CCXL.—*The Scission of Diaryl Ethers and Related Compounds by Means of Piperidine. Part V. The Nitration of Methyl-, Dimethyl-, and Polyhalogeno-derivatives of Diphenyl Ether.*

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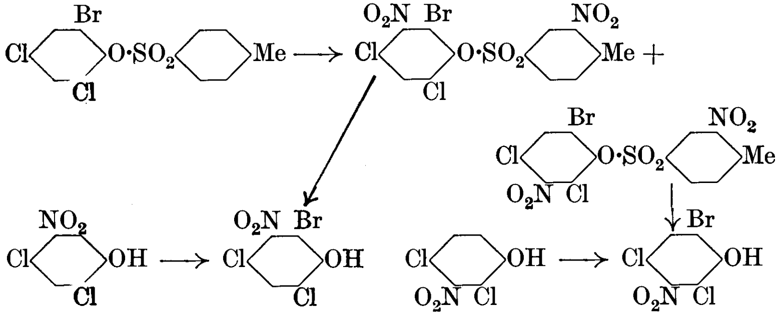
IN Part IV of this series (this vol., p. 1115) a number of observations were recorded which did not conform with previous results, and indicated lines on which further investigation was desirable. For example, it was shown that nitration of certain 4-chloro-4′-bromodiphenyl ethers was accompanied by elimination of halogen, and it was therefore important to discover whether 2-halogenated ethers would behave similarly. 2-*Chloro*-2′-*bromodiphenyl ether* has been prepared, and found to undergo dinitration in the 4 : 4′-positions without any marked tendency to suffer halogen elimination. Only when the nitrating conditions are drastic does this elimination become appreciable. This result falls into line with the general tendency, in diphenyl ethers, towards 4-nitration as against 2-nitration. It should also be pointed out that the introduction of a nitro-group into the ether molecule is not readily accomplished if either two nitro-groups or one nitro-group and a halogen atom are already present in the 2- and 4-positions in each benzene nucleus, although, as shown later, the presence of methyl groups favours the introduction of more than one nitro-group.

In view of the fact that 2 : 4-dichloro- and 2 : 4-dibromo-2′ : 4′-dinitrodiphenyl ethers readily undergo nitration in the 5-position (Groves, Turner, and Sharp, J., 1929, 512; Henley and Turner, this vol., p. 928), we have now nitrated 2-*chloro*-4-*bromo*-2′ : 4′-*dinitrodiphenyl ether*, in order to see if the presence of two dissimilar halogen atoms would cause anomalous nitration. The nitration produced only one substance, 2-*chloro*-4-*bromo*-5 : 2′ : 4′-*trinitrodiphenyl ether*, which readily underwent scission by piperidine to give 2 : 4-dinitrophenylpiperidine and 2-*chloro*-4-*bromo*-5-*nitrophenol*. This phenol was also produced by the action of piperidine on 2-*chloro*-4-*bromo*-5-*nitrophenyl* o-*nitro*-p-*toluenesulphonate*, which was the sole product of nitrating 2-*chloro*-4-*bromophenyl* p-*toluenesulphonate*. When, by the normal series of reactions, the two nitro-groups in the dinitro-*p*-toluenesulphonate were replaced by chlorine atoms, and the ester was hydrolysed, there resulted 2 : 5-*dichloro*-4-*bromophenol*, identical with the product obtained from 2 : 5-*dichloro*-4-*bromoaniline* by the diazo-method. This base was obtained by reducing 1 : 4-*dichloro*-2-*bromo*-5-*nitrobenzene*, which was in turn prepared by nitrating 2 : 5-dichlorobromobenzene. This series of reactions establishes the constitution of the above chlorobromotrinitro-ether.

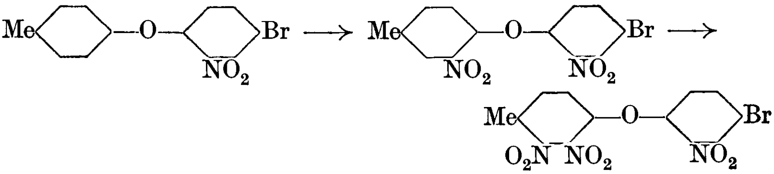
The nitration of more highly halogenated diphenyl ethers was also found to proceed without elimination of halogen. 2 : 4 : 6-*Trichloro-*, 2 : 4 : 6-tribromo-, and 4-*chloro*-2 : 6-*dibromo*-2′ : 4′-*dinitrodiphenyl ether* are almost quantitatively nitrated in the 3-position. The trinitro-compounds so formed undergo facile scission with piperidine in the usual manner. They show no tendency to undergo further nitration.

2 : 4-*Dichloro*-6-*bromo*-2′ : 4′-*dinitrodiphenyl ether* is mononitrated to give a mixture of the 3- and 5-derivatives. This mixture was at first regarded as a single substance, since recrystallisation did not affect its m. p. Similarly, 2 : 4-*dichloro*-6-*bromophenyl* p-*toluenesulphonate* was nitrated to give what was apparently a single substance. The essential proof that both products were mixtures is as follows : Both nitro-compounds gave as one of the products of piperidine scission a mixture of phenols. One of these phenols was 2 : 4-*dichloro*-6-*bromo*-3-*nitrophenol,* identical with the product of brominating 2 : 4-dichloro-3-nitrophenol, whilst the other was 2 : 4-*dichloro*-6-*bromo*-5-*nitrophenol,* also obtained by brominating 2 : 4-dichloro-5-nitrophenol. The two products of nitrating 2 : 4-dichloro-6-bromophenyl *p*-toluenesulphonate, *viz.*, 2 : 4-*dichloro*-6-*bromo*-3- and -5-*nitrophenyl* o-*nitro*-p-*toluenesulphonates,* were prepared for purposes of comparison from the dichlorobromonitrophenols and *o*-nitro-*p*-toluenesulphonyl chloride. A mixture of the two synthetic compounds behaved similarly to the nitration product in question :

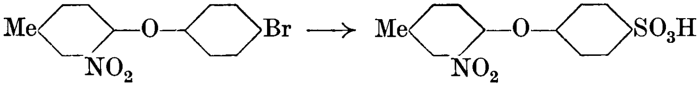


It was shown in Part IV (*loc. cit.*) that whereas either 4-chloro-2-nitro-4′-methyldiphenyl ether or its 2′-nitro-analogue could be converted into 4-chloro-2 : 2′-dinitro-4′-methyldiphenyl ether by mild nitration, more drastic conditions of nitration produced

4-chloro-2 : 6-dinitrophenol. We have been unable to effect the mononitration of 4-*bromo*-2′-*nitro*-4′-*methyldiphenyl ether*, whilst vigorous nitration conditions caused scission, 4-bromo-2 : 6-dinitrophenol being formed. The mononitration of 4-*bromo*-2-*nitro*-4′-*methyldiphenyl ether* can only be accomplished at the expense of leaving half the original material unchanged, but when the ether is treated with an excess of cold, fuming nitric acid, the main product, 4-bromo-2 : 6-dinitrophenol, is accompanied by a small quantity of 4-*bromo*-2 : 2′ : 3′-*trinitro*-4′-*methyldiphenyl ether*. The constitution of this substance follows from its scission by piperidine into 4-bromo-2-nitrophenylpiperidine and 2 : 3-dinitro-*p*-cresol, and it is important to note that, as would be expected, nitration occurs in the nucleus containing the methyl radical, and not in that attached to bromine, and that the nitro-group enters the *ortho* and not the *para* position with respect to the nitro-group originally present :

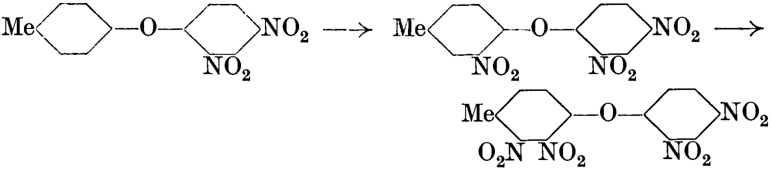


These differences in behaviour between the 4-chloro- and 4-bromonitrophenyl tolyl ethers are, however, less remarkable than a further observation we have made : Thus, whilst 4-chloro-2-nitro-4′-methyldiphenyl ether is converted by concentrated sulphuric acid into 2-nitro-4′-methyldiphenyl ether 4-sulphonic acid, the corresponding 4-bromo-ether is unaffected by the hot, concentrated acid, and yet, whereas 4-chloro-2′-nitro-4′-methyldiphenyl ether does not react with sulphuric acid, the analogous 4-bromo-ether readily loses bromine and 2′-*nitro*-4′-*methyldiphenyl ether* 4-*sulphonic* is formed :



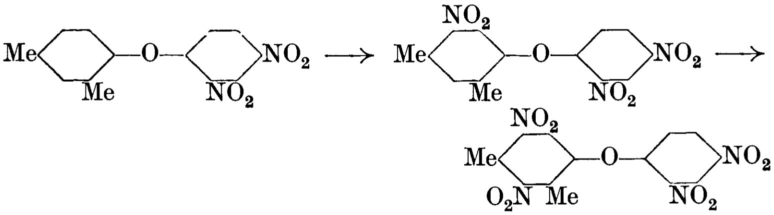
Elimination of a halogen atom is therefore in the one case associated with the presence of a meta nitro-group and in the other with the absence thereof, so no inference as to the cause of such eliminations is at present possible.

The results of our experiments on the nitration of 4-bromo-2-nitro-4′-methyldiphenyl ether suggested that 2 : 4-*dinitro*-4′-*methyldiphenyl ether* might be mononitrated in position 2′, and dinitrated in positions 2′ and 3′. This has been shown to occur, both mono- and di-nitration taking place without difficulty :

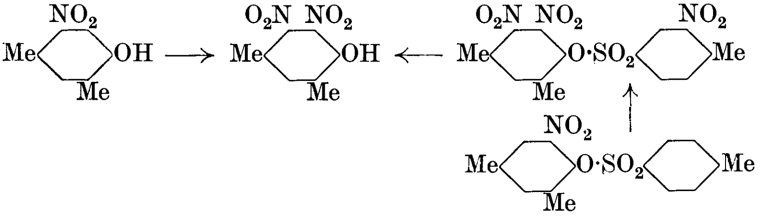


It should be pointed out that nitration of *p*-tolyl carbonate and subsequent hydrolysis gives 2-nitro-*p*-cresol (D.R.-P. 206,638), whilst nitration of 2-nitro-*p*-cresol produces both 2 : 3- and 2 : 5-dinitro-*p*-cresol (Dadswell and Kenner, J., 1927, 580).

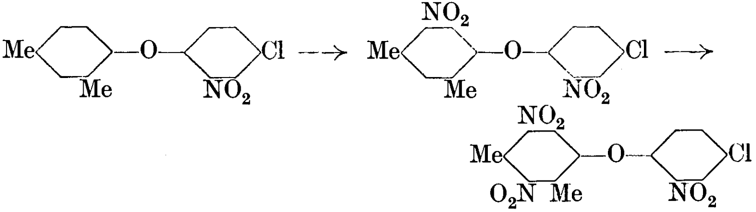
Further, since 2 : 4-dichloro-, 2 : 4-dibromo-, and 2-chloro-4-bromo-2′ : 4′-dinitrodiphenyl ether are nitrated in position 5, it seemed probable that 2 : 4-*dinitro*-2′ : 4′-*dimethyldiphenyl ether* would, when mononitrated, give 2 : 4 : 5′-*trinitro*-2′ : 4′-*dimethyldiphenyl ether*, just as *m*-4-xylyl succinate is nitrated in position 6 (Bischoff and von Hedenström, *Ber.*, 1902, **35**, 4080), but that whilst the presence of two halogen atoms would inhibit further nitration, the presence of two methyl radicals would make it possible, in which case the second nitro-group would enter position 3′. This anticipation was realised :



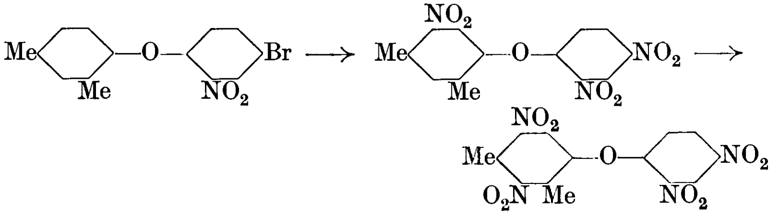
The constitution of the trinitro-ether was established by the method of piperidine scission, which gave the known 6-nitro-*m*-4-xylenol, and 2 : 4-dinitrophenylpiperidine. Piperidine scission of the tetranitro-ether gave dinitrophenylpiperidine and an unknown dinitro-*m*-xylenol, which must, however, have been either 2 : 6- or 5 : 6-dinitro-*m*-4-xylenol. Nitration of 6-nitro-*m*-4-xylenol would be expected to give 5 : 6-*dinitro*-m-4-*xylenol*, because here the hydroxyl group would have the most powerful controlling influence. This has been established as follows : The p-*toluenesulphonyl* derivative of 5-nitro-*m*-4-xylenol would be expected to undergo nitration in position 6, as well as in the tolyl group, since the 5-nitro-group is more strongly ortho- than para-directing. The nitration product was converted by piperidine into a phenol which must have been either 5 : 6- or 2 : 5-dinitro-*m*-4-xylenol, but which, since it was identical with the product of nitrating 6-nitro-*m*-4-xylenol (above), was the 5 : 6-compound. It therefore follows that the dinitroxylenol formed in the piperidine scission of the tetranitrodimethyldiphenyl ether is 2 : 6-*dinitro*-m-4-*xylenol*, and that the tetranitro-ether possesses the formula already assigned to it :



4-*Chloro-2-nitro-2′ : 4′-dimethyldiphenyl ether* was found to undergo nitration in a similar manner to that observed with the dinitrodimethyl ether :



The corresponding bromo-derivative underwent 5′-mononitration, but before a second nitro-group was introduced, elimination of bromine occurred, and there resulted a mixture of 2 : 4 : 5′-*trinitro*- and 2 : 4 : 3′ : 5′-*tetranitro-2′ : 4′-dimethyldiphenyl ether* :



Experimental.

2-*Chloro-2′-bromodiphenyl Ether*.—2-Chloro-2′-nitrodiphenyl ether was reduced with iron filings and dilute alcoholic hydrochloric acid, and the resulting crude base was submitted to the Sandmeyer reaction. The *chlorobromo*-ether so obtained was a pale yellow liquid, b. p. 195—196°/10 mm. or 225—226°/36 mm. (0·1394 G. gave 0·1614 g. AgCl + AgBr. $C_{12}H_8OClBr$ requires AgCl + AgBr, 0·1630 g.).

2-*Chloro*-2′-*bromo*-4 : 4′-*dinitrodiphenyl Ether.*—(I) 2-Chloro-2′-bromodiphenyl ether was added to a mixture of 5 parts of glacial acetic acid and 5 parts of nitric acid (*d* 1·5). On pouring the solution into water, an oil was obtained, and this, when dissolved in excess of nitric acid, gave the *dinitro*-compound, which crystallised from glacial acetic acid in almost colourless prisms, m. p. 150—151° (0·1490 G. gave 0·1312 g. AgCl + AgBr. $C_{12}H_6O_5N_2ClBr$ requires AgCl + AgBr, 0·1322 g.).

(II) The chlorobromo-ether was heated in nitric acid (*d* 1·5) solution (10 parts) for an hour at 100°. Some hydrogen halide was evolved, but the only product isolated from the solution was the above dinitro-derivative in a slightly impure condition.

2-*Chloro*-4-*bromophenol.*—This substance, m. p. 45°, was obtained by Kohn and Sussmann (*Monatsh.*, 1927, **48**, 193) by reductive elimination of bromine from 2-chloro-4 : 6-dibromophenol. It was more conveniently prepared as follows : Chlorine was passed into a solution of *p*-bromophenol in glacial acetic acid until the calculated increase in weight took place. The solution was diluted with water, and the precipitate dried in a vacuum; it formed wads of white needles, m. p. 50—51° (Found : Total halogen, 56·5. Calc. : 55·6%).

2-*Chloro*-4-*bromophenyl* p-*toluenesulphonate* crystallised from dilute alcohol in leaflets, m. p. 114—115° (0·0898 G. gave 0·0828 g. AgCl + AgBr. $C_{13}H_{10}O_3ClBrS$ requires AgCl + AgBr, 0·0823 g.).

2-*Chloro*-4-*bromo*-5-*nitrophenyl* o-*Nitro*-p-*toluenesulphonate.*—The chlorobromo-ester was added to 15 parts of nitric acid (*d* 1·5). After 20 mins. the solution was poured into water. The precipitated solid crystallised from diluted acetic acid in pale yellow leaflets, m. p. 107—108° (0·1254 G. gave 0·0940 g. AgCl + AgBr. $C_{13}H_8O_7N_2ClBrS$ requires AgCl + AgBr, 0·0986 g.). This dinitro-compound was heated for an hour at 10° with excess of piperidine. From the resulting solution there was obtained 2-chloro-4-bromo-5-nitrophenol, m. p. 83°.

2 : 5-*Dichloro*-4-*bromophenol.*—(*a*) The preceding dinitro-compound was reduced at 100° with stannous chloride and glacial acetic and hydrochloric acids. The solution obtained was treated with excess of alkali, and then extracted with ether. The crude diamino-compound obtained by evaporation of the ether was diazotised in concentrated sulphuric acid, and the solution poured on ice. The absence of any precipitate showed that no nitro-compound had escaped reduction. The solution was added to cuprous chloride in hydrochloric acid, and the whole distilled in steam. The white solid obtained crystallised from light petroleum (b. p. 80—100°) in needles, m. p. 71—72°.

(*b*) 2 : 5-Dichloronitrobenzene was reduced by iron filings, 70% alcohol, and a little hydrochloric acid. The crude 2 : 5-dichloroaniline, obtained in almost theoretical yield, was diazotised in concentrated sulphuric acid solution, using a solution of sodium nitrite in the same acid. The diazo-solution was poured on ice, a little solid removed by filtration, and the clear solution added to cuprous bromide–hydrobromic acid. The 2 : 5-dichlorobromobenzene formed was extracted with carbon tetrachloride, and distilled under reduced pressure. After crystallisation from alcohol, it melted at 35°, the m. p. given by Noelting and Kopp (*Ber.*, 1905, **38**, 3509) (0·1002 G. gave 0·2116 g. AgCl + AgBr. Calc. : AgCl + AgBr, 0·2106 g.).

The dichlorobromobenzene was added to 10 parts of nitric acid (*d* 1·5), the solution warmed to 50°, and water added until crystallisation began. Excess of water was gradually added, the precipitated nitro-derivative filtered off, and crystallised twice from alcohol. The 1 : 4-*dichloro*-2-*bromo*-5-*nitrobenzene* so obtained formed pale yellow leaflets, m. p. 57—58° (0·1016 G. gave 0·1768 g. AgCl + AgBr. $C_6H_2O_2NCl_2Br$ requires AgCl + AgBr, 0·1780 g.).

Reduction of this nitro-compound by the iron–alcohol–acid method gave 2 : 5-*dichloro*-4-*bromoaniline*, which crystallised from dilute alcohol in long colourless needles, m. p. 91—92° (0·0788 G. gave 0·1552 g. AgCl + AgBr. $C_6H_4NCl_2Br$ requires AgCl + AgBr, 0·1553 g.).

The dichlorobromoaniline was converted into 2 : 5-dichloro-4-bromophenol by applying the procedure of Noelting and Kopp (*loc. cit.*) for the preparation of 2 : 5-dichlorophenol. The decomposed diazo-solution was, however, at once steam-distilled, and the *phenol* so obtained dried, and crystallised from light petroleum (b. p. 80—100°). It melted at 71—72°, alone, or when mixed with the product from (*a*) above (0·0766 G. gave 0·1498 g. AgCl + AgBr. $C_6H_3OCl_2Br$ requires AgCl + AgBr, 0·1504 g.).

2-*Chloro*-4-*bromo*-2′ : 4′-*dinitrodiphenyl ether* was obtained in 95% yield from 2-chloro-4-bromophenol and chlorodinitrobenzene. It crystallised from a mixture of glacial acetic acid and alcohol in pale yellow leaflets, m. p. 122—123° (0·2172 G. gave 0·1926 g. AgCl + AgBr. $C_{12}H_6O_5N_2ClBr$ requires AgCl + AgBr, 0·1928 g.).

2-*Chloro*-4-*bromo*-5 : 2′ : 4′-*trinitrodiphenyl Ether.*—A solution of the last-named ether in 15 parts of nitric acid (*d* 1·5) was heated at 100° for ½ hour, cooled, and a little water added. After a few minutes, crystallisation set it, and then water was slowly added until complete precipitation occurred. The solid, after being dried at 100°, had m. p. 127—129°. It crystallised from a mixture of glacial acetic acid and alcohol in yellow needles, m. p. 132—133°

(0·1268 G. gave 0·1018 g. AgCl + AgBr. $C_{12}H_5O_7N_3ClBr$ requires AgCl + AgBr, 0·1005 g.).

Piperidine scission of the ether gave 2 : 4-dinitrophenylpiperidine, m. p. 93—94°, and 2-*chloro*-4-*bromo*-5-*nitrophenol*, which crystallised from light petroleum (b. p. 80—100°) in needles, m. p. 83° (0·1228 G. gave 0·1592 g. AgCl + AgBr. $C_6H_3O_3NClBr$ requires AgCl + AgBr, 0·1612 g.). The phenol did not depress the m. p. of the compound obtained by piperidine scission of the dinitro-sulphonyl compound described above.

Bromination of 2 : 5-*Dichlorophenol.*—A solution of the phenol (1 mol.) and sodium acetate (1 mol.) in glacial acetic acid was treated with 1 mol. of bromine, and heated at 100° for a few minutes. Dilution precipitated 2 : 5-*dichloro*-4 : 6-*dibromophenol*, which crystallised from glacial acetic acid in colourless needles, m. p. 99—100° (0·0806 G. gave 0·1734 g. AgCl + AgBr. $C_6H_2OCl_2Br_2$ requires AgCl + AgBr, 0·1665 g.). From the mother-liquor was obtained a small quantity of 2 : 5-dichloro-4-bromophenol, m. p. 65°, not depressing the m. p. of the substance described above.

2 : 4 : 6-*Trichloro*-2′ : 4′-*dinitrodiphenyl ether*, from trichlorophenol and chlorodinitrobenzene, crystallised from alcohol in small pale yellow prisms, m. p. 121—122° (Found : Cl, 29·1. $C_{12}H_5O_5N_2Cl_3$ requires Cl, 29·3%).

2 : 4 : 6-*Trichloro*-3 : 2′ : 4′-*trinitrodiphenyl Ether.*—The preceding compound (5 g.) was dissolved in 10 parts of nitric acid (*d* 1·5), and the solution heated for ½ hour at 100°, and cooled with gradual addition of water. Crystals separated and precipitation was completed by the addition of excess of water. The filtered and dried product (5·1 g.) had m. p. 143—144°. After crystallisation from a mixture of alcohol and glacial acetic acid, it formed small pale yellow prisms, m. p. 143—144°. A portion was dissolved in 20 parts of nitric acid (*d* 1·5) and the solution heated for ½ hour at 100°. Precipitation with water, followed by crystallisation gave a product, m. p. 144—145° (Found : Cl, 26·9. $C_{12}H_4O_7N_3Cl_3$ requires Cl, 26·1%).

The *trinitro*-compound readily underwent scission with piperidine at 100° to give 2 : 4-dinitrophenylpiperidine and 2 : 4 : 6-trichloro-3-nitrophenol, which, after being crystallised from light petroleum (b. p. 80—100°), had m. p. 71—72°.

2 : 4 : 6-*Tribromo*-2′ : 4′-*dinitrodiphenyl ether*, prepared from 2 : 4 : 6-tribromophenol and 1-chloro-2 : 4-dinitrobenzene, crystallised from diluted acetic acid. It melted at 131—132°. Raiford and Colbert (*J. Amer. Chem. Soc.*, 1926, **48**, 2652), who prepared it by a different method, gave m. p. 130·5° (Found : Br, 48·4. Calc. : Br, 48·3%).

2 : 4 : 6-*Tribromo*-3 : 2′ : 4′-*trinitrodiphenyl Ether.*—A solution of the last-named ether (3 g.) in 15 parts of nitric acid (*d* 1·5) was heated at 100° for ½ hour. Water was added until crystallisation began, and then slowly in excess. The dried precipitate (3·2 g.) had m. p. 175—177°, and after crystallisation from a mixture of glacial acetic acid and alcohol formed pale yellow prisms, m. p. 177—178° (Found : Br, 44·1. $C_{12}H_4O_7N_3Br_3$ requires Br, 44·3%). Scission of the *ether* with piperidine at 100° proceeded rapidly. It gave 2 : 4-dinitrophenylpiperidine, m. p. 92—93°, and 2 : 4 : 6-tribromo-3-nitrophenol, m. p. 89—90°, alone, or when mixed with a specimen obtained previously (Henley and Turner, this vol., p. 928).

4-*Chloro*-2 : 6-*dibromophenol.*—A solution of *p*-chlorophenol in glacial acetic acid was gradually treated with 2 mols. of bromine. The product was shaken with water, and the solid dissolved in alkali. Acidification gave the *chlorodibromophenol*, which separated from alcohol in needles, m. p. 89°; it was readily purified by sublimation (0·1888 G. gave 0·3422 g. AgCl + AgBr. $C_6H_3OClBr_2$ requires AgCl + AgBr, 0·3423 g.).

4-*Chloro*-2 : 6-*dibromophenyl* p-*toluenesulphonate* crystallises from dilute alcohol in leaflets, m. p. 107—108° (0·0860 G. gave 0·1012 g. AgCl + AgBr. $C_{13}H_9O_3ClBr_2S$ requires AgCl + AgBr, 0·1014 g.).

4-*Chloro*-2 : 6-*dibromo*-2′ : 4′-*dinitrodiphenyl ether*, prepared from 4-chloro-2 : 6-dibromophenol and chlorodinitrobenzene, crystallised from alcohol in pale yellow leaflets, m. p. 145—146° (0·2782 G. gave 0·3230 g. AgCl + AgBr. $C_{12}H_5O_5N_2ClBr_2$ requires AgCl + AgBr, 0·3194 g.).

4-*Chloro*-2 : 6-*dibromo*-3 : 2′ : 4′-*trinitrodiphenyl ether* was obtained by heating a solution of the last-named ether (5 g.) in 10 parts of nitric acid (*d* 1·5) for ½ hour, and then precipitating it with water. The dried product (4·9 g.) melted at 157—159°, and crystallised from a mixture of alcohol and glacial acetic acid in clusters of pale yellow prisms, m. p. 158·5—159·5° (0·0984 G. gave 0·1040 g. AgCl + AgBr. $C_{12}H_4O_7N_3ClBr_2$ requires AgCl + AgBr, 0·1028 g.). Scission with piperidine at 100° gave 2 : 4-dinitrophenylpiperidine and 4-*chloro*-2 : 6-*dibromo*-3-*nitrophenol*, which crystallised from light petroleum (b. p. 80—100°) in needles, m. p. 81—82° (0·0826 G. gave 0·1302 g. AgCl + AgBr. $C_6H_2O_3NClBr_2$ requires AgCl + AgBr, 0·1295 g.).

2 : 4-*Dichloro*-6-*bromophenol.*—This substance was first prepared by Garzino (*Gazzetta*, 1887, **17**, 495) by brominating 2 : 4-dichlorophenol. We have found the following method to give excellent results : A solution of 16·5 c.c. of bromine in 90 c.c. of glacial acetic acid was added fairly rapidly to a stirred solution of 50 g. of 2 : 4-dichlorophenol in a mixture of 500 c.c. each of water and

glacial acetic acid. When addition was complete the solution quickly became a pasty mass. Excess of water was added, the precipitate filtered, and shaken with 500 c.c. of boiling water. On cooling, almost pure 2 : 4-dichloro-6-bromophenol was obtained. After crystallisation from light petroleum (b. p. 60—80°), it had m. p. 68—69°.

In order to confirm the constitution of this phenol, it was also prepared as follows: Chlorine was passed into a solution of 35 g. of *o*-bromophenol in 200 c.c. of glacial acetic acid until an increase of 28 g. was obtained. The solution was freed from acetic acid by distillation, and the residue distilled under reduced pressure. The 2 : 4-dichloro-6-bromophenol boiled at 192°/12 mm., 198°/15 mm., or 204°/19 mm. After crystallisation from light petroleum it was identical with the product from dichlorophenol.

2 : 4-*Dichloro*-6-*bromo*-3-*nitrophenol* was obtained by brominating 2 : 4-dichloro-3-nitrophenol in glacial acetic acid in presence of sodium acetate; it crystallised from light petroleum (b. p. 80—100°) in pale yellow needles, m. p. 78—79° (0·1236 G. gave 0·2044 g. AgCl + AgBr. $C_6H_2O_3NCl_2Br$ requires AgCl + AgBr, 0·2046 g.).

2 : 4-*Dichloro*-6-*bromo*-5-*nitrophenol*.—Similar bromination of 2 : 4-dichloro-5-nitrophenol gave the 6-*bromo*-derivative which separated from light petroleum (b. p. 80—100°) in aggregates of colourless prisms, m. p. 92—93° (0·1256 G. gave 0·2092 g. AgCl + AgBr. $C_6H_2O_3NCl_2Br$ requires AgCl + AgBr, 0·2078 g.).

2 : 4-*Dichloro*-6-*bromo*-2′ : 4′-*dinitrodiphenyl ether*, prepared from 2 : 4-dichloro-6-bromophenol and chlorodinitrobenzene, crystallised from alcohol in pale yellow leaflets, m. p. 140—141° (0·2414 G. gave 0·2826 g. AgCl + AgBr. $C_{12}H_5O_5N_2Cl_2Br$ requires AgCl + AgBr, 0·2810 g.).

Nitration of 2 : 4-*Dichloro*-6-*bromo*-2′ : 4′-*dinitrodiphenyl Ether*.—A solution of the ether in 10 parts of nitric acid was heated for ½ hour at 100°. After cooling, water was added and the crude product (*A*) was collected. When dry it had m. p. 145—147°, and crystallised from a mixture of alcohol and glacial acetic acid in clusters of pale yellow prisms, m. p. 149—149·5° (0·1110 G. gave 0·1198 g. AgCl + AgBr. Calc. for mononitration : AgCl + AgBr, 0·1164 g.).

The mixture so obtained was heated with piperidine, and the alkaline solution of the phenols formed was rendered just neutral with hydrochloric acid. The precipitate was crystallised from light petroleum and then had m. p. 92—93°, alone or when mixed with a specimen of 2 : 4-dichloro-6-bromo-5-nitrophenol. Excess of hydrochloric acid was added to the solution from which this phenol had been precipitated, and the whole was extracted with ether.

The extract yielded a second phenol, m. p. 76—77°, which did not depress the m. p. of 2 : 4-dichloro-6-bromo-3-nitrophenol.

2 : 4-*Dichloro*-6-*bromophenyl* p-*toluenesulphonate*, prepared in the usual manner, crystallised from light petroleum in colourless rhombohedra, m. p. 82—83° (0·0844 G. gave 0·1010 g. AgCl + AgBr. $C_{13}H_9O_3Cl_2BrS$ requires AgCl + AgBr, 0·1012 g.).

Nitration of 2 : 4-*Dichloro*-6-*bromophenyl* p-*Toluenesulphonate.*—The ester was dissolved in 10 parts of nitric acid (*d* 1·5). After 20 minutes water was added until crystallisation began, whereupon excess of water was added. The crude nitro-derivative (*B*) crystallised from glacial acetic acid in pale yellow rhombohedra, m. p. 122—125° (0·1148 G. gave 0·1124 g. AgCl + AgBr. Calc. for mononitration : AgCl + AgBr, 0·1122 g.).

Piperidine scission of the mixture so obtained gave 1-*o*-nitro-*p*-toluenesulphonylpiperidine, m. p. 112°, and a mixture of phenol which melted at 72—73°. A mixture of 2 : 4-dichloro-6-bromo-3-nitro- and 2 : 4-dichloro-6-bromo-5-nitro-phenol closely resembled this product, from which, by the method of partial precipitation from alkaline solution, a pure sample of 2 : 4-dichloro-6-bromo-5-nitrophenol was isolated, m. p. 92—93°.

2 : 3 : 4-*Trichloro*-6-*bromophenol.*—This phenol, required at one stage of the investigation, was obtained by adding bromine water to a solution of 2 : 3 : 4-trichlorophenol until a colour persisted. Addition of water precipitated the *bromo*-derivative, which was dried in a vacuum, and then crystallised from light petroleum. It formed irregular rectangular plates, m. p. 84—85° (0·0858 G. gave 0·1914 g. AgCl + AgBr. $C_6H_2OCl_3Br$ requires AgCl + AgBr, 0·1920 g.).

2 : 4 : 5-*Trichloro*-6-*bromophenol* was similarly obtained from 2 : 4 : 5-trichlorophenol, and formed a microcrystalline powder, m. p. 81—82° (0·0834 G. gave 0·1872 g. AgCl + AgBr. $C_6H_2OCl_3Br$ requires AgCl + AgBr, 0·1866 g.).

o-*Nitro*-p-*toluenesulphonyl Chloride.*—Reverdin and Crépieux (*Bull. Soc. chim.*, 1901, **25**, 1040) obtained this compound by nitrating *p*-toluenesulphonyl chloride with mixed nitric and sulphuric acids. We have found it more convenient to add the chloride to 15 parts of nitric acid (*d* 1·5), with subsequent precipitation on ice.

2 : 4-*Dichloro*-6-*bromo*-3-*nitrophenyl* o-*nitro*-p-*toluenesulphonate*, from the last-named chloride and the appropriate phenol, crystallised from glacial acetic acid in almost colourless prisms, m. p. 122—122·5° (0·0344 G. gave 0·0332 g. AgCl + AgBr. $C_{13}H_7O_7N_2Cl_2BrS$ requires AgCl + AgBr, 0·0336 g.). The analogous 2 : 4-*dichloro*-6-*bromo*-5-*nitrophenyl* ester separated from glacial acetic acid in almost colourless rectangular plates, m. p. 134—135° (0·1196 G.

gave 0·1190 g. AgCl + AgBr. $C_{13}H_7O_7N_2Cl_2BrS$ requires AgCl + AgBr, 0·1169 g.).

4-*Bromo*-2-*nitro*-4′-*methyldiphenyl ether*, prepared from *p*-cresol and 2 : 5-dibromonitrobenzene, crystallised from alcohol in pale brownish leaflets, m. p. 109·5° (Found : Br, 26·7. $C_{13}H_{10}O_3NBr$ requires Br, 26·0%). Piperidine scission of the ether occurred with some difficulty, and it was necessary to use 50% sulphuric acid to extract the 4-bromo-2-nitrophenylpiperidine formed from its mixture with unchanged ether. The *p*-cresol formed was identified as its *p*-toluenesulphonyl derivative.

Nitration of 4-*Bromo*-2-*nitro*-4′-*methyldiphenyl Ether.*—A solution of the ether in a mixture of 5 parts of glacial acetic acid and 5 parts of nitric acid (*d* 1·5) was heated for 2 hours at 100°. The solution was treated with water, and the precipitate crystallised successively from glacial acetic acid and alcohol. The product so obtained was an equimolecular compound, or an inseparable mixture, of unchanged ether with 4-bromo-2 : 2′-dinitro-4′-methyldiphenyl ether, and formed pale yellow plates, m. p. 126—127° (Found : Br, 24·1. An equimolecular mixture requires Br, 24·2%). Piperidine scission of the substance proceeded readily, and 3-nitro-*p*-cresol, m. p. 33°, was isolated in addition to 4-bromo-2-nitrophenylpiperidine.

4-Bromo-2-nitro-4′-methyldiphenyl ether was dissolved in 10 parts of nitric acid (*d* 1·5) at 0°. After 10 minutes, the solution was poured into water, and the precipitated solid collected. Acidification of the filtrate, followed by ether extraction, yielded 4-bromo-2 : 6-dinitrophenol, m. p. 75—76°. The precipitated 4-*bromo*-2 : 2′ : 3′-*trinitro*-4′-*methyldiphenyl ether* crystallised from glacial acetic acid in pale yellow plates, m. p. 166° (Found : Br, 20·2. $C_{13}H_8O_7N_3Br$ requires Br, 20·1%). This trinitro-ether was submitted to piperidine scission. The cooled solution was well shaken with hydrochloric acid and ether, and the ethereal layer extracted with sodium hydroxide solution. Evaporation of the ethereal solution gave 4-bromo-2-nitrophenylpiperidine, whilst acidification of the alkaline solution gave 2 : 3-dinitro-*p*-cresol, m. p. 156—157° (Found : N, 12·0. Calc. : N, 12·1%).

4-*Bromo*-2′-*nitro*-4′-*methyldiphenyl ether* was obtained from *p*-bromophenol and 4-chloro-3-nitrotoluene. It crystallised from alcohol in pale yellow prisms, m. p. 82° (Found : Br, 26·3. $C_{13}H_{10}O_3NBr$ requires Br, 26·0%).

Nitrative Scission of 4-*Bromo*-2′-*nitro*-4′-*methyldiphenyl Ether.*—The ether was added to 10 parts of nitric acid (*d* 1·5). After 15 minutes, it was poured into water. The yellow solid precipitated was 4-bromo-2 : 6-dinitrophenol.

Action of Sulphuric Acid on 4-*Bromo*-2-*nitro*-4′-*methyl- and*

4-Bromo-2′-nitro-4′-methyl-diphenyl Ether.—The 2′-nitro-ether was heated at 100° with excess of concentrated sulphuric acid until solution occurred. Hydrogen bromide and a little bromine were given off even in the cold. On cooling and dilution, white silky needles of *2′-nitro-4′-methyldiphenyl ether 4-sulphonic acid* separated, and after these had been dried in a vacuum over sulphuric acid they had m. p. 131—132° (Found : S, 11·0. $C_{13}H_{13}O_6NS$ requires S, 10·4%).

Under similar conditions the 2-nitro-ether was unaffected.

2 : *4-Dinitro-4′-methyldiphenyl Ether.*—This was obtained from *p*-cresol and chlorodinitrobenzene, and crystallised from alcohol in very pale yellow rectangular plates, m. p. 97—98° (Found : N, 10·2. $C_{13}H_{10}O_5N_2$ requires N, 10·2%).

2 : 4 : *2′-Trinitro-4′-methyldiphenyl Ether.*—The last-named ether was dissolved in a mixture of 5 parts of glacial acetic acid and 5 parts of nitric acid (*d* 1·5). The solution was heated for 2 hours at 100°, cooled, and poured into water. The precipitate was crystallised from glacial acetic acid, and gave pale yellow rectangular needles, m. p. 175—176° (Found : N, 13·2. $C_{13}H_9O_7N_3$ requires N, 13·2%).

Piperidine scission of the ether gave 2 : 4-dinitrophenylpiperidine and 3-nitro-*p*-cresol.

2 : 4 : 2′ : *3′-Tetranitro-4′-methyldiphenyl Ether.*—2 : 4-Dinitro-4′-methyldiphenyl ether was added to 10 parts of nitric acid (*d* 1·5) at 0°. After 20 minutes, the solution was poured into water, and the resulting precipitate crystallised from glacial acetic acid. Brownish-yellow rectangular crystals were obtained, m. p. 184° (Found : N, 15·1. $C_{13}H_8O_9N_4$ requires N, 15·4%).

Piperidine scission of this ether gave 2 : 4-dinitrophenylpiperidine and 2 : 3-dinitro-*p*-cresol, m. p. 156—157°.

2 : *4-Dinitro-2′* : *4′-dimethyldiphenyl ether*, prepared from *m*-4-xylenol and chlorodinitrobenzene, crystallised from alcohol containing animal charcoal in brownish rectangular plates, m. p. 106° (Found : N, 9·9. $C_{14}H_{12}O_5N_2$ requires N, 9·7%).

Mononitration of 2 : *4-Dinitro-2′* : *4′-dimethyldiphenyl Ether.*—The last-named ether was added to a mixture of 5 parts of glacial acetic acid and 5 parts of nitric acid (*d* 1·5). The solution was heated at 100° for 2 hours, cooled, poured into water, and the precipitate collected. It crystallised from glacial acetic acid in yellow prisms, m. p. 129—130° (Found : N, 12·9. $C_{14}H_{11}O_7N_3$ requires N, 12·6%).

Piperidine scission of this ether gave 2 : 4-dinitrophenylpiperidine and 6-nitro-*m*-4-xylenol, m. p. 95° (Pfaff, *Ber.*, 1883, **16**, 616) (Found : N, 8·2. Calc. : N, 8·4%).

Dinitration of 2 : *4-Dinitro-2′* : *4′-dimethyldiphenyl Ether.*—The ether was added to 10 parts of nitric acid (*d* 1·5) at 0°. After 20 minutes, the solution was poured into water, and the precipitated 2 : 4 : 3′ : 5′-*tetranitro*-2′ : 4′-*dimethyldiphenyl ether* crystallised from glacial acetic acid. It formed a cream-coloured microcrystalline powder, m. p. 198° (Found: N, 14·8. $C_{14}H_{10}O_9N_4$ requires N, 14·8%).

Piperidine scission of the ether gave 2 : 4-dinitrophenylpiperidine and 2 : 6-*dinitro*-m-4-*xylenol*, which crystallised from light petroleum in small yellow needles, m. p. 162—163° (Found: N, 12·9. $C_8H_8O_5N_2$ requires N, 13·0%).

2 : 6-*Dinitro*-m-4-*xylyl* p-*toluenesulphonate* crystallises from alcohol in pale brown needles, m. p. 110—111° (Found: N, 7·8. $C_{15}H_{14}O_7N_2S$ requires N, 7·6%).

5-*Nitro*-m-4-*xylenol*.—This was prepared by nitrating *m*-4-xylenol with a mixture of glacial acetic acid and nitric acid (*d* 1·4) (compare Wallach and Blembel, *Annalen*, 1901, **319**, 99) (Found: N, 8·5. Calc.: N, 8·4%).

The p-*toluenesulphonyl* derivative crystallised from alcohol in colourless plates, m. p. 111—112° (Found: S, 10·3. $C_{15}H_{15}O_5NS$ requires S, 10·0%).

5 : 6-*Dinitro*-m-4-*xylyl* o-*Nitro*-p-*toluenesulphonate*.—The above sulphonate was added to 10 parts of nitric acid (*d* 1·5) at the ordinary temperature. After 10 minutes the nitration product was precipitated by adding water and was crystallised from alcohol–glacial acetic acid. It formed colourless plates, m. p. 140—141° (Found: N, 10·5. $C_{15}H_{13}O_9N_3S$ requires N, 10·2%).

When this *compound* was heated with piperidine, etc., it was converted into 5 : 6-*dinitro*-m-4-*xylenol*, which crystallised from alcohol in bunches of green needles, m. p. 119—120° (Found: N, 12·9. $C_8H_8O_5N_2$ requires N, 13·0%).

Nitration of 6-*Nitro*-m-4-*xylenol*.—This phenol was added to 10 parts of nitric acid (*d* 1·5) at room temperature. After 10 minutes the solution was poured into water, and the precipitate was crystallised from alcohol. It formed slender green needles, m. p. 119—120°, and was identical with the above 5 : 6-dinitro-*m*-4-xylenol.

4-*Chloro*-2-*nitro*-2′ : 4′-*dimethyldiphenyl ether*, formed from *m*-4-xylenol and 2 : 5-dichloronitrobenzene, crystallised from alcohol in rosettes of pale brown rectangular plates, m. p. 77—78° (Found: Cl, 13·1. $C_{14}H_{12}O_3NCl$ requires Cl, 12·8%).

4-*Chloro*-2 : 5′-*dinitro*-2′ : 4′-*dimethyldiphenyl Ether*.—The last-named ether was dissolved in a mixture of 5 parts each of nitric and acetic acids. After the solution had been heated at 100° for 2 hours, it was cooled and poured into water. The precipitate was crystallised from alcohol, and formed pale yellow prisms, m. p. 88—89° (Found : Cl, 11·2. $C_{14}H_{11}O_5N_2Cl$ requires Cl, 10·8%).

Piperidine scission of this compound gave 4-chloro-2-nitrophenylpiperidine, m. p. 48°, and 6-nitro-*m*-4-xylenol, m. p. 95°.

4-*Chloro*-2 : 3′ : 5′-*trinitro*-2′ : 4′-*dimethyldiphenyl Ether*.—4-Chloro-2-nitro-2′ : 4′-dimethyldiphenyl ether was added to 10 parts of nitric acid (*d* 1·5), and after 20 mins. the solution was poured into water. The solid precipitated crystallised from glacial acetic acid in pale yellow prisms, m. p. 140° (Found : Cl, 9·9. $C_{14}H_{10}O_7N_3Cl$ requires Cl, 9·5%).

Piperidine scission of this *substance* gave 4-chloro-2-nitrophenylpiperidine, m. p. 48°, and 2 : 6-dinitro-*m*-4-xylenol, m. p. 162—163°.

4-*Bromo*-2-*nitro*-2′ : 4′-*dimethyldiphenyl ether*, prepared from *m*-4-xylenol and 2 : 5-dibromonitrobenzene, was crystallised from alcohol and then from light petroleum (b. p. 60—80°). It formed small cream-coloured irregular rectangular plates, m. p. 89—90° (Found : Br, 25·0. $C_{14}H_{12}O_3NBr$ requires Br, 24·8%).

4-*Bromo*-2 : 5′-*dinitro*-2′ : 4′-*dimethyldiphenyl Ether*.—Nitration of the preceding ether with a mixture of 5 parts each of acetic and nitric acids (*d* 1·5) in the usual manner gave a product which crystallised from alcohol–glacial acetic acid in clusters of small pale yellow needles, m. p. 98—99° (Found : Br, 22·1. $C_{14}H_{11}O_5N_2Br$ requires Br, 21·8%).

Piperidine scission of this substance gave 4-bromo-2-nitrophenylpiperidine, m. p. 48—49°, and 6-nitro-*m*-4-xylenol, m. p. 95°.

Action of Fuming Nitric Acid on 4-*Bromo*-2-*nitro*-2′ : 4′-*dimethyldiphenyl Ether*.—This ether was added to 10 parts of nitric acid (*d* 1·5) at 0°, and the solution was warmed at 100° for 15 mins. The cooled solution was poured into water, and the precipitated solid crystallised from alcohol–glacial acetic acid. It formed a pale yellow microcrystalline powder, m. p. 182—183°, unaffected by re-nitration (Found : N, 13·6%).

Piperidine scission of this product gave 2 : 4-dinitrophenylpiperidine from the ethereal portion, and from the alkaline portion were obtained both 6-nitro-*m*-4-xylenol, m. p. 95°, and a little 2 : 6-dinitro-*m*-4-xylenol, m. p. 162—163°.

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