equatorial substituents in a 4-position have no effect on reaction rates[13a] at least for those reactions that involve a change of hybridization from sp^2 to sp^3.

Experimental[14]

Cyclohexanols.—4-*t*-Butylcyclohexanol (*cis–trans*) was a gift from the Dow Chemical Co. 2-Ethyl-, 2-*n*-propyl- and 2-*n*-butylcyclohexanols were purchased from the Aldrich Chemical Co.

2-Isopropyl-, 2-*t*-butyl-, 4-ethyl- (b.p. 80–83° at 10 mm.), 2,6-dimethyl- (b.p. 58–62° at 10 mm.), and 2,6-diisopropylcyclohexanol were prepared by hydrogenation of the corresponding phenols over Raney nickel catalyst at 100° and 100 atm.[15]

Cyclohexanones.—4-Isopropylcyclohexanone was a commercial sample (Frinton Laboratories). 3-Ethyl-, 3-isopropyl-, and 3-*t*-butylcyclohexanone were synthesized by reaction of cyclohex-2-enone with the appropriate Grignard reagent in the presence of cuprous chloride.[16a] Better yields were obtained using cuprous acetate in tetrahydrofuran.[16b]

The other cyclohexanones were prepared by chromium trioxide oxidation of the corresponding cyclohexanols.[17]

The ketones were fractionally distilled and then redistilled through an 18-in. spinning-band column. Only center fractions which gave single sharp peaks on gas chromatography using a Craig polyester succinate column at 100–130° were used. (The *cis–trans* mixtures of 2,6-dimethyl- and 2,6-diisopropylcyclohexanone were not completely resolved.) The physical constants are given in Table II. Some of the ketones were characterized by preparing their 2,4-dinitrophenylhydrazones which were purified by chromatography on alumina from benzene: 2-*t*-butyl, m.p. 161° (lit.[18] m.p. 162–162.5°); 2-isopropyl, m.p. 138° (*Anal.* Calcd. for $C_{15}H_{19}N_4O_4$: C, 56.40; H, 6.01. Found: C, 56.17; H, 6.20); and 2,6-dimethyl, m.p. 150° (lit.[19] m.p. 149–150°). 2,6-Diisopropylcyclohexanone did not form a 2,4-dinitrophenylhydrazone.

Dissociation Constants.—The cyanohydrin dissociation constants were measured in purified 95% ethanol (d^{25} 0.805) at 23 ± 1° as previously described.[20]

Acknowledgment.—The technical assistance of Mrs. Elsie E. Granell de Rodriguez is acknowledged. The work was financed in part by a grant from the National Science Foundation.

(13) (a) S. Winstein and N. J. Holness, *J. Am. Chem. Soc.*, **77**, 5562 (1955); (b) L. Munday [*J. Chem. Soc.*, 1413 (1964)] has recently measured the K_D-values of the cyanohydrins of 4-alkylcyclohexanones in 94% ethanol and finds a small decrease in K_D with *increasing* size of the alkyl group.

(14) Analyses were by Dr. C. Janssen, Beerse, Belgium.

(15) H. E. Ungnade and A. D. McLaren, *J. Am. Chem. Soc.*, **66**, 118 (1944).

(16) (a) F. C. Whitmore and G. W. Pedlow, Jr., *ibid.*, **63**, 758 (1941); (b) A. H. Birch and M. Smith, *Proc. Chem. Soc.*, 356 (1962).

(17) A. S. Hussey and R. H. Baker, *J. Org. Chem.*, **25**, 1434 (1960); H. C. Brown and C. P. Garg, *J. Am. Chem. Soc.*, **83**, 2952 (1961).

(18) H. L. Goering, R. L. Reeves, and H. H. Espy, *ibid.*, **78**, 4926 (1956).

(19) A. J. Birch, *J. Chem. Soc.*, 1642 (1947).

(20) O. H. Wheeler and E. E. G. de Rodriguez, *J. Org. Chem.*, **26**, 718 (1964).

N-Nitroamides and N-Nitrocarbamates. II. Amino Acid Derivatives[1]

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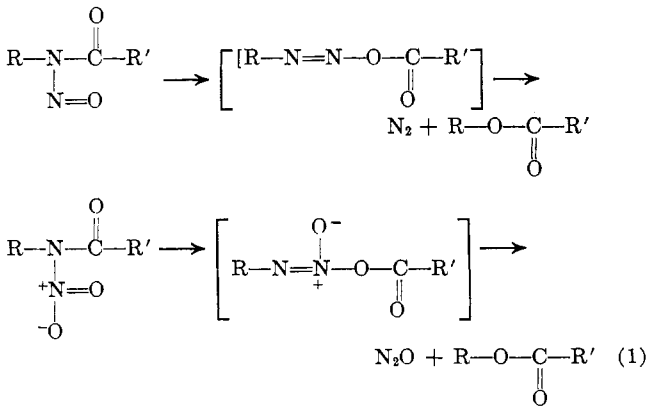
Nitration of N-carbethoxy and N-acyl derivatives of ethyl glycinate and ethyl alanate yielded the corresponding N-nitro compounds (II and VI) accompanied in the acyl case by the solvolysis products, ethyl α-nitratoglycinate and -alanate (V). A better method for the preparation of the N-nitro-N-acyl derivatives (VI) proved to be the reaction of acid chlorides with salts (XI and XII) of ethyl N-nitroglycinate and ethyl N-nitroalanate. These reactions of ambident ions proceed with surprisingly high per cents of N-acylation; only traces of products attributable to O-acylation were formed. Attempts to prepare N-nitrosoimines (III) by the pyrolysis of these N-nitroamide (VI) and N-nitrocarbamate (II) derivatives were unsuccessful.

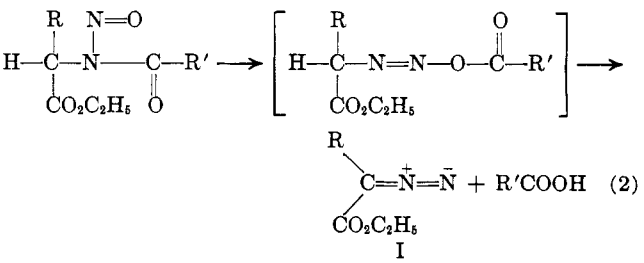
N-Nitrosoamides and N-nitroamides decompose thermally under similar conditions to give the corresponding esters as products (eq. 1).[2,3] N-Nitrosoamides of amino acid esters, however, decompose to



(1) Taken in part from a thesis submitted by R. J. Baumgarten to the Faculty of the Graduate School, The Johns Hopkins University, in partial fulfillment of the requirements for the Ph.D. degree.

(2) Paper I: E. H. White and D. W. Grisley, Jr., *J. Am. Chem. Soc.*, **83**, 1191 (1961).

(3) E. H. White, *ibid.*, **77**, 6011 (1955); E. H. White and C. A. Aufdermarsh, Jr., *ibid.*, **83**, 1181 (1961).

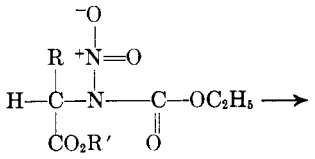


yield α-diazo esters I (eq. 2).[4] The present work was designed to find out whether an analogous reaction occurs during the decomposition of N-nitrocarbamates and N-nitroamides of amino acid esters II (eq. 3); it was hoped that nitrosoimines (III) would be formed in this reaction.

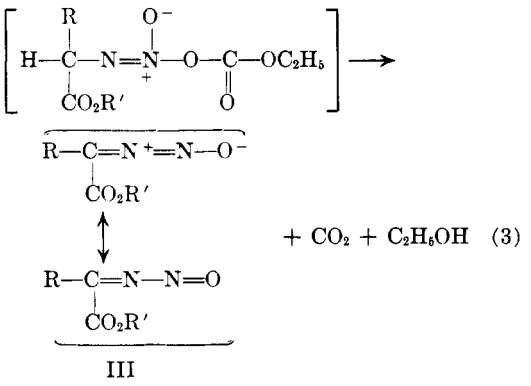
Preparation of the Nitroamides and Nitrocarbamates.—The N-nitrocarbamates IIa and b were readily prepared by nitration of the parent carbamates with fuming or with 100% nitric acid.[2,5] This procedure, when applied to the corresponding amides IV, on the other hand, yielded only the nitrate esters (Va and b)

(4) E. H. White and R. J. Baumgarten, *J. Org. Chem.*, **29**, 2070 (1964).

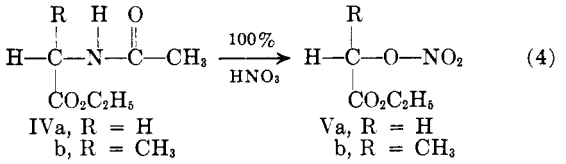
(5) A. Hantzsch and W. V. Metcalf, *Ber.*, **29**, 1683 (1896).



IIa, R = H; R′ = C_2H_5
b, R = CH_3; R′ = C_2H_5
c, R = H; R′ = CH_3



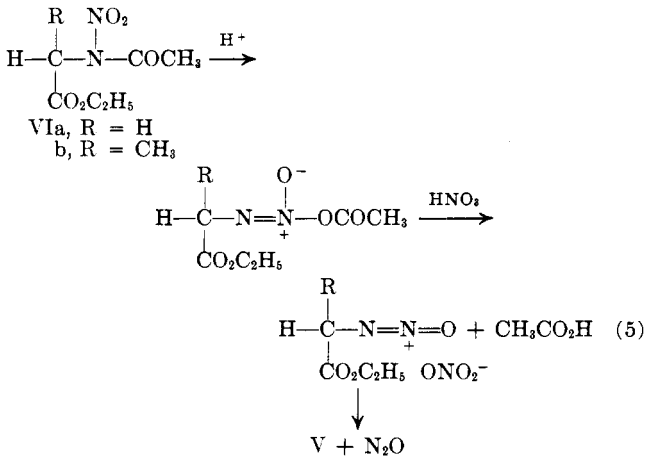
III



IVa, R = H
b, R = CH_3

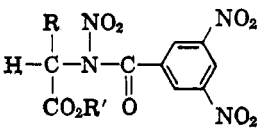
Va, R = H
b, R = CH_3

as products. This reaction probably involves an acid-catalyzed rearrangement[6] of the initially formed nitroamide VI, followed by anion exchange[7] and the loss of nitrous oxide.



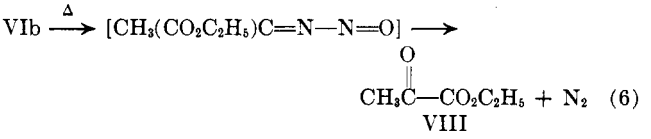
Ethyl N-acetyl-N-nitroalanate (VIb) could be prepared in low yield by the nitration of the corresponding amide IVb with an acetic anhydride–nitric acid mixture, but a more convenient procedure involved the treatment of the potassium salt of ethyl N-nitroalanate (XIb) with acetyl chloride. Similarly, the N-nitro-N-3,5-dinitrobenzoyl derivatives of amino acid esters (VII) were most readily obtained *via* the acylations of the appropriate nitroamine salts with 3,5-dinitrobenzoyl chloride (see section on the acylation of salts of the N-nitroamines).

Pyrolysis of the Nitroamides and Nitrocarbamates.—Nitrocarbamates IIa and b proved to be very stable



VIIa, R = H; R′ = C_2H_5
b, R = CH_3; R′ = C_2H_5
c, R = H; R′ = CH_3

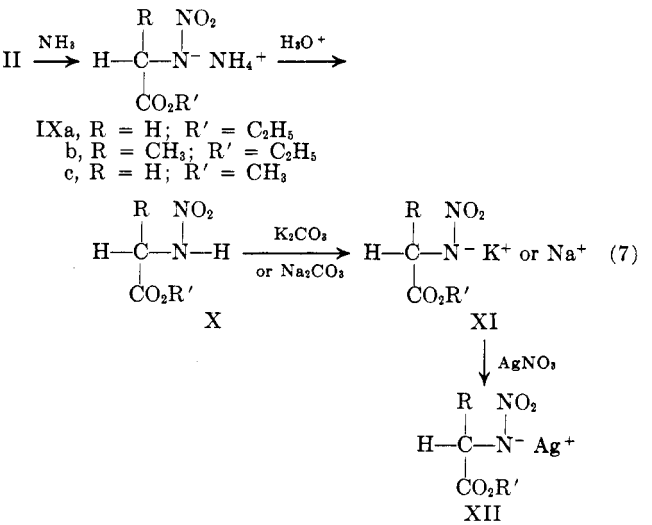
compounds; only partial decomposition occurred at 220° and complex mixtures of products were formed. Nitroamides VIb and VIIc decomposed at lower temperatures (*ca.* 120°), but the products were still complex. Ethyl pyruvate (VIII) and methyl glyoxylate, respectively, were formed in the latter reactions, possibly as decomposition products of the desired compounds (eq. 6). Small amounts of methyl diazoacetate



VIII

also were obtained from compound VIIc. Attention was next turned to an alternative, low-temperature method for the synthesis of the nitrosoimine intermediate III; the method used was the "salt" reaction which involved the treatment of salts of the nitroamines with acylating agents.

The Acylation of Nitroamine Salts.—The required nitroamine salts were prepared by the following sequence (eq. 7). The potassium salts proved to be more suitable than the sodium salts in that they were less hygroscopic and more highly crystalline.



IXa, R = H; R′ = C_2H_5
b, R = CH_3; R′ = C_2H_5
c, R = H; R′ = CH_3

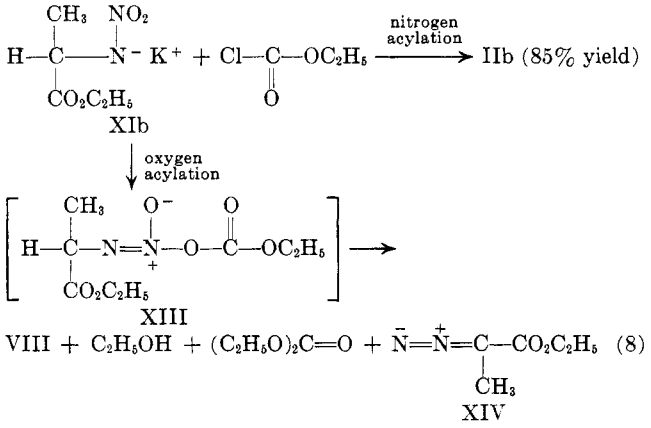
X

XI

XII

In a typical example of the "salt" reaction, ethyl chloroformate was allowed to react with the potassium salt of ethyl N-nitroalanate (XIb). Acylation on nitrogen was the principal reaction. Similar results were obtained from the reaction of ethyl chloroformate with the sodium and silver salts (XI and XII) of the N-nitroglycine and N-nitroalanine esters, and also from the reactions of the various salt derivatives with acetyl and 3,5-dinitrobenzoyl chloride (the latter acylations gave principally nitroamides VI and VII, respectively). Considerable differences in the acylation rates were observed. The sodium salts of the nitroamines reacted rapidly, the acylations reaching completion in about 1 hr. The potassium salts reacted more slowly, but a

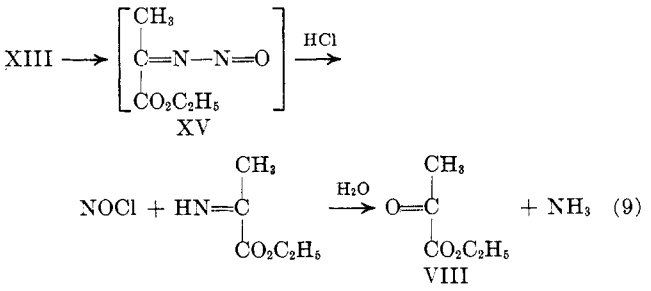
(6) R. Huisgen and H. Reimlinger, *Ann.*, **599**, 161 (1956).
(7) E. H. White and J. E. Stuber, *J. Am. Chem. Soc.*, **85**, 2168 (1963).



$$\text{VIII} + C_2H_5OH + (C_2H_5O)_2C{=}O + \bar{N}{=}\overset{+}{N}{=}C(CH_3)CO_2C_2H_5 \quad (8)$$

XIV

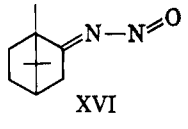
microdrop of pyridine greatly accelerated the rate. The effect of a microdrop of pyridine was, however, most marked in the acylations of the silver salts. Whereas the silver salts reacted at a negligible rate in the absence of pyridine, the addition of a trace of pyridine increased the rates of reaction to those of the sodium salts. The ammonium and morpholinium salts of ethyl N-nitroglycinate were unsatisfactory in that acylation of the free bases occurred; that is, the morpholinium salt gave mainly N-benzoylmorpholine and ethyl N-nitroglycinate when treated with benzoyl chloride. The products shown in eq. 8, other than the nitrocarbamate IIb, presumably came from the O-acylated intermediate XIII since the N-nitrocarbamates were stable under the reaction conditions. Ethyl pyruvate (VIII) may have been formed *via* the decomposition shown in eq. 6, or possibly it was formed by an acid-catalyzed denitrosation (eq. 9).



$$NOCl + HN{=}C(CH_3)CO_2C_2H_5 \xrightarrow{H_2O} O{=}C(CH_3)CO_2C_2H_5 + NH_3 \quad (9)$$

VIII

We have observed recently that model nitrosoimines such as XVI react with hydrogen chloride to give the corresponding imine hydrochlorides in high yield.[8] The



XVI

source of the diazo ester XIV is not known; it stems possibly from a reduction or a disproportionation of the nitrosoimine XV (eq. 10). The ethyl alcohol presumably

$$2XV \longrightarrow XIV + CH_3{-}C(=N{-}NO_2){-}CO_2C_2H_5 \quad (10)$$

stems from the monoethyl carbonate formed in the elimination reaction of XIII (as in eq. 3), and the diethyl carbonate from the reaction of ethyl chloroformate with the alcohol.

It is surprising that predominant N-acylation occurred in these ambident ion reactions, in apparent violation of Kornblum's rules[9,10] and in contrast to the predominant O-acylation observed earlier for salts of simple nitroamines[2] and salts of nitroparaffins.[11] Moreover, the failure of the silver salt to acylate in the absence of pyridine requires further discussion. A reasonable explanation is one based on intermolecular chelation. That our salts are of the chelate rather than the ionic type is probable since they are soluble in methylene chloride and have definite melting points.[12,13] Moreover, Zook and Gumby[14] have noted that certain salts such as the potassium salt of butyrophenone exist as trimers in ether solution. The sodium and potassium salts reported here may exist as large aggregates in solution, whereby the oxygens of the nitro group are coordinated with the metallic ions. This chelation may interfere with the acylation on oxygen in a manner similar to the effect Kornblum noted for the effect of hydrogen bonding on the inhibition of oxygen alkylation of phenols in highly polar solvents.[15] In the silver salt cases, both the nitrogens and oxygens of the nitroamino groups may be bonded in the chelate, thus inhibiting the acylation on both oxygen and nitrogen. The rate-accelerating effect of pyridine on these silver salts may stem from the breaking up of the complexes to form silver pyridine coordination bonds; O- and N-acylation of the freed nitro groups may then occur.

Experimental

Ethyl N-carbethoxyglycinate and ethyl N-carbethoxyalanate were prepared in 50–80% yields by the method of Fisher and Otto.[16] **Ethyl N-acetylglycinate (IVa)** and **ethyl N-acetylalanate (IVb)** were prepared in 65–70% yields by essentially the method of Karrer, *et al.*[17]

Ethyl N-carbethoxy-N-nitroglycinate (IIa, b.p. 68–70° at 0.2 mm., $n^{20}D$ 1.4478) was prepared in 94% yield by the method of Hantzsch and Metcalf.[5]

Ethyl N-Carbethoxy-N-nitroalanate (IIb).—This nitrocarbamate (b.p. 78–80° at 0.1–0.2 mm., $n^{24.5}D$ 1.4445) was prepared in 87% yield by the method of Hantzsch and Metcalf.[5]

Anal. Calcd. for $C_8H_{14}N_2O_6$: C, 41.02, H, 6.03; N, 11.96. Found: C, 41.10; H, 6.22; N, 11.91.

Ethyl N-Acetyl-N-nitroalanate (VIb).—Ethyl N-acetylalanate (IVb, 11 g., 0.069 mole) was added dropwise with stirring at 0° to a solution of 20 ml. (0.40 mole) of 90% nitric acid in 35 ml. (0.37 mole) of acetic anhydride (prepared at 0°). After all the amide had been added, the reaction was allowed to proceed 3.5 hr. at 0°. At this time the reaction was not yet complete, but due to the instability of the nitroamide under the reaction conditions, this reaction time was judged to be the best compromise. The reaction mixture was now poured over ice and slowly neutralized with an excess of sodium carbonate. The hydrolysis of the acetic anhydride was over when no more gas evolution was observed. The neutralized mixture was then extracted with ether, and the ether extract was washed with several portions of water to remove the excess amide. The ether extract was now dried and the ether was removed *in vacuo* to yield 2.5 g. (0.012 mole, 17%) of crude nitroamide. An infrared spectrum of the crude product indicated that it contained a considerable amount of an impurity with a band in the infrared at 6.05 μ. In the distillation of the crude nitroamide, the latter impurity was removed

(8) Unpublished work of R. J. Baumgarten.

(9) N. Kornblum, R. A. Smiley, R. K. Blackwood, and D. C. Iffland, *J. Am. Chem. Soc.*, **77**, 6269 (1955).

(10) N. Kornblum and A. P. Lurie, *ibid.*, **81**, 2705 (1959).

(11) E. H. White and W. J. Considine, *ibid.*, **80**, 626 (1958).

(12) A. Brandstrom, *Arkiv Kemi*, **6**, 155 (1953); **7**, 81 (1954).

(13) N. V. Sidgwick and F. M. Brewer, *J. Chem. Soc.*, 2379 (1925).

(14) H. D. Zook and W. L. Gumby, *J. Am. Chem. Soc.*, **82**, 1386 (1960); H. D. Zook and T. J. Russo, *ibid.*, **82**, 1258 (1960).

(15) N. Kornblum, P. J. Berrigan, and W. J. Le Noble, *J. Am. Chem. Soc.*, **82**, 1257 (1960).

(16) E. Fisher and E. Otto, *Ber.*, **36**, 2107 (1903).

(17) P. Karrer, E. Miyamichi, H. C. Storm, and R. Widmer, *Helv. Chim. Acta*, **8**, 208 (1925).

in the first fraction (b.p. 30–35° at 0.5 mm.). Nitroamide VIb had a boiling point of 64–66° (0.1 mm.) and the infrared spectrum contained bands at 5.73, 5.80, and 6.32 μ.

1-Carbethoxy-1-nitratomethane (Va).—Anhydrous nitric acid (15.8 g., 0.250 mole), prepared as described by Kaplan and Shechter,[18] was added slowly with stirring at 0° to 8.00 g. (0.0550 mole) of ethyl N-acetylglycinate (IVa). After 12 hr. (when gas evolution ceased), the reaction mixture was poured on ice and immediately extracted with four 25-ml. portions of ether. The ether extract was then washed with sodium carbonate solution, dried, and evaporated *in vacuo* to yield a yellow oil (n^{11}D 1.4206). This product was distilled at 28° (0.1 mm.) to give 5.50 g. (0.0370 mole, 67.3%) of a colorless, sweet-smelling oil (n^{11}D 1.4200, d^{20}_4 1.233). The corresponding values for the nitrate ester Va prepared by the method of Henry[19] were n^{11}D 1.4200, d^{20}_4 1.235 (lit.[20] d^{20}_4 1.235).

1-Carbethoxy-1-nitratoethane (Vb).—Anhydrous nitric acid (9.0 g., 0.14 mole) was added to 1.0 g. (6.3 mmoles) of ethyl N-acetylalanate (IVb) as described in the previous preparation. In this case the reaction was warmed to 25° after 1 hr., and then allowed to stand for 2 days. After the product was worked up and distilled at 25° (0.1 mm.), 0.61 g. (3.7 mmoles, 59%) of a colorless, sweet-smelling oil was obtained (n^{20}D 1.4139, d^{20}_4 1.150); lit.[19] (for nitrate ester Vb) b.p. 178° (760 mm.), d_{13} 1.1534. The infrared spectrum of this oil was identical with the infrared spectrum of a sample prepared from the corresponding alcohol by the method of Henry.[19]

Ethyl N-Nitroglycinate, Ammonium Salt IXa.—The procedure used to prepare ammonium salt IXa was based on the method of Hantzsch and Metcalf.[5] Anhydrous ammonia was passed into a solution of 28.8 g. (0.131 mole) of nitrocarbamate IIa dissolved in 200 ml. of anhydrous ether at 0° for 1 hr. During the passage of the ammonia much of the ether evaporated so that at the conclusion of the reaction the volume of the reaction mixture was restored to 200-ml. with anhydrous ether. The flaky crystals were immediately filtered, washed with several portions of dry ether, and dried to constant weight (20.9 g., 0.127 mole, 97%) in a vacuum desiccator. The product was very hygroscopic and unstable as indicated by an acrid odor which became stronger when the compound was allowed to stand for 1 day. Ethyl carbamate was also isolated as a product of this reaction.

Ethyl N-nitroalanate, ammonium salt IXb, m.p. 79–81° dec., was obtained in 88% yield by the method described above.

Anal. Calcd. for $C_5H_{13}N_3O_4$: C, 33.52; H, 7.27. Found: C, 33.72; H, 7.33.

Ethyl carbamate was also isolated from this reaction.

Ethyl N-nitroglycinate (Xa), n^{24}D 1.4610, m.p. 24–25° (lit.[5] m.p. 24–25°), was obtained in 89% yield from the acidification of ammonium salt IX, as described by Hantzsch and Metcalf.[5]

Ethyl N-Nitroglycinate, Potassium Salt XIa.—Nitroamine Xa (10 g., 68 moles) was dissolved in 25 ml. of anhydrous ether, and 4.7 g. (68 mequiv.) of anhydrous potassium carbonate was added while the solution was stirred at 0°. When the gas evolution had stopped, the sides of the flask were rinsed with ether, and the solid material was broken into small pieces with a stirring rod. The stirring was continued for 15 min. more at 0°, after which time the solid material was filtered and washed with anhydrous ether. After the white powder was dried in a vacuum desiccator for 1 hr., it weighed 10 g. (54 mmoles, 79%) and melted at 134–136° dec. Two recrystallizations at 10° from dry methanol gave white needles, m.p. 137–138° dec.

Anal. Calcd. for $C_4H_7KN_2O_4$: C, 25.80; H, 3.79; N, 15.05. Found: C, 26.10; H, 3.50; N, 15.10.

Similarly prepared was the **potassium salt of ethyl N-nitroalanate (XIb),** m.p. 131–133° dec. This salt was highly hygroscopic and it formed colloidal solutions with methylene chloride. Potassium bicarbonate also had this property and some of the samples of XIb were contaminated with potassium bicarbonate.

Methyl N-nitroglycinate, potassium salt XIc, was obtained in good yield as white crystals, m.p. 160–162° dec., when ethyl N-nitroglycinate (Xa) was treated with potassium carbonate in excess methanol at 20°. This salt was also prepared by stirring the potassium salt of ethyl N-nitroglycinate (XIa) with potassium carbonate for 2 hr. in methanol at 25°.

Ethyl N-nitroglycinate, sodium salt XId, and **ethyl N-nitroalanate, sodium salt XIe,** were prepared by similar procedures to the ones used for the potassium salts. Sodium carbonate reacted with nitroamine Xa at a slower rate than potassium carbonate and consequently 12 hr. of stirring at 0° were necessary for completion of the reaction. The crude sodium salt was dissolved in methylene chloride; the extract was filtered, dried, and then evaporated *in vacuo* to give a glassy residue of XId. The yield of crude salt was nearly quantitative. The sodium salt XId was hygroscopic and unstable in water.

Sodium salt XId was also prepared by the titration of ammonium salt IXa with ethanolic sodium ethoxide, but the product was found to be contaminated with an impurity which could not be removed.

Ethyl N-Nitroglycinate, Silver Salt XIIa.—The potassium salt of ethyl N-nitroglycinate (XIa, 1.17 g., 6.29 mmoles) was dissolved in 15 ml. of water and 1.07 g. (6.29 mmoles) of silver nitrate dissolved in 10 ml. of water was added dropwise while the solution was stirred at 0° in a flask protected from the light. After the silver salt precipitated, it was filtered and washed with water. The silver salt (XIIa, quantitative yield) was then dried *in vacuo* (0.1 mm.) for 24 hr. The dry silver salt melted at 168–170° with gas evolution. The silver salts of ethyl N-nitroalanate and methyl N-nitroglycinate were prepared by a similar procedure.

Ethyl N-Nitroglycinate, Morpholinium Salt.—Morpholine (1.90 g., 21.8 mmoles) was added dropwise at 0° to a stirred solution of 4.80 g. (21.6 mmoles) of ethyl N-carbethoxy-N-nitroglycinate (IIa) dissolved in 20 ml. of hexane. The crystals which precipitated were washed with hexane and ether. After three recrystallizations from a hexane–methylene chloride mixture, 1.01 g. (4.30 mmoles, 20%) of the white morpholinium salt, m.p. 100–101°, was obtained.

Infrared Spectra of the Nitroamine Salts.—Potassium bromide pellet infrared spectra of the morpholinium salt, silver salt XIIa, and potassium salt XIa showed no bands in the N-nitro region at *ca.* 6.3 μ. A methylene chloride solution of the morpholinium salt, however, had a band in this region, as did the methylene chloride solutions of the corresponding sodium and ammonium salts.

Pyrolyses of the N-Nitrocarbamates.—When ethyl N-carbethoxy-N-nitroglycinate (IIa) was heated in a sublimator, nitrocarbamate IIa distilled unchanged at oil-bath temperatures of 200° at 760 mm. When the oil bath was heated to 215–235°, most of nitrocarbamate distilled unchanged, but a small amount of a product with bands in the infrared at 4.45 and 6.01 μ appeared on the cold finger; the proportion of product with peaks at 4.45 and 6.01 μ increased at 240–255°.

Pyrolysis of the N-Nitroamides.—Methyl N-(3,5-dinitrobenzoyl)-N-nitroglycinate (VIIc) was heated at 135–140° under a pressure of 2 mm. in the presence of sodium carbonate, and the volatile products were collected at −80°. The infrared spectrum of the volatiles indicated that methyl glyoxylate (phenylhydrazone m.p. 132–133°, lit.[21] 129–130°) was the major product. A band in the infrared at 4.71 μ suggested that methyl diazoacetate was also a product. The infrared spectrum of the residue indicated that 3,5-dinitrobenzoic acid was probably present. Ethyl N-acetyl-N-nitroalanate (VIb) decomposed at 110° (25 mm.) to give a complex mixture of products from which ethyl pyruvate (VIII) (2,4-dinitrophenylhydrazone m.p. 151–153°, lit.[22] 154.5–155°) was isolated as the major volatile constituent.

Reaction of Ethyl N-Nitroalanate, Potassium Salt XIb, with Ethyl Chloroformate.—Potassium salt XIb (33.2 g., 0.166 mole) was suspended in 100 ml. of anhydrous methylene chloride. A microdrop of pyridine was then added, and the reaction mixture was cooled to 0°. Ethyl chloroformate (13.6 g., 0.125 mole) dissolved in 25 ml. of methylene chloride was then added dropwise over a period of 10 min. while the solution was stirred. Gas evolution was noted while the ethyl chloroformate was added. An infrared spectrum taken of an aliquot of the reaction solution after all the ethyl chloroformate had been added indicated that the reaction was essentially complete at this time and that primarily N-acylation had occurred. The reaction was stirred for an additional 30 min. at 0° (at which time no further gas evolution was observed). The volatiles were now distilled in a freeze-dry apparatus. Methylene chloride and traces of ethanol, ethyl α-diazopropionate (XIV), and diethyl carbonate were observed in the first fraction. The residue was a thick pasty mixture of the inorganic and organic products of the reaction. The organic

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material was extracted with 300 ml. of carbon tetrachloride and washed with three 100-ml. portions of water to remove all the salts. After the carbon tetrachloride was evaporated *in vacuo*, the reaction mixture was vacuum distilled at a pressure of 1 mm. Fraction A distilled at 24° and contained diethyl carbonate (1.04 g., 8.8 mmoles, 7.0%), ethyl pyruvate (VIII, 0.42 g., 3.6 mmoles, 2.9%), and ethyl α-diazopropionate (XIV, 2.0 mmoles, 1.6%). These volatile products were qualitatively identified by their infrared spectra and quantitatively by vapor phase chromatography. Since ethyl α-diazopropionate could not be passed through the columns without decomposition, the samples were first treated with hydrogen bromide, and the ethyl α-bromopropionate derivative was analyzed. The ethyl pyruvate could be isolated unchanged from the column. The less volatile fractions (B, $n^{24}D$ 1.4450; C, $n^{24}D$ 1.4451; and D, $n^{24}D$ 1.4453; lit.,[5] for nitrocarbamate IIb, $n^{24.5}D$ 1.4445) distilled at 70–74° (1 mm.) and gave infrared spectra which were identical with the infrared spectrum of ethyl N-carbethoxy-N-nitroalanate (IIb). The yield of nitrocarbamate IIb was 24.9 g. (0.106 mole, 85%). These samples of the nitrocarbamate gave only one peak when tested by vapor phase chromatography. The nonvolatile residue weighed 0.559 g. (principal infrared bands at 5.73, 6.45, and 6.50 μ). Thin layer chromatography indicated that several components were present. No ethyl acrylate, ethyl 1-carbethoxyethyl carbonate, or nitrous oxide was detected in this run.

Other Acylation Reactions with Ethyl Chloroformate.—In a similar manner ethyl N-nitroglycinate, potassium salt XIa, was treated with ethyl chloroformate to give 85% of ethyl N-carbethoxy-N-nitroglycinate (IIa), 3.6% of diethyl carbonate, and 2.2% of ethyl diazoacetate. This run was conducted without pyridine and 7 days at 0° were required for completion. A higher yield of ethyl diazoacetate was obtained when the reaction was conducted in the presence of sodium carbonate or sodium bicarbonate. Similar results were obtained with the respective sodium salts.

The reaction of the silver salt of ethyl N-nitroglycinate (XIIa) with ethyl chloroformate also led to predominantly N-acylation as determined from infrared spectra of the products.

Reaction of 3,5-Dinitrobenzoyl Chloride with the Silver Salt of Ethyl N-Nitroglycinate (XIIa).—3,5-Dinitrobenzoyl chloride (1.3 g., 5.6 mmoles) dissolved in 10 ml. of anhydrous methylene chloride was added dropwise to 1.5 g. (5.9 moles) of the silver salt XIIa suspended in 15 ml. of anhydrous methylene chloride containing a microdrop of pyridine. The reaction solution was stirred for 2.5 hr. at −80°, after which time it was pressure filtered at −80°. An infrared spectrum taken at −80° of the reaction solution at this time suggested that ethyl N-(3,5-dinitrobenzoyl)-N-nitroglycinate (VIIa) was the major product. Distillation of the volatiles left 0.82 g. (2.4 mmoles, 43%) of crude nitroamide VIIa (m.p. 104–107° dec.); after three recrystallizations from methylene chloride–hexane solutions, the melting point became 110–111° dec.

Anal. Calcd. for $C_{11}H_{10}N_4O_9$: C, 38.60; H, 2.95; N, 16.36. Found: C, 38.59; H, 2.82; N, 16.06.

Treatment of the methylene chloride insoluble material with 3 *N* hydrochloric acid, gave 0.30 g. of 3,5-dinitrobenzoic acid (1.4 mmoles, 25%, m.p. 201–203°, lit.[23a] m.p. 204–205°).

As with all the silver salt runs, the reaction proceeded at a negligible rate in the absence of pyridine.

Other "Salt" Reactions.—The silver salt of methyl N-nitroglycinate (XIIc) was similarly treated with 3,5-dinitrobenzoyl chloride at 25° to give 65% of methyl N-(3,5-dinitrobenzoyl)-N-nitroglycinate (VIIc) which melted at 142–143° after recrystallization from a mixture of methylene chloride and hexane.

Anal. Calcd. for $C_{10}H_8N_4O_9$: C, 36.60; H, 2.46; N, 17.07. Found: C, 36.73; H, 2.59; N, 16.81.

Also detected in this run were methyl diazoacetate, methyl N-nitroglycinate, 3,5-dinitrobenzoic acid, and 3,5-dinitrobenzoic anhydride.

Likewise, the silver salt of ethyl N-nitroalanate (XIIb) gave, at −10° with 3,5-dinitrobenzoyl chloride, 47% of the light yellow ethyl N-(3,5-dinitrobenzoyl)-N-nitroalanate (VIIb, m.p. 94–95.5° after recrystallization from methylene chloride–hexane).

Anal. Calcd. for $C_{12}H_{12}N_4O_9$: C, 40.45; H, 3.40; N, 15.73. Found: C, 40.43; H, 3.55; N, 15.11.

Also isolated was 43% of 3,5-dinitrobenzoic acid (m.p. 203–204°, lit.[23a] m.p. 204–205°).

At −80°, the sodium salt of ethyl N-nitroalanate (XIb) gave, with 3,5-dinitrobenzoyl chloride, 53% of nitroamide (VIIb), m.p. 94–95.5°.

The reaction of benzoyl chloride with the sodium salt of ethyl N-nitroglycinate (XIa) at −10° gave mainly ethyl N-benzoyl-N-nitroglycinate, as determined from the infrared spectrum. Ethyl diazoacetate and 44% of benzoic acid (m.p. 119–120°, lit.[23b] m.p. 121.7°) were also detected.

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On the Mechanism of the Conversion of β-Iodo Carbamates to Aziridines[1]

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The facile conversion of β-iodo carbamates with strong base to aziridines is shown to proceed *via* an intermediate N-carboalkoxy aziridine. The kinetics of the cyclization indicate abstraction of the proton from the carbamate nitrogen followed by a rate-determining ring closure made possible by neighboring group participation. Differences in rate of cyclization are explained on conformational grounds.

We have recently shown that *trans*-β-iodo carbamates can be converted to aziridines in good yield on treatment with alcoholic potassium hydroxide.[2] Since β-iodo carbamates are readily available from olefins, this represents a useful synthesis of fused aziridines from cyclic olefins. For instance, methyl (3α-iodo-2β-cholestane)carbamate (I), obtainable in 75% from 2-cholestene, is transformed in 90% yield[3] to cholesten(2β,3β)-imine (V) on refluxing for 1 hr. with 1.5 *N* methanolic potassium hydroxide. Three reaction paths, A, B, and C, come under consideration for the conversion of I to V in basic solution.

A rate-determining ring closure of I to VI (path C) can be eliminated by the fact that mild bases such as pyridine or sodium bicarbonate do not effect the conversion of I to V. Iodo amine II can in fact be readily converted to aziridine V but a facile hydrolysis of carbamate I to amine II would be unexpected in view of the known inertness of carbamates in basic medium.[4] We found, for example, that, on refluxing ethyl cyclohex-

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