

for the biological assays, Dr. G. Hobby for the toxicity tests and the Microanalytical Department for the microanalyses and the chemical assays.

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Derivatives of N-Phosphorylated Amino Acids

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The problem of the synthesis of N-phosphorylated amino acids has received renewed attention since the recognition of the importance of phosphorylated intermediates in metabolic processes. In previous reports,^{1,2} there has been described the phosphorylation of amino acids by means of phosphorus oxychloride. The reaction was conducted in the presence of magnesium oxide and gave magnesium salts of the N-phosphoryl amino acids of approximately the correct composition.

It appeared desirable to examine the possibility of preparing such N-phosphorylated amino acids by the use of diphenylphosphoryl chloride,³ which reacts readily with amines to give the corresponding aminophosphonates. It was hoped that the reaction of this reagent with esters of α -amino acids would yield products which, upon saponification of the ester linkage and hydrogenolysis of the phenyl groups, would be converted to the desired N-phosphorylated amino acids. The direct reaction of the chloride with free amino acids in alkaline solution was avoided in view of the report⁴ that the products so obtained are not aminophosphonates but are rather diphenylphosphoric acid salts of amino acids.

As will be noted in the experimental section of this note, the reaction of diphenylphosphoryl chloride with the esters of glycine, of DL-phenylalanine, and of L-glutamic acid leads to the expected diphenylphosphoryl amino acid esters without difficulty. The further steps in the proposed synthesis of N-phosphoryl amino acids were less successful, however. The attempted saponification of the diphenylphosphoryl amino acid esters by treatment with 1.1 equivalents of sodium hydroxide in acetone solution for one hour at 25° led to the recovery of the unchanged esters. Since such treatment readily causes the saponification of acyl amino acid esters such as benzoyl-glycine ethyl ester, it would appear that the phosphorylation of the α -amino group has greatly increased the stability of the carboxylic ester linkage. More vigorous treatment with 4 equivalents of alkali either at 25° for two hours, or at 70° for fifteen minutes, gave mixtures of products which could not be separated satisfactorily. Furthermore, hydrogenolysis of diphenylphosphoryl-L-glutamic acid diethyl ester with platinum oxide, followed by treatment with sodium

methylate in absolute methanol, gave a product whose elementary composition approximated the theory for the disodium salt of N-phosphoryl-L-glutamic acid diethyl ester, rather than for the expected tetrasodium salt of N-phosphoryl-L-glutamic acid. This result may also be attributed to the stabilizing effect of the N-phosphoryl group on the ester linkage.

In the course of these studies, the reaction of dibenzylphosphoryl chloride⁵ with amino acid esters (*e. g.*, glycine benzyl ester) was investigated, but thus far has not yielded crystalline products. This work is being continued.

Experimental

Reaction of Diphenylphosphoryl Chloride with Amino Acid Esters.—The ester hydrochloride of the appropriate amino acid was dissolved in a minimal quantity of water and the free ester was liberated into ice-cold ethyl acetate with the calculated amount of 10 N sodium hydroxide. To the ethyl acetate solution, there was added diphenylphosphoryl chloride (one mole per mole of amino acid ester), and the acid formed during the reaction was neutralized with aqueous bicarbonate. The ethyl acetate layer was then washed successively with water, dilute hydrochloric acid, water, aqueous bicarbonate solution and water. After being dried over sodium sulfate, the solution was concentrated to a small volume under reduced pressure, and the reaction product was precipitated by the addition of petroleum ether (30–60°). Recrystallization was effected from ethyl acetate–petroleum ether.

Diphenylphosphorylglycine Ethyl Ester.—From 5 g. of glycine ethyl ester hydrochloride there was obtained 3.7 g. of the product; m. p. 77–78°.

Anal. Calcd. for $C_{16}H_{18}O_6NP$: C, 57.3; H, 5.4; N, 4.2; P, 9.2. Found: C, 57.4; H, 5.5; N, 4.1; P, 9.1.

Diphenylphosphoryl-DL-phenylalanine Ethyl Ester.—From 5 g. of DL-phenylalanine ethyl ester hydrochloride there was obtained 4.2 g. of the product, m. p. 78–79°.

Anal. Calcd. for $C_{23}H_{24}O_6NP$: C, 64.9; H, 5.7; N, 3.3; P, 7.3. Found: C, 64.9; H, 5.7; N, 3.4; P, 7.2.

Diphenylphosphoryl-L-glutamic Acid Diethyl Ester.—From 5 g. of L-glutamic acid diethyl ester hydrochloride there was obtained 2.4 g. of the product; m. p. 73.5–74°.

Anal. Calcd. for $C_{21}H_{26}O_7NP$: C, 57.9; H, 6.0; N, 3.2; P, 7.1. Found: C, 57.8; H, 6.0; N, 3.3; P, 7.0.

One gram of this substance was subjected to hydrogenolysis in dry methanol in the presence of platinum oxide until 8 moles of hydrogen had been taken up. The reaction required six hours, after which time the catalyst was removed by filtration. To the filtrate was added the calculated quantity of freshly prepared sodium methylate in dry methanol, and the solution was kept at 4° for four hours. Anhydrous ether was then added and the resulting precipitate (0.25 g.) was washed with methanol–ether and with ether.

Anal. Calcd. for $C_6H_{10}O_7NPNa_2$: C, 33.1; H, 4.9; N, 4.3; P, 9.5; Na, 14.1. Found: C, 34.8; H, 4.5; N, 4.4; P, 9.8; Na, 13.3.

(5) Atherton, Openshaw and Todd, *J. Chem. Soc.*, 382 (1945).

DEPARTMENT OF PHYSIOLOGICAL CHEMISTRY

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The Melting Point of 4-Aminosalicylic Acid

BY WILLIAM SEAMAN, WILLIAM ALLEN, R. LILLIAN PASTERNAK AND ALFRED POLLARA

The melting point of 4-aminosalicylic acid (4-amino-2-hydroxybenzoic acid) is uncertain: 148°

(1) Neuberg and Oertel, *Biochem. Z.*, **60**, 491 (1914).

(2) Winnick and Scott, *Arch. Biochem.*, **12**, 201 (1947).

(3) Brigl and Müller, *Ber.*, **72**, 2121 (1939).

(4) Bernton, *ibid.*, **55**, 3361 (1922).