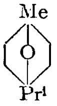
75. *Alicyclic Glycols. Part II. Derivatives of* cyclo*Hexane*-1 : 4-*diol.*

By L. N. Owen and P. A. Robins.

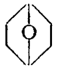
A study has been made of the properties of the *mono-* and *di-toluene-*p*-sulphonyl* derivatives of *cis-* and *trans-cyclo*hexane-1 : 4-diol. With alcoholic alkali, no 1 : 4-epoxide is formed, the main reaction being intramolecular elimination of toluene-*p*-sulphonic acid, with formation of *cyclo*hexenol or *cyclo*hexadienes. With potassium acetate, lithium chloride, and sodium iodide, the toluene-*p*-sulphonyloxy-groups are replaced by acetoxy-, chlorine, and iodine, respectively, though the simultaneous formation of olefinic products is usually observed. Improved methods are described for the preparation of the mono-acetates and -benzoates of the diol. With thionyl chloride, the *trans*-diol gives a polymeric sulphite ester.

In Part I (preceding paper), an account has been given of some reactions of the mono-methane-sulphonyl and -toluene-*p*-sulphonyl derivatives of *cyclo*hexane-1 : 2-diol, and it has been shown that the 1 : 2-epoxide is formed only when the sulphonyl group is *trans* in relation to the adjacent hydroxyl. In the carbohydrate field, it has been recognised for some time that when no actual or potential hydroxyl group is available in the *trans*-position on the adjacent carbon atom, it may be possible for an oxide ring of a different type to be formed. It is in such circumstances that compounds such as the 3 : 6-anhydro-sugars can be prepared, in which the anhydro-ring is very much more stable than one of the ethylene oxide type (see Peat, "Advances in Carbohydrate Chemistry", Vol. II, p. 56).

1 : 4-Cineole (I) provides a comparable example of a five-membered ring oxide in the alicyclic field, but it is only recently that the parent compound, 1 : 4-epoxy*cyclo*hexane (II) has been described. This has been obtained by Olberg, Pines, and Ipatieff (*J. Amer. Chem. Soc.*, 1944, **66**, 1096) by direct dehydration of *cyclo*hexane-1 : 4-diol over alumina, and also by Nudenberg and Butz (*ibid.*, p. 307) by hydrogenation of 1 : 4-epoxy*cyclo*hex-2-ene (III), prepared by condensation of furan with ethylene. Stereochemical considerations require a *cis* disposition of the oxide ring, probably in conjunction with a stabilised boat form for the *cyclo*hexane ring (II*a*), and, according to Ipatieff and Pines, the yield of oxide (73%) from the *trans*-diol is much higher than that from the *cis*-, which supports the suggestion of inversion during the reaction. With hydrogen bromide, the oxide gives *trans*-1 : 4-dibromo*cyclo*hexane (Ipatieff and Pines, *loc. cit.*), and, with acetic anhydride, the diacetate of *trans*-*cyclo*hexane-1 : 4-diol (Nudenberg and Butz, *loc. cit.*). The former reaction presumably proceeds in two stages, *via* 4-bromo*cyclo*hexanol, and it is possible that inversion occurs in the final replacement of hydroxyl by bromine. The reaction with acetic anhydride, also, may be a two-stage process if the anhydride contains traces of acetic acid, but acetylation of the intermediate 4-acetoxy*cyclo*hexanol would not be expected to cause inversion, so that this must occur at the ring-opening stage.



(I.)



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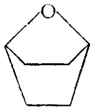
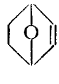


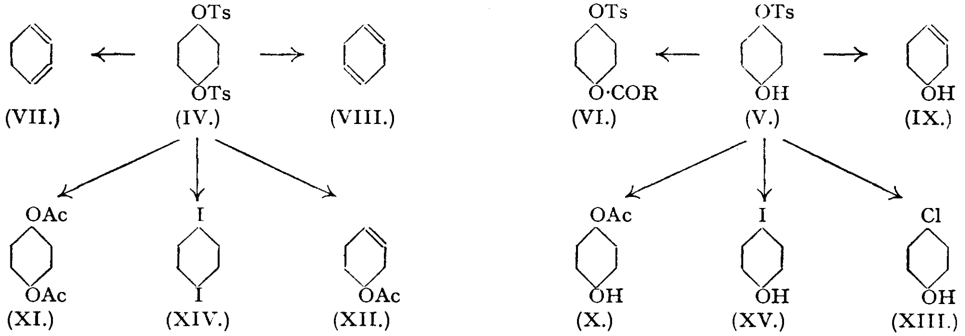
(II*a*.)



(III.)

It occurred to us that it might be possible to prepare the epoxide from a *trans*-monotosyl derivative of the diol, and although this aim was not realised, the properties of the toluene-*p*-sulphonyl derivatives themselves proved to be of some interest.

*cyclo*Hexane-1 : 4-diol was prepared by hydrogenation of quinol in methanol at 150° and 120 atm., with a Raney nickel catalyst, care being taken to ensure complete reduction, since traces of unchanged quinol cause considerable difficulty in the subsequent separation of stereoisomers. The diol was converted into the diacetate, from which the *trans*-form, m. p. 102—103°, was isolated by crystallisation, first from acetone, and finally from methanol; the residual *cis*-diacetate was then purified by distillation. Previous workers (cf. Ipatieff and Pines, *loc. cit.*) have used the ordinary saponification procedure for regeneration of the diols from the diacetates, but this has now been considerably simplified by adoption of the catalytic method of alcoholysis devised and used by Zemplén (*Ber.*, 1923, **56**, 1705; 1929, **62**, 1613; 1936, **69**, 1827) in the carbohydrate field. The stereochemically pure diacetates, dissolved or suspended in dry methanol, were separately treated with a trace of sodium methoxide and left for a few hours at room temperature; removal of solvent then yielded the diols in substantially pure stereochemical forms. These reacted readily with two mols. of toluene-*p*-sulphonyl chloride in pyridine to give the corresponding *bistoluene*-p-*sulphonyl* derivatives (IV), *cis*-, m. p. 98—99°, *trans*-, m. p. 157°.



(Ts = p-$CH_3{\cdot}C_6H_4{\cdot}SO_2$)

By reaction with one mol. of toluene-*p*-sulphonyl chloride in chloroform solution, added to the diols in pyridine at 0°, good yields of the *monotoluene*-p-*sulphonyl* derivatives (V), *cis*-, m. p. 94°; *trans*-, m. p. 112°; were obtained. Benzoylation of the latter compounds gave the *benzoyltoluene*-p-*sulphonyl* derivatives (VI; R = Ph), in which the usual order of m. p. was reversed, *cis*-, m. p. 152°; *trans*-, m. p. 94—95°; the same anomaly occurred with the *toluene*-p-*sulphonylacetyl*-derivatives (VI; R = Me), *cis*-, m. p. 104°; *trans*-, m. p. 81—83°. Several similar examples have been encountered in the present work, thus again emphasising the unreliability of relative m. p. as a criterion of configuration.

Reaction of the bistoluene-*p*-sulphonyl derivatives (IV) with alcoholic alkali, or with alcoholic alkoxides, resulted in the removal of two mols. of toluene-*p*-sulphonic acid, and formation of a mixture of *cyclo*hexa-1 : 3- (VII) and -1 : 4-(VIII)-dienes, the presence of the former being confirmed by its absorption spectrum. Probably because of the high volatility of these dienes, the yield in no case exceeded 25%, but there was no evidence of any epoxide formation in these reactions. The monotoluene-*p*-sulphonyl derivatives (V), on reaction with either aqueous alkali, alcoholic alkali, or acid, gave only *cyclo*hexen-4-ol (IX), and this product was also formed by heating with methanol alone in a sealed tube at 100°. It is therefore clear that, under the conditions employed, the toluene-*p*-sulphonyl derivatives of *cyclo*hexane-1 : 4-diol give the corresponding unsaturated compounds, rather than ethers, thus behaving like the *cis*-monotoluene-*p*-sulphonyl derivative of the 1 : 2-diol (see Part I).

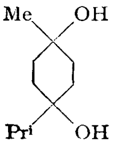
Investigations were then carried out on the replacement of the toluene-*p*-sulphonyl groups in these compounds by acetyl or halogen. Reaction of the *trans*-monotoluene-*p*-sulphonate with potassium acetate in boiling ethanol proceeded largely with loss of toluene-*p*-sulphonic acid, titration showing its formation to the extent of 85%; consequently, the main product isolated was *cyclo*hexen-4-ol, but, in addition, there was obtained in small yield a monoacetate of the diol, which gave a 3 : 5-*dinitrobenzoate*, m. p. 153—154°. For the 3 : 5-dinitrobenzoates of the *cis*- and *trans*-monoacetates of *cyclo*hexane-1 : 4-diol, Dimroth (*Ber.*, 1939, **72**, 2043) gives m. p. 119—122° and 145—146° respectively. Dimroth's " *cis* "-derivative, however, was prepared from the residues after crystallisation of *trans*-monoacetate, and was evidently not stereochemically pure, since we have now obtained the *cis*-3 : 5-dinitrobenzoate-acetate from pure *cis*-diol (see below) and find it to melt at 154—155°, and to be identical with the derivative mentioned above. The *trans*-monotoluene-*p*-sulphonate therefore gives a small amount of *cis*-monoacetate (X). The *trans*-bistoluene-*p*-sulphonate, under similar conditions, gave a high yield of toluene-*p*-sulphonic acid and volatile *cyclo*hexadienes, but again it was possible to show that replacement, with inversion, had also occurred, since both the *trans*-diacetate (XI) and the acetate (XII) of *cyclo*hexen-4-ol were identified. Evidently, however, the tendency for the formation of olefinic compounds is again the predominating factor.

One experiment was carried out on the replacement of toluene-*p*-sulphonyloxy by chlorine, in which the *cis*-monotoluene-*p*-sulphonate (V), treated with lithium chloride in boiling ethanol, gave 4-chloro*cyclo*hexanol (XIII). This was shown, by fractional crystallisation of the phenylurethanes, to be a mixture of *cis*- and *trans*-forms, with the latter predominating, thus indicating that the replacement had occurred with a high proportion of inversion; the development of acidity in the reaction mixture indirectly indicated the formation also of some *cyclo*hexen-4-ol.

On treatment of the *cis*-bistoluene-*p*-sulphonate with sodium iodide in boiling acetone solution, sodium toluene-*p*-sulphonate was precipitated in almost theoretical yield, and a mixture of *cis*- and (mainly) *trans*-di-iodo*cyclo*hexanes (XIV) was isolated; from the *trans*-bistoluene-*p*-sulphonates only the *trans*-di-iodide could be obtained. This suggests partial inversion in the former reaction and probably complete inversion in the latter (since inversion at both the 1 and 4 positions results in retention of the original configuration), but the yields of di-iodides were low in both reactions, and it is likely that *cyclo*hexadienes were formed simultaneously. The *trans*-monotoluene-*p*-sulphonate (V) yielded mainly 4-*iodo*cyclo*hexanol* (XV), the configuration of which could not be established because of its failure to give any crystalline derivatives.

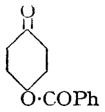
In addition to the attempts, described above, to prepare 1 : 4-epoxy*cyclo*hexane from the toluene-*p*-sulphonyl derivatives, investigations were carried out to determine whether the oxide was formed under conditions in which 1 : 4-terpin (XVI) is known to be converted into 1 : 4-cineole (cf. Wallach, *Annalen*, 1907, **356**, 204), but steam distillation of the diol in either oxalic or sulphuric acids gave *cyclo*hexen-4-ol as the only identifiable product. One further attack on the problem was made by dehydrochlorination experiments on 4-chloro*cyclo*hexanol, prepared in improved yield (*ca.* 60%) from the diol by the action of fuming hydrochloric acid at 80—90° (cf. Palfray *et al.*, *Bull. Soc. chim.*, 1928, **43**, 906; *Compt. rend.*, 1929, **189**, 701). The chlorohydrin failed to react with potassium hydroxide in boiling ether; with refluxing alcoholic alkali, or solid potassium hydroxide at 160°, a complex mixture was obtained. At present, therefore, the process of Ipatieff and Pines is still the only method for the preparation of 1 : 4-epoxy*cyclo*hexane from the 1 : 4-diol.

In attempts to prepare 4-chloro*cyclo*hexanol by reaction of the *trans*-diol with one mol. of thionyl chloride under various conditions, there was obtained, in good yield, a pale brown amorphous solid, soluble in chloroform, from which it was precipitated by gradual addition of ether or light petroleum. Fractionation in this way gave a series of buff-coloured solids of decreasing m. p., all of which contained sulphur, but no halogen, and gave, on saponification with alcoholic potassium hydroxide, potassium sulphite and the original *trans*-diol. The material is therefore formulated as a polymeric sulphite ester (XVII).



(XVI.)

(XVII.)



(XVIII.)

The few reports in the literature indicate considerable difficulty in obtaining mono-esters of cyclohexane-1 : 4-diol, either by partial esterification of the diol, or by partial saponification of the di-esters (Rothstein *et al.*, *Compt. rend.*, 1928, **186**, 1007; *Bull. Soc. chim.*, 1929, **45**, 855; *Ann. Chim.*, 1930, **14**, 461). Dimroth (*loc. cit.*) claimed the isolation, in poor yield, of both the *cis*- and *trans*-monoacetates by partial saponification of the mixed diacetates under rigorously controlled conditions. A crystalline monobenzoate of the *trans*-diol was also reported to be formed, in low yield, by the Schotten–Baumann process. These mono-esters are important in that they provide, on oxidation, esters of 4-hydroxy*cyclo*hexanone, a compound of potential value for the synthesis of hydroxypolycyclic compounds (cf. Aldersley and Burckhardt, *J.*, 1938, 545; Dimroth, *loc. cit.*), and improved methods for their preparation are desirable. In view of the ready formation, in good yield, of the monotoluene-*p*-sulphonates by the method already described, it was thought that other mono-esters could be obtained by similar means. By addition of one mol. of the appropriate acid chloride, in chloroform solution, to a pyridine solution of the stereochemically pure diol at 0°, the following yields were obtained: *trans*-monobenzoate, 78%; *cis*-monobenzoate, 48%; *trans*-monoacetate, 45%; *cis*-monoacetate, 47%. The monoacetates were characterised by conversion into their 3 : 5-dinitrobenoates, *cis*-, m. p. 154—155° (see above), and *trans*-, m. p. 146—147°. Furthermore, toluene-*p*-sulphonation of the *cis*-monoacetate and *cis*-monobenzoate gave the toluene-*p*-sulphonyl acetate and the toluene-*p*-sulphonyl benzoate, identical with those already prepared by acetylation or benzoylation of the *cis*-monotosylate. Both the *cis*- and *trans*-monobenzoates were oxidised by chromic acid to 4-benzoyloxy*cyclo*hexanone (XVIII) (*semicarbazone*); since completion of this work, a more recent publication of Dimroth has become available (*Ber.*, 1942, **75**, 317) in which the preparation of this ester of 4-hydroxy*cyclo*hexanone is described, though in much lower overall yield.

EXPERIMENTAL.

(Light petroleum, unless stated otherwise, refers to the fraction, b. p. 40—60°.)

cis- *and* trans-cyclo*Hexane*-1 : 4-*diol*.—Quinol (200 g.) in methanol (200 c.c.) was hydrogenated at 150° and 150 atm. over Raney nickel (20 g.) until no more hydrogen was absorbed (*ca.* 20 hours). The product, isolated by evaporation of the filtered solution, was acetylated by refluxing for 4 hours with acetic anhydride (400 g.), and the crude diacetate crystallised from boiling acetone (200 c.c.) to give long prisms of the *trans*-compound, m. p. 102—103° after two recrystallisations from methanol (yield, 130 g.). The oil recovered from the acetone mother liquors was diluted with benzene (50 c.c.), treated with light petroleum (100 c.c.), and seeded with *trans*-diacetate, to give a further 13 g. of this material. The residual solution was evaporated and distilled to give the *cis*-diacetate (130 g.), m. p. 35°, b. p. 130°/15 mm.

The *trans*-diacetate (130 g.) was covered with anhydrous methanol (200 c.c.) and treated with 20% methanolic sodium methoxide (2·5 c.c.). After 24 hours' standing with occasional shaking, the solid had dissolved, and the solution, concentrated to 90 c.c., was treated with ether (400 c.c.) and cooled to 0°, to give small prisms of the *trans*-diol (72 g.), m. p. 141°. The *cis*-diacetate (130 g.) was similarly treated, the crude product obtained by evaporation of the reaction mixture being crystallised from boiling acetone. The *cis*-diol was obtained as large prisms (25 g.), m. p. 108—110°; further quantities of less pure material were obtained from the mother liquors. It is particularly important that the diacetates be free from traces of quinol diacetate, since this inhibits the catalytic deacetylation, probably owing to reaction of the sodium methoxide with quinol.

Toluene-p-*sulphonyl Derivatives*.—(*a*) The *trans*-diol (20 g.), dissolved in dry pyridine (100 c.c.), was treated with toluene-*p*-sulphonyl chloride (68 g.), left overnight, and then poured into excess of dilute hydrochloric acid. The precipitated solid was collected, washed with water, dried, and crystallised from benzene to give the trans-*bistoluene*-p-*sulphonate* (61 g.) as needles, m. p. 159° (decomp., after rapid heating from 150°) (Found: C, 56·9; H, 5·75. $C_{20}H_{24}O_6S_2$ requires C, 56·6; H, 5·7%).

(*b*) The *cis*-diol (5 g.) similarly gave needles of the cis-*bistoluene*-p-*sulphonate* (13·3 g.), m. p. 98—99° after crystallisation from methanol (Found: C, 56·3; H, 5·5%).

(*c*) The *trans*-diol (20 g.) in pyridine (100 c.c.) was cooled to 0° and treated with a solution of toluene-*p*-sulphonyl chloride (32 g.) in pure chloroform (100 c.c.), added with stirring during 2 hours. After standing overnight, the trans-*monotoluene*-p-*sulphonate* (37 g.) was isolated; it crystallised from benzene–light petroleum (b. p. 60—80°) in needles, m. p. 111° (Found: C, 57·6; H, 6·3. $C_{13}H_{18}O_4S$ requires C, 57·75; H, 6·7%). With benzoyl chloride in pyridine it gave the trans-*benzoate-toluene*-p-*sulphonate*, plates from aqueous ethanol, m. p. 94—95° (Found: C, 64·2; H, 5·8. $C_{20}H_{22}O_5S$ requires C, 64·15; H, 5·9%). Acetylation gave the trans-*toluene*-p-*sulphonate-acetate*, long needles from benzene–light petroleum, m. p. 81—83° (Found: C, 57·6; H, 6·4. $C_{15}H_{20}O_5S$ requires C, 57·7; H, 6·45%).

(*d*) The cis-*monotoluene*-p-*sulphonate*, prepared in a similar way, crystallised from benzene–light petroleum (b. p. 60—80°) in needles, m. p. 94—95° (Found: C, 57·7; H, 6·7%). Benzoylation gave the cis-*benzoate-toluene*-p-*sulphonate*, prisms from ethanol, m. p. 150—151° (Found: C, 63·9; H, 5·9%). The cis-*toluene*-p-*sulphonate-acetate* crystallised from benzene–light petroleum in prisms, m. p. 104—105° (Found: C, 57·6; H, 6·55%).

Action of Alkali on the Toluene-p-*sulphonyl Derivatives*.—(*a*) The *trans*-bistoluene-*p*-sulphonate (15 g.) was heated with 5% ethanolic potassium hydroxide (150 c.c.) for 2 hours under partial reflux, 10 c.c. of distillate being collected in an ice-cooled receiver. The absorption spectrum of a portion of this distillate indicated the presence of *ca.* 2% of the conjugated *cyclo*hexa-1 : 3-diene. The distillate was diluted with several volumes of light petroleum, washed with water to remove alcohol, and treated with excess of bromine; on evaporation, a mixture of tetrabromo*cyclo*hexanes (2·5 g.), m. p. *ca.* 120°, was obtained, corresponding to a 20% yield of *cyclo*hexadienes. The main reaction mixture was neutralised with carbon dioxide, filtered, and concentrated to small bulk under a 12-inch Dufton column. The residue was diluted with water and extracted with ether. Removal of ether from the dried extracts gave only 0·5 g. of liquid residue, b. p. 64—66°/44 mm., $n_D^{21°}$ 1·4510, which was not 1 : 4-epoxy*cyclo*hexane; it was possibly the diethyl ether of the diol, but there was not enough for identification.

Essentially similar results were obtained with the *cis*-bistoluene-*p*-sulphonate, and also by the use of sodium methoxide or *tert.*-butoxide in place of the alkali.

(*b*) The *trans*-monotoluene-*p*-sulphonate (10 g.) in 5% aqueous potassium hydroxide (100 c.c.) was heated to 110°, with vigorous stirring, the distillate (containing oily drops) being collected. Water was added to the mixture at a rate sufficient to maintain its volume during the heating. When 100 c.c. had been collected, the distillate was saturated with salt and extracted with ether. The extracts were dried (Na_2SO_4), and the ether removed through a Dufton column. The residual oil (2·4 g.), b. p. 68—69°/16 mm., $n_D^{17°}$ 1·4820, was identified as *cyclo*hexen-4-ol by formation of the α-naphthylurethane, m. p. 132—133° (lit. 128°) (Found: C, 76·65; H, 6·45. Calc. for $C_{17}H_{17}O_2N$: C, 76·4; H, 6·4%).

Similar treatment of the *trans*-monotoluene-*p*-sulphonate with 5% methanolic potassium hydroxide again gave *cyclo*hexen-4-ol. Furthermore, the same product was obtained when a solution of the monotoluene-*p*-sulphonate (2 g.) in methanol (20 c.c.) was heated at 100° for 15 hours. There was no indication of the formation of 1 : 4-epoxy*cyclo*hexane in any of the above experiments.

Acid Hydrolysis of the trans-*Monotoluene*-p-*sulphonate*.—The compound (5 g.) in methanol (20 c.c.) and 2N-aqueous hydrochloric acid (20 c.c.) was heated under reflux for an hour, cooled, neutralised with sodium hydrogen carbonate, and concentrated under a Dufton column. The aqueous residue, saturated with salt, was thoroughly extracted with ether. Removal of solvent from the dried extracts gave *cyclo*hexen-4-ol (0·7 g.), b. p. 67—69°/15 mm., characterised as the α-naphthylurethane, m. p. 132—133°.

Reaction of the trans-*Monotoluene*-p-*sulphonate with Potassium Acetate*.—The derivative (10 g.) and potassium acetate (10 g.) in ethanol (100 c.c.) were refluxed for 15 hours. The mixture then required 31·4 c.c. of N-sodium hydroxide for neutralisation to phenolphthalein, representing an 85% yield of acetic acid. It was saturated with salt, and extracted with ether. The dried (K_2CO_3) extracts were evaporated to an oil, which on distillation gave *cyclo*hexen-4-ol (0·9 g.); 3 : 5-*dinitrobenzoate*, m. p. 101—102° (Found: C, 53·35; H, 4·1. $C_{13}H_{12}O_6N_2$ requires C, 53·4; H, 4·15%). The residue from the distillation was dissolved in pyridine (5 c.c.) and treated with 3 : 5-dinitrobenzoyl chloride, to give cis-cyclo*hexane*-1 : 4-*diol* 3 : 5-*dinitrobenzoate-acetate*, which crystallised from ethanol in needles (0·1 g.), m. p. 153—154° (Found: C, 51·5; H, 4·85. $C_{15}H_{16}O_8N_2$ requires C, 51·15; H, 4·6%).

Reaction of the trans-*Bistoluene*-p-*sulphonate with Potassium Acetate*.—The bistoluene-*p*-sulphonate (5 g.) and potassium acetate (5 g.) in ethanol (100 c.c.) were refluxed for 22 hours. On cooling, potassium toluene-*p*-sulphonate (4·4 g.) separated, and was removed. The filtrate was concentrated, diluted with water, and extracted with chloroform. Removal of solvent from the dried (Na_2SO_4) extracts gave an oil (0·7 g.) which slowly deposited a small quantity of *trans*-diacetate, m. p. and mixed m. p. 101°. The residual oil gave a blue colour with alcoholic sulphuric acid, suggesting the presence of *cyclo*hexenyl acetate (Lindemann and Baumann, *Annalen*, 1930, **477**, 48), and it was therefore dissolved in ethanol, treated with a trace of sodium ethoxide, and left overnight. The *cyclo*hexen-4-ol so obtained was identified as the α-naphthylurethane, m. p. and mixed m. p. 131°.

Reaction of the cis-*Monotoluene*-p-*sulphonate with Lithium Chloride*.—A solution of the monotoluene-*p*-sulphonate (10 g.) and lithium chloride (7·5 g.) in ethanol (100 c.c.) was refluxed for 17 hours, then concentrated and diluted with water (100 c.c.) to give a strongly acid solution, saturated with salt, and extracted with ether. From the extracts there was obtained 4-chloro*cyclo*hexanol (2·5 g.), b. p. 104—106°/10 mm. Its phenylurethane was separated into two forms by fractional crystallisation, the more abundant form, m. p. 133—134° from light petroleum (b. p. 60—80°), probably being the trans-*compound* (Found: C, 61·45; H, 6·25. $C_{13}H_{12}O_6N_2$ requires C, 61·5; H, 6·35%). The other form, present only in small amount, could not be completely purified; it had m. p. 87—96°, and probably corresponds to the single phenylurethane of 4-chloro*cyclo*hexanol of m. p. 99° reported by Senderens and Palfray (*Bull. Soc. chim.*, 1928, **43**, 906).

*Action of Sodium Iodide on the Bistoluene-*p*-sulphonates.*—(*a*) The *trans*-bistoluene-*p*-sulphonate (2 g.), sodium iodide (2·6 g.), and acetone (30 c.c.) were refluxed for 14 hours. After cooling, sodium toluene-*p*-sulphonate (1·4 g.) was removed, and the filtrate evaporated to dryness. The pasty solid was extracted with ether, and the extracts then washed with aqueous sodium thiosulphate, dried, and evaporated to a solid (0·2 g.) which was washed with a few drops of ethanol and purified by sublimation at 80°/10^{-4} mm., to give *trans*-1 : 4-di-iodo*cyclo*hexane, m. p. 142—143°. Repetition of the experiment, with ethanol in place of acetone, gave almost identical results.

(*b*) Treatment of the *cis*-bistoluene-*p*-sulphonate (3 g.) with sodium iodide (4 g.) in boiling acetone (50 c.c.) for 19 hours gave an almost theoretical precipitation of sodium toluene-*p*-sulphonate (2·7 g.). After working up in the same way, ether extraction gave a semi-solid product, which on trituration with ethanol left a residue of the *trans*-di-iodide (0·2 g.), which after sublimation at 60°/10^{-4} mm., had m. p. 143° and was identical with that obtained from the *trans*-bistoluene-*p*-sulphonate. The ethanolic mother liquors from the trituration yielded on treatment with water a further quantity of solid, which on fractional crystallisation from ethanol gave another crop of *trans*-di-iodide, and also 5 mg. of *cis*-di-iodo*cyclo*hexane, m. p. 68—69°.

The above experiment was repeated, the solution being heated for 2 hours at 100°. The products yielded 0·4 g. of mixed di-iodides, consisting largely of the *trans*-compound; a trace of the *cis*-isomer was again obtained by following the procedure outlined above.

Action of Sodium Iodide on the trans-*Monotoluene*-p-*sulphonate.*—The derivative (10 g.) was heated with sodium iodide (8 g.) in dry acetone (60 c.c.) in a sealed tube at 100° for 2 hours. After cooling, sodium toluene-*p*-sulphonate (6·7 g.) was removed, and the filtrate worked up to give a yellow oil (8 g.), $n_D^{15^\circ}$ 1·5268. Distillation of a portion, which occurred with some decomposition, gave 4-*iodo*cyclo*hexanol* as a brown viscous oil, b. p. 70—75°/0·002 mm., $n_D^{18^\circ}$ 1·5848 (Found: I, 56·0. $C_6H_{11}OI$ requires I, 56·1%). Non-crystalline products were obtained in attempts to prepare the phenyl- and α-naphthylurethanes and the 3 : 5-dinitrobenzoate.

Dehydration of cyclo*Hexane*-1 : 4-*diol.*—The *trans*-diol (15 g.) with anhydrous oxalic acid (80 g.) and water (70 c.c.) was steam-distilled for 2·5 hours. The distillate (1000 c.c.) was saturated with salt and extracted 8 times with ether, but the only product obtained was *cyclo*hexen-4-ol (2·3 g.), identified as the α-naphthylurethane, m. p. 132—133°. Repetition, using concentrated sulphuric acid (20 c.c.) in place of the oxalic acid, gave 4·4 g. of *cyclo*hexen-4-ol.

4-*Chloro*cyclo*hexanol.*—A solution of *cyclo*hexane-1 : 4-diol (114 g.; *cis* + *trans*) in fuming hydrochloric acid (250 c.c.; *d* 1·19) was heated in a strong 3 l.-flask, with wired stopper, at 80—90° for 14 hours. Two layers were formed, and, after cooling, the upper one was extracted twice with chloroform, the extracts being added to the lower layer, which was then washed with water and sodium hydrogen carbonate solution, dried, evaporated, and distilled, to give 4-chloro*cyclo*hexanol (75 g.) as a colourless liquid, b. p. 80—85°/5 mm., $n_D^{16^\circ}$ 1·4964.

Dehydrochlorination of 4-*Chloro*cyclo*hexanol.*—(*a*) 4-Chloro*cyclo*hexanol (10 g.) was refluxed with potassium hydroxide (8 g.) in methanol (40 c.c.) for 4 hours. On cooling, potassium chloride (4·4 g.; theory 5·5 g.) separated and was removed. The methanol solution was poured into water and, after being saturated with salt, the whole was extracted 7 times with ether. The combined extracts were dried (K_2CO_3) and evaporated, and the residue distilled to give a series of liquid fractions (5·5 g.), b. p. 120—220°/760 mm., $n_D^{21^\circ}$ 1·468—1·484. Since a complex mixture was evidently present it was not further investigated.

(*b*) 4-Chloro*cyclo*hexanol (40 g.) and solid potassium hydroxide (50 g.) were heated with stirring in a flask immersed in a bath and fitted with a short Vigreux column. When the bath temperature reached 140° a vigorous reaction set in, the internal temperature rose to 160°, and material, b. p. *ca.* 100°, began to distil, the distillate separating into two layers. The bath temperature was slowly raised to 220° during ½ hour, slow distillation continuing. After cooling, the residue was taken up in water and extracted with ether. Evaporation of the ether gave a dark halogen-free oil (7·3 g.) which was not further investigated. The lower layer of the distillate proved to be water, and was rejected. The upper layer (11 g.) was distilled to give a series of fractions, b. p. 80—170°, $n_D^{20^\circ}$ 1·458—1·466, containing much unsaturated material. This evidently complex mixture was not further investigated.

Reaction of trans-cyclo*Hexane*-1 : 4-*diol with Thionyl Chloride.*—The diol (5 g.) in dry pyridine (50 c.c.) and dry chloroform (50 c.c.) was treated at 0° with a solution of thionyl chloride (5 g., 1 mol.) in dry chloroform (50 c.c.), added during 1 hour with stirring. After 18 hours at ordinary temperature, the product, isolated in the usual way, was obtained on evaporation of the chloroform solution as a horny, pale-brown solid (7·2 g.). A similar result was obtained when the reaction was carried out in boiling chloroform in the absence of pyridine. The product, which contained sulphur but no halogen, was very soluble in chloroform, from which it was precipitated in several fractions, with m. p.s varying, in order, from 110° to 180°. The crude material (1 g.) was refluxed with 5% methanolic potassium hydroxide (30 c.c.) for 6 hours. After cooling, potassium sulphite (0·8 g.) was filtered off and identified. The filtrate was evaporated to dryness, and the residue, on extraction with acetone, gave *trans-cyclo*hexane-1 : 4-diol, m. p. and mixed m. p. 140—141°.

Monobenzoates of cyclo*Hexane*-1 : 4-*diol.*—The *trans*-diol (5 g.) in chloroform (50 c.c.) and pyridine (40 c.c.) was treated at 0° with benzoyl chloride (6 g.) in chloroform (50 c.c.) added during 1 hour with stirring. After being left overnight at ordinary temperature, and worked up in the usual way, the washed and dried chloroform solution was evaporated to a solid residue (8·4 g.) which on crystallisation from benzene–light petroleum (b. p. 60—80°) yielded *trans-cyclo*hexane-1 : 4-diol monobenzoate as prisms (7·4 g.), m. p. 87°. A small quantity of *trans*-dibenzoate, m. p. 149—150°, was isolated from the mother liquors. The *cis*-diol (5 g.), similarly treated, gave a viscous oil (8·3 g.) which on distillation gave a main fraction, b. p. 100° (bath temp.)/10^{-5} mm., $n_D^{17^\circ}$ 1·5408, of the cis-*monobenzoate* (Found: C, 70·6; H, 7·15. $C_{13}H_{16}O_3$ requires C, 70·9; H, 7·3%). A higher-boiling fraction, b. p. 150—210°/10^{-5} mm., yielded some *cis*-dibenzoate, m. p. 110—111°, which was also obtained by further benzoylation of a sample of the monobenzoate. Treatment of the *cis*-monobenzoate in pyridine solution with toluene-*p*-sulphonyl chloride gave the *cis*-benzoate-toluene-*p*-sulphonate, m. p. 148—150° from methanol–benzene, identical with that obtained by benzoylation of the *cis*-monotoluene-*p*-sulphonate.

Monoacetates of cyclo*Hexane*-1 : 4-*diol.*—The *trans*-diol (5 g.), treated with acetyl chloride (3·4 g.) under exactly the same conditions as those used for the benzoylation, gave a semi-solid product (5·4 g.) which on crystallisation from light petroleum (b. p. 60—80°) gave the monoacetate (2·7 g.) as long needles, m. p. 72°. The mother liquors yielded a quantity of the *trans*-diacetate (0·96 g.), m. p. 102°, together with some less pure monoacetate. The 3 : 5-dinitrobenzoate of the *trans*-monoacetate crystallised from benzene–light petroleum (b. p. 60—80°) in needles, m. p. 146—147° (Dimroth, *loc. cit.*, gives m. p. 145—146°). Similar treatment of the *cis*-diol (10 g.) with acetyl chloride (6·8 g.) gave a crude *cis*-monoacetate (6·4 g.) which could not be induced to crystallise. With 3 : 5-dinitrobenzoyl chloride in pyridine it gave the 3 : 5-dinitrobenzoate-acetate of the *cis*-diol, m. p. 153—155°, undepressed on admixture with the derivative obtained by the action of potassium acetate on the *trans*-monotoluene-*p*-sulphonate (see above). With toluene-*p*-sulphonyl chloride in pyridine, the *cis*-monoacetate gave the *cis*-toluene-*p*-sulphonate-acetate, m. p. 105—106°, identical with that obtained by acetylation of the *cis*-monotoluene-*p*-sulphonate.

4-*Benzoyloxy*cyclo*hexanone.*—The *trans*-monobenzoate (0·6 g.) in acetic acid (20 c.c.) was treated at ordinary temperature with chromium trioxide (0·2 g.) dissolved in water (1 c.c.) and acetic acid (15 c.c.). After standing overnight, the solution was diluted with ether, washed with sodium hydrogen carbonate solution, dried, and evaporated to a solid. The 4-benzoyloxy*cyclo*hexanone crystallised from light petroleum in plates (0·5 g.), m. p. 62° (Found : C, 73·5; H, 6·2. Calc. for $C_{13}H_{14}O_3$: C, 73·2; H, 6·5%) [Dimroth (*Ber.*, 1942, **75**, 317) gives m. p. 63—64°]. It gave a *semicarbazone*, leaflets, m. p. 195—196°, from light petroleum (b. p. 100—120°) (Found : C, 60·6; H, 6·1. $C_{14}H_{17}O_3N_3$ requires C, 61·1; H, 6·2%), and a 2 : 4-dinitrophenylhydrazone, m. p. 160—161° (Found : N, 14·2. Calc. for $C_{19}H_{18}O_6N_4$: N, 14·1%).

The benzoyloxy-ketone was also obtained, and identified as the 2 : 4-dinitrophenylhydrazone, by similar oxidation of the *cis*-monobenzoate of *cyclo*hexane-1 : 4-diol.

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