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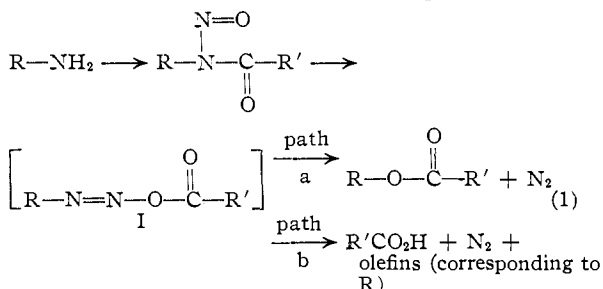
N-Nitrosoamides. IV. N-Nitrosoamides of Primary Carbinamines¹

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RECEIVED DECEMBER 2, 1959

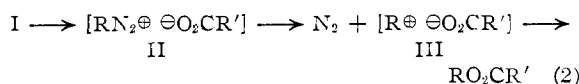
The decomposition of N-(*n*-butyl)-N-nitroso-trimethylacetamide in pentane in the presence of an excess of diazoethane yielded diazobutane and ethyl trimethylacetate. This result and other evidence indicate that the decomposition of nitrosoamides of primary carbinamines (RCH₂N(NO)COR') involves the following steps in sequence: rearrangement to a diazoester (RCH₂N=N-OCOR'), cleavage to a diazoalkane (RCHN₂) and an acid, and recombination to form the corresponding ester and nitrogen. A similar sequence is proposed for N-nitrosoamides of primary carbinamines.

The nitrosoamide decomposition is a general method for the conversion of aliphatic amines into esters and olefins.² Other investigations^{3,4} have



shown that the diazoester I is an intermediate in the reaction and that it is formed in the rate-determining step. The diazoester decomposes to form carboxylic esters whether RNH₂ is a primary carbinamine,^{2,5} a secondary carbinamine^{4,6} or a tertiary carbinamine⁷; however, the mechanism of the ester formation differs markedly depending on the type of the amine. Huisgen⁸ and Streitwieser³ have recently presented evidence indicating that diazoalkanes are intermediates in the decomposition of nitrosoamides of primary carbinamines; our work confirms this mechanism for the reaction.

In polar solvents, diazoesters I of primary carbinamines react by both intermolecular and intramolecular paths, *e.g.*, the decomposition of N-(*n*-butyl)-N-nitroso-3,5-dinitrobenzamide in acetic acid yielded both butyl acetate and butyl 3,5-dinitrobenzoate.² The intramolecular path leading to the latter ester is most likely that established for diazoesters of secondary carbinamines.⁹



In non-polar solvents, steps involving carbonium ion character are unfavorable and the reaction proceeds

(1) Taken in part from a thesis submitted by Carl A. Aufdermarsh, Jr., to the faculty of the Graduate School of Yale University in partial fulfillment of the requirements for the Ph.D. degree. Presented in part, before the Division of Organic Chemistry at the 130th Meeting of the American Chemical Society, Atlantic City, N. J., September 18, 1956.

(2) E. H. White, *THIS JOURNAL*, **77**, 6011 (1955); E. H. White, *ibid.*, **76**, 4497 (1954).

(3) R. Huisgen and H. Reimlinger, *Ann.*, **599**, 161 (1956).

(4) E. H. White, *THIS JOURNAL*, **77**, 6014 (1955).

(5) R. Huisgen and H. Reimlinger, *Ann.*, **599**, 183 (1956).

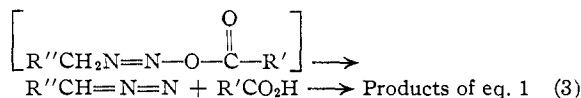
(6) R. Huisgen and C. Rüchardt, *ibid.*, **601**, 21 (1956).

(7) Unpublished work of R. R. Johnson.

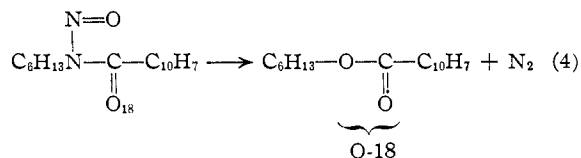
(8) A. Streitwieser and W. D. Schaeffer, *THIS JOURNAL*, **79**, 2893 (1957).

(9) E. H. White and C. A. Aufdermarsh, Jr., *ibid.*, **83**, 1179 (1961).

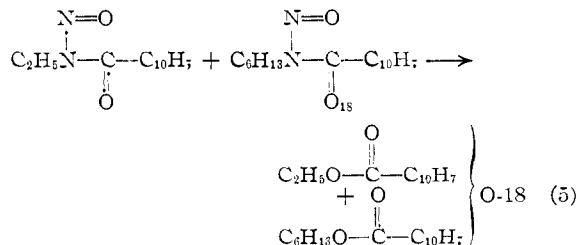
via an α elimination instead (eq. 3). The diazo



derivative can be isolated from the decomposition of compounds such as ethyl N-acetyl-N-nitrosoglycinate¹⁰; on the other hand, the isolation of diazoalkanes from the nitrosoamide reaction of non-conjugated primary carbinamines is not possible by ordinary techniques because of the speed of the diazoalkane-carboxylic acid reaction. Indirect evidence consistent with their formation as intermediates was obtained from two reactions involving compounds labelled with oxygen-18. The decomposition of N-(*n*-hexyl)-N-nitroso-2-naphthamide (carbonyl O-18) in hexane and also in dioxane yielded hexyl naphthoate with completely equilibrated oxygens, results consistent with the diazoalkane mechanism.



In contrast, nitrosoamides of secondary carbinamines, which decompose by the mechanism of equation 2, yield esters containing more than one-half of the O-18 in the carbonyl group.⁹ In the second O-18 reaction examined, the concurrent decomposition outlined in equation 5 gave 1-hexyl 2-naphthoate



containing almost that amount of oxygen-18 to be expected if both esters were formed from a common pool of naphthoic acid.

Direct evidence for the formation of diazoalkane intermediates was obtained from competition reaction 6.

Nitrosoamides of primary carbinamines are quite stable and a competition reaction with the rather unstable diazoethane normally would be out of the question. However, Huisgen³ has shown recently

(10) Ref. 2 and unpublished work of R. Baumgarten.

reaction the silver salt was not acylated on nitrogen since this would have yielded VII, a compound stable under the reaction conditions used; none was detected.¹⁴

Experimental¹⁵

Oxygen-18 Analyses.—These are reported in detail elsewhere.⁹

N-(1-Hexyl)-2-naphthamide-O¹⁸.—2-Naphthoyl chloride-O¹⁸ was prepared by refluxing 7.0 g. (40.7 mmoles) of 2-naphthoic acid-O¹⁸ (1.325, 1.343 atom % excess oxygen-18) in thionyl chloride (15 ml.) with a drop of pyridine for 2 hr. After removal of the excess thionyl chloride *in vacuo*, the residual acid chloride was dissolved in anhydrous ether and added slowly to an ice-cold solution of 1-hexylamine (10.2 g., 101 mmoles) in anhydrous ether. After standing for 10 minutes, the mixture was washed successively with water, dilute hydrochloric acid (twice), 5% sodium bicarbonate and water. The dried ether solution was concentrated *in vacuo*. After two recrystallizations from 550 ml. of a 10:1 hexane-ether mixture and drying, 7.50 g. (73%) of N-(1-hexyl)-2-naphthamide-O¹⁸ (1.326, 1.342 atom % excess oxygen-18), m.p. 104–105.5°, was obtained. The infrared spectrum was identical with that of an analytically pure sample of unlabelled N-(1-hexyl)-2-naphthamide (m.p. 106.0–106.7°) prepared by the Schotten-Baumann method.

Anal. Calcd. for C₁₇H₂₁NO: C, 79.98; H, 8.29; N, 5.49. Found: C, 80.13; H, 8.20; N, 5.51.

1-Hexyl 2-Naphthoate.—Equimolar amounts of 2-naphthoyl chloride and 1-hexanol were refluxed in pyridine for 3 hr. After cooling, pentane and water were added and the layers separated. The pentane phase was washed successively with water (6 times), 1 N potassium hydroxide and then water. The oil which remained after removal of the pentane *in vacuo* was evaporatively distilled at 70° and 0.07 mm. to give 1-hexyl 2-naphthoate, m.p. 21.5–22.2°, *n*_D²⁵ = 1.5597, *n*_D³⁵ = 1.5554.

Anal. Calcd. for C₁₇H₂₀O₂: C, 79.64; H, 7.86. Found: C, 79.77, H, 7.81.

N-(1-Hexyl)-N-nitroso-2-naphthamide-carbonyl-O¹⁸.—A solution of 7.0 g. (27.5 mmoles) of N-(1-hexyl)-2-naphthamide-O¹⁸ (1.326, 1.342 atom % excess oxygen-18) in 230 ml. of carbon tetrachloride was added in a slow stream to a stirred mixture of dinitrogen tetroxide¹⁶ (2.8 ml., 44.2 mmoles) and dry sodium acetate (6.75 g., 82.5 mmoles) in 50 ml. of carbon tetrachloride. The temperature was maintained at –5 to 0° in an ice-salt bath. After 30 minutes of stirring, the mixture was poured into ice water and the phases separated. The yellow organic layer was washed twice with 5% sodium bicarbonate, dried briefly over calcium chloride and concentrated *in vacuo* without heating. The residue was virtually pure N-(1-hexyl)-N-nitroso-2-naphthamide-carbonyl-O¹⁸ (7.43 g., 95%) in the form of bright yellow crystals, m.p. 38.5–40° dec. Recrystallization from hexane at –80° yielded crystals melting at 40.5–41.5° dec.

Anal. Calcd. for C₁₇H₂₀N₂O₂: C, 71.83; H, 7.11; N, 9.86. Found: C, 72.05; H, 7.00; N, 9.98.

Decomposition of N-(1-Hexyl)-N-nitroso-2-naphthamide-carbonyl-O-18. (A) **In Hexane.**—N-(1-Hexyl)-N-nitroso-2-naphthamide-carbonyl-O¹⁸ (1.00 g. 3.52 mmoles) (from amide containing 1.326, 1.342 atom % excess O-18) was dissolved in 3.4 liters of hexane containing 10 g. of suspended sodium carbonate. The mixture was stirred vigorously for 24 hr. at 46–59°, after which time the yellow nitrosoamide color had disappeared. After concentration to 1 liter, the mixture was filtered to remove the sodium naphthoate-sodium carbonate residue. Removal of the hexane *in vacuo* left a red oil which was evaporatively distilled at 55–100° and 0.1 mm. The middle fraction was chromatographed on Woelm neutral alumina to give 525 mg. (58%) of 1-hexyl 2-naphthoate-O¹⁸ whose infrared spectrum was identical with that of an analytically pure sample of the unlabelled ester. Acidification of the sodium salts (above) gave 0.142 g. (23.4%) of 2-naphthoic acid.

A sample of the ester (300 mg., 1.17 mmoles) was reduced by adding its ether solution dropwise with stirring

to 7.0 ml. of 1.1 M lithium aluminum hydride in ether. The mixture was stirred for several hours and allowed to stand overnight. The excess hydride was destroyed by the careful addition of 2 ml. of ice water to the ice cold reaction mixture. The precipitate was dissolved by the addition of 2.5 ml. of 10% sulfuric acid. The layers were separated and the aqueous layer was extracted with ether. The ether extracts were combined, washed with 5% sodium bicarbonate and water, dried and concentrated *in vacuo* leaving a pale yellow oil which was evaporatively distilled; crude 1-hexanol-O¹⁸ distilled at 30° and 20 mm. leaving 2-naphthylcarbinol-O¹⁸ as the residue. After drying over Drierite, the hexanol-1-O¹⁸ was evaporatively distilled at 40° and 18 mm. to give a pure sample (28.3 mg.), which contained 0.647 atom % excess oxygen-18 and which had an infrared spectrum identical with that of authentic, pure 1-hexanol. The 2-naphthylcarbinol-O¹⁸ was sublimed at 60–80° and 0.1 mm., recrystallized twice from 5 ml. of 2:3 ethanol-water and resublimed to give the pure carbinol (55.7 mg.), m.p. 80.3–81.7° (lit. 80–80.5°).¹⁷ It contained 0.567, 0.566 atom % excess oxygen-18.

The net loss of label (0.12 atom % excess O-18 from the amide to the alcohols) is attributed to the use of 10% sulfuric acid after the lithium aluminum hydride reduction. Since the 1-hexanol contained one-half of the O-18 present in the amide within experimental error, it is quite certain that complete equilibration of the O-18 occurred in this experiment.

(B) **In Dioxane.**—N-(1-Hexyl)-N-nitroso-2-naphthamide-carbonyl-O¹⁸ (1.00 g., 3.52 mmoles) (from amide containing 1.326, 1.342 atom % excess O-18) was dissolved in 100 ml. of dioxane containing 4.0 g. of sodium carbonate. The mixture was stirred vigorously at 47–60° for 26 hr. after which time the reaction mixture was colorless. The sodium salts were removed by filtration. Ether (100 ml.) and water (300 ml.) were added to the filtrate. After agitation and separation, the ether layer was washed each of five times with 100 ml. of water. The aqueous washings were combined and extracted with two 75 ml. portions of ether. The latter ether washings were in turn washed twice with water and combined with the original ether extract. After drying, the ether was removed *in vacuo* to give the crude ester as a light brown oil. This was evaporatively distilled to give 0.560 g. (62.3%) of pure 1-hexyl 2-naphthoate-O¹⁸ (0.656, 0.661 atom % excess oxygen-18), *n*_D²⁵ = 1.5595. The infrared spectrum was identical with that of an analytically pure sample. 2-Naphthoic acid (0.135 g., 23%) was obtained by acidification of the sodium naphthoate-sodium carbonate residue.

The ester was cleaved with lithium aluminum hydride as described in part A except that cold sulfuric acid was used and the contact time was kept to a bare minimum. A 68% yield of 1-hexanol-O¹⁸ was obtained (0.637, 0.642 atom % excess oxygen-18), *n*_D²⁵ = 1.4147; lit.¹⁸ *n*_D²⁵ = 1.4162.

The infrared spectrum was identical with that of an authentic sample of 1-hexanol. An 82% yield of pure 2-naphthylcarbinol-O¹⁸ (0.654, 0.648 atom % excess oxygen-18), m.p. 81.5–83.5°, was obtained. Within experimental error, both carbinols contained the same amount of oxygen-18.

N-Ethyl 2-naphthamide.—This amide was prepared by the reaction of 2-naphthoyl chloride with a twofold excess of ethylamine in ether. After working up by the procedure described for the hexyl derivative, N-ethyl-2-naphthamide, m.p. 133.5–134.7° (lit.¹⁹ 129–131°), was obtained by recrystallization from 2:1 hexane-chloroform.

Ethyl 2-naphthoate.—2-Naphthoyl chloride was refluxed with a twofold excess of ethanol in pyridine. The crude ester, which was isolated by ether extraction and water washing, was evaporatively distilled and recrystallized four times from pentane at –80° to give ethyl 2-naphthoate, m.p. 37.5–38.2°, *n*_D³⁵ = 1.5890 (supercooled); lit.²⁰ m.p. 32°, *n*_D^{22.7} = 1.5951 (presumably supercooled); *n*_D^{27.9} = 1.5732.

N-Ethyl-N-nitroso-2-naphthamide.—This compound was prepared in 85% yield from the amide by the procedure described for the preparation of N-(1-hexyl)-N-nitroso-2-naphthamide-carbonyl-O¹⁸. It melted at 63.0–64.8° after recrystallization from pentane at –80°.

(17) E. Bamberger and O. Boekmann, *Ber.*, **20**, 1118 (1887).

(18) J. F. Norris and F. Cortese, *This Journal*, **49**, 2644 (1927).

(19) H. L. Wheeler, *Am. Chem. J.*, **23**, 135, 147 (1900).

(20) "Elsevier's Encyclopedia of Organic Chemistry," Vol. XIIB, Elsevier Publishing Co., New York, N. Y., 1953, p. 4031.

(15) Analyses were by the Schwartzkopf Microanalytical Laboratory, Woodside 77, N. Y.

(16) E. H. White, *This Journal*, **77**, 6008 (1955).

Anal. Calcd. for $C_{13}H_{12}N_2O_2$: C, 68.40; H, 5.30; N, 12.28. Found: C, 68.39; H, 5.47; N, 12.32.

The Concurrent Decomposition of N-(1-Hexyl)-N-nitroso-2-naphthamide-carbonyl-O-18 and N-Ethyl-N-nitroso-2-naphthamide.—A crude azometric rate study showed that N-(1-hexyl)-N-nitroso-2-naphthamide rearranged *ca.* 1.5 times faster than N-ethyl-N-nitroso-2-naphthamide in dioxane at 55°. A mixture of 2.25 g. (7.93 mmoles) of N-(1-hexyl)-N-nitroso-2-naphthamide-carbonyl-O¹⁸ (1.33 atom % excess oxygen-18) and unlabelled N-ethyl-N-nitroso-2-naphthamide (1.20 g., 5.28 mmoles) was decomposed at 55° in 370 ml. of purified dioxane in the presence of 14.5 g. of anhydrous sodium carbonate. A mixture of 1-hexyl and ethyl naphthoates was obtained by the standard work-up procedure. Evaporative distillation partially separated the two esters. All attempts to purify the ethyl ester failed. However, the crude 1-hexyl ester was purified by chromatography, a second distillation and ten recrystallizations from pentane at -80°. Analysis of the pure material (m.p. 20.9–21.9°, $n_D^{20} = 1.5557$; pure ester prepared from the alcohol melted at 21.5–22.2°) gave values of 0.466, 0.460, 0.462 atom % excess oxygen-18.

Assuming that both nitrosoamides rearranged at the same rate, the theoretical O-18 value would be 0.400 atom % excess oxygen-18 if the reaction were completely intermolecular and 0.665% if the reaction were completely intramolecular. Since, in fact, N-(1-hexyl)-N-nitroso-2-naphthamide rearranged faster and was used in 50% excess, the true theoretical "intermolecular value" would be somewhat higher. The observed value (0.46%) shows that the reaction is largely, if not completely, intermolecular.

Trimethylacetyl Chloride.—The acid chloride was prepared from the redistilled acid (b.p. 83–90° at 20 mm.) and benzoyl chloride by the method of Brown²¹; it was stored in sealed vials.

Esters of Trimethylacetic Acid.—The ethyl ester was prepared by the addition of the acid chloride to an excess of ethanol and isolation by standard procedures, b.p. 120–123°; $n_D^{21} = 1.3929$ (lit.²² b.p. 118–118.2°; n_D^{18} 1.3922).

Anal. Calcd. for $C_7H_{14}O_2$: C, 64.58; H, 10.84. Found: C, 64.46; H, 10.86.

The butyl ester was similarly prepared, b.p. 161–163°; $n_D^{21} = 1.4050$ (lit.²³ b.p. 156°; n_D^{17} 1.4051).

Anal. Calcd. for $C_9H_{18}O_2$: C, 68.31; H, 11.47. Found: C, 68.58; H, 11.30.

The vapor phase chromatograms showed only a single peak for each ester.

N-(*n*-Butyl)-trimethylacetamide.—A 2 M solution of trimethylacetyl chloride (1 part) in ether was slowly added to 3 M solution of *n*-butylamine (3 parts) in ether at -20°, and the product was isolated by standard procedures; b.p. 93° at 0.02 mm., m.p. *ca.* 25°.

Anal. Calcd. for $C_8H_{19}NO$: C, 68.80; H, 12.08; N, 8.92. Found: C, 68.86; H, 12.04; N, 9.06.

N-Nitroso-N-(*n*-butyl)-trimethylacetamide.—This unstable nitrosoamide was prepared by a modification of the procedure reported earlier.¹⁹ A solution of the amide (1.0 g.) in dry methylene dichloride (15 ml.) was cooled to -75°. Nitrogen tetroxide (2 ml.), anhydrous sodium acetate (3 g.) and anhydrous sodium sulfate (2 g.) were added and the mixture was placed in a bath at -25°; a blue color developed. After 15 minutes, the excess nitrosating agent and part of the solvent was removed at -20° *in vacuo*. A purer product is obtained by this procedure since the hydrolysis of the nitrosating agent in the subsequent step would be quite exothermic and difficult to control. Cold ether was added to the residue and the solution (lemon-yellow in color) was washed in turn with dilute solutions of sodium chloride, sodium carbonate and sodium chloride at *ca.* -5°. The solution was dried (Na_2SO_4) and the solvent was removed at -30° *in vacuo* (some product was lost here by volatilization) to yield the oily nitrosoamide. The infrared spectrum (taken rapidly) showed that nitrosation was complete (no amide band at 6.1 μ , a characteristic nitrosoamide band at 5.9 μ , and in addition, characteristic changes in the fingerprint region of the spectrum).

(21) H. C. Brown, *THIS JOURNAL*, **60**, 1325 (1938).

(22) H. Olsson, *Z. physik. Chem.*, **133**, 234 (1928).

(23) L. Kahovic and K. W. F. Kohlrusch, *Monatsh.*, **74**, 104 (1942).

The nitrosoamide had a decomposition half-life of *ca.* 1 hr. at 25° in hydrocarbon solvents and from small scale runs, 55–80% of *n*-butyl trimethylacetate was isolated.

Diazoethane.—The procedure of Adamson and Kenner²⁴ was used for the synthesis of 2-methyl-2-(*N*-nitrosoethylamino)-4-pentanone; 30–40% yields were obtained. A modification of their procedure for the preparation of diazoethane was used. An excess of pure pentane was kept in the reaction vessel, the reaction vessel was maintained at 25°, and the nitrosoamine in pure pentane was added slowly (*ca.* 1 mole/hr.). The system was connected to the vacuum line through the receiver which was held at -75° and the pressure was adjusted to permit partial condensation and return of the pentane from the 0° cold finger (a pressure of 300 mm. was usually used). Yields of diazoethane of *ca.* 50% were obtained. The most prominent band in the infrared spectra of the pentane solutions was at 4.85 μ ($C=N=N$). The concentration of diazoethane was determined by back-titration of an aliquot added to an excess of benzoic acid in dry ether. Concentrations obtained in this way are probably *ca.* 15% low since we can estimate from the nitrosoamide rearrangement² that *ca.* 15% of ethylene will be formed in this reaction (regenerating benzoic acid).

Decomposition of N-(*n*-Butyl)-N-nitroso-trimethylacetamide in the Presence of Diazoethane. (A) Isolation of Diazoethane.—A freshly distilled 0.5 M solution of diazoethane in pentane (36 ml., 18 mmoles) was added to the nitrosoamide prepared from 1.0 g. (6.4 mmoles) of the amide. The solution was kept in darkness at 25° for 5 hr. in a flask equipped with a Dry Ice condenser and protected with Ascarite tubes. An additional fourteen ml. of the diazoethane solution (7 mmoles) was then added and the solution was allowed to stand for an additional 18 hr. Rough fractionation yielded

Fraction 1, 25° at 300 mm.
Fraction 2, 25° at 0.1 mm. (*ca.* 1 g.)
Fraction 3, 100° at 0.1 mm. (1.3 g.)
Residue (0.1 g.)

Fraction 1 was reacted with a solution of 3,5-dinitrobenzoic acid in ether. The infrared spectrum of the product indicated largely ethyl 3,5-dinitrobenzoate (the spectrum was compared with that of ester prepared from ethanol and the acid chloride). Recrystallization gave 40% of the pure ester, based on the diazoethane used. In a few runs, which were discarded, the diazoethane concentration rapidly dropped to zero for unknown reasons.

Fraction 2 contained a small amount of ethyl trimethylacetate (infrared spectrum); however, the major component was diazobutane. The infrared spectrum contained the expected band at 4.85 μ . When an ether solution of 3,5-dinitrobenzoic acid was added, nitrogen was evolved and the orange color disappeared. The ester isolated from this reaction (0.29 g., 1.1 mmoles, 17% for the three-step path from the amide) was essentially pure *n*-butyl 3,5-dinitrobenzoate, m.p. 60–63°. A comparison of the infrared spectrum with the spectra of the pure compounds showed that, at best, only a few per cent. of the ethyl ester was present. Recrystallization from heptane yielded the pure ester, m.p. 62–63° (lit.²⁵ 64°).

Fraction 3 was a crude mixture of the ethyl and butyl esters of trimethylacetic acid and many by-products from the decomposition of the diazoalkanes. Chromatography on alumina and distillation yielded fairly pure samples of the esters, identified by infrared spectra and vapor phase chromatograms.

(B) **Quantitative Run.**—1 g. (6.37 mmoles) of N-(*n*-butyl)-trimethylacetamide was nitrosated and the product was isolated at -10° as a yellow oil; its infrared spectrum indicated that complete nitrosation had occurred. Pure pentane (30 ml.) and 0.82 M diazoethane in pentane (55 ml., 45 mmoles) were added and the solution was filtered through anhydrous sodium sulfate into a flask equipped with a Dry Ice condenser and protected with tubes filled with Ascarite. The flask was kept in darkness at 20°; after 13 hr., the infrared spectra indicated that the nitrosoamide was completely decomposed. Aliquots were periodically removed for gas-liquid chromatographic analyses. From each aliquot, a 20 μ l. sample was removed and

(24) D. W. Adamson and J. Kenner, *J. Chem. Soc.*, 1554 (1937).

(25) E. H. White, *THIS JOURNAL*, **77**, 6081 (1955).

TABLE II
 VAPOR PHASE CHROMATOGRAPHY^a

 Peak height \times retention time (minutes) values for the components of the reaction $\text{CH}_3\text{CHN}_2 + \text{C}_4\text{H}_9\text{N}(\text{NO})\text{COC}(\text{CH}_3)_3$

Component	Time zero		13 ^b hours		20 hours	
	Reaction sample	Sample plus $\text{CH}_3\text{CO}_2\text{H}$	Reaction sample	Sample plus $\text{CH}_3\text{CO}_2\text{H}$	Reaction sample	Sample plus $\text{CH}_3\text{CO}_2\text{H}$
CH_3CHN_2 (as ethyl acetate)		<i>d</i>		77.6		52.0
$\text{C}_3\text{H}_7\text{CHN}_2$ (as butyl acetate)		<i>d</i>		25.5		18.5
Ethyl trimethylacetate	<i>c</i>	<i>d</i>	29.7		29.3	
Butyl trimethylacetate	<i>c</i>	<i>d</i>	1.77		1.73	

^a Perkin-Elmer Fractometer, Column A (1 meter; dioctyl phthalate), $T = 124^\circ$, helium carrier gas at 15 lb./in.² ^b The nitrosoamide was completely decomposed at this point. ^c Peaks corresponding to these components were found in the initial reaction mixture subjected to analysis. ^d In addition to these peaks, one for trimethylacetic acid was found at 6.9 min. and one for acetic acid at 2.0 min.

analyzed on a Perkin-Elmer Fractometer. A slight excess of acetic acid was then added to the remainder of the aliquot and 20 μ l. samples were then analyzed. The separation of the constituents was clean in both cases. The retention times (in minutes) under the conditions listed in Table II were: pentane (0.42); ethyl acetate (1.05); acetic acid (2.0); ethyl trimethylacetate (2.5); butyl acetate (3.4); and butyl trimethylacetate (8.3). The pentane used had in addition to the major peak, a small pip at 1.6 min. The pentane solution of diazoethane had a shoulder at 1.25 min., probably a mixture of heptanes from the carbene reaction (*n*-heptane, 1.3 min.), and in addition a band at 1.9 min. The chromatograms of the reaction mixture contained, in addition to these peaks, very small pips at 3.5 min., 5.0 min. and 5.8 min.

The ester concentrations were determined by comparing peak height \times retention time values (Table II) with those of mixtures of the pure esters. The following controls were run: (A) butyl trimethylacetate plus acetic acid gave only the two normal peaks on chromatography—butyl acetate was not formed on the column. (B) A standard mixture of the four esters was added to an excess of diazoethane in pentane and the mixture was kept in darkness for 24 hr. The initial ratio of peak heights for ethyl acetate, ethyl trimethylacetate, butyl acetate and butyl trimethylacetate was 8.7/0.70/1.0/0.12 and the final value was 8.5/0.71/1.0/0.11, showing that the esters are stable to diazoethane, (C) a mixture of butyl trimethylacetate and diazomethane when analyzed on the Fractometer gave no methyl trimethylacetate, *i.e.*, there is no reaction of the esters with diazoalkanes on the column.

The Reaction of Diazoisobutane with 3,5-Dinitrobenzoic Acid. (A) Reaction at 25°.—Diazoisobutane in ether was prepared by the method of Redemann.²⁶ To this ether solution (*ca.* 0.005 *M*) at 25° was slowly added a 0.05 *M* solution of 3,5-dinitrobenzoic acid in ether. The solution was washed with dilute sodium hydroxide, dried and evaporated. The residue was sublimed (100° and 0.5 mm.) to yield isobutyl 3,5-dinitrobenzoate containing 1.5% of *sec*-butyl 3,5-dinitrobenzoate. (The method for the determination of isomers is given in ref. 14.)

(B) Reaction at 80°.—Diazoisobutane in dioxane was prepared by the method of Adamson and Kenner.²⁴ This solution (*ca.* 0.1 *M*) at 25° was added below the surface of a 1 *M* solution of 3,5-dinitrobenzoic acid in pure dioxane maintained at 80°. The product was isolated as described above; it contained 5% of the secondary isomer and 1% of the tertiary isomer.

The Reaction of 2-Naphthoyl Chloride-O-18 with the Silver Salt of *N*-Nitrohexylamine.—Ethyl *N*-(1-hexyl)-*N*-nitrocarbamate was prepared by the method of Curry and Mason,²⁷ n_D^{25} 1.4468.

Anal. Calcd. for $\text{C}_9\text{H}_{18}\text{N}_2\text{O}_4$: C, 49.51; H, 8.33; N, 12.83. Found: C, 49.62; H, 8.36; N, 12.93.

N-Nitro-1-hexylamine was prepared in 90% yield by the saponification of the nitrocarbamate as described by Curry and Mason,²⁸ b.p. 90–92° at 0.5 mm., n_D^{25} 1.4590 (lit.²⁹ n_D^{25} 1.4593).

Anal. Calcd. for $\text{C}_8\text{H}_{14}\text{N}_2\text{O}_2$: C, 49.29; H, 9.65; N, 19.17. Found: C, 49.34; H, 9.78; N, 19.27.

The nitroamine was titrated with 0.1 *N* sodium hydroxide, and a slight excess of silver nitrate was added to the solution of the sodium salt. The white microcrystals which formed were filtered and dried at 0.1 mm. and 80° for 12 hr.

A solution of 2.00 g. (10.4 mmoles) of 2-naphthoyl chloride-O-18 (1.321, 1.342 atom % excess O-18, as determined by the analysis of a sample of 2-naphthamide prepared from it) in 40 ml. of carbon tetrachloride was added dropwise with stirring to a slurry of the silver salt of *N*-nitro-1-hexylamine (3.04 g., 12.0 mmoles) in 15 ml. of carbon tetrachloride. The nitrous oxide formed was carried by a stream of nitrogen through a condenser, a dry ice trap, an Ascarite filled drying tube and then collected in a sample tube cooled in liquid nitrogen. The nitrogen was then pumped from the sample (still cooled in liquid nitrogen) and the nitrous oxide was analyzed in a mass spectrometer. It contained 0.0 atom % excess O-18 (the average 46/44 ratios for this N_2O and tank N_2O were 2.02×10^{-3} and 2.03×10^{-3} , respectively). After 3 hr. of stirring at 25°, the reaction mixture was filtered, and the cloudy filtrate clarified by washing it with 5% sodium thiosulfate. It was then washed with water and 5% sodium bicarbonate, dried and concentrated at 20 mm. The residue, which consisted of 2-naphthoic anhydride, 1-hexyl 2-naphthoate and *N*-nitro-1-hexylamine (the infrared spectrum showed no *N*-(1-hexyl)-*N*-nitro-2-naphthamide) was treated with hexane and filtered to remove the anhydride. The hexane solution was chromatographed on neutral Woelm alumina and the ester was eluted with 5% ether–95% hexane. It was then distilled to give 1-hexyl-2-naphthoate (0.51 g., 1.98 mmoles, 19%), the infrared spectrum of which was identical with that of an analytically pure sample. The ester was cleaved as described above for the ester obtained from the *N*-nitrosoamide with the exception that the sulfuric acid treatment was not used; instead, the solid obtained by destroying the excess lithium aluminum hydride with water was triturated thoroughly with ether to remove any adsorbed product. An 81% yield of 2-naphthylcarbinol-O-18, m.p. 81.2–82.6° (lit.¹⁷ 80–80.5°), containing 0.673, 0.663 atom % excess O-18 was obtained in addition to a 63% yield of 1-hexanol-O-18 containing 0.667, 0.668 atom % excess O-18. The recovery of oxygen-18 was good, and within experimental error, the two alcohols contained the same amount of O-18.

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