CLXXXIII.—*A Study of the Rule of the Conservation of the Type of Substitution in Aromatic Substances. Part I. Chlorination of 2-Chloro-4-nitrotoluene.*

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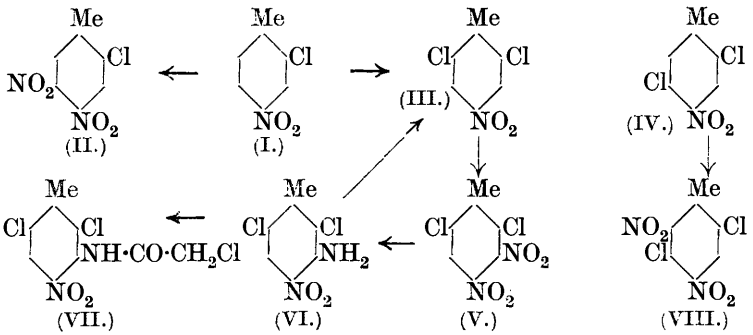
MORGAN and DREW (J., 1920, **117**, 793) have shown that the main product (more than 85%) of nitration of 2-chloro-4-nitrotoluene (I) is the 5-nitro-derivative (II). It was shown by one of us (J., 1922, **121**, 806) that, when (I) was chlorinated in the presence of certain catalysts, not the 5- but the 6-chloro-derivative (III) was produced in a yield of more than 30%, and no other isomeride was isolated in a pure condition. It was accordingly stated (p. 806) that "it is very probable that the separation of (III) in such large amount indicates that this is the chief product." Holleman (*Chemical Reviews*, 1924, 217) quite rightly points out that (III) had not been proved to be the principal product of the reaction, and considers it possible that (IV) may occur in the residual non-crystallisable oil in such large amount as actually to be the chief product of the reaction. As changes in substitution type are of great importance both from the synthetical and the theoretical point of view, an attempt has been made to determine more accurately the proportion of (III) formed.



The more obvious lines of attack have already been investigated (Davies, *loc. cit.*, p. 810) without success. As the monochlorination product of (I) is clearly an extremely complicated mixture, the method of estimation suggested by Holleman (*loc. cit.*, p. 217) was not adopted, but instead attempts were made to convert (III) into a derivative which could be separated from the mixture by chemical means. It is to be expected that (III) would be rather more easily substituted than (IV), and the behaviour of certain reagents on (III) was accordingly examined. It was not readily sulphonated, but was quantitatively converted into the nitro-derivative (V) by

nitration under mild conditions. This could not be smoothly converted into a nitrophenol by the action of alkali under various conditions, but it was readily transformed by the action of alcoholic ammonia into (VI) (the yield of pure substance being 77%), and insufficient of the isomeric 2 : 6-dichloro-3-nitro-*p*-toluidine was formed to admit of its being isolated. This change is incidentally still another instance of replacement in agreement with the rule of Kenner and Parkin (J., 1920, **117**, 852. See also J., 1925, **127**, 2344).

2: 6-*Dichloro*-4-*nitro*-m-*toluidine* (VI) has very slight basic properties and accordingly attempts were made to convert it into an acidic substance. It does not react with *p*-toluenesulphonyl chloride, and although good yields of the benzoyl and acetyl derivatives of the amine may be obtained, these compounds do not dissolve very readily in cold dilute alkali. The *chloroacetyl* derivative (VII), however, is quantitatively obtained, and easily dissolves in cold aqueous sodium hydroxide solutions, from which it is precipitated unchanged on acidification. It was hoped to be able to separate in this way (V) from (IV) or its nitro-derivative (VIII) (compare Cohen and Dakin, J., 1901, **79**, 1131).

The chlorination product from (I) was therefore nitrated under the gentle conditions which were sufficient to give (V), and after the removal of the catalyst the whole product was treated with alcoholic ammonia, but it was then found that some portion of the nitration product other than (V) gave amines with ammonia with the formation of large quantities of ammonium chloride. It is possible that the 5-chlorine atom in (VIII) had, despite the steric hindrance due to the two adjacent nitro-groups, reacted with the ammonia. As the chloroacetyl derivatives of the amines produced were themselves soluble in alkali, this method of separation by chemical means was abandoned.

Finally, crystallisation from methylated spirit of the nitration product of the chlorination mixture was resorted to, and 2 : 6-dichloro-3 : 4-dinitrotoluene (V) was isolated in a yield corresponding to 47·9% of 2 : 6-dichloro-4-nitrotoluene (III) in the chlorination product. This physical method of separation, although far from being an ideal one, makes it certain, when considered in connexion with the following facts, that (III) is the chief dichloronitrotoluene formed. First, it is impossible to separate by fractional crystallisation all the (V) produced, owing to the formation of liquid and low-melting solid mixtures of a complex nature. Secondly, it has been shown (Davies, *loc. cit.*, p. 810) that the monochlorination of (I) with the calculated amount of chlorine left some unchanged substance, and therefore that one or more trichloro-*p*-nitrotoluene derivatives were formed. In fact, a larger amount of (V) can be isolated

when the chlorine absorbed is about 1% greater than the quantity theoretically required to produce dichloro-*p*-nitrotoluenes (see p. 1417). Hence the monochlorination product of (I) contains considerable quantities of substances other than dichloro-*p*-nitrotoluenes.* Moreover, there is reason to believe that a portion of the chlorine goes into the side chain. On monochlorination of (III) in presence of either antimony trichloride or ferric chloride, a very complex mixture is formed from which nothing pure can be isolated by distillation or crystallisation, although mono-substitution could lead only to 2 : 5 : 6-trichloro-4-nitrotoluene. Nitration and reduction followed by condensation with phenanthraquinone gives only a small quantity of a phenanthrazine (m. p. 343°), which is possibly derived from 2 : 5 : 6-trichloro-4-nitrotoluene. It is certain from this experiment that the expected nuclear substitution of (III) has not occurred smoothly, and no doubt this anomalous reaction, whatever it may really be, occurs to some extent in the chlorination of the simpler 2-chloro-4-nitrotoluene. Side-chain substitution in presence of a catalyst is not so rare as is usually considered. One such instance, with 2-chloro-4-nitrotoluene, has already been pointed out (J., 1922, **121**, 812), with iodine as the catalyst. The present authors find that the action of bromine on *p*-nitrotoluene at 95—120° (this relatively high temperature being necessary to bring about a reaction) gives a 46% yield of pure *p*-nitrobenzyl bromide (m. p. 99°), and a similar result with toluene in presence of antimony tribromide and bromine is recorded by van der Laan (*Rec. trav. chim.*, 1907, **26**, 1).

It is difficult to advance a logical and satisfactory explanation which will account for a change of substitution type such as the one here established. As has been already pointed out (Davies, *loc. cit.*, p. 809), steric conceptions based on the atomic volumes of the groups whose positions of substitution are compared lead to contradictory conclusions, though Holleman (*loc. cit.*, p. 220) apparently considers the application of such ideas helpful as far as some rather simpler molecules are concerned. A more satisfactory, although far from convincing explanation may be found in a consideration of the difference in chemical nature of the two groups under comparison, and also in the experimental conditions of the

* In the actual experiments herein described, *p*-nitrotoluene was dichlorinated and 2-chloro-4-nitrotoluene was not first isolated and monochlorinated (see Davies, *loc. cit.*, p. 810, for the justification of this). In any case, the other possible isomeride, 3-chloro-4-nitrotoluene, could on further chlorination give no 2 : 6-dichloro-*p*-nitrotoluene, and therefore the dichlorination of *p*-nitrotoluene could not, when compared with the monochlorination of 2-chloro-4-nitrotoluene, favourably affect the proportion of 2 : 6-dichloro-3 : 4-dinitrotoluene (V) actually isolated.

reactions. Investigations are being carried out with special reference to these points of view.

EXPERIMENTAL.

2 : 6-*Dichloro*-3 : 4-*dinitrotoluene* (V).—A solution of dry 2 : 6-dichloro-4-nitrotoluene (III) (6·7016 g.) in concentrated sulphuric acid (33 c.c.) at 65° is treated with a mixture of nitric acid (3·3 c.c.; *d* 1·52) and concentrated sulphuric acid (17 c.c.). The temperature is kept at 80—85° for 8 minutes. The oil that has separated then solidifies and, after drying over phosphorus pentoxide in a cathode-ray vacuum, weighs 8·1517 g. (yield 99·8%). Its m. p., 129—130°, is raised only 1° by repeated crystallisation. Further exposure to a cathode-ray vacuum causes a steady loss in weight due, as shown by a blank experiment with pure dry material, to the volatility of the substance.

The oxidisable *o*-diamine obtained by reducing 2 : 6-dichloro-3 : 4-dinitrotoluene with zinc dust in dilute alcohol containing a trace of ammonium chloride was characterised as 1 : 3-*dichloro*-2-*methylbenzophenanthrazine*, yellowish-brown plates from anisole, m. p. 279—286° (corr.), by condensation with phenanthraquinone in glacial acetic acid. The azine is sparingly soluble in cold organic solvents and develops a cerise coloration in cold concentrated sulphuric acid (Found: Cl, 19·3. $C_{21}H_{12}N_2Cl_2$ requires Cl, 19·5%). The conversion of (V) into this compound is, however, not a quantitative process and, moreover, does not lend itself to the rough estimation of (V) in the presence of other *o*-dinitro-compounds of toluene.

2 : 6-*Dichloro*-4-*nitro*-m-*toluidine* (VI).—A mixture of 2 : 6-dichloro-3 : 4-dinitrotoluene (50 g.) and 200 c.c. of alcoholic ammonia (5%) is heated for ½ hour at 90—98° (10 atm.). The pressure is then released, 50 c.c. of alcoholic ammonia (10%) are added, and the mixture is heated for 2 hours at 127° and 7·3 atm. The product is allowed to crystallise, and after recrystallisation from alcohol 34 g. (77% yield) of the pure amine are obtained, only a small amount of low-melting material and a mere trace of ammonium chloride being produced. 2 : 6-*Dichloro*-4-*nitro*-m-*toluidine*, m. p. 136°, forms thin, deep yellow plates from benzene and brown prisms from alcohol and is soluble in mineral acids only if very concentrated (Found: Cl, 31·75. $C_7H_6O_2N_2Cl_2$ requires Cl, 32·1%). It is different from the only other possible isomeride, 2 : 6-dichloro-3-nitro-*p*-toluidine (m. p. 130—131°; Davies, *loc. cit.*, p. 814), and is converted through its diazonium sulphate into 2 : 6-dichloro-4-nitrotoluene in good yield. Its constitution is thus established.

2 : 6-*Dichloro*-4-*nitroaceto*-m-*toluidide*, obtained by boiling the base

and excess of acetyl chloride in benzene for 9 hours, separates from alcohol or benzene in colourless plates, m. p. 185°. The *benzoyl* compound, similarly prepared, forms colourless, feathery crystals, m. p. 215° (Found : N, 8·7. $C_{14}H_{10}O_3N_2Cl_2$ requires N, 8·6%). 2 : 6-*Dichloro*-4-*nitrochloroaceto*-m-*toluidide* (VII), also similarly prepared, separates from alcohol in colourless plates, m. p. 170° (Found : N, 9·4. $C_9H_7O_3N_2Cl_3$ requires N, 9·4%).

The mixture formed by dichlorinating *p*-nitrotoluene is nitrated under the conditions described on p. 1416, the product thoroughly washed with water and heated with alcoholic ammonia under the conditions described on p. 1416. The final product, containing much ammonium chloride, and amines formed by elimination of chlorine and a nitro-group, is treated with excess of benzene, the benzene–alcohol constant-boiling mixture removed on the water-bath, the dry amine chloroacetylated in benzene, the benzene and excess of chloroacetyl chloride are removed, ultimately in a vacuum, and the chloroacetylated amines extracted with cold sodium hydroxide solution and reprecipitated with cold hydrochloric acid. The product, however, melts below 158°, and is a mixture of chloroacetylated amines, from which, after three recrystallisations from alcohol, (VII) is isolated in a quantity corresponding to a yield of less than 40% of (III).

Estimation of 2 : 6-*Dichloro*-4-*nitrotoluene* (III) *as* 2 : 6-*Dichloro*-3 : 4-*dinitrotoluene* (V).—In the preliminary experiments 1 g.-mol (137 g.) of *p*-nitrotoluene was chlorinated in the presence of antimony trichloride until, after the removal of chlorine and hydrogen chloride, the increase in weight (69 g.) corresponded closely (within 0·2 g.) to the entry of 2 gram-atoms of chlorine. After nitration, and separation of (V) by repeated crystallisation from methylated spirit, the oily residue was distilled in steam, and the least volatile portion fractionally crystallised from alcohol. The product (2 g., m. p. 85·5°) was shown by a mixed melting-point determination to be 2-chloro-4 : 5-dinitrotoluene (II). The yield of (V) corresponded to a yield of 43% of (III), and it was found advantageous to have a slight excess of chlorine over the 2 gram-atoms theoretically required, because the trichloronitrotoluene derivatives did not appear to interfere in the separation of (V) to the same extent as did (II).

One g.-mol. of *p*-nitrotoluene (137 g.) mixed with 4·5 g. of antimony trichloride is chlorinated at 65—75° until the weight is 212·7 g. A current of dry air is blown through the liquid at 100° until all the chlorine and hydrogen chloride are removed. The increase in weight is now 0·7 g. in excess of the 69 g. theoretically required. A solution of exactly half the product (105·6 g.) in concentrated sulphuric acid (350 c.c.) is treated at 65° with a

mixture of nitric acid (20 c.c.; *d* 1·52) and concentrated sulphuric acid (50 c.c.). Having been kept at 80—85° for 8 minutes, the mixture is poured on to ice, and kept for 48 hours at 0°. The solid product is then washed with cold water and boiled with methylated spirit (300 c.c.), the solution (A) poured off, and the residue dissolved in a further 300 c.c. of alcohol (Solution B). After 5 hours, (B) deposits almost pure (V), and the filtrate is used to dissolve the less pure crystals from (A). The deposit from (B) is recrystallised from methylated spirit, pure (V) being produced (m. p. 130—131°), and the filtrate is used to crystallise the much less pure portions; when the m. p. of these has been raised to 125—128°, they are crystallised from spirit. The process is expedited by pouring off the mother-liquor from the first crop of crystals, which contains the largest amount of (V), while the solution is hot. (V) is the least soluble substance present. In this way more than 50 g. of a pure product (m. p. 130—131°) are obtained in a very short time; further small quantities are obtained from the intermediate fractions. The large volume of solution containing the most soluble portion, when concentrated and kept for several months, deposits a solid from which a very small quantity of (V) can be isolated. In the first experiment, which lasted a week, 56·8 g. of (V) were isolated, corresponding to a yield of 45·2% of (III). In the second estimation, which, owing to the more thorough examination of the oily portions, was more prolonged, 60·1 g. [corresponding to a yield of 47·9% of (III)] were obtained and there were indications that a small quantity of (V) still remained in the oily mixture.

The semi-solid final product was recrystallised from alcohol and, apart from a large quantity of oil, two crystalline fractions, m. p. 85—97° and 100—115°, were obtained. The second substance softened at 100—101°, which is the m. p. of (VIII), but this compound could not be obtained pure. It (4 g.) was reduced as described on p. 1416, and the amine obtained was condensed with phenanthraquinone (2 g.) in boiling acetic acid. The product formed yellowish-brown needles (0·85 g.), m. p. 307—309° (decomp.; corr.), from anisole and gave a cerise coloration with cold concentrated sulphuric acid (Found : Cl, 23·6%). Whatever this compound may be, its formation shows that almost all (V) has been removed from the 100—115° fraction (about 9 g.). The high percentage of chlorine, much greater than that required for the phenanthrazines from (II) and (V), shows that probably a trichloronitrotoluene derivative is present.

Chlorination of 2 : 6-*Dichloro*-4-*nitrotoluene* (III).—This compound (41·2 g.), mixed with ferric chloride (1·8 g.), is chlorinated at 65—80°

for 24 hours, the increase in weight being 7·8 g. (calc. for monochlorination, 6·9 g.). The high temperature of 80° is ultimately required, not only to expedite the process, but also to melt the solid which crystallises out towards the end of the reaction. The product after removal of inorganic matter distils at 135—155°/5 mm The colourless distillate is crystallised from spirit, and the portion (7 g.) which melts over the lowest range (60—78°) is nitrated with mixed sulphuric and nitric acids, the product reduced as described on p. 1416, and the base produced condensed with an excess of phenanthraquinone in glacial acetic acid. The compound (1·3 g.) produced separates from anisole, in which it is very slightly soluble in the cold, in deep yellow prisms, m. p. 343° (corr.) (Found : Cl, 26·6. $C_{21}H_{11}N_2Cl_3$ requires Cl, 26·8%), and may be 1 : 3 : 4-*trichloro*-2-*methylbenzophenanthrazine*, which would be the expected product if nuclear substitution had taken place in the chlorination. It is not easy, however, to understand why such a small quantity of it is formed, and why the chlorination does not proceed, as would be expected, to give 2 : 5 : 6-trichloro-4-nitrotoluene as the chief product. A pure substance could be obtained neither from the chlorination product nor from the nitration product of this by repeated crystallisation.

This phenanthrazine is different from that obtained from the highest-melting substance [after the removal of (V)] formed in the nitration of the dichlorination product of *p*-nitrotoluene. The lower-melting portions of this product, which almost certainly contains several 3 : 4-dinitrotoluene derivatives, were not examined from the point of view of the formation of phenanthrazine derivatives.

Summary.

The product of monochlorination of 2-chloro-4-nitrotoluene in presence of antimony trichloride, from which more than 30% of 2 : 6-dichloro-4-nitrotoluene had previously been isolated (J., 1922, **121**, 806), has now been shown to contain, in addition to considerable quantities of substances other than nuclear-substituted dichloro-4-nitrotoluenes, 47·9% of that compound, estimated as 2 : 6-dichloro-3 : 4-dinitrotoluene. This result, when compared with the nitration of 2-chloro-4-nitrotoluene (Morgan and Drew, J., 1920, **117**, 793), in which more than 85% of the product is 2-chloro-4 : 5-dinitrotoluene, shows that a change of substitution type has occurred.

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