[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, QUEEN'S UNIVERSITY]

METHANOLYSIS OF STEREOISOMERIC OXIDES OF 3-METHOXYCYCLOHEXENE

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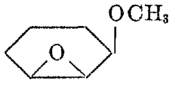
Two oxides (I and II) are formed by the action of alkali upon the mixed chlorohydrins of 3-methoxycyclohexene. They are stereoisomers because on further reaction the first oxide leads to α-pyrogallitol (III) and the second leads to β-pyrogallitol (IV). The main interest in the present work lies in the new synthesis of the difficultly accessible α-pyrogallitol (III).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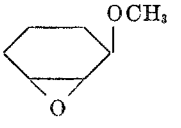
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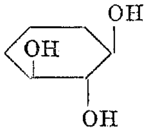
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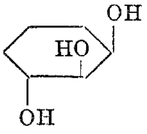
IV

When 3-methoxycyclohexene (V) (1) was treated with monochlorourea (2), a mixture of isomeric chlorohydrins was formed which has resisted all attempts to separate it by fractional distillation. Indeed Mousseron and his co-workers (3, 4), who used the same method for preparing the chlorohydrin of 3-ethoxycyclohexene, apparently considered that their product consisted of a single isomer. Nevertheless, at least two chlorohydrins must have been present in our product since it yielded two oxides on treatment with alkali. The first formed, or α-oxide of 3-methoxycyclohexene was obtained when the mixture of chlorohydrins was allowed to react with aqueous sodium hydroxide for about two hours, and the more slowly formed, β-oxide of 3-methoxycyclohexene was obtained by the more prolonged action of the alkali upon the unreacted chlorohydrin recovered from the preparation of the α-oxide. Other workers have shown in subsequent experiments in these laboratories that the stereoisomeric ethoxycyclohexene oxides and isopropoxycyclohexene oxides respectively, can be formed from the corresponding chlorohydrins in the same way.

Treatment of the first-formed or α-oxide of 3-methoxycyclohexene with methanol in the presence of sodium methoxide gave rise to a dimethyl ether of *cis-trans-cis*-cyclohexanetriol (VI or VII) (see below). It was purified through its 3,5-dinitrobenzoate (m.p. 143°). When either the crude or the purified dimethyl ether was demethylated with hydriodic acid, *cis-trans-cis*-cyclohexane-1,2,3-triol (III) was formed in good yield, and no other isomeric triols could be found in the reaction mixtures. Apparently the scission of the oxide ring occurred almost entirely in only one of the two possible directions.

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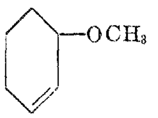

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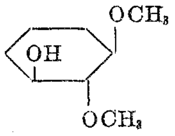

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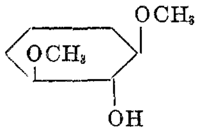
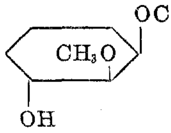


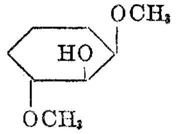
VII

Cis-trans-cis-cyclohexanetriol (III) has been prepared before: by Brunel (5) and by Posternak and Ravenna (6) *via* the iodohydrin of 3-ethoxycyclohexene; by Lindemann and de Lange (7) and by Christian, Gogek, and Purves (8) by the hydrogenation of pyrogallol; and by Gogek, Moir, McRae, and Purves (1) through the peroxidation of 3-methoxycyclohexene and of 3-acetoxycyclohexene. The yields in all of these methods were low and in each instance the desired triol had to be separated from large amounts of other isomers by tedious and wasteful fractional crystallizations of the tribenzoates. In contrast, the yield in the present method was good and the product was easily obtained free from isomers. Part of the improved yield was due to the adoption of an improved method of demethylating the intermediate ether (9, 10).

The more slowly formed, β-oxide of 3-methoxycyclohexene when treated with methanol and sodium methoxide gave a dimethyl ether of *cis-cis-trans*-cyclohexanetriol (VIII or IX) (see below). The diether gave only a single 3,5-dinitrobenzoate (m.p. 90°) clearly different from that derived from the α-oxide. Demethylation of either the crude diether, or of the diether purified through its dinitrobenzoate, gave only *cis-cis-trans*-cyclohexane-1,2,3-triol (IV). The scission of the β-oxide therefore took place at the same bond as did the scission of the α-oxide, demonstrating the unimportance of steric factors in determining the direction of the oxide scissions. This new synthesis of β-pyrogallitol (IV) is not of much practical interest since a satisfactory synthesis of this triol has already been reported (1).



VIII



IX

The conversion of the α-oxide to the known triol III and of the β-oxide to the known stereoisomeric triol IV is conclusive proof that the oxides are stereoisomers. Each of the oxides has been prepared many times over the course of ten years, and each has always exhibited its own constant physical properties, which suggests that the oxides have been satisfactorily separated from each other. The failure to obtain more than one crystalline dinitrobenzoate, or more than one crystalline triol from the reactions of each of the oxides is also evidence of their steric purity, particularly in the formation of the triols III and IV, whose separation from each other has been achieved by many workers, including one of us (1), even when one of the isomers was present in very small amounts.

There is strong theoretical and experimental support for the principle that the demethylation of a methyl ether takes place without change of configuration. The use of this principle in the successful prediction of the structures of all the cyclohexane-1,2,3-triols (1) would seem to establish its essential applicability to the present series beyond doubt. It follows that the diether formed from the α-oxide could have only structure VI or structure VII since on demethylation it gave the triol III. Similarly, the diether derived from the β-oxide could have only structure VIII or structure IX since on demethylation it led to the triol IV. The same conclusions follow from a rather elaborate use of the familiar principle that simple oxide rings open with inversion of configuration at the attacked centre (1). The present results do not lead to a decision between the alternative structures for the diethers, nor to a decision as to which of the structures (I or II) belongs to the α-oxide. However, it may be pointed out that the two oxides (I and II) together can lead only to the four diethers (VI, VII, VIII, and IX), that of these diethers, only VI and VII can lead to the triol III, and that VI can arise only from the oxide I, VII only from the oxide II. Furthermore, VI is resolvable while VII is not. Since the diether obtained from the α-oxide gave rise to the triol III, the structure of the diether and of the α-oxide could be determined from the resolvability or non-resolvability of the diether. Our progress towards determining its resolvability is recorded in the experimental part.

It is felt that some of these results have interesting applications to the theory of oxide scissions. In addition, the oxides have been made to react with diethyl sodiomalonate, with acidified water, and with *p*-toluenesulfonic acid, all reactions of some theoretical interest. The discussion of these points is postponed for later treatment.

EXPERIMENTAL

Melting points are corrected unless otherwise stated.

3-Methoxycyclohexene was made from cyclohexene dibromide and sodium methoxide, a method which leads to a product essentially free from 4-methoxycyclohexene (1).

Chlorohydrin of 3-methoxycyclohexene. 3-Methoxycyclohexene (182.3 g.) was mechanically shaken with glacial acetic acid (30 cc.), ice (300 g.), and a solution of monochlorourea (11) (1.99 *M* in hypochlorous acid, 259.3 cc.) for one hour. The same quantities of acetic acid, monochlorourea, and ice were added to the mixture and the shaking continued for another hour, after which the same amounts as before of acetic acid, monochlorourea, and ice were again added, and the shaking continued for four hours longer. The resulting emulsion was repeatedly extracted with ether and the ethereal solution was neutralized with sodium carbonate, dried, and distilled. A viscous, almost colorless oil, slightly turbid due to suspended urea, b.p. 110–123° at 17 mm., was collected in a yield of 183.7 g. or 69%. In another preparation, the crude product was fractionally distilled four times through small columns, yielding the following fractions of chlorohydrin, some contaminated by dichloride: (a) b.p. up to 100° at 11 mm., 14.7 g., $d_4^{20.0}$ 1.1748; $n_D^{18.7}$ 1.4892; (b) b.p. 100–106° at 11 mm., 20.2 g., $d_4^{20.0}$ 1.1864; $n_D^{19.5}$ 1.4911; (c) b.p. 106–109° at 11 mm., 50.3 g., $d_4^{20.0}$ 1.1869; $n_D^{20.8}$ 1.4919; (d) b.p. 109–112° at 11 mm., 50.7 g., $d_4^{20.0}$ 1.1861; $n_D^{20.0}$ 1.4918. The chlorohydrin was appreciably soluble in water.

Anal. Calc'd for $C_7H_{13}ClO_2$: Cl, 21.54; specific refractivity at 20° (r), 0.2459.
Calc'd for $C_7H_{12}Cl_2O$: Cl, 38.73; r, 0.2391.
Found for fraction (a): Cl, 27.39, 27.86; r, 0.2455.
for fraction (b): Cl, 24.11, 24.64; r, 0.2441.

for fraction (c): Cl, 22.85, 22.82; r, 0.2444.
for fraction (d): Cl, 21.61, 21.06; r, 0.2445.

A crystalline *phenylurethan of 3-methoxycyclohexene chlorohydrin* was formed by the reaction of phenyl isocyanate with fraction (b) in benzene solution. Two crystallizations of the product from ethanol gave large white crystals, m.p. 144–145°, in a yield of 4.5%.

Anal. Calc'd for $C_{14}H_{18}ClNO_3$: Cl, 12.49; N, 4.93.
Found: Cl, 12.25; N, 5.23.

Cyclohexene oxide. A sample made several years ago in these laboratories by Mr. F. R. Archibald according to Osterberg's method (12) was carefully purified by distillation to yield a product of b.p. 129.2–129.8°; $d^{20.0}_4$ 0.9718; $n^{20.5}_D$ 1.4512; molar refractivity at 20.0° (R), 27.21. Using Vogel's table of values (13), these results suggest that the atomic refractivity of epoxy oxygen is about 1.53; using Eisenlohr's values (14), they suggest a value of 1.70 for epoxy oxygen. Oxides of this series may therefore be readily differentiated from the isomeric carbonyl compounds by measurement of the molar refractivity.

α-Oxide of 3-methoxycyclohexene. Sodium hydroxide (24 g.) was dissolved in water (110 cc.) and cooled to room temperature. Methoxycyclohexene chlorohydrin [from fractions (c) and (d) above, 78.0 g.] was added and the mixture stirred for 105 minutes; the oily layer was separated and the aqueous layer repeatedly extracted with ether. After being dried, the combined oily and ethereal layers were twice fractionally distilled to give the following fractions: (a) b.p. 67–69° at 15 mm., 28.9 g. or 48%; (b) 69–102° at 15 mm., 5.4 g.; (c) b.p. 102° at 15 mm. to 115.5° at 17 mm., 22.7 g., a recovery of 29% of the original chlorohydrin. Fraction (a) was the α-oxide of 3-methoxycyclohexene; it had d^{20}_4 1.0350; $n^{20.3}_D$ 1.4532; molar refractivity at 20.0°, 33.49, implying a value of 1.40 (13) or 1.72 (14) for the atomic refractivity of the epoxy oxygen, in good agreement with that found in cyclohexene oxide. When crude methoxycyclohexene chlorohydrin was used for the preparation of the oxide, the yield based on the chlorohydrin was smaller, but the over-all yield from methoxycyclohexene was larger than when purified chlorohydrin was used. In one preparation from the crude chlorohydrin, α-oxide of b.p. 67–69° at 16 mm. was obtained in 34% yield based on the original chlorohydrin used, and 36% of the chlorohydrin was recovered unchanged.

Anal. Calc'd for $C_7H_{12}O_2$: Cl, 0.00; C, 65.58; H, 9.44.
Found: (first preparation) Cl, 0.14; (second preparation) C, 65.16, 65.79; H, 9.26, 9.68.

Ten years later another worker obtained α-oxide having $d^{20.0}_4$ 1.0352, $n^{20.0}_D$ 1.4530. A third worker, using a different method, also obtained a very similar product (see below).

β-Oxide of 3-methoxycyclohexene. Methoxycyclohexene chlorohydrin (b.p. 102–115.5° at 15 to 17 mm., 22.7 g.) which had been recovered from the preparation of the α-oxide, was stirred with a 35% excess of a 20% aqueous solution of sodium hydroxide for 11.5 hours. The preparation was repeatedly extracted with ether, and the ethereal extract was dried and fractionally distilled. When the fractions were united with the corresponding fractions from another larger preparation, and refractionated four times more, the following new fractions were obtained: (a) b.p. 75–85° at 12 mm., 21.2 g. or 36%—the β-oxide; (b) b.p. 85–102° at 12 mm., 8.9 g.; (c) b.p. 102–105° at 12 to 13 mm., 18.3 g., a recovery of 24% of the original chlorohydrin. Fraction (a) had d^{20}_4 1.0553; $n^{20.0}_D$ 1.4603; r, 0.2597 (see below). Fraction (c) had r, 0.2424.

Anal. Calc'd for $C_7H_{12}O_2$: Cl, 0.00; C, 65.58; H, 9.44;
for $C_7H_{13}ClO_2$ (chlorohydrin): Cl, 21.54;
for $C_7H_{12}Cl_2O$ (dichloride): Cl, 38.73.
Found for fraction (a): Cl, 1.77; for fraction (c): Cl, 26.91.

The results for fraction (a) suggest that the oxide preparation contained 8% of chlorohydrin as an impurity, or lesser amounts of chlorohydrin plus dichloride. Assuming the impurity to be entirely chlorohydrin, one can estimate the following constants for the pure β-oxide: $d^{20.0}_4$ 1.0436; $n^{20.0}_D$ 1.4575; R, 33.46; the correction for R is small. These corrected values would not be much changed if the impurity was assumed to be entirely methoxycyclohexene dichloride. The corrected value for the molar refractivity implies an atomic refractivity for the epoxy oxygen of 1.37 (13) or 1.69 (14), in good agreement with the previous values. The chlorine content and specific refractivity of fraction (c) demonstrate the relative unreactivity of the dichloride towards sodium hydroxide. Several other preparations of the β-oxide were made. In one of them, the chlorine content was low:

Anal. Found: Cl, 0.38; C, 64.92, 64.87; H, 9.43, 9.26.

Another worker carefully fractionated five combined samples of the crude β-oxide in a Podbielniak Miniature HyperCal column, and obtained two fractions of the oxide having $n_D^{20.0}$ 1.4580 and 1.4578, respectively, as well as α-oxide and chlorohydrin amounts that suggested that the crude unfractionated β-oxide preparations contained about 5% of pure α-oxide, about 63% of pure β-oxide, and about 32% of chlorohydrin plus dichloride, demonstrating the rather high effectiveness of the preliminary chemical separation.

Separation of the stereoisomeric oxides by fractional distillation alone. As a check on the previous work, crude samples of the α-oxide and the β-oxide were mixed and then subjected to three successive fractional distillations in the Podbielniak column. The α-oxide so prepared had the following properties: b.p. 75–76° at 25 mm., n_D^{20} 1.4530; d_4^{20} 1.0320. Analyses for carbon and hydrogen were very satisfactory. Corresponding properties of the β-oxide were: b.p. 88–93° at 25 mm., n_D^{20} 1.4595; d_4^{20} 1.0535. The oxides were colorless liquids of low viscosity.

Anal. Calc'd for $C_7H_{12}O_2$: Cl, 0.00; C, 65.58; H, 9.44.
Found (for the β-oxide): Cl, 1.29; C, 64.71, 64.71; H, 9.26, 9.35.

These results suggest that the β-oxide preparation contained about 6% of chlorohydrin. The persistent failure to remove this impurity, in spite of prolonged efforts, constitutes a blemish on our direct characterization of the β-oxide. Indirect characterization of the β-oxide has been achieved by the formation from it of several pure crystalline derivatives, two of which are described in this paper.

Methanolysis of the α-oxide of 3-methoxycyclohexene. (*a*). Anhydrous methanol (69.5 g.) and clean sodium (1.104 g.) were allowed to react and then heated under reflux intermittently for a total of 66 hours with the α-oxide of 3-methoxycyclohexene (25.1 g., $n_D^{20.0}$ 1.4530), being protected from atmospheric moisture during the reaction period. The very pale golden yellow solution was neutralized with a slight excess of glacial acetic acid, concentrated by distillation, separated from the precipitated sodium acetate, and fractionally distilled in the Podbielniak column at 13.5 to 14 mm. Eight fractions were collected, ranging in $n_D^{20.4}$ from 1.4589 to 1.4598, in a total yield of 25.0 g., or 80%. Fractions [1] to [6] were united as product for use in subsequent experiments; their properties were then: yield, 18.6 g. or 59%; b.p. 106.2–113.0°; $n_D^{20.4}$ 1.4590; $d_4^{20.4}$ 1.0532; R, 41.59. The expected value of R is 42.07 (13) or 41.76 (14).

(*b*). A large decrease in the amount of catalyst and in the reaction time lowered the yield but did not alter the character of the product. Anhydrous methanol (101.8 g.) and sodium (0.841 g.) were allowed to react and then heated under reflux for 36 hours with the α-oxide of 3-methoxycyclohexene (81.4 g., n_D^{20} 1.4530). The product was isolated as before to give four fractions: (a) b.p. 77–80°, n_D^{20} 1.4530, 31.1 g. (unchanged oxide); (b) b.p. 112–120°, n_D^{20} 1.4600, yield 16.8 g.; (c) b.p. 120–123°, n_D^{20} 1.4596, 15.3 g., d_4^{20} 1.0520; R, 41.68; (d) b.p. 120–122°, n_D^{20} 1.4595, 21.0 g. (all at 25 mm.). Fractions b, c, and d were united; together they represented a yield of "α-dimethoxycyclohexanol" of 84.3%, based on the unrecovered oxide.

Anal. Calc'd for $C_8H_{16}O_3$: C, 59.97; H, 10.06.
Found for fraction (c): C, 59.68; H, 10.17.

3,5-Dinitrobenzoate of α-dimethoxycyclohexanol. Redistilled α-dimethoxycyclohexanol ($d_4^{20.4}$ 1.0532, 10.147 g.) from the first methanolysis of the α-oxide, 3,5-dinitrobenzoyl chloride (recrystallized, m.p. 65–67°, 14.382 g.), and dry pyridine (12.5 ml.) were mixed and allowed to stand for 90 minutes. A further 12.5 ml. of dry pyridine was added to the solid mass, the mixture allowed to stand for 17.5 hours, and then treated with aqueous sodium bicarbonate solution. Light yellow crystals, m.p. 123.2–134.3° were recovered in a yield of

16.889 g. Extraction of the crystals with sodium bicarbonate solution for 90 minutes, followed by washing with water, left 15.735 g. of dried crystals, m.p. 131–138°. One recrystallization from ethanol gave 12.402 g. of very slightly yellowish needles (a yield of 55.3% based on the original alcohol), m.p. 141.7–141.9°. A small portion of this material was once more recrystallized from ethanol to give the analytical sample as white needles of m.p. 142.8°.

Anal. Calc'd for $C_{15}H_{18}N_2O_8$: C, 50.82; H, 5.09.

Found: C, 50.98, 51.09; H, 5.23, 5.35.

A careful search was made in the mother liquors for isomeric dinitrobenzoates, but the only substance found was ethyl 3,5-dinitrobenzoate, m.p. and mixture m.p. correct at 94.3–94.8°, yield 0.745 g. It gave a large depression of the m.p. on admixture with the 3,5-dinitrobenzoate of β-dimethoxycyclohexanol (see below). Redistilled α-dimethoxycyclohexanol from the second methanolysis of the α-oxide (b.p. 103.5–107.0° at 10.2 mm., $n_D^{20.0}$ 1.4610) was converted to the same 3,5-dinitrobenzoate, m.p. 142.3–142.7°, in a yield of 45%, by a slightly different procedure. This was the best indication that the products from the two runs were essentially similar.

Sterically pure α-dimethoxycyclohexanol. The purified dinitrobenzoate (12.4 g. of m.p. 141.7–141.9° and 0.7 g. of m.p. 142.3–142.7°) was saponified by boiling it with methanolic ethanolic potassium hydroxide for 12.75 hours. Bright red, mauve, and amber shades succeeded each other in the reaction mixture. Usual methods of purification led to the recovery of 3,5-dinitrobenzoic acid, m.p. 205.8–207.6°, in a yield of 87.9%, and of pure α-dimethoxycyclohexanol in a yield of 3.4 g. or 57.5%, b.p. 111–113° at 16.0 mm., $n_D^{19.8}$ 1.4590; $d_4^{20.0}$ 1.0518; R, 41.63. It was a clear, colorless, rather viscous liquid.

Synthesis of cis-trans-cis-cyclohexane-1,2,3-triol(α-Pyrogallitol). (a). Pure α-dimethoxycyclohexanol (2.330 g.), prepared from the hydrolysis of its dinitrobenzoate, was treated with an aqueous solution of hydrogen iodide (saturated at 0°, 6 cc.), and heated in a sealed tube at 80° for 90 minutes. The tube was then opened, its contents poured onto freshly prepared silver carbonate, and the mixture occasionally stirred for 16 hours. The aqueous phase was filtered, twice treated with hydrogen sulfide to remove traces of silver, again filtered, and evaporated to dryness. The white solid residue was now distilled in a Späth tube at 0.06 mm. to yield 1.4860 g., or 77.3% of an almost colorless solid distillate. On recrystallization from ethyl acetate, the distillate gave 1.4366 g. of white crystals, m.p. 107.7–108.2°. The melting point recorded for α-pyrogallitol is 108° (7). A portion of the pure α-pyrogallitol prepared in this way was converted into its *tribenzoate* to give 3.719 g. of crystals of m.p. 142.5–142.8° and 0.197 g. of crystals of m.p. 139.2–140.5° from the mother liquor, showing that the tribenzoate was homogeneous. Admixture of the first crop of crystals with authentic α-pyrogallitol tribenzoate (which had itself been directly compared with material made from pyrogallol) produced no depression of the melting point.

(*b*). Redistilled α-dimethoxycyclohexanol (b.p. 103.5–107.0° at 10.2 mm., $n_D^{20.0}$ 1.4610, 1 g.) from the second methanolysis of the α-oxide, was demethylated with hydrogen iodide according to a procedure less satisfactory than that already described, to give a white solid of m.p. 106.3–108.5° in substantial yield. Recrystallization of a small portion of the product gave crystals melting sharply at 108.9°. Benzoylation of a small portion of the product followed by three recrystallizations of the tribenzoate from ethanol gave crystals melting sharply at 140.8°. Admixture of the benzoate with a reference sample of the tribenzoate of α-pyrogallitol (m.p. 141.5–142.4°) which had been indirectly compared with material made from pyrogallol, gave a mixture m.p. of 141.3–143.0°. The mother liquors did not yield any β-pyrogallitol. This experiment showed that the methylation of the α-oxide had occurred almost entirely in one direction.

l-Menthoxyacetic ester of α-dimethoxycyclohexanol. l-Menthoxyacetic acid (15) was treated to remove non-acidic substances and twice distilled to give a yellow liquid, b.p. 159–172° at 10.2 mm., $n_D^{18.4}$ 1.4665, $[\alpha]_D^{26.6}$ −90.97° (*c*, 16 in 95% ethanol). The recorded rotation for this acid in 95% ethanol is $[\alpha]_D^{25}$ −91.5° (*c*, 2) (16). The pure acid (29.5 g.) was treated with thionyl chloride (48.1 g.) and heated in the absence of atmospheric moisture for 4 hours at 50°. After the excess thionyl chloride had been removed by distillation, the cooled liquid residue was poured into a mixture of dry pyridine (50 ml.) and α-dimethoxycyclohexanol (from the second methanolysis of the α-oxide, redistilled, b.p. 103.5–107.0° at 10.2 mm., 20 g.), and after being allowed to stand for 14 hours, the mixture was poured into water (125 ml.) and extracted with ether. The ethereal layer was washed twice with dilute hydrochloric acid, twice with dilute sodium hydroxide, and twice with water, and then evaporated to small volume. The residual syrup was divided into two portions to reduce the possibility of accidental loss. Distillation of the first portion gave 18.6 g. of a golden yellow liquid, b.p. 162–174° at 0.5 mm., $n_D^{25.5}$ 1.4708; $d_4^{25.5}$ 1.0157. Distillation of the second portion gave 15.0 g. of a similar liquid, b.p. 161–172° at 0.7 mm., $n_D^{18.5}$ 1.4722; $d_4^{18.5}$ 1.0230; $R_D^{18.5}$ 97.61. The expected value of R at 20° is 97.43 (13) or 96.74 (14). Vigorous attempts were made to bring about the crystallization of the material by the use of nine different solvents, but without success even after 3 months. The remainder of the second portion of the product (14.0 g.) was dissolved in ether, thoroughly extracted with a large excess of sodium bicarbonate solution for 4 hours, the ethereal layer washed and distilled to give a golden yellow liquid, b.p. 193–194° at 2.5 to 2.1 mm., in a yield of 12.1 g. After 12 days of alternate coolings to −78° and warmings to room temperature, this product finally crystallized partially, and 3.0 g. of crystals, m.p. about 26°, were recovered. Very difficult fractional crystallizations of the crystals from ligroin gave white, waxy crystals, m.p. 35.0–35.5° (uncorr.), $[\alpha]_D^{23.5}$ −65.63° (*c*, 1.2 in ligroin of b.p. 96–107°).

Anal. Calc'd for $C_{20}H_{36}O_5$: C, 67.38; H, 10.18.

Found: C, 67.10, 67.10; H, 10.32, 10.24.

Two other samples of the crystals were obtained from the same source, having $[\alpha]_D^{23.6}$ −64.11° and −64.10°, respectively (*c*, 2.0 and 1.6, respectively, in ligroin). The syrupy residue from which the crystals had separated had $[\alpha]_D^{26.3}$ −72.51° (*c*, 7.7 in ligroin), that is, a *higher* rotation than that of the pure crystals.

Methanolysis of the β-oxide of 3-methoxycyclohexene. Anhydrous methanol (96.3 g.) and sodium (0.685 g.) were allowed to react and then heated under reflux for 36 hours with the β-oxide of 3-methoxycyclohexene (77.1 g., n_D^{20} 1.4590). After neutralization of the solution with glacial acetic acid and removal of the methanol, the residue was fractionated in the Podbielniak column at 25 mm. Eight fractions were collected: (a) b.p. 79–104°, n_D^{21} 1.4558, 2.1 g.; (b) b.p. 104–112°, n_D^{21} 1.4594, 11.0 g.; (c) to (g) b.p. 120–130°, n_D^{21} 1.4598 or 1.4599, 72.6 g. in all; (h) b.p. 130–134°, n_D^{21} 1.4601, 2.8 g. Fraction (f) had d_4^{20} 1.0582; R (with arbitrary temperature correction), 41.49. The expected value for R is 42.07 (13) or 41.76 (14). Fractions (b) to (h) were united for further use and called "β-dimethoxycyclohexanol." Together they amounted to a yield of 92%, based on the β-oxide.

Anal. Calc'd for $C_8H_{16}O_3$: C, 59.97; H, 10.06.

Found for fraction (f): C, 59.78; H, 10.28.

3,5-Dinitrobenzoate of β-dimethoxycyclohexanol. 3,5-Dinitrobenzoyl chloride (1.3 g.), β-dimethoxycyclohexanol (redistilled, b.p. 98–104° at 10 mm., $n_D^{20.0}$ 1.4588, 1.00 ml.) and dry pyridine (5 ml.) were allowed to stand together for 4 hours. Saturated sodium bicarbonate solution (50 ml.) was then added, and after the mixture had been chilled overnight the originally oily precipitate became crystalline. The sticky, orange-yellow crystals were recovered, washed with water, and once recrystallized from ethanol (40 ml.) to give 0.7 g. of silvery white plates, m.p. 89.9–90.4°, a yield of about 30%. Dilution of the mother liquors gave silvery plates of m.p. 87.9–90.3°, so that isomeric dinitrobenzoates were not present in appreciable amounts. Two more recrystallizations of the crystals from ethanol gave the analytical sample of m.p. 90.3–90.4°—the m.p. was markedly depressed by admixture of the sample with ethyl 3,5-dinitrobenzoate.

Anal. Calc'd for $C_{15}H_{18}N_2O_8$: C, 50.82; H, 5.09.

Found: C, 50.91, 50.71; H, 5.44, 5.46.

Cis-cis-trans-cyclohexane-1,2,3-triol (β-pyrogallitol). (*a*). β-Dimethoxycyclohexanol (redistilled, b.p. 98–104° at 10 mm., 2.00 ml.), prepared in the methanolysis of the β-oxide, was heated in a sealed tube with aqueous hydrogen iodide (saturated at 0°, 5 ml.) at 65°

for 2 hours. The tube was then cooled, opened, and the upper layer of liquid removed in a pipette and added to a large excess of freshly precipitated silver carbonate. The lower liquid layer in the reaction tube was repeatedly washed with water, and these washings also were added to the silver carbonate and allowed to stand 2 hours with occasional stirring. The aqueous layer was then separated by filtration, saturated with hydrogen sulfide, again filtered, evaporated to dryness, taken up in ethanol (100 ml.), again filtered, and again evaporated to dryness. Distillation of the white crystalline residue (together with the corresponding residue from another run beginning with 1.00 ml. of the β-dimethoxycyclohexanol) from a Späth tube at 0.5 mm. gave a transparent white solid in a yield of 0.941 g., or about 36%. Recrystallization of the solid from ethyl acetate gave a product of m.p. 119.2–119.5°, and a mixture m.p. with authentic β-pyrogallitol (8) (m.p. 126.0–126.2°, made from pyrogallol), of 121.2–125.6°. One more recrystallization of the present product from ethyl acetate gave crystals of m.p. 124.7–125.0°. When 0.591 g. of these crystals was benzoylated with benzoyl chloride and pyridine, crystals melting sharply at 184.8° were obtained; the mixed m.p. with the *tribenzoate of* authentic *β-pyrogallitol* (m.p. 183.4–184.4°) was 184.2–184.8°. No α-pyrogallitol could be found in the mother-liquors.

(*b*) Because of the rather low yields obtained in the experiments with β-dimethoxycyclohexanol, a very faint possibility remained that the 3,5-dinitrobenzoate of β-dimethoxycyclohexanol might belong to the α-pyrogallitol series rather than to the β-pyrogallitol series. This possibility was removed by the following experiment. Saponification of the 3,5-dinitrobenzoate of β-dimethoxycyclohexanol (m.p. 90.3–90.4°, 0.425 g.) with alcoholic sodium hydroxide gave after the usual procedure, a clear, very slightly yellow liquid, b.p. up to 107° at 17.8 mm., in a yield of 0.1 g. Careful demethylation of the product with hydriodic acid according to the procedure described just above gave distilled crystals of m.p. 112.7–115.1° which on benzoylation gave crystals of m.p. 174.3–180.1° in a yield too small to permit further purification. These melting-points are of course well above those of pure α-pyrogallitol and its tribenzoate.

SUMMARY

1. A mixture of chlorohydrins is formed when 3-methoxycyclohexene is treated with monochlorourea in acid solution.

2. The mixed chlorohydrins of 3-methoxycyclohexene on treatment with alkali give rise to two stereoisomeric oxides which can be separated from each other by virtue of their different rates of formation.

3. Methanolysis of the first-formed or α-oxide of 3-methoxycyclohexene under alkaline conditions produces a dimethoxycyclohexanol which on demethylation gives the known α-pyrogallitol (*cis-trans-cis*-cyclohexane-1,2,3-triol).

4. The more slowly formed, or β-oxide of 3-methoxycyclohexene after a similar series of reactions gives β-pyrogallitol (*cis-cis-trans*-cyclohexane-1,2,3-triol).

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REFERENCES

(1) Gogek, Moir, McRae, and Purves, *Can. J. Chem.*, **29**, 938 (1951).
(2) McRae, Charlesworth, and Alexander, *Can. J. Res.*, **B 21**, 1 (1943).
(3) Mousseron, Manon, and Combes, *Bull. soc. chim. France*, 396 (1949).
(4) Mousseron, Winternitz, and Combes, *Bull. soc. chim. France*, 79 (1947).
(5) Brunel, *Compt. rend.*, **150**, 986 (1910).
(6) Posternak and Ravenna, *Helv. Chim. Acta*, **30**, 441 (1947).

(7) LINDEMANN AND DE LANGE, *Ann.*, **483**, 31 (1930).
(8) CHRISTIAN, GOGEK, AND PURVES, *Can. J. Chem.*, **29**, 911 (1951).
(9) IRVINE AND HYND, *J. Chem. Soc.*, **101**, 1128 (1912).
(10) HESS AND NEUMANN, *Ber.*, **68**, 1371 (1935).
(11) DETŒUF, *Bull. soc. chim.*, **31**, 102 (1922).
(12) OSTERBERG, *Org. Syntheses*, Coll. Vol. I, 179 (1932).
(13) VOGEL, *J. Chem. Soc.*, 1833 (1948).
(14) EISENLOHR, *quoted by* FAJANS in *Technique of Organic Chemistry*, Interscience Publishers, Inc., New York, 1945, Vol. I, p. 672.
(15) FRANKLAND AND O'SULLIVAN, *J. Chem. Soc.*, **99**, 2325 (1911).
(16) INGERSOLL, *Org. Reactions*, **2**, 376 (1944).