92. *By-products in Aromatic Nitration. Part II. Nitration of Diphenyl, Quinoline, and Benzophenone.*

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Alkali-soluble by-products in the nitration of these three substances have been examined. That from diphenyl is 3 : 5 : 4′-trinitro-4-hydroxydiphenyl. The yellow substance observed by Dufton (J., 1892, **61**, 782) in the nitration of quinoline is shown to be 6 : 8-dinitro-5-hydroxyquinoline, and is accompanied by small quantities of an isomeric substance. In the nitration of benzophenone *m*- and *p*-nitrobenzoic acids are formed as by-products, which have been shown to arise from a fission of the nitrobenzophenones by the action of the mixed acids. A trinitrohydroxybenzophenone has also been obtained from the nitration of 3 : 3′-dinitrobenzophenone. The mechanism of the formation of the hydroxy-by-products is discussed.

It was shown in Part I (Bennett and Youle, J., 1938, 1816) that nitrophenolic by-products arise in the nitration, not only of benzene and its homologues, but of nitrobenzene, aromatic sulphones and benzenesulphonyl chloride, and that the first step in their production is in all cases the entry of the hydroxyl group into the aromatic nucleus in the position to be expected under the normal influence of substituents already present, whether *o*-, *p*-, or *m*-directive.

A similar examination has now been made of the products of nitrating diphenyl, quinoline and benzophenone.

After the nitration of diphenyl with cold nitric acid, alkaline extraction of the products yielded 2% of a nitrophenolic substance oxidisable by chromic acid to *p*-nitrobenzoic acid. This by-product was identified as 3 : 5 : 4′-trinitro-4-hydroxydiphenyl by direct comparison with the normal product of nitration of 4-hydroxydiphenyl (Banus and Guiteras, *Anal. Fis. Quím.*, 1923, **21**, 126). Its formation in the nitration of diphenyl is evidently due, in the first place, to hydroxylation of the latter in the normal position for monosubstitution, followed by nitration as would be expected in both nuclei.

In reporting the nitration of quinoline, Dufton (J., 1892, **61**, 782) recorded the isolation of a small quantity of a by-product formed when quinoline nitrate was added to sulphuric acid and the reaction completed by addition of fuming sulphuric acid. This substance, which appeared as a yellow precipitate when the reaction mixture was diluted with water, decomposed at 255° and had the composition of a dinitrohydroxyquinoline. We have found that this by-product, after purification by crystallisation from concentrated nitric acid or from acetic acid, decomposes at 292—293°. It is a dinitro-5-hydroxyquinoline, presumably 6 : 8-*dinitro*-5-*hydroxyquinoline*, since it is identical with the product of nitrating 5-hydroxyquinoline with fuming nitric acid, and it is quite distinct from the dinitro-8-hydroxyquinoline of m. p. 315° (decomp.) formed by nitration of 8-hydroxyquinoline (Dikshoorn, *Rec. Trav. chim.*, 1929, **48**, 550). This identification was confirmed by converting the by-product by the action of phosphorus pentachloride into 5-*chloro*-6 : 8-*dinitroquinoline*, m. p. 145·5°, which was also found to be identical with the product of the action of phosphorus pentachloride on the synthetic dinitro-5-hydroxyquinoline. An attempt to prepare this substance by direct dinitration of 5-chloroquinoline yielded only the mononitro-compound 5-chloro-8-nitroquinoline (compare Fourneau, Trefouel, and Wancolle, *Bull. Soc. chim.*, 1930, **47**, 744). That drastic conditions here failed to effect dinitration is a striking instance of the way in which a free pole (in the pyridine nucleus) may co-operate with a nitro-group to prevent the further substitution of the benzene nucleus of quinoline.

In the purification of this by-product a second, more soluble, isomeric substance of m. p. 202° was detected. The amount of it was, however, small and variable, and in consequence of the loss of a number of specimens by enemy action its structure has not yet been ascertained.

When benzophenone was nitrated, either with fuming nitric acid in an excess of sulphuric acid, or with a large excess of fuming nitric acid alone, alkali-soluble material was formed to the extent of about 1% of the ketone used. This proved, however, to consist, not of nitrophenolic substances as in the other cases studied, but of a mixture of *m*- and *p*-nitrobenzoic acids.

Further experiments showed that these acids are the result of a disruption of the nitrated benzophenones by the nitrating acids: the products in this nitration are known to contain, besides 3 : 3-dinitrobenzophenone, some of the 3 : 4′-dinitro-ketone (Praetorius, *Annalen*, 1879, **194**, 338). A similar yield of the same mixture of nitrobenzoic acids was recovered, for instance, when dinitrobenzophenones from a previous nitration, after being freed from by-products, were again heated at 75° with mixed nitrating acids; and pure 3 : 3′-dinitrobenzophenone prepared from 3 : 3′-dinitrodiphenylmethane by Baeyer's method (*Annalen*, 1907, **352**, 192) yielded under similar conditions *m*-nitrobenzoic acid free from the *p*-isomeride, together with a small amount of a nitrophenol, which is presumably 2 : 5 : 3′-*trinitro*-3-*hydroxybenzophenone* formed in accordance with the general rule.

Although such a fission of an aromatic ketone by nitrating acid does not appear to have been described before, it may perhaps be regarded as a nitration reaction with displacement of the nitrobenzoyl group, somewhat analogous to the displacement of the aldehyde group in the nitration of vanillin described by Bentley (*Amer. Chem. J.*, 1900, **24**, 171). This implies that 3 : 3′-dinitrobenzophenone should yield, together with the *m*-nitrobenzoic acid, a little *m*-dinitrobenzene, but the presence of the latter substance was not actually observed.

As regards the mechanism of the formation of the hydroxy-by-products, the nitration involves attachment to nuclear carbon of the group NO_2, whether this is presented as part of the HNO_3 molecule or as the NO_2^+ ion, and it may be suggested that, just as metallic nitrites in reaction with alkyl halides may yield either nitro-compounds or nitrites as a result of a co-ordination of carbon with nitrogen or oxygen respectively, so in the aromatic nitration reaction the nitro-group becomes attached to a small extent through its oxygen atom with production of the nitrite of a phenol.

Experimental.

The m. p.'s here recorded are uncorrected unless otherwise stated.

By-product in Nitration of Diphenyl.—Diphenyl (100 g.) was mixed with nitric acid (103 c.c., *d* 1·45) and kept at laboratory temperature with occasional shaking for a month. The product, collected after pouring into water, was crystallised from ether, and the mother-liquor shaken with aqueous sodium hydroxide. The main part of the by-product separated as a bright red sodium salt, which was filtered off, washed with water, alcohol and ether, and decomposed with hydrochloric acid. Further small quantities of the same substance were obtained from the alkaline mother-liquor after acidification, and from the original acid mother-liquor of the nitration, by ether extraction, followed by removal in aqueous alkali. A pale yellow, crystalline solid was thus obtained and recrystallised from aqueous acetone, of m. p. 197° (yield, 2·09 g.), which had the composition of a trinitrohydroxydiphenyl (Found : C, 48·2; H, 2·5; N, 13·8. Calc. : C, 47·3; H, 2·3; N, 13·8%). Boiled with chromic acid mixture, this substance yielded *p*-nitrobenzoic acid. Its identification as trinitro-4-hydroxydiphenyl was confirmed by direct comparison with a specimen from the nitration of 4-hydroxydiphenyl, which had m. p. 196°, not depressed by admixture of the by-product.

By-products from Quinoline.—The yellow by-product from the nitration of pure quinoline as described by Dufton (*loc. cit.*) had m. p. 255° (decomp.), but crystallisation from hot nitric acid (*d* 1·4) at once gave large yellow-brown crystals, m. p. 293° (decomp.). This compound, which was evidently not obtained pure by Dufton, is, as he stated, a dinitrohydroxyquinoline (Found : C, 46·2; H, 2·2; N, 17·7. Calc. : C, 46·0; H, 2·1; N, 17·8%), and is identical with the product of nitrating 5-hydroxyquinoline. 6 : 8-*Dinitro-5-hydroxyquinoline* was prepared by careful addition of 5-hydroxyquinoline (from the 5-nitro-base by Skraup's method, *Monatsh.*, 1884, **5**, 533) to a slight excess of cooled fuming nitric acid, and heating at 100° for 2 hours. The product, which separated on dilution, was recrystallised from nitric acid. It had m. p. 293° (decomp.) (303° corr.) and a mixture with the by-product showed no depression.

A mixture of the synthetic 6 : 8-dinitro-5-hydroxyquinoline and phosphorus pentachloride (equal parts) with a little phosphorus oxychloride was boiled for a few minutes and poured into water. The precipitated solid was washed with dilute alkali, crystallised from alcohol, and finally from petroleum (b. p. 80—100°). 5-*Chloro*-6 : 8-*dinitroquinoline*, so obtained, formed pale yellow needles, m. p. 145·5°, readily soluble in cold acetone (Found : C, 42·8; H, 1·8; N, 16·9. $C_9H_4O_4N_3Cl$ requires C, 42·6; H, 1·6; N, 16·6%). A similar experiment with the by-product gave a chloro-compound of m. p. 145·5°, not depressed by admixture of the synthetic substance (Found : C, 43·5; H, 1·9; N, 16·2; Cl, 14·0. Calc. : as above and Cl, 14·0%).

Nitration of 5-Chloroquinoline.—5-Chloroquinoline was heated with a mixture of fuming nitric and fuming sulphuric acids at 100° for 2 hours. The product had m. p. 135°, depressed to 105° by addition of the above chloro-compound from the by-product, and analysis showed that it was 5-chloro-8-nitroquinoline (Found : C, 52·4; H, 2·6. Calc. : C, 51·9; H, 2·4%).

Isomeric Dinitrohydroxyquinolines.—For comparison the nitration of 8-hydroxyquinoline was repeated. The 5 : 7-dinitro-8-hydroxyquinoline, so obtained, closely resembled the by-product, but had m. p. 318° (decomp.) (Found : C, 46·5; H, 2·3; N, 17·5. Calc. : C, 46·0; H, 2·1; N, 17·8%) (Dikshoorn, *loc. cit.*, gives m. p. 325°). This substance was unaffected by heating with phosphorus pentachloride, but the corresponding chlorodinitroquinoline was obtained in poor yield by Dikshoorn, using Ullmann and Nadai's method (*Ber.*, 1908, **41**, 1870), and had m. p. 154°.

Nitration of 7-hydroxyquinoline with fuming nitric acid even in presence of fuming sulphuric acid yielded only the mononitro-compound, 8-nitro-7-hydroxyquinoline, m. p. 255° (decomp.) (Found : N, 14·2. Calc. : N, 14·7%).

A Second By-product.—When the purification of the by-product discussed above was effected by crystallisation from acetic acid, a second *substance* was found in the mother-liquors, separating from acetic acid as a canary-yellow microcrystalline powder, m. p. 202°, isomeric with the other (Found : C, 45·8; H, 2·5%). It was more readily soluble than 6 : 8-dinitro-5-hydroxyquinoline in acetic acid or in nitric acid. The separation of the two was also found to occur when the nitration mixture was fractionally precipitated by water, the isomeride of higher m. p. being thrown out first.

By-products in nitrating Benzophenone.—Benzophenone (100 g.) was nitrated with sulphuric acid (430 g.) and fuming nitric acid (100 g.) with final heating at 90° for 1 hour. Alternatively, the ketone was dissolved in 6 parts of fuming nitric acid at 70° and heated at 90—95° for 3 hours. The mixture was poured on ice, and the whole examined for alkali-soluble by-products. In a series of experiments there was always isolated about 1% of solids which melted variously between 114° and 190° and had the composition of nitrobenzoic acids (Found, for different specimens : C, 50·3; H, 3·1; N, 8·5; and C, 49·9; H, 3·1; N, 8·6. Calc. : C, 50·2; H, 3·0; N, 8·4%).

In one experiment the crude solid nitration product and the acid aqueous mother-liquor were examined separately; the by-product then isolated from the former was crude *m*-nitrobenzoic acid, m. p. 114—115°, not depressed by admixture of pure *m*-nitrobenzoic acid. The material isolated from the aqueous liquor was smaller in amount, and consisted of impure *p*-nitrobenzoic acid, with m. p. 190° (not depressed by an authentic specimen).

These results are not due to the presence of any trace of benzoic acid in the ketone used, since a careful repetition of the nitration with benzophenone which had been freshly melted and shaken under aqueous alkali, gave the same result.

Direct Fission of Nitrobenzophenones.—(1) *Experiments with the nitrated ketone.* The isolation of pure 3 : 3′-dinitrobenzophenone from the products of nitration by fractional crystallisation is not easy. The nitration was therefore carried out in more strongly acid conditions in order to increase the proportion of the symmetrical dinitro-compound (compare nitration of benzaldehyde by Baker and Moffitt, J., 1931, 314). Benzophenone (100 g.), dissolved in fuming sulphuric acid (7% excess SO_3 : 540 c.c.), was nitrated with a mixture of fuming nitric acid (51 c.c.) and oleum (140 c.c.) at 25—30°, the temperature being subsequently raised to 75° for 1 hour. The cooled mixture was poured on ice, and the filtered product recrystallised successively from acetone and acetic acid. The nitration products were thus divided into (A) the nearly pure 3 : 3′-dinitrobenzophenone (76 g.), and (B) the material recovered from the mother-liquors (65 g.).

When (A) was reheated at 75° for 2 hours with nitric acid (40 c.c.) and concentrated sulphuric acid (515 c.c.), and the mixture examined as before for alkali-soluble compounds, the main substance isolated (1% by weight) had m. p. 126°, not depressed by *m*-nitrobenzoic acid, but in addition there was obtained a small amount of a nitrophenolic substance, which separated as a microcrystalline powder from *m*-cresol and had m. p. 285° (decomp.). This was a less pure specimen of the further by-product described below (Found: C, 45·1; H, 2·3; N, 14·5%).

The material (B), similarly reheated with nitrating mixture, yielded 3% of crude *p*-nitrobenzoic acid, m. p. 225—240° after crystallisation from water.

(2) *Experiments with pure* 3 : 3′-*dinitrobenzophenone.* This ketone (70 g.), prepared from *m*-nitrobenzyl alcohol *via* the dinitrodiphenylmethane (Baeyer, *loc. cit.*) and having m. p. 149·5°, was heated at 75—80° for 2 hours with mixed acid (470 c.c. of sulphuric acid and 37 c.c. of nitric acid), poured on ice, and the products examined as before. The by-products isolated were separated into (*a*) a fraction soluble in ether (0·98 g.) which after crystallisation from water and from benzene had m. p. 135—138° (*m*-nitrobenzoic acid), and (*b*) material obtained as a white microcrystalline powder from hot *m*-cresol, and having m. p. 290°, which was almost pure *trinitrohydroxybenzophenone* (Found: C, 47·7; H, 2·7; N, 13·7. $C_{13}H_7O_8N_3$ requires C, 48·4; H, 2·2; N, 13·0%).

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