[Contribution from the Department of Chemistry, Massachusetts Institute of Technology, Cambridge 39, Mass.]

Proximity Effects. XX. Search for Transannular Reactions in Carbon-substituted Cycloöctane Derivatives[1]

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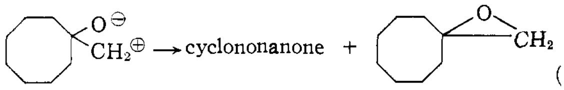
The reaction of cycloöctanone with diazomethane has been reinvestigated, and the results indicate that no transannular products are formed. Methylenecycloöctane oxide has been solvolyzed with formic acid and the only components isolated from this reaction were cycloöctanecarboxaldehyde, 1-cycloöctene-1-methanol, 1-hydroxycycloöctane-1-methanol, 2-cyclooctyl-1,3-dioxaspiro[4.7]dodecane, 2-methylenecycloöctanol, 1-cycloöctene-1-carboxaldehyde, and an unsaturated alcohol of unknown structure. None of the identified products result from transannular reactions.

The reaction of cycloöctanone with diazomethane to produce cyclononanone was first reported in 1939.[3] The only other product isolated was cyclodecanone, although isomeric oxides undoubtedly were formed. The reaction is known to proceed through a charged intermediate to give the next higher homologous carbonyl compound or an ethylene oxide (eq. 1).[4] It appeared possible that one of the charged portions of the doubly charged ion might be close enough to the opposite side of the cycloöctane ring to cause a transannular reaction.



(1)

Attempted purification of the products obtained from cycloöctanone and diazomethane generated *in situ* from nitrosomethylurethan by fractional distillation was unsuccessful, so they were first distilled and then isolated by gas chromatography on a silicone oil column. Recovered cycloöctanone (52.7%, 54.2%), cyclononanone (10.8%, 11.3%) and cyclodecanone (0.7%, 0.8%) were identified by comparison of their infrared spectra with the spectra of authentic specimens and by their 2,4-dinitrophenylhydrazones. Methylenecycloöctane oxide (6.3%, 6.2%) was identified by comparison of its infrared spectrum with that of an authentic sample, while methylenecyclononane oxide (0.4%, 0.4%) could not be isolated, but was identified by comparison of its retention time on gas chromatography with that of an authentic sample. The percentage yields and recovery of cycloöctanone stated refer to the products obtained from two similar reactions.

In addition to the compounds identified, there were several peaks on gas chromatography that represented compounds present in quantities too small to be isolated, the largest present to the extent of 0.2%. These results indicate that no transannular product was formed in a yield of more than 0.2% in this reaction.

The solvolysis of methylenecycloöctane oxide was investigated to determine (1) whether a transannular reaction would occur when a tertiary carbonium ion was generated on a cycloöctane ring, and (2) if a transannular reaction did occur, whether it involved a 1,3- or a 1,5-hydride shift. The results of solvolyses of *cis*-cycloöctene oxide[5] and of several tosylates in the cycloöctane series[6] do not distinguish between 1,3- and 1,5-hydride shifts. In addition, the results of ref. 6 indicate that a transannular hydride shift occurs only when it results in formation of a more stable carbonium ion.

Methylenecycloöctane oxide was prepared from methylenecycloöctane and monoperphthalic acid, and purified by fractional distillation; the yield of the oxide of 96.9% purity was 55%. The major impurites were cycloöctanone (1.6%), cycloöctanecarboxaldehyde (1.4%) and methylenecyclooctane (0.1%), calculated from gas chromatography. Several attempts were made to remove the aldehyde and ketone present as impurities, but because of the sensitivity of the oxide to rearrangement all were unsuccessful.

Methylenecycloöctane was prepared both by the reaction of cycloöctanone with triphenylphosphinemethylene[7] (modified procedure)[8] and also by the pyrolysis of N,N-dimethylcycloöctylmethylamine oxide.[9] The latter procedure was preferable for large scale preparations.

Methylenecycloöctane oxide was solvolyzed with formic acid (98–100%), since this acid has been shown to lead to good yields of transannular products in other instances.[5c] Preliminary experiments indicated that the major product of the solvolysis was cycloöctanecarboxaldehyde (*ca.* 40–50%), so the crude product was treated with Girard reagent T according to the method of Teitelbaum.[10] The regeneration of the carbonyl compounds was accomplished by treatment of the aqueous Girard reagent layer with 37% formaldehyde solution.[10] The resulting mixture, separated by condensing the effluent gases from a silicone oil gas chromatography column, contained a small amount of cycloöctanone in addition to cyclooctanecarboxaldehyde. The residue which did not react with the Girard reagent was saponified with

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[1] Supported in part by a research grant (NSF-G5505) of the National Science Foundation. Paper XIX. A. C. Cope, J. M. Grisar and P. E. Peterson, This Journal, **82**, 4299 (1960).

[2] National Science Foundation Fellow, 1957–1960.

[3] E. P. Kohler, M. Tishler, H. Potter and H. T. Thompson, This Journal, **61**, 1057 (1939).

[4] C. David Gutsche, "Organic Reactions," Vol. VIII, John Wiley and Sons, Inc., New York, N. Y., 1954, p. 367.

[5] (a) A. C. Cope, S. W. Fenton and C. F. Spencer, This Journal, **74**, 5884 (1952); (b) A. C. Cope, A. H. Keough, P. E. Peterson, H. E. Simmons and G. W. Wood, *ibid.*, **79**, 3900 (1957); (c) A. C. Cope, J. M. Grisar and P. E. Peterson, *ibid.*, **81**, 1640 (1959).

[6] A. C. Cope, S. Moon and P. E. Peterson, *ibid.*, **81**, 1650 (1959).

[7] G. Wittig and U. Schöllkopf, *Ber.*, **87**, 1318 (1954).

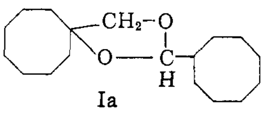
[8] F. Sondheimer and R. Mechoulam, This Journal, **79**, 5029 (1957).

[9] A. C. Cope, E. Ciganek, C. F. Howell and E. E. Schweizer, *ibid.*, **82**, 4663 (1960).

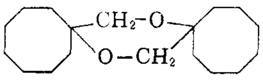
[10] C. L. Teitelbaum, *J. Org. Chem.*, **23**, 646 (1958).

aqueous sodium hydroxide solution, and then chromatographed on alumina in two portions, each giving seven major fractions: (1) non-polar material, (2) carbonyl compounds, (3) unsaturated alcohols, and (4) – (7) glycol.

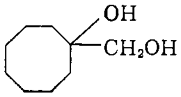
The first fraction contained a high-boiling liquid (I), 3.3%, which showed carbon–oxygen stretching bands in the infrared spectrum, but no hydroxyl or carbonyl bands. Compound I appeared to be a dimer of the oxide based on its molecular weight which was 280 (determined by the mass spectrum)[11] and its analysis which was correct for a molecular formula of $C_{18}H_{32}O_2$ after purification first by chromatography on silica gel, followed by distillation in a short-path still. Treatment of I with 2,4-dinitrophenylhydrazine hydrochloride in methanol afforded cyclooöctanecarboxaldehyde 2,4-dinitrophenylhydrazone, and in one case a small amount of 1-hydroxycyclooöctane-1-methanol (II). Treatment of II with 2,4-dinitrophenylhydrazine hydrochloride under similar conditions also gave cyclooöctanecarboxaldehyde 2,4-dinitrophenylhydrazone. On the above evidence two structures could be postulated for I, a and b, since there are several examples of the formation of 1,3-dioxolanes[12–14] or 1,4-dioxanes[15–17] from epoxides or 1,2-glycols on treatment with acids. The significant mass numbers in the mass spectrum of I can be explained by structure Ia, but cannot be explained satisfactorily by structure Ib.



Ia



Ib



II

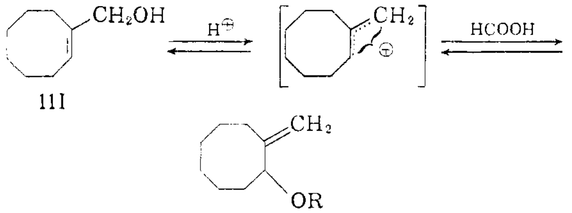
An authentic specimen of 2-cyclooöctyl-1,3-dioxaspiro[4.7]dodecane (Ia) was prepared by the reaction of cyclooöctanecarboxaldehyde and the glycol II in hexane in the presence of anhydrous copper sulfate. The infrared spectra of Ia and I were essentially identical. Upon treatment of the glycol with copper sulfate in the absence of cyclooctanecarboxaldehyde, there was no reaction, showing that the 1,3-dioxolane (Ia) was formed by reaction of the glycol II with the aldehyde.

Fraction two was composed of cyclooöctanone, cyclooöctanecarboxaldehyde and 1-cyclooöctene-1-carboxaldehyde (1.2%). They were separated by gas chromatography on silicone oil and identified by comparison of their infrared spectra with the spectra of authentic samples. Authentic 1-cyclooöctene-1-carboxaldehyde was prepared by oxidation of 1-cyclooöctene-1-methanol with activated manganese dioxide.

Fraction three was composed of 1-cyclooöctene-1-methanol (III), 14%, 2-methylenecyclooöctanol (IV), 2%, and a third unidentified alcohol (V), 0.3%. The mixture was analyzed by gas chromatography on silicone oil, and compounds III and IV were isolated by this method. Compound V was present in too small quantity to be isolated.

Compound III corresponded in analysis to the molecular formula $C_9H_{16}O$, had carbon–carbon double bond and hydroxyl bands in its infrared spectrum and took up 110% of the theoretical amount of hydrogen for one double bond. It was identified by comparison of its infrared spectrum with that of an authentic specimen of 1-cyclooöctene-1-methanol prepared by reduction of 1-cyclooöctene-1-carboxylic acid with lithium aluminum hydride, and by comparison of the phenylurethans prepared from the two samples.

The infrared spectrum of compound IV showed bands indicating the presence of hydroxyl and terminal methylene groups. Its phenylurethan corresponded in analysis to the derivative of an alcohol with the formula $C_9H_{16}O$. Treatment of 1-cyclooöctene-1-methanol with formic acid under conditions similar to those used in the original solvolysis gave IV in 6.4% yield, and 73.7% of recovered starting material. The infrared spectrum and phenylurethan of IV obtained by both methods were identical. Since none of the other products of the oxide solvolysis were found among the products of this reaction (except possibly in trace quantities), compound IV appears to be formed *via* an allylic rearrangement (eq. 2), and not through the tertiary carbonium ion (VIII, below).



III

IV, R = H (2)
VI, R = CH_3CO

Treatment of IV with acetic anhydride in pyridine gave an acetate that was identical with an authentic specimen of 2-methylenecyclooöct-1-yl acetate (VI), prepared in 9.6% yield from 2-hydroxycyclooöctanone acetate and triphenylphosphine-methylene in a modified Wittig reaction.[7,8] The authentic acetate was converted to 2-methylenecyclooöctanol in 65% yield by treatment with methanolic potassium hydroxide. The infrared spectrum of IV was essentially identical with that of authentic 2-methylenecyclooöctanol, and the phenylurethans of the two specimens were identical.

Compound V had a retention time similar to that of an alcohol isolated from the product mixture from the treatment of 1-cyclooöctene-1-methanol with formic acid. A very small amount, 8.5 mg.,

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[11] We are indebted to Prof. K. Biemann for mass spectra and their interpretation.

[12] C. D. Gutsche and H. H. Peter, THIS JOURNAL, **77**, 5971 (1955).

[13] A. R. Graham, A. F. Millidge and D. P. Young, *J. Chem. Soc.*, 2180 (1954).

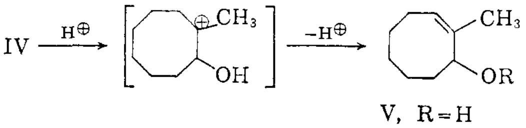
[14] W. J. Hickinbottom, *ibid.*, 1331 (1948).

[15] S. Danilow and E. Venus-Danilowa, *Ber.*, **60**, 1059 (1927).

[16] J. B. Cohen, J. Marshall and H. E. Woodman, *J. Chem. Soc.*, **107**, 887 (1915).

[17] A. Favorskii, *J. Russ. Phys. Chem. Soc.*, **38**, 741 (1906); *Chem. Zentr.*, **78**, I, 15 (1907).

was isolated by gas chromatography on silicone oil. Its infrared spectrum contained a hydroxyl band at 3360 cm.$^{-1}$, a carbon–carbon double bond band at 987 cm.$^{-1}$, and a weak band at 1365 cm.$^{-1}$ indicating the possible presence of a C–methyl group. Treatment of the material with phenyl isocyanate gave an oil that failed to crystallize. It seems likely that V is 2-methyl-2-cycloöcten-1-ol, formed by the isomerization of the *exo* double bond of 2-methylenecycloöctanol to the *endo* position in the strongly acidic medium, since it has been shown that methylenecycloöctane is easily isomerized to *cis*-1-methylcycloöctene by treatment with acetic acid containing *p*-toluenesulfonic acid.[18] A possible path to the proposed structure for V is



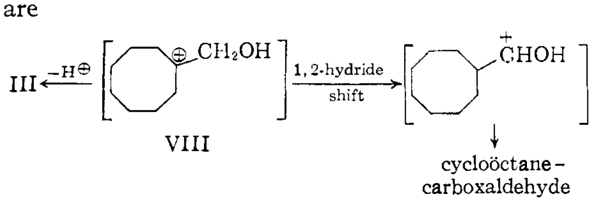
V, R = H
VII, R = CH_3CO

An attempt to synthesize 2-methyl-2-cycloocten-1-yl acetate (VII) by isomerization of the double bond of the acetate VI with glacial acetic acid containing *p*-toluenesulfonic acid failed, for the product contained only unreacted VI (89.8%), 1-cycloöctene-1-methyl acetate (9.9%) and a third component (0.3%), which from its retention time on gas chromatography did not appear to be an acetate.

The only product isolated from fractions 4–7 was 1-hydroxycycloöctane-1-methanol (II), 9%, which was identified by comparison (infrared spectrum, melting point and mixed melting point) with an authentic specimen, prepared by treatment of methylenecycloöctane with osmium tetroxide.

Small amounts of 1-cycloöctene-1-methanol and compound V, and traces of 2-methylenecyclooctanol, as well as two unidentified components present to the extent of 0.07% each, also were found in one of these fractions. The glycol in two of these fractions was converted to its isopropylidene ketal by treatment with acetone and anhydrous copper sulfate,[19] and the product mixture was chromatographed on alumina. No other identifiable products were found.

The results indicate that methylenecycloöctane oxide opens on solvolysis with formic acid to give products consistent with the formation of the most stable carbonium ion (VIII). The carbonium ion then rearranges to give cycloöctanecarboxaldehyde *via* a 1,2-hydride shift, or loses an allylic proton to give 1-cycloöctene-1-methanol. These paths are



2-Cycloöctyl-1,3-dioxaspiro[4.7]dodecane can be formed from a number of species present since methylenecycloöctane oxide or the glycol II can react with either cycloöctanecarboxaldehyde or the carbonium ion VIII to give the dioxolane. Also the dioxolane could be formed by the reaction of the carbonium ion VIII with cycloöctanecarboxaldehyde.

1-Cycloöctene-1-carboxaldehyde appears to have been formed by air oxidation of 1-cycloöctene-1-methanol, and 2-methylenecycloöctanol by allylic rearrangement of 1-cycloöctene-1-methanol.

The absence of any transannular products (at least in a yield larger than 0.3%) provides additional strong evidence that a transannular reaction does not occur if it requires transition from a more stable to a less stable state, *e.g.*, from a tertiary to a secondary carbonium ion, as in the present case.

Experimental[20,21]

Reaction of Cycloöctanone with Diazomethane.[8]—Several repetitions of this reaction have been carried out of which the following is typical. A small amount of nitrosomethylurethan[22] was added to a stirred mixture of 14.5 g. of cyclooctanone, 140 ml. of absolute methanol and 1.26 g. of anhydrous potassium carbonate. After the reaction had started, as indicated by the evolution of nitrogen, the remaining nitrosomethylurethan (47 g. total) was added dropwise. The addition time was 14.5 hr., and the temperature was maintained at −1 to 7° by means of an ice–salt-bath. More potassium carbonate was added at one point when no nitrogen evolution was observed. Upon completion of the addition, the mixture was stirred with cooling for 2 hr., then allowed to come slowly to room temperature overnight without stirring. The reaction mixture was filtered and the product, after concentration, was distilled through a semi-micro column giving 10 g., b.p. 77–96° (15–17 mm.).

Analysis of the product on silicone oil at 170–190° indicated the presence of six major components; all but methylenecyclononane oxide were isolated by condensation of the effluent gases from gas chromatography on silicone oil at 145–195°, and identified as follows. Except where otherwise noted infrared spectra were found to be identical to spectra of authentic samples, and solid derivatives had the same m.p. as authentic samples and showed no depression in mixed m.p.

Ethyl-N-methyl carbamate was identified by the infrared spectrum and by retention time on gas chromatography.

Cycloöctanone was identified by the infrared spectrum and by the 2,4-dinitrophenylhydrazone, m.p. 175.0–176.0°.

Methylenecycloöctane oxide was identified by the infrared spectrum and by retention time on gas chromatography.

Cyclononanone was identified by the infrared spectrum and by the 2,4-dinitrophenylhydrazone, m.p. 142.4–143.0°.

The component assigned the structure of methylenecyclononane oxide could not be isolated but its retention time on gas chromatography was essentially identical with that of an authentic sample, and addition of the authentic oxide to the product mixture produced no new peaks on gas chromatography.

Cyclodecanone was identified by the infrared spectrum and by the 2,4-dinitrophenylhydrazone, m.p. 162.2–163.6°.

Three minor components also were found by gas chromatography in yields of approximately 0.3%, 0.01–0.1% and 0.2%, respectively. The first appears to be an impurity in the original cycloöctanone, and the second has a retention time approximately corresponding to that of cycloöctanecarboxaldehyde.

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(18) A. C. Cope, D. Ambros, E. Ciganek, C. F. Howell and Z. Jacura, THIS JOURNAL, **81**, 3153 (1959); **82**, 1750 (1960).

(19) C. Niemann and C. D. Wagner, *J. Org. Chem.*, **7**, 230 (1942).

(20) Melting points are corrected unless otherwise stated, and boiling points are uncorrected. We are indebted to Dr. S. M. Nagy and his associates for analyses.

(21) Gas chromatography columns used are described by A. C. Cope and P. E. Peterson, THIS JOURNAL, **81**, 1643 (1959), footnote 24, with the following exceptions. Silver nitrate columns contained 52% by weight of silver nitrate. Firebrick for the silicone oil columns was treated with dilute sodium hydroxide, most of which was decanted, and the remaining water was removed under reduced pressure so as to leave the firebrick basic.

(22) W. W. Hartman and R. Phillips, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1942, p. 464.

The distillation residues of three similar preparations were combined and distilled in a short-path still at 0.05–5.0 mm. Gas chromatography of the distillate on silicone oil at 186° showed the presence of three additional components in yields of approximately 0.04%, 0.01% and 0.07%, respectively. The first two appear to be methylenecyclodecane oxide and cycloundecanone, respectively, based on their retention times on gas chromatography. None could be collected and identified positively.

Methylenecycloöctane.—Methyltriphenylphosphonium bromide[7] (33.0 g.) was added to 100 ml. of a 0.092 *M* ethereal solution of phenyllithium. The mixture was stirred under nitrogen at room temperature for 3 hr., and then 11.6 g. of cycloöctanone in 20 ml. of anhydrous ether was added during a few minutes. The mixture was stirred for 2.5 hr. and then allowed to stand overnight under nitrogen. The ether was replaced with 200 ml. of tetrahydrofuran, freshly distilled from sodium, and the mixture was heated under reflux for 5 hr. After filtration, the solvent was removed through a 28 × 1.5-cm. Vigreux column. Water and pentane were added to the residue, and the pentane layer was separated and washed with three 50-ml. portions of water. The first aqueous layer was extracted with an additional 25 ml. of pentane. The combined pentane extracts were dried over anhydrous magnesium sulfate. After filtration and removal of the solvent, the residue was distilled through a 30 × 0.5-cm. spinning band column giving methylenecycloöctane in four fractions totaling 6.21 g. (55%), 98.6% pure by analysis on silicone oil at 138–139°. Two other less pure fractions contained an additional 0.44 g. of methylenecycloöctane as calculated from gas chromatography, making the total yield 6.75 g. (65%). The refractive index of the purest fraction was n^{25}_{D} 1.4702. Gas chromatography of methylenecycloöctane from another preparation on a silver nitrate column at 68° showed it to be free from isomers. Methylenecycloöctane was also prepared by the decomposition of N,N-dimethylcycloöctylmethylamine oxide.[7]

Methylenecycloöctane Oxide.—Methylenecycloöctane (20 g.) was allowed to stand with 643 ml. of an ether solution containing 44.8 g. of monoperphthalic acid[23] in a refrigerator for 69 hr. The phthalic acid was removed by decantation and the ether solution was shaken with two 250-ml. portions of 5% sodium hydroxide solution and one 250-ml portion of water, and dried over anhydrous magnesium sulfate. After removal of the solvent, the residue was distilled through a 30 × 0.5-cm. spinning band column, giving 12.31 g. (55%) of methylenecycloöctane oxide, b.p. 93–96° (14 mm.), n^{25}_{D} 1.4708–1.4711. The material was 96.9% pure by analysis on a silicone oil gas chromatography column at 179°. An analytical sample was prepared by condensing the effluent gases from gas chromatography of the oxide prepared in a similar run, n^{25}_{D} 1.4707.

Anal. Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.20; H, 11.51.

Even successive passes through a gas chromatography column failed to remove traces of cycloöctanone that were present, and in addition small amounts of cycloöctanecarboxaldehyde and 1-cycloöctene-1-methanol (III) were formed by rearrangement of the oxide during gas chromatography. The columns used were treated with sodium hydroxide solution prior to impregnation with silicone oil, since on columns not treated in this manner the oxide rearranges completely to a mixture of cycloöctanecarboxaldehyde and III.

Methylenecyclononane Oxide.—Methylenecyclononane (0.734 g., 98% pure), obtained by decomposition of N,N-dimethylcyclononylmethylamine oxide,[9] was allowed to stand for 68 hr. in a refrigerator with 21.6 ml. of an ether solution containing 1.472 g. of monoperphthalic acid. The product was isolated in the same manner as methylenecyclooctane oxide. The residue remaining after removal of the solvent was 0.703 g., and the yield of epoxide, calculated by estimation of the peaks from gas chromatography on silicone oil at 198°, was 0.616 g. (77%). An analytical sample was purified by collecting the effluent gases from gas chromatography at 200–206°, n^{25}_{D} 1.4790.

Anal. Calcd. for $C_{10}H_{18}O$: C, 77.86; H, 11.76. Found: C, 77.68; H, 11.82.

cis-1-Methylcyclononene Oxide.—*cis*-1-Methylcyclononene[9] containing small amounts of the *trans* isomer and methylenecyclononane was treated with deoxygenated glacial acetic acid containing 0.25% *p*-toluenesulfonic acid[18] for 18.5 hr. giving the pure *cis* olefin (analyzed on a silver nitrate gas chromatography column at 85°). A 0.702-g. quantity was left in a refrigerator for 68 hr. with 20.6 ml. of an ether solution of 1.403 g. of monoperphthalic acid. The product was isolated as described above (0.624 g.). The yield of epoxide calculated from gas chromatography on silicone oil at 198° was 0.615 g. (79%). An analytical sample was isolated by gas chromatography on silicone oil at 200°, n^{25}_{D} 1.4720.

Anal. Calcd. for $C_{10}H_{18}O$: C, 77.86; H, 11.76. Found: C, 77.86; H, 11.80.

cis-1-Methylcycloöctene Oxide.—*cis*-1-Methylcyclooctene[9] (0.788 g.) was allowed to stand in a refrigerator for 70 hr. with 28 ml. of an ether solution containing 1.91 g. of monoperphthalic acid. The product was isolated as described above and amounted to 0.782 g. The yield calculated from gas chromatography on silicone oil at 174° was 0.759 g. (85%). An analytical sample of the epoxide was purified by gas chromatography on silicone oil, n^{25}_{D} 1.4645.

Anal. Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 76.97; H, 11.48.

1-Cycloöctene-1-methanol (III).—To a slurry of 15.4 g. of lithium aluminum hydride in 2 l. of anhydrous ether was added during 50 min. 24.6 g. of 1-cycloöctene-1-carboxylic acid[24] in 650 ml. of dry ether. The mixture was stirred for 1 hr., and then decomposed with 15.4 ml. of water, 15.4 ml. of 15% sodium hydroxide and 46 ml. of water, followed by vigorous stirring for 40 min. (method of Mićović and Mihailović).[25] The reaction mixture was filtered and the ether layer dried over magnesium sulfate. The solvent was removed by distillation at atmospheric pressure, and the residue distilled in a short-path still at 67.5–73° (0.43–0.52 mm.); yield 19.6 g. (88%), n^{25}_{D} 1.4957. An analytical sample was obtained from a similar preparation.

Anal. Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.14; H, 11.74.

The phenylurethan melted at 62.2–62.9° after several recrystallizations from methanol–water.

Anal. Calcd. for $C_{16}H_{21}O_2N$: C, 74.10; H, 8.16; N, 5.40. Found: C, 73.83; H, 8.25; N, 5.35.

Cycloöctanecarboxaldehyde.[26]—To the Grignard reagent prepared from 8.8 g. of magnesium turnings and 22.52 g. of cycloöctyl bromide in 200 ml. of anhydrous ether was added 17.95 g. of ethyl orthoformate in 20 ml. of anhydrous ether with stirring during 5 min. in a nitrogen atmosphere. The mixture was heated under reflux for 6 hr. The ether was removed by distillation, and the residue was cooled and acidified with 120 ml. of previously chilled 6 *N* sulfuric acid, added slowly with cooling. The mixture was steam distilled into aqueous sodium bisulfite solution. An oil which appeared in the distillate was separated. The aqueous layer was acidified with sulfuric acid, heated in a water-bath for 15 min., cooled and extracted with three 100-ml. portions of ether. The combined extracts were washed with sodium bicarbonate solution and with water, dried over magnesium sulfate and concentrated. Since only a very small amount of material was obtained by the foregoing procedure, the aqueous layer from the sulfuric acid treatment was neutralized and heated with excess sodium bicarbonate on a steam-bath for 0.5 hr., cooled, and extracted three times with ether, after adding sodium chloride. The combined extracts were dried over magnesium sulfate and the solvent removed. The two organic residues were combined (2 g. total crude weight) and purified *via* the bisulfite addition compound. The aldehyde was regenerated by the sodium bicarbonate method, extracted with pentane, and dried over magnesium sulfate. After removal of the solvent, the residue was distilled in a micro-still. The major portion distilled at 101.6–103.5° (11 mm.), n^{25}_{D} 1.4699. Its infrared spectrum showed a carbonyl band at 1717–1718 cm.$^{-1}$, and an aldehyde C–H stretching band at ap-

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[23] E. E. Royals and L. L. Harrell, Jr., THIS JOURNAL, **77**, 3405 (1955).

[24] A. C. Cope, M. Burg and S. W. Fenton, *ibid.*, **74**, 173 (1952).

[25] V. M. Mićović and M. Lj. Mihailović, *J. Org. Chem.*, **18**, 1190 (1953).

[26] L. Ruzicka and H. A. Boekenoogen, *Helv. Chim. Acta*, **14**, 1319 (1931).

proximately 2790 cm.$^{-1}$. A 2,4-dinitrophenylhydrazone was prepared and melted at 129.6–130.4° after several recrystallizations from methanol.

Anal. Calcd. for $C_{15}H_{20}N_4O_4$: C, 56.24; H, 6.29; N, 17.49. Found: C, 56.25; H, 6.31; N, 17.31.

1-Hydroxycycloöctane-1-methanol (II).—To 1 g. of osmium tetroxide in 67 ml. of dioxane was added in one portion with stirring a solution of 0.467 g. of methylenecycloöctane in 20 ml. of dioxane. The reaction mixture was stirred for 24 hr. and, after adding 50 ml. more dioxane, hydrogen sulfide gas was passed through the solution for 2.5 hr. The mixture was filtered and the solvent removed under reduced pressure. The solid residue after several recrystallizations from hexane yielded 0.116 g. (19%) of the pure glycol, m.p. 58.0–59.2°.

Anal. Calcd. for $C_{19}H_{18}O$: C, 68.31; H, 11.47. Found: C, 68.61; H, 11.55.

1-Cycloöctene-1-carboxaldehyde.—1-Cycloöctene-1-methanol (III) (0.220 g.) in 20 ml. of pentane was stirred under nitrogen with 2.2 g. of activated manganese dioxide[27] for 24 hr. The product was filtered and the solvent removed. Analysis of the aldehyde on a silicone oil column at 185° showed it to be 99.6% pure. An analytical sample was prepared by distillation of the product through a short-path still at 20 mm. (bath temperature 110–120°). The material was placed under nitrogen and analyzed as soon as possible.

Anal. Calcd. for $C_9H_{14}O$: C, 78.21; H, 10.21. Found: C, 78.01; H, 10.06.

The ultraviolet spectrum had $\lambda_{\max}$ 235 mμ (ϵ 7,800). A 2,4-dinitrophenylhydrazone was prepared, and melted at 185.0–186.2° after several recrystallizations from ethyl acetate–methanol.

Anal. Calcd. for $C_{15}H_{18}N_4O_4$: C, 56.59; H, 5.70. Found: C, 56.46; H, 5.77.

2-Hydroxycycloöctanone Acetate.[28]—An ice-cold solution of 3.54 g. of suberoin in 8.73 g. of pyridine was stirred with 5.82 g. of 96.5% acetic anhydride in a nitrogen atmosphere at room temperature. After 14.5 hr., 10 ml. of water was added and the solution was extracted with one 50-ml. and three 25-ml. portions of ether. The ether solution was extracted in the cold with 3% hydrochloric acid solution until the extracts were acidic to congo red. The ether solution was neutralized with 5% sodium bicarbonate solution and washed with two 10-ml. portions of a saturated sodium chloride solution. The ether layer was dried over magnesium sulfate for 20 hr., filtered, and distilled through a 22 × 1.5-cm. Vigreux column. The residue was distilled in a short-path still, yielding 4.06 g. (89%) of 2-hydroxycycloöctanone acetate, b.p. 85° (1.2 mm.), n^{25}_{D} 1.4691. Distillation of this material through a semimicro column yielded 3.51 g. (77%) of the compound, b.p. 86.0–87.5° (11 mm.), n^{25}_{D} 1.4694–1.4708, d^{25}_{4} 1.073; mol. refraction calcd. 47.86, found 47.77. A portion was purified by gas chromatography[21] on 30% polyethylene glycol phthalate on basic 60–80 mesh firebrick at 190°, n^{25}_{D} 1.4697.

Anal. Calcd. for $C_{10}H_{10}O_3$: C, 65.19; H, 8.76. Found: C, 65.04; H. 8.96.

2-Methylenecycloöct-1-yl Acetate (VI).—The Wittig method[7] (with modifications)[8] was followed in this preparation. Variation in the reaction time from 2 to 5 hr. did not materially affect the yield. To 1.149 g. of methyltriphenylphosphonium bromide[7] in 10 ml. of anhydrous ether was added with cooling 2.4 ml. of a 1.36 *N* ethereal solution of *n*-butyllithium. The mixture was stirred under nitrogen for 2 hr. at room temperature, and then 0.585 g. of 2-hydroxycycloöctanone acetate was added. The mixture was stirred for 4 hr. and allowed to stand overnight under nitrogen. The ether was replaced with dry tetrahydrofuran, and the mixture was heated under reflux for 2 hr. The reaction mixture was added to water, and extracted three times with ether. The combined extracts were washed with water and dried over magnesium sulfate. The product was purified by chromatography on neutral activity I alumina. By elution with pentane 0.055 g. of material was obtained which contained 0.052 g. (9%) of 2-methylenecycloöct-1-yl acetate as calculated from the gas chromatogram on silicone oil at 177° (analysis of this compound is described below).

2-Methylenecycloöctanol (IV).—2-Methylenecycloöct-1-yl acetate (VI) was converted to the corresponding alcohol in 65% yield by treatment at room temperature with a tenfold excess of a 10% solution of potassium hydroxide in aqueous methanol for 1.2 hr. The product was purified by chromatography on alumina, and was 96.5% pure based on gas chromatography on silicone oil at 185°. The phenylurethan was prepared, and was purified by chromatography on alumina (eluted with 3% ether in pentane), followed by recrystallization first from pentane, and then from methanol–water, m.p. 98.3–99.6° (hot-stage) (analysis of the compound is described below).

1-Cycloöctene-1-methyl Acetate.—Methylenecycloöctane (0.996 g.) in 25 ml. of carbon tetrachloride was heated under reflux on a steam-bath under a nitrogen atmosphere with 1.45 g. of N-bromosuccinimide and 0.05 g. of benzoyl peroxide. More benzoyl peroxide was added to start the reaction. After 1.1 hr. the mixture was filtered and shaken with one 15-ml. portion of 5% sodium bicarbonate solution and two 15-ml. portions of water, and dried over magnesium sulfate. The solvent was removed under reduced pressure, and the crude product was heated under reflux with 1.76 g. of tetraethylammonium acetate monohydrate[29] in 50 ml. of acetone in an atmosphere of nitrogen for 22 hr. Most of the acetone was removed by distillation, 100 ml. of water was added to the residue, and the mixture was extracted with three 50-ml. portions of ether. The combined extracts were dried over magnesium sulfate. After removal of the solvent, the odor of acetic acid was still present, so the material was taken up in 10 ml. of ether and shaken with two 10-ml. portions of dilute sodium bicarbonate and one 10-ml. portion of water, and dried over magnesium sulfate. After removal of the solvent the residue was distilled through a semi-micro column and four fractions were separated. The first two, b.p. 81–86° (1.7 mm.), contained 0.621 g. of material, n^{25}_{D} 1.4765–1.4769, that was 96.9% pure, corresponding to a yield of 41%, based on estimation of the peaks of a gas chromatogram on silicone oil at 186°. The acetate was further purified by gas chromatography at 186–189°, giving pure 1-cycloöctene-1-methyl acetate, n^{25}_{D} 1.4760.

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 72.57; H, 9.75.

Approximately 50 mg. of the acetate was saponified by heating with 5 ml. of a solution of 2 g. of potassium hydroxide in 30 ml. of methanol. After removal of the methanol, water was added, the mixture was extracted twice with ether, and the extracts were dried over magnesium sulfate. The infrared spectrum of the product, after removal of the solvent, was essentially identical with that of authentic 1-cycloöctene-1-methanol (III).

2-Cycloöctyl-1,3-dioxaspiro[4.7]dodecane (Ia).—1-Hydroxycycloöctane-1-methanol (0.0495 g.), 0.099 g. of cycloöctanecarboxaldehyde, 0.306 g. of anhydrous copper sulfate and 5 ml. of hexane were stirred at room temperature for 41 hr. in a nitrogen atmosphere. After filtration and removal of the solvent under reduced pressure, the residue was chromatographed on 7.5 g. of neutral activity I alumina. The crude 1,3-dioxolane (31 mg.) was eluted with pentane. A small amount of the original aldehyde and 28 mg. of the glycol were recovered by elution. The dioxolane was further purified by chromatography on 1.5 g. of 28–200 mesh silica gel, being eluted with 2% ether in pentane, giving 28 mg. (32%) of the product which was distilled at 0.09–0.2 mm. (bath temperature 90–130°) in a short-path still (analysis of this compound is described below).

Treatment of 1-hydroxycycloöctane-1-methanol (0.050 g.) with 0.308 g. of anhydrous copper sulfate in 5 ml. of hexane at room temperature for 41 hr. in a nitrogen atmosphere followed by chromatography resulted only in recovery of the glycol (39 mg.).

Solvolysis of Methylenecycloöctane Oxide.—To 60 ml. of formic acid (98–100%), kept at 22–23° by a water-bath, was added dropwise with stirring during 12 min. in a nitrogen atmosphere 11.87 g. of methylenecycloöctane oxide (96.9% purity). The last traces of oxide were dissolved in 10–15 ml. more of formic acid and added to the reaction flask, and the mixture was stirred for an additional 0.5 hr.

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(27) J. Attenburrow, A. F. B. Cameron, J. H. Chapman, R. M. Evans, B. A. Hems, A. B. A. Jansen and T. Walker, *J. Chem. Soc.*, 1104 (1952).

(28) We are indebted to Z. Jacura for this preparation.

(29) J. Stiegman and L. P. Hammett, THIS JOURNAL, **59**, 2536 (1937).

It was added to 120 ml. of water, and the organic material was extracted with three 120-ml. portions of methylene chloride. The combined extracts were treated with three 100-ml. portions of saturated sodium bicarbonate solution (until the *p*H of the wash solution was 7), and dried over magnesium sulfate under nitrogen in a refrigerator (to prevent oxidation of the cycloöctanecarboxaldehyde to the acid). After filtration, the solvent was removed by distillation under nitrogen.

The residue was heated under reflux for 80 min. with 25 g. of Girard reagent T, 500 mg. of IRC 50 (H) Amberlite Resin (Rohm and Haas) and 50 ml. of 95% ethanol (procedure of Teitelbaum),[10] then 25 ml. more of ethanol was added and the mixture was heated under reflux for an additional 40 min. After cooling and decanting from the resin, 200 ml. of water and 200 ml. of methylene chloride were added and the phases shaken together, and separated. An additional 100 ml. of water was added to the aqueous phase, and it was extracted with 100 ml. of methylene chloride and 50 ml. of ether. The combined extracts were washed with water and dried over magnesium sulfate. After removal of the solvent the residue was shaken for 64 hr. with 17.8 g. of sodium hydroxide in 90 ml. of water. The mixture was then extracted with two 50-ml. portions of methylene chloride and one 50-ml. portion of ether, and the combined extracts were dried over magnesium sulfate.

The combined aqueous phases from the reaction with Girard reagent were allowed to stand overnight under nitrogen in a refrigerator with a large excess of 37% formaldehyde solution, and extracted with three 150-ml. portions of pentane. The combined extracts were washed with five 100-ml. portions of water, and dried over magnesium sulfate under nitrogen.

Separation and Identification of the Carbonyl Components.—Two compounds were isolated from the carbonyl-containing portion of the solvolysis mixture by condensation of the effluent gases from a silicone oil gas chromatography column at 175°. The first was shown to be cycloöctanone by comparison of its infrared spectrum with that of an authentic sample, and the m.p. and mixed m.p. of the 2,4-dinitrophenylhydrazone with an authentic sample (174.8–176.0°, hot-stage).

The second carbonyl compound, cycloöctanecarboxaldehyde, was calculated by estimation of the peaks on the gas chromatogram to be present in the amount of 4.99 g., and was purified by passing it twice through a silicone oil column at 178°. To prevent the formation of cycloöctanecarboxylic acid, the effluent gases were collected directly in a tared vial, previously flushed with nitrogen. An infrared spectrum taken immediately showed the acid to be absent, but a strong band was present at 1185 cm.$^{-1}$, which was not present in the spectrum of the authentic aldehyde. This band was present only in samples of the aldehyde which had been regenerated by the formaldehyde procedure. A sample of the aldehyde which had been regenerated by heating for 10 min. on a steam-bath with dilute hydrochloric acid had an infrared spectrum which was essentially identical with that of the authentic aldehyde, and the two samples formed identical 2,4-dinitrophenylhydrazones (comparison of infrared spectra).

Non-carbonyl Components.—The residue from the saponification described above was chromatographed in two portions (2.091 g. and 3.001 g.) using neutral activity I alumina (100-g. and 150-g. quantities, respectively). In the first case twenty-nine 100-ml. fractions were collected and in the second seventy 150-ml. fractions. The eluates were combined into seven major fractions: fraction I (374 mg., 482 mg.), eluted with pentane; fraction II (265 mg., 298 mg.) eluted with ether-pentane (1:1); fraction III (726 mg., 1122 mg.) eluted with ether–pentane (1:1) and 100% ether; fraction IV (53 mg., 93 mg.) eluted with ether–methanol (97:3); fraction V (258 mg., 242 mg.) eluted with ether–methanol (19:1); fraction VI (220 mg., 556 mg.) eluted with ether–methanol (9:1); and fraction VII (30 mg., 41 mg.) eluted with ether–methanol (9:1) and 100% methanol.

Identification of 2-Cycloöctyl-1,3-dioxaspiro[4.7]dodecane (Ia).—The infrared spectrum of the material in fraction I showed carbon–oxygen stretching bands, but no hydroxyl or carbonyl bands. A 25-mg. quantity of material from fraction I was heated with excess 2,4-dinitrophenylhydrazine hydrochloride in methanol on a steam-bath for a short time, yielding 51.5 mg. of an orange derivative which was purified by elution with ether from 2 g. of neutral activity I alumina. A 16-mg. portion was chromatographed on a column containing a mixture of 10 g. of 100-mesh silicic acid (anal. reagent, Mallinckrodt) previously activated at 150° for 2 hr., and 5 g. of Celite. The material was introduced on the column in hexane containing a small amount of benzene, and there was obtained 20 mg. (crude) of cycloöctanecarboxaldehyde 2,4-dinitrophenylhydrazone identified by comparison of its infrared spectrum with that of an authentic sample. From another sample of the dioxolane (31 mg.) there was obtained on treatment with 2,4-dinitrophenylhydrazine hydrochloride 41 mg. (crude) of cycloöctanecarboxaldehyde 2,4-dinitrophenylhydrazone and 16 mg. (crude) of 1-hydroxycycloöctane-1-methanol (II), m.p. 61.0–61.4° (hot-stage), identified by mixed m.p. with an authentic sample.

From a similar solvolysis an analytical sample of Ia was obtained by purification upon 28–200-mesh silica gel, followed by distillation in a short-path still, at 0.1 mm. (bath temperature 137–150°), $n^{25}\text{D}$ 1.5000. The infrared spectrum of the dioxolane was essentially identical to that of an authentic sample.

Anal. Calcd. for $C_{18}H_{32}O_2$: C, 77.09; H, 11.50; mol. wt., 280. Found: C, 76.97; H, 11.22; mol. wt., 280 (by mass spectrometry).

The significant numbers found by mass spectrometry were 280, corresponding to the entire molecule; 279, corresponding to loss of $H^{\ominus}$ leaving a positive charge probably in the 2-position; and 169, corresponding to the loss of $C_8H_{15}^{\ominus}$ leaving a positive charge, also probably in the 2-position. The ratios of the intensities of the three masses were 1:1.2:68.6.

Identification of Components of Fraction II.—Small amounts of cycloöctanecarboxaldehyde, cycloöctanone and 1-cycloöctene-1-carboxaldehyde were isolated from fraction II by gas chromatography on silicone oil at 176–186°. These compounds were identified by comparison of their infrared spectra with those of authentic samples. The amounts of cycloöctanecarboxaldehyde and 1-cycloöctene-1-carboxaldehyde present in this fraction, estimated from their peak areas on gas chromatography, were 0.145 g. and 0.138 g., respectively. Because of the susceptibility of these compounds to oxidation these figures may be in error.

Identification of Alcohol Components.—1-Cycloöctene-1-methanol (III) and 2-methylenecycloöctanol (IV) were isolated by gas chromatography of fraction III on silicone oil at 178–181°, but compound V was not present in sufficient quantity to permit isolation. The amounts of III, IV and V present in fractions III and IV estimated from their peak areas on gas chromatography were 1.61 g., 0.23 g., and 0.03 g., respectively.

Compound III was identified as 1-cycloöctene-1-methanol by comparison of its infrared spectrum with that of an authentic sample, and by its phenylurethan, which was recrystallized from methanol–water, m.p. 61.8–62.8°, undepressed on mixed m.p. with an authentic specimen.

Compound IV was identified as 2-methylenecycloöctanol by comparison of its infrared spectrum with that of an authentic sample, and by its phenylurethan, which was recrystallized from methanol–water, m.p. 96.8–97.6°, undepressed on mixed m.p. with an authentic sample.

Anal. Calcd. for $C_{16}H_{21}O_2N$: C, 74.10; H, 8.16; N, 5.40. Found: C, 74.07; H, 8.24; N, 5.43.

Compound V had essentially the same retention time on gas chromatography on silicone oil as that of an alcohol (described below) which was isolated in small quantity from the treatment of 1-cycloöctene-1-methanol with formic acid.

Identification of 1-Hydroxycycloöctane-1-methanol (II).—A 501-mg. quantity from fractions V, VI and VII after several recrystallizations from hexane, yielded 122 mg. of 1-hydroxycycloöctane-1-methanol (II), m.p. 59.0–60.1°, undepressed on mixed m.p. with an authentic specimen. The infrared spectra of the two were essentially identical. Careful examination of the crude glycol fractions failed to produce any other identifiable compounds.

A 7-mg. sample of II was heated on a steam-bath with excess 2,4-dinitrophenylhydrazine hydrochloride in methanol giving 5.5 mg. (crude) of an orange derivative. After recrystallization first from 95% ethanol, and then from absolute methanol, the derivative melted at 127.5–131° (hot-stage), undepressed on mixed m.p. with authentic cycloöctanecarboxaldehyde 2,4-dinitrophenylhydrazone. The infrared spectrum of a sample from a similar reaction was essentially identical with that of authentic cycloöctanecarboxaldehyde 2,4-dinitrophenylhydrazone.

1-Hydroxycycloöctane-1-methanol Isopropylidene Ketal.—A 0.596-g. quantity of crude glycol from fractions VI and VII was stirred for 23.5 hr. with 4.01 g. of anhydrous copper sulfate in 200 ml. of reagent grade acetone[17] (previously dried with copper sulfate). After filtration and removal of the solvent, the residue, 0.644 g., was chromatographed on 20 g. of neutral activity I alumina, with 20 fractions of 50 ml. each being collected. A total of 0.579 g. of crude isopropylidene ketal was eluted with pentane, and a small amount of unreacted glycol (0.035–0.040 g.) was recovered.

A portion of the isopropylidene ketal was purified by distillation in a short-path still at 10 mm. (bath temperature 109–135°), $n^{25}\mathrm{D}$ 1.4617.

Anal. Calcd. for $C_{12}H_{22}O_2$: C, 72.68; H, 11.18. Found: C, 72.45; H, 11.28.

Treatment of 1-Cycloöctene-1-methanol (III) with Formic Acid.—To 200 ml. of formic acid (98–100%) was added with stirring in a nitrogen atmosphere 19.6 g. of 1-cycloöctene-1-methanol (III) during 4 min. The last traces of alcohol were rinsed in with an additional 35 ml. of formic acid. The mixture was stirred for 1 hr. at 22–25°, added to 400 ml. of water, and extracted with one 400-ml. and two 200-ml. portions of ether. The combined extracts were washed with two 200-ml. portions of water and five 200-ml. portions of saturated sodium bicarbonate solution. The solvent was removed by distillation at atmospheric pressure, and the residue was treated overnight with 20 g. of sodium hydroxide dissolved in 100 ml. of methanol and 40 ml. of water. A portion of the methanol was removed under reduced pressure, and then the mixture was added to 400 ml. of water and extracted with three 300-ml. portions of ether, saturated sodium chloride solution (20 ml.) being added. The combined extracts were dried over magnesium sulfate. After removal of the solvent, the residue was distilled through a 30 × 0.5-cm. spinning band column, yielding in five fractions a total of 16.6 g. containing 1.25 g. of 2-methylenecycloöctanol (IV) and 14.47 g. of recovered III, in addition to several minor components, the amounts being estimated from the areas of the peaks of gas chromatography. The first three fractions (1.45 g.) which were highly enriched in compound IV were combined and chromatographed on 75 g. of neutral activity I alumina, and there were obtained several fractions which were more highly enriched in IV. Complete isolation of IV was effected by gas chromatography on silicone oil at 182–184°. An analytical sample was obtained by this method, $n^{25}\mathrm{D}$ 1.4954.

Anal. Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.08; H, 11.54.

This sample of IV was identical (infrared spectrum) with authentic 2-methylenecycloöctanol and with IV obtained from the solvolysis of methylenecycloöctane oxide. Its phenylurethan, m.p. 97.5–98.5° (hot-stage), was undepressed in mixed m.p. with a sample of the phenylurethan of IV from the solvolysis of methylenecycloöctane oxide.

Compound V, isolated from the first three distillation fractions in 8.5-mg. quantity by gas chromatography on silicone oil at 182–194°, had a retention time similar to that of V in the solvolysis product mixture of methylenecyclooctane oxide. Its infrared spectrum had medium strength bands at 3360, 1430, 1055 and 987 cm.$^{-1}$, and a weak band at 1365 cm.$^{-1}$. On treatment with phenylisocyanate an oil formed which failed to crystallize.

Conversion of 2-Methylenecycloöctanol (IV) to 2-Methylenecycloöct-1-yl Acetate (VI).—2-Methylenecycloöctanol (IV) (0.251 g.), isolated from the reaction of 1-cycloöctene-1-methanol (III) with formic acid, was allowed to stand for 24.3 hr. at room temperature with 0.406 g. of acetic anhydride and 2.5 ml. of pyridine. The reaction mixture was added to 5 ml. of water and extracted with three 10-ml. portions of ether. The combined extracts were washed with one 10-ml. portion of water, three 5-ml. portions of cold 5% hydrochloric acid, and two 5-ml. portions of water, and dried over magnesium sulfate. The crude weight was 0.294 g. (89%). The crude material was combined with 0.032 g. from an earlier preparation, and purified by chromatography on neutral activity I alumina, yielding 0.236 g. of 2-methylenecycloöct-1-yl acetate (VI). An analytical sample was purified by gas chromatography on silicone oil at 187°, $n^{25}\mathrm{D}$ 1.4690. The infrared spectrum and the retention time on gas chromatography were essentially identical with those of authentic 2-methylenecycloöct-1-yl acetate.

Anal. Calcd. for $C_{11}H_{18}O_2$: C, 72.49; H, 9.96. Found: C, 72.62; H, 9.90.

Acid Treatment of 2-Methylenecycloöct-1-yl Acetate (VI).[18]—2-Methylenecycloöct-1-yl acetate (VI), 0.02 ml., was treated with 0.2 ml. of deoxygenated glacial acetic acid containing 0.25% *p*-toluenesulfonic acid in a nitrogen-filled vial for 48 hours at room temperature. The reaction mixture was then added to 2.2 ml. of 25% aqueous potassium carbonate solution. Ether was added and the mixture was agitated. Then 2.2 ml. of water was added and the mixture again agitated, and the ether layer separated. The aqueous layer was extracted twice more with ether, and the combined extracts were dried over magnesium sulfate. Gas chromatography of the product on silicone oil at 187° showed three components; the first (0.3%) was not identified, but is probably not an acetate because of its short retention time. The second (89.8%) corresponded in retention time to that of the starting material. A small amount was collected by gas chromatography, and was identified as 2-methylenecycloöct-1-yl acetate by comparison of its infrared spectrum with that of an authentic specimen. The third material (9.9%) corresponded approximately in retention time to that of 1-cycloöctene-1-methyl acetate, and addition of an authentic sample of the latter to the mixture produced no additional peaks.

[Contribution from the Department of Chemistry, Cornell University, Ithaca, N. Y.]

Highly Strained Bicyclic Systems. II. The Synthesis of Optically Active 2α- and 2β-Amino and Hydroxy Bicyclo[2,1,1]hexanes

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Stereospecific syntheses leading from (−)-β-pinene to (−)-5,5-dimethylbicyclo[2,1,1]hexan-2β-ol, (−)-5,5-dimethylbicyclo[2,1,1]hexan-2α-ol, (−)-2β-amino-5,5-dimethylbicyclo[2,1,1]hexane and (+)-2α-amino-5,5-dimethylbicyclo[2,1,1]-hexane are described. The key step in the synthesis of compounds in the 2α-series is the epimerization of (−)-5,5-dimethylbicyclo[2,1,1]hexane-2β-carboxylic acid. The success of this epimerization confirms the stereochemistry of all of the compounds described above.

Introduction.—In a recent publication,[3] we have described the synthesis of a number of *racemic*, 2-substituted bicyclo[2,1,1]hexanes of known stereochemistry. It appears desirable, for a variety of reasons, to have available for study *optically active* compounds of this type with the general formula I, bearing hydroxyl and amino groups in both the α- and β-configurations.[4] These compounds should be of particular value, for example, in helping to

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[1] Alfred P. Sloan Foundation Fellow.

[2] National Science Foundation Coöperative Fellow, 1959–1960.

[3] J. Meinwald and P. G. Gassman, This Journal, **82**, 2857 (1960).

[4] In reference 3, a β-designation is suggested for any substituent *cis* to the *gem*-dimethyl group.