in 30 minutes and the heating continued for another three hours. The reaction mixture was then added to a large amount of water and the whole extracted with chloroform. The chloroform extracts were dried and evaporated *in vacuo* leaving 16 g. of a heavy oil. The oil residue was purified by distillation at 0.2 mm. and the fraction boiling from 186–190°, 15 g., solidified to yield a white solid, m.p. 46–47°. One recrystallization from ethanol raised the melting point to 52–54° (see Table I).

S-[2′-(10-Phenothiazinyl)-1′-methylethyl]-pseudothiouronium Bromide.—10-(2′-Bromopropyl)-phenothiazine (16.0 g., 0.05 mole) and thiourea (3.8 g., 0.05 mole) were dissolved in 100 ml. of a 1:1 nitromethane–ethanol solution and heated under reflux for eight hours. The solvent was then removed *in vacuo* leaving a viscous oil which crystallized on trituration with nitromethane–ether to give 13.4 g., m.p. 180–184°. Two recrystallizations from nitromethane–ether raised the melting point to 187–189° (see Table I).

2′-(10-Phenothiazinyl)-1′-methylethylmercaptan.—S-[2′-(10-Phenothiazinyl)-1′-methylethyl]-pseudothiouronium bromide (29 g., 0.073 mole) and sodium carbonate (7.8 g., 0.073 mole) were dissolved in 300 ml. of a 1:1 water–ethanol solution and heated under reflux for two hours. The reaction mixture was then diluted with a large volume of water and made just acid with dilute hydrochloric acid causing 16.5 g. of solid to precipitate, m.p. 137–140°. One recrystallization from hexane raised the melting point to 140–142° (see Table I).

2′-(10-Phenothiazinyl)-1′-methylethyl Methyl Sulfide.—2′-(10-Phenothiazinyl)-1′-methylethylmercaptan (8.5 g., 0.0312 mole), sodium methylate (1.77 g., 0.0328 mole) and methyl iodide (4.6 g., 0.0328 mole) were dissolved in 300 ml. of absolute ethanol and the solution heated under reflux for one hour. The ethanol was then removed *in vacuo* and the residue poured into a large quantity of water. The aqueous mixture was extracted with chloroform and the chloroform extracts dried and then evaporated down *in vacuo* leaving 6 g. of solid, m.p. 73–75°. One recrystallization from hexane raised the melting point to 75–76° (see Table I).

2′-(10-Phenothiazinecarboxy)-ethyl Methyl Sulfide.—10-Phenothiazinecarboxy chloride (20.8 g., 0.08 mole), 2-hydroxyethyl methyl sulfide (7.4 g., 0.08 mole) and pyridine (6.4 g., 0.08 mole) were dissolved in 200 ml. of benzene and the solution heated under reflux for six hours. On cooling, the reaction mixture was washed with water and the benzene layer then dried and evaporated down *in vacuo* leaving a viscous oil residue. The residue was taken up in ether and some insoluble material (phenothiazine) was removed. The ether was removed *in vacuo* and the oil remaining solidified on trituration with a little methanol to yield 13 g. of product, m.p. 94–98°. Three recrystallizations from hexane raised the melting point to 108–109° (see Table II).

2′-(10-Phenothiazinyl)-1′-methylethyl-dimethylsulfonium Iodide.—2′-(10-Phenothiazinyl)-1′-methylethyl methyl sulfide (3.5 g.) and methyl iodide (5 g.) were dissolved in 20 ml. of nitromethane and allowed to stand in the dark at room temperature for 18 hours. Upon the addition of ether, 4.3 g. of product precipitated, m.p. 125–126° dec. Recrystallization from an ether–alcohol mixture did not change the melting point (see Table I).

2′-(10-Phenothiazinecarboxy)-ethyl-diethylsulfonium Iodide.—An attempt to prepare this compound using ether as the solvent did not yield any product even after two months. By using nitromethane a 26% yield of the sulfonium salt resulted after one week. 2′-(10-Phenothiazinecarboxy)-ethyl ethyl sulfide (5 g.) and ethyl iodide (10 g.) were dissolved in 25 ml. of nitromethane. After standing for one week a large quantity of ether was added and caused the precipitation of 1.9 g. of product, m.p. 120–121° dec. It was purified by dissolving in methanol and precipitating by the addition of ether without any change in melting point (see Table II).

2′-(10-Phenothiazinecarboxy)-ethyl-dimethylsulfonium Bromide.—2′-(10-Phenothiazinecarboxy)-ethyl methyl sulfide (5 g.) and 20 ml. of a 25% methanolic solution of methyl bromide were dissolved in 50 ml. of nitromethane. After standing for two weeks the reaction mixture was worked up in the usual manner to yield 4.0 g. of product, m.p. 146–147° dec. One recrystallization from a methanol–ether mixture did not raise the melting point (see Table II).

Abnormal Sulfonium Salt from 3′-(10-Phenothiazinyl)-propyl Methyl Sulfide and Isopropyl Iodide.—3′-(10-Phenothiazinyl)-propyl methyl sulfide (9.5 g.) was dissolved in 60 ml. of a 1:1 nitromethane–methanol mixture containing 20 g. of isopropyl iodide and the reaction mixture was heated under reflux for 16 hours. On the addition of ether, 6 g. of product precipitated, m.p. 137–138° dec. One recrystallization from a methanol–ether mixture did not change the melting point. The infrared spectrum was identical with that of 3′-(10-phenothiazinyl)-propyldimethylsulfonium iodide.

MONTREAL, CANADA

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, PURDUE UNIVERSITY]

The Reaction of Sodium Nitrite with Ethyl Bromoacetate and with Benzyl Bromide[1,2]

BY NATHAN KORNBLUM AND WILLIAM M. WEAVER

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The reaction of ethyl bromoacetate with sodium nitrite occurs rapidly in dimethylformamide (DMF), but the product is not ethyl nitroacetate; instead, depending on the temperature, oxalic acid or the furoxane II is produced. Treatment of benzyl bromide with sodium nitrite yields benzoic acid as the main product at 25° whereas at −16° phenylnitromethane is obtained in 55% yield; even at −16°, prolonged standing of the reaction mixture gives the diphenylfuroxane I. Evidence is presented for the view that nitrolic acids are intermediates both in the formation of carboxylic acids and furoxanes. The factors controlling the rate at which aliphatic nitro compounds are destroyed by the joint action of a nitrite ester and sodium nitrite are discussed.

The reaction of alkyl halides and α-haloesters with sodium nitrite recently has been shown to provide a very useful synthesis of nitroparaffins[3] and α-nitroesters.[4] However, ethyl bromoacetate was exceptional in that it failed to give any ethyl nitroacetate on treatment with sodium nitrite; while a very rapid reaction occurred no organic product was isolated.[4]

The reaction of sodium nitrite with benzyl bromide is apropos. At 25° only a small amount (*ca.* 7% yield) of phenylnitromethane is obtained, the main products being benzoic acid (37% yield) and nitrous oxide (42% yield). However, the reaction at −16 to −20° gives a 55% yield of phenylnitromethane, provided a reaction time of only three to five hours is employed; longer periods result in diphenylfuroxane (I) formation and a decreased

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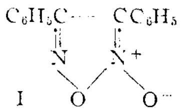
[1] Paper XVIII in the Series "The Chemistry of Aliphatic and Alicyclic Nitro Compounds."

[2] This research was supported by a grant from the Explosives Department of E. I. du Pont de Nemours and Co.

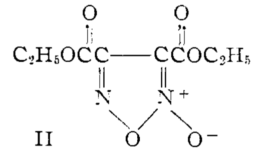
[3] N. Kornblum, H. O. Larson, D. D. Mooberry, R. K. Blackwood, E. P. Oliveto and G. E. Graham, *Chemistry & Industry*, 443 (1955); THIS JOURNAL, **78**, 1497 (1956); N. Kornblum and J. W. Powers, *J. Org. Chem.*, **22**, 455 (1957).

[4] N. Kornblum, R. K. Blackwood and J. W. Powers, THIS JOURNAL, **79**, 2507 (1957); N. Kornblum and R. K. Blackwood, *Org. Syntheses*, **37**, 44 (1957).

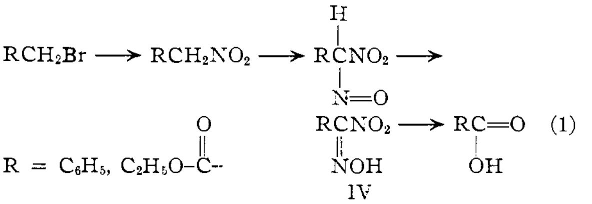

I

yield of phenylnitromethane. Thus, after twenty-one hours only a 15–25% yield of phenylnitromethane can be isolated and the furoxane I is obtained in 20-30% yield; after four days the yield of phenylnitromethane falls to 0% and that of the furoxane I rises to 45%.

The fact that a good yield of pure phenylnitromethane could be obtained by lowering the temperature suggested that at −16° ethyl bromoacetate might give ethyl nitroacetate; this proved to be a vain hope. However, for the first time, an organic product was isolated—the dicarbethoxyfuroxane II. Even a reaction temperature of −50 to −76° gave no ethyl nitroacetate; 38% of the bromoacetate was recovered and a 48% yield of the dicarbethoxyfuroxane II was isolated.


II

At 25° benzyl bromide and ethyl bromoacetate show more concordance in their reactions with sodium nitrite; the former gives benzoic acid the latter oxalic acid—ethyl hydrogen oxalate presumably being an intermediate. Carboxylic acid formation is readily understandable on the basis that the bromides react with sodium nitrite in the usual manner[3,4] to give nitro compounds and small amounts of the isomeric nitrite esters; under the influence of the sodium nitrite, nitrosation occurs[5,6] and the resulting nitrolic acids (IV) then decompose into carboxylic acids.



$$RCH_2Br \longrightarrow RCH_2NO_2 \longrightarrow R\overset{H}{\underset{N=O}{C}}NO_2 \longrightarrow \underset{IV}{R\underset{NOH}{\overset{\|}{C}}NO_2} \longrightarrow R\underset{OH}{C}{=}O \quad (1)$$

$$R = C_6H_5,\ C_2H_5O\text{-}\overset{O}{\overset{\|}{C}}\text{-}$$

Sequence (1) is consistent with the fact that in DMF 1-nitroöctane reacts with nitrite esters in the presence of sodium nitrite to give as much as a 52% yield of caprylic acid.[6] Phenylnitromethane and nitroacetic ester, being distinctly more acidic, would nitrosate even more readily than 1-nitrooctane.

Victor Meyer has reported that methyl-, ethyl- and *n*-propylnitrolic acids decompose under a variety of conditions giving, respectively, acetic, propionic and *n*-butyric acids.[7] In a direct test of the proposed sequence (1) crystalline phenylnitrolic acid (IV, R = C_6H_5) was dissolved in DMF containing sodium nitrite at 25°. Decomposition began within 15 seconds, as shown by the evolution of a colorless gas (presumably nitrous oxide), and an 81% yield of benzoic acid was obtained; in addition, a small amount (*ca.* 3% yield) of diphenylfuroxane (I) was isolated.

It will be recalled that at low temperatures benzyl bromide and ethyl bromoacetate give furoxanes when treated with sodium nitrite in DMF. This suggested the possibility that at low temperatures nitrolic acids might decompose into furoxanes. Accordingly, phenylnitrolic acid was treated with a DMF solution of sodium nitrite at −16 to −18°. A 74% yield of the diphenylfuroxane (I) and an 8% yield of benzoic acid resulted; thus, a nearly complete overturn in reaction course was achieved by a temperature decrease of slightly more than 40°.

As would be anticipated from sequence (1), the diphenylfuroxane (I) can be prepared from phenylnitromethane. The reaction proceeds most rapidly when both sodium nitrite and a nitrite ester are present; Table I presents the relevant data. In the absence of sodium nitrite the phenylnitromethane and benzyl nitrite are recovered and no furoxane is isolated (expt. 1). Similarly, when no nitrite ester is present sodium nitrite and phenylnitromethane react to a negligible extent (expts. 2 and 3). On adding a small amount of benzyl nitrite a 15% yield of diphenylfuroxane (I) is obtained (expt. 4) and, when nearly equimolar amounts of phenylnitromethane, benzyl nitrite and sodium nitrite are employed, an 82% yield of the pure furoxane I is isolated (expt. 5). It is noteworthy that in the last experiment 66% of the benzyl nitrite is recovered; the alkyl nitrite functions as a true catalyst.[6,8]

The data of Table I are readily understandable on the basis of the reaction sequence

$$C_6H_5CH_2NO_2 + NO_2^- \rightleftarrows \underset{V}{[C_6H_5CHNO_2]^-} + HNO_2 \quad (2)$$

$$V + C_6H_5CH_2ONO \longrightarrow \underset{VI}{C_6H_5\underset{NO}{\underset{|}{C}}HNO_2} + C_6H_5CH_2O^- \quad (3)$$

$$C_6H_5CH_2O^- + HNO_2 \longrightarrow C_6H_5CH_2OH + NO_2^- \quad (4)$$

$$VI \longrightarrow HNO_2 + C_6H_5C{\equiv}\overset{+}{N}\text{-}\overset{-}{O} \quad (5)$$

$$2C_6H_5C{\equiv}\overset{+}{N}\text{-}\overset{-}{O} \longrightarrow I \quad (6)$$

In the absence of benzyl nitrite, nitrosation of the anion V is very slow since nitrosation presumably does not occur by the direct action of nitrous acid but rather *via* N_2O_3. In general, before the requisite reaction between two molecules of nitrous acid can occur, these molecules will have encountered, and protonated, the anion V. On the other hand, a DMF solution containing only phenylnitromethane and benzyl nitrite (expt. 1) fails to react because in the absence of a base such as

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(5) N. Kornblum and J. H. Eicher, THIS JOURNAL, **78**, 1494 (1956).

(6) N. Kornblum, R. K. Blackwood and D. D. Mooberry, *ibid.*, **78**, 1501 (1956).

(7) V. Meyer, *Ann.*, **175**, 88 (1875). In this connection it is of interest that H. Wieland and L. Semper, *Ber.*, **39**, 2522 (1906), found that crystalline phenylnitrolic acid, on standing at ice temperature, or at room temperature, soon decomposes into nitrous acid and diphenylfuroxane (I).

(8) This is fully consistent with the over-all reaction obtained on summing up equations 2 to 6. It will be seen that for every molecule of benzyl nitrite consumed a molecule of nitrous acid and one of benzyl alcohol are formed. One can envision the latter two reacting to regenerate the supply of nitrite ester, or one can take the view that the concentration of nitrous acid is increased sufficiently to provide a working supply of nitrogen trioxide and this accomplishes the nitrosation of V.

TABLE I

CONVERSION OF PHENYLNITROMETHANE TO DIPHENYLFUROXANE (I) AT −16°

	Initial amounts						Recovery, %		
Expt.	$C_6H_5CH_2NO_2$, g. (mole)	$C_6H_5CH_2ONO$, g. (mole)	$NaNO_2$, g. (mole)	DMF, ml.	Urea,[a] g.	Reacn. time, hr.	C_6H_5-CH_2NO_2	$C_6H_5CH_2$-ONO	Yield, % Furoxane (1)
1	15.0 (0.11)	10.0(0.073)		250		21	88	77	0
2	6.85(.05)		5.3(0.075)	100	8.7	19	83		0
3	6.40(.046)		5.3(.075)	100		20	75		1
4	10.0 (.073)	1.4 (.01)	4.9(.070)	65	6.5	22	61	64	15
5	10.0 (.073)	8.0(.057)	4.9(.070)	65	6.5	22	0	66	82

[a] Urea added to increase the solubility of $NaNO_2$; *cf.* ref. 3.

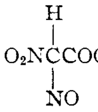
nitrite ion the concentration of the anion V is exceedingly small. Hence the need for all three.

The reaction of eq. 5 is probably a multi-step process about which nothing is really known. The justification for postulating benzonitrile oxide formation is that it is known to dimerize to the diphenylfuroxane (I).[9]

In their reactions with sodium nitrite in DMF, benzyl bromide and ethyl bromoacetate stand apart from other halides. Benzyl bromide gives a good yield of phenylnitromethane only at low temperatures (*vide supra*) while with ethyl bromoacetate, even at −50 to −76°, none of the nitro compound is obtained. Two factors appear to be responsible.

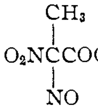
In the first place, phenylnitromethane and ethyl nitroacetate are distinctly more acidic than simple aliphatic and alicyclic nitro compounds and, in the second place, they are primary nitro compounds. The apparent pK_A of ethyl nitroacetate in 50% aqueous ethanol is *ca.* 7.4[10] and that of phenylnitromethane is 8.2, whereas 1-nitrobutane has an apparent pK_A of 10. Consequently, ethyl nitroacetate and phenylnitromethane are no sooner formed than they become importantly engaged in the equilibrium of eq. 2, the first step in their destruction.

The acidity of nitro compounds, however, is not the only factor which affects their rate of destruction by the joint action of sodium nitrite and a nitrite ester. At room temperature, under identical conditions, the reaction of benzyl bromide with sodium nitrite in DMF gives no phenylnitromethane, whereas from ethyl α-bromopropionate a 58% yield of ethyl α-nitropropionate is obtained—this despite the greater acidity of ethyl α-nitropropionate.[10] Here the importance of the second factor, the fact that phenylnitromethane and ethyl nitroacetate are *primary* nitro compounds becomes manifest. Of itself this does not result in sensitivity to the destructive processes, as witness the excellent yields of primary nitroparaffins such as 1-nitroheptane, 1-nitrodecane and 1-nitro-3-phenylpropane.[3] But when, as in the case of phenylnitromethane and ethyl nitroacetate, the acid-enhancing property of the nitro group is augmented by a second acid-strengthening group, some nitrosation to VI and VII occurs and, here, regeneration of the acidity needed for further nitrosation can be achieved by a nucleophilic displacement on hydrogen, rather than on a nitro group, as is necessary with VIII.[5,6] It seems an entirely reasonable assumption that the first of these two processes is distinctly more facile than the second and, on this basis, a simple explanation for the observation that phenylnitromethane is destroyed more rapidly than ethyl α-nitropropionate becomes available. The inability to synthesize ethyl nitroacetate by the new α-nitroester synthesis also becomes intelligible: here both factors which facilitate the destructive processes of equations 2 to 6 come into play.



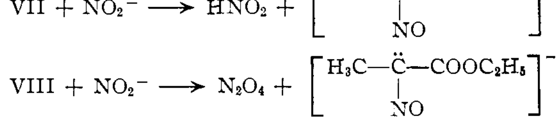
$$O_2N\overset{H}{\underset{NO}{C}}COOC_2H_5$$

VII



$$O_2N\overset{CH_3}{\underset{NO}{C}}COOC_2H_5$$

VIII



$$\text{VII} + NO_2^- \longrightarrow HNO_2 + \left[O_2N-\underset{NO}{\ddot{C}}-COOC_2H_5\right]^-$$

$$\text{VIII} + NO_2^- \longrightarrow N_2O_4 + \left[H_3C-\underset{NO}{\ddot{C}}-COOC_2H_5\right]^-$$

From the foregoing presentation, it is not surprising that the conversion of *p*-nitrobenzyl bromide to *p*-nitrophenylnitromethane, using sodium nitrite in dimethylformamide, is not as successful as when benzyl bromide is used. The best yield of *p*-nitrophenylnitromethane obtained in five runs (conducted under a variety of conditions) was 22%; bis-*p*-nitrophenylfuroxane was isolated in yields as high as 31%.[11]

Acknowledgment.—Our sincere thanks go to Drs. R. K. Blackwood and J. W. Powers for their assistance in several phases of this project.

Experimental

Reagents.—Ethyl bromoacetate ($n^{20}D$ 1.4513) and benzyl bromide ($n^{20}D$ 1.5760–1.5764) were Eastman Kodak Co. white label products. Dimethylformamide (DMF) was du Pont technical grade, dried by storing over calcium hydride. Sodium nitrite (J. T. Baker analyzed) was dried at 110–120°. Urea (U.S.P. quality) was dried at 100–110° for one hour.

Reaction of Ethyl Bromoacetate with Sodium Nitrite. (a) Starting at Room Temperature.—Ethyl bromoacetate (0.05 mole, 8.4 g.) was added all at once to a solution of 5 g. of sodium nitrite (0.075 mole) and 7 g. of urea in 60 ml. of DMF. During the first three minutes a yellow color gradually developed; at this point the temperature abruptly rose to 84°, the solution became dark red-brown, and a gas was evolved vigorously. Four minutes after mixing the solution was again of a very pale yellow color and the evolution

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[9] H. Wieland, *Ber.*, **40**, 1667 (1907); H. Wieland and L. Semper, *ibid.*, **39**, 2522 (1906).

[10] This value is arrived at by adding 1.5 to the pK_A of nitroacetic ester determined in water (5.85) by W. Ried, *Angew. Chem.*, **68**, 386 (1956). The adjustment by 1.5 pK_A units is based on the fact that benzoic acid has pK_A 4.2 in water while in 50% aqueous ethanol it has an apparent pK_A of 5.7 (ref. 4). The reasonableness of this assumption is attested to by the apparent pK_A's (in 50% aqueous ethanol) of ethyl α-nitropropionate (7.5), ethyl α-nitrobutyrate (7.6) and ethyl α-nitrocaproate (7.6).[4]

[11] A further complication arises from the unusually high instability of *p*-nitrobenzyl nitrite; N. Kornblum and W. M. Weaver, *J. Org. Chem.*, **23**, in press (1958).

of gas had ceased. At this time the DMF solution was poured into 400 ml. of ice-water and extracted with ethyl ether. The dried ether extract gave 0.70 g. of a non-lachrymatory liquid, $n^{20}\mathrm{D}$ 1.4520; ethyl nitroacetate has $n^{20}\mathrm{D}$ 1.4245. The aqueous DMF phase was acidified with hydrochloric acid, treated with calcium chloride and then neutralized with ammonium hydroxide. The resulting white precipitate of calcium oxalate monohydrate weighed 1.7 g. (23% yield) and reduced acidic permanganate at 80°.

Anal. Calcd. for $CaC_2O_4 \cdot H_2O$: $C_2O_4^{=}$, 60.3. Found: $C_2O_4^{=}$, 60.0, 58.7.

(b) **At −50 to −76°.**—Sodium nitrite (31.5 g., 0.45 mole) and urea (40 g.) were added to 320 ml. of DMF and cooled to below −50°. This was added, all at once, to a solution of 50.3 g. (0.3 mole) of ethyl bromoacetate in 100 ml. of DMF also cooled to below −50°. The mixture was stirred intermittently over 27 hours during which time the temperature was maintained between −76 and −50°. The product was poured into ice-water, extracted with benzene, washed with water and dried over magnesium sulfate. The solvent was removed and the residue was distilled at 3 mm. The first six fractions (b.p. 38 to 50°, $n^{20}\mathrm{D}$ 1.4510 to 1.4516) are essentially pure ethyl bromoacetate (18.7 g., 38% recovery). This was followed by an 0.8-g. interfraction ($n^{20}\mathrm{D}$ 1.4600) and then 7.22 g. (29% yield, 48% yield based on unrecovered bromide) of a yellow liquid, b.p. 130–134°, $n^{20}\mathrm{D}$ 1.4729–1.4736, was obtained. Redistillation of the 7.22 g. gave the furoxane II as a yellow liquid, b.p. 115° (1 mm.); lit. value[12] 120° (5 mm.), $n^{20}\mathrm{D}$ 1.4739. This compound absorbs in the infrared exactly as described by Boyer, *et al.*, for ethyl furoxandicarboxylate.[13]

Anal. Calcd. for $C_8H_{10}N_2O_6$: C, 41.74; H, 4.39; N, 12.18. Found: C, 41.98; H, 4.65; N, 12.35.

(c) **At −16°.**—Ethyl bromoacetate (16.7 g., 0.10 mole) was added to a stirred solution of 10.5 g. (0.15 mole) of sodium nitrite and 13 g. of urea in 150 ml. of DMF cooled to −16°. The solution was maintained at −16° for 25 hours and was then poured into ice-water and exhaustively extracted with ethyl ether. The combined extracts were washed with water and dried over magnesium sulfate. Distillation at 11 mm. gave 3.23 g. (28% yield) of impure dicarbethoxyfuroxane (II), b.p. 161–162°, $n^{20}\mathrm{D}$ 1.4674 to 1.4685. A small portion was converted to the diamide by shaking with aqueous ammonium hydroxide and recrystallized from water; m.p. 231–232° dec. Snyder and Boyer[12] report m.p. 232°.

(d) **In DMF–DMSO at −13 to −17°.**—Sodium nitrite is much more soluble in dimethyl sulfoxide (DMSO) than in DMF, but DMSO freezes at 18°, and therefore its use at low temperature is precluded. In an effort to obtain the advantages of both DMF and DMSO, ethyl bromoacetate (50.1 g., 0.3 mole), dissolved in 300 ml. of DMF, was cooled to −17° and stirred. A solution of 30.5 g. (0.45 mole) of sodium nitrite in 250 ml. of DMSO was added dropwise at such a rate that the reaction temperature never rose above −13°. Addition required 85 minutes after which the product was worked up immediately. No ethyl nitroacetate could be detected, but a 30% yield (10.6 g.) of impure dicarbethoxyfuroxane (II), b.p. 115-118° (1 mm.), $n^{20}\mathrm{D}$ 1.4699–1.4720, was obtained.

Reaction of Benzyl Bromide with Sodium Nitrite. (a) **At 25°.**—Benzyl bromide (28.4 g., 0.166 mole) was added to a solution of 18 g. of sodium nitrite (0.25 mole) and 20 g. of urea in 200 ml. of DMF. The solution was then diluted up to 250 ml. with DMF and held in a 25° bath. During the first hour very little gas was evolved, but the period from 1 to 1.5 hours was marked by copious evolution of gas; following this, gas evolution slowed down to a trickle. The gas is colorless and supports combustion, causing a glowing splint to ignite; it has a molecular weight of 41 (gas density determination). Consequently, it is taken to be nitrous oxide.

The reaction mixture was worked up by pouring it into ice-water, extracting with benzene, with ethyl ether and washing the combined extracts with water. After drying over magnesium sulfate the solvents were removed and the residue distilled at 3 mm. pressure. The first four fractions were yellow and totaled 1.7 g., b.p. 65 67°, $n^{20}\mathrm{D}$ 1.5008–1.5012; benzyl nitrite has $n^{20}\mathrm{D}$ 1.5008. After a small interfraction 1.46 g. (7% yield) of phenylnitromethane, b.p. 93°, $n^{20}\mathrm{D}$ 1.5309 (lit. value[3] $n^{20}\mathrm{D}$ 1.5315), was obtained. At this point crystals appeared in the condenser and the distillation was stopped. The residue was dissolved in ether, extracted with aqueous sodium bicarbonate and the extracts were acidified. The precipitated benzoic acid (5.62 g.) had m.p. 119–121°. The acidified solution was extracted with ether and an additional 1.23 g. (m.p. 118–120°) of benzoic acid was obtained. The total yield of benzoic acid was 37%.

(b) **At −16° for Four Days.**[14]—Benzyl bromide (17.1 g., 0.10 mole) was added to a stirred solution of 10.5 g. of sodium nitrite (0.15 mole) and 12 g. of urea in 150 ml. of DMF precooled to −16°. After 4 days at −16°, the solution was poured into ice-water, extracted with benzene and then with ethyl ether. The combined extracts were washed with water and dried over magnesium sulfate. The residue obtained after removal of the solvents was distilled at 3 mm. until the bath temperature reached 140°. The material remaining in the distillation flask was dissolved in benzene and washed with 10% aqueous sodium hydroxide and then with water. The benzene was removed *in vacuo* to give 5.35 g. (45% yield) of diphenylfuroxane, m.p. 113–115°; after two recrystallizations from ethanol the diphenylfuroxane melted at 115.5–116.5°. This m.p. was unchanged after recrystallization from petroleum ether (b.p. 65–67°); Wieland and Sember[7] report m.p. 114°.

Anal. Calcd. for $C_{14}H_{10}N_2O_2$: C, 70.57; H, 4.23; N, 11.75. Found: C, 70.73; H, 4.51; N, 11.94.

Boyer, *et al.*,[13] have examined the infrared absorption spectra of a series of furoxanes and have assigned six characteristic absorption bands to the furoxane nucleus. Diphenylfuroxane (Nujol mull) exhibited absorption in all six regions; namely, 1590, 1415, 1320, 1120, 1000 and 920 cm.$^{-1}$.

The material which distilled at 3 mm. consisted chiefly of benzyl nitrite, b.p. 44 to 63°, $n^{20}\mathrm{D}$ 1.5005 to 1.5008, 1.6 g. (11% yield).

The aqueous alkaline phase from the benzene extraction was acidified and extracted with ether. After removal of the ether there remained 0.21 g. (1.7% yield) of benzoic acid, m.p. 117–121°, lit. m.p. 121°.

The Contrasting Reactions of Ethyl α-Bromopropionate and Benzyl Bromide.[15]—(a) Ethyl α-bromopropionate (54.3 g., 0.30 mole) was poured into a stirred mixture of 600 ml. of DMF, 36 g. (0.52 mole) of sodium nitrite and 25 g. (0.15 mole) of phloroglucinol dihydrate in a 1-l. flask immersed in a 25° bath. After five hours the product was worksd up in the usual way giving 25.5 g. (58% yield) of ethyl α-nitropropionate, b.p. 54° (2 mm.), $n^{20}\mathrm{D}$ 1.4210, completely and readily soluble in 10% aqueous sodium bicarbonate. (b) An identical experiment employing 51.6 g. (0.30 mole) of benzyl bromide, 36 g. of sodium nitrite, 600 ml. of DMF and 25 g. of phloroglucinol dihydrate was carried out. After a reaction time of 1.5 hours the mixture was worked up; *ca.* 6 g. (15% yield) of benzyl nitrite was isolated, but neither phenylnitromethane nor benzyl bromide could be detected. After distilling off the benzyl nitrite 17.5 g. of a bright orange solid residue remained. Recrystallization[16] from ethanol gave 11 g. of yellow diphenylfuroxane, m.p. 116.5–117°.

Anal. Calcd. for $C_{14}H_{10}N_2O_2$: C, 70.57; H, 4.23; N, 11.77. Found: C, 70.49; H, 4.83; N, 11.91.

Experiments of Table I.—All the experiments listed in Table I employed reagents and solutions pre-cooled to −16° C.

Experiment 1 was worked up by pouring into ice-water and extracting with benzene. The extracts were washed with water and dried over anhydrous magnesium sulfate. Distillation at 3 mm. gave 7.69 g. (77% recovery) of benzyl nitrite, b.p. 39 to 60°, yellow, $n^{20}\mathrm{D}$ 1.5006–1.5010. After a small interfraction, 13.1 g. of colorless phenylnitromethane (88% recovery) was isolated, b.p. 86–88°, $n^{20}\mathrm{D}$ 1.5313 to 1.5314.

Experiment 2 was worked up by pouring into ice-water, extracting with benzene and with ethyl ether, and then washing with water. The extracts when dried and then distilled at 3 mm. gave 5.70 g. (83%) of phenylnitromethane, b.p. 93 to 97°, $n^{20}\mathrm{D}$ 1.5310 to 1.5316.

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(12) H. R. Snyder and N. E. Boyer, THIS JOURNAL, **77**, 4236 (1955).

(13) N. E. Boyer, G. M. Czerniak, H. S. Gutowsky and H. R. Snyder, *ibid.*, **77**, 4240 (1955).

(14) At −16° for three *hours* a 55% yield of pure phenylnitromethane is obtained.

(15) These experiments were carried out by Dr. R. K. Blackwood.

(16) Carried out by Dr. J. W. Powers.

Experiment 3 was worked up as experiment 2. The phenylnitromethane, 4.46 g. (75%), had n^{20}_{D} 1.5315 to 1.5319, b.p. 91 to 93° (3 mm.). The residue from this distillation on recrystallization from 95% ethanol gave 0.08 g. (1%) of diphenylfuroxane (I), m.p. 114–115°, mixed m.p. with diphenylfuroxane undepressed.

Experiment 4 was worked up as in experiment 3. The recovered benzyl nitrite (0.9 g.) was yellow and had n^{20}_{D} 1.5006 to 1.5009; the phenylnitromethane (6.14 g.) had b.p. 99–102° (5 mm.), n^{20}_{D} 1.5312 to 1.5315. The diphenylfuroxane (1.22 g., 15% yield) had m.p. 115–116°.

Experiment 5.—On working up as in experiment 3, 5.29 g. (66% recovery) of benzyl nitrite was isolated, b.p. 45 to 52° (5 mm.), n^{20}_{D} 1.5008 to 1.5011. No phenylnitromethane was detected. The diphenylfuroxane, 7.21 g. (82% yield), had m.p. 114–115°, mixed m.p. undepressed.

Preparation of Phenylnitrolic Acid.—The procedure of Wieland and Semper[7] was used three times. Crystalline products were obtained which decomposed spontaneously at room temp. as soon as they were isolated, large volumes of brown gases being produced. Two further experiments in which the procedure was modified by using nitrosyl chloride in place of nitrous acid failed to give any of the desired product. Phenylnitrolic acid was finally obtained as follows: sodium, 0.69 g. (0.03 mole) was dissolved in 100 ml. of dry methanol and then 4.11 g. (0.03 mole) of phenylnitromethane in 15 ml. of methanol was added at room temperature. The methanol was promptly removed *in vacuo*; the resulting salt was an ivory-white powder. Anhydrous ether, 100 ml., was then added, the mixture was stirred and the finely divided slurry was cooled to −78°. Dinitrogen trioxide (b.p. 10 to 13°) was vaporized through a tube packed with phosphorus pentoxide on glass beads, recondensed, and then allowed to drip into the well-stirred slurry. The addition was continued until a green-blue color persisted (*ca.* 2 hours). The reaction mixture was then stored overnight at −80°, washed with ice-water, and then extracted with small portions of ice-cold 2% aqueous ammonia retaining only those extracts colored orange-red. The combined orange-red extracts were layered with ice-cold ether and acidified (disappearance of orange-red color) with ice-cold saturated oxalic acid solution; the acidified solution was extracted two more times with cold ether. The ether extracts were washed with ice-water and dried over magnesium sulfate at −80°. The ether was removed *in vacuo* at, or below, 0°; pale yellow, crystalline phenylnitrolic acid, m.p. 55–57° dec., lit.[7] 57–58° dec., was obtained; 2.15 g. (48% yield); neut. equiv. calcd. for $C_7H_6N_2O_3$, 166; found (potentiometrically), 163.

Decomposition of Phenylnitrolic Acid. (a) At 25°.—Phenylnitrolic acid (1.0 g., 0.006 mole) was dissolved in a solution of 10 ml. of DMF containing 0.88 g. of urea and 0.63 g. (0.009 mole) of sodium nitrite. Within 15 seconds a colorless gas began to be evolved. The reaction flask was kept in a 25° bath for 14 hours after which the solution was poured into ice-water and extracted with ether. The combined extracts were washed with 5% aqueous sodium bicarbonate. The bicarbonate extracts were then acidified with hydrochloric acid and extracted with ether. The ether extracts were washed with water and dried over magnesium sulfate. When the ether was removed *in vacuo* 0.59 g. (81% yield) of benzoic acid, m.p. 119–121°, mixed m.p. 119–121°, was obtained.

The initial ether extracts, which had been washed with sodium bicarbonate solution, were washed with water and dried over magnesium sulfate. When the ether was removed *in vacuo* 0.02 g. (*ca.* 3%) of diphenylfuroxane (yellow crystals) was isolated, m.p. 109–113°.

(b) At −16 to −18°.—A duplicate experiment was conducted at −16 to −18° for 19 hours. The yield of benzoic acid was 0.06 g. (8%), m.p. 119–121° and that of diphenylfuroxane (I) was 0.56 g., m.p. 111–114°; recrystallization from ethanol gave 0.53 g. (74% yield), m.p. 114–115°.

Reaction of *p*-Nitrobenzyl Bromide with Sodium Nitrite in DMF.—Five experiments at temperatures of −16°, −10° and 25° were run; the reaction times ranged from 15 min. to 24 hours. The run at −16° for 15 minutes gave a 22% yield of *p*-nitrophenylnitromethane, yellow crystals, m.p. 88–91°, lit.[17] m.p. 90–91°. Substantial amounts of other products (not characterized) were obtained. Another run at −10° for 50 minutes gave, in addition to a 7% recovery of *p*-nitrobenzyl bromide, a 2% yield of *p*-nitrophenylnitromethane, a 31% yield of bis-*p*-nitrophenylfuroxane, m.p. 199–201°, lit.[18] m.p. 197–198°; a Nujol mull had the characteristic furoxane bands.[13] In addition, a 4% yield of the acetal of *p*-nitrobenzaldehyde with *p*-nitrobenzyl alcohol[11] was isolated, m.p. 209–211°; an authentic sample[11] melts at 210–211°; finally, a mixture of *p*-nitrobenzaldehyde and *p*-nitrobenzyl alcohol (in unknown proportions) was converted to *p*-nitrobenzoic acid by alkaline permanganate; yield 10%, m.p. 239–240°; a mixed m.p. with authentic *p*-nitrobenzoic acid was undepressed.

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[18] A. Werner, *Ber.*, **27**, 2848 (1894).

[CONTRIBUTION FROM THE VENABLE CHEMICAL LABORATORY, UNIVERSITY OF NORTH CAROLINA]

The Nucleophilic Reactivity of Aniline, Hydrazine and Phenoxide Ion toward 2,4-Dinitrochlorobenzene[1]

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With 2,4-dinitrochlorobenzene in 60% dioxane, aniline reacts considerably slower and hydrazine somewhat faster than hydroxide ion (see Table II). Addition of excess phenol causes the rate coefficient for the phenoxide reaction at first to rise and then to fall (Fig. 1); this effect is briefly discussed.

In an earlier paper[2] we reported rates of reactions of several nucleophilic reagents with 2,4-dinitrochlorobenzene in 60% dioxane solution. We now add similar data for the reagents aniline and hydrazine. The effect of phenol, in various concentrations, on the rate of reaction of phenoxide ion with this substrate is also reported.

Earlier work[3] has shown that hydrazine is a moderately strong nucleophilic reagent toward 2,4-dinitrochlorobenzene, whereas aniline is rather weak amongst amines in this regard. However, results obtained hitherto have not served to establish quantitatively, under uniform conditions, the nucleophilic reactivity of these reagents in respect to other reagents of diverse character.

Rate coefficients determined in the present work for aniline and hydrazine reactions are set forth in

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[1] Research supported by the Office of Ordnance Research, U. S. Army.

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