removed periodically, denitrated and examined by paper chromatography as described above. The reaction was terminated after 96 hr., at which time no methyl D-glucoside could be detected in the products. Reactions at higher temperatures effected decomposition of the nitrate derivative.

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N,N'-Diethylene-*N''*-ethyl-*N''*-(1,3,4-thiadiazol-2-yl)phosphoramide

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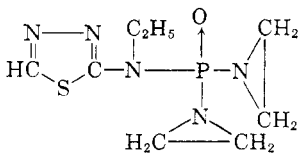
Carcinostatic activity has been reported for many derivatives of diethylenephosphoramide[1] and also for 2-ethylamino-1,3,4-thiadiazole.[2] It was therefore of interest to synthesize and test *N,N'* - diethylene - *N''* - ethyl - *N''* - (1,3,4 - thiadiazol - 2 - yl)phosphoramide (I), a potential "dual antagonist" incorporating these two active moieties



I

in one molecule. The product showed substantial activity against transplanted mouse tumors Sarcoma 180, 6C3HED lymphosarcoma, and C3H mammary adenocarcinoma by both oral and intraperitoneal administration. The synthesis is described below, and details of the testing will be reported elsewhere.[3] The compound is now undergoing clinical evaluation.

EXPERIMENTAL

N-Ethyl-*N*-(1,3,4-thiadiazol-2-yl)amidophosphoryl chloride was prepared by refluxing 16.4 g. (0.1 mole) of 2-ethylamino-1,3,4-thiadiazole hydrochloride[4] with 50 ml. of phosphorus oxychloride for 6 hr. and then removing excess phosphorus oxychloride by distillation under reduced pressure. The residual oil was washed with cold petroleum ether, (b.p. 30–60°), dried, and dissolved in 350 ml. of warm dry benzene. This solution was added slowly to a mixture of 9.5 g. (0.22 mole) of ethylenimine, 30.3 g. (0.3 mole) of triethylamine and 50 ml. of dry benzene at 10°. Agitation was continued for 2 hr. without cooling, after which the precipitated triethylamine hydrochloride was filtered off. The benzene was removed from the filtrate under reduced pressure, and the crude *N,N'*-diethylene-*N''*-ethyl-*N''*-(1,3,4-thiadiazol-2-yl)phosphoramide (19.7 g.) was purified by recrystallization from hexane; m.p. 95–96.5°.

Anal. Calcd. for $C_8H_{14}N_5OPS$: C, 37.1; H, 5.44; N, 27.0; S, 12.4. Found: C, 37.4; H, 5.67; N, 27.0; S, 12.6.

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(1)(a) S. M. Buckley *et al.*, *Proc. Soc. Exptl. Biol. Med.*, **78**, 299 (1951). (b) S. J. Sparks *et al.*, *Blood*, **8**, 655 (1953). (c) M. L. Crossley *et al.*, *Proc. Soc. Exptl. Biol. Med.*, **83**, 438 (1953). (d) M. L. Crossley *et al.*, *Cancer Research*, **19**, 142 (1959).

(2)(a) J. J. Oleson *et al.*, *J. Am. Chem. Soc.*, **77**, 6713 (1955). (b) M. M. Ciotti *et al.*, *Cancer Research*, **20**, 1195 (1960).

(3) A. W. Vogel and A. E. Sloboda, to be published.

(4) M. Freund and H. P. Schwartz, *Ber.*, **29**, 2487 (1896).

The Pyrolysis of 2-Methylnaphthalene

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The wide occurrence of traces of benzo(g,h,i)-perylene in many petroleum products, such as waxes and solvents,[1] in which other six ring aromatic hydrocarbons are seldom found, suggested the possibility that this compound might be produced in the thermal procedures (*e.g.*, distillation) by which these products are manufactured. It is possible that benz(g,h,i)perylene is formed by condensation of smaller molecules, which process could be studied by pyrolysis of likely precursors. Pyrolysis of simple compounds has produced polycyclic aromatic hydrocarbons in small amounts.[2] Recently Badger and Kimber have studied the pyrolysis of tetralin[3] and of indene[4] which yielded, among other compounds, benzo(a)pyrene and benzo(j)fluoranthene.

The pyrolysis of 2-methylnaphthalene was studied, naphthalenes being common constituents of many petroleums. The vaporized methylnaphthalene was passed through a heated copper tube, and the material leaving the tube collected and analysed by chromatography.

Most of the 2-methylnaphthalene passed through the tube unchanged, even at 950°. The only product in amounts large enough for crystallization was 2,2'-binaphthyl. Some 1,2'-binaphthyl was present but could not be isolated and, like the other products, was identified by absorption spectroscopy. The identity of most of the products was confirmed by fluorescence spectroscopy. The calculated yields

(1) This analytical study was performed in this laboratory and has not yet been published.

(2) L. A. Errede and J. P. Cassidy, *J. Am. Chem. Soc.*, **82**, 3653 (1960).

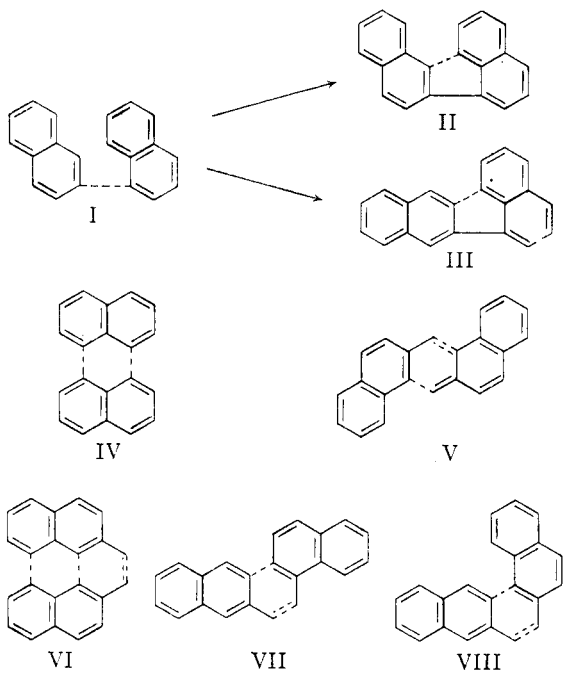
(3) G. M. Badger and R. W. L. Kimber, *J. Chem. Soc.*, 266 (1960).

(4) G. M. Badger and R. W. L. Kimber, *J. Chem. Soc.*, 2746 (1960).

were based, except for 2,2′-binaphthyl, on the absorption spectra of the compounds.[5]

The following compounds were identified in the pyrolysis product:

2,2′-binaphthyl; 1,2′-binaphthyl (I); benzo(j)-fluoranthene (II); benzo(k)fluoranthene (III); perylene (IV); dibenz(a,h)anthracene (V); benzo(g,h,i)-perylene (VI); benzo(b)chrysene (VII); dibenzo-(b,g)phenanthrene (VIII); benz(a)anthracene and chrysene.



In the formation of most of the products, the methyl group of 2-methylnaphthalene was, apparently, lost.[2] This could not be so, however, in the formation of benzo(g,h,i)perylene, dibenz(a,h)-anthracene, benzo(b)chrysene, and dibenzo(b,g)-phenanthrene. 1,2′-Binaphthyl was probably an intermediate in the formation of the two benzofluoranthenes. Formation of benzo(b)chrysene could be explained by assuming that some 1-methylnaphthalene was present in the starting material. The formation of benz(a)anthracene and chrysene can not, at present, be accounted for, although Badger suggests that the formation of these two compounds in the pyrolysis of tetralin[3] takes place through the intermediate formation of indene, pyrolysis of which also gives rise to these two compounds.[4]

Pyrolysis of 2-methylnaphthalene on a larger scale will, it is hoped, yield sufficient material for crystallization and characterization of many of the pyrolysis products.

EXPERIMENTAL

Two hundred grams of 2-methylnaphthalene was filtered, in hexane solution, through magnesia/Celite (2:1) to remove any tetracyclic or higher polycyclic aromatic hyrocarbons[6] and the hexane distilled from the 2-methylnaphthalene in the filtrate. Approximately 30 g. of purified 2-methylnaphthalene was weighed into a flask and heated to the boiling point. A slow stream of nitrogen bubbled through the liquid carried the vapor into a copper tube (0.6 × 50 cm.) packed with inert material (granular calcium sulfate). The tube was heated in a cylindrical combustion furnace and the effluent gases were collected in a series of three traps containing 2,2,4-trimethylpentane. The last trap was connected to an aspirator, by which a slightly reduced pressure was applied. The temperature of the furnace could be controlled and the pyrolysis was carried out at 700° and 950°.

After 2 hr. the contents of the traps were collected and the strongly fluorescent solution chromatographed on a small column of magnesia/Celite using 300 ml. of acetone-benzene-hexane (1:1:3) as developer. The filtrate was evaporated to constant weight under nitrogen, this being the weight of 2-methylnaphthalene which had passed through the pyrolysis tube. The column was extruded, the four fluorescent zones cut out and eluted separately. The two most strongly adsorbed fractions were treated with dilute hydrochloric acid (to dissolve the magnesia and liberate the hydrocarbons, which otherwise could not be eluted quantitatively).[6] The absorption spectra of the fractions showed the presence of several higher polycyclic aromatic hydrocarbons. An aliquot of each fraction was chromatographed on paper strips in a dimethylformamide isooctane system[6] and the fluorescent zones eluted. Those with significant ultraviolet absorption were rechromatographed in the same system or on acetylated paper in toluene-methanol-water (1:10:1)[7], until fractions were obtained with sufficiently well defined absorption spectra for identification and estimation of the polycyclic aromatic hydrocarbons to be made.

The results of pyrolysis of 2-methylnaphthalene at the two temperatures were as follows:

At 700°, 22 g. of 2-methylnaphthalene yielded 15 mg. of 2,2′-binaphthyl, 0.27 mg. of benzo(b)chrysene, 0.09 mg. of dibenz(a, h)anthracene, 0.05 mg. of benzo(k)fluoranthene, 0.04 mg. of benzo(g,h,i)perylene.

At 950°, 9.2 g. of 2-methylnaphthalene yielded 114 mg. of 2,2′-binaphthyl, 11 mg. of benzo(k)fluoranthene, 5.5 mg. of benzo(j)fluoranthene, 2.3 mg. of benzo(b)chrysene, 1.8 mg. of perylene, 1.5 mg. of dibenz(a,h)anthracene, 1.1 mg. of dibenzo(b,g)phenanthrene, 0.9 mg. of benzo(g,h,i)perylene, 0.8 mg. of benz(a)anthracene, 0.5 mg. of chrysene.

Benzo(j)fluoranthene and benzo(k)fluoranthene had absorption and fluorescence spectra identical with those reported.[8] Benzo(g,h,i)perylene, perylene, benzo(b)chrysene, chrysene, benz(a)anthracene, and dibenz(a,h)anthracene had absorption and fluorescence spectra identical with those of the commercially available compounds. The identity of the latter two hydrocarbons was further confirmed in parallel paper chromatograms with the pure compounds. Although the absorption spectrum of the compound identified as dibenzo(b,g)phenanthrene was very similar to that reported,[5] The pure compound was not available for comparison of the fluorescence spectra; identification of the compound must be only tentative. 2,2′-Binaphthyl was crystallized from benzene-ethanol and melted at 179.5–181° (corr.); the absorption spectrum of this compound was identical with that reported.[9]

(5) E. Clar, *Aromatische Kohlenwasserstoffe*, 2nd Edition, Springer-Verlag, Berlin (1952).

(6) W. Lijinsky, *Anal. Chem.*, **32**, 684 (1960).

(7) E. D. Bergmann and T. Gruenwald, *J. Appl. Chem. (London)*, **7**, 15 (1957).

(8) E. L. Wynder and D. Hoffmann, *Cancer*, **12**, 1194 (1959).

(9) R. A. Friedel and M. Orchin, *Ultraviolet Spectra of Aromatic Compounds*, No. 309, Wiley, New York (1951).

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Thiolcarbamates from the Reaction of Dialkylamines with Carbon Monoxide and Sulfur

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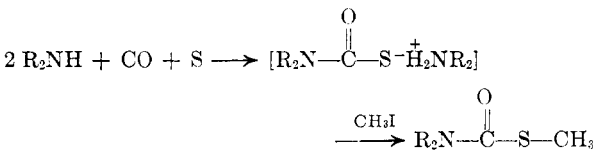
A new synthesis for mono-, di-, and trisubstituted ureas involving the reaction of carbon monoxide and sulfur with amines has been reported recently.[1]

It was of interest, therefore, to investigate the hitherto unreported reaction of dialkylamines with carbon monoxide and sulfur. It was found that di-*n*-butylamine and diisopropylamine reacted to yield their respective dialkylammonium dialkylthiolcarbamates in substantial yields.



R = isopropyl or *n*-butyl

EXPERIMENTAL[2,3]

Reaction of diisopropylamine with carbon monoxide and sulfur followed by reaction with methyl iodide. A mixture of diisopropylamine (101 g., 1 mole), sulfur (32 g., 1 mole), and tetrahydrofuran (200 ml.) was charged to a 1.4-l. bottom-stirred autoclave which was purged with nitrogen and then sealed. Carbon monoxide was injected into the autoclave until a pressure of 300 p.s.i. was reached. The stirred mixture was heated to 120° during 35 min. The temperature of the mixture was then maintained at 120° and the pressure at 400 p.s.i. by occasional injection of carbon monoxide during 1 hr. The autoclave was cooled to 0° and the gases were vented. Methyl iodide (142 g., 1 mole) was added dropwise to the stirred mixture at 0–10°. The thick slurry was stirred at room temperature for 3 hr. The mixture was filtered, and the crystals were washed with ether. Ether was added to the filtrate until no more crystals separated. The mixture was filtered and the filtrate was evaporated to an oil which was distilled to yield *S*-methyl diisopropylthiolcarbamate (53 g., 0.30 mole, 60% yield), b.p. 92–96.5°/14 mm., n_D^{25} 1.4831.

The infrared spectrum had a peak at 6.05 μ (C=O) and was identical with that of a sample prepared in the same manner having b.p. 96–96.5°/14 mm., n_D^{25} 1.4822.

Anal. Calcd. for $C_8H_{17}NOS$: C, 54.81; H, 9.78; N, 7.99; S, 18.22. Found: C, 54.99; H, 9.42; N, 7.92; S, 18.57.

In another experiment the mixture of crystals and liquid obtained from the reaction of diisopropylamine with carbon monoxide and sulfur was cooled to −10°. The slurry was filtered; the crystals were washed with ether (200 ml.) and pressed dry with a filter dam for 1 hr. The filtrate was cooled to −80° for 1 hr. The solid which separated was combined with the first crop to yield diisopropylammonium diisopropylthiolcarbamate (79.6 g., 0.30 mole, 60% yield). The infrared spectrum was identical with that of an authentic sample prepared from the reaction of carbonyl sulfide with diisopropylamine.

Reaction of di-n-butylamine with carbon monoxide and sulfur followed by methyl iodide. A mixture of di-*n*-butylamine (129 g., 1 mole), sulfur (32 g., 1 mole), and tetrahydrofuran (200 ml.) was treated in a similar manner to the case of diisopropylamine. The reaction mixture was heated to 90° during 30 min. at a carbon monoxide pressure of 200 p.s.i. The autoclave was maintained at a temperature of 90–94° and 200 p.s.i. for 10 min., then cooled to room temperature. Methyl iodide (142 g., 1 mole) was added under the usual conditions. There was obtained *S*-methyl di-*n*-butylthiolcarbamate (62.5 g., 0.31 mole, 62% yield), b.p. 79–80°/0.2 mm., n_D^{25} 1.4781 (lit.[4] b.p. 144.5–146°/20 mm.; n_D^{30} 1.4761).

The infrared spectrum had a peak at 6.1 μ (C=O) and was identical with that of a sample prepared in the same manner.

Anal. Calcd. for $C_{10}H_{21}NOS$: C, 59.07; H, 10.41; N, 6.89 S, 15.77. Found: C, 59.05; H, 10.57; N, 6.71; S, 15.77.

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(1) (a) F. Applegath, M. Barnes, and R. Franz, U. S. Pat. **2,857,430** (1958); *Chem. Abstr.*, **53**, 5296h (1959). (b) *Cf.*, F. Applegath and R. Franz. U. S. Pat. **2,874,149** (1959); *Chem. Abstr.*, **53**, 12187f (1959). (c) *Cf.*, F. Applegath and R. Franz, U. S. Pat. **2,857,392** (1958); *Chem. Abstr.*, **53**, 5286e (1959).

(2) All boiling points are uncorrected.

(3) Elemental analyses were performed by the Galbraith Laboratories, P. O. Box 4187, Knoxville, Tenn.

(4) H. Tilles, *J. Am. Chem. Soc.*, **81**, 714 (1959).

The Structure of the Crystalline Peroxide Formed in the Oxidation of Acetaldehyde

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Wieland[1] first proposed an addition product of peracetic acid and acetaldehyde to be an intermediate in the liquid-phase autoxidation of acetaldehyde to acetic acid, and Lösch[2] later isolated, analyzed, and determined the physical properties of such an intermediate. Since then there has been controversy over its structure. The following structures for this peroxide intermediate have been proposed. Wieland,[1] Lubarsky and Kagen,[3] Lösch,[2] Golding,[4]

(1) H. Wieland, *Ber.*, **54**, 2357 (1921).

(2) H. Lösch, P.B. 52007, pp. 23, 101. Office of Technical Service, U. S. Department of Commerce, Washington, D. C.

(3) G. D. Lubarsky and M. J. Kagen, *J. Phys. Chem.*, **39**, 847 (1935).

(4) D. R. V. Golding, U. S. Patent **2,833,814** (1958).