ARPA ORDER NO. 189-1

MEMORANDUM
RM-5201-ARPA
MARCH 1967

BASIC ENERGY-LEVEL AND EQUILIBRIUM DATA FOR ATMOSPHERIC ATOMS AND MOLECULES

Forrest R. Gilmore

PREPARED FOR:
ADVANCED RESEARCH PROJECTS AGENCY

The RAND Corporation
SANTA MONICA • CALIFORNIA

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This research is supported by the Advanced Research Projects Agency under Contract No. SD-79. Any views or conclusions contained in this Memorandum should not be interpreted as representing the official opinion or policy of ARPA.

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SUMMARY

This memorandum presents tables of the formation energies, dissociation energies, ionization energies, electronic energy levels, and vibrational level spacings for most atomic, diatomic, and triatomic molecules involving hydrogen, carbon, nitrogen, oxygen, and argon. Many positively and negatively charged ions are included. Tables of equilibrium fractional electronic-state populations, and graphs of the equilibrium constants for dissociation, ionization, and detachment for most of the atomic and diatomic species are appended. A brief discussion of the significance of such data precedes the tables and graphs.

CONTENTS

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I. INTRODUCTION

An important property of any reaction is its reaction energy, i.e., the amount of energy taken up or given off when unit amounts of the reactants are converted to the products. Heats of formation, dissociation energies, ionization energies, etc., represent specific types of reaction energies. When a reaction is exothermic, the reaction energy represents the energy available for excitation or heating of the products of the reaction. When a reaction is endothermic, the reaction energy must be supplied by the thermal or excitational energy of the reactants. Consequently, endothermic reactions will be very slow when the mean thermal energy is much less than the reaction energy, unless the reactants have above-thermal excitational energy. (The converse, however, is not true; reactions are not necessarily fast just because sufficient energy is available.)

An understanding of reactions involving excited states also requires a knowledge of the excited energy levels of the reacting or product species. Moreover, for the case of thermal equilibrium (i.e., for a Boltzmann distribution of excited-state populations), such energy levels can be used to calculate "equilibrium constants" which relate the forward to the backward rates of reactions (see Section 4). Finally, since most reaction energies and energy levels can be determined (by spectroscopic, calorimetric, or other measurements) with an accuracy far surpassing that attainable in reaction-rate measurements, such data form a firm foundation on which to build the often crude and speculative edifices of reaction mechanisms and rates. The present memorandum presents such data for atoms and simple molecules involving hydrogen, carbon, nitrogen, oxygen, and argon. These data have been obtained by a critical study of the recent literature, combined with new thermodynamic calculations for some of the species.

II. REACTION ENERGIES

The energy of a reaction may be defined as the amount of energy taken up when one molecule or one mole of reactants reacts to form products. Unless otherwise stated, all reactants and products are assumed to be in their ground rotational, vibrational, and electronic levels (i.e., no excitation). Such a reaction energy is equivalent to what chemists call "the heat of reaction at $0^{\circ}K$", since at absolute zero (in thermal equilibrium) all particles are in their lowest levels. Moreover, for gases at absolute zero no distinction needs to be made between the reaction enthalpy (or heat) and the reaction energy, since $\Delta H_0^{\circ} - \Delta E_0^{\circ} = \Delta(pV)_{T=0} = 0$, where by international convention the subscript "0" designates $0^{\circ}K$ and the superscript "o" the ideal gas state. (A similar relation holds for the free energy: $\Delta F_0^{\circ} = \Delta A_0^{\circ} = \Delta E_0^{\circ}$.)

Chemists usually consider the reaction energy to vary with temperature, because of the varying thermal energy of the reactants and products. However, only the zero-temperature reaction energy will be tabulated here, for two reasons. In the first place, the variation with temperature is usually relatively small except at high temperatures, and can be readily estimated if necessary. Secondly, and more important in the present context, it is highly unlikely that the reaction products will be formed with an initial energy distribution corresponding to the ambient gas temperature. Hence, the temperature-dependent reaction energy is not really pertinent to the reaction-rate problem, but only to the question of the net heating after the products are thermalized by subsequent collisions.

The sign of the reaction energy depends upon whether it is defined as the energy absorbed or the energy released on reaction. For the cases considered here it is conventional to define it as the energy absorbed during formation, dissociation, or ionization, or equivalently the excess of the internal energy of the products over that of the reactants.

Before standard heats of formation can be determined, it is also necessary to establish "reference states" which are the standard substances from which all the other species are formed. For the species of present interest the conventional reference states are H_2, N_2, O_2, and Ar in the ideal-gas (or isolated-molecule) state, and C in the form of graphite.

Table 1 gives the molecular weight, energy of formation, dissociation energy, and ionization energy for the (gaseous) atoms and small molecules of present interest, together with the relevant references. All energies are given in three different units: physical (electron volts per particle), spectroscopic (reciprocal of the wavelength of photons with that energy, in 10^3 cm^{-1}, also known as kilokaysers), and thermochemical (kilocalories per mole). Conversion factors are taken from the recent NAS-NRC list.[1] The accuracy of each value is indicated roughly by the number of decimal places shown. The energy of any other reaction involving these species may be readily calculated by adding the formation energies of the products and subtracting those of the reactants.

III. ENERGY LEVELS

The energy levels of atoms and atomic ions depend upon the arrangement of their orbital electrons. The lower energy levels of the atoms and ions of present interest are listed in Tables 2 to 11, together with their electronic state designation and statistical weight. (For an explanation of the latter terms see Herzberg[2] or Moore[3].) The ions H^-, H^+, and C^- have only one bound state, so they are not tabulated. All of the listed species except O^- actually have an infinite number of highly-excited states. The present tables, however, list only those states where all the bound electrons have principal quantum numbers less than 4. In most physical situations higher states will not play an important role, but if needed they can be obtained from the more extensive tabulations of Moore,[3] or they may be calculated from the Rydberg formula.[2]

Also included in Tables 2 to 11 are the equilibrium fractional populations of the different electronic states, for various temperatures up to 10,000°K. These results are often useful in problems concerning equilibrium gases. The reader is cautioned, however, that in many situations involving low-density gases, or transient processes even at high densities, equilibrium will not obtain and these tabulated populations will not be applicable.

Molecules, because of their additional rotational and vibrational degrees of freedom, have so many individual energy levels that it is rather impractical to tabulate them. Fortunately, however, for each degree of electronic excitation the rotational and vibrational levels are usually quite regular and can be represented by simple formulas, only the coefficients of which need to be tabulated (see Herzberg[4]). For present purposes it is probably sufficient to note that the vibrational levels of each electronic state are fairly evenly spaced, only slowly converging near the dissociation limit. The rotational levels are not evenly spaced, but vary approximately quadratically with the rotational quantum number; however, the spacing is generally so close (10^{-3} to 10^{-2} eV) that for most reaction-rate purposes the rotational energy levels can be treated as if they formed a continuum.

Tables 12 to 18 present the electronic energy, lowest vibrational interval, and fractional population for the lower electronic states of several diatomic molecules of present interest. Similar values for other diatomic molecules, but without the fractional population numbers, are given in Table 19. (Again, the reader is cautioned against use of the equilibrium population values in nonequilibrium situations.)

For triatomic molecules, existing knowledge of the lower excited electronic states is quite incomplete. Consequently, only the ground state and its lowest vibrational intervals, for the three normal vibrational modes, are listed in Table 20.

IV. EQUILIBRIUM CONSTANTS

In any ideal-gas mixture in complete thermal and chemical equilibrium that contains three or more species which can be related by a possible reaction, such as $XY \rightleftharpoons X + Y$ or $W + X \rightleftharpoons Y + Z$, the concentration ratios $(X)(Y)/(XY)$, $(Y)(Z)/(W)(X)$, etc., can be shown to depend only on the temperature.[5] Since these ratios are independent of the individual species concentrations, they are called equilibrium constants.

A reacting gas mixture that is initially out of chemical equilibrium will tend to approach equilibrium, and the ratios defined above will tend to approach their equilibrium values. As equilibrium is approached the various reaction rates do not actually become small, but instead each reaction becomes balanced by its reverse reaction. Consequently, it can be shown that in equilibrium the ratio of the forward to backward rate coefficients for each reaction is equal to its equilibrium constant. Unfortunately, a rate coefficient is measureable and has practical significance only in nonequilibrium situations. Among each reactant species there will always be particles with a range of velocities, and usually with a range of rotational, vibrational, or electronic levels. Generally some of these levels or velocities will be more reactive than others. In nonequilibrium situations the more reactive ones will be removed (by reaction) more rapidly than the others, resulting in an internal distribution of levels or velocities in each reacting species which makes it less reactive than if it had an equilibrium distribution.[6]

Molecular dissociation calculations based on a simple model show that when the mean thermal energy is much less than the dissociation energy the dissociation and association coefficients are only slightly smaller than their equilibrium values. Moreover, both coefficients are decreased by the same fraction, so that their ratio still equals the equilibrium constant.[7] However, other types of reactions may not have such a convenient behavior.

In the present work, equilibrium constants have been calculated for several pertinent dissociation and ionization reactions. Results up to 10,000°K are presented graphically in Figs. 1 to 4.

Table 1. MOLECULAR WEIGHTS AND ENERGIES OF FORMATION, DISSOCIATION, AND IONIZATION FOR SELECTED ATOMS AND MOLECULES

Species	Molec. Weight*	Energy (or Heat) of Formation**	Dissociation Energy**	Ionization Energy**	Reference ***
H^-	1.00852	1.~85 ev	–	0.754	8
		11.974×10^3 cm^{-1}		6.083	
		34.235 kcal/mole		17.392	
H	1.00797	2.239	–	13.598	3
		18.057		109.679	
		51.627		313.585	
H^+	1.00742	15.837	–	–	–
		127.736			
		365.213			
C^-	12.01170	6.24	–	1.13	9,10
		50.4		9.1	
		144.0		26.0	
C	12.01115	7.371	–	11.259	3
		59.452		90.814	
		169.979		259.648	
C^+	12.01060	18.630	–	24.382	3
		150.265		196.659	
		429.627		562.272	
N	14.0067	4.880	–	14.532	3
		39.359		117.214	
		112.532		335.129	
N^+	14.0062	19.412	–	29.601	3
		156.573		238.751	
		447.66!		682.618	
O^-	15.9999	1.079	–	1.478	11
		8.705		11.925	
		24.89		34.10	
O	15.9994	2.558	–	13 '18	3
		20.630		109.837	
		58.984		314.037	

Table 1 (Cont.)

Species	Molec. Weight*	Energy (or Heat) of Formation**	Dissociation Energy**	Ionization Energy**	References***
O^+	15.9989	16.175 ev	–	35.117	3
		130.467 $\times 10^3 cm^{-1}$		283.244	
		373.021 kcal/mole		809.829	
Ar	39.948	0	–	15.759	3
		0		127.110	
		0		363.423	
Ar^+	39.947	15.759	–	27.629	3
		127.110		222.848	
		363.423		637.149	
H_2	2.01594	0	4.477	15.425	13,14
		0	36.114	124.414	
		0	103.254	355.715	
H_2^+	2.01539	15.425	2.651	–	14
		124.414	21.379		
		355.715	61.125		
CO	28.0106	-1.179	11.108	14.013	15 to 18
		-9.513	89.595	113.029	
		-27.200	256.163	323.163	
CO^+	28.0100	12.834	8.354	27.8	19
		103.516	67.380	224	
		295.963	192.648	640	
N_2	28.0134	0	9.759	15.580	17,20, 21
		0	78.717	125.667	
		0	225.061	359.297	
N_2^+	28.0129	15.580	8.711	27.1	22
		125.667	70.264	219	
		359.297	200.893	626	
NO^-	30.0066	0.6	5.3	0.3	†
		5	43	2	
		14	123	7	

Table 1 (Cont.)

Species	Molec. Weight*	Energy (or Heat) of Formation**	Dissociation Energy**	Ionization Energy**	References***
NO	30.0061	0.931 ev	6.507	9.267	15 23, 24
		$7.506 \cdot 10^3 cm^{-1}$	52.483	74.747	
		21.46 kcal/mole	150.055	213.711	
NO^+	30.0056	10.198	10.857 ($N - O^+$)	30.5	19
		82.253	87.573	246	
		235.17	250.382	703	
O_2^-	31.9993	-0.43	4.08	0.43	25
		-3.5	32.9	3.5	
		-10.0	94.0	10.0	
O_2	31.9988	0	5.115	12.063	26,27
		0	41.260	97.295	
		0	117.967	278.178	
O_2^+	31.9983	12.063	6.670	24.2	22
		97.295	53.802	195	
		278.178	153.826	558	
OH^-	17.0079	-1.43	4.75 ($O^- - H$)	1.83	28
		-11.51	38.27	14.75	
		-32.9	109.4	42.2	
OH	17.0074	0.401	4.395	13.34	29 through 31
		3.24	35.45	107.6	
		9.26	101.33	307.6	
OH^+	17.0068	13.74	4.65 ($O - H^+$)	-	-
		110.8	37.5		
		316.8	107.2		
H_2O	18.0153	-2.476	5.116 (H - OH)	12.619	15,32
		-19.972	41.27	101.78	
		-57.103	117.98	291.0	
H_2O^+	18.0148	10.143	5.84 ($H - OH^+$)	-	-
		81.81	47.1		
		233.9	134.7		
CO_2	44.0100	-4.075	5.453 (CO - O)	13.769	15,32
		-32.865	43.982	111.06	
		-93.965	125.750	317.5	

Table 1 (Cont.)

Species	Molec. Weight*	Energy (or Heat) of Formation**	Dissociation Energy**	Ionization Energy**	References***
CO_2^+	44.0094	9.694 ev	5.179 ($CO - O^+$)	22.6	19
		78.19 $\times 10^3$ cm^{-1}	41.77	182	
		223.5 kcal/mole	119.4	521	
NO_2^-	46.0060	-3.6	5.6 ($NO - O^-$)	4.0	33
		-29	45	32	
		-83	128	92	
NO_2	46.0055	0.372	3.116 ($NO - O$)	9.78	15,34
		3.00	25.13	78.9	
		8.59	71.86	225.6	
NO_2^+	46.0050	10.15	2.60 ($NO^+ - O$)	-	-
		81.9	21.0		
		234.2	60.0		
N_2O	44.0128	0.881	1.677 ($N_2 - O$)	12.894	15,32
		7.107	13.523	104.00	
		20.32	38.66	297.35	
N_2O^+	44.0123	13.775	1.302 ($N - NO^+$)	-	-
		111.11	10.50		
		317.67	30.02		
O_3^-	47.9987	-0.4	1.5 ($O_2 - O^-$)	1.9	35
		-3	12	15	
		-9	34	44	
O_3	47.9982	1.506	1.051 ($O_2 - O$)	12.80	15,36
		12.15	8.48	103.2	
		34.74	24.25	295.2	
O_3^+	47.9977	14.31	0.32 ($O_2^+ - O$)	-	-
		115.4	2.5		
		329.9	7.3		

* Molecular weights are for the normal isotopic mixture, based on $C^{12} = 12.00000$.

** All reaction energies are for isolated particles in their lowest rotational, vibrational, and electronic state (microscopic description), or for ideal gases at 0°K (equivalent macroscopic description). All energies are given in three units: physical (electron volts), spectroscopic (10^3 cm^{-1} or kilokaysers), and thermochemical (kilocalories per mole).

*** To avoid unnecessary duplication, references are indicated only where they give directly a formation, dissociation, or ionization energy. Where a dissociation energy is calculated from the formation energies of the molecule and its dissociation products, references to the latter are given only opposite the products. Similarly, no direct references are given for formation energies calculated from measured dissociation or ionization energies.

† Electron affinity estimated, since observation of negative charge transfer[37] to O_2 shows that the magnetron measurement [33] is inaccurate.

Table 2. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF H

STATE	LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
1s	0	0.0000	2	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00
2s	82259	10.1986	2	0.	0.	0.	0.	0.	0.	0.	0.	5.41E-35
2p	82259	10.1986	6	0.	0.	0.	0.	0.	0.	0.	0.	1.62E-34
3s	97492	12.0872	2	0.	0.	0.	0.	0.	0.	0.	0.	0.
3p	97492	12.0877	6	0.	0.	0.	0.	0.	0.	0.	0.	0.
3d	97492	12.0872	10	0.	0.	0.	0.	0.	0.	0.	0.	0.
4s	102824	12.7482	2	0.	0.	0.	0.	0.	0.	0.	0.	0.
4p	102824	12.7482	6	0.	0.	0.	0.	0.	0.	0.	0.	0.
4d	102824	12.7482	10	0.	0.	0.	0.	0.	0.	0.	0.	0.
4f	102824	12.7482	14	0.	0.	0.	0.	0.	0.	0.	0.	0.

ENERGY LEVELS FROM MOORE (3).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00
82259	1.99E-26	2.75E-21	7.36E-18	2.06E-15	1.41E-13	3.78E-12	5.25E-11	2.71E-09	4.54E-08	3.76E-07	1.94E-06	7.24E-06
82259	5.98E-26	8.26E-21	2.21E-17	6.18E-15	4.24E-13	1.13E-11	1.57E-10	8.14E-09	1.36E-07	1.13E-06	5.83E-06	2.17E-05
97492	3.47E-31	4.29E-25	4.94E-21	3.93E-18	5.89E-16	2.9CE-14	6.55E-13	7.03E-11	1.98E-09	2.43E-08	1.70E-07	8.09E-07
97492	1.04E-30	1.29E-24	1.48E-20	1.18E-17	1.77E-15	8.7CE-14	1.97E-12	2.11E-10	5.95E-09	7.28E-08	5.11E-07	2.43E-06
97492	1.74E-30	2.15E-24	2.47E-20	1.97E-17	2.95E-15	1.45E-13	3.28E-12	3.51E-10	9.92E-09	1.21E-07	8.52E-07	4.05E-06
102824	7.5CE-33	1.99E-26	3.83E-22	4.39E-19	8.66E-17	5.27E-15	1.41E-13	1.96E-11	6.63E-10	9.30E-09	7.26E-08	3.76E-07
102824	2.25E-32	5.98E-26	1.15E-21	1.32E-18	2.6CE-16	1.58E-14	4.24E-13	5.87E-11	1.99E-09	2.79E-08	2.18E-07	1.13E-06
102824	3.75E-32	9.97E-26	1.91E-21	2.20E-18	4.33E-16	2.64E-14	7.06E-13	9.78E-11	3.31E-09	4.65E-08	3.63E-07	1.88E-06
102824	5.25E-32	1.40E-25	2.68E-21	3.07E-18	6.06E-16	3.69E-14	9.89E-13	1.37E-10	4.64E-09	6.51E-08	5.08E-07	2.63E-06

Table 3. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF C

STATE	LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
$2s^2\,2p^2\ {}^3P_0$	0	0.0000	1	1.37E-01	1.31E-01	1.28E-01	1.23E-01	1.21E-01	1.19E-01	1.17E-01	1.16E-01	1.14E-01
$^3P_1$	16	0.0020	3	3.64E-01	3.58E-01	3.54E-01	3.49E-01	3.46E-01	3.44E-01	3.41E-01	3.40E-01	3.38E-01
$^3P_2$	43	0.0054	5	4.99E-01	5.11E-01	5.18E-01	5.28E-01	5.33E-01	5.37E-01	5.42E-01	5.44E-01	5.48E-01
^1D	10194	1.2639	5	9.67E-33	2.18E-26	3.74E-22	7.34E-17	1.10E-13	1.44E-11	6.39E-09	2.47E-07	3.24E-05
^1S	21648	2.6839	1	0.	0.	0.	1.88E-35	1.07E-28	3.40E-24	1.45E-18	3.45E-15	1.10E-10
$2s\ 2p^3\ {}^5S^\circ$	33735	4.1825	5	0.	0.	0.	0.	0.	4.39E-36	2.62E-27	4.83E-22	5.06E-15
$^3D^\circ$	64091	7.9461	15	0.	0.	0.	0.	0.	0.	0.	0.	3.43E-27
$^3P^\circ$	75256	9.3303	9	0.	0.	0.	0.	0.	0.	0.	0.	4.60E-32
$^3S^\circ$	105801	13.1173	3	0.	0.	0.	0.	0.	0.	0.	0.	0.
$^1D^\circ$	97878*	12.1350	5	0.	0.	0.	0.	0.	0.	0.	0.	0.
$^1P^\circ$	119878*	14.8626	3	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2p^4\ {}^3P$	150000*	18.5972	9	0.	0.	0.	0.	0.	0.	0.	0.	0.
^1D	158000*	19.5890	5	0.	0.	0.	0.	0.	0.	0.	0.	0.
^1S	181000*	22.4406	1	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2s^2\,2p\ (^2P^\circ)\ 3s$	60776	7.5351	12	0.	0.	0.	0.	0.	0.	0.	1.47E-38	6.60E-26
3p	69722	8.6442	36	0.	0.	0.	0.	0.	0.	0.	0.	3.72E-29
3d	78426	9.7233	60	0.	0.	0.	0.	0.	0.	0.	0.	1.47E-32
4s	78184	9.6933	12	0.	0.	0.	0.	0.	0.	0.	0.	3.70E-33
4p	80866	10.0258	36	0.	0.	0.	0.	0.	0.	0.	0.	8.47E-34
4d	83850**	10.3958	60	0.	0.	0.	0.	0.	0.	0.	0.	8.06E-35
4f	84000*	10.4144	84	0.	0.	0.	0.	0.	0.	0.	0.	9.78E-35
$2s\ 2p^2\ (^4P)\ 3s$	116000**	14.3818	24	0.	0.	0.	0.	0.	0.	0.	0.	0.
3p	125000*	15.4976	72	0.	0.	0.	0.	0.	0.	0.	0.	0.
3d	132000*	16.3655	120	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	136169*	16.8824	24	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2s\ 2p^2\ (^2D)\ 3s$	138000*	17.1094	20	0.	0.	0.	0.	0.	0.	0.	0.	0.
3p	145000*	17.9772	60	0.	0.	0.	0.	0.	0.	0.	0.	0.
3d	154000*	19.0931	100	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	158000*	19.5890	320	0.	0.	0.	0.	0.	0.	0.	0.	0.
$(^2P)\ 3$	184000*	22.8125	108	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	194000*	24.0523	192	0.	0.	0.	0.	0.	0.	0.	0.	0.
$(^2S)\ 3$	170000*	21.0768	36	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	179000*	22.1926	64	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2p^3\ (^4S^\circ)\ 3$	216000*	26.7799	72	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	225000*	27.8957	128	0.	0.	0.	0.	0.	0.	0.	0.	0.
$(^2D^\circ)\ 3$	224000*	27.7717	180	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	233000*	28.8876	320	0.	0.	0.	0.	0.	0.	0.	0.	0.
$(^2P^\circ)\ 3$	243000*	30.1274	108	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	252000*	31.2432	192	0.	0.	0.	0.	0.	0.	0.	0.	0.

*ESTIMATED.
**INCLUDES ESTIMATED SUBLEVELS.
NONSTARRED ENERGY LEVELS FROM MOORE (3) AND MINNHAGEN (38).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 90814 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 3 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF C

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	1.13E-01	1.13E-01	1.12E-01	1.12E-01	1.11E-01	1.10E-01	1.09E-01	1.07E-01	1.04E-01	1.02E-01	1.00E-01	9.80E-02
16	3.36E-01	3.35E-01	3.34E-01	3.32E-01	3.30E-01	3.28E-01	3.25E-01	3.19E-01	3.12E-01	3.06E-01	2.99E-01	2.93E-01
43	5.50E-01	5.50E-01	5.50E-01	5.48E-01	5.45E-01	5.41E-01	5.37E-01	5.28E-01	5.17E-01	5.07E-01	4.97E-01	4.87E-01
10194	3.71E-04	1.60E-03	4.22E-03	8.44E-03	1.41E-02	2.11E-02	2.89E-02	4.63E-02	6.42E-02	8.17E-02	9.81E-02	1.13E-01
21648	1.96E-08	4.38E-07	3.48E-06	1.52E-05	4.60E-05	1.08E-04	2.14E-04	5.94E-04	1.22E-03	2.08E-03	3.14E-03	4.35E-03
33735	1.64E-11	2.09E-09	5.28E-08	5.29E-07	2.97E-06	1.14E-05	3.31E-05	1.64E-04	5.09E-04	1.18E-03	2.28E-03	3.82E-03
64091	1.61E-20	1.62E-16	7.53E-14	6.04E-12	1.62E-10	2.08E-09	1.60E-08	3.38E-07	2.98E-06	1.51E-05	5.33E-05	1.45E-04
75256	3.14E-24	1.57E-19	2.14E-16	3.68E-14	1.75E-12	3.51E-11	3.85E-10	1.40E-08	1.80E-07	1.22E-06	5.37E-06	1.75E-05
105801	3.00E-34	1.22E-27	3.09E-23	4.32E-2?	9.85E-18	6.71E-16	1.96E-14	3.07E-12	1.13E-10	1.67E-09	1.35E-08	7.20E-08
97878	1.49E-31	1.94E-25	2.30E-21	1.87E-1?	2.34E-16	1.41E-14	3.19E-13	3.42E-11	9.56E-10	1.16E-08	8.01E-08	3.75E-07
119878	1.20E-38	3.69E-31	3.62E-26	1.33E-22	6.23E-20	7.44E-18	3.41E-16	1.05E-13	6.24E-12	1.33E-10	1.43E-09	9.50E-09
150000	0.	3.27E-38	5.77E-32	1.67E-27	3.68E-24	1.47E-21	1.76E-19	2.29E-16	3.83E-14	1.77E-12	3.47E-11	3.74E-10
158000	0.	0.	6.92E-34	3.45E-29	1.15E-25	6.31E-23	9.77E-21	1.87E-17	4.11E-15	2.33E-13	5.36E-12	6.57E-11
181000	0.	0.	2.24E-39	5.41E-34	5.88E-30	8.08E-27	2.61E-24	1.51E-20	7.27E-18	7.45E-16	2.71E-14	4.80E-13
60777	1.40E-19	8.73E-16	2.95E-13	1.89E-11	4.26E-10	4.79E-09	3.32E-08	5.95E-07	4.71E-06	2.20E-05	7.24E-05	1.87E-04
69722	6.73E-22	1.52E-17	1.21E-14	1.43E-12	5.12E-11	8.23E-10	7.58E-09	2.10E-07	2.25E-06	1.32E-05	5.20E-05	1.55E-04
78426	2.14E-24	1.69E-19	3.11E-16	6.67E-14	3.72E-12	8.49E-11	1.03E-09	4.35E-08	6.25E-07	4.59E-06	2.15E-05	7.39E-05
78184	5.09E-25	3.89E-20	6.99E-17	1.47E-14	8.13E-13	1.83E-11	2.21E-10	9.22E-09	1.31E-07	9.59E-07	4.48E-06	1.53E-05
80866	2.22E-25	2.49E-20	5.80E-17	1.47E-14	9.29E-13	2.33E-11	3.07E-10	1.45E-08	2.27E-07	1.78E-06	8.75E-06	3.12E-05
83850	4.32E-26	7.46E-21	2.31E-17	7.17E-15	5.29E-13	1.50E-11	2.17E-10	1.18E-08	2.05E-07	1.73E-06	9.05E-06	3.39E-05
84000	5.43E-26	9.58E-21	3.01E-17	9.44E-15	7.02E-13	2.00E-11	2.91E-10	1.60E-08	2.78E-07	2.36E-06	1.24E-05	4.64E-05
116000	1.56E-36	2.75E-29	1.86E-24	5.22E-21	2.01E-18	2.06E-16	8.32E-15	2.13E-12	1.11E-10	2.13E-09	2.12E-08	1.33E-07
125000	0.	4.64E-31	7.44E-26	3.88E-22	2.37E-19	3.47E-17	1.87E-15	7.37E-13	5.22E-11	1.27E-09	1.51E-08	1.09E-07
132000	0.	1.38E-32	4.32E-27	3.63E-23	3.18E-20	6.17E-18	4.16E-16	2.29E-13	2.06E-11	6.00E-10	8.22E-09	6.64E-08
136169	0.	2.50E-34	1.17E-28	1.31E-24	1.42E-21	3.26E-19	2.51E-17	1.69E-14	1.75E-12	5.67E-11	8.44E-10	7.29E-09
138000	0.	7.27E-35	4.05E-29	5.14E-25	6.13E-22	1.51E-19	1.23E-17	9.06E-15	1.00E-12	3.40E-11	5.25E-10	4.67E-09
145000	0.	3.88E-36	4.23E-30	8.68E-26	1.48E-22	4.83E-20	4.94E-18	5.07E-15	7.14E-13	2.90E-11	5.14E-10	5.12E-09
154000	0.	3.64E-38	9.42E-32	3.58E-27	9.71E-24	4.53E-21	6.18E-19	9.77E-16	1.87E-13	9.57E-12	2.03E-10	2.34E-09
158000	0.	0.	4.43E-32	2.21E-27	7.37E-24	4.04E-21	6.25E-19	1.20E-15	2.63E-13	1.49E-11	3.43E-10	4.20E-09
184000	0.	0.	5.74E-38	1.70E-32	2.16E-28	3.34E-25	1.19E-22	7.93E-19	4.24E-16	4.69E-14	1.81E-12	3.37E-11
194000	0.	0.	0.	4.96E-34	1.05E-29	2.43E-26	1.19E-23	1.28E-19	9.65E-17	1.38E-14	6.52E-13	1.42E-11
170000	0.	0.	1.58E-35	1.79E-30	1.11E-26	9.80E-24	2.23E-21	7.58E-18	2.51E-15	1.94E-13	5.67E-12	8.41E-11
175000	0.	0.	3.74E-37	7.88E-32	7.73E-28	9.80E-25	2.97E-22	1.56E-18	7.02E-16	6.83E-14	2.39E-12	4.10E-11
216000	0.	0.	0.	2.20E-38	1.44E-33	8.03E-30	7.94E-27	2.46E-22	3.93E-19	5.90E-17	7.26E-15	2.25E-13
225000	0.	0.	0.	0.	1.01E-34	8.03E-31	1.06E-27	5.05E-23	1.10E-19	3.49E-17	3.06E-15	1.09E-13
224000	0.	0.	0.	0.	2.03E-34	1.56E-30	1.99E-27	9.02E-23	1.90E-19	5.87E-17	5.05E-15	1.78E-13
233000	0.	0.	0.	0.	1.42E-35	1.56E-31	2.65E-28	1.85E-23	5.31E-20	2.07E-17	2.13E-15	8.65E-14
243000	0.	0.	0.	0.	1.31E-37	2.15E-33	5.03E-30	5.68E-25	2.29E-21	1.16E-18	1.45E-16	6.93E-15
252000	0.	0.	0.	0.	0.	2.15E-34	6.71E-31	1.17E-25	6.41E-22	4.07E-19	6.13E-17	3.37E-15

Table 4. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF C^+

STATE	LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
$2s^2\ 2p\ {}^2P^o_{1/2}$	0	0.0000	2	4.42E-01	4.20E-01	4.05E-01	3.86E-01	3.75E-01	3.68E-01	3.59E-01	3.54E-01	3.47E-01
$P^o_{3/2}$	64	0.0079	4	5.58E-01	5.80E-01	5.95E-01	6.14E-01	6.25E-01	6.32E-01	6.41E-01	6.46E-01	6.53E-01
$2s\ 2p^2\ {}^4P$	43033	5.3353	12	0.	0.	0.	0.	0.	C.	5.27E-34	2.74E-27	2.47E-18
^2D	74932	9.2901	10	0.	0.	0.	0.	0.	0.	0.	0.	1.06E-31
^2S	96494	11.9634	2	C.	0.	0.	0.	0.	C.	C.	C.	C.
^2P	110653	13.7189	6	0.	0.	0.	C.	0.	C.	0.	0.	0.
$2p^3\ {}^4S^o$	142024	17.6083	4	0.	0.	0.	0.	0.	0.	0.	0.	0.
$^2D^o$	150465	18.6548	10	C.	0.	0.	0.	0.	C.	C.	C.	C.
$^2P^o$	168744	20.9210	6	0.	0.	0.	0.	0.	C.	C.	C.	0.
$2s^2\ (^1S)\ 3s$	116538	14.4485	2	0.	0.	0.	C.	0.	C.	0.	0.	0.
3p	131725	16.3314	6	C.	0.	0.	C.	0.	C.	C.	C.	0.
3d	145550	18.0454	10	C.	0.	0.	0.	0.	0.	C.	C.	0.
4s	157235	19.4942	2	C.	0.	0.	0.	0.	C.	C.	C.	0.
4p	162523	20.1498	6	C.	0.	0.	0.	0.	0.	0.	0.	0.
4d	168125	20.8443	10	0.	0.	0.	0.	0.	C.	0.	C.	0.
4f	168979	20.9502	14	0.	0.	0.	0.	0.	C.	0.	C.	C.
$2s\ 2p\ (^3P^o)\ 3s$	170643	21.1565	18	C.	0.	0.	0.	0.	C.	0.	0.	0.
3p	184786	22.9100	54	C.	0.	0.	0.	0.	C.	C.	C.	C.
3d	197742	24.5163	90	0.	0.	0.	0.	0.	0.	C.	C.	C.
4s	210000**	26.0360	18	C.	0.	0.	0.	C.	C.	C.	C.	C.
4p	215730**	26.7464	54	C.	0.	0.	0.	0.	C.	0.	0.	C.
4d	220465	27.3335	90	C.	0.	C.	C.	C.	C.	0.	0.	0.
4f	221458	27.4566	126	0.	0.	C.	0.	0.	C.	0.	0.	C.
$(^1P^o)\ 3s$	219000*	27.1518	6	0.	0.	0.	0.	0.	C.	0.	C.	0.
3p	234000*	29.0116	18	C.	0.	0.	C.	0.	C.	C.	C.	C.
3d	246000*	30.4993	30	0.	C.	0.	C.	C.	C.	0.	C.	0.
4s	260000*	32.2351	6	0.	0.	0.	0.	0.	0.	0.	C.	0.
4p	265000*	32.8550	18	C.	0.	C.	C.	0.	C.	C.	C.	C.
4d	270500*	33.5369	30	0.	0.	0.	0.	0.	C.	C.	0.	C.
4f	271400*	33.6484	42	0.	0.	0.	0.	C.	0.	0.	0.	0.
$2p^2\ (^3P)\ 3s$	257000*	31.8631	18	C.	0.	0.	C.	C.	C.	C.	C.	C.
3p	271000*	33.5989	54	C.	C.	0.	C.	0.	C.	0.	0.	C.
3d	283000*	35.0866	90	0.	C.	C.	C.	0.	C.	C.	C.	C.
4	304500*	37.7522	288	0.	0.	0.	0.	0.	0.	C.	0.	C.
$(^1D)\ 3s$	267000*	33.1029	10	0.	0.	C.	C.	C.	C.	0.	C.	C.
3p	281000*	34.8387	30	C.	C.	0.	C.	0.	C.	C.	C.	0.
3d	292000*	36.2025	50	0.	0.	C.	0.	0.	0.	0.	0.	0.
4	313000*	38.8061	160	C.	0.	0.	C.	C.	C.	C.	C.	C.
$(^1S)\ 3$	315000*	39.5499	18	C.	0.	0.	0.	C.	C.	0.	C.	C.
4	349000*	43.2494	32	C.	C.	0.	0.	C.	C.	0.	0.	C.

*ESTIMATED.
**INCLUDES ESTIMATED SUBLEVELS.
NONSTARRED ENERGY LEVELS FROM MOORE (3) AND GLAD (39).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 196659 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 4 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF C^+

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	3.44E-01	3.42E-01	3.40E-01	3.39E-01	3.38E-01	3.38E-01	3.37E-01	3.37E-01	3.36E-01	3.36E-01	3.35E-01	3.34E-01
6[illegible]	6.56E-01	6.58E-01	6.60E-01	6.61E-01	6.62E-01	6.62E-01	6.63E-01	6.63E-01	6.64E-01	6.64E-01	6.63E-01	6.62E-01
43033	7.40E-14	3.60E-11	2.22E-09	4.23E-08	3.85E-07	2.15E-06	8.48E-06	6.67E-05	2.91E-04	8.77E-04	2.07E-03	4.10E-03
74932	6.67E-24	3.19E-19	4.20E-16	7.11E-14	3.33E-12	6.65E-11	7.29E-10	2.65E-08	3.44E-07	2.36E-06	1.05E-05	3.47E-05
96494	2.45E-31	2.60E-25	2.71E-21	2.01E-18	2.86E-16	1.35E-14	2.95E-13	3.01E-11	8.18E-10	9.75E-09	6.69E-08	3.12E-07
110653	2.77E-35	2.26E-28	9.15E-24	1.79E-20	5.26E-18	4.37E-16	1.50E-14	3.02E-12	1.34E-10	2.29E-09	2.09E-08	1.22E-07
142024	0.	2.17E-36	1.78E-30	2.99E-26	4.41E-23	1.28E-20	1.20E-18	1.09E-15	1.41E-13	5.42E-12	9.23E-11	8.92E-10
150465	0.	4.21E-38	7.78E-32	2.33E-27	5.29E-24	2.16E-21	2.65E-19	3.60E-16	6.23E-14	2.97E-12	5.99E-11	6.62E-10
168744	0.	0.	7.27E-36	7.61E-31	4.43E-27	3.75E-24	8.26E-22	2.70E-18	8.72E-16	6.65E-14	1.93E-12	2.86E-11
116538	1.34E-37	2.54E-30	1.81E-25	5.31E-22	2.11E-19	2.22E-17	9.21E-16	2.46E-13	1.33E-11	2.65E-10	2.72E-09	1.74E-08
131725	0.	1.22E-33	3.74E-28	3.09E-24	2.65E-21	5.19E-19	3.49E-17	1.93E-14	1.76E-12	5.18E-11	7.19E-10	5.89E-09
145550	0.	7.13E-37	8.22E-31	1.75E-26	3.10E-23	1.04E-20	1.09E-18	1.17E-15	1.71E-13	7.18E-12	1.31E-10	1.34E-09
157235	0.	0.	6.05E-34	2.88E-29	9.27E-26	4.96E-23	7.56E-21	1.42E-17	3.10E-15	1.76E-13	4.06E-12	5.00E-11
162523	0.	0.	1.44E-34	9.82E-30	4.15E-26	2.74E-23	4.95E-21	1.20E-17	3.13E-15	2.04E-13	5.23E-12	7.01E-11
168125	0.	0.	1.63E-35	1.64E-30	9.22E-27	7.63E-24	1.65E-21	5.31E-18	1.65E-15	1.24E-13	3.56E-12	5.22E-11
168979	0.	0.	1.52E-35	1.61E-30	9.50E-27	8.13E-24	1.80E-21	5.95E-18	1.94E-15	1.49E-13	4.35E-12	6.46E-11
170643	0.	0.	8.78E-36	1.05E-30	6.71E-27	6.14E-24	1.44E-21	5.13E-18	1.77E-15	1.42E-13	4.28E-12	6.53E-11
184786	0.	0.	2.98E-38	9.37E-33	1.24E-28	2.00E-25	7.35E-23	5.18E-19	2.90E-16	3.34E-14	1.34E-12	2.56E-11
197742	0.	0.	0.	7.60E-35	1.96E-30	5.30E-27	2.95E-24	3.86E-20	3.37E-17	5.42E-15	2.81E-13	6.62E-12
210000	0.	0.	0.	9.84E-38	4.77E-33	2.10E-29	1.73E-26	4.09E-22	5.43E-19	1.20E-16	7.93E-15	2.27E-13
215730	0.	0.	0.	0.	2.80E-38	1.82E-33	1.01E-29	9.99E-27	3.10E-22	5.02E-19	1.28E-16	9.52E-15	2.99E-13
220465	0.	0.	0.	0.	0.	5.53E-34	3.70E-30	4.26E-27	1.66E-22	3.16E-19	9.10E-17	7.44E-15	2.52E-13
221458	0.	0.	0.	0.	0.	5.42E-34	3.78E-30	4.48E-27	1.83E-22	3.61E-19	1.07E-16	8.89E-15	3.06E-13
219000	0.	0.	0.	0.	0.	6.25E-35	3.95E-31	4.33E-28	1.57E-23	2.85E-20	7.90E-18	6.27E-16	2.07E-14
234000	0.	0.	0.	0.	0.	8.50E-37	9.78E-33	1.73E-29	1.29E-24	3.91E-21	1.60E-18	1.71E-16	7.18E-15
246000	0.	0.	0.	0.	0.	1.89E-38	3.52E-34	9.15E-31	1.21E-25	5.54E-22	3.07E-19	4.18E-17	2.13E-15
260000	0.	0.	0.	0.	0.	0.	8.00E-37	3.26E-33	8.46E-28	6.23E-24	4.95E-21	8.92E-19	5.68E-17
265000	0.	0.	0.	0.	0.	0.	4.85E-37	2.32E-33	7.65E-28	6.69E-24	6.05E-21	1.20E-18	8.30E-17
270500	0.	0.	0.	0.	0.	0.	1.39E-37	7.93E-34	3.41E-28	3.60E-24	3.75E-21	8.33E-19	6.27E-17
271400	0.	0.	0.	0.	0.	0.	1.46E-37	8.57E-34	3.85E-28	4.19E-24	4.46E-21	1.01E-18	7.71E-17
257000	0.	0.	0.	0.	0.	0.	6.26E-36	2.32E-32	5.21E-27	3.44E-23	2.55E-20	4.33E-18	2.62E-16
271000	0.	0.	0.	0.	0.	0.	2.14E-37	1.24E-33	5.44E-28	4.85E-24	6.17E-21	1.38E-18	1.05E-16
283000	0.	0.	0.	0.	0.	0.	0.	6.52E-35	5.11E-29	8.27E-25	1.10E-21	3.39E-19	3.11E-17
304500	0.	0.	0.	0.	0.	0.	0.	4.29E-37	9.42E-31	3.19E-26	7.95E-23	3.49E-20	4.52E-18
267000	0.	0.	0.	0.	0.	0.	1.42E-37	7.24E-34	2.63E-28	2.46E-24	2.34E-21	4.86E-19	3.46E-17
281000	0.	0.	0.	0.	0.	0.	0.	3.87E-35	2.75E-29	4.16E-25	5.67E-22	1.55E-19	1.38E-17
292000	0.	0.	0.	0.	0.	0.	0.	2.72E-36	3.28E-30	7.23E-26	1.31E-22	4.46E-20	4.74E-18
313000	0.	0.	0.	0.	0.	0.	0.	0.	6.82E-32	3.09E-27	9.58E-24	4.98E-21	7.39E-19
315000	0.	0.	0.	0.	0.	0.	0.	0.	1.82E-33	1.01E-28	3.66E-25	2.14E-22	3.51E-20
349000	0.	0.	0.	0.	0.	0.	0.	2.43E-36	3.78E-31	2.95E-27	3.15E-24	8.32E-22	

Table 5. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF N

STATE		LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 2CO	250	3CC	4CC	5CC	600	8C0	1CCO	1500
$2s^2 2p^3$ $^4S^o$		C	0.CCCO	4	1.COE CO	1.00E CO	1.COE 00	1.00E 00	1.00E 00	1.00E 00	1.0CE CC	1.CCE 00	1.CUE 00
	$^2D^o$	19228	2.3839	1C	C.	0.	0.	2.30E-30	2.34E-24	2.36E-20	2.40E-15	2.42E-12	2.44E-08
	$^2P^o$	28839	3.5755	6	0.	0.	0.	0.	1.37E-36	1.39E-30	4.47E-23	1.43E-18	1.45E-1[illegible]
$2s\ 2p^4$	^4P	88132	10.9267	12	0.	0.	0.	0.	0.	0.	0.	0.	5.80E-37
	^2D	121CCO*	15.CC17	1C	C.	0.	0.	0.	0.	C.	C.	C.	0.
	^2S	142110*	17.6189	2	0.	C.	0.	C.	0.	C.	0.	0.	C.
	^2P	1582C0*	19.6138	6	0.	0.	C.	0.	0.	0.	0.	0.	0.
$2p^5$	$^2P^o$	2329C0*	28.8752	6	C.	0.	0.	0.	0.	C.	0.	C.	C.
$2s^2 2p^2$ (^3P)	3s	84288	10.4501	18	0.	0.	0.	0.	0.	0.	0.	0.	3.48E-35
	3p	95780	11.8749	54	0.	0.	0.	C.	0.	0.	0.	0.	0.
	3d	104861	13.CCOR	9C	0.	0.	0.	0.	0.	C.	0.	0.	C.
	4s	103861	12.8768	18	C.	0.	0.	0.	0.	0.	0.	C.	0.
	4p	107420**	13.3180	54	0.	0.	0.	C.	0.	C.	0.	0.	0.
	4d	110315	13.6770	90	0.	0.	0.	0.	0.	0.	0.	0.	C.
	4f	110441	13.6926	126	0.	0.	0.	0.	0.	C.	0.	C.	C.
(^1D)	3s	99664	12.3564	1C	0.	0.	0.	C.	0.	C.	C.	C.	C.
	3p	11C973	13.7585	3C	0.	0.	0.	0.	0.	C.	0.	0.	0.
	3d	121CC0**	15.CC17	5C	C.	0.	0.	0.	0.	C.	0.	0.	C.
	4	1246C0**	15.4480	16C	C.	C.	0.	C.	0.	0.	C.	0.	C.
(^1S)	3s	116279	14.4164	2	0.	0.	C.	0.	0.	C.	0.	C.	C.
	3p	1284CC*	15.9192	6	C.	0.	0.	0.	0.	0.	0.	C.	C.
	3d	1375CC*	17.0474	1C	C.	0.	0.	C.	0.	C.		0.	0.
	4	142CCC*	17.6053	32	0.	0.	C.	C.	C.	C.	C.	0.	C.
$2s\ 2p^3$ ($^5S^o$)	3	153CC0*	18.9691	9C	0.	0.	0.	0.	0.	0.	0.	0.	C.
	4	156C0C*	19.3410	15C	0.	0.	0.	0.	C.	C.	C.	C.	C.
($^3D^o$)	3	192CC0*	23.8044	27C	C.	0.	C.	0.	C.	C.	C.	0.	C.
	4	202CCC*	25.0442	48C	0.	0.	C.	C.	0.	0.	0.	0.	0.
($^3P^o$)	3-4	215CC0*	26.6559	45C	0.	0.	C.	C.	0.	C.	C.	C.	C.
($^5S^o$,$^1D^o$,$^1P^o$)	3-4	259CCC*	32.1111	55C	C.	0.	0.	0.	0.	C.	C.	C.	C.
$2p^4$(^3P,^1D,^1S)	3-4	331CCC*	41.0377	75C	C.	0.	0.	C.	C.	C.	0.	0.	0.

*ESTIMATED.
**INCLUDES ESTIMATED SUBLEVELS.
NONSTARRED ENERGY LEVELS FROM MOORE (3) ERIKSSON (40) AND ERIKSSON AND JOHANSSON (41).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 117214 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 5 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF N

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	1.000E 00	1.000E 00	1.000E 00	9.99E-01	9.97E-01	9.95E-01	9.90E-01	9.74E-01	9.51E-01	9.20E-01	8.85E-01	8.47E-01
19228	2.46E-06	3.91E-05	2.47E-04	9.22E-04	2.47E-03	5.32E-03	9.78E-03	2.42E-02	4.57E-02	7.24E-02	1.02E-01	1.33E-01
28839	1.47E-09	9.29E-08	1.48E-06	1.06E-05	4.68E-05	1.48E-04	3.69E-04	1.45E-03	3.80E-03	7.71E-03	1.32E-02	2.00E-02
88132	8.75E-28	2.81E-22	1.32E-18	5.53E-16	5.11E-14	1.73E-12	2.88E-11	1.94E-09	3.87E-08	3.61E-07	2.02E-06	7.90E-06
121000	3.93E-38	1.43E-30	1.57E-25	6.24E-22	3.13E-19	3.92E-17	1.87E-15	6.10E-13	3.76E-11	8.14E-10	8.79E-09	5.82E-08
142110	0.	1.51E-36	1.26E-30	2.13E-26	3.19E-23	9.20E-21	8.61E-19	7.73E-16	9.80E-14	3.65E-12	6.01E-11	5.58E-10
158200	0.	0.	1.68E-33	8.55E-29	2.90E-25	1.61E-22	2.52E-20	4.69E-17	1.08E-14	6.07E-13	1.38E-11	1.65E-10
232900	0.	0.	0.	0.	6.20E-37	6.82E-33	1.16E-29	8.13E-25	2.31E-21	8.88E-19	8.97E-17	3.56E-15
84288	2.09E-26	3.85E-21	1.25E-17	4.03E-15	3.08E-13	8.85E-12	1.30E-10	7.31E-09	1.28E-07	1.08E-06	5.60E-06	2.06E-05
95780	1.61E-29	1.55E-23	1.52E-19	1.07E-16	1.47E-14	8.73E-13	1.43E-11	1.39E-09	3.62E-08	4.10E-07	2.57E-06	1.18E-05
104861	3.90E-32	1.39E-25	3.24E-21	4.27E-18	9.34E-16	6.15E-14	1.75E-12	2.63E-10	9.33E-09	1.34E-07	1.04E-06	5.36E-06
103861	1.60E-32	4.94E-26	1.05E-21	1.29E-18	2.68E-16	1.69E-14	4.67E-13	6.69E-11	2.29E-09	3.20E-08	2.45E-07	1.23E-06
107420	3.71E-33	1.91E-26	5.70E-22	8.96E-19	2.23E-16	1.63E-14	5.03E-13	8.55E-11	3.31E-09	5.06E-08	4.16E-07	2.22E-06
110315	7.70E-34	6.02E-27	2.37E-22	4.54E-19	1.31E-16	1.08E-14	3.68E-13	7.12E-11	3.04E-09	5.01E-08	4.36E-07	2.44E-06
110441	9.85E-34	7.84E-27	3.13E-22	6.04E-19	1.76E-16	1.45E-14	4.92E-13	9.67E-11	4.15E-09	6.85E-08	5.99E-07	3.35E-06
99664	1.82E-31	3.07E-25	4.36E-21	4.02E-18	6.73E-16	3.60E-14	8.68E-13	1.02E-10	3.02E-09	3.18E-08	2.66E-07	1.25E-06
110973	1.60E-34	1.37E-27	5.77E-23	1.15E-19	3.45E-17	2.91E-15	1.00E-13	2.03E-11	8.35E-10	1.48E-08	1.31E-07	7.39E-07
121000	1.96E-37	7.14E-30	7.84E-25	3.12E-21	1.56E-18	1.96E-16	9.35E-15	3.05E-12	1.88E-10	4.07E-09	4.39E-08	2.91E-07
124600	0.	2.88E-30	4.46E-25	2.27E-21	1.37E-18	1.59E-16	1.06E-14	4.12E-12	2.87E-10	6.82E-09	7.91E-08	5.55E-07
116279	2.34E-37	4.32E-30	3.02E-25	8.69E-22	3.42E-19	3.55E-17	1.46E-15	3.78E-13	1.98E-11	3.81E-10	3.74E-09	2.30E-08
128400	0.	1.21E-32	2.70E-27	1.79E-23	1.31E-20	2.21E-18	1.33E-16	6.21E-14	4.92E-12	1.29E-10	1.61E-09	1.20E-08
137500	0.	1.07E-34	5.73E-29	7.07E-25	8.27E-22	2.01E-19	1.62E-17	1.17E-14	1.26E-12	4.19E-11	6.28E-10	5.42E-09
142000	0.	2.58E-35	2.12E-29	3.56E-25	5.24E-22	1.52E-19	1.42E-17	1.27E-14	1.60E-12	5.96E-11	9.79E-10	9.08E-09
153000	0.	1.29E-37	3.05E-31	1.09E-26	2.82E-23	1.27E-20	1.69E-18	2.55E-15	4.70E-13	2.32E-11	4.75E-10	5.24E-09
155000	0.	0.	1.29E-31	5.63E-27	1.70E-23	8.67E-21	1.26E-18	2.21E-15	4.51E-13	2.40E-11	5.22E-10	6.05E-09
152000	0.	0.	0.	3.56E-33	6.84E-29	1.47E-25	6.77E-23	6.65E-19	4.66E-16	6.26E-14	2.79E-12	5.75E-11
202000	0.	0.	0.	1.04E-34	3.33E-30	1.07E-26	6.77E-24	1.07E-19	1.06E-16	1.84E-14	1.00E-12	2.43E-11
215000	0.	0.	0.	4.64E-37	2.91E-32	1.56E-28	1.51E-25	4.46E-21	6.87E-18	1.67E-15	1.18E-13	3.50E-12
255000	0.	0.	0.	0.	0.	1.49E-34	5.84E-31	1.43E-25	9.92E-22	7.45E-19	1.27E-16	7.63E-15
331000	0.	0.	0.	0.	0.	0.	0.	6.17E-33	5.06E-28	2.42E-24	1.73E-21	3.30E-19

Table 6. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF N

STATE		LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
$2s^2\ 2p^3\ {}^4S^o$		0	0.0000	1	1.97E-01	1.78E-01	1.65E-01	1.51E-01	1.42E-01	1.37E-01	1.30E-01	1.26E-01	1.21E-01
	$^2P^o$	48.7	0.0060	3	4.17E-01	4.03E-01	3.93E-01	3.79E-01	3.70E-01	3.65E-01	3.57E-01	3.52E-01	3.46E-01
	$^2P^o$	130.8	0.0162	5	3.85E-01	4.15E-01	4.42E-01	4.70E-01	4.87E-01	4.99E-01	5.13E-01	5.22E-01	5.33E-01
	^2D	15316	1.8985	5	0.	4.69E-39	1.04E-32	8.93E-25	5.14E-20	7.65E-17	7.07E-13	1.69E-10	2.52E-07
	^2S	32589	4.0428	1	0.	0.	0.	0.	0.	1.14E-35	3.81E-27	4.72E-22	2.92E-15
$2s\ 2p^3\ {}^4S^o$		46785	5.8005	5	0.	0.	0.	0.	0.	0.	1.86E-37	3.67E-30	1.98E-20
	$^2D^o$	92245	11.4366	15	0.	0.	0.	0.	0.	0.	0.	0.	6.79E-39
	$^2P^o$	109218	13.5410	9	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$^2S^o$	155127	19.2328	3	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$^2D^o$	144188	17.8766	5	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$^2P^o$	166766	20.6758	3	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2p^4$	^4P	218CCO*	27.0279	4	0.	0.	0.	0.	0.	0.	0.	0.	0.
	^2D	2290CO*	28.3916	5	0.	0.	0.	0.	0.	0.	0.	0.	0.
	^2S	264CCO*	32.7310	1	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2s^2\ 2p\ (^3P^o)\ 3s$		149056	18.4801	12	0.	0.	0.	0.	0.	0.	0.	0.	0.
	3p	169022	20.9555	36	0.	0.	0.	0.	0.	0.	0.	0.	0.
	3d	187693	23.2704	60	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4s	196955	24.4187	12	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4p	203384	25.2158	36	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4d	210284	26.0712	60	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4f	211271	26.1936	84	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2s\ 2p^3\ (^4P\ )\ 3s$		207974	25.7848	24	0.	0.	0.	0.	0.	0.	0.	0.	0.
	3p	226455	28.0761	72	0.	0.	0.	0.	0	0.	0.	0.	0.
	3d	244500	30.3134	120	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	266100	32.9913	384	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2s\ 2p^3\ (^2D\ )\ 3s$		252000	31.2432	20	0.	0.	0.	0.	0.	0.	0.	0.	0.
	3p	270000	33.4749	60	0.	0.	0.	0.	0.	0.	0.	0.	0.
	3d	288000	35.7065	100	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	309800	38.4092	320	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$(^2P\ )\ 3$	323100	40.0583	108	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	354800	43.9885	192	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$(^2S\ )\ 3$	308100	38.1985	36	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	339800	42.1287	64	0.	0.	0.	0.	0.	0.	0.	0.	0.
$2p^3\ (^4S^o)\ 3s$		364000	45.1291	72	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	396000	49.0965	128	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$(^2D^o)\ 3$	380000	47.1126	180	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	412000	51.0802	320	0.	0.	0.	0.	0.	0.	0.	0.	0.
	$(^2P^o)\ 3$	408000	50.5842	108	0.	0.	0.	0.	0.	0.	0.	0.	0.
	4	439000	54.4277	192	0.	0.	0.	0.	0.	0.	0.	0.	0.

*ESTIMATED.
ENERGY LEVELS FROM MOORE (3) AND ERIKSSON (42).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 238751 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 6 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF N^+

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	1.18E-01	1.17E-01	1.16E-01	1.15E-01	1.14E-01	1.14E-01	1.13E-01	1.12E-01	1.10E-01	1.09E-01	1.07E-01	1.06E-01
48	3.43E-01	3.41E-01	3.40E-01	3.38E-01	3.37E-01	3.36E-01	3.35E-01	3.32E-01	3.28E-01	3.24E-01	3.20E-01	3.15E-01
130	5.39E-01	5.42E-01	5.44E-01	5.45E-01	5.46E-01	5.46E-01	5.45E-01	5.42E-01	5.38E-01	5.32E-01	5.26E-01	5.19E-01
15316	9.71E-06	8.68E-05	3.74E-04	1.06E-03	2.32E-03	4.25E-03	6.90E-03	1.42E-02	2.37E-02	3.47E-02	4.64E-02	5.84E-02
32689	7.25E-12	7.90E-10	1.80E-08	1.68E-07	8.96E-07	3.29E-06	9.30E-06	4.41E-05	1.33E-04	3.05E-04	5.77E-04	9.59E-04
46785	1.43E-15	1.18E-12	1.04E-10	2.56E-09	2.81E-08	1.81E-07	8.05E-07	7.51E-06	3.68E-05	1.21E-04	3.03E-04	6.31E-04
92245	2.69E-29	1.54E-23	1.06E-19	5.87E-17	6.68E-15	2.65E-13	5.03E-12	4.15E-10	9.66E-09	1.02E-07	6.35E-07	2.73E-06
109218	8.03E-35	5.29E-28	1.86E-23	3.29E-20	8.94E-18	6.99E-16	2.29E-14	4.25E-12	1.77E-10	2.89E-09	2.52E-08	1.43E-07
155127	0.	0.	1.70E-33	6.97E-29	2.01E-25	9.84E-23	1.39E-20	2.35E-17	4.71E-15	2.50E-13	5.47E-12	6.43E-11
144188	0.	5.34E-37	5.38E-31	1.04E-26	1.71E-23	5.41E-21	5.41E-19	5.39E-16	7.43E-14	2.98E-12	5.24E-11	5.17E-10
166766	0.	0.	6.40E-36	5.83E-31	3.05E-27	2.38E-24	4.90E-22	1.44E-18	4.30E-16	3.08E-14	8.50E-13	1.21E-11
218000	0.	0.	0.	0.	9.08E-35	5.49E-31	5.81E-28	1.99E-23	3.45E-20	9.20E-18	7.07E-16	2.27E-14
229000	0.	0.	0.	0.	9.65E-37	9.05E-33	1.36E-29	7.92E-25	2.00E-21	7.07E-19	6.77E-17	2.60E-15
264000	0.	0.	0.	0.	0.	2.50E-38	1.15E-34	3.59E-29	3.00E-25	2.61E-22	5.03E-20	3.37E-18
149056	0.	7.79E-38	1.25E-31	3.38E-27	7.13E-24	2.74E-21	3.20E-19	4.03E-16	6.56E-14	2.98E-12	5.77E-11	6.16E-10
169022	0.	0.	2.60E-35	2.77E-30	1.63E-26	1.39E-23	3.07E-21	1.01E-17	3.25E-15	2.46E-13	7.12E-12	1.05E-10
187693	0.	0.	0.	2.14E-33	3.28E-29	5.91E-26	2.37E-23	1.91E-19	1.17E-16	1.43E-14	5.99E-13	1.19E-11
196955	0.	0.	0.	9.50E-36	2.35E-31	6.12E-28	3.31E-25	4.13E-21	3.48E-18	5.40E-16	2.73E-14	6.26E-13
203384	0.	0.	0.	2.03E-36	6.97E-32	2.35E-28	1.56E-25	2.65E-21	2.78E-18	5.10E-16	2.93E-14	7.45E-13
210284	0.	0.	0.	1.98E-37	9.71E-33	4.31E-29	3.57E-26	8.46E-22	1.12E-18	2.46E-16	1.62E-14	4.60E-13
211271	0.	0.	0.	1.85E-37	9.53E-33	4.40E-29	3.76E-26	9.35E-22	1.28E-18	2.88E-16	1.94E-14	5.59E-13
207974	0.	0.	0.	2.05E-37	8.92E-33	3.61E-29	2.77E-26	5.59E-22	7.22E-19	1.49E-16	9.37E-15	2.57E-13
226455	0.	0.	0.	0.	3.47E-35	2.94E-31	4.08E-28	2.10E-23	4.85E-20	1.61E-17	1.46E-15	5.39E-14
244500	0.	0.	0.	0.	8.78E-38	1.53E-33	3.78E-30	4.62E-25	1.98E-21	1.04E-18	1.36E-16	6.70E-15
266100	0.	0.	0.	0.	0.	4.90E-36	2.42E-32	8.33E-27	7.48E-23	6.87E-20	1.38E-17	9.58E-16
252000	0.	0.	0.	0.	0.	2.32E-35	7.28E-32	1.28E-26	7.07E-23	4.52E-20	6.85E-18	3.79E-16
270000	0.	0.	0.	0.	0.	2.20E-37	1.23E-33	5.11E-28	5.24E-24	5.33E-21	1.16E-18	8.54E-17
288000	0.	0.	0.	0.	0.	0.	1.15E-35	1.14E-29	2.16E-25	3.49E-22	1.08E-19	1.07E-17
309800	0.	0.	0.	0.	0.	0.	6.96E-38	1.95E-31	7.83E-27	2.21E-23	1.06E-20	1.48E-18
323100	0.	0.	0.	0.	0.	0.	0.	2.71E-33	1.72E-28	6.83E-25	4.28E-22	7.39E-20
354800	0.	0.	0.	0.	0.	0.	0.	2.41E-36	4.52E-31	4.06E-27	4.80E-24	1.37E-21
368100	0.	0.	0.	0.	0.	0.	1.28E-38	3.30E-32	1.25E-27	3.38E-24	1.57E-21	2.13E-19
339800	0.	0.	0.	0.	0.	0.	0.	2.93E-35	3.29E-30	2.01E-26	1.76E-23	3.96E-21
364000	0.	0.	0.	0.	0.	0.	0.	9.95E-38	2.56E-32	2.91E-28	4.13E-25	1.37E-22
356000	0.	0.	0.	0.	0.	0.	0.	0.	6.33E-35	1.64E-30	4.41E-27	2.44E-24
380000	0.	0.	0.	0.	0.	0.	0.	0.	2.39E-33	4.09E-29	8.00E-26	3.43E-23
412000	0.	0.	0.	0.	0.	0.	0.	0.	5.90E-36	2.30E-31	8.54E-28	6.10E-25
408000	0.	0.	0.	0.	0.	0.	0.	0.	4.53E-36	1.60E-31	5.46E-28	3.66E-25
439000	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.07E-33	6.84E-30	7.52E-27

Table 7. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O^-

STATE	LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
$2s^2\ 2p^5\ ^2P^o_{3/2}$	0	0.0000	4	9.40E-01	9.12E-01	8.87E-01	8.48E-01	8.20E-01	7.98E-01	7.70E-01	7.51E-01	7.24E-01
$^2P^o_{1/2}$	285	0.0353	2	6.05E-02	8.84E-02	1.13E-01	1.52E-01	1.80E-01	2.02E-01	2.30E-01	2.49E-01	2.76E-01

ENERGY LEVELS FROM BERRY ET AL. (43).

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	7.11E-01	7.02E-01	6.96E-01	6.92E-01	6.89E-01	6.87E-01	6.85E-01	6.82E-01	6.80E-01	6.78E-01	6.77E-01	6.76E-01
285	2.89E-01	2.98E-01	3.04E-01	3.08E-01	3.11E-01	3.13E-01	3.15E-01	3.18E-01	3.20E-01	3.22E-01	3.23E-01	3.24E-01

Table 8. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O

STATE		LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
$2s^2\ 2p^4\ {}^3P_2$		0	C.CCCC	5	8.12E-01	7.72E-01	7.42E-01	7.00E-01	6.74E-01	6.55E-01	6.31E-01	6.16E-01	5.97E-01
$^3P_1$		158.4	C.0196	3	1.56E-01	1.86E-01	2.08E-01	2.38E-01	2.56E-01	2.69E-01	2.85E-01	2.95E-01	3.07E-01
$^3P_0$		226.5	0.0281	1	3.18E-02	4.19E-02	5.01E-02	6.2CE-02	7.02E-02	7.61E-02	8.40E-02	8.90E-02	9.60E-02
^1D		15868	1.9673	5	C.	0.	6.6CE-34	1.14E-25	9.95E-21	1.95E-17	2.55E-13	7.49E-11	1.46E-07
^1S		33792	4.1896	1	0.	0.	0.	C.	0.	8.42E-37	5.1CE-28	9.46E-23	1.00E-15
$2s\ 2p^3\ {}^5P^o$		126304	15.6593	9	0.	0.	0.	C.	0.	C.	C.	C.	0.
$^3P^o$		189837	23.5362	3	0.	0.	0.	0.	0.	C.	C.	C.	C.
$2p^4\ {}^1S$		277CCO*	34.3427	1	C.	0.	0.	0.	0.	C.	0.	0.	0.
$2s^2\ 2p^3\ ({}^4S^o)$	3s	74903	9.2865	8	0.	0.	0.	0.	0.	C.	C.	0.	9.94E-32
	3p	87379	10.8333	24	0.	0.	0.	0.	0.	C.	C.	C.	1.14E-36
	3d	97443	12.0811	4C	0.	0.	0.	0.	0.	C.	C.	C.	0.
	4s	95757	11.8720	8	0.	0.	0.	0.	0.	C.	0.	0.	0.
	4p	99314	12.3130	24	0.	0.	0.	0.	0.	C.	C.	C.	0.
	4df	1029CO**	12.7576	116	0.	0.	0.	0.	0.	C.	C.	C.	0.
$({}^2D^o)$	3s	101523	12.5869	20	0.	0.	0.	0.	0.	C.	0.	0.	0.
	3p	1136CO**	14.0842	60	0.	0	0.	0.	0.	C.	C.	0.	C.
	3d	12394C**	15.3662	1CC	C.	0.	0.	0.	0.	C.	0.	0.	0.
	4	1287CO**	15.9564	320	0.	0.	0.	0.	0.	C.	C.	C.	C.
$({}^2P^o)$	3s	114416	14.1854	12	0.	0.	0.	0.	0.	C.	0.	0.	0.
	3p	1279CC**	15.8572	36	C.	0.	C.	0.	C.	C.	C.	C.	0.
	3d	138CCO*	17.1094	6C	0.	0.	0.	0.	0.	C.	C.	C.	C.
	4	1421CC*	17.6177	192	0.	0.	0.	0.	0.	C.	0.	0.	0.
$2s\ 2p^4\ ({}^4P)$	3	212CCO*	26.2840	216	0.	0.	0.	C.	0.	C.	C.	0.	C.
	4	222CCO*	27.5238	384	0.	0.	0.	0.	0.	C.	0.	C.	C.
$({}^2D)$	3	258COO*	31.9871	18C	C.	0.	0.	0.	0.	C.	0.	0.	0.
	4	268CCC*	33.2269	320	0.	0.	0.	C.	0.	C.	C.	0.	C.
$({}^2S)$	3	287CCC*	35.5825	36	0.	0.	0.	0.	0.	C.	0.	0.	0.
	4	298CCO*	36.9463	64	C.	0.	0.	C.	0.	C.	C.	C.	0.
$({}^2P)$	3	304CCO*	37.6902	108	0.	0.	0.	0.	0.	C.	0.	C.	0.
	4	314CCO*	38.9300	192	0.	0.	0.	0.	0.	C.	C.	C.	C.
$2p^3\ ({}^2P^o)$	3	409CCO*	5C.7082	1C8	0.	0.	0.	0.	0.	C.	C.	0.	0.
	4	419CCO*	51.9480	192	0.	0.	C.	0.	0.	C.	0.	0.	0.

*ESTIMATED.
**INCLUDES ESTIMATED SUBLEVELS.
NONSTARRED ENERGY LEVELS FROM MOORE (3) AND MCWEN (44).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 109837 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 8 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	5.86E-01	5.80E-01	5.76E-01	5.73E-01	5.70E-01	5.67E-01	5.65E-01	5.59E-01	5.52E-01	5.45E-01	5.38E-01	5.31E-01
158	3.14E-01	3.18E-01	3.20E-01	3.22E-01	3.23E-01	3.24E-01	3.24E-01	3.23E-01	3.21E-01	3.18E-01	3.15E-01	3.11E-01
226	9.96E-02	1.02E-01	1.03E-01	1.04E-01	1.05E-01	1.06E-01	1.06E-01	1.06E-01	1.05E-01	1.05E-01	1.04E-01	1.03E-01
15868	6.46E-06	6.27E-05	2.85E-04	8.42E-04	1.89E-03	3.55E-03	5.87E-03	1.24E-02	2.12E-02	3.14E-02	4.26E-02	5.41E-02
33702	3.25E-12	4.15E-10	1.05E-08	1.06E-07	6.00E-07	2.30E-06	6.76E-06	3.38E-05	1.06E-04	2.5CE-04	4.85E-04	8.21E-04
126304	0.	2.82E-32	5.11E-27	2.91E-23	1.91E-20	2.96E-18	1.67E-16	7.06E-14	5.28E-12	1.34E-10	1.65E-09	1.22E-08
189937	0.	0.	C.	4.41E-35	7.56E-31	1.48E-27	6.39E-25	5.69E-21	3.75E-18	4.87E-16	2.13E-14	4.38E-13
277000	0.	0.	0.	0.	0.	0.	2.73E-36	1.59E-30	2.07E-26	2.52E-23	6.31E-21	5.22E-19
74903	3.72E-24	1.76E-19	2.31E-16	3.89E-14	1.82E-12	3.61E-11	3.94E-10	1.42E-08	1.82E-07	1.23E-06	5.43E-06	1.77E-05
87379	1.41E-27	4.03E-22	1.75E-18	6.91E-16	6.13E-14	2.00E-12	3.26E-11	2.13E-09	4.20E-08	3.92E-07	2.22E-06	8.84E-06
97443	1.69E-30	2.05E-24	2.33E-20	1.84E-17	2.73E-15	1.34E-13	3.00E-12	3.18E-10	8.85E-09	1.07E-07	7.39E-07	3.46E-06
95757	1.14E-30	1.08E-24	1.05E-20	7.35E-18	1.00E-15	4.59E-14	9.75E-13	9.53E-11	2.50E-09	2.89E-08	1.94E-07	8.82E-07
99314	2.64E-31	4.19E-25	5.70E-21	5.11E-18	8.37E-16	4.41E-14	1.05E-12	1.22E-10	3.62E-09	4.58E-08	3.29E-07	1.59E-06
102900	9.65E-32	2.57E-25	4.93E-21	5.66E-18	1.11E-15	6.77E-14	1.81E-12	2.49E-10	8.36E-09	1.16E-07	8.96E-07	4.58E-06
101523	4.48E-32	9.79E-26	1.65E-21	1.72E-18	3.15E-16	1.81E-14	4.64E-13	5.98E-11	1.91E-09	2.57E-08	1.92E-07	9.62E-07
113600	2.27E-35	2.81E-28	1.51E-23	3.60E-20	1.23E-17	1.14E-15	4.31E-14	9.90E-12	4.80E-10	8.77E-09	8.38E-08	5.08E-07
123940	2.22E-38	1.22E-30	1.76E-25	8.55E-22	4.96E-19	7.00E-17	3.66E-15	1.38E-12	9.54E-11	2.28E-09	2.67E-08	1.91E-07
128700	0.	2.52E-31	5.76E-26	3.87E-22	2.87E-19	4.89E-17	2.98E-15	1.41E-12	1.15E-10	3.09E-09	4.00E-08	3.08E-07
114416	2.52E-36	3.52E-29	2.04E-24	5.15E-21	1.83E-18	1.76E-16	6.81E-15	1.63E-12	8.11E-11	1.51E-09	1.47E-08	9.03E-08
127900	C.	4.50E-32	9.51E-27	6.04E-23	4.30E-20	7.10E-18	4.22E-16	1.93E-13	1.52E-11	4.02E-10	5.11E-09	3.89E-08
138000	0.	2.24E-34	1.25E-28	1.58E-24	1.89E-21	4.68E-19	3.84E-17	2.85E-14	3.18E-12	1.09E-10	1.69E-09	1.52E-08
142100	0.	6.78E-35	5.59E-29	9.40E-25	1.39E-21	4.04E-19	3.78E-17	3.41E-14	4.39E-12	1.67E-10	2.82E-09	2.69E-08
212000	C.	0.	0.	3.51E-37	1.88E-32	8.94E-29	7.82E-26	2.02E-21	2.84E-18	6.51E-16	4.44E-14	1.30E-12
222000	0.	0.	0.	0.	9.15E-34	6.50E-30	7.82E-27	3.26E-22	6.47E-19	1.92E-16	1.60E-14	5.48E-13
258000	0.	0.	C.	0.	0.	3.05E-35	1.16E-31	2.72E-26	1.85E-22	1.38E-19	2.37E-17	1.45E-15
268000	0.	0.	0.	0.	0.	2.22E-36	1.16E-32	4.40E-27	4.22E-23	4.08E-20	8.52E-18	6.09E-16
287000	0.	0.	0.	0.	0.	0.	5.52E-36	5.19E-30	9.56E-26	1.50E-22	4.59E-20	4.46E-18
298000	0.	0.	C.	C.	0.	0.	4.14E-37	6.60E-31	1.77E-26	3.70E-23	1.41E-20	1.63E-18
304000	0.	0.	0.	0.	0.	0.	1.24E-37	2.64E-31	8.71E-27	2.12E-23	9.10E-21	1.16E-18
314000	0.	0.	C.	C.	0.	0.	0.	4.27E-32	1.98E-27	6.24E-24	3.27E-21	4.88E-19
405000	C.	0.	C.	0.	0.	0.	0.	0.	3.69E-36	1.33E-31	4.67E-28	3.18E-25
419000	0.	0.	0.	C.	0.	0.	0.	0.	8.40E-37	3.93E-32	1.68E-28	1.34E-25

Table 9. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O^+

STATE	LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 2CC	25C	3CC	4CO	5CC	6CO	8OC	1CCC	15CO
$2s^2\ 2p^3\ {}^4S^o$	C	0.CCCC	4	1.COE OC	1.OCE OC	1.COE OC	1.CCE CC	1.COE CC	1.COE CO	1.CCE CC	1.COE CO	1.COE CO
$^2D^o$	26819	3.3250	1C	C.	0.	C.	0.	7.62E-34	2.94E-28	2.82E-21	4.36E-17	1.68E-11
$^2P^o$	4C467	5.C171	6	C.	0.	0.	0.	0.	C.	3.7CE-32	7.76E-26	2.08E-17
$2s\ 2p^4\ {}^4P$	119933	14.8694	12	C.	0.	0.	0.	0.	C.	0.	0.	0.
^2D	165941	20.5797	1C	C.	0.	C.	C.	C.	C.	C.	C.	0.
^2S	195710	24.2643	2	C.	C.	0.	C.	0.	C.	0.	C.	0.
^2P	212650	26.3646	6	C.	0.	0.	0.	0.	0.	0.	C.	0.
$2p^5\ ^2P^o$	3174CO*	39.3516	6	C.	0.	0.	0.	C.	C.	C.	C.	0.
$2s^2\ 2p^3\ (^3P\ )\ 3s$	1866C4	23.1354	18	C.	0.	C.	0.	0.	C.	C.	C.	C.
$3p$	2C92C8	25.9378	54	0.	C.	C.	0.	0.	C.	C.	0.	0.
$3d$	232563	28.8334	90	C.	0.	0.	0.	0.	C.	C.	C.	C.
$4s$	239348	29.6746	18	C.	0.	0.	0.	0.	0.	C.	C.	C.
$4p$	246R6O**	3C.6C59	54	C.	0.	0.	0.	0.	C.	0.	0.	0.
$4d$	255CC6	31.6159	90	0.	0.	0.	0.	0.	0.	C.	0.	0.
$4f$	255932	31.7307	126	C.	0.	0.	C.	0.	C.	C.	C.	0.
$(^1D\ )\ 3s$	206372	25.6606	1C	C.	0.	0.	0.	0.	C.	C.	C.	0.
$3p$	229898	28.5C30	3C	0.	0.	0.	0.	0.	C.	C.	0.	0.
$3d$	252571	31.3140	5C	0.	0.	0.	0.	C.	C.	C.	C.	C.
4	27293C**	33.8381	16C	C.	C.	0.	0.	0.	C.	0.	C.	C.
$(^1S\ )\ 3s$	226851*	28.1252	2	C.	C.	0.	0.	0.	C.	C.	C.	0.
$3p$	25C251*	31.0264	6	0.	0.	0.	0.	0.	C.	C.	C.	0.
$3d$	275951*	34.2127	1C	0.	C.	C.	C.	0.	C.	0.	C.	C.
4	296CCC*	36.6984	32	0.	0.	C.	0.	0.	C.	C.	C.	C.
$2s\ 2p^3\ (^5S^o)\ 3$	281CCC**	34.8387	9C	0.	C.	0.	0.	0.	0.	0.	C.	0.
4	313CCC**	38.8C61	16C	C.	0.	0.	C.	0.	C.	C.	C.	C.
$(^3D^o)\ 3$	34CCCO*	42.1535	27C	0.	C.	0.	C.	0.	C.	C.	C.	0.
4	373CCC*	46.2449	48C	C.	0.	0.	0.	0.	C.	0.	0.	0.
$(^3P^o)\ 3\text{-}4$	383CCC*	47.4847	45C	0.	0.	0.	C.	0.	C.	C.	0.	C.
$(^3S^o, {}^1D^o, {}^1P^o)\ 3\text{-}4$	437CCC*	54.1797	55C	C.	0.	0.	0.	0.	C.	C.	C.	C.
$2p^4(^3P\ , {}^1D\ , {}^1S\ )\ 3\text{-}4$	534CCO*	66.2059	75C	0.	0.	C.	0.	0.	C.	C.	0.	0.

*ESTIMATED.
**INCLUDES ESTIMATED SUBLEVELS.
NONSTARRED ENERGY LEVELS FROM MOORE (3) AND ERIKSSON (45).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 283244 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 9 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O^+

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	9.99E-01	9.96E-01	9.90E-01	9.79E-01	9.65E-01	9.46E-01
26815	1.04E-08	4.95E-07	6.49E-06	4.07E-05	1.62E-04	4.72E-04	1.11E-03	4.01E-03	9.59E-03	1.97E-02	3.31E-02	4.99E-02
40467	3.41E-13	1.15E-10	5.59E-09	8.94E-08	7.15E-07	3.60E-06	1.31E-05	9.12E-05	3.62E-04	1.01E-03	2.24E-03	4.20E-03
119933	1.02E-37	3.17E-30	3.14E-25	1.16E-21	5.52E-19	6.33E-17	3.08E-15	9.66E-13	5.84E-11	1.26E-09	1.36E-08	9.10E-08
165991	0.	0.	6.67E-35	5.80E-30	2.94E-26	2.23E-23	4.50E-21	1.29E-17	3.77E-15	2.65E-13	7.21E-12	1.00E-10
195710	0.	0.	0.	5.74E-36	1.34E-31	3.33E-28	1.74E-25	2.07E-21	1.68E-18	2.53E-16	1.25E-14	2.79E-13
212650	0.	0.	0.	1.63E-38	9.06E-34	4.44E-30	3.98E-27	1.07E-22	1.55E-19	3.61E-17	2.49E-15	7.32E-14
317400	0.	0.	0.	0.	0.	0.	0.	1.32E-33	6.90E-29	2.38E-25	1.33E-22	2.08E-20
386604	0.	0.	0.	2.18E-33	3.18E-29	5.52E-26	2.15E-23	1.65E-19	9.80E-17	1.17E-14	4.81E-13	9.31E-12
409208	0.	0.	0.	6.03E-37	2.81E-32	1.20E-28	9.66E-26	2.19E-21	2.82E-18	6.03E-16	3.89E-14	1.08E-12
432563	0.	0.	0.	0.	1.05E-35	1.15E-31	1.94E-28	1.35E-23	3.87E-20	1.51E-17	1.55E-15	6.25E-14
439348	0.	0.	0.	0.	1.83E-37	2.62E-33	5.51E-30	5.31E-25	1.59E-21	8.90E-19	1.05E-16	4.71E-15
446860	0.	0.	0.	0.	3.69E-38	7.11E-34	1.90E-30	2.63E-25	1.23E-21	6.91E-19	9.45E-17	4.80E-15
455004	0.	0.	0.	0.	0.	8.76E-35	3.04E-31	6.21E-26	3.84E-22	2.66E-19	4.28E-17	2.48E-15
455932	0.	0.	0.	0.	0.	9.12E-35	3.26E-31	6.97E-26	4.45E-22	3.16E-19	5.17E-17	3.03E-15
466972	0.	0.	0.	2.80E-37	1.16E-32	4.55E-29	3.40E-26	6.94E-22	8.28E-19	1.67E-16	1.03E-14	2.76E-13
479898	0.	0.	0.	0.	9.15E-36	8.95E-32	1.39E-28	8.53E-24	2.43E-20	8.11E-18	7.90E-16	3.06E-14
492571	0.	0.	0.	0.	0.	1.06E-34	3.41E-31	6.19E-26	3.52E-22	2.29E-19	3.51E-17	1.95E-15
493930	0.	0.	0.	0.	0.	5.05E-37	3.11E-33	1.50E-27	1.72E-23	1.88E-20	4.34E-18	3.34E-16
496851	0.	0.	0.	0.	1.83E-36	1.58E-32	2.23E-29	1.18E-24	2.78E-21	9.36E-19	8.58E-17	3.16E-15
520251	0.	0.	0.	0.	0.	2.67E-35	7.97E-32	1.30E-26	6.80E-23	4.17E-20	6.11E-18	3.27E-16
575951	0.	0.	0.	0.	0.	1.20E-38	8.15E-35	4.55E-29	5.76E-25	6.84E-22	1.67E-19	1.35E-17
596000	0.	0.	0.	0.	0.	0.	8.15E-37	1.19E-30	2.99E-26	5.45E-23	2.17E-20	2.42E-18
781000	0.	0.	0.	0.	0.	0.	1.72E-34	1.22E-28	1.84E-24	2.48E-21	6.72E-19	5.88E-17
830000	0.	0.	0.	0.	0.	0.	0.	1.01E-31	4.54E-27	1.40E-23	7.17E-21	1.05E-18
840000	0.	0.	0.	0.	0.	0.	0.	2.62E-34	2.98E-29	1.84E-25	1.61E-22	3.63E-20
873000	0.	0.	0.	0.	0.	0.	0.	0.	6.01E-32	8.63E-28	1.47E-24	5.80E-22
883000	0.	0.	0.	0.	0.	0.	0.	0.	7.21E-33	1.34E-28	2.78E-25	1.24E-22
937000	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.92E-33	6.06E-29	6.42E-26
944000	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.52E-35	7.61E-32

Table 10. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF Ar

STATE		LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	Temperature (DEG K) 200	250	300	500	600	800	1000	1500
$3s^2\ 3p^6\ {}^1S$		0	0.0000	1	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00	1.00E 00
$3s^2\ 3p\ ^5(^2P^o_{1/2})$	3d	114854	14.2397	20	0.	0.	0.	0.	0.	0.	0.	0.
	4s	95188	11.8015	4	0.	0.	0.	0.	0.	0.	0.	0.
	4p	107421	13.3182	12	0.	0.	0.	0.	0.	0.	0.	0.
	4d	120721	14.9671	20	0.	0.	0.	0.	0.	0.	0.	0.
	4f	121654	15.0828	28	0.	0.	0.	0.	0.	0.	0.	0.
$3s^2\ 3p^5\ (^2P^o_{3/2})$	3d	112948	14.0034	40	0.	0.	0.	0.	0.	0.	0.	0.
	4s	93371	11.5762	8	0.	0.	0.	0.	0.	0.	0.	0.
	4p	105631	13.0962	24	0.	0.	0.	0.	0.	0.	0.	0.
	4d	119211	14.7799	40	0.	0.	0.	0.	0.	0.	0.	0.
	4f	120222	14.9052	56	0.	0.	0.	0.	0.	0.	0.	0.
$3s\ 3p^6\ (^2S)$	3d	222000*	27.5238	20	0.	0.	0.	0.	0.	0.	0.	0.
	4s	203000*	25.1681	4	0.	0.	0.	0.	0.	0.	0.	0.
	4p	215000*	26.6559	12	0.	0.	0.	0.	0.	0.	0.	0.
	4d	227900*	28.2553	20	0.	0.	0.	0.	0.	0.	0.	0.
	4f	228900*	28.3793	28	0.	0.	0.	0.	0.	0.	0.	0.

*ESTIMATED.
ENERGY LEVELS FROM CORE (3) BURNS AND ADAMS (46) AND HUMPHREYS AND PAUL(47).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 127110 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 10 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF Ar

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00	1.000E 00
114854	2.61E-35	3.93E-28	2.39E-23	6.25E-20	2.29E-17	2.25E-15	8.86E-14	2.19E-11	1.12E-09	2.14E-08	2.82E-07	1.33E-06
95188	7.29E-30	6.46E-24	5.97E-20	4.06E-17	5.40E-15	2.42E-13	5.08E-12	4.89E-10	1.27E-08	1.47E-07	9.85E-07	4.51E-06
107421	3.29E-33	1.70E-26	5.07E-22	7.97E-19	1.99E-16	1.46E-14	4.51E-13	7.80E-11	3.09E-09	4.88E-08	4.18E-07	2.33E-06
120721	3.84E-37	1.34E-29	1.43E-24	5.61E-21	2.77E-18	3.45E-16	1.64E-14	5.36E-12	3.35E-10	7.44E-09	8.31E-08	5.72E-07
121654	2.75E-37	1.10E-29	1.28E-24	5.35E-21	2.77E-18	3.59E-16	1.75E-14	5.99E-12	3.87E-10	8.81E-09	1.00E-07	7.01E-07
112948	2.06E-34	2.35E-27	1.19E-22	2.74E-19	9.08E-17	8.29E-15	3.07E-13	6.91E-11	3.31E-09	6.03E-08	5.76E-07	3.50E-06
93371	5.39E-29	3.68E-23	2.85E-19	1.71E-16	2.08E-14	8.67E-13	1.72E-11	1.51E-09	3.70E-08	4.08E-07	2.63E-06	1.17E-05
10567	2.39E-32	9.52E-26	2.39E-21	3.33E-18	7.57E-16	5.16E-14	1.51E-12	2.40E-10	8.53E-09	1.35E-07	1.11E-06	6.02E-06
119211	2.28E-36	6.40E-29	5.92E-24	2.09E-20	9.54E-18	1.12E-15	5.06E-14	1.54E-11	9.13E-10	1.95E-08	2.12E-07	1.42E-06
120222	1.54E-36	5.01E-29	5.10E-24	1.93E-20	9.28E-18	1.13E-15	5.29E-14	1.69E-11	1.04E-09	2.28E-08	2.52E-07	1.72E-06
222000	0.	0.	0.	0.	4.18E-34	2.98E-30	3.61E-27	1.52E-22	3.05E-19	3.15E-17	7.72E-15	2.63E-13
203000	0.	0.	0.	2.29E-36	7.77E-32	2.59E-28	1.71E-25	2.85E-21	3.03E-18	5.68E-16	3.22E-14	8.27E-13
215000	0.	0.	0.	4.95E-38	3.11E-33	1.68E-29	1.62E-26	4.88E-22	7.71E-19	1.43E-16	1.42E-14	4.41E-13
227900	0.	0.	0.	0.	5.01E-35	4.52E-31	6.61E-28	3.69E-23	9.07E-20	3.16E-17	3.01E-15	1.15E-13
228900	0.	0.	0.	0.	4.85E-35	4.60E-31	6.94E-28	4.06E-23	1.03E-19	3.70E-17	3.59E-15	1.39E-13

Table 11. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF Ar^+

STATE	LEVEL (CM-1)	LEVEL (EV)	STAT. WT.	TEMPERATURE (DEG K) 200	250	300	400	500	600	800	1000	1500
$3s^2 3p^5\ ^2P_{3/2}$	0	0.0000	4	1.00E 00	1.00E 00	9.99E-01	9.97E-01	9.92E-01	9.84E-01	9.63E-01	9.40E-01	8.88E-01
$^2P_{1/2}$	1432.0	0.1775	2	1.68E-05	1.32E-04	5.20E-04	2.89E-03	8.05E-03	1.59E-02	3.67E-02	5.99E-02	1.12E-01
$3s\ 3p^6\ ^2S$	108723	13.4796	2	0.	0.	0.	0.	C.	C.	C.	C.	C.
$3s^2 3p^4 (^3P) 3d^4D$	132476	16.4245	20	0.	0.	C.	C.	0.	C.	C.	C.	C.
3d other	146319	18.1408	70	C.	C.	C.	0.	0.	C.	C.	C.	C.
4s	136028	16.8649	18	0.	0.	0.	0.	0.	0.	C.	C.	C.
4p	158023	19.5918	54	0.	C.	C.	C.	C.	C.	0.	C.	C.
4d	186693	23.1464	90	0.	C.	C.	C.	C.	C.	0.	C.	C.
4f	195567	24.2466	126	0.	0.	0.	0.	0.	C.	0.	0.	0.
$(^1D) 3d$	164082	20.3431	50	C.	0.	0.	0.	0.	C.	C.	C.	C.
4s	148754	18.4427	10	0.	0.	C.	C.	C.	C.	C.	C.	C.
4p	171831	21.3038	30	0.	C.	0.	0.	0.	0.	0.	C.	C.
4d	199657	24.7537	50	C.	0.	0.	0.	0.	0.	C.	C.	C.
4f	209029	25.9156	70	C.	0.	0.	C.	0.	C.	C.	C.	C.
$(^1S) 3d$	179728	22.2829	10	0.	0.	0.	C.	0.	C.	0.	C.	C.
4s	167309	20.7431	2	0.	0.	0.	0.	0.	C.	C.	0.	0.
4p	192095	23.8161	6	C.	0.	0.	0.	C.	C.	C.	C.	C.
4d	220000*	27.2758	10	0.	0.	0.	C.	0.	C.	C.	0.	0.
4f	228000*	28.2677	14	0.	C.	0.	C.	0.	C.	C.	0.	C.
$3s\ 3p^5(^3P^o) 3d$	269000*	33.3509	90	C.	C.	0.	0.	0.	0.	C.	0.	0.
4s	249000*	30.8713	18	0.	0.	0.	0.	0.	C.	C.	C.	C.
4p	273000*	33.8468	54	C.	C.	0.	C.	0.	C.	0.	C.	0.
4d	301000*	37.3183	90	0.	0.	0.	0.	0.	0.	0.	0.	0.
4f	309000*	38.3101	126	C.	0.	0.	0.	C.	C.	C.	C.	C.

*ESTIMATED.
ENERGY LEVELS FROM MOORE (3) AND MINNHAGEN (48).
NOTE: STATES INVOLVING ELECTRONS WITH PRINCIPAL QUANTUM NUMBERS ABOVE N = 4 ARE NOT INCLUDED.
ALL LEVELS ABOVE 222848 CM-1 ARE SUBJECT TO AUTOIONIZATION.

Table 11 (Cont.). ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF Ar^+

LEVEL (CM-1)	TEMPERATURE (DEG K) 2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000
0	8.49E-01	8.20E-01	7.99E-01	7.83E-01	7.70E-01	7.60E-01	7.51E-01	7.38E-01	7.29E-01	7.21E-01	7.15E-01	7.11E-01
1432	1.51E-01	1.80E-01	2.01E-01	2.17E-01	2.30E-01	2.40E-01	2.49E-01	2.62E-01	2.71E-01	2.79E-01	2.85E-01	2.89E-01
108723	4.56E-35	2.74E-28	9.04E-24	1.52E-20	3.99E-18	3.04E-16	9.72E-15	1.76E-12	7.48E-11	1.16E-09	1.01E-08	5.72E-08
132476	0.	3.17E-33	1.02E-27	8.74E-24	7.78E-21	1.53E-18	1.04E-16	5.90E-14	5.44E-12	1.62E-10	2.27E-09	1.87E-08
146319	0.	3.85E-36	4.67E-30	1.03E-25	1.87E-22	6.40E-20	6.81E-18	7.47E-15	1.11E-12	4.70E-11	8.69E-10	8.95E-09
136028	0.	3.70E-34	1.67E-28	1.83E-24	1.95E-21	4.42E-19	3.38E-17	2.26E-14	2.36E-12	7.70E-11	1.16E-09	1.01E-08
158023	0.	0.	1.31E-32	6.49E-28	2.14E-24	1.17E-21	1.81E-19	3.48E-16	7.71E-14	4.42E-12	1.03E-10	1.28E-09
186693	0.	0.	0.	8.23E-33	1.19E-28	2.04E-25	7.88E-23	5.99E-19	3.54E-16	4.25E-14	1.76E-12	3.45E-11
195567	0.	0.	0.	3.00E-34	6.83E-30	1.67E-26	8.59E-24	9.99E-20	8.01E-17	1.21E-14	5.96E-13	1.35E-11
164082	0.	0.	6.66E-34	4.98E-29	2.25E-25	1.56E-22	2.93E-20	7.53E-17	2.05E-14	1.38E-12	3.63E-11	4.96E-10
148754	0.	1.35E-37	2.08E-31	5.42E-27	1.11E-23	4.20E-21	4.83E-19	5.95E-16	9.59E-14	4.34E-12	8.41E-11	9.01E-10
171831	0.	0.	9.72E-36	1.23E-30	8.30E-27	7.86E-24	1.89E-21	7.05E-18	2.51E-15	2.05E-13	6.30E-12	9.77E-11
199657	0.	0.	0.	2.22E-35	6.22E-31	1.79E-27	1.05E-24	1.49E-20	1.37E-17	2.29E-15	1.23E-13	2.97E-12
209029	0.	0.	0.	6.58E-37	2.99E-32	1.25E-28	9.91E-26	2.20E-21	2.80E-18	5.95E-16	3.85E-14	1.08E-12
179728	0.	0.	7.34E-38	1.60E-32	1.62E-28	2.10E-25	6.50E-23	3.54E-19	1.65E-16	1.65E-14	5.95E-13	1.05E-11
187309	0.	0.	5.67E-36	5.28E-31	2.81E-27	2.23E-24	4.63E-22	1.39E-18	4.23E-16	3.08E-14	8.66E-13	1.25E-11
192095	0.	0.	0.	5.95E-35	1.13E-30	2.41E-27	1.11E-24	1.05E-20	7.78E-18	1.07E-15	4.94E-14	1.06E-12
220000	0.	0.	0.	0.	8.76E-35	5.37E-3	6.02E-28	2.26E-23	4.19E-20	1.18E-17	9.51E-16	3.18E-14
228000	0.	0.	0.	0.	6.51E-36	5.82E-32	8.44E-29	4.65E-24	1.13E-20	3.92E-18	3.71E-16	1.41E-14
269000	0.	0.	0.	0.	0.	7.59E-37	4.08E-33	1.61E-27	1.59E-23	1.58E-20	3.39E-18	2.48E-16
249000	0.	0.	0.	0.	0.	9.09E-35	2.58E-31	3.89E-26	1.[illegible]E-22	1.15E-19	1.66E-17	8.93E-16
273000	0.	0.	0.	0.	0.	1.27E-37	7.74E-34	3.69E-28	4.20E-24	4.63E-21	1.07E-18	8.38E-17
301000	0.	0.	0.	0.	0.	0.	4.09E-37	7.47E-31	2.22E-26	5.01E-23	2.04E-20	2.49E-18
309000	0.	0.	0.	0.	0.	0.	5.73E-38	1.54E-31	5.99E-27	1.66E-23	7.93E-21	1.10E-18

Table 12. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF CO

		STATE						
		$X\ ^1\Sigma^+$	$a\ ^3\Pi$	$a'\ ^3\Sigma^+$	$d\ ^3\Delta$	$e\ ^3\Sigma^-$	$I\ ^1\Sigma^-$	$A\ ^1\Pi$
ENERGY	(CM-1)	0	49474	55354	60647	63709	64547	64747
	(EV)	0.0000	6.0099	6.8628	7.5191	7.8987	8.0026	8.0273
VIB.	(CM-1)	2143	1715	1209	1138	1094	1071	1481
INT.	(EV)	0.2657	0.2126	0.1499	0.1410	0.1357	0.1328	0.1836
TEMP. (DEG K)		FRACTIONAL POPULATION						
200		1.00E 00	0.	0.	0.	0.	0.	0.
250		1.00E 00	0.	0.	0.	0.	0.	0.
300		1.00E 00	0.	0.	0.	0.	0.	0.
400		1.00E 00	0.	0.	0.	0.	0.	0.
500		1.00E 00	0.	0.	0.	0.	0.	0.
600		1.00E 00	0.	0.	0.	0.	0.	0.
800		1.00E 00	0.	0.	0.	0.	0.	0.
1000		1.00E 00	3.68E-30	1.30E-34	0.	0.	0.	0.
1500		1.00E 00	4.77E-20	4.85E-23	6.43E-25	1.78E-26	2.73E-27	2.98E-27
2000		1.00E 00	5.49E-15	3.03E-17	1.44E-18	8.34E-20	1.57E-20	1.73E-20
2500		1.00E 00	5.99E-12	9.17E-14	9.35E-15	8.48E-16	1.80E-16	1.99E-16
3000		1.00E 00	6.37E-10	1.93E-11	3.28E-12	4.01E-13	9.20E-14	1.02E-13
3500		1.00E 00	1.79E-08	8.85E-10	2.17E-10	3.28E-11	7.94E-12	8.83E-12
4000		1.00E 00	2.19E-07	1.56E-08	5.04E-09	8.96E-10	2.25E-10	2.51E-10
4500		1.00E 00	1.53E-06	1.46E-07	5.84E-08	1.18E-08	3.03E-09	3.40E-09
5000		1.00E 00	7.29E-06	8.77E-07	4.15E-07	9.26E-08	2.42E-08	2.73E-08
6000		1.00E 00	7.58E-05	1.29E-05	7.91E-06	2.04E-06	5.45E-07	6.21E-07
7000		9.99E-01	4.05E-04	8.87E-05	6.48E-05	1.86E-05	4.97E-06	5.73E-06
8000		9.98E-01	1.42E-03	3.74E-04	3.12E-04	9.60E-05	2.57E-05	2.99E-05
9000		9.94E-01	3.77E-03	1.14E-03	1.05E-03	3.40E-04	9.08E-05	1.07E-04
10000		9.85E-01	8.15E-03	2.75E-03	2.71E-03	9.17E-04	2.45E-04	2.89E-04

Based on energy-level data from references 49 and 57.

Table 13. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF N_2

		STATE							
		X $^1\Sigma_g^+$	A $^3\Sigma_u^+$	$^3\Delta_u$	B $^3\Pi_g$	B' $^3\Sigma_u^-$	a' $^1\Sigma_u^-$	a $^1\Pi_g$	w $^1\Delta_u$
ENERGY	(CM-1)	0	49756	~58CCC	59310	65852	67739	68951	71698
	(EV)	0.CCOO	6.1688	~7.1909	7.3533	8.1644	8.3984	8.5486	8.88c2
VIB.	(CM-1)	2330	1433	~1464	1705	1493	1506	1666	1535
INT.	(EV)	0.2888	0.1777	~0.1815	C.2114	0.1851	0.1867	0.2066	0.1904
TEMP. (DEG K)		FRACTIONAL POPULATION							
200		1.COE CO	0.	0.	C.	0.	0.	0.	0.
250		1.00E 00	0.	0.	C.	0.	0.	0.	C.
300		1.COE 00	0.	0.	0.	0.	0.	0.	0.
400		1.00E 00	0.	0.	0.	0.	0.	0.	C.
500		1.00E 00	C.	0.	C.	0.	0.	0.	0.
600		1.00E 00	0.	0.	C.	0.	0.	0.	0.
800		1.00E 00	0.	0.	0.	0.	0.	0.	0.
1000		1.COE 00	3.72E-31	0.	0.	0.	0.	0.	0.
1500		1.00E 00	9.34E-21	6.77E-24	1.60E-24	1.78E-27	9.62E-29	5.27E-29	4.22E-30
2000		1.00E 00	1.51E-15	7.87E-18	2.51E-18	1.36E-20	1.15E-21	8.33E-22	1.30E-22
2500		1.00E CO	2.03E-12	3.46E-14	1.31E-14	1.84E-16	2.05E-17	1.75E-17	4.09E-18
3000		1.COE 00	2.49E-10	9.33E-12	3.97E-12	1.05E-13	1.40E-14	1.34E-14	4.09E-15
3500		1.00E 00	7.75E-09	5.10E-10	2.35E-10	9.83E-12	1.49E-12	1.54E-12	5.69E-13
4000		1.00E 00	1.02E-07	1.03E-08	5.04E-09	2.96E-10	4.94E-11	5.40E-11	2.31E-11
4500		1.00E 00	7.64E-07	1.06E-07	5.47E-08	4.19E-09	7.54E-10	8.62E-10	4.13E-10
5000		1.00E 00	3.82E-06	6.91E-07	3.69E-07	3.50E-08	6.68E-09	7.92E-09	4.15E-09
6000		1.00E 00	4.28E-05	1.15E-05	6.47E-06	8.48E-07	1.77E-07	2.21E-07	1.33E-07
7000		1.00E 00	2.40E-04	8.56E-05	5.02E-05	8.29E-06	1.84E-06	2.39E-06	1.59E-06
8000		9.98E-01	8.67E-04	3.86E-04	2.33E-04	4.59E-05	1.07E-05	1.43E-05	1.02E-05
9000		9.95E-01	2.33E-03	1.24E-03	7.64E-04	1.74E-04	4.19E-05	5.76E-05	4.34E-05
10000		9.89E-01	5.08E-03	3.13E-03	1.96E-03	5.00E-04	1.25E-04	1.75E-04	1.38E-04

Tables 13 to 18 are based on energy-level data from reference 50.

Table 14. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF N_2^+

		STATE							
		$X\ ^2\Sigma_g^+$	$A\ ^2\Pi_u$	$B\ ^2\Sigma_u^+$	$^4\Sigma_u^+$	$^4\Delta_u$	$D\ ^2\Pi_g$	$^4\Sigma_u^-$	$C\ ^2\Sigma_u^+$
ENERGY	(CM-1)	0	9016	25566	~44328	~51328	51203	~60328	64542
	(EV)	0.0000	1.1178	3.1697	~5.4958	~6.3637	6.3482	~7.4795	8.0020
VIB.	(CM-1)	2175	1873	2371	~1668	~1572	889	~1472	2051
INT.	(EV)	0.2696	0.2323	0.2940	~0.2068	~0.1949	0.1102	~0.1825	0.2543
TEMP. (DEG K)		FRACTIONAL POPULATION							
200		1.00E 00	1.50E-28	0.	0.	0.	0.	0.	0.
250		1.00E 00	6.44E-23	0.	0.	0.	0.	0.	0.
300		1.00E 00	3.67E-19	0.	0.	0.	0.	0.	0.
400		1.00E 00	1.82E-14	0.	0.	0.	0.	0.	0.
500		1.00E 00	1.19E-11	1.04E-32	0.	0.	0.	0.	0.
600		1.00E 00	9.05E-10	2.19E-27	0.	0.	0.	0.	0.
800		1.00E 00	2.03E-07	9.87E-21	5.92E-35	0.	0.	0.	0.
1000		1.00E 00	5.26E-06	9.68E-17	5.08E-28	4.37E-32	4.75E-32	0.	0.
1500		1.00E 00	4.07E-04	2.02E-11	9.09E-19	2.26E-21	2.58E-21	2.37E-25	1.67E-27
2000		9.96E-01	3.59E-03	9.16E-09	3.88E-14	5.21E-16	6.18E-16	4.76E-19	8.84E-21
2500		9.87E-01	1.32E-02	3.57E-07	2.32E-11	8.57E-13	1.05E-12	2.87E-15	9.49E-17
3000		9.69E-01	3.11E-02	4.05E-06	1.63E-09	1.18E-10	1.50E-10	9.45E-13	4.56E-14
3500		9.43E-01	5.67E-02	2.26E-05	3.34E-08	3.96E-09	5.16E-09	5.87E-11	3.70E-12
4000		9.12E-01	8.79E-02	8.13E-05	3.18E-07	5.43E-08	7.24E-08	1.28E-09	9.88E-11
4500		8.78E-01	1.22E-01	2.17E-04	1.81E-06	4.11E-07	5.58E-07	1.40E-08	1.25E-09
5000		8.42E-01	1.57E-01	4.73E-04	7.17E-06	2.06E-06	2.82E-06	9.34E-08	9.46E-09
6000		7.74E-01	2.25E-01	1.49E-03	5.49E-05	2.25E-05	3.10E-05	1.58E-06	1.90E-07
7000		7.12E-01	2.84E-01	3.32E-03	2.27E-04	1.21E-04	1.65E-04	1.15E-05	1.57E-06
8000		6.59E-01	3.33E-01	6.01E-03	6.37E-04	4.20E-04	5.56E-04	4.99E-05	7.40E-06
9000		6.13E-01	3.74E-01	9.46E-03	1.39E-03	1.09E-03	1.39E-03	1.53E-04	2.41E-05
10000		5.73E-01	4.06E-01	1.35E-02	2.52E-03	2.28E-03	2.80E-03	3.65E-04	6.05E-05

Table 15. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF NO

		STATE						
		$X\ ^2\Pi$	$a\ ^4\Pi$	$A\ ^2\Sigma^+$	$B\ ^2\Pi$	$b\ ^4\Sigma^-$	$C\ ^2\Pi$	$D\ ^2\Sigma^+$
ENERGY	(CM-1)	62*	~37965	44199	45505	~47092	52380**	53291
	(EV)	0.0077*	~4.7069	5.4799	5.6418	~5.8385	6.4941**	6.6071
VIB.	(CM-1)	1876	995	2342	1023	~1203	2365**	2279
INT.	(EV)	0.2326	0.1234	0.2903	0.1268	~0.1491	0.2932**	0.2826

TEMP. (DEG K)	FRACTIONAL POPULATION						
200	1.00E 00	0.	0.	0.	0.	0.	0.
250	1.00E 00	0.	0.	0.	0.	0.	0.
300	1.00E 00	0.	0.	0.	0.	0.	0.
400	1.00E 00	0.	0.	0.	0.	0.	0.
500	1.00E 00	0.	0.	0.	0.	0.	0.
600	1.00E 00	0.	0.	0.	0.	0.	0.
800	1.00E 00	8.47E-30	1.40E-35	0.	0.	0.	0.
1000	1.00E 00	7.49E-24	1.08E-28	7.45E-29	5.89E-30	1.67E-33	2.26E-34
1500	1.00E 00	6.58E-16	1.63E-19	2.41E-19	3.99E-20	1.27E-22	2.68E-23
2000	1.00E 00	6.31E-12	6.26E-15	1.40E-14	3.34E-15	3.48E-17	9.07E-18
2500	1.00E 00	1.56E-09	3.49E-12	1.01E-11	3.04E-12	6.30E-14	1.85E-14
3000	1.00E 00	6.20E-08	2.34E-10	8.24E-10	2.87E-10	9.31E-12	2.93E-12
3500	1.00E 00	8.61E-07	4.65E-09	1.91E-08	7.43E-09	3.26E-10	1.06E-10
4000	1.00E 00	6.17E-06	4.32E-08	2.02E-07	8.56E-08	4.65E-09	1.54E-09
4500	1.00E 00	2.83E-05	2.41E-07	1.27E-06	5.74E-07	3.63E-08	1.21E-08
5000	1.00E 00	9.52E-05	9.40E-07	5.51E-06	2.63E-06	1.86E-07	6.20E-08
6000	9.99E-01	5.73E-04	7.00E-06	4.98E-05	2.57E-05	2.09E-06	6.89E-07
7000	9.98E-01	2.00E-03	2.82E-05	2.37E-04	1.29E-04	1.13E-05	3.68E-06
8000	9.94E-01	4.94E-03	7.75E-05	7.56E-04	4.22E-04	3.88E-05	1.24E-05
9000	9.87E-01	9.73E-03	1.65E-04	1.83E-03	1.04E-03	9.85E-05	3.11E-05
10000	9.77E-01	1.63E-02	2.94E-04	3.65E-03	2.11E-03	2.02E-04	6.29E-05

*Average energy of the two spin components, above that of the lower component ($^2\Pi_{\frac{1}{2}}$).

**"Deperturbed" values.

Table 16. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF NO^+

		STATE					
		X $^1\Sigma^+$	a $^3\Sigma^+$	$^3\Delta$	$^3\Pi$	A $^1\Pi$	$^3\Sigma^-$
ENERGY	(CM-1)	0	~39934	~58804	~63764	73084	~73334
	(EV)	0.0000	~4.9511	~7.2906	~7.9055	9.0610	~9.0920
VIB.	(CM-1)	2344	~1572	~1972	~1672	1562	~1176
INT.	(EV)	0.2907	~0.1949	~0.2445	~0.2073	0.1937	~0.1458
TEMP. (DEG K)		FRACTIONAL POPULATION					
200		1.00E 00	0.	0.	0.	0.	0.
250		1.00E 00	0.	0.	0.	0.	0.
300		1.00E 00	0.	0.	0.	0.	0.
400		1.00E 00	0.	0.	0.	0.	0.
500		1.00E 00	0.	0.	0.	0.	0.
600		1.00E 00	0.	0.	0.	0.	0.
800		1.00E 00	2.46E-31	0.	0.	0.	0.
1000		1.00E 00	4.39E-25	0.	0.	0.	0.
1500		1.00E 00	9.76E-17	2.70E-24	2.01E-26	1.06E-30	1.87E-30
2000		1.00E 00	1.48E-12	3.67E-18	9.19E-20	4.55E-23	8.79E-23
2500		1.00E 00	4.80E-10	1.76E-14	9.15E-16	1.75E-18	3.54E-18
3000		1.00E 00	2.28E-08	5.04E-12	4.25E-13	2.01E-15	4.13E-15
3500		1.00E 00	3.60E-07	2.86E-10	3.43E-11	3.10E-13	6.33E-13
4000		1.00E 00	2.86E-06	5.94E-09	9.27E-10	1.36E-11	2.72E-11
4500		1.00E 00	1.43E-05	6.31E-08	1.21E-08	2.59E-10	4.99E-10
5000		1.00E 00	5.22E-05	4.19E-07	9.45E-08	2.73E-09	5.04E-09
6000		1.00E 00	3.63E-04	7.22E-06	2.08E-06	9.30E-08	1.57E-07
7000		9.98E-01	1.45E-03	5.57E-05	1.90E-05	1.14E-06	1.75E-06
8000		9.96E-01	4.10E-03	2.58E-04	9.93E-05	7.39E-06	1.04E-05
9000		9.90E-01	9.14E-03	8.48E-04	3.56E-04	3.09E-05	4.00E-05
10000		9.79E-01	1.72E-02	2.18E-03	9.78E-04	9.52E-05	1.15E-04

Table 17. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O_2

		STATE						
		$X\ ^3\Sigma_g^-$	$a\ ^1\Delta_g$	$b\ ^1\Sigma_g^+$	$C\ ^3\Delta_u$	$A\ ^3\Sigma_u^+$	$c\ ^1\Sigma_u^-$	$B\ ^3\Sigma_u^-$
ENERGY	(CM-1)	0	7882	13121	~34329	35004	36213	49358
	(EV)	0.0000	0.9773	1.6267	~4.2561	4.3398	4.4897	6.1194
VIB.	(CM-1)	1556	1483	1405	~820	775	616	688
INT.	(EV)	0.1930	0.1839	0.1742	~0.1017	0.0960	0.0764	0.0853

TEMP. (DEG K)	FRACTIONAL POPULATION						
200	1.00E 00	1.60E-25	0.	0.	0.	0.	0.
250	1.00E 00	1.34E-20	5.53E-34	0.	0.	0.	0.
300	1.00E 00	2.58E-17	1.62E-28	0.	0.	0.	0.
400	1.00E 00	3.29E-13	1.10E-21	0.	0.	0.	0.
500	1.00E 00	9.56E-11	1.39E-17	0.	0.	0.	0.
600	1.00E 00	4.20E-09	7.54E-15	0.	0.	0.	0.
800	1.00E 00	4.76E-07	1.99E-11	5.78E-27	9.21E-28	4.47E-29	0.
1000	1.00E 00	8.14E-06	2.25E-09	1.43E-21	2.90E-22	2.24E-23	3.73E-31
1500	1.00E 00	3.60E-04	1.24E-06	2.30E-14	6.30E-15	9.18E-16	8.26E-21
2000	9.98E-01	2.39E-03	2.91E-05	9.29E-11	2.89E-11	5.68E-12	1.25E-15
2500	9.92E-01	7.44E-03	1.94E-04	1.32E-08	4.37E-09	1.01E-09	1.57E-12
3000	9.84E-01	1.58E-02	6.82E-04	3.47E-07	1.19E-07	3.05E-08	1.78E-10
3500	9.72E-01	2.68E-02	1.67E-03	3.46E-06	1.21E-06	3.32E-07	5.08E-09
4000	9.57E-01	3.98E-02	3.25E-03	1.88E-05	6.68E-06	1.92E-06	6.08E-08
4500	9.41E-01	5.37E-02	5.43E-03	6.82E-05	2.45E-05	7.26E-06	4.08E-07
5000	9.23E-01	6.81E-02	8.16E-03	1.86E-04	6.73E-05	2.05E-05	1.83E-06
6000	8.88E-01	9.60E-02	1.48E-02	7.96E-04	2.90E-04	9.17E-05	1.64E-05
7000	8.53E-01	1.21E-01	2.24E-02	2.11E-03	7.75E-04	2.51E-04	7.39E-05
8000	8.21E-01	1.43E-01	3.00E-02	4.20E-03	1.55E-03	5.10E-04	2.19E-04
9000	7.91E-01	1.61E-01	3.72E-02	6.94E-03	2.56E-03	8.56E-04	4.93E-04
10000	7.65E-01	1.75E-01	4.36E-02	1.01E-02	3.74E-03	1.26E-03	9.21E-04

Table 18. ENERGY LEVELS AND EQUILIBRIUM FRACTIONAL ELECTRONIC POPULATIONS OF O_2^+

		STATE			
		$X\ ^2\Pi_g$	$a\ ^4\Pi_u$	$A\ ^2\Pi_u$	$b\ ^4\Sigma_g^-$
ENERGY	(CM-1)	98*	32571	38303	49238
	(EV)	0.0122*	4.0382	4.7488	6.1046
VIB.	(CM-1)	1843	1015	872	1163
INT.	(EV)	0.2286	0.1258	0.1081	0.1441
TEMP. (DEG K)		FRACTIONAL POPULATION			
200		1.00E 00	0.	0.	0.
250		1.00E 00	0.	0.	0.
300		1.00E 00	0.	0.	0.
400		1.00E 00	0.	0.	0.
500		1.00E 00	0.	0.	0.
600		1.00E 00	5.00E-34	0.	0.
800		1.00E 00	1.52E-25	2.81E-30	0.
1000		1.00E 00	1.89E-20	2.81E-24	2.96E-31
1500		1.00E 00	1.22E-13	2.92E-16	5.54E-21
2000		1.00E 00	3.16E-10	3.06E-12	7.71E-16
2500		1.00E 00	3.56E-08	8.02E-10	9.51E-13
3000		1.00E 00	8.38E-07	3.31E-08	1.10E-10
3500		1.00E 00	8.03E-06	4.72E-07	3.31E-09
4000		1.00E 00	4.39E-05	3.46E-06	4.25E-08
4500		1.00E 00	1.65E-04	1.67E-05	3.10E-07
5000		9.99E-01	4.74E-04	5.54E-05	1.52E-06
6000		9.97E-01	2.29E-03	3.41E-04	1.63E-05
7000		9.92E-01	6.92E-03	1.21E-03	8.73E-05
8000		9.81E-01	1.55E-02	3.01E-03	2.99E-04
9000		9.65E-01	2.82E-02	5.94E-03	7.58E-04
10000		9.44E-01	4.44E-02	9.93E-03	1.56E-03

*Average energy of the two spin components, above that of the lower component ($^2\Pi_{\frac{1}{2}}$).

Table 19. LOWER ELECTRONIC AND VIBRATIONAL ENERGY LEVELS OF SELECTED DIATOMIC MOLECULES. UNITS: cm^{-1} and ev

Molecule	State	Electronic Energy	Lowest Vibrational Interval	References
H_2	$X^1\Sigma_g^+$	0 cm^{-1} 0 ev	4161 0.516	51
H_2^+	$X^2\Sigma_g^+$	0 0	2191 0.272	14
CO^+	$X^2\Sigma^+$	0 0	2184 0.271	52
	$A^2\Pi$	20408 2.530	1535 0.190	
	$B^2\Sigma^+$	45633 5.658	1679 0.208	
NO^-	$X^3\Sigma^-$	0 0	(~1600) (~0.20)	*
O_2^-	$X^2\Pi_g$	0 0	[illegible] (0.143)	53
OH^-	$X^1\Sigma^+$	0 0	(3600) (0.446)	28
OH	$X^2\Pi$	0 0	3570 0.443	52
	$A^2\Sigma^+$	32402 4.017	2989 0.371	
OH^+	$X^3\Sigma^-$	0 0	2967 0.368	52
	$A^3\Pi$	27952 3.466	1986 0.246	

*Vibrational interval estimated from O_2.

Table 20. VIBRATIONAL SPACING OF TRIATOMIC MOLECULES

Molecule	Ground State	Vibrational Intervals (cm^{-1}; ev)			References
		ν_1	ν_2	ν_3	
H_2O	$^1A_1$	3657 0.453	1595 0.198	3756 0.466	32
H_2O^+	$(^2B_1)$	(~3200) (~0.40)	(~1500) (~0.19)	(~3300) (~0.41)	*
CO_2	$^1\Sigma_g^+$	1388 0.172	667 0.083	2349 0.291	32
CO_2^+	$^2\Pi_g$	1280 0.159	(~400) (~0.05)	(1469) (0.182)	32
NO_2^-	$^1A_1$	(1325) (0.164)	(829) (0.103)	(1270) (0.157)	54
NO_2	$^2A_1$	(1320) (0.164)	750 0.093	1618 0.201	32
NO_2^+	$(^1\Sigma_g^+)$	(1400) (0.174)	(538) (0.067)	(2360) (0.293)	55
N_2O	$^1\Sigma^+$	2224 0.276	589 0.073	1285 0.159	32
N_2O^+	$^2\Pi$	1737 0.215	461 0.057	1126 0.140	32
O_3^-	$(^2B_1)$	(1260) (0.156)	(800) (0.099)	(1140) (0.141)	56
O_3	$^1A_1$	1110 0.138	705 0.087	1042 0.129	32
O_3^+	$(^2A_1)$	(~1300) (~0.16)	(~700) (~0.09)	(~1600) (~0.20)	†

*Vibrational intervals estimated from Rydberg states of H_2O.
†Vibrational intervals estimated from NO_2.

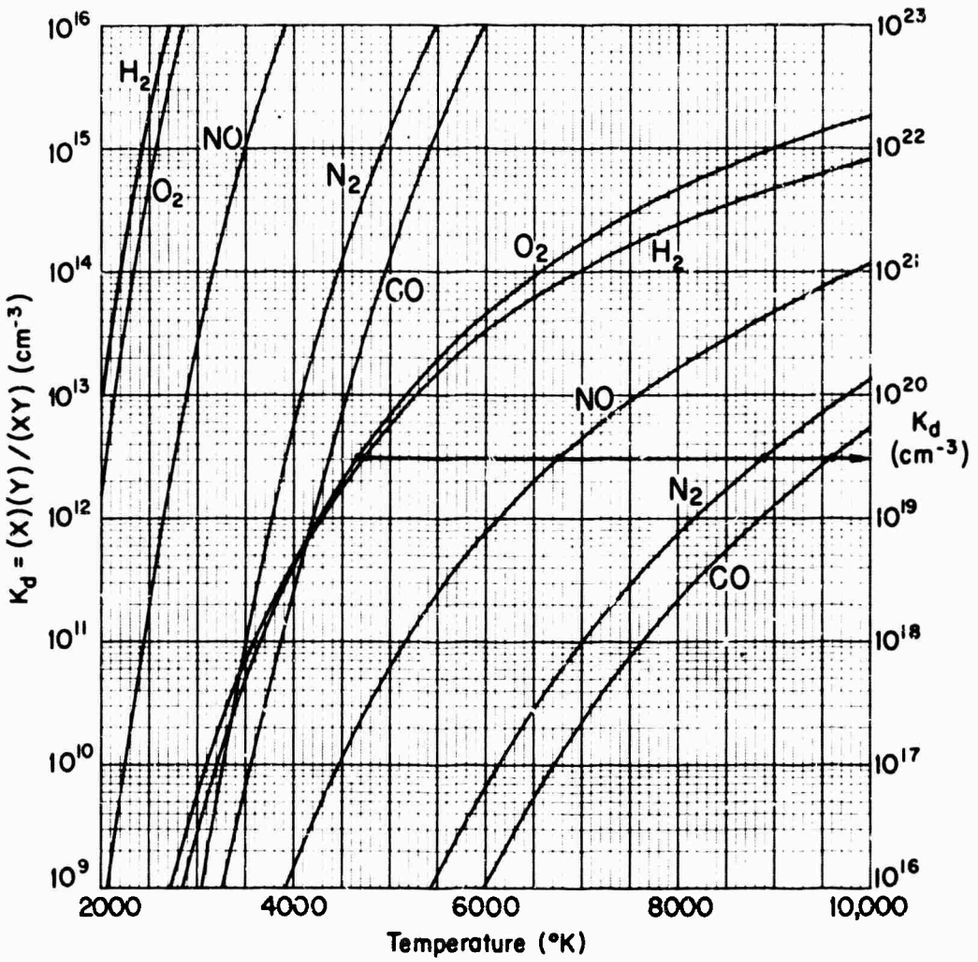

Fig. 1--Equilibrium constants for dissociation

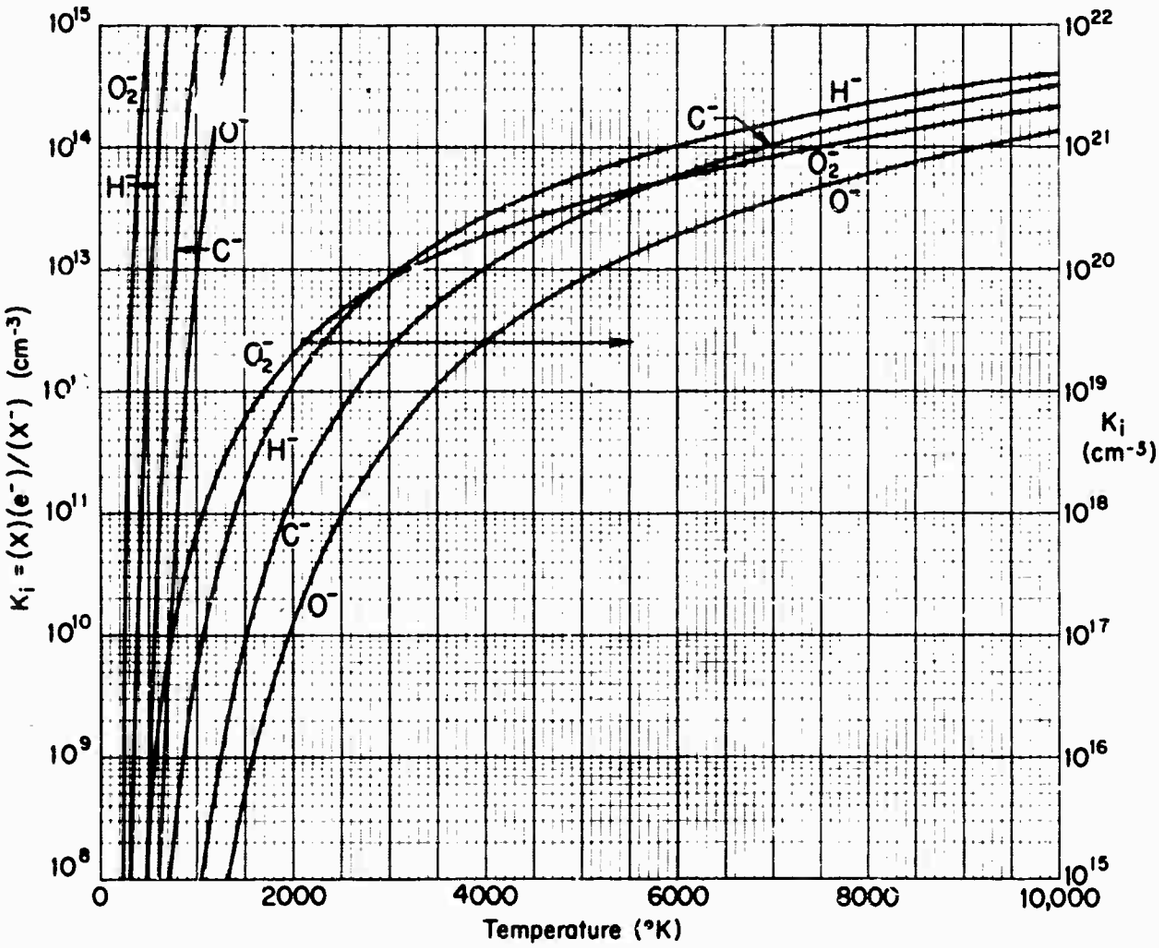

Fig. 2--Equilibrium constants for ionization (detachment) of negative ions

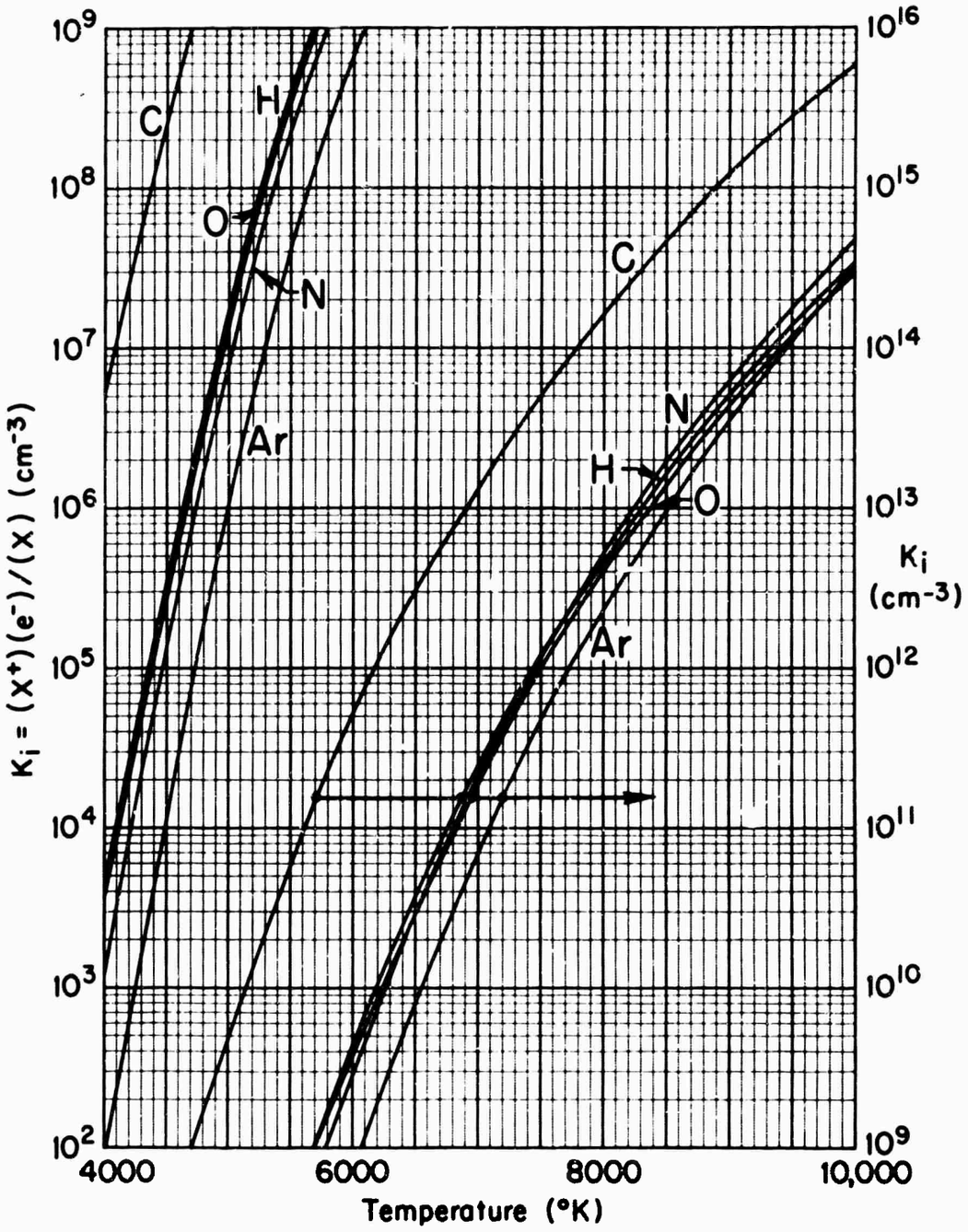

Fig. 3--Equilibrium constants for ionization of atoms

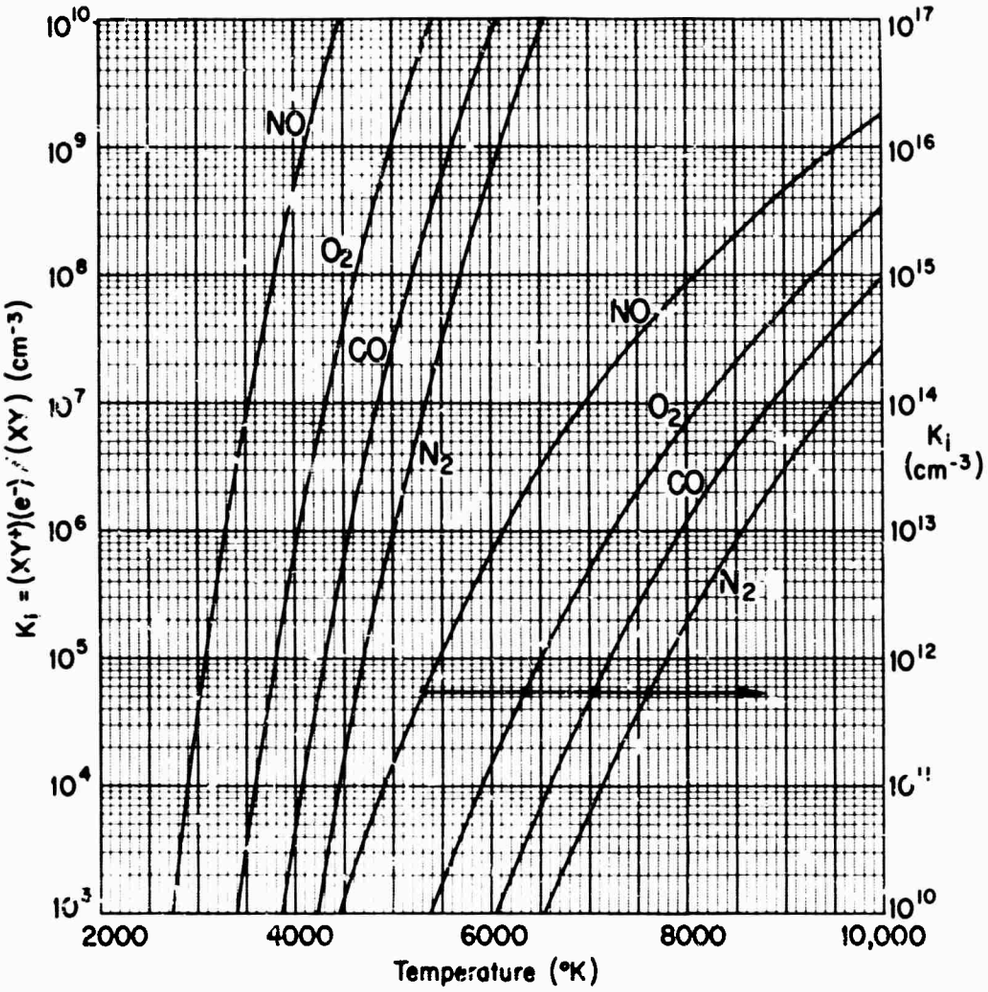

Fig. 4--Equilibrium constants for ionization of diatomic molecules

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DOCUMENT CONTROL DATA

1 ORIGINATING ACTIVITY	2a. REPORT SECURITY CLASSIFICATION
THE RAND CORPORATION	UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

BASIC ENERGY-LEVEL AND EQUILIBRIUM DATA FOR ATMOSPHERIC ATOMS AND MOLECULES

4. AUTHOR(S) (Last name, first name, initial)

Gilmore, Forrest R.

5. REPORT DATE	6a. TOTAL No. OF PAGES	6b. No. OF REFS.
March 1967	52	56

7. CONTRACT OR GRANT No.	8. ORIGINATOR'S REPORT No.
SD-79	RM-5201-ARPA

9a AVAILABILITY/LIMITATION NOTICES	9b. SPONSORING AGENCY
DDC-1	Advanced Research Projects Agency

10. ABSTRACT

Tables of the formation energies, dissociation energies, ionization energies, electronic energy levels, and vibrational level spacings for most atomic, diatomic, and triatomic molecules involving hydrogen, carbon, nitrogen, oxygen, and argon are presented. Many positively and negatively charged ions are included. Tables of the equilibrium fractional electronic-state populations, and graphs of the equilibrium constants for dissociation, ionization, and detachment for most of the atomic and diatomic species are appended. A brief discussion of the significance of such data precedes the tables and graphs.

11. KEY WORDS

Physics
Reentry vehicles
Atmosphere
Radiation
Ionization