(and hence, the heat of solution of gaseous hydrogen chloride in the latter medium), the heat of mixing of water with acetic acid is required. Two samples of water (282.8 and 255.1 mg.) were therefore dissolved in 225 ml. of stock acetic acid. The heat of mixing obtained from these experiments was found to be +9.1 ± 0.01 cal./11.8 mmoles of water, which is the amount transferred per millimole of hydrogen chloride when 4.01 *N* aqueous chloride is employed.

The heat of solution of cycloheptane in 225 ml. of the hydrogenation solvent, obtained from two determinations (220.3 and 226.4 mg. of cycloheptane), is +1.52 ± 0.09 kcal./mole. The heat of solution of benzyl chloride in the same solvent (two determinations, 385.8 and 297.7 mg.) is +0.42 ± 0.06 kcal./mole.

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CONTRIBUTION FROM THE DEPARTMENTS OF CHEMISTRY OF THE UNIVERSITY OF NORTH DAKOTA AND HOFSTRA COLLEGE]

A Simple Method for the Direct Oxidation of Aromatic Amines to Nitroso Compounds[1]

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A convenient method for the direct oxidation of a number of 2,6-dichloro- and 2,6-dibromo- aromatic amines to the corresponding nitroso compounds is described. The reagent is a mixture of glacial acetic acid and ordinary 30% aqueous hydrogen peroxide, with or without addition of catalytic amounts of sulfuric acid. The procedure consists of simply allowing the reactants to stand at room temperature (or warming slightly) and then filtering off the crystalline product. Use of the same reagent under more vigorous conditions is shown (two examples described in detail) to produce nitro compounds in good yield.

Although the direct oxidation of aromatic amines to nitroso compounds has been carried out successfully many times[2] with Caro's acid, the simple procedure described in the present communication is new. Emmons[3] has recently described a somewhat similar, though experimentally more complex, procedure for the direct oxidation of cyclohexylamine to bisnitrosocyclohexane. This was the only example of an aliphatic amine which could be oxidized directly to the nitroso compound. All other examples cited by Emmons were prepared *via* oxazirane intermediates. In the present method a solution of the amine in a mixture of glacial acetic acid and 30% aqueous hydrogen peroxide, with or without a catalytic amount of sulfuric acid, was warmed slightly (or allowed to stand at room temperature) for several hours. During this time crystals of the (dimeric) nitroso compound gradually separated from solution, and the product was isolated (in most cases) by simply filtering off the crystals. The method required a minimum of experimental manipulation, the simplest apparatus, and was well-suited for production of the nitroso compounds on a large scale.

The experimental results are summarized in Table I. No attempt was made to determine the optimum conditions for nitroso compound production, and no doubt the yields listed in the table could be substantially improved.

The advantage of the direct oxidation procedure is well illustrated by the example of tribromonitrosobenzene. Our simple method produced the compound from tribromoaniline in one step and in 80.8% yield. The crude product was of good quality even before recrystallization. The only method previously described in the literature, that of von Pechman and Nold,[4] involved five steps from the same starting material and proceeded *via* the diazonium salt, tribromobenzene, tribromonitrobenzene and tribromophenylhydroxylamine. The over-all yield was very low.

It was also found possible to oxidize tribromoaniline directly to the nitroso compound with Caro's acid, but the yield was only about one-third that obtained with the acetic acid–hydrogen peroxide reagent.

The direct oxidation of amines to aromatic *nitro* compounds by means of peroxy acids has been described many times,[5] most recently in a series of studies by Emmons[6] of the oxidizing action of peroxytrifluoracetic and peroxyacetic acids. It is therefore interesting that under the mild conditions used in the present study one can stop the reaction at the nitroso stage.

Under more vigorous conditions and by extending the reaction time it was possible to prepare nitro compounds directly from the amines by use of the 30% hydrogen peroxide–acetic acid reagent. An advantage of this reagent over those recommended for the same purpose by Emmons is that it does not involve preformed peracetic acid or use of the potentially hazardous 90% hydrogen peroxide.[7] Although the oxidation of several amines[8] to the corresponding nitro compounds has been successfully carried out in these laboratories using the acetic acid-30% peroxide reagent, the oxidation of only two—3,5-dibromo-4-amino-benzonitrile and 3,5-dichloro-4-aminobenzonitrile—is described in detail. The yield of pure nitro compound from the former amine was 68%, and from the latter, 83%. In each case the oxidation proceeded *via* the nitroso compound, which was not isolated. These nitroso compounds were prepared and characterized but,

[1] Abstracted in part from the M.S. Thesis of Raymond P. Bayer, University of North Dakota, 1957.

[2] A. von Baeyer, *Ber.*, **33**, 124 (1900); **34**, 855 (1901); H. H. Hodgson and J. S. Wignall, *J. Chem. Soc.*, 2216 (1927); W. D. Langley, *Org. Syntheses*, **22**, 44 (1942).

[3] W. D. Emmons, THIS JOURNAL, **79**, 6523 (1957).

[4] H. von Pechmann and A. Nold, *Ber.*, **31**, 562 (1898).

[5] J. D'Ans and A. Kneip, *ibid.*, **48**, 1144 (1915); F. P. Greenspan, *Ind. Eng. Chem.*, **39**, 847 (1947); E. Bamberger and F. Tschirmer, *Ber.*, **32**, 1675 (1899); W. D. Langley, *Org. Syntheses*, **22**, 44 (1942).

[6] W. D. Emmons, THIS JOURNAL, **79**, 5528 (1957); **76**, 3470 (1954).

[7] The referee has kindly pointed out that it is standard safety practice to work with an explosion proof shield when handling any quantity of *either* 30 or 90% peroxide.

[8] 2,4,6-Tribromoaniline, 2,4,6-trichloroaniline and 2,6-dichloroaniline: unpublished work, present authors.

TABLE I[a]

Nitrosobenzene	M.p., °C.[b]	Yield,[c] %	Carbon, %		Hydrogen, %		Nitrogen, %		Halogen, %	
			Calcd.	Found	Calcd.	Found	Calcd.	Found	Calcd.	Found
2,6-di-Cl–	175.5–176	91.3					7.96	7.74	40.29	40.43
2,4,6-tri-Cl–[d]	145–146	73.8	34.24	34.39	0.96	0.69	6.66	6.73	50.54	50.74
2,4,6-tri-Br–[e,f,g]	122–123	80.8								
2,6-di-Br–[e,h]	135–136	26.3	27.20	27.48	1.14	1.24	5.29	5.30	60.33	60.08
2,6-di-Br-4-Cl–[e,h]	110–111	42.0	24.07	24.09	0.67	0.67	4.68	4.58	65.23	65.36
2,6-di-Cl-4-Br–[e,i]	144–145	72.7	28.27	28.30	0.79	0.80	5.50	5.28	59.17	58.86
2,6-di-Cl-4-CH_3–[e,h]	163–164.5	22.6	44.24	44.36	2.65	2.59	7.37	7.42	37.32	37.38
2,3,6-tri-Cl-4-CH_3–[e,h]	189–190	21.4	37.45	37.22	1.80	1.82	6.24	6.11	47.38	47.36
2,6-di-Br-4-CH_3–[j,h]	136.5–138	28.7	30.14	30.09	1.81	1.75	5.02	4.64	57.30	56.44
2,6-di-Br-4-$COOC_2H_5$–[e,k]	133–134	37.8	31.98	32.15	2.09	2.03	4.14	3.98	47.29	46.63
2,6-di-Cl-4-$COOC_2H_5$–[e,h]	154–155	38.7	43.57	43.74	2.84	3.04	5.65	5.62	28.59	28.27
2,6-di-Cl-4-CN–[l]	220–221	76.6	41.82	42.05	1.00	0.83	13.94	13.87	35.28	35.36
2,6-di-Br-4-CN–	190–191	53.1	29.00	29.25	0.70	0.72	9.66	9.50	55.13	55.08

[a] Analyses by Clark Microanalytical Laboratories, Urbana, Ill.; all analytical samples were sublimed *in vacuo* for final purification. [b] All melting points were obtained in a Kofler hot-stage and are to be considered as corrected. [c] Yields are based on recrystallized product. [d] Described as melting at 152° by E. Havinga, *et al.*, *Rec. trav. chim.*, **77,** 746 (1958), who prepared it by oxidation of the hydroxylamine and reported a nitrogen analysis only. [e] Oxidation carried out in presence of catalytic amount of sulfuric acid and with warm (35–45°) solution of 30% peroxide in acetic acid as described under the preparation of trichloronitrosobenzene. [f] Recrystallized from acetic acid. [g] (Lit.[4] m.p. 120°); also prepared in 25.8% yield by use of Caro's acid essentially as described under the preparation of 2,6-dibromo-4-CN-nitrosobenzene. [h] Recrystallized from carbon tetrachloride. [i] Recrystallized from carbon tetrachloride–methanol. [j] Oxidation carried out at room temperature and without sulfuric acid as described under preparation of 2,6-dichloronitrosobenzene. [k] Recrystallized from carbon tetrachloride–ethanol. [l] Prepared (Caro's acid) and recrystallized as described in detail in Experimental section under preparation of 2,6-dibromo-4-cyanonitrosobenzene.

for reasons of no consequence here, the reagent used in the preparative experiments was Caro's acid.

The method of Seikel[9] was used for the preparation of 2,6-dichloro- and 2,6-dibromoanilines.

Although 2,6-dibromo-4-methylaniline was readily prepared by the method of Kosolapoff,[10] the preparation of 2,6-dichloro-4-methylaniline offered considerable difficulty. Attempts to chlorinate *p*-toluidine directly were unsuccessful. The method finally worked out involved treatment of the acetyl derivative of *p*-toluidine with chlorine in the presence of ferric chloride, and was not really satisfactory, for it led to a complex mixture from which the desired amine was isolated in very low yield. Two amines, A (crude m.p. 53–60°) and B (m.p. 58–59°) were isolated from the (hydrolyzed) crude chlorination product. Both A and B were converted to nitroso compounds by action of the acetic acid–30% hydrogen peroxide reagent, and gave bisnitroso compounds C and D melting at 190° and 164°, respectively. Elementary analysis indicated that C was a trichloro-4-methylnitrosobenzene and D a dichloro-*p*-methylnitrosobenzene. Therefore amine B was a dichloro-*p*-toluidine. From the method of preparation, which was similar to that employed by Lellman and Klotz[11] for 2,6-dichloro-4-methylaniline, and from the melting point of 58–59° (reported[11] m.p. 60°), it is clear that B was 2,6-dichloro-4-methylaniline. Amine A, a trichloro-*p*-toluidine, was apparently the same as that described by Schuloff, Pollak and Riess[12] and reported as melting at 59–60°. The latter authors were not sure whether the compound was the 2,3,5-isomer I or the 2,3,6-isomer II. However, in view of the fact that nitroso compounds C and D were both highly dimerized in dilute benzene solution[13] in concentrations at which mono-*o*-substituted aromatic nitroso compounds are not,[14] it is reasonably certain that amine A had formula II, and that Schuloff, Pollak and Riess had correctly assigned the structure of their trichlorination product of benzene-sulfonyl-*p*-toluidine as the 2,3,6-isomer.

The remainder of the amines oxidized to the nitroso compounds listed in Table I, and 3,5-dichloro-4-aminobenzonitrile were prepared by standard methods. 3,5-Dichloro-4-aminoethyl benzoate, a new compound, was not analyzed but was characterized by hydrolysis to the known[15] acid, and by oxidation to the nitroso compound (Table I).

Experimental

2,6-Dichloro-4-methylaniline and 2,3,6-Trichloro-4-methylaniline (II.)—A solution of 214 g. (2.0 moles) of *p*-toluidine in glacial acetic acid (800 ml.) was refluxed for 2 hours. Without isolating the resulting aceto-*p*-toluidide, the solution was cooled to 50° and, after addition of 2.0 g. (0.01 mole) of anhydrous ferric chloride, a moderately rapid stream of chlorine was passed through it, with stirring, for 3 hours. During most of this time the temperature remained between 50 and 60°. The mixture was stirred for another 0.5 hour with no passage of chlorine, and then water (1.5 liters) was added. The resulting gummy solid was removed, washed with water and then boiled with a mixture of concentrated hydrochloric acid (800 ml.) and water (600 ml.) for 45 hours. The insoluble material was suspended in a solution of sodium hydroxide (100 g., 2.5 moles) in water (200 ml.) and steam distilled. The solid distillate (A) was recrystallized six times from ethanol, and then gave crude 2,3,6-trichloro-4-methylaniline (20 g., 0.095 mole, 4.75%) melting over the range 52–60°.

The strongly acidic mother liquor from which the above gummy solid had been removed was diluted with a liter of water, and the resulting precipitate (P-1) was filtered off. The filtrate was neutralized cautiously with solid sodium hydroxide pellets and the solid (P-2) which formed was removed, combined with P-1, and the crude material dissolved in the minimum (25–30 ml.) of hot ethanol. Decolorization

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(9) M. K. Seikel, *Org. Syntheses*, **24**, 47 (1949). The authors would like to thank the members of the 1951–1952 class in Organic Chemistry at Oberlin College for the preparation of a considerable quantity of 2,6-dichloroaniline, and Dr. Roland G. Severson and the Organic Preparations class of 1956 at the University of North Dakota for the 2,6-dibromoaniline.

(10) G. M. Kosolapoff, THIS JOURNAL, **75**, 3596 (1953).

(11) E. Lellman and C. Klotz, *Ann.*, **231**, 322 (1885).

(12) R. Schuloff, R. Pollak and E. Riess, *Ber.*, **62**, 1850 (1929).

(13) Unpublished work, present authors.

(14) D. Ll. Hammick, *J. Chem. Soc.*, 3108 (1931); W. J. Mijs, S. E. Hoekstra, R. M. Ulmann and E. Havinga, *Rec. trav. chim.*, **77**, 746 (1958).

with Norite A (1 g.) and chilling the filtrate gave crude B, which, on crystallization again from ethanol, gave 2,6-dichloro-4-methylaniline (12.5 g., 3.6%) melting at 58–59° (lit.[11] m.p. 60°). A mixture of B and A melted over the range 30–60°, showing that they were not the same in spite of the similarity in melting ranges.

3,5-Dichloro-4-aminoethyl benzoate and 3,5-Dichloro-4-aminobenzoic Acid.—A solution of 49.9 g. (0.29 mole) of *p*-aminoethyl benzoate in a mixture of water (700 ml.), concentrated HCl (800 ml.) and 30% aqueous hydrogen peroxide (120 ml.) was stirred and kept at 25° for 2 hours. The precipitate which formed was washed with water and recrystallized from the minimum of ethanol, giving 42.5 g. (0.182 mole, 62.6%) of crude amino-ester melting at 60–64°. Attempts to purify this were not successful. A sample (1.0 g., 0.0043 mole) was boiled with 10% aqueous sodium hydroxide (100 ml.) for 2 hours. All had dissolved by this time. Acidification of the cooled solution gave a white solid which was washed with water and crystallized from ethanol (25 ml.). There resulted 0.5 g. (0.00243 mole, 56.4%) of acid melting with decomposition at 280°. The reported[15] melting point is 291°.

2,6-Dichloronitrosobenzene.[16]—A solution of 16.2 g. (0.10 mole) of 2,6-dichloroaniline in a mixture of glacial acetic acid (400 ml.) and 30% aqueous hydrogen peroxide (80 ml., 0.70 mole) was allowed to stand at room temperature for 48 hours. The straw-colored blades which had formed were removed and recrystallized from the minimum of hot glacial acetic acid. The resulting almost-white crystals weighed 16.1 g., (0.0913 mole) and melted at 173–175° to a pale green liquid. The analytical sample was obtained by recrystallization once from ethanol, then twice from benzene, followed by vacuum sublimation.

2,4,6-Trichloronitrosobenzene.—To a mixture of glacial acetic acid (200 ml.), 30% aqueous hydrogen peroxide (50 ml., 0.44 mole) and 3.0 ml. of concentrated sulfuric acid was added 20.0 g. (0.102 mole) of 2,4,6-trichloroaniline. The mixture was warmed gently in order to bring all the amine into solution and was then kept at 35–40° for 10 hours. The warm solution was diluted with an equal volume of water, and the solid removed and recrystallized from boiling acetic acid (150 ml.). There was obtained 16.5 g. (0.0753 mole) of colorless crystals melting at 145–146°. After two more crystallizations from acetic acid followed by vacuum sublimation, the analytical sample was white and still melted at 145–146°.

3,5-Dichloro-4-nitrobenzonitrile.—A mixture of 3,5-dichloro-4-aminobenzonitrile (4.7 g., 0.025 mole), glacial acetic acid (100 ml.), 30% aqueous hydrogen peroxide (30 ml.) and concentrated sulfuric acid (2.0 ml.) was heated (steam-bath) to 70–80° and kept at that temperature for 8.5 hours. After the first 0.5 hour, the solution turned green and a copious precipitate of a white crystalline material (undoubtedly the nitroso dimer) appeared. After 3.25 hours, 15 ml. more 30% peroxide and 50 ml. of glacial acetic acid were added, when essentially all of the solid dissolved and the solution became light yellow. On addition of 200 ml. of water and cooling, a solid was obtained which was crystallized from hot methanol (100 ml.). The yield of nitro compound melting at 166–167° was 4.5 g. (0.0208 mole, 83%). A sample was vacuum sublimed and analyzed.

Anal. Calcd. for $C_7H_2Cl_2N_2O_2$: C, 38.74; H, 0.93; Cl, 32.68. Found: C, 39.05; H, 0.76; Cl, 32.74.

The infrared spectrum of the substance (solutions in CCl_4 and CS_2) contained a strong band in the region of 2220–2240 cm.$^{-1}$ characteristic of aromatic nitriles[17] and prominent bands at 1550, 1350 and 870 cm.$^{-1}$ as expected[18] of a substituted nitrobenzene.

3,5-Dibromo-4-aminobenzonitrile and 3,5-Dibromo-4-nitrobenzonitrile.—In a 2-liter round-bottomed flask equipped with thermometer and mechanical stirrer were placed 34.0 g. (0.29 mole) of *p*-aminobenzonitrile, 950 ml. of water, 350 ml. of 48% aqueous HBr and 60 ml. of 30% aqueous hydrogen peroxide. The temperature was maintained at 25° and stirring was continued for 30 minutes, by the end of which time a yellow color due to free bromine appeared in the thick precipitate. The solid was removed, washed with water, and crystallized from hot ethanol (600 ml.) after decolorization with Norite A (2 g.). A second crystallization and decolorization gave rise to 50.0 g. (0.181 mole, 62.5%) of slightly off-white amine melting at 126–127°. Without further purification this material (6.9 g., 0.025 mole) was added to glacial acetic acid (100 ml.) containing 30% hydrogen peroxide (30 ml.) and 2 ml. of concentrated sulfuric acid, and the mixture was kept at 70–80° for 2 hours. After 0.5 hour, the solution became deep green, but by the end of 2 hours the color had faded to a clear light orange. Addition of water (200 ml.) and cooling gave a solid which was crystallized (final ice-bath cooling) from methanol (200 ml.). The yield of nitro compound melting at 175–176.5° was 5.2 g. (0.017 mole, 67.9%). A sample was sublimed *in vacuo* and analyzed.

Anal. Calcd. for $C_7H_2Br_2N_2O_2$: C, 27.48; H, 0.66; N, 9.16; Br, 52.25. Found: C, 27.74; H, 0.67; N, 9.57; Br, 52.26.

The infrared spectrum of the substance (solutions in CCl_4 and CS_2) contained the prominent peaks at 1550, 1340 and 870 cm.$^{-1}$ characteristic of the nitro group attached to a benzene ring[18] and also a strong band in the 220–2240 cm.$^{-1}$ region characteristic of the –CN group in aromatic nitriles.[17]

2,6-Dibromo-4-cyanonitrosobenzene.—To 20 ml. of concentrated sulfuric acid was added 25 g. (0.09 mole) of powdered potassium persulfate, and the suspension was stirred 1 hour (when essentially all had dissolved) then added to 150 g. of crushed ice and 50 ml. of water. The resulting solution of Caro's acid was added to a paste of powdered 3,5-dibromo-4-aminobenzonitrile (7.0 g., 0.026 mole), 16 ml. of concentrated sulfuric acid, and 5 ml. of water. The mixture was maintained at 70–80° with stirring for 1 hour, then set aside at room temperature for 2 days. The solid was removed, washed with warm 5% aqueous HCl, and water, then recrystallized (green solution) from hot acetic acid (150 ml.) three times. The yield of colorless nitroso compound was 4.0 g. (0.0138 mole). A sample was sublimed *in vacuo* and analyzed.

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(15) L. Elion, *Rec. trav. chim.*, **42**, 145 (1923).

(16) Descriptive material shown in the table is not reproduced in the Experimental section; typical procedures are described.

(17) L. J. Bellamy, "Infrared Spectra of Complex Molecules." Methuen, London, Second Edition, 1958, p. 264.

(18) *Ibid.*, pp. 300 and 303.