XXI.—*The Chlorination of Iodophenols. Part III. The Chlorination of* o-*Iodophenol.*

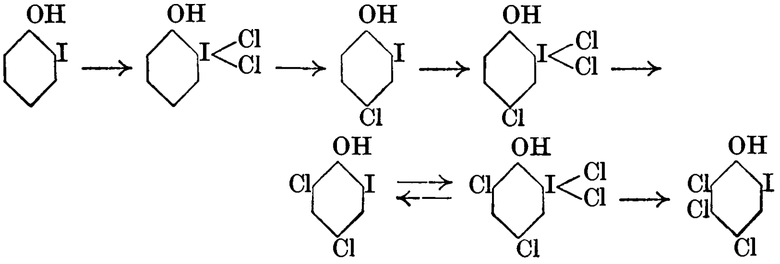
By Samuel Buchan and Hamilton McCombie.

The action of chlorine on solutions of the iodophenols and their derivatives has so far been studied systematically only with reference to *p*-iodophenol (Brazier and McCombie, J., 1912, **101**, 913; King and McCombie, J., 1913, **103**, 1762). The results obtained from that series are most interesting in that it was found possible in certain cases to stabilise the iododichlorides obtained from the parent phenol by substitution of the hydrogen in the hydroxyl group. It was shown that *p*-iodophenol on successive chlorinations gave rise to a series of unstable iododichlorides decomposing with formation of the mono-, di-, tri-, and tetra-chloroiodophenols. The benzoyl derivative of *p*-iodophenol and the benzoyl and acetyl derivatives of the chloro-substituted *p*-iodophenols, on the other hand, all gave stable iododichlorides.

Willgerodt (*Ber.*, 1892, **25**, 3495) stated that when *o*-iodophenol or 2 : 4 : 6-tri-iodophenol in chloroform solution was treated with chlorine, compounds were obtained in which iodine was replaced by chlorine. In the present investigations, however, it was found that *o*-iodophenol dissolved in carbon tetrachloride gave on chlorination a sequence of unstable iododichlorides and decomposition products very similar to those obtained from *p*-iodophenol. Also King and McCombie (*loc. cit.*) have pointed out that although 2 : 4 : 6-tri-iodophenol does not give an iododichloride when dissolved in chloroform, it does give one when in solution with carbon tetrachloride.

Jannasch and Hinterskirch (*Ber.*, 1898, **31**, 1710) obtained from the methyl ether of *o*-iodophenol an iododichloride which decomposed with evolution of hydrogen chloride, giving a decomposition product with one chlorine atom in the nucleus. Analogous compounds were obtained when *o*-iodophenetole was chlorinated by Jannasch and Naphthali (*Ber.*, 1898, **31**, 1714). These investigators assumed that the chlorine atom entered the ring in a position meta to the methoxy-group and, accordingly, gave the decomposition product the structure 5-chloro-2-iodoanisole. If, however, the reaction be regarded as the chlorination of one molecule by another instead of being a purely intramolecular change, it would seem reasonable to suppose that the entering atom would take up a position para to the more strongly directive methoxy-group. Ingold, Smith, and Vass (J., 1927, 1245) proved by synthetic means that the chlorine atom does migrate to the para-position relative to the methoxy-group.

When chlorine was led into an ice-cold 10% solution of *o*-iodophenol in carbon tetrachloride, an iododichloride was obtained which, when separated by filtration, decomposed rapidly with evolution of hydrogen chloride, giving 4-*chloro*-2-*iodophenol.* Usually, however, chlorination of *o*-iodophenol was accompanied by vigorous evolution of hydrogen chloride and the iododichloride ultimately obtained decomposed to give 4 : 6-*dichloro*-2-*iodophenol.* This same compound was obtained by the chlorination of 4-chloro-2-iodophenol and subsequent decomposition of the iododichloride. On chlorinating 4 : 6-dichloro-2-iodophenol an iododichloride was obtained which decomposed rapidly, giving again the dichloroiodophenol with only traces of the more highly halogenated trichloro-derivative.



Two of the derivatives—o-*iodophenyl allyl ether* and o-*iodophenyl phenylcarbamate*—were chlorinated and analysis showed that two chlorine atoms, besides those attached to the iodine, had entered the molecule. In the allyl ether it was fairly obvious that chlorination had resulted in saturation of the double bonds. Chlorine atoms entering the molecule of *o*-iodophenyl phenylcarbamate, however, have the choice of two rings and it is interesting to note that, although the 4- and 6-positions in both are vacant, they attach themselves to the ring with the nitrogen in preference to that with the hydroxyl group. In order to see more clearly the effect of competition between these two rings for available chlorine atoms, chlorination of unsubstituted diphenylcarbamate was carried out in the cold. On analysis it was found that three chlorine atoms had entered the molecule; two were, as before, in the ring attached to the nitrogen atom in positions 4 and 6, and the other was in position 4 in the phenolic ring.

When a stream of chlorine was led into a solution of *o*-iodophenol in carbon tetrachloride at 60—70°, only two compounds could be separated, namely, chloroanil and hexachloro*cyclo*hexadienone. In the *p*-iodophenol series tetrachloro-*p*-iodophenol was also obtained, but with *o*-iodophenol no compound containing iodine could be separated.

The stability of the ioddichlorides derived from *o*-iodophenol might be tabulated as follows.

Stable.	Moderately stable (1—3 months).	Unstable.	
Benzoate	Phenoxyacetophenone	Acetate	Allyl ether
Carbonate	Carbamate	Benzyl ether	Methyl ether
Toluenesulphonate	Dibromopropyl ether	Phenyl ether	Ethyl ether

o-*Iodophenyl ethyl carbonate* did not give an iododichloride.

EXPERIMENTAL.

o-Iodophenol was prepared from phenol by mercuration, followed by iodination with free iodine. The product was obtained pure by vacuum distillation.

2-*Iodophenyl acetate* was obtained as a colourless oil by the action of glacial acetic acid and acetic anhydride (3 : 1) on *o*-iodophenol (Found : I, 48·4. $C_8H_7O_2I$ requires I, 48·5%).

The iododichloride, which was unstable, melted and decomposed at 92—93°.

2-*Iodophenyl benzyl ether* was prepared by heating benzyl chloride and the sodium salt of *o*-iodophenol in alcoholic solution for 5 hours; purified by vacuum distillation, it was obtained as a colourless oil (Found : I, 41·1. $C_{13}H_{11}OI$ requires I, 40·9%).

The iododichloride was unstable.

2-*Iodophenyl benzoate* was obtained by the action of benzoyl chloride on *o*-iodophenol in sodium hydroxide solution. It crystallised from light petroleum (b. p. 40—60°) in white needles, m. p. 34° (Found : I, 39·1. $C_{13}H_9O_2I$ requires I, 39·2%).

The *iododichloride*, which was stable, melted and decomposed at 98—101° (0·099 gave 0·1304 AgI + AgCl. $C_{13}H_9O_2Cl_2I$ requires 0·1308).

2-*Iodophenyl phenylcarbamate* was prepared by heating *o*-iodophenol gently for ½ hour with the theoretical amount of phenylcarbimide and recrystallising the product from benzene; it formed white needles, m. p. 121—122° (Found: I, 37·6. $C_{13}H_{10}O_2NI$ requires I, 37·5%).

Chlorination was carried out in chloroform solution and after much evolution of hydrogen chloride an *iododichloride* was precipitated, m. p. 125° (decomp.). Analysis showed that four chlorine atoms had entered the molecule (0·1625 gave 0·2766 AgI + AgCl. $C_{13}H_8O_2NCl_4I$ requires 0·2742).

The iododichloride was fairly stable and decomposed slowly after 4 weeks with evolution of chlorine. On treating an acetic acid solution of the iododichloride with aqueous potassium iodide 2-*iodophenyl* 2 : 4-*dichlorophenylcarbamate* was precipitated in white needles, m. p. 145°. Its constitution was proved by condensing *o*-iodophenol with 2 : 4-dichlorophenylcarbimide (0·1040 gave 0·1334 AgI + AgCl. $C_{13}H_8O_2NCl_2I$ requires 0·1331).

4-*Chloro*-2-*iodophenol*.—A 10% solution of *o*-iodophenol in carbon tetrachloride was saturated at 0° with dry chlorine. The iododichloride, which was precipitated almost at once, was filtered off rapidly and kept cold. Rapid decomposition with evolution of hydrogen chloride took place. The decomposition product, which was dark in colour, was washed with bisulphite solution and recrystallised from light petroleum (b. p. 40—60°), 4-*chloro*-2-*iodophenol* being obtained as white needles, m. p. 78° (0·1848 gave 0·2768 AgI + AgCl. C_6H_4OClI requires 0·2748). The constitution of this compound was proved by synthesis from 4-chloro-2-nitrophenol. The *benzyl* derivative of 4-chloro-2-nitrophenol (white needles from methyl alcohol, m. p. 84—85°. Found: Cl, 13·4. $C_{13}H_{10}O_3NCl$ requires Cl, 13·5%) was reduced by refluxing it for 8 hours with a solution of stannous chloride in ether. The hydrochloride of the base was diazotised and added to potassium iodide solution. Debenzylation was effected by boiling the benzyl ether of 4-chloro-2-iodophenol with excess of a 30% solution of hydrogen bromide in glacial acetic acid for 48 hours.

4-*Chloro*-2-*iodophenyl acetate* was obtained by the decomposition of the iododichloride from 2-iodophenyl acetate or by the acetylation of 4-chloro-2-iodophenol. This proved its constitution. It was a colourless oil (0·3956 gave 0·5060 AgI + AgCl. $C_8H_6O_2ClI$ requires 0·5050). The iododichloride decomposed rapidly.

4-*Chloro-2-iodophenyl benzyl ether* was prepared by the decomposition of the iododichloride of 2-iodophenyl benzyl ether or by the benzylation of 4-chloro-2-iodophenol. This proved its constitution. It formed white needles, m. p. 60°, from light petroleum ether (0·1974 gave 0·2186 AgI + AgCl. $C_{13}H_{10}OClI$ requires 0·2171). The iododichloride melted and decomposed at 95—97°. It decomposed slowly over a period of 4 or 5 days.

4-*Chloro-2-iodophenyl benzoate* crystallised from light petroleum in white needles, m. p. 88° (0·1716 gave 0·1808 AgI + AgCl. $C_{13}H_8O_2ClI$ requires 0·1812).

The *iododichloride*, which was stable, melted with decomposition at 103—104° (0·2046 gave 0·3178 AgI + AgCl. $C_{13}H_8O_2Cl_3I$ requires 0·3170).

4-*Chloro-2-iodophenyl phenylcarbamate* was obtained from ethyl alcohol in white needles, m. p. 128° (0·2091 gave 0·2128 AgI + AgCl. $C_{13}H_9O_2NClI$ requires 0·2119).

The *iododichloride* was precipitated from chloroform with evolution of hydrogen chloride. It melted with decomposition at 146°. Analysis showed the presence of five chlorine atoms in the molecule, two of them being in positions 2 and 4 in the anilide ring (0·1715 gave 0·3202 AgI + AgCl. $C_{13}H_7O_2NCl_5I$ requires 0·3181).

4 : 6-*Dichloro-2-iodophenol.*—4-Chloro-2-iodophenol in carbon tetrachloride at 0° was chlorinated, and the iododichloride separated and allowed to decompose. The decomposition product crystallised from light petroleum in white needles, m. p. 62° (0·2288 gave 0·4039 AgI + AgCl. $C_6H_3OCl_2I$ requires 0·4051).

4 : 6-*Dichloro-2-iodophenol* was more easily obtained by rapid chlorination of *o*-iodophenol. Evolution of hydrogen chloride took place and the iododichloride eventually obtained decomposed to give the dichloroiodophenol. The constitution of this substance was proved by treating 2 : 4-dichlorophenol with iodine monochloride.

4 : 6-*Dichloro-2-iodophenyl acetate* was obtained by the decomposition of the iododichloride of 4-chloro-2-iodophenyl acetate. It was identical with the compound resulting from the acetylation of 4 : 6-dichloro-2-iodophenol and crystallised from light petroleum in white needles, m. p. 59° (0·1719 gave 0·2722 AgI + AgCl. $C_8H_5O_2Cl_2I$ requires 0·2711).

The iododichloride decomposed after 5—6 days, giving the parent substance.

4 : 6-*Dichloro-2-iodophenyl benzyl ether* was also prepared by

decomposition from the iododichloride of the 4-chloro-2-iodophenyl benzyl ether or by the benzylation of 4 : 6-dichloro-2-iodophenol. It formed white needles, m. p. 62°, from light petroleum (0·1998 gave 0·2718 AgI + AgCl. $C_{13}H_9OCl_2I$ requires 0·2738).

The iododichloride decomposed over several days, giving again 4 : 6-dichloro-2-iodophenyl benzyl ether.

4 : 6-*Dichloro-2-iodophenyl benzoate* was obtained as white crystalline cubes, m. p. 89°, from light petroleum or alcohol (0·1997 gave 0·2650 AgI + AgCl. $C_{13}H_7O_2Cl_2I$ requires 0·2653). The iododichloride was not obtained on chlorination.

4 : 6-*Dichloro-2-iodophenyl phenylcarbamate* was obtained from carbon tetrachloride solution in white needles, m. p. 181° (0·0976 gave 0·1248 AgI + AgCl. $C_{13}H_8O_2NCl_2I$ requires 0·1249). On chlorination in chloroform solution, hydrogen chloride was evolved but no iododichloride was precipitated.

Trichloro-o-*iodophenol*.—4 : 6-Dichloro-2-iodophenol was chlorinated at 0°, and the iododichloride filtered off and allowed to decompose. The products consisted of 4 : 6-dichloro-2-iodophenol with traces of the *trichloro*-derivative. Separation of the two was effected by repeated crystallisation from light petroleum; m. p. 52—54° (0·1528 gave 0·3114 AgI + AgCl. $C_6H_2OCl_3I$ require 0·3143).

2-*Iododiphenyl Ether*.—2-Nitrodiphenyl ether was reduced by refluxing it for 8 hours with stannous chloride in ether. The ether was distilled off, and the tin double salt decomposed with 30% sodium hydroxide solution. The base was extracted with ether, dried, and vacuum-distilled. Diazotisation was effected with sodium nitrite in the presence of sulphuric acid and the diazo-solution was added to aqueous potassium iodide. The oily product was steam-distilled and crystallised from methyl alcohol; m. p. 55—56° (Found : I, 42·8. $C_{12}H_9OI$ requires I, 42·9%).

Chlorination was carried out in a solution of carbon tetrachloride and light petroleum (50/50). The *iododichloride*, which was unstable and decomposed after 2 days, melted with decomposition at 81—82° (0·2008 gave 0·2871 AgI + AgCl. $C_{12}H_9OCl_2I$ requires 0·2856).

ω-2′-*Iodophenoxyacetophenone*.—*o*-Iodophenol was refluxed with the theoretical amount of ω-chloroacetophenone in sodium ethoxide solution for 5 hours and poured into water. The product crystallised from ethyl alcohol in white needles, m. p. 123° (Found : I, 37·7. $C_{14}H_{11}O_2I$ requires I, 37·6%).

The iododichloride, which was moderately stable and very light in colour, melted and decomposed at 98°.

Di-2-iodophenyl Carbonate.—To a 20% solution of *o*-iodophenol in pyridine was added twice the theoretical weight of carbonyl chloride, dissolved in toluene. After 4 hours the mixture was poured into dilute acid. White needles, m. p. 88°, were obtained from methyl alcohol (Found: I, 54·8. $C_{13}H_8O_3I_2$ requires I, 54·5%).

The *iododichloride*, which was stable, melted and decomposed at 108°. Analysis showed that chlorine was added on at both iodine atoms (0·1762 gave 0·2990 AgI + AgCl. $C_{13}H_8O_3Cl_4I_2$ requires 0·3008).

2-*Iodophenyl* p-*Toluenesulphonate*.—*o*-Iodophenol was dissolved in pyridine, and *p*-toluenesulphonyl chloride added slowly. The mixture was kept for 3 days and then poured into dilute acid. The *sulphonate* crystallised from methyl alcohol in white needles, m. p. 80° (Found: I, 34·2. $C_{13}H_{11}O_3IS$ requires I, 33·9%).

The *iododichloride*, which was stable, melted with decomposition at 95—97° (0·2440 gave 0·2866 AgI + AgCl. $C_{13}H_{11}O_3Cl_2IS$ requires 0·2862).

2-*Iodophenyl Allyl Ether*.—To a 5% solution of *o*-iodophenol in sodium ethoxide solution was added the calculated weight of allyl bromide and the whole was refluxed for 5 hours and poured into water. The oil obtained was purified by vacuum distillation (Found: I, 49·1. C_9H_9OI requires I, 48·9%).

The *iododichloride*, m. p. 84° (decomp.), decomposed slowly in air. Analysis showed that the double bond was saturated with chlorine (0·1946 gave 0·3936 AgI + AgCl. $C_9H_9OCl_4I$ requires 0·3916).

2-*Iodophenyl Dibromopropyl Ether*.—Dry bromine (2·5 g.) was added to 5 g. of 2-iodophenyl allyl ether in 25 c.c. of dry carbon tetrachloride, and the mixture kept over-night. When the solvent was distilled off, the *ether* was obtained as a colourless oil (0·1754 gave 0·2550 AgI + AgBr. $C_9H_9OBr_2I$ requires 0·2551).

The *iododichloride*, m. p. 118° (decomp.), decomposed slowly after about 4 weeks, giving 4-*chloro*-2-*iodophenyl dibromopropyl ether*, which crystallised from light petroleum in white needles, m. p. 52° (0·1934 gave 0·3186 AgI + AgBr + AgCl. $C_9H_8OClBr_2I$ requires 0·3210).

2-*Iodophenyl Ethyl Carbonate*.—Ethyl chlorocarbonate was added to a suspension of *o*-iodophenol in sodium bicarbonate solution and kept for 36 hours. The oil produced was extracted with ether, dried, and vacuum-distilled (Found: I, 43·7. $C_9H_9O_3I$ requires I, 43·8%).

An iododichloride could not be obtained.

Chlorination of a Warm Solution of o-*Iodophenol in Carbon Tetrachloride*.—*o*-Iodophenol (10 g.) was dissolved in 100 c.c. of carbon tetrachloride, and chlorine passed in, the temperature being kept at 60—70°, until all evolution of hydrogen chloride had ceased. The solvent was distilled off, and the residue extracted, first with light petroleum and then with methyl alcohol. From the petroleum extract, hexachloro*cyclo*hexadienone crystallised in white needles, m. p. 107°. On treatment with aqueous potassium iodide, pentachlorophenol was obtained, m. p. 187°. From the methyl-alcoholic extract, chloroanil was obtained in large bulk; m. p. 280°.

4-*Chloro*-2 : 6-*di-iodophenol.*—An attempt was made to prove the constitution of 4-chloro-2-iodophenol by the direct iodination of *p*-chlorophenol with iodine monochloride. The substance obtained crystallised from light petroleum in white needles, m. p. 106—107° (0·1713 gave 0·2778 AgI + AgCl. $C_6H_3OClI_2$ requires 0·2762). When this was chlorinated in carbon tetrachloride solution, an unstable iododichloride was obtained.

4-*Chlorophenyl* 2 : 4-*Dichlorophenylcarbamate.*—A 10% solution of diphenylcarbamate (m. p. 122°) in chloroform was chlorinated at 0° until evolution of hydrogen chloride ceased. The solvent was distilled off, and the solid residue crystallised from carbon tetrachloride; m. p. 157° (Found : Cl, 33·6. $C_{13}H_8O_2NCl_3$ requires Cl, 33·7%). The constitution of this compound was proved by the condensation of *p*-chlorophenol with 2 : 4-*dichlorophenylcarbimide.* The latter was prepared by passing a stream of carbonyl chloride over 2 : 4-dichloroaniline hydrochloride at 350—400°; after distillation (b. p. 234—236°), it crystallised from light petroleum in white needles, m. p. 61° (Found : Cl, 37·8. $C_7H_3ONCl_2$ requires Cl, 37·8%).

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