AgOAg under strong cooling (Ref 2) or by the action of dry AgNO₃ on acetyl chloride at -30 to -40°.


Acetylperoxide. See Diacetylperoxide

9. Acetylphenanthrene, CH₃C₆H₄·CO·CH₃

mw 220.3, OB to CO₂ 268.8% OB to CO -152.5% Bluish fluorescent leaflets (from alc), mp 123°; easily sol in eth, alc & bz, less sol in ligroin. Can be prep'd by treating phenanthrene (dissolved in benz) with acetyl chloride in the presence of AlCl₃ (Refs 1 & 2). It was tried in France as a possible replacement for centralite in some solventless smokeless propellants (poudres SD) and found to be of interest. On extrusion, the colloidal prep'd from NC.
and NG with 7% acetylphenanthrene and 2% centralite gave smooth, brilliant grains of dark green color. The propellant showed good stability in storage at temp as high as 90°

Refs: 1)Beil 7(276) 2)IB Farbenind, GerP 49,3688, ChemZtr 1930 I, 3486 3)R. Dalbert & H. Fischerouje, MP 30, 283-300(1948)

Acetylbiphenylamine. See Aminoacetophenone

ACETYLPHENYLHYDRAZONE AND DERIVATIVES

Acetylbiphenylhydrazine, C₆H₅N₂O Several isomers are listed in Beil 15, 236, 241, (62, 63) & [91, 92, 286]

Azidoacetylbiphenylhydrazine, C₆H₅N₂O - not found in Beil or CA through 1956

Mononitroacetylbiphenylhydrazine, C₆H₅N₂O₃ Several isomers are listed in Beil 15, 458, 464, 478, & [180, 183, 203]

Dinitroacetylbiphenylhydrazine, C₆H₅N₂O₅, mw 240.18, N23.33%. One isomer, 2,4-dinitro-β-acetylbiphenylhydrazine is described in Beil 15, 492

Trinitroacetylbiphenylhydrazine, C₆H₅N₂O₇, mw 285.18, N 24.56%. One isomer is described in the literature:

N′. Acetyl-N-(2,4,6-trinitrophenyl)-hydrazine or Acetylpicrylhydrazine, CH₄.CO.O.NH-C₆H₅(NO₂)₃; It yel ndls (from alc), grn-yel prisms (from dil alc); mp 210°(Ref 2), 223° (Refs 3 & 4) very diff sol in chlf & eth, insol in pet eth. Can be prepd by heating picryl hydrazine in glacial AcOH. No refs to its expl props


ACETYLPHENYLHYDROXYLAMINE AND DERIVATIVES

Acetylphenylhydroxylamine, C₆H₅N₂O₃. One deriv, N-acetyl-N-phenyl-hydroxylamine, CH₄.CO.O.N(OH).C₆H₅ is described in Beil 15,8 &(4). The deriv O-acetyl-N-phenyl-hydroxylamine, CH₄.CO.O.NH.C₆H₅ was not found in Beil or CA through 1956

Azidoacetylphenylhydroxylamine, C₆H₅N₂O₄ - not found in Beil or CA through 1956

Mononitroacetylphenylhydroxylamine, C₆H₅N₂O₄ - not found in Beil or CA through 1956

Dinitroacetylphenylhydroxylamine, C₆H₅N₂O₄, mw 241.16, N17.43%. One isomer, O-acetyl-N-(2,4-dinitrophenyl)-hydroxylamine is described in Beil 15, [11]

Trinitroacetylphenylhydroxylamine, C₆H₅N₂O₇, mw 286.16, N 19.58%. One isomer is described in the literature:

O-Acetyl-N-(2,4,6-trinitrophenyl)-hydroxylamine or O-Acetyl-N-picryl-hydroxylamine, CH₄.CO.O.NH.C₆H₅(NO₂)₃; dk yel nl (from alc), mp 130°, insol in w, dissolves in soda soin (red color). Was prepd by treating N-(2,4,6-trinitrophenyl)-hydroxylamine with boiling Ac₂O. No mention of its expl props

Refs: 1)Beil 15, [12] 2)W. Borsche, Ber 56, 1942(1923) & CA 18, 533(1923)

Acetylphenylnitramine. See Nitraminoacetophenone, under Aminoacetophenone

Acetylpicrylhydrazine. See N′-Acetyl-N-(2,4,6-trinitrophenyl)-hydrazine, under Acetylphenylhydrazine

Acetylpicrylhydroxylamine. See O-Acetyl-N-(2,4,6-trinitrophenyl)-hydroxylamine, under Acetylphenylhydroxylamine

ACETILPYRROLE AND DERIVATIVES

Acetylpyprole, Oxoethylpyrrole or Methylpyrylketone, C₆H₅NO. One isomer is listed in Beil 20, 165 and another in Beil 21, 271,(280) & [236]

Azidoacetylpyrrole, C₆H₅N₂O, mw 163.14, N 42.93% - not found in Beil or CA through 1956

Mononitroacetylpyrrole, C₆H₅N₂O₃, mw 154.12, N 18.18%. Two isomers are listed in Beil 21, 272
Dinitroacetylpyrrole, \( C_8H_8N_2O_6 \), mw 199.12, N21.10%. One isomer is described in the literature:

\[
3,4-\text{(or 4,5-)} \text{Dinitro-2-acetyl-pyrrole,}
\]

\[
\begin{align*}
\text{HC} &= \text{CH} - \text{N} \cdot \text{CO} \cdot \text{CH}_3 \\
\text{O}_2 \text{N} \cdot \text{C} &= \text{C} \cdot \text{NO}_2
\end{align*}
\]
or

\[
\begin{align*}
\text{O}_2 \text{N} \cdot \text{C} &= \text{CH} - \text{N} \cdot \text{CO} \cdot \text{CH}_3 \\
\text{O}_2 \text{N} \cdot \text{C} &= \text{CH}
\end{align*}
\]

Its monohydrate, yel ndls (from w), mp 106-7\(^o\), loses \( \text{H}_2\text{O} \) and then melts at 114\(^o\); easily sol in alc, eth & hot benz. Was obtained, along with other products by action of fuming nitric acid on 2-acetyl-pyrrole, or on 4-nitro-2-acetyl-pyrrole. No refs to its expl props.

Refs: 1)Beil 21,273 2)K. Freudenberg & CA 26,5072

**ACETYSALICYLIC ACID AND DERIVATIVES**

o-Acetysalicylic Acid or Aspirin (o-Acetyl-salicylsäure or 2-Acetoxy-benzoëssäure, in Ger) \( \text{C}_8\text{H}_6\text{O}_4 \cdot \text{COO} \), mw 180.15, OB to \( \text{CO}_2 \) -159.9%, OB to CO -79.9%. Col ndls, mp, 135-6\(^o\), Q \( \geq \) 859.3 kcal/mol; sol in w, sl sol in eth, very sol in benz. Was prep'd by Gerhardt from acetyl chloride and Na salicylate (Ref 2). Can also be prep'd by treating salicylic acid with \( \text{Ac}_2\text{O} \) or by other methods (Refs 1).

Several salts are described in Ref 3

Its lead salt, \( (\text{C}_8\text{H}_8\text{O}_4)_2\text{Pb} \), mw 565.50, was proposed as an ingredient of some propellent mixts.


Azidocetalsalicylic Acid or Salicylic Acid Triazoacetate, \( \text{CH}_3 \cdot \text{COO} \cdot \text{C}_8\text{H}_6(\text{N}_3) \cdot \text{COOH} \), mw 221.17, N19.00%. Col crys ts, mp 104\(^o\); easily sol in alc, acet, EtOAc, eth, chl f; diff sol in w. Was prep'd by treating salicylic acid with azidoacetyl-chloride in chl f and pyridine. No mention of explosive props.

Refs: 1)Beil—not found 2)K. Freudenberg et al, Ber 65B,1190(1932) & CA 26,5072

Mononitroacetylsalicylic Acid or Nitrosalicylic acid Acetate, \( \text{C}_8\text{H}_6\text{NO}_4 \). Several isomers are described in the literature, none of them is expl.

Refs: 1)Beil—not found 2)CA 44,131e (1950) 45,8339d(1950); 45,2475a(1951); 45,7550b,7551c(1951); 46,3019d(1952); 46,6109a (1952); 48,2676c(1954)

Dinitroacetylsalicylic Acid, \( \text{C}_8\text{H}_8\text{N}_2\text{O}_6 \), mw 270.15, N10.37%—not found in Beil or CA through 1956

Trinitroacetylsalicylic Acid, \( \text{C}_8\text{H}_8\text{N}_3\text{O}_6 \), mw 315.15, N13.33%—not found in Beil or CA through 1956

Acetyltetranitroaniline. See 2,3,4,6-Tetranitroaniline. See under Acetanilide

Acetyltrinitroaniline. See 2,4,6-Trinitroaniline. See under Acetanilide

Acetyltrinitroaniline. See 2,4,6-Trinitroacetanilide, under Acetanilide

Acetyltrinitrocyclooctane and Derivatives. See under Acetanilide

Acetyltrinitroanilide. See 2,3,4,6-Trinitroacetanilide, under Acetanilide
bases)(20 references) 3) G.N. Lewis, J Frankl Inst 226, 293-313(1938)(Acids and bases) 
4) W.F. Luder, Chem Revs 27, 547-83(1940) 
   (Electronic theory of acids and bases)(109 references) 5) R.P. Bell, "Acid-Base Catalysis," 
   Theory of Acids and Bases," Wiley, NY (1946) 7) R.P. Bell, Quart Revs 1, 113-25 
   (1947)(The use of the terms "acids" and "bases") 8) G.B.L. Smith, "Acid-Base 
   System" in Kirk & Othmer, 1(1947), 128-137 
   Bell, Acid-Base Catalysis and Molecular Structure, 151-210 in "Advances in Catalysis" 
   4, Academic Press, NY(1952) 
   Acid, Abietic. See Abietic Acid 
   Acid, Acetic. See Acetic Acid 
   Acid, Adipic. See Adipic Acid 
   Acid Analyses are given under individual 
   acids, such as acetic, nitric, sulfuric, etc 
   (See also Acidity in Acids) 
   Acid Anhydrides, Analysis is described in 
   Organic Analysis, Interscience, NY, 3 
   (1956) 
   Acid Boiling of Nitrocellulose. Same as 
   Preliminary Boiling of Nitrocellulose. See 
   Nitrocellulose, under Cellulose 
   Acid, Boric. See Boric Acid 
   Acide azoteux(Fr). Nitrous Acid 
   Acide azothydrique (Fr). Hydrazoic Acid 
   (see under Azides, Inorganic) 
   Acide azotique (Fr). Nitric Acid 
   Acide carboazotique (Fr). Picric Acid (see 
   under Phenol) 
   Acide carbolique (Fr). Phenol 
   Acid Egg or Blowcase is a type of "dis-
   placement pump"(qv) used for transferring 
   acids and other corrosive liquids from one 
   apparatus to another by means of compressed 
   air. Its description is given in Refs 1&2. 
   The use of acid eggs is safe for acids 
   having no dissolved org matter, otherwise 
   the gaseous phase in the egg (in the 
   presence of air) may develop into an expl mixt 
   and in case of spark or overheating, result 
   in expl (see also Air Lifts) 
   Refs: 1) Perry(1950), 1439 2) Riegel, Chem 
   Mach(1953), 172 
   Acid Elevator with ball valves, operated by 
   air and made of chemicallyaware, is described 
   by Riegel, Chem Mach(1953), 171 
   Acide métonique(Fr). Nitromethane 
   Acide oxypicrque (Fr). Trinitroresorcinol 
   Acide phénique (Fr). Phenol 
   Acide de Sprengel (Fr). Sprengel Explosive 
   Acid styphnique (Fr). Trinitroresorcinol 
   Acid, Hydroazoic. See Hydroazoic Acid, under 
   Azides, Inorganic 
   Acid, Hydrochloric. See Hydrochloric Acid 
   Acidity in Acids. If the acid used in manuf 
   of expls, propellants etc is white nitric, 
   its acidity is detd by dissolving (without 
   loss of fumes) a weighed sample in w and 
   titrating the resulting soln with std NaOH 
   soln in presence of an indicator such as 
   methyl red 
   % Acidity = \( \frac{R \times N \times 63.016}{W \times 10} = \text{TAN} \), 
   where R = burette reading, 63.016=equivalent 
   of nitric acid, W=wt of sample (For abbrevia-
   tions used in this sectn, see below) 
   If no other acid is present the above value 
   is equal to TNN and also to ANN. Water 
   content of such acid is equal to 100.00-TAN 
   If nitric acid is yellow or red it means 
   that some NO\text{\textsubscript{3}} is present in addn to HNO\text{\textsubscript{3}}. 
   On dilution of such acid with w, the following 
   reaction takes place: 2NO\text{\textsubscript{3}} + H\text{\textsubscript{2}}O = HNO\text{\textsubscript{4}} + HNO\text{\textsubscript{3}}. 
   The resulting nitrous and nitric acids will 
   be included in the value of total acidity of 
   the acid: 
   TAN = \( \frac{R \times N \times 63.016}{W \times 10} \) 
   The next step is to det NO\text{\textsubscript{3}} content, 
   which is usually done by drowning a sample
under w(without loss of fumes) and titrating the resulting soln with std KMnO₄ soln:

\[ 5\text{NO}_2 + \text{KMnO}_4 + \text{H}_2\text{O} = \text{KNO}_3 + \text{Mn(NO}_3)_2 + 2\text{HNO}_3 \]

\[ \%\text{NO}_2 = \frac{R \times N + 46.008}{w \times 10} \]

where 46.008 is equiv of NO₂.

As NO₂ forms equal amts of HNO₂ and HNO₃, only half of it goes for the formation of HNO₃ and the other half must be deducted from TAN

\[ \text{ANN} = \text{TAN} - \frac{1}{2}(\%\text{NO}_2) \times \frac{63.016}{46.008} \]

where 63.016 is equiv of HNO₃ and 46.008 equiv of NO₂.

For detn of acidity in colorless, non-fuming sulfuric acid, an aq soln of a weighed sample is titrated with std NaOH in the presence of an indicator, such as methyl red

\[ \text{R} \times \text{N} \times 49.041 \]

\[ \% \text{Acidity} = \frac{W \times 10}{\text{w} \times 10} = \text{TAS} \]

where 49.041 is equiv of sulfuric acid (½ of mw).

If no other acid is present the above value is equal to TSS and also to ASS. The w content is equal to 100.00-TAS

In case of fuming sulfuric acid (oleum) not contg any other acids, total acidity is higher than 100% and w content will be expressed as a negative value, such as -5.50%.

It is customary with such acids to express their acidity in terms of SO₃ as,

\[ \frac{R \times N \times 40.033}{w \times 10} \]

As oleums used in manuf of expls freeze at moderate winter temps, they usually contain 4-6% nitric acid which acts as an antifreeze. Outline of analysis of such oleums will be given after brief description of acidity detn in mixed nitric-sulfuric acid.

In making MA's from commercial oleums and anhyd nitric acids, nitrogen dioxide present in nitric acids, reacts with sulfuric acid forming nitrosylsulfuric acid (nitroso), as follows: 2NO₂ + H₂SO₄ = HNOSO₄ + HNO₂. The nitric acid in MA is therefore equivalent to the AN in the original NA, plus the HNO₃ equiv of ½ of the NO₂. The sum of these quantities is termed in the Hercules Manual (Ref 2), "Available HNO₃," (see Note b, below). Nitroso reacts with H₂O forming nitrous and sulfuric acids:

\[ \text{HNOSO}_4 + \text{H}_2\text{O} = \text{HNO}_3 + \text{H}_2\text{SO}_4 \]

and these acids will be included in TA detn by titration with std NaOH soln:

\[ \text{TAS} = \frac{R \times N \times 49.041}{w \times 10} \]

This value includes all of the free HNO₃, free H₂SO₄ and the nitric and sulfuric acid equivalents of nitroso.

Sulfuric acid content can be detd by titrating an aq soln of MA (after removal of NA by evapn a sample in an open dish until the disappearance of nitrogen oxides odor, and adding a few drops of H₂O to break up nitroso) with std NaOH soln:

\[ \text{TSS} = \frac{R \times N \times 49.041}{w \times 10} \]

where 49.041 is sulfuric acid equiv.

This value includes all of the free H₂SO₄, plus the sulfuric acid equiv of nitroso.

Nitric acid is usually detd by difference

\[ \text{TNS} = \text{TAS} - \text{TSS} \]

and

\[ \text{TN} = \text{TNS} \times 63.016 \]

It can also be detd by the ferrous sulfate method (which gives ANN). This method eliminates detn of sulfuric acid by evapn, because it can be detd by difference knowing total acidity and nitric acid content

Nitroso can be detd by titrating a sample of MA drowned in w (without loss of fumes) with std KMnO₄ soln until the appearance of permanent pink coloration: 5HNOSO₄ + 2KMnO₄ + 2H₂O → K₂SO₄ + 2MnSO₄ + 5HNO₃ + 2H₂SO₄

\[ \%\text{N-so} = \frac{R \times N \times 63.54}{w \times 10} \]

where 63.54 is nitroso equiv.

Sulfuric acid equiv of nitroso is equal to \((\%\text{N-so}) \times 98.082 = (\%\text{N-so}) \times 0.7718 \) and

\[ 127.082 \]
nitric acid equiv of nitroso

\[ (%\text{N-so}) \times 63.016 = 0.4959 \]

Following is an example of analysis of MA, taken from lab files of Keystone OW, Meadville, Penna:

\[ \text{TAS (by titration with NaOH)} = 87.3\% \]
\[ \text{TSS (by titration of the residue after avg HNO}_3 \text{ from a sample of MA)} = 42.11\% \]
\[ \text{N-so (by titration with KMnO}_4 \text{)} = 0.31\% \]

\[ \text{TNS} = \text{TAS} - \text{TSS} = 87.31 - 42.11 = 45.20\% \]
\[ \text{TNN} = \text{TNS} \times \frac{\text{HNO}_3}{\frac{1}{2}\text{H}_2\text{SO}_4} = 45.20 \times \frac{63.016}{49.041} = 58.08\% \]
\[ \text{ASS} = \text{TSS} - (\%\text{N-so}) \times \frac{\text{H}_2\text{SO}_4}{\text{HNOSO}_4} = 42.11 - (0.31 \times 0.7718) = 41.87\% \]

\[ \text{ANN} = \text{TNN} - (\%\text{N-so}) \times \frac{\text{HNO}_3}{\text{HNOSO}_4} = 58.08 - (0.31 \times 0.4959) = 57.93\% \]

To report: \( \text{H}_2\text{SO}_4 41.87, \text{HNO}_3 57.93, \text{N-so 0.31 and H}_2\text{O (by diff)} = 0.11\% \)

The sum of actual sulfuric, actual nitric and nitroso is called total actual acidity (TAA).

Notes:
1) If solids or mud are present, they have to be also reported.
2) If HCl is present (can be detd by Mohr or Volhard method), the Hercules Manual (Ref 2) gives: "available HNO\textsubscript{3}" = TAN -(0.68483 \times \text{NO\textsubscript{3}}) + (1.72812 \times \text{HCl}) and actual HNO\textsubscript{3} = TAN -(1.36967 \times \text{NO\textsubscript{3}}) + (1.72812 \times \text{HCl})

Analysis of oleum contg nitric acid as an antifreeze is essentially the same as that of MA. Following is an example: TAS (determined by titration with NaOH)

\[ \text{TAS} = 105.92\% \]
\[ \text{ANN (by a ferrous sulfate method)} = 5.10\% \]
\[ \text{N-so (by titration with KMnO}_4 \text{)} = 0.30\% \]

Nitric acid equiv of nitroso

\[ = 0.30 \times 0.4959 = 0.15\% \]
\[ \text{TNN} = \text{ANN} \times 0.15 + 0.15 = 5.25\% \]
\[ \text{TNS} \times 4.08 = 63.016 \]
\[ \text{TSS} - \text{TAS} - \text{TNS} = 105.92 - 4.08 = 101.84\% \]

\[ \text{Sulfuric acid equiv of nitroso} = 0.30 \times 0.7718 = 0.22\% \]

\[ \text{ASS} = \text{TSS} - 0.22 = 101.84 - 0.22 = 101.62\% \]
\[ \text{H}_2\text{O} = 100.00 - (101.62 + 5.10 + 0.30) = -7.08\% \]

To report: TAS 105.92, \text{H}_2\text{SO}_4 101.84, \text{HNO}_3 5.25 and N-so 0.30\%

Note: Nitric acid in oleum can also be detd by nitrometer method, which gives TNN.

Abbreviations:
- \text{AN} - actual nitric (unbound acid which actually participates in nitration)
- \text{ANN} - actual nitric as nitric
- \text{AN} - actual nitric as sulfuric
- \text{AS} - actual sulfuric
- \text{ASN} - actual sulfuric as nitric
- \text{ASS} - actual sulfuric as sulfuric
- \text{M}A - mixed acid
- \text{N} - normality of std soln
- \text{NA} - nitric acid
- \text{N-so} - nitroso
- \text{H}_2\text{SO}_4 - sulfuric acid
- \text{HNO}_3 - nitric acid
- \text{HNOSO}_4 - sulfamic acid
- \text{TNS} - total nitric as sulfuric
- \text{TNN} - total nitric as nitric
- \text{TAN} - total actual acidity
- \text{TSS} - total sulfuric as sulfuric
- \text{TAS} - total acidity as sulfuric
- \text{TAA} - total actual acidity

Acidity in Explosives. The presence of acid in explos is usually due either to mech entrainment of some of the nitrating acid resulting from defects in the manuf process, such as insufficient boiling or washing etc, or to spontaneous decompn of the expl due to heat or aging. In some cases the presence of moisture may cause hydrolysis and the formation of acidic products.

The org nitrates, such as NG or NC, are the types most sensitive to acids and most likely to decomp on aging or storage at elevated temps. The presence of very
slightly traces of acids in these compounds will hasten decomposition of the expl, resulting in the evolution of various oxides of nitrogen, and in the presence of moist, in the form of nitric and nitrous acids. Once the decomposition is started it becomes autocatalytic. The decomposition reactions are also exothermic so that in badly deteriorated compositions enough heat may develop to cause them to ignite.

The mechanically entrapped acids may be sulfuric, nitric, acetic, or any other acid used in the manufacture process. These acids will also initiate the decomposition of organic nitrates as described above.

The nitroaromatic compounds, such as TNT, are usually quite stable in the presence of traces of acids but not when in contact with metals. The danger from occluded acids in the case of the nitrocompounds arises from the reaction of the acid with the metal container in which the expl is usually confined. The metal salts produced by the action of the acids on the metal are capable of reacting with the nitrocompounds to form highly sensitive metallo-organic compounds, the presence of which greatly increases the hazards involved in handling and use. Some expls, such as P.A., are normally acidic because of their chemical structure, even when pure. In the presence of some metals, highly explosive salts (such as picrates) may form.

Not all expls and propellants that are acidic show low stability when subjected to the ordinary heat tests. However, such acidic compounds usually ignite more readily than neutral substrates. In the case of acidic propellants there is some irregularity in burning which may be observed. In many cases such propellants burn completely and exhibit abnormalities in chamber pressure and range in firing tests.

The effect of various acids on the stability of NC was examined by C. Krauz & A. Majtich, Chem. Obzor 7, 209-16 (1932) & CA 27, 2812 (1933). They found that mineral acids lower the stability of NC as also do some organic acids such as aliphatic carboxylic acids and some of their derivatives. Aliphatic dicarboxylic acids have only a slight influence on stability but hydroxy-dicarboxylic acids act also to some extent as stabilizers (See also Alkalinity in Explosives, Antacids and Stabilizers).

**Acidity in Explosives Test** is one of the standard tests for the detection of purity of expls and propellants. A rapid qualitative method consists of touching a sample with a strip of moistened indicator paper, such as blue litmus paper. For quantitative detection of acidity two methods can be used: a) If the sample melts below 100°C (such as TNT, DNT, etc) shake it with boiling neutral water, cool, filter the extract and titrate it with standard alkali (such as 0.05N NaOH) in presence of an indicator or by the pH of the extract. b) If the sample melts above 100°C (such as RDX) or does not melt at all (such as NC), dissolve it in neutral acetone, add neutral water to reagent the sample, filter the slurry and det the acidity of the filtrate either by titration with standard alkali or by the pH method.

More detailed descriptions are given under individual expls and propellants (See also Alkalinity in Explosives Test and also Angeli & Erani Test).

**Acidity of Mixed Nitric-Sulfuric Acids.** Briefly described under Acidity in Acids, can also be detd by conductometric titration as described by K. K. Savich, Zavod. Lab 8, 1059 (1939).

**Acidity of Nitrating Bath.** Det by the use of nomograph is described by Y. Lacroix, MP 37, 521 (1955).


**Acid Magenta.** A mixt of dilsulfonic and trisulfonic acids of paraarosaniline, used as a dye or stain. Was proposed for coating crystals of AN to render them non-hygrosopic and thus make them more suitable for use in expls, propellants and fertilizers. Quantities as low as 0.01-0.03% proved to be sufficient for effective waterproofing.
Refs: 1) Hackh(1944), 358(under Fuchsin)  
2) J.Whetstone, IEC 44, 2663-7(1952) (15 refs)  

Acid, Mixed. See Mixed Acid  
Acid, Nitric. See Nitric Acid  
Acid, Nitrous. See Nitrous Acid  

Acid Number or Acid Value is the number of milligrams of KOH required to neutralize the acidic constituents of one gram of material  
Ref: Clark & Hawley(1957), 10  

Acido (Ital): Ácido(Span). Acid  
Acidopentammincobalt (III) Salts. Prep and some props of several salts are given in OrgSynt CollVol 4(1953), 171-6  

Acid, Oxalic. See Oxalic Acid  
Acid, Picric. See 2,4,6-Trinitophenol, under Phenol  

Acid Pumps. Various centrifugal pumps as well as some piston pumps are described in Riegel ChemMach(1953), 138-171  

Acid Pump. A special type of pump operated by air pressure and manufd by the Tungstone Products Ltd, Market Harborough, England, is described in Riegel, ChemMach (1953), 173-5  

Acid Removal in the Manufacture of Explosives is discussed under individual expls  

Acid-Resistant Materials. As acid plants are usually attached to plants manufg expls, it is important to have some knowledge of acid-resistant materials, such as metals, bricks, plastics, gaskets, paints, cements and putties, etc. Basic info on this subject may be found in the refs listed below. A common type of acid-proof putty is one consisting of powd red iron oxide and asbestos fiber in a petroleum grease. During WW II, this type of putty was used at many US Ord Plants, including Wabash Ordnance Works  

An asbestos putty may be prepd by mixing 50 parts asbestos fiber, 2 ps white lead, 1 p Ba sulfate in a heavy oil or grease. An asbestos cement may be prepd by thoroughly mixing, just before use, a powd asbestos(free from cellulose filling) with a coml Na silicate soln(water glass). This cement may be applied on cracks but not on joints because it becomes as hard as stone on standing. A litharge putty may be prepd by mixing 73 ps of litharge, 8 ps of flock asbestos and 19 ps linseed oil. The mix sets in about 7 days and resists acids up to about 50% strength. The so-called "German putty" consists of 70 ps quartz flour, 8.5 ps fluosilicate, 1.5 ps clay in 20 ps of water glass (NaO 20, SiO 60 and H 2O 20%)  

A plastic rubber cement which resists most acids may be prepd by dissolving, with gentle heating and stirring, 1 p of rubber (reclaimed) or caoutchouc in 2 ps linseed oil and then adding 1 p of clay  

Following are examples of acid-resistant materials available in commerce and suitable for expls plants:  
a) DuPont Rubber Putty, manufd at DuPont's Repauno and Catney's Point plants  b) Pecora Cement, manufd by Semmet-Solvay Co. This has a silicate base  c) Charlab Chemical Putty, manufd by Charlotte Chemical Lab, Inc, Charlotte, NC. This stays plastic and may be applied at joints  

Many plastic materials are acid resistant, among them is "Teflon" (polytetrafluoroethylene). This material resists acids but does not withstand high temps. "Silastic" resists nitric acid well. Polyethylene plastic and chlorinated polyethylene are also good acid resisters  

For the prep of acid-resistant cloth some vinyl chloride is dissolved in methyl-ethyl ketone and 10 to 15% of tricresyl phosphate is added to this. The fabric is then impregnated with this soln and the solvent is evapd  

For instance, some $\text{H}_2\text{SO}_4$ is added to molten TNT prior to flaking to neutralize the slight excess of $\text{Na}_2\text{CO}_3$ which is added to crude TNT before "selliting" it. Nitric acid is used to form a number of expls directly by neutralizing some bases, eg, ammonia, methylamine, hydrazine, etc.

More info on uses of acids is given under individual acids and explosives.

Acid, Waste. See Waste Acid.

Acme or Liardet Powder. A blasting expl patented in 1893-4 by Liardet in England and France. It was prepd by thoroughly mixing 1 part wood meal (or pulverized pine needles) and 2 ps PA dissolved in 23 ps of water at 100°. A preheated mixt of $\text{K}$ chlorate and $\text{K}$ nitrate was then added to this. Due to the presence of a chlorate, the powder was very sensitive and caused two disastrous expls, one in Australia in 1893 and another in Pittsburgh in 1894.

Ref: Daniel (1902), 5 & 406

Acetic Acid or Propene-1,2,3-tricarboxylic Acid, $(\text{HO}_2\text{C})_3\text{C}(\text{CO})_2\text{H}:\text{CH}(\text{CO}_2\text{H}) \text{ mw 174.11, OB to CO } -82.7\%$, OB to CO $-27.6\%$. $\text{H}_2\text{SO}_4$ is used in the prepn of NC, which is an important component of many smokeless propellants and an occasional ingredient of some dynamites. Acids are also used to neutralize the residual basicity of some expls due to the use of alkalies in purification.

Acoustic Guidance Systems for Missiles.
During WWII the Germans utilized the sound produced by airplane engines as a guiding medium. The original acoustic homing device was called "Kranich" and the later version "Pudel." A brief description of these devices is given in PATR 2510 (1958), pGer 83

A brief description of guidance systems is given by A. S. Locke et al., "Guidance," Van Nostrand, vol 1 (1955) of series edited by G. Merrill and entitled 'Principles of Guided Missile Design' and in other books listed under "Guided Missiles"

Acqua (Ital). Water

Acrawax. A hard, light brown synthetic wax, mp 95-7°C; sol in hot alc, toluol, butyl acetate or turpentine, sl sol in mineral oil or mineral spirits, insol in w. A brand name for products, including Acrawax B and Acrawax C, which are modified fatty acid esters made by the Glyco Products Company, Brooklyn, NY. Waxes are used to desensitize expl; with ca 10% incorporated in simple mixt or less is used when wax is applied as coating. Its uses in Ordnance are given in some classified reports


ACRIDINE AND DERIVATIVES

Acridine or Dibenzo-pyridin (2, 3, 5, 6-Dibenzo-pyridin, in Ger),

\[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{N}
\end{array}
\]

mw 179.21, OB to CO\textsubscript{2} = 272.3%. Rhb crystals (from aq alc), mp 110-1°C, bp 345-6°C, Q\textsubscript{c} 1577.8 kcal/mol; sol in alc, eth & CS\textsubscript{2}; sl sol in w. Was first obtained in 1870 from crude anthracene (Ref 2). Can be prepd by dechlorination of 5-chloroacridine with hydrogen in presence of Raney nickel or by other methods. It forms nitrocompds, salts and addition compds, some of which may find use in the expl industry


Azidoacridine, C\textsubscript{13}H\textsubscript{8}N\textsubscript{4} - not found in Beil or in CA through 1956

Diazidoacridine, C\textsubscript{13}H\textsubscript{8}N\textsubscript{4} - not found in Beil or in CA through 1956

Mononitroacridine, C\textsubscript{13}H\textsubscript{8}N\textsubscript{3}NO\textsubscript{2}, mw 224.21, N 12.50%. Its 2- and 4-nitro isomers are listed in Beil 20, 462-3, (172) & [301-2]

Dinitroacridine, C\textsubscript{13}H\textsubscript{8}N(NO\textsubscript{2})\textsubscript{2}, mw 269.21, N 15.61%. Its 2,4- and x,x-dinitro are listed in Beil 20, 463 & (172)

Note: Some nitroacridines were first prepd by C. Graebe & H. Caro, Ann 158, 275-7 (1871), who used warm nitric acid of d ca 1.45 as the nitrating medium. Formulas repd by G & C are not the same as given in Beil.

Tetranitroacridine, C\textsubscript{13}H\textsubscript{8}N(NO\textsubscript{2})\textsubscript{4}, mw 314.21, N 17.83% - not found in Beil or in CA through 1956

Tetranitroacridine, C\textsubscript{13}H\textsubscript{8}N(NO\textsubscript{2})\textsubscript{4}, mw 359.21, N 19.50% - not found in Beil or in CA through 1956

Note: C. Graebe & H. Caro, Ann 158, 277 (1871) claimed the prepn of tetranitroacridine by nitrating acridine with mixed nitric-sulfuric acid. The compd was in the form of reddish plates having N content 16.38%. This compd did not appear to be tetranitroacridine. No refs to its expl props were made
Acridine Dichromate, \( \text{C}_{13}\text{H}_4\text{N}_2\cdot\text{H}_2\text{Cr}_2\text{O}_7 \), orange-yel ndls; was prepd in 1871 by treating a salt of acridine (such as nitrate) with \( \text{K}_2\text{Cr}_2\text{O}_7 \). Its structure was detd by Kahn (Ref 3).

Refs: 1) Beil 20, 461 2) C. Graebe & H. Caro, Ann 158, 273 (1871) 3) S. Kahn

Acridine Nitrate, \( \text{C}_{13}\text{H}_4\text{N}_2\cdot\text{HNO}_3 \), mw 242.23, N 11.57%. Yel crysts, mp dec, sol in w, (Ref 3). Its method of prepn by heating on a water bath \( \text{N-phenylanthranilic acid} \) with \( \text{HNO}_3 \) (Ref 1894), was first prepd in 1880 (Ref 2) by treating acridine with chromic acid, but its expl props were not reported.


Azidoacridone, \( \text{C}_{13}\text{H}_4\text{N}_4\cdot\text{O} \)–not found in Beil or in CA through 1956

Diazidoacridone, \( \text{C}_{13}\text{H}_4\text{N}_7\cdot\text{O} \)–not found in Beil or in CA through 1956

Mononitroacridone, \( \text{C}_{13}\text{H}_3\text{N}_0\cdot\text{O}_6 \), mw 240.21, N 11.66%. Four isomers are listed in Beil 21, 337-8, (313) & [282]

Dinitroacridone, \( \text{C}_{13}\text{H}_2\text{N}_0\cdot\text{O}_6 \), mw 285.21, N 14.73%. The following isomers are listed in the literature.

2,4-Dinitroacridone, orange-yel leaflets, mp > 360°

Refs: 1) Beil 21, 338 2) F. Ullmann et al, Bet 40, 4798 (1907)

2,7-Dinitro acridone, crysts, mp 360°

Refs: 1) Beil—not found 2) A. A. Goldberg, BritP 602, 333 (1948) & CA 42, 8827 (1948)

4,5-Dinitroacridone, orange crysts, mp 257-8°

**Trinitroacridone**, \(C_{13}H_{14}N_7O_7\), mw 330.21 N 16.97%, OB to CO \(_2\) -106.6%, OB to CO -43.6%. The following isomer is listed in the literature

2,4,7-Trinitro-9(10H)-acridone,

\[
\begin{array}{c}
\text{O} \\
\text{N} \\
\text{H} \\
\text{N} \\
\text{O} \\
\text{NO}_2 \\
\text{NO}_2 \\
\end{array}
\]

Yel ndls, mp 277°. It was isolated from the products of nitration of 9-aminoacridine


**Tetranitroacridone**, \(C_{13}H_6N_6O_6\), mw 375.21, N 18.67%, OB to CO \(_2\) -83.2%, OB to CO -27.7%. The following isomer is described in the literature:

2,4,5,7-Tetranitro-9(10H)-acridone,

\[
\begin{array}{c}
\text{O} \\
\text{N} \\
\text{H} \\
\text{N} \\
\text{O} \\
\text{NO}_2 \\
\text{NO}_2 \\
\end{array}
\]

Yel crys, mp > 350° with sublimation (Ref 2), 337° (Ref 3); diff sol in org solvents. Can be prepd by heating thioacridone with fuming nitric acid in a sealed tube at 240° or by other methods. Its expl props were not investigated


**Acrolein or Acrylic Aldehyde** (Propenal, Allyl Aldehyde or Ethylene Aldehyde), \(\text{CH}_2=\text{CHO}\), mw 56.06, OB to CO \(_2\) -199.8%, OB to CO -114.2%. Col liq, mp -87.7°, bp 52.5°, d 0.8389 at 20°/4°, \(Q_c^0\) 391.5 kcal/mol (Ref 3). Very sol in w, sol in alc or eth. Can be prepd by heating glyceraldehyd with dehydrating agents such as KHSO \(_4\). It is dangerous when exposed to heat or flame (Ref 5)

This poisonous, lachrymatory and highly obnoxious-smelling substance is usually given as a vapor during blasting operations in the "blow-out shots" (qv)(Ref 2) and has also been isolated from spent acids from the manuf of NG and PETN


**ACRYLAMIDE AND DERIVATIVES**

**Acrylamide** (Propenamid or Acrylsäureamid in Ger), \(\text{CH}_2=\text{CH}:\text{CO}:\text{NH}_2\); ndls, mp 84-5°, dec < 125°. Can be prepd by saturating a benz soln of acrylic chloride with -27.7%. The following isomer is described in the literature:

3-Nitroacrylamide, \(\text{CH}_2=\text{CH}:\text{CO}:\text{NH}_2\)-not found in Beil or in CA through 1956


**Azidoacrylamide**, \(\text{N}_3: \text{CH}:\text{CO}:\text{NH}_2\)-not found in Beil or in CA through 1956

3-Nitroacrylamide, \(\text{O}_2\text{N}: \text{CH}:\text{CO}:\text{NH}_2\), mw 116.08, N24.14%; yel crysts, mp 165° (dec). Was prepd by heating a mixt of 3-nitroacrylonitrile and 85% sulfuric acid at 50-55° for 7 hrs, and then pouring the mixt on ice

*Refs*: 1)Beil—not found 2)H.Shechter, *JACS* 74, 5056(1952) & CA 48, 9912(1954) 3)Nitroacrylnitramide, \(\text{O}_2\text{N}: \text{CH}:\text{CO}:\text{NH(NO}_2_2)\)-not found in Beil or in CA through 1956

**Acrylate.** A salt of acrylic acid (qv). Acrylates, such as \(\alpha\)-methylacrylate, ethylacrylate, etc, are described under the letters M, E, etc

**ACRYLIC ACID AND DERIVATIVES**

**Acrylic Acid or Ethylenecarboxylic Acid**
(Acrolein or Propenoic Acid), CH$_2$:CH.COOH, mw 72.06, OB to CO$_2$ -133.2%, OB to CO -66.6%. Col liq, d 1.062 at 16°/4°, mp 12.3-13°, bp 141.2°. Miscible with w and alc. A detailed method for its lab prepn is given by Kaszuba, who used acrylonitrile (qv), hydroquinone, powdered Cu and H$_2$SO$_4$ (Ref 2). The directions given by K should be followed closely, keeping the ingredients well chilled, otherwise a vigorous exothermic reaction (or even an expln) may occur (Ref 4). Other methods of prepn are given in Ref 3. Toxicity, fire and expln hazards are discussed in Ref 6.

**Note:** Some acrylate polymers have been used in Ordnance items.


**Acrylic Acid-Trinitrophenylester,** such as C$_{11}$H$_6$N$_3$O$_6$, polymerized by heating to ca 100° with dibenzoyl peroxide, yields an exp or readily combustible plastic.


**Azidoacrylic Acid,** N$_3$:CH:CH.COOH—not found in Beil or in CA through 1956

*Refs:* 1) Beil—not found 2) T.Lieser, GerP 860,636(1952) & CA 48,10060(1954)

**2-Nitroacrylic Acid,** O$_2$N.CH:CH.COOH, mw 117.06, N 11.97%; yel crystals, mp 136°. Was obtained by dehydrochlorination of 2-chloro-3-nitropropionic acid (mp 78-80°) and also by hydrolysis and deamination of 3-nitroacrylonitrile.

*Refs:* 1) Beil—not found 2) H. Stecher et al, JACS 74,3055-6(1952) & CA 48,9912(1954)

**Acrylic Esters,** Monomeric are discussed by E.H. Riddle, "Monomeric Acrylic Esters," 221 pp, Reinhold, NY(1954) (See also Methyl-acrylate and Ethyl-acrylate).

**Acrylic Resins and Plastics** are discussed in Kirk & Othmer 1(1947), 180-4 and in books on Plastics.

**ACRYLONITRILE AND DERIVATIVES**

**Acrylonitrile** (Propenenitrile or Vinyl Cyanide), CH$_2$:CN, mw 53.06, N 26.40%, OB to CO$_2$ -226.2% OB to CO -135.7%. Col liq, d 0.8004 at 25, frp -82 to 84°bp 78-80°. Miscible with w and ac.

Sax(1957), 244-5 Azidoacrylonitrile, $N_3CH:CH:CN$ not found in Beil or in CA through 1956
3-Nitroacrylonitrile, $O_2NCH:CH:CN$, mw 98.06, N 28.57%; yel oil, powerful vesicant and lachrymator, d 1.268 at 20/4°C, bp 53-40°C at 3.3-3.4 mm, np 1.4929 at 20°C. Was prep’d by adding dropwise 2-chloro-3-nitropropionitrile to a stirred suspension of anhyd Na acetate in absol eth. Its expl props were not investigated
Refs: 1) Beil—not found 2) H. Schechter et al. JCS 74, 3056(1952) & CA 48, 9912(1954)
ACT(Ardeer Cordite Tubular). A propellant manufd at Ardeer plant of Nobel’s Explosives Co and later by the Imperial Chemical Industries, Gr Brit
ACT 5 (Ardeer Cordite Tubular No 5). A batch No 320 B delivered in 1938 for the Brazilian Navy had to meet the following specification requirements: NC(N= 11.8 ±0.2)
65.0 ±1, NG 29.0 ±1 and centralite 6.0 ±0.5%
Graphite could be added to the extent of 0.2% and max moist content of ACT 5 was 1%
Ref: Adm Alvaro-Alberto, Rio de Janeiro; private communication Oct 14, 1958
ACT 5, Erosion of. The erosive action of ACT 5 as well as of some other propellants was investigated in Brazil by Admiral Alvaro-Alberto (Ref 2) from the point of view of Vieille’s erosion theory (Ref 1). This theory was modified using some later data of Muraour and of other investigators. A brief resumé of Alvaro-Alberto’s work on erosive action of propellants is given in CA 40, 2629-30(1946)
Action of Gas Explosions on Solid Propellants. In one series of experiments con-ducted in Russia, a glass tube, 25 mm in diam and 1.5 m long, was filled (after evacuation) with H-O gas (obtained by electrolysis of H$_2$O) at atm press and a large cryst (or a solidified drop) of an expl was placed on a piece of iron in the center of the tube. The gas mixt was detond by means of a 15 mg chge of LA placed in a side arm of the tube and the expln was photographed. None of the expls tested(PA, tetryl and PETN) ignited or detond, even when they were preheated to 100°C. In the second series of experiments, a steel tube 38 mm in diam and 1 m long was filled with H-O mixts at various pressures, the rest of the conditions were the same as in the first series. None of the expls tested was affected by the expln of the mixts at atm press. At 5 atm, blasting gelatin burned without deforming the tube, but at higher pressures it expld and the tube was blown to bits. Cast PETN did not burn or expl at 6 or 10 atm but it did expl at 15 atm and higher pressures. Powdered PETN exploded at 10 atm and higher. PA was unaffected at 5, 10 & 15 atm, but it burned at 20 & 24 atm and exploded at 30 atm
Ref: K.K. Andréév & V.P. Maslov, Dokl Akad-Nauk 25, 195-7(1939) & CA 34, 3495(1940)
Action of Light on Explosives and Propellants. See Light Sensitivity of Explosives and Propellants
Action of Light on Explosives and Propellants, Tests. See under Light Sensitivity Tests
Action of Inorganic and Organic Salts in the Combustion of Carbon in an Atmosphere of Nitric Oxide. See Catalysts in Combustion of Carbon
Action of Radiation. See Radiation Action Time of a Propellant in a Rocket. According to a definition of the Hercules Powder Co, the action time is the time interval of that part of the time-pressure curve which is above 10% of the max press of a rocket propellant. This value is
identical with the 10% burning time, as used at PicArsn
Activated Carbon or Charcoal. See Carbon (or Charcoal) Activated
Activated Complex Theory. See Absolute Rate Theory
Activation (or Radioactivation) Analysis
(Applications of Radiochemical Methods to Analytical Chemistry)(In collab with T.C.Castorina, PicArsn) Activation analysis is the quantitative determination of elements by the measurement of the radioactivity produced in them by nuclear bombardment

Measurement of radioactivity, as an analytical tool became possible after the discoveries of A.H.Becquerel(uranium radiation 1896), Pierre & Marie Curie (polonium & radium in 1898), Sir E.Rutherford (identification of Becquerel rays as consisting of alpha-, beta- and gamma-particles) and of F.Soddy(phenomenon of nuclear disintegration, in 1902)

Since not many natural radioactive elements are in existence analysis by radiochemical methods was rather limited until it became possible to "induce" radioactivity artificially in some of the non-radioactive elements, as was first done in 1934 by I. Curie & F.Joliot(Ref 1). This discovery greatly broadened the application of radiochemical analysis. The first application of artificial radioactivation for the identification of constituents in a mixt was reported by Meinke (Ref 16) to have been done in 1936 by Hevesy & Levi (Ref 2). In the activation method an element undergoes nuclear reactions by means of some source producing sufficiently high thermal neutron flux(preferably by a nuclear reactor) to yield radioactive isotopes. These isotopes are usually unstable and return to their ground state by releasing energy in the form of emitted radiations. By measuring these radiations it is possible to identify, in most cases, one or several components in a mixt. Such nuclear transitions are not affected by the state of chemical combination of the atom so that radiochemical measurement, can, in many cases, be made directly without preliminary separation, by gamma spectrometric methods.

At times, however, it does become necessary to resort to wet chemical methods for the more complete identification of the numerous components in the mixt.

Because of the extremely high sensitivity of the activation method of analysis detns of trace impurities (as low as 1 part per billion) are made possible. Such analyses can be made only with difficulty, if at all, by conventional chemical methods

Activation analysis now finds wide application in the identification of the rare earths and in the field of metallurgy. It has been also applied to some Ordnance problems, which are being reported in classified literature (Ref 19)

Detailed description of activation analysis can be found in many of the following refs

Activation Energies of Explosives. It is known that for most expls the following Arrhenius equation holds: \[ \log t = \frac{E}{RT} + \text{const} \]
where \( t \) is the "induction period" (time lag in secs prior to ign or expln after heating to a temp \( T \) in \( ^\circ \text{C} \)), \( R \) is the gas constant and \( E \) is the activation energy in kcal/mol for the reaction in question.

The following table, taken from Ref 1, gives the activation energies for some expls as calc'd from the above formula and using \( T \) values from tables I to IV of the above work. The value \( E_2 \) represents the actvn energy in the lower temp range for those expls which do not follow a straight line relationship over the entire temp range studied, while \( E_1 \) is the actvn energy at the higher temp range.

Note: The values \( E \) are lower than those reported by others, such as in Ref 2.

Refs:
1) H. Henkin & R. McGill, IEC 44, 1394(1952)
2) S. Roginsky, PhysZSow 1, 640(1932)
3) T. Urbanskii & Rychter, CR 208,900(1939)
4) A. J. B. Robertson, Tr-FaradSoc 44,677(1948)

### Table (Activation Energies)

<table>
<thead>
<tr>
<th>Explosive</th>
<th>( E_1 )</th>
<th>( E_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black powder</td>
<td>20.6</td>
<td>–</td>
</tr>
<tr>
<td>Diazodinitrophenol</td>
<td>29.0</td>
<td>48.0</td>
</tr>
<tr>
<td>Erythritol tetranitrate</td>
<td>22.8</td>
<td>51.0</td>
</tr>
<tr>
<td>Ethylenedinitramine</td>
<td>10.0</td>
<td>80-85</td>
</tr>
<tr>
<td>Lead azide</td>
<td>21.2</td>
<td>–</td>
</tr>
<tr>
<td>Lead styphnate</td>
<td>58.8</td>
<td>–</td>
</tr>
<tr>
<td>Mercurat fulminate</td>
<td>20.2</td>
<td>58.0</td>
</tr>
<tr>
<td>Nitrocellulose (12.6-13.4%N)</td>
<td>26.5</td>
<td>67.0</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>22.6</td>
<td>–</td>
</tr>
<tr>
<td>Pentaerythritol tetranitrate</td>
<td>22.0</td>
<td>–</td>
</tr>
<tr>
<td>Picric acid</td>
<td>27.4</td>
<td>–</td>
</tr>
<tr>
<td>Tetryl</td>
<td>14.4</td>
<td>–</td>
</tr>
<tr>
<td>Trinitrotoluene*</td>
<td>–</td>
<td>Not given</td>
</tr>
</tbody>
</table>

*In Ref 3, the \( E \) value for TNT is given as 14 kcal/mol in the temp range 390-450\(^\circ\text{C}\), while in Ref 4 the value is 32 kcal/mol for a lower temp.
Activation Energies of Fuels in High Temperature Combustion are discussed in the paper presented by J. B. Fenn & H. F. Calcott at the 4th Symposium on Combustion, Williams & Wilkens, Baltimore (1953), pp 231-9 (7 refs)

Note: The paper gives, in addition to activation energies of various fuels with stoichiometric amounts of air, the flame temps and the burning velocities

Activator (of a Land Mine). Same as Fuze of a Land Mine, also called Igniter

Active List of Permissible Explosives and Blasting Devices. This list approved by the US Bureau of Mines prior to Dec 31, 1945, may be found in the Bur of Mines Rept of Invest 3910, compiled by J. E. Tiffany & Z. C. Gaugler. There is also a supplement to this report. Earlier Repts of Investigations on the same subject are Nos 3134, 3665 & 3736. No other info on this subject was found in CA through 1956

Active Oxygen is oxygen of an org or inorg compd which is easily liberated in a free state, especially in presence of alkalies and heavy metals, like Pt. Such oxygen is found in peroxy compds, such as dibenzoyl peroxy, Na peroxy, etc. It liberates iodine from KI (Ref 1)

Following method for the detn of active oxygen in dibenzoyl peroxy is described in Ref 2

Weigh 0.605 g peroxy into a 125 ml Erlenmeyer flask, add 40 ml acetone and swirl gently until the sample dissolves (takes ca 2 mins). Add 5 ml of KI soln (prepd by dissolving 33 g cp KI in 67 ml H2O contg small ant of Hg) and swirl for ½ min. Titrate with N/10 Na thiosulfate to a colorless end point

% Active Oxygen = (ml Na2S2O3) x 0.1322

(See also Available Oxygen)

Refs: 1) Dr H. Walter, PicArsn; private communication 2) Bulletin No 9 of Lucidol Division, Novadel-Agene Corp, Buffalo, NY (1948)

Active Sheath (Aktive Mantelpatrone). A type of sheath (see Sheathed Explosives), consist of flameless, gas-producing mixts capable of self-sustenance of their gas-producing character. These sheaths usually consist of NG(with/or without NGc) and inert ingredients, such as NaHCO3, NaCl, Kieselguhr, etc [See also PATR 2510 (1958), p Ger 1]

Actuator, Explosive. See Explosive Actuator

Acyclic Mercaptans Containing 1-5 Carbon Atoms were found to be hypergolic when used in combination with a strong oxidizer such as fuming HNO3. Such mixts were proposed for use in self-igniting rocket fuels. In order to shorten the ign delay, the oxidizer was mixed with 2-20% by wt of H2SO4, NO or NO304. In one example, a 1:3 mixt by vol of ethylmercaptan(qv) and an oxidizer contg 15% by wt of H2SO4 gave an ign delay of 10 millisec at -40°F


Acylamine, Nitroso. See Nitrosoacylamines and Diaz Esters

Acylation (Acidylation). A reaction leading to the formation of an org compd contg one or several acyl radicals, RCO-


Acyl Hydroperoxides. See Peroxy Acids

Acyl Nitrates and Perchlorates are described by M. Schmeisser, AngewChem 67, 493-501 (1955)

Acyl Peroxides are peroxides contg one or more acyl(RCO-) groups. Such peroxides are described in this work under the names of the corresponding acyl radicals, such as di-acetyl peroxy, dibenzyl peroxy, etc

Following are some recent refs:

1) K. I. Ivanov et al, ZhObshchKhim 22, 2126-8 (1952) (in Rus); 22, 2181-2 (1952) (in Eng) & CA 48, 1257, 5084 (1954) 2) K. S. Minski & L. V. Stupen, ZhObshchKhim 27, 2875-7 (1957) (in Rus); 27, 2912(1957) (in Eng) & CA 52, 80,958 (1958)
Acyl Peroxides Reactions with Phenol were investigated by C. Walling & H. B. Hodgdon, Columbia Univ Tech Rept No 2, Sept 1954-Dec 1956. Project No TBZ-0001, Contract Cu-11-57-ORD-1270

Adams (Explosif). An expl, patented in 1893 in France, contained: K nitrate 54, sulfur 20, flowers of sulfur 13, PA 1, tungstic acid 0.5, HgO 0.5, Sb trisulfide 1 & water 10%.

Refs: 1) Daniel (1902), 5

Adamsite. Same as Diphenylaminechloroarsine

Adapter. A metal collar or bushing with external and internal threads. It is screwed into the nose of a projectile, when the nose opening is larger than the diameter of the fuze. The adapter serves as the seat for a fuze. The use of adapters permits the attachment of various sizes of fuzes to one particular shell. It also permits the use of a larger opening in the nose of a shell which facilitates the forming and machining of the interior cavity in the expl loaded into the shell. Chemical shells have adapters in order to provide a means of seating the burster casing.


Adenine. Same as 6-Aminopurine

Adhesivo (Ital). Adhesive

Adhesion is the sticking together of substances in contact with each other. The subject is discussed in the following references:


Adhesives are substances (such as glue, plaster, cement, etc) that bind solid materials together. Adhesives are used extensively in ord items and in the explosives industry. For instance, the solid ingredients (such as AN, K perchlorate, etc) of gelatin dynamites are held together by means of a gel consisting of NG and collodion cotton (see also Binders). In the manuf of large grain rocket propellants, the so-called "inhibitor strips" (qv) are usually attached by means of an adhesive (Ref 4). Adhesives are also used in the packing of ammunition (see under Packing and Packaging)

Testing of various adhesives and adhesive cloths for use in ord is described in Refs 6 & 8
Adiabatic Compression of Entrapped Gas or Vapor as a Cause of Initiation of Explosives. It has been shown by some Brit investigators that one of the important causes of initiation of sensitive exps by mech action(such as impact) is the adiabatic compression of minute gas or vapor bubbles entrapped by the expls. These tiny air spaces are heated by adiabatic compression and ignite the expls. If precautions are taken to eliminate all bubbles, the expl is comparatively insensitive. These bubbles serve as "hot spots." Another important source of hot spots is the presence of small grit particles (Ref 2, p 3).

This theory was tested by Yoffe (Ref 1) by comparing the energies required to initiate NG and PETN with and without entrapped air. Samples prepared without air in the form of a continuous film required much higher energies of initiation than samples with entrapped air. A simple method of including a gas phase in an expl is to spread it as a small annulus on a flat anvil. When this is struck with a flat hammer, the small amt of gas in the center is trapped and compressed. In these experiments the size of the annulus was such that the initial vol of the gas was ca \(5 \times 10^{-5}\) cc. A more detailed description of the theory of adiabatic compression and methods of testing are given in Ref 2.

Ref: R.B. Parlin et al, OSRD Report 2026 (1943)(Unclassified)

Adiabatic Flame Temperature is the maximum temp produced on combustion (of propellants, pyrotechnic compositions, etc)
assuming no heat is lost to or absorbed from the surroundings. The adiabatic flame temp is a calcd value.

Ref: Rocket Fundamentals, Appendix 2, OSRD Rept 3992 (1944)

Adiabatic Ignition of Propellants, Pyrotechnic Compositions, etc. When ign of a subst is effected in a highly insulated condition with no gain of heat from or loss of heat to the system, it is called adiabatic ignition. The ign can be initiated by a spark, flame, incandescent wire, etc and the heat developed by these sources must be taken into consideration when calculating the heat of expln or deton from experimental data.

Confidential OSRD Rept 4758 (1945) by the Explosives Research Laboratory, Bruceton, Pa presents a theoretical treatment of adiabatic ignition and also considerable experimental data. The theory of adiabatic ignition presented applies only to those decompositions which are not autocatalytic.

Adiabatic Ignition Test of Propellants was developed during WWII by the Hercules Powder Co at its Radford, Virginia plant. The test is described in confidential Hercules report RD 4 by W. S. Koski, Dec 20, 1943.

Adinau Explosive. An Amer pre-WWI expl: Ba nitrate 69.3, TNT 28.7 & Pb chromate 2%.

Refs: 1)L. Adinau, USP 1,056,389 (1913) & CA 7, 1612 (1913) & Colvent (1918), 250

ADIPIC ACID AND DERIVATIVES

Adipic or Adipinic Acid (Hexanedioic or 1,4-Butanediicarboxylic Acid)(Hexandisilure, in German), (CH₂COOH)₂, mw 146.14, OB to CO₂ 142.3%, OB to CO 76.6%. Fine, wh crystals or powd, d 1.360 at 25°/4°, mp 152°, bp 337°. Fl p 38°F (closed cup), v ap press 1 mm at 159.5°, v ap d 5.04 (air 1.00). Qv 668.6 kcal/mol; reacts with oxidizing materials; sol in w or eth and very sol in alc. Can be prepd by several methods. One of them, given in Ref 3, uses cyclohexanol and nitric acid in the presence of NH₄VO₃. The German method using tetrahydrofuran and CO is briefly described in Ref 2. Other methods are given in Refs 1 & 4. The toxicity, fire and expln hazards of adipic acid are discussed in Ref 5. Properties, reactions and current and potential uses of adipic acid and derivs are discussed in Ref 6.

Adipic acid is used in the manuf of nylon and of some other plastics. Some of its esters are useful gelatinizers and plasticizers (Refs 4 & 6).

Its salts are called adipates.

fatty acids, resins, higher alcohols, etc) and cellulose. The combination of cutin with cellulose has been called "cuto-cellulose" but its existence (as well as of adipocellulose) as a compound has never been proven. Some investigators believe that adipo- and cuto-cellulose are identical.

When treated with concd HNO₃ or mixed HNO₃-H₂SO₄, adipocellulose yields products resembling those obtained by nitration of cellulose and fats. Pulverized adipocellulose (cork, bark, etc) has been used as an absorbent for NG, NGc, etc in comi expls such as dynamites.


Adobe Shooting. Same as Mucapping or Plaster Shooting (see under Agriculture and Forestry Use of Explosives).

Adsorbents. See Adsorption and Adsorbents.

Adsorption and Adsorbents. Adsorption may be defined as the ability of a substance (adsorbent) to hold on its surface, including inner pores or cracks, thin layers of gases, liquids or dissolved substances (adsorbates).

Adsorption is a surface phenomenon and should not be confused with absorption (qv). Adsorption may be divided into physical and chemical (also called chemisorption). In physical adsorption the forces are those between the adsorbing surface and the molecules of the adsorbate, and are similar to Van der Waals forces. In chemisorption, which includes ion exchange, the forces are much stronger than those of physical adsorption and depend on chemical bond formation.

One of the most effective physical adsorbents is activated carbon. Kieselguhr, formerly used in dynamites, is also an effective adsorbent. Other physical adsorbents include activated alumina, clays, silica, charcoal, sawdust, wood pulp, vegetable meals, carbene and various salts. Some of these substances (sawdust, meals, AN, Na nitrate, etc) are used as absorbents for the liq components of dynamos, while other subs (carbene, charcoal, etc) are used for liq air or liq oxygen expls, such as oxyliquit (qv).

(See also Chemisorption, Ion Exchange and Surface Chemistry & Physics in this Dictionary and Absorption Analysis and Chromatography).


Adsorption Analysis. Adsorption Analysis is discussed in the following books:


ADT and ADV Propellants are described in confidential "Propellant Manual," SPIA/M2, Johns Hopkins Univ, Silver Spring, Maryland(1959), Unit Nos 394 & 395

Advance Detonation. In 1941, Woodhead (Ref 1) observed that the velocity of detonation of unconfined columns of pressed tetryl pellets was higher by several hundreds m/sec when there was a continuous cylindrical cavity in the column. Later (Ref 2), the same investigator observed that this phenomenon takes place with HE's more sensitive than TNT (such as gelignite, mix tetryl/TNT, etc) but is not observed with straight TNT. He also discovered that...
inside the cavity, under these conditions, a luminous shock wave of fairly const velocity travels nearly twice as fast as the vel of deton of the expl under test. If the cavity is not blocked, this shock wave appears at the open end of the cavity as an intense flame having temporarily a higher speed than when inside the cavity.

If this end of the cavity is blocked with a pellet of an adequately sensitive expl, the luminous wave on striking the pellet initiates in it a deton wave which travels in two opposite directions. As the deton initiated in the pellet is ahead of the main deton front, it is called the advance detonation. The pellet deton wave which travels toward the oncoming main deton front collides with it and with the luminous shock wave of the cavity producing a sharp increase in the brightness of the flame and a peak in the deton pressure.

Some practical applications of tubular charges and the phenomenon of advance detonation are mentioned in Ref 2


"Advanced" Missiles. This term may be applied to missile systems under development for present or future use. These missiles are described in books and papers on rockets, guided missiles, space weapons, missiles of the future, etc. See also R.B. Dow, "Fundamentals of Advanced Missiles," Wiley, NY (1958)

Aerial Bomb, Aerial Torpedo, etc are described in the following refs:


Aerial Burst Fuzes are devices designed to initiate an explosive in a bomb while it is still in flight. They were used by the Germans during WW II

function of the velocity of the projectile. Sarrau disproved this and stated that the resistance of air is a function of a certain value, now known as the "Mach Number" (nombre de Mach, in French).

Developments in the science of aerodynamics since WWII have been of considerable importance and have resulted in practical improvements in the flight of airplanes, projectiles and rockets.

(See also Aerodynamics, Supersonic)

Refs:

**Aerodynamics, High Speed.** See Aerodynamics, Supersonic

**Aerodynamics of Propulsion** are discussed in the following books:

**Aerodynamics, Supersonic (High Speed)** is treated in the following refs:

**Aeroelasticity.** This subject is treated in the following books:

**Aerogels** are gels in which the liq phase has been replaced by a gaseous phase in such a way as to avoid shrinkage which would occur if the gel had been dried directly from a liquid (Ref 1)

Aerogels of SiO₂, Al₂O₃, MgO, SnO₂ and cellulose were recommended as ingredients (0.1 to 5%) of priming compns, such as: the complex salt (1:1:1-Pb styphnate, basic Pb
styphnate & Pb hypophosphite) 48.5, tetra-
cene 5.0, diazodinitrophenol 7.0, Pb nitrate
19.0, ground glass 19.0, gum arabic 1.0 and
aerogel 0.5%. It has been claimed that the
addn of aerogels permits the use of more
water in the compn than would otherwise be
possible without the danger of the ingredi-
ents settling out. It also increases safety of
handling and improves charging charac-
teristics (Ref 2)
Refs: 1)R.K.Iler, "The Colloid Chemistry
of Silica and Silicates," Cornell-UnivPress,
Ithaca, NY(1950), 152 2)W.J.Taylor, USP
2,662,818(1953) & CA 48, 360 2 (1954)
Aerojet Engineering Corporation, Azusa,
California (A subsidiary of General Tire &
Rubber Co). This company has had a number of
US Govt contracts, mainly to develop
rockets, jatns, rocket fuels, etc
Aeroplex Propellants and Other Substances
prep'd by the Aerojet Corp are described in
numerous reports, many of which are classi-
fied. Some of these reports are listed under
Aeroplex Propellants (qv) (See also pA350)
Aerolit (Aerolit). A Danish permissible expl
which had the following approx compn: AN
78.1, K nitrate 7.5, beef suet 2.5, sulfur
8.8, sago flour 1.3, Mn dioxide 1.2 and
resin 0.6%
Refs: 1)A.S.Aerolit Co, DanP 19858, ab-
stracted in SS 10, 29(1915) 2)Marshall 1,
(1917), 392
Aeronautics is the art and science of flying
and navigation in the air. The study includes
not only the flight of airplanes but also of
guided missiles, space ships, rockets, satel-
lites, etc. Following are some recent books
on the subject:
1)K.F.Leidecker, "German-English Tech-
nical Dictionary of Aeronautics, Rocketry,
2)B.Kucherov, "Aeronautical Sciences and
Aviation in the Soviet Union," A Bib-
liography, Library of Congress, Washington,
DC(1955) 3)W.A.Hefflin, edit, "The
United States Air Force Dictionary," Air
Univ Press, Govt Printing Off, Washington,
DC(1956) 4)L.L.Buckford, "An ABC of
Aeronautics," Cassell, London(1957) 5)
H.W.Liepmann & A.Roshko, "Elements of
Aeroplex Propellants are solid rocket prop-
ellants developed and manufd by the Aero-
jet Engineering Corp, Azusa, Calif. They
consist of a finely divided crystalline stif-
dizer (such as Amm or K perchlorate) dis-
persed in a thermosetting resin(such as
styrene, methyl acrylate, etc), acting as a
fuel. In addition there are binders (such as
resins) and other ingredients. Aeroplex pro-
ellants differ from the usual NC or NC-NG
propellants not only in physical and chem-
ical properties, but also in their methods
of manuf
Refs: 1)Aerojet Rept 336(1948), "Investi-
gation of Aeroplex Propellants and Metal
Components for Booster Rockets" (Final
Summary) 2)Aerojet Rept 410(1949), "Basic
Development of the Aeroplex Propellants and
Associated Rocket Design and Production"
(Volumes 1, 2 and 3) 3) Warren(1958), 11
Note: In addition to the above unclassified
Aerojet reports there are many classified
reports, such as Nos 426, 444, 462, 475, etc
dealing with Aeroplex propellants
A good description of the prep'n of a typical
Aeroplex Propellant, including a flow-sheet
diagram, is given in the confidential report
of the 7th Joint Army-Navy-Air Force Meet-
ning on Solid Propellants
Aerosols are colloidal systems with gas(air)
as surrounding medium. Eg: smoke, fog or
mist. Smoke is used in chemical warfare, as
in shells and for producing smoke screens.
The term aerosol is also applied to some forms
of detergents, emulsifiers and wetting agents.
A generator for producing aerosols, smokes,
fogs and layers of gas was patented recently
in France(Ref 3)
One of the substances which is used as an
aerosol is dichlorodifluoromethane. It first
made its appearance during WWII in the
so-called "bug-bombs," used extensively by the Armed Forces (Ref 4).

Industrial uses of aerosols include aerosol propellants, antifoam sprays, fire extinguishers and paints. Herzka & Pickthal (Ref 5) describe aerosol propellants, containers, valves, filling methods, lab procedures, emulsified systems, etc.


Aetna Explosives Company was organized before WWI by the consolidation of several smaller companies including Aetna Powder Co (organized in 1880), Keystone, National Brewer, etc. Then in 1921, the Aetna Explosives Co was sold to the Hercules Powder Co, Wilmington, Del.

Ref: Van Gelder & Schlatter (1927), 541

AEV Propellant is described in confidential "Propellant Manual," SPIA/M2, Johns Hopkins Univ, Silver Spring, Maryland (1959), Unit No 396 (Conf).

Affusto (Ital); Affut (Fr); Afuste (Span). Gun carriage; mount

Affut automoteur (Fr). Self-propelled mount

Afosite. A black powder type blasting expl: AN 58-62, K nitrate 28-31, carbon 7-9 & sulfur 2-3%

Ref: Belgrano (1952), 174

Astor Tyne Powder. One of the older Brit "permitted" expls: NG + NGc 9, AN 58, MNN 1, wood meal 9, NaCl 22 & water 1%. It passed the Buxton gallery test and its swing was 2.52" vs 3.27" for Gelignite (Brit 60% dynamite, used as a standard)

Ref: Marshall 3 (1932), 120

After-Flame Ratio (AFR). Bichel investigated the duration of a flame by firing expls at night and photographing the flame through a quartz lens on a moving film. He found in all cases that the flame outlasted the time of deton and named the ratio: duration of deton to duration of flame, the "after-flame" ratio. Experiments with 100 g cartridges of 30 mm diam showed that safety explosives had a very short flame duration and consequently a high AFR. For instance, Ammon-Carbonite had an AFR of 1/7.4 vs 1/883 for blasting gelatin, 1/660 for 75% guhr dynamite and 1/330 for black powder.

Ref: Barnett (1919), 118-9

After-Separation. In the manuf of NG, the mixt after nitration (consisting of NG + spent acid) is transferred to a lead tank (separator) and allowed to stand so that the lighter NG may rise to the surface. After removing the acid through a stopcock in the bottom of the tank, the NG oil (or NG + NGc) is run to another tank where it is washed with Na₂CO₃, soln and then with water. The oil is then sent to a store-house where it is given further washing. Prior to the days of efficient refrigeration equipment and prior to the use of "separating compounds" (qv), the spent acid still contained an appreciable amount of NG. To remove additional NG, the operation of separation was repeated by allowing the spent acid to stand for 2-3 days. This was done not only to recover as much of the NG as possible for economic reasons, but also to reduce the NG content of the spent acid below the point where subsequent operations would be hazardous. This second separation was called "after-separation."

It was conducted in a lead tank (Nachscheider in Ger) similar to the first separator. The NG which floated to the top in the after-separation was skimmed off. The spent acid was then run to another building where it was denitrated with steam.

Ref: 1) Marshall 1 (1917), 211 2) Barnett (1919), 34-5

AFU Propellant is described in confidential "Propellant Manual," SPIA/M2, Johns Hopkins Univ, Silver Spring, Maryland (1959), Unit No 397.
Agar-Agar (Japanese Gelatin). A yel-white mucilaginous substance (hydrophilic polysaccharide) extracted from some marine algae or sea weeds. It is insol in cold water but sol in hot w, after previous slow swelling (Ref 2). Its aq soln (hydrosol) cannot be easily coagulated by salts (Ref 3).

Agar-agar is used for the prepn of glue, as a culture medium and as a binding agent in some propellant and expl compositions (Ref 1).


Agar-Agar in Analytical Chemistry. According to E. J. Bogan & H. V. Moyer, IEC, Anal Ed 14, 849-50 (1942) and CA 37, 575 (1943), agar agar may be used as a coagulant for BaSO₄ in dem of sulfur or SO₄²⁻ by pptn with BaCl₂.

Agar-Agar Substitutes can be obtained from floridean (red algae) starches.
Ref: H. Kirschnick, Seifen-Öle-Fette-Wachse, 82, 39-41 (1956) (Review with 16 refs)

Agave. An American aloe of the order Amaryllidaceae, widely cultivated in Mexico and Central America for its juice, which is used to make an alcoholic beverage called "pulque." The residual fibrous cellulosic material, after expressing the juice, is suitable for the prepn of cloths, cords, nets, etc. In addition there is a green waste material usually used for fuel and as a diuretic (Ref 3), but which can be dried and nitrated to yield nitroagave, an explosive similar to NC. The use of nitroagave in expls was patented by Trench, Faure and Mackie (Refs 1 & 2). The proposed mixt contained nitroagave, NC (dissolved in a volatile solvent), resin, ozocerite, charcoal or soot and glycercin.


AGB (American Glycerin Bomb) is a time bomb used for blasting of shallow wells. A brief description is given in Blaster's Handbook (1952), 449-50. The bomb is also mentioned by Cook (1958), 280.

Aged Propellants, Solubilities. Solubilities of some aged gun propellants were recently detd by P. E. Gagnon et al and reported in TM 229/59 of ARDE, Canada (1959).

Aging (Aging) of Dynamites. The term ageing is applied to the total physical changes which dynamites undergo on storage in the course of time. With some dynamites (such as gelatin dynamites) as little as 3 months storage, even at ambient temp, is sufficient to reduce the sensitivity to explosion by influence as measured by the gap test. This decrease in sensitivity might cause misfires of charges in bore-holes and for this reason the problem of ageing is of great importance.

The problem of ageing has been studied by many investigators and by such organizations as the US Bureau of Mines. The composition of dynamite is an important factor in ageing. Sawdust and woodpulp are hygroscopic and as they absorb moisture their absorbancy is reduced resulting in oxidation of part of the NG. AN is also hygroscopic and its crystallographic form is altered (see under Ammonium Nitrate) resulting in changes in particle size and setting up with loss of sensitivity. Tamping thus becomes more difficult.

The above discussion applies to "straight" (non-gelatinized) dynamites, but the greatest changes on ageing take place in the gelatin-dynamites, as was shown by tests conducted at the US Bureau of Mines (Ref 3). According to these tests the decrease in the velocity of detonation and of sensitiveness to explosion by influence of gelatin-dynamites proceeds more rapidly the smaller the diameter of the cartridge and the higher the percentage of explosive oil. For instance, low-freezing 60% gelatin-dynamites aged more rapidly than the corresponding 40% gelatin-dynamites.
If dynamite is aged too long, it may become so insensitive that it will burn in the bore-hole instead of detonating. This is very undesirable (in addition to the economics involved) because burning dynamite usually gives off large quantities of nitrogen oxides, which are very poisonous even in small quantities. The "misfire" of an aged gelatin-dynamite may be prevented if the charge is well tamped. This is because good confinement insures better and more complete detonation (Ref 3).

It should be noted here that occasionally gelatin dynamites stored under conditions of excessive humidity may leak NG due to partial pptn of the NC from the NC-NG colloid. Such dynamites are very sensitive and hazardous to handle (Ref 6).

According to Dr I.A. Grageroff, formerly of the Apache Powder Co, Benson, Arizona and of the Keystone Ordnance Works, Meadville, Pennsylvania, the decreased sensitivity to explosion by influence of aged gelatin-dynamites may be returned close to initial values ("rejuvenated") by prolonged rolling of the cartridges on a flat surface (Ref 5). Many miners are familiar with this method of "rejuvenation" of gelatin-dynamites.

There seems to be two main theories of the causes of the ageing of gelatin-dynamites. The first theory, called the "air-bubble theory" (Luftblasentheorie in Ger), attributes ageing to the disappearance of air bubbles, normally present in freshly prepared gelatins. The second theory, proposed by W.A. Hargreaves, formerly Inspector of Explosives in South Australia, states that a gelatin-dynamite has a webbed structure which does not possess sufficient sensitivity unless there is a considerable amount of free liquid NG between the webs. As soon as this liquid NG disappears (either by the formation of a gel with NC or by segregation, followed sometimes by exudation) the explosive becomes insensitive. In the opinion of Hargreaves (Refs 1 & 2), the gelatin is best prepd by first mixing the NC thoroughly in the cold with part of the NG and then, after gelatinization, adding the rest of the NG. He claimed that in this way some NG remained ungelatinized and the resulting gelatin-dynamite was less liable to age quickly.

Dr J. Mayer of Villa María, Argentina, discusses both the above theories and seems to favor the second one (Ref 4).

The following conclusions cited by Dr M are in agreement with Hargreaves' theory:

a) Gelatin-dynamites contg NG and soluble (low nitrogen content) NC age faster than those contg either partially soluble or completely insol NC. As an example Dr M cites "Meganit" prepd with insol NC. This explosive shows practically no ageing on long storage.
b) As NC deteriorates slowly in storage, losing part of its nitrogen, solubility in NG increases, thus "binding" more of the remaining free NG in the explosive. This results in a decrease in sensitiveness.
c) Substitution of part or all of the NG by a better gelatinizer for NC (such as NGc) results in a more rapid decrease in sensitiveness than the corresponding NG gelatin-dynamites.

Note: It should be noted that NGc is much more volatile than NG and some of the ageing might be caused by the loss of some NGc by evaporation.
d) Storing of gelatin-dynamite in hot climates causes faster ageing. This may be partly due to an increase of solubility of the NC in the NG or NGc and partly to evaporation of NG or NGc.
e) Dynamites contg free NG and no soluble NC (such as straight dynamites, ammionia dynamites, etc) show practically no ageing effects.
f) Gelatin-dynamites which contain, in addition to NC and NG or NG + NGc, some other HE's, which are gelatinizers for NC, such as DNT or TNT, age faster than those contg NC, explosive oils and a non-gelatinizing HE (such as PETN or RDX).

Note: Dr M recommends incorporation of 15-20% RDX in formulations of gelatin-dynamites as one way to prevent rapid ageing, especially in hot climates.
This discussion includes only a part of the experimental work conducted by Dr Mayer, for the remainder see his paper (Ref 4) 

**Author's Note:** If Hargreave's theory is valid and the "air-bubble theory" is wrong, what is the explanation for the fact that aged gelatin-dynamites can be "rejuvenated" by prolonged rolling of the cartridges on a flat surface as was reported by I.A. Grager-off? It seems that each theory may be partly right (See also Stettbacher, Explosivst 1954, 44) Refs: 1) W. A. Hargreaves, JSCI 33, 337-40 (1914) 2) Marshall 1(1917), 365 & 368 3) S.P. Howell & J.E. Crawshaw, US Bureau of Mines Rept of Invest No 2436(1922) 4) J. Mayer, Explosivst 1953, 39-41 5) Dr I.A. Grager-off, New York, NY; private communication 6) M.M. Inskoep, PicArsn, Dover, NJ; private communication

**Aging of Mine Explosives Containing Ammonium Nitrate and Chlorides** was studied recently in Belgium. The results are reported in Ref. The authors attribute ageing of explosives containing AN and NaCl partly to ionic exchange from NH₄NO₃ + NaCl to NH₄Cl + NaNO₃ and partly to a change in particle size as a result of the ionic exchange. Ref: A. Kreyenbuhl & R. Sartorius, Industrie Chimique Belge 20, Special Number, pp 247-57 (1955) & CA 50, 17451-2 (1956)

**Ageing (Aging) of Propellants.** This term is very loosely used meaning deterioration or degradation in storage and sometimes improvement of physical, chemical and ballistic props which take place directly after preparation of the propellant.

When cannon or rocket propellant grains are extruded are allowed to stand for several days to relieve strains or to improve gelatinization in these grains, it is referred in the US as "aging." On the other hand, when some propellants are "annealed" at 140°F in order to relieve stresses from the grains the process is not called aging but "curing." The term aging is also used when a propellant is subjected to storage for some time in order to detect any changes in its compn or ballistic props. This is actually a test for degradation or deterioration of the propellant (qv)

In Great Britain the term "ageing" has been used for the procedure which involves storing the previously dried (at about 50°C) propellant grains in a humid atm for one to two months to raise the moist content of the grains to the desired level. This is necessary because the drying treatment to remove the excess of volatiles results in a too low moisture content. A propellant not subjected to "ageing" would absorb moisture uniformly in storage and give erratic ballistics. In case of necessity the propellant might be "aged" rapidly by exposing the grains for a few hrs to a hot moist atm. This "artificial" method of "ageing" was claimed to be less satisfactory than the "natural" method. Refs: 1) V.N. Hicks, H.J. Frigand & J. Lemer, PicArsn; private communication 2) Marshall 1(1917), 325 3) Barnett(1919), 84

**Ageisd 2.** One of the Ger pre-WWI dynamites. It is described in PATR 2510 (1958), p Ger 3 Agfa. Abbr for the "Aktiengesellschaft für Anilinfarben," a Ger firm which manuf dyes, fine chemicals, photographic films, reagents, etc

**Agglutinant** (Ital). Augmenting (charge for mortar or subsidiary artillery charge) Agglutinant. Same as Binder

**Aging of Dynamites.** See Ageing of Dynamites

**Ageing of Propellants in Storage.** See Deterioration (Aging) of Propellants in Storage

**Agitation.** See Stirring and Agitation

**AGJ and AGK Propellants.** are described in confidentail "Propellant Manual," SPIA/M2, Johns Hopkins Univ, Silver Spring, Maryland (1959), Unit Nos 398 & 399

**Agriculture and Forestry Uses of Explosives.** One of the greatest of peacetime usages of expls is for agricultural purposes. According to Cottenet (Ref 4, p 6) expls used in agriculture should possess the following properties: a) Fairly high brisance
The most suitable expls for agriculture are the AN expls, such as coal mine permissible expls. Aromatic nitrocompds and some dynamites are not as suitable as AN expls but can be used. Expls contg chlorates and perchlorates are not suitable for most agricultural purposes because they develop poisonous gases. Chlorate and perchlorate explosives may be used, however, for clearing passes through jungles and forests and for the destruction of grasses and weeds in vegetable gardens and along railroads and highways.

Following are the principal uses of expls in agriculture and forestry:

a) Planting of trees. This is usually done in dry hard ground where digging is difficult. For this purpose, narrow holes, about 30" deep are drilled in the ground and expl charges, ½ to ½ lb, are fired. This not only enlarges the hole but loosens the surrounding soil so thoroughly that when a young tree is planted its root growth is greatly facilitated. (Refs 1 & 3; Ref 4, pp 43-54)

b) Clearing the land of stumps. This is usually done by firing an explosive directly in the woody root of the stump. This shatters the stump and blows it out. If it is desired to remove the stump intact (as for instance in the case of stumps contg valuable substances such as turpentine or resins) the charges are placed under the roots of the stump. (Refs 1, 2 & 3; Ref 4, pp 70-78)

c) Clearing the land of stones. This may be done, in the case of small stones, by exploding the charge under the stone. This method dislodges the stone and makes it easier to remove. In the case of larger stones (boulders), one or several charges of expl are placed on top or on the sides of the boulder. Each charge is covered by a thick layer of mud, clay or plaster and for this reason the method is called mudcapping or plaster shooting. This method, also called adobe shooting, breaks the boulder into smaller pieces which are more conveniently handled. The same purpose may be achieved by placing on a boulder one or several "shaped" charges. In some cases a boulder may be broken by exploding a length of detonating cord (eg, one filled with desensitized PETN) wound several times around the boulder and then mudcapped. (Ref 2 & Ref 4, pp 55-63). See also Ref 3a.

d) Converting rocky ground into tillable land. This may be accomplished by drilling holes in various parts of the rocky ground and exploding charges of brisant and powerful expls. For more information on this subject see Ref 4, pp 63-66.

e) Levelling ground to make it tillable. This is done by exploding charges of various strengths in holes drilled horizontally and vertically in high spots of the ground (Ref 4, pp 67-70).

f) Digging ditches. This may be done by punching, with the aid of an iron bar, a series of holes spaced 18 to 24" and in the line of the desired ditch. After placing one or more cartridges of expl in each hole and placing several extra cartridges in the center hole, the setup is fired by means of a cap placed in the center charge. This method of firing is called the propagation method and is suitable only for very wet ground which is free of sand. In cases of dry or sandy ground, the above method does not work and it is necessary to fire the charges simultaneously by means of electric blasting caps placed in each charge. (Refs 2 & 3)

g) Drainage of ground (such as in swamps, etc). This may be done either by digging wells (vertical drainage) or by digging draining ditches (horizontal drainage). Both methods are described in Ref 4, pp 89-93.

h) Controlling erosion. In rolling country, such as in Georgia and the Carolinas, this may be done by firing charges of dynamite in the soil in order to loosen it. As a result, the waters from heavy rainfalls would soak into the ground instead of running off rapidly and
carrying away the top soil (Ref 2, p 41)

i) Other agricultural uses of explosives include: diversion of the courses of water streams (Ref 4, pp 96-7); digging of wells (Ref 4, pp 100-101); digging of ponds for watering cattle (Ref 4, pp 100-101) and in other rural construction (Ref 4, pp 97-100)

j) Forestry uses of explosives. These uses are much the same as those for agricultural purposes: eg, removing trees or tree stumps, etc, described in Ref 4, pp 94-96. Other forest uses of explosives are the construction of roads through forests and lumber camps (Ref 3, p 38) and stripping of bark from trees. This latter is often necessary for the control of insect pests. For this work detonating cord (cordeau) is merely wrapped about the trunk of the tree and fired with a detonating cap. The stripped bark is then removed and burned, together with the insect pests (Ref 2, p 400)

Refs:

A-Gun. Same as Atomic Gun

A-Gun Shell. Same as Atomic Gun Shell

AHH Propellant is described in confidential "Propellant Manual," SPIA/M2, Johns Hopkins Univ, Silver Spring, Maryland (1959), Unit No 400

Aimable Cluster. This consists of a number of incendiary bombs held in a single container. When dropped from a plane, at a high altitude, the container opens a few thousand feet above the ground and allows the bombs to scatter over an area. For this reason it is called the delay opening type, and is distinguished from the quick-opening or short-delay type, which opens and scatters the bombs almost immediately below the airplane. As the parts from the quick-opening clusters constituted a major hazard to the planes which followed in formation flights, the USAF, after 1942, required the use of aimable clusters


Air Analysis and Air Sampling. The air of many explosives, chemical and ammunition plants is frequently contaminated with impurities which may be gases, mists, vapors of volatile solvents or high expls, dusts of high expls or other materials, etc. As most of these impurities are more or less toxic, it is necessary to insure that they are never in excess of the amounts considered safe by the health authorities for breathing by human beings.

For this reason analysis of plant air is of the utmost importance. Air analysis is also necessary for the detection of leaks or other abnormal conditions of manufacture.

Two general methods for testing air impurities are in use. One involves direct-reading instruments (such as thermal indicators, test paper indicators and other devices described in Ref 16, pp 245-53), the other involves removal of the impurity from a given vol of air and determination of the impurity by a suitable lab method.

The second method is more reliable.

The simplest and most widely used method of air sampling is to pass a continuous stream of air, by means of a pump or a suction bottle, from a fixed spot in bldg through a volume-measuring device connected to a series of two or three bubble bottles contg a solvent for the impurity to be removed from the air (Ref 16, pp 260-64). Instead of these devices, U-tubes filled with absorbers, such as activated charcoal, or silica gel may be used (Ref 16, 264-7). Sampling is followed by testing the removed impurity by colorimetric or other methods. For instance, either TNT or tetryl produce a red coloration in the presence of NaOH, whereas DNT gives a blue color.

Dusts, especially those insol in common
solvents, can be evaluated by passing a measured vol of air through tared filters (paper, asbestos mat or sintered glass) as described in Ref 16, pp 255-6. Collection of dusts can also be made by an electrostatic method (application of the Cottrell precipitator principle) (Ref 16, pp 256-7) or by an impinger (a device for collecting dust by impingement at high velocity against a glass surface, followed by entrapment in water or other suitable liquids).

Two types of devices, the "standard" impinger and the "midget" impinger are described in Ref 16, pp 257-60.

Sometimes "grab samples" of the air are taken in suitable glass containers (sizes up 2500 ml) and transferred to the lab for examination, but this method is not as satisfactory as the continuous sampling briefly described above.

In testing the atmosphere of various buildings of a plant manuf expls (as for instance TNT), it is necessary to det one or two ingredients, characteristic of each bldg. For instance, in the so-called "trihouse," it is necessary to know the concn in air of extremely toxic TeNM. It is also desirable to know the concn of TNT. In the bldg where nitric acid is recovered from the mono-waste acid, it is desirable to know the content of TeNM and of nitrogen oxides. In the bldg where spent sulfuric acid is concentrated by passing hot gases, of burning petroleum through the acid, it is desirable to know the content of SO2 in the air.

Some of the analyses are described in the refs listed below, others are given under the descriptions of manuf of individual expls.

Refs: 1) O. Martienssen, BritP 237,930 (1924) & CA 20, 1732 (1926) (Apparatus contg an electrically heated catalyst which glows more brightly if combustible or explosive gases are present in the air) 2) H. F. Gölzacher, Chem Fabrik 1935, 320 & CA 29, 7077 (1935) (Apparatus using a thermocouple for detecting expl gases and vapors in air) 3) J. S. Haldane & J. I. Graham, "Methods of Air Analysis," Griffin, London (1935) 4) W. Deckert & B. Prathithavanija, ZAnalChem 113, 182-9 (1938) & CA 32, 7858 (1938) (Colorimetric procedure using dimethyl-aniline for detg small quantities of chloropicrin in air, water, etc) 5) I. S. Shereshevskaya, PromOrgKhim 6, 59-64 (1939) & CA 34, 5017 (1940) (Detn of small quantities of aromatic nitrocompds in air using colorimetric and nephelometric methods) 6) J. B. Ficklen, "Manual of Industrial Health Hazards," Service to Industry, West Hartford, Connecticut (1940) (Included are methods for detn of over 90 noxious vapors, gases and dusts) 7) K. Kay, CanJRes 19B, 86-9 (1941) & CA 35, 3562 (1941) (Analyses of air for the presence of TNT is conducted by drawing the air from one point in the room through two sintered glass bubbling tubes setup in series and contg ca 150 ml acetone, at a rate of 0.5 l/sec, for a period about 1 hr. After a partial concn of acetonic soln by evapn at temp below 82°, the vol of concentrate is measured and 1 ml is withdrawn for test. After adding 0.1 ml of 20% ag NaOH soln to 1 ml of concentrate, the resulting red coloration is compared with standards prepd by dissolving known amts of TNT in measured vols of acetone) 8) W. F. Oettinger, USPublicHealthBull No 271, Washington, DC (1941), 113 (Detn of TNT in air by the method of Kay) (See ref 7) 9) S. P. Pinto & J. R. Fahy, JIndHygToxicol 24, 24-6 (1942) & CA 37, 847 (1943) (Detn of TNT in air by collecting the sample in isopropanol by means of a midget impinger, reducing the TNT to triaminotoluene with TiCl4, and estimating the triamino compd colorimetrically after diazotization and coupling as described in the paper) 10) F. H. Goldman, JIndHgyToxicol 24, 121-2 (1942) & CA 36, 5340 (1942) (Analyses of atmospheric samples contg DPhA, MF, NG, PETN, dimethylaniline, tetryl, TNT and DNT, collected by an impinger in suitable
solvents are described) 11) Kranke & von Gizycki (no initials given), SS 38,32(1943) & CA 38, 5085(1944) (Determination of nitrocompounds, especially TNT, by drawing 50-100 l of air through three wash bottles placed in series, each containing 10 ml of methanol, mixing the contents of the 1st and 2nd bottles, adding to the mix 2 ml of 2% aq NaOH solution and allowing to stand 10 mins. Meanwhile the contents of the 3rd bottle are tested by adding aq NaOH—no coloration should be produced. The red color of the solution in the 1st and 2nd bottles is compared with standard solutions of TNT in methanol. The test is claimed to be very sensitive: 0.5 mg TNT per m³ may be detected by using a 100 ml sample. If only a qualitative test is required, a piece of filter paper impregnated with 5% NaOH solution is suspended in the air) 12) F.H. Goldman & D.E. Rushing, JIndHygToxicol 25, 164-7(1943) & CA 37, 5927(1943) (TNT is detected by passing the air through diethylaminoethanol, as a collecting medium. A red-violet color is produced even by traces of TNT) 13) F.H. Goldman & D.E. Rushing, JIndHygToxicol 25, 195-6(1943) & CA 37, 5927(1943) (Tetryl is detected by passing the air through ethylaminoethanol as the collecting medium. A red color is produced) 14) Th. E. Cone, Jr, US Naval Med Bull 41, 219-20(1943) & CA 38, 529(1944) (A modification of the Kay method described in Ref 7. The method can be used for the detection of TNT, DNT and tetryl) 15) W.M. Cumming & W.G.D. Wright, Brit JIndMed 2, 83-5(1945) (Colorimetric detection of air-borne TNT, tetryl and DNT. This method is briefly described in CA 39, 5209(1945) & 16) H.B. Elkins, "The Chemistry of Industrial Toxicology," Wiley, NY (1950), 17-18 (Air analysis) and 245-73 (Air sampling) 17) E. Effenberger, ZAnalChem 34, 106-9(1951) (Quantitative detection of oxidizing impurities in air) 18) J.A. Raubal et al, ČeskoslovHygEpidemiol MikrobiolImunol 2, 300-3(1953) & CA 48, 13548(1954) (Polarographic detection of TNT in air) 19) M.V. Alekseeva et al "Determination of Harmful Substances in the Atmosphere of Industrial Plants," Goskhimizdat, Moscow,(1954) in Russian 20) N. Stradford, G.R.N. Strouts & W.V. Stubbings, "The Determination of Toxic Substances in Air," W. Heffer, Cambridge, England (1956)

Air Blast produced by jets of air suddenly escaping from compressed air pumps, pipes, etc., may cause explosion of firedamp

Ref: R. Loison & M. Giltaire, CA 49, 9279 & 16436(1955)

Air-Blast Effect; Air Blast Energy; Air Blast Impulse and Air Blast Pressure. See under Blast Effects of Air, Earth and Water

Air Blast Meter. See under Blast Effects, etc

Air Blast Pressure from Small Charges of Various Explosives are discussed in OSRD Rept 3479(1944)

Air Blast Pressures from Some Large Bombs are discussed in OSRD Rept 3046(1943)

Air Burst Effects of the Blast from Bombs and Small Charges are discussed in OSRD Rept 4246(1944)

Air Conditioning is the branch of engineering devoted to the study of factors affecting both the physical and chemical conditions of the atmosphere within any structure. These factors include temperature, humidity and motion, as well as distribution of dust, bacteria, odors and toxic gases. In air conditioning it is desirable that all factors be controlled but, if this is not feasible, at least the first three should be simultaneously controlled (see also Refrigeration and Ventilation)

Air conditioning is desirable in the manufacture and storing of some explosives, e.g. black powder


Aircraft Armament. See Air Warfare and Aircraft Ammunition

Aircraft Armament Tests are described in the US Ordnance Proof Manual No 16-16

Aircraft Flares. See under Flares

Aircraft Float Lights. See Night Drift Signals

Air, Liquid, Explosives. See Liquid Air and Liquid Oxygen Explosives

Airplane Take-off Apparatus. A device patented by Taylor et al includes a gas-generating charge consisting of a compact smokeless propellant and a separate oxidizing charge comprising one or more compressed masses, formed by casting an O-positive mixt of AN with a chromate compd and a solid nonalk nonoxidizable AN fusion promoter


Air Pollution (Atmospheric Pollution) is objectionable because it is a danger to the health of people and animals, causes damage to vegetation, corrosion of materials and unpleasant odors

In explosive industries, as for instance in the manufacture of TNT, pollution may be caused by TNT dust, the strongly acid fumes of oxides of nitrogen and sulfur and the vapors of tetratinomethane. All of these are harmful to both man and vegetation


See also Air Analysis and Sampling


Air Drying Treatment of Propellants. See under Propellants, Manufacture

Air Lifts are devices for lifting liquids by means of compressed air without the use of valves, cylinders, plungers or other mechanisms. The first air lift was invented by Carl Löschner in 1797. Later developments were made by Frizell(1880) and Pohle(1892)

Essentially, an air lift consists of a U tube with legs of uneven length. Liquid(such as an acid) enters the shorter leg and is carried over into the longer leg and then discharged by means of compressed air introduced near the base of the longer leg.
The rise of liquid in the longer leg is due to the fact that the air and liquid mixture is lighter than the liquid alone.

The pulsometer, one kind of air lift, is a 3-neck, bottle-like pot (made of chemical ware or Pyrex) with the first neck entering one side of the bottle at its bottom, the 2nd neck entering the other side part-way down and the 3rd (middle one) at the top of the pot. Liquid (such as acid) enters through the first neck (bottom) and is met by compressed air entering through the 2nd neck. The resulting air-bubbles lift, under pressure, the liquid through the 3rd neck to the desired height up a vertical tube set in the top of the bottle.

Pulsometers, used in Acid Recovery Houses of explosives plants, are sometimes called nigger beads. They serve for transferring the weak nitric acid from the bottom of one absorption tower to the top of the next.

Air lifts were formerly used for transporting corrosive liquids from one part of a plant to another, but have now mostly been replaced with acid or alkali resistant centrifugal pumps.


Air, Thermodynamic Properties are discussed in OSRD Rept 369(1942) and OSRD Rept 3550(1944)

Air-Tightness Test. Some explosives, propellants, pyrotechnic compositions and ammunition used at the present time deteriorate much quicker if they are stored under atmospheric conditions (especially in the presence of moisture) than if the containers in which they are stored are airtight. As airtight containers are currently in use, it is necessary to test them to determine whether there are any leaks in them. This can be done by pumping air into a closed container until a pressure of 3 to 5 lbs is reached and then noting the variations in the reading of the gauge attached to the air testing apparatus. The pump is connected to the metal container by a special test hole with which all the containers are provided. These holes are closed with air-tight plugs, while the tests are being conducted. The tests should be conducted at least once a year, often if there is a suspicion that the container leaks.

All containers which are leaking should be repaired, or the contents transferred to airtight containers. Leaks due to defective covers and gaskets can usually be repaired without removing the contents, but leaks in other parts require the transfer of the contents to airtight containers and removal of the defective container from the magazine, for repairs. These may be made either in a building containing no explosives or in the open. If it is necessary to repair the containers by soldering, the insides should first be thoroughly cleaned to remove all dust.

Note: In opening or closing containers, only non-sparking tools (such as those made of copper alloys or beryllium-bronze, etc) should be used.


Alx-la-Chapelle (Poudre d''). One of the older French blasting exps, which was a mixt of
finely pulverized Chile saltpeter (Na nitrate) and carbon

Ref: Daniel(1902) 8

Ajax Powder. A British “permitted” perchlorate explosive: NG 22.5, GC 0.75, TNT + DNT 3.0, W 10.5, KClO₄ 37.5, Amm oxalate 25.0 and H₂O 0.75%; power (swing of ball pend) 2.69", maximum chge 12 oz

Ref: Barnett (1919), 137

AJZ Propellant is described in confidential “Propellant Manual,” SPIA/M2, Johns Hopkins Univ, Silver Spring, Maryland (1959), Unit No 352

AK-14 and AK-14(Mod 1) Rocket Fuel Oxidizers are described in confidential “Propellant Manual,” SPIA/M2, Johns Hopkins Univ, Silver Spring, Md (1959), Unit Nos 1 & 352

Akardit. Ger name for Acardite. A (ko) or Type A Explosive. A Japan expl similar to Ger Hexamit: TNT (or TNAn) 60, HNDhA 24 & Al powder 16%. It was intended for use in torpedo warheads and depth charges to replace the Type 94 and Type 97H Explosives (See Japanese Type Explosives)


Akremit. An explosive, patented by Maumee Collieries Co of Terra Haute, Indiana, suitable for all open operations—stripping, open mining, quarrying, etc. It consists of a commercial grade AN and carbon black shipped in separate polyethylene containers to the place of operation and mixed there as needed. The mix is put into a blast hole so that there are no air pockets around the expl which is then detonated with a small "booster" charge of a cap-sensitive expl, such as gelatin-dynamite

Since neither the raw materials nor the finished mixture are cap-sensitive expls, they can be shipped at commercial freight rates rather than at the higher rates for expls

The effectiveness of Akremite in actual mining operations was described in Coal Age, May 1955

Ref: Anon, Chem Engrg 62, No 6, 108 (1955)

AL-31 Rocket Explosive is described in confidential “Propellant Manual” SPIA/M2, Johns Hopkins Univ, Silver Spring, Md (1959), Unit No 352

Albanite. A white flashless propellant developed during WWII in the USA for use in large Naval guns. The history of its development is given in Ref 1, pp 106-108, and in Ref 2, pp 129-31. It is actually the Brit Cordite N (a triple base propellant containing a large proportion of NGu with the remainder chiefly NG & NQ) but contg DINA in place of NG. Its composition and some properties were as follows: NC (12.6% N) 20.0, DINA 19.5, NGu 55.0, DBeuPh 4.0 & Et Centr 1.5%; to this may be added an amount of K₂SO₄ which varied with the weapon (eg 1.5% K₂SO₄ for the 6 in/47 gun); vol solvent ca 0.2% & moisture <0.1%. For compn contg 1.5% K₂SO₄, the adiabatic flame temp is 2390° K, the potential (CᵥTₒ) 870 cal/g, the force 98% of pyropropellant and burning rate 75% of pyro

During WWII Albanite and Cordite N were considered among the least erosive propellants

According to Riegel (Ref 3), Albanite is a better flashless propellant than FNH and has low sensitivity to shock


Additional Refs on Albanite:
A) Explosives Division, Burnside Laboratory, E.I. duPont de Nemours & Co, Inc, OSRD 3726 (1944) (Flashless propellant for Navy cannon) B) E.I. duPont de Nemours & Co, OSRD 4035 (1944) (Analytical procedure
A120


Albionite. According to Daniel(1902),8, it was an expl manufd by the Nobel Explosives Co, Ltd. Its compn is not given Albite. A Ger blasting expl, such as Gesteins-Albit ("Rock-blasting Albit"). It contained Na perchlorate 80, DNN 12, wood meal 3, phenanthrene 3 & NG 2%

Refs: 1)Naotdm, Expls(1927),129
2)P ATR 25 (1958), 69

Albite. An expl invented by Bernardini & Manuelli: AN 58,6, NGu 19,1 & GuN 22.3%. It was used during WW II for filling some Ital projectiles

Refs: 1)R.Molina, "Esplodenti," Hoepli, Milano(1930),343
2)Ordinance Sergeant, Aug 1943, p 16
3)All & En Expls(1946), 149
4)M.Giua, "Dizionario di Chimica," UTET, Torino, 2(1949), 128 & 165

Albumin and Protein, Nitrated. See Protein and Albumin Nitrated

Alcohol (Span). Alcohol

Alcohol. An organic alkyl compd contg a hydroxyl group. It is also the common name for ethyl alcohol or ethanol. This and other alcohols, as well as their nitrated derivs, are described under individual names, such as allyl-, amyl-, butyl-, ethyl-, methyl-, propyl-, etc

Alcohol, Nitration. See under individual alcohols

Alcohols, Heats of Combustion and Formation. See F.D.Rossini, BurSrdsJRes 13, 189(1934) and under individual alcohols

Alcohols, Nitrated, Heats of Combustion and Formation. See R.M.Currie et al, IEC 44,329-31(1952)(15 refs) and under individual alcohols

Alcohols, Nitrated. Preparation from nitr- paraffins by condensation with aldehydes in the presence of an alkaline catalyst is discussed by H.A.Aaronson in P ATR 1125 (1941)

Alcohol, Tribasic. See Glycerin or Glycerol

Alcohol. Aldehyde is an organic compd contg the monovalent —CHO radical. It is also the common name for acetaldehyde. This and other aldehydes are described under individual names, such as benzaldehyde, formaldehyde, etc

Aldehyde-Amine Condensation Products.

It was observed in 1850 by Laurent and Gerhardt that benzaldehyde and aniline react with the formation of the compound CH₃:CH:OH. H₂C:CH(OH). H₂C:CH(NH₂), now called a Schiff's base. It has also been called an azomethine because it may be considered as a deriv of azomethine, H₂C:NH, also known as methylamine. The Schiff's base may be regarded as the condensation product CH₃:CH:OH + H₂C:CH(OH). H₂C:CH(NH₂), from which a molecule of H₂O has been eliminated. A few years later (1864), Schiff found that many aromatic and aliphatic aldehydes can condense with aniline in a similar manner. The condensation may be effected by warming the compds together in approximately equimolecular proportions, either diluted with a suitable solvent(such as alcohol or AcOH) or without diluents. The azomethines derived from the lower aliphatic aldehydes and primary aromatic amines are less stable than those from aromatic aldehydes. Only comparatively few aldehydes and amines yield simple addition compds of the general formula R.CH(OH).HN. R', the majority give the corresponding azomethine R.CH:NR'
ammonia results in the formation of hexamethylenetetramine, \((\text{CH}_2)_6\text{N}_4\), used for the prepn of RDX.

Some azomethines, eg \(\text{H}_2\text{C}=\text{N}_6\text{C}_6\text{H}_6\text{CH}_3\), have a tendency to polymerize to di- or tri-meric forms.

For more information on this subject see Refs 2, 3, & 4.

Some of the aldehyde-amine condensation products have been recommended as ingredients of non-detonating, degrading, explosive compns (similar in properties to black powder) for use in the delay combustion-train devices of fuzes. Other ingredients of such compns are non-explosive, such as alkali metal nitrates and charred carbonaceous compounds (Ref 1).


**Aldehyde-Nitroparaffin Reactions.** The reaction between an aldehyde and a nitroparaffin usually proceeds as follows:

\[
\text{RCHO} + \text{R'NO}_2 \rightarrow \text{RCH(OH)}\cdot \text{CH}_2\text{NO}_2 + \text{H}_2\text{O}
\]

The first studies on this subject were apparently made by Haitinger (Ref 1) and then by Priebs (Ref 2). These were followed by Henry (Ref 3), Posner (Ref 4) and others. More recently Boileau (Ref 5) made aldehyde-nitroparaffin reactions the subject of his thesis. By means of these reactions he prepared a number of aliphatic nitroalcohols. He also studied the kinetics of aldehyde-nitroparaffin reactions conducted in a homogeneous medium and in the presence of basic catalysts.


**Aldehydes, Oxidation and Ozonization** is discussed by H. Wieland & A. Wingler, Ann 431, 301-22(1923) & CA 17, 2558(1923).

Aldehydes, Polarographic Method of Determination is discussed by M.B. Neiman, Zh Anal Khim 2,135-46(1957)

**Aldehydes, Role in Oxidation of Hexane.** It was reported by C.F. Cullis, Bull Fr 1950, 863-8 & CA 47, 2689-90(1953) that an expln might take place if a temp of ca 2270°C is reached during oxidation.

**Aldol and Aldol Condensation Reactions.**

An aldo is a compd of the general formula \(\text{RCH}_2\cdot \text{CHO}\cdot \text{CHR'}\cdot \text{CHO}\), where \(\text{R}\) and \(\text{R'}\) are alkyl radicals. Aldols were first studied by Butlerov who in 1861 obtained some sugar-like products later proved to be aldols.

Aldols can be obtained as result of the so-called **alcohol condensation reaction.** This takes place between an aliphatic aldehyde and another aldehyde or ketone. The second aldehyde has at least one \(-\text{CHO}\) group.

Formaldehyde is the most frequently used aldehyde for this reaction. A small amount of weak alkali serves as a catalyst. The reactions may be represented as follows:

\[
\text{RCHO} + \text{R'CH(OH)} = \text{RCH(OH)}\cdot \text{CH}(\text{OH})\cdot \text{CHR'}\cdot \text{CHO}
\]

\[
\text{RCHO} + \text{R'CH(OH)} = \text{RCH(OH)}\cdot \text{CH}(\text{OH})\cdot \text{CHR'}\cdot \text{CHO}
\]

The first member of the group is acetaldol (qv) which condenses on storage to paraldol.

Some aldols serve for the prep of explosives eg, paraldol, which on hydrogenation gives the 1,3-butylene glycol, yielding on nitration the explosive 1,3-butylene glycol dinitrate (qv).


**Aldol Condensation Product of 5-Amino-tetrazole.** See under Aminotetrazole.

5-Aldolimino-(α-tetrazole),
CH₃, CH(OH). CH₂, CH: N—C—NH—N

CH₂OH(CH(OH))₅CHO → CH₂OH(CH(OH))₅COOH
glucose

Aldonophytylamine Condensation Product
(no formula is given). A solid which can be prepd from a soln of a mixt of 1.5 mol of aldol-α-naphthylamine and 0.5 mol of aldol-β-naphthylamine in 1.5 mols of dil HCl with 1.5 mols of acetaldehyde. This was followed by neutralization, filtering, purification and drying

When 2 ps of this mixture were milled for 3 hours with 100 ps of black powder con- sisting of KNO₃, 75, alder charcoal 17 and sulfur 8%, the resulting product burned in fuses at the rate of 250-300 sec/yard (Ref 1), whereas ordinary fuse powder burns at the rate of 120 sec/yard (Ref 2). This aldol-naphthylamine condensation product was proposed as an ingredient of slow burning fuse powders

Refs: 1)R.C.Payn et al, USP 2,423,427 (1947) & CA 41,6050(1947) 2) Blasters' Hdb(1952),88

Aldonic Acids, Their Derivatives and Nitric Esters. Aldonic Acids are hydroxy-acids of aldoses, which are carbohydrates contg aldehyde groups (pentose, hexose, etc). The acids can be obtained by mild oxidation (with silver salts of bromine) of aldoses, eg: oxygen

CH₂OH(CH(OH))₅CHO → CH₂OH(CH(OH))₅COOH
glucose

A number of such compds were prepd and then converted to the corresponding nitric esters by Wolfrom et al of Ohio State Univ while working under a US Ordnance Corps contract(Ref 5 & 6). They found that all the pentanitratres prepd by them could be detonated by gentle heat or by a hammer blow on steel. Thermal stability tests have shown that the aldonamide pentanitrates are more stable than aldonic acid pentanitrates or their methyl esters and that the esters were less stable than the corresponding acids. All of their purified nitrates underwent rapid decompn at their mp's, accompanied by violent bubbling and evolution of nitrogen oxides. No residue was visible after decompn

In a surveillance period of 8 to 10 months the purified nitrates, maintained at 20-35° in a desiccator, exhibited no visible evidence of decompn

Some of the pentanitrates were suggested for use in propellants. To determine the suitability of these nitrates for this purpose, compatibility tests were made with NC (12.6%N). The aldonamide pentanitrate and the methyl ester of aldonic acid pentanitrate were found to be compatible with NC in film formation(employing ethyl acetate as the solvent) and the stability of the film was comparable to that of the free penta-

nitrate

Aldonamides(such as d-galactonamide and d-gluconamide) were prepd by the method of Glattfeld & Macmillan(Ref 2). This involved treating the corresponding lactones with liquid ammonia and nitration of the products by nitrogen pentoxide, as described by Caesar & Goldfrank(Ref 3). Methods of prepn of individual compds are given in Ref 6

Following are examples of pentanitrates of aldonamides, of aldonic acids and of
methyl aldonates. These compds resemble NC in their explosive and combustive properties
a) d-Galactonamide Pentanitrate, C₆H₁₂N₆O₁₄, mw 420.17, N 20.01%, OB to CO₂ 0.00%, OB to CO +22.9%. Long, slender crystals, mp 168°C(decomp); insol in eth, petr eth, chlf and w; sol in alc, methanol and dioxane.
Method of prepn and more information on properties are given in Ref 6
b) d-Glucosamide Pentanitrate, C₆H₁₂N₆O₁₄, mw 420.17, N 20.01%, OB to CO₂ 0.00%, OB to CO +22.9%. Crystals, mp 147°C(decomp); sol in chlf, insol in eth, petr eth, alc and dioxane; sl sol in chlf.

Method of prepn and more information on properties are given in Ref 6

c) d-Galacnic Acid Pentanitrate, C₆H₁₂N₆O₁₄, mw 421.16, N 16.63%, OB to CO₂ +5.7%, OB to CO +28.5%. Crystals, mp 138°C(decomp); sol in eth, acet, alc and dioxane; sl sol in chlf; insol in w.

Method of prepn and more information on properties are given in Ref 6
d) d-Gluconic Acid Pentanitrate, C₆H₁₂N₆O₁₄, mw 421.16, N 16.63%, OB to CO₂ 5.7%, OB to CO +28.5%. Crystals, mp 122°C(decomp); sol in chlf, insol in eth, petr eth, chlf.

Method of prepn and more information on properties are given in Ref 6
e) Methyl-d-galactonate Pentanitrate, C₇H₁₄N₆O₁₄, mw 435.18, N 16.10%, OB to CO₂ +5.5%, OB to CO +20.2%. Crystals, mp 107°C(decomp); sol in chlf, alc, eth and acetic acid; insol in light petr eth.

Method of prepn and more information on properties are given in Ref 6

f) Methyl-d-gluconate Pentanitrate, C₇H₁₄N₆O₁₄, mw 435.18, N 16.10%, OB to CO₂ +5.5%, OB to CO +20.2%. Crystals, mp 59°C(decomp); sol in chlf, alc, eth and acetic acid; insol in light petr eth.

Method of prepn and more information on properties are given in Ref 6


Aldorfit or Aldorfite [spelled by Escales (Ref 1) Aldorfit] is a permissible expl developed and manufd by the SSF(Schweizerische Sprengstoff-Fabrik) A-G, Dottikon, Switzerland. Several formulations are known of which the Aldorfit-pulverfarbig is the oldest. It contains AN 81, TNT 17, and wood meal 2% (Refs 2, 4, 5, & 7). Its loading d 0.9-1.05, mp--decomp >360°C; Qe 1010 1046 kcal/mol(H₂O vapor), calcd vol of gases at NTP 890 l/kg, temp of expln 2900°C, max vel of deton 4500 m/sec, impact sensitivity with 2kg wt 100 cm, Trauzl test value for 10g sample 363-375 cc vs 311 cc for TNT, compression of copper cylinder (7.0 x 10.5 mm) 1.89 mm vs 2.86 mm for TNT (Ref 4, pp 104, 114 & 123; Ref 5, p 133, 144, & 153; Ref 6, p 40). Some props are also given for Aldorfit contg 21.27% TNT (Ref 4, p 14)

A method of prepn of Aldorfite is described in Ref 3

Some recent formulations of Aldorfite contain aluminum, as for instance Aldorfite LL, aluminiumhaltig. Stettbacher (Ref 4, p 114 & Ref 5, p 144) reports its Trauzl value as 432 cc but gives no compn

(See also Gelatin-Aldorfite)


Aleurityl Azide, C₁₂H₂₄(OH)₃, CO . N₃; solid mp-dec on slow heating ca 52°C, expl when heated rapidly to ca 50°C, insol in w & petr eth, sol in chlf & alc and sl sol in eth & benz. Was prepd by refluxing aleuritic acid (9, 10, 16-trihydroxypalmitic acid), C₁₂H₂₄(OH)₃COOH with 30% N₂H₄. H₂O in MeOH and treating the resulting aleurityl hydrazide,
$C_{14}H_{5}(OH)_{4} \cdot CO \cdot HN \cdot NH_{3}$ with $NaNO_{2}$ in dil $AcOH$

Refs: 1)Beil—not found 2)A.L. Davis & Wm. H. Gardner, JACS 64, 1902-5(1942) & CA 36, 5770(1942)

Alexander's Explosive Compositions consisted of naphthalene (with one or more other solid hydrocarbons), $K$ picrate and oxidizers such as $KNO_{3}$ or $KClO_{4}$ in various proportions

Ref: Daniel (1902), 8

Alexander's Primary Explosive consisted of amorphous phosphorus 83 and $Pb(NO_{3})_{2}$ (or other oxidizing metal salt) 17%

Ref: Cundill, MP 5, 280(1892)

Algin or Alginic Acid is a protein of marine algae and is found in many seaweeds. Its principal source of prep is as a by-product of the extraction of iodine from kelp, principally from Laminaria digitata. It has been used mainly in Japan, for the prep of films, fabric dressing, and for thickening jellies. Its soln in $Na$ carbonate can be used as a mucilage (Refs 1 & 2)

Its salt, sodium alginate, is used in the manuf of priming compns and in loading ammo. The requirements of the US Army and Navy (Ref 3) are: a) moisture—not more than 20%, when detd as prescribed in paragraph F-4a of Ref 3 b) viscosity of a 1.25% aq soln at 20° shall be not less than 45 secs and not more than 60 secs, when detd as prescribed in par F-4b c) Water and methyl alcohol insolubles shall not be above 1%, when detd as prescribed in par F-4c


Algodón fulminante or Algodón pólvera (Span)(fulminating cotton). NC with about 13.4% N

Ref: Pérez-Arañ(1945), 358

Aliphatic Alkanolamine Perchlorate Salts.

These compounds, according to the US NavOrdLab Memorandum 10068, 3/24/1949, are characterized by low mp, good heat stability and moderate sensitivity

Aliphatic Amines and Imines, Nitrat ed Derivatives. A number of these compds are of interest in the field of explosives and are discussed under the individual compds, such as aminomethane, aminomethane, aminoguanidine, etc

Some aliphatic amines and imines and their nitrated derivs were prep’d and investigated before and during WW II by Division 8 of NDRC

Ref: J.R. Johnston et al, OSRD Rept 161 (PBL Rept 31093) (1941)

Aliphatic-Aromatic Nitramines. See individual compds

Aliphatic-Aromatic Nitrocompounds. See individual compds

Aliphatic Nitrocompounds. See individual compds

Aliphatic Peracids (Peroxyacids), called also Peroxides of the Structure $RC(=O)OOH$ include perfonic (perfomytic), peracetic (peroxyacetic), perpropionic (peroxypropionic), etc acids. They are described in the book by A.V. Tobolsky & R.B. Mesrobian, "Organic Peroxides," InterScience NY(1954), 33-6 & 167. Some of these compds are expl

Aliphatic Peracids (Peroxyacids). Analyses.

As these acids have similar props, the same analytical procedures can be applied to all of them. The following two methods have been used for detg the contents of these acids:

a) The method of d'Ans & Frey (Ref 2) based on the procedure of Baeyer & Villiger (Ref 1) consists in titrating of a soln of a peracid with std $K$ permanganate to a pink color adding to the resulting mixt an excess of $KI$ soln and titrating the liberated iodine with std Na thiosulfate

b) The method of Greenspan & MacKellar (Ref 3) is based on the use of std ceric sulfate for the initial hydrogen peroxide
titration, followed by an iodometric detn of the active oxygen present as peracid. It has been claimed that this method gives more reliable results than the method of d’Ans & Frey.


Alkaline Earth Metals explode when brought into intimate contact with Cl, S, O, and some other comds as by a strong impact. This property can be of use in producing expls for blasting or bursting projectiles (Ref 1). In Ref 2 it is stated that the alkali metals act as powerful detonators with org halogen comds such as CH₂Cl₂, CH₂Br₂, CH₂I₂, CHCl₃, etc. In Ref 3 are described tests for the reactivity of various combinations of alkali and alkaline earth metals with halogen substition comds. Many of these systems were found to be highly sensitive to heat or impact and those which are less sensitive react explosively under the influence of a detonator. It is suggested that the expl props of such mixts may be explained by the intermediate formation of small amts of highly expl comds (such as halogen acetylenes) which cause the expl decomn of the entire system.

Refs: 1) H. Staudinger, USP 1,547,076 (1925) & CA 19, 2879 (1925) 2) H. Staudinger, Z. Elektrochem. 31, 549-52 (1925) & CA 20, 537 (1926) 3) F. Lenze & L. Metz, SS 27, 255-8, 293-6, 373-6 (1932) & CA 27, 844 (1933)

Alkalies, Action on Aliphatic Nitrocompounds. Comds with hydrogen atoms attached to a primary or secondary carbon atom linked to an NO₂ group show weakly acid properties. Such comds dissolve or react slowly in strong alkalies to form salts. This formation of salts is usually comparatively slow. It is inferred that these nitrocomds exist in two forms: a normal nitro form, which is the more stable but less acidic, and an aci (or iso) form which is less stable. The aci form may be written as

$$ R.CH = N$$

(also called a nitronic acid). This acid form of an aliphatic nitrocompd has not yet been isolated. However, the aci forms of mixed aromatic-aliphatic comds, eg phenylnitromethane and the p-brom derivative, have been isolated (Ref 1). The aci form of phenylnitromethane is acidic, conducts an electric current and dissolves readily in Na₂CO₃ solution.

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has been proposed. On treatment with acids TNB is regenerated. It has been suggested that since color formation requires more than one \( \text{NO}_2 \) group, the true structure is a resonance hybrid and involves quinonoid systems. In a number of cases clear cut reactions can be obtained. Thus boiling TNB in methyl alcohol with a solution of Na methoxide proceeds according to the reaction:

\[
\begin{align*}
\text{NO}_2 + \text{CHONa} & \rightarrow \text{NO} \quad \text{OCH}_3 + \text{NaNO}_2.
\end{align*}
\]

yielding 3,5-dinitroanisole

Some reactions of nitrocompds with strong alkalies are quite vigorous. A mixt of powd TNT and powd KOH inflames when heated to only 80°. Compds formed by the action of alkalies on TNT are very sensitive expls. It has been suggested by some investigators that these substances are metallic salts of \((\text{O}_2\text{N})_x\text{C}_7\text{H}_5\cdot \text{CH}\cdot \text{C}_6\text{H}_4\text{(NO}_2)_y\), or of \((\text{O}_2\text{N})_x\text{C}_7\text{H}_5\cdot \text{CH}_2\cdot \text{C}_6\text{H}_4\text{(NO}_2)_y\).

Na carbonate reacts with TNT to form a black solid which is sol in water or methanol and melts above 200°. This solid is as sensitive to impact and heat as tetryl and is very unstable at 120° (Ref 6). A mixt of TNT and powd KOH inflames when heated to 130-150° and has been reported to expl spontaneously on standing at ordinary temp (Ref 6). It should be noted that substances formed during purification of crude TNT by the action of "sellite" (alkaline aq soln of Na\( \text{SO}_4 \)) may also ignite (or explode) spontaneously when in a dry state, as can be seen from the occurrence during WW II at the Keystone Ordnance Plant, Meadville, Pa. When a spent "sellite" liquor from the purification of TNT(red water) was removed from a storage tank, after remaining there for several days, the residue in the tank ignited( or exploded) as soon as it was dried by the heat of the sun. This accident was followed by an investigation of the "red water" residues in other tanks at KOW in order to determine their nature. The deposit collected at that time was very dark red (nearly black) and consisted of a mixture of at least three components: a) nearly white component soluble in water and insol in methanol(Na sulfate) b) a dark red component sol in methanol and sol in water and c) a greyish component insol in methanol or water. The red component was a more sensitive explosive than TNT, but not as sensitive as primary type explosives; whereas the greyish component was an explosive extremely sensitive to heat, friction and shock. Its performance was comparable to ordinary primary explosives. This explosive material was named "Keystonite." Its compn was not detnd due to the shutdown of the plant shortly after the compd was isolated.

Refs: 1)G.C. Smith, "TNT and Other Nitrobluenes," Van Nostrand, NY(1918) 2)M. Kostevitch, "Tarry Matter of Alpha Trinitrotoluene," Part II, Impr d'Art Voltaire, Paris(1927), 8 3) Sidgwick(1937), 259 et seq 4) Davis(1943), 136-7, 147, 149-51 & 170-1 5) Degering(1950), 139 et seq 6) Dept of the Army TM 9-1910(1955), 146 Alkalies, Action on Nitric Esters. Organic nitrates in general are readily saponified by alkaline solns. A simple metathetical reaction to yield the alkali nitrate and alcohol does not take place; instead, as a result of simultaneous oxidation and reduction, alkali nitrite and a variety of products are formed depending on the conditions of the reaction. The resistance of different nitric esters to alkalies varies considerably. Thus, starch nitrate is decomposed much more slowly than cellulose nitrate and amylopectin nitrate still more slowly. Jourdin & Tribot(Ref 4) investigated the
action of alkalies on military grade NC's and found that an attack takes place even by weak alkalies, such as Na carbonate, especially at elevated temps. This attack lowers the stability of the NC and found that an attack takes place even by weak alkalies, such as Na carbonate, especially at elevated temps. This attack lowers the stability of the NC. Residual alkalinity is the result of overneutralization of residual acids of the crude expls or of NC (used in propellants) to pH's higher than 7. Neutralization is usually done by aq solns of soda ash or by ammonia but can also be effected by chalk, lime, etc.


Alkalies, Action on Stability of Nitrocelluloses. See under Alkalies, Action on Nitric Esters

"Alkali Liability" of Starch or "Alkali Number" of Starch. See under Starch

Alkali Metal Amides, such as potassamide (KNH₂) and sodamide (NaNH₂), can be obtained by the action of pure liq NH₃ on these metals. The blue solns of the metals thus formed are the result of the reaction:

\[ M + \text{NH}_3 = \text{MNH}_2 + 1/2\text{H}_2. \]

Catalysts such as spongy Pt or Fe oxides greatly accelerate the reaction. These amides may serve for the prepn of the very explosive silver amides.


Alkali Metals and Halides of Metals, Mixtures. According to J. Cuielleron, BullFr 12, 88-9(1945) & CA 40, 4309(1946) mixts of Na or K with halides of metals (except those of the alkali or alkali-earth metals) or metalloids may be exploded by a hammer blow. The same results may be obtained by substituting oxygen-containing compds for the halides.

Alkali Metal Ozonates. See under Ozonates

Alkalinity in Explosives and in Propellants. Residual alkalinity in expls and in propellants is undesirable because even traces of alkalies may lower the stability and mp of an expl with a resulting increase in exudation. Alkalies also may form products which are more sensitive than the original expl. Some discussion on this subject is given under "Alkalies, Action on Nitric Esters" and under "Alkalies, Action on Nitrocompounds".

Residual alkalinity is the result of overneutralization of residual acids of the crude expl or of NC (used in propellants) to pH's higher than 7. Neutralization is usually done by aq solns of soda ash or by ammonia but can also be effected by chalk, lime, etc.


Alkalinity Test is one of the std tests for the purity of expls and propellants. It is conducted in the same manner as the acidity test (qv) except that titration is done by 0.05 N aq sulfuric acid instead of std aq NaOH soln. (See also under individual explosives and propellants)

Alkalsit is a Ger blasting expl which is described in PATR 2510(1958), p Ger 3

Alkanes, Nitrated Derivatives (Nitrated Aliphatic Hydrocarbons). The first nitroalkane described in the literature was 1,2-dinitroethane, prepd in Russia by A. Semenov. Since then hundreds of nitroalkanes, some of them explosive, were obtained. The reference given below describes old and new methods of prepn of nitroalkanes. Most of expl nitroalkanes are described in this dictionary under their parent names, such as methane, ethane, propane, etc.


Alkalites are Belgian industrial safety expls ("explosifs SGP"), which may be sheathed or not. Pepin Lehalleur (Ref 1) gives the following compn: AN 53.0, TNT 14.0, K nitrate 8.5, Al 1.5 & NaCl 23.0%; its charge limite of 900 g is equivalent to 705 g of dynamite No 1 (NG 75, kieselguhr 25); not stable in storage.

Dr Deffet (Ref 2) states that current
Alkalite contains: AN 59.0, TNT 12.5 K nitrate 2.0 Al 0.5 & NaCl 26.0%. If a sheath (gaine in Fr) is used, it consists of 140 g of Na bicarbonate per 100 g of Alkalite

Refs: 1) Pepin Lehalleur (1935), 420 2) Dr L. Deflet, Bruxelles; private communication, March 10, 1954

Alkenyl Aromatics of the general formula Ar. CH₂. CH₂. C:CH₃, were prep'd by reacting aromatic hydrocarbons (at moderate temp and press) with 1,3-diolefins in the presence of a catalyst (such as boron trihalide said with an organic carboxylic acid). The purified alkenyl aromatics can be nitrated to yield expl derivs.

Ref: W.N. Axe, USP 2,430,660 and 2,430,661 (1947) & CA 42, 3778(1948)

Alkogol(‘Rus). Alcohol
Alkohol (Ger). Alcohol

Alkyd Resins are the reaction products of polyhydric alcohols (such as glycerol, glycols, erythritol, etc) and resinifying polybasic acids (such as phthalic and maleic acids, the dimer of abietic acid, sorbic acid, tartaric acid, etc). The first alkyd resin was prep'd by Berzelius in 1847 from glycerol and tartaric acid, but the first resins to become industrially important were the glycerol-phthalate resins introduced in 1901 by W. Smith and used widely at about the time of WWI. Second in importance are the maleic alkyd resins (Refs 1 & 2)

Alkyd resins are finding wide use as substitutes for metals, wood, etc in numerous ordnance items, such as some parts of rocket motors (Ref 3)


Note: H. A. Bruson, "Preparation of Polymers Which Might be of Interest in Explosives," in the NDRC Div 8 Interim Rept PT-7, Feb 15 to March 15, 1943 on "Preparation and Testing of Explosives" p 25 claimed that on treating trinitroterbutylxylene ("musk xylene") with formaldehyde it is possible to introduce two methylol groups to form a dihydric alcohol,

\[
\text{C}_6\text{H}_5\text{C}(\text{NO}_3)\text{C. CH}_2\text{OH} \quad \text{C}_6\text{H}_5\text{C}(\text{NO}_3)\text{C. CH}_2\text{OH}
\]

which might serve as a primary material for prep of explosive "alkyd resins." It is not stated how these resins can be prep

Alkyd Resins, Analytical Procedures are given in OrgAnalysis, Interscience, NY, 2 (1954) and 3 (1956)

α-Alkylacrylonitriles and α-Alkylacrylo-oximes. Both of these groups were prep'd and examined in 1950 by Marvel et al (Refs 3 and 4) and a short resumé of their work is presented here

It should be noted that some of the nitriles, CH₂: C(R)CN (where R may by an aliphatic group), were prep'd in 1929-1935 in Belgium (see Ref 1) but not by the same method as reported by Marvel et al

Marvel et al also prep'd oximes of the general formula CH₂: C(R)NO₂ by treating α-alkylacroleins with NH₂OH, HCl and an aq soln of Na₂CO₃. The oximes prep'd by M et al by some previous investigators (Refs 1 & 2) are viscous oils which can be purified by distillation. With Et- and iso-Pr-homologs the distn proceeds smoothly but with some higher homologs some decompn and polymerization occurs on heating. Addition of a little hydroquinone facilitates the distillation. In the case of the iso-Pr homolog, hydroquinone prevents a violent reaction which has been observed to take place after bleeding air into the distillation system

In no case did M et al observe the "explosive decomposition" of the metacrolein oxime or of α-ethylacrolein oxime as previously reported in the literature (Ref 2)

Note: M.R. Ross & R. Rolih in a private communication reported to M et al that an explosion took place with α-ethylacrolein oxime

Following are examples of α-alkylacrylonitriles prep'd by Marvel et al (Ref 4):
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a) Ethylacrolein Oxime, \( CH_2: C(CH_2)_2: C(C(C_2)C_2\text{HO}) \). See Aminoalkyltetrazoles.
   \( \text{CH}: \text{NOH}, \ mw 99.13, \ N 14.13\%, \ OB \text{ to CO} -217.9^\circ \text{C}, \ OB \text{ to CO} -137.2^\circ \text{C}. \) Viscous oil, bp 78^\circ \text{C} at 30 mm, \( n_D^{19} 1.4820 \)

b) Isopropylacrolein Oxime, \( CH_2: C(iso-C_2H_5)C_2\text{HO}. \) See Aminoalkyltetrazoles.
   \( \text{CH}: \text{NOH}, \ mw 113.16, \ N 12.39\%, \ OB \text{ to CO} -233.3^\circ \text{C}, \ OB \text{ to CO} -148.5^\circ \text{C}. \) Viscous oil, bp 63^\circ \text{C} at 3.5 mm, \( n_20\ 1.4744 \)

Refs:
1) See Ref 1 in JACS 72, 5408
2) D. T. Mowry & R.R. Motter, JACS 69, 1831(1947)
3) C.S. Marvel et al, JACS 70, 1694(1948)
4) C.S. Marvel et al, JACS 72, 5408-9(1950)

Alkyl-Aluminum Compounds. See Aluminum Alkyls.

Alkylamides and Their Nitrated Derivatives. When an amide of a hydroxylaliphatic monocarboxylic acid of the general formula \( \text{HOCH}_2\text{CONR} \) (where R is an alkyl radical) is treated with nitric acid, nitric esters \( (\text{O}_2\text{NO}, \text{CH}, \text{CO}, \text{NHR}) \) are usually obtained. However, in some cases NO groups are also introduced yielding componds of the general formula \( \text{O}_2\text{NO}, \text{CH}, \text{CO}, \text{N}((\text{NO}_2)_R) \)

The following componds were patented by Filbert (Refs 1 & 2) for use as ingredients of blasting cap charges:

a) Gluconamide pentanitrate (qv)
   b) N-2-Hydroxyethylgluconamide hexanitrate (qv)
   c) N-2-Hydroxyethylglycolamide dinitrate (qv)
   d) N-Methylgluconamide pentanitrate (qv)
   e) N-Methyl-N-nitroglycolamide nitrate, described under N-Methyl-N-glycolamide (qv)

Refs: 1) W.F. Filbert, USP 2,443,903(1948)
   & CA 43, 1797-8(1949)
   2) Ibid 2,449,843(1948)
   & CA 43, 1797(1949)

Alkylamines, Alkylarylamines, Arylamines and Their Explosive Derivatives. Alkylamines alkylarylamines and arylamines may form nitrocompounds as well as various salts of which the nitrates, perchlorates and picrates may be explosive.

For more information on this subject see individual explosives, eg, tri- and tetranitrotoluene, ethylenediamine dinitrate, tetryl, etc.

Alkylaminoguanidines. See Aminoalkylguanidines and Alkylaminoguanidines.

Alkylaminotetrazoles. See Aminoalkyltetrazoles and Alkylaminotetrazoles.

Alkylaminotriazoles. See Aminoalkyltriazoles and Alkylaminotriazoles.

(See under individual componds, such as allylazide, phenylazide, etc)

Alkylaryl Ureas or Dialkylidaryl Ureas. See Centralite.

Alkylated Benzenes, Nitroderivatives of. Studies were made at Pic Arsn regarding the possibility of using some nitroderivs of alkylbenzene as gelatinizers in smokeless propellants. Although derivs of methylbenzene (toluene), such as DNT and TNT, previously examined, are effective gelatinizing and waterproofing agents when used with NC in smokeless propellants, it was assumed that gelatinization would be improved by using substances which were either liquid(oils) or at least had lower mp's than those of either DNT(ca 70^\circ \text{C}) or TNT(ca 80^\circ \text{C}). As the nitroderivs of ethylbenzene melt at much lower temps (DNEtB is liq at RT and TNEtB melts ca 37^\circ \text{C}), they were chosen for further study. For the results and additional information see under Ethylbenzene and Derivatives.

Ref: P. Varrato, Pic Arsn Tech Rep R91(1930)

Alkylated Benzidines, Nitrated Derivatives. Mertens, in 1887, obtained a compd which he considered to be tetrinitrodimethylanilide (Ref 1). P. van Romburgh proved in 1886, that the substance was tetrinitrodimethylbenzidine but he did not det the position of the NO groups (Ref 2). This was done in 1922 by G. van Romburgh, who established the structure as 3,3',5,5'-tetrinitrodimethylbenzidine, \( H_2C\text{HN(C}_2\text{H}_2\text{NO}_2)_2\text{C}_6\text{H}_4\text{(NO}_2)_4\text{H} \) \( \text{NH(CH}_3) \) \( mw 392.28, N 21.43\%, \) red crysts, dec ca 282^\circ \text{C} (Ref 3) The same investigator prepd 3,3',5,5'-tetranitrodipropylbenzidine, \( mw 448.39, N 18.74\%, \) red ndls, mp 200^\circ \text{C}, 3,3',5,5'-tetranitrodipropylbenzidine, \( mw 516.5\), etc
448.39, N 18.74%, red ndls, mp 250°C; 3,3',5,5'-tetranitrodiisobutylbenzidine, mw 476.44, N 17.64%, red crysts, mp 194°C; and 3,3',5,5'-tetranitrodiallylbenzidine, mw 446.36, N 18.91%, orange-red ndls, mp 205°C.

None of these compds were examined by G. van Romburgh from the point of view of ignitibility or explosibility.

Refs: 1) K.H. Mertens, Thesis, Univ of Leyden (1877) & Ber 19, 2127 (1886) 2) P. van Romburgh, Rec 5, 244 (1886) 3) G. van Romburgh, Rec 41, 38-43 (1922) & CA 16, 1238 (1922)

Alkylation is the process by which an alkyl radical is introduced by addition or substitution into a compd. Description of methods of alkylation may be found in Refs 1, 5 & 6.

Alkylation reactions assumed great importance during WWII for the prepn of toluene (used for the manuf of the explosive TNT and of DNT, which was used as an ingredient of smokeless propellants), for the prepn of high octane blending agents used in aviation gasoline and for the prepn of materials used in the manuf of synthetic rubbers and plastics. The alkylation reaction was also used for the prepn of cumene (which yields an explosive trinitrocompd on nitration) and of ethylbenzene, which in turn served as an ingredient of the production of styrene and dinitroethylbenzene. The last compd has been suggested as a component of smokeless propellants in lieu of DNT. Ethylbenzene can also be nitrated to trinitroethylbenzene, an explosive slightly less powerful than TNT but not as economical to produce (see under Ethylbenzene).

Explosives have also been prep'd from alkylated compds by methods other than nitration. For instance, some explosive primary and secondary dialkyl peroxides were obtained by interaction of alkylmethane sulfonate and hydrogen peroxide (Ref 4, Sept 1957, P 1463).

Some plastics obtained from the products of alkylation can be used in the manuf of various ordnance items.

A flow sheet and a brief description of a sulfuric acid alkylation process designed by M. W. Kellog is given in Ref 2.


Alkylation, Regeneration of Acid Used in is described in the following papers:

1) J. A. Lee, ChemMetEngg 53, 146-9 (July 1946) (Recovering alkylation spent acid by the Chemical Construction Corp process) (brief description and a flow sheet) 2) Chemico Bulletin 5-107 (1946) (Diagrammatic arrangement of the "Chemico" alkylation and regeneration process and a brief description of the process)

Alkyl Azides. Prepn and reactions of some alkyl azides are discussed by J. M. Clegg (Univ of Michigan, Ann Arbor), UnivMicrofilmsPubl No 12555 and Dissertation Abstr 15, 1310 (1955); CA 50, 259 (1956)

Alkyl Boranes. See under Boranes

Alkyl dichloroamines. See Dichloroalkylamines

Alkylene. An organic radical derived from an unsaturated hydrocarbon: eg, ethylene, propylene, etc

Alkyl Halides are described under individual compds, such as carbon tetrachloride, chloroform, etc

Alkyl Hydrazines are described under individual compds, if they are expl or used in Ordnance. The major physical and chemical props of a large number of alkyl-substituted hydrazines, currently of interest in the rocket propellant field, were detd by R. C. Harshman at the Olin Mathieson Chem Corp, Niagara Falls, NY and discussed in Jet Propulsion 27, 398-9 (1957)

Alkylidene. A divalent organic radical derived from an unsaturated aliphatic hydrocarbon: eg, ethylidene (H2 C. CH=), propylidene, (CH3CH=CH) etc

Alkylideneperoxide. The name coined by
Rieche & Meister for polymeric peroxides derived from alkenaldehydes or alkyl ketones. They assigned to them the formulae:

\[ R, C=CH\text{OO} \] and \[ R, C\text{C=CH}\text{OO} \]

The simplest known compd for the first group is ethylideneperoxide

\[ \text{CH}_3\text{CH}=\text{CHOO} \]

viscous tar, extremely explosive; whereas the simplest members of the second group are acetoneperoxides (dimetric and trimeric)

\[ (\text{CH}_3)\text{C}_{\text{x}}\text{OO} \]

Ref: A. Rieche & R. Meister, Ber 64, 2335-40 (1931)

Alkyl Nitramines. The effect of cold 98% HNO\text{3} on alkyl nitramines was detd by A.T. Blowquist & F.T. Fiedorek, OSRD 4134 (1944), 10.

They found that the reactions can be represented as:

\begin{align*}
\text{a)} & \quad \text{R-NH-NO}_2 \rightarrow \text{R-O-NO}_2 \\
\text{b)} & \quad \text{R}_2\text{NO}_3 \rightarrow \text{no reaction} \\
\text{c)} & \quad \text{R-N(R')-NO}_2 \rightarrow \text{R-O-NO}_3 + \text{R'-O-NO}_3
\end{align*}

Alkyl Nitramines, Nitroxy of the general formula O\_2N\_O \_ R \_ N(R') \_ NO\_3 were proposed as non-volatile plasticizers for triple-base propellants

Ref: J. Kincaid & R. McGill, USP 2,698,228 (1954) & CA 49, 5846 (1955)

Alkyl Nitrates as Liquid Monofuels. The desirability of having a non-explosion monofuel for application which involves its use in proximity to human life, such as in ATO (assisted take-off) of aircraft or the starting of airplane engines, was the reason for the Brit investigation of methyl-, ethyl-, propyl-, etc nitrates. It was found that n-propyl nitrate is satisfactory for these purposes

Ref: A.C. Hutchison, Report of the ICI (Imperial Chemical Industries), Ltd, Nobel Division, Stevenston, Ayrshire (1950)

N-Alkyl Nitroammonines were proposed as stabilizers for NC. See under Aniline, Mononitro-

N-Alkyl-N\_1-(2-nitroxyethyl)ethylene Dinitramines of the general formula, R \_ N(\text{NO})\_3 \_ \text{CH}_3 \_ \text{CH}_2 \_ \text{N(\text{NO})}_3 \_ \text{CH}_2 \_ \text{CH}_2 \_ \text{ONO}_2 \_ \text{were recently patented by Blomquist & Fiedorek (Ref 3) for use in propellants as explosive, practically non-volatile plasticizers for NC. These compds can be prepd either by the method of Franchimont & Klobbie (Ref 1), which involves the treatment of}
N-alkylethlenedinitramines with ethylene-dibromide, or, preferably, by the method of Wright & Chute (Ref 2). The latter method consists of converting N-alkylethylenediamines by means of ethylene oxide to the corresponding N-alkyl-N'-(2-ethanol)ethylene-diamines, followed by treatment with nitric acid and then acetic anhydride in the presence of a chloride or bromide ion:

\[ \text{R. NH. CH}_3 \cdot \text{CH}_2 \cdot \text{NH. CH}_3 \cdot \text{CH}_2 \cdot \text{OH} \]

\[ \begin{align*}
\text{HNO}_3 + \\
\text{Ac}_2\text{O} + \\
\text{Cl}^- \text{(or Br)} \\
\text{R. N(NO}_2\text{). CH}_3 \cdot \text{CH}_2 \cdot \text{N(NO}_2\text{). CH}_3 \cdot \text{CH}_2 \cdot \text{OH} \\
\text{ONO}_2
\end{align*} \]

As an example of such a compd the explosive N-methyl-\textit{N}'-(2-nitroxyethyl)ethylene-dinitramine is cited


\textbf{Alkyloamines, Nitrated Products.} The following explosive alkyloamines were prepared and examined in 1944 at PicArsn:

a) \textit{Bis(hydroxymethyl)methylenedinitramine} and b) \textit{Tri(hydroxymethyl)aminomethane trinitrate}

Both of these compds were found to be unstable even at RT and for this reason unsuitable for military purposes

\textbf{Ref:} H. A. Aaronson, PATR 1412 (1942)

\textbf{Alkyl Peroxides, Decomposition} was discussed in the following refs:


\textbf{Alkyl Silanes or Alkyl Silicones} are compds combining alkyl groups with silicon or silicon hydrides, eg, methylsilane \textit{CH}_3\textit{SiH}_3, dimethylsilane \textit{CH}_3\textit{SiH}_2, trimethylsilane \textit{CH}_3\textit{SiH}, tetramethylsilane \textit{CH}_3\textit{SiH}_3, and vinylsilane \textit{CH}_3\textit{CHSiH}_2. They are very reactive compds and some of them even ignite spontaneously in air. Their mixts with air are usually expl. These compds have been known for about one hundred years, but Ref 1 seems to give the first comprehensive description of their prepn. Several methods of synthesis of alkylsilanes are reviewed in Ref 6. One of the most common methods is the Grignard reaction, which involves the interaction of a suitable alkylmagnesium halide with a halosilane in anhydrous ether:

\[ 3\text{CH}_2\text{MgBr} + \text{SiHCl}_3 \rightarrow \text{Si(CH}_3)_2\text{H} + 3\text{MgBrCl} \]

In Ref 7 are given the temp-compn limits of spontaneous expln for 9 alkylosilanes with air at atm press, and in Ref 8 are discussed the combustion expln limits of several alkylosilanes at 1 atm press. The expln temp decreases in the order: tetramethylsilane > trimethylsilane > dimethylsilane > methylsilane > vinylsilane

Some alkylosilanes may be considered as suitable components of liquid rocket fuels

Although these compds are not expl they contain enough nitrogen to be of some interest as potential gas-producing components for propellants or industrial expls

Alkyltetrazylazides, such as methyl-, ethyl-, etc were patented by W. Friederich, USP 2,170,943(1939) & CA 34, 265(1940) for use as high expls (See under individual compds)

Alkyltrimetholmethane Triacetates or

Alkyl-tri-hydroxymethane Triacetates, RC(OH)OCCH₃, are compds prepd by acetylation of alkyltrimetholmethane (Alkyltrisoxymethane in Ger), RC(CH₄O)₃H. These acetates were patented as gelatinizers for NC's and acetylated celluloses for use in expls and smokeless propellant. A procedure for the prepn of methyltrimetholmethane tricetate, CH₃C(CH₂OOCCH₃), is given in Ref 1. It is a liq, bp 200° at 80 mm

In another patent(Ref 2) it is claimed that the above compds act as stabilizers for NC, NG, etc

Ref: 1) Bombrini Parodi-Delfino, FrP 793,590(1936) & CA 30, 4517(1936) 2)Paolo Parodi-Delfino, USP 2,096,451(1937) & CA 32, 357(1938)

Alkyltrimetholmethane Trinitrates or Alkyl-tri-hydroxymethane Trinitrates, RC(CH₄ONO)₃, are compds prepd by nitrating alkyltrimetholmethanes RC(CH₂OH). They were patented for use as expls, either alone or in mixts with other substances
Ref: Bombrini Parodi-Delfino, FrP 771,599 (1934) & CA 29,929(1935)

Alkynes (Acetylene Series). A group of unsaturated aliphatic hydrocarbons of the general formula CₙH₂ₙ-2, contg triple bonds. These compds were also called Alkynes

Alldorfit. Same as Aldorfit

Allegé Explosifs (lightened Explosives)(Explosifs de mine du genre dit allégé) are Fr coal mine expls of low packing density (0.6 to 0.9). For instance, the compn AN 88 and nitropoly styrene 12% has a d 0.65
Ref: L.Médard, MP 34, 104(1952)

Allenic Compounds are derivs of allene or propadiene, also called dimethylenemethane, CH₂:CH₂. Allene was probably first prepd in 1865(Ref 2), but the hydrocarbon was not actually identified until 1872 (Ref 3). A rather general method for the prepn of allene by treating 1,2-dihalopropene with Zn dust in alc, was first used in 1888(Ref 4). Many other methods of prepn are known and some of them are described in Ref 5

Numerous halo allenes are known, but the perhaloallenes of the type X₂C:CH₂ were unknown until a study at the Univ of Calif, LA (Ref 5) was undertaken as part of the US Dept of the Army Contract DA-04-495-ORD-527. It is expected that compds such as tetrafluoroallene, F₂C:C:CF₂ will be of interest as monomers for both homopolymerization and copolymerization studies and for the prepn of materials similar to Teflon which is the homopolymer of tetrafluoromethylene F₂C:CF₂. This study is being continued as of 1958


Note: This report is based chiefly on the dissertation by R.S. Bauer, "The Synthesis and Polymerization of Polyhalogenated Allenes," Univ of Calif, LA(1958)(86 Refs)

Allison Powder. A blasting expl consisting of porous black powder and some NG absorbed in the pores
Ref: 1)Cundill, MP 5, 281(1892) 2)Daniel (1902), 8

Allophylazoide (Allophan säureazid, in Ger),
The free base allophanylhydrazide was prepared by Audrieth et al. (Refs 3 & 5) in good yield (80%) by hydrazinolysis of methyl- or ethyl-allophanate under reflux. Some esters and salts of allophanylhydrazide were also prepared (Ref 3, pp 17-27 & 42-6).

Tests at PicArsn showed that allophanylhydrazide is not sufficiently compatible with NC for use in propellants (Ref 4).


Alloxan or N,N-Mesoxoyl Urea (Pyrimidine-tetron or Erythric Acid of Brugnatelli,)

\[
\text{OC-NH-OC} \\
\text{OC-CO-NH}
\]

mw 142.07, N 19.72%, mp dec ca 170°. Dark yel crysts, very sol in w and sol in alc. Can be prepared by oxidation of uric acid with HNO₃ (Ref 5) or by other methods (Ref 1).

Several investigators have reported explosions of alloxan after long storage and while attempting to open a glass-stoppered bottle containing alloxan by filing the neck of the bottle in which the stopper was frozen (Refs 2 & 3). One of the reports stated that a bottle of Kahlbaum's alloxan was found to have developed considerable pressure after storage at RT for 1 year (Ref 4).

It was remarked (Ref 6) that if it was possible to nitrate alloxan to the dinitro stage, the resulting product would be a perfectly oxygen-balanced explosive.

Refs: 1) Beil 24, 500, (428) & (301) (Includes several refs of prep described in Ord Synth) 2) A.S. Wheeler & M. T. Bogert, JACS 32, 809 (1910) & CA 4, 1906 (1910) 3) E.C. Franklin, JACS 32, 1362 (1910) & CA 4, 3138 (1910) 4) R. A. Gottmer, JACS 33, 85 (1911) 5) Karrer (1950), 802 6) L.F.
Audrieth et al, "Compounds of High Nitrogen Content," 2nd Quarterly Progr Rep, Univ of Illinois, Urbana, Ill, April 1, 1951

Alloys Suitable for Use in Ordnance Plants should be acid resistant, heat resistant and nonreactive with explosives. The most useful alloys in the manuf of acids and expls are various kinds of stainless steels. Among the non-ferrous alloys may be cited Chlorimet 2 and Chlorimet 3. During WWII the Germans used some high temp alloys such as Böhler, Chromadur, Remanit, Sicromal, Thermanit, Thermat, etc.


Allumage (Fr). Ignition or priming (of a grenade)

Allumeur (Fr). Igniter; any burning substance used to touch off a charge; primer (of a grenade)

Allumeur de sûreté (F). Safety igniter or fuse

ALLYLACETONE AND DERIVATIVES

Allylacetone or 5-Hexen-2-one, CH₂:CH:CH₂:CO:CH₃, mw 98.14; col, mobile liq, bp 129.5°, d 0.841 at 20°/200, vap d 3.39 (air = 1.00), Q₆ 856.5 kcal/mol. Was first prepd in 1877 by heating allylacetone and Chlorimet 2. Several other methods of prepn are listed in Ref 1. Its fire hazard is moderate and toxicity is unknown (allyl compds are generally toxic). It can react with oxidizing materials.

Refs: 1)Beil 1, 734,(382) & [792] 2)F. Zeidler, Ann 187, 35(1877)

Allylacetone Ozonide or Acetoneallyl Ozonide. If the formula of this compd,

\[ CH₂=CH:CH₂:CH₂:CH₃ \]

is correct, it is an Ozonide-peroxide, mw 162.14, OB to CO -118.4%, syrup d 118.476, expl violently on heating and dec on boiling with w. Was prepd by ozonization of allylacetone.

Refs: 1)Beil 1,734 2)C.Harries & K. Landheld, Ann 343, 349-9(1905)

Allylacetone Peroxide-Ozonide. Same as previous compd.

Allyl Alcohol or Vinyl Carbinol, CH₂:CH:CH₂OH, mw 58.08. Col liq with pungent, mustard-like odor; it is irritating to the eyes; mp -50°, bp 96-7°, d 0.8540 at 20°/4°, nD0°1.41545, fl p 70°F(open cup). Misc with w, alc, chlf, eth & petr eth. Can be prepd by heating glycerin with fomic acid (Refs 1 & 2) or by other methods. Used for the manuf of wargas, resins and plasticizers (Ref 3)
It forms an ozonide which is very unstable (Ref 1).


**Allylamine.** See Aminopropene

**Allylamine-Diphenylcarbamide Complex.** See under Diphenylcarbamides Suitable as Stabilizers and Gelatinizers in Smokeless Propellants

**Allylamine Perochlorate.** See under Aminopropene

**Allylamine Picrate.** See under Aminopropene

1-Allyl-5-amino-a-tetrazole or 5-(Allylamino)-1-amino-1H-tetrazole,

\[
\text{(CH}_3\text{ : CH : CH}_2\text{) HN: C = N(NH}_2\text{- N)}
\]

mw 140.15, N 59.97%. Lt yel ndls, mp 94°. Was prep'd from allylthio carbazide, Na azide and Ph oxide as described in Ref 2

Because of its high nitrogen content, it might be of interest as a component of propellant compns

Refs: 1) Beil—not found 2) R. Stoll & E. Gaertner, J PraktChem 132, 212 & 220 (1931); CA 26, 1608 (1932)

**ALLYLAMINOTETRAZoles**

1-Allyl-5-amino-a-tetrazole or 1-Allyl-5-amino-1H-tetrazole

\[
\text{H}_2\text{N: C = N(CH}_3\text{ ) CH : CH}_2\text{ - N)}
\]

mw 125.14, N 55.97%, OB to CO, -147.0%, OB to CO -95.9%. Crysts, mp 67-8°, \(Q^0 \text{ 682.9 kcal/mol & } Q^\gamma \text{ 67.6 kcal/mol (Ref 3)}\).

Was obtained as by-product in the prep'n of 1-allyl-5-amino-a-tetrazole from 5-amino-tetrazole, aq NaOH and allylbromide, as described in Ref 2

Because of its high nitrogen content, it might be of interest as a component of propellant compns


**ALLYLANILINE AND DERIVATIVES**

N-Allylaniline or Phenylallylamine CH\(_3\) : CH : HN: \(C\text{H}_2\), is listed in Beil 12, 170, (162) & [96]

N-Allylaniline Azide, \(C\text{H}_2\text{N}_2\text{N}_3\) —not found in Beil or CA through 1956

N-Allylnitroaniline, \(C\text{H}_2\text{N}_3\text{O}_2\), mw 178.19, N 15.72%. The following isomer is known.

N-Allyl-nitroaniline, red oil bp 174-5° at 12 mm. Was prep'd by oxidation of N-allyl-o-aminoaniline with FeCl\(_3\) and p-benzoquinone

Ref: 1)Beil-not found 2)V.C.Barry et al, JCS 1956, 894 3)N-Allyldintroaniline, C$_7$H$_8$N$_2$O$_4$, mw 223.19, N 18.83%. The following isomer is known:

N-Allyl-2,4-dinitroaniline, yel ndis, mp 75-6°C was prepd by treating allylamine with bromodinitrobenzene. Its expl props were not examined

Refs: 1)Beil 1, 751 2)P.vanRomburgh, Rec 4, 192(1885) 3)N-Allyl-trinitroaniline, C$_7$H$_8$N$_3$O$_6$, mw 268.19, N 20.89%. The following isomer is known:

N-Allyl-2,4,6-Trinitroaniline, called by P. van Romburgh Trinitrophenylallylamine, CH$_2$:CH:CH,:=NH, C$_7$H$_8$(NO)$_2$; solid, mp 80°C; was prepd from picrylchloride and allylamine. Its expl props were not examined

Refs: 1)Beil 12, 765 2)P.vanRomburgh, Rec 4, 192(1885)

Note: In the CA formula index for 1956, the formula C$_7$H$_8$N$_2$O$_4$ is assigned to allylamine-picrate, which is evidently in error as it is an addition salt with the empirical formula C$_7$H$_8$N$_3$O$_6$ (see under Aminopropene)

N-Allyl-tetranitroaniline, C$_7$H$_8$N$_4$O$_8$-not found in Beil or CA through 1956

Allylazide; 3-Triazopropene or 3-Azido-1-propene, N$_2$, CH$_2$:CH:CH$_2$ mw 83.09, N 50.57%. Mobile liq. bp 76.5°C, d 0.924 at 25/25°C; decomp violently on adding of concd H$_2$SO$_4$; its vapor explodes when heated. Was first prepd by heating an alc soln of allyl chloride with an aq soln of NaN$_3$. Fridman (Ref 3) studied its oxidation reaction, Sheinker & Syrkin (Ref 4) detd its vibrational spectra and Shott-L'vova & Syrkin (Ref 5) its dipole moments


Allylbenzeneoxonide or Phenylallylazonide, C$_7$H$_8$C$_6$H$_5$.O$_3$, liq. bp 70°C at 0.5 mm, d 1.1356 at 20°C, nD 1.5132 at 20°C. Can be prepd by ozonization of allylbenzene using the method of Harries (Ref 1) for ozonization of org compds. A detailed description of its prepn is given by Ryffel (Ref 3). Briner et al (Ref 4) detd the following props of allylbenzeneoxonide: sly in benz, Raman spectra, UV absorption spectra, dielectric constants and dipole moments

Note: According to Dr H.Walter of PicArs this oxonide is an explosive

A dimer of allylbenzeneoxonide was obtained from the distn residue of monomer


N-Allyl-$N'$, $N'$-diphenylocyurea (Diphenylcarbamylallylamine), (C$_7$H$_8$)$_2$. N.CO.NH-CH$_2$:CH$_2$:CH$_2$:CH$_2$:N.CO. was first prepd by refluxing carbamylurea with allylamine and anhydrous Na$_2$CO$_3$(Ref 2). It was suggested as a possible stabilizer or gelatinizer of NC in propellants (Refs 2 & 3)

Refs: 1)Beil-not found 2)R.Levy, MP 32, 309 & 312(1950) 3)P.Tavernier & M. Lamounoux, MP 37, 71 & 83(1956)

Allyl Ethers of Carbohydrates. A number of compds, such as allylglycerol, allylglycol, allylmannitol, allylsorbitol, allylptenterythritol, etc were prepd during and after WWII by Nichols & Yanovsky. They also discussed previous work on this subject and listed several refs. According to them the first compd of this type was triallylglycerol prepd in 1856 by M.Berthelot & S. de Luca


Note: Some of the above carbohydrate ethers
were nitrated to form expl derivs, eg allylpentaerythritol trinitrate and are described individually

**ALLYLGUANIDINE AND DERIVATIVES**

N-**Allylguanidine**, CH₃:CH:CH₂: NH . C(=NH) : NH₂ has been described in Beil 4,210 & [664] in the form of salts, among them the picrate

N-**Allylguanidine Azide**, C₄H₆N₅ – was not found in Beil or CA through 1956

N-**Allyl-** N’-nitroguanidine or 1-**Allyl-3-3- nitroguanidine**, CH₃: CH : CH₂: NH . C(=NH): NH·NO₂, mw 144.14, N 38.87%; crys, mp 107-8°. Can be prepd by the interaction of allylamine and N-methyl-N‘-nitroguanidine by the method B of Ref 3. This high nitrogen compd which may be suitable as a component of propellants was also prepd at the US Naval Powder Factory and described in conf rept (Ref 2)

*Refs:* 1)Beil – not found 2)US Naval Powder Factory, Indian Head, Md, Quarterly Rept No 2, 1 March to 31 May 1948 3)A.F. McKay, JACS 71, 1968-9(1949) & CA 43, 9035(1949)

**Allylnitrate**, CH₃: CH: CH₂-ONO₂, mw 103.08, N 13.59%; col limpid liq with suffocating odor, bp 106-106.8°, d 1.07 at 20/4°, nD 1.417 at 20°, insol in w. Was prepd by Henry by treating allylbromide with Ag nitrate in alc and treated with Pentaerythritol or Pentaerythritol ether Trinitrate, allylalcohol with mixt HNO₃/Ac₂O (Ref 3). It is an explosive

*Refs:* 1)Beil 1,438 2)L. Henry, Ber 5, 452(1872) 3)G. Desseigne, BullFr 1946, 98-9 & CA 41, 92(1947)

*Note:* Not listed in Beil 3rd Suppl, vol 1, part 2(1958)

**Allylnitrite**, CH₃: CH: CH₂: ONO₂, mw 87.08, N 16.09%. Liq which does not freeze at –20°; bp 43.5-44.5°, d 0.956 at 0° insol in w; its vapor expl at 100°. Was prepd by treating allylalcohol with glycinenitrile as described in Ref 2. Tarte detd its infrared & UV spectra (Ref 3)

*Refs:* 1)Beil 1,438 2)G. Bertoni, Gazz 15, 364(1885) & JCS 50 I, 218(1886) 3)P. Tarte, BullBelg, 60, 240(1951) & CA 46, 826 (1952); JChemPhys 20, 1570(1952) & CA 47, 7322(1952)

**Allyl, Nitro-; γ-Nitropropylene or 3-Nitropropene, O₂N: CH₃: CH: CH₂, mw 87.08, N 16.09%. Col liq, bp 125-30°, d 1.051 at 21° sometimes explodes on distn; insol in w, sol in alc & eth. Can be prepd by treating allylbromide with Ag nitrate in ether

Some of its salts are expl, eg the sodium salt, Na·C₄H₆·NO₂; ndls, easily sol in w; expl when heated above 200°

*Refs:* 1)Beil 1,203 2)P. Askenasy & V. Meyer, Ber 25,1701-3(1892)

** Allylnitric Acid,**

CH₃: CH: C<NO₂<NOH, mw 116.08, N 24.14%

OB to CO₂ –68.9, OB to CO –27.6%. Cryst, mp ca 68° (in capillary tube); expl violently ca 95°; sol in w and eth. Can be prepd by the action of nitrous acid (NaNO₂ + H₂SO₄) on sodium γ- nitrop propane inaq soln

*Refs:* 1)Beil 2,400 2)P. Askenasy & V. Meyer, Ber 25,1703-4(1892)

2-Allyloxymethyl-2-hydroxymethyl-1,3-propanediol Trinitrate; Monoallylpentaerythritol ether Trinitrate or Pentaerythritol-monoallylether Trinitrate,

\[
\begin{align*}
\text{CH}_3 \cdot \text{ONO}_2
\end{align*}
\]

O₂NO₂· H₅C –C – CH₂-O-CH₂· CH: CH₂,

\[
\begin{align*}
\text{CH}_3 \cdot \text{ONO}_2
\end{align*}
\]

mw 311.22, N 13.50%, OB to CO₂ –64.3%, OB to CO –23.1%. Liq, d 1.373 at 20°/20°, nD 1.4797. Can be prepd by nitrating monomallylpentaerythritol ether. It might be suitable as a gelatinizer for NC (see also Diallylpentaerythritol Ether Dinitrate)

*Refs:* 1)Beil – not found 2)R. Evans & J.A. Gallahan, JACS 75, 1248-49(1953) & CA 49, 3811(1955)

**ALLYL PENTAERYTHRITOL AND DERIVATIVES**

Allylpentaerythritol; Monoallylpentaerythritol
Ether or 2-[(Allyloxy)methyl]-2-(hydroxymethyl)-1,3-propanediol, \( \text{CH}_3\text{OH} \)

\[
\begin{align*}
\text{CH}_3 \colon & \text{CH}_2 \cdot \text{O} \cdot \text{CH}_2 \cdot \text{C} \cdot \text{CH}_2\text{OH}, \\
\text{CH}_2 \cdot \text{OH} &
\end{align*}
\]

col liq, bp 148-50° at 1 mm, d 1.135 at 20°/20°, \( n_D^2 \) 1.4843 at 20°. Was first prepd in an impure state by Nichols & Yanovsky from PE and allyl bromide, as described in Ref 2. Evans & Gallagher (Ref 3) prepd it in 35% yield by treating a suspension of PE in hexane with an aq KOH soln followed by the addition of allyl chloride.


**Allylpentaerythritol Azide**, \( \text{C}_6\text{H}_{15}\text{N}_3\text{O}_4 \)—not found in Beil or CA through 1956

**Allylpentaerythritol Mononitrate**, \( \text{C}_6\text{H}_{15}\text{NO}_4 \)—not found in Beil or CA through 1956

**Allylpentaerythritol Dinitrate**, \( \text{C}_6\text{H}_{14}\text{N}_2\text{O}_4 \)—not found in Beil or CA through 1956

**Allylpentaerythritol Trinitrate** or 2-[(Allyloxy)methyl]-2-(hydroxymethyl)-1,3-propanediol Trinitrate,

\[
\begin{align*}
\text{CH}_2 \cdot \text{ONO}_2 \\
\text{CH}_3 \cdot \text{CH}_2 \cdot \text{O} \cdot \text{H}_2 \cdot \text{C} \cdot \text{CH}_2 \cdot \text{ONO}_2, \\
\text{CH}_2 \cdot \text{ONO}_2 \\
\end{align*}
\]

mw 311.21, N 13.50%. Col liq, d 1.373 at 20/20°, \( n_D^2 \) 1.4797 at 20°. Was prepd by nitrating allylpentaerythritol (Ref 4)

The props of this liq explosive were investigated at the US Naval Powder Factory and are discussed in confidential reports (Refs 2 & 3)


**Allylpentaerythritol Trinitrate, Polymer** is discussed in US Naval Powder Factory conf reports listed as Refs 2 & 3 under Allylpentaerythritol Trinitrate

**p-Allylphenylmethylether.** Same as Anethole

**Allylphthalate.** Same as Diallylphthalate

**Allylpicrate, Picryll allylether or Allyl-2,4,6-trinitrophenylether**, \( (\text{O}_2\text{N})_3\text{C}_6\text{H}_4 \cdot \text{O} \cdot \text{CH}_2 \cdot \text{CH}: \text{OH} \)

**Allyltetrazole, Azide**, \( \text{C}_4\text{H}_6\text{N}_3\text{O}_2 \)—not found in Beil or CA through 1956

**Allyltetrazole, Nitrated Derivatives**—not found in Beil, or CA through 1956

**ALLYLTRIAZOLE AND DERIVATIVES**

1-Allyl-sym-triazole or 1-Allyl-1H-1,2,4-triazole

\[
\begin{align*}
\text{HC} \cdot \text{N}(\text{CH}_2 \cdot \text{CH}) \cdot \text{N} \cdot \text{C} \cdot \text{CH}_2 \\
\end{align*}
\]

mw 109.13, N 35.51%. Col liq, bp 198°, d 1.056 at 18°; easily sol in w, alc & benz. Was prepd by heating 1,2,4-triazole with Na ethylate soln and allyl bromide at 100°

*Refs:* 1) Beil 26, 14 2) G. Pellizzari & A. Soldi, Gazz 251, 381 (1905) & JCS 88, 1, 673 (1905)

1-Allyl-asidotriazole, \( \text{C}_5\text{H}_4\text{N}_4 \)—not found in Beil or CA through 1956

1-Allyl-nitrotriazole, \( \text{C}_5\text{H}_4\text{N}_4\text{O}_4 \)—not found
in Beil or CA through 1956

1-Allyl-dinitrotetrazole, C₆H₅N₃O₄ - not found in Beil or CA through 1956, but described in confidential Naugatuck Chemical Co. Progress Rept of June 15-Aug 15, 1949, p 3, NORD 10121

Allyl Type Alcohols, Polymerized. See under Polymerized Alcohols

 Allylene (Propyne or Propine), CH₃C=CH, mw 40.06. Gas, mp -102.7°, bp 20.2°. SL sol in w, sol in alc & eth. Its toxicity & expln hazards are discussed in Ref 3

It was reported that an expln occurred when an attempt was made to carry out the reaction

\[ HC\cdot CHCl_2 + 2NH_2 = NH\cdot CI + CH\cdot CN\cdot NH_2 \in a 1-liter steel vessel o Atruh15 with an initial NH₃ pressure of 8 atm. The expln was ascribed to a slow induction period followed by rapid acceleration of the reaction rate (Ref 2)

Refs: 1)Beil 1,246,(106), [222] & 19191 2)E.Banik, CA 50, 14229(1956) 3)Sax (1957), 255

Almatrites (Almatrity in Rus). Commercial expls developed in Russia in 1925. They contain chlorates and perchlorates together (Ho)(ClO₃)₆ with combustible org materials and are claimed to be as stable, but less sensitive than Cheddites. Following are compns and mw 450.23, N 12.45%.

When anhydrous golden-ndls (from AcOH); mp 88 and combustible (vaseline 5, paraffin 30 and rosin 65) 12%; d 1.15 and brisance 10.2 mm (compression of lead cylinder) vs 18.0 mm for TNT

b) Natrialmatrit No 19: Na chlorate 90 combustible (vaseline 5, paraffin 92.5 & rosin 2.5) 10%; d 1.40 and brisance 14.0 mm

c) Ammonalmatrit No 98: Amm chlorate 89, combustible (vaseline 8, paraffin 27 and rosin 65) 11%; d 1.17 & brisance 16.2 mm

Ref: E.Spitalkii & E.Krause, SS 20, 120-1 & 1945-5(1925) & CA 20, 1141(1926)

Almidon tetranitriico (Sp). Starch Tetranitrate or Nitrostarch (see under Starch)

Aloe, Nitroated. In 1876 Trench, Faure & Mackie in England, patented explosives contg nitrated aloe (or other nitrated cel-

lulosic material), collodion, charcoal, rosin, ozocerite, etc

Ref: Daniel (1902), 773(under Trench, Faure et Mackie)

Aloeemodine or 4,5,2'-Trihydroxy-2-methyl-anthraquinone (4,5,2'-Trixy-2-methyl-anthrachinon; Isoemodin; 3-OxymethylchrysaSin or Rhabarberon, in Ger).

\[ \text{HO} \cdot C₆H₄\text{C}=\text{O} \cdot C₆H₄(\text{OH}) \cdot \text{CH}_2\text{OH} \]

orange-red ndls, mp 224-225.5°, is described in Beil 8, 524,(745) & [565]

Azidoaloeemodine, C₁₅H₂₅N₃O₅ - not found in Beil or CA through 1956

Nitroaloemodine, C₁₅H₂₅N₃O₅ - not found in Beil or CA through 1956

Dinitroaloemodine, C₁₅H₂₃N₃O₅ - not found in Beil or CA through 1956

Trinitroaloemodine, C₁₅H₂₁N₃O₅ - not found in Beil or CA through 1956

Tetranitroaloemodine or 1,3,6,8-Tetranitro-4,5,2'-Trihydroxy-2-methyl-anthraquinone (Called in Beil 1.3.6.8-Tetranitro-4,5,2'-Trixy-2-methyl-anthrachinon or Tetranitroaloemodin),

\[ (\text{HO})_2\text{N}_2 \cdot C₆H₄\text{C}=\text{O} \cdot C₆(\text{NO}_2)₄(\text{OH}) \cdot \text{CH}_2\text{OH} \]

mw 450.23, N 12.45%. When anhydrous golden-ndls (from AcOH); mp- begins to soften ca 285° and then puffs off; its monohydrate, orange-red crysts (from alc), which softens ca 130° and puffs off at higher temp; sl sol in w, sol in alc. Was first prepd in 1841

(Ref 2) under the name of "Aloeinäsär," or "Aloeresinäsäre" as one of the nitration products of some aloe derivs. Its composition was established in 1848 (Ref 3). There are other methods of prepn, but the simplest method seems to be nitration of aloeemodine with nitric acid (d 1.5) with cooling as described in Ref 5

Several metallic salts are known of which the Ba salt deflagrates and the Ag salt expl on heating (Ref 4)

Refs: 1)Beil 8, 525 & (745) 2)E.Schnuck, Ann 39, 4 & 24 (1841) 3)E.Schnuck, Ann 65, 235(1848) 4)C.Finsch, Ann 134, 236-40
(1865) 5) E.Léger, CR 151, 1129(1910); CA 5, 1400(1911) & BullFr [4] 9, 90(1911)

Tetranitroaloemodine Nitrate, $C_{15}H_{36}N_6O_{15}$ – not found in Beil or CA through 1956

**Alox 600.** A polar wetting agent, one of a series of complex methyl esters of high mol wt alcohols, acids and lactones, manufd by the Alox Corp, Niagara Falls, NY. It is suitable as an additive (1 to 10%) to petroleum waxes (eg "Aristowax 160-165" of the Union Oil Co of Calif) to serve as a desensitizer for RDX or other expls, thus replacing previously used beeswax. Such a modified petroleum wax will wet RDX in water in the same way as does beeswax and seems to have about the same desensitizing action as beeswax. A series of such mixts were developed in the USA during WW II, as for instance, Bruceton Wax No 10, which consisted of "Aristowax 160-165"' 90 and "Alox 600"' 10%.

**Refs:**

**Aloxite.** A trade name for an abrasive prepd by fusing alumina (bauxite) in an electric furnace.

**Note:** This abrasive might be of use in primary compds in lieu of glass, etc

**Refs:**
1) Hackh(1944), 37 2) Webster's New International Dictionary, Merriam Co, Springfield, Mass (1951), 73

**Alperox C.** Trade name for tech lauroyl peroxide manufd by the Lucidol Division of Wallace & Tiernan, Inc, Buffalo, NY

**Alpha-Cellulose** is that portion of cellulosic material(pulp, paper, etc) which, after treatment with 17.5% NaOH(mercerized strength) at 200 and diln to 7.3% NaOH, can be separated by filtration. The residue of alpha-cellulose is a good index of the undegraded cellulose content of the material. The alkali treatment removes degreaded(oxidized or hydrolyzed) cellulose and short chain material. Some pentosans and hexosans may be included with the alpha-cellulose (See also Beta- and Gamma-Cellulose)

**Refs:**

**Alpha-Compounds,** such as $\alpha$-Mononitronaphthalene, $\alpha$-Trinitrotoluene, etc are listed under the corresponding parent compds, such as Naphthalene, Toluene etc

**Alpha Particles as Initiators of Detonation.** According to some investigators $\alpha$-particles emitted by radium or other sources can, by irradiation, initiate the detonation of very sensitive expls, such as nitrogen iodide, but not of expls such as acetylides or azides. Nitrogen iodide can also be irradiated by fission products (See also Initiation of Explosives by Irradiation)

**Refs:**

**Alphosone.** A brand of succinic peroxide (qv), manufd by the Lucidol Division of Wallace & Tiernan, Inc, Buffalo, NY

**Alisilite.** One of the current Belg high expls ("explosifs brisants") : AN 80, TNT 18 & Al 2%

**Ref:** Dr L. Deffe, Bruxelles; private communication, March 10, 1954

**ALT.** A solid propellant for rockets: K perchlorate 76.5 & asphalt base fuel 23.5%. Its props are described in conf rept (Ref 2)

**Refs:**
1) Armament Engrg(1954), 42 2) Propellent Manual, SP1A/M2, Johns Hopkins Univ, Silver Spring, Maryland (1959), Unit No 297(Conf)

**Alto esplosivo** (Ital). High Explosive (HE)

**Alum.** See Alums

**ALUMATOL.** A Brit expl of the ammonal type. It is practically 80/20 amatol in which part of the AN is replaced by Al powder: AN 77, TNT 20, Al 3%. During WWI alumatol was
used on a considerable scale for filling grenades and trench mortar bombs and as a blasting expl. It was found not very suitable for loading shells. When compressed to d higher than 1.2, there is danger of incomplete deton, while at lower d there is danger from set-back, and full power does not develop (Refs 1 & 2). Some alumatois contained charcoal, as for instance the French compsn: AN 65, charcoal 10, TNT 15 & Al 10% (Ref 1)

E. Cheylan studied the behavior of Al in the persence of AN with or without TNT and found the temary mixtures, Al-AN-TNT, stable when stored for 100 days at temperatures up to 90°. Mixts contg AN contaminatated by chlorides proved to be unstable. Cheylan assumes that the instability of some Al contg expls in storage is due to the use of AN containing chlorides (Ref 3).

Alumina. See Aluminum Oxide under Oxides Aluminized Explosives. See Aluminum Containing Explosives

ALUMINUM (Aluminium in Fr & Ger; Alluminio in Ital; Aluminio in Span; Aluminio in Port; Alumini in Rus; Aruminiiimu in Japan), Al, at wt 26.98%. Lt silvery metal, very maleable & ductile, mp 660°, bp 2056-7°, d 2.6978 at 25/4°, Qc (to Al2O3) 399.0 kcal, sp heat at 100° 0.2226 cal/g. It does not occur in the free state but its compds, such as feldspar (KAlSi3O8) mica (KAlSiO4), kaolin clay [H2Al2(SiO4)2. H2O], bauxite (Al2O3. 2H2O) are widely distributed as minerals. Al is considered the most abundant metal—it makes up 7.85% of known terrestial matter.

Al is nearly insol in w, nitric acid, acetic acid & ammonia; sol in hydrochloric & sulfuric acids and in alkalies.

Was first prepd in 1824-5 by H. Oerstead by heating Al chloride with K amalgam and and a few years later, by F. Wöhler who used metallic K as a reducing agent. The first industrial method of prepn was developed in 1854 by H. Sainte-Claire Deville, who used Al chloride and metallic Na, but Al thus produced was impure and very expensive. The first large-scale industrial method was developed in 1886 by Hall in USA (Ref 1) and simultaneously by Hroult in France (Ref 2).

This process, which involves electrolytic reduction of Al2O3 dissolved in molten cryolite (3NaF. AlF3), has been improved in later years and is known now as the Hall-Hroult method. Detailed descriptions of this and of some other current methods of prepn are given in Refs 5, 11, 12, 15 & 20. As the source of stable Al2O3, the abundant mineral bauxite, Al2O3·2H2O, is usually used.

Al is generally considered non-toxic, except when it is inhaled in the form of dust (Ref 23)(See under Aluminum Dust)

Al possesses a great affinity for oxygen and when finely divided (powdered, flaked, etc) it burns in the air. It burns also when made in the form of a thin ribbon similar to that of Mg. When Al powder is mixed and heated with an oxide of a metal below it in the electromotive series, displacement takes place, for instance in Thermite (qv):

$$\text{Fe}_2\text{O}_3 + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 2\text{Fe}$$

Temps of 3000-3500° are obtained as a result of this reaction.

Al has a high heat of combustion, as shown by the equation:

$$2\text{Al} + 1.5\text{O}_2 \rightarrow \text{Al}_2\text{O}_3 + 393.3 \text{ kcal/mol or 7291 cal/g}$$

(Ref 11)

Aluminum is very reactive and some of its reactions proceed with expl violence. Bauer (Ref 7) discussed the danger of expln when Al or its alloys are melted in cast iron crucibles. Kohlmeyer (Ref 8) described an extremely violent expln which destroyed app and injured the observer. The expln occurred when Al powder and Na2SO4 in the mol ratio 8:3 were melted at ca 800°. Clogston (Ref 9) discussed fire and expl hazards on heating Al or Mg powders with chlorinated hydrocarbons, such as CCl4, CH2Cl2, CHCl3, etc. Lindeijer (Ref 16) reported a fatal expln on heating a
a mixt of powdered Al with CCl₄. Van Hinte(Ref 18) reported a spontaneous ignition caused by reaction betn Al and tri-
chloroethylene. Charmandarian (Ref 19)
reported that the action of powdered Al, Mg, etc on molten AN, hydrazonium nitrate and Na sulfate is very violent and often explos.
Stettbacher (Refs 13 & 17 and many other investigators studied the influence of the addn of Al to expls and this subject is discussed under "Aluminum Containing Explosives"
The important reaction of metallic Al is its behavior with O or water. Under many conditions the reaction is self-stopping because of the formation of an impervious film of Al₂O₃.

Explosion of Al dust is discussed under Aluminum Dust and Its Explosion

Uses of Al in industry are too numerous to be described here. They are listed in Refs 5, 11, 12, 15 & 20. The uses of Al powder in expls are discussed under Aluminum Containing Explosives. Al powder is also used in incendiaries and in pyrotechnic compositions. Discussion on uses of finely divided Al and some other metals is given in Ref 16a


Aluminum (Analytical Procedures). The Al ion is usually detected in qualitative analysis by the precipitation of Al(OH)₃ which results from heating the aq soln with NH₄OH and NH₄Cl. The ppt dissolves on adding a sufficient excess of NaOH. In a quantitative method, the ppt of Al(OH)₃ is filtered off, ignited and weighed as Al₂O₃. Alizarin-S("aluminon"(Amm aurintricarboxylate) and some other reagents give distinctive ppts with the Al ion. Al can also be detd colorimetrically, spectrographically and polarographically. Detailed descriptions of analytical procedures are given in Refs 5-8 & 10-15. An optical method for the study of powdered Al grains intended for use in AN expls is described in Ref 9

Aluminum, in flaked, grained or atomized form intended for use in US ammo should conform to the requirements of specifications listed as Refs 1, 2 & 3. The tests and detn include:
a) Optical examination of particles of Al with a 20-30 power microscope to det their form
b) Granulation(fineness), using US Std sieves conforming to the requirements of Federal Specification RR-S-366 c) Apparent density, using a tared 100 ml graduate d) Material volatile at 105° e) Oil and grease—by extraction with ether f) Silicon g) Zinc h) Iron i) Copper j) Magnesium k) Free
Aluminum Alkyls were prepared in 1865 by the action of aluminum on mercury alkyls (Refs 1 & 6) (see also Note below). Later they were made by the action of "electron metal" (alloy of Al and Mg) on a solution of the alkyl halide in ether (Refs 2 & 6). The Al trialkyls are volatile liquids, violently attacked by air or water.

Following are examples: trimethylaluminum \( \text{Al}(\text{CH}_3)_3 \), d 0.752 at 20°/4°, mp 15.0°, bp 126.1°; triethylaluminum \( \text{Al}(\text{CH}_2)_2\text{CH}_3 \), d 0.837 at 20°/4°, mp -52.5°, bp 185.6°; tri-n-propylaluminum \( \text{Al}(\text{n-C}_3\text{H}_7)_3 \), d 0.823 at 20°/4°, mp -107°, bp ca 250° (Refs 3, 4, 5 & 6).

These three compounds are inflammable in air and for this reason may be of interest as components of liquid propellants for rockets.

Note: The preparation of a compound called "Aethyl-alumininum" was claimed by W. Hallwachs & A. Schaffarik, Ann 109, 207 (1859) but it was not properly identified and its properties (except that it is violently decomposed by water) were not described.

References:
1) G. B. Buckton & W. Odling, Ann Suppl 4, 109 (1865)
2) E. Krause & B. Wendt, Ber 56, 466 (1923)
3) A. V. Grosse & J. M. Mavity, JOC 106 (1940)
4) A. W. Laubengayer & W. F. Gilliam, JACS 63, 477 (1941)
5) K. C. Pitzer & H. S. Gutowski, JACS 68, 2204 (1946)
6) Sidgwick, ChemElems (1950), 414-15

Aluminum Alkyl Halides of the general formula \( \text{AIR}_x \) and \( \text{AIR}_x \) were prepared by Grignard and other investigators by treating Al with alkyl halides: \( 2 \text{Al} + 3 \text{RX} = \text{AIR}_x + \text{AIR}_x \).

Most of these compounds are liquids or low melting solids which easily catch fire in air and react violently with water. As examples of these compounds may be cited aluminum ethyl diiodide, \( \text{Al}(\text{C}_2\text{H}_5)_2\text{I} \) solid, mp 35-7°, bp 158-60° at 4 mm and aluminum diethyl iodide, \( \text{Al}(\text{C}_2\text{H}_5)_2\text{I} \), liq, bp 118-20° at 4 mm.

For additional information on preparation and properties, see:

References:
1) W. Hallwachs & A. Schaffarik, Ann 109, 207 (1859)
2) V. Grignard & R. L. Jenkins, Bull Fr 37, 1376 (1925)
3) A. V. Grosse & J. M. Mavity, JOC 5, 106-121 (1940) (12 refs)
4) Sidgwick, ChemElems 1(1950), 417-18

Aluminum Alkyl Hydrides. As an example of such compds may be cited *aluminum tetramethyl hydride*, \( \text{AlH}_2(\text{CH}_3)_4 \), a viscous liq. volat in vacuo and burning explosively with a purple flame in air. It is hydrolyzed by \( \text{H}_2\text{O} \) and is decomd above 160° yielding \( \text{Al}(\text{CH}_3)_3 \). Was prepd by the action of an electric discharge on a mixt of \( \text{Al(CH}_3)_3 \) and hydrogen.


Aluminum Azide. See under Azides, Inorganic

Aluminum Block (of Kreulen) is a hollow Al block used for detg the tendency of coal and other materials to spontaneous combustion.

*Ref:* D. Kreulen, Brennstoff-Chem, 11, 261-2 (1930) & CA 25, 394 (1931)

**Aluminum Block Expansion Test** is similar to the Lead Block Expansion Test, but superior to it when testing brisant expls, especially those contg Al. A brief description of this test is given under Trauzl Tests

Aluminum Boride. See under Borides.

Aluminum Borohydride. See under Borohydrides.

Aluminum Carbide. See under Aluminum Acetylides and Aluminum Carbide under Acetylides.

Aluminum Chlorate. See under Chlorates.

Aluminum Chloride. See under Chlorides.

Aluminum Chloride-Nitromethane Complex.

See under Chlorides.

**Aluminum Containing Alloys.** Al forms various alloys with other metals. Some of the alloys melt at temps below the mp of either metal (eg, Al-Cu, Al-Ag), others above that of either metal and some at intermediate temps (eg, Al-Sn, Al-Fe, Al-Zn) (Ref 6, p 281). Some alloys contain large percentages of Al while others contain only small percentages. Several Al-contg alloys are listed by Perry (Ref 6, pp 1527-1531). The more common alloys, of which Al is the largest constituent, are tabulated by Thorpe (Ref 2) who also lists 20 books and pamphlets relating to Al and its alloys. The metallurgy of Al alloys is discussed in Ref 5 and the phase diagrams of the most important Al systems are given in Refs 1 & 4. Al and its alloys find wide application in the fabrication industry in castings and the making of wrought products. Alloys for casting generally contain larger amts of added elements than those for wrought products. The nominal compositions of commercial cast and wrought alloys and their typical mechanical and physical props are given in Ref 4. Clark & Hawley (Ref 8) give an example of wrought "age-hardenable" alloys which are modifications of Duralumin or of castable alloys containing Al and ca 12%. Other industrial products of Al alloys are granules of various sizes used for adding to molten steel, for Thermite reactions and for expls. Requirements of the most important alloy of Al(Mg-Al) used in expls are described in a joint Army-Navy Spec (Ref 3). The tests and detns are listed under Aluminum (Analytical Procedures). The alloy of Al with Mg is used in pyrotechnic compositions and as a metal additive to some high explosives.

According to Pérez Ara (Ref 9a) the addition of Al-Zn alloy has certain advantages over straight Al because the alloy is less reactive (oxidizable) in the presence of moisture.

Examples of tracer and incendiary compns which use Al-Mg alloy in projectile ammo, taken from Ref 7, follow:

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Red Tracer</th>
<th>Incendiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>50/50 Al/Mg alloy</td>
<td>40</td>
<td>37</td>
</tr>
<tr>
<td>Chlorinated rubber</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Strontium nitrate</td>
<td>55</td>
<td>56</td>
</tr>
<tr>
<td>Barium nitrate</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Polyvinyl chloride</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>Linseed Oil</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Asphaltum</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

A further advantage of the addition of Al lies in the fact that $\text{Al}_2\text{O}_3$ formed during the reaction does not remain as a solid but vaporizes, thus increasing the overall volume of gases and the pressure. These increases are due to the fact that the bp of $\text{Al}_2\text{O}_3$ is only 2980° while the temp developed on expln of HE's is usually above 4500°.
According to Médard (Ref 25), important studies of aluminized expls in France were made by Douillet about 1935. At that time he showed that although the binary mixt of AN 82 & Al 18% gave a Trauzl test value (CUP or cup; in Fr) much higher than PA, it was inferior to mixts in which part or all of the AN was replaced by a nitro-compd such as TNT, or pentolite.

Stettbacher (Ref 12) gave several tables showing the differences in some expl props of non-aluminized and aluminized expls, from which the data for the table were taken.

This table shows considerable increase in E and substantial increases in $Q_e$ and $T_e$ due to the addition of Al, whereas the vols of gases evolved decrease.

Muraour (Ref 11) discussed the advantage obtained by adding Al to mixts TNT/HNDPhA. Such mixts without Al were used by the Germans during WWI for filling torpedoes and sea mines. When about 15% Al was incorporated in such mixts, the heat of expln was raised about 40%. It seems that the adtn of 15% Al adopted by the Germans for their underwater expls is about optimum (cont’d on next page).

### TABLE

**Comparison of Properties of Explosives with and without Aluminum**

(Reduction to CO + H₂ in Aluminized Explosives)

<table>
<thead>
<tr>
<th>Composition</th>
<th>Max Loading Vol Evolved l/kg</th>
<th>$Q_e$ kcal/kg</th>
<th>$Q_v$ kcal/kg</th>
<th>Temp of Expln $T_e$ °C</th>
<th>Spec Press of Energy f atm</th>
<th>Max d E</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNT</td>
<td>1.62</td>
<td>654.0</td>
<td>950.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>TNT 81.8 + Al 18.2</td>
<td>1.78</td>
<td>559.0</td>
<td>1472.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Erythritetetranitrate</td>
<td>1.70</td>
<td>704.8</td>
<td>1467.7</td>
<td>4729.8</td>
<td>4759.0</td>
<td>44080</td>
</tr>
<tr>
<td>ETen 67.75 + Al 32.25</td>
<td>1.99</td>
<td>452.4</td>
<td>2350.0</td>
<td>2361.7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Penthinit[NG 74.9%, NC of 12.1%N 4.2% &amp; PETN 20.9%]</td>
<td>1.64</td>
<td>719.5</td>
<td>1597.8</td>
<td>1616.5</td>
<td>4857.2</td>
<td>4885.9</td>
</tr>
<tr>
<td>Penthinit 69.+ Al 31</td>
<td>1.93</td>
<td>496.5</td>
<td>2274.0</td>
<td>2286.8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Blasting Gelatin[NG 91.3%, NC (of 12.24% N) 8.7%]</td>
<td>1.61</td>
<td>711.1</td>
<td>1612.5</td>
<td>1631.0</td>
<td>4970.2</td>
<td>4998.4</td>
</tr>
<tr>
<td>Bl Gel 68.7 + Al 31.3</td>
<td>1.92</td>
<td>488.7</td>
<td>2287.9</td>
<td>2300.6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Oxyliqu(Tiq oxygen 75%, $C_6H_{25}$)</td>
<td>1.1</td>
<td>610.8</td>
<td>2287.0</td>
<td>2303.0</td>
<td>–</td>
<td>6383.0</td>
</tr>
<tr>
<td>Oxy 67.05 + Al 32.95</td>
<td>1.6</td>
<td>410.8</td>
<td>2747.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

*Note:* For definition of (f) and (E) see Ref 12.
because it is close to the amount required to reduce the CO₂ to CO and the H₂O to H₂.

Médard (Ref 25 & 29) detd some props of aluminized expls and gave a table comparing Trauzl test values (CUP in Fr) and in some cases deton velocities of nitrocompds contg from 0 to 40% Al. It seems that in most cases 15 to 20% is the optimum but this amount can be as high as 25% or even 30% when PETN or RDX is present. Among the aluminized expls investigated by Médard were

a) Nn₀30: AN 80.2, TNT 10.6 & Al 9.2%; CUP 132 (PA 100)  
  b) Nn₀31: AN 78.5, pento-lite (PETN/TNT-80/20) 12.3 & Al 9.2%; CUP 138  
  c) Nn₀33: AN 69, TNT 10 & Al 21%; CUP 146  
  d) 63-CSE-1949: AN 67, pento-lite (80/20) 12 & Al 21%; CUP 147

**Note:** The first two expls have a positive oxygen balance and lower CUP while the last two have a negative OB and higher CUP.

Médard also examined an industrial aluminized expl Nn₀32: AN 78, DNC1B 12 & Al 10% (Ref 2, p 223), as well as Sorfanex A: AN 48, NG 40, NC 2, Al 8 & liq DNT 2% (Ref 23, p 218) and Seurani N°1: NH₄CIO₄ 31, PETN 48, Al 3 & plasticizer (polyvinylacetate in liq DNT) 18% (Ref 29, p 219).

Le Roux (Ref 31) claimed that compns contg phlegmatized RDX and granulated Al are more powerful and possess higher deton velocities than those contg pulverized Al. They can be easily loaded by compression to d's higher than those with pulverized Al. As an example of such expls may be cited: RDX 80, MNN 5 & granulated Al 15%; CUP ca 155 (PA 100), deton vel ca 7350 m/s at d 1.60.

Belgrano (Ref 34) gave compns and props (Trauzl test values, gap test values & deton velocities) of a number of Ital aluminized expls. Most of them seem to be too weak for military purposes. An Ital military aluminized plastic HE consisting of RDX 67.2, NG 16.3, Al 12.2, wax 4.1 & unacc 0.2%, is listed in Ref 9. This expl was used during WWII for filling some projectiles. Other Ital, Al-contg military expls of WWII were Nitramite and Trialine-105.

Following is some additional information on the props and uses of Al in expl compns as well as the advantages of such uses:

Baron (Ref 6) reported that replacement in AN-expls of carbonaceous material by a light metal, such as Al, reduces the amount of gas liberated on expln, but the loss in power due thereto is more than compensated by the greater production of heat. Holmes (Ref 7) proposed incorporation of small amts of Al powder in blasting expls consisting of black powder & AN. Schwarzer (Ref 10) proposed incorporation of Al powder in expls consisting of NG & kieselguhr.

Stettbacher (Ref 12, 24 & 36) in addition to the previously mentioned advantages gained by the use of Al in expls, gave examples of military aluminized expl compositions developed during WWII, such as:

a) German underwater expl contg TNT 62, HNDPhA 23 & Al 15%  
  b) British and American expl contg TNT 42, RDX 40 & Al 18%  
  c) Russian expl contg erythritetetranitrate & Al powder

Cooley et al (Ref 15) & Anon in OpNav 30-3M (Ref 16) discussed the uses of aluminized expls by the Japanese. Belyaev & Nalbandyan (Ref 17) described expl props of gasless mixts of Al with K chlorate. Ratner & Khariton (Ref 18) found that a small addn of Al, such as 5-10%, to AN raised not only the blasting power but also the brisance. When large amts of Al were added, such as 20%, the brisance was not affected. This was explained by volatilization of the Al₂O₃, which absorbs heat. The blast effect was increased because expansion of the detonation products caused the temp to drop; the Al₂O₃ vapor condensed and its latent heat of vaporization was liberated to enhance the blast effect.

All & EnExpls (Ref 19) gives a general discussion on aluminized expls and its use by belligerents during WWII.

Shidlovskii (Ref 21) described expl mixts...
of powdered Al & Mg with water. Perverzev (Ref 22) reported that the max increase in expl force of a nitroaromatic is achieved when the amt of Al is sufficient to completely reduce CO₂ and H₂O vapor. Goto & Sito (Ref 23) discussed expln and inflammation of Al powder in air (see under Aluminum Dust and Its Explosion).

Dinamite Nobel SA (Ref 26) patented aluminized HE’s such as RDX with 10-25% of Al. Polverifici Giovanni Stacchini SA (Ref 27) patented HE’s contg Al 5-30, TNT 30-90 & PETN 5-65% and also (Ref 28) expls in which half of the TNT of the preceding patent was substituted by DNN.

Tominaga and Kanno (Ref 30) reported that Al powder used in flashlight powders can be partially replaced by CaS₂ or FeS₂ which results in their improvement. The presence of KNO₃ promotes uniform burning and reduces the combustion rate. Stearin and coconut binders are superior to paraffin with respect to promoting uniform combustion. Sakamaki (Ref 33) patented compns for use in electric detonators, such as Pb dinitroresorcinone 55, perchlorate 20, sulfur 10, Al 10 & binder (jelly of CC) 5%. Byers (Ref 35) patented AN-expls contg atomized Al particles (cryst size ca 30 µ) as an activator. An intimate mixt of ingredients was obtained by introducing atomized Al directly into the nitrate crystall bath. The resulting expls were reported to be easily activated.

Sartorius (Ref 37) investigated several metals and metalloids as possible replacements of Al in expl compns. None of the straight substances seems to be as satisfactory as Al, even including Mg, but the author thinks that beryllium in alloys is promising and needs further investigation. Silicon, although less satisfactory in expls than Al from the point of view of power & deton velocity, might find application if the price was less than that of Al. Nuhsbaum (Ref 37a) patented a cartridge for an expl charge which contained within a separate casing an admixt of substances having high burning temps, such as powdered Al, Mg, ferrosilicon or red phosphorus. Richardson (Ref 38) patented expl compns consisting of particles of sulfur coated with a liq nitroaromatic and finely powdered AN & Al. Wallerius (Ref 41) claimed that incorporation of 8-12% Al powder together with the necessary amt of inorg nitrate for its combustion in plastic expls based on liq org nitrogen compds, lowered their costs and sensitivity to shock. Frutiger (Ref 42) patented expl compns claimed to be of high stability and low sensitivity to shock by mixing methylhydrazine perchlorate with 1-2.5% carbonaceous material (such as graphite, starch or woodmeal) and up to 10% of Al powder. To make such expls plastic, gelatinized acetylcellulose may be used as the carbonaceous material.

Note: Nav Ord Repts (Refs 43 & 46), being conf. were not used here as sources of info.

PATR 2510 (Ref 44) listed several Ger aluminized expls used prior to and during WWII.

Streng & Kirschenbaum (Ref 45) claimed that an expl consisting of Al powder and a stable oxidizer is rendered more powerful and safer to handle and to store if some water is incorporated.

A recent study of the role of Al in expl mixts is that of Cook and co-workers (Ref 42). The low relative "brisance" of aluminized explosives has been attributed in the past to incomplete reaction of Al at the "Chapman-Jouguet plane," and the high blast potential to after-burning of the Al. Thus, early shaped charge studies indicated that Al acts effectively as a diluent as far as the end effect is concerned. More careful studies by Cook showed, however, that Al lowers the detonation pressure and velocity even more than an ideal diluent. The effective endothermic reaction of Al in the deton wave is shown in the following results of deton pressures measured by the shaped charge method:

(See next page)
This table shows that the deton pressures of Tritonal and HBX are smaller than those of TNT and Composition B respectively, even though the d's of the former expls are higher. This is significant in view of the known effect of d on press. The same situation may be observed by compg the deton vel (D), as represented below:

### Velocity Comparison (by Cook)

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Density d, g/cc</th>
<th>Detonation Pressure (atm x 10^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNT</td>
<td>1.59</td>
<td>150</td>
</tr>
<tr>
<td>80/20-TNT/Al</td>
<td>1.68</td>
<td>140</td>
</tr>
<tr>
<td>TNT</td>
<td>0.81</td>
<td>46</td>
</tr>
<tr>
<td>80/20-TNT/Al</td>
<td>0.94</td>
<td>45</td>
</tr>
<tr>
<td>Composition B</td>
<td>1.71</td>
<td>230</td>
</tr>
<tr>
<td>80/20-Comp B/Al</td>
<td>1.81</td>
<td>170</td>
</tr>
<tr>
<td>73.2/26.8-Comp B/Al</td>
<td>1.83</td>
<td>155</td>
</tr>
</tbody>
</table>

These results show that Al lowers the deton val of TNT and of 60/40 RDX/TNT even more than does NaCl which acts as a heat absorbing or endothermic material. Therefore, Al must have a strong endothermic effect at the C-J plane. This would be the result if Al (gas) was to form in appreciable amount in the detonation wave. But if Al_2O_3 (crys) was the sole Al product, the det vel of the TNT/Al and RDX/TNT/Al mixts would be appreciably higher than the corresponding expls without Al due to the high heat of formation of Al_2O_3(crys). The only comps of Al which might form in deton besides the oxides are AlN and AlH. Al_4C_3 exists only in the solid state, decompg on vaporization. Cook showed that none of these can be important as deton products and the significant products are therefore considered to be only Al_2O_3(gas), Al_2O(gas) and AlO (gas).

Besides the Al-contg expls described in this section, there are many other expls which are described individually, such as: Alumatol, Ammonal, Anagon, APX-44, ASN, Baronal, Berclavit B, Bonit, Borortrepr, Burrowite, DBX, Dentex; German Fillers Nos 15, 19, 105, 109, 110 & 13-113; HBX, Hexa, Hexamite; Japanese Explosives Types 1, 2, 88 & 92; Minex, Minol, Minol 2, Nitramite, Nitrobaronit, Nobel's 704, Novit Pentonal, Soveronite, Sofranex A, Torpex-2, Torpex D-1, Trialen or Trialine 105, Tritonal and UWE.

Some Al can be added with some advantage to practically every explosive compn provided the Al does not react with any of the compounds. This is the case with Comp A, Comp B, Ednatol, PETN, RDX, TNT, etc. *Refs:* 1)G.Roth, GerP 172,327 (1900) 2) L.Lheure, MP 12,125(1903-4) 3)W.Venier, BritP 6,705(1906) & CA 1,929-30(1907) 4) R.Förger, "Das Ammonal," Wien(1917)(200 pp) 5)Kast (1921),378-86 6)Ch.Baron, CR 208, 10-12(1939) & CA 33, 4423(1939) 7)H.Holmes, USP 2,168,030(1939) & CA 33, 9648(1939) 8)M.Tonegutti, Suppl Technico della Rivista d'Artiglieria & Genio 1941, 108-17 9)OrdSergeant Aug 1943, 16 & 18 10)F.Schwarzer, SwissP 228,654(1943) & CA 38, 4445(1944) 11)H.Muraour, Protar 9, 62-3(1943) 12)A.Stettbacher, Protar 9, 33-45, 212-18, 233-42(1943) & CA 38, 4445 (1944) 13)Davis(1945), 25 14)A.Pérez
A151


Aluminum Containing Explosives; Trauzl Test Values. According to Davis (Ref 1), the standard Trauzl test does not give reliable results with expls contg Al or other materials which produce high temperatures on detonation. This is because the hot gases of reaction erode the lead inside the Trauzl block (cylinder), thus increasing its volume in addn to the increase produced by expansion of the gases. Médard (Ref 2) claimed that more reliable results are obtained when the French modification of the test is used. The result thus obtained is called the "coefficient of utilizatpratique," abbreviated to CUP or cup. The test is described in Ref 2 Refs: 1) Davis (1943), 2) L. Médard, MP 33, 344-51 (1951)

Aluminum Containing Flares. See Aluminum Flares

Aluminum Containing Rocket Propellants. See Aluminum Dust in Rocket Propellants

Aluminum Cordeau, according to Davis (1943) p 11, is a detonating fuse consisting of Al tubing filled with PA

Aluminum Dust and Its Explosions. Dusts of Al and of some of its alloys (such as Al/Mg) are hazardous materials to handle because they are inflammable and may cause explns or fires. Particularly dangerous are mixts of dusts with gases contg oxygen such as air. Mason and Taylor (Ref 1) reported that the low expl limit for Al dust in dry air is ca 40 mg Al per l air and if the SiO2 content in air was twice the concn of Al dust, no expln took place. Berger (Ref 3) discussed the danger of expln of fire during grinding of the light metals Al or Mg. Brown (Ref 4) discussed dust expln hazards in plants producing or handling Al, Mg or Zn powders. Sata & Harisaki (Ref 5) studied
the ignition and expln of Al dust in air in various proportions and at different pressures. Fieldner & Rice (Ref 6) reported that tests of explosibility of various dusts, of comparable fineness, showed that Al, pure Fe, Mg, Dow metal, Ti and Zr are more expl than other metals or coal dust. Hartmann & Greenwald (Ref 7) discussed the explosibility of various metallic dusts. Hartmann & Nagy (Ref 8) discussed the effect of relief vents on reduction of pressure developed by dust explns of Al, Mg, etc. Goto & Suito (Ref 9) claimed that the expln or inflammation of Al powder is a chain reaction in which radiation participates to some extent. The designation "radiation chain" was suggested. Schlipfer (Ref 10) studied Al dust-air explns by the method of producing a steady dust flow. Anon (Ref 12) discussed the hazardous nature of Al and other metallic dusts.

According to Hart & Tomlinson (Ref 11), while the explosibility of metal powders depends upon many factors, such as ignition, temperature, particle size, particle size distribution, shape, moisture content, energy required for ignition, etc, the metals may be arranged in decreasing order of explosibility of their dusts as follows: a) Zr & Ti (usually shipped under w or alc) b) Mg (less than 200 mesh) c) Mg/Al alloy (less than 200 mesh) d) Al (less than 6 microns) and e) Si Powdered Mg, Al and alloys of these are discussed in Ref 13

Toxicology, fire & explosion hazards of Al dust are discussed in Ref 13


**Aluminum Dust in Rocket Propellants.** The possibility of using Al dust as a fuel ingredient of rocket propellants was investigated by Stettbacher. The dust was mixed with liq hydrocarbons such as benz, mineral oil, etc, and liq oxygen was added as an oxidizer. Other combustible metal dusts, such as Mg and Be, could be incorporated with Al. Heats of combustion of some of these mixtures were given.

*Ref:* A. Stettbacher, Explosivst 1956, 27

**Aluminum Flares** are military devices contg pyrotechnic compns which are mixts of finely powdered substances compressed into candles. The most important ingredients in a pyrotechnic compn are the fuel and the oxidizing agent. To these are usually added other materials to intensify the color of the light produced, decrease the burning rate, act as a binder and waterproof the compn.

Powdered Mg, Al and alloys of these are the fuels generally used. The oxidizing agent selected is determined by the color, intensity of light and burning rate desired. The nitrates of Ba, Sr, Na and K, the perchlorates of Amm and K, and the peroxides of Ba, Sr and Pb are among the most important oxidizing agents used. Effective color intensifiers are organic chlorine compounds such as hexachlorobenzene, polyvinyl chloride and chlorinated waxes. Polyvinyl chloride, ethyl cellulose, metallic resinates, oils, waxes and asphaltum have been used as binding agents.

Flares are used for illuminating purposes in: a) projectiles to illuminate enemy
territory b) trip flares to prevent enemy infiltrations c) airport flares to provide illumination for landing d) parachute flares for observation and bombing operations e) reconnaissance f) bombardment flares for high-altitude bombing and g) tow-target flares for target practice for antiaircraft gun crews.

Some typical Al flare compositions and their characteristics follow:

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Trip Flare</th>
<th>Airport Flare</th>
<th>Reconnaissance and Landing Flare</th>
<th>Bombardment Flare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al, powder</td>
<td>21.5</td>
<td>-</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>Al, Grade A</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Al, Grade B</td>
<td>-</td>
<td>20.0</td>
<td>26.0</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Barium nitrate</td>
<td>69.5</td>
<td>62.0</td>
<td>66.0</td>
<td>34</td>
</tr>
<tr>
<td>Strontium nitrate</td>
<td>-</td>
<td>11.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sodium oxalate</td>
<td>5.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur</td>
<td>4.0</td>
<td>3.5</td>
<td>6.25</td>
<td>-</td>
</tr>
<tr>
<td>Linseed oil</td>
<td>-</td>
<td>1.5</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Castor oil</td>
<td>-</td>
<td>-</td>
<td>1.75</td>
<td>1</td>
</tr>
</tbody>
</table>

Characteristics

- Candlepower: 50,000 (Trip Flare), 60,000 (Airport Flare), 75,000 (Reconnaissance and Landing Flare), 800,000 (Bombardment Flare)
- Candlepower, per in²: 22,000 (Trip Flare), 50,000 (Airport Flare), 32,000 (Reconnaissance and Landing Flare), 71,000 (Bombardment Flare)
- Burning rate, in/min: 2.7 (Trip Flare), 5.0 (Airport Flare), 3.7 (Reconnaissance and Landing Flare), 6.1 (Bombardment Flare)
- Explosion temp, °C: 600 (Trip Flare), 600+ (Airport Flare), - (Reconnaissance and Landing Flare), 490 (Bombardment Flare)


Aluminum Hydride. A series of aluminum hydrides, analogous to borohydrides, were described in Ref 1. They include the soluble polymer (AlH₃)ₓ as well as its insoluble polymer.

Occasionally explns have been reported during evapn of ethereal solns of AlH₃ or related compds used as reducing agents in organic reactions. On one occasion, a violent expln occurred when the residue obtained on evapn of a dimethylcellulosolve soln of AlH₃ contaminated with AlCl₃, was warmed, but no explns took place when AlH₃ free of AlCl₃ was used (Ref 2).

Refs: See top of the right column.
In Institute of Temple University they had a mix of aluminum chloride and lithium hydride in that for a number of years at the Researchuminohydride, explosions appeared: a) A.V. Grosse stated Aluminum-Lithium Hydride or Lithium lowing letters (Ref 5) dealing with Al-oxygen (Feb 1959) (15 refs) by Cady (Ref 1). After this accident the following letters (Ref 5) dealing with Al-oxygen explosions appeared: a) A.V. Grosse stated that for a number of years at the Research Institute of Temple University they hadexploded mixtures of Al powder with oxygen and air and had also detonated Al powder mixed with liq oxygen (Ref 3). They found that Al powder mixed with a stoichiometric amount of liq oxygen to form Al₂O₃ is a very powerful expl, giving 3.85 times the amount of energy of an equal wt of TNT b) A.T. Ba stated that he too had a classroom expl of a mixt of liquid oxygen and Al when conducting the experiment according to Cady's description. However, Bawden had also performed the experiment about 100 times, obtaining a flash each time rather than an explo.

In 1936 David Bruce, a student at the College of the Pacific, did his master's thesis on the study of powdered Al-liq O₂ reactions. He learned that such a mix would always expl rather than flare up if there were enough O₂ to oxidize 83 to 90% of the Al, when ignited with a burning taper. He also learned that such a mixt could be exploded by an electric spark from a Ford A continuous spark would not ignite the mixt until it reached expl proportions by ev of the liq oxygen. Then an expln rather than a flare was always obtained. This expln noteworthy because a small amount of the mixt produced a powerful shock wave. The above results were not published because it was found that similar experiments had been previously described (Ref 2)

Austin et al (Ref 6) discussed the expl hazard of Al-liq O₂ mixts in detail


Aluminum-Lithium Hydride or Lithium Aluminohydride, AlLiH₄, wh solid prep'd frc aluminum chloride and lithium hydride in

<table>
<thead>
<tr>
<th>Substance, Composition or Device</th>
<th>Illuminating Power Relative (P₁)</th>
<th>Absolute (P₂) (Lumens x 10⁻⁶) seconds/gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg 56, NaNO₃ 39 &amp; binder 5%</td>
<td>0.62 - 1.01</td>
<td>180 - 293</td>
</tr>
<tr>
<td>Al 49.3 &amp; NaNO₃ 50.7%</td>
<td>0.40 - 0.84</td>
<td>116 - 244</td>
</tr>
<tr>
<td>Al 39.4, NaNO₃ 40.6 &amp; MgO 20%</td>
<td>0.87</td>
<td>252</td>
</tr>
<tr>
<td>Al 39.4, NaNO₃ 40.6 &amp; Al₂O₃ 20%</td>
<td>0.74</td>
<td>214</td>
</tr>
<tr>
<td>Al 39.4, NaNO₃ 40.6 &amp; NaCl 20%</td>
<td>0.44</td>
<td>128</td>
</tr>
<tr>
<td>Mg 58 &amp; KClO₄ 42%</td>
<td>0.43</td>
<td>125</td>
</tr>
<tr>
<td>Al 49 &amp; KClO₄ 51%</td>
<td>0.30</td>
<td>87</td>
</tr>
<tr>
<td>Mg 29.2 &amp; NH₄ClO₄ 70.8%</td>
<td>0.27</td>
<td>78.5</td>
</tr>
<tr>
<td>Al 27.7 &amp; NH₄ClO₄ 73.3%</td>
<td>0.27</td>
<td>78.5</td>
</tr>
<tr>
<td>Al 43.3 &amp; NH₄ClO₄ 56.1%</td>
<td>0.45</td>
<td>130</td>
</tr>
<tr>
<td>Mg 52.7 &amp; NaClO₄ 47.3%</td>
<td>1.23</td>
<td>357</td>
</tr>
<tr>
<td>Mg 78.2 &amp; NaClO₄ 21.8%</td>
<td>1.67</td>
<td>485</td>
</tr>
<tr>
<td>Al 33.7 &amp; NaClO₄ 66.3%</td>
<td>0.35</td>
<td>106</td>
</tr>
<tr>
<td>Al 51.2 &amp; NaClO₄ 48.8%</td>
<td>0.83</td>
<td>241</td>
</tr>
<tr>
<td>Mg 37.3 &amp; KClO₄ 62.7%</td>
<td>0.25</td>
<td>72.5</td>
</tr>
<tr>
<td>Al 30.6 &amp; KClO₄ 69.4</td>
<td>0.23</td>
<td>67</td>
</tr>
<tr>
<td>Mg 49.1 &amp; Pb(NO₃)₂ 50.9%</td>
<td>0.31</td>
<td>90</td>
</tr>
<tr>
<td>Al 30.8 &amp; Pb(NO₃)₂ 69.2%</td>
<td>0.26</td>
<td>75.5</td>
</tr>
<tr>
<td>Zn 65.3 &amp; KClO₄ 34.7%</td>
<td>0.013</td>
<td>3.8</td>
</tr>
<tr>
<td>Cu 57.5 &amp; NH₄ClO₄ 42.5%</td>
<td>0.0000091</td>
<td>0.026</td>
</tr>
<tr>
<td>Si 20.7 &amp; KClO₄ 79.3%</td>
<td>0.013</td>
<td>3.8</td>
</tr>
<tr>
<td>NC alone</td>
<td>0.0034</td>
<td>0.99</td>
</tr>
<tr>
<td>NC 60 &amp; KClO₄ 40%</td>
<td>0.044</td>
<td>13</td>
</tr>
<tr>
<td>TNN 31.7 &amp; KClO₄ 68.3%</td>
<td>0.047</td>
<td>14</td>
</tr>
<tr>
<td>Resin 13.7 &amp; NaClO₄ 86.3%</td>
<td>0.088</td>
<td>25.5</td>
</tr>
<tr>
<td>Woodmeal 27.6 &amp; NeClO₄ 72.4%</td>
<td>0.044</td>
<td>13</td>
</tr>
</tbody>
</table>

Ref: P. Tavernier, MP 31, 309-426 (1949), especially tables on pp 368-382

Aluminum-Liquid Oxygen and Liquid Air Explosives. An expln of a mixt Al powder and liq oxygen, injuring 17 persons, occurred during a lecture demonstrating the ignition of such a mixt (Ref 4). The procedure used in the demonstration was one previously described by Cady (Ref 1). After this accident the following letters (Ref 5) dealing with Al-oxygen explosions appeared: a) A.V. Grosse stated that for a number of years at the Research Institute of Temple University they had expl
ethereal soln: $\text{AlCl}_3 + 4\text{LiH} = \text{LiAlH}_4 + 3\text{LiCl}$ (Ref 1). The compd is a powerful reducing agent, converting $\text{SiCl}_4$ into silane, etc (Ref 3). Although $\text{AlLiH}_4$ is considerably more stable than aluminum hydride ($\text{AlH}_3$), expls similar to the ones described under aluminum hydride may take place (Ref 2).


Aluminum (or Magnesium)-Methanol (or Water) Explosives. According to Shidlovskii (Ref 1), mixts of $\text{Al}$ and $\text{H}_2\text{O} (2:3)$ or $\text{Mg}$ and $\text{H}_2\text{O} (1:1)$ are capable of combustion when subjected to intense heat. The Mg mixture can be detonated with a primer while the Al mixt cannot. The same investigator claimed (Ref 2) that on the basis of theoretical calcns of heat evoln, mixts of $\text{Mg}$ or $\text{Al}$ with $\text{H}_2\text{O}$ or alcs are potentially more powerful expls that the usual military materials, with $\text{Mg}$-$\text{MeOH}$ giving the max gas evoln. The tests were conducted in bombs or lead enclosures with tetryl detonators to set off the mixts of powdered metal and the liquid. All mixts tested were found to be powerful expls with $\text{Mg}$-$\text{H}_2\text{O}$ being most sensitive to shock, while $\text{Al}$-$\text{H}_2\text{O}$ and $\text{Mg}$-$\text{MeOH}$ were less sensitive and required a booster.

According to an investigation by Médard (Ref 3), mixts of $\text{Mg} + \text{H}_2\text{O}$, $\text{Mg} + \text{MeOH}$ or $2\text{Al} + 3\text{H}_2\text{O}$ are comparable in their power to guncotton but they are not able to propagate the deton unless a small quantity of a sensitizer (such as 7% of PETN) is incorporated. For instance, the mixt contg $\text{Al}$ (powder) 30, $\text{H}_2\text{O}$ 30, and PETN 40% has a vel of deton of 5140 m/sec at d 1.55, coefficient d'utilisation pratique (CUP)(French Trauzl test value) 119 (PA 100), and may be detonated by a Briska primer. It is practically insensitive to shock but its exudation, as detd by the method of Burlot, [MAF 14, 303 (1935)], and its stability make it unsatisfactory for use as a military explosive.

Refs: 1) A. A. Shidlovskii, Dokl Akad N 51, 131-3 (1946) & CA 40, 6817 (1946) 2) A. A. Shidlovskii, Zh Prikl Khim 19, 371 (1946) & CA 41, 110% (1947) 3) L. Médard, MP 33, 491-503 (1951) 4) A. G. Streng & D. Kirshenbaum, USP 2, 836,484 (1958) (Aqueous metal powder expls similar to the ones described under explosives; eg $\text{Al}$ 42, AN 30 & $\text{H}_2\text{O}$ 28%)

Aluminum Methyl. Same as Trimethyl Aluminum

Aluminum Nitride. See under Nitrides

Aluminum Ophorite. Under this unusual name, an expl mixt was patented and claimed to be suitable for military purposes. It consisted of Al foil finely ground in oil (which was not in excess of 2% of the mixt) and mixed with pulverized alkali and metal perchlorates.

Ref: D. B. Bradner, USP 1,775,063 (1930) & CA 24, 5161 (1930)

Aluminum Oxide-Silicon Carbide Fiber, developed by the Carborundum Co at Niagara Falls, NY, will withstand temps of 2300°F. The fiber is suitable for insulation of gas-turbines and jet-engine exhaust systems, and its mixt with asbestos will resist fire and reduce heat loss through radiation.

Ref: Anon, Common Defence Bulletin, No. 143, Washington, DC (Sept 1952)

Aluminum Perchlorate. See under Perchlorates

Aluminum Picrate. See under Picrates

Aluminum Plate Test for Detonators is briefly described under Plate Tests and also in Davis (1943), 26

Aluminum Soap Gels are briefly described in Science in World War II, Chemistry, edited by W. A. Noyes, Jr, Little, Brown & Co, Boston (1948), 411-12: "Properties of Aluminum Soap Gels as Thickening Agents".

Aluminum Soaps of Mixed Isooctoic Acids when mixed with hydrocarbon fuels produce jellied gasoline suitable for use in flame throwers and incendiary bombs.

Ref: I. Cohen, USP 2,741,629 (1956) & CA 50, 11693 (1956)

Aluminum Stearate. See under Stearates

Aluminum Stearate Gels. See under Stearates

Aluminum Triethyl. Same as Triethyl Aluminum

Aluminum Tripropyl. Same as Tripropyl Aluminum
**ALUMS**

*Alum* is the generic name given to an important group of double sulfates of the general formula $M'_3(SO_4)_2\cdot M'_2(SO_4)_3\cdot 24H_2O$, which is sometimes written as $M'_3M'_2(SO_4)_{12}\cdot 12H_2O$, where $M'$ is a monovalent metal or group such as Na, K, Li, Rb, Cs, Tl, NH$_4$, Ag etc and $M''$ is a trivalent metal such as Al, Cr, Fe, Mn, In, Co etc (Ref 3). Alums are prepd by mixing aqueous solutions of the corresponding salts and crystallizing out the alum. Alums are all soluble in water and crystallize with 24 moles of water in crystals belonging to the regular systems, usually octahedral or cubic. Some alums, because of their high water of crystallization, have been used in commercial expls as cooling agents. Those alums which have been used for this purpose are described below.

For more information on alums see Refs 1, 2, 3, 4, & 5


**Ammonium-Aluminum Alum, (NH$_4$)$_2$SO$_4\cdot$Al$_2$(SO$_4$)$_3\cdot 24H_2O$, mw 906.64, mp 92.5$^\circ$, d 1.64 at 20$^\circ$/40$^\circ$, nd 1.4591. Col octagonal crystals losing 24 H$_2$O at 200$^\circ$. The solv of the hydrate in w is given by Locke (Ref 1). Ammonium alum is used in medicine, as a mordant in dyeing, in water purification, in paper sizing and in the dressing of skins (Ref 5) and can be used in expls as a cooling agent. For more information see Refs 2, 3, 4 & 6


**Ammonium Chrome Alum** (Alum Ammonium Chrome), (NH$_4$)$_2$SO$_4\cdot$Cr$_2$(SO$_4$)$_3\cdot 24H_2O$, mw 956.72, mp dec 100$^\circ$, d 1.72; gm or violet crystals. Can be prepd by treating an aqueous soln of (NH$_4$)$_2$CrO$_4$ with H$_2$SO$_4$ and a stream of SO$_3$ (Refs 1 & 3). Sol in w, sl sol in alc. It has been used in some expls (eg, Chromeammonite Reinforced) (qv), as an oxidizer, and as a cooling agent. On expln it also evolves fairly large amts of gases, N$_2$, H$_2$O and SO$_2$.


**Potassium-Aluminum Alum** (Kalinite), K$_2$SO$_4\cdot$Al$_2$(SO$_4$)$_3\cdot 24H_2O$, mw 948.75, mp 92$^\circ$, loses 18H$_2$O at 64.5$^\circ$, d 1.76 at 26$^\circ$/4$^\circ$. Col monoclin crystals, sol in w. Its anhydrous salt, KAl(SO$_4$)$_2$, mw 258.19, d 2.75 at 20$^\circ$, when heated with carbon produces "Homberg's Pyrophorus," a flammable compd contg K sulfide (Ref 3). It has also been used in expls, such as Clark's Powder (qv)

**Refs:** 1) Mellor 5 (1924), 343 2) Thorpe 1 (1947), 294 3) Kirk & Othmer 1 (1947), 655 4) Cond Chem Dict (1956), 52

**Potassium-Chrome Alum** (Chrome Alum), K$_2$SO$_4\cdot$Cr$_2$(SO$_4$)$_3\cdot 24H_2O$, mw 998.86, mp 89$^\circ$, d 1.813. Viol crystals turning gm on melting; in soln the change occurs at ca 78$^\circ$ (Ref 1). The satd soln at 18$^\circ$ contains 28.2% K$_2$SO$_4$, Cr$_2$(SO$_4$)$_3\cdot 24H_2O$ of which 51.8% exists as a violet salt (Ref 2). Chrome alum is used in paper making, photography, dyeing, printing and tanning. It has also been used in an expl called Chromeammonite (qv)

**Refs:** 1) Mellor 11 (1931), 454 2) Thorpe 3 (1946), 100 3) Cond Chem Dict (1956), 279

**Potassium-Iron Alum** (Ferric Potassium Sulfate or Iron Alum), K$_2$SO$_4\cdot$Fe$_2$(SO$_4$)$_3\cdot 24H_2O$, mw 1006.5, mp 33$^\circ$, d 1.806. Prepd by mixing equimolecular amts of ferric and K sulfate and concg the soln spontaneously. It forms fine violet octahedra crystals, liable to decompose to a brown deliquescent mass. Iron alum is sol in w, insol in alc.

This
A157

alum is used in dyeing and in calico printing and probably can be used as a cooling agent in expls. If caustic potash is added to a soln of the alum and the brown liquid allowed to evaporate, yel-brn crysts of $5K_2SO_4 \cdot 2Fe_2(SO_4)_3 \cdot 16H_2O$ separate. These crysts have the peculiar optical props of toumalone (Ref 1)


Sodium-Aluminum Alum (Soda Mum),

**Amalgam** is a liquid, semiliquid or solid alloy of mercury with Na, Ag, Ca, Li, NH$_4$, Au, etc. The most important amalgam is that of Na and it will be a liquid when the amt of Na is less than $1.25\%$, or a solid when the amt of Na is higher. It can be prepd by gradually adding small pieces of Na to Hg under kerosene or mineral oil while avoiding a rise in temp, (Refs 3 & 4). A good description of amalgams is given in Thorpe's (Ref 2). Na amalgam is easier to handle than Na metal; it is used as a reducing agent.

Other uses of amalgams are given in Ref 2.

Dowling (Ref 1) pointed out the danger of expln in amalgam barrels (Note: The type of amalgam is not indicated in Ref 1)

Refs: 1)W.R.Dowling, CA 5, 2240(1911) 2)Thorpe 1(1937), 298-300 3)InorgSynth 1(1939),5-18 4)Kirk & Othmer 1(1947),447

**Amosite.** An expl patented in the early 1900's by the Société Anonyme des Explosifs Favier, Vilvorde, Belgium and permitted for use in England: $NH_4ClO_4$ 32 to 36, $NaNO_3$ 29 to 33, NB 30 to 36 & agar-agar 0.15 to 0.5%

Ref: Escales, Chloratspr(1910),163

**Amatex.** According to Ref 1 there are several composns known under this name, such as Amatex 5, which consists of AN 25, TNT 50 & RDX 25%. More important is Amatex 9: AN 50, TNT 41 & RDX 9%, which was used by the Brit during WWII in large GP, MC, HC & A/S bombs. It was prepd by mixing 60/40 amatol with 15% Comp B. The latter was added to eliminate the tendency of large amatol-filled bombs toward low order detonation. The sensitivity and brisance of Amatex 9 was slightly higher than that of amatol 60/40

According to Jiménez(Ref 2), Amatex is an amatol sensitized by a small amt of HNDPhA

Refs: 1)All & EnExpls(i946), 133 2)J.M. Jiménez, "Explosivos," Ediciones Ejército, Madrid(1951), 28
AMATOL

"Military Nitrato of Ammonia"

[Called Amatol or Füllpulver(Fp) No 13 & No 13a in Germany; Amatol in GrBrit, Fr & Rus; Amatolo in Spain; Amatola in Italy and Shotoyaku in Japan](Fr abbreviation NT)

Amatols are expl mixts of AN with TNT in various propns. They were invented in 1915(Refs 4 & 6) by the Brit in order to extend the available supply of TNT which was very scarce at that time. Two mixts were used by the British: an 80/20 amatol (a plastic mass resembling wet brown sugar) and a 50/50 amatol (a cast mass resembling cast TNT). The 1st figure refers to AN, the 2nd to TNT. (The Germans who also adopted amatols had the 1st figure referring to TNT and the 2nd to AN.) The US Govt, shortly after its entrance into WWI authorized the use of above amatols for loading HE shells. The first mixt was loaded, while hot, either by extrusion or pressing, whereas the second mixt could be cast-loaded, which was an advantage. Amatols were cheaper than TNT and, on explosion, produced greater volumes of gas per unit weight. The addition of AN, rich in oxygen, results in more complete combustion of the TNT. For this reason the smoke produced by the deton of amatol is of a light yellowish-white color in contrast to the heavy black smoke produced by straight TNT. All amatols have lower velocities of deton and brisance than TNT, but are more powerful as judged by Ballistic Mortar and Trauzl tests. The impact sensitivity of amatols is comparable to that of TNT, but with increasing proportions of AN amatols become more difficult to deton. All amatols are hygroscopic and in the presence of moisture attack metals such as copper, brass, bronze and lead(Ref 14)

Explosive Properties. Some explosive properties of the more important amatols are given in the table shown on the following page

Hackel(Ref 5) reported that with a 2kg hammer there was no difference in impact sensitivity between amatol and straight TNT (value about 60cm) but with larger weights amatol proved to be more sensitive. For one explosion in ten trials using a 5kg wt, Hackel obtained the following results in cm: TNT 40–42, 10/90 AN/TNT 27, 40/60 21, 50/50 19, 60/40 15, 70/30 18, 80/20 24–26 & 90/10 39

Smith(Ref 7) claimed that the explosive action of amatol is increased by incorporating into it (by absorption) a highly inflammable liquid such as benzene or gasoline. A method for increasing the density of a charge of amatol in which the percentage of the TNT is less than that required to make the amatol flow at a temp within 10–20° above the mp of TNT has been reported by Snelling(Ref 8)

Systematic measurements of the influence of boundary conditions on the detonation velocity of 60/40 amatol charges of finite radii have been made by Copp & Ubbelohde (Ref 15). Various physico-chemical conditions which control the thermal decomposition and the rate of energy release were investigated by the method of Dautriche. A summary of mean deton velS (D) for cast 60/40 amatol confined in cylindrical tubes of steel, lead and cardboard (which approximates an unconfined chge) is given in their paper. Results of their work have shown that the grist size of AN and the boundary conditions, have a marked influence on the value of D(mean vel of deton at a given chge radius), but not on the value of Do(vel of deton at infinite chge radius)

Preparation of Amatols

80/20 Amatol. AN(US Spec JAN-A-175), previously ground by running through a crusher, dried to contain not more than 0.25% moisture and screened to remove foreign materials and to obtain required size(see Note), was heated to 90–95° in a mixing kettle, provided with a steam jacket and mechanical agitation. To this was added gradually, with constant agitation, the calcd amt of molten TNT at ca 95° and the mixt thoroughly blended by continuing the agitn for at least 15 mins, while maintaining the temp at 95°. At the end of this period the hot amatol was transferred to the loading apparatus(Refs 6 & 10)
### Explosive Properties of Amatols
*(Taken mostly from Ref 19)*

<table>
<thead>
<tr>
<th>Composition &amp; Properties</th>
<th>80/20</th>
<th>60/40</th>
<th>50/50</th>
<th>45/55</th>
<th>40/60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition: AN</td>
<td>80</td>
<td>60</td>
<td>50</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>TNT</td>
<td>20</td>
<td>40</td>
<td>50</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>Nitrogen Content</td>
<td>31.7%</td>
<td>28.4%</td>
<td>26.8%</td>
<td>25.9%</td>
<td>25.1%</td>
</tr>
<tr>
<td>Oxygen Balance to CO₂</td>
<td>+1.20%</td>
<td>-17.6%</td>
<td>-27.0%</td>
<td>-31.7%</td>
<td>-36.4%</td>
</tr>
<tr>
<td>Oxygen Balance to CO</td>
<td>+11.06%</td>
<td>+2.13%</td>
<td>-2.32%</td>
<td>-4.55%</td>
<td>-6.78%</td>
</tr>
<tr>
<td>Color</td>
<td>Lt buff</td>
<td>Lt buff</td>
<td>Buff</td>
<td>Buff</td>
<td>Buff</td>
</tr>
<tr>
<td>Melting Point, °C</td>
<td>-</td>
<td>-</td>
<td>81</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density, g/cc</td>
<td>1.46</td>
<td>1.61</td>
<td>1.59</td>
<td>-</td>
<td>1.54</td>
</tr>
<tr>
<td>Detonation Velocity, m/sec</td>
<td>5080*</td>
<td>5500*</td>
<td>5600*</td>
<td>6470</td>
<td>6500</td>
</tr>
<tr>
<td>Detonation Velocity, ft/sec</td>
<td>-</td>
<td>-</td>
<td>19,680</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brisance by Sand Test, assuming 100% for TNT</td>
<td>75</td>
<td>85</td>
<td>86–90</td>
<td>-</td>
<td>95</td>
</tr>
<tr>
<td>Explosion Temperature, °C</td>
<td>280–300</td>
<td>270</td>
<td>254–265</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Heat of Explosion, cal/g at Cᵥ</td>
<td>1004</td>
<td>-</td>
<td>950</td>
<td>-</td>
<td>920</td>
</tr>
<tr>
<td>Heat Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact Sensitivity Test, 2kg wt, assuming 100cm fall for TNT</td>
<td>90–95</td>
<td>95–100</td>
<td>93–100</td>
<td>-</td>
<td>93–100</td>
</tr>
<tr>
<td>Pendulum Friction Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power (by Ballistic Mortar Test or by Trauzl Test), assuming 100% for TNT</td>
<td>130</td>
<td>128</td>
<td>120–125</td>
<td>-</td>
<td>120</td>
</tr>
<tr>
<td>Power by Trauzl Test, assuming 100% for PA</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>112</td>
<td>-</td>
</tr>
<tr>
<td>Rifle Bullet Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy of Air Blast</td>
<td>-</td>
<td>-</td>
<td>84</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Energy of Shock in Water</td>
<td>-</td>
<td>-</td>
<td>94</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shaped Charge Efficiency</td>
<td>-</td>
<td>-</td>
<td>54</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*According Ref 15, vel of deton of 60/40 amatol charged at 1.50 in a steel tube 17 mm diam is 6060 m/sec when prepd with a finely ground AN, vs 5860 m/sec when using a coarse AN. Evans (Ref 156) gives for 60/40 amatol 5600 m/sec at d 1.6, for 50/50 amatol 5850 at d 1.6 and for 80/20 amatol 5200 at d 1.6
Note: In order to obtain a mixt sufficiently plastic to consolidate well on loading without separation (leaking) of molten TNT, it is necessary to use AN of proper granulation. American practice was to use AN, which met the following requirements:

Through a No. 10 US Std Sieve—n not less than 99%, through a No. 10 & on No. 35—32 to 48% and through a No. 100—15 to 30%.

50/50, 60/40 and 40/60 Amatols. AN (US Spec JAN-A-175), previously ground, dried (to contain not more than 0.25% moisture) and screened to remove foreign materials, was heated to 90–95° and gradually added to calc'd amount of molten TNT in a kettle, provided with a steam jacket and mech agitn. The rate of addn was such that no segregation or lumping of AN took place. Agitn was continued at 90–95°, until thorough blending and uniform fluidity were achieved. Then the mixt was cooled to ca 85° and ready for cast loading (Refs 6 & 10).

Notes: Mitra & Ram (Ref 14) conducted studies on the optimum conditions for crystn, drying and caking of AN and detd the effects on amatol fluidity. Some of their concns were as follows: a) the cryt form of AN is of little importance but spherically shaped cryts make satisfactory amatols b) cryt of AN at a temp of 160°, followed by drying at 100 gives a product suitable for pouring 65/35 amatol c) it is of importance to keep the moist content of AN below 0.15% before mixing with TNT. Médard & Le Roux (Ref 15a) reported that in prep of various AN expls (including the amatols) the best vel of deton, sensitivity to ignition and coeff of self-excitation are obtained when a heavy wheel (5 tons) is used for pulverizing AN.

Shell-loading with 80/20 Amatol. Part of the mixt maintained in the kettle at 90–95° (See above under Preparation) was transferred to the hopper of an extruder which was provided with a stirrer and jacket heated with steam at 3–5 lbs pressure. The extruding machine consisted of a steel tube in which a worm screw rotated slowly. This machine was counterweighted so that the amatol was forced into the shell under a definite limited pressure. The shell, previously cleaned inside and uniformly coated with a special varnish, was placed at the mouth of the extruder and filled to within inches of the top. After removing the shell a cavity for a "booster surround" was formed by driving or pressing a hardwood plug into the nose of the shell. After removing the cavity was filled with molten TNT. After this has solidified, a booster cavity was drilled as described under TNT. Extrusion was carried out automatically and no one was allowed in the building while the shell was filling. No tools containing copper materials used, which means that brass or bronze equipment, as customarily used in the loading straight TNT, was excluded. After filling the first shell, the density of the amatol charge was determined as prescribed by US Army Spec 50–15–3A. It should not be below 1.38. Note: The density was detd by weighing the empty shell before loading (\(W_e\)), weighing it filled with water (\(W_w\)), (making allowance for the surround cavity), thoroughly filling the shell and reweighing it after loading by extrusion with TNT (\(W_t\)). This gives:

\[ \text{Density (of amatol)} = \frac{W_t - W_e}{W_w - W_e} \]

If \(d\) is below 1.38, the pressure in the truder is increased until the desired \(d\) is attained (Refs 6 & 10 and US Army Spec 50–15–3A).

Note: H. Graham et al (Ref 13) described a procedure for filling shell with 80/20 amatol which produced \(d\)'s up to 1.47. In this pr. the amatol was first flaked by passing it through milling rolls heated to about 100° with space between the rolls about 0.019 and then cooled to RT. The empty shell (bomb), nose down, was stemmed with an hammer for 15 to 20 mins while the amatol flakes were added in 20 increments. This method of filling, it was claimed, would to the advantage of uniform distribution which was never obtained by other method of filling.
Shell-Loading with 50/50 Amatol. A part of molten amatol was brought to a temp ca 85° and poured into the shell through a tightly fitted funnel, called a riser, so that the level of the charge before solidification came within approximately 1" below the bottom of the booster casing. After allowing the charge to solidify, with occasional breaking of the crust until the central portion of the pour was still slightly mushy, a second pour was made to the desired height. Immediately after the second pour a rod was inserted through the second pour until it came into contact with the first pour. When the charge had cooled, the rod was removed with a twisting action and the cavity was filled with molten TNT.

The same precautions had to be observed as was mentioned under “Loading with 80/20 Amatol”. The density of loaded 50/50 amatol had to be >1.50 and it was determined as described under 80/20 amatol or in US Army Spec 50-15-15C (Refs 6 & 10). Note: This method of loading is applicable to any castable amatol, such as 60/40 and 40/60.

Recovery of TNT from Scrap Amatol. During WWI, a method was developed and used for the recovery of TNT from amatol scrap. The recovered TNT, however, was often discolored and of doubtful quality due to the low grade TNT and AN used in making amatol. During WWII, the TNT specified for amatol was of higher quality and since the AN was made from synthetic ammonia, it did not contain impurities which reacted with TNT to affect its color or purity. Therefore, the process formerly used which involved the extraction of the AN with hot water, filtering and grainning the molten TNT, yielded a Grade I TNT from scrap 50/50 amatol complying with the minimum requirements of the US Army (Ref 9).

Stability of Amatols. According to Ref 17a, p 183, the vacuum stability of 50/50 amatol is a little less than that of TNT at temps of 100 and 120°, there evidently being very s l reaction betw TNT and AN at those temps. At temps below the mp of TNT (ca 80°), there is no evidence of reaction. After storage at 50° for 3 months, there is no change in the sensitivity brisance or stability.

Inasmuch as some amatols prep'd in France showed instability, an investigation on stability of various mixts of AN and TNT was conducted after WWII at the Laboratoire Centrale des Poudres, Paris (Ref 16). The results showed that mixts of military grade TNT and pure AN decomposed with the evolution of ammonia. This attacked the TNT to form various unstable colored compds, some of them containing as much as 21.5% N, compared to 18.45% for TNT. One such compd of brownish-red color was claimed to be:

\[
\text{CH}_3\text{C}_6\text{H}_4(\text{NO}_2)_2\text{N}-\text{ONH}_4
\]

which is similar to that previously obtained by Korczinski (Ref 1) as a result of the reaction of ammonia with TNT.

Also, due to the hygroscopic nature of AN, amatols are very unstable in storage (Ref 1) unless it is possible to exclude moisture. At 90% RH and 30°, 80/20 amatol would contain 61% moisture in 2 days. This not only lowers the sensitivity and vel of deton to a low order but results in failure to detonate. In the presence of Fe, hydrolysis of moist AN may take place with the formation of NH₄OH, which reacts with TNT to form an exudate of a brown oily material igniting at 67°. This can be detected by discoloration of the explosive and the odor of NH₃. In this case the shell cannot be safely washed out with steam and it is necessary to use cold water.

To prevent the corrosion caused by contact of amatol with metal, it was an American practice to coat the insides of shells with acid-proof black paint prior to loading, and to prevent moisture entering amatol in loaded shells a seal was formed by pouring some molten TNT on top of amatol. This TNT served as a booster surround.

Bourjol (Ref 17) investigated samples of amatol stored for 25 years in Zn boxes and
found that considerable deterioration of TNT took place. Lab experiments have shown that if Al is used in lieu of Zn, the TNT remains unaffected.

Exudation of TNT from Amatol Shells. The study of exudation began in the USA shortly after WWI because it was observed that some amatol and TNT loaded shells were exuding a brown oil (Refs 2 & 3). Samples of the exudate were collected at Pic Arsn and the mechanism and significance of exudate formation was the subject of an exhaustive study. Exudation of oil from TNT and amatol filled shell was found to be purely a physical phenomenon resulting from the effect of elevated temperature upon TNT containing impurities. The danger of such a condition lies not in the explosive properties of the exudate but in the decreased density of the charge (due to formation of cavities), making possible a premature explosion upon set-back when the shell is fired. (Cavitation is more pronounced in straight TNT than in amatols.) The TNT oil when present in the booster charge also desensitizes the booster so that duds may result. The presence of gas within TNT or amatol shell is due to a chemical reaction between TNT and alcohol. This reaction is not progressive and will continue only so long as there is alcohol present. Exudation is not as serious a problem from the standpoint of safety as is commonly supposed. Yet, it is not desirable to issue for use shells invented in 1915 at the Research Dept, Woolwich, soon became the main fillings for HE shells in the Brit Land Service (Ref 4, p 152 & 171). According to Ref 12, the use of amatols during WW II was as follows: a) 60/40 amatol - in GP, Medium Capacity, High Capacity & A/P bombs; also in depth charges, rockets, grenades, land & sea mines b) 80/20, 70/30, 60/40 or 50/50 in shells of all types.

Uses of Amatols

France. Although amatols are described in several Fr papers (Refs 16, 16a & 17), there is no info on their uses in France (see also Refs under Amatol, Analysis).

Germany. The following modified amatols with low TNT content were used during WWI for cast-loading some ammo (Ref 4, p 173): a) AN 60-65, Na nitrate 10, dicyandiamide 5 & TNT 25-20% b) AN 65-67, Na nitrate 12-10, Na acetate 3 & TNT 20%. According to Ref 14a, the following compn was used during WWII: AN 40-45, TNT 50 & RDX 10-5%. Several modified amatols, No 39, 40 & 41 are listed on p 4 of Ref 19a. On pp 47-8 of the same Ref are listed: a) 40/60 amatol (called in Ger Füllpulver No 13 or Fp 60/40)- used in GP, SAP & A/P bombs and shells b) 50/50 amatol (called in Ger Füllpulver No 13a or Fp 50/50)- used in GP bombs and land mines, such as the Tellermine c) 70/30 amatol (called in Ger Fp 30/70)- used in some A/P bombs d) 60/40 amatol (called in Ger Füllpulver No 88 or Fp 4/60)- used in some shells, grenades and radio-guided bombs e) 95/5 amatol (Fp 5/95, in Ger)- use is not known (See also Ref 12, p 82).

Great Britain. The 80/20 and 60/40 amatols, invented in 1915 at the Research Dept, Woolwich, soon became the main fillings for HE shells in the Brit Land Service (Ref 4, p 152 & 171). According to Ref 12, the use of amatols during WW II was as follows: a) 60/40 amatol - in GP, Medium Capacity, High Capacity & A/P bombs; also in depth charges, rockets, grenades, land & sea mines b) 80/20, 70/30, 60/40 or 50/50 in shells of all types.

Italy. The 80/20, 70/30 and 60/40 amatols were used for filling various kinds of shells, bombs, grenades and bombs (The 60/40 was known as "esplosivo 60/40") (Ref 12, 13a & 16b). According to Ref 16b, the 90/10 amatol
was used in mining. Its props were: Trauzl test value 365 cc, deton vel 2500 m/sec and gap test value (distanza colpo, in Ital) 2.0 cm

Japan. The 50/50 amatol known as shotoyaku was used in some bombs and projectiles (Ref 11, p 27). According to Ref 12, the use of amatol was limited due to the shortage of TNT. It had been reported in Naval mines

Russia. According to Blinov (Ref 15a), two types of amatol were used during WWII: a) 80/20 amatol - in many types of ammo, such as 76.2 & 107 mm HE shells, 82, 107 & 120 mm mortar shells, and 122 mm HE howitzer shells b) 50/50 amatol in some ammo and to a lesser extent than 80/20 amatol. A similar expl call Ammoksil (qv) contained TNX in lieu of TNT

United States of America. The US Govt shortly after its entrance into the WWI authorized the use of 50/50 amatol for shells from 75 mm up to and including 4.7" and 80/20 amatol for shells from 4.7" up to and including 9.2" (Ref 6, p 124). According to Ref 12, the use of amatols during WWII was as follows: a) 50/50 and (80/20 amatols in LC (light case)), GP and SHP bombs b) 50/50, 60/40 and 80/20 amatols were used in various shells. During the early part of WWII, some 65/35 amatol was used in some shells and bombs (Ref 19a, p 182)

Note: The rapid production during WWII of a huge supply of TNT (obtained by nitration of plentiful petroleum toluene), removed the necessity of using AN as a substitute for TNT. Another factor contributing to the disuse of amatols as military expls was the appearance during WWII of materials more powerful than TNT, such as PETN and RDX, as well as their binary mixts pentolites, cyclotols, etc

The use of cast amatols, such as: AN 35, TNT 34, Na nitrate 30, chalk 0.9 & stearic acid 0.1% was recently patented for military and civilian applications (Ref 17b)


Additional Refs on Amatol:
a)Van Gelder & Schlatter (1927), 954-6 (Amatol, also called Military Nitrate of Ammonia, was manufactured in the US during the latter part of WWI. Judging by the ams of its ingredients produced at the same period: AN 95,500,000 lbs and TNT 101,800,000
lbs, the amount of amatols produced was probably ca 150,000,000 lbs, because most of the TNT produced went for the manufacture of amatols. A) Stettbacher, Explosivst 1954, Nr 3/4, p 40 (Properties for 50/50 amatol: d 1.5-1.55, gas vol at NTP 930 1/kg, Qe 840 kcal/kg with H2O vapor, temp of deton 2640°, max vel of deton 5000 m/sec and impact sensitivity 90 cm with 2 kg wt) C) M. A. Cook et al, JPhysChem 59, 675-80 (1955) (Deton vel and wave shape were measured as a function of charge diam for 50/50 amatol and a loosely packed mixt of 50/50 AN/TNT as compared with pure AN and Comp B contg AN. Vel of deton of amatol and loose mixt AN/TNT were practically the same for identical diams of chge, ranging from ca 4700 m/sec for diam 3.81 cm, 5000-6000 m/sec for diam 5.04 cm and 6000-6500 m/sec for diams 7.62-17.78 cm)

**Amatol, Analytical Procedures**

*Identification of Amatol.* a) Place about 0.05 g of previously pulverized unknown material in a 5-cc beaker, add 2 to 3 cc of distilled water, stir for 5 mins and observe the color of aliquot. It is colorless in case of amatols. b) Test the aliquot with a strip of Universal pH indicator paper; there shall be no change in color. c) Add a drop of Nessler's reagent – brown ppt in case of amatol. If the test is negative, the substance is not amatol.

If the above test is positive confirm the identity of amatol by one or several of the following tests: A) Place about 0.05 g of unknown material in an indenture of a white porcelain spot-test plate and add 2-3 drops of 65 to 68% aq soln of ethylenediamine and stir – the color of soln shall be maroon. B) Repeat the test using a new 0.05 g sample and 3-4 drops of DPhA soln (1g in 100 cc of concd CP sulfuric acid), stir and wait 1 min; the color of soln shall be dirty green. C) Repeat the test using a new sample, an equal amt of thymol and 3 drops of concd sulfuric acid; stir the mixt and wait for 5 min – green coloration indicates the presence of amatol (Ref 5)

*Note:* The same colorations are obtained in with ammonals

**Analysis of Amatol**

*Moisture.* a) Weigh to 1/10 mg a dry 50 ml Pyrex crystallizer covered with a ribbed watch glass, introduce a previously pulverized sample of ca 5 g and obtain exact total wt of the crystallizer, cover and sample. b) Heat for 2-3 hrs at a temp not above 75°, cool in a desiccator and reweigh. The diff in wt divided by wt of sample and multiplied by 100 gives % moisture.

*Note:* The ribbed cover is used to catch the small amt of TNT which sublimes on heating TNT by Benzene Solution. a) Weigh to 1/10 mg a dry sintered glass crucible, place ca 2g of thoroughly pulverized sample and reweigh to 1/100 mg. b) Insert the crucible into the stopper of a heavy walled filtering flask placed on a steam bath, fill the crucible to 2/3 with hot benz, cover with a watch glass, allow to stand for ½ min and apply gentle suction. c) Repeat the operation several times, using a total of 75-100 ml benz, in order to extract all the TNT. d) Dry the crucible to const wt, cool and weigh. Loss in wt = TNT + moisture. e) Crystallize the TNT from the benz soln and det the mp of one or several crysts, using Fisher-Johns or other apparatus.

**Ammonium Nitrate.** a) In the manner described above, extract 2 grams of the original sample, by running through the sintered glass crucible a total of 150 ml of water at 84°. b) Evaporate the combined filtrates to a small volume, transfer quantitatively to a tared small dish and continue evapn just to dryness, at temps not higher than 100°. c) Leave overnight in a desiccator and rinse the residue 2-3 times with anhydrous ether in order to remove traces of TNT. d) Dry the dish with AN and weigh (Ref 1)
Miaud & Dubois (Ref 3) and previously Bourgoin (Ref 2) devised a rapid method for
detn of AN in amatols by comparing index of
refraction at 20° of its aq soln with a
curve (or table) giving relation between
conc of AN and index of refraction.
Miaud (Ref 4) devised a rapid method for
detn of TNT in amatols by comparing density of
its benzolic soln with a table giving relation
between densities of TNT in C₆H₆ and
% TNT in C₆H₆.

Refs:  1) Anon, War Dept TM 9-2900(1940),
126-7  2) L.Bourgoin, Anales de l'Acfas
(Canada) 9, 90-1(1943) & CA 40, 1317(1946)
3) P. Miaud & P. Dubois, MP 32, 225-9(1950)
4) P. Miaud, MP 32, 227-38(1950)  5)
Anon, Dept of the Army TM 9-1910 & Dept
of the Air Force TO 11A-1-34(1955), 269-7
Note: According to N. Liszt of PicArsn, the
following method is recommended for analysis
of mixts of TNT with nitrates:  a) Quantitatively
transfer an accurately weighed sample (ca 1g) to a dry, tared, sintered glass
extraction thimble and extract with anhyd
methylene chloride CH₂Cl₂, using a Soxhlet
or equivalent apparatus into a tared flask
placed on a water bath  b) Adjust the temp
of the bath so that the solvent drips from the
end of the condenser at the rate of 2-3
drops per second  c) When extraction is com-
plete, evaporate the liquid in the flask to
dryness under stream of dry air and then in a
vacuum desiccator to const wt  d) Subtract
the wt of flask from tot wt, thus obtaining
the wt of TNT  e) Subtract the wt of TNT
from wt of sample (ca 1g), thus obtaining the
wt of AN (or its mixt with materials insol
in methylene chloride)  f) Dry the thimble
for TNT extraction and transfer its contents
quantitatively into 300 ml Erlenmeyer flask
using water  g) Determine AN content as
%.

TNT in C₆H₁₆ was developed by H.L. Cuiterman and
described in PATR 2384(1956). This method
or equivalent apparatus into a tared flask
placed on a water bath  b) Adjust the temp
of the bath so that the solvent drips from the
end of the condenser at the rate of 2-3
drops per second  c) When extraction is com-
plete, evaporate the liquid in the flask to
dryness under stream of dry air and then in a
vacuum desiccator to const wt  d) Subtract
the wt of flask from tot wt, thus obtaining
the wt of TNT  e) Subtract the wt of TNT
from wt of sample (ca 1g), thus obtaining the
wt of AN (or its mixt with materials insol
in methylene chloride)  f) Dry the thimble
for TNT extraction and transfer its contents
quantitatively into 300 ml Erlenmeyer flask
using water  g) Determine AN content as
%.

Ref: Dr L.R. Littleton, Washington, DC; private communication

Amatoxol. A HE contg AN 80 and Toxol
(TNT 70 & TNX 30) 20%. Its power by the
Trauzl test 118 (PA 100), rate of deton
5100 m/sec and sensitiveness to impact
110+(PA 100)
Ref: Dr L.R. Littleton, Washington, DC; private communication

Amber (Succinum), C₁₀H₁₆O(?), d 1.07 to 1.09,
hardness 2 to 2.5. A fossilized, bituminous
resin which is derived from an extinct variety
of pine. It is pale yel to brn or red-brn and
varies from transparent to opaque. It is used
as a semi-precious stone or in experiments
on static electricity (See also Note under
Amberites)
Ref: 1) Hackh(1943),41  2) CondChemDict
(1956),55
Amberites. Fast burning smokeless propellants manufd by Curtis and Harvey Ltd in Gt Britain beginning in 1891. The original propellant, described by Cundill(Ref 1), consisted of inol NC 40-47, NG 40-30 and paraffin 20-23%, together with a small quantity of shelllac soln.

Daniel (Ref 2) gives the following compositions for Amberite No 1: NC(insol) 40-47, NC(sol) 20-23 and NG 40-30%. For its prep'n the mixture of 13% and 12% nitrocelluloses together with NG was granulated and treated on the surface with a volatile solvent so that only the sol NC was gelatinized. On drying the grains, the two types of NC were cemented and the surface of the grains hardened. Small quantities of paraffin, shellac or linseed oil could be incorporated as moderants.

The following compositions contained no NG: a)Amberite No 2A: NC(insol) 13.0, NC(sol) 59.5, Ba and K nitrates 19.5, paraffin 6.1 and vol matter(mostly H\textsubscript{2}O) 1.9% (Ref 2) and b)Amberite No 2b: NC(insol) 53.2, NC(sol) 24.1, Ba and K nitrates 10.8, paraffin 9.6 and vol matter (mostly H\textsubscript{2}O) 2.3%(Ref 2).

Beginning in 1894, WM(woodmeal) was included in the formulation and the resulting compn was called "Blasting Amberite". In 1899, the incorporation of charcoal and calcined WM was started (Ref 2).

In Refs 3,4 & 5, the formulation of an Amberite used as a shot-gun propellant is given as follows: NC 71.0, Ba nitrate 18.6, K nitrate 1.2, WM 1.4, was 5.8% and vol matter 2.0%. In Ref 6, the following properties of a British Amberite are given: Q\textsubscript{v} 745 cal/g and total vol of gases evolved per gram at NTP 791 ml of which 156 ml is water vapor.

Note: The name Amberite is also used for the compressed amber(qv) scrap used for electrical insulation.

Ref: Hackh(1944),42

Amberlac: Trade name for a rosin modified oxidizing type phthalic alkyd resin or modified polyester type resin manufd by Rohm & Haas, Phila Pa.

It was used by Aerojet Engrg Corp, Azusa, Calif in some experimental smokeless propellants. Eg: a)RL-210 propellant- Amberlac 75 & Paraplex AP-31 25% and b)RL-223 propellant- Amberlac 85 & Duraplex 15%

Refs: 1) Aerojet Engineering Corp Rept No 192(1946), 16-17 2) CondChemDict(1956), 55

Amberlite. Trade name for resorcinol type resins used for wood adhesives and manufd by the Rohm & Haas Co, Phila 5,Pa. Also a trade-mark name for insoluble crosslinked polyelectrolytes (ion-exchange resins). Used for water conditioning and other purposes.

Ref: Cond Chem Dict(1956), 56

Note: It may be used as a binding agent in propellant or expl composns.

Amberol. Trade name for oil-soluble phenol formaldehyde - maleic glyceride resins. Used in paints, varnishes, lacquers, etc.

Ref: Cond Chem Dict(1956), 56

Note: It may be used as a binding agent in propellant or expl composns.

Äme(Fr). Bore(of a firearm).

Äme de canon(Fr). Cannon bore.

American Ammonium Nitrate Dynamites. See under Ammonium Nitrate Dynamites.

American Ammonium Nitrate Explosives. See under Ammonium Nitrate Explosives.

American Ammonium Nitrate Gelatins. See under Ammonium Nitrate Gelatins.


American Dynamite of 1894 contained NG and a mixture of sieved coke and Ca acetate as the absorbent

Refs: 1) Callahan & Higgins, USP 525,188 (1894) 2) Daniel (1902), 18

American Dynamites, Gelatinized. According to Davis (Ref 2), blasting gelatin (qv) is not used very widely in the US; the somewhat less powerful gelatin dynamite or simply Gelatin finds much greater use. Gelatin is essentially a straight dynamite in which a gel, consisting of NG (or NG+NGc) with 2 to 5.4% NC is used instead of liq NG or a liq mixt of NG+NGc. The resulting composn is elastic similar to blasting gelatin

The composn of typical American 30 to 70% strength gelatins used in 1915 were given by Munroe & Hall (Ref 1) and also by Davis (Ref 2). They contained 23 to 60% NG (or NG+NGc), 0.7 to 2.4% NC, 62.3 to 29.6% Na nitrate, 13 to 7% combustible material (wood pulp in those with 50 and 60% NG, wood pulp and in some cases rosin and sulfur in other grades) & Ca carbonate 1%

Bebie (Ref 3) gives two examples: a) NG 62.5, NC 2.5, Na nitrate 27.0 and wood pulp 8.0% and b) NG 36, NC 2, vegetable meal 2, nitrates and/or perchlorates 52 & nitro-compounds(of toluene, naphthalene or diphenylamine) 8%. Bebie also cites Gel-Coalites as a brand of gelatinous permissible expls manufd by the Atlas Powder Co of Wilmington, Del, but does not give their composns


American Dynamites, Ordinary, with Ammonium Nitrate. See under Ammonium Nitrate Dynamites

American Dynamites, Ordinary, with Ammonium Nitrate. A series of non-gelatinized, so-called "straight" dynamites or dynamites with active base, reported to contain: NG 15-60, combustible materials (wood pulp, sawdust, ivory nut meal, raw corn flakes, sulfur, etc for grades below 40% NG or wood pulp alone for other grades) 20-14, Na nitrate 64-23 & Ca or Mg carbonate (ant-acid) 1%. Deton velos are between 4500 and 6250 m/sec depending on the NG content

The "standard" 40% straight dynamite used at the US BurMines in comparative tests contains: NG 40, Na nitrate 44, wood pulp 15 & Ca carbonate 1% (Ref 2 and Ref 3, p 333)

Refs: 1) C.E. Munroe & C.Hall, US BurMines Bull 80 (1915) 2) Davis (1943), 344-5 3) Davis (1943), 140

American Dynamites, Low Freezing, Ordinary. A series of non-gelatinized or "straight" dynamites reported to contain: NG 15-35, AN 15-30, Na nitrate 51-24, combust material(mixt of WP, flour and sulfur) 18-10 & Ca carbonate or Zn oxide 1%

Refs: 1) C.E. Munroe & C.Hall, US BurMines Bull 80 (1915) 2) Davis (1943), 341

American Electroplastics Corporation Explosive, according to the analysis made at PicArsn, contained: AN 70.97, NS 21.56, Al metal 4.50, oil 2.94 and Pb tetaethyl 0.033. Its brisance, as detnd by the Sand Test 24.3 g (vs 34.3 g for the Trojan Demolition Expl and 28.5 g for 80/20 amatol); impact test with 2 kg wt 14 cm (vs 25 cm for tetryl and 17 cm for PETN); 75° International Test, 100° Heat Test and 120° Vacuum Stability Test—sl more satisfactory than for the Trojan Demolition Expl. It is more difficult to initiate than the Trojan Explosive
The Electroplastics Corp expl was considered unsatisfactory for military use because of its fairly high sensitivity and low brisance value.

Ref: PATR 1117(1941)

**American Explosive.** A non-gelatinized permissible explosive manufd by the American Cyanamid and Chemical Corp, New York, NY.

Ref: Bebie(1943), 20(The compn is not given)

**American Forcite Powder Co.** was organized in New Jersey in 1883 by H.A.deCastro. In 1913 it became the property of Atlas Powder Co, Wilmington, Del.

Ref: VanGelder & Schlatter(1927), 453 & 465

**Americanite.** A very powerful liquid expl invented in 1890 by Smolianinoff and tried successfully in the US for loading shells up to 203 mm. There were no premature at a muzzle velocity of 654 m/sec. The expl consisted of NG 80 to 97 and a liq alcohol 20 to 3%

Ref: Daniel(1902), 19

**American Permissible Explosives.** See under Permissible and Permitted Explosives

**American Powder.** Also called White German Powder. See Augendre Powder

**American Smokeless Propellants,** listed in Marshall, v I(1917), 327, contained a)GC 80 sol NC 19.5 & urea 0.5 and b)GC 80, sol NC 10, NG 9 & urea 1%. Urea was later replaced by diphenylamine as a stabilizer.

**American Stability Tests at 65.5° and 80°.**

See under Stability Tests

**American Table of Distances for Storage of Explosives,** as revised and approved by the Institute of Makers of Explosives, September 30, 1955, is given by Sax(1957), 154;7 and Cook(1958), 354-6

**Amianto(Fr); Amianto(Ital & Span).** Asbestos

**Amidation** is the process of forming an amide

**Amide(Explosif), designated also as l'explosif amylacé,** was patented in 1886 in France. It contained “sulfurless black powder” (AN+KNO₂+charcoal) 32-60 & NG 68-40%

Ref: Daniel(1902), 20

Note: The above “sulfurless black powder” was similar in compn to Amide Powder described below

**Amide Powder.** (Amidpulver, in Ger). One of the earliest types of Ger smokeless artillery propellants. The original compn patented in 1885 by Gänns contained AN 35-38, K nitrate 40-46 & charcoal 14-22%. Its formulation was modified several times until a powder which was flashless and nearly smokeless was obtained. The improved compn: AN 37, K nitrate 14 & charcoal 49% was used during WWI as a cannon propellant. Amide powder left only a small residue on combustion. This was attributed to the formation and ignition of potassium which is formed on burning the powder

Ref: 1) Thorpe I(1937), 304 2) Davis(1943), 49 3) Bebie(1943), 20-21 4) PATR 2510 (1958), p Ger 4

Note: According to Daniel(1902), 20, Amidpulver was exported from Germany to England under the name of Chillworth Special Powder

**AMIDES, IMIDES AND DERIVATIVES**

**(Inorganic)**

**Amides and Imides, Inorganic.** An inorganic amide, also called ammonobase, is a compd in which one hydrogen in ammonia is replaced by a metal, as for instance sodamide, NaN₃. An inorganic imide is a compd in which two hydrogens are replaced by metals, eg, lead imide, PbNH₂

Metallic amides and imides can be pptd from liq ammonia solns of certain metallic salts by the action of potassium amide, KN₃

Some amides and imides are explosive, eg, silver amide and lead imide. (Compare with Nitrides) (See also Polyamides)


**Alkali Amides,** such as potassium amide and sodamide are described individually. A general description of the prepn and props of various alkali amides is given by F.W. Bergstrom & W.F. Fernelius, ChemRevs 12, 43-179(1930). Alkali amides can be used for the
prepn of other metallic amides, some of them expl (see Auric Imidoamide, Cadmium Amide, Silver Amide, etc)

**Auric Imidoamide or Gold Amide-Imide**

Au(NH)NH₂ or HN: Au.NH₂. Powder, extremely expl and sensitive. Was first obtained in the Middle Ages by alchemists and named *aurum fulminans* (*fulminating gold*). It was prepd by treating gold oxide with an ammoniacal soln of a salt of gold. Fulminating gold does not expl when wet and must be stored under w to avoid accidents. A number of explosions with the dry salt have been reported in the literature. When fulminating gold is kept at 100° for several hrs, it becomes so sensitive that it scarcely can be touched without exploding (Ref 1)

Franklin (Ref 2) prep'd it by treating potassium-auri-bromate with potassamide in liq NH₃ soln

Mellor (Ref 1) stated that if aq ammonia is added to a soln of auric chloride, a mixt of fulminating gold and a yel solid identified as *auric imidochloride*, HN:AuCl is formed and the chloride cannot be removed even by prolonged digestion with aq ammonia. The mixt is expl

**Cadmium Amide**, Cd(NH₂)₂, wh powder expl when rapidly heated. Can be prepd by treating Cd iodide or KCd cyanide with a soln of potassamide in liq NH₃. When heated to 180° in vacuo, Cd amide loses NH₃ leaving Cd nitrde, Cd₃N₂, a black amorphous powder which expl violently when brought in contact with w

*Ref:* Mellor 8(1928), 261

**Fulminating Gold.** See Auric Imidoamide

**Fulminating Silver.** See Silver Amide

**Gold Amide-Imide.** See Auric Imidoamide

**Lead Imide**, PbNH. Orange-red ppt which expl violently when heated or or coming in contact with w, dil acids or liq NH₃. It is obtained when PbI₂ (or some other Pb salt) is brought together with K amide in liq NH₃ soln: PbI₂ + 2KNH₂ = PbNH + NH₃ + 2KI

Refs: 1) E.C. Franklin, JACS 27, 842(1915) 2) Mellor 8(1928), 265 3) Franklin(1935), 61 & 325-6

**Potassium Amide or Potassamide**, KNH₂. Col, delq leaflets, mp 239°. Was first prepd ca 1810 by Gay-Lussac and Thénard by heating metallic K in an atmosphere of NH₃. When metallic K is brought in contact with liq NH₃, it slowly dissolves to form an intensely blue soln, which gives the amide on standing for several weeks (or even months). The reaction can be greatly accelerated by sunlight or by the presence of some substances acting as catalysts. A relatively minute amt of Pt black, placed in a liq NH₃ soln of metallic K, causes an immediate and fairly vigorous reaction resulting in the formation of KNH₃ in the course of a few minutes

According to Mellor (Ref 1, p 255), KNH₂ reacts vigorously with w and the reaction may be accompanied by inflammation

Potassamide can serve for the prepn of other metallic amides and imides, some of them expl, eg AgNH₂ or PbNH

(See also Ref under Alkali Amides)

Refs: 1) Mellor 3(1923), 582-3 2) Franklin (1935), 57

**Silvery Amide**, AgNH₂, bulky wh ppt which darkens on exposure to air and shrinks in vol; very expl and its sensitiveness to deton is not materially changed by lowering the temp to ~190° (Ref 4). Can be prepd by mixing a soln of potassamide with Ag nitrate (or iodide) in liq NH₃, followed by washing by decantation and careful drying (Refs 2, 4 & 5). Franklin (Ref 2 & 5) warned that AgNH₂ can expl on the slightest provocation, shattering test tubes containing the material and tearing holes in several layers of strong towelling wrapped around the tube for the protection of the operator

It seems that silver amide is identical with the compd previously known as *fulminating silver of Berthollet* (*l'argent fulminant de Berthollet* in Fr and Bertholett's schen Knallsilber in Ger), also called by Mellor (Ref 1) silver *imide* or silver *nitride*. This compd,
as a dark extremely expl solid, was first mentioned, but not identified, by J. Kunckel, in 1767. Berthollet prep'd it in 1788-9 by treating pptd Ag oxide with concd aq ammonia and described some props. Several other investigators prep'd this expl and various formulae were assigned to it, such as $\text{Ag}_2\text{N}$ and $\text{Ag}_3\text{N}$ (see Ref 1), until the present formula $\text{AgNH}_2$ was established.

**Refs:** 1) F. Raschig, Ann 233, 93(1886) 2) E. C. Franklin, JACS 27, 833(1905) 3) Mellor 3(1923), 381 4) Mellor 8(1928), 259

**Sodium Amide or Soda Amide, $\text{NaNH}_2$.** Wh cryts, mp 206.4\(^\circ\); dissolves in liq NH\(_3\) and is vigorously hydrolyzed by H\(_2\)O. It was first prep'd ca 1810 by Gay-Lussac and Thénard by the action of NH\(_3\) gas on molten metallic Na heated to 300\(^\circ\). Can also be prep'd by dissolving metallic Na in liq NH\(_3\) and then placing in the soln a a spiral of Fe wire, which catalytically accelerates the otherwise very slow reaction: Na + NH\(_3\) = NaNH\(_2\) + H

Mixts of sodium amide with nitrates and chlorates expl when triturated (Ref 1, p 255)

When finely divided soda amide was exposed to air in the presence of a little w, a yel-red solid was formed identified as sodium amidoperoxide, NaNH\(_2\)O. It is stable in dry air but decomp by moisture (Ref 1, p 255)

Fused NaNH\(_2\) dissolves metallic Mg, Zn, Mo, W, quartz, glass, many natural silicates and many other substances.

**Refs:** 1) Mellor 8(1928), 253-5 2) F. W. Bergstrom & W. C. Fernelius, Chem Revs 12, 67(1933) & 20, 413(1937) 3) Franklin(1935), 54-5 4) Inorg Synth 1(1939), 74-7 & 2(1946), 128-35

**Nitramide or Nitroxylamide, O\(_2\)N.NH\(_3\), mw 62.03, N 45.17\%.** Wh solid, mp 72-5\(^\circ\) with decomp; puffs off on rapid heating. Sol in w (slowly dec) and in common solvents, except pett ether. Was first, prep'd in 1890 by Mathieu-Plessy but not properly identified. Thiele & Lachman prep'd it in 1894 (Refs 1, 2 & 3) from nitrourethane, O\(_2\)N.NHCOO.C\(_2\)H\(_5\), and described its props. Since then nitramide was prep'd by various investigators, mostly by hydrolysis and decarboxylation of potassium - N - nitrocarmamate (Ref 4,5&6). Only small quantities should be prep'd at a time and kept in a desiccator placed in a refrigerator because the compd is unstable, although it does not expl at ord temp

Thiele & Lachman (Refs 2 & 3) prep'd alkali nitramidates and ammonium nitramidate; but could not analyze them because they existed for only a few seconds. A little more stable was mercuric nitramidate, O\(_2\)N.NHg. This was obtained on treating an aq soln of nitramide with a soln of mercuric nitrate in HNO\(_3\)

(See also Ref under Alkali Amides)


**Amides and Imides, Organic.** An organic amide is a compd contg the monovalent -CO.NH\(_2\) radical (eg, acetamide CH\(_3\).CO.NH\(_2\), oxamide H\(_2\)N.CO.CO.NH\(_2\), benzamide C\(_6\)H\(_5\).CONH\(_2\), etc). An organic imide is a compd formed from acid anhydrides in which one oxygen is replaced by NH, as for instance C\(_2\)H\(_5\)<\(\text{CO}>\)NH (succinimide)

These compds are not explosive but some of their nitrocompds (nitramides) are. For instance, the silver salt of nitroderivatives of acetamide (qv) are explosive (See also Urea or Carbamide, Formamide and Polyanalides)


**Amides and Imides, Organic. Analytical Procedures.** Some procedures are described in Organic Analysis, Interscience, NY, vol 3(1956)
Amides and Imides, Organic, Nitroated are compds of the general formula R.NH.NO₂ and R₂N.NO₃, in which R is an acyl radical, such as CH₃CO⁻. Most of these compds are unstable and sensitive to moisture. A general description of organic nitramides may be found in the books on Organic Chemistry, such as Gilman vol 4(1953), 979-81. Some nitramides are described individually or as a class in the following refs:

Refs: 1)H.J.Backer, "Ahrens Sammlung Chemischer und Chemisch-technischer Vorträge" 18 359-474(1912), translated by H. Stone, Ohio State University, Columbus, Ohio (Historical and prepn & props of numerous nitramides and nitramines) 2)R.Adams & C.S. Marvel, OSRD Rept 86(1941) (Historical survey of nitramides, synthesis of intermediates and their nitration to the final products. Only few of the prepd nitramides were of interest as expls or as components of expl compns) 3)Series of papers by A.H.Lamberton, J.Barrott, I.N.Denton & others, entitled "Nitrarnines and Nitramides" in JCS 1951, 1282-89; 1952, 1886-94; 1953, 1998-2005; 1953, 3341-49; 1953, 3349-52; 1954, 2391-95; 1955, 1655-57; 1955, 3997-4002

Amidines or Aminoamines are compds contg the monovalent radical -C(:NH)NH₂, as for instance, acetamidine, CH₃C(:NH)NH₂. They are cryst solids, sol in alc and eth. Some of these compds have been known for about 1/4 of a century but they were not studied intensively until after WWII, when papers by P.Oxley, W.F.Short, M.W.Partridge, T.D. Robson, J.Miller and others appeared in the Journal of the Chemical Society, beginning in 1946. The compds described by the above authors were not investigated from the point of view of their explosiveness, but one might suspect that some of them are expl.

General methods of prepn of amidines are given in Ref 3, p 671. With organic and inorganic acids, amidines form salts which are more stable than the amidines. For instance, acetamidine (ethaneamidine or α-amino-α-iminoethane) CH₃C(:NH)NH₂, is an unstable solid melting ca 166-70° with decompn. Its hydrochloride, which is prepd by the action of HCl gas on acetonitrile in abs alc cooled in ice-salt, reacts with AgNO₃ to give acetamide nitrate C₂H₅N₂⁺HNO₃, crysts, mp 148°(dec). The picrate of acetamidine C₂H₅N₂+C₆H₅N₂O₇, mw 287.19, N 24.39%, mp 252°, is an explosive (See also Aminoguanidine, Biguanide, Cyanoguanidine, Guanidine and Guanyl urea)


4-Amidino-1-(nitrosoaminoamidino)-1-tetrazene. One of the names for Tetracene, also called Marvel, OSRD Rept 86(1941) (Historical survey of nitramides, synthesis of intermediates and their nitration to the final products. Only few of the prepd nitramides were of interest as expls or as components of expl compns) 3)Series of papers by A.H.Lamberton, J.Barrott, I.N.Denton & others, entitled "Nitrarnines and Nitramides" in JCS 1951, 1282-89; 1952, 1886-94; 1953, 1998-2005; 1953, 3341-49; 1953, 3349-52; 1954, 2391-95; 1955, 1655-57; 1955, 3997-4002

Amidogène. Two mixts were known under this name: a)A black-powder type expl patented in 1882 by Gempelé, and manufd for some time in Switzerland, was prepd by mixing the following ingredients in moist condition: K nitrate 73, sulfur 10, bran or starch 8, charcoal 8 & Mg sulfate 1% b)A dynamite-type expl contained NG 70-75, AN 4-7, paraffin 3-10 & powdered charcoal or coal 18-13%. This mixt was hygroscopic and its NG exuded (See also Aminoguanidine, Biguanide, Cyanoguanidine, Guanidine and Guanyl urea)

Refs: 1)Cundill, MP 5, 346(1892) 2)Daniel (1902), 20-21 3)Thorpe 4(1940), 463

Amidoguanidine. See Aminoguanidine

Amidon (Poudre à l'), a blasting expl patented in 1884, consisted of black powder mixed with 2 to 5% of starch (Compare with "Starch Powder")

Ref: Daniel(1902), 21
Amidon nitré (Fr). Nitrostarch

Amidotriazole of Thiele. See 3-Amino-asym-triazole

Amidpulver. See Amide Powder

Amilol. Same as Amylphthalate

Aminated (Aminized) Cellulose or Amino-cellulose. By attaching amino-groups to a cellulose molecule (such as cotton), products are obtained which react differently than the untreated celluloses. Due to the presence of amino groups the aminated celluloses combine with acidic substances, such as acid dyes, some flame-proofing agents, rot-resisting compounds, and acidic explosives, such as 2,4-dinitrochlorobenzene, 2,4,6-trinitrochlorobenzene, etc.

A series of papers on amination of cellulose appeared after WWII in various journals (see Refs)

Note: It may be possible to form rapid-burning materials suitable for propellants, fuses, quick matches, etc by combining aminated cellulose with an oxidizer, eg, aminocellulose nitrate or perchlorate

(See also Aminoethylcellulose)

Refs: 1) L. Vignon, CR 112, 487 (1891) (Direct addition of the amino nitrogen to cellulose was reported but the results have not been reproducible, according to Ref 2) 2) T. S. Gardner, J Polym Sci 1, 121 & 289 (1946) 3) J. D. Guthrie, Textile Research J 17, 625 (1947) 4) C. L. Hoffpaur & J. D. Guthrie, Ibid 20, 617 (1950) 5) W. A. Reeves & J. D. Guthrie, Ibid 23, 522 (1953) 6) W. A. Reeves et al, Ibid 23, 527 (1953)

Aminated Cellulose Acetate Esters. Prepn and props of cellulose acetate esters contg amino nitrogen are described in a paper by T. S. Gardner, J Polym Sci 1, 121-6 (1946) and in some refs listed in that paper

Amination is the process of forming an amine (qv). This may be done by any one of the reactions described in textbooks on Organic Chemistry (see Ref 3). The most important method is the reduction of nitrocompds or cyanides. Other methods, such as the hydrolysis of nitriles, or the replacement of hydroxyl by an amino group, are not used commercially.

The process of reduction of nitrocompds was discovered in 1842 by N. Zinin, a prof at the Univ of Kazan, Russia. He prepd aniline by reducing nitrobenzene with (NH₄)₃S. A less expensive reducing agent, Fe and dil acid, was proposed in 1854 by Béchamp. The reduction process by Fe and acid was used on a large scale by Perkin. With cheap aniline the synthetic dyestuff industry was born

Amination by reduction may be achieved by using the metals Fe, Sn, Zn (in acid or neutral solns), Zn or Fe (in strongly alkaline solns), Zn (in weak alk soln), sulfides, FeSO₄ & hydrosulfites (in alkaline solns), hydrogen in the presence of catalysts, etc. These methods are described in Refs 1, 2 & 4

The greatest industrial use of amination by reduction was made during WWII in Germany (mostly by IG Farbenindustrie), as well as in Gt Britain and the USA

Although the amination process does not produce any explosives, it is mentioned here because it can be used for transforming some discarded explosive nitrocompds into non-explosive amines, which might be useful as dye intermediates or other purposes. For instance, during WWII, some nitroxylenes were reduced to produce mixed xylidines for use with aviation gasoline. The reduction method can also be used for the harmless destruction of discarded explosives. For instance, at least one of the US Ordnance installations destroyed unwanted TNT by placing it in shallow basins dug in the ground and adding iron scrap in water acidified with sulfuric acid


AMINES

Amines are compounds derived from ammonia by substituting hydrocarbon radicals (R) for
hydrogen. They may be primary $\text{RNH}_2$, secondary $\text{R}_2\text{NH}$ (called also imines), tertiary $\text{RN}_2\text{H}$ or quaternary $\text{R}_3\text{NH}$ amines. Their

preparation and properties are given in Organic Chemistry books, Chemical Encyclopedias and Chemical Dictionaries.

(See Refs 1, 2, 3a & 5)

Amines have been used for the following purposes related to explosives, propellants, pyrotechnic compositions and fuels: a) Stabilizers for NC propellants, diphenylamine, nitrodiphenylamine and phenyl-$\beta$-napthylamine, the last examined in France (Ref 3) b) Sensitizers for some explosive and propellant compositions (Ref 4 and addnal ref d) c) Smoke-producing compounds (Addnl Ref d) d) Liquid fuels for rockets in conjunction with strong oxidizers, such as nitric acid (some of these are hypergolic) (Refs 6 & 8 and addnal refs e, g, i, k & l) e) Additives to gasoline and other motor fuels (Addnal refs a, b, c & f)

Refs: 1) Kirk & Dohmen 1,702-17 2) Hickinbottom (1948), 105, 281-4 & 292-332 3) L. Médard, MP 32, 305-7 (1950) (Phenyly-$\beta$-napthylamine as a stabilizer for smokeless propellants) 3a) Degering (1950), 199-221 & 292-321 4) H. Maisner, USP 2,712,989 (1955) & CA 49, 14325-6 (1955) (An organic amine was proposed as an addn to nitroparaffin-gel rocket propellants to make them exp, e.g., a rocket propellant consisting of MeNO$_3$ blended with 10-50% NC and contg Cr acetylacetonate up to 3% by wt became an expl after incorporating some amine) 5) Clark & Hawley (1957), 68-9 6) L. R. Rapp & M. P. Strier, Jet Propul. 27, 401-4 (1957) (The effect of chemical structure on the hypergolic ignition of amine fuels) 7) V. Mignichian, Organic Synthesis, Vols 1 & 2, Reinhold, NY (1957) 8) R. Fuchs, Explosivst 1958, 89-97 (Aliphatic and aromatic primary, secondary and tertiary amines were examined from the point of view of their hypergolicity when used with strong nitric acid as an oxidizer. Various devices for such investigations are discussed)

Addnal Refs on Amines: a) SODC, BritP 530, 597 (1940) & CA 36, 893 (1942) (Secondary amines as blending agents in high octane number motor fuels) b) SODC, BritP 559, 851 (1944) & CA 39, 4750 (1945) (Primary or secondary isoalkylamines in which the isoalkyl groups contain from 4 to 5 carbon atoms, as antiknock blending agents for high octane motor fuels) c) A. G. Mazurkiewicz & V. G. Oberholzer, J. Inst Petrol. 32, 685 (1946) & CA 41, 5281 (1947) (Aromatic amines as antiknock addns to motor fuels) d) H. E. Britt, USP 2,420,416 (1947) & CA 41, 4874 (1947) (An exceedingly dense white smoke is produced when a liq amine such as C$_2$H$_4$ (NH$_2$)$_2$ is treated with a volatile org acid, such as CH$_3$COOH) e) V. L. King, USP 2,474,183 (1949) & CA 43, 6811 (1949) (Rocket propellants are obtained by treating alkyl-substituted mono- or poly-nuclear aromatic amines with 95% or stronger nitric acid(some of these are hypergolic) (Ref 4 and addnl ref d) c) Smoke-producing compounds (Addnl Ref d) d) Liquid fuels for rockets in conjunction with strong oxidizers, such as nitric acid (some of these are hypergolic) (Refs 6 & 8 and addnal refs e, g, i, k & l) e) Additives to gasoline and other motor fuels (Addnal refs a, b, c & f)
chem structure and hypergolic ignition of numerous amine fuels with WFNA oxidizer was conducted at Reaction Motors, Inc, Denville, NJ in order to determine the suitability of such amines as rocket fuels. For instance, dinitroaniline and hypergolic ignition of nitrated explosives. For instance, dinitro-
numerous amine fuels with WFNA oxidizer chlorobenzene reacts with 2 equivalents of aniline to form dinitrodiphenylamine and DNDPhA may be obtained in one operation without further nitration. For instance, the action of potassium methyl nitramine on picryl chloride produces the explosive 2,4,6-trinitrophenylmethylnitramine, known as tetryl:

\[
\text{(O}_2\text{N)}_3\text{C}_6\text{H}_2\text{Cl} + \text{KNNO}_2 \rightarrow \text{(O}_2\text{N)}_3\text{C}_6\text{H}_2\text{N}\text{NO}_2 + \text{CH}_3 + \text{KCl}
\]

(Ref, p 175)

Amines Halogenated. See Halogenated Amines

Amines Nitrated and Nitrited. The various types of amines have been converted into derivatives containing oxynitrogen groups. In some cases the desired derivatives can be produced directly from the amine by the action of nitric or nitrous acids or their anhydrides but often indirect syntheses are required. Many amine derivatives containing oxynitrogen groups are explosive. If a hydrogen of an NH$_2$ group is substituted by an NO or an NO$_2$ group, the resulting compounds are known correspondingly as nitroamines (or N-nitroamines), R$_2$NNO and nitramines (or N-nitramines), R.NH.NO$_2$. There are also nitrosamines (or C-nitrosamines) and nitroamines (or C-nitroamines) in which the NO and NO$_2$ groups are attached to C atoms, e.g., ON.C$_6$H$_2$.NH$_2$ and O$_2$.N.C$_6$.H$_4$.NH$_2$. The corresponding derivatives of secondary amines are called nitrosimines, nitrimines, nitrosoamines and nitroamines.

In amine nitrate, the HNO$_3$ group is connected to a molecule of an amine to form an addition salt, such as R.NH$_2$.HNO$_3$ or R$_2$.NH.HNO$_3$. The term amine nitrate is also applied to amines containing nitroxy(ONO) groups, such as O$_2$.NO.CH$_2$.R.NH$_2$. In order to distinguish between nitrates and nitrate esters, the amines containing ONO$_2$ groups are called nitroxyamines.

Some nitrated and nitrited amines may be...
combinations of the above types, such as nitraminonitrates, nitraminonitro compds, nitraminonitroxy compds, nitronitrosamines, etc. Note: There is frequently a lack of clarity in the nomenclature of nitrated compounds used by various authors. For instance, eight papers in the JCS 1949, pp 1631-58 (see Addnl Refs on Amines, Nitrated) are entitled "Studies on Nitroamines", but they all actually deal with Nitramines.

The literature on the various types and individual oxynitrogen derivs (expl and non-expl) was considerable even before WW II. Since many nitrated amines are expl (the nitro, nitramino and nitrato groups are explosives), WW II served as a strong stimulus for a more intensive study of them, so that today the published material in this field is so extensive that a listing of more than a small number of the most significant refs is not practicable in this dictionary. Some of the more general articles on nitrated amines are given below, while other articles are given as Addnl Refs on Amines, Nitrated.

Individual amines and their nitrated derivs used in expl, propellent and pyrotechnic compns are described separately under their own names, such as: cyclonite, nitroguanidine, tetryl, etc.

Attention is also directed to the section on "Nitration" edited by W.deC.Crater in the annual series entitled "Unit Processes Reviews" in the September issues of IEC beginning in 1948 and ending in 1955. The review was resumed in 1957 by W.R.Tomlinson, Jr.

Inasmuch as the nitramines are the most important of the nitrated amines, it would be appropriate to say a few words about them. According to Backer (Ref 1) some nitramines were prepd as early as 1869 by Griess, but they were not identified as such until much later when Zincke repeated some of Griess' work. In 1877, Mertens of Holland prepd an explosive by nitration of dimethylaniline but he did not establish its structure. In 1883, van Romburgh, also of Holland, proved that the compd prepd by Mertens was a nitramine.

After this, van Romburgh worked with aromatic nitramines while Franchimont (first alone and then with Kobbie and van Erp) studied aliphatic nitramines. Considerable work was done, beginning about 1890, in Germany and in Italy. In later years, work on nitramines was conducted not only in Holland and Germany but in other countries as well. Great advances were made during and after WW II, particularly in the USA (where most of the work is still classified) in Canada (where many papers have been published in Canad JRes and JCS) and in Russia.

Aromatic nitramines are much easier to prepare than the aliphatic nitramines. For this, the aromatic amine can be treated with concd nitric acid either alone or in the presence of a dehydrating agent such as sulfuric acid or acetic acid-acetic anhydride (Ref 2, p 320).

In the prepn of aliphatic nitramines, the indirect methods are preferable, as for instance, dehydration of amine nitrates with acetic anhydride. The presence of a chloride ion acts as a catalyst.

For more information on the prepn of nitramines, see Refs 3 & 4 and individual compds listed under corresponding amines. (See also Amines, Catalyzed Nitration.)


Addnl Refs on Amines, Nitrated: a) A.P.N. Franchimont, Rec 16, 226-8(1897) (Contribution to the knowledge of aliphatic nitramines) b) J. Pinnock, Ber 30, 833-43(1897) (Aromatic nitramines and nitrosoamines) c) E. Bamberger, Ber 30, 1248-63(1897) (Alkyl nitramines) (earlier refs are given) d) G.R. Clemo & J.M. Smith, JCS 1928, 2414-22 & CA 23, 117-18 (1929) (Nitration of substituted tertiary aromatic amines. One of the compds prepd was tetryl) e) Dynamit A-G, Brit P 384,966(1931) (Aliphatic...
nitrated mono- and polyamines, such as methylaminonitrate and ethylenediaminedinitrate, are melted in mixts with AN to be cast in shells, etc) f)P.Naoum & R. Sommerfeld, USP 1,968,158(1934) (Nitrates of aliphatic nitramines used in cast AN explosives) g)A.F. Shouten, Rec 56,541-561(1937) (Prepn and props of some explosive nitramines, such as 1,2-bis[2,4,6-trinitrophenyl]-nitramino)-ethane and 1,2-bis[N-(4-methyl-2,6-dinitrophenyl)-nitramino]-ethane) h)W.L.C. Veer, Rec 57,989-1015(1938) (Prepn and props of several explosive nitramines, such as 1,3-bis[2',4',6'-trinitrophenyl-nitramino]-propane; 1,3-bis[N-(4'-methyl-2',6'-dinitrophenyl)-nitramino]-propane; 1,3-bis[N-(4'-chloro(or bromo)-2',6'-dinitrophenyl)-nitramino]-propane; 1,3-bis[N-(5',4'-chloro(or bromo)-2',4',6'-trinitrophenyl)-nitramino]-propane; etc) i)K.F. Waldköetter, Rec 57,1294-1310(1938) (Prepn and props of some explosive nitramines, such as: N-(2,4,6-trinitrophenyl)-N-nitro-β-aminoollyl nitrate; N-[4-chloro(or bromo)-2,6-dinitrophenyl]-N-nitro-β-aminoethyl nitrate; N-[5-chloro(or bromo)-2,4-dinitrophenyl]-N-nitro-β-aminoethyl nitrate; etc) j)P.P. Shorygin et al, ZhObshKhim 8,986-90(1938) & CA 33,3781(1939) (Nitrination of aromatic amines) k)E. Macciotta et al, Series of articles in Gazz and other Italian journals beginning 1930 and ending 1947(See CA 24, 4279-80(1930); 26,1585-6(1932); 27,4528(1933); 31,3889 & 4965(1937); 33,8592(1939); 36,1593-5(1942) and 41,4115(1947)) l)G. Römer, Report on Explosives, PB&L Rept 85,160(1946) (Aliphatic nitramines 1,7-dinitroxy-2,4,6-trinitro-2,4,6-triazahexapeptide and 1,9-dinitroxy-2,4,6,8-tetranitro-2,4,6,8-tetrazanomane obtained as by-products in the manuf of RDX)(See PATR 2510(1958) under Aliphatic Nitramines of WW II and Hexogen, E-Salz and KA-Salz Processes) m)Collective, Series of papers on the prepn and props of nitramines in Can J Res 26B,pp 89-103, 114-37, 257-70, 271-80, 284-93 and 294-308(1948) & CA 42,4918,4919,5843 and 5844(1948) n)L. Hege, Przemysl Chem 4, 522-4(1948) & CA 43,4218(1949) (A review on the prepn of nitramines) o)Collective, Can J Res 27B, 218-37,462-8, 469-74, 489-502, 503-19 & 520-44(1949) & CA 43,8534-5, 9072-75(1949) (Series of papers on the prepn of some explosive nitramines by nitrolysis of hexamethylenetetramine) p)Collective, JCS 1949,1631-58 & CA 44, 1410-13(1950) (Eight papers on the prepn and props of several nitramines, called in these papers "nitroamines"). The compds in these papers which contain about or more than 14% nitro- or nitroxynitrogen are listed individually in this dictionary because they may be potential components of explosive propellent or pyrotechnic comps) q)HACSIR (Canada), Brit P 615,419 & 615,793(1949) (Nitramines and their preparation, mostly polymethylene polynitramines, eg 3,7-dinitro- pentamethylenetramine, cyclotetramethylenetetramine, cyclotrimethylenetrimine, 1,9-diacetoxypentamethylene-2,4,6,8-tetranitramine, 1,9-dinitroxy-2,4,6,8-tetranitramine, etc) r)W.L.C. Veer, Rec 57,989-1015(1938) & CA 24,72341-3(1950) & CA 45,1048-9(1951) (Prepn and props of linear secondary nitramines) s)A.T. Blomquist & F.T. Fiedorek, USP 2,481,283(1949) & CA 44,4925(1950)(Prepn and props of some nitroalkylnitramines) t)A.T. Blomquist & F.T. Fiedorek, USP 2,485,855(1949) & CA 44,3516(1950)(Prepn and props of some nitramines and nitrated aminoalcohols) u)J.A. Harpham et al, JACS 72,341-3(1950) & CA 45,1048-9(1951) (Prepn and props of linear secondary polynitramines, some of which are explosive, eg 1,8-dicyclohexylxyl nitramine-3,6-dinitro-3,6-di azaoctane) v)W.W. & W.J. Dunning, JCS 1950,2920-28(1950) & CA 45,4642-44(1951) (Methylennitramines) w)I. Berman et al, Can J Chem 29,767-76(1951) & CA 46,2084(1952)(Nitrolysis of hexamethylenetetramine) x)J.W. Bachmann et al, JACS 73,2769-73(1951) & CA 46,2084(1952)(Cyclic and linear nitramines formed by nitrolysis of hexamine) y)Collective, JCS 1951,1282-89 & CA 46,
Amines, Nitrated and Nitrited, Analytical Procedures. Many of the procedures used for the analytical determination of amines are applicable to nitramines and nitrosamines (see Refs under Amines). Detn of the nitro-group in nitramines is given in Org Analysis 2(1954), 78, 80, & 85


[Secondary nitramines prepd by nitrating secondary amines or their nitrates are proposed for use as explosives, e.g. Bis(2-nitro-ethyl)-nitramine]
Amines

Amines have been used with good results in some processes. Aminoacetic Acid; Aminoethanoic Acid; Glycine are some of the amines used. Complexes are explosive and are described under Amine Picrates.

Addi. Refs E.g.i.k & 1 under Amines and Imines

Aminized Cellulose. See Aminated Cellulose

Aminoacetic Acid; Aminoethanoic Acid; Glycine or Glycocoll (Gelatin Sugar or Glycocin) (Leim zucker or Leimsii in Ger and Sucre de Gelatine, in Fr) H₂N·CH₂·COOH, mw 75.07, N 18.66%. Col crys, mp 232–6° (decomp), d 1.161. Very sol in w, sl sol in alc, insol in eth. Was obtained from its ammonium salt, as described in Ref 2. Some of its salts are expl, eg Ag₃H₂N₂O₄.


AMINOCETOPHENONES AND DERIVATIVES

Aminoacetophenone; Acetylphenylamines or Aminophenacys, H₂N.C₆H₄.CO.CH₃. Three isomers are described in Beil 14, 41,45,46, (364,365,366) & [28,30]

Aminoacetophenones, Azido Derivatives

C₄H₄N₂O₃, mw 176.18, N 31.80%. One isomer o-azido aminoacetophenone or o-aminophenacyl azide, H₂N.C₆H₄.CO.CH₃.N₃, crysts, mp 66-70 is described by J.H.Bayer & D.Straw, JACS 75, 1642 & 2684-5(1953). Diazotization of this comp and treatment with NaN₃ in dil acid gave expl o-azidophenacyl azide

Aminoacetophenone, Diazido Derivative, C₄H₄N₂O₃ was not found in Beil or CA through 1956

Mononitraminoacetophenones, C₅H₄N₂O₃. The following isomer is described in Beil:

2-Nitraminoacetophenone or 2-Acetylphenylnitramine, (O₃N)H.N.C₆H₄.CO.CH₃, crysts, mp 103-4°, was prepd from methylantranil, Na nitrite and HCl
Its silver salt, \((O_2N)\text{AgN} \cdot \text{C}_2\text{H}_5 \cdot \text{CO} \cdot \text{CH}_3\), yields voluminous powders, deflagrates suddenly on heating with evoln of yell vapor.

**Refs:** 1) Beil 16, (401) 2) E. Bamberger, Ber 48, 548 & 557–8 (1915) & CA 9, 1780 (1915)

**Dinitroaminocetophenone** and higher nitrat derivs were not found described in Beil or CA through 1956.

**Aminoaacidines**, \(\text{C}_4\text{H}_{16}\text{N}_2\text{O}_1\), mw 194.23, N 14.48%. Three isomers are described in the literature. No azido- or diazido-compds were found in Beil or CA through 1956. Mononitro-, dinitro- and trinitro-aacidines are described in the literature but none of them are reported to be expl. If tetranitroaminoaacidine was known it very likely would be an expl because its NO\(_2\) nitrogen content is ca 15%. This compd however, is not listed in Beil or CA through 1956.

Following are some refs on amino-acridine, aminoacridine nitrate and mono-, di- & trinitroaminoaacidines.


**Aminoalcohols** (Hydroxyamines; Alcamines or Alkanolamines) contain both the amino- and the hydroxyl groups attached to different C atoms, usually adjacent, such as: monoethanolamine or 2-aminoethanol \(\text{HOCH}_2\text{CH}_2\text{NH}_2\), diethanolamine or 2,2'-iminodiethanol \(\text{HOCH}_2\text{CH}_2\text{NH} \cdot \text{CH}_2\text{NH} \cdot \text{CH}_2\text{OH}\), and triethanolamine \(\text{HO(CH}_2\text{OH})_3\text{N}\). Many amino alcohols and their derivs are important products of commerce and some of them serve for the prep of expls.

**Aminoalcohols, Nitrated and Nitrited.** Similar to the amines, aminoalcohols may be converted into various types of derivatives contg oxynitro groups. Many of these comp are expl, as for instance, diethanolnitraminedinitrate \(\text{O}_2\text{NO} \cdot \text{CH}_2\text{CH}_2\text{NH} \cdot \text{CH}_2\text{O} \cdot \text{CH}_3\); diethanolnitrosaminodinitrate \(\text{O}_2\text{NO} \cdot \text{CH}_2\text{CH}_2\text{CH}_2\text{NH} \cdot \text{CH}_2\text{O} \cdot \text{CH}_3\); nitroxyethyleneaminenitrate, \(\text{O}_2\text{NO} \cdot \text{CH}_2\text{CH}_2\text{OH} \cdot \text{HNO}_3\); 1,9-dinitroxypentamethylene-2,4,6,8-tetranitramine, \(\text{O}_2\text{NO} \cdot \text{CH}_2\text{CH}_2\text{N} \cdot \text{NO}_2\) \(\cdot \text{CH}_2\text{CH}_2\text{N} \cdot \text{NO}_2\) \(\cdot \text{CH}_2\text{N} \cdot \text{NO}_2\) \(\cdot \text{CH}_2\text{CH}_2\text{O} \cdot \text{NO}_2\). The individual nitrated derivs are described under the parent aminoalcohol.

**Refs:** 1) Sidgwick (1942), 41–3 2) Kirk & Othmer I (1947), 729 3) Hickinbottom (1948), 158–60

their nitrate esters). Some nitrate esters are suitable as nonvolatile NC gelatinizers

**Aminoalcohols, Aliphatic, Nitrated Derivatives**, investigated during WW II under the direction of Prof A.T. Blomquist included:

a) \(N-(\beta\)-Nitroxyethyl\)nitramine, designated as NENA

b) \(N-(\beta\)-Nitroxyethyl\)methylnitramine, designated as MeNENA
c) \(N-(\beta\)-Nitroxyethyl\) ethylnitramine, designated as EtNENA
d) \(N-(\beta\)-Nitroxypropyl\)methylnitramine, designated as Me₂NENA
e) \(N-(\beta\)-Nitroxypropyl\)nitramine, designated as isoMeNENA

\(\text{Nitrate}\) g) \(N\)-Bis(\(\beta\)-Nitroxyethyl)nitramine, designated as DINA

h) \(N\)-Bis(\(\beta\)-Nitroxyethyl)methylnitramine and i) \(N\), \(N\)-Bis(\(\beta\)-Nitroxypropyl) nitramine

All of these compds, with the exception of a), e) and i), were prep'd by the catalyzed Bamberger reaction. This reaction, which appears to be generally applicable to the prep of secondary nitramines, is as follows:

\[
\text{R}_2\text{NH}^+\text{NO}_3^- + \text{AC}_2\text{O} \rightarrow \text{R}_2\text{NNO}_2 + \text{H}_2\text{O}
\]

Ref: A.T. Blomquist & F.T. Fiedorek, ORSD Rept 4134(P B 18867X1944), pp 28-9 (Several refs are given in the report together with the description of each of the above compds)

**Aminoolkylguanidines and Alkylaminoguanidines.**

Aminoolkylguanidines are compds in which an amino-group has replaced a H atom of the alkyl group of an alkylguanidine (eg, aminomethylguanidine \(\text{H}_2\text{N}:\text{NH} \cdot \text{CH}_2\text{NH}_2\), aminoethylguanidine, etc), whereas alkylaminoguanidines are compds in which one or more alkyl-groups have replaced a H atom of the amine group of an aminoguanidine (eg, methylaminoguanidine, \(\text{H}_2\text{N} \cdot \text{Cl}:\text{NH} \cdot \text{NHCH}_3\)).

Since both types of substituted guanidines are described together in many papers, the refs given in this work in most cases include both types.

It should be noted that derivs contg one or two alkyls of low molecular weight (such as methyl, ethyl, propyl, etc) are compds of high nitrogen content and may be of interest as components of propellants and explosives. Their nitrated and/or nitrited derivs would be of even more interest. The individual explosive derivs are described under the parent compd.

Below are some refs to alkylamino- and aminoolkylguanidines:

**Refs:** 1) E. Strack, Z. Physiol Chem 180,198(1929) & CA 23,1880(1929) (Prep of 1-propyl-3-amino-guanidine) 2) G.W. Kirsten & G.B.L. Smith, JACS 58,800-1(1936) & CA 30,8250(1936) (Prep of salts of 1-methyl-3-amino-guanidine, 1-ethyl-3-amino-guanidine and 1-n-butyl-3-amino-guanidine)

3) J.J. Pitha et al, JACS 70,2823(1948) & CA 42,5965(1948) (Prep of 1-n-methyl-3-aminoguanidine, 1-ethyl-3-aminoguanidine)

4) A.H. Greer & G.B.L. Smith, JACS 72,874-5(1950) & CA 45,1958(1951) (Prep and prop of 1-methyl-1-aminoguanidine and its salts)

5) R.A. Henry & G.B.L. Smith, JACS 73, 1858-9(1951) & CA 46,2502(1952) (Prep of 1-methyl-3-aminoguanidine)

6) W.H. Finnegan et al, JACS 74,2981-3(1952) & CA 48,9329(1954) (Prep of 1-methylaminoguanidine and its salts)

**Nitratated Derivatives of Aminoolkylguanidines and of Alkylaminoguanidines.** Following are some refs to compds of this group contg alkyl groups of low molecular weight:

**Refs:** 1) R.A. Henry & G.B.L. Smith, JACS 73, 1858-9(1951) & CA 46,2502(1952) [From the reaction betw methylamine and nitroguanidine the above authors isolated, among other products, 1-methyl-2-amino-3-nitroguanidine. Its isomer 1-methyl-1-amino-3-nitroguanidine was prep'd by the interaction of methylhydrazine and 1-methyl-1-nitroso-3-nitroguanidine, using the method described in JACS 69,3028(1947) & 71,1968(1949)] 2) J.E. DeVries & E.S. Clair Gantz, JACS 76,1009 (1954) & CA 48,7999(1954) (Dissociation constants of 1-methyl-1-amino-3-nitroguanidine) 3) L.A. Burkardt, AnalChem 28,323(1956) & CA 50,7540(1956) (X-ray diffraction spectra of 1-amino-1-methyl-2-nitroguanidine) (This compd was apparently prep'd at the US NavOrd Test Sta, China Lake, Calif but no ref to its method of prep is given in this paper)

**Aminoolkyltetrazoles and Alkylaminotetrazoles.** Aminoolkyltetrazoles are compds in which an amino-group has replaced a H atom of the alkyl group of an alkyltetrazole (eg, aminomethyltetrazole,
A 181

H₂N·H₂C-C-NH-N —N—N

whereas alkylaminotetrazoles are compds in which one or more alkyl-groups have replaced a H atom of the amino group or an aminotetrazole (eg, methylaminotetrazole)

N — CH-NH·CH₃

(See also Aminomethyltetrazole, Aminoethyltetrazole, etc)

Aminoalkylltriazoles and Alkylaminotriazoles.
Aminoalkylltriazoles are compds in which an amino-group has replaced a H atom of the alkyl group of an alkyltriazole (eg, aminoethyltriazole), whereas alkylaminotriazoles are compds in which one or more alkyl-groups have replaced a H atom of the amino group of an aminotriazole (eg, methylyaminotriazole)

Inasmuch as both types of triazole derivs (when one or two alkyls of low mw) are high nitrogen compds, they may be of interest as components of explosives and propellants.

Below are some of the references to alkylamino- and aminoalkyl-tetrazoles:

1) J.Thiele & H.Ingle, Ann 287,249-53(1895) (Some alkyl derivs of aminotetrazole) 2) J.von Braun & W.Keller, Ber 65,1677-80(1932) & CA 27,723(1923) (Synthesis of tetrazole compds from acid nitriles)

3) R.M.Herbst et al, JOC 16,139-49(1951) & CA 45, 6629-31(1951) (18 refs) (Prep of various 1-alkyl-5-aminotetrazoles by the interaction of alklycyanides with hydrazoic acid in benzene soln in the presence of a concd acid; some props of alkylamino- and aminotetrazoles) 4) L.A. Burkardt & D.W. Moore, AnalChem 24,1579-85 (1952) (X-ray diffraction patterns of some tetrazole derivs)


1-Amino-5-allylamino-α-tetrazole (Called Amino-1-allylamino-5-tetrazol by Stollé, CH₃·CH·CH₂·NH·C-(NH₂)·N, mw 140.15, N 59.97%. Lt yel ndls, mp 94°. Was obtained in poor yield by Stollé et al starting from allylthiosemicarbide, NaN₃ and PbO₂ (Ref 2,p 220). Although the compd is not an expl, yet as a high nitrogen compd it may prove to be useful as an ingredient of propellants.


Note: No azido- or nitrated derivs of 1-allylamino-α-tetrazole were found in Beil or CA through 1956.
Aminoaminotetrazine. Same as Diaminotetrazine
Aminoaminoctriazone. Same as Diaminotriazine
Aminoaminotriazole. Same as Diaminotriazole
Aminoaniline. Same as Phenylenediamine, also called Diaminobenzene

AMINOANISOLEs AND DERIVATIVES

Aminoanisoles (Anisidines, Methoxyaminobenzenes or Aminophenolmethyl Ethers), H₂N·C₆H₄·OCH₃, mw 168.15, N 16.66%. Ten isomers are described in: Beil 13, 388–90, 421–2, 520–1,(121, 136–7, 186) & [191–2, 194–5, 215–16, 284 & 286] (See also CA 42,148i, 3968c, 7053d, 8175h & 8790a)
Nitraminoanisoles, (O₂NHN)C₆H₄·OCH₃ – not found in Beil
Dinitroanisoles, H₂N(O₂N)₂·C₆H₄·OCH₃, mw 213.15, N 19.72%. Ten isomers are described in: Beil 13, 393–5, 423–4, 525, 527–9,(122, 137, 188–90, 193) & [186, 290, 293]
Dinitrotriaminoisoles, (O₂NHN)C₆H₄·OCH₃ – Not found in Beil or CA through 1956
Trinitroanisoles; Methoxy-trinitroanisoles or Trinitroanisidines, H₃N(O₂N)₃·C₆H₂·OCH₃, mw 258.15, N 21.71%, OB to CO₂ – 62.0%, OB to CO – 18.6%. The following isomers are described in the literature:

2,4,6-Trinitro-3-aminoanisole or 3-Methoxy-2,4,6-trinitroanisole, O₃N·C·C(OCH₃)₃ = C·NO₂

2,4,6-Trinitro-3-aminoanisole or 3-Methoxy-2,4,6-trinitroanisole, O₃N·C·C(OCH₃)₃ = C·NO₂

2,4,6-Trinitro-3-aminoanisole or 3-Methoxy-2,4,6-trinitroanisole, O₃N·C·C(OCH₃)₃ = C·NO₂

Red crystals (from alc or water), mp 114–120° or 126–128°, when finely pulverized. Easily sol in acet & NB, sol in benz & eth. Can be prepd by saponifying 2,3,5-trinitro-4-chloracetaminoanisole or by several other methods listed in Ref 1. Its expl props were not detd

Refs: 1)Beil 13,(140) & [294] 2)R.Reverdin, Beil 13,388–90, 421–2, 520–1,(121, 136–7, 186) & [191–2, 194–5, 215–16, 284 & 286] (See also CA 42,148i, 3968c, 7053d, 8175h & 8790a)

Nitraminoanisoles, (O₂NHN)C₆H₄·OCH₃ – not found in Beil
Dinitroanisoles, H₂N(O₂N)₂·C₆H₄·OCH₃, mw 213.15, N 19.72%. Ten isomers are described in: Beil 13, 393–5, 423–4, 525, 527–9,(122, 137, 188–90, 193) & [186, 290, 293]
Dinitrotriaminoisoles, (O₂NHN)C₆H₄·OCH₃ – Not found in Beil or CA through 1956
Trinitroanisoles; Methoxy-trinitroanisoles or Trinitroanisidines, H₃N(O₂N)₃·C₆H₂·OCH₃, mw 258.15, N 21.71%, OB to CO₂ – 62.0%, OB to CO – 18.6%. The following isomers are described in the literature:

2,4,6-Trinitro-3-aminoanisole or 3-Methoxy-2,4,6-trinitroanisole, O₃N·C·C(OCH₃)₃ = C·NO₂

2,4,6-Trinitro-3-aminoanisole or 3-Methoxy-2,4,6-trinitroanisole, O₃N·C·C(OCH₃)₃ = C·NO₂

2,4,6-Trinitro-3-aminoanisole or 3-Methoxy-2,4,6-trinitroanisole, O₃N·C·C(OCH₃)₃ = C·NO₂

Red crystals (from alc or water), mp 114–120° or 126–128°, when finely pulverized. Easily sol in acet & NB, sol in benz & eth. Can be prepd by saponifying 2,3,5-trinitro-4-chloracetaminoanisole or by several other methods listed in Ref 1. Its expl props were not detd

Refs: 1)Beil 13,(140) & [294] 2)R.Reverdin, Beil 13,388–90, 421–2, 520–1,(121, 136–7, 186) & [191–2, 194–5, 215–16, 284 & 286] (See also CA 42,148i, 3968c, 7053d, 8175h & 8790a)
Aminoanisole, Analytical Procedures are discussed in OrgAnalysis 3(1956),184

Aminoanthracene. Same as Anthramine

AMINOANTHRAQUINONES AND DERIVATIVES

Aminoanthraquinones, $C_6H_4 - \overset{\text{O}}{\text{CH}}_2_\text{NH}_2$, 

mw 223.22, N 6.28%, are described in Beil 14, 177, 191,(436,449) & [99, 107]

Aminoanthraquinones, Azido Derivatives, $C_6H_4N_2O_3$ – were not found in Beil or CA through 1956

Aminoanthraquinones, Diazo Derivatives, $C_6H_4N_3O_3$ – were not found in Beil or CA through 1956

Mononitroaminoanthraquinones, $C_4H_N_2O_4$, mw 268.22, N 10.45%, are described in Beil 14,187–9,195–6,(447–8,458–9) & [105–6,117]

Nitraminoanthraquinones, $C_6H_4 - \overset{\text{O}}{\text{CH}}_2_\text{NH}_2$.

NHNO$_3$, mw 268.22, N 10.45%, are listed in Beil 16,671,(401) & [348]

Note: One of the compds, 2-nitraminoanthraquinone, patented by the ChemFabrik Griesheim-Elektron, SwissP 62,348(1912) & CA 8,2263 (1914), was reported to expl at 206°. It is a yel powder obtained by treating anthraquinone-2-isodiazotate with an oxidizing agent

Dinitroaminoanthraquinones, $C_4H_8N_2O_6$, mw 313.22, N 13.42% are listed in Beil 14,190, 197 & [106]

Nitronitraminoanthraquinones, $C_14H_8N_2O_6$, mw 313.22, N 13.42%. The following isomers are listed in the literature:

2(?)-N-Nitro-1-nitraminoanthraquinone,

CO

\[ \text{C}_6\text{H}_4 - \overset{\text{O}}{\text{CH}}_2_\text{NH}_2 - (\text{NO}_2)\text{NHNO}_2 \]

obt by treating its Na salt(see below) with dil HCl; expl at 149–50° on rapid heating and 10–15° lower if slowly heated. Its Na salt was obtained by slowly adding 10 g aminoanthraquinone to 100 cc HNO$_3$(d 1.50) at −10°, stirring for 1½ hrs and treating the mixt with 20% CH$_3$COONa. Yel-brn crys of the Na salt separate out

Refs: 1)Beil 16,[348] 2)E.Terres, Monatsh 41,603–12(1921) & CA 15,3835(1921)

4-Nitro-1-nitraminoanthraquinone,

CO

\[ \text{C}_6\text{H}_4 - \overset{\text{O}}{\text{CH}}_2_\text{NH}_2 - (\text{NO}_2)\text{NHNO}_2 \]

explg ca 117°; insl in w, sol in aq NaOH soln & concd H$_2$SO$_4$. Can be prepd by treating 1-nitraminoanthraquinone with HNO$_3$(d 1.50)

Refs: 1)Beil 16,679 2)Höchster Farbw, ChemZt 1905 I, 313

3-Nitro-2-nitraminoanthraquinone,

CO

\[ \text{C}_6\text{H}_4 - \overset{\text{O}}{\text{CH}}_2_\text{NH}_2 - (\text{NO}_2)\text{NHNO}_2 \]

explg at 180–291°, depending on the rate of heating; sl sol in acet & NB, sol in concd H$_2$SO$_4$ & in alkalis, insol in other org solvents. Can be prepd by treating 2-aminoanthraquinone with HNO$_3$(d 1.50) plus some urea at below −10°. Its Na salt expl when heated over an open flame

Refs: Beil 16,679 & (401) 2)R.Scholl et al, Ber 37,4431–5(1904)

Dinitronitraminoanthraquinones, $C_14H_8N_4O_6$, mw 358.22, N 15.64%, OB to CO$_2$ −102.7%. The following isomers are described in the literature:

2,4-Dinitro-1-nitramino-anthraquinone,

CO

\[ \text{C}_6\text{H}_4 - \overset{\text{O}}{\text{CH}}_2_\text{NH}_2 - (\text{NO}_2)\text{NHNO}_2 \]

...
crysts, mp — expl at 137–142° on rapid heating, decomp ca 100° on slow heating, sometimes expl when treated with a small amt of concd H₂SO₄; diff sol in org solvents of low bp. Was prepd by treating its Na salt with dil HCl. The Na salt was obtained in the same manner as the Na salt of ?-N-nitro-1-nitrosoanthraquinonone (above) by prolonging the reaction at —10° to 2 hrs and then continuing for 15 hrs at 0°.

Refs: 1) Beil 16, 348 2) E. Terres, Montasn 41, 603–12 (1921) & CA 15, 3835 (1921)

1,2-Dinitro-2-nitroanthraquinone,

\[
\text{C}_6\text{H}_4\left(\text{C}_6\text{H}(\text{NO}_3)_2\right)\text{NHNO}_2. \text{Lt yel ndls, explg ca 99°; sol in acet and some other org solvents. Can be prepd by treating 2-aminoanthraquinone with HNO}_3(\text{d} 1.52) \text{ at 35–40°.}
\]

Refs: 1) Beil 16, 679 2) R. Scholl et al, Ber 37, 4436–7 (1904)

Trinitroanthraquinones, C₁₄H₁₁N₄O₄, mw 358.22, N 15.64%; higher nitrated derivs were not found in Beil or CA through 1956

Aminocarylguanidines; Arylaminoquanidines; Aminocaryl tetrazoles; Arylaminotetrazoles; Aminocaryltribrazoles and Arylamino tribrazoles; are compds similar to aminoalkylguanidines, alkylaminoguanidines, etc except that they contain aryl-groups instead of alkyl-groups.

There are also alkylaryl derivs of amino-quanidines, tetrazoles and triazoles.

Some of these compds are described individually, such as aminobenzohydroxytriazole, aminobenzotriazole, aminobenzyltetrazole, aminoethoxyphényltetrazole, aminomethoxyphenyltriazole and aminophenyltetrazole.

Refs — see under the individual compounds mentioned above

Aminoazourolic Acid (Amidoazourolisulure, in Ger), H₂N·C(NO₃)·N·NH·C(\text{NO}_\text{H})·NH₂, mw 146.12, N 57.52%. Orange-red ndls with a bluish surface luster, mp — decomp explosively ca 184°; sl sol in cold w, sol in hot w, nearly insol in usual org solvents. Can be prepd by treating an aq soln of dihydroxy-quinidine hydrobromide, H₂O·N·C(NH₂)·BH·OH + HBr, under strong cooling with an aq soln of NaOH.

On heating with dil HCl, aminoazourolic acid partly decomp and also forms a deriv of tetrazine, isonitrosoaminodihydrotetrazine hydrochloride

\[
\text{HN:C} \quad \text{C:N·OH + HCl}
\]

\[
\text{NH·NH}
\]

Refs: 1) Beil 3, 121 2) H. Wieland & H. Bauer, Ber 40, 1683–7 (1907)

AMINOAZOBENZENES AND DERIVATIVES

Aminoazobenzenes; Phenylazoanilines or Benzeneazoanilines,

\[
\text{C}_6\text{H}_₅·\text{N·N·C}_6\text{H}_₄·\text{NH}_₂, \text{mw 197.23, N 21.31%; exist as three isomers of which the para (4) – isomer is of interest because it forms salts some of which, such as the picrate (Ref 1, p 311) and the perchlorate (Ref 3) are explosive.}
\]

4-(or p-) Aminoazobenzene exists as yel monocl crysts, mp 125–127°, v sl sol in hot w; more sol in eth and hot alc. Many methods for its prepn are listed in Ref 2. Its Qₑ was reported as 7983.7 cal/g (Ref 4) and as 1573.7 kcal/mol (Ref 2 p [150]). Fire hazard and toxicity are unknown. When heated to decomp, it emits toxic fumes (Ref 5).


Note: R. L. Datta & N.R. Chatterjee, JCS 115, 1008(1919) reported that aminoazobenzene exploded at 598°.
Aminoazobenzenes, Azido Derivatives, C_{11}H_{10}N_{6} were not found in Beil or CA through 1956

Aminoazobenzenes, Diazido Derivatives, C_{11}H_{10}N_{6} were not found in Beil or CA through 1956

Mononitroaminooazobenzenes, C_{11}H_{12}N_{6}O_{2}, mw 242.23, N 23.13%. Five isomers are listed in Beil 16,311,(310) & [151,178]; without indicating whether they are explosive or not

Nitronitraminoazobenzenes, C_{12}H_{12}N_{6}O_{4}, mw 287.23, N 24.38%, not found in Beil or CA through 1956

Dinitroaminooazobenzenes, C_{12}H_{12}N_{6}O_{4}, mw 287.23, N 24.38%. The following isomers are listed in Beil 16,342 & (309), without describing their expl props:

2,3'-Dinitro-4-aminooazobenzene, O_{2}N-C_{6}H_{4} -N:N-C_{6}H_{4}(NO_{2})_{2}NH_{2}, yel pdr; mp 175-6° (decomp)

4,6-Dinitro-3-aminooazobenzene, C_{6}H_{4} -N:N -C_{6}H_{4}(NO_{2})_{2}NH_{2}, red ndls, mp 200°

Dinitronitroaminooazobenzenes, C_{12}H_{12}N_{6}O_{6}, mw 332.23, N 25.30%; Trinitroaminooazobenzenes, C_{12}H_{12}N_{6}O_{6}, mw 332.23, N 25.30% and Tetranitroaminooazobenzenes, C_{12}H_{12}N_{6}O_{6}, mw 377.24, N 26.0% were not found in Beil or CA through 1956

Aminoazobenzotriazole. See Aminoazobenzotriazole

AMINO AZO BENZOTRIA ZOLE AND DERIVATIVES

Aminoazobenzotriazoles or Aminoditriazole-azobenzenes are compds of the general formula TrC_{6}H_{4} -N=N-C_{6}H_{4}(NH_{2})Tr, where Tr is a triazole radical

A high-nitrogen compd with the empirical formula C_{12}H_{12}N_{6}, mw 279.26, N 45.15%, is listed in Beil as 5-Amino-(4,5'-azobenzi-triazole) and its formula is given as:

\[
\begin{align*}
\text{N} & \quad \text{C} - \text{CH} - \text{C} - \text{N} \equiv \text{N} \\
\text{N} & \quad \text{NH} - \text{C} - \text{CH} = \text{CH} \quad \text{H}_{2} \text{N} \cdot \text{C} - \text{C} - \text{C} - \text{N} \equiv \text{N} \\
\text{HC} & \quad = \text{CH} - \text{C} - \text{NH} \\
\end{align*}
\]

In this formula, the connections of the azo-groups are made at positions 4 and 5' and not at positions 1 and 1', as is customary. By placing the azo nitrogens in positions 1,1' and rewriting the above formula as is proposed in our nomenclature, we obtain the formula

\[
\begin{align*}
\text{H}_{2} \text{N} \cdot \text{C} & \quad \text{C} - \text{C} - \text{N} \equiv \text{N} \\
\text{HC} & \quad = \text{CH} - \text{C} - \text{NH} \\
\end{align*}
\]

and the name 2'-Amino-4,5:5'-dinitriazole-azobenzene, yel-brn leaflets, mp > 300°. Can be prep'd by treating an aq soln of 5-aminobenzotriazole hydrochloride with NaNO_{2}


Aminoazobenzotriazoles, Azido Derivatives, C_{12}H_{12}N_{6}, mw 332.23, N 25.30%; Trinitroaminooazobenzotriazoles, N_{8}O, mw 377.24, N 26.0% and Aminoazobenzoditriazole, see Aminoazoxybenzenes, Azido Derivatives, C_{12}H_{12}N_{6}O_{2}, and higher nitrated derivatives were not found in the literature through 1956

AMINO AZOXYBENZENES AND DERIVATIVES

Aminoazobenzenes, C_{12}H_{12}N_{6}O_{2} (N_{8})C_{6}H_{4} -NH_{2}, mw 213.23, N 19.71%. Several isomers are described in Beil 16,654 & [338-9]

Aminoazobenzenes, Azido Derivatives, C_{12}H_{12}N_{6}O_{2} were not found in Beil or CA through 1956

Aminoazobenzenes, Diazido Derivatives, C_{12}H_{12}N_{6}O_{2} were not found in Beil or CA through 1956
3'-Nitro-3-amino-azoxybenzene, O,N,N.C.H₄, (N₂O)·C₆H₄·NH₂, mw 258.23, N 21.70%. Was obtained by reduction of 3,3'-dinitroazoxybenzene by hydrogen in the presence of Pt black in ether (Ref 2). Its expl props were not investigated.

**Refs:** 1) Beil 14, 40 & [28] 2) M.P. DeLange, Rec 45, 48 (1926)

Dinitronitraminobenzaldehyde, (O₂N·HN)-(O₂N)·C₆H₄·CHO and higher nitrated derivatives were not found in Beil or in CA through 1956.

**AMINOBENZAMIDES AND DERIVATIVES**

Aminobenzaldehydes, H₂N·C₆H₄·CHO, mw 121.13, N 11.56%. Three isomers, o-, m-, and p-, exist and are described in Beil 14, 21, 28, 29 (356,359) and (21-2).

**Note:** Prepn of o-aminobenzaldehyde is described in OSRD Rept 739 (1942).

Aminobenzaldehydes, Azido Derivatives, C₆H₄N₃O — were not found in Beil or CA through 1956.

Aminobenzaldehydes, Diazo Derivatives, C₆H₄N₂O — were not found in Beil or CA through 1956.

Mononitroaminobenzaldehydes, H₂N(O₂N)·C₆H₄·CHO, mw 166.13, N 16.86%. Several isomers are described in Beil 14, 28-9, 39, (364) & [21, 27].

Nitraminobenzaldehyde, (O₂N·HN)·C₆H₄·CHO, mw 166.13, N 16.88%. Its isomer, 2-Nitraminobenzaldehyde is described in Beil 16, (400) and

**Dinitraminobenzaldehydes, H₂N(O₂N)₂·C₆H₄·CHO, mw 211.13, N 19.90%. Following isomer is described in Beil:**

3,5-Dinitro-4-aminobenzaldehyde. Yel crysts (from alc), mp 171°; easily sol in chl, bz, AcOH and et acet; diff sol in eth and pet eth. Can be prep'd by treating 3,5-dinitroanil with alcoholic NH₄ or by nitrating (4-aminobenzal)aniline with mixed HNO₃-H₂SO₄ at not higher than 5-6°. Its expl props were not investigated.

3,5-Dinitro-2-aminobenzamide,

\[ \text{HC}=\text{C(CONH}_2\text{)}\text{C} \cdot \text{NH}_2 \]

\[ \text{O}_2\text{N} \cdot \text{C} \text{==CH} \text{==C} \cdot \text{NO}_2 \]

Yel ndls, mp 278° (Ref 3) or 284° (Ref 2); sol in acet & AcOH, s1 sol in alc, eth, benz & w. Can be prepd either by warming 2-chloro-3,5-dinitrobenzoyl chloride with concd NH_3OH soln or by bubbling a current of NH_3 gas through an ethereal soln of 2-fluoro-3,5-dinitrobenzoyl chloride (Ref 3). Its expl props were not investigated.

**Refs:**
1) Beil 16, 602 
2) R. Meldola & L. Eynon, JCS 87, 2–3 (1905) 
3) W. H. Gray & w.

Aminobenzenesulfonic Acid. Same as Aminophenylsulfonic Acid

Aminobenzamidoxytetrazotoc Acid Methyl Ether, \( \text{H}_2\text{N} \cdot \text{C}_6\text{H}_4 \cdot \text{C} \cdot \text{N}_2 \cdot \text{O} \cdot \text{CH}_3 \), mw 191.19, N 36.63%. Ndls (from w), mp 110° and degradates at higher temps. Very sol in alc & eth. Was prepd by reduction of methyl ether of nitrobenzamidoxytetrazotoc acid with SnCl_2 in HCl.

**Refs:**
1) Beil 9, 332 
2) J. Blanksma & N.

Aminobenzimidazole (Benzimidazolimid or N,N-o-Phenylenguanidin in Ger)

\[ \text{C}_6\text{H}_4\text{N} \cdot \text{NH} \cdot \text{C} \cdot \text{NH}_2 \]

mw 133.15, N 31.56%. Ndls (from w), mp 222–224°, v sol in alc & acet, sol in w, diff sol in eth & benz. Can be prepd by prolonged treatment of o-phenylenediamine with cyanogen bromide in water or by other methods. Some of its salts are explosive: nitrate, \( \text{C}_6\text{H}_4\text{N}_2 \cdot \text{HNO}_3 \), mw 196.17, N 28.56%. ndls (from w), mp – expl at 225°; picrate, \( \text{C}_6\text{H}_4\text{N}_2 + \text{C}_2\text{H}_4\text{NO}_3 \), mw 326.26, N 23.20%, mp – decomp explosively at 270°.

**Refs:**
1) Beil 24, 116 & (240) 
2) P. Pierron, Ann Chim (Paris) [8] 15, 189 & 193 (1908) & CR 151, 1365 (1910) 
3) G. Pellizzari & A. Gaiter, Gazz 48 II, 173 (1918) & CA 13, 1584 (1919) 
4) IG Farbenind, FrP 773, 944 (1934) & CA 29, 2177 (1935).

Aminobenzazides and Nitrated Derivatives. See under Aminobenzoic Acids and Derivatives

3,5-Dinitro-2-aminobenzamide, on a heated spatula. It is sparingly sol in boiling alc or acet. Can be prepd by mixing an aq soln of the hydrochloride with PA.

**Refs:**
1) Beil 16, 602 & [306] 
2) R. Meldola & L. Eynon, JCS 87, 2–3 (1905) 
3) W. H. Gray, JCS 1926, 3178–9
methods of prepn of 2-aminobenzimidazoles. The methods of Pierron and Pellizzari & Gaier are considered best

4(or 6)-Aminobenzimidazole or 4-Amino-1,3-
benzodiazole, \( \text{H}_2\text{N} \cdot \text{C}_6\text{H}_4 -\text{NH} \cdot \text{CH} \). Crysts, mp 120–121°. Was prepd by condensing 1,2,3-triaminobenzene with formic acid, similar to the method Woolley used for the prepn of 5(6)-aminobenzimidazole(qv). Its picrate \( \text{C}_9\text{H}_{10}\text{N}_3 \cdot \text{C}_6\text{H}_6\text{N}_6\text{O}_2 \), obtained by crystn from water or orange colored needles, decomps ca 250°.

Refs: 1)Beil & not found 2)C.T.Bahner et al, JACS 74,3689(1952) & CA 48,5183(1954)

(2'-Aminobenzo)-5',6':4,5-(1-hydroxy)-vic-
triazole; 6-Amino-benzazimidole or 2'-Amino-
1-hydroxy-1H-benzotriazole (1-Oxy-6-amino-
benzotriazol in Beil),

\[
\begin{align*}
\text{H}_2\text{N} & \cdot \text{C} \cdot \text{CH} \cdot \text{C} \cdot \text{N(OH)} \cdot \text{N} \\
\text{HC} = \text{CH} & \cdot \text{C} \cdot \text{N(OH)} \cdot \text{N}
\end{align*}
\]

mw 150.14,N 37.32%. Solid which decomps on heating or on standing. Can be prepd by the reduction of 6-nitro-benzazimidol(See under Benzazimidol) with tin and concd HCl. It is from was orange colored needles, decomp ca from water, light-reddish-

brown crysts, mp 108.5–109°. Was first obtained by Woolley (Ref 1) by the condensation of 1,2,4-triaminobenzene with formic acid. He reported the mp of the resulting compd as 105–106°. Van der Want(Ref 2) prepd the same compd and obtained, by crystn from water, light-reddish-

brown crysts, mp 108.5–109° with decompn. Its picrate melts ca 205.5° with decompn.

Refs: 1)Beil – not found 2)D.W.Woolley, J BiolChem 152,225(1944) 3)G.M. van der Want,Rec 67,45–51(1948) & CA 42,5020(1948)

5(or 6)-Aminobenzimidazole or 5-Amino-1,3-
benzodiazole, \( \text{H}_2\text{N} \cdot \text{C}_6\text{H}_4 -\text{NH} \cdot \text{CH} \). Crysts, mp 108.5–109°. Was first obtained by Woolley (Ref 1) by the condensation of 1,2,4-triaminobenzene with formic acid. He reported the mp of the resulting compd as 105–106°. Van der Want(Ref 2) prepd the same compd and obtained, by crystn from water, light-reddish-

brown crysts, mp 108.5–109° with decompn. Its picrate melts ca 205.5° with decompn.

Refs: 1)Beil – not found 2)D.W.Woolley, J BiolChem 152,225(1944) 3)G.M. van der Want,Rec 67,45–51(1948) & CA 42,5020(1948)

Aminobenzimidazoles, Azido Derivatives,
\( \text{C}_7\text{H}_6\text{N}_6 \) – were not found in Beil or CA
through 1956

Aminobenzimidazoles, Diazido Derivatives,
\( \text{C}_7\text{H}_6\text{N}_6 \) – were not found in Beil or CA
through 1956

4(or 7)-Amino-6(or 5)-nitrobenzimidazole,
\( \text{C}_7\text{H}_6\text{N}_6\text{O}_2 \), mw 178.15, N 31.43%. Yel crysts, mp 240–1°(dec). It was prepd by refluxing 5-nitro-1,2,3-triaminobenzene and formic acid in aq HCl, as described in Ref 2


Aminobenzimidazole, It yel ndls(from benz + petr eth), mp 82–83°(decomp); dfgr on rapid heating; insol in w & ligroin; sol in many org solvents. Can be prepd from the hydrazide of anthranilic acid as described in Ref 2


3-Aminobenzazide, It yel ndls(from dil alc), mp 85°, easily sol in eth. Was prepd by interaction of 3-aminobenzohydrazide and benzene-
diazonium sulfate in aq soln. Its expl props were not investigated
Aminobenzoic Acid, Diazido Derivatives,

C₆H₄N₂O₂ – were not found in Beil or CA through 1956

2-Nitro-4-aminobenzamide, H₂N·C₆H₄(NO₂)₂·CO·N₂, mw 207.15, N 33.81%. Red floc ppt; defgr on heating; insol in w, alc or eth. Was prep'd by treating 4-aminobenzohydrazide in AcOH with NaN₂

Ref: 1)Beil 14,440 2)T.Curtius & F.Bollenbach, JPrChem 76,296(1907) & JCS 92 i, 1078(1907)

Notes: No other nitrated aminobenzazides were found in Beil or CA through 1956

Mononitroaminobenzoic Acids, H₂N·C₆H₄(NO₂)·CO·N₂, mw 182.13, N 15.38%. Various isomers are described in Beil 14,373,374, 375,378,414,415,417,439,440,(555,556,557, 565,583) & [233,234,245] Nitrinitroaminobenzoic Acids, O₃N·HN·C₆H₄(NO₂)·COOH, mw 227.13, N 18.50%. Two isomers: 2-nitro-6-nitramino- and 4-nitro-2-nitramino-aminobenzoic acids are listed in Gazz 55, 1632(1955) by G.Berti, S.Carboni & A.Da Settimo [See also CA 50,10041a(1956)]

Dinitroaminobenzoic Acids or Dinitroanthronilic Acids, H₂N·C₆H₄(NO₂)₂·COOH, mw 227.13, N 18.50%. The isomers 2-amino-3,5-dinitro-, 3-amino-2,4-dinitro- and 4-amino-3,5-dinitro- are described in Beil 14,379,445, (555,565) & [236,273] The isomer 3-amino-4,6-dinitro-is described by H.Goldstein & R.Stamm Helv 35,1472(1952), the 2-amino-3,5-dinitro- by H.Goldstein & A.Giddey in Helv 37,1121 & 1124(1954) and the 4-amino-3,5-trinitro-benzoic acid by H.Goldstein & A.Giddey in Helv 37,2084 & 2087(1954)

Dinitronitraminobenzoic Acids, O₂N·HN-C₆H₄(NO₂)₂·COOH, mw 272.13, N 20.59%. The following isomers are described in the literature:

3,4-Dinitro-2-nitraminobenzoic Acid or 3,4-Dinitro-N-nitroanthranilic Acid. Yel, unstable solid, which may be stored for some time in the dark. No mp given. Sol in alc & eth; less sol in w; nearly insol in chl & benz. Was prep'd by adding HNO₃(d 1.48) dropwise to a soln of 4-nitroaminobenzoic acid, while maintaining the temp below -5°. Its expl props were not investigated

Ref: Beil – not found 2)G.Berti, S.Carboni & A.Da Settimo, Gazz 55,1637, 1640-1 (1955) & CA 50,10041a(1956)

3,5-Dinitro-4-nitraminobenzoic Acid. Its monohydrate, C₆H₅N₂O₄·H₂O, exists as yel plates which lose H₂O at ca 95°, decomp ca 135–136° and explodes when heated on a Pt foil. Very sol in alc, eth & AcOH; sol in warm w, diff sol in chl; nearly insol in benz. Was prep'd by nitration of 3,5-dinitro-4-aminobenzoic acid with HNO₃(d 1.48) at 0°

Ref: 1)Beil 16,[350] 2)L.Elion, Rec 42, 175–6(1923) & CA 17,3489(1923)

Trinitroaminobenzoic Acid, H₂N·C₆H₄(NO₂)₃·COOH and higher nitrated aminobenzoic acids were not found in Beil or CA through 1956

Aminobenzophenones, C₆H₄·CO·C₆H₄·NH₂. Several isomers and some nitrated compds, none of them expl, are listed in Beil 14. No azido- or diazido- derivs were found in Beil or CA through 1956

AMINOBENZOTRIAZINES
AND DERIVATIVES

Aminobenzotriazines, C₇H₆N₄, mw 146.15,
N 38.34%. The following isomers are listed in the literature:

3-Amino-asym-benzotriazine or 3-lmino-2,3 (or 3,4)-dihydro-1,2,4-benzotriazine (originally called Aminophentriazin),

\[
\text{HC} = \text{CH} - \text{C} - \text{N} = \text{N} \quad \text{CH} = \text{CH} - \text{C} - \text{N} = \text{NH} \quad \text{CH} = \text{CH} - \text{C} - \text{N} - \text{NH}
\]

Yel ndls, mp 207°. Sol in hot alc and less in 5'. 6':4,5- (a-vic-triazole or (3'-Aminobenzo)tertals, mp 207'. Sol in hot alc and less in 5',6':4,5-(a-vic-triazole. It may also be called 3'-Aminophentriazin).

1-Peryl-4-nitro-5-nitraniino benzo triazole. It is described here because it has a fairly high N content.

Ref: 1)Beil 26,(44) & [90] 2)F. Arndt, Ber 46,3528 (1913) 3)F. Arndt & B. Eistert, Ber 60,2602 (1927) & CA 22,1162 (1928) 4) F. J. Wolf et al, JACS 76,3551-2 (1954) & CA 49,12494 (1955)

3'- Aminobenzo-asym-triazine (Called in JCS 6-Aminobenzo-1,2,4-triazine),

\[
\text{HC} = \text{CH} - \text{C} - \text{N} = \text{N} \quad \text{HC} = \text{CH} - \text{C} - \text{N} = \text{CH}
\]

Shiny golden plate-lets, mp 298°-9° (dec). Was obtained by hy- drogenation of N-2,4-dinitrophenyl-N'-formyl-amidrazine, 2,4-(02 N) C6H4 - NH - NH - CHO, in hot ethanol in the presence of palladium-charcoal. It is described here for the same reason as the above compd

Ref: 1)Beil - not found 2) R. A. Abramovitch & K. Schofield, JCS 1955,2333 & CA 15,12077 (1956)

Aminobenzotriazines, Azido Derivatives, C7H7N3 - were not found in Beil or CA through 1956

Aminobenzotriazines, Diazido Derivatives, C7H7N10 - were not found in Beil or CA through 1956

Mononitroaminobenzotriazines, C6H6N4O2, and higher nitratd and nitrited, derivs were found in Beil or CA through 1956

AMINOBENZOTRIAZOLES AND DERIVATIVES

Aminobenzotriazoles, C6H6N4, mw 134.14, N 41.77%. One isomer, \[
\text{HC} = \text{CH} - \text{C} - \text{NH} - \text{N} \quad \text{H}_2\text{NC} = \text{CH} - \text{C} \quad \text{N}
\]
described in Ref 1 as 5(or 6)-Aminobenzotriazole. It may also be called (3'-Aminobenzo)-5',6':4,5-(a-vic-triazole or (3'-Aminobenzo)-1H-1,2,3-triazole. It forms several salts and a dinitroderiv which contains a phenyl group in the triazole ring. This deriv is called in Ref 2: 1-Phenyl-4-nitro-5-nitraminobenzo triazole and may also be called: \[
(3'-\text{Nitro}-4'-\text{nitro}-\text{benzotriazole})-5',6':4,5-(1-\text{phenyl}-\text{a-vic-triazole}).
\]

[Ref 3. We propose naming the nitro compound \[\text{HC} = \text{CH} - \text{C} - \text{NH} - \text{N} \quad \text{HC} = \text{CH} - \text{C} - \text{N} = \text{CH}
\]

N 27.99%. Lt yel ndls obtnd by treating 1-phenyl-5-acetaminobenzo triazole with nitric acid (d 1.52) (Refs 2 & 3)

Another isomer of aminobenzotriazole,

\[
\text{HC} = \text{CH} - \text{C} - \text{NH} - \text{N} \quad \text{HC} = \text{CH} - \text{C} - \text{N} = \text{CH}
\]

listed in Ref 1 as:

\[
\text{HC} = \text{CH} - \text{C} - \text{NH} - \text{N} \quad \text{HC} = \text{CH} - \text{C} - \text{N} = \text{CH}
\]

It defgrs at ca 175° and its probable formula is

\[
\text{O}_2\text{N} - \text{C} - \text{C} - (\text{NO}_2) = \text{C} 
\]

N 27.99%. Lt yel ndls obtnd by treating 1-phenyl-5-acetaminobenzo triazole with nitric acid (d 1.52) (Refs 2 & 3)

Another isomer of aminobenzotriazole,

\[
\text{HC} = \text{CH} - \text{C} - \text{NH} - \text{N} \quad \text{HC} = \text{CH} - \text{C} - \text{N} = \text{CH}
\]

Another isomer of aminobenzotriazole,

\[
\text{HC} = \text{CH} - \text{C} - \text{NH} - \text{N} \quad \text{HC} = \text{CH} - \text{C} - \text{N} = \text{CH}
\]

Another isomer of aminobenzotriazole,
Aminobenzoylazides or Aminobenzenzides.
See under Aminobenzoic Acids and Derivatives

5-Amino-1-benzyl-vic-tetrazole or 1-Benzyl-
5-amino-vic-tetrazole, [1-Benzyl-tetrazolon-
(5)-imid, in Ger], H N C=N(C\textsubscript{6}H\textsubscript{5}CH\textsubscript{2}) N
\[ \text{N} \]
\[ \text{N} \]

or HN:C-N(C\textsubscript{6}H\textsubscript{5}CH\textsubscript{2}) N, mw 175-19.

Hydrogenative fission of aminobenzyl-
tetrazole gave aminotetrazole (Ref 4)

Refs: 1)Beil 12,1318 & [753] 2)A.W.Hof-
mann, CR 55,901(1862) 3)F.L.Davis & F.H.
Huntress, USP 1,828,960(1932) & CA 26,849
(1932)

Aminobiphenyls, Azido Derivatives, C\textsubscript{12}H\textsubscript{10}N\textsubscript{4} - not found in Beil or CA through 1956

Aminobiphenyls, Diazido Derivatives, C\textsubscript{12}H\textsubscript{10}N\textsubscript{4} - not found in Beil or CA through 1956

Mononitroaminobiphenyls, C\textsubscript{6}H\textsubscript{5} · C\textsubscript{6}H\textsubscript{4}(NO\textsubscript{2})\textsubscript{2}NH\textsubscript{2} or (O\textsubscript{2}N)C\textsubscript{6}H\textsubscript{5} · C\textsubscript{6}H\textsubscript{4} · NH\textsubscript{2}, mw 214.22, N 13.08%.
Several isomers are described in Beil 12,1320–
1(547) & [750-3, 760-1]

Dinitroaminobiphenyls, C\textsubscript{12}H\textsubscript{10}N\textsubscript{2}O\textsubscript{4}, mw 259.22, N 16.21%.
Several isomers are described in Beil 12,1321(546) & [750, 762-3]

Dinitronitraminobiphenyls, C\textsubscript{12}H\textsubscript{10}N\textsubscript{2}O\textsubscript{6} - not found in Beil or CA through 1956

Trinitroaminobiphenyls, C\textsubscript{12}H\textsubscript{10}N\textsubscript{3}O\textsubscript{3}, mw 304.22, N 18.42%. OB to CO \(-157.5\), OB to CO \(-52.6%. Following isomers are described in
the literature:

3,5,4'-Trinitro-2-aminobiphenyl, (O\textsubscript{2}N)C\textsubscript{6}H\textsubscript{5} · C\textsubscript{6}H\textsubscript{4} · NH\textsubscript{2}(NO\textsubscript{2})\textsubscript{3}. Prisms(from pyridine)
mp 239\degree. Can be prep'd by treating 3,5,4'-
trinitro-2-p-toluensulfonilaminobiphenyl,
O\textsubscript{2}N · C\textsubscript{6}H\textsubscript{5} · C\textsubscript{6}H\textsubscript{4}(NO\textsubscript{2})\textsubscript{2} · NH · SO\textsubscript{3} · C\textsubscript{6}H\textsubscript{4} · CH\textsubscript{3}, with H\textsubscript{2}SO\textsubscript{4}. Its expl props were not investigated

Refs: 1)Beil 12,[761] 2)F.Bell, JCS 1928, 2775 & 1930,1075

3,2',4'-Trinitro-4-aminobiphenyl, (O\textsubscript{2}N)\textsubscript{2}C\textsubscript{6}H\textsubscript{5} · C\textsubscript{6}H\textsubscript{4}(NO\textsubscript{2})\textsubscript{2}NH\textsubscript{2}. Orange-yel needles(from glac AcOH), mp 192-3\degree. Was prep'd in small
quantity by heating 4'-bromo-2,4,3'-trinitro-
biphenyl with satd alcoholic NH\textsubscript{4} in a sealed
tube at 150\degree for 8-10 hrs. Its expl props were not investigated

Refs: 1)Beil 12,[764] 2)J.W.Le Fèvre et
al., JCS 1927,2337
Trinitronitraminobiphenyl, C₁₅H₂₅N₆O₆; Tetranitroaminobiphenyl, C₁₅H₂₅N₆O₄ and higher nitrated derivs were not found in Beil or CA through 1956

Aminobiuret. Same as Allophanyihydrazide

Amino-Boranes are complexes of boranes (BH₃) with amines. Most of the secondary and tertiary amines form these complexes. The following amine boranes are manufd by the Callery Chemical Co: a)Dimethylamine-borane, (CH₃)₂NH·BH₃, wh solid b)Trimethylamine-borane, (CH₃)₃N·BH₃ wh solid c)Pyridine-borane, C₅H₄N·BH₃, col liquid

These amine-boranes are relatively stable complexes and are of interest because they act as selective reducing agents, polymerization catalysts, anti-oxidants and stabilizing agents. They may also be used for the prepn of diborane and as petroleum additives. Further information may be obtained from Tech Bull C-200 (Ref 2)


Aminoboronhydride Compounds. Many aminoboronhydride compds and their derivatives are volatile and self-inflammable. A series of papers by H.I. Schlesinger et al published in JACS on boron hydrides (qv) include the prepns and props of the following aminoboronhydrides and their derivatives: borine-amine, H₂N·BH₃ or BH₃N·H; dimethylaminoborine (or dimethyaminoboric acid) (CH₃)₂BNH₂; dimethylaminodiborane (CH₃)₂NB₂H₃; borinetramine B₃N₃H₄; borinetrimethylene (CH₃)₃NBNH₂; amidinodiborane H₂N·B₂H₄ or B₂H₄N; methylaminodiborane CH₃HN·B₂H₄; dimethylaminodiborane (CH₃)₂NB₂H₄ and the very volatile and self-inflaming chloroderivative of dimethylaminodiborane, (CH₃)₂NB₂H₄Cl (See also under Boron)


Aminoboron—Silicon Compounds. See Silylaminoboron Compounds

Aminobutane. Same as Butylamine

2-Amino-1-butanol or 1-Butanol-2-Amine, CH₃·CH₂·CH(NH₂)·CH₂OH, is the parent compd of the following derivative:

2-Nitramino-1-butanol Nitrate or 1-Nitroxy-2-nitramino-butane, CH₃·CH₂·CH(NH·NO₂)·CH₂OH, m.w. 179.14, N 23.46%, OB to CO₂ 67.0%, OB to CO -22.3%. Properties — not found in Beil or CA through 1956

According to Ref 2, the prepn is in agreement with the following scheme:

CH₃·CH₂·CH(NH₂)·CH₂OH
Add ClCOO·C₂H₄,
followed by
aq NaOH
CH₃·CH₂·CH·CH₂·OH
NH·COO·C₂H₄
Add the above
mixt with stir-
ring to 98% nitric acid at 10°

CH₃·CH₂·CH·CH₂·ONO₂
(NO₂)·COO·C₂H₅
Add anhyd NH₃
to the ethereal
soln of the above
nitrated (ammonolysis)

CH₃·CH₂·CH(NH₄⁺)·CH₂·ONO₂
NO₃⁻
Add concd hydro-
chloric acid
CH₃·CH₂·CH(NH·NO₂)·CH₂·ONO₂
Details of this method of prepn are given in Ref 2, pp 122-3 and in the patents (Ref 3, p 15), but no props are described. This nitrate was suggested as a possible gelatinizer for NC.


**AMINOCARBAZOLES AND DERIVATIVES**

**Aminocarbazoles**, \( \text{C}_6\text{H}_4\ldots\text{C}_6\text{H}_4\ldots\text{NH}_2 \)  

mw 182.22, N 15.38%. Its 1-amino, 2-amino- and 3-amino-isomers are described in Beil 22, 460 (642) [370-1] and 1-aminocarbazole is also described by H. Lindemann & F. Werther in Ber 57, 1316 (1924)

**Note:** There is also an N-aminocarbazole or \( \text{N,N-diphenylethydrazine, C}_6\text{H}_4\ldots\text{C}_6\text{H}_4\ldots\text{N}_2 \)

described in Beil 20, (166)

**Aminocarbazoles, Azido Derivatives**,  
\( \text{C}_4\text{H}_8\text{N}_4 = \text{not found in Beil or CA through 1956} \)

**Aminocarbazoles Diazido Derivatives**,  
\( \text{C}_4\text{H}_8\text{N}_4 = \text{not found in Beil or CA through 1956} \)

**Mononitroaminocarbazoles**, \( \text{C}_4\text{H}_8\text{N}_2\text{O}_2 \), mw 227.22, N 18.49%. The 2-nitro-3-amino- and 4-nitro-3-amino isomers are listed Beil 22, 373-4

**Note:** No higher nitrat ed aminocarbazoles were found in Beil or CA through 1956. It is suggested that these compds may have some value in ex pl compns or fuse powders as flash reducing agents or burning rate modifiers.

**Aminocarbonylaminosuccinyl Diazone or Aminocarbonyliminosuccinyl Diazone (Amidocarbon-iminobemsteinsäure-di azid in Ger),**  
\[ \text{H}_2\text{N} \ldots \text{CO} \ldots \text{N} \ldots \text{CH} \ldots \text{CO} \ldots \text{N} \ldots \text{CH} \ldots \text{CO} \ldots \text{N} \ldots \text{CH} \ldots \text{CO} \ldots \text{N} \ldots \text{CH} \ldots \text{CO} \ldots \text{N} \]

mw 224.15, N 50.0%. Oil, expl violently on heating. Can be prep'd by adding dropwise the calcd amt of concd aq. \( \text{NaNO}_2 \) to aminocarbonyliminosuccinyl dihydrazide (in \( \text{HCl} \) and covered with a layer of ether), while maintaining the temp at -10° or below.

**Refs:** 1) Beil - not found 2) T. Curtius & W. Dörr, J Pr Chem 125, 442-3 (1930) & CA 24, 3214 (1930)

**Aminocellulose.** See Aminated Cellulose

**AMINOCARBAZOL ES AND DERIVATIVES**

**1-Amino-5-(o-chlorophenyl)-1H-tetrazole or 1-Amino-5-(2'-chlorophenyl)-1H-tetrazole,**  
\( \text{C}_6\text{H}_5\ldots\text{C}_6\text{H}_4\ldots\text{C}_6\text{H}_5\ldots\text{N}_2 \ldots\text{N}_2 \ldots\text{N}_2 \)

mw 195.62, N 35.80%. Leaflets (from alc), mp 173°, decomp at higher temps with vigorous evoln of gas; sl sol in eth, benz, chlf & hot w, nearly insol in cold w, fairly sol in hot alc & toluene, sol in hot acet. Was obtained by heating 1-(o-chlorobenzal amino)-5-phenyl-1H-tetrazole (sl wet with alc) with concd HCl for 10 hrs. Serves for the prepn of other tetrazoles, some of them descrb'd in Beil 13, 572, 574, 576, 579, 589, 590, 593, 598, 601, 212, 216, 222, 226, 227) & [319, 324, 326, 330, 333, 338]

**Aminohydroxyanthraquinone and Derivatives**

2,4,5,7-Tetranitro-8-aminio-1H-anthraquinone, described under Aminohydroxyanthraquinone and Derivatives Aminocompounds are described individually, such as aminoacetic acid, aminobenzoic acid, aminocarbazole, aminotetrazole, aniline, etc

**AMINOCRESOLS AND DERIVATIVES**

**Aminocresols; Aminohydroxytoluenes; Methylaminophenols or Aminohydroxymethylbenzenes, H\text{N.C}_6\text{H}_4(\text{CH}_3)\text{OH}**. All possible isomers are described in Beil 13, 572, 574, 576, 579, 589, 590, 593, 598, 601, (212, 216, 222, 226, 227) & [319, 324, 326, 330, 337, 338]

**Aminocresols, Azido Derivatives**, \( \text{C}_6\text{H}_4\text{N}_4 \ldots \text{O} \ldots \text{C}_6\text{H}_4\ldots\text{NH}_2 \)

not found in Beil or CA through 1956
Aminocresols, Diazo Derivatives, C₇H₇N₂O₂ not found in Beil or CA through 1956
Mononitraminocresols, O₂N·HN·C₆H₅(CH₃)OH were not found in Beil or CA through 1956
Mononitroaminocresols, H₂N·C₆H₅(CH₃)(NO₂)OH
All possible isomers are described in Beil 13, 574, 578, 595, 605, (213, 228) & [319, 345, 346]
Nitronitraminocresols, C₆H₅N₂O₄ were not found in Beil or CA through 1956
Dinitroaminocresols, C₆H₅N₂O₄, mp 213.5, N 19.72%. The following isomers are described in the literature:

2,4-Dinitro-6-amino-m-cresol; 2,6-Dinitro-4-amino-3-hydroxy-toluene or 2,6-Dinitro-4-amino-3-hydroxy-1-methyl-benzene, H₂N·C₆H₅(CH₃)(NO₂)₄OH. Yel crystals (from alc), mp 151°C (Ref 3), 156°C (Ref 4); decompts at sl. temp; insol in cold w; sol in alc, very sol in eth. Can be prepd by heating 2,4,6-trinitro-3-hydroxytoluene with ammonium sulfide, as indicated in Ref 5.

On treating dinitroaminocresol with nitrous acid, the diazo compd, C₆H₅(CH₃)(NO₂)₄OH·N·N·C₆H₅(CH₃)(NO₂)₄OH, is obtained as golden yel leaflets which expl violently on heating to ca 160°C.

Refs: 1) Beil 13, 591 & 327 2) W. Kellner & F. Beilstein, Ann 128, 166-7 (1863)
3) C. L. Liebermann & W. A. von Döpp, Ann 163, 104-5 (1872) 4) O. Emmerling & A. Oppenheim, Ber 9, 1094 (1876)
5) R. B. Drew, JCS 117, 1617 (1920)

2,6-Dinitro-4-amino-m-cresol; 2,4-Dinitro-6-amino-3-hydroxy-toluene or 2,4-Dinitro-6-amino-3-hydroxy-1-methyl-benzene, H₂N·C₆H₅(CH₃)(NO₂)₄OH. Ruby-red ndls (from alc); mp 160°C (Ref 2), 166.5-167.5°C (Ref 3); diff sol in w. Can be prepd by heating 2,4-dinitro-6-acetamino-3-hydroxytoluene with HCl (Ref 3).

Refs: 1) Beil 13, 595 & 335 2) R. Nietzki & F. Ruppert, Ber 23, 3479-80 (1890)
3) M. T. Bogert & G. H. Conn, JACS 51, 907 (1929)
& CA 23, 1888 (1929)

2,6-Dinitro-3-amino-p-cresol; 3,5-Dinitro-2-amino-4-hydroxy-toluene or 3,5-Dinitro-2-amino-4-hydroxy-1-methyl-benzene,

H₂N·C₆H(CH₃)(NO₂)₄OH. Brn-red ndls (from alc), mp 141-142°C. Can be prepd by briefly heating 3,5-dinitro-2-amino-4-methylaminotoluene with aq NaOH.

Refs: 1) Beil 13, 601 2) A. Sommer, JPR Chem 67, 551 (1903) & JCS 84, 656 (1903)
4,6-Dinitro-3-amino-o-cresol; 3,5-Dinitro-6-amino-2-hydroxy-toluene or 3,5-Dinitro-6-amino-2-hydroxy-1-methyl-benzene, H₂N·C₆H(CH₃)(NO₂)₄OH. Yel ndls (from w). Can be prepd by treating 3,5-dinitro-2-azo-1-methyl-benzene with concd H₂SO₄.

Note: The identity of this compd was not definitely established. It might be 2,6-Dinitro-3-amino-p-cresol.

Refs: 1) Beil 13, 614 2) P. Drost, Ann 313, 315 (1900)

Eso-Dinitro-eso-amino-cresol or x,x-Dinitro-x-amino-x-hydroxy-methyl-benzene, H₂N·C₆H(CH₃)(NO₂)₄OH. Red ndls (from w); mp ca 172°C with decomps. Can be prepd by treating 3,5-dinitro-4-azo-1-methyl-benzene with concd H₂SO₄.


Dinitronitraminocresols, O₂N·HN·C₆H(CH₃)(NO₂)₄OH; Trinitroaminocresols, H₂N·C₆H(CH₃)(NO₂)₄OH and higher nitrated derivs of aminocresols were not found in Beil or CA through 1956.

Aminodiazacycalkenes Nitrat Derivatives. Several nitrated products of 2-amino-1,3-diazacyclo-2-hexenes and 2-amino-1,3-diazacyclo-2-pentenes are described in the literature. Inasmuch as some of these compds contain more than 40% nitrogen, they may be of interest as components of propellants. Some of these compds are described here individually, as well as in the following refs:

1) Beil—not found 2) A. F. McKay & G. F. Wright, JACS 70, 3990 (1948) & CA 43, 2203 (1949) (The nitration products of 2-nitramino-Δ¹,1,3-diazacycloalkenes) 3) A. F. McKay & D. F. Manchester, JACS 71, 1972 (1949) & CA 43, 9065 (1949) (The nitration products of some substituted 2-nitramino-1,3-diazacycloalkenes) 4) L.
Aminodiazacyclohexanone. See Aminotetrahydro-pyrimidone
Aminodiazacyclohexene. See Aminotetrahydro-pyrimidone
Aminodiazacyclopentane. See Aminimidazole
Aminodiazacyclopentanone. See Aminimidazolidone
Aminodiazacyclopentane. See Aminimidazole

4-Amino-diazoaminobenzene, C{sub 6}H{sub 4}N:N.
NH.C{sub 6}H{sub 4}NH{sub 2}, mw 212.25, N 26.40%. White
ndls (from dil alc), dec at 157° and expl when heated in a tube; sol in alc diff sol
in ether & insol in w, or petr ether. Was prepd by treating 4-acetamino-diazoamino-
benzene with Na ethylate.

Ref: 1) Beil 16, 732 2) R. Willstätter & M. Benz, Ber 39, 349 (1906) & CA 1, 302
(1907)

2-Amino-7-diazonaphthalene Bromide Hydro-
bromide, [H.N.C{sub 16}H{sub 8}.N + N] Br.HBr,
mw 331.03, N 12.7%. Yel ndls, mp expl
violently. Prepd by diazotizing 2,7-naph-
thalenediamine in alcoholic soln with hydro-
bromic acid and amyl nitrite. The compd
expl also on contact with concd HNO{sub 3}.

Ref: 1) Beil 16, 610 2) F. Kaufler & U. Karrer, Ber 40, 326 (1907) & JCS 92, 795
(1907)

Aminodibenzofuranes. See Aminodiphenyl-
eoxides

6-Amino-2,2'-dicarboxyphosphiny-6'-diazonium
Chloride, H{sub 2}N

\[
\begin{array}{c}
C_6H_4\text{-C}_6H_4\text{COOH}\CLUS
\\text{HOOC}
\end{array}
\]

mw 319.70, N 13.14%. Red-brn prisms, mp
defgr ca 100°, stable in storage and insensi-
tive to impact. Was prepd by diazotization of
aminodiphenic acid

Ref: 1) Beil—not found 2) J. Schmidt & R.
Schall, Ber 40, 3003 (1907) (footnote 1)

Note: Beil 16, 612 gives the name and
structural formula for the 4'-diazonium salt
but the props are those given in Ber for the
6'-diazonium compd. No litr was found for
the 4'-compd

Aminodiestholan or Dihydroxyethylamine.
Same as Diethanolamine

Aminodimethylidiazacycloptenene. See Amino-
dimethylimidazoline

AMINODIMETHYLIMIDAZOLINE
AND DERIVATIVES

Aminodimethylimidazoline or Aminodimethyl-
diazacycloptenane, C{sub 6}H{sub 11}N{sub 3}, mw 113.16, N
37.14%, may be considered as the parent
compd of the following derivs:

Aminodimethylimidazoline, Azido Derivative,
C{sub 6}H{sub 9}N{sub 3} not found in Beil or CA through
1956

Aminodimethylimidazoline, Diazido Derivative,
C{sub 6}H{sub 9}N{sub 3} not found in Beil or CA through
1956

2-Amino-4,4-dimethyl-1-nitro-1,2-imidazole
or 2-Amino-4,4-dimethyl-1-nitro-1,3-diaza-
cyclo-2-pentene, H{sub 2}C-N(NO{sub 2})-C.NH{sub 2},

\[
(CH_3)_{2}C-\text{N(NO}_2)\text{-C. NH}_2
\]

mw 158.16, N 35.43%—not found in Beil or
CA through 1956

2-Amino-4,4-dimethyl-1-nitro-1,3-imidazole
Nitrate or 2-Amino-4,4-dimethyl-1-nitro-
1,3-diazyacyclo-2-pentene Nitrate,
H{sub 2}C-N(NO{sub 2})-C.NH{sub 2}

\[
(CH_3)_{2}C-\text{N(NO}_2)\text{-C. NH}_2
\]

mw 221.18, N 31.67%. Crysts (from abs alc),
mp 179-181°. Was prepd by refluxing 1-(β-
nitroxy-tert-butyl)-3-nitroguanidine with
some n-butanol for 30 mins followed by
evaporation of the soln

Ref: 1) Beil—not found 2) L. Fishbein &
J. A. Gallaghan, JACS 76, 3219(1954) & CA
49, 8991 (1955)
2-Nitramino-4,4-dimethyl-1-nitro-$\Delta^2$-imidazole
or 2-Nitramino-4,4-dimethyl-1-nitro-1,3-
diaacyclo-2-pentene,
\[ H_2C-N(NO_2)\cdot-C\cdot NH\cdot NO_2 \]
\[ (CH_3)_2C\cdots\cd-
Mononitroaminodiphenylamines, $\text{H}_2\text{N}$(O$_2$N)$_2$·C$_6$H$_4$·NH·C$_6$H$_4$, mw 229.23, N 18.33%. The isomers 4-nitro-2-amino- and 6-nitro-2-amino-diphenylamine, are described in Beil 13,29,(10) & [21]

Nitronitraminodiphenylamines, $\text{C}_6\text{H}_4\text{N}_2\text{O}_4$, mw 274.23, N 20.43%, were not found in Beil or CA through 1956

Dinitroaminodiphenylamines, $\text{H}_2\text{N}$(NO$_2$)$_2$·C$_6$H$_4$(NO$_2$)$_2$, mw 274.23, N 20.43%. The isomers 2',4'-dinitro-2-amino-; 2',4'-dinitro-3-amino- and 2',4'-dinitro-4-amino-diphenylamine are described in Beil 13,41 & (7)

Dinitronitraminodiphenylamines, $\text{H}_2\text{N}$(NO$_2$)$_2$·C$_6$H$_4$·NH·C$_6$H$_4$·NO$_2$, mw 274.23, N 20.43%. The isomer 4,3'-dinitro-2-aminodiphenylamine is described in Beil 13,17 & [32,60]

Dinitroaminodiphenylamines, $\text{H}_2\text{N}$(NO$_2$)$_2$·C$_6$H$_4$·NH·C$_6$H$_4$·NO$_2$, mw 319.23, N 21.94%. Not found in Beil or CA through 1956

Trinitroaminodiphenylamines, $\text{C}_{12}\text{H}_5\text{N}_3\text{O}_6$, mw 319.23, N 21.94%, OB to CO$_2$ at 112.8%. The following isomers are described in the literature:

2',4',6'-Trinitro-2-amino-diphenylamine or N-Picryl-m-phenylenedia mine, $\text{H}_2\text{N}·\text{C}_6\text{H}_4$·NH·C$_6$H$_4$(NO$_2$)$_3$. Red crs from xylene, mp 177°-18°(decomp with frothing), expl on rapid heating; nearly insol in ether & alc, easily sol in acet, NB & xylene. Can be prepd by heating an alc mixt of o-phenylenediamine, picryl acetate and K acetate at 50°, followed by washing the resulting crs with warm w, warm alc and then recrystallizing from boiling xylene

Refs: 1)Beil 13,17 2)H.Leemann & E. Grandmoujin, Ber 41,1308(1908)

2',4',6'-Trinitro-3-amino-diphenylamine or N-Picryl-m-phenylenediamine, $\text{H}_2\text{N}·\text{C}_6\text{H}_4$·NH·C$_6$H$_4$(NO$_2$)$_3$. Red crs(from acet), mp 206°-7°, expl on rapid heating; easily sol in acet, diff sol in alc & AcOH. Can be prepd by a 2-hr heating of picryl chloride with equivalent quantities of m-phenylenediamine-hydrochloride and Na acetate in alc

Refs: 1)Beil 13,41 & [26] 2)G.Jaubert, Ber 31,1181(1898)

2,4,6-Trinitro-3-aminodiphenylamine, $\text{H}_2\text{N}·\text{C}_6$H$(\text{NO}_2)_3$·NH·C$_6$H$_4$. Red ndls(from acet by pptg with alc), mp 191°. Can be prepd by heating a mixt of aniline and 2,3,4,6-tetranitroaniline in benz, or by other methods. Its expl props were not examined

Refs: 1)Beil 13,61 & (17) 2)C.F.vanDuin, Rec 38,94(1919)

2',4',6'-Trinitro-4-amino-diphenylamine or N-Picryl-p-phenylenediamine, $\text{H}_2\text{N}·\text{C}_6$H$_4$·NH·C$_6$H$_4$(NO$_2$)$_3$. DK red(almost black) crs from et acet, mp 185°-7°, expl on rapid heating; sol in et acet & amyl alc, v sol in boiling AcOH or chlf. Can be prepd by treating picryl chloride with p-phenylenediamine in alc, or by other methods

Refs: 1)Beil 79 2)E.Wedekind, Ber 33,343 (1900) 3)R.Ciusa & C.Agostinelli, Atti AccadLin (5)151,240(1906) 4)G.T.Morgan & M.G.Micklewait, JCS 93,608(1908) 5)T.C. Jones et al,JCS 117,1278(1920)

3,2',4'-Trinitro-4-amino-diphenylamine, $\text{H}_2\text{N}·\text{C}_6$H$_4$(NO$_2$)$_3$·NH·C$_6$H$_4$(NO$_2$)$_3$. Red-brn ndls from AcOH, mp 226°. Can be prepd from 2-nitro-1,4-phenylenediamine and 4-chloro-1,3-dinitrobenzene. Its expl props were not investigated

Refs: 1)Beil 13,121 2)Höchster Farbwerke, GerP 110,360(1899) & ChemZtr 1900 II,301 3)F.Reverdin & E.Delétra, Ber 37,1727(1904)

Trinitronitraminodiphenylamines, $\text{C}_{12}\text{H}_5\text{N}_3\text{O}_6$, mw 364.23, N 23.08% - were not found in Beil or CA through 1956
Aminodiphenyleneoxides, C₁₀H₅N₂O₢, mw 364.23, N 23.08%, OB to CO₂ -87.86%. The following isomer is listed in Beil:

2,4,6,3'-Tetranitro-3-amino-diphenylamine 
(Ca 198 [called in Beil N-[3-Nitro-phenyl]-2,4,6-trinitrophenyldiamin-(1,3)]), H₃N(NO₃)₃-C₆H-NH-C₆H₄-N₂O₢. Crystals (from acetic), mp 272°C (decomp). Can be prepared either by heating 2,3,4,6-tetranitroaniline with 3-nitrobenzene in benzene or by fusing N-nitro-N-methyl-2,4,6-trinitro-1,3-phenylenediamine with 3-nitroaniline at 110-120°C. Its expl props were not reported.

Ref's: 1) Beil 18,[422-3] 2) F. Brumberg, Doctoral Dissertation, Gottingen (1925), pp 12, 22 & 27 3) N. M. Cullinane, JCS 1932,2367

Dinitrodiphenyleneoxides, C₁₂H₇N₃O₉, mw 363.20, N 19.28%. The following isomer is described in Beil:

x-Tetranitro-3-aminodiphenyleneoxide, dk red ndls decomp above 280°C; diff sol in alc, acet, chlf & NB, more sol in AcOH. Was prepared by heating 3-bromo-x-tetranitrodiphenyleneoxide with an NCl in a sealed tube at 150°C. This compd is undoubtedly a mild expl, but its expl props were not examined.


Aminodiphenyleneoxides, Azido Derivatives, C₁₂H₇N₃O₉ - not found in Beil or CA through 1956

Aminodiphenyleneoxides, Diazo Derivatives, C₁₂H₇N₃O₉ - not found in Beil or CA through 1956

Mononitrodiphenyleneoxides, C₁₁H₉N₂O₃, mw 228.20, N 12.28%. The following isomers are described in the literature: 3-nitro-2-amino-diphenyleneoxide, mp 222°(Refs 1 & 2), 2-nitro-3-aminodiphenyleneoxide, mp 238-9° (Refs 1 & 2) and 6-nitro-2-aminodiphenyleneoxide, mp 268° (Ref 3)

Ref's: 1) Beil 18,[422-3] 2) F. Brumberg, Doctoral Dissertation, Gottingen (1925), pp 12, 22 & 27 3) N. M. Cullinane, JCS 1932,2367

Aminodiphenylethers, Diazido Derivatives, C₁₀H₇N₃O₉, not found in Beil or CA through 1956
Aminoethane and Derivatives

Aminoethane or Ethylamine, $\text{CH}_2 \cdot \text{CH} \cdot \text{NH}_2$, mw 45.08, N 31.07%. Col liq, mp \(-80.6^\circ\), bp 16.60, d 0.689 at 15°/15°; easily inflammable. Forms numerous salts and other derivs. Prepn and props are given in Beil 4,87–94,(342–5) & [586–9]

Aminoethane, Azido Derivative, called $\beta$-Azidoaminoethane, $\beta$-Azidoethylamine or $\beta$-Triazoeethylamine, $\text{N}_2 \cdot \text{CH} \cdot \text{CH} \cdot \text{NH}_2$, mw 84.08, N 66.64%. Liq, bp 47° at 16.5 mm, d 1.0429 at 25/4°, $N_D$ 1.4635 at 25°; decomp vigorously on contact with $\text{H}_2\text{SO}_4$. This high nitrogen compd was prepd and investigated as described in the refs


Mononitroaminoethane, $\text{O}_2 \cdot \text{N} \cdot \text{C}_2\text{H}_4 \cdot \text{NH}_2$, mw 90.08, N 31.10% – not found in Beil

Nitraminoethane, $\text{N}$-Nitroethylamine or Ethyl-nitramine, $\text{CH}_2 \cdot \text{CH} \cdot \text{NHNO}_2$, mw 90.08, N 31.10%. Col, non-volatile liq with acidic reaction, mp +6°, d 1.1675 at 15°, $Q^\circ$ 372.82 kcal/mol and $Q_c$ 23.1 kcal/mol(Ref 4). Was prepd in 1888 from ethylester of N-ethylcarbamic acid and nitric acid(Ref 3). Other methods of prepn are given in Refs 3 & 5.

Nitraminoethane forms numerous salts, of which the following are explosive: $\text{Ba(C}_2\text{H}_4\text{N}_2\text{O}_2)_2$, mp 228°, expl at higher temps; $\text{Cu(C}_2\text{H}_4\text{N}_2\text{O}_2)_2 + 2\text{H}_2\text{O}$(?) – expl on rapid heating; and $\text{Hg(C}_2\text{H}_4\text{N}_2\text{O}_2)_2$ – expl on heating Ref 2

Nitronitramine, O₂N·C₃H₄·NHNO₃, mw 135.08, N 31.11%, was not found in Beil or in CA through 1956

1-Nitramino-2-nitroxyethane, known as NENA, is a deriv of aminoethanol. See Aminopropanoic or Aminopropionic Acid

Aminoethanecarboxylic Acid. See Aminopropanoic or Aminopropionic Acid

Aminooethanedi peroxide or Ethylaminoperoxide, H₃N·C₂H₄·2H₂O₃, oil; obtained by treating a concd ethereal soln of aminoethane with a concd ethereal soln of H₂O₃. Its expl props have not been examined.

Refs: 1)Beil – not found 2)G.L. Matheson & O. Maas, JACS 51,680–1(1929)

Aminoethanoic Acid. Same as Aminooetic Acid or Glycine

**AMINOETHANOL (ETHANOLAMINE) AND DERIVATIVES**

Aminoethanol; Monoethanolamine; Aminooethyl Alcohol or β-Hydroxyethylamine (Amino-oxyäthan in Ger), H₃N·CH₂·CH₂·OH, mw 61.08, N 22.93%. Prepn and props in Beil 4,274(424) & [717]

Note: Aminoethanol(monoethanolamine) intended for use by the US Ordnance Corps must comply with the requirements of Specification MIL-M-2776

Aminoethanol, Azido Derivative, C₂H₆N₄O – not found in Beil or CA through 1956

Aminoethanol, Diazido Derivative, C₂H₆N₄O – not found in Beil or CA through 1956

Aminoethanol-bis[copper(I)] diazido], Ethanolamine di(cupric oxide) or Monoethanolaminotetrazido-copper, [(N₃)₂·Cu-H₂N·CH₂-OH-Cu(N₃)₂], dk grn cryssts explg ca 186° or when thrown on a preheated metal block. It was obtained in a impure state and in small yield from Cu diazide and aminoethanol.

Refs: 1)Beil – not found 2)M. Straumanis & A. Cirulis, ZAnorgChem 251, 352-3(1943) & CA 37,6574(1943)

1-Nitramino-2-ethanol or β-Nitraminoethanol Alcohol(1-Hydroxy-2-nitramino-ethane)(α-Oxy-β-nitramino-äthan, in Ger), (O₂N·HN)CH₂-CH₂·OH, mw 106.08, N 26.41%. Thck, col syrup, misc wih w. Was prepd by boiling 3-nitrooxzoatetrahydroxylidre,

H₂C-O

H₂C-N·NO₃

(called in Ref 2 μ-céto-N-nitrotetrahydrooxazol), with water

Its silver salt, Ag₃H₂N₂O₄, a col or sl greyish powd, detonated on heating but not as violently as the mercuric salt, Hg(C₂H₆N₂O₄)₄, white, fine ndls, very sl sol in w


Aminoethanol(Ethanolamine) Dinitrate; Nitroxy-oethanolamine Nitrate or Nitroxyethylammonium Nitrate[β-Nitroxyethylamine Nitrate, Nitroxy-ethanolamine Nitrate(Called in CA Formula Index vol 50, p 12F, 2-Aminoethanol Nitrate Nitrate) or Nitroxyethylammonium Nitrate], O₃NO·CH₂·CH₂·NH₂NO₃ or (NO₃)(H₂N·CH₂-CH₂·ONO₃), mw 169.10, N 24.85%, OB to CO₉₋₁₄.2%. Wh crysts, mp 103°, d 1.53(cast). Can be prepd by the nitratation of aminoethanol with concd HNO₃ or mixed HNO₃-H₂SO₄(Refs 2 & 3). It is a powerful expl, with a Trauzl value of 78.5% of NG, or 93% of TNT, but it is unstable, acidic and hygroscopic. Although it was patented in Germany for use in expls (Ref 2), Méard(Ref 5) does not consider it suitable for that purpose on account of its extreme hygroscopicity(See also Ref 4)

1-Nitramino-2-ethanol nitrate; N-(β-Nitroxyethyl) nitramine or 1-Nitramino-2-nitroxy-ethane or NENA (called in Ref 4 1-Nitroxy-3-nitro-2-aza-propane), (O₅N·HN)·CH₂·CH₃·ONO₂, mw 151.08, N 27.81%, OB to CO₂ -15.9%, OB to CO +5.3%. Yel oil, fr p 15°, volatizes rapidly at 360° without expl; but it expld when struck with a 2 kg hammer falling from a height ca 107 cm(50% pt) vs 33 cm for RDX. When heated at 135°, it became acidic in 75 mins. It is nearly insol in w. Power by ballistic mortar test 133.9%(TNT = 100%). Its UV absorption spectra are discussed in Ref 4.

NENA can be prep'd from aminoethanol and ethylchlorocarbonate by the following series of reactions:

a)H₂N·CH₂·CH₂·OH + C₂H₅·COCl + aqNaOH → C₂H₅·COO·HN·CH₂·CH₂·OH
b)Add the reaction mixt dropwise with stirring to 98% HNO₃ at 10°. C₂H₅·COO·HN·CH₂·CH₂·OH HNO₃→ C₂H₅·COO·N(NO₂)₂·CH₂·CH₂·ONO₂

Add NH₃ to the ethereal soln of the above nitrate(ammonolysis) and then add HCl immediately.

\[
\text{C}_2\text{H}_5\cdot\text{COO} \cdot \text{N(NO}_2)_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{ONO}_2 \quad \text{then added NH}_3 \quad \text{HCl immediately}
\]

\[
\text{NH}_3 \quad \text{O}_2\text{N} \cdot \text{HN} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{ONO}_2
\]

followed by HCl

NENA is of interest from the standpoint of expl props because it possesses a structure intermediate between ethylenglycol dinitrate (EGDN) and ethylendinitrinate (EDNA). It was proposed as a gelatinizer of NC for use in propellants and also as an ingredient of some expl comps.

NENA being sl acidic(pH 2.7), can form salts, some of them expl: silver salt, C₅H₄N₂O₄Ag, wh solid darkening on exposure to light and decompg ca 120°(Ref 1, p 72)


2-Amino-2,2-di nitroethanol or 2,2-Dinitromonoethanolamine, H₂N·C(NO₂)₂·CH₂OH, mw 151.08, N 27.81% – not found in Beil or CA through 1956. It may be considered as the parent compd of its K salt although the salt was not prep'd from it.

Its potassium salt, H₂N·C(NO₂)₂·CH₂OK, yel pdr, prep'd from K dinitroethanolate and NH₃, as described in patents listed as Ref 2. It was proposed as a potential ingredient of expl and propellent comps.

\[\text{Refs: 1)Beil – not found 2)F.R.Schenck & G.A.Wetterholm, SwedP 148,217(1954); BritP 129,469(1955); USP 2,731,460(1956) (Example 7) & CA 50,1893,7125(1956)}\]

Aminoethanol, Alkylderivatives of. N-alkyl derivatives of aminoethanol and of aminodi-ethanol were patented in Germany for use as/or in explosives.

\[\text{Refs: 1)Beil – not found 2)Dynamit A-G, GerP 513,653(1930) & CA 25,1675(1931)}\]

Aminoethanol Derivatives, Proposed by E. von Herz for use as/or in expls included among other comds the acyl- and sulfonyl-derivs of nitrated aminoethanol. As an example of an acyl derivative may be cited the compd, [O₂NO·CH₂·CH₂·N(NO₂)CO]₂, mp 88°, prep'd by the condensation of HO·CH₂·CH₂·NH₂ with (COOH)₂, followed by nitration. As an example of a sulfonyl (sulphuryl) derivative may be cited [O₂NO·CH₂·CH₂·N(NO₂)SO₂], prep'd by condensing HO·CH₂·CH₂·NH₂ with SO₃Cl₂, followed by nitration(Ref 3). The same inventor proposed another deriv of amino ethanol, C₄H₄(NO₂)₃·N(NO₂)·CH₂·CH₂·ONO₂, which may be called, 1-nitroxy-N-nitro-N'-(2',4',6'-trinitrophenyl)-aminoethane or trinitrophenyl-ethanol nitramine nitrate(Ref 2).

\[\text{Refs: 1)Beil – not found 2)E.von Herz, GerP 530,704(1930) & CA 26,309(1932) 3)E.von Herz, GerP 543,174(1930) & CA 26,2598(1932)}\]
AMINOETHOXYPHENYLTETRAZOLES AND DERIVATIVES

Aminoethoxyphenyltetrazoles, \( C_9 H_8 N_4 O \), mw 205.22, N 34.13%. The following isomer is described in the literature:

5-Amino-1-p-ethoxyphenyl-\( \alpha \)-vic-tetrazole or 1-p-Ethoxyphenyl-5-amino-1H-1,2,3,4-tetrazole, \( (p-C_6 H_4 O \cdot C_6 H_4) \)

\[
H \equiv N \equiv \equiv \equiv \equiv N
\]

wh ndls, mp 197°C(with previous shrinkage); fairly sol in hot w, nearly insol in cold w & eth, sol in hot alc & sl sol in cold alc. Can be prepd by passing a stream of \( CO_2 \) gas through a boiling mixt of p-ethoxyphenylthiourea, \( PbCO_3 \), and \( NaNO_2 \) in alcohol. Its nitroso compd is expl(see below)

Refs: 1)Beil - not found 2)R.Stollé et al, JPrChem 134,282-3 & 301(1932)

Azidoaminooethoxyphenyltetrazoles, \( C_9 H_{10} N_4 O \), - not found in Beil or CA through 1956

Diazidoaminooethoxyphenyltetrazoles, \( C_9 H_{10} N_4 O \) - not found in Beil or CA through 1956

5-Nitrosamino-1-p-ethoxyphenyl-\( \alpha \)-vic-tetrazole, \( (p-C_6 H_4 O \cdot C_6 H_4) \)

\[
O \equiv \equiv \equiv \equiv \equiv N \equiv \equiv \equiv \equiv \equiv \equiv N
\]

mw 234.22, N 35.88(wh ndls(from acet), mp defgr ca 117°; insol in w, sl sol in hot benz, fairly sol in eth, sol in alc & acet. Can be prepd by adding dropwise to a soln of 5-amino-1-p-ethoxy-phenyl-\( \alpha \)-vic-tetrazole in dil HCl a calcld amt of aq \( NaNO_2 \). The resulting ppt is treated with dil soda soln and dil HCl is added to the dissolved portion. The portn undissolved in soda soln is unreacted aminoethoxyphenyltetrazole


5-Nitramino-1-p-ethoxyphenyl-\( \alpha \)-vic-tetrazole, \( (p-C_6 H_4 O \cdot C_6 H_4) \)

\[
O \equiv \equiv \equiv \equiv \equiv N \equiv \equiv \equiv \equiv \equiv \equiv N
\]

mw 250.22, N 33.59% - not found in Beil or CA through 1956

Note: No higher nitrated derivs were found in the literature

Aminoethylamine. See Ethylenediamine

Aminoethylation. In connection with its general research activities in the field of solid propellants, the Interior Ballistics Laboratory of the BRL(Ballistics Research Laboratory) of Aberdeen Proving Ground studied the polyaminoethylation of cellulose in an exploratory program. The product of this reaction process was called AEC, aminoethylcellulose. It was formed by the graft polymerization of ethylenediamine onto cellulose and could be perchlorated to yield a reasonably stable product AECP, aminoethylcellulose perchlorate. The subsequent successful course of the preparative and burning-characteristic studies led to an expanded program of research and development in this area. Under a contract with the Department of the Army, Ordnance Corps, the Wyandotte Chemicals Corporation, Wyandotte, Mich, undertook an investigation comprising research and development work on AEC, AECP and other fast burning propellants

By March 1, 1957, the aminoethylation of the following materials and compds had been achieved by the Wyandotte Chemicals Corp: cellulose, cellulose derivatives, regenerated cellulose, 2-hydroxymethyl-2-nitro-1,3-propanediol, nylon, polyurethane, polyvinyl alcohol, polyvinylchloride, protein(wool), starch and toluene diisocyanate

Preparation of Aminoethylcellulose Perchlorate and Other Fast-Burning Propellants', Summary Reports: No 1 (June 1955), No 2 (May 1956) and No 3 (June 1957); Contract No DA-20-018-ORD-13364, Project No TB 3-0230, Wyandotte, Mich

Aminoethylation of Cellulose Derivatives and of Regenerated Cellulose. Cellulose obtained by regeneration from a cuprammonium soln of cotton (in the manner described in Rept No 2, p 14) from the Wyandotte Chem Corp gave an amorphous product contg ca 23.5% N when heated with ethyleneimine in a sealed tube at 120°C in the presence of toluene. The cellulose derivatives carboxymethylcellulose and hydroxyethylcellulose (prepd in the manner described in Rept No 3, pp 14–18) gave solid products with nitrogen contents of 24.8 and 28.1% respectively, when heated with ethyleneimine in a sealed tube, in the manner described in Rept No 1, p 6

All the above products resembled aminoethylcellulose and could be perchorlated in the manner described under Aminoethylcellulose Perchlorate


Aminoethylation of N-(2-Hydroxypropyl)-ethylenediamine. "Monolene", which is the trade name of the Wyandotte Chemicals Corp for N-(2-hydroxypropyl)-ethylenediamine, OH

(CH₃·CH·CH₂)·HN·CH₂·CH₂·NH₂

on treatment with ethyleneimine, in the manner described in Rept No 2, p 18, yielded a dark solid ppt contg 29.2% N


Aminoethylation of Toluene Diisocyanate (AETDI). Inasmuch as the aminoethylation of polyurethane had apparently degraded the polyurethane and yielded a methanol-insol product, it was of interest to det whether toluene diisocyanate, CH₃·C₆H₄(NCO)₂, a precursor constituent of polyurethane, could also be aminoethylated to yield an insol product

For aminoethylation, a soln of 1 g of toluene diisocyanate (80% 2,4-isomer and 20% 2,6-isomer) in 10 ml toluene was heated for 16 hrs at 100°C in a sealed tube with 10 ml of ethyleneimine and 0.1 ml of benzyl chloride. The material insoluble in the cooled reaction mixt was washed with methanol and ether and dried. The yield was 8.6 g for a 98% conversion of ethyleneimine to AETDI. The product was a white rubbery solid which swelled strongly in methanol, gradually decompd at ca 150°C and melted when placed on a block at 300°C. When 3.0 g of this product was perchlorated with 70% perchloric acid in methanol, the AETDIP was obtained in a low yield (4.7 g instead of the calcld 7.0 g) but the perchlorate burned readily leaving only a small residue

Ref: Same as under Aminoethylvinyl Chloride, Rept No 3, p 29

Aminoethylcellulose (AEC) (Polyaminomethylated Cellulose). The aminoethylation of cellulose with ethyleneimine had been studied prior to WW II but not for the purpose of using the product as a propellant. Most of the aminoethylated celluloses prepd before work was undertaken by the BRL and the Wyandotte Chem Corp under contract with the Dept. of the Army, Ordnance Corps (see Ref 1 under Aminoethylation Reactions) contained only a small amt of nitrogen. The material prepd at BRL contained up to 20% N (Refs 2 & 3) and the material prepd by the Wyandotte Corp contained 26+% N (Ref 4)

The structure and formula of AEC has not been clearly established but is assumed to be:
OR H OH method showed ca 53% HNO₃, indicating an approx 90% conversion to AECN. The material burned slowly, leaving considerable residue.

Ref: C.T.Lenk et al, "Studies on the Preparation of Aminoethylcellulose Perchlorate and Other Fast Burning Propellants", Wyandotte Chem Corp, Summary Rept No 3(1 June 1957), 18

Aminoethylcellulose Perchlorate(AECP) or Polyaminoethylcellulose Perchlorate. This salt was prepd by adding 70% perchloric acid to a vigorously stirred AEC(amoenoethylcellulose)methanol mixt cooled with an ice bath. A series of methanol washes removed excess acid from the salt(Ref 1 and Ref 2,No 2,p 5). Yields of 80–85% conversion were obtained with the N content of the product 10–11% and the Cl content 20–21%. The N content of AEC used for preparing the perchlorate was 26+%

Following are some properties of AECP:

- explosion temp(PA method) 305–10⁰(5 sec);
- impact test with 2kg wt—detonated at 12";
- hygroscopicity(% gain in wt at RT and 77% RH) 23% after 6 days and 22.3% after 13 days;
- thermal stability—relatively stable at 85⁰ for long periods of time but decomp extensively at 125⁰ within a week;
- tensile strength—decreases with increase in perchlorate content;
- solubility—in solvents, sometimes dissolved at elevated temps with decomp, swelled in some polar liquids; dissociated to some extent in H₂O;
- compatibility with NC— incompatible

It seems that this substance is not as suitable for use in propellants as the polyethyleneimine perchlorate(qv)

AMINOETHYLGUANIDINE AND DERIVATIVES

Aminoethylguanidine, H₂N·CH₂·CH₂·NH·C(NH)·NH₂, may be considered as the parent compd of the following derivs:

Azidoaminoethylguanidine, C₃H₆N₇ – not found in Beil or CA through 1956

Diazidoaminoethylguanidine, C₃H₆N₁₈ – not found in Beil or CA through 1956

1-β-Nitraminoethyl-1-nitroso-2-nitroguanidine, O₄N·HN·CH₂·CH₂·N(NO)·C(N·NO₂)·NH₂, mw 221.14, N 44.34%. Yel crysts (from abs methanol), mp 113°C with decomp. Was obtained by treating 1-nitro-2-amino-2-nitramino-midazolidine, CH₂·N(NO₂)·C(NH₂)·(NH·NO₂)

CH₂ ———— NH

with NaNO₂ and aq HNO₃. Its expl props were not examined. Being a high nitrogen compd, it might prove to be useful as a component of propellants

Refs: 1) Beil – not found 2) R.H. Hall, A.F. McKay & G.F. Wright, JACS 73,2207(1951) & CA 46,1988(1952)

Note: No higher nitrated or nitrited derivs were found in Beil or CA through 1956

β-Aminoethylnitramine. See under Ethylene-diamine

Aminoethylnylon(AEN) and Its Perchlorate (AENP). A product(AEN) contg 29.2 to 29.8% N was obtained by heating a small amt of nylon with ethyleneimine in a sealed tube. The procedure was the same as for aminoethylolation of cellulose(see Rept No 1,p 6). AENP was prepd by adding, with stirring, a soln of 50 ml of 70% perchloric acid in 200 ml ethanol to 4 g AEN(28.8% N) in 100 ml ethanol. After standing for several hours the AENP was filtered off, washed by decantation with methanol and ether and dried. The product contained ca 20.2% Cl and burned readily but with more smoke than aminoethylcellulose perchlorate.(See also Aminoethylation)


Aminoethylpolyurethane(AEPU). A white, rubbery solid contg ca 30.6% N was obtained by treating 1 g of polyurethane(dis solved in 25 ml of toluene) with 10 ml ethyleneimine and 0.1 ml benzyl chloride in a sealed tube at 100°C for 43 hours. Material remaining insol in the cooled reaction mixt was washed with methanol and ether and then dried. Aminoethylolation of polyurethane was accompanied by degradation. The dried product should be suitable for perchloration(See also Aminoethylolation of Toluene Diisocyanate)

Ref: Same as under Aminoethylpolyvinyl Chloride

Aminoethylpolyvinyl Alcohol(AEPVA) and Its Perchlorate(AEPVAP). Treatment of PVA(“Elvanol”) with ethyleneimine in a bomb reactor at 100°C as indicated in Rept No 2,p 37, produced AEPVA with as high as 26.8% N. Treatment of the dry product with 70% perchloric acid in the manner used for aminoethylcellulose perchlorate(AECP) yielded the perchlorate(AEPVAP) with 20.3% Cl and 10.8% N(See also Aminoethylation)


Aminoethylpolyvinyl Chloride(AEPVC). A deep, gummy product, difficult to work with and contg 25.6% N, was obtained by treating one gram of PVC(in 10 ml toluene) with 10 ml of ethyleneimine and 0.1 ml benzyl chloride in a sealed tube at 100°C for 43 hours. Material remaining insol in the cooled reaction mixt was washed with methanol and ether and finally dried(See also Aminoethylation)

Ref: C.T.Lenk et al, “Studies on the Preparation of Aminoethylcellulose Perchlorate and
Other Fast-Burning Propellants’’, Wyandotte Chemicals Corp, Summary Rept No 3(1957), pp 27–29

Aminoethylpropylureas (AEP). A spongy tan gum, contg ca 27.8% N, was prepard by treating wool fabric with ethyleneimine in the manner described under Aminoethylvinylchloride. The aminooethylated wool fabric became a gum when soaked in methanol.(See also Aminoethyl Reactions)

Ref: Same as under Aminoethylpolyvinyl Chloride

AMINOETHYLPROPYLUREAS AND DERIVATIVES

Aminoethylpropylureas, C₅H₁₁N₂O may be considered as the parent compds of the following derivs:

Azidoaooxynoethylpropylureas, C₅H₁₃N₃O – not found in Beil or CA through 1956

Diazidoaooxynoethylpropylureas, C₅H₁₃N₅O – not found in Beil or CA through 1956

N-(β-Atitraminoethyl)-N'-propyl-urea),
O₂N·HN·CH₂·CH₂·HN·CO·NH·C₅H₇, mw 190.20, N 29.46%, crys, mp 78.9–80.5°.
It was prepard by Hall & Wright as described in Ref 2

Refs: 1)Beil – not found 2)R.H.Hall & G.F.Wright, JACS 73,2212(1951)

N-(β-Nitraminoethyl)-N-propyl-N'-nitro-urea,
O₂N·HN·CH₂·CH₂·N(C₃H₇)·CO·NH·NO₂, mw 235.20, N 29.78%, crys, mp 130.2–130.5°.
It was prepard by Hall & Wright as described in Ref 2(see above)

Refs – same as above

Aminoethylstarch(AES) and Its Perchlorate.
A gummy substance contg ca 28.3% N was prepard by heating anhydrous soluble starch with ethyleneimine in toluene in the presence of a small amt of ethylenechlorohydrin in a sealed tube at 100° for 48 hours and then repeating the procedure. Details of the method are given in Rept No 2, p 39. A product contg ca 26% N was also prepard at atmospheric pressure as indicated in Rept No 2, pp 39–40

Treatment of AES with perchloric acid in the manner described under aminoethylcellulose perchlorate gave aminoethylstarch perchlorate (AESP) with a N content ca 14% and Cl 16.8 to 20%.

Since the AES prepard from sol starch was not stable at elevated temps, other starches, such as rice, cor, tapioca and potato were investigated(Rept No 3, p 20). None of them can be recommended because agglomeration occurred and workup was difficult.

After this, a modified sealed tube procedure was used for soluble starch which gave AES with 28.4% N and the AESP with 21.9% Cl. Details of the procedure are given in Rept No 3, p 20(See also Aminoethyl Reactions)


AMINOETHYL TETRAZOLES AND DERIVATIVES

Aminoethyltetrazoles and Ethylaminotetrazoles, C₅H₁₃N₅, mw 113.13, N 61.91%. The following isomers are described in the literature:

5-Amino-1-ethyl-tetrazole or 5-Amino-1-ethyl-1H-tetrazole, H₂N·C=N(C₃H₇)·N·

It is prepard by Hall & Wright as described in Ref 2

5-Ethylamino-α-tetrazole or 5-Ethylamino-1H-tetrazole, \((C_3H_6N_5)\) crystalline, mp 175–6°C (Ref 4). This is one of the 5-alkylaminotetrazoles prepared and studied after WW II at the US Naval Ordnance Test Station, China Lake, Calif. It is the product of so-called thermal isomerization of 5-amino-1-ethyl-tetrazole. When 5-amino-1-ethyl-tetrazole is kept in the molten state at ca 200°C, about 4% of it is isomerized to 5-ethylaminotetrazole and the following equilibrium is established according to the equation

\[
\text{H}_2\text{N} \cdot \text{C} \cdot \text{N}(\text{C}_2\text{H}_5) \cdot \text{N} \rightleftharpoons \text{C} \cdot \text{NH} \cdot \text{N} \cdot \text{C} \cdot \text{NH} \cdot \text{N} \cdot \text{N} \cdot \text{N}
\]

(\(C_3H_6\)HN \cdot C-NH-N \ (Refs 3 & 4)

Since the mp of the isomerized product (5-ethylaminotetrazole) is higher than that of 5-amino-1-ethyl-tetrazole, the equilibrium may be continuously displaced toward the isomerized product by cooling the melt to below the mp of the isomerized product (Ref 3).

The isomerized product can also be prepared directly, similarly to one of the methods of preparation of 5-methylaminotetrazole described in Ref 2, p 785.


5-β-Aminoethyl-1H-tetrazole, \(\text{H}_2\text{N} \cdot \text{C}_2\text{H}_4 \cdot \text{C} \cdot \text{NH} \cdot \text{N}\). Its hydrochloride, \(\text{C}_5\text{H}_7\text{N}_5 \cdot \text{HCl}\), crysts, mp 128–9°C (from eth–alc), was obtained by refluxing 5-β-benzamidoethylyltetrazole suspended in dil hydrochloric acid.

Ref: 1) Beil – not found 2) C. Ainsworth, JACS 75, 1372–9 (1953) & CA 49, 6928 (1955)

Azidoaminoethyltetrazoles, \(\text{C}_3\text{H}_6\text{N}_5\) – not found in Beil or CA through 1956

Diazidoaminoethyltetrazoles, \(\text{C}_3\text{H}_6\text{N}_5\) – not found in Beil or CA through 1956

Aminoethyltetrazoles, Nitrate and/or Nitrated Derivatives were not found in Beil or CA through 1956

AMINOETHYLTRIAZOLES AND DERIVATIVES

Aminoethyltetrazoles, \(\text{C}_4\text{H}_7\text{N}_5\), mw 112.14, N 49.97%. The following isomers of this high-nitrogen compound are described in the literature:

3-Amino-5-ethyl-α-sym-triazole or 5-Amino-3-ethyl-1H-1,2,4-triazole [Called in Ger 3-Äthyl-1,2,4-triazolon-(5)-imid],

\[
\text{C}_3\text{H}_6 \cdot \text{C} \cdot \text{NH} \cdot \text{N} \rightleftharpoons \text{C} \cdot \text{NH} \cdot \text{C} \cdot \text{NH}_2
\]

or

\[
\text{H}_2\text{N} \cdot \text{C} \cdot \text{NH} \cdot \text{N} \rightleftharpoons \text{C} \cdot \text{NH} \cdot \text{C} \cdot \text{NH}_2
\]

or

\[
\text{H}_2\text{N} \cdot \text{C} \cdot \text{NH} \cdot \text{N} \rightleftharpoons \text{N} \cdot \text{C} \cdot \text{NH}_2 \]

Crysts (from ethyl acetate), mp 152°C. Can be prepared from aminoguanidine nitrate and propionic acid. Its nitrate, \(\text{C}_5\text{H}_7\text{N}_5 \cdot \text{HNO}_3\), mw 175.15, N 39.99%, crysts (from eth acet + alc), mp 167°C, is a mild explosive which is soluble in hot water and alcohol.

Ref: 1) Beil 26, (79) 2) J. Reilly & D. Madden
1-\((\beta\text{-Aminoethyl})\alpha\text{-sym-triazole or 1-(2')-Aminoethyl-1H-1,2,4-triazole,}\)

\[
C_2H_4 \cdot NH_2
\]

\[
\begin{array}{c}
\text{HC} - \\
\text{N} - \\
\text{N} - \\
\text{N} - \\
\text{CH}_2
\end{array}
\]

Its dihydrochloride, \(C_2H_4N_2 \cdot 2HCl\), N 30.28%, crysts, mp 182–3°, was prepd by hydrolyzing 1\(\beta\)-phthalimidoethyl 1,2,4-triazole with 6 normal HCl(Ref 2)


3-\((\beta\text{-Aminoethyl})\alpha\text{-sym-triazole or 3-(2')-Aminoethyl-1H-1,2,4-triazole,}\)

\[
\begin{array}{c}
\text{HC} - \\
\text{N} - \\
\text{N} - \\
\text{C} \cdot C_2H_4NH_2
\end{array}
\]

crysts, mp 83–5°. Was obtained by treating 3-\(\beta\)-aminoethyl-1,2,4-triazole dihydrochloride in abs alc with Na methylene(Ref 2)

Its dipicrate, \(C_4H_6N_10O_4\), N 23.97%, crystallized from alc as yell cubes, mp 190°


4-\((\beta\text{-Aminoethyl})\alpha\text{-vic-triazole or 1H-1,2,3-Triazole-4-ethylamine,}\)

\[
\begin{array}{c}
\text{HC} - \\
\text{N} - \\
\text{N} - \\
\text{H}_2NC_2H_4 \cdot C - \\
\text{N}
\end{array}
\]

crysts, mp 157.5–159°; sol in w & in hot alc; nearly insol in eth, acet, ethyl acetate & chlf. Was prepd by treating 1,2,3-triazole-4-ethylamine hydrochloride with Na ethoxide in ethanol, whereas the hydrochloride was obtained from 1,2,3-carboxaldehyde by a series of reactions described in Ref 2


Azidoaminoethyltriazoles, \(C_4H_6N_2\) – not found in Beil or CA through 1956

Azidoaminoethyltriazoles, \(C_4H_6N_4\) – not found in Beil or CA through 1956

3-Nitramino-5-ethyl\(\alpha\text{-sym-triazole or 5-Nitramino-3-ethyl-1H-1,2,4-triazole,}\)

\[
\begin{array}{c}
\text{C}_2\text{H}_4 \cdot \text{C} \cdot \text{NH-N} - \\
\text{N} - \text{C} \cdot \text{NH-NO}
\end{array}
\]

or

\[
\begin{array}{c}
\text{ON} \cdot \text{HNC-NH-N} - \\
\text{N} - \text{C} \cdot \text{C}_2\text{H}_4
\end{array}
\]

also called 5-Nitroimidino-3-ethyl-1H-1,2,4-triazole, \(\text{ONN:C} \cdot \text{NH-N} - \text{C} \cdot \text{C}_2\text{H}_4\)

3-Ethyl-1,2,4-triazol-5-diazoniumhydroxide,

\[
\begin{array}{c}
\text{HO} \cdot (\text{N})\cdot \text{C} \cdot \text{NH-N} - \\
\text{N} - \text{C} \cdot \text{C}_2\text{H}_4
\end{array}
\]

in Beil or CA through 1956

Nitraminoethyltriazole, \(C_4H_6N_2\) – not found in Beil or CA through 1956

Nitronitraminoethyltriazole, \(C_4H_6N_4\) – not found in Beil or CA through 1956

3-(\beta-Ethylaminoethyl)\(\alpha\text{-sym-triazole Dipicrate,}\)

\(C_6H_{14}N_2O_4\), mw 598.40, N 23.41%, ndls, mp 161°. Was prepd by interaction of 3-(\(\beta\)-chloroethyl)-1,2,4-triazole hydrochloride and ethylamine, followed by treatment of the reaction product with picric acid

Refs: 1)Beil – not found 2)C.Ainsworth
Aminoethylureas, C₂H₄N₆O - not found in Beil or CA through 1956

Diazidoaminoethylureas, C₃H₈N₉O - not found in Beil or CA through 1956

3-(2-Aminoethyl)-1-nitrourea or 3β-Aminoethylnitrourea, H₂N·CH₂-CH₂-NH-C(:O)-NH₂, mp 148.13, N 37.83%. Crysts, mp 136-7º (decomp)

According to CA 46, 1988a(1952), the compd prepd by S.S.Barron, R.H.Hall & G.F.Wright, JACS 73, 2205(1951), from 2-nitrimino-2-imidazolidone and called by them 2-hydroxy-2-nitriminoimidazoline, might be the above nitrourea

The same compd was prepd by M.W.Kirkwood & G.F.Wright, JACS 76, 1838(1954), who named it 3β-Aminoethylnitrourea and was characterized by its X-ray diffraction pattern

The kinetics of the alkaline hydrolysis of 3β-aminoethylnitrourea has been studied at 25º by M.A.Weinberger & A.F.McKay, JACS 77, 1321–7(1955); CA 49, 10272(1955)

3-(2-Nitraminoethyl)-1-nitrourea, 3-(β-Nitraminoethyl)-1-nitrourea, or (2-Nitraminoethyl)-nitrourea, (Called 1β-Nitraminoethyl-3-nitrourea by McKay et al.), O₂N·HN(CH₂-CH₂-NH-C(:O)-NH·NO₂, mw 193.13, N 36.24%. Wh crysts(from et acet or hot w), mp 104–105º. Was prepd from 1-nitro-2-nitriminoimidazolidineCH₂-N·NO₂

and Na₂CO₃ or NaOH in H₂O.


Aminoformaldehyde and Derivatives. See Formamide and Derivatives

Aminoguanazole and Derivatives

4-Aminoguanazole; 4-Amino-3,5-diimino-1,2,4-triazolidine; 3,4,5-Triamino-α-sym-triazole or Guanazine, H₃N·C·NH·NH

or H₂N·C=N·N, mw 126.13, N 66.64%.

Col crysts(from w or alc), mp 255–7º(decomp), easily sol in w, diff sol in alc and insol in eth, benz and ligroin, reacts strongly alkaline. Was prepd by heating its hydrobromide with Pb hydroxide for several hours in w at 100º. The hydrobromide was obtd by treating either hydrazine or N,N'-diaminoguanidine hydrobromide with cyanogenbromide (Ref 2, 3 & 4). Its constitution was established by Stollé (Refs 4 & 5)

It forms salts, some of which are explosive, eg, the nitrate, C₃H₆N₆·HNO₃, crysts, mp 210º, expl when heated on a Pt foil(Ref 3)

Azidoaminoguanazoles, C₂H₄N₉ – not found in Beil or CA through 1956

Diazidoaminoguanazoles, C₁H₂N₁₃ – not found in Beil or CA through 1956

Nitratated and/or Nitritated Derivatives of 4-Aminoguanazole were not found in Beil or CA through 1956

AMINOQUANIDINE AND DERIVATIVES

Aminoguanidine or Guanylhydrazine (Kohlen säure-aminid-hydrizid or Hydrazinmonocarbon-säure-aminid in Ger) (Was called Amidoguanadin by Thiele, abbr as AGu, H₂N - C(NH) - NH - NH₂, mw 74.09, N 75.63%, OB to CO₂ - 108%. Crysts, mp - decomp, sol in w, insol in alc. Can be prepd by the reduction of nitroguanidine by Zn dust in dil AcOH or by other methods.

Aminoguanidine Nitrate (AGuN), CH₄N₄ - HNO₃, mw 137.11, N 51.08%, OB to CO₂ - 17.5%, OB to CO - 5.85%. Crysts, mp 144-145⁰; expl at higher temp. Sol in w and alc. Its soly in w at various temps is given in Ref 3. Can be prepd in nearly theoretical yi eld by treating 1 mol of aminoguanidine bicarbonate with 1 mol of dilute (1:1) nitric acid (Ref 3). When an aq soln of the nitrate was heated with NaN₃ and AcOH, as described in Ref 2, p 48, a yel amorphous substance, C₂H₄N₁₆O, was obtained. It expld on heating. Due to the high mp of AGuN it cannot be used alone for cast loading projectiles. Its mp may be somewhat reduced by incorporating either AN or GuN. For instance, the mp of a 50/50 mixt of AGuN/AN is 109⁰ and of an 85/15 mixt of AGuN/GuN is 126° (Ref 3).


Aminoguanidine Picrate (AGuP) (Called Amidoquanidinpickrat by Thiele), CH₄N₄+C₂H₅N₃O₇, mw 303.20, N 32.34%. Yel crysts (from w); mp - expl. Can be prepd by the action of PA or a picrate on a salt of aminoguanidine in aq soln

Refs: 1) Beil 6,279 2) J. Thiele, Ann 270, 27(1892)

Azidoaminoguanidine, CH₄N₉ – not found in Beil or CA through 1956

Diazidoaminoguanidine, CH₄N₁₃ – not found in Beil or CA through 1956

Nitrosaminoguanidine, ON·HN·C(NH)·NH·NH₂, mw 88.07, N 63.62%. This compd is not found in Beil or CA through 1956

Aminoguanidine or Guanylhydrazine (Kohlen säure-amidin-hydrazid or Hydrazinmonocarbon-säure-amidin in Ger) (Was called Amidoquinidine by Thiele), abbr as AGu, H₂N - C(NH) - NH - NH₂, mw 74.09, N 75.63%, OB to CO₂ - 108%. Crysts, mp - decomp, sol in w, insol in alc. Can be prepd by the action of nitroguanidine and/or nitritated derivs, studied in France (Ref 6)

Ref: 3) Larger(1950), 470

Due to the high mp of AGuN it cannot be used alone for cast loading projectiles. Its mp may be somewhat reduced by incorporating either AN or GuN. For instance, the mp of a 50/50 mixt of AGuN/AN is 109° and of an 85/15 mixt of AGuN/GuN is 126° (Ref 3).


Aminoguanidine diazonium Hydroxide (Amidoquinidine diazohydroxyd, in Ger) are the names (misnomers) first given by K. A. Hofmann & R. Roth, Ber 43, 682-4(1910) to a compd of the formula C₂H₄N₁₆O, which is now known as guanyl nitrosaminoguanyltetrazene, also called tetracene

Nitraminoguanidine (NAGu) Aminonitroguanidine (N¹ - Nitro-N-aminoguanidine or 1-Amino-3-nitroguanidine), CH₄N₉O₂, mw 119.09, N 58.82%, OB to CO₂ - 33.6%

Note: NAGu, possessing a labile H atom, is
capable of existing in two forms, one of which has acid characteristics and consequently is able to form metallic derivatives. The structure of the normal form is assumed to be $O_2N\cdot\text{NH} \cdot C(\text{NH}) \cdot \text{NH} \cdot \text{NH}_2$ and of the pseudo-acid form $\text{HO}\cdot N_2\cdot C(\text{NH}) \cdot \text{NH} \cdot \text{NH}_2$.

NAGu consists of white monoclinic crystals (from w), apparent d 0.22 g/cc, mp 184° (decomp); expl. ca 190°. When heated on a metallic spatula near a flame, each particle of NAGu is ignited by the flame. It may be ground in a mortar without producing an expln. One of the methods for its prepn is the interaction of nitroguanidine with hydrazine sulfate in ammonia. This and other methods are described in Refs 1, 2, 3, 4a, 6, 7, 8, 9.

The following properties of NAGu were detd at Picatinny Arsenal: brisance (by sand test) 39.8 g (TNT 43.0 g); minimum c hge for detonating 0.4 g of NAGu in sand test, 0.27 g of MF & 0.20 g tetryl; power (by ballistic mortar test, deflection with 10 g sample) 14° (TNT 12° 25'); impact test with 2 kg wt 22 cm (tetryl 30 cm); friction pendulum test (with steel shoe) snaps but does not burn or detonate; ignitability – not ignited by black powder fuse; explosion temp (5 secs) 190°; hygroscopicity at 30° and 90% RH, 0.72% in 96 hrs; 100° heat test, % loss in 1st 48 hrs 0.12, 2nd 48 hrs 0.15 and no explosion in 100 hrs; 120° vacuum stability test, 11+cc in 16 hrs; solubility at 30° in g/100 cc of water 1.07 (0.32 at 10°), ethanol 0.59, methanol 0.55, acetone 3.3 and ethylenedichloride 0.32 (See also Ref 7a); $\Delta H^\circ 270.14$ kcal/mol and $Q_f^\circ +5.30$ kcal/mol (Refs 4a and 11).

NAGu reduces Fehling’s soln with the formation of an expl copper salt, it also reduces an ammoniacal AgNO$_3$ soln with the formation of an expl silver salt and some gases (See under Nitraminoguanidine Salts).

**Refs:**
1) Beil 3, [101] 2) R. Phillips & J. W. Williams, JACS 50, 2465-70 (1928) (Prepn and props of NAGu) 3) E. R. Riegel & K. W. Buchwald, JACS 51, 492 (1929) (Ultraviolet absorption of NAGu, etc) 4) E. Lieber & G. B. L. Smith, Chem Revs 25, 225 (1939) 4a) A. J. Phillips, JACS 50, 2465-70 (1928) 5) T. E. O’Connor, G. Fleming & J. Reilly, JSCI 68, 309-10 (1949) (Diazotization of NAGu, etc) 6) E. L. Lieber & G. B. L. Smith, JOC 8, 2436 (1939) 7) E. L. Lieber et al, JACS 73, 2327 (1951) (Prepn of NAGu by adding hydrazine hydrate dropwise and with stirring, to a conf procedure of NOTS 7a) 8) R. A. Henry et al, JACS 72 (1950) (NAGu was obtained together with AGu and diaminoguanidine by hydrazinolysis of NGu in aq soln) 9) R. A. Henry et al, JACS 73, 474 (1951) & CA 46, 1987 (1952) (Prepn of NAGu by adding hydrazine hydrate dropwise and with stirring, to NGu. Analysis for detn of purity is described) 10) E. L. Lieber et al, JACS 73, 4726 (1951) (Heats of combus bygroscopicity at 300° and 90% RH, 0.72% in and formn of NAGu and other compds) 11) W. S. McEwan & M. W. Rigg, JACS 73, 4726 (1951) (Prepn of NAGu in 50-60% yields by treating N$_2$H$_4$ \cdot H$_2$O with H$_2$NC$\cdot$NH \cdot NO$_2$ in an unbuffered H$_2$O-system, and neutralizing prior to isolating the NAGu) 12) R. A. Henry, USP 2, 617, 826 (1952) & CA 47, 9352 (1953) (Prepn of NAGu in 50-60% yields by treating N$_2$H$_4$ \cdot H$_2$O with H$_2$NC$\cdot$NH \cdot NO$_2$ in an unbuffered H$_2$O-system, and neutralizing prior to isolating the NAGu) 13) F. L. Scott et al, JApplChem 2, 370 (1952) & CA 48, 3354 (1954) (Prepn of NAGu by adding an aq soln of N$_2$H$_4$ \cdot H$_2$O to an aq soln of azido-nitroamine, N$_3$C$\cdot$(NH) \cdot NH \cdot NO$_2$) 14) W. D. Kummer & P. T. Sah, JOC 18, 669 (1953) & CA 48, 6969 (1954) (The structure of NGu and NAGu)

Addl Refs on NAGu: a) R. A. Henry &

**Nitroaminoguanidine (NAGu) Salts.** As mentioned under nitroaminoguanidine, this compd exists in two forms: the normal and the pseudo-acid. The existence of a pseudo-acid form explains the possibility of formation of metallic salts.

The following heavy metal salts, which may be considered as derived from the pseudo-acid form of nitroaminoguanidine are explosive:

- **Barium Nitroaminoguanidine (BaNAGu),**
  
  \[ \text{Ba} \left[ \text{N:N:C}(:\text{NH})\cdot\text{NH}\cdot\text{NH}_2 \right]_2 \]
  
  mw 373.32, N 37.50%, OB to CO\(_2\), H\(_2\)O & BaO -21.4%. Crysts, mp 187\(^\circ\), expl at higher temp. Can be prepd by treating an aq soln of NAGu at ca 85\(^\circ\) with a hot slurry of Ba(OH)\(_2\), filtering and cooling to obtain crysts (Ref 2).

  A detailed description of the method used at PicArsn is given in Ref 3. BaNAGu was patented for use in priming compositions and for other purposes (Ref 4).

- **Lead Nitroaminoguanidine (LNAGu),**
  
  \[ \text{Pb} \left[ \text{N:N:C}(:\text{NH})\cdot\text{NH}\cdot\text{NH}_2 \right]_2 \]
  
  mw 443.37, N 31.59%, OB to CO\(_2\), H\(_2\)O & PbO -18.0%. It is the most important of the NAGu salts. Pale yell crys, apparent d 0.092-0.096 g/cc, loading d 1.47, mp 182\(^\circ\); insol in org solvents, hydrolyzed by boiling water. Can be prepd by treating an aq soln of NAGu with Pb hydrate (Ref 2). In Ref 4 is given a detailed description of the lab method of prepn used at PicArsn: LNAGu (1g) was dissolved in 25 cc H\(_2\)O and brought to 65\(^\circ\). Pb hydrate (1g), contg 85% H\(_2\)O, was slurred in 15 cc of H\(_2\)O to which was added dextrin or urea in the amt of 0.5 to 1% of the wt of NAGu. The slurry was poured into the agitated NAGu soln during a period of 3 min and the resulting ppt of LNAGu filtered off, rinsed with H\(_2\)O and dried.

  The following props of LNAGu were:

**Refs:**
1) Beil - not found 2) K.D. Ashley, USP 2,251,101 (1941) & USP 2,286,327 (1942) 3) A.J. Phillips, PATR 1183 (1942), 8 4) L.R.V. Clark, USP 2,325,742 (1943) & CA 38, 489-90 (1944)

**Copper Nitroaminoguanidine (CuNAGu),**

\[ \text{Cu} \left[ \text{N:N:C}(:\text{NH})\cdot\text{NH}\cdot\text{NH}_2 \right]_2 \]

mw 299.73, N 46.73%, OB to CO\(_2\), H\(_2\)O & CuO -26.7%. Crysts, mp -expl. Can be prepd by treating an aq soln of NAGu with Cu hydrate (Ref 2).

A detailed description of the method of prepn from NAGu, Cu hydrate and Cu acetate is given in Ref 3. CuNAGu was patented for use in priming and other explosive compositions.

**Refs:**
1) Beil - not found 2) K.D. Ashley, USP 2,251,101 (1941) & USP 2,286,327 (1942) 3) A.J. Phillips, PATR 1183 (1942), 8 4) L.R.V. Clark, USP 2,325,742 (1943) & CA 38, 489-90 (1944)
determined at PicArsn: *brisance* (by sand test, when initiated by MF) 29.9g (TNT 43.0g); explosion temp (5 secs) 208°; impact sensitivity with 2 kg wt 9cm (tetral 30cm); hygroscopicity at 30° and 95% RH 1.91% in 96 hrs; 100° heat test; % loss of wt: 1st 48 hrs 0.40, 2nd 48 hrs 0.77 and no explosion in 100 hrs

LNAGu was patented for use in priming and initiating compositions (Refs 5, 6, 7, & 8)

Tests conducted at PicArsn (Ref 4) have shown that a compn consisting of LNAGu 33.6, KCIO₃ 14.3, Sb₂S₃ 21.5 and glass 30.6%, loaded wet with 2% of shellac, proved to be suitable for caps in lieu of MF or LA compns. The impact test of the above mixt with a 2 kg wt was 2.5 cm, and the delay assembly of a M-48 fuse contg that mixt gave no failures in 30 tests.

Refs: 1) Beil - not found 2) A.J. Phillips, PATR 1104(1941) & PB Rept 3054(1941) 3) K.D. Ashley, USP 2,251,101(1941) & CA & 35,7195(1941) (LNAGu and a process of making it) 4) A.J. Phillips, PATR 1183(1942) p 8 4a) K.D. Ashley, USP 2,286,327(1942) (Ba salt of pseudo-acid of NAGu) 5) L.R.V. Clark, USP 2,325,742 & 2,326,008(1943) & CA 38,488-90(1944) (Use of heavy metals salts such as Pb in initiating expls) 6) L.R.V. Clark, CanP 435,873(1946) and USP 2,405,189(1946) & CA 40,6818(1946) (Electric blasting cap contg a base chge of PETN and a superimposed initiating chge comprised of a mixture of LNAGu 80 and KClO₃ 20%. LNAGu can be rendered more stable for storage by incorporating 0.1 to 5% of an anhydrous salt, such as CuSO₄, capable of taking up H₂O and NH₃; this prevents catalytic decomp of LNAGu)

7) American Cyanamide Corp, BritP 593,878 (1947) & CA 42,7046(1948) (Improvement of the method of prepn described in USP 2,251,101 for the purpose of increasing the loading density of crysts from 0.4 to 0.6 or even 1.0. In the new method, pptn from the aq soln of NAGu and lead hydroxide is made in the presence of more than 0.001% of a hydrophilic colloid based on the wt of the slurry. Suitable colloids include Me cellulose, animal glue, gelatin, agar-agar and pepsin. Examples of various mixts suitable for blasting caps are given in the patent) 8) L.R.V. Clark, USP 2,456,583(1948) & CA 43,3200 (1949) (Same as previous patent)

Nickel Nitroaminoguanidine (An additive product), 2CH₄O₂N₄ + NiO, mw 312.87, N 44.77%, OB to CO₂ -20.4%. Brownish solid; mp - expld with a flash on heating in a flame, but did not expl on heating in a test tube to 220°. Expld mildly on impact. Insol in w and in most org solvents; dissolves in caustics with a blue coloration; decomp by H₂SO₄ with the formation of poisonous gases. Can be prepd by boiling a dil soln of ammoniacal NiSO₄ with a 1% soln of NAGu in the presence of some metallic Ni for 20 min.

An intense deep-blue coloration develops when a trace of a Ni salt is added to an aq soln of NAGu containing some caustic alkali. The coloration lasts 15-20 min and as little as 0.0002 mg may be detected by this method. Cobalt and a number of other metals failed to give this test (Ref 2, p 2467)


Silver Nitroaminoguanidine (SNAGu). An explosive silver compd was obtained by the interaction of aq NAGu and ammoniacal silver nitrate in the cold. The composition of this product was not determined (Ref 2)

Refs: 1) Beil - not found 2) R. Phillips & J.F. Williams, JACS 50,2467-9(1928)

Nitronitrosaminoguanidine, O₂N·NH·C(:NH)·OH·NH·NH·NO, mw 148.09, N 56.72%, OB to CO₂ -10.8%. Solid, expld at 210°, Trauzl test value 70% PA, impact sensitivity expressed as FI (figure of insensitivity) 93% PA. No method of prepn is given in the literature and in Ref 2.
Aminoguanidine and Derivatives, Analytical Procedures. Some info on this subject may be found in the following papers: 1) R. P. Zimmerman & E. Lieber, Anal Chem 22, 1151–5(1950) (21 refs) & CA 45, 499(1951) (Behavior of some comns contg NH-NO₂ groups, such as NAGu, in attempts to reduce them with titanous chloride) 2) R. A. Henry et al, JACS 75, 95 & 96(1953); CA 48, 2052(1954)

(Detn of purity of NAGu by the modified Jamieson method using K iodate for titration)

Aminoguanidinium-3,5-bis(nitramino)-2-(azirinoguanidinium)-1,6-dinitrobiguanidine, or Di-(aminoguanidinium)-1,6-dinitro-2-aminoguanyl-bigu anide in cold H₂O acidified with conc HNO₃ to pH 4.5. X-ray data is given

Refs: 1) Beil - not found 2) R. A. Henry et al, JACS 75, 95 & 96(1953); CA 48, 2052(1954)

1,6-Dinitro-2-(aminoguanyl)-biguanidine, Ammonium Salt, C₃H₁₄N₁₂O₄, mw 326.21, N 51.53%. Wh crysts, mp 115-11.5(°decmp). Was prep'd by adding concd HNO₃ to bis-(aminoguanidinium)-1,6-dinitrobiguanidine and NH₄Cl for 10 min

Refs: 1) Beil - not found 2) R. A. Henry et al, JACS 75, 957 & 959-60(1953); CA 48, 2051(1954)

1,6-Dinitro-2-(aminoguanyl)-biguanidine Nitrate, C₃H₁₄N₁₂O₄·HNO₃, mw 354.32, N 63.26%. Yel crysts, mp 166–7(°dec); sol in w. Was obtained by refluxing nitroguanidine and hydrazine hydrate in MeOH

Refs: 1) Beil - not found 2) R. A. Henry et al, JACS 75, 957 & 960(1953); CA 48, 2050 et seq(1954)

Bis-(aminoguanidinium)-1,6-dinitrobiguanidine or Di-(aminoguanidinium)1,6-dinitrobiguanidine, O₂N·HN·C(·NH)·NH·C·NH·N₂O₄

may be considered as the parent compd of the derivs described below

Aminoguanidinium-3,5-bis(nitramino)-3,5-asymmetric triazole or Aminoguanidinium-3,5-di(nitramino)-1,2,4-triazole. See under Diaminotriazoles

AMINO GUANYLBIGUANIDINE
AND DERIVATIVES

2-(Aminoguanyl)-biguanidine,
H₂N·C(·NH)·NH·N₂O₄

may be considered as the parent compd of the derivs described below

Azidoaminoguanylbiguanidine, C₃H₁₀N₁₂ and Diazidoaminoguanylbiguanidine, C₃H₁₀N₁₈ — were not found in Beil or CA through 1956

Nitroaminoguanylbiguanidine and Nitramino guanylbiguanidine, C₃H₁₀N₁₈O₂ — were not found in Beil or CA through 1956

1,6-Dinitro-2-(aminoguanyl)-biguanidine,
O₄N·HN·C(·NH)·NH·C·NHNO₃ + 2C₂H₆N₄

mw 411.37, N 64.70%. Rosettes or yel-orange
ndls, mp 147–8 (decompn); readily sol in cold
H₂O, sparinglysol in ether, sol in hot w with decompn; dec on
prolonged heating in alc. Was prep by shaking
benzaldehyde in alc with bis-(aminoguanidinum)-1,6-dinitro-2-aminoguanyl-biguanidine
in w. X-ray data are given

Note: C₆H₁₄N₄ = benzalaminoguananidine

Refs: 1) Beil - not found 2) R.A. Henry et al,
JACS 75, 957 & 960(1953); CA 48, 2052(1954)

Aminoguanylnitroaminoguanyl-tetrazene. See
under Bis-(aminoguanyl)-tetrazene

Bis-(benzalaminoguanidinium)-1,6-dinitro-
biguanidine or Di-(benzalaminoguanidinium)-
1,6-dinitrobiguanide. O₂N·HN·C(·NH)·NH·C·NH·C·HN·NO₃ + 2C₂H₁₀N₄,

mw 513.48, N 40.92%. Wh platelets, mp 193°(dec). Was prep by refluxing bis-
(benzalaminoguanidinium)-1,6-dinitrobiguanidine and benzaldehyde in MeOH or by re-
fluxing 1,6-dinitrobiguanide with benzal-
aminoguanidine in MeOH. X-ray data are given

Note: C₆H₁₄N₄ = benzalaminoguananidine

Refs: 1) Beil - not found 2) R.A. Henry et al,
JACS 75, 959(1953) & CA 48, 2051(1954)

Aminoheptanes or Heptylamines, C₇H₁₅N. Several isomers are described in Beil 4,193
(385) & [652]. The most common isomer is
1-Aminohexane or n-Heptylamine, CH₃·(CH₂)₆·
CH₂·NH₂. Its perchlorate was investigated
by R.L. Datta & N.R. Chatterjee, JCS 115,
1008(1918) and found to explode at 265°

Aminohexanes or Hexylamines, C₇H₁₅N. Several isomers are described in Beil 4,188,
(384) & [649-50]. The most common isomer is
1-Aminohexane or n-Hexylamine, CH₃·
(CH₂)₆·CH₂·NH₂. Its perchlorate was
investigated by R.L. Datta & N.R. Chatterjee, JCS 115, 1008 (1918) and found to explode at 278°.

1-Aminohexahydro-2,4,6-triimino-sym-triazine or Amino-isomelamine, called in CA Hexahydro-2,4,6-triimino-s-triazine,

(HN:)C-N(NH₂)₂-C(:NH),

H-N=C(NH)-NH

mw 141.14, N 69.47%. Solid, mp-decomp ca 242°. Can be prepd by treating its hydrochloride with 10% NaOH soln. The hydrochloride was prepd by heating a mixt of K dicyanoguanidine with hydrazine dichloride in water on a steam bath for 3 hrs, followed by filtration.

Amino-isomelamine was patented for use in resin formulations, ion exchange resins, pharmaceuticals, etc (Ref 2). It forms salts, such as picrate, mp 233°.

Note: Amino-isomelamine is included because of its high N content as a possible component of propellants.


Aminohydrazinomercaptotriazoles or Aminohydrazinotriazolethiones, C₅H₅N₂S, mw 146.12, N 26.41%. The following isomer is described in the literature:

4-Amino-5-hydrazino-3-mercapto-4H-s-triazole, or 4-Amino-5-hydrazino-4H-1,2,4-triazole-3-thione (Called in Beil 4-Amino-5-hydrazono-3-thiono-1,2,4-triazolidin) (Called 4-Amino-3-hydrazino-5-mercapto-1,2,4-triazole in Refs 3, 4 & 5), H₂N-HN-C=N-N or H₂N-N:C-NH-NH.

H₂N-N—SH  H₂N-N—CS

Col ndls, mp 228° (Ref 2), 230–1° (Ref 3), 228° (Ref 4), sl sol in w, insol in alc & eth, easily sol in dil acids & alkalies. Can be prepd from 2,5-dimercapto-1,3,4-thiadiazole or by other methods (Refs 2–5).


Aminohydrazinotetrazoles, CH₃N₂, mw 115.11, N 85.19%. The following isomer is listed in the literature:

1-Amino-5-hydrazino-vic(1,2,3,4)-tetrazole

(Amino-1-hydrazino-5-tetrazol, in Ger), H₂N-HN-C=N(NH₃)₂-N. Stolle' and Gaertner

\[
\begin{array}{c}
\text{N} \\
\text{N}
\end{array}
\]

(Ref 2, p 213), stated that this compd can be prepd by treating thiocarbohydrazide with PbO and NaN₃, but they did not describe the method. They did, however, give the method of prepn of 1-amino-5-hydrazino-vic-tetrazole hydrochloride, CH₃N₂·HCl, it yel crys which vigorously decomp with evoln of gas ca 171°; easily sol in w, giving a strongly acidic soln. Its method of prepn consisted of heating 1-dibenzalamino-5-hydrazinotetrazole with 20% hydrochloric acid.

When an aq soln of aminohydrazinotetrazole hydrochloride was treated with NaNO₂ and a part of the reaction mixt evaporated to dryness, the resulting crysts (contaminated with NaCl) explos vigorously when heated in a flame. A still stronger expln took place when a benzene extract of the above reaction mixt was evapd and the resulting crysts heated in a flame.

Refs: 1) Beil – not found  2) R. Stolle & E. Gaertner, JPrChem 132, 213 & 222–3 (1931); & CA 26, 1607 (1932)

Aminohydrazinotriazoles, C₅H₅N₂O, mw 114.12, N 73.65%. The following deriv is listed in the literature:

3-Amino-5-hydrazino-1,2,4-triazole Dihydrochloride, H₂N-HN-C-NH-N + 2HCl,

\[
\begin{array}{c}
\text{C}-\text{NH}_2
\end{array}
\]
N 44.9%, crystals, mp 217° with vigorous decomp.; dissolves in w, giving a strongly acidic soln, nearly insol in alc and insol in eth. Was prep'd by adding the dinitroso deriv of guanazole to a soln of SnCl₂ in HCl.

Refs: 1) Beil - not found 2) R. Stolle & W. Dietrich, JPrChem 139, 199 (1934) & CA 28, 2714 (1934)

AMINOHYDROXYANTHRAQUINONES AND DERIVATIVES

Aminohydroxyanthraquinones (Oxyaminoanthrachinone, in Ger), C₄₆H₂₉NO₃. Various isomers are described in Beil 14, 267-8, 272-3, 275, (502-3, 510, 512) & [167-8, 172-4] Azidoaminohydroxyanthraquinones, C₄₆H₂₇N₃O₅ - not found in Beil or CA through 1956 Diazidoaminohydroxyanthraquinones, C₄₆H₂₅N₅O₇ - not found in Beil or CA through 1956 Mononitroaminohydroxyanthraquinones, C₄₆H₂₃NO₃ - not found in Beil Nitraminohydroxyanthraquinone, C₄₆H₂₁N₂O₃ - not found in Beil

Nitronitrinaminohydroxyanthraquinones, C₄₆H₂₃NO₅. The isomer 3-nitro-2-nitramino-1-hydroxyanthraquinone is described in Beil 16, 681 Dinitroamino-, Dinitronitramino-, Trinitroamino- and Trinitronitramino- hydroxyanthraquinones were not found in Beil or CA through 1956 Tetranitroaminohydroxyanthraquinones, C₄₆H₂₁N₃O₁₃ - not found in Beil or CA through 1956

Tetranitroaminohydroxyanthraquinone (Aminochrysamidic Acid or Chrysammidic Acid), (2,4,5,7-Tetranitro-8-amino-1-oxy-anthracinon or Chrysammid-säure in Ger) (Called by Schunck Aminochrysamminsäure),

H₂N-C₄₆H₂(H(NO₃))₂ CO

ammonium salt, dk olive-grn ndls, was obtained by heating 2,4,5,7-tetranitro-1,8-dihydroxyanthraquinone (chrysamidic acid) with NH₄. This salt, as well as those of potassium and barium deton violently on heating.

Refs: 1) Beil 14, 274 2) E. Schunck, Ann 65, 236-8 (1848)

Note: No higher nitrated derivs of aminohydroxyanthraquinones were found in Beil or CA through 1956

Aminohydroxyazobenzenes, HO-C₆H₄-N:N-C₆H₄-NH₂ or C₆H₄-N:N-C₆H₄(OH)-NH₂. Various isomers are described in Beil 16, 304, 322, (338) & [148, 159]

Note: No azido- or diazido-derivs were found in Beil or CA through 1956. Only one mononitro- and one dinitro-deriv are listed in Beil 16, 402 & [149] but neither is expl. No higher nitrated derivs were found in Beil or CA through 1956

Aminohydroxybenzene. Same as Aminophenol

AMINOHYDROXYBENZOIC ACIDS AND DERIVATIVES

Aminohydroxybenzoic Acids (Amino-oxybenzosäuren, in Ger), H₄N-C₆H₄(OH)-COOH, are described in Beil 14, 577, 579, 587, 589, 592-3, (649-50) & [350, 352, 355-7, 359-60]

Azidoaminohydroxybenzoic Acids, C₆H₅N₃O₃ - not found in Beil or CA through 1956

Diazidoaminohydroxybenzoic Acids, C₆H₅N₅O₇ - not found in Beil or CA through 1956

Nitroaminohydroxybenzoic Acids, C₆H₅N₂O₃ - not found in Beil or CA through 1956

Nitroaminohydroxybenzoic Acids, C₆H₅N₂O₃, mw 198.13, N 14.14%. The following isomers are described in the literature: 3-amino-5-nitro-4-hydroxy- and 3-amino-6-nitro-4-hydroxybenzoic acids.

Refs: 1) Beil 14, 598 2) J. Nevole, Ber 77B,
61(1944) & CA 39,288(1945) (3-amino-4-hydroxy-5-nitro-benzoic acid)

Nitraminohydroxybenzoic Acid and Nitroaminobenzoic Acid were not found in Beil or CA through 1956

Dinitroaminohydroxybenzoic Acids, C₆H₄N₂O₇, mw 243.13, N 17.28%, are not described in Beil, but the following nitrile is known:

2,6-Dinitro-4-amino-3-hydroxybenzonitrile or 2,4-Dinitro-6-amino-3-cyano phenol, H₂N-C₆H(NO₂)₃(OH)-CN, mw 224.13, N 25.00%. Red-yel pdr, mp-expl. Was prepd by treating its K salt with HCl, whereas the K salt was obtained by warming picromatic acid with KCN. Some of its salts are expl (Refs 1 & 2)

Refs: 1)Beil 14,590 2)W.Borsche & A. Heyde, Ber 38,3941-2(1905)

Dinitronitramino- and Trinitroaminohydroxybenzoic Acids were not found in Beil or CA through 1956

Amino- and Hydroxy-methylNitramines. See Hydroxy- and Amino-methyl nitramines

2-Amino-2-hydroxymethyl-1,3-propanedial Trinitrate. See Tris(hydroxymethyl)-amino methane Trinitrate

1-Amino-5-hydroxy-1,2,3-triazole-4-carboxylic acid hydrazide or 1-Amino-4-hydrazidocarbon-5-hydroxytriazole, (Called 1-Amino-4-hydrazidocarbon-5-oxo triazole in Ref 2), HO-C-N(NH₂)₂-N, mw 158.13, N 53.15%. Crysts, mp-decomp. Was prepd by heating 1-naphthalene-sulfone-4-carbethoxy-s-hydroxytriazole with an excess of hydrazine hydrate in a sealed tube for 4 hrs at 95°

Its diammonium salt, C₆H₁₄N₄O₇, N 58.9%, crysts, mp 210° accompanied by expln, was obtained from the mother liquor of the previous operation


Aminohydroxytriazolopyrimidine. Same as Aminotriazolopyrimidinol, p A271

AMINOIMIDAZOLES
AND DERIVATIVES

2-Aminoimidazole; 2-Amino-1,3-di azole or 2-Aminoglyoxaline [Imidazolon-(2)-imid, in Ger], H₂N-C₆H(NO₂)₂ or H₂N-C₆H₃-NH,

HC ______ N  

HC ______ NH

mw 83.09, N 50.57%. Prepn and props are in Refs 1 & 2

This high nitrogen compd forms salts, eg nitrate, C₆H₄N₂.HNO₃, plates mp 135-60° and picrate, C₆H₄N₂.C₆H₅N₂O₇, ndls, mp 236°


Note: No azido-, diazido-, nitro-, nitramino-, amino- and Hydroxy-methylnitramines. See nitroso- or nitronitrosamines were found in Beil or CA through 1956

4(5)-Aminoimidazole or 4(5)-Aminoglyoxaline [Imidazolon-(4 or 5)-imid, in Ger],

HC-NH-CH or H₂N-C-NH-CH, mw 83.09,

H₂N-C ______ N  

HC ______ N

N 50.57%. Prepn and props are in Refs 1, 2 & 3

4(5)-Aminoimidazole Dipicrate, C₆H₄N₃ + 2C₆H₄N₂O₇, ndls, darkening at 200° and melting ca 234°. A small quantity was prepd by Fargher by treating 4(or 5)-aminoimidazole with picric acid in w. Its expl props were not determined (see Refs 2,p 673)

4(5)-Amino-5(4)-imidazolcarboxamidine, C₄H₇N₄, mw 125.14, N 55.97%, was reported as the dihydrochloride, C₄H₇N₄·2HCl, N 35.3%. It was prepd by heating adenine sulfate with HCl in a sealed tube at 150° ± 2° for 2 hrs.

Refs: 1) Beil 24 - not found 2) L.F. Cavalieri et al., JACS 71,3976(1949) & CA 45,121(1951)

Note: No azido-, diazo-, nitro-, nitrino-, nitroso- or nitrinitrosamine-derivs were found in Beil or CA through 1956

AMINOIMIDAZOLIDINES

Aminoimidazolidines or 2-Aminotetrahydroimidazole, H₂C-NH-CH-NH₄. This substance may be considered the parent compd of:

1-Nitro-2-amin-2-nitraminimidazolidine, H₂C=NO-N(N₂)-C(NH₂)-NH₂, mw 230.13, N 34.15%. Solid, mp 275-76.5° C. May be considered the parent compd of:

2-Aminoimidazolidines or 2-Aminotetrahydroimidazole, H₂C-NH-CH-NH₄. This substance may be considered the parent compd of:

1-Nitro-2-amin-2-nitraminimidazolidine, H₂C=NO-N(N₂)-C(NH₂)-NH₂, mw 230.13, N 34.15%. Solid, mp 275-76.5° C. May be considered the parent compd of:


Note: No azido- and diazido-derivs were found in Beil or CA through 1956

AMINOIMIDAZOLINES

Aminoimidazolines and derivatives

2-Amino-Δ²-imidazoline; 2-Amino-Δ¹-1,3-diazacyclopentene; 2-Amino-4,5-dihydro-2-imidazole or N,N'-Ethyleneuguanidine,

[Imidazolidon-(2)-imid, in Ger] H₂C-NH-C-NH₄
or H₂C-NH-C=NH, mw 85.11, N 49.38%. Its

H₂C-NH
prepn and props are given in Beil 24,p 3

It forms salts and yields nitrated and nitrited derivs, but no azido- or diazo-derivs were found in Beil or CA through 1956

2-Nitrimino-Δ³-imidazoline or 2-Nitrimino-Δ²-1,3-diazacyclopenteneH₂C-NH-C-NH₂

mw 130.11, N 43.07%. Solid, mp 220-1° C with decomp. Can be prepd by treating an aq alkaline soln of nitroguanidine with diaminedihydrochloride. Its expl props were not examined.


2-Amino-1-nitro-Δ²-imidazoline,

H₂C=NO-N(N₂)-C(NH₂)-NH₂, mw 230.13, N 34.15%. Solid, mp 133.5° C. Can be prepd by treating 2-amino-1-nitro-Δ²-imidazoline hydrochloride with NH₄OH. Prepn of the hydrochloride is described in Ref 2,p 1618

Its nitrate, C₄H₇N₅O₅, mw 193.12, N 36.26%, mp 161°(with decomp), was prepd by treating N-β-nitroxyethyl-N'-nitroguanidine, O₅NOC₄H₇-CH₃-N=CH(NH₂)NH₂NO₂, as indicated in Ref 2,p 1619. Its picrate, C₄H₇N₅O₅, mw 359.22, N 27.30%, crystals, mp 189.6° C, was prepd by treating 2-amino-1-nitro-Δ²-imidazoline hydrochloride with a saturated picric acid soln.

Reps: 1) Beil 24 - not found 2) A.F.McKay & J.E.M.Milks, JACS 72,1618-19(1950) &
1-Nitro-2-nitramino-Δ³-imidazoline,

\[ H_2C-N(NO)C-NH-NO_2, \text{mw 159.11, N 44.02%}. \]

Crysts, mp 141.2° with decompn. Can be prepd by treating a soln of 2-nitramino-Δ²-imidazoline in 70% nitric acid with NaNO₂. Treating 1-nitroso-2-nitramino-Δ²-imidazoline with aromatic amines inaq ethanol at 30° gave 1-substituted-2-nitramino-Δ³-imidazolines and 1,2-disubstituted-3-nitroguanidines.

Ref s: 1) Beil 24 – not found 2) A.F. McKay, JACS 77, 1058(1955) & CA 49,8929(1955)

Aminoimidazoline and Imidazolidine Substituted Derivatives

a) 1-Methyl-2-nitramino-Δ³-imidazoline,

\[ H_2C-(CH_3)C-NH-NO_2, \text{mw 144.14, N 38.87%}. \]

Crysts, mp 115–116°. Methods of prepn are described in Refs 6, p 386 and 10, p 965.

b) 1-Ethyl-2-nitramino-Δ³-imidazoline,

\[ C_6H_5NO, \text{mw 174.16, N 32.17%}. \]

Its prepn is described in Ref 6, p 386.

c) 1-(2-Hydroxyethyl)-2-nitramino-Δ³-imidazoline or 1-β-Hydroxyethyl-2-nitramino-Δ³-imidazoline,

\[ C_6H_5NO, \text{mw 219.16, N 31.82%}. \]

Crysts, mp 114.8–115.2°. Its prepn by nitration of p-aninoacetanilide with 1-nitroso-2-nitramino-Δ²-imidazoline is described in Ref 6, p 387.

d) 1,2-Bis(2-nitrimino-3-nitro-1-imidazolidyl)-ethane or Bis-1-(2-nitrimino-2-imidazolidinyl)-ethane,

\[ C_8H_5NO, \text{mw 264.16, N 31.82%}. \]

Crysts, mp 114.8–115.2°. Its prepn by nitration of comp d with mixed HNO₃-H₂SO₄ is described in Ref 6, p 387.

e) 1,2-Bis(2-nitrimino-2-imidazolidin-1-yl)-ethene or Bis-1-(2-nitrimino-2-imidazolidinyl)-ethene,

\[ C_8H_5NO, \text{mw 286.26, N 39.14%}. \]

Crysts, mp 300–301° (decomp). Its prepn is described in Ref 6, p 387.

f) 1-(2-Nitroxyethyl)-2-nitrimino-Δ³-imidazoline,

\[ C_6H_5NO, \text{mw 220.15, N 39.14%}. \]

Crysts, mp 300–301° (decomp). Its prepn is described in Ref 6, p 387.

g) 1-(2-Nitroxyethyl)-3-nitro-2-imidazolidine or 1-β-Nitroxyethyl-2-nitrimino-3-nitroimidazolidine,

\[ C_8H_5NO, \text{mw 264.16, N 31.82%}. \]

Crysts, mp 115–116° with decomp. Its prepn by nitration of comp e with HNO₃ in Ac₂O medium is described in Ref 6, p 387. It combines violently with phenylhydrazine giving a partially charred mass.

h) 1-(2-Nitroxyethyl)-3-nitro-2-imidazolidone or 1-β-Nitroxyethyl-2-nitrimino-3-nitroimidazolidone,

\[ C_8H_5NO, \text{mw 220.15, N 25.45%}. \]

Crysts, mp 101–2°. Its prepn by hydrolysis of f is described in Ref 6, p 388.

i) 1,2-Bis(2-nitrimino-3-nitro-1-imidazolidyl)-ethane or Bis-1-(2-nitrimino-3-nitroimidazolidinyl)-ethane,

\[ C_8H_5NO, \text{mw 376.26, N 37.23%}. \]

Crysts, mp 180–19° with decomp. Its prepn
by nitrating compd e) in Ac₂O-HNO₃ is described in Ref 6, p 388

i)1,2-Bis(3-nitro-2-oxo-1-imidazolidyl)ethane or Bis-1-(3-nitro-2-imidazolidonyl)ethane, C₈H₆N₄O₄, mp 288.22, N 29.16%. Crysts, mp 242-3° with decompn. Its prep by hydrolysis of compd h) in boiling water is described in Ref 6, p 388

j)1-Methyl-2-nitrimino-3-nitroimidazoline, C₈H₉N₄O₄, mp 133.6-134°. Its prep is described in Ref 6, p 388

k)1-Ethyl-2-nitrimino-3-nitroimidazoline, C₈H₉N₄O₄, mp 169-70° with decomp. Its prep by nitration of 1-ethyl-2-nitramino-2-imidazoline is described in Ref 6, p 388

l)Guanidinoethylarninoimidazoline, Nitrated and Nitrated Derivatives are described under Aminoimidazolin-1-yl-ethylguanidine

m)1-Nitro-2-amino-4-methyl-Δ²-imidazoline Nitrate, C₈H₆N₄O₄, mp 207.15, N 31.67%. Crysts, mp 150°. Was obtained in 43% yield by treating 1-nitro-2-amino-4-methyl-Δ²-imidazoline hydrochloride with aq alc AgNO₃ soln (Ref 7, p 2207)

n)1-Nitro-2-nitramino-4-methyl-Δ²-imidazoline or 1-Nitro-2-nitramino-4-methyl-Δ³-1,3-diazacyclopentene, C₈H₇N₄O₄, mw 189.14, N 37.03%. Crysts, mp 121.6-123°. Was obtained by treating 1-nitro-2-nitramino-2-imidazoline with HNO₃ + Ac₂O (Rev 3, pp 1971-2 & Ref 4, p 3963). The 2-nitro-2-amino-4-methyl-2-imidazoline, crysts, mp 170.5°, was prep according to the method described in Ref 5

o)1-Nitro-2-ethoxycarbonyl-nitraminoimidazoline, C₈H₅N₃O₅, mw 221.18, N 31.67%. Crysts, mp 133.6-134°. Its prep is described in Ref 2, p 3993

p)1-Nitro-2-propoxy-2-nitraminoimidazoline, C₈H₅N₃O₅, mw 235.20, N 29.78%. Crysts, mp 124.4-125.5°. Its prep is described in Ref 2, p 3993 and Ref 9, p 2215

q)1-Nitro-2-propylamino-2-nitraminoimidazoline, C₈H₄N₄O₄, mw 234-22, N 35.88%. Crysts, mp 124.8-125.7°. Its prep is described in Ref 2, pp 3993-4 and its reactions are given in Ref 8

r)1-Nitro-2-propylamino-Δ²-imidazoline, C₈H₉N₄O₃, exists in the form of its hydrate, C₈H₉N₄O₄, and salts, such as the nitrate, C₈H₉N₄O₃, mw 235.20, N 29.78%, mp 148.8-149° and the styphnate, C₁₃H₁₄N₄O₇, mw 417.30, N 23.50%, mp 163-163.5° with decomp (Ref 8, p 2212)

s)2-Nitrimino-3-propylimidazol-2-one, C₈H₀N₃O₃, mw 144.14, N 38.87%. Crysts, mp 76.5-77°. Its prep is described in Ref 10, p 965

u)1-Nitro-2-propylamino-Δ²-imidazolinium Nitrate, C₈H₉N₄O₄, mw 207.15, N 33.81%. Crysts, mp 172° with decomp. Its prep is described in Ref 10, p 965

v)1-Nitro-2-propylamino-Δ²-imidazolinum Nitrate, C₈H₉N₄O₃, mw 221.18, N 31.67%. Crysts, mp 157.5° with decomp. Its prep is described in Ref 10, p 965

AMINOIMIDAZOLINOL
AND DERIVATIVES

2-Amino-2-imidazolinol or 2-Hydroxy-2-
\( \text{OH} \)

aminoimidazolidine, \( \text{CH}_2\text{-NH-} \)
\( \text{C-NH}_2 \)

mw 103.13, N 40.75%. May be considered
the parent compd of:

2-Nitrarnino-2-imidazolinol or 2-Hydroxy-2-
nitriminoimidazolidine, \( \text{CH}_2\text{-NH-} \)
\( \text{C-NH}_2 \)

mw 148.13, N 37.83%. Crysts, mp 136–7°
(decomp). One of the hydration products ob-
tained by Barton et al(Ref 2) from 2-nitrarnino-
imidazolidine(see also Ref 3). Its explosive
props were not detd.

Refs: 1)Beil – not found 2)A.F.McKay, et al, CanjChem
29, 384, 387 & 389–90(1951) & CA 61, 7094–5(1952)

Note: No higher nitrated- or nitrited-derivs as
well as azido- and diazido-derivs were
found in Beil or CA through 1956

AMINOIMIDAZOLIN-1-YL
AND DERIVATIVES

Aminoimidazolin-1-yl-ethylguanidine,
\( \text{CH}_2\text{-CH}_2\text{-NH-C(:NH)-NH}_2 \)

\( \text{CH}_2\text{N-C-NH}_2 \), may be considered a parent
compd of the following subst-
tances:

1-[2-(2-Nitramino-\( \Delta^2 \)-imidazolin-1-yl)ethyl]-
3-nitro-guanidine; 1-[2-(3-Nitroguanidino)-
ethyl]-2-nitramino-\( \Delta^2 \)-imidazolone or 1-\( \beta \)-
Nitroguanylaminooethyl-2-nitramino-\( \Delta^2 \)-
imidazoline,

\( \text{CH}_2\text{.CH}_2\text{-NH-C(:NH)-NH-NO}_2 \)

\( \text{CH}_2\text{N-C-NH-NO}_2 \), mw 260.22, N 43.07%.

\( \text{CH}_2\text{N-C-NH-NO}_2 \) Crysts(from \( \text{H}_2\text{O} \), mp 197° with
decon. Was prepd by adding 1,5-diamino-
3-azapentane, \( \text{NH}(\text{CH}_2\text{-CH}_2\text{-NH}_2)_2 \), to methyl-
nitrosonitroguanidine, \( \text{CH}_2\text{N(NO)(C(:NH)-NH)NO}_2 \),
as described in Ref 2,p 387. Its expl props
were not examined.

1'-[\( \beta \)-(2-Nitramino-\( \Delta^2 \)-imidazolin-1-yl)ethyl]-
3'-nitro-1'-nitroso-guanidine; 1-[\( \beta \)-(3'-Nitro-
1'-nitrosoguanidino)ethyl]-2-nitramino-\( \Delta^2 \)-
imidazolone or 1-(N-Nitroguanyl-N'-nitroso-
\( \beta \)-aminoethyl)-2-nitramino-\( \Delta^2 \)-imidazoline,

\( \text{H}_2\text{C-N=C-NH-NO}_2 \), mw 289.22, N 43.56%.

\( \text{H}_2\text{C-N=C-NH-NO}_2 \) Yel cry sts, mp 176° with decon.

Prepd by treating a soln of the previous
compd in dil nitric acid with Na nitrite, as
described in Ref 2,pp 389–90. Its expl props
were not examined.

1'-[\( \beta \)-(2-Nitrimino-3-nitro-\( \Delta^2 \)-imidazolin-1-
yl-ethyl]-1',3'-dinitro-guanidine; 1-[\( \beta \)-(1',3'-
Dinitroguanidino)ethyl]-2-nitrimino-3-nitro-
\( \Delta^2 \)-imidazolide or 1-(N-Nitroguanyl-N'-
\( \beta \)-aminoethyl)-2-nitrimino-3-nitromi-
dazolide, \( \text{CH}_2\text{-CH}_2\text{N(NO)(C(:NH)-NH)NO}_2 \),

\( \text{H}_2\text{C-N=C-NH-NO}_2 \) Crysts, mp 161–2°

\( \text{H}_2\text{C-N=C-NH-NO}_2 \) prepd by treating
1-[2-(2-nitramino-2-imidazolin-1-yl)ethyl]-3-
nitroguanidine with nitric acid and acetic
anhydride as described in Ref 2,p 389. Its expl props
were not examined.

Refs: 1)Beil – not found 2)A.F.McKay, et al, CanjChem
29, 384, 387 & 389–90(1951) & CA 61, 7094–5(1952)

Note: Azido- and diazido-derivs of amino-
imidazolinol were not found in Beil or CA
through 1956

2-Amino-(or 5)-\( \Delta^2 \)-imidazolone [Glykocyami-
din, 4-Oxo-2-imino-imidazolidin or Hydanto-
inimid-(2), in Ger]

\( \text{OC} \)} N
OC-NH-C-NH$_2$ or H$_2$C-NH-C-NH, mw 99.09

H$_2$C—N

OC—NH

N 42.41%. Prepn and props are in Beil 24,244 & 25,451.

Note: No azido-, diazido-, nitrated and/or nitrited derivs of aminomidazolone were found in Beil or CA through 1956.

4-Amino-7H-imidazo-[4,5-d]-triazine, also called 6-Aminimidazol-1,2,3-triazine,

HC—N—C—NH—NH, mw 136.12, N 61.75%.

This high nitrogen compd was obtained by treating its nitrate with aq Ag$_2$O. The nitrate, C$_3$H$_5$N$_3$, HNO$_3$, ndls, mp 189°, obtained by electrolysis of ammoniacal-alcoholic soln of ammonium carbonate (Ref 2) and the picrate, C$_3$H$_5$N$_5$, C$_6$H$_5$N$_3$H$_3$NO$_3$, small yel prisms, mp 252° (Ref 3).


Note: Azido-, diazido-, nitrated and/or nitrited derivs were not found in Beil or CA through 1956.

AMINOIMINODIHYDROTRIAZOLE AND DERIVATIVES

Aminoiminodihydrotriazoles, C$_3$H$_5$N$_5$, mw 99.10, N 70.68%. The following isomer is listed in the literature:

4-Amino-3-imino-2,5-dihydro-$\alpha$-sym-triazole

or 4-Amino-3-imino-2,5-dihydro-2H-1,2,4-triazole [Called in Beil, 4-Amino-1,2,4-triazolona(3)-imid], HN—C—NH

H$_2$N—N—C—NH

(from alc), mp 208°; very sol in w, sol in alc. Was prepd by treating its hydrobromide with moist Ag$_2$O. The hydrobromide was obtained by heating N,N'-diaminoguanidine, CH$_2$N,0,N,7,arange prisms, mp 252°, by treating its nitrate with aq Ba(OH)$_2$ soln. The nitrate, C$_3$H$_5$N$_5$, HNO$_3$, ndls, mp 184°, was obtained by heating N,N'-diaminoguanidine nitrate with AcOH on a water bath. The aq soln of the above triazole gives with aq AgNO$_3$ a wh ppt sol in NH$_3$ or in HNO$_3$. When treated with HNO$_3$ the triazole gives nitrate, C$_3$H$_5$N$_5$ + HNO$_3$, crysts, mp 194°, and when treated with picric acid picrate, crysts, mp 192°. Expl props of these compds were not examined.

Refs: 1) Beil 26,39 2) A. Gaiter, Gazz 451, 457(1915) & CA 10,603(1916).

Note: Azido-, nitrated and/or nitrited derivs of aminomidazolone were not found in Beil or CA through 1956.

AMINOIMINOMETHYLDIHYDROTriaZOLE AND DERIVATIVES

4-Amino-5-imino-3-methylidihydro-$\alpha$-sym-triazole or 4-Amino-5-imino-3-methylidihydro-1H-1,2,4-triazole [Amino-5-methyl-1,2,4-triazolona(5)-imid, in Ger], HN—C—NH—N

H$_2$N—N—C—CH$_3$

mw 113.13, N 61.91%. Ndls from alc. Was prepd by treating its nitrate with aq Ba(OH)$_2$ soln. The nitrate, C$_3$H$_5$N$_5$-HNO$_3$, wh ndls, mp 184°, was obtained by heating N,N'-diaminoguanidine nitrate with AcOH on a water bath in the presence of a small amt of concd HNO$_3$. Treatment of an aq soln of the nitrate with a concd aq soln of picric acid yielded the picrate, C$_3$H$_5$N$_5$·C$_6$H$_5$(NO$_2$)$_3$OH, small yel crysts decompg ca 189°. Expl props of these compds were not examined.
Aminoindazoles and Derivatives

Aminoindazole, Benzodiazole or Benzopyrazoles, C_6H_5N_4. Several isomers are described in Beil 24,112 & 59 and 25,317-18 & 308. Some isomers described in Beil are also called Indazolonimide.

Azidoaminindazole, C_7H_6N_6 and Diazidoaminindazole, C_7H_6N_6 – were not found in Beil or CA through 1956.

Mononitratoaminindazole, (O_2N)C_7H_6N_6 – not found in Beil or in CA through 1956.

5,7-Dinitro-6-amino-indazole, (O_2N)_2C_7H_6N_6·NH_2, mw 223.15, N 31.39%. Brn-yel scales, mp - melted with decomp on heating on Pt foil in flame; very diff sol in w, easier in boiling AcOH. Was prep'd by heating 5,7-dinitro-6-indazolesulfonic acid with ammonia.


5,7-Dinitro-6-nitramino-indazole, (O_2N)_2C_7H_6N_6·NH(NO_2)_2, mw 268.15, N 31.34%. Refs to this compd and higher nitrated derivs, which undoubtedly would be expl were not found in Beil or CA through 1956.

Aminoisomelamine. See 1-Aminohexahydro-2,4,6-triimino-sym-triazine.

5-Amino-2-mercapt-o-1,3,4-thiadiazole; [5-Lmino-2-thion-1,3,4-thiodiazolidin or 5-Amino-1,3,4-thiodiazolthion-(2) in Ger], H_2N-C-S-C-SH, HN-C-S-C-S or H_2N-C-S-C-S;

\[
\begin{align*}
\text{N} & \quad \text{N} \\
\text{HN} & \quad \text{HN} \\
\text{N} & \quad \text{NH}
\end{align*}
\]

mw 133.07, N 31.58%, OB to CO_2 & SO_2 -114.2%. OB to CO & SO_2 -90.2%. According to Beil (Ref 1), there are two forms of this compd, one, called endo-iminothiobiazol, which melts at 245°(with decomp) and the other called imino-thiol-dihydro-thiobiazol, which melts at 234°. Their prep'n is described in Beil and in refs listed in it. The yields were low (ca 25%).

Audrieth & Scott (Ref 2), in the course of their work on high-nitrogen compds under contracts with US Ordnance Corps, prep'd a compd which they named 3-amino,5-thiol-1,2,4-thiadiazole; they assigned to it the structures HS-C=N-N and S:C-NH-NH

\[
\begin{align*}
\text{S} & \quad \text{C-NH_2} \\
\text{S} & \quad \text{C-NH}
\end{align*}
\]

Crysts, mp 232-237°; very sl sol in w; dissolves in bases from which solns it may am inoindazole, CAHN, were not found in Be rep'td by addition of acid. It was obt Beil or CA through 1956 in yields up to 60% by deamination of bis-thiocarbamyl-hydrazide, H_2N-CS*NH*NH*CS.NH_2.

Ammonium azidoaminoindazole, 766,N is also called Indazolonimide, S-CNHNH_2 and S-C:NH_2, Crysts, mp 232-237°. Because of the fairly high nitrogen content in Beil 24,112 & 59 and 25,317-18 & 308, the compatibility with NC, Audrieth & Scott suggested its possible use as a flash-reducing agent in gun propellants to replace K_2SO_4 currently used.

Because of the fairly high nitrogen content of aminothiodiazole, it's low sol in H_2O and its compatibility with NC, Audrieth & Scott suggested its possible use as a flash-reducing agent in gun propellants to replace K_2SO_4 currently used.


Aminomesitylenes and Derivatives

Aminomesitylenes or Amino-1,3,5-trimethylbenzenes (Trimethylanilines or Mesidines), C_6H_4N, mw 132.20, N 10.36%. Several isomers are listed in Beil 12,1160, 1163,(503) & [631].

Azidoaminomesitylenes, C_6H_4N_4 – not found in Beil or CA through 1956.

2-Amino-4,6-diazo-mesitylene; Bistrazomesidine
or Aminomesitylenebisazoimide, \((CH_3)_3C_6\) \(N_2H_4\), mw 217.23, N 45.14%. Col crysrs, mp 68°; swells if heated rapidly; decomp vigorously with evoln of gas by concd H\(_2\)SO\(_4\). Was prepd by treating hydrochloric acid soln of triaminomesitylene trihydrochloride successively with NaNO\(_2\) and NaN\(_3\) at -5°, as described in Ref 2.


Mononitroaminomesitylenes, \((CH_3)_3C_6H(NO_2)\) - \(NH_3\), mw 180.20, N 15.55%. One isomer, 4-nitro-2-amino-mesitylene is described in Beil 12,1162 & [632].

Nitrotriaminomesitylene, \((CH_3)_3C_6H(NO_2)\) - \(NHN_3\), not found in Beil or CA through 1956

Dinitroaminomesitylenes, \((CH_3)_3C_6(NO_2)\) \(NH_3\), mw 225.20, N 18.66%. One isomer, 4,6-dinitro-2-amino-mesitylene, yel ndls, mp 193–5°, is listed in Beil 12,1163.

Dinitronitraminomesitylene, \((CH_3)_3C_6(NO_2)\) \(NHN_3\) – not found in Beil or CA through 1956

6-Nitro-4-azido-2-amino-mesitylene(Triazonitroaminomesitylene or Nitromesidineazoimide), \((CH_3)_3C_6NH(NO_2)\) \(N\), mw 221.22, N 31.66%, Lt yel crysrs (from petr eth), mp 83–84°. Was prepd by adding NaN\(_3\) to a soln of nitroaminomesitylene diazonium chloride


Aminomesitylenebisazoimium Chloroauroate Hydrochloride. Diazotization of triaminomesitylene trihydrochloride, followed by treatment with a soln of chloroauroic acid, gave two expls, \(C_6H_4N_4ClAu\) and \(C_6H_5N_3ClAu\), both solid

Refs: 1)Beil – not found 2)G.T.Morgan & G.R.Davies, JCS 123,236–7(1923) & CA 17, 1633(1923)

1 -Amino-mesitylene; 1 -Amino-1,3,5-trimethyl-benzene; 3,5-Dimethylbenzylamine

or Aminomesitylenebisazoimide, \((CH_3)_3C_6\) \((N_2)_2H\), mw 217.23, N 45.14%. Col crysrs, mp 68°; swells if heated rapidly; decomp vigorously with evoln of gas by concd H\(_2\)SO\(_4\). Was prepd by treating hydrochloric acid soln of triaminomesitylene trihydrochloride successively with NaNO\(_2\) and NaN\(_3\) at -5°, as described in Ref 2.

Aminomesitylenebisazoimide,200-300 psi and the temp 180-200°. Alumina \((CH_3)_3C_6N_3\) - \(NH-NO_2\) mw 266.22, N 42.74%. was not found in Beil or CA through 1956

Aminomesitylenebisazoimide,\( \left( \text{CH}_3 \right)_3C_6N_3\) - \(\text{NH}-\text{NO}_2\) - \(\text{N} \), mw 262.23, N 42.74% was not found in Beil or CA through 1956

As a fire hazard, aminomethane is dangerous when exposed to flame; as an explosion hazard, it is moderate when exposed to sparks or flame. It can react vigorously with oxidizing materials(Ref 8).

Being a weak base, aminomethane forms salts with acids, some of which are expl. It
also forms some expl addn cmpds. Aminomethane is used in the synthesis of wetting agents (such as Igepon T), drugs, photographic developers, dye intermediates, solvents, etc. It has also been used for the prep of tetryl. In this synthesis aminomethane is treated with dinitrochlorobenzene to form N-methyl-2,4-dinitroaniline, which on nitration yields N-methyl-N,2,4,6-tetranitroaniline(tetryl) (Refs 4,5 & 7). During WW II millions of pounds of tetryl were manufd by this process


Azidoaminomethane, N₃CH₂·NH₂ – not found in Beil or CA through 1956

Aminomethane Chlorite, CH₃·NH₂·HClO₄, mw 99.53, N 14.07%, OB to CO₂ ~48.2%. Syrup. Its aq soln was prep'd by Levi by neutralizing a 30% soln of aminomethane with 2N H₂SO₄ and treating the resulting mixt with Ba(ClO₄)₂, followed by filtration. The filtrate was evapd in vacuo over CaCl₂ to a dense, syrupy liq contg about 66% of CH₃NH₂·HClO₄, but no crysts were formed. When this syrup was poured onto a cold iron plate, a slight expln occurred.

Refs: 1)Beil 4,549] 2)G.R.Levi,Gazz 52 1, 207–9(1922) & CA 16,2474(1922)

Aminomethane Nitrate or Methylamine Nitrate (Man-Salz, in Ger), CH₃·NH₂·HNO₃, mw 94.07, N 29.78%, OB to CO₂ ~34.0%. Prism crysts, mp 109–11°, sol in w and very hygroscopic. Can be prep'd by neutralizing aminomethane with nitric acid or by reacting methyl-nitrate with ammonia

This salt was thoroughly investigated in Germany before and during WW II. A detailed description of the method for its prep and its explosive props are given in PATR 2510(1958), under Man-Salz

Addnl info not included in the German Sec-(PATR 2510) follows: Aminomethylnitrate is of satisfactory thermal stability and is more powerful than TNT (the Trauzl test gives 325 cc expansion vs 290 cc for TNT, which is about 112% TNT). Its vel of deton is ca 6600 m/sec at a d not specified; Q v 215.4 kcal/mol and Q v 81.6 kcal/mol(Ref 5). It has been used in some cast expl mixts, such as with dinitrodimethylsulfamide(Ref 2)

Dynamit A--G(Ref 3) proposed expl compns prep'd by m'ting together AN with nitrates of simple or multiple aliphatic amines, such as aminomethane nitrate or diaminoethylene dinitrate. SECI(Ref 4) proposed an expl compn consisting of aminomethane nitrate and AN prep'd by heating a mixt of formaldehyde, or its polymers or higher homologs, in the presence of H₂O with AN in excess of the amt theoretically required for the prep of aminomethane nitrate. The dried product could be waterproofed by mixing or coating with molten paraffin

Aminomethane nitrate was used during WW II in Germany in admixt with NaNO₃, Ca(NO₃)₂ and RDX(10–15%) for bomb and shell loading(Ref 6). Some of these mixts melted at ca 76° and could be easily cast-loaded

Refs: 1)Beil 4,36 & [318] 2)P.Naoûm, GerP 499,403(1928) & CA 24,4160(1930) 3)Dynamit A--G,FrP 742,312(1933) & BritP 384,966(1932), CA 27,3612,5981(1933) 4)SECI,FrP 815,880
Nitroaminomethane or C-Nitromethylamine, O₂N-CH₂-NH₂ — not found in Beil or CA through 1956

Nitroaminomethane, Methylnitramine or N-Nitromethylamine, CH₃-NH-NO₂, mw 76.06, N 36.84%, OB to CO₂ -42.1%. Nds(from ether), mp 38°, d 1.2433 at 48.6°, nD₁.46162 at 48.6°(Ref 2); expl violently when heated in a capillary(Ref 5). Easily sol in w, alc, chlf & benz; less sol in eth; very sl sol in petr eth. Was first prepd by Franchimont & Klobbie(Ref 2) by nitration and hydrolysis of methyl-N-methyl-carbamate, CH₃CO₂-NH·CH₂. Other methods are known (Refs 1 & 4). Johnson(Ref 5) prepd it in 66% yield by nitration and hydrolysis of ethyl-N-methyl-carbamate. Detailed description of procedure is given. It is a powerful expl, with a Trauzl test value of 144%PA. Its toxicity is probably similar to that of aminomethane(qv)

Nitroaminomethane was patented for use as an additive to Diesel fuels(Ref 10). There is no info at our disposal about its uses in expls or prplnts

Its Raman spectra are discussed in Ref 7 and UV spectra in Refs 8 & 9

Many salts of nitroaminomethane are known, some of them more or less explosive, eg, ammonium, barium, cobalt, cadmium, copper, nickel, potassium, silver, sodium and zinc (Refs 1,2 & 3)


Aminomethane Nitroform or Methylaminonitroform, CH₃NH₂-CH(NO₂)₂, mw 182.10, N 30.77%, OB to CO₂ -8.8%. Powerful expl(Trauzl test 168% PA), but unstable and hygroscopic

Ref: A.H.Blatt et al, OSRD Repot 1944(1944)

Aminomethane Perchlorate, CH₃NH₂-HClO₄, mw 131.52, N 10.65%; OB to CO₂, H₂O, N₂O & Cl₂ -18.2%; OB to CO₂, H₂O, N₂ & Cl₂ -12.2%. Crysts, d 1.68(cast), mp 210°(242°, Ref 5); expl violently ca 338°; sol in w(110 g in 100 ml at 15°). Can be prepd by neutralizing aminomethane with perchloric acid

Aminomethane perchlorate is a more powerful explosive than TNT(Trauzl test value 160% of TNT) but much more sensitive to impact, comparable to L.A. Its vel of deton is 7540 m/sec at d 1.68 and 6600 at d 1.565. Corresponding pressures of gases developed at explu are 1000 and 750 kg/cm²

As this expl has a high mp and is highly sensitive to shock, additives are mixed with it to lower its mp and sensitivity. It is suitable, when in such mixts, for loading in STET projectiles. It also can be used in AN mining expls as well as in plastic expls (Refs 4,5 % 6)

[See also Man-Salz Perchlorate in PATR 2510(1958)]


Nitroaminomethanecarboxylic Acid. Same as Nitrinoacetic or Nitraminoethanoic Acid
AMINOMETHOXYPHENYL TETRAZOLES
AND DERIVATIVES

Aminomethoxyphenyltetrazoles; Anisylaminotetrazoles or Anisidinotetrazoles, C₉H₇N₈O₃,
MW 191.19, N 36.63%. The following isomers are described in the literature:

5-Amino-1-(m-methoxyphenyl)-a(or 1H)-tetrazole or 1-(2-Anisyl)-5-amino-tetrazole
(o-CH₃O-C₆H₄)

H₄N-C---N---H₄

mp 172°C (Ref 2); crystals (from acetone), mp 174°C (Ref 3); soluble in hot w., easily
soluble in cold w. Was first prepd by Stolle (Ref 2) by prolonged heating of o-
methoxyphenylthiourea with PbCO₃ and NaN₃, while passing in CO₂ gas. Henry et al
(Ref 3) prepd it by cyclization of o-anisylguanylazide

Ref: 1) Beil - not found 2) R.A. Henry et al, JACS 76,92(1954)

5-Amino-1-(p-methoxyphenyl)-a(or 1H)-tetrazole
(p-CH₃O-C₆H₄)

H₄N-C---N---H₄

mp 209-10°C. Can be prepd by cyclization of p-anisylanilhydroxylazide

Ref: 1) Beil - not found 2) W.G. Finnegan et al, JOC 18,788(1953) 3) R.A. Henry et al,
JACS 76,92(1954)

Aminomethoxyphenyltetrazoles, Identification by Means of IR Spectroscopy. See W.G. Finnegan
et al, JACS 77,4420(1955)

Aminomethoxyphenyltetrazoles, Azido-C₉H₇N₈O and Diazo-C₉H₇N₈O Derivatives were not
found in Beil or CA through 1956

Aminomethoxyphenyltetrazoles, Nitrated and/or Nitrimino Derivatives were not found in Beil or
CA through 1956

AMINOMETHYLAMINOimidazolidines
AND DERIVATIVES

Aminomethylaminimidazolidines, C₆H₅N₄, mw 116.17, N 48.23%. The isomer 2-amino-
2-(methylamino)-imidazolidine may be considered the parent compd of the following derivs:

5-Amino-1-(m-methoxyphenyl)-a(or 1H)-tetrazole or 1-(3-Anisyl)-5-amino-tetrazole
(m-CH₃O-C₆H₄)

H₄N-C---N---H₄

mp 140.5-141.5°C.

Was prepd by cyclization of m-anisylguanilazide, H₃N-C(N₃)-N(m-CH₃O-C₆H₄)

Ref: 1) Beil - not found 2) M.W. Kirkwood & G.F. Wright, JOC 18,634 & 639-40(1953); CA 48,
6968(1954)
Aminomethylimidazoline, Azido-\(\text{C}_3\text{H}_4\text{N}_2\) and Diazido-\(\text{C}_3\text{H}_4\text{N}_4\) Derivatives—not found in Beil or CA through 1956

Aminomethylanilines. Same as Methylphenylenediamines

Aminomethylbenzene. Same as Aminotoluene

1'-Aminomethylbenzene or 2'-Aminotoluene. Same as Benzylamine

AMINOMETHYL BIPHENYLS AND DERIVATIVES

Aminomethylbiphenyls or Methylbiphenylamines, \(\text{C}_3\text{H}_4\text{N}\) exist in several isometric forms, such as \(\text{H}_2\text{N} \cdot \text{C}_6\text{H}_4\cdot \text{C}_6\text{H}_4\cdot \text{CH}_3\);

\(\text{H}_2\text{N} \cdot \text{C}_6\text{H}_4\cdot \text{C}_6\text{H}_4\cdot \text{CH}_3\)

There is also the isomer aminobiphenylmethane, \(\text{H}_2\text{N} \cdot \text{C}_6\text{H}_4\cdot \text{CH}_3\) and \(\text{C}_6\text{H}_4\cdot \text{C}_6\text{H}_4\cdot \text{C}_6\text{H}_4\). They are described in Beil 12, 1326 & [770-1]

Azidoaminomethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\) and Diazidoaminobiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\) — were not found in Beil or CA through 1956

Mononitroaminomethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\). The isomer 3-nitro-4-methylamino-biphenyl is described in Beil 12,[760] and the isomer 2-nitro-2-amino-biphenylmethane in JCS 1948, 299

Nitraminomethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\) O and

Nitrotrinitromethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\) — were not found in Beil or CA through 1956

Dinitroaminomethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\). The isomer 3,5-dinitro-4-methylamino-biphenyl is described in Beil 12,[762] and the isomer 3,4'-dinitro-4-amino-biphenyl-methane in JCS 1933, 1064

Dinitronitroaminomethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\). The isomer 3,5-dinitro-4-methylnitroso-biphenyl is described in Beil 12,[762]

Dinitronitromethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\) — not found in Beil or CA through 1956

Trinitroaminomethylbiphenyls, \(\text{C}_3\text{H}_4\text{N}_2\), mw 318.24, N 17.61%. The isomer N-(2,4,6-trinitro-benzyl)-aniline, or phenyl-(2,4,6-trinitrobenzyl)-amine is described in Beil 12,
Aminotoluinobenzene, H₃N-C₆H₄-NH-C₆H₄
CH₃, and N-phenyltluenediamine or aminotoluoluene, H₂N
C₆H₄-NH-C₆H₄
H₂C

Azidoaminomethylidiphenylamines, C₁₅H₁₅N₆ – not found in Beil or CA through 1956
Diazidoaminomethylidiphenylamines, C₁₅H₁₅N₆ – not found in Beil or CA through 1956

Mono nitroaminomethylidiphenylamines, C₁₅H₁₅N₄O₂, mw 243.26, N 17.28%. Several isomers described in Beil 13, 30, 130 & [21, 66]

Nitronitroaminomethylidiphenylamines, C₁₅H₁₅N₄O₂ – not found in Beil or CA through 1956

Dinitroaminomethylidiphenylamines, C₁₅H₁₅N₄O₄, mw 288.26, N 19.44%. Several isomers are described in Beil 13, 42, 79, 81, 131, 155 & [13, 14, 26, 42]

Dinitrnonitromethylidiphenylamines, C₁₅H₁₅N₆O₄ – not found in Beil or CA through 1956

Trinitroaminomethylidiphenylamines, C₁₅H₁₅N₆O₄, mw 333.26, N 21.02%. Several isomers, none of them expl, are described in Beil 13, 30, 61, 79 & 81

Trinitronitromethylidiphenylamine, C₁₅H₁₀N₆O₄, mw 378.26, N 22.22%, OB to CO₂ ~ -97.3%. The following isomer is described in the literature:

2,4,6-Trinitro-3-methyl nitramino-diphenylamine, also called in Beil N-Nitro-N-methyl-N'-phenyl-2,4,6-trinitrophenyldiamine- (1,3), O₂N-C₆H₄-NH-C₆H₄(NO₂)₂-N(NO₂)-CH₃, Yel crys ts (from AcOH), mp 183°; easily sol in boiling acet., diff sol in alc. Was prep by treating aniline with methyl-(2,3,4,6-tetranitrophenyl)-nitramine in benz


Tetranitroaminomethylidiphenylamines,
C₁₅H₁₀N₆O₈ – not found in Beil or CA through 1956

Tetr metodinitromethylidiphenylamines,
C₁₅H₁₀N₆O₈, mw 423.26, N 23.17%, OB to CO₂ -77.5%. The following isomers are described in the literature:

2,4,6,2'-Tetranitro-3-methyl nitramino-diphenylamine, also called in Beil N-Nitro-N-methyl-N'-[2-nitro-phenyl]-2,4,6-trinitrophenyldiam in (1,3), O₃N-C₆H₄-NH-C₆H₄(NO₂)₂-N(NO₂)-CH₃, Yel crys ts (from AcOH), mp 200°(dec). Was prep by treating 2,4,6-tetranitro-3-methyl nitramino-diphenylamine with HNO₃(d 1.49) at RT. Its expl props were not examined

Refs: 1) Beil 13, (18) 2) C.F. van Duin & B.C.R. van Lennep, Rec 38, 366(1919)

2,4,6,3'-Tetranitro-3-methyl nitramino-diphenylamine, also called in Beil N'-Nitro-N-methyl-N' [3-nitro-phenyl]-2,4,6-trinitrophenyldiam in (1,3), O₃N-C₆H₄-NH-C₆H₄(NO₂)₂-N(NO₂)-CH₃, Yel cryst (from AcOH), mp 206°. Was prep by heating methyl-(2,3,4,6-tetranitrophenyl)-nitramine with 3-nitro-aniline in benz. Its expl props were not examined

Refs: 1) Beil 13, [34] 2) C.F. van Duin & D.R. Koolhaas, Rec 46, 380(1927)

2,4,6,4'-Tetranitro-3-methyl nitramino-diphenylamine, also called in Beil N'-Nitro-N-methyl-N'-[4-nitro-phenyl]-2,4,6-trinitrophenyldiam in (1,3), O₃N-C₆H₄-NH-C₆H₄(NO₂)₂-N(NO₂)-CH₃, Or ange-yel crys ts (from AcOH), mp 200°. Was prep by treating methyl-(2,3,4,6-tetranitrophenyl)-nitramine with 4-nitroaniline in boiling benz. Its expl props were not examined

Pentanitroaminomethylidiphenylamines, 
\( \text{C}_8\text{H}_8\text{N}_4\text{O}_{10} \) – not found in Beil, or CA through 1956

Pentanitronitramidiphenylamines, \( \text{C}_4\text{H}_8\text{N}_4\text{O}_{12} \)

mw 468.26, N 23.94%, OB to \( \text{CO}_2 \) – 61.5%. The following isomer is described in the literature:

2,4,6,2',4'-Pentanitro-3-methylnitramidiphenylamine, also known in Beil, \( N\text{-Nitro-}N\text{-methyl-N'-(2,4-dinitrophenyl)-2,4,6-trinitrophenyldiamin} \). \((1,3), (\text{O}_2\text{N})_2\text{C}_6\text{H}_3\text{NH}\text{C}_6\text{H}(\text{NO}_2)_2\text{; N(NO}_2)_2\text{.CH}_3\text{.} \)

Crystals (from AcOH), 1-amino-1-methyl-2-nitroguanidine, stated to have been prep by R.A.Henry, W.G. Finnegan & J.Cohen. No reference, no method of prep or no props are given. 5) Dr Ronald A.Henry, NOTS, China Lake, Calif; private communication 5056/RAH: ef, 22 Dec 1958

Aminomethylguanidines and Derivatives

Aminomethylguanidines and Methylamino- guanidines, \( \text{C}_4\text{H}_8\text{N}_4 \), mw 88.12, N 73.59% are high nitrogen comds, which might be useful as components of prplnts or expls. None of these comds was found in Beil. The following isomers and derivs were either prep or could be prep if there was a need or interest:

1-Amino-1-methylguanidine (using the numeration recommended by ACS), \( \text{H}_2\text{N}-(\text{CH}_3)\text{C}:(\text{NH})\text{NH}_2 \). Its nittrated deriv was described in Ref 3 as 1-Amino-1-methyl-3-nitroguanidine, \( \text{H}_2\text{N}-(\text{CH}_3)\text{C}:(\text{NH})\text{NH-NO}_3 \), mw 133.12, N 52.61%, rosettes or flat ndls (from alc), mp 170–175°. It was prep by Henry & Smith (Ref 3) from methylhydrazine and 1-methyl-1-nitoso-3-nitroguanidine using a method developed by McKay & Wright (Ref 2)

Note: According to Dr. Henry (Ref 5) the above aminomethyl nitroguanidine is the same as 1-Amino-1-methyl-2-nitroguanidine mentioned by Burkardt (Ref 4) and its formula is \( \text{H}_2\text{N}-(\text{CH}_3)\text{C}:(\text{NH})\text{NO}_2 \text{-NH}_2 \). The name 1-amino-1-methyl-2-nitroguanidine is preferred because it uses the smallest possible numbers (Ref 5)


2-Amino-1-methylguanidine, \( \text{(CH}_3)\text{HN-} \text{C}:(\text{NH})\text{NH}_2 \). Its nittrated deriv 2-amino-1-methyl-3-nitroguanidine was mentioned in Ref 2 without giving its method of prep or props. Its formula is presumed to be \( \text{(CH}_3)\text{HN-} \text{C}:(\text{NH})\text{NH}_2 \text{-NO}_3 \)

According to Dr Henry (Ref 3), "Actually this compound has never been isolated in the free form: only its benzal hydrazone has been described. At this time this work was done we could not think of a straightforward synthesis leading to the free compound. I believe that we could do it today if there was a need or interest"

Refs: 1) Beil – not found 2) R.A. Henry & G.B.L. Smith, JACS 73, 1858–9(1951) & CA 46, 2502(1952) 3) Dr Ronald A. Henry, NOTS, China Lake, Calif; private communication 5056/RAH: ef 22 Dec 1958

1-Amino-2-methylguanidine, \( \text{H}_2\text{NHN-} \text{C}:(\text{NH})\text{NH}_2 \). This compd was one of the products obtained by Henry and Smith (Ref 2) as result of the reaction between methylamine and nitroaminoguanidine. It was first named 3-amino-1-methylguanidine

According to Dr Henry (Ref 3), "Direct nitration of 1-amino-2-methylguanidine is not possible because the hydrazino group would be
oxidized. If the hydrazino group could be protected, one would probably get a mixture of nitramines, for example: 1-amino-2-methyl-3-nitroguanidine, H$_2$NNH-C(:NCH$_3$)-NHNO$_2$ and 1-amino-2-methyl-2-nitroguanidine, H$_2$NNH-C(:NH)NNO$_2$. This latter isomer is also un-

Note: The formula for 1-amino-2-methyl-2-nitroguanidine is given in Ref 3 and it does not seem to agree with the numeration proposed by the ACS. If the formula of the last compd is right, then its name should be 1-amino-3-methyl-3-nitroguanidine

Refs: 1)Beil - not found 2)R.A.Henry & G.B.L.Smith, JACS 73,1859-9(1951) & CA 46, 2502(1952) 3)Dr Ronald A.Henry,NOTS, China Lake, Calif; private communication 5956/RA:ef 22 Dec 1958

Methylaminoguanidine, (CH$_3$)NH-NH-C(NH$_3$)$_3$; NH or (CH$_3$)HN-N-C(NH$_3$)$_3$), was prepd as the sulfate by heating on a water bath concd solns of methylhydrazine and S-methyl-


Azidoaminomethylguanidine, C$_3$H$_7$N, - does not exist as such because it is assumed to isomerize at once to the corresponding tetrazyl-guanidine compd

Nitronitrinomethylguanidine, C$_3$H$_6$N$_2$O$_4$ and Dinitrinomethylguanidine, C$_3$H$_7$N$_2$O$_4$ - not found in Beil or CA through 1956

Aminomethylimidazoline and Derivatives. See under Aminoimidazoline and Aminoimidazolidine Substituted Derivatives

Aminomethyleneitramines and Hydroxymethyl nitramines. See under Hydroxy- and Aminomethyleneitramines

Aminomethyleneitrosolic Acid, Nitrosoformamidoxime or Nitrosoaminoformamidoxime (Called Amido-methyleneitrosolsäure by Wieland), ON-C(:NOH)-NH$_3$, mw 89.00 N 35.90%. Green plates changing readily to a yel amor-

The potassium salt, KCH$_3$N$_2$O$_4$, crystallizes from 80% alc in brilliant, steel-blue ndls, which dec at 21°C or expl at 220°C(Refs 1 & 2). Its aq soln treated with aq AgNO$_3$ and HNO$_3$ yields the very explosive silver fulminate

Refs: 1)Beil 3,97 2)H.Wieland,Ber 38, 1456-61(1905) & JCS 88,421(1905) 3)H. Wieland,Ber 42,820(1909)

AMINOMETHYLPROPANE DIO ILS AND DERIVATIVES

2-Amino-2-methyl-1,3-propanediol; 2-Amino-2-methyl-1,3-dihydroxy-propane or Bis(hydroxymethyl)methylaminomethane(called in Beil β-Amino-β-methyl-trimethylenglykol), HO-CH$_2$-C(NH$_3$)$_2$-CH$_2$-OH, is described in

Beil 4,303. It may be considered the parent compd of the following derivs:

2-Amino-2-methyl-1,3-propanediol Dinitrate or 2-Amino-2-methyl-1,3-dinitroxypropane, also called Bis[nitroxyethyl]methylaminomethane or β-Amino-β-methyl-trimetelylen glycol Dinitrate, O$_2$NO-CH$_2$-C(NH$_3$)$_2$-CH$_2$-ONO$_2$, mw 195.14, N 21.54%, OB to CO$_2$ -69.7%. Col liq, d 1.368 at 20/20°, n$D$ 1.4759 at 20°, expl on heating, unstable even at RT. Was prepd at PicArsn by nitration of 2-methyl-2-amino-1,3-propanediol, drowning the spent acid in w and making the soln alkaline. It was considered unsuitable for military pur-

Refs: 1)Beil - not found 2)H.Aaronson, PATR 1412(1944)

Note: Description of this compd was not
found in CA through 1956

2-Nitramino-2-methyl-1,3-propanediol Dinitrate, O₂NO·CH –(NH·NO₂)→CH₂·ONO₂

not found in Beil or CA through 1956

Azidoaminomethylpropanediol, C₆H₁₄N₄O₂, Diazidoaminomethylpropanediol, C₆H₁₄N₄O₂, and Azidoaminomethylpropanediol Dinitrate, C₆H₁₄N₄O₂ – were not found in Beil or CA through 1956

**Note:** R.C. Elderfield et al [OSRD Rept 158 (1941), 7-8] prep by condensing 2-amino-2-methyl-1,3-propanediol with 2,4-dinitrochlorobenzene the product identified as 2,4-dinitrophenyl-bis(hydroxymethyl)methylamine, mp 162-3°C, which on nitration with mixed nitric/sulfuric acid gave 2,4,6-trinitrophenyl-(bis-hydroxy)tertbutyl nitramine dinitrate, mp 159°C. (See also under Anilinomethylpropanediol

**AMINOMETHYLPROPANOLS AND DERIVATIVES**

2-Amino-2-methyl-1-propanol, 2-Amino-2-methyl-1-hydroxypropane or Hydroxyaminomethylpropanediol, CH₃–C·CH₂·OH. May be considered the parent compd of the following derivs:

2-Nitramino-2-methyl-1-propanol Nitrate, 1-Nitroxy-2-nitramino-2-methyl-propane or 1-Nitroxy-2-nitramino-2,2-dimethylethane, NH·NO₂

| CH₃–C·CH₂·ONO₂, mw 179.14, N 23.46%; crystals, mp—not given. |

Can be prep'd from 2-amino-2-methyl-1-propenol according to the reactions given in Ref 2, as follows:

NH₂

| CH₃–C·CH₂·OH | ClCOOC₂H₅ followed by aq NaOH |

| NH·COOC₂H₅ | HNO₃ at 10°C |

| CH₃–C·CH₂·OH | NH₃ followed by HCl |

| CH₃–C·CH₂·ONO₂ | |

It was proposed as a possible gelatinizer for NC in propellants

**Refs:** 1) Beil – not found 2) A.T. Blomquist & F.T. Fiederek, USP 2,485,855 (1949), pp 6 & 15; CA 44,3516-17 (1950)

Azidoaminomethylpropanol, C₆H₁₄N₄O, Diazidoaminomethylpropanol, C₆H₁₄N₄O and Azidotriminopropanol Nitrate, C₆H₁₄N₆O₇ were not found in Beil or CA through 1956

Aminomethylpyridine. Same as Aminopicoline

**AMINOMETHYL- AND METHYLAMINOTETRAZOLES AND DERIVATIVES**

Aminomethyltetrazoles and Methylamino-tetrazoles, C₆H₄N₄, mw 99.10, N 70.68%. The following isomers were found in the literature:

5-Amino-1-methyl-α-tetrazole or 5-Amino-1-methyl-1H-tetrazole, called in Beil 1-Methyl-5-amino-tetrazol or 1-Methyl-tetrazol-(5)-imid, H₂N–C–N(CH₃)–N

| N | Ndl's or crystals, mp 218–223.5°C | N |
5-Methylamino-α-tetrazole or 5-Methylamino-1H-tetrazole, CH$_3$-HN-C-NH-N

Crystals, mp 185°. Can be prepared by hydrogenation of 5-methylbenzylamino-tetrazole or by other methods (Refs 3 & 4). Its X-ray absorption spectra are discussed in Ref 2, thermal isomerization in Ref 5, UV and IR absorption spectra in Ref 6, and kinetics of thermal isomerization in Ref 7.


Aminomethylthiazoles and Derivatives

Aminomethylthiazoles and Methylaminothiazoles, C$_4$H$_6$N$_2$S, may be considered the parent...
comps of the following derivs:

2-Amino-4-methyl-5-nitrothiazole,
\[ \text{O}_2\text{N-C-S-C-NH}_2, \text{ mw } 159.17, \text{ N } 26.41\% \]
\[ \text{H}_2\text{C-C-N} \]
Crysts(from alc), mp 220°. Can be prepd by hydrolysis of 2-acetamido-4-methyl-5-nitrothiazole(Ref 2), or by other methods(Refs 3,4 & 5)


Azidoaminomethylthiazole, \[ \text{C}_6\text{H}_4\text{N}_3\text{S-N} \]
not found in Beil or CA through 1956

2-Nitramino-4-methylthiazole, \[ \text{HC-S-C-NHNO}_2 \]
\[ \text{H}_2\text{C-C-N} \]
not found in Beil or CA thru 1956

2-Nitramino-4-methyl-5-nitrothiazole,
\[ \text{O}_2\text{N-C-S-C-NHNO}_2, \text{ or O}_2\text{N-C-S-C=N-NO}_2 \]
\[ \text{H}_2\text{C-C-N} \]
\[ \text{H}_2\text{C-C-NH} \]
\[ \text{mw } 204.17, \text{ N } 27.45\%. \text{ Yel plates, mp } 185° \text{ (decomp) (Ref 3). Was prepd by nitrating 2-amino-4-methylthiazole with mixed nitric-sulfuric acids, as indicated in Ref 3} \]


AMINOMETHYLTRIAZOLEs AND DERIVATIVES

Aminomethylthiazoles, \[ \text{C}_6\text{H}_5\text{N}_5\text{S} \]
mw 98.11, N 57.11%, OB to CO\textsubscript{2} -146.8%, OB to CO -97.8%. & E.C.Copp,JPharm and Pharmacol 7,112 (1955) & CA 50,964c(1956)

2-(N-Methylnitramino)thiazole, \[ \text{HC-S-C-N(CH}_3\text{N}_2\text{NO}_2 \]
\[ \text{HC-C-N} \]
Crysts, mp 271.5-272°. Can be prepd by treating 2-nitraminothiazole with dimethyl sulfate or ethereal diazomethane as described in Ref 2


3,5-Dinitro-4-methyl-2-nitrimino-A\textsubscript{4}-thiazoline
(listed in CA as 3,5-Dinitro-4-methyl-2-nitrimino-4-thiazoline), \[ \text{O}_2\text{N-C-S-C=N-NO}_2 \]
\[ \text{H}_2\text{C-C} \]
\[ \text{H}_2\text{C-C-} \]
\[ \text{NH} \]
\[ \text{H}_2\text{C-C-} \]
\[ \text{N-NO}_2 \]
\[ \text{W} \]
\[ \text{h solid, mp expl ca } 98° \text{. Was prepd by treating the previous compd with mixt of 90-100% nitric acid, acetic anhydride and glacial acetic acid(Ref 2)} \]

When the nitro compd was warmed with solvents, such as benz & acet or glacial AcOH, brown fumes of nitrogen dioxide were liberated. (See also Aminothiazoles)

Refs: 1)Beil - not found 2)S.J.Viron & A. Taurins, CanJChem 31,891(1953) & CA 49,2423(1955)
These high nitrogen compds might be of use in expl & propellent compns. The following isomers and their derivs are described in the literature:

1-Amino-5-methyl-α-vic-triazole or 1-Amino-5-methyl-1H-1,2,3-triazole, H$_2$C-C-N(NH$_2$)–N, mw 126.11, N 29.97%, OB to CO $-75.8\%$, OB to CO $-31.8\%$, yel ndls, mp 175.0 (decompn)

The following OB to CO $-31.8\%$, yel ndls, mp 225.0 (decompn) isomers and their derivs are described in the literature:

3-Nitramino-5-methyl-α-sym-triazole or 3-Amino-5-methyl-1H-1,2,4-triazole, H$_2$C-C-NH-N, also called 3-Amino-5-methyl-α-sym-triazole, mp 175.0, mp 148° (Refs 1 & 2), mp 151–2° (Ref 4); very sol in w & alc, diff sol in ether. Can be prepd by heating 1-benzalamino-5-methyl-α-vic-triazole with Nitrosamino-5-methyltriazoles, C$_3$H$_5$N, 0, OH, N, HNO$_3$, mw 161.13, N 43.47%, OB to CO $-54.6\%$, OB to CO $-24.8\%$, wh crysts, mp 176–7° (Ref 4), 171° (Refs 1 & 2), Q$_c^\gamma$

466.68 kcal/mol and Q$_f$ +54.59 kcal/mol

(Ref 4) b)picrate, C$_3$H$_5$N$_4$·C$_6$H$_5$N$_2$O$_7$, mw 327.22, N 29.97%, OB to CO $-75.8\%$, OB to CO $-31.8\%$, yel ndls, mp 225° (decompn)


Azidoaminomethyltriazoles, C$_3$H$_4$N$_2$ – not found in Beil or CA through 1956

Nitrosaminomethyltriazoles, C$_3$H$_4$N$_2$O, mw 127.11, N 55.10%. The compd listed in Beil 26, 20 (Ref 78) as 5-Nitrosamo-3-methyl-1,2,4-triazol seems to be the nitroso deriv of previous aminomethyltriazole. It can be called 5-Nitrosamino-3-methyl-β-sym-triazole, H$_2$C-CN=N–NH

3-Nitrosamino-5-methyl-α-sym-triazole, H$_2$C-CN=N–NH, also called 3-Nitrosamino-5-methyl-α-sym-triazole, N=C-CN=N–NH, also called 5-Nitrosamino-3-methyl-α-sym-triazole, H$_2$C-CN=N–NH

3-methyl-1H-1,2,4-triazole (called in Ref 2 Amidomethyltriazole). Wh ndls, mp 148° (Refs 1 & 2), mp 151–2° (Ref 4); very sol in w & alc, diff sol in ether and nearly insol in other organic solvents. Can be prepd from acetylamino-guanidine nitrate and soda by the procedure described in Ref 2. No methods of prepn are given in Refs 3 & 4

It forms salts, such as: a) nitrate, C$_3$H$_5$N$_4$·HNO$_3$, mw 161.13, N 43.47%, OB to CO $-54.6\%$, OB to CO $-24.8\%$, wh crysts, mp 176–7° (Ref 4), 171° (Refs 1 & 2), Q$_c^\gamma$

466.68 kcal/mol and Q$_f$ +54.59 kcal/mol

(Ref 4) b) picrate, C$_3$H$_5$N$_4$·C$_6$H$_5$N$_2$O$_7$, mw 327.22, N 29.97%, OB to CO $-75.8\%$, OB to CO $-31.8\%$, yel ndls, mp 225° (decompn)

Nitraminomethyltriazole described in Ref 2 was obtained as col rosettes or ndls, mp 212-13° with decomp. Williams (Ref 5) gives mp 206-7°. Was prepd by Henry from 1-acetamido-3-nitroguanidine as described in Ref 2, p 5344. Spectrophotometric studies of dissociation constant are discussed in Ref 4 and IR absorption spectra in Ref 3a. Its Q^v is 465.67 kcal/mol and Q_f -12.72 kcal/mol (Ref 5). Was first prepd by Staedel (Ref 2). Its Qv is 406.60 kcal/mol (Ref 4).

Aminonaphthalenes or Naphthylamines, C_{10}H_{7}N_{2}, mw 143.18, N 9.78%, are described in Beil 12, 1265, (519, 532) & [675, 710].

Azidoaminonaphthalenes, C_{10}H_{6}N_{3}, NH, and Diazidoaminonaphthalenes, C_{10}H_{7}(N_3).NH, were not found in Beil or CA through 1956.

Dinitroaminonaphthalenes, (O_2N)_{2}.C_{10}H_{5}.NH, mw 233.18, N 18.02%. Several isomers are described in Beil 12, 1262-4, 1315-16, (530) & [708, 734-5].

Dinitronitraminonaphthalenes, (O_2N)_{2}.C_{10}H_{5}.NH.NO_2, and Dinitronitraminonaphthalenes, (O_2N)_{2}.C_{10}H_{5}.NH.NO_2, were not found in Beil or CA through 1956.

Trinitroaminonaphthalenes, (O_2N)_{3}.C_{10}H_{4}.NH, mw 278.18, N 20.14%. The following isomers are described in the literature:

2,4,5-Trinitro-1-aminonaphthalene or 2,4,5-Trinitro-α-naphthylamine, yel ndls or microscpic prisms; mp ca 264° with darkening and defgr at higher temp (Ref 2); melts with decomp at 305° (Ref 3); decomp at 310° (Ref 4). Was first prepd by Staedel (Ref 2) by heating the ethyl ether of 2,4,5-trinitro-α-naphthylamine with alc NH_3 in a sealed tube at 50° for 2 hours. A simpler method is to pass NH_3 gas through an amyl alcohol soln of 4-chloro-1,3,8-trinitro-naphthalene (Ref 3). Other methods are described in Ref 4.

Trinitronitraminonaphthalenes, (O_2N)_{3}.C_{10}H_{4}.NH.NO_2 — were not found in Beil or CA through 1956.

Aminonaphthalenes and derivatives
Aminonicotinic Acid or Amino-3-pyridinecarboxylic Acid (Aminonicotinsäure or Amino-pyridin-carbonsäure in Ger), \( \text{C}_9\text{H}_7\text{N}-(\text{C}_6\text{H}_4\text{NH}_2)\)-COOH.

Aminonicotinic acids are aminopyridinecarboxylic acids in which the carboxyl group is attached to position 3 (if it is attached to position 2 the compound is called aminopicolinic acid). Four isomers of aminonicotinic acid with amino groups in 2,4,5 or 6 positions are known. There is also an isonicotinic acid in which the carboxyl group is in position 4 and the amino group is in position 3 (see also Aminopicolinic Acid).

\[
\text{COOH}
\]

\[
\text{NO}_2
\]

\[
\text{H}_2\text{N}-(\text{C}_6\text{H}_4\text{NH}_2)
\]


6-Nitraminonicotinic Acid [6-Nitramino-pyridin-carbonsäure-(3), in Ger], solid, decomposes explosively at 233°. It was prepared by nitrating 6-amino-isonicotinic acid with \( \text{HNO}_3 + \text{H}_2\text{SO}_4 \).


3-Nitramino-isonicotinic Acid or 3-Nitramino-4-pyridinecarboxylic Acid, \( \text{O}_2\text{NHN(C}_6\text{H}_4\text{NH}_2\text{)}\)-COOH, mw 183.12, N 22.95%. Crystals, mp 188°. It is prepared from 3-amino-4-pyridinecarboxylic acid in 30% concd \( \text{H}_2\text{SO}_4 \) while maintaining the temp below 0°, pouring the mixt onto 150 g of chopped ice, making alkaline with \( \text{NH}_4\text{OH} \) and bringing the mixt to a pH of 1 with \( \text{HCl} \).
Ref/s: 1)Beil – not found 2)S.Carboni & G.Berti,Gazz 84,883(1954) & CA 50,992(1956)

Note: No higher nitrated derivs of aminonicotinic and amino-iso-nicotinic acids were found in Beil

Aminonitroform, Aminotrinitromethane or Trinitroaminomethane(TNAMe), H$_2$N-C(NO$_2$)$_3$, mw 166.06, N 33.74%. Solid substance obtained before WW II from TeNMe(tetranitromethane) by Dr Hans Walter in the laboratory of Dr Friedrich L. Hahn at the University of Frankford a/Main

Dr W used the following series of reactions:

$$
\text{HCHO} \xrightarrow{\text{KOH}} \text{KC(NO$_2$)$_3$} \xrightarrow{\text{chlorine}} \text{ClC(NO$_2$)$_3$} (\text{oil}) \xrightarrow{2\text{NH}_3} \text{H$_2$N-C(NO$_2$)$_3$} + \text{NH}_4\text{Cl},
$$

but he failed to publish the results of his work(Ref 3)

It should be noted that during WW II large quantities of TeNMe were obtained in Germany and other belligerents as a by-product in the manuf of TNT. Inasmuch as TeNMe is a very dangerous oxidizer and very toxic, attempts were made at the laboratory of the Keystone Ordnance Works, Meadville, Pennsylvania, to transform TeNMe into a less obnoxious substance. In addition to transforming it to nitroform through the reaction:

$$
\text{HC(NO$_2$)$_3$} + \text{NaHSO$_4$} \xrightarrow{\text{Acid}} \text{C(NO$_2$)$_3$SO$_4$Na},
$$

attempts were made to reduce the TeNMe to TNAMe, H$_2$N-C(NO$_2$)$_3$, with the view of nitrating this compd to O$_3$N-HN-C(NO$_2$)$_3$. The work was not completed because the plant was closed at the termination of hostilities

Ref/s: 1)Beil – not found 2)CA through 1956 – not found 3)Dr Hans Walter & Dr B.T.Fedoroff, Picatinny Arsenal, Dover, N); private communications

Aminonitroguanidine. See under Aminoguanidine

Aminonitrosaminodiadiazole. See under Diaminothiadiazole

Aminonitrotetrazole. See under Aminotetrazoles

Aminonitrotoluenes. See under Aminotoluene

Aminonitrothiazole. See under Aminothiazole

Aminonitrotriazole. See under Aminotriazole

Amiflafliroguafllalfe. See under Aminothiazole

Aminonitrinaphthalenic and amino-iso-nicotinic acids were not found in Beil.

Aminonitroxylenes. See under Aminoxylenes

AMINOÖXAZOLINES

Aminoöxazoline, C$_5$H$_7$N.O may be considered a parent compd of the following derivs:

2-Nitraminoöxazoline, CH$_2$ -O-C-NH-NQ, mw 131.09, N 32.06%. Crysts(from 95% ethanol), mp 111-115.5°. Can be prepd either from 1-β-chloroethyl-3-nitrourea, ethanol and KOH(Ref 2) or by treating the ring isomer of 3-β-aminoethylnitroura(see formula II, p 1837 of Ref 3) with NaNO$_3$ and AcOH(Ref 3). Its expl props were not examined

2-Nitraminoöxazoline and Nitric Acid. A trace of an expl oily substance was obtained on treating 2-nitraminoöxazoline with 100% HNO$_3$ (Ref 3)

2-Nitraminoöxazoline and Diazomethane. A trace of an expl oily subst was obtained on treating 2-nitraminoöxazoline with diazomethane (Ref 3)


Azidoaminooxazoline, C$_5$H$_7$N.O, and Diazidoaminooxazoline, C$_5$H$_7$N.O were not found in Beil or CA through 1956

Aminoöxyethan. Ger for Amino(poly)hydroxyethane (see Aminoethan)

Aminoöxyanthraquinone. Ger for Amino(poly)hydroxyanthraquinone
AMINOXYTRIAZOLES
AND DERIVATIVES

Aminoxytriazoles, $C_2H_4N_2O$, mw 100.08, N 55.99%, are high nitrogen compds and might prove to be useful as ingredients of prppls. The following isomers are described in the literature:

4-Amino-3-oxy-1,2,4-triazole or 4-Amino-3-hydroxy-1,2,4-triazole (Called in Beil 4-Amino-1,2,4-triazolon-(5)), $HC=NH-NH$ or $HC=NH-N$,

\[ H_2N-N-CO \quad H_2N-N-C \quad OH \]

Crysts, mp 181°. Was prep'd by heating carbohydrazide (Beil 3,121) with the ethylester of orthoformic acid in a sealed tube at 100° (Ref 2). It forms salts, such as silver aminoxytriazole, Ag$C_2H_4N_2O$ (Refs 2 & 3).

Note: This triazole was believed by Curtius to have the structure, $OC-NH-NH$ and he called it "Methenylcarbohydrazid" (Ref 2). The correct structure was established by Stoll (Ref 3).


5-Amino-3-oxy-1,2,4-triazole (Called in Beil 5-Oxo-3-imino-1,2,4-triazolidin, Urazolmonomimid, 5-Amino-1,2,4-triazolon-(3) or Imidurazol) (Called in JCS 1-iminourazole), $H_2N-C-NH-NH$ or $OC-NH-NH$. Wh ndls, mp 285°. Was obtained by heating amino-guanidinehydrochloride and urea at 150-160°.


Azidoaminooxytriazole, $C_4H_7N_2O$ - not found in Beil or CA through 1956

Nitrotriazole and/or Nitrotriazolines were not found in Beil or in CA through 1956

Aminopentanes. Same as Amylamines

AMINOPHENETOLES
AND DERIVATIVES

Aminophenetoles, Aminophenolethylethers or Phenetidines (Ethoxyaminobenzenes, Ethyloxyanilines or Ethoxyanilines), $H_2N-C_6H_4-OC_2H_5$. The three known isomers are described in Beil 13,359,404,436, (109,129, 146) & [166,211,224].

Azidoaminophenetoles, $C_4H_9N_4O$ and Diazidoaminophenetoles, $C_4H_7N_2O$ - not found in Beil or CA through 1956.

Mononitroaminophenetoles, $H_2N-C_6H_4(NO_2)-OC_2H_5$, mw 182.18, N 15.38%. Several isomers are described in Beil 13,388-90, 422, 520-1(136-7, 186) & (192,284,286).

Nitroaminophenetoles, $O_2NHN-C_6H_4-OC_2H_5$, not found in Beil or CA through 1956.

Dinitroaminophenetoles, $H_2N-C_6H_4(NO_2)_2-OC_2H_5$, mw 227.18, N 18.50%. Several isomers are described in Beil 13,393,423,525, (138,188,190,193) & [292-3].

Nitronitroaminophenetoles, $O_2NHN-C_6H_4(NO_2)-OC_2H_5$ and Dinitronitroaminophenetoles, $O_2NHN-C_6H_4(NO_2)_2-OC_2H_5$ - not found in Beil or CA through 1956.

Trinitroaminophenetoles, Trinitrophenetidines or Ethoxytrinitroaniline, $H_2N-C_6H_4(NO_2)_3-OC_2H_5$, mw 272.18, N 20.59%, OB to CO$_2$, -76.4%, OB to CO$_2$ -29.4%. The following isomers are found in the literature:

2,4,6-Trinitro-3-aminophenetole, 2,4,6-Trinitrophenetidine or 3-Ethoxy-2,4,6-trinitroaniline. Lt yel crystals, mp 107-8°. Can be prep'd by boiling pure 2,3,4,6-tetranitroaniline with abs alc and NaOAc. Another method consists of treating 2,4,6-trinitro-m-dichlorobenzene first with EtOH and then with NH$_3$ (Refs 1,2,3). Its expln temp is 236° when heated at the rate of
5°/min and 257° when heated 20°/min; impact test values with a 10 kg wt > 24 cm max fall for 0/6 shots vs 18-19 cm for tetryl; thermal stability at 95°-no change in 30 8-hour days (Ref 3)


2,3,5-Trinitro-4-aminophenetole or 2,3,5-Trinitro-p-phenetidine (called 4-Ethoxy-2,3,6-trinitroaniline by Lorang). Red ndls with greenish sheen (from methanol), mp 125-7°; easily sol in acet, hot alc, AcOH and NB. Reacts in the same manner as the previous compd. Was prepd in an impure state in 1884 by Köhler, but he did not establish its structure (Ref 1,p 532). Much later it was prepd in a pure state by heating 2,3,5-trinitro-4-toluene sulfaminophenetole with concd H2SO4 at 70-80°(Ref 2). There is also another method of prepn(Ref 3). It is unquestionably an exp of superior stability against heat, but it was not investigated from this point of view


Note: No higher nitratred and/or nitrited derivs were found in Beil or CA through 1956

**AMINOPHENOLS AND DERIVATIVES**


Azidoaminophenols, C6H4N3O and Diazidoaminophenols were not found in Beil or CA through 1956

Mononitroaminophenols or Aminonitrophenols, H3N-C6H4(NO2)-OH, mw 154.12, N 18.18%. Several isomers are described in Beil 13, 388,390-1,421-2,520-1 & [121, 136, 185-6]

Nitraminophenols, O2NHN-C6H4-OH and Nitronitraminophenols, O2NHN-C6H4(NO2)OH not found in Beil or CA through 1956

Dinitroaminophenols or Aminodinitrophenols, H3N-C6H4(NO2)2-OH, mw 199.12, N 21.10%, OB to CO2 -84.3%, OB to CO -4.02%. As these compds and some of their derivs are mild expls, a brief description of each iso-mer is given

3,5-Dinitro-2-amino phenol or 2-Amino-3,5-dinitrophenol, yel solid, mp 218°. It was found in Beil or CA through 1956


4,6-Dinitro-2-amino phenol; 2-Amino-4,6-dinitrophenol or Pieramic Acid(PAA) (Dinitrophenamin Acid or 1-Hydroxy-2-amino-4,6-dinitrobenzene). Dark-red ndls (from alc) or prisms(from chlf), mp 169-170°; v sl sol in cold w, 10.14 g in 100 g at 22°, more sol in hot w, easily in alc, benz & AcOH; diff sol in eth & chlf. Was first prepd in 1853(Ref 2) by reducing PA with H2S in alc NH3. Other reducing agents such as Zn in NH3, alc (NH4)2S, or aq Na2S, can be used. Lyons & Smith(Ref 5) prepd PAA in good yields by reducing PA with iron turnings in a very dil soln of Fe or Na chloride at 80-85°. Other methods of prepn are listed in Ref 1 as well as in Refs 7 & 7a

According to Daniel(Ref 3), Turpin prepd PAA about 70 years ago in France on an industrial scale and used it, as well as its Na salt, in expl compns such as PAA 30 to 50% and KNO3, 70 to 50%
PAA is a mild explosive and its expl props were examined by Will (Ref 4). Its Q\textsuperscript{v}

\[ Q\textsuperscript{v} = 678.49 \text{ kcal/mol} \text{ (Ref 6)} \]

\[ Q\textsuperscript{f} = 676.9 \text{ kcal/mol} \text{ (Ref 6)} \]

\[ Q\textsuperscript{f} = 677-74 \text{ kcal/mol} \text{ (Ref 8)} \]

\[ Q\textsuperscript{v} = 281(1853) \text{ kcal/mol} \text{ (Ref 6)} \]

\[ Q\textsuperscript{f} = 603.44, \text{ N} = 13.93\% \]

\[ Q\textsuperscript{v} = 55.8 \text{ Ref (8)} \]

\[ Q\textsuperscript{f} = 60.5 \text{ Ref (6)} \]

\[ Q\textsuperscript{v} = 61.8 \text{ Ref (8)} \]

\[ Q\textsuperscript{v} = 676.9 \text{ Ref (6)} \]

\[ Q\textsuperscript{v} = 676.15 \text{ Ref (8)} \]

\[ Q\textsuperscript{v} = 603.44, \text{ N} = 13.93\% \]

\[ Q\textsuperscript{v} = 55.8 \text{ Ref (8)} \]

\[ Q\textsuperscript{v} = 60.5 \text{ Ref (6)} \]

\[ Q\textsuperscript{v} = 61.8 \text{ Ref (8)} \]

\[ Q\textsuperscript{v} = 676.9 \text{ Ref (6)} \]

\[ Q\textsuperscript{v} = 676.15 \text{ Ref (8)} \]

PAA is a mild explosive and its expl props were examined by Will (Ref 4). Its Q\textsuperscript{v} is 678.49 kcal/mol (Ref 6) or 677–74 (Ref 8), and Q\textsuperscript{f} is 676.9 (Ref 6) or 676.15 (Ref 8); Q\textsuperscript{v} is +57.8 (Ref 8) and Q\textsuperscript{f} +60.5 (Ref 6) or +60.5 (Ref 6) or 61.8 kcal/mol (Ref 8).

PAA forms salts, some of which are explosive (see below).

**References:**


**Ammonium Picramate**

\[ (NH_4)_6C_6H_4N_3O_8 \]

dk plates, mp 165° and dec at higher temp. Was prepd by Girard by neutralizing PAA with ammonia.

**References:**

1) Beil 1395 2) A. Girard, Ann 88, 281 (1853)

**Barium Picramate**

\[ Ba(C_6H_4N_3O_8)_2 \]

red nlds with golden reflection, which can be safely heated to 200° but which detonate at a higher temp. It was prepd by Girard by mixing a hot aq soln of Amm picramate with an aq soln of Ba nitrate.

**References:**

1) Beil 1395 2) A. Girard, Ann 88, 281 (1853)

**Chromiumhexammine Picramate or Hexaminochromic Picramate**

\[ [Cr(NH_3)_6(C_6H_4N_3O_8)_2] \]

brn, amor ppt. Was prepd from hexamninechromic hydroxide and picramic acid.

**References:**

1) Beil – not found 2) H. J. S. King, JCS 125, 1335 (1924)

**Copper Picramate**

\[ Cu(C_6H_4N_3O_8)_2 \]

yel grn amor ppt; insol in w & alc and sol in acids and NH_4; detonated mildly on heating. It was prepd by Girard by treating an aq soln of Amm picramate with a soln of a Cu salt.

**References:**

1) Beil – not found 2) J. Daniel (1902), 615 3) B. W. Dunn, "Rept of Chief Inspector,
Thalliumdiethyl Picramate (called by Goddard Thalliumdiethyl-4,6-dinitro-2-amino-phenoxide), \( \text{C}_2 \text{H}_5 \text{Tl} \cdot \text{C}_6 \text{H}_4 \text{N}_2 \text{O}_5 \), mw 432.57, N 9.71%. Small carmine-red plates with metallic lustre, mp 159° with decomp (darkening ca 140°); expl violently when moistened with fuming HNO₃. Moderately sol in alc, acet and pyridine, sl sol in chlf, eth or toluene, insol in CCl₄ & petr eth. Was prep’d by Goddard by treating an aq soln of picramic acid with thalliumdiethyl bromide, \( \text{Tl} \cdot (\text{C}_2 \text{H}_5)_2 \text{I} \) Br.

Refs: 1) Beil 13,197  2) A.E. Goddard, JCS 119,1313(1921)

2,3-Dinitro-4-aminophenol or 4-Amino-2,3-dinitro-phenol. Red cryst ppt. It was prep’d in small quantity by heating 2,3-dinitro-4-acetamidophenol with concd H₂SO₄ for a few mins, as described in Ref 2. It was not possible to isolate the 2,3-DNAPh in a state suitable for analysis since it began to decom with the evoln of gas as soon as it was freed from acid by washing on a filter. The mobile nitro-group in proximity to the amino-group is the determining cause of the instability.

Refs: 1) Beil 13,525 & (188)  2) R.Meldola & J.G.Hay, JCS 91,1482(1907)

2,5-Dinitro-4-aminophenol or 4-Amino-2,5-dinitro-phenol (Called by Girard 3,6-Dinitro-4-aminophenol). Dk-violet ndls (from alc, w or benz); mp 166–167° with sublimation. Easily sol in alc, acet or AcOH, sol in w, diff sol in benz and insol in ligroin. Can be prep’d by heating 2,5-dinitro-4-acetamidophenol with concd H₂SO₄ (Ref 3) or by heating 2,5-dinitro-4-aminophenol (Ref 2).

Refs: 1) Beil 13,[292]  2) F.Reverdin & H.P.A. Roethlisberger, Helv 5,304(1922)  3) A.Girard, BullFr 435,776(1924) & JCS 126,1,959(1924)

2,6-Dinitro-4-aminophenol or Isopicramic Acid (Isopicraminsäure in Ger). Yel-brn ndls (from w), mp 170° with sl decomp. Sl sol in w(0.082 g/100 g at 22° and 0.812 g at 100°), very sol in alc and less sol in benz. It expl on heating above the mp. Was first prep’d in 1883 by C.W.Dabney (Ref 1,p 528). Reverdin et al (Ref 2) prep’d it by heating 2,6-dinitro-4-acetamidophenol, \( \text{CH}_3 \text{CO-NH} \cdot \text{C}_6 \text{H}_4 \cdot (\text{NO}_2) \cdot \text{OH} \), with HCl. It forms salts, some of them expl, eg potassium isopicramate, \( (\text{O}_2 \text{N})_2 \cdot \text{C}_6 \text{H}_4 (\text{NH}_3) \cdot \text{OK} \), bluish-black ndls (from alc) v sol in w or alc (Ref 1,p 528)

Note: Its structure as 2,6-dinitro-3-aminophenol was established by Borsche & Feske (Ref 3). Prior to this, some investigators considered it as 2',4-dinitro-3-aminophenol (See Beil 13,(137)). The correct formula is given in Beil 13,(216)
JPrChem

Refs: 1)Beil 13, 527, (190) & [293] 2) F.Reverdin et al Ber 37, 4452(1905); 38, 1598(1906) & 39, 126(1907)

3,5-Dinitro-4-aminophenol or 4-Amino-3,5-dinitrophenol. Red ndls with greenish luster; subl ca 150° and melts at 230-231° easily sol in alc and hot w, sl sol in benz and nearly insol in ligroin. Can be prep'd by heating 3,5-dinitro-4-(3-nitro-4-methylbenzene-sulfamino)-phenetole with concd H₂SO₄ on water bath (Ref 2) or by other methods (Refs 1 & 3)


Dinitronitraminophenols, O₃NHN.C₆H₂(NO₂)_₃.C₂H₅OH. mw 244.12, N 22.95%. Not found in Beil or CA through 1956

Trinitronitraminophenols, H₂N.C₆H₂(NO₂)₃.C₂H₅OH, mw 244.12, N 22.95%, OB to CO₂ -45.9%, OB to CO -6.55%. The following isomers were found in the literature:

3,5,6-Trinitro-2-aminophenol or 2-Amino-3,5,6-trinitrophenol, crystals, mp- expl ca 167°. Was prep'd by Heller et al (Ref 2) by heating 2-acetamido-3,5,6-trinitrophenol with concd H₂SO₄ on a water bath, pouring the reaction mixt into water and recrystallizing from benzene

Its brominated product, yel ndls, structure not established, expld ca 180°


2,4,6-Trinitro-3-aminophenol (TNAPh) or 3-Amino-2,4,6-trinitrophenol or 3-Aminopicric Acid. Yel-bm flat ndls (from alc), mp 178-180°(was reported by Blanksma as 218° and in Ref 5 as 222-3°); nearly insol in cold alc or w, sl sol in hot alc or benz. Several methods of prep of are described in the literature. C.F.van Duin et al (Ref 3) prep'd it by treating an aceton soln of tetranitroaniline with an aq soln of CH₃COONa at RT. Several other methods are given in Refs 1, 2 & 4

In a recent patent (Ref 5) is described the method of prepn of 3-amino-2,4,6-trinitrophenol, mp 222-3°; from 3-chloropicric acid and gaseous NH3.

Explosion props of TNAPh, as detd by van Duin et al, are as follows: explosion temp 225°(when heated at the rate of 20°/min) and 231°(when heated at the rate of 5°/min) (corresponding temps for TNT are 321° & 304° and for tetryl 196° & 197°); impact sensitivity with Lenze-Kast app and 10kg wt-maxim fall for 0/6 shots 22-24cm (TNT >24 and tetryl14cm), and minim fall for 6/6 shots >24 cm (TNT & tetryl >24 cm); thermal stability at 95°-no change in 30 8-hour days (Ref 3, pp 169-177 & Ref 5). These results show that as an explosive 2,4,6-trinitro-3-aminophenol lies between TNT and tetryl in sensitivity to impact and thermal stability


2,3,6-Trinitro-4-aminophenol or 4-Amino-2,3,6-trinitrophenol. Red ndls(from AcOH), mp-decomp ca 145° and then expl. Can be prep'd by heating 2,4,6-trinitroacetamidophenol, CH₃CO-NH-C₆H₂(NO₂)₃OH, for a short time in a water bath with concd H₂SO₄(Ref 2). Its constitution, previously reported as the 2,3,5-trinitro isomer, was established by Meldola & Reverdin as the 2,3,6-isomer(Ref 3)

In earlier work, Meldola & Hay(Ref 2, pp 1382-4) described the diazotization of the same TNAPh. One of the products obtained by them was the highly expl trinitroquinonediazide


Trinitronitraminophenol, O₃NHN-C₆H₂(NO₂)₃.C₂H₅OH, not found in Beil or CA through 1956
Note: No higher nitrated derivs were found in Beil or CA through 1956

Aminophenols and Derivatives, Analytical Procedures are discussed in OrgAnalysis, Interscience, NY, 3(1956), 184
Aminophenolethylether. Same as Aminophenolate
Aminophenolmethylether. Same as Aminoanisole
Aminophenylacetic Acid. See Anilinoacetic Acid

AMINOPHENYLARSONIC ACID AND DERIVATIVES

Aminophenylarsonic Acid or Aminobenzene-
arsonic Acid, H$_2$N-C$_6$H$_4$O-As(OH)$_2$. Its o-, m- and p-isomers are known; the para is of interest because its dinitro deriv is explosive

p-Aminophenylarsonic Acid or p-Aminobenzenearsonic Acid, also called Arsanilic Acid; Atoxylic Acid; Arsenic Acid Anilide or m-Arsenic Acid Anilide, col ndls(from w or alc); loses at 150° a mol of w to form the anhydride H$_2$N-C$_6$H$_4$AsO$_2$; begins to brown at 280° but can be heated over 350° without melting or completely decompg;

sparringly sol in cold w, AcOH or alc; easily sol in boiling w or alc and in MeOH; almost insol in eth, acet, benz & chlf. Was first prepd in 1863 by Béchamp by heating anilinoarsenic acid(see Beil 16,878). Cheetham & Schmidt(Ref 3) prepd it by heating arsonic acid in a large excess of aniline. Detailed description of lab method of prepn of p-a
tinophenylarsonic acid is given in Ref 3


Azidoaminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As, and Diaza
dioaminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As, not found in Beil or CA through 1956

Nitroaminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As. The deriv 3-nitro-4-amino-phenylarsonic acid is described in Beil 16,881,(483) & [508] and 2-nitro-4-aminophenylarsonic acid in Beil 16, (484) & [510]

Nitrozidoaminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As - not found in Beil or CA through 1956

Nitronitraminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As - not found in Beil or CA through 1956

Dinitroaminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As, mw 307.05, N 13.69%. The following isomer is described in the literature

3,5-Dinitro-4-amino-phenylarsonic Acid or
2,6-Dinitro-1-amino-4-benzene-arsonic Acid,

\[
\begin{align*}
\text{As} & \text{O(OH)}_2 \\
\text{HC} & \text{=CH} \\
\text{O}_2 & \text{N-C(NH$_2$) =C-NO$_2$}
\end{align*}
\]

Grn-yel ndls or pdr, mp 285-950

Two isomers: 1-(2-amino-phenyl )-ethanal and 9-(4-amino-

Nitroaminophenylarsonic Acid, C$_6$H$_5$N$_2$O$_4$As - not found in Beil or CA through 1956

AMINOPHENYLETHANOL AND DERIVATIVES

(See also Anilinoethanol)

β-Aminophenylethanol; 2-Aminophenyl-ethyl alcohol; β-Ethanolaniline or β-Hydroxyethylaniline, H$_2$N-C$_6$H$_4$-CH$_2$-CH$_2$OH. Two isomers: β-(2-amino-phenyl)-ethanol and β-(4-amino-phenyl)-ethanol are described in Beil 13,242 & [362] (See also under Anilinoethanols, C$_6$H$_5$·NH·CH$_2$·CH$_2$·OH)
Azidoaminophenylethanol, C₆H₅N₂O and
Diazidoaminophenylethanol, C₆H₅N₂O – were
not found in Beil or CA through 1956

Nitroaminophenylethanol, C₆H₄N₂O₃; Nitrami-
nophenylethanol, C₆H₅NO₃ and Nitronitrami-
nophenylethanol, C₆H₅NO₄ – were not found
in Beil or CA through 1956

Dinitroaminophenylethanol, C₆H₄N₂O₅, mw
227.18, N 18.50%. The following isomer is
known:

2-(2',6'-Dinitro-4'-aminophenyl)-ethanol,
H₂N-C₆H₄(NO₂)₂-CH₂-CH₂OH. Yel ndls, mp
161–5°. Was prep'd by reduction of 2-(2',4',6'-
trinitrophenyl)-ethanol with hydrogen sul-
fide. Its expl props were not investigated

Refs: 1) Beil – not found  2) G.D. Parkes &
A.C. Farthing, JCS 1948, 1277–8 & CA 43,
592(1949)

Dinitronitraminophenylethanol, C₆H₄N₂O₇ and
Trinitronitraminophenylethanol, C₆H₄N₆O₉
were not found in Beil or CA through 1956

Trinitroaminophenylethanols, H₂N-C₆H₄(NO₂)₃
CH₂-CH₂-OH – not found in Beil or CA
through 1956. [Cf with β-(2,4,6-Trinitroani-
lino)ethanol described under Anilinoethanol]

Note: No other nitrated derivs of aminophenyl-
ethanols were found in Beil or CA through 1956
[Cf with β-(2,4,6-Trinitroanilino)-ethanol
Nitrato described under Anilinoethanol]

AMINOPHENYLPERIMIDINES
AND DERIVATIVES

Aminophenylperimidines, C₁₇H₁₃N₄. Three
isomers are described in Beil 25, 369

α-Aminophenylperimidine Azomide or 1,2,3-
Benzotriazino[3,4-α]perimidine, C₁₇H₁₆N₄,
mw 270.28, N 20.73%. Dk red solid, mp–
expl suddenly at 140°; sol in alc eth, acet,
MeOH, chll, AcOH, benz, ethyl acetate and
in hot dil sulfuric acid; insol in w. Was
prep'd by Sachs & Steiner from a-aminophen-
ylperimidine and Na nitrite in AcOH
with cooling

Refs: 1) Beil 26, 382  2) F. Sachs & M.
Steiner, Ber 42, 3674(1909) 3) J.H. Erickson,
et al, 'The 1,2,3- and 1,2,4-Triazines, Tetra-
zines and Pentazines', Interscience, NY
(1956), 41

AMINOPHENYLPHOSPHONIC ACIDS
AND DERIVATIVES

Aminophenylphosphonic Acids or Aminoben-
zenephosphonic Acids, C₆H₄NO₃P. The meta-
isomer is described in Beil 16, 383 & [410]
and the para-isomer in Beil 16, [401]
Aminophenylphosphonic Acid, Azido–,
C₆H₅N₂O₄P and Diazido–, C₆H₅N₆O₆P
Derivatives were not found in Beil or
CA through 1956

Nitroaminophenylphosphonic Acids,
C₆H₄N₂O₅P. Two isomers are described in
Beil 16, [401], neither of them expl

Compound C₆H₅N₂O₄P + 3H₂O, called by
Michaelis 'Salpetersäure-Diazophenylphos-
säure', prisms, losing 2H₂O at 130°, melt-
ing with decmpn at 180° and explg violently
at sl higher temp; very stable; sl sol in eth
and easily sol in w & in alc. Was prep'd by
treating boiling nitric acid soln of m-aminophen-
yporphosphonic acid with nitrous acid.
Numerous salts are known

Refs: 1) Beil 16, 823  2) A. Michaelis & E.
Benziger, Ann 188, 288–92(1877)

Note: No higher nitrated and/or nitrited
derivs were found

AMINOPHENYLTETRAZOLES
AND DERIVATIVES

Aminophenyltetrazoles, C₆H₅N₄, mw 161.17,
N 43.46%, OB to CO₂ - 173.7%, OB to CO
- 104.2%, are compds with one amino- and
one phenyl-group attached directly to the
tetrazole ring or compds with the amino-group
attached to a phenyl-group which, in turn, is
attached to the tetrazole ring

Both types of tetrazoles are high-nitrogen
compds and may be of interest as ingredients
of prplnts and expls
The following aminophenyltetrazoles and their derivatives were found in the literature:

1-Amino-5-phenyl-α-tetrazole; 1-Amino-5-phenyl-1H-tetrazole or 5-Phenyl-1-aminotetrazole, C₆H₅-C-N(NH₂)-N. Crysts, mp 155°, expl on rapid heating; very sl sol in cold w, easily sol in alc and hot w, nearly insol in eth, insol in acids and alkalies. Was prepd by heating 1-benzalamino-5-phenyltetrazole with HCl (Ref 2). Another method of prep is given in Ref 3. Some props are given in Refs 4 & 5.  


1-(p-Aminophenyl)-α-tetrazole or 1-(p-Aminophenyl)-1H-tetrazole,HC-N(C₆H₅,NH₂)-N. 

N ——— N

Ndls(from w), mp 155°. Can be prepd by the reduction of 1-[4'-nitrophenylene]-α-tetrazole with tin chloride and fuming HCl. Heating the product with K permanganate in dil H₂SO₄ gave the tetrazole.  

Refs: 1)Beil 26,347 2)M.Freund & T. Paradies,Ber 34,1321(1901)

5-Amino-(2-phenyl)-β-tetrazole or 2-Amino-(2-phenyl)-2H-tetrazole [Called in Beil 2-Phenyl-tetrazolon-(5)-imid],H₂N-C=N-N-C₆H₅. N ——— N

Yellowish crysts(from w), mp 142°, decmp on further heating. Diff sol in cold & hot w, sol in eth, alc, AcOH and concd HCl. Can be prepd by heating 2-phenyl-5-carbethoxyamino-tetrazole with concd HCl(at 200°) or concd H₂SO₄(at 105–110°). Its double salt with silver nitrate decomps ca 200° and expl mildly when heated in an open flame.  

Refs: 1)Beil 26,(246) 2)R.Stollé & O.Orth, Ber 58B,2103-4(1925)

N'-Amino-N'-phenyl-N'-(tetrazolyl-5)-triazene or Diazotetrazolephenyldrazine, called in Beil 3-Phenyl-1-[tetrazolyl-(5)]-tetrazen-(1) or [Tetrazol-5-diazo]-[α-phenylhydrazid], H₂N \[N=N::N-C-NH-N, mw 204.20, N 54.88%; \]

H₂C₆ \[N ——— N \]

OB to CO₂ -141.0%. Orange-yel crysts(from methanol+ethanol); decomps ca 130°; near.
insol in w. Can be prepd by the interaction of phenylhydrazide with 5-diazotetrazole (Refs 1 & 2). It was proposed by Rathsburg for use in compositions for caps, detonators etc. Instead of mixing the ingredients by mechanical means R proposed the prepn of “mixed crystals” by the method described in his patent (Ref 3).

Some of its salts are explosive and may be used in priming and initiating compositions.


5-Nitrosamino-1-phenyl-α-tetrazole or 5-Nitrosamino-1-phenyl-1H-tetrazole [Called in Beil 1-Phenyl-tetrazol-diazonium-hydroxyd- (5)], (ON)HN.C–N(C₆H₅)₂–N, mw 190.17, N 44.20%, OB to CO₂ -134.6%. Spongy mass, exploding mildly ca 108°. Easily sol in acet and alc(dec); insol in w, diss in aq Na₂CO₃ from which it may be recovered by acidifying with AcOH (but not with mineral acids). May be prepd by treating 5-amino-1-phenyl-α-tetrazole with an aq soln of NaNO₂ + HCl.

It forms salts, some of which are expl, eg, the silver salt, AgC₂H₅N₆O, mw 297.06. N 28.3%, wh voluminous ppt obtained by treating the nitroso compd with alc AgNO₃, decomps ca 224° and expl mildly when heated rapidly in a sealed glass tube above the mp.


1-Amino-5-(p-nitrophenyl)-α-tetrazole or 1-Amino-5-(4'-nitrophenyl)-1H-tetrazole, (O₂N·H·C₆H₄)C–N(NH₂)–N, mw 206.17, N 40.77%, OB to CO₂ -116.4%. Long col ndls, mp 154°; moderately sol in hot w & eth, easily sol in alc. Was prepd from p-nitrobenzal-amino-1-p-nitrophenyl-5-tetrazole and concd sulfuric acid as described in Ref 2. Its expl props were not investigated.


Note: R. Stollé et al [JPrChem 137,336 (1933) & CA 27,4233 (1933)] obtained among the products of reaction between di-p-nitrobenzohydrazide chloride in alc and Na azide, a small quantity of a substance which deflagrated violently ca 149°. It was suggested that this compd was the p-nitrobenzenyl azide of 1-amino, 5-p-nitrophenyltetrazole (See also under Di-p-nitrobenzohydrazide Azide).

5-Amino-1(p-nitrophenyl)-α-tetrazole, 5-Amino-1-(4-nitrophenyl)-1H-tetrazole or 5-(p-Nitrophenyl) 5-aminotetrazole, H₂N·C–N(C₆H₄NO₂)–N, mw 190.17, N 40.77%, OB to CO₂ -116.4%. Spongy mass, Pale yel plates, which on heating in a capillary tube, began to darken at ca 170°, shrank suddenly at ca 176° and melted with frothing at 221–3°. Can be prepd either by nitration of 5-amino-1-phenyltetrazole (Ref 2) or by treating p-nitrophenylcyanamide with hydrazoic acid (Ref 2 & 3).

Refuxing a xylene suspension of 5-amino-1-(p-nitrophenyl)-tetrazole for 2 hours yielded pale yel ndls melting with decomps at 221–3°. The product proved to be 5-(p-nitrophenylamino) tetrazole, O₂N·C₆H₄·NH·C–NH–N (Ref 3) N 40.77%, OB to CO₂ -116.4%. Long col ndls, mp 154°; moderately sol in hot w & eth, easily sol in alc. Was prepd from p-nitrobenzal-amino-1-p-nitrophenyl-5-tetrazole and concd


5-Amino-1-(m-nitrophenyl)-α-tetrazole, 5-Amino-1-(3'-nitrophenyl)-1H-tetrazole or 1-(m-Nitrophenyl)-5-aminotetrazole, H₂N·C–N(C₆H₄NO₂)–N, mw 190.17, N 40.77%, OB to CO₂ -116.4%. Long col ndls, mp 154°; moderately sol in hot w & eth, easily sol in alc. Was prepd from p-nitrobenzal-amino-1-p-nitrophenyl-5-tetrazole and concd
Fine yellow needles, which shrank at ca. 170° and melted with decomposition at 226.5–228°. Was obtained by treating m-nitrophenylcyanamide with hydrazoic acid (Ref 2).

Reflexing a xylene suspension of the crystals for 2 hrs effected a thermal rearrangement. The resulting fine pale-yellow needles melted with decomposition at 226° and proved to be 5-(m-nitrophenylamino)tetrazole, \( \text{C}_3\text{N}_2\text{H}_5\text{N} - \text{NH} - \text{N} \) (Ref 2).

References:
1) Beil 22, [521]; 2) O. Seide, Ber 57, 1804–5 (1924).

\( \alpha \)-Nitramino-\( \gamma \)-picoline or 2-Nitramino-4-methylpyridine. Lt yellow prisms, mp 182° with decomposition. Was prepd by nitrating 2-amino-4-methylpyridine with \( \text{HNO}_3 \) (d 1.4) in concd \( \text{H}_2\text{SO}_4 \) in the cold.

References:
1) Beil 22, [521]; 2) O. Seide, Ber 57, 794 (1924).

\( \alpha \)-Nitramino-\( \delta \)-picoline or 2-Nitramino-5-methylpyridine. Lt yellow needles, mp 183–183.5° (decomp). Was prepd by nitrating 2-amino-5-methylpyridine with \( \text{HNO}_3 \) and \( \text{H}_2\text{SO}_4 \) (Refs 2 & 3).

References:
1) Beil – not found; 2) S. J. Childress & R. L. McKee, JACS 73, 3504 (1951) & CA 46, 5583 (1952); 3) L. A. R. Hall & C. A. van der Werf, JACS 73, 4466 (1951) & CA 47, 136 (1952).

Note: No higher nitrated aminopicolines were found in Beil or CA through 1956.

**AMINOPICOLINES AND DERIVATIVES**

Aminopicolines or Aminomethylpyridines, \( \text{C}_6\text{H}_4\text{N} - \text{NH} \) are described in Beil 22, [633] & [342–3].

Azidoaminopicolines, \( \text{C}_6\text{H}_4\text{N} - \text{NH} \) and Diazidoaminopicolines, \( \text{C}_6\text{H}_4\text{N} - \text{NH} \) – not found in Beil and CA through 1956.

Nitroaminopicolines or Aminonitropiclines, \( \text{H}_3\text{C}(\text{C}_4\text{N})\text{H}_2(\text{NH}_3\text{N})\text{NO}_2 \), mw 153.14, N 27.44%. Several isomers are described in Beil 22, (633) & [342–3] and in the following refs:

a) E. D. Parker & W. Shive, JACS 69, 63–7 (1947) & CA 41, 2044–5 (1947)

b) G. R. Lappin & F. B. Sleza, JACS 72, 2806–7 (1950) & CA 44, 9966–7 (1950)

c) S. J. Childress & R. L. McKee, JACS 73, 3504 (1951) & CA 46, 5583 (1952)

d) H. E. Baumgarten & H. Chien-Fan Su, JACS 74, 3228–31 (1952) & CA 47, 5958 (1953)

Nitraminopicolines, \( \text{H}_3\text{C}(\text{C}_4\text{N})\text{H}_2(\text{NH})\text{NO}_2 \), mw 153.14, N 27.44%. The following isomers are described in the literature:

\( \alpha \)-Nitramino-\( \beta \)-picoline or 3-Nitro-3-methylpyridine. Lt yellow needles, mp 159° with decomposition. Was prepd by nitrating 2-amino-3-methylpyridine with \( \text{HNO}_3 \) (d 1.4) in concd \( \text{H}_2\text{SO}_4 \) in the cold.

References:
1) Beil 22, [521]; 2) O. Seide, Ber 57, 1804–5 (1924).

Aminopicolinic Acids or Aminopyridinecarboxylic Acid (Amino-pyridin-carbonsäure, in Ger), \( \text{H}_2\text{N}(\text{C}_4\text{N})\text{COOH} \). Aminopicolinic acids are aminopyridine carboxylic acids in which the carboxyl group is attached in position 2 (next to the nuclear N). Two isomers, 3-amino- and 4-amino- are described in Beil 22, 541 & [463]. If the carboxyl is attached to position 3 of aminopyridinic acid, the compd is called aminonicotinic acid (qv).

Azidoaminopicolinic Acid, \( \text{C}_6\text{H}_4\text{N}_2\text{O}_3 \) and Diazidoaminopicolinic Acids, \( \text{C}_6\text{H}_4\text{N}_2\text{O}_3 \) – not found in Beil or CA through 1956.

Nitroaminopicolinic Acid, \( \text{C}_6\text{H}_4\text{N}_2\text{O}_3 \) – not found in Beil or CA through 1956.

3-Nitrimopicolinic Acid, \( \text{O}_2\text{N}-\text{HN}(\text{C}_4\text{N})\text{COOH} \), mw 183.12, N 22.95%. Crystals, mp 178–80° with decomposition. Was prepd by cautiously adding nitric acid (d 1.4) to 3-aminopicolinic acid in concd sulfuric acid at a temp not above 5°, allowing to stand for
20 mins and pouring the mixt onto ice. After neutralizing most of the acidity, the ppt was washed with w and dried.

An aq NaOH soln of 3-nitraminopicolinic acid, acidified with AcOH precipitated the sodium salt, C₆H₅N₂O₄Na, which decomp explosively at 218⁰.

Refs: 1) Beil – not found 2) S. Carboni & G. Berti, Gazz 84, 683(1954) & CA 50, 991(1956)

Nitronitraminopicolinic Acid, C₆H₅N₂O₄ and Dinitroaminopicolinic Acid, C₆H₄N₂O₆ – not found in Beil or CA through 1956

Aminopicric Acid. See 3-Amino-2,4,6-trinitrophenol under Aminophenols

AMINOPROPANES AND DERIVATIVES

Aminopropanes or Propylamines, C₃H₇-NH₂, mw 59.11, N 23.70% are described in Beil 4,136,152,(360,368) & [619,629]

Aminopropane Salts. Some salts of aminopropane containing phosphoric groups are explosive, eg, the perchlorate of 1-aminopropane, CH₃CH₂CH₂-NH₃+HClO₄, solid, expd on heating to 290⁰ in a reaction tube

Refs: 1) Beil 4,360 2) R.L. Datta & N.R. Chatterjee, JCS 115, 1008(1919)

Azidoaminopropanes or Azidopropylamines, C₃H₇N₃, mw 100.13, N 55.96%. The following isomers are described in the literature:

2-Azido-1-aminopropane or β-Azidopropylamine, CH₃CH(CH₃)-NH₃+. Col liq, bp 44-6⁰ at 16 mm. Was prepd by heating β-bromopropylaminohydrobromide with Na azide in w

Refs: 1) Beil 4,(368) 2) M.O. Forster & J.C. Withers, JCS 101,493(1912)

3-Azido-1-aminopropane or γ-Azidopropylamine, N₃CH₃CH₂CH₂-NH₃+. Col liq, bp 56-7⁰ at 16 mm, d 1.0043 at 25/4⁰, nD 1.4615 at 25⁰, miscible with w, alc or eth; volatile with steam. Was prepd by prolonged heating of γ-bromopropylamino-hydrobromide with Na azide in w. Its picrate melts at 96⁰

Refs: 1) Beil 4,(368) 2) M.O. Forster & J.C. Withers, JCS 101,493(1912)

Diazidoaminopropanes, C₃H₇N₃ – not found in Beil or CA through 1956

Mononitroaminopropanes, and Nitraminopropanes, C₃H₇N₂O₂, mw 104.11, N 26.91. The following isomers were found in the literature:

1-Nitraminopropane; PropylNitramine or N-Nitropropylamine, H₂C-CH₂-CH₂-NHO₂. Col liq, frp -21⁰ to -23⁰, bp 128-9⁰ at 40 mm, d 1.1046 at 15⁰, sl sol in w, misc with alc & eth. Prep is described in Refs 1 & 2. Forms solid salts, some of which are explosive, eg, the potassium salt, KC₃H₅N₂O₂, scales ex-pldg mildly on heating and the silver salt, AgC₃H₅N₂O₂, ndls, detonating strongly on heating

Refs: 1) Beil 4,570 & (569) 2) Simon Thomas, Rec 9, 75-7(1890)

2-(or β-)Nitraminopropane; IsopropylNitramine or N-Nitroisopropylamine, (CH₃)₂CH-NH-NO₂. Col liq, frp -4⁰, bp 90-1⁰ at 10 mm, d 1.098 at 15⁰. Forms salts, some of which are expl, eg, the potassium salt, KC₃H₅N₂O₂, ndls, expl on heating and the silver salt, AgC₃H₅N₂O₂, plates, detong on heating

Refs: 1) Beil 4,571 2) Simon Thomas, Rec 9, 77-9(1890)

Dinitroaminopropanes and Nitronitraminopropanes, C₃H₇N₂O₄, mw 149.11, N 28.18%, OB to CO₂ -59.0%. The following isomer was found in the literature:

1,1-Dinitro-2-aminopropane; α,α-Dinitro-β-aminopropane or β,β-Dinitroisopropylamine, (O₂N)₂CH-CH(CH₃)-NH₂. Yel crys, mp decomp ca 120⁰. Can be prepd from acetaldehyde-ammonia, CH₂CH(OH)NH₂ and dinitromethane

Refs: 1) Beil 4,156 & [631] 2) P. Duden et al, Ber 38,2038(1905)
Note: No higher nitrated aminopropanes were found in Beil or in CA through 1956.

**AMINOPROPANE DIOLS AND DERIVATIVES**

Aminopropanediols, Aminopropylene glycols (Aminodihydroxypropanes or Dihydroxypropylamines) (Called Aminodiocyanopropan or Dioxypropylamin) in Ger, \( H_2N\cdot C\cdot H\cdot O\cdot H \), mw 91.11, N 15.37%. The following isomers are described in the literature:

1-Amino-2,3-propanediol or 3-Amino-1,2-propanediol (Glycerol-\( \alpha \)-monoamine, 1-Amino-2,3-hydroxypropanec, 1-Aminopropane-2,3-diol or \( \gamma \)-Aminopropylene glycol) (\( \beta \), \( \gamma \)-Dioxypropylamin, in Ger), \( H_2N\cdot C\cdot H\cdot C\cdot CH\cdot OH\cdot C\cdot H\cdot OH \). Viscous oil, d1.1752 at 20°/4°, bp 264° at 739 mm with (sl decomp), n D 1.49 at 10°; readily sol in w & alc, insol in eth or benz. Can be prep by mixing glycidol, \( C\cdot H\cdot O\cdot C\cdot H\cdot CH\cdot OH \), with \( NH_4 \) (Ref 2) or by other methods (Refs 1 & 3)

Refs: 1) Beil 4,301 (447) & [753] 2) L.Knorr & E.Knorr, Ber 32,752-4 (1899) 3) H.P.den Otter, Rec 57, 18-20 (1938) & CA 32,3354 (1938)

2-Amino-1,3-propanediol (Glyceral-\( \beta \)-monoamine, \( \beta \)-Aminotrimethylene glycol, 2-Amino-1,2-dihydroxypropano or 2-Aminopropane-1,3-diol) (\( \beta \), \( \beta \)-Dioxyisopropylamin, in Ger), \( HO\cdot CH\cdot CH\cdot NH\cdot CH\cdot C\cdot CH\cdot OH \). Extremely hygroscopic syrup. Can be prep by the reduction of 2-nitro-1,3-propanediol (Ref 3) or by other methods

Refs: 1) Beil 4,303 & (448) 2) E.Schmidt & G.Wilkendorf, Ber 52,398 (1919) 3) H.P.den Otter, Rec 57,13-16 (1938)

Azidoaminopropanediols, \( C\cdot H\cdot N\cdot O\cdot N \) and Diazidoaminopropanediols, \( C\cdot H\cdot N\cdot O\cdot O\) - not found in Beil or CA through 1956

1-Amino-2,3-propanediol Dinitrate; 1-Amino-2,3-dinitropropano or 3-Amino-1,2-propanediol Dinitrate, \( H_2N\cdot CH\cdot C\cdot (ONO\cdot _2)\cdot CH\cdot (O\cdot NO\cdot _2) \), mw 181.11, N 23.20%. Its nitrile salt, \( C\cdot H\cdot N\cdot O\cdot + H\cdot NO\cdot _2 \), crystals (from BuOH), mp 90°. Was prep by Barbière (Ref 2) by nitrating the nitrile salt of 3-amino-1,2-propanediol with 97% HNO\( _3 \) at -5° removing the excess HNO\( _3 \) in vacuo, pptg the reaction product with ether at -10° and recrystg the final product from BuOH

Refs: 1)Beil - not found 2) J.Barbière, BullFr 11,470 (1944) & CA 40,2111 (1946)

Note: No other nitrated derivs were found in Beil or CA through 1956

Aminopropanediol Derivatives of den Otter. Several derivs were obtained by H.den Otter (See Ref 2 at the end of this section) by coupling aminopropanediols with aromatic nitro- or halogen-nitro compounds. On nitration of these derivs, several compds were obtained

Coupling reactions were achieved by boiling alcoholic solns of aminopropanediols under reflux with the necessary quantities of nitro- or halogen-nitro compounds. On nitration of these derivs, several compds were obtained

Among the numerous products listed in Tables 1-4 of Ref 2, the following have expl properties comparable to those of a HE, such as tetryl:

\( 2\cdot(2',4',6'\cdot Trinitrophenyl-nitramino)-1,3- dinitroxy-propane or 2\cdot(2',4',6'\cdot Trinitrophenyl-nitramino)-1,3-propanediol Dinitrate, \( (O\cdot NO)\cdot CH\cdot C\cdot [NH\cdot (NO\cdot _2)]\cdot (C\cdot H\cdot (NO\cdot _2)\cdot CH\cdot (ONO\cdot _2) \), mw 437.20, N 22.43%. Lt yel solid, mp 142-35° (with decomp); insol in w, alc & eth, sol in
acert, NB, AcOH, etc. Expl on heating or on impact (Ref 2, listed at the end of this section)

2-(2',4',6'-Trinitro-3-chlorophenyl-nitramino)-1,3-dinitroxy-propone or 2-(2',4',6'-Trinitro-3-chlorophenyl-nitramino)-1,3-propanediol Dinitrate, \( \text{(O}_2\text{N})_2\text{CH}_2\cdot\text{C[HN(NO)}_2])_2\text{C}_6\text{H}_4\text{(NO)}_2 \), mw 442.26, N 40.79%. Lt yel sol, mp softens ca 40° becoming resinous; insol in w, alc & eth, sol in acet, NB, AcOH. Expl on heating or on impact (Ref 2)

2-(2',4',6'-Dinitronaphthyl-nitramino)-1,3-dinitroxy-propone or 2-(2',4',6'-Dinitronaphthyl-nitramino)-1,3-propanediol Dinitrate, \( \text{(O}_2\text{N})_2\text{CH}_2\cdot\text{C[HN(NO)}_2])_2\text{CH}_2\text{(NO)}_2 \), mw 442.26, N 19.00%. Yel crysts, mp 117° (softening at a lower temp); insol in w, eth & chlf, sol in alc, acet, AcOH & benz. Expl on heating or on impact (Ref 2)

1',3'-Bis-(1,3-Dinitroxy-2-trinitrobenzene) 2',4',6'-trinitrobenzene I called by den Otter, Tetranitrate of 1,3-Bis-[1',3'-dihydroxypropyl-2'-nitramino]-2,4,6-trinitrobenzene, \( \text{CH(ON)}_2\cdot\text{CH(ON)}_2\cdot\text{CH}(_2\text{(ON)}_2 \rangle \), C 37.20, N 20.79%. Lt yel solid softening ca 60° and decomps ca 73°; insol in w, chlf, CCl₄, pet eth, sol in alc, eth, acet, benz, NB. Expl on heating or on impact (Ref 2)

Aminopropanoic Acids, Aminopropionic Acids and Derivatives

Aminopropanoic Acids, Aminopropionic Acids or Alamines, \( \text{H}_2\text{N-C}_3\text{H}_7\text{COOH} \). Several isomers are described in Beil 4, 381, 401 & [809, 827]

Azidoaminopropanoic Acid, \( \text{C}_6\text{H}_5\text{N}_2\text{O}_4 \) and Diazidoaminopropanoic Acid, \( \text{C}_6\text{H}_5\text{N}_2\text{O}_4 \) - not found in Beil or CA through 1956

3-Nitraminopropanoic Acid, \( \text{O}_2\text{N-H-N-CH}_2\cdot\text{CH}_2\cdot\text{COOH} \), mw 134.09, N 20.89%. Ndls, mp 73°. Was obtained by treating its amide,
O₂N·HN·CH₂·CO·NH₂, with NaOH soln. Its barium and silver salts are expi.

Refs: 1)Beil 4,576 2)A.P.N.Franchimont & H.Friedmann, Rec 26,220–2(1907)

Note: No higher nitrated aminopropanoic acids were found in Beil or in CA through 1956

AMINOPROPANOLS AND DERIVATIVES
(Propanolamines and Derivatives)

Aminopropanols or Aminopropyl Alcohols
(Aminoxypropanes or Hydroxyaminopropanes), C₃H₇(NH₂)OH, mw 75.11, N 18.65%. Three isomers are described in Beil 4,288,289,(432,433,437) & [733,734,736]. Their picrates are listed under Picric Acid solo of the nitrate 'NO₂⁺I.

Azidoaminopropanols, C₃H₇N₃O and Diazidoaminopropanols, C₃H₇N₂O – not found in Beil or CA through 1956

Aminopropanol Nitrate, C₃H₇N₃O₄ – not found in Beil or CA through 1956

Nitroaminopropanol, C₃H₇N₂O₃ and Nitraminopropanol, C₃H₇N₂O₃ – not found in Beil or CA through 1956

3-Amino-2-nitroxypropane Nitrate or Amino-isopropanol Dinitrate, H₂N·CH₂·CH(NO₃₂)·CH₃ + HNO₃, mw 183.13, N 22.94%. Crysts from abs alc, mp 94°. Was prep’d by Barbière (Ref 2) by treating 3-amino-2-propanol nitrate with concd HNO₃ at -5°, removing the excess HNO₃ in vacuo, pptg the reaction product with eth at -10° and recrystallizing it from abs alcohol.


Nitroaminopropanol Nitrate, C₃H₇N₃O₄; Nitraminopropanol Nitrate, C₃H₇N₂O₃ and Dinitroaminopropanol, C₃H₇N₂O₆ – not found in Beil or CA through 1956

Nitraminopropanol Nitrate, 1-Nitramino-2-nitroxy-propane, 1-Nitramino-2-propanol Nitrate or N-(β-Nitroxypropyl)nitrime called by Blomquist & Fiedorek Iso-Me-NENA,

\[
\text{H}_2\text{N} \cdot \text{CH}_2 \cdot \text{CH(ONO}_2\text{)} \cdot \text{CH}_3 , \text{mw 165.11, N } 25.45\% , \text{ OB to CO}_2 \sim 43.6\% , \text{ OB to CO } -14.5\% . \text{ Col crysts, mp 86–7°. Was prep’d, starting with 1-aminoo-2-propanol and ethylchlorocarbonate, by the following series of reactions:}
\]

\[
\text{H}_2\text{N} \cdot \text{CH}_2 \cdot \text{CH(OH)} \cdot \text{CH}_3 \xrightarrow{\text{C}_6\text{H}_5\text{COCl}} \text{C}_6\text{H}_5\text{COOH} \text{ followed by aq NaOH}
\]

\[
\text{(C}_3\text{H}_7\text{COO}) \cdot \text{HN} \cdot \text{CH}_2 \cdot \text{CH(OH)} \cdot \text{CH}_3
\]

\[
\text{N} \cdot (2-\text{propanol)urethane}
\]

Urethane added dropwise → \[
\text{(C}_3\text{H}_7\text{COO})\text{N(NO}_2\text{)}_- \cdot \text{CH}_3
\]

NH₃ added to the ethereal soln of the nitate \[
\text{(NH}_3^+ \cdot \text{NO}_3^-) \cdot \text{CH}_3
\]

CH(ONO₂)·CH₃

HCl added immediately \[
\text{O}_2\text{N} \cdot \text{HN} \cdot \text{CH}_2 \cdot \text{CH}_3
\]

Details of the method of prepn are given in Refs 2 & 3

Iso-Me-NENA was proposed as a possible plasticizer for NC in prepns of prplnts and as an ingredient of expl compns.

Refs: 1)Beil – not found 2)J.M.T.Blomquist & F.T.Fiedorek,OSRD Rept 4134 or PBRept 18867(1944),45–7 3)ibid,USP 2,485,855(1949), 5–6 & 12–13; CA 44,3516–17(1950)

AMINOPROPENES AND DERIVATIVES

3-Amino-1-propene, γ-Amino-α-propylene or Allylamine, CH₃·CH·CH₂·NH₂, mw 57.09, N 24.53%. Col liq, d 0.761 at 22°/4°, bp 56.50° at 756 mm; misc with w, alc & eth.

Prepn in Ref 3 and props in Ref 1

Its perchlorate was reported to expl ca 262° and the picrate at 270° (Ref 2)


Note: R.Levy,MP 32,309–12(1950) prep’d several solid compds as possible stabilizers in smokeless propellants. One of these compds (p 312),(C₃H₇)₂·N·CO·NH·CH₂·CH·CH₂, mp 82°, was prep’d by refluxing for 6 hrs allylamine with (CH₃)₂·N·CO·Cl
Azidoaminopropene, C₈H₅N₄ — not found in Beil or CA through 1956

3-Nitramino-1-propene or Allylaminitrarmerine,
CH₂ : CH-CH₂ -NH(NO₂), or other nitrated
derivs of aminopropene were not found in
Beil or CA through 1956

Note: E.E. Lewis & M.A. Naylor, JACS 69, 1968
(1947) prepd allylamminopicate as pale crystls,
mp 141-141.5°, A.J. Restaino et al., JACS 78,
2940(1956) prepd the compd with mp 144.5°. Both
compds seem to be identical with the picrate
listed on p A253(explodes at 270°)

Aminopropoxyaminimidazolidine, Nitrated.
See 1-Nitro-2-n-propoxy-2-nitraminoimidazolidi-
ne under Aminimidazoline and Aminoimid-
azolidine, Substituted Derivatives

Aminopropyaminimidazolidine, Nitrated.
See 1-Nitro-2-propylamino-2-nitraminoimidazoli-
dine and 1-Nitro-2-propylamino-2- imidazoline
Nitrath under Aminoimidazoline and Amino-
imidazolidine, Substituted Derivatives

γ-Aminopropyleneglycol. See 1-Amino-2,3-
propanediol under Aminopropanediols (1924) discussed diazotization and nitration of

Aminopseudocumenes or Amino-1,2,4-trimethyl-
benzenes, (CH₃)₂C₆H₃-NH₂. Several isomers are
known of which the 5-aminopseudocumene is
the most important. Its mono- and dinitro-
compds are known but they are not expl. Azido- and
diazido- derivs were not found in Beil or CA through 1956

Some of its salts are expl. For example, that of
2,4,6-trinitro-m-cresol, explgs ca 477°(Ref 2)
Refs: 1) Beil 12, 1150-3, 1159, (498-9, 502) &
629-31] 2) R.L. Datta et al., JACS 45, 2442(1923)

AMINOPURINES AND DERIVATIVES

Aminopurines or 1-Methylpyridazines,
C₅H₅N₄, mw 133.13, N 51.83%, are compds of
higher nitrogen content and may be of
interest as gas producing components of
expls and prpnts. The following isomers are
described in Beil:

2-Aminopurine, 2-imino-2,3-dihydropurine or
Isodine, C₅H₅N₄ + H₂O, ndls. Can be prepd
by heating 2,3-diamino-5-formaminopyrimi-
dine or by other methods
Refs: 1) Beil 26, 414 2) O.Isay, BeR 39, 264
(1906)

6-Aminopurine, 6-imino-1,6-dihydropurine or
Adenine, C₅H₄N₄ + 3H₂O, wh ndls or leaflets
loosing w at 110°, mp 360.5° with decompn
on rapid heating in a capillary tube. Can be
derived from nucleic acid. Numerous methods
for its prpn are listed in Ref 1. Its Q can
be 663.74 kcal/mol

Refs: 1) Beil 26, 420, (126) & [252] 2) P.A.
Levene & L.W. Bass, 'Nucleic Acids,' NY;
(1931,95) 3) J.Baddiley et al., JCS 1943,
386-7 & CA 37, 6667(1943) (Synthes of
adenine) 4) CA — see under Adenine

Azidoaminopurine, C₅H₅N₄; Nitroaminopurine,
C₅H₅N₂O₂ and Nitraminopurine, C₅H₅N₂O₂ —
not found in Beil or CA through 1956

AMINOPYRIDINES AND DERIVATIVES

Aminopyridines or Pyridylamines(formally
called Pyridonomides), C₅H₅N₄, mw 94.11,
N 29.77%. Several isomers are listed in
Beil 22, 428, 431, 433,(629,633) & [322,339,
340]

Azidoaminopyidine, C₅H₅N₄ — not found in
Beil or CA through 1956

Note: E.Koenigs et al, Ber 57B, 1172-8 & 1179-87
(1924) discussed diazotization and nitrination of
4-aminopyridine. as well as the prpn of salts,
such as picrate, yell ndls, mp 215-16°(p 1175)

Mononitroaminopyridines and Nitraminopyridi-
dines, C₅H₅N₂O₂, mw 139.11, N 30.21%, are
listed in Beil 22,(631,702) & [335-6, 465,
519-21). Prepn of pure compds is described
by L.N. Pino and W.S. Zeh ung, JACS 771354-
5(1955) & CA 50,3435(1956). Although these
compds are not expl some of their salts and
derivs are mild expls, eg, the sodium salt of

2-nitraminopyridine was reported to degr on
heating. Methylation of 2-nitraminopyridine
with Me₂SO gave an expd compd, C₅H₅N₂O₂,
mw 153.14, N 27.44%, darkens at 185°, melts
at 189° and degr at higher temps

Refs: 1) Beil — not found 2) A.E. Chichibabin
& A.V. Kirsanov, Ber 60, 2433-8(1927) & CA
22, 961(1928)

Nitronitraminopyridines, C₅H₅N₂O₃, mw 184.11,
N 30.43%. The following derivs are described
in the literature:

5-Nitro-2-nitraminopyridine, CH₃N=C-NH-N=O
O,N-C=CH-CH
Plate or ndls(from w), mp decomp on heating.
Its sodium salt was reported to be a mild expl

A254
Aminopyridinecarboxylic Acid. See Aminonicotinic Acid

**AMINOPYRIDYLPYRAZOLE AND DERIVATIVES**

3-Amino-5-pyridyl-pyrazole or 3-Amino-5-pyridyl-1,2-diazole, C₅H₆N₄, mw 160.18, N 34.98%, may be considered as the parent compd of the following:

Azidoaminopyridylpyrazole, C₅H₆N₄ – not found in Beil or CA through 1956

4-Nitro-3-amino-5-pyridyl-pyrazole, C₅H₆N₂C-N=NH₃, mw 205.18, N 34.12%.

Dinitroaminopyridines, C₅H₄N₄O₄, mw 184.11, N 30.43%. The following isomers are listed in the literature:

3,5-Dinitro-2-aminopyridine, CH=NO₂

3,5-Dinitro-4-aminopyridine, O₂N=CH=NO₂

Yel ndls (from w), mp 190.2°, diff sol in cold w, easily sol in inorg acids, insol in alkalis. Can be prep'd by treating 5-nitro-2-aminopyridine or 3-nitro-2-aminopyridine with concd H₂SO₄.

**Note:** No other nitrated derivs of 3-amino-5-pyridyl-pyrazole were found in Beil or CA through 1956

**AMINOQUINOLINE AND DERIVATIVES**

Aminoquinoline (Amino-chinolin, in Ger), (C₅H₆N)NH₂, mw 144.17, N 19.43%. Several isomers are described in Beil 22,443–5, 447,450,(637–640) & [350,352–3,355–6]

Note: Nitration of 4-aminoquinoline was investigated by J.C.E.Simpson & P.H.Wright, JCS1948,2023–4 & CA 43,3002(1949)
Azidoaminoquinoline, \( C_9H_N_2 \), and Diazidoaminoquinoline, \( C_9H_N_4 \) — not found in Beil or CA through 1956

Nitraminoquinolines, \( C_9H_NNH-N0_2 \), mw 189.17, N 22.21%. Two isomers are described in Beil 22,593 & [522]

\[
\begin{align*}
\text{Nitroaminoquinolines, } (C_9H_N) & \xrightarrow{\text{NO}_2} \text{, mw } 189.17, \text{ N } 22.21\%.
\end{align*}
\]

Several isomers are described in Beil 22,445,452,(637,639) & [352,354,357]

\[
\begin{align*}
\text{Nitronitraminoquinolines, } (C_9H_N) & \xrightarrow{\text{NO}_2} \text{, mw } 234.17, \text{ N } 23.93\%. \text{ The following isomer is described in the literature:}
\end{align*}
\]

6-Nitro-4-nitraminoquinoline. Golden yel ndls decompg ca 203°(Ref 2), orange-yel ndls decompg without melting at 216°(Ref 3). Was obtained by adding mixed HNO₃ + H₂SO₄ to 4-aminoquinoline dissolved in H₂SO₄ (Ref 2). Can also be obtained by adding concd HNO₃ to 6-nitro-4-aminoquinoline dissolved in concd H₂SO₄ at -15 to -20°


Dinitroaminoquinolines, \( C_9H_N \xrightarrow{(NO_2)_2} \), mw 234.17, N 23.93%. The following isomers are described in the literature:

5,7-Dinitro-8-aminoquinoline. Lt yel ndls, mp 187-8°. Can be prep’d by warming 5,7-dinitro-quinolinecarbamic acid with aq H₂SO₄ on a water bath, as described in Ref 2, or by other methods(Ref 1)

Ref's: 1)Beil 22,452,(640) & [358] 2)R.P. Dikshoorn, Rec 48,525(1929)

6,8-Dinitro-5-aminoquinoline. Dark yel ndls decompg ca 275°. Can be prep’d by heating a mixture of methyl-(or ethyl)-6,8-dinitroquinoline carbamate with concd H₃CO₄ at 105°(Refs 1 & 2)

Ref's: 1)Beil 22,[354] 2)R.P.Dikshoorn, Rec 48,244(1929)

3(?),6-Dinitro-4-aminoquinoline. Pale yel ndls, mp 282-3°. Was prep’d by adding HNO₃(d 1.40) to a stirred soln of 4-aminoquinoline dissolved in concd H₂SO₄ at -7° to +2°

Ref's: 1)Beil — not found .2)J.C.E.Simpson & P.H.Wright, JCS 1948,2023-4

Note: No higher nitrated derivs of aminoquinoline were found in Beil or CA through 1956, but some of them probably can be prep’d

Amino Resins and Plastics. The commercially important amino resins are the urea-formaldehyde and the melamine-formaldehyde condensates. Of lesser importance are the sulfonamide, aniline and thiourea resins

Ref: 1)Kirk & Othmer 1(1947),741-771(84 refs)

Note: Amino resins and plastics, as well as other resins and plastics, are finding more and more extensive use in ordnance

AMINORESORCINOLS AND DERIVATIVES

Aminoresorcinols, \( H_2N\cdotC_9H_4(OH)_2 \), mw 125.12, N 11.20%. Three isomers are described in Beil 13,782-3,787 & [468-9]

Azidoaminoresorcinols, \( C_9H_N_2O_2 \) and Diazidoaminoresorcinols, \( C_9H_N_2O_2 \) — not found in Beil or CA through 1956

Mononitroaminoresorcinols, \( H_2N\cdotC_9H_4(OH)_2NO_2 \), mw 170.12, N 16.47%. Two isomers are described in Beil 13,783,(315)

Nitraminoresorcinols, \( O_2NHN\cdotC_9H_4(OH)_3 \) — not found in Beil or CA through 1956

Dinitroaminoresorcinols, \( H_2N\cdotC_9H_4(OH)_2(NO_2)_2 \), mw 215.12, N 19.54%. One isomer, the
4,6-dinitro-2-aminoresorcinol, is described in Beil 13,(783)

Dinitroaminoresorcinols, \(O_2NHN\cdot C_4H\)
\((OH)_2(\text{NO}_2)_2\) – were not found in Beil or CA through 1956

Trinitroaminoresorcinols, \(H_2N\cdot C_6(\text{NO}_2)_2(\text{NO}_2)_2\),
\(mw\ 260.12, N 21.54\%, \text{OB to CO } -36.97\%\). The following isomer was found in the literature:

\[
\text{2,4,6-Trinitro-5-aminoresorcinol,} \quad O_2N\cdot C=C(\text{OH})-C(\text{NO}_2)\quad \text{Dark yellow crystals}
\]

\(H_2N\cdot C=C(\text{NO}_2)\cdot C(\text{OH})\)
(from benz + alc), decompg at 236-70. Was prep'd by treating pentanitroaniline (free from benz) with \(CH_2\text{COONa or Na}_2\text{CO}_3\) in aq acet. Its expl props were not investigated.

Refs: 1)Beil 13,(474) 2)B.Flürsheim & E.L.Holmes, JCS 1928,3044 & CA 23,823 (1929)

Note: No higher nitrated derivatives of aminoresorcinols were found in Beil or CA through 1956

**AMINOSALICYLIC ACID AND DERIVATIVES**

Aminosalicylic Acids or Aminohydroxybenzoic Acids, \(C_6H_4O_2(\text{OH})\cdot NH_2\) are described in Beil 14,577,579,(649,650) & [350,352]

Azidoaminosalicylic Acid, \(C_6H_4N_2O_3\) and Diazidoaminosalicylic Acid, \(C_6H_4N_2O_3\) – not found in Beil or CA through 1956

Nitroaminosalicylic Acids, \(C_6H_4N_2O_4\). Two isomers are described in Beil 14, 579,586, (649) & [350,354]

Note: No higher nitrated and/or nitrited derivs were found in Beil or CA through 1956

**AMINOSTYRENES AND DERIVATIVES**

Aminostyrenes, Vinylanilines or Aminovinylbenzenes, \(CH_2:CH\cdot C_6H_4\cdot NH_2\), \(mw\ 119.16, N 11.76\%. Three isomers, 2-, 3- and 4-, are described in Beil 12,1187 & [648]

Azidoaminostyrene, \(C_6H_4N_2\) and Diazidoaminostyrene, \(C_6H_4N_2\) – not found in Beil or CA through 1956

\(\alpha\)-Aminostyrene or Styrylamine, \(C_6H_4\cdot CH:\) \(\text{CH}\cdot \text{NH}_2\), is listed in Beil 12,1188 & [648] but no description of its props and no method of prep are given

4-Aminostyrene Polymer, \((C_6H_4N)_x\), is an amor substance which softens ca 76° and melts ca 81°. Can be prep'd by heating 4-aminoacinnamic acid (Ref 3) or by reduction of its ethylester with Sn+HCl (Ref 2)

Refs: 1)Beil 12,1188 2)G.Bender, Ber 14, 2359-61 (1881) 3)A.Berthenshen & F. Bender, Ber 15,1982(1882)

Mononitroaminostyrenes, \(C_6H_4N_2O_2\), \(mw\ 164.16, N 17.07\%\) – not found in Beil or CA through 1956

2,\(\omega\) (or 3,\(\omega\))-Dinitro-4-amino-styrene or 3(or 2)-Nitro-4-(\(\beta\)-nitrovinylaniline (Called by Friedländner 'Nitroparamido-\(\omega\)-nitrostyrol'), \(O_2N\cdot CH:CH\cdot C_6H_4(\text{NO}_2)\cdot NH_2\), \(mw\ 209.16, N 20.09\%. Red-brown ndls(from alc), mp-not given. Was obtained by treating 4-aminoacinnamic acid with mixed nitric-sulfuric acid in the cold. Its expl props were not investigated.

Refs: 1)Beil 12,1188 2)P.Friedländer & M.Lazarus, Ann 229,247 (1885)

Note: No other nitrated and/or nitrited derivs were found in Beil or CA through 1956

**AMINOTETRAZOLE AND DERIVATIVES**

Aminotetrazoles, \(CH_3N_2\), \(mw\ 85.06, N 82.34\%, OB to CO \(-65.8\%, OB to CO \(-47.0\%\). The following isomers are theoretically possible:

a)1-amino-\(\alpha\)-tetrazole or 1-amino-1H-tetrazole
b)2-amino-\(\beta\)-tetrazole or 2-amino-2H-tetrazole
c)5-amino-\(\alpha\)-tetrazole or 5-amino-1H-tetrazole
d)5-amino-\(\beta\)-tetrazole or 5-amino-2H-tetrazole. Of these the best known is item c
Items a and c exist only in the form of derivs, while item b or derivs were not found in the literature.

1-Amino-a-tetrazole or 1-Amino-1H-tetrazole, HC-N(NH₂)ₙ-N, appears to be known in the form of its derivs such as: a)1-amino-5-phenyl-a-tetrazole and its chlorophenyl-, nitro- and dichloroamino-derivs (see under Aminophenyltetrazoles) b)1-amino-5-(p-tolyl)-a-tetrazole and its dichloramino-deriv (see under Aminotolyltetrazoles) and c) 1-benzylideneamino-5-phenyl-a-tetrazole (qv)


2-Amino-β-tetrazole or 2-Amino-2H-tetrazole, HC=N-N-NH₂. This compd or its derivs were not found in Beil or CA through 1956.

5-AMINO-a-TETRAZOLE or 5-AMINO-1H-TETRAZOLE (One of the Ger names is Tetrazolon-imid and Thiele called it 'Amidotetrazotsäure'). It is usually designated as 5-ATZ, H₂N-C-NH-N or H₂N-C-NH-N. It crystallizes from w in the form of monohydrate, wasprisms or lflts, which lose 1H₂O above 100° and melts at 200-3°. It is diff sol in alc; insol in eth; sol in aq solns of bases and strong acids; sol in w to the extent of 117g per 100g H₂O at 18° and 7g at 100°(Ref 12,p 23). Its Qᵥ° 246.2 kcal/mol and Qᵥ of 5-ATZ as a high-nitrogen compd which might be of interest as a component of proplnts(or expls) or as a starting material for various derivs. According to these investigators the high chemical stability of the tetrazole ring plus the fact that substitutions in the ring are usually accomplished together with the synthesis of tetrazole itself, leaves only the amino group of 5-ATZ available for useful chemical reactions. Therefore, the reactions of 5-ATZ aside from salt formation deal principally with the reactions of this functional group. The amino group of 5-ATZ can be likened to that of aniline.

X-ray diffraction spectra and IR absorption spectra of 5-ATZ are given in Ref 12, pp 81-9, IR absorption spectra in Ref 10a, X-ray diffraction patterns in Ref 11a, UV and IR absorption spectra in Ref 12a

5-ATZ was first synthesized in 1892 by Thiele(Ref 2) by treating aminoguanidine with nitrous acid. The intermediate guanylazide was cyclized by ammonia to 5-ATZ:

\[
\begin{align*}
\text{Aminoguanidine} & \quad \xrightarrow{\text{NH}_2 \text{OH}} \quad \text{Guanylazide} \\
\text{H}_2\text{N-C(NH}_2\text{)-NH-NH}_2 \quad & \quad \xrightarrow{\text{HONO}} \quad \text{5-ATZ}
\end{align*}
\]

Dilute acids may be used in lieu of ammonia. Several other methods of prep are described in the literature. In the method of Stolle(Ref 4) 5-ATZ is obtained by treating aminoguanidine with nitrous acid. Lieber & Levering(Ref 10), after modifying and working out Stolle's method in detail, obtained yields up to 74.5%. The same investigators prep 5-ATZ in 70% yield by the reduction of tetrazolylazide(or its K salt) with H₂S. Garbrecht & Herbst(Ref 11b) prep 5-ATZ by hydrogenolysis of 5-benzylaminotetrazole in abs alc in presence of Pd charcoal catalyst.

Audrieth & Currier(Ref 12) investigated 5-ATZ as a high-nitrogen compd which might be of interest as a component of proplnts(or expls) or as a starting material for various derivs. According to these investigators the high chemical stability of the tetrazole ring plus the fact that substitutions in the ring are usually accomplished together with the synthesis of tetrazole itself, leaves only the amino group of 5-ATZ available for useful chemical reactions. Therefore, the reactions of 5-ATZ aside from salt formation deal principally with the reactions of this functional group. The amino group of 5-ATZ can be likened to that of aniline.

X-ray diffraction spectra and IR absorption spectra of 5-ATZ are given in Ref 12, pp 81-9, IR absorption spectra in Ref 10a, X-ray diffraction patterns in Ref 11a, UV and IR absorption spectra in Ref 12a.
ATZ forms metallic salts, some of them expl, eg, the silver salt, AgCH₂N₃. Wh amor ppt obtained by treating an aq soln of 5-ATZ with a AgNO₃ soln. It defgr on heating(Ref 2, p 59). The mercury salt, prepd in 1942 in derivs (Ref 6a) on treating 5-ATZ with Hg(NO₃)₂, expl on impact or heating.

When 5-ATZ was treated with NaNO₃ +aq HCl under cooling, Thiele obtained a compd which was not analyzed because it exploded at ca 0°. Details of the procedure are given in Ref 2, p 62.

Although not expl by itself, 5-ATZ may serve as the starting material for the prep of expl derivs such as the nitrate, nitramino-compd, di(tetrazolyl-5):N'N'-hexazadiene, etc, some of which are described below.

5-ATZ is a high nitrogen compd and can be used as a cooling agent in propellants. For instance, Hale & Audrieth(Ref 9) claimed that incorporation of up to 25% of 5-ATZ in smokeless propellants reduced the amt of flash and smoke without changing the ballistic potential or sensitivity to mechanical action.


5-Nitraminotetrazole (3-NATZ) of O'Connor, O₂N-HN-C-NH-N, mw 130.07, N 64.62%, OB CO₂ -9.2%, OB to CO 0%. Col crysts, mp 195°, expl at sl higher temp, fairly sol in w; insol in alc, acet, eth, chl & benz (Ref 2); Qₚ 209.2 kcal/mol(Ref 9). It was prepd by treating nitroguanylazide with aq ammonia as described in Ref 2.

Its disodium salt, Na₂CN₄O₄, mw 174.05, N 48.29%, OB to CO₂ -9.2%, OB to CO 0%. Yel ndls, mp – expl violently with a bright yel flash ca 207°. Very sol in w, sl sol in eth & benz; insol in acet, CS₂ & chl. Was prepd by treating guanylazide with an aq Na acetate soln(Ref 2).

Refs: 1)Beil – not found 2)T.E.O' Connor et al,JSCI 68,309(1949) & CA 44,3443(1950) 3)W.S.MeEwan & M.W.Rigg,JACS 73,4726(1951)

Note: Lieber et al(see next item) could not
Aldolcondensation Product of 5-Aminotetrazole, \( \text{CH}_3\text{CH(OH)}\cdot\text{CH}_3\cdot\text{CH}:\text{N-C-NH-N} \),

\[
\begin{array}{c}
\text{N} \quad \text{N} \\
\text{N} \quad \text{N}
\end{array}
\]

mw 155.16, N 45.14%. Col lfts or prisms, mp ca 170°; fairly sol in hot w; sl sol in hot alc; insol in eth, ace & chlf. Was prepd by heating anhydrous 5-aminotetrazole with anhydrous freshly distilled (in an atm of \( \text{CO}_2 \)) acetaldehyde for several hours on a water bath.

Its silver salt, \( \text{AgC}_5\text{H}_4\text{N}_5\text{O} \), wh expl ppt, was prepd by adding to an alc soln of the above aldon condensation product, the calcd amt of \( \text{AgNO}_3 \) in alc and some alc ammonia.

When 5-ATZ was treated with freshly re-distilled benzoaldehyde (instead of acetaldehyde), the resulting mixt consisted of cryts explg at 183°, which proved to be guanylaminotetrazole together with some guanylaminotetrazole nitrate and some unreacted 5-aminotetrazole.

**Refs:**
1) Beil – not found

\( [N^6,N^6\text{-Bis(o-tetrazolyl-5)}]\text{-hexazadiene} \) or \( N^6,N^6\text{-}(\text{Ditetrazolyl-5)}\text{-hexazadiene} \). Hofmann & Lieber called it *Bisdiazotetrazolylhydrazide*. Beil names it 1,6-Bis-[tetrazolylinden-(5)]-hexazdien or 1,6-Di-[tetrazolyl-(5)]-hexazdien, \( \text{N-NH-C=N:NH-NH-N:}=\text{N-C-NH-N} \) or \( \text{N-NH-C=N-N:}=\text{NH-N:} \).

Another method of prepn consists in treating nitroguanylazide with ammonia (Ref 2, p 2327).

Guoundium-5-nitrimotetrazole, \( \text{CH}_3\text{N}_3+\text{CH}_3\text{N}_3\text{O}_2 \), mw 187.148, N 66.65% was obtained in the form of wh platelets (which melted after purification at 225-226°) from guanidine carbonate, \( \text{AcOH} \) and nitraminoguanidine as described in Ref 2, p 2328.

**Refs:**
1) Beil – not found
2) E. Lieber et al, *JACS* 73, 2327-28 (1951) & CA 46, 1987 (1952)
3) E. Lieber et al, *JACS* 73, 2329-31 (1952)

(UV spectra of 5-NATZ and its salts)

Potassium-5-nitramotetrazole, \( \text{KCHN}_6\text{O}_2 \), mw 168.17, N 49.98%, was obtained as almost colorless plates on treating nitramino-guanidine with \( \text{K nitrite} \) in water, as described in Ref 2, p 2328. The compd exploded with a purple flash when dropped on a hot bar at ca 220°.

Diammonium-5-nitrimotetrazole, \( (\text{NH}_4)_2\text{-CN}_6\text{O}_2 \), mw 164.14, N 68.27%, col short ndls, mp 220-1°. Was obtained by heating 5-nitramotetrazole with ammonia on a steam bath and then chilling the mixture. Another method of prepn consists in treating nitroguanylazide with ammonia (Ref 2, p 2327).

Guanidinium-5-nitramotetrazole, \( \text{CH}_3\text{N}_3+\text{CH}_3\text{N}_3\text{O}_2 \), mw 187.148, N 66.65% was obtained in the form of wh platelets (which melted after purification at 225-226°) from guanidine carbonate, \( \text{AcOH} \) and nitraminoguanidine as described in Ref 2, p 2328.

**Refs:**
1) Beil – not found
2) E. Lieber et al, *JACS* 73, 2327-28 (1951) & CA 46, 1987 (1952)
3) E. Lieber et al, *JACS* 73, 2329-31 (1952)

(UV spectra of 5-NATZ and its salts)
A 261


and its salts and derivs (Ref, pp 25-31)

b) 4-(5-Tetrazolyl)-semiarcbazide,
H2N-NH-C-NH-C-NH-N,
\[ \begin{array}{c}
\text{O} \\
\text{N} \\
\text{N}
\end{array} \]

and its salts and derivs (Ref, pp 31-45 & 48-49)

c) 4-(5-Tetrazolyl)-carbamyl Azide,
N3C-NH-C-NH-N, and its derivs (Ref, pp 46-8)
\[ \begin{array}{c}
\text{O} \\
\text{N} \\
\text{N}
\end{array} \]

d) 5-Tetrazolylammonium Cyanate,
ONCH-H2N-C-NH-N, (Ref, pp 49-56)
\[ \begin{array}{c}
\text{N} \\
\text{N} \\
\text{N}
\end{array} \]

e) N-(5-Tetrazolyl)-urea, H2N-C-NH-C-NH-N,
\[ \begin{array}{c}
\text{O} \\
\text{N} \\
\text{N}
\end{array} \]

and its derivs (Ref, pp 57-67 & 68-71)

f) 1-(5-Tetrazolyl)-semicarbazide,
H2N-N-C-NH-C-NH-N,
\[ \begin{array}{c}
\text{O} \\
\text{N} \\
\text{N}
\end{array} \]

and its derivs (Ref, pp 71-75)

g) N-Alkyl-N'-(5-tetrazolyl)ureas and N,N-Alkyl-N'-(5-tetrazolyl)ureas (Ref, pp 75-78)

h) 1-Octadecyl-5-octadecyl-aminotetrazole,
(C18H37)HN-C-N(C18H37)-N (Ref, pp 79-81)
\[ \begin{array}{c}
\text{N} \\
\text{N} \\
\text{N}
\end{array} \]


Aminotetrazole Substituted Derivatives.
Many substituted alkyl-, dialkyl-, aryl-, alkylaryl-, etc compds are described in the literature, for instance, methylaminotetrazole, which is described as 5-amino-1-methyl-α-tetrazole. Other substituted 5-aminotetrazoles,
such as ethyl-, ethylmethyl-, propyl-, isopropyl-, dimethyl-, diethyl, etc are described by R.M. Herbst, C.W. Roberts & E.J. Harvill, JOC 16, 139–49 (1951) & CA 45, 6629 (1951)

Addnl Refs on AZT Substituted Compounds

m-Aminotetrol or 2,4,6-Tinitro-3-methyl-nitramino-aniline. See Methylaminoaniline and Derivatives

AMINOTHIAZIAZOLE

AND DERIVATIVES

2-Amino-1,3,4-thiadiazole or 2-Amino-1,3,4-thiadiazoline, called by Freund "Imidothiazobalin", H2C=S-CN-NH2 or HC=S-CN-NH.

Col crystals, mp 191–4°; easily sol in hot w & in alc; insol in eth, benz & chlf. Was prepd by treating with aq NaOH the hydrochloride of aminothiadiazole (ndls, mp 149–50°) which was prepd by prolonged treatment of 1-formyl-thio-semicarbazide with an excess of acetyl chloride at RT (Ref 2). If the last reaction was conducted under pressure, acetylaminothiadiazole was obtained


Note: Several later refs are given in CA

Azidoaminothiadiazole, C2H2N3S — not found in Beil or CA through 1956

2-Nitrosamino-1,3,4-thiadiazole, called by Freund "Nitrosimidothiazobalin", C2H2N2O, mw 130.13, N 43.06%. Yel crysts, mp 220° (dec). Was prepd by treating 2-amino-5-ATZ derivs with aq Na nitrate while cooling


5-Azido-2-nitrosamino-1,3,4-thiadiazole or 5-Azido-2-nitrosimino-1,3,4-thiadiazoline, N2C=S-CN-NH-N or N2C=S-CN-NH-N, mw 171.15, N 57.29%. Dk brn ppt which expl violently ca 150°, sl sol in w, eth and hot alc. Was prepd by treating 5-hydrazino-2-amino-1,3,4-thiadiazole dihydrochloride with aq Na nitrate while cooling


5-Azido-2-nitrosamino-1,3,4-thiadiazole or 5-Azido-2-nitrosimino-1,3,4-thiadiazoline, N2C=S-CN-NH-NO or N2C=S-CN-NH-NO, mw 171.15, N 57.29%. Dk brn ppt which expl violently ca 150°, sl sol in w, eth and hot alc. Was prepd by treating 5-hydrazino-2-amino-1,3,4-thiadiazole dihydrochloride with aq Na nitrate sol. at 0°
prepd by nitrating 2-amino-1,3,4-thiadiazole with fuming nitric acid at 40°


2-Nitramino-1,3,4-thiadiazole, C₄H₄N₃O₃S, crysts, mp 177°. Was prepd by nitrating the 2-amino-1,3,4-thiadiazole dissolved in concd H₂SO₄.


Note: Apparently the last two derivs of and treatment with phosphoric acid (Refs 2 & 3) or by nitrating 2-aminothiazole with mixed nitric-sulfuric acids (Ref 4)

AMINOTHIAZOLES AND DERIVATIVES

2-Aminothiazoles, called in Beil Thiazolone-(2)-imid, H₂S-C-NH₂ or H₂S-C:CNH,

\[
\begin{align*}
\text{HC} & \quad \text{HC} \\
\text{___} & \quad \text{___} \\
\text{N} & \quad \text{NH}
\end{align*}
\]

mw 100.14, N 27.97%. Yel crysts, mp 90–92°; easily sol in hot w; diff sol in alc & eth. Can be prepd by refluxing an aq suspension of thiourea and chloroacetaldehyde alcohol until the oily layer was no longer turbid (Refs 2 & 3)

Moran & Morrow obtained a col cryst perchlorate when they added aminothiazole to 20% perchloric acid. When its soln, cooled to 0°, was treated with ethyl nitrite in view to obtain diazonium perchlorate and then stirred, a sharp expln occurred and the cracking detonation was repeated at short intervals, even when the soln was allowed to remain unstirred in contact with fragments of ice. On account of these explns and because of its great solv, no attempts were made to isolate the diazonium perchlorate. When gold chloride was cautiously added to the above soln, an orange ppt was obtained. It was collected, washed with a little ice water and dried on a porous plate in a desiccator over KOH. The partly dried material was somewhat Nitrimino-3,4,5-trinitro thiazoine, mp 172–5°. Was prepd by treating a sulfuric acid soln of 2-aminothiazole with 90–95% nitric acid mixed with concd sulfuric acid. Abs alc was added dropwise to destroy the excess of nitric acid (Ref 3) (See also Ref 2)


2-Nitramino-5-nitrothiazole, O₂N-C-S-C-NHNO₂

\[
\begin{align*}
\text{HC} & \quad \text{HC} \\
\text{___} & \quad \text{___} \\
\text{N} & \quad \text{NH}
\end{align*}
\]

Crysts, mp—explodes at 162–7°. Was prepd by treating a sulfuric acid soln of 2-aminothiazole with 90–95% nitric acid mixed with concd sulfuric acid. Abs alc was added dropwise to destroy the excess of nitric acid (Ref 3) (See also Ref 2)


2-Nitramino-dinitrothiazole, C₁₄H₁₄N₄O₈S — was not found in Beil or in CA through 1956

2-Nitramino-3,4,5-trinitrothiazolone or 2-Nitrimino-3,4,5-trinitro-4-thiazolone, O₂N-C-S-C-N-O₂

\[
\begin{align*}
\text{___} & \quad \text{NO}_2
\end{align*}
\]

O₂N-C — N-NO₂
Wh crysts, mp 121–3° with violent decompn. Was prepd by nitrating 2-nitramino-5-nitrothiazole with 99–100% nitric acid in the presence of acetic anhydride and glacial acetic acid. The crude product must be well washed or it becomes gummy and explodes. (See also Aminomethylthiazole and Derivatives)

Ref: 1)Beil - not found 2)S.J.Viron & A.Taurins,CanJRRes 31,887(formula VI) & 890-1 & CA 49,2423(1955)

Addnl Refs on Aminothiazoles and Derivs:

5-Amino-1,3,4-thiodiazoltbion-(2). See 5-Amino,2-mercapto-1,3,4-thiadiazole

3-Amino-5-thiol-1,2,4-thiadiazole. See 5-Amino,2-mercapto-1,3,4-thiadiazole

5-Amino-vic(or 1,2,3,4)-thiotriazole [1.2.3.4-Thiotriazolon-(5)-imid or 5-Imino-1.2.3.4-thiotriazolamin] and by Oliveri-Mandala "Thiocarbamidsäureazid", \( \text{H}_2\text{N}-\text{C} \equiv \text{S} \), mp 128–130°. Sol in warm alc, AcOH, ethyl acet & aniline; more diff sol in chlf & CS\(_2\); insol in benz; decomp by boiling w. Was prepd by treating thiosemicarbazide hydrochloride with anaq soln of NaOH in the cold

It forms salts, some of them expl, eg, \( \text{CH}_3\text{N}_2\text{S} + \text{HCl} \), crysts, defgr at 96°

Ref: 1)Beil 27,781 2)M.Freund & A. Schander, Ber 29,2502–2505(1896)

Note: This compd, known already for over 60 years, was recently described in the confidential rept of the Naugatuck Chem Div, US Rubber Co, Progress Rept Mar 15–Apr 15,1949(Nord 10,121),788. This rept was not used here as a source of information

**AMINOTHIATRIAZOLE AND DERIVATIVES**

5-Amino-1,2,3,4-thiotriazole, called in Beil 1.2.3.4-Thiotriazolon-(5)-imid or 5-Imino-1.2.3.4-thiotriazolamin and by Oliveri-Mandala "Thiocarbamidsäureazid", \( \text{H}_2\text{N}-\text{C} \equiv \text{S} \), mp 128–30°; sol in warm alc, AcOH, ethyl acetate & aniline; more diff sol in chlf & CS\(_2\); insol in benz; decomp by boiling in w. Can be prepd by treating a cooled aq soln of thiosemicarbazide hydrochloride with aq NaNO\(_2\) soln

Its hydrochloride, \( \text{CH}_3\text{N}_2\text{S} + \text{HCl} \) expl at 96°

Ref: 1)Beil 27,781 2)M.Freund & A. Schander, Ber 29,2502(1896) 3)E.Oliveri-Mandala, Gazz 441,672(1914)

**NITRAMINO THIOTRIAZOLE**, \( \text{CH}_3\text{N}_2\text{OS} \) and **NITRAMINOTHIOTRIAZOLE**, \( \text{CH}_3\text{O}_2\text{S} \) - not found in Beil or CA through 1956

**AMINOTOLUENES AND DERIVATIVES**

Aminotoluene, Aminotoluols, Aminomethylbenzenes, Methylanilines, Tolylamines or
Toluidines, CH₃C₆H₄NH₄, are described in Beil 12,772,853,880,(372,397,410 & [429, 463,482] Azidoaminotoluene, C₆H₅N₃ and Diazidoaminotoluene, C₆H₅N₇ - not found in Beil or CA through 1956

Mononitroaminotoluened, CH₃C₆H₅(NO₂)·NH₄, mw 152.15, N 18.41%, are described in Beil 12,249-2,486, 484, 876-7,996,1000,(392, 394-5,408,438-9) & [458-60, 476,534-5]

Nitroaminotoluened, CH₃C₆H₅NHNO₂, are described in Beil 16,670 & 672

Nitronitroaminotoluenes, CH₃C₆H₅(NO₂)₂·NH₂, mw 197.15, N 21.32%, are described in Beil 12,848,1000,1006 and 16,671-2

Dinitroaminotoluened, CH₃C₆H₅(NO₂)₂·NH₂, mw 197.15, N 21.32%, are described in Beil 12,851-2,878-9,1009,(396,409,442) & [462-3, 479-80,482,537-9]

Dinitronitroaminotoluenes, CH₃C₆H₅(NO₂)₂·NHNO₂, mw 242.15, N 23.14%, OB to CO₂ -72.7%, OB to CO -26.4%. The following isomers are described in the literature:

3,5-Dinitro,2-nitroaminotoluene or 4,6-Dinitro, 2-methyl-phenylnitramine, HC=C(CH₃)-C-NO₂. N,C=CH-CH C-NO₂

Yel crysts(from benz), mp 92°, defgr violently when heated above its mp. Easily sol in alc, eth & benz. Can be prepd by treating 6-aminotoluene sulfuric acid with nitric acid(d 1.51) at -10° to 0°. It forms salts, such as AgC₇H,N, and Ba(C₇H,N)₂.1-Arino-5-Ar-p-tolyl)-a(or 1H)-tetrazole, [Amino-(1-p-toly)-5-tetrazol, in Ger]

HC=C(NO₂)-C(NO₂), N-C=N(CH₂C₆H₄)-N.

3,5-Dinitro-4-nitroaminotoluene or 2,6-Dinitro-4-methyl-phenylnitramine, HC=C(CH₃)-C-NO₂. N,C=CH-CH C-NO₂. Col crysts, mp 104°, defgr when heated above its mp, easily sol in w; very sol in org solvents, except benz.

Can be prepd by treating 4-aminotoluene-sulfonic acid with nitric acid(d 1.48) at -5°. Forms salts, such as AgC₇H₅NO₃


Trinitroaminotoluened, CH₃C₆H(NO₃)₃·NH₂, mw 242.15, N 23.14%, OB to CO₂ -72.7%, OB to CO -26.4%. The following isomer is described in the literature:

2,4,6-Trimino-3-aminotoluene or 2,4,6-Trimino-3-methyl-aniline, O₂N-C=C(CH₃)-C-NO₂.

HC=C(NO₂)-C-NH₂

Yel prisms(from alc), mp 136-138°; easily sol in alc & eth; sol in alc solns of NaOH & Ba(OH)₂ and in NH₃. Can be prepd by treating 2,4,6-trinitro,3-ethoxy-toluene with alc NH₃ at ord temp(Ref 2) or by other methods listed in Refs 1 & 3. Its expl props were not examined


Note: No other isomers of trinitroaminotoluenes and no higher nitrated derivs were found in Beil or CA through 1956

AMINOTOLYLTETRAZOLES
AND DERIVATIVES

Aminotolyltetrazoles or Tolyltetrazolonimides (Cf with Tolyaminotetrazoles), C₆H₅N₄, mw 175.19, N 39.98%. The following isomers are described in the literature:

1-Amino-5-(p-tolyl)-1H-tetrazole,[Amino-(1-p-toly)-5-tetrazol, in Ger]

(p-CH₃-C₆H₄)- C-N(NH₃)·N.

Long ndls, mp 141°, decom at higher temps; sl sol in cold w, fairly sol in hot w, mod-erately sol in eth, sol in alc & acet. Can be prepd by heating 1-p-tolyal-amino-5-(p-toly)-tetrazole, (p-CH₃-C₆H₄)-C-N[N(CH₂p-CH₃C₆H₄)]-N,

with 30% hydrochloric acid (Ref 2)
Although not known as an expl., 1-ATTZ may serve as the starting material for the prep. of derivs., some of them expl.(see below)

Refs: 1) Beil 26 - not found  2) R. Stoll, et al., J. Prakt. Chem. 138, 2 & 6-7(1933)

2-Amino-5-tolyl-β(or 2H)-tetrazole, (CH₃C₆H₄)C=N=N-NH₂ - not found in Beil

or CA through 1956

5-Amino-2-tolyl-β(or 2H)-tetrazole, H₂N-C≡N-N(CH₃C₆H₄) - not found in Beil

or CA through 1956

5-Amino-1-(o-tolyl)-α(or 1H)-tetrazole, H₂N-C≡N-o-CH₃C₆H₄-N. Crysts, mp 191-2°.

Was prepd by cyclization of a substituted guanylazide as described in Refs 2 & 3. Its rate of isomerization is given in Ref 4. Relative basicities are given in Ref 4.


5-Amino-1-(m-tolyl)-α(or 1H)-tetrazole, H₂N-C≡N-m-CH₃C₆H₄-N. Crysts, mp 162-3°.

Was prepd by cyclization of a substituted guanylazide as described in Ref 2. Its thermal isomerization is discussed in Ref 2 and the rate of isomerization is given in Ref 3. Relative basicities are given in Ref 4.


5-Amino-1-(p-tolyl)-α(or 1H)-tetrazole, H₂N-C≡N-p-CH₃C₆H₄-N. Crysts, mp 175.5-177°; easily sol in hot alc., diff sol in hot w., very diff sol in eth. Was prepd by Stollé(Ref 2) on treating p-tolylthiourea with Pb monoxide and Na azide in hot alc. Henry et al(Ref 3) prepd it by cyclization of a substituted guanylazide. Its rate of isomerization is given in Ref 4.


Azidoaminotolyltetrazole, C₆H₃N₄ and Diazidoaminotolyltetrazole, C₆H₃N₁₁ - not found in Beil or CA through 1956

1,1'-(N-Dichloramo)-5-(p-tolyl)-α(or 1H)-tetrazole(p-CH₃C₆H₄-C≡N-Cl), mw

244.09, N 28.69%. Crysts, mp expl. Can be prepd by treating 1-amino, 5-phenyl-α-tetrazole with an aq soln of hypochiorous acid (which can be prepd by passing chlorine gas through an aq soln of Na₂CO₃).

It should be noted that the dichloramino compd is a very violent and extremely sensitive expl. It expl even when in the wet condition on being touched with a spatula or with the fingers.

Refs: 1) Beil - not found  2) R. Stollé, et al., J. Prakt. Chem. 138, 2, 7 & 8(1933) & CA 27, 4798(1933)

1,1'-Azido-5,5'-di(p-tolyl)-tetrazole,

(p-CH₃C₆H₄-C≡N-N-N-C≡N-p-CH₃C₆H₄), N-N=N-N

mw 346.35, N 40.44%, OB to CO₂ -180.2%, OB to CO -106.3%. Lt yel ndls, expl violently on heating or on impact; insol in w, sl sol in MeOH & acet; sol in benz(decomp on standing). Was prepd by treating dichloraminotolyltetrazole (see above) with an aq soln of KI, followed by addn of thiosulfate to remove the iodine.

This compd is very unusual as it contains ten nitrogen atoms linked together in a chain.
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Refs: 1)Beil — not found 2)R.Stollé et al., JPrChem 138,2 & 7–8, CA 27,4798(1933)

Nitro- and/or Nitroso-Derivatives of Aminotolyltetrazoles were not found in Beil or CA through 1956

AMINOTRIAZINES AND DERIVATIVES

Aminotriazines and Iminodihydrotriazines, C₃H₄N₄, mw 96.09, N 58.31%. The following isomers of these high nitrogen compounds are described in the literature:

2-Amino-sym(or 1,3,5)-triazine,

HC=NH₂ or HC=N-C:NH.
N=CH-N

Ndls decomg ca 228° (Ref 2) or 224° (Ref 4). Was first obtained in a small amt by Diels and called "Monoaminocyanurwasserstoff" (Ref 2). In the method patented in GBritain (Ref 3), the 2-amino-s-triazine was produced by heating formylguanidine with HCONH₂ in the presence of an alkali metal hydroxide such as NaOH at 160° until the mixt became wholly liq. The liq was then distilled at 250°.


3-Amino-asym(or 1,2,4)-triazine, HC=N-N

Wh ndls, mp 171.5–172.5°; sol in w. Was prepd by adding an aq soin of glyoxal to an aq suspension of aminoguanidine bicarbonate, as described in Ref 2. Relative basicities are given in Ref 5.


Nitrated and/or Nitrited Aminotriazines were not found in Beil or CA thru 1956

Azidoaminotriazine, C₃H₄N₅, not found in Beil or CA through 1956

Nitro- and Nitroso- derivs — not found in Beil or CA through 1956

6-Amino-2,4-sym-triazinediol. Same as Ammelide

AMINOTRIAZOLES AND DERIVATIVES

Aminotriaazoles, C₃H₄N₅, mw 84.08, N 66.64%, OB to CO₂ 114.2%, OB to CO -76.1%. The following aminotriaazole isomers are theoretically possible: a)1-amino-a-vic(or 1H-1,2,3)-triazole b)2-amino-β-vic(or 2H-1,2,3)-triazole c)4-amino-α-vic(or 1H-1,2,3)-triazole d)5-amino-α-vic(or 1H-1,2,3)-triazole e)2-amino-β-as(or 2H-1,2,4)-triazole f)3-amino-α-as(or 1H-1,2,4)-triazole(also called 5-amino-2H-1,2,4-triazole or 5-amino-3H-1,3,4-triazole) and g)4-amino-α-as(2H-1,2,4)-triazole

No description was found in the literature for compounds b), c), d) or e)

Among the nitratd and/or nitrited derivatives only 3-amino-α-as(or 1H-1,2,4)-triazole nitrate and 3-nitramino-α-as(or 1H-1,2,4)-triazole were found in the literature

1-Amino-α-vic-triazole or 1-Amino-1H-1,2,3-triazole[1,2,3-Triazolon-(1)-imid, in Ger](Called in Ber "N-Amino-osotriazol"),HC-N(NH₂)-N.

HC

Crysts, mp 51°; decomp explosively with a sharp report at higher temps. Was prepd by von Pachmann by heating a mixt of 1-benzamino-α-vic-triazole
with dil HCl in a sealed tube at 90–100° (Ref 2). The constitution of his "aminoosotriazole" was established by Stollé (Refs 3 & 4). It forms salts, some of them expl, e.g., the picrate, which melts with decomp ca 130° and then defgr (Ref 2).

Ref's: 1) Beil 26, 12 2) H. von Pechmann & W. Bauer, Ber 42, 669 (1909) 3) R. Stollé, Ber 59, 1742 (1926) 4) J. G. Erickson et al, "The 1,2,3- and 1,2,4-Triazines, Tetrazines and Pentazines", Interscience, NY (1956), 154

3-Amino-o-sym-triazole; 3-Amino-1H-1,2,4-triazole or 5-Amino-2H-1,2,4-triazole (1.2.4-Triazolon(3)-imid, in Ger) (Called by Thiele "Amidotriazol'"); HC=NH-N

<table>
<thead>
<tr>
<th>N-</th>
<th>C=NH</th>
</tr>
</thead>
</table>

This compd is manufd by the Fairmont Co (Ref 5) under the name 5-Amino-1,3,4-triazole. Yel crysrs, mp 159° (Ref 2), 156–7° (Ref 4) or 156–9° (Ref 5); sublimes and partially decomp at higher temps. Sol in w, alc or chlf; very sl sol in acetic ester and nearly insol in acet or eth (Refs 1 & 2). Its Qv is 343.10 kcal/mol and Qv~18.3 kcal/mol (Ref 4). According to Ref 2b, its power is low and Fr = 72% PA. Was first prepd by evaporating a soln of formlaminoguanidine nitrate with soda on a water bath (Ref 2).

HC=HN-NH + 2HNO3 + Na2CO3 →

<table>
<thead>
<tr>
<th>O</th>
<th>HN=CNH2</th>
</tr>
</thead>
</table>

2NaNO3 + CO2 + 2H2O + HC=NH-N

| N- | C=NH |

This and some other methods of prep are listed in Ref 1.

In Ref 3 is given a detailed description of a method of prep from formylaminoguanidine sulfate and soda soln. Rathsburg (Ref 2a) patented its use in primers, detonators, etc.

The silver salt of 3-amino-o-sym-triazole is a weak expl (Ref 2).

Note: The amino triazole examined by Williams et al (Ref 4) was obtained from the Fairmont Chemical Co. This material was purified by dissolving in dioxane, decolorizing by charcoal and recrystallizing 3 times from dioxane.


4-Amino-1-sym-triazole or 4-Amino-1H-1,2,4-triazole (Called in some papers, 4-Amino-1,2,4-triazole), HC=N-N

| N- | C=NH |

ndls, mp 82–3°; sol in w or HCl, sl sol in chlf & pet eth. Although this compd was claimed to have been prepd as early as 1899 (Ref 1), its structure was not estab until 1906 (Ref 2). According to Erickson et al (Ref 6), S. Ruhemann & R. W. Merri- mann, JCS 87, 1768–9 (1905), believed that this amidotriazole was 1,4-dihydro-s-triazine, N-NH-CH, and named it tetrazoline, but

HC=NH-N

this structure proved to be wrong.

A detailed description of the prep of 4-amino-1-sym-triazole by heating formylhydrazine at 150–200° is given in Ref 3. Formylhydrazine was obtained by heating a mixt of ethylformate and hydrazine hydrate in alc for 18 hours. In Refs 4 & 5 is described a method of prep of this amidotriazole starting with the treatment of hydrazine hydrate and carbon monoxide at high pressure and elevated temps.

It forms numerous salts and additive compds, some of them expl, eg: a) C2H4N4 + AuCl3, yel amor pdr, mp 120°, expl at
higher temps  b)C₂H₄N₄ + AgNO₃, wh ppt, defgt on heating  


5-Amino-2H-1,2,4-triazole or 5-Amino-3H-1,3,4-triazole. Same as 3-Amino-1H-1,2,4-triazole, listed here as 3-Amino-a-sym-triazole 

Ref: Private communication from Dr Ronald A.Henry,NOTS,China Lake,Calif,5056/RAH:jj, 18 Nov 1958

Azidoaminotriazole, C₃H₇N₃ – not found in Beil or CA through 1956

3-Amino-a-sym-triazole Nitrate or 3-Amino-1H-1,2,4-triazole Nitrate, HC-NH-N + HNO₃,  

\[ \text{N}_-\text{C-NH}_2 \]  

mw 147.10, N 47.61%, OB to CO₂ -38.1%, OB to CO -16.3%. Crysts, mp 180.5 -181.5°C(Ref 3), 174°C(decomp)(Ref 2). Its Q° is 318.0 kcal/mol and Q°' +109 kcal/mol(Ref 3). Was obtained by Henry(Ref 2) on heating 1-formamido-3-nitroguanidine with anhyd Na₂CO₃ in a small amt of water for 25 min according to the procedure developed by J.Thiele & K.Heidenreich,Ber 26, 2599(1893) for the prep of aminomethyltriazole. The reaction may be represented as follows:

\[ \text{HC-NH-NH} + \text{Na}_2\text{CO}_3 \rightarrow \text{O} \text{HN-C-NH}_2\text{NO}_2 \]

2NaOH + CO₂ + HC-NH-N  

\[ \text{N}_-\text{C-NH}_2\text{NO}_2 \]

The formamido nitroguanidine was prep'd by heating nitraminoguanidine with 3 times its weight of formic acid. The 3-nitramino-1,2,4-triazole may also be prep'd by nitration of its parent compd, 3-aminotriazole


Note: Expl props of the above nitraminotriazole were determined by Henry et al and were supplied to SPIA for its propellant ingredients manual. OSRD 2014(1944) gives power & brisance less than PA and FI 72% PA

Addnl Refs on Aminotriazoles and Their Derivatives:  a)J.Reilly & P.J.Drumm, JCS 1926,1729–37[Prepn and props of aminopropyl-1,2,4-triazoles and their salts and derivs. One of the derivs described in this paper is expl. See also diazo-5-isopropyl-asym(1,2,4)-triazole, under D's] b)O.Dimroth & W. Michaelis, Ann 459,39–46(1927) & CA 22,423 (1928)[Discussion on intramolecular rearrangement of 5-amino-1,2,3-triazole derivatives:

\[ \text{R}^4\text{HN-C-}\text{NR}^1\text{-N} \rightarrow \text{R}^4\text{HN-C-}\text{NR}^2\text{-N} \]

\[ \text{R-C} \rightarrow \text{N} \]

\[ \text{R-C} \rightarrow \text{N} \]
A 270

(Stability of diazonium salts of the triazole series)

j) J. Reilly & D. Madden, JCS 1929, 815–6

Can be prepd by treating 1H-vic-triazolo[d] pyrimidine-5,7-diol monohydrate with 25% NaOH soln in the manner described in Ref 2

Refs: See under next item

5(4)-Amino-α-vic-triazole-4(5)-carboxamide or 5(4)-Amino-1H-1,2,3-triazole-4(5)-carboxamide, H₂N-C-NH-N or H₂N-OC-C-NH-N,

or 5(4)-Amino-1H-1,2,3-triazole-4(5)-carboxamide, H₂N-OC-C-NH-N

Can be prepd by treating 1H-vic-triazolo[d]-pyrimidine-5,7-diol with NH₄OH in the manner described in Ref 2


Aminotriazolecarboxylic Acids, C₃H₄N₂O₄, mw 128.09, N 43.74%. The following isomers and some derivatives are described in the literature:

5-Amino-α-sym-triazole-3-carboxylic Acid or 5-Amino-1H-1,2,4-triazole-3-carboxylic Acid [Called in Beil, 5-Imino-1,2,4-triazolincarbonsäure-(3)],

Crysts with ½ H₂O(from w), decamp at 182–3° when heated rapidly. Can be prepd by prolonged heating of 4-amino-1,2,4-triazole-3,5-dicarboxylic acid with concd KOH on a water bath

Refs: 1) Beil 26, 311 2) T. Curtius et al, Ber 40, 818(1907) & CA 1, 1418(1907)

5(4)-Amino-α-vic-triazole-4(5)-carboxylic Acid or 5(4)-Amino-1H-1,2,3-triazole-4(5)-carboxylic Acid,

Crysts, mp 160–1°(decompn).

Can be prepd by treating 1H-vic-triazolo[d] pyrimidine-5,7-diol monohydrate with 25% NaOH soln in the manner described in Ref 2

Refs: See under next item

5(4)-Amino-α-vic-triazole-4(5)-carboxamide or 5(4)-Amino-1H-1,2,3-triazole-4(5)-carboxamide, H₂N-C-NH-N or H₂N-OC-C-NH-N,

or 5(4)-Amino-1H-1,2,3-triazole-4(5)-carboxamide, H₂N-OC-C-NH-N

Can be prepd by treating 1H-vic-triazolo[d]-pyrimidine-5,7-diol with NH₄OH in the manner described in Ref 2


5-Nitosamino-α-sym-triazole-3-carboxylic Acid or 5-Nitosamino-1H-1,2,4-triazole-3-carboxylic Acid [Called in Beil, 5-Nitosimino-1,2,4-triazol-carbonsäure-(3)] or 5-Diazo-1,2,4-triazol-carbonsäure-(3)],

ON-HN-C-NH-N , ON-N:C-NH-N

or HO-N:N-C-NH-N , mw 157.09,

or HO-N:N-C-NH-N

N 44.59%. Solid, explg when dry at 120–130° as well as on friction. Can be prepd by treating the sodium salt of 5-amino-1,2,4-triazole-3-carboxylic acid with NaNO₂ in dil aq HCl at ca -3° (Refs 2 & 3)

Its ethyl ester is even more expl than the acid (Ref 3, p 8)


Nitraminotriazolecarboxylic Acid, C₃H₅N₃O₄ – not found in Beil or CA through 1956

Aminotriazolidione and Derivatives

4-Amino-1,2,4-H-triazole-3,5-dione, called
in Beil 4-Amino-3,5-dioxo-1,2,4-triazolin or Azodicarbonhydrazid, OC=N=N, mw 114.07, N 49.12%. Violet, very unstable pdr, mp-expl ca 72°. Was prepd by treating disilver salt of 4-aminourazol with ether soln of iodine in presence of BaO and MgO

Refs: 1)Beil 26,(64) 2)R.Stoll, Ber 45, alkaline aq soln of 2,4,5-triamino-6-hydroxy-pyrimidine with NaNO, +AcOH (Ref 2). Prepn of its hydrochloride is described in Ref 3, Nitro sam inotriazol edione, C, HNS03 and NitT- which also gives the UV absorption spectra are given in Ref 3. Amino-IH-1, 2,3-triazolo-[d]-pyrimidines, C, HN,0, mw 136.12 N 61.75%. The following isomer is described in the literature:

7-Amino-α-vic-triazolo-[d]-pyrimidine or 7-Amino-5-hydroxy-1H-1,2,3-triazolo-[d]-4,6-diazine, N=C(NH3)-C-NH-N. Col crys ts, decomp without melting above 310°. Can be prepd by treating an aq soln of 4,5,6-triamino-2-hydroxypyrimidine with NaNO, in H2O, followed by 20 min heating on a water bath (Ref 2). UV absorption spectra are given in Ref 3


Nitrosaminotriazolopyrimidinol, C,H3N2O2 and Nitraminotriazolopyrimidinols, C,H3N2O3 - not found in Beil or CA through 1956

AMINOTRIAZOLOPYRIMIDINOLS AND DERIVATIVES

Aminotriazolopyrimidinols or Aminohydroxy-pyrimidines, C,H,N2O, mw 152.12, N 55.25%. The following two isomers are described in the literature:

5-Amino-7-hydroxy-α-vic-triazolo-[d]-pyrimidine; 5-Amino-1H-1,2,3-triazolo-[d]-pyrimidin-7-ol or 5-Amino-7-hydroxy-1H-1,2,3-triazolo-[d]-4,6-diazine, N=C(OH)-C-NH-N. H,N-C=N C=N N

Col microscopic ndls, decomp above 300° without melting. Can be prepd by treating an alkaline aq soln of 2,4,5-triamino-6-hydroxy-pyrimidine with NaNO, +AcOH (Ref 2). Prepn of its hydrochloride is described in Ref 3, which also gives the UV absorption spectra

Refs: 1)Beil - not found 2)L.O.Roblin et al, JACS 67,293(1945) & CA 39,1846(1945) 3)L.F.Cavalieri et al, JACS 70,3875-8(1948) & CA 43,1424(4948)

Nitro-2,4,6-mphenylenediamine, under Phenylpenylenediamines

AMINOURAZOLES AND DERIVATIVES

Aminourazoles, C2H4N4O2, mw 116.08, N 48.27%.
The following isomer is described in the literature:

4-Aminourazole; 4-Amino-3, 5-dioxo-sym-triazolindine; 4-Amino-3, 5-dioxo-1, 2, 4-triazolindine; (called p-Urazine in JCS 95, 237) [Called in Beil, 4-Amino-3, 5-dioxo-1, 2, 4-triazolindine, OC-NH-NH. Crysts, mp 273° to 276° (decomp). Soly in w 0.032 g/100 g at 0° and 4.02/100 g at 65°; diff sol in alc and insol in eth. Was first prepd in 1894 by Curtius and Heidenreich (Ref 2) but its correct structure was not established until 1907 (Refs 3 & 4) (see note below). Several methods of prepn are listed in Beil (Ref 1) and the following two methods are described in detail in Ref 5: a) heating carbohydrazide, OC(NH-NH₂)₂, with HCl and b) heating carbohydrazide

\[
\text{NH-CONH₂, with HCl}
\]

N-carboxamide, OC-NH-NH₂

Note: Curtius et al (Ref 2) assigned to p-Urazine the structure HN-CO-NH and called it "Bishydrazicarbonyl" or "Diharnstoff" (Diurea)


Nitrosaminourazole, C₂H₆N₄O₂ and Nitraminnourazole, C₂H₄N₃O₂ – not found in Beil or CA through 1956

AMINOXYLENES AND DERIVATIVES

Aminoxylenes, C₆H₄N, mw 121.18, N 11.56%. All possible isomers are known and listed in Beil 12, 1101, 1103, 1106–7, 1111, 1131, 1134–5, 1141, (478, 480, 482, 483, 487–8, 490) & [601–4, 606, 613–14, 618]

Azidoaminoxylenes, C₆H₄N₄ and Diazidoaminoxylenes, C₆H₄N₇ – not found in Beil or CA through 1956

Nitraminoxylenes, (O₂N-NH)C₆H₄(CH₃)₂. One isomer, Eso-Nitramino-p-xylene or 2, 5-Dimethylphenyl nitramine, is mentioned in Beil 16, 675

Nitroaminoxylenes, C₆H₄N₂O₂. Various isomers are described in Beil 12, 1102–3, 1105–6, 1110, 1127–9, 1132, 1135, 1140–2, (479, 481, 487–490) & [605–6, 612–13, 617–18, 620]

Nitronitraminoxylenes, C₆H₄N₂O₄. One isomer, 5-nitro-4-nitramino-m-xylene, is described in Beil 16, [346]

Dinitroaminoxylenes, C₆H₄N₂O₄. Various isomers are described in Beil 12, 1111, 1130, 1132, 1141, (479–82, 490) & [613]

Dinitronitraminoxylenes, C₆H₄N₂O₄, mw 256.18, N 21.87%. The following isomer is described in the literature:

3, 5-Dinitro-2-nitramino-p-xylene or 4, 6-Dinitro-2, 5-dimethylphenyl-3-nitramine, HC=C(CH₃)₂-C-NH-NO₂. Nds, mp 130° (decomp) and defgr when heated to higher temps. Sol in alc, ethyl acetate and ether. Was obtained (together with 3, 5-dinitro-p-xylene-2-diazonium nitrate) by treating 3-amino-p-xylene-2-sulfonic acid with HNO₃ (d 1.51) at −5°. Its expl props were not investigated


Trinitroaminoxylenes, C₆H₄N₂O₆, mw 256.18, N 21.87%. The following isomer is described in the literature:

2, 4, 6-Trinitro-5-amino-m-xylene or 2, 4, 6-Trinitro-sym-m-xylidene or 2, 4, 6-Trinitro-3, 5-dimethylaniline, O₂N-C=C(CH₃)₂-C-NO₂

H₂N-C=C(NO₂)₂-C-CH₃
Yel crysts, mp 206°. Can be prepd by heating 2,4,6-trinitro-5-methoxy-1,3-dimethyl-benzene for 2 hours with aic NH₃ in a sealed tube on a water bath(Ref 2) or by heating 5-bromo-2,4,6-trinitro-m-xylene with aic NH₃, 04(Ref 3). The originally assigned empirical for-

**Trinitronitraminoxylenes**, (O₂N·HN)C₉(CH₃)₉(NO₂)₃, mw 301.18, N 23.26% – Not found in Beil or in CA through 1956.

**AMMELIDE AND DERIVATIVES**

*Ammelide; 6-Amino-s-triazine-2,4 diol or 5,6-Dihydro-6-imino-s-triazine-2,4(1H, 3H)-dione* (called in Beil 4,6-Dioxo-2-imino-hexahydro-1.3.5-triazin; Isocyandiaurenemonoimid; 2.4-Dioxy-6-amino-1.3.5-triazin or Melanuresäure)

H₂N·C=N—CO  H₂N·C≡N——C—OH
 | | | | | |
HN—CO—NH  N=C(OH)—N

mw 128.09, N 43.74% Prepn and props are in Beil 26, 243, (73) & [132]
[See also CA 28, 4706 (1934); 31, 3490 (1937); 32, 502 (1938); 40, 7072 (1946); 43, 698 (1949); 44, 1136 (1950); 46, 6163 (1952); 50, 1041, 9062 & 9151 (1956)]

*Nitroammelide or 6-Nitramino-s-triazin-2,4-diol* (Designated by Cason as TM-1),

O₂N·HN·C=N—CO  O₂N·HN·C≡N——C—OH
 | | | | | |
HN—CO—NH  N=C(OH)—N

mw 173.10, N 40.46%, OB to CO₂ – 32.4% OB to CO – 4.6% Col powd, decompg sharply without melting at 248°; appreciably sol in w(hydrolyzing slowly in cold and rapidly in hot w with formation of cyanuric acid). Was prepd by Cason on treating triacetylmalamine with a 1/1 mixt of fuming HNO₃ and Ac₂O at 25° for 5 hrs (Refs 2 and 3). The originally assigned empirical formula, C₈H₅N₂O₃ (Ref 2), proved to be erroneous and should be C₃H₃N₅O₄ (Ref 3). When analyzing a sample by combustion, it is necessary, in order to avoid explosion, to mix it thoroughly with copper oxide (Ref 2)

When nitroamnellide was treated with ammonia an amorphous product contg 47.4% N was obtained.

As nitroamnellide and its ammonium salt are high nitrogen compds and as their OB to CO is close to zero, they may be of possible value in cool propellent compositions.

**AMMELINE AND DERIVATIVES**

*Ammeline; 4,6-Diamino-s-triazin-2-ol or 3,4,5,6-Tetrahydro-4,6-diamino-s-triazin-2(1H)-dione* (called in Beil 6-Oxo-2-imino-hexahydro-1.3.5-triazin; Isocyandiaurenemonoimid or 2-Oxy-4.6-diamino-1.3.5-triazin, or Melanuresaurenitroamnellide, called by Atkinson N',N'-

H₂N·C=N—N—C(NH₂)—N  HN·C—NH—CO
 | | | | | |
N=C(NH₂)—N  HN·C(:NH)—N

mw 127.11, N55.10% Prepn and props are in Beil 26, 244, (74) & [132]
[See also CA 32, 502 (1938); 40, 7072 (1946); 41, 1179 & 4003 (1947); 43, 698, 2786 & 5809 (1949); 44, 2158 (1950); 46, 6163 (1952); 48, 9413 & 9414 (1954); 49 14008, 14816 & 15734 (1955); & 50, 1041, 9062, 9151 & 10109 (1956)]

*Mononitroamnellines*, C₃H₅N₂O₃, mw 172.11, N48.83% – not found in Beil or CA through 1956.

*Dinitroamnelline*, called by Atkinson N',N'-
**Dinitroammeline**, \( \text{O}_2\text{N-HN-C—N—C-OH,} \)

\[ \text{N=C(NH-NO}_2\text{)}—\text{N} \]

mw 217.11, N 45.16%, OB to CO\(_2\) -18.4%, OB to CO + 3.7%. Wh crysts decompg sharply at 228\(^\circ\); can be detonated by a sharp blow (Ref 3). It is sol in w (slow hydrolysis) and in aq Na bicarbonate solns; insol in organic solvents. It was first prepd by Cason, but not properly identified (Ref 2). Atkinson (Ref 3) improved the method of prepn and identified the product as \( \text{N}^4, \text{N}^6\)-dinitroammeline. For its prepn, the finely ground melamine was added to a 1/1 mixt of H\(\text{NO}_3\) and Ac\(_2\)O at 0-5\(^\circ\) and stirred for 2 hrs. The resulting solid was filtered off and washed with AcOH and then with w. The purification was achieved by dissolving the product in aq Na bicarbonate soln followed by filtering and acidification with HCl as indicated in Ref 3. The yield was ca 50%

Dinitroammeline is an explosive, fairly stable in storage and comparable to tetryl in impact sensitivity

Following are the results of some tests conducted at PicArsn, Dover, NJ: heat of combustn at Cv 1673 cal/g; explosion temp (5 sec test) 275\(^\circ\); impact sensitivity 9" (PicArsn app, 2 kg wt, 0.014g sample) and 37cm (BurMines app, 2 kg wt); 100\(^\circ\) heat test (%loss of wt) 0.14 in 1st 48 hrs, 0.0 in 2nd 48 hrs and no expln in 100 hrs; 100\(^\circ\) vacuum stability test 0.88cc gas evolved in 49 hrs per 5g sample

**Refs:** 1)Beil – not found 2)J.Cason, JACS 69, 496(1947) & CA 41, 4158(1947) 3)E.R. Atkinson, JACS 73, 4443(1951) & CA 47, 138(1953) 4)PicArsn, GenLab; private communication 5)Corinfskii, ZavodLab 12, 418-21(1941)(Detn of ammeline by pptn as its picrate after separation of melamine)

**Ammeline Picrate or Diamino-hydroxytriazine Picrate**, \( \text{C}_6\text{H}_5\text{N}_6\text{O-} \cdot \text{C}_6\text{H}_5\text{N}_3\text{O}_7\cdot \text{H}_2\text{O}, \)

golden-yel crysts, mp 266\(^\circ\). It loses water of crysnt only when it is heated in vacuo over P\(_2\)O\(_5\) at 140\(^\circ\). Can be prepd by treating ammeline with hot concd picric acid to which some oxalic acid is added to facilitate the soln of ammeline

**Refs:** 1)Beil – not found 2)A.Ostrogovich and G.H.Gheorghiu, Gazz 60, 648(1930) & CA 25, 957(1931)

**Ammiachno-selitrennyi Porokh.** One of the early Russian comps used as a propellant and as a blasting expl: AN 85 & powdered carbon 15%

**Ref:** N.N.Ushakov & I.V.Lebedev, "Manufacture of Explosives", Gosizdat, Lenin-grad(1934)

**Ammiak.** Russian for Ammonia

**Ammiak or Ammoniakat.** Ger names for Ammine
AMMINE OR AMMONIATE
AND COORDINATION
(Ammoniakat in Ger and Ammoniacate in Fr)

The complex compds in which ammonia (NH₃) functions as a neutral group are very numerous and frequently very stable. They belong to the so called "coordination" compds, known since beginning of the 19th century but not properly systematized and explained until 1893 when Alfred Werner introduced his theory. In his theory, now nearly universally adopted(with slight modification, such as by Sidgwick and Lowry, etc), there are two types of valencies: a) primary (principal, main, ordinary or ionic) and b) secondary (auxiliary or non-ionic), now called "coordinate covalence". The difference between ionic and non-ionic valences is not as great as Werner at first supposed, and is of degree rather than of kind. The same kind of anion radical or molecule may be held by either or both types of valence. There is, however, an upper limit for both types of linkages. In case of non-ionic linkages, the maximum number of atoms, radicals or molecular groups, which can be directly connected with central atom(metal), is called the "coordination number" of this atom. This number is for most metals six, but it can be also four, five, three and two for the same metal(as for instance Co). For Mo the "coordination number" was reported to be eight.

In writing the formula of a "coordinated complex", the "coordinated group", called "nucleus" or the "first sphere" is enclosed in square brackets, while the acid radicals are placed outside in the so-called "second or ionization sphere". For instance in the formula [M Rₘ Xₙ]⁻, M is a metal (such as Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni or Zn), R is a non-ionic(neutral) radical(such as NH₃, H₂O, ethylenediamine, diethylenetriamine, pyridine, etc), m is "coordination number" of M, X is a negative(acidic) radical(such as Cl⁻, CN⁻, NO₂⁻, NO₃⁻, ClO₄⁻, ClO₂⁻, IO₃⁻, etc) and n is number of monovalent acidic radicals. An example of this type of complex is the compd [Co(NH₃)₆](NO₃)₂, in which the electrovalency of the nucleus is 3 (positive), the same as for the Co atom. If one or several NH₃ groups are replaced by neutral groups, such as H₂O, the electrovalency of the nucleus remains the same, as for instance in the compd [Co(NH₃)₆ H₂O](NO₃)₂. If however, one or several negative(acidic) radicals replace neutral radicals in the nucleus, the electrovalency of the nucleus is reduced—one positive valence less for each negative valence introduced. For instance in the compd [Co(NH₃)₆Cl] (NO₃)₂ the electrovalency of the nucleus is two and in the compd [Co(NH₃)₆Cl]⁺ it is equal to zero. If the negative valency in the nucleus exceeds the positive valency of the central metal, as in the compd [Co⁺(NH₃)₆(NO₃)]⁻K⁺, the nucleus as a whole becomes negative and has to be associated with a corresponding number of positive ions(such as K) outside.

In naming the complexes, the constituents of the nucleus are taken first(starting with the acid radical or extra neutral radical, if any present, and followed by the neutral group and metal) and then comes the name of the radical outside the bracket. For instance, the compd [Co(NH₃)₆Cl] (NO₃)₂ is called "chloropentammine cobalt (III) nitrate" and the compd [Co(NH₃)₆H₂O] (NO₃)₂ is "aquopentamminecobalt (III) nitrate", etc.

Ammonia can form many "coordinated complexes" with the above mentioned metals and these complexes, called "ammines" or "ammoniates" are among the most important. Usually divalent metals form complexes with four NH₃ groups, while trivalent metals usually coordinate with six NH₃ groups. There are, however, many exceptions.

Many metal ammines are explosive and those which were investigated in various
countries from that point of view are listed in tables A, B, C, D, E, F & G.

It should be noted that until Werner's time, complexes were usually designated by names denoting color: *luteo* for yellow, *purpureo* for purple-red and *roseo* for pink. Some compounds were called *praseo* to designate their green color.

As a rule, the colors of Co and Cr ammines are largely independent of the nature of the metal, but depend on the number of neutral and acidic radicals. For instance, hexammines are yellow (*luteo*), chloropentammines are purple-red (*purpureo*) and aquopentammines are pink (*roseo*). Some nitrates were reported to be higher for confined compounds than for unconfined samples.

According to Friederich and Vervoorst (Ref 11, p 49) the chlorate and perchlorate complexes decompose with explosive violence, when heated, and the reactions proceed as follows:

\[
[M(NH_3)_6](ClO_4)_2 \rightarrow MCl_2 + 2N_2 + 6H_2O
\]

\[
[M(NH_3)_6](ClO_4)_2 \rightarrow MCl_2 + 3N_2 + 6H_2O + 3H_4
\]

\[
[M(NH_3)_6](ClO_4)_2 \rightarrow MCl_2 + 2N_2 + 6H_2O + O_2
\]

where *M* represents a suitable metal.

**Uses:** Some metal ammines were patented for use as primary explosives. This excludes those which are unstable at ambient temps (evolve *NH_3*) and are too hygroscopic.

(See Tables A to G, pp A277 to A282)

**References on Ammines:**
2) R. Escales, *SS* 2, 413-14 (1907) [According to R. Escales, the "Kupfernitrat-Ammoniak", listed here in Table E as "tetramminecopper (II) nitrate" and abbreviated as CuTAN, was proposed in 1887 by A. Nobel, BritP 16920, for use as follows: a) CuTAN 4, AN 91 & TNT 5% b) CuTAN 5, NG 30-35, Na nitrate 30.5 & meal 39.5% c) CuTAN 10, NG 48, CC 2, NaN_3 30, WM 9.6 & soda 0.4%.] The first of these belonged to the class of "AN explosives", the second to "carbonites" and the third to "gelatin-dynamites". The firm G. Roth of Austria used the compns cong CuTAN 30-40, K nitrate 42-25, sulfur 10-7.0 & Al 18-28% for filling some blasting caps]
3) R. Salvatori, *Chem Ztr* 1910, 1444 & *CA* 5, 1568 (1911)
<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Compound</th>
<th>Formula</th>
<th>Color</th>
<th>Density g/cc</th>
<th>Melting Point, °C</th>
<th>Avg. Exp. Temp, °C</th>
<th>Impact Sensitivity, cm</th>
<th>Test TNT = 100</th>
<th>Sand Bomb Test TNT = 100</th>
<th>Req. for Initiation, g Primary Explosive</th>
<th>Vol of Dens, m/sec</th>
<th>Solubility in Various Solvents</th>
<th>References</th>
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</thead>
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<tr>
<td>C41</td>
<td>Diaminecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>1.92</td>
<td>192</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Dissolves in H2O with decomp</td>
</tr>
<tr>
<td>C42</td>
<td>Tetraminecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>2.55</td>
<td>192</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7, p 43 &amp; 51</td>
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<td>C43</td>
<td>Tetraminecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>195</td>
<td>218</td>
<td>218</td>
<td>-</td>
<td>-</td>
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<td>7, p 43 &amp; 11, pp 116 &amp; 164</td>
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<tr>
<td>C44</td>
<td>Tetraminecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>3.23</td>
<td>192</td>
<td>15</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>7, p 43, 45, 54-6</td>
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<td>C45</td>
<td>Hexaminecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>1.78</td>
<td>205</td>
<td>15</td>
<td>46</td>
<td>57</td>
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<td>7, pp 42-1 &amp; 49 &amp; 11, pp 66 &amp; 144</td>
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<td>C46</td>
<td>Hexaminecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>-</td>
<td>370</td>
<td>-</td>
<td>53</td>
<td>59</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11, pp 66 &amp; 144</td>
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<td>Hexazinecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>-</td>
<td>250</td>
<td>500</td>
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<td>-</td>
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<td>C48</td>
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<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>-</td>
<td>250</td>
<td>500</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>65, pp 175-6 &amp; 181</td>
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<td>C49</td>
<td>Hexazinecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>-</td>
<td>250</td>
<td>500</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>65, pp 175-6 &amp; 180</td>
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<td>C50</td>
<td>Hexazinecyclohexyl (II)</td>
<td>[C4H8H4]2(NH3)2</td>
<td>Col</td>
<td>-</td>
<td>250</td>
<td>500</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>65, pp 175-6 &amp; 180</td>
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Note: Decomposed or exploded violently when heated on a metallic spalula.
<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Compound</th>
<th>Formula</th>
<th>Color</th>
<th>Density, g/cm³</th>
<th>Melting Point, °C</th>
<th>Flash Point, °C</th>
<th>Impact Sensitivity</th>
<th>Test Results</th>
<th>Explosive Speed, m/s</th>
<th>Solubility in Various Solvents</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Triazidodiamminecobalt (III)</td>
<td>[Co(NH₃)₅(NO₂)₂]</td>
<td>Green or blue</td>
<td>0.7</td>
<td>187 (decomp)</td>
<td>0</td>
<td>Very sensitive</td>
<td>THT = 100</td>
<td>1000 m/s</td>
<td>Soly in H₂O at RT: 5.08 g/100 cc; al sol in dioctane &amp; acetone; in sol in other solvents</td>
<td>5, pp 245-32</td>
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<tr>
<td>2</td>
<td>Triazidodiamminecobalt (III)</td>
<td>[Co(NH₃)₅(NO₂)₂]</td>
<td>Blue</td>
<td>1.0</td>
<td>158</td>
<td>44</td>
<td></td>
<td></td>
<td></td>
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<td>7, p 162</td>
</tr>
<tr>
<td>3</td>
<td>Tetramminecobalt (III) Chlorate</td>
<td>[Co(NH₃)₅Cl]</td>
<td>Yellow-green</td>
<td>3.0</td>
<td>150</td>
<td>0</td>
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<td></td>
<td></td>
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<td>46, p 376</td>
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<td>4</td>
<td>Disazidodiamminecobalt (III) Azide (cis)</td>
<td>[Co(NH₃)₅(N₂)₂N₄]</td>
<td>Blk</td>
<td>0.6</td>
<td>182</td>
<td>0</td>
<td>Very sensitive</td>
<td></td>
<td></td>
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<td>7, pp 49-50</td>
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<td>5</td>
<td>Disazidodiamminecobalt (III) Azide (trans)</td>
<td>[Co(NH₃)₅(N₂)₂N₄]</td>
<td>Blk</td>
<td>0.6</td>
<td>182</td>
<td>0</td>
<td>Very sensitive</td>
<td></td>
<td></td>
<td></td>
<td>55, pp 235-6</td>
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<td>6</td>
<td>Disazidodiamminecobalt (III) Iside (cis)</td>
<td>[Co(NH₃)₅(N₂)₂]</td>
<td>Blue</td>
<td>0.8</td>
<td>180</td>
<td>0</td>
<td>Not sensitive</td>
<td></td>
<td></td>
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<td>55, pp 235-6</td>
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<td>7</td>
<td>Disazidodiamminecobalt (III) Iside (trans)</td>
<td>[Co(NH₃)₅(N₂)₂]</td>
<td>Yellow-green</td>
<td>0.8</td>
<td>180</td>
<td>0</td>
<td>Not sensitive</td>
<td></td>
<td></td>
<td></td>
<td>55, pp 235-6</td>
</tr>
<tr>
<td>8</td>
<td>Disazidodiamminecobalt (III) Nitrate (cis)</td>
<td>[Co(NH₃)₅(N₂)₂NO₃]</td>
<td>Violet-blue</td>
<td>0.8</td>
<td>200</td>
<td>0</td>
<td>Not sensitive</td>
<td></td>
<td></td>
<td></td>
<td>55, pp 235-6</td>
</tr>
<tr>
<td>No.</td>
<td>Name of Compound</td>
<td>Formula</td>
<td>Color</td>
<td>Density, g/cm³</td>
<td>M.P., °C</td>
<td>A.E., Temp. 2 kg wt: 2 kg wt</td>
<td>Impact sensiti. 2 kg wt</td>
<td>Traval Test THT = 100</td>
<td>Send Bomb Test THT = 100</td>
<td>Req for Initi. in Various Solvents</td>
<td>Notes:</td>
</tr>
<tr>
<td>-----</td>
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<tr>
<td>Co 9</td>
<td>Diamidotetramine-cobalt (III) Nitrate</td>
<td>[Co(NH₃)₄(N₂)₃(NO₃)₄]</td>
<td>Violet-blt</td>
<td>—</td>
<td>dec &gt;150</td>
<td>180° (sizzles off with yel. flame)</td>
<td>Not sensitive</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 20°: 1.71 g/100 cc of soln; v. al sol in 93% alc</td>
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<tr>
<td>Co 10</td>
<td>Diamidotetramine-cobalt (III) Perchlorate (crs)</td>
<td>[Co(NH₃)₄(N₂)₃ClO₄]</td>
<td>Violet-blt</td>
<td>—</td>
<td>dec &gt;160</td>
<td>200</td>
<td>Very sensitive</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 20°: 1.02 g/100 cc of soln; v. al sol in 93% alc</td>
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<tr>
<td>Co 11</td>
<td>Diamidotetramine-cobalt (III) Perchlorate (crs)</td>
<td>Same as above</td>
<td>Green-blt</td>
<td>—</td>
<td>dec &gt;160</td>
<td>220</td>
<td>Very sensitive</td>
<td>—</td>
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<td>Soly in H₂O at 20°: 1.70 g/100 cc of soln; v. al sol in 93% alc</td>
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<tr>
<td>Co 12</td>
<td>Thioacetamidotetramine-cobalt (III) Perchlorate</td>
<td>[Co(NH₃)₄(SCN)₂]₂ClO₄</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>925</td>
<td>33</td>
<td>—</td>
<td>48</td>
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<td>Co 13</td>
<td>Dithiocyanamidotetramine-cobalt (III) Perchlorate</td>
<td>[Co(NH₃)₄(SCN)₂]₂ClO₄</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>335</td>
<td>33</td>
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<tr>
<td>Co 14</td>
<td>Aquapentamminecobalt (III) Chlorate Monohydrate</td>
<td>[Co(NH₃)₅(N₂)₃ClO₄]·H₂O</td>
<td>Pink</td>
<td>—</td>
<td>&gt;100</td>
<td>150–150</td>
<td>Not sensitive</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 18°: 103.8%</td>
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<tr>
<td>Co 15</td>
<td>Aquapentamminecobalt (III) Perchlorate Monohydrate</td>
<td>[Co(NH₃)₅(N₂)₃ClO₄]·Cl·H₂O</td>
<td>Pink</td>
<td>—</td>
<td>ca 250</td>
<td>Not sensitive</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 18°: 7.4%</td>
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<tr>
<td>Co 16</td>
<td>Aquapentamminecobalt (III) Tetrade</td>
<td>[Co(NH₃)₅(N₂)₃(N₂)₃]</td>
<td>Red</td>
<td>—</td>
<td>dec &gt;120</td>
<td>194–200 (decomp)</td>
<td>Not sensitive</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 20°: 5.87 g/100 cc of soln; insol in alc &amp; eth</td>
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<tr>
<td>Co 17</td>
<td>Aquapentamminecobalt (III) Chlorate</td>
<td>[Co(NH₃)₅(N₂)₃ClO₄]</td>
<td>Red</td>
<td>ca 300</td>
<td>(decomp)</td>
<td>ca 500 (sizzles off with yel. flame)</td>
<td>Not sensitive</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 20°: 0.00 g/100 cc of soln; insol in alc &amp; eth</td>
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<tr>
<td>Co 18</td>
<td>Aquapentamminecobalt (III) Nitrate</td>
<td>[Co(NH₃)₅(N₂)₃(N₂)₃(NO₃)₄]</td>
<td>Red</td>
<td>—</td>
<td>200</td>
<td>300 (defg)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Soly in H₂O at 20°: 0.611 g/100 cc of soln; insol in alc &amp; eth</td>
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<tr>
<td>Co 18a</td>
<td>Chloropentamminecobalt (III) Nitrate</td>
<td>[Co(NH₃)₅(C₁₅₀₃₄NO₃)₄]</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>(See the original paper for description)</td>
<td>—</td>
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Note: Its chromate, bichromate and picrate were also prep'd
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<th>Name of Compound</th>
<th>Formula</th>
<th>Color</th>
<th>Density g/cc</th>
<th>Melting Point °C</th>
<th>Avg. Exp. Temp</th>
<th>Impulse Sensitivity, cm</th>
<th>Travel Test TMT = 100</th>
<th>Send Test TMT = 100</th>
<th>Req. for Initiation, p</th>
<th>Primary Expl.</th>
<th>Val of Duro, m/sec</th>
<th>Solubility in Various Solvents</th>
<th>References</th>
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<td>Co29</td>
<td>Chloropentaminecobalt (III) Chloride</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>₂</td>
<td>Purple</td>
<td>— — — (exp)</td>
<td>— — —</td>
<td>2kg wt</td>
<td>1kg wt</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Co20</td>
<td>Chloropentaminecobalt (III) Chloride</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>₂</td>
<td>Red</td>
<td>— — 320</td>
<td>21</td>
<td>—</td>
<td>73</td>
<td>0.20 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Co21</td>
<td>Pentaminecobalt (III) Perchlorate</td>
<td><a href="ClO%E2%82%84">Cu(NH₃)₅Cl</a>₂</td>
<td>Red-brown</td>
<td>— — 200</td>
<td>Note: This compound seems to be identical with the Co21 compound</td>
<td>Sols in H₂O at 18°. 11%</td>
<td>47 and 54</td>
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<td>Co21b</td>
<td>Formaminecobalt (III) Nitrate</td>
<td><a href="NO%E2%82%83">Co(NH₃)₅(HCO₃)</a>₂</td>
<td>(See the original paper for description)</td>
<td>— —</td>
<td>—</td>
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<td>Co22</td>
<td>Nitratescobalt (III) Nitrate</td>
<td><a href="NO%E2%82%83">Co(NH₃)₅NO₃</a>₂</td>
<td>Red</td>
<td>— — 310</td>
<td>48</td>
<td>—</td>
<td>84.5</td>
<td>0.24 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Co23</td>
<td>Hexaminecobalt (III) Chloride, monohydrate or &quot;Lutetocobaltamine Chloride&quot;</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>·H₂O</td>
<td>Yellow</td>
<td>— — 120</td>
<td>—</td>
<td>150</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3. p 1444</td>
</tr>
<tr>
<td>Co24</td>
<td>Hexaminecobalt (III) Chloride</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>·H₂O</td>
<td>Orange-Yel</td>
<td>Note: Explodes on percussion</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>10. p 522</td>
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<td>Co25</td>
<td>Hexaminecobalt (III) Nitratescobalt</td>
<td><a href="NO%E2%82%83">Co(NH₃)₅Cl</a>₂</td>
<td>Yellow</td>
<td>— — 355</td>
<td>100</td>
<td>—</td>
<td>35</td>
<td>0.24 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>Co26</td>
<td>Hexaminecobalt (III) Perchlorate</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>₂</td>
<td>Yellow</td>
<td>— — 295</td>
<td>50</td>
<td>—</td>
<td>85</td>
<td>0.27 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Co27</td>
<td>Hexaminecobalt (III) Nitrate</td>
<td><a href="NO%E2%82%83">Co(NH₃)₅Cl</a>₂</td>
<td>Yellow</td>
<td>— — 202</td>
<td>(hot block)</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>3. p 1444</td>
</tr>
<tr>
<td>Co28</td>
<td>Hexaminecobalt (III) Perchlorate</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>₂</td>
<td>Dark green</td>
<td>93</td>
<td>0.25 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>3. p 1444</td>
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<td>Co29</td>
<td>Hexaminecobalt (III) Perchlorate</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>₂</td>
<td>Dark green</td>
<td>93</td>
<td>0.25 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>3. p 1444</td>
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<tr>
<td>Co30</td>
<td>Hexaminecobalt (II) Perchlorate</td>
<td><a href="ClO%E2%82%84">Co(NH₃)₅Cl</a>₂</td>
<td>Dark green</td>
<td>93</td>
<td>0.25 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>3. p 1444</td>
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<tr>
<td>Co31</td>
<td>Diamminecobalt (II) Sels</td>
<td><a href="N%E2%82%82H%E2%82%84">Cu(NH₃)₅Cl</a></td>
<td>Dark green</td>
<td>93</td>
<td>0.25 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
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<td>3. p 1444</td>
</tr>
<tr>
<td>Co32</td>
<td>Diamminecobalt (II) Sels</td>
<td><a href="N%E2%82%82H%E2%82%84">Cu(NH₃)₅Cl</a></td>
<td>Dark green</td>
<td>93</td>
<td>0.25 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>3. p 1444</td>
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<tr>
<td>Co33</td>
<td>Tetramminecobalt (II) Sels</td>
<td><a href="N%E2%82%82H%E2%82%84">Cu(NH₃)₅Cl</a></td>
<td>Dark green</td>
<td>93</td>
<td>0.25 of MF</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>—</td>
<td>—</td>
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<td>3. p 1444</td>
</tr>
</tbody>
</table>

Note: It was prepared by the reaction of Cu(NH₃)₅Cl with silver chloride. Its explosive prop is not given in Ref. 3.
| No | Name of Compound          | Formula                  | Color  | Density g/cc | Melting Point °C | Avg Expl Temp 2kg wt | 1kg wt | Impact Sensitivity, cm | Travel Test TNT = 100 | Seed Break Test TNT = 100 | Req for Initiation, g Primary Expl | Val of Dose, m/sec | Solubility in Various Solvents | References |
|----|---------------------------|--------------------------|--------|--------------|-------------------|------------------------|--------|------------------------|------------------------|-------------------------------|------------------------|-------------------------|------------|
| Cu4 | Tetranninecobber (II) Iodate | [Cu(NH3)4]2(I2) | Blue   | 2.31         | 235                | 140                   | 3       | 15                     | 39                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Cu5 | Tetranninecobber (II) Chlorate | [Cu(NH3)4]2(ClO4) | Blue   | 1.01         | ca 125              | ca 160                | 15       | 39                     | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Cu5a| Tetranninecobber (II) Iodate | [Cu(NH3)4]2(IO4) | Blue   | 1.01         | ca 125              | ca 160                | 15       | 39                     | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Cu6 | Tetranninecobber (II) Nitrate | [Cu(NH3)4]2(NCNO) | Purple | -            | ca 330              | 19                    | 41       | 0.24 MF or 0.19 Terryl | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Cu7 | Tetranninecobber (II) Perchlorate | [Cu(NH3)4]2(ClO4) | Blue   | -            | 100                 | 50                    | 66       | 41                     | 0.24 MF or 0.19 Terryl | 78                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Cu9 | Hexanninecobber (II) Chromate | [Cu(NH3)4]2(OCN4) | Blue   | -            | Decomp at room temp | -                    | 41       | 0.24 MF or 0.19 Terryl | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Mn1 | Dianninecobber (II) Fulminate | [Mn(NH3)4]2(NO3) | Yellow | -            | Dec             | Deco                 | 41       | 0.24 MF or 0.19 Terryl | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Ni1 | Pentanninecobber (II) Iodate | [Ni(NH3)4]2(IO4) | Lt violet | 2.97       | dec              | 210                 | 41       | 0.24 MF or 0.19 Terryl | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Ni2 | Hexanninecobber (II) Acide | [Ni(NH3)4]2(N2) | Lt blue | -            | Sunn green exp vial | -                    | 41       | 0.24 MF or 0.19 Terryl | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Ni3 | Hexanninecobber (II) Iodate | [Ni(NH3)4]2(IO4) | Lt violet | 1.99       | dec             | 195                | 41       | 0.24 MF or 0.19 Terryl | 78                     | 80                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Ni4 | Hexanninecobber (II) Chlorate | [Ni(NH3)4]2(ClO4) | Blue   | 1.52        | dec              | 210                | 47       | 41                     | 0.24 MF or 0.19 Terryl | 78                            | 41                     | 0.24 MF or 0.19 Terryl | 23 and 44, p 376 |
| Ni4a| Hexanninecobber (II) Iodate | [Ni(NH3)4]2(IO4) | Blue   | 1.57        | dec              | 275                | 55       | 41                     | 0.24 MF or 0.19 Terryl | 78                            | 500 at d 1.56 (pressed) | 23 and 44, p 376 |

**Notes:**
- This sensitive explosive may form by the action of AN on Cu in presence of moisture (See Ref 33).
- It is unstable and loses NH3 in air.
- This salt exists also as a hydrate.
- Sol in H2O
- When ignited burns slowly. It would not initiate tetryl.
- Not for primary expl.

**References:**
- 7, pp 43 & 50
- 7, pp 42 & 46
- 11, pp 66 & 144
- 15, p 329
- 23 and 44, p 376
### TABLE F

<table>
<thead>
<tr>
<th>No</th>
<th>Name of Compound</th>
<th>Formula</th>
<th>Color</th>
<th>Density g/cc</th>
<th>Melting Point, °C</th>
<th>Avn. Expl Temp, °F</th>
<th>Impact Sensitivity, cm</th>
<th>Travel Temp Test</th>
<th>Send Bomb Test</th>
<th>Req for Initiation, g</th>
<th>Primary Explos</th>
<th>Vol of Deton, m/sec</th>
<th>Solubility in Various Solvents</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diamminezinc(I)</td>
<td>[Zn(NH₃)₂(OH)₂]⁺⁺</td>
<td>Col</td>
<td>-</td>
<td>-</td>
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<tr>
<td>1a</td>
<td>Diamminezinc(II)</td>
<td>[Zn(NH₃)₂(NO₃)₂]⁺⁺</td>
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<td>-</td>
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<td>2</td>
<td>Throminezinc(II)</td>
<td>[Zn(NH₃)₂(NO₂)₂]⁺⁺</td>
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<td>3.27</td>
<td>170</td>
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<td>3</td>
<td>Terrazinezinc(II)</td>
<td>[Zn(NH₃)₂(SO₄)₂]⁺⁺</td>
<td>Col</td>
<td>1.84</td>
<td>220</td>
<td>15</td>
<td>69</td>
<td>79</td>
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<td>4</td>
<td>Terrazinezinc(II)</td>
<td>[Zn(NH₃)₂(HCl)₂]⁺⁺</td>
<td>Col</td>
<td>2.82</td>
<td>214</td>
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<td>5</td>
<td>Terrazinezinc(II)</td>
<td>[Zn(NH₃)₂(NCl)₂]⁺⁺</td>
<td>Col</td>
<td>-</td>
<td>305</td>
<td>-</td>
<td>-</td>
<td>70</td>
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<td>6</td>
<td>Hexamminezinc(II)</td>
<td>[Zn(NH₃)₆]⁺⁺</td>
<td>Col</td>
<td>(See original paper)</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
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### TABLE G

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<tr>
<th>No</th>
<th>Name of Compound</th>
<th>Formula</th>
<th>Color</th>
<th>Density g/cc</th>
<th>Melting Point, °C</th>
<th>Avn. Expl Temp, °F</th>
<th>Impact Sensitivity, cm</th>
<th>Travel Temp Test</th>
<th>Send Bomb Test</th>
<th>Req for Initiation, g</th>
<th>Primary Explos</th>
<th>Vol of Deton, m/sec</th>
<th>Solubility in Various Solvents</th>
<th>References</th>
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<tbody>
<tr>
<td>1</td>
<td>Cyclonite (RDX)</td>
<td>C₅H₅N₃NO₃</td>
<td>White</td>
<td>1.82</td>
<td>204</td>
<td>260</td>
<td>32</td>
<td>100</td>
<td>157</td>
<td>125</td>
<td>0.10</td>
<td>8180</td>
<td>1 d 1.65</td>
<td>71, p 76</td>
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<tr>
<td>2</td>
<td>Lead Acide (not dest)</td>
<td>Pb(N₃)₂</td>
<td>White</td>
<td>4.80</td>
<td>Dec</td>
<td>340</td>
<td>10</td>
<td>32</td>
<td>60</td>
<td>39</td>
<td>1 1/2</td>
<td>5180</td>
<td>d 4.0</td>
<td>71, p 173</td>
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<td>3</td>
<td>Mercuric Fulminate</td>
<td>Hg(OCN)₂</td>
<td>White</td>
<td>4.43</td>
<td>Dec</td>
<td>210</td>
<td>5</td>
<td>20</td>
<td>51</td>
<td>49</td>
<td>1</td>
<td>5000</td>
<td>d 4.0</td>
<td>71, p 187</td>
</tr>
<tr>
<td>4</td>
<td>Tetryl</td>
<td>(C₅H₅N₃)₂NO₂</td>
<td>Yellow</td>
<td>1.73</td>
<td>130</td>
<td>257</td>
<td>26</td>
<td>100</td>
<td>125</td>
<td>115</td>
<td>0.20</td>
<td>7850</td>
<td>1 d 1.71</td>
<td>71, p 300</td>
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<tr>
<td>5</td>
<td>Tetryl</td>
<td>(C₅H₅N₃)₂NO₂</td>
<td>Buff</td>
<td>1.65</td>
<td>81</td>
<td>475</td>
<td>ce 100</td>
<td>Not affected</td>
<td>100</td>
<td>100</td>
<td>0.24</td>
<td>6225</td>
<td>1 d 1.56</td>
<td>71, p 318</td>
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**Notes:** The tests for the ammoniacal Ns are Cr, Ca, Ce, Co, Cr₂O₃, Cr₂O₇, Cr₂O₅, CaO, and CaS and for the standard explosives listed at the end of the table were conducted according to the methods used at Picatinny Arsenal, Dover, N. J., and described in FST 1451 (1950) by W. H. Rickesbach and A. J. Clark. The tests for the other nitrates were conducted either by methods used in Germany and described in SS 21, 50 - 52 - 65 - 69 (1926) or by methods devised by individual investigators. Explosion temps were determined for unaccelerated samples, but there was no uniformity in methods of determination—in some cases the samples were heated very gradually, in other cases very slowly; in some cases the samples were heated on a metallic spooler, in other cases they were dropped on a heated metal plate, etc. All this makes the values of explosion temps only approximate.
[Prepn and props of amminocobalt (III) comds with chloric and perchloric acids. Three varieties are described: the lutoe (yellow), purpureo(purple) and roseo(rose). The perchlorates are very stable at ord temps while the chlorates decomp slowly; the lutoe-derivs being more stable than the roseo- and purpureo-comds] (See items Co4, Co15, Co19, Co21a, Co28 & Co29 in our tables C & D) 4) F.Ephraim, Ber 45, 1322-31(1912) & CA 6, 2709-10(1912) (The nature of partial valences in metal ammines) 5)F.Ephraim, ZPhysChem 81, 513-42(1912-13) & 83, 196-220(1913); CA 7, 1658 & 3863(1913) (The nature of residual valence in ammines) 6) F.Ephraim, Ber 46, 3103-31(1913) CA 8, 597(1914) (The nature of residual valence; influence of the anion on the stability of complex cations in metal ammonia comds) 7) F.Ephraim & A.Jahnsen, Ber 48, 41-56(1915) & CA 9, 2194-5(1915) |Various metal amnomines of bromates, chlorates and iodates were prepd and examined at the Univ of Bern, Switzerland. The general method of prepn of hexammines was to pass ammonia gas into a concd aq soln of the corresponding oxyhalide salt: $6\text{NH}_3 + \text{Cu(ClO}_3\text{)}_2 \rightarrow [\text{Cu(NH}_3\text{)}_6]^{-}(\text{ClO}_3\text{)}_2$. In some cases hexammines can be prepd by treating the corresponding tetrammine at room or lower temp. Many tetrammines can be prepd by passing ammonia gas into an aq soln of the corresponding oxyhalide salt, while others are prepd by heating the corresponding hexamine to above 100°. The comds described by E and J are explosive and they are listed in the above table. The explosion temps were detnd for confined and unconfined samples and were found in some cases, to be higher for confined samples than for unconfined ones! (See items Cd2, Cd3, Cd4, Cd5, Cd6, Co3, Cu4, Cu5, Cu8, Cu9, Ni1, Ni3, Ni4, Zn2, Zn3 and Zn6 in tables A,B,E & F) 8)F.Ephraim & E.Bollé, Ber 48, 638-48(1915) & CA 9, 2195(1915) (The nature of residual valence of zinc ammines. Table in Ber 48, p 646 gives calcd values for absol temps of dissociation and heats of formation of various Zn ammines) 9)G.L.Clark et al, JACS 42, 2496-8(1920) & CA 15, 456(1921) (Cobaltammines such as trinitriamminecobalt (III)) (See item Co2 in table B) 10)G.R.Levi, Gazz 53, 522-5(1923); JCS 124, II, 767 (1923) & CA 18, 362 (1924) |Prepn and some props of several cobalt ammines, such as hexamminecobalt (III) chlorite $[\text{Co(NH}_3\text{)}_6\text{Cl}]^{-}(\text{ClO}_3\text{)}_2 \cdot \text{H}_2\text{O}$ and chloropentamminecobalt (III) chlorite $[\text{Co(NH}_3\text{)}_5\text{Cl}]^{-}(\text{ClO}_3\text{)}_2$ are given. These complexes are less stable than the corresponding chlorates and perchlorates] (See items Co20 and Co24 in table D) 11)W. Friederich & P.Vervoort, SS 21, 49-52, 65-9, 84-7, 144-5(1926) & CA 21, 1184(1927) |Metal ammine-Cd, Co, Cu, Ni and Zn chlorates and perchlorates were prepd by passing ammonia gas over the desired metallic chlorate or perchlorate solns, followed by cooling, agitation, filtering, and drying the pptd salt. Most of these comds proved to be explosives of the primary type. As a rule, they were deliquescent and hydrolyzed rapidly in moist air. Their explosive props are given in tables A,B,C,D,E&F. Methods of testing are described on pp 50-1 of this reference. Tetramminecopper (II) chlorate was the only one of the examined comds capable of detonating TNT! (See items Cd7,Co30,Cu5,Cu7,Ni5,Zn2, and Zn6 in tables A,D,E & F) 11a)Mellor, "A Comprehensive Treatise," v 8(1928), pp 229-52 479-80(See item Cu2 in table D) 12)J.N. Friend, edit, "Textbook of Inorganic Chemistry," Griffin, London, v 10(1928), "The Metal Ammines" by M.J. Sutherland 13) L.Wöhler & A.Berthmann, Ber 62, 2750-1 (1929) & CA 24, 1348(1930)(Prepn and props of diammine Mn and Zn fulminates) (See items Mn1 and Zn1 in tables E & F) 14)Gmelins Handbuch der anorganischen Chemie,Verlag Chemie, Berlin, System No 58, Kobalt, Th & Co(Cobaltammines)(1932) 15)J.M.Cros & L.LeBoucher, Anales de la Sociedad Española de Física y Química(Madrid) 33, 229-40(1935) & CA 29, 4279(1935) |Prepn and props of some
amines, such as tetrammine-copper(II) iodate and hexamminenickel(II) iodate (See items Cu5a and Ni4a in tables E & F). 16) G. Spacu & P. Voichescu, ZAnorgChem 226, 273-88 (1935) & CA 30, 3737(1936) (Ammoniates of some copper salts) 17) G. Spacu, ZAnorgChem 230, 181-6(1936) & CA 31, 2117(1937) (Ammoniates of uranium(VI) and uranium(IV) chlorides) 18) A. F. Wells, ZKrist 95, 74-82(1936) & CA 31, 1676(1937) (The crystal structure of silver tetranitrodiamminocobaltiate [Co(NH₃)₆(NO)₄]Ag and some other ammines) 19) N. R. Agafoshin, ZhObshKhim 7, 2235-9 (1937) & CA 32, 72(1938) (Complex compounds of Cu ammines with picric acid and some other nitrophens such as [Cu(NH₃)₄][C₆H₅(NO₂)₃] and [Cu(NH₂)₁][C₆H₅(NO₂)₃]O₂. Both complexes seem to be explosive. They are not listed in our tables) 20) H. Brinzinger and H. Plessing, ZAnorgChem 235, 110-14(1937) & CA 32, 2450(1938) (Studies of nitrosopentamminecobaltic salts such as red complex [Co(NH₃)₆(NO)](NO₂)₇·0.5H₂O. They are not listed in our tables) 20a) L. Milward et al., JCS 1938, 233-6 & CA 32, 8296(1938) (Constitution of nitrosopentammine cobalt salts, among them the complex listed in the previous reference) 21) R. Duval, CR 206, 1652-4(1938) & CA 32, 5720(1938) (Studies of trinitrotetramminocobalt(III) [Co(NH₃)₆(NO₃)₃] (See item Co2 in table B) 22) W. Strecker & E. Schwinn, JPraktChem 152, 205-18(1939) & CA 33, 5314(1939) (Introduction of the azide group into complex compounds to replace Cl was studied. Among the complexes prepared were several ammines such as diaminediacium(II)dizide, diamminecopper(II) azide, tetramminecopper(II) azide, chloropentamminechrom(III) azide, hexamminechrom(III) azide and hexamminenickel(II) azide (See items Cd1, Cr5, Cr6, Cu1, Cu3, and Ni2 in tables A, D & E) 23) D. B. Donskaya and M. A. Portnov, ZhObshKhim 9, 526-31(1939) & CA 33, 9091(1939) (The soly of Zn and Cd nitrates in liq ammonia and prepn of ammines such as tetrammine- and hexamine Zn nitrates) (See items Zn4a and Zn7 in table F) 24) A. Cirulis, Naturwissenschaften 27, 583(1939) & CA 33, 9175(1939) (Prepn and props of some Cu ammines) 25) C. O. Davis, USP 2,168, 562(1939) & CA 33, 9648(1939) (An explosive obtained by dissolving a nitrate, such as AN, in anhyd liq ammonia, dispersing in the soln a comminuted sensitizer, such as Al, S or DNT, and evaporating free NH₃, thus leaving the nitrate in a continuous phase) 26) L. E. Agronomov, ZhObshKhim 10, 1120-40 (1940) & CA 35, 1333-5(1941) (Prepn and props of some boronhydride ammoniates) 27) M. A. Cook et al, USP 2,220,891-2(1940) & CA 35, 1636(1941) (Blasting expls containing AN and ammine complexes are prepd by interaction of inorganic nitrates, other than those of alkali metals, with ammonia) 28) T. W. Hauff & H. H. Holmes, USP 2,222,175(1940) & CA 35, 1636(1941) (Nonsetting expls obtained by coating AN grains with tetramminezinc nitrate) 29) O. Schmitz-Dumont, ZElektrochem 47, 221-2(1941) & CA 35, 5052(1941) (Interaction of Co and Cr ammines with alkali metal amides results in formation of Co and Cr amides) 30) W. V. Smith, CanP 401,643(1941) & CA 36, 1744(1942) (Prepn of nitrosopentammine nitrite) (See item Znla in table F) 31) O. Schmitz-Dumont et al, ZAnorgChem 248, 175-207(1941) & CA 37, 6205-7(1943) (Prepn of trivalent Co and Cr amides from corresponding ammines and alkali metal amides) 32) E. I. du Pont de Nemours and Co, BritP 544,582(1942) & CA 36, 6804(1942) (Solid complexes obtained on treating metal nitrates with ammonia are recommended as ingredients of AN explosives) 33) A. J. Phillips, PATR 1302(1943) (Tetramminecopper nitrate; its prepn and explosive props; danger of formation when AN or its mixts come in contact, in presence of moisture, with copper or its basic salts) (See item Cu6 in table E) 34) M. Straumanis & A. Cirulis, ZAnorgChem 251, 336-7(1943) and CA 37, 6573(1943) (Prepn and props of some Cu azide complexes among them, the tetramminecopper(II) azide) (See item Cu3 in table D) 35) A. Cirulis &
L. M. Orlova, ZavodLab 8, 502(1939) & CA 36, 6935(1942)(Destruction of cobaltic ammines can be achieved by treating with thiosulfate in acid soln:
\[
2[Co(NH3)6]+ 2Na2S2O3 + 12HCl = 2CoCl2 + Na2S4O6 + 12NH4Cl + 2NaCl
\]
Ammissible(Ital). Permissible or "Permitted" (Explosive)
Ammoksil or Ammonxyl: Russian AN mining expls such as: a)AN 82 & TNX(called in Russ "ksilit" or "xylyl") 18%  b)AN 82, TNX 12 & A1 powd 6%. Properties of b) are: rate of deton 5300 m/sec, temp of expln 3380°, heat of expln 1180 cal/g and vol of gases evolved on expln 836 1/kg at STP
Ref. A. D. Blinov, Artillery Course, Voyennoye Izdatel'stvo, Moscow, 2(1949)
Ammon. Ger for Ammonia or Ammonium
Ammons were AN mining expls of varying comps developed in England prior to WW II during a shortage of glycerin to replace NG expls. Their strength was about 78% of blasting gelatin and vel of deton and sensitivity to shock and friction values were lower than those for NG expls of corresponding strength. They were appreciably hygroscopic and their oxygen balance was near zero
AMMONAL (USA)

[Ammonal, Alumatol, Burrowite, Minol and Nobel’s 704 (GBritain); Ammonal (France); Ammonal and Fillers 19, 110 & 13-113 (Germany); Ammonal, Toluol-Ammonal and Nitramit (Italy); Amonal (Spain); Ammonal (Russia) and Ammonauru (Japan)]

Ammonals are explosive mixtures containing, as the principal ingredients, AN and powdered Al incorporated with high explosives, such as TNT, DNT, RDX and HN3PhA. Powdered carbon was also used in the first ammonals.

**Historical and Properties.** The idea of incorporating powdered Al in expl mixts was originated by R. Escales in 1899 and by H. von Dahmen in 1900 but the explosives called “Ammonal” were patented in 1900 by G. Roth (Refs 1, 3 & 6). Originally all ammonals contained AN, Al and charcoal. The incorporation of charcoal was based on the assumption that the following reactions take place:

\[ 3\text{NH}_4\text{NO}_3 + 2\text{Al} \rightarrow 3\text{N}_2 + 6\text{H}_2\text{O} + \text{Al}_2\text{O}_3 + 522 \text{kcal} \]

The reaction might also proceed as follows.

\[ 4\text{NH}_4\text{NO}_3 + 2\text{Al} + \text{C} \rightarrow \text{Al}_2\text{O}_3 + \text{CO} + 8\text{H}_2 \]

(Refs 3 & 18)

If the above reactions occur, then the volume of gasous products is increased as a result of the presence of carbon and the high temp developed by oxidation of the Al.

Later, a small quantity of TNT was added to make the expl comp more sensitive to deton and to increase its power and brisance. When ammonals were first tried for military purposes in Austria, it was found necessary to increase the amount of TNT in order to obtain higher loading densities.

One of the earliest Ger ammonals was invented by Führer. It contained: AN 83, charcoal 3, Al 14%. In France, Lheure proposed the following mixture: AN 71, charcoal 4 & Al 25%, which was tested and approved in 1902 by the Commission des Substances Explosives. Finally (sometime after WWI), the Austrians, Germans, French and British omitted the charcoal altogether in military ammonals and these explosives became simply mixtures of amatols with aluminum. (See also Alumatol and Amatol)

In the ammonals not contg carbon, the mixture of TNT and AN detonate, developing a very high temp, which causes volatilization of the Al powder. Secondary reactions which follow, involve the oxidation of vaporized Al, either by air (if it is present) or by the products formed on deton of TNT and AN, such as CO and H2O:

\[ 3\text{CO}_2 + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 3\text{CO} \]

\[ 3\text{H}_2\text{O} + 2\text{Al} \rightarrow \text{Al}_2\text{O}_3 + 3\text{H}_2 \]

These highly exothermic reactions develop much additional heat, causing greater expansion of the gases and consequently greater blast effect.

Between WW I and WW II, ammonals were investigated in the Chemisch-technischen Reichsanstalt, Germany, by Haid & Schmidt (see Ref 20), who reported that Al reacts not only with O2 but also with N2 with the formation of Al nitride (80 kcal/Al2N2). For this reason the Germans developed aluminized explosives with a negative oxygen balance. The ammonals developed by the Austrians and used during WW I had positive oxygen balances. Expls contg Al were also investigated by the eminent Swiss chemist A. Stettbacher (Ref 14), who showed that the addition of Al increases the power while it slightly decreases the performance of the explosives. Stettbacher also found that Al-contg explosives (such as ammonals, etc) were most suitable in underwater performance and as such were used during WW II in depth bombs and torpedoes.

As in the case of AN in amatols, the AN of ammonals might be hydrolyzed in the presence of moisture with the formation of ammonia but, due to the presence of Al, the amount of ammonia will be much greater. This amount might be as much as 3 times greater with ammonals than with 80/20 amatol.
The presence of ammonia is very undesirable because it reacts with TNT to form a complex addition compd which ignites at 67°. In addition, the reaction between Al and moisture produces hydrogen, which is highly inflammable in oxygen or oxygen-containing compds. If ammonia is detected in ammonals (identified by odor or brown coloration), the shells should not be washed out be steam but by means of a stream of cold water.

The effect of incorporating Al in AN/TNT mixts was reported to be as follows: a) increase in sensitivity to impact, to friction and to rifle bullet impact; b) increase of temp of deton from ca 1710° to ca 3914° and even to 4000°; c) increase in strength (power) about 20%; d) increase, in some cases, of total vol of gases evolved on deton; e) decrease in vel of deton and, in some cases, in brisance (Ref 18, p 372 & Ref 19, pp 85-6)

In general, the current ammonals are fairly insensitive and stable mixtures but they are hygroscopic due to the presence of AN. Even if a small amount of moisture is absorbed, the Al (especially if impure) often reacts with it resulting in a slow evolution of hydrogen gas. This gas evolution usually occurs in storage, particularly at high temps. Ammonals are soluble (except the Al component) in water and acetone. They react (in the presence of moisture) with the same metals as the amatols, that is, copper, bronze, lead and copper-plated steel (Ref 19).

Preparation of Ammonals. In the USA ammonals were prep'd by a method similar to that used for the prepn of amatols: the calcd amt of TNT (or other aromatic nitro-compd) was placed in a kettle (provided with a steam jacket and an agitator) and heated between 85° and 100°. To this was added gradually and with stirring, the calcd amt of powdered AN, previously preheated to the same temp (85 to 100°). Finally, Al powder was added and the mass cooled while continuing the agitn. The resulting mixt was in the form of a grayish pdr. If the ammonal mixt contained less than 40% TNT it had to be press-loaded but with 40% TNT or more such a mixt could be cast loaded directly into ammunition components. In prepping cast mixts a dry blend of the powdered Al and AN was added with stirring to molten TNT heated in a steam-jacketed kettle.

According to PepinLehalleur (Ref 12), ammonals were prep'd in France by a method similar to that used to prepare black powder. The calcd amt of the ingredients (total 35kg) were wetted with water to make about a 4% moisture content and then worked for about 1 hour on a wheel mill similar to that described in Ref 15, p 46.

Composition and Uses of Ammonals as Commercial Explosives. Originally, ammonals were used as commercial blasting explosives and only with the outbreak of WW I did the use of ammonals for military purposes begin. As commercial explosives they may be used for any blasting operation except in "gaseous" (fiery) coal mines (German regulation prohibit their use in such mines). Ammonals are especially useful in blasting soft rocks because the force of the explo does not break the rock into pieces which are too small for building or other purposes. The ammonals used in coal mining should contain reduced amts of Al, as well as some compds (such as a dichromate) which serve to reduce their temp of explosion. The density of ammonals used in commerce was ca 1.0 g/cc.

The table, p A289, gives compositions of some commercial blasting ammonals.

Composition and Uses of Ammonals as Military Explosives. Originally, ammonals were used as commercial blasting explosives, but with the outbreak of WW I they began to be used for military purposes such as filling grenades, aerial bombs, land and sea mines and trench mortar projectiles. The Austrians also used ammonals for loading cannon shells, but loading densities were too low (see Notes below) to achieve good explosive efficiencies.
## A289

### Commercial Blasting Ammonals

<table>
<thead>
<tr>
<th>Components</th>
<th>Felixdorf Factory Ammonals (Austrian)</th>
<th>Ammonals (German)</th>
<th>Ripping Ammonal (British)</th>
<th>St Helen's Powder (British)</th>
<th>Nuevo Anagon Ammonal (Spanish)</th>
<th>German Ammonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃NO₃</td>
<td>80.75</td>
<td>72.0</td>
<td>93 - 95.5</td>
<td>84 - 87</td>
<td>92 - 95</td>
<td>70.0</td>
</tr>
<tr>
<td>KNO₃</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>84.5</td>
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<tr>
<td>Ba(NO₃)₂</td>
<td></td>
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<td>91.8</td>
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<tr>
<td>Al(powder)</td>
<td>15.00</td>
<td>23.5</td>
<td>2.5 - 3.5</td>
<td>7 - 9</td>
<td>2 - 3</td>
<td>5.5</td>
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<tr>
<td>Alloy Al/Zn</td>
<td></td>
<td>18.0</td>
<td></td>
<td></td>
<td></td>
<td>1.7</td>
</tr>
<tr>
<td>Red Charcoal</td>
<td></td>
<td>4.5</td>
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<tr>
<td>Charcoal</td>
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</tr>
<tr>
<td>Pitch</td>
<td></td>
<td>2 - 3</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K₂Cr₂O₇</td>
<td></td>
<td>3 - 4</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Moisture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>References</td>
<td>Ref 4, p 394</td>
<td>Ref 4, p 393</td>
<td>Ref 4, p 393</td>
<td>Ref 4, p 393</td>
<td>Ref 17, Ref 18, p 247, p 372</td>
<td>Ref 19, p 84</td>
</tr>
</tbody>
</table>

*Was also used for military purposes, requiring a booster (Ref 23, p 4)

Marshall (Ref 4, p 393) cites the values for properties obtained by Bichel for ammonal A (see above table) compared with the same properties of dynammon contg AN 95.5 and red charcoal 4.5% (See table below)

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Density, d</th>
<th>Vel of Deton, m/sec</th>
<th>Heat of Expln, cal/g</th>
<th>Total Vol of Gases, l/kg</th>
<th>Vol of Gases at NTP (minus H₂O vapor), l/kg</th>
<th>Expln Press (Colcd), kg/cm²</th>
<th>Power by Trouxli Test, cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynammon</td>
<td>865</td>
<td>3380</td>
<td>7270</td>
<td>976</td>
<td>360</td>
<td>3608</td>
<td>250</td>
</tr>
<tr>
<td>Ammonal A</td>
<td>900</td>
<td>3450</td>
<td>1600.5</td>
<td>594</td>
<td>418</td>
<td>9425</td>
<td>329</td>
</tr>
</tbody>
</table>
Notes: a) Although ammonals can be cast and compressed to densities as high as 1.65 (Ref 19, p 85), such highly compressed materials are very difficult to detonate and require very strong boosters. In order to assure their complete deton by conventional methods of initiation, the ammonals are usually pressed to a density of ca 1.2. However, this density is not sufficient for the safe firing of shells at high velocities because there is always the danger of premature explosions due to set-back. b) According to Marshall (Ref 5, p 558), ammonal is said to be insensitive to blows and can be fired through the armour plating of a warship without exploding. This probably refers to the Austrian ammonal: AN 58.6, Al 21.0, TNT 18.0 & charcoal 2.4%, compressed to a high density — say 1.6.

Originally, ammonals were not considered very favorably by military authorities due to their failure to realize the full effectiveness of Al in explosives. Also, Al was very scarce and very expensive during WW I. As soon as the price of Al dropped and the supply became plentiful (sometime after WW I), several new formulations for ammonals were reported. They were used during WW II and these mixtures were more effective than those used during WW I. The uses of ammonals during WW II included: demolition charges, blockbusters, aerial bombs (such as concrete-fragmentation bombs) and underwater ammunition, (such as mines, torpedoes and depth charges). Inasmuch as ammonals produce brilliant flashes on explosion, they are suitable for use in shells employed for testing purposes.

The table, gives the compositions of some ammonals used for military purposes during WW I and WW II (See this page).

Note 1: American military ammonal, designated as 1 in attached table, was developed during WW I. It is a grayish powder which may be cast loaded. Its properties are: mw 102, OB to CO₂ 55%, OB to CO 22%, density 1.65, brisance (by sand test) 47.8 g (TNT 48.0 g), power (by ballistic mortar) 122% of TNT.
impact sensitivity 91cm (TNT 90 cm) with 2kg wt, Bur of Mines App and 11" (TNT 14"), with 2kg wt, Pic Arsn App; expln temp 265° (dec), sensitivity to initiation required 0.20g of MF, stability to heat- si inferior to TNT. It was used as a shell filler (Ref 21, pp 12-13)

Note 2: Ammonal designated in the table p A290, as 2 is similar in composition to the "British Service Ammonal" used for demolition purposes. It must be press-loaded because it does not contain sufficient TNT to permit cast loading (Ref 19, p 84)

Note 3: Properties of the Austrian ammonal listed as 1 and also known as "ammonal T," are given by Sukharevskii and Pershakoff (Ref 10), as follows: density ca 1.6 (Ref 13 gives 1.62), heat of formation +550 cal/g, heat of expln 1465 cal/g (Ref 13 gives 1485), vol of gases of expln (including H₂O vapor) 605 1/kg, temp of explosion 4050°, vel of deton 5400 m/sec (Ref 13 gives 5650), specific energy f (Abel) 9900 (TNT 8080), power by Trauzl test 470cc (TNT 290); (Trauzl test values for ammonals and other Al-contg explosives are always unduly high due to the erosion of the lead testing block resulting from the enormous heat liberated on combustion of Al); brisance by copper crusher test 2.8 mm (TNT 3.6mm) or 77.7% of TNT; brisance by Kast formula 85.5 x 10⁶ (TNT 86.1 x 10⁶) or 99.2% of TNT; sensitivity to friction-insensitive; sensitivity to impact (2kg wt) 60cm (TNT 90cm). The Austrian "ammonal T" was invented in 1917 by R. Förg to be used for underwater ammunition such as torpedoes, sea mines and depth charges. This explosive has no advantage over TNT or PA when used in air, but underwater it is definitely more effective. It has been claimed that this ammonal was used in torpedoes which destroyed during WW I the French cruiser Léon Gambetta and the Italian cruiser Garibaldi (Ref 13)

Hofwimmer & Heckel (Ref 7) claimed that some German ammonals had vel of deton as high as 5650 m/sec (at d 1.62), total vol of gases of expln 740 1/kg, max press (calcd) 2693 kg/cm², temp of deton 3720° and specific energy (f) 10820. The Felixdorf Powder Works in Austria (Ref 2) reported that some Austrian ammonals gave better fragmentation test values than PA

Additional Information on Ammonals and Their Uses:

Germany In addition to the ammonals listed in the above tables and in Ref 23, p 4, there was Füllpulver 19 (Fp 19): AN 35, TNT 55 & Al 10% used in some HE shells of mountain artillery; Füllpulver 13-113 (Fp 13-113): AN 70, TNT 20 & Al 10%—used in some GP bombs and Füllpulver 110 (Fp 110); AN 90, Al 2.5, naphthalene 5 & wood meal 2.5%—used press-loaded in some bombs (Ref 23, pp 47-8)

Great Britain Taylor & Gay (Ref 24) give the following compn and props of one of the current "non-permitted" expls: AN 83, TNT 12 & Al 5%. It is free-running powder of d 1.1 and power 88% of blasting gelatin. Used for blasting in quarries and for general work under dry to damp conditions

Italy Several pre-WW II ammonals were listed by Molina (Ref 8a), including a) AN 54, Al 24, MNB 20 a carbon 2% b) AN 65, Al 17 (of which 16% was coarse and 1% fine), TNT 15 & carbon 3%. It was not stated whether they were used by the Italians. All & EnExplos (Ref 19, p 84) lists the following ammonal used during WW II for military purposes: AN 84.5, K nitrate 1.5, Ba nitrate 0.5, Al powder 5.5 & BkPdr 8.0%. It required a booster for detonation Mangini (Ref 19a) lists the following compns suitable for military purposes: a) AN 72 to 95, Al powder 2 to 25 & carbon 0.8 to 3% b) AN 46 to 64, Al powder 17 to 22, carbon 3 & TNT 15 to 30%. The last expl was also called "toluol-ammonal". TNN was used in some compns in lieu of TNT. Belgrano (Ref 20b, p 163) lists a compn similar to ammonal, which is called "dinammon" (See also Nitramite)
Japan. An expl consisting of AN & charcoal and known as ammon-yaku, was listed as a "substitute powder". Its uses are unknown (Ref 17b, p 29 & Ref 21, p 212)

Russia. Several ammonals were used for civilian and military purposes, of which the following seem to be most common: a) AN 82, TNT 12 & Al powder 6% b) AN 80 & Al 20%, in which the Al was not too finely pulverized — otherwise it coated the AN grains thus impeding the reaction. This mix had the following props: Trauzl test value 520 cc; brisance(by the Hess lead crusher test) 15.5 mm at d 1.0 & 22 mm at d 1.3, vs 13.0 for loose uncompressed TNT; tot vol of gases evolved on deton 700 l/kg at NTP; heat of expl 1680 cal/g (with Al2O3 as solid) and 1270 cal/g (with Al2O3 as gas) (Refs 19 & 20a)

Spain. In addition to the ammonals listed in the above tables and in Refs 17 & 18, it would be of interest to list here a fairly powerful and brisant expl developed in 1933 by Prof A. Blanko and called amonal 1. It contained AN 92.4 carbon 6.6 & Al 1% and was used by the Forces of Gen Franco during the Spanish Civil War. Its expl props compared favorably with those of 75% dynamite (Ref 17b)

Fire and explosion hazards of ammonal are briefly discussed in Sax (Ref 21a), but its toxicity is not mentioned. It would be safe to assume that toxicity of ammonals is similar to that of mixts of amatol (Ref 21a, p 266) with aluminum (Ref 21a, pp 259 & 261)


Ammonals, Analytical Procedures

Identification of ammonals by color reactions described under Amatols (qv) and in Ref 2, pp 269-70, is also applicable to ammonals. This procedure does not, however, identify the Al always present in ammonals. For detn of Al it is necessary to apply one of the procedures listed below

Quantitive Analysis of Ammonals. Wogrinz (Ref 1) described the procedure which is essentially as follows: a) Thoroughly pulverize and dry the unknown material and weigh accurately a sample of ca 1g. Place it on a tared filter and rinse thoroughly with several portions of chloroform. Dry and weigh the residue on the filter. Loss in wt is equal to TNT or other nitrocompds in amatol b) Rinse the residue with several portions of cold water, dry and reweigh. The loss in wt is equal to AN c) Fold the filter with residue,
insert it in a small cylindrical glass vessel and introduce it in a vertical position into about 50 cc of 50% KOH soln in an Erlenmeyer flask which is a part of an apparatus consisting of a gas measuring burette and a levelling bulb d) Connect the flask by means of its ground glass neck to the ground glass fixture connected to a three way stopcock of the burette which is filled with water e) With the stopcock closed to the flask and open to atmosphere, move the levelling bulb until the level of water in the burette is at zero f) Open the stopcock to the flask and tip the apparatus slightly to make the glass cylinder (inside the flask) fall g) Contact of Al with KOH soln will cause the evoln of hydrogen and movement of the level of water in the burette. The reaction lasts about 1 hour. From the volume of hydrogen evolved the amt of Al is calcd. h) If there is any black residue in the flask, the presence of carbon is indicated and if the residue is yel or brown, the wood meal is present.

Quantitative Procedure Used at Picatinny Arsenal: a) Quantitatively transfer an accurately weighed sample (ca 1g) to a tared sintered glass extraction thimble and extract with anhyd methylene chloride (ca 1g) using a tared flask placed on a water bath. b) Adjust the temp of the bath so that the solvent drips at the rate 2-3 drops per second. c) When extraction is complete evaporate the liquid in the flask to dryness under a stream of dry air and then in a vacuum desiccator to const wt d) Subtract the wt of the flask from the tot wt, thus obtaining the wt of TNT e) Dry the thimble with the residue and extract AN with water into a second tared flask. f) Determine the amt of AN according to Spec JAN-A-175, Par F-4j, or identify it by one of the color reactions, such as with DPhA or thymol. g) Dry the thimble with the residue, weigh it and extract the Al with concd HCl. h) Determine the amt of Al as aluminum 8-hydroxyquinolinate, Al(CgH-ON), according to Spec JAN-M-454, Par F-4c(2) or by other procedures described in the books on analytical chemistry i) Dry the thimble and reweigh. Total wt, minus the wt of thimble gives the wt of residue. If the residue is black, it is carbon and if the color is yellowish or brown, the possibility of presence of wood meal is indicated.

Ammonalmatrite. See under Almatrites

Ammonchäusit. See Wetterammonchäusit in PATR 2510(1958), p Ger 260, table 64

Ammoncarbonites. Belgian, Brit & Ger coal mining, permissible expls contg large amts of AN and small amts of NG, such as: a) AN 82.0, K nitrate 10.0, NG 4.0 & WM 4.0% b) AN 56.4 Na nitrate 7.0, NG 5.0, glycerin 5.0, WM 4.0 & Na chloride 22.6 c) AN 80.3, K nitrate 5.0, NG 4.0, NC 0.2, coal dust 6.0 & starch 4.5%

Note: Ger Ammoncarbonites are described in Ref 4


Ammonex. Under this name are known thirteen castable AN expls, not contg TNT, prepd and examined during WWII at PicArsn, Dover, NJ. Their compns are given in Table p 294
<table>
<thead>
<tr>
<th>Compnd and some props</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amm nitrate</td>
<td>60.5</td>
<td>78.0</td>
<td>78.0</td>
<td>36.3</td>
<td>38.0</td>
<td>38.0</td>
<td>43.0</td>
<td>43.0</td>
<td>42.0</td>
<td>32.5</td>
<td>42.0</td>
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</tr>
<tr>
<td>Urea</td>
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<td>6.3</td>
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<td>—</td>
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</tr>
<tr>
<td>Al (flake)</td>
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<td>1.0</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<td>Al (granular)</td>
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<td>—</td>
<td>—</td>
<td>30.0</td>
<td>45.0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Avg d of chge</td>
<td>1.63</td>
<td>1.62</td>
<td>1.46</td>
<td>1.41</td>
<td>1.64</td>
<td>1.47</td>
<td>—</td>
<td>1.35</td>
<td>1.66</td>
<td>1.63</td>
<td>1.56</td>
<td>1.61</td>
<td>—</td>
</tr>
<tr>
<td>Appr pour point*, °C</td>
<td>86</td>
<td>98</td>
<td>98</td>
<td>95</td>
<td>92</td>
<td>92</td>
<td>—</td>
<td>97</td>
<td>98</td>
<td>100</td>
<td>94</td>
<td>92</td>
<td>—</td>
</tr>
<tr>
<td>Avg wt of chge (lbs)</td>
<td>0.91</td>
<td>0.88</td>
<td>0.80</td>
<td>0.77</td>
<td>0.90</td>
<td>0.80</td>
<td>—</td>
<td>0.74</td>
<td>0.91</td>
<td>0.89</td>
<td>0.85</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>in 3” M42 Shell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>% Tnt fragms compd to TNT</td>
<td>24</td>
<td>28</td>
<td>41</td>
<td>73</td>
<td>87</td>
<td>86</td>
<td>—</td>
<td>69</td>
<td>95</td>
<td>84</td>
<td>85</td>
<td>100</td>
<td>—</td>
</tr>
</tbody>
</table>

### Exudation in 3” Shell:
- 7 days at 50°
- 7 days at 65°

### Stability:
- 100° Vac stab test
- 100° Heat test
- 120° Vac stab test

### Rifle bullet test,
(5 trials)
- 2 low
- 1 low
- 4 high

*Note: Pour point is the temp below which mixt does not readily flow by gravity and pouring temp(min) is about 5°C above pour point
The following conclusions may be reached in regard to the table, p A294:  
a) Ammonex A developed by Phillips (Ref 1) while satisfactory with regard to stability and loading characteristics is of low brisance (when cast-loaded at high d in 3\" M42 shell and subjected to fragmentation test)

b) Ammonex M is comparable to TNT in brisance (fragmentation test), loading characteristics, stability and exudation and for these reasons may be considered as a suitable expl for shell-loading  
c) Ammonex J, while as satisfactory in brisance and exudation as M, cannot be poured below 100\°

d) Ammonex L, while not as stable as M or TNT, is comparable to pentolite and tetrytol in other props. It is very sensitive to rifle bullet impact  
e) Ammonex E, while favorable with regard to fragmentation and stability, exudes a dark-brown oily liq when stored at 50\° or 65\° for 7 days. This liq forms upon cooling needle-like crysts

f) Ammonex F, while satisfactory in brisance and in 100\° stability tests, is unsatisfactory in regard to exudation and<br>120\° vac stab test  
g) Ammonex K, while satisfactory in regard to brisance and exudation, is unsatisfactory in regard to 120\° vac stab test and pour point. It is very sensitive to rifle bullet impact  
h) Ammonex D, while not too low in brisance, is unsatisfactory due to exudation and high pour point  
i) Ammonex I is unsatisfactory due to its high pour point  
j) Ammonexes B and C, as well as previously mentioned Ammonexes G & H were not given in Refs 1 and 2

Refs:  
1) A.J. Phillips, PATR 1106(1941)
2) R.D. Sheeline, PATR 1234(1943)

Ammongelatine. A type of Ger permissible gelatin dynamite. Several comps are listed in PATR 2510(1958), p Ger 5

Ammongelatine Dynamit. A type of gelatinous or plastic expl invented in 1879 by A. Nobel, in Sweden. One formulation contained NG 71, CC 4, charcoal 2 & AN 23\%, another contained NG 25, CC 1, charcoal 12 & AN 62\%. The 1st dynamite was gelatinous, whereas the 2nd was plastic and rather crumbly

Note: In these expls, AN particles were coated with NG-CC jelly. It was supposed that this jelly carries the expl impulse originating in the detonator to the AN causing it to decomp explosively with the formation of N$_2$, H$_2$O and O$_2$. The O$_2$ reacted with charcoal or other combustibles

Formulations of these dynamites were later changed to include HE's such as TNT, TNX, liq DNT, NS, NGc, etc. These compds act not only as sensitizers for AN but also as antifreezes

Compds similar to Ammongelatines are manufd by the DuPont Co under the name of "Extra Dynamites" (Ref 3)

Refs:  
1) Naoum, NG(1928), 11  
2) Davis (1943), 335  
3) Blaster's Handbook(1952), 59-62

Ammongelignite. A type of current Brit "non-permitted gelatinous AN expl. It is described under Ammonium Nitrate Gelatines

Ammongelit I. An expl mentioned in Explosivstoffe 1957,168 (compn not given)
AMMONIA
(Anhydrous and Aqueous)

(Called Ammoniak in Ger, Ammoniaque in Fr, Ammiyak in Rus, Ammoniaca in Ital, Amonfaco in Span), NH₃, mw 17.03, N 82.25%, mp -77.7°, bp -33.4°. Col gas with pungent odor at ord temp and press, col liq when compressed; usually stored in "Hortonspheres" at press 40 - 50 psi; critical temp 132.4°, crit press 111.5 atm, d 0.771 g/l at 0° and 0.817 g/cc at -79°; autoignition temp 651°, vap press 10 atm at 25 °, expl range (in air) 16.0 - 25.0%. Fire and expl hazard moderate when exposed to flame(Ref 32). Sol in water, alcohol and ether. Anhydrous ammonia is irritating to eyes, skin and mucous membranes of the respiratory tract. Ammonia gas at concns above 0.5% in the air is fatal to humans after prolonged breathing. When confined under pressure, anhyd ammonia may shatter the container with expl force (For a general discussion of the properties of ammonia see Refs 12,14,17, 30,32,34,39,72 & 86).

Ammonia is by far the most important of the hydride compds. It can be prep by: a) synthesis from its elements b) hydrolysis of nitriles and amides c) reduction of oxides of nitrogen and d) the dry distillation of nitrogenous subs, such as coal, bones, etc. The history and occurrence of ammonia have been discussed in detail by Mellor (Ref 6), Gmelin (Ref 13), Gamburg (Ref 25), Kirk and Othmer(Ref 32) and Mittasch (Ref 47).

The use of ammonia-water solns had been mentioned by the alchemists. In the 18th century Priestley isolated ammonia gas and demonstrated it could be decomposed by passing it over a hot wire or through an electric spark. Van Scheele first identified the component gases and Berthollet and also Henry discovered that they consisted of 3 parts hydrogen and one part nitrogen. The principal source of ammonia until about the twenties of this century was the by-product of distillation of coal for gas, coke and tar. Ammonia, in this process, was ob-
tained as an aqueous soln(ammonia liquor) and could be recovered either as Amm sulfate or as NH₃ gas, which could be liquifed. Other nitrogen contg materials, such as bones, horns, etc could be utilized for prep of ammonia. Manuf of ammonia from coal is described by Kirk and Othmer(Ref 32), Riegel(Ref 38), Just et al(Ref 62), Little(Ref 69), Martin et al(Ref 71), Shreve(Ref 80), Osthaus(Ref 81) and Groggins(Ref 86). Fulton(Ref 45) and Groggins(Ref 86) describe the processes for the recovery of anhydrous ammonia from its aq solns.

The first successful attempt to prep ammonia by direct synthesis of atmospheric nitrogen and hydrogen was made at the beginning of the century by F. Haber. He passed a mixt 1 vol N₂ and 3 vols H₂ at moderately high temps and under press over a contact catalyst. This procedure, which consists of reduction of nitrogen from N₂ to N⁻⁻⁻ was inspired by previously developed method of Birkenland & Eyede in which atmospheric nitrogen was oxidized to the state of its oxides. In this method, called "fixation of nitrogen," B & E passed air at a rapid rate through an electric arc spread out to form a flame and the resulting N oxides were removed as soon as they formed. It should be noted that as early as 1780 Cavendish prepd a small quantity of N oxides by passing a series of electric sparks through the air. The method of Haber is the "direct synthesis" methods, whereas Frank and Caro process, Serpek process and Bagnulo process are "indirect synthesis" methods.

In the Frank & Caro process, invented in 1895 - 7 and known as the "calcium cyanamide method," a carbide, such as Ca carbide absorbs nitrogen to form cyanamide(fertilizer), which by a further treatment may be transformed either into cyanide or into ammonia. This process was used in Europe, USA and Canada (Refs 38 & 71). In the Serpek process introduced in France and not adopted in the USA, nitrogen was "fixe d" as Al nitride and this gave ammonia when treated with steam(Refs 38 and 71). In the Bagnulo process, invented in Italy, ammonia and other N-contg substances
are obtained by a continuous method either from Ca cyanamide or from the reaction of hydrocarbons with nitrogen and water (Ref 43).

Of all the known methods of manuf of ammonia, the most important is the "direct synthesis," which consists essentially of producing a gaseous mixt of 3 vols of hydrogen and 1 vol of nitrogen, purifying the mixt and synthesizing to ammonia by passing it at high press and temp through a converter contg a catalyst. The resulting anhydrous ammonia is stored in liq form and under moderate pressure in the so-called "Horton-spheres." It may be shipped to its destination in a special tank car or truck.

Since the development of the Haber process, many patents were issued to various persons and companies, but essentially all the "direct synthesis" methods are based on the original process—the main differences are in construction of converters and in some minor details. A comprehensive description of "direct synthesis" methods and a general discussion on methods of manuf of ammonia is given in Kirk and Othmer (Ref 32) and Faith, Keyes & Clark (Ref 35) (See also Refs 4, 7, 19, 20, 21, 23, 25, 27, 32, 33, 35, 36, 38, 39, 42, 48, 49, 50, 60, 62, 70, 71, 77, 79, 80, 81 & 82).

A flow diagram of the direct synthesis of ammonia as practiced at the TVA (Tennessee Valley Authority), is given on pp A298-9.

Following is the list of "direct synthesis" processes practiced currently in various countries:

a) Haber-Bosch (Refs 19, 32, 38, 39, 42, 48 & 80)
b) Casale (Refs 19, 38, 39 & 80)
c) Claude (Refs 19, 32, 38, 39, 49, 50, 76 & 80)
d) Fauscr (Refs 19, 32, 39, & 80)
e) Mont-Cenis (Refs 19, 32, 38 & 80)
f) Air Liquide (Ref 80)
g) DuPont (Refs 20 & 80)
h) General Chemical (Ref 19)
i) Kellogg (Refs 64 & 80)
j) Mathieson (Ref 38)
k) NEC (Nitrogen Engineering Corp)
Il) FNRL (Fixed Nitrogen Research Laboratory)
(Ref 80)
m) Uhde (Ref 39)

The following may be added to the information on the manuf of ammonia: Mitchell (Ref 26) discusses the manuf of ammonia from natural gas as practiced at the Lion Chemical Corp plant. Holroyd (Ref 27) discusses synthesis of ammonia by the Haber-Bosch process as practiced at the IG Farbenindustrie plants at Ludwigshaven and Oppau, Germany. Guillaumeton (Ref 33) reviews the production of synthetic ammonia during WWII in USA and Canada. Cope (Ref 36) discusses US production facilities for ammonia. Odelhög (Ref 44) patented an ammonia synthesis process using a granular catalyst consisting of either Fe + Ni, Fe + Co, Fe + Mg or Fe + V at temp 300° and press 50 kg/cm². Vergues & Patry (Ref 46) describe manuf of ammonia from natural gas in a plant located at Saint-Marcel, Pyrénées, France. Anon (Ref 48) gives a flow chart and a brief description of the Lion Oil Co plant at El Dorado, Arkansas. The plant was designed to produce ammonia from natural gas by modification of the Haber-Bosch process. Shearon & Thompson (Ref 49) describe the modified high pressure Claude process plant, at Yazoo City, Mississippi. The authors also state that the first Claude units were installed in USA in 1927 and, with modifications from the Casale process, are now owned by the DuPont Co. The US Govt plant at Morgantown, West Virginia, was designed, built and operated during WWII by the DuPont Co using its own modification of the high pressure Casale process. Reidel (Refs 63, 64, 65) describes some recently constructed ammonia synthesis plants, such as the Spencer Chemical Co plant at Vicksburg, Miss and the Kellogg process plant. The Spencer plant is also described in Refs 66 & 68. Anon (Ref 67) and Reidel (Ref 79) describe the Phillips Chemical Co plant near Houston, Texas. It is the NEC (Nitrogen Engineering Corp) medium pressure process utilizing natural gas as starting material. Resen (Ref 70) describes the manuf of ammonia at the Lion Oil Co plant in Louisiana. Frankenburq (Ref 51) studied the relationship between the nature and the effectiveness of ammonia synthesis catalysts. Other studies of synthesis catalysts were made by Odelhög (Ref 44), Enomoto & Horiuchi (Refs 53 & 54), Nielsen (Ref 60), Emmett (Ref 74) and Faith..
FLOW DIAGRAM FOR THE PRODUCTION OF ANHYDROUS AMMONIA
TENNESSEE VALLEY AUTHORITY, WILSON DAM, ALABAMA, U.S.A.
et al (Ref 83). The thermodynamics of ammonia synthesis was reported by Oldham (Ref 22), Enomoto & Horiuchi (Ref 54), Jagannathan (Ref 56), Harrison and Kobe (Ref 61) and Schmidt (Ref 78).

Schlachman (Ref 21) lists the US War Dept sponsored synthetic ammonia plants operating during WWII and Faith Keyes & Clark (Ref 83) gives a list of current US ammonia plants.

General properties of ammonia are discussed in Mellor (Ref 6), Gmelin (Ref 13), Thorpe (Ref 15), ChemRevs (Ref 17a), Kirk & Othmer (Ref 32) and in Ullmann (Ref 59). Franklin (Ref 1) described the reactions of liq ammonia. Von Braun et al (Ref 16) reported a violent and explosive reaction of liq ammonia with some organic halogen compounds. For example, when the reaction between liq ammonia and BrH2C-CH2Br was carried out at RT, there occurred a spontaneous evolution of heat resulting in a violent explosion. Reeves & Giddens stabilized cellulose nitrate with ammonia (Ref 31). Sampkey (Ref 28) observed that the residue resulting from the reaction of ammonia with Hg exploded in a steel U tube connected with a glass Hg manometer when an attempt was made to clean the tube with a steel rod. Some of the gray-brown solid residue was recovered and detonated by heating in a crucible. Analysis indicated that the residue consisted of dehydration products of Millon's base (See CR 140, 853 (1905)) and was readily sol in Na2S2O3·5H2O.

The explosion of mixt of ammonia with electrolytic gas and oxygen was reported by Partington and Prince (Ref 2) and with carbon monoxide and oxygen by Beeson and Partington (Ref 3). Jorissen et al (Refs 5, 8 & 9) studied the explosion regions of hydrogen-ammonia-air, hydrogen-ammonia-oxygen, ammonia-air and ammonia-oxygen-nitrogen mixts. Scliephake et al (Ref 10) also investigated the explosion of ammonia-air mixts while Franck and Dürring (Ref 11) made similar studies under high pressure. Rozlovsksif (Ref 24) detd the ignition limits of ammonia-oxygen mixts in a heated quartz vessel. When the pressure (P) of the gas mixt increased from 40 to 100 mm Hg, the min ignition temp (T) decreased from 1100° to 1025°. At a given P, T was the lowest for 33% or 50% ammonia; the minimum press at which the mixt could be ignited was at 33% concn of ammonia. Pieters (Ref 29) detd the expln limit of gases by a new type apparatus which gave values of 15.0 to 25% ammonia in air. Shaphorst (Ref 37) found that dry mixts of air contg 16.5 to 26.8% ammonia were combustible, whereas damp mixts were neither combustible nor explosive. Other studies of explosibility of ammonia-air mixts were made by Clarke & Wright (Ref 73) and by Banik (Ref 84).

The handling of ammonia safely has been discussed by Brandt (Ref 40) and the toxicity of ammonia fumes by inhalation, by Wheatherby (Ref 55). Ohno (Ref 57) noted that the toxicity of gaseous ammonia was much smaller than that of sulfur dioxide. Both gases produce irritation of mucous membrane and eyes, bronchitis, hyperemia, hemorrhage, edema, exudation and pneumonia. Krop (Ref 58) lists the toxicity and health hazards of ammonia and other substances used as fuels in rocket propellants. Also see Sax (Ref 82) for additional information on the hazards of ammonia.

For use in the explosive industry, anhydrous ammonia is converted by oxidation, at high temp and pressure, in the presence of a suitable catalyst, to 60% nitric acid, called "dilute nitric" before being concentrated to 98 - 99% strength acid called "strong nitric." The "strong nitric" is used in the manuf of NG, NC, NS, DNT, TNT, PA, PETN, RDX and tetryl, whereas the "dilute nitric" serves the expl industry for the manuf of AN which is used either for prepn of various expl mixts (such as amatol, ammonal, etc) or for the prepn of fertilizers.

There are many other uses of ammonia discussed by Kirk and Othmer (Ref 32). Serruys (Ref 18) investigated ammonia and some other substances as possible motor fuel substitutes. Canright (Ref 41), Clark
(Ref 52), Baker(Ref 75) and Gordon & Glueck
Ref 85) investigated ammonia-oxygen systems as a liq propellant for rocket motors.
Ammonia was also used during WWII in the USA for the neutralization of residual acidity in crude TNT prior to its purification by sel-lite(aqueous soln of Na sulfite). Use of ammonia in lieu of soda ash as a neutralizer produced a lighter colored TNT (See Trinitrotoluene, Manufacture of) 

Requirements for ammonia used in the manuf of explosives are listed in Specification JAN-A-182

References: 1) E.C. Franklin, JACS 27, 820-51 (1905) 2) R. Partington & A.J. Prince, J CS 125, 2018-25 (1924) & CA 19, 400 (1925)
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CA 44, 10273(1950) & CA 45, 9816(1951)

CA 44, 10274(1950)

45)D.Fulton, USP 2,519,451(1950) & CA 41, 10274(1950)

46)J.Vergues & M.Patry, Chim & Ind 63, 487-93(1950) & CA 44, 11043 & 11062(1950)

47)A.Mittasch, "Geschichte der Ammoniaksynthese," Verlag Chemie, Weinheim (1951)

48)Anon, ChemEngg 58, No 8, 174-7(1951)

49)W.H.Shearon, Jr & H.L. Thompson, IEC 44, 254-64(1952) & CA 46, 4183(1952)

50)H.L.Thompson et al, Chem EngProgress 48, 468-76(1952) & CA 46, 10558(1952)


54)S.Enomoto & J.Horiuchi, ProcJapanAcad 28, 499-504(1952) & CA 47, 7741(1953)

55)J.ResInstitCatalysis 2, 87-104(1953)


57)S.Ohno, Igaku Kankyuu(Japan) 23, 1258-64(1953) & CA 47, 12703(1953)

58)S.Krop, JetPropulsion 24, 223-7(1952) & CA 48, 1322(1954)

59)Ullmann, v 3(1953), pp 523-602


66)Anon, ChemEngg 61,No 4, 126(1954)

67)Anon, ChemEngg 61, No 5, 140 & 142(1954)


72)O.Schmitz, "Untersuchungen über Reaktionen in flüssigen Ammoniak," Westdeut Verlag, Köln(1955)


76)P.V. Maqua, InstNaclCarbon(Oviedo, Spain), Bol Inform 4, No 19, 1-30(1955)

77)Y.Okura & T.Nagakawa, JSochHighPressureGasInd 19, 26-9(1955)

78)Anon, ChemEngg 58, No 8, 174-7(1951)

79)W.H. Shearon, Jr & H.L. Thompson, IEC 44, 254-64(1952) & CA 46, 4183(1952)


AMMONIA, ANALYTICAL PROCEDURES

Detection of small quantities of ammonia in air, water, etc can be done by colorimetric methods using reagents such as Nessler’s (Refs 1–6 and 8–10), phenol & hypochlorite (Ref 12). A detailed description of the colorimetric detn of NH₃ in air by use of Nessler’s reagent is given by Jacobs (Ref 9, p 364). The concn of ammonia in air may be obtained also by passing a known vol of the air through two bubblers in series contg known vols of standard 0.02N sulfuric acid until the color of methyl-red indicator changes from yellow to red. Detailed description of this method is given in Ref 9, pp 363–4. A midget impinger may be used instead of bubblers. Description of oxidimetric detn of ammonia is given by Hutka & Ruzdik (Ref 7).

Procedures described on the following pages are used at the US Ordnance plants for analyses of anhydrous and aq ammonias:

1. Ammonia, Anhydrous, Synthetic. Commercial anhydrous ammonia contains as principal impurities: moisture, traces of oil, some rust, dirt, etc. The product intended for use at the US Ordnance plants for the manuf of nitric acid, Amm nitrate, Amm picrate and Na azide must comply with the following requirements of the US Spec (Ref 15):

   a)Moisture – max 0.5% by wt
   b)Oil – max 5 ppm

The procedures for sampling and testing of ammonia and calculations given in the above specs can be slightly simplified (especially in calcns), as was done during WWII at the Keystone Ordnance Works lab, to make them less time-consuming.

Following is a description of the sampling and testing of anhydrous ammonia:

Sampling is usually done by two persons, each equipped with a full-face mask and heavy rubber gloves. Connect to the unloading valve in the dome of the tank a stainless-steel sampling line with a 1-inch union and a ½-inch valve, and attach to the sampling line by a rubber tubing connection the adapter equipped with a rubber stopper as shown on figs in the Spec (Ref 15). Attach to the side-outlet connection of the adapter a 4- or 5-foot length of rubber tubing to carry the NH₃ vapors, released by the sampling, to one side of the sample taker. Place yourself facing the sampling jet with your back against the wind and ask the operator to open the discharge valve slightly. Let the NH₃ run out for a few mins to sweep the pipes and then carefully fill two or three duPont special centrifuge tubes graduated from 0 to 100 ml. These tubes will serve for moist detn. If it is required to det oil content, fill with liq NH₃ two 2-l round-bottom flasks.

Immediately after each sample is taken, tightly close the containers by means of rubber stoppers provided with Bunsen valves (in order to prevent the penetration of moist from the atm) and take the samples to the lab.

Procedures:

a)Moisture Content. Wearing a full-face mask, loosen up slightly the stoppers and plunge each centrifuge tube slowly into a cooling bath contg salt-ice mixt. Remove after ca 1 hr one of the tubes and warm its tip by holding it between the fingers. If the liq starts to boil, continue the evapn of NH₃ for a little longer, etc. For the final test, remove the stopper, let the gas escape and warm the bottom of tube with the hand. If the smell of NH₃ is gone, take the reading. Each small division of the tube corresponds to 0.05% by vol. Divide the reading by the d of liq NH₃ = 0.682 in order to obtain % moisture by wt in the NH₃. Check if there is any oil or rust at the bottom of the tube.

Note: A much more complicated formula for calcg % moisture is given in the Spec (Ref 15), but it is not necessary to employ it unless required by the Govt inspector.

b)Oil Content. If an appreciable amt of oil is present in liq NH₃, some droplets will be
visible at the bottom of centrifuge tubes used in the previous operation. In this case proceed as follows:

Place in each of the 2000 ml round-bottom flasks (see under Sampling) a piece of 14–20 mesh washed coke (known commercially as 'anti-bump'), loosen slightly the stoppers and place the flasks in the cooling bath, as in procedure a. When the bulk of NH₃ has been transferred to a bath containing tap water at RT and continue the evaporation. Finally bring the temp of the bath to ca. 30°C by adding some hot water in order to complete the evaporation of NH₃. Rinse the inside of each flask with four 10 ml portions of carbon tetrachloride delivered from a pipette, transferring each set of washings into a 75 ml separatory funnel containing no grease on its stopcock. After separation of layers and allowing evaporation of water from the top layer, draw the liquid in each funnel through a dry filter paper (previously washed with carbon tetrachloride) into a small (30–60 ml) tared dish. Evaporate the tetrachloride on a steam bath, cool each dish in a desiccator and weigh. Run a blank on 40 ml of tetrachloride and calculate oil in ppm from the equation \( \frac{(W_1 - W_2) \times F \times 1000}{V} \), where

\[ W_1 = \text{wt of residue in mg}, \quad W_2 = \text{wt of blank}, \quad V = \text{vol of sample in ml}, \quad 0.682 = d \text{ of sample} \]

\[ F = \text{evaporation factor (0.871 for a freshly prepared standard)} \]

The presence of ammonia was indicated by the appearance of brown turbidity due to the formation of NH₄I and the intensity of this turbidity was determined colorimetrically using the Nalco Phototester, which was previously calibrated using freshly prepared standards.

**References for Ammonia, Analytical Procedures:**

1) C.L. Berthollet, Crell Ann 2, 390 (1788) (Action of ammonia on silver oxide produced an extremely sensitive compd named "fulminating silver") (See next ref) 2) F. Raschig, Liebig's Ann 233, 93-101 (1886) (Zur Kenntniss des Berthollet'schen Knallsilbers) (Investigation of Berthollet's fulminating silver showed that it is Ag₃N) 3) M. Berthelot & M. Delépine, CR 129, 326-30 (1899) & JCS 76 II, 748 (1899) (Ammoniacal silver nitrate AgNO₃ · 2NH₃ was prepd by treating 1 mol AgNO₃ with 2 mols NH₃ in an aq soln and evaporating the water) 4) C. Matignon, Bull Fr, 4, 3-6, 618 (1908) & CA 2, 245 (1908) (An explosion at l' École de Sèvres of a mixt of Ag nitrate alkali and ammonia, after it had stood quietly for 24 hrs, was evidently due to silver ammine formed by interaction of the foregoing ingredients) 5) A. Tingle, IEC 11, 379 (1919) & CA 13, 1152 (1919) (Ammoniacal solns of silver oxide have to be handled with care because they might contain fulminating silver) 6) E. J. Witzemann, IEC 11, 893 (1919) & CA 13, 2449 (1919) (Several explosions took place while W was studying the oxidation of organic compds by silver oxide and was using ammonia to remove the non-reacted Ag₂O. It was claimed that silver fulminate, formed as a product of the reaction was the cause of these explosions) 7) J. Egger, 2Elektrochem 27, 547-58 (1921) & CA 16, 1013 (1922) (Investigation of sensitiveness of some expls, among them Ag₂O · 2NH₃ and NH₃ · N₂) 8) H. Vasbinder, Pharm Weekblad 87, 861-5 (1952) & CA 47, 4083 (1953) (Discussion on hazards of ammoniacal silver solns. One of the solns obtained on mixing Ag nitrate, Amm hydroxide and gum arabic exploded on warming. Another soln, prepd by pptg Ag oxide from Ag nitrate soln with Na hydroxide, washing the oxide, dissolving it in Amm hydroxide, adding dropwise Ag nitrate until a permanentppt was formed and then centrifuging, exploded on two occasions after standing for 10-14 days. Both these solns were used as permanent marking ink. It is suggested that the
explosions were caused by an amorphous substance $Ag_2HN$, very sensitive to heat and shock even when wet, which formed as a result of the following reactions:

a) $Ag_2O + 4NH_3OH \rightarrow 2Ag(NH_3)_2OH + 3H_2O$

b) $2Ag(NH_3)_2OH \rightarrow Ag_2HN + 3NH_3 + 2H_2O$

**Ammoniacate.** French for Ammoniate (See Ammine)

**Ammonia Derivatives of Polynitro-Alcohols.** Several compounds, some of them explosive, were patented recently by Swedish inventors. For their preparation, polynitro-alcohols (having all NO$_2$ groups attached to the same C atom and the OH group or groups attached to the adjacent C atom) were treated with ammonia (or an N-substitution deriv thereof) in aq or other solns.

Following equations illustrate this process:

a) $R'(NO_2)_2\cdot CH_2\cdot OH + NH_3 \rightarrow R'(NO_2)_2\cdot CH_2\cdot NH_2 + H_2O$

b) $R(NO_2)_2\cdot CH_2\cdot OH + R'(NO_2)_2\cdot CH_2\cdot NH_2 \rightarrow R\cdot C(NO_2)_2\cdot CH_2\cdot NH_2 + H_2O$

Ammoniakat (Ger). Ammoniate described in this work as Ammine

Ammoniak (Ger). Ammonia (in old Ger chem terms it was equivalent to "ammonium")

**Ammonia Dynamites** are listed in this work as Ammonium Nitrate Dynamites, with the exception of the following:

a) **Ammonia Dynamite or Ammonia Powder:** AN 78, NG 18, paraffin & charcoal 4%. It was a powerful expl suitable for all types of blasting (Ref 1)

b) **Ammonia Dynamite No 1.** A French expl: AN 45, NG 40, Na nitrate 5% & wood flour 10% (Ref 2)

c) **Ammonia Dynamite No 2.** A French expl:

For their preparation, polynitro-alcohols (having all NO$_2$ groups attached to the same C atom and the OH group or groups attached to the adjacent C atom) were treated with ammonia (or an N-substitution deriv thereof) in aq or other solns.

Another example is the reaction between urea and trinitroethanol: $2(O_2N)_3C\cdot CH_2\cdot OH + H_2N\cdot CO\cdot NH_2 \rightarrow H_2O + [(O_2N)_3C\cdot CH_2\cdot NH_2]_2\cdot CO$

(See also Azetidine or Cyclotrimethyleneimine, Dinitro)

Ref: CondChemDict(1942), 287 (not listed in newer editions)

Ammonia Dynamites or Ammonia Gelatins are listed in this work as Ammonium Nitrate Gelatins and also as Ammongelatin Dynamites. See also Ammongelatine in PATR 2510, p Ger 5

Ammonia Gelignite: AN 70, NG 29,3 & NC 0.7%

Ref: CondChemDict(1942), 287 (not listed in newer editions)

Ammoniok (Ger). Ammonia (in old Ger chem terms it was equivalent to "ammonium")

Ammoniakk (Ger). Ammoniate described in this work as Ammine

Ammoniakkrut is the first known expl based on AN. It was patented in Sweden on
May 31, 1867 by J.H. Norrbin & C.J. Ohlsson. Slightly later (June 9, 1867) Björckmann patented, also in Sweden, an expl contg AN 72.46, NG 18.12, sawdust (or charcoal) 8.70 & benzene or creosote 0.72%, and named sererin (Ref 1, p 713)

The original expl of Norrbin & Ohlsson consisting of AN 80 & charcoal 20% was difficult to ignite and was replaced by AN 80, charcoal 6–10 & NG 14–10% (Refs 2–5). The modified compn, in which NG served as a sensitizer for the insensitive AN, was much more powerful than the Guhrdynamite, previously invented (ca 1866) by A. Nobel, if it contd an equal amt of NG (Ref 1, p 21). Davis (Ref 6) listed Ammoniakkrut as an expl consisting of AN, either alone or in admixture with charcoal, sawdust, naphthalene, PA or NB.

The modified ammoniakkruts were used to some extent in Sweden, but were found to be too hygroscopic and exudable. A=Nobel purchased in 1870 Norrbin & Ohlsson’s patents and reduced the hygroscopicity and exudability of Ammoniakkrut by coating the particles of AN with paraffin, stearin or naphthalene (Brit P 1570 of 1873). Still better results were obtained when AN particles were coated with NG gelatinized with colloidion cotton. The resulting expls became known as gelatin dynamites (qv)


Ammonia Nitrate (Poudre): AN 80, nitroglycerine 10, K chlorate 5 & coal tar 5% Ref: Daniel, "Dictionnaire" (1902), 24

Ammonia Oxidation consists of treating anhydrous ammonia with air (or oxygen) at high temp and pressure and in the presence of a catalyst (such as Pt gauze) to obtain nitrogen oxides and eventually nitric acid. For the manuf of explosives includes such facilities. Some information on ammonia oxidation plants is given under Nitric Acid, Manufacture

Ammonia Powder. See under Ammonia Dynamos

Ammoniaque (Fr). Ammonia

Ammoniaque (Dynamite) (Fr). Ammonia Dynamite

Ammoniate. Same as Ammine

Ammonio-Nitrogen Iodide. See under Iodides

Ammonique Dynamite. A safety expl prep by mixing guhrdynamite (75% strength) 50, Amm carbonate 40 & K nitrate 10%. The nitrate was incorporated to prevent the formation of CO

Ref: Daniel, "Dictionnaire" (1902), 22

AMMONITE

(Ammonit in Germany and in Russia; Explosif Favier type N n° 1c in France; Explosif Favier n° 1 in Belgium; Ammonite in Italy and Amonita in Spain) (Formerly called in England "Miner’s Safety Explosive".) A type of AN expl known since 1884 (Refs 1 & 2) and manufd since then in many varieties in several European countries. In England they were manufd by the Miner’s Safety Explosives Co, Ltd at Stanford-le-Hope, Essex (Ref 5); in France by the Poudrie d’ Esquerdes; in Belgium by the Usine de Vilvøede (Ref 3) and in Germany by several plants (See Refs 9 & 12–14). Most ammonites were used as commercial expls (particularly in coal mining) but some of them were used in military applications chiefly as substitutes for HE’s based on aromatic nitro compds (such as TNT) or nitric esters (such as NG) (See also Ersatzsprengstoffe in PATR 2510)

According to Cundill (Ref 4) the first expl of this type manufd in England consisted of a cylindrical container, made by compressing a mixt of AN 91.5 and MNN 8.5%, and filled either with a pulverized mixt of AN and MNN or with dynamite or NC. The resulting cartridge was wrapped in paper and then waterproofed. In France similar cartridges were...
prepd by using mixts of AN with either 8.5
– 12.6% DNN or with 4.5% of TNN(See also
Ref 3). According to Marshall(Ref 7) the
original expl invented by Favier consisted
of an AN, MNN, paraffin and resin. Another
compn listed by Marshall(Ref 7,p 389) and
then by Cook(Ref 18) was the ammonite contg
AN 88, DNN 12%, which passed the Brit
Woolwich test and was on the ‘‘Permitted
List’’. In order to pass the more stringent
Brit Rotherham test(in which the expl was
litigated, without stemming, into the gas mixt),
the previous compn had to be modified to
AN 75, TNT 5 and NaCl 20%(Ref 7,p 390).
This expl was placed on the ‘‘Permitted
List’’ in 1914(Ref 6), under the name of
ammonite No 1. Its compn was modified after
WW I to AN 79.5, TNN 5.5 and NaCl 15%. A
similar expl known as ammonite No 2 con-
tained AN 79.5, DNN 5.5 and NaCl 15 1/2%. Both of these expls passed the Brit Buxton
Test(Ref 10). Barnett(Ref 8) gives for amm-
one No 1 and No 5 the same compn: AN 75,
TNN 5, NaCl 20% plus 0.5% moisture and for
ammonite No 4: AN 66, Na nitrate 10, DNN 4
& KCl 20%, plus 0.5% moisture. The only
difference betw the No 1 and No 5 was that
the latter was put up in waxed paper and the
former in metal foil cases. Molina(Ref 9a)
gives compn of Ital ammonite No 1 as: AN 88,
DNT 3, vegetable flour 6 & NG 3%, plus
traces of DPhA

According to Naoum(Ref 9) and Pepin-
Lehalleur(Ref 14), seven types of ammonites
were used in Germany. Their compns was,
in general, 70 to 88% of AN(of which 10% could
be replaced by K nitrate), 7 to 20% of aro-
matic nitrocarbons and 1 to 6% of a vegetable
meal w/ or wo a solid hydrocarbon. Besides
these components the Ammonits 1, 3, and 6
contd up to 4% of NG, the Ammonits 3, 4, & 5
contd 3 to 10% of K perchlorate and the Am-
onit 5 contd 2 to 12% of Al. These expls
are described in Ref 9, pp 424–5 and in
Ref 11,p 118. Ger Ammonit 1 contg AN 80,
TNT 12, rye meal 4 and NG 4% was also
known as Astralit or Donarit(Ref 12,p 309)
and Ammonit 2 contg AN 81, TNT 17 and
rye meal 2% was also known as Aldorfit
(Ref 12,p 309). A variety of Ammonit 2, contg
DNT, was also known as Astralit ON(See
PATR 2510,p Ger 10). Slightly different
compns for Ammonit 1, Ammonit 2 and
Donarit 2 are given in Ref 13,p 94

Table 2,p Ger 6 in PATR 2510 gives
compns of Ammonits in Germany developed
during WW II

For the prepn of ammonites, the thoroughly
pulverized and dried ingredients were stirred
in a pan for 1 or 2 hrs, then heated(by in-
direct steam or hot water) above the mp of a
nitrocarbon and then cooled while stirring.
The result of such treatment was that the
grains of hygroscopic ingredients(such as
AN) were coated with nonhygroscopic nitro-
carbons(See Ref 7,p 388 and Ref 14)

Ammonites are apparently no longer manufd
in western European countries, but are still
very much in use in Russia. Radevich
(Ref 16) describes some Russian pre-WWII
ammonites and Bebie(Ref 17) says that am-
onites are the main types of expls used in
industrial practice in Russia. The following are
some Russian ammonites as described in
additional Refs 20, 22 and 23 listed below:
a)AN 88 & TNT 12%(called Ammonite No 2)
b)AN 73, K nitrate 15 & TNT 12% c)AN 77.6,
TNT 18.4 & WM 4% d)AN 54.5–57.5, TNT
8.5–9.5, finely ground pine bark(contg less
than 12% of H₂O) 2.5–3.5 & NaCl 31–33% e)
AN 59.5–62.5, TXN 9.5–10.5, pine bark
2.5–3.5 & NaCl 25–27%(See also Ammoksil
or Ammonxyl, Ammonal, Ammonpek, Am-
nonol and Dynanammon in this section and Am-
onit I in PATR 2510, under Commercial
Explosives)

Refs on Ammonites: 1)Favier,GerP 31,411
(1884) 2)Ibid,BritP 2139(1885) 3)Charton,
MP 4,159–60(1891) 4)Cundill,MP 5,334–5
(1892)(Favier explosives) 5)Daniel(1902)22
6)Anon,JSCI 33,986(1914) 7)Marshall 1
(1917),388–90 8)Barnett(1919),133 9)Naoum,
NG(1928),424–6 9a)Molina(1930),339 10)
Marshall 3(1932),119 & 153 11)F.A.Pershakov,
Addn Refs on Russian Ammonites: 19) A.G. Suvorov & V.L. Machkarin, Chim & Ind 36, 785 (1936) & CA 31, 2437 (1937) (The higher the moist content of ammonites, the larger the ams of noxious N oxides formed. For ammonites having a positive O balance of not more than 5% and intended for use in underground work, the max permissible moist content is ca 0.5% because with larger ams of w, the ams of N oxides produced would be excessive. With ammonites having a negative O balance the ams of moist can be as high as 2%. This type of ammonite is therefore preferred for underground work under damp conditions) 20) K.K. Andreyev & M.M. Purkal' n, Dokl Akad Nauk 51, 445-8 (1946) & CA 40, 6817 (1946) (Investig of deton of ammonite, contg AN 73, KNO3, 15 & TNT 12%, showed that the ams of sand surrounding the chge greatly influenced not only the decompn of the chge itself but also the formation of CO and N oxides. Since in actual practice it is difficult to duplicate the favorable conditions established by lab expt, the addn of K nitrate will usually not solve the problem of reducing noxious gases. More promising results were obtained by changing the compn of ammonites in order to obtain higher heat of expln and by more thorough pulverization and mixing of the ingredients. For instance the charge of ammonite contg AN 77.6, TNT 18.4 & WM 4%, when surrounded by quartz sand, gave smaller ams of noxious gases than a similar compd contg K nitrate) 23) B.D. Agranovich et al, Russ P 67, 692 (1946) & CA 43, 3200 (1949) (Non-brisant ammonites can be prepd by adding to a finely ground mixt of AN and a HE (such as TNT or TNX) in a mixing drum, first the ground pine bark (contg not more than 12% of moist) and then NaCl) 24) V.A. Assonov & E.P. Maksimova, Gornyi Zhur 126, No 7, 25-8 (1952) & CA 47, 319-20 (1953) (It is claimed that compressed ammonite is superior to the powder in shattering effect and in resistance to moist, thus not requiring a water-impervious cover).
27) N.E. Yaremenko & A.V. Korenistov, Ibid 28–30 (It is claimed that pressed ammonite is in no way superior to the powd and the added cost of pressing is not justified)

28) N.I. Kozlov, Ibid 126, No 10, 21–2 (1952) & CA 47, 1391 (1953) (It is claimed that there is no significant diff between pressed and powdery ammonites when used in very small bore-holes for blasting hard rocks)

**Ammonite Goudronite.** A Russian coal mining expl consisting of AN and tar (goudron). Its props are given by N.A. Shilling, “Explosives and Loading of Ammunition”, Oboronazi, Moscow (1946), 107 (See also Ammonite and Dynammon)

**Ammonium Azides.** See under Azides (Inorganic)

**Ammonium Bicarbonate.** See under Bicarbonates

**Ammonium Dichromate (Dichromate).** See under Chromates, Bichromates, etc

**Ammonium Borate.** See under Borates

**Ammonium Bromate.** See under Bromates

**Ammonium Carbonate.** See under Carbonates

**Ammonium Chlorate.** See under Chlorates

**Ammonium Chloride.** See under Chlorides

**Ammonium Chromate.** See under Chromates

**Ammonium Cobaltic Hexanitrate.** See Ammonium Hexanitrocobaltate or Ammonium-cobaltic Hexanitrite (Cobaltic ammonium nitrite), (NH₄)₃Co(NO₃)₆·½H₂O. It was prep'd according to Mellor (Ref 1) in 1857 by O.W. Gibbs on mixing an acidified soln of cobalt chloride with ammonium nitrite. The following expl props were determined at PicArsn: expln temp (5 sec) 230°; impact sensitivity (Bur Mines app, 2 kg wt) 35 cm and sand test 45% of TNT. It requires 0.30 g of MF for its initiation (Ref 2)

**Refs:**
1) Mellor 8 (1928), 504  

**Ammonium Hydroxide.** See Ammonia, Aqueous

**Ammonium Hypophosphite.** See under Hypophosphites

**Ammonium, Metal (Metal Ammonium).** Solutions of mercury and the alkali metals in liq ammonia were first prep'd and studied by Weyl (Ref 1). According to his views, the metals are joined to the nitrogen of ammonia, forming substituted ammonium radicals. Many investigators later studied the solns of metals in liq ammonia and while a few of the investigators were in favor of Weyl’s theory (Joannis in 1892, Moissan in 1898 and Benoit in 1923), others were against it (Seeley in 1871, Ruff and Geisel in 1906, Kraus in 1908, Biltz in 1920 etc)

Kraus & Johnson (Ref 2) reinvestigated the solns of lithium in liq ammonia and came to the conclusion that there is no evidence indicating that Li is joined to the nitrogen of ammonia, forming a substituted ammonium ion

**Note:** The compds formerly called "metal-ammoniums" are now called ammines (qv) or "ammoniates"

**Refs:**
1) W. Weyl, Ann Physik (Poggendorff’s Ann) 121, 601 (1864) & ChemZtr 1864, 601–4  
2) C.A. Kraus & W.C. Johnson; JACS 47, 725–31 (1925) (16 refs) & CA 19, 1360 (1925)  
AMMONIUM NITRATE
(AN or Amm Nitrate)

(Ammonsalpeter in German, Nitrate d’ammoniaque in French, Ammoniynaya Selitra in Russian, Nitrato amónico in Italian, Nitrato amonico in Spanish, Hsiao Hsuan An in Chinese and Amonum Shosanen in Japanese). \( \text{NH}_4\text{NO}_3 \), mw 80.05, N35.00%, OB to \( \text{H}_2\text{O} \) and \( \text{N}_2 + 20.0\% \) cryst d at 25° 1.725 (Ref 127a) (for densities of various modifications, see below), d of material used for manuf of amatol 1.06 or higher (Ref 127a), d of molten material 1.402 at 175° and 1.36 at 200°. Hardness on Moh’s scale 1.1, mp 169.6 - 169.9° (with slight sublimation) (Ref 122a), mp of technical grade ca 165°, bp of pure material ca 210° at 11 mm Hg pressure and it distills practically without decomposition. It decomposes at 230° and 760 mm Hg pressure, and above 325° it deflagrates. There may be some decomposition at as low as 100°, since constant weight cannot be obtained at this temp, and decomposition is quite perceptible above the mp of AN. If confined, AN may explode between 260 and 300°. When liquid AN is cooled below its fr p, there are formed cubic crysts which, on further cooling, undergo (at 125.2°) transition into tetragonal crysts. There are five allotropic modifications of solid AN (Refs 122 & 122a).

The following table gives the crystallographic characteristics of the different forms of AN:

<table>
<thead>
<tr>
<th>Form</th>
<th>Crystal System</th>
<th>Density, g/cc</th>
<th>Range °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid</td>
<td></td>
<td></td>
<td>Above 169.6</td>
</tr>
<tr>
<td>I Epsilon (( \epsilon ))</td>
<td>Regular (cubic) (isometric)</td>
<td>1.594 at 130 ±5°</td>
<td>125.2 to 169.6</td>
</tr>
<tr>
<td>II Delta (( \delta ))</td>
<td>Rhombohedral or tetragonal</td>
<td>1.666 at 93 ±5°</td>
<td>84.2 to 125.2</td>
</tr>
<tr>
<td>III Gamma (( \gamma ))</td>
<td>Orthorhombic</td>
<td>1.661 at 40 ±1°</td>
<td>32.1 to 84.2</td>
</tr>
<tr>
<td>IV Beta (( \beta ))</td>
<td>Orthorhombic</td>
<td>1.725 at 25°</td>
<td>-16 to 32.1</td>
</tr>
<tr>
<td>V Alpha (( \alpha ))</td>
<td>Tetragonal</td>
<td>1.710 at -25 ±5°</td>
<td>-18 to -16</td>
</tr>
</tbody>
</table>

The heat of transition from form III to form II is 310 kcal/mol and that from form II to form I is 979 kcal/mol. Whetstone (Ref 113) studied the initiation of transition between forms III and IV. The effect of foreign substances on the transition IV → III was studied by Campbell and Campbell (Ref 81) who found that in the case of a solid solution of 8 to 10% of KNO₃ in AN the temperature of transition of form III into form IV is depressed by about 20°. Such solid solutions can be prepared either by fusion or by co-crystallization from aqueous solutions. Hendricks et al (Ref 40) found form III to be orthorhombic and form V to exist up to −18° and not to −16°. Bowen (Ref 30) showed that there is also a metastable inversion occurring at about 50° as follows: orthorhombic form (\( \beta \)) (32.1° to −16°) → tetragonal form (\( \delta \)) (125.2° to 84.2°).

The heat of transition of various modifications of AN was studied also by Steiner and Johnston (Ref 36). According to Assonov and Rossi (Ref 68), beta orthorhombic crysts, which are stable up to 32.1°, do not cake provided that the moisture content is less than 0.5%. If the temp is raised above 32.1°, these crysts (d 1.725) undergo an increase of about 3% in volume and then break up into a fine, cryst powder having a d of 1.66. When stored in the open, this powder hardens (cakes) like cement. This is especially pronounced in the presence of moisture. Caking is also observed when crysts of the gamma form are cooled below 32.1°. This occurs with relatively dry samples having less than 0.15% moisture.
Historical (Refs 31, 62, 71 & 72)

AN is very seldom encountered in nature. The first description of its preparation and properties was in 1659 by Glauber, who treated \((\text{NH}_4)_2\text{CO}_3\) with \(\text{HNO}_3\) and called the resulting salt "Nitrumflammans". Gmelin, at the start of the 19th century, called AN "Flammender Salpeter". Grindel and Robin were the first, in the beginning of the 19th century, to use it in explosives as a replacement for \(\text{KNO}_3\) in black powder. In 1840 Reise and Millon reported that a mixture of powdered AN and charcoal exploded on heating to \(170^\circ\). In 1867 the Swedish chemists Ohlsson and Norrbin patented an explosive called "Ammoniakrut" which consisted of AN with a small amount of other ingredients. Nobel purchased the patent in 1870 and started to work on the possibility of rendering the AN less hygroscopic by various treatments. He partly succeeded in doing this in his "Extra Dynamites" or "Ammongelatin Dynamites", patented in 1879. In these explosives AN crystals were coated with a jelly consisting of NG and collodion cotton (Refs 5, 9, 10 & 84).

The study of AN was continued and in the eighties of the 19th century Berthelot published a theoretical equation for its decomposition (Refs 1 & 2). At the beginning of the present century Kast and Naoum studied and described such explosive properties of AN as sensitivity to detonation, impact and heat, rate of detonation, Trauzl block value etc.

Until the time of the Oppau disaster (1921), AN was not considered to be an explosive. This disaster called for more extensive research into its properties, and numerous works were published as a result of such investigations (Refs 15a & 15b). However, the findings of the various investigators were somewhat at variance. While some claimed that AN itself cannot be detonated unless it is strongly confined and a very strong initiating charge is used, others claimed that it can be detonated even on strong heating if confined, because the gases formed by decomposition are explosive, detonate first and cause the explosion of any remaining molten material. Although the Oppau disaster certainly showed that AN is an explosive, fires and explosions continued to occur throughout the world, although generally on a small scale.

After the termination of World War II, the US Government began shipments to Europe of so-called FGAN (Fertilizer Grade Ammonium Nitrate), which consisted of grained AN coated with about 0.75% of wax and conditioned with about 3.5% of clay. Since this material was not considered to be an explosive, no special precautions were taken during its handling and shipment - workmen even smoked during the loading of the material. Numerous shipments were made without trouble prior to April 16 and 17, 1947, when one of the worst explosions in history occurred. The SS Grandcamp and the SS Highflyer, moored in the harbor at Texas City, Texas and loaded with FGAN, blew up. For description and probable causes, see under "Ammonium Nitrate Explosions and Fire Hazards".

As a consequence of this disaster, a series of investigations was started in the United States in an attempt to determine the possible causes of the explosions. At the same time a more thorough study of the explosive properties of AN and its mixtures with organic and inorganic materials was instituted.

The explosion at Texas City had barely taken place when a similar one aboard the SS Ocean Liberty shook the harbor of Brest, France on July 28, 1947. As investigations following the Texas City and Brest explosions showed that AN is much more dangerous than previously thought, more rigid regulations governing its storage, loading
and transportation in the United States were promptly enacted.

At present, AN is classified as "an explosive ingredient" and oxidizing material. Its manufacture, use, storage distribution and possession are regulated by the Federal Explosives Act, which is administered by the US Bureau of Mines. A yellow label, the same as for Amm perchlorate, is required on all railroad shipments. Since 1947, fortunately, there have been no major disasters with AN, only a few fires have occurred.

Preparation of AN (General Discussion)

Until World War I, AN was manufactured chiefly by neutralizing, with weak HNO₃, the NH₃ present in aqueous by-products of the artificial gas and coking industries. As the HNO₃ was then manufd from Chile saltpeter, it contained HCl, HNO₃, and boric acid as impurities, while the gas liquor NH₃ used contained pyridine and thiocyanates. Consequently, the AN also contained the same impurities. Such AN was used in blasting explosives and, to some extent, in mixed fertilizers. In 1913 the manuf of HNO₃ from NH₃ produced from atmospheric nitrogen was begun in Europe. This acid was of a higher degree of purity and, as it was neutralized with synthetic NH₃, the AN produced was much purer than that obtained by the earlier process.

Some later achievements and problems in the manuf of AN and Amm sulfate have been reported by Perelman and Klevke (Ref 69). In a patent issued for nitrogen fertilizers from NH₃ and nitric acid, Lutz (Ref 100) described a procedure for the prep of AN. Strel'zoff (Ref 98) described a process for the manuf of AN from NH₃ and aq HNO₃, in which the heat of reaction is utilized to evaporate and condense the soln so that the cryst AN can be withdrawn without any addition of external heat. By maintaining the reaction zone at a relatively high pressure and the concentrating zone at a low pressure, a sufficient temp gradient was set up to allow a rapid and efficient transfer of heat from the hot vapors of the reactor to the soln to be boiled and concd. A typical arrangement producing 32100 lb/hr is described in the patent. Seaman et al (Ref 102) reported the production of AN by continuous vac crystn. An apparatus to control the AN content of waste water from manufg plants has been described by Krichmar (Ref 117).

Laboratory Procedure. A. Pérez Ara (Ref 76) gives the following laboratory method of manuf of AN: Dilute in a beaker 100 ml of commercial nitric acid with an equal amount of water. Add cmol Amm hydroxyde slowly, by neutralizing, with weak HNO₃, the NH₃, while stirring and cooling the soln, until it is alkaline to litmus paper. Evaporate on a steam bath to the formation of a crust. Cool the soln and separate crysts from the mother liquor. Dry the crysts and, if desired, purify by recrystn from distd water.

Plant Processes. Following are some of the processes for manuf of AN:

1. Passing NH₃ gas into 40-60% HNO₃. This is the most common method of manuf and is described further with more detail. Symmes (Ref 19) was one of the first to describe this process in detail and later assigned the patent to the Hercules Powder Co (Ref 33).

2. By the double decomposition of calcium nitrate and ammonium carbonate (or sulfate) in solution: Ca(NO₃)₂ + (NH₄)₂CO₃ → CaCO₃ + 2NH₄NO₃

3. By the double decomposition of ammonium sulfate and sodium nitrate in solution: (NH₄)₂SO₄ + 2NaNO₃ → 2NH₄NO₃ + Na₂SO₄. This process, patented by Freeth and Cockedge (Ref 13), was an economical one up to the time of the development of synthetic NH₃ and of HNO₃ by ammonia oxidation.
4. By using sodium nitrate instead of common salt in the ammonia-soda process:
\[ \text{NaNO}_3 + \text{NH}_4\text{HCO}_3 \rightarrow \text{NH}_4\text{NO}_3 + \text{NaHCO}_3 \]

5. By mixing the gases (NO\textsubscript{2} + O\textsubscript{2} + H\textsubscript{2}O) obtained as by-products of ammonia oxidation plants, with ammonia gas and extra air in order to bring about the following reaction: 
\[ 4\text{NO}_2 + \text{O}_2 + 2\text{H}_2\text{O} + 4\text{NH}_4 = 4\text{NH}_4\text{NO}_3 \]
In this process, AN is deposited as a powder when the material fudge is stopped.

The first of these processes is now usually conducted on a plant scale as follows, the operation being continuous:

a. 40% nitric acid is gradually fed into a stainless steel open vessel (reactor or separator) and an equimolecular quantity of gaseous NH\textsubscript{3} is introduced simultaneously beneath the surface of the acid. The reaction 
\[ \text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_2\text{NO}_3 \]
is exothermic and causes the solution to boil, thus partially concentrating it.

b. As soon as the reactor is full and/or the solution has reached a conc of about 50-55% AN, a valve at the bottom is opened and the liquor is continuously drawn to a cooler. From there it is run into a storage tank. While the solution is being removed from the reactor, it is continuously replaced with equivalent amounts of HNO\textsubscript{3} and NH\textsubscript{3}.

c. The AN solution in storage can either be shipped directly as such (to be used as fertilizer) or it can be converted into solid AN by evap. Several methods of evaporation and crystallization are used, as described below:

Methods of Evaporation of AN Solutions

A. Batch Process (Refs 93, 102). The saturated solution from the storage tank is gravity fed to open evaporating pans ("high pans") provided with stainless steel or aluminum heating coils and air agitation. The soln is evaporated to about 98% at a temp of 155-160\textdegree C (310-320\textdegree F). The evaporn is stopped when the material fudge. The fudge is transferred into flat grainers ("low pans") provided with slowly rotating stainless steel paddles. Stirring the syrup in the open, cools it, drives off the remainder of the water and produces small, rounded crystals of AN. When the granulation has reached a certain point, a coating material is added and the stirring continued for a while to insure uniform coating. One ton of AN so produced requires approx 440 lbs of NH\textsubscript{3} and 1630 lbs of 100% HNO\textsubscript{3} (Yield 98%)

B. Continuous Process of Graining (Spray Granulation or Prilling (Refs 104 & 118). The AN solution is transferred from the storage tank to evaporating pans ("high pans") where it is evapd to a concn of about 95%. The hot soln (about 140\textdegree) is pumped to the top of a spraying chamber (20 ft square by 70 ft high) and fed into the chamber through a sprayer. As the soln falls, the remainder of the water evaporates, leaving spherical grains about the size of buckshot, called "prills", which fall to the bottom of the tower. In order to prevent caking of these particles, they are dried further and coated with substances such as wax, paraffin and, in the case of FGAN, with diatomaceous earth, clay etc. The resulting product is called "Nitraprill" and can be stored without becoming caked (See Note, p A340)

C. Continuous Vacuum Crystallization (Refs 102, 118). The AN, after being concentrated in "high pans" to about 75-80% strength, is transferred to a special stainless steel vacuum crystallizer, similar to the "Oslo-Crystal" classifying type. Evapn is conducted at an absol press of 2 mm of Hg and a temp of 36\textdegree C (97\textdegree F). The resulting slurry, contg about 40% by weight of crystals, is continuously removed from the bottom and run through a centrifuge. The crystals, contg about 1% water, are dried to a 0.1% moisture content. The mother liquor is returned to the system (See also Ref 54) (See Note, p A340)
Other methods of manufg AN are based on complete utilization of the heat of reaction. They include the following:

6. Fauser Process. This method originated in Italy and has assumed considerable importance in Europe (Refs 52 & 85)

7. Bamag Meguin A-G Process (Refs 58 & 85)

8. Caro and Frank Process (Refs 41 & 85)

9. Tomolo Process (Refs 34 & 85). Some comparatively recent patents for the production of AN have been assigned to the du Pont Co (Refs 63, 64 & 66) (See also Refs 95 & 127)

10. TVA Process (Refs 85, 93 & 102). In 1933 the Tennessee Valley Authority inherited a World War I plant designed to produce ammonia by a roundabout and obsolete method in the following steps: first the manuf of lime and subsequently Ca carbide, then Ca cyanamide, ammonia, nitric acid and finally AN. In 1940 a modern high-pressure ammonia plant was constructed, in which there were used an improved ammonia synthesis catalyst and a water-gas conversion catalyst. During WW II, the TVA produced 29000 tons of anhydrous ammonia, 10000 t of AN liquor, 64000 t of AN crystals and over 375,000 t of phosphate and nitrate fertilizer. When the Ordn Dept in 1943 reduced its demand for AN, TVA changed to the production of AN suitable for use as a fertilizer. In cooperation with the US Dept of Agric, the TVA developed an improved method of conditioning grained AN. This process was subsequently adopted by Ordn plants. In 1948 the batch graining process was replaced by a continuous crystallization plant operated at low temp; hence it is the safest known method for prepg cryst AN. In spite of the superiority of the coke-air-water process of ammonia production over the old cyanamide process, a more economical process is one based on the use of natural gas as the raw material. The TVA plant has been converted to the use of gas for this more efficient process of producing fertilizer and munition grades of AN. The TVA flow diagram for AN is included. (See next page)

11. Stengel Process (Refs 99, 105, 114 & 118). The neutralization of ammonia with preheated nitric acid takes place in a packed, tubular reactor at about 204°. The molten AN collects on the packing, flows to the bottom of the reactor and through a centrifugal separator, the bottom portion of which is also filled with packing. The heat of the highly exothermic reaction between NH3 and HNO3 serves to evaporate any water present. Air blown through the material controls the moisture content at almost any desired level. The molten product leaving the bottom of the reactor is essentially water free (0.2%) and goes to a weir box. A sheet of AN forms on water-cooled Sandvik belts, at the end of which is a breaker which reduces the sheet to flakes. The flakes are transferred to grinders, screens and a coating drum (See also the patented process of Davis, Ref 96). The Stengel process is in use at the Sterlington plant of the "Commercial Solvents" (See enclosed flowsheet)

Besides the above Stengel Process, there are two other modern commercially important processes — the Prilling Process and the Crystallization Process (See inclosed flowsheets)

In the Prilling Process, such as practiced by the Lion Oil Co (Division of Monsanto Chemical Co, El Dorado, Arkansas), the production centers around a prilling tower, where a concd soln of AN forms into small droplets which flow downward against a stream of air. The resulting slightly moist prills are screened, dried and cooled by air and again screened

In the Crystallization Process, such as practiced by Aburdarverksmidjan HF plant,
FLOW DIAGRAM FOR THE PRODUCTION OF AMMONIUM NITRATE
TENNESSEE VALLEY AUTHORITY, WILSON DAM, ALABAMA, U S A

FLOW DIAGRAM FOR THE PRODUCTION OF AMMONIUM NITRATE
BY THE STENGEL PROCESS (COMMERCIAL SOLVENTS)
FLOW DIAGRAM FOR THE PRODUCTION OF AMMONIUM NITRATE BY THE PRILLING PROCESS (LION OIL CO)

FLOW DIAGRAM FOR THE PRODUCTION OF AMMONIUM NITRATE BY THE CRYSTALLIZATION PROCESS (ABURDARVERKSMIDJAN HF)
the production centers around a vacuum crystallizer, where a satd soln of AN is cooled under vacuum to produce a slurry, which goes next to a centrifuge where crysts of AN are separated. After removal of moisture in a dryer, the crysts are coated with clay to prevent their caking.

Note: High Pan Fires and Explosions. Numerous fires, sometimes resulting in explosions, have occurred during the concn of AN in "high pans". In view of this, it might be inferred that unconfined, pure AN may be detonated by heat alone. However, this is not the case, as investigations of such fires and explosions have shown that, there was confinement and there was definite proof of the presence of some organic inflammable materials such as TNT, carbonaceous matter, organic nitrates etc. The burning of these organic materials has been considered to yield so much heat that the bulk of the AN begins to decompose and the rate of such decomposition increases so rapidly that it becomes explosive. For more information on this subject, see Ref 86.

Preparation of Fertilizer Grade Ammonium Nitrate (FGAN). As many explosives plants produce fertilizer grade AN, a short description of the American process is included. After transferring the AN fudge liquor from the "high pan" to the "low pan" (graining kettle) (see above under Methods of Evaporation), agitation and cooling are continued until the fudge breaks into grains. At this point, coating material [wax and clay; petrolatum, rosin and paraffin wax (PRP); or similar material] is added and stirring is continued until coating is complete. This coating (0.5 to 1.0%) with a waxy, water-repellant substance is necessary in order to render the nitrate less hygroscopic. In order to prevent caking of the coated grains, 3 to 5% of a so-called "conditioning" (anticaking) agent such as powdered clay (kaolin), kieselguhr, "Celite," plaster of Paris, tricalcium phosphate etc is introduced and mixed with the AN. Very good results with a product called "Kittitas" (qv) have been reported. The AN is screened and the portion passing through an 8-mesh screen is bagged in moisture-proof bags at a temp not exceeding 93°C (200°F) (See Note, p A340).

The finished FGAN is required to meet the following specifications: moisture-0.25% (max), ether-soluble matter 0.75% (max), water-insol matter, such as clay 3.50% (max), nitrogen 32.50% (min); granulation: through US Std Sieve No 8 100% (min), on US Std Sieve No 35 55% (min) and through US Std Sieve No 100 8% (max).

For more information on preparation of FGAN, see Refs 74, 82 & 87.

Properties of Ammonium Nitrate. Refs 5, 8, 11, 16, 56, 84, 109, 128, & 129 give one or several of the following properties of AN:

Ability to Propagate Detonation. AN has a very low ability to propagate a detonating wave. It happens very often that if a charge (cartridge) is long and of small diameter and unconfined, the detonating wave dies out (dampens) before it reaches the opposite end of the cartridge.

Ballistic Mortar Test Value. See under Power.


Behavior Towards Metals and Other Substances. According to Mellor, vol 7 (Ref 16), fused AN will not react at room temperature with As, Sn or Hg but will react with Al, Zn, Pb, Sb, Bi, Ni, Cu, Ag and Cd. Of these metals, Zn is attacked very rapidly and so is Cu. Fe reacts in the presence of moisture with the formation of ammonia (Ref 122a). According to Kast (Ref 31), the presence of KMnO₄ may cause the spontaneous ignition of AN. Investigations conducted at Pic Arsn (Ref 88) showed that different Cr compounds catalyze...
the decompn of AN. According to Ref 122a, p 120, AN is decomposed by strong alkalis with the liberation of ammonia, and by sulfuric acid with the formation of \((\text{NH}_4)_2\text{SO}_4\) and HNO\(_3\). In the presence of moisture, AN reacts with copper to form tetramminocupric nitrate, \([\text{Cu}(\text{NH}_3)_4](\text{NO}_3)_2\), which is of the same order of brisance and sensitivity to impact as lead azide. For this reason, tools of brass or bronze should not be used in operations with explosives contg AN. AN has little if any effect on coatings of acid-proof black paint, shellac, baked oil or NRC Compound (Ref 122a) (See Note, p A340)

Brisance, by the following methods: a) Lead Cylinder Compression Test, 54% of that of TNT b) 200 g Sand Test, only partial explosion occurs (Ref 122a) c) Kast Formula (Max Potential Work), 17,000 for complete and 5,800 for incomplete decompn as compared with 86,000 for TNT (Ref 56) d) Fragmentation of 40 mm shell (average charge 44.5 g at d 1.0) - 16 fragments for AN coated with wax vs 66 fragments for TNT

Note: According to Ref 122a, p 123, because of its low rate of detonation, the brisance of AN is relatively low. Fragmentation tests in small shell loaded with AN and with TNT showed the nitrate to produce only 24% as many fragments as TNT

Coefficient of Expansion. See Thermal Expansion

Decomposition Reactions. Berthelot stated that AN can decompose according to any of the seven equations given below. The heats of decompn (indicating the heat evolved at const vol and 300°K) were calcd by C.G. Dunkle of Pic Arsn, based on the latest NDRC values. Unless otherwise stated, these values are for the solid salt. For molten AN, add about 4,000 cal/mol to these values. Values in square brackets are those of Scott and Grant (Ref 90), and were calcd from the data of Bichowsky and Rossini (Ref 57). The values for heat liberated are at const press and 18° for solid AN, with all products of decompn in gaseous form. It should be noted that the temps of decompn indicated here for some of the reactions are only approx and are not those originally given by Berthelot (Ref 1), but by later investigators. None of the Berthelot’s reactions occurs as a single reaction, but is always accompanied by other reactions. The higher the temp of decompn, the more the reaction approaches reaction c (see below)

Berthelot’s reactions are:

a. \(\text{NH}_4\text{NO}_3 \rightarrow \text{HNO}_3 + \text{NH}_3 + 38.30 \text{kcal}\). This reaction takes place at a temp somewhat above the mp of AN(169.9°). The corresponding value for the solid salt is -41.70 kcal

b. \(\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2 + 2 \text{H}_2\text{O} + 13.20 \text{kcal} (\text{H}_2\text{O gas}) \text{ and } 33.10 (\text{H}_2\text{O liq}).\) For the same reaction the value of -10.7 kcal is given in Ref 122a, p 121. According to Berthelot, this reaction takes place at 180-200° when the AN is not confined. Other oxides (than \(\text{N}_2\text{O}\)) form at 230 to 285°. Berthelot also reported that AN decom with puffs of smoke when heated to 260°

c. \(\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2 + 0.5 \text{O}_2 + 2 \text{H}_2\text{O} + 30.50 \text{kcal} [28.47] (\text{H}_2\text{O gas}) \text{ or } 50.40 (\text{H}_2\text{O liq}).\) For the same reaction, the value of +27.72 kcal is given in Ref 122a. This reaction is stated to take place when AN is heated under strong confinement or when initiated with a powerful detonator. It is the principal reaction of complete detonation of AN. According to calcn, this reaction develops temp 1500° and pressure 11200 kg/cm\(^2\). The gas evolved is calcd to be 980 l/kg at STP

d. \(\text{NH}_4\text{NO}_3 \rightarrow \text{NO} + 0.5 \text{N}_2 + 2 \text{H}_2\text{O} + 9.0 \text{kcal} [6.87] (\text{H}_2\text{O gas}) \text{ or } 28.90 (\text{H}_2\text{O liq}).\) This is supposed to be one of the side reactions taking place during incomplete detonation and one which develops a pressure of 4860 kg/cm\(^2\) and a temp of 518°
e. $3 \text{NH}_4\text{NO}_3 \rightarrow 2 \text{N}_2 + \text{N}_2\text{O}_4 + 6 \text{H}_2\text{O} + 20.80$
kcal $[21.80] \ (\text{H}_2\text{O} \text{ gas})$ or $40.60 \ (\text{H}_2\text{O} \text{ liq})$.
This reaction cannot take place alone because $\text{N}_2\text{O}_4$ exists only in the dissociated
state as $\text{NO} + \text{NO}_2$.

f. $4 \text{NH}_4\text{NO}_3 \rightarrow 2 \text{NO}_2 + 3 \text{N}_2 + 8 \text{H}_2\text{O} + 29.80$
kcal $[24.46] \ (\text{H}_2\text{O} \text{ gas})$ or $49.80 \ (\text{H}_2\text{O} \text{ liq})$.
This is another possible side reaction, occurring during incomplete detonation. For
this reaction Ref 122a, p 121 gives the value of $96.0 \text{ kcal}$ which does not agree with
the value given by Berthelot. Ref 122a also gives the following endothermic reaction of
decomposition, which was not listed by Berthelot:

$$4 \text{NH}_4\text{NO}_3 \rightarrow 3 \text{NO}_2 + 5 \text{H}_2\text{O} + \text{N}_2 + \text{NH}_3 + \text{NO} \rightarrow 84.88 \text{ kcal}$$

The reaction takes place under certain conditions, such as in the presence of spongy Pt and
gaseous HNO$_3$ (Ref 1).

Later investigators have shown that the following other reactions of decomposition are possible:

h. $8 \text{NH}_4\text{NO}_3 \rightarrow 16 \text{H}_2\text{O} + 2 \text{NO}_3 + 5 \text{N}_2 + 16.58 \text{ kcal} \ [31.12] \ (\text{H}_2\text{O} \text{ gas})$ or ca $55 \text{ kcal}$
($\text{H}_2\text{O} \text{ liq}$ with HNO$_3$ dissolved therein). This reaction takes place under certain conditions,
such as in the presence of spongy Pt and gaseous HNO$_3$ (Ref 1).

i. $\text{NH}_4\text{NO}_3 \rightarrow 0.5 \text{NH}_3 + 0.75 \text{NO}_3 + 0.25 \text{NO} + 0.25 \text{N}_2 + 1.25 \text{H}_2\text{O} \rightarrow 21.20 \text{ kcal}$. Kaiser
(Ref 52) lists this reaction of decomposition of AN when under confinement and at 200 to
260$^\circ$. This endothermic reaction is followed, at 260 to 300$^\circ$, by explosion of the gaseous
products of reaction. This explanation is an exothermic reaction liberating 48.94 kcal which
is more than 1.5 times as great as the heat liberated by the reaction c (see above)

j. According to Ref 122a, p 121, the most important reactions of decomposition of AN, when
heated under various conditions, are:

$$\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2 \text{H}_2\text{O} + 10.7 \text{ kcal}$$
$$4 \text{NH}_4\text{NO}_3 \rightarrow 2 \text{NO}_2 + 8 \text{H}_2\text{O} + 3 \text{N}_2 + 96.0 \text{ kcal}$$
$$4 \text{NH}_4\text{NO}_3 \rightarrow 3 \text{NO}_2 + 5 \text{H}_2\text{O} + \text{N}_2 + 2 \text{NH}_3 + \text{NO} \rightarrow 84.88 \text{ kcal}$$

In the last reaction the decomposition is endothermic, and if the gaseous mix of products of
decomposition is heated, these react exothermically with explosive effect
(See also Heat of Decomposition, Heat of Dissociation and Heat of Explosion of AN)

**Detonation Rates (Velocities of Detonation).**
Rates as low as 1000 and as high as 3000 m/sec have been reported in the literature
for AN depending on the conditions and methods of testing. The most important
factors affecting the velocity are: density, degree of confinement, charge diameter,
particle size (especially at low densities), strength of initiating impulse (nature and
quantity of booster charge), temperature of sample and the presence of certain impurities
such as organic materials or oxidizable
metals (Refs 45 and 94)

According to Ref 122a, p 123, values from 1100 to 2700 m/sec were observed for AN,
depending on whether the detonation was incomplete or complete. Because of the insensitivity of AN its rate of detonation is
affected by its particle size, apparent density, degree of confinement, efficiency of
booster charge and temperature of charge.
Increase in rate is brought about by decrease
in particle size, decrease in apparent density of charge and increase in confinement. Increase in the temp of charge from 15 to 140° has been found to result in an increase of 400 m/sec in the rate

The following table gives values for rates of detonation of AN, and its mixtures under various conditions of testing. These values were taken from different sources as indicated.

<table>
<thead>
<tr>
<th>Rate, m/sec</th>
<th>Density, g/cc</th>
<th>Charge dia, mm</th>
<th>Container</th>
<th>Initiation by</th>
<th>Charge temp, °C</th>
<th>Investigator</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure AN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1140</td>
<td>0.68-0.73</td>
<td>26.2</td>
<td>Shelby tube</td>
<td>75 g tetryl</td>
<td>15</td>
<td>Gawthrop</td>
<td>29</td>
</tr>
<tr>
<td>1560</td>
<td>0.68-0.73</td>
<td>26.2</td>
<td>53.5 cm long, 4.85 mm wall</td>
<td>75 g tetryl</td>
<td>71</td>
<td>Gawthrop</td>
<td>29</td>
</tr>
<tr>
<td>1230</td>
<td>0.69</td>
<td>50</td>
<td>Steel tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Kast</td>
<td>31</td>
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<tr>
<td>1310</td>
<td>0.84</td>
<td>25</td>
<td>Steel tube</td>
<td>50 g tetryl</td>
<td>Room</td>
<td>Kast</td>
<td>31</td>
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<tr>
<td>1470</td>
<td>0.83</td>
<td>26</td>
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<td>60 g tetryl</td>
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<td>Kast</td>
<td>31</td>
</tr>
<tr>
<td>1530</td>
<td>0.79</td>
<td>80</td>
<td>Steel tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Kast</td>
<td>31</td>
</tr>
<tr>
<td>1550</td>
<td>0.88</td>
<td>80</td>
<td>Steel tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Kast</td>
<td>31</td>
</tr>
<tr>
<td>1820</td>
<td>0.84</td>
<td>100</td>
<td>Steel tube</td>
<td>200 g PA</td>
<td>Room</td>
<td>Kast</td>
<td>31</td>
</tr>
<tr>
<td>1850</td>
<td>0.82</td>
<td>26.2</td>
<td>Shelby tube</td>
<td>100 g tetryl</td>
<td>Room</td>
<td>Perrott</td>
<td>37</td>
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<tr>
<td>1920</td>
<td>0.64</td>
<td>100</td>
<td>Steel tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Kast</td>
<td>31</td>
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<tr>
<td>2440</td>
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<td>50</td>
<td>Lead tube</td>
<td>100 g PA</td>
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<td>2700</td>
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<tr>
<td>1200</td>
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<td>3000</td>
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<td></td>
</tr>
<tr>
<td>AN + 1% Nitrostarch</td>
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<td></td>
</tr>
<tr>
<td>1940</td>
<td>0.82</td>
<td>26.2</td>
<td>Shelby tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Perrott</td>
<td>37</td>
</tr>
<tr>
<td>AN + 5% Nitrostarch</td>
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<td></td>
</tr>
<tr>
<td>2060</td>
<td>0.82</td>
<td>26.2</td>
<td>Shelby tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Perrott</td>
<td>37</td>
</tr>
<tr>
<td>AN + 10% Nitrostarch</td>
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<tr>
<td>2470</td>
<td>0.82</td>
<td>26.2</td>
<td>Shelby tube</td>
<td>100 g PA</td>
<td>Room</td>
<td>Perrott</td>
<td>37</td>
</tr>
<tr>
<td>Fertilizer Grade Ammonium Nitrate (FGAN)</td>
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<tr>
<td>1106</td>
<td>0.90</td>
<td>114.3</td>
<td>Paper tube</td>
<td>225 g Comp C</td>
<td>Room</td>
<td>Macy</td>
<td>88</td>
</tr>
<tr>
<td>1350</td>
<td>0.91</td>
<td>31.7</td>
<td>Steel tube</td>
<td>50 g Comp A3</td>
<td>Room</td>
<td>Macy</td>
<td>88</td>
</tr>
<tr>
<td>2109</td>
<td>1.4</td>
<td>30</td>
<td>Glass tube</td>
<td>50 g Comp A3</td>
<td>&gt;169°</td>
<td>Macy</td>
<td>88</td>
</tr>
</tbody>
</table>

Note: Booster charges of PA, tetryl, Comp A3, Comp C, etc were compressed
The above results show that rates of detonation increase (within certain limits) with increased strength of initiating agent, increase in confinement, increased diameter of charge, increase in diameter of charge, increase in temp and the presence of organic compounds whether explosive or nonexplosive.

According to Aufschläger (Ref 24) the rate of deton of AN increases with increasing diameter of the charge, and if the diameter is great enough, unconfined AN can detonate; the rate decreases with increased distance from the initiator.

Aufschläger also found that: a) A 10 g charge of AN in a Trauzl lead block, under slight confinement, can be detonated completely by a No 8 blasting cap, but with a No 6 cap deton was not complete and with smaller caps no deton occurred. The Trauzl test value was about 165 cc b) Increasing the grain size of the AN seemed to improve propagation of deton, but if the crystals were too large the d was decreased to such an extent that the blasting effect was decreased. With AN of max d, such as is obtained by fusing and then solidifying the salt (d 1.65), only partial deton took place as indicated by the Trauzl test c) When large quantities of AN were tested under slight confinement or no confinement, they could be detonated only by a very strong initial impulse d) The sensitivity of AN is increased by the incorporation of even very small quantities (1-2%) of organic substances such as coal dust, wood pulp etc e) The velocity of deton of AN decreases with decrease in confinement, decrease in diameter of container and increase in distance from point of initiation. The influence of change in initiating agent is not very great. The lowest velocity (1270 m/sec) was obtained with No 5 to 8 caps in steel tubes of 40 mm diameter. The highest value (2450 m/sec) was obtained in 60 mm seamless steel tubes (Mannesmann’s), using PA as the booster.

Kast (Ref 23) reported velocities of detonation ranging from 1200 to 1900 m/sec when AN was loaded at d of 0.65 to 1.0 in wrought iron tubes having diams from 2.5 to 10 cm and the charges were detonated by means of boosters consisting of 50 to 300 g of tetryl or PA. Monroe (Ref 25) found that AN could not be detonated at ord temps when unconfined, but when confined, it could be detonated by several different detonators. The certainty with which deton could be effected increased with the degree of confinement. On the other hand, the certainty of deton by initiation decreased with an increase in d of the AN; that is, the salt tended to become "dead pressed" (See also studies by Parisot, Ref 67).

C.G. Dunkle of Pic Arsn conducted studies of the rate of deton of TNT and amatols at a d of 1.5 in Shelby steel tubing of 1/4" ID and initiated by pressed tetryl pellets. His data (Ref 70) indicated, by extrapolation, that the rate of deton of AN, under the experimental conditions given, should be 3700 m/sec. The amatols uniformly deton under the conditions mentioned, but the 50/50 amatol consistently failed to deton when extruded, lead tubing was substituted for steel tubing.

"Limiting charge diameters" for AN under varying degrees of confinement were reported by Belyaev & Khariton (Ref 77) in studies summarized as follows: a) Deton of AN does not differ in principle from other explosives and is not unique b) In a series of experiments, dry AN (d 0.7-0.8) was packed in long, thin-walled glass tubes and cardboard casings of various diameters. These charges were initiated by means of a mixt of AN and 3% of TNT. This mixt, serving as a "booster", occupied the upper portion of the tube (or casing) and was set off by an electric detonator. Stable, nondamping deton of AN were observed where the charge diam ("limit charge diameter")
was greater than 80 - 100 mm. The smaller the diameter of the charge, the more abrupt was the damping. c) When using heavy casings, such as concrete, or when exploding under water, the "limit charge diameter" decreased to 30 - 40 mm d) Explosives having lower heats of explosion than AN, such as mixts of AN with inert substances, have greater "limit charge diameter" values

Cook et al (Ref 119) measured the deton rates of pure AN (as well as of its mixts with TNT and with Comp B) as a function of charge diam. A hand-tamped charge of AN in paper tubing diam 12.72 cm, failed to deton. Average rates in larger diam paper tubes were: 1300 m/sec in 16.0 cm diam tube, 1500 in 19.99 cm, 1750 in 25.4 cm, 2150 in 35.7 cm, 2360 in 40.4 cm and 2760 m/sec in 46.0 cm diam tube

According to Rinkenbach (Ref 130), rates of deton of pure AN packed in steel tubes at approx d 0.96 g/cc were as follows: 2570 m/sec in 5" ID tube, 1681 in 4" and failure in 3" ID tube

Sakurai (Ref 120) determined the "shock wave velocity" of AN at an apparent d of 0.91 g/cc to be 3200 m/sec when measured in air and initiated by a TNT booster

Dissociation Pressures, as given in Ref 112a, are as follows:

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>188.2</th>
<th>205.1</th>
<th>215.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm Hg</td>
<td>3.25</td>
<td>7.45</td>
<td>11.55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>223.1</th>
<th>236.7</th>
<th>249.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg Hg</td>
<td>15.8</td>
<td>27.0</td>
<td>41.0</td>
</tr>
</tbody>
</table>

Entropy (Absolute), as given in Ref 122A is 36.0 cal/mol/°C at 25°

Explosion by Heat. See Sensitivity to Initiation by Heat

Explosion by Initiation. See Sensitivity to Detonation by Detonators and Boosters

Explosion Temperature – cannot be determined (Ref 122a, p 121)

Fire and Explosion Hazard. According to Ref 122a, p 123, AN is a fire hazard, since it is a powerful oxidizing agent and will increase the intensity of combustion of any flammable material mixed with or adjacent to it. More information on the subject as well as on the handling of AN in storage and shipping may be found in Ref 127a and Ref 86a

Flash Point or Ignition Temperature may be detd by various methods such as those outlined in Refs 89 and 101. According to Ref 89, pure AN can be decomposed by a flame at a temp of 395–6°, while a petrolated AN decomps at ca 380°. According to US Dept Agric Circ No 719, the fl p of AN is ca 500°

Formation, Heat of. See Heat of Formation

Fragmentation Test. See under Brisance

Fusion Heat. See Heat of Fusion
Friction Sensitivity. As shown by the US Bur Mines Pendulum Friction Test, neither pure AN or FGAN can be detonated when subjected to the test with a steel shoe.

Gas Developed on Decomposition and Detonation. According to Kast (Ref 31) the total volume of gas produced by AN when complete deton takes place is 980 l/kg, while incomplete deton yields 945 l/kg. Macy (Ref 88) gives for incomplete deton 937 l/kg as an average derived from the values given by Brunswig (Ref 9), Berthe-lot (Ref 1), Colver (Ref 11) and Marshall (Ref 10). Ref 122a, p 120, gives 980 l/kg or 78.44 lb/mol for complete deton. This is a calculated value for gas volume at STP.

Heat of Combustion. According to Médard and Thomas (Ref 110) the values $Q_v$ are 627.8 cal/g and 50.3 kcal/mol and $Q_p$ are 616.9 cal/g and 49.4 kcal/mol.

Heat of Decomposition. Kast (Ref 31) gives 207 cal/g for AN at d of 1.0 g/cc, as derived from the reaction: $8 \text{NH}_4\text{NO}_3 + 16 \text{H}_2\text{O} + 2 \text{NO}_2 + 4 \text{NO} + 5 \text{N}_2$. Dunkle of PicArsn, NJ, calculated the heat of decomn as 414 cal/g or 33.14 kcal/mol from the following Berthe-lots' reaction: $\text{NH}_4\text{NO}_3 \rightarrow \text{2H}_2\text{O (liq)} + \text{N}_2\text{O}$. One of the older literature values for the heat of decomn was 347 cal/g. The average of these three values is 323 cal/g or 25.86 kcal/mol.


Heat of Dissociation at Various Temperatures. Ref 112a gives the following values:

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>169.6</th>
<th>200</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH, kcal/mol</td>
<td>39.33</td>
<td>38.92</td>
<td>38.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>300</th>
<th>350</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH, kcal/mol</td>
<td>37.65</td>
<td>37.12</td>
</tr>
</tbody>
</table>

Heat of Explosion or Detonation. As calculated from constants given by Brunswig, Berthe-lot, Colver and Marshall, an average value for $Q_v$ is 630 cal/g (H₂O liq). According to Ref 122a, p 121, the detonation reaction is: $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2 + 2 \text{H}_2\text{O (gas)} + 0.5 \text{O}_2 + 27.72$ kcal. This is equivalent to 346.3 cal/g. One of the older literature values for $Q_v$ was 375 cal/g with H₂O liq. Kast gave a value of 347 cal/g at a d of 1.0 g/cc (Ref 31).

Heat of Formation. Mellor gives for $Q_f$ 88.1 kcal/mol or 1101 cal/g (Ref 16). As calculated from NDRC data (Rpt A-116), the value for $Q_f$ is 84.5 kcal/mol or 1056 cal/g, which corresponds to 87.2 kcal/mol or 1090 cal/g for $Q_v$. Ref 122a gives 87.93 kcal/mol and 1098.46 cal/g respectively. Médard and Thomas (Ref 110) report a value of 1059 cal/g or 84.8 kcal/mol for $Q_v$ and 1091 cal/g or 87.4 kcal/mol for $Q_f$. (See also values reported by Tavernier, Ref 123).

Heat of Fusion. 18.23 kcal/g (Ref 122a, p 120).

Heat of Sublimation. See Latent Heat of Sublimation.

Heat, Specific. See Specific Heat.


Humidity and Hygroscopicity. Pure AN is not deliquescent at RT and at RH up to about 75%, but at higher RH the salt starts to deliquesce. Moisture uptake of dried cryst AN exposed in a 5-7 mm layer for 7 days at 20.1°C was as follows: 17% at 78% RH, 27.5% at 87.75% RH and 36.5% at 97.5% RH (Ref – Pic Arsn data).

The following values were taken from a curve in Ref 82 for the RH of air at various temps when in equilibrium with a saturated solution of AN:

<table>
<thead>
<tr>
<th>°C</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>% RH</td>
<td>82</td>
<td>75</td>
<td>70</td>
<td>67</td>
<td>63</td>
<td>59</td>
<td>56</td>
<td>53</td>
<td>51</td>
<td>48</td>
</tr>
</tbody>
</table>

The following values, detnd at Pic Arsn, give % gain in wt of AN stored in thin layers at 22.2°C (72°F) at different RH’s:
Hygroscopicity of AN

<table>
<thead>
<tr>
<th>Exposure, days</th>
<th>% Gain at 52% RH</th>
<th>% Gain at 76% RH</th>
<th>% Gain at 90% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2</td>
<td>14.1</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
<td>26.1</td>
<td>62</td>
</tr>
<tr>
<td>3</td>
<td>0.2</td>
<td>29.1</td>
<td>84</td>
</tr>
<tr>
<td>6</td>
<td>0.2</td>
<td>69.1</td>
<td>133</td>
</tr>
<tr>
<td>7</td>
<td>0.2</td>
<td>74.1</td>
<td>145</td>
</tr>
<tr>
<td>8</td>
<td>0.2</td>
<td>78.4</td>
<td>156</td>
</tr>
</tbody>
</table>

Hygroscopicity. See Humidity and Hygroscopicity

Ignition Temperature. See Flash Point

Impact Sensitivities at Room Temperature, PicArsn App, 2 kg wt: 31" for cp AN and 29–32" for AN coated with about 1% wax; BurMines App, 2 kg wt: no action for cp or wax-coated AN. Tests conducted at the same time with PicArsn App for standard explosives gave: 17" for Explosive D (Ammon picrate), 12–15" for TNT, 8" for tetryl, 4" for LA and 2" for MF (See also Ref 122a)

Impact Sensitivity at Various Temperatures, PicArsn App, 2 kg wt (Ref 88):

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>Impact Test, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>AN, cp: 31 27 27 12</td>
</tr>
<tr>
<td></td>
<td>AN, wax-coated: 30 22 23 12–13</td>
</tr>
</tbody>
</table>

The test at 175° shows that AN in molten condition is much more sensitive than the solid material. This had been previously shown by Kast (Ref 31) who gave 16–20 cm impact sensitivity with 10 kg wt and 12 cm with 20 kg wt. Ref 122a gives for molten AN 12" with 2 kg wt, PicArsn App

Initiation Sensitivity. See Sensitivity to Initiation

Latent Heat of Sublimation = 41.8 kcal/mol at 25° (Addnl Ref H) (See p A340)

Lead Block Test Value. See Trauzl Block Test value, under Power

Lead Cylinder Compression Test. See under Brisance and a Note under Power

Maximum Potential Work. See under Brisance

Oxidizing Properties of AN. Due to the fact that AN contains ca 20% of available oxygen, it serves as a powerful oxidizing agent. Various metals (especially Zn) react with AN even at RT, but the reaction is more vigorous when the mixture is heated. All organic compds, when heated with AN, burn with the evolution of CO₂, CO, N₂, N₂O etc (Ref 94). Hardesty and Davis (Ref 83) found that peanut-hull meal may be oxidized by AN with the formation of CO₂, N₂, N₂O, O₂ and small amounts of C₂N₂ and NO₂. Aqueous solns of AN corrode metals, such as Cu, but not as much as do NH₃ and HNO₃ (Ref 45)

Power. Values as detd by the Trauzl Lead Block Test (Lead Block Expansion Test) have been reported as high as 225 cc for complete detonation, as compared with 305 cc for PA and 300 cc for TNT. For incomplete detonation, a value of 165 cc has been reported (Ref, OSRD Rpt 2014). Comparing the Trauzl Block Test values of current Russian AN explosives used in open-pit mining, such as Ammonite No 2 and Dynamon K, which have test values of 280 cc and 300 cc respectively, Assonov and Rossi (Ref 68) concluded that it was cheaper to replace them with straight AN, for which they gave a test value of 225 cc. According to Ref 122a, p 123, both lead block expansion and lead cylinder compression tests gave 55% of TNT. In the standard Ballistic Pendulum Test, AN undergoes only partial detonation. If the test is modified so that a No 16 blasting cap is used, AN is found to be 79% as powerful as TNT (Ref 130)

Pressure Developed on Detonation. For the reaction: \( \text{NH}_4\text{NO}_3 \rightarrow \text{N}_2 + 2 \text{H}_2\text{O} + 0.5 \text{O}_2 \), the calcd pressure is 11200 kg/cm² at a temp of 1500°. Robinson (Ref 15) reported a pressure of 12.5 long tons/in² in 0.5 \( \times 10^{-8} \) sec for straight AN and 15.2 lb t/in² for a mixt of AN with 0.5% TNT. The pressure rose steadily and rapidly with increasing amounts of TNT in mixts to a max value of 55 lb t/in² for straight TNT
Propagation of Detonation. See Ability to Propagate Detonation

Rates of Detonation. See Detonation Rates

Rifle Bullet Test. AN at a d of 1.2 g/cc was unaffected in 10 trials. The presence of small ams of wax-coating did not affect these results (Refs 122 a & 128)

Sand Test Value. See under Brisance

Self-Ignition. See Spontaneous Ignition

Sensitivity to Impact. See Impact Sensitivity

Sensitivity to Initiation by Detonators and Boosters. As a rule AN is much more difficult to detonate or explode than any of the standard explosives. Even with strong initiators, such as a No 8 cap, the process of explosion (or deton) does not always go to completion with the formation of N₂, O₂ and H₂O, but various quantities of nitrogen oxides are also formed. This is especially pronounced when confinement is not complete (Ref 26). If AN is unconfined, it cannot be initiated to complete deton by a No 8 cap (Ref 60). If AN is partly or completely confined, a No 8 cap may be considered in some cases as a sufficient initiator, but more complete deton is obtained either by combining a No 8 cap (or a weaker cap) with a booster (Ref 28), or by using a stronger cap, such as No 16, alone (Ref 130). It is much easier to deton the molten salt than the solid material (Refs 28 & 29). The pressed crystal material is much easier to deton than the cast material, and the sensitivity to deton of the crystal material increases with packing d. The dry salt is easier to deton than the moist. In finely divided, low-density form, pure AN with an apparent d of 0.75 deton more completely (and gives higher Trauzl block value) than does technical grade AN

The relative insensitivity to deton of pure AN was demonstrated at the Bur of Mines by Scott and Grant (Ref 90) by firing 5 g charges at d 0.84 with caps contg various ams of 80/20-MF/KClO₃ mixture. These tests were made in the sand test bomb with small paper cartridges in a manner similar to the miniature cartridge test described in Ref 78. The results of the tests were as follows:

<table>
<thead>
<tr>
<th>Cap</th>
<th>Wt, g, of MF-KClO₃</th>
<th>Crushed by 5 g of AN*</th>
<th>Crushed by 5 g of TNT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No 6</td>
<td>1.0</td>
<td>21</td>
<td>253</td>
</tr>
<tr>
<td>8</td>
<td>2.0</td>
<td>43</td>
<td>254</td>
</tr>
<tr>
<td>10</td>
<td>3.0</td>
<td>58</td>
<td>261</td>
</tr>
</tbody>
</table>

* After correction for sand crushed by initiator

The above results show that only part of the 5 g sample of AN detonated. On the other hand, some tests conducted at the Bur of Mines with the ballistic pendulum, showed that, when properly confined, AN can be deton completely even with a No 6 cap (Ref 90)

Munroe (Ref 25) noted that an increase in temp results in increase in the sensitivity to initiation as well as the Trauzl lead block value of AN

Belyaev and Khariton (Ref 77) stated that sensitiveness to initiation is increased by increase in confinement and also by diam of the AN charge. For instance, charges at d 0.7-0.8 g/cc, under strong confinement such as steel tubing, could be initiated completely in smaller diameter containers than when the charges were relatively unconfined in glass or cardboard tubes

Sherrick reported (Ref 27) the following observations in studying the sensitivity of AN to initiation: a) Attempts to ignite 3 g of AN in a test tube by means of a black powder fuse failed b) Attempts to detonate AN loaded at d 0.7 in 1.5" id Shelby steel tubing having wall thickness of ¼" did not result in
more than feeble, partial deton when 100 g boosters of TNT, tetryl, PA or TNA were used. c) At a red heat, 5 g of AN merely decompd without flame, leaving no residue. d) The explosibility of AN decreased with increasing d and decreasing confinement.

Sensitivity to initiation of AN is also increased when impurities, especially organic materials, are present (Refs 20, 21, 73 and 89).

According to Ref 122a, p 122, it has been practicable to deton large charges of properly confined AN by means of a booster charge of tetryl, but not by means of a LA or MF blasting cap. Sensitivity to initiation decreases with increase in loading d, and if this exceeds 0.9 charges of 1 to 3 lbs cannot be detonated completely even by large booster charges. Charges larger than 3 lbs can be detonated completely at d's not greater than 1.1. The admixture of up to 8% of non-explosive carbonaceous material somewhat sensitizes AN to initiation. Molten AN is much more sensitive than the solid material and can be detonated with practically no confinement.

**Sensitivity to Initiation by Heat.** There is no agreement among various investigators as to what is the minimum temp at which AN under confinement explodes or detonates. It is safe to assume that this is above 260° and more probably nearer 300°. However, some investigators reported that pure AN can be initiated if heated above its mp (169.9°), if confined and under pressure of 2500 psi or more (Refs 21, 106 & 122a). It is very probable that explosion starts, not inside the molten mass itself, but because the gases of decompn form an expl mixture which explodes (or detons) first and initiates the deton of the undecd, molten AN.

It should be noted that heating pure unconfined AN never produces an explosion or detons, but only a more or less rapid decompn accompanied by a flash and a hissing sound (Refs 17, 75 & 86). For instance, if a cryt or a piece of cast AN is thrown upon a hot plate at a temp of about 500°, the material immediately catches fire and burns rapidly with a yellowish flame and a crackling or hissing sound, but leaves no residue. If a large piece of cast AN is thrown upon a red-hot plate, the decompn proceeds so rapidly and with so much noise that it resembles an explosion. This phenomenon apparently explains why some earlier investigators believed that AN could be exploded by heating, even if unconfined (Ref 18).

In experimental work conducted at the Bur of Mines after the Texas City disaster, it was shown that pure AN can be initiated when heated between 277 and 334°, FGAN at 114 to 350° and a mixture of FGAN and bag paper at 134 to 153°, when under confinement.

The sensitivity of AN to initiation by heat may be increased or decreased by the presence of certain inorganic impurities. For instance, small amts of Cu increase sensitivity to heat because of the formation of a small amt of copper nitrite, which causes instability (Ref 90). The formation of Cu nitrite also was reported in Mellor, v 7 (Ref 16). Mellor also reports that the presence of Fe, Al or especially Zn in powdered form lowers the temprature required for the decompn of AN. Kast (Ref 31) reported that the presence of KMnO₄ in powdered form may cause the spontaneous heating of AN. Investigations conducted at Pic Arsn showed that different Cr compds such as the oxide and nitrate catalyze the decompn of AN, and in some cases explosions occurred at temps as low as 200°. Among the inorganic substances which lessen the sensitivity of AN to heat are clay, kieselguhr, powdered limestone etc. The same effect was expected of Amm sulfate until the disaster at Oppau in 1921 (Refs 15a & 15b) rendered the safety of such a mixt uncertain. Amm sulfate had been used for many years as a desensitizer for AN in fertilizers and it was considered that such mixts could not be
exploded or detonated. This was disproved according to Scott and Grant (Ref 90) by Kast, who claimed that under certain conditions mixtures containing less than 40% of Amm sulfate may react exothermically according to the equation: 4 NH₄NO₃ + 2(NH₄)₂SO₄ → 16 H₂O (gas) + 2 SO₃ (gas) + 6 N₂ (gas) + 145.2 kcal

The sensitivity of AN to heat is always increased by the presence of organic compounds, provided that the proportions of these do not exceed certain limits. Among the substances investigated are cellulose, paper, pulverized carbon, soot, sawdust, waxes, paraffin, TNT, NS, DNT and drip oil. For instance, the presence of 5% NS in AN increased the sensitivity to such an extent that the mixture detonated when heated to about 150°. The presence of paper bags such as the containers for FGAN was a contributing factor to the Texas City disaster in 1947. In connection with this disaster, tests conducted at Pic Arsn and Aberdeen PG showed that transformation of the combustion of a mixture of FGAN and bagging paper into detonation required the building up of a gas pressure greater than a certain critical value. This was calculated to be about 100 psi (abs) or perhaps less.

Sensitivity and Stability of Molten AN. (See also Decomposition Reactions). Klevke reported practically no decompn of AN during evapn of its solns at atmospheric or reduced pressures (Ref 53). Klevke also claimed to obtain the undecomposed AN in the gas phase (Ref 59). Tram and Velde (Ref 49) found that when AN (either neutral, slightly acidic or alkaline) was left standing in a molten condition at 175°, it underwent only slow decompn provided that no chlorine was present as an impurity. Samples of AN containing nitric acid and a small amount of chlorite decomposed spontaneously at temps as low as 140°.

Shah and Oza (Ref 42) studied the decompn of AN when heated and reported that dissoion began before decompn started (180°) and NH₃ was evolved while HNO₃ accumulated in the residue. On heating to higher temps, other products of decompn, such as N₂, N₂O and H₂O were also formed. The decompn of AN was slow at 240°, but became rapid at 290°. Between these temps, N₂O and H₂O were the main decompn products and the amt of N₂O formed was directly proportional to the pressure. Gas phase explosions occurred at some point near 300°.

Kretzschmar (Ref 48) also studied the thermal decompn of AN and reported that decompn began at 170° and became quite appreciable at 220°. During this time N₂O, H₂O and N₂ were evolved. At a higher temp (250°), a little oxygen was also evolved. In no case were other nitrogen oxides formed.

The explosiveness of molten AN was studied also by Kaiser (Ref 52) who reported the following:

A small sample of AN in an evacuated tube was heated gradually to desired temps, and samples of the gas produced by decompn were pumped out, measured and tested. Decompn proceeded very quietly at temps below 200°, and only a small amt of gas was formed even on heating for several hours. The reaction proceeded more vigorously at higher temps and became rather violent at ca 260°. Between 260 and 269° a gray smoke was produced and, after a time, an explosion took place. This also occurred after heating above 250° for 10 hours, at which time more than 93.4% of the nitrate had decomposed.

The main reaction of decompn of AN heated in an evacuated tube was: 4 NH₄NO₃ + 2 NH₃ + 3 NO₂ + NO + N₂ + 5 H₂O, but there were also found present small amts of N₂O and HNO₃ in the gaseous products of decompn. Some of the above products of decompn (ammonia and nitrogen oxides) interacted with the evoln of heat. This heat might raise the temp of the gases above the molten AN to such an extent that they could explode and cause the explosion of the molten AN in the tube. In order to avoid the danger of expla
it is necessary to remove the gases produced by decomp as rapidly as they are formed. There is a possibility that some substances present in impure AN act as catalysts and accelerate the reactions of decomp.

Sensitivity to Initiation by Influence (Sensitivity to Sympathetic Detonation). According to Abinder and some other Russian investigators (Ref 60), cartridges or shells loaded with AN or explosives conntg large amts of AN transmit deton by influence to other cartridges or shells provided they are laid side-by-side, even with a small air space between them; but detonation usually is not transmitted if the cartridges or shells are laid end-to-end. The presence of 1% or less or moisture does not affect the sensitivity of AN to initiation by influence, but the presence of more than 2.5% moisture renders AN insensitive to initiation. The presence of small amounts of organic substances or of inorganic reducing materials such as Fe increases the sensitivity of AN. Less than 0.1% of paraffin has practically no effect on the properties of AN.

Shock Wave Velocity. See under Rate of Detonation (last paragraph)

Solubility of AN in Various Solvents
[Taken from Land-Börnst (Ref 22); ICT (Ref 35); Seidell (Ref 69a); Kirk & Othmer (Ref 84); PATR]

Solubility in Water

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>g/100 g soln</th>
<th>g/100 g water</th>
<th>Temp, °C</th>
<th>g/100 g soln</th>
<th>g/100 g water</th>
<th>Temp, °C</th>
<th>g/100 g soln</th>
<th>g/100 g water</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20</td>
<td>40.0</td>
<td>66.7</td>
<td>30</td>
<td>69.9</td>
<td>232</td>
<td>80</td>
<td>85.2</td>
<td>576</td>
</tr>
<tr>
<td>-10</td>
<td>48.4</td>
<td>93.8</td>
<td>40</td>
<td>74.8</td>
<td>297</td>
<td>90</td>
<td>88.1</td>
<td>740</td>
</tr>
<tr>
<td>0</td>
<td>54.2</td>
<td>118</td>
<td>50</td>
<td>77.6</td>
<td>346</td>
<td>100</td>
<td>89.4</td>
<td>843</td>
</tr>
<tr>
<td>10</td>
<td>60.0</td>
<td>150</td>
<td>60</td>
<td>80.4</td>
<td>410</td>
<td>140</td>
<td>97.4</td>
<td>989</td>
</tr>
<tr>
<td>20</td>
<td>65.2</td>
<td>187</td>
<td>70</td>
<td>83.3</td>
<td>499</td>
<td>160</td>
<td>99.2</td>
<td>989</td>
</tr>
</tbody>
</table>

More data are given in Ref 69a, vol 1, pp 1105–6 and Suppl, pp 385–7

Solubility in Aqueous Nitric Acid

See Ref 69a, vol 1, p 1107
A – Grams of HNO₃ per 100 g of soln saturated with AN
B – Grams of AN per 100 g of satd soln

At 0°

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0</td>
<td>9.2</td>
<td>21.0</td>
<td>27.0</td>
<td>33.2</td>
<td>39.1</td>
<td>41.4</td>
<td>45.8</td>
</tr>
<tr>
<td>B</td>
<td>54.3</td>
<td>43.5</td>
<td>34.5</td>
<td>31.9</td>
<td>31.0</td>
<td>33.2</td>
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<td>39.5</td>
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</table>

At 15°

<table>
<thead>
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<th>B</th>
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<th>B</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.0</td>
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<td>21.7</td>
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<td>45.0</td>
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<tr>
<td>B</td>
<td>62.4</td>
<td>52.0</td>
<td>42.2</td>
<td>40.9</td>
<td>39.9</td>
<td>40.8</td>
<td>46.8</td>
<td>52.5</td>
</tr>
</tbody>
</table>
### Solubility in Aqueous Nitric Acid (continued)

- **At 30°**

<table>
<thead>
<tr>
<th></th>
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<th>8.6</th>
<th>20.8</th>
<th>26.4</th>
<th>37.5</th>
<th>40.1</th>
<th>42.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>70.2</td>
<td>60.9</td>
<td>51.5</td>
<td>48.5</td>
<td>48.6</td>
<td>51.0</td>
<td>55.6</td>
</tr>
</tbody>
</table>

- **At 75°**

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>12.8</th>
<th>16.0</th>
<th>26.3</th>
<th>31.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>84.1</td>
<td>73.7</td>
<td>71.8</td>
<td>67.5</td>
<td>66.8</td>
</tr>
</tbody>
</table>

### Solubility in Pyridine (Ref 128)

20 to 25 g in 100 g of satd soln at 25°

### Solubility in Acetone

Slightly soluble (Ref 84, v 1, p 818)

### Solubility in Aqueous Solutions of Ammonium Sulfate, Ammonium Acid Sulfate, Sodium Chloride, Sodium Nitrate, Lead Nitrate, Uranyl Nitrate and Ammonium Thiocyanate

Ref 61a, Seidell, v 1, pp 1108–1112 (1940)

### Solubility in Acetic Acid *

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>Solubility</th>
<th>Temp, °C</th>
<th>Solubility</th>
<th>Temp, °C</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.16</td>
<td>63.5</td>
<td>1.89</td>
<td>110.6</td>
<td>31.25</td>
</tr>
<tr>
<td>17.7</td>
<td>0.28</td>
<td>72.8</td>
<td>3.45</td>
<td>120.0</td>
<td>55.5</td>
</tr>
<tr>
<td>21.4</td>
<td>0.33</td>
<td>80.9</td>
<td>5.51</td>
<td>131.4</td>
<td>75.0</td>
</tr>
<tr>
<td>27.0</td>
<td>0.39</td>
<td>85.7</td>
<td>7.26</td>
<td>149.7</td>
<td>86.3</td>
</tr>
<tr>
<td>33.6</td>
<td>0.51</td>
<td>97.1</td>
<td>13.68</td>
<td>167.5</td>
<td>100.0</td>
</tr>
<tr>
<td>45.8</td>
<td>0.88</td>
<td>101.0</td>
<td>17.15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Gram moles of AN per 100 g mols of satd soln (Ref 46)

Note: According to Eichelberger (JACS 56, 801 (1934), one liter of a satd soln of AN in pure acetic acid contains 3.5 g of AN at 16.46°

### Solubility in Ammonia (Ref 61a, v 1, p 1108)

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>g AN</th>
<th>g NH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>-60</td>
<td>1.39</td>
<td>4.43</td>
</tr>
<tr>
<td>-30</td>
<td>0.83</td>
<td>0.37</td>
</tr>
<tr>
<td>-10.5</td>
<td>0.97</td>
<td>0.35</td>
</tr>
<tr>
<td>0</td>
<td>0.64</td>
<td>0.35</td>
</tr>
<tr>
<td>33.3</td>
<td>0.77</td>
<td>0.24</td>
</tr>
<tr>
<td>35.9</td>
<td>0.64</td>
<td>0.20</td>
</tr>
<tr>
<td>46.8</td>
<td>0.48</td>
<td>0.20</td>
</tr>
<tr>
<td>94.0</td>
<td>0.48</td>
<td>0.20</td>
</tr>
<tr>
<td>190.8</td>
<td>0.48</td>
<td>0.20</td>
</tr>
</tbody>
</table>

### Solubility in Aqueous Ammonia at 25°

(Ref 69a, v 1, p 1108)

<table>
<thead>
<tr>
<th>g NH₃ per 100 g H₂O + NH₃</th>
<th>g AN per 100 g H₂O + NH₃</th>
<th>g H₂O per 100 g H₂O + NH₃</th>
<th>g AN per 100 g H₂O + NH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>390</td>
<td>21.8</td>
<td>316.8</td>
</tr>
<tr>
<td>2.80</td>
<td>381</td>
<td>47.5</td>
<td>247.0</td>
</tr>
<tr>
<td>4.82</td>
<td>372.8</td>
<td>67.0</td>
<td>220.0</td>
</tr>
<tr>
<td>10.1</td>
<td>354.7</td>
<td>100</td>
<td>214.0</td>
</tr>
<tr>
<td>15.9</td>
<td>337.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Solubility in Liquid Ammonia

(Ref 69a, v 1, p 1115)

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>g AN per 100 cc NH₃</th>
<th>Temp, °C</th>
<th>g AN per 100 cc NH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50.6</td>
<td>70.1</td>
<td>-40.8</td>
<td>75.1</td>
</tr>
<tr>
<td>-46.5</td>
<td>72.6</td>
<td>-36.6</td>
<td>77.0</td>
</tr>
<tr>
<td>-45.0</td>
<td>73.4</td>
<td>-34.0</td>
<td>77.9</td>
</tr>
<tr>
<td>-44.0</td>
<td>73.5</td>
<td>25</td>
<td>235.86</td>
</tr>
</tbody>
</table>

Note: According to Ref 84, v 1, p 818, the solns of AN in liquid NH₃ are called "Diver's Liquids". The amount of NH₃ taken up by 100 g AN is 42.5 g at -10°C and 31.5 g at 18°C, forming liquids containing 30% and 24% respectively of NH₃.

### Solubility in Absolute and Aqueous Ethanol

(Ref 69a, v 1, p 1112)

<table>
<thead>
<tr>
<th>% Ethanol by Weight</th>
<th>°C</th>
<th>100</th>
<th>86.77</th>
<th>76.12</th>
<th>51.65</th>
<th>25.81</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2.5</td>
<td>11</td>
<td>23</td>
<td>70</td>
<td>140</td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>4</td>
<td>14</td>
<td>32</td>
<td>90</td>
<td>165</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>5</td>
<td>18</td>
<td>43</td>
<td>115</td>
<td>196</td>
<td>277</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>6</td>
<td>24</td>
<td>55</td>
<td>144</td>
<td>244</td>
<td>365</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>7.5</td>
<td>30</td>
<td>70</td>
<td>183</td>
<td>320</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>9</td>
<td>41</td>
<td>93</td>
<td>230</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>10.5</td>
<td>56</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Note: Kirk and Othmer (Ref 84, p 818) give the amt of AN dissolved in 100 g of abs ethanol as 3.8 g at 30°C and 10.1 g at 80°C. Additional data are given in Ref 69a, Suppl, p 390.

### Solubility in Absolute and Aqueous Methanol

(Ref 69a, p 1112)

<table>
<thead>
<tr>
<th></th>
<th>H₂O</th>
<th>CH₃OH</th>
<th>AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>16.7</td>
<td>21.3</td>
<td>27.1</td>
</tr>
</tbody>
</table>

Note 1: Kirk & Othmer (Ref 84, p 818) give the amt of AN dissolved in 100 g of abs methanol as 20 g at 30°C and 39.6 at 60°C; Note 2: Schiff & Monsacchi, ZPhysChem 21, 277 (1896), give the soly of AN in 100 g of abs methanol as 14.6 g at 14°C, 16.3 g at 18.5°C and 17.1 g at 20.5°C.

### Solubility in 95% Isopropanol

(Ref 69a, Suppl, pp 391-2)

<table>
<thead>
<tr>
<th>Temp, °C</th>
<th>g/100 g soln</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>3.23</td>
</tr>
<tr>
<td>40</td>
<td>3.81</td>
</tr>
<tr>
<td>50</td>
<td>4.50</td>
</tr>
<tr>
<td>60</td>
<td>5.45</td>
</tr>
<tr>
<td>70</td>
<td>6.37</td>
</tr>
<tr>
<td>75</td>
<td>6.89</td>
</tr>
</tbody>
</table>
Solubility in Ethanol-Methanol-Water Mixtures at 30°C (Ref 69a, v 1, p 1112)
(Various proportions of water were added to a mixt of 51.7% methanol and 48.3% ethanol by wt)

<table>
<thead>
<tr>
<th>Solubility</th>
<th>Grams per 100 g of sotd soln</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>3.4 5 10 15 20 25 29.9</td>
</tr>
<tr>
<td>Alcohol (mixt)</td>
<td>84.9 82.9 74.6 63.5 48.2 22.4 0</td>
</tr>
<tr>
<td>AN</td>
<td>11.7 12.3 16.4 24 35.1 54 70.1</td>
</tr>
</tbody>
</table>

Solubility in Ethyl Acetate at 19°C - 0.050 g per 100 g of solvent (Ref 22)

Solubility in Furfural at 25°C - 0.4 g per 100 g of soln (Ref 69a, Suppl, p 392)

Solubility in Carbon Tetrachloride and in Chloroform at 20°C - Insoluble (Ref 22)

Solubility in Various Organic Compounds

Determined in Russia. Khaishbashev et al (Ref 79) investigated about 200 organic compds and came to the following conclusions: a) AN is miscible in all proportions with compds contg OH or NH groups provided that the mol wt is not too high; b) Total or partial insolubility is observed with hydrocarbons and with the compds contg NO₂ or halogen groups. For instance, AN is miscible in all proportions with mannitol, resorcinol, urea and acetamide, while with p-phenylenediamine it forms a mol compd in the ratio of 3 parts AN to 1 p of the diamine. In the liquid state AN is partially miscible with m-phenylenediamine, PA, TNT and cholesterol. Eutectic mixts are formed with many of the organic compds investigated by K

Specific Gas Energy. Gmelins Handbuch (Ref 56) gives 5575 kg/1 for complete deton and 3840 kg/1 for partial deton

Specific Gas Volume. See Gas Volume Developed on Decomposition or Detonation

Specific Heat. Bellati in 1886 (Ref 3), Behn in 1908 (Ref 7) and Crenshaw and Ditter in 1932 (Ref 43) detmd sp heat values. The following values, in calories per gram per °C, represent average rounded figures taken from all three sources:

Kirk and Othmer (Ref 84, 1, p 819) give the sp ht for temps from 0°C to 31°C as 0.407. Mellor (Ref 16) gives the following values for sp ht at atm pressures: Form II 0.426, Form III 0.355 and Form IV 0.407. The value for Form V at temps -190 to 20°C is given as 0.423 ± 0.00143 cal/g

Ref 122a, p 120 gives the sp heat of AN as 0.397 cal/g at 0°C and 0.428 cal/g at 100°C (For additional information on sp ht values at low temps, see Refs 22 and 35)

Landolt & Börnstein, 3 Erg, 3 Teil, p 2276 gives sp heat 0.508 at 0°C

Specific Volume. See Gas Developed on Decomposition and Detonation

Spontaneous Ignition, Self-Ignition, Heat of Spontaneous Combustion. As far as is known, there is no recorded instance of the spontaneous heating of pure AN, but there have been...
several fires in which it was reported that impure AN underwent self-ignition. Laboratory tests have shown that self-ignition may take place when organic substances or easily oxidizable metals (such as Zn), plus some moisture, are present. The chance of self-ignition is greater if some free nitric acid is present or if the material is stored or transported at high temps. On the other hand, the presence of small quantities (0.5–1.0%) of organic materials, such as paraffin, wax or petrolatum (generally used for coating purposes) did not cause any spontaneous combustion at temps as high as 60°C. However, if there is a fire somewhere in the neighborhood of AN or FGAN, which is in contact with some org material (such as sawdust), self-ignition may take place if the temp of the material becomes sufficiently high (say 150°C). Under these circumstances FGAN requires about 50 minutes for self-ignition.

**Stability.** See Thermal Stability

**Temperature Developed on Decomposition.** Temps ranging from 800 to 1230°C are reported, depending on how the reaction proceeds (Ref 56).

**Temperature Developed on Detonation.** For the reaction of complete deton to yield nitrogen, water and oxygen, the temp developed has been estimd to be 1500°C. Macy et al (Ref 88) gave 2120°C as the temp calcd from the data of Brunswig, Berthelot, Colver and Marshall.

**Thermal Conductivity.** Golubev and Lavrent'eva (Ref 65) gave a value of 0.205 kcal/meter/hr/°C, which is equivalent to 0.1375 Btu/ft/hr/°F.

**Thermal Expansion.** Cubical coefficient of expansion (γ) (Ref 56):

<table>
<thead>
<tr>
<th>°C</th>
<th>γ × 10⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>-60</td>
<td>677</td>
</tr>
<tr>
<td>-20</td>
<td>852</td>
</tr>
<tr>
<td>0</td>
<td>920</td>
</tr>
<tr>
<td>18</td>
<td>982</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>°C</th>
<th>γ × 10⁶</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>982</td>
</tr>
<tr>
<td>60</td>
<td>1069</td>
</tr>
<tr>
<td>100</td>
<td>1113</td>
</tr>
</tbody>
</table>

**Thermal Stability.** In general, pure AN may be considered stable up to its mp (169.9°C). Reports of early investigators, such as Berthelot (Refs 1 & 8), that the salt begins to decompose at temps as low as 100°C, were apparently correct because the substance was not pure. In the days when nitric acid (used for the manuf of AN) was prepd from Chile saltpeter, some nitrites and chlorides, as well as other impurities, remained in the AN, and it was apparently due to them that the stability of the product was not satisfactory. Tran & Velde (Ref 49) found that as little as 0.1% of Amm or Na chloride increases greatly the probability of decomn of AN, while 1–2% of such impurities are definitely the cause of increase of decomn of molten AN.

In summarizing the present stability data on AN, prepd from synthetic ammonia and ammonia oxidation nitric acid, it may be said that up to temp of its mp, AN is fairly stable. At slightly above its mp (say ca 170°C), slow decomn begins, but this is hardly perceptible until temps 200–210°C are reached. From this point on the decomn, accompanied by evoln of gas, is fairly rapid and, if the substance is confined, explosion may take place above 260°C (See Refs 91, 92 and 124 for more in-formation on the thermal decomn of AN).

Following are the results of some tests conducted for the US Govt (after Texas City disaster) in order to determine the safety factors of AN:

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>100°C Heat Test</td>
<td>0.74% loss in wt in the first 48 hrs, 0.13% loss in the 2nd 48 hrs and no explosion in 100 hrs</td>
</tr>
<tr>
<td>b)</td>
<td>120°C Vacuum Stability Test</td>
<td>0.1–1.0 cc gas evolved from 5 g of pure AN in 40 hrs and 1.2 cc gas from AN coated with 1% wax</td>
</tr>
<tr>
<td>c)</td>
<td>150°C Vacuum Stability Test</td>
<td>0.3 cc gas from 5 g pure AN in 40 hrs and 3.2 cc gas from FGAN</td>
</tr>
</tbody>
</table>
| d)   | Storage at 80°C | N content of pure AN decreased in 2 weeks from 33,3%
to 32.9%, but that of AN coated with 1% wax decreased in N content only from 32.7 to 32.6%

Note: According to Ref 122a, p 123, AN is a very stable material even at 150° as indicated by the Vacuum Stability Test at that temp. It can be heated at 100° for 100 days without appreciable decompn. This does not appear to begin until the compd melts. At 220° there are formed nitrous oxide, water and nitrogen, and this reaction is used for the manuf of nitrous oxide. If an organic material such as cellulose is present, decompn of the mixt begins at 100° and is pronounced at 120°. Admixture with TNT has little, if any, effect on the stability of AN at temps lower than 120°.

Toxicity. Not toxic (Ref 122a, p 123)

Trauzl Block Test Value. See under Power

Uses. AN is one of the most widely used components of explosives. The most important explosives contg high percentages of AN include amatols, ammonals, ammonites, dynamites, dynamosons, Favier type explosives, grisoumites, grisoutines, schneiderites etc. In addition, AN and mixts containing it have been used extensively as fertilizers.

For additional information on the uses of AN, see “Ammonium Nitrate Explosives and Propellants”, and also “Ammonium Nitrate Fertilizer”.

Note: According to Ref 128, AN has been used as an ingredient of mixtures for large bombs.

Vacuum Stability Test Values. See under Thermal Stability

Vapor Pressure. See Dissociation Pressure

Velocity of Detonation. See Detonation Rate

Volume of Gases of Explosion. See Gas Volume Developed on Decomposition or Detonation

Water Resistance and Prevention of Caking. AN and its expl mixts are hygroscopic and absorb moisture unless this tendency is prevented by coating the AN particles with a water-repellent agent. Gorsheid (Ref 47) studied the hygroscopicity and caking tendency of AN and its admixt with Amm sulfate. He reported that a moisture content in AN varying between 0.5 and 30–40% showed no difference in the absorption of water. Thick layers of nitrate absorbed but little moisture and if the nitrate was covered with a thin layer of sand, the absorption of moisture was reduced still further. The size of the lumps of nitrate was almost without effect. At 32° AN changes from one modification to another. Dry AN does not cake at this point, but if more than 0.1% of moisture is present, severe caking accompanies the transition. Drying the moist salt results in caking. Although methods of mixing and small variations in the relative amts of AN and Amm sulfate in a mixt of these compds did not affect their absorption of moisture, increase in the relative amt of Amm sulfate decreased the caking tendency. If a double salt was formed, the mixture caked about as much as AN alone, but when these were mechanical mixtures, the caking was less.

Snelling (Ref 14) suggested that the waterproofing of AN may be accomplished by allowing the crystals to fall through an atmosphere of nitronaphthalene vapor in such a manner that a water resistant coating is deposited. More recently Davidson and Rigby (Ref 97) proposed coating AN grains with a small amount of methylcellulose. Other coating materials such as clay, chalk, silica, alumina etc were used by Whetstone (Ref 103), but the best results were obtained by spraying AN crystals with “acid magenta”. Goodale (Ref 107) found that coating of AN with 0.1–5.0% of 2,2-dinitropropane combined with about 5–30% of a nonvolatile liquid rendered the AN less hygroscopic and less watersoluble. Le Roux (Ref 108) noted improvement in resistance to water of explosives containing AN coated with transformer oil, paraffin, naphthalene acids, Al or Ca naphthenate, rosin, natural resins, Ca resinate, abietic acid,
beeswax, polyvinyl acetate dissolved in liq DNT, silicone grease dissolved in trichloroethylene, MNT, tetrachloronaphthalene, starches, Na or Al alginate, kaolin or Al stearate (See also Explosifs N)

According to Lytle (Ref 111), the water resistance of AN used in explosive compositions may be improved by the addition of a solid hydrophilic urea-HCHO-type reaction product such as Uformite, Cascamite, Melmac and other resinous products such as gums and adhesives. Taylor (Ref 112) obtained water-resistant explosives containing AN coated with 0.4–15% of a gel-producing manogalactan such as guar flour, locust-bean gum or carob-bean gum. Improved resistance to water damage of coal-blasting explosives was achieved by Davidson and Rigby (Ref 116), who incorporated at the time of manufacture a small amount of a water-swellable and water-soluble ether of a polysaccharide such as methylcellulose. Nylander (Ref 121), in order to prevent formation of hard lumps on storage, treated AN with 0.01–5% of Na polymetaphosphate. For example, an aqueous soln satd at 160° with AN was granulated at 70° until the water content was reduced to 0.1% and during the final stages of the drying there was added 0.25% of Na hexametaphosphate.

Shneerson et al (Ref 126) recently determined the effects of cooling, moisture content, K nitrate content and compression up to 0.2 kg/cm² on the caking characteristics of AN. He concluded that caking occurred at the transition of forms III and IV into each other at 32.27°. Based on thermographic investigations of granulated AN, Alekseenko and Boldyrev (Ref 125) suggested rapid cooling and low moisture content as effective means for decreasing caking. Enoksson & Enoksson (Ref 122) decreased the tendency to lump formation in AN in incorporating 0.005 to 5% of an alkyl sulfate, alkyl sulfonate, alkylaryl sulfonate of alkyl phosphate. In the examples given, the following compounds were added either before or after crystallization of AN: (C₆H₅)₃NPO₄, iso-propylamine dodecylsulfate, RCHMeOSONa where R is an alkyl group having about 12 carbon atoms: C₄H₉OSONa, C₆H₅CH₂C₂H₄CH(SO₄Na)CH₂CH(CH₃)₃ and 3,4(NaOS)₃(MeO)C₆H₄NHOCC₆H₅S₅.

Addnl Refs:  
B) M.F. Lindsley, Jr, USP 2, 126, 401 (1938) & CA 32, 7728 (1938)  
C) R.McGill, OSRD Rept 830 (1942)  
E) Société Technique de Recherches et d'Exploitation, FrP 953, 420 (1949) & CA 45, 7314 (1951)  
F) National Research Council, "Compendium on the Hazards of Water Transportation and the Manufacture, Handling, Storage and Stowage of Ammonium Nitrate and Ammonium Nitrate Fertilizers," PB 119969 or NRC R 4702 (1953) (255 pp, diagrams, graphs & tables)  
G) Nitroglycerin Aktiebolaget, BritP 742, 636 (1955)  
H) N.W. Luft, Ind Chemist 31, 502 (1955) & CA 50, 5388 (1956)

Note: Comments on Plant Processes for manuf of AN (private communication, March 1960) from Dr. Ralph D. Miller, Tech Director Agricultural Chem Div, Spencer Chemical Co, Kansas City, Missouri:

Under Continuous Process of Graining. There is no continuous graining carried on at this time and certainly none in the United States for the preparation of fertilizer materials. There may be some used for the preparation of dynamite grade AN where they can prepare exceedingly fine particle size material. Actually, all of the large producers and all of the materials made for fertilizer are made either by the Stengel process or by prilling through towers.

For the prilling operation "high pans" have been completely eliminated and the AN solutions are evaporated to approximately 95% in vacuum evaporators. Exit the vacuum evaporators, the material is pumped to the top of the prilling tower dependent upon the size and design. The height may vary from 70 feet to 200 feet. The material is sprayed through nozzles or spray headers, and as it falls, some more of the water is evaporated. This leaves spherical particles called prills. These materials are dried further through various types of drying equipment, either counter or co-current flow with hot air and are then parted with diatomaceous earth or kaolin clay to prevent caking.

There is no wax or paraffin used today in modern FGAN nor has there been since 1948.

Under Continuous Vacuum Crystallization. This process is not used today, except for a small quantity which is manufactured by TVA. Here, the liquor is concentrated by vacuum crystallizers, and no "high pan" is used to concentrate the liquor prior to entering the crystallizer. All AN produced today in the neutralizers reaches about 80% to 85% concentration. Therefore, "high pans" are not necessary.

Under Preparation of Fertilizer Grade Ammonium Nitrate. This process has not been used for making ammonium nitrate fertilizer since 1948, as mentioned above.

Under Behavior Towards Metals and Other Substances. AN very definitely attacks shellac, baked oils and natural rubber compounds if applied as a coating. The only materials that we know of which can be used as coatings for AN and AN solutions are certain polyvinyl chloride coatings and a number of epoxy resins. The Ordnance Department used acid-proof black paint, shellac, baked oil and rubber paints. All were quite unsuccessful over long periods of time.
AMMONIUM NITRATE BLASTING EXPLOSIVES, HIGH EXPLOSIVES AND PROPELLANTS

As was mentioned above under the heading "Ammonium Nitrate Historical", the use of AN in expls began about 1867 when Norrbin & Ohlsson patented their expl called "Ammoniakrut'" (Refs 2,3). This expl consisted of AN in mixts with combustibles such as charcoal, sawdust, naphthalene, picric acid, NG or nitrobenzene. Nobel acquired the patent and soon introduced a new series of AN expls called "extra dynamites", examples of which were 71/4/2/23–NG/collodion cotton/charcoal/AN and 25/1/12/62-NG/collodion cotton/charcoal/AN (Refs 52 & 94). AN has steadily increased in importance in the expl industry, especially in the "permissibles" used in coal mining. One of the principle advantages of AN, besides its low cost, is its low temp of expln, which makes it suitable for use in gassy and dusty coal mines (Ref 16). The hygroscopicity of AN retarded to some extent its use in general expl mixts. During WW I AN found extensive application in military expls such as anatol, ammonal, sabulite etc. These expls are described under their individula names. Notwithstanding its hygroscopicity and tendency to pack, AN was recommended in Russia prior to WW II for use as a military expl (Ref 39).

AN Blasting Explosives allowed for use in American coal mines are called "permissibles", those in England "permitted", in France "explosifs antigrisouteux", in Belgium "explosifs S.G.P. (sécurité, grisou, poussière)" and in Germany "sichere Sprengstoffe" (Ref 94). According to Taylor and Rinkenbach (Ref 14), one of the early "permissibles" was the duPont Monobel, consisting of 80/10/10–AN/NG/combustible and other ingredients. Early British "permitted explosives" included Ammonite (88/12–AN/DNN), Westfalite (95/5–AN/resin), Bellite (83.5/16.5 and 93.5/6.5–AN/DNB) and others. French safety expls included "grisounaphthaliteroche" (91.5/8.5–AN/DNN), "grisoudynamite" (70/29/1–AN/NG/collodion cotton) and "grisoudynamitecouche" (87.5/12/0.5–AN/CC). Germany, Belgium and other countries developed many similar high-AN, non-NG safety expls (Ref 94).

Schmerber (Ref 5) examined mixts of organic ingredients with such proportions of AN as to give sufficient or excess oxygen for complete combustion. The calcd values for temp (t) developed on expln and also the specific gas pressure (f) were selected as characteristic of these mixts. It was observed that the (f) values for mixts contg excess 0 were proportional to the lead block expansion values in cc (Trauzl test). The approx calcd percentages of AN required to obtain maximum expln temps (t) of 1500° and 1900° (reqd in France for coal mining expls) are given in the table on the following page.

Assonov and Rossi (Ref 40) compared the Trauzl block values of Russian expls used in open mining, such as "ammonit No 2" and "dynamon K", having Trauzl values of 280 and 300 cc respectively, and concluded that it was cheaper to replace them with straight AN, which gave a Trauzl value of 225 cc. Abinder and Andreev (Ref 41) disagreed with the conclusion of Assonov and Rossi, and reported a loss of about 35% in expl energy when AN is used without combustibles. Satisfactory agreement between calcd and expit values for expl pressure was found for mixts of AN with TNT and with NG expls (Ref 35).

An AN expl, having no special name but which could be detonated, consisted of granulated AN (85 to 97%) coated with a small quantity of solid, nonexpl vulcanized oil (for example, the product obtained by treating cottonseed oil with sulfur chloride) and mixing with a sensitizing, detong substart such as
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Organic Ingredient | % AN for Complete Combustion | Calculated Values (t) | Approx % AN Req'd to Obtain t
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2122</td>
<td>8449</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>93.75</td>
<td>2107</td>
<td>8179</td>
</tr>
<tr>
<td>Carbon</td>
<td>93.02</td>
<td>2100</td>
<td>8497</td>
</tr>
<tr>
<td>Toluene</td>
<td>93.99</td>
<td>2171</td>
<td>8553</td>
</tr>
<tr>
<td>Nitronaphthalene</td>
<td>90.86</td>
<td>2174</td>
<td>8632</td>
</tr>
<tr>
<td>Nitrotoluene</td>
<td>90.05</td>
<td>2229</td>
<td>8650</td>
</tr>
<tr>
<td>Dinitronaphthalene</td>
<td>87.45</td>
<td>2244</td>
<td>8697</td>
</tr>
<tr>
<td>Dinitrotoluene</td>
<td>85.11</td>
<td>2298</td>
<td>8710</td>
</tr>
<tr>
<td>Trinitronaphthalene</td>
<td>83.39</td>
<td>2352</td>
<td>8833</td>
</tr>
<tr>
<td>Trinitrotoluene</td>
<td>78.10</td>
<td>2398</td>
<td>8979</td>
</tr>
<tr>
<td>Trinitroxylene</td>
<td>81.75</td>
<td>2507</td>
<td>9032</td>
</tr>
<tr>
<td>Picric Acid</td>
<td>69.42</td>
<td>3469</td>
<td>10084</td>
</tr>
<tr>
<td>Nitroglycerine</td>
<td>0</td>
<td>2561</td>
<td>9076</td>
</tr>
</tbody>
</table>

NS (Refs 11, 13). Snelling also patented (Ref 17) an expl constg of AN intimately mixed with sensitizers such as TNT, NS and other expls. Wyler (Ref 18) patented a detonable expl constg of AN (76 to 96%) and hexamethylenetetramine. To this there may be added one or several of the following: NS, NaNO₃, ZnO, hydrocarbons etc. Snelling and Wyler (Ref 22) proposed sensitizing AN by a coating of 1 to 6% of one of the following: aniline, toluidine, naphthylamine, anthramine, diphenylamine, dietylamine, phenylendiamine, tolylenediamine, benzidine, tolidine, phenylhydrazine, diphenylhydrazine, tolylhydrazine, phenylhydroxylamine, azobenzene or azoxybenzene. Champney (Ref 25) used crystd AN having a packing d of 0.5 to 0.8 g/cc, as detd under a pressure of 10 psi, mixed with various other ingredients such as NG, NaNO₃ and bagasse pitch. McFarland (Ref 63) sensitized AN by the addition of 6 to 8% NG. The presence of 6% water was considered advantageous in blasting, as it appeared to decrease the brisance without affecting the strength of the expl.

The popular duPont "Nitramon" blasting agents were invented in 1934 by Kirst et al (Ref 30). These expls contd AN as the principal ingredient with at least one sensitizer, such as DNT, paraffin or a mixt of fuels. The fineness and intimacy of contact of the constituents were so controlled that, at a d of 1.0 g/cc, the unconfined expl required a detong impulse greater than that from any common detonator. Kirst et al (Ref 32) also patented an expl of high blasting strength and relatively high density consisting of a mixt of coarse and fine particles of AN and a sensitizing agent such as NG, DNT, etc. Handforth and Johnson (Ref 33) developed a blasting expl of relatively low d, composed of AN having an apparent d less than 0.8 g/cc and a sensitizer such as NG. Hauff and Kirst (Ref 34) reported an expl suitable for blasting coal composed of AN with a puffed, porous texture and an apparent d less than 0.7 g/cc plus a sensitizer such as NG. The porous texture of the AN was obtained by subjecting the slightly moist salt to a special treatment under vacuum. During the past several years a number of additional expls of the "Nitramon" type have appeared. These included "Nitramon A", "Nitramex", "Vibronite B" and various trade name "Nitramon types" (Ref 94).

Many developments of AN coatings and dope additives have improved the resistance to water and moisture of high-AN, low-NG dynamites.
The more important coatings are the Ca stearate coating proposed by Baker (Ref 31) and the Cairns "PRP" (petrolatum, rosin, paraffin) coating (Ref 47). Winning (Ref 51) described the use of pregelatinized starch products such as rye flour, cereals, meals and similar starch additives [See also the AN/paraffin expls by Stettbacher (Ref 43)].

One problem in the use of AN/fuel mixts for commercial blasting has been the difficulty in detong such expls and insuring the propagation of deton in long columns having small diams. Stoops (Ref 23) reported improved sensitiveness of AN dynamites obtained by making use of the water of crystn of some metal nitrates and heat to yield a molten mixture contg AN, which then was absorbed by a suitable combustible. Spaeth (Ref 24) described another method, in which AN/urea mixts were heated to the mp and absorbed by dynamite pulps. Coatings of trimethylolethylmethane trinitrate were also used by Spaeth (Ref 27). Stettbacher (Ref 20) suggested the use of PETN and other explosives as additives, as did Lewis and Johnson (Ref 26), for increasing the sensitivity of dynamites. Cairns (Ref 36) increased the sensitivity to deton by coating crystals of AN with a soln of inorg nitrates such as Ca, Mg or Zn, and drying the mixts. Davis (Ref 38) disclosed an expl of improved sensitivity to deton and of decreased sensitivity to unintentional initiation, which could be prepd by dissolving AN in liq ammonia and dispersing in it finely divided sensitizers such as Al, sulfur, DNT, NS etc. After evaporating the NH₃, a product remains in which the sensitizer is distributed in a continuous phase. Davis (Ref 45) also developed an expl of good sensitivity to initiation prepd by treating 92 p of AN with a solid aromatic compd such as DNT, and a solid fuel such as diphenylamine or p-toluidine which is soluble in the nitrocompound. The Davis' ammonia process (Ref 38) yields soft and pliable mixts that propagate deton reliably in regular dynamite cartridges and even in charges having small diams. However, these AN/fuel mixts were not easily waterproofed without excessive loss of sensitiveness (Ref 94).

Cook et al (Ref 48) developed another type of expl based on the reaction of AN with Ca cyanamide to yield Ca nitrate and ammonia. An organic substance is added to act as a fuel. During mixing at an elevated temp such as 80°, the freed ammonia renders the mixt plastic and facilitates intimate mixing of the AN with the fuel and/or expl sensitizer. Upon cooling, the mixt remains plastic, and while in this condition may easily be packed at any desired density. A few hours after packing, the free NH₃ reacts with the Ca nitrate to form Ca nitrate-amine and the product 'sets' like concrete. Following are examples of mixts proposed by Cook:

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Density g/cc</th>
<th>Deton rate, m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>83/12/5-AN/DNT/Ca(NO₃)₂NH₃</td>
<td>1.30</td>
<td>3830</td>
</tr>
<tr>
<td>83/12/5-AN/DNT/Ca(NO₃)₂</td>
<td>-</td>
<td>1750</td>
</tr>
<tr>
<td>81.5/12/6.5-AN/DNT/Ba(NO₃)₂NH₃</td>
<td>1.30</td>
<td>3500</td>
</tr>
<tr>
<td>81.5/12/6.5-AN/DNT/Ba(NO₃)₂</td>
<td>-</td>
<td>2250</td>
</tr>
<tr>
<td>81.5/12/6.5-AN/DNT/Sr(NO₃)₂NH₃</td>
<td>1.27</td>
<td>3325</td>
</tr>
<tr>
<td>81.5/12/6.5-AN/DNT/Sr(NO₃)₂</td>
<td>-</td>
<td>1900</td>
</tr>
</tbody>
</table>

One formulation of Cook's expls was used with satisfactory results when pressed wafers, sealed in cans, were subjected to trials in shooting of oil wells (Ref 54).

Two high-AN 'permissibles' which had excellent safety properties for use in gassy and dusty coal mines and also nearly ideal blasting properties were developed by Wahl (Ref 44) and by Cook et al (Ref 46). These features were achieved by careful regulation of reaction rate, which was established by appropriate intimacy of mixing and by control of particle size of the product. Whitworth & Hornell (Ref 61) reported a low density blasting expl also suitable for use in gassy and dusty coal mines and particularly useful for obtaining lump coal. This expl compn consisted of a liq expl org nitrate (such as a nitrated 80/20 mixt of glycerol and glycol) 6–12%, an org expl sensitizer (such as NGu in needle like crystals) ca 10, a bulky, subdivided vegetable material (such as peat) ca 7, AN (or other inorg power producing salt) ca 57–59, resin ca 0.5, diammonium phosphate ca 0.5 and a salt (such as NaCl), which acts as a flame-coolant and retardant ca 11%.

The expl described had a bulk d 0.73–0.76 g/cc.
Taylor (Ref 72), in prep of low density AN expls used a special low d (bulk d < 0.99 at 1.77 atm) dendritic NaCl as the coolant. Such NaCl was prepd by rapidly adding KNO₃ to a boiling soln of equimol quantities of NaNO₃ & KCl satd with respect to the resulting NaCl. Using these NaCl crysts, the following expl compn was prepd by Taylor: AN (bulk d 0.71 at 1.7 atm) 55.5, NaNO₃ 10, mixt 80/20-NG/NGc 10, peat (bulk d 0.20 at 1.7 atm) 12, dendritic NaCl 12, diammonium phosphate 0.2 and rosin 0.3%.

Farr (Ref 66) in 1951 developed a dynamite compn having high d and a low vel of deton when confined. This consisted of AN (coarse and coated with 1% microcryst wax) 82, NG 5, NaNO₃ 5, corn flour 2, wood pulp 1.5, apricot pip pulp 4 and chalk 0.5%. The same investigator developed an improved AN dynamite (which could be detonated by a No 8 blasting cap) of the following compn: AN 85.4, TNT 2.5, liq DNT 1.5, granulated soft coal 6.1 and NaNO₃ 4.5%. Farr also suggested that improvement in AN/NG expls was achieved by the use of crystal AN contg from 4 to 11% KNO₃ distributed in solid soln throughout the AN crysts (Ref 67).

Semigelatin dynamites represented a significant advance in the development of high AN dynamites. These dynamites made use of colloid cotton, nitrobodies and waterproofing agents in the form of a gelatin to which was added balanced-dope materials (Ref 28). These products had excellent physical and expl props for small diam blasting. Whetstone & Taylor (Ref 62) patented an expl incorporating AN in a liq mixt with certain low-melting eutectics. For instance, a liquid mixt consisting of AN 50, urea 25, Na acetate trihydrate 15 and Na₂S₂O₃·5H₂O 10 parts, was gelled by boiling with 3% starch soln and into this 20 p of NG contg 1% NC was dispersed. The resulting product was a soft plastic expl having greater sensitivity than similar compds using dry AN. Hauff & Holmes (Ref 49) prepd a nonsetting expl by coating AN crysts with Zn tetrammino nitrate. Sakurai & Sato (Ref 73) measured, by means of a plastometer, the stress-strain relationship resulting from the addn of 20 to 80% of AN to NG gels. A plot of these data gave an "S"-shaped curve. The mechanical properties of these dynamites depended upon the amt of AN, its cryst form, density and surface props. Young's modulus became greater as the d of AN decreased.

Some more recent safety AN blasting expls have been described by Taylor & Reid (Ref 86), Davis et al (Ref 84), Rinkenbach & Carroll (Ref 89), Scalera & Bender (Ref 90) and Taylor (Ref 91). Taylor & Reid described an expl prepd by grinding together AN 53.1 & TNT 11.9 parts so that all the mixt passed through a 150 mesh Brit Std Sieve. To this was added 35 parts of AN, all of which passed a No 60 sieve and only 50% of which passed a No 120 sieve. The resulting expl compn had a vel of deton of 2400 m/sec and was sensitive to a No 3 commercial fulminate detonator (Ref 86). Davis et al (Ref 84) described a NG-free blasting compn contg: AN/NaNO₃ mixt 60, DNT/TNT mixt 10–30 and finely divided metallic fuel 0.5–10%. The nitrate mixt contained 30–80% AN which passed a 100 mesh sieve. The DNT/TNT mixt contd 1–50% DNT, but the DNT content was not to exceed 10% of the entire compn. The fuel was preferably ferrosilicon contg at least 40% Si. The resulting mixt was blended at 160°F and packed into 1–2" diam cartridges at 120–150°F to obtain a cold d of 1.3–1.5 g/cc. It could be initiated by a cap sensitive primer to give a rate of deton 3500–3900 m/sec and had approx the same blasting strength as an equiv length of tamped dynamite. The compn was less toxic, much less shock sensitive and formed more rigid cartridges than dynamite. Rinkenbach & Carroll (Ref 89) proposed a blasting expl consisting essentially of mixed crysts of AN, urea and a dry pulverized absorbent for liq thoroughly mixed with the said crysts. They patented also a cast expl of high d consisting of AN, urea and an expl sensitizer. Scalera & Bender (Ref 90) rendered AN blasting compns
water-resistant by incorporating ethylenic monomers which polymerize on contact with water. Taylor & Reid’s invention (Ref 91) was related to a safety AN blasting expl for use in dusty mines.

The properties of AN and the recommended practices for the use of AN in field-compounded expls have been described by Cooley (Ref 96). Parrott (Ref 97) described the use of AN blasting agents in strip-mine operations and Cook (Ref 98) has dealt with large diam bore holes using AN expls not contg NG. One of the cheapest types of AN blasting expls is prep in advance like the Lee and Akrel mixt of AN with 1–12% carbon black packed in polyethylene tubes, or they may be preped at the place of use (Ref 79). For instance, on the Mesabi Range, Minnesota, in blasting iron ore, good results were obtained using 9" diam bore holes and pouring into each hole one 80 lb bag of AN, followed by one gal of fuel oil. It was found that in large diam holes (5" or more), AN is capable of propagating deton if it is sufficiently fine grained and adequately boosted. It was also found that, for large diam holes, it is not necessary to prepare an intimate AN/fuel mixt to make available at least most of the high explosive potential of such mixts (Ref 94). In very recent developments, Crater et al (Ref 92) reported that a compn consisting of AN mixed with about 5% fuel oil gave satisfactory results when poured into large diam holes and strongly primed with dynamite to insure deton. The holes must be dry, as propagation of deton under unfavorable conditions is less satisfactory than when a nitro-carbon-nitrate mixt, such as 91/4/5-AN/DNT/carbonaceous material is used. Present trends in the use of high-AN/fuel mixts suggest that important new developments can be expected in future AN blasting expls.

AN High Explosives. As outlined above, AN is an important constituent of dynamites, but it is also a significant constituent of a number of other expls in which it is present in large proportions. These expls may be divided into two main types: a) expls in which a sensitizer, itself detonable, is used as a means of increasing the sensitivity to deton of AN and b) expls in which the material employed to sensitize AN is not detonable. In general, AN expls have low rates of deton (2000–
3500 m/sec) and high gas vols. Consequently, they have low shattering and good heaving or pushing effects. Their ballistic pendulum test values are 115–125% that of TNT. When used in quarries, it has been found that AN expls often show a shattering effect greater than expected on the basis of their low rates of deton, and this is ascribed to their large vols of gases having a disproportionate effect on shattering power. Although AN expls are rarely graded commercially in terms of strength percent, their strength may be as great as 65% dynamite, i.e., equivalent to a 65% straight NG dynamite on an equal weight basis.

AN Explosives Containing Detonable Sensitizers. There is no sharp line of division between AN dynamites and some other AN expls; the difference being mainly that AN expls are formulated with a lower percentage of NG or NS and therefore a higher percentage of AN. The presence of as little as 1% NG or NS in AN is sufficient to cause marked sensitization. Commercial AN expls are made by incorporating 3–10% NG or NS and 40–89% AN. The remaining component is usually a small amt of wood pulp or other carbonaceous material which would also be sensitized by NG. TNT, nitrotoluenes, naphthalene and other similar materials have been proposed for use as sensitizers, and some of them have actually been used, especially in foreign countries. However, in the US, NG and NS are the principle detonable sensitizers.

AN Explosives Containing Nondetonable Sensitizers. Many substances which are not in themselves expls greatly increase the sensitivity of AN when added to it. To these belong: powdered metals (such as flaked Al) and combustible org materials (such as rosin, many metallic resinates, hexamethylenetetramine, many org bases, and paraffin oils and waxes). Usually these AN expls are prep'd by coating granules of AN, either alone or mixed with NaCl, with a thin layer of sensitizer. If it is desired to make an expl of exceptional safety, there is employed an amt of sensitizer insufficient to make the expl capable of deton by the action of an ordinary blasting cap, but requiring either a US Corps of Engineers cap or a heavy booster charge such as TNT or amatol. A mixt of 92.5 AN, 4 DNT and 3.5% paraffin wax is representative of this type of expl. By controlling the d, bulk strength from less than 40 to 75% that of straight dynamite may be obtained. The vel of deton varies with the grade of AN and the diam of the charge, but it usually is between 3500 and 5000 m/sec. When properly initiated, the deton can be propagated across an air gap of 8–15 in. In order to exclude moisture, all AN expls must be packed in sealed metal containers. The simultaneous action of Zn, humidity and AN on nitrocompds such as TNT and TNX is apt to produce some dangerous products. As Al does not react under the same conditions, it is recommended for packing any mixt contg AN and nitrocompd expl (Ref 74).

In 1917 a patent was granted to Vereinigte Köln-Rottweiler Pulverfabriken (Ref 6) for a cast AN expl contg nitrocompds and "cell-pitch lye". One such compn cont'd at least 60 AN, less than 20 NaNO₃, less than 30 TNT and up to 10% "cell-pitch lye" (qv). The addn of "cell-pitch lye" lowers the mp considerably, aids in the mixing of the nitrates and nitrocompds, and prevents separation of the ingredients. Müller (Ref 12) proposed mixing molten AN, in an autoclave at a pressure of 0.5 to one atm, with hydrocarbons or hydrocarbon derivatives. Cook & Talbot (Ref 65) studied the sensitivity to explosion of AN/ hydrocarbon mixts. Manuelli & Bernardini (Ref 8) melted together AN and GuN (guanidine nitrate) or biguanidine nitrate, or AN and dicyandiamide with/without the addition of NGu, in such proportions that the product melted below 130°. To the above could be added oxidizing agents, either with or without oxidizable subs. Heating AN and dicyandiamide together produces salts of biguanide and guanidine according to the temp and duration of the process. An expl compn consisting of AN 25 and urea nitrate 75%,
to which may be added some NC and Al, also was reported (Ref 15). In another procedure AN was melted with a nitrate or nitrates of aliphatic mono- or polyamines and then cast (Ref 21). Morris (Ref 29) obtained a nongelatinous HE by agitating hot, pulverized AN with a molten or partly molten mixt of a nitrocompd, such as TNT or DNB, and PETN at a temp not exceeding 100°. Davis (Ref 42) described a plastic expl consisting of granular AN and molten TNT for loading into shell. Some promising low-melting AN expls were developed at Pic Arsn. It was found that mixts of AN with Na acetate or with urea and NaN₃ could be melted and cast at 103° (Ref 50). By the addn of Al to such mixts, expls were obtained having brisance and stability characteristics equal to TNT. However, when cast-loaded into 3" shell and detonated, the expl was of too low brisance for military use. Addn of Amm picrate to the basic ternary mixt resulted in an expl of satisfactory brisance; but upon storage at elevated temps, the expl exuded (See also Addnl Ref H on p A352)

In an effort to overcome the objection of exudation, two additional low-melting AN expls were developed at Pic Arsn (Ref 53). The most promising compns, designated as Ammonex I, J and M, had the following compents and properties:

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>I</th>
<th>J</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>42.0</td>
<td>32.5</td>
<td>36.0</td>
</tr>
<tr>
<td>Na nitrate</td>
<td>17.0</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Ca nitrate, anhyd</td>
<td>–</td>
<td>7.5</td>
<td>8.0</td>
</tr>
<tr>
<td>Dicyandiamide</td>
<td>5.5</td>
<td>5.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Guanidine nitrate (GuN)</td>
<td>5.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Expl D (Amm picrate)</td>
<td>30.0</td>
<td>50.0</td>
<td>45.0</td>
</tr>
<tr>
<td>Avg chge d, g/cc</td>
<td>1.35</td>
<td>1.66</td>
<td>1.61</td>
</tr>
<tr>
<td>Approx pour point, °C</td>
<td>97</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td>Av wt chge in 3&quot; shell, lbs</td>
<td>0.74</td>
<td>0.91</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Note: Compns, designated Ammonex K and L, were also developed with tetryl added in amounts equivalent to those of the Amm picrate used in the above mixts. These mixts were not superior to those contg Amm picrate when subjected to shell fragmentation tests.
process for the liquifaction of AN of mp 152° used in expl charges, by mixing AN with dicyandiamide (mp 205°) in the proportions 85/15 was described in 1917. The resulting mixt (fluid at 115°) was considered to be easier and less dangerous to use than AN alone (Ref 7). (See also Ref 70 for description of methods of prep of AN expls by Médard and LeRoux)

Some miscellaneous AN expls having no special names include the following: a) A mixt of AN 93.6 and charcoal 6.4% similar to "thorite" (qv) with the addition of a little Al was used in bombs during the Spanish Civil War. This mixt had low brisance but comparatively high power (see also Ref 68) b) Mixts of AN with trinitrophenoxyethanol, (O₂N)₃C₆H₄·O·C₂H₂OH (Ref 63) c) A stabilized AN/NG expl compn in which 4 to 12% of KNO₃ was distributed in solid soln throughout the AN crysts. The expl had stable rate of deton, small setting tendency and good thermal stability d) A 50/45.5/4.5 mixt of AN/RDX/beeswax that has the characteristics: OB to CO₂ 24%, power by Bal Mort 122% TNT, Qᵥ 209.3 kcal/mol, Qₑ 94.5 kcal/mol, calc temp of expln 4890°K and gas vol 43.2 mol/kg e) A 60/40 AN/methylamine nitrate mixt that has the characteristics: OB to CO₂ 1.6%, power 122% TNT, Qᵥ 108.0 kcal/mol, Qₑ 102.2 kcal/mol, calc temp of expln 3430°K and gas vol 43.7 mol/kg f) A mixt contg AN 60–40, RDX 15–20, TNT 0–10, hydrated potters clay 25 and water 2–6.25 (Ref 75) g) A mixt of AN 35–60, TNT 0–10, NC 0–0.5, carbohydrate 0.5–5, NaCl with seaweed 5–25, WM (wood meal) with starch 0–10 and water 5–15% (Ref 76) h) An expl compn prepd by blending mixt A 8.8–12.5% with mixt B 91.2–87.5%. The mixt A consisted of Na cellulose glycolate 0.8, glutinous millet powd 2.5, glutinous rice powd 2.5, nonglutinous rice powd 3.0, flour 3.5 and potato starch 4.5 parts to which 8% of water was added. The mixt B consisted of NG 22, NC 1, AN 62.2 and WM 2 parts (Ref 77) i) An expl prepd by mixing 918 g of AN, 80 g of TNN or TNT dissolved in concd nitric acid, followed by neutralization of acid by blowing ammonia into the mixt (Ref 78) j) A compn consisting of AN 78.5–83.5, hydrazine nitrate 5–10, TNT 7.5, Al dust 0.5, coal 3 and chalk 0.5%. The introduction of up to 10% of hydrazine nitrate in an AN expl markedly increases sensitivity and deton rate. AN and hydrazine nitrate are preferably mixed together prior to the addition of other ingredients, or they may be fused, solidified and subdivided prior to such addition (Ref 80) k) An expl obtained by neutralization of an acidic nitrated polyl such as NG by the addition of amines or amides such as urea, especially in the form of a melt with AN in a eutectic mixt. The expl is stable in storage, especially when the amine or amide is present in excess (Ref 87) l) An expl prepd by treatment which consists of neutralizing an acid-contg nitrated org prod, such as NG+nitroglycol or nitrosucrose, with a mixt or soln of AN (with or without other nitrates) in ammonia and/or org bases such as amines, amides and urea. The neutral mixt is then converted to a powerful expl by the addition of fuels, such as peat or wood flour and powd Al, and a gelatinizing agent such as NC (Ref 83) m) A cored AN expl cartridge having a granular base charge consisting of AN 88.5, TNT 7.5, coal dust 3, chalk dust 0.5 and Al powd (d 0.9–1.0) 0.5% is overlaid with a cast core of HE such as 40% RDX (100–200 mesh) in 60% TNT. The core diam may be varied so as to alter the strength from 60 to 90% of the same wt of NG and the deton rate is simultaneously varied between 4000 and 8000 m/sec (Ref 85) n) A Brit "non-permitted" expl contg 92 AN and 8% carbonaceous material (Ref 95)

It is known that expls contg AN possess the undesirable property of changing their vol if there are large variations in temp. If this expansion occurs in thin-walled ammunition components, considerable damage may result. This abnormal expansion is due to the fact that AN exists in five cryst modifications and great
changes in vol occur at the transition points. According to G. Romer (Ref 57), E. Janecke observed that if 5–10% KNO₃ is melted with 95–90% AN and the melt grained, mixed crystals are formed which do not possess any sharp transition points and undergo no abnormal expansion or contraction. It was also observed that, in mixts contg AN and PETN, if part of the PETN is replaced with "Tetra-Salt" (See Tetra-methylammonium Nitrate) the abnormal expansion of the expl is very much reduced (Ref 57).

**AN Propellants.** Propellants based on AN have had limited uses for military purposes, particularly in Germany and Austria, since 1885 when Gänß (Ref 1) patented a powd made from 35–38 AN, 40–45 KNO₃ and 14–22% charcoal. This compn came into use under the name "Amidpulver." An improved "Amidpulver" contained AN 37, KNO₃ 14 and charcoal 49%. It gave a flashless discharge and only a moderate amt of smoke when fired in a gun. Another propellant, first manufd in Austria in 1890 and used during WW I by the Austrians and Germans, was called "Ammonpulver." This compn incorporated 85 AN and 15% charcoal in addition to a small amt of an aromatic nitro compd. "Ammonpulver" was cheap, powerful, flashless, smokeless, and insensitive to shock and friction but it had the disadvantage of being difficult to ignite, as well as giving irregular ballistic effects and tended to disintegrate on storage under widely varying temp conditions. According to one report (Ref 55), the "Ammonpulver" used during WW I contained AN 50, NC (12% N) 22, DEGN 22, hydrocellulose 5 and Centralite 1% (Ref 52). (See also "Ammonpulver" in PATR 2510, p Ger 5).

Mayr (Ref 4) has discussed the advantages and disadvantages of using AN in gun propellants. DuPont (Ref 10) adopted a propellant for use in guns by using 92.5% AN imbedded in 7.5% of colloided NC

Roffey et al (Ref 56) formed a propellant by evapg a soln of AN, with small amts of KNO₃ or Mg(NO₃)₂ added, to dryness and grinding the resulting cake. Some AN propellants developed by the Aerojet Engrg Corp (Ref 58) include those shown on the following page. Taylor and Whetstone (Ref 59) prep'd a rocket propellant by melting together at 90° AN 67 and magnesium nitrate 10 parts and adding, just before casting, 8 parts of ammonium dichromate to yield a gas-producing mixt. In a paper reported in the 3rd Symposium on Combustion (Ref 64) Taylor and Sillitto described the use of AN as a solid to provide gas for propulsive purposes. A cast of a compressed mixt of AN with 3% or more of potassium dichromate reacts completely, when ignited, to give gaseous water, nitrogen and a mixture of oxides of nitrogen. Hannum (Ref 81) described a liq propellant consisting of AN or ammonium perchlorate dispersed in a poly-nitro aliphatic hydrocarbon such as nitromethane, nitroethane, 1-nitropropane, 2-nitropropane, 1,1-dinitropropane, 2,2-dinitropropane, 1,2-dinitropropane, 1,3-dinitropropane or mixts thereof. The Std Oil Co of Indiana also has contributed to the development of solid propellants based on AN (Ref 88).

AN propellants assume importance in the type of compn known as "composite propellants." These contain no NC or NG, and are uncolloided, heterogeneous mixts consisting of org fuel, inorg oxidizing agent and org binder. Such compns can be manufd by a simple mixing operation and then molded in the desired form by pressing. The development of improved binding agents less affected by extreme temps will expand the future usefulness of this type of propellant compn (Ref 82).

Some AN propellent compns developed in the USA since WW II are classified and cannot be described in this work.

The Table on next page lists some recently developed US AN propellants which are not classified.
<table>
<thead>
<tr>
<th>Composition, %</th>
<th>SP-42</th>
<th>SP-43</th>
<th>SP-45</th>
<th>SP-47</th>
<th>SP-49</th>
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<tbody>
<tr>
<td>AN</td>
<td>70.00</td>
<td>49.00</td>
<td>50.00</td>
<td>40.00</td>
<td>20.00</td>
</tr>
<tr>
<td>NH₄ClO₄</td>
<td>31.00</td>
<td>20.00</td>
<td>24.85</td>
<td>24.85</td>
<td></td>
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<tr>
<td>KClO₄</td>
<td>35.00</td>
<td>20.00</td>
<td>24.85</td>
<td>24.85</td>
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<tr>
<td>Paraplex P-10</td>
<td>29.83</td>
<td>19.90</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>t-Butyl hydrogen peroxide</td>
<td>0.17</td>
<td>0.10</td>
<td>0.20</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Composition, %</td>
<td>SP-51</td>
<td>SP-52</td>
<td>SP-54</td>
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<tr>
<td>AN</td>
<td>71.70</td>
<td>50.00</td>
<td>50.00</td>
<td>56.00</td>
<td></td>
</tr>
<tr>
<td>Nitromethane</td>
<td>23.00</td>
<td>23.00</td>
<td>23.00</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>Paraplex P-10</td>
<td>26.85</td>
<td>26.45</td>
<td>123.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t-Butyl hydrogen peroxide</td>
<td>0.15</td>
<td>-</td>
<td>0.50</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>cat KNR-neoprene cement</td>
<td>28.30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Dibenzoyl peroxide</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

References on Ammonium Nitrate Blasting Explosives, etc:
1) D.R. Günt, Ger P 37, 631(1885); Davis(1943), p 49
2) R. Escales, SS 1,456-7(1906)
3) O. Guttmann, SS 2,57(1907)
4) J. Mayr, SS 2,401-3(1907)
5) H. Schmerber, SS 12,128-32 & 151-5(1917); CA 12,426(1918)
6) V.K.R.P., Ger P 303,980(1917)
7) Dynamit AG, Ger P 305,567-8(1917) & JSCI 39,430A(1920)
8) C. Manuell & L. Bernardini, Brit P 138,371(1917) & CA 14,2086(1920)
9) P. G. Paris, USP 1,282,623(1918) & CA 13,188(1919)
10) F. L. Dunn, USP 1,341,207(1920) & CA 14,2265(1920)
11) W.O. Snelling, USP 1,343,063(1920); J.B. Bronstein & C. E. Waller, USP 1,345,077(1920) & CA 14,2420(1920)
12) E. Miller, Brit P 152,199(1920) & CA 15,756(1921)
13) W.O. Snelling, USP 1,395,775(1922) & CA 16,648(1922)
15) Société d'Explosifs et des Produits Chimiques, Fr P 585,671(1924)(not found in CA)
16) E. Audibert, Rev Ind Minérale 1925, 1-14 & CA 19,1198(1925)
17) W.O. Snelling, USP 1,617,192(1927) & CA 21,1013(1927)
18) J. Wyler, USP 1,720,459(1929) & CA 23,4344(1929)
19) F. Olsen & C. J. Bain, USP 1,752,391(1930) & CA 24,2606(1930)
20) A. Stettbacher, Swiss P 150,015(1930) & CA 26,4955(1932); USP 1,867,287(1932) & CA 26,4720(1932); NC 4,166(1933)
21) Dynamit A-G, Brit P 384,966(1932) & CA 27,5981(1933); Fr P 742,312(1933) & CA 27,3612(1933); P. Naoum & R. von Sommerfeld u Falkenhayn, USP 1,968,158(1934) & CA 28,5986(1934)
22) W.O. Snelling & J. Wyler, USP 1,827,675(1932) & CA 26,601(1932)
23) B. L. Stoops, USP 1,908,569(1933) & CA 27,3823(1933)
24) C. P. Spaeth, USP 1,924,910(1934) & CA 28,2538(1934)
25) H. Champney, USP 1,924,912(1933) & CA 27,5542(1933)
26) H. A. Lewis & N. G. Johnson, USP 1,922,938(1934) & CA 28,7018(1934)
27) C. P. Spaeth, USP 1,932,050(1934) & CA 28,646(1934)
28) Can P 340,401(1934) & CA 28,5906(1934)
29) W. E. Kirst et al, USP 1,992,216 & -17 CA 29,2744(1935)
30) S. G. Baker, Jr, USP 2,048,050(1936) & CA 30,6200(1936)
31) W. E. Kirst et al, USP 2,069,612(1937) & CA 31,2010(1937)
32) W. E. Kirst et al, USP 2,069,612(1937) & CA 31,2010(1937)
33) S. L. Hanford & N. G. Johnson, USP 2,087,285(1937) & CA 31,6466(1937)
34) T. W. Hauff & W. E. Kirst, USP 2,125,161(1938) & CA 32,7728(1938)
35) H. Muraour & G. Aunis, MP 28,182-203(1938) & CA 33,8406(1939)
36) R. W. Cairns, USP 2,130,712(1938) & CA 32,9504(1938)
Addnl Refs: A) Societé Roth (Germany), FrP 303, 427(1900) & 353, 864(1905); CA 1, 1343 (1907) (An expl suitable for loading shells contained: AN 45, DNT or TNT 19.5, Al 22.0, BkPdr 4.5, PbO 1.0 sulfur 2.5 & KNO3 with charcoal 5.5%) B) A. Haller, Bull Soc Encour-IndNar 119, 761(1920) & CA 15, 1401(1921) (Expls consisting of AN coated with paraffin were used by the French during WWI as bursting chges in airplane bombs, trench mortar projectiles and hand grenades) C) T. J. R. Alexander, BritP 297, 375(1927) & CA 23, 2827(1929) (A very intimate mixt suitable for use in expls can be obtained by heating to 140° equimol quantities of a concd soin of AN and Na perchlorate, followed by crys- tallization) D) Pepin Lehalleur(1935), 352-3 lists several AN expls manufdd betw WWI & WWII by the Pouderies de l'Etat(France) and supplied to industry for cartridges. These expls were known under the general name Explosifs de Favier and included the following: a) Grisou-naphthalite couche AN 95 & TNT 5% b) Grisou-naphthalite salpêtrée AN 90, K nitrate 5 & TNT 5% c) Grisou-naphthalite roche AN 91.5 & DNN 8.5% d) Grisou-naphthalite roche salpêtrée AN 86.5, K nitrate 5 & DNN 8.5% e) Poudre Favier pour mines non-grisouteuses AN 87.5 & DNN 12.5% f) Grisou-tetrylite couche AN 88, K nitrate 5 & tetryl 7% g) Poudre de mine C 1b AN 78 & Amm trinitrocresylate 22% E) A. G. White, USP 2,128, 576(1938) & CA 32, 8782(1938) (Blasting expls consisting of AN mixed with a faster burning substance such as black powder) F) Wm. E. Kirst, USP 2,145, 399 (1939) & CA 33, 3590(1939) (Expl, consisting of AN mixed with an org sensitizer such as DNT which is normally solid but fusible) G) E. I. du Pont de Nemours & Co, BritP 531, 562 (1941) & CA 35, 8299(1941) [Blasting expls consisting of AN sensitized with inorganic sensitizers (such as Al, Mg, Sb, Zr, ferro- silicon, Ca silicide, S etc) or organic sensi- tizers (such as DPHA, hexamethylenetetramine, acid amides, nitrocompds, alcs, nitrates, sugars, etc). These substances are dis- 

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A. J. Phillips, PATR 1106(1941) [A number of commercial AN expls tested at PicArsn, have been found to have satisfactory brisance values, but they were unsuitable for general military use because they could not be cast or extruded, but only compressed. When compressed to obtain suitable high density, they were found to be relatively insensitive to detonation. An effort had been made to de- 

velop AN expls which were highly brisant and castable. Two promising expls were de- 

veloped: No 1 which contd AN 80.1 Na acetate 9.9 & Al 10.0% and No 2 which contd AN 60.5, Na nitrate 18.0, Al 11.0 & urea 10.5%. Both compns could be cast-loaded at ca 103° but the cast material was more difficult to initiate than the pressed material, especially at low d. Compn No 2 was easier to initiate and it was of excellent stability. The sand test value of pressed material initiated with a No 8 elec detonator was almost equal to TNT, but the cast material gave lower results. The cast Compn No 2 fragmentation test value, listed in PATR 1234 was not as satisfactory as expected and new expls, known as Amatexes were developed (See Ref 53) H) CondChemDict (1942), p 287 lists the following expl compns AN 80, NG 10, K chlorate 5 & coal tar 5% J) E. I. du Pont de Nemours & Co, BritP 535, 137(1941) & CA 36, 1496 (1942) (Coal blasting expl consisting of AN, a solid capable of functioning as both a deto- nation sensitizing agent and a binder and a liq medium capable of softening superficially the particles of binder) K) J. Barab, USP 2,280, 360(1942) & CA 36, 3650(1942) [A low d expl mixt detonable by a No 6 or No 8 cap is prepd by intimately mixing very finely divided AN and combustibles (such as coal, rosin, Al & TNT), compressing the mixt thus formed and crushing the resulting mass into a pdr, detonable by a No 6 or No 8 cap] L) A. J. Phillips, PATR 1302(1943) (Study of corrosive action AN expls, such as amatols on Cu in presence of moisture. In the first stage of reactions are formed basic Cu nitrates and ammonia and these readily combine giving tetrammine copper nitrate, which is expl)
Société Suisse des Explosifs, Swiss P 228,940(1943) & CA 43 2437(1949) (An expl mixt consisting of AN 70, PETN 10, TNT 10 & NaNH₄PO₄•4H₂O 10%. The phosphate is incorporated in order to lower the mp of the mixt and to give it higher stability) O.A.H. Blatt, OSRD Rept 2014(1944) lists the following mixts suitable for military purposes:
a)AN 55 & ethylenediamine nitrate 45%; casting temp 105° and power by Trauzl test 126% PA
b)AN 50 & ethylenediamine nitrate 50%; mp 102.5°, d 1.6333 at 25°; impact sensitivity—requires fall height 161% that of TNT; decomp with evoln of brn fumes at 278°
c)AN 60, ethylenediaminedinitrate 20 & TNT 20%; the components were mixed dry and then molded at 108°; power by ballistic mortar is 135% TNT, impact sensitivity—requires fall height 170% that of TNT; decomp with evoln of brn fumes at 260°
d)AN 60 & methylamine nitrate 40%; can be cast at 58°; power by Trauzl test 121% PA O)OpNav Rept 30-3M(1945), p 27, PBL Rept 53045(1945) and PB Rept 50394 (1946) list the following AN expls used by the Japanese during WWII; Ammonarü Abeneyaku (Shobenyaku), Angayaku, "E" Explosive, Shoanbakuyaku, Shoanayaku, Shooyaku, Shotoyaku, Torpex-Type Explosives, Type 4(Mk2K₉), Type 4(Mk3), Type 4(Mk5K₉) and Type 88 Explosives. These comps are listed in this work in alphabetical order corresponding to their given names X)A.Stettbacher, Switzerland listed in private communication, 10 March 1954, the following AN expls as currently manufd in Belgium: Alkalite, Alsilite, Centralite TA, Cooppalite Dynamite III, Flammivore, Fractorite, Matagnite, Nitrocooppalite, Sabulite, Sécurite C and Sécurite G. Their compositions are given in this work in alphabetical order corresponding to their given names
P)PB Rept 1154(1945) & All & EnExpls(1946), p 134 list an AN expl used during WWII by the Italians for press-loading some 47 mm AP shell. Its compn was AN 73.4-75.0, RDX 22.0 & Wax 5.0-6.6. R)T.Watanabe, JapP 176, 113(1948) & CA 45, 4930(1951) (A blasting expl consisting of AN 71.7 NG 8.0, CC 0.3 & pulverized seaweeds 20.0%) S)Belgrano (1952), pp 33-6 & 45 lists many Italian AN expls, for example: a)AN 75, K perchlorate 10, DNN 10, Ca silicide 4 & wood flour 1% b)AN 69, K perchlorate 8, TNT 20 & Al 3% c)AN 82, DNN 9, TNT 3, cellulose 2 & Mn dioxide 4% d)AN 76, K perchlorate 8, TNT 12, sawdust 2 & Al 2% e)AN 68, K perchlorate 10, TNT 12, Ca silicide 8 & sawdust 2% f)AN 79.5, TNT 10, Ca silicide 8 & wood flour 2.5%
**Deton Impact-Friction Pendulum**

<table>
<thead>
<tr>
<th>Explosive</th>
<th>Charge Density, g/cc</th>
<th>Cook-Off Temp (ave)</th>
<th>Deton Velocity, m/sec</th>
<th>Wax-Gap, inches</th>
<th>Drop Height, feet</th>
<th>Number Exploded to Total Samples</th>
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</thead>
<tbody>
<tr>
<td>N-IV Prill with 6% Fuel oil</td>
<td>0.90</td>
<td>270</td>
<td>2,490</td>
<td>0</td>
<td>3½</td>
<td>0/5</td>
</tr>
<tr>
<td>Ditto, coated with 3% diatomaceous earth</td>
<td>0.90</td>
<td>270</td>
<td>2,670</td>
<td>0</td>
<td>3½</td>
<td>0/5</td>
</tr>
<tr>
<td>N-IV Prill without oil</td>
<td>0.86</td>
<td>292</td>
<td>No detonation</td>
<td></td>
<td>3½</td>
<td>0/10</td>
</tr>
<tr>
<td>Nitramite</td>
<td>–</td>
<td>255</td>
<td>–</td>
<td></td>
<td>3½</td>
<td>2/4</td>
</tr>
<tr>
<td>Nitramon</td>
<td>–</td>
<td>239</td>
<td>–</td>
<td></td>
<td>3½</td>
<td>3/6</td>
</tr>
<tr>
<td>40% gelatin extra dynamite</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td></td>
<td>½</td>
<td>42/42</td>
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<tr>
<td>TNT</td>
<td>–</td>
<td>240 &amp; 260</td>
<td>–</td>
<td></td>
<td>1</td>
<td>16/30</td>
</tr>
<tr>
<td>Explosive &quot;D&quot;</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td></td>
<td>2½</td>
<td>7/20</td>
</tr>
</tbody>
</table>

**Notes:**

a) "Cook-Off" Temperature is the temp at which the material decomp by heat and this provides a measure of its thermal sensitivity. In the test conducted at the Spencer Chem Co, a sample was placed in steel (or aluminum) cylindrical oven, 2 1/2" long and 3/4" ID and sealed with a threaded plug. The oven was wrapped with nichrome resistance wire and insulating asbestos. Elec energy supplied to the resistance wire raised the temp of the oven at the rate of 13 to 15° per min and was measured by a thermocouple and galvanometer. The point at which the material decompd was noted by a sharp rise in temp (caused by the energy release on decomp) and usually an audible reaction.

b) Detonation Velocity was detd with the apparatus using the Beckman-Whitley High-Speed Framing-Camera. This test was conducted in conjunction with the "Wax-Gap" test.

c) Wax-Gap Test. In this test a Shelby steel seamless tube (2" ID, 36" long and 0.120" wall thickness) was closed at the bottom with paper tape and charged to near the top with the test expl. Acrawax plugs of the same diam as the tube and of varying thicknesses may be placed on top of the charge. Two elec wires (connected to the deton velocity app) were inserted in the charge, one near the middle of the tube, marked "Start", and the other near the bottom of the tube marked "Stop". The charge was detonated by a No 6 elec blasting cap and pentolite booster (cylinder 2 x 8", weighing 675 g), placed on top of the Acrawax. If no deton took place with, say a 4" wax thickness, the test was repeated with a thinner wax and so on until a complete deton of charge was produced. When no deton was produced with any thicknesses of wax and only without wax, the gap was marked as 0. Those expls that were deton through longer wax-gaps were considered more sensitive.

d) Impact-Friction Pendulum used by the Spencer Chemical Co consists essentially of a hammer with a 9-ft handle and a 400-lb head. The hammer delivers energy to an expl sample by falling a specified distance before striking the sample. Variations in energy delivered are achieved by adjusting the height from which the hammer is released. The hammer is drawn to this height in an arc, by an electric winch and released from a distance by a lanyard connected to a trigger.
AMMONIUM NITRATE DYNAMITE (AND) OR AMMONIA DYNAMITE (AMMONYDYNAMIT, IN GER)

A type of "straight" (powdery) dynamite in which up to 50% of liq nitric ester (NG or NG + antifreeze additives) is replaced by AN and the remaining nitric ester acts as a sensitizer for the insensitive AN. These expls, which originated in the USA about 50 years ago, are notable for their heaving rather than shattering effect and their strength is lower than that of "straight" dynamites. AND's have been used for blasting soft rocks, clays and for earth excavations. They are not suitable, however, for use in coal mining except "strip-mining", called "open-cast mining" by the British.

The included table gives compns of typical American AND's:

**AMERICAN AMMONIUM NITRATE DYNAMITES (AMER AND's)**

<table>
<thead>
<tr>
<th>Composition(%) and some properties</th>
<th>American</th>
<th>American &quot;Ordinary&quot;</th>
<th>American Low-Freezing</th>
<th>Monobel (permissible USA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NG</td>
<td>9.50</td>
<td>9.50</td>
<td>12.0</td>
<td>16.5</td>
</tr>
<tr>
<td>NGc, NSug etc</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ammon nitrate</td>
<td>79.45</td>
<td>69.25</td>
<td>11.8</td>
<td>25.1</td>
</tr>
<tr>
<td>Na nitrate</td>
<td>-</td>
<td>10.20</td>
<td>57.3</td>
<td>46.2</td>
</tr>
<tr>
<td>Carbonaceous fuel</td>
<td>9.75(a)</td>
<td>9.65(a)</td>
<td>10.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Sulfur</td>
<td>-</td>
<td>-</td>
<td>6.7</td>
<td>5.4</td>
</tr>
<tr>
<td>Anti-acid</td>
<td>0.40</td>
<td>0.50</td>
<td>1.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.90</td>
<td>0.90</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Density, g/cc</td>
<td>-</td>
<td>-</td>
<td>1.30</td>
<td>1.31</td>
</tr>
<tr>
<td>Rate of deton, m/sec</td>
<td>-</td>
<td>-</td>
<td>2700</td>
<td>3300</td>
</tr>
<tr>
<td>Ballistic pendulum, % TNT</td>
<td>-</td>
<td>-</td>
<td>89</td>
<td>91</td>
</tr>
<tr>
<td>Lead block expansion, cc per/ g sample</td>
<td>-</td>
<td>-</td>
<td>19.9</td>
<td>27.5</td>
</tr>
</tbody>
</table>

(a) The carbonaceous combustible material (such as wood pulp and flour) contained 0.40% of grease or oil which was added to AN to counteract its hygroscopicity

(b) The carbonaceous combustible material of these Amer dynamites was mixed with some sulfur

AND's were also used in some European countries and compn and props of some of these AND's are given in the tables shown on top of the next page.

Some AND's were used for military purposes, such as demolition, excavation and cratering work.

DuPont Co, Wilmington, Del has been manufg several brands of ammonia dynamites, such as "DuPont Extra", "Red Cross Extra", "Red Cross Blasting FR" etc. Some of their props are given in Ref 8, but their compn seems to be a trade secret.

According to Stettbacher (Ref 7), the Ger AN expls contg more than 4% of NG were not considered as safe for use in coal mines. The name "Ammonsalpetersprengstoffe" was applied only to AN expls contg not more than 4% NG.
### EUROPEAN AND's

<table>
<thead>
<tr>
<th>Designation of AND</th>
<th>Composition, %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amm nitrate</td>
<td>Na nitrate</td>
</tr>
<tr>
<td>French 1</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>French 2</td>
<td>20</td>
<td>75</td>
</tr>
<tr>
<td>French 3</td>
<td>22</td>
<td>75</td>
</tr>
<tr>
<td>NG powder (Brit)</td>
<td>10</td>
<td>80</td>
</tr>
</tbody>
</table>

### EUROPEAN AND's

<table>
<thead>
<tr>
<th>Designation</th>
<th>Density, g/cc</th>
<th>OB to CO₂, %</th>
<th>Pb block expansion, cc/10 g</th>
<th>Pb block crushing, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>French 1</td>
<td>1.38</td>
<td>+0.75</td>
<td>400</td>
<td>22.0</td>
</tr>
<tr>
<td>French 2</td>
<td>1.20</td>
<td>+9.7</td>
<td>335</td>
<td>15.5</td>
</tr>
<tr>
<td>French 3</td>
<td>1.33</td>
<td>+7.8</td>
<td>330</td>
<td>16.0</td>
</tr>
<tr>
<td>NG powder (Brit)</td>
<td>1.0</td>
<td>–</td>
<td>Power: 78% of blasting gelatin</td>
<td></td>
</tr>
</tbody>
</table>

These expls were also called "Sicherheits-sprengstoffe". [See also pp 6 and 177 in PATR 2510 (1958)]

AMMONIUM NITRATE EXPLOSIONS
FIRES AND HAZARDS

Glauber, who first prepd AN in 1659, identified the compd as "Nitrum Flammens", because it evolved luminous gas when heated but did not explode. In 1835 Turner (Ref 1) stated that when AN is exposed to fire it liquifies, emits aq vapor and detonates. However, Berzelius reported that when AN is heated to about 300° (572°F) or dropped into a glowing hot crucible, it burns with a weak hissing noise and a yellow flame (Ref 2). About the same time Gmelin (Ref 3) also observed that if AN is thrown on a red-hot porcelain plate, it burns with a pale yellow light, produces a very slight noise and gives off H₂O, nitrous acid and nitrogen.

According to Munroe, AN explodes when thrown on red-hot charcoal (Ref 15); with pure AN, explosion does not occur (Ref 80).

The value of AN as an explosive was recognized in 1867 when Ohlsson and Norrbin patented a mixt of it with organic fuels such as charcoal, sawdust, naphthalene, nitrobenzene etc (Ref 49). These mixts were difficult to detonate until Nobel added NG to them. When unconfined, such mixts, called "extra dynamites" could be burned without detonation if spread in a thin layer or if the end of the cartridge were ignited.

In 1883 Berthelot listed AN as an explosive and showed that one g-mol of AN liberated 10.3 kcal of heat when undergoing incomplete decompn and 30.7 kcal when completely confined (Refs 4, 6). According to Berthelot, the probable equation of detonation is: 2NH₄NO₃ = 2N₂ + 4H₂O + O₂, because this reaction developed the highest temp. Brunswig (Ref 7) stated that the above reaction occurred as the result of sudden heating of AN to a very high temp under great pressure, and actually can be effected only with the aid of a strong detonator. The reaction: 2NH₄NO₃ = 2NO + N₂ + 4H₂O occurred as the result of insufficient initial impulse, as with a weak detonator.

In 1921 Krase et al (Ref 8) reported that the decompn of AN proceeds at an appreciable rate at 210° and is accompanied by the evolution of heat in accordance with the equation: NH₄NO₃ = N₂ + 2H₂O + 0.5O₂ + 29.5 kcal. The exothermicity of this equation accounts for the explosive properties of AN. Rosendahl in the same year (Ref 9) stated that when AN was heated above its melting point, decompn into H₂O and N₂O was greatest at about 200°. This decompn was local and did not result in deton, but if AN were subjected suddenly to a high temp such as is obtainable only with other expls, it can be exploded. The decompn of AN by heat was studied also by Saunders (Ref 18), who observed that at some temp near 300° the decompn proceeds explosively. Födransperg (Ref 13) stated in 1922 that even when large masses are ignited, AN burns quietly without expln. Although Kast (Ref 31) found that when AN was heated above 300° there resulted an evolution of heat at an accelerated rate followed by expl decompn, the work at Neubabelsberg (Rev 32) showed that AN could not be detonated when subjected to the heat of thermite or wood fires. The findings of Kaiser (Ref 40), who studied the explosiveness of molten AN, showed the following reaction to take place at 200 to 260°: 4NH₄NO₃ = 2NH₃ + 3NO₂ + NO + N₂ + 5H₂O and although this reaction is endothermic, Kaiser showed that the gaseous products could explode. In general, the findings of Kaiser were in agreement with independent studies made by Shah and Oza (Ref 36) and Kretzschmar (Ref 38), who also studied the thermal decompn of AN. In 1936 Torsuev (Ref 41) accepted the point of view that any deton of AN which is caused by thermal decompn results from the explosive decompn of the N₂O formed at the beginning of the reaction. Abinder (Ref 42) in the same year found that no expln resulted when samples of 53 and 1110 lbs of AN (loose and packed in bags, barrels or boxes) were burned in an open flame. The temp of combustion was found to be below 800° (See Note, p A363).
Although Parisot (Ref 46) in 1939 summarized the findings of other workers as establishing that AN cannot be detonated by either direct heating or heating in an open vessel, Nuckolls (Ref 48) stated that AN can be exploded at high temp under certain conditions, but that this was not accomplished readily. In 1945 Davis (Ref 51) observed that under favorable conditions of pressure, rapid heating and retention of heat, AN may be exploded when heated to approx 300°. Davis and Hardesty (Ref 52) also emphasized the fire hazard of AN, but referred to the expln hazard only obliquely. Summarizing the foregoing, it must be admitted that the literature, up to this time, was confusing and to some extent contradictory with respect to the fire and expln hazards of AN. Fortunately, more recent studies of the mechanism of expln of AN have been made by Delsemme (Ref 68), and kinetic studies relative to its rates of explosive decompn and hazardous behavior have been made by Henkin & McGill (Ref 71), Hainer (Ref 77) and Burns et al (Ref 74).

Between 1896 and 1948 there occurred about eighteen fires, serious explosions and disasters in which AN was involved (Ref 61). Of these, five were fires only and thirteen involved accidental explosions of various degrees of severity. A list of these incidents, together with a resume of the conditions, and a complete bibliography of the fire and explosion hazards of AN have been reported by Scott and Grant (Ref 61). Other reports on the fire and explosion hazards of AN have been made by Sherrick (Ref 21), Munroe (Ref 25), Nuckolls (Ref 48), Davis (Ref 51) and Whetstone & Holmes (Ref 53).

A disastrous expln of 1,000,000 lbs of AN occurred during crystn in October, 1918 at the Morgan Plant of the T. A. Gillespie Co in New Jersey. Other explosions at the Oakdale and Repauno plants had occurred in 1916 during the evapn process. These explns were attributed to the presence of organic impurities. However, a fire occurred on board the SS 'Halfried' at Brooklyn on Apr 14, 1920 in which about half of over 4,000,000 lbs of AN was consumed without expln (Ref 62). On July 26, 1921 two carloads of 99.3% pure AN exploded at the AG Lignose factory in Germany while being loaded and presumably being broken up by blasting (Ref 14). The most disastrous expln involving AN that has occurred to date was at Oppau, Germany on Sept 21, 1921, when 9,000,000 lbs of a mixt of AN & (NH₄)₂SO₄ detonated, killing more than 1,000 people and leaving a crater 250 ft in diam and 50 ft deep (Refs 10, 11,16, 18). The Oppau explosion aroused the world to a new awareness of the explosibility of AN, since (NH₄)₂SO₄ is not an explosive. Although the exact cause was never determined, it was suspected that blasting of the caked material into lumps was the cause although thousands of similar blasting operations had been carried out before. The mixt of salts had been assumed to be insensitive to detonation, but many subsequent investigations showed that a mixture of equal parts of AN & (NH₄)₂SO₄ can detonate with a velocity as high as 1400 m/s (Refs 26, 44, 73), and that sensitivity of the nitrate to detonation increases with an increase in temp (Refs 27, 29). It has been shown also that the effect of an increase in density of AN varied with the degree of confinement (Refs 21, 22).

Kast (Ref 30) studied the sensitiveness to impact and heat of AN, AN/salt mixts and AN/combustibles mixts. He reported in 1926 that the presence of up to 30% of (NH₄)₂SO₄ has practically no effect on the explosibility of AN, and that sensitiveness to impact as well as to heat increases with increasing amounts of KMnO₄ in AN mixts. Naoum and Aufschläger (Ref 26) had found in 1924 that mixts of AN with (NH₄)₂SO₄ were explosive, but with increasing amts of sulfate deton became more difficult. An intimate mixt of equal parts of dry, powd nitrate and sulfate were detonated by an extremely strong impulse only. Torsuev (Ref 41) in
agreement with Kast, observed that addition of \((\text{NH}_4)_2\text{SO}_4\) rendered AN less sensitive and dangerous. Blinov (Rev 44) criticized the results of Torsuev and showed that it is possible to ignite nitrate-sulfate mixtures with a Bickford fuse; and he detonated them, as had Naoum and Aufschläger previously, when the ingredients were pulverized and thoroughly mixed. The effects of the following other inert and inorganic additives on AN have been reported: KCl (Refs 19, 30), acids (Refs 39, 76), \(\text{H}_2\text{O}\) (Ref 68), \(\text{H}_2\text{O} \& \text{Fe}\) (Ref 42), Fe, Cu, Al, brass, Zn, & stainless steel (Ref 63), \(\text{K MnO}_4\) or \(\text{K}_2\text{Cr}_2\text{O}_7\) (Ref 45), inorg coating (Ref 70) and chalk (Ref 72).

Stengel and Broadhacker (Ref 75) proposed preventing phys disintegration of AN, produced from \(\text{NH}_3\) and \(\text{HNO}_3\), by adding to the \(\text{HNO}_3\) used sufficient \(\text{H}_2\text{SO}_4\) to yield a product contg 0.25–5.0\% \((\text{NH}_4\text{SO}_4\). The sulfate may also be mixed directly with the molten AN after its formation. Comparative tests made by alternately heating and cooling 10 g samples between 22 and 55° showed that 80 to 100\% of pure AN disintegrated into particles having less than \(\frac{1}{3}\) the size of those originally present; but samples containing 2\% \((\text{NH}_4\text{SO}_4\) showed no disintegration.

Later incidents of fire or expln involving AN were the burning of two carloads of this material in transportation from Muscle Shoals, Alabama (Ref 28). Bashford (Ref 23) described an explosion at Nixon, NJ and attributed it to traces of TNT found in the AN. Shreve (Ref 35) described an explosion that took place during the graining of AN at a plant of the Ammonite Co, but no explanation of the cause was given. Fire and expln at Roseburg, Oregon is described in Ref 79.

At Brest, France, a shipload of 6,600,000 lbs of AN exploded on July 28, 1947, killing 21 persons, injuring 100 others and doing major damage for a distance of three miles (Refs 61 & 78). Another cargo of AN fertilizer (FGAN) (2280 tons) on the SS Grandcamp at Texas City, Texas, detonated on Apr 16, 1947 and set off a series of fires and explosions that led to the deton (16 hours later) of 960 tons of FGAN on the SS High Flyer berthed 600 ft from the Grandcamp (Refs 59, 64, 66). These explosions took the lives of over 600 persons, injured 300 others and caused property damage of over $58,000,000. US Bureau of Mines personnel reached the scene some 12 hours after the initial expln, investigated the disaster and prepared a detailed description of the event. Suggestions were given for prevention of such accidents in the future (Ref 64). Investigations of different phases of this disaster were made at Picatinny Arsenal, the US Bureau of Standards, the Bureau of Explosives of the Amer Assoc Railroads and the National Board of Fire Underwriters. Detailed accounts of these investigations are given in a number of reports (Refs 54, 55, 56, 59, 62, 66). It has been accepted generally that the fire on board the SS Grandcamp had its origin in the careless handling of lighted cigarettes on the part of stevedores engaged in loading the cargo, and that other possible origins were highly improbable. The paper bags containing the FGAN were not marked to indicate the hazardous nature of the material, the stevedores handling it lacked knowledge of the danger in the presence of fire and the captain of the ship did not enforce the regulations against smoking in the hold of the ship. In May, 1947 the Secy of the Treasury appointed an interagency committee to develop additional information relative to the hazards involved in the transportation, handling and storage of AN and recommend a national safety policy in this connection. In 1947, the interagency committee issued two of three parts of its report (Refs 57, 58).

Irrespective of the origin of the fire on the Grandcamp, the following surmises were offered as possible explanations of the transformation of combustion of the nitrate and paper into detonation (Ref 62): a) abnormal sensitivity of FGAN b) impact of falling steel members on molten FGAN c) addition of steam to the gaseous combustion products.
in the hold d) entry of fuel oil from adjacent tanks and its admixture with FGAN to form a sensitive explosive e) initiation by the fire of small-arms ammunition adjacent to the hold in which fire occurred f) formation of gaseous products of combustion or thermal decomps which were explosive and detonated upon ignition after reaching a lower limit of concentration and g) transformation of combustion into detonation as a result of increasing gas pressure due to conditions of partial confinement. Each of these possible causes was evaluated with respect to its probability as the cause of an explosion.

PicArsn and BurMines data on sensitivity and some other expl properties of FGAN and pure AN (Refs 59 & 62) were as follows:

<table>
<thead>
<tr>
<th>Test</th>
<th>FGAN</th>
<th>AN</th>
<th>TNT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PA Impact Test, 2 kg wt, inches</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At 25°</td>
<td>30</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>At 90° (molten TNT)</td>
<td>–</td>
<td>–</td>
<td>3</td>
</tr>
<tr>
<td>At 175°(molten)</td>
<td>12</td>
<td>12–13</td>
<td>–</td>
</tr>
<tr>
<td><strong>Pendulum Friction Test, steel shoe</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unaffected in 10 trials</td>
<td></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Explosion Temp Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 sec</td>
<td>333–85</td>
<td>325</td>
<td>–</td>
</tr>
<tr>
<td>5 sec</td>
<td>–</td>
<td>–</td>
<td>475d</td>
</tr>
<tr>
<td><strong>Rate of Deton, m/sec</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At 25°</td>
<td>1350</td>
<td>1190</td>
<td>6800</td>
</tr>
<tr>
<td>Molten</td>
<td>2109</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

The above data show that FGAN is not abnormally sensitive to initiation by impact, friction or heat, but the molten FGAN is much more sensitive than the cryst material. However, a 52-lb wt allowed to fall 10 ft on a mixt of molten FGAN and bagging paper confined in a steel tube caused no expln. The impact on, and immersion in similar mixts of burning wood or charcoal also failed to cause deton of FGAN. The probability of expln by impact on molten FGAN appears to be unlikely. The injection of steam into the hold, as was done aboard the SS Grandcamp, was not a logical cause of the expln. This was not done aboard the High Flyer. Steam is one of the major products of decomps or expln of AN and is not reactive with the nitrate. Steam should retard rather than accelerate the decomps of molten FGAN, and its wetting effect on paper bagging should tend to retard the burning of this. The possible effect of fuel oil, which might have soaked into FGAN and formed a sensitive explosive mixture, was also considered. Tests at PicArsn (Ref 59) showed no reactivity between fuel oil and FGAN even at 120°. Numerous investigators have studied the effects of organic combustibles on AN, for example: TNT (Refs 12, 24, 43, 50), petrolatum or paraffin (Refs 24, 42, 44, 47, 67, 69), petrolatum-rosin-paraffin (PRP) (Refs 51, 52, 72), combustibles such as wood pulp, etc (Refs 17, 20, 30, 34, 42, 63, 70, 74) and other organics (Refs 37, 41, 60). In general, it has been found that such mixts are only slightly more sensitive than AN itself. Elliott (Ref 63) made an investigation of an expln that occurred during evapn by air agitation of an AN solution in a high-pan with the possibility that lubricating oil in the air compressor might have passed.
through the air filter. His tests showed that no rapid exothermic reaction took place in mixts of compressor oil and AN at temps below 250°. Tests also showed that highly confined AN at 146° could be detonated by means of a No 8 detonator, but not when the AN was at 21°. The possibility that fuel oil may have been a factor in causing the Texas City explosion was dismissed as negligible.

Since there were 16 cases of small-arms ammunition in a hold of the Grandcamp adjacent to that in which the fire started, their initiation and sympathetic deton of the burning cargo have been suggested as being responsible for the expln. As small-arms ammunition contains no HE charge and the propellant charges are small and separated by cartridges, fire involving the ammunition should result only in the combustion and low-order expln of the charges, with high-order deton of these only a remote possibility. Also, there was a heavy steel bulkhead between the two holds, and the transmission of such an explosive wave through this would be improbable. However, Abinder (Ref 42) found in 1936 that a shell loaded with AN and detonated, did transmit the deton by influence to other shells. The fact that a similar explosion following a fire took place on board the High Flyer, which had no small-arms ammunition cargo aboard, disposes of this possible explanation of the explosion on the Grandcamp.

Sherrick (Ref 21) suggested in 1924 that the expl decompn of nitrous oxide, a product of the decomp of AN, or its mixt with carbon monoxide, might be capable of causing the deton of AN. Mixts of equal vols of nitrous oxide and carbon monoxide were detonated by means of an electric spark by Berthelot and Vieille (Refs 5 & 33), who found the rate of deton of the mixt to be 1106 m/s. As would be expected, some carbon monoxide, as well as carbon dioxide, was produced by the burning of a mixt of FGAN and bagging paper in tests made at Pic Arsn (Ref 59). In laboratory tests, the gaseous phase produced by heating the mixt at 175° underwent expln, but whether the residual solid material was detonated could not be determined. It can be postulated that as the burning of paper and wood dunnage progressed, the concn of nitrous oxide and carbon monoxide could increase until the limit of inflammability was reached, when deton of this would occur and cause deton of unburned FGAN.

The final surmise as to the cause of transformation of fire into expln aboard the Grandcamp was an increase in gas pressure due to a condition of confinement. In an effort to simulate the conditions existing in the hold of the Grandcamp, small and intermediate scale tests in bomb cases were made at Pic Arsn and Aberdeen Proving Ground. These indicated that a certain minimum gas pressure must be developed before the deton of a burning FGAN-paper mixt can take place (Ref 63). Charges of 2,000 and 3,000 lbs of bagged FGAN in 12,000 lb T10 Bomb cases underwent only burning when some degree of venting was provided. However, when confinement was complete, deton of the entire charge occurred after 64 min of heating of an attached auxiliary tube contg approx 8 lb FGAN and bagging paper and also after only 45 sec of burning of a mixt of FGAN, excelsior and kindling in the center of the bomb charge. It was calculated that the gas pressure at the instant of expln was not greater than 235 psi in the case of the charge that detonated in 45 sec, approx 75 psi or less for the auxiliary bomb that detonated in 64 min and approx 22 psi for the vented bomb in which the FGAN-paper charge burned for 120 min without expln. Branconier and Delsemme (Ref 72) found that it is necessary to have sufficient confinement to build up a pressure of 1400 psi in order to cause the expln of AN solely by heating. If the AN is not stabilized or has a coating of the PRP type, the minimum pressure required for expln is only 42 psi.

In the hold of the Grandcamp, the condition of confinement was one of venting, as the hatch was open at the instant of explosion. Whether
a gas pressure of 42 psi could be developed under this condition or whether the hull of the ship could have withstood this much pressure is not known. There is the possibility that collapse of part of the burning mass could have produced a localized pressure of 42 psi or more and caused transformation of burning in this region into detonation which was then transmitted to the rest of the FGAN in the hold.

In conclusion, it might be said that most of the investigators of AN prior to the Texas City disaster recognized, especially after the Oppau disaster, that this compound may be exploded by impact or a powerful detonator, but very few recognized the possibility of exploding it by heat alone. With the knowledge of the explosibility of AN acquired after the disaster, it is now known that AN and mixtures of it with organic materials and even ammonium sulfate can be caused to detonate by heating under conditions of confinement. With this knowledge, the problems of handling, storage and transportation of these materials can be solved by controlling conditions so as to insure safety and, in spite of potential hazard, prevent accidental explosions similar to those at Texas City and Brest.

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Note: Dr R.D. Miller of Spencer Chemical Co, Kansas City, Missouri, pointed out (private communication, March 1960) that the Inter-Agency Rept which was issued after Texas City disaster stated that two reactions, one endothermic and the other exothermic, occur at the same time: "AN melts at about 170°C (338°F). If the melt is heated to about 210°C (410°F) in an open container it will begin to decompose into N2O (the "laughing gas" of commerce) and H2O. This reaction produces heat, and it would, therefore, ordinarily be expected that a mass of decomposing AN would become progressively hotter and decompose at an accelerating rate until finally the decomposition would become explosive. However, a process which absorbs heat is going on at the same time as the heat-producing decomposition which gives N2O and H2O. This process includes the simultaneous vaporization and dissociation of AN into gaseous NH3 and H2O."
AMMONIUM NITRATE, FERTILIZER
GRADE (FGAN)

The history of restoring fertility to the soil shows that in 500 BC the Celts of Western Europe had learned the virtues of lime, wood ashes and compost. However, agricultural science as such is only a hundred years old. The foundations of soil chemistry were laid down in 1840 by Justus Liebig, a German chemist, in his classic text "Organic Chemistry in its Applications to Agricultural Chemistry". Complete, mixed fertilizers embodying various proportions of nitrogen, phosphate and potash were virtually unknown in England and Europe until 1925–30, but mixed fertilizers dominated the American market although most of the individual ingredients were imported prior to World War II. Both nitrogen and phosphorus have double roles: they are plant nutrients and materials useful in the production of war munitions (Ref 24).

Since 1930 increasingly larger quantities of nitrogen in the form of anhydrous ammonia and ammoniating liquors contg mixts of AN-ammonia-water or urea-ammonia-water have been used. Most of the AN used as fertilizer in the USA is applied directly to the soil. AN shows a marked tendency to cake and absorb moisture from the air (Ref 27) when the humidity exceeds 60% at 30°. A study by Gorshtein (Ref 4) of the hardening and caking of AN in storage showed that the granulated material with a max of 0.15% H₂O does not cake under any storage conditions; with a 0.4 to 0.5% H₂O content, caking is excessive at temps above 31.5°, while a higher H₂O content (0.5 to 1.5%) has no influence on the degree of caking. The rate of hardening is reduced sharply by an increase in particle size and is retarded by coating the nitrate with 0.1% paraffin. Gorshtein also describes a series of expts on producing granulated AN and mixed fertilizers (such as AN + (NH₄)₂SO₄ + CaO + phosphorite) employing Kestner evaporators and crystallizers (Ref 4).

During the past twenty years many developments of AN coatings and additives for improved moisture resistance have been disclosed. For instance, Baker (Ref 5) reported a Ca stearate coating, Cairns (Ref 10) the PRP (paraffin, rosin, petrolatum) coating, and Winning (Refs 11 & 12) a pregelatinized starch products coating. It was not until 1943 that the TVA (Tennessee Valley Authority) developed American FGAN, consisting of AN coated with 1% PRP and 4% kaolin dust (Ref 15). The method of prep of Amer FGAN is described briefly under "Ammonium Nitrate". In 1945 the US Dept of Agric (Refs 13 & 14) published the results of investigations which showed the fire hazards of FGAN, but no definite statement was made with respect to its explosibility by heat. Previous to these publications, dynamite manufacturers for many years practiced the coating of AN with up to 2% of petrolatum or PRP. Cook (Ref 2) showed in 1924 that mixts of AN with 1% petrolatum were more sensitive to initiation than uncoated AN. US Bur Mines investigations indicated that 1% nitro-starch increased the sensitivity of AN to expln at elevated temp and under confinement (Ref 3). Torsuev (Ref 6) stated that the presence of org matter in AN facilitated its thermal decomp with the formation of an expl mixt of gases. His claim that even 0.1% of paraffin is dangerous was denied by Abinder (Ref 7) and also by Blinov (Ref 8), but both agreed that larger amounts of paraffin than 0.1% would considerably increase the sensitivity of AN.

The explosibility of AN with approx 7% rosin was investigated by Hopper (Ref 9), who found that rosin increased the sensitivity to initiation and rendered the mixt less hygroscopic. The mixt was also satisfactory with respect to stability, brisance and impact sensitivity, being unaffected in the rifle bullet and pendulum friction tests. Marshall (Ref 23) and Banik (Ref 26) studied the explosibility of Amer FGAN contg 1% petrolatum and 5% kaolin in comparison with Brit FGAN contg
99.8% AN and about 0.15% H₂O. Marshall reported laboratory and field tests which showed that the Amer FGAN ignited more readily and decomposed more quickly than Brit FGAN when these were subjected to heat; when confined, the Amer product exploded violently, whereas the Brit product either did not explode at all or did so only mildly. When heated in steel tubes 2 ft long which had an ID of 0.45" and a wall thickness of 0.08", the Brit FGAN burst the tube only at the end where it was heated, whereas the Amer FGAN burst the tube from end to end. This test showed that the explosion propagated throughout the unheated mass. Admixture of either type of FGAN with paper and wood (packing materials) in the form of small pieces did not cause the explosion of the unconfined mass. An intimate mixture of Brit FGAN and 1% hydrocarbon, when heated strongly under confinement, exploded in a manner similar to that of Amer FGAN (Ref 23). In general, the discussion of Bank (Ref 26) is in agreement with the findings of Marshall. Cook and Talbot (Ref 28) reported that AN grains coated with hydrocarbons were more sensitive to initiation than uncoated AN or AN coated with inorganic materials. Max sensitivity occurred in fine-grained AN coated with 0.75 to 1.5% wax. A No 6 blasting cap was sufficient to deton this material, and the expln propagated indefinitely in charges 1.875" in diam (See Note, p A340)

Early investigation of the sensitivity of mixed fertilizers was made by Rosendahl (Ref 1), who reported that mixts of Amm nitrate & sulfate decomposed on heating according to the equation: 2NH₄NO₃ + (NH₄)₂SO₄ = 3N₂ + 8H₂O + SO₂. Hardesty and Davis (Ref 16) observed the spontaneous development of heat in mixed fertilizers. Macy et al (Ref 17) at PicArsn, tested FGAN, consisting of AN nodules coated with 0.75% wax and about 24% that of TNT at the same density h)An electric spark passed through the gas over a 1.6 g sample of FGAN heated for 5 min at 175° in a partially closed glass tube, resulted in a flash
Eriksen (Ref 20) found that 2,000 and 3,000 lb charges of bagged FGAN can be detonated by the application of heat alone if confinement is such that the products of decomp can develop a gas pressure of about 100 psi. When some degree of ventilation was provided, FGAN could not be detonated by heat and underwent burning only. Eriksen also showed (Ref 21) that six-ply asphalt laminated paper bags stored with FGAN at 60° (140°F) were adversely affected after a period of eight weeks; similar bags without FGAN were not appreciably affected by the same storage conditions, and FGAN stored in such bags at a temp as high as 88° (190°F) remained unchanged. Rinkenbach (Ref 18) summarized these studies and others in a lecture delivered at PicArsn, Dover, NJ. The relative sensitivity of pure AN, wax-coated AN and FGAN to initiation by heat was studied by Varrato (Ref 25). These materials had the following characteristics:

<table>
<thead>
<tr>
<th>Composition, %</th>
<th>Pure AN</th>
<th>Wax-coated AN</th>
<th>Wax-coated FGAN-A</th>
<th>Wax-coated FGAN-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>99.83</td>
<td>94.45</td>
<td>96.03</td>
<td>96.22</td>
</tr>
<tr>
<td>Wax (PRP)</td>
<td>0.03</td>
<td>0.38</td>
<td>0.40</td>
<td>0.68</td>
</tr>
<tr>
<td>Clay</td>
<td>0.14</td>
<td>0.17</td>
<td>3.57</td>
<td>3.10</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.04</td>
<td>0.02</td>
<td>0.04</td>
<td>0.12</td>
</tr>
<tr>
<td>Nitrogen content, %</td>
<td>34.62</td>
<td>34.81</td>
<td>32.98</td>
<td>33.40</td>
</tr>
<tr>
<td>Granulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Through No 8 US Std sieve</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>On No 325 US Std sieve</td>
<td>57.5</td>
<td>55.0</td>
<td>58.0</td>
<td></td>
</tr>
<tr>
<td>Apparent density, g/cc</td>
<td>0.97</td>
<td>1.06</td>
<td>1.01</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Varrato's tests showed that AN coated with 0.38% wax was not more sensitive to initiation by heat than pure, uncoated AN. The sample of AN coated with 0.38% wax was more sensitive than FGAN-A. The most sensitive of the above mixes was that contg about 0.7% wax (FGAN-B).

Ottoson (Ref 19) investigated a mixt called 'Cal-Nitro', contg 60% AN and 40% CaCO₃, supplied by the Semmett Solvay Co of Hopewell, Va. He found that Cal-Nitro was less reactive with paper and sawdust than ordinary FGAN. It did not yield significant amts of expl gases when decompd at reactively low temps, and bagged Cal-Nitro represented a slightly lesse fire hazard than bagged FGAN 'Uraform' (95% AN and 5% urea-formaldehyde resin), also investigated by Ottoson (Ref 19), was found to be more explosive than FGAN, since its expl temp of 280° is considerably lower than that of FGAN (333–385°). The impact sensitivity values for 'Uraform', obtained with PicArsn test apparatus, using a 2 kg wt, were 23" at 20° and 8" for molten material at 175°. These values are to be compared with 31" and 12" respectively for FGAN under the same test conditions. A detonation velocity of 1760–1910 m/s at d 0.80 was obtained for Uraform as against 1350 m/s at d 0.90 for FGAN.

A more recent study by Burns et al (Ref 29) of the explosibility of AN may be summarized as follows:

<table>
<thead>
<tr>
<th></th>
<th>Explosion took place at:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature, °C</td>
</tr>
<tr>
<td>Pure AN</td>
<td>277 to 344</td>
</tr>
<tr>
<td>Pure AN with 1.5% bagging paper</td>
<td>134 to 153</td>
</tr>
<tr>
<td>FGAN</td>
<td>304 to 350</td>
</tr>
<tr>
<td>FGAN 1.5% bagging paper</td>
<td>140 to 153</td>
</tr>
</tbody>
</table>
According to Burns, the incorporation of about 25% of an inert material such as limestone materially decreased the expln hazard of AN.

In conclusion it may be said that currently produced American FGAN, as well as some other ammonium nitrate fertilizers, can explode when confined and subjected to heat, impact or initiation by powerful detonators or boosters.

References on Ammonium Nitrate, Fertilizer Grade (FGAN):

**AMMONIUM NITRATE GELATIN (ANG) OR AMMONIA GELATIN DYNAMITE**

ANG is a blasting type expl similar in compn to Ammonium Nitrate Dynamite, except that gelatinized NG is used in lieu of straight NG. For the prepn of 'gel', the NG is thoroughly mixed with 2 to 5.4% of colloid cotton (CC) and the mass is left for several hours at 40-45°C. The resulting soft gel is mechanically incorporated with previously pulverized and thoroughly mixed AN, carbonaceous material, anti-acid, etc, to give a plastic mass. The above mixt of solid ingredients is called in the USA "dope" and it serves as an absorbent for NG. The presence of gel makes these explosives gelatinous or semi-gelatinous and more water-resistant than corresponding ammonia dynamites. As these expls produce comparatively small amounts of abnoxious gases, it is permissible to use them for underground quarrying, mining (except gaseous and dusty coal mines) and tunneling operations. Their velocity of deton is 4750 to 5750 m/sec, when confined.

The table shown on next page gives compn and some props of ANG's

<table>
<thead>
<tr>
<th>Composition(%) and some properties</th>
<th>American (Non-Permissible)</th>
<th>Belgian (Non-Permissible)</th>
<th>British (Not-Permitted)</th>
<th>French (Non-Permissible)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30% 40% 50% 60%</td>
<td>30% 40% 50% 60%</td>
<td>30% 40% 50% 60%</td>
<td>30% 40% 50% 60%</td>
</tr>
<tr>
<td>NG</td>
<td>22.9 26.2 29.9 35.3</td>
<td>36-64</td>
<td>63.0</td>
<td>25.7</td>
</tr>
<tr>
<td>Collodion cotton</td>
<td>0.3 0.4 0.4 0.7</td>
<td>2.5 2-3.5</td>
<td>2.0 1.3</td>
<td>0.9 0.3</td>
</tr>
<tr>
<td>Amm nitrate</td>
<td>4.2 8.0 13.0 20.1</td>
<td>0-25</td>
<td>30.0</td>
<td>59.2</td>
</tr>
<tr>
<td>Na nitrate</td>
<td>54.9 49.6 32.0 33.5</td>
<td>0-35</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>K nitrate</td>
<td>- - - -</td>
<td>0-46</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carbonaceous fuel</td>
<td>8.3 8.0 8.0 7.9</td>
<td>6.5-15</td>
<td>5.0</td>
<td>5.8 6.0</td>
</tr>
<tr>
<td>Sulfur</td>
<td>7.2 5.6 3.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inert ingredients</td>
<td>- - - -</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anti-acid</td>
<td>0.7 0.8 0.7 0.8</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Moisture</td>
<td>1.5 1.4 1.6 1.7</td>
<td>1.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density, g/cc</td>
<td>- - - -</td>
<td>1.44</td>
<td>1.5</td>
<td>1.5 1.2</td>
</tr>
<tr>
<td>Rate of deton, m/sec</td>
<td>4400 4900 5300 5700</td>
<td>7000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ballistic pendulum, percent TNT</td>
<td>83 88 92 97.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pb block expansion, cc per 10g sample</td>
<td>- - -  -</td>
<td>485</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pb block crushing, mm</td>
<td>- - - -</td>
<td>21.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Power, % of blasting gelatin</td>
<td>- - - -</td>
<td>90</td>
<td>78</td>
<td>82</td>
</tr>
</tbody>
</table>

*Carbonaceous fuel consisted of 2.5% cereal meal and 0.5% lamp-black

**Wood meal
AMMONIUM NITRATE, ANALYTICAL PROCEDURES

I. Qualitative Tests for AN. This can be done either by detecting the NH$_4^+$ ion or the NO$_3^-$ ion

A) Detection of the NH$_4^+$ Ion. Add to 2-3 ml of liquid to be tested, a few drops of Nessler's reagent. If ammonia is present (free or bound) in small quantities, the liquid turns dark yellow to reddish-brown (Ref 3 & Ref 6, p 145). If a large amount of NH$_4^+$ ion is present, a brown ppt of NH$_3$I.H$_2$O is formed (Ref 3)

B) Detection of NO$_3^-$ Ion. If it is desired to detect AN in the absence of nitric acid and inorganic or organic nitrates, use the diphenylamine method. For this pour about 5 ml of liquid to be tested into a narrow test tube of ca 25 ml capacity and while holding the tube in an inclined position (ca 45° angle), add slowly ca 2 ml of DPhA reagent (prepd by dissolving 1 g DPhA in 100 ml concd H$_2$SO$_4$) in such a manner that the reagent flows down the wall of the tube without mixing with the sample. If NO$_3^-$ ion is present, a blue ring appears at the interface (Ref 3 & Ref 6, p 140)

Note: Instead of using DPhA, the ferrous sulfate reagent may be used. The reagent can be prep'd by dissolving the max amt of powdered FeSO$_4$.7H$_2$O in cold ca 60% sulfuric acid (previously prep'd by slowly adding with stirring 1 vol of concd H$_2$SO$_4$ to 1 vol of water, cooled in ice). This test is conducted in the same manner as the DPhA test and the presence of a brown ring indicates the presence of a nitrate (Ref 6, p 140)

II. Quantitative Tests for AN. The following methods may be used:

A) Colorimetric Methods are applicable for det of small quantities of AN such as 0.1-10 mg. This can be done by using one of the following reagents: Nessler's (Refs 3 & 6), m-xylenol (Refs 5 & 12) or sulfanilic acid & a-naphthylamine (Ref 6, p 140)

B) Other Quantitative Methods. For larger quantities of AN, the gravimetric, volumetric, gasometric and other methods can be used, such as:

a) Nessler's Reagent Method consisting of weighing NH$_3$I.H$_2$O precipitated on treating a soln of AN with the reagent (Ref 3)

b) Ammonium Chloroplatinate Method consisting of weighing (NH$_4$)$_2$PtCl$_6$ (Ref 3)

c) Direct Titration of Nitrates with Titanous Chloride Using Alizarin as an Adsorption Indicator, described by Wellings (Ref 1)

d) Volumetric Determination of Nitrates with Ferrous Sulfate as Reducing Agent, described by Kolthoff et al (Ref 2) (See also Ref 3, p 644)

e) Schulze-Tiemann Method for Determination of Nitrates, described in Ref 9, p 218

f) Oxidimetric Nitrate Analysis of Fertilizers and Other Commercial Products, described by Leithe (Ref 10)

g) Formaldehyde Method, proposed by Miller for rapid detn of nitrogen in AN fertilizers (Ref 11) (See also Ref 8, p 6)

h) Devarda Method, in Allen's modification, described in Ref 9, pp 218

i) Kjeldahl Method, described in Ref 6, pp 142-5

j) Nitrometer Method, described in Ref 8, pp 6-7

k) Refractometric Method, described by Miaud & Dubois (Ref 14)

l) Phase Analysis in Non-Aqueous Medium, described by Sartorius & Kreyenbuhl (Ref 18)

Gordon & Campbell (Ref 17) described the differential method of analysis in the investigation of thermal decompn of inorganic oxidants, such as AN

Jacobs (Ref 12) stated that AN is usually estimated in dusts by detn of the NH$_3$ content of a sample either by nesslerization or by the m-xylenol reagent. When the dust also contains nitrocompds (such as nitroated derivs of toluene), it is necessary to make a distn in the presence of an alkali (as in the Kjeldahl method) and then test the distillate by one of the above reagents
Detn of moisture in AN is described by the following investigators: a) Guichard (Ref 4) — detn of small amts of w by continuous weighing on a specially designed analytical balance b) Roberts & Levin (Ref 13), — detn of small amts of w employing azeotropic distn and subsequent detn of w in the distillate by titration with Karl Fischer reagent c) Eberius (Ref 15) — detn of w by the Karl Fischer method in explosives chemistry d) Jensen et al (Ref 16) — detn of moist using a modified high frequency apparatus e) Engelbrecht et al (Ref 19) — a rapid method for detn of moist in AN using the Karl Fischer reagent f) Zil’berman (Ref 7) — cal’cn of moist content in AN melt by detg bp’s at pressures of 500 to 560 mm Hg and interpolating the results from concn-temp curves prep’d for pressures 520, 540 & 560 mm Hg.

Kast-Metz (1946) described detn of AN in some expl mixts, such as blasting expls of black powder type, permissible expls, etc. (See also under Amatol and Ammonal).

AN intended for military uses must comply with the following requirements of Spec JAN-A-175 (Ref 8, p 2)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Grade II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (max), %</td>
<td>0.15</td>
</tr>
<tr>
<td>Ether solubles (max)</td>
<td>0.10</td>
</tr>
<tr>
<td>Water insolubles (max)</td>
<td>0.18</td>
</tr>
<tr>
<td>Insolubles retained on US Std No 40 (420 micron) sieve (max)</td>
<td>0.01</td>
</tr>
<tr>
<td>Acidity, as HNO₃ (max)</td>
<td>0.02</td>
</tr>
<tr>
<td>Alkalinity, as NH₃ (max)</td>
<td>0.025</td>
</tr>
<tr>
<td>Sulfates as (NH₄)₂SO₄ (max)</td>
<td>0.05</td>
</tr>
<tr>
<td>Chlorides as NaCl (max)</td>
<td>0.50</td>
</tr>
<tr>
<td>Solu in nitric acid (min)</td>
<td>—</td>
</tr>
<tr>
<td>NH₄NO₃ content (min)</td>
<td>99.0</td>
</tr>
</tbody>
</table>

Note: Apparent density for Grade I, Class B AN shall be not less than 1.06

Note: Grade II AN covered by US Army Spec 50-11-59E, July 1944 is a material of 97% purity.

Grade I AN, Classes A & B are intended for use in the manuf of cast-loaded amatols, while Class C is for extrusion-loaded amatol (80/20). Grade III AN is intended for use as a nitrating agent in the manuf of expls.

Following is a brief description of tests:

A) Moisture may be determined by one of the following methods:

a) Weigh accurately ca a 10 g sample in a tared wide-form weighing dish, heat at 100° C for 2 hrs, cool in a desiccator and reweigh. Calc the loss of wt as %-age of moisture.
b) Transfer a weighed 100 g portion of the sample to the 500 ml flask of the apparatus shown on Fig 1 and add 200 ml of perchloroethylene, which has been stored over anhydrous CaCl₂ in a moisture tube the interior of which has been cleaned with chromic acid. Connect a moisture tube (see Fig 2) and reflux condenser by means of tight cork stoppers, and support on a ring stand with the flask resting on a wire gauze. Heat to a brisk boiling and maintain so for 15 mins. Cool and disconnect the apparatus.
extracted material of previous procedure to a beaker and stir with hot w to dissolve the bulk of material. Filter through a tared sintered glass crucible and wash the residue in the crucible with hot distilled water until it is free from nitrate. Dry to const wt at 100°C, cool and weigh. Calc the residue as %-age of water-insolubles (Ref 8, p 4)

D) Insoluble Material Retained on US Std No 40 Sieve. Treat a 100 g sample in a beaker with hot distilled w and pour the soln through the sieve. Transfer quantitatively any insol matter from the beaker to the sieve by means of a jet of hot distilled water and when no more insol matter passes through the sieve, dry the sieve with residue at 100°C for 1 hr. Transfer the dry residue to a piece of glazed paper and then to a tared weighing dish. Weigh the dish and calc the increase in wt as the %-age of insol matter retained on the sieve (Ref 8, p 4)

E) Acidity. Dissolve a 100 g sample in 400 ml of distilled water, filter and titrate the filtrate with N/10 NaOH soln using methyl red indicator. Run a blank detn on the same amt of distilled water and methyl red. Calc acidity as %-age of nitric acid (Ref 8, p 4)

F) Alkalinity. If the previous detn showed acidity, report no alkalinity. If the soln prepd for acidity detn is alkaline toward methyl red, titrate with N/10 sulfuric acid and calc the alkalinity as %-age of ammonia (Ref 8, p 4)

G) Nitrites. Weigh to 0.1 mg ca a 1 g sample, dissolve it in 20 ml distilled water, add 1 ml of 10% aq sulfuric acid and 1 ml of freshly prepd, colorless 0.5% m-phenylenediamine-hydrochloride soln. No yel or yel-brown color should develop.

Note: If the m-phenylenediamine-hydrochloride soln is colored when prepd, decolorize it by treating with animal charcoal (Ref 8, p 4)

H) Sulfates. Weigh to 0.1 mg ca a 10 g sample and dissolve in ca 20 ml distilled w in a porcelain dish. Add a little more Na carbonate
(free from sulfates) than necessary to transform AN to carbonate and evaporate to dryness. Cool the dish and acidify the residue with HCl, taking care to avoid loss during effervescence. Evap to dryness, moisten the residue with HCl and again evap to dryness to insure complete removal of nitrates. Dissolve the residue in distd w, filter if necessary, heat to boiling, and add 5 ml of a 10% Ba chloride soln. Allow the ppt to settle and transfer the liq and ppt quantitatively to a tared sintered glass crucible of medium porosity. Wash the ppt with hot distd w, dry the crucible at 100° for 2 hrs, cool in a desiccator and weigh. Calc the wt of Ba sulfate to %age of Amm sulfate in the sample

Note: If the amt of sulfates in Grade III AN is not above 0.02%, the following turbidometric proc may be used:

Transfer ca a 5.0 g sample, weighed to 0.1 mg to a tall-form beaker of ca 180 ml capacity, add 20 ml concd HCl and boil the mixt gently. From time to time replace the HCl lost by evapn, and continue boiling until a KI-starch paper moistened with distd w is no longer colored by the vapor. Evap the soln to dryness, dissolve the residue in a little distd w and transfer the soln to a 50 ml Nessler tube. Add 5.0 ml of 10% Na citrate soln, mix the contents and add 2.0 ml of 10% BaCl₂ soln. Dilute the mixt to the mark with distd w. Add 10.0 ml of 2% (1:20) HCl soln, mix and allow to stand 10 mins. Simultaneously and in the same manner prep in the 2nd Nessler tube a std contg 0.001 g of Amm sulfate, 5 g AN (sulfate-free) and the same reagents as in the 1st Nessler tube. Shake both tubes and compare the turbidity, while holding the bottoms of the tubes over a source of strong light. Consider the Amm chloride content of the sample to be not more than 0.02% if the turbidity of the test soln is not greater than that of the std. If the turbidity in sample tube is greater, use the gravimetric procedure described above (Ref 8, p 4)

1) Chlorides. Add to ca a 10 g sample weighed to 0.1 mg in a porcelain casserole, ca 80 ml of 10% NaOH soln and boil until all ammonia is driven off. Dissolve the residue in ca 150 ml cold distd w, neutralize with nitric acid and add a slight excess of Ca carbonate (free from chlorides). Titrate with N/10 Ag nitrate soln, using K chromate as an indicator. Calculate the chlorides found to %age of NH₄Cl in the sample

Note: If the amt of chlorides in Grade III AN is not above 0.02%, the following turbidometric procedure may be used:

Transfer a 5.0 g sample, weighed to 0.1 mg, to a 100 ml low-form Nessler tube, add 50 ml of distd w and shake until the soln is complete. Add 10 ml of 10% HNO₃ soln, followed by 2.0 ml of 10% AgNO₃ soln and mix well. Protect the tube from the direct light. Simultaneously and in the same manner prepare in the 2nd 100 ml Nessler tube a std contg 0.001 g of NH₄Cl and 5 g of AN (chloride-free) and the same reagents as in the 1st Nessler tube. As soon as the AgNO₃ soln is added, shake both tubes and compare the turbidity while holding the bottoms of tubes over a source of strong light. Consider the Amm chloride content of the sample to be not more than 0.02% if the turbidity of the test soln is not greater than that of the std. If the turbidity in sample tube is greater, use the gravimetric test described above (Ref 8, p 5)

1) Solubility in Nitric Acid. Add an 80 g sample with stirring to 100 g of 97.5 to 99.0% nitric acid in a 200 ml beaker. After allowing the soln to cool, transfer a 100 ml portion to a 100 ml Goetz (or equal) oil sedimentation tube and centrifuge at 1800 rpm for 20 mins, using an 8-in centrifuge head. The sample is considered completely sol if the vol of sediment does not exceed 0.15 ml (Ref 8, p 8)

K) AN Content may be detd by one of the following methods:
a) Volumetric Method. Add to 100 ml distd w in an Erlenmeyer flask 25 ml of ca 40% formaldehyde soln and a few drops of pHpt indicator. Neutralize the soln with ca 0.15N NaOH soln and introduce ca 1 g of sample weighed to 0.1 mg. Heat the mixt to 60° and titrate, after cooling it to RT, with ca 0.15N NaOH soln to a pink end point which persists for 30 secs

\[
\% \text{ AN} = \frac{8.005AB}{W_t} - 1.494D - 1.212E, \quad \text{where}
\]

\[A = \text{ml of NaOH soln used in the titration}
\]
\[B = \text{normality of NaOH soln as detd by titration against AN of known purity}
\]
\[D = \%\text{-age of Amm chloride in sample}
\]
\[E = \%\text{-age of Amm sulfate in sample}
\]
\[W_t = \text{weight of AN on dry basis}
\]

b) Gasometric Method. In this proced the content of AN is calcd from nitrate nitrogen content as detd by the nitrometer method. The method depends on the following reaction taking place when nitrates or nitric acid are shaken with mercury in the presence of concd sulfuric acid:

\[
2\text{NH}_4\text{NO}_3 + 4\text{H}_2\text{SO}_4 + 3\text{Hg} \rightarrow (\text{NH}_4)_2\text{SO}_4 + 3\text{HgSO}_4 + 4\text{H}_2\text{O} + 2\text{NO}
\]

The amt of nitric oxide liberated is measured and the amt of AN is calcd as will be shown under Calculation.

The apparatus used for this test, the duPont nitrometer is described in most books on Analytical Chemistry, eg Scott & Furman (Ref 3, p 651), but the description of proced is usually not sufficiently elaborate for anyone not familiar with the apparatus. The proced described below was used during WWII for training technicians. It contains enough details to permit learning the handling of the apparatus by anyone without previous experience. The same proced can be used in detn nitric acid, K or Na nitrate, NC, NG, etc and it is not considered necessary to describe it again under these items.

The assembled nitrometer is shown in the attached fig.

If the nitrometer is in an unassembled condition, cut a 9½ ft piece of special thick-walled rubber tubing (such as AHTh No 8842), hang it vertically doubled up to form an upright U-shape, and fill it with 10% NaOH soln. After about ½ hour, drain the tube, rinse with tap water, and cut into the following lengths: 3 ft for tubing A to B, 3½ ft from F to E, 2 ft from B to D and 1 ft from B to C. Roll each piece under the foot and wash the inside and outside with tap water. Pass a long stiff round brush through the tubes to remove all dusty material, and then wash with w and with acet. Dry by passing air dehydrated by bubbling through two Drexel wash bottles contg concd H$_2$SO$_4$ and finally through glass wool (to catch acid droplets mechanically entrained).

Before assembling the glass parts of the nitrometer, fill them with a mixt of concd H$_2$SO$_4$ and K bichromate to which a little oleum is added. Let stand overnight, drain, and thoroughly wash first with tap w and then with distd w. After this, rinse three times with acet and dry by passing air dehydrated by bubbling through two Drexel tubes contg concd H$_2$SO$_4$. Wash the stopcocks in the same manner and grease them slightly when assembling the apparatus. Tie a piece of soft wire around each rubber-to-glass joint and attach the assembled apparatus by means of clamps to a vertical stand specially designed for the nitrometer.

Preparation of Nitrometer for Standardization

and Tests. Break the capillary e of the compensating tube C and with the cock d open, raise the levelling bulb A and pour into it pure, dry, redistd mercury until C and D are completely filled and 2-3" of mercury are left in A. Close cock d and open e and f of the reaction bulb E. Raise the levelling bulb F and pour into it pure mercury until E is filled and 2-3" of mercury remain in F and close e.
repeat the operation every hour during the day and allow to stand overnight. Attach to the capillary $k_3$, previously greased slightly on the outside, a piece of heavy rubber tubing sufficient to reach capillary $e$ of $C$. Without attaching rubber tubing to $e$, expel the wet air in $k_2$ and in the rubber tubing by raising $F$ slightly, opening $f$ and then communicating $E$ with $K_2$ for a few seconds by the 2-way stopcock $c$. Close $c$ & $f$ and immediately attach the rubber tube to $e$ (previously greased on the outside with a stopcock grease. With the cock $d$ remaining closed, lower the bulb $A$, reopen $c$ & $f$ and carefully transfer from $E$ sufficient amt of air to fill $C$ to the position ca $P$. Close the cock $c$ and raise the bulb $A$ slightly in order not to draw any more air into $C$. Detach the rubber tubing from $K_2$ and from $e$, wipe off $e$ and heat its upper part until softening of the glass, draw out the end and seal the tube. In order to expel all the air from $E$ and the capillary $K_2$ on top of it, raise $F$ and by manipulating the two-way cock $c$ (with $f$ open), remove the acid through $K_2$ into a small beaker and as soon as the mercury fills the capillary, close the cock.

**Standardization of Nitrometer.**

Weigh to 0.1 mg in a glass-stoppered bottle, 0.70-0.71g of finely pulverized CP K nitrate, previously dried at 100°. Dissolve it in ca 1 ml distd w and pour the soln into cup $a$ of the nitrometer.

**Note:** If KNO$_3$ is 100% pure, the quantity 0.7078 g will evolve in the nitrometer exactly 70 divisions of measuring tube $D$. This is because the tube $D$ is designed to hold exactly 300.1 mg in its 100 divisions, which means that each division corresponds to 3.001 mg NO. As the mw of KNO$_3$ is 101.11 and that of NO 30.01 each 1.0111 g KNO$_3$ evolves 0.3001 g NO, which corresponds to 100 divisions of $D$, and each 0.7078 g KNO$_3$ will be equivalent to:

$$\frac{0.7078 \times 100}{1.0111} = 70.0 \text{ divisions}$$
By lowering \( F \) and opening \( f \& c \) draw the contents of cup \( a \) slowly into \( E \) being careful not to introduce any air in \( E \). Close the cock \( c \), but leave the cock \( f \) open. 

_Caution._ From this point until further notice the stopcock \( f \) must remain open. If it is closed the pressure produced by the evolving NO will blow the reaction bulb \( E \) to pieces.

Rinse the weighing bottle (after removal of KNO\(_3\) soln) with 2 ml of cool 94.5\% ±0.5 \((H_2SO_4)\) and transfer it into \( a \). By opening the cock \( c \), accompanied by slight lowering of bulb \( F \), draw a small portion of the acid from \( a \) to \( E \) and wait until the top of \( E \) cools. A gentle swirling of the mercury in the upper portion of \( E \) will hasten cooling. Introduce through \( c \) the balance of the acid slowly (to prevent overheating) and close \( c \). Repeat the operation of rinsing two more times and then rinse the inside upper part of \( a \) 2 times with a stream of concd H\(_2\)SO\(_4\) from a Schuster dropping bottle (AHTth No 2250), transferring the acid each time into the bulb. About 10 ml of 94.5\% ±0.5 H\(_2\)SO\(_4\) should be used altogether. This amt will dissolve ca 0.34 ml NO at RT.

_Note:_ Soly of NO in sulfuric acid varies with concn and temp. In order to have concordant results the acid of the same concn must be used in all tests and its amt must be approx proportional to the vol of NO evolved in the reaction. Still better, is to use always approx the same amt of acid and the amt of sample which would evolve approx the same vol of NO (ca 70 divisions of the measuring tube \( D \)) as does 0.70-0.71 g of CP KNO\(_3\) used in standardization.

After introducing the last 2 ml portion of H\(_2\)SO\(_4\), close the cock \( c \) and lower the bulb \( F \) as far as it will go. At this point, inspect the cock \( c \) to det if any air is leaking into \( E \), which, of course would ruin the test. Make sure that \( f \) is open. Put on a full-view mask, wrap bulb \( E \) in several layers of toweling and remove it from the stand. Holding the bulb \( E \) vertically and much above \( F \) (one hand on the top of the bulb while the other at its bottom, place one of the fingers of each hand on the stopcocks \( c \& f \) in such a manner as to prevent them from becoming loose. Shake the bulb \( E \), gently at first and then more and more vigorously to start the reaction. After ca 1 min examine \( E \) to see if there is any gas formed. Continue to shake for another min and this is usually sufficient for evoln of the bulk of NO. Care must be taken not to shake the bulb so vigorously that the acid is carried down through \( f \) into the connecting rubber tubing.

Remove the toweling and raise \( E \). The mercury will flow into \( F \) as the vacuum is created. When 1-2 inches of Hg (not of emulsion) is left in \( E \), close the cock \( f \).

_Note:_ If too much Hg is left in the bulb, the reaction will proceed slowly and a longer time will be required for the residue to settle. Also some of the gas is liable to be held in the emulsion by the suspension.

With the cocks \( c \& f \) tightly closed and held in the manner described above, place \( E \) in a nearly horizontal position and shake vigorously for exactly 2 mins. By this time, the mass will be a nearly homogeneous emulsion. Replace \( E \) on the stand and allow the mixt to settle.

While waiting, slightly grease the outside of capillaries \( K_1 \& K_2 \) and see that they are filled with mercury. Raise or lower the measuring tube \( D \) so that \( K_1 \) will be on the same level as \( K_2 \). Slip a piece of heavy rubber tubing \( h \), 7" long, over \( k_1 \) and push it all the way through. Place the end of \( K_2 \) just against \( K_1 \), and push the rubber tubing \( h \) over the junction until both capillaries are equally covered.

Lower \( A \), raise \( F \) above \( E \) and, by opening \( f \), let the mercury enter \( E \) from \( F \) with formation of some pressure. Open the cock \( d \) and examine for any leakage. Normally the mercury in capillary will move slightly due...
to the presence of rubber connections and traces of air

If there is no leak, leave d open and, by manipulating carefully with cock c, allow the gas to flow slowly from E to D. Towards the end of transfer, partly close c to slow down the rate of flow and just as soon as the acid starts to fill the capillary, close c. No acid shall enter D and no gas shall remain in the capillary. Close d, but leave f open.

Allow the gas in D to stand until it acquires RT.

Note: During this time, clean the reaction bulb E in prep for the test of the sample. For this, lower the bulb F, fill the cup a with concd H₂SO₄ and open the 2-way cock c to admit the acid into E. Suck in some air by manipulating c right and left and then create some vacuum in E by closing c and leaving f open, while F remains sl below E. Close f, remove E from the stand and shake it, while holding in two hands to wash the white deposit of mercuric sulfate from the walls. Replace E on the stand, raise F above E, open f, and, after the mixt has settled, let the acid and a few drops of mercury run through c and K₂ into a small beaker. Repeat the operation of cleaning once more and after the operations are completed, leave both capillaries in stop-cock c and the capillary k₂ filled with mercury so as not to introduce any air in subsequent operations.

Before proceeding with actual measuring of vol of NO evolved, calculate the divisions in D expected to be produced by the amt of KNO₃ used, from the following equation:

\[ R = \frac{Wt \times 100}{1.0111} \text{ divisions, where } R = \frac{\text{expected divisions in the measuring tube } D}{\text{weight of KNO₃ sample}} \]

If the expected vol of NO is 70.0 divisions (which corresponds to exactly 0.7078 g KNO₃), manipulate A, C & D by lowering and raising them until the position is arrived at, in which the top of the meniscus in D is at 70.0 and at the same time the top of the meniscus in C is on the same level as in D.

Note: A convenient arrangement for leveling the mercury in D & C is to paste on a block W (approx 5 x 5 x 10 cm) two pocket-sized mirrors M₁ & M₂ so that the two long sides touch. Attach this block of wood by means of a clamp S in the center between C & D. Move W forwards and backwards as well as up and down until the images of the two menisci form a single image as represented on the fig.

Paste a strip of paper P on the compensating tube C even with the top of the meniscus and this completes the standardization. Tighten the screws on the clamp C as this should never be moved, otherwise it will be necessary to restandardize the apparatus.

Note: Another method of standardization called the "absolute method" is described in the Spec (Ref 8, p 7).

**Determination of AN by Nitrometer Method**

The best results are obtained with the nitrometer method when sufficient quantity of the sample is taken to produce 70 ±10 divisions of tube D. In case of AN, the calcn is as follows: 80.05 g of CP material produces 30.01 g NO and 0.8005 g produces 0.3001 g NO which corresponds to 100 divisions. In order to obtain 70 divisions, the amt AN must be

\[ \frac{70.0 \times 0.8005}{100} = 0.5604 \text{ g} \]

If the sample is impure, larger amts are required to obtain 70 divisions.

Procedure. Weigh to 0.1 mg ca 0.56 g or larger sample of finely pulverized material dried at 100° and proceed exactly as described under standardization of nitrometer.

Calculation

\[ \% \text{ AN} = \frac{R \times 80.05}{Wt \times 100} \]
where \( R \) = divisions of \( D \) and \( Wt \) = weight of sample

Note: The Spec (Ref 8, pp 6-7) prescribes the taking of a sample of exactly 1 g and to proceed in practically the same manner as described above.

L) Apparent Density. Transfer a 20 g sample to a stoppered glass cylinder ca 6" high, 0.08" ID and graduated in divisions of 0.5 ml. Drop the cylinder vertically 30 times from a height of 2.5", permitting the base to strike against a hard leather pad. Level off the surface of the column and note the vol occupied by the AN. Calc the d by dividing the wt by the vol occupied (Ref 8, p 9).

M) Granulation. Place a 100 g sample and a silver quarter (25¢) on a specified nest of sieves, properly superimposed and assembled with a bottom pan. Break up lumps or aggregates by gentle brushing with a camel’s hair brush. Cover and shake for 3 mins by means of a mechanical shaker geared to produce 300 ±15 gyrations and 150 ±10 taps of the striker per min. Weigh the portions retained or passed by the various sieves and calc the results to a %-age basis (Ref 8, p 9).

N) Zinc Oxide Content. Weigh to 0.1 mg ca 10 g sample in a tared evap dish and heat on a hot plate until the disappearance of fumes. Then heat it over a gas burner to a dull red heat, cool in a desiccator, and weigh. Calculate the wt of residue to %-age of ZnO. If the residue is red in color, det the %-age of iron oxide present by dissolving the residue in HCl, pptg any iron present by the addn of NH₄OH, catching the ppt on a filter, igniting and weighing. Correct the wt of residue by subtracting from it any iron oxide present (Ref 8, pp 8-9).

Note: ZnO is added sometimes to AN to prevent its caking. It is also added to AN in order to enhance its burning qualities in pyrotechnic compositions.

Jet Propulsion Laboratory at California Institute of Technology, Pasadena, Calif. under the Dept of the Army, Ordnance Corps, ORDCIT Project, Contract No DA-04-495-Ord 18, has been investigating the methods of analysis.

In their Progress Report No 20-310 (Ref 20) are given descriptions and evaluations of the following methods of moisture detn: a) Abderhalden Drying Procedure (by loss of wt) b) New Procedure for Determination of Moisture by Loss of Weight c) Oven-Drying at 130° d) Modified Karl Fischer Titration Apparatus for Use with AN Coated with ZnO e) Q-Metry Method (attempts to use this method were unsuccessful).

In the Progress Rept No 20-311 (Ref 21) are given the following procedures: a) Assay of AN by a Redox Titration with Alkali Hypobromite Solution [This method is based on the method described by G. M. Arcand & E. H. Swift in AnalChem 28, 440(1956)] b) Determination of Total Ash in AN (using a proced of slow sublimation) and c) Determination of Zinc Oxide in AN (using a thioacetamide separation as ZnS and subsequent chelatometric titration with ethylenediaminetetraacetic acid) d) Determination of Zinc Oxide by a Short Procedure (for samples which do not require a sulfide separation).

Note: The Specification procedure described in Ref 8, pp 8-9) is not applicable if AN contains other materials, such as an anticaking agent Attasorb. Zinc oxide acts not only as an anticaking agent but it also enhances the burning characteristics of AN which is important in case of pyrotechnic compns and may be of propellants.

In the Progress Rept No 20-365 (Ref 22) are given the following procedures: a) Assay of AN by Quantitative Distillation of Ammonia (modification of the Kjeldahl method described in various books, such as in Ref 3) b) Assay of AN by Quantitative Reduction with Ferrous Ammonium Sulfate (modification of a method described in Ref 2).
c) Reduction of An with Titanous Salts (modification of Knecht & Hibbert Method described in various papers and books)

Note: It has been claimed in the Progr Rept 20-365 that none of the existing methods of reduction of nitrate by titanous ion are accurate when analyzing AN. The modification proposed in the rept is not as accurate as ferrous sulfate or other methods and for this reason cannot be recommended

References on Ammonium Nitrate, Analytical Procedures:
1) A. W. Wellings, TransFaradSoc 28, 665-7 (1932)
2) I.M. Kolthoff et al, JACS 55, 1454-7 (1933)
3) Scott & Furman (1939), 637-7 & 640-44
4) M. Guichard, CR 215, 20-1(1942) & CA 38, 5470 (1944)
5) H. Yagoda & F.H. Goldman, JInd Hyg Toxicol 25, 440(1943)
7) D.E. Zil'berman, ZaVodLab 11, No 1, 108-9(1945) & CA 39, 4025 (1945)
9) Kast-Metz (1946), 218, 337-8, 439, 441, 446-7
12) Jacobs(1949), 364-6
14) P. Miaud & P. Dubois, MP 32, 224(1950)
15) E. Eberius, AngewChem 64, 195-202 (1952)
17) S. Gordon & C. Campbell, AnalChem 27, 1102(1955)
18) R. Sartorius & A. Kreyenbuhl, MP 38, 89-103(1956)

Ammonium Nitrate, Analytical Procedures Used by the Spencer Chemical Co, Kansas City, Missouri

I) Ammonia, Anhydrous. See under Ammonia

II) Ammonium Nitrate Solution. (Standard Procedure FP-4)

A) Sampling. When each car is completely loaded, it is sampled while the liq is still hot and before the sepn of any crysts. Four clean and dry 12 to 16 oz Pyrex bottles are placed on the sampling pole and lowered through the liq in the car and raised again to the top at a uniform rate, such that the bottles are filled approx 2/3rd full. The bottles are then tightly stoppered and sent to the lab for analysis.

B) Preparation of Sample. Place three of the bottles on a steam heated water bath, retaining one bottle as a reserve sample. Heat until all crysts are completely dissolved and then pour all three bottles into a heated, dry 500 ml Florence flask. Mix well and analyze as follows:

C) Procedures:

1) Acidity or Alkalinity. Pour two 100 ml samples, accurately measured in a 100 ml graduate, into a 400 ml beaker contg 200 ml distd w. Add 5 drops of methyl-red indicator (prepd by dissolving 0.1 g of MR in 100 ml of 70% alcohol and neutralized to a salmon pink color). If the soln is yel, titrate with N/10 sulfuric acid and if red, titrate with N/10 NaOH soln. Calculate alkalinity as NH₃ and acidity as nitric acid

\[
\text{Alkalinity} = \frac{\text{ml } H_2SO_4 \times N \times 0.017}{\text{SpGr of Sample}}
\]
Acidity = \( \frac{\text{ml NaOH} \times N \times 0.063}{\text{SpGr of Sample}} \)

2) Ammonium Nitrate Content:
   a) By Titration. Using a heated 1 ml graduated pipette, transfer ca 0.8 ml of hot sample into each of two tared and covered 30 ml beakers. Weigh quickly and wash into two 250 ml Erlen flasks. Dil each to ca 100 ml with distd w, add 25 ml neutral 20% formaldehyde and heat to 60°. Cool to 30° and titrate with N/10 NaOH soln using 5 drops of phenolphthalein indicator (prepd by dissolving 1 g phph in 100 ml of 70% neutral alc)

   \[
   \text{ml NaOH} \times N \times 0.08005 \times 100
   \]

   % AN = \[
   \frac{\text{Wt of Sample}}{\text{Sp Gr of Sample}}
   \]

   b) By Fog Point. Add ca 75 ml of hot sample into a well dried 100 ml beaker. Insert a thermometer, turn on an electric stirrer and run it until cloudiness appears in the AN soln. Check temp and det % AN from the table given on p 4 of Standard Procedure FP-4. For instance, if the Fog Point is at 55.5°C, the % AN is 78.89 and if it is at 58.0°, the % AN is 79.68, etc.

   c) By Specific Gravity. Fill to near the top of a preheated hydrometer jar with hot sample. Insert a 1.300-1.400 hydrometer and a thermometer, from 38° to 82° graduated in 1/10°. Stir the soln carefully with a thermometer and when the hydrometer has come to equilibrium, take a reading at the bottom of the meniscus and note simultaneously the temp to the nearest 1/10°. Det % AN from the table given on pp 5-6 of Standard Procedure FP-4. For instance, if sp gr at 60°C is 1.362, % AN is 78.76% and if sp gr at 70.1° is 1.360, % AN is 79.67 etc.

III) Unparted Ammonium Nitrate Prills

In order to det if product meets specific purchaser’s specifications, the following detns described in Spencer’s Standard Procedure FP-5A are used:

1) Ammonium Nitrate Content
2) Moisture Content
3) Average Particle Size (ca 1.8 mm)
4) Water Insoluble Material (example given 0.0024%)
5) Chlorine as Cl (less than 5 ppm)
6) Ash
7) pH of 10% Solution at 20°
8) Acidity as Nitric Acid
9) Alkalinity as NaOH
10A) Ether Soluble
10B) CCl₄ Extractible Material
11) Foreign Material (visual)
12) Particle Size
13) Density
14) Nitrites
15) Sulfates
AMMONIUM NITRIDES

In order to explain certain anomalous behavior of cobaltous amide, Co(NH₃)₂, obtained as a result of the reaction:
Co(SCN)₂ + 2KHN₃ = 2KSCN + Co(NH₃)₂,
it was suggested by Bergstrom (Ref), that actually reaction proceeds further and cobaltous nitride and ammonia are formed:
3Co(NH₃)₂ → CoN₂ + 4NH₃,
As a large part of NH₃ is always retained by the nitride, the resulting compd, CoN₂·xNH₃, may be called "ammonium cobaltous nitride". A similar compd, AlN·xNH₃, called "ammonium aluminum nitride" was prepd by pouring a soln of NH₃·Br in liq NH₃ into a soln of Na K ammonoaluminate. The amt of NH₃ retained by these complexes varies within certain limits depending on the temp and pressure. Attempts to prepare a similar complex from stannous nitride, Sn₃N₁₀, were unsuccessful.


AMMONIUM NITRITE

NH₄NO₃, mw 64.04, N 43.74%. Wh to yel ndl-like deliquescent crysts, d 1.69, mp −12 to sublime at 32–30° and decomps explosively >60°; fl p 158° F. Readily sol in w(with evoln of heat); sol in alc and nearly insol in eth, chlf or ethyl acetate. Was first prepd in 1812 by J.J. Berzelius by treating Pb nitrite with Amm sulfate or by treating Ag nitrite with Amm chloride. Later, 1874, M. Berthelot used the reaction betw Ba nitrite and Amm sulfate and also the interaction of ammonia with nitric oxide and oxygen. O.L. Erdmann & S.P. Sørensen prepd it by passing a mixt of nitrogen oxides(obtained by the action of arsenic trioxide on nitric acid) over coarsely ground Amm carbonate, kept cool by ice; the half liq mass was treated with alc, the unchanged carbonate filtered off and the Amm nitrite precipitated by the addn of ether. The nitrite so obtained was of 90–94% purity and was further purified by dissolving in alc and pptg by ether. All these methods are described in Mellor (Ref 1) and in Gmelins (Ref 4). Amm nitrite cannot be obtained by evaporating its aq soln (Ref 2). A procedure for prepg its aq soln was patented by Kahr (Ref 5).

Amm nitrite is an explosive sensitive to heat or shock. When a very small quantity of the dry salt is heated slowly on a spatula, the salt volatilizes and burns with a pale flame. When an appreciable quantity is heated above 60°, a violent expln takes place. Its concd aq soln decomps explosively when heated to 60–70° and if a similar soln is acidified with 1 drop of concd HCl, HNO₃, or H₂SO₄, a spontaneous decompn takes place even at room temp. Following props were detd by Kast (Ref 3): heat of formation 65 kcal/mol or 1016 cal/g, heat of expln 803 cal/g, temp of expln 2210°, tot vol of gas evolved on expln 1050 l/kg, vel of deton(V)(calcd) ca4000 m/sec at d ca 1, spec energy(f) 9865 kg/l, brisance (by Kast formula f(V)) 39500 vs 86000 for TNT. Heat of formation in Lange’s Handbook is given as −61.5, while in Hodgman’s Handbook it is +62.5, kcal/mol.

Amm nitrite cannot be stored under ordinary conditions because it is very deliquescent and unstable, decomps slowly in winter and rapidly in summer into N and H₂O. The salt may be transported in dry ether, free from alc. The dry salt may be preserved for some time under an atm of hydrogen and in the presence of Amm carbonate and CaO. Its fire hazard and toxicity are discussed in Sax (Ref 6).

Ammonium Nitroform. See Ammonium Trinitromethane under Methane and Derivatives

Ammonium Oxalate. See under Oxalates

Ammonium Perbromate. See under Bromates, Perbromates, etc

Ammonium Perchlorate. See under Perchlorates

Ammonium Perchromate. See under Bichromates, Chromates, etc

Ammonium Periodate. See under Iodates, Periodates, etc

Ammonium Permanganate. See under Manganates, Permanganates, etc

Ammonium Peroxochromate. See under Bichromates, Chromates, etc

Ammonium Persulfate. See under Sulfates and Persulfates

Ammonium Picrotate; Explosive "D" or Dunitite. See 2,4,6-Trinitrophenol, Ammonium Salt and Phenol and Derivatives

Ammonium Picrate Mixtures. See under Phenol and Derivatives

Ammonium Salts of Aromatic Nitro Compounds such as of Nitrophenol, m-Nitrocresol or of Picric Acid. For prepg phlegmatized and substantially shockproof Amm salts of the above aromatic nitro comds, ammonia gas (in excess) is dissolved in a viscous petroleum jelly or viscous lubricating oil having no substantial solvent effect upon the Amm salt and having a high bp. The above reaction medium is brought into contact at RT with the desired nitrocompd in the solid state and the resulting Amm salt of the nitrocompd is removed

Ref: E.Berl & W.Berl, USP 2,350, 322(1944) & CA 38, 4961(1944)

Ammonium Salts, Quaternary. Several org quaternary Amm salts were prepd by Tadros et al. When, in the prepn of 4-formyl-2-nitrophenyltrimethylammonium salt, a mixt of 4-dimethylamino-3-nitrobenzaldehyde

$(\text{CH}_3)_2\text{N-C}_8\text{H}_5(\text{NO}_2)_3\cdot\text{CHO}$ with methyl sulfate

$(\text{CH}_3)_2\text{SO}_4$ was heated to ca 140°, a violent expln took place


Ammonium Salts Which are Explosive, examined by H.Kast and described in SS 21, 205–9(1926) and SS 22, 6–9, 30–4, 56–61, 77–80, 99–102 & 131–5(1925) included: azide, bichromate, chlorate, nitrate, nitrite, perchlorate, permanganate and trichromate

Ammonium Sulfamates. See under Sulfamates

Ammonium Sulfate. See under Sulfates and Persulfates

Ammonium Sulfito. See under Sulfites

Ammonium Tartrate. See under Tartrates

Ammonium Triazidocuprate. Same as Triazidocuprate, Ammonium

Ammonium Trinitrate, $\text{NH}_4\text{NO}_3\cdot2\text{HNO}_3$, prismatic ndls, mp 29–30° and Ammonium Dinitrate, $\text{NH}_4\text{NO}_3\cdot\text{HNO}_3$, lfts or plates, mp ca 12°. Both salts were obtained by Groschuff(Ref 1) from AN and anhyd nitric acid under cooling. Both salts were found to be hygroscopic and the dinitrate decomd by water. Duke & Llevellyn(Ref 2) gave a detailed description of prepn of trinitrate as well as its cryst structure as detd by means of X-rays. Its expl props were not examined


Ammonium Trinitrocresylate or Ecrasite. See Trinitrocresol, Ammonium Salt, under Cresol and Derivatives

Ammonium Ulmate or Ammonium Humate is a substance obtained in 1889 by Gaens on boiling peat(previously washed) with a soln of $\text{Na}_2\text{CO}_3$. An expl mixt contg this 'ulmate', KNO₃ and collodion cotton(gelatinized by
ethyl acetate) was patented by Gaens (Ref 1) and another expl prep'd by mixing the "ul- mate" with molten naphthalene was patented by Reuland

Refs: 1) Daniel (1902), p 322 (under Gaens) 2) Ibid, p 681 (under Reuland)

Ammonium Urate. See under Urates

Ammonkarbonit. See Ammoncarbonit in PATR 2510(1958), p Ger 5

Ammon-Nobilit. See in PATR 2510(1958), p Ger 5

Ammono-Basic Lead Nitrate, Pb₃(NO₄)₆·nNH₃₄, N(detd) ca 7.6%. Wh to yel amorphous powder obtained by Franklin by the action of K amide on Pb nitrate, both dissolved in liq NH₃. The resulting ppt which settled with difficulty was dried and analyzed. Its expl props were not detd

Ref: 1)E.C. Franklin, JACS 27, 846(1905)

Ammonolysis is the direct reaction of ammonia with an organic compd. This reaction is used for the prep'n of various amines, nitramines, etc and some of these products are or may be converted into expls


Ammonpek. A Russian coal mining expl consisting of AN 95 and coal tar pitch (pek) 5% Ref: A.D. Blinov, "Kurs Artilleriee, 'Voyennoye Izdatel'stvo, Moscow, v 2(1949)

Ammonpentritin or Ammonpenthinite is a Pentritin in which some AN is incorporated (up to 50%) in order to obtain expls suitable for blasting purposes. Pentritins are plastic non-exudable expls invented ca 1928 by Dr A. Stettbacher, Zürich, Switzerland. One of the first mixts contained PETN 80 & NG 20% and was considered suitable for loading shells and as a base chge in detonators (using 0.04 g of LA as a primary chge). If CC (collodion cotton) is incorporated, the expl is called Gelatinpentritin. Pentritin was prep'd and investigated at the Gamsen-Briquge plant of the Société Suisse des Explosifs and proved to be an outstanding expl, particularly effective for underwater explns. Incorporation of ca 15% of Al increases the efficiency but higher amts seem to decrease it. For low-freezing Pentrinit, NG is mixed with 20-25% of NGc (nitroglycol)

The enclosed table gives the composition and some props of Ammonpentritins

<table>
<thead>
<tr>
<th>Ammonpentritins of Stettbacher</th>
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<tbody>
<tr>
<td><strong>Compn &amp; Props</strong></td>
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<tr>
<td><strong>PETN</strong></td>
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<td><strong>NG</strong></td>
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<td><strong>NGc</strong></td>
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<td><strong>CC</strong></td>
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<td><strong>AN</strong></td>
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<tr>
<td><strong>DNT(liq)</strong></td>
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<tr>
<td><strong>Vaselin</strong></td>
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<td><strong>d/loading</strong></td>
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<td><strong>d(max)</strong></td>
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<tr>
<td><strong>Deton</strong></td>
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<td><strong>Vel, m/s</strong></td>
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<td><strong>Gas Vol</strong></td>
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<td><strong>at NTP, l/kg</strong></td>
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<tr>
<td><strong>Trauzl Test</strong>,</td>
</tr>
<tr>
<td><strong>Value, cc</strong></td>
</tr>
</tbody>
</table>

(See also Gelatinpentritin and Pentrinit)

Refs: 1) A. Stettbacher, SS 23, 345-8(1928) 2) Ibid, AngewChem 43, 844-7(1930) 3) Ibid, Nitrocellulose 4, 179,199,222-7(1933) & 5, 6-12(1934) 4) Davis(1943), 281 5) Stettbacher(1948), 83-5 6) Stettbacher, Pólyorás (1952), 113 7) Dr A. Stettbacher, Zürich, Switzerland; private communication Dec 14, 1953

Ammonpulver. See PATR 2510(1958), p Ger 5

Ammonsalpeter(Ger). Ammonium Nitrate

Ammonsalpetersprengstoffe(Ger). Ammonium Nitrate Explosives (see PATR 2510, p Ger 5)

Ammon Semi-gelatine or Semi-gelatine is one of the modern Brit "non-permitted" expls
based on AN: NG and NGc 15.0, NC 0.3, AN 78.7 & carbonaceous material 6.0%. It is a cohesive substance with d of 1.2 and its power is equal to 82% that of blasting gelatin
Ref: Taylor & Gay(1958), 26

Ammonsprenggelatine. A gelatinized dynamite consisting of NG(gelatinized with 2–3% CC) 38–47, AN 45–55, dry meal 3.5–5.0 and Na₂CO₃ 0.5%
Ref: CondChemDict(1942), 287(not listed in newer editions)

Ammonsulfatpeter. Ger name for mixes of AN & Amm sulfate used in fertilizers
Ref: Stettbacher(1948), 81

Ammontol or Russian Mixture(Russkaya Smes'). A castable HE mix used for filling projectiles: AN 50, TNT 38 and TNX(called 'ksilil' in Russian) 12%
Ref: A.D. Blinov, 'Kurs Artilleriee,,' Voyennoye Izdatel' stvo, Moscow, v 2(1949), 64–5

Ammonyaku. A mixt of AN & charcoal used by the Japanese as a 'substitute explosive'

Ammoxyl. See Ammoksil

Ammonyaku. A mixt of AN & charcoal used by the Japanese as a 'substitute explosive'

AMMUNITIONS AND WEAPONS OR ARMS

(Munitionen und Waffen in Ger; Munitions et Armes in Fr; Boyevyiy Sredstva) in Russ; Municiones y Armas in Spain; Munizioni(Projetti) e Armi in Ital]. Ammunition is any material used in warfare and designed to inflict damage upon the enemy. The term includes the complete round of ammunition as well as other components or elements. Reduced to its fundamentals, ammunition usually consists of a container(metallic or other material) containing propellant and a missile with or without explosive. Weapons may be subdivided into small arms(calibers up to about 0.60" in the US) such as pistols, revolvers, carbines, rifles, submachine guns & machine guns; artillery ammunition(calibers of 20 mm and larger in the US), such as guns(cannons), howitzers & mortars as well as recoilless rifles, rocket launchers & pyrotechnic pistols

The basic types of ammunition are:

I. Small Arms Ammunition(SAA), which includes various kinds of bullets to be fired by propellants enclosed in metallic cartridges from weapons called 'small arms' and which are carried by one or two men. US small arms are weapons 0.60 inch or under in caliber and include: rifles(except recoiless), semi-automatic rifles, automatic rifles, pistols, revolvers, carbines, machine guns and submachine guns. This category also includes shells used in shot gun and rifle grenades

Note: The British also use inches to express calibers of their small arms and ammunition, whereas nearly all other countries of the world use the metric system

II. Artillery Ammunition consists of projectiles(shells) to be fired from weapons larger than 0.60 inch in caliber. Calibers of US artillery ammunition and weapons are given mostly in millimeters, some, however are given in inches(eg, most naval guns)

Artillery ammunition may be classified as follows:

A) According to Service Use: This includes:

a) Service Ammunition—designed to inflict damage on the enemy

b) Practice Ammunition—designed for training troops in marksmanship. The filler of the projectile may be inert or consist of a small explosive charge serving as a 'spotting charge'

c) Drill or Dummy Ammunition—designed to train gun crews in the motions of loading and firing a weapon without actually firing it; there is no explosive filling

d) Blank Ammunition—designed primarily for saluting purposes and for simulated fire. It is also used for accustoming animals(such as horses, mules, dogs, etc) to the sound of fire; there is a propellant which is retained by a wad but no projectile

Note: This classification may also be applied to small arms ammunition

B) According to Tactical Use. This includes
the following projectiles (shells): HE (high explosive), HE-T (high explosive with tracer), AP (armor-piercing), AP-T (armor-piercing with tracer), CP (concrete-piercing), SAP (semi-armor-piercing), HEAT (high-explosive, antitank), HEP-T (high explosive-plastic, with tracer), HEI (high explosive-incendiary), HVAP (hyper-velocity armor-piercing), HVTP-T (hyper-velocity target practice, with tracer), TP-T (target-practice, with tracer), Incend (incendiary), Illum (illuminating) and Can (canister).

C) According to the Type of Weapon from which the Projectile is Fired. This includes two types of artillery weapons: a) Fixed Artillery or Artillery of Position—designed for permanent emplacements. This may include: siege artillery, harbor and seacoast defense artillery, antiaircraft artillery and sometimes antitank artillery. Guns (cannons), mortars and howitzers of calibers 155 mm and higher are used for this type of artillery. b) Mobile Artillery—designed to be movable from place to place to accompany or follow the troops. This may include: field artillery (self-propelled and towed), tank and antitank artillery, armored vehicles artillery and antiaircraft artillery. Weapons of smaller than 155 mm are used for this type of artillery but there are some mobile guns (usually towed) which are larger than 155 mm. Artillery used on gunboats, as well as naval and railroad artillery, may also be included in this type. Naval artillery is of all calibers (large and small) whereas railroad artillery comprises mostly large caliber weapons, such as the 155 mm gun and larger. Antiaircraft artillery may also be considered as one of the types of mobile artillery, but it is usually considered separately.

Note: It is regrettable to say that there are no modern comprehensive treatises on US, Brit, French, Ital, Spanish, etc Artillery Weapons. Most of the existing books are either too brief or obsolete. The Russian book "Kurs Artilleriei" by Blinov (Ref 52) is fairly comprehensive but it is now out of print (A copy is available in the Library of Congress).

III. Aircraft Ammunition includes anything fired or dropped from a plane, such as shells, bullets, rockets, bombs, aerial torpedoes, aerial mines and pyrotechnic devices.

IV. Rocket Ammunition is fired from a device called a "launcher," such as the "bazooka" of WW II fame. Rocket launchers consist of either guide rails or guide tubes fitted with some electric ignition device. Each rocket carries its own propelling type motor and a warhead containing an HE or a chemical agent.

V. Jatos consist of propelling-type motors used to furnish auxiliary thrust in the launching of aircraft, rockets, guided missiles, target drones and mine clearing detonating cables.

VI. Guided Missiles consist of propelling-type motors fitted with warheads containing HE or other active agents and equipped with guidance devices.

VII. Grenades are explosive- or chemical-filled projectiles of a size and shape convenient for throwing by hand or projecting from a rifle or a launcher.

VIII. Bombs are containers filled with an explosive, chemical or other agent, designed for release from aircraft.

IX. Land Mines are containers, metal, plastic or wood, filled with HE or chemical agents, designed for placing in or on the ground for initiation by and effect against enemy vehicles or personnel. This includes some booby traps (Other booby traps are not land mine types).

X. Demolition Materials consist of explosives and explosive devices designed for demolition purposes or for blasting in connection with military construction.

XI. Pyrotechnic Ammunition includes devices used for signaling, illuminating or igniting purposes. It may be classified according to tactical use as ground devices, which are fired or used on the ground, and aircraft devices released from aircraft. Following are examples of pyrotechnic items: flares (trip, airport, ground, aircraft, parachute, reconnaissance & landing, observation, bombardment and tow range); photoflash cartridges and bombs; tracers in artillery projectiles; igniters (in incendiaries and for jet propulsion units); signal smokes and gunflash simulators.
XII. Miscellaneous Ammunition includes items not listed in the above groups, such as torpedoes (sea, aerial and bangalore), depth charges, sea mines, destroyers, cartridge-actuated devices (designed to facilitate an emergency escape from high-speed aircraft), etc.

Ammunition: Complete Round of, includes all the components necessary to fire a weapon once. In the case of small arms ammo, a complete round consists of a primed cartridge with propellant and a bullet with/or without a tracer. In the case of artillery ammo, a complete round consists of propellant in a primed cartridge case or in bags, an igniter train and a projectile and/or high explosive shell.

American artillery ammo may be divided into the following three classes, depending upon the type of enclosure used in loading the propellant charge:

a) Fixed Ammunition. The propellant charge is enclosed in a metallic cartridge which is provided at the base with a primer and an igniter and at the open end with a rigidly fixed projectile. The round is all in one unit.

b) Semifixed Ammunition. The propellant charge is contained in several cloth bags which are placed in the cartridge provided at the base with a primer and an igniter. The other end of the case is loosely attached to a projectile so that it can be removed before firing in order to adjust the number of bags to the desired muzzle velocity and range selected for the projectile. The unit is self-contained and ready to fire.

c) Separate-loaded Ammunition. The propellant charge is contained in several bags which are transported separately from the projectile. In loading the gun, the projectile is inserted through the breech of the gun and rammed into place; this is followed by bags of propellant, loaded one by one until the desired charge is reached; the breech is then closed and the primer-igniter and the firing mechanism inserted.

The above classification applies only to the US artillery ammunition. Other countries may have different systems.

For instance, the German artillery of WW II consisted of the following two types:

a) Einheitsmunition oder Patronenmunition (One-piece Ammunition or Cartridge Ammunition), corresponding to US fixed ammunition.

b) Kartuschnmunition oder Getrenntmunition (Canister Ammunition or Separated Cartridge Ammunition). This was somewhat intermediate between US semi-fixed and separate-loaded ammunition. It consisted of a projectile which was placed in the weapon first and a canister (cartridge), provided with a primer and containing several bags with propellant charges, which was loaded into the breech afterward. The canister was not fixed to the projectile. The number of bags with propellant charges could be varied according to the range requirement at the place of firing.

The Russians, according to Blinov, vol 5 (Ref 52), used the following types of artillery complete rounds:

a) Patronnoye Zariazbeniye (Cartridge Loading). This corresponds to US "fixed" ammunition and is used for rounds up to and including 100 mm.

b) Patrony s Sostavnymi Zariadami v Metalicheskikh Ghil' zakh (Rounds with Composite Charges in Metallic Cartridges)—corresponds approximately to US "semi-fixed" ammunition, but the round is loaded in two operations; first the projectile (snariad) and then the metal cartridge case (ghil' za) with the propellant (porokh). This type of ammo was fired from 107, 122 and most 152 mm weapons.

c) Razdel'nnoye Zariazbeniye (Separate-loaded Ammunition) — corresponds to the US "separate-loaded" ammo, but the round is loaded in three operations; first the projectile (snariad), then the cloth bag (kartoozy) with propellant (porokh) and finally igniter (vosplamennitel'). This type of ammo, also known as Kartooznoye Zariazbeniye, was used in 152 mm M1935 cannon and in all cannons and howitzers of larger caliber.

Note: More information on German ammo & weapons may be found in PATR 2510 (1958) (Ref 100) and in Refs 25, 45, 73, 75, 76, 89 & 102. A comprehensive treatise on Russian artillery may be found in the books of Blinov (12 vols) (Ref 52) and a brief description is given in conf PATR 2145 (1955) (Ref 89a) and
in Ref 45. Russ ammo in general is described in Ref 44 and in conf Ref 74. Russ machine guns and other automatic weapons are described in conf vol 2 of Chinn's books (Ref 73). Some French ammo & weapons are described in Refs 12 & 14 and in a series of booklets by Pichene (Ref 63, 64, 65, 66, 67, 68, 81, 86 & 88). A few Fr items are described in TM 9–1985–6 (Ref 79), which is identical with OP 1668 (1946) (Ref 44a). Some info on British items (mostly obsolete) is given in Refs 1, 2, 3, 4, 5, 6, 7, 28 & 96. Several Brit ammo items are described in conf TM 9–1985–6 (Ref 79). Incomplete info on Italian ammo is given in Refs 44a & 79. Some info on Japanese ammo may be found in Refs 40, 77 & 78. No info at our disposal exists on ammo & weapons of Austria, Belgium, Egypt, Greece, India, Mexico, South American countries (except Argentina), Persia, Spain, Sweden, Switzerland, Turkey, and of the countries with communistic governments (Albania, Bulgaria, China, Hungary, Poland, Rumania and Yugoslavia).

**Calibers and Uses of Small Arms Ammunition (USA)**

Cal .22 (0.223") (5.59 mm)—for cal .22 long and short rifles (TM 9–1990)
Cal 7.62 mm (0.300"), M61—for cal 7.62 mm NATO rifles M14 & M15 and for AR–10 "Armalite" rifles (Ref 100, pp 34–9)
Cal 7.62 mm—for cal 7.62 mm machine gun M60 (Ref 100, p 44)
Cal .30 (0.3075") (7.81 mm) M2—for rifle M1, carbine, Krag (subcaliber) machine gun and rifle–grenade cartridges (TM 9–1990)
Cal .32 (0.314") (7.98 mm)—for automatic Colt revolver and S & W revolver (TM 9–1990)
Cal 9 mm (0.354")—for Parabellum pistol (TM 9–1990)
Cal .380 (0.356") (9.04 mm)—for automatic pistol, called 9 mm short (TM 9–1990)
Cal .38 (0.359") (9.12 mm)—for super automatic Colt special and S & W (TM 9–1990)
Cal .38 (0.375") (9.52 mm)—for short Cal (TM 9–1990)
Cal .45 (0.4505") (11.44 mm)—for automatic pistols, revolvers and submachine guns (TM 9–1990)
Cal .50 (0.5110") (12.98")—for machine guns, including multiple MG, M55 shotgun shells: 12, 16, 20 and .410 gage (TM 9–1990)

**Calibers and Uses of Artillery Ammunition and Rockets (USA)**

Cal 20 mm (0.787") (fixed)—for 20 mm automatic guns AN–M2, M3, BRHS & M24 mostly used as aircraft cannons (TM 9–1991)
Cal 37 mm (1.457") (fixed)—for 37 mm automatic guns M1A2, M4, M6 & M9, used as AA and as aircraft cannon (TM 9–1991) & Ref 49, pp 140–1
Cal 40 mm (1.575") (fixed)—for 40 mm automatic AA gun M1 (Bofors) (Ref 49, p 146)
Cal 40 mm (fixed)—for 40 mm guns M1A2, Navy MK1 and for twin self–propelled gun M42 (TM 9–1991 and Ref 100, pp 14 & 20)
Cal 57 mm (2.244") (fixed)—for 57 mm gun M1 (TM 9–1991)
Cal 57 mm (fixed, perforated cartridge)—for 57 mm recoilless rifle (TM 9–1991 & Ref 100, p 39)
Cal 2.36" (59.9 mm) rocket M6A3—for 2.36" rocket launcher "Bazooka" (Ref 49, p 178)
Cal 60 mm (2.632") mortar ammo—for 60 mm mortars M2 & M19 (TM 9–1991 & Ref 49, p 161)
Cal 75 mm (2.953") (fixed)—for 75 mm guns M3, M6, M17 and the "Skysweeper" (Ref 100, p 15)
Cal 75 mm (fixed) & semifixed—for 75 mm howitzers M1A1 (pack) and M3 (TM 9–1991)
Cal 75 mm (fixed, perforated cartridge)—for 75 mm recoilless rifle M20 (TM 9–1991)
Cal 76 mm (2.992") (fixed)—for 76 mm guns M1A1 C & M29 (TM 9–1991)
Cal 3" (76.2 mm)—for 3" AA gun M3 and A/T gun M5 (Ref 49, p 148)
Cal 81 mm (3.19") mortar ammo—for 81 mm mortars M1, M21 & M29 (TM 9–1991) & Ref 49, p 165
Cal 3.25" (82.55 mm) rocket M2 (referred to as "target rocket")—for 3.25" rocket projector M1 (Ref 49, p 180)
Cal 3.5" (88.9 mm) rocket—for 3.5" rocket launcher (Ref 100, p 42)
Cal 90 mm (3.54") (fixed)—for 90 mm guns M1, M1A1, M1A2, M2, M2A1, M3, M3A1 & T8 (TM 9–1991 & Ref 100, p 15)
Cal 90 mm (fixed)—for 90 mm self–propelled
gun M56, also known as "assault gun" (Ref 100,p 40)
Cal 105 mm(4.134") (semifixed)—for 105 mm howitzers M2A1, M3 & M4(TM 9–1901)
Cal 105 mm mortar ammo—for 105 mm mortar T13(Ref 49,p 168)
Cal 105 mm(perforated cartridge)—for 105 mm recoilless rifle(Ref 100,p 40)
Cal 106 mm(4.17") (perforated cartridge ammo) for 106 mm recoilless rifle M40A1(Ref 100, p 39)
Cal 4.2"(106.7 mm) mortar ammo—for 4.2" mortar M2, M3 and M30(TM 9–1901) & Ref 100,p 43)
Cal 4.5"(114.3 mm) (separate-loading)—for 4.5" gun and for howitzer M1(Ref 57)
Cal 4.5" rockets—for 4.5" rocket launchers M23, T36 & T66(Ref 49,p 182 & Ref 100, p 43)
Cal 120 mm(4.72") (separate-loading)—for 120 mm AA gun M1(TM 9–1901)
Cal 155 mm(6.10") (separate-loading)—for 155 mm guns M1 & M2 and howitzer M1
(TM 9–1901 & Ref 100,p 18)
Cal 155 mm mortar ammo—for 155 mm mortar T25(Ref 49,p 170)
Cal 155 mm(perforated cartridge ammo)—for 155 mm recoilless rifle(Ref 57)
Cal 175 mm(6.89")—for 175 mm self-propelled gun T235(Ref 100,p 11)
Cal 7.2"(182.9 mm) rocket—for 7.2" multiple rocket launcher M17(Ref 49,p 182)
Cal 8"(203 mm) (separate loading)—for 8" gun M1 and howitzer M2(TM 9–1901)
Cal 8" rocket T25—for 8" rocket launcher T53(Ref 49,p 194)
Cal 240 mm(9.449") (separate-loading)—for 240 mm howitzer M1(TM 9–1901)
Cal 280 mm(11.024") (separate-loading)—for 280 mm gun(Ref 100,p 9)
Cal 318 mm(12.91") rocket "Little John"—for 318 mm rocket launcher(Ref 100,p 24)
Cal 14"(355.6 mm) (separate-loading)—for 14" guns(TM 9–1904)
Cal 762 mm(30.29") rocket "Honest John"—for 762 mm rocket launcher(Ref 100,p 23)
Cal 914 mm(35.98") mortar ammo—for 914 mm mortar, nicknamed "Little David" (Ref 49,pp 172–3)
Calibers of guided missiles: Corporal, Dart, Hawk, Jupiter, Lacrosse, Nike(Ajax & Hercules) Redstone, etc are classified(Ref 10 pp 25–33 & 41)
Subcaliber and blank ammunition are described in TM 9–1901, etc
Notes: a)Mortars are either smooth-bore or rifled b)Some of the items listed above may be still in the development stage and some were used during WWII but not since (for example, the 914 mm mortar)

(See also Bangalore Torpedoes, Bullets, Bombs, Cartridges, Demolition Materials, Depth Charges, Grenades, Guided Missiles, Jatos, Land Mines, Projectiles, Pyrotechnic Devices, Rockets, Sea Mines, Shells and Torpedoes)

References on Ammunition and Weapons:
A388

References for Ammunition and Weapons, Manufacture


E.M.J.Pedersen, ArOrdn 15, 347-51 (1935)
Ammunition, Self-Destroying. In firing from guns (such as AA) against enemy aircraft, great damage could be caused if the shells which failed to explode in the air fell on friendly territory and exploded there. In order to prevent this, a feature is incorporated (either in the fuze or in the explosive train of a shell) which destroys such a shell in the air before it strikes the ground. Ammunition provided with this feature is called "self-destroying."

Ref: A.B. Schilling, PicArsn, Dover, NJ; private communication (1960)

Amonal 1. A Spanish expl proposed by Prof A. Blanco (See under Amonal)

Amorçage (Fr). Priming; initiation

Amorçage (Explosif d') (Fr). Priming; initiating explosive

Amorce. A French word meaning primer, cap, detonator or fuse. In England the word has been used to mean a toy pistol cap. According to Ref 1, amorces consisting of a mixt of minute quantities of red phosphorus, K chlorate and gum are less dangerous than those contg MF. According to Ref 2, the word "amorce" is also applied to "snaps for bon-bon crackers." Amorces should not contain more than 60 grains (3.88g) of chlorate and 10 grains (0.65g) of red phosphorus per 1000. Some amorces contain Ag fulminate in an amount not exceeding 15 grains (0.97g) per 1000 amorces. Ref 3 gives the compn and prepnn of some Ger amorces [See also PATR 2510 (1958), pp Ger 7]


Amorce détonateur (Fr). Detonator; initiator

Amorce électrique (Fr). Electric primer; electric blasting cap

Amorce fulminate (Fr). Blasting cap

Amorce à percussion (Fr). Percussion cap
Amperometric Titrations (Polarometric Titrations). In a strict sense, the term “amperometric” should be applied to titrations in which a polargraphic diffusion-controlled limiting current is measured, according to the procedures described in references 3 to 8. This method has to be differentiated from galvanometric titration of E. Salomon [Z Physik Chem 24, 55(1897) & 25, 366(1898)], or the dead-stop end-point method of C. W. Foulk and A. Bawden [JACS 48, 2045(1926)].

Heyrovsky and Berezický (Ref 1) were the first to perform titrations based on the measurement of polargraphic diffusion currents and they used the term polarographic titration. Majer (Ref 2) simplified the technique by measuring diffusion currents at a constantly applied emf rather than recording a series of polarograms, and proposed the name polarometric titration. Kolthoff and Pan (Ref 4) proposed the term amperometric titration as more consistent with the terminology applied to other electrometric titrations, such as potentionometric and conductometric.

Amperometric titrations can be conducted either with a dropping mercury electrode or with rotating platinum electrodes. Both procedures are described by Laitinen (Ref 8) and by others (see References given by Laitinen).


Amphibious Cargo Vehicle (BARC). See under Amphibious Trucks, Tractors and other Vehicles

Amphibious Devices for Tanks. During landing operations troops and their equipment are particularly vulnerable to enemy fire until they have arrived on the beach and have been able to set up their weapons for defence. Amphibious trucks (qv) were designed for bringing troops, weapons and supplies, and amphibious devices were developed to allow the tanks to move from ships to shore a few miles away. The first of these devices, called D3 Device, was developed in England and then produced in the US for the invasion of France during WW II. The device consisted of a canvas framework (resembling a boat) attached to the top of a tank, thereby giving it the necessary flotation. A propeller arrangement was attached to the tank engine so that the ensemble could move under its own power. When not in use, the canvas folded down on top of the tank. The disadvantage of this device was that the tank and its occupants were submerged about 20 ft under water and the tank weapons could not be fired while moving through the water. In addition, the canvas framework was very vulnerable to wave action.

An improved amphibious device was developed in the USA. It consisted of metal boxes filled with plastic foam and attached to the front, rear and sides of the tank in such a manner that they could be detached from the tank by the crew without getting out. The tank was propelled through the water at speeds up to 6 mph by simply driving the tanks in the normal manner. The advantages of this system were that the tank turret was above water and the weapons could be fired if necessary on approaching the enemy’s shore. This device was used for light and medium tanks (See also Amphibious Vehicles and Amphitrack)


Amphibious Vehicles are vehicles which can propel themselves through water and on land. Among these vehicles may be listed amphibious trucks which were made by installing amphibious bodies (resembling boats) on trucks. The smallest truck was 1/4 ton and the largest 2 1/2 tons. The latter truck was nicknamed...
Dukw (Refs 1 & 2). These vehicles proved to be very valuable during WW II for bringing men, weapons and supplies ashore from ships anchored beyond the range of enemy land-based guns. The amphibious vehicle BARC is the largest wheeled vehicle (60 tons) utilized by the US Army. When in the water it resembles a boat. The BARC can haul large bulky cargoes (see also Amphtrack).


**Amphipathic Substance.** Same as Surface-active Substance

**Amphoteric Substance.** A substance having both acid and basic props, such as aminoacids, alkali hydroxide, etc

Ref: Hackh (1944), 50

**Amphibian**. An amphibious track vehicle developed in the USA during WW II. This vehicle could land troops, carry supplies and weapons across the water and its armament is used for returning fire in the face of intense hostile resistance. Several models are described by V. J. Croizat in the Army Ordn 31, 365-7 (Nov-Dec 1946)

**Ampoule (Chemical)** (also Ampule or Ampul). In addition to the usual meaning of a small sealed vessel for holding a liquid, this term was found listed without definition in a British paper entitled a "Comprehensive List of Government Explosives," 1955, Admiralty BR 819 (19/54), War Office Code No 11155

**AMT-2504** is a code name for a rubber composite propellant described in classified "Propellant Manual SPIA/M2," The Johns Hopkins Univ, Silver Spring, Md (1959), Unit No 515

**AMT-2035AX-3; AMT-2091-AX; AMT-2096-4AX; AMT-2106-AX and AMT-2109-BT** are code names for fuel-oxidizer propellants described in classified "Propellant Manual SPIA/M2," (1959), Unit Nos 470, 473, 474, 475 and 476

**AMTB.** See Anti-Motor-Torpedo Boat

**Amvis (Explosive).** A Brit "permitted" expl patented in 1896 by W. J. Orsman and manufd beginning 1897 for some time by the Roburite Explosives Co. Its compn was: AN 88 to 91, DNB or chloronaphthalene 4 to 6 and wood flour 4 to 6%. It was packed in paper cartridges waterproofed by means of ceresine. A detonator contg 1 g of 95/5-MF/KClO₃ mixt was used for its initiation. Colver (Ref 2) gives the following compn for Amvis Powder: AN 90, chlorodinitrobenzene 5 and wood meal 5%

**AMYL ACETATES**

Amyl Acetate or Amylacetic Ester (commonly known as Banana Oil), CH₃·CH₂·CH₂·CH₃·COOCH₃, mw 130.18. Several isomers are known of which n-amyl acetate and isoamyl acetate are the most important. They can be prepd by heating amyl alcohols with acetic acid in the presence of some sulfuric acid. Industrial methods of prepn are given in Ref 9, pp 102-3. Commercial products are usually mixts of n- and iso-amyl acetates. When amyl acetate is prepd from "fusel oil" (a by-product obtained in the manuf of ethyl alc by fermentation), the chief component is isoamyl acetate

n-Amyl Acetate, CH₃·CH₂·CH₂·CH₂·CH₃·COOCH₃. Col liq with a pear-like banana-like odor, d 0.879 20/20°, mp -70.8°, bp 148.4° at 737 mm, fl p (closed cup) 77°F (25°), ignition temp 750°F (399), LEL (lower expln limit) in air 1.1% by vol, n²0 1.4012. Sol in w(0.2% at D)

iso-Amyl Acetate, (CH₃)₂CH·CH₂·CH₃·COOCH₃. Col liq with banana-like odor, d 0.876 15°/4°, mp -78.5°, bp 142° at 757 mm, fl p (closed cup) 92°F (ca 33°), ignition temp 710°F (ca 380°), Prepd from iso-amyl alcohol and acetic acid in the presence of some sulfuric acid.

**1004.9 cal/g and Qₜ is 1011 cal/g (Ref 7,p 310)**

iso-Amyl Acetate, (CH₃)₂CH·CH₂·CH₃·COOCH₃. Col liq with banana-like odor, d 0.876 15°/4°, mp -78.5°, bp 142° at 757 mm, fl p (closed cup) 92°F (ca 33°), ignition temp 710°F (ca 380°), Prepd from iso-amyl alcohol and acetic acid in the presence of some sulfuric acid.
Amyl acetates are dangerous when exposed to flame or heat. When heated they emit acrid fumes. Their explosive hazard is moderate (Ref 8). Toxicity is discussed in Refs 6 & 8. Ritter et al (Ref 3a) determined the temp at which mixts of air with satd vapor of amyl acetate (in contact with some of the liq) in a stopped flask are explosive. Pressure of expln was also determined. Amyl acetates are used for the manuf of fruit essences and as high-boiling solvent constituents of lacquers and other coating materials (Refs 5 & 9). They were also used as colloidal agents for NC (Refs 2, 3 & 4) employed in the manuf of smokeless propellants. For instance, one of the US shot-gun propellants was prepd by agitating at RT (in a jacketed vessel) a pulped, wet NC (contg 5% Ba nitrate & 2% K nitrate) with an emulsion of amyl acetate and water (contg some Ba- and K nitrate). After allowing to stand for a few minutes, the steam was turned into the jacket and agitation continued for 5-6 hours during which time most of the amyl acetate and some water were distilled off. The contents of the vessel were then run out and the grains of propellant dried and sieved (Ref 3). Refs: 1) Beil 2; 131-2 (60-1) & [143-4] 2) Marshall 1(1917),336 3) Barnett (1919),82 3a) R. Ritter et al, Jahresber CTR 8,201-2 (1930) & CA 26,4474(1932) 4) Davis (1943), 321 5) Kirk & Othmer 5(1950),826 6) Ibid 7 (1951),854 7) P. Tavernier, MP 38,310 (1956) 8) Sax(1957),287 9) Faith, Keyes & Clark(1957),102-3 10) US Specification TT-A-516 (Amyl acetate for use in organic coatings)

Iso-Amylacetyl Azide ([isoamy]essigsäure-azid, in Ger), (CH₃)₃CH-CH₂-CH₂-CO-N₃, mw 141.17, N 29.77%. Oil with a pungent odor, puffs off when heated on a spatula; easily sol in alc, ether and some other org solvents. Can be prepd by treating an aq soln of HCl salt of isoamylacetylhydrazide with NaNO₂ + HCl.

Refs: 1) Beil — not found 2) J. Curtius, JPraktChem 125,159-60(1930) & CA 24, 3217 (1930)

AMYL ALCOHOLS

Amyl Alcohol, C₆H₁₁OH, mw 88.15. Eight isomers are known, all of them liquid except 2,2-dimethylpropanol, which is a solid. They are sl sol in water and miscible with oils or org solvents, such as alcs, esters, ethers, ketones and aromatic hydrocarbons. Its most important isomers are:

n-Amyl Alcohol; 1-Pentanol or n-Butylcarbinol, CH₃·CH₂·CH₂·CH₂·CH₂·OH. Col liq with a mild odor, d 0.824 20°/20°, mp –79°, bp 138.10, f.p (closed cup) 100°F (ca 38°), ignition temp 700°F (371°C), LEL 1.2% by vol in air, nD²⁰ 1.4581 and sp heat 793.7 kcal/mol, while its QP calc by Taverner (Ref 6, p 309), is 980 cal/g.

iso-Amyl Alcohol; iso-Butylcarbinol or 3-Methyl-1-butanol, (CH₃)₂·CH·CH₂·CH₂·OH. Col liq with a mild odor, d 0.813 15°/4°, mp –117.2°, bp 132.0°, f.p (closed cup) 114°F (ca 46°), ignition temp 450°F (232°C), nD²⁰ 1.41

Amyl alcohols can be prepd either from fusel oil or by a synthetic method which involves hydrolysis of amyl chloride, which in turn is prepd by the chlorination of a mixt of pentane and isopentane obtained from petroleum. The alc prepd by synthetic method has, according to Ref 5, p 147, the following props: d 0.812 to 0.820 20°/20°, boiling range 120 to 130°, nD²⁰ 1.409 and f.p (open cup) 113°F (45°).

Industrial methods for the prepn of amyl alcohols are discussed in Ref 8.

Their fire hazard and toxicity are given in Ref 7. The explosion hazard of amyl alcohols is moderate when exposed to flame (Ref 7). Ritter et al (Ref 3a) determined the temp at which mixts of air with satd vapor of amyl alcohol (in contact with some of the liq) in a stopped flask is explosive. Pressure of expln was also measured.

Amyl alcohols are used as solvents for lacquers.
and for the manuf of amyl acetates. At the end of WW II amyl alcohols and their derivatives were replaced to a great extent by other solvents such as methyl-isobutyl ketone and butyl alcohols and their derivatives (Ref 8, p 113)

Amyl alcohol was used in France, beginning in 1896–7, as a stabilizer for the military propellant called Poudre B and were known as Poudres B(AM). The propellants were prepd from a mixt of sol and insol NC gelatinized with ether-alcohol to which some amyl alcohol was added. After incorporation, the mass was worked between rollers at 70° and the rolled sheets either cut into strips or extruded through a die into ribbons. It was then dried at 50° and washed with water. Amyl alc being less volatile than ether-alc remained in the finished product. Poudre B (AM₉), used for small caliber guns, contained 2% of amyl alcohol, whereas Poudre B(AM₉₈) used for large naval guns contained 8% of amyl alcohol as a stabilizer. These propellants became porous in storage because part of the stabilizer evaporated. Experience showed that amyl alcohol acted only as a temporary stabilizer. Several disastrous explns of Poudres B(AM) occurred. The most notable were the total destruction of the French battleships, the Iena in 1907 and the Liberte in 1911. At first the explns were attributed to appreciable loss of the stabilizer because of volatility. Later, it was realized that while amyl alcohol reacts with nitrogen oxides liberated from deteriorating propellant to form amyl nitrate or nitrite, these in turn were not very stable in the presence of acidic decomposition products and would decomp with the liberation of oxides of nitrogen which would further accelerate the decomposition of the propellant. Since any aliphatic alcohol could be expected to behave similarly, subsequent stabilizers were made from aromatic compds or derivatives which formed stable NO₂ compounds with oxides of nitrogen


Note: Nitration of amyl alcohol with mixed acid at low temp to obtain C₆H₁₃NO₂ is described by J. B. Hinkamp et al, USP 2, 618, 650 (1952) & CA 48, 1412(1954)

**AMYLAMINE AND DERIVATIVES**

Amylamine; Aminopentane; Aminomethylbutane, C₆H₁₃-NH₂. Several isomers are known, including isoamylamine, (CH₃)₂-CH·-CH₂·CH₃·NH₂. They can be prepd by the reaction of amyl chlorides with ammonia in the presence of alcohol as a mutual solvent. Datta & Chatterjee (Ref 2) detd expln temps of amylamine picrate and amylamine perchlorate and found them to be 270° and 262°, respectively


[α-Nitroisoamyl]-isonitramine, called by Traube Nitropentylisonitramin, (CH₃)₆ CH·-CH₂·CH(NO₂)₃ · N₂H. Prepd as the Na salt from 4-nitro-2-methylbutane, 2 mols NaO-CH₃ and NO. By treating aq solns of the Na salt with Ba(OH)₂ (or BaCl₂), CuSO₄ and Pb(CH₃COO)₂, ppts of explosive Ba-, Cu- and Pb-nitroisoaminitranitramine were obtained

Refs: 1) Beil 1, 687 2) W. Traube, Ann 110, (1898)

Amylazide; Azidopentane; Azidomethylbutane or Methyltriazobutane, C₆H₁₃N₃, mw 113.16, N 37.14%. The isomer 1-Azidopentane or d-1-Azido-2-methylbutane, N₃H₂·C·CH(CH₃)·CH₃·CH₃, liq bp 72° at 138 mm, d 0.8770
at 25/4°C (Ref 2) & 0.8695 at 25°C (Ref 4);
\[ n^D_2 = 1.4240 \] (Ref 2) & 1.4248 (Ref 4); 
\[ Q^D_\text{f} = -36.1 \text{ kcal/mol} \] (Ref 5).
Refs 2 & 3 give optical rotations and Ref 4 viscosities from 15 to 45°C.
The expl props of amylazide were not investigated.


Amylenezoinide, \( C_3H_{10}O_3 \); col viscous liq expldg on moderate heating. Was prepd by ozonization of amylene dissolved in dry hexane cooled in salt-ice mixt. The resulting mixt was distilled in vacuo to remove the hexane. The product was called 'Normales Ozonid.' Another ozonide corresponding to the formula between \( C_3H_{10}O_3 \) & \( C_3H_9O_4 \) was prepd from the crude product as described in Ref 2, p 3100. This ozonide expd more violently than the \( C_3H_9O_3 \)

Refr: 1)Beil - not found 2)C.Harries & K.Haeffner, Ber 41,3099-3100(1908) & CA 3, 66(1909)

Amylether; Diamylether or Amyloxide, 
\( (C_6H_{13})_2O \), mw 158.28. Several isomers are known. The commercial product is a mixt, principally of isoamy ether and n-amylether, formed as a by-product in the manuf of amy alcohol from amyl chloride (Ref 2). This ether is a clear and sl yell liq, d 0.78-0.81 
\[ 20^0/20^0, \] mp <75°C, boiling range 165-210°C, fl p(open cup) ca 135°F(57°C), n^D_2 1.42.

Very sl sol in w and miscible with alc or ether. Its fire hazard is moderate when exposed to heat or flame. Toxicity details unknown (Ref 4). It is used principally as a solvent. When mixed with 15-20% of ethanol it dissolves ethylcellulose but not NC


AMYLGUANIDINE AND DERIVATIVES

\( n \)-Amyluanidine, \( CH_3(CH_2)_xNH-C(-NH)-NH_2 \), is listed in Beil 4,[642]

1-Nitro-3-n-amylguanidine (NAmGu), \( CH_3(CH_2)_xNH-C(-NH)-NHNO_2 \), mw 174.20, N 32.17%. Col leaflets, mp 98.8-99.3°C; sl sol in alc, very diff sol in ether and cold w, decomp slowly in hot w. Was prepd by heating NGu at 60-70°C with 10% aq soln of amylamine. Its \( Q^f \) is 1004 kcal/mol(obs) and 884.8 kcal/mol(calcld)

Refr: 1)Beil 4,[642] 2)T.L.Davis & S.B. Luce, JACS 49,2304(1927) 3)A.D.Little, expd more violently than the Cs

Refr: 1)Beil 4,[644] 2)T.L.Davis & S.B. Luce, JACS 49,2304(1927)

1-Nitro-3-tert-amylguanidine, \( CH_3(CH_2)_xNH-C(C(CH_3)_2)-NH-C(-NH)-NHNO_2 \). Col plates, mp 154.8-155.6°C; sl sol in alc and very dif in ether and cold w, decomp slowly in hot w. Was prepd by heating NGu at 60-70°C with a 10% aq soln of tert-amyamine

Refr: 1)Beil 4,[644] 2)T.L.Davis & S.B. Luce, JACS 49,2304(1927)

1-Nitro-3-iso-amylguanidine, \( (C_6H_{13})_2CH(CH_2)_xNH-C(-NH)-NHNO_2 \), Col ndls, mp 145.5-146.2°C. Was prepd by heating NGu at 60-70°C with a 10% aq soln of tert-amyamine

Refr: 1)Beil 4,[644] 2)T.L.Davis & S.B. Luce, JACS 49,2304(1927)

Dinitroamnylguanidine, \( C_6H_{13}N_2O_4 \), mw 219.20, N 31.95% - not found in Beil or CA through 1956(would probably be a weak explosive)

Amylmonaloylazidic Acid(IsoamyIalonazid säure, in Ger),\( (C_6H_{13})_2CH(CH_2)_xCH_2-CH(CO-N_2H)-COOH, \) mw 199.21, N 21.10%. Lt yell oil expldg weakly when heated on a spatula. Diff sol in w, sol in alc and very sol in eth or chlf. Can be prepd by treating an aq soln of the K salt of isoamylmonaloylhydrazidic acid with HCl+NaNO_3

Refr: 1)Beil - not found 2)T.Curtius & W.Wirbatz, JPraktChem 125, 274(1930) & CA 24, 3216(1930)
Amyl Nitrate (Mixed Isomers), $\text{C}_6\text{H}_{11}\cdot\text{ONO}_2$, mw 133.15, N 10.52%. Col to pale yel, liq with ethereal odor, bp 145 to 156$^\circ$, d 0.99, fl p 118°F. Can be prepd by treating commercial amyl alcohol with mixed nitric-sulfuric acid. Its main constituent is isoamyl nitrate, $\text{C}_6\text{H}_{11}\cdot\text{CH}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{ONO}_2$ called in Ger "Isoamyl Nitrat" or "Salpetrigsaure-isoamyl-ester." It is col to pale yel liq, bp 147-8$^\circ$, and d 0.996 at 21.7$^\circ$; very sl sol in w and insol in alc or eth. Was first obtained, accdg to Beil, in 1847-8 by Rieckner (Ref 1). A commercial method of prepn of isoamyl nitrate was patented during WW II by Olin (Ref 2). Vapor pressures in mm Hg at various temps are given for commercial product in Ref 4. They are 0.9 mm at 10$^\circ$, 2.7 at 20$^\circ$, 5.15 at 30$^\circ$, 9.7 at 40$^\circ$, 17.4 at 50$^\circ$, 29.7 at 60$^\circ$, 70.5 at 80$^\circ$, 166 at 100$^\circ$, 335 at 120$^\circ$, 612 at 140$^\circ$ and 760 at 147.5$^\circ$. Values given in Ref 5 are 1.6 mm at -10$^\circ$, 2.4 at 0$^\circ$ and 3.3 at 10$^\circ$.

Commercial amyl nitrate has been used as an ignition accelerator for compression-ignition engine fuels (Ref 3). It also was investigated as a possible monofuel in rocket or ATO engines but found to be unsuitable. Amyl nitrate is capable of decompn on a Ni catalyst but the reaction is barely self-sustaining and large quantities of soot are deposited which quickly choke the pipes of motors (Ref 4).


Amyl Nitrite, $\text{C}_6\text{H}_{11}\cdot\text{ONO}$, mw 117.15, N 11.96%, exists in several isomeric forms of which isoamyl nitrite (Isoamyl nitrit or Salpetrigsaure-isoamyl-ester, in Ger), $\text{C}_6\text{H}_{11}\cdot\text{CH}\cdot\text{CH}_2\cdot\text{CH}_2\cdot\text{O}-\text{NO}$, is the most important. It is a pale yel liq with an ethereal odor, bp 99$^\circ$, d 0.8528 at 20$^\circ$/40, n$^D$ 1.38708. Sl sol in w and miscible with alc or eth. Can be prepd by treating isoamyl alcohol with a mixt of NaNO$_2$ + H$_2$SO$_4$ + H$_2$O or by other methods (Ref 1). A detailed description of a lab procedure for the prepn of isobutyl nitrite is given in OrgSynth (Ref 3) and this method is suitable for the prepn of isoamyl nitrite. Its QP is 812.64 kcal/mol and its Q$^T$ is 44.66 kcal/mol (Ref 2). Its ignition temp in air is 408°F(209$^\circ$) and in oxygen 396$^\circ$F(202$^\circ$) (Ref 4); temp range of flammability in air extends from 45.5$^\circ$ to 134.1$^\circ$F (Refs 5 & 6). More info on limits of inflammability can be found in Ref 6.

Amyl nitrite is used as a first aid treatment (by inhalation) until intravenous injec- tions can be given. Its inhalation into the lungs presents, however, a danger because it might form an expl mixt with air (Refs 5 & 6).


Amylodextrin is an intermediate product of acid degradation(hydrolysis) of starch. It is
sol in water and gives a blue coloration with iodine. The final product of hydrolysis is D-glucose.


Amyloid, $(C_{6}H_{10}O_{5})_{x}$, has $m.w. (162.14)$. Marshall (Ref 2, p 150) calls it "hydrocellulose" and gives its formula as $C_{12}H_{22}O_{11}$. It is a gelatinous cellulose hydrate produced when a freshly prepared solution of cellulose in concentrated sulfuric acid is diluted with water. Amyloid is 13.25% of which was attacked by hot alkali to a smaller degree than amylose nitrate.


Amylose (also called Polyamylose) is a linear polymer with the formula $(C_{6}H_{10}O_{5})_{x}$. It consists of 200-1000 glucose units joined together through $\alpha$-1,4-glucoside linkages. Its structural formula is given in Ref 8, p 766. It is a white substance present in starch granules together with amylopectin (qv). Amylose may be separated from amylopectin by fractionating starch. Most existing methods of fractionating employ swelling agents which may bring about hydrolysis of glucosidic linkages so that the products isolated from starch may not be the true constituents of native starch. The "selective absorption method" employed by Ashford et al (Revs 5 & 6) in the study of starch avoids the use of harsh swelling agents but employs adsorbing agents (such as cotton activated charcoal or Fuller's earth) to remove amylose from amylopectin when in aqueous solution. The cotton-amylose adsorbate is formed instantly when a cold corn starch paste (2%) is brought into contact with cotton and can be washed free of amylopectin with water. The cotton-adsorbate is then readily decomposed by boiling water to give a clear solution of amylose and the solid is obtained by concentrating the solution to

ca $\frac{1}{10}$ of the original vol at a temp not exceeding 55°, adding an equal vol of alc, separating the flocculent amylose by centrifuging and grinding the product under absol alc. The soln of amylopectin was concd to ca $\frac{1}{10}$ at 50–55° and 20–25 mm Hg and treated with an equal vol of alc. The resulting flocculent ppt was centrifuged, dehydrated with alc, washed with ether and dried in a desiccator (Ref 5, pp 248 & 251–2).

Nitration of amylose was carried out according to the Will & Lenze method, using mixed nitric-sulfuric acid as described under nitration of starch (Ref 4). The resulting product had $N=12.96\%$, soly in alc 20% and stability (by Abel and Bergmann-Junk tests) higher than for aminopolymer nitrate (Ref 5). In the later paper (Ref 6), Ashford et al described amylose nitrate with $N=13.25\%$. Hot alkali attacked it slightly more than amylopectin nitrate.

The purpose of Ashford et al (Ref 5) in fractionating corn starch was to obtain homogeneous products giving on nitration more stable products than crude starch. This was accomplished to a certain degree. In order to make possible a more thorough study of the props of amylose and amylopectin, a fractionation of nitrated starch was undertaken and a study was made of the characteristics of the resulting amylose nitrate and amylopectin nitrate. Separation of these two products was achieved by fractional disso-lution, employing alcohol as a solvent. A detailed description of the procedure is given in Ref 5, p 252. The separated nitrates of amylose and amylopectin had props similar to the nitrated starch fractions.

Amylose and its nitrated starch products were also studied by Pringsheim et al (Ref 2). They claimed that nitration of amylose, even with a large excess of nitrating acid, always gave a mixt of compds nitrated to varying degrees. The yield of crude nitrates was always good. On superheating the solns, they often spontaneously underwent decompn with evoln of nitrous fumes. All the nitrates described in Ref 2 were unstable. They became yel in a desiccator and finally lost up to 75% of the N.

Refs: 1) Beil — not found
2) H. Pringsheim, Ber 58, 1889–93 (1925) & CA 20, 380 (1925)
3) Hackh (1944), 53
5) Ibid 248–53 (1946)
7) Merriam-Webster's Unabridged Dictionary (1951), 92
8) Kirk & Othmer 12 (1954), 764 & 766 (under Starch)

Amyloide. See Amylether

Amylphthalate. See Diamyphthalate

iso-Amypicrate or iso-Amyl-(2,4,6-trinitrophenyl)ether (Pikrinsäureisooamyläther, in Ger), $\text{C}_6\text{H}_4\cdot\text{O}\cdot\text{C}_4\text{H}_6\text{N}_3\cdot\text{C}_6\text{H}_5\cdot\text{O}_2\text{C}_6\text{H}_5\cdot\text{C}_6\text{H}_5\cdot\text{O}$, mw 299.24, $N = 14.04\%$. Nearly col hexagonal plates, mp 68–9°. It is decompd by air but may be stored in a vacuum; decompd by water or acids. Can be prepd by treating dipicrylsulfide with boiling sodium isoamylate

Reqs: 1) Beil 6, 290 & [281]
2) C. L. Jackson & W. F. Boos, Am Chem J 20, 452 (1898) & JCS 125, 199 (1898)
AN. Abbreviation for Ammonium Nitrate

AN-507. A resin-based solid rocket propel- lant contg Amm perchlorate 75 and fuel 25%. The fuel consists of styrene 50 & "A-10 Polyester Resin" 50%. The d of AN-507 is 0.058 lb/in.\(^3\), Isp 195 secs, burning rate 0.365 in/sec, temp sensitivity 0.16%/\(^\circ\)F. Its smoke is light
Ref: Armament Engr(1954),42

AnAc. Ger designation of ethylidenaniline (Äthylidenanilin, in Ger),\(\text{C}_6\text{H}_5\text{CH}-\text{N-C}_6\text{H}_5\), which was used during WW II as one of the numerous fuels in liquid propellants
Ref: Dr H.Walter, PicArsn; private communica-

AN-525; AN-525J; AN-557; AN-565J; AN-579Y; AN-581W; AN-583AF; AN-584J.
Code names for cast fuel-oxidizer powders described in classified "Propellant Manual SPIA/M2,'', The Johns Hopkins Univ, Silver Spring, Md(1959), Unit Nos 2, 255, 299, 256, 356, 357, 358 & 359

AN-586Y; AN-628BF; AN-2011; AN-2017; AN-2030; AN-2035AX; AN-2502EB.
Code names for fuel-oxidizer propellants described in classified "Propellant Manual SPIA/M2'" (1959), Unit Nos 477, 478, 257, 298, 360, 479 & 489

Anagon Powder(Anagon-Sprengpulver, in Ger).
According to Escales(Ref 1) it is a mixt of neutral inorg nitrates with pulverized Al, charcoal & alizarin or resinified linseed oil. Mêdar(Ref 2) gives compn of Anagon as: AN 84.5, K nitrate 1.5, Al 5.5, charcoal 8.0 & Ba nitrate 0.5%
Refs: 1)Escales, Ammonsprengstoffe(1909), 104 2)L. Mêdar, MAF 22,596(1948)

"Analmatch" is an automatic lab system which does away with routine lab work. This system was invented by the Ger firm Achema and is now available in US through Chicago Apparatus Co
Ref: Anon, C&EN 36, 48(9 June 1948)

ANALYTICAL CHEMISTRY

Following is a selected list of books on this subject:

Analytical Procedures for Acids. See under individual acids, such as Acetic Acid, Nitric Acid, Sulfuric Acid, etc and also under explosives and propellants for manuf of which these acids are used

Analytical Procedures for Explosives and for Primary Materials Used for their Manufacture are described under corresponding primary materials, such as Aniline, Anisole, Benzene, Toluene, etc

Analytical Procedures for Propellants are described under Propellants

Anarchists' and Revolutionists' Explosives and Weapons. See Explosives and Weapons Used by Anarchists and Revolutionists

Anasite. An expl compn consisting of AN, K nitrate, myrobalans and a small amt of agar-agar
Ref: CondChemDict(1942), 287 (not listed in newer editions)

ANB. Code name for a cast double-base propellant described in classified "Propellant Manual SPIA/M2," Johns Hopkins Univ, SilverSpring, Md (1959), Unit No 407

Anbenyaku. A Japanese expl: AN 55 & DNB 45% used during WW II as a bursting chge in some projectiles. It was manufd at Nanman Arsenal, Manchuria, under the name of Sho- benyaku (Refs 1 & 2). A blasting expl also called Anbenyaku was patented after WW II by Watanake. It consisted of AN 71.7%, NG 8.0%, CC 0.3% & powdered seaweed (Ref 3)
Ref: 1) G.C. Tibbitts et al, PB Rept 50394 (1945) 2) R.A. Cooley et al, PBL Rept 53045 (1945) 3) T. Watanabe, JapP 176,113 (1948) & CA 45,4930 (1951)

Anchorite. One of the Brit "permitted" expls: AN 34, Na Nitrate 33, TNT 12, Amm chloride 20 & moisture 1%; max chge 14 oz; ballistic pendulum swing by 4 oz of expl 2.73" vs 3.27" for std Gelignite contg 60% NG
Ref: Barnett (1919), 132

Anderson's Explosives, patented in 1908 in Denmark had the following compositions:
a) Pb peroxide 60 & PA 40% b) Pb peroxide 45, PA 20, TNT 10, GC 15 and NG 10%
Ref: Colver (1918), 324–5
Andre's Explosive, patented in 1895, contained AN 85, K nitrate 3 and wood flour 12% of Electronite No 2
Ref: Daniel(1902),28

ANE. Code name for a cast double-base propellant described in classified 'Propellant Manual SPIA/M2' (1959), Unit No 408

Anello di forzamento(Ital). Driving band(of a projectile)

Anello graduato(Anello mobile) (Ital). Time ring(of a fuze)

Anello superiore della spoletta(Ital). Upper time train ring


Anethole, p-Allylphenylmethylether or p-Propenylanisole(''Anisoin'', or 'Anise Camphor''),CH₂CH:CH·CH₃OCH₃. Wh crystals tending to melt at warm RT. It was brought into contact with air or oxygen. The first org compd to be treated with fuming nitric acid to produce a nitrocompound. This nitrocompd[C₁₀H₁₂(NO₃)ₓ]ₙ, mw 222.20, N₁₂.60%, was prepd in 1842 by Cahours(Ref 2) and is called in Beil "Dinitroanisoin,' because the name of polymeric anethole (C₁₀H₁₂O)ₓ is 'anisoin'. Anethole combines with PA to yield a mild expl, C₁₀H₁₂O+C₄H₇N₃O₇, red ndls(from alc), mp 70°(decomp) Refs: 1)Beil 6,566-70,(280-1) & [522-3] 2)A.Cahours,Ann 57,73(1842) 3)Colver (1918),82-3


Angayaku. Japanese expl comps: a)AN/RDX-75/25, 78/22 or 84/16 b)GuN/RDX/AN-34/15/51 or 32/20/48 used during WW II. All of them were white, nontoxic mixts comparable in performance to amatols. The expls(a) were used for press-filling some bombs, while expls(b) were used for cast-loading some shells and bombs. It was claimed that expls(b) had low coefficient of shrinkage and therefore could be poured in quite large casts in a single pour, whereas
with similar expls based on TNT, it was necessary to break down between increments in the larger casts

Refs: 1)Anon, OpNav 30-3M(1945),27
2)Anon, Allied and Enemy Explosives,Aberdeen Proving Ground,Md(1946),135 3)G.C. Tibbitts et al, PB Rept 50394(1946),48 & 62 and Appendix A

Angeli, Angelo (1864–1931) An Italian professor of chemistry who made some contribution to the explosives industry (See ''Angeli Test'' below) Ref: L.Cambi,Gazz 63,527–60(1933) & CA 28,1231(1934) (An obituary and a bibliography of Angeli's 238 publications from 1889 to 1931)

Angeli Test (Saggio Angeli in Ital) (Detection of Acidity in NC Propellants). The presence of small amounts of acids, which are not easily detectable by indicator papers or by means of tests involving heating may readily be detected by the following procedure:

Cut ca 0.5g of sample in very thin slices (shavings), place them in a small beaker and add a few ml of dest w contg 3–4 drops of 0.2% alc soln of p-dimethylaminoazobenzene (''butter yellow''), (CH₃)₂N::C₆H₄N::C₆H₄, serving as an indicator.

Stir the mixt in cold and observe the color of the shavings: if it is yellow, the sample is alkaline, if it is red, the sample is acid and if the color is buff, the sample is neutral. In the last case it is advisable to heat the mixt slightly in order to be sure that the sample is neutral. If the sample is acidic, the degree of reddening indicates the extent of decompn of the propellant. If the red color appears and then disappears almost immediately, it might indicate that the material is in an advanced stage of decompn and that oxides of nitrogen, being evolved during the test, are attacking the indicator with probable formation of a compd such as (CH₃)₂::NR:C₆H₄N::NH-C₆H₄(?), where R is the acid group (Ref 2)

This test can also be used for deter acidity or alkalinity of expls

If it is required to examine the decomposing effects of light on expls or propellants, the same test can be used and if the resulting coloration is too intensely red, a weaker soln of indicator is advisable.

Refs: 1)A.Angeli, Atti R Accad, Lincei 27, 164(1918); JSCI 37,608A(1918) & CA 13, 262(1919) 2)A.Angeli & G.Erani, Gazz 50 I, 139(1920) & CA 14,2858(1920) 3)A.Angeli, SS 17,115(1922) & CA 16,4064(1922) 4)Molina(1930),428–30 5)Reilly(1938),90

Ångström, A.J. (1814–1874) A Swedish physicist, noted for optical research. He proposed a unit of wave length equal to 10⁻⁷ m. This unit is called the ångström and is abbreviated to Å, Å or AU

Ref: Hackh(1944),57

ANH. Code name of a cast double-base propellant described in classified ''Propellant Manual SPIA/M2,'', Johns Hopkins Univ, SilverSpring, Md(1959), Unit No 409

Anhydro-[cortarinine-(2,4,6-trinitrotoluene)] or 1’-(2,4,6-Trinitrobenzyl)-hydrocotarine

\[
\begin{align*}
&\text{H}_2\text{C}_6\text{O} \quad (\text{OCH}_3) \quad \text{CH}_2\text{C}_6\text{H}_4\text{(NO}_2)_3 \\
&\text{HC} \quad \text{CH} \quad \text{N} \quad \text{CH}_3 \\
&\text{H}_2\text{C} \quad \text{C} \quad \text{H}_2
\end{align*}
\]

mw 446.37, N 12.55%. Yel prisms, by pptg with MeOH from chloroformic soln; melts when slowly heated to 130°C with expl decompn. Sparingly sol in most neutral solvents but readily dissolves in cold chlf. Can be prepd by grinding a mixt of TNT, alc and cortarine

Refs: 1)Beil 27,(459) 2)E.Hope & R. Robinson, JCS 99,2133(1911)

Anhydroacetoneurea or 2-Oxo-4,4,6-trimethyltetrahydropyrimidine

\[
\begin{align*}
&\text{H}_2\text{C}_6\text{C} \quad \text{C} \quad \text{NH} \quad \text{CO} \\
&\text{HC} \quad \text{C} \quad \text{NH}_2 \\
&\text{(CH}_3)₂
\end{align*}
\]

when nitrated with mixed nitric sulfuric acid yielded Trinitroanhydroacetoneurea, C₈H₆N₂O(NO₂)₃, mw 275.18, N 25.45%. Wh ndls(from alc), which flash when heated in a flame. It is diff sol in cold w and decmp by boiling w. Its Ag and Ba salts are powerful expls
Ref:s: 1)Beil 24,71 2)W.Traube & H. Lorenz, Ber 32,3161-3(1899)

**ANHYDROENNEAHEPTITOL AND DERIVATIVES**

Anhydroenneaheptitol or Tetrahydro-3,3,5,5-tetrakis(hydroxymethyl)-4-oxopyrane,C₆H₁₄O₆, mw 222.23. Wh crysts (from alc), mp 156°. Can be prepd by the interaction of acetone with a large excess of formaldehyde in water in the presence of slaked lime as a condensing agent(Ref 1-4). Its Qᵦ is 1158.1 kcal/mol and QЄ 300.0 kcal/mol(Ref 5)


**ANHYDROENNEAHEPTITOL**

Anhydroenneaheptitol, Azido-C₆H₁₄N₂O₆ and Diazido-C₆H₁₄N₂O₆ Derivatives were not found in Beil or CA through 1956

Anhydroenneaheptitol, Mononitro- C₆H₁₄N₂O₆

Dinitro- C₆H₁₄N₂O₁₀

Trinitro- C₆H₁₄N₃O₁₂

and Tetrinitro- C₆H₁₄N₄O₁₄ Derivatives were not found in Beil or CA through 1956

Anhydroenneaheptitol Pentanitrate(AEHP) or Tetranitroxy-3,3,5,5-tetrakis(nitroxyethyl)-4-oxopyrane, called also 2H-Pyran-3,3,5,5-(4H,6H)-tetramethanol; 2,2,4,4-Tetrakis(hydroxymethylnitrate)-1-pyran-1-nitrate (Pentanitrate de l’anhydro-ennéaheptite, in French),

\[ (\text{O}_2\text{NO}_2\text{H}_2\text{C}_6 \text{C} = \text{C} (\text{ON}_2\text{O})_2 - \text{C} (\text{CH}_2\cdot\text{ONO}_2)_2, \text{H}_3\text{C} = \text{O} \) ———— \text{CH}_2 \]

mw 447.23, N 15.64%, OB to CO₂ -30.4%, OB to CO +1.8%. Crysts, mp 132.5-136°; explodes at higher temps. Can be prepd by nitration of AEH as described in Refs 2 & 4. It was patented by von Herz for use in blasting caps(Ref 2). He claimed that AEHP possessed greater brisance and lower sensibility than PETN. According to Blatt(Ref 3), the power of AEHP, detd by ballistic mortar, is 137% of TNT and the impact sensibility, when detd with BurMines app and 2 kg wt, is 30 cm vs 16 cm for PETN. Mécard & Thomas (Ref 5) give for Qᵦ at 18° 1105.2 kcal/mol and QЄ 184.1 kcal/mol


**ANHYDROFORMALDEHYDEANILINE AND DERIVATIVES**

Anhydroformaldehydeaniline; Trimeric Methyleneaniline or 1,3,5-Triphenyl-trimethylenetriamine, H₃C——N(C₆H₅)——CH₂

(\text{H}_3\text{C}_6\text{N} ————\text{CH}_2 ————\text{N(C}_6\text{H}_5)\text{)}

Crysts, mp 140-150°; nearly insol in w; very sl sol in alc more sol in eth and easily sol in chlf & benz. Its prepn is described in Refs 1-4. It has been used in plastics and as an accelerator in the vulcanization of rubber


Anhydroformaldehydeaniline, Azido-C₆H₁₄N₅O₄, Diazido-C₆H₁₄N₅O₄ and Triazido-C₆H₁₄N₁₂ Derivatives were not found in Beil or CA through 1956

Nitroanhydroformaldehydeaniline,C₆H₁₄N₅O₂, mw 360.40, N 15.55%. Red solid, mp 136-41°; burns slowly in open flame leaving large amt of ash; sl sol in alc more sol in eth and easily sol in chlf & benz. Its prepn is described in Refs 1-4. It has been used in plastics and as an accelerator in the vulcanization of rubber

Ref:s: 1)Beil - not found 2)R.L.Shriner et al, OSRD Rept 2054(1943), 11 & 15 3)CA through 1956 – not found

**ANHYDROGLUCOSE**

Anhydroglucose, C₆H₁₀O₄; wh ndls, mp 117-18°; v sol in w, sol alc, v sl sol in ethylacetate. Was prepd by Fischer & Zach by hydrolysis of glucosides(Refs 1 & 2)

Note: It is logical to assume that this compd can be nitrated to form explosives. None of
the nitrated derivs was, however, found in Beil or CA through 1956


Anhydrohydrastinine-[2,4,6-trinitrotoluene] or 1'-[2,4,6-trinitrobenzyl]-hydrohydrastinine,

\[ \text{H}_2\text{C} = \text{O} \quad \text{N} \quad \text{N} \quad \text{CH}_3 \]

mw 416.34, N 13.64%. Or-yel prisms(from ethyl acetate); mp decomp explosively ca 143°. Can be prep by grinding a mixt of TNT, methanol and hydrastinine


Anhydro-(4-hydroxy-3-carboxy-azo benzene-4'-diazoniumhydroxide, called in Beil
Anhydro-(4-oxy-azo benzol-carbonsäure-(3)-diazoniumhydroxyd-(4'))

\[ \text{OH} \quad \text{N} : \text{N} \quad \text{O} \quad \text{OC} \]

mw 268.23, N 20.89%. Brn-blk powder, mp – deflagrates at 130–2°; fairly stable; insol in most of org solvents; dissolves in aq pyridine with formation of salts. Can be prep by the diazotization of anilinosaliclyc acid as described in Ref 2

Refs: 1)Beil 16,375 2)C.Bülow, Ber 44, 608–10(1911)

1,5-Anhydro-D-sorbitol. Same as Polygalite or Acerite, formerly called Styracite

3,6(?)-Anhydro-D-sorbitol, \( \text{C}_6\text{H}_12\text{O}_5 \), crystals, mp 113°, obtained by treating anhydro-D-glucose with Na amalgam in weak alk soln. It seems logical to assume that it can be nitrated to form expls but none of such products was found in Beil or CA through 1956

Refs: 1)Beil 17,(129) 2)E.Fischer & K. Zach, Ber 45,2070–1(1912)

Anhydrous Ammonia. See under Ammonia

Anhydrous Powder. Same as Baked Powder

Anilides are compds contg the monovalent \( \text{C}_6\text{H}_5\text{NH} \)-radical, such as acetanilide, \( \text{C}_6\text{H}_5\text{NH}-\text{COCH}_3 \), nitrilamide, \( \text{C}_6\text{H}_5\text{NH}-\text{NO}_2 \), etc. Some of the nitrated products are expl

Refs: 1)Hackh(1944),58 2)Kirk & Othmer 1(1947),913–14
ANILINE

(Aminobenzene or Phenylamine)

C₆H₅NH₂, mw 93.12, N 15.04%, OB to CO₂ -266%. Col oily liq, fr p -6.2º, bp 184.4º, d 1.022 at 20º/4º, nD 1.5863 at 20º, sp ht 0.518 cal/g at 20-25º, at ht of vapn 113.9 cal/g, H ¢ 815 cal/g, H °C 810.4, fl p 168ºF (75.5º) & vap press at various temps(Refs 4 & 6). It is sl sol in w and very sol in alc, eth or benz. Was first prepd in 1826 by Unverdorben. The usual method of prepn of aniline is the reduction of nitrobenzene with iron in dil HCl or ammonolysis of chlorobenzene. Tech methods for its prepn are given in Refs 4 & 10. Aniline was formerly used as a stabilizer for smokeless propellants but its strongly basic character and volatility are serious objections to such use (Ref 2). Snelling & Wyler(Ref 3) proposed the use of aniline as a sensitizer for AN. The principal commercial use of aniline is in the manuf of dyes and synthetic rubber additives(Refs 4 & 10), while its military uses are: a) as a fuel in liq rocket propellants(Refs 5a, 7, 9 & 12) b) as an intermediate in the manuf of diphenylamine and Centralites. employed as stabilizers in NC propellants (Refs 4 & 10) and c) as the starting material for the production of tetryl

Its higher nitrated compds are powerful expls (see below). Military requirements of aniline are discussed in US Spec MIL-A-10450A and its toxicity in Refs 4,7 & 11. Aniline is extremely poisonous and if adsorbed through the skin may lead to cyanosis and death (Ref 5)


SALTS OF ANILINE WITH INORGANIC ACIDS:

Aniline, Azidoderivatives. See under Azidoaniline

Anilinochlorate, C₆H₅N + HClO₄; col prisms exploding ca 75-6º or on impact; sol in w and v sol in alc or eth. Can be prepd by treating aniline with aq chloric acid. It is unstable given in Refs 4 & 10.

Aniline was formerly used as a stabilizer for smokeless propellants(Refs 4 & 10) & as a primary compd, diazobenzene nitrate, known in France as aniline fulminante. The reaction proceeded as follows:

C₆H₅NH₂, HNO₃ + HNO₃ → C₆H₅N₂, HNO₃ + 2H₂O

Nitrous acid was obtained by the interaction of nitric acid with arsenic acid

Refs: 1) Beil 12,116-7 2) M. Beamer & F.W.Clarke, Ber 12,1066(1879)

Anilinioiodate, C₆H₅N + HI₃O; scales, d 1.48 at 13º, expl at 125-30º on rapid heating but remains unchanged on slow heating; sol in hot w & v sol in hot alc. Can be prepd by treating aniline with aq iodic acid

Refs: 1) Beil 12,117 2) M. Beamer & F.W. Clarke, Ber 12,1066(1879)

Anilinonitrate, C₆H₅N + HNO₃; col crysts, mp 182-4º, yields nitraniline when heated to 190º, d 1.356 at 4º; very sol in w, alc or eth. Can be prepd by treating aniline with 70% nitric acid as described in Ref 2, p 1798. Its Q° is 787.9 kcal/mol(Ref 2, p 100), QP° 795.1 (Ref 3) and Qf +42.5 kcal/mol(Ref 3)

Note: According to Daniel(1902), pp 462-3, aniline nitrate served in France for the prepn of a primary compd, diazobenzene nitrate, known in France as aniline fulminante. The reaction proceeded as follows:

C₆H₅NH₂, HNO₃ + HNO₃ → C₆H₅N₂, HNO₃ + 2H₂O Nitrous acid was obtained by the interaction of nitric acid with arsenic acid


Anilinoperchlorate, C₆H₅N + HClO₄, plates,
decomp slowly at 180° and expl at 250° (Ref 3) or 275° (Ref 4); deton on impact, sol in w, alc, acet & hot AcOH, insol in eth.
Can be prepd by treating aniline with aq perchloric acid

Refs: 1) Beil 12,117,(141),(66) 2) M. Beamer & F.W. Clarke, Ber 12,1066(1879) 3) R.L. Datta & N.R. Chatterjee, JCS 115, 1008(1919) 4) F. Arndt & P. Nachtwey, Ber 59,446(1926)

Anilinoperchromate, C₆H₇N + HCrO₄; crysts similar in appearance to KMnO₄; very explosive and unstable; sol in eth, insol in w and nearly insol in benz & ligroin. Can be prepd by treating aniline with aq perchromic acid, as described in Ref 2

Refs: 1) Beil 12,117 2) O.F. Wiede, Ber 30,2187(1897)

Dianilinocupric Nitrite, 2C₆H₇N + Cu(NO₃)₂; green plates, deflagrates on heating to 85° or on treatment with liq ammonia or with cold concd sulfuric acid; insol in w, alc or eth. Can be prepd by treating aniline with the green soin obtained when a mixt of equiv solns of K nitrite and Cu sulfate is treated with alc and filtered(Ref 2)

Refs: 1) Beil 12,[67] 2) H.J.S. King, JCS 1929,2593

p,N,N-Trilithio aniline, Li. C₆H₄. N(Li)₃; bright yel ppt; when dry expl violently on contact with air. Was prepd by adding an ethereal soin of n-butyl lithium to p-bromaniline, as described in Ref 2

Refs: 1) Beil- not found 2) H.Gilman & C.G. Stuckwisch, JACS 71,2933(1949) & CA 45,5127(1951)

Salts of Aniline with Organic Compounds:

Aniline fulminatinge (Fr). Diazobenzene Nitrate
(See Note under Anilinonitrate on previous page)

Anilinopicrate (AP),C₆H₅N + C₆H₅N₂O₇; yel crysts, darkened ca 168°, melted at 181° and exploded at 398° (Ref 3); d 1.558. Can be prepd by mixing equim quantities of aniline and picric acid in w

Note: According to Daniel (Ref 1a), aniline picrate was used in the following expls proposed by Street: a) AP 13.5, K chlorate 67.3, castor oil 9.6 & starch 9.6% b) AP 1.8, K chlorate 80.0, MNB 9.1 & castor oil 9.1%


Anilinotetranitrobenzene, C₆H₇N + C₆H₄N₂O₈; red ndls, very unstable(Beil 12,115)

Anilinonitrotoluene, C₆H₄N + C₆H₅N₂O₆; red ndls, mp 123-4°; can be prepd by mixing equim quantities of aniline and 1,3,5-TNB in alc


Anilinotetranitrobenzene, C₆H₇N + C₆H₄N₂O₈; red ndls, very unstable(Beil 12,115)

Anilinonitrotoluene, C₆H₄N + C₆H₅N₂O₆; red ndls, mp 123-4°; can be prepd by mixing equim quantities of aniline and 1,3,5-TNB in alc


Nitrated Derivatives of Aniline

Mononitroanilines, C₆H₅N₂O; mw 138.12, N 20.28%, OB to CO₂ -150.6%. If the substitution takes place in the ring, O₂N.C₆H₄.NH₂, the compd may be called nitroaniline, mono-nitroaniline or nitroanisobenzenes. If the substitution takes place in the -NH₂ group, the compd may be called nitraniline, N-nitroaniline or phenyl nitramine. In order to avoid confusion the last group of nitrated anilines is described under phenylamine

Mononitroanilines or Nitroanilines, O₂N.C₆H₄.NH₂, exist in three isomeric forms: ortho-, meta-, and para-. They are commercially available and extensively used in industry. None of these isomers can be obtained in good yield by direct nitration of aniline and it is necessary to employ indirect methods such as the Holleman method of acetylation of aniline to acetanilide followed by nitration(Ref 2) or by ammonolysis
of chloronitrobenzenes, similar to the amnonolysis of chlorobenzene described in
Refs 4 and 10, listed above under Aniline
o-(or 2-Mononitroaniline(o-MNA); yel-orange
rhmbs, mp 71.5°, bp 284.1°, d 1.442 at
15°, Qp 765.9 kcal/mol(Ref 3); for vap press
at various temps see Ref 8. Other props and
prepn are given in Refs 1, 7, 9 & 9
m-(or 3-)Mononitroaniline(m-MNA); yel, rhmb
crysts, mp 114°, bp 306.4°, d 1.437 at 14°,
Qp 766.3 kcal/mol(Ref 3) & 754.1(Ref 6), Qf 16 kcal/
mol; for vap press at various temps see
Ref 8. Other props and prepn are given in
Refs 1, 4, 7 & 9
p-(or 4-)Mononitroaniline(p-MNA); yel, monoc
dois, mp 146.7°, bp 331.7°, d 1.437 at 14°,
Qp 760.2 kcal/mol(Ref 3); for vap press at
various temps see Ref 8. Other props and
prepn are given in Refs 1, 4a, 5, 7 & 9
Mononitroanilines serve for the prepn of
higher nitrated derivs, some of which are
used in the expls industry
Note: According to Daniel (Ref 1a), com-
crinal mononitroaniline was used in the
following expls proposed by Street: a)MNA
13.5, K chlorate 69.4, azobenzene 14.3 &
castor oil 2.8% b)MNA 7.7, K chlorate
79.1, MNB 11.0, CC 1.1 & castor oil 1.1%
Refs: (Mononitroanilines) 1)Beil 12,687,
(339) & [367] (o-MNA); Ibid 698,(345) & [374]
(m-MNA); Ibid 711,(349) & [383](p-MNA)
1a)Daniel(1902),742 2)A.F.Holleman et al,
Ber 44,704 ff(1911) 3)F.Swarts, Rec 33,
281-98(1914) 4)Marshall l(1917), 273
4a)R.Robertson, JCS 119,18(1921) 5)Org-
Synth 9,64-5(1924) & CollVol 1(1941),pp 388-9
6)W.H.Rinkenbach, JACS 52, 116(1930) 7)
Pepin Lehalleur(1935), 260. 7a)Kirk & Othmer
1(1947),921-2 8)Jordan(1954), 181 & 196
9)Sax(1957),943-4
N-AlkylNitroanilines, which contain groups
such as Me, Et or iso-Pr and a nitrogroup in
either the 3 or 4 position on the ring, were
proposed(1n quantities of 0.5 to 5%) as stab-
ilizers of NC in smokeless propellants. A
eu-ectic mixt of N-ethyl-and N-methyl-4-
nitroaniline was found to improve the plasti-
cizing qualities of propellants
Ref: J.A.Gallaghen & I.Pincus,USP 2,696,430
(1954) & CA 49,5845-6(1955)
4-Nitro-N-nitrosaniline, (O,N)C6H6, NHNO
also called 4-Nitro-phenylnitrosamine, is
described under Phenylnamine
Nitro-N-nitranilines, (O,N)C6H5, NHNO3,
also known as Nitrophenylnitramines, are
described under Phenylnamine
Dinitroanilines(DNA)or Dinitroaminobenzenes,
(O,N)C6H4, NH2, mw 183.12, N 22.95%, OB
to CO2, -91.2%. Six isomers exist of which
the 2,4-DNA and the 3,5-DNA are of interest
either as components of expl comps or as
intermediates in the prepn of higher nitro
derivs
2,3-Dinitroaniline, orange-yel. ndls, mp 127°.
Other props and prepn are given in Ref 1a
2,4-Dinitroaniline(2,4-DNA); yel, monocl prisms,
ndls of plates; mp 186-8°, explodes when
heated in a flame at ca 548°(Ref 26); d 1.615 at
14°; insol in cold w, v sl sol in hot w, sl sol
in alc; Qp 718.9 kcal/mol(Ref 4), Qf (average)
711.5(Ref 13 & 14), Qv (calcld) 103.2 and Qf
(calcld average) 18.1 kcal/mol(Refs 13 & 14);
temp of expln (calcld) 2110°K(Ref 14). Was
first prepd in 1870 by heating 4-chloro-1,3-
dinitrobenzene with ammonia(Ref 1b). More
recent methods of prepn are described in
Refs 6, 8 & 12. The X-ray diffraction pattern
for its detn is given in Ref 11 and a spectrographic
method for its detn in Ref 9
The 2,4-DNA is a weak expl. Its power is
col 88% TNT as detd by BalMort. Its expl
props were investigated by Robertson(Ref 3),
Rinkenbach(Ref 4) and by Wohler & Wenzel-
berg(Ref 5). Its Fl(figures of insensitivity) is
> 120% PA(Ref 3) and the 50% impact
sensitivity figure with a 2-kg wt was reported
as 12.8 m kg/cm³ or 112% TNT(Ref 5). Its
thermal stability at 140° is satisfactory
DNA was used by the Germans during WW II
as an additive to TNT, presumably to render
the TNT less brisant so that excessively
small fragments would be eliminated (Ref 6a).
Another reason for use of DNA was unques-
tionably to stretch the available supply of TNT
2,5-Dinitroaniline, orange-yel crystals, mp 137°. Other props and prep are in Ref 12
2,6-Dinitroaniline, yel ndls, mp 138-142°, or leaflets, mp 137°. Other props and prep are in Ref 1d

3,4-Dinitroaniline, lemon-yel ndls (from w), mp 154°. Other props and prep are in Ref 1e

3,5-Dinitroaniline(3,5-DNA), yel ndls, mp 158-61°, sl sol in cold w, sol in hot w, alc & eth; sl sol in benz(Ref 1f). Was prep'd in 1891 by Bader(Ref 2) from 1,3,5-TNB and by Flürscheim(Ref 2a) who improved the method. A synthesis from 3,5-dinitrobenzoic acid utilizing the Schmidt reaction(Ref 7) is described in Ref 10. 3,5-DNA is a weak explosive, similar in props to 2,4-DNA. Nitration of 3,5-DNA yields a very powerful explosive, 2,3,4,5,6-pentanitroaniline

Blanksma & Verberg (Ref 5a) prep'd 3,5-DNA and a number of its derivs, some of which proved to be explosive

Refs:[Dinitroanilines]: 1a)Beil 12, 747 & [405](2,3-DNA) 1b)Beil 12, 747, (361)&[405] (2,4-DNA) 1c)Beil 12, 757, (365)&[413](2,5-DNA) 1d)Beil 12, 758, (365)&[413] 1e) Beil 12, 759, (3,4-DNA) 1f)Beil 12, 759, (366) &[414](3,5-DNA) 2)R.Bader, Ber 24, 1654(1891)
2a)B.Flürscheim, JPraktChem 71, 537(1905)

2,4-Dinitro-N-nitraniline or N,2,4-Trinitroaniline, (O,N)2C6H4. NHNO2, also called 2,4-dinitrophenylnitramine, is described under Phenylamine

Trinitroanilines(TNA) or Trinitroaminobenzenes, (O,N)3C6H4. NH2, mw 228.12, N 24.56%, OB to CO2 56.1%. The following isomers are known of which only 2,4,6-TNA is of importance in the expl industry

2,3,4 Trinitroaniline(2,3,4-TNA): It yel crystals, mp 190°. Can be prep'd by oxidation of 2,3,4-trinitromethylamine with chromic acid in AcOH

Refs: 1)Beil 12, [419] 2)P.van Romburgh & D.W.Wensink, PrAkadAmsterdam 17,1036 (1915)

2,4,5 Trinitroaniline(2,4,5-TNA): It yel ndls, claimed to be prep'd from 3-nitroacetanilide as described in Ref 2 According to Ref 3 this procedure yielded the 2,3,4,6-tetranitroaniline instead of 2,4,5-TNA

Refs: 1)Beil 12,763 2)O.N.Witt & E.Witte, Ber 41,3095(1908) 3)C.F.van Duin & B.C.R. Lennep, Rec 39,148(1920)

2,4,6-Trinitroaniline(2,4,6-TNA) or Picramide. Orange-red (with bluish tinge) monocl-prism-crysts(from AcOH), mp 189-92°, bp- explodes; d 1.762 at 20°,Qp (av) 678 4 kcal/mol (Refs 8 & 17), Qs (av) 680 (Refs 7,8, 17), Qe 191.2(Ref 19) and Qf (av) 21.6 kcal/mol(Refs 12 & 17) It is nearly insol in w, sl sol in alc or eth and sol in benz, acet, liq NH3, or hot ethyl acetate (some numerical data is given below under solubility). Apparently was first prep'd in 1854 by Pisani by treating picryl chloride with Amm carbonate(Refs 2 & 3)

Witt & Witte prep'd TNA by nitrating with conc nitric acid a soln of aniline in glacial AcOH (or in concd H2SO4) at about 5°, but the yields were poor. Better yields were obtained by nitrating mono- or dinitro-anilines (Ref 14).

Other methods of prep are described in Refs 13 & 15. Sancho(Ref 12a) described prep of TNA, called in Span "picramina," at the Fábrica de Granada. Oglobin and Markina (Ref 20) described the separation of 2,4,6-TNA
from its mixts with mono- and dinitroanilines. Lothrop et al (Ref 18) detnd infrared spectra of 2,4-TNA. Toxicity is given in Ref 21.

Following are some expl props of 2,4,6-TNA:

**Brisance**—no data found in open literature.

**Detonation Rate**—by the Dautriche method, for compressed TNA in cardboard cartridges 30 mm diam and 3 mm thick: at d 1.5 7000m/sec for TNA vs 7300 for PA and at d 1.7 7600 vs 8200 for PA (Ref 16).

**Fl**—see under Impact Sensitivity.

**Gap Test Value** (Coefficient de self-excitation, in Fr). A paper cartridge 30 mm diam & 78.5 mm long contg 50 g TNA (d 0.85) and initiated by 2g of MF caused the deton of another cartridge placed at a distance of 7.5 cm (PA gave 13 cm and TNA 6.5 cm in the same test).

**Hygroscopicity**—considerably higher than for TNT (Ref 16).

**Impact Sensitivity**. Fl (figure of insensitivity) 111% PA (Ref 6); impact work for 50% expln with 2kg wt is 10.4 kg m/cm$^2$ (Ref 11); impact sensitivity by the French method with 10kg wt for 50% point 36 cm vs 17 cm for PA (Ref 16). Blatt (Ref 22) gives Fl = 122% PA.

**Initiation Sensitivity** (Sensibilité à l’amorce, in Fr). A 50 g sample loaded at d 0.85 in a Kraft paper cartridge, 30 mm in diam, required ca 1 g MF for complete deton (Ref 16).

**Power.** The pressure bomb method gave ca 110% TNT (Ref 14, p 132), while the Trauzl test; Fr modif, gave a value (called CUP) equal to 92% PA (Ref 16). Blatt (Ref 22) gives Trauzl test value 98% TNT.

**Sensitivity to Impact.** See Impact Sensitivity.

**Sensitivity to Initiators.** See Initiation Sensitivity.

**Solubility.** Desvergnes (Ref 10) gives solys in g per 100 g in the following solvents: water 0.106 at 19.5°, 0.120 at 50° & 0.123 at 100°, ethyl acetate 1.898 at 19.5°, acetone 4.798 at 19.5°, 96% alcohol 0.120 at 19.5°, abs alc 0.127 at 19.5°; methanol 0.245 at 19.5°, benzene 0.907 at 19.5°, chloroform 0.322 at 17°; ether 0.121 at 17°; pyridine 13.64 at 17°; CS$_2$ 0.013 at 17.5°; CCl$_4$ 0.003 at 17.5°, and toluene 0.108 at 21.5°.

**Stability.** According to Daniel (Ref 2a) stability of TNA is satisfactory and according to Robertson (Ref 6, p 13), the vacuum stability test at 140° gave values comparable to TNT.

**Temperature of Explosion** is, according to Burlot & Tavernier (Ref 16, p 122), ca 3700°C.

**Uses.** According to Daniel (Ref 2a) one of the first patents on the use of TNA in expls was issued to the Chemische Fabrik Griesheim as well as to Pierre & Pottgiesser. TNA has advantages over PA because it is nearly insol in w and it is not acidic. Marshall (Ref 4a) and Colver (Ref 5a) stated that although TNA is a powerful expl it has not been widely used. This probably because other HE’s such as TNT, are more available and cheaper to produce. Sancho (Ref 12a) stated that TNA was used in mixts with TNT for cast loading some projectiles: Derivs of aniline are in great demand in industry other than as expls.

( in Russ & in English) 21) Sax(1957), 1222 days at RT (Refs 8 & 16). TeNA did not
22) Blatt, OSRD 2014(1944) 23)Vivas, Feigenspan & Ladr eda 2(1946) (Trinilina – as re-placement for PA) No change in color or props was observed after exposure to light at RT for periods as long as 17 years(Ref 16,p 102T). Crystallographic data are given in Ref 44 and infrared absorption spectra values in Ref 43. According to Ref 16,p 103T, TeNA is non toxic, while according to Ref 46, it is highly toxic. Additional info on chem and phys props of TeNA can be found in Refs 4,7,9,11,16,17, 20,40,41, & 42

According to Flürscheim (Ref 16 p 977T), TeNA was discovered in 1904, but he does not indicate where this discovery was described. The first patent on prepn and uses of TeNA was granted in 1910 to Flürscheim (Ref 2). He prepd TeNA by one-stage nitration of m-nitroaniline as described in Refs 2,3,4 & 5. Essentially, the same method was used recently by Lothrop(Ref 43) and by van Duin & Lenne(Ref 12) prepd TeNA starting with 3-acetanilide. Purification of TeNA can be achieved by washing crystals with a 40-70% aq soln of acetone at a temp not over 30°(Ref 34), or by crystn from ethyleneglycol (Ref 37).

Good descriptions of prepn and props of TeNA are given by Colver(Ref 11a) and by Flürscheim(Ref 16)

Explosive Properties of TeNA:
Brisance. According to Stettbacher(Ref 16) and some other investigators (Refs 6 & 7), TeNA is more brisant than tetryl, while Clark(Ref 32), gives its brisance, as detnd by the sand test, as only 102% that of TNT. According to Flürscheim(Ref 16, p 105T), the brisance, as detnd by the steel plate test

2,4,6-Trinitroaniline Nitrates, (O₂N)₃C₆H₄N⁺
NH₄⁻, HNO₃, mw 389.12, N 24.23%, OB to CO₂
-30.5%. Crysts (from alc), which defl on heating. Was prepd by adding a chilled mixt of p-nitroaniline with fuming nitric acid to chilled oleum and allowing to stand until crysts are formed

Refs: 1)Beil–not found 2)E.Macciotta & Zaïra Orani,Gazz 60,408-14(1930) & CA 24, 4280(1930)

2,4,6-Trinitro-N-nitraniline or N,2,4,6-
Tetranitroaniline, (N)₃C₆H₄N₂⁺. HNO₃⁻ is de-scribed as 2,4,6-Trinitro-phenylnitramine under Phenylamine

Tetranitroanilines(TeNA), (O₂N)₃C₆H₄NH₃, mw 273.12, N 25.64%, OB to CO₂
-32.2%. The following two isomers are theoretically possible, of which only the 2,3,4,6-TeNA is of interest to the expl industry

2,3,4,5-Tetranitroaniline(2,3,4,5-TeNA)– not found in Beil or in CA through 1956

2,3,4,6-Tetranitroaniline(TrNA)(Chishoki -
anin in Jap). Golden-yel crystals (from acet), mp 216-17º(dec), puffs off at 222º; d(cryst) 1.867; Q² 654.3 kcal/mol(av values of Refs 22,27 & 33), QP 653 kcal/mol (Ref 27), Qe 265.1 and Qf 14.0 kcal/mol(Ref 45). It is a neutral compd. Solys of TeNA in various solvents were reported in Refs 4,16 & 21. Ref 21 gives solys of TeNA at RT in g per 100 g of the following liquids: water 0.07, acetone 7.50, benzene 0.13, CS₂ 0.0056
CCl₄ 0.0036, ethanol 0.34, ether 0.81, me-thanol 0.45 and toluene 0.188. TeNA is also sol in ethyleneglycol(Ref 37).

Hygroscopicity for pure lab prep'd TeNA is very low (gain in wt. 0.1% for a sample exposed for 48 hrs in highly humid atm at 32º) and noticeably higher for commercial products(Refs 4,16 & 19)

Behavior toward metals: TeNA, whether wet or dry, did not attack steel, iron, tin, copper, brass, lead, aluminum or zinc in 14 days at RT (Refs 8 & 16). TeNA did not attack inorganic nitrates in storage(Ref 16,p 99T)
and by the fragmentation test, is much greater than that of TNT.

**Detonation Rate.** According to Flürscheim (Ref 16, p 104T), the velocity of deton is "great" and exceeds that of tetryl and NG, but he did not give any numerical data. The value given in Blatt (Ref 41a) is 7630 m/sec at d 1.6.

**Detonation Temperature.** See Explosion Temperature.

**Explosion Temperature.** According to Ref 4, p 186, a 0.1g sample of TeNA in a test tube deflagrated at 220° when heated in an oil bath. In Ref 12, the expln temp is given as 237° for a sample heated at the rate of 5°/min and 247° when heated at the rate of 20°/min. According to Ref 21, there is a violent combustion at 225°.

**Gas Volume.** 1g of TeNA evolved on expln 10.55 l at 3238°C vs 6.76 at 2217° for TNT (Ref 16, p 103T)

**Impact Sensitivity.** According to Flürscheim (Ref 16, p 102T), TeNA is sl less sensitive than tetryl and sl more sensitive than PA. This agrees with tests conducted by Robertson (Ref 18, p 18), who gives for FI(Figure of Insensitiveness) 86%PA for TeNA, 70% PA for tetryl and 115%PA for TNT. The values given in Ref 12 are 54-55cm fall for TeNA vs 51-53cm for tetryl, when using the Kast app and a 2kg hammer (See also Ref 41a).

**Initiation Sensitivity.** According to Ref 32, p 667, for 0.5g TeNA compressed at 3400 psi in a No 8 cap with reinforcing cup, the min wt of initiator reqd was 0.175g MF or 0.05g L.A. According to Ref 16, p 105T a 100g cartridge of TeNA requires ca 0.5g MF for complete deton (See also Ref 41a).

**Power:**
- a) by Trauzl Test 140%TNT (av value of Refs 5, 7, 16 & 31)
- b) by BalMort 121% TNT (av value of Refs 13 & 15)
- c) by BalPend 146%TNT (Ref 16, p 104T) and 155%TNT, as calc'd by Waller using the formula of Mallard & LeChatelier (Ref 16, p 104T) (See also Refs 41a and 41b).

**Note:** Although some of these data show higher values for TeNA than for tetryl, the Manometric Bomb (Druckmesser) Test of Bichel gives values lower than for tetryl (Ref 16, p 104T).

**Stability of Dry Material.** According to Flürscheim (Ref 16, pp 97T-99T), a sample of dry TeNA, produced on an industrial scale and without any purification other than washing with water, proved to possess satisfactory stability for use in military and commercial explosives. The following tests were used:

- a) Abel Test at 65.5°-satisfactory
- b) Vacuum Stability Test at 100° for the commercial product predried 18 hrs at 30-40°C in a oven in a bath. In Ref 12, the expln temp is given as Stability Test at 100°C for the commercial product.
- c) 135° German Test -no fumes in 60+ hrs
- d) British Storage Test at 90°F (32°C)-satisfactory
- e) International Test at 75°-satisfactory
- f) French Litmus Test -neutral litmus paper was not reddened in 5 days at RT
- g) French Railway Test -neutral litmus paper was not reddened by 100cc of w with which 1g of TeNA had been shaken for 350 hrs at 120°
- h) Refs 12 & 36 state that TeNA starts to evolve nitrous acid fumes after 18 hrs at 70°
- i) Ref 12 stated that the vacuum stability test at 120° was unsatisfactory
- j) Hinschelwood & Bowen (Ref 14) reported that TeNA in small crysts required about 350 hrs at 120° for complete decomp, while at 140° the time was reduced to 70 hrs. The vel of decomp increased steadily throughout, falling sharply near the end of the reaction (See also Ref 41a).

**Stability in Presence of Moisture** is unsatisfactory (Refs 6, 7, 19, 28 & 38). According to Cameiro (Ref 38) this poor stability is due to the presence of an NO$_3$ group in the 3rd position of the aniline ring. This labile group allows moisture to slowly hydrolize it with the formation of HNO$_3$ and 3-hydroxy-2,4,6 TNA. This phenolic compd attacks metals similarly to PA. Bradley (Ref 7), reported that this instability can be remedied by coating the crysts of TeNA with a small...
of TeNA with a small amt (about 5%) of paraffin (see also Refs 41c & 43a)

Strength. See Power

Temperature of Explosion Two calcd values are given in Ref 16, p 1037: 3238° & 3500° vs 3127° & 3370° for tetryl and 2217° for TNT

Uses. According to Flueurschim (Refs 4, 5, 6, 11a & 16), TeNA is suitable as a substitute for tetryl in composite detonators and detonating cord as well as a filler for projectiles, bombs, mines and torpedoes. It is also suitable as a component of HE compositions, where it serves to sensitize cheaper insensitive comds, such as nitrobenzene, nitronaphthalenes and AN. Formulations of some mixts contg TeNA are given below. As a military explosive it was used to some extent by the Germans during WW II as a "substitute" explosive (Ersatzsprengstoff) in order to conserve TNT and other scarce nitroaromatic HE's. It could be used to a much greater extent, even in peace time, if it were more stable in the presence of moisture (Ref 47) (see above under Stability in Presence of Moisture). TeNA was called Chishoki-anin in Japan but there is no info whether or not it was used there for military purposes.

O'Neil & Schuricht (Ref 29) proposed the use of TeNA for coating grains of some NC propellants. According to Ref 26a, TeNA was used in Russia as a booster. It was manufd in US by Aetna Expl Co and by Verona Chem Co

**Tetranitroaniline Explosives.** Flürscheim (Ref 1) proposed the following expl comps contg TeNA: a) Molten mixt of TeNA/DNB (1:2) 6 & AN 94%; Trauzl test 265cc vs 254 for TNT or 430 for TeNA b) Molten mixt of TeNA/MNN/DNN(5:3:7) 4.5 & AN 94.5%; Trauzl test 205cc c) Molten mixt of TeNA/DNB 1:2 20 & AN 80%; Trauzl test 360cc d) Molten mixt TeNA/DNB (1:2.5) 12 & AN 88%; Trauzl test 500cc e) Molten mixt TeNA/DNB (23:77) 7, AN 87 & charcoal 6%. Flürscheim (Ref 4) patented expl comps are given in Ref 9, such as Trauzl Test value prepbd by heating pulverized mixts of TeNA 164% PA and Fl (figure of insensitiveness) 60 to 95% with TNT (or other low melting nitro-compd) 40 to 5% in such a manner that the TNT melts and permeates the TeNA crysts, thus rendering them waterproof. Oxidizers, such as inorganic nitrates, may also be incorporated.

**Refs:**
1) Beil 12, [428] 2) B. Flürscheim & T. Simon, PrChSoc 26, 81(1911) & CA 5, 865 (1911) 3) B. Flürscheim & E. Holmes, JCS 1928, 3041 & CA 23, 823(1929) 4) Detd at PicArsn by Mrs. L. E. Neuman, PACLR 124, 345(1948) 5) P. Karrer (1950), p 23, 4, 5, 6-Pentanitroaniline (PNA), (O<sub>2</sub>N<sub>2</sub>)<sub>2</sub>C<sub>6</sub>N<sub>4</sub>H<sub>2</sub>, mw 318.12, N 26.42%, OB to CO<sub>2</sub> ~15.1%. Golden-yel prisms, mp 196-8° (dec)(Ref 7). Q<sub>2</sub> (H<sub>2</sub>O liq) 686.8 kcal/mol (2159 cal/g)(Ref 4). When dropped into a red-hot crucible, a few centigrams at a time, PNA flashes without deton. It is insol in w, sol in acet (~25g in 100cc at 20°), AcOH (~10g in 100cc at 20°), benz (~5g in 100cc at 20°) and sl sol in conc H<sub>2</sub>SO<sub>4</sub> (~2g in 100cc at 20°)(Ref 3).

In most respects the chemical and physical props of PNA are similar to those of TeNA. The 3-and 5-NO<sub>2</sub> groups of PNA are reactive and may be easily hydrolyzed. In the 100° Heat Test (Ref 5) PNA lost 1.58% in the 1st 48 hrs, 5.90% in the 2nd 48 hrs and did not explode in 100 hrs.

PNA was prepbd for the first time in an impure state in 1910 by Flürscheim and Simon (Ref 2). In 1928 Flürscheim and Holmes (Ref 4) prepbd PNA in a pure state (mp 192°) by nitration of 3,5-dinitroaniline using 100% H<sub>2</sub>SO<sub>4</sub> and conc HNO<sub>3</sub> at 75° for 3 hours. The structure assigned from chemical evidence was confirmed by infrared spectra data (Ref 7).

PNA is a powerful and brisant expl, being comparable to RDX or PETN. Its sensitivity to impact is between values for PETN and LA, which would make this expl unsuitable for use as a filler for projectiles. It could be used, however, as an initiating expl. Some numerical data for its power and sensitivity are given in Ref 9, such as Trauzl Test value 164% PA and F1 figure of insensitiveness) 36% PA.

**Note:** The toxicity of PNA is not discussed in Sax(Ref 8) but it is logical to assume that toxic effects of PNA are similar to those of TeNA (Ref 8, p 1170).

**Refs:**
1) Beil 12,[428] 2) B. Flürscheim & T. Simon, PrChSoc 26, 81(1911) & CA 5, 865 (1911) 3) B. Flürscheim & E. Holmes, JCS 1928, 3041 & CA 23, 823(1929) 4) Detd at PicArsn by Mrs. L. E. Neuman, PACLR 124, 345(1948) 5) P. Karrer (1950), p 23, 4, 5, 6-Pentanitroaniline (PNA), (O<sub>2</sub>N<sub>2</sub>)<sub>2</sub>C<sub>6</sub>N<sub>4</sub>H<sub>2</sub>, mw 318.12, N 26.42%, OB to CO<sub>2</sub> ~15.1%. Golden-yel prisms, mp 196-8° (dec)(Ref 7). Q<sub>2</sub> (H<sub>2</sub>O liq) 686.8 kcal/mol (2159 cal/g)(Ref 4). When dropped into a red-hot crucible, a few centigrams at a time, PNA flashes without deton. It is insol in w, sol in acet (~25g in 100cc at 20°), AcOH (~10g in 100cc at 20°), benz (~5g in 100cc at 20°) and sl sol in conc H<sub>2</sub>SO<sub>4</sub> (~2g in 100cc at 20°)(Ref 3).
ANILINE AND DERIVATIVES, ANALYTICAL PROCEDURES

Aniline intended for US military use must comply with the requirements of Specification MIL-A-10450A (Ref 12) which prescribes the following tests:

A) Aniline Content (minim 99.5%) is detd volumetrically by the potassium bromate-bromide method based on the following reaction:

\[ C_6H_5NH_2 + KBrO_3 + 5KBr + 6HCl \]
\[ C_6H_5BrNH_2 + 6KCl + 3H_2O + 3HBr \]

The original bromination method was described in 1876 by Koppeschaar (Ref 1).

a) Preparation and Standardization of 0.2N KBrO_3-KBr Solution. Dissolve in distd w contained in 1 l volumetric flask, 5.56 g of KBrO_3 and 30 g of KBr and make up to the mark. Standardize this soln against purified aniline (prepd by distn of commercial aniline as described on p 2 of Spec MIL-A-10450A) as follows: Weigh to 0.1 mg 2.5 to 3 g of the purified aniline, transfer to a 1 l volumetric flask contg 900 ml distd w and 50 ml concd HCl. Fill the flask to the mark and shake it until the soln is uniform. Transfer a 100 ml aliquot to a 400 ml beaker, add 10 ml concd HCl and cool the soln to 15°. Titrate slowly with the 0.2N KBrO_3-KBr soln. Near the end of titration, test, after the addition of each drop of the soln, by spotting KI-starch test paper. The end point is indicated by the lit blue coloration which can be duplicated after a 2-min period. When the end point is reached, an addnl drop of the KBrO_3-KBr soln will color the mixt yel, thereby corroborating the end point indicated by the test paper. Calculate the normality of KBrO_3-KBr by the following formula:

\[ N = \frac{\text{Grams aniline in aliquot}}{(\text{ml KBrO}_3-\text{KBr soln}) \times 0.01552} \]

b) Procedure. Conduct the test in exactly the same manner as for standardization and calculate percentage of aniline by the following formula:

\[ \% \text{Aniline} = \frac{(\text{ml KBrO}_3-\text{KBr soln}) \times N \times 1.552}{W_t} \]

Here, \( N \) is the normality of KBrO_3-KBr soln and \( W_t \) is the weight of sample in aliquot.

B) Nitrobenzene (NB) Content (max 0.2%) is detd by titrating the steam distd NB with std titanous chloride, based on the following reaction:

\[ C_6H_5NO_2 + 6TiCl_3 + 6HCl \rightarrow C_6H_5NH_2 + 6TiCl_4 + 2H_2O \]

a) Apparatus used in the standardization and test is shown in the fig on the following page.

b) Preparation of Methylene Blue Indicator (MBI). Weigh into a 500 ml Erlen flask 0.5 g KBrO_3 and dissolve in distd w of MB dye, especially prepd for oxidation contained in 1 l volumetric flask, 5.56 g of KBrO_3 and 30 g of KBr and make up to the mark. Standardize this soln against (Na_2C_4H_4O_6.2H_2O). Heat to boiling in an atm of CO_2 and add dropwise the TiCl_3 soln to disappearance of blue color. Filter rapidly, dil to 500 ml and store in a tightly stoppered bottle. If the blue color reappears due to oxidation, discolor the soln before using by adding a few drops of TiCl_3 soln.

c) Preparation of 0.05N Ferric Ammonium Sulfate Solution. Weigh into a large beaker 24.1 g of Fe(NH_4)(SO_4)_2.12H_2O for each liter of std soln desired. Dissolve in a mixt of 50 ml 40% sulfuric acid (by wt) and 50 ml distd w and filter into 1 l vol flask. Dil to the mark with distd w and thoroughly mix. Store it in the stock bottle C (see fig).

d) Preparation of 0.15N Titanous Chloride Solution. Filter the commercial 15–20% soln of TiCl_4 in strong HCl, through asbestos, place the filtrate (stock solution) in a gas washing bottle and pass CO_2 through the soln to remove air. Close both exits of the bottle with rubber tubing and pinch cock assemblies. Det the strength of this "stock soln" by pipetting 5 ml into a 300 ml Erlen flask contg 25 ml distd w and 25 ml of 40% sulfuric acid, boiling the soln and titrating hot with std ferric ammonium sulfate soln using MBI (methylene blue indicator). The vol of stock soln required for the prepn of
95% ethanol in 500 ml Erlen flask equipped with a 3-hole rubber stopper and connected through one of the holes to the CO₂ generator (see fig). Sweep the air from the flask for 10 mins with a strong current of CO₂ and add through another hole of the stopper from a burette 15–20 ml of 0.15N TiCl₃ soln. Place the flask in a 2 l beaker contg 200–300 ml of cold tap w and heat the beaker at such a rate that the w boils in not less than 15 mins. Maintain at boiling temp for 15 mins and while continuing the current of CO₂ but at a slightly slower rate than before, add 2 ml MBI (colorless) and titrate hot with std Fe(NH₄)₂(SO₄)₃ to the appearance of a blue color persisting for 30 secs. Apply temp and calibration correction to both TiCl₃ and Fe(NH₄)₂(SO₄)₃ burette readings (see table at top of following page) and calculate R (relation) as:

\[
\frac{\text{ml TiCl}_3 \text{ soln}}{\text{ml Fe(NH}_4\text{)}_2\text{(SO}_4\text{)}_3} = \frac{W_t}{V_t - RV_t} \times 0.02302
\]

Note: Same app was used but H₂ generator interchanged with CO₂ generator

the desired amt of 0.15N soln is obtained from the following formula:

\[
V = \frac{0.15 \times V_1 \times 5}{N_2 \times V_2}, \text{ where}
\]

\[V_1 = \text{ml of std TiCl}_3 \text{ desired} ; \ N_2 = \text{normality of std Fe(NH}_4\text{)(SO}_4\text{)}_3 \text{ soln} ; \ V_2 = \text{ml of this soln consumed in the titration of 5 ml stock TiCl}_3\]

Assemble the app as shown in fig and transfer to a thoroughly clean stock bottle B, 150 ml of concd HCl (for each liter of std soln desired), diluted with an equal vol of freshly boiled and cooled distd w. Add the accurately measured vol of stock soln (value V calc'd from the above formula), dilute w to the required vol and pass a rapid stream of CO₂ through the soln for 1 hr. Connect bottle B to hydrogen generator (see fig) and fill the burette F₁ with TiCl₃ soln and then discharge it. Leaving the stopcock of burette partly open, pass a moderately rapid stream of hydrogen through B and F₁ for 30 mins in order to remove any air. Close the stopcock of F₁ and allow the soln to age for several weeks in an atm of hydrogen before using it

e) Relation (R) of TiCl₃ and Fe(NH₄)(SO₄)₃ Solutions. Add 25 ml of 40% (by wt) sulfuric acid to a mixt of 150 ml distd w and 50 ml

(f) Standardization of 0.15N TiCl₃ Solution. The soln is standardized against purified p-nitroaniline, based on the reaction:

\[
\text{H}_3\text{N} \cdot \text{C}_6\text{H}_4\text{NO}_2 + 6\text{TiCl}_3 + 6\text{HCl} \rightarrow \text{H}_3\text{N} \cdot \text{C}_6\text{H}_4\text{NH}_3 + 6\text{TiCl}_4 + 2\text{H}_2\text{O}
\]

Note: Purification of a good grade commercial p-MNA can be achieved by crystallizing twice from 95% ethanol and three times from distd w. This should give a prodct having a mp betw 147.3 & 148.2°. This will be called standard p-MNA

Accurately weigh 0.3 g of std p-MNA, transfer to 250 ml vol flask, dissolve in ca 100 ml distd w & an equal amt of 40% sulfuric acid and dilute to the mark. After thorough mixing, pipette two 25 ml aliquots into two 500 ml Erlen flasks, add to each flask 25 ml 40% sulfuric acid, 50 ml 95% ethanol & 100 ml distd w. Sweep the flask for 10 mins with a strong current of CO₂, add 50 ml of 0.15N TiCl₃ soln and proceed as described above under (e). Calculate normality of TiCl₃ by the following formula:

\[
N = \frac{W_t}{V_t - RV_t} \times 0.02302
\]
Temperature Corrections for TiCl₃ and Fe(NH₄)(SO₄)₂ Solutions

<table>
<thead>
<tr>
<th>Burette reading, ml</th>
<th>Corrections to be subtracted, ml</th>
<th>Corrections added, ml</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16°</td>
<td>18°</td>
</tr>
<tr>
<td>5</td>
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<tr>
<td>40</td>
<td>0.04</td>
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</table>

Note: These temp corrections are applied to burettes calibrated at 20°. The corrections for TiCl₃ and Fe(NH₄)(SO₄)₂ solns are different from those applicable to aq solns generally due chiefly to the large amt of HCl present. The cubic coeff of expansion of the solns is on the average 0.000254 ml per degree per ml betw 18° and 25°C. If all calibrations are done at the same temp, no temp corrections are necessary.

N = normality of TiCl₃ soln; Wt = weight of p-MNA used; V₁ = ml of TiCl₃ used; R = relation (see procedure e); V₂ = ml of Fe(NH₄)(SO₄)₂ used

Procedure for Determination of NB.

Pipette a 50 ml sample (ca 51g) into a 1 l round bottom flask to which is attached a 24-inch reflux condenser cooled with tap w. Pour slowly through the inner tube of condenser 200 ml concd HCl and cool the mixt in the flask to RT. Disconnect the condenser and connect the flask to steam distn app, provided with a Kjeldahl spray trap and condenser and distil with steam into a 500 ml Erlen flask contg 50 ml 95% ethanol until the total vol in the receiver is ca 200 ml. Stop the distn, transfer the distillate to a 500 ml vol flask and dil to the mark with 95% ethanol.

Note: If it is suspected that the NB content is not above 0.1%, the entire distillate may be titratd with Fe(NH₄)(SO₄)₂, directly in the receiver without transferring it to vol flask.

Pipette an aliquot (100 ml or more) into a 500 ml Erlen flask equipped with a 3-hole rubber stopper and connected through one of the holes to CO₂ generator (see fig).

Sweep the air from the flask for 10 mins with a strong current of CO₂ and add from a burette, through another hole in the stopper, 40–50 ml std 0.15N TiCl₃ soln. While continuing to pass CO₂ over the soln, quickly remove the rubber stopper and insert the one carrying a Hopkins condenser cooled with tap w, in order to prevent loss of NB in subsequent operations. Place the flask in a 2 l beaker with a porcelain grid in the bottom and contg 200–300 ml cold tap w. Heat the beaker at such a rate that w boils in not less than 15 mins, and continue boiling for 15 mins while still passing CO₂ but at a sl slower rate than at the beginning of the operation. Add 2 ml MBI (colorless) and titrate, while hot and still passing CO₂, with 0.05N Fe(NH₄)(SO₄)₂ (see proced e) to the appearance of a blue color which persists for 30 secs. Calculate NB content from the following formula:

\[
\% \text{NB} = \frac{(V₁ - RV₂) \times N \times 2.0518}{Wt}, \text{where}
\]

\[
V₁ = \text{ml of TiCl₃ soln used; } N = \text{its normality; } R = \text{relation (see proced e); } V₂ = \text{ml of Fe(NH₄)(SO₄)₂ used.}
\]
Fe(NH₄)(SO₄)₂ soln; Wt = weight of sample, but without any nitroaniline, treated in exactly the same manner as above ( burette reading R₁). The difference R₂ − R₁ is proportional to the amount of sample taken.

Aniline, Polynitro Derivatives. As no info is available on the analysis of these compounds, we asked the opinion of Mr. F. Pristera and Dr. H. Walter, who had wide experience in analysis of polynitro derivs of toluene, phenol, etc. If the sample is a solid, its mp must be detd and if it is a liquid, its bp. Next comes the analysis by IR (if an apparatus is available). Experiments at PicArsn showed that IR spectrograms of various nitrated derivs of toluene permitted distinguishing, not only the degree of nitration but also the position of NO₂ groups (Refs 13 & 14). In later work spectrograms of o- and p-nitroanilines [See paper by F. Pristera et al published in Anal Chem 32, 497(1960)] showed distinct differences between these two compounds. If IR spectrograms do not give any definite info, it is advisable to det C and H contents by microcombustion method and also to det N content by micro-Dumas combustion method.

If the sample does not contain more than two (or three) NO₂ groups, the titanous chloride method (described above under detn of nitrobenzene in aniline) may be applicable. This method determines the nitro-nitrogen but not the amino-nitrogen. No info is available on application of the TiCl₃ method to tri-, tetra- and pentanitroanilines, but it definitely works with mono- and di-nitro derivs.

In the opinion of Dr. H. Walter, the application of the TiCl₃ method to aromatics contg more than 3 symmetrically arranged NO₂ groups might lead to inaccurate results, because this method exhibits a solvolytic effect on the 4th, 5th, etc. groups. As these nitrogroups are very loose, they split off quantitatively by boiling w/ (especially at pH > 7) leaving a phenolic (−OH group) instead. This reaction may probably be used for analysis of compounds, such as pentanitroaniline, as follows:

Fe(NH₄)(SO₄)₂ soln; Wt = weight of sample treated in exactly the same manner as above (burette reading R₁). The difference R₂ − R₁ is proportional to the amount of sample taken.

**C) Moisture Content** (max 0.25%). Det moist by the Method 3001.5 of Federal Specification VV-L-791e(1953), with the exception that available on the analysis of these compounds.

**D) Specific Gravity** (1.015 to 1.019 at 25°C/4°C). Det it by pycnometer method such as described in Federal Specification VV-L-791e (1953), Method 402.1 or in IEC, Anal Ed 16, 55(1944).

Anilines, Nitrated, Analysis. Mono-nitroanilines can be detd by methods described in Refs 4-7 & 9-10.

Dr. H. Walter (Ref 15) used in his work the following method for detn of nitroanilines:

Weigh a sample, transfer it to a round-bottom flask equipped with a reflux condenser cooled with tap w and introduce through the inner tube of condenser, a quantity of acetic anhydride slightly in excess of that required for acetylation. After introducing through the condenser an amt of pyridine = to ca 10% of acetic anhydride, the reaction of acetylation starts spontaneously and then proceeds at a much slower rate. The following reaction takes place:

\[
\begin{align*}
H₂N-C₆H₄-N₂O₂ + (CH₃CO)₂O & \rightarrow CH₃CO-NH-C₆H₄-NO₂ + CH₃COOH
\end{align*}
\]

After allowing to stand for 1 hr, add distd w through the condenser in an amt sufficient to hydrolyze surplus anhydride to acetic acid. Transfer to a 1 L vol flask and dilute to the mark. Pipette an aliquot into a beaker and titrate with N/10 NaOH soln in presence of an indicator, such as phenol-phthalein. Take the burette reading (R₁). Run a blank by titrating with N/10 NaOH the same quantity of acetic anhydride...
The resulting aminostyphnic acid can be identified by the mp and also in the form of its lead salt, obtained by the action of Pb acetate on aminostyphnic acid.

Dr Walter stated also that diazobenzene-sulfonic acid (prepared by diazotization of sulfanilic acid) readily couples with aromatic \(-\text{NH}_2\) in acid medium or with \(-\text{OH}\) group in alkaline medium, provided at least one ortho- or para- standing H-atom is available. The reaction proceeds as follows:

\[
\begin{align*}
\text{H}_2\text{N} & \text{H} + \text{N}\text{N} & \text{SO}_3^- \rightarrow \\
\text{H}_2\text{N} & \text{N}:\text{N} & \text{SO}_4^-
\end{align*}
\]

In this method, an alc soln of benzene-sulfonic acid (previously standardized with phosgene by weighing the pptd diphenyl-carbamide) is added from a burette to a sample of aniline (or its nitrated compd not higher than tetranitro-) until the appearance of a dirty-bluish coloration, when a drop of the reaction mixt is placed on a filter paper previously impregnated with amino-\(\beta\)-naphthol indicator (spot test). This method is not applicable for analysis of penta-nitroaniline (Ref 15).

Refs:
1) W.F. Koppeschaar, ZAnalChem 15, 233(1876) (Dtn of aniline by bromination)
2) M. François, JPharmChim 9, 521(1899) & JCS 76 II, 713(1899) (Volumetric estimation of aniline by bromine w in presence of sulfate of indigo)
3) G. Dénièges, JPharmChim 10, 63(1899) & JCS 76 II, 826(1899) (A claim for priority with respect to the method described by François)
4) F.L. English, IEC 12, 994(1920) (Application of TiCl₄ method to dtn of nitro nitrogen in p- and m-MNA's)
5) B.M. Margosches & W. Kristen, Ber 56, 1947(1923) (Kjeldahl method is applicable to m-MNA but not to o- & p-MNA or to 2,4-DNA)
6) M. Koltchoff & C. Robinson, Rec 45, 171 & 174(1926) (Dtn of nitro-nitrogen in p- & m-MNA by TiCl₄ method)
7) A.R. Day & W.T. Taggart, IEC 20, 545(1928) (Dtn of m- and o-MNA by bromination method)
8) Kirk & Othmer 1(1947), 918 (Small quantities of aniline can be detd colorimetrically by means of a purplish-violet color formed on treatment with hypochlorite soln or by conversion of this to a permanent blue dye on treatment with ammonia or phenol)
9) W. Kemula et al RocznikiChem 29, 263(1952) & CA 50, 3956(1956) (Separation of mixts of various isomers of nitrated aniline by the method or partition chromatography)
10) L.D. Johnson et al, AnalChem 27, 1494-8 (1955) and 28, 392(1956) (Bromination method is not always applicable in analysis of mixts of nitrated aniline and phenols)
12) US Specification MIL-A-10450A
13) F. Pristera, ApplSpectroscopy 7, 115-21(1953)
15) Dr Hans Walter and Mr. Frank Pristera, PicArsn; private communication(1960)

Note: Dr Walter also suggested the following method for analysis of trinitroaniline.

Dissolve a sample in AcOH, dilute with w and add Na nitrite:

\[(\text{O}_2\text{N})_3\text{C}_6\text{H}_4\cdot\text{NH}_2\text{NaOH}\rightarrow (\text{O}_2\text{N})_3\text{C}_6\text{H}_4\cdot\text{N}^\equiv\text{N}\text{OOC-CH}_3\]

Add an excess of dimethylaniline and transfer the resulting dark-red soln, contg \((\text{O}_2\text{N})_3\text{C}_6\text{H}_4\cdot\text{N}=\text{N}\cdot\text{C}_6\text{H}_4\cdot\text{N}(\text{CH}_3)_2\), into a volumetric flask. Take an aliquot and test it colorimetrically.

For analysis of tetranitroaniline, the following method was suggested:

Boil a sample with w to transform it to aminopicric acid \((\text{O}_2\text{N})_3\text{C}_6\text{H}_4(\text{OH})\cdot\text{NH}_2\). Add KOH and bubble through the resulting aq soln of potassium aminopircate \((\text{O}_2\text{N})_3\text{C}_6\text{H}_4(\text{OK})\cdot\text{NH}_2\) a stream of \(\text{CO}_2\):

\[(\text{O}_2\text{N})_3\text{C}_6\text{H}_4(\text{OK})\cdot\text{NH}_2+\text{CO}_2\rightarrow (\text{O}_2\text{N})_3\text{C}_6\text{H}_4(\text{OH})\cdot\text{NH}_2+\text{KHCO}_3\]

Extract the resulting aminophenol with ether, evaporate and weigh.
ANILINOACETIC ACID AND DERIVATIVES

Anilinoacetic Acid; Aminophenylacetic Acid; N-Phenylglycocol or N-Phenylglycine (Anilinoessigsäure in Ger), \( \text{C}_6\text{H}_5\cdot\text{NH} \cdot \text{CH}_2 \cdot \text{COOH} \), is described in Beil 12,468(263) & [249].

Anilinoacetic Acid, Azido—, \( \text{C}_6\text{H}_5\text{N}_3\text{O}_2 \) and Diazido— \( \text{C}_6\text{H}_5\text{N}_2\text{O}_2 \). Derivatives were not found in Beil or CA through 1956.

Mononitroanilinoacetic Acid, \( \text{C}_6\text{H}_5\text{N}_2\text{O}_4 \). Its three isomers are described in Beil 12,695, 709 & 725.

2,4-Dinitroanilinoacetic Acid or N-(2,4-Dinitrophenyl)-glycine, \( (\text{O}_2\text{N})_2\text{C}_6\text{H}_4\cdot\text{NH} \cdot \text{CH}_2 \cdot \text{COOH} \). Golden-yell scales (from hot w), mp 112° (Ref 1); yell crysts (from hot methanol), mp 205° (Ref 2 & 4). Several methods of prep are listed in Beil (Refs 1 & 2). It is evident that one value of the reported mp (115° and 205°) is wrong. Waldemann (Ref 5) did not clarify the point, although he also prep the dinitroanilinoacetic acid. The mp of his compd is not given.

Nearly all metallic salts of the dinitro compd, especially those of Pb, Ba & Ag are explosive (Refs 1 & 3).


2,4,6-Trinitroanilinoacetic Acid, N-Picrylglycocol or N-Picrylglycine, \( (\text{O}_2\text{N})_3\text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{COOH} \), mw 286.16, N 19.58%. Yell ndls (from hot w), mp 161°; sl sol in w and sol in alc. Can be prep by the interaction of glycine and picrylchloride. It is undoubt-edly an expl and its salts even more so.

Refs: 1)Beil 12,770 2)K.Hirayama, ZPhysiolChem 59,290(1909) & CA 4,222 (1910)

Tetranitroanilinoacetic Acid, \( \text{C}_6\text{H}_5\text{N}_2\text{O}_{10} \) — not found in Beil or CA through 1956.

ANILINOAZOBENZENE AND DERIVATIVES

4-Anilino-azobenzene, Phenylazodiphenylamine or 4-Benzeneazo-diphenylamine, \( \text{C}_6\text{H}_5\cdot\text{NH} \cdot \text{C}_6\text{H}_4\cdot\text{N} \cdot \text{N} \cdot \text{C}_6\text{H}_4 \), is described in Beil 16,314.

Anilinoazobenzene, Azido—, \( \text{C}_6\text{H}_5\text{N}_3 \) and Diazido—, \( \text{C}_6\text{H}_5\text{N}_2 \). Derivatives were not found in Beil or CA through 1956.

Mononitroanilinoazobenzene, \( \text{C}_6\text{H}_5\cdot\text{N}_2\text{O}_2 \). Several isomers are described in Beil 16,315, (311) & [153,178].

Dinitroanilinoazobenzene, \( \text{C}_6\text{H}_5\cdot\text{N}_2\text{O}_4 \). Several isomers are described in Beil 16,314 & [148,149,153].

Trinitroanilinoazobenzene, \( \text{C}_6\text{H}_5\cdot\text{N}_3\text{O}_6 \), mw 408.32, N 20.58%. Several isomers are described in Beil 16,314 & [149,153].

Note: No higher nitrated derivs were found in Beil or CA through 1956, although the compds hexanitroanilinoazobenzene, \( \text{C}_6\text{H}_9\cdot\text{N}_9 \cdot \text{O}_6 \), mw 543.32, N 23.20%, and higher nitrated derivs would be expected to be expl.

ANILINOBENZALDEHYDE AND DERIVATIVES

Anilinobenzaldehyde, \( \text{C}_6\text{H}_5\cdot\text{NH} \cdot \text{C}_6\text{H}_4 \cdot \text{CHO} \). One isomer is described in Beil 14,37.

Anilinobenzaldehyde, Azido—, \( \text{C}_6\text{H}_5\cdot\text{N}_3\text{O} \) and Diazido—, \( \text{C}_6\text{H}_5\cdot\text{N}_2 \). Derivatives were not found in Beil and in CA through 1956.

Mononitroanilinobenzaldehyde, \( \text{C}_6\text{H}_5\cdot\text{N}_2\text{O}_3 \).— not found in Beil.

Dinitroanilinobenzaldehyde, \( \text{C}_6\text{H}_5\cdot\text{N}_3\text{O}_4 \).—

Two isomers are listed in Beil 14,(357) & [22].

Trinitroanilinobenzaldehyde, \( \text{C}_6\text{H}_5\cdot\text{N}_4 \).—

Higher nitrated derivs were not found in Beil or CA through 1956.

Anilinobenzene. One of the names for Diphenylamine.
ANILINOBENZENEDIAZONIUM HYDROXIDE AND DERIVATIVES

\( \text{p-Anilinobenzenediazonium Hydroxide; Diphenylamine-4-diazonium Hydroxide or Phenylamine-4-diazonium Hydroxide,} \)

\( \text{C}_6\text{H}_5\cdot\text{NH-C}_6\text{H}_4\cdot\text{N}_2\cdot\text{OH}, \) known only in the form of salts, some of which are explosive

Ref: Beil 16,602-3, (371) & [307]

\( \text{p-Anilinobenzenediazonium Azide, C}_{11}\text{H}_{18}\text{N}_8 \)

not found in Beil or CA through 1956

\( \text{p-Anilinobenzenediazonium Nitrate or Diphenylamine-4-diazonium Nitrate, C}_6\text{H}_5\cdot\text{NH}--\)

\( \text{C}_6\text{H}_4\cdot\text{N}_2\cdot\text{ONO}_2, \) mw 258.23, N 21.70%. Yel ndls, explo surg lightly on heating. Was prep by treating N-phenyl-N-(4-nitrosophenyl)-hydroxylamine with nitrogen oxide

Refs: 1)Beil 16,603 2)E.Bamberger et al,

Ber 31,1515(1898)

\( \text{p-Anilinobenzenediazonium Nitrate, Azido-, C}_{13}\text{H}_{18}\text{N}_8\text{O}_3 \)

and Diazoido-, C_{13}H_{18}N_8O_3 Derivatives were not found in Beil or CA through 1956

\( \text{Nitroanilinobenzenediazonium Nitrate,} \)

\( \text{C}_{13}\text{H}_{18}\text{N}_8\text{O}_3 \)

not found in Beil or CA through 1956

1-Anilino-2,6-dinitrobenzenediazonium Azide, C_{12}H_{16}N_6O_4 — not found in Beil and CA through 1956

1-Anilino-2,6-dinitrobenzenediazonium Chloride, C_{12}H_{16}NH-C_{6}H_4(NO_2)_2N_2Cl;

decom at 175° when slowly heated and

e xpld mildly when heated rapidly

Refs: Same as under Nitrate, described below

1-Anilino-2,6-dinitrobenzenediazonium Nitrate; 2,6-Dinitrophenylamine-4-diazonium Nitrate, indexed in CA as 4-Anilino-3,5-

Dinitrobenzenediazonium Nitrate, C_{6}H_{5}\cdot\text{NH}--

\( \text{C}_6\text{H}_4\cdot\text{N}_2\cdot\text{ONO}_2, \) mw 348.23, N 24.14%, OB to CO\(_2\) — 95.7%. Yel-bn ndls, mp decomp at 148° with emission of light on slow heating

and detonates violently on rapid heating or when struck; s1 sol in alc. Was prep by treating 2,6-dinitro-4-aminodiphenylamine nitrate with iso-amyl nitrite in alcohol

Refs: 1)Beil 16, [307] 2)H.Lindemann & W.Wessel, Ber 58,1227(1925) & CA 19,2824 (1925)

1-Anilino-2,6-dinitrobenzene-4-diazonium Sulfate, C_{6}H_{5}\cdot\text{NH-C}_6\text{H}_4(\text{NO}_2)_2\cdot\text{N}_2\cdot\text{OSO}_3\text{H},

decom at 180° when heated slowly and

e xpld mildly when heated rapidly

Refs: Same as under Nitrate described above

1-(2,4-Dinitroanilino)-benzene-4'-diazonium Azide C_{12}H_{16}N_4 — not found in Beil or CA through 1956

1-(2,4-Dinitroanilino)-benzene-4'-diazonium Chloride or 2,4-Dinitrophenylamine-4'-diazonium Chloride, (O_2N)_2C_{6}H_{5}NH-C_{6}H_4-

N_2Cl. Its monohydrate, in the form of golden-yel ndls, was prep by diazotization of 2',4'-dinitro-4-aminodiphenylamine

Refs: 1)Beil 16,603 2)G.T.Morgan & M.G.Micklethwait, JCS 91,603(1908)

1-(2,4-Dinitroanilino)-benzene-4'-diazonium Nitrate, Arnd

Diazido-, C_{12}H_{16}N_8O_3 Derivatives were not found in Beil or CA through 1956

N

2-Nitroanilinobenzenediazonium Salts were found in Beil

Nitrate, indexed in CA as 4-Anilino-3,5-

Dinitrobenzenediazonium Nitrate, C_{6}H_{5}\cdot\text{NH}--

\( \text{C}_6\text{H}_4\cdot\text{N}_2\cdot\text{ONO}_2, \) mw 348.23, N 24.14%, OB to CO\(_2\) — 95.7%. Yel-bn ndls, mp decomp at 148° with emission of light on slow heating

and detonates violently on rapid heating or when struck; s1 sol in alc. Was prep by treating 2,6-dinitro-4-aminodiphenylamine nitrate with iso-amyl nitrite in alcohol

Refs: 1)Beil — not found 2)F.Steppes,

GerP 291,156(1915) & CA 11,889(1917)

3)A.H.Blatt & F.C.Whitmore,NDRC Div B

Rept Serial No 442 and OSRD 1085(1942),23

4)A.H.Blatt,OSRD 2014(1944) (Under Di-

azonium Salts)

Note: No higher nitrated derivs of Anilino-

benzenediazonium salts were found in Beil

or CA through 1956

ANILINOBENZOIC ACID

AND DERIVATIVES

Anilinobenzoic Acid; Diphenylaminocarboxy-
l Acid or N-Phenylanthranilic Acid, C_{6}H_{5}--

\( \text{NH-C}_6\text{H}_4\cdot\text{COOH. Several isomers are de-} \)

scribed in Beil 14,327,(533, 585) & [213]
Anilinobenzoic Acid, Azido—, C_{11}H_{10}N_{3}O_{2} and Diazido—, C_{11}H_{10}N_{3}O_{2} Derivatives were not found in Beil or CA through 1956

Mononitroanilinobenzoic Acid, C_{11}H_{10}N_{2}O_{4}. Several isomers are described in Beil 14, 328–9, 374,377,442 & [214,233]

Dinitroanilinobenzoic Acid, C_{11}H_{10}N_{4}O_{4}. Several isomers are described in Beil 14, 329,380,445,(560,572) & [214,235]

4-Anilino-3,5-dinitrobenzoylazide or 2,6-Dinitrodiphenylamino-4-carboxylazide, C_{11}H_{9}N_{3}O_{4}, mw 328.24, N 25.61%. Pale red crystals (from benz), mp 135°; defl on rapid heating; easily sol in NB, sol in benz, diff sol in gasoline. Can be prepd by treating 4-anilino-3,5-dinitrobenzoylazide with Na nitrite in AcOH

Refs: 1)Beil 14,(274) 2)H. Lindemann & W. Wessel, Ber 58,1228(1925) & CA 19, 2824(1925)

Trinitroanilinobenzoic Acid, C_{13}H_{10}N_{4}O_{9}, mw 348.23, N 16.09%. Several isomers are described in Beil 14, 329,393,429,(533,560, 572) & [236]

Tetranitroanilinobenzoic Acid, C_{13}H_{10}N_{4}O_{8}, mw 393.23, N 17.81% – not found in Beil or CA through 1956

**ANILINOBENZONITRILE AND DERIVATIVES**

Anilinobenzonitrile or Cyanodiphenylamine, C_{11}H_{9}N=CH-CN – not found in Beil or CA through 1956. It may be considered as the parent compd of the following derivs:

Anilinobenzonitrile, Azido—, C_{11}N_{3}N_{3} and Diazido—, C_{11}H_{10}N_{4} Derivatives were not found in Beil or CA through 1956

Nitroanilinobenzonitrile or Nitrocyanodiphenylamine, C_{11}H_{10}N_{3}O. Several isomers are known


m-(2,4-Dinitroanilino)-benzonitrile or 2,4-Dinitro-3'-cyanodiphenylamine, (O_{2}N)_{2}C_{6}H_{4}-\text{NH}-C_{6}H_{4}-CN, mw 284.23, N 19.71%. Yel crystals, mp 190°. Was prepd by condensation of 3-aminobenzonitrile with 1-chloro-2,4-dinitrobenzene (Ref 2)


m-(2,4,6-Trinitroanilino)-benzonitrile or 2,4,6-Trinitro-3'-cyanodiphenylamine, (O_{2}N)_{3}C_{6}H_{4}-\text{NH}-C_{6}H_{4}-CN, mw 329.23, N 21.27%. Golden-yel crystals (from alc); mp 180°; sl sol in w, insol in petr ether; moderately sol in alc & CCl_{4}; readily sol in warm NB and chlf and very sol in acetone. Was prepd by condensation of 3-aminobenzonitrile with picryl chloride (Ref 2, p 364).

Its expl props were not examined


Trinitroanilinobenzonitrile, C_{11}H_{10}N_{4}O_{8} – not found in Beil or CA through 1956

Anilinobenzoylazide, Dinitro. See 4-Anilino-3,5-dinitrobenzoylazide under Anilinobenzoic Acid

Anilinobutane. Same as Butylaniline

**ANILINOBUTANOL AND DERIVATIVES**

Anilinobutanols; Butanolanilines, called also Aminophenylbutanols and Phenylaminobutanols, C_{10}H_{15}NO. Several isomers are described in the literature and they may be considered as parent compds of the following derivs:

Anilinobutanol, Azido—, C_{10}H_{14}N_{3}O and Diazido—, C_{10}H_{14}N_{4}O Derivatives were not found in Beil or CA through 1956

Mononitroanilinobutanols, C_{10}H_{14}N_{2}O were not found in Beil or CA through 1956

2-(2',4'-Dinitroanilino-N-)-1-butanol or 2-(2',4' -Dinitrophenylamino)-1-butanol,

(O_{2}N)_{2}C_{6}H_{4}-\text{NH}-\text{CH}_{2}-\text{CH}_{2}-\text{CH}_{3}, mw 255.23,
N 16.47%. Col solid, mp 113–113.5°. Was prep by Elderfield et al (Refs 2 & 5) by condensation of 2,4-dinitrochlorobenzene with 2-amino-l-butanol in alc soln and in the presence of NaOH. When nitrated it yields the explosive which may be named:

2-(N,2',4',6'-Tetranitroanilino)-1-butanol Nitrate; 2-(2',4',6'-Trinitro-N-nitranilino)-1-nitroxybutanol; 2-(N-Picryl-N-nitramino)-1-butanol Nitrate; 2-(2',4',6'-TrinitrophenylNitramino)-1-butanol Nitrate or 2-(N,2',4',6'-Tetranitrophenylamino)-1-butanol Nitrate. Elderfield called it (Ref 2); 2-(2',4',6'-Trinitropheny lamino)-butanol-N-nitramine Nitrate; McGill (Ref 4); 2,4,6-Trinitrophe nyli sodiobutylolnitramine Nitrate and Blatt (Ref 6): 2,4,6-Trinitrophenyl-(1-methylol)-propylnitramine Nitrate.

\[
\text{CH}_2(\text{ONO}_2)\text{CH}_2\text{CH},\text{CN(NO)}
\]

mw 390.23, N 21.53%, OB to CO\(_2\) ~ 57.4%, OB to CO ~ 16.4%. Yel crysts, d 1.39, mp 140–140.5° (decomp); insol in w & alc, sol in molten TNT and acetone. Was prep by Elderfield et al by nitrating 2-(2',4'-dinitroanilino)-1-butanol with mixed nitric-sulfuric acids. A detailed description of the procedure is given in Ref 5.

Tetranitroanilinobutanolnitrate is a powerful expl (Bal Mortar Test 117% TNT). When heated above its mp it defragrated at 205–10° with a brilliant puff without deton, when heated to 216° it ignited in 5 secs. Its Sensitivity to Impact is comparable to that of tetryl (Ref 6). Fairly stable in storage and when heated to 100°; when heated in a closed tube at 135° for 30 mins, it exploded. Loss of wt in the 75° International Test 0.1%; Hygroscopicity Test at 90% RH and 25° gain in wt 0.06% and at 100% RH 0.19% (Refs 2 & 3). Its \(Q\_0\) 1250.6 kcal/mol & \(Q\_c\) ~ 35.7 kcal/mol (Ref 3). Some other props are given in Ref 7, which is also classified.

Refs: 1)Beil 12,756 2)A.Moulder, Rec 26, 186–7(1907)

2-(2',4',6'-Trinitro-N-nitranilino)-iso-butyr ic Acid; N-(2,4,6-Trinitrophenyl)-N-nitro-a-amino-iso-butyr ic Acid; N,2,4,6-Tetranitro-N-iso-butyric acid -aniline or \(\alpha\)-PicrylNitramino-iso-butyr ic Acid, called in CA, \(\alpha\)-Trinitropenynitraminobutyric Acid, \(\alpha\)-[2,4-Dinitroanilino]-iso-butyrsäure, \((O\text{N})\text{C},\text{H}_2\text{NH-C(CH)}_2\text{COOH, mw 269.21, N 15.61%}.\) Lt yel leaflets from dil AcOH, mp 190–10° (decomp beginning at 175°). Was prep by Moulder (Refs 1 & 2) by the action of HCl(d 1.19) on the nitrile of \(\alpha\)-[2,4-Dinitroanilino]-iso-butyr ic acid.

Refs: 1)Beil 12,756 2)A.Moulder, Rec 26, 186–7(1907)

2-(2',4',6'-Trinitro-N-nitranilino)-iso-butyr icaid; N-(2,4,6-Trinitrophenyl)-N-nitro-a-amino-iso-butyr icaid; N,2,4,6-Tetranitro-N-iso-butyric acid -aniline or \(\alpha\)-PicrylNitramino-iso-butyr icaid, called in CA, \(\alpha\)-Trinitropenynitraminobutyric Acid, \(\alpha\)-[2,4-Dinitroanilino]-iso-butyrsäure, \((O\text{N})\text{C},\text{H}_2\text{NH-C(CH)}_2\text{COOH, mw 269.21, N 15.61%}.\) Lt yel leaflets from dil AcOH, mp 190–10° (decomp beginning at 175°). Was prep by Moulder (Refs 1 & 2) by the action of HCl(d 1.19) on the nitrile of \(\alpha\)-[2,4-Dinitroanilino]-iso-butyr icaid.

Ref: 1)Beil 12,756 2)A.Moulder, Rec 26, 186–7(1907)

2-(2',4',6'-Trinitro-N-nitranilino)-iso-butyr icaid; N-(2,4,6-Trinitrophenyl)-N-nitro-a-amino-iso-butyr icaid; N,2,4,6-Tetranitro-N-iso-butyric acid -aniline or \(\alpha\)-PicrylNitramino-iso-butyr icaid, called in CA, \(\alpha\)-Trinitropenynitraminobutyric Acid, \(\alpha\)-[2,4-Dinitroanilino]-iso-butyrsäure, \((O\text{N})\text{C},\text{H}_2\text{NH-C(CH)}_2\text{COOH, mw 269.21, N 15.61%}.\) Lt yel leaflets from dil AcOH, mp 190–10° (decomp beginning at 175°). Was prep by Moulder (Refs 1 & 2) by the action of HCl(d 1.19) on the nitrile of \(\alpha\)-[2,4-Dinitroanilino]-iso-butyr icaid.

Ref: 1)Beil 12,756 2)A.Moulder, Rec 26, 186–7(1907)
and initiating expl mixts as, for instance, with NS.

Among the heavy metal salts, Filbert preferred the basic lead salt, \((\text{O}_2\text{N})\text{C}_6\text{H}_5\cdot \text{N}_(\text{PbOH})\cdot (\text{CH}_3)\cdot \text{COO}(\text{PbOH})\) (probable formula), which was prep. by treating trinitronitranilinosbutyric acid with lead nitrate in the presence of some NaOH. This salt is extremely sensitive to static electricity and fairly sensitive to shock and friction. It offers a marked advantage over lead styphnate in ease of ignition—in a loose condition it may be fired with a current of only 0.32 amp vs 0.38 amp required for lead styphnate.

Filbert claimed that the basic lead salt is especially suitable for use as an ignition agent in fast electric blasting caps. Methods of prepn and other props are given in Beil 12,182 & [106] (See also Aminophenylethanol).

Mononitroanilinoethanols, \((\text{O}_2\text{N})\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{OH}\), mw 182.18, N 15.38%—not found in Beil. Mononitroanilinoethanol Nitrate, \(\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{ONO}_2\), mw 182.18, N 15.38%—not found in Beil.

2-Anilinoethanethiol, Azido—, \(\text{C}_6\text{H}_5\text{N}_3\text{O}\) and Diazido—, \(\text{C}_6\text{H}_5\text{N}_3\text{O}\) Derivatives were not found in Beil or CA through 1956.

Note: In seismographic work it is desirable that there be no appreciable delay between the application of the current and the firing of the cap. Investigations by means of an oscillograph showed that caps contg the above basic lead salt as an ignition agent exhibited a time lag of 0.004 sec when fired by a current of 1 amp, compared with 0.006 sec when lead styphnate was used under the same conditions. In both cases, the time lag was greatly diminished by applying larger currents.


Anilinodiazonium Hydroxide and Derivatives. See Aminobenzenediazonium Hydroxide and Derivatives.

**ANILINOETHANOL AND DERIVATIVES**

2-(or \(\beta\)-)Anilinoethanol; Phenylaminoethanol; Phenylethanolamine; \(\beta\)-Ethanol-N-amine; \(\beta\)-Anilinoethyl Alcohol; \(\beta\)-Hydroxyethylamine or \(\beta\)-Hydroxyethylaminobenzene (called in Beil \(N\)-(\(\beta\)-Oxy-\(\alpha\)-anil) aniline), \(\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{OH}\), mw 137.18, N 10.21%. Col liq turning yel and then brn on standing, bp 167–70° at 19 mm, d 1.1129 at 25°/25°, n° 1.5749. Was first obtained in 1873 by Ladenburg. Methods of prepn and other props are given in Beil 12,182 & [106] (See also Aminophenylethanol).

Mononitroanilinoethanols, \((\text{O}_2\text{N})\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{OH}\). Several isomers were prep. and examined by Kremer from the point of view of their physiological props. (Ref 2) 1)Beil—not found 2)C.B.Kremer, JACS 61,1323 (1939) & CA 33,6259 (1939).

Nitronitranilinoethanols, \((\text{O}_2\text{N})\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{ONO}_2\), not found in Beil. Nitronitranilinoethanol Nitrate, \((\text{O}_2\text{N})\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{ONO}_2\), not found in Beil. Nitronitranilinoethanol Nitrate, 

2-(2’,4’-Dinitroanilino)ethanol; \(\text{N}-(2,4\text{-Dinitrophenylethanolamine; } 2,4\text{-Dinitrophenylanilinoethanol; } 2,4\text{-Dinitrohydroxyethylaniline or } 2,4\text{-Dinitro}-1-(\beta\text{-hydroxyethyl})\text{-aminobenzene; } \text{O}_2\text{N})\text{C}_6\text{H}_5\cdot \text{NH}\cdot \text{CH}_2\cdot \text{CH}_2\cdot \text{OH}\), mw 227.18, N 18.50%. Orange-yel crysts, mp 89.92°. Was prep. by Moran (Ref 2) from 2,4-dinitrochlorobenzene and aminoethanol. This method is described by Clark (Ref 3). Other methods of prepn are described in Refs 4 & 5. On nitration this compd yields the highly explosive 2-(2’,4’,6’-trinitro-N-nitranilino)-ethanol nitrate, designated as Pentryl (See p A425). (Ref 4)


(A new method of prepn of 2,4-dinitrophenyl derivs of aminoalcohols, among them aminoethanols)
Dinitroanilinoethanol Nitrate, \((O_2N)_2C_6H_4NH-CH_2-CH_2ONO_3\), mw 272.18, N 20.59% - not found in Beil and CA through 1956

Dinitronitraminoethanol, \((O_2N)_2C_6H_4N(NO_2)_2\)-CH_2-CH_2OH, mw 272.18, N 20.59% - not found in Beil and CA through 1956

Dinitronitraminoethanol Nitrate, \((O_2N)_2C_6H_4N(NO_2)_2\)-CH_2-CH_2(OONO_2), mw 317.18, N 22.08% - not found in Beil or CA through 1956

2-(2',4',6'-TRINITRO-N-NITRANILINO)ETHANOL; 2,4,6-Tritritrophenylaminothanol; 2,4,6-Trinitrohydroxyethylaniline; Hydroxyethylpicramide or 2,4,6-Trinitro-1-(β-hydroxyethylamino)-benzene, \((O_2N)_2C_6H_4\cdotNH\cdotCH_2\cdotCH_2\cdotOH\), mw 272.18, N 20.59%. Yel ndls, mp 109-109°, insol in eth & petr eth, sl sol in w. Can be prepd by the interaction of picryl chloride and aminothanol. When nitrated it gives expl Pentryl(see below)

Refs: 1)Beil - not found 2)P.van Romburgh & C.W.Zahn, Rec 57, 444(1938) 3)K.F.Waldkotter, ibid, 1297(1938)

2-(2',4',6'-TRINITRO-N-NITRANILINO)ETHANOL NITRATE; 2-(N,2,4,6-TETRANITRO-1-(β-NITROXYETHYL)NITRAMINO)-BENZENE; sym-TrinitrophenylNitrminoethyl Nitrate; N-(2,4,6-Trinitropheryl)-N-nitro-β-aminoethyl Nitrate; β-(2,4,6-Trinitrophenylamino)ethyl Nitrate or TrinitrophenylethanolNitrmine Nitrate, designated as Pentryl[Note: According to A.Stettbacher, Protar 8, 91 (1942), the word "Pentryl" has been used to designate mixes of PETN and TNT, known also as Pentolites, \((O_2N)_3C_6H_2\cdotN(NO_2)_2\)-CH_2-CH_2(OONO_2), mw 362.18, N 23.22%, OB to CO_2 = 35.3%, OB to CO 0%. Small cream-colored crysts, d 1.82(abosl), d 1.73(maxim by compression), d 0.45(apparent), d 0.74(compressed in detonators at 3400 psi = 239 kg/(cm^2); mp 126-9°(with sl decompn); expl at 235° when heated at the rate 20°/min from 100°C on(Ref 6); ignites in 1.5 sec at 270-80°(Ref 8a). Was first prepd in 1925 by Moran(Ref 2) by nitrating 2,4-dinitrophenylaminoethanol with mixed nitric-sulfuric acid. E.von Herz(Ref 3) prepd pentryl by nitrating phenylaminoethanol, and patents were granted for its use as an explosive

Clark(Ref 4) gives the following method for the prepn of pentryl: a)Dissolve, with stirring, 100g of 2,4-dinitroanilinoethanol in 1000g of 95% sulfuric acid maintained at 20-30° by a cold water jacket, and pour this soln gradually over a period of 12-15 mins into stirred nitric acid(47°Be = d 1.48 = 86% HNO_3), also maintained at 20-30°. b)Continue stirring for 30 mins at 30° then slowly raise the temp to 40° and maintain at this temp for 30 mins. c)At the end of this second 30-min period raise the temp to 50° and hold at this temp for 30 mins. d)Drown the mixt in a large amt of ice water and separate the resulting ppt of pentryl by filtration e)Rinse the ppt on the filter, first with cold water, then with cold dilute Na carbonate soln and finally with water (yield of the crude product is ca 90% of theoretical)

f)Dry the product and purify it by recrystallization from benzene. A melting point of 128° was reported for the product

Waldkotter(Ref 7) prepd pentryl from the same ingredients as Clark and reported a mp of 129°. Desseigne(Ref 10) gives detailed description for the prepn of pentryl starting with the condensation of dinitrochlorobenzene and monoethanolamine, followed by nitratation of the resulting product with mixed nitric-sulfuric acid. Pentryl was also prepd and investigated in Russia(Ref 5)

The explosive props of pentryl were detnd by Clark(Ref 4) at the USBurMines and by L.Médard(Ref 9) for the "Commission des Substances Explosives." Some of these props are also listed by Desseigne(Ref 10). A few props were detnd by van Romburgh (Ref 6). A brief description of pentryl is given by Davis (Ref 8)

Following are the properties of pentryl taken from various sources:

Action of Light. See Light, Action of Ballistic Mortar Test. See Power, by Ballistic Mortar
Behavior Toward Flame. Whether confined or not, pentryl burns when ignited with a brilliant white flame without detonating. The same thing happens when pentryl is compressed at high pressure and confined in a detonator cap and then ignited by the spit of a fuse (Ref 4, p 1386)

Brisance by Fragmentation Test. When using a malleable iron grenade container with a 16.5g sample of explosive, the brisance was found to be greater than that of TNT and somewhat greater than that of PA (Ref 4, p 1390)

Brisance by Lead Block Compression (Crushing) Test. When using the procedure described in the USBurMines Bull 346 (1931), the compressions of 64.0g samples weighing 50.0g and of density 0.75 were: 14.8 mm for TNT (100%), 18.5 mm for Pentryl (125%) and 16.4 mm for PA (111%) (Ref 4, p 1389) (See also Ref 8a). This test serves also as a measure of percussive force of expls

Brisance by Lead Plate Cutting Test. When using the proc described in ChemMetEngg 26, 1126–32 (1922) and exploding a sample compressed at 2320 psi (163.1 kg/cm²), pentryl cuts a hole in the plate equal in size to that made by tetryl and slightly larger than PA or TNT (Ref 4, pp 1387–8) (See also Ref 8a)

Brisance by Sand Bomb Test (Sand Crushing Test). When a No 2 USBurMines bomb was used with 0.50g samples compressed in a No 8 detonator shell at 3400 psi (239.0 kg/cm²) and initiated by 0.30g of MF (compressed at 3400 psi), the amt of sand crushed by pentryl alone (after deducting ca 11.5g crushed by 0.30g MF) was 56.0g (129%) vs 43.6g (100%) for TNT, 54.2g (124%) for tetryl and 45.3g (104%) for PA (Ref 4, p 1387) (See also Ref 8a). The bomb and procedure are described in IEC 25, 664–5 (1925)

Note: Some authorities believe that the sand test measures the strength of an explosive

Compressibility. When subjected to a pressure of 2500 kg/cm², pentryl attained a density of 1.73. At a pressure of 400 kg/cm² its d was ca 1.5, at 1000 ca 1.63, at 1500 ca 1.68 and at 2000 ca 1.70 (Ref 9, p 52)

Dead-Pressing. Clark subjected pentryl to pressures as high as 5830 psi (409.8 kg/cm²) in a detonator cap and then ignited and observed no dead-pressing (Ref 4, p 1387); Médard used pressures as high as 2500 kg/cm² and reported no dead-pressing (Ref 9, pp 51–2)

Detonation Equations. When pentryl is detonated in the absence of oxygen (or air), it does so approximately as indicated in the reaction:

\[ C_8H_6NO_t + 4O_2 \rightarrow 8CO + 3H_2O + 3N_2 \]

When sufficient oxygen is present the reaction may be represented by:

\[ C_8H_6NO_t + 4O_2 \rightarrow 8CO_2 + 3H_2O + 3N_2 \]

If K chlorate is used as the oxidizer, 47.4 parts of it are required for 52.6 parts of K and 64.0 parts of density 0.75 were: 14.8 mm for a sample confined at 0.90 (Ref 4, pp 1387) (See also Ref 8a). This test serves also as a measure of percussive force of expls

Detonation Velocity (Rate of Detonation). When using the Mettagang method as described in USBurMines Bull 346 (1931), the average velocity for a sample compressed to d 0.80 in a light lead tube over 0.5 m long and 0.5" (1.27 cm) id was 5000 m/sec vs 4450 m/sec for TNT compressed to d 0.90 (Ref 4, p 1389)

Note: The above velocities are not maximum because low densities were used. The Hercules Powder Co reported 5254 m/sec for a sample confined at d 1.0 in a 1/4" glass tube (Ref 8a). Médard (Ref 9, p 51) reported the vel of deton detd by the method of Dautriche for samples packed in cardboard cartridges of 30 mm diam and initiated by 1.5g MF, as 5330 m/sec at d 0.90, 5560 at d 0.99 and 7340 at d 1.65. In another ser-
reported 7300 m/sec at d 1.60 vs 7100 for PA

Drop Test. See Impact Sensitivity Test

Effect of Pressure on Performance in Detonators. See Pressure Effect, etc

Explosion(or Ignition) Temperature. When 0.02g charges of pentryl were dropped on molten Wood's metal preheated to various temps, no expln or ignition took place at 233°(5 trials), but at 235° the sample ignited in 3 secs after it touched the hot surface. The same time interval was observed at 240°, while at 250° it was 2 secs, at 260° 1.5 to 2 secs and at 270°-280° 1.5 secs (Ref 4, p 1389)

Note: According to van Romburgh(Ref 6), pentryl exploded at 230° when heated from 100° at the rate of 20°/min

Flame Action. See Behavior Toward Flame

Fragmentation Test. See Brisance by Fragmentation Test

Friction Sensitivity. When using a Type A "Pendulum Friction Device" with a steel shoe and the procedure described in USBur Mines Bull 346(1931) and in IEC 25, 664-5(1925), pentryl proved to be somewhat more sensitive to friction than tetryl and very much more sensitive than PA or TNT(Ref 4, p 1386)

Gap Test(Propagation Test or Sympathetic Detonation Test). In order to ascertain the relative ability of the disturbance sent out by the explosion of a shielded detonator charged with pentryl as the base charge to transfer deton over an air gap to a receiving charge of an explosive(such as dynamite), Clark used the same method as he described for DDNP in IEC 25, 668(1933)

When a shielded detonator contg a base charge of pentryl(0.50g) and a priming charge of MF(0.20g) (reinforced) was fired in a galvanized tube, it propagated deton to a charge of 40% straight dynamite located at a distance of 54 ft(16.5 m). This distance is 37% greater than that required for the Commercial No 8 tetryl detonators and about 4 times greater than that for a No 8 (80/20-MF/K chloride) detonator(Ref 4, pp 1389-90)

Heat of Combustion, $Q_v$(calcd) 911.1 kcal/mol

Heat of Explosion, $Q_e$(calcd) 372.4 kcal/mol

Heat of Formation, $Q_f$(calcd from above heat of combustion) 43.4 kcal/mol(Ref 12)

Explosion(or Ignition) Temperature. See Explosion(or Ignition) Temperature

Impact Sensitivity Test(Drop Test). When using the "Small Impact Device," described in USBur Mines Bull 346(1931) and in IEC 25, 664-5(1925), the following max heights of drop in cm for a 2-kg hammer to produce "no explosion" in 5 trials were obtained: pentryl 30, tetryl 27.5 and TNT 100+. These tests show that the sensitivity to impact of pentryl is sl less than that of tetryl but considerably greater than that of TNT(Ref 4, p 1386). Diatt(Ref 8a) gives FI(figure of insensitiveness) 61% PA. Médard(Ref 9) reported that a 5-kg hammer falling from a height of 0.26 m (energy 1.30 kg m) on a sample of pentryl placed in a Bourges cap produced 56 explns out of 100 trials, while a 2-kg hammer falling from a height of 0.75 m(energy 1.50 kg m) produced 50 explns out of 100 as against 1.05 m(energy 2.10 kg-m) for tetryl. Desseigne(Ref 10, p 263) reported that PA required 5.0 kg m energy(more than three times that for Pentyrl) for 50% detonations

Initiation, Sensitivity to(Sensitivity to Detonation by Initiating Agents). This may be expressed in terms of the minimum wt of an initiating agent which causes complete deton of an explosive used as a base charge. Complete deton is indicated when there is no further increase of sand crushed in the BurMines No 2 "sand bomb test" with an increased wt of initiator(except that resulting from the additional wt of the initiator itself). This proc is described in USBur Mines Tech Paper 125(1916) and Rept Invest 2558(1923)
Following are minimum amounts of two primary explosives required to cause complete detonation of 0.50g of pentryl loaded as a base charge into a No 8 detonator case and compressed at 3400 psi (239.0 kg/cm²): 0.150g of MF & 0.025g of LA. The corresponding values for PA are 0.225 & 0.12, for TNT - 0.240 & 0.16 and for tetryl - 0.165 & 0.03g (Ref 8a).

The above values indicate that the sensitivity of pentryl to detonation is similar to that of tetryl and greater than that of TNT and PA (Ref 4, p 1387).

Médard (Ref 9) reported that 0.20g of MF assures complete detonation of pentryl at d’s 1.50 to 1.65 and that 0.25g is required at d 1.73.

**Lead Block Compression (Crushing) Test.** See Brisance by Lead Block Compression (Crushing) Test.

**Lead Block Expansion Test.** See Power by Trauzl Test.

**Lead Cylinder Compression Test.** Same as Lead Block Compression (Crushing) Test.

**Lead Plate Cutting Test.** See Brisance by Lead Plate Cutting Test.

**Light, Action of.** Slight decoloration after exposure to light for several months (Ref 4, p 1388).

**Percussive Force.** See Brisance by Lead Block Compression (Crushing) Test.

**Power by Ballistic Mortar Test.** Was detnd at the USBurMines as 133% of TNT and by the Hercules Powder Co as 84% of blasting gelatin (Ref 8a).

**Power (or Strength) by Trauzl Test (Lead Block Expansion Test).** This test is supposed to represent the comparative "disruptive power" of explosives. When using 1g samples and a small lead block and the procedure described in the USBurMines Bull 346 (1931), the following values for expansion of the cavity in the block (in cc) and for relative strengths were obtained:

<table>
<thead>
<tr>
<th>Solvent</th>
<th>25°C</th>
<th>50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>0.70</td>
<td>v sol</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>trace</td>
<td>trace</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.07</td>
<td>0.26</td>
</tr>
<tr>
<td>Ethanol</td>
<td>0.11</td>
<td>0.48</td>
</tr>
<tr>
<td>Ether</td>
<td>0.16</td>
<td>-</td>
</tr>
<tr>
<td>Ethylene dichloride</td>
<td>0.72</td>
<td>2.68</td>
</tr>
<tr>
<td>Methanol</td>
<td>0.67</td>
<td>2.14</td>
</tr>
<tr>
<td>Nitroglycerin</td>
<td>v sol</td>
<td>v sol</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.63</td>
<td>1.70</td>
</tr>
<tr>
<td>Water</td>
<td>trace</td>
<td>trace</td>
</tr>
</tbody>
</table>
Specific Work (Travail Spécifique, in French). Méard (Ref 9, p 51) report—124 vs 100 for PA and Desseigne (Ref 10, p 263) gave 126 vs 100 for PA and 114 for tetryl.

Stability, Thermal. When detnd by the 75° International Heat Test, described in US Bur Mines Bull 96(1916)—no loss of wt in 48 hrs. When the temp was raised to 120°, red fumes (nitrogen oxides) appeared in 4 hrs (Ref 4, p 1388) (See also Ref 8a)

Storage under Distilled Water for 15 days at RT resulted in no loss of brisance and strength, as detnd by the "sand bomb test." No decompn took place and the water remained neutral (Ref 4, pp 1387–8)

Strength. See Power by Trauzl Test and Brisance by Sand Bomb Test

Surveillance Test at 75°. Slight decomposition accompanied by a change of color from cream to yellow and a lowering of the mp from 128° to 127.5° took place after 40 days, but this did not affect its strength and brisance as detnd by the "sand bomb test" (Ref 4, p 1388)

Sympathetic Detonation Test. See Gap Test

Thermal Stability. See Stability, Thermal

Toxicity. According to Sax (Ref 11), its toxicity is unknown, but when heated to decompn it emits highly toxic fumes of nitrogen oxides. Hercules Co reported that it causes dermatitis (Ref 8a)

Trauzl Test. See Power (Strength) by Trauzl Test

Velocity of Detonation. See Detonation velocity

Work Specific. See Specific Work

Uses. Pentryl was proposed for use as a base charge in detonators in lieu of tetryl or nitromannite, as well as for some other purposes either alone or mixed with other explosives. Addition of an oxidizing agent (such as K chlorate) to pentryl greatly enhances its strength and is recommended by Clark as of distinct economic advantage (Refs 3, 4, 5, 8, 9, 10 & 11)


Pentryl Homologs. A series of explosive compds related to pentryl were prep'd by den Otter (Ref 2) by nitrating the products of reaction obtained by reacting 1-amino-2,3-propanediol or 2-amino-1,3-propanediol with dinitrochlorobenzene, dinitrodichlorobenzene or dinitrochloronaphthalene. Most of these compds are listed in this work separately. Waldkötter (Ref 3) prep'd a series of compds, some of them explosive, obtained by nitrating the products of the interaction of hydroxyethylamine with halo-benzene. Kremer & Meltsner (Ref 4) prep'd a number of chloro-nitroamino- and chloraminoaniline alkanols, intermediates of pentryl homologs

ANILINOETHANOL, HALOGEN DERIVATIVES

Halo-nitro-anilinoethanols: Halo-nitro-1-(β-hydroxyethylamino)-benzene, or Halo-nitro-phenylaminoethanols were prepd and examined by K.F.Waldkötter, Rec 57,1298–1310 (1938). Among these compds, the halo-dinitro-N-nitroanilinoethanol nitrates of general formula \((\text{O}_x\text{N})_y\text{C}_6\text{H}_x(\text{X})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\) (where \(X\) is a halogen) proved to be explosive. They can be prepd by nitrating either halo-nitro-1-(β-hydroxyethylamino)-benzene or halo-dinitro-1-(β-hydroxyethylamino)-benzene with absol nitric acid at -10 to -15°. Some dibromo-nitroanilinoethanol nitrates, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Br})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), are also explosive but much weaker than the corresponding dinitro-compounds.

2-(4'-Chloro-2' -nitroanilino)-ethanol and 2-(5'-Bromo-2'-nitroanilino)-ethanol, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Cl})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), are also explosive but much weaker than halo-nitro-N-nitranilinoethanol nitrates, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Br})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), orange and yel ndls, mp 102° and 132° resp, were prepd and examined by K.F.Waldkötter, Rec 57,1299 & 1303(1938). The 5'-chloro deriv seems to exist in two modifications, mps 132° and 116°.

2-(4'-Bromo-2',6'-dinitroanilino)-ethanol, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Br})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), is also explosive but much weaker than halo-nitro-N-nitranilinoethanol nitrates, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Br})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), orange and yel ndls, mp 114°, was prepd and examined by K.F.Waldkötter, Rec 57,1301(1938)

2-(4',6'-Dichloro-2' -nitroanilino)-ethanol Nitrates, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Cl})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), N 13.02%. Pale yel crysts, mp 69°, decomp at 178° and inflames at 305°. It is a weak explosive. Was prepd and examined by K.F.Waldkötter, Rec 57,1307-8(1938)

2-(4',6'-Dibromo-2' -nitroanilino)-ethanol Nitrates, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Br})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), N 19.91%. Yel crysts, mp 90–92°. Seems to exist in a modification which melts at 81°, decomp at 105° and inflames at 250°. It is an explosive. Sol in chlf, insol in w, sl sol in eth and very sol in petr eth. Can be prepd by nitrating 2-(4'-chloro-2'-nitroanilino)-ethanol with absol nitric acid at -15°.

Refs: 1)Beil - not found 2)K.F.Waldkötter, Rec 57,1299(1938)

2-(5'-Chloro-2',4'-dinitro-N-nitranilino)-ethanol Nitrates, \((\text{O}_2\text{N})_x\text{C}_6\text{H}_x(\text{Cl})-\text{N}-(\text{NO}_3)_y-\text{CH}_2-\text{CH}_2(\text{ONO}_2)_y\), N 19.91%. Yel crysts, mp 81°, decomp at 180° and inflames at 253°; insol in w, very sl sol in petr eth, sl sol in eth and sol in chlf.
It is an explosive. Can be prepd by nitrating either 2-(5'-chloro-2'-nitro-anilino)-ethanol or 2-(5'-chloro-2',4'-dinitro-anilino)-ethanol with absolute nitric acid at -10°. Refs: 1) Beil - not found 2) K.F. Waldkötter, Rec 57, 1302-3(1938)

2-(5'-Bromo-2',6'-dinitro-N-nitramino)-ethanol Nitrante, \( (O_2N)_2C_6H_5(Br):N(NO_2):CH_2 \) C\( _6H_5(ONO_2) \), N 17.67%. Col crysts, mp 95°; decompt at 180° and inflames at 256°; insol in w & petr eth, sl sol in eth and sol in chlf. It is an explosive. Can be prepd by nitrating 2-(5'-bromo-2',6'-dinitro-anilino)-ethanol with absol nitric acid at -15°. Refs: 1) Beil - not found 2) K.F. Waldkötter, Rec 57, 1301(1938)

Anilinoethylaminoethanol AND DERIVATIVES

Anilinoethylaminoethanol; Anilinoethylaminoethanolamine or N-(\( \beta \)-Hydroxyethyl)-N'phenyl-1,2-diaminoethane, \( C_6H_5\cdot NH\cdot CH_2\cdot CH_2\cdot NH\cdot CH_2\cdot OH \). May be considered as the parent compd of derivs described below, although they were not prepd from it.

Anilinoethylaminoethanol, Azido-\( \longrightarrow \), \( C_6H_5NH_3O \) and Diazido-\( \longrightarrow \), \( C_6H_5N_2O \) Derivatives were not found in Beil or CA through 1956

Mononitroanilinoethylaminoethanol, \( C_6H_5NH_2NO_2 \) was not found in Beil

\( N\)-[2-(2,4,6-Trinitroanilino)-ethyl]-aminoethanol or \( N\)-(\( \beta \)-Nitroxyethyl)-N'-(2,4,6-trinitrophenyl)-1,2-diaminoethane, \( (O_2N)_2C_6H_5-NH\cdot CH_2\cdot NH\cdot CH_2\cdot CH_2\cdot ONO_2 \), mw 360.24, N 23.33%, OB to \( CO_2 \) -75.5%. Was not found in Beil and CA through 1956

Note: This product would be expected to appear on nitration of the above dinitro deriv. Instead, an indefinite compd was obtained by Elderfield, as reported in OSRD 158, p 8, and the work was abandoned.

ANILINOQUANIDINE AND DERIVATIVES

Anilinoquanidine or Phenylaminoguanidine, \( C_6H_4\cdot NH\cdot NH\cdot C(\cdot NH)\cdot NH_2 \), is described in Beil 15, 290,(71) & [106]

Anilinoquanidine, Azido-\( \longrightarrow \), \( C_6H_4N_3 \) and Diazido-\( \longrightarrow \), \( C_6H_4N_2O \) Derivatives were not found in Beil

Anilinoquanidine Nitrante, \( C_6H_4\cdot NH\cdot NH\cdot C(\cdot NH)\cdot NH\cdot HO_2 \), mw 213.20, N 32.85%. Pink crysts, mp 178°. Prepn and props are given in Ref 2

Ref: 1) Beil - not found 2) F.L. Scott et al, JACS 75, 4053-4(1953) & CA 48, 11395(1953)

1-Anilino-3-nitroguanidine or 1-Phenylaminoguanidine-3-nitroguanidine, \( C_6H_4\cdot NH\cdot NH\cdot C(\cdot NH)\cdot NH\cdot NO_2 \), mw 195.18, N 35.89%. Wh crysts, mp 164°-172°. Methods of prepn are described in Refs 2-5

Ref: 1) Beil - not found 2) R.A. Henry, JACS 72, 5344(1950) & CA 46, 6088(1952)

3) F.L. Scott et al, JApplChem(London) 2,
Note: Isomers called Anilophenylnitroguanidines are described by R.A. Henry, JACS 72, 5344(1950) & CA 46(6088(1952)

5,7-Dinitro-6-(2',4',6'-trinitroanilino)-indazole, $(O_2N)_2C_6H_2-NH-C_6H_3N_2$, mw 599.24, N 23.41% is described in Beil 25,318

6-(2',4',6'-Trinitroanilino)-indazole, $(O_2N)_2C_6H_2-NH-C_6H_3N_2$, mw 299.24, N 23.41% is described in Beil 25,317

6-(2',4',6'-Trinitroanilino)-indazole, called in Ref 2 'Trinitrophenyl-B-1-Aminooindazol,' $(O_2N)_2C_6H_2-NH-C_6H_3N_2$, mw 344.24, N 24.42%.

Dinitroanilinoguanidine, $C_7H_4NO_4$, and vents. Was prepared by treating 6-aminoindazole with 2-chloro-1,3,5-trinitrobenzene in alc soln and in the presence of Na acetate. Its expl props were not examined.

Ref: 1)Beil 25,317 2)E.Noelting,Ber 37, 2582(1904)

5,7-Dinitro-6-(2',4',6'-trinitroanilino)-indazole, $(O_2N)_2C_6H_2-NH-C_6H_3(NO_2)_2N_2$. This undoubtedly explosive compd is not described in Beil or CA through 1956. It may be possible to prepare it by careful nitration of either 5,7-dinitro-6-anilino-indazole or of 6-(2',4', 6'-trinitroanilino)-indazole.

Note: No higher nitrated derivs were found in Beil or CA through 1956.
ANILINOMETHYLPROPANEDIOL
AND DERIVATIVES

2-Anilino-2-methyl-1,3-propanediol or 2-
Phenylamino-2-methyl-1,3-dihydroxy-propane,
C_{10}H_{12}N\cdot\text{-CH}_{2}\cdot\text{CH}_{2}OH, may be con-
sidered as the parent compd of derivs
listed below:

Anilinomethylpropanediol, Azido-,
C_{10}H_{12}N_{2}O_{2} and Diazido, C_{10}H_{12}N_{2}O_{4} – not
found in Beil or CA through 1956

Nitroanilinomethylpropanediol, C_{10}H_{14}N_{2}O_{4} –
not found in Beil or CA through 1956

2-(2',4',6'-Dinitroanilino)-2-methyl-1,3-
propanediol or 2-(2',4'-Dinitrophenylamino)
2-methyl-1,3-dihydroxy-propane, called by
Elderfield 2,4-Dinitrophenyl-bis(hydroxy-
me thylamine=). (na .......)

N-Anilino-N' -nitroguanidine See Anilino-
guanidine

... 

2-(2',4',6'-Trinitro-N-nitranilino)-2-nethyl-
1,3-propanediol Dinitrate or 2-(2',4',6'-
Trinitrophenyl-N-nitramino)-2-methyl-
1,3-dinitroxy-propane, called by Elderfield,
2,4,6-Trinitrophenyl-(bis(hydroxy-tertiary-
butylamino)-Dinitrate, (O_{3}N)_{2}C_{6}H_{4}.-
N(NO_{2})\cdot\text{-C(CH}_{2})_{2}\text{(CH}_{2}O\text{NO}_{2})_{2}\text{, mw 451.23, N 21.73%,}
OB to CO_{2} -37.2%, OB to CO
-1.77%. Crysts, mp 159°; expl on heating
in a test tube above the mp or when struck
with a hammer. It is explosive.

Refs: 1)Beil – not found 2)R.C.Elderfield,
OSRD Rept 158(1941),8 & 14(PBL Rept
31094) 3)A.H. Blatt,OSRD Rept 2014(1944)
– not found

Note: No higher nitroated derivs were found
in Beil or CA through 1956

Anilinonaphthalene. See Phenylaminophthaline
or Phenylaminonaphthalene

N-Anilino-N' -nitroguanidine See Anilinoguanidine

ANILINOPHENOL AND DERIVATIVES

Anilinophenol or Hydroxydiphenylamine,
called in Beil Oxy-diphenylamin, C_{8}H_{4}N-
C_{6}H_{4}OH. Several isomers are described in
Beil 13,365,410,444,(131,150) & [213 & 231]

Anilinophenol, Azido–, C_{12}H_{10}N_{2}O and
Diazido–, C_{12}H_{10}N_{2}O Derivatives were not
found in Beil or CA through 1956

Mononitroanilinophenols or Hydroxynitro-
diphenylamines, C_{12}H_{10}N_{2}O, mw 230.22,
N 12.71%. Two isomers are described in
Beil 13,421 & 444

Dinitroanilinophenols or Hydroxydinitro-
diphenylamines, C_{12}H_{10}N_{2}O, mw 275.22,
N 15.27%. Several isomers are described in
Beil 13,365,444,(138,150) & [169,216]

Dinitronitroanilinophenols or Hydroxydini-
tronitrodimphenylamines, C_{12}H_{10}N_{2}O, mw
320.22, N 17.50%. Two isomers are de-
scribed by G.Leandri,AnnChim(Rome) 40,
2-(2',4',6'-Trinitrophenyl-bis(hydroxy)-
tertiary. mw 320.22, N 17.50%. The isomers contg
butylnitramine Dinitrate,
(\text{O}_{2}\text{N})_{3}\text{C}_{6}\text{H}_{4}.-
NO_{2}
. C(CH_{2})(CH_{2}\text{NO}_{2})_{2}, mw 451.23,
N 21.73%, OB to CO_{2} -37.2%, OB to CO
-1.77%. Crysts, mp 159°; expl on heating
in a test tube above the mp or when struck
with a hammer. It is explosive.

Ref: 1)Beil – not found 2)R.C.Elderfield,
OSRD Rept 158(1941),7 & 9-10(PBL Rept
31094) 3)A.D.Little,Inc, "Report on Study of Pure Explosive Compounds," Pt 4(1952),546(Part is unclassified)

Tetranitroanilinophenols, called in Beil,
Trinitroxy-diphenylamine, C_{12}H_{10}N_{2}O,
mw 320.22, N 17.50%. The isomers contg
NO_{3} groups in the 2,4,6-positions are called
picrylaminoalphenols. Several trinitroanilino-
phenols are described in Beil 13,365,411,
425,445,(111,150,187) & [217,231], but none
of them seems to be explosive

Tetranitroanilinophenols, C_{12}H_{10}N_{2}O,
365.25, N 19.18% and higher nitrated derivs
were not found in Beil or CA through 1956

ANILINOPHENYL TETRAZOLE
AND DERIVATIVES

5-Anilino-1-phenyl-1,2,3,4-tetrazole, called
in Ger, I-Phenylinimophenyltetrazolon-(5)-anil, C_{15}H_{11}N_{6}, mw 237.26, N 29.52%. Ndls (from a lc), mp 162–3°C, decmp >220°C (Refs 1 & 2), leaflets, mp 159°C (Ref 3), ndls mp 162°C (Ref 4). Was prpd in 1900 from aminodiphenylguanidine and Na nitrite in HCl (Refs 1 & 2). Other methods of prpn are given in Refs 3 & 4 (Refs: 1) Beil 26,408 & [245] 2) M, Busch & P, Bauer, Ber 33,1069(1900) 3) R, Stolle, Ber 55,1292–3(1922) & CA 16,3898(1922) 4) E. Oliveri-Mandala, Gazz 52,II,139(1922) & CA 17, 1642(1923)

Anilinophenyltetrazole, Azidod-, C_{15}H_{11}N_{6} and Diazido-, C_{15}H_{11}N_{11} Derivatives were not found in Beil or CA through 1956

Mononitroanilinophenyltetrazole, C_{15}H_{10}N_{6}O_{2}, mw 282.26, N 29.78%. Nitronitranilinophenyltetrazole, C_{15}H_{10}N_{6}O_{2}, mw 327.26, N 29.96%; Dinitroanilinophenyltetrazole, C_{15}H_{10}N_{6}O_{4} and higher nitrated derivs were not found in Beil or CA through 1956. If prpd, some would undoubtedly be explosive

ANILINOPHTHALIMIDE AND DERIVATIVES

N-Anilinophthalimide or N-Phenyl-N',N'-phthalimidyldrazine, C_{14}H_{10}N_{3}O_{2}, is described in Beil 21,502,(388) & [371]

Anilinophthalimide, Azido-, C_{14}H_{10}N_{3}O and Diazido-, C_{14}H_{10}N_{11} Derivatives were not found in Beil or CA through 1956

Mononitroanilinophthalimide, C_{14}H_{10}N_{6}O_{2}. One isomer is described in Beil 21, 503 & (389)

Dinitroanilinophthalimide, C_{14}H_{10}N_{6}O_{4} – not found in Beil or CA through 1956

N-(2',4'-Dinitroanilino)-3-nitrophthalimide or N-(2',4'-Dinitrophenyl-3-nitrophthalimidyldrazine, CO OH CO

O_{2}N_{2}C_{6}H_{4}HN-N-C_{6}H_{4}(NO_{2}), mw 373.24, N 18.77%. Yel crstls, mp 249–50°C. Can be prpd by the interaction of 2,4-dinitro-phenylhydrazide with 3-nitrophthalic acid (Refs: 1) Beil – not found 2) J.Cerezo & E. Olay, Anales de la Soc. Española Quim 32,1090(1934) & CA 29,2932(1935)

Dinitronitrinilinonitrophthalimide, C_{14}H_{8}N_{6}O_{10}, mw 418.24, N 20.10%. Trinitroanilinonitrophthalimide, C_{14}H_{8}N_{6}O_{10}, and higher nitrated derivs were not found in Beil or CA through 1956. If prpd, some would undoubtedly be explosive

Anilinopropane or Phenylaminopropane. See Propylanilne

ANILINOPROPANEDIOL AND DERIVATIVES

Anilinopropanediol; Phenylaminopropanediol or Phenylaminodihydroxypropane, C_{14}H_{12}NO_{2}, exists in the following two forms:

1-Anilino-2,3-propanediol; 3-Anilino-1,2-propanediol; γ-Anilinopropylene glycol; 3-Phenylamino-1,2-propanediol or 1-Phenylamino-2,3-dihydroxy-propane. Called in Beil [β, γ-Dioxypropyl]-anilin, C_{6}H_{4}–NH,CH_{2},CH(OH),CH_{2}(OH). Solid, mp 52°C, bp 249°C at 50 mm (Refs 1 & 2), bp 175–85°C at 0.5 mm (Ref 3). Methods for its prpn are given in Refs 2 & 3. On nitration, it gives the derivs described below


2-Anilino-1,3-propanediol or 2-Phenylamino-1,3-propanediol, C_{6}H_{4}, NH.CH(CH_{2}OH), not found in Beil. May be considered as the parent comp of derivs listed below.

Anilinopropanediol, Azido-, C_{6}H_{4}N_{3}O_{2} and Diazido-, C_{6}H_{4}N_{11} Derivatives were not found in Beil or CA through 1956

1-Nitroanilino-2,3-propanediol, (O,N)C_{6}H_{4}–NH,CH_{2},CH(OH),CH_{2}OH—not found in Beil or CA through 1956

2-Nitroanilino-1,3-propanediol, (O,N)C_{6}H_{4}–NH,CH(CH_{2}OH), not found in Beil

1-(2',4'-Dinitroanilino)-2,3-propanediol; 2',4'-Dinitroanilino-2,3-propanediol; 3-(2',4'-Dinitrophenylamino)-1,2-propanediol
or 1-(2',4'-Dinitrophenylamino)-2,3-dihydroxy-propane, \((O_2N)C_6H_4 NH.CH_2 CH(OH).CH_2 OH\), mw 257.20, N 16.34%. Yel solid, mp 95°C, insol in w, petr eth, ether, chlf, CCl\(_4\) & benz, sol in alc, AcOH & benz. Can be prepd either by boiling an alc soln of 3-amino-1,2-propanediol with 2,4-dinitrochlorobenzene in the presence of Na acetate (Ref 2) or by nitrating 3-anilino-1,2-propanediol with fuming nitric acid (Ref 3).

Refs: 1) Beil—not found 2) H.P. den Otter, Rec 57, 20 & 22 (1938) & CA 32, 3354 (1938) 3) R.C. Elderfield et al, OSRD Rept 158 (1941), PBL Rept 31,094, pp 22-4

2-(2',4'-Dinitroanilino)-1,3-propanediol; 2-(2',4',6'-Dinitrophenylamino)-1,3-propanediol or 2-(2',4',6'-Dinitrophenylamino)-1,3-dihydroxy-propane, \((O_2N)C_6H_4 NH.CH(CH_2 OH)_2\), mw 257.20, N 16.34%. Yel solid, mp 133-5°C, same solubilities as for 1-(2',4'-dinitroanilino)-2,3-propanediol. Can be prepd by boiling an alc soln of 2-amino-1,3-propanediol with 2,4-dinitrochlorobenzene in the presence of Na acetate (Refs 2 & 3). This substance exploded weakly on heating in an open dish or test tube and upon being struck with a hammer on an iron surface (Ref 3, p 7).

Refs: 1) Beil—not found 2) H.P. den Otter, Rec 57, 15-17 (1938) & CA 32, 3354 (1938) 3) R.C. Elderfield et al, OSRD Rept 907 (1942), 6-7 (PBL Rept 31085)

1-(2',4',6'-Trinitroanilino)-2,3-propanediol; 3-(2',4',6'-Trinitrophenylamino)-1,2-propanediol or 1-(2',4',6'-Trinitrophenylamino)-2,3-propanediol, \((O_2N)C_6H_4 NH.CH_2(CH_2 OH).CH_2 OH\), mw 302.20, N 18.54%. Yel solid, mp 136°C, insol in w, eth, petr eth, chlf & CCl\(_4\), sol in alc, acet, benz & NB. Can be prepd by boiling an alc soln of 3-amino-1,2-propanediol with 2,4,6-trinitrochlorobenzene in the presence of Na acetate. It exploded on heating or on impact.

Refs: 1) Beil—not found 2) H.P. den Otter, Rec 57, 22-3 (1938) & CA 32, 3354 (1938)

2-(2',4',6'-Trinitroanilino)-1,3-propanediol; 2-(2',4',6'-Trinitrophenylamino)-1,3-propanediol or 2-(2',4',6'-Trinitrophenylamino)-1,3-dihydroxy-propane, \((O_2N)C_6H_4 NH.CH(CH_2 OH)_2\), mw 302.20, N 18.54%. Yel solid, mp 150°C, insol in w, petr eth, chlf, CCl\(_4\) & benz; sol in w, alc, acet & NB. Can be prepd by boiling an alc soln of 2-amino-1,3-propanediol with 2,4,6-trinitrochlorobenzene in the presence of Na acetate. It exploded on heating or on impact but milder than its higher nitrated product described below.

Refs: 1) Beil—not found 2) H.P. den Otter, Rec 57, 22-3 (1938) & CA 32, 3354 (1938)

1-(2',4',6'-Trinitro-N-nitranilino)-2,3-propanediol Dinitrate; 1-(N,2',4',6'-Tetranitroanilino)-2,3-propanediol Dinitrate; 3-(2',4',6'-Trinitrophenylaminotritro)nitro-no)-1,2-propanediol Dinitrate or 3-(2',4',6'-Trinitrophenylaminotritro)-1,2-dinitrooxy-propane, \((O_2N)C_6H_4 N(NO_2).CH_2.CH(ONO_2).CH_2(ONO_2)\), mw 457.20, N 22.42%, OB to CO\(_2\) -27.4%, OB to CO +5.5%. Lt yel crysts; mp 140-5°C and decomp ca 80°C, insol in w, petr eth, CCl\(_4\), sol in alc, ether, acet, chlf, benz & NB. Was first prepd in 1933 (Ref 2) by condensing glycerol with phenylamine and nitrating the resulting product. Later, it was prepd by nitrating 3-anilino-1,2-propanediol or its dinitrocompound with either fuming nitric acid (Ref 3) or mixed nitric sulfuric acid (Ref 4). It is a very powerful explosive which is unstable in storage.

ANILINOPROPANOL
AND DERIVATIVES

Anilinopropanol; Anilinopropylalcohol; Phenylaminopropanol or Proponalaniline
C₇H₁₃NO. One isomer, called in Ger
γ-Anilinopropylalkohol or [Oxy-propyll-
anilin, C₇H₇NH₂CH₂OH, is described in Beil 12, 109

Anilinopropanol, Azido-C₇H₁₂N₄O and
Diazido-C₇H₁₂N₂O Derivatives were not found in Beil or CA through 1956
Mononitroanilinopropanols, C₇H₊N₂O₃, mw 196.20, N 14.28%. Several isomers
were prepd and examined by Kremer
(Ref 2) from the point of view of their
physiological action
Refs: 1)Beil—not found 2)C. B. Kremer,
JACS 61, 1323(1939) & CA 33,6259(1939)

Nitronitranilinopropanols, C₅H₁₄N₃O₃, mw
241.20, N 17.42%—not found in Beil or CA
through 1956
Dinitroanilinopropanols, C₆H₁₃N₂O₄, mw
241.20, N 17.42%. The following isomer
was found in the literature:
2-(2',4'-Dinitroanilino)-1-propanol or 2-
Methyl-N-(2',4'-dinitrophenyl)-ethanol-
amine. Listed in CA 50, 2694a as N-(
2,4-Dinitrophenyl)-alaninol, (O₂N)C₇H₇-
NH.CH₂OH,
| mp 94-95°. Was prepd by
CH₃

mixing 2,4-dinitrobenzenesulfonate with 2-
amino-1-propanol (or its chloride or oxalate)
and aq Na carbonate soln
Refs: 1)Beil—not found 2)J.C.
Crawhall & D. F. Elliott, BiochemJ 61,264
(1955) & CA 50,2694(1956)

Dinitroanilinopropanol Nitrate, (O₂N)C₇H₇-
H₂, NH₂CH₂ONO₂, mw 286.20, N 19.58%

and higher nitrated
compds were not found in Beil or CA through 1956

Chloronitroanilinopropanols, C₇H₁₃N₂O₂Cl,
N 12.14%. In the course of a study of the
condensation of substituted nitrobenzenes
with aminoalcohols to produce intermediates
from which analogs of penryl (see under
Anilinoethanol) might be obtained, several
chloroanilinoalkanols, among them chloro-
anilinopropanols, were prepd and described
by C. B. Kremer & M. Meltsner in JACS 64,
1285(1942) & CA 36,4490(1942)

ANILINOPROPIONIC ACID
AND DERIVATIVES

Anilinopropionic Acid or Phenylalanine,
C₇H₁₃NO₂. Two isomers are described in
Beil 12,488,492 & [253]

Anilinopropionic Acid, Azido-C₇H₁₂N₂O₃ and
Diazido-C₇H₁₂N₂O Derivatives were not
found in Beil or CA through 1956
Mononitroanilinopropionic Acids, C₅H₁₄N₂O₄.
One isomer is described in Beil 12,725

Dinitroanilinopropionic Acids, C₆H₁₃N₂O₄,
255.19, N 16.47%. One isomer is described in Beil 12, (364).

**Trinitroanilinopropionic Acid, C₆H₄N₃O₈, mw 300.19, N 18.67%—not found in Beil or CA through 1956**

Anilinopropyl Alcohol. See Anilinopropanol y-Anilinopropylenglycol. See 3-Anilino-1,2-propanedol or 1-Anilino-2,3-propanediol

**ANILINOSUCCINIC ACID AND DERIVATIVES**

Anilinosuccinic Acid, called in Ger Anilinobenzsteinsäure or N-Phenyl-asparaginsäure, C₆H₄NH.CH(COOH).CH₂COOH. Several isomers are described in Beil 12, 508 & [262] Anilinosuccinic Acid, Azido-C₆H₆N₄O₄ and Diazido-C₆H₆N₂O₄ Derivatives were not found in Beil or CA through 1956

Mononitroanilinosuccinic Acid, C₁₀H₈N₂O₄— not found in Beil

Dinitroanilinosuccinic Acid, C₁₀H₈N₂O₄— not found in Beil

**2,4,6-Trinitroanilinosuccinic Acid,** called in Ger: N-Pikryl-asparaginsäure, (O₅N)₃C₆H₄NH.CH(COOH).CH₂COOH, mw 248.20, N 22.58%. Rhombic lfts, mp 137°, diff sol in w, easily sol in alc & ether. Was prepd by mixing an aq soln of asparaginic (aminosuccinic) acid with an equivalent quantity of picryl chloride in toluene and, after making the mix strongly basic (by adding NaOH), shaking it for 3 hours. Its expl props were not investigated


**ANILINOTETRAZOLE AND DERIVATIVES**

5-Anilino-(or 1H)-tetrazole or 5-Phenylamino-tetrazole, called in Beil Tetrazolon-(5)-anil, C₆H₄HN.C–NH–N, || || mw 161.17, N —— N

N 43.46%. Ndls, mp 206° (with vigorous evolution of gas); very sol in hot alc, sol in hot w, diff sol in eth. Was first prepd by Stollé et al (Refs 2 & 3) together with other products. A higher melting product (211-12°) was obtained by Finnegan et al by heating 1-phenyl-5-aminotetrazole, mp 160-1°, as described in Ref 5


(See aslo Aminophenyltetrazole)

Anilinotetrazole, Azido-, C₆H₄N₄ and Diazido-C₆H₆N₄ Derivatives were not found in Beil or CA through 1956

5-Nitroanilino-(or 1H)-tetrazole or 5-(nitrophenylamino)-tetrazole, C₆H₄N₂O₂, mw 206.17, N 40.77%. Not found in Beil but its o-, m- and p-isomers are described by W.L. Garbrecht & R.M. Herbst in JOC 18, 1278-82(1933) & CA 48, 12092-3(1954). This paper also gives UV absorption curves for some of these compds

5- (2',4'-Dinitroanilino)-(or 1H)-tetrazole or 5-(2',4'-Dinitrophenylamino)-(or 1H)-tetrazole, (O₅N)₂C₆H₄NH.C–NH–N, || || mw 251.17, N

N —— N

39.04%. Bm-red powd, mp 174° with decmpn, diff sol in hot w, eth & hot alc. Was obtained by heating 2,4-dinitrochlorobenzene with Na aminotetrazole in toluene for 6 hrs on an air bath and under reflux

*Refs: 1) Beil—not found 2) R. Stollé et al, JPraktChem 139, 64(1933) & CA 28, 1345(1934) 5(2',4',6'-Trinitroanilino)-(or 1H)-tetrazole; 5-(2',4',6'-Trinitrophenylamino)-(or 1H)-tetrazole or 5-(Picylamino)-(or 1H)-tetrazole, (O₅N)₂C₆H₄NH.C–NH–N, || || mw 296.17, N 37.79%,

N —— N
OB to CO₂ -54.0%, OB to CO -16.2%. Yel pdr, mp 224°, expl at higher temps, easily sol in acet, more diff in alc & w, hardly sol in eth. Can be prepd by heating 5-aminotetrazole with picryl chloride in AcOH for 2 hrs (Ref 2, p 63).

Its silver salt, C₇H₇N₃O₂Ag, N 27.89% and Ag 26.98%, brownish-yel solid, is a powerful explosive (Ref 2, p 64). Its copper salt (greenish powder) and lead salt (golden-yel powd) are not as powerful explosives.

**Note:** None of these salts was recommended by Stollé for use as igniting or initiating agents in blasting caps or detonators.


**ANILINOTOLUENE; DIPHENYL METHYLAMINES AND DERIVATIVES**

**Anilinotoluenes; Phenyltoluidines; Diphenylmethyldiphenylamines, C₁₃H₁₁N.** All isomers are described in Beil 12,180,787,857,905,(166) & [105,436,467,493]

**Anilinotoluene, Azido-C₁₃H₁₃N₃ and Diazido-C₁₃H₁₁N₃.** Derivatives were not found in Beil or CA through 1956

**Mononitroanilinotoluenes; Mononitrophenyltoluenides; Nitrodiphenylmethyldiphenylamines, C₁₃H₁₃N₃O₂, are described in Beil 12,787,876,906 &.[437].**

**Dinitroanilinotoluenes; Dinitrophenyltoluidines; Dinitrodiphenylmethyldiphenylamine, C₁₃H₁₃N₃O₄, are described in Beil 12,752,787,851,857,879,906, 1010 & [409,443].**

**Trinitroanilinotoluenes; Trinitrophenyltoluidines; Trinitrodiphenylmethyldiphenylamines, C₁₃H₁₃N₃O₄, are described in the literature:**

**Note:** There seems to be confusion in the literature in regard to identification of some trinitro- and tetrinitro- derivs. The compds are therefore listed according to their names and props as reported by the authors. The structural formule of some compds cannot be given because they were not definitely established.


Can be prepd by treating o-toluidine with picryl chloride or by other methods

**Refs:** 1)Beil 12,787,(377) & [437] 2)F. Reverdin & P.Crépieux, Bull Fr [3]29,236 (1903) & Ber 36,31(1903) 3)F. Kehmann et al, Helv 4,540(1921) & CA 15,3449(1921)

3-(2',4',6'-Trinitroanilino)-toluenes; N-(2', 4', 6'-Trinitrophenyl)-m-toluidine; 2',4',6'-Trinitro-3-methyl-diphenylamine or Picryl-m-toluidine. Called by James et al 2,4,6-Trinitrophenyl-m-tolylamine, (O₂N)₃C₆H₄.NH.C₆H₄.CH₃; exists in stable yel form, mp 129° and in labile red form, mp 118.5°(Ref 3), mp 119°(Ref 4). Can be prepd by treating m-toluidine with picryl chloride in alc (Ref 2) or by other methods (Refs 1,3 & 4)

**Refs:** 1)Beil 12,857,(399) & [467] 2)M. Busch & E. Pungs, JPraktChem 79,549-50 (1909) 3)T.C.James et al, JCS 117,1276 (1920) 4)B. Linke, Ber 56,851(1923)

4-(2',4',6'-Trinitroanilino)-toluenes; N-(2', 4',6'-Trinitrophenyl)p-toluidine; 2',4',6'-Trinitro-4-methyl-diphenylamine or Picryl-p-toluidine. Called by James et al 2,4,6-Trinitrodiphenyl-p-tolylamine, (O₂N)₃C₆H₄.NH.C₆H₄.CH₃. Exists, according to Ref 2, as yel monocl ndls, mp 165° or as red rhombic ndls, mp 165-9°, and according to Ref 3 as orange-yel ndls, mp 163-4°, or as blood-red prisms, mp 165°. Can be prepd by treating p-toluidine with picryl chloride
A439

in alc (Ref 2) or by other methods (Refs 1 & 3)

Refs: 1.) Beil 12,906(414) & [494] 2.) M. Busch & E. Pungs, J PraktChem 79, 547(1909)
3.) T. C. James et al, JCS 117, 1276(1920)

2,2',6-Trinitro-N-methyl-diphenylamine or I-(2',4'-Dinitro-N-methylanilino)-(2,6-dinitrobenzene), 
(O_2N)_2C_6H_3.N(CH_3).C_6H_3(NO_2)_2; orange-yel ndls, mp 221°. Can be prepd by heating a mixt of 2,6-dinitrochlorobenzene, N-methyl-o-nitraniline, K_2SO_4, CuI and amy1 alcohol

Refs: 1) Beil -not found 2) H. Hillemann, Ber 71B, 50(1938) & CA 32, 2134(1938)

Tetranitroanilinotoluenes; Tetenitrophenyntoluidines; Tetenitrodiphenylamelines and Tetenitromethylidiphenylamines, C_{13}-H_N_2_O_8, mw 363.24, N 19.28%. The following isomers are described in the literature:

Ref: 1) Beil -not found 2) A. F. Childs & S. G. P. Plant, JCS 1948, 1993 & CA 43, 2176(1949)

Note: According to A. F. Childs & S. G. P. Plant, JCS 1948, 1993 & CA 43, 2176(1949), the product obtained by Reuverdin & Crépieux is actually 2,2',4'-trinitro-4-methyl-diphenylamine, mp 221° (see above). Further nitration of this compd under more vigorous conditions gaves 2,6,2',4'-tetranitro-4-methyl-diphenylamine, mp 169° (see below)
4,6,2',4'-Tetranitro-2-methyl diphenylamine
or N-(2',4'-Dinitrophenyl)-4,6-dinitrotoluidine, (O,N),C,H,NH,C,H,(CH),(NO),; yel ndls, mp 190°. Can be prepd by heating, on a steam bath, 2',4'-dinitro-2-methyl-

diphenylamine with a mixt of glacial AcOH and nitric acid (d1.42) until a straw colored soln is obtained (ca ½ hr). Its expl props were not examined

Refs: 1) Beil - not found 2) G.G. Coker et al, JCS 1951, 112 & CA 45,8510(1951)

4,6,2',4'-Tetranitro-3-methyl-diphenyl-amine, or N-(2',4'-Dinitrophenyl)-4,6-dinitrotoluidine, (O,N),C,H,NH,C,H,(NO),; yel plates (from AcOH), mp 208-9°. Was obtained on heating on a water bath 3-methyl-2',4'-dinitrotodiphenylamine with concd H2SO4 and HNO3 (d 1.42) until the soln became pale yel (ca ½ hr). Its expl props were not examined

Refs: 1) Beil - not found 2) A.M. Moulder, Rec 25, 121-2(1906)

2,2',4',6'-Tetranitro-4-methyl diphenylamine or N-(2',4',6'-Trinitrophenyl)-2-nitro-p-toluidine, (O,N),C,H,NH,C,H,(NO),; CH2; golden-brn plates, mp 217-19°. Can be prepd by heating a mixt of picryl chloride and 3-nitro-p-toluidine to 160° (Ref 2). Its expl props were not examined


2,6,2',4'-Tetranitro-4-methyl diphenylamine or N-(2',4'-Dinitrophenyl)-2,6-dinitro-p-toluidine- (O,N),C,H,NH,C,H,(NO),; CH2; bright yel ndls (from alc), mp 169°. Can be prepd by heating 2,2',4'-trinitro-4-methyl-diphenylamine on a steam bath with concd HNO3 (d 1.42) (Ref 2). Its expl props were not examined


Penta nitro anilinotoluenes, C13H7N6O10, mw 408.24, N 20.59% were not found in Beil or CA through 1956. There is, however, Penta nitro-N-methyl-p-biphenylamine, known also as N-Methyl-N,2',4',6-pentanitroxenyl-amine, which has the same empirical formula as above. This expl compd is described in this work under Methylbiphenylamine and Derivatives

Hexanitroanilinotoluenes; Hexanitrophenyltoluidines; Hexanitrodiphenylmethamines and Hexanitromethyl diphenylamines,

C14H7N6O13, mw 453.24, N 21.63%. The following isomer is described in the literature: 2,4,6,2',4',6'-Hexanitro-N-methyl diphenylamine or N-Methyl dipicyclamine, (O,N),C,H,NH,C,H,(NO),; leaflets (from alc); mp 236-79; insol in w, vsl sol in eth & hot alc; sol in AcOH and v sol in acet. Was prepd by nitrating N-methyl-N-phenyl-2,4-dinitroaniline with nitric acid (d 1.49) (Refs 1 & 2). Its expl props are: power by Trauzl Test 87% PA and FI (figure of insensitiveness) 92% PA (Ref 4). Hantzsch & Opolski (Ref 3) also prepd the compd as its aci isomer, (O,N),C,H,NH,C,H,(NO),; NO, OCH2; violet crysts, mp 140-1° with decompn

Refs: 1) Beil 12,766 2) A.Moulder, Rec 25,121-2(1906) 3) A.H. Hantzsch & S. Opolski, Ber 41,1747-8(1908) 4) A.H. Blatt, OSRD, 2014(1944), listed as Hexanitrodiphenylmethamine

ANILINOTRIAZOLES AND DERIVATIVES

Anilinotriazoles, C6H5N4, mw 160.18, N 34.98%. The following isomers are described in the literature:

4-Anilino-1,2,3-triazole, called in Beil 1.2.3-Tri azolon-(4)-anil,

H2C=NH-N    HC=NH-N.

C6H5 N: C—N   C6H5HN: C—N
Crysts, mp 139-40°. Methods of prep are given in Beil 26, 134 & [75]. Its constitution was discussed in JCS 123,265(1923)
3-Anilino-1,2,4-triazolone-(3)-anil,
HC–NH–NH
\[\text{or} \quad \text{HC–NH–N} \]
\[\text{or} \quad \begin{array}{c}
\text{N} \quad \text{or} \\
\text{C} \quad \text{N} \\
\text{C}_6 \quad \text{H}_5 \\
\text{C}_6 \quad \text{H}_3
\end{array} \]
Crysts, mp 1800°. Prepn is given in Beil 26, CHOH [76]
(See also Aminophenyltriazoles and Derivatives, p A249L)

Anilinotriazole, Azido-C₆H₃N₃, and Diazido-
C₆H₃N₁₆ Derivatives were not found in Beil or CA through 1956

Nitrosoanilinotriazole, C₆H₅N₃NO, mw 189.18,
N 37.02%. Yel crystals decompg ca 117-18°

Ref: Beil 26, 134 & [75]

Note: This compd might be of interest on acct of its high nitrogen content

Mononitroanilinotriazole, C₆H₅N₃O₃, mw 205.18, N 34.12% and higher nitrated derivs were not found in Beil or CA through 1956

2,4-Dinitroanilino-trimethylolmethane; N-
(2,4-Dinitrophenylamino)-trimethylolmethane; N-(2,4-Dinitrophenyl)-(tris-hydroxymethyl-methyl)-amine; 2-(2',4',6'-Dinitroanilino)-2-hydroxymethyl-1,3-propanediol; 2,4-Dinitrophenyltrimethylolmethyamine or 2,4-
Dinitrophenyltri-hydroxymethylmethyamine,

\[
\begin{align*}
\text{CH}_3\text{OH} \\
\text{(O}_2\text{N)}_2\text{C}_6\text{H}_5\text{NH-C-CH}_3\text{OH}, \text{mw 287.23}, \\
\text{CH}_3\text{OH}
\end{align*}
\]

N 14.63%, OB to CO₂ -108.6%. Golden-yel crystals from dil alc, mp 100°. Ws obtained in 76% yield by condensation of chloro-2,4-
Dinitrobenzene with 2-amino-2-hydroxyethyl-
1,3-propanediol, as described in Ref 2, p 12.
Its Q¹ is 1222.9 kcal/mol and Q⁰ = -65.7(Ref 3)

Refs: 1)Beil – not found 2)R.C.Elderfield, OSRD Rept 158(1941),7 & 12(PBL Rept 31094) 3)G.B.Kistiakowsky, OSRD Rept 702 (1942)

ANILINOTRIMETHYLOLMETHANE AND DERIVATIVES

Anilinotrimethylolmethane; N-(Trimethylol-
methane)-aniline; Phenylaminotrimethylol-
methane; N-Phenyl-(tris-hydroxymethyl)-
methyamine; 2-Anilino-2-hydroxymethyl-
1,3-dihydroxypropane; 2-Anilin-2-hydroxy-
methyl-1,3-propanediol or Phenyltrimethylol-
methyamine, C₆H₃.NH.C(CH₃OH)₃. This may be considered as the parent compd of the derivs described below:

Anilinotrimethylolmethane, Azido-C₁₀C₆N₄O₁ and Diazido-C₁₀H₁₂N₄O₃ Derivatives were not found in Beil or CA through 1956

Mononitrotrimethylolmethane, C₁₀H₄N₄O₃ – not found in Beil or CA through 1956

N-(2,4,6-TRINITRO-N-NITRANILINO)-
TRIMETHYLOLMETHANE TRINITRATE; N-
(2,4,6 Trinitrophenyl-N-nitramino)-trimethylolmethane Trinitrate or N-(2,4,6-
Trinitrophenyl)-(tris-nitroxy methyl-methyl)-
nitramine, designated as Heptryl. Called by
Kistiakowsky N-Nitro-N-picyr-trimethylol-
methyamine Trinitrate. Also called: 2-(2',-
4', 6'-Trinitro-N-nitraminol)-2-nitroxy methyl-
1,3-dinitroxy propanone; 2-(N,2',4',6'-Tetra-
nitroanilino)-2-nitroxy methyl-1,3-propanediol
Dinitrate or 2,4,6-Trinitrophenyltrimethylol-
nitramine Trinitrate, \((\text{O}_2\text{N})_2\text{C}_6\text{H}_5\text{N(NO}_2\text{)}_2\text{C(CH}_3\text{ON}_2\text{)}_3, \text{mw 512.23}, \text{N 21.87%}, \text{OB to CO}_2 \text{-21.9%}, \text{OB to CO} +9.37%. Yel
crysts, mp 154-7° (decompn); ignites at 180° and explodes >360° with a purple flash. Was prepd by nitrating 2,4-dinitro-anilino-trimethylolmethane (see above) with mixed nitric-sulfuric acid, as described in Ref 2, pp 14-15. Heptryl was purified by dissolving the crude material in acetone and adding alcohol.

Heptryl is a HE comparable in power, brisance and sensitivity to PETN (Refs 2,4 & 6)

Following are some props of Heptryl:

a)Brisance, comparable to PETN

b)Heat of combustion, Qc 1160.7 kcal/mol (Refs 3,5 & 6)

c)Heat of formation, 57.7 kcal/mol (Ref 5)

d)Hygroscopicity at 25° & 90% RH, gained 0.07%; and at 100% RH, gained 0.2% (Ref 6)

e)Ignition temperature, ca 180° (Ref 6)

f)Impact sensitivity. A small sample wrapped in tin foil detonated when struck with a hammer on an iron anvil, and did not detonate when a concrete anvil was used (Ref 2)

g)International Test, 75° (thermal stability), loss of wt 0.5% (Ref 6)

h)Power by Ballistic Mortar Test, 143% TNT (Refs 4 & 6)

i)Stability (thermal) at 100°, not acid and no expln in 300 mins (Ref 4)

j)Stability (thermal) at 135°, exploded in 13 mins in a closed container (Refs 4 & 6)

Refs: 1)Beil- not found  2)R.C. Elderfield, OSRD Rep 158(1941), 8 & 14-16 (PBL Rept 31094)  3)G.B.Kistiakowsky, OSRD Rep 702(1942), Table I, Compd Gb2  4)R.McGill, OSRD Rep 830(1942), 29


ANILINOVALERIC ACIDS AND DERIVATIVES

Anilinovaleric (Anilinovalerianic) and Anilinoisovaleric (Anilinoisovalerianic) Acids, C_{11}H_{18}NO_{2} are described in Beil 12,497 Anilinovaleric & Anilinoisovaleric Acids, Azido-, C_{11}H_{14}N_{3}O_{4} and Diazido-C_{11}H_{14}N_{2}O_{4} Derivatives were not found in Beil or CA through 1956

Mononitroanilinovaleric Acids, C_{11}H_{14}N_{2}O_{3}- not found in Beil

Dinitroanilinovaleric Acid, C_{11}H_{14}N_{4}O_{6}, is described in Beil 12,(364). a-(2,4,6-Trinitro-anilino)-isovaleric Acid(called N-Pykrylvalin in Ger), (O_{3}N)_{3}C_{6}H_{2}{NH.CH(COOH).CH(CH_{3})_{2}}, mw 328.24, N 17.07%. Lt yel ndls, mp 171°, easily sol in alc or eth, sl sol in w (0.029% at RT). Was prepd by shaking 1 mol of a-aminoisovaleric acid, 1 mol NaOH and 1 mol picryl chloride for 3 hrs in toluene


Note: No higher nitrated anilinovaleric acids were found in Beil or CA through 1956

Anilite. A liquid expl consisting of butane and liq nitrogen peroxide, N_{2}O_{4}. It is sensitive to mechanical action and equal in strength to 161% PA.

Ref: Anon, “Elements of Armament Engineering”, US Military Academy, West Point, NY (1954), 71

Anilith or Anilite Some small antipersonnel aerial bombs used by the French during WW I consisted of two separate compartments, one filled with liquid nitrogen peroxide, N_{2}O_{4}, the other with a liq combustible material

such as carbon disulfide or gasoline. When such a bomb was released from an airplane, a small propellant on the nose of the bomb actuated the mechanism which caused the two liquids to mix. During the flight, the bomb became filled with a very powerful and sensitive mixture (called anilite or anilithe) which detonated without any initiator upon impact with the target.

Refs: 1) A. Holler, Nature 106, 831-4 (1920) & CA 15, 1401 (1921) 2) T. L. Davis, Army Ordn 20, 93 (1939) 3) Davis (1955), 355 4) Bebie (1943), 27-8

**ANILINOXYLENE AND DERIVATIVES**

Anilinoxylene; Phenylxylidines; Ditolylamines and Dimethyldiphenylamines, C₁₄H₁₈N. All isomers are described in Beil 12, 787, 858, 907, 1115, (377, 414, 415) & [437, 467, 494]

Anilinoxylene, Azido, C₁₄H₁₄N₃ and Diazido-C₁₄H₁₄N₂ Derivatives were not found in Beil or CA through 1956

Mononitroanilinoxylene, C₁₄H₁₄N₂O. Several isomers are described in Beil 12, 1001 & [530]

Dinitroanilinoxylene, C₁₄H₁₄N₂O₂. Several isomers are described in Beil 12, 787, 1002 (443, 479-481, 483, 488) & [462, 479, 481, 494, 536, 618]

Trinitroanilinoxylene, C₁₄H₁₂N₃O₆, mw 332.27, N 16.86%. Several isomers are described in Beil 12, 906, 907, 1109, 1115, 1133, (377, 414) & [608]

Tetranitroanilinoxylene, C₁₄H₁₁N₄O₆, mw 377.27, N 18.56%—not found in Beil or CA through 1956

Pentanitroanilinoxylene etc, C₁₄H₁₀N₃O₁₀, mw 422.27, N 19.90%—not listed in Beil or CA through 1956

Hexanitroanilinoxylene etc, C₁₄H₈N₇O₁₂, mw 467.27, N 20.98%. The following isomers are listed in the literature:

2,3,6(?),2',3',6'(?)-Hexanitro-4,4'-dimethyl-diphenylamine, called by Lehne Hexanitrodiphenylamine, [CH₄C₆(H(NO₃)₃)₂]NH, yel crys, mp 285°, very diff sol in org solvents. Can be prepd by treating either p,p'-ditolylamine or N-nitroso-p,p-tolylamine with cold fuming nitric acid. It expl props were not investigated

Refs: 1) Beil 12, 1013 2) A. Lehne, Ber 13, 1545 (1880)

2,4,6,2',4',6'-Hexanitro-3,3'-dimethyl-diphenylamine or Biss(3-methyl-2,4,6-trinitro-phenyl)-amine, [CH₃C₆(H(NO₃)₃)₂]NH, bm tables (from alc), mp 60°. Can be prepared by warming 4,6-dinitro-3,3'-dimethyldiphenylamine with nitric acid (d 1.5) on a water bath. Its expl props were not investigated

Refs: 1) Beil 12, [482] 2) J. C. S. 125, 2404 (1924)

Anilinoxylene, Azido, C₁₄H₄N₄ and Di-azido-C₁₃H₁₄N₂ Derivatives were not found in Beil or CA through 1956

Animal and Vegetable Fats and Oils, Nitrated. See Fats and Oils, Nitrated

Anilite or Anilithe. The name given to some Panclastite type expls used by the French during WW I for filling some aeroplane bombs. These bombs contained two compartments divided by a horizontal partition. One compartment contained liquid nitrogen tetroxide, N₂O₄ (called in Fr 'peroxide d'azote'), while the other contained CS₂, NB, MNT or gasoline. As long as the liquids were not mixed they could be transported without hazard in a plane. When the bomb was released, a small propeller on its nose, actuated by passage through the air, opened a valve which permitted the two liquids to mix. This transformed the contents into a very powerful expl mix which was so sensitive that it required no fuze but exploded immediately.
upon impact with the target. When it was desired to have these bombs explode in the air before they reached targets, they were provided with a time fuze.

Anilite was cheap to prepare and so were the bombs using it. The power and brisance of these bombs was slightly higher than those containing TNT or PA.

The term "anilite" was extended after WWII to any liquid containing N₂O₄ as an oxidizer, and a liquid carbonaceous material (such as benzene, butane, etc) as a fuel.

Several formulations of "anilite", consisting of N₂O₄ and butane were investigated before WWII at PicArsn (Ref 4). The mixes: N₂O₄/butane = 70/30, 60/40 and 50/50, examined at PicArsn were extremely sensitive to rifle bullet test (using cal .30 rifle at a distance of 30 yards from the muzzle to open bomb containing the sample). All samples were unstable (they were constantly fuming) and very hazardous to handle. The 70/30 mix had a rate of deton 10% higher than TNT and brisance by fragmentation test ca 130% of TNT. In fragmentation test a 3-inch AA M42 shell loaded with 70/30-anilite gave 408 fragments vs 351 fragments for TNT.

Refs: 1) A. Haller, BullSocEncourIndNat 119,761-5(1920) & CA 15, 1401(1921)
2) Pascal(1930), 193-4
3) Pepin Lehalleur (1935), 360
4) C. J. Bain, "Tests of Liquid Nitrogen Peroxide Explosive", PATR 985 (1939)
5) Davis (1943), 355
6) Pérez-Arañ (1945), 229
7) Kirk & Othmer 6(1951),58

**ANISALDEHYDES AND DERIVATIVES**

Anisaldehyde or Methoxybenzaldehyde, H₃CO.C₆H₄.CH, mw 136.14

Note: Although the name "anisaldehyde" previously was reserved for the "p-methoxybenzaldehyde", current nomenclature extends the term "anisaldehyde" to all methoxybenzaldehydes, provided it is indicated which of the isomers is being described. Thus there will be o- (or 2-), m- (or 3-) and p- (or 4-) anisaldehydes.

These compds are described as "methoxybenzaldehydes" in Beil 8, 43, 59, 67(519, 525, 529) & [40, 53, 64]

Note: A. Albert & A. Hampton, JCS 1952, 4985-93 & CA 48, 8231(1954) described prep'n 95% yield from m-HO.C₆H₄.CH with Me₂SO₄ & NaOH in MeOH and its nitration to 3,2-MeO(3N):C₆H₃.CHCHO. AA M42 shell loaded with 70/30-anilite Anisaldehyde, Azido-, C₆H₃.NO₂ and Diazido-C₆H₄N₂O₂ Derivatives were not found in Beil or CA through 1956.

Mononitroanisaldehydes or Mononitromethoxybenzaldehyde, H₃CO.C₆H₄-(NO₂)CH. Several isomers are described in Beil 8, 56, 57, 62, 63, 83, (523, 527, 533) & [58, 77]

Dinitroanisaldehydes or Dinitromethoxybenzaldehydes, H₃CO.C₆H₄(NO₂)₂.CH, mw 226.14, N 12.39%. The following isomers are described in the literature:

x,x-Dinitro-(m-anisaldehyde) or x,x-Dinitro-3-methoxy-benzaldehyde of mp 110°, first prep'd by Tiemann & Ludwig(Ref 2), was later (Ref 3) identified as a mixt of 2,6- and 4,6-dinitro-3-methoxy-benzaldehydes.

x, x-Dinitro-(m-anisaldehyde) or x, x-Dinitro-3-methoxy-benzaldehyde of mp 155°, prisms, first prep'd by Tiemann & Ludwig (Ref 2), was later identified as 2,6-dinitro-3-methoxy-benzaldehyde, mp 157° (Ref 3).

Refs: Same as above and also J. Troger & C. Eicker, JPraktChem 116, 29(1927)

4,6-Dinitro-(m-anisaldehyde) or 4,6-Dinitro-3-methoxy-benzaldehyde, prisms, mp 131°. Other props & prep'n are in Refs.

Refs: 1)Beil 8,(62) 2)H.H.Hodgson & H.G. Beard, JCS 1927, 2381

3,5-Dinitro-(p-anisaldehyde) or 3,5-Dinitro-4-methoxy-benzaldehyde, yel ndls, mp 86°. Other props & prep'n are in Refs.


Trinitroanisaldehyde or Trinitromethoxy-benzaldehyde, H₃C.O.C₆H₄(NO₂)₃, CHO, mw 271.14, N 15.50%—not found in Beil or CA through 1956

p-Anisaldehyde Perchlorate or 4-Methoxy-benzaldehyde Perchlorate, 2 C₆H₄O₂⁺ + HClO₄⁻; col deliq prisms or plates. Was prep'd from ethereal soln of anisaldehyde and 70% perchloric acid as described in Ref 2. Its expl props were not investigated.

Refs: 1)Beil 8,(529) 2)K. A. Hofmann et al, Ber 43, 2629(1910)

**ANISALDEHYDEPHENYLHYDRAZONE AND DERIVATIVES**

p-Anisaldehydephénylhydrazone; Methoxy-benzaldehyde-phenylhydrazones or Anisylidene-phenylhydrazine, H₃C.O.C₆H₄, CH:N.H.C₆H₄ is described in Beil 15,192,(51) & [80]

Anisaldehydephenylhydrazone, Azido-C₆H₃N₃O and Diazido-, C₆H₃N₂O Derivatives were not found in Beil or CA through 1956

p-Anisaldehyde-(N-nitrosophenylhydrazone), CH₃.O.C₆H₄, CH:N.N(NO).C₆H₄ is described in Beil 15,417

p-Anisaldehyde-[2-(3- and 4-)nitrophenyl-hydrazones]H₂C.O.C₆H₄, CH:N-NH.C₆H₄(NO₂), are described in Beil 15,(137) & [180, 183, 199]

p-Anisaldehyde-(2, 4-dinitrophenylhydrazone), H₂C.O.C₆H₄, CH:N.NH.C₆H₄(NO₂), mw 316.27, N 17.72%, is described in Beil 15,[218]

Anisaldehyde-trinitrophenylhydrazones, H₂C.O.C₆H₄, CH:N.NH.C₆H₄(NO₂), mw 361.27, N 19.39%, not found in Beil, but one isomer anisaldehyde-picrylhydrazone or 4-methoxy-benzaldehyde-2,4,6-trinitrophenylhydrazone is described by J. J. Blanksma & M. L. Wackers, Rec 55, 665(1936)

p-Anisaldehyde-phenylhydrazone Peroxide,
H₂C.O.C₆H₄, CH=N.NH.C₆H₄, mw 258.27, N 10.85%.

Yel ndls (from benz + petr eth), dec 83-4° and expl when heated, in a flame; v sol in eth, sol in alc or benz and diff sol in petr eth. Was prep'd by treating anisaldehyde-phenylhydrazone with hydrogen peroxide. It turns brown by action of light but is stable in the dark

Refs: 1)Beil 15,(51) 2)M. Busch & W. Dietz, Ber 47, 3287(1914)

3-Nitro-(p-anisaldehyde)-phenylhydrazone, H₂C.O.C₆H₄(NO₂), CH:N.NH.C₆H₄, is described in Beil 15, 193 & [80]

3-Nitro-(p-anisaldehyde)-(4'-nitrophenylhydrazone), H₂C.O.C₆H₄(NO₂), CH:N.NH.C₆H₄(NO₂) is described in Beil 15,476 & [200]

**Nitroanisaldehyde-dinitrophenylhydrazones**, H₂C.O.C₆H₄(NO₂), CH:N.NH.C₆H₄(NO₂), mw 361.25, N 19.39%. They are not found in Beil, but the isomer, 2-nitro-(p-anisaldehyde)-2',4'-dinitrophenylhydrazone) is described by W. R. Boon, JCS 1949, Suppl Issue, p S230 and the isomer 4-nitro-o-anisaldehyde 2,4-dinitrophenylhydrazone by W. Berends et al, Rec 74, 1341(1955)

**Nitroanisaldehyde-trinitrophenyl hydrazones**, H₂C.O.C₆H₄(NO₂), CH:N.NH.C₆H₄(NO₂), not found in Beil or CA through 1956

**Dinitroanisaldehyde-phenylhydrazones**,
A446

H₂CO.C₆H₇(NO₂)₂.CH:N.NH.C₆H₅. Two isomers: 2,6-dinitro-3-methoxybenzaldehyde-phenylhydrazone, mp 185° and 4,6-dinitro-3-methoxybenzaldehyde-phenylhydrazone, mp 210°, are described by J. Troger & C. Eicker, J PraktChem, 116, 21 & 29 (1927), of which only the first compd is listed in Beil 15, [80].

Dinitroanisaldehyde-nitrophenylhydrazones, H₂CO·C₆H₇(NO₂)₂.CH·NH·C₆H₅(NO₂), mw 361.25, N 19.39%. The following isomers are described in the literature:

2,6-Dinitro-(p-anisaldehyde)-4-nitrophenylhydrazone or 2,6-Dinitro-3-methoxybenzaldehyde-4-nitrophenylhydrazone, It orange plates exploding at ca 260°. Was obtained by treating 2,6-dinitro-3-methoxybenzaldehyde with p-nitrophenylhydrazone, as described in Ref 2.


3,5-Dinitro-(p-anisaldehyde)-(4'-nitrophenylhydrazone), dk brn crystals, mp 275°. Was prepd by treating 3,5-dinitro-4-methoxybenzaldehyde with p-nitrophenylhydrazone as described in Ref 2.


4,6-Dinitro-(m-anisaldehyde)-(4'-nitrophenylhydrazone), terra-cotta ndls mp > 300°. Was prepd by treating 4,6-dinitro-3-methoxybenzaldehyde with p-nitrophenylhydrazone as described in Ref 2.


Dinitroanisaldehyde-dinitrophenylhydrazones, H₂CO·C₆H₇(NO₂)₂.CH·N·NH·C₆H₅(NO₂), not found in Beil or CA through 1956.

Dinitroanisaldehyde-trinitrophenylhydrazones, H₂CO·C₆H₇(NO₂)₂.CH·N·NH·C₆H₅(NO₂), not found in Beil or CA through 1956.

Trinitroanisaldehyde-trinitrophenylhydrazone, H₂CO·C₆H(NO₂)₃.CH·N·NH·C₆H₅(NO₂), was not found in Beil or CA through 1956.

Anisenyltetrazotic Acid. An old name for Anisyltetrazole.

ANISIC ACIDS AND DERIVATIVES

Anisic or Methoxybenzoic Acid, H₂CO·C₆H₄·COOH, mw 152.14.

Note: Although the name “anisic acid” previously was reserved for the “p-methoxybenzoic acid”, current nomenclature extends the term “anisic acid” to all methoxybenzoic acids, provided it is indicated which of the isomers is being described. Thus there will be o- (or 2-), m- (or 3-) and p- (or 4-) anisic acids.

These compds are described as methoxybenzoic acids in Beil 10, 64, 137, 154, (27, 64, 69) & [39, 80, 91].

Note: According to Davis (1943), p 170, nitration of p-anisic acid yields trinitroanisole (see under Anisole and Derivatives).

Anisic Azide. See Anisoylazide

Anisic Acid, Azido-, C₆H₅N₃O₃ and Diazido-, C₆H₅N₃O₃ Derivatives were not found in Beil or CA through 1956.

Mononitroanisic or Nitromethoxybenzoic Acids, H₂CO·C₆H₅(NO₂)·COOH are described in Beil 10, 117, 146, 147, 181, (50, 51, 52, 67, 79) & [66, 67, 68, 84, 85, 106].

Dinitroanisic or Dinitromethoxybenzoic Acids, CH₃O·C₆H₅(NO₂)₂·COOH, mw 2421.4, N 11.57%. The following isomers are described in the literature:

2,4-Dinitro-(m-anisic) or 2,4-Dinitro-(3-methoxybenzoic) Acid, ndls (from w), mp 240-1°(dec). Was prepd by treatg 2,3,4-trinitrobenzoic acid with aq K methylate.


2,6-Dinitro-(m-anisic) Acid, col ndls (from w), mp 195°(Ref 2), 199°(Ref 3). Can be prepd by oxidation of 2,6-dinitro-3-methoxybenzaldehyde with aq KMnO₄ soln (Refs 2 & 3).

H-H. Was first prepd by nitration of 3-nitroanisic acid (Ref 2). Other methods of prepn are given in Refs 1,3,5


Trinitroanisic or Trinitromethoxybenzoic Acids, \(\text{CH}_3\cdot\text{O}\cdot\text{C}_6\text{H}(\text{NO}_2)_3\cdot\text{CO}_2\text{H}\), mw 287.14, not found in Beil or CA through 1956

Anisic Alcohol or Anisalcohol. Same Anisyl Alcohol

Anisic Peroxide. See Dianisoylperoxide

Anisidine. Same as Aminoanisole

\(\text{o-Anisidino-diazo-copper}, [(\text{N}_2)_2\text{Cu}\cdot\text{C}_6\text{H}_4\text{ONH}_2]\), crysts explg at ca 125\(^\circ\), but not on impact; insol in common org solvents, sol in dil sulfuric acid. Was prepd by mixing methanolic solns of Cu nitrate (or chloride) and o-anisidine with aq soln of Na azide, followed by cooling

Refs: 1)Beil – not found 2)A.Cirulis & M.Straumanis, JPraktChem 162, 315(1943) & CA 38, 1969(1944)

Anisidinotetrazole. Same as Anisylamino-tetrazole
ANISOLE AND DERIVATIVES

Anisole (Ans), Methoxybenzene or Methylphenylether, \( \text{CH}_3\text{O-CH}_4 \), mw 108.13, OB to \( \text{CO}_2 \) -251.5% Col liq, fr p -37.3°, bp 154.5°, d 0.995 at 20/4°. Prepn & other props are in Beil 6, 138, (79) & (139).

Anisole, Azidoderivatives. See Azidoanisole and Derivatives under Azides, Organic Nitration of Anisole has been discussed in many papers such as:

1) C.A. Bunon et al, Nature 158, 514 (1946)
2) C.A. Bunon & G.J. Minkoff, JCS 1947, 1416

Mononitroanisoles (MNA) or Nitroanisoles, \( \text{CH}_3\text{O-CH}_4(\text{NO}_2) \), mw 153.13, N 9.15%, OB to \( \text{CO}_2 \) -151.5%.

Three isomers: o-(or 2-) Nitroanisole, col liq, fr p 9.4°, bp 272-3, d 1.253 at 20/4°. Prepn & other props are given in Refs 1, 4, 5 & 6. It yields on nitration a mixt of 2,4- & 2,6-DNA.

m-(or 3-) Nitroanisole, col ndls (alc), mp 38°, bp 258°, d 1.373 at 18°. Prepn & other props are given in Refs 2, 5 & 6. It yields on nitration a mixt of 2,5-2,3- & 3,4-DNA.

p-(or 4-) Nitroanisole, col prisms, mp 54°, bp 274°, d 1.233 at 20°. Prepn & other props are given in Ref 3. It yields on nitration 2,4-DNA.

Refs: (Mononitroanisoles) 1) Beil 6, 217 (114) (209) (o-MNAs)
2) Beil 6, 224 (116) (214) (m-MNAs)
3) Beil 6, 230 (119) (220) (p-MNAs)
4) E.H. Wetz, USP 1578943 (1926) & CA 20, 1631 (1926) 5) P.H. Griffiths et al, JCS 1934, 525 (1938)
6) R.M. Schramm & E.H. Westheimer, JACS 70, 1782-4 (1948) & CA 42, 6337 (1948)

Dinitroanisoles (DNA), \( \text{CH}_3\text{O-CH}_4(\text{NO}_2)_2 \), mw 198.13 N 14.14%, OB to \( \text{CO}_2 \) -97.0%. The following isomers (of which the 2,4-DNA is the most important) are described in the literature:

2,3 – Dinitroanisole crystals, mp 118-19°. Other props and prepn are given in Ref 1a. An improved method of its prepn is given in Ref 42

2,4-Dinitroanisole (2,4-DNA) (Disol, in Ger). Wh prisms with amber tinge for pure material and yel crysts for tech grade. The monoc-l prism form of a new modifn is described in Ref 10 and dimorphism in Ref 11.

Tech grade DNA yields have ca 89° and d 1.34 at 20°; mp of labile form 86.9° and stable form 94.6° (Ref 5); bp – for sublimes (Ref 46); 9° 820.2 kcal/mol (Ref 23), \( Q_f \) 45.0 kcal/mol (Ref 23) and \( Q_e \) 92.1 kcal/mol (Ref 45).

Badcochen (Ref 25) gives for \( Q_e \) the same value as for \( Q_f \) given above; \( Q_f \) fusion 3.9 kcal/mol (Ref 17). It is sl sol in w; sol in alc or ether. Numerical values for the soly in w and in twelve org solvents are given in Ref 3. Chemical behavior of 2,4-DNA is described in Refs 4, 5, 12, 13, 31, 38 & 40.

Binary systems of 2,4-DNA with various compds are listed in Ref 43 and absorption spectra curves are given in Refs 21, 27 & 37. Like other nitroaromatic compds it is toxic and this is discussed in Refs 16, 30, 33 & 44.

A colorimetric method of detn of 2,4-DNA is given in Ref 28.

Various methods of prepn of 2,4-DNA are discussed in Refs 2, 3, 4, 6, 19, 20, 24, 31, 32, 35 & 41, but it seems that the best lab methods are: a) nitration of o- or p-MNAs and b) interaction of 4-chloro-1,3-dinitrobenzene with K or Na hydroxide in aq methanol. Yields as high as 95% were reported with the latter method.

2,4-DNA is an expl about 10% less powerful then TNT and less sensitive to impact (Refs 15 & 26); its sensitivity to initiation is such that it can be fired by No 8 detonator but not very well by No 6 detonator (Ref 26). Its calcd temp of expln is 1805°K (Ref 45).

It has been proposed as a component of some expl compn. Under the name of “Disol” it was used in Germany as a component of “Amatol 40”; DNA 50, AN35 & RDX 15% – an explosive employed for filling some warheads of V-1 (Ref 47, p 4). In the USA it has been used by military personnel as an insect repellant (Ref 38).

2,4-DNA yields on nitration 2,4,6-TNA, a powerful explosive.

2,5-Dinitroanisole, col ndls (from benz + ligroin), mp 96.7°, d 1.476 at 18°. Other props and prepn are in Ref 1c.
2,6-Dinitroanisole, col nls (from alc), mp 116-118°, d 1.319 at 20°. Other props and prep. are found in Ref 1d

3,4-Dinitroanisole, golden-yel nls, mp ca 70°. Other props and prep. are found in Refs 2a & 18

3,5-Dinitroanisole (3,5-DNAns), col cryts, mp 105-105.8°, bp - sublimes, d 1.558 at 20°/4°. Chemical reactions are described in Refs 12, 13 & 29. Urbański (Ref 14) studied eutectic mixts of 3,5-DNAns with hexanitromannitol and with nitroerythritol. Methods of prep. are discussed in Refs 2b, 8, 9, 22, 31 & 34. The method of prep. from 1,3,5-trinitrobenzene and Na methylate in anhyd methanol is described in detail in Ref 8

3,5-DNAns is an expl. less powerful than TNT and slightly less sensitive to impact than TNT (Ref 15)


5-Nitroso-2,4-dinitroanisole, CH₃O•C₆H₄(NO)–(NO₂)₂, mw 227.13, N 18.50%, orange-yel crystals (from AcOH), mp 158°(dec). Was obtained by oxidation with chromic acid of N–(4,6-dinitro-3-methoxyphenyl)-hydroxylamine as described in Ref 2
Refs: 1) Beil 6, [253] 2) W. Borsche & E. Feske, Ber 59, 818 (1926)

**Trinitroanisoles (TNAns)**, CH₃O•C₆H₄(NO)–(NO₂)₃, mw 243.13, N 17.28%, OB to CO₂ - 62.5%. The following isomers are all exp.: 2,4,6-Trinitroanisole, lt yel ndls, mp 155°; sol in alc, exp on heating. Prepd by Vermeulen by nitration at 80° of 2,3-DNAns with mixed nitric-sulfuric acid (Reps 3 & 9)

2,3,5-Trinitroanisole, leaflets or rhombic bipyramidal crystals, mp 104-106.8°, d 1.618 at 15°; sol in w, alc acet or pyridine. Quantitative soly in var org solvents given in Ref 30. Prepd by the nitration of 3,5-DNAns with mixed nitric-sulfuric acid (Reps 4 & 9)

2,4,5-Trinitroanisole, almost colorless crysts from alc, mp 104-107°; sl sol in ligroin, sol in alc. Prepd according to Vermeulen by nitrating 2,5-DNAns with mixed nitric-sulfuric acid (Reps 4 & 9)

**2,4,6-Trinitroanisole (TNAns) (Nitrolit; Methyl Picrate or 2,4,6-Trinitrophenylmethyl Ether)** [Trinitroanisole in Fr; Trinitroanisol or Trisol in Ger; Trinitroanisol' in Rus; Trinitroanisolo in Italy; Trinitroanisol in Spain; Type 91 Explosive in Japan]. Pale-yel leaflets, mp 65-67° (coml) and 68.4° (pure); bp 310°, d (cast) 1.4, d ar max loading press 1.7; Q°c 792.1 kcal/mol (av value from Refs 31,41,46 & 50), Q°p 784.4 kcal/mol (Ref 31), Qf 42.5 kcal/mol (Ref 68), Q°e (calcd) 136.5 kcal/mol (Ref 68), Q vapn 15 kcal/mol (Ref 59), Q subl (Ref 63) appr dipole moment (Ref 64) and absorption spectra (Reps 44,52 & 66),

**Solubilities of TNAns in Various Solvents, as Determined by Desvergnes (Ref 26)** (g TNAns per 100 g solvent)

<table>
<thead>
<tr>
<th>Solvent</th>
<th>15°</th>
<th>50°</th>
<th>100°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.02</td>
<td>0.14</td>
<td>0.39</td>
</tr>
<tr>
<td>Chloroform</td>
<td>25.6</td>
<td>334.5</td>
<td>-</td>
</tr>
<tr>
<td>Carbon tetra-chloride</td>
<td>0.51</td>
<td>3.65</td>
<td>-</td>
</tr>
<tr>
<td>Benzene</td>
<td>95.</td>
<td>597.9</td>
<td>-</td>
</tr>
<tr>
<td>Toluene</td>
<td>86.5</td>
<td>421.5</td>
<td>-</td>
</tr>
<tr>
<td>Methanol</td>
<td>5.24</td>
<td>27.65</td>
<td>-</td>
</tr>
<tr>
<td>Abs alcohol</td>
<td>2.37</td>
<td>21.36</td>
<td>-</td>
</tr>
<tr>
<td>96% alcohol</td>
<td>2.31</td>
<td>17.79</td>
<td>-</td>
</tr>
<tr>
<td>Ether</td>
<td>4.18</td>
<td>7.86 (34°)</td>
<td>-</td>
</tr>
<tr>
<td>Acetone</td>
<td>194</td>
<td>813.2</td>
<td>-</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>89.4</td>
<td>368.5</td>
<td>-</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>0.43</td>
<td>1.11</td>
<td>-</td>
</tr>
<tr>
<td>Pyridine</td>
<td>40.4</td>
<td>221.</td>
<td>-</td>
</tr>
</tbody>
</table>

The toxicity of TNAns is discussed in Refs 16, 49,57,67 & 70; its chem reactions in Refs 7,11,15,16,21,23,27,32,35,38,45, 47,55,65,69 & 70

TNAns forms eutectics with the following compds:

<table>
<thead>
<tr>
<th>%</th>
<th>mp</th>
<th>Refs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picryl sulfide</td>
<td>13</td>
<td>62.5</td>
</tr>
<tr>
<td>Tetryl</td>
<td>70.5</td>
<td>22.8</td>
</tr>
<tr>
<td>o-Nitroaniline</td>
<td>33.3</td>
<td>30.2</td>
</tr>
<tr>
<td>Erythritol-tetranitrate</td>
<td>74</td>
<td>addition</td>
</tr>
<tr>
<td>Picryl nitrate</td>
<td>37.5</td>
<td>45</td>
</tr>
<tr>
<td>TNT</td>
<td>40</td>
<td>42</td>
</tr>
<tr>
<td>TNT/TNB</td>
<td>54.4</td>
<td>30</td>
</tr>
<tr>
<td>PA/TNB</td>
<td>38.</td>
<td>37.5</td>
</tr>
<tr>
<td>(3.8/34.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TTN/PA</td>
<td>51.</td>
<td>37</td>
</tr>
</tbody>
</table>

TNAns is hygroscopic and is decompd by hot water with the formarion of iso-picric acid (qv) (Ref 26). TNAns was prepd in 1849 by Cahours by direct nitration of anisole (Ref 6). This method according to Davis (Ref 51) is dangerous as it may produce an
expln. He recommends for lab prepn the method of Jackson (Ref 7) in which a methanolic soln of picryl chloride is treated with an excess of sodium methlylate or strong NaOH soln. Deposits of red crysts of \((\text{O}_2\text{N})_2\text{C}_6\text{H}_4\text{OCH}_3\text{NaOCH}_3\) are obtained which on treatment with acid yield 2,4,6-TNAns. Davis (Ref 51) describes this lab method in detail. For plant scale prodn see Refs 9, 24, 34, 36, 40 & 60. Additional info on the prepn and props is given in Refs 5, 10, 24, 36 & 61. Damschroeder & Shriner (Ref 45) observed that 2,4,6-TNAns prepd from picryl chloride and MeONa in MeOH exists in 4 forms: sq plates - mp 50-1°, hexagonal plates - mp 56-7°, prisms - mp 58-9° and needles - mp 69-9° (stable form). Ovenston (Ref 58) reported the monotropic transformation in 2,4,6-TNAns. He prepd \(\beta\)-TNAns (mp 57.5°) by sealing \(\alpha\)-TNAns (mp 68°) in glass, immersing it in boiling H_2O, supercooling and inducing crystn with broken glass. According to Ovenston, in a lab completely free of \(\alpha\)-form, the \(\beta\)-form may be the sole product in TNAns in the usual synthesis of TNAns.

**Explosive Properties.** TNAns was developed as a substitute for PA which is high-melting and tends to react with metals. The dry TNAns does not attack metals since it contains no hydroxyl groups, and it therefore does not form dangerous metallic salts, as does PA. Its relatively low mp permits cast loading of the expl, but it will exude at tropical storage temps. TNAns is compatible with NC with which it forms colloidal mixts.

The following expl props have been reported:

**Booster Sensitivity, by Gap Test**, 6.5 cm vs 13 cm for PA (Ref 62)

**Brisance, by Sand Test**, 43g vs 43 for TNT (Ref 57) and 110% TNT (Ref 28); by Copper Cylinder Crusher Test 92% PA or 100% TNT (Refs 18 & 52a)

**Detonation Rate** 6660 m/s at d 1.59 (Refs 18 & 68), 6900 m/s (Ref 57) and 7640 m/s vs 6880 for TNT (Refs 24 & 52a)

**Explosion Temperature** 165 - 296° (Ref 57), 225° (Ref 48) & 279 - 500° (Ref 53)

**Impact Sensitivity** 15-16" vs 14" for TNT by PicArsnApp using 2kg wt; max value for no expln with 5kg wt - 19 cm or 20% positive at 100 cm and 30% positive at 110 cm vs 50% positive at 30 cm for PA (Ref 24); FI 120-124% PA and by Rifle Bullet Test-no deton from impact of .30 cal bullet fired from 90 ft (Ref 57) (See also Ref 52a)

**Impact Work** for 50% explns with 2 kg wt: 10.1 m kg/cm² or 89% TNT (Ref 37)

**Power** by BalMort 106% of TNT (Refs 19 & 68) by Trauzl Test 98% PA (Refs 18 & 22) and 112% TNT (Ref 68); by Manometric Bomb Test - develops 2850 kg/cm² at loading d 0.25 vs 3230 for PA (Ref 24, p 282); by French Trauzl Test (CUP) 96% PA (Ref 62) (See also Ref 52a)

**Pressure** (maximum theoretical) if exploded in own volume and without loss of heat - 9235 kg/cm² at d 1.5 (Refs 20 & 52a)

**Sensitivity to Initiation** for 0.5 g sample of TNAns loaded in a detonator cap at 1100 kg/cm², a min of 0.37 g MF or 0.28 g LA is reqd (Refs 13 & 52a)

**Specific Energy (f)** 8232 vs 8080 for TNT or 102% TNT (Ref 18)

**Stability** - fairly stable in dry state, but in the presence of moisture it will hydrolyze to PA which reacts with metals to form sensitive picrates; in the presence of ammonia, TNAns gives picramide (Ref 36). Due to its low mp, TNAns will exude if stored at elevated temps.

**Temperature of Explosion or Detonation:** 2366°K (calcd) (Ref 68)

**Uses.** Because of low mp (exudation) and poor stability in presence of moisture, TNAns was not used extensively for military purposes. It was used, however, as a substitute explosive and also when it was necessary to lower the mp of other expls, such as PA. Following are some uses of TNAns:

**France.** According to Pepin Lehalleur (Ref 40) TNAns was manufd at the Poudrerie de Saint-Fons by nitration of DNAms but he does not describe its uses.
Germany. According to Marshall (Refs 12 & 34a) straight TNAs and its mixts with HE’s and AN were used to some extent for filling bombs and shells. Straight TNAs was used in some boosters, and mixts of TNAs with hexanitrodiphenyl sulfide for filling bombs (Ref 51a). Straight TNAs (Trisol) was used in long range projectiles (Ferngeschützgranaten), which were fired against Paris (Refs 60 & 72). It was also used in sea mines and torpedoes (Ref 57, p 110)

Great Britain — no information at our disposal

Italy — no info about its use for military purposes, but it was used in a mining expl consit of TNAs 20 & AN 80%. Belgrano(Ref 66a) analyzed the expl and reported its props as Trauzl test value 420 cc and gap test 2 cm

Japan. Straight TNAs, under the name of Type 91, was used during WW II in AP shells and bombs such as in jet-driven suicide planes (Refs 52a,53,54 & 57). Its mixtures with AN and some HE’s were used by both Army & Navy. These included A(oko) or Type A, called also Otsu-B(TNAs(or TNT) 60 HNDPhA 24 & Al 16%) (Ref 52a & Ref 53, p 32) - it was intended to replace Type 97H, called also Seigata (TNT 60 & HNDPhA 40%) in torpedo warheads; B₄ or Type 2 (incendiary expl congt TNAs 60 or 70 & Al powder 40 or 30%) (Ref 52a); “E” (Explosive), called also Nitrolit (TNAs 60 & AN 40%) (Refs 52a & 57, p 110); H₂ Kongo (H₂ Mixture) (TNAs 70 & HNDPhA 30%) - press-loaded in bomb auxiliary boosters (Ref 52b & Ref 53, p 31); same expl cast-loaded in bombs, sea mines and depth changes was called Type 98 (Ref 53, p 32); Type 98H (Navy) (TNAs 60 & HNDPhA 40%) - cast-loaded in bombs, torpedoes, depth charges & other ammo, replacing PA & TNT(Ref 52a & Ref 57, p 109); Type 94M (TNAs 60&RDX 40%) — used in some shaped charges & booster surround; its use in torpedo warheads was discontinued due to its sensitivity to sympathetic detonations (Ref 52a & Ref 53, p 32)

Russia — no information at our disposal

Switzerland — used under the name of Trisol (Ref 60). Was manufd during WW II by the SSF A-G, Dottikon(Aargau)

United States of America. According to Colver(Ref 14) an Amer inventor Hudson Maxim patented in 1904-5 the use of TNAs in the manuf of smokeless propellants. In a later patent (Ref 8) is given the compn of TNAs 40-50 & pyrocellulose 60-40%. Recent investigation at the Armour Res Inst (Ref 71) has shown that TNAs is useful as an anticracking additive to cast TNT and Comp B. Optimum percentages are: 0.4-0.8% for TNT and 0.8-1.0% for Comp B. Exudation of samples congt 0.1-0.2% TNAs in Comp B and 0.1-0.4% in TNT was only slightly higher than that for straight TNT. At higher percentages of TNAs the extent of exudation was too great (Ref 71)

3,4,5-Trinitroanisole, sl yel needles, mp 119-120°, sl sol in ligroin, sol in AcOH. Can be prepd according to Vermeulen (Ref 9) by nitration of 2,5-DNAns with mixed nitric-sulfuric acid (Ref 2)

Trinitroanisolene Complex, $\text{C}_8\text{H}_5\text{O}\cdot\text{C}_6\text{H}_4(\text{NO}_2)_3$ - $3\text{CH}_3\text{C}_4\text{H}_4\text{NO}_2$, red amor ppt, expl on heating; sol in alc or acet. It was obtained on treating a benzolic soln of TNAns with a benzolic soln of ethyl sodium acetate. Another expl complex was obtained on treating TNAns with a benzolic soln of ethyl sodium malonate. It was obtained on heating; sol in alc or acet. It was obtained on treating a benzolic soln of ethyl sodium acetate with a benzolic soln of ethyl sodium malonate.

Ref: C.L. Jackson & F.H. Gazzolo, Amer Chem J 23, 376(1900) & JCS 78, 1, 433-4(1900)
**Tetranitroanisoles (TeNAns)**, \( \text{CH}_3\cdot\text{O} \cdot \text{C}_6\text{H}_4\cdot(\text{NO}_2)_4 \), mw 288.13, N 19.45%, OB to CO\(_2\) -38.9%. Three isomers are theoretically possible: 2,3,4,5-TeNAns, 2,3,4,6-TeNAns and 2,3,5,6-TeNAns, but only the latter two are described in the literature:

2,3,4,6-Tetranitroanisole (2,3,4,6-TeNAns), granular or plates, mp 94\(^\circ\)C, d 1.64; v sl sol in w, alc or eth; sl sol in cold chlf, readily sol in hot chlf. Prepd by nitrating m-nitroanisole (Refs 1 & 3). This expl is reported to be more powerful and brisant than TNT. It gelatinizes NC. Its sensitivity to impact is comparable to that of tetryl and it explodes on heating at about 300\(^\circ\). The nitro-group in the 3 position is readily replaced, for example, by a hydroxyl group on heating with water. 2,3,4,6-TeNAns was used in Germany in primary expl mixts and as an ingredient in HE compositions (Ref 5). This isomer is reported to be equal in expl props to the 2,3,5,6-isomer (described below) but because of its lower mp, the use of 2,3,4,6-TeNAns is preferred to the higher melting compd (Ref 5)

2,3,5,6-Tetranitroanisole (2,3,5,6-TeNAns) exists in two cryst modifications: col with mp 153.5\(^\circ\) and yel with mp 112\(^\circ\); on crystn from alc, col crysts appear first, then change to the yel modifn (Ref 2). It is non-hygroscopic. Desvergnes (Ref 6) reported the following solubility data:

\[
\begin{align*}
g \text{2,3,5,6-TeNAns/100 g Solvent at 29\(^\circ\)} & \\
\text{Chloroform} & 0.79 \\
\text{Carbon tetrachloride} & 0.07 \\
\text{Benzene} & 1.55 \\
\text{Toluene} & 1.02 \\
\text{Methanol} & 4.39 \\
\text{Abs alcohol} & 2.38 \\
\text{96% alcohol} & 1.88 \\
\text{Ether} & 1.66 \\
\text{Acetone} & 1.15 \\
\text{Ethyl acetate} & 37.0 \\
\text{Carbon disulfide} & 0.08 \\
\text{Pyridine} & *
\end{align*}
\]

*Also dissolves in pyridine with evoln of nitrous gases, imparting a red coloration to the soln

2,3,5,6-TeNAns can be prd by nitration, with mixed nitric-sulfuric acid, of either 2,3,5-TNAns or 3,5-DNAns (Ref 4)

**Explosive Properties:**

- **Explosion Temperature**: 300\(^\circ\) (Ref 4)
- **Impact Sensitivity**: 20 to 35 cm vs 25 cm for tetryl & 110 cm for TNT, using 2 kg wt (Ref 4); **Power**, by Lead Block Expansion, 380-400 cc vs 290 cc for TNT or 131-180 cc for tetryl & 110 cm for TNT (Ref 4); **Reactivity** - the nitro group in the 3 position is readily replaced; **Stability** - claimed to be as stable as TNT (Ref 4) but powerful and brisant than TNT. It gelatinizes not found so by others. See also Ref 8

**Uses:** TeNAns was used in Germany in initiating and other expl mixts (Refs 3 & 7) but later was found to be too reactive and too sensitive for military or coml application. No information at our disposal about its uses in other countries


**ANISOLE AND DERIVATIVES, ANALYTICAL PROCEDURES**

**A** Anisole gives with SeO\(_2\) or with Na selenite in concd H\(_2\)SO\(_4\) a dark green coloration (Ref 1). For quantitative estimation of anisole, Dr H. Walter (Ref 7) suggests the bromination method, simply by adding bromine water. This gives 2,4,6-tribromoanisole. Det its mp(87-89\(^\circ\)) and mixed mp

**B** Mononitroanisoles. The following method is suggested by Dr H. Walter: Hydrolyze the sample by boiling it with aq KOH in the presence of some alcohol:

\[
\text{H}_3\text{CO} \cdot \text{C}_6\text{H}_4\cdot\text{NO}_2 \xrightarrow{\text{KOH, KO-C}_6\text{H}_4\cdot\text{NO}_2} \text{Acidify with aq HCl and extract the resulting nitrophenol with ether. Evap the ether,}
\]
recrystallize the residue from hot alc and identify the crysts by mp, mixed mp and/or IR spectra. When the sample contains a mixt of several isomers, the presence of o- and p-isomers is indicated by the intense yellow coloration produced in aq KOH. The m-isomer does not produce this coloration in the presence of KOH.

IR spectrograms of m- and p-nitroanisoles were prep'd at PicArsn by Pristera et al (Ref 6).

C) Dinitroanisoles. The following methods are suggested by Dr H. Walter:

Method 1. Dissolve a sample in aq methanol, add KOH and reflux:

$$(O_2N)_2C_6H_2-OCH_3 \xrightleftharpoons{CH_3OK} (O_2N)_2C_6H_2-OK$$

Evaporate the resulting soln of potassium dinitrophenolate to near dryness and dissolve the residue in concd H$_2$SO$_4$ (with cooling). Add gradually concd HNO$_3$(d 1.5) in order to obtain PA:

$$(O_2N)_2C_6H_2-OK \xrightarrow{HNO_3} (O_2N)_2C_6H_2-OH$$

Add an excess of Na acetate and then Pb acetate. Separate the resulting ppt of Pb picrate and weigh. PA content may also be detd colorimetrically.

Method 2. Dissolve the sample in aq methanol, add KOH and gently reflux. Cool the soln and add aq HCl, followed by stannous chloride:

$$H_3CO-C_6H_2(NO_2)_2 \xrightarrow{KOH} KO-C_6H_2(NO_2)_2 \xrightarrow{HCl} HO-C_6H_2(NO_2)_2 \xrightarrow{Reduction with SnCl_2} HO-C_6H_2(NH_2)_2$$

Treat the resulting diaminophenol with diazotized sulfanilic acid to obtain the orange colored dye:

$$(H_2N)_2(HO)C_6H_2 + NiN-C_6H_4-OSO_3 \xrightarrow{+} (H_2N)(HO)C_6H_2-N=N-C_6H_4-OSO_3H$$

Transfer the soln to a vol flask, take an aliquot and test it colorimetrically.

Note: If additional identification is desired, det nitrogen content by titanous chloride method described on p A415.

The IR spectrogram of 2,4-DNAns was made at PicArsn by Pristera et al (Ref 6).

A method of analysis of 2,4-DNAns samples contg 2,4-dinitrochlorobenzene was developed at PicArsn by S.M.Kaye (Ref 4). In this method the amt of 2,4-DNCIB is estimated from the amt of chloride detd by means of a photo-electric turbidimeter.

D) Trinitroanisole. The following method is suggested by Dr H. Walter:

Dissolve a sample in aq methanol, add KOH and reflux:

$$(O_2N)_3C_6H_2-OCH_3 \xrightarrow{CH_3OK} (O_2N)_3C_6H_2-OK$$

Det the content of potassium picrate either colorimetrically or gravimetrically, such as by pptn with Pb acetate.

IR spectrogram of 2,4,6-TNAns was prep'd at PicArsn by Pristera et al (Ref 6).

Identification of TNAns when in mixt with HNDPhA, such as was encountered in the Japanese 45 mm rocket was done at PicArsn by Weissberger (Ref 2) as follows:

Procedure: a) 0.4g sample of rocket chge was treated in a tared 100 ml beaker with 50 ml of hot benzene and the mixt allowed to stand on a hot bath for 10 mins with frequent stirring. b) The beaker was removed, cooled to 10-12° and, by means of a filtering stick, the supernatant soln of a material, later identified as TNAns, was removed. c) The residual material, later found to be HNDPhA, was washed 3 times with 5 ml of cold benzene (10°) and dried to const wt. The increase in wt of the beaker was considered as the amt of HNPhA. d) After evaporating the benzene from soln (b) the residue was identified as TNAns by its mp (65-67°) and its equivalent wt of 13.5 was detd by reduction with titanous sulfate. e) The residue in beaker of proced (c) was identified as HNDPhA by its mp (242°) and its equiv wt of 12.6. f) The TNAns was confirmed, as such, by the mp of a mixt of the unknown material and pure TNAns (mixed mp), and the similarity of spectrophotometric curves and...
the X-ray diffraction pattern of the unknown material and pure TNAns. g) The HNDPhA was confirmed, as such, by the same tests as in proceed(e).

**Note:** If additional identification is desired det nitrogen content by titanous chloride method, described on p A415

**E) Tetranitroanisole.** The following method is suggested by Dr H. Walter:

Reflux a sample with methanolic KOH in excess, whereby potassium styphnate is formed

\[ \text{H}_3\text{CO} \cdot \text{C}_6\text{H}(\text{NO}_2)_4 \xrightarrow{\text{KOH in} \ \text{C}_2\text{H}_5\text{OH}} \]

\[ \text{KO} \cdot \text{C}_6\text{H}(\text{NO}_2)_4 \cdot \text{OK} \]

Weigh the sample and identify the styphnate by decompg a portion of it withaq HCl, extracting the free styphnic acid formed with ether, evapng the ether, and recrystallizing the residue from ethanol. Identify styphnic acid by detg its mp, mixed mp and/or IR spectra.

**Note:** If additional identification is desired det nitrogen content by titanous chloride method, as described on p A415

**Refs:**

**Anisolebutane.** Same as Butylanisole

**Anisoleethane.** Same as Ethylanisole

**Anisolemethane.** Same as Methylanisole

**Anisolepropane.** Same as Propylanisole

**Anisoylazide or Methoxybenzoylazide**
(Anisic Azide or Methoxybenzazide)
\[ \text{H}_3\text{CO} \cdot \text{C}_6\text{H}_4 \cdot \text{CO} \cdot \text{N}_2, \text{mw} 177.16, \text{N} 23.72\%. \] Following isomers are described in the literature

**m-Anisoylazide or 3-Methoxybenzoylazide,**
mp 22.5°, dec 61°. Was prep’d by treating 3-methoxybenzoylchloride in acetone with aq Na azide

**Refs:**
1) Beil — not found 2) C. Naegeli et al, Helv 21, 1139 (1938) & CA 33, 540 (1939) (not listed)

**p-Anisoylazide or 4-Methoxybenzoylazide,**
mp 69°, dec 80° (Ref 3); dec explosively (Ref 2). Sah & Chang (Ref 2) prep’d it in 95% yield by diazotization of p-methoxybenzoylhydrazide. Naegeli et al (Ref 3) prep’d it by adding the caicd amt of Na azide to an acetonic soln of p-methoxybenzoylchloride. They also claimed that this compd was first prep’d in 1933 by O. Brunner & R. Wohrl, Monatsh 63, 376 (1933)

**Refs:**

**Note:** This compd is listed in CA 33, 540 (1939), but the props are those of the 3-isomer

**Anisoylperoxide.** See Dianisoylperoxide

**ANISYL ALCOHOL AND DERIVATIVES**

**Anisyl Alcohol or Methoxybenzyl Alcohol,**
\[ \text{H}_3\text{CO} \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_3 \text{OH}. \] All three isomers: o-, m- and p- are described in Beil 6, 893, 896, 897, (439, 440) & (878, 881 & 883)

**Anisyl Alcohol, Azides,** \[ \text{C}_6\text{H}_4\text{N}_2\text{O}_2. \]

**Anisyl Alcohol, Nitrate,** \[ \text{H}_3\text{CO} \cdot \text{C}_6\text{H}_4 \cdot \text{CH}_3 \cdot \text{ONO}_2. \] All three isomers o-, m- and p- were prep’d by J. W. Baker & T. G. Heggs, Chemistry & Industry 1954, 464 from Ag nitrate and the corresponding chlorides. The p-isomer was too unstable to distil

**Mononitroanisylalcohols,** \[ \text{C}_6\text{H}_4\text{NO}_2. \] Several isomers are described in Beil 6, 901, (440) & [880, 884] and in various papers

**Dinitroanisylalcohols,** \[ \text{C}_6\text{H}_4\text{N}_2\text{O}_4, \text{mw} 228.16, \]
N12.28%. Two isomers: 3-methoxy-2,6-dinitrobenzyl alcohol, mp 139.5-40.5° and 3-methoxy-4,6-dinitrobenzyl alcohol, mp 135-6° were prep by E.L. Jackson, JACS 79, 2912(1957) & CA 51, 14615(1957)

Dinitroanisylalcohol Nitrate, C₆H₅N₂O₆ and higher nitrated derivs were not found in Beil or CA through 1956

Anisylaminotetrazole and Derivatives. See Aminomethoxyphenyltetrazole and Derivatives

**ANISYLTETRAZOLE AND DERIVATIVES**

Anisyltetrazole or Methoxyphenyltetrazoles, C₆H₅N₂O₆, mw 176.18, N 31.80%. The following isomer is described in the literature:

5-[4'-Methoxyphenyl]-tetrazole, formerly called "Anisylaminotetrazolic Acid",

\[
\text{H}_2\text{CO-C}_6\text{H}_4-\text{C}==\text{N}-\text{N} \quad \text{or}
\]

\[
\text{H}_2\text{CO-C}_6\text{H}_4-\text{C}==\text{N}-\text{NH} \quad \text{or}
\]

cryst, mp 228°(dec) and burns when heated on a Pt foil; easily sol in alc, insol in cold w, sl sol in hot w & in eth. Was prepd from ethyl ether of anisiminohydrzone hydrate as described in Ref 2

Ref: 1) Beil 26, 395 2) W. Lossen & J. Colman, Ann 298, 115(1897)

Anisyltetrazole, Azidodervative, C₆H₅N₂O₆ not found in Beil or CA through 1956

Anisylnitrotetrazole or MethoxyphenylNitro-tetrazole, H₂CO-C₆H₄-\text{C}==\text{N}(\text{NO₂})₂-N or

\[
\text{H}_2\text{CO-C}_6\text{H}_4-\text{C}==\text{N}==\text{N}==\text{NO}_2 \quad \text{not found in Beil or CA through 1956}
\]

5-[3'-Nitro-4'-methoxyphenyl]-tetrazole, formerly called "Nitroanisyltetrazolic Acid",

\[
\text{H}_2\text{CO-C}_6\text{H}_4(\text{NO}_2)\text{-C}==\text{N}-\text{N} \quad \text{or}
\]

\[
\text{H}_2\text{CO-C}_6\text{H}_4(\text{NO}_2)\text{-C}==\text{N}-\text{NH} \quad \text{or}
\]

N 31.67%. Its monohydrate consists of yel ndls, mp 203°; insol in cold w, sl sol in hot w, and sol in eth, was prepd by nitrating the previous compd with nitric acid (d 1.4) (Refs 1 & 2)

Refs: 1) Beil 26, 395 2) W. Lossen & J. Colman, Ann 298, 115(1897)

**Dinitroanisyltetrazole**, C₆H₅N₂O₆ not found in Beil or CA through 1956

**Trinitroanisyltetrazole**, C₆H₅N₂O₆ not found in Beil or CA through 1956

**ANJ.** Cast double-base propellant described in conf "Propellant Manual," SPIA/M2(1959), Unit No 410

**AN-M-69 Bomb.** An incendiary bomb, weighing 6 lb used in WWII. It was filled with either Napalm Filling (Napalm 9, gasoline 91%) or IM Filling (isobutylmetacrylate polymer 5.0, fatty acids (such as stearic) 2.5, naphthenic acid 2.5, q 40% NaOH soln 3.0 & gasoline 87%)


**ANP-512DS, ANP-514DD, ANP-528DV, ANP-2502EB, ANP-2512EE, ANP-2541CD, ANP-2566EN & ANP-2569EK** are polyurethane fuel-oxidizer propellants; ANP-2639AF & ANP-2655AF are polyurethane propellants for rockets and ANR is a cast-double-base propellant

Ref: "Propellant Manual," SPIA/M2(1959), Unit Nos 480-4, 516-18, 568-9 & 381 (Conf)

**ANS or Antisanizinate.** A castable expl: AN 60, PETN 20, GuN 10 & DCDA 10%, developed by M. Tonegutti and used during WWII by the Italian Navy for filling some ammunition. Its comparatively low mp(104°) was due to the presence of GuN and DCDA. Incorporation of some Al increased the efficiency of ANS when used in underwater ammo, such as torpedoes, depth charges, and sea mines

Ref: Belgrano(1952), 96&187

**Anschütz Thermometers.** German-made thermometers known for their precision

**Ansonit Caps.** See PATR 2510(1958), p Ger 7

**ANT-623 & ANT-638BY** are Aeroplex fuel-oxidizer propellants described in conf "Propellant Manual," SPIA/M2(1959), Unit Nos 486 & 487

**Antiacids.** See Antiacids

**ANTHRACENE AND DERIVATIVES**

Anthracene or p-Naphtalene, 

\[
\text{\includegraphics[width=0.5\textwidth]{anthracene.png}}
\]
A458

mw 178.22; col monocryts with blue fluorescence, mp 216.5-218°, bp 345°, d 1.25 at 274/°, fl 250°F(closed cup). Insol in w, sl sol in alc, eth, chl & CS₂, sol in benz. It is one of the principal ingredients of coal tar, from which it is usually obtained commercially. It has been used as a flash-reducing agent in propellants and for producing gray smokes in trench warfare (Refs 2&3), but its principal use is in manuf of alizarin dyes (Ref 4). In BritP 23, 579(1893) (Ref 1a), anthracene was proposed in expl mixts with AN, K nitrate with or without K chrts, mp-expl ca 1200. Was prepd by treating chlorate. US military requirements for tech- grade anthracene are given in spec exposure to UV light. 

Anthracene Peroxide (Transannular Photoperoxide of Anthracene),

\[ \text{C}_2\text{H}_4\text{O}_2 \]

Dinitroanthracenes, \( \text{C}_{14}\text{H}_2(\text{NO}_2)_2 \), mw 268.22, N 10.45%. One isomer, 9,10-dinitroanthracene, is described in Beil 5, 666, (327) & [579]

Trinitroanthracene, \( \text{C}_{14}\text{H}_2(\text{NO}_2)_3 \), and higher ntratd compds were not found in Beil

Anthracene Peroxide (Transannular Photoperoxide of Anthracene),

\[ \text{C}_2\text{H}_4\text{O}_2 \]

crysts, mp-expl ca 120°. Was prepbd by treating anthracene (in dil CS₂ soln) with air under exposure to UV light


Anthracene, Azido-, \( \text{C}_{14}\text{H}_2\text{N}_3 \) and Diazido-, \( \text{C}_{14}\text{H}_2\text{N}_6 \) Derivatives were not found in Beil or CA through 1956

Note: Nitration of anthracene is discussed in the following papers:

1)P.P.Shorygin et al, ZhObshchKhim 8, 981 (1938) & CA 33, 3781(1939) (Anthracene reacts with \( \text{N}_2\text{O}_4 \) in CHCl₃ at 0° & 20-30°, yielding 40% 9,10-dinitro- & 4-8% 9-nitroanthracene)

2)R.Oda, JSciChemInd, Japan 42, Suppl binding 414-18(1939) & CA 34, 3259-60(1940) (Action of nitric acid in acetic acid produced various products, such as 9-nitroanthrone; 9,10-dinitroanthracene, 2,7-dinitroanthraquinone, etc)

3)R.Oda & M.Kotake, JapP 133052(1939) & CA 35, 3270(1941) (Treatment of anthracene suspended in glacial AcOH + % its vol of w, with nitric acid yielded a mixt of 50-60% of 2,7-dinitroanthraquinone and 40/50% of anthraquinone)

Mononitroanthracenes, \( \text{C}_{14}\text{H}_2\text{NO}_2 \), mw 223.22, N 6.28%. One isomer, 9-nitroanthracene, is described in Beil 5, 666 & [578]

Dinitroanthracenes, \( \text{C}_{14}\text{H}_2(\text{NO}_2)_2 \), mw 268.22, N 10.45%. One isomer, 9,10-dinitroanthracene, is described in Beil 5, 666, (327) & [579]

Trinitroanthracene, \( \text{C}_{14}\text{H}_2(\text{NO}_2)_3 \), and higher ntratd compds were not found in Beil

Anthracene Peroxide (Transannular Photoperoxide of Anthracene),

\[ \text{C}_2\text{H}_4\text{O}_2 \]

crysts, mp-expl ca 120°. Was prepbd by treating anthracene (in dil CS₂ soln) with air under exposure to UV light


Anthracene, Azido-, \( \text{C}_{14}\text{H}_2\text{N}_3 \) and Diazido-, \( \text{C}_{14}\text{H}_2\text{N}_6 \) Derivatives were not found in Beil or CA through 1956

Note: Nitration of anthracene is discussed in the following papers:

1)P.P.Shorygin et al, ZhObshchKhim 8, 981 (1938) & CA 33, 3781(1939) (Anthracene reacts with \( \text{N}_2\text{O}_4 \) in CHCl₃ at 0° & 20-30°, yielding 40% 9,10-dinitro- & 4-8% 9-nitroanthracene)

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Mononitroanthracenes, \( \text{C}_{14}\text{H}_2\text{NO}_2 \), mw 223.22, N 6.28%. One isomer, 9-nitroanthracene, is described in Beil 5, 666 & [578]
nitrating anthrachrysone with mixed nitric-sulfuric acids

Refs: 1)Beil 8, 553 & 586  2)G.Heller & P.Lindner, Ber 55, 2675-6(1922) & CA 17, 1012(1923)

Anthracite. A nongelatinous permissible expl manufd by Independent Explosive Company of Pennsylvania

Ref: Bebie(1943), 28

Anthracite Particles(Cool Dust). Their fire & expln hazard, as well as toxicity are discussed in Sax(1957), 304

ANTHRAMINE AND DERIVATIVES

Anthramine or Aminoanthracene, C_{14}H_{10}N_{2},
mw 193.24, N 7.25%, Exists in the form of three isomers; 1-aminoanthracene

\[
\begin{align*}
\text{NH}_3 & \quad \text{yel crysts, mp} \\
127-30^\circ & \quad \text{(Ref 1)}; 2\text{-aminoanthracene} \\
\end{align*}
\]

\[
\begin{align*}
\text{NH}_3 & \quad \text{yel leaflets, mp} \\
236-8^\circ & \quad \text{(Ref 2) and 9-aminoanthracene,} \\
\end{align*}
\]

Snelling & Wyler (Ref 4) proposed the use of anthramine (specific isomer not indicated and therefore presumably a commercial product which is a mixt of isomers) as a coating agent for AN crysts or to increase their sensitivity to initation


Anthramine, Azido-, C_{14}H_{18}N_{4} and Diazido-, C_{14}H_{14}N_{2}, Derivatives were not found in Beil or CA through 1956

Mononitroanthramines, C_{14}H_{10}N_{2}O_{2}. One isomer 9-amino-10-nitroanthracene is described by S.Hunig & K.Requardt, Ang Chem 68, 152(1956) & CA 50, 12944-5(1956)

Dinitroanthramine, C_{14}H_{10}N_{2}O_{4} – not found in Beil or CA through 1956

Trinitroanthramine, C_{14}H_{10}N_{2}O_{6} – not found in Beil or CA through 1956

Anthranilic Acid. Same as Aminobenzoic Acid

Anthranoylazide. See Aminobenzazide under Anthracite

Particles(CoaI Dust). Their fire & expln hazard, as well as toxicity are discussed in Anthraquinone and Derivatives, p A189

ANTHRAQUINONE AND DERIVATIVES

Anthraquinone or Dihydro-diketo-anthracene,

\[
\text{C}_{14}\text{H}_{8}\text{O}_{2} \quad \text{mw 208.20 is des-} \\
\]

cribed in the following refs: 1)Beil 7, 780-5, (407-9)&[709-13]  2)Kirk & Othmer 1(1947), 944-7 (several refs)  3)Faith, Keyes & Clark (1957), 122-125(manuf)

Anthraquinone Azides or Triazoanthraquinones also called Azidoanthraquinones, C_{14}H_{18}N_{2}O_{2},
mw 249.22, N 16.86%, OB to CO_{2} –187.8% & to CO –99.5%. Following isomers are described in the literature:

1-Azido-Anthraquinone, bright yel ndls (from MeOH) (Ref 2). Its expl props were not examned. Prepn is described in Refs 1 & 2

2-Azido-Anthraquinone, bright yel ndls (from coned HCOOH), mp 160-162\circ, turning brown on exposure to light. Defl on heating above the mp. Prepn is described in Refs 1 & 3

Refs: 1)Beil 7(416)&(722)  2)L.Gattermann & R.Ebert, Ber 49, 2119(1916)  3)A. Schaarschmidt, Ber 49, 1637(1916)

Anthraquinone Diazide or Ditriazoanthraquinone, also called Diazidoanthraquinone C_{14}H_{16}N_{4}O_{2}, mw 290.24, N 28.96%, OB to CO_{2} –159.9% to CO –82.7%. Following isomers, most of them unstable, are described in the literature:

1,4-Diazidoanthraquinone, red brn, unstable (Ref 1 & 2)
1,5-Diazidoanthraquinone, yel-brn to red brn, unstable (Refs 1 & 2)

1,8-Diazidoanthraquinone, brn, unstable (Refs 1 & 2)

2,6-Diazidoanthraquinone, lt brn crysrs light sensitive, defl 202° on rapid heating, expl when heated in a test tube (Refs 1 & 2)

Refs: 1) Beilstein, Anm 7, [723] 2) K. Brass & F. Albrecht, Ber 61, 983-93 (1928) & CA 22, 2938-9 (1928)

Nitroazidoanthraquinone or Nitroanthraquinone Azide, C₄H₆N₃O₄, mw 294.22, N 19.04%, OB to CO₂ -146.8% & to CO -70.7%. Following isomers are described in the literature:

4-Nitro-1-azido-anthraquinone, yel ndls (from pyridine), mp 245° (dec), expl on rapid heating. Prepd by gentle warming of 4-Nitroanthraquinone-1-diazoxyaminel with acetic anhydride and pyridine (Ref 2)

1-Nitro-2-azido-anthraquinone, Pale yel-grn crysrs (from pyridine), mp 210° (dec), changing on exposure to light and in the air to pale orange-red (Ref 3). Prepd by rubbing β-anthraquinone-azide with conc nitric acid

Refs: 1) Beilstein, Anm 7, [723] 2) L. Gattermann & H. Rolles, Ann 425, 147 (1921) & CA 16, 929 (1922) 3) F. Bayer & Co, Ger Pat 337,734 (1921) & Chem Ztr 1921, IV, 262

1,5-Dinitro-2,6-diazido-anthraquinone, C₄H₆N₄O₄, mw 380.24, N 29.47%, OB to CO₂ -101.0% & to CO -42.1%. Bright yel ndls (from C₄H₆NO₂), mp 200-202°(dec). Prepd by treating 2,6-Diazoanthraquinone with fuming nitric or sulfuric acids

Refs: 1) Beilstein, Anm 7, [723] 2) F. Bayer & Co, Ger Pat 337,734 (1921) & Chem Ztr 1921, IV, 262


with mixed nitric-sulfuric acid)

Nitranthraquinones or Mononitranthraquinones, C₄H₆NO₄, mw 253.20, N 5.53%. The 1- and 2-isomers are described in Beil 7, 791-2, (415) & [719-20]. The 2-isomer is best formed by persulfate oxidation of 2-aminoanthraquinone [Kirk & Othmer 7 (1947), 955]

Dinitroanthraquinones, C₄H₆N₂O₄, mw 298.20, N 91.40%. Several isomers are described in Ref 1 and their purification in Ref 2. Nitration gives predominantly α-deriv (Ref 3)


Trinitro-, Tetrinitro-, Pentanitro- and Hexanitroanthraquinones were not found in Beil or CA through 1956

β-Anthraquinonesulfonamide, C₄H₄SO₃N₃, mw 281.29, N 14.94%, OB to CO₂ (assuming S to SO₂) -179.2%. Yel plates, mp 153° and defl with copious evolution of smoke when heated on a spatula. Prepd by heating anthraquinonesulfonchloride with Na azide in alco soln

Refs: 1) Beil – not found 2) T. Curtius & H. Derlon, J. Prakt Chem 125, 420-1 (1930) & CA 24, 3230 (1930)

Antacid Compounds or Antacids (Antazide or Säuerbindende Stoffe in Ger). Some explosives and propellants, especially those contg org nitrates (such as NG, NGc, NC, etc) may contain traces of mechanically entrapped acids, especially sulfuric acid. In other cases, acids (nitric and nitrous) might form on decomp of the above organic nitrates during storage, especially at high temps and in the presence of moisture. If these traces of acids are not immediately neutralized, they
A461

might soon cause autocatalytic decompns of the expls or proplns, thus rendering them useless for service. These decompns often develop into spontaneous combustion and even explns. Neutralization of the acids may be achieved by incorporating in the formulations of expls and proplns some weakly basic substances, such as CaCO₃, ZnO, MgCO₃, urea, etc. These substances, "antiacids," may also be considered as "stabilizers" although this term usually applies to substances, such as diphenylamine, centralite, acardite, etc, which function in a different manner but achieve the same ultimate purpose.


Addn Refs: A)Olin-Mathieson Chem Corp, BritP 738441(1955) & CA 50, 8148(1956) (Addn of metallic Mg, Ca, Zn & Al or their oxides or carbonates for stabilization of hydrazine) B)B.P.Enoksson, USP 2736742 (1956) & CA 50, 6796(1956)(Addn to acid-contg nitrated products such as NG, NGc or NC of AN & ammonia and/or org bases, such as amines, amides, urea, etc) C)Nitroglycerin Aktiebolaget (Sweden), BritP 766588 (1957) & CA 51, 8438(1957)(Same as in previous ref)

Antiaircraft (AA) refers to the weapons, ammunition and personnel used for defense against enemy aircraft.


Antiaircraft Gunfire Control Systems are described in A.S.Locke et al, "Guidance," Van Nostrand, NY(1955), 22-33

Antiaircraft Projectile Charges of Willing contained a HE mixed with a material, such as emery capable of impairing the operation of internal combustion engines.

Ref: M.S.Willing, USP 2,103,807(1935) & CA 32, 1935(1938)

Anticaking Treatment of Explosives and Substances Used in Explosive Compositions. Substances such as AN have a tendency to cake in storage, thus rendering them difficult to load in cartridges, shells, etc. The problem of caking was recently investigated by LeRoux (Ref 2). Among the substances proposed to prevent caking ("anticaking agents") of substance, such as AN may be mentioned:

a)Coating compounds (materies d'enrobage, in Fr), such as petroleum oils, petroleum tars, paraffins & waxes (natural & synthetic) and resins. To these may be added organic substances which form gels in the presence of water, such as starches, dextrin, gum-arabic, Na-Al alginates, etc

b)Powdering agents (agents de poudrage, in Fr), such as finely powdered kaolin, bentonite, CaCO₃, MgCO₃, MgO, ZnO, SiO₂, Al₂O₃, talc (Mg silicate), Al, metallic soaps (such as Al stearate), etc. LeRoux proposed to incorporate ca 1% of Ca stearate in AN expls, such as "explosifs N" and "explosifs NR"

Whetstone (Ref 1) proposed to add "Acid Magenta" to a satd soln of AN, just before crystn. It has been claimed that this treatment modifies the form of crysts in such a manner that their agglomeration does not form cakes but leaves them as granules.

Anticaking agents used with AN are described in this work on the following pages:

A314(under "Continuous Process of Graining), A315 & A318 (under Crystallization Process), A318(under Preparation of FGAN), A334-5 (under Water Resistance and Prevention of Caking), A342-4(under AN Blasting Explosives) and A364(under FGAN)


Anticarro(Ital). Antitank

Antichar(Fr). Antitank

Anticoppering or Decoppering Agents. See under Fouling of Guns and Antifouling Agents

Anticracking Additives to Cast Explosives. The
problem of cracks in HE shells was investigated at Pic Arsn, by Heredia (Ref 1) and more recently by Johnson (Ref 3). According to Johnson, it has been reported that the problem of cracked cast changes has arisen when cooling with temps below 120°F (48.9°C) for Comp B and below 65°F (18.3°C) for TNT are utilized in an attempt to decrease solidification time. This condition has brought about the need for some compd(s) which, when added in small percentages to the melt, will prevent or minimize to a large extent cracked casts which are the result of thermal stresses. Previous work done at the Iowa Ordnance Plant, Burlington, Iowa and by the US Navy indicated that the addition of small amounts of certain compds reduced the tendency of cast expls to crack when they were cooled at temps below 120°F for Comp B and 65°F for TNT.

Additives used by the US Naval Ordnance Test Station, Inyokern, Calif included 0.5 to 1.0% α-MNN, 0.5% catechol, 0.25% anthracene and 0.25 to 0.75% Span 80A. In addition, small percentages of o- and p-nitrotoluene mixts, such as 3.36/1 were found to be effective. However, the high-melting eutectic-forming additives anthracene, α-MNN and catechol were preferred because little exudation occurred at temps up to within ca 5° of the eutectic temp.

Based on these earlier studies, a contract was entered into with the Armour Research Foundation, Chicago, Illinois for the purpose of finding compds that would overcome this tendency to crack. Optimum percentages of α-MNN, 2,4,6-TNAns and 1,2-dihydroxybenzene were investigated by the ARF (Ref 2) relative to prevention of cracks due to thermal shock and exudation when these compds were added to TNT and Comp B. Visual examination of laboratory casts (ca ¾" diam by 3¾" length), when compared to control castings without crack preventing agents, showed progressive improvement in the casts with regard to the reduction in number of cracks as the percentage by wt of each additive was increased (such as from 0.1 to 1.5%) until the optimum percentage range was reached. Unfortunately, however, the amt of exudate increased as the percentage of each additive was increased. Lab tests also have shown that the effectiveness of the additives as crack preventative agents was less for Comp B than for TNT.

These rather optimistic results of lab tests, were not confirmed when the same additives were used at Picatinny Arsenal in cast-loaded 155 mm shell. The degree of cracking in the 155 mm shell casts was detd by means of radiographs (which is a standard production inspection procedure), which showed that there was no apparent difference between the degrees of cracking in an additive-contg cast and an ordinary cast. Exudation, as evaluated by subjecting the loaded shell to 160°F (71.1°C) storage test for 30 days, showed that the casts contg additives exuded more than those without them.

Further work on this subject is necessary.


Antidetonating or Antiknock Compounds (Antidetonants, in Ital and Antidetonants, in Fr). Substances such as lead tetraethyl Pb(C₂H₅)₄, tin tetraethyl Sn(C₂H₅)₄, ferrocyanide Fe(CO)₅, nickel cyanide Ni(CO)₅, aniline, etc possess the property of preventing knock in internal combustion engines and for this reason are also called "antiknock" substances. For their description see Refs 3, 5, 7 & 8.

Several theories exist on the mechanism for antiknock action, such as outlined in Refs 1 & 5. Demougin (Ref 6, p 139), H.Moureu & C.Dufresse attribute the action of...
"antidétonants" to their "antioxydizing power (pouvoir antioxygène, in Fr) which hinders the formation of peroxides

Some of the "antidétonants," such as tin tetraethyl, were proposed in France (Ref 6) as additives (in small quantities) to propellants as "flash reducing substances ("substances antilueurs," in Fr). The idea was based on the hypothesis that on the burning of a propellant such substances would evolve a dust of extremely small solid particles which when dispersed through the gases such as CO & H₂ would cool them thus preventing their combustion


Further investigation of TNT with abnormal frothing recorded 164 secs before addn of surface-active agents and as low as 59 secs after the addn

Several instances of molten TNT becoming frothy when cast-loaded into shells were reported in the US during WWII. This resulted in undesirable cavitation at the interface between the solidified TNT and the upper part of the shell wall and also at the interface between the two layers of TNT when two pourings were made. Investigation conducted at PicArsn (Ref 3) showed that incorporation of small amts (such as 0.1%) of the surface-active agents Duponol C or Span 85 was sufficient to reduce frothing to the level of good grades of TNT. These additives did not reduce the stability of TNT and did not appreciably change its props such as setting point

The test for frothiness was conducted by melting ca 25g of TNT in a 6-inch test tube which was placed in a water-bath at ca 95°C. The tube, about half filled with molten TNT, was stoppered, removed from the bath and vigorously shaken 5 times at the rate of one shake per 2 secs. The tube with contents was immediately placed in a thermostatic bath maintained at 86±1°C. The end point of frothing (duration of foam) was recorded as the time in seconds required for the froth to break only 3 bubbles remained. The approxiamte amt of froth was also noted. Some standard grades of TNT showed duration of frothing as low as 50 secs, while TNT with abnormal frothing recorded 164 secs before addn of surface-active agents and as low as 59 secs after the addn

Further investigation of TNT with abnormal frothing showed that its surface tension (47 dynes/cm²) was only slightly lower than that for a std TNT (51 dynes/cm²), but there was also a sample of TNT with a low frothing value, which had an abnormally low surface tension (38 dynes/cm²). The viscosity of frothy TNT was of the same order as that of the std lot of TNT. Chemical analysis of frothy TNT did not indicate any difference from std TNT. It was found, however, that incorporation in std TNT of small amts of impurities, such as wax or grease increased the frothing value, but incorporation of 0.06% acid-proof black paint or 0.07% tetrtnitromethane
had no adverse effect on the frothing value.

Of the two surface-active agents investigated, the Duponol C, manufd by the duPont Co, is a solid and said to contain Na lauryl sulfate, while the Span 85, manufd by the Atlas Powder Co, is an oily liq and said to contain sorbitol trioleate. The use of Span 85 is preferred because, being purely organic, it does not contain any metallic ions, such as Na and also because, being a liquid, it dissolves quicker in molten TNT.

Plant-scale tests at Iowa Ordnance Plnt, Burlington, Iowa have shown that the addn of 0.1% of Span 85 to molten TNT is effective in preventing frothing and the consequent pithing and cavitation of the cooled charge. It has also been found that the presence of 0.1% of Span 85 has no significant adverse effect on the stability or impact sensitivity of TNT, and does not cause formation of TNT-water emulsion during the "streaming-out" of TNT chges. However, it causes significant reduction in sensitivity to initiation and a slight exudation in storage at 65°. TNT contg only 0.05% of Span 85 was found to have essentially normal sensitivity and brisance and to undergo no exudation in storage at 65°. It was recommended that authorization be granted for the addition of not more than 0.05% of Span 85 to TNT during loading operations.


**Antifouling Agents.** See under Fouling of Guns

**Antifreezes and Their Uses in Explosives**

and Propellants. For general description of various "antifreezes" used for general purposes see Refs 8.

As some of the liq components of expls and propellants freeze at prevailing winter temps in Europe, Canada, US, etc, it is desirable to lower the fp of such liqs by incorporating a substance exercising an antifreezing effect. Such substance is called in Ger "das gefrierpunktherabsetzendes Mittel."

Widest uses of antifreezes are in NG contg expls, such as dynamites. Dynamites contg antifreezes are called "low-freezing" ("schwergefrierbare," in Ger) and "non-freezing" ("ungefrierbare," in Ger) dynamites ("Dynamite" in Ger).

**Note:** NG freezes at +13°, but when in comps, its crysnt is rather slow. When an expl contg NG is stored in cold weather for a long time, it freezes to a mass as hard as a stone. Such a mass is unsuited for use because NG became insensitive. In order to make such an expl fit to use, it must be heated in order to melt NG. This operation, called thawing, is time-consuming and very dangerous, especially if conducted carelessly. It is possible that some accidents took place because on thawing part of the liquid NG escaped from the cartridges and was present in full strength at their surfaces. It is therefore highly desirable to prevent freezing of NG contg expls.

According to Escales (Ref 2, pp 37-46) and Naoum(Ref 3, pp 15-21 & 356-81), the first attempt to reduce fp of NG was made by A.Rudberg(Swed P of April 30, 1866) who added materials like benz or NB and later Nobel(Swed P, July 8, 1876) proposed the addn of Me and Et nitrates, acetins, or NB. A.Wahlenberg & K.Sundström proposed in 1877 addn of o-MNT; K.Amark(1879) proposed nitrosochrom, nitramannit and amyl nitrare and Lieberr(1889) isoamyl nitrate. While Me & Et nitrates were the most suitable from the chem point of view, their volatility was too great. The other comps were effective only in such large quantities that they reduced the sensitiveness, strength and brisance of NG very appreciably.
A more promising "antifreeze" was obtained in 1890 by A. Wohl (Ger P 58947) who succeeded in polymerizing glycerin and nitrating to an expl oil, tetranitrodiglycerin, [C₃H₅(NO₂)₃]₂O very difficult to freeze. This process, however, attracted no attention at that time.

A. Mikolajczak proposed in 1903 and patented the addn of dinitroglycerin (glycerin dinitrate), C₃H₄(OH)ONO₂, and developed a simple method for its prep'n.

S. Nauckhoff investigated the question of reducing the fr p of NG and showed in his paper (Ref 1) that all previously proposed agents could not completely achieve their purpose.

The solution of the problem was more closely approached by the use of highly-nitrated aromatic hydrocarbons, especially the low-melting eutectic mixts of the isomers of di- and tri-nitrotoluenes (such as "TNT oil" or "drip oil" which dissolve readily in NG even at low temps and desensitize it much less than the mono-nitro compds. However, these compds did not produce dynamites which were absolutely non-freezing at the lowest winter temps reached in some countries such as in Canada or Siberia.

Further research in this field showed that nitric esters homologous or related to NG, such as previously mentioned dinitroglycerin and tetranitrodiglycerin, as well as dinitrochlorohydrin, acetyl dinitroglycerin and dinitro glycol, being miscible in all proportions with NG and nearly equivalent in expl strength, were the most suitable antifreezes. Of these compds, the tetranitrodiglycerin (manuf patented by the "Zentralstelle fur Wissenschaftlich-technische Untersuchungen" in Neubabelsberg) found little use on acct of certain tech difficulties of manuf, which dinitrochlorohydrin does not present. Dinitro glycerin, although it is a satisfactory antifreeze, came into very little practical use on account of its solubility in w. Dinitrochlorohydrin, C₃H₄Cl(ONO₂)₂, was used quite extensively until the invention in 1904 (Ger P 179879) of glycol dinitrate, C₃H₄(ONO₂)₂, or simply nitroglycol (abbreviated in our work as NGc). This substance has been widely used in the US since 1912 in "low-freezing dynamites" (qv). In actual practice a mixt of 20-30% glycol and 80-70% glycerine is nitrated in the same manner as straight NG.

In addition to the foregoing antifreezes may be mentioned nitrosorbite (Ref 6, p 238) and nitrated sugar mixts (Ref 3, pp 251-8 & Ref 6, pp 239-40). A mixt of nitrosucrose and NG, prep'd by nitrating a soln of 20 (or 25) parts of cane sugar and 80 (or 75) parts of glycerin is known in the US as nitrohydrene and is suitable for use in non-freezing dynamites. Another low-freezing liq tried in the US dynamites was obtained by nitrating glycerin 60, glycol 20 and sugar 20%.

According to E. Mohrenweiser of PicArsn, "gelatin-dynamites" freeze at a much slower rate than "straight-dynamites" and the higher the content of NC (which serves as a colloiding agent), the better is their resistance to low temps. The same applies to NG-contg propellants such as "ballistite," "cordite" and "solventless propellants." Most of these propellants do not contain any antifreezes. For instance, "double-base" rocket propellants manuf'd during WW II by the Hercules Powder Co at Radford, Va for shipment to Russia did not contain any antifreeze. There was added however, a small amt of liq plasticizer intended to facilitate the gelatinization of NC by NG. Some current US propellants contain DEGDN in lieu of NG and they are low freezing. These propellants were invented in 1934 by the German Gen U. Gallwitz [See PATR 2510 (1958), p Ger 70, as "G" Pulver]. The same inventor proposed in 1935, the use of nitrated polyglycol and TEGDN. Incorporation in "G" Pulver of large amt of NG produced a propellant known as "Gudolpulver" [See PATR 2510 (1958), p Ger 81], proposed in 1937 by the Dynamite A-G.


Antifrost Celladyne. An older Brit low-freezing dynamite which passed the Buxton test: NG + NGc 56.5, CC 3, NaN03 6, NaCl 10.5 & borax 24%. Its ballistic pendulum swing was 2.51", vs 3.27" for 60% Gelignite  
Ref: Marshall 1 (1917), 110  
Note: The swing of 60% Gelignite, a std Brit expl is given by Barnett (1919), 184  

Antifrost Gelamonite No 1. An older Brit "permitted" low-freezing dynamite: NG + NGc 24, CC 1, DNT + TNT 2, AN 36, WM 1 & NaCl 36%. Its ballistic pendulum swing was 2.30" vs 3.27" for 60% Gelignite  
Ref: Marshall 3 (1932), 120  

Antifrost Penryhn Powder. One of the older Brit "permitted" expls: AN 58.5-61.5, NG 7.5-9.5, WM 7.5-9.5, NaCl 20.5-22.5 & moisture 2.0%  
Ref: Thorpe 4 (1940), 556  

Antifrothing Agents. See Antifoaming Agents  

Antifume Blasting Gelatin. An older SoAfrican (Transvaal) expl consisting of "blasting gelatin," to which a small quantity (ca 5%) of an oxidizer, such as AN, K nitrate, K chlorate or K perchlorate, was added. This expl was used in mines with poor ventilating facilities, where the formation of even small quantities of the highly poisonous CO (as often occurs on expln of ordinary "blasting gelatin") is very undesirable  
Ref: Naoum, NG(1928), 321  

Antigel de Sûreté. One of the older Belgian permissible expls of the type "explosifs SG": NG 25, Na nitrate 20, DNT 15, Amm sulfate 5, cellulose and/or WM 35%  
Ref: Marshall 1 (1917), 376  

Antigrisou D'Arendonck. One of the oldest Belgian permissible expls: AN 72, NG 27 & CC 1%  
Ref: 1)Daniel(1902), 28 2)Gody(1907), 701  

Antigrisou(Explosifs) are expls safe for use in coal mines in the presence of firedamp ("grisou", in French). The terms "anti-grisou," "antigrisouteux" and "grisoutine" have been used in France, but in Belgium such expls are known as "explosifs Securit&-Grisou-Poussière") (See tables on pp 419-21 of Ref 4). All these expls contain large amts AN. The following "anti-grisou" expls called also antigrisous were introduced (before WWI) by Favier (Ref 2, pp 593-4)' and manufd for some time by the SA des Explosifs Favier at Vilvorde (Troix Fontaines, near Bruxelles):  

<table>
<thead>
<tr>
<th>Names of Explosives</th>
<th>AN</th>
<th>DNN</th>
<th>TNN</th>
<th>NH₄Cl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antigrisou No 1</td>
<td>87.6</td>
<td>12.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antigrisou No 2</td>
<td>87.6</td>
<td>12.4</td>
<td></td>
<td>8.0(added)</td>
</tr>
<tr>
<td>Antigrisou No 3</td>
<td>81.0</td>
<td>6.0</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>Antigrisou II</td>
<td>80.9</td>
<td>11.7</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>Grisonite roche</td>
<td>92.0</td>
<td>8.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grisonite couche</td>
<td>95.5</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Pêrez-Ara (Ref 5) gives for No 1: AN 81, DNN 6 & NH₄Cl 13% and for No 2: AN 81, TNN 6 & NH₄Cl 13%  
The calcd temp of expln of No 1 is ca 2000°, of No 2 1878°, and of No 3 1400°
According to Pepin Lehalleur (Ref 4) the Antigrisou No 1 was used during WWI for filling some HE shells. It was safe to handle, inexpensive and insensitive, but not as powerful and brisant as TNT.

Pepin Lehalleur (Ref 4, p.343) gave also the following compns of “antigrisou” explosives reported in 1935 to be in use in France at that time.

<table>
<thead>
<tr>
<th>Components</th>
<th>Roche</th>
<th>Couche</th>
<th>salpêtrée</th>
</tr>
</thead>
<tbody>
<tr>
<td>NG</td>
<td>29.1</td>
<td>11.7</td>
<td>12.0</td>
</tr>
<tr>
<td>CC</td>
<td>0.9</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>KNO₃</td>
<td>—</td>
<td>—</td>
<td>5.0</td>
</tr>
<tr>
<td>AN</td>
<td>70.0</td>
<td>88.0</td>
<td>82.5</td>
</tr>
</tbody>
</table>

Médard (Ref 6) gives the following compns of current "explosifs antigrisouteux."

<table>
<thead>
<tr>
<th>Components</th>
<th>N no 7</th>
<th>N no 9</th>
<th>N no 62</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN</td>
<td>76.0</td>
<td>48.2</td>
<td>12.0</td>
</tr>
<tr>
<td>DNN</td>
<td>7.0</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>TNT</td>
<td>—</td>
<td>9.15</td>
<td>—</td>
</tr>
<tr>
<td>PETN</td>
<td>—</td>
<td>—</td>
<td>23.0</td>
</tr>
<tr>
<td>WF*</td>
<td>2.0</td>
<td>1.65</td>
<td>—</td>
</tr>
<tr>
<td>NaCl</td>
<td>15.0</td>
<td>41.0</td>
<td>65.0</td>
</tr>
</tbody>
</table>

*WF = wood flour

The first of these expls, belonging to the type "l’explosif-couche nitraté," was proposed in 1933 by Burlot & Schwob. Its CUP value (coefficient d’utilisation pratique) is 87(PA = 100) and gap test value (coefficient de sél-excitation) 6cm (See also C(Explosifs), CSE(Explosifs), Dynamites, Grisou-dynamites, Grisou-dynamites chlorourées, Grisoumites, Grisoutines, Grisotites, N(Explosifs), etc)


### Antiknock Compounds

See Antidetonating Compounds

**Antilueur** (Fr). Antiflash

**ANTIMONY** (Stibium in Lat; Antimon, in Ger; Antimoine, in Fr; Antimonio, in Ital & Spanish; Soot'ma, in Russian), Sb, at wt 121.76. Lt greyish metal, mp 630.5°C, bp 1380°C, d 6.684 at 25/40, sp heat 0.049, latent heat of fusion 38.3 cal/g, Moh’s hardness 3-3½. Temp of ignition of powder in air >600°C (Ref 9, p 37). It is insol in w; sol in aqua regia & in hot concd H₂SO₄.

Native Sb element is known, but it is too rare to be commercially important. It exists in nature in the form of several ores of which the most important is stibnite, which is sulfide, Sb₂S₃. Commercial method for obtaining free Sb consists of fusing stibnite with iron turnings or shavings, followed by slagging off the resulting iron sulfide with NaCl or Na sulfite. Detailed descriptions of methods of Sb recovery from ores are given in Ref 5 pp 64-9.

According to Kirk & Othmer (Ref 5, p 51), metallic Sb is non-toxic, although many of its compds are toxic. According to Sax (Ref 10) antimony is highly toxic, but because it is usually associated in industry with lead and arsenic, it is often difficult to assess the toxicity of Sb and its compds. According to Elkins (Ref 7, p 67) "occasionally workers exposed to the dust of antimony or its compds exhibit symptoms of gastrointestinal upset, usually acute rather than chronic in character". Elkins gives MAC for Sb dust or fume in air ca 1 mg/m³ (Ref 7, p 225), while Jacobs (Ref 6, p 253) gives 0.1 mg/m³. The same author gives on p 766, 0.5 mg/m³ as "probable safe concn limits of exposure for toxic dusts, fumes and mixts," as recommended by the US Govt hygienists. Physiological action of Sb and its compds is described in Mellor (Ref 1, p 385).

In addn to the above common metallic form (rhombohedral crysts), Sb also exists in yellow, black and the so-called explosive forms.

The yellow form is non-metallic and corresponds to yel phosphorous or yel arsenic.
It is obtained by adding oxygen to Sb hydride at -90°. It is unstable and changes to the black form at temps above -90°. According to Krebs et al (Addnl Ref C), the yel form is a mixed polymer contg chemically bonded H atoms.

The black, amorphous, form is produced by sudden cooling of Sb vapors. The black form is more active and more easily volatilized than the metallic form. It is said (Ref 5, p 51), that if Sb is distilled in high vacuum, it deposes as an amorphous powder which might explode on heating or scratching.

The explosive antimony, prep'd either electrolytically or by other methods, is described below under the title "Antimony, Explosive."

Antimony is used in many alloys, chiefly for its props of hardening the softer metals, such as Pb. The best known of these alloys are: type metal, bearing metal, hard lead and pewter. The powdered Sb is used in some pyrotechnic compns, as a fuel (Ref 9, p 32) and as a source of white light (Refs 3a & 8)

Following are some pyrotechnic compns listed by Davis (Ref 3a), expressed in parts by wt:

<table>
<thead>
<tr>
<th>Components</th>
<th>White Lights</th>
<th>White Stars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sb, metal</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Amm picrate</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>K nitrate</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>Ba nitrate</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Sulfur</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>PbO</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Sb₂S₃</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dextrin</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lampblack</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Paraffin</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Charcoal dust</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Izzo (Ref 8) lists quite a number of pyrotechnic compns contg Sb powder, of which the following were selected as examples:

One of the white light compns listed in Izzo (Ref 8, p 217) contained black antimony 20, K nitrate 54, sulfur 20, charcoal 2.5 & lampblack 3.5%

Antimony was also proposed as a compo of expl compns (Addnl Refs A & B)

According to Weingarten (Ref 11), metallic antimony is not used in any current US military pyrotechnic compns, but the US Military Specification MIL-A-10841B, 10 Sept 1958, deals with Antimony, Technical, intended for use in pyrotechnics (See Antimony, Analytical Procedure


Addnl Refs: A)L.Carta, CanP 378158(1938) & CA 33, 2339(1939) (Expls contg K chlorate, antimony, sulfur & Na bicarbonate with suitable binding and combustion controlling agents, such as flour, coal, wood, grease & petroleum) B)S.Kinoshita & T.Sakamaki, JapP 2498(1953) & CA 48, 6700(1954) (Use of antimony powder in electric detonator compns. Eg: Sb 80, Pb mononitroresorcinate 10 & K chlorate 10% with a suitable binder) C)H. Krebs, et al,
Antimony, Explosive. According to Mellor (Ref 1), it was first prepared in 1855 by G. Gore and then in 1858 by R. Böttger. It is a black powder usually obtained by electrolysis of solutions containing antimony trichloride, tribromide, or triiodide using Pt, Cu, Zn, Hg or graphite as cathodes. At a low temp or high current density, it favors production of an explosive deposit but if the current exceeds a certain limiting value, the deposit might explode during the electrolysis. The deposited material is a black, inhomogeneous, amorphous mass, which always contains varying amounts (such as 4-15%) of occluded or absorbed halide. It explodes when subjected to a mechanical action (such as impact, grinding or scratching) or when rapidly heated to 110-125°C. The heat of explosion of a sample containing 4% of SbCl₃ is, according to Coffin & Hubley (Ref 14), ca 22.2 cal/g. Sidgewick (Ref 13) gives for a sample, containing 10-15% of a halide, ca 2.4 kcal/atom. According to theory of Coffin (Ref 6), the explosion of Sb is due to heat evolved when the amorphous structure (probably gel-like) is changed to crystalline. According to Glazunov & Lazarev (Ref 8), the explosive properties of Sb depend upon the quantity of Cl in the space lattice of the Sb. The groups SbCl₃ and SbCl are formed in the space lattice by the reactions SbCl₄ → SbCl₂⁺ + 2Cl⁻ and SbCl₅⁻ → SbCl₂⁺ + 3Cl⁻. Within limits, the greater the current density, the more undecomposed SbCl₃ and SbCl²⁺ remain. According to Krebs et al (Ref 15), the explosive form of Sb is a mixed polymer containing chemically bonded Cl atoms. According to Frongia & Ladu (Ref 11), the explosive Sb is inhomogeneous, and crystallization to normal Sb can begin simultaneously at various points throughout the mass. The heat thus liberated propagates the reaction. Application of heat, or electricity renders the reaction explosive.


Antimony, Analytical Procedures. Various qualitative and quantitative procedures for detn of Sb including its detection in air are given in Refs 1, 2 & 3. Specification requirements for refined antimony are given in Ref 4 and the US Military Specification requirements for technical antimony are given

The military requirements and tests are given as follows:

A) Color and Appearance. The material shall be a grayish-black powder when visually examined.
B) Purity. The material shall contain not less than 98.0% by wt of Sb, when tested as described below:

Transfer ca 0.2 g sample weighed to 0.1 mg to a 500 ml Erlen flask containing 5 g NaHSO₄ and 20 ml concd H₂SO₄. Heat until soln is complete and if any sulfur is visible, volatilize to a mechanical shaker geared to produce 300±15 gyrations and 150±10 taps of the striker per minute. Shake for 3 mins and weigh each sieve to the nearest 0.1 g. Calculate the percentage passing through each sieve as follows:

\[
\% Sb = \frac{6.088 \times (V_1 - V_2)}{W} \times 100
\]

\( W \) = normality of KMnO₄ soln; \( V_1 \) = ml of KMnO₄ soln used for sample; \( V_2 \) = ml of KMnO₄ soln used for blank and W = weight of sample

C) Moisture (max 0.1% by wt). Dry a glass-stoppered weighing bottle in a vacuum oven at 50–55° and 25" Hg for 1 hr, cool in a desiccator, and tare it to 0.1 mg. Transfer ca 10 g of the sample to the bottle and weigh. Heat unstoppered in the same vacuum oven as above for 2 hrs, stopper the bottle, cool it in vacuum desiccator and reweigh. Calculate as follows:

\[
\% \text{ Moisture} = \frac{100 \times (W_2 - W_1)}{W_2 - W_1}
\]

\( W_1 \) = weight of empty bottle; \( W_2 \) = wt of bottle with sample before removal of moisture and \( W_3 \) = wt of bottle with sample after removal of moisture

D) Granulation of the material shall be such that not less than 99.5% will pass through a No 80 US Std sieve(177-micron), not less than 90% through a No 140 sieve(105-micron) and not less than 75.0% through a No 270 sieve(53-micron), when tested as described below:

Weigh to the nearest 0.1 g clean, dry sieves and assemble them in order of increasing fineness, with the coarsest sieve on top, so that the material passing through a sieve is transferred directly to the next one in the series. Place under the bottom sieve a pan. Weigh a 200 g sample to the nearest 0.5 g and place it on the upper(No 80) sieve, cover it and attach the assembly by means of clamps to a mechanical shaker geared to produce 300±15 gyrations and 150±10 taps of the striker per minute. Shake for 3 mins and weigh each sieve to the nearest 0.1 g. Calculate the percentage passing through each sieve as follows:

\[
\% \text{ through No 80} = \frac{100 \times (W - A)}{W}
\]

\( W \) = wt of sample used

\[
\% \text{ through No 140} = \frac{100 \times (W - A - B)}{W}
\]

\[
\% \text{ through No 270} = \frac{100 \times (W - A - B - C)}{W}
\]

\( W \) = wt of sample used


Antimony Azide. See under Azides, Inorganic Antimony Chloride. See under Chlorides Antimony Pentasulfide. See under Sulfides Antimony Selenide. See under Selenides Antimony Sulfides. See under Sulfides Antimony Telluride. See under Tellurides Antimony Trichloride. See under Chlorides Antimony Triethyl. Same as Triethylstibine Antimony Trimethyl. Same as Trimethylstibine Antimony Trisulfide. See under Sulfides

Anti-Motor-Torpedo-boat(AMTB) was used during WWII to combat Italian motor-torpedo-boats, each equipped with a powerful gun and running close under the heights along the coast. AMTB's were equipped with...
(See also under Flash Reducing Compounds)

1) P. Demougin, MP 25, 139-41 (1932-3)
2) J. Fauva & (?) LePaire, MP 25, 142-59 (1932-3)
3) M. Prettre, MP 25, 160-7 (1932-3)
4) Davis (1943), 323
5) Kirk & Othmer 2 (1948), 69-75 (12 refs) and 1st Suppl (1957), 77-88 (68 refs)

**ANTIPYRINE AND DERIVATIVES**

Antipyrine; 2,3-Dimethyl-1-phenyl-3-pyrazolin-5-one or Phenazone, listed in Beil as 1-Phenyl-2,3-dimethyl-pyrazolon-(3) or 'Phenazon,' \( \text{OC} - \text{N(CH}_3\text{)} - \text{N(CH}_3\text{)} \)

\[
\text{HC} \quad \text{C(CH}_3\text{)}
\]

is described in Beil 24, 27, (194) & [11]

There is also an isomer called:

3-Antipyrine or 2,5-Dimethyl-1-phenyl-4-pyrazolin-3-one, listed in Beil as 1-Phenyl-2,5-dimethyl-pyrazolon-(3), \( \text{(H}_3\text{C})_2\text{N} - \text{N(CH}_3\text{)} - \text{N(CH}_3\text{)} \)

\[
\text{HC} \quad \text{C(CH}_3\text{)}
\]

Ref: Beil 24, 34, (198) & [17]

4-Azidoantipyrine, \( \text{C}_9\text{H}_1\text{N}_4\text{O} \), mw 229.24, N 30.55%. Lt yel crys from benz or petr eth; mp 74°(dec); easily sol in alc, benz or acet; insol in petr eth. Can be prepd by diazotization of 4-aminoantipyrine sulfate, followed by addn of \( \text{NaN}_3 \). Its expl props were not examined

Ref: Beil 24, 56

**Antipyrine Complexes with Nitrates of Some Rare Earth Metals** are mild expls

Ref: Beil 24, (196)

**Antipyrine Complexes with Perchlorates of Some Rare Earth Metals** and of some other metals are mild expls

Ref: Beil 24, [14-15]

A471

90 mm guns on the special mount M3 which permitted abnormal depression of the gun tube

Ref: F.W.F. Gleason, 'A Glossary of Ordnance Terms,' 'Army Ordn 29, 368 (1947)

**Antioxidants.** In general, an antioxidant is a substance which prevents or retards oxidation of various constituents of materials. For some substances, for example rubber, an antioxidant means an age-resistor; and substances like tannic acid, anthraquinone or aniline are used. It is said that antioxidants possess "antioxidant power" ('pouvoir antioxygene,' in French). A fairly comprehensive description of antioxidants is given in Kirk & Othmer (Ref 5)

In case of propellants, several French investigators (Refs 1, 2, 3), called some substances, which prevent oxidation of CO to CO\(_2\), "antioxidants." These substances are usually incorporated in propellants to suppress the flash and are called in Fr 'antilueurs.' These investigators found that when small amts of certain substances, particularly KCl, K hydrogen tartrate or powdered tin, which are volatile at high temps, are vaporized in an atm of mixed CO and air, the temp of ignition of CO is raised to such an extent that the gas exiting from a weapon does not ignite at the muzzle. For instance, for a mixt contg 24.8% CO and 75.2% air, the regular temp of ignition, 656° was raised to 1010° by a simple addn of 3.5% KCl to the propellant. For a propellant producing a CO-air mixt contg 44.1% CO, 2.5% KCl was sufficient to raise the ignition temp to 1000°. It was also found that KCl has no effect upon the ignition temp of hydrogen-air mixt.

In another series of experiments it was found that addn of small quantities of so-called "antidetonating substances" ('antidetonants,' in Fr), such as tin tetraethyl (Ref 1), reduced the flash, because these "antidetonants" acted as "antioxidants" since they prevented the formation of peroxides.

Davis (Ref 4) gives a short resume of work of these French investigators (Refs 1, 2, 3)
**Nitroantipyrines Nitrate**, C\textsubscript{11}H\textsubscript{11}N\textsubscript{3}O\textsubscript{4} + HNO\textsubscript{3}. One isomer 3-nitroantipyrine nitrate, mp 143\(^\circ\), is described in Beil 24,(198)

**Nitroantipyrine Picrates**, C\textsubscript{11}H\textsubscript{11}N\textsubscript{3}O\textsubscript{4} + C\textsubscript{6}H\textsubscript{5}NO\textsubscript{2}. Two isomers: yel crys, mp 165\(^\circ\) and yel crys, mp 101\(^\circ\) are listed in Beil 24,(198)

**Nitrosoantipyrine**, C\textsubscript{11}H\textsubscript{11}N\textsubscript{3}O\textsubscript{4}. One isomer 4-nitrosoantipyrine is described in Beil 24,(217)

**Nitronitrosantipyrines**, C\textsubscript{11}H\textsubscript{10}N\textsubscript{4}O\textsubscript{6}, mw 262.22, N 21.37%. The following isomers are described in the literature:

- **1-(m-Nitro)-4-nitrosoantipyrine**, called in Ger 4-Nitroso-2,3-dimethyl-1-[3-nitrophenyl]-pyrazolon-(5), OC=N(C\textsubscript{4}H\textsubscript{4}NO\textsubscript{2})-N(CH\textsubscript{3})
  \begin{align*}
    &\text{ON} \equiv \text{C} \equiv \text{C}(\text{CH}_3) \\
    &\text{Green crys; mp} \text{begins to dec at } 165\,\text{C} \text{ and deflagrates at } 188-90\,\text{C}; \text{insol in common} \\
    &\text{solvents. Was obtained by treating 1-m-nitroantipyrine with calc'd amt of Na nitrite in AcOH, and cooling} \\
    \text{Refs:} & \text{1)Beil 24,(217) 2)A.Michaelis et al, Ann 378, 302(1911) & CA 5,1274(1911)}
  \end{align*}

- **1-(p-Nitro)-4-nitrosoantipyrine**, called in Ger 4-Nitroso-2,3-dimethyl-1-[4-nitrophenyl]-pyrazolon-(5), OC=N(C\textsubscript{4}H\textsubscript{4}NO\textsubscript{2})-N(CH\textsubscript{3})
  \begin{align*}
    &\text{ON} \equiv \text{C} \equiv \text{C}(\text{CH}_3) \\
    &\text{Green crys; mp} \text{turns yel & bm at ca } 176\,\text{C} \text{ and melts at } 188-9\,\text{C}; \text{sol in acet}; \text{sl sol in w, alc & AcOH}; \text{insol in petr eth.} \\
    &\text{Its expl props were not investigated} \\
    \text{Refs:} & \text{1)Beil 24,(217) 2)A.Michaelis et al, Ann 378,332(1911) & CA 5,1274(1911)}
  \end{align*}

**Dinitroantipyrines**, C\textsubscript{11}H\textsubscript{10}N\textsubscript{4}O\textsubscript{8}, mw 278.22, 20.14%. The following isomers are described in the literature:

- **1-(o-Nitro)-4-nitro-antipyri ne or 1-o-4-Dinitroantipyrine**, called in Ger 4-Nitro-2,3-dimethyl-1-[2-nitrophenyl]-pyrazolon-(5), OC=N(C\textsubscript{4}H\textsubscript{4}NO\textsubscript{2})-N(CH\textsubscript{3})
  \begin{align*}
    &\text{O} \equiv \text{N} \equiv \text{C} \equiv \text{C}(\text{CH}_3) \\
    &\text{Ndls, mp 244\,\text{C}; sl sol in w, alc or chI; more sol in AcOH; insol in ligroin. Was prepd by treating 1-o-nitroantipyrine with conc'd nitric acid at temp below 60\,\text{C}. Its expl props were not investigated} \\
    \text{Refs:} & \text{1)Beil 24,(220) 2)A.Michaelis et al, Ann 378, 321(1911) & CA 5,1275(1911)}
  \end{align*}

**Antisubmarine Weapons** include: guns, mines, nets & boom, projector charges, bombs, depth charges & depth bombs, torpedoes, rockets, and guided missiles

**Antitank(A/T) Ammunition and Weapons** include: A/T grenades, guns, incendiaries, mines, rifle grenades and rockets

**Antisazxonite** (Ital). Same as ANS(Esplosivo)


Antonite Cova. An Italian mining expl manufactured by the Società Vulcania di Brescia

References: 1) Daniel (1902), 2) Escales,...

Antonite Galleria Extra. An Italian mining expl consisting of AN & TNT in propn to give an oxygen balance of ca. +2.5%. Its props are reported as Traul test 400 cc, vel of deton (by Dautriche method) 4300 m/sec, impact sensitivity with 2 kg wt 100 cm, expln temp >180°, temp of expln 2570°, expln pressure 8290 kg/cm². It was manufactured by the Società Vulcania di Brescia

References: Same as above, pp 17 & 32

ANU. A cast double-base propellant described in conf Propellant Manual SPIA/M2 (1959), Unit No 412

Anvil of a Percussion Primer is a metallic item of a special shape, which is pressed into the open end of a metallic cup containing primer compn (such as one consisting of MF, K chlorate, Sb sulfide & ground glass). A paper disc is placed over the compn, prior to insertion of anvil, to provide a moisture seal. The ensemble is pressed into an ammunition component (such as a cartridge) and fired by striking the bottom of the cup with a firing pin which crushes the primer compn against the anvil

References: 1) Davis (1943), 455 2) Ohart (1946), 47 3) Anon, Ammunition General, TM 9-1900 (1956), 72-3 4) A. B. Schilling, PicArsn; private communication (1960)

AOE; AOK; AOR; AOV. Cast double-base propellants described in conf "Propellant Manual," SPIA/M2 (1959), Unit Nos 414, 415, 416 & 417

AP. See Armor-piercing

Apache Coal Powder. A nongelatinous permissible expl manufactured by the Apache Powder Co

References: Bebel (1943), 28

Apache Powder Co, located in Benson, Arizona was established in 1921 by W. W. Edwards (1876-1922), formerly of Aetna Explosives Co. Apache Co has been manufacturing various grades of dynamites and its principal trade is in copper mines of S. Arizona (such as Bisbee) and adjacent territory

References: Van Gelder & Schlatter (1927), 634

APC. See Armor-piercing Capped

Äpfelsäure (Ger). Malic Acid

Aphostisie. An older Brit "permitted" expl: AN 58-62, K nitrate 28-31, charcoal 3.5-4.5, WM 3.5-4.5, sulfur 2-3 & moisture 0-1.5%

References: 1) Daniel (1902), 29 2) Escales, Ammonperm (1909), 188

APIGENIN AND DERIVATIVES

Apigenin: 4', 5, 7-Trihydroxyflavone or 4', 5, 7-Trihydroxy-2-phenylchromone, called in Ger 5, 7, 4'-Trihydro-2-[4'-oxy-phenyl]chromon

\[ \text{Beil } 18, 181, (396) & (172) \]

Apigenin, Azido-C₄H₆N₃O₃ and Diazido-C₄H₆N₃O₃, Derivatives were not found in Beil or CA through 1956

Mononitroapigenins, C₆H₄NO₃. One isomer is listed in Beil 18, 183

Dinitroapigenins, C₆H₄N₂O₉ – not listed in Beil
**Trinitroapigenins, C_{18}H_{27}N_{3}O_{11}.** Two isomers: yel ndls, mp 296° and orange leaflets, mp 245-6° are listed in Beil 18,183

**Tetranitroapigenins, C_{15}H_{10}O_{5}(NO_{2})_{4}, mw 450.23, N 12.45%.** One isomer x,x,x,x-tetranitro-4',5,7-trihydroxyflavone, nearly col ndls, mp 243-4°(dec), diff sol in common solvents, is described in Refs 1-3. Can be prepd by nitrating apigenin with mixed nitric sulfuric acid. Its expl props were not investigated

A compd of mp 258°, described in Ref 4, was prepd by heating with 20% HNO_{3} the brn-vetexin (Ref 4), C_{19}H_{20}O_{7}, obtd from air-dried and powdered bark of Vitex peduncularis

**References:**
1)Beil 18,184
2)A.G.Perkin, JCS 73, 1025(1898)
3)Ciem, 420(1900)
4)G.Barger, JCS 8911, 1222(1906)
5)V.N.Sharma, JSciIndResearch(India) 14B, 267(1955) & CA 50,5649(1956)

**Aplastic Anemia and Toxic Hepatitis** can be caused by exposure to TNT or other aromatic polynitro compds and to polynitramino compds

**References:**
2)R.F.Sievers et al, Occupational Medicine 1, 351-62(1946)

**Apparatus for Blasting Coat,** patented by Davis et al, consists of a pressure-resistant metal tube, the end of which is sealed by a rupture disk for releasing the gas pressure at the desired value. The tube contains a chge of gas-generating expl, such as AN + starch, with a nichrome elec heater embedded in it. The material is heated until decompd and sufficient gas pressure is generated to rupture the disk.

**References:**
C.O.Davis et al,USP 2,736,261(1956) & CA 50,10412(1956)

**Apparatus for Indicating the Presence of Explosive or Flammable Vapors or Gases** was developed by H.T.Ringrose, BritP 711,133 (1954) & CA 48,8544(1954)

**Apparatus(Laboratory) for Continuous Preparations(Including Nitrations) of Explosives** is described by F.Tabouis & J.Vaganay, MP 37,413-16(1955)
"Enzyklopädie der Technischen Chemie,"

APQ. A cast double-base propellant described in conf "Propellant Manual," SPIA/M2(1959), Unit No 419

Aprotic Solvents are those which have no tendency either to lose or to gain a proton. To these belong the hydrocarbons and their halogen derivs, such as benzene, pentane, toluene, chloroform, carbon tetrachloride, chlorobenzene, etc. Because of the inert nature of these solvents, no dissociation or other reaction can take place when a single acid or base is dissolved

Ref: P.B.Bell, "Acids and Bases," Methuen, London(1952), 36 & 81

Aptitude à la Déflagration(Fr). Sensitivity to Deflagration

Aptitude à la Déflagration par Choc Mécanique(Fr). Sensitivity to Deflagration by Impact(See under Impact Sensitivity Tests)

Aptitude à la Détonation(Fr). Sensitivity to Detonation(See under Sensitivity to Initiation by Detonators and Boosters)

Aptitude à l' Inflammation, Épreuve(Fr). Sensitivity to Inflammation, Test. This French test, also called épreuve de combustion; combustion en gouttière or combustion en tas conique, is described here under Flame Tests

APU. A cast double-base propellant described in conf "Propellant Manual," SPIA/M2(1959), Unit No 421

APX Explosives. A series of experimental expls developed and tested in the US during WW II, such as APX-5A, which contained EDNA 87, wax 5 & Al 8%

Ref: All & EnExps(1946), 144

Note: There was also APX-4A which contained Comp A 92 & Al 8%

Apyrite. A single-base smokeless propellant invented at the end of the last century by Skoglund of Sweden and manuf for many years by the Graknut Co. It was used by the Swedish Navy

Ref: Daniel(1902),29

AQG; AQL; AQN; AQO. Cast double-base propellants described in conf "Propellant Manual," SPIA/M2(1959), Unit Nos 422,423,425 & 426

Aquadag. A colloidal suspension of graphite in w used as a lubricant. The Acheson Graphite Co manuf it by grinding graphite and tan-nin in w and then adding dil ammonia. If a mineral oil is used instead of ammonia, the resulting product is called Oildag

Ref's: 1)Hackh(1944),70 2)Kirk & Othmer(1949), 226

Aquametry is a generic term for detn of water content in various substances. Following is a partial list of methods used in aquametry:

a) Oven drying method  b) Karl Fischer reagent methods  c) Distillation methods, which, in general, depend on a heterogeneous azeotropic distn with hydrocarbons(such as benzene) or org halides(such as CCl₄) in which the water separating as a phase in the distillate is measured volumetrically  d) Absorption methods are usually based on the evoln of w at elevated temps into a stream of inert gas by which it is carried into a tared tower contg an active desiccant, such as Dehydrite[anhyd Mg(ClO₄)₂], Drierite(anhyd CaSO₄), CaCl₂, P₂O₅, etc.  e) Evaporation method in which w remains as a residue(see under Ammonia, Analytical Procedures)  f) Specific gravity method, such as used in estimating the strength of alcohols, some acids, etc.  g) Refractive index method  h) Viscosity method  i) Electric conductivity method  j) Dew point test  k) Cloud point test  l) Heat of dilution test(such as used in detn of sulfuric acid strength)  m) Boiling point test  n) Polarimetric tests  o) Calcium carbide test, based on measuring the vol of
Acetylene evolved on contact of CaC\(_2\) with w (See also determinations of moisture under individual substances)


**AquA Regia or Aqua Regis** (Nitrohydrochloric or Nitromuriatic Acid) (L'eau régale, in Fr; Königswasser or Goldscheidenwasser, in Ger; Tsarskaya Vodka, in Rus; Aqua Regia, in Span; Acqua Regia, in Ital).
The name aqua regia(or regis) was given to a liq dissolving gold. It was prep'd by dissolving sal ammoniac(NH\(_4\)Cl) in strong nitric acid, E. Davy prep'd in 1831 a similar solvant by mixing HCl with HNO\(_3\). It is now usually prep'd by mixing 1 vol of concd HNO\(_3\) with 3-4 vols of concd HCl. The liq is at first colorless, but it gradually becomes orange-yel due to the storage even at temps as low as 50\(^\circ\)C. This reaction is believed to proceed in two steps: HNO\(_3\) + HCl ——> H\(_2\)O + NOCl(nitrochloride) and NO\(_3\) + 2HCl ——> Cl\(_2\) + H\(_2\)O + NOCl

Aqua regia dissolves not only gold, but also other noble metals(such as platinum) as well as sulfur

It is not advisable to bottle and store aqua regia(Ref 6)


**ARA. A cast double-base propellant described in/conf "Propellant Manual," SPIA/M2 (1959), Unit No 429**

**Arabic, Gum.** See under Gums

**ARABINOSE AND DERIVATIVES**

*Arabinoses, C\(_4\)H\(_9\)-CHO(OH)\(_2\), mw 150.13.*

Colorless monosaccharides of which \(\alpha\)-arabinose or \(L\)-arabinose is the common form; rhombic crystals, mp 159.5\(^\circ\), d 1.585 at 20/4\(^\circ\).

It is usually obtained from plant gums by hydrolysis with mineral acids. There is also \(D\)-arabinose which is produced by the degradation of \(D\)-glucose

Refs: 1)Beil 1,859,(435) & [900] 2)Kirk & Othmer 2(1948),869

*Arabinose, Azido-, C\(_4\)H\(_9\)N\(_3\)O\(_4\) and Diazido-, C\(_4\)H\(_9\)N\(_2\)O\(_4\) Derivatives were not found in Beil or CA through 1956

*Arabinose, Mononitrate, C\(_4\)H\(_9\)NO\(_3\), Dinitrate, C\(_4\)H\(_9\)N\(_2\)O\(_4\) and Trinitrate, C\(_4\)H\(_9\)N\(_3\)O\(_3\) — were not found in Beil or CA through 1956

*Arabinose Tetranitrate, C\(_4\)H\(_9\)-CHO(ONO\(_2\))\(_4\), mw 330.13, N 16.97%, OB to CO\(_2\) ± 0%, OB to CO +24.2%. Col monocl crystals; mp 85\(^\circ\), dec ca 120\(^\circ\) and expl at higher temps; sol in acet, alc & AcOH; insol in w & ligroin. Was prep'd by nitrating \(D\)-arabinose as described in detail by Will & Lenze(Ref 2). It explodes also by shock; not stable in storage even at temps as low as 50\(^\circ\)

Refs: 1)Beil 1,863 2)W.Will & F.Lenze, Ber 31,72(1898) 3)Davis(1943),240

**Note:** No refs were found in CA through 1956

**ARBBITOL AND DERIVATIVES**

*Arbitol(Arabit in Ger), C\(_4\)H\(_4\)(OH)\(_3\), mw 152.15, exists in several forms, of which \(D\)-arabitol is most common; col prismatic crystals, mp 103\(^\circ\); can be prep'd by reduction of \(D\)-lyxose or \(D\)-arabinose

Refs: 1)Beil 1,531,(281) & [604] 2)O.Ruff, Ber 32,555(1899) & 33, 1802(1900)

*Arbitol, Azido, C\(_4\)H\(_9\)N\(_3\)O\(_4\) and Diazido, C\(_4\)H\(_9\)N\(_2\)O\(_4\) Derivatives were not found in Beil or CA through 1956

*Arbitol, Mononitrate, C\(_4\)H\(_9\)NO\(_3\), Dinitrate, C\(_4\)H\(_9\)N\(_2\)O\(_4\) and Trinitrate, C\(_4\)H\(_9\)N\(_3\)O\(_3\) — were not found in Beil or CA through 1956

*Arbitol Pentanitrate, C\(_4\)H\(_9\)-CHO(ONO\(_2\))\(_5\), mw 377.15, N 18.57%, OB to CO\(_2\) + 6.36%, OB to CO +27.5%. Wh syrupy mass; sol in alc, eth & acet. Can be prep'd by nitrating \(D\)-arabitol with fuming nitric acid at ~5\(^\circ\), followed by addn of concd sulfuric acid. Its expl props were not investigated
Araldite is an epoxy resin bonding agent, made by Bond Master Rubber & Adhesive Co, Irvington, NJ, used in some US elec deto- nators, such as the T44. In this item, the pin and the inside of the plug are coated with Formvar for insulation and then bonded together with Araldite

Refs: 1)P.B.Tweed, Ordnance 44,654(1960) 2)P.B.Tweed, PicArsn; private communication(1960)

Aranoz, Ricardo. A Spanish general specializing in Ordnance, who died in 1932. In 1906 he introduced in Spain the modern progressive smokeless propellants and did considerable work on their improvement. He also did some work on HE’s, such as tetryl, and was the author of several publications on expls and propellants

Refs: 1)Pérez Ara(1945),426 & 429 2)Vivas, Feigenspan & Ladrega, vol 3 (1948), 86(footnote) & 212

ARB. A cast double-base propellant described in conf "Propellant Manual," SPIA/M2(1959), Unit No 430

Arbalest or Crossbow. A weapon, invented in the 4th century, consisted of a stock (arbier) and a short powerful bow fixed transversely near the end of the stock facing the target. The stock contained a groove to guide the missile(such as an arrow, stone, dart or bullet), a notch to hold the string of the bow, and a trigger to release it. The end of the stock opposite the bow was placed against the shoulder, gun fashion, and the string was released by trigger

This weapon was used successfully for over 10 centuries(including Norman invasion of England in the 11th century and battle of Crécy in the 14th century) and even competed for some time with early firearms, which were not as efficient as arbalests of the 14th and 15th centuries

Refs: 1)Webster’s Unabridged Dictionary (1951),137 2)Encyclopedia Britannica, vol 6(1952),755(Crossbow) 3)Collier’s Encyclopedia, vol 2(1957), under Archery Archery. The term derived from the Latin "arcus"(a bow), covers the equipment and procedures of shooting with all types of bows and arrow for war, hunting and sport. History of development and a comprehensive survey of various types of bows and arrows are given in Collier’s Encyclopedia, NY, vol 2(1957) 135–41 (See also Arbalest)

Arcites are rocket propellants developed recently in the US by Atlantic Research Corp, Alexandria, Virginia. They usually contain oxidizers(such as AN or NH₄ClO₄), binders (such as polyvinyl chlorides) and plasticizers(such as dibutyl sebacate)

Ref: Warren(1958), 11

Arcites 251,309,358,362 & 368 are described in conf "Propellant Manual," SPIA/M2(1959), Unit Nos 460,462,547,546 & 524

Ardeer Cordite. A solventless cordite developed in 1919 at the Ardeer plant of Nobel Co: NC(12.2%N) 50, NG 42 & phenylbenzylurethane 8%. Its stability did not meet Brit military requirements, mainly on account of acid products which developed in the presence of moisture


Ardeer Plant of Nobel’s Explosives Co, Ltd is located at Stevenston, Scotland

Ardeer Powder. An older Brit 'permitted' expl: NG 31–34, kieselguhr 11–14, Mg sulfate 47–51, K nitrate 4–6 Na carbonate 0.5 & Amm carbonate 0.5%

Refs: 1)Daniel(1902),30 2)CondChemDict (1942),287(not listed in newer editions)

Argarit. A Swiss expl contg PETN. Its compn is based on Stettbacher’s patents which are now expired

Ref: Dr A.Stettbacher, Zürich; private communication, June 25, 1958

Argent fulminant de Berthollet(Fr). Fulminating Silver of Berthollet

ARGENTINE ARMAMENT. Argentina is capable of producing all explosives required for
their industrial and military purposes, as well as for most of their ammunition and small arms. It still depends on foreign countries (such as Sweden, France, GtBritain, Italy and USA) for cannons, howitzers, mortars, some machine guns and rockets.

According to Capitán de Navio López (see Ref), most of their small arms come from foreign countries; a great variety of them exist, but it is expected that some standardization will be achieved when all (or most) of the arms will be manufd in Argentina. One of the first small arms manufd in Argentina was the pistol Colt C/45. The production of weapons was gradually extended to the manuf of rifles and machine-guns. Larger caliber weapons up to 12.7 mm and even 20 mm and 40 mm are also produced but on a small scale. Most ammo and some rockets (such as 57 mm) are also manufd.

The current armament of the Argentine Army includes:

a)7.65 mm rifles and carbines (such as the Mauser, previously manufd in Germany & Spain, but now to a limited extent in Argentina)
b)7.65 & 12.7 mm machine guns
c)20 & 40 mm automatic guns
d)80 mm antiaircraft gun
e)105 mm howitzer and
f)75, 105 and 155 mm cannons

The current armament of the Argentine Navy includes:

a)20 and 40 mm automatic guns
b)75, 80, 120, 127.5, 150 & 190 mm cannons

e)105 mm howitzer and
f)75, 105 and 155 mm cannons

The following explosives and propellants are used by the Argentine Army and Navy:

a)TNT (Trotil) is used as a HE filling for most shells, bombs, grenades, mines, torpedoes & rockets. Some of the shells imported from the US are filled with ammonium picrate. The possibility of using PETN (Pentril) and RDX (Hexogeno) has also been investigated.
b)Tetryl is used for boosters
c)Mercuric fulminate (fulminato de mercurio) and lead azide (nitruro de plomo) are used in primers
d)Mercuric fulminate and lead stypnate (trinitroresorcinato) are used in detonators
e)Single-base propellants (NC, DNT & DPhA), multiperforated, are used in various cannons
f)Single-base propellants (NC with DPhA), single perforated, are used in rifles, pistols and machine guns
g)Double-base propellants (NC, NG & centralite), tubular solventless and tubular using acet as a solvent, are used in various cannons
h)Triple-base propellants (NC, NG & NGu), laminated, are used in mortars
i)Propellants consisting of NC, NG, DNT & TNT, are used in rockets

Following is a list of Argentine plants manufg explosives, ammunition and weapons:

A. Government Owned Plants

a)Fábrica Militar de Pólvora y Explosivos, Villa María, Córdoba (NC, NG, NC & NG propellents, NC-NG rocket propellant, TNT, RDX and dynamites)
b)Fábrica Naval de Explosivos Azul, Azul, Provincia Buenos Aires (NC, NG, NC & NC-NG propellants, TNT and dynamites)

Note: This modern plant (1955) may be considered among the best in the Americas. It was constructed by Bofors AB (Sweden) and by other European firms. Manuf of TNT is continuous (by the method of Bofors) and so is the manuf of NG (method of Meissner). Stainless steel is used for all apparatus. Its laboratory is well equipped not only for analytical work, but also for research. The sr author (BTF) of this book had the privilege of visiting this plant in 1955

c)Fábrica Militar José de la Quintana, Córdoba (Ball powder for small caliber weapons, PETN, RDX, TNT, LA and LSt)

Note: Ball powder is called in Argentine "pólvora W", where "W" stands for Western Powder Co
d) Fábrica Material Pirotecnico, Pilas, Pcia Buenos Aires (Primacord, fuses, detonators MF, LA, LSt and various pyrotechnic mixtures and items)

e) Fábrica Militar de Municiones, San Lorenzo, Santa Fe (MF and ammo for small arms)

f) Fábrica Militar de Municiones, San Francisco, Córdoba (Ammo for small arms)

g) Fábrica Militar, Río Tercero, Córdoba (Artillery ammo)

h) Fábrica Militar de Armas Portátiles, Rosario, Santa Fe (Pistols, rifles and machine guns)

B. Privately Owned Plants

1) DESA, Sierras Bayas, Pcia Bs Aires (NG, RDX & dynamites)

2) Delbene y Serris, Olavarria, Pcia Bs Aires (Black powder & chlorate expls)

3) FADEX, San Vicente, Pcia Bs Aires (NG & dynamites)

4) FAPOL, Tandil, Pcia Bs Aires (Black powder)

5) FOTI, Rafaela, Santa Fe (Black powder)

6) LG-PCM, Haedo, Pcia Bs Aires (Various pyrotechnic compns & items)

7) COASA, Florencio Varela, Pcia Bs Aires (MF, LSt and ammo for pistols, rifles & shotguns)

8) Scorzatto Hnos y Cía, Luján, Pcia Bs Aires (Ammo for shotguns)

9) Spreafico SAIC, Florencio Varela, Pcia Bs Aires (MF, detonators for hand grenades, signal cartridges and ammo for shotguns)

10) La Bengalà, Moreno, Pcia Bs Aires (Pyrotechnic items)

11) Imaz y Ryser, Miramar, Córdoba (MF, initiating compns and percussion caps)

12) Armotor SA, Bs Aires (Pistols)

13) Belenda, Scapusio y Cía, SRL (Machine guns 7.65 & 12.7 mm, hand grenades and pyrotechnic pistols)

14) CATI-TA, Bs Aires (Shells for 120 & 150 mm cannons)

15) Dillon Ernesto Pablo, San Martín, Pcia Bs Aires (Revolvers)

16) DeBoer y Barbieri SRL, Bs Aires (Shotguns)

17) Establecimiento "Klockner" SAIC, Bs Aires (Rifles, rocket launchers and shell bodies)

18) Establecimiento Metalurgico "Guerrino Venturini," San Isidro, Pcia Bs Aires (Revolvers)

19) Fábrica de Armas "Centauro", Lanús, Pcia Bs Aires (Automatic carbines and compressed air rifles & pistols)

20) Fábrica de Armas "Mabely", Lanús, Bs Aires (Same as above)

21) Fábrica de Armas "Halcon", SRL, Avellaneda, Pcia Bs Aires (Machine pistols, automatic rifles & carbins and shotguns)

22) FADA, Chascomús, Pcia Bs Aires (Shotguns)

23) FAPESA, Bs Aires (Fuzes)

24) Garb Monetti y Cía, Mar del Plata, Pcia Bs Aires (Automatic pistols)

25) GUK Metal SRL, Haedo, Pcia Bs Aires (Signal pistols and launching equipment)

26) HADFASA, Bs Aires (Carbines, pistols and automatic pistols)

27) Infantino Hnos y Cía, San Antonio de Padua, Pcia Bs Aires (Pistols)

28) Indurgica Argentina SRL, Ramos Mejía, Pcia Bs Aires (AA gun carriages and gun sights)

29) Industrias "Marcati", Avellaneda, Pcia Bs Aires (Compressed air and automatic rifles)

30) Krahmer, Pfef/er y Cía, Bs Aires (Compressed air rifles and Cal .22 pistols)

31) Lambda SRL, Bs Aires (Semi-automatic carbines)

32) Luan, Comercial e Industrial, Bs Aires (Machine pistols and pistols Cal .22)

33) Martin Bass y Cía, Bs Aires (Pistols)

34) Metalurgica Industrial Argentina, Bs Aires
crust deposited in wine casks during fermentation of grape juice. It consists of ca 70% potassium hydrogen tartrate and was used during WWI by the French as a flash reducing agent. It was packed in flat, circular cotton bags (sachets antilueurs), which were assembled along with the smokeless propellant and black powder igniter in silk cartridge bags to make up a complete propellant charge. Since the antiflash material tended to reduce the ballistic effect of the charge, it was necessary to add an additional quantity (appoint) of smokeless propellant. Thus, for ordinary firing of the 155 mm gun, the charge consisted of 10 kg of poudre BM7 along with an igniter system contg a total of 115 g of black powder. For a flashless round, 3 bags each contg 500 g of argol were used with an additional 305 g of smokeless propellant to restore the ballistics to normal.

**Abbreviations:**
- **Bs Aires** – Buenos Aires;
- **CATI-TA** – Compañía Argentina de Talleres Industriales, Transportes y Anexos; **Cía** – Compañía; **COASA** – Cartuchería Orbea Argentina Sociedad Anónima;
- **DESA** – Dieterle Explosivos Sociedad Anónima;
- **FADA** – Fábrica Argentina de Armas; **FADEX** – Fábrica Argentina de Explosivos; **FAPESA** – Fábrica Argentina de Productos Eléctricos Sociedad Anónima; **FAPOL** – Fábrica Argentina de Pólvoras; **FOTI** – trade name for Manufactura Argentina de Pólvoras; **HAFDASA** – Hispano Argentina Fábrica de Armas Sociedad Anónima; **Hnos** – Hermanos (Brothers); **LG-PCM** – Laboratorios Giorgi – Pirotecnia Civil y Militar; **OTMESRL** – Organización Técnica de Mecánica Especializada Sociedad de Responsabilidad Limitada; **Pcia** – Provincia; **SA** – Sociedad Anónima; **SAIC** – Sociedad Anónima Industrial y Comercial; **SRL** – Sociedad de Responsabilidad Limitada; **TALA** – Talleres de Armas Livianas Argentinas

**Refs:**
1) Davis (1943), 325-6
2) Hackh (1944), 73

**Argonit.** A plastic HE manufd at Dottikon, Switzerland: PETN 70-80 & liq waste TNT 30-20%

**Ref:** Dr A. Stettbacher, Zürich; private communication, 23 Aug 1958

**Argus.** A type of older Brit blasting powder: K nitrate 87-82, charcoal 17-20 & sulfur 0.5-1%

**Ref:** Daniel (1902), 30

**Arkite.** An older Brit "permitted" expl, similar to duxite: NG 31-3, CC 0.5-1, K nitrate 26-8, WM 8-10, & Amm oxalate 29-31%. An expln of arkite during its manuf is described in Ref 1

**Refs:**
1) A.P. Desborough, HMIexploS Explos SpecRept 193 (1910) & CA 4, 2879(1910)
2) Marshall 1 (1917), 374
3) Barnett (1919), 136

**Arlberg Dynamite.** An older dynamite prep'd by mixing 65 parts of NG with 35 ps of absorbent, a mixt of kieselguhr, Ba nitrate & charcoal
Ref: Cundill, MP 5, 288(1892)

Arma (Ital). Arm or weapon
Arma bianca (Baionetta) (Ital). White arm (bayonet)
Armada (Span). Fleet, Navy
Arma da fuoco (Ital). Firearm; gun

Armament is the aggregate of a nation's military strength, which includes all the items used by the Army, Navy and Air Force (ships, aircraft weapons, ammunition, expls, tanks, transportation, etc), as well as the personnel to man them. It also includes all military installations (fortifications, barracks, ammo magazines, etc) and all industries working for war purposes

Ref: Webster's Unabridged Dictionary (1951), 149

Note: In connection with armored vehicles such as tanks, the word armament indicates the protective plate (see also Armor)
Ref: A.B.Schilling, Pic Arsn; private communication (1960)

Armament Engineering. This subject is discussed in the following book:
Anon, "Elements of Armament Engineering", US Military Academy, West Point, NY (1954) (722 pp) (It contains the following parts: a) military expls, b) fundamentals of ballistics, c) ammunition and weapons, including atomic weapons & guided missiles and d) a brief glossary of armament engineering terms)

Armament Research Establishment (ARE) is a Brit military institution located at Halstead, Kent, England

Armament Research Establishment, Canada (AREC) is located at Valcartier, Québec

Armament Research Establishment, Royal Arsenal (ARERA) is located at Woolwich, England
(See also Woolwich Research Department)

Armamento (Ital & Span). Arming
Arme (Fr). Arm; rifle

Armé (Fr). Cocked; armed
Arme à chargement par la culasse (Fr). Breech-loading weapon

Armed Forces (Wehrmacht in Ger; Armée, in Fr). This term includes in the US: Army, Navy & Air Forces; in Germany Heere, Kriegsmarine & Luftwaffe and in France: Armée de Terre, Armée de Mer and Armée de l'Air

Armée (Fr). Armed Forces; Army
Armée de l'Air (Fr). Air Force
Armée de Mer (Fr). Navy; Fleet (lit Sea Force)

Armée de Terre (Fr). Army (lit Land Force)

Armée Mécanique (Fr). Tank Corps (lit Mechanized Army)

Arme à feu (Fr). Firearm
Arme à feu automatique (Fr). Automatic firearm

Arme portative (Fr). Small Arm (lit portable arm)

Armeria (Ital). Armory

Arming. This term applies to fitting or equipping an item to be ready for action. Arming corresponds in a rough way to cocking in a small arm. A fuze may be armed (set for detonation) by utilizing forces exerted within or outside the gun. Various methods of fuze and booster arming are described by Ohart (1946), 127 & 166

Armor is a covering intended to protect a person, ship, tank, aircraft combat vehicle, etc from the destructive effects of various types of missiles. For individual protection of a person a flexible fabric of interlinked metal rings (called mail) is commonly used. For protection of other items, the most common material is steel, but research indicates the possibility of aluminum, titanium and even of some non-metallic material

A comprehensive description of various
types of armor is given in Refs 1, 2, 3, especially in Ref 2


Armored Car (Military) may be defined as a wheeled motor-vehicle (such as truck, jeep, station wagon), protected by a light armor and provided with one or more machine-guns, rocket launchers, hand & rifle grenades and, in some cases, with light guns (such as 20 mm or 37 mm). The first armored motor car was designed in 1898 by R.P. Davidson, Colonel in the Illinois National Guard (Ref 5). This car was actually semi-armed (Ref 1). Soon after this, armored cars were built in England (the Pennington) and in France (the Charron). Italians employed a number of armored cars in their campaigns in Africa (1913) (Ref 5). Russians used some armored cars (as well as some armored trains) in WWI, Russian Civil War (1918-21) and WWII. Some idea about German armored cars of WWII may be obtained from Refs 4, 6 & 7.

US armored cars have been primarily employed for reconnaissance, although in some cases, they were used against tanks. Newman (Ref 2) gives photographs of US armored scout car with AA machine-gun mounts and of US armored half-track scout cars. Barnes (Ref 3) gives photographs of US armored car M8 (used during WWII in all theaters) and of US armored car M38, 6 x 6.

Historical development of armored cars is described in Refs 1 & 5.


Armored Ships. The necessity of protecting ships by some kind of armor was realized after the introduction of HE shells in sea warfare (ca 1849), and introduction of AP shells at a later date. The first ship protected by armor was "La Gloire" the French wooden ship, dressed in 1859 in iron plates. Two years later, the British launched the 9000-ton Warrior with 4½" thick iron plates all around and 6 ft below the waterline.

The advantage of armor was shown during the American Civil War in the battle (1862) between Merrimac (South) and Monitor (North). Both ships withstood numerous hits by HE shells and were not incapacitated.

From that time on, the warships of all nations were protected by armor. A more perfect protection against artillery was achieved in the 20th century when the construction of wooden ships was abandoned in favor of steel ships.


Armored Train is one in which locomotive and cars are protected by a light armor capable of withstanding the impact of bullets. Such trains can carry artillery (artillery train) or troops provided with weapons, such as small arms, rockets, etc. In case of cars carrying artillery, each gun can be provided with a shield.

Before the appearance of motor cars and construction of good highways, armored trains were considered very useful. They were employed successfully in American Civil War (1861-5), Franco-Prussian War (1870-1) and South-African War (1899-1900) (Ref 1). In Russia, where the roads are generally in a poor condition, armored trains were used in WWI and in Russian Civil War (1918-20). Some of the Russian "armored" trains were makeshift affairs consisting of an ordinary locomotive protected by sandbags and several flat cars with sandbags laid along the sides (Ref 2).

(See also Artillery Train)
Ref's: 1) Encyclopedia Britannica 2 (1952), 388 2) M.M.Kostevitch, Buenos Aires, Argentina; private communication (1955)

**ARMOR-PIERCING (AP) PROJECTILE**
(Panzergeschoss, in Ger; Projectile perforant in Fr; Proietto perforante, in Ital; Proyectil perforante, in Span; Broneprobivayoushchii snariad, in Rus). AP projectiles are designed to penetrate the armor plate of ships, tanks, etc and may be divided into the following types:

A) A solid projectile containing no explosive, such as AP Bullet, which usually contains a core of hardened steel, a gilding metal jacket and a base (Ref 5, p 185; Ref 6, p 76 & Ref 12, p 76) and AP Shot, called in Ger Panzergranate, which usually consists of a solid steel cylindrical block pointed at the nose, provided with a rotating band and tracer. AP shots are used now mostly for target practice and are provided with tracers (Ref 6, pp 108-9; Ref 10, p 8 & Ref 14)

There is also the so-called HVAP (high-velocity armor-piercing) shot which consists of a tungsten carbide core surrounded by a steel body and provided with a cone-shaped steel nose and a pointed windshield (See below) (Ref 6, pp 108 & 111; Ref 10, p 8)

B) A hollow projectile (shell) containing a HE charge and a base-detonating fuze are designed to penetrate the armor (or concrete) without exploding until they are inside the target. They are usually made of high-carbon, heat-treated alloy steel (in contrast with the common forged steel of the HE shell) and are fashioned with an extremely hard nose and a relatively soft, tough body with thick walls, especially in the forward section.

AP shell intended to penetrate face-hardened armor is usually provided with a slightly blunted nose which is fitted with a cone-shaped cap made of soft and tough forged alloy steel, face hardened. Such shell is called APC (armor-piercing capped). The cap of this shell is fitted with a conical cup, called windshield or ballistic cap, (also called false ogive) the purpose of which is to improve streamlining of projectile as it speeds toward the target. Windshield, usually made of thin Al, shatters on impact with armor, leaving the projectile with only its steel capped nose. The tough steel nose strikes into the armor and weakens it. The projectile then starts to penetrate the softened-up armor spot, while the nose cap breaks away from the remaining part of the projectile. This remaining portion then penetrates the armor and explodes inside the target by the action of base fuze (Ref 6, p 107-9)

It is important that the HE charge be so insensitive that it will not be exploded by the tremendous shock caused by the impact of the shell on the armor. However, it must be sensitive enough to be detonated by the action of the fuze. Black powder fulfills this condition and was used until the end of the last century. It was replaced later in some countries by some AN expls, such as ammonals. These expls were more powerful than black powder, but inferior to ammonium picrate (Exp D) and guanidine picrate (Gu P) commonly used now.

An interesting AP shell was patented during WWI by Quartieri & E. Molinari (Ref 1). In order to render such shell insensitive to shock, the forward part was partly filled with HE (such as TNT or PA) desensitized by 1 to 10% camphor or paraffin. This served as a cushion to take up the stress of impact. A thin felt was placed over the chge and the middle and base part of the shells were filled with a straight HE, such as TNT. Then the booster and the base fuze were inserted. A schematic view of such shell is given in CA 10, 694(1916)

An ingenious complex filling for AP and A/C shells was used by the German during WWII. It had in the forward section an insensitive charge (KCI, followed by KCI/wax/TNT), in the middle section a moderately sensitive chge of TNT/wax in different proportions and in the base section a fairly sensitive chge of straight TNT (Ref 12, p Ger 48)

Because of the thickness of the projectile
walls, the bursting chge of AP and APC projectiles is comparatively small, representing only 5 to 25% of the total wt of the shell.

The so-called API (armor-piercing incendiary) projectile contains an incendiary mixture and the API-T (armor-piercing incendiary tracer) is similar to API but has a tracer in the rear of the bullet (Ref 6, p 65). Various AP and SAP (semi armor-piercing) bombs are described by Ohart (Ref 6, pp 232-4).

C) A projectile designed to utilize the principle of the Munroe-Neumann Effect (qv) is called Shaped Charge Projectile (SCP) or Hollow Charge Projectile. They are similar in appearance to conventional projectiles, except that the forward part of the bursting chge is cast with an indentation in the shape of a cone. The cone surface is usually provided with a metallic liner which increases the penetrating effect (Ref 6, pp 41-3). These projectiles function immediately on impact with armor or concrete, making a relatively small hole through it and hurling hot fragments at a very high velocity inside the target. These fragments are very effective as A/P (antipersound) missiles especially in small enclosures, such as the interior of tanks, pill-boxes, etc. In addition to the damage caused by the flying fragments, a greater damage is probably caused by the blast effect of the chge and by the high temperature (ca 2000°C) and suffocating effect of the gases developed on expln. Combinations of these effects are usually 100% fatal whereas the fragments alone are not.

These projectiles are filled with cast HE, such as cyclotol, pentolite, TNT and are provided with a base fuze and a cap designed to provide the necessary stand-off required for proper formation of the jet.

As most of the US recent shaped charge projectiles are classified, the reference here is made to unclassified WWII items described by Ohart (Ref 6), such as: bombs (p 240), HEAT (high-explosive antitank) shells (pp 108, 110, 112 & 138), HEAT rockets such as 4.5-in (p 347). A greater variety of shaped charge ammunition was used during WW II by the Germans, as can be seen from the following examples: Faustpatrone (shaped charge A/T rocket) (p 46); 75 mm SC shells (pp 74 & 76); 88 mm, 100 mm & 105 mm SC shells (p 77); Haftohlladung (adhering shaped charge) used for destroying tanks (p 85); shaped charge handgrenade (p 86); Panzerhandmine and Haftmine (shaped charge adhering mines) used for destroying tanks (p 87); shaped charge bombs DS (p 92); 105 mm & 75 mm SC projectiles (p 92); Panzerfaust & Panzergranate (shaped charge A/T rocket grenades) (p 126); Panzerschreck (shaped charge A/T rocket) (p 127); Panzerwurfmine (shaped charge A/T hand grenade) (p 127) shaped charge pistol grenades (p 133); shaped charge rifle grenades (p 152); and shaped charge rockets (pp 161 & 168).

M28); 343 (HEAT, T41 rifle grenade, 
Energa) 12)Anon, Ammunition General," 
TM9-1900(1956), 76 13)B.T.Fedoroff et al, 
"Dictionary of Explosives, Ammunition and 
Weapons" (German Section), PATR 2510 
(1958) 14)A.B.Schilling, PicArsn; private communication (1960)

**Armor Testing.** The purpose of testing is to det the effect produced on armor (such as plates, castings, weldments, etc) on impact of various projectiles, such as HE, AP, APC, HEAT, HVAT, etc. The tests are described in Ordnance Proof Manual No. 22-10 (1950)

*Note:* Discussion on evaluation of weld-cracking tests on armor steel was given by S.Weiß et al, Welding J (NY), 35, 348-56s (1956) (20 refs) & CA 50, 13705-6 (1956)

**Armour Research Foundation (ARF),** of the Illinois Institute of Technology, Chicago, Illinois, is an organization doing work on explosives, propellants and related items under US Govt contracts. Their reports are listed, when used as refs, under indvdl compds

**Armory.** This term usually means a Government establishment where arms and other military items are stored for distribution to troops. Some US armories (such as Springfield Armory, Springfield Mass) are also engaged in manuf arms and other items, while others serve as a drilling place for troops

*Ref:* Webster's Unabridged Dictionary (1951), 151

**Arms.** See under Ammunition and Weapons

**Armstrong AirBreaker** is a blasting device activated by compressed air, used for breaking down coal in fiery mines. For its description see J.Taylor & P.F.Gay, "British Coal Mining," Newnes, London (1958), 137 & 140-2

**Armstrong Gun.** A rifled gun, constructed according to the system of built-up, wrought-iron ordnance, invented ca 1855 by Sir W.G. Armstrong of England

*Ref:* Webster's Unabridged Dictionary (1951), 151

**Armstrong's Explosive or Mixture** is a red solid substance prepd by blending under a volatile liq (such as alc or acet) 75 parts of powdered K chlorate with 25 ps of red phosphorus and then allowing the volatile liq to evaporate. The mixt is very explosive and sensitive. Extreme care must be exercised in handling it, because it may detonate on a slight shock, touch or when brought into contact with a drop of concd H₂SO₄. The mixt is known for over 100 years and it has caused many mishaps

Germans used this mixt for loading the so-called "Hinterhaltsminen" the land mines left by them on retreat

Stettbacher calcd the heat generated by the reaction: 5KClO₃ + 6Pₐ(red)= 3P₂O₅ + 5KCl as equal to 1417 kcal/kg

*Ref:* A. Stettbacher, Protar 10, 159-60 (1944)

**Army (Heere or Armee, in Ger; Armée de terre, in Fr; Esercito, in Ital; Ejército, in Span; Armiya, in Rus).** A large organized body of men, armed for war and designed for land service. It is a part of the Armed Forces (qv)

According to the definition given in ORDP 50-13, p 84 (Ref 4), the Department of the Army (US) is charged with the responsibility of providing support for national and international policy and the security of the US by planning, directing, and reviewing the military and civil operations of the Army Establishment, to include the organization, training and equipping of land forces of the US for the conduct of prompt and sustained combat operations on land in accordance with plans for national security


**Army Ordnance Corps (US)** is an organization which is responsible for procurement, storage
and distribution (to the Army, Navy, Air Force, Marine Corps, National Guard, etc) of small arms, automatic weapons, artillery, fire control equipment, ammunition & explosives, bombs & mines, transport & combat vehicles, rockets & guided missiles, tanks, and other

Up until 1950 it was known as Army Ordnance Department. The Dept was created by an Act of Congress, 14 May 1812. Prior to this, in colonial days, the colonists used ammunition and weapons seized from the British either on land or seas; and originally the Quartermasters Corps handled supply problems. Some muskets were produced by locksmiths imported from France and West Indies. Colonial government storage depots were established, but no provisions were made for producing new weapons until 1794 when Congress authorized the establishment of Springfield Armory (constructed in 1794-5) and Harper's Ferry, W Va, (1796). Springfield Armory has been an arms-making center for many years and also served as a military storehouse. The armory at Harper's Ferry was destroyed by Federal troops early in the Civil War so that Confederate troops could not use it.

After establishing the Army Ordnance Department, the construction of several arsenals (qv) was authorized by the Congress. For testing of weapons and ammunition, the so-called Sandy Hook Proving Ground, New York, was established. This was replaced in 1917 by the Aberdeen Proving Ground, Maryland.

During WWI the Ordnance Dept expanded until it had on payroll 6000 officers, 60000 enlisted men and 73000 civilians. After WWII the Dept was rapidly demobilized and munition plants and machinery were converted to peacetime production. The Dept personnel, both military and civilian, was drastically reduced in numbers. It average yearly budget was reduced to ca 10 million dollars.

The greatest expansion of the Dept took place just prior and during WWII when an average yearly budget was boosted to ca 7 billion dollars. Total of ca 34 billion dollars was assigned to the Dept during WWII.

After WWII the activities of the Dept were greatly reduced, but were again increased when the Korean War started (1950). At this time the Army Ordnance Department was renamed the Army Ordnance Corps.

Still greater expansion of Ordnance Corps took place in the last ten years.

Refs: 1)Anon, "Supervisor Development Program," Training Branch, PicArsn, Dover, NJ, Sept 1953 (Revised), 21-4 2)A.B. Schilling, PicArsn; private communication (1960)

Arnoudts' Explosive. A blasting expl contg K chloride 60 & sugar 40% with added turpentine 2, vegetable tar 2 & K permanganate .00125 parts
Ref: Ch. Arnoudts (of Guatemala), USP 964,365 (1910) & CA 4, 2733 (1910)

ARO. A cast double-base propellant described in conf "Propellant Manual," SP1A/M2 (1959), Unit No 433

Aroclor. Trade name for a series of poly-chlorinated polyphenyls manufd by the Monsanto Chem Co of St Louis as liquids, resins or solids. The use of one of the Aroclors as an ingredient of propellants contg no NC is discussed in Ref 1. Other uses of Aroclors are listed in Ref 2.

Following are some examples of propellants listed in Ref 1:

<table>
<thead>
<tr>
<th>Amm picrate</th>
<th>K nitrate</th>
<th>Et cellulose</th>
</tr>
</thead>
<tbody>
<tr>
<td>54.6</td>
<td>36.4</td>
<td>3.6</td>
</tr>
<tr>
<td>71.6</td>
<td>17.9</td>
<td>6.0</td>
</tr>
<tr>
<td>38.5</td>
<td>31.5</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Aromatic-Aliphatic Nitrocompounds and Nitrate Esters. Title of OSRD Report No 176, Nov 1941, by L.F. Fieser

Aromatic Alkylamino Alcohols. Their nitration
in two stages, first with 36% and then with 99% nitric acid, both nitrations in the cold, is described by J.Barbiere, BullFr 7, 621-6 (1940) & CA 36, 1913 (1942)

Aromatic Compounds are substances characterized by benzene-type structures (ring or cyclic), and in many cases having pleasant odors. The compounds which are of interest in ordnance are described in this work individually, such as benzene, phenol, toluene, etc.

For more info on this subject see textbooks on organic chemistry (such as Karrer's, Fieser & Fieser's, etc) and also Kirk & Othmer 2 (1948), 109-12

Aromatic Compounds, Nitration. See under Aromatic


Aromatic Hydrocarbons, Detection in Aqueous Solutions. Presence of small amounts of aromatic hydrocarbons in water (1 to 500 ppm) may be detected by means of formaldehyde-sulfuric acid reagent as described by H.E.Morris et al, IEC, AnalEd 18, 294-5(1946)

Aromatic, Nitrated Derivatives. Aromatic nitrocompounds are ring type substances, which contain one or more NO₂ groups attached to carbons (such as nitrobenzene, trinitrotoluene, etc). Aromatic nitroamino compds or C-nitroamino compds are those containing NO₂ groups attached to carbons (as 2,4,6-trinitroaniline) and should not be confused with nitramino compds which are N-nitroamino derivs and which have the NO₂ group attached to the amino nitrogen to give an NH-NO₂ group. If the NO₂ group replaces a H atom of an imino group :NH, to give :N.NO₂, the deriv is called a nitrimino compd, but if the :N.NO₂ is not attached through the double bond but joins two other groups through single bonds [as in -CH₂,N(ONO₂)-CH₂], the compd is still called nitramino-, as in cyclotrimethylene-trinitramine. Nitronitramino compds have NO₂ groups attached to both the carbon and nitrogen of an amino compd, as in 2,4,6-trinitrophenylmethylnitramine.

Throughout this work care has been taken to differentiate clearly between nitroamines, nitramines, nitronitramimines and nitrimines. In the literature, especially in Brit, this differentiation is not always made.

In aromatic compounds contg aliphatic alcholic groups, such as anilinoethanol, benzyl alcohol, etc, the NO₂ group can be introduced into both the aromatic and aliphatic portions of the molecule as in N₂,N₂,N₂,C₆H₃-N(ONO₂)-CH₂-CH₂-ONO₂. In this compd the NO₂ group replaces the H of the aliphatic OH group. The resulting ONO₂ group is called a nitrate or an oxynitro derivative. The term nitrate is also used when HNO₃ combines directly with an organic molecule without replacing any H, as in aniline nitrate.

Many nitrated aromatic and aromatic-aliphatic derivs have been prepd and theoretically many more can be prepd. Numerous compds of these types, already prepd are expl, but relatively few possess a combination of props which make them acceptable for use as military or industrial expls.

The individual nitrated compds are described in this work under what may be considered their parent compds; eg TNT under toluene, PA (2,4,6-trinitrophenol) under phenol, etc.

Aromatic, Nitrited Derivatives. These derivs are similar to nitrated derivs except that they contain nitroso- groups, :NO, in lieu of nitro groups. If the NO group is attached directly to C, the deriv is called nitroso- and if to the nitrogen of an amino group, the deriv is called nitrosamino-. There are also nitronitroso-, nitronitrosamino- and nitrosinitroamino- derivs.

Many of these compds are known but only few of them are explosives suitable for military or industrial purposes. They are described in this work under their parent compds; eg 2,4 dinitrosoresorcinol under
resorcinol, trinitrodinitroso-β-naphthol under naphthol, etc.

Aromatic Peroxides. See under Peroxides, Organic, with the Structure RC(O)OOH

Aromatic Silanes. See under Silanes


Aromatic Triazenes. Compds of general formula Ar. NH-N-N-Ar were investigated by Campbell in regard to their reactions with nitric oxide. Some of the compds prep'd by him proved to be expl

Eg: When 1,3-di-p-tolyltriazene, \( \text{C}_6\text{H}_4\text{C}_6\text{H}_4\text{NHN} : \text{N} : \text{C}_6\text{H}_4\text{CH}_3 \), in dry toluene at 0°, was treated with NO at 23° and 758 mm pressure, a solid compd was obtained. It was filtered off, dissolved in anhyd isopropanol and pptd by adding ether as wh hygroscopic ndls which exploded when struck with a hammer or when heated to ca 75°. Its empirical formula was reported as \( \text{C}_6\text{H}_4\text{N}_2\text{O}_4 \) (which corresponds to mw 165.15 and N25.45%), but the structure was not detd

Ref: T.W.Campbell, JACS 73, 4019-20 (1951) & CA 46, 7573 (1952)

ARP. A cast double-base propellant described in conf "Propellant Manual," SPIA/M2 (1959), Unit No 434

Arquebus or Harquebus was the first practical firearm (invented in 15th century). It had a bent stock and the touchhole was at the side of the barrel with a little pan for priming. Its range was 400 to 500 paces. Later models were equipped with matchlock which was also used in the early musket which replaced the arquebus, late in the 16th century. But before the replacement took place, the caliber of the arquebus was standardized and the resulting weapon was called in England caliver and in France arquebus de calibre


Arrested Burning of Gun Propellants. A convenient apparatus for recovery partially burned gun propellant grains as result of arrested burning was described by J.F. Kincaid & B.P. Dailey in OSRD Rept 1836 (1943)

Arrosage des poudres (Fr). Spraying of propellants with gelatinizers or phlegmatizers in order to make them progressive-burning can be conducted by various methods. For example, Fauveau & Delpy describe a procedure in which the propellant grains were sprayed with an alcoholic soln of camphor and centralite using a painter's spray-gun

Ref: J. Fauveau & R. Delpy, MP 31, 162 (1949)

Arrow is a slender shaft with a pointed head used as a missile which is propelled by releasing the tension of the string of a long bow. A bow consists of a strip of wood or other elastic material with a tension cord connecting both end. The bow and arrow constituted one of the earliest weapons. A later development of the long bow was the crossbow, also known as arbaless (qv). Eventually both were replaced by firearms

Ref: Webster's Unabridged Dictionary (1951), 154 & 318

Arrow Projectile (Pfeilstabiles Geschoss, in Ger), also called Needle Shell (Ref 5), is a slender, very long, fin-stabilized, projectile, fired from a smooth-bore gun at supersonic velocity. Its development, described in Refs 1 & 4, may be considered as one of the outstanding Ger achievements of WWII. Some info on these projectiles is given in Ref 3, pp 9-10

It seems that slender projectiles developed during WWII by Dr Otto Gessner of Peenemünde and described by Domberger (Ref 2, pp 22-3) and also in Ref 3, p 69, under Gessner Projectile are also arrow projectiles.

The so-called Röchling Anticoncrete Projectile (Röchlingsgranate 42, Beton) resembled in appearance the arrow projectile, except that instead of the fin assembly of the arrow projectile it had a discarding flange serving as a driving band. It was manufd by the firm Röchling at Saarbrücken, Saar (Ref 4, p 160 & Ref 6)
Arsenic Acid. See Aminophenylarsanic Acid

ARS. A cast double-base propellant described in conf "Propellant Manual", SPIA/M2 (1959), Unit No 435

ARSENALES. A US arsenal is a military installation of the Army Ordnance Corps (qv), primarily involved with the development, manufacture, loading, storage and issue of materiel used by the armed forces for the conduct of war. Arsenals with primary function of storage are usually called Depots.

As it is mentioned under Army Ordnance Corps, the oldest US military installation, which may be considered as a manufacturing arsenal, is Springfield Armory, Springfield, Mass, established in 1794-5. The first US military establishment named "Arsenal" was the Watervliet Arsenal, Watervliet, NY. It was authorized by Congress in 1812, built in 1813, but known as "the arsenal near Troy" or Gibbonsville Arsenal, until named Watervliet in 1817. Watertown Arsenal, Watertown, Mass was established in 1816, but its history dates back to 1800 when an arsenal was created at Charlestown, Mass. Frankford Arsenal, Philadelphia, Pa was authorized by Congress in 1815, constructed in 1816. The Augusta Arsenal, Georgia was authorized in 1816-17, but a new site was chosen in 1827. All the above arsenals were "manufacturing arsenals," to distinguish them from "storage and repair arsenals," also called "depots."

New arsenals were established as the nation grew to the West, particularly during and after the Mexican War (1846-8). Two arsenals (which are actually depots) which continued to the present, are Benicia Arsenal (Depot), Benicia, Calif (established in 1851) and San Antonio Arsenal (Depot), Texas (1858)

During the Civil War, Rock Island Arsenal was established in 1863 at Rock Island, Ill to supply the Union troops in the Mississippi Valley.

Although Picatinny Arsenal, Dover, NJ, was established in 1879-80 (as a powder depot), the history of arms-making at Picatinny
goes back beyond the Revolution, when cannon balls were made at what was known as Middle Forge. Its present name "Pica-tinny Arsenal" dates from 1907 when the propellant plant was built.

During the WW I, the activities of arsenals were greatly expanded and a permanent storage arsenal, Raritan Arsenal, Metuchen, NJ was built (1918). In 1920 the Ogden Arsenal (for storage and repair) was built.

Other US arsenals, include in alphabetical order: Detroit Arsenal, Detroit, Mich; Edgewood Arsenal, Maryland (Army Chemical Center), near Aberdeen; Indiana Arsenal (Ordnance Works) (Hoosier Ordnance Plant, Charlestown, Ind; Joliet Arsenal (Elwood Ordnance Plant and Kankakee Ordnance Works), Joliet, Ill; Lake City Arsenal; Independence, Mo; Radford Arsenal (Ordnance Works), Radford, Va; Raritan Arsenal (Depot), Metuchen, NJ; Ravenna Arsenal, Apco Ohio; Redstone Arsenal, Huntsville, Alabama; Red River Arsenal (Depot), Texarkana, Tex; Rocky Mountain Arsenal, Denver, Colo and Schuylkill Arsenal, Philadelphia, Pa.

The name "arsenal" is not used for the Ordnance establishments of the US Navy or Air Force.


Arsenic. As, at wt 74.91; exists in three modifications all corresponding to the formula As₄, mw 299.64. The most common form is the crystalline or α-form, known also as metallic arsenic. Its mp is 814°C at 36 atm press, sublimation point 615°C, d 5.72° at RT (5.6-5.9 for commercial grade) and hardness 3.5 Mohs. Prep & props are given in Refs 1-6; toxicity, fire & expln hazards of As dust are discussed in Ref 7. Arsenic is used in some alloys and for hardening lead shot.

US military requirements for As metal intended for use in the manuf of Mg arsenide are covered by spec MIL-A-10852B.

Arsenic compds have been used in some pyrotechnic combs (see Arsenic Disulfide and Arsenic Trisulfide described under sulfides) and as chemical warfare agents (see Arsenic Tribromide described under Bromides, Arsenic Trichloride described under Chloride and Arsine and Derivatives listed under Arsine).


Arsenic Azide. See under Azides, Inorganic

Arsenic Disulfide. See under Sulfides

Arsenic Hydride or Hydrogen Arsenide. See Arsine and Derivatives

Arsenic Pentasulfide. See under Sulfides

Arsenic Sulfides. See under Sulfides

Arsenic Tribromide. See under Bromides

Arsenic Trichloride. See under Chlorides

Arsenic Trioxide. See under Oxides

Arsenic Trisulfide. See under Sulfides

**ARSENIDES** are metallic derivs of arsenic. As they can be prep'd by heating of some metals with arsenic, they may be called arsenic alloys. Ullmann calls them Metallic Arsenide. A number of arsenides occur in
nature; some of them are definite compds,
while others are mixts. The compd of hydrogen
and arsenic, hydrogen arsenide or arsenic
hydride is described below as arsenine

Several arsenides are described in Refs
1,2,4&5

US military specification MIL-M-12057A
covers requirements and tests for technical
grade magnesium arsenide.\* Purified grade,
Mg₃As₂ is a chocolate-colored solid, mp ca
800° & d 3.148 at 25°/4°. It can be prepd by
strongly heating (to red heat) a mixt of
powdered Mg with As in atm of hydrogen.
Sand may be used as a diluent in order to
slow down the reaction (Ref 1, p 66; Ref 3,
p 413 & Ref 4, p 122)

*Note: Mg arsenide is intended for use in the
manuf of CWAs: arsenie, diphenylaminechloro-
arsine, and diphenylphosphorine

Refs: 1)Mellor 9 (1929), 61-90 2)Thorpe 1
(1937), 472 3)Gmelin, Syst Nr 27(1938),
413-14 (Magnesiumarsenid) 4)Kirk & Othmer
2 (1948), 122 5)Ullmann 3 (1953), 851

ARSINE AND DERIVATIVES
Arsine (Hydrogen Arsenide; Arseniuretted
Hydrogen; Arsenic Hydride or Trihydride)
(Arsenwasserstoff in Ger), AsH₃, mw 77.93;
col gas; with offensive odor resembling that
of garlic; sp gr 2.695 (Air = 1.0); fr p -113.5°,
bp -55°; dec ca 230°; moderatly sol in w; sl
sol in alc; insol in eth. It decomposes with
heat and is inflammable

Arsine is a nerve and blood poison and a
concn of 500 ppm is lethal for a man after
exposure for a few minutes. MAC (max
allowable concn) in air is 0.05 ppm (Refs 4,
5 & 9)

It can be prepd by the action of H₂SO₄ on
metallic zinc mixed with arsenic compds
(Ref 8) or by other methods (Refs 1-3 & 6 & 7)

Detection and detn of arson in air, urine
etc is discussed in Ref 4

Refs: 1)Mellor 9 (1929) 2)Thorpe 1 (1937),
472-5 3)Kirk & Othmer 2 (1948), 121-2 4)
Jacobs (1949), 246-7 5)Elkins(1950), 66-7
& 227 6)Gmelin Syst Nr 17(1952), 195-233
7)Ullmann 3 (1953), 851 8)CondChemDict
(1956), 113 9)Sax(1957), 321

Arsine Derivatives, Organic. Many arson
derivs were proposed as CWAs. More than
60 of such derivs are listed by Wachtel
(Ref, pp 189-92). The most known of these
compds is Lewisite or MI, which is β-chloro-
vinyldichloroarsine, Cl-CH:CH-AsCl₂, first
isolated in 1917 by Dr W. Lee Lewis and
developed as a war gas by the US Chemical
Warfare Service (Ref, pp 202-6). Another im-
portant arson CWA is Adamsite (Brit) (des-
ignated in the US as DM) or diphenylamine-
chloarosine

\[ \text{ClAs} \quad \text{C}_2\text{H}_4 \quad \text{NH} \] (Ref, p 206)

Arsine derivs used by the Germans were not
as effective as Lewisite. They included: a)
Dick,US designation ED, ethyldichloroarsine
C₂H₅·AsCl₂ (Ref, p 194); b)Clark I (US
designation DA) biphenvylchloarosine,
(C₆H₅)₂AsCl (Ref, p 196) and Clark II,
biphenylcyanoarsine, (C₆H₅)₂As-CN (Ref, p
199). Another Ger arson deriv was phenyl-
dibromoarsanne, C₆H₅·AsBr₂,

Ref: C.Wachtel, "Chemical Warfare,"
ChemPubCo, Brooklyn (1941), 184-206

Arsol One of the names for cyclotrimethylene-
tinitrosamine (R-Salz, in Ger), described
in this work under Cyclotrimethyletenitrime

ART. A cast double-base propellant de-
scribed in conf "Propellant Manual," SP1A/
M2(1959), Unit No 436

Artifice (Fr). Pyrotechnic device or compos-
tion

Artifices(Fr). Fireworks

Artifices à fumées colorées (Fr). Colored
smoke devices used for signalling during
daytime

Artifices de guerre(Pyrotechnie militaire)
(Fr). Military pyrotechnics

Artifices incendiaires (Fr). Incendiary pyro-
technic devices

Artifices lumineux(Fr). Illuminating devices
used for nighttime signalling

Artifices producants un sifflement(Fr).
Whistle-producing devices, designed for
signalling by sound. They were usually made
by loading long, narrow tubes ca 10 mm diam and made from reed, cardboard or plastic, with a mix of K picrate 87 & K nitrate 13%
Ref: Pepin Lehalleur (1935), 478
Artifices de signalisation(Fr). Pyrotechnic signals
Artifices pour signaux(Fr). Same as pétards pour signaux
Artificial Baricade means an artificial mound or revetted wall of earth of a minimum thickness of 3ft, erected as protection around places storing expls, propellants or ammo
Ref: Cook(1958), 355
Artificial Silica can be prepd by decompg silicon fluoride with water. It possesses high absorptive value and was used by M.Berthelot in France for prepg some dynamites
Ref: Marshall 1 (1917), 360
Artifizi da guerra(Ital). Military pyrotechnics
Artifizi pirotecnici per usi bellici(Ital). Pyrotechnic devices for use in war
Artiglieria(Ital). Artillery; ordnance
Artillería(Span). Artillery; ordnance
Artillerie(Fr & Ger). Artillery; ordnance
Artilléria(Rus). Artillery; ordnance
Artillery is the branch of the armed forces which uses weapons of caliber greater than firearms. This includes cannons, howitzers, mortars and rocket launchers, which may be mounted on wheels and towed by horses or motor vehicles, or mounted on tanks, motor vehicles, boats, ships etc
The calibers of US artillery weapons are listed under Ammunition and Weapons
Artillery Ammunition. See under Ammunition and Weapons
Artillery Ammunition Components Tests. The purpose of these tests is to determine if the components of a round of artillery ammo (such as cartridge cases, powder bags, propelling & bursting charges, projectiles, boosters, igniters and fuzes) function according to the requirements of the US Armed Forces Specifications. These tests may be conducted also in order to obtain data for further research and development
Descriptions of testing methods for various components are given in the following Ordnance Proof Manuals:
a)OPM No 8-10(1947) (General)  b)OPM No 8-11(1943) (Projectiles)  c)OPM No 8-12 (1937) (Propellants)  d)OPM No 8-13(1948) (Fuzes)  e)OPM No 8-14(1943) (Primers for cannons)  f)OPM No 8-15(1942) (Boosters) and  g)OPM No 8-16(1942) (Cartridge cases and bags)
Artillery Cannon and Cannon Equipment. General specification for manuf and inspection is in MIL-A-13931(Ord)
Artillery Carriages & Mounts; Recoil Mechanisms; Rocket Launchers; Auxiliary Equipment and Parts. General specifications for these items are in MIL-A-13917A(Ord)
Artillery Materiel and Its Testing. Artillery materiel includes items such as cannons, mounts & carriages, recoil systems, sighting systems, subcaliber guns, rocket launchers, aircraft armament and recoilless weapons. The purpose of tests is to determine whether or not the submitted materiel meets the requirements of the US Armed Forces Specifications
The following Ordnance Proof Manuals describe these tests:
a)OPA No 16-10(1947) (Artillery materiel; general)  b)OPA No 16-10-75(1944) (Pilot units)  c)OPA No 16-10-75A(1952) (Winterization testing of artillery materiel)  d) OPA No 16-11(1943) (Cannons)  e)OPA No 16-12(1943) (Carriages & mounts)  f)OPA No 16-13(1942) (Recoil systems)  g)OPA No 16-14(1943) (Telescopic sights)  h)OPA No 16-15(1942) (Subcaliber guns)  i)OPA
No 16-16(1944) (Aircraft armament) j) OPA No 16-17(1948) (Erosion and service life tests) k) OPA No 16-20(1951) (Recoilless weapon materiel development tests)

Artillery Propellants. See under Propellants

Artillery Rockets. See under Rockets

Artillery, Railway. This term covers artillery, mostly of large caliber, mounted on special carriages attached to heavy duty platforms (flat cars) of special trains (mostly armored trains). Protection of gun crews is usually achieved by means of steel shields.

A comprehensive description of British & French, Italian and US railway artillery used during WWI is given in Ref 1

Newman (Ref 2) describes three pieces of US railway artillery: a) 8-inch Railway Gun b) 12-inch Railway Mortar and c) 14-inch Railway Gun. US Railway Artillery which was at the beginning of WWII a part of the Coast Artillery, was disbanded in March 1942.

Two examples of Ger railway artillery of WWII, used on the Russian Front are given in Ref 3, p 263: a) 310 mm Glött Gun and b) 510 mm Self-Propelled Mortar Karl Gerät.


Artillery Train comprises a number of pieces of artillery (ordnance) mounted on carriages equipped for marching, together with their munitions and the vehicles transporting them.

Ref: Merriam-Webster's(1951), 157

Arukōru(Jap). Alcohol

Aruminyūmu(Jap). Aluminum

Arylamines and Their Explosive Derivatives are described individually, such as aniline, anilinoethanol, etc

Arylamines, Qualitative Reactions were discussed by S. L. Burnistrov, ZhAnalKhim 1, 263(1946) & CA 43, 534(1949)

Arylaminoguanidines; Arylaminotetrazoles and Arylaminotriazoles and Their Explosive Derivatives are described individually

Arylazides. See under Alkyl- and Arylazides

Arylparaffins. Theory of nitration of side chains of arylparaffins was discussed by A. I. Titov, UspKhim 21, 881-913 (1952)

ARZ. A cast double-base propellant described in conf "Propellant Manual," SPIA/M2(1959), Unit No 437

ASA (Azide-Styphnate-Aluminum). British initiating mixes of LA, LSt & Al (flake powder) for detonators using tetryl as a base charge. Brit "Service ASA" contains the crystalline "Service Azide," while commercial ASA contains dextrinared LA.

The No 6 commercial detonator consists of an Al cap containing 0.35 g of ASA as an upper layer and 0.25 g of tetryl as a lower charge. The larger and stronger detonator, No 8, contains 0.35 g ASA & 0.55 g tetryl. PETN can be used as an alternative base charge for tetryl to obtain detonators of increased initiating power or to reduce the detonator charge required. The corresponding charge of ASA & PETN are 0.20 & 0.22 g respectively for the No 6 cap and 0.20 & 0.45 g for the No 8.

Still stronger detonators may be produced by using three layers: ASA, an intermediate charge of PETN or tetryl slightly compressed and a base charge of PETN or tetryl very highly compressed.


Asbestos(Earth-Flax; Stone-Flax; Mountain Cork) (Asbest in Ger; Amianthe in Fr). Asbestos is a class name for several native fibrous materials, but commercial asbestos is mainly the fibrous form of serpentine known as chrysolite, which is a hydrox
magnesium silicate, 3 Mg O.2SiO,-2H2O. Other types of asbestos often contain silicates of magnesium, iron and aluminum as well as of magnesium. Commercial forms of asbestos can be white, grayish, bluish or greenish in color. Asbestos is acid- and heat-resistant and may be spun or woven (Refs 2-4).

Uses of asbestos include: acid- & fire-proof cord, gloves, clothing, pads, paper, carpet, gaskets & filtering disks, acidproof cements & putties & as filter bed in Gooch crucibles and funnels (Refs 2-4). Powdered asbestos was used as an absorbent for NG in some older dynamites (Ref 1). Fibrous asbestos has been used in Ascarite and in Asch-Tu-Ess. Ascarite is an absorbent for CO2 made of asbestos with NaOH and Asch-Tu-Ess is a solid generator of H2S made by compressing asbestos with a sulfide decomp on heating. Platinized asbestos has been used as a catalyst both in laboratory and plant. Hutchinson (Ref 5) proposed to use asbestos in solid gas generating units employed for actuation of pressure-operated mech devices in blasting operations, propulsion of rockets, etc. In these units, self-sustained, exothermic, nondetonating, gas-evolving, decompn reactions are obtained by igniting local areas of NGu and/or GuN sometimes taken as a measure of the "mineral matter" of the original material.

Ash is a solid left after a combustible material is thoroughly burned at not too high temp. Ashes vary in compn, both qualitatively and quantitatively, but in most cases they consist of oxides and non-volatile salts of Na, K, Ca, Mg & Fe. Some sand and silicates may also be present. The amt of ash is sometimes taken as a measure of the "ash content" of the original material and for asbestos sheet, compressed, MIL-A-7021A


Ascaridol(α-Terpinene Peroxide or 1,4-Epidioxy-2-p-menthene),

H3C—[O—O]—CH(CH3)2, mw 166.21. Liq bp 83° at 4-5 mm & 96-7° at 8 mm,dec explosively >130° at atm pressure; nD 1.4769 at 25°. A naturally occurring (in ethereal oil of Chenopodium seeds) transannular peroxyde, which may also be obtained from α-terpinene and other substances. It is toxic Refs: 1)Beil 19, 17,(61) & (18) 20. Wallach, Ann 392, 59(1912) 3)E.K.Nelson, JACS 33, 1404(1911) & 35, 84(1913) 4)K. Bodendorf, ArchPharmacie 271, 1-35(1933) 5)H. Hock & F.Depke, Ber 84, 122 & 349(1951) 6)Tobolsky & Mesrobian(1954) 24-6, 166 & 178

Ascarite. See under Asbestos

Ash is a solid left after a combustible material is thoroughly burned at not too high temp. Ashes vary in compn, both qualitatively and quantitatively, but in most cases they consist of oxides and non-volatile salts of Na, K, Ca, Mg & Fe. Some sand and silicates may also be present. The amt of ash is sometimes taken as a measure of the "ash content" of the original material. Ashes are given in specification MIL-A-13651 and for asbestos sheet, compressed, MIL-A-7021A


US military requirements for crude asbestos are given in specification MIl-A-13651 and for asbestos sheet, compressed, MIL-A-7021A


Ascaridol(α-Terpinene Peroxide or 1,4-Epidioxy-2-p-menthene),

H3C—[O—O]—CH(CH3)2, mw 166.21. Liq bp 83° at 4-5 mm & 96-7° at 8 mm,dec explosively >130° at atm pressure; nD 1.4769 at 25°. A naturally occurring (in ethereal oil of Chenopodium seeds) transannular peroxyde, which may also be obtained from α-terpinene and other substances. It is toxic Refs: 1)Beil 19, 17,(61) & (18) 20. Wallach, Ann 392, 59(1912) 3)E.K.Nelson, JACS 33, 1404(1911) & 35, 84(1913) 4)K. Bodendorf, ArchPharmacie 271, 1-35(1933) 5)H. Hock & F.Depke, Ber 84, 122 & 349(1951) 6)Tobolsky & Mesrobian(1954) 24-6, 166 & 178

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multiplied by 100 gives % of volatiles. Place the crucible in a muffle furnace (or use Bunsen burner or an electric heater) and heat gently at first (until most of the smoke disappears) and then increase the heat gradually to a dull red (700-750°) in order to destroy all the carbonaceous material. Avoid heating to higher temps to prevent fusing of ash to the walls of the crucible. Occasionally stir the ash with a platinum wire. Cool the crucible in a desiccator and weigh. Heat again for 30 mins, cool and reweigh. Repeat until a const wt is obtained (Ref 3, p 598).

B) If the substances is an explosive, the direct heating in a muffle furnace or in a flame is not advisable because all the ash would be blown out by the expln. In order to avoid this, the sample must be treated prior to combustion with some liquid, such as H\(_2\)SO\(_4\), oil, isopropanol, etc, preventing the expln and slowing down the combustion.

For example, when analyzing PA, weigh ca 5 g in a tared crucible and add few drops of concd H\(_2\)SO\(_4\). This will decom PA with form of carbonaceous material. Heat carefully to remove the excess H\(_2\)SO\(_4\) and to burn the bulk of carbon. Cool, add few drops of concd H\(_2\)SO\(_4\) + HNO\(_3\) and heat at below dull red to eliminate all carbonaceous material. Cool in a desiccator and weigh. The difference between this wt and the wt of empty crucible gives ash as sulfates.

During WWII in analyzing TNT for sodium content in the ash, the following method for combustion of TNT was used at Keystone Ordnance Works, Meadville, Pa:

Weigh on a rough balance in a tared platinum dish a 25 g sample and moisten it with a little isopropanol. Heat the dish, under the hood, with the colorless flame of a Bunsen burner until all the TNT is melted. Care must be taken not to heat platinum in a yellow flame as the incandescent carbon of such a flame attacks platinum, forming carbide which is extremely brittle. If the material has not already ignited, ignite it, remove the burner, close the hood and allow the combustion to proceed by itself. Do not be alarmed if the material flashes at the end of burning. Transfer the dish into a muffle furnace preheated to 700-750° and leave there to bum off all the carbon (ca 5 mins). Cool the dish in a desiccator and weigh.

If it is desired to transform the carbonates and oxides to sulfates, add a few drops of dil H\(_2\)SO\(_4\) (ca 10%) and with the aid of a rubber policeman rub down the sides of the dish moistening them with the liquid in the dish. Evaporate the liquid and heat the dish in the muffle furnace at below dull red (Ref 1).

C) If the sample is a propellant, treat 1-2 g in a tared crucible (porcelain or platinum) with a few drops of concd nitric acid and heat on a steam bath, under the hood, until the evolution of nitrogen oxides subsides. Continue heating until the liquid fraction evaporates, thus leaving a gummy mass. Transfer the crucible to a triangle, and using a low flame heat carefully until most of the carbonaceous matter has been burned off. Finish the combustion at ca 600° for ca 1 hr, cool in a desiccator and weigh (Refs 1 & 2).

D) If the material is a liquid or a syrup consisting of water with some dissolved combustible substance (such as a red water or thick liquor of TNT manuf), pipette out 10 ml to a tared, low form, procelain crucible, and evaporate the water with stirring, on a steam bath. Transfer to oven at 135° and heat for 4 hrs. Cool in a desiccator and weigh. This gives total solids.

Moisten the residue with ca 10 ml of acetone, slant the dish at ca 45° angle and ignite. Remove the gas burner, cool the dish, and repeat the above treatment. Heat the crucible on a gas burner or in a muffle furnace until the disappearance of carbonaceous matter, cool in a desiccator and weigh (Ref 1).

(See also under individual compounds)

Refs: 1) Clift & Fedoroff, I(1942) & 3(1943)
2) Olsen & Greene (1943), 37 & 64  
3) Snell & Biffen (1944), 598

ASN. An expl compn developed by CPV (Ref 1): AN 70, PETN 20 & dicyanodiamide 10%. It was used during WWII both in Germany and Italy as an underwater explosive. Its props were: rate of deton at d1.55, 5500 m/sec and equation of expl decompn:

\[ 14 \text{NH}_4\text{NO}_3 + \text{C(CH}_2\text{ONO}_2\text{)}_4 + 2(\text{CN-NH}_2\text{)}_2 \rightarrow 9\text{CO}_2 + 36\text{H}_2\text{O} + 20\text{N}_2 \]

Vol of gases evolved according to the above reaction is 972 l/kg at NTP and heat evolved 938 kcal with H2O in vapor phase.

Brandimarte (Ref 3) describes the prepn of ASN, as follows: PETN (20 parts) was added at 115-180° to a binary mixt of 70 ps AN and 10 ps dicyanodiamide, which had been previously fused for 6-8 hrs. The mixt was analyzed and found to contain ca 2% of GuN and ca 6% of biguanide nitrate, which were formed by interaction betw dicyanodiamide and AN.

An improved underwater expl compn was prepd by mixing 90 parts of ASN with 10 ps Al powder.


Asphalines. Brit blasting expls used at the end of the 19th century: a) Asphaline No 1 was prepd by thoroughly mixing 54 parts of KClO4 with 42 ps of bran and/or wheat, barley, etc & 4 ps of K sulfate, in presence of small amt of w. After drying the mixt could be bound and waterproofed by incorporating a small amt of mineral oil, paraffin, soap or ozocerite. b) Asphaline No 2 consisted of 75 parts asphaline No 1 and 25 ps K nitrate.

Refs: 1) Cundill’s Dictionary, MP 5, 287 (1892) 2) Gody (1907), 263

Asphalt; Asphaltum or Mineral Pitch (Earth Pitch; Jew’s Pitch or Trinidad Pitch) is a solid or semisolid black or dark brown amorphous material found native in many parts of the world. One of the greatest known deposits is in Trinidad (“Pitch Lake”). A soft variety, which is found on the surface of Dead Sea, has been known since Biblical times.

Asphalt is one of the bitumens, to which also belong tar and pitch. Bitumen, as well as asphalt, is a mixt of hydrocarbons associated sometimes with mineral matter. The org constituents are sol in CS2 and may be roughly divided into asphaltenes and carbenes. The former are insol in ether and mineral oils, whereas the latter are insol in CCl4 or CHCl3.

The common form of asphalt is a black, compact, amorphous, brittle mass of dull luster, which breaks showing a polished surface and fuses at 188-90°F (ca 87°C), d 1.40-1.42 at 77°F (25°C) and Moh’s hardness 1 to 2.

Large amt of asphalt used in the US is artifical. It is obtained as the residue from distillation of asphalitic and mixed base crude petroleum oils.

Another variety of artificial asphalt is one of the by-products of manuf of coal gas. This asphalt is the residue left in the retorts after removal from coal tar (by distillation) of aromatic hydrocarbons, phenols, cresols, etc.

The mixt of asphalt with sand and lime-stone used in roofing and for paving roads is commonly called “asphalt”.

The purest variety of natural bitumens is gilsonite or mineral rubber. It belongs to the group of asphalites. Gilsonite is easily distinguished from the other asphalts by its brown streak, lower d, fixed carbon and low sulfur content. Its d is 1.03-1.10 at 77°F (25°C), softening point (ring & ball) 270-400°F (132-204°C) and soly in CS2 > 98%. There are three commercial grades: “selects,” “seconds” (standard) and “jets” (Ref 3, p 166)

Uses: Asphalt is used for paving streets, surfacing floors & roofs; as an ingredient of paints, varnishes, cements; for impregnating...
belting material and as a bonding and waterproofing agent. Davis (Ref 1) lists uses of asphalt in some commercial pyrotechnic compns and Sutton (Ref 7), Warren (Ref 8) and Herrick & Burgess (Ref 9) describe uses of asphalt in rocket propellants. US military specification MIL-A-3029(1) deals with asphalt used in waterproofing fiber ammunition containers.

Powdered gilsonite has been used as a component of some US pyrotechnic and ignition compns.

The following requirements for gilsonite are given in specification JAN-A-356:

a) Granulation - through No 100 US Std Sieve 99% (min)

b) Sp gr at 25/25° 1.05 ± 0.05

c) Softening point 125° (min)

d) Mineral matter 1.0% (max)

e) Grit - none

f) Volatile matter 1.0% (max)

g) Reaction of water extract - alkaline to methyl orange

h) Solubility, %, min - in CCl₄ 99, in petr ether 30 and in CS₂ 99

For description of tests see the above specifications.


Asphalt-Perchlorate Castable Propellants

for use in JATO’s were developed at GALCIT (Guggenheim Aeronautical Laboratory, California Institute of Technology) and by Aerojet Corp, Azuza, Calif. The original propellant was called Galcit and it consisted of K perchlorate and asphalt.


Asphaltenes. See under Asphalt

Aspirin and Derivatives. See Acetylsalicylic Acid and Derivatives

Asplund Process of Pulping. See under Pulp and Pulping

Assisted Take-off (Units), abbreviated to ATO. This term usually refers to an auxiliary rocket engine specifically used for providing extra thrust to a heavily loaded aircraft during the take-off run and initial climb. It is generally understood that an ATO is a liquid propellant engine to distinguish it from RATO (rocket-assisted take-off) which is operated by a solid propellant. ATO and RATO are designed to operate only during take-off, and all or any part of power-plant system can be jettisoned after completion of take-off. The term JATO (jet-assisted take-off) was coined during the early part of WWII for a solid-propellant rocket power plant that would give assistance to the take-off of heavily-laden airplanes and seaplanes. The term JATO is discontinued in favor of RATO.
1.0 & paraffin oil 2.5% was used during WW as a filling for trench mortars and hand grenades (Ref 1)

According to Izzo (Ref 2) some Astralits were manufd in Italy by the Società Dinamite

According to Antonelli (Ref 4), the Ger Astralit IA contained AN 68.3, TNT 25.0, NG 4.0 & WM 2.7% and the corresponding Brit Astralit contained GC instead of WM


Astrodyne Synthetic Rubber Propellant, a solid rocket propellant made from synthetic gum stock mixed with AN in rubber-making machinery. After mixing, the material is extruded at low pressing into shapes with the desired cross section and then cured by heating for 3 days at ca 180°F


Astronautics or Space Travel (Astronavigatsia, in Russian) is the study of the physical possibilities of voyaging through space to other celestial bodies, including stars

The subject considered for many years as fiction, became a reality when the Russians launched their "Spootnik" in 1956

Although space travel is outside of the scope of our work, it would be appropriate to give a partial list of books on this subject:

1) N.A. Rynin et al "Mezhpianetniye Soobshcheniya (Astronavigatsia)," Gosizdat, vols 1-9 (1928-1939) (Vol 9 contains a comprehensive bibliography covering nearly every publication in any language up to 1931)

2) A. Ananoff, "L'Astronautique," Librairie Arthème Fayard, Paris (1949)

3) H.H. Koelle & H.J. Kaeppler, "Literature Index of Astronautics" (German & English), W. Pustet Verlag, Tittmoning (Bayern) (1954) (A recent bibliography on Astronautics)


5) A. Zaehriger, "Solid Propellants and Astronautics," 5th Congress International Astronautical Federation, Innsbruck, Austria, Aug 1955 & CA 49, 10627 (1955)

6) Willy Ley, "Rockets, Missiles and Space Travel," The Viking Press, NY (1957), 489-520 (An extensive bibliography in all languages on space travel)


9) A. Fritz, "Start in die dritte Dimension," Herold-Verlag, Stuttgart (1958)


12) E. Bialborski, "Raketen, Satelliten, Raumschiffe," Urania-Verlag, Leipzig (1958)


15) Russian Journals translated into English may be obtained from Consultant Bureau, Inc, New York 11, NY

AT. Rus abbrn for amatol

ATJ. A cast double-base propellant described in conf "Propellant Manual," SP1A/M2 (1959), Unit No 444

Atlas. One of the numerous US missiles


Atlas Dynamite, patented in 1883 by Kalk contained NG and, as an absorbent, a mixt of NC, NS, nitromamite and powdered glass

Ref: Daniel (1902), 32

Atlas Powder Company (APC), Wilmington, Delaware, was organized in 1912 to comply with the decree of US Federal Court dissolving the E.I. du Pont de Nemours Powder Co into three separate units: E.I. du Pont de Nemours & Co, Atlas Powder Co and Hercules Powder Co. The name "Atlas" was chosen to represent the brand of dynamite which had been assigned to the new Company

Ref: Van Gelder & Schlatter (1927), 211 & 465-78

Atlas Powders were blasting expls manufd
by the Atlas Powder Co before WWI. Some of these powders were used in building the Panama Canal.

Following are two examples of Atlas Powders given in Marshall 1 (1917), 364:

a) No 1: NG 61.1, wood pulp 14.1, KNO₃ 21.6, MgO (or CaCO₃) 3.0 & moisture 0.2%

b) No 2: NG 45.7, wood pulp 10.5, KNO₃ 40.9, CaCO₃ 1.9 & moisture 1.0%

Note: According to Mr. G. D. Clift, none of the Atlas Powders analyzed by him while working before WWI at the duPont laboratory, contained KNO₃, but only NaNO₃.

Atmospheric Pollution. See Air Pollution

ATN. A case double-base propellant described in Conf "Propellant Manual" SPIA/M2 (1959), Unio No 447

ATO. See Assisted Take-off

Atomic Ammunition. See Atomic Weapons and Ammunition

Atomic Artillery. See Atomic Weapons and Ammunition

Atomic (or Nuclear) Bomb.* A weapon invented during WWII and developed in the United States as a joint effort with the British and Canadian governments. It utilizes for its destructive effect the energy of an Atomic or Nuclear Explosion (qv). Since atomic explosions are of two types, fission and fusion, atomic bombs are of corresponding types. However, it has been necessary to first initiate an atomic explosion with a nuclear fission reaction in order to bring about the conditions under which a nuclear fusion(thermonuclear) reaction can occur. Thus a Fusion Bomb, (Hydrogen or H Bomb, a Thermonuclear Bomb) must contain means of initiating both types of atomic explosion.

The three bombs exploded during WWII — in the New Mexico desert on July 16, 1945, over Hiroshima on Aug 6, 1945, and over Nagasaki on Aug 9, 1945 — were all of the fission type and of tens of kiloton (thousands of tons of TNT equivalent) yield. Efforts since the war have had two aims. One is the development of fusion bombs. The first one was tested at Eniwetok in the spring of 1948. The bomb of several megaton (millions of tons of TNT equivalent) yield reported in 1955 seem to be of a three-stage fission-fusion-fission type. An ordinary fission bomb at the center is surrounded by lithium deuteride, the fusion component, which on initiation emits fast neutrons. These induce fission in the outer component, U238. Efforts are in progress to minimize or eliminate the fission reaction and thus produce a relatively "Clean" Bomb of fusion type, with reduced output of poisonous radioactive isotopes of extremely long half-life. Problems here are similar to those involved in the attempt to generate power for industrial purposes by fusion reactions. The second aim was the development of atomic (presumably fission) bombs of smaller size and yield, adaptable to missions of military units in the field, Atomic Artillery.

It is necessary, in the construction of an atomic bomb, to utilize the energy released by the nuclear reaction or reactions in such a way that an explosion of the desired yield takes place. This requires control, so that the explosion occurs when wanted and not before (usually obtained by keeping the fissionable material in units smaller than critical size) and then effecting a chain reaction which takes place so quickly that a large amt of material undergoes nuclear reaction before the bomb flies apart. The latter is done by bringing the parts together quickly, for instance by shooting one part as a projectile against the other part as a target. A suitable tamper of dense material can be used to delay the break-up.


3) H. Sabatier, MAF 20, 437-59 (1946) [Note sur la bombe-uranium]

4) A. K. Solomon, Fortune 33, No 5, 115-22, 173-4 & 176 (1946); CA 40, 6969 (1946) [Physics of the atomic bomb]

5) W. L. Lawrence, "Dawn over Zero; The Story of the Atomic Bomb," Knopf, NY (1947)

*Written by C. G. Dunkle


8) Encyclopaedia Britannica 2 (1952) 647A to 647D

9) G. Gili, Buenos Aires (1952), 197-213 (Bombas atómicas y explosiones de fisión nuclear)


(Other refs are given under Atomic Energy)

**Atomic (or Nuclear) Energy; Atomic (or Nuclear) Reactions; Atomic (or Nuclear) Explosions.** In chemical reactions the atomic nuclei maintain their charges, masses, and individual identities. These all change in atomic or nuclear reactions, first revealed in the discovery of radioactivity by Becquerel in 1895 and of radium by the Curies in 1898. The natural radioactive disintegrations evolved energies per atom almost a million times those evolved in chemical reactions, but resisted all attempts to change their rates or control them by any chemical means. Therefore physicists began bombarding various nuclei, first with alpha- and beta-particles and gamma rays from natural sources; and later with protons, deuterons, etc. from artificial sources. In 1939, discoveries made almost simultaneously by E. Fermi in Italy, by O. Hahn, F. Strassmann et al in Germany, the Joliotis and others in France, and J. Chadwick et al in England, gave a new dimension to nuclear research. Uranium nuclei, bombarded by neutrons, were found to split into two other nuclei of roughly equal masses, forming such pairs as Kr and Ba or Xe and Sr.

The energy of the process, about 200 mev (million electron volts) is out of all proportion to the energies of only 5 mev or so given by nuclear transmutations known up to that time. For comparison, since 23 kcal/mole or per gram atom is equivalent to only 1 ev (electron volt) per particle, a heat of explosion of 240-250 kcal/mole (TNT) is less than 11 ev per molecule.

The evolution of energy in a nuclear reaction follows from the Einstein relation between mass m and energy: $E = mc^2$ (where $E = $ energy in ergs, $m = $ the mass in grams and $c = $ velocity of light in cm/sec). The measured mass of a nucleus is not exactly the sum of the masses of the nucleons (protons and neutrons) present, but somewhat less. The small discrepancy represents the loss of mass due to the association or binding together of these particles. The energy equivalent to this loss, by the Einstein relation, is called the binding energy.

Nuclear forces between any two nucleons are very much alike, whether they are neutrons or protons, and arrangements contg equal numbers of each tend to be most stable in light nuclei. As the size and weight of the nucleus increase, however, Coulomb repulsion gains in relative importance because it falls off only with the square of the distance, much more slowly than the nuclear force. Thus, with increasing atomic weight the number of neutrons increases more and more, relative to the number of protons.

The binding energy per nucleon, if plotted against the mass number (total number of nucleons) of the nucleus, jumps sharply from its minimum of 1.0 mev for hydrogen, rises above 8.5 mev to a level stretch for mass numbers from 40 to 80, and then falls off slowly, dropping below 8.0 mev for mass numbers over 175. The atoms near the center of the sequence therefore have the largest binding energies and hence the greatest stability against nuclear disintegration. The lighter elements and the much heavier ones are less firmly bound aggregates of nucleons. Reactions which either convert heavy elements into those near the center of the

*Written by C.G.Dunkle*
A501

table by fission, or combine lighter nuclei to make heavier ones by fusion, evolve large amounts of energy. These are the two types of Nuclear Reactions applicable to production of Atomic Explosions

Three nuclei known to undergo fission are $^{235}$U, $^{238}$U and Pu. One of these on capturing a neutron can apparently oscillate violently and then, like an oversized raindrop, split into approximately equal halves along with smaller droplets or neutrons. The splitting is a statistical process rather than one that always occurs in the same way; sometimes one pair of product nuclei results and sometimes another; sometimes two neutrons are produced and sometimes three. A typical fission reaction producing two neutrons is:

$$^{235}\text{U} + n \rightarrow ^{92}\text{Pu} + ^{139}\text{La} + 3\text{n} + 17.6 \text{ mev}$$

(Subscripts indicate atomic number or positive charge on the nucleus, superscripts indicate mass number)

The product nuclei as initially formed are highly unstable isotopes and emit delayed neutrons as well as electrons and gamma photons while settling down into their stable configurations, which are usually isotopes of different elements from those first formed. The neutrons, both prompt and delayed, continue the reaction by encountering other fissionable nuclei.

Thus one neutron suffices to start the reaction while 2 or 3 are produced by it, and are available to initiate fissions of other nuclei. This makes a chain reaction possible, and in fact inevitable if neutrons are generated more rapidly than they escape or are otherwise lost, for any excess if present grows exponentially with extreme rapidity. Since the rate of escape depends on surface area and is thus proportional to the square of the length whereas the rate of production depends on the mass or volume and is thus proportional to the cube of the length, there is for each fissionable material a critical mass. Smaller masses remain unchanged, but if brought together quickly enough to form a mass exceeding the critical size, undergo the fission reaction at once. The initiating neutron can come from a cosmic ray or from an artificial source.

Fusion or thermonuclear reactions produce more energy than fission. Furthermore, the reactants are cheap and easily available, and the products are harmless and thus give hope for developing a "clean" nuclear bomb. Reactions of this general type supply the energy of the sun and other stars, where gravitational forces hold the reactants together despite temperatures of several million degrees K. Since strong Coulomb repulsion must be overcome for the nuclei to collide and hold together long enough to react, it is likely that the only reactions practically realizable on an industrial scale are those between nuclei having small charges, such as the following:

$$^1\text{D}^2 + ^1\text{D}^2 \rightarrow ^1\text{He}^4 + 3.2 \text{ mev}$$
$$^1\text{D}^2 + ^1\text{T}^3 \rightarrow ^1\text{He}^3 + ^1\text{H}^4 + 4.0 \text{ mev}$$
$$^1\text{D}^2 + ^1\text{T}^3 \rightarrow ^1\text{He}^4 + ^2\text{n} + 17.6 \text{ mev}$$
$$^1\text{H}^1 + ^3\text{Li}^7 \rightarrow ^4\text{Be}^7 + 17.2 \text{ mev}$$

Temperatures high enough to induce transitory fusion reaction can be reached with a fission reaction. Despite the short duration of the fusion, thermonuclear bombs have yields in the megaton (TNT equivalent) range as compared to kilotons from fission bombs. Problems involved in starting the fusion without a preliminary fission, or of holding the reactants together in a steady fusion reaction for power generation, have not been solved.

The fission reaction has been successfully applied to industrial power production; here the reaction is conducted not explosively, but in such a way as to provide a steady source of energy for power generation by conventional heat engines. This method is suitable also for large vehicles such as atomic energy submarines and atomic energy aircraft (See also Atomic Weapons and Ammunition).

Atomic or Nuclear Explosions evolve quantities of energy, per unit mass of reactant, from
a million to a billion times those available from chemical explosives. Therefore, the shock waves, although basically of the same nature as those from HE, have much higher pressures in the positive pulse, lower pressures in the negative phase, and much longer duration.

The atomic explosion not only produces high temperatures and a great shock wave but emits intense IR and UV radiation, with burning effects over several square miles, intense enough to char wood and cause third-degree burns. The heavy flux of neutrons emitted would suffice in itself to be deadly to individuals close to the explosion. The great amounts of gamma radiation can be deadly even to those who are some distance away from the explosion and indoors. Besides the radiation emitted at the instant of explosion, the blast scatters radioactive materials as fallout over wide areas, and much of it is carried hundreds of miles downwind. These materials decay, and this decay also yields radiation which is harmful. Alpha- and beta-particles emitted in the blast itself have only short ranges and present no problems, but those emitted by the fallout material make it a very serious hazard. They can do great damage if the material is breathed or ingested as dust, or introduced into wounds. Gamma radiation may also be dangerous over a wide area after the explosion.

In view of the foregoing, considerable study has been devoted to effects of nuclear blasts on houses, industrial structures, underground piping and vaults, and to design of blast-resistant construction. For both military and civil defense against nuclear as well as chemical and biological weapons, much effort has been applied to developing means of detecting nuclear radiations and other effects of these weapons, design and construction of fallout shelters, and other defense measures.


Atomic Explosions. See under Atomic Energy

Atomic Gun (A-Gun) Shell. See under Atomic Weapons and Ammunition

Atomic Reactions. See under Atomic Energy

Atomic Rifle (Dave Crockett). See under Atomic Weapons and Ammunition

Atomic Rockets. See under Atomic Weapons and Ammunition

Atomic Shell. See under Atomic Weapons and Ammunition

Atomic Submarine. See under Atomic Weapons and Ammunition

Atomic Weapons and Ammunition* are a natural consequence of the tremendous power and destructiveness of nuclear explosions. Atomic artillery has been developed by adaptation of the fission process to projectile warheads. Development of an atomic shell for the 280-mm gun was announced in 1953 in newspaper releases. The process has been adapted for local tactical application to smaller shell fired from guns of regulation caliber, though with some loss of efficiency in the use of the fissionable material. Development of an atomic rifle called the "Davy Crockett", a weapon for use by the foot soldier, was developed about 1958, according to newspaper reports. This weapon is sufficiently portable to be mounted on a jeep or carried by several men. The warhead has considerable destructive force but the effective radius is so small that infantrymen firing it will not be endangered by the blast. Danger from radioactive fallout is minimized

Atomic rockets are obtainable through application of the nuclear reaction to propulsion rather than explosion. In 1952, construction of a nuclear fission rocket within ten years was predicted. A small atomic pile would heat hydrogen to a temperature of several thousand degrees and expel it through a nozzle. A chunk of fissionable uranium would serve as the fuel and, because the only gas in the exhaust stream would be hydrogen, the lightest possible molecule, the thrust of a nuclear rocket would be very large. The specific impulse might be around 900 sec, from three to four times that available from the most powerful chemical rocket fuels

Energy from nuclear fusion might also be used for propelling jets and rockets. Formidable difficulties would be encountered, however. For reactions occurring at ca 10^8 K, such as those between the hydrogen isotopes, chamber pressures of around 100 atm could give rates of energy production comparable to those from the familiar chemical fuels. The rates would be much lower for heavier atoms, and increase with the square of the combustion pressure. The half-life of burnup in the most rapid reactions may drop to periods as short as those of chemical fuels. Despite the high temperatures, the radiated

*Written by C. G. Dunkle
energy can fall short of that produced, particu-
larly with an inefficiently radiating mate-
rial such as a gas like hydrogen which is
easily ionized completely.

On the other hand, the fraction of com-
pletely ionized particles in the gases under-
going nuclear combustion must not exceed a
certain upper limit because the correspon-
ding densities lie in the range of high vacua. Only
if a considerable proportion of the particles
remain un-ionized can the densities be kept
high enough to make chamber diameters of
several dozen meters sufficient. At tempe-
rances and pressures of interest here, the
mean free path is about $10^7 \text{ cm}$ in a fully
ionized plasma. Sänger discusses three types
of nuclear rocket propulsion: (1) direct ex-
pansion of the gases in a pure nuclear rocket,
(2) admixture of the gases with surrounding
air in turbojets, ramjets etc., or with other
gases in thermal atomic rockets, and (3) con-
version of energy into photon gas in the
photon rocket. He concludes the combustion
pressures available to attain the required
chamber loading in practice seem inadequate
for the last two methods, except possibly in
central power stations, marine propulsion
plants, or in pure nuclear rockets of very
large dimensions.

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pp 1-2 (Foot Soldier's Atomic Weapon Devel-
oped Here) (A photo and few words about the
weapon known as "Davy Crockett," developed
at Picatinny Arsenal ca 1958) (See
also Refs under Atomic Energy)

Atomization is the reduction of a substance
to very small particles often approaching the
size of atoms or molecules. In case of
liquids, atomization is done by spraying.
The same method may be applied to solids
when they melt without decomp. Spraying
may also be applied to solns of solids in
volatile liquids, such as acetone, alcohol,
etc. Solids may also be diminished to very
small size by the methods used for prep of
colloids such as by using a colloid mill
or a homogenizer, as described in Ref 1.
Another method for prep of small solid
particles is electric atomization, which is
achieved by passing an electric arc between
electrodes of pure metal in distilled water
contained in a vessel made of practically
insol material. This method produces a
stable colloidal soln of the metal used as
the electrodes (Ref 3)

Some atomized metals are used in expl
and pyrotechnic compns. The following US
specifications give tests and requirements
for such metals:
a) JAN-A-289 [Aluminum powder, flaked, grained or atomized (for use in ammunition)]
b) JAN-A-512 [Aluminum, powdered (grained or atomized) (from secondary metal)]
c) JAN-M-454 (Magnesium-aluminum alloy, powdered)
d) JAN-M-382A (Magnesium powder, for use in ammunition)
e) JAN-M-476A (Manganese, powder, for use manufactured by the Minerals & Chemicals Corp of America (Ref 1). It has been used as an anticaking agent for substances, such as AN (eg. Attaisorb 0.5, ZnO 0.2 and the rest AN) (Ref 2)


Atoxyl Acid. See p-Aminophenylarsonic Acid, p A245

ATT (Attenuated) Ballistite. A ballistite, claimed to be flashless, was made in France from a mixt of CP₃ (NC with ca 13% N) & CP₂ (NC with ca 12% N) treated with NG and a non-volatile solvent (Ref 2, p A259)

An improved variety, called superattenuated ballistite and used during WWII by the French and Italians, contained CP₁, CP₂, CP₃, NG 25 & DNT 15%. It was made without volatile solvent (Ref 1 & Ref 2, p 327)

Refs: 1) Pascal (1930), 227 2) Davis (1943), 259 & 327

Attaisorb. A light-weight, free-flowing, highly adsorptive powd derived from the mineral attapulgite, a hydrated Mg-Al silicate. It is manufd by the Minerals & Chemicals Corp of America (Ref 1). It has been used as an anticaking agent for substances, such as AN (eg. Attaisorb 0.5, ZnO 0.2 and the rest AN) (Ref 2)


Attenuated Ballistite. See ATT


Attenuation is, in most general sense, reduction in concentration, density, effectiveness, etc. It is also a general term for the decrease in amplitude of waves of various kinds as they progress

Attenuation of shock waves in air as a function of distance was detd by R.G. Stoner & W. Bleakney, J Appl Phys 19, 670-8 (1948) & CA 42, 8475 (1948). They measured the velocity of propagation produced on expln in air of chgs TNT or 50/50 Pentolite 1.45 to 8 lb (either spherical or cylindrical in shape) and then calc'd peak pressures by applying the velocity-pressure relation derived from the Rankine-Hugoniot equations

Attrition Mill is an apparatus containing two-sided knives which grind the material very fine by friction. Attrition mills are used at some expls plants, such as Wabash Ordnance Works. For drawings and description, see
A507

Perry (1950), pp 1123 (Fig 24) and 1143-4 (Figs 48 & 49)

ATX or NBSX. Code letters designating 1,7-Dinitroxy-2,4,6-trinitro-2,4,6-triazaheptane or 1,7-Dinitroxy-1,3,5,7-tetramethylene-2,4,6-trinitramine,
\[ O_2N-CH_2-N-CH_2-N-CH_2-N-CH_2-ONO_2 \]

See under 1,7-Dihydroxy-1,3,5,7-tetramethylene-2,4,6-triamine and Derivatives

ATZ. See Aminotetrazole and Derivatives

Audemars Explosives, patented in 1855 in England, were prep by nitrating purified barks of mulberry or of some other trees

Refs: 1) Cundill's Dictionary, MP 5, 288 (1892) 2) Daniel (1902), 33

Aufschlager, Gustav (1853-1934). Ger engineer specializing in expls. He established in 1882 the Dynamitfabrik Muldenhütten bei Freiberg in S and in 1884 the Dresdener Dynamitfabrik. Since 1889, he was the Generaldirektor of the Dynamit AG, Hamburg. Numerous publications on expls; one of the editors of the Zeitschrift für das gesamte Schiess- und Sprengstoffwesen, abbreviated in our work as SS

Refs: 1) Anon, Angew Chem 36, 65 (1923) 2) F. Ebeling, SS 28, 1-2 (1933) 3) P. Müller, SS 29, 127-8 (1934)

Augendre Powder, also called American Powder or White German Powder (Poudre blanche allemande or Teutonite, in Fr). The original mixt patented in France in 1849 contained KCIO₃, 48-50%, FeCy₄, 25-29%, & sugar 23-25%. It was intended as a replacement for black powder as a propellant, but proved to be too sensitive for this purpose. If found use, however, in primer compns and percussion caps. The modified compn: KCIO₃, 41.7, K,FeCy₄, 25.0, sulfur (or sugar) 20.8, & charcoal 12.5% was proposed for use in electric primers. Its modifications were also used in Germany


AUN. A cast double-base propellant described in conf “Propellant Manual,” SP1A/M2 (1959), Unit No 449

“Aunt Jemina” Explosive was a white powdery material developed in the US during WWII consisting of a mixt of flour with a white finely powdered HE which was not sufficiently toxic to hurt a person tasting it. The mixt was insensitive to handling and could be heated (baked) without explg it. It was intended to be shipped ostensibly as flour to neutral countries, where it could be used for purposes of sabotage

Ref: W. A. Noyes, “Chemistry” (Science in WWII, OSRD), Little, Brown & Co, Boston (1948), 51

AURAMINE AND DERIVATIVES

Auramine; Auraminebase or Tetramethyl-p₄-diaminoimidino-benzophenone (called in Beil 4,4’-Bis-dimethylamino-benzophenon), (CH₃)₂N-C₆H₄-C=N(H)-C₆H₄-N(CH₃)₂, mw 267.36, N 15.72%. Col lfts mp 136°, insol in w; sol in alc & eth. Can be prepd by treating its hydrochloride (see below) in aq alc with dil NaOH, as described in Ref 3, or by heating 4,4’-bis-dimethylamino-diphenylmethane with sulfur followed by treatment with ammonia (Ref 1, p 92)


Auramine Hydrochloride; Auramine O or Auramine of Commerce,

\((H_3C)_2N-\square-C-\square-N(CH_3)_2, H_2O\)

\(NH_2NH_2\) or

\((H_3C)_2N-\square-C-\square-N(CH_3)_2, H_2O\)

\(NH_2Cl\)

Yel powd; mp 267° for anhyd salt (Ref 2, p 3264); sol in alc; diffc sol in w. Can be prepd by heating tetramethyldiaminobenzophenone with NH₄Cl in presence of Zn (Ref 2)
Shidlovskii (Ref 5, pp 243-245) gives for Auramine O: mp 216-18°, d ~ 1.3, latent heat of vaporization 26.8 kcal/mol or 110 kcal/kg and vapor pressure 2.0 mm Hg at 260°. Its vapor is yel with a definite grn tinge. If it is desired to obtain a smoke of pure yel color, some Chrysoidine (brn dye) is mixed with Auramine O.

Auramine hydrochloride (Auramine O) in various colored smoke pyrotechnic comps. Davis (Ref 3) gives yel and green smoke-signal grenade comps used by the US planes during WWI and Izzo (Ref 4) gives yel and orange smoke comps used by the US CWS and by some European countries. Shidlovskii (Ref 5, p 252) lists several colored smoke comps contg Auramine O, which seem to be of Russian origin.

**TABLE**

Some US Smoke Compositions with Auramine O

<table>
<thead>
<tr>
<th>Comp</th>
<th>34</th>
<th>15</th>
<th>38.0</th>
<th>16.4</th>
<th>11.7</th>
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<tr>
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<td>33</td>
<td>24.4</td>
<td>25.9</td>
<td>25.9</td>
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<tr>
<td>NaHCO₃</td>
<td>--</td>
<td>--</td>
<td>28.5</td>
<td>23.0</td>
<td>24.0</td>
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<tr>
<td>Lactose</td>
<td>24</td>
<td>26</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Sulfur</td>
<td>9</td>
<td>--</td>
<td>2.1</td>
<td>10.1</td>
<td>10.3</td>
</tr>
<tr>
<td>Chrysoidine</td>
<td>9</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Indigo</td>
<td>26</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>a-Aminoanthraquinone</td>
<td>--</td>
<td>--</td>
<td>24.6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1,4-Di-p-toluidineanthraquinone</td>
<td>--</td>
<td>--</td>
<td>28.3</td>
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<td>--</td>
</tr>
<tr>
<td>Color of smoke</td>
<td>Yel</td>
<td>Grn</td>
<td>Yel</td>
<td>Grn</td>
<td>Grn</td>
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**TABLE**

Some European Smoke Compositions with Auramine O

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<th>Comp</th>
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<th>34</th>
<th>27</th>
<th>10</th>
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<tr>
<td>KCIO₃</td>
<td>30</td>
<td>34</td>
<td>33</td>
<td>34</td>
<td>30</td>
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<tr>
<td>Lactose</td>
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<td>25</td>
<td>24</td>
<td>25</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Chrysoidine</td>
<td>10</td>
<td>--</td>
<td>9</td>
<td>--</td>
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<tr>
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<td>--</td>
<td>14</td>
<td>20</td>
<td>26</td>
<td>--</td>
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<tr>
<td>Oxalate of malachite-green</td>
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<td>--</td>
<td>20</td>
<td>--</td>
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<td></td>
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<tr>
<td>Color of smoke</td>
<td>Yel</td>
<td>Yel</td>
<td>Yel</td>
<td>Grn</td>
<td>Grn</td>
<td>Grn</td>
</tr>
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</table>

**TABLE**

Some US Smoke Compositions with Auramine O

<table>
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<tr>
<th>Comp</th>
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<th>5</th>
<th>4</th>
<th>5</th>
<th>4</th>
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<tr>
<td>KCIO₃</td>
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<td>34</td>
<td>33</td>
<td>34</td>
<td>30</td>
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<tr>
<td>Lactose</td>
<td>20</td>
<td>25</td>
<td>24</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Chrysoidine</td>
<td>10</td>
<td>--</td>
<td>9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Indigo</td>
<td>--</td>
<td>--</td>
<td>14</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Oxalate of malachite-green</td>
<td>--</td>
<td>--</td>
<td>20</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Color of smoke</td>
<td>Yel</td>
<td>Yel</td>
<td>Yel</td>
<td>Grn</td>
<td>Grn</td>
</tr>
</tbody>
</table>

Methods of detection of auramine are described in Ref 6.


**Auramine, Azido-C₁₃H₁₉N₆ and Diazido-C₁₃H₁₉N₆ Derivatives** were not found in Beil or CA through 1956.

**Mono-, Di-, Tri- and Tetranitroauramines** were not found in Beil or CA through 1956.

**Auranti.** See 2,2',4,4',6,6'-Hexanitrodiphenylamine, Ammonium Salt, under Diphenylamine and Derivatives.

**AURINE AND DERIVATIVES**

Aurine; Corallin or 4,4'-Dihydroxyfuchson, called in CA 4-[Bis(p-hydroxyphenyl)methylene]-2,5-cyclohexadien-1-one and in Beil 4,4'-Dioxy-fuchson; Pararosolsäure or p-Chinon-mono-[bis-(4-oxy-phenyl)-metid],

Auramine hydrochloride intended for use in some US colored smoke comps must be tested according to specification MIL-A-3664 and comply with the following requirements:

a) Purity — not less than 86.0% when tested by both chemical and spectrophotometric analysis specified in 4.4.2
b) Moisture — not more than 3.5% when tested as specified in 4.4.3

c) Particle size — not less than 99% when tested as specified in 4.4.4

d) Apparent density — 0.35 ± 0.15 when tested as specified in 4.4.5

e) Performance. The material fired in yellow smoke grenades shall burn without flaming and shall emit a continuous cloud of yel smoke for a period of 70 ± 20 secs when tested as specified in 4.4.6. The smoke shall be distinguishable as to color against a contrasting color background, at a distance of 10000 ft on a clear day.
Aurine is used in small amount (ca. 0.25%) as a component of EC Propellant for Blank Cartridges and Fragmentation Hand Grenades. A gravimetric method of aurine determination in EC was established in 1883 under the name of Austin propellant, while a colorimetric method is given in US Military Standard MIL-STD-286A.

A historical discussion on the nomenclature of aurine is given in Beil (Ref 8). The items used during WWII were practically the same as used by the Germans. Some of the Austrian weapons were of WWI vintage, as for example: 47/32 mm Antitank Gun Boeler; 7.65 cm FK 5/8(ö); 7.65 cm FK 17(ö); 8 cm FK 18(ö); 10 cm IFH 14(ö); 10 cm IFH 14/37(ö) and 10 cm GebH 16(ö). No information about current items.

Abbreviations: F - Feld (field); Geb - Gebirg (mountain); H - Haubitze (howitzer); K - Kanone (cannon); L - leicht (light); (ö) - österreichisch (Austrian)

Austrian Propellants of WWI. Compositions of the following two propellants were determined in Russia by Dr M.M. Kostevich: a) NC (ca. 13.25% N) 42, NG 40; Ba nitrate 16 & vaselin 2%; b) NC (ca. 12.1% N) 67 NG 26 & vaselin with diethylphthalate and volatiles 7.0%.

Derivatives were not found in Beil or CA through 1956.

References:
1) Beil 8, 365 2) E. Ackermann, Ber 17, 1625-6 (1884) 3) No later data was found in Beil or CA through 1956.

Aurous Acetylide. See Gold Acetylides under Acetylides.

Aurum Fulminans or Aurum Tonitruans.
Old Latin names for Fulminating Gold (qv). German names, Knallgold and obsolete "Donnergewaltig Gold"; Or fulminant, in Fr

Austin Powder Co, Cleveland, Ohio was established in 1883 under the name of Austin Black Powder Mills by L. Austin (1817-1887) and his brothers (Ref 1). The plant manufactures mining explosives among them "Austin Red-D-Gel" (gelatinous permissible expl) and "Austin Red Diamond" (nongelatinous permissible expl) (Ref 2).

References:
1) Van Gelder & Schlatter (1927), 265 2) Bebe (1943), 30

Australian Ammunition, Explosives and Weapons. No information at our disposal.

Australian Warplants. No information.

Austrian Ammonal or Austrian Military Explosive. See under Ammonals.

Aurine Perchlorate, C₁₉H₄₁O₅ + HClO₄ + H₂O; red crystals, forming on prolonged heating an anhydrous salt. Was first prepared by Hofmann (Ref 2) by treating aurin in AcOH with concd HClO₄. It was also obtained by Pfeiffer (Ref 3).

References:
1) Beil 8, 671 & 418 2) K. A. Hofmann et al. Ber 43, 184 (1910) 3) P. Pfeiffer, Ann 412, 333 (1917)

Aurine, Azido- C₁₉H₃₃N₄O₃ and Diazido- C₁₉H₃₄N₂O₃ Derivatives were not found in Beil or CA through 1956.

Mono-, Di- and Trinitroaurines were not found in Beil or CA through 1956.

Tetranitroaurine, C₁₉H₁₀(NO₂)₄O₃, mw 470.30, N 11.91%; brownish microscopic needles; mp ca. 140° when carefully heated. It is a mild explosive, sol in alc, nearly insol in w, eth, chlf or benz. Was prepared by treating 1 part of powdered aurin with 4 parts of nitric acid (d 1.51) in the cold. The positions of the nitro groups are not given.

Its silver salt, C₁₉H₂(NO₃)₄O₃Ag is a mild explosive.
Austrian Warplants, Arsenals, etc. Dr W. J. Lohninger, formerly of Austria and now at Picatinny Arsenal, remembers the following war establishments operating in Austria during WWII: a) Govt Explosives and Ammunition Plant at Wollersdorf b) Govt Arsenal, Wien c) Govt Proving Ground Bruck und Leitha d) Govt Proving Ground Steinfeld (Wiener Neustadt) e) AG Dynamit Nobel, Wien, Plant at St Lambrecht f) Donnau Chemie AG, Moosbierbaum g) Eisenwerke Oberdonnaun, Linz h) Gebrüder Böhlér AG with Plants at Deutschendorf, Kopfenberg, St Egidy, St Marein, Waidhofen and Wien i) Krupp Metallware Werk, Berndorf (Wien) j) Metallwerke Plansee Reutte, Tyrol k) Nibelungenwerke, St Valentin l) Steyr-Daimler-Puch AG, Wien with Plants at Wien, Steyr, Linz and Graz.

No information at our disposal about the current war establishments.

**Authorized or Acceptable Explosives** are those which conform to certain regulations of transport, safety in handling, etc. They are to be distinguished from permissible (Brit permitted) expls. Both kinds authorized and permissible expls belong to the class of safety expls.

**Autoclaves** are thick-walled steel cylindrical vessels, designed to withstand very high pressures. They are used for prep of some products and for the study of reactions at high pressure and high temp. The contents of autoclaves may be agitated either by rocking the autoclave or by a mechanical agitator, such as turbine type, placed inside the autoclave. Heating or cooling may be accomplished by a jacket (with circulating liquid), by internal coils, or by electrical resistance wires (or strips).

**Autogenous Ignition; Autoignition; Self-...**
**A511**

ignition; Spontaneous Ignition. See under Ignition

Autoignition Temperatures of Organic and Inorganic Powders in Air was determined by D. Costa et al, Chimica e Industria(Milano), **34**, 645-54(1952); CA **47**, 12817(1953)

**Automatic Arms.** See under Automatic Weapons

**Automatic Computers and Calculators.** Computing mechanisms are of two distinct types: (a) arithmetical or digital computers and (b) continuously acting (geometrical) or analog computers that range from simplecams and levers to enormously complex devices. The latter have been used for the direction of naval and anti-aircraft gunfire (Ref 1, p 1), and both types of computers assist materially in ballistic and thermochemical calculations and other means of evaluating effects of propellants and explosives

Following is a partial list on automatic computing machines:

**Automatic Control.** See under Automation

**Automatic Feed Mechanism.** A mechanical arrangement in an automatic weapon which repeatedly inserts fresh cartridges in position for firing

Ref: Same as under Automatic Weapon(qv)

**Automatic (Self-Acting) Weapon.** A weapon that acts by itself without application of power from an outside source. This may be accomplished either by employing propellant gas pressure, or force of recoil and mechanical spring action for ejecting the empty cartridge case after the first shot, loading the next cartridge from the magazine, firing and ejecting this cartridge and repeating the above cycle as long as the firing mechanism is held in the proper position and there is ammunition in the magazine. Machine-gun, heavy and light are typical examples of automatic weapons

The semi-automatic is similar to the automatic but the trigger must be pulled for each round fired. Many automatic weapons are designed to permit semi-automatic fire

Besides machine-guns there exist automatic and semi-automatic small arms, such as machine-rifles and machine-pistols

The so-called contact mine belongs also to the class of automatic weapons

Refs: 1) Hayes(1938),630 2) M. M. Johnson, Jr & Ch. T. Haven, "Automatic Weapons, Their History, Development and Use," W. Morrow,
Automation; Automatic Control; Automatic Process Control. Automation is, according to definition given in Ref 19, the technique of improving human productivity in the processing of materials energy and information utilizing in various degrees, elements of automatic control and of automatically executed product programming. Automatic control consists, according to the definition given by Perry (Ref 6), of maintaining within limits, or altering in predetermined manner, the energy and sometimes the material balance of matter undergoing treatment in a process. The process is controlled automatically by measuring the state of a selected process variable, either continuously or at frequent intervals, and then correcting the input of energy or material to maintain the value of the variable within acceptable limits.

For more information on this subject, consult some of the following references:

Autopropulsion or Propulsion par réaction. French term indicating reaction engines carrying as a source of energy not only a combustible substance (carburant) but also an oxidizer (comburant). The fuels used in such engines are called propérgols and the devices that utilize the principles of autopropulsion are called "engins autopropulsés." The German weapon V-2 was driven by such a motor (See also Jet Propulsion and Reaction Motors). Refs (French): 1) P. Blanc, MAF 20, 877-1004 (1946) & 21, 885-1006 (1947) 2) J. J. Barré, MAF 22, 323-76 (1948) 3) J. Oudin, MAF 22, 379-412 (1948) 4) J. Fauveau, MP 31, 287-305
(1949) 5) P. Blanc, MAF 25, 103-16 (1951)
6) P. Carrière, MAF 25, 253-360 (1951)
7) E. Roth, MAF 30, 551-5 (1956)
8) H. Moreu, MAF 32, 405-35 (1958)

**Autooxidation** is a low-temperature oxidation of a substance (usually a liquid) by the atmosphere without the aid of other oxidizing agents, but requiring, in many cases, the presence of inductors for initiation of oxidation.

For detailed description of mechanism of autooxidation see Refs 1, 3, 5 & 6.

The process of autooxidation was used during WWII by the Germans for manufacture of some chemicals, among them hydrogen peroxide (Ref 2).

Evans (Ref 4) discussed expln hazards of autooxidized solvents.

Refs: 1) J. L. Bolland, Quarterly Revs 3, 1-21 (1949)
2) Kirk & Othmer 7 (1951), 735 and 9 (1952), 677
3) L. Bateman, Quarterly Revs 8, 147-67 (1954)
4) A. G. Evans, J Roy Inst Chem 80, 386-9 (1956)
5) H. E. De La Mare & W. A. Vaughan, J Chem Educ 34, 64-70 (1957)

**Autoxygen Company Process of Nitration.**

The Autoxygen Company of New York, NY, during WWII, proposed a method of nitration of substances which it claimed would eliminate the use of sulfuric acid, reduce the proportion of nitric acid to material nitrated, and eliminate the necessity for reworking spent acid.

In this process, the material to be nitrated is dissolved or suspended in an inert solvent which forms azotropes with water (such as petr eth, CCl₄, etc) and treated with conc nitric acid under such conditions that water formed during nitration is removed as an azo trope. Dilution of nitric acid is thus avoided. The azo trope which distills at the temperature of nitrated is cooled by condensation and the solvent minus the water is continuously returned to the nitrating vessel.

After the nitrination, the solvent is removed by distillation, leaving as residue the nitrated product plus unused nitric acid.

This method was investigated at PicArsn, Dover, NJ and found to have only a very limited application (Ref 1). The azeotropic method seems to be suitable for nitration of benzene (Ref 2).

**Autozone.** G. M. Schwab, Umschau 1922, 538-9

& CA 17, 468 (1923) coined this word for an isomer of ozone, which does not seem to exist. The word “autozone” could not be found in Mellor’s, Kirk & Othmer’s, Ulmann’s, Hackth’s, CondChemDictionary nor CA’s indices except the one referring to 17, p 468.

**AUV.** A cast double-base propellant. It is described in Conf “Propellants Manual,” SPIA/M2, (1959), Unit No 451.

**Auxoexplose or Auxoplosophore; Explosophore or Plosophere.** According to Lothrop & Handrick (Ref 3), Pletz (Ref 1) proposed the theory of *explosophores* and *auxoexplo ses* analogous to the Witt theory of chromophores & auxochromes and to the Ehrlich theory of toxophores and autoxides.

According to the Pletz theory the expl props of any given substance depend upon the presence of definite structural groupings called explosophores, while the auxoexploses modify or fortify the expl props brought about by explosophores.

On the basis of this theory, Pletz examined eleven classes of organic compounds and subdivided all expls into the following eight classes contg explosophores:

a) –NO₂ and –ONO₂ groups connected to inorg or org radicals [eg: HNO₃, C(NO₂)₂, C₆H₆(NO₂₂)₂ & C₆H₆(NO₂)₂]

b) –N=– and –N=N [eg: Pb(N₂)₂ & CH₄N₂]

c) –NX₂ group (eg: NCl₃ & RNCl₂).
d) C=N-group [e.g.: HONC & Hg(ONC)_2]  
e) -OCIO_4 & -OCIO groups [e.g.: KClO_4, KClO_3 and org chlorates and perchlorates]  
f) -O-O- & -O-O-O- groups [e.g.: peroxides & ozonides]  
g) -C=C-group [e.g.: acetylene or its derivs]  
h) A metal atom connected by an unstable bond to the carbon of certain org radicals [e.g.: org compds of Hg, Tl & Pb]  

While the arrangement of Pletz embraced the whole expl field in a purely empirical fashion the distinction between the terms explosophore and auxoexplose was not clearly defined. This was done later in the US, mostly under the direction of Dr A.H. Blatt as a wartime project. The object of this work has been the collation and classification of information through relationships which exist between org structure and the expl props of HE's which are of interest in military applications.

In the course of this work the term 'plosophile' was coined (Ref 2 & Ref 3, pp 423-4) for a group of atoms which on substitution into a hydrocarbon is capable of forming an expl compd. Inspection of the groups which can function in this way indicated that there are two classes of plosophores, differing sharply in effectiveness and consistency in producing power and hence they were called primary and secondary plosophores.

Primary plosophores include the following groups: nitrate ester, aromatic nitro, aliphatic nitro, and nitramines; while the secondary plosophores include the remainder, such as azo, azido, nitroso, peroxide, fulminate, chlorate, bromate, perchlorate, perbromate, etc groups.

It was also established that primary plosophores are responsible for high power and brisance of expls and these are at the maximum in compds whose oxygen balance to CO_2 (see under Available Oxygen) is favorable (close to zero). The relationship between power and oxygen balance vanishes when one considers secondary plosophores and further, with few exceptions, secondary plosophores do not, as a rule, exceed primary plosophores as power-producing groups. Although the secondary plosophores cannot be recommended in the synthesis of powerful HE's, they often impart desirable qualities of another kind, for example, in forming initiating expls [e.g. Pb(N_3)_2, Hg(ONC)_2].

When two or more different primary plosophores are present in a single molecule, the compd is called hybrid (e.g.: nitrate & aliphatic nitro, nitrate & aromatic nitro, nitramine & aromatic nitro). It was established that hybrids are as powerful (or more) as pure types, although they tend to exhibit somewhat greater variability. This property of hybrids is of importance, because it extends enormously the synthetic possibilities for expls.

A very common feature of many expls is the presence in them of a large variety of substituent groups which are not plosophoric, since they do not in themselves produce expl molecules, but which may be expected to alter the expl props in the same way as an auxochromic group is found to vary the intensity or shade of a dye. Such substituents are designated auxoplosive. To these belong hydroxyl, carbonyl, chloride, sulfide, ether, amino, etc groups. Very often their presence affects the oxygen balance favorably, but with hardly an exception auxoplosive groups are detrimental to power whether or not they improve oxygen balance. The chief justification for the presence of such groups in powerful expls is expedience in synthesis.


Auxoplosive Group, Same as Auxoexplose or Auxoexpophore

"Available Diphenylamine" is the total percentage of DPhA and derivs available for stabilization of NC propellants. The term is confined to the product obtained by the
soda-distillation method (see Available Stabilizer) and consists of residual DPhA of the propellant, plus the N-nitrosodiphenylamine, converted by the soda-distillation treatment to DPhA, and a small amt of 2-nitrodiphenylamine

Ref: E.F. Reese, private communication (1960)

Available Energy of Explosives. See under Power of Explosives

Available Ethyl Centralite. See under Available Stabilizer

Available HNO₃ in mixed acids is equal to actual nitric plus half the HNO₃ equivalent of the nitrogen oxides, calc'd as NO₃ (see also p. A81, under Acidity of Acids)

Available Oxygen; Active Oxygen; Effective Oxygen; Oxygen Balance to CO, and to CO₂. Available oxygen is oxygen which can be utilized as an oxidizer. The amount of such oxygen depends on the conditions of reaction. For instance, the amount of available oxygen in KMnO₄ is five for each 2KMnO₄ in an acidic medium and only three in an alkaline medium. Methods of determination of the available oxygen are given in Refs 1 & 5.

Active oxygen is oxygen which is generally liberated in the free state, especially in the presence of small amounts of alkali, heavy metals, etc. Such oxygen is found in all peroxo compounds. Two methods for determination of active oxygen in peroxides are given in Refs 2 & 3 (see also p. A101).

In many cases available and active oxygen are identical.

Oxygen balance to CO₂ (OB to CO₂) for an organic compound, is the percentage of oxygen required for complete conversion of the carbon to CO₂, the hydrogen to H₂O and the nitrogen to N₂. For any compound containing x atoms of C, y atoms of H, and z atoms of O, the OB to CO₂ = \(-\frac{1600(2x+y/2-z)}{\text{MolWt.}}\). Thus an explosive having perfect OB to CO₂ has zero balance (e.g., NGC), one lacking sufficient oxygen has a negative balance (e.g., TNT), and one containing excess oxygen has a positive balance (e.g., Amm nitroform). It is noted that with very few exceptions, explosives have decidedly negative OB to CO₂.

The above method of computation makes no distinction between oxygen already bound to carbon or hydrogen and that bound to nitrogen. The latter is termed in Ref 4, the effective oxygen. It differs from other explosives in that it is not yet reduced but is still available for combustion.

Oxygen balance to CO (OB to CO) of an organic compound, is the percentage of oxygen required for complete conversion of C to CO₂, H to H₂O, and N to N₂. It is calculated from the formula \(-\frac{1600(x+y/2-z)}{\text{MolWt.}}\). This calculation is required for compounds used or intended for use in propellants or in industrial explosives of low brisance, acting by heating action.

Refs: 1) W. W. Scott & N. H. Furman, "Stand-ard Methods of Chemical Analysis," Van Nostrand, NY (1939), 675 (The determination of available oxygen in metal peroxides is sometimes required on account of their use as oxidizing agents in various processes, such as the use of MnO₂ in the manufacture of chlorine from HCl. There are two methods for such analysis: a) Direct method consists of treating a weighed amount of a peroxide by a measured amount of a standard reducing agent, such as ferrous sulfate: MnO₂ + 2FeSO₄ + 2H₂SO₄ → MnSO₄ + Fe₂(SO₄)₃ + 2H₂O, followed by titration with standard KMnO₄ the excess of reducing agent. This gives the exact amount of reducing agent required by the peroxide. b) Indirect method consists of treating a peroxide with HCl and KI, followed by titration of liberated iodine with std thiosulfate: MnO₂ + 4HCl → MnCl₂ + 2H₂O + Cl₂; Cl₂ + 2KI → 2KCl + I₂; and I₂ + 2Na₂S₂O₃ → 2NaI + Na₂S₄O₆.

2) Lucidol Division, Novadel – Agene Corp., Buffalo, NY, Bulletin No 9 (1948) (Active oxygen in a peroxide is detd by treating its acetone solution with HCl and KI, followed by titration of liberated iodine with N/10 Na₂S₂O₃).

3) R. Cliegie et al., Ann 565, 16 (1949) (Active oxygen in a peroxide is
detd by adding it to a soln of NaI in glacial AcOH, previously freed from oxygen by bubbling pure CO₂ gas. After allowing to stand for 30 mins, the soln is dild with O₂-free water and the liberated iodine is titrated with N/10 Na₂S₂O₃. 4)W.G. Lothrop & G.R. Handrick, ChemRevs 44, 421(1949) (The relationship between performance and constitution of pure organic compounds)
5)H.H. Willard, N.H. Furman & C.E. Bricken, "Elements of Quantitative Analysis," Van Nostrand, NY(1956) 234-5 (Available oxyg in MnO₂ is detd by heating a sample in dil sulfuric acid soln with a known wt of Na oxalate until the dioxide has dissolved: MnO₂ + H₂C₂O₄ + 2H₂O → Mn²⁺ + 2CO₂ + 2H₂O. The excess of oxalate is then titrated with 0.1N KMnO₄ soln)

Available Stabilizer (Diphenylamine and/or Ethyl Centralite) in Aged or Stored Propellants is determined by Method 217.2(T) listed in specification MIL-STD-286. In this method, ca 5g sample of propellant (previously cut into small pieces as described in Method 509.3 of MIL-STD-286) is placed in a 1000 ml balloon flask contg 100 ml of distd w and 100 ml of 30% NaOH soln. After connecting the flask to a condenser, adapter, receiver (a 750 ml Erlen mfl contg 25 ml distd w), and a steam generator, the mixture is steam distilled until 350-400 ml of distillate is collected in the receiver. After adding to the contents of receiver 5g NaCl they are transferred to a separatory funnel where the stabilizers are extracted with ether.

If only DPhA or only Et centralite is present the ether is evaporated with a current of dry air and the contents of stabilizer detd by a standard volumetric bromination described in Method 201.1 (in case of DPhA) or in Method 202.2 (in case of Et Cent) of spec MIL-STD-286. If both stabilizers are present, their contents are detd by the volumetric bromination procedure described in Method 217.2(T) of spec MIL-STD-286.

Average Particle Size Measurements. See under Particle Size Measurements.

Aviation Gasoline-Explosive Characteristics of. Studies of the explosiveness of gasoline air mixts showed that: a) Ignition temps increased and expl press decreased as the fuel/air ratio varied towards the limits of flammability. b) Ign temp increased slightly and the expl press decreased as RH increased. c) Ign temp increased with increasing air vel & increasing altitude and the expl press decreased rapidly at alts above 20000 ft. d) Both ign temp and expl press decreased rapidly at low ambient temp.


Avigliana 3 or Nitramite. An ammonal-type expl contg AN 71-72, Al 22 & paraffin or pitch 7-6%.

Refs: 1) Allied & Enemy Explosives(1946), 84 2) Giua, Dizionario 2(1949), 165

Avigliana Dynamite Factory, located at Avigliana, near Torino, Italy is one of the largest and best equipped factories in Europe. It was founded in 1872. See Nobel Società Generale di Esplosivi e Munizioni (Nobel-SGEM) under Italian Warplants.

Axite. A Brit double-base smokeless, sporting propellant manufd by Kynoch Ltd. It is essentially Cordite MD II (GC 65, NG 30 & MJ 5%) to which 2% of K nitrate has been added (Ref 2). Marshall (Ref 1) gives its compn as: GC 63.1, NG 29.7, MJ with oil 5.1, K nitrate 1.9 & volatile matter 0.2%.

Refs: 1) Marshall 1 (1917), 308 2) Barnett (1919), 78

Az. Fr abbrn for azote (nitrogen)

Aza (Nomenclature). The name aza is now applied to hetero nitrogen atoms occurring in a ring. In this system of nomenclature a hetero oxygen is called oxa and sulfur thia. The compd commonly known as cyclonite,
RDX or cyclotrimethylenetetranitramine,
\[
\begin{align*}
H_2C-N(NO_2)-CH_3 \\
(O,N)N=\text{-}-N(NO_2)
\end{align*}
\]
may be called 1,3,5-trinitro-1,3,5-triazacyclohexane, and the compd known as cyclotetramethylenetetranitramine or HMX,
\[
\begin{align*}
H_2C-N(NO_2)=CH_2 \\
(O,N)N^7-N(NO_2), \\
H_2C-N(NO_2)-CH_3
\end{align*}
\]
may be called 1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane.

The aza nomenclature is also applied by some to linear nitrogen compds. For example, the compd,
\[
\begin{align*}
(O_2NO)CH_2CH_2(NO_2)CH_2CH_2(O-NO_2),
\end{align*}
\]
known as diethanolnitramine dinitrate (DINA),
may be called 1,5-dinitro-3-nitro-azapentane
and the compd,
\[
\begin{align*}
CH_3\cdot N\cdot CH_2\cdot CH_2\cdot N\cdot CH_3,
\end{align*}
\]
may be called 2,5-dinitro-2,5-diazahexane

Ref: 1) A.M. Patterson, JACS 55, 3912 (1933) 2) N. Jones & G.D. Thom, Can J Res 27B, 832 (footnote) (1949)

**Azacyclo-**. A prefix indicating the presence of a hetero nitrogen in a saturated carbon ring [See Aza (Nomenclature)]

3-Aza-4-oxa-2-hexene; 2,5,5-Trinitro or 2,4,4-Trinitro-3-aza-2-pentene 3-oxide,
\[
\begin{align*}
H_3C-C(NO_2)\text{-}N\cdot O\cdot C(\text{NO_2})\text{-}CH_3 \\
H_3C-C(NO_2)\text{-}N\cdot C(\text{NO_2})\text{-}CH_3
\end{align*}
\]
N 25.23%. Sl yel crystals, mp 121.2-121.6°. Was prep'd by Belew et al from ammonium 1-nitroethanenitronate and 1,1-dinitroethane and previous to this, it was prep'd by A.D. Little labs using aq K salt of 1,1-dinitroethane.

Its expl props were not investigated

Ref: 1) Beil - not found 2) J.S. Belew et al, JACS 77, 1112-13 (1955) & CA 50, 1648-9 (1956)

**AZAUROIC ACIDS**

Azauoric Acids are compds represented by the general formula ON-C(R):N-NH-C(R):NOH.

The following azauoric acids or their derivs might find application in the expl industry.

**Methylazauoric Acid,** ON-CH:N-NH-CH:NOH,
\[
\begin{align*}
w 116.08, N 48.277. Dk yel prisms (from methanol), mp ca. 138° with deton; sl sol in w or alc. Was first prep'd by Wieland & Hess (Refs 1 & 2) on passing bromine vapor through hydrazoformaldoxime suspended in cold w.
\end{align*}
\]

Its metallic salts are expl (Refs 1 & 2) especially the lead salt which was patented by Rathsburg (Ref 3) for use in detonators. The lead salt is more sensitive to friction than MF (Ref 4)


Note: No later refs through 1956 were found

**Ethylazauoric Acid,** ON-C(CH_3):N-NH-C(CH_3):NOH,
\[
\begin{align*}
w 144.14, N 38.877. Orn-red ndls (from methanol), mp 142° (dec); sl sol in w; appreciably sol in eth & in hot alc; nearly insol in chlor, benz & ligroin. Can be prepd by reducing ethyl nitrolic acid with sodium amalgam (Refs 1 & 2) or by other methods (Refs 1 & 3)
\end{align*}
\]

Its expl props were not investigated

Ref: 1) Beil 2, 192-3 2) J.S. Belew et al, JACS 77, 1112-13 (1955) & CA 50, 1648-9 (1956)
3) L. Semper & L. Lichtenstadt, Ann 400, 302 (1913) & CA 8, 63 (1914)

Azeotrope. A liq mixt which exhibits a max or min boiling point

Azeotropic Distillation. See under Azeotropy

Azeotropy (l'Azeotropisme, in Fr). Azeotropy may be defined as the capability of a liquid to form with other liquids, some mixts, which possess constant boiling points (max or min). An azeotropic mixt resembles a chemical individual in boiling without undergoing change in compn, but differs from it in losing this characteristic as soon as the pressure is altered.

According to Timmermans (Ref 2), M. Berthelot discovered in 1863 that some org liqs (such as pinene-ethanol) form const boiling point mixts, but this phenomenon was already observed for some inorganic liqs in about 1859 when H.E. Roscoe et al distilled some aq inorganic acids. Many azeotropic mixts were discovered since then in the 2nd half of the 19th and the beginning of the 20th century, but no industrial application was made until 1917, when the Germans started to manuf absolute ethanol by azeotropic distn.

After WW1 other European countries, than Germany, and also US started to use azeotropic distn in prep of abs ethanol, as well as of some other anhydrous substances (such as abs AcOH) and by the middle thirties the method became well established.

Azeotropic distn can be employed in the explosives industry as, for instance, for removal of water formed during nitration (See Autogen Company Nitration) and also for detn of water in various liquids (See under Aquametry).


Azete (Azacyclobutadiene or Pyriculine).

N=CH. This four-membered nitrogen-contg heterocyclic compd was reported to be obtained by Abderhalden & Paquin (Ref 2) according to Gensler (Ref 3) the cmpd obtd by A&P was not azete but probably allylamine.

Elderfield (Ref 4) lists azetidine, l-azetine and azetidinones as derivs of azete.


AZETIDINE AND DERIVATIVES

Azetidine (Trimethyleneimine or
Cyclotrimethyleneimine, \( \text{H N-CH}_3 \),
\[
\begin{array}{c}
\text{H} \\
\text{C-CH}_3
\end{array}
\]

mw 57.09, N 24.53%. Liq, bp 63° at 748 mm; miscible with w & alc. Was first described in 1888 (Ref 1,2&4), but was not isolated in pure state until 1899 (Refs 1,3&4). An improved method of prepn of azetidine is reported in Ref 5.


Azido-, \( \text{C}_3\text{H}_5\text{N}_4 \) and Diazido-, \( \text{C}_3\text{H}_5\text{N}_4 \)

Derivatives of Azetidine were not found in Beil or CA through 1956.

1-Nitrosoazetidine or N-Nitrosotrimethyleneimine, \( \text{ON-N-CH}_3 \), mw 86.09, N 32.54%. Lt yel oil; bp 196-7°; miscible w. Was prep by heating azetidine with \( \text{NaNO}_2 \) in dil AcOH. Its expl props were not examined.

Ref: 1)Beil 20, 3  2)C. C. Howard & W. W. Marchwald, Ber 32, 2035(1899).

Note: No later refs were found in CA through 1956.

Nitroazetidine, \( \text{C}_4\text{H}_6\text{N}_2\text{O}_2 \) — was not found in Beil or CA through 1956.

Dinitroazetidine or Dinitrottrimethyleneimine, \( \text{C}_4\text{H}_6\text{N}_2\text{O}_4 \), mw 147.09, N 28.57%. The following isomer is found in the literature:

3,3-Dinitroazetidine, \( \text{H N-CH} \),
\[
\begin{array}{c}
\text{H} \\
\text{C-C(NO}_2)_2
\end{array}
\]

N 28.57%; was obtained from 2,2-dinitro-1,3-propanediol and aq ammonia.


2-Azetidinone (2-Ketotrimethyleneimine),

\( \text{HN-CO} ; 2,4\)-Azetidinedione, \( \text{HN-CO} \)
\[
\begin{array}{c}
\text{H}_2\text{C-C}_3 \\
\text{OC-CH}_3
\end{array}
\]

and 1-Azetine, \( \text{N=CH} \) are derivs of azete
\[
\begin{array}{c}
\text{H}_2\text{C-C}_3
\end{array}
\]

and are known only in the form of derivs.

AZIDES, INORGANIC

Azides: Trinitrides or Triazoates (formerly called Azomides) are the salts of hydrazoic acid, HN₃. This acid is a little stronger than acetic acid. The −N₃ radical in HN₃ resembles the chloride ion (Cl⁻) in its chemical behavior. Hydrazoic acid was first prep'd by Curtius (Ref 1) by the reaction of nitrous acid with hydrazine. For addnl info see Hydrazoic Acid. Azides may be divided into two main classes: inorganic and organic. The org azides and the complex azide compds are listed under their indivdl names as given in CA. Inorg azides are described below.

Due to their extreme sensitivity only a few azides are suitable for use in the expl industry (Ref 3). The prep'n and props of most known azides are described in the general Refs 2,4,5,6,8,9,10,11,12,14,15,17,18,19,25 &27; their structure and stability (Refs 13, 14a,25&26); their sensitivity to initiation by impact and heat (Refs 7,8,20&21); their thermochemistry (Refs 23&24); the theory of decomn (Refs 16&16a); Raman spectra (Ref 18a); and their analytical determn (Ref 22) are described in the references indicated.

LIST OF INORGANIC AZIDES

**Aluminum Triazide** (formerly called Aluminum Azoidide) \( \text{Al}(N_3)_3 \), mw 153.04, N 82.38%; Wh crys, sol in tetrahydrofuran, insol in eth or benz, hydrolyzed by w (Ref 3). Prep'd in quant yield by adding an eth soln of excess \( \text{HN}_3 \) to a frozen ether soln of \( \text{AlH}_3 \) and thawing (Ref 3).

A tetrahydrofuran soln of \( \text{Al}(N_3)_3 \) is prepd by other props given in Ref 7). Amm azide was reaction of \( \text{AICI}_3 \) and \( \text{NaN}_3 \) in benz, and ex- first prepd in 1890 by Curtius (Ref 1) by the extraction with tetrahydrofuran. When the tetrahydrofuran soln of \( \text{Al}(N_3)_3 \) was boiled under reflux with phenyl cyanide for 25 hrs, the product after decompn with \( \text{HCl} \) gave 76.5% yield of 5-phenyltetrazole (qv). Reaction of "nascent" \( \text{Al}(N_3)_3 \), with phenyl cyanide gave an almost quant yield. Similar reaction of the "nascent" azide with thioacetamide gave 55% yield of 5-methyltetrazole and a 65% yield of penta-methylenetetrazole (Cardiazole) from thio-caprolactam (Ref 3). According to Mellor (Ref 2) when a soln of ammonia-alum is treated with an alkaline azide, \( \text{Al(OH)}_3 \) is pptd and not \( \text{Al}(N_3)_3 \) (Ref 1). \( \text{Al}(N_3)_3 \) is sensitive to percussion and deceptitates in a flame (Ref 3).

See also **Methylaluminum Diazide** \( [\text{CH}_3 \text{Al}(N_3)_2] \) which reacts with sulfuric acid, occasionally igniting with expln.


**Ammonium Azide** (formerly called Ammonium Trinitride or Ammonium Azoidide), \( \text{NH}_4N_3 \), mw 60.06, N 93.29%; col, nonhygr, rhmb plates; mp expl 160° (Ref 5), starts to sublime at 133-4°, bp expl above temp limit for slow decompn ca 300°, d 1.346 at 20°, \( Q_f \) -26.0 kcal/mol (Refs 17&21) \( Q_f \approx 19 \) kcal/mol (Ref 9) \( Q_P \) or \( v \) approx 98 kcal/mol (Ref 6) & \( Q_e \) 31.2 kcal/mol (Refs 6&9); sol in w, sl sol in alc or \( \text{NH}_4\text{OH} \), insol in eth. It forms with ammonia a diamonate \( \text{NH}_3N_3.2\text{NH}_3 \), in clear, col elongated plates, which is stable at -33°, unstable at 0° and undergoes transition at -9° (Ref 7). One g liq \( \text{NH}_3 \) dissolves 0.7 g Amm azide at -33° and 1 g at 0° (Ref 7), forms a eutectic with \( \text{NH}_3 \) at -87° and 76% \( \text{NH}_3 \) concn (Ref 14). Addnl soly data and other props given in Ref 7). Amm azide was first prep'd in 1890 by Curtius (Ref 1) by the action of \( \text{NH}_3 \) on hydrazoic acid. Detailed descrpns of methods of prepn can be found in Refs 4,10,11,13,15,16&18.

While it sublimes below 250° at press 0 to 150 mm Hg, it shows slow decompn between 250-450° at 70 mm and betw 250°-310° at 150 mm. Amm azide is one of the more stable azides (Ref 20). According to Gray & Waddington it vaporizes and dissociates into \( \text{NH}_3 \) & \( \text{HN}_3 \) and then the \( \text{HN}_3 \) explodes. A hot wire causes Amm azide to burn quietly in air rather than detonate (Ref 20). This azide detonates violently when properly initiated, heated rapidly or heated under confinement (Refs 2 & 10). Temp of expln is 1400° and specific energy 7102 kg/l (Ref 9). It is considered a non-brisant expl as it decomposes occasionally igniting with expln. Infrared spectra studies of solid Amm azide are presented by Dows et al (Ref 19a) and the crys structure detd by Frelve (Ref 17a).

By mixing ammonium azide and hydro-chloroplatinic acid and concg the soln by evapn, a very expl residue was obtained (Ref 10, p 355)

**Ammonium Azide Ammonates.** Ammonium azide forms with ammonia addition products:

a) **Monoammonate**, \( \text{NH}_4N_3\cdot\text{NH}_3 \), its existence was established from a study of the system ammonium azide-ammonia (Refs 7&8) b) **Diammonate**, \( \text{NH}_4N_3\cdot2\text{NH}_3 \), clear, col elongated plates stable at -33°, but incapable of existence at 0° (Ref 7) c) **Tetrammonate**,
NH₄N₃·4NH₃, found to exist at low temp (Refs 8 & 12) and d) Pentammonate, NH₄N₃·5NH₃, which crystallizes which undergoes transition into the diammonate at −71°, with the eutectic located at −67° and 76% ammonia (Ref 14).

The expl props of these solvates have not been studied. See discussion under Hydrazine Azide.


Note: N.W.Luft, IndChemist 31, 502-4(1955) & CA 50, 5388(1955), gives latent heat of sublimation at 25° 38.9 kcal/mole

Ammono-basic Mercurelazid. See under Mercuric Azide
Ammono-basic Ferric Azide. See under Ferric Azide
Ammono-basic Nickel Azide. See under Nickel Azide

Antimony Triazide (formerly called Antimony Trinitride), Sb(N₃)₃, mw 247.83, N 50.87%; yel solid which exploded on heating. Was obtained by Browne et al using an antimony anode in the electrolysis of a soln of ammonium azide in liq NH₄ at −67° (Refs 3 & 5). An electrical discharge through a mix of N₃ and Sb vapors results in the formation of antimony nitrile, SbN, which when heated decomp with a mild expln (Ref 2). The nitride prepn and props are also discussed in Refs 6, 7, 8 & 9. SbN is extremely sensitive to moisture and decomp on being heated to 550° (Refs 6 & 10) [Also see Refs 1 & 4 for unsuccessful efforts to isolate Sb(N₃)₃].


Arsenic Triazide, As(N₃)₃, mw 327.05, N 62.73%; prepn attempted by Vournazos (Ref 1) by reacting Na azide with As tribromide: 3NaN₃ + AsBr₃ = 3NaBr + As(N₃)₃, but he obtained instead wh needles of the complex sodium arsenic bromoazide, Na₃[AsBr₃(N₃)₃], in methyl alc soln (Ref 2).

There are no expl props given in the literature.

Refs: 1) A.C. Vournazos, ZAnorgChem 164, 264(1927) & CA 21, 3841(1927) 2) Melior 8(1928), 337
Barium Diazide (formerly called Barium Trinitride), Ba(N\(_3\)), mw 243.43 N 51.79%;
wh monoclinic prisms, mp expl at 150° (Ref 16), ignites 190-200° (Ref 11), d 2.936, Q\(_{\text{soln}}\) at 19.8° ~7.8 kcal/mol (Ref 2), Q\(_f\) 5.32 kcal/mol (Ref 27), enthalpy of formation, free energy and entropy (Ref 27); very sol in w (12.5% at 0°, 16.2% at 10.5°, 16.7% at 15° and 17.3% at 17°), v sl sol in alc (0.017% at 16°), insol in eth (Refs 3 & 10). The toxicity is discussed by Sax (Ref 28) and is considered very sl (Ref 19). First prepd in 1890 by Curtius (Ref 1) by neutralizing pure hydrazoic acid with Ba hydroxide soln. This method of prepn is also described by Audrieth (Ref 12) and in Refs 4 & 18. Can also be prepd by the action of hydrazoic acid on Ba oxide or carbonate (Ref 10). When evap over sulfuric acid, crystals of monohydrate barium azide, Ba(N\(_3\))\(_2\)\(\cdot\)H\(_2\)O, are formed which have a mean idex of refraction of 1.7 (Ref 4). A safe, semi-industrial method has been developed for the production of Ba(N\(_3\))\(_2\) using ethyl nitrite, Ba(OH)\(_2\) and hydrazine hydrate (yield 44-55%) (Ref 19). An alternative method consists of treating Ba(ClO\(_2\))\(_2\) with an equimolar quant of KN\(_3\), yielding 80% Ba azide (Refs 10a & 19).

Ba azide is not as powerful an expl as Ca azide, but it is nearly as powerful as Sr azide. According to Curtius and Rissoin (Ref 3), Ba azide does not expl by percuss and behaves on a hot plate like Ca azide. In a capillary it expl at 217-221°, and at about 180° metallic Ba is present. Tiede (Ref 6) observed that in vacuo, Ba azide begins to decom at 120° and evolves N\(_2\) at 160°. Hitch (Ref 8) noted that Ba azide undergoes no change until 180° when N\(_2\) is evolved; at 225° the salt explodes. Wöhler and Martin gave 152° as the temp at which the salt expl (Ref 7).

The thermal decomp of solid Ba azide was studied by Gynuter et al (Ref 14) and by Yoffe (Ref 18a), the former investigators reporting a heat of decomp of 13.7 kcal. They supposed that expln occurs as a result of another primary reaction with the formation of nitride or of a strong exothermal reaction between the primary products of decomp (See also Ref 25). According to Ryabinin (Ref 17) to achieve decomp of a thin tablet of Ba (N\(_3\))\(_2\) within 3 min at atm press, a temp of 170° is required. This temp rises with the press on the tablet: at 2000 kg/cm\(^2\) it is ca 210°, at 10,000 kg/cm\(^2\) ca 225° and at 45,000 kg/cm\(^2\) ca 235°. Garner & Reeves (Ref 26) found that the thermal decomp of Ba(N\(_3\))\(_2\) obeys a 6th power law, whereas, Ca(N\(_3\))\(_2\) and Sr(N\(_3\))\(_2\) obey a 3-rd power law. The mechanism of the thermal decomp of unirradiated and of briefly preirradiated Ba azide was postulated by Mott (Ref 13) and in Refs 4 & 18. Can also be studied by Thomas, & Tompkins (Ref 20).

The thermal decomp of solid metallic azides found that all salts obeyed the equation: log k = \(-\frac{E}{2.303RT}\) in which, for Ba azide, log A = -5.99 and E = 11.6 kcal/mol in the temp range 295 to 380°K. According to Ebler (Ref 5) Ba azide is not decompd by exposure to radium. Gyunter et al (Ref 15) also found that, unlike other azides, Ba azide is not decomd by X-rays of radium. X-rays of less than 0.7 A\(^0\) also have no ef- efect while soft X-rays produce a weak blue fluorescence. By using a Hadding tube, Gyunter et al, decomd approx 6% of Ba(N\(_3\))\(_2\) with more than half of the decomp product appearing as nitride. This fact was connected with the impact sensitivity of Ba azide. Groocock & Tompkins (Ref 24) described a technique for studying the effects of pre-irradiation and of prolonged bombardment with 100 and 200 V electrons on Ba azide at RT.

The expl props of Ba azide were studied by Ficheroncle & Kovache (Ref 19) who found that this salt detond 14% of the time with a 2 kg wt at a height of 100 cm. It is extremely sensitive to friction. When laid in a train it
does not behave like a primary expl, but large quantities deflagrate violently and lead to explosion. According to Haid et al (Ref 11) dry Ba azide may be safely transported in cardboard boxes in quantities up to 500 g, but with a water content of 10%, larger quants of it can be transported without danger.

The spectra of Ba azide were photographed by Petrikaln (Ref 9) who observed not only triplet lines but also that those of the singlet system were emitted. In addition the oxide bands of the molecule were present in all spectra of the azides of Ca, Sr and Zn. For Raman Effect of the cryst Ba azide see Ref 17a

Ba azide has not been used as an expl, but it has been used in the manuf of fluorescent lamps and radio tubes (Ref 12a & 19). It has also found use as a blowing agent during vulcanization of cellular rubber (Ref 22). The expl reaction of Ba azide is prevented by adding gelatin, machine oil or Neugen (poly-ethylene glycol laurate) Garner & J.F.R. Crooks, ProcRoySoc 233A, 267-82(1954) & CA 48, 8059(1954)

References:


Beryllium Diazoide (formerly called Beryllium Trinitride), Be(N₃)₂ mw 93.07, N 90.31%; wh solid, soln in tetrahydrofuran, insol in eth and easily hydrolyzed by w (Ref 1). Obtained by Wiberg & Michaud (Ref 4) when MeBe was sublimed and reacted with a dry eth soln of excess HN₃ at -116°. Removal of eth and excess HN₃ by vac distn yielded Be(N₃)₂. In a reactn betw a beryllium salt and an azide, Curtius & Rissom (Refs 1 & 2) obtb an impure beryllium azide; it detonated only sl in a flame and is insensitive to initiation by percussion (Ref 3)

References:

1) T. Curtius & J. Rissom, JPraktChem 58, 277(1898) & JCS 76 II, 92(1899) 2) Meller 8(1928), 350 3) Gmelin, System No 26
Bis (Hydroxylamino) Azide (called Dihydroxyl-Ammonium Trinitride by Dennis & Isham), (NH₂OH)₂·HN₃, mw 109.10, N 64.20%; col, trans, leaf-like crysts, mp 66°; v sol in w, sol in alc and insol in eth. This compd was prepd in 1906 by Dennis & Isham (Ref 1) upon evapng a mixt of hydroxylamine and hydrazoic acid, both in methyl alc solns. The recovered crysts were purified by dissolving in a mixt of 1 g methyl alc and 20 p ether, filtering and rapidly evapng the solvent in a vacuum desiccator (See also Ref 2). No expl props were determined (Also see Hydrazoic Acid).

Refs: 1)L.M.Dennis & H.Isham, JACS 29, 22-4(1907) & CA 1, 528(1907) 2)L.F.Audrieth, ChemRevs 15, 200-202(1934) & CA 29, 700 (1935)

Bismuth Triazide, Bi(N₃)₃, mw 335.07, N 37.63%. The prepn of this compd was attempted by Vournazos (Ref 1) who treated Bi iodide with an equimolar part of Na azide. The following reaction occurred: 2 Bi I₃ + 2 NaN₃ + H₂O = BiOI + BiI₄ + 2HN₃ + 2NaI and with twice this amt of Na azide: BiI₄ + 2NaN₃ + H₂O = BiOI + 2NaI + 2HN₃. It was thought by Vournazos that an unstable bismuth iodo-diazide, Bi I(N₃), was formed but immediately hydrolyzed (Ref 2)

Refs: 1)A.C.Vournazos, ZAnorgChem 164, 263(1927) 2)Mellor 8 (1928), 337

Boron Triazide, B(N₃)₃, mw 136.89, N 92.10%; wh hex crysts, sol in tetrahydrofuran insol in eth; prepd by Wiberg and Michaud (Ref 1) by the addn of diborane to a frozen eth soln of excess HN₃ at -20° and thawing at RT. The residue was isolated by distn at -65° to -45° for 4½ hrs. B(N₃)₃ is extremely explosive and deton with water or eth vapor, but it can be stabilized as NaB(N₃)₄ by reaction of an eth soln of excess B(N₃)₃ and NaN₃. Upon addn of an eth soln of Me₃N to B(N₃)₃, the partial azides, BH(N₃)₂ and BH₂N₃, form stable addn compds

Bromine Azide (Bromoazide), BrN₃, mw 121.94, N 34.45%; orange-red liq, fr p-45°; bp expl, misc in all proportions with eth, less sol in benz or ligroin (Refs 2 & 3). Prepd by Spencer (Ref 1) by passing a stream of bromine, di-luted with N₂, over Na or Ag azide and condensing the resulting liq bromoazide. It may be prepd also by heating NaN₃ or AgN₃ with a soln of bromine in eth, benz or ligroin (Refs 1&3)

Bromoazide is a very powerful expl compd and extremely sensitive to heat and to mechanical shock. Eth, benzene or ligroin solns of BrN₃ are stable in the dark, but when concd, they are likely to expl on shaking, and gradually decompose on standing. In general, BrN₃ resembles N₂ but is more volatile and is immediately decompd by water. The only evidence for the existence of BrN₃ in aq soln was the formation of a little HN₃ with consequent diminution of free N₂ (Ref 1). The liq BrN₃ expl in contact with P, As, Na and Ag foil, but the vapor, when diluted with N₂ and passed over Ag or Na leaf, gives a film of the corresponding azide and bromine (Ref 2)

Bromoazide gives a pungent vapor which
irritates the eyes. It has toxicological props similar to hydroazodic acid, causing giddiness, headache, and slakening of the muscles when inhaled (Ref 6). It is dangerous, when heated, emitting highly toxic fumes of bromine and explodes. Reacts with water or steam to produce toxic or corrosive fumes, and it can react on contact with reducing materials (Ref 6).


Cadmium Diazide Cd(N₃)₂, mw 196.46, N 42.78%; wh biaxial crysts, mp expln 291° (Ref 3); d 3.24 at 20° (Ref 12), Qₑ 558-625 cal/g (Refs 2 & 4); sol in water and is hygroscopic. First prepd by Curtius & Rissom (Ref 1) by dissolving CdCO₃ in 16-17% hydrazoic acid, and by Brown et al (Ref 5) by electrolysing solns of Amm azide in liq NH₃ using a cadmium anode. Birckenbach (Ref 10) prepd the pure compd by the method of Curtius & Rissom and Bassiere from a mixt of solns of Cd(NO₃)₂ and NaN₃ by evapn in cold over H₂SO₄, after removal by filtration of the first ppt formed (Ref 12). The usual method of prepn is by the action of hydrazoic acid on CdO or CdCO₃ (Refs 1, 7, 8, 9 & 11).

Cd(N₃)₂ is an extremely sensitive and dangerous expl which detonates on heating or on rubbing with a horn spatula (Ref 10). Thermal decompn in high vac between 100 and 120° leads to the reaction 3Cd(N₃)₂ = Cd₃N₆ + 8N₂. Wöhler and Martin reported the following expl props: Impact Sensitivity by 0.964 kg falling wt on 0.01 to 0.02 g. compressed sample reqd energy of 18.54 kg m/cm² vs 4.76 kg m/cm² for LA under 0.600 kg impact on same sample wt (Ref 3); Loading Density at 1100 kg/cm³ = 3.200 g/cc (Ref 4); Minimum Initiating Charge: required for tetryl 0.01 g, for PA 0.02 g, for TNT 0.04 g and for TNA 0.10 g (Ref 4); Temperature on Explosion 3829° (Ref 4) and Work Density (an approx measure of deton value) 116.8 kg/cm³ (Ref 4).

According to Wöhler (Ref 6), Cd azide is much more powerful than LA but is more difficult to prepare because of its high soln in water (Ref 13).

The cryst structure of Cd(N₃)₂ was studied by Bassiere (Ref 12). Bowden and Singh (Refs 14 & 15) studied the effects of irradiation and nuclear bombardment on Cd(N₃)₂ crysts. They observed no ignition or detonation due to bombardment with slow neutrons, fission products, α-particles or γ-particles. Irradiation with intense electron beams by X-rays, Hydrogen, Argon or Mercury-ions led to expls which proved thermal in origin. The critical thickness for thermal initiation and growth of Cd(N₃)₂ is 24µ at 320°, 201 at 325° and 17µ at 330° (Ref 15). According to Bowden and Singh, neutron bombardment of Cd(N₃)₂ does not affect its rate of deton, given as 4200 m/sec (Ref 15).

Cd(N₃)₂ in aq soln, forms with pyridine a col, crystall compd, Cd(N₃)₂·2C₄H₄N₂ (Ref 1). Other complex salts described in Ref 13a using a cadmium anode. Birckenbach (Ref 10) (See also Table A under Ammines) prepd the pure compd by the method of Curtius & Rissom and Bassiere from a mixt of solns of Cd(NO₃)₂ and NaN₃ by evapn in cold over H₂SO₄, after removal by filtration of the first ppt formed (Ref 12). The usual method of prepn is by the action of hydrazoic acid on CdO or CdCO₃ (Refs 1, 7, 8, 9 & 11).

Calcium Diazide (formerly called Calcium Trinitride), Ca(N₃)₂, mw 124.13, N 67.71; col, rhomb ndls (Ref 2); mp dec 100° (in vacuo); N₂ evolved at 110° (Refs 2, 3 & 15) expl 158° (Refs 5 & 11) Qₑ 625 cal/g (Ref 4), Qₑ -11.0 k cal/mol (Ref 20) sol in W (38.1% at 0° & Chem 37, 610-8(1926) & CA 20, 2791(1926) 45% at 15.20), v sl sol in alc (0.211% at 16°) & insol in eth (Ref 1). Its toxicity is discussed by Sax (Ref 21) under azides.

Ca(N₃)₂ was first prepd in 1898 by Dennis & Benedict (Ref 2) and by Curtius & Rissom (Ref 1) by dissolving calcium oxide or carbonate in dil aq HN₃ and concg the filtrate by evapng (Refs 7 & 9)

Ca(N₃)₂ expl between 144-156°. Heated in a capillary tube, metallic Ca appears at 120-130° (Ref 11) and in vacuo expl between 160-170° (Ref 14). The kinetics of the thermal decompn has been studied by Andreev (Ref 10), Garner & Reeves (Ref 19) and others; ionic conductance of the solid by Jacobs & Tompkins (Ref 18) in the temp range 290-370°K, and initiation and propogation of expln by Bowden & Williams (Ref 16) who measured the rate of deton as 770 m/sec. Haid et al (Ref 8) ignited Ca(N₃)₂ by rubbing a small sample in a mortar and in the Lead Block Expansion test obtained a value of 120 ml

The spectra of calcium azide explns were photographed by Petrikaln (Ref 6) and the Raman Effect studied by Kahovec & Kohlrausch (Ref 13)

Ca(N₃)₂, as well as Ba(N₃)₂ or NaN₃, has been recommended as a cellulating agent in dihydrazinate in N₂ at 100° and its chem identity established by means of press-concn and press-temp curves (Refs 1 & 2). No references to expl props found.

Calcium Diazide Monohydrazinate (formerly called Calcium Trinitride Hydrazinate), Ca(N₃)₂·N₂H₄, mw 154.16, N 72.69; wh, fluffy pwd, mp dec at 120° (losing hydrazine); bp expl violently at 308°; v sol in w. Prepd by the gradual dehydrazination of Ca diazide dihydrazinate in N₂ at 100° and its chem identity established by means of press-concn and press-temp curves (Refs 1 & 2). No references to expl props found.

**Calcium Diazide Dihydrazinate** (formerly called Calcium Trinitride Dihydrazinate) 
Ca(N$_3$)$_2$.2N$_2$H$_4$, mw 188.22, N 74.37; wh, rect, orthorhombic crystals, mp dec slowly at RT, bp exp violently at 335$^\circ$; v sol in w, sol in anhyd hydrazine (34.7% at 23$^\circ$), mod sol in methanol (7% at 23$^\circ$) v sl sol in alc (0.4% at 23$^\circ$); pract insol in CHCl$_3$, chlf, benz, acet.

CO(N$_3$)$_2$, mw 112.06, N 75.00%; extremely volat, long ndls very sol in w, alc hydroxide dissolved in hydrazoic acid and eth but insol in petr eth; undergoes hydrolysis to yield CO$_2$ and HN$_3$; it has a penetrating odor and like other carbonyl compds is highly toxic and dangerous (Ref 7).

CO(N$_3$)$_2$ was first prepd in 1894 by Curtius & Heindenreich (Ref 1 & 2) by the action of sodium nitrite on the hydrochloride of carbohydrazide, CO(NH-NH$_2$)Cl$_2$. Kesting (Ref 3) found that this reaction did not always proceed homogenously and that hydrazidicarboxyazide, (NHCON)$_2$, was always formed as a by product in ca 20% yield. The two compds could be separated by carrying out the diazotization under benz. Kesting (Ref 3) obtbd CO(N$_3$)$_2$ in about 70% yield from CO(OEt)$_2$ refluxed for 2 days on a w bath with 59% N$_2$H$_4$.H$_2$O.

Carbonyl diazide is an extremely dangerous expl as it may explode violently, even under H$_2$O, on sl friction or when exposed to light (Refs 1, 2, 3, 5 & 6).

Like sulfuryl azide, CO(N$_3$)$_2$ decomposes in such solvents as benz and aniline, and converts aromatic hydrocarbons into pyridine bases and also into primary amines (Ref 1 & 4). Kesting (Ref 3) found that CO(N$_3$)$_2$ in H$_2$O and NaNO$_3$ under benz, when slowly treated with HCl yielded (NHCON)$_2$ and when CO(N$_3$)$_2$ in alc was heated with piperidine, it gave hydrazidocarboxy piperidide, mp 179$^\circ$.

No addnl info on CO(N$_3$)$_2$ was found in the literature.

**Ref's:**
1) Beil 3, 130 & [102]
2) T.Curtius & K.Heindenreich, Ber 27, 2684(1894); JPrakt Chem 52, 454(1895) & JCS 68 1, 12(1895)
3) W.Kesting, Ber 57B, 1321-4(1924) & CA 19, 920(1924)
4) T.Curtius & A.Bertho, Ber 59, 53, 4236-8(1931) & CA 26, 666(1932)
5) L.F. Audrieth, ChemRevs 15, 216-7(1934)
6) Thorpe 2 (1938), 278 & 323
7) Sax (1957), 442

**Carbonyl Diazide** (formerly called Carbonyl Nitride & Carbazoimide) (Called Kohlens~ure. Cerium Hydroxydiazide, Ce(OH)(N$_3$)$_2$, mw 241.19, N34.85%; yel expl residue obtained by Curtius & Darapsky from freshly pptd Ce nitrate and NaNO$_3$ under benz, mp 310-180 (Ref 2), 3200 (Ref 3) or 3260 in vacuo (Refs 4 & 12); bp dec at 350$^\circ$.

CO(N$_3$)$_2$ was first prepd in 1894 by Curtius & Heindenreich (Refs 1 & 2) by the action of sodium nitrite on the hydrochloride of carbamidic acid, CO(NH$\cdot$NH$_2$)$_2$HCl$_2$. Kesting (Ref 3) found that this reaction did not always proceed homogenously and that hydrazidicarboxyazide, (NHCON)$_2$, was always formed as a by product in ca 20% yield. Two compds could be separated by carrying out the diazotization under benz. Kesting (Ref 3) obtbd CO(N$_3$)$_2$ in about 70% yield from CO(OEt)$_2$ refluxed for 2 days on a w bath with 99% N$_2$H$_4$.H$_2$O.

Carbonyl diazide is an extremely dangerous expl as it may explode violently, even under H$_2$O, on sl friction or when exposed to light (Refs 1, 2, 3, 5 & 6).

**Cerium Hydroxydiazide**, Ce(OH)(N$_3$)$_2$, mw 241.19, N34.85%; yel expl residue obtained by Curtius & Darapsky from freshly pptd Ce hydroxide dissolved in hydrazoic acid and evapn of the soln formed (Refs 1 & 2). No references to expl props found.

**Cerium Triazide**, Ce(N$_3$)$_3$, mw 266.20, N47.36%; expl ppt obtained by Curtius & Darapsky (Ref 1) by boiling a mixt of Ce nitrate and NaNO$_3$ under benz, mp 310-180 (Ref 2), 320 (Ref 3) or 328 (Ref 12); mp dec at 350$^\circ$ evaporating N$_2$ (Ref 3), Qf 2.37 k cal/mol (Ref 13); lattice energy 146 k cal/mol (Ref 14); v sol in w (307% at 16$^\circ$), sl sol in alc.
A529

1.04% at 16°, insol in eth (Ref 2). Its toxicity is not known. First prepd in 1898 by Dennis & Benedict (Ref 1) and also by Curtius & Rissom (Ref 2) by dissolving freshly ppted CsOH in aq HN₃ and evap the soln in air or over sulfuric acid. Moldenhaur & Möttig (Ref 6) prepd the compd by reacting Cs metal with N₂, activated by an electrical spark, to skin or mucous membranes of sufficient severity to threaten life or cause permanent physical damage. The effects of continuous or repeated exposure are unknown.

Chlorine azide was first prepd in 1908 by Raschig, (Ref 1) upon acidification with acetic or boric acid of a mixt of Na hypochlorite and Na azide in aq soln:

NaOCl + 2HAc + NaN₃ → 2NaAc + H₂O + CIN₃

Although Raschigs' method was satisfactory, Frierson et al (Ref 8) preferred for the lab prepn, passing chloro gas into an ethereal suspn of silver azide at RT:

AgN₃ + Cl₂ → AgCl + CIN₃

Chlorine azide gas, with a sweetish odor similar to that of HClO, is an extremely dangerous expl. It expl violently in contact with a flame, on exposure to sunlight and sometimes even spontaneously (Refs 1,5,6,7, 10,11 & 12). Gleu (Ref 4) found CIN₃ decompd at 400° and 2 mm press without expln into the elements, N₂ and Cl₂. Decompn was accompanied by red radiation and intense short wave radiation in the blue and ultraviolet regions. Pannetier (Ref 13) observed that the deton of pure CIN₃ by a simple electric spark, resulted in a continous spectrum from ultraviolet to red with max intensity at 5000-5500A°. The kinetics of expln corresponded to complete rupture of the mol, recombination of the individual atoms giving rise to the spectra. Expln of CIN₃ occurred at all press above 0.1 mm (Ref 14).

The chemical reactions of CIN₃ have been studied by Raschig (Ref 2), Gutmann (Ref 3), and by Frierson et al (Refs 8 & 9). Reaction with lq ammonia resulted in the formation of an expl liq (Refs 8 & 9); reaction with pentane gave hydrazoic acid (Ref 8); and reaction
with Na and P resulted in violent explns, with spontaneous deton occurring within a few minutes in the case of P (Ref 8). Gutmann (Ref 3) found that tertiary sodium arsenite, Na₃AsO₃, does not react with the inorg salts of HN₃, but with chloro- and jodoazides it gives the alkali azide and halide and is oxidized to arsenate. Chlorine azide with silver azide forms Azino-Silver Chloride, N₃AgCl, which is a deep blue solid, stable only below -30° and expl violently in the dry state (Ref 9), decompg into AgCl and N₃. When moistened with non aq liqs, the compd, N₃AgCl, decmp rapidly but without expl as the temp is raised. It is not sensitive to mech shock but extremely sensitive to temps above -30° (Ref 9).


Chromium Azide Complexes In attempting to prepare Cr azide from a soln of Cr(NO₃)₃ and NaN₃ in pyridine, Oliveri-Mandalà (Ref 5) found that when more than 3 mols of C₃H₅N were added a greenish-violet ppt slowly separated. This subst was washed with cold w, alc and then acet to give a green crust of chromium triazide pyridine complex, Cr(N₃)₃·3C₃H₅N, which was insol in most org solvents but sl sol in C₅H₅N or glycerol. The dried (in vacuo) subst exploded violently on heating (Refs 5 & 7). Another complex sodium chromium azide, CrN₃·3NaN₃, green crystall, was prepared by Oliveri-Mandalà & Comella (Ref 6) by adding 3 mols of NaN₃ in alc to a soln of
of freshly prep'd Cr(OH)$_3$ in concd aq HN$_3$.

Aq solns of sodium chromium azide did not react with Cr or N$_2$, but with AgNO$_3$ gave an expl complex salt. The sodium chromium azide is considered to be the Na salt of chromihydracetic acid, H$_2$Cr(N$_3$)$_4$, but this acid was not isolated because it decomposed too readily.

Attempts to obtain it by the methods of Wöhler & Martin (Ref 4) failed.

Strecker & Schwinn (Ref 8) prep'd the following chromium azide complex salts:

- [Cr(NH$_3$)$_6$] (N$_3$)$_3$ and [Cr(NH$_3$)$_4$ Cl] (N$_3$)$_4$ [See Table A under Ammines and also see Ref 10 for prep and props of cis-diazidobis-ethylenediamine chromium azide, cis-[Cr(en)$_2$ (N$_3$)$_3$] N$_3$.]


"Hydrazoic Acid and the Metal Azides" a literature survey

**Cobalt Triazide** (formerly call Cobalt Tri-nitride or Cobalt Azozimide) Co(N$_3$)$_3$, mw 142.99, N58.78%; red-brown crystals (anhdy), mp 148° (0.02 g in 5 sec) (Ref 5), hygroscopic and easily hydrolyzed (Ref 4). The basic cobalt azide, Co(OH)N$_3$, was first prep'd in 1898 by Curtius & Rissom (Ref 1). An aq soln of cobalt azide was studied by Dennis & Isham (Ref 2). The anhyd salt, prep'd by the action of cobaltous carbonate on hydrazoic acid, was prep'd by Wöhler (Ref 3) and by Wöhler & Martin (Ref 4). Methods of prep are also described in Refs 6,7,8 & 10.

According to Wöhler (Ref 3), Co azide is extremely easily detoned by friction, and a 0.01-0.05g compressed sample is detoned by impact (Ref 5). Wöhler & Martin (Ref 4) consider Co azide even more expl and more dangerous than either Pb or Ag azide. A thin layer of Cr azide crystals exploded by a hot wire gave a measured vel of deton of 3400 m/s (Ref 10). After being subjected to neutron bombardment no measurable difference in vel of deton was observed.

**Cobalt Azide Complexes** - Curtius & Rissom (Ref 1) found that potassium cobaltoazomidine, [KN$_2$Co(N$_3$)$_3$], prep'd when strong solns of the two azides were mixed. This compd appeared as bright-blue crystals (pink in soln) which expl at 225°, The ammonium anologue, [(NH)$_3$Co(N$_3$)$_3$], was similar in appearance and props (Ref 1).

Dennis & Isham (Ref 2) observed that on adding pyridine to an aq soln of Co azide, a pink ppt formed which partially dissolved in excess pyridine and on evapn in air yielded a green cryt ppt, insol in water. Another portion of the pink ppt was filtered, washed with water, then with a small amnt of pyridine and finally redissolved in excess pyridine. A dark-red soln was obtained which on evapn in a desiccator produced small red transp crsysts, [Co(N$_3$)$_6$Co(N$_3$)$_3$], insol in w, and which became opaque in w or on exposure to air (Ref 2).

Strecker & Oxenius (Ref 9) were unable to prep by the usual methods Co complexes cong the azido group, because of the tendency of Co(N$_3$)$_2$ to hydrolyze. They succeeded, however, in prep by using other methods the following complexes: a) Hexamminecobaltic azide, [Co(NH$_3$)$_6$] (N$_3$)$_3$, yell solid by interacting hexamminecobaltic sulfate with Ba azide in aq soln, b) Chloropentamminecobaltic azide [Co(NH$_3$)$_5$ Cl] (N$_3$)$_4$, dk red solid by treating chloropentamminecobaltic sulfate with Ba azide in aq soln (See Table C under Ammines) c) Tetramminediazidocobaltic azide, [Co(NH$_3$)$_4$ (N$_3$)$_3$] N$_3$, red-brown by treating
tetramminediazidocobaltic chloride with hydrazoic and (See also Table B under Ammines) d)Diethylendiamminediazidocobaltic azide, [Co(C$_2$H$_4$N$_2$)$_3$(N$_3$)$_2$]N$_2$, grn—by treating diethylendiamminediazidocobaltic chloride with hydrazoic acid. All these complexes are sol in w and are expl when dry.

Several other complexes of this type are described in Refs 9 and 6.


Cupric Azide (formerly called Cupric Azoinide or Copper Trinitride) Cu(N$_3$)$_2$, mw 147.59, N 56.93%; dk brn with red tinge, rhmb crystals, mp—begins to dec slowly ca 120° and rapidly ca 150° (Ref 13), deton ca 174° (Ref 4); d at 25° 2.20 to 2.25 (Ref 17), Qf 139.4 kcal/mol (Ref 20); sol in all acids and in most org bases, sl sol in w, hydrolyzed by boiling w to CuO, insol in neutral solvents (Ref 10)

Cupric azide, with ½ or 1 mol H$_2$O, was first prepd in 1898 by Curtius & Rissom (Ref 1) by mixing dil aq solns of Cu sulfate and Na azide, washing the ppt with ice w and drying it in a desiccator (Ref 18). They also obtd it by the action of 3.87% hydrazoic acid on Cu pdr by Zn. Browne et al (Ref 6) found that, in addn to Cu(N$_3$)$_2$, some CuN$_3$ was formed on electrolysis of a soln of Amm azide in liq NH$_3$ at -67°, using a copper anode. Pure, anhyd Cu(N$_3$)$_2$ was prepd by Straumanis & Cirulis (Refs 11 & 13) by the following methods: a) from Cu(NO$_3$)$_2$·3H$_2$O and aq NaNO$_3$ b) from Cu(NO$_3$)$_2$·3H$_2$O and LiN$_3$·H$_2$O in abs alc c) from Cu(N$_3$)$_2$·2NH$_3$ by decompt at 100-50° d) from Cu pdr and aq HN$_3$, as dk coarse crstys and e) from CuO and concd HN$_3$, as dk grn crstys of intermediate size and particularly sensitive to expln (Ref 13). Although these azides differed slightly in appearance, they all had the same crstn structure as shown by X-ray photographs (Ref 11). For addnl info on prepn of cupric azide, see Refs 7, 9, 19 & 21

According to Curtius and Rissom (Ref 1), the(ahyd)Cu(N$_3$)$_2$ was considered to be very sensitive to shock or heat, even when water wet. Based on more recent data, Cirulis (Ref 11 & 13) states that the product is sensitive only when dry or wet with ether; the moist product wet with alc is rather insensitive to friction or shock. The sensitivity of the dry azide to friction is so great that it explodes while being removed from filter paper (Refs 7, 18 & 21)

Explosive Properties — Brisance — sl greater than Pb(N$_3$)$_2$ (Ref 13)

Detonation Rate — 5000 to 5500 m/sec (Ref 11)

Explosion Temperature — 174° for 0.02g sample/5 sec (Ref 4) to 202-5° (Refs 9 & 11); not decompd thermally without expln (Ref 5)

Friction Sensitivity — extremely sensitive (Refs 7, 11, 13, 18 & 21)

Gas Volume on Explosion — 607 l/kg as compared to 308 l/kg for LA (Ref 13)

Impact Sensitivity (1 kg wt) — det under impact (Ref 4); 1 cm for crstn product and 2 cm for amor product against 4 cm for LA (Refs 11, 13, & 21)

Initiating Efficiency — very small quantities are needed to initiate other expls, for example PETN is initiated by 0.0004g Cu(N$_3$)$_2$ compared with 0.0025g by LA and 0.18g by MF (Ref 13)
Power by Trauzl Test – 115 cc/10g sample (Refs 9 & 11)

Stability in Storage – No loss in wt on storage at RT for one year (Ref 13).

The use of polyvinyl alc or gelatin for the desensitization of cupric azide, its decompn in moist air or high temp and its use in detonators were described recently (Ref 20a)

Infrared absortion spectra were obtained by Delay et al (Ref 17) in the range 3-19µ.

Cirulis (Ref 13) found that LA loaded into copper caps can form copper azide if moisture is present. Hydrazine and hydroxylamine reduce Cu(N₃)₂ to white, cuprous azide, CuN₂ (Ref 11). Other reactions involving cupric azide are described below:

Cupric Amminoazide (Ammoniate of Copper Azide), Diammine copper azide, [Cu(NH₃)₄]₂(N₃)₂, mw 181.65, N 61.69%; green crystals, expl when heated or struck. Obtained by Dennis & Isham (Ref 2) by shaking freshly pptd black cupric hydroxide, while still moist, with an excess of hydrazoic acid, and washing and dissolving the ppt in aq ammonia. This compd was also prepd by Browne et al (Ref 6) and studied by Strecker & Schwinn (Ref 8) and by Straumanis & Cirulis (Ref 11) (See also Ref 21, p 149 and Table D under Ammines in this dictionary).

Tetrammine copper azide, [Cu(NH₃)₄]₂(N₃)₂, mw 215.72, N 64.90%, blue crystals, expl at 202° and on impact. Prepbd by Strecker & Schwinn (Ref 8) and by Straumanis & Cirulis (Ref 11) from cupric azide and NH₃, (either liq or the dry gas). Only the di- and tetrammino-compds were prepd, (See also Ref 21, p 149 and Table D under Ammines).

Cupric Azide, Basic (Anhydrous Cupric Oxyazide), CuO·Cu(N₃)₂, mw 227.13, N 37.00%; yel solid, expl at 203-5° (Ref 11), ignites 245° (Ref 3). Cirulis & Straumanis (Ref 11) assigned to it the formula Cu(OH)₃N₂. Basic compd was first prepd by Wöhler & Krupko (Ref 3) on heating cupric azide in w at 70-80°, followed by drying in air free from CO₂, until hydrazoic acid is evolved. This compd expl at 7 to 8 cm under 1 kg impact (Ref 11) and is about one third as sensitive as normal cupric azide (Refs 7 & 21, p 154). The basic azide, Cu(N₃)₂·Cu(OH)₂, is formed on retention of water by the oxyazide or prepared by reacting an alc soln of Cu(NO₃)₂ with an aq soln of dimethyl or diethylamine and NaN₃ (Ref 11, p 332-4). Another basic azide, Cu(N₃)₂·2Cu(OH)₂, was prepd by treating Cu(N₃)₂(N₃)₂ with water at 80° until the water becomes col. This product is a yel powder, insol in water, hydrolyzed by water above 80°, and is sol in acids and bases. It expl at 199-200° and under 1 kg impact at 8 cm (Ref 11, p 332-4) (See also Refs 7, 9 & 21, p 155).

Cupric Azide Complexes. Cupric azide forms numerous complex compds, such as [Cu(C₅H₅N)₂](N₃)₄ and [Cu(C₅H₅N)₂(N₃)₄]·(N₃)₄, wherein the azide group is analogous to the corresponding halides (Ref 8). The cupric pyridazide azide, Cu(N₃)₂·2CuH₄N, mw 305.78, N 36.65%; brn ndls insol in water but readily sol in dil acids. Was first prepd by Dennis & Isham (Ref 2) by the action of pyridine on cupric azide. It was studied by Strecker & Schwinn (Ref 8) and by Cirulis & Straumanis (Ref 11, p 341). This compd expl at 205° and under a 1 kg impact at 20 cm. It is an expl weaker than Cu(N₃)₂·2NH₃ (Refs 7 & 21).

The copper azide chloride, Cu(N₃)₂·3CuCl₂·6H₂O or Cu(N₃)₂·3CuCl₂ prepbd by Straumanis & Cirulis (Ref 16) expl at 207-8°. The hydrate cannot be dehydrated. Therefor the anhyd compd should be prepd from abs alc.

The general types of copper azide addn compds: a) [Cu(N₃)₂]⁺ b) [Cu(N₃)₄]⁻ c) [Cu(N₃)₂]⁺ and d) [N₃]⁺Cu₉Cu(N₃)₂⁺ have been prepd and studied by Straumanis & Cirulis (Ref 16). These brn to grn azido cuprates were prepd by dissolving Cu(N₃)₂ in aq or alc solns of sol azides. Compds a) & b) are stable in concd aq solns, c) is stable only in alc soln, and d) only in the presence of an excess of RNH₂N₃ or HN₃. The same authors have prepd and studied nonelectrolyte complexes (Ref 11, p 335 & Ref 14) and other azido cuprates with org cations in Refs 12,
Many of these compounds are expl and det when heated or struck (See also Ref 21, p 150-4 and Azidocomplexes under Ammonites)

Refs:

Cuprous Azide (formerly called Cuprous Trinitride or Cuprous Azomide), CuN3, mw 105.56, N39.81%; wh or sl yel-grn crystals changing under sunlight to deep red with a violet tinge; mp - deflg ca 174° (Ref 5) to 220° (Ref 4) expl 217° in 5 sec(Ref 19); d 3.26 (Ref 15); Qe 58.7 k cal/mol (Ref 7); Qf =-67.2 k cal/mol (Ref 17); theor temp on expn 3152° (Ref 7); practically insol in water (0.08g/l) and in 2% HN3 (0.29g/l) at RT (Ref 14)

Curtius in 1890 (Ref 1) described the existence of cuprous azide, (deep red in color), obtained by treating cuprous oxide with hydrazoic acid. Wöhler & Krupko (Ref 4) reported a new subst, CuN3, prep'd by gradually adding a soln of NaN3 to an excess of a concd soln of copper sulfate to which K sulfate had been previously added, followed by AcOH in sufficient quant to dissolve the ppt. Browne et al (Ref 8) found that some CuN3 was formed by electrolysis of a soln of ammonium azide in liq NH3 at -67° using Cu electrodes, although earlier investigations by Turrentine & Moore (Ref 3) produced electrochemically a compd corresponding to the formula CuN3·2H2O. Straumanis & Cirulis (Ref 14) found that in the reaction of Cu with HN3, CuN3 was formed as an intermediate which was subsequently oxidized to Cu(N3)2. Cirulis reported (Ref 11) that CuO or Cu(OH)2, with an aq soln of HN3 yielded CuN3 as fine moss-grn crystals which expld when dry by whisking with a brush. Denigès (Refs 12 & 13) in a study of the analogy between the azide ion and the halogen ion described the prepn of CuN3 which was obtained as white hexahedral crystals whose props paralleled those of the cuprous halides

In a study of the cryst structure of CuN3, Wilsdorf found (Ref 15) that the azide obtained either by reduction of a CuSO4 soln by KHSO4 and addn to NaN3 or by treating Cu powdr with NH4OH show the same X-ray pattern. Suzuki (Ref 16) made thermodynamic studies of CuN3 and from the reaction Cu + 3/2 N2 = CuN3 obtained the following results: ΔF° = 71.219 cal & ΔH° = 60,250 cal

Cuprous azide is highly sensitive to heat,
impact and friction. The brisance is close to that of Ag azide. Its expl props are affected
by cryst size: small crysts (0.06 to 0.09 mm) expl on impact and, when 3 mm in size and
dry, may expl by the touch of a feather.
Spontaneous deton can occur even under
water (Ref 2). It will expl in contact with a
red-hot wire and deton either in open air or
in vacuo by mechanical effect (Ref 10). Deton
by impact under 0.60 kg falling wt occurs
from 9.5 cm for 0.01 g sample to 24 cm for
0.05 g sample of small crysts (Refs 4 & 5)
A recent study of the sensitivity of cuprous
azide to heat and impact by Singh (Ref 20)
confirms earlier investigations showing that
sensitivity increases with an increase in
cryst size. The activation energy involved
in its thermal decompn has been established
as 26.5 k cal (Ref 20). In addn to heat of
deton, temp develpd on expln, work density
and loading density, Wöhler & Martin (Refs
6 & 7) also report the following info with
respect to the initiating efficiency of CuN₃:

<table>
<thead>
<tr>
<th>HE</th>
<th>CuN₃, g</th>
<th>LA, g</th>
<th>MF, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetryl</td>
<td>0.025</td>
<td>0.025</td>
<td>0.29</td>
</tr>
<tr>
<td>PA</td>
<td>0.045</td>
<td>0.025</td>
<td>0.30</td>
</tr>
<tr>
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<td>0.37</td>
</tr>
<tr>
<td>TNX</td>
<td>0.40</td>
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<td>0.40</td>
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Cuprous azide is thus indicated to be an
efficient initiator. For addnl info on prepn
of cuprous azide see Refs 9 & 18

In a large variety of detonators, in which
LA has been loaded into brass containers,
cuprous azide is formed on the surface of
containers stored under hot and humid con-
ditions. Extreme care should be exercised
in handling cuprous azide or any components
of ammunition in which it may be formed

Refs: 1)T.Curtius, Ber 23, 3023(1890)  2)
L.Wöhler, ZAngChem 24, 2096(1911) & Chem
Ztg 35, 1096(1911)  3)J.W.Turrentine & R.L.
Moore, JACS 34, 375-82(1912) & CA 6, 1410
(1912)  4)L.Wöhler & W.Krupko, Ber 46,
Cyanazide, See under Cyanocompounds and Derivatives

Cyanuric Triazide, See under Cyanocompounds and Derivatives

Dicyandiazide, See under Cyanocompounds and Derivatives

Fluorine Azide, FN, mw 61.02, N68.86%, grn-yel solid at -154°, mp explodes on evapg and at RT decompn of Na azide. It was prepd by A.W. Browne & J.F. Haller in 1942 by treating HN₃ with fluorine in a stream of N₂ [J.F. Haller, Dissertation, Cornell U (1942) cited by N.V. Sidgwick, "The Chemical Elements and their Compounds", Vol 1 (1950) p 718 Oxford University Press, London]. No further work is known to have been reported since the original prepn of fluorine azide

Gallium Triazide, Ga(N₃)₃, mw 195.79, N 64.39%; col crysts, sol in tetrahydrofuran, sens to moisture. Prep'd by Wiberg & Michaud (Ref 1) by adding an eth soln of excess HN₃ to a frozen eth soln of GaH₃ and thawing the mixt at RT. Excess HN₃ and eth were removed by distn at -25° and heating to RT in vacuo. The eqn for the reaction is GaH₃ + 3HN₃ → Ga(N₃)₃ + 3H₂. Analysis of the azide gave GaH₃₃. (N₃)₃. No expl props were given


Gold Azide (Aurous Azide), AuN₃, mw 239.22, N17.5%; orange ndls extremely expl were obtained by Curtius & Rissom (Ref 1) on evapg a soln of a mixt of gold chloride and Na azide. They also obtd a Sodium Gold Azide, as an orange, crystn, extremely expl residue, on evapg a soln of a mixt of aurochloric acid and Na azide. The structure of these compds was not supported with evidence. While investigating methods of prepng Au azide, Rogers (Ref 3) obtd sodium gold azide

Dicyandiazide, See under Cyanocompounds and Derivatives

Fluorine Azide, FN, mw 61.02, N68.86%, grn-yel solid at -154°, mp explodes on evapg or CCl₄. Its method of prepn was the treating a soln of aurochloric in eth with dry Na and at RT decomps to N₂ and N₂F₂. It was prepd by A.W. Browne & J.F. Haller in 1942 azide. The color of the soln changed rapidly by treating HN₃ with fluorine in a stream of from bright yel to deep rd-bn indicating N₂ (J.F. Haller, Dissertation, Cornell U 1942) cited by N.V. Sidgwick, "The Chemical Elements and their Compounds", Vol 1 (1950) p 718 Oxford University Press, London]. No further work is known to have been reported since the original prepn of fluorine azide


Hydrazine Azide (formerly called Hydrazine Azomide, Hydrazine Trinitride or Hydrazonium Azide) (called by Curtius Diammonium Azide, N₄H₄), N₄H₄-HN₃, mw 75.08, N93.29%; rhmb, hygr crysts; mp 75.4(Ref 6); v sol in w, sol in hydrazine(190% at 23°), methanol (61% at 23°) and in alc (1.2% at 23°C), not appreciably sol in chlf, carbon tetrachloride benz, carbon disulfide, ethyl acetate or diethyl ether (Ref 6). First prepd by Curtius in 1891 (Ref 1) by neutralizing hydrazoic acid with hydrazine
hydrate or by pouring hydrazine hydrate
over ammonium azide and evap the mixt in
a flat-dish placed in a desiccator. This
latter method of prepn was patented by Müller
in 1936 (Ref 10). The cryst product obtained
by Curtius was in the form of long
lustrous plates or prisms (mp ca 50°) which
detonated violently on rapid heating but the
azide also burned quietly with a smoky yel
flame when heated slowly (Ref 1). The moist
salt is also expl (Ref 11). Curtius & Rissom
(Ref 2) reported that hydrazine azide begins
to melt at 65° and decomp energetically at
108°. Dresser & Browne (Ref 6) prep a very
pure material (mp 75.4°) which was relatively
stable since it showed only very sl decompn
when heated to 110° in vacuo for several
days. Thrown upon a hot plate it burned with
a puff, but without deton. According to Dresser
& Browne, hydrazide azide is entirely insens-
titive to ordinary mech shock or impact (Ref
6). This compd reacts readily with benzalde-
hyde and with acet and is regarded by Ephraim
(Ref 11) as a polymer of imide, (NH)n (See
also Refs 4,7 & 9).

Hydrazine Azide Monohydrazinate, N3H5N3-
N3H4, mw 107.13, N 91.53%; wh delq crysts,
mp 66.4°; v sol in w or in anhyd hydrazine.
Prepd by treatment of a nearly satd soln of
hydrazine azide in anhyd hydrazine with an
equal vol of abs alc (Ref 6). This solvate
was first obtained by Riegger in the lab of
Cornell Univ (Ref 3) and has the same
empirical formula as normal hydrazonitrous
acid (3-hydrazinopentazane) or as heptazane
(Refs 5 & 6). In order to establish the identity
of this monohydrazinate and establish whether
higher solvates exist, the temp-concn diagram
was detd for the system hydrazine azide-
hydrazine. This investigation showed only one
solvate formed, with eutectics located at 51°
and -17°C (Ref 6) (Also see Refs 7 & 9). No
expl props were mentioned.

Hydrazine Azide Hemiammonate, (N3H5N3)_2NH4,
mw 167.21, N 92.16%; wh delq crysts which
exhibit extreme hygr on exposure to air but
stable in the absence of moisture. It was
isolated and identified by Howard & Browne
(Ref 8) in a study of equilibria in the system
hydrogen azide-ammonia. It is easily prepd
by condensing liq ammonia upon solid
hydrogen azide and permitting the soln to
evap to dryness upon warming to RT (Ref 8,
p 2352). In liq ammonia, the hemiammonate
undergoes ammonolysis to an extent that
varies directly with temp and with the concn
of ammonia. (See also Ref 9). No expl props
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HYDROGEN AZIDE AND HYDRAZOIC ACID
(formerly called Azoinide, Ammonitric Acid,
Hydrazonitrous Acid or Hydronitric Acid)
(Stickstoffwasserstoffssäure in Ger). It exists
as anhydrous and as aqueous hydrogen azide.
The latter is called hydrazoic acid. The
structure of hydrogen azide and of hydrazoic
acid has been the subject of a number of in-
vestigators, such as Mendeléeff (Ref 2),
Thiele (Ref 27 & 28), Turrentine (Ref 35),
Franklin (Ref 62), Hendricks & Pauling (Ref
63), Herschberg et al (Ref 98), Pauling &
Brockway (Ref 103), Davis (Ref 104), Buswell
et al (Ref 105), Eyster (Ref 111), Shomaker
& Spurr (Ref 118), and Lieber et al (Ref 140).
Various other investigators studied the be-
behavior of azides and proposed structures
(See Refs 58,69,71,79,90,96,101,117,136,137,142,147,148,150 & 154). It is now generally agreed that the hydrogen azide molecule has a hydrogen atom linked by a bond at an angle 112° to the linear azide group:

\[ \begin{array}{c}
\text{N} \\
\text{N} \\
\text{N}
\end{array} \quad \begin{array}{c}
1.14\text{Å} \\
1.25\text{Å} \\
112° \quad \text{H}
\end{array} \]

**Hydrogen Azide, Anhydrous, HN₃, mw 43.03, N 97.66% Col liq, fr p -80° (Ref 18), bp 35.7° (Ref 99) & 37° (Ref 18), dₚ = 1.126/(1+0.0013 t), where t = 0 to 20° (Ref 99); Q_decomp(liq) 67 ± 5 kcal/mol(Ref 77), Q_vapzn at 12.40 7.3±0.01 siinfie a

Rossini (Ref 146) gives for heat of formn at 4°K, the products from the decompn of HN₃ are con- 20 mm is reported to parallel closely its

Browne & Lundell(Ref 23) found pure anhyd HN₃ to have low electrical conductivity but the addn of potassium azide very greatly increased its conductivity. Hydrogen azide is sol in w, alc or eth and is itself a solvent for many subs as found by qual investigations of McKinney(Ref 59). Vapors of HN₃ are consi-dered dangerous (Refs 94,123,124 & 160); low concns produce eye irritation and head-ache, high concns affect the central nervous system and continued exposure may cause death (Refs 3,67,84,102,131 & 133). The gas, aq solns and its salts act as protoplasmic poisons (Refs 67,84,145 & 151). Two cases of accidental poisoning have been reported (Refs 66,86)

Anhydrous hydrogen azide was first prepd in 1891 by Curtius & Radenhausen by fractionally distilling the aq soln with fused calcium chloride(Ref 4). In 1907 Dennis & Isham isolated the pure compd in larger quannty and detd some physical and chem props (Ref 18). The pure compd is extremely expl but it can be kept for days at RT in sealed tubes without change (Refs 18 & 130). After months of storage its tendency to expl spontaneously becomes much greater (Ref 93). It expl readily when subjected to the slightest shock or when heated. Thermal decompn takes place at 290° and at 4 cm press, 9-11% of HN₃ decompd in 25 min (Ref 80).

Traces of impurities catalyze the reactn to expln (Ref 93). Gaseous HN₃ also decomp explosively under the influence of an elec spark, with emission of yel light, at all press of HN₃ above 5 mm (Ref 156). Introduction of H₂, N₂ or A into the system markedly inhibits expl reaction, H₂ exerting the largest inhibitive effect (Ref 156). When frozen at 4°K, the products from the decompn of gaseous HN₃ by elec discharge formed a blue solid identified as NH₄N₃ (Ref 152). Depo-

kcal/mol (Ref 99), Q_vapzn at 12.40 7.3±0.01 siinfie a

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reaction is propagated by atoms of nitrogen. The free radical of N\(^*\), or possibly N\(_2\), has been detected by Thrush (Ref 158). Infrared spectroscopic studies of the decomp of HN\(_3\) have been reported by Dowes et al (Ref 157) and by Becker & Pimentel (Ref 159), and an exptl value of the dissocon energy has been dte by Pannetier & Gaydon (Ref 139).

The mechanism of the expl decomp of pure hydrogen azide and of its mixts with H\(_2\) has been studied in some detail by Avanesov & Rukin (Ref 108). The propagation of a deton is periodic and consists of the transfer of the elastic impulse in the still unchanged gas and of the decomp of the particles which have been subjected to the impulse (Ref 108).

Use. Liq HN\(_3\) has been found by McKinney (Ref 59) to act as a solvent for many substs, especially inorg compds.

**Hydrogen Azide, Aqueous or Hydrazoic Acid (HA), HN\(_3\) + nH\(_2\)O (aq distillate has contd up to 27% HN\(_3\) Ref 94, p 183) was first obtained in 1890 by Curtius (Ref 1) on treatment of benzoyl azide with NaOH, followed by distn with H\(_2\)SO\(_4\). Subsequently Curtius used instead of NaOH, Na ethylate (Ref 5) and also alc ammonia (Ref 8). Methods of prepn employed by other investigators may be divided into the following general classes:

a) **direct syntheses (Refs 78, 88 & 131a) b) interaction of hydrazine and nitrous acid** (Refs 7, 9, 11, 35, 55, 62 & 64) c) **oxidation of hydrazine** (Refs 15, 19, 20, 21, 22, 36, 42, 48, 49, 52, 68, 74 & 95) d) **ammonolysis of nitrous oxide and nitrites** (Refs 6, 12, 14, 64, 81 & 87) and e) **oxidation of triazines and decomp of higher hydronitrogens** (Refs 7, 16, 43, 83, 110 & 153).

Addnl info on methods of prepn may be found in the books of Mellor (Ref 75), Gmelin (Ref 100), Thorpe (Ref 132) & Kirk & Othmer (Ref 144) and in a review by Audrieth (Ref 94).

**Note:** See also "A Safe Method for Preparation of Uncontaminated Hydrazoic Acid" by M.D. Kemp, JChemEduc 37, 142 (March 1960).

Ultra violet decomp of HA has been studied by many investigators (Refs 70, 119, 122, 126, 129, 135 & 143). The threshold of photodecomp is at 2550 Å (Ref 119) and decomp occurs after a short induction period (Refs 122 & 126) at a rate indicated by the gases evolved (Ref 126). The energy of activation of the decomp of HA was calcd as 695 cal/mol (Ref 129b). In the electrolysis of aq solns of HA, low intensity UV emission has been observed in the gaseous phase (Refs 107, 112 & 120). West (Ref 13) made conductivity measurements of HA and calcd the limiting value to be 1.86 x 10\(^{-5}\). Oliveri-Mandalà also made conductivity measurements and calcd a dissociation constant and anionization constant. Also see values reported by Quintin (Ref 113) and by Yui (Ref 116).

Roth & Muller (Ref 77) calcd the Qf (dil soln) as -53.3 kcal/mole and Q\(_{\text{neutn}}\) by Ba(OH)\(_2\) as 10.0 kcal/mole. Rossini et al (Ref 146) reported Qf values at 25°C for HA solns of various concns. Other thermodynamic props have been calcd by Eyster & Gillette (Ref 114) and by Waddington & Gray (Ref 155). Racz (Ref 125) has reviewed the literature on the stability, thermodynamics and photochemistry of HA.

The chemical reactions of HA have been the subject of numerous investigations. It reacts with acids (Refs 17, 21, 26, 33, 37, 45, 56, 60, 64, 82, 92 & 109), oxidizing agents (Refs 14, 32 & 76), reducing agents (Ref 34), and it forms expl derivs such as azides (Refs 38, 39 & 44), tetrazoles (Refs 24, 25, 30, 31, 40 & 60) and others (Refs 46, 47 & 61). Platinum black and Raney nickel decomp solns of hydrazoic acid to form ammonia and nitrogen (Refs 51 & 106). Other reactions are also described (Refs 29, 41, 43, 53, 57, 59, 128, 132, 147a & 149).

Explns involving HN\(_3\) or HA may be avoided by carrying the gas as it is formed into a stream of nitrogen or air and absorbing the gas in Ba hydroxide soln (Ref 134). During the investigation of the vel of deton of hydrazoic acid, the bottle contg it exploded on agitation, killing a man (Ref 65). The vel of deton of pure HN\(_3\) has been measured by photographic techniques as 2650 ± 100m/sec (Ref 108).

Uses - The acid character of hydrazoic acid...
has made it the basis for use in several analytical methods (Refs 10, 13 & 56). It is a
unique compd of hydrogen and nitrogen, many derivatives of which are expld and,
being solids, are used in commd and military expls.

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Iodine Azide or Iodoazole (called Jodazid or Azoidijodid in Ger), IN, mw 168.93 N 24.88%; yel, volat solid, extremely dangerous expl when exposed to heat or shock; sol in w, giving a neutral soin which on standing hydrolyzes into hydrazoic and hypiodous acid; also sol in many org solvs in which it slowly decomp into iodine and nitrogen. Its toxicity is severe, as a single exposure can cause injury to the skin or mucous membranes of sufficient severity to threaten life or cause permanent
physical impairment (Ref 10). Iodine azide was first prepared in 1900 by Hantzsch (Ref 1) on adding an ethereal solution of iodine to an aqueous suspension of silver azide cooled to 0°C followed by extracting with eth at below 0°C (Refs 4, 5, 7, 8 & 9).

When in a dry state, iodine azide may decompose spontaneously with great violence into its elements. According to Gutmann (Ref 2), tertiarly sodium arsenite, Na₃AsO₃, does not react with inorganic salts of hydrazoic acids (metal azides) but with chloro- or iodoazides it gives sodium azide, alkali halide and sodium arsenate. By means of a photon counter, the radiation emitted on detonation of iodine azide (prepared by a modification of Hantzsch's method) clearly showed UV radiation which was not found on detonation of nitrogen triiodide, N₃I, an extremely sensitive and dangerous explosive (Ref 6).

According to Mellor (Ref 3), A.C. Vournazos prepared some complex azides of iodine by reacting zinc nitrate with sodium iodoazide forming sodium zinc iodoazide, Na[ZnI₂N₃], which reacted with silver iodide to form sodium silver zinc iodoazide, Na[Ag(ZnI₂N₃)], and with lead iodide to form sodium lead zinc iodoazide, PbI₂[(ZnI₂N₃)₄Na₄]. No explosive properties of these complex iodine azides were described.


Iron Azide or Ferric Triazide, Fe(N₃)₃ or [Fe(N₃)₄] (N₃) m, mw 181.92, N 59.30%; dk brn hygroscopic easily hydrolyzed and very unstable, mp-expl 200°C (Ref 10). It was first prepared and isolated in 1917 by Wöhler & Martin (Ref 5), by treating dry ferric sulfate with sodium azide in abs methanol, removing the pptd sodium sulfate by filtration, and concentrating the solution of ferric azide in a vacuum desiccator.

Earlier, Turrentine (Ref 4) obtained ferric azide in solution by electrolysis of a dil sodium azide solution using iron electrodes and later by Browne et al (Ref 6) on using iron electrodes in liquid ammonia solutions of ammonium azide, but the product was ammonolized to an ammonium basic ferric azide. Curtius et al (Refs 1 & 2), with ferric alum and NaN₃, obtained ferric azide in solution and they also reported that iron dissolves in dil aq hydrazoic acid to form the azide, but the solution decomposes on evaporation giving either the basic azide or hydroxide. In 1934, Franklin (Ref 9) noted that aq hydrazoic acid reacts on iron to form ferric azide, nitrogen and ammonia together with a small amount of hydrazine. According to Franklin, ferrous azide, Fe(N₃)₂, is formed first and oxidizes to ferric azide when the solution is warmed with excess hydrazoic acid present. Ricca (Ref 11) studied the reactions of the ferric ion with hydrazoic acid on electrolysis of their solutions and obtained results which would indicate that ferric azide has the structure [Fe(N₃)₄](N₃)₂.

Aq solutions of ferric azide have a deep red coloration similar to that produced by Fe(CN)₅. This characteristic coloration is also produced when ferric salts are added to aq solutions of hydrazoic acid, thus serving as a colorimetric test for HN₃ (Ref 3).

Racz (Ref 10) studied the thermolysis and UV radiation emitted by ferric azide. He reported that, when enclosed, ferric azide explodes at ca 200°C in air and at 230°C in nitrogen. Decomposition of this azide was accompanied by strong UV emission which began at 270°C, at activation energies of 47, 33 and 64 kcal. By comparison with the results of other azides, it is inferred that the processes occurring at 47 and 64 kcal energies are independent of the metal, while that occurring at an activation energy of 33 kcal indicates a different mechanism of thermolysis (Ref 10). Santappa (Ref 12) studied the ferric azide-vinyl monomer system when irradiated with UV light of wave...
length 300-400 μm and found the quantum yield varied linearly with the monomer conc, and the rate of Fe²⁺ production was dependent on the org impurities present. Vinyl monomers studied were acrylonitrile, methyl methacrylate and methacrylic acid.

The toxicity or hazardous nature of ferric azide is not given in Sax nor were there found any other expl props reported in the literature (Refs 7 & 8).


Lanthanum Triazide, La(N₃)₃, mw 222.97, N37.25%, Curtius and Darapsky prep'd the basic salt, Lanthanum Hydroxyazide, La(OH)(N₃)₃·½H₂O, by boiling a soln of lanthanum nitrate and sodium azide. The white slimy mass of basic lanthanum azide was obtained either on evapg the mixed soln in vacuo or on treating it with a mixt of alc & eth. No props of the product were reported nor were there any addnl refs found in which any attempts were made to prepare and isolate the lanthanum azide.

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LEAD AZIDE OR LEAD DIAZIDE (LA)
(Formerly called Lead Trinitride, Plumbic Nitride, Plumbamido, or Lead Hydronitride)
called Bleiaziid in Ger, Azoture or Nitruro de plomb in Fr, Acido di piombo or Azotiduro di piombo in Ital, Azida de plomo, Plumbazido or Nitruro de plomo in Span, Azid svntsa in Russian and Chikkaen in Japan), Pb(N₃)₂, mw 291.26, N 28.86%, Col crysts which exist in two mods: orthorhombic (α) and monoclinic (β) forms (Refs 44,45,113,137,142 & 144); mp - decomp into Pb and N₂ (Ref 143) at 245 to 250°C (Ref 17), expn temp LA 315°C to 360°C (Refs 16,17,28,44,73,106,124 & 149) and 275°C for dextrinated (Ref 106); cryst d 4.71 (α) (Refs 92 & 144), 4.93 (β) (Ref 144), 4.38 (dextrinated) (Ref 141), apparent d cryst 0.8 (Ref 103) & dextrinated 1.5 (Ref 141); Q expn 260 cal/g (Ref 73) to 367 cal/g (Refs 16,91,111,167) Q activation 10-11 kcal/mol (Ref 70) to 55 kcal/mol (Refs 47,58,84,106,111 & 133) Q'P = -114.5 kcal/mol (Refs 137 & 149) to -126.3 kcal/mol (Ref 123), -115.5(α) and -115.8(β) kcal/mol (Ref 137)

LA is very sol in AcOH, sol in w to the extent of 0.02% at 18°C and 0.09% at 70°C (Ref 141); Ref 128a gives 0.05/100 g H₂O at 100°C; almost insol in eth, acet, alc, ammonia or org solvents. The sol of α-LA in w is 8.5 x 10⁻⁵ mol/l which gives a concn solubility product of 2.6 x 10⁻⁶ and a thermodynamic solubility product of 1.8 x 10⁻⁹ (Ref 134). LA may be dissolved in mono-ethanolamine or in a 50/50 mixt of mono-ethanolamine/ammonia, from which it may pptd by addg dil AcOH. The resulting prod, according to Majrich (Ref 66) is impure

LA is not considered particularly toxic but inhalation of its dust should be avoided as this causes headaches and distention of blood vessels. It has been recommended that the LA content of air should be less than 0.2 mg/cubic meter in order to avoid toxicity by inhalation (Ref 141). An investigation of LA as an industrial hazard (Ref 96) has indicated that the storage and distribution of Pb from LA in tissues following ingestion are similar, in general, to other Pb salts. The acute toxicity of LA is associated with the azomide radical (See Hydrazoic Acid in this section) rather than with the lead. Also, see Sax (Ref 150), Eddy (Ref 95), Schwartz (Ref 90), Ref 97 and Siefert (Ref 102) for further discussions of the toxic effects of LA

LA was first prepd in 1891 by Curtius (Ref 1) by adding Pb acetate to a soln of Na or Amm azide. Curtius & Rissom (Ref 2) prepd it by the action of hydrazoic acid on a lead salt. Turrentine (Ref 6) obtd LA during electrolysis of a 3% soln of Na azide to 360°C (Refs 16,17,28,44,73,106,124 & 149) on lead anodes. Browne et al (Ref 20) found and 275°C for dextrinated (Ref 106); cryst LA was formed when a soln of NH₃N₃, in 4.71 (a) (Refs 92 & 144), 4.93 (Ref 144), liq NH₃ at -67°C, was electrolyzed with a Pb anode. Some details of prep of LA have been described by Hyronimus (Ref 3), Stettbacher (Refs 13,85 & 114), Hodgkinson (Ref 18), Hale (Ref 29), Matter (Ref 32), Wallbaum-Wittenberg (Ref 79), Meissner (Ref 78) and by many others (See Refs 15,19,35,41,59,64,68,72,86,94,122a,126 & 151). Plant methods of manuf of LA have been given by Meissner (Ref 60) von Herz (Refs 53 & 61), Gómez (Ref 141a) and Stettbacher (Ref 52) and procedures for continuous manuf by Matter (Ref 39a), Meissner (Ref 40), Greceanu (Ref 93) and others (Ref 104), Moskovich(Ref 75) prepd stable gelatine emulsions of LA. Darier & Goudst (Ref 22) described a procedure for preventing expn of LA by effecting the reaction within the interstices of a porous inert absorbent material

The hazards involved in the manuf of the pure crystalline material delayed its practical use for many years. Although manufd and used in foreign countries since 1920, its military and coml uses in the USA, since 1931, have been restricted to an impure colloidal form or "dextrinated" LA (Ref 122a). The prep of colloidal LA has been described by Rintoul & Weir (Ref 21), Snelling (Ref 23), Lowndes (Ref 24), Rinkenbach (Ref 51), Fleischer & Burtle (Ref 108), Moskovich (Ref 74), Böström et al (Ref 145) and Fonda & Fonda (Ref 125). In these procedures the objective was to obtain rounded aggregates of
uniform size and to prevent the formation of large crystals (See Ref 72). The existence of LA in (a) and (β) forms was first reported in 1931 by Garner & Gomm (Ref 44) and by Miles (Ref 45). According to Moskovitch & Alek-sandrovich (Ref 65) and Hattori & McCrone (Ref 144) the stable form (a) is prepd by mixing equal vols of 1M Pb(NO₃)₂ and 2M NaN₃ solns and recrystg the pptd LA from sodium acetate soln. The less stable (β) form is prepd by slow diffusion of Pb⁺⁺ and N₃⁻ ions into water. β-LA transforms readily in soln to α-LA (See also Manufacture of LA, which follows Laboratory Methods)

**Laboratory Methods of Preparation of Dextrinized LA**

(Caution: All operations should be conducted behind a barricade of safety glass or transparent plastic)

1) **Method Used in Some American Laboratories:**
   a) Dissolve 2.33 g of Na azide and 0.058 g NaOH in 70 ml H₂O (distilled or permutite treated) by shaking in a 125 ml separatory funnel. This is soln A b) Dissolve 6.9 g Pb nitrate and 0.35 g dextrin in 90 ml H₂O (distilled or permutite treated) in a 250 ml tall form beaker, and add 1 or 2 drops of 10% NaOH to bring the pH to ca 5. This is soln B c) Heat soln B to 60-65° on a water bath and agitate it with a formaldehyde plastic or hardwood stirrer. The stirring should be as efficient as possible to prevent the formation of large crystals. Stirring while vigorous should not produce any spattering of the mixt and the stirrer should not rub against the walls of the beaker d) Add soln A (which is in the 125 ml separatory funnel) dropwise to soln B, with continuous agitation. The addition should require about 10 mins e) Remove the beaker from the water bath and continue stirring the mixt in beaker while cooling to room temp (about 1 hr) f) Remove the stirrer and rinse it into a beaker with a stream of distilled w g) Allow the ppt of LA to settle and filter by suction the contents of the beaker through a filter paper placed in a 100 ml plastic Büchner funnel

h) Stop the suction, add 50 ml of distilled H₂O to the Büchner and stir the ppt with a plastic rod or spatula, taking care not to tear the filter paper i) Remove the H₂O by suction and repeat the operation of washing two more times j) Set aside the mother liquor and the wash waters and (under a hood) destroy the azides in soln by adding the required amt of Na nitrite, followed by a slow addn of 92% sulfuric acid:

\[
\text{NaN}_3 + \text{NaNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{N}_2\text{O} + \text{N}_2 + \text{H}_2\text{O}
\]

When the azide is destroyed, which is indicated by the sample turning litmus paper red and starch-iodide paper blue, pour the soln into a sink (See also under Destruction or Killing of LA) k) By means of a plastic or wooden spatula transfer the wet ppt to an open Al dish 1) Dry the sample for 8-15 hrs (but no more than 24 hrs) at 65° and examine it under the microscope. The LA crystals should be approximately spherical in shape, opaque in appearance, averaging not over 0.07 mm in diam. They should be free flowing and contain an average of 92.5% Pb(N₃)₂. There should be no needle-shaped crystals. The yield will be ca 5 g m) If it is desirable to save the sample, wet it with a small amt of H₂O and transfer to a rubber-stoppered plastic or hard rubber bottle.

Note: It is not advisable to use a sintered glass funnel or crucible for filtering because friction between the glass and LA might result in an expln, even under water, especially if a glass rod or spatula is used for stirring or transferring the sample

II) **Argentine Naval Powder Factory Method**

(Azul, Prov Buenos Aires): a) Dissolve 8-9 g of Pb nitrate in filtered water free of Cl⁻, chlorides and gritty materials b) Dissolve 3g of Na azide in 100 ml w and det the approx alkalinity by titrating a 5 ml of soln with N/10 H₂SO₄, using phpht as an indicator. If the amt of acid required to discolor the phpht is 8 to 10 ml, the soln is satisfactory; if less than that add a few drops of NaOH soln c) Dissolve 0.3 g of potato dextrin in a small
d) Provide a reaction vessel, consisting of a round bottom stainless steel beaker of about 0.5 l capacity, highly polished inside, equipped with a water jacket and a stainless steel agitator with two double blades placed one above the other and not touching the walls or the bottom of the vessel.

e) Transfer the Pb nitrate solution in the vessel, start the agitator and circulate water preheated to 50° through the jacket. Test the neutrality of solution by placing a few drops on a glazed white porcelain plate and adding one drop of methyl orange indicator. If the solution is acidic, add a few drops of aq NaOH and re-test the solution.

f) Add the dextrin solution and while stirring as rapidly as possible (in order to obtain small uniform crystals) run in the Na azide solution slowly while maintaining the temp at 50±5°. g) Decant the mother liquor using a rubber tube syphon.

h) Refill the reaction vessel with water, agitate for a few mins, allow to settle and decant.

i) Tilt the vessel and transfer its contents (using a jet of water) into a filter cloth bag and wash the bag and contents in three changes of water.

j) Store the bag in a plastic container.

k) Dry it when required at 60-65°. The yield will be ca 6.5g.

Note: This laboratory method is essentially the same as the Argentinian plant procedure; the only difference is in quantity of materials used. When using 440-450 g of Pb nitrate, 150 g Na azide and 15 g dextrin about 330 g LA are obtained (Some European plants use as much as 10 times these quantities, producing up to 3300 g in one batch) (Ref 141a).

III) German Method is essentially the same as the plant procedures described in Ref 157a, under Bleiazid, except that the quantities are much smaller.

IV) Italian Method is essentially the same as the plant procedure described in Ref 126, pp 230-33, except that the quantities are much smaller.

V) Spanish Method. The procedure used at the Pirotecnia de Sevilla on an industrial scale, is described by Vivas, Feigenspan & Ladreda (Ref 104a, pp 316-22). The same method can be used in the laboratory provided the quantities are much smaller.

Plant Manufacture of Dextrinated LA by the duPont Method. The procedure briefly described below is essentially the same as was observed by B.T. Fedoroff at the Kankakee Ordnance Works, Joliet, Illinois, which was operated by the United States Rubber Company. This method is based on the duPont method developed before WW II [See Bleiazid, pp Ger 12-13 of PATR 2510 (1958)].

In the manuf of LA, the size and shape of the crystal is most important. The crystals produced by the duPont method are free-flowing, light buff, spherical in shape, opaque in appearance under the microscope and averaging not over 0.07 mm in diam. Their Pb(N₃)₂ content is ca 92.5%.

Dextrin is used as a colloid agent, which prevents the formation of large sensitive crystals of LA and regulates, to some extent, the shape, though not so much as NaOH and the agitation. It has been found that an unsatisfactory dextrin could be much improved by its pptn from an aq soln of alcohol. Furthermore, the addn of various substances such as K or Na ferrocyanide, Na oxalate, Na tartrate and Rochelle salt improves the colloid action of dextrin. The use of amts of dextrin in excess of the prescribed duPont method tends to lower the purity and make the final LA product more hygroscopic. In the duPont process, yellow potato dextrin with not more than 0.2% insol material is used.

As the concn of solns employed in the manuf of LA affects crystal size and shape to some extent it is advisable not to deviate from the following concns: 7.325±0.075% Pb(NO₃)₂, 3.175 ± 0.025% NaN₃ and 4.1 g dextrin per liter of Pb nitrate soln.

Unless the Pb nitrate content is sufficient to give 10% excess over theory, fine white crystals appear in the mother liquor which will not settle out properly and which mix with
the LA to give it a white appearance. This condition is not particularly serious, but the yield and purity are lowered and the resulting product tends to cake on the drying pans and to be dusty.

Procedure  

a) Prepare the stock soln A by dissolving 169 lb (ca 73.9 kg) lead nitrate in about 750 l of water treated by the permute demineralizing process. Care must be taken to remove all grit and insol matter. As this soln is usually acidic (pH 4.2-4.6), add slowly 25 to 30 g NaOH in dil aq soln. NaOH serves to neutralize all acid either occluded or that due to hydrolysis of lead nitrate. An excess of NaOH must be avoided because it tends to produce elongated crystals of LA which are very sensitive. Add to the stock soln 9 lb (ca 4.08 kg) potato dextrin previously dissolved in about 100 l of water AND then bring the soln to 7.325 ± 0.07% Pb(NO₃)₂ content.  

b) Prepare the stock soln B by diluting with treated w the refined solution (contg ca 27% NaN₃) delivered from the Sodium Azide (qv) plant to 3.175 ± 0.02% NaN₃ content. Add 794 g NaOH in pellets. This quantity of caustic is supposed to be sufficient to keep neutralized most of the free acid formed during the interaction of lead nitrate soln for pptg LA. This quantity of NaOH is also just sufficient to control the purity of the finished LA, because it prevents a small amt of lead as Pb(OH)₂ or Pb(OH)NO₃. Adjust the concn of stock soln B to 3.175 ± 0.025% NaN₃ content.  

c) Drop 60 l of stock soln B (10% in excess) from a 1000 l storage tank to the stainless steel measuring tank of ca 100 l capacity. f) While agitating the soln at 95 RPM and maintaining the temp at 135-140°F add the soln B at a rate of 2 l per min. When the soln is all in, start to circulate cold w through the jacket, while continuing the agitation until the temp drops to 90° or lower. g) Stop the agitation and when LA settles, decant the mother liquor to the "killing tank," where the azide content is destroyed with NaNO₂ and HNO₃, as described under Destruction (Killing) of Azides. h) Wash the ppt of LA into a rubber bucket and transfer on filter cloth spread over a vacuum Nutsch. Rinse the ppt with water and four changes of w and send it to the killing tank. i) Leave on the last wash just enough of LA which are very sensitive. Add to the w to cover the LA and pack the wet LA (24-26% moisture) in drums for shipment. The overall ppt time cycle is 60 mins, and 7.6 lbs LA (92.3% purity) is produced per pptn.

Analytical procedures for plant control and for finished products are described under Lead Azide, Analytical Procedures and under Sodium Azide Analytical Procedures.

Note: A plant method used in Argentina is similar to the laboratory method described above, except that much larger quantities of lead nitrate, sodium azide and dextrin were used. A plant method used in Germany before and during WWII is described in Ref 157a, under Bleiazid. A plant method used in Italy is described in Ref 126, pp 230-33 and the method used in Spain is described in Ref 104a, pp 316-22.

Explosive Properties of LA. Many compds have been proposed as substitutes for MF but none has been found more suitable than LA. The others are either too sensitive, too expensive or less effective than LA in initiating efficiency. As early as 1893 the Prussian Government investigated the azides of Pb, Ag and Hg for possible uses as detonants, but a fatal accident caused these experiments to be discontinued. No further work was done with LA until Wöhler in 1907 called attention to it again as a possible substitute for MF (Refs 15 & 59). Since that time...
considerable interest in and study of the expl props have resulted:

**Brisance by Sand Test.** Dextrinized LA 95% as brisant as pure, crystalline LA; 75% as MF and 37% as diazodinitrophenol (Ref 141); calcd by Kast formula LA 107 × 10⁴ and MF 128 × 10⁴ (Ref 73) by Lead Plate Test, LA is much less effective than MF (Ref 13). Stewart (Ref 11) claimed LA had same brisance as MF.

**Detonation Rate.** 4500 m/sec at d 3.8 to 5300 m/sec at d 4.6 (Refs 28 & 73), 5400 m/sec at max d (Ref 91). For addnl values and discussions see Roth (Ref 106), Bowden & MacLaren (Ref 138), Cook (Ref 107) and others (Refs 13, 43, 48, 50, 57, 59, 67, 86, 118, 131, 141, & 151). Deton effect on plastic material test conditions; for pure LA vs 11,900 kg/cm² for MF calcd by Kast formula (Ref 73) (See also Refs 11 & 53)

**Explosion Temperature.** 315° for pure LA and 275° for dextrinized LA (min temps for ignition in 5 sec) (Ref 106) (See also Refs 33, 79, 83, 110, 111, 122a & 132)

**Friction Sensitivity.** LA is more sensitive than MF (Refs 73, 79 & 110). Bowden & Gurton (Ref 112) deter the effect of grit particles for frictional initiation of LA

**Gas Evolution on Explosion.** 308 l/kg for LA vs 315 l/kg for MF (Ref 91)

**Impact Sensitivity.** Dextrinized LA is less sensitive to impact than MF, Pb stypnate, diazodinitrophenol, tetracene or crystalline LA. When wet with water or alc LA is still sensitive to deton by impact (See also Refs 9, 11, 16, 29, 33, 35, 73, 79, 81, 91, 110, 122a, 131, 136, 140, 159 & 166); with 2 kg wt LA 12 cm vs MF 5 cm (Ref 82), with 500 g wt LA 30-40 cm vs 10.5 cm for MF (Ref 35a)

**Initiating Efficiency.** More efficient initiator than MF and slightly less efficient than diazodinitrophenol (See Table under Mercurous Azide and Refs 16, 29, 38, 46, 48, 49, 59, 71, 73, 79, 81, 94, 101 & 116)

**Power by Trauzl Test.** Dextrinized LA is 89% as powerful as pure LA and 80% as powerful as MF (Ref 141); 181 cc expansion for 10g LA vs 128 cc for MF calcd by Kast formula (Ref 73) (See also Refs 11 & 153)

**Pressure.** Developed on Explosion (own vol). 94,930 kg/cm² vs 90,260 kg/cm² for Ag azide, both at loading d 3.0 g/cc under 1100 kg/cm² press (Ref 16). Noddack & Grosch (Refs 132 & 147) calcd the surface press on explosion as 11,900 kg/cm² for LA vs MF 14,3000 kg/cm².

**Stability to Heat.** % loss in wt in 75°C International Test: 0.17 for LA vs 0.18 for MF; 100°C Heat Test: 0.5% loss 1st 48 hrs and 0.1% 2nd 48 hrs vs expln for MF under same test conditions; 100°C Vac Stab Test: 0.4cc gas evolved in 40 hrs (Ref 141). The thermal stability of both dextrinated and pure LA is exceptional (Ref 116)

**Specific Energy.** 4380 kg/l (Ref 28), 361.2 joules/gm (Ref 169)

**Stability in Storage.** LA has been found unchanged with respect to purity or brisance after storage for 25 months at 50° or after storage under a w-alc mixt at RT; storage at 80° for 15 months caused no decrease in brisance, and after similar storage, a priming compn contg LA showed no decrease in sensitivity to stab action (Ref 141) (See also Refs 11, 28, & 79). On the otherhand, MF stored at 80° for 1 day was reduced to 92% purity and its initiating efficiency was practically destroyed (Ref 141)

**Temperature Developed on Explosion.** 3420° (Ref 16) to 3450° (Refs 73 & 91); 3484° (Ref 128a, p 1)

**Thermal Decomposition.** LA has been the subject of study by a large number of investigators: Hitch (Ref 17) found LA extremely hard to decomp without explg. Garner & Gomm (Ref 44) in studying the rate of decomp of α and β-forms found that β-LA decomp much more rapidly than α-LA; the critical increments were α-form 47,600 cals and β-form 38,800 cals. The kinetics of
thermal decompn of α-LA were studied by Evans (Ref 165), Hill (Ref 156) and Griffiths & Goocock (Refs 152 & 155) who found initial rapid evolution of gas, followed by the formation of surface nuclei which grow three-dimensionally. The decay stage followed the contracting sphere mechanism. Garner (Refs 88 & 161) also investigated the reaction kinetics of LA decompn while Hawkes & Winkler (Ref 106) indicated that thermal expln of LA may be spontaneous. The min energy requirements for ignition of LA and other expls have been reported (Ref 164).

According to Suzuki (Ref 133), Ryabinin (Ref 105), Tsukerman (Ref 103), Apin (Ref 84), Yoffe (Ref 121), Ubelohde et al (Ref 111) expl decomp occurred after an induction period. Moskovich & Aleksandrovitch (Ref 65) found that during the induction period, Pb atoms formed at the cryst surface were autocatalytic in accelerating decompn. Experiments by Apin (Ref 84) showed that the decompn velocity increased slightly during the induction period, then rapidly, and finally expln occurred. Muraour (Ref 77), Andréev (Ref 168) and Bowden et al (Refs 120 & 148) have studied the effects of pressure and confinement on the decompn rate of azides, fulminates and other expls. Also studies of LA decompn in vacuo have been reported by Schumacher (Ref 55) and Burlot (Ref 56). Muraour & Schumacher (Ref 56a) and of the influence of heat have been reported by Belyaev (Ref 83), Weyl (Ref 122) and the effect of shock from electrons by Muraour (Ref 54). The critical amt of LA for ignition in H2-O2 mixt and CH4-air mixt has also been detd (Ref 117).

Andréev (Ref 154) published a book on the thermal decompn and expln of subs which includes a discussion on azides. Recent exptl work on azide research has been reviewed in a symposium on the initiation and growth of explosions in solids [Proc Roy Soc 246A, pp 145-297 (1958)]. Wyatt (Ref 160) discussed ignition by electric discharge, Bowden (Ref 162) ignition by neutrons, α-particles and fission products, Kaufman (Ref 163) discussed the effect of nuclear radiation and Groocock (Ref 155) Todd and Parry (Ref 172) the effect of high energy x-rays on the thermal decompn of LA. Low x-ray dosage caused LA crysts to decrepitate with heat and to increase in hardness. Higher x-ray dosage produced severe damage, 98% destruction of a Service LA sample was observed after an x-ray dose of 3.5 x 10⁶ röntgen. In air the solid decompn prod was basic lead carbonate, 2PbCO₃·Pb(OH)₂. In the absence of CO₂ but in the presence of w, the prod was Basic Lead Azide of unknown formula. According to Renaud (Ref 119) LA when treated for 20 min with a supersonic intensity of 100 w/sq cm and 1 megacycle/sec showed no explosibility. Audubert (Ref 76) found that slow thermal decompn of LA gave rise to UV radiation (See Refs 67a & 69).

Effects of Radiation. LA exposed to gamma radiation by Warren et al and by Kosenwasser, as reported in Ref 139, exhibited post-irradiation gas evolution as measured by vac stab test appar. Bowden & Singh (Ref 135) irradiated Pb, Ag and Cd azides with electrons, neutrons, fission prods and x-rays. All azides were exploded by an intense 75-kv electron stream. Thermal neutron irradiation did affect the subsequent decompn of Li and Pb azides. Muraour & Ertaud (Ref 129) also subjected LA to a neutron flux. Raney (Ref 158) reported that a total flux of 7.5 x 10¹⁶ n/sq cm converts LA to Pb carbonate. According to Berchtold & Eggert (Ref 128) ignition of LA by exposure to energy from a photographic "electron" flash bulb at a distance of 6 cm, reqd 240 W-sec energy. The dissociation of LA by absorption of light energy was described by Eggert (Refs 130 & 167).

Other Properties. Delay et al (Ref 100) and Mohler (Ref 98) obtd infrared absorption spectra of LA and other expls in the range 3 to 19μ. Kahovec & Hohlrausch (Ref 109) detd the Raman Effect of crystalline LA. Wöhler (Ref 7) observed that LA decompd in
direct sunlight quicker than other azides. In sunlight or under w, LA becomes yel-brown and then it yel; NH₄ is evolved as a result of the reduction, by Pb, of the HNO₃ formed on hydrolysis; the Pb is oxidized to form a Basic Lead Azide PbO·Pb(N₃)₂ (qv) (Ref 9). Delyaev & Maryushko (Ref 87) measured the heat conductivity of LA and obtd a Specific Heat value of 0.09 cal/gm/°C vs a value of 0.1 for MF. Roth's (Ref 169) value of the ratio of mean specific heats is 1.337. Hattorie & McCrone (Ref 144) measured the Refractive Index and the Molecular Refraction of form I (α) and form II (β) LA.

According to Stewart (Ref 11) moist LA is not affected by contact with steel or Fe whereas MF changes under storage in contact with these metals. Also Cu, brass and Al had considerably less effect on LA than on MF (Ref 28). LA does corrode Cu with the formation of the extremely sensitive Cupric Azide (qv) (Ref 99). Eschback & Lübbecke (Ref 39) avoided the reaction of LA with Cu or brass parts by coating them with Cd. Warren (Ref 89) has also studied the action of LA on copper.

According to Seavey & Kerone (Ref 63) LA can be made safe for handling by wetting it with a non-flammable liq, such as dichloroethyl ether, which is a non solvent and is less volatile than w but is capable of complete removal by drying. Moskovich (Ref 75) prep'd stable gelatin emulsion of LA and detd their props. Strecker & Claus (Ref 26a) found that selenium monobromide reacted with LA suspended in benz forming Pb chloride and selenium. Klatt (Ref 80) noted that LA in HF produced an insol ppt of PbF₂ with evolution of gaseous HN₃. The characteristics of LA have been modified by Birkenbach & Rorig (Ref 30) by the formation of mixed crystals or double salts, such as Pb(N₃)₂·PbCl₂ and Pb(N₃)₂·PbBr₂. The double salt with Pb bromide was not exploded by a 10-kg hammer falling through 100 cm, whereas, the Pb chloride double salt exploded when the same hammer fell 65 cm. Pure LA exploded when a 2-kg hammer fell 35-40 cm. Friederich (Ref 25) by simultaneous or successive pptn obtd LA in mixed or double crysts with other subs, such as basic lead azide (qv), heavy metal hydroxides, carbonates, basic chlorides and sulfates, and neutral and basic salts of nitro compds. Such mixed LA crysts are claimed to be suitable for use in expl compns.

**Destruction or Killing of LA.** Explosives of the initiating type, such as LA, cannot be burned, hence relatively large quants are destroyed by detonating them; small quants are depred chemically. LA can be chemically destroyed by any one of the following methods (Ref 141): (a) mix LA with at least 5 times its weight of a 10% NaOH soln and allow the mixt to stand for 16 hrs with occasional stirring. The resulting supernatant soln of Na azide is decanted and disposed of by drainage into the ground. (b) dissolve LA in a 10% ammonium acetate soln and add a 10% Na or K bichromate soln until no more yellow lead chromate is pptd. (c) Wet LA with 500 times its weight of w, slowly add 12 times its weight of a 25% sodium nitrite soln, agitate, and then slowly add 14 times its weight of a 36% nitric acid or glacial acetic acid soln. A red color produced on adding ferric chloride soln indicates LA is still present. Toxic fumes of nitrogen oxides (See Sax, Ref 150, p 950-1) are liberated in this process: Pb(N₃)₂ + 2NaNO₂ + 4HNO₃ + Pb(NO₃)₂ + 2NaNO₂ + N₂O₃ + 2N₂ + 2H₂O. (d) dissolve LA in 50 times its weight of a 15% ceric ammonium nitrate. The LA is depred with the evolution of nitrogen.

**Uses.** Hyronimus of France (Ref 3) should be credited with the first success, in 1907, in the attempt to use LA in the expl industry. He proposed the use of LA in detonators to replace either wholly or in part the MF which had been used theretofore. In 1908 and later Wöhler (Ref 4) also secured patents for the use of LA as a substitute for MF in filling detonators and primers. Soon afterwards LA was manufd in Germany and in France and compd detonators were used in Europe during WWI. Some years later the manuf of LA
detonators was begun in the USA but, since 1930, its military and comi uses have been restricted to "dextrinated" LA.

A number of investigators have conducted tests or reviewed the literature relative to the use of LA as a detonation agent. These include reports by Stettbacher (Reps 13, 31, 85 & 114), Taylor & Cope (Ref 14), Hale (Ref 29), Taylor & Rinkenbach (Ref 33), Audrieth (Ref 59), Ubbeholde et al (Ref 111), Rosenwasser (Ref 170), Evans et al (Ref 171) and others (Reps 5, 8, 10, 12, 16, 27, 34, 36, 17, 12, 14, 62, 127, 141, & 157). The large and extensive patent literature is evidence of the importance of LA as a detonating expl.

LA is used as an initiating agent in military ammo and in priming compns which are physical mixes of materials that are very sensitive to impact or percussion, and when exploded undergo very rapid auto combustion. LA has many advantages over MF: (a) it is safer to handle, (b) its nitrogen content is higher, (c) it possesses a lower sensitivity to impact and percussion when pressed and is more easily detonted by flame than by shock or friction, (d) while MF and some other initiating compds become "dead" at high press, LA acquires a higher brisance and penetrating power when compressed to high density. (e) it is less expensive than MF to prepare and (f) its raw materials are readily available (See also Lead Azide Explosive, Primer and Detonator Compositions).

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3) F. Hyronimus, FrP 384792(1907); JSCI 27, 524-5(1908) & CA 3, 1690(1909); BritP 1819 (1908); USP 908674(1909) & CA 3, 1088 (1909) and GerP 224669 (1910) & ChemZtg 1910 II, 771 4) L. Wöhler, BritP 4468(1908); FrP 387640(1908); GerP 196824(1908) & Chem Ztg 1908 I, 1439; USP 904289(1909) & CA 3, 717 (1909) and USP 1128394(1915) & CA 9, 1118(1915) 5) L. Wöhler, SS 6, 253(1911) & CA 5, 3730(1911) 6) J. W. Turrentine, JACS 33, 822(1911) & CA 5, 2455(1911) 7) L. Wöhler, ChemZtg 35, 1096(1911) & CA 6, 2894-5(1912)
8) A. L. Kibler, OrigComm 8th Int Cong Appl Chem (Appendix) 25, 235-8(1913) & CA 7, 2117(1913) 9) L. Wöhler & W. Krupko, Ber 46, 2052-3(1913) & CA 7, 3088(1913) 10) Anon, ProfNotes US Naval Inst Proc 40, 882-3 (1914) & CA 8, 2483(1914) 11) A. J. Stewart, US Artillery 41, 212-23 (1914) & CA 8, 3120 (1914) 12) Anon, Sprengstoffe, Waffen u Munition 9, 29(1914) & CA 9, 1392(1915)
yielded uniform products. Feitknecht & Sahli (Ref 4) prepd basic LA by hydrolysis of LA with H₂O, by reaction of LA with NaOH, and by pptn from Pb salt solns by a mixt of NaN₃ and NaOH.

X-ray examination (Ref 4) showed three forms of Pb(N₃)₂·PbO: Iα, the unstable reaction product of Pb(N₃)₂ with 1 equiv NaOH; Iβ, the stable reaction product of Pb(N₃)₂ with 1 equiv NaOH; and Iγ, the reaction product of Pb(N₃)₂ with PbO·½H₂O and the hydrolysis product of Pb(N₃)₂ with H₂O. Three forms of 3Pb(N₃)₂·5H₂O were identified: IIα, the reaction product of Pb(N₃)₂ with 1.2 equiv NaOH; IIβ, the ppt from Pb(NO₃)₂ with 1 NaOH and 1 NaN₃; and IIγ, the ppt from Pb(NO₃)₂ with 1.2 NaOH and 0.8 NaN₃. Basic LA, form III, Pb(N₃)₂·2PbO·Pb(N₃)₂·3PbO; form IV, 2Pb(N₃)₂·7Pb(OH)₃; and form V, Pb(N₃)₂·4PbO to Pb(N₃)₂·9PbO were also reported by Sahli (Ref 4).

Basic LA is less sensitive to impact or temp than normal LA. According to Mellor, however, (Ref 3) an intimate mixt of LA and oxide in proportions necessary to form the sub-oxide showed the same sensitivity as pure LA.

Friederich (Ref 2) proposed the use of basic LA in mixed or double crysts with other subs, such as L.A, heavy metal carbonates etc. The double crysts were obtd by simultaneous or successive pptn.


Lead (IV) Azide. Treatment of Pb₃O₄ with aq HN₃ soln yielded a yel-red soln with a considerable Pb(IV) azide content. Normal HN₃ soln and Pb₃O₄ gave compds of PbN₃ to PbN₁₀, while concd HN₃ solns yielded a compd slightly lower than PbN₁₀. These aq Pb(IV) azide solns decompd spontaneously with evolution of N₂ and pptn of Pb(N₃)₂. Attempts to prepare solid Pb(IV) azide by mixing ethyl acetate or acetone solns of (NH₄)₂ PbCl₄ and NaN₃ gave a dk-red soln. This soln on treatment with petr eth gave an unstable expl azide thought to be NH₄Pb(IV) azide.

Ref: H. Möller, ZAnorgChem 260, 249-54 (1949) & CA 44, 5750-1 (1950)
Lead Azide; Various Military Types.

Although LA has been known since 1891 and patented in 1907 for use in detonators (see general discussion and Uses under Lead Azide), its adoption for military purposes was slow due to hazards involved in its manuf. Notwithstanding its many advantages over MF, some countries (such as Russia) still did not replace MF with LA in all primers and detonators. It is known that Germany, GtBritan and US started to use LA for military purposes in the early thirties. Germany and US adopted dextrinated LA, while GtBrit preferred cryst LA built around a nucleus of Pb carbonate (called "service" LA). Commercial manuf of LA in the US began ca 1932 by the du Pont Co and this material (dextrinated LA) was adopted some time later by the US Ordnance Corps. Another type of LA, the so-called colloidal, was known since about 1918 (see Refs 21, 23, 24 etc under general discussion on Lead Azide), but it was not until 1932 that it was investigated at PicArsn with a view of its use for military purposes (Ref 1). The material investigated at PicArsn was prep'd by the method patented by Rinkenbach (Ref 2). This investigation showed that CLA was much less hygroscopic than the DLA supplied by the du Pont Co and that it was about 3 times as efficient when used in detonators. Another type of non-dextrinated LA, the so-called PVA-LA (polyvinyl alcohol LA) was developed and patented in 1947 by Fleischer & Burtle (Ref 6) and assigned to Olin-Mathieson Chem Corp. This substance proved to be superior not only to DLA but also to CLA, as was later shown by Wagner et al at PicArsn (Refs 23 & 24).

According to Wagner (Ref 24), the DLA was considered satisfactory for military purposes until it was required to produce a small detonator for use in 20 mm ammo. The development of this detonator, which began at PicArsn ca 1947 is described in detail by Seeger (Ref 14). This detonator, designated as M47 or T32E1, was a short, stab-type contg as a primary chge ca 15 mg NOL No 130 [basic LSt 40, LA 20, tetracene 5, Sb₂S₃ 15 & Ba(NO₃)₂ 20%], as a base charge not less than 34 mg RDX and as an intermediate charge LA. As the dimensions required for this detonator were very small (0.290" long and 0.145" diam, outside), there was not enough room to contain the amt of DLA needed to achieve what was required from this detonator. This meant that a more efficient expl than DLA was required. As no other initiating expls seem to be superior to LA, it was decided to investigate the non-dextrinated LA's and to compare their properties with dextrinated LA's. A total of six LA's (including the dextrinated) were investigated at PicArsn (see table, p A559), while experimental LA's RD-1343 and RD-1352 were investigated in GtBritain. Since Gt Brit reports ERDE 7/R/58 and ERDE 10/R/57, describing prepn and props of RD-1343 and RD-1352 are conf, they were not used.

Following LA's are listed by Wagner (Ref 24):
A) Dextrinated Lead Azide: (abbrd as DLA), known also as Type I LA (US). Its prepn and props are described under Lead Azide.
B) Service Lead Azide: (abbrd as SLA) (Brit). It is the std United Kingdom LA consisting of LA crysts each contg a nucleus of Pb carbonate. Its method of prepn is probably conf. No repts describing its prepn were available at PicArsn. Its props were detd at PicArsn on a sample procured from the Western Cartridge Co, which used to manuf this material for Canada during WW II (Ref 24). Most of these props are listed in the table, p A559.

Brit service LA is practically non-hygroscopic and is superior in functioning characteristics to dextrinated LA, but it offers no substantial advantage over RD-1333 LA. It has been considered at Gt Brit that storage of SLA under w is hazardous due to the possibility of growth of crysts and formation of agglomerates which deton spontaneously. At least one expln was attributed to this cause. Long-term storage tests conducted at PicArsns did not show any growth of crysts (Refs 22 & 24).
C) Colloidal Lead Azide: (abbrd as CLA) or Type II (US) is non-dextrinated LA of very small (3-4 micron) particle size, patented in 1933 by Rinkenbach (Ref 2). For its prep, to an aq soln contg 4% of Na azide was rapidly added, while mechanically agitating and maintaining the temp at 25°, a soln of Pb nitrate or Pb acetate in slight excess of the amt necessary for the equation:

\[ 2\text{NaN}_3 + \text{Pb(NO}_3\text{)}_2 \rightarrow \text{Pb(N}_3\text{)}_2 + 2\text{NaNO}_3 \]

The resulting slurry was filtered and the ppt washed with several portions of w and dried. This product could be handled and pressed without danger of expln (Ref 2). This statement is not consistent with the impact test values given in table, p A559. This table also gives some other props of CLA, as was reported in Ref 24. Its loading d was not reported at 15000 psi, but in Ref 1 it is given as 2.77 vs 2.93 for crystalline LA. Stability in storage is given in Ref 18.

According to Ref 24, the CLA is not suited for uses requiring good flow characteristics, but, because of its very fine particle size it is ideal as a spot charge and a priming chge in low energy electric initiators. It successfully replaced the milled dextrinated LA formerly used for this purpose, thus eliminating the milling operation which was always considered dangerous, even under carefully controlled conditions. For prep a spot charge for a low energy elec detonator, a dry colloidal LA is mixed with a concd soln of NC in ethal (or other solvent) and a small quantity of resulting paste is placed on the bridge wire to form a droplet (spot). For a type of detonator in which the bridge wire is located inside a cavity, the charge of LA can be made in the form of a pellet by pressing wet LA into the cavity.

US Military requirements and tests for colloidal LA (called also Type II) are given in Ref 19. The tests are essentially the same as for DLA (Type I) (See item VII under Lead Azide, Plant Analytical Procedures), except the particle size detn.

D) Polyvinylalcohol Lead Azide: (abbrd as PVA-LA), patented by Fleischer & Burtle (Ref 6) can be prepd by adding to the soln of NaN, a soln of Pb nitrate contg ca 3% of PVA in soln. The resulting product consists of LA crysts coated with PVA. This method of prep is very similar to prep of dextrinated LA described in detail under Lead Azide. PVA-LA possesses practically the same sensitivity to impact as DLA, but is much more efficient in detonators and is practically non-hygrosopic. Its assay is usually 93-96% LA. Its ignitability is practically the same as for straight LA and better than for DLA. Some props of PVA-LA contg 96.07% LA are given in the table. For more info on PVA-LA see Refs 23 & 24.

Note: Fleischer & Burtle (Ref 6) also patented LA's prep by pptg in presence of one of the following substances: polyethylene glycols (such as "Carbowax" and hexaethylene-glycol) and ureaformaldehyde polymer (such as "Uformite). Their props were claimed to be similar to those of PVA-LA.

E) RD-1333 LA (Brit). It is an experimental expl developed as a possible substitute for the SLA, which has been considered to be too sensitive for some operations. Method of prep of RD-1333 is described in conf Brit rept (Ref 12). Its props were examined at Pic Ars and are given in conf rept (Ref 21). The props of RD-1333 listed in the Table, p A559 were taken from an unclassified rept (Ref 24).

F) Dextrinated Colloidal Lead Azide (abbrd as DCLA), was prepd on an experimental basis by the Olin-Mathieson Chem Corp, in essentially the same way as the DLA except that process controls were regulated to give an end product of a very small (1-2 micron) particle size. Its props are described in Ref 24. See also the table on p A559.

G) RD-1343 LA (Brit). It is an experimental LA, considered to be an improved version of RD-1333-LA. Its prep and props are described in conf Brit rept (Ref 20).
### Various Types of Lead Azide (Comparison of Some Properties)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Dextrinated (Type I, US)</th>
<th>British Service</th>
<th>Colloidal (Type II, US)</th>
<th>PVA (US)</th>
<th>RD-1333 (Brit Exptl)</th>
<th>Dextrinated Colloidal</th>
<th>RD-1343 (Brit Exptl)</th>
<th>RD-1352 (Brit Dextr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td></td>
<td>Wh</td>
<td>Wh</td>
<td>Wh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead azide, %</td>
<td>92.7</td>
<td>98.1</td>
<td>99.9</td>
<td>96.0</td>
<td>98.7</td>
<td>95.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total lead, %</td>
<td>69.3</td>
<td>71.5</td>
<td>71.67</td>
<td>71.6</td>
<td>71.06</td>
<td>69.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particle size, mean, microns</td>
<td>24.5</td>
<td>55.0</td>
<td>3.4</td>
<td>19.0</td>
<td>34.5</td>
<td>1.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apparent density, g/cc (Ref 1)</td>
<td>1.83</td>
<td>-</td>
<td>0.85</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Density (pressed at 15000 psi), g/cc</td>
<td>3.14</td>
<td>3.31</td>
<td>-</td>
<td>3.81</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sand test values</td>
<td>13.8**</td>
<td>-</td>
<td>15.0**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Expln temperature (5 secs), °C</td>
<td>340</td>
<td>350</td>
<td>344**</td>
<td>340</td>
<td>345</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Impact sensitivity:</td>
<td></td>
<td>Wh</td>
<td>Wh</td>
<td>Wh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PicArsn App, 2 kg wt, inches</td>
<td>4-6</td>
<td>2</td>
<td>2-3</td>
<td>4-5</td>
<td>5</td>
<td>3-6(?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>charge wt, mg</td>
<td>28</td>
<td>37</td>
<td>25</td>
<td>30</td>
<td>23</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BurMinApp, 2 kg wt, cm</td>
<td>13-28</td>
<td>30(?)-</td>
<td>-</td>
<td>13-16</td>
<td>15</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PicArsn App, 500 g wt, in</td>
<td>12(?)-</td>
<td>-</td>
<td>6**</td>
<td>18</td>
<td>15</td>
<td>-</td>
<td></td>
<td></td>
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<tr>
<td>Charge wt, mg</td>
<td>28</td>
<td>-</td>
<td>-</td>
<td>31</td>
<td>21</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BurMinApp, 500 g wt, cm</td>
<td>100+</td>
<td>-</td>
<td>35**</td>
<td>100+</td>
<td>100+</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum stability (avg):</td>
<td></td>
<td>Wh</td>
<td>Wh</td>
<td>Wh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100°, gas evolved, ml/g/40 hrs</td>
<td>0.32</td>
<td>-</td>
<td>-</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>120°, gas evolved, ml/g/40 hrs</td>
<td>0.46</td>
<td>-</td>
<td>-</td>
<td>0.44</td>
<td>0.43</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>100° Heat Test:</td>
<td></td>
<td>Wh</td>
<td>Wh</td>
<td>Wh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss in sample wt in 8 hrs, %</td>
<td>-</td>
<td>0.11</td>
<td>-</td>
<td>0.12</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Loss in sample wt in 48 hrs, %</td>
<td>0.34</td>
<td>0.08</td>
<td>-</td>
<td>0.13</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Loss in sample wt in 96 hrs, %</td>
<td>0.39</td>
<td>0.16</td>
<td>-</td>
<td>-</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Explosion in 100 hrs</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Minimum chge in mg required to initiate 60 mg RDX base chge of M47 Detonator *</td>
<td>90</td>
<td>25</td>
<td>-</td>
<td>30</td>
<td>25</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hygroscopicity at 90% RH and RT (% gain in 56 hrs)</td>
<td>1.18</td>
<td>0.07</td>
<td>0.02**</td>
<td>0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Solubility, g/100 g H₂O</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At ca 10°</td>
<td>0.056</td>
<td>0.019</td>
<td>-</td>
<td>0.017</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>At ca 35°</td>
<td>-</td>
<td>0.032</td>
<td>-</td>
<td>0.041</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Soly in 50% alc at ca 35°</td>
<td>-</td>
<td>0.009</td>
<td>-</td>
<td>0.022</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

* LA was used as an intermediate charge; as a primary chge was used 15 mg of NOL No 130 mixt (basic LSt 40, LA 20, tetracene 5, Ba nitrate 20 & Sb sulfide 15%). All chges of M47 were consolidated at ca 15000 psi

** Values given in PATR 255 (1932)
H)RD-1352-LA (Brit). It is an experimental dextrin LA prep with the idea of improving the existing Brit LA's. Its prep and props are given in Brit conf rept (Ref 17).

Remarks on Table: a) LA content was detd by measuring the nitrogen content of the sample and calcg % LA [See US Ordnance Corps Gasometric Method, item III C a, under Lead Azide Plant, Analytical Procedures] b) The % lead in a sample on a LA basis is always less than that given by a total lead analysis (See item III D, under Lead Azide Plant, Analytical Procedures). A sample calcn showing this is outlined below: mw of Pb(N)₂ = 291.26; at wt of Pb 207.21 and % Pb in Pb(N)₂ = 207.21/291.26 = 71.08. If % Pb(N)₂ in a DLA is 92.8, then % Pb in sample based on LA is 71.08 x 92.8 = 65.8, as against 69.3 found by analysis. The % excess of Pb: 69.3 - 65.8 = 3.5 is due to Pb contg impurities, believed to be organic complexes of lead hydroxide. This is also true for other LA's contg organic matter (such as PVA LA, DC LA, RD-1333, RD-1343 and RD-1352). The Pb contg impurity in case of Brit SLA is Pb carbonate.

c) Particle size was detd either according to procedures given in Ref 19 or by the improved microscopic method of Lavitt (Ref 10).

Note: According to Wagner (Ref 24), it has always been generally accepted that a few of the accidental expls which have occurred with LA during its history were caused by the fracture of crysts which were too large or too easily fractured. Some of the recent investigators, such as Garner & Gomm (Ref 3) and Miles (Ref 4) are inclined to think that accidental expls might be caused by the beta variety of crysts which are formed during manuf together with alpha-crysts and remain in stored LA. This view seems inconsistent with the recent work conducted at the Armour Research Foundation (Ref 15), in which it was shown that if any beta-variety were made, it would be rapidly transformed to the alpha-form when the material is stored under water.

According to Wagner (Ref 24) it is believed that the sensitivity of LA is due at least in part, to internal stresses formed in the crystal which are an inherent result of the manufg process. Consequently both large and small crysts could be stressed, making them extremely sensitive to impact. More evidence that cryst size is not a controlling influence on impact sensitivity may be found in Ref 11.

d) Apparent density given in the table for duPong DLA and for CLA was detd by Burton & Hopper (Ref 1) by filling with a slight tapping a tared 5 ml graduate to the mark and weighing the ensemble.

e) Density of pressed sample was detd by the mercury displacement method. For this a tared No 6 cap was filled with Hg and weighed. After emptying the cap, it was filled with a sample, compressed at 15000 psi and accurately weighed. After adding some Hg to fill the empty space in the cap created by compressing, the cap was reweighed.

\[ d = \frac{A}{B - C} \times 13.546 \]

A = wt of sample, B = wt of Hg necessary to fill the cap C = wt of Hg to fill the empty space and 13.546 the d of Hg

f) Sand test values were taken from Ref 1. They were detd by the proced described in Ref 7.

g) Explosion temperature values were detd as described in Ref 7.

h) Impact sensitivities were detd as described in Ref 7.

Note: Most of the impact sensitivity values recorded in the table, pA559 are averages of those reported in various CLR and GLR reports of PicArsn. The values which appeared to be doubtful are marked with (?). It seems that the values obtained for LA with PicArsn app are more reliable than those obtained with BurMines app. This unrealibility is particularly noticeable when a 2 kg wt is used with BM app. As readings for LA's are very small when using the 2 kg wt, it is difficult to differentiate between samples because their sensitivities are so similar. It is easier to
evaluate the sensitivities if larger readings are obtained, such as when using a 500 g wt
i) Vacuum stability test and 100°C Heat test
were determined according to Ref 7. Judging from
the data as recorded in the table, p A559, all types of LA's investigated at PicArsn were of satisfactory stability
j) Minimum charge of LA required to initiate
60 mg of RDX was determined by loading each of
many caps used for M47 detonator with 60 mg
RDX (base charge) and different amounts of LA
(initiating charge). The smallest amount of LA re-
quired to cause high order detonation (as judged
by the diam of hole punched in a lead
disk on firing a cap against it) in 100% of
firing was considered the minm charge
k) Hygroscopicity was determined according to the
procedure described in Refs 9 & 13. The same
info is given in Ref 14

In this procedure a 2-3 g dry sample
was transferred by means of a wooden spat-
ula to a tared Petri dish (ca 90 mm diam and
13 mm high). After redrying the sample at
95°C for ca 30 mins, the ensemble was cooled
for 20 mins in a desiccator and reweighed.
All weighings were made as quickly as pos-
sible. The dried sample and dish were placed
in a humidor maintained at 90% RH and
30°C and left there for a specified period, such as
24, 48, or 56 hours

Note: Results in the table, p A559 indicate
that of all the examined types of LA's only
DLA is very hygroscopic. This means that
it can pick up moisture in excess of permitted
max 0.5% from the time of its removal from
the dry house until it is used for loading
detonators (Ref 24). From this it is logical to
assume that some of the picked up moist
would have to be volatilized before DLA
could be raised to a temp high enough to be
initiated by flame. This means that the
higher the moist content, the harder it will
be to initiate DLA especially by heat tran-
sfer and the lower will be the output. This
decrease in output might be the result of a
substantial decrease in the stable deton rate
or the inability of DLA to attain a high rate
of deton in a limited column length. If moist
content of DLA is 0.8% or higher, the deto-

nators used by the US Ordnance Corps usu-
ally function low order. It has been tenta-
ively established that in order to obtain a
high order detonation a column length of at
least 0.1" is required if dry DLA is used and an
appreciably longer column must be used if
DLA is moist. Most US detonators are long
enough to permit the use of DLA with a moist
content 0.5% or sl higher, but this does not
apply to the M47 detonator, which has a LA
column only ca 0.11" long and ca 0.12" in
diam. As it is practically impossible to have
DLA completely dry, its use in short deto-
nators, such as M47, cannot assure 100%
functioning high order. For these reasons,
it has been proposed to use in short deto-
nators non-hygroscopic materials, such as
PVA-LA, RD-1333-LA etc, which are be-
sides more effective than DLA

Aside from impairing the functioning of
LA, moisture in a detonator has other detri-
mental effects, such as hydrolysis with
formation of small quantities of hydrazoic
acid. This acid can react with Cu or Cu-
bearing alloys such as gilding metal cup
forming extremely sensitive Cu(N₃)₂ (See
under Copper Azide). In order to prevent this
danger the Brit use in their detonators, tin-
coated copper cups, while the US practice
includes coating of gilding metal cups with lac-
quers (such as Red No 1105) or paints (such
as acid-proof black paint Type I or II). With
these methods there is always the possibility
of scraping off part of the coating thus leaving
Cu exposed to the action of LA. For this
reason, the US Navy prefers to use Al cups,
but the Ordnance Corps considers Al not
very suitable because it does not provide
sufficient confinement and also because some
difficulties are encountered with shrinkage of
Al cups during loading. The ideal material
seem to be stainless steel because it is not
attacked by LA and because it provides suf-
ficient confinement (Refs 22 & 24

Another approach to prevent the formation
Cu(N₃)₂ has been suggested by the Linden Laboratories, Inc in their Final Rept Contract DAI-28-017-501-ORD-(P)-1405, April 1955. The method consists of treating the crystals of LA with a limited amt of H₂CO₃, H₂S or HI, so as to form lead carbonate, sulfide or碘ide on the surface without penetration into the crystal (Ref 22). This treatment will unquestionably reduce the efficiency of LA because it will be contaminated by inert materials.

l) Solubility of LA in water or in 50% alcohol was detd as described in item VII F under Lead Azide Plant Analytical Procedures.

In addn to above listed tests, the various LA's were loaded in M47 caps as intermediate chgs together with NOL No 130 as a primary chge and RDX as a base chge and subjected to the following tests given in the Purchase Description PA-PD-202, with Rev 1 dated 30 Sept 1952 and Amend 1 dated 27 Jan 1953:

A) Detonator acceptance test, conducted by firing each detonator against a lead disc gave satisfactory results because all samples punched holes not smaller than 0.156" in diam.

B) Detonator periodic functioning test, conducted by firing detonators, previously subjected to long-term storage at 71° against a lead disc as in previous test, also gave satisfactory results.

C) Detonator safety test, conducted by assembling M47 detonators into M505 fuzes and firing statically in M97A1 HEI 20 mm shells, gave satisfactory results.

Other tests included: ballistic firing test, booster initiation test and waterproofers test. They all gave satisfactory results.

In conclusion, it may be said that although all six types of LA's investigated at Pic Arsn are satisfactory, the PVA-LA and the RD-1333 LA stand out as being generally superior to DLA. The other types investigated: Brit SLA, CLA and DCLA, while superior to DLA in some respects such as output and hygroscopicity, have certain disadvantages, as can be concluded from the table, p A559 (See also Ref 24).

The latest Brit extn LA's, RD-1343 and RD-1352 cannot be discussed because they are classified materials.


LEAD AZIDE PLANT, ANALYTICAL PROCEDURES. The lead azide plant of the Kankakee Ordnance Works (KOW), Joliet, Illinois, operated by the US Rubber Co manuf dextrinated crystalline LA from Na azide and Pb nitrate in presence of dextrin. Na azide also was manuf at KOW; the analytical procedures are described under Sodium Azide, Analytical Procedures

Most of the procedures (unless otherwise stated) described below were taken from the "Lead Azide Laboratory Manual" (Ref 9) with grateful acknowledgment to the US Rubber Co

The procedures given below include not only the analysis of LA, but also analyses of primary materials used in the manuf of LA, as well as various solns, wastes, etc.

1) Lead Nitrate, intended for use in the manuf of LA is a commercial, specially washed product, which has to comply with the requirements of the US Military Spec MIL-L-20549, which are: a) Color-white, b) Moisture - 1.25% (max), c) Purity 98.0% min (calcd on the basis of the material as received), d) Water-insoluble matter - 0.20% (max), e) Acidity 0.50% max (calcd as HNO3), f) Copper—none

Procedures:

a) Color — by visual examination

b) Moisture. Accurately weigh approximately 10g in a tared glass-stoppered dish, remove the stopper and heat the dish for 5 hrs at 125°. Cool in a desiccator, stopper and reweigh

% Moisture = Loss of wt

Wt of sample

c) Purity. Transfer an accurately weighed sample (ca 1g) to a 250 ml beaker and dissolve in 100 ml distd w. Add dropwise 10 ml of satd Na sulfate soln contg 5% of sulfuric acid. Catch the ppt on a tared Gooch or Selas No 2001 crucible, wash with a 1% sulfuric acid soln and then with 50% alc. Heat the crucible and contents in a muffle furnace to const wt, cool in a desiccator and weigh

\[
\% \text{Pb}(\text{NO}_3)_2 = \frac{\text{Wt of } \text{PbSO}_4 \times 1.0922}{\text{Wt of sample}} \times 100
\]

Note: When using a Selas crucible, it is important to have it properly cleaned after each test. For this remove as much ppt as possible by inverting the crucible and tapping lightly, but do not use a glass or metal rod to pry the ppt. Convert the remaining sulfate to chloride by immersing the crucible in hot 1:1 HCl; wash it with hot distd w, employing both straight and reverse washings; dry thoroughly in oven and weigh to const wt. Repeat the operations until two successive washings agree within at least 0.005 g

d) Water-insoluble matter. Dissolve a 25 g sample (weighed on a trip balance) by heating it in a 500 ml beaker with 250 ml distd w. Filter the hot soln through a tared Gooch or Selas No 2001 crucible and wash the residue
thoroughly with hot distilled water. Dry the crucible at 100° for 2 hrs, cool in a desiccator and weigh.

\[
\% \text{WtM} = \frac{\text{Gain in Wt}}{\text{Wt of sample}} \times 100
\]

**Procedures:**

**a) Solubility in Water.** Agitate mechanically for 1 hr at 2-4° a 20 g sample in 1 l distilled water and, after allowing the slurry to settle for 30 mins, decant and filter about 150 ml of supernatant liquid. Pipette 100 ml of clear liquid to a tared 150 ml beaker and evaporate to dryness over steam. Dry for 2 hrs in an oven at 100°, cool in a desiccator and weigh.

\[
\text{Soly g/l} = \text{Gain in wt} \times 10
\]

**b) Insolubility in Water.** Dissolve in hot water a 5 g sample, digest it on a steam bath for 1 hr and filter while hot through a tared Gooch crucible. Wash the crucible with hot water, dry for 2 hrs at 100°, cool and weigh.

\[
\% \text{Insol} = \frac{(\text{Gain in wt})}{\times 100}\]

**c) Copper.** Dissolve a 100 g sample (weighed on a trip balance) in distilled water and precipitate all lead as sulfate by slowly adding a saturated aqueous solution of sodium sulfate containing 5% sulfuric acid. Filter through a filter paper, catching the filtrate in a Nessler tube. Add NH₄OH until alkaline and note if any Cu is present as indicated by the appearance of a blue color.

**Note:** A more sensitive test for Cu is the addition of a few drops of a dilute solution of K₃Fe(CN)₆ to the slightly acidic filtrate. A reddish-brown color due to CuFe(CN)₆ indicates the presence of Cu.

**d) Dextrin.** There seems to be no US military spec for potato dextrin used in munitions of LA, but there is Spec MIL-D-3994 covering the requirements of corn dextrin for use in pyrotechnic mixtures.

The following tentative specs were proposed by the Eastern Laboratories of the E.I. du Pont Co (Ref 9, p 24) for yel potato dextrin suitable in munitions of "dextrinated LA":

- **a) Solubility in Water.** 10 g/l (min) at 2-4°.
- **b) Insolubility in Water.** 0.3% (max) at 90°.
- **c) Starch.** Present or absent (see Note below).
- **d) Acceptor.** After plant trial prep of LA.

**Note:** The color obtained should be recorded, as it is a definite clue to the compn of the dextrin sample. The iodine test can indicate the extent of hydrolysis dextrin has gone through, and the solubility characteristics of the dextrin.

**d) Acceptance.** Prepare in the lab a sample of LA as described under Laboratory Preparation of Lead Azide, using the dextrin under test. See if the resulting LA meets the requirements of military specs.

**Note:** Requirements of MIL-D-3994 for corn starch used in pyrotechnic mixtures are more numerous and include:

- **a) Granulation.** Not less than 99.5% must pass a No. 80 US Std sieve.
- **b) Water, uncombined.** Not more than 5.0%.
- **c) Ash.** Not more than 0.15%.
- **d) Water insoluble material.** Not more than 2.5%.
- **e) Acidity as AcOH.** Not more than 0.18%.
Reducing sugars, as dextrose — not more than 4.0%

Lead Nitrate Dilution Tank. According to Ref 9, p 43, a basic unit at KOW consisted of a 1000 liter batch composed of 163 lb (ca 73.9 kg) Pb nitrate, 9 lb dextrin (ca 4.08 kg) and sufficient amount of NaOH to raise pH to 4.6-4.8 (each 10g NaOH raises pH about 0.1). Sodium hydroxide was USP or CP standard. The Pb(NO₃)₂ content in the tank was 73.25±0.75 g/l stored in the dark) to faint, but definite yellow end-point. The yellow ppt forming during the titration is an aid in observing the end-point. The yellow ppt was taken by the operator after each batch was made and analyzed in the lab as follows:

Determination Lead Nitrate Content: Method 1. Pipette 5 ml sample into a 400 ml beaker containing 150 ml distilled water and 20 ml acetate buffer soln (previously prepared by mixing 200 ml 50% CH₃COO-NH₄ soln with 800 ml 1:4 CH₃COOH/H₂O). Add dropwise 5 ml of 10% K₂Cr₂O₇ soln and boil on hot plate until the color of the soln becomes orange. Remove from heat and let settle. Filter through No 40 paper and wash the ppt with hot water until wash water becomes colorless.

Discard the filtrate and transfer the ppt quantitatively to an iodine reaction flask by successive washings with 3N HCl and hot water. Cool, add 10 ml of 10% KI soln and titrate with N/10 Na₂S₂O₃ soln until near discoloration. Add 5 ml of 0.5% starch soln and continue titration to greenish coloration.

Following reactions take place:

\[ 2\text{PbCrO}_4 + 6\text{KI} + 16\text{HCl} \rightarrow 2\text{PbCl}_2 + 2\text{CrCl}_3 + 6\text{KCl} + 8\text{H}_2\text{O} + 3\text{I}_2 \]

Calculation:

\[ \text{Pb(NO}_3\text{)}_2 \text{ g/l} = \frac{(\text{ml Na}_2\text{S}_2\text{O}_3) \times 1000 \times F}{3000 \times 5} \]

where \( F \) represents grams of \( \text{Pb(NO}_3\text{)}_2 \) corresponding to ml of std \( \text{Na}_2\text{S}_2\text{O}_3 \) soln. The stdzn of \( \text{Na}_2\text{S}_2\text{O}_3 \) soln is conducted in the same manner, using 1.8 g of CP lead nitrate weighed to the nearest mg.

Determination of pH by Bromcresol Green. Place 10.0 ml sample in a test tube and add 1.0 ml of 0.04% brom cresol green indicator (prepared by dissolving 100 mg powdered indicator in 2.9 ml N/20 NaOH and diluting to 250 ml with distilled water). After shaking the mix, compare its color with standards in the LaMotte comparator. With brom cresol green, the pH should be 5.2 to 5.4.

Note: More exact control of titre can be achieved by using a pH meter, such as The Coleman Industrial Tester No 15.

Refined Sodium Azide Liquor was made at the Sodium Azide Plant (qv) and transferred to the Lead Azide Plant.

According to Ref 9, p 37, the capacity of the basic unit at KOW was 900-950 lbs of soln with the following average analysis:

\( \text{NaN}_3 : 320 \text{ g/l}, \text{NaOH} 1-7 \text{ g/l}, \text{Na}_2\text{CO}_3 0.01-0.05\% \) and IM (insol matter) < 0.008%

An 8 oz sample was taken by the operator while the soln was in the "refined scale tank" and brought to the lab. After detg the sp gr of the soln by means of a 1.1-1.2 hydrometer, the following determinations were made:
a) Determination of NaN₃ Content. Assemble the apparatus consisting of "gas evolution flask" [Pyrex Erlen flask ca 130 mm high and ca 68 mm diam, std taper 29/42 with hollow stopper, having inside permanently attached in the center of bottom, a cylindrical vial, 25 mm diam and 30 mm high; a "gas measuring burette" 100 ml capacity provided with a bulb and a levelling bulb (reservoir)]. Prepare an aliquot by pipetting 20 ml of liquor into 1000 ml volumetric flask, diluting to the mark with distd w and shaking the flask. Pipette exactly 20 ml of this soln into the inside of the Erlen flask surrounding the vial ("outer space") and exactly 5 ml of 43% ceric ammonium nitrate soln into the vial ("inner space"). Connect the Erlen flask to the gas measuring burette filled with w (saturated with N₂ & CO₂) and let stand for 10 mins. Remove burette stopcock for 10 secs, in order to equalize the pressure inside and outside the reaction chamber. Raise levelling bulb until just above level of stopcock hole. When burette is full of w and it begins to seep into stopcock chamber, replace the stopcock and the levelling bulb. Open stopcock and if there are any bubbles in top of gas burette, repeat the previous operation. Loosen the evoln flask from the clamp and shake, gently at first. Replace flask in clamp and after allowing to stand for 10 mins level the water in the bulb with that in the gas burette and take reading. Note temp of burette jacket and of const temp bath and correct barometric press to 0°.

\[ A = \text{NaN}_3 \text{ g/l} = 0.63639 \times V \times \frac{100 (P-W)}{100 + 0.3661t^o} \]

V - observed vol of N₂, P - vap press of w at observed temp t° in °C. The value 0.63639 is obtained from the formula

\[ \left( \frac{2 \text{NaN}_3 \times 1000}{3 \text{N}_2} \times 4 \times 1.25057 \right) / 760.0, \]

where 1.25057 g/liter is density of N₂ at std conditions

Note: If Na₂CO₃ is present as an impurity, the value V includes CO₂ because ceric ammonium nitrate, being sl acidic reacts with carbonates liberating CO₂

b & c) Determination of NaOH and Na₂CO₃ Contents by a modification of the method described in vol 2, p 514 of "A Manual for Explosives Laboratory," Lefax, Philadelphia (1943)

Procedure: Pipette a 10 ml sample into a 250 ml Erlen, dil with ca 100 ml CO₂-free distd w, add 1 drop of pHpt indicator and titrate with N/10 std sulfuric acid just to the disappearance of pink color. This occurs when all NaOH is neutralized and the carbonate has been converted to bicarbonate. Take the burette reading as R₁. Add 5 drops of methyl-yellow indicator and titrate to the first slight indication of change of color from yel to reddish. This occurs when all bicarbonate is converted to sulfate. Take the burette reading as R₂.

Calculations:

\[ \% \text{ Total alkalinity as NaOH} = \frac{R_1 \times \text{N of acid} \times 0.0401 \times 100}{\text{Wt of sample in aliquot}} \]

As the reading (R₂ - R₁) corresponds to bicarbonate obtained by conversion of carbonate, the amt corresponding to Na carbonate must be \(2(R₂ - R₁) ml\)

\[ C = \% \text{ Na}_2\text{CO}_3 = \frac{2(R_2 - R_1) \times \text{N of acid} \times 0.053 \times 100}{\text{Wt of sample in aliquot}} \]

As the reading R₁ corresponds to NaOH plus bicarbonate, the amt corresponding to NaOH must be: \(R_1 - (R_2 - R_1) = (2R_1 - R_2) \text{ ml}\) and

\[ B = \frac{(2R_1 - R_2) \times \text{N of acid} \times 0.0401 \times 100}{\text{Wt of sample in aliquot}} \]

Note: It was mentioned in the previous proced that the value V includes CO₂. For calcn of actual % NaN₃, the formula

\[ A = \frac{\text{Wt of sample in aliquot}}{10 \times (\text{sp gr of soln}) - C \times 0.6134} \]

is given in Ref 9, p 37. As the amt of Na₂CO₃ in refined NaN₃ liquor is only ca 0.05%, it is sufficient to calc % NaN₃ from the formula

\[ A = \frac{10 \times (\text{sp gr of soln})}{\text{Wt of sample in aliquot}} \]

d) Insoluble Matter (IM) in Composite. Pipette a 25 ml sample into a bottle contg several other samples of refined liquor. Shake the composite, det its sp gr by a 1.1 to 1.2
hydrometer. Filter 100 ml of composite through a tared No 2001 Selas porcelain crucible. Wash the crucible with several portions distilled w, heat at 100°C for 2 hrs. cool in a desiccator for 30 mins and weigh

\[ \% \text{ IM} = \frac{\text{Wt of IM} \times 100}{100 \times \text{sp gr}} \]

**V) Sodium Azide Feed Tank.** Soln in this tank was pumped from the "refined storage" tank (see IV). The basic unit consisted at KOW (Ref 9, p 39) of 825 l of soln. The concns of NaN₃, NaOH and Na₂CO₃ were the same as in the "refined storage" tank. Analytical procedures were the same as in IV, except that no NaCO₃ and IM detns were made.

**VI) Sodium Azide Dilution Tank.** The basic unit of KOW (Ref 9, p 40) consisted of 1000 l soln of 31.75 kg NaN₃ and 794 g NaOH. Specifications: NaN₃ 31.75 ± 0.25 g/l, NaOH 0.794 g/l (approx) and NaN₃/NaOH 40.0 ± 0.5. An 8 oz sample is taken by sampler for the following determinations:

a) **Determination of NaN₃ Content** — same as proc (a) under IV

b) **Determination of NaOH Content.** Fill a 100 ml vol flask with sample and transfer it quantitatively to a 500 ml Erln flask. Titrate with N/10 sulfuric acid using pbphr as indicator

\[ \text{NaOH g/l} = \frac{(\text{ml H}_2\text{SO}_4) \times N \times 40.01}{100} \]

where N is normality of H₂SO₄ and 40.01 is equiv wt of NaOH

_Note: Calculations used in making sodium azide dilutions are discussed in Ref 9, pp 41-2

**VII) Lead Azide by Military Specification Methods.** US Govt Spec MIL-L-3055 issued in 1949 was revised in 1952 and then replaced in 1957 by the Purchase Description X-PA-PD-1217, which was issued only for use pending final revision of MIL-L-3055, which has not yet been made at this time (1960). The original MIL-L-3055 deals only with one type of LA-crystalline and lists the following requirements: a) **Color** — wh to buff, b) **Form** — aggregates free from needle-shaped crysts having a max dimension of 0.1 mm, c) **LA content** — 91.5% (minim) d) Total lead 68.50 to 71.15%, e) **Acidity** — none, f) **Solubility in water** — 1.0% (max), g) **Sand test** — when 0.15 g LA is used to initiate 0.40 g of tetryl in the test, not less than 45 g of sand shall be crushed.

The X-PA-PD-1217 deals with two types of LA: Type I (crystalline) and Type II (colloidal). Requirements for crystalline are the same as in MIL-L-3055 whereas requirements for colloidal LA are: a) **Color** — wh to buff, b) **Form** — average particle size shall be no greater than 5 microns and the max size of any particle shall be 10 microns, c) **LA Content** — 99.0% (minim)

Following tests are taken mostly from MIL-L-3055 and X-PA-PD-1217:

A) **Color.** Dct by visual examination

B) **Form.** For Type I LA: spread a thin layer of crysts on a glass slide, allow to dry in the air at RT and examine under a microscope using a magnification 150 × (approx). If
LA NEEDLE SHAPED CRYSTALS

Needle shaped crystals are present, measure their max dimensions. Type II LA: use a microscope equipped with a Filar type micrometer eye-piece and such an objective (approx 43x) that the total magnification of the optical system is approx 550x. Detailed description of procedure is given on pp 7-10 of X-PA-PD-1217

Note: For the tests described below use samples previously dried in a vacuum oven at 65° to const wt. This requires ca 3 hrs (Never go beyond 25 hrs)

C) LA Content. Several methods are known of which the following direct titration method described by J.D. Hopper & O.E. Burton in PATR 255 (1932) seems to be the simplest, although it is not as accurate as the gasometric method used by the US Ordnance Corps

Procedure. Dissolve 0.25 g sample in 10 ml of 2N NaOH soln and add 200 ml of freshly boiled and cooled distd w. Neutralize the soln with dil sulfuric acid using litmus as indicator. Add (from a pipette) exactly 25 ml of 0.1N ceric sulfate soln and after allowing the mixt to stand 5 mins, add from a burette an excess of 0.1N ferrous ammonium sulfate soln, recently standardized by 0.1N K permanganate soln, as evidenced by the disappearance of yel coloration. Titrate with 0.1N K permanganate soln until the appearance of a permanent faint pink coloration. The reactions involved in the analysis are:

\[
Pb(N_2) + 2NaOH \rightarrow 2NaN + Pb(OH)_2
\]

\[
2NaOH(excess) + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O
\]

\[
2NaN + H_2SO_4 \rightarrow Na_2SO_4 + 2HN
\]

\[
2HN + 2Ce(SO_4)_2 \rightarrow 3N + Ce_2(SO_4)_3 + H_2SO_4
\]

\[
2Ce(SO_4)_2(excess) + 2(NH_4)_2Fe(SO_4)_2 \rightarrow Ce_2(SO_4)_3 + Fe_2(SO_4)_3 + 2(NH_4)_2SO_4
\]

\[
10(NH_4)_2Fe(SO_4)_2(excess) + 2KMnO_4 + 8H_2SO_4 \rightarrow K_2SO_4 + 10(NH_4)_2SO_4 + 2MnSO_4 + 5Fe_2(SO_4)_3 + 8H_2O
\]

Due to the fact that doubts have been expressed concerning the validity of the values obtained from the assay of the gasometric method of analysis, Croom & Pristera of Pic Arsn (Ref 15) investigated this method. They also studied the US Navy distillation-titration method and the British direct titration method not only from the point of view of their precision but also of their applicability to LA's contg additives, inorganic (Pb carbonate in Brit "Service" LA) or organic (dextrin, PVA, etc)

a) US Ordnance Corps Gasometric Method, known also as the Modified Nitrogen Evolution Method. It was developed in 1947 at PicArsn by F. Pristera et al and originally described in ChemLabRept 120347. It was later incorporated in the US Military Spec MIL-L-3055(1950) and then in the Purchase Description X-PA-PD-1217 (1957). The previously used method described in the US Spec 50-13-12 was not applicable to LA's contg carbonates (such as the Brit "Service" LA). Therefore the modified method was developed. Following is its description

Apparatus: Assemble the app as shown on fig
and insert the burette contg distd w satd with nitrogen into one hole in the rubber stopper of the reaction flask. Add 90 ml of 10% NaOH soln satd with nitrogen to the 125 ml carbon dioxide absorption flask. Fill the gas burette and levelling bulb with a 0.1% soln of "Nacconol" (or other approved org detergent) satd with nitrogen. Control the temp of the system by circulating water by means of a pump betw the water-reservoir which serves as a jacket for the reaction flask and the glass jacket of the gas burette.

**Procedure.** Place a part of a wet sample in a tared Büchner funnel. Remove the bulk of liquid by suction and the rest by air-drying followed by heating in a vacuum oven at 65° to const wt (requires 3 or more hrs, but not more than 25 hrs). Transfer from the funnel an accurately weighed portion of dried LA (ca 1.7g) to a glass vial shown on fig. Add 3 ml of distd w to the vial and place it erect in the reaction flask contg 75 ml of 15% ceric ammonium nitrate soln satd with nitrogen and containing ca. 2 ml of 50% aq soln of Dow Corning Antifoam AF Emulsion. Connect the reaction flask to the apparatus, taking care not to upset the vial contg the sample. In order to insure that the reaction and absorption flasks are connected to the apparatus without air leaks, apply a coat of molten paraffin wax to all rubber-to-glass joints. Open stopcocks 1 and 2 to the atmosphere by adjusting them as shown by position A on fig. Adjust the water level in the gas burette to zero with the aid of the levelling bulb and after waiting 10 mins to allow the system to come to temp equilibrium, read the thermometer in the water jacket to 0.1°. Turn stopcocks 1 and 2 to position B and shake the reaction flask so that the vial inside of it is upset and assumes a horizontal position, thus allowing the sample to react with ceric ammonium nitrate, also called ammonium hexanitrocerate:

\[
\text{Pb}(N_\text{O}_\text{3})_2 + 2(NH_4)_2\text{Ce(NO}_\text{3})_6 \rightarrow 3\text{N}_2 + 2\text{Ce}(\text{NO}_\text{3})_3 + 4\text{NH}_2\text{NO}_3 + \text{Pb}(\text{NO}_\text{3})_2
\]

**Note:** If a carbonate is present, it would react with Amm hexanitrocerate (in acid medium) with formation of CO. If this gas was allowed to go to the measuring burette the results for LA content will be too high. In order to remove CO from the gas mixt, a flask contg NaOH soln ("caustic trap") is inserted between the reaction flask and the burette (see fig). As the gas is evolved from the reaction flask, lower the levelling bulb so that the liquid level in the bulb is 11 below that in the gas burette. Occasionally gently agitate the reaction flask to aid in completing the decompn of LA. As soon as the evoln of gas ceases, add to the flask (if necessary) a measured amt of w from the 50 ml burette until the water level in the burette will be between 450 and 500 ml divisions of the burette. Allow the temp of the system to adjust itself to within 0.1° of its temp at the beginning of the detn and then measure the vol of gas at the existing atm press, detd to the nearest 0.1 mm Hg with the aid of a mercurial barometer having a brass scale. Correct the observed reading to 0°

\[
\% \text{ LA} = \frac{0.1558 \times (A-B) \times (C-D)}{(273 + t) \times W}, \text{ where}
\]

for eqivalent weight of LA
A = ml of gas measured in gas burette, B = ml of w added to reaction flask from burette, C = atm press in mm Hg, D = vapor press of w in mm Hg at temp t, t = temp of w in the jacket surrounding gas burette, W = wt of dry sample in grams

Note: For routine plant analysis at KOW, detn of LA content was done by the gasometric method similar to detn of NaN₃ content described under IV Refined Sodium Azide Liquor, Ref 9, pp 40 & 53a. This method was simpler and more rapid although probably not as accurate as the Ordnance Corps method

b) US Navy Distillation – Titration Method, known also as NOL Method was developed at the Naval Ordn Lab and described in Ref 10. It consisted of treating LA with dil sulfuric to produce volatile hydrazoic acid. This was distilled into a measured excess of Amm hexanitrocerate and the excess cerate was then detd by titration with std Na oxalate

As this method proved to be inaccurate for some types of LA (see Discussion, which follows the description of methods), the following modified version was developed at PicArsn and described in Ref 14, pp 5-6 and Ref 15, pp 5-6

Apparatus consists of a heating mantle, a 125 ml round-bottom reaction flask a three-way side-arm adapter, a 50 ml burette with a No 5 rubber stopper, a water-cooled condenser, a support with a clamp, a curved adapter and a 125 ml Erlen flask, serving as a receiver. Std tapered ground glass joints are used to connect the distilling flask side-arm adapter, condenser and curved adapter. The three-way side-arm adapter has a female joint, at its upper end, to which the burette is fitted with the No 5 rubber stopper. A thin film of silicone grease may be applied to ground-glass joints

Procedure. Air-dry a portion of the sample in a Büchner funnel and then heat in a vacuum oven at 55 to 60° for 3 hrs or until const wt is obtained. Transfer an accurately weighed portion of from 2 to 3 milli-equivalents (0.2991 to 0.4366 g) of the dried sample to a small porcelain (or glass) crucible and cover the sample with w. Add to the reaction flask a small amt of 50% Dow Corning Antifoam AF Emulsion and place the crucible in the flask, using rubber-tipped tweezers. Connect the ground glass joints of the apparatus and insert in the upper end of the three-way adapter a 50 ml burette, using a No 5 rubber stopper. Fill this burette with 3N perchloric acid and place 40-50 ml (accurately measured) of 0.1N Amm hexanitrocerate in the Erlen flask. Arrange this flask in such a position that the adapter from the condenser extends below the surface of liq. After checking all the joints for tightness, run the perchloric acid from the burette to the reaction flask and close the stopcock of burette. Heat the flask for about 12 mins to distil off hydrazoic acid formed as result of reaction: Pb(N₃)₂ + 2HClO₄ → Pb(ClO₄)₂ + 2HN₃. The acid reacts with Amm hexanitrocerate in the Erlen flask as follows: 2HN₃ + 2(NH₄)₂Ce(NO₃)₆ → 3N₂ + 2Ce(NO₃)₃ + 2HNO₃ + 4NH₄NO₃. Disconnect the adapter and rinse it by a stream of distd w into Erlen flask, add 1 drop of 0.25M 5-nitro-1,10-phenanthroline (nitroferroin) and titrate the excess of cerate with std 0.1N Na oxalate until the color changes from red to pale greenish blue. Make a blank detn on the reagents and apply correction if necessary. Standardize the cerate by titrating 40.0 ml of soln with std Na oxalate obtained from the NBS (National Bureau of Standards)

\[
\% \text{LA} = \left( \frac{A \times B}{(C-E) \times D \times 4.2} \right) \times \frac{0.2886}{W}
\]

A = ml of Amm hexanitrocerate soln in Erlen flask, B = normality, C = ml of Na oxalate, D = its normality, E = ml Na oxalate soln used in blank detn, W = wt of sample in grams

c) British Direct Titration Method, known also as ERDE (Explosives Research and Development Establishment) Method, was described in ERDE Report 17/R/53. Essentially it consists of prep a soln of the sample and quantitatively pptg the azide with a known excess of std Ag nitrate soln. The excess Ag nitrate
is then titrated with std thiocyanate (See also under Discussion, which follows)

This method is also described in the Brit Spec IG 237, a copy of which is included as Appendix in PicArsn, ExplDevSectn Rept No 57 (1959), Appendix. Other Brit tests for LA, described in the same Spec include: matter insoluble in nitric acid, acidity, moisture and bulk density

Discussion. In the opinion of Croom & Pristera (Ref 15, pp 4-5), although the Brit ERDE method is applicable to all LA's and is the simplest (because it does not require any special equipment), it is undesirable because it is very tedious and because Ag azide pptd in the course of analysis is a very sensitive expl. The NOL method (Ref 10 & Ref 15, pp 2 & 5-6) is undesirable because it is rather tedious, is inapplicable to LA's contg certain organic additives (such as PVA) and often gives low results with other types of LA. This inaccuracy is probably due to partial coating of unreacted LA with insol Pb sulfate (formed on treating LA with dil sulfuric acid), thus preventing this coated portion from completely reacting with sulfuric acid. Replacement of sulfuric acid by perchloric acid as described in the distillation-titration procedure given below gave satisfactory results.

The US Ordnance Corps method (Ref 15, pp 3-5 and Ref 14, pp 4-5) requires a complicated apparatus difficult to assemble, but if the method is used for control work, these disadvantages are encountered only on initial installation, because the equipment can be used countless times without any readjustments or repairs. Once the equipment is assembled, the method enjoys the advantage of being applicable to all types of LA. Also, it has a shorter working time, eliminates the tedious prep and standardization of reagents, it uses a larger sample (which tends to reduce any error in weighing and also lessens the possibility of obtaining a non-homogeneous sample), and it is relatively safe because the sample is placed under water immediately after weighing

D) Total Pb Content in LA. This test, not required now for the Army material, is simple and can be used for the detn of purity of LA samples, if desired

Procedure: Dissolve with const stirring a ca lg accurately weighed sample (previously dried at 65° for 3 hrs) in 50 ml of std Amm acetate soln heated in a 400 ml beaker. The principal reaction is probably:

$$\text{Pb(N}_3\text{)}_2 + 2\text{CH}_3\text{COONH}_4 \rightarrow 2\text{NH}_3\text{N}_3 + (\text{CH}_3\text{COO})_2\text{Pb}$$

Add ca 200 ml distd w, heat to boiling and while stirring rapidly, add gradually 10 ml of a 10% potassium chromate soln:

$$(\text{CH}_3\text{COO})_2\text{Pb} + K_2\text{CrO}_4 \rightarrow \text{PbCrO}_4 + 2\text{CH}_3\text{COOK}$$

Digest on a steam bath for 1 hr with frequent stirring and filter through a tared Gooch or Selas No 2010 crucible. Wash the ppt of PbCrO₄ in crucible with hot distd w, dry for 2 hrs at 100°, cool in a desiccator and weigh

$$\% \text{ Pb} = \frac{0.64109 \times \text{Wt of ppt} \times 100}{\text{Wt of sample}}$$

Note: For cleaning the Selas crucible, remove as much of ppt as possible by inverting the crucible and lightly tapping the base with the fingers. Dissolve the rest of ppt in warm 1:1 HCl and wash the crucible with hot distd w, employing straight and reverse washings. Dry in an oven until two successive weighings agree within at least 0.0005 g

E) Acidity in LA by the Standard Method (Army). Mix the original wet sample and transfer ca 10 g portion to a tared Gooch or Selas No 2001 crucible. Wash with five 20 ml portions of cold (0 to 15°) distd w, which has been boiled and cooled prior to the test. Allow each portion of w to remain in contact with LA for 3 mins. Add to the filtrate 5 drops of 0.1% methyl orange indicator and note if the sample is free from acidity as shown by the absence of a red tinge

Note: For the routine analysis of LA intended for the Navy a dried sample (ca 1 g) is
accurately weighed in a tared Grooch or Selas crucible and, after subjecting it to the same treatment as above, the filtrate is tested for acidity. The crucible, with washed LA, is dried at 65°C to const wt and the loss of wt gives the solubility of LA in water (see Solubility in Water). The Navy test has the advantage of determining the acidity and soly on the same sample. Its disadvantage seems to be a too small sample (1 g) to permit accurate detn. It probably would be better to use a larger sample

b)Open Vessel Technique. The test is essentially the same as above except that an open dish, approx 55 mm in diam and 30 mm high is used. The weighing operation must be conducted as quickly as possible to avoid absorbtion of atm moisture

Note: Investigation of the above two methods conducted at PicArsn (Ref 8) have shown that values obtained by the "closed vessel technique" are on the average 0.06% higher (when tests are conducted at 43-47% RH) then obtained by the "open vessel technique"

% Moisture = Loss in wt × 100 Wt of sample

F)Solubility of LA in Water. Transfer ca 5 g of air-dry sample to a tared filtering crucible, dry in a vacuum oven at 65°C to const wt (ca 3 hrs), cool in a desiccator and weigh. Wash the dry LA with five 10 ml portions of distd w at 0 to 15°C, allowing each portion to remain in contact with the sample for 3 mins. Remove each wash by suction and aspirate for 5 mins after the last wash. Dry the crucible at 65°C to const wt, cool in a desiccator and reweigh

% Soly = Loss of wt × 100 Wt of sample

Note: The same method can be used for soly in 50% alcohol, etc

G)Sand Test, used to det initiating efficiency of LA, is conducted according to description given in Ref 6, p 5 and Ref 7, pp 7-9

VIII)Moisture in Dried LA. LA's dried at the Plant usually contain small amounts of moisture (0.3-0.4%). The following two methods for the detn of this moisture were studied at PicArsn by Bernstein (Ref 8):

a)Closed Vessed Technique. Transfer carefully by a wooden spatula ca 2 g sample to a tared, flat top Pyrex, weighing vessel approx 55 mm in diam and 30 mm high, provided with a ground joint cap. Close the dish and accurately weigh the ensemble. Remove the cap and heat the vessel in an oven at 65°C for 1 to ½ hrs. Cool for 20 mins in a desiccator over freshly prepd CaCl₂, cap the vessel and reweigh

% H₂O = (Loss in wt) × 100 Wt of wet sample

Note: Since the azide had been packed usually a day or more before the moisture detn was completed, it was necessary to calculate in advance the wt of wet azide to pack in order that each bag should contain 25 lbs of dry LA. For this purpose it was assumed that the moisture content of the lot (four drums) being packed would be approx the same as the ave of the ten preceding analyzed lots. From this ave value, the wt of wet material equiv to 25 lbs of dry LA was calcld. This result, plus a tare of containers constitutes the pack weight (Ref 9, p 54)

Eg: If average moist content of 10 preceding lots was 25.26% and tare of containers 10 lbs 6 oz, the ave wt of wet LA equiv to 25 lbs of dry LA = 25 3.449 lbs = 33 lbs 7oz.
This gives for pack weight = 33 lbs 7 oz + 10 lbs 6 oz = 43 lbs 13 oz

X) Moisture in Wet LA by Density Measurements. For rapid estimation of moisture in Nutsch blends of LA going into a drum, the following procedure was used at the Kankakee OW.

A wet sample was packed to about 1/4 capacity of a tared calibrated 125 Erlen flask and the ensemble weighed on a trip balance. Water was added to the mark and the ensemble reweighed. The gain of wt in grams was approx equal to the vol in ml of w added and vol of wet LA was equal to capacity of flask (ca 125 ml) minus vol of w add. By dividing the wt of wet LA by its vol, the density was detd (Ref 9, p 55)

Calculation. Percentage of moisture in wet LA may be calc'd from the formula:

\[
\% H_2O = \left(\frac{D}{d} - 1\right) / (D-1) \times 100, \text{ where}
\]

D = density of dry sample, d = density of wet sample and 1 = density of water

Eg: If D = 4.38 and d = 2.18, then

\[
\% H_2O = \left(\frac{4.38}{2.18} - 1\right) / (4.38-1) \times 100 = 1.01 \times 100 = 29.9\%
\]

XI) Ball Drop Test. In order to det the sensitivity of LA to impact, a composite sample was taken from each lot manufd at the Kankakee OW, dried as usual and subjected to the following test described in Ref 9, p 56:

A steel ball, 1/2" diam and weighing 8.33 g, was dropped from a height 25" on a 0.08" layer of LA spread on 1" thick SAE 3260, nickel-chrome, hardened steel block which rested on a 1/2" thick by 12" diam cast iron base. Ten consecutive drops should produce no detonations in a properly manufd LA, but when the ball was dropped from the height of 45", it should deton in all trials. Care was taken not to drop the ball on the same spot twice, as a pellet made by the first drop would usually fire if hit a second time. If detonations occurred at 25" drop, lower heights were tried until no detons were produced

XII) Ethyl Alcohol Solution. Since LA is very sensitive, it was shipped and stored at KOW wet with not less than 20% (usually 25-27%) of a 50 ± 0.5% (by wt) denatured alcohol (Ref 9, p 57). Alcohol served as an antifreezing agent. The compn of an alc soln can be detd from the table, density vs % alc after detg the density by means of a Leach pycnometer standardized at 25°, using the following formula:

\[
d = \frac{Wt \ of \ pycn \ with \ alc \ soln - Wt \ of \ pycn \ empty}{Vol \ of \ pycn \ at \ 25^\circ}
\]

Note: Alcohol used at the Kankakee plant was Grade SD No 1, delivered in No 50 drums. It contained 5 parts of methanol per 100 parts of ethanol. No analysis is necessary because alc is produced and shipped under Govt supervision

XIII) Killing Tank at KOW contained, according to Ref 9, p 59, various waste liquids and slurries in which azides are likely to be present. When a sufficient quantity of such material was accumulated (not less than 1000 liters), the operator stirred the contents of the tank and took a 6 oz sample. If a small portion of the sample gave a positive test for azides (a red ppt of iron azide obtained on adding few drops of 1% feCl₃ soln), a quantitative test was conducted as follows:

Determination of Azide as NaN₃. Pipette a 25 ml portion of the sample into a 500 ml Erln flask and dil with w to 150-200 ml. Titrate with 40% sulfuric acid to just to the phpt end-point, not overrunning it. Add N/10 ceric sulfate soln in 5 ml portions until the soln becomes deep yel, indicating an excess of ceric sulfate. Record the exact amt used. Add 10 ml of 40% sulfuric acid and 2 drops of o-phenanthroline indicator (prepd by dissolving 14.85 g of o-phenanthroline monohydrate, C₁₄H₁₄N₂.H₂O in 1 l of 0.025 M freshly prepd ferrous sulfate
Add N/10 ferrous sulfate soln to an orange (or pink) end-point in order to reduce the residual ceric sulfate to cerous salt. The following reactions take place:

\[
2\text{Ce(SO}_4^2\text{)} + 2\text{NaN}_3 \rightarrow 2\text{N}_2 + \text{Na}_2\text{SO}_4 + \text{Ce}_2\text{(SO}_4^2\text{)}_3
\]

\[
2\text{Ce}(\text{SO}_4^2\text{)} + 2\text{FeSO}_4 \rightarrow \text{Fe}_2(\text{SO}_4^2\text{)}_3 + \text{Ce}_3(\text{SO}_4^2\text{)}_5
\]

Calculation:

\[
\text{Na}_3 \text{g/l} = \left(\frac{\text{CeSO}_4 \text{ used, ml}}{\text{FeSO}_4 \text{ used, ml}}\right) \times \frac{\text{Na}_3 \times \text{N of CeSO}_4}{75}
\]

Note: Killing of contents of the tank was usually done by adding a mixt of 1 part 30% NaNO\text{2} and 2 parts of 30% HNO\text{3}.

\[
\text{Na}_3 + \text{NaNO}_2 + 2\text{HNO}_3 \rightarrow 2\text{NaNO}_3
\]

\[
+ \text{N}_2\text{O} + \text{N}_2 + \text{H}_2\text{O}
\]

\[
\text{Pb(N}_3\text{)} + 2\text{NaNO}_3 + 4\text{HNO}_3 \rightarrow \text{Pb(NO}_3\text{)}_2
\]

\[
+ 2\text{NaNO}_3 + 2\text{N}_2\text{O} + 2\text{N}_2 + 2\text{H}_2\text{O}
\]

**XIV) Nitric Acid for Killing** was used (Ref 9, p 61) in mixt with 30% NaNO\text{2} soln and should be ca 30% and not below 22%.

Procedure: Cool to 20° the sample collected in an 8 oz glass-stoppered bottle and fill a hydrometer jar to about ¾. Insert hydrometer of range 1.0-1.2 and take reading at 20°. Det approx concn from tables, density vs concentration, such as

<table>
<thead>
<tr>
<th>d at 20°</th>
<th>% HNO\text{3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.115</td>
<td>20.0</td>
</tr>
<tr>
<td>1.120</td>
<td>20.8</td>
</tr>
<tr>
<td>1.125</td>
<td>21.6</td>
</tr>
<tr>
<td>1.130</td>
<td>22.4</td>
</tr>
<tr>
<td>1.134</td>
<td>23.0</td>
</tr>
<tr>
<td>1.140</td>
<td>24.0</td>
</tr>
<tr>
<td>1.152</td>
<td>25.8</td>
</tr>
<tr>
<td>1.156</td>
<td>26.4</td>
</tr>
<tr>
<td>1.160</td>
<td>27.0</td>
</tr>
<tr>
<td>1.164</td>
<td>27.6</td>
</tr>
<tr>
<td>1.168</td>
<td>28.2</td>
</tr>
<tr>
<td>1.170</td>
<td>28.8</td>
</tr>
<tr>
<td>1.172</td>
<td>29.4</td>
</tr>
<tr>
<td>1.180</td>
<td>30.0</td>
</tr>
</tbody>
</table>

**XV) Disposal of Laboratory Samples Containing Azides at KOW.** According to Ref 9, pp 69-71 the following were some of the rules observed in the lab of Kankakee OW:

a) No more than 25 g of dry LA was allowed in the lab at a time.

b) No azide-contg sample was allowed to be mixed with an acid since this would form the extremely toxic hydrozoic acid (gas).

c) No azide-contg sample was allowed to be mixed with salts of heavy metals, especially of Cu, Cd, Ag, and Pb since these would form sensitive azides.

d) All LA samples contg a high percentage of NaN\text{3} such as crude, refined, mother liquor, clear liquor, lime treatment, feed tank and wringer cake (see under Sodium Azide), were saved and returned to operations, as an economy measure.

e) All LA moisture samples were, after final weighing, saved and returned to the plant for mixing with finished product.

f) All Government composite samples were, after removal of the portion for analysis, mixed with 95% alcohol and returned to the Govt Inspector.

g) All LA samples, suspected to be impure (such as contaminated, exposed to direct sunlight, exposed to temps in excess of 65°, etc.) were returned to the plant to be destroyed as described under Killing Tank. Small amts of azide were killed in the lab with ceric ammonium nitrate soln:

\[
2\text{NaN}_3 + 2\text{Ce(NH}_3\text{)}_2(\text{NO}_3\text{)}_4 \rightarrow 4\text{NH}_4\text{NO}_3
\]

\[
+ 2\text{NaNO}_3 + 2\text{Ce(NO}_3\text{)}_3 + 3\text{N}_2
\]

**XVI) Laboratory Disposal of LA by the Method of Wm. H. Rinkenbach.** Disperse with stirring ca 1 oz of waste LA in 1.5 gal 10% Ammonium acetate soln, add 2.5 oz of Na nitrate dissolved in 1 pint of w, and then 7 oz of glacial AcOH or its equivalent of weaker acid. After allowing the soln to stand in a warm place for at least 1 hour, dispose of it.

Notes: A) The above proced results in a clear soln, which contains no toxic materials and can be easily disposed of by pouring it into...
a sink or a stream  B) This procedure does not possess the disadvantages of other methods, such as: a) Solution in Amm acetate and decompn with Na bichromate. This method produces a sludge which cannot be disposed of by dumping into a sink b) Decompn with ceric ammonium nitrate soln. This reagent is expensive and somewhat corrosive c) Decompn by Na nitrite and nitric acid. This mixture is very corrosive and the procedure requires stirring during decompn to keep the heavy LA in suspension  C) The procedure of WHR can be used to remove azides from bags used for storing wet LA or for catch-bags placed underneath sinks, without injuring the fabric. For this, the bags are impregnated with Amm acetate soln and then subjected to treatment with Na nitrite soln and AcOH. For removing LA or other azides from machinery, tables, floors, etc, it is usually sufficient to wipe the object with a rag impregnated with Amm acetate soln, followed by wiping with Na nitrite soln and AcOH

XVII) Laboratory Disposal of LA by the British Method. Disperse with stirring ca 1 oz of LA in 250 ml of 15% aq Na nitrite soln, and add slowly 250 ml of 25% aq AcOH soln. Carry out this operation in the hood behind a protecting screen

XVIII) Laboratory Disposal of LA by the Method Used at the du Pont's Plant at Pompton Lakes, NJ. Disperse slowly with stirring ca 1 g sample in ca 16 ml of 25% aq ceric ammonium nitrate soln and allow to stand. Fumes from the decompn are not toxic

XIX) Laboratory and Plant Disposal of LA by the Method Used at the du Pont's Plant at Pompton Lakes, NJ. Disperse with stirring ca 1 g sample in 500 ml w and mix it with 9 ml of a 30% aq Na nitrite (commercial grade) soln. Finally add ca 18 ml of a 24% aq nitric acid and test with ferric chloride for the completion of destruction

XX) Laboratory Disposal of LA by the Method Used at Picatinny Arsenal. Disperse with stirring ca 1 oz sample in 1.5 gal of 10% Amm acetate soln and add sufficient Na bichromate soln to ppt all lead as chromate. Test for the completion of destruction by transferring a portion of slurry to a filter paper and treating the filtrate with a few drops of Na bichromate soln. Confirm the absence of LA by washing, with distd w, the residue on filter, free of sol azide salts, drying it, and subjecting a 20 mg portion to the impact test, using 2 kg wt. The material should not detonate

XXI) Laboratory Test for the Presence of LA. The following proced was used at PicArsn and described in ChemLabRept 94772(1943) for detection of azides in loaded housings of friction primers:

Procedure: Place three of the loaded housings in a 50 ml beaker, add 20 ml of 25% aq Amm acetate soln and heat to boiling. Allow to boil gently for 5 mins. Remove the housings, washing them with a stream of distd w. Boil the soln for another 5 mins and filter, catching the filtrate in a small beaker. Acidify the filtrate with 3 drops of concd nitric acid and add 5 ml of 10% aq Ag nitrate soln. After allowing to stand for 30 mins, filter and wash the ppt on filter paper with w. Remove the filter paper, spread it on a watch glass and pour ca 10 ml of 10% ceric ammonium nitrate soln on top of ppt. The evolution of odorless gas (nitrogen) indicates the presence of an azide (in this case, it is silver azide)

Refs: 1) M. Marqueyrol & P. Loriette, MP 18, 93-5(1921) & CA 16, 1667(1922) (Detn of LA in primer compns as conducted at the Laboratoire Centrale des Poudres, Paris) 2) S. M. Moskovich, Visti Institutu Fizichnoi Khemii-Akademiya Nauk Ukraina (Russia), 6, 179-87 (1936) & CA 31, 6579(1937) (Potentiometric detn of LA was conducted by dissolving 0.02 g LA in 50 ml of 2% Ba nitrate, making the soln acid with 1 ml of 2N nitric acid, plus 2 ml of 2N AcONa and titrating with 0.1N Ag nitrate) 3) J. W. Arnold, IEC, AnalEd 17, 215-17(1945) & CA 39, 2267(1945) (Assay of LA & Na azide by cerate oxidimetry) 4) R. Haul & E. Scholz, Naturwissenschaften 32,

Lead Azide Explosive, Primer and Detonator Compositions. LA has replaced MF for many purposes. Its chief applications are as an initiating agent for less sensitive HE charges and as an ingredient of priming compns which are very sensitive to impact or percussion. Priming compns are used for the ignition of initial detonating agents, BkPdr, small arms propellants, etc. Most military priming compns consist of a mixt of one or more initial deton agents, oxidizing agents, fuels, sensitizers and binding agents (Ref 98)

Some typical primer and detonator compns used in USA are as follows (Refs 88, 95, 97 & 98): Percussion Type — LA/KClO₄/Sb₂S₃/ground glass 33.6/14.3/21.5/30.6 and LA/KClO₄/Sb₂S₃/Pb(SCN)₄ 5/53/17/25 (Ref 87); Friction Type — LA/KClO₄/Sb₂S₃/carborundum 28.3/33.4/33.3/5.0; Relay Type — LA Pressed at 5000 psi and covered with an onion skin; and Detonator Type — LA generally sensitized by the addn of lead styphnate (LSt), PbO₂Ce₃H(NO₃)₂·H₂O, to lower the ignition temp

Grant and Tiffany (Ref 84) detd that the order of initiating efficiency of priming compositions increased as follows:

<table>
<thead>
<tr>
<th>Priming Composition</th>
<th>%</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead styphnate (LSt)</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>LA/LSt</td>
<td>20/80</td>
<td>2</td>
</tr>
<tr>
<td>Mercury fulminate/KClO₄</td>
<td>80/20</td>
<td>2</td>
</tr>
<tr>
<td>LA</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>LA/LSt/Aluminum</td>
<td>80/17/3</td>
<td>3</td>
</tr>
<tr>
<td>LA/LSt</td>
<td>40/60</td>
<td>3</td>
</tr>
<tr>
<td>Diazodinitrophenol/KClO₄</td>
<td>75/25</td>
<td>3</td>
</tr>
<tr>
<td>LA/LSt/Al/KClO₄</td>
<td>80/18/0.5/1.5</td>
<td>4</td>
</tr>
<tr>
<td>LA/LSt</td>
<td>60/40</td>
<td>4</td>
</tr>
<tr>
<td>LA/LSt</td>
<td>80/20</td>
<td>5</td>
</tr>
</tbody>
</table>

The sand crushed per unit wt of expl in the detonator was taken as a measure of the
initiating efficiency of the expl chge. This test is called the miniature - cartridge test (Ref 85). The testing of detonators was described in previous reports (Refs 9,32,43,73 &80).

Modern detonators are compd detonators loaded with a base chge, a priming chge and sometimes an ignition chge. The common base charges in use are tetryl, PETN and TNT (Refs 5,11,15,18,30,31,36,38,39,42,44, 48,49,53,59,60,65,81,82,86,94 & 98). RDX was proposed in 1922 (Ref 23) as a base detonator chge but it has not found practical use. Grant and Tiffany (Ref 84) found the order of increasing efficiency of detonator base charges to be: MF/KClO₃ 80/20, tetryl, PETN and RDX. The influence of other factors such as priming chge, reinforcing capsule and outside diameter of shell was also investigated.

Although Blechta (Ref 33) concluded that LA was too sensitive and unsuitable for practical use, the large and extensive patent and technical literature is evidence of the interest and application of LA in detonators. Hyronimus (Ref 1) was the first to propose the use of LA in priming chges. The use of layers of a HE nitro compd and a covering layer of LA suitable for blasting caps, primers or detonators was patented by Wöhler (Ref 2) Rheinisch-Westfälische AG (Ref 3), Burkard (Ref 7), Will (Ref 5), Matter (Refs 11 & 31), Eschbach (Ref 15), Friederich (Ref 24), Nobels Expl Co & Morris (Ref 30), Oerlikon (Ref 36), Symmes (Ref 38), Hercules Powder Co (Ref 39), Eschbach & Wippenhohn (Ref 42), Meissner (Ref 44), Lewis (Refs 48 & 53), Biaszi (Ref 49), Johnson (Ref 60), Rubenstein & Imperial Chem Inds (Ref 65), Burrows (Ref 81), Lyte (Ref 82) and Bain & Carl (Ref 89). General discussions of the use of LA in detonator compositions may be found in Refs 5, 18,29,51,52,79,84,88,97 & 98). According to Kast (Ref 29) LA loaded into detonators at 600 to 5000 kg/cm² showed increased initiating efficiency.

Various multi-component LA compns or admixtures with LA to alter its sensitivity characteristics have also been developed, for example: LA/KClO₃ by Wöhler (Ref 8); PETN/LA/KClO₃ or tetryl/LA/KClO₃ by Claesssen (Ref 4); NC/LA 3/1p or NC/LA/NaNO₃ 11/6/3p by Buell (Ref 6); LA/TNT 80/20 or LA/TNT/gum arabic 70-95/5-30/0.2-0.4p by Runge (Ref 10); NC/PA/LA by Stine (Ref 12); LA/LSr/resin by Eschbach (Ref 16); NC/LA 10-20/90-80 or NG/NC 97-70/7-30% with LA by Hudson (Ref 13); paraffin/cork flour/LA by Sprengluft-Ges (Ref 14); LA/tetryl 40-95/60-5% by Cook & Grotta (Ref 21); Pb salt of trinitrophloroglucinol/LA or Pb derivs of tetryazole/LA by Rathenburg (Ref 19); LA/LSr by von Herz (Ref 12); LA/LSt by Kowatsch (Ref 22); LA/Pb salt of trinitrophloroglucinol/LA or Pb derivs of tetrazole/LA by Eshbach & Wippenhohn (Ref 42); LA/TNT, tetryl or PETN by Matter (Ref 28); LSt/LA/Al or graphite (3%) by Ashcroft & Imperial Chem Inds (Ref 37); LA/diazodinitrophenol by Symmes (Ref 38) and 80-20/20-80% mixt by Hercules Powder Co (Ref 39); LA/powd glass 98/2% or LA/powd quartz 99/1% and LA/tetracene/CaSi₂ 80/10/10% by Eschbach & Wippenhohn (Ref 42); LA/CaSi₂/Ba(NO₃)₂/tetracene by Imperial Chem Inds & Weale (Ref 40); LA/2,4,6-trinitro-1,3,5-triazidobenzene by Turek (Ref 45); LSt or dibasic picrate/LA (10-20%)/resin by Eshbach & Friederich (Ref 50); LA/binder/ester gum, cellulose acetate or Canada balsam by Olsen et al (Ref 55); LA/tetracene with or without other substs such as PbO₂, Sb sulfide, Ba(NO₃)₂ or CaSi₂ by McNutt (Ref 56); LA with KClO₃/S/Pb thiocyanate ~40/ 10/50% by duPont (Ref 58); LA/natural, synth or rubber substitute by Snelling (Ref 63); LA/Ba(NO₃)₂/tetracene by Weale (Ref 62); LA/diazoguanidine picrate with or without tetryl by Imperial Chem Inds (Ref 67); LA/nitrosoguanidine by Olsen & Seavey (Ref 61); LA/nitratohypophosphite by Brun & Burns (Ref 68); LA/ground glass by Hatch (Ref 70); LA/ various expl additives, which lower flash point, by Dynamit-AG (Ref 72); LA/Pb nitrosoresorcinate by Kerke & Carroll (Ref 71); LA/
PETN or tetryl or NC(30-60%) by Lawrence (Refs 74 & 78); LA/tetracene 85-90/10-15% by von Herz (Ref 75); LA/BkPdr or smokeless powd 60-95/5-40% by Hanley (Ref 83) and LA/normal Pb salt of 2,4-dinitorresorcinol by Rubenstein (Ref 92).

LA and its priming or deton coilms have also been desensitized by special treatment or devices, for example: addn of 0.05 to 20% by wt of oil, grease or paraffins (Ref 26); removal of insol carbonates of Pb in LA (Ref 34); for an elec blasting cap the use above the LA chge of Pb thiocyanate/KClO$_3$/ground pyro pdr loose mixt free from admixture with LA (Ref 47); LA wetted with non flammable, non solvent liq of low volatility, such as dichloroethyl ether, but capable of complete removal by water (Ref 54); a stratified primer reqd a relatively small quantity of LA compn (Ref 64); a detonator particularly suitable for coal mining consists of an outer polyvinyl resin shell and an inner iron walled capsule charged with LA (Ref 76); by blending with LA a small quant (0.5 to 3%) of finely divided Ca stearate, blasting caps with an approp chge from the main chge by a foil of D'Arets base chge were made less sensitive to shock or frictional impact (Ref 86); the addn of 4-20% of NC having a fiber length 30 to 250µ to LA reduced its sensitivity and improves loading characteristics (Ref 91); by using an elec ign device the priming compn LA/LSt 80/20% was replaced by LA alone (Ref 93); detonators for use in presence of firedamp were made safe by mixing from 3 to 20% of an inert material, such as KCl, Na$_2$CO$_3$, NaNHCO$_3$, KBr or wax, with both the primary (LA or LA/LSt-65/35%) and secondary (PETN or tetryl) charges (Ref 94) and by the use of dextrinated LA for initiating compns (Ref 96).

Since LA reacts with Cu or brass detonator capsules to form extremely dangerous Cupric Azide (qv), this difficulty has been overcome by the use of Al, Al alloy, iron or paper containers; for example: Al detonator shells were patented by Eschbach (Ref 15), Biazzi (Ref 49), Lewis (Ref 53), duPont (Ref 58), Noddin (Ref 59), Rubenstein & Imperial Chem Inds (Ref 65) and others; according to Galewsky (Ref 18), German military detonators of WWI substituted for the Cu shells first Zn, then Fe and finally Al; Eschbach (Ref 35) also proposed protecting LA, in Cu containers, from moisture and CO$_2$ by applying a cast seal to container mouth equipped with an elec igniter; Noddin (Ref 59) coated the Al shell surface with Al$_2$O$_3$ to make it corrosion resistant; detonator casings for LA expls were also made of an alloy contg Cu or Zn (Ref 17) contg Cu 90-95% and Al5-10% or replacing Al in part by Mg (Ref 41), nitrated alloy steel (Ref 47), alloy of Zn 95.0-98.5%, Cu 4.0-1.5% and Ag 1.0-0.1% (Ref 57) or high Al alloy subjected to anodic oxidation (Ref 58); von Hertz (Ref 46) proposed the use of vulcanized fiber casings, Lignozapolska Akcyjna (Ref 66) casings made wholly of Pb; and Dhôme & Deffrenne (Ref 69) the use of a steel shell protected by an exterior layer of Pb; Salzberg (Ref 77) treated the charged with LA (Ref 76); by blending with gilding metal shell with lauryl mercaptan LA a small quant (0.5 to 3%) of finely divided and Martin (Ref 90) separated the priming charge of Pb; and Dhôme & Deffrenne (Ref 69) the use of dextrinated LA for initiating compns (Ref 96).

Ref. 1) F. Hyronimus, Fr.P 384792(1907); JSCI 27, 524-5(1907) & CA 3, 1690(1909); USP 908674(1909) & CA 3, 1088(1909); Brit P 1819(1908); Ger P 224669(1910) & Chem Ztr 1910 II, 771 2)L. Wêhler, Brit P 4468(1908); Fr P 387640(1908); Ger P 196824 & Chem Ztr 1908 I, 1439 and USP 904289(1909) & CA 3, 717(1908) 3) Rheinisch-Westfälische Sprengstoffe AG, Ger P 238942(1910) & CA 6, 2170(1912) 4) C. Claessen, Fr.P 459979(1913) & CA 8, 3238(1914); Ger P 284400(1916) & CA 10, 970(1916) and Swed P 40749 & 40595(1916) & CA 10, 2525 & 2800(1916) 5) W. Will, SS 9, 52-3(1914) & CA 8, 1508(1914) 6) W. H. Buell, Brit P 21082(1914) & CA 10, 970(1916); USP 1174669(1916) & CA 10, 1435 (1916) 7) E. Burkard, Brit P 16405(1914) & CA 11, 889(1917) 8) L. Wôhler, USP 1128394(1916) & CA 9, 1188(1915) 9) C. G. Storm & W. C. Cope, Bur Mines Tech Paper 125(1916) 10) W. Runge, USP 1168746 & 1185830(1916) & CA 10, 822
USP 2116878(1938) & CA 32, 5214(1938)
69)  A. D. H. Me & P. D. Defrenne, FrP 826286
(1938) & CA 32, 7728(1938)  70)  G. B. Hatch, 
USP 2156942(1939) & CA 33, 6600(1939)
71)  E. B. Kerone & C. C. Carroll, USP 2177657
(1940) & CA 34, 1176(1940)  72) Dynamit-
AG vorm Alfred Nobel & Co, BritP 528299
(1940) & CA 35, 7716(1941); FrP 852495
(1940) & CA 36, 2414(1942)  73)  R. L. Grant &
A. B. Coates, BurMines RI 3696(1943)
74)  R. W. Lawrence, CanP 398139(1941) & CA
35, 6796(1941)  75)  E. von Herz et al, GerP
702269 (1941) & CA 35, 8299(1941)  76)  W.
Eischbach, GerP 75101(1941) & CA 38,
2212(1944)  77)  P. L. Salzberg, USP 2255600
(1942) & CA 36, 274(1942)  78)  R. W. Law-
rence, BritP 546276(1942) & CA 37, 3274(1943)
79)  Davis(1943), 424-30  80)  R. L. Grant, Bur
Mines RI 3696(1943)  81)  L. A. Burrows, CanP
411756(1943) & CA 37, 3943(1943); USP
2427899(1947) & CA 42, 764(1948)  82)  G. A.
Lyte, USP 2360698(1944) & CA 39, 1294
(1945)  83)  E. J. Hanley, USP 2363863(1944)
& CA 39, 3672(1945)  84)  R. L. Grant & J. E.
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IEC 37, 661-6(1945) & CA 39, 3671(1945)
85)  R. L. Grant & J. E. Tiffany, IEC, Ana Ed
17, 13-19(1945) & CA 39, 1053-5(1945)  86)
L. A. Burrows & W. E. Lawson, USP 2402235
(1946) & CA 40, 5568(1946)  87)  L. F.
Audrieth, USP 2410801(1946) & CA 41, 866
(1947)  88)  R. C. Biel & L. R. Carl, USP 2415806(1947) & CA
41, 2901(1947)  89)  C. A. Martin, USP 2423837
(1947)  91)  L. Rubenstein & B. Campbell, USP
246477(1947) & CA 43, 6828(1949)  92)  L.
Rubenstein, USP 2493551(1950) & CA 44,
3022(1950)  93) Dynamit-AG vorm Alfred Nobel
& Co, GerP 803644(1951) & CA 45, 5930-
(1951)  94)  H. Elsner, GerP 803645(1951) &
CA 46, 1260(1952)  95)  K. Kir & Othner 6
(1951), 8 96)  L. Rubenstein, USP 2653863
(1953) & CA 48, 2376(1954)  97) Arment-
Engrg(1954), 47-9  98)  TechMan TM 9-1910
& Tech Ord TO 11A-1-34(1955), 113-6

Lead Azide Explosive, Primer and Detonator Compositions, Analytical Procedures. Following are some typical methods of analysis:

I) Analysis of an Unknown Sample by the Method Used in the Laboratoire Centrale des Poudres as described by M. Marqueyrol & P. Lorriette in MP 18, 93-9(1921):

a) Extract a weighed portion of sample with ether in a tared filtering crucible and evaporate the extract at RT. Dry at 60°, weigh and test for nitro compds, such as PA, TNT, tetryl, etc.

b) Extract the residue on filter with a small amt of w, evaporate the extract at 60° in a tared crystallizer and weigh it. Test the contents of crystallizer for chlorates, nitrates, etc.

c) Add to the residue left after extraction with eth and with w, 10 ml of cold 5% ag soln of KCN and leave for 2 hrs while periodically agitating. Filter and wash the ppt with a few ml of KCN soln and then with w. This treatment dissolves MF if it is present. Test for its presence by adding a drop of nitric acid to few drops of soln. If this causes some pptn, det the MF content by electrolys of soln and weighing the Hg deposited on cathode.

d) Place the residue insol in cyanide in a small distillation flask, add few ml w contg ca 1 ml AcOH, cool the mixt and collect the distillate in a Ag nitrate soln of ca 5% strength. Formation of ppt of AgN₃ indicates the presence of LA in the original sample. Remove AgN₃ by filtration, wash it with w, then alc and finally with ether. Dry in air and weigh.

II) Analysis of Mixtures Containing Lead Azide, Antimony Sulfide, Lead Sulfocyanate and Potassium Chlorate. As an example of such mixts may be cited the T-4 Primer Composition used in M15A2 Detonator. Its ave analysis is: LA 5.0, Sb sulfide 17.0,
Pb sulfocyanate 25.0 & K chlorate 53.0%. It can be analyzed as described under Method 1 and Method 2

Method 1. US Military Spec MIL-D-2493 (1950) superseding the US Army Spec 50-78-7(1946), describes the following procedures

a) Moisture content. Dry to const wt at 55–65°, or in a desiccator contg Ca chloride, an accurately wt sample 0.40 to 0.70 g and calculate the loss in wt as the percentage of moisture (M)

b) Antimony sulfide content. Transfer ca 1g of air-dried sample, accurately weighed, to a beaker contg 100 ml of 1% nitric acid and allow to digest for 10 mins at RT, with occasional stirring. Filter through a Selas or Gooch crucible and wash the residue with distd w. Retain the filtrate and washings for the next procedure. Rinse the crucible with alc & eth, dry at ca 70° for 1 hr, cool in a desiccator and weigh. Calc % Sb₂S₃ on moisture-free basis

\[ \% \text{Sb}_2\text{S}_3 = \frac{W \text{ of residue in crucible} \times 101}{W(1 - 0.01M)} \]

where \( W \) = wt of sample and \( M \) = % of moisture

c) Lead sulfocyanate content. Dilute the combined filtrate and aq washings of the previous proced to ca 300 ml with distd w. Add, while vigorously agitating, 15 ml of 10% Ag nitrate soln and continue agitation until the ppt coagulates. Allow to stand for ca 10 mins and filter through a Gooch crucible having a thick asbestos mat. Wash the residue, which consists of a mixt of Ag sulfocyanate and Ag azide, with distd w. Assemble the crucible to another suction flask. Add to the crucible, while applying a very light suction, 25 ml of 3% ceric ammonium sulfate soln and cover the crucible with a watch glass to retain spatterings due to gas evolution. Adjust the rate of suction so that the 25 ml of soln passes through the crucible in 5 mins. Repeat this treatment and wash the material accumulated on the watch glass into the crucible with a stream of distd w. Using a rubber policeman on a glass rod, tamp the ppt in the crucible into compact pad which will not crack when air is drawn through it. Continue treating the residue with ceric ammonium sulfate until no further evolution of gas is observed and then repeat the treatment three more times. Be sure to return to the crucible any asbestos which might pass into the suction flask. Wash the residue(Ag sulfocyanate) with distd w, followed by alc and eth. Aspirate until free of ether, dry at ca 135° for 1 hr, cool in a desiccator and weigh. Calc % Pb(SCN)₂ on a moisture-free basis

\[ \% \text{Pb(SCN)}_2 = \frac{A \times 97.4 \times 0.985}{W(100 - 0.01M)}, \]

where \( A = \) wt of residual sulfocyanate, \( M = \% \) moisture and \( W = \) wt of sample

Note: This method is tedious, requiring up to 10 hrs, and it is not sufficiently accurate

d) Lead azide content. Assemble the apparatus shown in the fig, p A582, and protect it by screens from effects of air currents in order to maintain the temp around the app as constant as possible. B and I are thermometers

Procedure: Transfer ca 2 g, accurately weighed, to a 125 ml Erlen flask D, add 5 ml of 10% Ag nitrate soln and 10 ml distd w. Shake the flask and wash down its sides with a stream of distd w. Fill a 5 ml delivery burette A with 60% ceric ammonium nitrate soln and connect the flask D, by means of a tightly fitting rubber stopper C, to the gas measuring burette E. Clamp this assembly in position, open stopcock F and, using the leveling bulb G, adjust the water level in the burette E to the zero point. Close the stopcock F and test the system for gas-tightness by raising and lowering the bulb G and releveling the water in G with that in E. Consider the system to be gas-tight if the w level in E returns to zero point
Add to the 400 ml beaker H ca 200 ml of w of the same temp as shown by the thermometer I, and raise the beaker until the flask D is covered with w to about 2" above the bottom. Clamp the beaker in position and allow the app to stand with occasional shaking until the temp as indicated by B is the same as that indicated by I. Adjust the height of G so that the level of w in it is the same as in the burette E. Record the observed level in E, the temp of the gas and the atm pressure. Calc % Pb(N₃)₂ on a moisture-free basis

\[
\%\text{Pb(N}_3\text{)}_2 = \frac{(E-5.0) \times (P-V) \times 0.0570 \times 1.08}{W(1 - 0.01M) \times (1 + 0.00367t)}
\]

where E = ml of gas collected in burette E, P = atm press, mm Hg(see Note), V = vapor press of w at \(t^0\), M = % moisture in the sample, t = temp shown by thermometers B and I, W = wt of sample, grams

Note: If the atm press is observed on a mercurial barometer having a brass scale, calc the corrected atm press(P) as follows:

\[
P = P_1 - 0.000163P_1t_1,
\]

where \(P_1\) = reading in mm Hg of mercurial barometer and \(t_1\) = temp of barometer

e)Potassium chlorate content is calc'd on a moisture-free basis by subtracting from 100 the sum of the percentages of Sb₂S₃, Pb(SCN)₂ and Pb(N₃)₂

Method 2 for Analysis of Primary Mixtures Used in Detonators T-4, T-32, etc. It has been observed that the analysis of this primer by the methods of US Military Spec MIL-D-2493(1950) usually gives too high results for Pb sulfocyanate and Sb sulfide contents and too low results for K chlorate content. It has also been observed that the detn of Pb sulfocyanate by washing with ceric ammonium sulfate(as described in proced c of Method 1) is an extremely slow operation(usually requires ca 10 hrs) and different analysts do not check with each other. It is believed that one of the reasons for the inaccuracy of
results is due to the fact that no satisfactory test is provided for the detn of completeness of washing with ceric ammonium sulfate. A similar condition exists in the detn of Sb sulfide (procéd b of Method 1), where no test is provided for the completion of washing of the sample with 1% nitric acid. The only detn of Method 1 which gives accurate results is the procéd d for detn of the LA content.

In view of the above mentioned difficulties in analysis by Method 1, Method 2 was developed at PlcArsn by B.T. Fedoroff, M.L. Mauger & O.J. Hearns and described in ChemLabRept 130535 (1951). The method was incorporated in the Purchase Descriptions PA-PD-202 (1952) and PA-PD-124 (1953).

Method 2

a) Moisture content — same as procéd a) in Method 1

b) Potassium chlorate content. Weigh accurately a (ca 1g) moisture-free sample directly in a tared 30 ml sintered glass crucible of medium porosity. Add from a burette, 3 ml of Solution No. 1 [prepéd by shaking in a 1 l amber or blue glass bottle ca 800 ml dist w with 40 g KSCN, followed by 1 g Pb(SCN)₂, 1 g Sb₂S₃, and 1 g Pb(N₃)₂]. After allowing to stand overnight, filter a portion of the soln reqd for analysis into another smaller bottle. Swirl the crucible for exactly 1 min, taking care not to spill any liq; aspirate by suction and wipe the bottom and the side of crucible on the outside with tissue or filter paper. Continue the washing using one more 3.0 ml portions, two 2.0 ml and two 1.0 ml, making a total of 12.0 ml. Remove the crucible from the adapter and wash it on the outside with a stream of w. Empty the suction flask and wash it, as well as the adapter, with a stream of distilled w. Place a clean test tube in the flask and insert the stem of the adapter. Insert the crucible and wash its contents with 1 ml of Soln No. 1 as above; aspirate with suction catching the filtrate in the test tube. Remove the test tube, add 1 ml of distilled w and test the soln for the presence of chlorate ion as follows:

Incline the tube at an angle of ca 45° and run down the side of the tube from a dropper, ca 0.5 ml of a soln contg 1.0 g DPh₃A in 100 g of concd sulfuric acid, so that there will be two distinct layers. If an appreciable amt of chlorate ion is present, a distinct blue ring will be visible at the border of the two layers. On shaking the tube, the ring disappears, but the contents assume a blue coloration, which lasts several seconds depending on the amt of chlorate ion present. If only a trace of chlorate is present the blue ring may not form, but upon shaking the test tube a slight bluish coloration will appear momentarily, lasting only a fraction of a second. If a definite blue ring forms in this test, repeat the washing of residue in the crucible using one 1 ml and one or two 0.5 ml portions of Soln No. 1 depending on the outcome of the test for the chlorate ion.

Note: If a total of more than 14.0–14.5 ml of Soln No. 1 is required to remove the chlorate, it is advisable to repeat the whole procéd b starting with a new sample and performing all operations exactly as described after complete removal of the chlorate ion, wash the inside of the crucible with 1.0 ml of Solution No. 2 [prepéd by shaking vigorously in a 500 ml amber or blue glass bottle ca 400 ml distilled w with 1 g of Pb(SCN)₂, 1 g Sb₂S₃ and 1 g Pb(N₃)₂, allowing to stand overnight and filtering a portion of liq required for analysis into another smaller bottle] and aspirate immediately. Wipe the bottom and the sides of crucible on the outside with tissue or filter paper and dry the crucible in an oven at 80 ± 1° for 30 mins; cool in a desiccator and weigh. Calc % KClO₃ on a moisture-free basis

% KClO₃ = \( \frac{B \times 100}{W} \), where B = loss in wt
of the crucible with sample and $W = \text{wt of moisture-free sample}$

c) **Antimony sulfide content.** Weigh accurately ca 1 g of air-dried sample directly in a tared 30 ml sintered glass crucible of medium porosity. Add 5 ml of 1% nitric acid and swirl the crucible constantly for 1 min taking care not to spill its contents in order to dissolve the bulk of the ingredients of the compn except Sb sulfide. Filter the mixt into a vacuum flask by applying suction, remove the crucible from adapter and wash it on the outside with a stream of distd w. Empty the suction flask and wash it, as well as the adapter with a stream of distd w. Place in the flask ca 1 ml of a satd soln of ferric ammonium sulfate[prepd by shaking vigorously in a 500 ml bottle 125 ml of (NH$_4$)$_2$Fe$_2$(SO$_4$)$_3$·24H$_2$O with ca 120 ml distd w, allowing to stand overnight and filtering a portion into a smaller bottle], insert the adapter with crucible. Add 5 ml of 1% nitric acid and aspirate. If the liq in the flask turns red (due to the formation of ferric sulfo cyanate), repeat washing of residue with one or two 5 ml portions of 1% nitric acid and test again for the presence of the sulfo cyanate ion.

**Note:** If more than 50 ml of 1% nitric acid is required to complete the removal of the sulfo cyanate ion, repeat the entire proced c, starting with a new sample.

Rinse the crucible and contents with factory alc and then with eth. Aspirate until the disappearance of the eth odor and dry the ensemble in an oven at 80 ± 1° for 30 mins. Cool in a desiccator and weigh. Calc % Sb$_2$S$_3$ on a moisture-free basis

$$\% \text{ Sb}_2\text{S}_3 = \frac{C \times 100}{W(1 - 0.01M)}$$

where $C = \text{wt of residue(Sb}_2\text{S}_3) \text{ in the crucible, } M = \% \text{ moisture in air-dried sample and } W = \text{wt of air-dried sample before washing it with 1% nitric acid}$

d) **Lead azide content** – same as proced d) in Method 1

e) **Lead sulfo cyanate content.** Calculate $% \text{ Pb(SCN)}_2$ content in the sample on a moisture-free basis by subtracting from 100 the sum of the percentages of KClO$_3$, Sb$_2$S$_3$ and Pb(N$_3$)$_2$.

**III) Analysis of Mixtures Containing Lead Azide, Potassium Chlorate, Antimony Sulfide and Carborundum(or Glass).** As examples of such mixts may be cited: *Primer Composition I:* KClO$_3$ 33.4, LA 28.3, Sb$_2$S$_3$ 33.2 & carborundum 5.1% and *Primer Composition II:* KClO$_3$, 15.4, LA 33.4, Sb$_2$S$_3$, 21.1 & glass 30.1%.

Methods of analysis of such mixts were developed at PicArsn by T.D.Dudderar & E.F.Reese and described in Chem Lab Rept 42863(1935). These methods were incorporated in the US Army Spec 50–78–7 (1946) which was superseded by the US Military Spec MIL–D–2493(1950) and the Purchase Description PA–PD–124(1953).

Following are the procedures:

a) **Moisture content** – same as proced a in Item II

b) **Potassium chlorate content.** Weigh accurately in a small (ca 15 ml), previously ignited, cooled and tared Grooch or Selas crucible ca 1 g moisture-free sample. Add 3 ml of distd w, previously sard with LA, at temp 25 ± 2° and agitate for exactly 1 min, breaking up (very cautiously) any lumps with a rubber policeman attached to a glass rod. Apply suction and repeat the operation 5 times, making a total of six 3 ml extractions. Rinse the sample in the crucible with a few ml of alc and then with eth; dry for ca 15 mins at 95°, cool in a desiccator and weigh. Save the residue for the next proced.
% $\text{KClO}_3$ = $\frac{\text{Loss in wt} \times 100}{w}$, where $W =$ wt of sample

Note: For a mixt contg glass instead of carborundum, four 3 ml extractions are sufficient

c) Lead azide content. Extract the residue of proced b with 5 ml portions of satd amm acetate soln at ca 25°C (hot soln must not be used as it dissolves Sb sulfide to some extent), agitating each portion for ca 30 secs. Continue the washings until they no longer give a yel ppt with a few drops of K bichromate soln. The use of more than 60 ml of amm acetate soln should be avoided. Wash the residue with distd w, followed by a few ml of alc and then eth. Dry for ca 15 min at 100 ± 10°C, cool in a desiccator and weigh. Save the residue for the next proced. Calc on a moisture-free basis

% LA = $\frac{\text{Loss in wt} \times 100}{W}$, when $W =$ wt of sample used in proced b

d) Antimony sulfide content. Treat the residue from proced c directly in the filtering crucible with cold concd HCl until nearly all the sulfide is removed. This can be approx judged by the disappearance of hydrogen sulfide odor. In order to remove the last traces of sulfide, rinse the residue with hot concd HCl. Finally wash it with w, alc and eth and ignite to remove separated sulfur and organic matter; cool in a desiccator and weigh

% $\text{Sb}_2\text{S}_3$ = $\frac{\text{Loss in wt} \times 100}{W}$, where $W =$ wt of sample used in proced b

e) Carborundum or glass content. Subtract the tare of ignited empty crucible(see proced b) from the wt of crucible with residue after the Sb sulfide detn and calculate the difference as the percentage of carborundum in the sample

IV) Analysis of Mixtures Containing Lead Azide, Potassium Chlorate, Antimony Sulfide, Glass and Shellac. As an example of such mixts may be cited the primer composition contg: KClO$_3$ 14.0, LA 33.0, Sb$_2$S$_3$ 21.0, glass 30.0 & shellac 2.0%. Its method of analysis was developed at PicArsn by T.D.Dudderar and described in ChemLab Rept 49334(1937). It does not seem to be incorporated in any specs

Following are the procedures:

a) Moisture content - same as proced a under Item II

b) Shellac content. Weigh accurately ca 2g moisture-free sample (dried at 55°C for 30 mins) in a tared 50 ml beaker and add 5 ml of absolute alcohol(previously satd at RT with KClO$_3$, which is appreciably sol in alc). Warm cautiously on a steam bath over a thin sheet of asbestos for 15 mins, breaking up any lumps by very cautious use of a rubber policeman attached to a glass rod. Cool to RT, let settle and decant the alc shellac soln through a small tared, previously washed crucible. Repeat the extraction with new portions of abs alc until the shellac is completely removed(about 3 times). Transfer the residue in the beaker by means of a rubber policeman to the above crucible, rinse the beaker with several portions of chlf into the crucible and after aspirating, dry the crucible with the residue at 55°C for 15 mins, cool in a desiccator and weigh. Save the residue for use in the next proced. Calc % shellac on a moisture-free basis

% Shellac = $\frac{\text{Loss of wt in the crucible} \times 100}{W}$, where $W =$ wt of sample

c) Potassium chlorate content. Extract the residue of previous proced with distd w satd with LA, etc as described in proced b under Item III
d) **Lead azide content.** Extract the residue of previous proceed with amm acetate soln, etc, as described in proced c)under Item III
d

e) **Antimony sulfide content.** Extract the residue of previous proceed with HCl, etc, as described in proced d)under Item III
e

f) **Glass content** – same as proced e)under Item III

V) **Analysis of Mixtures Containing Lead Azide, Barium Nitrate, Basic Lead Styphnate and Antimony Sulfide.** As an example of such mixts may be cited the NOL No 130 Primer Mixture used in T-32E1 and M47 Detonators: LA(dextrinated) 20.0, Ba(NO₃)₂ 20.0, LSt (basic) 40.0, tetracene 5.0, & Sb₂S₃ 15.0%. Its max moisture content is 0.3%. The method of analysis of such mixts was developed at PicArsn by J.Campisi, ChemLabRept 52-H1-2114(1952) and was incorporated in the Purchase Descriptions PA-PD-202(Rev 1)(1952) and PA-PD-124 (1953)

Following are the procedures:

a) **Moisture content.** Place ca 0.5 g of air-dried sample into a tared weighing bottle with outside ground cap and reweigh the ensemble accurately. Remove the cap and heat the bottle in an oven maintained at 60 ± 5° for 2 hrs, cool in a desiccator and reweigh

\[
\text{% Moisture} = \frac{\text{Loss in wt} \times 100}{\text{Wt of sample}} = M
\]

b) **Barium nitrate content.** Place ca 0.5 g moisture-free sample in a tared 20 ml, medium porosity, sintered glass crucible and reweigh the ensemble accurately. Add 3 ml of LA-satd distd w at temp 5 ± 2°, agitate by swirling for exactly 1 min and, if necessary, break up gently any lumps with a rubber policeman attached to a glass rod. Remove the liq by suction and repeat these procedures 5 times, making a total of six 3 ml extractions. Rinse the sample in the crucible 3 times with factory alcohol (90-95% by vol), dry in an oven at 60 ± 5° for 30 mins, cool in a desiccator and weigh. Save the residue for the next proceed. Calc % Ba(NO₃)₂

\[
\text{% Ba(NO₃)₂} = \frac{\text{Loss in wt} \times 100}{W}
\]

W = wt of sample
c

b) **Basic lead styphonate content.** Extract the residue of previous proceed with six 5 ml portions of satd amm acetate soln at temp not higher than 25°. Agitate by swirling each portion for ca 30 secs, allowing the liq to remain in the crucible for ca 2 mins and then remove it by suction. Finally wash the residue with w until the filtrate is colorless. This treatment dissolves not only basic LSt but also LA. Transfer quantitatively the extract and washings to a 250 ml volumetric flask. Dilute to the mark with distd w and mix thoroughly. Pipette accurately 2 ml of this soln to a 50 ml volum flask and dilute to mark with distd w. Fill a "Corex" glass spectrophotometric cell, having a width of ca 1 cm with this soln, and det the optical density of combined styphonate and acetate ions at a wavelength of 410 millimicrons. Agitate by swirling for exactly 1 min and, if necessary, break up gently any lumps with a rubber policeman attached to a glass rod. Remove the liq by suction and repeat these procedures 5 times, making a total of six 3 ml extractions. Rinse the sample in the crucible 3 times with factory alcohol (90-95% by vol), dry in an oven at 60 ± 5° for 30 mins, cool in a desiccator and weigh. Save the residue for the next proceed. Calc % Ba(NO₃)₂

\[
\text{% Ba(NO₃)₂} = \frac{\text{Loss in wt} \times 100}{W}
\]

W = wt of sample

c

Note: If the cells are not identical, it is necessary to correct the optical density for the difference in the amt of light which the two cells
scatter and absorb. To do this, fill both cells with amm acetate soln and measure the optical density of the cell, which originally contained the basic LSt soln, at a wavelength of 410 millimicrons.

d) **Tetracene content.** Wash the wet residue of previous proced 3 times with factory alc(90-95% by vol), remove alc by suction, dry the crucible in an oven at 60 ± 5° for 30 mins, cool in a desiccator and weigh(C). Transfer the dried residue in the crucible to a 125 ml beaker, with a stream of distd w. Add 25 ml distd w and boil the slurry on a hot plate for 5 mins. Filter through the above crucible, wash the residue 3 times with boiling w and then with factory alc. This treatment removes the tetracene. Dry the crucible & the residue in an oven at 60 ± 5° for 30 mins, cool in a desiccator and weigh(D). Calc % Tetracene on a moisture-free basis

\[
\% \text{Tetracene} = \frac{(C - D) \times 100}{W}, \text{ where } C = \text{wt of crucible with residue after completion of proced c, } D = \text{same after boiling with w to remove tetracene, and } W = \text{wt of sample of proced b}
\]

e) **Antimony sulfide content.** The residue in crucible after removing all other ingredients of sample is Sb₂S₃. Calc'd on a moisture-free basis

\[
\% \text{Sb₂S₃} = \frac{(D - E) \times 100}{W}, \text{ where } D = \text{wt of crucible with sample (see proced d), } E = \text{tare of crucible, and } W = \text{wt of sample of proced b}
\]

f) **Dextrinated lead azide content.** Calculate by subtracting from 100 the combined percentages of Ba nitrate, basic LSt, tetracene and Sb sulfide

Note: LA was removed from mixt together with basic LSt on treatment with satd amm acetate (see procedure d)

---

VI) **Analysis of Mixtures Containing Lead Azide and Aluminum.** As an example of such mixts may be cited the M41 Primer Mixture: LA 90 & Al 10%. Its method of analysis was developed at PicArsn by F. Pristera & L. May, ChemLabRept 113523(1945)

Following are the procedures:

a) **Moisture content** – same as in proced a in Item II

b) **Aluminum content.** Transfer an accurately weighed ca 1 g moisture-free sample to a 150 ml beaker and add with stirring 2 ml of 50% alc, followed by 50 ml distd w, 3 ml glc AcOH and 5 ml of 25% Na nitrite soln. Cover the beaker with a watch glass and lift it as soon as the evolution of gas subsides. Stir the mixt and allow it to stand for ca 3 mins with occasional stirring. Total reaction of destruction of LA shall not last more than 5 mins. Decant the supernatant liquid immediately and transfer Al residue quantitatively to a tared sintered glass crucible of fine porosity, in order to be able to retain the superfine Al. Wash the Al in the crucible with cold w, followed by acetone, dry at 100° for 30 mins, cool in a desiccator and weigh. Calc % Al on a moisture-free basis

\[
\% \text{Al} = \frac{(A - B) \times 100}{W}, \text{ where } A = \text{wt of crucible with Al, } B = \text{wt of empty crucible, and } W = \text{wt of sample}
\]

c) **Lead azide content.** Subtract from 100 the percentages of Al and of moisture

Refs for Analytical Procedures are listed before each method of analysis.
**Lithium Azide** (formerly called Lithium Azomide or Lithium Trinitride), LiN₃, mw 48.96, N85.83%; anisotropic, col crys, mp expl 115° to 298° (Ref 1); sol in w (36.1% at 10° and 66.4% at 16°), sol in alc (20.3% at 16°) and insol in eth (Ref 1); Q₂⁻ -2.58 kcal/mol at 298°K, lattice energy 194 kcal/mol at 298°K (Ref 21). Prepd in 1898 by Curtius & Rissom (Ref 1) by the action of a soln of lithium sulfate on barium azide and evapn of the clear liq. In the same year, Dennis & Benedict (Ref 2) prepd lithium azide by dissolving lithium hydroxide in hydrazoic acid and allowing the soln to evap in air. They obtd the hydrated salt with 1 mol of water of crys, LiN₃·H₂O (Ref 3). Hoth & Pyl (Ref 8) made lithium azide by interaction of sodium azide and lithium chloride in aq alc soln. Frankenburger & Zimmermann (Ref 9) produced LiN₃ by passing O₂-free N₂ over Li heated to 500-600°. Nitrogen, cong very small amts of O₂ produced a glow in the gas in immed contact with the solid azide. More recently Hofman-Bang (Ref 22) prepd 99.5% pure Li azide by dissolving NaN₃ and LiSO₄·H₂O in water and adding 96% alc. The filtrate of solid Li azide, as detd by Jacobs & Tomkins (Ref 18), obeyed the general equation: log k = log A - (E/2.303RT) where k is the specific conductivity in ohm⁻¹ cm⁻¹; A is a constant and E is activation energy in kcal/mol. For Li azide log A = 0.840, E is 19.1 and T, the temp range 300-370°K. The Raman Effect of crys Li azide was detd by Kahovec & Kohlrausch (Ref 14); the observed frequency, 1368.7 cm⁻¹, corresponded to the oscillation in a linear triatomic molecule. The chem reaction between LiN₃ and benzene diazonium chloride has been de- scribed by Huisgen (Ref 20). The formation of an expl Lithium Borazide, LiB(N₃)₄, a wh solid sol in ether, easily hydrolyzed and very sensitive to impact and pressure was reported by Wiberg & Michaud (Ref 19). This compd was obtd on evapg to dryness a mixt of ether solns of excess HN₃ and LiBH₄; Li azide and B azide were assumed as intermediate products in the stepwise reaction.

**Explosive Properties.** Li azide, although detond with difficulty, propagates at a velocity of 990 m/sec (Ref 15). Wohler & Martin (Ref 5) obtd an expln temp of 245° for 0.02 g of the subst which detond violently after 5 sec, but this compd could not be detond by impact. The photochemical decompn of Na, K & Li azides in solns irradiated by UV light of 2537Å wave length was studied by Bonnemay (Refs 13). For low concns the reactn was homogenous and decomp proceeded at a vel proportional to the concn, but independent of the cation. At high concns the vel of decompn was not explained by a simple law (for example Beer's Law) but showed, after an induction period, that reaction proceeded by chains which formed at the start of photolysis. Crystalline Li azide can be initiated to expln by intense electron streams but not by slow neutron bombardment (Ref 16).

**Other Properties.** The mol refractions of Li, Na and K azides were detd in solns of varying concns by Petrikalns & Ogrins (Ref 12). They also detd the density and refractive index for crys Na and K azides. The ionic conductance of solid Li azide, as detd by Jacobs & Tomkins (Ref 18), obeyed the general equation: log k = log A - (E/2.303RT) where k is the specific conductivity in ohm⁻¹ cm⁻¹; A is a constant and E is activation energy in kcal/mol. For Li azide log A = 0.840, E is 19.1 and T, the temp range 300-370°K. The Raman Effect of crys Li azide was detd by Kahovec & Kohlrausch (Ref 14); the observed frequency, 1368.7 cm⁻¹, corresponded to the oscillation in a linear triatomic molecule. The chem reaction between LiN₃ and benzene diazonium chloride has been de- scribed by Huisgen (Ref 20). The formation of an expl Lithium Borazide, LiB(N₃)₄, a wh solid sol in ether, easily hydrolyzed and very sensitive to impact and pressure was reported by Wiberg & Michaud (Ref 19). This compd was obtd on evapg to dryness a mixt of ether solns of excess HN₃ and LiBH₄; Li azide and B azide were assumed as intermediate products in the stepwise reaction.

The reaction between Ba and Li azides...
and $N_2$ at 400-500° and 280-320 atm was studied by Ariya & Prokof'eva (Ref 17) but no expl props were det'd. Their enthalpies of formation were recalcd as 0.1 and 3.1 kcal/mol for the respective azides. (See also refs 6, 7, 10 & 23)


**Magnesium Diazide** (formerly called **Magnesium Azoimide** or **Magnesium Trinitride**), Mg($N_2$)$_2$, mw 108.37, N 77.56%; wh ppt sol in w, insol in eth or tetrahydrofuran. The prepn of Mg diazide was attempted in 1898 by dissolving the metal in dil $HN_3$, but the product decompd on evapg the soln and was not isolated (Ref 1). Turrentine (Ref 2) studied the electrochem corrosion of Mg in Na azide soln and obtbd a wh flocculent ppt, probably basic magnesium azide, Mg(OH)N$_3$, but he did not identify the product. Browne & Houlehan (Ref 3) reported that metallic Mg reacted vigorously with a liq NH$_3$ soln of Amm azide to form Mg azide; however, this compd probably united with NH$_3$ to form an ammonate. Wiberg & Michaud (Ref 6) obtbd Mg($N_2$)$_2$ in almost quant yield from an eth soln of excess HN$_3$ and a frozen ethedioxane soln of Et$_2$Mg. The reaction began below 0° and ended in about 30 min at RT. Distn removed the excess solvent and HN$_3$, Mg azide was found to deton only slightly in flame and to be sensitive to moisture. According to Wiberg and Michaud (Ref 6) it can be isolated from w only as Mg(OH)N$_3$ and it can not be volatilized in high vac at RT


**Manganese Diazide** (formerly called **Manganese Azoimide** or **Manganese Trinitride**), Mn($N_2$)$_3$, mw 138.99, N 60.47%; wh hygro powd easily hydrolyzed, mp expl at 203 in 5 sec., (Ref 5),
Q° = 676 cal/g (Ref 4), Q = -92.2 kcal/mol (Ref 4). By dissolving Mn in dil HN₃, Curtius
& Rissom (Ref 1) obtd a basic manganese azide, Mn(OH)N₃, but the soln decmpd on evapn.
On continuing this work, Curtius & Darapsky (Ref 2) found that an aq soln of
MnAlum and Na azide on pptn with alc and eth gave the basic Mn azide previously
obtd. Wöhler (Ref 3) studied the reaction of Mn carbonate on HN₃ in acet and obtd Mn(N₃)₂
which was not as easily detond as Co azide but exploded more violently than Zn
azide. It was prepd by shaking together finely divided dry basic Mn azide with HN₃ in
acetone until the solid became entirely sol in w (Ref 4). The expl temp for a 0.02 g
sample to det in 5 sec was 203° and a compressed sample detond under impact of a
2 kg falling wt (Ref 5). Franklin (Ref 6) reptd that Mn azide was prepd by reactng the
metal with aq hydrazoic acid, HN₃.
Refs: 1)T. Curtius & J. Rissom, JPraktChem 58, 261(1898) & JCS 76 II, 90(1899)
2)T. Curtius & A. Darapsky, JPraktChem 61, 408 (1900) & JCS 78 II, 474(1900)
3)L. Wöhler, ZAngChem 27 I, 335(1914) & CA 9, 1115(1915)
4)L. Wöhler & F. Martin, Ber 50, 594(1917)
JCS 112 I, 383(1917) & CA 11, 2901(1917)
5)L. Wöhler & F. Martin, ZAngChem 30 I, 33 (1917); JSCI 36, 570(1917) & CA 11, 3432
(1917) 6)E. C. Franklin, JACS 56, 569(1934) & CA 28, 2289(1934)

Mercuric Azide (formerly called Mercuric Trinitride) (called Quecksilberazide in Ger),
Hg(N₃)₂, mw 284.66, N 29.52%; clear to lemon yel crystals, existing as ortho prisms (stable
α-form) or aggregates terminating in prisms or ndls (abnormally sensitive, unstable β-form)
(Ref 8 & 12); mp – begins to dec with gas evoln ca 212°, bp ca 215°, expl at 220° (Ref
3) to 300° (Ref 4); sl sol in cold w (0.26 g in 100 g sol at 20°), sol in hot w; its toxicity is
not known (see Mercurous Azide).
It was first prepd in 1894 by Berthelot & Vieille (Ref 1), by Wöhler (Refs 2 & 3) and
later by Stettbacher (Ref 6) all essentially from a soln of NaN₃ decmpd by concd H₂SO₄
and/or passing the HN₃ formed into mercuric oxide in boiling w. The HgO was quantitatively
converted to Hg(N₃)₂ which crystd from the slowly cooled soln. An alternative method
of prepn consisted in mixing a concd soln of NaN₃ and mercuric nitrate; Hg(N₃)₂ pptd as
wh powdery mass was less sensitive than LA, but according to Stettbacher (Ref 6) it
could be converted into the highly sensitive β-form by soln and crystn. Alpha-Hg(N₃)₂
was prepd by Miles (Ref 8) by mixing a satd soln of mercuric chloride with an equiv soln
of NaN₃ made sl acid with hydrazoic acid. According to Miles, a mixt of α and β crysts
was always obtd when the α azide was re-crystd from w or acetone. Stettbacher (Ref 6)
considers the prepn of mercuric azide as one of the most dangerous and treacherous of
chem operations as this subst presents one of the few examples of "Crystal Tension"
(qv) (Ref 7).
According to Stettbacher, mercuric azide develops the same vol of gas on deton as
MF but it is 20 times more brisant. Wöhler & Krupko (Ref 3) observed that its sensi-
tivity depended on the crist size of the azide. Mercuric azide is considered to be more
sensitive to impact and friction than MF and is so unstable that it frequently undergoes
spontaneous deton at the slightest touch even under w (Refs 5 & 7). Hitch (Ref 4)
noted this sensitivity expecially when the azide was prepd from mercuric nitrate and
Na or K azide solns but by careful thermal studies he decmpd it quanly into its elements
without expln below 300°. Miles (Ref 8) reptd that in every case when β-crys of
Hg(N₃)₂ were present the material was likely to expl, and in w or more rapidly in mercuric
nitrate soln, the β-type was unstable being transformed to the α-type, as in the parallel
case of LA.
Klatt (Ref 10) studied the bp rise of solns of Hg(N₃)₂ in HF (hydrogen fluoride) and
found indications that 3 ions per mol were formed: HgN₆H₄⁻⁺ and 2F⁻.
The ignition of Hg(N₃)₂ by exposure to the intense light produced from a photographic
"electron" flash bulb at 6 cm dist was detd by Eggert (Ref 11) as requiring 300 w-sec elec energy. Wöhler (Ref 2) observed that Hg(N₃)₂ remained unchanged in the dark under water but on exposure to sunlight or heat the yel color changed successively to orange, brn, black and finally grey, yielding the metal.

A compd called in Ger Ammon-basisches Mercuriazide, Hg₃NN₃, was obtd by Strecker & Schwinn (Ref 9) as yel crysts, insol in w or alc, which detond violently on heating or on impact. It was prepd by several methods, one of which was the dropwise addn of concd H₂SO₄ to a soln of mercuric azide in hot w, as long as any yel ppt formed, followed by filtration and drying. The second crop of crysts were obtd by heating the mother liquor on a w bath and filtering the ppt.


Mercurous Azide (formerly called Mercurous Trinitride) (called Stickstoffquecksilberoxydul or Stickstoffcalomel in Ger), Hg₃N₃, mw 242.63, N 17.32%; wh anisotropic ndls; mp started Noddack & Grosch (Ref 20) calcd the expln temp to dec with evoln of gas at 215°, expl at 270° (Ref 8); Q_{expl} 266 cal/g or 64.4 kcal/mol (Ref 7); Q_{f} 70.2 (Ref 21) to 77.3 kcal/mol (Ref 19); v sl sol in w (0.025 g) in 100 g (Ref 6). According to Sax (Ref 22), mercurous azide is highly toxic. When heated it emits fumes of Hg and may expl on exposure to light or heat.

In 1890-1 Curtius (Refs 1 & 2) prepd Hg₃N₃ by reactg solns of HN₃ or Na azide with HgNO₃ to ppt the azide (Ref 2a). Berthelot & Vieille, prepd it by adding a dil aq soln of NH₃ to Hg(NO₃)₂ followed by washing the product (Ref 3) and later also Wöhler & Krupko (Ref 6) who detd some of its expl characteristics and its decompn by light.

According to Curtius (Ref 2), Hg₃N₃ is more stable than either Ag or Pb azide but it does become yel on exposure to light and yields a blk compd with aq NH₃. Wöhler (Ref 5) observed that Hg₃N₃ turned yel because of the formation of colloidal Hg; the yel color passed to orange, brn, blk and finally to grey when exposed to light. In darkness, Wöhler & Krupko kept the salt under water for several months without change; the dry salt, in vacuo and darkness, did not change in 24 hrs at 120-140° (Ref 6). Wöhler & Martin (Ref 7) reported an expl temp of 281° in 5 sec for a 0.02 g sample and deton of a compressed sample under impact. Taylor & Rinkenbach (Ref 11) obtd the following values for sensitivity to impact and friction:

<table>
<thead>
<tr>
<th>Sensitivities</th>
<th>Detonating Compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg₃N₃ Pb(N₃)₂ AgN₃</td>
<td></td>
</tr>
</tbody>
</table>

Impact Test, US BM App:
- 500 kg wt,
- 0.02 g sample, cm 6 43 41

Pendulum Friction Test: (10% point for min wt and height to cause expln)
- Added wt, kg 1 0.45 4.35
- Fall, cm 50 37.5 33
- Swings, No 16-17 12 39

(See also Refs 13, 14, 16 & 18 for addl info on prep & props)

Noddack & Grosch (Ref 20) calcd the expln temp, measured the gas press produced and obtd the energy output from Hg₃N₃ in primers set off in a closed bomb. For a 1 g compressed charge, they obtd an expln press value of...
10,900 kg/sq cm (Ref 20)

Infrared absorption spectra of HgN₃ in the range 3 to 19 microns were obtd by Delay et al (Ref 17). The formation of a complex salt involving Hg⁺ azide, [Hg(C₂H₄N)] (N₃)₂, is described by Strecker & Schwinn (Ref 15)

**Uses.** The great sensitivity of certain metal-azides to heat, impact and friction suggested their possible use as detonants. As early as 1893 (Refs 5 & 14), the Prussian Govnt investigated mercurous and other azides for their possible application in detonators and Wagner & Wöhler & Martin (Ref 7) detd the min amt of the various azides necessary to initiate deton in different HE's, as follows:

**INITIATION EFFICIENCY OF AZIDES**

<table>
<thead>
<tr>
<th>Initiator, g</th>
<th>Tetryl</th>
<th>PA</th>
<th>TNT</th>
<th>TNA</th>
<th>TNX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd azide</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>0.1</td>
<td>–</td>
</tr>
<tr>
<td>Ag azide</td>
<td>0.02</td>
<td>0.035</td>
<td>0.07</td>
<td>0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>Pb azide</td>
<td>0.025</td>
<td>0.025</td>
<td>0.09</td>
<td>0.28</td>
<td>–</td>
</tr>
<tr>
<td>Cu⁺ azide</td>
<td>0.025</td>
<td>0.045</td>
<td>0.095</td>
<td>0.375</td>
<td>0.40</td>
</tr>
<tr>
<td>Hg⁺ azide</td>
<td>0.045</td>
<td>0.075</td>
<td>0.145</td>
<td>0.55</td>
<td>0.50</td>
</tr>
<tr>
<td>Tl azide</td>
<td>0.07</td>
<td>0.115</td>
<td>0.335</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Mercurous azide, although ranking 5th in the above comparative efficiency rating, was suggested by Wöhler & Martin (Ref 7) and proposed by others (Refs 4,9,10 & 12) as a constituent of priming mixts for use in detonators. Grotha (Refs 9 & 10) patented a mixt of HgN₃/MF/KClO₃-20/60/20%. He claimed that it had great brisanse, was not readily “dead pressed” and, unlike other mixts contg MF, it was not hygroscopic nor rendered ineffective by moisture. It was claimed further that this mixt does not attack copper to form the dangerous Cu azide, thus providing an advantage over Pb azide which does react with copper (Also see patents by Blechta (Ref 12)).


**Nickel Dioxide** (formerly called *Nickel Tri-nitride or Nickel Azoidime*), Ni(N₃)₂, mw 142.76, N 58.88%; sandy, hygr grn pdr, mp—exp 200°, Qₚ 656 cal/g(Ref 4), Qₚ -91.9 kcal/mol (Ref 4); very sol in w which it holds tenaciously (ca 13%) but soon undergoes
Hydrolysis (Ref 4). In 1898 Curtius & Rissom (Ref 1) obt'd basic nickel azide, Ni(OH)N₃, with some Ni(N₃)₂ (7) by reacting nickel carbonate with aq HN₃. It was a grn cryst compd exploding at 247-71°. Curtius & Darapsky (Ref 2) continuing this work found that solns of Ni alum and Na azide, pptd with alc and eth, produced the neutral Ni(N₃)₂ + H₂O. Wohler & Martin (Ref 4) obt'd Ni azide by shaking together finely divided Ni carbonate or the basic Ni azide with an ethereal soln of HN₃ until the solid became partly sol in w. Franklin reported (Ref 10) that Ni azide was formed by reacting the metal with aq hydrazoic acid, HN₃. Ni azide is a very sensitive expl, detong violently even at the slightest touch (Ref 5).

Dennis & Isham (Ref 3) prepd the addn compds, Ni(N₃)₂(C₆H₅N)₄ and Ni(C₆H₅N)₆, as grn ppts by treating Ni azide with pyridine. Both compds were unstable in air and non expl. Browne et al (Ref 6) obt'd an ammono-basic nickel azide by electrolyzing solns of NH₄ azide in liq NH₃, using Ni electrodes. The pink deposit which formed on the electrodes exploded on heating. It turned grn on treatment with w, gradually dissolved and settled out as an expl ppt. Ricca & Pirrone (Ref 8) prepd an addn compd from 1 vol of 15% NiSO₄ and 3 vols of a 5% aq soln of a compd obt'd by mixing equal vols of sat'daqg(CN)₂ and NaN₃. The grn compd, Hg(CN)₂-Ni(N₃)₂, did not explode when heated. A lt blue solid, sol in w and exploding violently was described by Strecker & Schwinn (Ref 11). This complex compd called hexamminenickel azide, [Ni(NH₃)₆]²(N₃)₂, is listed in Table E under Ammines (See also Refs 7 & 9). Double salts, such as Ni(N₃)₂·NH₄N₃ and Ni(N₃)₂·KN₃, have been reported (Refs 1 & 4).

Nitrosyl Azide, NON₃, mw 72.04, N77.79%, yel unstable compd (above −50°), mp −66 to −57 depending on method of prepn; bp 1.5° (extrapolated value); Qvapzn 5.6 kcal/mol; vapor pressure 30 mm at −66°, 60 mm at −58° and 200 mm at −32° represented by log p = 7.306 − 1215.6/T where p = mm press and T = degrees Kelvin; Trouton constant 20.2

Nitrosyl azide was first prepd in 1957 by H.W.Lucien [Ref JACS 80, 4458-60(1958)] from the reactions between: a)NaN₃ and nitrosyl chloride b)NaN₃ and nitric acid, c) NaN₃ and nitrosyl hydrogen sulfate and d) hydrazoic acid and nitrosyl hydrogen sulfate at temps below −30°. It was necessary to exercise due precaution against explns in all reactions. Successful prepn were obtd only when the reagents were slowly mixed at the lowest practical temp and gradually warmed to the desired reaction temp. According to Lucien, explns occurred at least once in each reaction type except in those experiments in which either ether was used as a solv or anhyd NaN₃ was used. Of seven attempts to treat NaN₃ with nitrosyl hydrogen sulfate, only two were successful. Almost the same record of success was reported for the reaction between NaN₃ and wh fuming nitric acid. Low yields, not exceeding 6%, were attributed to the instability of NON₃ and to the slow and incomplete reactions by which it was prepd. The yields of the various reactions decreased in the order:

NOHSO₄ + NaN₃
NOCI + NaN₃ (moist)
H₂SO₄/HNO₃ (1:1) + NaN₃
HNO₃ (70%) + NaN₃
NOHSO₄ + HN₃
NOCI (anhyd) + NaN₃

Although the extremely low yields (1%) in the last reaction were increased (to 5%) by adding water, excessive water resulted in reactions difficult to control.

Nitrosyl azide was characterized by conventional analytical data and a study of its decompn into equimolar quants of nitrous oxide and nitrogen. The infrared spectra of samples from each of the procedures of prepn were compared and all showed similar absorption patterns. No other properties of NON₃ were reported.

Phosphorus-Nitrogen Azide, [PN(N₃)₃], mw 387.09, N75.99%, col oil, insol in w, sol in org solvs, stable to alkali, decompd by concd NaN₃ and nitrosyl hydrogen sulfate and HNO₃. It was prepd by reacting (PNCI₃)₃ with hydrazoic acid and nitrosyl hydrogen sulfate Na azide in acetone under N₂ to form the trimeric phosphonitrile azide which was readily detd by friction.


Potassium Azide (formerly called Potassium Trinitride or Potassium Azoidide), KN₃, mw 81.12, N51.80%, wh tetrag crysts (Refs 2,12 & 50); mp 320°(Ref 7), 343°(Ref 13), 350°(Refs 10 & 48) and decompg 355°-360°(Refs 2,7 & 13); d 2.038 g/cc (Ref 12), 2.045 g/cc (calcd in Ref 12) and 2.056 g/cc (Ref 14); Qf 0.33 kcal/mol(Ref 45) Qhydration 157 kcal/mol (Ref 45), ionic conductance of crysts, E = 30.1 kcal/mol in temp range 390-500°K for log A = 4.59 in equation log k = log A − (E/2.303RT) (Ref 42). KN₃ is sol in w (49.2 g in 100 g solv at 17°), sl sol in alc (0.14 g in 100 g solv at 16°), insol in eth (Ref 2), and its soly in NH₃ is considerable and approxs that of KBr; in liq SO₂ potassium azide the salt becomes yel and explodes (Ref 5). The refractive index and conductivity of aq solns and soly of KN₃ in alc, w and benz were detd by Cranston & Livingstone (Ref 14). The density, refractive index and mol refraction of crystn K azide also have been reported (Ref 27). According to Sax (Ref 49) its toxicity is similar to that
of other azides; its expln hazard is moderate but it must be considered a dangerous material.

Potassium azide was claimed to be first prepd in 1898 by Dennis & Benedict (Ref 1b) and in the same year by Curtius & Rissom (Ref 2), both by methods involving evapn of a soln of KOH neutralized with a slight excess of hydrazoic acid, HN₃. This same method of prepn was described in 1894 by Dennis (Ref 1a). Browne & Houlehan (Ref 3) obtd KN₃ by reactng metallic K with NH₄N₃ in liq NH₃. Other methods of prepn are described by Hoth & Pyl (Ref 16), Moldenhauer & Möttig (Ref 17), Wattenburg (Ref 17a), Franklin (Ref 18), Audrieth et al (Refs 21, 30 & 37) and others (Refs 15, 22, 29, 39 & 51).

According to Curtius & Rissom (Ref 2), K azide was neither volatile nor hygro. When heated the salt melted, boiled and gave off nitrogen; the residue inflamed with a feeble deton. It did not explode under impact of a hammer (Ref 8). Hitch (Ref 9) studied the slow thermal decompn at high temps and found that K azide behaved similarly to Ba azide, depositing metallic K, but not decompg violently enough to break the apparatus. Audubert (Ref 26) reported an energy of activation of 20-22 kcal/mol for its thermal decompn; Garner & Marke (Ref 24) 36.1 kcal/mol with decompn appreciable at 220° in the presence of K vapor, and in vacuo decompn occurred in two stages at 330-350° (see Ref 32). Jacobs & Tompkins (Ref 41), who also observed that decompn was catalyzed by a constant vapor pressure of K, proposed a mechanism for its decompn and detd a value of 41.5 kcal/mol as the energy reqd.

The photo-chemical decompn of aq solns of K azide was accompanied by intense UV emission (Refs 25, 28, 33, 34, & 35). Tompkins & Young (Ref 46) noted that color centers developed and the salt decompd into its elements when freshly pptd K azide was irradiated with UV light. In studying the electrolysis of aq K azide solns, Audubert & Racz (Ref 31) observed that low intensity UV radiation appeared. The Raman Effect of both cryst and K azide in soln has been reported by Kahovec & Kohlrausch (Ref 38). Wohlgemuth (Ref 20) studied the KN₃ – H₂O system and found the eutectic at -12.9° contained 26.2% KN₃. The satd soln contained 29.3% KN₃ at 0°, 51.4% at 100° and formed no hydrate. The optical props of K azide solns were reported by Ångstrom (Ref 6).

The structure of the K azide mol has been studied by Frevel (Ref 23) and others who have obtd diffraction data (Ref 36), neutron diffraction measurements (Ref 40) and its mol refraction (Ref 43).

According to Browne & Hoel (Ref 11) K azide reacts with iodine in the presence of carbon disulfide to form K iodide and liberate nitrogen. When manganese dioxide is gently heated with K azide, the reaction proceeds with considerable violence forming K manganate (Ref 4). These authors also used K azide impregnated paper to detonate Ag azide in a lecture demonstration. According to Mellor (Ref 18), R. Stan studied the reduction of K azide by chromous salts.

The mechanism of K azide formation with labeled N¹⁴ and its reactions are discussed by Clusius et al (Refs 44 & 47).

Potassium azide can be used for the qualitative detection of thorium and for its quantitative detmn either alone or in the presence of other rare earths (Ref 1a).


Rubidium Azide (formerly called Rubidium Trinitride or Rubidium Azoimide), RbN₃, mw 127.50, N32.96%; col tetrag, sl hygro crysts (Ref 1); mp 260°C, N₂ evolved in vacuo (Ref 3), 300°C (Ref 3), 321°C (Ref 5), 330°C (Ref 2), 395°C in vacuo (Ref 5) and regular evolution of N₂ at 310°C once decomp has begun (Ref 3); d 2.937 g/cc (Ref 8); Q₉ 0.07 kcal/mol (Ref 18); lattice energy 152 kcal/mol (Ref 18); soln in w (114g/100g w at 17°C), sl soln in alc (0.182g/100g alc at 16°C) insol in eth (Ref 2).

Rubidium azide was first prepd in 1898 by Dennis & Benedict (Ref 1) & in the same year by Curtiss & Rissem (Ref 2) both by neutralizing RbOH with NH₃ and allowing the soln to evapor in air. It is also formed
when N₃ activated electrically reacts with Rb metal (Refs 7 & 9). The toxicity of Rb azide is not discussed in Sax (Ref 19). Also see general Refs 6, 13, 14 & 20.

This compd was found to be sensitive to impact by drop hammer (Ref 8), but stable to heat and light at RT (Ref 3). During electrolysis of its solns N₃ is liberated in an active form (Ref 4). In the thermal decompn of Rb azide, the residue contains the nitride, Rb₃N, which is a grey pdr extremely sensitive to moisture (Ref 11). The structure of Rb azide was detd by Pauling (Ref 10) and by Büssen et al (Ref 12); its diffraction data tabulated by Frevel et al (Ref 16) and the Raman Effect of both crystn was heated under reflux in benz high vac and 0oC. Attempts to prep Si azide by the reaction of SiH₄ and NaN₃ were unsuccessful; Si (N₃)₄ is highly expl and sensitive to moisture.


Silicon Tetrozide, Si(N₃)₄, mw 196.19, N85.68%; wh crystals, sol in bz and eth. It was prepd by the reaction of SiCl₄ and NaN₃ in dry benz in the presence of LiAlH₄ ether. The soln was heated under reflux on a w bath for 20-30 hrs, decanted and the benz sublimed at high vac and 0oC. Attempts to prep Si azide by the reaction of SiH₄ and NaN₃ were unsuccessful.

Sil (N₃)₄ is highly expl and sensitive to moisture.


SILVER AZIDE (formerly called Silver Azimid or Silver Trimitride) (called Silberazid in Ger; Nitrure d'argent in Fr; Acido d'argento o Azidotrduro d'argento in It and Acido de plata in Span), Ag₃N₃, mw 149.90; N 28.03%, col ortho ndls from NH₃ (Ref 88) mp 250oC (Ref 1) in vacuo 185oC (Ref 21); N₃ evolved above 250oC (Ref 21) and expl 297-300oC (Refs 10,21 & 60); d 5.1g/cc (Ref 50) to 4.8g/cc (Ref 37a). Q_{ave}^T =74.2 kcal/mol (Ref 80), Q_{react} 68kcal/mol (Ref 60), lattice energy 204.7 kcal/mol (Ref 80), ΔT_{fus} 78.69kcal/mol from elec chem cell (Ref 63); Q activation 20-21 kcal/mol (Ref 41), 35 kcal/mol (Ref 79) to 41 kcal/mol (Refs 65 & 71); Q_{detox} 65.5 kcal/mol (Refs 14 & 16) and sp heat 0.12 cal/g (Ref 66). The soly of Ag azide in w has been reported as 3.9×10⁻⁸ mol/l at 17oC (Ref 68), 5.1×10⁻⁸ mol/l at 25oC (Ref 43) and 8.4×10⁻⁹ g/l.
(Ref 37). (Also see Refs 7, 8, 38 & 74). It is non-hygro and only very sl sol in alc, eth or acet (Ref 27). Ag azide, like other Ag cmpds, can be absorbed into the body circulation and subsequently deposited in various body tissues causing a generalized greyish pigmentation of the skin—a condition known as "argyria" (Ref 89). According to Sax there is no known method by which silver de- posited in a body can be eliminated. The expn hazard of AgN₃ is severe when it is exposed to shock or heat.

Silver azide was first prepd in 1890-1 by Curtius (Ref 1) by passing hydrazoic acid, HN₃, into neutral silver nitrate soln. This and other methods of prepn were later described by Thiele (Ref 2), Angeli (Ref 3), Dennis (Ref 4), Curtius & Rissom (Ref 5), Dennis & Isham (Ref 8), Wöhler & Matter (Ref 9), Hodgkinson (Ref 20) & Hitch (Ref 21). Turrentine (Ref 9a) electrolyzed 3% Na azide soln using Ag anode; Brown et al by electrolysis at the Ag anode in Amm azide soln (Ref 24). See also Darier & Goudet (Ref 25), Meissner (Ref 30), Taylor & Rinkenbach (Ref 27), Majrich (Ref 38), Wallbaum-Wittenburgh (Ref 46), Stettbacher (Ref 73), Bertho & Aures (Ref 76) and others (Refs 29, 57, & 58).

Darier & Goudet (Ref 25) describe the prepn with a min risk of expln by effecting the reaction within the interstices of a porous absorbent material which is inert and maintains the expl crystals separate from each other. Taylor & Rinkenbach (Ref 27) prepd Ag azide in the pure state, as white colloidal aggregates, by mixing fairly concd solns of AgNO₃ and NaN₃. The colloidal prod was more stable and less sensitive than the crystals. Meissner (Ref 30) described an app for the prepn of Ag azide by a continuous process and Stettbacher (Ref 73) detailed a recent lab procedure for its prepn.

Explosive Properties:

Brisance by Sand Test, 41.1 g sand crushed vs 37.2 g by MF (Ref 27)

Detonation Rate, 1500 m/sec (unconfined and initiated by hot wire), 1700 m/sec (unconfined and initiated by impact with grit particle), and 1900 m/sec (unconfined in vacuo at 0.1 mm Hg) (Ref 59)

Explosion Temperature, °C. 290 in 5 sec for a 0.02g sample (Ref 15) to 308° in 1 sec for a 0.02 g sample (Ref 58)

Friction Sensitivity, extremely sens, but more stable to friction than either Cu, Ni or Co azides (Ref 15) (also see Ref 28)

Impact Sensitivity, 3 in with 2 kg wt and 6 cm with 1 kg wt or 41 cm with 500 g wt vs 43 cm for LA both in BM App (Refs 28 & 58)

Initiating Efficiency, see table under Mercury Azide (or Ref 16)

Lead Block Expansion, 22.6 cc for 2g sample vs 25.6 cc for MF (Ref 9, p 247)

Stability, color remains white when kept in the dark but on exposure to sunlight crysrs darken. It is stable at 75° (Refs 28 & 46)

Temperature Developed on Explosion 3545° vs 3420° for LA (Ref 16)

Work Density, 96.5 kg/cc vs 98.9 kg/cc for LA (Ref 16). Other expl props have been described in Refs 12, 13, 16, 18, 32, 35, 48, 51, 72, 75, 81, 83 & 94.

General Properties: The x-ray cryst structure of Ag azide was detd by Bassière (Ref 36) and his results were confirmed by West (Ref 39). Pfeiffer (Ref 55) also studied the x-ray struct of Ag azide and detd the Ag-N bond dist as 2.56 Å and the Ag-Ag bond dist as 3.00 Å. The optical and elec props, di-electric const, UV absorption spectra and photo conductivity were detd by McLaren & Rogers (Ref 84). Suzuki (Ref 64) calcld the std free energy, ΔF°; entropy, ΔS°; and the heat content, ΔH° for the reactn AgN₃ + Hg = HgN₃ + Ag. The normal AgN₃-Ag electrode potential, referred to hydrogen, was measured by Brouty (Ref 49) as 0.2945V. Bowden & McLaren (Ref 90) studied the expln of Ag azide in an elec field and found that with 45V across the crys, expln occurred when the current rose to ca 150 μA within minutes. Berchtold & Eggert (Ref 67) observed that Ag azide exposed to the energy from a photographic "electron" flash bulb at a dist of
6 cm, reqd 300 w-sec for ignition to deton. Bowden & Singh (Ref 69) found that Ag and other azides were all exploded by an intense electron stream but not by slow neutron bombardment.

**Decomposition.** The thermal decompn of Ag azide has been the subject of considerable investigation. Freshly prepd, pure, col crys Ag azide in sunlight or Hg light becomes violet, gray, and finally black with the evolution of N₂. The compd remains unchanged when kept in the dark at RT but evolution of N₂ continues, even in the dark, when Ag azide is heated (Ref 10). Bowden & McAuslan (Ref 82) studied the slow thermal decompn by means of a scanning electron microscope and observed between 120° and 250° a crystallographic phase change at 180°. Small crysts of Ag azide iradiated in vacuo with UV light (2000-3600Å) reqd a critical amt, corresponding to 8 x 10⁻⁴ cal/sq mm of crystal surface, to initiate expln (Ref 77). Light emitted by the explosn of one cryst of azide did not initiate expln of another cryst, but tiny flying fragments did. The effect of light on Ag azide and other expls was recently reported by Eggert (Ref 92) and by McAuslan (Ref 93). The UV absorption and UV irradiation on thermal decompn of Ag azide has been studied by many investigators (Refs 31,40, 42, 45 & 85), also IR absorption (Refs 53). Audubert & Calmar (Ref 86) found that surface dissocn of Ag azide showed nitrogen active with 2 half-lives characterized by different emission spectra. Thermal decompn has also been studied by Evans & Yoffe (Ref 87), Bowden (Ref 70), Sawkill (Ref 78), Gray & Waddington (Ref 80), Bartett et al (Ref 91) and others. Bartett et al (Ref 91) investigated the thermal decompn of both allotropic forms of Ag azide and obtd activation energies of 44 to 46 kcal/mole for the low-temp form and 31 to 32 kcal/mol for the high-temp form.

**Chemical Reactions.** Hantzsch (Ref 6) reacted iodine with Ag azide and obtd Iodine Azide (qv) and Spencer (Ref 26) reacted bromine with Ag azide to form the highly unstable Bromine Azide (qv); Frieson & Browne (Ref 52) formed Azino Silver Chloride, N₄AgCl, stable only below -30°, by reacting chlorine azide (qv) with Ag azide. Friedlander (Ref 22) reacted tetramethylammonium iodide with Ag azide and obtd tetratetramethylammonium azide (qv). Guanidine Azide (qv), HN₃(CH₃)₂·HN₃, was prepd by reacting guanidine chloride with Ag azide (Ref 34). Silver azide in anhyd acet reacts with α-acetobromo sugars to form β-acetoazido sugars (Ref 56). The formation of complexes between Ag and azide ions has been described by Leden & Schönn (Ref 74). Klatt (Ref 47) noted that the molal bp rise of a soln of Ag azide in HF indicated formation of 4 ions per mole: AgFH⁺, H₂N⁺F⁻ and 2F⁻. Tingle (Ref 23) warned against the expl nature of ammoniacal silver oxide solns due to the unexpected ready formn of Ag azide. A method of analyzing components contg Ag azide and other expls was recently investigated by Eggert (Ref 92) and by McAuslan (Ref 93). Originally the cost and extreme sensitiveness acted as serious deterrents to its extended use. Blechta (Ref 33) proposed mixing Na azide with granular substs, such as tetryl, PETN, MF, etc and adding AgNO₃ soln to ppt Ag azide as a film over them. The efficiency of such initiators was about the same as that of pure Ag azide. In Italy Ag azide was manufd, by the analogous method used for Pb azide, in the form of an amor powder for use in some priming compns (Refs 54 & 62). Sprenger (Ref 17) described a method for opening and examining blasting caps contg Ag azide, but C.G.Storm considered the procedure dangerous. Ag azide is photosensitive and gelatin emulsions of it, prepd by methods analogous to those for AgBr emulsions, were relatively insensitive to shock or temp rise (Ref 11) (Also see Refs 44 & 61).

**Revs:** 1)T.Curtius, Ber 23, 3032(1890) & JCS 60 1, 57(1891) Ber 24, 3344-5(1891) &

"SODIUM AZIDE" (Formerly called Sodium Azomide or Sodium Trinitride) (called Natriumazid or Stickstoffnatrium in Ger; Azothydrure or Nitrure de sodium in Fr; Acido di sodio or Azotidruro di sodio in Ital; Azida de sodio or Nitruro de sodio in Span and Azid natriya in Russian), NaN₃, mw .65.02, N 64.63%. Wh hex crystals, mp decmp (in vacuo) with evolution of N₂ from 275°(Refs 17 & 29) to 330°(Refs 17, 20, 48, 50 & 69) at atm press for complete decmp; d₄ 1.8473 (Refs 25, 27 & 30), Q activation 10 to 34 kcal/mol below 365° and 20 to 50 kcal/mol above 365° (Refs 69, 72, 77 & 115); Qf -5.08 kcal/mol at 298°K (Ref 188); lattice energy 175 kcal/mol at 298°(Refs 78& 188); ionic conductance of crs obeyed equation log k = log A - (E/2.303RT) where log A = 0.490 and E = 25.0 kcal/mol in temp range 375 to 490°K (Ref 156); sp heat from 0° to 100° is 0.2934 cal/gm/°C (Ref 86)

The solv of NaN₃ in acet, CHCl₃, hexane, cyclohexane, CCl₄, trichloroethylene or ethyl acetate at 25° is less than 0.005 g/100 ml of soln (Ref 130); the solv in methanol at 25° is 2.48 g/100 ml soln (Ref 130); in ethanol at 0° 0.22 g/100 ml solvent, 0.46 at the bp of soln; and in benz at bp solv is 0.10 g/100 ml solv (Ref 30). Curinius (Ref 1) found NaN₃ solv in H₂O to be 40.2 g/100 g at 10° and 41.7 g/100 g H₂O at 17°, it is insol in ether. According to Friedman's (Ref 12) NaN₃ was
insol in sulfur dioxide but readily sol in liq 

NH$_3$. Wohlgemuth (Ref 60) studied the system 

H$_2$O-Na$_3$N and found a eutectic at $-15.1^\circ$ 

(21.6% Na$_3$N), a point of transition at $2.1^\circ$ 

(27.8% Na$_3$N), and a metastable eutectic at 

$-20^\circ$ (26.8% Na$_3$N). The satd aq soln at 0$^\circ$ 

contd 28% Na$_3$N and at 100$^\circ$ 35.6% Na$_3$N, 

Crysts of Na$_3$N$\cdot$3H$_2$O were isolated by 

Wohlgemuth (Ref 60). Cranston & Livingstone 

(Ref 30) and Günther & Perschke (Ref 46) 
detd densities, refractive indices and elec 

conductivity of aq Na$_3$N solns; the electro-

lysis also was studied by Turrentine (Ref 11), 

Briner & Winkler (Ref 24), Schmidt (Ref 140) 

and by Semenchenko & Serpinskii (Ref 58), 

Audubert et al (Refs 82 & 87), Verdier (Ref 

93), and Jolibois & Clérin (Ref 95); mol 

refraction by Petrikalns & Ogrins (Ref 79), 

optical props by Ångstrom (Ref 13). From his 

studies of the props of aq Na$_3$N solns, Yui 

(Ref 88) detd the true dissociation constant 

of HN$_3$. Nuclear spin resonance of aq Na$_3$N 

and other Na compds has been reported in 

Ref 187

Structure. Na$_3$N was assumed by Curtius & 

Rissom (Ref 4) to be hexagonal crysts. This 

form was established by A.C.Gill as reported 

by Dennis & Benedict (Ref 3). According to 

West (Ref 59) the hexagonal units of Na$_3$N 

contain 3 mols. He detd their cryst dimen-

sions and showed by powd photographs their 
anisotropic nature on thermal expansion. By 

means of X-ray and Laue photographs 

Hendricks & Pauling (Ref 27) detd the 
rhombohedral unit cell dimensions and the 
interatomic distances of Na$_3$N. The config-

uration of Na$_3$N was detd also by Frevel 

(Ref 68) who found the N-N distance of 
1.150 ± 0.016 Å in good agreement with the 
value 1.17 Å reported by Hendricks & Pauling. 
However, Bassière (Refs 81 & 102) claimed 
that the azide ion in Na$_3$N was asymetric 
with N-N distances of 1.10 and 1.26 Å (see 
also Ref 75). Dreyfus & Levy (Ref 200) 
observed that Na$_3$N and KN$_3$ subjected to 
thermal or mech shock showed distortion 
along slip planes. By X-ray diffraction 
techniques Krasner & Keating (Ref 199) in-
vestigated stacking faults introduced into 

Na$_3$N by grinding or exposure to radiation. 

Joebstl & Rosenwasser (Ref 202) in a study 
of the optical and electron microscopy of 

Na$_3$N observed that crysts from soln go 
through a change from needle and hexagonal 
forms, respectively, to microcrystalline ag-

ggregates. Both KN$_3$ and Na$_3$N, as a result of 
ageing, will form etch pits, oriented over-

growths and other surface defects. It is 
therefore necessary in interpreting physical 
data obtd with azide crysts to know the 
preparative method and history of the mate-
ial examined

Toxicity. Sodium azide is more acutely toxic 
than LA and is considered 3 times as potent 
as org azides (Ref 192). According to Sax 
(Ref 194) Na$_3$N is classed by ICC and Coast 
Guard regulations as a poison B subst and 
must be packed in wooden boxes, with in-
side containers of securely closed paper bags 
placed within a waterproof duplex bag. Net 
wt of material must not exceed 100 lbs. The 
mimn lethal dose of Na$_3$N following injection 
(Ref 103) is 35 to 38 mg/kg of body wt, while 
up to 150 mg/kg of body wt (ca 66 mg NaN$_3$) 
can be injected intraperitoneally without 
causing death. When a 0.005 to 0.010 g 

tablet was swallowed (Ref 36), there ensued 
within 5 min violent heart stimulation, throb-
bing at the base of brain and loss of con-
sciousness for 10 mins followed by rapid 
recovery. Less severe attacks recurred during 
the following hour. The symptoms are similar 
to those caused by strychine. According to 
Hurst (Ref 90), a single dose of Na$_3$N was 
more lasting in effect than KCN. Repeated 
doses of NaN$_3$ produced necrosis or demy-
elination in optic nerves of the brain (Ref 
179). Black et al (Ref 159) reported that an 
oral dose of NaN$_3$ had a rapid hypotensive 
effect and produced a sustained lowering of 
blood pressure

Other effects due to intoxication by NaN$_3$ 
(Ref 34) include respiratory arrest, develop-
ment of convulsions, at first clonic, later
tetanic, and finally heart failure (Ref 174). Biehler (Ref 45) noted that NaN₃ when injected stimulated respiration and acted as a central irritant. Small doses decreased blood press while repeated dosage increased it and caused a transient decrease in body temp. The final effect can result in rigor mortis although the onset is earlier in case of exposure to NaF (Ref 163). The reaction between hemoglobin and NaN₃ has been discussed by Sjöstrand (Ref 148) and by Kikuchi et al (Ref 176). According to Ponz (Ref 158) NaN₃ partially inhibits absorption of glucose thru the intestines. Neither HN₃ nor NaN₃ is excreted unchanged in the urine (Ref 116). The effect of NaN₃ on muscular activity is similar to that produced by 2,4-dinitrophenol (Ref 198). Death due to intoxication with NaN₃ can be prevented by prophylactic ingestion of methemoglobin-forming agents, such as NaNO₃ (Ref 74).

Preparation. Sodium azide was first prepd in 1891 by Curtius (Ref 1) by saponification of benzoylazide with an alc or aq soln of NaOH. Wislicenus (Ref 2) prepd NaN₃ by passing col cryst ppt formed which, after excess a mixt of NH₃ and NO over molten Na or by treating sodium amide at 150°-250° with nitrous oxide:

\[ 2\text{NaNH}_2 + \text{N}_2\text{O} = \text{NaOH} + \text{NaN}_3 + \text{NH}_3 \uparrow \]

In 1898 Dennis & Benedict (Ref 3) and Curtius & Rissom (Ref 4) independently made NaN₃ by evapg a soln of NaOH neutralized with HN₃. The prepn of NaN₃ has been described also by Dennis & Browne (Ref 5), Thiele (Ref 6), Orelkin et al (Ref 19), Browne & Wilcoxon (Ref 28), Wilcoxon & Grotta (Ref 32), Moldenhauer & Möttig (Ref 43), Dynamit-AG (Ref 65), Newman (Ref 63), Westfälische-Anhaltische Sprengstoffe-AG (Ref 64), Acken & Filbert (Ref 106), Abe et al (Refs 138, 142 & 169), Wehrle et al (Ref 135), Funoaka & Iwanaga (Ref 167), Clusuis et al (Refs 181 & 189), Dreyfus & Levy (Ref 200) and others (Refs 37, 38, 62, 84, 107, 109, 113, 133, 143, 144, & 201).

Sodium azide is manufd in France, Germany, Italy and the USA by the sodamide process which is the one generally employed commercially. (See under Manufacture of Sodium Azide) This reaction discovered by Wislicenus (Ref 2) and known as the Wislicenus Method gives a 90% yield in lab prepn. The method was investigated thoroughly by Dennis & Browne (Ref 5). A later modn of this process is based on the catalytic conversion of Na to NaN₃ in liq NH₃ and treatment of the resulting suspension with N₂O under press at RT (Ref 133). The reaction between hydrazine, ethyl nitrate and caustic soda (or sodium ethylate) in alc soln also forms NaN₃:

\[ \text{N}_2\text{H}_4 + \text{C}_2\text{H}_5\text{ONO} + \text{C}_2\text{H}_5\text{ONa} = \text{NaN}_3 + 2\text{C}_2\text{H}_5\text{OH} + 2\text{H}_2\text{O} \]

This process is considered particularly attractive for coml development as it requires no particular precautions in handling the reactants during the manuf of NaN₃ (Ref 133).

According to Schlenk & Wichselfelder (Ref 14) when thin slices of Na were gradually added to free hydrazine in pure, dry N₂, a col cryst ppt formed which, after excess N₂H₄ was distd off in vacuo exploded violently when removed from the vessel or when brought in contact with moisture. On similarly treating hydrazine, entirely free from the hydrate, and evapg the yel soln, brilliant cryst lfts of sodium hydrazide, NH₄NHNa were identified. This compd exploded violently at the least breath of air or trace of moisture. It could be decompd without expln by soln in benz contg a little alc (Ref 37).

Manufacture of Sodium Azide was conducted at the Kankakee Ordnance Works, Joliet, Illinois, (Ref 144) by the "liquid phase process" as follows: For this five 12-lb bricks of sodium were melted in an electrically heated melter and the molten Na at 350°F (176.7°C) dropped to a high-pressure autoclave contg 375 lbs liq ammonia and 1 lb ferric nitrate catalyst. The Na reacted to form Na amide and hydrogen:

\[ 2\text{Na} + 2\text{NH}_3 = 2\text{NaNH}_3 + \text{H}_2 \]

the latter being vented out of the autoclave.
along with some ammonia at a gage press 300 psi. The temp was held below 105°F (40.6°) by cold w in the autoclave jacket. When this reaction had subsided the remaining hydrogen was vented and about 55 lbs of nitrous oxide gas was added to the charge through a standpipe the end of which was directed beneath the gas disperser agitator in the autoclave. The following reaction took place: 2NaNH₂ + N₂O → NaN₃ + NaOH + NH₄. In this operation as much of the N₂O as possible was fed continuously and at such rate that the concn of N₂O in the vapor space was less than 25% by vol, to prevent forming an expl mixt with NH₃. When no more N₂O was absorbed the charge was blown into a 247 gal drowning tank which contained enough w to give a final soln strength of 8% NaN₃. The yield from Na to NaN₃ in the crude solution was 87%

The next step was the removal of ammonia from the "crude soln", which was done by steam-stripping in an evaporator to an ammonia recovery system, where NH₃ was absorbed in w. The resultant NH₃-free crude soln was filtered through a Nutsch type filter to remove the catalyst and other insol impurities. The filtrate referred to as clear liquor was stored in a 1000 gal tank from which it could be transferred by suction into either of two 280 gal jacketed evaporators. The evaporation was conducted under 24" vacuum with 50 lb steam press in the jacket. A total of 425 gal of "clear liquor" was concentrated until a sample of its "mother liquor" showed the strength of 35% NaOH. During this operation the bulk of NaN₃, being less sol in w than NaOH, pptd. Then the mixt was cooled to 80-90°F (27-32°) (to cause the pptn of addnl NaN₃) and dropped to a wringer. The yield was ca 75% NaN₃ and the overall cycling time was 5-6 hrs.

The "mother liquor" was wrung out of the slurry and drained from the wringer to a catch tank from which it was pumped to a storage tank to be reworked. The crystals of NaN₃ were washed on the wringer with 100 lbs of treated w, which was pumped through spray nozzles inside the basket, and the washings sent to the mother liquor storage tank. (The total, about 350 gals, was referred to as the first mother liquor). Then the crysts were dissolved directly in the wringer with about 65 gals of treated w, which yielded the refined solution of 27% NaN₃ strength. The "refined soln" was pumped to a weigh tank from which it was dropped (after it was sampled and the wt recorded) to a 1000 gal storage tank. When required the "refined soln" was pumped to the LA manufg plant (See under Lead Azide).

The "first mother liquor" (see above), max 350 gals, was evapd until the NaOH concn reached 50%. After cooling to 80-90°F, the slurry was dropped to a wringer where the second mother liquor was wrung out to the catch tank from which it was pumped to a 240 gal storage tank. The second crop of crysts remaining in the wringer was not washed but dissolved in treated w and delivered to a 240 gal receiver tank from which the soln was sucked into the clear liquor evaporator to be reworked. The refining process gave an overall recovery yield of 94-96%.

The "second mother liquor" was analyzed for its NaN₃ content and if it was over 2%, the liquor was reworked in the mother liquor evaporator. If the liquor contained less than 2% NaN₃ it was sent to the 710 gal killing tank, where the azide was destroyed by a caled amt of Na nitrate and concd sulfuric acid to produce the reaction:

\[
\text{NaN}_3 + \text{NaNO}_3 + \text{H}_2\text{SO}_4 + \text{N}_2\text{O} + \text{N}_2 + \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}
\]

After destroying the azide, the waste liquor of the killing tank was siphoned to a settling pond from which it was sent to a stream

Explosive Properties. According to Curtius (Ref 1) NaN₃ is neither volatile nor hygr, its solns may be evapd to dryness without undergoing any change, and it explodes only when heated to a high temp. This stability to heat was confirmed by Curtius & Risson.
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(Ref 4), Dennis & Benedict (Ref 3) and Dennis & Browne (Ref 5). Wöhler & Martin (Ref 18) exploded NaN₃ without true deton, by heating a 0.02 g sample but did not explode it by impact on a compressed 0.01 to 0.05 g sample. Bowden & Williams (Ref 132) were unable to propagate deton in NaN₃.

**Thermal Decomposition.** Wattenburg (Ref 48) observed that NaN₃ must be heated to 250° before decompn starts and that formation of Na₂N is a necessary stage in the decompn of NaN₃ to N₂ and Na. According to Garner & Marke (Ref 69) the decompn in a vac at 257-365° was similar to that of KN₃, but the catalytic effect of Na vapor was small. Decompn followed an induction period and then occurred in two or three steps (Refs 89 & 108). Audubert (Refs 72 & 80) noted that intense UV radiation was emitted during slow thermal decompn of NaN₃ and KN₃ (Ref 71). In a closed system the nature of gas or its absence had no effect but in a moving current of gas UV radiation was more intense (Ref 76). Bonnemay (Ref 100) detd the effect of bases and neutral salts on decompa rate. Thermal decompn of NaN₃ has been studied extensively by Yoffe (Ref 131) and by Jacobs & Tompkins (Ref 139).

**Effects of Radiation.** The threshold for decompn of NaN₃ by electron bombardment is at 11.65 ± 0.2 volt-electrons (Ref 52). Groocock & Tompkins (Ref 160) studied the decompn with 100 and 200 v-electrons at RT and found theoretical calcns agreed with exptl results. Muller & Brous (Ref 52) found that photochemical decompn occurred at wave lengths below 405 mμ at a rate directly proportional to the UV intensity. No relation between energies necessary for electronic and photochemical decompn was apparent. NaN₃ turned brown under X-ray and slow neutron bombardment (Refs 149 & 184). When irradiated NaN₃ was dissolved in H₂O, N₂ gas was evolved and OH⁻, NH₃ and N₂H₄ were present. Heal (Ref 196) showed also that NaN₃ irradiated at or below RT was initially pale green and later became brn on standing a few hrs at RT. Irradiated NaN₃ dissolved in liq NH₃ gave a blue soln similar to that obtd from Na in liq NH₃. By irradiation of NaN₃ with alpha rays from Po or Rn, a new radioisotope was produced (Ref 61). Rosenwasser et al (Ref 184) investigated the induced coloring of NaN₃ exposed to gamma rays and to neutron bombardment. Gamma-rays produced a broad band at 3600 Å and a band at 6000 Å when gamma-irradiated NaN₃ was heated above 90°.

**Absorption and Emission of Radiation.** Raman spectra of NaN₃ have been detd by Petrikalns & Hochberg (Ref 41), Kahovec & Kohlrausch (Ref 111) and by Sheinker & Syrkin (Ref 120). Moler (Ref 99) expressed the absorption spectra of aq NaN₃ soln as log of extinction coeff vs wave length. Sheinker (Ref 127) noted that the UV absorption spectra of aq NaN₃ soln were markedly different from those of typical aliphatic azides. Infrared absorption spectra were reported by Lieber et al (Ref 129) and by Delay et al (Ref 105) in the range 3 to 19 μ. From the intensities of bands observed, it was concluded by Delay et al that the sym form was more abundant than the unsym form in azides of Na, Cu, Aq and Hg but the reverse was true for azides of Tl and Pb.

The optical absorption and UV absorption of aq NaN₃ were detd by Bonnemay & Verdier (Refs 92 & 104). In both cases Beer's law was not obeyed except for narrow regions of concns and wave lengths. The kinetics of the photochemical effects on NaN₃ decompn has been discussed in detail by Bonnemay (Ref 94).

**Chemical Reactions.** Forster (Ref 8) described the interaction of benzyldoximic chloride with NaN₃ to give wh ndls (mp 124°) of 1-hydroxy-5-phenyltetrazole which decompd spontly. The reaction of acid chlorides with NaN₃ was described by Schroeter (Ref 9) Waltmann (Ref 83) and Kiss & Vinkler (Ref 124). While Schroeter found that coml NaN₃ reacted smoothly and rapidly with acid chlorides to form isocyanates (Also see Refs...
63 & 83), Naegeli et al (Ref 39) obtd good results only when pure NaN₃ was used. Nelles (Ref 54) observed a similar diff in reactivities of pure and coml NaN₃. At the time of Schroeter's investigation coml NaN₃ was prepd by the Thiele-Stoll method (Refs 6 & 7), but later was manufd from N₂O & NaNH₂, and contd impurities which hindered its reaction with acid chlorides. Impurities were not removed even by librating the acid from the salt and neutralizing with the purest NaOH. However, Nelles (Ref 54) found that if NaN₃ were rubbed with a trace of N₂H₄·H₂O and pptd from a little w with a little acet, it was not only as reactive as pure NaN₃ made from N₂H₄ and NH₄NO₂, but because of its greater surface area it was even more reactive (See also Ref 197 for prepn of activated NaN₃.). According to Stollé (Refs 22 & 57) the reaction between NaN₃ and benzalbenzyldrazide, dibenzhydrazide or diacylhydrazide chlorides gives various tetrazole and hydrazide azide derivs, some of which are expls. Goyal & Saxena (Ref 173) also studied the reactions of acid chlorides with NaN₃ and reported that dry NaN₃ and CrO₂Cl react explosively in CCl₄ below 0° probably forming a solid, CrO₂(N₃)₂.

The interaction of nitrosates with NaN₃ was described by Forster & van Geldern (Ref 10). Sommer (Ref 15) treated aq NaN₃ with CS₂ and obtd, on cooling to 0°, yel prisms of sodium azidodithiocarbonate, N₃CS₂Na·H₂O, stable below 10° and only moderately expl but deferg violently on Pt foil. The anhyd salt exploded on impact and detonated on gentle heating. NaN₃ with AgNO₃ gave a white Ag salt, insol in HNO₃ and NH₄OH, and explosive at the slightest touch when dry (see Silver Azide). On adding 3 moles of NaN₃ in alc to Cr(N₃)₃, Oliveri-Mandalà & Comella (Ref 21) sepd grn crysts of Cr(N₃)₃·3NaN₃ which in aq soln with AgNO₃ gave an expl complex salt. Currier & Browne (Ref 23) absorbed CS₂ vapors in 5% satd aq solns of NaN₃ and formed an azido salt which possessed no dangerous expl props but decompd slowly on long standing. According to Spencer (Ref 26) dry bromine reacted with NaN₃ to give the highly unstable expl bromazide:

\[ NaN₃ + Br₂ = NaBr + BrN₃ \]

and bromine water reacted instantly with NaN₃ to give a mixt of hydrazoic and hypo-bromous acids:

\[ NaN₃ + Br₂ + H₂O = NaBr + HN₃ + HBrO \]

Hofmann & Hofmann (Ref 31) found that NaN₃ reacted with molecular H₂ and O₂ to form NaNH₂ and NaN₂O, resp. NaN₃ with colloidal Pd and CO₂ was unchanged (Ref 53).

Anhyd HF decomp NaN₃, evolving HN₃ (Ref 47). Hoffmann (Ref 51) studied the mechanism of reaction of various types of ultramarines on NaN₃ and observed that rose ultramarine gave the most vigorous reaction, evolving N₂. Stollé et al (Refs 55 & 56) re-acted 1,4-dichloro or 1,4-dibromophthalazine and dichloroquinazolines with NaN₃. The synthesis of aromatic nitro compps with an azide group in the side chain was accomplished by Yushchenko (Ref 67) by reacting either NaN₃ or AgN₃ with the appropriate chloride or iodide in alc or acet soln. Kuz'min & Zemlyanskii (Ref 66) prepd the monoazides of Ph styryl and Ph 3-nitrostyryl ketones by reacting NaN₃ with the appropriate starting materials. According to Labruto & Landi (Ref 73), the reaction of benzoyl chloride with NaN₃ without solv and in the presence of NaOH or KOH was spontaneous and violent, evolving suffocating and lachrymous vapors. The reaction between phenylcarbylamidine chloride, PhN·CCl₃, and NaN₃ is quant in acet giving a product Ph N·N·N·N·C·N₃₉, mp 99° (Ref 85).

By dissolving Cu(N₃)₃ in aq or alc solns of NaN₃ Straumanis & Cirulis (Ref 98) obtd sodium triazio-ocuprate Na[Cu(N₃)₃], anhyd after heating above 120°. This compd exploded at 216-23° and under impact of drop hammer. Explosion also took place when Hg (NO₃)₂ was added to Na[Cu(N₃)₃] (Ref 98). The addn of NaN₃ to an amine soln of Cu⁺⁺ salts pptd complex non-electrolytes (Ref 97). Wiberg &
Michaud (Ref 164) prep'd a wh solid complex salt, sodium hexazidostannate, Sn(N₃)₄·2NaN₃ or Na₂Sn(N₃)₄, from SnCl₄ in tetrahydrofuran soln heated with an excess of NaN₃. After filtration and evapn of solv, the solid complex was sol in tetrahydrofuran, insol or only sl sol in ether or benz and was hydrolyzed by moist air. In tetrahydrofuran soln the salt detonated on boiling. In the reaction betwn FeCl₃ and NaN₃ no complex Fe azides were formed (Ref 150). The prepn of azido compds by the reaction of NaN₃ with epoxides was described by Vander Werf et al (Ref 166) and by Ingham et al (Ref 190). Vander Werf et al (Ref 166) found that (N₃CH₂)₂CHOH when hydrogenated catalytically gave (H₂NCH₂)₂CHOH (bp 3 mm Hg 93-5°) which decompd violently above 150°. The di-HCl salt and the picrate both melted with decompn at 184° and 233.6° respectively.

Adamson (Ref 110) described the prepn of NaC₄N₄ from BaC₄O₄ and NaN₃ in a N₂ atm to yield 75-80% of prod after 30 min heating. Henneberry & Baker (Ref 118) modified Adamson’s method, to prevent explns, by fusing NaN₃ and BaCO₃ at 630° for 20 min to form NaCN. The reduction of NaN₃ by amalgamated Al was reported by Labruto (Ref 125). Other reactions involving NaN₃ include: isomerization of halohydrins (Ref 152), reaction with anthraquinone derivs in acid media. Feigl (Ref 35) used (Ref 155) and monobromomalonic ester to the iodine-azide reaction to detect small form diazidomalonic ester (Ref 155), synthesis of phenanthridines by interaction with fluoren-9-ols (Ref 168), conversion of secondary nitro compds to amides or lactams (Ref 178) and the prepn of toxic fluoreine compds by using "activated" NaN₃ (Ref 197). Miller et at (Ref 195) discussed the role of NaN₃ in S_N mechanisms involving aromatic substitions. Werle et al (Ref 161) reported that NaN₃ was decompd by animal or plant tissues, such as liver & kidney extracts and potato, sugar beet or apple extract. Levey (Ref 165) noted that a small amt of NaN₃ inhibited the anthrone reaction used for detn of total carbonates, but NaN₃ did not affect the fercicyanide test for reducing sugars or the skatole test for fructose.

The Iodine-Sodium Azide Reaction. This reACTION:

\[ 2NaN₃ + I₂ = 2NaI + 3N₂ \]

has been used for the gasometric detection of thiocyanates, sulfides and thiosulfates (Refs 35,40,101,117,122,126 & 128). According to Senise (Ref 126) at pH 5.8 as little as 0.035 microgram can be detected by a spot test at a concn limit of 1 x 10⁻⁶. When NaN₃ was measured with a Lunge nitrometer, the vol showed a linear relationship to the amt of S⁷⁺, S₂O₃⁻² and SCN⁻ present (Ref 122). LeRosen et al (Ref 117), by using equal vols of a satd soln of I₂ in 1% KI and of 10% NaN₃ in 1% starch, obtd a new streak reagent for detecting CS₂ by bleaching of the blue color. The effect of catalysts on the iodine-azide reaction has received considerable attention from many investigators (Refs 35,40,70,91,121,141,145,153 & others). Sulfhydryl compds as catalysts were listed by Friedmann (Ref 70), and thioureas were given by Feigl (Ref 171) and Kayama (Ref 121). The kinetics of the catalytic activity of cysteine and related compds was studied by Whitman & Whitney (Ref 153). Awe & Naiyoks (Ref 141) detd the catalytic order of effectiveness of S compds and noted that the reaction did not take place in acid media. Feigl & Chargov (Ref 35) used the iodine-azide reaction to detect small quants of CS₂ and for the detn of azides. According to Moss (Ref 147) Niello, the blk metalic-like mixt of the sulfide of Cu, Ag & Pb, used to inlay ornamental designs engraved in metal, can be identified by its ability to decomp catalytically a soln of NaN₃ in iodine.

Uses of Sodium Azide. The principal use of NaN₃ in the expl ind is in the prepn of alkali alkaline earth and other azides (Refs 37,38,42,96,113,201,% others) (See Lead Azide, Plant Manufacture, etc). Meissner (Ref 44) used equiv quants of NaN₃ and a heavy metal salt, such as Pb acetate, for the continuous prepn of LA. Matter (Ref 33) found that NaN₃ was freed from carbonates by the addn of aq...
solns of hydroxides or salts of alkaline earth metals, such as those of Ba, and this NaN₃ was then suitable for use in the prepn of other metal azides. Buell (Ref 16) proposed as a priming chge for exps a mixt of NaN₃-KClO₃/Sb₂S₃ - 35/30/35%

NaN₃ is used as an initiator for emulsion polymerization (Ref 137), as a cellulating agent (Ref 134) and as a retarder (Ref 183) in the manuf of sponge rubber. The addn of NaN₃, an alkali bicarbonate and an alkali to form a compn of pH 9-12 prevents or reduces plating out or coagulation of styrene and butadiene latexes stored in contact with metals (Ref 162). NaN₃ is used also to decomp nitrates in the presence of nitrates (Ref 172). The rate of nitrate decomp is increased with an increase in azide concn.

Acosta (Ref 172) detd the optimum ratio to be C₃NaNO₃/C₃NaN₃ = 3.9. Compds of the structure R₂R (-O) (-NH) have been prepd from the corresponding sulfoxide and NaN₃ + H₂SO₄ in chlf soln (Ref 171):

(CH₃)₂S→O + HN₃ → (CH₃)₂ S ← O + N₂

According to Black & Kleiner (Ref 112), encouraging therapeutic effects, without toxicity, were exerted by NaN₃ and some other compds in 31 cases of advanced cancer and leukemia in man. Cudkowicz (Ref 175) found that NaN₃ and hydroxylamine reduced growth of transplantable tumors up to 50%. NaN₃ has been used to some extent in the treating of wounds under conditions where the slow oxidizing action is considered desirable in inhibiting growth of anaerobic bacteria (Ref 114). Jones (Ref 182) reported that NaN₃ and merthiolate solns will preserve blood typing serums if they are kept sterile, whereas, under ordinary storage conditions untreated serums deteriorate

NaN₃ prevented fungus growth (Ref 193) which caused darkening of sake cake (Japanese beer). Fales (Ref 146) noted that the effect of NaN₃ on alcoholic fermentation was to increase efficiency in the conversion of glucose to fermentation products. NaN₃ is also useful as a wine preservative, inhibiting or preventing growth of microorganisms (Ref 177). The enzymic oxidation of polyphenols, causing red stain in pulp wood (Ref 170), and enzymic oxidation of lignin can be inhibited or prevented by NaN₃ (Ref 180). Since NaN₃ inhibits microbiological reactions in soil (Ref 123), its use in soil polymerization (Ref 137), as a cellulating has had the following effects: a) inhibiting agent (Ref 134) and as a retarder (Ref 185) biological oxidation of iron (Ref 119) b) inhibiting oxidation of manganese (Ref 186) c) markedly inhibiting pyruvic oxime oxidation form a compn of pH 9-12 prevents or reduces (Ref 136) d) completely inhibiting biological plating out or coagulation of styrene and oxidation of arsenite to arsenate (Ref 151) butadiene latexes stored in contact with and e) useful in the treatment of tobacco shank in soil but with some other toxic effects (Ref 191). Hill et al (Ref 157) proposed using NaN₃ to control the growth of weeds comp nitrites in the presence of nitrates fects (Ref 191).

Hill et al (Ref 157) proposed using NaN₃ to control the growth of weeds comp nitrites in the presence of nitrates fects (Ref 191).

SODIUM AZIDE PLANT, ANALYTICAL PROCEDURES. The sodium azide plant of the Kankakee Ordnance Works (KOW), Joliet, Illinois, operated by the US Rubber Co., used as starting materials anhydrous ammonia, sodium ferric nitrate (catalyst) and nitrous oxide.

Following are the analytical procedures used at the KOW plant, as described in Ref 7.

I) Anhydrous Ammonia Synthetic. The methods of analysis described in US Spec JAN-A-182 were used (See under Ammonia, Analytical Procedures.)

II) Sodium was in the form of bricks packed in barrels or tank cars. It had the following props: purity — min 99.95%, metallic Ca — max 0.04%, chlorides — max 0.005%, mp 97.6°, bp 880° and sp gr 0.970. The tests used at KOW are described in Ref 7, pp 25a to 25d. These tests are not included in US Spec JAN-S-328(1946) which requires only the following tests:

a) Foreign Matter. When examined visually the metal must be substantially free of foreign impurities.

b) Solidification Point. The value must be 97.0 ± 2° when detd in the apparatus shown on fig (next page).

Procedure: Free the metal from any adhering oil or other impurities by shaving a thin layer. Fill a clean, dry, 1" × 6" Pyrex test tube, about 1/4 full with the clean sample and plunge the lower part of the tube in an oil bath at 105°. When the temp of molten sodium
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was knocked down and sampled by means of a cup. The requirement was that the cake contain less than 1% NaOH and the test was as follows (Ref 7, p 26).

Procedure: Weigh a 10.00-g sample on a tared 4" watch glass and brush up all spilled crystals immediately, because they are very poisonous. Transfer the sample to a 400-ml beaker contg ca 150 ml distd w neutral to phpt and stir until completely dissolved. Titrate rapidly to colorless end-print with 0.1N sulfuric acid. Avoid overrunning the end point, which causes evoln of the very poisonous gas HN₃.

\[
\% \text{ NaOH} = \frac{A \times N \times 0.0401 \times 100}{W}
\]

where \( A \) = burette reading, \( N \) = normality of H₂SO₄, and \( W \) = wt of sample.

Note: The cake must contain at least 99% NaN₃ on the dry basis. A small amt of NaOH is not harmful but traces of Na carbonate produce Pb carbonate which inhibits the formation of desirable form of LA crysts. The presence of any appreciable carbonate will also tend to lower the purity of the final product. The cake must be practically free of NaCl.

VI) First Mother Liquor is the liquid wrung from one evaporator chge (See under Manufacture of Sodium Azide) of normal or average analysis: NaOH (actual) 34.4%, NaN₃ (actual) 2.5% and Na₂CO₃ (actual) 0.2%. A 25-ml sample was dipped by hand from the catch tank after the charges had been centrifuged and all samples composited for one week. At the end of each month, an 8-oz sample was taken from the storage tank for monthly inventory and was analyzed in the same way as the weekly composites. Procedures:

a) NaN₃ Content. Pipette exactly 10.00 ml of sample into an accurately tared glass-stoppered weighing bottle and accurately weigh it. Use this weight for all 10.00-ml samples and save the contents of the bottle for the detn of NaOH (see proced c). Using the same

reaches ca 105°, remove the tube, wipe it off and quickly assemble the apparatus. Stir continuously until the temp stops falling and then start to rise. Stop stirring and note the max temp, which is known as "incorrected setting point". After this the temp falls slightly and remains stationary for ca 1 min. Record this temp as the "solidification point" of Na

III) Ferric Nitrate (catalyst in reaction between Na and NH₃) was procured in No 50 drums. It was of analytical grade and had the following props: insoluble matter – max 0.01%, chloride – max 0.001% and sulfate 0.10%. No analysis was made at KOW (Ref 7).

IV) Nitrous Oxide was procured in car load lots of 200 50 lb cylinders. It was USP grade, free of impurities to the lowest practical amt and which were designated on the label of each container. No analysis was made at KOW (Ref 7).

V) Wringer Cake is a solid contg ca 99% Na azide, obtained after centrifuging the slurry obtained on evaporation of crude Na azide soln, as described under Manufacture of Sodium Azide. Basic unit weighs 100-250 lb and a 100-g sample is taken of each cake immediately after it is wrung and washed. A strip of cake of the width of the centrifuge
pipette, transfer another 10.00-ml sample to a Kjeldahl distn flask and add 300 ml of freshly boiled distd w. Add a few boiling chips to prevent bumping and close the flask with a stopper equipped with a spray trap and a closed separatory funnel. Place the flask on a cold electric heating unit. Transfer exactly 50.00 ml of approx N/3 NaOH soln to a 1000-ml Erlen receiving flask and dilute with ca 200 ml of freshly boiled distd w. Assemble the flasks and a condensing apparatus, closing the receiving flask with a tight-fitting rubber stopper through which passes the tube (adapter) from the condensing app and a tube connected to a U-tube contg soda-lime. The tip of adapter must be slightly immersed in the contents of the receiving flask. Add 20 ml of 40% sulfuric acid to the separator funnel of Kjeldahl flask.

Heat the liq in the Kjeldahl flask and continue boiling until most of the air has been driven from the apparatus and replaced with water vapor. This will be shown by the disappearance of air bubbles escaping from the tip of adapter tube in the receiver. Through the separatory funnel, slowly add 20 ml of 40% sulfuric acid, making sure that the resulting partial vacuum does not cause the receiver liq to back up more than half way in the condenser. Close the stopcock of the separatory funnel.

Caution. Never add the acid before the system is filled with vapor, as high concns of hydrazoic acid may cause explns if air is present. Be careful to avoid leakage of acid vapor, as HN3 is very poisonous.

Continue the distn until ca 200 ml of the liq is distilled into the receiver.

The following reactions takes place: in the Kjeldahl flask, 2NaN3 + H2SO4 → 2HN3 + Na2SO4, and in the receiver, HN3 + NaOH → NaN3 + H2O.

Disconnect the inlet to the condenser and remove the heater. Elevate the adapter of the condenser about 2" out of the receiver, and with a stream of freshly boiled distd w, rinse the condenser and adapter 3 times into the receiver. Also, wash down the outside of the condenser end into the receiver.

Remove the receiver, rinse its inside and add 3 drops of phpt indicator. Titrate the excess of NaOH with approx N/3 HCl to just disappearance of pinkish coloration. The following reactions take place:

\[ \text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} \]
\[ \text{Na}_2\text{CO}_3 + \text{HCl} \rightarrow \text{NaHCO}_3 + \text{NaCl} \]

Save contents of the receiver for the next proced.

Calculation:

\[ \text{Apparent} \% \text{NaN}_3 = \frac{(\text{AB} - \text{CD}) \times 0.0650 \times 100}{\text{W}} \]

where A = ml NaOH soln used in receiver, B = its normality, C = ml HCl used in titration, D = its normality, W = wt of 10 ml sample in the weighing bottle, and 0.0650 = NaN3/1000 (Refs 4 & 7)

b)Na2CO3 Content. To the titrated distillate in the receiver add exactly 10.00 ml of approx N/3 NaOH (which makes a total of 60 ml NaOH in the receiver) and then 10 ml of neutral 10% BaCl2 soln. Wash down with freshly boiled distd w, stopper, gently shake and allow to stand for 3 mins. Titrate dropwise with approx N/3 HCl using continuous swirling until pinkish color of phpt just disappears. The following reactions take place:

\[ \text{NaHCO}_3 + \text{NaOH} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \]
\[ \text{Na}_2\text{CO}_3 + \text{BaCl}_2 \rightarrow \text{BaCO}_3 + 2\text{NaCl} \]

Run a blank detn using exactly 10.00 ml of N/3 NaOH, 10 ml of 10% BaCl2 soln and ca 100 ml of freshly boiled distd w.

Calculation:

\[ \text{Actual} \% \text{Na}_2\text{CO}_3 = \frac{\text{(B - S)} \times \text{N} \times 0.1060 \times 100}{\text{W}} \]

where B = ml N/3 HCl required for blank, S = ml HCl required for distilled sample, N = normality of HCl soln, W = wt of 10-ml sample and 0.1060 = Na2CO3/1000 (Refs 4 & 7)

c)NaOH Content. Transfer quantitatively the
contents of the weighing bottle (See beginning of proced a) to a 100 ml-vol flask and dil to the mark with freshly boiled disted w. Pipette a 10.00-ml aliquot into a 500-ml Erlen flask, dil with ca 100 ml w and titrate with N/3 H2SO4, using phpt as an indicator:

2NaOH + H2SO4 → Na2SO4 + 2H2O
2Na2CO3 + H2SO4 → 2NaHCO3 + Na2SO4

Calculation:

Apparent % NaOH = \frac{ml H_2SO_4 \times N \times 0.0400 \times 100}{Wt \ of \ sample \ in \ 10 ml \ aliquot}
N = normality of N/3 H2SO4, and 0.0400 = NaOH/1000

Actual % NaOH = Apparent % NaOH – (0.3774 \times %Na2CO3), where 0.3774 = NaOH/Na2CO3

Actual % NaN3 = Apparent % NaN3 – (0.6134 \times %Na2CO3), where 0.6134 = NaN3/Na2CO3 (Ref 7)

VII) Second Mother Liquor, obtained as described under Manufacture of Sodium Azide, normally contained ca 46.3% NaOH, 1.0% NaN3, and 0.15% Na2CO3. An 8-oz sample was taken of each chge from the catch tank when washing of the wringer cake was completed. If the NaN3 content was 2.00% or less, the liq was pumped to a storage tank from which a 25-ml sample was taken and composited for 1 week. At the end of each month, an 8-oz sample was taken from the storage tank for monthly inventory

Procedures:
a) NaN3 Content – same as in item VIa
b) Na2CO3 Content – same as in item VIb
c) NaOH Content – same as in item VIc
d) Specific Gravity. Fill a hydrometer jar about \frac{1}{2} full of sample and det sp gr using a hydrometer of range 1.4 – 1.6. The usual reading was ca 1.52 (Ref 7)

VIII) First Clear Liquor, obtained as described under Manufacture of Sodium Azide, normally contained 11-12% NaOH, 9-10% NaN3 and 0.15% Na2CO3. A 25 ml sample was taken of every chge from the ammonia evaporator at the completion of evaporation and composited for one week. A month-end inventory sample (8 oz) was taken from storage at the end of each month

Procedures:
a) NaOH Content. Pipette exactly a 10.00 ml sample into an accurately tared glass-stopped weighing bottle, close the bottle and accurately weigh the ensemble. Record the wt of the sample. Using the same pipette, transfer another 10.00-ml sample into a 500-ml Erlen flask contg some boiling chips to prevent bumping on boiling and add ca \frac{1}{2}" of neutral distd w. Boil on a hot plate under the hood with the suction fan on until all ammonia is driven off. (Test with moist red or neutral litmus paper held over the mouth of the flask — no change in color indicates the absence of ammonia fumes)

Wash down the sides of the flask, cool and titrate with N/3 H2SO4 in presence of 3 drops of phpt indicator

Calculation:

Apparent % NaOH = \frac{ml H_2SO_4 \times N \times 0.0400 \times 100}{Wt \ of \ sample}
where N = normality of N/3 H2SO4, and 0.0400 = NaOH/1000

b) NaN3 Content. Alkalize the above sample with NaOH and transfer quantitatively to a Kjeldahl distillation flask. Dilute contents of the flask to 300 ml, add a few boiling chips and proceed as described in proced a) under item VI (First Mother Liquor)

Calculation – same as in proced a of item VI

c) Na2CO3 Content – same as in proced b) of item VI (Ref 7)

dx) Lime Treatment Tank contained liquor obtained from the wringer producing the second wringer cake. The liquor normally contained ca 9-10% NaN3, 10-13% NaOH and up to 0.75% Na2CO3. Its sp gr by hydrometer was ca 1.2. An 8-oz sample was taken and after analysis according to item VI (First Mother Liquor), the amt of lime necessary to ppt the carbonate as CaCO3 was calcd and
added to the tank. Then the contents of the tank was filtered and the filtrate was the second clear liquor. (See next item.) (Ref 7)

X) Second Clear liquor, obtained on filtering the contents of the lime treatment tank, had almost the same compn as before, except that its $\% \text{Na}_2\text{CO}_3$ was reduced to ca 0.25%. A 25-ml sample was taken after each lime treatment and filtered, and all samples were composited for one week. At the end of each month, an 8-oz sample was taken from storage tank for monthly inventory, and was analyzed in the same way as were the weekly composites:

**Procedures:**

- (a) $\text{Na}_2\text{N}_3$ Content - same as the proced a) of item VI (First Mother Liquor)
- (b) $\text{Na}_2\text{CO}_3$ Content - same as the proced b) of item VI
- (c) $\text{NaOH}$ Content. Wash the contents of the weighing bottle contg the 10.00-ml sample into a 500-ml Erlen flask, dil with ca 75 ml dist w and titrate with N/3 $\text{H}_2\text{SO}_4$ in presence of phpt indicator

**Calculation:**

Apparent $\% \text{NaOH} = \frac{\text{wt of sample} \times N \times 0.0400 \times 100}{\text{N is normality of} \text{H}_2\text{SO}_4, \text{and} 0.0400 = \text{NaOH}/1000}$

Other calcns are the same as in item VI (First Mother Liquor) (Ref 7)

XI) Crude Sodium Azide Liquor was obtained from the drowning tank of the autoclave. It usually contained 7-10% NaOH, 9-11% $\text{Na}_2\text{N}_3$, 0.1-0.5% Na$_2$CO$_3$, and some ammonia. A 250-ml sample of each drowning tank chge was taken from the crude scale tank. The bottle was stoppered and kept in the lab’s refrigerator until ready for analysis.

**Preparation of Samples.** Prepare a composite of samples collected in a 24-hour period, taking for each increment of the composite a weight proportional to the total weight of the corresponding sample. The entire composite should be less than the volume of an 8-oz bottle. Tare the bottle on a torsion balance and add to the tare the weight desired for the first increment. Pour the corresponding sample into the bottle to balance, then increase the tare by the weight of the next increment, and so on. Conduct all this work very rapidly in order to prevent excessive loss of ammonia. Stopper the composite sample tightly, shake and place in the refrigerator until ready for use.

**Procedures:**

- (a) $\text{NaN}_3$ Content - Same as in item VI
- (b) $\text{NaOH}$ Content - (First Mother Liquor)
- (c) $\text{Na}_2\text{CO}_3$ Content
- (d) $\text{NH}_3$ Content. Add gradually 100 g of the composite sample to 40% sulfuric acid and dilute to 1 l. This must be done under a hood so as to prevent exposure to $\text{HN}_3$ fumes. Pipette a 10.00-ml aliquot into a Kjeldahl distilling flask and dil to 300 ml with w:

\[
\text{H}_2\text{SO}_4 + 2\text{NaN}_3 \rightarrow 2\text{HN}_3 + \text{Na}_2\text{SO}_4
\]

\[
\text{H}_2\text{SO}_4 + 2\text{NH}_3\text{OH} \rightarrow (\text{NH}_4)_2\text{SO}_4 + 2\text{H}_2\text{O}
\]

Arrange the apparatus as described in proc a) of item VI, add from a separator funnel 20.0 ml of 5% NaOH:

\[
(\text{NH}_4)_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{NH}_3\text{OH}
\]

and distil into 80.00 ml N/3 $\text{HCl}$ contained in a receiver, until ca 100 ml of liq is left in the Kjeldahl:

\[
\text{NH}_3\text{OH} \rightarrow \text{NH}_3 + \text{H}_2\text{O}
\]

\[
\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}
\]

Break the connections, wash the app with neutral distd w into the receiver and titrate the excess of acid with N/3 NaOH, using methyl-red as indicator.

Run a blank in exactly the same manner but without sample.

**Calculation:**

\[
\% \text{NH}_3 = \frac{(B-S) \times N \times 0.0170 \times 100}{\text{wt of 10 ml aliquot}}
\]

where $B = \text{ml} \ N/3 \text{NaOH required for blank}, S = \text{ml} \ N/3 \text{NaOH required for sample}, N = \text{normality of NaOH and } 0.0170 = \text{NH}_3/1000$ (Ref 7)
XII) Refined Sodium Azide Liquor. See item IV under Lead Azide Plant, Analytical Procedures

XIII) Sodium Azide Feed Tank. See item V under Lead Azide Plant, Analytical Procedures

XIV) Sodium Azide Dilution Tank. See item VI under Lead Azide Plant, Analytical Procedures

XV) Sodium Azide, Crystalline. If NaN₃ was not manufactured at KOW, but purchased outside, it had to comply with the following US Army requirements and tests as listed in the Pic Arsn Tentative Spec PXS-764Rev 2, Jan 9, 1942, which became Military Spec MIL-S-20552(1951) (Ref 4):

a) NaN₃ Content. Same as proced a) in item VI, except that the sample introduced in the Kjeldahl flask is ca 1 g and the amounts of reagents in the receiving flask (which has a capacity of 500 ml) are 50 ml of approx N/3 NaOH and 50 ml of freshly boiled distd w. This test gives % of apparent NaN₃.

b) Na₂CO₃ Content — same as proced b) in item VI. This test gives % of actual Na₂CO₃. In order to calc % actual NaN₃ subtract from the % apparent NaN₃ the % actual Na₂CO₃ multiplied by 0.6134

c) Alkalinity of NaN₃. Dissolve a weighed 5 g portion of the sample in 100 ml of freshly boiled and cooled distd w which is contained in a 250 ml beaker. Add a few drops of phpht indicator and if the soln is alkaline, titrate with approx N/10 HCl and correct for a blank detn with the same quantities of w and indicator.

Calculation:

\[
\% \text{ Alkalinity as NaOH} = \frac{\text{ml HCl} \times N \times 0.040 \times 100}{W}
\]

where N = normality of HCl, W = wt of sample, and 0.040 = NaOH/1000 (Ref 7)

Colorimetric Determination of Sodium Azide in Aqueous Ammonia (See under Manufacture of Sodium Azide)

After detg the sp gr of the aq ammonia sample with a hydrometer, place a 200-ml sample in a 400-ml beaker and boil on a hot plate in the hood until most of the NH₃ has boiled off (ca ½ hr). Add 2 drops of phpht and titrate with N/3 HCl until the pink color just disappears. Transfer to a 200-ml vol flask and adjust to the mark with neutral distd w. Add 1 ml of 10% FeCl₃ soln to each of two 100-ml Nessler tubes. Pipette 10-ml of the neutralized sample to one of the Nessler tubes and dil to 100-ml mark with w. Stopper and mix. Fill also the other tube (contg only FeCl₃) slightly below the mark and stopper and mix. Add to the 2nd tube dropwise, from a 10-ml burette, the standard soln contg 0.001 g NaN₃ per 1 ml (prep'd by dissolving 1 g CP NaN₃ in 11) of distd w) until the intensity of coloration matches that of the sample. For this, stopper and mix well after each addn and compare the coloration by holding the tubes side by side against a white background

\[
\% \text{NaN₃} = \frac{(\text{ml of std NaN₃}) \times 0.001 \times 100}{10 \times \text{Sp gr}}
\]

(Ref 7, p 66)

XVII) Sodium Azide, Technical, Prepared From Hydrazine and Ethyl Nitrate

Impurities present in tech NaN₃ may be subdivided into w-insol, such as carbonates and oxides of heavy metals and w-sol, such as carbonates of Na & Ca, various nitrates and chlorides, hydrazine salts and ammonium salts

Barlot & Marsaule (Ref 6) recommended a method of analysis based on the following reaction:

\[
\text{NaN₃} + \text{NaNO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{N}_2 + \text{N}_2\text{O}
\]

This method is a modification of method originated by Glen & Rvell

Procedures:

a) Insoluble Matter (1M). Dry the sample to const wt at 90°, weigh exactly 10.000 g and dissolve in 100 ml of distd w. Filter through a tared fritted glass crucible and transfer the
filtrate to a 250-ml vol flask (Filtrate No 1). Wash the residue in the crucible with dist w and transfer the washings to the same vol flask. Dry the crucible with residue to const wt at 100° and calc % IM

b) Calcium Carbonate Content. As CaCO₃ is appreciably sol in w contg azides, it might be present in the filtrate No 1 of proced a). In order to det CaCO₃, take 50 ml of Filtrate No 1 (which corresponds to 2 g of solid material) and dil it to 250 ml. Transfer a 50-ml aliquot (which corresponds to 2/5 = 0.4 g of solid) to a beaker, add 5 ml of satd aq Amm oxalate and 1 ml of glacial AcOH. The following reaction takes place:

$$(\text{NH}_4)_2\text{C}_2\text{O}_4 + \text{Ca} (\text{CH}_3\text{COO})_2 \rightarrow 2\text{NH}_4(\text{CH}_3\text{COO}) + \text{CaC}_2\text{O}_4$$

Filter the ppt of CaC₂O₄ through paper, wash the ppt thoroughly with boiling w and transfer it quantitatively into a 250-ml beaker. Add 100 ml of boiling w and 20 ml of 1:3 sulfuric acid. Titrate the hot mixt with N/10 KMnO₄. The following reaction takes place:

$$5\text{CaC}_2\text{O}_4 + 2\text{KMnO}_4 + 8\text{H}_2\text{SO}_4 \rightarrow 5\text{CaSO}_4 + \text{K}_2\text{SO}_4 + \text{MnSO}_4 + 10\text{CO}_2 + 8\text{H}_2\text{O}$$

Calc % CaCO₃ from the following formula:

$$\frac{R \times N \times 0.0500 \times 100}{W}$$

where R = ml KMnO₄, N = its normality and W = wt of solid sample in aliquot (0.4 g).

c) Sodium Carbonate Content. Transfer a 50 ml aliquot of filtrate No 1, corresponding to 2 g of solid sample, to a beaker; heat the liq to boiling and add 5 ml of 5% BaCl₂ soln. After keeping on a water bath for ½ hr, filter through a tared sintered glass crucible. Transfer the ppt (BaCO₃) quantitatively into the crucible and wash it with w. Dry the ensemble to const wt at 100° and calc % total carbonates as Na₂CO₃ from the formula:

$$W_1 \times 106 \times 100$$
$$197.37 \times W$$

where $W_1$ = wt of residue and $W$ = wt of sample in aliquot (2 g)

Actual % Na₂CO₃ is found by subtracting, from $W_1$, 1.059 times the amt of CaCO₃ found in proced b). Save the filtrate and washings (Filtrate No 2) for proced h)

d) Nitrates Content. Take another 50 ml aliquot of filtrate No 1 (see proced a) add ca /g NaNO₃, then 5 ml glacial AcOH and heat at bp for ca 15 min to decomp azides (which otherwise interfere). After cooling the soln, add nitron acetate, filter through a tared sintered glass crucible and weigh the residue (nitron nitrate). Calculate % NO₃ from the formula

$$\frac{62 \times W_1 \times 100}{375.38 \times W}$$

where $W_1$ = wt of nitron nitrate (mw 375.38) and $W$ = wt of solid sample in 50-ml aliquot (2 g)

e) Chlorides Content. Transfer 10 ml of filtrate No 1 (see proced a) to a small beaker, add an excess of 5% AgNO₃ soln, then 1 ml of concd HNO₃ and heat. If there is any ppt, filter dry the ppt, weigh and calc chlorides as %NaCl from the following formula

$$\frac{58.45 \times W_1 \times 100}{143.34 \times W}$$

where $W_1$ = wt of ppt (AgCl) and $W$ = wt of solid sample in 10-ml aliquot (0.4 g)

If only turbidity is present repeat the operations, taking a larger sample

Note: Protect from direct light as much as possible the ppt of AgCl

f) Ammonium Salts Content. Take another 50 ml aliquot of filtrate No 1 (See proced a) and decomp the azides as described in proced d). Cool the soln, neutralize with NaOH and det % ammonia colorimetrically by means of Nessler's reagent

g) Hydrazine Salts are detd by colorimetric method of Pesez & Petit (Ref 2) based on the formation of intense orange-red azine when treated with p-dimethylaminobenzaldehyde. The reaction must be conducted in very dil soln in order to avoid secondary re-actions
**Procedure.** Transfer ca 0.2-g accurately weighed sample to a 100-ml vol flask and add distd w to the mark. Stopper and shake until completely dissolved. Pipette out 5 ml and add 1 ml of the reagent (prepd by dissolving 1 g of p-dimethylaminobenzaldehyde in 50 ml absol alc and 5 ml concd HCI). If hydrazinium ion is present, the soln turns yel at first and then, after 10-15 mins, intensely red-orange. Compare the intensity of coloration of similarly treated solns (standards) contg 0.0001 mg to 1 mg of \( \text{N}_2\text{H}_4 \) per ml

**b) Sodium Azide Content.** Transfer the filtrate No 2 (see proc d) to a 200-ml vol flask and adjust to the mark. Pipette out 25 ml (which would correspond to \( 2/8 = 0.25 \) g of solid sample), dil with 50 ml distd w, add 0.5 g \( \text{NaNO}_3 \) and a few drops of phpht indicator. After making the soln neutral, add exactly 100 ml of N/10 HCl, shake for several minutes and titrate the excess HCl with N/10 NaOH (burette reading \( R_2 \)). Det the NaOH equiv of the HCl by titrating 100 ml with NaOH (burette reading \( R_1 \)). Calculate % \( \text{NaN}_3 \) from the formula:

\[
\frac{(R_1 - R_2) \times N \times 0.0650 \times 100}{W \times 2}
\]

where \( N \) = normality of NaOH, \( W \) = wt of sample in 25-ml aliquot, and 0.0650 = \( \text{NaN}_3 \)/1000

It should be noted that if a solid tech Na azide is used as a starting material for the above test it is necessary to remove the carbonates prior to adding \( \text{NaNO}_3 \). This can be done by dissolving the sample in distd w and neutralizing the soln with HCl, using methyl-orange, methyl-yellow or equivalent test paper

**Note.** Barlot & Marsaule (Ref 6) also describe two other methods for detn of \( \text{NaN}_3 \): a)The argentometric method of Volhard and b)The iodometric method based on the reaction \( 2\text{NaN}_3 + I_2 \rightarrow 2\text{NaI} + 3\text{N}_2 \). Some other methods of analysis of sodium azide are listed in Refs 1,3,5 & 8.

**Refs on Sodium Azide Plant, Analytical Procedures**


2) M.Pesez & A. Petit, Bull Fr 1947, 122-3 & CA 41, 5820 (1947) (Detn of hydrazine, applicable to analysis of SA)

3) J.H. van der Meulen, Rec 67, 600-2(1948) & CA 43, 1288(1949) (Detn of azides and hydrazoic acid with K permanganate)

4) US Military Spec MIL-S-20552 (29 Dec 1951) (Sodium azide, requirements and tests)

5) E.Werle & R.Fried, BiochemZ 321, 500-7(1951) & CA 47, 8125(1953) (A photometric method for detn of \( \text{NaN}_3 \))

6) J.Barlot & S.Marsaule, MP 35, 7-13(1953) & CA 49, 5843(1955) (Analysis of tech SA prepd from hydrazine and ethyl nitrate)

7) B.C.Carlson, "Lead Azide Laboratory Manual" USRubber Co, operator of Kankakee Ordnance Works, Joliet, Ill (1953)

8) Y.Mizushima & S. Nagayama, JIndExplsSocJapan 17, 113-5(1956) & CA 50, 16557(1956) (Microdetn of azides by ceric ammonium nitrate)

9) D.G.Young, formerly of Kankakee OW, Joliet, Ill; private communication, 1960 (info on manuf and analysis of \( \text{NaN}_3 \))
Strontium Diazide (Formerly called Strontium Azomide or Strontium Trinitride), Sr(N₃)₂, mw 171.68, N₄8.96%. Col rhmb, hygr crysts; mp decomp at 140° (in vacuo) with evolution of N₂ at 110° (Ref 3); \( Q_{\text{exp}} \) 295 cal/g (Ref 4), \( Q_{\text{form}} \) -1.72 to 0.1 kcal/mol (Refs 20 & 23); lattice energy 494 kcal/mol (Ref 23); ionic conductance of solid Sr(N₃)₂ obeyed equation \( \log k = \log A - (E/2.303RT) \) in which \( \log A = -10.70 \) and \( E = 5.1 \) kcal/mol in the temp range 300 to 380°K (Ref 21).

The low activation energy for the structure sensitive conductance in K, Ca & Sr azides was assced with the mobility of surface lattice defects. Sr azide is sol in w (45.8g/100 g w at 16°); sl sol in alc.(0.095% at 16°) and insol in eth.(Ref 2). The toxicity of Sr(N₃)₂ is not discussed by Sax (Ref 24) but its effects should be considered similar to those of the alkali and alkaline earth azides.

Sr azide was first prepd in 1898 by Dennis & Benedict (Ref 1) and in the same year by Curtius & Rissom (Ref 2) by the action of HN₃ on the oxide, hydroxide or carbonate of Sr. Its prepn has also been described by Mellor (Ref 7), Gmelin (Ref 9), Audrieth (Ref 10) and others (Refs 11, 15, 18, & 25). The cryt structure of Sr(N₃)₂ was investigated to a limited extent by A.C.Gill (cited in Ref 1) and in detail by Llewellyn & Whitmore (Ref 15) who established its orthorhmb nature as ionic, with a linear sym azide ion, N-N=1.12Å, and Sr to N distance of 2.63 to 277Å. Kahovec & Kohlrausch (Ref 16) detd, from the Raman Effect, both on cryt powd and in soln, frequencies which corresponded to sym oscillation in a linear triatomic molecule. The spectra emitted during expln of Ca, Ba, Sr & Zn azides were photographed by Petrikaln(Ref 6). According to Garner & Maggs (Ref 13) the threshold for absorpition of UV light by N₃ ions in soln and in the solid state is 2600-2700Å and that for photochemical reaction is in the same region.

Explosive Properties. Curtius & Rissom (Ref 2) reported that Sr azide decomp violently at 194 to 196° while Wöhler & Martin (Ref 5) observed a temp of 169° for deton of a 0.02 g sample in 5 sec. Under impact of a 2 kg falling wt, a compressed Sr azide sample (0.01 to 0.05g) flamed but did not detonate. Later studies by Haid et al (Ref 8) showed that Sr azide, in contact with a direct flame, behaved similarly to Ca azide but it did not ignite as easily and it burned more slowly than Ca azide. On heating a 0.2g sample on molten Wood’s metal, it ignited between 190 & 200° and then burned with expl violence. A 300 g sample, confined in an iron box 6 x 6 x 6 cm of 1 mm wall thickness, exploded in 1/2 to 1 min when heated in a flame. Haid et al (Ref 6) also reported that Sr azide ignited from friction on rubbing in a mortar and in the Lead Block test gave a value of 30 ml. Its expl strength is considered approx equal to that of Ba azide.

Thermal Decomposition. In a study of the thermal decompn of Sr azide between 99 and 124°, Maggs (Ref 12) observed a marked induction period, followed by an acceleration of the reaction. Decompn occurred in three stages, with an activation energy value of 20 kcal/mol causing the acceleration reaction. This process was unaffected by exposure of Sr azide to emission from Ra or UV light. Garner (Ref 14) listed the three stages of thermal decompn as: a)surface reaction from which alkali earth atoms result b)subsequent reaction within the cryts and c)finally the spreading of decompn from reaction centers. Experiments by Garner & Reeves (Ref 22) showed the thermal decompn of Ca and Sr azides obeyed a third-power law, whereas Ba azide obeyed a sixth-power law. Electrical conductivities of these azides were low and did not change during thermal decompn until the nuclei came into contact.

Other Properties and Uses. Veenemans & Loosjes (Ref 17) proposed using Sr azide in mixt with Ba azide as the cathode for elec discharge tubes. However, Ficheroule & Kovache (Ref 19) reported that due to its extreme sensitivity to hydrolysis and because Sr azide reacts with CO₂ to yield Sr CO₃,
these props make it difficult to manuf and, therefore, Sr azide presents no advantage over Ba azide for use in vac tubes


Related to sulfuryl azide are the salts of azidosulfonic acid, HSO₃N₃. Traube & Vockeroth (Ref 1) prepd the K salt by treatment of a concd aq soln of potassium nitrite with finely powdered hydrazine sulfonic acid:

$$\text{NH}_2\text{NSO}_3\text{H} + \text{KNO}_2 \rightarrow 2\text{H}_2\text{O} + \text{KSO}_3\text{N}_3$$

It crystallizes from soln as flat prisms which exploded on heating. The addn of mineral acid yielded hydrazic acid and sulfuric acid. The NH₄, Na and Ba salts have also been prepd, but their props were not described


**Thallium Azide** (Formerly called Thallous Trinitride or Thallium Azomide), TIN₃, mw 246.41, N₁₇.₀₅₇₇₉₅₆, pal yel tetrag crysts which form as wh ppt; mp 330-40° (Refs 1 & 6), explodes 430° (Ref 6); Qexp/s 232 cal/g or

**Sulfuryl Diazone**, SO₃(N₃)₂, mw 148.11, N₅₆.₇₇₇₉₅₆, col liq first prepd in 1922 by Curtius & Schmidt (Ref 2) by the interaction of sulfuryl chloride and finely divided, sl moist Na azide: SO₂Cl₂ + 2NaN₃ → SO₃(N₃)₂ + 2NaCl. It explodes violently when heated and often spontaneously at RT. Sax (Ref 9) does not list this compd but it has a suffocating odor and the pronounced physiological effects of hydrogen azide (qv)

It is hydrolyzed slowly by cold alc or water, but more quickly on warming the solv. Alcholic AgNO₃ reacts with SO₃(N₃)₂ instantaneously to form Ag azide (qv). When heated with org aromatic hydrocarbons, such as benz (Refs 3 & 4), p-xylene (Ref 2) and p-cymene (Ref 5), sulfuryl azide completely decomposed (Also see Refs 6, 7, & 8)

$$\text{AgNO}_3 + \text{SO}_3(\text{N}_3)_2 \rightarrow \text{AgN}_3 + \text{SO}_2 + \text{N}_2$$

It crystallizes from soln as flat prisms which exploded on heating. The addn of mineral acid yielded hydrazic acid and sulfuric acid. The NH₄, Na and Ba salts have also been prepd, but their props were not described

55.60 kcal/mol (Ref 3), $Q_{\text{form}} = 55.45$ kcal/mol (av value) (Refs 17, 18, 19 & 21); lattice energy 164 kcal/mol (Ref 19). It is easily sol in hot w, sl sol in cold w (Ref 1); the Soly Prod calc'd by Suzuki (Ref 16) is 2.19 $\times 10^{-4}$ vs 2.88 $\times 10^{-4}$ for AgN\(_3\). According to Sax (Ref 24) this compd is highly toxic.

TIN\(_3\) was first prep'd in 1896 by Dennis & Doan (Ref 1) by adding a thallous sulfate soln to a concd soln of KN\(_3\) contg a little free hydrazoic acid. Curtius & Rissom (Ref 2) used essentially the same procedure while Brouty (Ref 10) prep'd the compd from equimolar proportions of NaN\(_3\) & TINO\(_3\) and Rosenwasser (Ref 22) from TINO\(_3\) & KN\(_3\) or TICI & NaN\(_3\) solns. Its prepn has also been described by Mellor (Ref 7), Gmelin (Ref 9) and others (Refs 13, 20 & 25). According to Rosenwasser (Ref 22), Tl azide has numerous cryst habits depending on its method of prepn. Both perfect and imperfect Maltese crosses and rectangular plates, which transform by heat to acicular prisms, were obtd. TlNO\(_3\) forms as a fine wh cryst ppt and when crystd from a hot aq soln, it separates as lt-yel orthorhombic ndls which, on exposure to sunlight, assume a dk brn appearance (Ref 1) and form metallic Tl (Ref 18).

Delay et al (Ref 12) detd IR absorption spectra in the range 3 to 19\(\mu\) and from the intensities of the bands concluded that the sym form was more abundant in the azides of Ag, Cu, Hg & Na but the reverse was true for the azides of Pb & Tl. Gray & Waddington (Ref 18) stated that TlNO\(_3\) crys are isomorphous with those of Na & Rb azides. The elec conductivity of TlNO\(_3\) is 5.9 $\times 10^{-8}$ mho at 275° (Ref 18). Brouty (Ref 10) detd the mean activity coefficient of TlNO\(_3\) by EMF measurements and calc'd ionic radii of Tl\(^+\) & N\(_3^-\). Conductivity measurements by Brouty (Ref 11) did not agree with Onsager's theory; deviations were found at very high dilutions. An electro-chem cell used by Suzuki (Ref 16) gave a $\Delta F$ 298° value of 59.17 kcal/mol for TlNO\(_3\) vs 78.69 kcal/mol for AgN\(_3\). Nair & Nancollas (Ref 23) derived thermodynamic association constants for formation of the ion pairs TlNO\(_3\), and of other thallous ion pairs with univalent anions, at 10°, 25 & 40°.

**Explosives Properties**

Dennis & Doan (Ref 1) who first prep'd TlNO\(_3\) state that it is not expl, resembling K and Na azides in this particular. However, just two years later Curtius & Rissom (Ref 2) reported that TlNO\(_3\) exploded when struck or heated strongly. Wöhler & Martin (Ref 4) detd an ExpIn Temp as low as 320° in 5 sec for a 0.02g TlNO\(_3\) sample and obtd deton of a 0.01 to 0.05g compressed sample under a 2 kg impact. These investigators also detd the Temp Developed on ExpIn on TlNO\(_3\) as 330°, its Press (own volume) as 36900 kg/cc, Work Density as 72.0 kg/cc, Loading Density at 1100 kg/cc as 3.89 g/cc and its Initiating Efficiency for various HE's (see table under mercurous azide and Ref 5). Bowden & Williams (Ref 14) reported a Rate of Detonation of 1500 m/sec for TlNO\(_3\), in confined layers, when initiated at RT by impact on a grit particle. Grit particles melting above 500°, such as Pb chloride, borax, bismuthnite and chalcolite, markedly increased the impact sensitivity of TlNO\(_3\).

**Thermal Decomposition**

of TlNO\(_3\) in an atm of N\(_2\) at any press, according to Audubert & Racz (Ref 8) was not accompanied by any UV radiation. UV light was emitted in O\(_2\) or air at press from 2-10 mm. The energy of activation for thermal decompn at temp below 228 ± 8° is 43 ± 2.5 kcal/mol and above 228 ± 8° is 21.6 ± 2.0 kcal/mol. At press above 10 mm O\(_2\) or air the value is 65.8 ± 2 kcal/mol. Audubert & Racz (Ref 8) suggested that Tl, like Na, can inhibit photogenic reaction and in O\(_2\) there are two processes producing UV radiation. Yoffe (Ref 15) observed that there was very little decompn when TlNO\(_3\) was heated in a vacuum. Decompn occurred when TlNO\(_3\) was heated in an elec furnace. At 420° TlNO\(_3\) melted to a col liq, at 490° it decomposed rapidly and when the N\(_2\) press was 17 cm some of the azide ignited with a green
flash after 2 sec. At 500° the time for expln was less than 1 sec and at 530° expln occurred instantaneously. At 530° expln occurred even when TIN was dropped into an evacuated vessel. A bomb calorimeter was used by McEwan & Williams (Ref 17) to decomp TIN at 24° under 30 atm of He. Gray & Waddington (Ref 18) found that addn of TlS increased the sensitivity of TIN to heat. Evans & Yoffe (Ref 20) attempted to correlate the expl sensitivity of the inorg azides with their cryst structure. They found that the decomp depended on the formation of neutral azide radicals. The expl sensitivity was therefore detd by the degree of elec neutrality possessed by the azide group in the cryst lattice. A consideration of the refractive indices and appropriate cryst structure led them to the conclusion that the expl sensitivity was dependent on the ionization potential of the metal forming the azide.


Thallous-Thallic Azide, TIN₃-Tl(N₃)₃, mw 576.87, N29.12%, bright yel triclinic crysts highly expl by heat, percussion or even gentle friction. This compd as a double salt was first prepd in 1896 by L.M.Dennis & M.Doan (JACS 18, 973-5) by dissolving thallic hydroxide in 1.6% hydrazoic acid at ca 0° and concg the soln in a vac desiccator. The thallium content was detd by dissolving some of the crysts in dil HCl, reducing the thallium to thallic by H₂SO₄, removing the excess H₂SO₄ by heating, and then titrating with KMnO₄. The nitrogen content could not be detd by the same method used for TIN, because the double salt, TIN₃-Tl(N₃)₃, could not be dissolved either in w or dil acids without evolution of N₂. A few milligrams of sample spread in a long porcelain boat contg granular copper oxide, in an atm of CO₂, exploded violently when the temp of the boat had risen but slightly. Another portion when mixed with very fine, freshly ground copper oxide and heated as before decomposed quietly and gradually giving a nitrogen content of 29.3%. The supposition that this compd is a double salt was confirmed by its behavior when treated with hot water. No further work appears to have been
reported on this azide (Gmelin, System No 38, Lieferung 2 (1940), 235)

**Tin Azide.** Curtius & Rissom (Ref 1) prepd Sn(N₃)₂ only in a very impure state from a 17% HN₃ soln and tin-foil. A non-expl wh compd, insol in w, was separated. An aq soln of stannous chloride and NaN₃ gave a wh ppt which was thought to be a mixt of stannous azide & hydroxide which when heated with H₂SO₄ gave off HN₃ (Ref 3). Browne & Houhelan (Ref 2) obtd no reaction from tin in contact with NH₄N₃ in liq NH₃ after 4 hrs.

Attempts by Wiberg & Michaud (Ref 4) to prepare Sn(N₃)₄ were unsuccessful. A tetrahydrofuran soln of SnCl₄ refluxed for 5 hrs with excess NaN₃ resulted in a wh, solid, complex salt, Sn(N₃)₄.2NaN₃ or Na₂Sn(N₃)₄, insol or only sl sol in eth or benz and hydrolyzed by moist air. A tetrahydrofuran soln of the complex salt, sodium hexazido-stannate, detonated on boiling over a free flame but it was not sensitive to percussion (see Ref 5).


**Zinc Diazide** (formerly called Zinc Azoimide or Zinc Trinitride), Zn(N₃)₂, mw 149.43, N 56.25%, wh hygro powd, easily hydrolyzed. It was first prepd in 1892 by Wislicenus (Ref 1) by the action of nitrous oxide on Zn amide at 150-250°. Curtius & Rissom (Ref 2) obtd the basic zinc azide, ZnOHN₃, by dissolving the metal in dil HN₃ and allowing the soln to evap in air. The product, ill-defined anisotropic crysts, was insol in w. Dennis & Isham (Ref 3) prepd Zn(N₃)₂.2NH₃ and Zn (N₃)₄.2C₃H₄N by dissolving Zn in alcoholic HN₃, adding dry NH₃ or pyridine in excess, and allowing the soln to evap. Both products were wh, crystalline ppts, insol in w, and decompd without expln when heated but when thrown on a hot plate they produced a bright flame and a sharp report. Zn in contact with NH₄N₃ in liq NH₃ did not react, except very slowly when Pt was present (Ref 4). By shaking together the finely divided, dry Zn carbonate or basic Zn azide with HN₃ in ether until the solid became entirely sol in H₂O, Wöhler (Ref 5) obtd Zn(N₃)₂ and detd some of its props. The toxicity of Zn(N₃)₂ is not discussed by Sax (Ref 16).

According to Wöhler & Martin (Ref 6), Zn(N₃)₂ is detonated under impact of a 2 kg wt and exploded in 5 sec at 289°. The heat of detonation is 360 cal/g (Ref 6) and Qf with excess NaN₃ resulted in a wh, solid, -50.8 kcal/mol (Ref 14). These investiga-tors consider Zn(N₃)₂ a rather weak expl approaching in its expl props, the alkaline earth azides which are not as powerful as the heavy metal azides.

Petrikaln (Ref 7) photographed the spectra of Zn(N₃)₂ and other azides. With the azides of Ca, Sr and Ba, not only triplet system lines but also those of the singlet system of the diffuse and sharp series. In addn the oxide bands were present in all the spectra. Kahovec & Kohlrausch (Ref 13) detd the Raman spectra of basic zinc azide crysts.

An addn compd with mercuric cyanide, Hg(CN)₂·Zn(N₃)₂, which deflagrated but did not explode when heated, was prepd by Ricca & Pirrone (Ref 10) from aq solns of NaN₃, ZnSO₄ and Hg(CN)₂. Streecker & Schwinn (Ref 12) prepd some Zn azide complex salts, [Zn(C₄H₃N₃)₂] (N₃)₂ and [Zn (C₃H₄(NH₂)₂)] (N₃)₂, and detd their props. A group of mixed Zn halogen azides of the type [ZnX₂N₃] M were prepd by Vournazos (Ref 8).

For addnl information or discussion also see Mellor (Ref 9), Audrieth (Ref 11) and Gmelin (Ref 15).

**Refs:** 1)W.Wislicenus, Ber 25, 2085(1892) & JCS 62 II, 1151(1892) 2)T.Curtius & J. Rissom, JPraktChem 58, 292 & 305(1898) &
AZIDES, ORGANIC

Azido or Triazo- Compounds, contg one or more \(-\text{N}_3\) groups, are the org derivatives of hydrazoic acid, \(\text{HN}_3\). These compds are usually unstable to heat and often decompose violently. They may be divided into four classes:

a) Alkyl Azides – obtd by reacting \(\text{NaN}_3\) with alkyl sulfates or halides:

\[
\text{RSO}_4^- + \text{NaN}_3 \rightarrow \text{RN}_3 + \text{R-}\text{SO}_4^-\text{Na}
\]

The azide group in these compds usually hydrolyzes to form \(\text{HN}_3\).

b) Aryl Azides (Diazoimidest) – obtd by reacting \(\text{NaN}_3\) with aromatic diazonium salts in acid soln:

\[
\text{ArNCl}^- + \text{NaN}_3 \rightarrow \text{ArN}_3 + \text{NaCl} + \text{N}_2
\]

Most of these azides are yei liquids, insol in w, more stable than the alkyl azides and do not hydrolyze.

c) Acyl Azides – prepd by the action of \(\text{HNO}_2\) on a hydrazide or of an acid chloride on \(\text{NaN}_3\):

\[
\begin{align*}
\text{R-CO-NH-NH}_2^- + \text{HNO}_2 & \rightarrow \text{RCON}_3 + 2\text{H}_2\text{O} \\
\text{R-COCl} + \text{NaN}_3 & \rightarrow \text{RCON}_3 + \text{NaCl}
\end{align*}
\]

These compds are liquids or low melting solids, sl sol in w and sol in common org solvents.

d) Azide Salts – obtd by treating org salts with metallic azides:

\[
\begin{align*}
\text{H}_2\text{N-C-}:(\text{NH})\text{-NH}_2^-\text{HCl} & + \text{AgN}_3 \rightarrow \\
\text{H}_2\text{N-C-}:(\text{NH})\text{-NH}_2^-\text{HN}_3 & + \text{AgCl}
\end{align*}
\]

For purposes of org nomenclature the terms “azido” and “triazo” are used synonymously in the literature. The ary azides are often called in German diazoimidest. Aliphatic diazo compds contain the group \(-\text{CN}_2\), represented as a resonance hybrid of the structure

\[
=\text{C} = \text{N} \equiv \text{N} \text{ and } =\text{C} \equiv \text{N} \equiv \text{N}
\]

The monovalent azide group, \(-\text{N}_3\), is closely related to the divalent diazo group and can be regarded as derived from the latter by replacement of a tetravalent carbon atom by a trivalent nitrogen atom. The structure may be represented as a resonance hybrid

\[
R - \text{N} = \text{N} = \text{N} \text{ and } R - \text{N} \equiv \text{N} \equiv \text{N}
\]

The acyl derivatives of hydrazoic acid can be regarded as derivatives of acids in which the acidic hydroxyl group has been replaced by an azide group.

The literature contains reviews of the chemistry of org azides (Refs 5 & 11). Smith (Ref 8) has reported on the acyl azides, Benson (Ref 9) on those \(\alpha\)-azidoalkylidenimines which undergo cyclic isomerizations to tetrazoles and Boyer & Canter (Ref 15) made a thorough survey of the available information on alkyl and aryl azides. Cirulis & Straumanis (Ref 6) prepd a number of new azides of org bases but none of these azides showed expl props. Schaad (Ref 14) obtd a patent for the manuf of esters of hydrazoic acid based on the reaction of alkenes, cyclic olefins, arylalkenes & cycloalkylalkenes with \(\text{HN}_3\) in the presence of an acid cataly.

The dipole moments and structures of the org azides and aliphatic diazo compds were studied by Sidgwick et al (Ref 4). Sheinker & Syrkin (Ref 13) made vibrational spectra measurements of org azides and deduced the configuration of azide compds. UV spectra confirmed the observations made on Raman and IR spectra. Heats of combustion and formation of org azides were detd by Murrin & Carpenter (Ref 16). Patterson et al (Ref 7) discussed the CA method of naming and indexng org azides. For addnl info and discussion of org azides see the general references (Refs 1,2,3,5,8,10 & 12).

This discussion or listing of org azides is based on the following conditions:

a) When an azide or azido compd is one of the derivatives (others are nitro, nitroso etc) of a parent compd, such as methane, the azide derivative, as well as others, may be located under the parent compd. For example, methyl azide is discussed under Methane and benzoyl azide under Benzoic Acid.

b) When an azido compd is the only derivative...
of a parent compd or if the compd is generally known as azido, for example azidotiothiocarbonic acid, it is discussed in this section if it has expl props
c)Derivatives of acids in which the acidic hydroxyl group has been replaced by an azide group, for example acetazide, allophanoylazide, crotonylazide, oxamylazide, phthalylazide etc, are placed in alphabetical order according to their first letter. Therefore, org azides or azido compds discussed or listed in this section all begin with letter A. Others will be found and discussed under their appropriate alphabet letter
d)Some azido compds, such as azidoaniline or azidoanisole, are also included in this section when considered more convenient than to list them under their parent compd


LIST OF ORGANIC AZIDES OR AZIDO COMPOUNDS

- Acetonetetrazylazide. See under Acetonyltetrazole and Derivatives, p A47
- Acetylglycineazide. See p A69
- Acryloylazide. See under Acrylic Acid and Derivatives, p A97
- Adipydiazide. See under Adipic Acid and Derivatives, p A104
- Aleuritylazide. See p A123-4
- Alkylazides. See pp A129 & A130
- Alkyltetrazylazides. See p A133
- Allophanoylazide. See p A133-4
- Allylazole. See p A137
- o-Aminoazidoacetophenone or o-Aminophenylazide. See under Aminoacetophenone and Derivatives, p A178
- Aminobenzazide or Aminobenzoylazide. See under Aminobenzoic Acid and Derivatives, p A188-9
- iso-Amylacetylazide. See under Amyl Acetate, p A394
- Amylazole. See under Amylamine and Derivatives, p A395
- Amylmalonoylazide. See p A396
- iso-Amylureidoacetyl Azide. See p A399
- Anilinobenzenediazonium Azide. See under Anilinobenzenediazonium Hydroxide and Derivatives, p A421
- Anilinodinitrobenzoyl Azide. See under Anilinobenzoic Acid and Derivatives, p A421
- Anisalamishydrazone Azide. See p A444
- Anisicazide or Anisoylazide. See p A456
- Anthracenic Acid Azide. Same as Aminobenzazide (qv), p A188-9
- Anthranoylazide. Same as 4-Aminobenzazide (qv), p A189
- Anthraquinone Azide. See under Anthraquinone and Derivatives, p A459
- Azide or Acetazidin is listed in Ref 1 as a compd of formula CH₃C(:NNH₃)-N:NH. No compd of this formula was found in CA through 1957

In English, azidine is the name suggested for the radical -C(=NH)N₂ by analogy with amidines which are derived from the amides by replacement of oxygen in -CONH₂ by the
divalent amido residue =NH or =NR. Thus, for the structural change –CON→ –C(=NH)N, the nomenclature should be azide → azidine, according to Scott et al (Ref 4), except the term azidine does not appear to have been used previously in the literature

Carbamoyl azides (called by Scott et al carbamylazides), R’R’NCON,, in which either R’ or R’’ is H, form an enolic structure which contains the hydroxy-substituted azidine radical and thereby become resistant to the Curtius rearrangement: RCON→ N₂ + RCON → RN = CO. The carbamoyl azides, as a group, were classified by Bertho (Ref 3) as resistant to the Curtius rearrangement. However, other work by Stollé (Ref 2) showed that while some members of this group (R₁ or R₂ = H and R₁ or R₂ = alkyl/aryl) failed to become rearranged, others (R₁ or R₂ = C₆H₅) did so. Scott et al offered a different interpretation for the resistance of carbamoyl azide to such change.


Azidoacenaphthene. See under Acenaphthene and Derivatives, p A12
Azidoacetaldehyde. See under Acetaldehyde and Derivatives, p A15
Azidoacetamide. See under Acetamide and Derivatives, p A16
Azidoacetaimidophenol. See under Acetimidophenol and Derivatives, p A20 & 21
Azidoacetimidophenol, Dinitro. See under Acetimidophenol and Derivatives, p A21
Azidoacetanilide. See under Acetanilide and Derivatives, p A23
Azidoacetate (Triazoacetate) Salts. The normal Pb, Ag, K or uranyl triazoacetate salt has been proposed as an ingredient of priming compositions. For example, Pb triazoacetate/Pb styphnate/Pb thiocyanate/Pb nitrate/glass: 10/32/6/30/20%
Ref: P. H. Burdett & G. M. Calhoun, USP 2356211(1944) & CA 39, 194(1945)

Azidoacetic Acid. See under Acetic Acid and Derivatives, p A27
Azidoacetic Anhydride. See under Acetic Anhydride and Derivatives, p A31
Azidoacetone. See under Acetone and Derivatives, p A39
Azidoacetoneacetylhydrazide. See under Acetone and Derivatives, p A39
Azidoacetonitrile. See under Acetonitrile and Derivatives, p A45
Azidoacetonyliditetrazole. See under Acetonyltetrazole and Derivatives, p A47
Azidoacetonyltetrazole. See under Acetonyltetrazole and Derivatives, p A47
Azidoacetophenone. See under Acetophenone and Derivatives, pp A47-8
Azidoacetophenoneoxime. See under Acetophenoneoxime and Derivatives, p A49
Azidoacetoxime. See under Acetoxime and Derivatives, p A51
Azidoacetyl-dl-alanine. See under Acetylalanine and Derivatives, p A54
Azidoacetyl-dl-alanine Chloride. See under Acetylalanine and Derivatives, p A54
Azidoacetyl Chloride. See under Acetyl Chloride and Derivatives, p A57
Azidoacetyl Diphenylamine. See under Acetyl Diphenylamine and Derivatives, p A58
Azidoacetylglycine. See Acetylglycine Azide, p A69
Azidoacetyldimedoxide, Acetone. See under Acetone and Derivatives, p A39
Azidoacetyl Salicylic Acid. See under Acetyl salicylic Acid and Derivatives, p A87
Azidoacrylic Acid. See Acryloylazide under Acrylic Acid and Derivatives, p A97
Azidoamide; (Carbamyl Azide). See under Carbamic Acid and Derivatives and Beil 3, 129, (59) & [102]
Azidoaminoacetophenone. See under Aminoacetophenone and Derivatives, p A178
Azidoaminobenzoic Acid. See Aminobenzazide under Aminobenzoic Acid and Derivatives, p A188-9

Azidoaminoethane. See under Aminoethane and Derivatives, p A199

Azidoaminomethylguanidine. See under Aminomethylguanidine and Derivatives, p A232

Azidoaminopropane. See under Aminopropane and Derivatives, p A250

Azidoaminothiadiazole, Nitroso. See 5-Azido-2-nitrosamino-1,3,4-thiadiazole under Aminothiadiazole and Derivatives, p A262

AZIDOANILINE AND DERIVATIVES

Azidoaniline; Aminodiazobenzeneimide; Aminotriazobenzeneimide, N,N′-C6H4-NH3, mw 134.14, N 41.77, OB to CO2 ~179%. The following isomers are known:

3-Azidoaniline, yel oil of unpleasant odor; mp-explodes on heating; volatile with steam; easily sol in alc or eth. It was prepd by heating 3-azido-phenyloxamic acid with concd KOH soln

Refs: 1)Beil 12, 772 2)P.Griess, Ber 18, 963(1885)

4-Azidoaniline, lfts (from eth), mp 62-5°; volatile with steam and puffs off on stronger heating; very sol in alc, eth or chlf & sl sol in w. It was first prepd by heating 4-azidophenyloxamic acid with concd KOH soln (Ref 2). Silberrad & Smart (Ref 3) prepd it by slowly distilling acetyl-p-azidoaniline in 40% KOH soln. This compd forms expl salts (Ref 4)


Azidoaniline Perchlorate, N,N′-C6H4-NH3ClO4, mw 234.61, N 23.88%, OB to CO2 ~78.4%; red plates, mp - puffs off without melting. It can be prepd by treating 4-azidoaniline with perchloric acid. It is very sensitive to expln by impact. This compd was prepd and investigated by the duPont Co during WW II

Refs: 1)Beil - not found 2)A.H.Blatt, OSRD Rpt 2014(1944), under Azides

p-Azidoaniline Picrate, N,N′-C6H4-NH3·HOC6H4(NO3)2, mw 363.26, N 26.99%, OB to CO2 ~107.9%; mp 64-5° (from MeOH). It was prepd in 75% yield from 4-azidoaniline and excess picric acid in MeOH, the soln freed of picric acid by treatment with aq Na2CO3. By the same method p-azidodimethylaniline picrate, mp 47% (from petr eth) was obtd in 78% yield. These compds were isolated as picrates to identify the respective azidoamines

Refs: 1)Beil - not found 2)S.Maffei & A.M.Rivolta, Gazz 84, 750-2(1954) & CA 49, 13925(1955)

AZIDOANISOLE AND DERIVATIVES

Azidoanisole or Methylazidophenylether, C6H5N3O, mw 149.15, N 28.18%, OB to CO2 ~177.0%:

2-Azidoanisole (called o-Methoxy-diazobenzolimid in Ger), N,N′-C6H4-OCH3, yel oil. It was prepd from o-methoxybenzenediazoniumperbromide and NH3

Refs: 1)Beil 6, 293 2)H.Rupe & K. von Majewski, Ber 33, 3405(1900)

4-Azidoanisole (p-Azidoanisole), N,N′-C6H4·OCH3; yel plates (from petr eth or eth), mp 35-36°; dec at 150° and 20 mm. It was prepd from p-methoxybenzenediazoniumperbromide and NH3

Refs: 1)Beil 6, 294 & (142) 2)H.Rupe & K.vonMajewski, Ber 33, 3405-6(1900) 3) M.D.Forster, JCS 89, 238(1906) M.O.Forster & H.E.Fierz, JCS 91, 852(1907) 4)O.Dimroth & K.Pfister, Ber 43, 2763(1910) 5)H. Bretschneider & H.Rager, Monatsh 81, 970(1950) & CA 45, 7973(1951)
4-Nitro-2-Azidoanisole, N, C, H, (NO), OCH, mw 194.15, N 28.86%, OB to CO, 115.3; yel ndls having odor of bitter almonds. It was prep’d by Griess

Refs: 1)Beil 6, 294 2)P.Griess, JCS 20, 88(1867)

Azidoanthraquinone. See under Anthraquinone and Derivatives, p A459-60

Azidoantipyrine. See under Antipyrine and Derivatives, p A471

Azidoazobenzene. See under Azobenzene, p A647

Azidoazomethine-Tetrazole Equilibrium. See under Tetrazole Equilibrium and J.H. Boyer & E.J. Miller, Jr, JACS 81, 4671(1959)

p-Azidobenzaldehyde. See under Benzaldehyde and Beil 7, 266 & (145)

Azidobenz-anti-aldoxime, Methyl Ester. See under Benzaldoxime and Beil 7, 266

Azidobenzene; Triazobenzol; Diazobenzolimide or Phenyl Azide. See under Benzene and Beil 5, 276, (141) & [207]

Azidobenzenediammoniumhydroxide. See under Benzenediammoniumhydroxide and Beil 16, 493

Azidobenzenedioxime. See under Benzenedioxime and Beil 7, 266 & (145)

Azidobenzenesulfonic Acid. See under Benzenesulfonic Acid and Beil 11, 80 & [37]

Azidobenzfuroxan. See under Benzfuroxan and Derivatives

Azidobenzoic Acid. See under Benzoic Acid and Beil 9, 418, (168-9) & [286]

Azidobenzoic Acid Amide. See under Benzoic Acid Amide and Beil 9, 418

Azidobenzoic Acid Hydrazonium Hydroxide. See under Benzoic Acid Hydrazonium Hydroxide and Beil 16, 548

Azidobenzoic Acid, Methyl Ester. See under Benzoic Acid and Beil 9, 418

Azidobenzonitrile. See under Benzonitrile and Beil 9, 418-9 & (169)

N-[(α-Azidobenzylidene)-N'-benzylidene]-hydrazide. See under Benzalazine and Derivatives

4-[4-Azidobenzylideneamino]-phenol. See under Benzylideneaminophenol and Beil 13, (155)

Azidobromobenzene (1-Bromo-4-Triazobenzene). See under Bromobenzene and Beil 5, 277, (142) & [208]

1-Azido-2-Bromoethane. See under Bromoethane and Beil 1, (33)

Azido-5-Bromonicotinic Acid. See under Bromonicotinic Acid and (Beil – not found) R.Graf et al, JPraktChem 138, 244(1933)

1-Azido-4(or 5)-Bromo-2-Nitrobenzene. See p-Azidobenzaldehyde and Beil 7, (143)

1-Azidobutane; (2-Triazobutane). See under Azidobutane and (Beil – not found) J.H. Boyer & J.Hamer, JACS 77, 951-4(1955)

1-Azidobutaneone (1-Triazobutanone-2). See under Butanone and Beil 1, 671

Azidobutanoneoxime. See under Butanoneoxime and Beil 1, 671

Azidobuttersäure (Ger). Azidobutyric Acid α-Azidobutyric Acid or α-Triazobutyric Acid. See under Butyric Acid and Beil 2, 287,299, (126) & [257]

Azidobutyric Acid Amide. See under Butyric Acid Amide and Beil 2, 287 & 299

Azidobutyric Acid Azide. See Azidobutyrylazide

Azidobutyric Acid, Ethyl Ester. See under Butyric Acid and Beil 2, 287,299 & (126,130)

Azidobutyric Acid Hydrazide. See under Butyric Acid Hydrazide and Beil 2, (126)

Azidobutyrylazide. See under Butyric Acid and Beil 2, (126)

Azidocaffeine. See under Caffeine and Beil 26, 477

3-Azido-d-camphor or Camphorylazide. See under Camphor and Beil 7, 133

3-Azidocarbazole. See under Carbazole and Beil 20, [290]
Azido Carbon Disulfide. See under Carbon Disulfide and Beil 3, [160]

Azidocarbonyl Dianion Hydroxide. See under Carbonyl Diazonium Hydroxide and (Beil — not found) R.Hofsommer & M.Pestemer, ZElectrochem 53, 383-7(1949) & CA 44, 4431-2(1950)

Azidocarboxyphenyloxamic Acid. See under Carboxyphenyloxamic Acid and Beil 14, 418

Azidochloroethane (1-Azido-2-Chloroethane). See Chloroethyl Azide under Ethyl Chloride and Beil 1, (33)

2-Azido-3-cumaranone. See under Cumaranone and Beil 17, [127]

Azidocyanformamidine. See under Cyaniformamidine and Beil 3, [102]

Azidocyaniminoaminomethane. See under Cyaniminoaminomethane and Beil 3, [102]

Azidocycloheptane. See Cycloheptyl Azide under Cycloheptane and J.H.Boyer et al, JACS 78, 325-7(1956) & CA 50, 12855(1956)

Azidocyclohexane. See Cyclohexyl Azide under Cyclohexane and J.H.Boyer et al, JACS 78, 325-7(1956) & CA 50, 12855(1956)

Azidocyclopentane. See Cyclopentyl Azide under Cyclopentane and J.H.Boyer et al, JACS 78, 325-7(1956) & CA 50, 12855(1956)

2-Azido-4-diazobenzenesulfonic Acid. See under Diazobenzenesulfonic Acid and Beil 16, 565

1-Azido-1,2-dibromoethane. See under Di-bromoethane and Beil 1, (33)

Azidodiethyl ether. See under Diethyl ether and Beil 1, (171)

Azidodiethylsuccinate (Azidobernstien-säurediäthylester in Ger). See under Diethylsuccinate and Beil 2, (270)


Azidodimethylazobenzene. See under Dimethylazobenzene and Beil 16, 63,65 & 66

Azidodimethylbenzaldehyde. See under Dimethylbenzaldehyde and Beil 7, 313

Azidodimethylbenzene. See Xylyl Azide under Dimethylbenzene (Xylene) and Beil 5, 389 & (188)

Azidodimethylbenzoic Acid. See under Dimethylbenzoic Acid and Beil 9, 538

Azidodimethyldinitrobenzene. See under Dimethylbenzene (Xylene) and Beil 5, 382 & (188)

Azidodimethyldinitrobutylbenzene or Azidodinitrobutylxylene. See under Butylxylene and Beil 5, 448 & [340]

Azidodimethylindazole. See under Dimethylindazole and Beil 23, [166]

Azidodimethylnitrobenzene. See under Dimethylbenzene (Xylene) and Beil 5, 381-2

4-Azido-3,5-dimethylpyrazole. See under Dimethylpyrazole and Beil 23, (25)

Azidodinitroacetamidophenol. See under Acetamidophenol and Derivatives, p A21

Azidodinitrobenzene (Dinitrophenyl Azide). See under Benzene and Beil 5, 279 & [209]

2-Azidodinitroiphenyl. See under Biphenyl and P.A.Smith & B.B.Brown, JACS 73, 2438 (1951) & CA 46, 494-5(1957)

2-Azidodinitrophenol. See under Phenol and (Beil — not found) A.H.Blatt, OSRD Rpt 2014(1944)

3-Azido-2,4-Dinitrophenylhydrazone Propionate. See under Phenylhydrazone Propionate and J.H.Boyer, JACS 73, 5248(1951) & CA 47, 489-90(1953)

Azidodinitrotoluene. See under Toluene and Beil 5, 350-1, (174) & [350]

Azidodinitroxyylene. See under Xylene and Beil 5, 382 & (188)
Azidodiphenylamines. See under Diphenylamine and Beil 12, [429]

AZIDODITHIOCARBONIC ACID
AND DERIVATIVES

Azidodithiocarbonic Acid (Azidothioformic Acid) (called Azidothioameisensäure or Dithiokohlen säureazide in Ger),
HSCS=N=NNH, mw 119.17, N 35.27%; wh or sl yel crys, mp 50-65°(dec), explodes at 70°; sol in alc, methanol, eth, benz & AcOH and fairly sol in w. It was first prepd by Sommer (Ref 2) by treatment of a cold concd soln of Na azidodithiocarbonylic acid with concd HCl, but no evidence was offered to identify the compd. It’s prepn has been described by Oliveri-Mandalà (Ref 3), Smith et al (Refs 4 & 9), Audrieth (Ref 8) and others. Azidodithiocarbonic Acid can be prepd, according to Smith et al (Refs 4 & 9), by refluxing for 48 hrs at 40° pure CS₂ and a concd aq soln of recrystd NaN₃, filtering the soln, washing the crys with chilled concd HCl & ice w and drying the product. If HSCSN₃ is stored in a desiccator in the dark, below 10°, it is stable for several days
This compd is sensitive to light and heat. At RT it decomposes at a rate characteristic of monomolecular reactions. Decompn is catalyzed in the dry state, but not in aq solns, by an intermediate prod or by the thiocyanic acid formed:
HSCSN₃ → HSCN + S + N₂↑
In aq soln the compd is much more stable (Ref 4). Elec conductivity, potentiometric titration and cryoscopic detns all show that HSCSN₃ is an acid comparable in strength to H₂SO₄ (K=2.14 × 10⁻²) (Ref 7). The electrode potential of an azidocarbondisulfide-azidodithiocarbonate electrode was found to be 0.275V (Ref 10). The diln (in l/mol) at which the salt is completely dissociated in CH₃Cl, the ratio of this diln to that of AcOH taken as 1, and the ratio of the dissocn constant to that of AcOH taken as 1, was found by Hantzsch & Voight (Ref 6) to be as follows: 1450, 24160 & 1290.

Dry azidodithiocarbonic acid is very sensitive to expln by friction, impact or heat. It detonates with a puff on contact with a hot wire below red heat. It is easily oxidized by various reagents to a more expl solid, (SCN₃)₂, azidocarbondisulfide (Ref 4).

Browne & Smith (Ref 5) discussed several possible methods for detg the presence of SCN⁻ ion:
a) titration of the free acid using methyl red indicator
b) gravimetric detn as the Ag salt or as AgCl or equiv
c) titration with AgNO₃ as in the Gay-Lussac or Volhard method for titrating Cl⁻ ion and
d) titration with iodine dissolved in alc
Of these methods the Volhard titration method was preferred.
Many derivs and salts of azidodithiocarbonic acid are known some of which are expl (see below).


Acyl and Aryl Derivatives of Azidodithiocarbonic Acid:

Allyl Azidodithiocarbonate, C₅H₅·SCSN₃, mw 159.24, N 26.39%; unstable and undergoes fairly rapid decompn. It was prepd by the interaction of allyl bromide and Na azidodithiocarbonate in acet. No careful study of the props of this compd was made.
Benzohydryl Azidodithiocarbonate, \((C_6H_5)_2CH-SCSN_3\), mw 285.40, N 14.72%; col crys, mp 67°C; very sol in acet, EtOAc, benz, CS₂, CHCl₃ or CCl₄, moderately sol in alc, MeOH or eth. It was prepd by the interaction of benzohydryl bromide and Na azidodithiocarbonate. After filtering to remove the pptd NaBr, the yel liq, separated dithiocarbonate in acet. The ppt was recrystd by the addn of w, was dissolved in eth and from chlf benz which, after drying and cooling, separated in small col crys.

Benzoyl Azidodithiocarbonate, \(C_6H_5CO-SCSN_3\), mw 223.28, N 18.82%; col monoclinic plates, mp 92-4°C (dec); very sol in CHCl₃, moderately sol in eth, benz, CS₂ or CCl₄ and sl sol in acet, EtOAc, alc or MeOH. It was prepd by the interaction of benzoyl chloride and Na azidodithiocarbonate, either in aq soln or in acet. The product was puri-ified by crystn from chlf.

Benzyl Azidodithiocarbonate, \(C_6H_5CH_2SCSN_3\), mw 209.30, N 20.08%; col monoclinic prisms, mp 66°C; very sol in acet, EtOAc, Cs₂ or CHCl₃; sl sol in alc or MeOH and moderately sol in eth or benz. It was prepd by the interaction of benzyl chloride and Na azidodithiocarbonate, either in aq soln or in acet. The product was purified by crystn from chlf.

p-Bromobenzoyl Azidodithiocarbonate, \(BrC_6H_4CO-SCSN_3\), mw 302.19, N 13.91%; col rhmb plates, mp 99-101°C (dec); very sol in CHCl₃, moderately sol in CS₂ or CCl₄ and sl sol in acet, EtOAc, alc, MeOH, eth or benz. This compd was pptd, together with NaCl, by the interaction of p-bromobenzoyl chloride and Na azidodithiocarbonate in acet at RT. The ppt NaCl was removed by filtration and the crude prod which separated on addn of water was purified by re-crystn from chlf.

Methyl Azidodithiocarbonate, \(CH_3SCSN_3\), mw 133.20, N 31.55%; col rhmb prisms, mp 34°C; moderately sol in alc, MeOH, or eth and sl sol in acet, EtOAc, benz, CS₂, CHCl₃ or CCl₄. This prod was obtb by the interaction of methyl bromide and Na azidodithiocarbonate in acet and was purified by crystn from chlf. It is slowly attacked by concd aq alkalies.

Triphenylmethyl Azidodithiocarbonate, \((C_6H_5)_3C-SCSN_3\), mw 361.50, N 11.63%; col orthorhmb tablets or bipyramides; mp 102-4°C (dec); very sol in CHCl₃; moderately sol in benz or CS₂; sl sol in acet, EtOAc, alc, MeOH or eth. It was prepd by the interaction of triphenylmethyl chloride and Na azidodithiocarbonate in acet. The ppt was recrystd from chlf.

Remarks on Acyl and Aryl Derivatives

All of the above org azidodithiocarbonates were wh crystn compds which at RT undergo spontaneous decompn with ultimate plates, mp 92-4°C (dec); very sol in CHCl₃, quant formation of the corresponding thiocyanate or isothiocyanate, sulfur and nitrogen. The velocity of this decompn is sufficiently retarded at low temp to permit storage of samples at 0°C for several days without de-terioration.

Unlike the inorganic salts of the azidodithiocarbonic acid, the org derivs are not particularly expl. They puff midly when held in a flame or when heated rapidly on a hot plate. On exposure to light they show no photosensitivity and undergo no coloration.

Refs: 1)Beil - not found 2)L.F.Audrieth et al, JACS 52, 1928-35(1930) & CA 24, 3221 (1930)

Alkali and Alkaline Earth Salts of Azidodithiocarbonic Acid

The azidodithiocarbonates of the alkali and alkaline earth metals are all wh, deliq crystalline compds; sol in w, alc, eth or acet and insol in Cs₂, CCl₄, chlf or benz. These salts usually contain w of hydration which makes them more stable than the anhyd heavy metal salts. However, they decomp slowly at RT and rapidly on heating. They have been prepd by three methods:

a)direct interaction of a metallic azide with carbon disulfide
b)action of the free azidodithiocarbonic acid upon the hydroxide or carbonate of a metal or
c)double decomp of Ba azidodithiocarbonate and an alkali sulfate
Their sensitivities to friction and their brisance increase with increasing atomic wt. The Amm, K, Rb & Cs salts are characterized by their peculiar sensitivity to light. All change color when exposed to sunlight. The Cs salt may even decomp violently during the process of crystn from aq soln. The alkali salts, especially Na, can be used to prepare the heavy metal salts, such as Pb(SCSN)_2, and the alkyl or aryl derivatives of azidodithiocarbonic acid

Although many of the alkali and alkaline earth salts have been prep'd, studied and found to be explosive (Refs 1,2 & 3), only the more important ones are described here


Ammonium Azidodithiocarbonate, NH₄SCSN₃, mw 136.21, N 41.14%; wh cryst, non-deliq solid; mp-turns red-org at 90°, begins to decomp at 110° and melts with gas evolution at 120°; readily sol in w, alc, MeOH or acet, somewhat sol in eth and practically insol in benz or xylene. It was prep'd by: a) prolonged treatment of NH₄N₃ in aq soln with CS₂ b) neutralizing free azidodithiocarbonic acid with aq NH₄OH or c) bubbling NH₃ gas through an ethereal soln of the azido-acid. The third procedure was adjudged the most satisfactory

On exposure to direct sunlight the salt undergoes coloration, within a few minutes, to a very light orn tint. A partial reversal of this color change takes place slowly in the dark

When strongly heated the salt suddenly decomps with considerable flame and a puff of smoke. On heating in a sealed tube the salt explodes violently

Reps: 1)Beil 3, [159] 2)L.F.Audrieth et al, JACS 49, 2130(1927) & CA 21, 3326(1927)

Potassium Azidodithiocarbonate, KSCSN₃, mw 157.27, N 26.72%; wh deliq crysts, mp 126° (dec with evolution of gas); very sol in w, fairly sol in acet or MeOH; very sl sol in eth and practically insol in alc, benz, CCl₄, CS₂ or chlf. It was prep'd by the action of an aq soln of KN₃ on CS₂ at 40°. The concd clear filtrate was slowly cooled over ice until crystals formed

The K salt is rather sensitive to expln by shock, heat or friction. Crystals may expl violently when broken or rubbed in an agate mortar. When heated rapidly in air the subst decompates with a sharp expln, but less violently than the heavy metal azides. On expln in air, a spectacular flame is produced with the liberation of much heat and the formation of numerous products:

\[ 2KSCSN₃ + 5O₂ → K₂S₃O₄ + 2CO₂ + 3N₂ \]

Although many of the alkali and alkaline earth salts have been prep'd, studied and the liberation of much heat and the formation of numerous products:

Ammonium Azidodithiocarbonate, NH₄SCSN₃, Aq solns of K azidodithiocarbonate are quite stable at 10° or lower, as is the dry salt itself. At somewhat higher temps the aq solns gradually become turbid. Samples of the dry salt stored in a desiccator at RT are somewhat sol in eth and practically insol gradually turn yel. Solns of the K azido salt, in benz or xylene. It was prep'd by-

a) prolonged when treated with various oxidizing agents or when subjected to electrolysis, yield the more expl wh ppt, azidocarbondisulride, (SCSN)₂. An important catalytic effect is exerted by the K azido salt in the reaction between aq KN₃ and I₂ in the presence of CS₂


Sodium Azidodithiocarbonate, NaSCSN₃, mw 141.16, N 29.77%; col powd of no distinct cryst form; mp explodes between 139-43°. It was prep'd by dehydration of either the tetra-hydrate or the dihydrate at RT over P₂O₅ in a vac desiccator. Sl decomps take place as evidenced by the development of a pink color on the cryst surface. This color disappeared on exposure to air
A635

The anhyd Na salt explodes violently when rubbed vigorously on a porous plate or when thrown upon a hot plate. It is not very sensitive to shock (Ref 4). Bromine Azidodithiocarbonate, BrSCSN₃, mw 198.08, N 21.22%; wh amor prod, unstable above −5°, turns yel to brn on standing or when rapidly heated to 200°. Attempts to prep Br azidodithiocarbonate by interaction of liq Br₂ and solid azidocarbodisulfide at RT resulted in violent explosions. In org solvs more controllable reactions take place with the probable formation of BrSCSN₃. Bromine reacts with Ag azidodithiocarbonate in eth to form a tribromo azidodithiocarbonate, Br₃SCSN₃, and in chlf or CCl₄ to form a mixt of the monobromo and tribromo compds.

Due to the extreme instability of these compds, their complete isolation, exact detn of their compn and props were not accomplished.


Chlorine Azidodithiocarbonate, CISCSN₃, mw 153.62, N 27.35%; wh solid, changing gradually, even at temp below −15°, to a viscous yel oil; insol in w or chlf. The vapor of the oil affects the eyes, appears to act as a heart depressant, and causes blistering on contact with the skin. It was formed by passing Cl₂ gas through an anhyd soln of azidocarbodisulfide in chlf at −15°, after removal of excess Cl₂ and vapzn of part of the solv.

Dry azidocarbodisulfide in contact at RT with Cl₂, either in gaseous form or in concd aq soln, causes a violent expln. Only a few degrees rise in temp can cause this reacting mass to explode, almost immedy, yielding the usual prods of decompn of the halogenoid compd.


Cyanogen Azidodithiocarbonate, NC-SCSN₃, mw 144.19, N 38.86%; wh crysts, stable at 0°; a large sample explodes at 65-70°; a small sample becomes yel at 60° and at 81° fusion takes place, with decompn and formation of a yel-orn residue; very sl sol in w, CCl₄, or CS₂, sol in most org solvs, especially acet or ethyl acetate at 0°. It is formed by the...
interaction of azidocarbondisulfide and mercuric cyanide in acet, but is best prepd by reacting cold aq soln of Na azidothiocarbonate with an ethereal soln of cyanogen bromide.

Cyanogen azidodithiocarbonate is insensitive to impact and is much more stable than azidocarbondisulfide. On expln by heat it develops a dk orn vapor comparable in odor to thiocyanogen and to cyanogen thiocyanate. It undergoes spontaneous decompn at RT, with the liberation of N₂, leaving a solid residue of sulfur, thiocyanogen and cyanogen thiocyanate. As the temp is raised, the velocity of decompn undergoes marked acceleration. At 40°, for example, complete decompn takes place within 80 hrs.

When a current of NH₃ gas is brought into contact with the dry solid compd, expl decompn occurs immedly. Bubbled through an ethereal soln of the CN salt, NH₃ gas ppts a wh solid consisting chiefly of NH₄ azidodithiocarbonate. The CN salt and concd H₂SO₄ react with explosive violence. Other dil acids react more slowly than concd acids but all eventually effect soln of cyanogen azidodithiocarbonate.

Refs: 1)Beil – not found 2)L.F.Audrieth & A.W. Browne, JACS 52, 2799-2805(1930) & CA 24, 3963(1930)

Guanidine Azidodithiocarbonate, HNC(NH₂)₂- HSCSN₃, mw 178.25, N 47.15%; col prisms, mp 88-90° (dec); readily sol in w or acet, sol in alc and almost insol in eth. It was prepd by interacting aq guanidine carbonate with freshly prepd solid azidodithiocarbonic acid or by reacting aq guanidine azide, HNC(NH₂)₂- HN₃, with purified CS₂.

Like the inorg compds of the azido acid, and unlike the alkyl and aryl derivs, the guanidine salt is photosensitive. In the dark it may be stored below 10°, in vacuo, for days without appreciable decompn. On long standing at RT, the salt decomps quanty, yielding N₂, sulfur and guanidine thiocyanate. In aq soln the azido salt reacts with AgNO₃ to form the insol Ag azidodithiocarbonate when heated on a Pt foil, guanidine azidodithiocarbonate decomposes rapidly, with evolution of much gas, but without deton.

Refs: 1)Beil – not found 2)J.Craik et al, JACS 56, 2380-1 (1934) & CA 29, 700(1935)

Heavy Metal Salts of Azidodithiocarbonic Acid. Some heavy metal salts of azidodithiocarbonic acid, such as Ag, Cu⁺⁺, Hg⁺⁺, Hg⁺, Cd, Bi, Fe+++ & Zn, were prepd and studied in 1915 by Sommer (Refs 1a & 1b) before the acid was identified. He obtd these salts by reacting the appropriate aq metal azide with CS₂ at 40-50° or by reacting Na azidodithiocarbonate with the metal nitrate or chloride. No ppts were obtd with Sn, Al, Cr, Fe++, Ni, Co & Mn salts. The heavy metal salts prepd by Sommer (Refs 1a & 1b) were considered to be of a complex nature and fearfully expl. Many were sol in org solvents, insol in acids and gave a color in solns different from that of the metallic ion.

Rathsburg (Ref 2) obtd some of these salts by the procedures of Sommer and proposed their use, when they were phlegmatized with resin or paraffin solns, in priming comps. The Pb azidodithiocarbonate was considered of special importance and was prepd by treatment of the Na salt with Pb(NO₃)₂. Smith et al (Ref 3) prepd and studied the chem and expl props of the azidodithiocarbonates of Cu, Ag, An, Zn, Cd, Hg⁺⁺, Tl, Pb & Bi for their value as primer or detonator expls.

These heavy metal salts were prepd by treating a fresh aq azidodithiocarbonic acid soln with an aq soln of the respective metal ion. The following list of salts studied includes the props which were detd by Smith et al (Ref 3):

Bismuth, formula not established; yt to reddish orn ppt, highly sensitive and may det under water
Cadmium, Cd(SCSN₃)₂·2H₂O; long, fine ndls which undergo slow, spontaneous thermal decompn. The anhyd salt is very sensitive and may det, even under water on sl mechanical shock
Copper, a mixt of cupric & cuprous
Azidodithiocarbonates; yel ppt which undergoes slow thermal decompn, forming an inert prod. This salt may det violently under sl mechanical shock.

Gold, a mixt of aurous azidodithiocarbonate & azidocarbodiisulfide; bulky wh fibrous ppt which changes to om on standing

Lead, Pb(SCSN₃)₂, it grn-yel crysts, fairly stable but may det under sl mechanical shock

Mercuric, Hg(SCSN₃)₂; silky ppt which undergoes spontaneous thermal decompn at RT, yielding mercuric thiocyanate. This salt may det violently under sl mechanical shock

Mercurocyan, N(CH₃)₂N⁺SCN⁻; dk brn when first formed but becomes wh when the suspended ppt is stirred. This salt may det violently under sl mechanical shock

Silver, AgSCSN₃; wh photosensitive compd, either in aq suspension or in the dry state, which darkens on exposure to light. It may detonate violently under sl mechanical shock

Thallous, TlSCSN₃; it yel crysts which may det violently under sl mechanical shock

Zinc, formula not established; yel, reg octahedra crysts which are exceedingly sensitive to friction and shock, even under water

**Remarks:** Azidodithiocarbonates of the heavy metals in the first and second groups of the periodic system show a sensitivity to mechanical impact that varies inversely with atomic wt, while the brisance of expln varies directly with the atomic wt. The sensitivity of compds of metals in the series Hg to Bi varies directly and the brisance inversely with the atomic wt. Certain of these compds, suitably stabilized and partially desensitized, should prove useful in primer or detonator compns

**Refs:** 1a)Beil - not found 2)L.F.Audrieth et al, JACS 49, 2131-2 (1927) & CA 21, 3326 (1927)

Triethyllead Azidodithiocarbonate, (C₂H₅)₃PbSCSN₃, mw 412.56, N 10.19%; mp (ignites without detonation). It can be prepd by the action of aq Na azidodithiocarbonate on triethyllead acetate, yielding about 80% prod

This compd may be used as a component of ignition compns for elec blasting caps

**Refs:** 1)Beil - not found 2)L.A.Burrows et al, USP 2105635(1938) & CA 32, 2357-8 (1938)

Azidoethane (Triazoethane). See Ethyl Azide under Ethan and Beil 1, [71]

Azidoethanol (2-Triazoethanol). See under Ethanol and Beil 1, 340 & (171)

Azidoethylalcohol or Azidoethanol (Triazoeholanol). See under Ethanol and Beil 1, 340 & (171)

Azidoethylamine. See under Aminoethane and Derivatives, p A199

Azidoethylazidoacetate (Triazoethyli Triazoacetate). See under Ethyl azidoacetate and Beil 2, 229

Azidoethylbenzamide. See under Ethylbenzamide and Beil 8, (97)

Azidoethylbenzene, N1C6H4•C3H8. See under Ethylbenzene, and P.A.Levene et al, J Biol Chem 120, 777(1937) & CA 32, 484-5(1938)

Azidoethylene (Vinyl Azide), CH2•CH-N, mw 69.07, N 60.84%; yel liq, bp 26° at 760 mm Hg; it was prepd by the action of alcoholic KOH or NH3 on 2-iodoazidoethane

Refs: 1)Beil 1, (82) 2)M.O.Forster & S.H. Neuman, JCS 97 II, 2574(1910)

Azidoethylenediurethane. See under Ethylene-diurethane and Beil 4, (450)

Azidoethylmethylketone-Semicarbazone. See under Ethylmethylketone-Semicarbazone and Beil 3, 102

Azidoethylnitrate (Triazoehtanolnitrate). See under Ethyl Nitrate and (Beil - not found)

Azidoethylurea. See under Ethylurea and Beil 4, (360)

[a-Azidoethyl]-Urethane. See under Ethylurethane and Beil 3, (11)

[b-Azidoethyl]-Urethane. See under Ethylurethane and Beil 4, (360)

Azidofluorenone. See under Fluorenone and Beil 7, [410]

Azidoformamide. See Carbamyl Azide under Formamide and Beil 3, 129 & (59)

Azidoformamidine or Guanyl Azide. See under Formamidine and Beil 3, 130 & (60)

Azidoformamidine Dinitrate. See under Formamidine

Azidoformamidine Nitrate. See under Formamidine

Azidoformamidine, N-Nitro. See under Formamidine

Azidoformamidine Perchlorate. See under Formamidine

Azidoformamidine Picrate. See under Formamidine

Azidoformic Acid. See under Formic Acid

Azidoformic Acid Dimethylamide. See under Formic Acid Dimethyl Amide and Beil 4, [575]

Azidoformic Acid, Ethylester. See under Formic Acid and Beil 3, 129 & [101]

Azidoformic Acid, Methylester. See under Formic Acid and Beil 3, 129 & [101]

α-Azidoformylbutyrylglycine Azide, (formerly called in Ger "Azidoglutarsiiureglycinazid), N3•CO(CH2)3•CO-NH•CH2•CO•N3, mw 239.21, N 40.99%; thick oil which explodes when touched with a flame


2-Azidoformylphenylisocyanate (2-Isocyanate Benzoyl Azide), OC:N-C6H4•CON, mw 188.15, N 29.78%; Needles (from benz), mp 60°(dec) on careful heating; explodes violently on rapid heating or on impact. It can be prepd by heating phthalic acid diazide in benz


β-Azidoformylpropionylglycine Azide (formerly called in Ger "Azidosuccinylglycinazid"), N3•CO•CH3•CO-NH•CH2•CON, mw 211.15, N 46.44%; leaflets which explode when touched with a flame

Azidogallacetophenone. See under Gallacetophenone and Beil 8, (686)

Azidogluutaricacideglucose Azide. Same as α-Azidoformylbutyrylglycine Azide (qv)

Azidoglycolic Acid. See under Glycolic Acid and Beil 3, 244, (94) & [175]

Azidoguanidine Perchlorate. See under Guanidine

Azidoguanidine Picate. See under Guanidine

3-Azidoheptane (3-Triazohexane). See under Heptane and P.A. Levene et al, J Biol Chem 20, 759(1937) & CA 32, 486-7(1938)

6-Azido-2,3,5,2',4',5'-Hexamethylazobenzene. (CH₃)₃N₃(C₆H₄)N=N-C₆H₄(CH₃)₃, mw 307.39, N 22.797%; red needles (from eth), mp 90-1 (dec); explodes mildly on rapid heating or on contact with concd H₂SO₄. It can be prepd from 6-amino-2,3,5,2',4',5'-hexamethylazobenzene as described in Ref 2

Refs: 1)Beil 16, 76 2)T.Zincke & H. Jaenke, Ber 21, 546(1888)

Azidohemimellitine or Azido-1,2,3-trimethylbenzene. See under Hemimellitine and Derivatives

Azidohexane (Triazohexane). See under Hexane and P.A. Levene et al, J Biol Chem 120, 759(1937) & CA 32, 486-7(1938)

Azidohydride. See individual azido derivatives of the hydrogen acid ester of a polyatomic alcohol, such as glycol glyceral, etc

Azidohydrocinnamic Acid. See under Hydrocinnamic Acid and Beil 8, (205-6)

Azidohydroquinone. See under Hydroquinone and Beil 6, (419)

Azidohydroxyacetophenone. See under Hydroxyacetophenone and Beil 8, (419)

Azidohydroxybenzaldehyde. See under Hydroxybenzaldehyde and Beil 8, (262)

5-Azido-3-[2-Hydroxy-1-Naphthyl]-azo]-1, 2,4-Triazole. See under Hydroxynaphthylazotriazole and R. Stoll & W. Dietrich, J Prakt Chem 139, 193-210(1934) & CA 28, 2714(1934)

Azidohydroxyphenylpropionic Acid. See under Hydroxyphenylpropionic Acid and Beil 10, [152 & 156]

Azidohydroxytetrazole. See under Hydroxytetrazole and A.H. Blatt, OSRD Rpt 2014 (1944)


1-Azido-2-iodoethane. See under Iodoethane and Beil 1, (33)

Azido-4-iodopicolinyl. See under Iodopicolinic Acid and R. Gros et al, Ber 64B, 21-6(1931) & CA 25, 2429(1931)

Azidooiodosobenzene (Triazooiodosobenzene). See under Iodosobenzene and Beil 5, (142)

Azidooiodoxybenzene (Triazooiodoxybenzene). See under Iodoxybenzene and Beil 5, (142-3)

Azidolactic Acid. See under Lactic Acid and Beil 3, (110)

Azidomethane (Methyl Azide). See under Methane and Beil 1, 80 & [48]

Azidomesitylene or Azido-1,3,5-Trimethylbenzene. See under Mesitylene and Derivatives

Azidomethoxyacetophenone. See under Methoxyacetophenone and Beil 8, [87]

Azidomethoxytoluene. See under Methoxytoluene and Beil 6, (181,195 & 207)
4-Azidomethylaniline (4-Methyl-4-azidomethylaniline). See under Methylaniline and Beil 12, [429]

Azidomethylisole. See under Methylisole and Beil 6, (181, 195 & 207)

Azidomethylbenzene (Azidotoluene). See Toly 1 Azide under Toluene and Beil 5, 349, (174) & [273]

Azidomethylbutane. See Amylazide under Amylamine and Derivatives, p A395

Azidomethylbutanone. See under Methylbutanone and Beil 1, (353)

Azidomethylcarbamide. Same as Azidomethyl Isocyanate (qv)

Azidomethylidinitrobutylbenzene. See under Methylbutylbenzene and Beil 5, 439

Azidomethylcarbamy 1 Azide. See under Methylcarbamic Acid and Beil 3, (17)

Azidomethylketone Semicarbazide. See under Methylketone Semicarbazide and Beil 3, 102

Azidomethyl Ketoxime,(Triazomethyl-ethyl Ketoxime). See under Methylketoxime and Beil 1, 671

Azidomethylformate (Azidoformicacid, Methyl Ester) (called Carbazidsauremethylester in Ger), N₃-CO₂-CH₃, mw 101.07, N 41.58%; col liq, bp 102-3°C, explodes on heating near bp. It can be prepd by the action of ammonium nitride on chloromethylformate in ether


Azidomethylfuroyl. See Methyulfuroylazide under Methylfuroic Acid and H.B.Stevenson & J.R. Johnson, JACS 59, 2528(1937) & CA 32, 937-8(1938)

Azidomethyl Isocyanate; Azidomethyl Carbimide or Triazomethyl Carbimide (called Azidomethylcarbimid in Ger), N₃-CH₂-N:CO, mw 98.07, N 57.14%, OB to CO₂ -65.3%; col sharp smelling oil, bp 44-5° at 32 mm, d 1.2580 at 18°C. It can be prepd from azidoacetyl chloride and NaN₃ in ether. Explosions often happened during its prepn

Refs: 1)Beil 3, (17) & 26, (77) 2)M.O. Forster & R. Müller, JCS 97 I, 1062(1910)


N-Azidomethyl-N'-phenylurea. See under Methylphenylurea and Beil 12, (233)

Azidomethylurea or Triazomethylcarbamide (called Azidomethylharnstoff in Ger), H₂N-CO-NH-CH₃-N₃, mw 115.10, N 60.85%, OB to CO₂ -76.5%; cryst (from acet), mp 56°C; easily sol in acet, insol in benz & chlf. It can be prepd from azidomethylisocyanate and NH₃ in dry ether. Its expl props were not investigated

Ref: 1)Beil 3, (27) 2)M.O. Forster & R. Müller, JCS 97 I, 1065(1910)

Azidonaphthalene. See under Naphthalene and Beil 5, 565, (265) & [459]

Azidonitroacetyl Chloride. See under Acetyl Chloride and Derivatives, p A56

Azidonitrobenzene. See under Benzene and Beil 5, 278, (143) & [209]

2-Azido-4-nitrobenzenesulfonic Acid. See under Benzenesulfonic Acid and Beil 11, 81

5-Azido-6-Nitro-Benzofurazan-3-oxide. See under Benzofurazan and R.J. Gaughran et al, JACS 76, 2233 (1954) & CA 49, 6238(1955)

5-Azido-6-nitrobenzofuroxan. See under Benzfuroxan and J.R. Gaughran et al, JACS 76, 2235(1954)

2-Azido-6-nitro-1,4-benzoquinone-4-trimethylimide or Trimethyl-[3-azido-5-nitro-4-hydroxyphenyl]-ammonium Hydroxide,

\[ \text{N}_3 \cdot \text{C} \cdot \text{COH} = \text{C} \cdot \text{NO}_2 \]

\[ \text{H} \cdot \text{C} = \text{C} \text{===CH}_2 \text{, mw 255.23, N 27.44%,} \]

\[ \text{N(CH}_3)_3 \cdot \text{OH} \]
OB to CO₂ -128.5%; red needles or scales (from w), mp becomes brn ca 109° and then explodes. It can be prepd from 2,6-dinitro-1,4-benzoquinone-4-trimethylamine by reduction [with (NH₄)₂S], diazotization and treatment with NaN₃.

Refs: 1) Beil 13, (198) 2) M.R.Meldola & W.F. Holley, JCS 105 I, 1477(1914); PRoySoc 30, 159-60(1914) & CA 8, 3026-7(1914)

Azido-N-Nitroformamidine. See under Formamidine

Azidotrimesitylene. See under Mesitylene and Beil 5, [316]

Azidonitronaphthalene. See under Naphthalene and Beil 5, [459]

Azidonitrobenzene. See under Phenol and Beil 6, 294

Azidonitrotoluene. See under Toluene and Beil 5, 350 & (174)

6-Azido-2-nitro-4-trimethylammonium-1-benzoquinone. Same as 2-Azido-6-nitro-1-benzoquinone-4-trimethylimide (qv)

Azidooxalacid Ethylester or Oxalylethylester Azide (called Azido-oxalsäure-äthylester or Oxalsäure-äthylester-azid in Ger), N₃-CO-CO₂-C₆H₅, mw 143.10, N 29.37%, OB to CO₂ -83.97%; col oily liq, bp explodes very violently on heating; sol in eth, insol in w. It can be prepd from the hydrazide of oxalylethylester and NaN₃ in well cooled ag soln


Azidooxamate. See Oxamylazide under Oxamic Acid and Beil 2, (244)

Azidooxanilic Acid. See Oxanilazide under Oxanilic Acid and Beil 12, 772

Azidooxanethane Diazonium Hydroxide. See under Oxomethanediazonium Hydroxide and (Beil - not found) R.Hofsommer & M.Pestemer, ZElectrochem 53, 383(1949) & CA 44, 4331 (1950)

Azidoöxytetrazole. See under Oxytetrazole and (Beil - not found) A.H. Blatt, OSRD Rpt 2014 (1944)

Azidopentane. See Amyl Azide, p A395

Azidophenol (Hydroxyphenylazomide). See under Phenol and Beil 6, 293-4

Azidophenol, Methyl Ester. Same as Azidophenylacetamide

Azidophenolacetic Acid. See under Phenolacetic Acid and CA 51, 17816 (1957)

Azidophenylazide. See under Aminoacetophenone and Derivatives, p A178

5-Azido-1-Phenyl-5-Azidobenzene (1-Phenyl-5-Azidotetrazole). See under Phenyltetrazole

5-Azido-2-phenyl-1,3,5-oxadiazole (2-Azido-5-phenyl-1,3,4-furodiazone) N₅-CO-C₆H₅

Azidonitronaphthalene. See under Naphthalene 5-Azido. 1 Phenyl-5-Azidobenzene (1-Phenyl-5-Azidotetrazole) See under Phenyltetrazole

5-Azido-2-phenyl-1,3,5-oxadiazole (2-Azido-5-phenyl-1,3,4-furodiazone) N₅-CO-C₆H₅

Azidonitrophenol. See under Phenol and Beil 6, 294

Azidonitrobenzene. See under Phenol and Beil 6, 294

5-Azido-2-phenyl-1,3,5-oxadiazole (2-Azido-5-phenyl-1,3,4-furodiazone) N₅-CO-C₆H₅

Azidonitrophenol. See under Phenol and Beil 6, 294

Azidonitrobenzene. See under Phenol and Beil 6, 294

5-Azido-2-phenyl-1,3,5-oxadiazole (2-Azido-5-phenyl-1,3,4-furodiazone) N₅-CO-C₆H₅


Azidophenyl Propanion Acid (α-Azidohydrocinnamic Acid). See under Hydrocinnamic Acid and Beil 9, (205)


(1'-Azidophthalazine-4',5'-5,1-tetrazole, (Tetrazolo-1,2-azido-4-phthalazine-1,2-dihydride),

H₄C-
\[\begin{array}{c}
\text{C} \\
\text{N} \\
\text{N}
\end{array}\]

neq 212.18, N 52.81%; needles, mp 152°; easily sol in alc, diff sol in eth, nearly insol in w. It can be prepd by boiling for 3 hrs under reflux, 5 g of 1,4-
dichlorophthalazine (mp 163°) dissolved in eth, with 5 g of NaN₃


Azidopropene (Propyl Azide). See under Propene and R.E. Schaad, USP 2557924(1951) & CA 46, 1028(1952)

Azidopropanedicarbonic Acid. See under Propanedicarbonic Acid and Beil 2, (276)

3-Azido-1,2-propanediol Dinitrate. See under Propanediol

Azidopropene Oxime. See under Propano-oxime and Beil 1, 661


Azidopropanone. See Azidoacetone under Acetone and Derivatives, p A39

3-Azido-1-propene. See Allylazide, p A137

Azidopropionaldehyde. See under Propionaldehyde and J.H. Boyer, JACS 73, 5248-52(1953) & CA 47, 490(1953)

Azidopropionic Acid (α-Triazopropionic Acid). See under Propionic Acid and Beil 2, 263 (114 & 115) & [234]

Azidopropionic Acid Amide. See under Propionic Acid Amide and Beil 2, 263-4 & (114)

Azidopropionic Acid, Ethyl Ester. See under Propionic Acid and Beil 2, 263-4 & (114)

Azidopropionic Acid, Methyl Ester. See under Propionic Acid and J.H. Boyer, JACS 73, 5248-52(1951) & CA 47, 489-90(1953)

Azidopropionitrile. See under Propionitrile and J.H. Boyer, JACS 73, 5248-52(1951) & CA 47, 489-90(1953)

Azidopropionylazide. See under Propionic Acid and Beil 2, (115)

Azidopropylamine. Same as Azidoamino-propane described under Aminopropane and Derivatives, p A250

Azidopropyleneglycol Dinitrate. See under Propyleneglycol and A.H. Blatt, OSRD Rept 2014(1944)

1-[Azido-iso-propylidene]-semicarbazide. See under Propylidenesemicarbazide and Beil 3, 102

Azidopropylurea. See under Propylurea and Beil 4, (368)

1'-Azidopseudocumene or Azidotrimethylbenzene. See under Pseudocumene and Beil 5, 405

Azido-2,5-pyrazinedicarboxyl. See under Pyrazinedicarboxyl and P.E. Spoor & A. Erickson, JACS 60, 400-2(1938) & CA 32, 2535(1938)

Azidoquinazolinetetrazole. See under Quinazolinetetrazole and R. Stollé & F. Hanusch, JPraktChem 136, 120(1933)

Azidosalicylic Acid. See under Salicylic Acid and M.J. Sullivan & C.K. Banks, USP 2633470 (1953) & CA 48, 2107(1954)

Azido-iso-succinic Acid. See under Succinic Acid and Beil 2, (272)

Azido-iso-succinic Acid Diamide. See under Succinic Acid Diamide and Beil 2, (272)

Azido-iso-succinic Acid, Diethylester. See under Succinic Acid, and Beil 2, (272)

Azidosuccinic Acid, Diethylester. See under Succinic Acid and Beil 2, (270)

Azidosuccinic Acid, Dihydrazide. See under Succinic Acid and Beil 2, (271)

Azidosuccinic Acid. See under Succinic Acid and Beil 2, (271)

Azidosuccinylidiozide. See under Succinic Acid and Beil 2, (271)

Azidosulfonic Acids. See under names of individual sulfonic acids

Azidotetramethylazobenzene. See Tetramethylazobenzene and Beil 16, 74

Azidotetrazole. See Tetrazolylazide under Tetrazole and Beil 26, 347, (110) & [197 & 361]

o-Azidotoluene. See Benzylazide under
Toluene and Beil 5, 350, (174) & [274]
Azidotoluene. See Tolyazide under Toluene and Beil 5, 349(174) & [273]
Azidotriazole. See under Triazole and Beil 26, 21
2-Azido-3,5,6-trichloro-1,4-benzoquinone. See under Trichlorobenzoquinone and A.
Korczynski & St. Namyslowski, BullFr 35, 1186(1924) & CA 19, 644(1925)
Azido-1,2,3-trimethylbenzene or Azido-
hemimellitene. See under Hemimellitene and Derivatives
Azido-1,2,4-trimethylbenzene or Azidopseudo-
cumene. See under Pseudocumene and Derivatives
Azido-1,3,5-trimethylbenzene or Azidomesy-
ylene. See under Mesitylene and Derivatives
1-Azido-2,4,6-trinitrobenzenes; (Trinitrophenyl Azide or Picryl Azide). See under Benzene and Beil 5, 279, (144) & [209]
Azidotrinitromethane. See under Methane
Azido-iso-valeric Acid. See under Valeric Acid and Beil 2, 318
Azido-iso-valeric Acid Amide. See under Valeric Acid Amide and Beil 2, 318
Azido-iso-valeric Acid, Ethylester. See under Valeric Acid Ethyl Ether and Beil 2, 318 & (139)
Azido-iso-valeryl Azide. See under Valeric Acid and Beil 2, 316
Azidoxylene or Dimethylphenyl Azide. See under Dimethylbenzene and Beil 5, [296 & 303]

Azethane. Same as Diazoethane
Azietylene. Same as Diazetoethane
Azimethane. Same as Diazomethane
Azimethylene. Same as Diazomethane

Azimid. A heterocyclic compd, C₆H₄N₆,
\[
\begin{align*}
\text{N} \quad \text{C} \quad \text{N} \\
\text{N} \quad \text{C} \quad \text{N} \\
\text{N} \quad \text{C} \quad \text{N}
\end{align*}
\]
listed in Beil 26, 691 as Triazole-4',5':4-5-
triazol or 4',5'-Azimino-1,2,3-triazol

Azimide. Same as Benzazide or Benzoyl Azide
Azimido- or Azimino-. The bivalent group,
-NH-N:N-, called triazene in this work (See Nomenclature, p III)
Azimidobenzene, C₆H₄N₆. The p-amidobenzene
is the parent compd of anhydro-p-amino-
diazocompds (Beil 26, 55)

Azimidodi-; Azinitrosodi-; Oxazimido-; Oxaz-
nitroso- and Nitrosoazimidocompds. See H.
Conrad & C. Willgerodt, JPraktChem 55, 375-
98(1897) & JCS 72 1, 518(1897)

Azimidol-4,5-dicarboxylic Acid or 1-Hydroxy-
1,2,3-triazole-4,5-dicarboxylic Acid [called 1-Oxy-1,2,3-triazol-dicarbonsaure-(4,5) in Ger]. See under Triazoles

5,6-Azimino-benzimidazole or 2-Hydroxy-5,6-
azimino-benzimidazole (called 5,6-Azimino-
benzimidazolon or 2-Oxy-5,6-azimino-
benzimidazol in Ger);

3,3'-Azimino-bis[4-methyl]furazan (called 1,3-Bis-[4-methyl-1,2-5-oxidiazolyl-(3)]-
triazen or 4,4'-Dimethyl-[3,3'-diazaamino-
furazan] in Ger),
AZOCOMPOUNDS

Org compds having two hydrocarbon radicals attached to the azo group, \(-\text{N}^\equiv\text{N}-\), and having the general formula \(R-\text{N}^\equiv\text{N}-R'\) are called azocompds. If the radicals \(R\) and \(R'\) are the same, azo is usually prefixed to the name of the compd from which the radical is derived: for example, \(\text{CH}_2\text{N}^\equiv\text{N}-\text{CH}_3\) is called azomethane. However, there appears to be no uniform and consistent system of naming azocompds, especially when the radicals \(R\) and \(R'\) are identically substituted aromatic or aliphatic derivatives. For example, the prefix "bis" or "di" is used in the literature for both aromatic and aliphatic azocompds in addition to the azo designation.

In this work we have usually listed the azocompds without any prefix, as a first name, unless the compd is known and found in the literature only as an azobis- or azodi-derivative, for example azobis-formic acid.

When the radicals \(R\) and \(R'\) are different substituents, azo is placed between the names of the compds from which the radicals are derived: for example, \(\text{C}_6\text{H}_5\text{N}^\equiv\text{N}-\text{CH}_3\) is called benzene-azo-methane. This system suffices for naming the simpler compds, but is impracticable for the complicated dye-stuff compds which are commonly known by trivial names. For example, amino-cresotinic acid can be converted into its p-nitrobenzoyl deriv, the nitro group reduced, and the resulting amino group diazotized and coupled with p-amino-benzoyl-\(J\) acid. The resulting dye, called "Diazo Light Scarlet 5BI" can be coupled with \(\beta\)-naphthol to give a complex azo dye-stuff which can be given no simple name (Ref 6, p 450):

\[
\begin{align*}
\text{HOOC} & \quad \text{OH} \\
\text{NH} & \quad \text{CH}_3
\end{align*}
\]

\[
\begin{align*}
\text{H}_3\text{OS} & \quad \text{NH} \\
\text{C} & \quad \text{OH}
\end{align*}
\]

\[
\begin{align*}
\text{NH}_2 & \quad \text{CO}
\end{align*}
\]
The azocompds differ markedly from the diazocompds. The latter also contain doubly linked nitrogen atoms but they are attached to the same carbon atom, as represented by the characteristic diazo structural formula, >C=N=N or >C=N=N. As a group, azo compds are more stable and less reactive than the diazo derivs.

Azo compds may be divided into the following classes:

a) Aliphatic – in which both radicals are aliphatic
b) Mixed – in which one radical is aliphatic and the other aromatic
c) Aromatic – in which both radicals are aromatic
d) Hydroxy – aromatic compds contg a hydroxyl substituent and
e) Amino – aromatic compds contg an amino substituent

The last two classes include the largest group of synthetic org compds known, the azo dyes. The aromatic azocompds (class c, above) which are all colored solids, ranging from red to violet, are the most important to the expl industry.

Aromatic azocompds can be prepd by:

a) Reduction of aromatic nitro derivatives in alkaline soln

$$\phi \cdot \text{NO}_2 \overset{\phi \cdot \text{NH} \cdot \text{NH} \cdot \phi}{\text{Alkali}} \rightarrow \phi \cdot \text{N} \cdot \text{N} \cdot \phi$$

b) Oxidation of the corresponding hydrazo compd

$$\text{Ar} \cdot \text{NH} \cdot \text{NH} \cdot \text{Ar} \rightarrow \text{Ar} \cdot \text{N} \cdot \text{N} \cdot \text{Ar}$$

c) Condensation of an amine with a nitroso compd

$$\text{Ar} \cdot \text{NO} + \text{H}_2\text{N} \cdot \text{Ar} \rightarrow \text{Ar} \cdot \text{N} \cdot \text{N} \cdot \text{Ar}$$

These compds can be oxidized by peracetic acid to azoxy compds. They are easily reduced, first to hydrazo compds and then to two primary amines. Azo compds are unaffected by aqueous acids and alkalies. They are sol in concd HCl or HF acids and compds can be obtd from these solns which contain the acid
LIST OF AZOCOMPOUNDS

Azoaminobiphenyl. See Azobis(p-aminobiphenyl)

Azo-aminotetrazole or 5-Azo-5'-aminotetrazolyl. See Di(tetrazolyl-5):N',N'-triazene

Azoaniline; Azobisaniline or Azodianiline, H2N-C6H4-N::N-C6H4-NH2, mw 212.25, N 26.40%.
Three isomers: o,o', m,m' and p,p' are described in Beil 16, 303,305,334(309,319) 
& [148,149,174]. There are also isomers, diaminoazobenzenes, C6H5-N::N-C6H4(NH2)2.
They are described under D

No azido-, diazido-, nitro-, dinitro-, etc derivs of azoaniline were found in Beil or CA through 1956, but there exist nitrated comds of diaminoazobenzenes

AZOANISOLE AND DERIVATIVES

Azoanisole or Azobisanisole (called Dimethoxy-azobenzol in Beil), C6H5-O-C6H4-N::N-C6H4-O-CH3, mw 242.27, N 11.56%.
Three isomers are described in the literature: o,o'-Azoanisole (Ref 1); m,m' - Azoanisole (Ref 2) and p,p'- Azoanisole (Ref 3). The nitro derivs of Azobisanisole may be of interest as expl ingredients


Dinitroazoanisole or 4,4'-Azobis(3-nitroanisole), C6H5-O-C6H4(NO2)-N::N-(NO2)C6H4-O-CH3, mw 332.27, N 16.86%.
Bright orn prisms (from nitrobenzene), mp 2590. It was prepd by diazotizing 3-nitro-p-anisidine, O2N(CH3)OC6H4NH2, and treating the diazonium soln with aq CuOH. This action yielded 2,2'-dinitro-p,p'-bisanisole and a considerable amt of the azobisnitroanisole obtained from the acetic acid insol residue. See also Ref 2 for prepn by oxidation of 4-methoxy-2-nitroaniline


Tetranitroazoanisole, CH3-O-C6H4(NO2)2-N::N-(NO2)C6H4-O-CH3, - not found in Beil or CA through 1956

Hexanitroazoanisole or 3,3'-Azobis-(2,4,6-trinitroanisole) (called 2,4,6.2'.4'.6'-Hexanitro-3,3'-dimethoxy-azobenzol in Ger),
CH3-O-C6H(NO2)2-N::N-C6H(NO2)4-O-CH3; 
mw 512.28, N 21.88%; dk red-yel cryst (from AcOH) or red-bn cryst (from MeOH), mp 126-70, explodes on strong heating; easily sol in glacial acetic acid, sol in cold alc or eth, insol in w. It was prepd by nitration of m,m'-azonoisole with KNO3 and concd H2SO4

Refs: 1)Beil 16, [38] 2)K.Elbs & O.H. Schaaf, JPraktChem 120, 2,3 & 11(1928) & CA 22, 4508(1928)

Azobenzaldehyde; Azobisbenzaldehyde or Azobisbenzaldehyde, OHC-C6H4-N::N-C6H4-CHO, mw 238.24, N 11.76%. Two isomers are described in the literature: m,m' - orn-colored plates, mp 1500 and p,p'-, red-orn crysts, mp 237-90. No azido-, diazido- and nitrated derivs were found in Beil or CA through 1956

Ref: Beil 16, 209-10

AZOBENZENE AND DERIVATIVES

Azobenzene; Azobenzene or Diphenyldiimide (also called Benzeneazobenzene in CA), C6H4-N::N-C6H4; mw 182.22, N 15.37%.
OB to CO2 -254.68%; onn monoclinic crysts, mp 680; bp 2970 and d 1.203 at 200 40°; Oe 1544.6 kcal/mol (Ref 4); Temp of Expln 540° (Ref 3); Vapor Press at various temps (Ref 9); sl sol in eth, ligroin & alc (4.2 g in 100 g alc at 20°). Azobenzene is quite toxic to animals (Refs 6 & 8) but its effect on humans is not known (Ref 10). It can be prepd by reduction of nitrobenzene with Na stannite, Fe in aq NaOH or by other methods (Ref 1). The industrial prepn is described in Ref 7

There are many other references in the literature on the physical & chemical props of azobenzene

Azobenzene was used in France in "Cheddite" type expls (Ref 2)
Cheddite Type Explosives

<table>
<thead>
<tr>
<th>Composition</th>
<th>1 (%)</th>
<th>2 (%)</th>
<th>3 (%)</th>
<th>4 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azobenzene</td>
<td>11.17</td>
<td>13.89</td>
<td>7.68</td>
<td>17.5</td>
</tr>
<tr>
<td>KClO₃</td>
<td>66.66</td>
<td>66.66</td>
<td>79.12</td>
<td>-</td>
</tr>
<tr>
<td>NaClO₃</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>75.0</td>
</tr>
<tr>
<td>Azobenzene picrate</td>
<td>16.61</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NG</td>
<td>2.78</td>
<td>13.89</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Castor oil</td>
<td>2.78</td>
<td>2.78</td>
<td>1.10</td>
<td>7.5</td>
</tr>
<tr>
<td>Dinitrocellulose</td>
<td>-</td>
<td>2.78</td>
<td>1.10</td>
<td>-</td>
</tr>
<tr>
<td>Mononitrobenzene</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11.00</td>
</tr>
</tbody>
</table>

It was also proposed as a sensitizer for AN expls (Ref 5). Many of the salts and other derivs of azobenzene are expl (see below).


4-Azidoazobenzene, N₃C₆H₄N:N:C₆H₄; mw 223.23, N 31.38%; it yields needles (from dil alc), mp 91-93°C, sol in most org solvents; can be prepd by treating diazotized 4-aminoazobenzene with NaN₃ soln. Its explosive properties were not investigated.


Azobenzene Addition Compounds and Salts

Azobenzene-Dipotassium Hydroazobenzene, C₆H₄·N:N·C₆H₄·C₆H₄·NK·NK·C₆H₄; dk violet crysts; prepd from azobenzol and 4-phenyl benzophenone K salt in ether. It is readily oxidized in air to form azobenzene. This compd is probably very unstable although no expl props are given.

Refs: 1) Beil 16, (220) 2) W. Schlenk et al, Ber 47, 485(1914) & CA 8, 1580-1(1914)

Azobenzene Nitrate, C₆H₄·N:N·C₆H₄·HNO₃; red crysts, very unstable.


Azobenzene Perchlorate, C₆H₄·N:N·C₆H₄·HClO₄; yel plates with bluish tinge; explodes ca 208°C; easily hydrolyzed.

Refs: 1) Beil 16, (219) 2) K. A. Hofmann et al, Ber 43, 1083(1910) & CA 4, 2464(1910)

Azobenzene Picrate, C₆H₄·N:N·C₆H₄·H₂O; yel needles (from 65°C); sol in alc; hot plates; explodes on strong heating (Refs 1 & 3). It was used in some “Cheddite” type composite expls in France (See under Azobenzene).


Azobenzene-1,3,5-Trinitrobenzene, C₆H₄·N:N·C₆H₄·2C₆H₄(NO₂)₃; or plates, explode on strong heating; sol in alc, eth, & benz.

Refs: 1) Beil 16, (219) 2) K. A. Hofmann & H. Kirmreuther, Ber 43, 1767(1910) & CA 4, 2801(1910)

Azobenzene-2,4,6-Trinitrotoluene, C₆H₄·N:N·C₆H₄·2CH₃·C₆H₄(NO₂)₃; crysts, mp ca 65°C, explodes on strong heating.


Nitroso and Nitrocompounds of Azobenzene

Monoazirazoazobenzene, C₆H₄·N:N·C₆H₄·NO₂; mw 227.22, N 18.49%, OB to CO₂ at 186.6°C; three isomers are described in the literature.

2-Nitroazobenzene. Blood-red crysts (from alc or eth), mp 105-6°C; readily sol in chlf, benz, hot alc, hot ligroin & hot glacial acetic acid.

Refs: Beil 16, 50-1 & [16]
3-Nitroazobenzene. Orn-red ndls (from alc); mp 95.5-96° (sinters ca 94°, prior to melting; readily sol in hot alc, hot ligroin & hot glacial acetic acid

Ref: Beil 16, 52 & [17]

4-Nitroazobenzene. Reddish-orn lfts or ndls (from ligroin), mp 135°; readily sol in chl, acet, benz, hot alc, hot ligroin & hot glacial acetic acid and very sl in cold ligroin

Ref: Beil 16, 54, (226) & [17]

Nitrosonitroazobenzene (called 2-phenyl-5-nitro-benztriazol-1-oxyd in Ger), $C_8H_4\cdot N\cdot N\cdot C_6H_4(NO)\cdot (NO_2)$; mw 256.22, N 21.87%; yel ndls, mp 175°; its sublimate melts at 160°. It was obtd by heating 2,4-dinitrohydrazo- benzene with glacial acetic acid


Dinitroazobenzene, NO$_2$-$C_8$H$_4$-$N\cdot N\cdot C_6$H$_4$-$NO_2$; mw 272.22, N 20.58%, OB to CO$_2$ -141.0%; five isomers are described in the literature:

2,2'-Dinitroazobenzene. Yel crysts (from toluene), mp 209-10°; readily sol in hot glacial acetic acid or toluene, diffic sol in ether, petr eth, alc or carbon tetrachloride

Ref: Beil 16, 51, (225) & [16]

3,3'-Dinitroazobenzene. Orn ndls, mp 153°; 100 g alc dissolves 0.1 g at 15° and 2.2 g in boiling alc, 100 g ether dissolves 0.5 g at 15° and 0.8 g in boiling eth, 100 g benz dissolves 3.8 g at 15° and 36.4 g in boiling benz

Ref: Beil 16, 52 & [17]

2,4'-Dinitroazobenzene. Orn-red lfts (from alc), mp 131-2°,

Ref: Beil 16, 54

4,4'-Dinitroazobenzene. Orn-red ndls (from xylene) & scarlet ndls (from glacial acetic acid) mp 222-3°, readily sol in hot glacial acetic acid, moderately sol in hot acet, 100 g benz dissolves 1.8 g at 15° and 5.2 g in boiling benz; nearly insol in eth, petr eth and cold alc

Ref: Beil 16, 54, (226) & [17]

2,4-Dinitroazobenzene, (NO$_2$)$_2$-$C_8$H$_4$-$N\cdot N\cdot C_6$H$_4$; red ndls (from alc) mp 116-9°, prepbd by reacting yel mercuric oxide with a hot alcohol soln of 2,4-dinitro-hydrazobenzene.

Treatment with fuming nitric acid gives, according to the extpl conditions, either 2,4,4'-trinitro-azoxybenzene or 2,4,4'-trinitro-azoxybenzene

Ref: Beil 16, 58

Nitrosodinitroazobenzene (called 2-phenyl-4,6-dinitro-benztriazol-1-oxyd in Ger), $C_8$H$_4$-$N\cdot N\cdot C_6$H$_4(NO)\cdot (NO_2)$; mw 301.22, N 23.25%; golden-yel lfts, mp 249-50°; prepbd by boiling picrylhydrazobenzene with alc or acetic acid. According to Freund (Ref 3) this compd is identical with the dinitrosoazobenzene (qv) of Willgerodt & Ferko (Ref 2) to which the formula $C_{12}H_7N_4O_4$ had been erroneously assigned


Dinitrosoazobenzene, (ON)-$C_8$H$_4$-$N\cdot N\cdot C_6$H$_4$-(NO); mw 210.33, N 19.98%; wh crysts, mp - sublimes at 140° and melts at 178°. It can be prepbd by heating 2,4-dinitrochlorobenzene with phenylhydrazine and alc in a sealed tube at 120-30° or by heating nitrosohydrobenzene with alc and also by mixing a soln of phenylhydrazine hydrochloride in dil alc with caustic alkali and adding an alcoholic soln of 2,4-dinitrochlorobenzene


Dinitrosonitroazobenzene, $C_8$H$_4$-$N\cdot N\cdot C_6$H$_4(NO_2)$; mw 285.22, N 24.56%; golden-yel scales, mp 247.5° prepbd by boiling picrylhydrazide with acetic acid, strong HCl or dil $H_2SO_4$ for a short time. A subst of brownish color, melting at 145°, was also formed (See Nitrosodinitroazobenzene)

Refs: 1)Beil - not found 2)C.Willgerodt & M.Ferko, JPraktChem 37, 345(1888) & JCS 54 II, 829(1888)
Trinitroazobenzene, C$_{12}$H$_4$N$_2$O$_6$; mw 317.22, N 22.08%, OB to CO$_2$ -108.5%; five isomers are described in the literature:  

2,4,2'-Trinitroazobenzene, (NO$_2$)$_2$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); red ndls or plates (from benz), mp 173°; readily sol in hot benz or chlf, sol in alc or acet, diffc sol in eth and insol in petr eth  

Ref: Beil 16, 58

2,4,3'-Trinitroazobenzene, (NO$_2$)$_2$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); red ndls or plates (from benz), mp 172-3°; sol in hot glacial acetic acid, benz or chlf  

Ref: Beil 16, 58

2,4,4'-Trinitroazobenzene, (NO$_2$)$_2$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); red ndls (from alc), mp 170-2°; readily sol in hot alc, eth, chlf, benz or glacial acetic acid  

Ref: Beil 16, 58

2,6,4'-Trinitroazobenzene, (NO$_2$)$_2$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); red-yel ndls (from chlf + alc), mp 168°; readily sol in glacial acetic acid or chlf, diffc sol in alc or eth  

Ref: Beil 16, (227)

2,4,6-Trinitroazobenzene, (NO$_2$)$_2$C$_6$H$_4$-N:N-C$_6$H$_4$; dk-red prisms (from alc), mp 142°; readily sol in chlf or benz and diffc sol in hot alc; prep'd by reacting yel mercuric oxide with a hot alcoholic soln of 2,4,6-trinitrohydrazobenzene  

Ref: Beil 16, 59

Tetranitroazobenzene, C$_{12}$H$_4$N$_4$O$_8$; mw 362.22, N 23.20%, OB to CO$_2$ -83.9%; two isomers are described in the literature:  

2,4,2',4'-Tetranitroazobenzene, (NO$_2$)$_4$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); pale orn ndls (from acet + alc) or orn colored tablets (from glacial acetic acid), mp 220-2°; readily sol in benz, chlf or glacial acetic acid; diffc sol in alc or ether; the alc or acetone soln turns blue on treatment with caustic soda soln. Green & Rowe (Ref 2) prep'd this compd both by nitration of 2,2'-dinitroazobenzene with mixed nitric-sulfuric acid and by oxhd of 2,4-dinitroaniline in tetrachloroethane soln with an aq soln of hypochlorite. Elderfield et al (Ref 3) investigated the latter method and found that the yields were low (40% max) in small runs and even lower in larger runs  

Ref: 1)Beil 16, 59 & (227) 2)A.G.Green, JCS 101, 2450(1912) 3)R.C.Elderfield et al, OSRD Rpt No 158(1941) or PBL Rpt No 31094(1941), 25

2,4,6,4'-Tetranitroazobenzene, (NO$_2$)$_4$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); orn-yel ndls (from concd HNO$_3$), mp 163-4; diffc sol in alkalies, turning the soln red. Ciussa (Ref 2) prep'd this compd by treating the dipotassium salt of 2,4,6,4'-tetranitrohydroxazobenzene, C$_{12}$H$_4$O$_6$N$_6$K$_2$, with concd nitric acid  

Ref: 1)Beil 16, 59 & (227) 2)R.Ciussa, Atti Accad. Lincei Rend 18 II, 66(1909) & CA 4, 1740(1910); Gazz 41 I, 694(1911) & CA 5, 3804(1911)

Pentanitroazobenzene, C$_{12}$H$_4$N$_5$O$_{10}$; mw 407.22, N 24.08%, OB to CO$_2$ -64.8%; one isomer is described in the literature:  

2,4,6,2',4'-Pentanitroazobenzene, (NO$_2$)$_5$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); orn colored ndls (from glacial acetic acid; mp 213°, explodes on heating above its mp; readily sol in acet, ethyl acetate or nitrobenzene; diffc sol in alc, eth or benz. It was prep'd by heating an acetonic soln of 2,4,6,2',4'-pentanitrohydroxazobenzene, [(NO$_2$)$_2$C$_6$H$_4$-NH-NH-C$_6$H$_4$-(NO$_2$)$_4$], with an excess of lead peroxide for ½ hr  

Ref: 1)Beil 16, 60 2)H.Leemann & E.Grandmougin, Ber 41, 1307(1908) & CA 2, 2257(1908)

Hexanitroazobenzene, C$_{12}$H$_4$N$_6$O$_{12}$; mw 452.22, N 24.78%, OB to CO$_2$ -49.5%; one isomer is described in the literature:  

2,4,6,2',4',6'-Hexanitroazobenzene, (NO$_2$)$_6$C$_6$H$_4$-N:N-C$_6$H$_4$(NO$_2$); blood-red prisms (from NB, glacial acetic acid or concd HNO$_3$); mp 215-6°; diffc sol in eth, alc or benz. It can be prep'd by oxhd of 2,4,6,2',4',6'-hexanitrohydroxazobenzene with HNO$_3$ (d 1.3) or N oxide gases (obtd from HNO$_3$ and As$_2$O$_3$) in glacial acetic acid soln. The
hexanitrohydrazobenzene can be obtd by treating picryl chloride, (NO₂)₂-C₆H₄·Cl, with hydrazine, H₂N-NH₂, or in two stages:

a) by suspending a mixt of dinitrochlorobenzene, (NO₂)₂-C₆H₄·Cl, with hydrazine in hot w contg Na or Ca carbonate to form tetrannitrohydrazobenzene, (NO₂)₄-C₆H₄·NH·NH·C₆H₄(NO₂)₂
b) on treating the latter compd with concd HNO₃, two addnl NO₂ groups are introduced and the -NH·NH- group is oxidized to a -N:N- group

Hexanitroazobenzene is a very power-ful and brisant high expl. Its Power as measured by the Trauzl test is 113% PA or 123% TNT and its Impact Sensitivity is between that of tetryl and PA; the FI value is 67% PA. According to Davis (Ref 3) this expl is suitable for boosters and compound detonators. The presence of the azo group in hexanitroazobenzene makes it more power-ful and brisant than hexanitrodiphenylamine (qv)

Refs: 1)Beil 16, 60 2)E.Grandmougin & H.Leemann, Ber 39, 4385(1906) & CA 1, 861 (1907); Ber 41, 1295(1908) & CA 2, 2256-7 (1908) 3)Davis(1943), 189-90 4)A.H.Blatt, OSRD 2014(1944)

AZOBENZENEDIAZONIUM DERIVATIVES

Azobenzene-4-diazonium Chloride, C₆H₄·N:N·C₆H₄·NO₂Cl; mw 244.68, N 22.90%; orn prismatic crysts, mp dec; explodes when touched with a red hot rod; sol in w, sl sol in alc. It can be prepd by several methods, one of which is diazotization of p-aminobenzene with NaNO₂ in HCl (Refs 1,3&4)

Azobenzene-4-diazonium Dichromate, [C₆H₄·N:N·C₆H₄·NO₂]₃Cr₂O₇; mw 624.47, N 17.94%; yel solid, mp explodes ca 134°. It can be prepd by treating azobenzene-4-diazonium chloride with K dichromate (Refs 2 & 3)

Azobenzene-4-diazonium Hydroxide, C₆H₄·N:N·C₆H₄·N(N)OH; known only in soln and in the form of salts, many of which are expl. One expl deriv of the hydroxide is the compd called anhydro-(4-hydroxybenzene-3-carboxylic acid-4'-diazonium hydroxide) (qv)

An isomer of the hydroxide, called azobenzene-4-isodiazohydroxide, C₆H₄·N:N·C₆H₄·Ni(NO₂)₂; is known only in the form of its sodium salt (Ref 1)


AZOBENZENECARBOXYLIC ACIDS AND DERIVATIVES

Azobenzencarboxylic Acid or Benzene-

Azobenzoic Acid, C₆H₄·N:N·C₆H₄·COOH, mw 226.23, N 12.38%. Three isomers: o-, m- and p- are described in Beil 16, 225,229, 235,(287,289) & [97-8]

Nitrobenzenecarboxylic Acids, C₆H₄NO₃, mw 271.23, N 15.49%. Various isomers are described in the literature, but none of them seems to be expl

Refs: 1)Beil 16, 238 2)L.Chardonnens (1907); Ber 41, 1295(1908) & CA 2, 2256&7 3)Davis(1943), 189-90 4)A.H.Blatt, OSRD 2014(1944)

Note: No higher nitrated derivs of azobenzene-

Azobenzencarboxylic Acid as well as azido- and diazido-

compds were found in Beil or CA through 1956

Azobenzenedicarboxylic Acids. See Azobenzoic Acids

AZOBACKEIOIC ACIDS AND DERIVATIVES

Azobenzoic Acid; Azodibenzoic Acid or

Azobenzenedicarboxylic Acid, HOOC-·C₆H₄·N:N·C₆H₄·COOH, mw 270.24, N 10.37%. Three isomers: o,o'-, m,m' - and p,p'- are described in Beil 16, 228,232,233,236 & (287). Of these only the para-isomer is of interest because its nitro- and dinitro- derivs form expl salts (see below)

Azobenzene-4,4'-dicarboxylic Acid or p-

Azobenzoic Acid (called p,p'-Azobenzoesäure
in Gcr), HO₂C-C₆H₄-N-N-C₆H₄-COOH; mw 270.24, N 10.37%; orn or red crs; mp dec ca 330°, without melting. It can be nitrated to mono and dinitro-derivs (Ref 1, pp 236-7)

x-Mononitroazobenzene-4,4'-dicarboxylic Acid or Nitro-p-azobenzoic Acid, HO₂C-C₆H₄-N-N-C₆H₄(NO₂)-CO₂H; mw 315.24, N 13.33%; it yel platelets (from alc); mp dec ca 270°, without melting. Its silver salt, Ag₃C₆H₄N₂O₆, yel amor powd, insol in w, was reported to explode on heating (Ref 1s 1, p 236) & (2)

x,x'-Dinitroazobenzene-4,4'-dicarboxylic Acid or Dinitro-p,p'-Azobenzoic Acid, HO₂C-C₆H₄(NO₂)-N-N-C₆H₄(NO₂)-CO₂H; mw 360.24, N 15.55%; yel ndls (from alc); mp dec ca 257°, without melting. Beil (Ref 1, p 238) lists several of its salts without mentioning whether or not they are expl. Its silver salt, Ag₃C₆H₄N₂O₆, dk yel amor powd, insol in w, is undoubtedly an expl compd


Azobenzol. Same as Azobenzene

Azobis(p-aminobiphenyl) (called 4'-Azo-4-amino-biphenyl or Diaminoazobiphenyl in Ger), H₂N-C₆H₄-C₆H₄-N-N-C₆H₄-C₆H₄-NH₂, mw 364.43, N 15.38%; yel-red ndls (from benz), mp 287; sol in hot ac, hot benz or chlor; sl sol in eth and insol in w. Its prep and props are described in Refs 1 & 2. The chloride salt, (ClN₃C₆H₄C₆H₄N):, called azodiphenyl diazonium chloride by Willstätter & Kalb (Ref 2), prismatic crists with a violet lustre (orn-red when powd) expl at ca 95°

Refs: 1) Beil 16, 380 2) R. Willstätter & L. Kalb, Ber 39, 3480(1906) & CA 1, 300-1(1907)

Azobisanisole. See Azoanisole and Derivatives

Azobis(ethylenenitronitrate), O₂NO--O
CH₂CH₃N₂-C₆H₄-C₂H₅-ONO₂, mw 240.14, N 23.33%; mp 126-8° (after washing with petr eth). It was prepd by treating ethylene in CCl₄ & dioxane with nitrogen tetroxide at 0-10°

In a similar manner there were prepd: bis(propylenenitronitrate), [H₃C-CH(NO₂)-O]₂
CH₃N₂, mp 131-2°, from propylene and bis (amylennitronitrate) [H₃C₂-CH(NO₂)-]+
CH₃N₂, mp 102-4°, from amylene. He also claimed the prepn of bis(isobutylene) and bis(1-octene) derivs; no props are given

Because of their reactivity, these nitroso nitrates are useful in the prepn of compds contg OH, NH₂, COOH and NOH groups

Refs: 1) Beil – not found 2) J. A. Crowder, USP 2402315(1946) & CA 40, 6092(1946)

AZOBISFORMIC ACID OR AZODIFORMIC ACID AND DERIVATIVES

Azobisformic Acid; Azodiformic Acid or Azodicarboxylic Acid (called Diimiddicarbonsäure, Azoameisenäure or Azodicarbonsäure in Ger); HOOC-N-N-COOH, mw 118.05, N 23.75%. Its prepn and props are described in Beil. The potassium salt, K₂C₆N₂O₄, a yel powd, explodes when heated above 100°


Azobis(methylformate) or Azobisformic Acid, Dimethylester, H₂COO-N-N-COOCH₃, mp 122.08, N 22.95%; orn-yel oil, bp 96° at 25 mm; explodes on rapid heating. It can be prepd by treating the dimethylester of hydrazodicarboxylic acid with fuming nitric acid

Refs: 1) Beil 3, (58) & [97-8] 2) O. Diels & P. Fritzsche, Ber 44, 3026(1911)

Azobisformamide or Azodicarboxamide (called Azodicarbonäurediamid or Azodicarbonamid in Ger), H₂N-CO-N-N-CO-NH₂, mw 116.08, N 48.27%; orn prismatic ndls, mp 225-30°
A652

(dec depending on rate of heating); Picard & Boivin (Ref 4) reported a mp of 180° with decomp; \( Q_c (av) \) 254.83 kcal/mol (Ref 5) Qt 69.91 (Ref 5). It was prep'd by oxidig hydrazodicarboxamide, \((NHCONH)_2\), with \( K_2CrO_7 \) in dil \( H_2SO_4 \). This compd when heated with aniline-HCl to 220° gives 4-phenylurazole, mp 202-3° (Ref 3).


Azobisformamidine or Azodicarboxamidine (called Azoformamidin Azodicarbosläure-diamidin or Azodicarboxamidin in Ger), \( H_2N:C(:NH)-N:N-C(:NH)-NH_2 \), mw 114.12, N 73.65%. Its prep'n and props are described in Refs. Some of its salts are explosive. The dinitrate, \( C_6H_4N_4+2HNO_3 \), yel platelets (from warm w) explodes at 180-40° without melting. It can be prep'd by treating a nitric acid soln of aminoguanidine nitrate with an suitable solvent (Ref 1a). Some of its salts are explosive. (from EtOAc) (Ref 2) and

73.65%)

\( \text{Dinitrate}, C_6H_4N_4+2HNO_3 \), yel platelets (Ref 2); tri ethylacetyl acetate is a

8) sols in w at 1q-150, 20⁰-280, 40⁰ 610 and 61⁰-1490 mg/l and in many org solvs was detd (Ref 2); triethylacetaceta is a

suitable solvent (Ref 9); insol in dil alkali (Ref 8); its toxicity and expln hazards are discussed by Sax (Ref 11).

Azobischloroformamidine was first prep'd in 1934 by Schmelkes & Marks (Refs 2 & 3) by careful chlorination of azodicarboxamidine or hydrazodicarboxamidine with NaOCl or Cl gas. Braz et al (Ref 5) and Takagi et al (Ref 6) prep'd this compd by converting guanidine nitrate into nitroguanidine, reducing it to amino guanidine, oxidig to azodicarboxamidine, \( [\text{N:C(NH)}]_3 \), and finally chlorinating with NaOCl. Braz et al obtd a 42-5% yield of prod, 96-8% pure, melting at 146-7° while Takagi obtd yel ndls decomp at 155°.

Explosive and other props of a pure sample were detd at PicArsn in 1936 by Aaronson (Ref 4):

\( \text{Brisance (using tetryl and MF as initiator)} \)

29.7 g sand crushed vs 43g for TNT

\( \text{Explosion Temp, °C (5 sec)} \) 183°
Hygroscopicity at 31°C and 90% RH 0.10%

Ignitibility by flame–flame of match causes burning at point of contact but does continue to propagate flame

Sensitivity to detonation—not deton by spbt of BkPdr fuse, 0.4 MF in a No 6 blasting cap caused only partial deton

Sensitivity to impact 5" vs 14" for TNT (2 kg wt)

Solubility at 25° g/100 g solvent
- water 0.03
- alcohol 1.25
- ether 0.4
- acetone 4.0

Stability Tests:
- 65.5° KI Heat test 4 min
- 100° Heat test
  - % Loss 1st 48 hrs 47.7
  - % Loss 2nd 48 hrs 47.9
- 120° Vac Stab test 11° cc in 3 hrs

Azobischloroformamidine is sensitive to expln by impact and has a fairly high brisance value but due to its poor stability at elevated temps, it appears unsuitable for use in military expls

Kumler (Ref 10) detd the dipole moment, UV & IR spectra and structure of azobischloroformamidine; Wright (Ref 8) studied its X-ray diffraction pattern

Most of the studies reported in the literature have been directed to the antiseptic, disinfectant, dosage or sterilizing action of azobischloroformamide. Galvin (Ref 7) froze the compd with H₂O into a cake, sheet or film for application as a disinfectant or germicidal agent


Azobis(ethylformamide) or Azodicarboxyethylamide (called Azodicarbonsäure-bisäthylamid in Ger), H₄C₂N₂H₂CO.N₂H₂CO.N₂H₂C₂H₄, mw 172.19, N 32.54%; orn-red lfts, mp 133°. Its silver salt, AgCH₂N₂O₄, -red- % Los ls 48 his_19 yel powd, explodes mildly ca 144g. It was 120 Vac Stab tests &3, h prepd by the action of ammoniacal AgNO₃ on azodicarboxyethylamide in alc

Refs: 1) Beil 4, (354) & [609] 2) O. Diels & E. Ingold, JACS 46, 2000-7(1913)
Q_{activation} 34 kcal/mol (Ref 4); Q_c 1217 kcal/mol and Q_{f} 54.63 kcal/mol (Ref 6). This compd was first prep'd in 1896 by Thiele & Heuser (Refs 1 & 2) on treating a cold soln of hydrazoisobutyronitrile with Br_2 water in HCl. Rohm & Haas (Ref 7) obtd a patent for the simple and inexpensive prep'n of this compd and related derivatives from the reaction of Na, Ca or alkyl hypochlorites on the corresponding amino compd. Thus, by adding (CH_3)C(NH_2)CN with stirring at 5-10\(^\circ\) to a soln of NaOCl and pptg with H_2O, \(\alpha,\alpha\)-azobisbutyronitrile was prep'd.

Carlisle (Ref 3) reported an expln occurred when its soln in acet was concd in a glass-lined steam jacketed vessel. The cause of this expln was not detd but examination of the subst showed that it was slightly flammable but did not explode when unconfined. Therefore, on heating in a closed system a pressure release valve should be provided.

On heating azobis-isobutyronitrile in water, gas is evolved and there is formed tetramethylsuccinonitrile, mp 170\(^\circ\) (Refs 2 & 7). This decompn of azobisisnitriles, as shown by Thiele & Heuser (Ref 2) is a convenient synthetic method for obtg tetrasubstituted succinonitriles. Three new such compds, decomp products of azonitriles, were prep'd and characterized by Overberger et al (Ref 4).

Azobisisobutyronitrile is reported useful as a blowing agent for the production of polymer foams and as a polymerization catalyst (Refs 4 & 7). The tetramethylsuccinonitrile product of its decompn is toxic (Ref 5).


**3,3\(^{\prime}\)-Azobis-(4-methyl) furazan** (called 4,4\(^{-}\)-Dimethyl-[3,3\(^{-}\)-azo-1,2,5-oxadiazol or 4,4\(^{-}\)-Dimethyl-3,3\(^{-}\)-azofurazan in Ger),

\[
\text{H}_3\text{C}-\text{C}--\text{C}:\text{N}--\text{N}--\text{C}--\text{C}--\text{H}_3
\]

\[
\text{N}--\text{O}--\text{N} \quad \text{N}--\text{O}--\text{N}
\]

mw 194.16,

N 43.29%; orn-yel lfts, mp 107\(^\circ\); sol in common org solvs, insol in w. It can be prep'd by treating methylaminofurazan, H_3C:C=N:ON-N:C=NH_3 in 30\% H_2SO_4 with dry K_MnO_4 at 60-70\(^\circ\).

**Refs:** 1)Beil 27, [866] 2)G. Ponzio & G. Ruggeri, Gazz 53, 304 (1923) & CA 17, 3873-4 (1923)

**5,5\(^{\prime}\)-Azobis-(3-propyl-sym-triazole) or 3.3\(^{-}\)-Dipropyl-5,5\(^{\prime}\)-azo-1,2,4-triazole,**

\[
\text{N}--\text{C}:\text{N}--\text{C}--\text{N}--\text{C}--\text{N}--\text{N}--\text{C}:\text{N}--\text{C}--\text{N}--\text{C}--\text{C}--\text{H}_3\]

\[
\text{C}_2\text{H}_5 \cdot \text{CH}_2 \cdot \text{C}=\text{N}--\text{NH} \quad \text{HN}--\text{C}--\text{CH}_2 \cdot \text{C}--\text{H}_3
\]

mw 248.29, N 45.13%; pale yel crysts; mp dec without melting; easily sol in alk and repptd by weak acids; sol in concd H_2SO_4, giving a yel soln, and pptd by w. It was prep'd by oxidg 5-amine-3-n-propyl-1,2,4-triazole with KMnO_4 in alk soln. Reduction of azobispropyltriazole with SnCl_2 in acid soln gave a col soln of the hydrazo-compd which easily reverted to the azo-compd on oxidn.

From a concd soln of chloroauric acid and diazotized aminopropyltriazole, there was separated: 5-diazo-3-n-propyl-1,2,4-triazole chloroaurate, [(C_2H_5N=CH_2Cl)_2H_2O], which darkened on heating and melted at 135\(^\circ\) (dec) and 5-diazo-3-isopropyl-1,2,4-triazole chloroaurate, [C_2H_5N=CH_2Cl], as a yel ppt, stable at RT but exploded violently on heating and decomp in warm alc soln.

**Refs:** 1)Beil 26, [190] 2)J. Reilly & P. J. Drumm, JCS 1926, 1733 & 1735 & CA 20, 3293-4 (1926)

**Azobis-(stilbene). See Azostilbene and Derivatives**

**Azobutylonitrile. See Azobis-(isobutyronitrile)**

**Azoderivatives of Eulite. See under Eulite and Derivatives**

**Azodicarboxamide. See Azobisformamide under Azobisformic Acid and Derivatives**
Azodicarboxamide. See Azobisformamidine under Azobisformic Acid and Derivatives.

Azodicarboxyethylamide. See Azobisethylformamide under Azobisformic Acid and Derivatives, p A653

Azodicarboxyhydrazide (called 4-Amino-3,5-dioxo-1.2.4-triazolin in Ger), \( \text{O} = \text{C} - \text{N} - \text{NH}, \)
mw 114.07, N 49.12%; violet powd, very unstable, exploding ca 72°.

Refs: 1)Beil 26, (64-5)  2)R.Stoll, Ber 45, 288(1912) & CA 6, 1005(1912)

Azodicarboxylic Acid. See Azobisformic Acid, p A651

Azodicarboxymethylamide. See Azobismethylformamide under Azobisformic Acid and Derivatives, p A653

Azodiformic Acid. See Azobisformic Acid and Derivatives

Azodimethylbenzene. See Azoxylene and Derivatives

Azodiphenylidiazonium Chloride. See under Azobisaminobiphenyl

Azoethane(called in Ref 3 Azobisethane), \( \text{C}_4 \text{H}_6 \cdot \text{N} = \text{N} - \text{CH}_2, \)

mw 86.14, N 32.53%. Col liq, bp 58°, \( \rho \) 1.3852 at 20°. Can be prepd from 1,2-diethylhydrazine (Ref 3) or its dihydrochloride (Ref 2). Its expl props were not examined.


Azoformic Acid. See Azobisformic Acid and Derivatives

Azomide. Same as Hydrazoic Acid (qv).

See under Azides, Organic

3,3'-Azoinazole (called Indazolylidenediazenyliden-hydrazin in Ger), \( \text{C}_4 \text{H}_6 \text{N}_4 \).

Three structural formulae are given in Beil mw 262.27, N 32.05%; dk-red brn crys, with green luster (with 1 \( \text{C}_4 \text{H}_6 \text{O} \) from alc); mp 229.5°; sol in alc or chlf; diff sol in common org solvs and in w. Its prepn and props are described in Refs

Refs: 1)Beil 24, 141  2)E.Bamberger et al, Ann 305 347(1899) & Ber 39, 427(1906)

Azomethane (called Dimethyldiimid in Ger), \( \text{H}_3 \text{C} - \text{N}: \text{N} = \text{CH}_2, \)

mw 58.08, N 48.23%; OB to \( \text{CO}_2 \) -192.8%; col gas which can be liquefied and then solidified at -78° to col leaflets; bp 1.5° at 751 mm, d of liq 0.744 at 0°/15°. This compd can be prepd by the action of \( \text{HNO}_3 \) on \( \text{N}, \text{N}': \text{dimethylhydrazine}, \text{H}_3 \text{C} - \text{H} \cdot \text{N}: \text{N} = \text{CH}_2, \) or by other methods (Refs 1,3 & 6). Its expl props have been reported by Allen & Rice (Ref 3)

The thermal expln of gaseous azomethane (Ref 3) occurs in accordance with the Semenov theory of thermal explosions as described in Ref 2. This process was studied also by Taylor & Jahn (Ref 4)

Kodama et al (Ref 5) studied the reaction of azomethane with methanol at ca 300°, measured the press change and analyzed the reaction products resulting from the decomp


Azomethines or Schiff Bases. See under Aldehyde-Amine Condensation Products, pp A120-1

Azomethylenbenzene. See Azotoluene and Derivatives

Azomethylfurazon. See 3,3'-Azobis (4-methyl) furazan

AZONAPHTHALENE AND DERIVATIVES

Azonaphthale (called Azonaphthalin or Dinaphthyl-dimi-id in Ger), \( \text{C}_{19} \text{H}_{18} \cdot \text{N} = \text{N} - \text{C}_{19} \text{H}_{17}, \)

mw 282.33, N 9.92%. Three isomers are described in the literature: 1,1'- or \( \alpha, \alpha' \)- Azonaphthale (Ref 1); 1,2'- or \( \alpha, \beta \)- Azonaphthale (Ref 2) and 2,2'- or \( \beta, \beta' \)- Azonaphthale (Ref 3). The nitro derivs of
azonaphthalene may be of interest as expl
ingredients


Dinitroazonaphthalene or Azobis-(nitr-
obennaphthalene), C_{10}H_{4}(NO_{2})_2-N=N-C_{10}H_{4}(NO_{2})_2, mw 372.33, N 15.05%. Several dinitro-derivs are described in the literature:

1,1'-Dinitro-2,2'-azonaphthalene; orn-red rods
(from benz), mp 305-6 (Ref 8); yel ndls (from benz), mp 315° (Ref 7); prepd by oxidn of 1-nitro-2-naphthylamine with phenyl iodoso-acetate yielding also some naphthofurazan oxide

4,4'-Dinitro-2,2'-azonaphthalene (called
2,2'-azobis (4-nitronaphthalene in CA); brn-
red crysts, mp 315°. Prepd from the action of hydrazine in alc on 1-chloro-2,4-dinitronaphthalene, warmed 6 hrs on a w bath. The product was a mixt of the dinitro compd, the di-NH_{4} salt of 2,4-(C_{10}H_{4})(NO_{2})_2, m-nitro-
naphthylazimidole and some 2,4-dinitro
naphthalene. The reaction of anhyd hydrazine with 1-chloro-2,4-dinitronaphthalene gave only the 4,4'-dinitro-2,2'-azonaphthalene and 2,4-dinitronaphthalene (Refs 1 & 2)

2,2'-Dinitro-1,1'-azonaphthalene; orn-red
rods (from benz), mp 219°; prepd by oxidn of 2-nitro-1-naphthylamine with phenyl iodo-
osoacetate yielding also naphthofurazan, identical with the product obtd by oxidg 1-
nitro-2-naphthylamine (Ref 8)

3,3'-Dinitro-1,1'-azonaphthalene; red-brn ndls, mp 315°; sparingly sol in acet; in concd
H_{2}SO_{4} gave a Prussian-blue color which was
permanent for days, and changed to bright
yel on dilution with w; soln in aq NaOH gave
an intense emerald color; prolonged boiling
with alcoholic KOH produced a brn powdr.
It was prepd by the action of sodium sulfate on 3-nitronaphthalene-1-diazoacetate, previously obtd by diazotizing 3-nitro-1-
naphthylamine and treating the diazonium
chloride with aq sodium acetate (Ref 5)

4,4'-Dinitro-1,1'-azonaphthalene; red crysts
(from nitrobenz), mp 334° (Ref 4) to 310°
(from toluene) (Ref 6); sl sol in boiling
acetic acid to give a yel soln; sparingly sol in acet, boiling benz or chloro-
benz; almost insol in boiling alc; and gave
a bright blue color in concd H_{2}SO_{4} soln
which changed to bright yel on dilution with
water. It was prepd by the action of sodium sulfite on 4-nitronaphthalene-1-diazonium
chloride (or sulfate) (Refs 4 & 6)

5,5'-Dinitro-1,1'-azonaphthalene; yel-brn
ndls (from nitrobenz) orn-yell ndls (by subln),
mp 322-3° (Ref 3) & 280° (from toluene) (Ref 6);
sparingly sol in boiling alc, glacial
acetic acid or benz; the color in concd H_{2}SO_{4}
sln was reddish-violet, which changed to
yel on heating. It was prepd by the reaction of 5-nitro-1-naphthalenediazonium sulfate
with cuprous hydroxide (Refs 3 & 6)

Refs: 1)Beil 16, [26] 2)E. Müller &
K. Weisbrod, JPraktChem 111, 309(1925) &
CA 20, 750(1926) 3)H.H. Hodgson et al,
JCS 1942, 746 & CA 37, 1422(1943) 4)H.H.
Hodgson et al, JCS 1944, 16 & CA 38, 2030
(1944) 5)H.H. Hodgson & D.E. Hartway, JCS
1945, 452 & CA 39, 4863(1945) 6)B.M.
Bogoslovskii & Z.S. Kazakova, ZhObshchKhIm
22, 1183-6(1952) & CA 47, 6388(1953) 7)
G.B. Bartlin et al, JCS 1954, 3123 & CA 49,
11608(1955) 8)K.H. Pausker & J.G. Scroggie,
JCS 1954, 4502 & CA 49, 13226(1955)

Trinitro, C_{20}H_{11}N_{3}O_{6}, Tetranitro, C_{20}H_{10}N_{4}O_{6},
Pentanitro-, C_{20}H_{9}N_{5}O_{9} and Hexanitro-, C_{20}H_{8}N_{6}O_{12}, Derivatives of Azonaphthalene
were not found in Beil or in CA through 1956

AZOPHENETOLE AND DERIVATIVES

Azophenetole or 4,4'-Azodiphenetole (called
Diathoxy-azobenzol in Beil), C_{6}H_{4}·O·C_{6}H_{4}N·-
N·C_{6}H_{4}·O·C_{6}H_{4}, mw 270.32, N 10.36%. Several
isomers are described in the literature:
2,2'-or o,o'-azophenetol (Ref 1), 3,3'- or
m,m'-azophenetol (Ref 2), 4,4'- or p,p'-
azophenetol (Ref 3), 2,4'- phenetol (Ref 4)
and 3,4' phenetol (Ref 5). The nitro derivs
of azobisphenetol may be of interest as expl ingredients. No azido or diazido-derivs were found in Beil or CA through 1946


Dinitroazophenetole \([C_7H_4 \cdot O \cdot C_6H_4(NO_2)N]_2\), mw 360.32, N 15.55%. Two dinitro derivs are described in the literature: x,x'-Dinitro-2,2'-diethoxy-azobenzene; bright red-yel ndls (from chlf), mp 190°; sol in boiling alc. It was prep'd by nitrating o,o'-azophenetol with cold, fuming nitric acid. The expl props of the product were not examined (Ref 1)

5,5'-Dinitro-2,2'-diethoxy-azobenzene: brownish-red ndls (from chlf); mp 284-5°, sublimes without decompn; sol in cold chlf or cold benz; insol in boiling alc; dissolves without decompn with a yel-red color in cold concd H_2SO_4. It was obtd together with the x,x'-dinitro compd on nitrating o,o'-azophenetol

Ref: Beil 16, 92 & 94

Tetranitroazophenetol, \(C_{16}H_{4}O_{10}\), not found in Beil or CA through 1956

Hexanitroazophenetole (called 2,4,6,2',4',6'-Hexanitro-3,3'-diethoxyazobenzol in Ger), \([C_7H_4 \cdot O \cdot C_6H_4(NO_2)N]_2\); mw 540.32, N 20.74%, OB to CO_2 -71.1%; light orn ppt, which on recrystn from alc or glacial acetic acid gives dk red-yel to red crysts; mp 138-9°; easily sol in glacial acetic acid, cold alc, benz or eth; insol in w. Its prepn and props are described in Ref 2

Refs: 1)Beil 16, [38] 2)K. Elbs & O.H. Schaaf, JPrakChem 120, 2-14(1928) & CA 22, 4508(1928)

AZOPHENOL AND DERIVATIVES

Azophenol; Azodiphenol or Dihydroxyazobenzene (called Dioxy-azobenzol or Azophenol in Beil) HO-C_6H_4N-N-C_6H_4OH, mw 214.22, N 13.08%. Three isomers are described in the literature: o,o'-azophenol or 2,2'-dihydroxyazobenzol (Ref 1); m,m'-azophenol or 3,3'-dihydroxy-azobenzol (Ref 2) and p,p'-azophenol or 4,4'-dihydroxy-azobenzol (Ref 3). The nitro derivs of azobisphenol may be of interest as expl ingredients


Note: No azido- or diazido-derivs were found in Beil or CA through 1956

Mononitroazophenol, \(C_{12}H_{4}N_2O_4\), one isomer is listed in Beil 16, 96 and in CA 21, 1971 (1927)

Dinitroazophenol, \(C_{12}H_{4}N_2O_6\), the 3,3'-dinitro-4,4'-dihydroxyazobenzene isomer is described in Beil 16, (239) & [58] and in CA 34, 392 (1940). The 4,6-dinitro-3,4'-azodiphenol is listed in CA 15, 2844(1921)

Trinitroazophenol, \(C_{12}H_{4}N_3O_6\), not found in Beil but the p.p'-azodiphenol tetranitro deriv is listed in CA 34, 392(1940)

Tetranitroazophenol (called 3,5,3',5'-Tetranitro-4,4'-dioxyazobenzol in Ger), HO(NO_2)_2-C_6H_4N-N-C_6H_4(NO_2)_2OH; mw 394.22, N 21.32%; crysts (from glacial acetic acid), mp 261-2° with decompn (Ref 3). This compd was first prep'd by Robertson (Ref 2) by nitration of o-p-azophenol in acetic acid soln with a slight excess of HNO_3 in the same solvent. After recrystn from hot acetic acid, yel crystals melting sharply at 230° were obtd. Lauer et al (Ref 3) prep'd the compd by slowly adding dinitro-p-azophenol to fuming HNO_3, cooled in an ice-salt bath. On purifying the crude product by crystn from glacial acetic acid, crystals melting at 261° were obtd. The expl props of the product were not examined

Hart & Detroit (Ref 4) measured the dissocon constant of 3,5,3',5'-tetranitro-4,4'-dihydroxybiphenyl in methanol to detn the effect of NO_2 groups, ortho or para to the OH function, on the acidity of the compd

Jurisch (Ref 5) patented the use of 4,4'-dihydroxy-3,3'-dinitrobiphenyl or other o-nitrophenol-type dimers, trimers, etc, having recurring benzene nuclei contg OH & NO_2 groups in ortho position to each other for reducing Ca carbonate, Ca phosphate and Mg phosphate scales in steam boilers
Azopropane; Azobispropane; Azoisopropane; Azodipropene or Dimethylazethane (called 2,2'-Azopropane or Diisopropylidimid in Ger), C₆H₁₄N₂, mw 114.19, N 24.53%. Two isomers are described in the literature:

1,1'-Azopropane, H₃C·CH₂·CH₂·N·N·CH₃; CH₂·CH₃; pale yel liq, bp 104° (Ref 8) to 113.5° (Ref 10), np at 20° 1.4053 (Ref 10) to 1.4060 (Ref 8). This compd was prepd by oxidn of 1,2-di-n-propyldihydroazine by mercuric oxide in w.

2,2'-Azopropane, (H₃C)₂CH·N·N·CH(CH₃)₂; faintly straw-colored oil, nauseatingly sweet; bp 88.5°, d₄ at 23° 0.7408, nD at 20° 1.3899 (Ref 3); QP 1053.4 kcal/mol (Ref 7), Q activation 40.9 kcal/mol (Refs 4 & 11); insol in w, dil acid or alk, neutral to litmus (Refs 1 & 2). This compd is a powerful poison, especially injurious to the liver; and moderate red cell disintegration occurs from azopropane intoxication (Ref 3).

It was prepd by oxidn of 1,2-di-isopropylhydrazine·HCl with copper or mercurous oxide in water (Refs 2, 8 & 10); and is reduced by H & colloidal Pd to 1,2-diisopropylhydrazine. The thermal decompo of azopropane was studied by a number of investigators (Refs 4,5,6,9&11).

The expl props of this compd were not reported. No azido or nitro derivatives were found in the literature.
3,3'-Dinitro-p-azostilbene or Azobis (3-nitrostilbene), called in Ref 2: 3,3'-Dinitro-4,4'-distyryl-azobenzene, C₆H₅-CH:CH-CH(CH₃)₂-N=N-C₆H₄(NO₂)₂-CH:CH-C₆H₅; carmine-red crysts; mp 260-1°. Prepn and props are given in Ref 2

Refs: 1) Beil - not found 2)L. Chardonnens & P. Heinrich, Helv 23, 1405(1940) & CA 35, 2122(1941)

9,9'-Dinitro-p-azostilbene, called in Beil Bis-[4'-nitrostilbenyl-(4)]-diimid or [4'-Nitro-stilbene]-<₄azo->-[4'-nitro-stilben], (Q₉)N-C₆H₄-CH:CH-C₆H₄-N-N-C₆H₄-CH:CH-C₆H₄(NO₂); yel-red crysts; mp 263°. It is listed in Beil 16, 84 without reference to its source; was not found in CA through 1956

5,5'-Dinitro-o-azostilbene, called in Ref 2: 5,5'-Dinitro-2,2'-distyryl-azobenzene, C₆H₄-CH:CH-C₆H₄(NO₂)₂-N=N-C₆H₄(NO₂)-CH:CH-C₆H₄; brick red crysts, decmpg ca 265° with melting. Prepn and props are given in Ref 2

Refs: 1) Beil - not found 2)L. Chardonnens & P. Heinrich, Helv 23, 1414(1940) & CA 35, 2122(1941)

Note: No dinitro deriv of m-azostilbene was found in Beil or CA through 1956. No Azido-C₉H₈N₄; diazido- C₉H₈N₄, trinitro- C₉H₈N₈O₆, or tetranitro- C₉H₈N₈O₈ derivatives of o-, m- and p-azostilbenes were found in Beil or CA through 1956

Azotetrazole, C₅H₄N₆, mw 166.12, N 84.33%: 5,5'-Azotetrazole (called Di[tetrazolyl-(5)]-diimid in Ger);

NHN-C=N-N:CH=CH-C=N

According to Beil (Ref 1) this compd was not prepd in the free state but its prepn by Rathsburg (Ref 4) by oxidg aminotetrazole in alc solns with permanganate or persulfates is described in CA 17, 1147(1923). A diazotetrazole was prepd by diazotizing aminotetrazole.

The British abstract of the parent of Rathsburg (Ref 4) shows an azotetrazole with the structure:
A660

N—NH—C—N:—N—C=—N—N=N

which we call

tetrazolyl-5'-azo-1-tetrazolyl; but its method

of prepn is not given

Salts of azotetrazole were prepd in 1898
by Thiele (Ref 2) and claimed for use in
initiators, detonators and percussion caps by
Rathsburg (Ref 4) and von Herz (Ref 3). The
Ba, Ca, K Na and NH4 salts of azotetrazole
are described by Thiele (Ref 2) who noted
that all of these were expl, especially those
of the heavy metals, Ag, Hg & Pb. According
to Rathsburg (Ref 4) the more important salts
of azotetrazole are those of Cd and Pb. Imp-
act sensitivity tests showed that the Pb
salt fired once in six shots at 7 cm with a
100 g wt vs 12 cm for tech grade MF (Ref 5)

Blasting detonators proposed by Rathsburg
(Ref 4) contd a top charge of Pb azotetrazole
over Pb or Cd tetrazolyl azide over TeNMA

Derivs of azotetrazole are described in
Ref 6


Azidooazotoluene, C14H13N4; mw 251.28, N 27.28%

Three isomers are described in the literature:

4-Azido-2,3'-dimethylazobenzene; dk-red
prisms or small orn-red crysts (from alc),
mp 65°; other props and prepn are given in
Ref 1

4'-Azido-2,3'-Dimethylazobenzene; yel lfts
(from alc), mp 58-60° or red-bn ndls (from
alc), mp 67°; other props and prepn are given
in Ref 2

6-Azido-3,4'-dimethylazobenzene; yel-red
crysts (from alc), mp 85°; other props and
prepn are given in Ref 3

Refs: 1)Beil 16, 63 2)Beil 16, 65 3)Beil
16, 66

Nitroderivatives of Azotoluene

Mononitroazotoluene, C14H13N2O2; mw 255.27,
N 16.46%. Four isomers are described in the
literature:

x-Nitro-2,2'-dimethylazobenzene; ndls (from
alc), mp 87°; prepd by treating o,o'-
azotoluene with nitric acid (Ref 1)

x-Nitro-3,3'-dimethylazobenzene; crystals (from
glacial acetic acid), mp 192-5°; prepd by
treating m,m'-azotoluene with a mixt of cold
nitric & sulfuric acids (Ref 2)

6-Nitro-2,4'-dimethylazobenzene; red oil,
bp ca 215° at 11 mm press; prepd from 2-
nitroso-3-nitrotoluene and aniline in glacial
acetic acid (Ref 3)

2-Nitro-4,4'-dimethylazobenzene; orn-red
triclinic crysts (from alc), mp 80°; prepd by
treating p,p'-azotoluene with 5 parts nitric
acid at a temp not exceeding 30° (Ref 4)
Refs: 1)Beil 16, 63 2)Beil 16, 65 3)Beil 16, (228) 4)Beil 16, 71

Dinitroazotoluene, C_{14}H_{11}N_{3}O_{4}; mw 300.2; N 18.66%. Five isomers are described in the literature:

3,3'-Dinitro-2,2'-dimethylazobenzene; brn crysts (from glacial acetic acid), mp 198°; prepd by diazotizing 6-nitro-2-aminotoluene in dil HCl and treating the diazonium chloride soln with a cuprous chloride soln in HCl (Ref 1)

4,4'-Dinitro-2,2'-dimethylazobenzene; red-bm lfts (from toluene), mp 258°; readily sol in boiling glacial acetic acid or nitrobenzene and in benz, diffc sol in alc; prepd by treating 5-nitro-1-methylbenzene-2-diazonium sulfate with a cuprous chloride soln in HCl (Ref 1)

5,5'-Dinitro-2,2'-dimethylazobenzene; red ndls (from toluene or nitrobenzene), mp 273°; sl sol (giving an orn color) in boiling alc, benz or toluene; prepd by treating the 4-nitrotoluene diazonium salt with cuprous chloride in concd HCl soln (Ref 1)

x,x-Dinitro-3,3'-Dimethylazobenzene; red ndls (from glacial acetic acid), mp 192-3°; prepd by treating m,m'-azotoluene with 4 parts cold nitric acid at a temp not exceeding 30° (Ref 2)

2,2'-Dinitro-4,4'-Dimethylazobenzene; prisms (from glacial acetic acid), mp 114°; readily sol chlf or eth; obtd by dissolving p,p'-azotoluene in 3 parts cold nitric acid (Ref 3)

3,3'-Dinitro-4,4'-Dimethylazobenzene; red lfts (from benz), mp 149°; sol in boiling benz; prepd by treating 2-nitro-4-aminotoluene with a soln of the Na salt of chlorous acid (Ref 3)

Trinitroazotoluene; C_{14}H_{11}N_{3}O_{6}; mw 345.27, N 20.29%. Two isomers are found in the literature:

x,x,x-Trinitro-4,4'-Dimethylazobenzene; a and β-trinitro derivs (a), mp 189° and (β), mp 138° were reported by Janovsky (Ref 2) on nitrating p,p'-azotoluene with nitric acid. On further treatment with HNO₃ both a and β-trinitro compds gave the same tetranitro compd, mp 198-200°

Refs: 1)Beil 16, 71 2)J.V. Janovsky, Monatsh 9, 836 (1888) & JCS 56 1, 250-1 (1889); Monatsh 10, 591 & 593 (1889) & JCS 58 1, 140 (1889)

Tetranitroazotoluene; C_{14}H_{10}N_{8}O_{8}; mw 390.27, N 21.54%. Three isomers are described in the literature:

x,x,x,x-Tetranitro-4,4'-Dimethylazobenzene; by further treatment of either a or β-trinitroazotoluene with nitric acid, Janovsky (Ref 2) reported a tetranitroazotoluene melting at 198-200°

Refs: 1)Beil 16, 71 2)J.V. Janovsky, Monatsh 9, 839 (1888) & JCS 56 1, 251 (1889)

3,3'-Azo-1,2,4-triazole),

H:C:N:N:C:N:C:N-NH

It yel powdr; sl sol in alkali soln, and is
pptd again on acidifying this soln. It was pptd by the oxidn of 3-amino-1,2,4-triazole or 5-amino-1,2,4-triazole-3-carboxylic acid with permanganate in caustic soda soln. A red Ag salt is obt by reaction of azotriazole with an ammoniacal silver soln

**Nitroderivatives of Azoxylene**

Mononitroazoxylene, \( \text{C}_{16}\text{H}_{12}\text{N}_{O}_{3} \); Dinitroazoxylene, \( \text{C}_{16}\text{H}_{10}\text{N}_{O}_{4} \); Trinitroazoxylene, \( \text{C}_{16}\text{H}_{11}\text{N}_{3}\text{O}_{2} \); Tetranitroazoxylene, \( \text{C}_{16}\text{H}_{14}\text{N}_{6}\text{O}_{6} \); and higher nitroderivs of azoxylene were not found in Beil or CA through 1956

**Azoxylene and Derivatives**

Azoxylene; Azodimethylbenzene or Tetramethylazobenzene (called Bis-[dimethyl-phenyl]-dimid; Tetramethylazobenzol or Azoxylol in Ger), \( \text{H}_{3}\text{C}_{2}\text{C}_{6}\text{H}_{6}\text{N}:\text{N}:\text{C}_{6}\text{H}_{3}\text{N}^{+}\text{CH}_{3}^{+} \); mw 238.32, N 11.76%. Five isomers are listed in the literature: 4,4'-azo-o-xylene or 3,4,3',4'-Tetramethyl-azobenzene (Ref 1); 4,4'-azo-m-xylene or 2,2',4'-terramethyl-azobenzene (Ref 2); 4,5'azo-m-xylene or 2,4,3,3's-tetramethyl-azobenzene (Ref 3); 2,5,5'-azo-m-xylene or 3,5,3',5'-tetramethyl-azobenzene (Ref 3) and 2,2'-azo-p-xylene or 2,5,2',5'-tetramethyl-azobenzene (Ref 4). The azido or nitro-derivs of azoxylene may be of interest as expl ingredients

**Azoles** are heterocyclic compds characterized by a five membered ring contg nitrogen. They include diazoles, triazoles and tetrazoles, as well as compds contg other atoms such as O and S in the ring: oxazoles, dioxazoles, thiazoles, thiadiazoles etc. Some azoles or their derivs are expl, for example the triazoles and the tetrazoles

**Azon Guided Missile** is one of the American weapons developed during WW II and consisted of a 1000-lb demolition bomb with a "radio brain" attached. This enabled the bombadier to sight the target in the Norden bombsight and allow the bomb to drop. Once the bomb was dropped, the bombadier guided its flight in azimuth (right or left of target) by remote control. A 1,000,000 candlepower flare on the tail of the Azon was automatically ignited after the bomb left the plane which permitted the bombadier to follow the Azon with his eye. More accurate guided missiles were developed in the USA after WW II (See also Razom)
Azotate (ou Nitrate) (Fr). Nitrate
Azotate (ou Nitrate) d'ammoniaque (Fr). Ammonium Nitrate
Azotate (ou Nitrate) de plomb (Fr). Lead Nitrate
Azotate (ou Nitrate) de potasse (Fr). Potassium Nitrate
Azotate (ou Nitrate) de soude (Fr). Sodium Nitrate
Azote (Fr). Nitrogen

Azote Powder Company of Indianapolis, Ind. patented in 1898 a method of nitrating starch (previously dried at 100-140° and then cooled) using 1 liter of mixed nitric-sulfuric acid (1:2) per 200 g of starch. Nitration was done in a hermetically closed vessel at a temp below 4°

Ref: Daniel (1902), 48

Azothydrates (Fr). Azides
Azothydrique (Acide) (Fr). Hydrazoic Acid
Azotidrato (o Azotidruro) d'argento; Acido d'argento (Ital). Silver Azide
Azotidrato (o Azotidruro) di piombo; Acido di piombo (Ital). Lead Azide
Azotidrato (o Azotidruro) di sodio; Acido di sodio (Ital). Sodium Azide

Azotine. A blasting expl patented by A.Bercsey contd NaNO₂, sulfur, charcoal and petroleum residues
Ref: Daniel (1902), 48

Azotique (Acide) (Fr). Nitric Acid

Azotometer. An apparatus for detg gasometrically the nitrogen content of compds in soln. See also Nitrometer, described under Ammonium Nitrate, Analytical Procedures, p A373

Azotures (Fr). Azides

Azoxime. Same as 1,2,4-Oxdiazole
AZOXYCOMPOUNDS

Azoxy compds are a small class of stable subssts which contain the characteristic azoxy group, represented by R–N=N–R'.

The azoxy group is not symmetrical and the oxygen atom is attached to only one nitrogen atom, but not to both. The link uniting nitrogen to oxygen is a co-ordinate (semi-polar) link as indicated. In the majority of azoxy compds known, the two groups R and R' attached to nitrogen are aromatic radicals.

The most common method of preparing azoxy compds is by the reduction of nitro compds:

\[ R-\text{NO}_2 + R'-\text{NO}_2 \rightarrow R-\text{NO} + R'-\text{NO} + \text{H}_2\text{C} \]

A variety of reducing agents have been used but the usual ones are sodium methoxide in MeOH or sodium arsenite. The azoxy compd results from the condensation of the nitroso and the hydroxylamine compds produced during the reduction. The nitroso and hydroxylamine compds can be prepd separately and condensed together to give the azoxy compd. Even when the nitroso and the hydroxylamine compds contain different substituted groups, with only one or two exceptions sym azoxy compds (R = R') are formed, and not the unsym azoxy compd, as expected. Another method for prepg azoxy compds is by the oxidn of azo compds:

\[ \text{Ar-N:N-Ar} \rightarrow \text{Ar-NO:O-N-Ar} \]

The best oxidg agent for this purpose is 30% hydrogen peroxide dissolved in glacial acetic acid.

Nearly all aromatic azoxy compds crystallize well; they are completely stable towards strong HCl but if warmed with concd H_2SO_4 they undergo rearrangement. The true structure of azoxy compds was revealed by A. Angeli's discovery of isomerism in azoxy compds:

\[ \text{X} \bigcirc{N:N} \bigtriangleup \text{O} \quad \text{α-p-(x)azoxybenzene} \]

\[ \bigtriangleup{N:N} \bigcirc{X} \bigtriangleup \text{O} \quad \text{β-p-(x)azoxybenzene} \]

In nomenclature, the prefixes α and β are used to distinguish between the two structures; α indicates that the substituent is attached to the benzene ring which is linked to trivalent nitrogen.


**AZOXYANILINE AND DERIVATIVES**

**Azoxydianiline or Diaminoazoxybenzene** (called Azoxyanilin or Diaminoazoxybenzol in Ger), H2N-C6H4(N2O)-C6H4-NH2; mw 228.25, N 24.55%. Three isomers are described in the literature: o,o'-azoxyaniline or 2,2'-diaminoazoxybenzene (Ref 1); m,m'-azoxyaniline or 3,3'-diaminoazoxybenzene (Ref 2); and p,p'-azoxyaniline or 4,4'-diaminoazoxybenzene (Ref 3). Some of its nitro derivs may be of interest as expl ingredients


**Azido**, C12H13N4O, and **Diazido**, C12H10N4O,

Derivs were not found in Beil or in CA through 1956

**Mononitroazoxyaniline**, C12H14N4O3, was not found in Beil or in CA through 1956

**4,4'-Diamino-3,3'-dinitroazoxybenzene**, H2N-C6H4(NO2)-(N2O)-C6H4(NO2)-NH2; mw 318.25, N 26.41%; orn-red tabular ndls (from phenol + alc), mp 328-30(decomp). This compd was prepd by refluxing with acetic acid and concd HCl 4,4'-bis (acetamido)-3,3'-dinitroazoxybenzene, previously obt by oxidn of 4-amino-2-nitroacetanilide in dioxane with Caro's acid soln. No other props of the nitroazoxyaniline were given

Ref: 1)Beil – not found 2)C.M.Atkinson et al, JCS 1954, 2026-7 & CA 49, 5486-7 (1955)

**Trinitro**, C12H5N3O8, **Tetranitro**, C12H5N4O8, or higher nitro derivs of azoxyaniline were not found in Beil or in CA through 1956

**AZOXYANISOLE AND DERIVATIVES**

**Azoxyanisole or Azoxydianisole** (called Azoxyanisol or Dimethoxy-azoxybenzol in Ger), CH3-O-C6H4(N2O)-C6H4-O-CH3; mw 258.27, N 10.85%. Three isomers are described in the literature: o,o'-Azoxyanisole (Ref 1); m,m'-Azoxyanisole (Ref 2) and p,p'-Azoxyanisole (Ref 3). The nitro derivs of Azoxyanisole may be of interest as expl ingredients


**Azido**, C14H11N4O3, and **Diazido**, C14H12N4O3, Derivs of azoxyanisole were not found in Beil or in CA through 1956

**Nitroderivatives of Azoxyanisole**

**Mononitroazoxyanisole**, C14H13N4O3, Derivs were not found in Beil or in CA through 1956

**Dinitroazoxyanisole**, H2CO-C6H4(NO2)-(N2O)-C6H4(NO2)-O-CH3; mw 348.27, N 16.09%. Two isomers are described in the literature:
AZOXYBENZALDEHYDE AND DERIVATIVES

5,5'-Dinitro-2,2'-dimethoxyazoxybenzene, lifs (from benz), mp 209°; was prep'd by electrolytic reduction of 2,4-dinitroanisole in an alkaline soln with a Hg cathode or in a nearly neutral soln with a Cu or Ag cathode.


5,5'-Dinitro-3,3'-dimethoxyazoxybenzene, mp between 170 & 200°, was formed in small quantity by the reduction of 3,5-dinitroanisole with Na₂S₂ in alc, in addn to a larger quantity of 5-nitro-3-aminoanisole.


Trinitro, C₆H₄(N₂O)₃O₄, Tetranitro, C₆H₄(N₂O)₄O₁₁, and higher nitro derivs of azoxyanisole were not found in Beil or in CA through 1956.

AZOXYBENZALDEHYDE AND DERIVATIVES

Azoxybenzaldehyde; Azoxybisbenzaldehyde or Azoxydibenzoaldehyde, OHC-C₆H₄(N₂O)C₆H₄-CHO, mp 254.24, N 11.02%. Its three isomers: o,o'-, m,m'- and p,p'- are described in Beil 16, 640,641, (387) & [334]. Of these the para- is of interest because it flashes easily and because its nitrocompd is known:

p,p'-Azoxybenzaldehyde, yel ndls (from benz, alc or dil AcOH), mp 194° (Ref 2), 190° (Ref 3); decom or flashes up at higher temp with evol of flame; sol in benz or AcOH; sI sol in alc ligroin and hot w. Can be prep'd by reducing p-nitrobenzaldehyde or by other methods.


x-Nitro-p,p'-azoxybenzaldehyde, OHC-C₆H₄-(N₂O)-C₆H₄(NO₂)-CHO, mw 299.24, N 14.04%. Yel ndls (from AcOH), mp 171-2°; sol in hot AcOH; sI sol in alc & ether; insol in w. Was obtained on heating p,p'-azoxybenzaldehyde with fuming nitric acid.


AZOXYBENZENE AND DERIVATIVES

Azoxybenzene, C₆H₅-(N₂O)-C₆H₅; mw 198.22, N 14.13%. Exists in two modifications: ordinary, mp 36°; and isoazoxybenzene; mp 84°. Snelling & Wyler (Ref 2) found that AN is sensitized by the addn of 1-6% azoxybenzene. Some of its azido derivs and high nitro compds may be of interest as expl ingredients.


Azidoazoxybenzene, C₆H₅N₂O₄, not found in Beil or in CA through 1956.

3,3'-Diazidoazoxybenzene, N₂-C₆H₄-(N₂O)-C₆H₄-N₂; mw 280.25, N 39.99%; ochre col crystals (from petr eth); mp 85-6°, explodes when heated in a tube above its mp. It was prep'd by diazotizing 3,3'-diamino-azoxybenzene, pptg the perbromide of the tetrazo deriv, and treating the latter with NH₃.


2-Nitroso-azoxybenzene, ON-C₆H₅-N:(O):N-C₆H₅; mw 227.22, N 18.49%; sulfur-yel crystals, mp ca 106° with a blue-green color becoming orm-red. It was prep'd by heating on a steam bath 2-hydroxyl-amino-azoxybenzene with freshly pptd mercury oxide in ether.

Ref: 1) Beil 16, [316] 2) G. Cusmano & L. Della Nave, Gazz, 51 1, 68 (1921) & CA 15, 2840 (1921).

Nitroderivatives of Azoxybenzene

Mononitroazoxybenzene, O₆N-C₆H₄-(N₂O)-C₆H₅; mw 243.22, N 17.28%. Three isomers are described in the literature:

2-Nitroazoxybenzene; yel ndls or prisms, mp 49°; readily sol in eth or benz, less sol in alc. Its prep'n and other props are given in Ref 1.

3-Nitroazoxybenzene α-form; yellowish ndls.
4-Nitroazoxybenzene (α-form); yellowish
crystals (from alcohol or ligroin), mp 153° (β-form); yellow crystals (from benzol), mp 149°. Its preparation and other properties of both α & β forms are given in Ref 3.

Dinitroazoxybenzene, O₂N-C₆H₄(N₂O)-C₆H₄-NO₂; mW 288.22, N 19.44%. Seven isomers are described in the literature:

2,2'-Dinitroazoxybenzene; yellow needles, mp 175.5°; readily soluble in alcohol, acetone, or hot benzene; less soluble in alcohol or ligroin. Its preparation and other properties are given in Ref 1.

2,3'-Dinitroazoxybenzene; yellowish needles (from concentrated HNO₃), almost white needles (from concentrated formic acid), mp 143-6.5°; very soluble in cold concentrated formic acid, soluble in ether or carbon disulfide, moderately soluble in benzol or toluene, very difficult to dissolve in cold alcohol. Its preparation and other properties are given in Ref 3.

2,4'-Dinitroazoxybenzene; mp 135°, obtained by adding to 4,4'-dinitroazoxybenzene on treating β-4-nitroazoxybenzene with HNO₃ (Ref 3).

2,4'-Dinitroazoxybenzene; sulfur-yellow needles (from benzol) or lemon-yellow crystals (from glacial acetic acid), mp 192-3°. Its preparation and other properties are given in Refs 4 & 8.

2,5'-Dinitroazoxybenzene, O₂N-C₆H₄(N₂O)-C₆H₄-NO₂; it yields needles (from alcohol), mp 141°. Its preparation is given in Ref 5.

2,6'-Dinitroazoxybenzene; it is prepared from benzol, mp 172°. Its preparation is given in Ref 5.

3,5'-Dinitroazoxybenzene; nearly colorless crystals (from glacial acetic acid), mp 171-3°; soluble in all solvents. Its preparation is given in Ref 6.


Trinitroazoxybenzene, (O₂N)₂-C₆H₄(N₂O)-C₆H₄-NO₂; mW 333.22, N 21.02%. Four isomers are described in the literature:

2,4,2'-Trinitroazoxybenzene; nearly colorless tablets or prisms (from alcohol), mp 187-9°; readily soluble in alcohol, acetone, or hot acetic acid, nitrobenzol or hot HNO₃; difficult to dissolve in alcohol or ligroin. Its preparation and other properties are given in Ref 1.

2,4,3'-Trinitroazoxybenzene; sulfur-yellow needles (from benzol) or prisms (from alcohol), mp 175.5°; readily soluble in alcohol, acetone or hot benzene; less soluble in alcohol or ligroin. Its preparation and other properties are given in Ref 1.

2,2'-Dinitroazoxybenzene; yellow needles (from concentrated HNO₃), almost white needles (from concentrated formic acid), mp 143-6.5°; very soluble in alcohol, acetone, or hot benzene; less soluble in alcohol or ligroin. Its preparation and other properties are given in Refs 1 & 2.

2,3'-Dinitroazoxybenzene; sulfur-yellow needles (from HNO₃) or sulfur-yellow prisms (from benzol), mp 135-7°. Its preparation and other properties are given in Ref 1.

2,4,6-Trinitroazoxybenzene, (O₂N)₃-C₆H₄-(N₂O)-C₆H₄-NO₂; nearly colorless needles (from conc. HNO₃) or yellowish needles (from conc. formic acid), mp 202°; very soluble in alcohol, acetone or hot benzene; moderately soluble in ether or toluene; difficult to dissolve in cold alcohol. Its preparation and other properties are described in the literature:

Ref: 1) Beil 16, 629, (379) 3) A. Angeli & B. Valori, Atti Accad. Lincei Mem 5 (1913) 139 (1913) & JCS 104, 1, 533-4 (1913)

Tetranitroazoxybenzene, C₁₂H₈N₆O₆; mW 378.22, N 22.22%. Two isomers are described in the literature:

3,5,3',5'-Tetranitroazoxybenzene, (O₂N)₃-C₆H₄-(N₂O)-N(C₆H₅(NO₂))₂; yellow needles (from HNO₃ or alcohol + acetone), mp 185°; soluble in benzol or acetone, the acetate solution gives a violet color in the
presence of alkali; the addn salt with HCl is unstable. The prepn of the tetranitro compd is described in Ref 1. Gore & Wheeler (Ref 4) detd its absorption spectrum and some other props

2,4,6,3'-tetranitroazoxybenzene, (O<sub>3</sub>N)<sub>3</sub>C<sub>6</sub>H<sub>2</sub>-(N<sub>2</sub>O)-C<sub>6</sub>H<sub>4</sub>-NO<sub>2</sub>; yellowish prisms (from benz) mp 192°. By prolonged treatment of 2,4,6-trinitroazoxybenzene with HNO<sub>3</sub> (d 1.52), the tetranitro compd was obtd (Refs 2 & 3)


Pentanitroazoxybenzene, C<sub>12</sub>H<sub>8</sub>N<sub>7</sub>O<sub>11</sub>, not found in Beil or in CA through 1956

2,4,6,2',4',6'-hexanitroazoxybenzene, (O<sub>3</sub>N)<sub>3</sub>C<sub>6</sub>H<sub>2</sub>-(N<sub>2</sub>O)-C<sub>6</sub>H<sub>4</sub>(NO<sub>2</sub>)<sub>3</sub>; mw 468.22, N 23.93%. This compd is listed in Refs 2 & 3 but no information is given concerning its method of prepn or expl props, except mention that the compd is reactive


AZOXYBENZENECARBOXYLIC ACID AND DERIVATIVES

Phenylazoxybenzoic Acid or Azoxybenzenemonocarboxylic Acid [called Azoxybenzol-carbonsäure-(2) or (4) in Ger]; C<sub>8</sub>H<sub>4</sub>-(N<sub>2</sub>O)-C<sub>6</sub>H<sub>4</sub>-COOH; mw 242.23, N 11.57%. Two isomers are described in the literature:

Azoxybenzene-2-Carboxylic Acid; yol prisms or small Ifts (from benz); mp 105-6°, 110-11° & 118°; readily sol in common org solvs, diffic sol in w; the soln in concd H<sub>2</sub>SO<sub>4</sub> rapidly becomes dk-red. Its prepn is described in Ref 1

Azoxybenzene-4-Carboxylic Acid. This compd exits in both a and β forms: α-form-yel Ifts (from alc); mp 231°, readily sol in alc or glacial acetic acid; β-form-yel ndls (from alc); mp 241°; readily sol in alc or glacial acetic acid.

The prepn and other props of both α- and β-forms are described in Ref 2


Azido, C<sub>13</sub>H<sub>8</sub>N<sub>3</sub>O, and Diazo, C<sub>13</sub>H<sub>8</sub>N<sub>2</sub>O<sub>3</sub>, Derivatives were not found in Beil or in CA through 1956

4'-Nitroazoxybenzene-4-Carboxylic Acid, O<sub>2</sub>N-C<sub>6</sub>H<sub>4</sub>-(N<sub>2</sub>O)-C<sub>6</sub>H<sub>4</sub>-COOH; mw 287.23, N 14.63%; yol cryst powd; mp ca 260° with decompn; prepd from β-azoxybenzene-4-carboxylic acid by treatment with HNO<sub>3</sub> (d 1.48) in glacial acetic acid

Ref: Beil 16, (389)

Dinitroazoxybenzene-monocarboxylic Acid, C<sub>13</sub>H<sub>6</sub>N<sub>2</sub>O<sub>7</sub>, was not found in Beil or in CA through 1956

3,5,3'-trinitroazoxybenzene-5'-carboxylic Acid, HOOC-C<sub>6</sub>H<sub>4</sub>-(N<sub>2</sub>O)-(N<sub>2</sub>O)-C<sub>6</sub>H<sub>4</sub>-COOH; mw 377.23, N 18.57%; col ndls (from alc), mp 216°; sol in NaOH, giving a red color in strong alkali; dissolves in Na<sub>2</sub>CO<sub>3</sub> soln or 0.1N NaOH with no color change. This compd was obtd when 3,3'-dinitro-5,5'-dicyanazoxybenzene was boiled in HNO<sub>3</sub> (d 1.48) for 16 hrs. The NH<sub>4</sub> salt was prepd by adding strong NH<sub>4</sub>OH dropwise to a suspension of the compd in warm w until the subst dissolved. Repeated crystn from w gave fine cream-col ndls which lost their w of crystn in vacuo at 60°

Refs: 1)Beil - not found 2)A.Bolliger & F.Reuter, JProcRoySocNSWales 73, 74 (1939) & CA 34, 5419-20 (1940)

Tetranitro, C<sub>13</sub>H<sub>6</sub>N<sub>2</sub>O<sub>11</sub>, and higher nitro derivs of azoxybenzene-monocarboxylic acid were not found in Beil or in CA through 1956
AZOXYBENZENEDICARBOXYLIC ACID AND DERIVATIVES

Azoxydibenzoic Acid or Azoxybenzenedicarboxylic Acid (called Azoxybenzoesäure or Azoxybenzol-dicarbonsäure in Ger), HOOC-C₆H₄-(N₂O)-C₆H₄-COOH; mw 286.24, N 9.79%. Three isomers are described in the literature: o,o' -azoxybenzoic acid or azoxybenzene-2,2'-dicarboxylic acid (Ref 1); m,m' azoxybenzoic acid or azoxybenzene-3,3'-dicarboxylic acid (Ref 2); and p,p' -azoxybenzoic acid or azoxybenzene-4,4'-dicarboxylic acid (Ref 3). The prep and props of these isomers are described in the refs indicated


Azido, C₁₄H₄N₅O₃, and Diazido, C₁₄H₄N₆O₅, Derivatives were not found in Beil or in CA through 1956

Monoazidoxazoxybenzoic Acid, C₁₄H₄N₅O₃, was not found in Beil or in CA through 1956

5,5'-Dinitroazoxybenzene-3,3'-dicarboxylic Acid or 3,3'-Dinitro-5,5'-dicarboxyazoxybenzene, HOOC-C₆H₄(NO₂)-(N₂O)-C₆H₄(NO₂)-COOH; mw 376.24, N 14.89%; cream-col small ndls (from anisole + alc), mp 288; readily sol in alc but nearly insol in cold w, eth or benz.
It was prepd by treating 3,5-dinitrobenzoic acid with NaOH soln and pptg the product Attempts to methylate or benzoylate azodicarbamide. The col purified crysts of the acid wr1otfu di5Bi6ri C ho g ben zoyl guani dine benzoate decompd at 162-30℃ Refs: 1)Beil 9, 300 2)H.Wieland & H. Bauer, Ber 40, 1687-90(1907) & JCS 92 I, 492(1907)

AZOXYDICARBOXYLAMIDE DIOXIME AND DERIVATIVES

Azoxydicarbamidoxime (called Azoxy-carbonsäure-bisamidoxim in Ger), HO-N:C(NH₂)-N₂O-C(NH₂)-N-OH; mw 162.12, N 51.84%; red-orn cryts (from w at 60°), mp explodes ca 99° without leaving a residue; sol in hot w with slow decomp; insol in org solvs. This compd was obtained, in addn to other products, by Wieland (Ref 2) on carefully treating with HNO₃ the alkaline soln of dihydroxyguanidine hydrobromide, HO-NH-C(:NH)-NH-OH, HBr. The latter compd was prepd by reacting at ~20° cyanogen bromide and hydroxylamine dissolved in a mixt of methyl alc and anhyd eth. The reaction between cyanogen bromide and free hydroxylamine in alcoholic ethereal soln at RT is violent and almost expl

The silver salt of azoxydicarbamidoxime, Ag₃C₄H₄N₆O₃, dk-brn flakes, was reported to detonate when heated on a Pt foil

Refs: 1)Beil 3, 124 2)H.Wieland, Ber 38, 1452-3(1905) & JCS 88 I, 421(1905)

Azoxydicarbamidoxime Dibenoate, C₄H₄·CO·O·N:C(NH₂)-(N₂O)-C(NH₂)·N·O·OC·C₄H₄; mw 370.32, N 22.70%; yel ndls (from glacial acetic acid) mp – explodes at 155°. This compd was obtd in addn to col ndls of benzoylguanidine benzoate [C₄H₄·CO·NH-C(NH₂):N·O·OC·C₄H₄], when dihydroxyguanidine and benzoyl chloride reacted in the presence of sodium bicarbonate.
Attempts to methylate or benzoylate azodicarbamidoxime by means of methyl sulfate or benzoyl chloride either in Na₂CO₃ or NaHCO₃ soln were without success. The yel material isolated was purified by repeated shaking with acet until it was sol in dil NaOH, which quickly caused decomp into benzoic acid, nitrogen, and hydroxy-carbamide. The col purified crysts of the benzoylguanidine benzoate decompd at 162-3°

Refs: 1)Beil 9, 300 2)H.Wieland & H. Bauer, Ber 40, 1687-90(1907) & JCS 92 I, 492(1907)

Azoxyethane, C₄H₆-(N₂O)-C₄H₆, as well as its Azido, Diazido, Nitro, Dinitro, Nitroso,
and Nitronitroso Derivatives were not found in Beil or CA through 1956

AZOXYMETHANE AND DERIVATIVES

Azoxymethane, \( H_2C-\left(\text{N}_2\text{O}\right)-\text{CH}_3 \); mw 74.08, N 37.82%; col liq, bp 98° at 760 mm Hg; \( n_D \) 1.4300 at 17°. It was prep by oxidg azomethane with perbenzoic acid. Azoxymethane was de compd by hot concd aq alkali with the formation of volatile base and was mpn 30 glca 315°; isoacin. With methane was decompd by oxidg azomethane with perbenzoic acid. Azoxymethane with perbenzoic acid. Azoxymethane and Nitronitroso Derivatives


4,4'-Dinitro-2,2'-azoxybenzene, yellowish brn-red iridescent ndls (from nitrobenzene), mp 305°-315°; insol in w, alc, ether, benz or glacial acetic acid. This compd was obtd as one of the products from the reaction of hydrazine or hydrazine hydrate and 4-chloro-1,3-dinitronaphthalene in alc

Ref: 1)Beil 16, 1956

Trinitro, \( C_{29}H_{11}N_3O_7 \); Tetranitro, \( C_{29}H_{10}N_6O_9 \); and higher nitro derivatives of azoxynaphthalene were not found in Beil or in CA through 1956

AZOXYNAPHTHALENE AND DERIVATIVES

Azoxynaphthalene, \( C_{10}H_7-\left(\text{N}_2\text{O}\right)-C_9\text{H}_6 \); mw 298.33, N 9.39%. Two derivs are described in the literature:

1,1'-or α-α'-Azoxynaphthalene (Ref 1) and 2,2'-or β-β'-Azoxynaphthalene (Ref 2)


Azidoazoxyphenetole, \( C_{29}H_{13}N_4O_4 \) or Diazido Derivatives \( C_{29}H_{12}N_5O_4 \), were not found in Beil or in CA through 1956

Mononitroazoxyphenetole, \( C_{29}H_{13}N_3O_3 \), not found in Beil or in CA through 1956

Dinitroazoxyphenetole, \( O_2N-C_{10}H_6-\left(\text{N}_2\text{O}\right)-C_{10}H_6\text{NO}_2 \); mw 388.33, N 14.43%. Two isomers are described in the literature:

5,5'-Dinitro-1,1'-azoxyphenetole, orn-yel to brn-red powd (when dry); mp-decomp above 200°, slowly turning brn; sol in concd \( H_2SO_4 \) with a red color, turning blue-violet on heating. This compd was obtd by reducing 1,5-dinitronaphthalene with \( Zn \) dust and \( NH_4Cl \) or phenylhydrazine and NaOH

3,3'-Dinitro-4,4'-diethoxyazoxybenzene, C_{12}H_8O_6N_4, mw 376.32, N 14.89%; yel cryst powd (from azoxybenzene with NaNO_2 in glacial acetic acid), mp 185\(^\circ\); readily sol in glacial acetic acid or by sapon of 3-nitro-4-hydroxy-4'-azoxyphenetole with HNO_2 (d 1.48) in glacial acetic acid

Ref: Beil 16, 1328


X, X, X-Trinitro-4,4'-diethoxyazoxybenzene, C_{16}H_18N_3O_7, mw 421.32, N 16.62%. Two isomers identified by mp have been reported:

I. mp 168\(^\circ\); sulfur-yel ndls (from hot ethyl acetate); readily sol in boiling eth, chlf, benz or glacial acetic acid; diff sol in cold alc; insol in w.

II. mp 187\(^\circ\); yt yel ndls (from hot ethyl acetate); readily sol in boiling ethyl acetate; moderately sol in chlf or benz; diff sol eth or hot glacial acetic acid; insol in alc.

The prep and other props of these trinitroazoxyphenetoles is given in Beil

Ref: Beil 16, 639

Tetranitro, C_{16}H_14N_4O_11, and higher derivs of azoxyphenetole were not found in Beil or in CA through 1956

AZOXYPHENOL AND DERIVATIVES

Azoxyphenol or Dihydroxyazoxybenzene, C_{11}H_{16}N_2O_2, mw 230.22, N 12.17%. Three isomers are described in the literature: o,o'-azoxyphenol (Ref 1), m,m'-azoxyphenol (Ref 2), and p,p'-azoxyphenol (Ref 3). The nitro derivs of azoxyphenol may be of interest as expl ingredients


Azido, C_{11}H_{13}N_4O, and Diazido, C_{11}H_{13}N_4O, Derivs of azoxyphenol were not found in Beil or in CA through 1956

3-Nitro-4,4'-dihydroxy-azoxybenzene, HO-C_6H_4-N(O):N-C_6H_4(NO_2):OH; mw 275.22, N 15.27%; om-yel ndls (from alc), mp 195\(^\circ\); can be prep by treating 4,4'-dihydroxyazoxybenzene with NaNO_2 in glacial acetic acid or by sapon of 3-nitro-4-hydroxy-4'-benzoylhydroxy-azoxybenzene with concd KOH soln

Ref: Beil 16, [328]

Dinitro, C_{12}H_4N_4O_7, Trinitro, C_{12}H_7N_3O_9 and higher nitro derivs of azoxyphenol were not found in Beil or in CA through 1956

AZOXYPROPAE AND DERIVATIVES

Azoxypropane or Dimethylazoxyethane, C_6H_{11}N_2O; mw 130.19, N 21.52%. Two isomers were reported:

1,1'-Azoxypropane, (HC)_2-CH-(N_2O)-CH_2; col liq, bp 670\(^\circ\) at 20 mm Hg; d 0.902 at 20\(^\circ\), and n_D 1.4365 at 20\(^\circ\). It was prepd by oxidg 1-azopropane, in dry methylene dichloride, with perbenzoic acid. This compd was decmpd by hot concd aq alkali and dissoc into propionic acid and n-propylhydrazine. The UV and IR spectra were reported

Ref: Beil 16, 639

2,2'-Azoxypropane, (H_2C)_{2}-CH-(N_2O)-CH_2; col liq, bp 380\(^\circ\) at 14 mm Hg. It was prepd by oxidg 2-azopropane as described for 1-azopropane. Catalytic reduction of 2,2'-azoxypropane produced N,N'-di-2-propylhydrazine. The UV and IR spectra were reported

Ref: Beil 16, 639

3-Nitro-4,4'-dihydroxy-azoxybenzene, HO-C_6H_4-N(O):N-C_6H_4(NO_2):OH; mw 275.22, N 15.27%; om-yel ndls (from alc), mp 195\(^\circ\); can be prep by treating 4,4'-dihydroxyazoxybenzene with NaNO_2 in glacial acetic acid or by sapon of 3-nitro-4-hydroxy-4'-benzoylhydroxy-azoxybenzene with concd KOH soln

Ref: Beil 16, [328]

Dinitro, C_{12}H_4N_4O_7, Trinitro, C_{12}H_7N_3O_9 and higher nitro derivs of azoxyphenol were not found in Beil or in CA through 1956

AZOXYPHENOL AND DERIVATIVES

Azoxyphenol or Dihydroxyazoxybenzene, C_{11}H_{16}N_2O_2, mw 230.22, N 12.17%. Three isomers are described in the literature: o,o'-azoxyphenol (Ref 1), m,m'-azoxyphenol (Ref 2), and p,p'-azoxyphenol (Ref 3). The nitro derivs of azoxyphenol may be of interest as expl ingredients


Azido, C_{11}H_{13}N_4O, and Diazido, C_{11}H_{13}N_4O, Derivs of azoxyphenol were not found in Beil or in CA through 1956

Mononitro, C_{11}H_{13}N_4O_3, and Trinitro, C_{11}H_4N_3O_9, Derivs were not found in Beil or in CA through 1956

2,2'-Dinitro-2,2'-Azoxypropane or 2,2'-Dinitro-2,2'-Dimethylazoxyethane (called
Azidof

These azoxytoluenes can be found in the Blatt

Nitroso,

Beil or in

Refs:

ingredients Tetra nitroozoxytoluene, refs indicated. Nitro or other derivs of (1942), CH,.C

and

mp 69-70° readily sol in alc or eth (Ref 4); (from ale) or sulfur-yel plates (from ligroin);

4,4'-dimet hylazoxytoluene; ligroin or benz (Ref

mp 37-90°, almost sol in common org solvs, petr eth or

little ndls (from petr eth) or It yel lfts (from dil alc); mp

59-60°, explodes and chars on rapid heating (Ref 1); iso-o', o'-azoxyltoluene; It yel long

ndls (from petr eth), prisms (from benz) or little ndls (from methyl alc + w); mp 80-2°;

readily sol in common org solvs, petr eth or cold benz; insol in w; its solns are It yel in color (Ref 2); m,m'-azoxyltoluene or 3,3'-dimethylazoxytoluene; It yel ndls (from eth);

mp 37-90°; readily sol in alc, eth, chlf, CS₂, ligroin or benz (Ref 3); p,p'-azoxyltoluene or

4,4'-dimethylazoxytoluene; pale yel ndls (from alc) or sulfur-yel plates (from ligroin);

mp 69-70°; readily sol in alc or eth (Ref 4); and w,w'-azoxyltoluene, C₆H₄-CH₂-(N₃O)-

CH₂-C₆H₄ (Ref 5). The prepn and other props of these azoxyltoluenes can be found in the

deferred ingredients. Nitro or other derivs of azoxyltoluene may be of interest as expl

AZOXYTOLUENE AND DERIVATIVES

Azoxytoluene or Dimethylazoxybenzene,

CH₃C₆H₄-(N₃O)-C₆H₄-CH₃; mw 226.27,

N 12.38%. Five isomers are described in the literature: o,o'-azoxyltoluene or 2,2'-dimethylazoxybenzene; yel plates (from petr eth) or It yel lfts (from dil alc); mp

59-60°, explodes and chars on rapid heating (Ref 1); iso-o', o'-azoxyltoluene; It yel long

ndls (from petr eth), prisms (from benz) or little ndls (from methyl alc + w); mp 80-2°;

readily sol in common org solvs, petr eth or cold benz; insol in w; its solns are It yel in color (Ref 2); m,m'-azoxyltoluene or 3,3'-dimethylazoxytoluene; It yel ndls (from eth);

mp 37-90°; readily sol in alc, eth, chlf, CS₂, ligroin or benz (Ref 3); p,p'-azoxyltoluene or

4,4'-dimethylazoxytoluene; pale yel ndls (from alc) or sulfur-yel plates (from ligroin);

mp 69-70°; readily sol in alc or eth (Ref 4); and w,w'-azoxyltoluene, C₆H₄-CH₂-(N₃O)-

CH₂-C₆H₄ (Ref 5). The prepn and other props of these azoxyltoluenes can be found in

the refs indicated. Nitro or other derivs of azoxyltoluene may be of interest as expl

Ingredients. Azoxytoluene or Dimethylazoxybenzene,

C₆H₄N₃O₂, derivs of azoxyltoluene were not found in

Beil or in CA through 1956

Nitradoso, C₆H₄N₃O₂, and Dinitrosso,
ndls (from benz or glacial acetic acid), mp 212-6°; was prepd by treating 2,6-dinitro-4-
hydroxylaminotoluene with concd HCl (Ref 1)

Tetranitroazoxytoluene is a HE of power
and brisance less than that of PA (Ref 2)

Refs: 1)Beil 16, (380) 2)Blatt (1944) 3)
E.Bueding & N.Jolliffe, JPharmacol 88, 300-
12 (1945) & CA 41, 510 (1947)

Pentanitroazoxytoluene, C_{14}H_{8}N_{7}O_{11}, and
Hexanitroazoxytoluene, C_{14}H_{8}N_{13}O_{13}, were not
found in Beil or in CA through 1956

AZOXYXYLENE AND DERIVATIVES

Azoxyxylene or Tetramethylazoxybenzene,
(CH_{3})_{2}C_{6}H_{4}-(N_{2}O)_{2}C_{6}H_{4}(CH_{3})_{2}; mw 254.32,
N 11.02%. Five isomers are described in
the literature: 3,3'-azoxy-o-xylene or
2,3,2',3'-tetramethylazoxybenzene (Ref 1),
4,4'-azoxy-o-xylene or 3,4,3',4'-tetramethyl-
azoxybenzene (Ref 1), 2,2'-azoxy-m-xylene
or 2,6,2',6'-tetramethylazoxybenzene (Ref 2),
4,4'-azoxy-m-xylene or 2,4,2',4'-tetramethyl-
azoxybenzene (Ref 2), and 2,2'-azoxy-p-
xylene or 2,5,2',5'-tetramethylazoxybenzene
(Ref 2)

Refs: 1)Beil 16, 631 & [321] 2)Beil 16,
632 & [321]

Azido, C_{16}H_{14}N_{3}O, and Diazido, C_{16}H_{16}N_{4}O,
Derivs of azoxyxylene were not found in Beil
or in CA through 1956

Mononitro, C_{16}H_{14}N_{2}O_{1}, Dinitro, C_{16}H_{18}N_{2}O_{3},
and higher nitro derivs of azoxyxylene were
not found in Beil or in CA through 1956
TABLE I
Comparison of US, Tyler, British and German Sieve Series

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<th>BritStdlnstitution(BSI)</th>
<th>German DIN 1171</th>
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Note: This table combines information given in 1)Lange's Handbook of Chemistry 2)Chemical Rubber Co's Handbook of Chemistry and Physics and 3)R. D. Cadle's "Particle Size Determination," Intercience, NY(1955). The IMM (Institution of Mining and Metallurgy, London) Series, given in Ref 3, has been largely replaced by the BSI Series, and is not included in this table. The Tyler screens are manufd by the W. S. Tyler Co, Cleveland, Ohio. The French use AFNOR screens which are similar to the German DIN Series.
### TABLE II

Calibers (Millimeter - Inch Equivalents)

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22) E. S. Sancho, "Quimica de los Explosivos," A. Aguado, Madrid (1941)
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33) A. Mangini, "Quaderni di Chimica e Trattato di Pratique dei Materiali Industriali No 14, Esplosivi," Patron, Bologna (1947)
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35) C. Belgrano & C. Lipzg (1908)
38) A. Stettbacher, "Pólvoras y Explosivos," G. Gill, Buenos Aires (1952)
41) M. A. Budnikov et al., "Explosives and Propellants," Oborongiz, Moscow (1955)
42) A. G. Gorst, "Propellants and Explosives," Gosizdat, Moscow (1957)
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An alphabetical listing of items discussed in this volume, which may not necessarily begin with letter A, and which may represent alternate names of items or compounds already listed alphabetically in the text

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MEMORANDUM FOR Defense Technical Information Center, ATTN: DTIC-OQ  
(Mr. Larry Downing), Ft. Belvoir, VA 22060  

SUBJECT: Distribution Limitation Change

1. Request the distribution limitation statement be upgraded from Statement A (Approved for Public Release) to Statement C (U.S. Government Agencies and Their Contractors). Reason: Administrative/Operational Use, effective 23 January 2009 for the following documents:

   AD422747 ADA011845  
   AD257189 ADA019502  
   AD274026 ADA057762  
   AD653029 ADA097595  
   AD745472 ADA134347  
   AD768062

2. Organization requesting this change is:

   Commander  
   U.S. Army RDECOM-ARDEC  
   ATTN: AMSRD-AAR-MEE  
   Bldg. 321  
   Picatinny Arsenal, NJ 07806-5000

3. Any questions please contact the undersigned at (973) 724-4287 or ross.benjamin@us.army.mil.

ROSS C. BENJAMIN  
Director, Energetics, Warheads  
& Manufacturing Technology  
Directorate, METC
MEMORANDUM FOR Defense Technical Information Center, ATTN: DTIC-OQ
(Mr. Larry Downing), Ft. Belvoir, VA 22060

SUBJECT: Recinding Distribution Limitation Change Request dated 23 Jan 09

1. After further review, I am recinding my request dated, 23 Jan 09, SUBJECT: Distribution Limitation Change Request. The below documents should remain with distribution Statement A (Approved for Public Release):

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   AD257189   ADA019502
   AD274026   ADA057762
   AD653029   ADA097595
   AD745472   ADA134347
   AD768062

2. Rationale: The change was not advisable since the documents have already been in the public domain (distribution statement A) for many years and the information is widely available.

3. Any questions please contact the undersigned at (973) 724-4287 or ross.benjamin@us.army.mil.

ROSS C. BENJAMIN
Director, Energetics, Warheads & Manufacturing Technology
Directorate, METC