Chloroazobenzenes: Studies on Syntheses

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Dedicated to Prof. Dr. OTTO NEUNHOEFFER on his 65-th birthday

Thirteen chloroazobenzenes were synthesized by reduction of chloronitrobenzenes or by oxidation of their corresponding chloroanilines. Five of the compounds have not been previously prepared or described. Reduction by LiAlH₄ was the method of choice, but it proved inadequate for the syntheses of chloroazobenzenes from o-chloronitrobenzenes. This reaction eliminated chlorine if ortho to the aniline nitrogen and an additional chlorine atom; in the other cases steric hindrance of azo bond formation resulted in low yields. Chromatographic systems for the separation of pure chloroazobenzenes from the crude reaction mixtures were developed and are described.

Results and Discussion

The synthesis of chloroazobenzenes depends in part on the starting material. Some methods are based on oxidation of the amino group of chloroanilines and others require the reduction of the nitro group of chloronitrobenzenes. EDWARD ¹ oxidized primary aromatic amines to azobenzenes using benzoylperoxide (yield 5—20%). The oxidant used by WHEELER and GONZALES ² was MnO₂ (yield 5 to 90%); and they observed that halogenoanilines substituted in the p-position were especially reactive in the order F > Cl > Br > I. DANIELS and SAUNDERS ³ produced 4,4’-dichloroazobenzene (yield 20%) enzymatically in a system that contained p-chloroaniline, H₂O₂ and horseradish peroxidase in acetate buffer at pH 4.6. KREMER and BENDICH ⁴ reduced chloronitrobenzenes to chloroazobenzenes (yield 40—80%) and other products with monoethanolamine in the presence of anhydrous Na₂CO₃, but reduction with LiAlH₄ in ether solution as described by CORBETT and HOLT ⁵ proved to be a superior method for the synthesis of chloroazobenzenes (yield up to 95%). However, present results indicate that this method is not suitable for production of chloroazobenzenes from o-chloronitrobenzenes. Chlorine that was ortho to the nitro group and an additional chlorine atom, was eliminated in the course of the reaction. Chlorine ortho to the nitro group and without an adjacent chlorine atom was not eliminated, but the yield of dichloroazobenzene was low (<5%). Nitrobenzenes with chlorine substituents in meta and/or para position produced azo compounds in yields as great as 95 per cent. These differences can be explained only by steric hindrance. Apparently, a halogen atom ortho to an amino or nitro group interferes sterically with the formation of an azo bond. DAINS and KENYON ⁷ also noted halogen losses when substituted aromatic nitro and nitroso compounds were reduced to aoxobenzenes with sodium alcoholates. Losses amounted to as much as 62 per cent. They were not a function of location of the halogen but depended on the nature of the alcohol used.

Some of the reactions yielded quantities of tar, so that purification of chloroazobenzenes presented difficulties. The physical properties of chloroazobenzenes, chlorohydrazobenzenes and chloroazoxybenzenes are very similar, but they were separated by chromatography on neutral aluminum oxide (Woelm, Act. I) columns that were developed by nonpolar solvents (ligroine, benzene, toluene). Effluents were fractionated and examined by gas chromatography for di-, tetra- and hexachloroazobenzenes (DCAB, TCAB, HCAB). As a final step in the purification of all azobenzenes **, the compounds were recrystallized from acetone and their homogeneity was established by thin layer and gas chromatography.

The azobenzenes synthesized are listed in Table I. Compounds 2, 3, 4, 6, 7, 9, 10, and 12 were produced from their corresponding chloronitrobenzenes. The UV- and IR-spectra indicated that all compounds were trans-isomers. New compounds. a See reference 6. b For UV and IR characterization see reference 11.

Table I. Some azobenzenes a and their melting points. a, b The UV- and IR-spectra indicated that all compounds were trans-isomers. New compounds. c See reference 6. d For reference see Table I.

Table II. Yields of azobenzenes a, a In per cent of the theoretical yields. b For reference see Table I.

**Experimental Section**

Gas chromatography. A F & M Model 700 gas chromatograph with flame ionization detection aided the separation and purification of chloroazobenzenes from the crude synthetic products. Columns: 1.8 m long, 3 mm o.d. stainless steel, packed with 5% UC-W98 on Chromosorb W. Carrier: helium, 30 cc/min., oven temperature 250 °C. Retention times of azobenzenes: azobenzene 20 sec., DCAB 55 – 65 sec., TCAB 120 to 155 sec., and HCAB 270 – 310 sec.

Thin-layer chromatography for the separation of DCAB, TCAB and HCAB was performed on MN-Polygram® Cel 300 AC-10 sheets (Brinkman Instruments, Inc., Westbury, N.Y.) developed with glacial acetic acid:acetone (or pyridine):methanol = 10:20:70 (v/v). Movement was in the order: Rf DCAB > Rf TCAB > Rf HCAB. For the separation of DCAB from TCAB and HCAB, the preferred solvent system was H2O: acetic:acetone (or pyridine):methanol = 20:20:60 (v/v) and movement was in the order: Rf DCAB > Rf TCAB > Rf HCAB. Compounds. Activated MnO2: 59.4 g MnCl2·4 H2O in 1000 ml H2O were mixed with 31.6 g KMnO4 in 2000 ml H2O and the pH of the mixture was made alkaline with KOH. The precipitated MnO2 was collected by filtration, washed with H2O, activated at 120 °C and stored in a desiccator until used.

2,2',3,3'-Tetrachloroazobenzene (5): 15 g NaOH were dissolved in 30 ml H2O. To this solution 10 g 2,3-dichloronitrobenzene, 100 ml methanol and 10 g zinc powder were added and the reaction mixture was refluxed for 16 hours. After cooling, it was acidified with HCl, diluted with H2O, and partitioned with ether. The ether extract was evaporated to dryness and the residue dissolved in ligroin (60 – 70 °C) and transferred to a 30 cm chromatographic column packed with neutral aluminium oxide (Woelm, Act. I). The column was eluted with ligroin and fractions of the effluent were examined by gas chromatography for the presence of 5. Fractions containing 5 were combined, dried by evaporation and the compound was recrystal-

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The azobenzenes synthesized are listed in Table I. Compounds 2, 3, 4, 6, 7, 9, 10, and 12 were produced from their corresponding chloronitrobenzenes. Dichloronitrobenzene with zinc powder in alkaline methanol. Compounds 11 and 13 were produced from their corresponding chloroanilines by oxidation with MnO2, using the method of Wheeler and Gonzales. The oxidation of 2,6-dichloroaniline with lead tetraacetate yielded compound 8. The chloroazobenzene yields obtained, and those reported by other authors, are summarized in Table II.

**Figures and Tables**

- Table I: Some azobenzenes and their melting points.
- Table II: Yields of azobenzenes.

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B. Dains and W. O. Kenyon, J. Amer. chem. Soc. 53, 2357 [1931].


Unsubstituted azobenzene (I) was purchased from K & K Laboratories, Inc., Plainview, N. J.
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lized from acetone. Red needles, mp: 204–205 °C. Yield: 5 per cent.

Anal. Calcd for C₁₂H₁₂N₂Cl₄: C 45.02; H 1.89; N 8.76; Cl 44.33. Found: C 45.09; H 1.85; N 8.91; Cl 44.23.

2,2′,6,6′-Tetrachloroazobenzene (9): 5 g 2,6-dichloroaniline and 15 g freshly prepared lead tetraacetate were reacted in the cold (ice bath) with stirring for 1 hour. The precipitate was collected by filtration and washed with benzene. The benzene washes were combined with the filtrate, the solution was treated with Na₂CO₃ and anhydrous Na₂SO₄ and refiltered. The benzene filtrate was evaporated to dryness, and the residue was dissolved in ligroin (60–70 °C) and purified by column chromatography as described for compound 5, with the addition of elution with benzene; the bulk of 9 was eluted by the benzene. The eluate was dried by evaporation, the residue was dissolved in toluol and rechromatographed on neutral aluminium oxide (Woelm, Act. I) column that was developed with toluol. Fractions of the eluate containing 9 were combined, evaporated to dryness and the compound was recrystallized from methanol and acetone. Green plates, mp: 128 °C. Yield: 5 per cent.

Anal. Calcd for C₁₂H₁₂N₂Cl₄: C 45.02; H 1.89; N 8.76; Cl 44.33. Found: C 45.09; H 1.84; N 8.84; Cl 44.48.

3,3′-Dichloro-4,4′-dimethylazobenzene (11): To 3.5 g 3-chloro-4-methylaniline dissolved in 150 ml benzene, 10.8 g activated MnO₂ were added. The reaction mixture was refluxed for 10 hours. The insoluble residue was collected by filtration, extracted with hot benzene, and the filtrate and washes were combined, concentrated by evaporation and compound 11 crystallized when cold acetone was added. Recrystallized from acetone. Orange needles, mp: 132–133 °C. Yield: 75 per cent.

Anal. Calcd for C₁₂H₁₂N₂Cl₄: C 45.02; H 4.33; N 10.03; Cl 25.41. Found: C 45.03; H 4.54; N 9.27; Cl 25.38.

2,2′,4,4′,5,5′-Hexachloroazobenzene (12): To an ice-cooled solution of 12 g 2,4,5-trichloronitrobenzene in 150 ml anhydrous ether, 6 g LiAlH₄ suspended in 150 ml of cold anhydrous ether were added dropwise with constant stirring. After 2 hours at room temperature, the reaction mixture was refluxed for 15 minutes and cooled. Excess LiAlH₄ was destroyed by the dropwise addition of H₂O, and the ether phase was separated and evaporated to dryness. The residue was dissolved in ligroin (60–70 °C) and transferred to a 30 cm neutral aluminium oxide column (Woelm, Act. I). The column was developed first with ligroin and then with benzene. Gas chromatographic analysis demonstrated that the benzene eluate contained the bulk of 12. This material was evaporated to dryness and the product was recrystallized from acetone. Orange needles, mp: 216–217 °C. Yield: 5 per cent.

Anal. Calcd for C₁₂H₁₂N₂Cl₄: C 37.04; H 1.04; N 7.21; Cl 54.71. Found: C 37.13; H 1.27; N 7.61; Cl 53.41.

2,2′,4,4′,6,6′-Hexachloroazobenzene (13): 4.9 g 2,4,6-trichloroaniline in 150 ml benzene were refluxed for 10 hours with 10.8 g activated MnO₂. The reaction product was purified by the procedures described for compound 11 and recrystallized from an ether-acetone mixture. Red-brown needles, mp: 193 °C. Yield: 20 per cent.

Anal. Calcd for C₁₂H₁₂N₂Cl₄: C 37.04; H 1.04; N 7.20; Cl 54.72. Found: C 37.04; H 1.04; N 7.20; Cl 54.38.

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