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CATALYTIC REDUCTION OF NITROANILINE AND PARAPHENYLENEDIAMINE IN THE PRESENCE OF ALDEHYDES AND KETONES¹

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RECEIVED JULY 28, 1931

PUBLISHED DECEMBER 10, 1931

It has recently been found that condensation takes place between aldehydes and ketones with *p*-nitro- or nitrosophenols during catalytic reduction at room temperature.²

Due to the many similarities between the amino group and the hydroxy group it seemed likely that a similar condensation would take place between *p*-nitroaniline and aldehydes and ketones. However, it was found that the reaction followed a somewhat different course.

When a solution of *p*-nitroaniline in acetone was catalytically reduced at room temperature in the presence of a platinum catalyst (Adams'), N,N'-bis-isopropyl-*p*-phenylenediamine was formed. Various derivatives of this compound were prepared including the dinitroso derivative, the dibenzoyl and diacetyl derivatives and the di-hydrochloride. Similarly, N,N'-bis-*sec*-butylamino-*p*-phenylenediamine and N,N'-bis-amy1-3-amino-*p*-phenylenediamine were obtained by the catalytic reduction of solutions of *p*-nitroaniline in methyl ethyl ketone and diethyl ketone, respectively.

It was also found that N,N'-bis-isopropyl-*p*-phenylenediamine could be formed by the catalytic reduction at room temperature of a mixture of *p*-phenylenediamine and acetone.

On the other hand, it was found that only N,N'-bis-benzoyl-*m*-phenylenediamine³ could be obtained by benzoylation of the reduction product of a solution of *m*-nitroaniline in acetone at room temperature.

No N,N'-bis-isopropyl-*o*-phenylenediamine was formed by the catalytic reduction at room temperature of a solution of *o*-nitroaniline in acetone. Benzoylation of the products of reduction gave three compounds, N,N'-bis-benzoyl-*o*-phenylenediamine,⁴ N,N'-bis-isopropyl-N-benzoyl-*o*-phenylenediamine, *o*-C₆H₅CON(C₃H₇)C₆H₄NHCOC₆H₅ and probably N-isopropyl-N'-benzoyl-*o*-phenylenediamine, *o*-C₆H₅CONHC₆H₄NHC₃H₇. The latter compound may have been the isomeric N-isopropyl-N-benzoyl-*o*-phenylenediamine but consideration of the relative activity of primary amines as compared with secondary amines toward acid chlorides makes this rather unlikely.

The mechanism of the condensation between these nitroanilines and

¹ Presented in part at the Spring Meeting of the American Chemical Society, at Indianapolis, Indiana, March, 1931.

² Major, *THIS JOURNAL*, **53**, 1901 (1931).

³ Ruhemann, *Ber.*, **14**, 2652 (1881).

⁴ Hinsberg and Udranszky, *Ann.*, **254**, 254 (1889).

ketones during reduction must be similar to that between nitrophenol and ketones during the same process. *p*-Nitroaniline resembles *p*-nitrophenol in its greater readiness to condense with ketones during reduction than its ortho or meta isomers.² For some reason, unknown at the present time, the amino groups in *p*-nitroaniline and in *p*-phenylenediamine are also more active in these reactions than most amino groups including that in *p*-aminophenol.

Formation of *N*-isopropyl-*o*-phenylenediamine during the catalytic reduction of *o*-nitroaniline and acetone suggests that possibly some intermediate group, probably the hydroxylamine radical, is formed during the reduction of the nitro group which is more reactive toward ketones than is the amino group.⁵

In contrast to the formation of *N,N'*-bis-*sec.*-alkyl-*p*-phenylenediamines when a mixture of *p*-nitroaniline and an aliphatic ketone was reduced, it was found that *N,N,N',N'*-bis-tetrabenzyl-*p*-phenylenediamine⁶ was formed when a mixture of *p*-nitroaniline and benzaldehyde was catalytically reduced.

This difference between the condensation between *p*-nitroaniline with aldehydes and that with ketones during reduction is very similar to the difference between the condensation of aldehydes and ketones with *p*-nitrophenol during the same reaction.² The condensation of two molecules of benzaldehyde with each nitrogen atom was probably due to the much greater activity of aldehydes as compared with ketones.

Experimental Part

Reduction of Solutions of Nitroanilines and *p*-Phenylenediamine with Ketones.—A solution of 0.1 of a mole of the nitroaniline or *p*-phenylenediamine in 0.7–0.8 mole of the ketone was catalytically reduced by hydrogen in a Burgess–Parr Reduction Apparatus⁷ at room temperature. The catalyst used for the hydrogenation was in every case 0.2 g. of platinum oxide.⁸ After the theoretical amount of hydrogen had been absorbed and the solution had become practically colorless the volatile solvent was distilled *in vacuo*. The residue was treated in three different ways which will be discussed below.⁹

⁵ Major, *THIS JOURNAL*, **53**, 1903, 2803 (1931). A reviewer writes, "An intermediate hydroxylamine radical is postulated in this case but does not seem to be necessary in the others. It seems to me that this is an unnecessary differentiation. The ortho and para compounds would be expected to behave alike except that steric influences would come more strongly into play in the ortho compounds. It is rather reasonable to expect the monosubstitution product from the ortho isomers and the disubstitution product from the *p*-isomers. The meta isomer should be different."

⁶ Meldola and Coste, *J. Chem. Soc.*, **55**, 600 (1889).

⁷ Manufactured by the Burgess–Parr Company, Moline, Ill.

⁸ Adams and Shriner, *THIS JOURNAL*, **45**, 2171 (1923).

⁹ The reaction mixture obtained by the reduction of a solution of *p*-nitroaniline in diethyl ketone was not concentrated. Instead, it was extracted with dilute hydrochloric acid. The residue obtained by evaporation of the mixture obtained by the

Benzoylation of the Residue.—After a portion of the residue had been mixed with ice water, it was shaken with an excess of a mixture of benzoyl chloride and sodium hydroxide for ten minutes. The excess of benzoyl chloride was hydrolyzed by slightly warming the mixture and shaking it until the odor of benzoyl chloride had practically disappeared. The alkaline mixture was filtered. The precipitate was washed with a moderate amount of alcohol. The portion which remained undissolved consisted of *N,N'*-dibenzoylphenylenediamine.¹⁰

TABLE I
N,N'-DIBENZOYLPHENYLENEDIAMINES

Nitroaniline	Mixture reduced Ketone	Recrystallized from	Yield, ^d %	M. p. °C.
Para	Dimethyl	Alcohol	Minute	> 250 ^a
Para	Diethyl	.....	70	> 250 ^a
Meta	Dimethyl	Glacial acetic acid	50	240 ^b
Ortho	Dimethyl	Glacial acetic acid	35	> 275 ^c

Formula	Carbon, %		Hydrogen, %		
	Calcd.	Found	Calcd.	Found	
C ₂₀ H ₁₆ O ₂ N ₂	..	..	..	..
C ₂₀ H ₁₆ O ₂ N ₂	75.8	75.34	5.12	5.31	
C ₂₀ H ₁₆ O ₂ N ₂	75.8	75.52	5.12	4.90	
C ₂₀ H ₁₆ O ₂ N ₂	75.8	75.43	5.12	5.03	5.37

^a Hinsberg and Udranszky, *Ann.*, **254**, 254 (1889), state that the m. p. of *N,N'*-dibenzoyl-*p*-phenylenediamine is over 300° and that it is relatively insoluble in acetic acid, alcohol, ether and water.

^b Ruhemann, *Ber.*, **14**, 2652 (1881), gives 240° as the m. p. of *N,N'*-dibenzoyl-*m*-phenylenediamine and states that it is difficultly soluble in alcohol.

^c Hinsberg and Udranszky, *Ann.*, **254**, 254 (1889), state that the m. p. of *N,N'*-dibenzoyl-*o*-phenylenediamine is over 280° and that it is very slightly soluble in most organic solvents.

^d All yields recorded in this table as well as those in other tables indicate the percentage obtained of the theoretical amount of the compound that would have been obtained if the reaction had followed such a course that it gave a maximum yield of it to the exclusion of other related compounds.

Water was added to the above-mentioned alcoholic extract. The precipitate that was obtained was then fractionated as described in Table II. As shown in Table II, *N,N'*-bis-*sec*-alkyl-*N,N'*-bis-benzoyl-*p*-phenylenediamines were isolated from the reduction products of mixtures of dialkyl ketones and *p*-nitroaniline, while *N,N'*-bis-isopropyl-*N*-benzoyl-*o*-phenylenediamine and probably *N*-isopropyl-*N'*-benzoyl-*o*-phenylenediamine were obtained from the reduction products of a mixture of *o*-nitroaniline and acetone.

reduction of a solution of *o*-nitroaniline in acetone was dissolved in dilute hydrochloric acid and filtered. These acid solutions were used for the various reactions studied in place of the residues obtained by concentration of the reduction product as in the other cases.

¹⁰ The solid which was obtained by the benzoylation of the reduction product of a solution of *p*-nitroaniline in methyl ethyl ketone was quite oily. It was extracted with ether instead of alcohol. A small amount of unidentified solid which may have been *N,N'*-dibenzoyl-*p*-phenylenediamine did not dissolve. Ether was evaporated from the filtrate of this. A solid residue remained which was recrystallized from alcohol as shown in Table II.

TABLE II
 ANALYSES OF THE ALCOHOLIC EXTRACTS

Nitroaniline	Mixture reduced		Recrystallized from			Yield, %	M. p., °C.		
	Base	Ketone	from						
Para	Dimethyl		Toluene			..	148-160		
Para	Methyl ethyl		Alcohol			70	159-160		
Para	Diethyl		Propanol-2, Benzine			20	132 ^a		
Meta	Dimethyl		.....			Negligible	.....	
Ortho	Dimethyl		.....^b			5	147-148 ^c		
Ortho	Dimethyl		.....^d			5	159-160		
Formula	Carbon, %		Hydrogen, %			Nitrogen, %			
	Calcd.	Found	Calcd.	Found	Found	Calcd.	Found	Found	
Mixture	..	..	..	..	..	..	..	..
C ₂₈ H ₃₂ O ₂ N ₂	78.5	78.41	78.46	7.52	7.38	7.50	..	..
C ₃₀ H ₃₆ O ₂ N ₂	78.9	79.07	79.20	7.96	7.82	7.95	..	..
.....	
C ₂₃ H ₂₂ O ₂ N ₂	77.1	77.34	77.10	6.19	6.27	5.94	7.82	7.96	
C ₁₆ H ₁₈ ON ₂	75.6	..	..	7.12	..	..	11.01	11.23	

^a Appeared in the form of plates.

^b Recrystallized from alcohol; solid extracted with hot toluene in which N,N'-dibenzoyl-*o*-phenylenediamine is insoluble; recrystallized from alcohol.

^c Appeared in the form of prisms.

^d Water was added to the alcoholic filtrate from the second recrystallization from alcohol mentioned in note *b*. The precipitate which formed was extracted with dilute hydrochloric acid. Alkali precipitated this solid, m. p. 159-160°, from the acid extract.

Treatment with Nitrous Acid of the Residue Left by Concentration of the Reduction Mixture.—Another portion of the residue was dissolved in an excess of cold dilute hydrochloric acid. A cold dilute solution of the calculated amount of sodium nitrite in water was slowly added to this solution. After the reaction mixture had stood for fifteen minutes in an ice-bath the white solid precipitate was filtered. All of the nitroso derivatives, except N,N'-bis-amyl-3-N,N'-bis-nitroso-*p*-phenylenediamine, were at first purified by dissolving them in glacial acetic acid, filtering the solutions and reprecipitating the solids with water.

 TABLE III
 N,N'-BIS-*sec.*-ALKYL-N,N'-BIS-NITROSO-PHENYLENEDIAMINES

Nitroaniline	Mixture reduced		Recrystallized from			Yield, %	M. p., °C.		
	Base	Ketone	from						
<i>p</i> -Nitroaniline	Dimethyl		Alcohol			80	110-111		
<i>p</i> -Phenylenediamine	Dimethyl		Alcohol			40	110-111		
<i>p</i> -Nitroaniline	Methyl ethyl		Benzine			10	62		
<i>p</i> -Nitroaniline	Diethyl		Benzine			20	96		
<i>m</i> -Nitroaniline	Dimethyl		.....			Negligible	..		
<i>o</i> -Nitroaniline	Dimethyl		.....			Negligible	..		
Formula	Carbon, %		Hydrogen, %			Nitrogen, %			
	Calcd.	Found	Calcd.	Found	Found	Calcd.	Found	Found	
C ₁₂ H ₁₈ O ₂ N ₄	57.5	57.96	58.07	7.27	7.62	7.54	22.35	21.85	
C ₁₂ H ₁₈ O ₂ N ₄	..	..	..	..	..	..	22.35	21.89	
C ₁₄ H ₂₂ O ₂ N ₄	60.4	60.59	60.66	7.92	8.26	8.15	..	..
C ₁₆ H ₂₆ O ₂ N ₄	62.75	62.86	62.89	8.56	8.44	8.20	..	..

N,N'-Bis-*sec.*-alkyl-*p*-phenylenediamine Hydrochlorides.—Concentrated hydrochloric acid was added to N,N'-bis-nitroso-N,N'-bis-*sec.*-alkyl-*p*-phenylenediamine.

Fumes of the oxides of nitrogen were evolved and the solid dissolved. This solution was warmed for a short time on a steam-bath and then evaporated to dryness at room temperature *in vacuo*. The solid residue was dissolved in warm methanol and reprecipitated by the addition of dry ether. The hydrochlorides were white solids which turned pink when exposed to air and light. They decomposed without melting when they were heated.

Anal. Calcd. for p -(C₃H₇NH)₂C₆H₄·2HCl: N, 10.56; Cl, 26.77. Found: N, 10.39, 10.40; Cl, 26.55. Calcd. for p -(C₄H₉NH)₂C₆H₄·2HCl: C, 57.4; H, 8.95. Found: C, 57.06; H, 8.98.

N,N'-Bis-isopropyl-*p*-phenylenediamine.—A solution of sodium carbonate was added to a solution of N,N'-bis-isopropyl-*p*-phenylenediamine di-hydrochloride in water. A white solid precipitated which rapidly turned pink in the presence of air and light. It was recrystallized from petroleum ether. White plate-like crystals were obtained; m. p. 53°.

Anal. Calcd. for C₁₂H₂₆N₂: N, 14.57. Found: N, 14.58, 14.69.

N,N',-Bis-isopropyl-N,N'-bis-benzoyl-*p*-phenylenediamine.—A suspension of N, N'-bis-isopropyl-*p*-phenylenediamine in water was benzoylated with a mixture of benzoyl chloride and sodium hydroxide. A white solid was obtained which was recrystallized from 50% ethyl alcohol. Fine needle-like crystals were obtained; m. p. 180–181°.

Anal. Calcd. for C₂₈H₂₈O₂N₂: C, 77.9; H, 6.99; N, 7.00; mol. wt., 400. Found: C, 78.17, 78.29; H, 7.48, 7.40; N, 7.17, 7.19; mol. wt. (Menzies-Wright Method),¹¹ 384, 380.

N,N',-Bis-isopropyl-N,N'-bis-acetyl-*p*-phenylenediamine.—A solution of N,N'-bis-isopropyl-*p*-phenylenediamine in acetic anhydride was heated at 100° for three hours. In order to decompose excess of acetic anhydride, water was added and the solution was warmed for a short time. The excess of acetic acid was neutralized with sodium hydroxide. The precipitate which formed was removed by filtration. The filtrate was extracted with ether, the ether evaporated and the solid residue added to the original precipitate. This combined solid was then recrystallized from a mixture of benzene and petroleum ether. A white solid was obtained; m. p. 180°. It was somewhat soluble in water, no more soluble in acids or alkalis than in water, and readily soluble in most organic solvents.

Anal. Calcd. for C₁₆H₂₄O₂N₂: C, 69.5; H, 8.76; N, 10.12. Found: C, 68.88, 69.11; H, 8.61, 8.59; N, 10.09, 10.04.

N,N'-Bis-benzal-*p*-phenylenediamine.—The calculated amount of benzaldehyde was added to a solution of *p*-phenylenediamine in acetic acid. The mixture was shaken for five minutes. A crystalline solid separated. It was recrystallized from alcohol and appeared in the form of leaves; m. p. 140°.¹²

Anal. Calcd. for C₂₀H₁₈N₂: C, 84.6; H, 5.64. Found: C, 84.72, 84.75; H, 5.83, 6.01.

Treatment of the Residue, Left after Concentration of the Mixture Obtained by the Reduction of *p*-Nitroaniline and Acetone, with Acetic Acid and Benzaldehyde.—The residue left after concentration of the reduction product of 0.5 mole of *p*-nitroaniline and four moles of acetone was dissolved in dilute acetic acid. This solution was shaken for ten minutes with an excess of benzaldehyde in order to remove *p*-phenylenediamine. The mixture was then extracted three times with ether and the aqueous solution was made

¹¹ Menzies and Wright, Jr., THIS JOURNAL, 43, 2314 (1921).

¹² Ladenburg, *Ber.*, 11, 599 (1878), gives 138–140° as the m. p. of N,N'-dibenzal-*p*-phenylenediamine which has been crystallized from alcohol.

slightly alkaline with sodium carbonate. An oily solid precipitated. It was separated and twice distilled; b. p. 281–283°; yield, 55%. It solidified to a light yellow solid which was recrystallized from benzine; m. p. 53°. It oxidized rather readily in the presence of air and light and gave colored oxidation products.

Anal. Calcd. for $C_{12}H_{20}N_2$: C, 74.9; H, 10.47. Found: C, 75.09, 75.04; H, 10.00, 10.26.

A small amount of this solid was dissolved in cold dilute hydrochloric acid and then treated with sodium nitrite. The precipitate which was obtained was dissolved in glacial acetic acid and reprecipitated with water; m. p. 110–111°. A mixture of this compound with pure *N,N'*-bis-isopropyl-*N,N'*-bis-nitroso-*p*-phenylenediamine also melted at 110–111°.

N,N,N',N'-Tetrabenzyl-*p*-phenylenediamine.—A solution of 0.5 mole of *p*-nitroaniline, 0.3 mole of benzaldehyde and 50 cc. of methyl alcohol was reduced by hydrogen in the previously described manner.

As the reduction proceeded a white solid precipitated. When reduction ceased this solid was removed by filtration. It was recrystallized from acetone and then from *n*-butyl alcohol. White needle-like crystals were obtained; m. p. 152°. The substance was insoluble in water, slightly soluble in dilute acids and in methanol, and readily soluble in 1,4-dioxane. More of the same solid was obtained from the filtrate from the original reaction mixture by the addition of chloroform as a diluent. This new solution was washed with a solution of sodium bisulfite in water in order to remove benzaldehyde and with a solution of sodium carbonate in water to remove acids and then evaporated on a steam-bath. The residue was washed with methanol and recrystallized from *n*-butyl alcohol. The total yield was 50%.

Anal. Calcd. for $C_{34}H_{32}N_2$: N, 6.00. Found: N, 6.27, 6.12.

The author takes pleasure in acknowledging his indebtedness to Mr. Douglass F. Hayman, who made nearly all of the analyses recorded in this paper.

Summary

1. It has been shown that *N,N'*-bis-*sec*-alkyl-*p*-phenylenediamines, accompanied generally by *p*-phenylenediamine, are formed by the catalytic reduction at room temperature of mixtures of *p*-nitroaniline with various aliphatic ketones.

2. *N,N'*-Bis-isopropyl-*N,N'*-bis-nitroso-*p*-phenylenediamine has been formed by the action of nitrous acid on the reduction product of a solution of *p*-phenylenediamine in acetone.

3. Benzoylation of the reduction mixture obtained by the reduction of a solution of *o*-nitroaniline in acetone gave *N,N'*-bis-benzoyl-*o*-phenylenediamine, *N,N'*-bis-benzoyl-*N*-isopropyl-*o*-phenylenediamine and probably *N*-benzoyl-*N'*-isopropyl-*o*-phenylenediamine.

4. Evidence for the formation of only *m*-phenylenediamine during the reduction at room temperature of a solution of *m*-nitroaniline in acetone was obtained.

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