339. *The Resorcitols. Part I.*

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A procedure has been evolved for the separation of almost all the *cis*- and *trans*-isomers present in commercial resorcitol (*cyclo*hexane-1 : 3-diol). Derivatives have been prepared, but a previously reported conversion of the *cis*- into the *trans*-isomer is not confirmed. *cyclo*Hex-2-enone and 3-benzoyloxy*cyclo*hexanone have been prepared and the structure of the former has been established by chemical and physical methods.

From the mixture obtained by hydrogenation of resorcinol (Sabatier and Mailhe, *Compt. rend.*, 1908, **146**, 1193; Lindemann and Baumann, *Annalen*, 1929, **477**, 78; Rothstein, *Ann. Chim.*, 1930, **14**, 461; Coops, Dienske, and Aten, *Rec. Trav. chim.*, 1938, **57**, 303; Dimroth and Resin, *Ber.*, 1942, **75**, *B*, 322), *cis*- and *trans*-resorcitols have been isolated by methods involving fractional crystallisation of derivatives, but the methods were not efficient. Attempts at direct crystallisation have hitherto failed (*e.g.*, Rothstein, *loc. cit.*) and it now appears that this was due to attempting to separate first the less soluble *trans*-compound; actually it seems that much of the more soluble, but more readily crystallised, *cis*-compound must be isolated before any of the *trans*-isomer can be obtained. By a crystallisation process using acetone as solvent, the separation of the isomers has now been achieved, 97% of the total resorcitols present in the original mixture being isolated as pure *cis*- (m. p. 85—85·5°) and *trans*-resorcitol (m. p. 118—118·5°). These have been characterised by the preparation of derivatives and it is to be noted that the rule that *cis*- have lower melting points than the corresponding *trans*-isomers is by no means rigidly adhered to in these derivatives; exceptions are the 1-*benzoate* 3-*phenylurethanes*, 1-*benzoate* 3-p-*nitrobenzoates*, 1-benzoate 3-(3′ : 5′-dinitrobenzoates) (Dimroth and Resin, *loc. cit.*), bis(hydrogen phthalates) (Part II, succeeding paper), and possibly the bisphenylurethanes and *diacetates* (*trans* not crystallised).

The partial conversion of *cis*-resorcitol into *trans*-resorcitol dibenzoate (Rothstein, *loc. cit.*) could not be confirmed.

Oxidation of resorcitol in acid aqueous solution at 35—40° with dichromate gave *cyclo*hex-2-enone. As it was not possible to characterise this ketone from data recorded in the literature (Kötz *et al.*, *Annalen*, 1907, **358**, 197; *J. pr. Chem.*, 1909, **80**, 499; von Braun, *Ber.*, 1926, **59**, 1999; Dimroth and Resin, *loc. cit.*; Dimroth and Stockstrom, *ibid.*, p. 326), its structure was further investigated. The molecular refractivity showed an exaltation of 1·26 units (cf. Kötz, 0·21 unit), and the ultra-violet absorptions of the ketone and of its semicarbazone were in line with those of other αβ-unsaturated ketones. The semicarbazone could be made to melt anywhere between about 160° and 185° or sharp at 184—186° according to the conditions (cf. Kötz, 161°; von Braun, 198°); the 2 : 4-dinitrophenylhydrazone melted at 164·5° (cf. Dimroth *et al.*, 167·5—169°). An oxime could not be crystallised (Kötz gives its m. p. as 75—76°). Oxidation of the unsaturated ketone with cold aqueous alkaline permanganate gave an almost quantitative yield of glutaric acid, again indicating the Δ^2-structure; direct oxidation of resorcitol with warm aqueous permanganate gave succinic acid. Using a procedure analogous to that adopted by Aldersley, Burkhardt, Gillam, and Hindley for quinitol monoacetate (*J.*, 1940, 13), resorcitol monobenzoate was oxidised to 3-benzoyloxy*cyclo*hexanone (85% yield), which is unstable, especially if impure, decomposing to benzoic acid and a liquid from which *cyclo*hex-2-enone 2 : 4-dinitrophenylhydrazone can be prepared. The same substance has since been made by Dimroth and Resin (*loc. cit.*) who used a similar but apparently less effective method.

EXPERIMENTAL.

cis-*Resorcitol.*—Resorcinol was hydrogenated in aqueous solution at 90—100° in presence of a nickel catalyst. The product (resorcitol), which was kindly supplied by Messrs. Howards & Sons, Ilford, was a viscous, nearly colourless syrup with an odour of peppermint. After standing for several weeks, it became translucent and semi-solid. Resorcitol (20 g.) was extracted with boiling benzene (500 c.c.), and the solution kept for six months, whereafter the crystalline deposit (stout needles) was collected and recrystallised from acetone. A solution of resorcitol in two-thirds of its weight of acetone was seeded with the crystalline fraction and kept overnight at 0°. The solid was collected, washed with acetone, and recrystallised from acetone to yield *cis*-resorcitol as prisms, m. p. 85—85·5°, b. p. 137°/13 mm., 125°/5 mm. (yield of materials, m. p. 83—85·5°, 24%).

trans-*Resorcitol.*—The combined mother- and wash-liquors were concentrated to give a solution containing three-fifths of its weight of solute; the solution was seeded with *cis*-resorcitol (no *trans*-isomer being available at this time) and stirred at −10° until thick with crystals (*ca.* 3 hours) and then at 0° for 30 minutes. The solid was collected, washed with ether–acetone (1 : 1) and then sodium-dried ether, and recrystallised from acetone. *trans*-Resorcitol separated from acetone or ethyl acetate as small prisms, m. p. 118—118·5°, b. p. 135°/13 mm. (yield of materials m. p. 112—115°, 16%). Further crops of, alternately, the *cis*- and *trans*-isomers were obtained from the ether-freed mother-liquors by concentrating so that the ratio (by weight) of acetone to solute was 1 : 1·75, cooling to −5° to −10° and stirring for 1½—1¾ hours after seeding with 2 g. of the appropriate isomer. The crops thus obtained were, after washing with acetone and sodium-dried ether (1 : 1), almost pure. Prolonged stirring tended to give a mixture of isomers, melting at *ca.* 60°; in such cases it was best to redissolve the material in the mother-liquors and repeat the crystallisation. Accumulation of the impurities of commercial resorcitol in the mother-liquors decreased the tendency of the low-melting mixture to separate; on that account although these impurities could be removed (by distillation) at any stage in the series of crystallisations, it was found undesirable to reduce their concentration to below 10% of the weight of resorcitol being crystallised.

By crystallising *cis*- and *trans*-isomers alternately, more than 57% of the resorcitol present could be isolated in 10 crystallisations. In an experiment, the object of which was to determine the relative proportions of *cis*- and *trans*-isomers in the original hydrogenation product, and which was continued to nearly 60 crystallisations (including recrystallisations), 97% of the resorcitol present was obtained in the form of pure, recrystallised isomers. The ratio *cis*- : *trans*-resorcitol was thus found to lie between the limits 1·21 : 1 and 1·35 : 1, the uncertainty depending on the composition of the residual 3% of syrupy resorcitol. Total yields were : *cis*-, 49% and *trans*-isomer, 38%; uncrystallised resorcitol, 2½%; low-boiling impurities (b. p. <135°/13 mm.) other than water, 4%; high-boiling impurities (b. p. >140°/13 mm.) 5½%. This was, however, an early experiment, and the 60 crystallisations would have been reduced by about half if the technique described above had been known.

Derivatives.—cis-*Resorcitol diacetate* separated as prisms, m. p. 36·5—36·8°, b. p. 179°/90 mm., from alcohol (Found : C, 59·8; H, 7·8. $C_{10}H_{16}O_4$ requires C, 60·0; H, 8·1%). The trans-*diacetate* is a colourless oil, b. p. 178°/90 mm., 208°/245 mm. (Found : Ac, 43·0. $C_{10}H_{16}O_4$ requires 2Ac, 43·0%).

Monobenzoates. *trans*-Recorcitol dibenzoate (obtained by use of pyridine), m. p. 123—124° (literature, 121—123°, 122·5°) (0·2 mol.), in alcohol (350 c.c.) and water (200 c.c.) was treated, slowly and with stirring, with potassium hydroxide (0·2 mol.) in water (100 c.c.). The solution was kept at 75—80° until no longer alkaline to phenolphthalein. The mixture was diluted with water (300 c.c.) and cooled, and a small amount (5 g.) of dibenzoate removed by filtration. The filtrate was extracted with chloroform, the dried extract evaporated, and the product distilled to yield trans-*resorcitol monobenzoate* as a colourless viscous liquid, b. p. 146—147°/2 mm. (Found : Bz, 48·0. $C_{13}H_{16}O_3$ requires 1Bz, 47·7%). The cis-*monobenzoate*, similarly prepared from the *cis*-dibenzoate, m. p. 66—66·5°) (literature 65°, 65·5°), is a colourless oil (Found : Bz, 47·5%).

cis-*Resorcitol* 1-*benzoate* 3-p-*nitrobenzoate* separated from alcohol as almost colourless prisms, m. p. 125—127·5° (Found : C, 64·5; H, 5·4; N, 3·6. $C_{20}H_{19}O_6N$ requires C, 65·3; H, 5·2; N, 3·8%). trans-*Resorcitol* 1-*benzoate* 3-p-*nitrobenzoate* forms almost colourless prisms, m. p. 97—97·5°, from alcohol (Found : equiv., 184·5. $C_{20}H_{19}O_6N$ requires equiv., 184·5).

trans-*Resorcitol* 1-*benzoate* 3-*phenylurethane* forms prisms, m. p. 112—112·5°, from alcohol (Found : C, 70·7; H, 6·1 : N, 4·5. $C_{20}H_{21}O_4N$ requires C, 70·8; H, 6·2; N, 4·1%). The cis-*isomer* forms microscopic prisms, m. p. 167·5—168·5°, from pyridine–alcohol (Found : C, 72·2; H, 6·41; N, 4·45%).

cyclo*Hex*-2-*enone.*—*cis*-Resorcitol (58 g.) in sulphuric acid (34 g.) and water (130 c.c.) was covered with alcohol-free ether (200 c.c.) and treated slowly with a solution of sodium dichromate (49·5 g.) in water (75 c.c.), with stirring, at 35—40°. When the addition was complete, the mixture was maintained at 60° for 5 minutes. The mixture separated into three layers. The two lower layers were separated and extracted with ether (5 × 20 c.c.). The extract was washed with water and then sodium hydrogen carbonate solution, and dried (Na_2SO_4). Removal of the ether, followed by distillation, gave a major fraction, b. p. 100—110°/90 mm., which on redistillation yielded *cyclo*hex-2-enone (11·25 g.), b. p. 105°/100 mm., 175°/760 mm., $d_{4°}^{20°}$ 0·9931, $[R]_L$ 28·51 (calc. 27·25), $n_D^{20°}$ 1·4892. A further quantity of the unsaturated ketone was obtained from the aqueous liquids (total yield, 22 g.). *cyclo*Hex-2-enone develops a brown colour when kept at room temperature for a few days, but remains colourless when stored at 0°. It has a burning taste and a characteristic penetrating odour, and is sternutatory (Found: C, 73·8; H, 8·5. Calc. for C_6H_8O: C, 74·95; H, 8·4%). Its light absorption in alcohol has maxima at 3230 A. (ε, 30) and 2240 A. (ε, 12,200) and a minimum at 2700 A. (ε, 6). *cyclo*Hexenone semicarbazone separates as colourless prisms from alcohol; the m. p. was indefinite, about 165—170°, but the resolidified melt melted sharply at 184—186°; this derivative has light absorption in alcohol: maximum at 2640 A. (ε, 21,000). *cyclo*Hexenone 2 : 4-dinitrophenylhydrazone separated as deep-orange-red needles, m. p. 164·5°, from *n*-butanol–ethanol (Dimroth and Resin, *loc. cit.*, give m. p. 167·5—169°) (Found: C, 52·5; H, 4·6; N, 20·5. Calc. for $C_{12}H_{12}O_4N_4$: C, 52·2; H, 4·4; N, 20·3%).

3-*Benzoyloxy*cyclo*hexanone.*—A solution of *cis*- or *trans*-resorcitol monobenzoate (8·8 g.) in glacial acetic acid (15 c.c.) was treated with chromium trioxide (3·1 g.) in water (2 c.c.) and acetic acid (8 c.c.) at 0—5°. After being kept overnight, the solution was neutralised by 20% sodium hydroxide solution, the temperature being maintained below 10° throughout. The mixture was extracted with chloroform, and the extract dried (Na_2SO_4) and evaporated. The oily product crystallised on standing and was recrystallised from benzene–light petroleum, from which 3-benzoyloxy*cyclo*hexanone (7·3 g., 83%) separated as minute prisms, m. p. 61—62°. Wasteful recrystallisation from benzene gave the pure substance, m. p. 63·5° (Dimroth *et al.*, *loc. cit.*, give m. p. 61—62°) (Found: C, 71·3; H, 6·3. Calc. for $C_{13}H_{14}O_3$: C, 71·6; H, 6·5%). After a year, a specimen had decomposed into benzoic acid and a mobile liquid which contained *cyclo*hex-2-enone, characterised as its 2 : 4-dinitrophenylhydrazone, m. p. and mixed m. p. 164·5°.

Oxidation of cyclo*Hex-2-enone.*—Finely powdered potassium permanganate (5·77 g.) was added gradually to a mixture of *cyclo*hex-2-enone (0·96 g.), water (5 g.), and crushed ice. The mixture was neutralised, filtered, acidified with hydrochloric acid (Congo-red), and evaporated to dryness, and the residue extracted with acetone. The extract gave glutaric acid (1·32 g.), m. p. and mixed m. p. 94—96°.

Oxidation of cis-*Resorcitol.*—A solution of *cis*-resorcitol (2·32 g.) and sodium carbonate (0·05 g.) in water (20 c.c.) was treated with powdered potassium permanganate (12·7 g.) at 65—70°. When reduction was complete, the mixture was treated as described above, to yield succinic acid (1·6 g.), m. p. and mixed m. p. 185—186°.

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