Enol Esters. VII. Isolation and Rearrangement of Terminal Fatty Oxirane Esters

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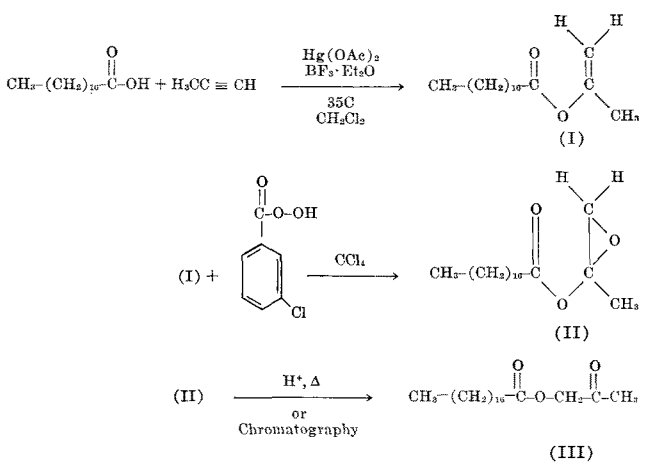
Abstract

Isopropenyl esters of mono- and dibasic fatty acids were epoxidized with m-chloroperbenzoic acid in carbon tetrachloride. The isolation of the resulting oxirane ester was difficult because of the spontaneous rearrangement to a hydroxyacetone ester. Rapid gel filtration was the only method that consistently afforded good yields of the oxiranes. The infrared spectra of these oxirane esters had many strong, sharp bands which were completely lacking in the rearranged product. The isomerization, carried out in several ways, could easily be followed spectrally and a qualitative estimate of purity made.

Introduction

DURING THE COURSE of our investigations of the synthesis and reactions of isopropenyl esters of fatty acids, it was desired to prepare oxirane derivatives. Preliminary work at this laboratory with p-nitroperbenzoic acid (1) attested to its efficacy as an epoxidizing agent for isopropenyl stearate. The rate of epoxidation of the isopropenyl double bond was higher with p-nitroperbenzoic acid than with m-chloroperbenzoic acid, but no kinetic study was made. The present work was carried out with m-chloroperbenzoic acid because of its commercial availability. Early in the work it was noted that some acyloxy ketone was formed along with the desired oxirane. This observation was not totally unexpected since the rearrangement of epoxides to ketones with the aid of acid catalyst and/or heat has been well documented (2–4).

Practical conditions for isolation and rearrangement of these oxirane esters have been determined. Their purity was qualitatively measured by IR analysis since the ordinary methods of determining oxirane content caused conversion to hydroxyacetone esters or gave anomalous results. Analysis with HBr in acetic acid by a modified Durbetaki (5) method gave a fading end-point, characteristic of terminal oxiranes. The reaction sequence, illustrating the preparation of 2-methyl-2-stearoyloxyoxirane, is shown.



[1] Previous paper in series: E. S. Rothman, J. Org. Chem. *32*, 1683–1684 (1967).

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Experimental Procedures

All melting points were obtained with a Kofler hot stage. IR spectra were determined on a Perkin Elmer Grating Infrared Spectrophotometer Model 237B by using CS_2. Materials used are given below.

m-Chloroperbenzoic Acid. Obtained from Food Machinery Corporation, this was used as received after iodometric analysis.

Sephadex LH-20. A cross-linked dextran, this was obtained from Pharmacia Fine Chemicals Inc.

Carbon Tetrachloride. J. T. Baker reagent grade was used as received.

Alumina. Grade F-20, lot No. 104–32, was used as received from the Aluminum Corporation of America.

Boron Trifluoride Etherate. This was prepared by distillation of Matheson, Coleman, and Bell material.

1,4-Dioxane. Eastman Kodak practical material was purified with HCl according to the method of Fieser (6).

Petroleum Ether. J. T. Baker reagent grade was used as received.

Stearic Acid. Humko Hystrene 97S was recrystallized once from acetone at −20°; estimated 96% pure (GLC).

Diisopropenyl Sebacate and Diisopropenyl Adipate. These materials were prepared according to the method of Rothman et al. (7).

Isopropenyl Stearate (I). This compound was prepared by isopropenylation of stearic acid. Stearic acid 1000 g (3.52 mole), methylene chloride 8000 ml, mercuric acetate 112 g (0.351 mole), and boron trifluoride etherate 2.5 g (0.018 mole) was treated with propyne bubbled through the stirred mixture for 7 hr. The temperature was kept between 35–37C by means of a water bath and control of the flow rate of the propyne through the low-boiling methylene chloride solvent. The gas flow was stopped, and the solution was stirred over-night under anhydrous conditions. Powdered sodium acetate was added, the mixture was stirred vigorously until its color lightened, then it was filtered free of solids and mercury. The filtrate was passed through a short column of Florisil, which was washed with methylene chloride. The residue obtained by evaporation of the percolate was chromatographed on a 20:1 ratio Florisil column with petroleum ether. The eluate, upon drying, gave a 75% yield of isopropenyl stearate, the IR of which (Fig. 1) showed bands at 1751, 1674, 1205, 1148, 1120, and 868 cm^{-1}. This compound was identical in every respect with an authentic sample prepared by transesterification with isopropenyl acetate (8). This was recrystallized from petroleum ether at −20C. The resultant white wax had mp of 38–39.5C.

Preparation of 2-Methyl-2-stearoyloxyoxirane (II). Isopropenyl stearate 32.4 g (0.10 mole) in 300 ml of carbon tetrachloride was treated with 33.5 g (0.17 mole) of m-chloroperbenzoic acid (86.60%). Upon continued shaking, most of the solids went into solution. After standing 12 hr at room temperature, the m-chlorobenzoic acid was removed by filtration. The volume was reduced by rotary evaporation at room temperature with a water bath, and another crop of precipitated acid was removed by filtration.

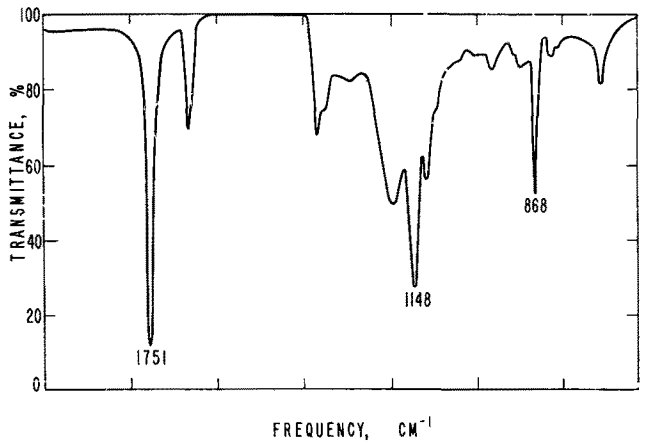


FIG. 1. Infrared spectrum of isopropenyl stearate.

The concentrated filtrate was immediately diluted with petroleum ether and rapidly passed through a short column (1:1 ratio) of alumina. After the column was washed with petroleum ether, the combined vacuum-dried eluates weighed 33.4 g (0.098 mole), 98% yield. IR showed this to be 2-methyl-2-stearoyloxyoxirane (Fig. 2), with bands at 1748, 1190, 1160, 1130, 1105, 1085, 1004, 929, 885, 821, and 718 cm^{-1}. A transmittance ratio of 3.87 was obtained in a 1.0-mm cell at 10 g/liter. A trace of m-chlorobenzoic acid was present. The analytical sample, mp 38–39.5C, was obtained by recrystallization from petroleum ether at −20C.

Anal. Calc'd for $C_{21}H_{40}O_2$: C, 74.06; H, 11.84
Found: C, 74.21; H, 11.02.

Estimation of Purity of Oxirane Ester. The purest oxiranes obtained to date have the highest transmittance ratios. For example, for 2-methyl-2-stearoyloxy oxirane this ratio is 62.0 over 16.0, which equals 3.87. This is obtained by dividing the highest transmittance between 1130 and 1160 cm^{-1} by the transmittance at 1130 cm^{-1}. The rearrangement product, hydroxyacetone stearate, has its strongest peak in the fingerprint region at 1147 cm^{-1}, just midway between the two peaks. The presence of rearranged material absorbing at 1147 cm^{-1} (dotted peak in Fig. 2) could, depending on its concentration, markedly lower this ratio.

Hydroxyacetone Stearate (III) (two methods of preparation).

a) Standard chromatographic treatment on alumina of 2-methyl-2-stearoyloxyoxirane, by using petroleum ether and a mixture with methylene chloride, afforded high conversion to hydroxyacetone stearate. Any unrearranged oxirane was eluted before the major product. Hydroxyacetone stearate, recrystallized from petroleum ether, afforded plates with mp 57.5–58.5C (7) (Fig. 2). The compound rapidly reduced Fehling's solution and triphenyltetrazolium reagent and was identical in every respect with an authentic specimen (Fig. 3). A partially resolved, strong-band pair appeared at 1750 and 1738 cm^{-1} and a single moderately strong band at 1147 cm^{-1}.

b) To 2.82 g (0.019 mole) of boron trifluoride etherate in 80 ml of 1,4-dioxane, in a flask which was equipped with a drying tube, was added 2.15 g (0.0063 mole) of 2-methyl-2-stearoyloxyoxirane. The reaction mixture was refluxed 3 hr, cooled, poured into 80 ml of benzene, and washed with water till neutral. The solution was shaken with Drierite and evaporated by bubbling nitrogen through it at room temperature to give a pale orange oil, weight 1.94 g. The oil solidified on standing and had an IR spectrum identical with that of an authentic sample of hydroxyacetone stearate. Recrystallization from petroleum ether at −20C afforded silvery plates, mp 57.5–58.5C. This compound rapidly reduced Fehling's solution and triphenyltetrazolium reagent and was identical in every respect with the sample above.

2,2-Sebacoyloxybis(methyloxirane). To a solution of 30 g (0.11 mole) of diisopropenyl sebacate in 300 ml of carbon tetrachloride at 23C were added 45.7 g (0.23 mole) of m-chloroperbenzoic acid (86.60%); the mixture was stirred continuously for 23 hr. At this time a filtered, vacuum-dried aliquot showed complete absence of the olefinic absorption bands near 1666 and 869 cm^{-1}. After concentration in a rotary evaporator the filtered mixture yielded 37 g of oil, which were immediately diluted with carbon tetrachloride to a thin liquid. A 1¼-in. ID chromatographic column was prepared beforehand. This consisted of 220 g of unequilibrated dry Sephadex LH-20, covered with glass beads to keep the gel filtration medium beneath the surface of the denser carbon tetrachloride solution.

The solution of oil was immediately placed on the dry Sephadex LH-20 column and washed from the column with the same solvent. The first fractions gave, after drying, 21.3 g of pale yellow oil. IR showed acid and rearrangement product to be absent. The bisoxirane showed limited solubility in hexane, but repeated extraction with hexane gave 21.0 g (0.067 mole), 64% yield, of colorless oil. The colored impurity was insoluble in hexane. The analytical

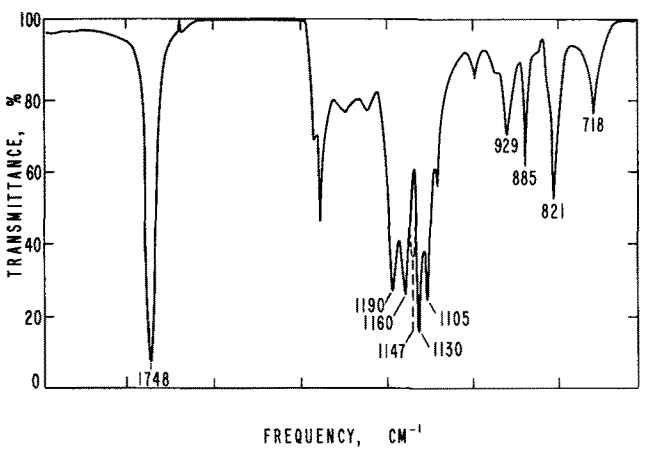


FIG. 2. Infrared spectrum of 2-methyl-2-stearoyloxy oxirane. (Dotted curve is hydroxyacetone stearate.)

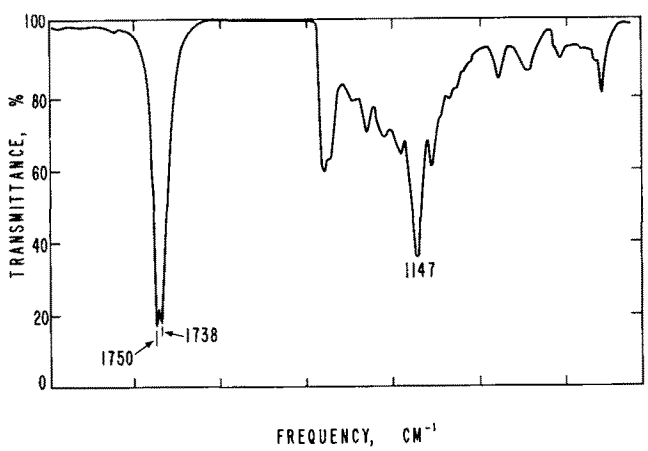


FIG. 3. Infrared spectrum of hydroxyacetone stearate.

sample was prepared by bubbling dry nitrogen through the oil at room temperature. IR analysis showed bands at 1748, 1188, 1155, 1125, 1104, 1083, 923, 886, and 816 cm^{-1}. A transmittance ratio of 3.21 in a 0.5-mm cell at 10 g/liter was obtained by a ratio of maximum transmittance between 1125 and 1155 cm^{-1} to transmittance at 1125 cm^{-1}.

Anal. Calc'd for $C_{16}H_{26}O_6$: C, 61.13; H, 8.34
Found: C, 60.91; H, 8.01
$d_4^{30} = 1.0740$ $n^{29C} = 1.4521$

Bis(hydroxyacetone sebacate). This rearrangement product was obtained in small amounts from late eluates of the chromatography. It is formed in high yield during attempts to chromatograph 2,2′-sebacoyloxybis(methyloxirane) on alumina in the standard manner with carbon tetrachloride. The product, recrystallized three times from petroleum ether, resulted in rectangular rods, mp 70–70.5C. This compound rapidly reduced Fehling's solution and triphenyltetrazolium reagent. IR showed a partially resolved, strong-band pair at 1752 and 1739 cm^{-1} and a moderately strong band at 1145 cm^{-1}.

Anal. Calc'd for $C_{16}H_{26}O_6$: C, 61.13; H, 8.34
Found: C, 61.20; H, 8.30

Bis(hydroxyacetone)adipate. The epoxidation of diisopropenyl adipate according to the procedure for diisopropenyl sebacate afforded bis(hydroxyacetone) adipate in 85% yield. IR analysis showed that this oxirane rearranged much more rapidly than the others described in this paper, and it was not possible to isolate it. The analytical sample of bis(hydroxyacetone)adipate, recrystallized from cold petroleum ether, formed large rectangular plates, mp 49.5–50.5C. IR showed a partially resolved, strong-band pair at 1756 and 1742 cm^{-1} and a moderately strong band at 1137 cm^{-1}.

Anal. Calc'd for $C_{12}H_{18}O_6$: C, 55.80; H, 7.03
Found: C, 55.82; H, 6.99.

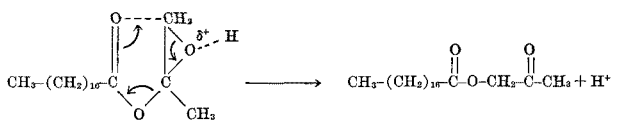
Results and Discussion

When a solution of the isopropenyl ester in carbon tetrachloride was stirred with at least one equivalent of m-chloroperbenzoic acid, the disappearance of the 1674 and 868 cm^{-1} bands showed that the isopropenyl bond had been completely epoxidized. These oxiranes slowly rearranged, even below room temperature.

The higher-molecular-weight bisoxirane rearranged less rapidly than the bisoxirane of lower molecular weight. The mono-oxirane was more stable than either of the bisoxiranes described. This rearrangement, particularly of the lower-molecular-weight diester, was so rapid that actual isolation of the oxirane was not possible. Only the hydroxyacetone ester could be isolated.

Heat hastens this conversion, and acid readily catalyzes this reaction. The rate of epoxidation of these isopropenyl esters at reduced temperature is impractically slow even if a better solvent for m-chloroperbenzoic acid is used, such as chloroform. Standard chromatography of the oxirane ester on silica gel, alumina, or Florisil causes rapid rearrangement to the hydroxyacetone ester. This rearrangement can be readily followed spectrally. The two most important peaks for qualitatively measuring the purity of 2-methyl-2-stearoyloxyoxirane are those at 1130 and 1160 cm^{-1}. By dividing the highest transmittance between 1130 and 1160 cm^{-1} by the transmittance at 1130 cm^{-1}, a ratio is obtained which is qualitatively indicative of the purity of the oxirane in question.

The rearrangement product, hydroxyacetone stearate, has its strongest peak in the fingerprint region at 1147 cm^{-1}, just midway between the 1160 and 1130 cm^{-1} peaks. The presence of this material, absorbing at 1147 cm^{-1}, (dotted peak in Fig. 2) can markedly lower this ratio, depending on its concentration. As the rearrangement proceeds, this ratio becomes smaller. When hydroxyacetone alone is present, only a single moderately strong peak is found in the fingerprint region. The many sharp peaks of the oxirane ester are completely gone, and the carbonyl region is now occupied by a partly resolved, strong doublet instead of the single oxirane carbonyl peak. This facile rearrangement and the fact that it is acid-catalyzed may be reasonably explained by a one-stage, concerted process.



All attempts to open the oxirane ring with nucleophilic reagents resulted only in rearrangement to the hydroxyacetone ester.

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