

TABLE II

TABLE XI

$$\begin{array}{c} \text{N}=\text{O} \\ | \\ \text{R}-\text{N}-\text{C}-\text{R}' \\ || \\ \text{O} \end{array}$$

PRODUCTS OF THE NITROGEN ELIMINATION FROM R-N-C-R'

Run	R	R'	Solvent	Temp., °C.	Yields ^a		<i>n</i>	Isomer distribution ^b %		
					Ester, %	Acid, %		iso	butyl esters <i>sec</i>	<i>tert</i>
1	<i>n</i> -Butyl	3,5-Dinitro-	Hexane	69	83	17	99	1		
2		phenyl	Heptane	75	82	..	99	1		
3			Decalin	192 ^d	30	40	96	4		
4			Acetic acid ^e	70	13	..	78	22		
5	<i>n</i> -Butyl	Methyl	Heptane ^c	85	79	16				
6			CCl ₄	77	67 ^c	18	99	1		
7			Dioxane ^c	95	78	19				
8			<i>p</i> -Xylene	95	..	21				
9			CHCl ₃	61	..	21				
10	Isobutyl	3,5-Dinitro-	Hexane	69	66	33	95.5	3.5 ^f	1	
11		phenyl	Heptane	98	61	..	91.5	7.5	1	
12			Decalin	115	44	49	87	11	2	
13			Acetonitrile + Na ₂ CO ₃ ^g	81	30	..	91	7	2	
14			Acetonitrile	81	11	53	45	25	30	
15			Acetic acid ^e	25	8	..	45	15	40	
16			Dioxane	80	64	35	91	8	1	
17	Isobutyl	Methyl	Heptane	90	..	33				
18			CCl ₄ ^c	77	62	37	94	4.5	1.5	
19			Pyridine	85	..	35				
20	<i>sec</i> -Butyl	3,5-Dinitro-	phenyl	CCl ₄	30	26	59	100		
21	<i>sec</i> -Butyl	Phenyl	Pentane	25	23	64		100		
22	<i>sec</i> -Butyl	Methyl	CCl ₄	60	..	67		100		
23	Cyclohexyl	Methyl	Pentane	36	50	38				
24	Cyclohexyl	Ethoxyl	CCl ₄	70	36	43				
25	α -Phenyl ethyl	Methyl	Pentane	36	35	..				
26			Dioxane	45	32	55				

^a Yields for runs 1–19 were based on I, those for runs 20–26 were based on the amide used in the two-step process of nitrosation and rearrangement (the nitrosoamides were unstable in the latter cases, and not isolated). No attempts were made to isolate products in those runs for which no yield data are given. For olefin yields, see footnote 9. ^b Isomer distribution determined by comparison of the infrared spectra with those of standard mixtures of the authentic esters. The errors for runs 1, 2, 6, 10, 11, 12, 18 = $\pm 1\%$; (*tert* error $\pm 0.5\%$); for runs 3, 4, 13, 16 = $\pm 2\%$; (*tert* error $\pm 1\%$); and for runs 14 and 15 *ca.* $\pm 5\%$. ^c Yields determined by saponification for runs 5, 7 and 18 and gravimetrically for the remaining runs. ^d The only run in which tar formation occurred. ^e The ester yields refer to the dinitrobenzoates. Acid interchange could not have been important in these runs, since *n*-butyl 3,5-dinitrobenzoate was recovered in 95% yield after being subjected to the same reaction conditions. In addition to the normal products, the corresponding amide was formed in these runs, 20% in run 4 and 25% in run 15. ^f This unusual formation of the secondary isomer was noted in other reactions of isobutyl derivatives; these results will be reported later. ^g An unidentified product was also obtained in this run.

63°, trace at 68°¹⁰ (authentic sample, 63.5–64°, lit.¹¹ 64°). The infrared spectrum was superimposable on that of authentic *n*-butyl 3,5-dinitrobenzoate, and a comparison with the spectra of mixtures of the normal and *sec*-butyl isomers showed that less than 1% of the secondary isomer could have been formed. The actual formation of traces of *sec*-butyl 3,5-dinitrobenzoate was indicated by the infrared spectrum of the leading fraction (enriched in the secondary isomer) from the chromatography of the crude ester on neutral alumina.

The yields of esters are lower from amides of secondary aliphatic carbinamines (runs 20, 21 and 22), with olefin and acid yields proportionately higher

(path b). Cyclohexyl and α -phenylethyl derivatives give intermediate yields (runs 23–26), whereas amides of tertiary carbinamines give quite low yields of the corresponding esters.¹² Stereochemically, esters are formed from nitrosoamides of optically active secondary carbinamines with either partial retention or partial inversion of configuration, depending on the reaction conditions.¹³

Effect of the Acyl Group.—The ester yields and isomer distributions were essentially the same for the nitrosoacetamides, benzamides and dinitrobenzamides used (Table II). The yields from the nitrosourethans¹⁴ and the nitrososulfon-

(12) To be reported later.

(13) The stereochemistry of this reaction is reported in paper III, THIS JOURNAL, **77**, 6014 (1955).

(14) The reaction of nitrosourethans with bases is often used to prepare diazoalkanes; in some cases, however, carbonyl containing by-products have been detected as well (D. Y. Curtin and S. M. Gerber, THIS JOURNAL, **74**, 4052 (1952)) and in others, dialkyl carbonates have been isolated (F. W. Bollinger, F. N. Hayes and S. Siegel, *ibid.*, **72**, 5592 (1950)). In all probability, these by-products are the dialkyl carbonates expected from the thermal nitrogen elimination reaction reported in this paper (path a, R' = OEt). See also footnote 7.

(10) The high melting crystals were found to be adducts formed by the ester with trace amounts of hydrocarbons from the stopcock grease used. The adduct from the ester and pure hexadecane was a crystalline material, *m.p.* 69–69.5°. Even in a carefully cleaned vessel, the ester from the nitrogen elimination contained a trace of the adduct, suggesting that a small portion of the olefin had polymerized.

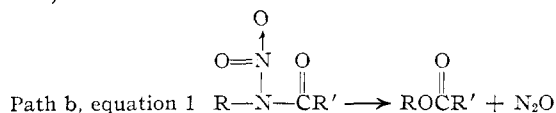
(11) R. L. Shriner and R. C. Fuson, "Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1948, p. 226.

amides (*vide infra*) were slightly lower however.

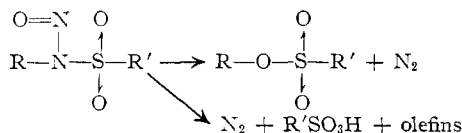
Effect of the Solvent.—The highest yields and the purest esters are obtained from the nitrogen elimination in relatively non-polar solvents; a number of these solvents were used with essentially the same results (Table II). In the more polar solvents, the acids formed in the elimination step (path b) are more important than the solvents in determining the yields and amount of isomerization. The effect of the solvent itself was determined by carrying out the reaction in the presence of anhydrous sodium carbonate.¹⁵ Under these conditions, the isomer distribution was not appreciably different from that observed in non-polar solvents (compare runs 13 and 14). In acetic acid and in acetonitrile (in the absence of sodium carbonate) some denitrosation to the amide occurs, the yield of ester is low (path a), and the proportion of isomerized ester is high (runs 4, 14 and 15). The relative rates of nitrogen elimination in the solvents tested were in the order acetic acid > dioxane > hexane.

Effect of Temperature.—The nitrosoamides of primary carbinamines eliminate nitrogen at *ca.* 60–80°, those of aliphatic secondary carbinamines at *ca.* 20–30°, and those of α -phenylethylamine at *ca.* 50° (*ca.* 10–15 hr. required). The highest yields and the purest esters are obtained at the lowest practicable temperatures (compare runs 1 and 3; 10, 11 and 12).

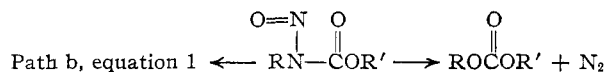
Miscellaneous Applications.—A number of analogs of the nitrosoamides undergo similar elimination reactions. (i) N-(*n*-Butyl)-N-nitroacetamide in carbon tetrachloride at 77° (15 hr.) yielded *n*-butyl acetate (75%), acetic acid and 1-butene (23%), and nitrous oxide (compare with runs 5 and 6).



(ii) N-(*n*-butyl)-N-nitroso-*p*-toluenesulfonamide (plus one mole of sodium carbonate) in hexane at 69° (15 hr.) yielded *n*-butyl *p*-toluenesulfonate (55%) and *sec*-butyl *p*-toluenesulfonate (7%). In



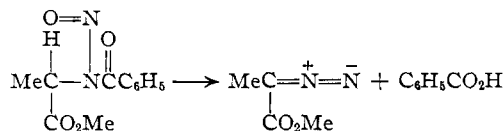
the absence of sodium carbonate, the reaction was markedly affected by the toluenesulfonic acid formed (path b). In this case, mixed butyl *p*-toluenesulfonates (25%), *p*-toluenesulfonic acid and butene (21%), and N-(*n*-butyl)-*p*-toluenesulfonamide (25%) were formed. (iii) N-Cyclohexyl-N-nitrosourethan in carbon tetrachloride at 77° (3 hr.) yielded cyclohexyl ethyl carbonate,¹⁴ cyclohexene, carbon dioxide, ethanol and nitrogen (run 24).



Application of the new method to several other

(15) In non-polar solvents, sodium carbonate had no effect on either the yields of esters or on the distribution of isomers.

derivatives yielded different results. Methyl N-benzoyl-N-nitrosoalanate yielded only methyl α -diazopropionate and benzoic acid; whereas both N-methyl-N-nitrosoarea and N-nitrosoacetanilide¹⁶ in



refluxing carbon tetrachloride yielded complex mixtures of products containing none of the expected ester.

Experimental

Preparation of Nitrosoamides.—The N-nitrosoamides described in this paper were prepared by the methods given earlier.¹

Nitrogen Elimination from I.—A solution of N-(isobutyl)-N-nitroso-3,5-dinitrobenzamide (1.154 g., 3.90 mmoles) in 500 ml. of hexane was refluxed with stirring for 15 hr. The butenes were collected by bubbling the effluent gases through carbon tetrachloride traps.⁹ The reaction mixture was cooled and the 3,5-dinitrobenzoic acid filtered (0.268 g., 1.27 mmoles, 33%). The hexane solution was washed with aqueous sodium hydroxide, dried and evaporated to dryness to yield 0.685 g. (2.56 mmoles, 66%) of crude isobutyl 3,5-dinitrobenzoate, m.p. 84–85° (authentic sample 86–87°, lit.¹¹ 86°). The isomer distribution was determined for this product by the method given below.

In general, for the nitrogen elimination from I, a solution of the nitrosoamide in the appropriate solvent was maintained at the lowest temperature at which nitrogen evolution occurred, until the evolution had ceased. If sodium carbonate was not used, the acid formed was titrated with standard base, the organic phase separated, washed with water and then dried. The solvent was removed¹⁷ (*in vacuo* if possible) and the product distilled or recrystallized, depending on its properties. During the course of this work, infrared spectra were taken of the esters (before purification) dissolved in carbon tetrachloride (0.3 M). The isomer contents were determined by comparing these spectra with infrared spectra of mixtures of the esters of known composition.

A Procedure for the Deamination Omitting the Isolation of Intermediates—Preparation of Acetamides.—One mole of the amine was chilled to –80° and acetic acid¹⁸ slowly added (1.5 moles). The flask was removed from the cooling bath, one mole of acetic anhydride added, and after the exothermic reaction had subsided, the acetic acid was removed by distillation. The crude amide was nitrosated using any of the methods reported earlier,¹ and the elimination of nitrogen carried out as described in the previous section. By this procedure, redistilled *n*-butyl acetate (*n*^{25D} 1.3919, lit.,¹⁹ *n*^{25D} 1.3914) was obtained by the three-step reaction from *n*-butylamine in 56% yield.

N-(*n*-Butyl)-N-nitroacetamide.²⁰—A solution of 90% nitric acid (50 ml., d. 1.50) in acetic anhydride (100 ml.) was prepared at –15°, N-(*n*-butyl)-acetamide²¹ (21.5 g., 0.187 mole) was added slowly, and the mixture allowed to stand at 4° for 10 hr. The solution was poured into a mixture of ice and water, the product extracted with pentane, and the extract washed with a sodium carbonate solution (10%), with water, and then dried. The pentane was removed under vacuum and the yellow oil distilled, b.p. 45–47° at 0.5 mm. (21.4 g., 0.134 mole, 71.5%), *n*^{25D} 1.4542. Infrared spectrum: C=O, 5.79 μ ; NO₂, 6.34 μ . *Anal.*

(16) W. A. Waters, *J. Chem. Soc.*, 113 (1937).

(17) In the case of a volatile ester and a water-miscible solvent, pentane was added and the other solvent extracted out with water.

(18) The acetic acid is used to moderate the otherwise violent reaction of acetic anhydride with the amine.

(19) J. C. Munch, *THIS JOURNAL*, **48**, 997 (1926).

(20) This procedure is a modification of that used by W. E. Bachmann, W. J. Horton, E. L. Jenner, N. W. MacNaughton and C. E. Maxwell, *ibid.*, **72**, 3132 (1950).

(21) Prepared by the general method given in the preceding section, and distilled, *n*^{25D} 1.4385. R. H. Wiley, O. H. Borum and L. L. Bennett, *ibid.*, **71**, 2899 (1949) report *n*^{25D} 1.4388.

(5) D. H. Hey, J. Stuart-Webb and G. H. Williams, *J. Chem. Soc.*, 4657 (1952).