

AD-A224 945

2

REPORT DOCUMENTATION PAGE			DTIC FILE COPY		Form Approved OMB No. 0704-0188
1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS ELECTE AUG 8 1990 S B D			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION/AVAILABILITY OF REPORT Approval for public release; distribution unlimited			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE		4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report No. DU/DC/TR-14			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report No. DU/DC/TR-14		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
6a. NAME OF PERFORMING ORGANIZATION Department of Chemistry Duke University		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION Office of Naval Research		
6c. ADDRESS (City, State, and ZIP Code) Durham, NC 27706		7b. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, VA 22217-5000			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Office of Naval Research		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-89-J-1545; R&T Code 4135008		
8c. ADDRESS (City, State, and ZIP Code) 300 North Quincy Street Arlington, VA 22217-5000		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO. NR	PROJECT NO. 053	TASK NO. 841	WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Synthesis and Characterization of $(Me_3Si)_2AsCH_2RCH_2As(SiMe_3)_2$ ($R = CH_2, SiMe_2$) and $Ph_2GaCl(Ph)_2Ga(Me_3Si)As(CH_2)_3As(SiMe_3)Ga(Ph)_2ClGaPh_2$					
12. PERSONAL AUTHOR(S) W.K. Holley, J.W. Pasterczyk, C.G. Pitt, and R.L. Wells					
13a. TYPE OF REPORT Technical		13b. TIME COVERED FROM _____ TO _____		14. DATE OF REPORT (Year, Month, Day) 1990-7-28	15. PAGE COUNT eleven (11)
16. SUPPLEMENTARY NOTATION Accepted for publication in <u>Heteroatom Chemistry</u>					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	Gallium-arsenic, bisarsine, synthesis		
19. ABSTRACT (Continue on reverse if necessary and identify by block number)					
<p>The synthesis and characterization of $(Me_3Si)_2AsCH_2RCH_2As(SiMe_3)_2$ [$R = CH_2$ (1), $SiMe_2$ (2)] is described. Compound 1 reacts with four equivalents of Ph_2GaCl to produce $Ph_2GaCl(Ph)_2Ga(Me_3Si)As(CH_2)_3As(SiMe_3)Ga(Ph)_2ClGaPh_2$ (3), whose structure was deduced by use of 1H and $^{13}C(^1H)$ NMR spectroscopy.</p>					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL Richard L. Wells			22b. TELEPHONE (Include Area Code) (919)684-6404	22c. OFFICE SYMBOL	

OFFICE OF NAVAL RESEARCH

Grant NOOO14-89-J-1545

R&T Code 4135008

Technical Report No. DU/DC/TR-14

Synthesis and Characterization of $(\text{Me}_3\text{Si})_2\text{AsCH}_2\text{RCH}_2\text{As}(\text{SiMe}_3)_2$ ($\text{R} = \text{CH}_2, \text{SiMe}_2$)
and $\text{Ph}_2\text{GaCl}(\text{Ph})_2\text{Ga}(\text{Me}_3\text{Si})\text{As}(\text{CH}_2)_3\text{As}(\text{SiMe}_3)\text{Ga}(\text{Ph})_2\text{ClGaPh}_2$

by

W. K. Holley, J. W. Pasterczyk

C. G. Pitt, and R. L. Wells

Prepared for Publication in Heteroatom Chemistry

Duke University
Department of Chemistry
Durham, NC 27706

July 28, 1990

Reproduction in whole or in part is permitted for
any purpose of the United States Government

This document has been approved for public release
and sale; its distribution is unlimited

[Manuscript No.: HC-WM-70-90]

Synthesis and Characterization of
 $(\text{Me}_3\text{Si})_2\text{AsCH}_2\text{RCH}_2\text{As}(\text{SiMe}_3)_2$ ($\text{R} = \text{CH}_2, \text{SiMe}_2$) and
 $\text{Ph}_2\text{GaCl}(\text{Ph})_2\text{Ga}(\text{Me}_3\text{Si})\text{As}(\text{CH}_2)_3\text{As}(\text{SiMe}_3)\text{Ga}(\text{Ph})_2\text{ClGaPh}_2$

W.K. Holley, J.W. Pasterczyk, C.G. Pitt, and R.L. Wells*

Department of Chemistry, Paul M. Gross Chemical Laboratory

Duke University, Durham, NC 27706 U.S.A.

Received 18 June 1990

ABSTRACT

The synthesis and characterization of $(\text{Me}_3\text{Si})_2\text{AsCH}_2\text{RCH}_2\text{As}(\text{SiMe}_3)_2$ [$\text{R} = \text{CH}_2$ (1), SiMe_2 (2)] is described. Compound 1 reacts with four equivalents of Ph_2GaCl to produce $\text{Ph}_2\text{GaCl}(\text{Ph})_2\text{Ga}(\text{Me}_3\text{Si})\text{As}(\text{CH}_2)_3\text{As}(\text{SiMe}_3)\text{Ga}(\text{Ph})_2\text{ClGaPh}_2$ (3), whose structure was deduced by use of ^1H and $^{13}\text{C}\{^1\text{H}\}$ NMR spectroscopy.

INTRODUCTION

For the past several years our group has been exploring ways of forming the Ga-As bond. Methods of doing this pioneered by us include the reaction between a silylarsine and a halogallane to eliminate a halosilane [1, 2], and coupling between a lithium arsenide and a halogallane to eliminate lithium halide [3, 4]. Along with the alkane elimination routes employing primary or secondary arsines and tertiary alkyl gallium compounds first utilized by Coates [5, 6], these methods have provided the primary routes toward forming Ga-As bonds. In all of this work to date, the arsenic-containing reactants have all been

solution to the phenolphthalein endpoint. Elemental analyses were performed by E + R Microanalytical Laboratory, Corona, NY. Melting points were obtained in sealed tubes on a Buchi 510 melting point apparatus and are uncorrected. Infrared spectra were run on a Perkin Elmer 297 infrared spectrometer. Raman spectra were obtained in the range 50-1200 cm^{-1} on neat samples using the Ar 514.5 nm line for excitation with the image focused into a double monochromator and measured with a photomultiplier tube. Mass spectra were obtained on a Perkin Elmer 5988A GC/MS in the DIP/EIMS mode at 20 eV.

Preparation of (Me₃Si)₂As(CH₂)₃As(SiMe₃)₂ (1)

A combination of 2.40 g (6.44 mmol) of LiAs(SiMe₃)₂·2THF and 0.370 g (3.27 mmol) of 1,3-dichloropropane in 40 mL of pentane was placed into a 50 mL round-bottom flask. The mixture was stirred for 24 h at RT under dry Ar forming a white solid presumed to be LiCl. The mixture was then filtered and the solvent stripped from the filtrate leaving behind a light yellow oily liquid. The liquid was fractionally distilled *in vacuo* (0.01 torr). The fraction distilling at 125 °C was saved and weighed 0.73 g (47% yield). Analysis found for C₁₅H₄₂Si₄As₂ (calc): %C, 37.13 (37.17); %H, 8.79 (8.73). ¹H NMR (C₆D₆, 20 °C): δ = 0.29 (s, SiMe₃, 36H), 1.83-1.88 (m, CH₂, 4H), 1.91-2.04 (m, CH₂, 2H). ¹³C{¹H} NMR (22.50 MHz, C₆D₆, 20 °C): δ = 1.78 (SiMe₃), 15.23 (CH₂), 34.68 (CH₂). IR data (neat film, KBr plates, cm^{-1}): 3785 w, 3730 w, 3635 w, 2960 vs, 2905 vs, 2855 ssh, 2790 msh, 2640 w, 2470 w, 2330 w, 2080 w, 1992 w, 1934 m, 1866 m, 1443 s, 1418 ssh, 1400 s, 1370 msh, 1337 msh, 1330 msh, 1312 s, 1288 s, 1260 vssh, 1249 vs, 1219 s, 1198 s, 1140 m, 1025 m, 915 msh, 860 vssh, 830 vs, 778 ssh, 748 vs, 738 vssh, 690 vs, 672 msh, 621 vs, 600 s. Raman data (cm^{-1}): 1196 m, 862 m, 840 m, 750 m, 690 s, 676 s, 630 vs, 554 m, 538 s, 522 w, 348 vs, 246 msh, 205 s, 178 s, 108 m. The mass spectrum showed a molecular ion at $m/e = 484$, as well as lower mass ions including those corresponding to (M-H)⁺, (M-Me)⁺, and (M-SiMe₃)⁺ at $m/e = 483$, 469, and 411, respectively.

Preparation of (Me₃Si)₂AsCH₂Si(Me)₂CH₂As(SiMe₃)₂ (2)

A combination of 2.371 g (6.366 mmol) of LiAs(SiMe₃)₂·2THF and 0.501 g (3.19 mmol) of bis(chloromethyl)dimethylsilane in 5 mL of THF and 40 mL of pentane was placed in a 50 mL round-bottom flask. The mixture was stirred for 24 h at RT under N₂ forming a white solid presumed to be LiCl. The mixture was filtered and the solvent stripped leaving behind a yellow liquid. The liquid was fractionally distilled *in vacuo* (0.01 torr) and the fraction distilling at 120 °C was saved. Yield: 1.21 g, 72%. Analysis found for C₁₆H₄₆Si₅As₂ (calc): %C, 36.34 (36.34); %H, 8.62 (8.77). ¹H NMR (C₆D₆, 20 °C): δ = 0.29 (s, SiMe₃, 36H), 0.37 (s, SiMe₂, 6H), 0.76 (s, CH₂, 4H). ¹³C{¹H} NMR (22.50 MHz, C₆D₆, 20 °C): δ = -5.80 (SiMe₂), -1.04 (CH₂), 1.51 (SiMe₃). The ¹³C methylene resonance was identified through an INEPT sequence.

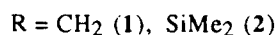
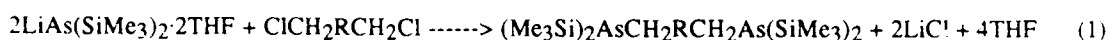
Preparation of Ph₂GaCl(Ph)₂Ga(Me₃Si)As(CH₂)₃As(SiMe₃)Ga(Ph)₂ClGaPh₂ (3)

A solution of 0.259 g (1.00 mmol) of Ph₂GaCl in 30 mL of benzene and a solution of 0.124 g (0.250 mmol) of **1** in 10 mL of benzene were combined in a 50 mL one-necked round-bottom flask equipped with a Teflon Kontes valve. The stopcock was closed, and the solution stirred for 6 days at RT. The volatiles were then vacuum-transferred into another flask, hydrolyzed, and titrated to reveal that 0.519 mmol of Me₃SiCl had been produced in the reaction. The solid residue was extracted with eight 10 ml portions of ligroin which were then combined and filtered. Cooling the filtrate to -17 °C for 10 days produced 0.047 g (14.4% yield) of tiny white fibrous crystals which were dried *in vacuo*. Mp 181-182 °C (dec.). Analysis found for C₅₇H₆₄Cl₂Si₂Ga₄As₂ (calc): %C, 52.25 (52.47), %H, 5.24 (4.94). ¹H NMR (C₆D₆, 20°C): δ = -0.06 (s, SiMe₃, 18H), 1.37-2.32 (m, CH₂, 6H), 7.17-7.42, 7.60-7.63, 7.77-7.86, 8.09-8.12 (m, Ph, 40H). ¹³C{¹H} NMR (75.429 MHz, C₆D₆, 20 °C): δ = 0.62 (SiMe₃), 15.69 (CH₂), 28.27 (CH₂), 128.16 (Ph), 128.43 (Ph), 136.64 (Ph), 136.79 (Ph), 137.65 (Ph), 138.50 (Ph), 145.44 (Ph), 146.37 (Ph). IR data (Nujol mull, KBr plates, cm⁻¹): 3065 ssh, 3045 s, 2730 w, 2670 wbr, 1952 wbr, 1879 wbr, 1840 wbr, 1612 w, 1580 w, 1425 vs, 1410

msh, 1341 m, 1333 m, 1301 m, 1280 m, 1258 s, 1231 m, 1219 m, 1190 m, 1170 w, 1158 m, 1150 msh, 1141 wsh, 1080 s, 1070 msh, 1060 msh, 1048 wsh, 1025 s, 1000 s, 958 m, 919 w, 886 msh, 841 vssh, 831 vs, 806 ssh, 750 ssh, 730 vs, 70 vs, 667 s, 650 wsh, 645 m, 620 s. Raman data [10] (cm^{-1}): 1122 vs, 1024 m, 998 s, 694 w, 660 m, 622 w, 356 m, 226 w, 180 w, 146 m, 92 m, 70 m.

RESULTS AND DISCUSSION

The synthesis of $(\text{Me}_3\text{Si})_2\text{AsCH}_2\text{RCH}_2\text{As}(\text{SiMe}_3)_2$ [$\text{R} = \text{CH}_2$ (1), SiMe_2 (2)] proceeds in organic solvents according to equation 1. Many other bisarsines have been synthesized by



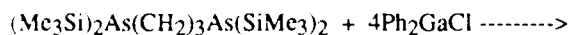
this alkali metal arsenide route, including $\text{Ph}_2\text{As}(\text{CH}_2)_n\text{AsPh}_2$ ($n = 1-6$) [11-15], $\text{Cy}_2\text{As}(\text{CH}_2)_4\text{AsCy}_2$ ($\text{Cy} = \text{cyclohexyl}$) [11], $\text{Me}_2\text{As}(\text{CH}_2)_n\text{AsMe}_2$ ($n = 1, 5$), $\text{Me}(\text{Cl})\text{As}(\text{CH}_2)_n\text{As}(\text{Cl})\text{Me}$ ($n = 2, 3$) [14], and $(\text{Me}_3\text{Si})_2\text{AsCH}_2\text{As}(\text{SiMe}_3)_2$ [8]. Other methods of making bisarsines have included the reaction of acetyl chloride, As_2O_3 , and AlCl_3 to make $\text{Cl}_2\text{AsCH}_2\text{AsCl}_2$ [16, 17], the synthesis of $(\text{HO})(\text{O})(\text{Ph})\text{AsCH}_2\text{CH}_2\text{As}(\text{Ph})(\text{O})(\text{OH})$ from ethylene bromide and phenyldichloroarsine in aqueous NaOH [18, 19], and interestingly the insertion of vinyl fluoride into the As-As bond of tetramethyldiarsine to make $\text{Me}_2\text{AsCH}_2\text{CHFAsMe}_2$ [20]. Curiously, though, the attempted preparation of $(\text{Me}_3\text{Si})_2\text{AsCH}_2\text{CH}_2\text{As}(\text{SiMe}_3)_2$ and $\text{Ph}_2\text{AsCH}_2\text{CH}_2\text{AsPh}_2$ using ethylene dibromide and $\text{LiAs}(\text{SiMe}_3)_2 \cdot 2\text{THF}$ or KAsPh_2 , respectively, yielded ethylene deinsertion products of the type $\text{R}_2\text{As}-\text{AsR}_2$ [8, 15], even though formal ethylene deinsertion probably did not occur since it is believed that the desired products were not obtained even transiently. Since these desired products can be obtained in a different manner [12-14, 19], the problem may likely be caused by the use of the bromide, though this issue is far from settled. However, this synthetic route was recently taken advantage of in the synthesis of $\text{Mes}_2\text{AsAsMes}_2$ ($\text{Mes} = \text{mesityl}$) from LiAsMes_2 and ethylene dibromide [21].

The new compounds **1** and **2** are both colorless, air- and water-sensitive, vacuum-distillable oils. Their sharp boiling points, elemental analyses, ^1H and ^{13}C NMR spectra, and for **1** its mass spectrum, are all consistent with the proposed formulations. It should also be noted that several of the IR and Raman bands of **1** correspond to those found in $(\text{Me}_3\text{Si})_n\text{AsH}_{3-n}$ ($n = 1-3$) [22, 23], particularly for $n = 2$, as may be expected for C_s local symmetry about the arsenic atoms.

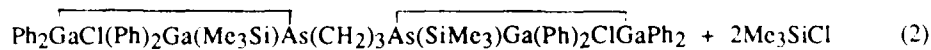
In analogy to our syntheses of the mono-mixed-bridge compounds

$\overline{\text{Ph}_2\text{GaAs}(\text{SiMe}_3)_2\text{Ga}(\text{Ph})_2\text{X}}$ ($\text{X} = \text{Cl}, \text{Br}$) [24, 25], reaction of **1** with 4 equivalents of Ph_2GaCl in benzene yields a compound formulated as the bis-mixed-bridge

$\overline{\text{Ph}_2\text{GaCl}(\text{Ph})_2\text{Ga}(\text{Me}_3\text{Si})\text{As}(\text{CH}_2)_3\text{As}(\text{SiMe}_3)\text{Ga}(\text{Ph})_2\text{ClGaPh}_2}$ (**3**) (equation 2). The stoichiometry of the chlorotrimethylsilane byproduct was confirmed by hydrolysis and



(1)



(3)

titration of the reaction volatiles for HCl. Compound **3** was obtained as very fine, whisker-like colorless crystals from ligroin and as a solvate from toluene, neither of which has as yet proved suitable for characterization by x-ray crystallography.

A number of pieces of evidence lead us to believe that we have the correct formulation for **3**. The fact that the material was obtained as crystals with a definite melting point indicates that it is a single compound, as is supported also by its clean ^1H and $^{13}\text{C}\{^1\text{H}\}$ NMR spectra. The production of one equivalent of Me_3SiCl per arsenic atom corresponds to what is found in the synthesis of the mono-mixed-bridge compounds [24, 25]. The positions and correct integrations of the ^1H NMR signals argues for a proton stoichiometry as formulated, and the $^{13}\text{C}\{^1\text{H}\}$ NMR spectrum, particularly the fact that eight phenyl carbon signals are observed, is consistent with the proposed idealized C_{2v} symmetry structure shown in Figure 1. In this structure there are two types of phenyl groups, those proximal and those

(Insert Figure 1 here)

distal to the trimethylsilyl groups, each of which has four different types of carbons, assuming free rotation about the Ga-C_{ipso} bonds. This gives eight different types of phenyl carbons, as is observed in the ¹³C{¹H} NMR spectrum. Any sort of conformational flexibility about the trimethylene backbone must be rapid on the NMR time scale since the time-averaged ¹H and ¹³C{¹H} NMR spectra of the flexible species would be similar to those of the rigid structure as drawn. However, because there are two different types of phenyl groups, any sort of fluxionality consisting of Ga-Cl bond cleavage followed by rotation about the corresponding Ga-As bond with subsequent reformation of the Ga-Cl bond cannot be rapid on the NMR time scale since this would make the phenyl groups which are proximal and distal to the trimethylsilyl group chemically equivalent. Likewise, fluxional processes involving Ga-As bond cleavage accompanied by conformational changes about the dangling arm with subsequent Ga-As bond reformation are ruled out.

It should be noted here that in the x-ray crystal structures of the mono-mixed bridge compounds, the halogen atoms are out of the Ga-As-Ga' planes which should render both the phenyl and trimethylsilyl groups inequivalent on the NMR time scale; this is not observed [24, 25]. In the solution NMR studies of those compounds, however, it is impossible to distinguish whether an envelope-flapping or an arm-off mechanism as described above is operating. Regardless, in **3** an envelope-flapping motion would be NMR invisible because the two different groups on the arsenic atoms render the two phenyl groups on each gallium atom chemically inequivalent.

Acknowledgements

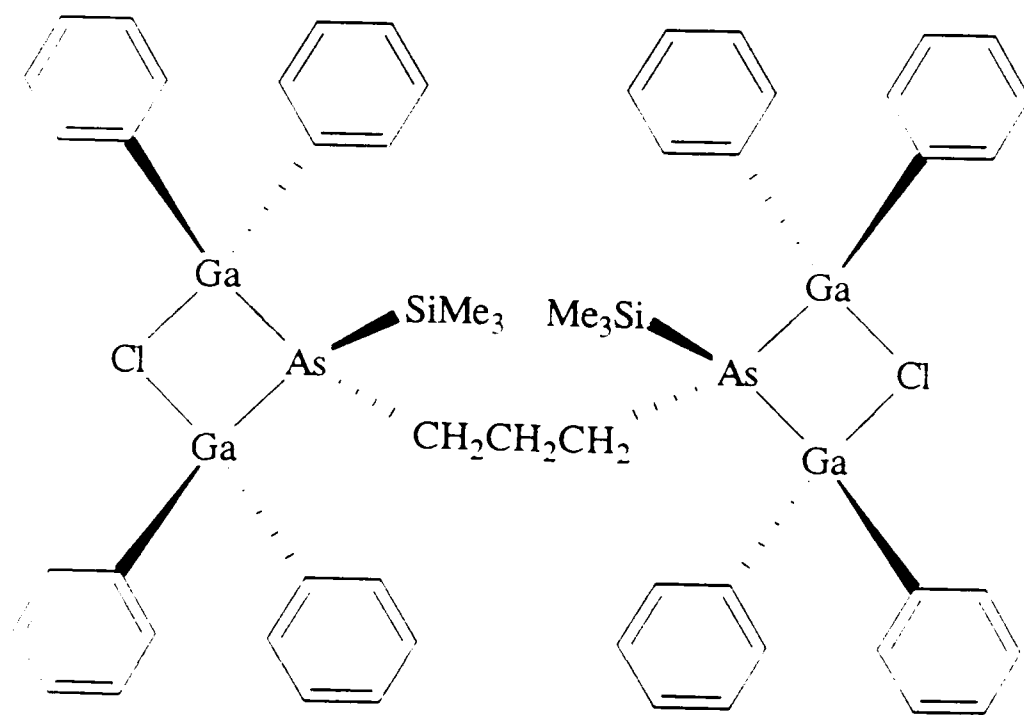
We thank the Office of Naval Research for financial support, and Dr. Richard MacPhail and Mr. Douglas Cates for obtaining the Raman spectra.

References and Note

- [1] C.G. Pitt, A.P. Purdy, K.T. Higa, R.L. Wells, *Organometallics*, 5, 1986, 1266.
- [2] A.P. Purdy, R.L. Wells, A.T. McPhail, C.G. Pitt, *Organometallics*, 6, 1987, 2099.
- [3] C.G. Pitt, K.T. Higa, A.T. McPhail, R.L. Wells, *Inorg. Chem.*, 25, 1986, 2483.
- [4] R.L. Wells, A.P. Purdy, K.T. Higa, A.T. McPhail, C.G. Pitt, *J. Organomet. Chem.*, 325, 1987, C7.
- [5] G.E. Coates, J. Graham, *J. Chem. Soc.*, 1963, 233.
- [6] O.T. Beachley, Jr., G.E. Coates, *J. Chem. Soc.*, 1965, 3241.
- [7] C.J. Sandroff, J.P. Harbison, R. Ramesh, M.J. Andrejco, M.S. Hegde, D. M. Hwang, C.C. Chang, E. M Vogel, *Science*, 245, 1989, 391.
- [8] G. Becker, G. Gutekunst, H.J. Wessely, *Z. anorg. allg. Chem.*, 462, 1980, 113.
- [9] H. Gilman, R.G. Jones, *J. Am. Chem. Soc.*, 62, 1940, 980.
- [10] Due to excessive fluorescence, relative intensity data for this compound should be regarded as uncertain.
- [11] K. Issleib, A. Tzschach, *Angew. Chem.*, 73, 1961, 26.
- [12] W. Hewertson, H.R. Watson, *J. Chem. Soc.*, 1962, 1490.
- [13] K. Sommer, *Z. anorg. allg. Chem.*, 376, 1970, 150.
- [14] K. Sommer, *Z. anorg. allg. Chem.*, 377, 1970, 278.
- [15] A. Tzschach, W. Lange, *Chem. Ber.*, 95, 1962, 1360.
- [16] F. Popp, *Chem. Ber.*, 82, 1949, 152.
- [17] H. Gutbier, H.G. Plust, *Chem. Ber.*, 88, 1955, 1777.
- [18] A.J. Quick, R. Adams, *J. Am. Chem. Soc.*, 44, 1922, 805.
- [19] J. Chatt, F.G. Mann, *J. Chem. Soc.*, 1939, 610.
- [20] W.R. Cullen, L.D. Hall, J.E.H. Ward, *J. Am. Chem. Soc.*, 94, 1972, 5702.
- [21] R.L. Wells, K.T. Higa, A.T. McPhail, C.G. Pitt, A.P. Purdy, *Abstracts of Papers, 199th National Meeting of the Am. Chem. Soc., Boston, MA, 1990, INOR 158.*
- [22] H. Bürger, U. Goetze, W. Sawodny, *Spectrochimica Acta*, 26A, 1970, 671.

- [23] K. Hassler, S. Seidl, *J. Organomet. Chem.*, 384, 1990, 263.
- [24] R.L. Wells, W.K. Holley, S. Shafieezad, A.T. McPhail, C.G. Pitt, *Phosphorus, Sulfur, and Silicon*, 41 (1989) 15.
- [25] W.K. Holley, R.L. Wells, S. Shafieezad, A.T. McPhail, C.G. Pitt, *J. Organomet. Chem.*, 381, 1990, 15.

Figure Caption: **Figure 1.** Proposed structure for **3**.



TECHNICAL REPORT DISTRIBUTION LIST - GENERAL

Office of Naval Research (2) Chemistry Division, Code 1113 800 North Quincy Street Arlington, Virginia 22217-5000	Dr. Robert Green, Director (1) Chemistry Division, Code 385 Naval Weapons Center China Lake, CA 93555-6001
Commanding Officer (1) Naval Weapons Support Center Dr. Bernard E. Douda Crane, Indiana 47522-5050	Chief of Naval Research (1) Special Assistant for Marine Corps Matters Code 00MC 800 North Quincy Street Arlington, VA 22217-5000
Dr. Richard W. Drisko (1) Naval Civil Engineering Laboratory Code L52 Port Hueneme, CA 93043	Dr. Bernadette Eichinger (1) Naval Ship Systems Engineering Station Code 053 Philadelphia Naval Base Philadelphia, PA 19112
David Taylor Research Center (1) Dr. Eugene C. Fischer Annapolis, MD 21402-5067	Dr. Sachio Yamamoto (1) Naval Ocean Systems Center Code 52 San Diego, CA 92152-5000
Dr. James S. Murday (1) Chemistry Division, Code 6100 Naval Research Laboratory Washington, D.C. 20375-5000	Dr. Harold H. Singerman (1) David Taylor Research Center Code 283 Annapolis, MD 21402-5067
Defense Technical Information Center (2) Building 5, Cameron Station Alexandria, VA 22314	