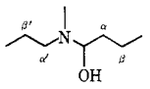
of this same monohemiaminal which they refer to as thionupharoline. We wish to thank Professor MacLean for communicating his results to us prior to publication.

(7) We erroneously referred to α-thiohemiaminals as β-thiohemiaminals in an earlier paper (ref 5). The α and β positions of a hemiaminal are designated as follows. The α and β positions of the corresponding immonium ion are similarly designated.



(8) R. T. LaLonde and C. F. Wong, *J. Org. Chem.*, **38**, 3225 (1973).

(9) (a) F. Bohlmann, *Chem. Ber.*, **91**, 2157 (1958); (b) T. M. Moynehan, K. Schofield, R. A. Y. Jones, and A. R. Katritzky, *J. Chem. Soc.*, 2637 (1962); (c) M. W. Wiewioroski and J. Skolick, *Bull. Acad. Pol. Sci., Ser. Sci. Chim.*, **10**, 1 (1962).

(10) R. T. LaLonde and C. F. Wong, unpublished observations.

(11) R. T. LaLonde, C. F. Wong, J. T. Woolever, E. Auer, K. C. Das, and A. I-m. Tsai, *Org. Mass Sppectom.*, in press.

(12) Conceivably an A'B' quinolizidine moiety belonging to the same absolute configurational series as (−)-deoxynupharidine combined with an AB hemiaminal belonging to the enantiomeric deoxynupharidine series could also give a C_{30} thiaspirane possessing a negative CD band in the 300-nm region. However, (+)-deoxynupharidine has never been reported nor has its incorporation in any of the Nuphar alkaloids been observed. Therefore we assume that all quinolizidine moieties of the thiaspiranes belong to the same enantiomeric series as (−)-deoxynupharidine.

(13) The work-up procedure is the same as that described above in the conversion 6'-hydroxythiobinupharidine to thiobinupharidine-6'-d_1.

Reaction of Phosgene with *N*-Methyleneaniline Derivatives

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The reaction of *N,N'*-diphenylmethylenediamine (**1**) and 1,3,5-triphenylhexahydro-*s*-triazine (**2**) with phosgene is accompanied by cleavage of a carbon–nitrogen bond to give *N*-chloromethyl-*N*-phenylcarbamoyl chloride (**5**) and 1,3,5-trisaza-1,3,5-triphenyl-1,5-bis(chloroformyl)pentane (**7**), respectively. 4-Aminobenzylaniline upon reaction with phosgene produces *N*-phenyl-*N*-4-isocyanatobenzylcarbamoyl chloride in high yield, which on reaction with hydrogen chloride undergoes a carbon–nitrogen bond cleavage to give phenyl isocyanate and 4-isocyanatobenzyl chloride.

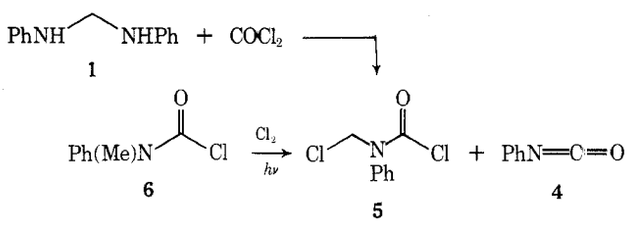
The reaction of aniline with aqueous formaldehyde in the presence of mineral acids to give diphenylmethane derivatives proceeds in two steps. Initially, phenyl-*N,N*-acetals of formaldehyde are formed, which rapidly rearrange in the presence of the acid catalyst to give benzylamines and finally diphenylmethane derivatives.[1] These di- and oligomeric amines are the precursors of commercially important di- and polyisocyanates. It is of interest to study the reaction of the intermediate products with phosgene, because small amounts could be present in the polyamine mixture.

Reaction of aniline with aqueous formaldehyde in the absence of acid produces a mixture of phenyl-*N,N*-acetals (aminals) in which *N,N'*-diphenylmethylenediamine (**1**) and 1,3,5-triphenylhexahydrotriazine (**2**) could be detected by nmr spectroscopy. Using a ratio of aniline–formaldehyde of 10:1 only one methylene signal at δ 4.45 (attributed to **1**) was present, while a solution prepared from a ratio of aniline–formaldehyde of 2:1 showed two methylene signals at δ 4.4 and 4.75 ppm (attributed to **1** and **2**; ratio approximately 1:1).

In order to investigate the reaction of *N*-methyleneanilines with phosgene, model compounds **1** and **2** were synthesized independently.[2] The model compound selected for the benzylamine intermediates, *p*-aminobenzylaniline (**3**), was prepared by reduction of the Schiff base[3] derived from *p*-nitrobenzaldehyde and aniline (Scheme III). The literature procedure,[4] using 4-nitrobenzyl chloride and aniline, followed by reduction did not produce **3** in our hands.

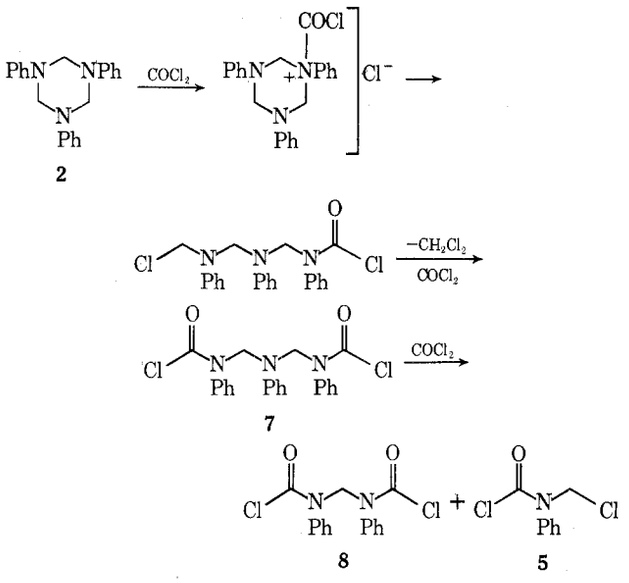
The model compounds with the exception of **2** are secondary amines, and formation of disubstituted carbamoyl chlorides is expected in their reaction with phosgene.[5] However, complications could arise due to the lability of the carbon–nitrogen bonds in phenyl-*N,N*-acetals of formaldehyde, and to a lesser degree in benzylamines. When **1** was treated with excess phosgene, a mixture of products was obtained which contained phenyl isocyanate (**4**) and the novel *N*-chloromethyl-*N*-phenylcarbamoyl chloride (**5**). The latter compound was synthesized independently in 80% yield by monochlorination of *N*-methyl-*N*-phenylcarbamoyl chloride (**6**) (Scheme I). Initial attack of phosgene on one of the nitrogens of **1** leads to the formation of hydrogen chloride, which cleaves the other carbon–nitrogen bond. This pathway explains both of the observed reaction products.

Scheme I



The reaction of **2** with phosgene gave **5**, the novel biscarbamoyl chloride **7** and a third unknown product of intermediate molecular weight as observed by gel permeation chromatography. Since the center nitrogen atom in **7** is the most likely site of attack of phosgene, the unknown compound could have the biscarbamoyl chloride structure **8** (see Scheme II), based on comparative gel permeation chromatography with **5** and **7**. The nmr spectrum of the biscarbamoyl chloride **7** shows, as expected, only one signal for the methylene protons at δ 4.85 ppm; the mass spectrum of the compound shows, due to its thermal lability, only fragments (HCl, $PhNCH_2$, PhNCO, PhN, etc.) and no molecular ion peak.

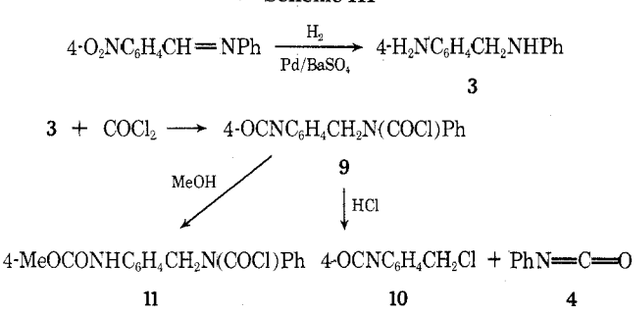
Scheme II



The initial reaction of the hexahydro-*s*-triazine **2** with phosgene occurs at one of the nitrogen atoms, giving rise to the formation of a polar complex which rearranges to a linear carbamoyl chloride. This reaction is reminiscent of the reaction of tertiary alkylamines with phosgene, in which a secondary carbamoyl chloride and an alkyl halide is produced.[5] Subsequent reaction of the linear carbamoyl chloride with phosgene leads to the formation of **7** and methylene chloride by the same reaction sequence. Reaction of **7** with phosgene finally produces **5** and **8**. However, both products **5** and **8** could also arise from the initially formed linear carbamoyl chloride.

The reaction of **3** with excess phosgene under mild conditions produces the expected previously unreported *N*-phenyl-*N*-4-isocyanatobenzylcarbamoyl chloride (**9**) in 90% yield; however, variable amounts of phenyl isocyanate (**4**) and 4-chloromethylphenyl isocyanate (**10**) were obtained as lower boiling by-products. The structure of **9** was verified by conversion to the crystalline carbamate derivative **11** (Scheme III).

Scheme III



In order to elucidate the pathway of formation of the lower boiling isocyanate by-products **4** and **10**, the carbamoyl chloride **9** was treated under the reaction conditions (refluxing chlorobenzene) with phosgene and hydrogen chloride, respectively. While no reaction was observed with phosgene, complete conversion of **9** to **4** and **10** occurs in the presence of dry hydrogen chloride. The formation of isocyanates from secondary carbamoyl chlorides has only been shown to occur when *N*-*tert*-butyl-*N*-alkylcarbamoyl chlorides were thermolyzed in polar solvents with or without an added catalyst ($FeCl_3$).[6] The facile reaction of *N*-phenyl-*N*-4-isocyanatobenzylcarbamoyl chloride (**9**) with hydrogen chloride constitutes a new synthesis of isocyanates from secondary arylbenzyl carbamoyl chlorides.

This reaction apparently proceeds by initial protonation of the nitrogen, followed by elimination of the benzyl chloride **10**.

The cleavage of the carbon–nitrogen bond in carbamoyl chlorides derived from the aminals of formaldehyde **1** and **2** is even more pronounced as evidenced by the formation of fragmentation products **5** and **8**.

Experimental Section[7]

Preparation of Starting Materials. *N,N'*-Diphenylmethylenediamine (**1**) and 1,3,5-triphenylhexahydro-*s*-triazine (**2**) were prepared according to the literature.[2]

4-Aminobenzylaniline (3). A solution of 5.66 g (0.25 mol) of nitrobenzylideneaniline in 100 ml of diethyl ether was purged with nitrogen and hydrogenated in the presence of 0.56 g of 5% palladium on barium sulfate. The theoretical uptake of 8.66 p.s.i. of hydrogen was observed within 0.5 hr. Filtration and evaporation of the solvent under vacuum gave 4.7 g (95%) of crude **3**, which crystallized to a white granular solid. Recrystallization from 10 ml of diethyl ether gave 3.7 g (75%), mp 47.5–48° (lit.[4] mp 49°). The thin layer chromatogram of the total mixture showed one spot: nmr ($CDCl_3$) δ 3.53 (s, 3, NH), 4.1 (s, 2, $-CH_2-$), 6.45–6.8, 7.0–7.3 (m, 9, aromatic).

Reaction of *N,N'*-Diphenylmethylenediamine (1) with Phosgene. A solution of 50 g (0.25 mol) of **1** in 200 ml of chlorobenzene was added to a solution of 150 g (1.5 mol) of phosgene in 300 ml of chlorobenzene at 12°. After slowly heating to 90° (3.2 hr) excess phosgene was removed with nitrogen, and the solvent was evaporated to give a liquid residue which contained phenyl isocyanate (**4**), ir 2220 cm^{-1} (N=C=O), and chloromethylphenylcarbamoyl chloride (**5**), ir 1735 cm^{-1}; nmr δ 5.48 (s, 2, CH_2). Attempted vacuum distillation gave 19.5 g of a fraction, bp 86–89° (0.05 mm), consisting of a mixture of **4** and **5**; however a major portion of the mixture underwent thermal degradation.

***N*-Chloromethyl-*N*-phenylcarbamoyl Chloride (5).** Into a solution of 17.0 g of *N*-methyl-*N*-phenylcarbamoyl chloride (**6**) in 200 ml of carbon tetrachloride was introduced 7.0 g of chlorine, and the resulting solution was irradiated with a 110-W medium pressure uv lamp. A Dry Ice condenser attached to the reaction flask prevented loss of chlorine and solvent during the exothermic reaction. The progress of the chlorination was followed by nmr (disappearance of $N-CH_3$, appearance of $N-CH_2Cl$ signal). Toward the end of the reaction it often became necessary to add more chlorine in small increments in order to complete the chlorination. To avoid overchlorination, the reaction was terminated with trace amounts of starting material left unchanged. Solvent removal under vacuum left a syrupy crude material which crystallized on standing. Recrystallization from boiling hexane gave 16.2 g (80%) of **5**: mp 45–46°; ir (CCl_4) 1735 cm^{-1} (C=O); nmr δ 5.4 (s, 2, CH_2). *Anal.* Calcd for $C_8H_7Cl_2NO$: C, 47.09; H, 3.45; N, 6.87; Cl, 34.75. Found: C, 47.15; H, 3.47; N, 6.71; Cl, 34.85.

Reaction of 1,3,5-Triphenylhexahydro-*s*-triazine (2) with Phosgene. A solution of 15.0 g of phosgene in 25 ml of benzene was added at once to 9.45 g of **2**, dissolved in 50 ml of warm (40–50°) benzene. The reaction mixture was kept for 30 min at ambient temperature. On concentrating the solution under vacuum, a colorless crystalline precipitate was separated, which was filtered off, washed with a small amount of cold benzene, and dried under vacuum; 2.0-g yield (15%) of 1,3,5-trisaza-1,3,5-triphenyl-1,5-bis(chloroformyl)pentane (**7**): mp 120° dec (from chloroform); ir (KBr) 1720 cm^{-1} (C=O). The colorless needles turn rapidly yellow and orange if exposed to air.

Anal. Calcd for $C_{22}H_{19}Cl_2N_3O_2$: C, 61.69; H, 4.47; N, 9.81. Found: C, 61.51; H, 4.33; N, 10.03.

The filtrate was evaporated to dryness, leaving a yellow-orange syrup, which on exposure to air turned deep red and became highly viscous. The gel permeation analysis of a freshly prepared sample showed the presence of 11.4% of phenyl isocyanate, 56% of *N*-phenyl-*N*-chloromethyl carbamoyl chloride (**5**), 24.2% of an unknown (possibly **8**), and 4.6% of **7** besides trace amounts (3.8%) of benzene.[8]

***N*-Phenyl-*N*-4-isocyanatobenzylcarbamoyl Chloride (9).** A solution of 9.9 g (0.05 mol) of 4-aminobenzylaniline (**3**) in 100 ml of dry chlorobenzene was added dropwise to a stirred solution of 19.8

g (0.2 mol) of phosgene in 100 ml of dry chlorobenzene. After completion of addition the reaction mixture was slowly heated to 50°, and after stirring for 90 min the solvent was removed by distillation. Vacuum distillation of the residue gave 13 g (91%) of a slightly impure *N*-phenyl-*N*-4-isocyanatobenzylcarbamoyl chloride (**9**), containing small amounts of phenyl (**4**) and 4-chloromethylphenyl isocyanate (**11**), as indicated by glc. Repeated fractional distillation produced pure **9**: bp 166° (0.25 mm); ir ($CHCl_3$) 2247 cm^{-1} (N=C=O), 1739 cm^{-1} (C=O); nmr ($CDCl_3$) δ 4.85 (s, 2, CH_2). *Anal.* Calcd for $C_{15}H_{11}N_2O_2Cl$: C, 62.84; H, 3.87; N, 9.77. Found: C, 62.96; H, 3.97; N, 10.05.

In a larger scale experiment (0.15 mol) phenyl isocyanate (**4**), [bp 39° (0.005 mm)] and 4-chloromethylphenyl isocyanate (**10**) [bp 68° (0.005 mm), mp 31–33° (lit.[9] mp 34°)] were isolated by fractional distillation.

Reaction with Methanol. A solution of 2.86 g (0.01 mol) of **9** in 10 ml of methanol was allowed to stand at room temperature overnight. Concentration of this solution gave 2.91 g (92%) of the methyl carbamate **11**, mp 108–109° after recrystallization from methanol. *Anal.* Calcd for $C_{16}H_{15}N_2O_3Cl$: C, 60.28; H, 4.74; N, 8.79. Found: C, 60.10; H, 4.95; N, 8.77.

Reaction with Hydrogen Chloride. A slow stream of dry hydrogen chloride was added to a refluxing solution of 1.5 g of **9** in 15 ml of dry chlorobenzene. After refluxing for 4 hr, complete conversion to **4** and **10** was observed as indicated by monitoring of the reaction mixture by nmr spectroscopy and glc.

Acknowledgment. We are indebted to F. P. Recchia and E. Goerland, who conducted part of the experimental investigation.

Registry No.—**1**, 622-14-0; **2**, 91-78-1; **3**, 24007-66-7; **4**, 103-71-9; **5**, 52123-54-3; **6**, 4285-42-1; **7**, 52123-55-4; **9**, 52123-56-5; **11**, 52123-57-6; phosgene, 75-44-5; nitrobenzylideneaniline, 785-80-8; methanol, 67-56-1; hydrogen chloride, 7647-01-0.

References and Notes

(1) P. Cohn, *Z. Angew. Chem.*, **14**, 313 (1901).
(2) M. Wakae and K. Konishi, *Osaka Furitsu Kogyo-Shoreikan Hokoku*, **29**, 47 (1963); *Chem. Abstr.*, **59**, 6280 (1963).
(3) O. Fischer, *Ber.*, **14**, 2525 (1881).
(4) C. Paal and O. Sprenger, *Ber.*, **30**, 69 (1897).
(5) H. Babad and A. G. Zeiler, *Chem. Rev.*, **73**, 75 (1973).
(6) J. N. Tilley and A. A. R. Sayigh, *J. Org. Chem.*, **28**, 2076 (1963).
(7) Melting and boiling points are uncorrected. Analyses were by Schwarzkopf Microanalytical Laboratory, Woodside, N. Y. Ir spectra were determined using a Beckman IR-8 spectrophotometer. Nmr spectra were obtained from samples in $CDCl_3$ solutions with a Varian T-60 instrument using tetramethylsilane as the internal standard. Gas chromatography was carried out on a Model 810 F & M gas chromatograph; 5% silicon grease columns were used. Gel permeation chromatography was conducted on a Waters 200 chromatograph.
(8) The indicated per cent values are by area ratio.
(9) British Patent 752,931 (1956); Farbenfabriken Bayer A.-G.; *Chem. Abstr.*, **51**, 7420 (1957).

Carbon-13 Magnetic Resonance Spectral Study of Some Phosphorinanes and Their 1-Sulfides[1]

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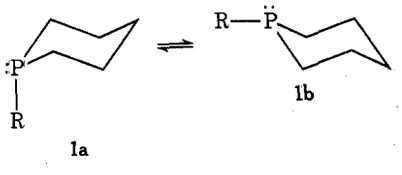
The ^{13}C nmr spectra of a group of five 1-substituted phosphorinanes (**1**) and of their corresponding sulfides (**4**) were obtained. Chemical shift trends within each group can be interpreted in terms of the familiar α,β,γ effects. The known axial predominance in **1** of *P*-methyl, -ethyl, and -phenyl is manifested in their ^{13}C spectra by slightly higher field $C_{3,5}$ signals than seen for the *tert*-butyl and isopropyl compounds, and also by the small value for the sterically sensitive $^2J_{PC_{3,5}}$ in the former (3.0–3.5 Hz) relative to the latter compounds (6–7 Hz). In the sulfides, all compounds appear to have a predominance of the conformer with equatorial carbon substituent, as judged from shift effects at $C_{2,6}$ and $C_{3,5}$. Of value in reaching this conclusion was a comparison of the spectra of the conformationally biased 1,4-disubstituted 4-phosphorinanols with their sulfides. The greater shielding exerted at $C_{3,5}$ by axial sulfur rather than by axial methyl was especially useful in this study. The ^{31}P nmr signal was the more upfield for that isomer where the steric compression was the greatest.

Carbon-13 nmr spectroscopy has been employed with much success in the determination of structural and stereochemical features of several types of six-membered heterocyclic compounds.[2d] Little is known, however, about the ^{13}C properties of the ring where phosphorus is the heteroatom; only 4-hydroxy derivatives of this system have been studied so far.[3,4] This phosphorinane system is of special interest because of the remarkably small value for $\Delta H°$ in the equilibrium of **1a** and **1b** (−0.68 kcal/mol for R = CH_3).[5] Indeed, entropy effects cause the equilibrium position at 27° to rest on the side of the axial conformer when R is methyl (K = 0.56),[5] ethyl (K = 0.65),[6] or phenyl (K = 0.72).[6] We have now obtained the ^{13}C nmr spectra of these and other 1-substituted phosphorinanes and have established relations between chemical shifts and structural and conformational properties of this system.



1a **1b**

Carbon spectra of phosphorus compounds contain more information than just chemical shift values; the ^{31}P atom couples with carbon to produce doublets of easily measured magnitude through two and sometimes three bonds. The size of two-bond coupling for trivalent phosphorus is subject to steric control[3,7,8] and consequently is of value in conformational analysis.

We have included in our study a consideration of the consequences of adding a fourth group to phosphorus. We have used the sulfides of the phosphorinanes for this purpose, since they are easily prepared, nonhygroscopic crystalline solids. While a proton nmr conformational study of the sulfide of phosphorinane itself (**1**, R = H) has been reported,[9] no attention has been given previously to the stereochemical consequences of placing both sulfur and an alkyl group on phosphorus.

Phosphorinanes. Carbon-13 nmr data for five 1-substituted phosphorinanes are recorded in Table I. Assignments were made as follows. (1) Relative to a carbon substituent, the phosphino group shields the attached carbons, presumably because of weak inductive electron displacement to carbon. This causes the carbon of the PCH_3 group (mostly axial[5]) to absorb about 5 ppm upfield from CH_3 when axial