602. 4 : 4′- *and* 2 : 4′-*Dihydroxydiphenyl Sulphones.*

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The formation of sulphones from phenol, hitherto accomplished by means of fuming sulphuric acid, is achieved more readily by the use of ordinary concentrated acid. The yield of the 2 : 4′-dihydroxy-isomeride is increased thereby. A new method has been devised for the separation of 4 : 4′- and the 2 : 4′-dihydroxy-isomerides, which have now been obtained in a pure state.

It is well known that phenol readily reacts with concentrated sulphuric acid yielding a mixture of the corresponding *o*- and *p*-sulphonic acids, the former preponderating at ordinary temperatures whilst at 100° the latter is the main product (Kekulé, *Z. Chem.*, 1867, 197; *Ber.*, 1869, **2**, 330; Post, *Ber.*, 1875, **8**, 1547; Obermüller, *Ber.*, 1907, **40**, 3637; 1908, **41**, 698). In a publication (*J. pr. Chem.*, 1942, **160**, 41) containing all the appropriate references, Machek and Haas recalled that

Zehntner and Fauser (*ibid.*, 1927, **112**, 233) by treating a slight excess of phenol with fuming sulphuric acid at 180—190° had obtained 4 : 4′-dihydroxydiphenyl sulphone, m. p. 239°, together with a very small quantity of an isomeride, m. p. 173°—174°. Machek and Haas (*loc. cit.*), in a repetition of the above work, not only raised the melting point of the 4 : 4′-isomeride but also established the second product as the 2 : 4′-isomeride, m. p. 186°.

It is now shown that a somewhat similar result can be obtained by using ordinary sulphuric acid instead of the fuming. Under this condition a crude product is obtained, which contains less tarry matter and a larger proportion of the 2 : 4′-isomeride.

Machek and Haas consider that the sulphones result through the union of two molecules of the first-formed phenolsulphonic acids with the elimination of a molecule of sulphuric acid :

$$o\text{-OH}\cdot C_6H_4\cdot SO_3H + p\text{-HO}_3S\cdot C_6H_4\cdot OH \longrightarrow o\text{-OH}\cdot C_6H_4\cdot SO_2\cdot C_6H_4\cdot OH\text{-}p + H_2SO_4$$

They apparently overlooked that they employed slightly more than two molecules of phenol per molecule of sulphuric acid. In these circumstances, it seems more reasonable to regard sulphone formation as the reaction of the phenolsulphonic acids with the excess of phenol (this reaction is recorded in B.P. 471,010 and U.S.P. 2,122,958) :

$$p\text{-OH}\cdot C_6H_4\cdot SO_3H + C_6H_5\cdot OH \longrightarrow (p\text{-OH}\cdot C_6H_4)_2SO_2 + H_2O$$

Furthermore, it appears from the present investigation that the phenol-*o*-sulphonic acid lends itself more readily than the phenol-*p*-sulphonic acid to sulphone formation, for whereas some of the latter has been found in the aqueous filtrates no *o*-acid has been detected.

The small yield (4—5%) of the 2 : 4′-isomeride formed in the reaction with fuming sulphuric acid without temperature control is to be expected owing to the initial evolution of heat, which favours *p*-sulphonation by raising the temperature. If, when employing ordinary concentrated sulphuric acid, the temperature be first raised from that of the room to 165° and then quickly to 190—200°, or, if the reaction mixture is kept at 25—30° for several days and then quickly heated to 190—200° and maintained at this temperature for many hours, the yield of the 2 : 4′-isomeride in the resulting product is raised to approximately 16 and 24%, respectively.

It is remarkable that, although the 4 : 4′- and the 2 : 4′-dihydroxydiphenyl sulphones are both insoluble in benzene, they both yield well-defined crystalline compounds containing one molecule of benzene if benzene is added to a concentrated solution of the sulphone in acetone. From these compounds the benzene is not removed *in vacuo* but it is removed by heating them at 120°. The benzene is also readily liberated by boiling the compound with water or by simple evaporation to dryness with alcohol.

Owing to the great difference in the solubilities of these benzene compounds in a mixture of acetone and benzene, the less soluble 4 : 4′-derivative can readily be separated from the more soluble 2 : 4′-isomeride. In this manner both isomerides have now been obtained in a pure state, the 4 : 4′- and the 2 : 4′-dihydroxydiphenyl sulphones melting at 249·5° and 186·7° respectively.

Previous investigators give the melting point of the 4 : 4′-dihydroxydiphenyl sulphone prepared by the sulphonation of phenol as 239°, 243°, and 245°, and that for the 2 : 4′-isomeride similarly prepared as 173—174°, 183—184°, and 186°. It is not surprising that they did not obtain these compounds pure since they tried to separate the preponderating 4 : 4′-isomeride from the small amount of less soluble 2 : 4′-isomeride by fractional crystallisation from water. Mauthner (*Ber.*, 1906, **39**, 1351) gives the melting point of the synthetic 4 : 4′-compound as 245—246°, and Machek and Haas (*loc. cit.*) record m. p. 183—184° for the synthetic 2 : 4′-isomeride.

EXPERIMENTAL.

(M. p.s were determined on a standardised thermometer.)

Sulphuric acid 98% (13 c.c., 1 mol.) was added to phenol (53 g., 2·5 mols.) contained in a distilling flask fitted with a thermometer dipping into the reaction mixture and a receiver attached to the side-arm. The temperature of the mixture was quickly raised to 165° and maintained there for 6 hours during which some water was evolved. The temperature was then maintained at 195—200° for a further 6 hours during which more water and a little phenol distilled. Whilst still molten, the contents of the flask were poured into water and steam-distilled to remove the excess of phenol. Sufficient boiling water was added to effect complete dissolution. The solution was decolorised with charcoal, filtered, and left to cool, whereupon a mass of crystals separated (43 g.). Concentration of the aqueous filtrate to a very small bulk gave a further yield of crystals, m. p. *ca.* 170° (6 g.) (total yield, 49 g., 86%). The product consists of 4 : 4′-dihydroxydiphenyl sulphone containing approx. 16% of the 2 : 4′-isomeride. The two isomerides were separated as described later.

If, in the above experiment, the initial mixture was kept at 25—30° for 3 days before being heated as described above, the yield of sulphones was 78% and they contained approx. 24% of the 2 : 4′-isomeride.

The final aqueous filtrate from the sulphones was neutralised with aqueous ammonia and concentrated; a slight excess of a warm saturated aqueous solution of *p*-toluidine hydrochloride was added. On cooling, p-*toluidine phenol*-p-*sulphonate* separated; this crystallised from aqueous alcohol in prismatic crystals, m. p. 211°, unchanged by admixture with an authentic specimen (Found: N, 4·9; S, 11·1. $C_{13}H_{15}O_4NS$ requires N, 5·0; S, 11·3%).

Separation of the Isomers.—The well-dried crude product was dissolved in the minimum quantity of boiling acetone. Warm benzene (twice the volume of acetone used) was then added and the mixture set aside overnight in a cool place. A considerable quantity of *solvate* was deposited as prismatic crystals (*A*). These were removed and heated to 120° to remove the combined benzene (Found: loss on heating, 23·9. $C_{12}H_{10}O_4S,C_6H_6$ requires C_6H_6, 23·8%). The resulting 4 : 4′-dihydroxydiphenyl sulphone, which melted at 246—247°, still contained traces of the 2 : 4′-isomeride and was again subjected to the acetone–benzene treatment. The crystals so obtained were added to boiling water, whereupon they dissolved with brisk evolution of benzene. The aqueous solution on cooling yielded 4 : 4′-dihydroxydiphenyl sulphone as very long needles, m. p. 249·5°. Further similar treatment with acetone–benzene did not raise the m. p. The dimethoxy-derivative, prepared in the usual manner and crystallised from alcohol, melted at 132° (Machek and Haas give m. p. 130·5°). The *dibenzoate*, prepared in the usual way, crystallised from alcohol in needles, m. p. 248·5° (Found: C, 68·3; H, 4·05; S, 7·0. $C_{24}H_{18}O_6S$ requires C, 68·1; H, 3·9; S, 7·0%).

The acetone–benzene filtrates from (*A*) in the above process were mixed and concentrated to about two-thirds of their volume. When the solution was kept overnight in a cool place, a further crop of crystals was obtained, consisting of a mixture of the two isomerides which were separated through the benzene adduct as previously described. The filtrate from these crystals was concentrated to a small bulk, and the semi-solid mass obtained on cooling was drained and washed with acetone–benzene (1 : 4). The crystals were decomposed by boiling water and then dissolved completely. On cooling, the 2 : 4′-isomeride was deposited as small needles. After several crystallisations from boiling water, it was obtained free from the last traces of the more soluble 4 : 4′-isomeride and melted at 186·7°. The product obtained by Machek and Haas (*loc. cit.*) from the sulphonation mixture and also by synthesis melted at 183—184° but they obtained a specimen from the mixture, by sublimation *in vacuo*, which had m. p. 186°. The dimethoxy-derivative, prepared in the usual manner, melted, after crystallisation, at 125·5° (Machek and Haas give m. p. 124—125°). The *dibenzoate* crystallised from alcohol in fine needles, m. p. 185·5° (Found: C, 68·3; H, 4·0; S, 7·0%).

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