# CCLXVII.—*Halogen Derivatives of* o- *and* p-*Azophenol.*

By Louis Hunter and Ronald Sidney Barnes.

Previous attempts to obtain halogen derivatives of *o*- and *p*-azophenol (2 : 2′- and 4 : 4′-dihydroxyazobenzene) have resulted in the isolation of the tetrabromo-compounds (Weselsky and Benedikt, *Annalen*, 1879, **196**, 340) and of a trichloro-*o*-azophenol (Bohn and Heumann, *Ber.*, 1882, **15**, 1499). That the direct action of elementary halogens on these phenols is not entirely one of simple

substitution is shown by the fact that the latter authors isolated only *s*-trichlorophenol from the action of chlorine upon *p*-azophenol.

The present investigation was originally undertaken with a view to obtaining some of the higher chloro-derivatives of the azophenols, and later as a means of preparation of some substituted aminophenols. So well did these azophenols lend themselves to progressive halogenation that, with the exception of tribromo- and tri-iodo-*o*-azophenol, all the anticipated stages from the mono- to the tetra-halogen substitution products have been obtained, *viz.*, those possessing substituent halogen in positions ortho and para to the hydroxyl groups, although all the possible isomerides were not isolated. The chloroamine method of halogenation (Orton and King, J., 1911, **99**, 1185) was used throughout this investigation, toluene-*p*-sulphondichloroamide ("dichloramine-T") being employed (Bradfield, Cooper, and Orton, J., 1927, 2854; Bradfield, Orton, and Roberts, this vol., p. 782). The bromo-compounds described are the first to be prepared by the chloroamine method, thus bringing bromination into line with chlorination and iodination in this respect. The results amply illustrate the extreme delicacy of the chloroamine method.

The positions taken up in the azophenol molecules by the substituent halogen atoms were readily determined by reduction to the corresponding aminophenols, and it was thus found that *p*-azophenol yielded only the 3 : 3′- and not the 3 : 5-dihalogeno-derivative on dihalogenation, and that in the mono-substituted *o*-azophenols the halogen atom occupied the 5-position apparently to the exclusion of the 3-position.

Owing to its structure *p*-azophenol is more liable to oxidation than its *o*-isomeride, and instead of substitution iodinating agents cause partial oxidation to a quinhydrone-like complex,

$$O{:}C_6H_4{:}N{\cdot}N{:}C_6H_4{:}O,HO{\cdot}C_6H_4{\cdot}N{:}N{\cdot}C_6H_4{\cdot}OH,$$

which on further oxidation is transformed into *p*-quinoneazine, $O{:}C_6H_4{:}N{\cdot}N{:}C_6H_4{:}O$. Iodination of *p*-azophenol or of its derivatives by all the usual methods was unsuccessful, though *o*-azophenol was iodinated normally.

The action of more than four equivalents of halogenating agent led in the chlorination of *p*-azophenol to the production of complex chloroquinones of a type similar to *p*-quinoneazine which have not been further investigated, but in all other cases yielded the tetra-substituted compound.

## EXPERIMENTAL.

*o*- and *p*-Azophenols were prepared by Willstätter's modification (*Ber.*, 1906, **39**, 3492) of Weselsky and Benedikt's method (*loc. cit.*). As pointed out by Robertson (J., 1913, **103**, 1472), *p*-azophenol

monohydrate obtained by this method is the *trans*-form; and the compounds described in the present work retain the *trans*-configuration, since tetra-substituted derivatives are readily obtained. Similar arguments apply to *o*-azophenol, although no second modification of this compound has yet been obtained.

In the following account the typical procedure is described in detail for a chlorination, a bromination, and an iodination; all other halogenations are similar unless special precautions are mentioned. In most preparations, and more particularly in iodinations, acetic acid stable to halogens (Orton and Bradfield, J., 1924, **125**, 960) was used as a solvent.

*Derivatives of* p-*Azophenol* (4 : 4′-*Dihydroxyazobenzene*).—3-*Chloro*-4 : 4′-*dihydroxyazobenzene*. *p*-Azophenol (1·5 g.) was dissolved in glacial acetic acid (600 c.c.) and mixed with a solution of dichloramine-T (0·82 g.) in acetic acid (30 c.c.). A few drops of dilute hydrochloric acid were added, and the mixture was kept in the dark for about ½ hour; chlorination was then complete as shown by the absence of free chlorine. Since dilution with 1 l. of water failed to precipitate the product, caustic soda was added until the mixture was almost neutral. The brown deposit formed was washed, dried, and crystallised from 20% aqueous alcohol, giving fine red granules (1·1 g.), m. p. 184° (Found : Cl, 14·7. $C_{12}H_9O_2N_2Cl$ requires Cl, 14·3%).

The constitution of the compound was fixed by reduction with stannous chloride and hydrochloric acid, and isolation of a mixture of aminophenols; moreover, on further chlorination the substance was transformed into 3 : 3′-dichloro-4 : 4′-dihydroxyazobenzene, the constitution of which has been proved.

3-*Chloro*-4 : 4′-*diacetoxyazobenzene* crystallised from alcohol in fine orange needles, m. p. 160—161°, and the *dibenzoyl* derivative in yellow needles, m. p. 158—159°.

3 : 3′-*Dichloro*-4 : 4′-*dihydroxyazobenzene* formed rust-red needles, m. p. 195°, from alcohol (Found : Cl, 24·7. $C_{12}H_8O_2N_2Cl_2$ requires Cl, 25·0%). Reduction with stannous chloride yielded *o*-chloro-*p*-aminophenol. The *diacetyl* derivative crystallised from alcohol in fine orange needles, m. p. 199°, and the *dibenzoyl* derivative from benzene in bright yellow needles, m. p. 226°.

3 : 5 : 3′-*Trichloro*-4 : 4′-*dihydroxyazobenzene* formed yellow-brown needles, m. p. 172°, from 50% aqueous alcohol (Found : Cl, 33·4. $C_{12}H_7O_2N_2Cl_3$ requires Cl, 33·5%). Reduction with stannous chloride and hydrochloric acid gave a mixture of the hydrochlorides of a mono- and a di-chloro-*p*-aminophenol, and on further chlorination the compound yielded 3 : 5 : 3′ : 5′-tetrachloro-4 : 4′-dihydroxyazobenzene, of known constitution.

The *diacetyl* derivative crystallised from benzene in fine orange needles, m. p. 207—208°, and the *dibenzoyl* derivative in yellow prisms, m. p. 189°.

3 : 5 : 3′ : 5′-*Tetrachloro*-4 : 4′-*dihydroxyazobenzene* was isolated as the hexahydrate, which formed fine yellow needles, m. p. 225°, from aqueous acetic acid (Found : $H_2O$, 22·9. $C_{12}H_6O_2N_2Cl_4,6H_2O$ requires $H_2O$, 23·4%). The anhydrous substance had m. p. 240° (Found : Cl, 40·4. $C_{12}H_6O_2N_2Cl_4$ requires Cl, 40·3%). Its product of reduction was 2 : 6-dichloro-4-aminophenol, m. p. 165°. Its *diacetyl* derivative formed yellow needles, m. p. 240°, from alcohol, and the *dibenzoyl* derivative orange needles, m. p. 244°, from benzene.

3-*Bromo*-4 : 4′-*dihydroxyazobenzene*. A solution of *p*-azophenol (2 g.) in stable acetic acid (600 c.c.) was treated with a solution of the brominating agent prepared by mixing solutions of dichloramine-T (1·6 g.) in acetic acid (50 c.c.) and potassium bromide (1·5 g.) in water (20 c.c.). After 30 minutes no free bromine could be detected, and the product was precipitated by partly neutralising the acetic acid and diluting the mixture with water. The product crystallised from aqueous alcohol in yellow needles (2·6 g.), m. p. 153°, which rapidly darkened on exposure to light (Found : Br, 26·9. $C_{12}H_9O_2N_2Br$ requires Br, 27·3%).

Reduction afforded a mixture of *p*-aminophenol and its monobromo-compound, and the constitution of the azophenol was confirmed by further bromination, yielding 3 : 3′-dibromo-4 : 4′-dihydroxyazobenzene (see below).

3-*Bromo*-4 : 4′-*diacetoxyazobenzene* crystallised from benzene in orange needles, m. p. 142°, and the *dibenzoyl* derivative in yellow prisms, m. p. 165—166°.

3 : 3′-*Dibromo*-4 : 4′-*dihydroxyazobenzene* crystallised from alcohol in light brown needles, m. p. 175°, which darkened on exposure (Found : Br, 42·4. $C_{12}H_8O_2N_2Br_2$ requires Br, 43·0%). Reduction yielded *o*-bromo-*p*-aminophenol, m. p. 154°, thus confirming the constitution of the azophenol.

The *diacetyl* derivative crystallised from alcohol in yellow-orange needles, m. p. 161°, and the *dibenzoyl* derivative from benzene in pale yellow needles, m. p. 227°.

3 : 5 : 3′-*Tribromo*-4 : 4′-*dihydroxyazobenzene* crystallised from aqueous alcohol in brown needles, m. p. 184° (Found : Br, 53·1. $C_{12}H_7O_2N_2Br_3$ requires Br, 53·0%). It gave a mixture of mono- and di-bromo-*p*-aminophenols on reduction, and by further bromination, 3 : 5 : 3′ : 5′-tetrabromo-4 : 4′-dihydroxyazobenzene, the constitution of which has been proved.

3 : 5 : 3′-*Tribromo*-4 : 4′-*diacetoxyazobenzene* crystallised from

alcohol in light brown prisms, m. p. 172°, and the *dibenzoyl* derivative from benzene in yellow needles, m. p. 216°.

3 : 5 : 3′ : 5′-Tetrabromo-4 : 4′-dihydroxyazobenzene was obtained as yellow-brown needles, m. p. 252° (decomp.), from acetic acid (Found : Br, 60·4. Calc. : Br, 60·4%), and was identical with the substance described by Weselsky and Benedikt (*loc. cit.*); it yielded 2 : 6-dibromo-4-aminophenol, m. p. 190°, on reduction. The *diacetyl* derivative formed yellow granules, m. p. 240°, from benzene, and the *dibenzoyl* derivative orange needles, m. p. 265°.

3 : 3′-*Dichloro*-5 : 5′-*dibromo*-4 : 4′-*dihydroxyazobenzene*. 3 : 3′-Dichloro-4 : 4′-dihydroxyazobenzene was brominated completely, with 2 equivs. of the brominating agent, in 15 minutes, and a quantity of the product separated; the remainder was obtained by dilution with water. It crystallised from alcohol in fine yellowish-red needles, m. p. 262° (Found : Ag halides/original weight, 151·7. $C_{12}H_6O_2N_2Cl_2Br_2$ requires 150·4%). It reduced to 2-chloro-6-bromo-4-aminophenol, m. p. 177° (decomp.) (compare Raiford, *Amer. Chem. J.*, 1911, **46**, 422).

*Action of Iodine Chloride on* p-*Azophenol*.—Solutions of *p*-azophenol (1 g.) in stable acetic acid (230 c.c.) and of dichloramine-T (0·6 g.) and potassium iodide (0·72 g.) in acetic acid (50 c.c.) were mixed. After 25 minutes the iodine chloride had disappeared and purple granules were deposited (0·8 g.) which crystallised from alcohol in bluish-black needles, m. p. 185° (Found : N, 12·8. Calc. : N, 13·2%). The compound was identified as the quinhydroneazine (Willstätter and Benz, *Ber.*, 1906, **39**, 3482) by reduction with sulphur dioxide to *p*-azophenol (m. p. 204°), by stronger reduction to *p*-aminophenol (m. p. 183°), by oxidation in dry ether solution with dry silver oxide to quinoneazine (m. p. 158°), and by a mixed melting-point determination with an authentic specimen prepared by the method of these authors. The same substance was given by the action of excess of the iodinating agent on *p*-azophenol.

*Derivatives of* o-*Azophenol* (2 : 2′-*Dihydroxyazobenzene*).—5-*Chloro*-2 : 2′-*dihydroxyazobenzene* formed fine brown granules, m. p. 164°, from aqueous alcohol (Found : Cl, 14·4. $C_{12}H_9O_2N_2Cl$ requires Cl, 14·3%). Its constitution was decided by further chlorination to 5 : 5′-dichloro-2 : 2′-dihydroxyazobenzene.

5-*Chloro*-2 : 2′-*diacetoxyazobenzene* crystallised from alcohol in fine orange needles, m. p. 117°, and the *dibenzoyl* derivative in brown prisms, m. p. 119°.

5 : 5′-*Dichloro*-2 : 2′-*dihydroxyazobenzene* was obtained in orange-yellow needles, m. p. 267°, from alcohol (Found : Cl, 25·2. $C_{12}H_8O_2N_2Cl_2$ requires Cl, 25·1%). On reduction with stannous chloride and hydrochloric acid and removal of tin, a hydrochloride

was obtained which was immediately converted into the acetyl compound by means of acetic anhydride and sodium acetate. The product formed white needles, m. p. 170°, from alcohol, and was proved to be 4-*chloro*-2-*acetamidophenyl acetate* (Found : Cl, 14·5. $C_{10}H_{10}O_3NCl$ requires Cl, 15·6%) by comparison with the compound (m. p. and mixed m. p. 170°) produced by the reduction and subsequent acetylation of *p*-chloro-*o*-nitrophenol.

5 : 5′-*Dichloro*-2 : 2′-*diacetoxyazobenzene* crystallised in orange-red needles, m. p. 199°, from alcohol, and the *dibenzoyl* derivative formed pale brown needles, m. p. 243°.

3 : 5 : 5′-Trichloro-2 : 2′-dihydroxyazobenzene was obtained by the usual method as orange needles, m. p. 235°, from benzene, identical with the product prepared by the method of Bohn and Heumann (*loc. cit.*). Its constitution was proved by its further chlorination to the 3 : 5 : 3′ : 5′-tetrachloro-compound. The *diacetyl* derivative crystallised from alcohol in pale orange prisms, m. p. 189°, and the *dibenzoyl* derivative in yellow-brown granules, m. p. 247°, from benzene.

3 : 5 : 3′ : 5′-*Tetrachloro*-2 : 2′-*dihydroxyazobenzene* formed silky, orange-red needles, m. p. 246—247°, from benzene (Found : Cl, 40·2. $C_{12}H_6O_2N_2Cl_4$ requires Cl, 40·4%). By reduction with stannous chloride a *hydrochloride* (Found : Cl as chloride, 16·2; total Cl, 50·1. $C_6H_5ONCl_2,HCl$ requires Cl as chloride, 16·5; total Cl, 49·6%) was obtained. The corresponding *base*, m. p. 107° (decomp.), was identical with 2 : 4-*dichloro*-6-*aminophenol*, m. p. 109° (decomp.), prepared by the reduction of 2 : 4-dichloro-6-nitrophenol (Fischer, *Annalen*, 1870, Spt. 7, 193). A mixture of the two specimens had m. p. 107°.

3 : 5 : 3′ : 5′-*Tetrachloro*-2 : 2′-*diacetoxyazobenzene* crystallised from alcohol in pink needles, m. p. 195°, and the *dibenzoyl* derivative in yellowish-brown prisms, m. p. 186°.

5-*Bromo*-2 : 2′-*dihydroxyazobenzene* formed a brown, microcrystalline solid, m. p. 154°, from aqueous alcohol (Found : Br, 27·1. $C_{12}H_9O_2N_2Br$ requires Br, 27·3%). Further bromination gave the 5 : 5′-dibromo-compound.

5-*Bromo*-2 : 2′-*diacetoxyazobenzene* formed dark orange needles, m. p. 142°, and 5-*bromo*-2 : 2′-*dibenzoyloxyazobenzene* crystallised from benzene in light brown needles, m. p. 215°.

5 : 5′-*Dibromo*-2 : 2′-*dihydroxyazobenzene* was obtained from alcohol in orange-red needles, m. p. 249° (Found : Br, 42·65. $C_{12}H_8O_2N_2Br_2$ requires Br, 43·0%). On reduction it gave *p*-bromo-*o*-aminophenol hydrochloride (Found : Ag halides/original weight, 146·8. Calc., 147·6%), from which the base was obtained as a white

crystalline solid, m. p. 87° (Schlieper, *Ber.*, 1893, **26**, 2469, records m. p. 88°).

5 : 5′-*Dibromo*-2 : 2′-*diacetoxyazobenzene* crystallised from benzene in orange granules, m. p. 211°, and the *dibenzoyl* derivative in pale brown needles, m. p. 202°.

3 : 3′ : 5 : 5′-Tetrabromo-2 : 2′-dihydroxyazobenzene obtained by the chloroamine method of bromination formed orange-brown needles, m. p. 262°, from benzene (Found : Br, 59·7. Calc. : Br, 60·3%), identical with the substance prepared by Weselsky and Benedikt's method (*loc. cit.*). Its constitution was assumed by these authors, but has now been established by reduction of the compound to 2 : 4-dibromo-6-aminophenol, m. p. 97—98° (Thiele and Eichwede, *Annalen*, 1900, **311**, 373, gave m. p. 98—99°), the hydrochloride of which was analysed for halogen (Found : Ag halides/original weight, 170·5. Calc., 171·2%).

3 : 5 : 3′ : 5′-*Tetrabromo*-2 : 2′-*diacetoxyazobenzene* crystallised from benzene in brown granules, m. p. 210—211°, and the *dibenzoyl* derivative in coarse orange granules, m. p. 214°.

5-*Iodo*-2 : 2′-*dihydroxyazobenzene*. *o*-Azophenol (2 g.) was dissolved in stable acetic acid (200 c.c.), and a solution of 33% excess over one equivalent of iodinating agent added. The latter was generated by adding finely powdered potassium iodide (2·1 g.) slowly with shaking to a solution of dichloramine-T (1·5 g.) in acetic acid (100 c.c.). The mixture was gently warmed on the water-bath, and the course of the reaction was followed by titrating 10 c.c. of the mixture at 10-minute intervals with thiosulphate. When the titre had fallen to one-quarter of the original value, the mixture was cooled and the excess of iodine was destroyed by addition of a solution of sodium sulphite. Dilution with water yielded a brown precipitate which crystallised from alcohol in brown needles (2·2 g.), m. p. 149—150° (Found : I, 37·3. $C_{12}H_9O_2N_2I$ requires I, 37·4%). Further iodination yielded the 5 : 5′-di-iodo-compound.

5-*Iodo*-2 : 2′-*diacetoxyazobenzene* crystallised from benzene in brown prisms, m. p. 138°, and the *dibenzoyl* derivative from alcohol in pale brown needles, m. p. 159°.

5 : 5′-*Di-iodo*-2 : 2′-*dihydroxyazobenzene*, prepared by the treatment of *o*-azophenol with two equivalents of iodinating agent, crystallised from alcohol in brown needles, m. p. 153° (Found : I, 54·2. $C_{12}H_8O_2N_2I_2$ requires I, 54·5%).

Reduction yielded the *hydrochloride* of p-*iodo*-o-*aminophenol* (Found : Ag halides/original weight, 138·8. $C_6H_7ONClI$ requires 139·4%), from which the *base* was obtained in white needles, m. p.

139°; it was identical with the product formed by reducing *p*-iodo-*o*-nitrophenol.

5 : 5′-*Di-iodo*-2 : 2′-*diacetoxyazobenzene* formed dark brown granules, m. p. 145°, from alcohol, and the *dibenzoyl* derivative pale brown needles, m. p. 147°.

3 : 5 : 3′ : 5′-*Tetraiodo*-2 : 2′-*dihydroxyazobenzene* was obtained in the usual way in brown needles, m. p. 98—99°, from benzene (Found: I, 70·65. $C_{12}H_6O_2N_2I_4$ requires I, 70·8%). On reduction it gave the *hydrochloride* of 2 : 4-*di-iodo*-6-*aminophenol* (Found: Ag halides/original weight, 157·1. $C_6H_5ONI_2$,HCl requires 154·4%), from which the *base* was obtained as white needles, m. p. 120°, identical with the substance obtained by the reduction of 2 : 4-di-iodo-6-nitrophenol; a mixture of the two substances melted at 120·5°.

3 : 5 : 3′ : 5′-*Tetraiodo*-2 : 2′-*dibenzoyloxyazobenzene* formed grey-brown needles, m. p. 241°, from alcohol. The corresponding diacetyl compound was not prepared, since hot acetic anhydride caused decomposition of the azophenol.

*Analytical Note.*—In this and the following paper mixed-halogen analyses were conducted by the Carius method, and expressed either as percentages of each halogen or as a percentage ratio of the weight of the mixed silver halides to the original weight of the substance, according to whether or not the mixed silver halides were converted into silver chloride and reweighed.

UNIVERSITY COLLEGE OF NORTH WALES,
BANGOR.

[*Received, May 26th*, 1928.]