version of III into IV. The pyridine was diluted with ether; the mixture washed well with water and then $NaHCO_3$ solution. Column chromatography of the residue obtained from evaporation of the ether through silica gel using ethyl acetate–hexane (1:40) as an eluent yielded 0.070 g of IV: mp 168–170°; the spectra was identical with that cited above.

Acknowledgment. I would like to express my appreciation to the UMKC Research Council for financial support of this research. In addition, I am extremely grateful to Dr. George R. Pettit at Arizona State University for providing me with a generous supply of isocholesterol.

Registry No.—I, 2115-49-3; II, 5168-22-9; II (7α-hydroxy), 51231-32-4; III, 51231-33-5; IV, 51231-34-6; V, 6593-12-0; TsCl, 98-59-9.

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(10) For an example and of a similar long-range C-19 coupling to a 1α-H, see N. Bhacca and D. H. Williams, "Application of NMR Spectroscopy in Organic Chemistry," Holden-Day, San Francisco, Calif., 1964, p 117.

(11) Apparently a large excess of TsCl is required for cis dehydration of II at room temperature.

A Study of the Diepoxidation of the Isomeric 2,4-Hexadienes

Gene E. Heasley* and Ronald V. Hodges

Department of Chemistry, Bethany Nazarene College, Bethany, Oklahoma 73008

Victor L. Heasley

Department of Chemistry, Point Loma College (formerly Pasadena College), San Diego, California 92106

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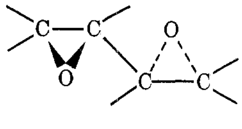
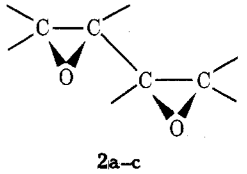
The literature contains little data on the conversion of conjugated dienes to diepoxides.[1] We recently had need to prepare and characterize the diepoxides arising from the *trans,trans-*, *cis,cis-*, and *cis,trans-*2,4-hexadienes.[2] We wish to report here the results of diepoxidation of each of these three dienes with three different peroxy acids and the infrared and proton nmr spectral properties of each of the diepoxide isomers.

Results

The six possible diastereomeric 2,3,4,5-diepoxyhexanes are identified as follows: *trans,trans, meso*-(2*S*,3*R*,4*S*,5*R*)-, **1a**; *rac*-(2*S*,3*R*,4*R*,5*S*- or 2*R*,3*S*,4*S*,5*R*)-, **2a**; *cis,cis, meso*-(2*R*,3*R*,4*S*,5*S*)-, **1b**; *rac*-(2*R*,3*R*,4*R*,5*R*- or 2*S*,3*S*,4*S*,5*S*)-, **2b**; *cis,trans*, *rac*-(2*R*,3*R*,4*S*,5*R*- or 2*S*,3*S*,4*R*,5*S*)-, **1c**; *rac*-(2*R*,3*R*,4*R*,5*S* or 2*S*,3*S*,4*S*,5*R*)-, **2c**.



1a-c



2a-c

Table I
Diepoxidation of the 2,4-Hexadienes

Peroxy acid[a]	Diene	1a–c/2a–c[b]	Yield, %
MCPB	*trans,trans-*	1.8	83
PB	*trans,trans-*	2.0	63
PA	*trans,trans-*	1.5	32
MCPB	*cis,cis-*	1.7	87
PB	*cis,cis-*	2.2	64
PA	*cis,cis-*	1.7	43
MCPB	*cis,trans-*	2.2	60
PB	*cis,trans-*	2.2	45
PA	*cis,trans-*	2.0	20

[a] MCPB = *m*-chloroperoxybenzoic acid, PB = peroxybenzoic acid; PA = peroxyacetic acid. [b] **1a** and **2a** from *trans,trans;* **1b** and **2b** from *cis,cis;* **1c** and **2c** from *cis,trans.*

Table I shows the ratios of diepoxides **1a–c** to **2a–c** and the yields obtained from treatment of each diene with three peroxy acids (peroxyphthalic acid was also studied but gave no significant yield with any diene). Each diene yielded two diepoxides which were readily separated by vpc, with isomers **1a–c** having a shorter retention time than isomers **2a–c** in each case.[3] Each isomer was isolated by preparative vpc and/or spinning band distillation. As expected, the reaction with peroxy acid was stereospecific; *i.e.*, each diene yielded two isomers which could be shown to be stereoisomerically pure by means of ir or nmr.

As shown in Table I, isomers **1a–c** are formed in larger amounts than **2a–c**, with the ratio of the two showing little variation for the three dienes and three peroxy acids. The substantially lower yield observed with peroxyacetic acid in each case is probably due to ring-opening reaction of diepoxide or monoepoxide with acetic acid. The aromatic acids (especially *m*-chlorobenzoic acid) precipitate from solution and are therefore not so readily available for further reaction. Significant amounts of monoepoxides were not present when the reactions were terminated.

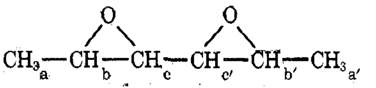
The fact that isomers **1a–c** are formed in larger amounts than isomers **2a–c** can be explained by assuming that the first-formed monoepoxide exists in an essentially *s*-trans conformation (about the 3,4 bond) and that attack by peroxy acid anti to the epoxide oxygen is then sterically favored over syn attack. If the monoepoxide existed in both *s*-cis and *s*-trans conformations and if diepoxide were formed by anti attack on either conformation, then the ratio of diepoxides formed would be expected to show considerable variation between each of the three hexadienes. This is true because the *s*-cis forms of *cis,trans-* and (especially) *cis,cis*-2,4-hexadiene monoepoxides should be much less stable than that of the trans,trans isomer, because of greater steric repulsions from the methyl groups in the former cases. It has recently been reported[4] that epoxidation of 1,3-cyclohexadiene monoepoxide with *m*-chloroperoxybenzoic acid yields 95% trans and only 5% cis diepoxide. This result is in line with the above explanation, since peroxy acid should suffer greater steric hindrance by syn attack on 1,3-cyclohexadiene monoepoxide than on the *s*-trans form of the 2,4-hexadiene monoepoxides (the double bond and oxygen lone-pair electrons are closer together in the former).

Experimental Section

General. Hexadienes were obtained from Chemical Samples Co. (*trans,trans-* and *cis,cis-*, 98%) and Aldrich (*cis,trans-*, 99%). *m*-Chloroperoxybenzoic acid (85%) and peracetic acid (40%) were commercial materials; peroxybenzoic acid was prepared by a standard procedure.[5] Infrared spectra were obtained with a Beckman IR-10 spectrophotometer. Nmr spectra were obtained on a Varian XL-100 spectrometer.

Reaction Procedure and Analysis. The peroxy acid was dissolved in chloroform (0.26 *M*), the solution was cooled to 0°, and the diene was added (mole ratio peroxy acid/diene, 2.2). The solution was kept at 0° and sampled directly by vpc until reaction was complete (2-3 days). Yields were determined by vpc with *p*-chlorobromobenzene as internal standard. In cases where the diepoxides were isolated, the chloroform solution was shaken with a cold sodium bisulfite-sodium bicarbonate solution and the aqueous phase was then saturated with ammonium sulfate. The phases were separated and the aqueous phase was extracted once more with ether. Vpc analysis was accomplished on the following column: 17% Carbowax 20M, 8 ft × 0.25 in., 100°, 60 ml/min. Retention times of 12, 12, 13, 14, 16, and 17 min were observed for **1a, 1c, 1b, 2a, 2c,** and **2b,** respectively. Quantitative vpc analysis was done with a Hewlett-Packard 7620A FID chromatograph.

Nmr Spectra. Spectra of all six isomers showed three regions of absorptions at approximately 1.3, 2.5, and 2.9 ppm with integrated intensities of 3:1:1, respectively. The absorption near 1.3 ppm which occurred as a sharp doublet (two doublets for the cis,trans isomers, **1c** and **2c**) is assigned to the methyl groups. The coupling constant exhibited in the absorption near 1.3 ppm can be found in the lowest field absorption, *ca.* 2.9. Also, irradiation at the frequency of the methyl proton absorptions (for isomer **2c**) caused decoupling to appear in the lowest field absorption but did not effect the absorption near 2.5 ppm. Protons H_b ($H_{b'}$) are therefore assigned to the absorption near 2.9 ppm and protons H_c ($H_{c'}$) to the absorption near 2.5 ppm (see structure below). The low-field absorptions each show two couplings in common, due to adjacent protons, J_{bc}, and evidently the longer range coupling $J_{bc'}$. Spectra for isomers **1a, 2a, 1b,** and **2b** appear to be essentially first order, owing to equivalency of primed and nonprimed hydrogens (structure above). In isomers **1c** and **2c** the epoxide rings are cis and trans and more complex spectra result. Apparent coupling constants are reported for isomers, **1a, 2a, 1b,** and **2b** but we were not able to obtain constants for **1c** and **2c.** Summary of nmr data (100 MHz, CCl_4, parts per million downfield from TMS) follows: **1a,** 1.28 (d, CH_3, J_{ab} = 5.2 Hz), 2.36 (dd, CH_3CHCH, J = 0.9, J' = 0.7 Hz), 2.83 (dd of quartet, CH_3CH, J_{ba} = 5.2, J = 0.9, J' = 0.7 Hz); **2a,** 1.27 (d, CH_3, J_{ab} = 5.2 Hz), 2.49 (dd, CH_3CHCH, J = 1.0, J' = 0.8 Hz), 2.83 (dd of quartet, CH_3CH, J_{ba} = 5.2, J = 1.0, J' = 0.8 Hz); **1b,** 1.36 (d, CH_3, J_{ab} = 5.3 Hz), 2.62 (dd, CH_3CHCH, J = 2.5, J' = 1.5 Hz), 3.02 (dd of quartet, CH_3CH, J_{ba} = 5.3, J = 2.5, J' = 1.5 Hz); **2b,** 1.33 (d, CH_3, J_{ab} = 5.4 Hz), 2.69 (dd, CH_3CHCH, J = 2.8, J' = 1.4 Hz), 2.97 (dd of quartet, CH_3CH, J_{ba} = 5.4, J = 2.8, J' = 1.4 Hz); **1c,** 1.30 (d, CH_3), 1.35 (d, CH_3), 2.48 (m, CH_3CHCH), 2.95 (m, CH_3CH); **2c,** 1.28 (d, CH_3), 1.36 (d, CH_3), 2.51 (m, CH_3CHCH), 2.89 (m, CH_3CH).



Ir Spectra. The medium to strong absorptions for each hexadiene diepoxide isomer are shown below. These absorptions allow the six isomers to be readily distinguished from each other. Bands near 1250, 945, and 825 cm^{-1} which have been previously assigned to the epoxide function[6] are observed in these compounds. Also (as observed previously for the *cis*- and *trans*-2-butene oxides[6]) the absorption near 940 cm^{-1} is essentially constant but the 800-cm^{-1} absorption is higher for the all-trans isomers **1a** and **2a** than for the all-cis isomers **1b** and **2b**; isomers **1c** and **2c,** which contain both cis and trans epoxide rings, show two absorptions each, in the 810-845-cm^{-1} region. Summary of ir spectra (CCl_4 solvent, except CS_2 solvent for 900-700-cm^{-1} region) follows: **1a,** 2990, 2920, 1420, 1445, 1375, 950, 830, 745 cm^{-1}; **2a,** 2990, 2920, 1446, 1380, 1240, 1010, 945, 835, 748 cm^{-1}; **1b,** 2990, 2920, 1440, 1402, 1375, 1255, 1125, 1042, 990, 940, 820, 740 cm^{-1}; **2b,** 2990, 2920, 1445, 1390, 1379, 1260, 1128, 1042, 1090, 940, 810, 740 cm^{-1}; **1c,** 2990, 2920, 1450, 1415, 1395, 1260, 1100, 950, 810, 840, 740 cm^{-1}; **2c,** 2990, 2920, 1446, 1385, 1250, 1142, 1100, 945, 922, 817, 845, 740 cm^{-1}.

Acknowledgment. Financial support for this work was provided by the Research Corporation. We wish to thank Dr. K. D. Berlin and Oklahoma State University for providing the use of the nmr spectrometer.

Registry No.—**1a,** 51065-35-1; **1b,** 51153-42-5; **1c,** 51153-43-6; **2a,** 51153-44-7; **2b,** 51153-45-8; **2c,** 51153-46-9; *trans,trans*-2,4-hexadiene, 5194-51-4; *cis,cis*-2,4-hexadiene, 6108-61-8; *cis,trans*-2,4-hexadiene, 5194-50-3.

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(3) Assignment of structures **1a-c** to the compounds of shorter vpc retention time is based on the following structure proof (described in detail in ref 2). Isomers **2a-c** but not isomers **1a-c** are obtained from the 3,5-dibromo-*trans*-3-hexenes (meso and *dl*) by the sequence of reactions

$$\text{dibromide} \xrightarrow{KMnO_4} \text{dibromo glycol} \xrightarrow{\text{base}} \text{diepoxide}$$

Isomer **2c** is obtained from the dibromide assigned the meso structure and a mixture of **2a** and **2b** is obtained from the dibromide assigned the racemic structure.

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A Novel Reaction of Alkyl 3-Chloropropionimidate Hydrochlorides

Curtis L. Schilling, Jr.

Union Carbide Corporation, Tarrytown Technical Center,
Tarrytown, New York 10591

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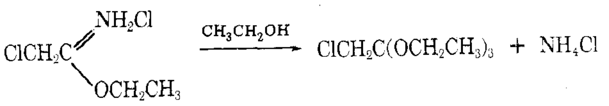
The treatment of imino ester hydrochlorides with excess alcohol is a general reaction for the preparation of ortho esters.[1] The reaction of ethyl chloroacetimidate hydrochloride with ethanol, for example, yields triethyl orthochloroacetate (70–73% yield) and ammonium chloride.[2] Treatment of the corresponding methyl or ethyl 3-chloropropionimidate hydrochlorides with methanol or ethanol, respectively, however, does not yield the expected trimethyl or triethyl ortho-3-chloropropropionates. Unexpectedly high yields of alkyl 3-alkoxypropionates are obtained instead.



$$ClCH_2C(=NH_2Cl)(OCH_2CH_3) \xrightarrow{CH_3CH_2OH} ClCH_2C(OCH_2CH_3)_3 + NH_4Cl$$

$$ClCH_2CH_2C(=NH_2Cl)(OR) \xrightarrow[ROH]{} ROCH_2CH_2CO_2R + RCl + NH_4Cl$$

$R = CH_3, CH_3CH_2$

This simple reaction seems remarkable in view of known reactions of 3-halo-substituted imidate hydrochlorides, nitriles, or acids, wherein the halide substituent is retained under reaction conditions similar to those of the present work. For example, 3-chloro- or 3-bromopropionimidate hydrochlorides react with water to form the corresponding esters and ammonium chloride.[3-5] 3-Halo-substituted nitriles are converted to the corresponding 3-halo esters or amides in reactions where imidates are presumably intermediates.[6,7] Similar results are observed for 4-halo-substituted nitriles,[8,9] and 3-halo-substituted propionic acids can be esterified without displacement of the halide group.[8]

3-Chloropropionamide is not an intermediate leading to the observed products, since it does not yield any ethyl 3-ethoxypropionate under reaction conditions (refluxing ethanol in the presence of equimolar ammonium chloride). The 3-chloropropionamide which is isolated no doubt arises from the known thermal decomposition of imidate