tion in this media is predominantly electrophilic in nature.[3] Accordingly, aqueous fluorination of sodium dinitroacetonitrile produced fluorodinitroacetonitrile in moderate yield. The reaction proceeded smoothly

$$NaC(NO_2)_2CN + F_2 \longrightarrow FC(NO_2)_2CN + NaF$$

even with fluorine concentrations as high as 50 vol %. The product was removed from the aqueous mixture by an additional helium purge. Pure fluorodinitroacetonitrile is a colorless liquid with bp 74° and fp −13°. The composition of the compound was established by elemental analysis. Table I presents the characteristic

TABLE I
INFRARED SPECTRUM OF $FC(NO_2)_2CN$[a]

Absorption bands, μ
4.40 (m sharp)
6.12 (v s)
7.47 (wk sh)
7.74 (s)
9.20 (m s)
11.83 (m s sharp)
12.59 (s)

[a] Abbreviations are m = medium, v = very, wk = weak, sh = shoulder, and s = strong.

infrared absorption bands. The F^{19} nmr spectrum of $FC(NO_2)_2CN$ consists of a singlet at +91.4 ppm *vs.* CCl_3F).

Variation of the fluorine concentration, the reaction temperature and the ratio of reactants employed did not increase the yield of product above 30–35%. Increasing the concentration of $NaC(NO_2)_2CN$ in the reaction mixture resulted in the isolation of substantial amounts of acetonitrile upon fluorination. The formation of acetonitrile is probably a result of attack by the fluorine on oxygen or nitrogen to form unstable intermediates which would hydrolyse in the aqueous media. Possible hydrolysis products such as fluorine nitrate, and nitrate ion, were also found. The amount of acetonitrile in the fluorination product could be suppressed by use of dilute reaction mixtures containing as little as 3% $NaC(NO_2)_2CN$. Another reason for the moderate yield of product was the hydrolysis of $FC(NO_2)_2CN$ to fluorodinitroacetamide.

$$FC(NO_2)_2CN + H_2O \longrightarrow FC(NO_2)_2CONH_2$$

Fluorodinitroacetamide was obtained in quantitative yield by adding the stoichiometric amount of water to a HCl-saturated ether solution of fluorodinitroacetonitrile. The product was isolated by evaporation at 0° and extraction with methylene chloride. Fluorodinitroacetamide formed white feathery crystals, mp 32°. The infrared spectrum of $FC(NO_2)_2CONH_2$ contained peaks not present in the spectrum of the nitrile at 2.90 and 5.75 μ. The compound is soluble in water and attempts to isolate an alkali metal salt of the amide were not successful.

Experimental Section

Materials.—Sodium dinitroacetonitrile was prepared by the literature method.[4] The fluorine was obtained from General Chemical Co. and was used after it was passed through a NaF scrubber.

Fluorodinitroacetonitrile.—A solution of 10 g (65 mmoles) sodium dinitroacetonitrile in 300 ml of water was placed in a 500-ml, four-necked flask equipped with a magnetic stirrer, thermometer, and two gas inlet tubes. After cooling to 0°, a stream of 25% fluorine in helium was introduced at a rate of 1.1./hr. The temperature was maintained at 0° and the fluorination product was swept out of the reaction mixture by an additional stream of helium which was introduced through a gas dispersion tube. The off-gas was passed through four traps at −78° and then vented in order to avoid collecting fluorine nitrate which was sometimes formed. The fluorination was continued until the yellow color in the cyanodinitromethide ion faded away. In order to achieve complete removal of the product from the solution, the helium sweep was maintained for another hour. The combined fractions of all four −78° traps were dried over Drierite and condensed into a −30° trap. Fluorodinitroacetonitrile (2.6 g), mp −13°, was obtained in a 29% yield. Its vapor pressure at 25° was 65 mm.

Anal. Calcd for $C_3FN_3O_4$: C, 16.11; N, 28.19. Found: C, 16.16; N, 28.10.

Fluorodinitroacetamide.—Fluorodinitroacetonitrile (3 g, 20 mmoles) was condensed into a mixture of 30 ml of ether and 0.4 ml of water which had been saturated with hydrogen chloride. The hydrolysis proceeded smoothly on thawing. After standing for 1 hr at room temperature all volatile material was pulled off, keeping the reaction flask in a bath of 20°. The remaining semisolid was dissolved in 15–20 ml of methylene chloride and shaken over BaO to remove excess hydrogen chloride. Crystallization of the product took place when the solution was cooled slowly to −70°. The hygroscopic fluorodinitroacetamide was obtained in a 96% yield. It melted at 32° after sublimation under high vacuum.

Anal. Calcd for $C_2H_2FN_3O_5$: C, 14.38; H, 1.20; N, 25.15. Found: C, 14.91; H, 1.01; N, 24.87.

Registry No.—Fluorodinitroacetonitrile, 15562-09-1; fluorodinitroacetamide, 15562-10-4.

(3) V. Grakauskas, Abstracts, 140th National Meeting of the American Chemical Society, Chicago, Ill., Sept 1961, p 23M.
(4) C. O. Parker, *et al.*, *Tetrahedron*, **17**, 79 (1962).

The Reaction of Asparagine, Glutamine, and Derivatives with Phosgene

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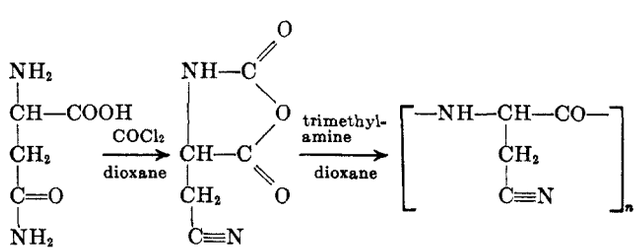
Several methods exist for the conversion of asparagine and glutamine derivatives into their corresponding nitriles.[1–4] An easy and convenient agent for the dehydration of these amino acids has now been found to be phosgene in dioxane. This reaction was discovered subsequent to the attempted preparation of the N-carboxy anhydride of asparagine by the usual procedure of passing phosgene through a dioxane sus-



(1) M. Zaoral and J. Rudinger, *Collect. Czech. Chem. Commun.*, **24**, 1993 (1959).
(2) C. Ressler and H. Ratzkin, *J. Org. Chem.*, **26**, 3356 (1961).
(3) B. Liberek, *Bull. Acad. Polon. Sci., Ser. Sci. Chim.*, **10**, 227 (1962).
(4) B. Liberek, Cz. Buczel, and Z. Gnyonka, *Tetrahedron*, **22**, 2303 (1966).

pension of the amino acid. When the resulting anhydride was polymerized, the polymer isolated was poly-β-cyano-L-alanine, as shown by infrared absorption at 2235 cm^{-1} (C=N stretching).

In order to investigate this dehydration reaction further, we treated N^{α}-carbobenzoxy-L-asparagine with phosgene in dioxane. The product, which was isolated in 81% yield, was identical with authentic N^{α}-carbobenzoxy-β-cyano-L-alanine.[1,3] Hydrogenation of this material with palladium catalyst produced α,γ-diaminobutyric acid as confirmed by paper chromatography.

The dehydration reaction with L-glutamine and N^{α}-carbobenzoxy-L-glutamine gave lower yields. The resulting carbobenzoxy-γ-cyano-α-aminobutyric acid separated as an oil.[2] Hydrogenation led to ornithine and traces of proline which were identified by paper chromatography.

This convenient dehydration, which is free of side reactions, suggests various applications, for instance, for the synthesis of the neurotoxic amino acid β-cyano-L-alanine[5,6] and of asparaginyl and glutaminyl peptides.[7]

Experimental Section

All melting points are uncorrected. Prior to analysis the polymers were dried at 105° and the other compounds at 50° *in vacuo* over phosphorus pentoxide.

β-Cyano-N-carboxy-L-alanine Anhydride (I).—Dry phosgene was passed for 3 hr through a suspension of 13 g of asparagine (0.1 mole) in anhydrous dioxane at 60°. Excess phosgene was removed from the solution by a stream of dry nitrogen, and the solvent was distilled *in vacuo* at 45°; the crystalline residue was dissolved in ethyl acetate. The anhydride, which crystallized on the addition of petroleum ether (60–70°), was collected and washed with petroleum ether, and recrystallized from ethyl acetate–petroleum ether. The infrared spectrum showed an absorption peak for nitrile at 2235 cm^{-1}. The yield was 10.2 g (60%), mp 75° dec.

Anal. Calcd for $C_5H_4N_2O_3$: C, 42.86; H, 2.88; N, 20.00. Found: C, 42.59; H, 3.00; N, 19.81.

γ-Cyano-N-carboxy-L-butyric Anhydride.—This compound was prepared in the same manner by passing phosgene through a glutamine suspension and was recrystallized from ethyl acetate–petroleum ether. The infrared spectrum showed an absorption peak for nitrile at 2235 cm^{-1}. The yield was 42%, mp 90–92°.

Anal. Calcd for $C_6H_6N_2O_3$: C, 46.76; H, 3.92; N, 18.18. Found: C, 46.76; H, 3.96; N, 18.16.

Poly-β-cyano-L-alanine.—β-Cyano-N-carboxy-L-alanine anhydride (19 g) was dissolved in dry dioxane (500 ml) and triethylamine (0.1 ml) was added. Polymerization proceeded at room temperature (magnetic stirring) with evolution of carbon dioxide. After 48 hr the product was filtered and washed with dioxane and ether. The infrared spectrum showed an absorption peak for nitrile at 2235 cm^{-1}. The yield was 10 g. The polymer is insoluble in the common solvents, dimethylformamide, water, acetic acid, ethanol, and sodium bicarbonate.

Anal. Calcd for $(C_4H_4N_2O \cdot {}^1/_4H_2O)_n$: C, 47.76; H, 4.22; N, 27.86. Found: C, 48.18; H, 4.15; N, 27.22.

A sample of the poly-β-cyano-L-alanine was hydrolyzed in 6 *N* hydrochloric acid for 24 hr at 105°, and chromatographed in *n*-butyl alcohol–glacial acetic acid–water (25:6:25 v/v). Only one spot, identical with authentic aspartic acid, was detected with ninhydrin on the paper chromatogram.

N-Carbobenzoxy-β-cyano-L-alanine.—Dry phosgene was passed for 1 hr at room temperature through a solution of carbobenzoxy-L-asparagine (13.2 g) in anhydrous dioxane, and the reaction mixture left for 2 hr at room temperature. The excess of phosgene was removed by a stream of nitrogen and most of the solvent was distilled off *in vacuo* at 45°. Upon the addition of 1 *N* hydrochloric acid, the residue crystallized and was recrystallized from ethylene chloride. The infrared spectrum showed an absorption peak for nitrile at 2235 cm^{-1}. The yield was 10 g (81%), mp 131–134°, $[\alpha]^{25}D$ −19.0 (*c* 1.25 methanol) (lit.[6] mp 128°, $[\alpha]^{21}D$ −18.6 (*c* 1.28, methanol); lit.[4] mp 133–134°, $[\alpha]^{21}D$ −19 (*c* 1.26, methanol).

Anal. Calcd for $C_{12}H_{12}N_2O_4$: C, 58.06; H, 4.87; N, 11.29. Found: C, 58.15; H, 5.05; N, 11.29.

Hydrogenation of this compound with palladium on charcoal under acidic conditions produced α,γ-diaminobutyric acid, as indicated by paper chromatography with an authentic sample of α,γ-diaminobutyric acid.

N-Carbobenzoxy-γ-cyano-α-amino-L-butyric acid.—The reaction was carried out and the product treated as described for the preparation of N-carbobenzoxy-β-cyano-L-alanine. On acidification, a thick oil was obtained which was extracted in ethyl acetate, dried over sodium sulfate and concentrated to dryness under reduced pressure. The infrared spectrum of this oil showed an absorption peak for nitrile at 2235 cm^{-1}. The yield was 75%.

Anal. Calcd for $C_{13}H_{14}N_2O_4$: N, 10.68. Found: N, 10.35.

Hydrogenation of this compound with palladium on charcoal under acidic conditions led to ornithine and proline as established by paper chromatography with authentic samples of ornithine and proline.

Registry No.—Asparagine, 70-47-3; glutamine, 56-85-9; phosgene, 75-44-5; I, 15275-68-0; γ-cyano-N-carboxy-L-butyric anhydride, 15231-19-3; N-carbobenzoxy-β-cyano-L-alanine, 3309-41-9; N-carbobenzoxy-γ-cyano-α-amino-L-butyric acid, 15231-21-7.

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Studies in the Xanthone Series. IX.[1] The Mechanism of the *para* Claisen Rearrangement of 1-(3,3-Dimethylallyloxy)-3,5,6-trimethoxyxanthone

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In a previous publication,[2] we reported that a Claisen rearrangement of 1-(3,3-dimethylallyloxy)-3,5,6-trimethoxyxanthone (**1**) gave four products, **2**, **3**, **4**, and **5**.[3] It was suggested[2] that the main product, **5**, formed by migration of the 3,3-dimethylallyl group to the *para* position, results from a Claisen rearrangement

(1) Part VIII: A. Jefferson and F. Scheinmann, *J. Chem. Soc., Sect. C*, 175 (1966).

(2) E. D. Burling, A. Jefferson, and F. Scheinmann, *Tetrahedron*, **21**, 2653 (1965).

(3) 2,4-Di-(3,3-dimethylallyl)-1-hydroxy-3,5,6-trimethoxyxanthone was also isolated in one experiment.[2] It was suspected that this product arose from rearrangement of an impurity in **1** since analogous migrations gave no diallylation: see (a) H. D. Locksley, I. Moore, and F. Scheinmann, *J. Chem. Soc., Sect. C*, 2265 (1966); (b) F. Scheinmann and H. Suschitzky, *Tetrahedron*, **7**, 31 (1959); (c) reference 4. Thus if 1-hydroxy-3,5,6-trimethoxyxanthone **2** reacts as an ambident anion (N. Kornblum, P. J. Berrigan, and W. J. le Noble, *J. Amer. Chem. Soc.*, **85**, 1141 (1963)) allylation at C-2 and then oxygen will yield 2-(3,3-dimethylallyl)-1-(3,3-dimethylallyloxy)-3,5,6-trimethoxyxanthone as an impurity in **1**. Mass spectral examination showed that with some ether samples the impurity arising from concurrent O- and C-isoprenylation was indicated as a small peak at *m/e* 438 with respect to the molecular ion peak at *m/e* 370 due to the ether **1**. Both molecular ions lost a fragment of 55 mass units consistent with loss of C_4H_7 from a 3,3-dimethylallyl ether or side chain. The radioactive ether **1** used for the mechanism studies was free from this and other impurities as shown by mass spectral and chromatographic evidence.