acid, also warmed to 55°. After several minutes the mixture was cooled in an ice-bath and the crystals of 7-methyl-1,2,3,4-dibenzophenazine were collected on a filter. These were washed with 30 ml. of a 4:1 (v. v.) solution of ethanol-glacial acetic acid and then recrystallized from benzene-acetone solution. After a further treatment with Norite in benzene, 209 mg. of the pure phenazine was obtained,[14] m.p. 220–221° (reported[7] 217°, uncor.).

A 57.2-mg. sample of the phenazine was radioassayed, giving 6.4×10^{-3} μc./mmole (the rate of drift was about nine times that of background). This corresponded to 0.08% of 3,4-dinitrotoluene in the dinitrotoluene. The phenazine was recrystallized from benzene and re-assayed. A 56.7-mg. sample gave 3.5×10^{-3} μc./mmole, corresponding to 0.04% of 3,4-dinitrotoluene.

Run 2.—A 2.00-g. sample of *p*-nitrotoluene-1-C^{14} (5.50 μc./mmole) was nitrated under conditions identical with those of run 1. The crude dinitrotoluene was recrystallized this time from methanol-water, giving 2.541 g. (96%). This product was "diluted" with 1.696 g. of 3,4-dinitrotoluene and reduced as before; the diamine hydrogen sulfates were again obtained in 85% yield. The phenazine was prepared as before and recrystallized from acetone, m.p. 220.5–222.0°.

Radioassay of a 60.0-mg. sample gave 9.6×10^{-3} μc./mmole, corresponding to 0.12% of 3,4-dinitrotoluene. The phenazine was recrystallized from benzene and reassayed. A 60.1-mg. sample gave 3.3×10^{-3} μc./mmole, corresponding to 0.04% of 3,4-dinitrotoluene.

Run 3.—In the nitration flask was placed 2.94 g. of *p*-nitrotoluene-1-C^{14} (5.50 μc./mmole) and 2.81 g. of 85.0% sulfuric acid. The mixed acids added were composed of 2.54 g. of 94.1% sulfuric acid, 1.25 g. of 91.8% nitric acid and 0.18 g. of water. (The amount of nitric acid used was 14.8% less than the theoretical amount.) The reaction temperature and time were the same as in runs 1 and 2. After pouring the reaction mixture into ice and water, the crude dinitrotoluenes were collected on a filter, as before (3.85 g.), but instead of being recrystallized, this time they were steam distilled; 0.381 g. of low-melting *p*-nitrotoluene was recovered from the distillate and 3.028 g. of dinitrotoluene from the residue. This 3.028 g. of material was mixed with 2.010 g. of 3,4-dinitrotoluene, the mixture was reduced as before and the diamines were precipitated as hydrogen sulfate salts (5.31 g., 87%).

A sample of the phenazine was prepared directly from the diamine hydrogen sulfates in this run, dissolving 0.5 g. of the salt in 10 ml. of water and 25 ml. of methanol and adding this solution to a solution of 0.5 g. of *o*-phenanthrenequinone in 25 ml. of acetic acid at 60°. The phenazine was decolorized with charcoal and recrystallized before assay. The radioactivity found corresponded to 0.30% of 3,4-dinitrotoluene. The phenazine was recrystallized and re-assayed twice. The activities found corresponded to 0.25 and 0.20% of 3,4-dinitrotoluene after the second and third recrystallizations.

The remaining diamine salt was converted to free diamine and a sample of the phenazine was prepared as in runs 1 and 2. Radioassay gave an activity corresponding to 0.20% of 3,4-dinitrotoluene. Recrystallization of the phenazine and re-assay gave an activity corresponding to 0.18% of 3,4-dinitrotoluene.

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[14] This was a much smaller yield of the phenazine than was obtained in preliminary experiments with non-radioactive materials. The yields were somewhat higher also in runs 2 and 3 when carried out on a smaller scale and when a smaller proportion of acetic acid was used.

[CONTRIBUTION FROM THE DEPARTMENTS OF CHEMISTRY AND CHEMICAL ENGINEERING, THE UNIVERSITY OF TEXAS]

Determination of Isomer Distribution in the Nitration of *o*-Nitrotoluene by Isotope Dilution Analysis. 2,3-Dinitrotoluene[1]

BY ROYSTON M. ROBERTS, JOEL D. WATKINS AND KENNETH A. KOBE

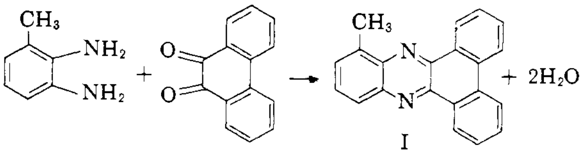
RECEIVED JUNE 27, 1958

The proportion of 2,3-dinitrotoluene formed by nitration of *o*-nitrotoluene with mixed acids has been determined by isotope dilution analysis. It is less than 0.4% of the total amount of dinitrotoluenes.

Recently we have described studies on isomer distribution among the products of nitration of toluene[2] and *p*-nitrotoluene[3] by mixed acids. The proportions of the minor isomers were determined in each case by isotope dilution analysis. We are now extending this work by a similar study of the nitration of *o*-nitrotoluene.

The nitration of *o*-nitrotoluene has been reported to produce a mixture of 2,4- and 2,6-dinitrotoluene in the proportion of 66.6 and 33.3%, respectively.[4] This analysis was based on comparison of the melting point of a nitration product with melting point-composition curves of known mixtures. There is no record in the literature of the detection or isolation of either of the other two isomeric dinitrotoluenes, 2,3- and 2,5-dinitrotoluene, which may possibly be formed in minor amounts by nitration of *o*-nitrotoluene. The accurate determination of the amount of 2,3-dinitrotoluene produced is the subject of this paper.

The procedure applied to this determination was the inverse isotope dilution technique. This involved nitrating radioactive *o*-nitrotoluene, "diluting" the mixture of dinitrotoluenes produced with non-radioactive 2,3-dinitrotoluene, re-isolating the 2,3-dinitrotoluene in some form from the mixture and determining its radioactivity. The re-isolation of the 2,3-dinitrotoluene was accomplished in a manner analogous to that described for the separation of 2,4- and 3,4-dinitrotoluenes in the preceding paper.[3] This involved reduction of the mixed dinitrotoluenes to mixed toluenediamines and treatment of these in alcoholic acetic acid solution with *o*-phenanthrene-quinone, which condensed with 2,3-diaminotoluene to give insoluble 6-methyl-1,2;-3,4-dibenzophenazine (I). Under the conditions



I

of the experiment, the other isomeric diamines do

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[1] Supported by U. S. Army Ordnance Research under Contract No. DAI-23-072-501-ORD-(P)-6. Taken from the M.A. thesis of Joel D. Watkins, The University of Texas, 1957.

[2] R. M. Roberts, P. Heiberger, J. D. Watkins, H. P. Browder, Jr., and K. A. Kobe, THIS JOURNAL, **80**, 4285 (1958).

[3] R. M. Roberts, H. P. Browder, Jr., and K. A. Kobe, *ibid.*, **80**, 1165 (1958).

[4] W. H. Gibson, R. Duckbam and R. Fairbairn, *J. Chem. Soc.*, **121**, 278 (1922).

not form phenazines or other products which interfere with the isolation of the phenazine, since none of them has the amino groups on adjacent positions of the toluene ring.

Essentially the same nitration conditions used with *p*-nitrotoluene[3] were applied to *o*-nitrotoluene. In run 1, the theoretical amount of nitric acid was used, and in run 2 the theoretical amount plus 10% excess; all other conditions were identical in these two runs. The temperature was kept between 65 and 77° during the reaction. The crude dinitrotoluenes produced in runs 1 and 2 were dissolved in warm ethanol and reprecipitated by the addition of cold dilute sulfuric acid solution. After drying, weighed amounts were "diluted" with weighed amounts of pure non-radioactive 2,3-dinitrotoluene. The mixed dinitrotoluenes were treated as described above and 6-methyl-1,2;3,4-dibenzophenazine was isolated and purified to constant radioactivity by recrystallization from benzene. The considerably higher yields of the phenazine obtained in this work allowed repeated recrystallizations between radioassays and reduced the possibility that the final low constant radioactivities found were due to contamination rather than to minute but real amounts of radioactive 2,3-dinitrotoluene present among the nitration products.

The calculation of the proportion of 2,3-dinitrotoluene formed in the nitrations was made as described before.[2] The results are given in Table I. The close agreement between the results of runs 1 and 2 also supports the view that there is a very small but real amount of 2,3-dinitrotoluene produced in these reactions.

TABLE I

2,3-DINITROTOLUENE PRODUCED BY NITRATION OF *O*-NITROTOLUENE

Run	1	2	3
Reactants, g.			
o-Nitrotoluene-1-C^{14}	2.01	2.00	2.01
Nitric acid, 82%	1.12	1.23	1.06
Sulfuric acid, 90%	3.88	3.88	4.02
Water	....	....	0.52
Yield of dinitrotoluenes, %	93	94	48
Isotopic dilution			
Dinitrotoluenes, g.	2.202	2.515	1.268
2,3-Dinitrotoluene, g.	2.024	2.299	1.160
Radioactivity, μc./mmole[a]			
o-Nitrotoluene-1-C^{14}	4.90	4.90	4.90
Phenazine			
One recrystn.	0.0210	....	....
Two recrystn.	.0184	0.0207	0.0140
Three recrystn.	.0182	.0187	.0124
Four recrystn.	.0182	.0184	.0123
2,3-Dinitrotoluene, % in dinitrotoluenes	.34	.35	.23

[a] The values shown were usually the average of two or more assays. Reproducibility was within about 1%.

Run 3 was designed to duplicate as nearly as possible plant conditions for the dinitration of toluene.[5] This amounted to using a slightly more dilute acid mixture which contained an amount of nitric acid 5.4% less than the theoretical. The result on the small scale (run 3) was much less complete conversion to dinitrotoluenes, under the same conditions of temperature and time of reaction used in runs 1 and 2. It was necessary to recrystallize the crude dinitrotoluenes to separate them from the unchanged *o*-nitrotoluene before isotope dilution. The proportion of 2,3-dinitrotoluene calculated to have been formed in this run was slightly less than that found in runs 1 and 2 (Table I).

Experimental[6]

Materials.—*o*-Nitrotoluene-1-C^{14} was prepared by nitration of toluene-1-C^{14} (Tracerlab, Inc.) at 30° with mixed acids.[2] It was separated from the *m*- and *p*-isomers by distillation through the Podbielniak still described before[2]; b.p. 141.1–141.7° (90 mm.), n^{20}D 1.5466 (lit.[7] 1.54662). For radioassay, the *o*-nitrotoluene-1-C^{14} was oxidized by potassium permanganate[8] to *o*-nitrobenzoic-1-C^{14} acid, which was recrystallized from 5% sulfuric acid solution; m.p. 147.2°.

2,3-Dinitrotoluene was synthesized from *p*-toluidine (Matheson, Coleman and Bell). The first step was nitration of *p*-toluidine hydrogen sulfate according to Nolting and Collin.[9] 2-Nitro-*p*-toluidine was obtained in 96% yield, m.p. 76–77°. This product was acetylated by means of acetic anhydride and the 2-nitroaceto-*p*-toluidide was converted to 2,3-dinitrotoluene following the procedure of Page and Heasman.[10] Details are given on the deamination step since Page and Heasman give none, and considerable difficulty was encountered before a satisfactory procedure was worked out. A mixture of 10.53 g. of 2,3-dinitro-*p*-toluidine[11] and 4.05 g. of sodium nitrite was suspended in 275 ml. of absolute ethanol and cooled to 0°. With efficient stirring, 35 ml. of concd. sulfuric acid was added dropwise so that the temperature remained below 10°. After the addition was complete, the mixture was stirred in the ice-bath for an hour and then allowed to come to room temperature during another hour. Finally, the solution was placed on a steam-cone and warmed very cautiously to about 80°, to avoid excess frothing. The reaction mixture was then poured into cold water, causing precipitation of crude 2,3-dinitrotoluene; 8.01 g. (82%), m.p. 50–53°. Repeated recrystallization from 95% ethanol was required to raise the m.p. to 59.5–60°.[10] The identity of the product was checked by oxidizing it to 2,3-dinitrobenzoic acid, m.p. 201°.[12]

o-Phenanthrenequinone was Eastman Kodak Co., white label. The sulfuric acid was reagent grade. The fuming nitric acid (Merck) was treated with urea to remove oxides of nitrogen and stored under refrigeration. The acids were standardized by titration.

Apparatus.—The nitration apparatus was the same used in the nitration of *p*-nitrotoluene.[3]

Radioassays were made as described previously.[2] Samples of about 50-mg. size were assayed.

Nitration of *o*-Nitrotoluene. Run 1.[13]—In the nitration flask was placed 2.01 g. of *o*-nitrotoluene-1-C^{14} (4.90 μc./mmole) and 1.94 g. of 90.0% sulfuric acid. The flask was then placed in the water-bath at 65° and the contents were allowed to come to bath temperature. In a separate flask were mixed 1.94 g. of 90.0% sulfuric acid and 1.12 g. of 82.0% nitric acid[3] (the amount of nitric acid used was the theoretical amount). The mixed acids were warmed to bath

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[5] United States Rubber Co., Joliet Arsenal–Kankakee Unit, "Standard Operating Procedure for TNT Manufacture," Joliet, Ill., Sec. V, p. 255; Sec. VI, p. 291.

[6] Melting points were determined with calibrated Anschütz thermometers in a Hershberg-type apparatus. Boiling points are uncorrected.

[7] R. Dreisbach and R. Martin, *Ind. Eng. Chem.*, **41**, 2875 (1949).

[8] R. M. Roberts and S. G. Panayides, *J. Org. Chem.*, **23**, 1080 (1958).

[9] E. Nolting and A. Collin, *Ber.*, **17**, 263 (1884).

[10] H. J. Page and B. R. Heasman, *J. Chem. Soc.*, 123, 3235 (1923).

[11] The presence of 2,3-dinitroaceto-*p*-toluidide (resulting from incomplete hydrolysis in the preceding step) is not undesirable; in fact, the separate hydrolysis step may be unnecessary.

[12] O. Brady, J. Day and P. Allam, *ibid.*, 981 (1928).

[13] Although only the experiments on radioactive materials are described, each step of the procedure was pre-tested thoroughly using ordinary materials.

temperature and added dropwise to the stirred *o*-nitrotoluene–sulfuric acid mixture during 6 minutes, while the temperature of the reaction mixture rose to about 70°. The reaction mixture was stirred an additional 16 minutes and then poured into 200 ml. of chipped ice and water. The precipitated crude dinitrotoluene was collected on a filter and dried; 2.51 g. To remove traces of occluded acids, it was dissolved in warm 95% ethanol and reprecipitated by the addition of excess cold 5% sulfuric acid solution; 2.48 g. (93%) of material was recovered, m.p. 45–50°. A 2.202-g. sample of this material was mixed with 2.024 g. of pure 2,3-dinitrotoluene, along with 8.4 g. of powdered iron and 7.1 ml. of 50% ethanol, and reduction was carried out by the addition of 0.8 ml. of concd. hydrochloric acid in 2.1 ml. of 50% ethanol, as described previously.[3] The toluenediamine sulfates were precipitated with 0.65 ml. of concd. sulfuric acid, collected on a filter and washed with ethanol; 4.21 g. (80%), m.p. 245–247°.

6-Methyl-1,2;3,4-dibenzophenazine was prepared by dissolving a 0.99-g. sample of the diamine sulfate in 48 ml. of a mixture of water and methanol (equal volumes) and adding this solution to a solution of 0.99 g. of *o*-phenanthrenequinone in 50 ml. of glacial acetic acid at 65°.[3] The crude phenazine which separated was, after cooling, collected on a filter, washed with methanol and dried; 0.93 g., m.p. 170–172°. One recrystallization from benzene (with *ca.* 40% loss of material) gave straw-colored crystals melting at 227–228°, and further recrystallization did not raise the m.p.

A sample of 6-methyl-1,2;3,4-dibenzophenazine prepared from pure 2,3-dinitrotoluene had the same properties.

Anal.[14] Calcd. for $C_{21}H_{14}N_2$: C, 85.69; H, 4.79; N, 9.52. Found: C, 85.62; H, 4.74; N, 9.56.

The phenazine from the isotope dilution experiment was radioassayed, recrystallized from benzene and reassayed. This was repeated until the radioassays were constant, within experimental error. The results are given in Table I.

Run 2.—The amounts of reactants are given in Table I. The sulfuric acid was divided between the *o*-nitrotoluene and the nitrating mixture as in run 1. The amount of nitric acid was 10% in excess of the theoretical; otherwise the experiment was identical to run 1. The yield of crude dinitrotoluenes was 96%. "Dilution," reduction and formation of the phenazine were carried out as before. Results of radioassays of the phenazine are given in Table I.

Run 3.—Amounts of reactants are given in Table I. Owing to the deficiency of nitric acid and, possibly, to the presence of additional water in this run, there was a considerable amount of unchanged *o*-nitrotoluene which had to be separated from the dinitrotoluenes. This was done by one recrystallization of the crude product from methanol. The recrystallized product, m.p. 42–50°, weighed 1.268 g.; the yield given in Table I is based on this material and ignores the unchanged *o*-nitrotoluene which was recovered from the fitrate. "Dilution" of the recrystallized product and further treatment were as in runs 1 and 2.

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[14] Clark Microanalytical Laboratory, Urbana, Ill.

AUSTIN 12, TEXAS

[CONTRIBUTION NO. 1033 FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF PITTSBURGH]

The Phenylation of Ketones by Reaction with Phenyl Halides and Alkali Amides[1]

BY WILLIAM W. LEAKE[2] AND ROBERT LEVINE

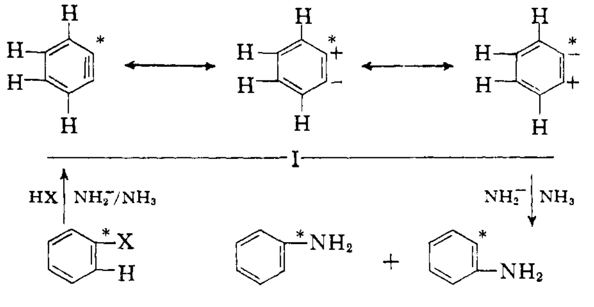
RECEIVED AUGUST 20, 1958

Four dialkyl ketones and one alkyl aryl ketone have been phenylated in fair to good yields by reaction with bromobenzene and excess sodium amide in liquid ammonia solution. In addition to the phenylated ketones, smaller amounts of aniline and diphenylamine are also formed. The products are believed to be formed from the addition of the ketone anions, amide ion and the anion of aniline to benzyne, the dehydrohalogenated derivative of bromobenzene.

In 1936, Bergstrom, *et al.*,[3] reported that the reactions of chloro-, bromo- and iodobenzene with excess potassium amide in liquid ammonia give mixtures of aniline, diphenylamine, triphenylamine and *p*-aminobiphenyl.

However, it was not until recently[4,5] that Roberts, *et al.*, elegantly demonstrated that the reactions of halobenzenes with alkali amides in liquid ammonia probably proceed by an elimination–addition mechanism which involves the transitory existence of an electrically neutral benzyne intermediate I. Thus, these workers found that the reactions of chloro- and iodobenzene-1-^{14}C gave essentially equal amounts of aniline-1-^{14}C and aniline-2-^{14}C.

Although alkali metal derivatives of ketones can be alkylated[6] by reaction with alkyl halides and acylated[7] by reaction with esters to give, respectively, high yields of the homologous ketones and *β*-diketones, the direct phenylation of these metallic derivatives by reaction with phenyl halides had apparently not been effected prior to the present study. Since the interaction of alkali amides with halobenzenes to give aniline (and its phenylated derivatives) may be regarded as involving the phenylation of the anion of ammonia, *i.e.*, amide ion, it was of interest to determine whether other anions, *e.g.*, ketone anions, could be phenylated.



Orienting experiments were performed with diethyl ketone. In Table I it may be seen that the interaction of the anion of this ketone (one equivalent), fluorobenzene (one equivalent) and one equivalent in excess of lithium or sodium amide (runs 1 and 2) gave only recovered starting materials.

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[1] For a preliminary communication on part of this work, see W. W. Leake and R. Levine, *Chemistry & Industry*, 1160 (1955).

[2] Monsanto Chemical Company Research Fellow.

[3] F. W. Bergstrom, R. E. Wright, C. Chandler and W. A. Gilkey, *J. Org. Chem.*, **1**, 170 (1936).

[4] J. D. Roberts, H. E. Simmons, Jr., L. A. Carlsmith and C. W. Vaughan, THIS JOURNAL, **75**, 3290 (1953).

[5] J. D. Roberts, D. A. Semenow, H. E. Simmons, Jr., and L. A. Carlsmith, *ibid.*, **78**, 601 (1956).

[6] For pertinent references, see R. Levine and W. C. Fernelius, *Chem. Revs.*, **54**, 498 (1954).

[7] R. Levine and W. C. Fernelius, *ibid.*, pp. 490–497.