

### 117. *The Ullmann Biaryl Synthesis. Part I. Atypical Products of Syntheses of 2,4-Dinitrophenyl and Related Compounds.*

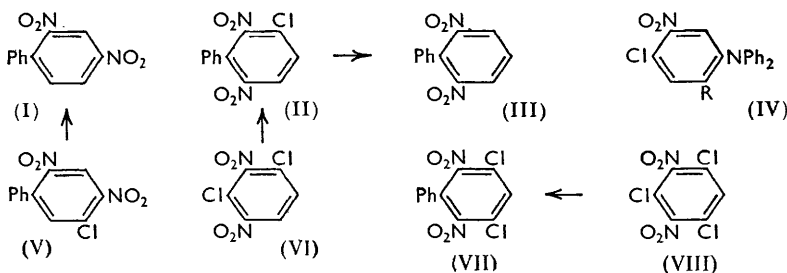
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Re-examination of the Ullmann condensation of 1-chloro-2,4-dinitrobenzene with iodobenzene has revealed two novel side-reactions which may be of a general character: the formation of (a) 3-chloro-2,6-dinitrobiphenyl by direct substitution of the chloronitro-compound, and (b) 4-chloro-3-nitrotriphenylamine by apparent reduction of a nitro-group and subsequent phenylation.

The synthesis of some chlorinated nitrobiphenyls is described.

ULLMANN condensation of 1-chloro-2,4-dinitrobenzene with iodobenzene has yielded in our hands, *inter alia*, two atypical products, 3-chloro-2,6-dinitrobiphenyl (II) and 4-chloro-3-nitrotriphenylamine (IV; R = H). Other examples of this abnormal biaryl formation and reductive arylation of the nitro-group in reactions of this type have been described, thus indicating the fairly general nature of these side-reactions. The synthesis of some 3-chloro- and 3,5-dichloro-2,6-dinitrobiphenyls is reported.

The preparation of 2,4-dinitrophenyl (I) in 3–20% yield by the Ullmann reaction between 1-chloro-2,4-dinitrobenzene and iodobenzene has been reported in the literature.<sup>1</sup> As access to the biaryl in quantity was required, and as this method appeared to be the



most feasible route, the reaction was studied in greater detail. Modification of the experimental conditions raised the yield to 40%. Isolation of the product (I) was impeded, however, by oily by-products which increased in quantity proportionately with excess of iodobenzene used. Distillation followed by chromatography failed to reveal biphenyl or its 2,4,2',4'-tetranitro-derivative in the non-crystalline fraction of the product. Instead, 3-chloro-2,6-dinitrobiphenyl and 4-chloro-3-nitrotriphenylamine were obtained. The proportion of the latter increased with increasing excess of iodobenzene, and the former was not isolated at all at low temperatures, where the relative proportions of by-products of all kinds decreased.

The structure of the 3-chloro-2,6-dinitrobiphenyl was indicated by analysis, by replacement of the halogen atom by piperidine under mild conditions (*o/p* relation between the chlorine atom and the nitro-groups), and by conversion by ammonia into a primary base which on de-amination gave the previously unknown 2,6-dinitrobiphenyl (III), identified by comparison with authentic material prepared by Ullmann condensation of 1-chloro-2,6-dinitrobenzene with iodobenzene.

The second by-product developed a deep blue colour in warm concentrated sulphuric acid solution, which, with the analysis, indicated that it might be a chloronitrotriphenylamine. Reaction with piperidine, as with the biaryl (II), confirmed the relative orientation of the chlorine atom. Reduction and de-amination as above furnished 4-chlorotriphenylamine (in low yield), identical with material prepared from *p*-chloroaniline by a

<sup>1</sup> Gull and Turner, *J.*, 1929, 496; Price and Convery, *J. Amer. Chem. Soc.*, 1957, 79, 294.

modification of Marsden's technique<sup>2</sup> for the *N*-arylation of primary amines. These results reveal the structure (IV; R = H).

Before identification of our first by-product, the isomeric 3-chloro-4,6-dinitrobiphenyl (V) was synthesised for comparison by partial Ullmann condensation of 1,3-dichloro-4,6-dinitrobenzene with iodobenzene. In this reaction, isolation of the normal product (V) [which was identified by degradation *via* 3-amino-4,6-dinitrobiphenyl to 2,4-dinitrobiphenyl (I)] was greatly impeded by relatively large proportions of by-products analogous to those obtained in the synthesis of the biaryl (I). The yield of 3,5-dichloro-2,6-dinitrobiphenyl (VII) approached that of the normal unsymmetrical material (V), and the product of reductive arylation of one nitro-group, namely, 2,4-dichloro-5-nitrotriphenylamine (IV; R = Cl), was likewise formed in relatively high yield (cf. Table 1).

TABLE 1.

Reactants		Normal unsym. biaryl (%) *	Abnormal biaryl		Redn. product Deriv. of 3-NO <sub>2</sub> -C <sub>6</sub> H <sub>4</sub> -NPh <sub>2</sub>	
(A) Deriv. of 1,2,4-C <sub>6</sub> H <sub>3</sub> Cl(NO <sub>2</sub> ) <sub>2</sub>	R in RI (mols.)		% of (A) which reacted	Deriv. of 2,6,3-(NO <sub>2</sub> ) <sub>2</sub> C <sub>6</sub> H <sub>2</sub> Cl-Ph		% *
Unsubst.	Ph (2.0)	80	30	3	5	4-Cl
"	" (1.0)	95	42	2.5	0.5	"
"	<i>p</i> -C <sub>6</sub> H <sub>4</sub> Me (1.5)	80	33	5	0.5	4-Cl-4',4''-Me <sub>2</sub>
"	<i>p</i> -C <sub>6</sub> H <sub>4</sub> OMe (1.5)	88	39	8	1	4-Cl-4',4''-(OMe) <sub>2</sub>
"	<i>o</i> -C <sub>6</sub> H <sub>4</sub> Cl (1.5)	75	55	1.5	0	—
"	<i>m</i> -C <sub>6</sub> H <sub>4</sub> Cl (1.5)	70	24	1.5	0	—
"	<i>p</i> -C <sub>6</sub> H <sub>4</sub> Cl (1.5)	70	30	7	0	—
5-Me	Ph (1.25)	28	13	12	11	{ 4-Cl-6-Me or 6-Cl-4-Me
5-OMe	"	67	34	0	2	{ 4-Cl-6-OMe or 6-Cl-4-OMe
5-Cl	"	62	27	15	5	4,6-Cl <sub>2</sub>
"	<i>p</i> -C <sub>6</sub> H <sub>4</sub> Me (1.25)	77	8	17	3	4,6-Cl <sub>2</sub> -4',4''-Me <sub>2</sub>
"	<i>p</i> -C <sub>6</sub> H <sub>4</sub> OMe (1.0)	75	31	7	0	—

\* Calc. on (A) which reacted.

Other examples of these atypical Ullmann reactions are summarised in Table 1. The consistent formation of abnormal biaryls related to 3-chloro-2,6-dinitrobiphenyl indicates a fairly general nature for this side-reaction. In the condensation of 1,3-dichloro-4,6-dinitrobenzene with *p*-iodotoluene the yield of abnormal biaryl, 3,5-chloro-4'-methyl-2,6-dinitrobiphenyl, exceeded that of the "normal" product. 3-Chloro-5-methoxy-2,6-dinitrobiphenyl could not, however, be isolated after reaction of 3-chloro-4,6-dinitroanisole with iodobenzene. In most of the examples the triphenylamine derivatives were also formed although not in specific cases, in particular not with the isomeric chloriodobenzenes.

In contrast to the 2,4-isomer, 2,6-dinitrobiphenyl (III) was obtained rapidly and essentially pure by condensation of 1-chloro-2,6-dinitrobenzene with iodobenzene, as in condensation of picryl chloride with iodobenzene.<sup>3</sup> It is clear from the experimental conditions that 1-chloro-2,6-dinitrobenzene is much more readily attacked by copper than is the 2,4-isomer, in agreement with the greater activating influence of the *o*- than of the *p*-nitro-group on the halogen atom in the Ullmann reaction.<sup>4</sup> Further, a chlorine atom with neighbouring nitro-groups is an ideal system for unsymmetrical Ullmann reaction with iodobenzene, permitting selective biaryl syntheses where differentiation between the reactivities of halogen atoms of polyhalogenonitro-compounds towards copper could be exploited. In this way the structures of the halogenated biaryls (III) and (VII) were further confirmed by synthesis from iodobenzene and 1,3-dichloro- and 1,3,5-trichloro-2,4-dinitrobenzene respectively. Similar confirmatory syntheses of other derivatives of 3-chloro-2,6-dinitrobiphenyl are listed in Table 2.

<sup>2</sup> Marsden, *J.*, 1937, 627.

<sup>3</sup> Rule and Smith, *J.*, 1937, 1096.

<sup>4</sup> Davey and Latter, *J.*, 1948, 264; Mascarelli, Longo, and Ravera, *Gazzetta*, 1938, 68, 33.

Partial reduction of 2,4-dinitrobiphenyl (I) by iron powder or sodium polysulphide gave 2-nitro-4-biphenylamine as the sole characterisable product. The isomeric 4-nitro-2-amine was best obtained by Hofmann degradation of 4-nitrobiphenyl-2-carboxamide.

#### EXPERIMENTAL

In Ullmann reactions copper bronze (from B.D.H.) was used without pretreatment. Chromatography was over activated alumina (B.D.H. chromatography grade). Light petrol-um refers to the fraction of boiling range 40—60°.

*General Technique.*—Copper bronze was added portionwise to the stirred preheated mixture (thermometers in the bath and mixture) at such a rate that undue rise in temperature was avoided. This normally required 25—50 min. Heating and stirring were continued for the remainder of the stipulated time. The mass was then allowed to cool, and the organic fraction extracted exhaustively with boiling chloroform. Infrequently, additional extractions with other solvents were necessary (as recorded). The liquors were filtered from excess of copper and copper halides (which were dried and weighed), then concentrated. The final residue, except where stated, was fractionally distilled under reduced pressure.

*Reaction of 1-Chloro-2,4-dinitrobenzene with Iodobenzene.*—(a) *With excess of iodobenzene.* Fractional distillation of the product obtained from the chloronitro-compound (50 g.), iodobenzene (100 g., 2 mol.), and copper (50 g.) at 200° in 6.5 hr. yielded, after separation of copper and cuprous halides (105 g.), (1) unchanged iodobenzene, etc. (36 g.), b. p. 25—45°/0.5 mm., and halogenodinitrobenzene (10 g.), b. p. 120—30°/0.3 mm., (2) an orange-red viscous oil (24 g.), b. p. 160—85°/0.3 mm., and (3) a crimson viscous oil (9 g.), b. p. 185—210°/0.3 mm. A dark undistillable residue (8 g.) was discarded.

Fraction (2) crystallised from benzene—light petroleum, furnishing yellow needles of 2,4-dinitrobiphenyl (I) (11.5 g.), m. p. 110°. The mother-liquors, after removal of solvent, were chromatographed in benzene—light petroleum (1 : 2) giving as the initial eluate an orange oil from which pale yellow prisms of 3-chloro-2,6-dinitrobiphenyl (II) (1.8 g.), m. p. 92—93°, were obtained by treatment with cold methanol. Repeated crystallisation successively from benzene—light petroleum and methanol raised the m. p. to 94—95° (Found: C, 51.9; H, 2.3; N, 10.0; Cl, 12.9.  $C_{12}H_7O_4N_2Cl$  requires C, 51.7; H, 2.5; N, 10.1; Cl, 12.8%). Further elution of the chromatogram with the same solvent gave only uncrystallisable red-brown oils. Final washing of the adsorbent with ethyl acetate furnished a small quantity (2 g.) of the normal biaryl (I).

Fraction (3), similarly chromatographed, yielded orange platelets (from methanol) of 4-chloro-3-nitrotriphenylamine (IV; R = H) (3 g.), m. p. 117—118° (Found: C, 66.6; H, 4.1; N, 8.4; Cl, 10.5.  $C_{18}H_{13}O_2N_2Cl$  requires C, 66.6; H, 4.0; N, 8.6; Cl, 10.9%). Further elution of the column with benzene—light petroleum gave only uncrystallisable oils. Final washing of the chromatogram with ethyl acetate furnished a small quantity (1 g.) of the nitro-biaryl (I).

A similar reaction at 185—190° was less complete after 6.5 hr., *ca.* 30% of the dinitro-halide being recovered, but the nature of the product was little changed. After reaction at 165°, recovery of unchanged reactants was 65%, but 13 g. of normal biaryl were contained in 16.5 g. of the crude fraction, b. p. 155—165°/0.2 mm., and 1.4 g. of the triphenylamine by crystallisation (from methanol) of a small fraction (2.3 g.), b. p. 180—190°/0.2 mm.; there was no distillation residue; 3-chloro-2,6-dinitrobiphenyl was not isolated.

The halogenonitro-biaryl (II) with piperidine (3 mol.) at 100° for 1.5 hr. gave 2,6-dinitro-3-piperidinobiphenyl in yellow needles (from ethanol), m. p. 103—104° (Found: N, 12.5.  $C_{17}H_{17}O_4N_3$  requires N, 12.8%). Similar treatment of the tertiary base (IV; R = H) afforded 3-nitro-4-piperidinotriphenylamine as crimson needles (from ethanol), m. p. 115° (Found: N, 10.9.  $C_{23}H_{23}O_2N_3$  requires N, 11.3%).

(b) *Equimolar reaction.* 1-Chloro-2,4-dinitrobenzene (50 g.), iodobenzene (50 g.), and copper (50 g.), treated as in section (a), gave inorganic material (90 g.), unchanged iodobenzene (6 g.) and chlorodinitro-compound (2.5 g.). Treatment of the organic product as previously described furnished the nitro-biaryl (I) (24 g., 42%), the halogenated biaryl (II) (1.7 g.), and the triphenylamine derivative (IV; R = H) (0.3 g.).

*3-Amino-2,6-dinitrobiphenyl.*—A solution of 3-chloro-2,6-dinitrobiphenyl (II) (2.6 g.) in ethanol (50 ml.) was cooled to 0°, saturated with gaseous ammonia, then heated in a steel bomb at 100° for 6 hr. After removal of solvent and excess of ammonia, the residue was dissolved in

benzene and filtered from precipitated ammonium chloride. Addition of light petroleum to the filtrate furnished 3-amino-2,6-dinitrobiphenyl (2.2 g.) in yellow plates, m. p. 187—189° (Found: C, 55.8; H, 3.5; N, 16.5.  $C_{12}H_9O_4N_3$  requires C, 55.6; H, 3.5; N, 16.3%).

2,6-Dinitrobiphenyl.—(a) *De-amination of 3-amino-2,6-dinitrobiphenyl.* The finely powdered base (1 g.) was dissolved in cold concentrated sulphuric acid (5 ml.), then powdered sodium nitrite (1 g.) was added during 10 min. to the stirred solution. After 15 min. the liquors were poured into ethanol (50 ml.), and the red solution set aside overnight at 20—25°. Water (50 ml.) was then added and the liquors were extracted with chloroform (2 × 50 ml.). The combined extracts were washed with aqueous sodium carbonate and water. The brown residue, after distillation of solvent, was refluxed with ethanol (5 ml.), and the dark solution decanted when cool from insoluble material. Crystallisation of the latter from ethyl acetate (2.5 ml.) gave 2,6-dinitrobiphenyl (III) (0.2 g.) in pale yellow needles, m. p. 188—189° (Found: C, 58.8; H, 3.1; N, 11.8.  $C_{12}H_9O_4N_2$  requires C, 59.0; H, 3.3; N, 11.5%).

(b) *By interaction of 1-chloro-2,6-dinitrobenzene and iodobenzene.* The reagents (23 g. and 28.5 g. respectively), on treatment with copper (25 g.) at 180° for 2 hr., gave excess of copper and cuprous halides (44 g.) after extraction of the organic products with boiling acetone (2 × 250 ml.). The combined extracts were concentrated to 75—100 ml. On cooling, 2,6-dinitrobiphenyl (23 g.) separated in yellowish needles, m. p. and mixed m. p. 189—190° (Found: N, 11.4%). No characterisable product was isolated from the small quantity (1.5 g.) of pale red residual oil obtained after exhaustive crystallisation of the nitro-biaryl from the mother-liquors.

3-Amino-4-chlorotriphenylamine.—4-Chloro-3-nitrotriphenylamine (IV; R = H) (1.5 g.), dissolved in ethanol (50 ml.) containing concentrated sulphuric acid (5 ml.), was refluxed with stannous chloride (4 g.) for 2.5 hr. The solvent was removed and the residue was treated with 15% aqueous sodium hydroxide (150 ml.). The product which separated recrystallised from benzene—light petroleum as pale grey needles of 3-amino-4-chlorotriphenylamine (1 g.), m. p. 146—147° (Found: C, 73.5; H, 5.1; N, 9.2; Cl, 12.6.  $C_{18}H_{15}N_2Cl$  requires C, 73.3; H, 5.1; N, 9.5; Cl, 12.1%).

The same product was obtained (yield, 85%) on hydrogenation of the nitro-compound with Raney nickel in ethanol at 20—25°.

4-Chlorotriphenylamine.—(a) *From 4-chloroaniline.* Iodobenzene (12 g.) and the chloroaniline (4 g.) were refluxed in nitrobenzene (50 ml.) containing potassium carbonate (8 g.) and copper bronze (3 g.) for 7 hr., then cooled, and benzene (50 ml.) was added. The liquors were filtered from suspended inorganic material, and distilled *in vacuo*, giving a fraction (4 g.), b. p. 130—150°/0.3 mm., which solidified. Crystallisation from ethanol—ethyl acetate gave white needles of 4-chlorotriphenylamine (2.25 g.), m. p. 106—107° (Found: C, 77.3; H, 5.0; N, 5.0; Cl, 12.5.  $C_{18}H_{14}NCl$  requires C, 77.3; H, 5.0; N, 5.0; Cl, 12.7%).

(b) *By de-amination of 3-amino-4-chlorotriphenylamine.* The amine (1 g.) was dissolved at 15—20° in glacial acetic acid (6 ml.) containing sulphuric acid (2.5 ml.) and diazotised by sodium nitrite (2.5 g.). After *ca.* 5 min. the dark solution was added to 35% hypophosphorous acid (50 ml.). Water (250 ml.) was added after 10 min., then the organic material was extracted with light petroleum. The extracts were washed with water, dried ( $Na_2SO_4$ ), and evaporated. The residual purple oil crystallised slowly from methanol at 0° in white needles mixed with a greater quantity of coloured resin. Recrystallisation of manually selected needles from methanol afforded 4-chlorotriphenylamine, m. p. and mixed m. p. 106—107° (there was insufficient for analysis).

*Condensation of 1,3-Dichloro-4,6-dinitrobenzene with Iodobenzene.*—The cuprous halides, etc. (48 g.), obtained by filtration of the chloroform extract of the product from dichlorodinitrobenzene (45 g.), iodobenzene (47.5 g., 1.25 mol.), and copper (25 g., 2 mol.) at 195° for 6 hr. were additionally extracted with boiling acetone (200 ml.). After removal of the mixed solvent, the residue was stirred with boiling methanol (250 ml.). The crystalline precipitate of 3,5-dichloro-2,6-dinitrobiphenyl (VII) which immediately separated was filtered off from the cooled liquors, and the pure material (5.5 g.) was obtained as white rods, m. p. 234—235°, by a single crystallisation from ethyl acetate or acetone (Found: C, 45.8; H, 2.0; N, 9.3; Cl, 22.9.  $C_{12}H_6O_4N_2Cl_2$  requires C, 46.0; H, 1.9; N, 8.9; Cl, 22.7%). The methanolic mother-liquors were concentrated, then the residue was fractionally distilled *in vacuo*, giving (1) unchanged iodobenzene (12 g.) and dichlorodinitro-compound (17 g.), b. p. 135—155°/0.5 mm., and (2) a red viscous oil (18 g.), b. p. 160—190°/0.5 mm. A residue (4 g.) was discarded. A solution of

fraction (2) in benzene (25 ml.) and light petroleum (50 ml.), cooled to 0° overnight, deposited orange needles, m. p. 106—110°. Recrystallisation of this material from methanol gave pure 3-chloro-4,6-dinitrobiphenyl (V) (7.4 g.) in pale yellow needles, m. p. 113—114° (Found: C, 52.0; H, 2.4; N, 10.3; Cl, 12.3.  $C_{12}H_7O_4N_2Cl$  requires C, 51.7; H, 2.5; N, 10.1; Cl, 12.8%). The benzene-light petroleum mother-liquors were directly chromatographed. Elution with the same solvent mixture gave primarily a yellow oil which crystallised from methanol (after decantation when warm from a small quantity of the highly insoluble material, m. p. 234°) in lemon-yellow feathery plates of 4,6-dichloro-3-nitrotriphenylamine (IV; R = Cl) (2 g.), m. p. 110—111° (Found: C, 60.3; H, 3.2; N, 7.4; Cl, 20.0.  $C_{18}H_{12}O_2N_2Cl_2$  requires C, 60.2; H, 3.3; N, 7.8; Cl, 19.8%). A further quantity of the biaryl (V) (1.4 g.) was obtained on continued elution of the column with the same solvent.

3-Amino-4,6-dinitrobiphenyl.—The chlorodinitro-compound (V) (3.5 g.), in ethanol (60 ml.), treated with ammonia in the same way as its isomer (II), furnished 3-amino-4,6-dinitrobiphenyl (2.9 g.) in yellow plates (from benzene-light petroleum), m. p. 156—158° (Found: C, 55.7; H, 3.3; N, 15.9.  $C_{12}H_9O_4N_3$  requires C, 55.6; H, 3.5; N, 16.3%).

De-amination of the base in the same way as for the 2,6-dinitro-isomer gave 2,4-dinitrobiphenyl (I) (ca. 10%), m. p. and mixed m. p. 110°.

Condensation of 1-Chloro-2,4-dinitrobenzene with *p*-Iodotoluene.—The chlorodinitro-compound (50 g.), *p*-iodotoluene (81 g., 1.5 mol.), and copper (50 g.), at 195° for 6 hr., yielded inorganic material (93 g.). Fractional distillation of the organic product gave low-boiling material (20 g.), unchanged chlorodinitrobenzene (10 g.), and a viscous red oil (33 g.), b. p. 165—200°/0.5 mm. Further distillation was impeded by decomposition of higher-boiling material. Crystallisation of the oil from benzene-light petroleum gave yellow needles of 4'-methyl-2,4-dinitrobiphenyl (15.5 g.). Recrystallisation from methanol afforded the pure compound (14 g.), m. p. 87—88° (Found: C, 60.4; H, 4.0; N, 10.8.  $C_{13}H_{10}O_4N_2$  requires C, 60.5; H, 3.9; N, 10.9%). The red residual oil, obtained after removing the solvent from the benzene-light petroleum mother-liquors, was chromatographed in benzene-light petroleum (1:2), yielding (1) vermilion prisms (0.3 g.) (from methanol) of 4-chloro-4',4'-dimethyl-3-nitrotriphenylamine(?), m. p. 151—152° (Found: C, 68.2; H, 4.7; N, 8.0; Cl, 9.9.  $C_{20}H_{17}O_2N_2Cl$  requires C, 68.1; H, 4.8; N, 7.9; Cl, 10.1%), (2) pale yellow rods (3 g.) (from benzene-light petroleum) of 3-chloro-4'-methyl-2,6-dinitrobiphenyl, m. p. 129—130° (Found: C, 53.5; H, 3.2; N, 9.9; Cl, 12.1.  $C_{13}H_9O_4N_2Cl$  requires C, 53.3; H, 3.1; N, 9.6; Cl, 12.1%). Final elution of the chromatogram with benzene containing 5% of ethyl acetate gave a further 3 g. of the normal biaryl, m. p. 87—88°.

Condensation of 1-Chloro-2,4-dinitrobenzene with *p*-Iodoanisole.—A reaction similar to the above with *p*-iodoanisole (87 g.) in place of *p*-iodotoluene yielded copper salts, etc. (98 g.), and material (10 g.), b. p. up to 70°/0.4 mm., unchanged chlorodinitro-compound (6 g.), a viscous red oil (43 g.), b. p. 185—205°/0.3 mm., deep red resin (5 g.), b. p. 210—250°/0.3 mm., and a residue (10 g.). The viscous oil crystallised from benzene-light petroleum (1:1; 400 ml.) at 5° to give crude 4'-methoxy-2,4-dinitrobiphenyl (24.5 g.), m. p. 88—92°. Further crystallisation successively from the same solvent and methanol afforded the pure compound in yellow needles (19 g.), m. p. 94—95° (Found: C, 57.0; H, 3.7; N, 9.9.  $C_{13}H_{10}O_5N_2$  requires C, 56.9; H, 3.6; N, 10.2%). The combined mother-liquors were evaporated and the residue was chromatographed in benzene-light petroleum (1:1), to give in the initial eluate pale yellow rhombs (5.2 g.), m. p. 123—124° (after two crystallisations from methanol), of 3-chloro-4'-methoxy-2,6-dinitrobiphenyl (Found: C, 50.7; H, 2.6; N, 8.8; Cl, 11.3.  $C_{13}H_9O_5N_2Cl$  requires C, 50.6; H, 2.9; N, 9.1; Cl, 11.5%). Further elution of the column with benzene-ethyl acetate (4:1) gave the normal biaryl (4.5 g.).

Similar chromatography of the high-boiling resin gave an initial eluate which, after removal of solvent, crystallised slowly from methanol-ethyl acetate in orange-brown rhombs of 4-chloro-4',4'-dimethoxy-3-nitrotriphenylamine (0.8 g.), m. p. 163—164° after further crystallisation from the same solvent (Found: C, 62.5; H, 4.2; N, 7.5; Cl, 9.1.  $C_{20}H_{17}O_4N_2Cl$  requires C, 62.4; H, 4.4; N, 7.3; Cl, 9.2%). The structure of this material was confirmed by synthesis, reported in Part II of this series.

Condensation of 1-Chloro-2,4-dinitrobenzene with *o*-Chloroiodobenzene.—The chlorodinitro-compound (20 g.), *o*-chloroiodobenzene (35 g., 1.5 mol.), and copper (20 g.) reacted at 195° for 6 hr. After separation of cuprous halides, etc. (38 g.), fractionation of the organic products gave (1) unchanged iodo-compound (5 g.), b. p. 45—50°/0.4 mm., and chlorodinitrobenzene

(5 g.), and (2) a viscous yellow oil (18 g.), b. p. 165—185°/0.4 mm. A small residue (3 g.) was discarded. Crystallisation of fraction (2) from benzene—light petroleum, then from methanol, furnished yellow needles of 2-chloro-2',4'-dinitrobiphenyl (10 g.), m. p. 107° (Found: C, 51.7; H, 2.3; N, 10.1; Cl, 12.6.  $C_{12}H_7O_4N_2Cl$  requires C, 51.7; H, 2.5; N, 10.1; Cl, 12.8%). The combined mother-liquors were evaporated and the residue was chromatographed in benzene—light petroleum (1 : 2), to give a pale yellow oil which slowly crystallised from methanol at 0° in almost colourless prisms (0.3 g.) of 3,2'-dichloro-2,6-dinitrobiphenyl, m. p. 82° (Found: C, 45.8; H, 1.9; N, 9.2; Cl, 22.8.  $C_{12}H_6O_4N_2Cl_2$  requires C, 46.0; H, 1.9; N, 8.9; Cl, 22.7%). Further elution of the chromatogram gave the normal biaryl (1.5 g.).

*Condensation of 1-Chloro-2,4-dinitrobenzene with m-Chloriodobenzene.*—A reaction comparable to the above, with the *m*-chloriodo-isomer, yielded inorganic material (33 g.). Separation of the organic products in the same way gave unchanged chloriodo-compound (12 g.), b. p. 55—60°/0.3 mm., and chlorodinitrobenzene (6 g.), followed by a viscous orange-yellow oil (11.5 g.), b. p. 175—195°/0.3 mm. A small higher-boiling residue was not investigated. The oil was chromatographed in benzene—light petroleum (1 : 2), affording a yellow oil which slowly solidified on trituration with methanol at 0°. After two crystallisations of this material from methanol, 3,3'-dichloro-2,6-dinitrobiphenyl (0.35 g.) was obtained as pale yellow prisms, m. p. 121—122° (Found: C, 45.7; H, 1.7; N, 9.0; Cl, 22.8%). Further elution of the column with benzene gave the normal biaryl, 3-chloro-2',4'-dinitrobiphenyl (4.75 g.), in pale yellow needles (from methanol), m. p. 79° (Found: C, 51.5; H, 2.8; N, 10.2; Cl, 12.5%).

*Condensation of 1-Chloro-2,4-dinitrobenzene with p-Chloriodobenzene.*—A comparable reaction with the *p*-chloriodo-isomer gave inorganic products (32.5 g.), unchanged iodo-compound (14 g.), b. p. 55—60°/0.5 mm., chlorodinitrobenzene (6 g.), an orange-red viscous oil (13.5 g.), b. p. 170—200°/0.7 mm., and a small residue (2 g.). The viscous oil slowly deposited pale yellow prisms when kept overnight at 0° in benzene—light petroleum. Recrystallisation of these from the same solvent, and subsequently methanol, gave pure 4-chloro-2',4'-dinitrobiphenyl (4.8 g.), m. p. 91—92° (Found: C, 51.3; H, 2.3; N, 10.0; Cl, 12.7%). The combined mother-liquors were evaporated and the residue chromatographed in benzene—light petroleum (1 : 1), furnishing primarily a yellow oil which crystallised from methanol—ethyl acetate to give almost colourless prisms of 3,4'-dichloro-2,6-dinitrobiphenyl (1.5 g.), m. p. 162—163° (Found: C, 46.4; H, 1.9; N, 9.3; Cl, 22.7%). Final elution of the chromatogram with benzene containing 5% of ethyl acetate yielded the normal biaryl (1.1 g.).

*Condensation of 3-Chloro-4,6-dinitrotoluene with Iodobenzene.*—The chlorodinitro-compound (43 g.), iodobenzene (51 g.), and copper (45 g.) reacted at 195° for 6 hr. After separation of inorganic material (57 g.), which was additionally washed with boiling acetone (250 ml.), fractional distillation of the combined extracts *in vacuo* gave unchanged iodobenzene (30 g.) and chloronitrotoluene (31 g.), b. p. 130—140°/0.5 mm., and a viscous red oil containing suspended crystals (12 g.), b. p. 160—190°/0.3 mm. A black undistillable residue (2 g.) was discarded. The oil was stirred with warm methanol (75 ml.), and the insoluble material filtered off from the cooled solution. Recrystallisation of the solid from ethyl acetate gave white rods of 3-chloro-5-methyl-2,6-dinitrobiphenyl (2 g.), m. p. 225—226° (Found: C, 53.7; H, 3.2; N, 9.7; Cl, 12.3.  $C_{13}H_9O_4N_2Cl$  requires C, 53.3; H, 3.1; N, 9.6; Cl, 12.1%). The residue, after removal of solvent from the mother-liquors, was chromatographed in benzene—light petroleum (1 : 2), giving initially a red oil (6 g.) which slowly crystallised from methanol in bright yellow plates of 2-chloro-5-methyl(or 5-chloro-2-methyl)-3-nitrotriphenylamine (2 g.), m. p. 102—103° (Found: C, 67.7; H, 4.4; N, 8.2; Cl, 10.6.  $C_{19}H_{15}O_2N_2Cl$  requires C, 67.4; H, 4.4; N, 8.3; Cl, 10.5%). Further elution of the chromatogram with benzene furnished a yellow oil (3 g.) which crystallised from methanol during 48 hr. at 0°, to give pale yellow needles of 3-methyl-4,6-dinitrobiphenyl (1.8 g.), m. p. 104—105° (Found: C, 60.7; H, 3.7; N, 10.6.  $C_{13}H_{10}O_4N_2$  requires C, 60.5; N, 3.9; Cl, 10.9%).

*Condensation of 3-Chloro-4,6-dinitroanisole with Iodobenzene.*—Fractional distillation of the organic products (copper and cuprous halides amounted to 50 g.) after reaction of the substituted anisole (42.3 g.), iodobenzene (46.5 g.), and copper (30 g.) at 195° for 6 hr. yielded [after recovery of iodobenzene (13 g.) and the anisole derivative (14 g.), b. p. 170—175°/0.5 mm.], a red viscous oil (24.5 g.), b. p. 200—230°/0.5 mm. Trituration of this oil in methanol gave a yellow solid which after two crystallisations from methanol furnished pale yellow needles of 5-methoxy-2,4-dinitrobiphenyl (10.2 g.), m. p. 143—144° (Found: C, 57.0; H, 3.6; N, 10.2.  $C_{13}H_{10}O_5N_2$  requires C, 56.9; H, 3.6; N, 10.2%). The combined mother-liquors were evaporated, and the

residue chromatographed in benzene–light petroleum (1 : 1), giving as the initial eluate an oil which was crystallised from methanol and methanol–ethyl acetate successively to yield orange prisms of 4-chloro-6-methoxy (or 6-chloro-4-methoxy)-3-nitrotriphenylamine (0.7 g.), m. p. 138–139° (Found: N, 8.1; Cl, 9.8.  $C_{19}H_{15}O_3N_2Cl$  requires N, 7.9; Cl, 10.0%). Further elution of the column with the same solvent gave oils. Final washing with ethyl acetate furnished the normal biaryl (1.25 g.).

The structure of the normal condensation product was confirmed by comparison with the material obtained (yield, 75%) by refluxing the chlorinated biaryl (V) in methanol with sodium methoxide (1.1 mol.) for 2 hr. (Found: N, 10.0%).

*Condensation of 1,3-Dichloro-4,6-dinitrobenzene with p-Iodotoluene.*—Reaction between the chloronitro-compound (23.7 g.), *p*-iodotoluene (27.1 g.), and copper (12.6 g.) at 195° for 5.5 hr. gave copper salts, etc. (26 g.), from which traces of organic material sparingly soluble in chloroform were finally extracted with boiling acetone (150 ml.). The combined organic extracts were evaporated and stirred with hot methanol (60 ml.). The yellow-brown crystalline precipitate thus obtained was separated when cool. Crystallisation of the solid from ethyl acetate (charcoal) gave pale yellow prisms of 3,5-dichloro-4'-methyl-2,6-dinitrobiphenyl (4.2 g.), m. p. 254° (Found: C, 47.4; H, 2.6; N, 8.7; Cl, 21.9.  $C_{13}H_9O_4N_2Cl_2$  requires C, 47.7; H, 2.4; N, 8.6; Cl, 21.7%). The mother-liquors were stripped of solvent, then chromatographed in benzene–light petroleum (2 : 3). The initial eluate, a red oil, gave primarily a small quantity (0.1 g.) of the material, m. p. 254°, from benzene–methanol (1 : 3) at 0°; then methanol alone gave orange-red plates of 2,4-dichloro-4',4''-dimethyl-5-nitrotriphenylamine (1 g.), m. p. 127° (from methanol–ethyl acetate) (Found: C, 62.3; H, 4.3; N, 7.2; Cl, 17.9.  $C_{20}H_{16}O_2N_2Cl_2$  requires C, 62.0; H, 4.1; N, 7.2; Cl, 18.3%). Subsequent elution of the chromatogram with benzene alone gave an oil (8 g.), which on fractional distillation yielded unchanged chloronitro-compound (5.5 g.) and a viscous oil (2.8 g.), b. p. 165–180°/0.5 mm., the latter crystallising readily from methanol in pale yellow plates of 3-chloro-4'-methyl-4,6-dinitrobiphenyl (1.8 g.), m. p. 114–115° (Found: C, 53.2; H, 3.1; N, 10.0; Cl, 12.5.  $C_{13}H_9O_4N_2Cl_2$  requires C, 53.3; H, 3.1; N, 9.6; Cl, 12.1%).

*Condensation of 1,3-Dichloro-4,6-dinitrobenzene with p-Iodoanisole.*—The chloronitro-compound (23.7 g.), *p*-iodoanisole (23.4 g.), and copper (12.6 g.), at 195° for 5 hr., yielded copper salts, etc. (27 g.), after final separation of organic material with boiling acetone (150 ml.). Fractional distillation of the combined organic products gave low-boiling material, unchanged chloronitro-compound (6 g.), a red oil containing suspended crystals (14 g.), b. p. 180–200°/0.3 mm., and a residue (2 g.). The red oil was stirred with hot methanol (50 ml.), and the liquor decanted from the crystals while still warm. The solid was then washed with a little warm methanol and crystallised from ethanol–ethyl acetate, giving pale yellow prisms of 1,3-dichloro-4'-methoxy-2,6-dinitrobiphenyl (1.8 g.), m. p. 203–204° (Found: C, 45.4; H, 2.5; N, 8.6; Cl, 20.9.  $C_{13}H_9O_5N_2Cl_2$  requires C, 45.5; H, 2.3; N, 8.2; Cl, 20.7%). The combined mother-liquors were evaporated and the residue was chromatographed in benzene–light petroleum (1 : 2), affording initially a further quantity (0.2 g.) of the material, m. p. 203–204°. Successive elution with the same solvent and benzene alone furnished a yellow oil (10 g.), which, crystallised three times from methanol, gave pale yellow prismatic needles of 3-chloro-4'-methoxy-4,6-dinitrobiphenyl (6.5 g.), m. p. 83–84° (Found: C, 50.9; H, 3.0; N, 9.5; Cl, 11.8.  $C_{13}H_9O_5N_2Cl$  requires C, 50.6; H, 2.9; N, 9.1; Cl, 11.5%). Final elution of the column with ethyl acetate gave an oily solid (*ca.* 2 g.). Crystallisation of the latter from methanol yielded the material, m. p. 83–84° (0.75 g.), mixed with traces of a higher-melting substance; this fraction was not further investigated.

*3-Chloro-2,6-dinitrobiphenyl (II).*—1,3-Dichloro-2,4-dinitrobenzene (VI) (7.5 g.), iodobenzene (8.0 g.), and copper (4 g., 2 mol.), on reaction at 175° for 3 hr., gave copper salts, etc. (8.1 g.), unchanged iodobenzene (2 g.), chlorodinitro-compound (1.5 g.), b. p. 125–130°/0.6 mm., and a yellow oil (6 g.), b. p. 170–175°/0.8 mm. The last furnished 3-chloro-2,6-dinitrobiphenyl (II) (4.2 g., 48%) as pale yellow prisms, m. p. 94–95° (from methanol) undepressed on admixture with material obtained as by-product from the synthesis of 2,4-dinitrobiphenyl (I) (Found: N, 10.0%).

No product isomeric with the biaryl (II) was isolated even after chromatography.

*Synthesis of Halogenated Derivatives of 2,6-Dinitrobiphenyl.*—1,3-Dichloro- or 1,3,5-trichloro-2,4-dinitrobenzene (1 mol.), the iodo-compound (1 mol.), and copper (2 mol.) were allowed to react at 190–195° for 2.5–3 hr. The required chlorinated biaryl was isolated from the organic

products by crystallisation (method A) or by chromatography in benzene–light petroleum (1 : 2) (method B). In every example the synthetic product was identical with the material obtained as by-product from the appropriate Ullmann synthesis. The reaction scale was 0.01–0.005 mole. Optimum conditions for individual condensations were not determined. The results are detailed in Table 2.

*2-Nitro-4-biphenylamine*.—A stirred solution of 2,4-dinitrobiphenyl (I) (23 g.) in ethanol (500 ml.), and water (125 ml.) containing 2–3 drops of concentrated hydrochloric acid and iron powder (11.2 g.) was refluxed for 3 hr. The red solution was cooled, filtered from iron oxides, then evaporated, finally under reduced pressure. Addition of cold water (500 ml.) solidified the brown residual oil. Two crystallisations of this from benzene–light petroleum (charcoal) afforded pure *2-nitro-4-biphenylamine* (12 g.) in yellow plates, m. p. 110–111° (Found: C, 67.2; H, 4.6; N, 13.1.  $C_{12}H_{10}O_2N_2$  requires C, 67.3; H, 4.7; N, 13.1%).

Partial reduction of the nitro-compound was also effected with sodium polysulphide by standard techniques. The product (yield, 40%) was, however, more difficult to purify.

*De-amination*. A mixture of the nitro-amine (2.1 g.), concentrated hydrochloric acid (20 ml.), and ethanol (75 ml.) was heated until dissolution was complete, then cooled to 0°. Sodium nitrite (1.1 g.) was added with stirring. Next morning the red solution was decanted

TABLE 2.

Halogenonitro-compound	Iodo-compound	Product: deriv. of 2,6-dinitrodiphenyl	Yield (%) approx.	Method of isoln.	Found: N (%)
1,3,2,4- $C_6H_3Cl_2(NO_2)_2$	<i>p</i> - $C_6H_4MeI$	3-Cl-4'-Me	15	B	9.4
"	<i>p</i> - $C_6H_4I\cdot OMe$	3-Cl-4'-OMe	25	B	9.3
"	<i>o</i> - $C_6H_4ClI$	3,2'-Cl <sub>2</sub>	7.5	A	9.3
"	<i>m</i> - $C_6H_4ClI$	3,3'-Cl <sub>2</sub>	50	A	9.0
"	<i>p</i> - $C_6H_4ClI$	3,4'-Cl <sub>2</sub>	50	A	9.3
1,3,5,2,4- $C_6HCl_3(NO_2)_2$	PhI	3,5-Cl <sub>2</sub>	30	A	8.7
"	<i>p</i> - $C_6H_4MeI$	3,5-Cl <sub>2</sub> -4'-Me	15	A	8.7
"	<i>p</i> - $C_6H_4I\cdot OMe$	3,5-Cl <sub>2</sub> -4'-OMe	25	A	8.5

from inorganic material and a little red insoluble resin into water (600 ml.). Extraction of the liquors with chloroform (2 × 50 ml.), followed by evaporation, furnished a dark oil. This was filtered in benzene–light petroleum (1 : 1) (100 ml.) through alumina to give, after removal of solvent, 2-nitrobiphenyl, m. p. and mixed m. p. 37° (from 90% methanol at 0°), in pale yellow needles.

*4-Nitro-2-biphenylamine*.—4-Nitrobiphenyl-2-carbonyl chloride (5.5 g.), b. p. 160–170°/1 mm. [prepared by refluxing the acid<sup>5</sup> (7.5 g.) with thionyl chloride (20 ml.) for 2 hr., then fractionally distilling the product], was added in benzene (15 ml.) to aqueous ammonia (*d* 0.880; 125 ml.) at 0°. Light petroleum (50 ml.) was then added, and the white solid filtered off and dried at 100°. The crude amide (4.8 g.) was added to a stirred solution of bromine (5 g.) in aqueous sodium hydroxide (20 g. in 80 ml. of water) at 0–5°. The solution was then heated to 95° for 30–45 min., cooled, and extracted with ether (2 × 100 ml.). The ethereal extracts were washed with water, dried (Na<sub>2</sub>SO<sub>4</sub>), and concentrated to 50 ml. Addition of dry hydrogen chloride to the ethereal concentrate precipitated a colourless hydrochloride (3.3 g.) which, after decantation of solvent, was treated with 3% aqueous ammonia, to give a low-melting solid (2.6 g.). Crystallisation from benzene–light petroleum (twice) gave orange-yellow needles of the amine (1.9 g.), m. p. 71–72° (Found: C, 67.0; H, 4.7; N, 13.2.  $C_{12}H_{10}O_2N_2$  requires C, 67.3; H, 4.7; N, 13.1%).

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