

Methyl 1-Cyclooctenecarboxylate. This ester was prepared as described previously^{16,17} and purified by gas chromatography. The purified ester, n_D^{25} 1.4858, showed ultraviolet absorption at λ_{\max} 220 μ (ϵ 10,800) and strong infrared absorption at 1715 and 1640 cm^{-1} .

Methyl 5-Oxocyclooctanecarboxylate. To a cold solution of 0.80 g. of *cis*-5-hydroxycyclooctanecarboxylic acid in 20 ml. of acetone was added 4.0 ml. of chromic acid-sulfuric acid solution¹⁸ with cooling in an ice bath. The mixture was stirred for 10 min. at room temperature, diluted with 20 ml. of cold water, and

(16) A. C. Cope and M. Brown, *J. Am. Chem. Soc.*, **80**, 2859 (1958).

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

(18) K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 39 (1946).

extracted with four 25-ml. portions of ether. The reddish ether extracts were washed with aqueous sodium thiosulfate until colorless, dried, and evaporated to a volume of 25 ml. This solution was treated with ethereal diazomethane until color persisted, then was evaporated, leaving 0.85 g. of a crude product, which was separated by gas chromatography into 45% of 5-hydroxycyclooctanecarboxylic acid lactone and 55% of the keto ester as a liquid, n_D^{25} 1.4792, which showed infrared absorption maxima at 1705 and 1740 cm^{-1} .

Anal. Calcd. for $\text{C}_{10}\text{H}_{16}\text{O}_3$: C, 65.19; H, 8.76. Found: C, 65.13; H, 8.75.

A 2,4-dinitrophenylhydrazone of the keto ester recrystallized from aqueous ethanol melted at 151.0–151.5°.

Proximity Effects. XLII. The Reaction of Lithium Diethylamide with *cis*- and *trans*-4-Octene Oxide¹

Arthur C. Cope and James K. Heeren

Contribution from the Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139. Received January 11, 1965

Treatment of cis- and trans-4-octene oxides with lithium diethylamide gave trans-5-octen-4-ol as the major product in each case. Among the minor products no cis-5-octen-4-ol was detected, nor were there any products attributable to proximity effects. The formation of trans-5-octen-4-ol was shown to proceed largely by removal of a proton from a position α to the oxirane ring rather than by removal of a proton on the ring followed by generation of a carbene intermediate.

Treatment of *cis*-cyclooctene and *cis*-cyclododecene oxides with strong bases gave products of transannular reactions.^{2,3} Because a straight-chain olefin of sufficient length could assume a conformation approximating that of a medium-sized ring, it was of interest to determine whether such an olefin oxide on treatment with a strong base would give any products that could be ascribed to proximity effects. Accordingly the reactions of lithium diethylamide with *cis*- and *trans*-4-octene oxides were studied. The symmetrical olefin oxides were chosen in order to simplify the separation and identification of products. Neither *cis*-4-octene oxide nor *trans*-4-octene oxide was found to yield any products which could be attributed to a proximity effect.

The results of five separate reactions run under identical conditions except for reaction time are summarized in Table I. The major product in each case was an alcohol ($\text{C}_8\text{H}_{16}\text{O}$) which consumed 1 molar equiv. of hydrogen on catalytic reduction forming 4-

Table I. Products of the Reaction of Lithium Diethylamide with *cis*- and *trans*-4-Octene Oxides^a

4-Octene oxide	Time, hr.	Recovered oxide, %	Allylic alcohol, %	Amino alcohol, %	Glycol, ^b %	Aldehyde, %
<i>trans</i>	7	67	16	..	16	Trace
<i>trans</i>	24	33	45	..	9	Trace
<i>trans</i>	72	12	75	3
<i>cis</i>	7	41	32	7
<i>cis</i>	72	16	55	14

^a Compositions of mixtures were determined by combinations of chromatography on alumina and gas chromatography on 1,2,3-tris(2-cyanoethoxy)propane (TCEP) or silicone oil columns. ^b Identified as *meso*-4,5-octanediol, presumably formed during the isolation of products by attack of lithium hydroxide on unchanged epoxide.

octanol (characterized as the 3,5-dinitrobenzoate). Treatment of the unsaturated alcohol with active manganese dioxide⁴ resulted in partial oxidation to an α,β -unsaturated ketone, as shown by ultraviolet and infrared spectra. The infrared spectrum of the unsaturated alcohol itself had a strong band at 975 cm^{-1} (*trans* double bond). The alcohol was identified as *trans*-5-octen-4-ol by comparison with an authentic specimen prepared by treatment of *n*-butyraldehyde with the lithium salt of 1-butyne followed by lithium aluminum hydride reduction of the resulting 5-octyn-4-ol. *cis*-5-Octen-4-ol was prepared by partial hydrogenation of 5-octyn-4-ol over Lindlar catalyst, and was shown to be absent (in amounts detectable by gas

(1) Supported in part by a research grant (NSF-GP-1587) of the National Science Foundation. Paper XLI: A. C. Cope and D. L. Nealy, *J. Am. Chem. Soc.*, **87**, 3122 (1965).

(2) A. C. Cope, M. Brown, and H. H. Lee, *ibid.*, **80**, 2855 (1958).

(3) A. C. Cope, H. H. Lee, and H. E. Petree, *ibid.*, **80**, 2849 (1958).

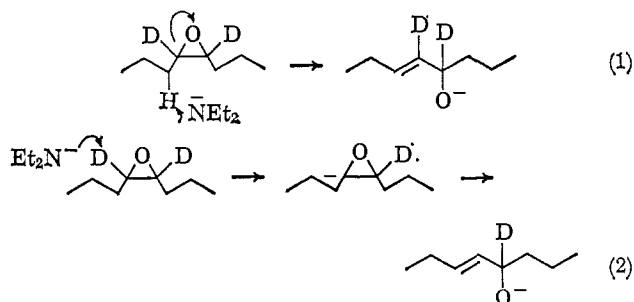
(4) J. Attenburrow, A. F. B. Cameron, J. H. Chapman, R. M. Evans, B. A. Hems, A. B. A. Jansen, and T. Walker, *J. Chem. Soc.*, 1094 (1952).

chromatography) in any of the mixtures obtained from the lithium diethylamide reactions.

The amino alcohol from the reaction of *cis*-4-octene oxide with lithium diethylamide was identified as *threo*-5-(*N,N*-diethylamino)octan-4-ol by comparison with an authentic sample prepared by treating *cis*-4-octene oxide with diethylamine. The reason why no *erythro*-5-(*N,N*-diethylamino)octan-4-ol was found among the products from the *trans* oxide was apparent on inspection of molecular models of the two oxides. The *trans* isomer presents much greater hindrance to backside attack.

The presence of small amounts of di-*n*-propylacetaldehyde in the mixture of products obtained from the *trans* oxide may be attributed to removal of a proton on the oxirane ring followed by 1,2-shift of an *n*-propyl group.

Reaction of the epoxide with lithium diethylamide to give the allylic alcohol might proceed by either one of two mechanisms. The first involves removal of a proton α to the oxirane ring by diethylamide ion, followed by opening of the ring by the electron pair of the carbanion so generated. The second involves removal of a proton on the oxirane ring to give a carbene, followed by a 1,2-hydride shift. The reactions of *cis*-cyclooctene oxide and *cis*-cyclododecene oxide with lithium diethylamide proceed with initial removal of a proton on the oxirane ring as shown by deuterium labeling.⁵ To determine which mechanism was followed by the aliphatic epoxides the reactions were studied with *cis*- and *trans*-4-octene oxide-4,5-*d*₂. *cis*-4-Octene-4,5-*d*₂ was prepared by addition of deuteriodiborane to 4-octyne followed by treatment of the resulting trialkenylboron with deuterioacetic acid. The olefin, containing 80% *d*₂ (determined by mass spectrometry),⁶ was converted to the epoxide (80% *d*₂) by treatment with mono-perphthalic acid. *trans*-4-Octene-4,5-*d*₂ (92% *d*₂) was prepared from 4-octyne and calcium ammonia-*d*₃⁷ and was similarly converted to the epoxide without loss of deuterium. If the first (carbanion) mechanism operated, the allylic alcohol isolated would retain two deuterium atoms per molecule; if the second (carbene) were correct, only one of the two deuterium atoms would be retained.



The *trans*-5-octen-4-ol isolated from treatment of (80%) *cis*-4-octene oxide-4,5-*d*₂ with lithium diethylamide was found by mass spectrometry to contain 70% *d*₂ species; the *trans*-5-octen-4-ol (92%) from *trans*-4-octene oxide-4,5-*d*₂ contained 84–85% *d*₂ species.

(5) A. C. Cope, G. A. Berchtold, P. E. Peterson, and S. H. Sharman, *J. Am. Chem. Soc.*, **82**, 6370 (1960).

(6) We are indebted to Professor Klaus Biemann for determination of the mass spectra and for assistance in their interpretation.

(7) K. N. Campbell and J. P. McDermott, *J. Am. Chem. Soc.*, **67**, 282 (1945).

Thus the carbanion mechanism operated almost exclusively in these two cases. The fact that *cis*-cyclooctene and *cis*-cyclododecene oxides reacted by the carbene mechanism must be attributed to the influence of steric effects that are present in the medium ring epoxides and absent or relatively unimportant in the aliphatic epoxides that were studied.

Experimental⁸

***trans*-4-Octene Oxide.** *trans*-4-Octene was prepared in 83% yield from 4-octyne and sodium in liquid ammonia, b.p. 64° (100 mm.), *n*²⁵_D 1.4098 (lit.⁹ 1.40909). Gas chromatography (silicone oil, 180°) showed 3% contamination by 4-octyne. A mixture of commercial 40% peracetic acid (90 ml.) and sodium acetate trihydrate (18 g.) was added dropwise with stirring to 33.2 g. of *trans*-4-octene. The temperature was kept at 27–30° during the addition, which was completed in 1.3 hr. The mixture was then cooled to 5° and 60 g. of sodium hydroxide in 60 ml. of water was added dropwise during a period of 1 hr. while the temperature was kept below 35°. The layers were separated and the aqueous layer was extracted twice with ether. The combined organic layers were filtered through magnesium sulfate and distilled through a 15-cm. column packed with glass helices. A total of 27.6 g. (69%) of *trans*-4-octene oxide was obtained, b.p. 68–73° (46–48 mm.), *n*²⁵_D 1.4090.¹⁰

Anal. Calcd. for C₈H₁₆O: C, 74.94; H, 12.59. Found: C, 74.91; H, 12.44.¹⁰

Reaction of *trans*-4-Octene Oxide with Lithium Diethylamide. A 50-ml. erlenmeyer flask was fitted with a magnetic stirring bar and a serum cap through which protruded two hypodermic needles, one for a nitrogen inlet, the other for a vent. The flask was swept with nitrogen and then was immersed in a Dry Ice bath. A 1 *M* solution of *n*-butyllithium (20 ml.) was added with a hypodermic syringe, then 4 ml. of diethylamine was added dropwise in 5 min. Stirring was continued for 5 min. and the mixture was allowed to warm to room temperature. *trans*-4-Octene oxide (2.205 g.) was added dropwise with a hypodermic syringe, and the mixture was stirred under nitrogen for 72 hr. At the end of this time the flask was chilled in an ice bath and 5 ml. of saturated ammonium chloride solution was added dropwise. When the initial reaction had subsided, the mixture was stirred for a few minutes and then treated with 5-ml. portions of saturated ammonium chloride until the aqueous extracts were odorless. The ether solution was filtered through magnesium sulfate and the solvent was removed under nitrogen. The infrared spectrum of the crude product, 2.18 g., showed absorption in the hydroxyl and carbonyl (1725 cm.⁻¹) regions. Treatment of a few drops of the crude product with 2,4-dinitrophenylhydrazine reagent gave a yellow 2,4-dinitrophenylhydrazone which was recrystal-

(8) Melting points are corrected and boiling points are uncorrected. Conditions and equipment used for gas chromatography were those described by A. C. Cope and P. E. Peterson, *ibid.*, **81**, 1643 (1959); liquid phases used were silicone oil, 1,2,3-tris(2-cyanoethoxy)propane (TCEP), and γ -methyl- γ -nitropimelonitrile (NMPN). Microanalyses were performed by Dr. S. M. Nagy, and combustion analyses for deuterium by J. Nemeth, Urbana, Ill.

(9) K. N. Campbell and L. T. Eby, *ibid.*, **63**, 216 (1941).

(10) The analytical sample was obtained from an earlier preparation described by H. E. Petree (Ph.D. Thesis, Massachusetts Institute of Technology, p. 44, 1955).

lized from methanol, m.p. 151.2–151.6°, $\lambda_{\text{max}}^{\text{EtOH}}$ 359 m μ (ϵ 21,100). This compound was shown to be the 2,4-dinitrophenylhydrazone of di-*n*-propylacetaldehyde (see below).

Anal. Calcd. for $\text{C}_{14}\text{H}_{20}\text{N}_4\text{O}_4$: C, 54.53; H, 6.54; N, 18.17. Found: C, 54.87; H, 6.50; N, 18.2.

The remainder of the product mixture was separated on a silicone oil column at 175°. The carbonyl component that was collected gave the 2,4-dinitrophenylhydrazone described above. The other component collected was an alcohol, n_{D}^{25} 1.4373, later shown to be *trans*-5-octen-4-ol.

Anal. Calcd. for $\text{C}_8\text{H}_{16}\text{O}$: C, 74.94; H, 12.58. Found: C, 75.13; H, 12.51.

The allophanate¹¹ was recrystallized from absolute ethanol, m.p. 156.0–156.5°.

Anal. Calcd. for $\text{C}_{10}\text{H}_{18}\text{N}_2\text{O}_4$: C, 56.05; H, 8.47. Found: C, 56.28; H, 8.54.

The alcohol (122 mg.) on hydrogenation over platinum in ethanol absorbed 22.9 ml. (98%) of hydrogen. The catalyst was separated and the solvent was evaporated. A 3,5-dinitrobenzoate was prepared from the residue (46 mg.) and was recrystallized from pentane, m.p. 50°, undepressed on admixture with the 3,5-dinitrobenzoate of authentic 4-octanol. The infrared spectra of the two derivatives were identical.

The initial unsaturated alcohol (187 mg.) on treatment with 1.0 g. of active manganese dioxide⁴ in pentane overnight followed by filtration and evaporation of the solvent yielded 137 mg. of a mixture displaying absorption at 1695, 1675, 1630, and 975 cm^{-1} in the infrared and at 225 m μ in the ultraviolet spectrum.

The reaction of lithium diethylamide with *trans*-4-octene oxide was repeated under identical conditions in order to determine yields. The crude product obtained from 2.84 g. of the oxide was separated by chromatography on alumina (activity I), yielding 0.365 g. (13%) of unchanged *trans*-4-octene oxide, 2.25 g. (79%) of the alcohol $\text{C}_8\text{H}_{16}\text{O}$, and 95 mg. (3%) of the carbonyl component, isolated as the 2,4-dinitrophenylhydrazone. When the reaction time was decreased from 72 to 24 hr. the products were: unchanged oxide, 33%; alcohol, 45%; carbonyl component, trace; and *meso*-4,5-octanediol, 9%. The glycol was identified by comparison of infrared spectra and a mixture melting point with an authentic sample.¹² When the reaction time was 7 hr. the products were: recovered oxide, 67%; alcohol, 16%; carbonyl component, trace; and *meso*-4,5-octanediol, 16%.

Di-n-propylacetaldehyde. To a cooled solution of *n*-propylmagnesium bromide prepared from 37.3 g. of *n*-propyl bromide and 8.1 g. of magnesium turnings in ca. 200 ml. of ether was added 20.0 g. of ethyl ethoxyacetate¹³ in 50 ml. of ether during 0.5 hr., while the reaction mixture refluxed gently. When addition of the ester was complete, the mixture was stirred for 1 hr. and then was chilled in an ice bath while 100 ml. of saturated ammonium chloride solution was added dropwise. The mixture was refluxed for 15 min. and the layers were separated. The pasty aqueous phase was

extracted twice with ether, and the combined ether portions were dried over magnesium sulfate. Removal of the solvent under reduced pressure left 25.0 g. (93%) of crude dipropyl(ethoxymethyl)carbinol. A solution of the crude carbinol (1 ml.) in 1 ml. of 85% phosphoric acid was heated in a short-path still. The distillate (water and di-*n*-propylacetaldehyde) after drying had an infrared spectrum identical with that of the carbonyl component isolated from the reaction of lithium diethylamide and *trans*-4-octene oxide. The two 2,4-dinitrophenylhydrazones also had identical infrared spectra and their mixture melting point was not depressed.

5-Octyn-4-ol. A 100-ml. flask equipped for magnetic stirring was fitted with a serum cap through which two hypodermic needles protruded. The flask was swept with nitrogen and then was cooled to -50° . *n*-Butyllithium (50 ml. of a 1 *M* solution in ether) was added, the stirrer was started, and gaseous 1-butyne was added by inflating a balloon to a volume of approximately 1 l. and allowing the gas to bubble into the butyllithium solution through a hypodermic needle, the tip of which was below the surface of the ether solution. The process was repeated twice so that a total of 3 l. of 1-butyne was added. The resulting mixture was stirred at -50 to -10° for 2 hr. and at 0 to 10° for 2 hr. more. At the end of this time, 3.6 g. of freshly distilled *n*-butyraldehyde was added dropwise in 15 min. with a hypodermic syringe. The temperature was maintained below 10° during the addition. The mixture was stirred under nitrogen at room temperature overnight and then was cooled in an ice bath and treated with saturated ammonium chloride solution until the washings were no longer basic. The ether solution was washed with water and dried over magnesium sulfate. Removal of the solvent left 7.11 g. of a yellow oil which was distilled in a short-path still. The higher boiling of the two fractions (b.p. 85° at 10 mm.), 3.06 g. (37%), showed a single major peak when analyzed by gas chromatography (silicone oil, 180°). Preparative gas chromatography (TCEP, 145°) gave an analytical sample, n_{D}^{25} 1.4461.

Anal. Calcd. for $\text{C}_8\text{H}_{14}\text{O}$: C, 76.14; H, 11.18. Found: C, 75.90; H, 11.07.

The allophanate was recrystallized from absolute ethanol, m.p. 166.5–166.8°.

Anal. Calcd. for $\text{C}_{10}\text{H}_{16}\text{N}_2\text{O}_3$: C, 56.59; H, 7.60. Found: C, 56.32; H, 7.63.

trans-5-Octen-4-ol. A mixture of 0.5 g. of lithium aluminum hydride and 1.0 g. of 5-octyn-4-ol in 50 ml. of dry dioxane was refluxed for 1 hr.¹⁴ Most of the dioxane was removed under reduced pressure and 50 ml. of ether was added. Water (0.5 ml.) was added to the stirred ether suspension, followed by 0.5 ml. of 15% sodium hydroxide solution and 1.5 ml. of water.¹⁵ The inorganic salts were collected on a filter and the filtrate was washed with water to remove traces of dioxane. The ether solution was dried over magnesium sulfate and the solvent was removed under reduced pressure. Distillation of the residue, 0.71 g. (70%), in a

(11) Prepared by a method described by A. Behal, *Bull. soc. chim.*, [4] 25, 473 (1919). See also M. A. Spielman, J. D. Barnes, and W. J. Close, *J. Am. Chem. Soc.*, 72, 2520 (1950).

(12) W. G. Young, L. Levenas, and Z. Jasaitis, *ibid.*, 58, 2274 (1936).

(13) R. C. Fuson and B. H. Wojcik, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 260.

(14) A detailed description of lithium aluminum hydride reductions of acetylenic alcohols is given by E. B. Bates, E. R. H. Jones, and M. C. Whiting, *J. Chem. Soc.*, 1854 (1954).

(15) V. M. Mićović and M. L. Mihailović, *J. Org. Chem.*, 18, 1190 (1953).

short-path still yielded 403 mg. of a colorless oil, n_D^{25} 1.4371, with the same retention time (TCEP, 145°) as the octenol from the reaction of lithium diethylamide with *trans*-4-octene oxide. The infrared spectra of the two alcohols were identical. The mixture melting point of the allophanates was not depressed, and their infrared spectra were identical.

cis-5-Octen-4-ol. 5-Octen-4-ol (450 mg.) in 10 ml. of hexane was hydrogenated over 50 mg. of Lindlar catalyst. The hydrogen uptake was very rapid until 95% of 1 mole had been absorbed. The uptake thereafter was quite slow, and the hydrogenation was stopped when a total of 93 ml. (100.5%) had been absorbed. Filtration and removal of solvent left 420 mg. (93%) of a pale yellow oil from which the pure *cis* alcohol, n_D^{25} 1.4395, was obtained by gas chromatography (silicone oil, 160°). The retention time of the *cis* alcohol was slightly longer than that of the *trans* isomer and a mixture of the two showed a split peak on silicone oil or on TCEP at 145°. Under the same conditions the *trans* alcohol obtained from the lithium diethylamide reactions showed a single peak with no splitting or shoulder. The infrared spectrum of the *cis* alcohol had a strong band at 750 cm^{-1} (*cis* C-H out-of-plane deformation).

Anal. Calcd. for $\text{C}_8\text{H}_{16}\text{O}$: C, 74.94; H, 12.58. Found: C, 75.13; H, 12.49.

The allophanate was recrystallized from pentane-ethyl acetate, m.p. 155.0–155.5°.

Anal. Calcd. for $\text{C}_{10}\text{H}_{18}\text{N}_2\text{O}_3$: C, 56.05; H, 8.47. Found: C, 55.93; H, 8.53.

cis-4-Octene Oxide. *cis*-4-Octene prepared from 4-octyne and diborane by a procedure analogous to the one described below for *cis*-4-octene-4,5- d_2 was shown by gas chromatography (TCEP, 25°) to contain less than 1% of 4-octyne and no detectable *trans*-4-octene. A larger sample prepared by hydrogenation of 4-octyne over Lindlar catalyst had n_D^{25} 1.4121 (lit.⁹ 1.41127). Gas chromatography (TCEP, 25°) showed the presence of 2% of the *trans* isomer. Epoxidation of 21.0 g. of this sample of *cis*-4-octene in the manner described for the *trans* isomer gave a mixture of *cis*- and *trans*-4-octene oxides in a ratio of 96:4 (gas chromatography on silicone oil, 175°). Distillation through a 30-cm. spinning-band column gave 21.0 g. (88%) but did not separate the isomers.

Reaction of cis-4-Octene Oxide with Lithium Diethylamide. The reaction was carried out as with the *trans* isomer, except that the reaction time was 14 hr. The oxide (2.85 g.) yielded 2.65 g. of crude product. A 300-mg. portion was chromatographed on 15 g. of alumina (activity I), and the fractions were analyzed by gas chromatography. Unchanged *cis*-4-octene oxide (132 mg., 41%) was eluted with ether-pentane (1:9 to 3:7). An alcohol (102 mg., 32%) was eluted with ether-pentane (1:1 to 4:1); its infrared spectrum was identical with that of *trans*-5-octen-4-ol. An amino alcohol later shown to be *threo*-5-(*N,N*-diethylamino)octan-4-ol (33 mg., 7%) was eluted with methanol-ether (1:4 to 1:1). When the reaction time was increased to 72 hr., the products were: recovered oxide, 16%; *trans*-5-octen-4-ol, 55%; *threo*-5-(*N,N*-diethylamino)octan-4-ol, 14%. A sample of the amino alcohol was obtained by short-path distillation of the mixture of products, collecting only the last few drops of

distillate, n_D^{25} 1.4398. The picrate was recrystallized from methanol-ether, m.p. 88.5–89.0°.

threo-5-(*N,N*-Diethylamino)octan-4-ol. A 300-ml. bomb charged with 2.85 g. of *cis*-4-octene oxide and 15 ml. of diethylamine was heated at 200° for 72 hr. After cooling, most of the excess diethylamine was removed under reduced pressure. The residue was made strongly acidic with concentrated hydrochloric acid and extracted with ether until the extracts were colorless. The aqueous layer was evaporated under reduced pressure to a thick sirup which was dissolved in 5 ml. of water. Crushed sodium hydroxide pellets were added until the mixture was strongly alkaline, and it was extracted with ether until the extracts were colorless. The combined ether extracts were washed once with water and filtered through magnesium sulfate, and the ether was removed under reduced pressure. Short-path distillation of the residue (1.86 g.) yielded 1.53 g. (35%) of an oil, n_D^{25} 1.4400.

Anal. Calcd. for $\text{C}_{12}\text{H}_{27}\text{NO}$: C, 71.58; H, 13.52; N, 6.96. Found: C, 71.56; H, 13.46; N, 7.21.

The picrate, recrystallized from methanol-ether, had m.p. 89.0–89.8°.

Anal. Calcd. for $\text{C}_{18}\text{H}_{30}\text{N}_4\text{O}_8$: C, 50.22; H, 7.03; N, 13.02. Found: C, 50.25; H, 7.04; N, 12.84.

The infrared spectrum of this picrate was identical with that of the picrate of the amino alcohol isolated from the reaction of lithium diethylamide with *cis*-4-octene oxide, and a mixture melting point was not depressed.

Preparation of erythro-5-(N,N-Diethylamino)octan-4-ol. This amino alcohol (1.31 g., 30%) was prepared from *trans*-4-octene oxide (2.85 g.) by the procedure described for the *threo* isomer. Short-path distillation yielded 950 mg. (21%) of an oil, n_D^{25} 1.4451, homogeneous to gas chromatography (silicone oil, 175°).

Anal. Calcd. for $\text{C}_{12}\text{H}_{27}\text{NO}$: C, 71.58; H, 13.52; N, 6.96. Found: C, 71.47; H, 13.34; N, 7.03.

cis-4-Octene-4,5- d_2 . A three-necked flask was cooled in an ice bath and connected to a pressure-compensated dropping funnel and an outlet to two traps in series each equipped with a sintered glass filter stick inlet fully covered by the liquid in the trap. The system was maintained under a nitrogen atmosphere. Deuteriodiborane was generated by dropwise addition of a solution of 4.2 g. of lithium aluminum deuteride in 75 ml. of ether to a stirred solution of 21.3 g. of boron trifluoride etherate in 75 ml. of ether in a period of 1–2 hr. The gas evolved passed into a solution of 54.0 g. of 4-octyne in 50 ml. of ether in the first trap. The second trap contained acetone to destroy any deuteriodiborane that failed to react. When addition of lithium aluminum deuteride was complete and the apparatus had been swept with nitrogen, the trap containing the trialkenylboron was removed and the contents were stirred for an additional 24 hr. At the end of this time 40 ml. of deuterioacetic acid was added and the mixture was stirred for 72 hr., and then treated with three 100-ml. portions of water. The combined water layers were extracted with 50 ml. of ether, and the organic layers were washed with saturated sodium bicarbonate solution until the washings were basic, and then once with water. The residue, after drying (magnesium sulfate) and distillation of the ether, was distilled through a Vigreux column. A

sample of the distillate was purified by gas chromatography (NMPN, 25°) and was shown by mass spectrometry to contain 20% d_1 , 80% d_2 , and less than 1% d_0 species. Fractional distillation of the remainder of the crude deuterated *cis*-4-octene gave ultimately 3.53 g. which consisted of 85% deuterio-*cis*-4-octene and 15% 4-octyne by gas chromatographic analysis (NMPN, 25°).

cis-4-Octene Oxide-4,5- d_2 . To 104 ml. of a 0.277 M solution of monopero-phthalic acid in ether was added 3.52 g. of deuterio-*cis*-4-octene (85% pure). The flask was stoppered and allowed to stand in the dark at room temperature for 72 hr. The ether solution (containing 57% deuterio-*cis*-4-octene oxide, 20% 4-octyne, and 23% deuterio-*cis*-4-octene by gas chromatographic analysis; silicone oil at 180°) was decanted and the precipitate of phthalic acid was washed with two 20-ml. portions of ether. The combined ether solutions were washed with saturated sodium bicarbonate solution and water, and dried over magnesium sulfate. The residue after distillation of the ether was distilled through a 15-cm. packed column, yielding 1.60 g. (47%) of deuterio-*cis*-4-octene oxide contaminated with 2% of 4-octyne and a trace of deuterio-*cis*-4-octene. A sample of the oxide was collected by gas chromatography (silicone oil, 180°) and analyzed for deuterium.

Anal. Calcd. for $C_8H_{14}D_2O$: 12.5 atom % excess D. Found: 11.00 atom %.

Mass spectrometry showed that the deuterium distribution was d_1 , 20% and d_2 , 80%.

Reaction of Lithium Diethylamide with cis-4-Octene Oxide-4,5-d₂. *cis*-4-Octene oxide-4,5- d_2 , 1.30 g., was treated with lithium diethylamide prepared from 10 ml. of *n*-butyllithium for 72 hr. in the manner described for the nondeuterated oxide. The deuterated *trans*-5-octen-4-ol (440 mg., 40%) obtained by chromatography of the products on alumina (activity I) was distilled in a short-path still and the distillate was analyzed for deuterium distribution by mass spectrometry: d_0 , 2%; d_1 , 26%; d_2 , 70%; and d_3 , 2%. Repetition of the reaction gave an alcohol with the following deuterium distribution: d_0 , 2%; d_1 , 24%; d_2 , 70%; and d_3 , 4%.

trans-4-Octene-4,5- d_2 . Deuterioammonia¹⁶ (98% ND_3) was condensed at -70° in a 20-ml. test tube containing a small cube of sodium. The liquid ammonia- d_3 was allowed to vaporize slowly (1 hr.) through a hypodermic needle into a mixture of 4-octyne (2.01 g.) and calcium turnings (1.47 g.) in 25 ml. of ether under a nitrogen atmosphere. The calcium slowly turned to a dark gray powder as the mixture was stirred at -40° for 1 hr. It was then allowed to warm to room temperature, and the excess ammonia- d_3 was vented into the cylinder (chilled in a Dry Ice bath) in which it had

(16) Merck and Co. Ltd., Canada.

been supplied. The mixture was allowed to stand overnight and then was cooled in an ice bath and water (10 ml.) and saturated ammonium chloride solution (10 ml.) was added. The ether layer was washed with water and dried over magnesium sulfate. Gas chromatography (NMPN, 47°) showed that it contained 96% deuterio-*trans*-4-octene and 4% 4-octyne. A sample of the deuterated olefin collected on the same column showed the following deuterium distribution by mass spectrometry: d_1 , 4%; d_2 , 92%; and d_3 , 4%.

trans-4-Octene Oxide-4,5- d_2 . To the above ether solution of deuterio-*trans*-4-octene was added 85 ml. of a solution of monopero-phthalic acid (0.0588 g./ml.) in ether. The solution was allowed to stand in the dark for 32 hr. An aliquot was withdrawn, treated with saturated sodium bicarbonate solution, dried over magnesium sulfate, and analyzed by gas chromatography (silicone oil, 180°). The product consisted of 86% *trans*-4-octene oxide-4,5- d_2 , 3% 4-octyne, 8% unchanged *trans*-4-octene-4,5- d_2 , and 3% of an unidentified higher boiling substance. After 48 hr. the analysis was unchanged. The ether solution was decanted, the residual phthalic acid was washed with ether, and the combined ether solutions were treated with saturated sodium bicarbonate and dried over magnesium sulfate. After removal of ether the residue was distilled, yielding 1.675 g. (70% from 4-octyne). A sample of the oxide was collected by gas chromatography (TCEP, 125°) and analyzed for deuterium.

Anal. Calcd. for $C_8H_{14}D_2O$: 12.5 atom % excess D. Found: 12.52 atom %.

Mass spectrometry showed that the deuterium distribution was d_1 , 4%; d_2 , 92%; and d_3 , 4%.

Reaction of Lithium Diethylamide with trans-4-Octene Oxide-4,5-d₂. *trans*-4-Octene oxide-4,5- d_2 (1.30 g.) was treated with 0.0128 mole of lithium diethylamide for 72 hr. in the manner described for the nondeuterated analog. Analysis of the products by gas chromatography (silicone oil, 180°) showed the presence of 63% deuterio-*trans*-5-octen-4-ol, 29% *trans*-4-octene oxide-4,5- d_2 , 4% *trans*-4-octene-4,5- d_2 ,¹⁷ and 4% 4-octyne.¹⁷ A sample of the allylic alcohol was collected by gas chromatography (TCEP, 120°) and analyzed for deuterium.

Anal. Calcd. for $C_8H_{14}D_2O$: 12.5 atom % excess D. Found: 11.57 atom %.

The deuterium distribution determined by mass spectrometry was d_0 , 2%; d_1 , 11%; d_2 , 85%; and d_3 , 2%. A sample of the alcohol isolated from the reaction mixture by chromatography on alumina (activity I) followed by distillation showed essentially the same distribution: d_0 , 2%; d_1 , 12%; d_2 , 84%; and d_3 , 2%.

(17) Present in the starting oxide. See the preceding paragraph.