[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY]

Proximity Effects. VII. Stereospecific Syntheses of *cis*- and *trans*-1,5-Cycloöctanediols

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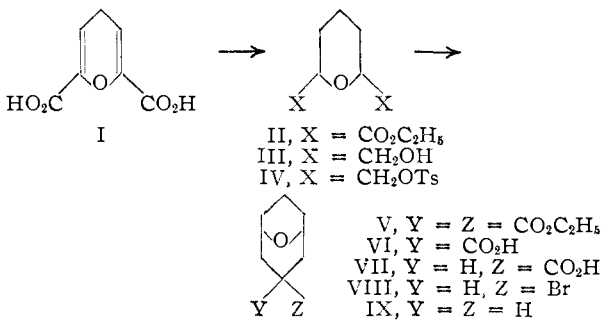
1,5-Epoxycycloöctane (IX) has been prepared by a reaction sequence beginning with pyran-2,6-dicarboxylic acid (I). This acid was hydrogenated and then esterified to form diethyl tetrahydropyran-*cis*-2,6-dicarboxylate (II). The ester was reduced with lithium aluminum hydride to *cis*-2,6-bis-(hydroxymethyl)-tetrahydropyran (III), which was converted to the ditosylate IV. The reaction of the ditosylate with diethyl malonate formed diethyl 3,7-epoxycycloöctane-1,1-dicarboxylate (V), which was saponified to the corresponding dicarboxylic acid VI. The mixture of stereoisomeric monocarboxylic acids VII formed on decarboxylation was converted to a mixture of silver salts, which on treatment with bromine formed a mixture of the stereoisomeric 1-bromo-3,7-epoxycycloöctanes (VIII). Removal of the bromine by hydrogenolysis in the presence of Raney nickel in triethylamine yielded the 1,5-epoxide IX. Cleavage of 1,5-epoxycycloöctane with a mixture of trifluoroacetic acid and acetic anhydride formed *trans*-1,5-cycloöctanediol (X), 4-cycloöcten-1-ol (XI) and a very small amount of *trans*-1,4-cycloöctanediol. The reaction of the 1,5-epoxide with acetyl bromide formed *trans*-5-bromocycloöctyl acetate (XII) and 4-cycloöcten-1-ol. Treatment of the bromoacetate XII with tetraethylammonium acetate followed by saponification yielded *cis*-1,5-cycloöctanediol (XIII) and 4-cycloöcten-1-ol.

This paper reports stereospecific syntheses of *cis*- and *trans*-1,5-cycloöctanediol. The synthesis employed was similar to the one used for preparation of the *cis*- and *trans*-1,4-cycloöctanediols described in the preceding paper.[1] The key intermediate in these syntheses was 1,5-epoxycycloöctane, which was prepared by the reaction sequence outlined below.



Pyran-2,6-dicarboxylic acid (I)[2] was reduced catalytically in the presence of palladium-on-Norit forming *cis*-tetrahydropyran-2,6-dicarboxylic acid, which was esterified without isolation, forming diethyl *cis*-tetrahydropyran-2,6-dicarboxylate (II). Reduction of the ester with lithium aluminum hydride formed the crystalline *cis*-glycol III, which was converted to the crystalline ditosylate IV. The alkylation of diethyl malonate with this ditosylate formed the cyclic ester V in 72% yield. It is of interest that only this product of dialkylation was isolated, even though its formation requires the intramolecular alkylation of an intermediate in which two bulky substituents in a six-membered ring occupy the sterically unfavorable axial positions. Saponification of the dicarboxylic ester V formed the corresponding acid VI (83%), and decarboxylation yielded a mixture of the stereoisomeric monocarboxylic acids VII in 98% yield. Both of these isomers were isolated in pure form. The less soluble and higher melting form with m.p. 137.2–137.8° was purified by crystallization from carbon tetrachloride, while the lower melting isomer, which was present in much smaller amount, was isolated from the mother liquors by partition chromatography by the method of Ramsey and Paterson.[3] The evidence available at present is insufficient to determine which acid contains the carboxyl group *cis* and which *trans* to the oxide bridge.

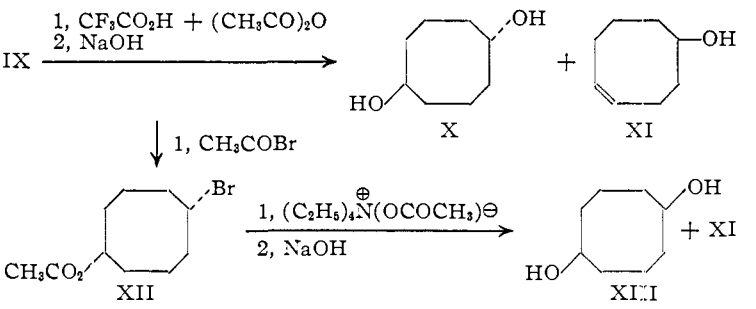
The method chosen for removal of the carboxyl group in VII was treatment of the corresponding silver salt with bromine. For this purpose, the mixture of the stereoisomers VII was converted to a mixture of the corresponding silver salts. Subsequent treatment with bromine in carbon tetrachloride formed a mixture of the stereoisomeric bromides VIII in 54% yield (allowing for 22% recovery of the higher melting acid VII). Attempts to remove the bromine atom in VIII by hydrogenolysis in the presence of palladium-on-Norit or platinum-in-glacial acetic acid containing sodium acetate were unsuccessful, because the catalysts became poisoned rapidly. However, the hydrogenolysis was successful in the presence of Raney nickel in triethylamine as a solvent and afforded 1,5-epoxycycloöctane (IX) (82%), a very volatile solid, m.p. 52.5–53.9°, with a camphoraceous odor.

Cleavage of the 1,5-oxide IX by treatment with a mixture of zinc chloride and acetic anhydride gave almost exclusively 4-cycloöcten-1-ol and very little glycol. The amount of elimination was decreased by using a mixture of acetic anhydride and trifluoroacetic acid for the cleavage. With this mixture, the products isolated after saponification were 4-cycloöcten-1-ol (40%), identified as the phenylurethan, and a mixture of glycols (28%) that was separated by chromatography on alumina. This mixture contained *trans*-1,5-cycloöctanediol (X) and *trans*-1,4-cycloöctanediol in a ratio of approximately 4:1. The *trans*-1,5-glycol was obtained as a very viscous oil that has failed to crystallize during a period of months. It formed a crystalline bis-*p*-nitrobenzoate, m.p. 182.3–183.3°, which is different from any of the other seven isomeric cycloöctanediol bis-*p*-nitrobenzoates (mixed melting points are depressed, and the infrared spectra of the isomers differ). The formation of a small amount of *trans*-1,4-cycloöctanediol in this reaction may be explained by addition of

(1) A. C. Cope and B. C. Anderson, THIS JOURNAL, **79**, 3892 (1957).

(2) E. E. Blaise and H. Gault, *Bull. soc. chim. France*, [4] **1**, 129 (1907).

(3) L. L. Ramsey and W. I. Paterson, *J. Assoc. Offic. Agr. Chemists*, **31**, 139 (1948).



acetic acid to the double bond in 4-cycloöcten-1-yl acetate in the presence of the very strong acid, trifluoroacetic acid.

Cleavage of the 1,5-epoxide IX with acetyl bromide formed *trans*-5-bromocycloöctyl acetate (XII) (47%) and 4-cycloöcten-1-yl acetate (20%). The reaction of the bromoacetate XI with tetraethylammonium acetate in acetone proceeded with inversion of configuration and afforded (after saponification) *cis*-1,5-cycloöctanediol (XIII) (14%) and 4-cycloöcten-1-ol (26%). The alcohols were separated by chromatography on alumina. The *cis*-1,5-glycol was obtained as a crystalline solid, m.p. 73.8–74.5°, which formed a bis-*p*-nitrobenzoate, m.p. 181.4–182.8°, that was different from the corresponding derivative of the *trans* isomer (mixed melting point and comparison of infrared spectra).

Evidence pointing to the steric proximity of groups attached to the 1- and 5-positions of the cycloöctane ring was obtained by observation of the behavior of *trans*-5-bromocycloöctyl acetate on saponification. This reaction resulted in the formation of the 1,5-epoxide IX.

Experimental[4]

Diethyl Tetrahydropyran-*cis*-2,6-dicarboxylate (II).—Diethyl oxaloacetate was regenerated from the commercial sodium enolate by treatment with dilute sulfuric acid and ether and isolated by extraction with ether and distillation; b.p. 92.5° (2.4 mm.), $n^{25}D$ 1.4482–1.4491. To the freshly distilled ester (179 g.) at 0° was added 40 g. of formalin (37% formaldehyde), sufficient 95% ethanol to give a homogeneous solution and 0.85 ml. of glacial acetic acid. Piperidine (3 ml.) was added with stirring while the temperature was maintained at 5–10°, and the solution was then placed in a refrigerator at 5°. After 7 hr. a solution of 1.5 ml. of piperidine and 0.41 ml. of glacial acetic acid in a small volume of ethanol was added to the yellow mixture with stirring, and it was allowed to stand at 5° for an additional period of 36 hr. The nearly solid mass was filtered, and the solid was washed with ice-cold methanol until the yellow color was removed. After drying at 1 mm. and room temperature overnight, there was obtained 136.4 g. (74%) of methylene bis-(diethyl oxaloacetate) as fine white crystals, m.p. 74.7–76.2° (lit.[5] m.p. 81°).

The above ester (228 g.) was stirred and heated under reflux with 230 ml. of concentrated hydrochloric acid and 230 ml. of water until the oily drops of the ester disappeared (about 2 hr.). The solution was concentrated under reduced pressure, and the residue was dried at 1 mm. for 4 hr. and recrystallized from a mixture of acetone and benzene to give 64.4 g. (71%) of α,α'-diketopimelic acid, m.p. 127.8–129.6° (lit.[6] m.p. 127°). Pyran-2,6-dicarboxylic acid[2] was prepared by dissolving 64.4 g. of finely powdered α,α'-diketopimelic acid in 325 ml. of concentrated sulfuric acid with stirring at 10–20° and allowing the solution to stand at 0° for 2.5 hr. The solution was poured into 3 l. of ice and water and the solid was collected on a filter and washed with 3 l. of water and 300 ml. of methanol. After drying at 0.5 mm. and room temperature, the yield of pyran-2,6-dicarboxylic acid was 54 g. (93%) (no definite m.p. below 300°).

A suspension of 54 g. of crude pyran-2,6-dicarboxylic acid in 600 ml. of absolute ethanol was hydrogenated at room temperature and 26–21 p.s.i. in the presence of 5 g. of 10% palladium-on-Norit. After 3.5 hr. the reduction was complete and the very slightly soluble acid had dissolved. The catalyst was removed by filtration and washed with two 150-ml. portions of hot absolute ethanol. Benzene (1.2 l.) and 2 ml. of concentrated sulfuric acid were added and the solution was refluxed overnight. The solution was slowly concentrated at atmospheric pressure during a period of 4 hr. and finally under reduced pressure. The residue was dissolved in ether and the solution was washed with saturated sodium bicarbonate solution, water, saturated sodium chloride solution and dried over Drierite. Distillation of the product gave 64.8 g. (91%) of diethyl *cis*-tetrahydropyran-2,6-dicarboxylate, b.p. 95° (0.07 mm.), $n^{25}D$ 1.4527, d^{25}_4 1.118.

Anal. Calcd. for $C_{11}H_{18}O_5$: C, 57.38; H, 7.88. Found: C, 57.35; H, 7.94.

A sample of the ester was refluxed overnight with potassium hydroxide in ethanol. The solution was concentrated, diluted with water, acidified and extracted with chloroform in a continuous extractor. The extract was dried over magnesium sulfate and concentrated to dryness. The residue of tetrahydropyran-*cis*-2,6-dicarboxylic acid had m.p. 191–192.2° (lit.[7] m.p. 193°).

***cis*-2,6-Bis-(hydroxymethyl)-tetrahydropyran (III).**—A solution of diethyl tetrahydropyran-*cis*-2,6-dicarboxylate (64.2 g.) in 550 ml. of dry ether was added with stirring to a slurry of lithium aluminum hydride (13.6 g.) in 400 ml. of dry ether with stirring in a 3-l., three-necked flask which was protected against moisture. The rate of addition was such that a gentle reflux was maintained. After refluxing for an additional 1.5 hr., the excess lithium aluminum hydride was destroyed by the cautious addition of water. The complex was decomposed with approximately 275 ml. of 20% sulfuric acid. The ether layer was separated and dried over magnesium sulfate. The aqueous layer was extracted with chloroform in a continuous extractor for 26 hr. and the chloroform extract dried over magnesium sulfate. The extracts were combined and the product distilled to give 37.6 g. (92%) of *cis*-2,6-bis-(hydroxymethyl)-tetrahydropyran. The product solidified on standing overnight in a refrigerator and had m.p. 41–44.4°. After several recrystallizations from ether–petroleum ether (30–60°) it had m.p. 45.7–46.4°.

Anal. Calcd. for $C_7H_{14}O_3$: C, 57.44; H, 9.65. Found: C, 57.33; H, 9.69.

***cis*-2,6-Bis-(hydroxymethyl)-tetrahydropyran Ditosylate (IV).**—To a solution of *cis*-2,6-bis-(hydroxymethyl)-tetrahydropyran (37.6 g.) in 130 ml. of dry pyridine was added at 0° in one portion *p*-toluenesulfonyl chloride (108 g.) in 400 ml. of dry pyridine. The solution was stirred at 0° for approximately 20 hr. and poured with stirring into about 2 l. of ice and water. The product separated as an oil but soon solidified. It was collected on a filter, washed with large amounts of water and recrystallized from methanol to give 103 g. (95%) of *cis*-2,6-bis-(hydroxymethyl)-tetrahydropyran ditosylate, m.p. 93–94°. An analytical sample that was recrystallized from methanol had m.p. 93.8–94.8°.

Anal. Calcd. for $C_{19}H_{22}O_7S_2$: C, 55.49; H, 5.76. Found: C, 55.42; H, 5.61.

Diethyl 3,7-Epoxycycloöctane-1,1-dicarboxylate (V).—A 3-l. stainless steel autoclave was charged with a solution of diethyl malonate (13.6 g.) in 100 ml. of dry tetrahydrofuran. Sodium hydride (4.1 g.) was added over the course of 2 hr., followed by *cis*-2,6-bis-(hydroxymethyl)-tetrahydropyran ditosylate (35 g.) and 1400 ml. of dry tetrahydrofuran. The autoclave was sealed and rocked and heated at 110–120° for 27 hr. The mixture was rinsed from the bomb with dry ether and concentrated under reduced pressure. To the

(4) Melting points are corrected and boiling points are uncorrected. We are indebted to Dr. S. M. Nagy and his associates for analyses.

(5) This preparation is a modification of a procedure described by H. Gault, *Bull. soc. chim. France*, [4] 1, 24 (1907).

(6) E. E. Blaise and H. Gault, *ibid.*, [4] 1, 78 (1907).

(7) W. Czornodola, *Roczniki Chem.*, 16, 459 (1936); *C. A.*, 31, 1807 (1937).

concentrate was added about 350 ml. of 10% hydrochloric acid, and the product was extracted with three 170-ml. portions of ether. The extracts were combined, washed with saturated sodium chloride solution and dried over magnesium sulfate. Two additional preparations were made under similar conditions from 35 and 33 g. of the ditosylate, respectively. The ether extracts of the three preparations were combined, concentrated and the product was distilled, yielding 43.6 g. (72%) of diethyl 3,7-epoxycycloöctane-1,1-dicarboxylate, b.p. 104° (0.15 mm.), $n^{25}D$ 1.4639. An analytical sample had b.p. 104° (0.15 mm.), $n^{25}D$ 1.4650, d^{25}_4 1.133.

Anal. Calcd. for $C_{14}H_{22}O_5$: C, 62.20; H, 8.21. Found: C, 62.40; H, 8.17.

The residue from the distillation was dissolved in methanol and treated with Norit; it yielded 4.25 g. of the recovered crystalline ditosylate.

3,7-Epoxycycloöctane-1,1-dicarboxylic Acid (VI).—Diethyl 3,7-epoxycycloöctane-1,1-dicarboxylate (43.6 g.) was heated under reflux with potassium hydroxide (27 g.) in 130 ml. of 95% ethanol and 20 ml. of water for 21 hr. The solution was concentrated under reduced pressure, 130 ml. of water was added to the residue and the aqueous solution was acidified. The precipitated dicarboxylic acid was removed by filtration and the mother liquor was extracted continuously overnight with chloroform. A total of 28.8 g. (83%) of crude 3,7-epoxycycloöctane-1,1-dicarboxylic acid was obtained, m.p. 167° dec. (the fraction separated by filtration) and 182° dec. (from the chloroform extracts). An analytical sample was obtained by recrystallization from ethyl acetate and had m.p. 186.5–187° dec.

Anal. Calcd. for $C_{10}H_{14}O_5$: C, 56.07; H, 6.59; neut. equiv., 107. Found: C, 56.18; H, 6.71; neut. equiv., 108.

Decarboxylation of 3,7-Epoxycycloöctane-1,1-dicarboxylic Acid.—3,7-Epoxycycloöctane-1,1-dicarboxylic acid (28.8 g.) was heated at 200° until the evolution of gas ceased. The product, a mixture of the stereoisomeric 3,7-epoxycycloöctane-1-carboxylic acids, weighed 22.8 g. (98%), m.p. 122.5–134°.

Separation of the Isomeric 3,7-Epoxycycloöctane-1-carboxylic Acids (VII).—A 1.509-g. sample of the mixture of isomers was recrystallized once from carbon tetrachloride and gave 1.05 g. of material with m.p. 133–137°, a recovery of 70%. This proved to be one of the isomeric 3,7-epoxycycloöctane-1-carboxylic acids. After two additional recrystallizations, it had m.p. 137.2–137.8°.

Anal. Calcd. for $C_9H_{14}O_3$: C, 63.54; H, 8.29; neut. equiv., 170. Found: C, 63.58; H, 8.21; neut. equiv., 168.

The other isomeric 3,7-epoxycycloöctane-1-carboxylic acid was isolated by partition chromatography[3] of the mother liquors from recrystallization of the mixture. The mixture (100 mg.) was chromatographed on 40 g. of 100-mesh silicic acid and during the elution with isoöctane two bands appeared on the column. They were fractionally eluted with 4 fractions being collected. Fraction 1 (41 mg., main portion of the first band) had m.p. 137–137.6°; fraction 2 (9 mg., remainder of the first band) had m.p. 134–135.6°; fraction 3 (19 mg., front portion of the second band) had m.p. 87.2–89.7°; and fraction 4 (18 mg., main portion of the second band) had m.p. 89.6–90.4°.

Fractions 3 and 4 were combined and recrystallized from hexane and furnished the second isomeric 3,7-epoxycycloöctane-1-carboxylic acid, m.p. 90–90.6°. The infrared absorption spectrum of this acid was different from the spectrum of the higher melting isomer.

Anal. Calcd. for $C_9H_{14}O_3$: C, 63.54; H, 8.29; neut. equiv., 170. Found: C, 63.85; H, 8.51; neut. equiv., 163.

1-Bromo-3,7-epoxycycloöctane (VIII).—A mixture of the isomeric 3,7-epoxycycloöetane-1-carboxylic acids (11.6 g.) and 50 ml. of water was heated to boiling and neutralized to the phenolphthalein end-point with 30% potassium hydroxide. The solution of the potassium salts was again heated to boiling and treated with a solution of silver nitrate (11.6 g.) in 10 ml. of water with constant agitation. The mixture was allowed to cool and filtered. The solid was washed with 100 ml. of methanol and dried at 1 mm. to give 15.3 g. (81%) of silver 3,7-epoxycycloöctane-1-carboxylate.

The silver salt (14.89 g.) was dried at 0.05 mm. and 90–100° for 34 hr. in a 500-ml. round-bottomed three-necked flask. The flask was then equipped with a Hershberg stirrer and an addition funnel. Carbon tetrachloride which had been dried over phosphorus pentoxide was added and about 50 ml. of the solvent distilled from the flask. A solution of bromine (8.8 g.) in 40 ml. of carbon tetrachloride (the solution was dried over phosphorus pentoxide) was then added dropwise over a period of 17 min. while the temperature was maintained at 0–5°. The mixture was stirred for an additional period of 15 min. at 0–5° and then allowed to warm with stirring to room temperature; during this time some carbon dioxide was evolved. Upon heating under reflux carbon dioxide was evolved vigorously and ceased after 1.3 hr. After cooling, the silver bromide was removed by filtration and washed with a total of 100 ml. of hot carbon tetrachloride. The combined extracts were washed with 20 ml. of 10% sodium carbonate solution and dried over magnesium sulfate. The solution was concentrated under reduced pressure, and the residue was fractionally distilled through a semi-micro column to give 3.76 g. of the crude bromide. Decomposition was noted during the distillation of the last fraction and the distillation was stopped. The residue on short-path distillation yielded an additional 0.964 g. of a waxy solid, making a total of 4.73 g. (43%) of 1-bromo-3,7-epoxycycloöctane. All of the fractions eventually solidified. A center cut had these properties: b.p. 78.5° (1.5 mm.), m.p. 34.7–40°, $n^{26}D$ 1.5298.

Anal. Calcd. for $C_8H_{13}BrO$: C, 46.84; H, 6.39; Br, 38.97. Found: C, 46.75; H, 6.38; Br, 38.72.

The sodium carbonate extract was acidified and 1.97 g. of the higher melting isomer of 3,7-epoxycycloöctane-1-carboxylic acid was separated, m.p. 136.2–137.8° and m.p. 137–137.8° after recrystallization from carbon tetrachloride.

1,5-Epoxycycloöctane (IX).—1-Bromo-3,7-epoxycycloöctane (8.99 g.) in 50 ml. of dry triethylamine was shaken with hydrogen overnight in the presence of approximately 2 g. of Raney nickel at 1500 p.s.i. and 90–100° in a 200-ml. glass-lined autoclave. After cooling, ether was added to the mixture and the solid was removed by filtration and washed several times with ether. The ether solution was washed with iced dilute hydrochloric acid, and the aqueous solution was extracted with two 15-ml. portions of ether. The combined extracts were washed with saturated sodium bicarbonate solution, saturated sodium chloride solution and dried over Drierite. The ether was distilled through a fractionating column and the residue was fractionated through a semi-micro column. The fractions solidified, and a center fraction had the following properties: b.p. 81° (30 mm.), m.p. 52.5–53.9° (after sublimation).

Anal. Calcd. for $C_8H_{14}O$: C, 76.14; H, 11.18. Found: C, 75.90; H, 10.88.

Cleavage of 1,5-Epoxycycloöctane with Acetic Anhydride and Trifluoroacetic Acid.—To 1,5-epoxycycloöctane (1.033 g.) was added a cold mixture of acetic anhydride (2.52 g.) and trifluoroacetic acid (7 g.). The solution was allowed to warm to room temperature, and after 40 min. it was heated at 80–85° for 1 hr. The solution was concentrated at 30 mm. by distillation through a semi-micro column with a final bath temperature of 105°. The dark residue was heated under reflux overnight with potassium hydroxide (4.6 g.) in 14 ml. of ethanol and 7 ml. of water. The solution was concentrated under reduced pressure, water was added to the residue and concentrated hydrochloric acid was added with cooling until a *p*H of 8–9 was reached. The aqueous mixture was extracted continuously with chloroform for 48 hr. and the chloroform removed under reduced pressure, leaving 860 mg. of a dark viscous oil. This product was taken up in 14 ml. of 1:1 ether–benzene and chromatographed on 30 g. of Activity III alumina, in a column 20 mm. in diameter, collecting 30-ml. fractions. Fractions 1, 4–9, 13–14, 30–31, 55–63 and 64–75 were discarded.

4-Cycloöcten-1-ol (XI).—The combined fractions 2 and 3 were distilled in a short-path still under reduced pressure to give a colorless liquid, $n^{25}D$ 1.4952. A 114-mg. sample was treated with 274 mg. of phenyl isocyanate, and the mixture was heated on a steam-bath for a few minutes and allowed to stand at room temperature overnight. Removal of the excess reagent at 1 mm. left 209 mg. of a phenylurethan with m.p. 86.8–93°. After several recrystallizations from hexane it had m.p. 94.5–95.4° and was identified as 4-cycloöcten-1-ol phenylurethan by comparison of the infrared spectrum with the spectrum of an authentic sample.[1]

***trans*-1,5-Cycloöctanediol Bis-*p*-nitrobenzoate.**—Fractions 15–20 (62 mg.) were treated with *p*-nitrobenzoyl

Fraction	Eluent	Weight, mg.
1	Benzene–ether (1:1)	5
2–3	Benzene–ether (1:1)	364
4–9	Benzene–ether (1:1)	32
13–14	Ether	9
15–20	Ether	63
21–29	Ether	30
30–31	0.5% methanol–ether	3
32–37	0.5% methanol–ether	115
38–46	0.5% methanol–ether	75
47–54	0.5% methanol–ether	27
55–63	1.5% methanol–ether	11
64–75	10% methanol–ether	12

chloride (192 mg.) in a few milliliters of dry pyridine, and the solution was allowed to stand overnight. The solution was poured into water and the solid collected on a filter and washed with water. The product was dissolved in benzene and chromatographed on 5 g. of Activity II alumina to give 133 mg. (72%) of *trans*-1,5-cycloöctanediol bis-*p*-nitrobenzoate, which after recrystallization from ethanol had m.p. 182.3–183.3°.

Anal. Calcd. for $C_{22}H_{22}O_8N_2$: C, 59.72; H, 5.01; N, 6.33. Found: C, 59.91; H, 5.19; N, 6.32.

The infrared absorption spectrum of the *trans*-1,5-cyclooctanediol bis-*p*-nitrobenzoate was quite different from the spectra of the bis-*p*-nitrobenzoates of the other seven cyclooctanediols.

Treatment of fractions 21–29 (30 mg.) with *p*-nitrobenzoyl chloride (140 mg.) in the manner described above gave 76 mg. (86%) of *trans*-1,5-cycloöctanediol bis-*p*-nitrobenzoate, m.p. 182–182.8° after recrystallization from ethanol.

trans-1,5-Cycloöctanediol bis-*p*-nitrobenzoate (25 mg.) was heated under reflux with 0.2 g. of potassium hydroxide in 5 ml. of ethanol for 2 hr. The ethanol was removed under reduced pressure, water added and the aqueous solution extracted continuously with chloroform for 2 hr. After drying over magnesium sulfate and removal of solvent, there was left 5 mg. (63%) of *trans*-1,5-cycloöctanediol as an oil which has not crystallized in a period of several months.

Identification of *trans*-1,4-Cycloöctanediol.—Fractions 47–54 (27 mg.) were treated with *p*-nitrobenzoyl chloride (105 mg.) in dry pyridine, and the product was isolated by the procedure described above. The crude bis-*p*-nitrobenzoate amounted to 89 mg. and after six recrystallizations was identified as *trans*-1,4-cycloöctanediol bis-*p*-nitrobenzoate, m.p. 154.9–156.3°, not depressed on mixture with an authentic sample.[8]

Cleavage of 1,5-Epoxycycloöctane with Acetyl Bromide.—To 1,5-epoxycycloöctane (1.01 g.) was added acetyl bromide (2.25 g.), and the mixture was heated under reflux for 75 min. The mixture was cooled, poured into water and the product was extracted with three 15-ml. portions of ether. The combined extracts were washed with saturated sodium bicarbonate solution, water, saturated sodium chloride solution and dried over magnesium sulfate. After removal of the ether the product was distilled through a semi-micro column. A low boiling fraction (1) 228 mg., b.p. 40° (0.2 mm.), $n^{25}D$ 1.4702, was separated from three fractions totaling 948 mg., b.p. 82–83° (0.2 mm.), $n^{25}D$ 1.4955–1.4984. Fraction 1 was identified as 4-cycloöcten-1-yl acetate (20% yield) by saponification to the alcohol (75 mg., $n^{25}D$ 1.4969), which was converted to the phenylurethan, m.p. and mixed m.p. with an authentic sample[1] (after recrystallization from hexane) 93–94.5°. The higher boiling fractions correspond to a 47% yield of *trans*-5-bromocycloöctyl acetate (XII).

1,5-Epoxycycloöctane from *trans*-5-Bromocycloöctyl Acetate.—*trans*-5-Bromocycloöctyl acetate (599 mg.) was heated under reflux with potassium hydroxide (522 mg.) in 5 ml. of absolute ethanol. The mixture was poured into 30 ml. of water and the product was extracted with four 10-ml. portions of ether. The combined extracts were washed with water and saturated sodium chloride solution and dried over magnesium sulfate. The solvent was removed at atmospheric pressure and the product sublimed at 90 mm. and 50°. There was obtained in two fractions 107 mg. (42%) of 1,5-epoxycycloöctane, m.p. 48.2–52.4°.

***cis*-1,5-Cycloöctanediol (XIII).**—Crude *trans*-5-bromocycloöctyl acetate (0.99 g.) and tetraethylammonium acetate monohydrate (1.7 g.) were heated under reflux in 20 ml. of reagent grade acetone for 16 hr. Most of the acetone was removed by distillation and water was added. The product was extracted with ether and the extract washed with water and saturated sodium chloride solution and dried over magnesium sulfate. The ether was removed under diminished pressure and the product heated under reflux with 2 g. of potassium hydroxide in 15 ml. of 95% ethanol. The ethanol was removed under reduced pressure, water was added and the aqueous solution was extracted with ether. The aqueous solution also was extracted continuously with chloroform for several hours, and the total amount of glycol from the two extracts (300 mg.) was chromatographed on 10 g. of grade II alumina in a column 10 mm. in diameter, collecting 15-ml. fractions.

Fraction	Eluent	Weight, mg.
1	Benzene–ether	5
2–10	Benzene–ether	123
11–16	Ether	0
17–23	1% methanol–ether	78

Fractions 2–10 were distilled in a short-path still under reduced pressure and yielded 4-cycloöcten-1-ol, $n^{25}D$ 1.4951, identified as the phenylurethan (m.p. and mixed m.p. of 92.4–93.4°, and by its infrared spectrum, which was identical to the spectrum of an authentic sample[1]).

Fraction 18 solidified on removal of the eluent and had m.p. 72.5–73.5°. After 2 recrystallizations from ether–petroleum ether (30–60°) there was obtained crystalline *cis*-1,5-cycloöctanediol, m.p. 73.8–74.8°.

Anal. Calcd. for $C_8H_{16}O_2$: C, 66.62; H, 11.19. Found: C, 66.72; H, 11.13.

The infrared absorption spectrum of the *cis*-1,5-glycol was different from the spectra of the other seven cycloöctanediols.

The combined fractions 19–23 had m.p. 68.7–71.9° and yielded the pure *cis*-1,5-glycol upon recrystallization.

***cis*-1,5-Cycloöctanediol Bis-*p*-nitrobenzoate.**—A sample of the above diol (20 mg.) was treated with *p*-nitrobenzoyl chloride (75 mg.) in a few milliliters of dry pyridine. The yield of *cis*-1,5-cycloöctanediol bis-*p*-nitrobenzoate was 51 mg. (83%). After two recrystallizations from ethanol, the derivative had m.p. 181.4–182.6°. A mixture with *trans*-1,5-cycloöctanediol bis-*p*-nitrobenzoate had m.p. 159–168°. An analytical sample had m.p. 181.4–182.8°.

Anal. Calcd. for $C_{22}H_{22}O_8N_2$: C, 59.72; H, 5.01; N, 6.33. Found: C, 59.99; H, 5.13; N, 6.33.

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(8) A. C. Cope, A. H. Keough, P. E. Peterson, H. E. Simmons, Jr., and G. W. Wood, THIS JOURNAL, **79**, 3900 (1957).