79. *Alicyclic Glycols. Part VIII.** 1 : 2-*Bishydroxymethyl*cyclo*hexane.*

By G. A. Haggis and L. N. Owen.

Reduction of *cis*- or *trans*-hexahydrophthalic ester with lithium aluminium hydride occurs without epimerisation, and gives, respectively, *cis*- or *trans*-1 : 2-bishydroxymethyl*cyclo*hexane (I); the *trans*-isomer has been resolved through the bis-(–)-menthylurethane. Cyclodehydration to octahydro*iso*benzofuran (II) occurs very readily when the diol is treated under mild conditions with dehydrating agents; (II) is also obtained by hydrolysis of the dimethanesulphonates with aqueous alkali, and is formed as a by-product in the preparation of the disulphonyl esters from the diol, and in certain other reactions. From the diol of appropriate configuration, (II) has been prepared in *cis*- (II*a*), *trans*- (II*b*), and (+)-*trans*-forms. Fission of the tetrahydrofuran ring in (II*a* and *b*) has been effected with hydrogen bromide, acetyl chloride, acetyl bromide, *p*-nitrobenzoyl bromide, and toluene-*p*-sulphonyl chloride, and the structures of the products have been established.

The regeneration of some alcohols by reductive fission of their urethanes with lithium aluminium hydride is reported.

1 : 2-BISHYDROXYMETHYL*cyclo*HEXANE (I) was first prepared, in poor yield and accompanied by the intramolecular ether, octahydro*iso*benzofuran (II), by reduction of diethyl hexahydrophthalate with sodium and alcohol (Wieland, Schlichtling, and Langsdorff, Z. *physiol. Chem.*, 1926, **161**, 74). It was later obtained as a minor product from the hydrogenation of the hexahydro-ester over a chromite catalyst at 385° (U.S.P. 2,105,664), the main reaction then being hydrogenolysis to 2-methyl*cyclo*hexylmethanol. In our hands, Bouveault–Blanc reduction of dimethyl hexahydrophthalate has given the diol in 68% yield, with only a small amount of cyclic oxide, and as Wieland *et al.* recovered much hexahydrophthalic acid in their experiments it is probable that their low yield of diol was due to use of imperfectly dried alcohol. By precipitation with light petroleum and recrystallisation from benzene, they obtained a solid, m. p. 57°, but its configuration was not established.

Although in the present work only 14% of the diol was obtained in this solid form, it was shown by preparation of derivatives that the non-crystallisable portion also consisted mainly of this isomer. The hexahydro-ester used in the reduction had been prepared by hydrogenation of dimethyl phthalate, and was probably largely the *cis*-form (cf. Price and Schwarcz, *J. Amer. Chem. Soc.*, 1940, **62**, 2891), but it does not follow that the composition of the resulting diol would be similar because under the Bouveault–Blanc conditions it is likely that a considerable proportion of the *cis*- would isomerise to *trans*-ester before reduction occurred. Noyce and Denney (*ibid.*, 1950, **72**, 5743) found that reduction of (+)-α-methylbutyric acid with lithium aluminium hydride gave (–)-2-methylbutanol with complete retention of configuration; with sodium and alcohol such a reaction would certainly have resulted in partial or complete racemisation, and the newer method, if of general application, will provide a valuable means of correlating the configuration of alcohols with the corresponding acids in cases where the α-carbon atom is involved in the stereoisomerism. Accordingly, we studied the reduction by lithium aluminium hydride of dimethyl *trans*-hexahydrophthalate. The product, obtained in excellent yield, crystallised completely and was identical with the solid, m. p. 57°, which consequently must be the *trans*-diol. Similar reduction of *cis*-hexahydrophthalic anhydride and of *cis*-diethyl hexahydrophthalate gave a stereochemically pure diol, m. p. 42—43°, which must be the *cis*-isomer. The stereo-specificity of the method is therefore established. Independent confirmation was provided by resolution of the *trans*-diol and isolation of the (+)-form, m. p. 61—62°, $[\alpha]_D^{24}$ +21°.

Reaction of the *trans*-diol with (–)-menthoxyacetyl chloride gave an oily menthoxy-

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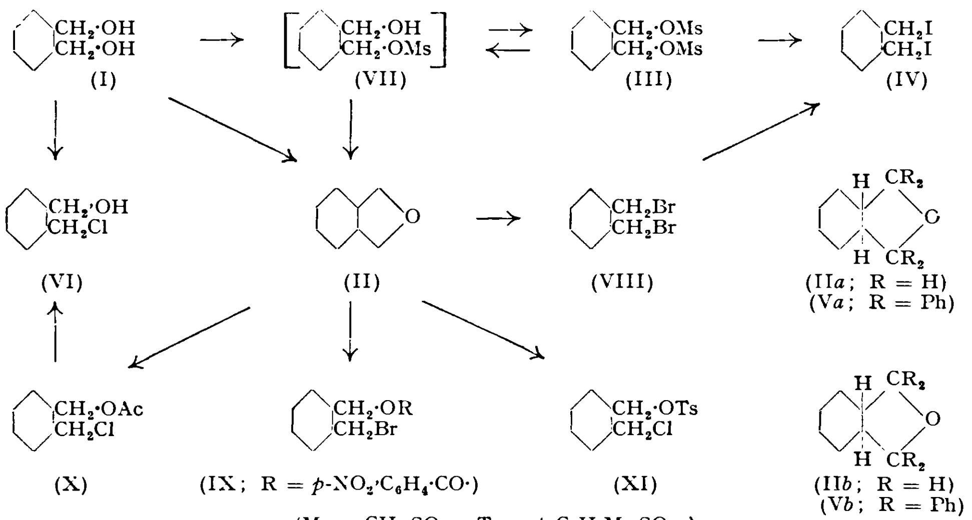
* Part VII, Owen and Smith, *J.*, 1952, 4035.

acetate. Preparation of the acid sulphate was not attempted since the diol was readily dehydrated by cold sulphuric acid. The di(acid phthalate) was prepared as a solid but no crystalline alkaloid salts could be obtained. The resolution was finally accomplished by use of (—)-menthyl *iso*cyanate. This comparatively inaccessible resolving agent was prepared first by Neville and Pickard (*J.*, 1904, **85**, 688) by dehydration of ethyl (—)-menthylcarbamate, and later (Vallée, *Ann. Chim.*, 1908, **15**, 410; Tschugaeff and Glebko, *Ber.*, 1913, **46**, 2759) by reaction of (—)-menthylamine hydrochloride with carbonyl chloride in toluene at 140—150°; a modification of the latter method was used in the present work.

The diols were characterised by preparation of several derivatives. The yields of ditoluene-*p*-sulphonates and dimethanesulphonates (III) were not as good as expected; this was traced to the simultaneous formation of the cyclic oxide (see p. 391).

The *cis*- and *trans*-dimethanesulphonates and ditoluene-*p*-sulphonates reacted with sodium iodide in boiling acetone to give the *cis*- and the *trans*-1 : 2-bisiodomethyl*cyclo*hexane (IV); the *trans*-isomers reacted more rapidly than the *cis*-, the difference being more marked with the toluene-*p*-sulphonates and clearly being due to variation in the degree of steric hindrance.



(Ms = $CH_3{\cdot}SO_2{\cdot}$; Ts = p-$C_6H_4Me{\cdot}SO_2{\cdot}$.)

Examination of scale models shows that both the *cis*- and the *trans*-diol can take up strainless conformations in which the two hydroxyl groups are near to one another, and Dr. L. P. Kuhn, who kindly determined the infra-red spectra of the two isomers (*J. Amer. Chem. Soc.*, 1952, **74**, 2492), reported that both showed strong intramolecular hydrogen bonding in solution. Wittig and Waltnitzki (*Ber.*, 1934, **67**, 667) had already shown that the *cis*- and the *trans*-tetraphenyl-substituted diols, which they prepared by reaction of diethyl *cis*- and *trans*-hexahydrophthalates with phenyl-lithium, gave on dehydration the *cis*-(V*a*) and the *trans*-(V*b*) tetraphenyl-substituted octahydro*iso*benzofuran. It was to be expected, therefore, that octahydro*iso*benzofuran would also exist in two stereoisomeric forms (II*a*) and (II*b*).

Preliminary experiments, carried out with the mixture of *cis*- and *trans*-1 : 2-bishydroxymethyl*cyclo*hexane obtained by Bouveault–Blanc reduction, showed that dehydration to the cyclic oxide occurred under mild conditions, such as treatment with sulphuric acid in cold acetone or boiling under reflux with methanolic hydrogen chloride. Octahydro*iso*benzofuran was also obtained, accompanied by unsaturated material, by dehydration over alumina at 200—250°.

Other than direct dehydration, the most usual method for preparation of intramolecular ethers involves interaction of a monohalide or monosulphonyl ester with alkali.

Attempted preparation of the monochloride (VI) by reaction of the *trans*-diol with fuming hydrochloric acid gave a mixture of the required compound and the oxide. The monochloride decomposed slightly on distillation under reduced pressure, and rapidly at 200°, with evolution of hydrogen chloride and formation of the oxide. 4-Chlorobutanol is similarly unstable to distillation (Bennett and Heathcoat, *J.*, 1929, 268). Attempts to prepare the monotoluene-*p*-sulphonate by slow reaction of a dilute solution of the *trans*-diol in pyridine with 1 mol. of the acid chloride were unsuccessful, some ditoluene-*p*-sulphonate and cyclic oxide being formed. Reaction of the *trans*-monochloride with a suspension of silver toluene-*p*-sulphonate in benzene gave the oxide as the only identifiable product.

Since a pure monotoluene-*p*-sulphonate could not be obtained, the hydrolysis of the disulphonates was studied. Reaction of a primary sulphonate group with alkali normally leads to hydrolysis (in aqueous solution) or to solvolysis (in alcoholic solution); aqueous hydrolysis of a disulphonate of the type (III) should therefore give a monosulphonate (VII) as an intermediate, which under the alkaline conditions would be expected to form (II). The *trans*-ditoluene-*p*-sulphonate was unaffected by boiling aqueous potassium hydroxide, probably because of its insolubility, and with the methanolic reagent it gave mainly the dimethyl ether of the *trans*-diol. Similar resistance to hydrolysis by aqueous alkali has been noted by Newth and Wiggins (*J.*, 1948, 155) for the ditoluene-*p*-sulphonate of 2 : 5-bishydroxymethyltetrahydrofuran. Dimethanesulphonates, however, are usually rather more soluble in aqueous solution, and would be expected to be more reactive. This was found to be so, and the *cis*-derivative (III) when boiled for 3 hours with aqueous potassium hydroxide gave *cis*-octahydro*iso*benzofuran in 60% yield. Similar treatment of *trans*-(III) gave *trans*-octahydrobenzofuran, and from the (—)-*trans*-dimethanesulphonate there was obtained (+)-*trans*-octahydro*iso*benzofuran, $[\alpha]_D^{22}$ +110°.

The low yields obtained in the preparation of the sulphonyl esters were explained when it was found that from a large-scale preparation the oxide could be isolated as a by-product. With the *trans*-diol, 10% was recovered as oxide after toluene-*p*-sulphonation; methanesulphonation of the *cis*-diol gave 31% of the *cis*-oxide and only 32·5% of the dimethanesulphonate. It is clear that in these reactions the intermediate monosulphonate (*e.g.*, VII) reacts in two ways, either with more acid chloride to give the disulphonate (III), or with loss of sulphonic acid under the influence of pyridine to give the oxide (II), and this was supported by the observation that if the acid chloride was added in one portion to a solution of the diol in pyridine, or if the diol was added slowly to the acid chloride in pyridine (rather than the usual procedure of gradual addition of the acid chloride to the diol in pyridine) the yield of dimethanesulphonate was increased as a consequence of the higher initial concentration of acid chloride. The instability of the intermediate monoester in the presence of pyridine accounts for the lack of success in the attempted preparation of the monotoluene-*p*-sulphonate.

The formation of the cyclic oxide in this reaction is formally analogous to the conversion of a 1 : 4- or 1 : 5-diol into the corresponding tetrahydro-furan or -pyran by treatment with 1 mol. of a sulphonyl chloride in boiling pyridine or 2 : 6-lutidine (Reynolds and Kenyon, *J. Amer. Chem. Soc.*, 1950, **72**, 1593), which probably proceeds through the intermediate monosulphonate. There have been no previous reports, however, of such a cyclisation occurring at low temperatures, and we therefore studied the methanesulphonation of butane-1 : 4-diol (from which, with benzenesulphonyl chloride and boiling pyridine, Reynolds and Kenyon had obtained 35% of tetrahydrofuran) under the same conditions as were used for the alicyclic diol. The dimethanesulphonate was obtained in excellent yield, and no tetrahydrofuran could be detected; it follows that cyclisation under mild conditions is not general, and probably occurs with 1 : 2-bishydroxymethyl*cyclo*hexane because of the favourable disposition of the hydroxyl groups. Reaction of the dimethanesulphonate of butane-1 : 4-diol with boiling aqueous alkali gave tetrahydrofuran in 58% yield.

Octahydro*iso*benzofuran was soluble in concentrated sulphuric acid, and was recovered unchanged on dilution with water. Although stable to neutral potassium permanganate it was rapidly oxidised in the cold by the alkaline reagent, or on heating with the acid reagent. The *trans*-isomer gave an insoluble complex with hydroferricyanic acid, similar to that formed by 1 : 8-cineole (Baeyer and Villiger, *Ber.*, 1901, **34**, 2690); the oxide was regenerated by treatment with sodium hydrogen carbonate solution. The boiling point and refractive index of the *cis*-oxide were slightly higher than those of the *trans*-isomer, but the two forms were best differentiated by conversion into crystalline derivatives by fission of the heterocyclic ring by use of some of the reagents known to be effective with tetrahydrofuran systems (cf. Owen, *Ann. Reports*, 1945, **42**, 171; Jones and Taylor, *Quart. Reviews*, 1950, **4**, 195; Clarke and Owen, *J.*, 1950, 2109). Reaction with acetic anhydride and zinc chloride gave only a poor yield of an impure diacetate, with much polymeric material. Reaction of the *trans*-oxide with hydrogen bromide at 90° gave the *trans*-dibromide (VIII) in good yield; this was converted into the *trans*-di-iodide (IV) by reaction with sodium iodide in acetone, and into the *trans*-diol by reaction with potassium acetate and silver acetate, followed by deacetylation. Ring-fission had therefore occurred normally, without affecting the configuration. Similarly, reaction of the *cis*- and the *trans*-oxide with *p*-nitrobenzoyl bromide (conveniently prepared by treatment of the readily available chloride with hydrogen bromide), in the presence of zinc chloride, gave the *cis*- and the *trans*-2-bromomethyl*cyclo*hexylmethyl *p*-nitrobenzoate (IX); although these had almost identical melting points, 79° and 81° respectively, the mixed m. p. showed a large depression, and there is no doubt that each was a stereoisomeric individual.

The *trans*-oxide reacted rapidly with acetyl chloride, without a catalyst, to give *trans*-2-chloromethyl*cyclo*hexylmethyl acetate (X), which on deacetylation gave the *trans*-monochloride (VI). With acetyl bromide, the *cis*- and the *trans*-oxide similarly gave the corresponding 2-bromomethyl*cyclo*hexylmethyl acetates, which on deacetylation and *p*-nitrobenzoylation gave products (IX) identical with those from the direct reaction of the oxides with *p*-nitrobenzoyl bromide. *trans*-2-Bromomethyl*cyclo*hexylmethyl acetate reacted slowly with sodium iodide in boiling acetone, but the iodo-compound could not be obtained pure, though on deacetylation and *p*-nitrobenzoylation it gave crystalline *trans*-2-iodomethyl*cyclo*hexylmethyl *p*-nitrobenzoate. Reaction of the *trans*-oxide with toluene-*p*-sulphonyl chloride, catalysed by zinc chloride, furnished a product which was mainly 2-chloromethyl*cyclo*hexylmethyl toluene-*p*-sulphonate (XI).

Entel, Ruof, and Howard (*J. Amer. Chem. Soc.*, 1952, **74**, 441) obtained octahydro*iso*benzofuran, probably as a mixture of *cis*- and *trans*-forms, by hydrogenation of phthalan, but did not describe its reactions.

In connection with the resolution of the *trans*-diol, incidental experiments were carried out on the regeneration of alcohols from their urethanes. It was found that methyl phenylcarbamate was smoothly and rapidly reduced by lithium aluminium hydride in boiling ether to *N*-methylaniline (no attempt was made to isolate the regenerated methanol). The bis-(—)-menthylurethane of the *trans*-diol similarly gave the *trans*-diol and *N*-(—)-menthylmethylamine. The (—)-menthylurethane of (—)-menthol was more resistant, and only a small yield of (—)-menthol was obtained, most of the derivative being recovered unchanged (a higher-boiling solvent might have been advantageous). Read and Roebuck (*J.*, 1952, 812) failed to hydrolyse this compound with boiling alcoholic potassium hydroxide, although the corresponding phenylurethane was readily attacked. Salmon and Powell (*J. Amer. Chem. Soc.*, 1939, **61**, 3507) reported the regeneration of 5 : 6-dimethyl 1 : 2-*iso*propylidene glucose from its phenylurethane by reaction with boiling methanolic sodium methoxide, but the bis-(—)-menthylurethane of our *trans*-diol was unaffected by this treatment, although fission was smoothly effected with alcoholic potassium hydroxide.

EXPERIMENTAL

p-*Nitrobenzoyl Bromide.*—A stream of dry hydrogen bromide was passed through molten *p*-nitrobenzoyl chloride at 100°. After 4 hours the evolved gas contained no hydrogen chloride; the product crystallised from carbon tetrachloride as yellow needles, m. p. 64°. Adams and Ulich (*J. Amer. Chem. Soc.*, 1920, **42**, 599) recorded m. p. 63—64°.

(—)-*Menthyl* iso*Cyanate.*—Carbonyl chloride was passed through a suspension of (—)-menthylamine hydrochloride (65 g.) in boiling xylene (400 c.c.) until no more hydrogen chloride was evolved (*ca.* 3 hours). Removal of xylene and distillation of the residue gave (—)-menthyl *iso*cyanate (58 g.) as a colourless oil, b. p. 77—80°/1 mm., n_D^{22} 1·4605, $[\alpha]_D^{22}$ −64·2° (*c*, 5 in benzene). Vallée (*loc. cit.*) recorded $[\alpha]_D$ −61·89°.

Dimethyl Hexahydrophthalate.—Dimethyl phthalate (200 g.), in methanol (300 c.c.), was hydrogenated at 50—60°/100 atm. over Raney nickel (25 g.) until uptake was complete (*ca.* 24 hours). After filtration and removal of solvent, the ester was distilled (196 g.), b. p. 104—109°/2 mm., n_D^{20} 1·4590. The *trans*-dimethyl ester was prepared from this *cis–trans*-mixture by treatment with methanolic sodium methoxide (cf. Price and Schwarcz, *loc. cit.*). *cis*-Hexahydrophthalic anhydride and *cis*-diethyl hexahydrophthalate were prepared by the method of Price and Schwarcz (*loc. cit.*).

1 : 2-*Bishydroxymethyl*cyclo*hexane.*—(i) Dimethyl hexahydrophthalate (150 g.), in dry ethanol (3 l.), was reduced at reflux temperature with sodium (300 g.) added in portions. When the reaction had moderated, the temperature was kept at 160° (bath) until all the sodium had dissolved. Water (500 c.c.) was then added, and most of the alkali neutralised with 20% sulphuric acid (*ca.* 1200 c.c.). The solution was then cooled and filtered from sodium sulphate, and alcohol removed by distillation. The diol was isolated by continuous extraction of the residual aqueous solution with ether. The ethereal solution was dried (K_2CO_3) and evaporated, and the residue distilled to give 1 : 2-bishydroxymethyl*cyclo*hexane (73·5 g., 68%) as a colourless, viscous oil, b. p. 110—130°/0·3 mm., n_D^{20} 1·4914. A small quantity of a water-insoluble oil was obtained from the liquid-air trap after distillation. This was dried (K_2CO_3) and distilled to give octahydro*iso*benzofuran (0·3 g.), b. p. 69—70°/15 mm., n_D^{19} 1·4678. Fractional distillation of the alcoholic distillate did not yield any more of this material.

The diol (73 g.) was dissolved in benzene (50 c.c.) and stored at 0°; *trans*-1 : 2-bishydroxymethyl*cyclo*hexane, which was slowly deposited, recrystallised from benzene–light petroleum (b. p. 60—80°) as small plates (10 g.), m. p. 57°. Wieland *et al.* (*loc. cit.*) gave m. p. 57°. The mother-liquors on evaporation gave a viscous oil, which was shown to be principally the *trans*-isomer by preparation of the ditoluene-*p*-sulphonate (see below).

(ii) *trans*-Dimethyl hexahydrophthalate (20 g.) in dry ether (40 c.c.) was added slowly to a cooled, stirred solution of lithium aluminium hydride (4·5 g.) in dry ether (200 c.c.). After 1 hour, dilute sulphuric acid was added until all solid had dissolved, and the aqueous layer was separated and continuously extracted with ether. The combined ethereal solutions were dried (K_2CO_3) and evaporated to a yellow oil (13·5 g., 94%) which soon solidified and had m. p. 53—54°. One crystallisation from benzene–light petroleum (b. p. 60—80°) gave the pure *trans*-diol, m. p. and mixed m. p. 57°.

(iii) Similar reduction of *cis*-diethyl hexahydrophthalate (52 g.) in ether (100 c.c.) with lithium aluminium hydride (11 g.) in ether (500 c.c.) gave a yellow oil (30·9 g., 94%) which solidified and had m. p. 37—41°. Recrystallisation from benzene-light petroleum (b. p. 60—80°) gave cis-1 : 2-*bishydroxymethyl*cyclo*hexane*, m. p. 42—43° (Found : C, 66·6; H, 11·2. $C_8H_{16}O_2$ requires C, 66·6; H, 11·2%); on admixture with the *trans*-diol, it liquefied.

(iv) Similar reduction of *cis*-hexahydrophthalic anhydride (31 g.) with lithium aluminium hydride (8 g.) in ether gave the *cis*-diol (18·3 g., 63%), m. p. and mixed m. p. 41—42°.

Derivatives of the cis-*Diol.*—The *cis*-diol (2·3 g.) and toluene-*p*-sulphonyl chloride (6·7 g.) in pyridine (30 c.c.) at 0° (overnight) gave the cis-*ditoluene*-p-*sulphonate* (3·9 g., 54%), needles (from methanol), m. p. 84—85° (Found : C, 58·2; H, 6·3; S, 14·3. $C_{22}H_{28}O_6S_2$ requires C, 58·4; H, 6·2; S, 14·2%). A similar procedure was used for the cis-*dimethanesulphonate*, needles (57%) (from methanol), m. p. 75—76° (Found : C, 40·2; H, 6·9; S, 21·0. $C_{10}H_{20}O_6S_2$ requires C, 40·0; H, 6·7; S, 21·35%), and for the cis-*di*-p-*nitrobenzoate*, a pale yellow powder (90%) (from acetone–ethanol), m. p. 142° (Found : C, 59·7; H, 5·1; N, 6·4. $C_{22}H_{22}O_8N_2$ requires C, 59·7; H, 5·0; N, 6·3%).

The *cis*-diol (0·5 g.) and phenyl *iso*cyanate (1 g.) at 100° (1 hour) gave the cis-*bisphenylurethane* (1·15 g., 87%) [from benzene–light petroleum (b. p. 60—80°)], m. p. 102° (Found : C, 69·3; H, 6·8; N, 7·5. $C_{22}H_{26}O_4N_2$ requires C, 69·1; H, 6·8; N, 7·3%).

Derivatives of the trans-*Diol.*—By the methods used for the *cis*-derivatives, there were prepared the trans-*ditoluene*-p-*sulphonate* (48%), stout needles (from methanol), m. p. 108° (Found : C, 58·9; H, 6·5; S, 13·9. $C_{22}H_{28}O_6S_2$ requires C, 58·4; H, 6·2; S, 14·2%), the trans-*dimethanesulphonate* (84%), fluffy needles (from methanol), m. p. 92° (Found : C, 40·3; H, 6·9; S, 21·55. $C_{10}H_{20}O_6S_2$ requires C, 40·0; H, 6·7; S, 21·35%), and the trans-*di*-p-*nitrobenzoate* (95%), a yellow powder (from acetone–ethanol), m. p. 168° (Found : C, 60·5; H, 5·2; N, 6·5. $C_{22}H_{22}O_8N_2$ requires C, 59·7; H, 5·0; N, 6·3%) (two further crystallisations from dioxan had no effect on the m. p. or analyses).

When the *trans*-diol (0·5 g.) and phenyl *iso*cyanate (1 g.) were warmed together for a few minutes, then stored at room temperature for an hour, a solid was obtained which when crystallised from benzene–light petroleum (b. p. 60—80°) gave the trans-*monophenylurethane* (0·85 g., 93%), m. p. 145° (Found : C, 68·5; H, 8·05; N, 5·5. $C_{15}H_{21}O_3N$ requires C, 68·4; H, 8·0; N, 5·3%). Reaction of the same quantities for 3 hours at 100°, however, gave, by similar recrystallisation, the trans-*bisphenylurethane* (1·1 g., 85%), m. p. 139°, depressed to 124° on admixture with the monourethane (Found : C, 69·1; H, 6·95; N, 7·3. $C_{22}H_{26}O_4N_2$ requires C, 69·1; H, 6·85; N, 7·3%).

The *trans*-diol (1·33 g.) was heated at 100° with phthalic anhydride (2·7 g.) in pyridine (5 c.c.) for 1 hour. The cooled solution was treated with excess of dilute sulphuric acid, and the precipitated gum was dissolved in chloroform, extracted with sodium carbonate solution, and reprecipitated with acid. It was again dissolved in chloroform, dried (Na_2SO_4), recovered by evaporation, and dissolved in acetone. Addition of light petroleum (b. p. 40—60°) and cooling to 0° gave the *di*(*hydrogen phthalate*) (2·65 g.), m. p. 168—173°, raised to 173—175° by recrystallisation from the same solvent (Found : C, 65·9; H, 5·8. $C_{24}H_{24}O_8$ requires C, 65·5; H, 5·5%). Attempts to form solid salts with strychnine, quinine, and cinchonidine failed.

Derivatives from the Stereoisomeric Mixture of Diols (*mainly* trans).—(i) The diol (1 g.) and acetic anhydride (2·5 g.) were boiled under reflux for 2 hours. The solution was diluted with water, and the ester extracted with chloroform, washed with sodium hydrogen carbonate and water, and dried (Na_2SO_4). Removal of solvent, followed by distillation, gave 1 : 2-*bisacetoxymethyl*cyclo*hexane* as a colourless oil (1·2 g.), b. p. 85—86°/0·2 mm., n_D^{20} 1·4591 (Found : C, 63·05; H, 8·95. $C_{12}H_{20}O_4$ requires C, 63·15; H, 8·8%).

(ii) The diol (1 g.) in pyridine (10 c.c.) was treated at 0° with benzoyl chloride (2·5 g.). After 1 hour at 0°, working up as in (i) (with an acid wash) gave 1 : 2-*bisbenzoyloxymethyl*cyclo*hexane* as a viscous oil (1·5 g.), b. p. 210—215° (bath)/7 × 10^{-5} mm. (Found : C, 74·5; H, 6·6. $C_{22}H_{24}O_4$ requires C, 75·0; H, 6·35%).

(iii) The diol (10 g.) in pyridine (30 c.c.) was cooled to 0° and a solution of toluene-*p*-sulphonyl chloride (30 g.) in pyridine (50 c.c.) was added slowly to the stirred solution. After 2 hours water was added to precipitate the toluene-*p*-sulphonate (15 g.). By fractional crystallisation from acetone–methanol this was separated into the *trans*-compound, m. p. 108° (9·5 g.), and the material, m. p. 87—88° (1·7 g.) undepressed on admixture with the *cis*-isomer, m. p. 84—85°, recorded above. The aqueous filtrate from the toluene-*p*-sulphonation was extracted with chloroform, and the extract washed with dilute sulphuric acid and aqueous sodium hydrogen carbonate, and dried (Na_2SO_4). After removal of chloroform, distillation gave octahydro*iso*benzofuran (0·95 g.), b. p. 68°/15 mm., n_D^{15} 1·4705.

Similarly, reaction of the diol (10 g.) in pyridine (50 c.c.) with methanesulphonyl chloride (18 g.) in pyridine (25 c.c.) gave a methanesulphonate (20 g.) which on fractional crystallisation gave the *trans*-compound (13 g.), m. p. 92°, and impure *cis*-isomer, m. p. 72—73° (0·3 g.).

Resolution of trans-1 : 2-*Bishydroxymethyl*cyclo*hexane*.—The *trans*-diol (19 g.) and (−)-menthyl *iso*cyanate (50 g.) in benzene (50 c.c.) were heated at 100° overnight. Benzene was removed under reduced pressure, and the semi-solid residue was dissolved in light petroleum (b. p. 60—80°) containing a little benzene. On cooling, a powdery solid separated (51 g.), having m. p. 110—120°, $[\alpha]_D^{22}$ −57·9° (*c*, 2 in C_6H_6). Fractional crystallisation from light petroleum (b. p. 60—80°), containing a little benzene, and finally from methanol, gave the *bis*-(−)-*menthylurethane* (9·6 g.), m. p. 150—151°, $[\alpha]_D^{20}$ −66·2° (*c*, 2 in C_6H_6) (Found : C, 71·5; H, 10·85; N, 5·8. $C_{30}H_{54}O_4N_2$ requires C, 71·1; H, 10·75; N, 5·5%).

The urethane (9·5 g.) in ethanol (100 c.c.) containing potassium hydroxide (6 g.) was heated under reflux overnight. Ethanol and (−)-menthylamine were removed by steam-distillation, and the diol was isolated by continuous extraction of the residue with ether. Evaporation of the dried extracts, followed by distillation, gave the (+)-trans-*diol* (2·2 g.), b. p. 110—113°/0·2 mm., which rapidly solidified, m. p. 61—62°, unchanged on crystallisation from benzene–light petroleum (b. p. 60—80°), from which it formed needles, $[\alpha]_D^{24}$ +21·4° (*c*, 4 in C_6H_6) (Found : C, 66·6; H, 11·2. $C_8H_{16}O_2$ requires C, 66·6; H, 11·2%).

The following derivatives were prepared by methods previously described : *dimethanesulphonate*, m. p. 80—90°, unchanged by recrystallisation, $[\alpha]_D^{24\cdot5}$ −29·2° (*c*, 4 in C_6H_6) (Found : C, 40·0; H, 6·9; S, 21·1. $C_{10}H_{20}O_6S_2$ requires C, 40·0; H, 6·7; S, 21·35%); *ditoluene*-p-*sulphonate*, m. p. 109—110°, $[\alpha]_D^{21\cdot5}$ −24·8° (*c*, 5 in C_6H_6) (Found : C, 58·4; H, 6·4; S, 13·8. $C_{22}H_{28}O_6S_2$ requires C, 58·4; H, 6·2; S, 14·2%); *bisphenylurethane*, m. p. 132—133°, $[\alpha]_D^{22}$ −20·4° (*c*, 3 in $CHCl_3$) (Found : C, 69·5; H, 7·0; N, 7·55. $C_{22}H_{26}O_4N_2$ requires C, 69·1; H, 6·85; N, 7·3%).

cis-1 : 2-*Bisiodomethyl*cyclo*hexane*.—(i) The *cis*-ditoluene-*p*-sulphonate (5·2 g.) was boiled under reflux for 16 hours in acetone (80 c.c.) containing sodium iodide (7·5 g.). Sodium toluene-*p*-sulphonate (3·45 g., 78%) was filtered off, and the solvent removed under reduced pressure. Addition of water to the residue precipitated a heavy oil, which was dissolved in chloroform and washed with sodium thiosulphate solution and with water. Evaporation of the dried (Na_2SO_4) extract and distillation of the residual oil gave cis-1 : 2-*bisiodomethyl*cyclo*hexane* (2·6 g., 62%) as a pale yellow liquid, b. p. 100° (bath)/0·002 mm., n_{D}^{17} 1·6151 (Found : C, 26·7; H, 3·9; I, 69·1. $C_8H_{14}I_2$ requires C, 26·4; H, 3·9; I, 69·7%).

(ii) The *cis*-dimethanesulphonate (13·7 g.) in boiling acetone (200 c.c.), containing sodium iodide (19 g.), after 5 hours gave sodium methanesulphonate (9·9 g.) and the *cis*-di-iodide (8·9 g., 54%), b. p. 80° (bath)/10^{-4} mm., n_{D}^{20} 1·6096.

trans-1 : 2-*Bisiodomethyl*cyclo*hexane*.—(i) The *trans*-ditoluene-*p*-sulphonate (25 g.), in boiling acetone (400 c.c.), containing sodium iodide (35 g.), after 2·5 hours gave sodium toluene-*p*-sulphonate (21 g., 100%). The crude trans-1 : 2-*bisiodomethyl*cyclo*hexane* obtained by dilution of the filtrate with water solidified at 0° and crystallised from methanol as needles (14·1 g., 70%), m. p. 39—40° (Found : C, 26·7; H, 3·9; I, 69·6. $C_8H_{14}I_2$ requires C, 26·4; H, 3·9; I, 69·7%).

(ii) The *trans*-dimethanesulphonate (5 g.) in acetone (80 c.c.) containing sodium iodide (7 g.) similarly gave the *trans*-di-iodide (3·05 g., 50%), m. p. and mixed m. p. 39—40°.

Reaction of the trans-*Ditoluene*-p-*sulphonate with Methanolic Potassium Hydroxide*.—The ester (10 g.) was heated under reflux with potassium hydroxide (5 g.) in methanol (100 c.c.) for 3 hours. Potassium toluene-*p*-sulphonate (9·2 g., 99%) was filtered off, and methanol removed by distillation. Water and ether were added, and the ethereal layer was separated, dried (Na_2SO_4), and evaporated; distillation then gave a product (1·87 g.), b. p. 78—93°/12 mm., n_{D}^{18} 1·4560—1·4505, from which trans-1 : 2-*bismethoxymethyl*cyclo*hexane* was obtained by repeated fractionation, as an oil, b. p. 92—94°/12 mm., n_{D}^{18} 1·4495 (Found : C, 69·9; H, 11·8. $C_{10}H_{20}O_2$ requires C, 69·7; H, 11·7%).

*Octahydro*iso*benzofuran* (cis + trans).—(i) The liquid diol (10 g.) (mainly *trans*) was dissolved in dry acetone (150 c.c.) containing sulphuric acid (1 c.c.). Anhydrous sodium sulphate was added, and the solution left at room temperature for 48 hours. Acid was neutralised with solid sodium hydrogen carbonate, and, after filtration and removal of acetone, distillation gave octahydro*iso*benzofuran (2·7 g., 31%) as a mobile oil, insoluble in water, and having a terpene-like odour, b. p. 56—57°/7 mm., b. p. 175°/760 mm., n_{D}^{20} 1·4680. [Wieland *et al.* (*loc. cit.*) gave b. p. 170—175°; Entel, Ruof, and Howard (*loc. cit.*) b. p. 179°/740 mm., n_{D}^{25} 1·4683.] A similar experiment using ether as solvent instead of acetone gave a much lower yield of oxide. Dehydration of the pure *trans*-diol with acetone and sulphuric acid gave the *trans*-form, b. p. 65—70°/15 mm., n_{D}^{26} 1·4655.

(ii) A solution of the liquid diol (5 g.) in methanol (50 c.c.) containing 1% of hydrogen chloride was refluxed for 24 hours and then neutralised by sodium hydrogen carbonate solution. The product was extracted with ether, and on distillation gave the oxide (0·85 g., 19%), b. p. 66—70°/12 mm., n_{D}^{20} 1·4685, and unchanged diol (0·35 g.).

(iii) A mixture of the liquid diol (50 g.) with activated alumina (12 g.) was heated (oil-bath) in a distillation flask. Distillation began at 200° (internal temp.), and the temperature was gradually raised to 250°. The distillate separated into two layers, the upper of which was dried (K_2CO_3) and distilled, the fraction (35 g.) of b. p. 65—90°/15 mm., n_{D}^{20} 1·4850, being collected. The residue was viscous and probably contained some unchanged diol. The distillate, which was unsaturated, was stirred with saturated magnesium sulphate solution (250 c.c.), and 2% aqueous potassium permanganate was added slowly until a filtered portion remained pink for 10 minutes. The product was isolated from the filtered solution by steam-distillation, and was dried (K_2CO_3) and distilled to give the oxide (22 g., 50%), b. p. 65—66°/9 mm., n_{D}^{20} 1·4680. Repetition of the experiment on a small scale with the pure *trans*-diol gave similar results.

cis-*Octahydro*iso*benzofuran*.—(i) The *cis*-diol (25 g.) in pyridine (200 c.c.) was cooled to 0° and a solution of methanesulphonyl chloride (44 g.) in pyridine (100 c.c.) was added slowly with stirring. After 2 hours water was added, and the *cis*-dimethanesulphonate was collected and recrystallised from methanol (yield 17 g., 32·5%). The aqueous filtrate was extracted with chloroform, and the chloroform solution was washed with dilute sulphuric acid and sodium hydrogen carbonate, and dried (Na_2SO_4). Removal of chloroform and distillation of the residual oil gave cis-*octahydro*iso*benzofuran* (6·75 g.), b. p. 59°/9 mm., 174—175°/751 mm., n_{D}^{21} 1·4712 (Found : C, 76·1; H, 11·2. $C_8H_{14}O$ requires C, 76·1; H, 11·2%). A comparative experiment, in which the pyridine solutions were cooled in a freezing mixture, and the acid chloride added all at once, gave a 61% yield of the dimethanesulphonate.

(ii) The *cis*-dimethanesulphonate (55 g.) was boiled under reflux for 3 hours with 15% aqueous potassium hydroxide (300 c.c.). Steam-distillation, and extraction of the distillate with ether, afforded the *cis*-oxide (12·9 g., 56%), b. p. 68—72°/16 mm., n_D^{21} 1·4694. The product was slightly unsaturated. The residue from the distillation (3·5 g.) was strongly unsaturated and probably contained 2-methylene*cyclo*hexylmethanol.

trans-*Octahydro*iso*benzofuran*.—The *trans*-dimethanesulphonate (23 g.) was boiled under reflux for 3 hours with 15% aqueous potassium hydroxide (150 c.c.). The product was isolated as described above, and on distillation furnished trans-*octahydro*iso*benzofuran* (5·8 g., 61%), b. p. 75—76°/25 mm., 172·5—173°/751 mm., n_D^{17} 1·4695 (Found: C, 75·8; H, 11·2%). No diol was isolated by continuous ether-extraction of the aqueous residue from the steam-distillation.

When the *trans*-oxide (0·1 g.) was added to a solution of potassium ferricyanide (0·05 g.) in 20% hydrochloric acid (5 c.c.) a yellow precipitate was formed. This complex was filtered off, washed thoroughly with 20% hydrochloric acid, and dried at room temperature in a high vacuum. It could not be recrystallised, and decomposed without melting at 130—150° (Found: C, 52·3; H, 7·0; Fe, 11·9. Calc. for $H_3FeC_6N_6,2C_8H_{14}O$: C, 56·5; H, 7·5; Fe, 11·9%). When it was added to sodium hydrogen carbonate solution effervescence occurred and the oxide was regenerated.

(+)-trans-*Octahydro*iso*benzofuran*.—Reaction of the (−)-dimethanesulphonate (2 g.) with boiling aqueous potassium hydroxide as described above gave (+)-trans-*octahydro*iso*benzofuran* (0·34 g.), b. p. 74°/26 mm., n_D^{24} 1·4655, $[\alpha]_D^{22}$ +110° (*c*, 5 in C_6H_6) (Found: C, 76·0; H, 11·2%).

Methanesulphonation of Butane-1 : 4-*diol and Conversion into Tetrahydrofuran*.—Butane-1 : 4-diol (10 g.) in pyridine (30 c.c.) was cooled to 0° and a solution of methanesulphonyl chloride (28 g.) in pyridine (50 c.c.) added slowly with stirring. After 2 hours the product was worked up in the usual way to give the *dimethanesulphonate* (22 g.), needles (from methanol–acetone), m. p. 116° (Found: C, 29·6; H, 5·7; S, 25·7. $C_6H_{14}O_6S_2$ requires C, 29·3; H, 5·7; S, 26·0%). The aqueous filtrates were acidified and extracted three times with light petroleum (b. p. 100—120°). The dried (K_2CO_3) extracts were carefully fractionated, but no tetrahydrofuran could be detected.

The dimethanesulphonate (17 g.) was boiled under reflux with 16% aqueous potassium hydroxide (125 c.c.), a homogeneous solution being formed after 15 minutes. Direct distillation gave a low-boiling fraction, b. p. 63—95°, which was dried (K_2CO_3) and redistilled to give tetrahydrofuran (2·9 g., 58%), b. p. 64·5—65·5°, n_D^{23} 1·4085.

trans-2-*Chloromethyl*cyclo*hexylmethanol*.—The *trans*-diol (10 g.) was heated at 80—90° with fuming hydrochloric acid (10 c.c.; *d* 1·19) for 19 hours (sealed tube). The upper layer was separated, washed with water and sodium hydrogen carbonate solution, dried (Na_2SO_4), and distilled to give crude trans-2-*chloromethyl*cyclo*hexylmethanol* (5·2 g.), b. p. 79—83°/0·3 mm., n_D^{16} 1·4878—1·4942. A fraction, b. p. 82—83°/0·3 mm., n_D^{16} 1·4918, was analysed (Found: C, 60·3; H, 9·5; Cl, 21·2. $C_8H_{15}OCl$ requires C, 59·1; H, 9·3; Cl, 21·8%). Hydrogen chloride and crude oxide (0·65 g.) were found in the liquid-air trap after the distillation. When the monochloride was heated to about 200° it lost hydrogen chloride, and the residue had a strong odour of the oxide. Treatment of the crude monochloride with *p*-nitrobenzoyl chloride in pyridine gave a p-*nitrobenzoate* (60%) which from methanol formed fine needles, m. p. 61—62°, by slow crystallisation, or a microcrystalline powder, m. p. 64—65°, by rapid crystallisation. The two forms were interconvertible, and mixtures showed intermediate m. p.s (Found: C, 57·8; H, 5·9; N, 4·5. $C_{15}H_{18}O_4NCl$ requires C, 57·8; H, 5·8; N, 4·5%).

Attempted Preparation of the trans-*Monotoluene*-p-*sulphonate*.—(i) To a solution of the *trans*-diol (2 g.) in pyridine (20 c.c.) at 0° a solution of toluene-*p*-sulphonyl chloride (2·65 g.) in chloroform (20 c.c.) was added dropwise, with stirring, during 4 hours. Pyridine and chloroform were removed under reduced pressure below 35°, and the residue was dissolved in chloroform, washed successively with dilute sulphuric acid and sodium hydrogen carbonate solution, and dried (Na_2SO_4). Removal of solvent then gave a viscous yellow oil (2·15 g.), n_D^{19} 1·5185, having an odour of the oxide. This was dissolved in methanol (2 c.c.), cooled to 0° and filtered from a small quantity of *trans*-ditoluene-*p*-sulphonate, m. p. and mixed m. p. 108°. Removal of solvent from the filtrate, followed by methanesulphonation in pyridine, gave an oil from which a small quantity of *trans*-dimethanesulphonate, m. p. and mixed m. p. 92°, separated on addition of methanol and cooling at 0°. Similar results were obtained when the toluene-*p*-sulphonation was carried out in chloroform–pyridine (1 : 1) solution during 4 days.

(ii) *trans*-2-Chloromethyl*cyclo*hexylmethanol (4 g.) in dry benzene (50 c.c.) was heated under reflux with silver toluene-*p*-sulphonate (12 g.) for 16 hours. Filtration and removal of solvent gave an oil with a strong odour of the oxide; the latter was removed in a high vacuum at room temperature to leave a residue (0·3 g.) of viscous oil which failed to give any crystalline derivatives. The material collected in the liquid-air trap was dried (K_2CO_3) and distilled to give the *trans*-oxide (0·8 g.), b. p. 74°/20 mm., n_D^{28} 1·4647.

trans-1 : 2-*Bisbromomethyl*cyclo*hexane*.—Dry hydrogen bromide was passed into *trans*-octahydro*iso*benzofuran (50 g.) at 80—90°. Absorption was rapid at first, but became slower when, after 1½ hours, a lower aqueous layer began to separate. After a further 3½ hours the reaction was discontinued and the brown oil was dissolved in chloroform, washed with water and sodium hydrogen carbonate solution, and dried (Na_2SO_4). Removal of solvent, followed by distillation, gave trans-1 : 2-*bisbromomethyl*cyclo*hexane* (68 g., 63%), b. p. 102°/0·5 mm., n_D^{20} 1·5390 (Found : C, 35·6; H, 5·5; Br, 59·25. $C_8H_{14}Br_2$ requires C, 35·6; H, 5·2; Br, 59·2%).

Reaction of the dibromide (1 g.) with sodium iodide (3·5 g.) in boiling acetone for 1½ hours gave a precipitate (0·62 g., 81%) of sodium bromide. Evaporation of the filtered solution and addition of water to the residue gave a solid, which on recrystallisation from methanol furnished *trans*-1 : 2-bisiodomethyl*cyclo*hexane (0·45 g.), m. p. and mixed m. p. 39—40°.

trans-1 : 2-*Bisacetoxymethyl*cyclo*hexane*.—The *trans*-dibromide (47 g.), acetic acid (150 c.c.), fused potassium acetate (60 g.), and acetic anhydride (10 c.c.) were boiled under reflux overnight. The isolated product still contained bromine and it was therefore refluxed for 2 hours with silver acetate (15 g.) in acetic acid (150 c.c.), and worked up to yield the trans-*diacetate* (16·3 g.), b. p. 104—107°/0·5 mm., n_D^{23} 1·4580 (Found : C, 62·5; H, 8·8. $C_{12}H_{20}O_4$ requires C, 63·15; H, 8·8%). This (7 g.) was stored for 48 hours in methanol (60 c.c.) containing sodium methoxide (0·2 g.). The solution was then neutralised with carbon dioxide and evaporated to a viscous oil which was taken up in ether, dried (Na_2SO_4), evaporated, and distilled to give the *trans*-diol (3·55 g.), m. p. *ca.* 43°, raised to 57° by recrystallisation. Toluene-*p*-sulphonation gave the *trans*-ditoluene-*p*-sulphonate, m. p. and mixed m. p. 108°.

Toluene-p-*sulphonate of* trans-2-*Chloromethyl*cyclo*hexylmethanol*.—The *trans*-oxide (5 g.), toluene-*p*-sulphonyl chloride (8·2 g.), and zinc chloride (5 mg.) were heated together for 3 hours at 100°. The dark, viscous product was dissolved in chloroform and washed with sodium hydrogen carbonate solution and with water. Evaporation of the dried (Na_2SO_4) solution gave a brown oil, having a strong odour of toluene-*p*-sulphonyl chloride. Treatment with charcoal in methanol and filtration of a solution in benzene through activated alumina eliminated acid chloride and some of the colouring matter to give crude trans-2-*chloromethyl*cyclo*hexylmethyl toluene*-p-*sulphonate* (7·1 g.) as a brown oil, n_D^{24} 1·5228 (Found : S, 9·15; Cl, 11·9. $C_{15}H_{21}O_3SCl$ requires S, 10·1; Cl, 11·2%).

When a solution of this product (5·8 g.) with sodium iodide (20 g.) in acetone (100 c.c.) was boiled under reflux for 48 hours, a mixture of sodium toluene-*p*-sulphonate and sodium chloride (3·1 g., 69%) was precipitated. Evaporation of the filtered solution, and extraction of the residue with chloroform, gave an oil which when dissolved in methanol and cooled to 0° deposited the *trans*-di-iodide (0·5 g.), m. p. and mixed m. p. 39—40°.

trans-2-*Chloromethyl*cyclo*hexylmethyl Acetate*.—The *trans*-oxide (10 g.) and acetyl chloride (10 g.) were heated at 100° for 3 hours. Water was added, and the ester was extracted with chloroform, washed with sodium hydrogen carbonate solution and with water, dried (Na_2SO_4), freed from solvent, and distilled to give trans-2-*chloromethyl*cyclo*hexylmethyl acetate* (13·6 g.), as a colourless oil, b. p. 87—89°/0·2 mm., n_D^{23} 1·4731 (Found : C, 58·6; H, 8·4; Cl, 17·45. $C_{10}H_{17}O_2Cl$ requires C, 58·7; H, 8·4; Cl, 17·3%). This ester (4 g.) was dissolved in 1% hydrogen chloride in methanol (100 c.c.). After 48 hours at room temperature the acid was neutralised with solid sodium hydrogen carbonate, and methanol distilled from the filtered solution. The residue was extracted with ether, and the ethereal extract distilled to give *trans*-2-chloromethyl*cyclo*hexylmethanol (1·8 g.), b. p. 78—82°/0·25 mm., n_D^{20} 1·4883—1·4940. The drift in refractive index was possibly due to the presence of a little unchanged acetate, but the product readily gave the *p*-nitrobenzoate, identical with that prepared previously, m. p. and mixed m. p. 61—62° or 64—65°.

2-*Bromomethyl*cyclo*hexylmethyl Acetate*.—(i) The *cis*-oxide (5·4 g.) was mixed with acetyl bromide (5·7 g.); a vigorous reaction ensued and external cooling was necessary. When the reaction subsided the mixture was heated at 100° for 30 minutes and then worked up as for the chloro-compound, to give cis-2-*bromomethyl*cyclo*hexylmethyl acetate* as a pale yellow oil (8·8 g.), b. p. 84—85°/0·15 mm., n_D^{18} 1·4967 (Found : C, 48·5; H, 7·0; Br, 32·8. $C_{10}H_{17}O_2Br$ requires C, 48·2; H, 6·9; Br, 32·1%). Deacetylation of this material (0·8 g.) as described for the chloro-compound gave the crude monobromide (0·6 g.), which with *p*-nitrobenzoyl chloride in pyridine gave cis-2-*bromomethyl*cyclo*hexylmethyl* p-*nitrobenzoate*, needles (from ethanol), m. p. 79° (Found : C, 50·8; H, 5·3; N, 3·9. $C_{15}H_{18}O_4NBr$ requires C, 50·6; H, 5·1; N, 3·9%).

(ii) The *trans*-oxide (4·05 g.) and acetyl bromide (4·3 g.) similarly gave trans-2-*bromomethyl*cyclo*hexylmethyl acetate* (6·7 g.), b. p. 80—83°/0·2 mm., n_D^{15} 1·4938 (Found : C, 48·2; H, 6·8; Br, 32·9%). Deacetylation and *p*-nitrobenzoylation gave trans-2-*bromomethyl*cyclo*hexylmethyl* p-*nitrobenzoate* as powdery crystals (from methanol), m. p. 80—81° (Found : C, 50·7; H, 5·1; N, 3·9%). The m. p. was depressed to 63° on admixture with the *cis*-isomer of m. p. 79°.

*Reaction of Octahydro*iso*benzofuran with* p-*Nitrobenzoyl Bromide*.—(i) The *cis*-oxide (0·27 g.), *p*-nitrobenzoyl bromide (0·52 g.), and a trace of zinc chloride were heated at 100° for 10 minutes. The product was dissolved in chloroform and washed with aqueous sodium hydrogen carbonate. The dried (Na_2SO_4) solution was evaporated to give a solid (0·6 g.), m. p. 76—78°, which by one recrystallisation from methanol yielded the *cis*-bromide *p*-nitrobenzoate, m. p. and mixed m. p. 79°.

(ii) The *trans*-oxide (0·25 g.) reacted similarly with *p*-nitrobenzoyl bromide (0·47 g.) and a trace of zinc chloride to give the *trans*-bromide *p*-nitrobenzoate (0·35 g.), m. p. and mixed m. p. 80—81°.

trans-2-*Iodomethyl*cyclo*hexylmethyl* p-*Nitrobenzoate*.—*trans*-2-Bromomethyl*cyclo*hexylmethyl acetate (11·5 g.) and sodium iodide (20 g.) in acetone (100 c.c.) were boiled under reflux for 1 hour. Sodium bromide (4·38 g., 95%) was filtered off, and the acetone distilled from the filtrate. The residue was extracted with chloroform, and the extract was washed with sodium thiosulphate solution to remove free iodine, and dried (Na_2SO_4). Removal of solvent gave an oil which distilled (some decomp.) to give an impure acetate–iodide (11·1 g.), b. p. 108—113°/0·5 mm., n_D^{12} 1·5171—1·5230. A fraction, b. p. 112°/0·5 mm., n_D^{12} 1·5220, was analysed (Found : I, 35·5. Calc. for $C_{10}H_{17}O_2I$: I, 42·9%). Deacetylation with methanolic hydrogen chloride, followed by *p*-nitrobenzoylation, gave trans-2-*iodomethyl*cyclo*hexylmethyl* p-*nitrobenzoate*, needles (from methanol), m. p. 55—56° (Found: C, 44·8; H, 4·7; N, 3·5. $C_{15}H_{18}O_4NI$ requires C, 44·7; H, 4·5; N, 3·5%).

Reduction of Methyl Phenylcarbamate.—The urethane (5 g.) in dry ether (20 c.c.) was added to a solution of lithium aluminium hydride (1·8 g.) in dry ether (100 c.c.). When the reaction subsided the solution was boiled under reflux for 2 hours. Water was then added, with sufficient sodium hydroxide to redissolve the precipitate, and the ethereal layer was removed, dried (K_2CO_3), and evaporated; distillation of the residue gave *N*-methylaniline (4·1 g.), b. p. 193—195° (acetyl derivative, m. p. 101°; toluene-*p*-sulphonyl derivative, m. p. 94—95°).

Reduction of the (−)-*Menthylurethane of* trans-1 : 2-*Bishydroxymethyl*cyclo*hexane*.—The more soluble fractions from the original resolution were used. The urethane (10 g.) and lithium aluminium hydride (1·5 g.) in dry ether (130 c.c.) were boiled under reflux for 3 hours. After the addition of water and sodium hydroxide the solution was steam-distilled to remove ether and amine; the latter was recovered by ether-extraction of the distillate and on distillation furnished *N*-(−)-menthylmethylamine (4·75 g.), b. p. 95—96°/13 mm., n_D^{21} 1·4569, $[\alpha]_D^{20}$ −68·9° (*c*, 2 in $CHCl_3$). Read and Hendry (*Ber.*, 1938, **71**, 2544) give b. p. 87°/12 mm., n_D^{17} 1·4587, $[\alpha]_D^{17}$ −69·2°. The toluene-*p*-sulphonyl derivative had m. p. 60—61°, $[\alpha]_D^{20}$ −36·8° (*c*, 2 in $CHCl_3$). Read and Hendry (*loc. cit.*) give m. p. 61°, $[\alpha]_D^{17}$ −37·5°.

The alkaline residue from the steam-distillation was continuously extracted with ether and gave the *trans*-diol (2·3 g.), b. p. 130—131°/0·5 mm., m. p. 55—56°, $[\alpha]_D$ −5·0° (*c*, 7 in EtOH); this was not optically pure [cf. the (+)-*trans*-diol, above] because the bismenthylurethane used was not a pure diastereoisomer. The toluene-*p*-sulphonate had m. p. 108°, not depressed by the (±)-derivative.

Reduction of the (−)-*Menthylurethane of* (−)-*Menthol*.—The urethane (Read and Roebuck, *loc. cit.*) (3·45 g.) and lithium aluminium hydride (0·6 g.) in dry ether (60 c.c.) were boiled under reflux overnight. Water and excess of sulphuric acid were added, and the ethereal layer was removed. The aqueous portion was extracted with ether, and the combined ethereal solutions on evaporation gave a residue which on sublimation at 100° (bath)/25 mm. gave (−)-menthol (0·15 g.), m. p. 40—41°, $[\alpha]_D^{20}$ −50·1° (*c*, 3 in EtOH). The involatile residue from the sublimation (2·4 g.), m. p. 107—109°, was unchanged urethane.

ORGANIC CHEMISTRY DEPARTMENT, IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
SOUTH KENSINGTON, LONDON, S.W.7.

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