

## Synthesis of Compounds Related to Muscarufin

### III.\* The Ullmann Reaction with *o*-Chloro-iodobenzene

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Reaction of *o*-chloro-iodobenzene with copper gave 2,2'-dichlorodiphenyl in relatively poor yield. Chlorobenzene and, surprisingly, *o*-dichlorobenzene were the major by-products but several others were also isolated.

*m*-Chloro- and *p*-chloro-iodobenzene gave fair yields of the symmetrical dichlorodiphenyls. No dichlorobenzenes were detected in the reaction products.

The results are discussed in relation to the mechanism of the Ullmann reaction.

Attempts to convert 2,3,5-triacetoxy-1,4-bis-(2-carbomethoxyphenyl)-benzene into 3-hydroxy-2,5-bis-(2-carboxyphenyl)-*p*-benzoquinone were not successful. This has been due mainly to the ready formation of dilactones (*cf.* Part I<sup>1</sup>) and to the instability to alkali of any monohydroxyquinone which might have been formed.

Some analogues without carboxyl groups were therefore prepared. The simplest, 3-hydroxy-2,5-diphenyl-*p*-benzoquinone, was obtained from 2,5-diphenyl-*p*-benzoquinone by Thiele acetylation, acid methanolysis and oxidation with nitrous acid. It dissolved readily in dilute aqueous alkali giving a violet solution, which turned brown in a few minutes. No hydroxyquinone could be recovered from this solution.

An analogue with chlorine atoms in place of the carboxyl groups was prepared with the intention of replacing them at a later stage by carboxyl groups. The Ullmann coupling of *o*-chloro-iodobenzene and 2,5-di-iodohydroquinone dimethylether gave a mixture, which was more heterogeneous than those obtained from similar couplings. On careful fractionation it gave 2,2'-dichlorodiphenyl (I), 2,5-dimethoxy-1,4-bis-(2-chlorophenyl)-benzene (II, 8% yield based on the di-iodo compound) and a product A.

Compound II on oxidation with nitric acid gave 2,5-bis-(2-chlorophenyl)-*p*-benzoquinone. This compound, which has previously been obtained in small

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quantities from *o*-chlorobenzenediazonium chloride and *p*-benzoquinone<sup>2</sup> was converted into 3-hydroxy-2,5-bis-(2-chlorophenyl)-*p*-benzoquinone by the route described above.

The product A, C<sub>14</sub>H<sub>12</sub>Cl<sub>2</sub>O<sub>2</sub>, m. p. 106° (yield 11 %), on treatment with nitric acid gave a quinone, C<sub>12</sub>H<sub>6</sub>Cl<sub>2</sub>O<sub>2</sub>, and was therefore presumed to be 2',4-dichloro-2,5-dimethoxydiphenyl (III).

An independent synthesis was made by a mixed Ullmann coupling of *o*-chloro-iodobenzene and 2-chloro-5-iodohydroquinone dimethylether, which gave a mixture from which 2,2'-dichlorodiphenyl, 2',4-dichloro-2,5-dimethoxydiphenyl (III) and 4,4'-dichloro-2,2',5,5'-tetramethoxydiphenyl (IV) were isolated by distillation. An unexpected by-product, 2,5-dichlorohydroquinone dimethylether (V), was also encountered in this reaction. Compound III proved to be identical with A and oxidation with nitric acid gave 5-chloro-2-(2-chlorophenyl)-*p*-benzoquinone identical with that obtained from A.

As there appeared to be a side-reaction involving a transfer of chlorine atoms in the mixed Ullmann couplings with *o*-chloro-iodobenzene it was of interest to study the reaction of *o*-chloro-iodobenzene with copper in greater detail. This reaction has previously been used for the synthesis of 2,2'-dichlorodiphenyl by Bretscher<sup>3</sup> (20 % yield) and by van Alphen<sup>4</sup>. The reaction was run under the same conditions as before, except that the reaction time was prolonged to avoid traces of unchanged starting material which might complicate the isolation procedure. No special precautions were taken to exclude air and commercial copper bronze was used without purification or activation.

Careful fractionation of the reaction product by distillation and chromatography on alumina gave: chlorobenzene (VI, 8 %), *o*-dichlorobenzene (VII, 5 %), 2,2'-dichlorodiphenyl (I, 39 %), dibenzofuran (VIII, 3 %), triphenylene (IX, 0.5 %) and two unidentified products.

Coupling of *m*-chloro-iodobenzene under the same conditions gave chlorobenzene (6 %) and 3,3'-dichlorodiphenyl (55 %) while *p*-chloro-iodobenzene gave chlorobenzene (11 %) and 4,4'-dichlorodiphenyl (63 %). No dichlorobenzene was detected in either case and the high boiling material was therefore not investigated. These results are in agreement with those of Ullmann<sup>5</sup> and van Alphen<sup>6</sup>.

The copper bronze used in these experiments contained small amounts of fatty acids (ca. 0.4 %), partly as copper salts. According to previous experience in this laboratory it is a superior reagent for Ullmann couplings; it gives reproducible yields and usually no unchanged iodo-compounds can be recovered from reactions carried out above 220°. The isolation of dibenzofuran and small quantities of aliphatic ketones indicated, however, some uncontrolled reaction with atmospheric oxygen and with impurities in the copper. The reaction was therefore repeated under anaerobic conditions with purified copper.

The fatty acids and their copper salts were removed by ether extraction and the copper was then heated to 360° *in vacuo*. The coupling reaction was carried out under oxygen-free nitrogen using the same conditions of time and temperature as in the previous experiment. The reaction product was fractionated in a spinning band column and the distillation residue was chromatographed on alumina. Somewhat surprisingly a large amount of starting material was recovered (48 %). Chlorobenzene (VI, 8 %), *o*-dichlorobenzene



## DISCUSSION

The Ullmann reaction with *o*-chloro-iodobenzene and copper gives *o*-dichlorobenzene as a by-product. Mixed Ullmann couplings with *o*-chloro-iodobenzene give other products in which aromatic iodine has been replaced by chlorine.

Somewhat similar halogen exchange reactions can be brought about by heating an iodo-arene with copper(I) chloride either alone or in a basic solvent. An analogous reaction for the conversion of bromo-arenes into the chloro-analogues has recently been patented<sup>7</sup>. These reactions appear to be a new example of copper-catalysed  $S_N$  reactions<sup>8</sup>.

However, in the reaction of *o*-chloro-iodobenzene with copper no copper(I) chloride is present initially and it appears therefore as if copper(I) chloride or its equivalent is formed during the reaction and then reacts with an iodo-arene to give the halogen exchange product. This is somewhat surprising as aromatic chlorine is not attacked by copper unless it is activated, *e. g.* by a nitro or carbonyl group in the *ortho* position.

The mechanism of the Ullmann reaction is not known but has been the subject of much discussion, and free radicals, "crypto-radicals", copper organic compounds and carbanions have been proposed as intermediates. It has been suggested that the intermediate either dimerises or reacts with a second molecule of iodo-compound (*cf.* review by Fanta<sup>9</sup>); in the latter case the reaction may be related to the copper-catalysed substitution reactions<sup>8</sup>.

The mobility of chlorine in the reaction with *o*-chloro-iodobenzene may be related to an intermediate or to the main reaction product, 2,2'-dichlorodiphenyl. The latter appears unlikely and it thus seems possible that chlorine can be eliminated from the intermediate from *o*-chloro-iodobenzene though not from the intermediates from *m*-chloro- and *p*-chloro-iodobenzene.

This recalls the lability of *o*-halogenophenyllithium and *o*-halogenophenylmagnesium halides, which split off metal halide giving dehydrobenzene (benzyne), which undergoes addition reactions, reacts with dienes and polymerises to diphenylene, triphenylene *etc.*<sup>10</sup> The isolation of small amounts of triphenylene in the present case is a slight indication of the formation of dehydrobenzene.

On this analogy the reactive intermediate in the Ullmann reaction is likely to be an arylcopper. Phenylcopper is reported to react with certain carbonyl groups and also with allyl bromide, acyl halides *etc.*<sup>11</sup> and it is thus possible that *o*-chlorophenylcopper can eliminate copper(I) chloride to give dehydrobenzene.

Further work is, however, necessary to establish this and to clarify the relation to the main reaction and to the dehalogenation process, which is a major side reaction in Ullmann couplings.

In the present investigations chlorobenzene was obtained as the normal dehalogenation product; some of the corresponding "dehydrogenation" products, a dichloro-iododiphenyl and a trichloroterphenyl were also isolated and together account for one third of the dehalogenation. These findings are analogous to those of Rapson and Shuttleworth<sup>12</sup>, who obtained 2-carbethoxy- and 4-carbethoxydiphenyl from the reaction of iodobenzene with copper in the presence of ethyl benzoate.

No satisfactory explanation can as yet be given for the formation of dibenzofuran.

## EXPERIMENTAL

The melting points were determined on a Kofler block. The ultraviolet spectra were measured in ethanol (99.5 %) with a Beckman DU instrument. The infrared spectra were recorded on a Perkin Elmer No. 21 instrument with a sodium chloride prism. Light petroleum refers to the fraction b.p. 40–60°. The copper used was a lithographic bronze containing ca. 0.2–0.5 % fatty acids, mainly stearic, palmitic and oleic acids, partly as the copper salts.

*3-Hydroxy-2,5-diphenyl-p-benzoquinone.* Perchloric acid (15 ml, *d* 1.67) was added with stirring to 2,5-diphenyl-*p*-benzoquinone<sup>13</sup> (20 g) suspended in acetic anhydride (300 ml). The temperature was kept below 35°. Stirring was continued for 24 h and the mixture was then poured onto crushed ice. After standing overnight the product was collected (21 g) and a portion recrystallised from ethanol (charcoal), prisms, m. p. 195–198°. Kvalnes<sup>14</sup> reported m. p. 191°. (Found: C 70.9; H 5.3. Calc. for C<sub>24</sub>H<sub>20</sub>O<sub>3</sub>: C 71.3; H 5.0.)

The crude triacetate (20 g) was heated under reflux with absolute methanol (200 ml) and concentrated sulphuric acid (10 ml) for 1 h. Most of the solvent was distilled off and after cooling the hydroxyhydroquinone was collected, washed with methanol and dried. It was very sensitive to air and was therefore not purified but was suspended in acetic acid (200 ml) and oxidised with sodium nitrite (8 g) in water (40 ml) at room temperature. After a few minutes the red product was filtered off and was then recrystallised from acetic acid giving 3-hydroxy-2,5-diphenyl-*p*-benzoquinone as dark red plates, m. p. 235–238° (slight decomp.). Overall yield 50 %. (Found: C 78.2; H 4.7. Calc. for C<sub>18</sub>H<sub>12</sub>O<sub>3</sub>: C 78.3; H 4.4.) It was further characterised as the acetate (acetic anhydride, perchloric acid, room temperature), yellow needles from acetic anhydride, m. p. 174–175°. (Found: C 75.3; H 4.6. Calc. for C<sub>20</sub>H<sub>14</sub>O<sub>4</sub>: C 75.5; H 4.4.)

*2,5-Dimethoxy-1,4-bis-(2-chlorophenyl)-benzene* (II). 2,5-Di-iodohydroquinone dimethylether (40 g, 0.1 mole), 2-chloro-iodobenzene (95 g, 0.4 mole) and copper bronze (300 g) were mixed and heated in a salt bath. The reaction started at 210° and the temperature rose to 270°. After cooling, the mass was extracted exhaustively with chloroform (Soxhlet) and after removal of the solvent the extract was distilled at 0.5–1 mm. Fraction 1: b. p. below 110°, 27 g; 2: 110–130°, 2.7 g; 3: 130–160°, 5.8 g; 4: 160–230°, 15.2 g; 5: 230–290°, 8.8 g.

Fraction 1 was discarded; fraction 2 solidified and was found to be 2,2'-dichlorodiphenyl, m. p. 45–54°. Fraction 3 on trituration with cyclohexane gave a product A (1.6 g) m. p. ca. 100° and fraction 4 on trituration with benzene-cyclohexane mixtures gave a compound B (2.6 g), m. p. ca. 200°. Fraction 5 gave only small amounts of high melting material, which was not further investigated.

The non-crystalline parts of fractions 3–5 were combined and redistilled through a 5 cm Vigreux column and further quantities of A (1.5 g) and B (0.3 g) were obtained by trituration of the distillate.

The investigation of A is described later, B proved to be the desired terphenyl derivative II. It was recrystallised from benzene giving prisms containing ca. 1 mole of benzene of crystallisation. The dried product melted at 214–216°. (Found: 15 % loss of weight on drying at 100°, 1 mm. Calc. for C<sub>20</sub>H<sub>16</sub>Cl<sub>2</sub>O<sub>2</sub> · C<sub>6</sub>H<sub>6</sub>: 18 %. Found: C 66.9; H 4.6; Cl 19.5. Calc.: C 66.9; H 4.5; Cl 19.7.)

*2,5-Bis-(2-chlorophenyl)-p-benzoquinone.* Finely powdered 2,5-dimethoxy-1,4-bis-(2-chlorophenyl)-benzene (1.2 g) was suspended in nitric acid (25 ml, *d* 1.42) and the mixture was shaken for 10 min. Water (100 ml) was then added and after a few hours the precipitate was collected and recrystallised from ethyl acetate to give yellow plates or prisms, m. p. 200–202° (0.7 g). (Found: C 65.8; H 3.1; Cl 21.2. Calc. for C<sub>18</sub>H<sub>10</sub>Cl<sub>2</sub>O<sub>2</sub>: C 65.7; H 3.1; Cl 21.5.)

*3-Hydroxy-2,5-bis-(2-chlorophenyl)-p-benzoquinone.* The quinone (1.1 g) in acetic anhydride (20 ml) was shaken with perchloric acid (2 ml, *d* 1.67) for 15 h. The dark solution was poured onto ice and the product was collected and recrystallised from methanol (charcoal) giving 2,3,5-triacetoxy-1,4-bis-(2-chlorophenyl)-benzene, prisms, m. p. 154–158° (0.65 g). (Found: C 61.3; H 3.7; Cl 15.1. Calc. for C<sub>24</sub>H<sub>18</sub>Cl<sub>2</sub>O<sub>6</sub>: C 60.9; H 3.8; Cl 15.0.)

The triacetate (0.33 g) was heated under reflux with absolute methanol (25 ml) and concentrated sulphuric acid (1 ml) for 1 h. On addition of water (50 ml) the hydroxy-

hydroquinone precipitated as a colourless solid (0.22 g). A small portion was recrystallised from methanol and sublimed giving prisms, m. p. 206–209°. (Found: C 61.6; H 3.3. Calc. for  $C_{18}H_{12}Cl_2O_2$ : C 62.3; H 3.5.) The main portion (0.19 g) was dissolved in acetic acid (5 ml) and oxidised with sodium nitrite (0.2 g) in water (1 ml). After 0.5 h the mixture was diluted with water (20 ml) and the orange product was collected (0.18 g). Sublimation gave 3-hydroxy-2,5-bis-(2-chlorophenyl)-*p*-benzoquinone as yellow prisms, m. p. 187–190°. (Found: C 62.2; H 2.7; Cl 20.3. Calc. for  $C_{18}H_{10}Cl_2O_3$ : C 62.6; H 2.9; Cl 20.5.)

*Investigation of A.* The crude product was recrystallised from cyclohexane and from methanol giving needles, m. p. 105–106°. Qualitative tests indicated the presence of chlorine and the absence of iodine. (Found: C 59.5; H 4.3; Cl 25.2. Calc. for  $C_{14}H_{12}Cl_2O_2$ : C 59.4; H 4.3; Cl 25.1.) Ultraviolet absorption spectrum:  $\lambda_{\max}$  303 m $\mu$ , ( $\epsilon$  6700),  $\lambda_{\min}$  270 m $\mu$  ( $\epsilon$  1200), shoulder at ca. 255 m $\mu$ .

For oxidation, A (0.5 g) was shaken for a few minutes with nitric acid (10 ml, *d* 1.42). Water (50 ml) was then added and the product collected (0.4 g). Sublimation and recrystallisation from methanol gave needles, m. p. 111–112°, resolidifying and finally melting at 117–118°. The analytical sample was resublimed. (Found: C 56.7; H 2.2; Cl 26.1. Calc. for  $C_{12}H_8Cl_2O_2$ : C 56.9; H 2.4; Cl 28.0.)

*Synthesis of 2',4-dichloro-2,5-dimethoxydiphenyl (III).* Chlorohydroquinone dimethylether (17.2 g, 0.10 mole) in acetic acid (25 ml) was treated with iodine monochloride (19.4 g, 0.12 mole) in acetic acid (10 ml). When the initial reaction had subsided the mixture was heated overnight on the water bath. The cooled solution was treated with sulphur dioxide and some water, the colourless precipitate was collected and recrystallised from ethanol giving pure 2-chloro-5-iodohydroquinone dimethylether, m. p. 114–116°, in 56 % yield. Posternak *et al.*<sup>15</sup> report m. p. 114–115°.

*o*-Chloro-iodobenzene (12 g, 0.05 mole), 2-chloro-5-iodohydroquinone dimethylether (7.5 g, 0.025 mole) and copper bronze (48 g) were mixed and heated in a salt bath. At 210° the reaction raised the temperature to 245°. The mixture was kept at this temperature for 20 min, then cooled and extracted with chloroform (Soxhlet). Evaporation of the solvent gave an oil, which was distilled through a 5 cm Vigreux column at ca. 0.5 mm. Fraction 1: b. p. 75–80°, 1.1 g; 2: 90–98°, 0.9 g; 3: 98–118°, 1.4 g; 4: 140–150°, 2.6 g; 5: 180–190°, 1.9 g.

The first two fractions deposited crystalline material, which was filtered off and washed with cyclohexane. The product (0.3 g) was freed from oily contaminants by sublimation and was finally purified by recrystallisation from methanol, prisms m. p. 132–133°. A second form, needles m. p. 125–127°, was occasionally observed. Mixed melting point with 2,5-dichlorohydroquinone dimethylether gave no depression. Fraction 3 solidified on standing, recrystallisation from methanol gave 2,2'-dichlorodiphenyl, m. p. 49–54°. Fraction 4 on trituration with methanol gave a product, m. p. 102–105° (1.8 g); recrystallisation from methanol and from cyclohexane raised the m. p. to 105–106° alone or in admixture with A. It was further oxidised to 5-chloro-2-(2-chlorophenyl)-*p*-benzoquinone as described for A; the same dimorphism was encountered and the mixed m. p. gave no depression.

Fraction 5 solidified and was recrystallised from ethanol to give needles (0.6 g, m. p. 143–150°). Further recrystallisation from acetic acid gave plates, m. p. 154–156°, undepressed by 4,4'-dichloro-2,2',5,5'-tetramethoxydiphenyl obtained from the reaction of 2-chloro-5-iodohydroquinone dimethylether with copper. Posternak *et al.*<sup>15</sup> report m. p. 151°. (Found: C 56.0; H 4.7; Cl 21.0. Calc. for  $C_{16}H_{16}Cl_2O_4$ : C 56.0; H 4.7; Cl 20.7.)

*Ullmann coupling of o-chloro-iodobenzene.* *o*-Chloro-iodobenzene (95 g, 0.4 mole) and copper bronze (256 g) were intimately mixed in a flask fitted with a reflux condenser and a thermometer and placed in a salt bath (180°). The temperature was raised and at ca. 190° the reaction raised the temperature to 230°. When the reaction had subsided the temperature was raised further and kept at 250–260° for 2 h. The reflux condenser was replaced by a still head and some volatile material distilled off at atmospheric pressure directly from the reaction vessel. Fraction 1: b. p. 130–140°, 3.5 g; 2: 150–180°, 2.8 g. The residue was extracted with chloroform yielding on evaporation of the solvent a brown oil (ca. 40 g) which was distilled through a 5 cm Vigreux column at ca. 10 mm to give fractions 3: 45–60°, 0.15 g; 4: 60–150°, 0.91 g; 5: 140–145°, 8.95 g, and then at ca. 1.5 mm giving: 6: 105–125°, 13.8 g; 7: 125–140°, 2.2 g; 8: 140–175°, 1.5 g; 9: 175–185°, 2.3 g; 10: 185–210°, 1.2 g. The distillation was interrupted and the residue extracted with chloroform to give fraction 11: 3.1 g, a brown oil.

Fraction 1 from b. p. and IR data was found to be fairly pure *chlorobenzene*. Nitration gave *2,4-dinitrochlorobenzene*, m. p. 49–52°, undepressed by an authentic sample.

Fraction 2 was similarly found to be mainly *o-dichlorobenzene*. Treatment with chloro-sulphonic acid gave *bis-(3,4-dichlorophenyl)-sulphone*, m. p. 175–177°, undepressed by an authentic specimen. Fraction 3 contained largely *o-dichlorobenzene* (IR), and fraction 4 appeared to be heterogeneous (IR, UV).

Fractions 5–7 largely solidified on standing and on recrystallisation afforded crude *2,2'-dichlorodiphenyl*, m. p. 55–60° (16.3 g).

Fraction 8 was triturated with ethanol to give *product C*, m. p. 156–170° (0.12 g).

The mother liquors from fractions 5–8 were combined and chromatographed on alumina (1 kg). Elution with light petroleum (1.7 l) gave an oil (4.7 g), which solidified on standing. Recrystallisation from methanol gave *2,2'-dichlorodiphenyl*, m. p. 57–60°, (3.9 g). Further elution with the same solvent (12.1) gave a semi-solid product (3.2 g) which was recrystallised from methanol to give *substance D*, m. p. 78–83° (ca. 2 g). Further elution with light petroleum gave crude *C* (0.5 g).

Fractions 9 and 10, which were strongly fluorescent yellow oils were combined and chromatographed on alumina (200 g). Elution with *cyclohexane* (450 ml) gave an oil (2.9 g), which on trituration with ethanol gave *C* (0.7 g). Further elution gave fractions (0.2 g) which were triturated with ethanol to give a *product E*, m. p. 95–105° (0.04 g). Elution with *cyclohexane-benzene* (9:1) gave a crystalline *material F*, m. p. ca. 190° (0.2 g).

Fraction 13 was chromatographed on alumina. The light petroleum eluate gave crude *C* (0.5 g) and *E* (0.1 g). Light petroleum-benzene (9:1) gave crude *F* (0.3 g) and a waxy product *G* (0.2 g) m. p. around 80°. Elution with benzene stripped the column giving a brownish yellow resin *H* (0.6 g).

*Product C* (total ca. 1 g) was recrystallised from ethanol and sublimed to give prisms, m. p. 179–181°. Qualitative tests indicated the presence of chlorine and absence of iodine.

*C* dissolved in concentrated sulphuric acid to give a blue solution. No satisfactory analysis has so far been obtained.

*Product D* (total ca. 2 g). Recrystallisation from methanol gave plates, m. p. 83–85°. The picrate was crystallised from ethanol, yellow needles, m. p. 98–101°. The UV-spectrum agreed with that of dibenzofuran and mixed m. p.s with authentic dibenzofuran and its picrate gave no depression.

*Product E* (total ca. 0.1 g) was not obtained in a state of purity. It melted around 100° and gave a picrate, m. p. ca. 150°.

*Product F* (total ca. 0.2 g) was recrystallised from ethanol and sublimed to give needles, m. p. 197–199°. The picrate was prepared in acetone and was recrystallised from ethanol; needles, m. p. 222–225°. The UV and IR-spectra agreed with those given for triphenylene and the mixed m. p.s with a commercial sample and the picrate prepared from it gave no depression.

*Product G* (total ca. 0.3 g). The IR spectrum of this waxy material contained bands characteristic for aliphatic ketones but no aromatic bands. This product must be a mixture of aliphatic ketones originating from the fatty acids in the copper bronze.

*Product H* was a brown resin with an extremely strong yellow fluorescence. The IR indicated that it was contaminated with aliphatic and ketonic material and it was not further investigated.

*Ullmann coupling of m-chloro-iodobenzene.* *m*-Chloro-iodobenzene (0.4 mole) was allowed to react with copper under the conditions described above. Direct distillation from the reaction mixture gave fraction 1: b. p. 130–135°, 3.8 g. The chloroform extract on distillation gave fraction 2: b. p. below 50°/15 mm, 0.1 g; 3: 123–130°/1.5, 21.1 g; 4: 130–140°, 8.0 g; 5: 140–160°, 3.5 g.

Fraction 1 was fairly pure *chlorobenzene* (b. p., IR) and was characterised as the *2,4-dinitro-derivative*. Fraction 2 contained largely *chlorobenzene*. No evidence for the presence of *m-dichlorobenzene* was obtained from the IR spectrum.

The IR spectra of fractions 3 and 4 were identical but fraction 5 was contaminated by aliphatic and ketonic material. All these fractions however solidified in the refrigerator and on recrystallisation from methanol gave *3,3'-dichlorodiphenyl*, m. p. 28–29.5°, in 55% yield. The mother liquors and the distillation residue were not investigated.

*Ullmann coupling of p-chloro-iodobenzene.* *p*-Chloro-iodobenzene (m. p. 54–57°) treated in the same way gave a distillate, b. p. 130–135°, 6.7 g, identified as chloro-

benzene by IR and by nitration. The extract could not be conveniently distilled because of the tendency of the product to sublime. It was therefore sublimed on to a cold finger (160–170°, 2 mm) and the sublimate was recrystallised from methanol giving 4,4'-dichlorodiphenyl, m. p. 144–148°, in 63 % yield. No evidence was obtained for the presence of a dichlorobenzene and the sublimation residue was not investigated.

*Coupling of o-chloro-iodobenzene under modified conditions.* Copper bronze (260 g) was exhaustively extracted with ether in a Soxhlet apparatus (extract: 1.0 g of a green wax), transferred while moist to a 250 ml three-necked flask fitted with thermometer, reflux condenser and a nitrogen inlet tube, and dried by heating *in vacuo*, finally at 360°/3 mm for 2 h. After cooling the flask was filled with oxygen-free nitrogen and *o*-chloro-iodobenzene (0.4 mole), which had been freshly distilled through a 30-plate column (b. p. 136.5–137.5°/50 mm), was then added with a slow current of nitrogen passing through the apparatus, the flask was placed in a salt bath (180°) and the temperature was raised to 250° (0.5 h) and kept at this level for 2 h. There was no marked evolution of heat and in contrast to previous experiments the inner temperature was all the time somewhat below that of the bath. The reflux condenser was then replaced by a still head and some volatile material formed was distilled off in a current of nitrogen. The distillate (2.8 g, b. p. 150–210°) was shown by IR spectra to contain chlorobenzene and *o*-dichlorobenzene.

After cooling, the contents of the flask were extracted with chloroform (Soxhlet), most of the solvent was removed and the oil obtained was combined with the previous distillate and distilled through a spinning band column. The following fractions were collected: 1: b. p. 126–135°/760 mm, 1.8 g; 2: 156–175°/760, 0.9 g; 3: 100–103°/9, 46.9 g; 4: 139–149°/9, 0.5 g; 5: 149–156°/9, 8.2 g; 6: 171–181°/9, 1.0 g; 7: 189–191°/7, 2.1 g.

Fraction 1. *Chlorobenzene* as shown by b. p., IR and conversion to 2,4-dinitrochlorobenzene.

Fraction 2. *o*-Dichlorobenzene as shown by b. p., IR and conversion to bis-(3,4-dichlorophenyl)-sulphone.

Fraction 3 on standing acquired a reddish colour. B. p. and IR indicated *o*-chloro-iodobenzene.

Fraction 4. UV and IR spectra indicated a mixture of *o*-chloro-iodobenzene and 2,2'-dichlorodiphenyl. No dibenzofuran or diphenylene peaks were detected in the spectra.

Fraction 5 solidified and was recrystallised from methanol to give 2,2'-dichlorodiphenyl (7.3 g, m. p. 55–61°).

Fraction 6 was a brown oil. The UV-spectrum was of the 2,2'-dichlorodiphenyl type.

Fraction 7 on standing became reddish and partly solidified. Recrystallisation from methanol gave a *product K* (0.3 g, m. p. 67–68°).

The distillation residue on extraction with chloroform gave a reddish brown solution evaporated to give a brown oil (6.3 g), which was chromatographed on alumina (1 kg). The first and the last fractions of the light petroleum eluate (5 l) solidified giving an additional quantity of *K* (0.7 g) and a *product L* (1 g, m. p. ca. 120°). The intermediate fractions were colourless oils. Light petroleum-benzene (9:1, 4 l) gave colourless resins, with a blue fluorescence under a quartz lamp. The UV-spectra gave no indication of the presence of triphenylene. Benzene (2 l) stripped the column giving brownish resins with intense yellow fluorescence.

*Substance K* (total 1 g). Recrystallisation from methanol gave needles, m. p. 85–87° (strongly depressed by dibenzofuran). Qualitative tests indicated the presence of chlorine and iodine. (Found: C 41.3; H 1.9; Cl 20.3; I 36.2. Calc. for C<sub>12</sub>H<sub>7</sub>Cl<sub>2</sub>I: C 41.3; H 2.0; Cl 20.3; I 36.4.) UV-spectrum:  $\lambda_{\max}$  252 m $\mu$  ( $\epsilon$  15 000),  $\lambda_{\min}$  233 m $\mu$  ( $\epsilon$  10 000). IR-spectrum (KBr-disc): 3 090 w, 1 640 w, 1 577 w, 1 545 m, 1 492 w, 1 460 s, 1 440 m, 1 375 s, 1 303 w, 1 275 w, 1 248 w, 1 125 w, 1 112 m, 1 080 m, 1 042 m, 1 012 s, 950 w, 890 m, 865 w, 820 m, 755 s, 730 m, 705 m, 675 m.

The C–H out-of-plane region thus indicates 1, 2 and 4 adjacent hydrogen atoms. The UV-spectrum rules out 2,2'-substitution and makes a 2-iododiphenyl improbable<sup>18</sup>. *Substance K* therefore is probably 2,4'-dichloro-3'-iodo- or 2,3'-dichloro-4'-iodo-diphenyl (X).

*Substance L* (total 1 g) was recrystallised from methanol and sublimed (0.05 mm) giving needles, m. p. 122–124°. It contained chlorine but no iodine. The analysis was consistent with a dichlorodiphenyl or a trichloroterphenyl. (Found: C 64.9; H 3.4;



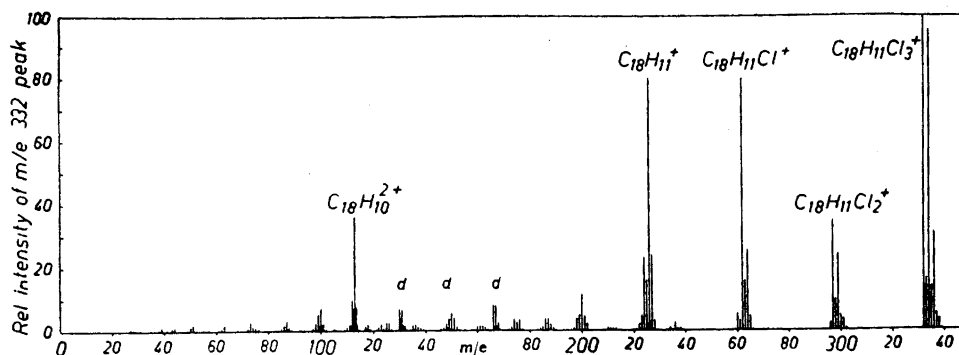


Fig. 2. Mass spectrum of compound *L* (*d* denotes doubly-charged ion).

Cl 32.0. Calc. for  $C_{18}H_{11}Cl_3$ : C 64.8; H 3.3; Cl 31.9.) Molecular weight determination according to Rast gave results, which were inconsistent with the low volatility of the substance.

The mass spectrum was kindly recorded by Ing. R. Ryhage, Laboratory for Mass Spectrometry, Karolinska Institutet, Stockholm, using an instrument with an all-glass heated inlet system<sup>17</sup>. The mass numbers were checked by recording the mass spectrum of a mixture of compound *L* and methyl *n*-eicosanate<sup>18</sup> obtained from Prof. E. Stenhagen. In the mass spectrum (Fig. 2) groups of peaks near  $m/e = 332, 297, 262$  and  $226$  (!) indicate the successive loss of three chlorine atoms from a parent molecule  $C_{18}H_{11}Cl_3$  ( $m/e = 332, 334, 336, 338$ ) and compound *L* can therefore be assigned the empirical formula  $C_{18}H_{11}Cl_3$ .

The ultraviolet spectrum had no maxima and was very similar to that given for 2,2'-dichlorodiphenyl<sup>19</sup>.

Infrared spectrum (KBr-disc): 3 090 m, 1 975 w, 1 950 w, 1 900 w, 1 818 w, 1 715 w, 1 635 w, 1 605 w, 1 590 w, 1 575 m, 1 493 s, 1 458 s, 1 440 s, 1 410 s, 1 260 w, 1 189 w, 1 160 w, 1 140 m, 1 080 w, 1 052 s, 1 039 s, 978 w, 956 w, 820 w, 803 s, 755 vs, 735 s, 728 m, 703 m, 690 s. The C—H out-of-plane region is thus consistent with 4 and 3 neighboring hydrogens and substance *L* is therefore probably 2-chloro-1,3-bis-(2-chlorophenyl)-benzene (XI).

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#### REFERENCES

1. Erdtman, H. and Nilsson, M. *Acta Chem. Scand.* **10** (1956) 735.
2. Schimmelschmidt, K. *Ann.* **566** (1950) 184.
3. Bretscher, E. *Helv. Phys. Acta* **2** (1929) 257.
4. van Alphen, J. *Rec. trav. chim.* **51** (1932) 453.
5. Ullmann, F. *Ann.* **332** (1904) 38.
6. van Alphen, J. *Rec. trav. chim.* **51** (1932) 361.
7. Hardy, W. B. and Fortenbaugh, R. B. *U.S.2,769,818* (1956). *Cf. Idem. J. Am. Chem. Soc.* **80** (1958) 1716.
8. Bunnet, J. F. and Zahler, R. E. *Chem. Rev.* **49** (1951) 273.
9. Fanta, P. E. *Chem. Rev.* **38** (1946) 139.
10. Wittig, G. *Angew. Chem.* **69** (1957) 245.
11. Gilman, H. and Straley, J. M. *Rec. trav. chim.* **55** (1936) 821.
12. Rapson, W. S. and Shuttleworth, R. G. *Nature* **147** (1941) 675.

13. Schildneck, P. R. and Adams, R. *J. Am. Chem. Soc.* **53** (1931) 2373.
14. Kvalnes, D. E. *J. Am. Chem. Soc.* **56** (1934) 2478.
15. Posternak, T., Alcalay, W., Luzzati, R. and Tardent, A. *Helv. Chim. Acta* **31** (1948) 525.
16. Dunn, T. M. and Iredale, T. *J. Chem. Soc.* **1952** 1592.
17. Ryhage, R. *To be published.*
18. Asselineau, J., Ryhage, R. and Stenhagen, E. *Acta Chem. Scand.* **11** (1957) 196.
19. Friedel, R. A. and Orchin, M. *Ultraviolet Spectra of Aromatic Compounds*, Wiley and Sons, Inc., New York 1951, No 182.

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