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

Proximity Effects. V. Reaction of Cycloöctene Dibromide with Tetraethylammonium Acetate

BY ARTHUR C. COPE AND HERBERT E. JOHNSON[1]

RECEIVED MARCH 8, 1957

The reaction of cycloöctene dibromide with tetraethylammonium acetate in acetone, unlike the reaction with silver acetate in acetic acid, has been found to yield only normal elimination and displacement products, rather than compounds formed by "transannular reactions." The compounds isolated were 1-bromocycloöctene (9%), 2-cycloöcten-1-yl acetate (45%), *cis*-2-bromocycloöctyl acetate (9%) and *trans*-1,2-cycloöctanediol diacetate (5%). *trans*-2-Bromocycloöctyl acetate has been prepared from *cis*-cycloöctene oxide and hydrogen bromide and shown to react with tetraethylammonium acetate to form 2-cycloöcten-1-yl acetate (45%) and *cis*-1,2-cycloöctanediol diacetate (17%). The reaction of cycloöctene dibromide with silver acetate in dry acetic acid at 60° has been found to give the same products in approximately the same yields that were obtained at 110–120°.

The results described in the preceding paper[2] show that the reaction of cycloöctene dibromide with silver acetate in dry acetic acid yields only a small amount (2.3%) of *trans*-1,2-cycloöctanediol diacetate, the remaining products being formed by "transannular reactions." Indirect evidence showed that the liquid cycloöctene dibromide probably contained a minimum of 77% of *trans*-1,2-dibromocycloöctane, indicating that most or all of the "transannular products" are formed during the reaction of cycloöctene dibromide with silver acetate, rather than in the addition of bromine to cycloöctene. Since the reaction of silver acetate with halides proceeds by an ionization (S$_N$1) mechanism,[3] it was of interest to investigate the reaction of cycloöctene dibromide with a reagent known to react by a bimolecular (S$_N$2) mechanism. This paper describes the reaction with such a reagent, tetraethylammonium acetate.[4]

Reaction of cycloöctene dibromide with tetraethylammonium acetate in refluxing acetone for 17 hr. resulted in incomplete reaction, and 20% of the dibromide was recovered. Extension of the reaction time to 72 hr. produced essentially complete reaction, and only 1% of the dibromide was recovered. Distillation of the products gave two low boiling fractions: (1) 9% of 1-bromocycloöctene and (2) 45% of 2-cycloöcten-1-yl acetate (yields based on cycloöctene dibromide). The identity of fraction 1 was established by comparison of the physical properties and infrared spectrum with data for an authentic sample of 1-bromocycloöctene. Hydrolysis of fraction 2 followed by the reaction of the resulting alcohol with phenyl isocyanate formed 2-cycloöcten-1-yl phenylurethan, identical by comparison of melting point, mixed melting point and infrared spectra with an authentic sample.[5] The absence of isomeric phenylurethans was established by chromatography of the derivative.

Chromatography of the higher boiling material (fraction 3) on alumina yielded: (a) 1% of cyclooctene dibromide, (b) 9% of *cis*-2-bromocyclooctyl acetate and (c) 5% of *trans*-1,2-cycloöctanediol diacetate.

Hydrolysis of (b) with dilute sulfuric acid formed a 2-bromocycloöctanol which was converted into a 3,5-dinitrobenzoate, m.p. 116.5–117.5°. This derivative was found to be identical with an authentic sample of *cis*-2-bromocycloöctyl 3,5-dinitrobenzoate, which was prepared by the following method. Bromination of cycloöctanone with N-bromosuccinimide formed 2-bromocycloöctanone, which was reduced with sodium borohydride to a mixture of *cis*- and *trans*-2-bromocycloöctanol. The mixture yielded two 3,5-dinitrobenzoates, m.p. 117.0–117.5° and 94–95°, which were separated by crystallization from hexane. The lower melting derivative was identified as the *trans* isomer by comparison with an authentic sample, obtained as follows. The reaction of *cis*-cycloöctene oxide with anhydrous hydrogen bromide in carbon tetrachloride formed *trans*-2-bromocycloöctanol. This alcohol formed a 3,5-dinitrobenzoate, m.p. 95.0–95.6°, that was identical (mixed m.p. and comparison of infrared spectra) with the derivative melting at 94–95° obtained from the mixture of 2-bromocycloöctanols formed by reduction of 2-bromocycloöctanone. The higher melting 3,5-dinitrobenzoate isolated from the mixture, m.p. 117.0–117.5°, accordingly is the *cis* isomer.

Fraction c was saponified and the neutral product was treated with acetone and anhydrous copper sulfate. Subsequent purification by chromatography yielded the isopropylidene ketal of *trans*-1,2-cycloöctanediol, identified by comparison of the infrared spectrum with the spectrum of an authentic sample and showed that no other glycols were present.

The formation of unsaturated compounds from cycloöctene dibromide and tetraethylammonium acetate probably occurs by an elimination process (E2) in which acetate ion serves as the base. Two products could be formed initially by such a process, 1-bromocycloöctene and 3-bromocycloöctene. The first of these compounds was one of the products isolated, while the second would react with tetraethylammonium acetate under the conditions employed to form 2-cycloöcten-1-yl acetate, which also was isolated. Another possible route to 2-cycloöcten-1-yl acetate would involve initial formation of a 2-bromocycloöctyl acetate (probably the *cis* isomer, which has been shown to be one of

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[1] National Institutes of Health Postdoctoral Fellow, 1955–1956.

[2] A. C. Cope and G. W. Wood, THIS JOURNAL, **79**, 3885 (1957).

[3] S. Winstein and R. E. Buckles, *ibid.*, **64**, 2780 (1942).

[4] (a) L. N. Owen and P. N. Smith, *J. Chem. Soc.*, 4035 (1952); (b) J. D. Roberts, W. G. Young and S. Winstein, THIS JOURNAL, **64**, 2157 (1942); (c) J. Steigman and L. P. Hammett, *ibid.*, **59**, 2536 (1937).

[5] A. C. Cope, M. R. Kinter and R. T. Keller, *ibid.*, **76**, 2757 (1954).

the products), followed by elimination of hydrogen bromide, with acetate ion serving as the base.

trans-1,2-Cycloöctanediol diacetate, the only glycol derivative isolated from the reaction mixture, could be formed either through a succession of neighboring group participations,[3] or more probably by two Walden inversions, with *cis*-2-bromocycloöctyl acetate as an intermediate. Insufficient *cis*-2-bromocycloöctyl acetate was available to determine whether it would react with tetraethylammonium acetate with inversion. However, the reaction of the more accessible *trans*-2-bromocyclooctyl acetate with tetraethylammonium acetate in refluxing acetone for 72 hr. gave 45% of 2-cycloöcten-1-yl acetate and 17% of *cis*-1,2-cyclooctanediol diacetate (formed by inversion) as the only isolable products. With the shorter reaction time of 24 hr., 43% of the original *trans*-2-bromocycloöctyl acetate was recovered. The observation that *trans*-2-bromocycloöctyl acetate and tetraethylammonium acetate form *cis*-1,2-cyclooctanediol diacetate leads to the conclusion that the intermediate in the reaction in which *trans*-1,2-cycloöctanediol diacetate is formed from cyclooctene dibromide is *cis*-2-bromocycloöctyl acetate.

It is of interest that all of the products isolated from the reaction of cycloöctene dibromide and tetraethylammonium acetate can be formed by normal displacement or elimination reactions from *trans*-1,2-dibromocycloöctane. This result provides good evidence that cycloöctene dibromide is essentially homogeneous and is the *trans*-1,2-dibromide. If appreciable amounts of a dibromide other than the 1,2-isomer had been present, the diacetate formed from it by a normal displacement reaction should have been isolated as a glycol after saponification. As noted above, only the *trans*-1,2-glycol was isolated (as the isopropylidene ketal, by chromatography), under conditions capable of revealing the presence of a fraction of 1% of an isomer.

The results of the bimolecular displacement reaction of cycloöctene dibromide with tetraethylammonium acetate leading solely to normal products are in contrast to the reaction of the dibromide with silver acetate in dry acetic acid, in which abnormal "transannular" products are formed predominantly.[2] A conclusion that receives strong support from these data is that the transannular hydride shift characterizing the "transannular reactions" is favored by the transitory formation of a carbonium ion, as in the removal of bromide ion from cycloöctene dibromide by silver ion (S$_N$1 or ionization mechanism), and does not occur in the bimolecular nucleophilic displacement (S$_N$2, reaction with tetraethylammonium acetate. Other "transannular reactions" observed to date have involved the reaction of cyclic olefins with medium-sized rings with performic acid,[6,7] acid hydrolysis or solvolysis of the epoxides of such cyclic olefins[6,8] and the reaction of cyclodecylamine with nitrous acid.[9] All of these reactions were conducted in polar media and proceed through intermediates with at least partially charged (ionic) character. In contrast, reactions involving cyclic compounds with ring sizes favoring "transannular reactions" that have been observed to give only normal products in non-polar media include, in addition to the reaction of cycloöctene dibromide with tetraethylammonium acetate in acetone, the addition of bromine to *cis*-cycloöctene in carbon tetrachloride forming *trans*-1,2-dibromocycloöctane and the reaction of hydrogen bromide with *cis*-cycloöctene oxide in carbon tetrachloride forming *trans*-2-bromocycloöctanol.

In order to make certain that the strikingly different course of the reaction of cycloöctene dibromide with silver acetate[2] and tetraethylammonium acetate was not due in part to a temperature effect, the reaction with silver acetate (previously conducted at 110–120°) was repeated at 60°. The high-boiling diacetate fraction was saponified and gave the same yields of *cis*- and *trans*-1,4-cyclooctanediol and *trans*-1,2-cycloöctanediol that were formed at 110–120°.[2] No 1-bromocycloöctene appeared to be present in the low-boiling fraction. The cycloöctenyl acetate fraction was saponified and the mixture of cycloöctenols was converted to a mixture of phenylurethans, which was chromatographed as before.[2] The first fractions eluted yielded a small amount of 4-cycloöcten-1-yl phenylurethan, m.p. 92–94°, identical with a slightly purer sample, m.p. 93–94°, obtained by the cleavage of 1,4-epoxycycloöctane with acetic anhydride and boron trifluoride.[10] The identity of this derivative was established by ozonization, reduction of the ozonide with sodium borohydride and treatment with phenyl isocyanate, which formed the known 1,4,8-octanetriol tris-phenylurethan.[2] Proof that the previously isolated[2] phenylurethan of m.p. 73–74° was a mixture was obtained by cocrystallization of equal quantities of 3-cycloöcten-1-yl phenylurethan and 4-cycloöcten-1-yl phenylurethan. The material that crystallized had an infrared spectrum identical to the spectrum of the phenylurethan of m.p. 73–74°. As before, the majority of the fractions from the chromatogram were mixtures of 3- and 4-cycloöcten-1-yl phenylurethan, while the final fractions yielded 3-cyclooocten-1-yl phenylurethan, m.p. 102–103°.

Experimental[11]

Reaction of *trans*-1,2-Dibromocycloöctane with Tetraethylammonium Acetate.—A solution of 22.3 g. (0.0825 mole) of cycloöctene dibromide and 62.2 g. (0.30 mole) of tetraethylammonium acetate monohydrate[4c] in 300 ml. of dry acetone was refluxed for 72 hr. At this time the acetone was removed by warming under reduced pressure and the pasty residue was taken up in water and ether. The ether layer was separated and the aqueous phase further extracted with ether. Combination of the ether extracts, drying over anhydrous magnesium sulfate and distillation of the ether left a light yellow residue. Fractional distillation of this

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(6) A. C. Cope, S. W. Fenton and C. F. Spencer, THIS JOURNAL, **74**, 5884 (1952).

(7) V. Prelog and K. Schenker, *Helv. Chim. Acta*, **35**, 2044 (1952); V. Prelog, K. Schenker and W. Kung, *ibid.*, **36**, 471 (1953); V. Prelog and V. Boarland, *ibid.*, **38**, 1776 (1955).

(8) A. C. Cope, A. Fournier, Jr., and H. E. Simmons, Jr., THIS JOURNAL, **79**, 3905 (1957).

(9) V. Prelog, H. J. Urech, A. A. Bothner-By and J. Würsch, *Helv. Chim. Acta*, **38**, 1095 (1955).

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

(11) Melting points are corrected and boiling points are uncorrected. We are indebted to Dr. S. M. Nagy and his associates for analyses Alumina used for chromatography was supplied by Merck and Co. Inc., and treated as described in footnote 20 of the preceding paper.

material gave three fractions: (1) 1.44 g. (9%), b.p. 35–40° (0.2 mm.), $n^{25}D$ 1.5003; (2) 6.26 g. (45%), b.p. 49–51° (0.2 mm.), $n^{25}D$ 1.4688; (3) 3.98 g., b.p. 75–79° (0.2 mm.), $n^{25}D$ 1.4830.

Fraction 1 was dissolved in petroleum ether and passed onto a column of 10-mm. diameter containing 65 g. of grade I alumina. Elution with 160 ml. of petroleum ether gave 0.94 g. of a volatile liquid. Distillation of this material afforded 1-bromocycloöctene, b.p. 108° (30 mm.), $n^{25}D$ 1.5150, with an infrared spectrum identical with the spectrum of an authentic sample.[12]

A portion of fraction 2 was saponified and converted to its phenylurethan by a procedure previously described.[2] Chromatography of 2.54 g. of this material over 200 g. of grade I alumina in a 24-mm. diameter column and elution with benzene–ether (9:1) gave 2-cycloöcten-1-yl phenylurethan as a colorless solid, m.p. 92.5–93.5°, in 80% yield. The mixed melting point of this derivative with an authentic sample[5] showed no depression, and comparison of the infrared spectra showed them to be identical. Although the last fractions (5% of the phenylurethan isolated) eluted from the column were somewhat impure as indicated by the range in melting point, no derivative could be isolated from them other than 2-cycloöcten-1-yl phenylurethan.

Fraction 3 was dissolved in petroleum ether and passed onto a column of 24-mm. diameter containing 200 g. of grade I alumina. Elution with 600 ml. of petroleum ether gave (a) 0.25 g. (1%) of cycloöctene dibromide, $n^{25}D$ 1.5510, identified by comparison of its infrared spectrum with that of an authentic sample. Elution with 800 ml. of 10% ether in petroleum ether gave (b) 1.87 g. (9%) of *cis*-2-bromocycloöctyl acetate. Distillation resulted in isolation of this compound as a colorless, pleasant-smelling liquid, b.p. 72° (0.25 mm.), $n^{25}D$ 1.4960.

Anal. Calcd. for $C_{10}H_{17}BrO_2$: C, 48.20; H, 6.88. Found: C, 48.47; H, 6.86.

A solution of 62 mg. of *cis*-2-bromocycloöctyl acetate in 8 ml. of methanol containing 1 ml. of concentrated sulfuric acid and 3 ml. of water was allowed to stand at room temperature for 16 hr. Most of the volatile material was removed below room temperature by evaporation under reduced pressure. The remaining residue was poured into water and the mixture was extracted with ether. After drying the extracts over anhydrous sodium sulfate, the ether was evaporated, leaving 52 mg. of a nearly colorless liquid. This material was treated with 99 mg. of *p*-toluenesulfonyl chloride and 55 mg. of 3,5-dinitrobenzoic acid in 10 ml. of dry pyridine[13] to give 68 mg. of a nearly white solid, m.p. 107–113°. One crystallization from hexane gave shiny, colorless plates, m.p. 116.5–117.5°. A mixed melting point with an authentic sample of *cis*-2-bromocycloöctyl 3,5-dinitrobenzoate (see below) showed no depression and the infrared spectra of the two compounds were identical in every respect.

Further elution of the column with 1700 ml. of 50% ether in petroleum ether gave (c) 0.97 g. (5%) of *trans*-1,2-cyclooctanediol diacetate. This material was saponified and converted to its isopropylidene ketal with acetone in the presence of anhydrous copper sulfate. Chromatography of the product according to the procedure previously described[2] revealed no isomeric cycloöctanediols, the ketal being the only material that was eluted from the column. The infrared spectrum of the eluted ketal was identical with that of an authentic sample of the isopropylidene ketal of *trans*-1,2-cycloöctanediol.

2-Bromocycloöctanone.—N-Bromosuccinimide (8.40 g., 0.047 mole) was added to a solution of 5.92 g. (0.047 mole) of cycloöctanone in 30 ml. of carbon tetrachloride, and the mixture was refluxed for 2 hr. During this time the reaction proceeded to completion as evidenced by the disappearance of the N-bromosuccinimide. After filtration of the succinimide the solvent was removed by heating under reduced pressure, leaving a dark residue. Distillation afforded 7.50 g. (78%) of 2-bromocycloöctanone as a colorless liquid, b.p. 65–73° (0.2–0.5 mm.), $n^{25}D$ 1.5126; a redistilled analytical sample had b.p. 79–81° (1 mm.), $n^{25}D$ 1.5161, d^{25}_4 1.382.[14]

Anal.[14] Calcd. for $C_8H_{13}BrO$: C, 46.85; H, 6.39; Br, 38.97. Found: C, 47.13; H, 6.41; Br, 38.94.

***cis*- and *trans*-2-Bromocycloöctanol.**—A solution of 2.0 g. (0.054 mole) of sodium borohydride in 50 ml. of absolute methanol was added over a period of 30 minutes to a solution of 2.74 g. (0.0134 mole) of 2-bromocycloöctanone in 20 ml. of absolute methanol. The temperature of the mixture was kept below 25° throughout the addition. After the mixture stood for an additional period of 2 hr. at room temperature, most of the methanol was removed by evaporation under reduced pressure. Fifty milliliters of water was added and the mixture was acidified with dilute hydrochloric acid. The mixture was extracted with ether, and the extracts were dried over anhydrous sodium sulfate and evaporated, leaving a nearly colorless liquid. Distillation gave 1.91 g. (69%) of a colorless liquid mixture of *cis*- and *trans*-2-bromocycloöctanol, b.p. 85–90° (0.7 mm.), $n^{25}D$ 1.5140. Redistillation afforded material of b.p. 72–75° (0.3 mm.), $n^{25}D$ 1.5172. The mixture was not analytically pure, presumably because of some hydrolysis or loss of hydrogen bromide.

***cis*- and *trans*-2-Bromocycloöctyl 3,5-Dinitrobenzoates.**—A 442-mg. sample of the bromohydrin mixture from the reduction of 2-bromocycloöctanone was converted in the usual manner with 460 mg. of 3,5-dinitrobenzoic acid, 820 mg. of *p*-toluenesulfonyl chloride and 15 ml. of pyridine to 766 mg. (94%) of a mixture of dinitrobenzoates, m.p. 82–94°. Three crystallizations from hexane gave pure *cis*-2-bromocycloöctyl 3,5-dinitrobenzoate as colorless, glistening plates, m.p. 117.0–117.5°.

Anal. Calcd. for $C_{15}H_{17}BrN_2O_6$: C, 44.90; H, 4.27; Br, 19.87. Found: C, 44.98; H, 4.39; Br, 19.72.

Evaporation of the mother liquors gave an oil that slowly solidified, m.p. 58–70°. Four crystallizations from hexane gave *trans*-2-bromocycloöctyl 3,5-dinitrobenzoate as colorless needles, m.p. 94–95°. A mixed melting point with an authentic sample (see below) was undepressed and the infrared spectra of the two compounds were identical.

Anal. Calcd. for $C_{15}H_{17}BrN_2O_6$: C, 44.90; H, 4.27; Br, 19.87. Found: C, 45.29; H, 4.52; Br, 20.20.

***trans*-2-Bromocycloöctanol.**—A slow stream of anhydrous hydrogen bromide was passed into a solution of 5.38 g. (0.043 mole) of *cis*-cycloöctene oxide in 50 ml. of carbon tetrachloride for a period of 2 hr. The temperature of the mixture was kept at approximately 20° by a cold water-bath. Evaporation of the solvent left a dark residue which was distilled, yielding 6.46 g. (74%) of *trans*-2-bromocycloöctanol as a colorless liquid, b.p. 80–88° (0.2 mm.), $n^{25}D$ 1.5246. Redistillation afforded material of b.p. 74–75° (0.1 mm.), $n^{25}D$ 1.5246.

Anal. Calcd. for $C_8H_{15}BrO$: C, 46.39; H, 7.30; Br, 38.59. Found: C, 46.13; H, 7.26; Br, 38.37.

A 393-mg. sample of the bromohydrin was treated with 410 mg. of 3,5-dinitrobenzoic acid and 744 mg. of *p*-toluenesulfonyl chloride in 15 ml. of pyridine to give 726 mg. (96%) of derivative, m.p. 90–92°. Three crystallizations from hexane gave pure *trans*-2-bromocycloöctyl 3,5-dinitrobenzoate as clusters of colorless needles, m.p. 95.0–95.6°.

***trans*-2-Bromocycloöctyl Acetate.**—A mixture of 5.95 g. (0.029 mole) of the *trans*-bromohydrin and 3.54 g. (0.035 mole) of acetic anhydride was cooled in an ice-bath. Several drops of concentrated sulfuric acid were added with swirling. After the initial reaction subsided, the mixture was kept at room temperature for 2 hr. and then diluted with 50 ml. of ether. Calcium carbonate was added, and after 30 minutes the mixture was filtered. The ether was evaporated and the residue distilled to give 6.87 g. (96%) of *trans*-2-bromocycloöctyl acetate as a colorless liquid, b.p. 84–85° (0.5 mm.), $n^{25}D$ 1.4962.

Anal. Calcd. for $C_{10}H_{17}BrO_2$: C, 48.20; H, 6.88; Br, 32.08. Found: C, 48.31; H, 6.94; Br, 32.34.

Reaction of *trans*-2-Bromocycloöctyl Acetate with Tetraethylammonium Acetate.—A solution of 3.28 g. (0.013 mole) of *trans*-2-bromocycloöctyl acetate and 6.0 g. (0.029 mole) of tetraethylammonium acetate monohydrate in 70 ml. of dry acetone was refluxed for 72 hr. At the end of this time the acetone was removed by warming under reduced

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[12] Prepared by Morton Brown by the procedure of E. P. Kohler, M. Tishler, H. Potter and H. T. Thompson, THIS JOURNAL, **61**, 1057 (1939).

[13] A method of preparing carboxylic esters described by J. H. Brewster and C. J. Ciotti, Jr., *ibid.*, **77**, 6214 (1955).

[14] D. S. Smith, Ph.D. Thesis, Massachusetts Institute of Technology, 1952.

pressure and the product isolated as described above for the products of the reaction of cycloöctene dibromide with tetraethylammonium acetate to give 2.17 g. of a colorless liquid, b.p. 50–87° (0.4 mm.), n^{25}D 1.4675. Redistillation of this material through a semimicro column gave: (a) 0.95 g. (45%), b.p. 41° (0.2 mm.), n^{25}D 1.4675, identified as 2-cycloocten-1-yl acetate by hydrolysis and conversion to the phenylurethan; (b) 0.40 g. of intermediate fractions, b.p. 41–82° (0.2 mm.), n^{25}D 1.4675–1.4680; and (c) 0.51 g. (17%) of *cis*-1,2-cycloöctanediol diacetate, b.p. 82° (0.2 mm.), n^{25}D 1.4645. A solution of 464 mg. of (c) in 10 ml. of methanol containing 5 ml. of water and 2 g. of sodium hydroxide was refluxed for 2 hr. After cooling, most of the methanol was removed by warming the mixture under reduced pressure. The residue was diluted with water and extracted continuously for 20 hr. with chloroform to give 235 mg. (80%) of a white solid, m.p. 69–75°. One crystallization from hexane gave 190 mg. of colorless glistening plates of *cis*-1,2-cycloöctanediol, m.p. and mixed m.p. with an authentic sample 78.0–78.5°.

Reaction of *trans*-1,2-Dibromocycloöctane with Silver Acetate at 60°.—To a stirred suspension of 42.5 g. (0.25 mole) of silver acetate in 200 ml. of glacial acetic acid and 20 ml. of acetic anhydride at room temperature was added 25.3 g. (0.095 mole) of cycloöctene dibromide. After 2 hr. at room temperature essentially no reaction had taken place. The mixture was then heated to 60° and held at that temperature for 24 hr. After that period the solids were collected on a filter, washed well with glacial acetic acid, slurried with 20% aqueous nitric acid, again separated by filtration, washed with water and dried, giving 33.7 g. (96%) of silver bromide. The acetic acid filtrates were returned to the reaction flask along with 10 g. of silver acetate and stirred for an additional period of 17 hr. at 60°. No more silver bromide precipitated. About 80% of the acetic acid was removed by warming under reduced pressure, and the remaining residue was poured into water. After thorough extraction of the mixture with ether, the extracts were washed with saturated sodium bicarbonate solution until free from acid. The extracts were dried over anhydrous potassium carbonate and evaporated, leaving a nearly colorless residue. Distillation of the residue gave 8.84 g. (57%) of an unsaturated acetate fraction, b.p. 110–112° (20 mm.), n^{25}D 1.4680–1.4693, and 5.34 g. (26%) of a diacetate fraction, b.p. 95–102° (0.25 mm.), n^{25}D 1.4650.

A sample of the unsaturated acetate fraction was saponified and converted to a mixture of phenylurethans. This mixture (4.53 g.) was chromatographed on 400 g. of grade I alumina in a 30-mm. diameter column, eluting with 4:1 petroleum ether:ether followed by 2:1 petroleum ether:ether. Thirty-two crystalline fractions were obtained. From the first three fractions material of m.p. 92–94° was obtained by repeated crystallization from hexane. A mixed melting point with 4-cycloöcten-1-yl phenylurethan of m.p. 93–94° obtained from another source[10] was undepressed, and the infrared spectra of the two compounds were identical with the exception of a small band at 10.2 μ and minor intensity differences indicating the presence of a small amount of an impurity in the derivative with m.p. 92–94°. Crystallization of the intermediate fractions from either hexane or methanol–water failed to narrow the melting range. From the last fractions, material of m.p. 102–103° was obtained as colorless needles from hexane. No depression in melting point was observed upon admixture of this derivative with an authentic sample of 3-cycloöcten-1-yl phenylurethan, and the infrared spectra of the two samples were found to be identical in detail.

A mixture of 21 mg. of the phenylurethan of m.p. 92–94° and 20 mg. of 3-cycloöcten-1-yl phenylurethan was crystallized from methanol–water to give 31 mg. of colorless needles, m.p. 76–78°. The infrared spectrum of this material was found to be identical in every respect to that of the mixture of phenylurethans, m.p. 73–74°, described in the preceding paper.[2]

Saponification of the diacetate fraction gave the same yields of *trans*-1,2-, 1,4- and *cis*-1,4-cycloöctanediol as reported in the preceding paper.[2]

Ozonolysis of 4-Cycloöcten-1-yl Phenylurethan.[15]—An ethyl acetate solution of 35 mg. of 4-cycloöcten-1-yl phenylurethan,[10] m.p. 93–94°, was ozonized, reduced and treated with phenyl isocyanate as previously described[2] to give 78 mg. (98%) of an octanetriol tris-phenylurethan. Several crystallizations from hexane gave 55 mg. of colorless crystals, m.p. 126.5–128.0°. One further crystallization from methanol–water afforded 38 mg. of 1,4,8-octanetriol tris-phenylurethan, m.p. and mixed m.p. with an authentic sample,[2] 127–128°. The infrared spectra of the two compounds were identical in every respect.

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[15] Conducted in part by Dr. G. W. Wood.

CAMBRIDGE, MASSACHUSETTS

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

Proximity Effects. VI. Stereospecific Syntheses of *cis*- and *trans*-1,4-Cycloöctanediols

BY ARTHUR C. COPE AND BURTON C. ANDERSON

RECEIVED MARCH 8, 1957

1,4-Epoxycycloöctane (I) has been prepared by a sequence of reactions beginning with 3,6-epoxycycloheptanecarbonitrile (II and III, *cis* and *trans* isomers). Each of the nitriles was hydrogenated to a single primary amine, but in the synthesis a mixture of amines formed by hydrogenation of a mixture of II and III was employed. The mixture of amines (IV and V) was treated with nitrous acid, and the mixture of alcohols formed was oxidized with N-bromosuccinimide to the ketone IX. Wolff–Kishner reduction of IX yielded I. The 1,4-oxide I was cleaved with acetic anhydride and boron trifluoride to a diacetate, which upon saponification formed *trans*-1,4-cycloöctanediol. The 1,4-oxide I also was cleaved with acetyl bromide, forming *trans*-4-bromocycloöctyl acetate, which was converted into a diacetate by treatment with tetraethylammonium acetate. Saponification of the diacetate yielded *cis*-1,4-cycloöctanediol. The *cis*- and *trans*-1,4-cycloöctanediols obtained by these syntheses proved to be identical with compounds previously prepared by "transannular reactions" from *cis*- and *trans*-cycloöctene, respectively, thereby confirming the structures and stereochemical assignments previously suggested for these compounds.

It has been shown that the solvolysis of *cis*-cycloöctene oxide with formic acid followed by saponification, or hydrolysis of the oxide with dilute hydrochloric acid, forms a 1,4-cycloöctanediol as well as *trans*-1,2-cycloöctanediol.[1] The 1,4-cyclooctanediol formed in this manner tentatively was assigned the *cis* configuration on the basis of a reaction mechanism that was proposed to explain its formation. Later, similar reasoning was used to assign tentatively the *trans* configuration to a 1,4-cycloöctanediol obtained by solvolysis of *trans*-cycloöctene oxide with formic acid followed by saponification.[2] The assignments of configuration to these diols have been confirmed in the

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[1] A. C. Cope, S. W. Fenton and C. F. Spencer, THIS JOURNAL, **74**, 5882 (1952).

[2] A. C. Cope, A. Fournier, Jr., and H. E. Simmons, Jr., *ibid.*, **79**, 3905 (1957).