CXLI.—*The Chlorination of Iodophenols. Part IV. The Action of Chlorine on Derivatives of* p-*Iodophenol.*

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THE action of chlorine on *p*-iodophenol was shown by Brazier and McCombie (J., 1912, **101**, 968) to result in the formation of a dichloride which rapidly decomposed, yielding 2-chloro-4-iodophenol. This substance in turn yielded a dichloride which decomposed with the formation of 2 : 6-dichloro-4-iodophenol, and this was converted by similar stages into 2 : 3 : 6-trichloro- and 2 : 3 : 5 : 6-tetrachloro-4-iodophenol. The authors also described an iododichloride from *p*-iodophenyl acetate, which decomposed only after 10 days had elapsed since its preparation, and stable iododichlorides from *p*-iodophenyl benzoate and from the nuclear-substituted chloro-derivatives of the acetate and benzoate. Mascarelli and Martinelli (*Atti R. Accad. Lincei*, 1907, **16**, i, 183) observed that the dichlorides of *p*-iodoanisole and *p*-iodophenetole decomposed very readily with the formation of ring-substituted products. The fact that some derivatives of *p*-iodophenol gave unstable iododichlorides whereas others gave stable ones led to the present work being undertaken with the view of studying the effect on the stability of the iododichloride of replacing the phenolic hydrogen atom by different groups.

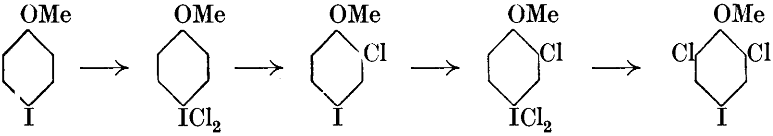
The ethers of *p*-iodophenol which were examined were found, when classified according to the degree of stability of their dichlorides, to fall into one or other of two very clearly defined groups. When *p*-iodoanisole, *p*-iodophenetole, p-*iodophenyl propyl ether*, and *p*-iodophenyl *iso*propyl ether were chlorinated, they yielded iododichlorides the stability of which was of an order similar to that of the dichloride of *p*-iodophenol. On the other hand, p-*iodophenyl β-bromoethyl ether* gave a stable *iododichloride*, the dichlorides of *p*-iodophenyl βγ-dichloropropyl ether and 2-chloro-4-iodophenyl βγ-dichloropropyl ether decomposed only after standing for a month exposed to the atmosphere, and those of p-*iodophenyl βγ-dibromopropyl ether* and 2-*chloro*-4-*iodophenyl βγ-dibromopropyl ether* were stable. It would appear that the raising of the negative character of the group forming the side chain has the effect of increasing the stability of the dichloride.

A similar comparison may be drawn between the iododichlorides of p-*iodophenyl benzyl ether* and of ω-p-*iodophenoxyacetophenone*. The former decomposed in the course of a fortnight, the latter was stable. The introduction of the carbonyl group, which raises the negative tone of the side chain, has the same effect as the halogens upon the stability of the dichloride. From a consideration of its chemical constitution ω-*p*-iodophenoxyacetophenone must be regarded as taking its place between *p*-iodophenyl benzyl ether and *p*-iodophenyl benzoate, and it has been observed that the degree of its stability lies between these two comparative extremes.

The iododichlorides from the esters of *p*-iodophenol were then studied. These, probably on account of the more negative nature of the side chain, exhibit a much greater tendency towards stability than do the unsubstituted ethers. Up to the present the only ester of this series which has been observed to yield an unstable dichloride is the acetate and this is in agreement with the fact that the ionisation constant of acetic acid is low compared with those of other acids from which the esters of *p*-iodophenol were prepared. Further, while no method has been devised for determining the degree of stability of those dichlorides which do not decompose on standing, from general observations such as lightness of colour and the behaviour at a slightly elevated temperature, it may be said that the esters of those acids the affinity constants of which are high yield the iododichlorides which are most stable. For example, the *iododichloride* from p-*iodophenyl cinnamate* is very pale yellow, that from p-*iodophenyl* p-*toluenesulphonate* is almost white, and the dichloride from p-*iodophenyl* αβ-*dichloro*-β-*phenylpropionate* actually is dull white.

The reactivity of the unsubstituted ring in p-*iodophenyl phenylcarbamate*, $C_6H_4I{\cdot}O{\cdot}CO{\cdot}NHPh$, is noteworthy. This substance on chlorination yielded a dichloride of p-*iodophenyl* 2 : 4-*dichlorophenylcarbamate*.

The decomposition of these unstable derivatives was studied with the view of determining whether it followed the same course as that of the dichloride of *p*-iodophenol itself. The iododichloride of *p*-iodoanisole decomposed, yielding 2-*chloro*-4-*iodoanisole*. This substance in turn gave an iododichloride which decomposed with the formation of 2 : 6-*dichloro*-4-*iodoanisole*.



The decomposition of *p*-iodophenetole proceeded along similar lines. *p*-Iodophenyl benzyl ether yielded an iododichloride which decomposed with the formation of 2-*chloro*-4-*iodophenyl benzyl ether*. This substance on chlorination yielded an iododichloride which slowly decomposed with the loss of chlorine and the regeneration of the parent substance. A very small evolution of hydrogen chloride took place, but the quantity of the dichloro-derivative which was probably formed was too small to be separated.

p-Iodoanisole was chlorinated at 75—80° in carbon tetrachloride solution over a period of 4 days; iodine was liberated and the main product was *pentachloroanisole*.

In all cases the constitutions of the iododichlorides have been established by analysis and by the regeneration of the parent substance from the dichloride in glacial acetic acid by treatment with potassium iodide.

EXPERIMENTAL.

Ethers.

p-Iodoanisole was obtained by diazotising *p*-anisidine in dilute sulphuric acid, treating the diazo-solution with potassium iodide, and steam-distilling the resulting mixture. The product crystallised from methylated spirits and water in white needles, m. p. 51°.

The iododichloride was precipitated when a stream of chlorine was passed through an ice-cold 10% solution of *p*-iodoanisole in dry carbon tetrachloride (0·0693 g. gave 0·1176 g. AgI + AgCl. Calc. for $C_7H_7OCl_2I$: 0·1190 g.).

2-*Chloro*-4-*iodoanisole*, obtained by warming the above dichloride on the water-bath, separated from methylated spirits and water in white crystals, m. p. 83°, and was identical with the ether obtained by the methylation of 2-chloro-4-iodophenol with methyl sulphate (0·1396 g. gave 0·1952 g. AgI + AgCl. C_7H_6OClI requires 0·1966 g.).

The *iododichloride*, obtained in the same manner as the previous dichloride, had m. p. 73° (decomp.) (0·0752 g. gave 0·1465 g. AgI + AgCl. $C_7H_6OCl_3I$ requires 0·1474 g.).

2 : 6-*Dichloro*-4-*iodoanisole* resulted from the decomposition of 2-chloro-4-iodoanisole dichloride and from the methylation of 2 : 6-dichloro-4-iodophenol. It formed white crystals, m. p. 75—76°, from methylated spirits and water (0·0508 g. gave 0·0796 g. AgI + AgCl. $C_7H_5OCl_2I$ requires 0·0872 g.).

The *iododichloride* was unstable, m. p. 97° (decomp.) (0·0778 g. gave 0·1237 g. AgI + AgCl. $C_7H_5OCl_4I$ requires 0·1265 g.).

p-Iodophenetole was prepared from *p*-phenetidine in a manner similar to that for *p*-iodoanisole, and obtained from methyl alcohol and water in white crystals, m. p. 28—29°. The iododichlorides of this series behave similarly to those of the *p*-iodoanisole series.

The iododichloride was unstable, m. p. 73·5° (decomp.) (0·1016 g. gave 0·1675 g. AgI + AgCl. Calc. for $C_8H_9OCl_2I$: 0·1693 g.).

2-*Chloro*-4-*iodophenetole*, obtained by decomposition of *p*-iodophenetole dichloride, formed white crystals, m. p. 47°, from methyl alcohol and water (0·1490 g. gave 0·1984 g. AgI + AgCl. C_8H_8OClI requires 0·1995 g.).

p-*Iodophenyl Propyl Ether*.—*p*-Iodophenol was refluxed with propyl chloride and sodium ethoxide, and the resulting solution poured into water. The oil obtained was extracted with ether and purified by regeneration from the iododichloride.

The *iododichloride* decomposed with evolution of hydrogen chloride in the course of 24 hours (0·2013 g. gave 0·3162 g. AgI + AgCl, which gave 0·2617 g. AgCl. $C_9H_{11}OCl_2I$ requires 0·3156 g. and 0·2602 g.).

p-Iodophenyl *iso*propyl ether was prepared from *iso*propyl chloride in a manner similar to that for the propyl ether.

The *iododichloride* decomposes in 24 hours (0·1793 g. gave 0·1771 g. AgI + AgCl. $C_9H_{11}OCl_2I$ requires 0·1748 g.).

p-*Iodophenyl β-bromoethyl ether* was prepared by refluxing a 5% alcoholic solution of *p*-iodophenol for 4 hours with the corresponding quantities of ethylene dibromide and sodium ethoxide. When the resulting solution was poured into water, a white precipitate was obtained which crystallised from ethyl alcohol in white cubes, m. p. 68° (0·2036 g. gave 0·2616 g. AgI + AgBr, which gave 0·1821 g. AgCl. C_8H_8OBrI requires 0·2634 g. and 0·1788 g.).

The *iododichloride* was stable, m. p. 101° (decomp.) (0·2085 g. gave 0·3700 g. AgI + AgBr + AgCl, which gave 0·3034 g. AgCl. $C_8H_8OCl_2BrI$ requires 0·3719 g. and 0·3007 g.).

p-*Iodophenyl Allyl Ether*.—An alcoholic solution of *p*-iodophenol, allyl bromide, and sodium ethoxide was refluxed for 6 hours and poured into water, the excess of phenol removed with sodium hydroxide, and the precipitated oil taken up in ether, dried, and distilled; b. p. 145°/15 mm. (Found : I, 49·1. C_9H_9OI requires I, 48·8%).

The *iododichloride*, m. p. 81° (decomp.), of *p*-iodophenyl βγ-dichloropropyl ether was obtained on chlorinating the allyl ether in carbon tetrachloride. It decomposed in the course of a month when exposed to the atmosphere (0·1843 g. gave 0·3691 g. AgI + AgCl, which gave 0·3259 g. AgCl. $C_9H_9Cl_4I$ requires 0·3702 g. and 0·3273 g.).

p-*Iodophenyl βγ-Dibromopropyl Ether*.—*p*-Iodophenyl allyl ether was treated with dry bromine in dry carbon tetrachloride. The brown oil which remained after the removal of the solvent solidified after being kept for a night in a vacuum and then separated from ethyl alcohol in white crystals, m. p. 50·5° (0·2270 g. gave 0·3324 g. AgI + AgBr, which gave 0·2346 g. AgCl. $C_9H_7OBr_2I$ requires 0·3303 g. and 0·2315 g.).

The *iododichloride* was stable, m. p. 87° (decomp.) (0·2004 g. gave 0·3655 g. AgI + AgBr + AgCl, which gave 0·2937 g. AgCl. $C_9H_9OCl_2Br_2I$ requires 0·3665 g. and 0·2928 g.).

2-Chloro-4-iodophenyl allyl ether was prepared from 2-chloro-4-iodophenol in a manner similar to that for *p*-iodophenyl allyl ether.

The *iododichloride*, m. p. 101° (decomp.), of 2-chloro-4-iodophenyl βγ-dichloropropyl ether was obtained by the chlorination of the corresponding allyl ether. Its stability is of an order similar to that of the iododichloride of *p*-iodophenyl dichloropropyl ether (0·1835 g. gave 0·3967 g. AgI + AgCl, which gave 0·3619 g. AgCl. $C_9H_8OCl_5I$ requires 0·4000 g. and 0·3617 g.).

2-*Chloro*-4-*iodophenyl* βγ-*Dichloropropyl Ether*.—The above dichloride was dissolved in hot glacial acetic acid and treated with potassium iodide, the liberated iodine being removed with sodium bisulphite. The resulting oil was thrown out with water, taken up in ether, and dried (0·1711 g. gave 0·3262 g. AgI + AgCl. $C_9H_8OCl_3I$ requires 0·3225 g.).

2-*Chloro*-4-*iodophenyl* βγ-*dibromopropyl ether*, obtained by the bromination of 2-chloro-4-iodophenyl allyl ether, formed white crystals, m. p. 48°, from ethyl alcohol (0·2217 g. gave 0·3696 g. AgI + AgBr + AgCl, which gave 0·2858 g. AgCl. $C_9H_8OClBr_2I$ requires 0·3680 g. and 0·2797 g.).

The *iododichloride* was stable, m. p. 130° (decomp.) (0·2181 g. gave 0·4337 g. AgI + AgBr + AgCl, which gave 0·3645 g. AgCl. $C_9H_8OCl_3Br_2I$ requires 0·4323 g. and 0·3596 g.).

p-*Iodophenyl benzyl ether*, obtained by refluxing an alcoholic solution of *p*-iodophenol with the corresponding quantities of benzyl chloride and sodium ethoxide, formed white needles, m. p. 62°, from alcohol (Found : I, 40·9. $C_{13}H_{11}OI$ requires I, 40·9%).

The iododichloride was unstable and decomposed in 2—3 weeks.

2-*Chloro*-4-*iodophenyl benzyl ether* resulted from the decomposition of the above dichloride and was also prepared from 2-chloro-4-iodophenol, benzyl chloride, and sodium ethoxide. It formed white needles, m. p. 64°, from ethyl alcohol (0·1846 g. gave 0·2049 g. AgI + AgCl, which gave 0·1566 g. AgCl. $C_{13}H_{10}OClI$ requires 0·2031 g. and 0·1544 g.).

The iododichloride, m. p. 92° (decomp.), was unstable and appeared to decompose more readily than the previous one; only a minute quantity of hydrogen chloride was evolved, however, and the product of decomposition was the parent 2-chloro-4-iodophenyl benzyl ether.

ω-p-*Iodophenoxyacetophenone* was obtained by refluxing an alcoholic solution of *p*-iodophenol and the corresponding quantities of ω-chloroacetophenone and sodium ethoxide and pouring the solution into water; it separated from ethyl alcohol in white crystals, m. p. 103° (Found : I, 37·4. $C_{14}H_{11}O_2I$ requires I, 37·4%).

The *iododichloride* was stable, m. p. 75° (decomp.) (0·2070 g. gave 0·2626 g. AgI + AgCl, which gave 0·2168 g. AgCl. $C_{14}H_{11}O_2Cl_2I$ requires 0·2642 g. and 0·2179 g.).

Esters.

p-*Iodophenyl ethyl carbonate*, obtained from ethyl chloroformate and *p*-iodophenol in presence of 5% sodium bicarbonate solution, formed white crystals, m. p. 38°, from light petroleum (Found : I, 43·7. $C_9H_9O_3I$ requires I, 43·5%).

The *iododichloride* was stable, m. p. 132° (decomp.) (0·2466 g. gave 0·3547 g. AgI + AgCl, which gave 0·2916 g. AgCl. $C_9H_9O_3Cl_2I$ requires 0·3545 g. and 0·2925 g.).

4 : 4′-*Di-iododiphenyl carbonate* was prepared by the addition of a toluene solution of carbonyl chloride to a pyridine solution of *p*-iodophenol. The white precipitate was boiled in ether, in which it was insoluble, and crystallised from carbon tetrachloride; m. p. 193° (Found : I, 54·7. $C_{13}H_8O_3I_2$ requires I, 54·5%). It yielded a stable *bisiododichloride.* This had no characteristic decomposition point, because, when heated in a melting-point apparatus, it lost chlorine while still solid and the m. p. observed was that of the ester itself (0·2032 g. gave 0·3495 g. AgI + AgCl, which gave 0·2897 g. AgCl. $C_{13}H_8O_3Cl_4I_2$ requires 0·3489 g. and 0·2878 g.).

p-*Iodophenyl* p-*Toluenesulphonate.*—Benzene solutions of *p*-iodophenol and *p*-toluenesulphonyl chloride were mixed in the presence of sodium hydroxide, the benzene was removed by distillation, the residual oil poured into light petroleum, and the precipitate crystallised from methyl alcohol. White crystals, m. p. 99°, were formed (Found : I, 34·05. $C_{13}H_{11}O_3IS$ requires I, 34·0%).

The *iododichloride,* a pale—almost white—stable substance, m. p. 115° (decomp.), was obtained from a chloroform solution of the ester (0·0822 g. gave 0·0962 g. AgI + AgCl, which gave 0·0795 g. AgCl. $C_{13}H_{11}O_3Cl_2IS$ requires 0·0964 g. and 0·0795 g.).

p-*Iodophenyl cinnamate* was prepared by adding cinnamoyl chloride to a solution of *p*-iodophenol in pyridine and pouring the mixture into dilute hydrochloric acid; the precipitate obtained formed white crystals, m. p. 122°, from methyl alcohol (Found : I, 36·4. $C_{15}H_{11}O_2I$ requires I, 36·3%).

The iododichloride. When a solution of *p*-iodophenyl cinnamate (1 mol.) in carbon tetrachloride containing chlorine (1 mol.) was kept for 2 hours, a stable *iodochloride* was precipitated, m. p. 121° (decomp.) (0·0756 g. gave 0·2192 g. AgI + AgCl, which gave 0·1798 g. AgCl. $C_{15}H_{11}O_2Cl_2I$ requires 0·2175 g. and 0·1793 g.).

By keeping a solution of *p*-iodophenyl cinnamate in the presence of excess of chlorine for a few days in sunlight, a dull white iododichloride, m. p. 170° (decomp.), was obtained which, on treatment with potassium iodide in warm glacial acetic acid, gave p-*iodophenyl* αβ-*dichloro*-β-*phenylpropionate*; this formed white crystals, m. p. 127°, from ethyl alcohol (0·1592 g. gave 0·1963 g. AgI + AgCl. $C_{15}H_{11}O_2Cl_2I$ requires 0·1974 g.).

p-*Iodophenyl* αβ-*Dibromo*-β-*phenylpropionate.*—*p*-Iodophenyl cinnamate in carbon tetrachloride was treated with dry bromine, and the solution kept for a few days in sunlight. The solvent was drawn off in a current of dry air, and a white crystalline substance obtained,

m. p. 153° after recrystallisation from ethyl alcohol (0·2471 g. gave 0·2966 g. AgI + AgBr, which gave 0·2104 g. AgCl. $C_{15}H_{11}O_2Br_2I$ requires 0·2960 g. and 0·2100 g.).

The iododichloride was stable, m. p. 130° (decomp.).

p-*Iodophenyl Phenylcarbamate.*—*p*-Iodophenol and phenylcarbimide were refluxed for 3 hours, and the product poured into benzene; the white precipitate was crystallised from benzene; m. p. 148° (Found : I, 37·3. $C_{13}H_{10}O_2NI$ requires I, 37·5%).

p-*Iodophenyl 2 : 4-Dichlorophenylcarbamate.*—2 : 4-Dichloroaniline hydrochloride was heated at 350—400° in a stream of carbonyl chloride. The distillate on redistillation at 234° lost hydrogen chloride, yielding 2 : 4-dichlorophenylcarbimide, which was coupled with *p*-iodophenol in the manner already described. The product formed white crystals, m. p. 151·5°, from benzene (0·2068 g. gave 0·2636 g. AgI + AgCl. $C_{13}H_8O_2NCl_2I$ requires 0·2611 g.).

Iododichloride from p-*Iodophenyl Phenylcarbamate.*—When chlorine was passed through a chloroform solution of the ester, a stable *iododichloride* was formed and nuclear substitution took place, with evolution of hydrogen chloride. When the iododichloride was treated with potassium iodide in warm glacial acetic acid, a substance which is identical with the *p*-iodophenyl 2 : 4-dichlorophenylcarbamate described above was produced. Substitution therefore takes place in the 2′ : 4′-positions. The iododichloride has m. p. 142° (decomp.) (0·1026 g. gave 0·1710 g. AgI + AgCl, which gave 0·1527 g. AgCl. $C_{13}H_8O_2NCl_4I$ requires 0·1711 g. and 0·1520 g.).

Hot Chlorination of p-*Iodoanisole.*—A stream of chlorine was passed into a carbon tetrachloride solution of *p*-iodoanisole at 70—80° for 4 days. The yellow needles which had separated were recrystallised from methyl alcohol, long white needles of *pentachloroanisole,* m. p. 108°, being obtained (Found : Cl, 62·7. $C_7H_3OCl_5$ requires Cl, 63·2%).

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