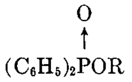
TABLE I



$(C_6H_5)_2P(\rightarrow O)OR$

Compd.	R	Yield, %	M.p. or b.p., °C. (mm.)	λ_{max}, μ P–O–C	λ_{max}, μ P→O	Calcd., % C	Calcd., % H	Calcd., % P	Found, % C	Found, % H	Found, % P
1[2a]	CH_3	92.5	178 (2.4)[a]	9.6	8.1						
2	$(CH_3)_2CH$[b]	60.2	97–99	10.1	8.2						
3	$(CH_3)_3C$	80.1	111–112	10.2	8.2	70.06	6.98	11.29	70.28	6.94	11.34
4	C_6H_{11}	78.5	120–121	10.1	8.2	71.98	7.05	10.31	71.86	6.80	10.36
5	*trans*-4-$(CH_3)_3CC_6H_{10}$[c]	72.0	132–133	9.9	8.2	74.15	8.15	8.70	73.94	8.18	8.71
6	$CH_2{=}CHCH_2$	75.0	162–165 (5)	9.8, 10.05[d]	8.15	69.77	5.81	12.02	69.65	5.72	12.03
7	C_6H_5[e]	97.9	135–136	10.85[f]	8.2						
8	α-$C_{10}H_7$	92.7	122–124	10.95[f]	8.1	76.74	4.98	9.00	76.45	4.91	9.10

[a] This crystalline solid liquifies upon standing in air with no essential change in its infrared spectrum. [b] A. E. Arbuzov, *J. Russ. Phys. Chem. Soc.*, **42**, 395 (1910); *Chem. Zentr.*, **81** (II), 453 (1910). [c] The *trans* isomer is tentatively assigned for this compound in analogy with the corresponding acetates; see R. U. Lemieux, R. K. Kullnig, H. J. Bernstein, and W. G. Schneider, *J. Am. Chem. Soc.*, **80,** 6098 (1958). It was observed that the broad peaks for H-1 in the *trans* alcohol and acetate had half-widths of 22 c.p.s. while the *cis* isomer and its acetate had a sharp signal with a half-width of 7 c.p.s. In **5**, H-1 appeared as a broad signal centered at δ 4.3 with a half-width of 22 c.p.s. at the following settings on a near-saturated solution in $CDCl_3$: filter band width, 4; radio frequency field, 0.2; sweep time, 250 sec.; sweep width, 500; spectrum amplitude, 1.6. [d] Two bands of equal intensity. [e] A. Michaelis and A. Link, *Ann.*, **207,** 193 (1881). [f] See ref. 8 and 9.

TABLE II

CHEMICAL SHIFT PARAMETERS FOR DIPHENYL ALKYLPHOSPHINATES[a]

Compd.	$-CH_3$	$>CH_2$	H–C<	Aryl–H
1	3.70 d[b]			7.25–8.20 m
2	1.28 d[c]		4.64 o	7.28–8.25 m
3	1.45 s			7.25–8.05 m
4		1.57 m	4.45 m	7.28–8.25 m
5	0.75 s	1.53 m	4.38 m	7.20–8.12 m
6[d]		4.40 m[e]		7.20–8.05 m
7				6.97–8.28 m
8				7.08–8.45 m

[a] Given in δ-values downfield from internal TMS. Except for **6** in which deuteriochloroform was the solvent, all other determinations were made in methylene chloride as solvent. Multiplicity of signals: d, doublet; s, singlet; m, multiplet; o, octet. [b] J_{P-H} = 11.0 c.p.s. [c] J = 6.0 c.p.s. [d] Multiplets as expected for the alkyl group are observed centered at δ 5.12, 5.39, and 6.0 which is similar to the pattern given by alkyl alcohol (see NMR Spectra Catalog I, Varian Associates, Palo Alto, Calif., 1962, spectrum 34). [e] This is the CH_2 group attached to the oxygen atom.

was heated at reflux for 1.5 hr. and, after washing with 15% aqueous ammonium chloride solution, was dried over magnesium sulfate and concentrated. A solid was isolated which was recrystallized from benzene–heptane; yield 40.05 g. (80.1%).

Acknowledgment.—The senior author gratefully acknowledges partial support by the Research Foundation, Oklahoma State University.

Reactions of Diethyl N-Alkoxyphosphoramidate Anions with Carbon Dioxide and Carbon Disulfide

RANDOLPH T. MAJOR AND ROBERT J. HEDRICK

Cobb Chemical Laboratory, University of Virginia,
Charlottesville, Virginia

Received November 12, 1964

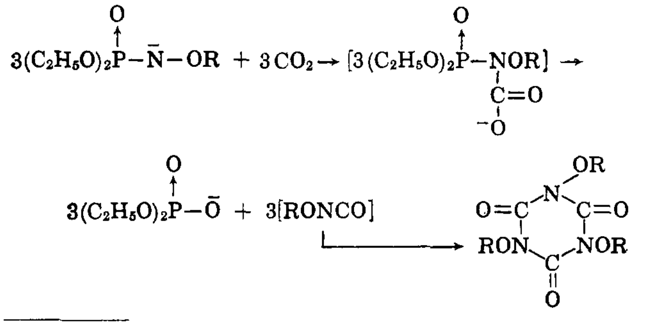
For over 60 years chemical investigators have tried, unsuccessfully, to synthesize N-alkoxyisocyanic acids, RONCO.[1] It seemed possible to us that these novel compounds might be made by the interaction of sodium diethyl N-alkoxyphosphoramidates and carbon dioxide. Wadsworth and Emmons have reported that sodium diethyl N-alkylphosphoramidates and carbon dioxide produce alkyl isocyanates.[2]

Wadsworth and Emmons[2] reported the preparation of diethyl N-methoxyphosphoramide. By utilization of a similar synthesis diethyl N-ethoxyphosphoramide has now been made. However, reaction of carbon dioxide with sodium diethyl N-alkoxyphosphoramidates did not yield N-alkoxyisocyanates but their trimers, 1,3,5-trialkoxyisocyanuric acids, $(RONCO)_3$.

1,3,5-Tribenzyloxyisocyanuric acid and several substituted benzyl derivatives have been made by McKay, *et al.*,[1c] by the treatment of the corresponding benzyloxyamine hydrochlorides with phosgene followed by treatment of the resulting intermediate with triethylamine.

It seems rather probable that the N-alkoxyisocyanic acids were formed first in the reaction between carbon dioxide and sodium diethyl N-alkoxyphosphoramidates and that the monomer then polymerized in the presence of the anions present. Trimerization of isocyanates is well known.[3]

Both 1,3,5-trimethoxy- and 1,3,5-triethoxyisocyanuric acid were relatively stable, crystalline compounds.



---

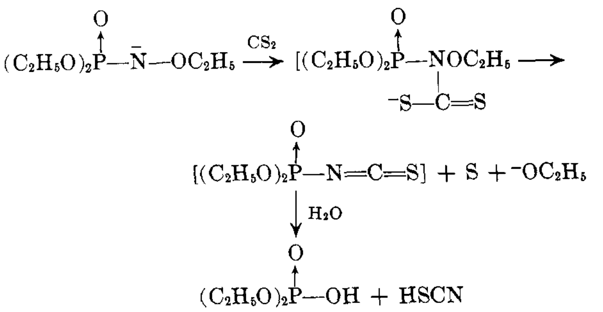
(1) (a) L. W. Jones, *Am. Chem. J.*, **20,** 1 (1898); (b) L. W. Jones and L. Neuffer, *J. Am. Chem. Soc.*, **39**, 652 (1917); (c) A. F. McKay, D. L. Garmaise, G. Y. Paris, and S. Gelblum, *Can. J. Chem.*, **31**, 343 (1960).

(2) W. S. Wadsworth, Jr., and W. D. Emmons, *J. Am. Chem. Soc.*, **84,** 1316 (1962); *J. Org. Chem.*, **29**, 2816 (1964).

(3) (a) E. H. Rodd, "Chemistry of Carbon Compounds," Vol. IB, Elsevier Publishing Co., New York, N. Y., 1952, p. 939; (b) V. E. Shashoua, W. Sweeney, and R. F. Tietz, *J. Am. Chem. Soc.*, **82**, 866 (1960).

Their infrared and n.m.r. spectra were in harmony with the structure shown above.[4] Fusion of 1,3,5-triethoxyisocyanuric acid with potassium hydroxide gave N-ethoxyamine.

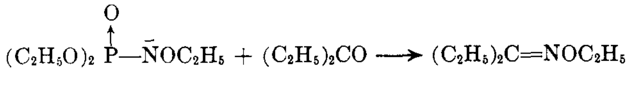
Wadsworth and Emmons have also found that interaction of a sodium diethyl N-alkylphosphoramidate and carbon disulfide gave alkyl isothiocyanates.[2] However, in our laboratory, when sodium diethyl N-ethoxyphosphoramidate was treated with carbon disulfide no evidence of the presence of N-ethoxyisothiocyanic acid in the reaction product was obtained. However, the distillate from the reaction product contained ethanol. The addition of water to the reaction product gave free sulfur and thiocyanate ions. A likely pathway of this reaction is given below.



$$(C_2H_5O)_2\overset{\overset{O}{\uparrow}}{P}-\bar{N}-OC_2H_5 \xrightarrow{CS_2} [(C_2H_5O)_2\overset{\overset{O}{\uparrow}}{P}-\underset{\underset{^{-}S-C=S}{|}}{N}OC_2H_5 \longrightarrow$$

$$[(C_2H_5O)_2\overset{\overset{O}{\uparrow}}{P}-N=C=S] + S + {}^{-}OC_2H_5 \xrightarrow{H_2O} (C_2H_5O)_2\overset{\overset{O}{\uparrow}}{P}-OH + HSCN$$

When sodium diethyl N-ethoxyphosphoramidate was treated with 3-pentanone, O-ethyldiethylketoxime was obtained. This finding is similar to Wadsworth and Emmons' observation that the interaction of benzaldehyde and sodium diethyl N-methoxyphosphoramidate gave O-methylbenzaldoxime.[2]



$$(C_2H_5O)_2\ \overset{\overset{O}{\uparrow}}{P}-\bar{N}OC_2H_5 + (C_2H_5)_2CO \longrightarrow (C_2H_5)_2C=NOC_2H_5$$

Experimental

Diethyl N-Alkoxyphosphoramides.—To 0.06 mole of the N-alkoxyamine in 100 ml. of dry ether was added 5.2 g. (0.03 mole) of diethyl phosphorochloridate, prepared by the method of McCombie, Saunders, and Stacey.[5] After the mixture had been stirred for 1 hr. at room temperature, the precipitated N-alkoxamine hydrochloride was removed by filtration. The ether was removed by distillation and then the residual oil was fractionated *in vacuo*.

Diethyl N-methoxyphosphoramide[2] was obtained in a yield of 80%, b.p. 107° (0.5 mm.).

The diethyl N-ethoxyphosphoramide, b.p. 110–112° (0.5 mm.), which was obtained was a colorless liquid. The neat liquid showed strong infrared absorption bands at 3.2, 3.45, 7.2, and 8.5 and broad, intense bands at 9.2–10.5 μ. This infrared spectrum was very similar to that of diethyl N-methoxyphosphoramide. The n.m.r. spectrum in carbon tetrachloride showed overlapping triplets, the one at τ 8.6 having twice the area of the one at 8.8. Overlapping quartets were seen at τ 5.9 and 6.2. The former had twice the area of the latter.[6] The compound exploded when an elemental analysis was attempted.

Sodium Diethyl N-Alkoxyphosphoramidates.—A solution of 0.05 mole of freshly distilled diethyl N-alkoxyphosphoramide in 20 ml. of dimethoxyethane was added to 2.4 g. of sodium hydride (50% in mineral oil) suspended in 80 ml. of dimethoxyethane. The mixture was then stirred at room temperature for 1 hr.

1,3,5-Triethoxyisocyanuric Acid.—The above suspension of sodium diethyl N-ethoxyphosphoramidate from 0.5 mole of diethyl N-ethoxyphosphoramide was cooled to 3° and stirred. Carbon dioxide was bubbled through the suspension; a clear solution was obtained. The temperature of the reaction mixture was raised to that of the room and the mixture was stirred for an additional hour. When the temperature was raised to 65° a gummy precipitate formed. The mixture was cooled and filtered. The precipitate was a hygroscopic, water-soluble gum which did not melt. It contained no nitrogen and generally behaved like the inorganic phosphorus-containing salt obtained by Wadsworth and Emmons.[2] Dimethoxyethane was removed from the filtrate by distillation. The residue was an oil which solidified when it was cooled. Recrystallization from benzene–petroleum ether gave 1.2 g. (28% of theory) of colorless crystals, m.p. 145°. Infrared KBr showed important bands at 3.4 (m), 5.7 (s), 7.1 (s), 7.3 (s), 9.7 (s), 9.9 (s), and 14.25 (s) μ. The n.m.r. spectrum (in $CDCl_3$) showed a triplet at τ 8.6 and a quartet at 5.7 with relative areas of 3:2. The solid was unaffected by boiling 6 N hydrochloric acid.

Anal. Calcd. for $C_9H_{15}N_3O_6$: C, 41.37; H, 5.80; N, 16.09; mol. wt., 261. Found: C, 41.69; H, 5.98; N, 16.58; mol. wt. (micro-Rast,[7] average of two determinations), 251.

A small amount of the compound was mixed with solid potassium hydroxide in a flask fitted with an outlet tube leading to a solution of dilute hydrochloric acid. The mixture was heated with a small flame. When no further reaction was apparent, the hydrochloric acid solution was evaporated under reduced pressure. A white solid remained as a residue which was shown to be N-ethoxyamine hydrochloride by comparison of its infrared spectrum with that of authentic N-ethoxyamine hydrochloride.[8]

1,3,5-Trimethoxyisocyanuric Acid.—Carbon dioxide was introduced at room temperature into the above suspension of sodium diethyl N-methoxyphosphoramidate from 0.05 mole of diethyl N-methoxyphosphoramide. The reaction mixture was heated to 80° and stirred for 1 hr. Then the mixture was cooled and the gummy precipitate was filtered. The filtrate was distilled. The solid residue was recrystallized from carbon tetrachloride–petroleum ether, m.p. 197–198°. The infrared spectrum was similar to that of 1,3,5-triethoxyisocyanuric acid, showing important bands (KBr) at 3.4 (m), 5.7 (s), 7.2 (s), 9.7 (s), and 14.2 (s) μ. The n.m.r. spectrum (in deuterated dimethyl sulfoxide) showed only a singlet at τ 6.2.

Anal. Calcd. for $C_6H_9N_3O_6$: C, 33.44; H, 4.20; N, 20.37. Found: C, 32.88; H, 4.14; N,19.88.

Reaction of Sodium Diethyl N-Ethoxyphosphoramidate with Carbon Disulfide.—A solution of 9.8 g. (0.05 mole) of diethyl N-ethoxyphosphoramide in 20 ml. of dimethoxyethane was slowly added to a suspension of 2.4 g. of 50% sodium hydride in dimethoxyethane. After the mixture had been stirred for 90 min. at room temperature, 3.7 g. (0.047 mole) of carbon disulfide in 10 ml. of dimethoxyethane was added while the mixture was cooled in an ice bath. The clear solution which was obtained was warmed on a steam bath. No volatile material was collected in a Dry Ice–acetone cooled receiving flask which was connected with the flask containing the reaction mixture. Then, the dimethoxyethane was removed by distillation at reduced pressure. The distillate gave a positive test for ethanol by Feigl's test,[9] whereas dimethoxyethane itself gave a negative test. The residue from the distillation was a thick, light red suspension. Water was added to this residue and then the aqueous mixture was filtered. The filtrate gave a positive test for thiocyanate ion.[10] The precipitate was a yellow solid which was readily soluble in carbon disulfide. Its infrared spectrum was identical with that of elemental sulfur.

O-Ethyldiethylketoxime.—A solution of 5.8 g. (0.03 mole) of diethyl N-ethoxyphosphoramide in 50 ml. of dry dimethoxyethane was slowly added, with stirring, to a slurry of 1.7 g.

---

[4] L. Kakovic and K. W. F. Kohlrausch, *Z. Physik. Chem.*, **193**, 188 (1944).

[5] H. McCombie, B. C. Saunders, and G. J. Stacey, *J. Chem. Soc.*, 380 (1945).

[6] All infrared spectra were taken on a Perkin-Elmer Infracord and all n.m.r. spectra were taken on a Varian A-60.

[7] E. J. Cowles and M. T. Pike, *J. Chem. Educ.*, **40**, 422 (1963).

[8] L. W. Jones, *Am. Chem. J.*, **20**, 46 (1898).

[9] F. Feigl, "Spot Tests in Organic Analysis," Elsevier Publishing Co., New York, N. Y., 1960, p. 358.

[10] F. Feigl, "Spot Tests," Vol. 1, R. E. Oesper, Transl., Elsevier Publishing Co., New York, N. Y., 1954, p. 340

(0.3 mole) of sodium hydride in 50 ml. of dimethoxyethane. To the suspension which was obtained was added 3.0 g. (0.036 mole) of 3-pentanone. The mixture was then stirred at room temperature for 30 min. and cooled, and the sticky precipitate was filtered and washed with dimethoxyethane. The filtrate was then fractionated. In addition to dimethoxyethane, a small amount of O-ethyldiethylketoxime was obtained, b.p. 131–134°.[11] The infrared spectrum of this liquid was identical with that of authentic O-ethyldiethylketoxime.

Acknowledgment.—We are indebted to Merck and Company, Inc., for a grant which supported part of this work.

[11] A. I. Vogel, W. T. Cresswell, G. H. Jeffery, and J. Leicester, *J. Chem. Soc.*, 514 (1952).

Reduction of N-Alkoxyphthalimides

RANDOLPH T. MAJOR AND ROBERT J. HEDRICK

Department of Chemistry, University of Virginia, Charlottesville, Virginia

Received November 17, 1964

Orndorff and Pratt have reported that the interaction of phthalic anhydride and hydroxylamine gave two compounds, one white and the other yellow.[1] These authors were unable to assign definite structures to these substances. Pratt and Gibbs later made the methyl ethers of the white compound and of the yellow compound but also were uncertain as to the structures of these compounds.[2]

More recently, Roderick and Brown found that there was no detectable difference between the infrared spectra of the white and yellow forms of Orndorff and Pratt's products.[1] Also, they found that the yellow color of the "yellow form" was due to a slight amount of impurity that could be removed by several methods. They concluded that both so-called forms were N-hydroxyphthalimide.[3]

The findings of Kühler and Wegler[4] confirmed the conclusions of Roderick and Brown.

It occurred to the present authors that a new class of isoindoline derivatives, N-alkoxyisoindolines (I), might be made by the reduction of N-alkoxyphthalimides, provided that the alkoxy group was not removed during the reduction.

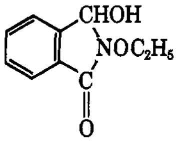
The methyl and ethyl ethers of N-hydroxyphthalimide were prepared by the interaction of an aqueous solution of sodium bicarbonate and the appropriate alkyl sulfate with N-hydroxyphthalimide. Hydrolysis of the resulting N-alkoxyphthalimide with boiling dilute hydrochloric acid gave alkoxyamine hydrochlorides.[5]

N-Alkoxyisoindolines (I) were indeed obtained on the reduction of the methyl and ethyl ethers of N-hydroxyphthalimide with lithium aluminum hydride. The correctness of the N-alkoxyisoindoline structure for the reduction products was confirmed by elemental analysis, infrared spectra, and n.m.r. spectra.

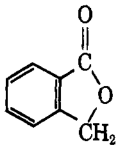
Reduction of N-ethoxyphthalimide with the weaker reducing agent, sodium borohydride, did not yield N-ethoxyisoindoline but rather 2-ethoxy-3-hydroxyphthalimidine (II). This structure for the reduction product was demonstrated by elemental analyses, infrared spectra, and n.m.r. spectra. Horii, Iwata, and Tamura have shown that the analogous compounds, N-alkylphthalimides, were reduced by sodium borohydride to 2-alkyl-3-hydroxyphthalimidine.[6]

However, reduction of N-methoxyphthalimide with sodium borohydride did not yield a phthalimidine derivative. The only organic product which was isolated was phthalide (III). The same compound was obtained by Horii, Iwata, and Tamura in varying amounts by the reduction of N-alkylphthalimides.[6] The formation of phthalide on reduction of N-methoxyphthalimide may be accounted for in a way analogous to that suggested by Horii, Iwata, and Tamura.[6] It is suggested that the N-methoxyisoindoline which was formed, first was reduced further to a borohydride complex of *o*-hydroxymethyl-N-methoxybenzamide which was later hydrolyzed to phthalide. It would appear that in the case of N-ethoxyphthalimide that the more bulky N-ethoxy group interfered with a similar reduction to *o*-hydroxymethyl-N-ethoxybenzamide.

I



II



III

Experimental[7]

N-Alkoxyphthalimides.—N-Hydroxyphthalimide (0.64 mole) was dissolved in a solution of 120 g. of sodium bicarbonate in 300 ml. of water. To this solution was slowly added 0.7 mole of dialkyl sulfate with stirring. In the case of diethyl sulfate the addition took place at room temperature for 8 hr. while in the case of dimethyl sulfate the addition took place at approximately 15° for 90 min. The precipitate of N-alkoxyphthalimide was filtered and recrystallized from 95% ethanol and then from 1-butanol; yield, 60–64%.

N-Methoxyphthalimide.—The infrared spectrum (KBr) showed important bands at 3.4 (w), 5.8 (s), 6.8 (m), 7.2 (m), 8.4 (s), 8.8 (s), 9.2 (m), 9.8 (s), 10.0 (s), 11.0 (s), 11.3 (s), 12.6 (m), and 14.2 (s) μ; m.p. 133°.[2]

Anal. Calcd. for $C_9H_7NO_3$: C, 61.0; H, 3.98. Found: C, 61.37; H, 4.11.

N-Ethoxyphthalimide.—The infrared spectrum (KBr) showed bands at 3.4 (w), 5.8 (s), 6.8 (m), 7.1 (m), 7.3 (m), 8.4 (s), 8.9 (s), 9.2 (m), 9.8 (s), 10.2 (s), 11.3 (s), 12.6 (m), and 14.2 (s) μ; m.p. 97–98°.[1]

Alkoxyammonium Chlorides.—The N-alkoxyphthalimides were refluxed with an excess of 6 *N* hydrochloric acid for 2 hr. On cooling, phthalic acid precipitated. The filtrate from this mixture was evaporated under reduced pressure. The residue was recrystallized from ethanol–ether; yield, 56–60%. Meth-

---

[1] W. R. Orndorff and D. S. Pratt, *Am. Chem. J.*, **47**, 89 (1912).

[2] D. S. Pratt and H. D. Gibbs, *Phillippine J. Sci.*, **8A**, 165 (1913).

[3] W. R. Roderick and W. G. Brown, *J. Am. Chem. Soc.*, **79**, 5196 (1957).

[4] E. Kühler and R. Wegler, *Ann.*, **616**, 183 (1958).

[5] J. Petraczek, *Ber.*, **16**, 827 (1883).

[6] Z. Horii, C. Iwata, and Y. Tamura, *J. Org. Chem.*, **26**, 2273 (1961).

[7] All infrared spectra reported were determined on a Perkin-Elmer Infracord. N.m.r. spectra were obtained on a Varian A-60 instrument.