

C 58.41; H 2.95; I 38.75. Calc. for $C_{16}H_9I$: C 58.54; H 2.76; I 38.66).

2-Cyanopyrene. Yield (crude) 15%. M.p. 201–202° (chlorobenzene), (Ref. 1, 203–204°).

1. Vollmann, H., Becker, H., Corell, M. and Streeck, H. *Ann.* **531** (1937) 1.
2. Berg, A. *Acta Chem. Scand.* **10** (1956) 1362.
3. Bolton, R. *J. Chem. Soc.* **1964** 4637.
4. Huisgen, R., Mack, W., Herbig, K., Ott, N. and Anneser, E. *Chem. Ber.* **93** (1960) 413.
5. Lund, H. and Berg, A. *Kgl. Danske Videnskab. Selskab, Mat.-Fys. Medd.* **22** (1946) No. 15.

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Reaction of Tabun with Fluoride in Aqueous Solution

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In a previous communication¹ it was shown that fluoride is able to reactivate cholinesterase after the inhibition of this enzyme by methyl-isopropoxy-phosphoryl fluoride (Sarin). Further experiments revealed that cholinesterase inhibited by dimethylamido-ethoxy-phosphoryl cyanide (Tabun) can be reactivated by fluoride.² It is possible that fluoride, known to have a striking reactivity towards the phosphoryl group,³ is able to make a nucleophilic attack at the phosphorus atom of the phosphorylated cholinesterase, followed by reactions finally leading to the reactivation of the enzyme. The affinity of fluoride for the phosphorus atom in organophosphorus compounds can be demonstrated by the ability of fluoride to react with Tabun in aqueous solution as shown by the following experiments:

Upon addition of 7.3×10^{-3} M sodium fluoride to a 1.0×10^{-3} M Tabun solution in 0.1 M potassium chloride at pH 7.4 the pH of the solution immediately rose to 9.2 and continued to rise slowly with time. This observation indicated that a substance with a high pK_a was split off from Tabun without the formation of

equimolar amounts of a monobasic phosphorus acid. In further experiments cyanide ion could be demonstrated upon addition of sodium fluoride to freshly prepared Tabun solutions. The cyanide ions were determined according to a method given by Asmus and Garschagen⁴ which method was not disturbed by the presence of sodium fluoride. During these experiments the pH of the solution was kept at 7.4 by means of a barbital buffer

Table 1. Amount of CN^- liberated at pH 7.4 and 25°C from 10^{-5} M Tabun in veronal buffer solution after incubation with 10^{-4} M sodium fluoride. The third column shows CN^- formed from a 10^{-4} M Tabun solution only. The figures are corrected for blank values.

Incubation, min	CN^- in % of total amount of Tabun cyanide obtained from	
	10^{-5} M Tabun + 10^{-4} M NaF	10^{-4} M Tabun alone
11	13	4
20	24	5
31	27	7
41	31	9

Table 2. Amount of CN^- liberated at pH 7.4 and 25°C from 10^{-5} M Tabun in veronal buffer after incubation for 33 min with varying amounts of sodium fluoride.

Conc. of NaF M	CN^- in % of total amount of Tabun cyanide obtained from	
	10^{-5} M Tabun + NaF	10^{-4} M Tabun alone
1×10^{-2}	103	15
5×10^{-3}	103	15
1×10^{-3}	101	15
5×10^{-4}	83	15
2×10^{-4}	52	15
1×10^{-4}	36	15
5×10^{-5}	27	15
1×10^{-5}	14	15

in order to diminish the alkaline hydrolysis of Tabun,⁵ which would lead to free cyanide. Tables 1 and 2 show the amount of cyanide obtained under various experimental conditions. The reaction is quantitative within 30 min if a 100-fold excess of fluoride is used. With lower fluoride concentrations longer reaction time is needed.

In another experiment dimethylamido-ethoxy-phosphoryl fluoride was prepared from 0.02 moles of Tabun by incubation with 0.06 moles of potassium fluoride in 6 ml of water at room temperature for 1 h. The mixture was then extracted twice with 4 volumes of ether, the ether was evaporated *in vacuo* (0° and 6 mm Hg) and the obtained residue was purified by distillation (35°C, 1 mm Hg). The obtained liquid (Found: C 31.0; H 7.1; F 12.1. Calc. C 31.0; H 7.1; F 12.2) showed anticholinesterase activity; the pI_{50} for butyrylcholinesterase at 25°C, pH 8.1, and 30 min of

incubation was 7.6. In a similar experiment dimethylamido-ethoxy-phosphoryl fluoride was prepared from the corresponding chloride according to a reaction described by Schrader.⁶ This compound had the same pI_{50} . The IR-spectra of both preparations showed absorption at 850–880 cm^{-1} where the absorption of the P–F bond is normally found. No P–CN or P–OH bonds were found, while both the absorption produced by the dimethylamidogroup and the ethoxygroup could be seen (Fig. 1).

From the experiments it can be concluded that fluoride in aqueous solution is able to replace the cyanide at the phosphorus atom.

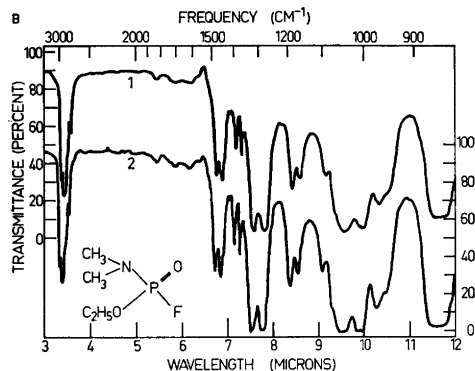
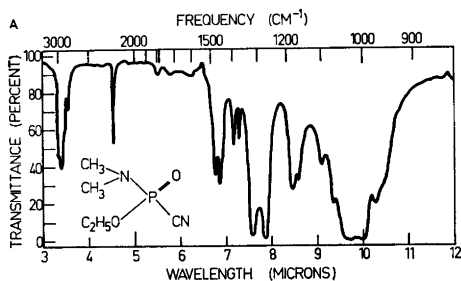


Fig. 1. Infrared spectra of A) dimethylamido-ethoxy-phosphoryl cyanide (Tabun) and B) dimethylamido-ethoxy-phosphoryl fluoride prepared from Tabun (1) and from dimethylamido-ethoxy-phosphoryl chloride (2).

1. Heilbronn, E. *Acta Chem. Scand.* **18** (1964) 2410.
2. Heilbronn, E. *To be published.*
3. Dostrovsky, I. and Halmann, M. *J. Chem. Soc.* **1953** 508.
4. Asmus, E. and Garschagen, H. *Z. anal. Chem.* **138** (1953) 414.
5. Larsson, L. *Acta Chem. Scand.* **12** (1958) 783.
6. Schrader, G. *Monographien zu Angewandte Chemie und Chemie-Ingenieur-Technik*, Nr. 62, 2. erweiterte Auflage, (1952) 15, Verlag Chemie, GMBH, Weinheim.

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Correction to "An X-Ray and Neutron Diffraction Study of Metacinnabarite"*

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The cell edge of HgS (metacinnabarite) is 5.8517 Å and not 5.8717 Å as given on p. 1552. The distance Hg–S is then 2.5338 Å.

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