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OXIRANE AS A NEIGHBORING GROUP; SYNTHESIS OF 3-OXETANOL DERIVATIVES

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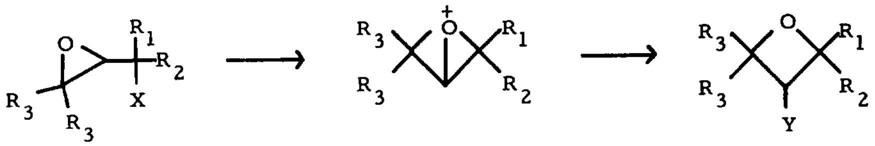
Solvolysis reactions of esters of several 2,3-epoxy-1-propanols (1) have led to formation of esters of 3-oxetanols (3). 1-Oxabicyclobutonium cations (2) probably are intermediates in the rearrangements (1). These reactions, under study as a part of a program to delineate the interaction between an oxirane function and a reaction center, are of synthetic value — only a few 3-oxetanols have been prepared previously and those by methods not extensible to a variety of systems (2).



1 2 3

1a-3a $R_1 = R_2 = CH_3$, $R_3 = H$, X = Y = 3,5-dinitrobenzoate

1b-3b $R_1 = CH_3$, $R_2 = R_3 = H$, X = Y = 3,5-dinitrobenzoate

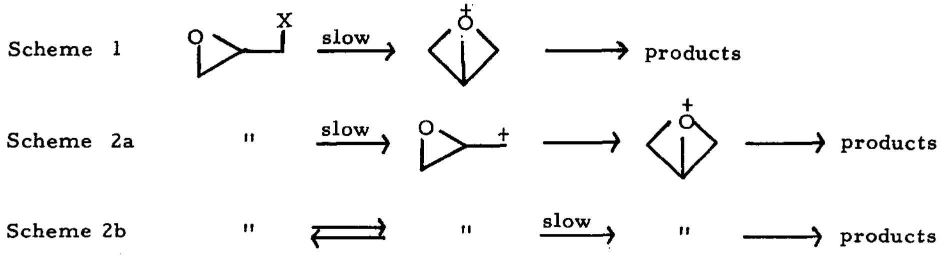
1c-3c $R_1 = R_3 = CH_3$, $R_2 = H$, X = Y = 3,5-dinitrobenzoate

1d-3d $R_1 = R_2 = CH_3$, $R_3 = H$, X = OH, Y = p-toluenesulfonate

3-Oxetanyl 3,5-dinitrobenzoates 3a, 3b (3), and 3c (4), products of internal return, were formed in yields exceeding 80% in solvolyses of 3,5-dinitrobenzoates 1a, 1b, and 1c in 80% aqueous acetone (5). Free 3-oxetanols were only minor products; acyclic products that might have resulted from acid-catalyzed cleavage of the oxirane rings were not present in significant amounts. p-Toluenesulfonate 3d was isolated in good yield from a reaction of alcohol 1d and p-toluenesulfonyl chloride in pyridine. The nmr spectra provide particularly strong evidence for the 3-oxetanyl structures assigned to the rearranged products. For example, the spectrum (hexadeuteroacetone) of 3c exhibits absorptions at δ 1.14 (d, 3, J = 6.5, $HCC\underline{H}_3$), 1.25 (s, 3, $CH_3CC\underline{H}_3$), 1.42 (s, 3, $C\underline{H}_3CCH_3$), 4.46 (q, J = 6.5, with each line a d, J = 2, 1, $\underline{H}CCH_3$), 5.05 (d, 1, J = 2, HCY), and 9.30 (s, 3, aryl H's).

Rearrangements of 1a and 1b at 100° in 80% aqueous acetone containing 2,6-lutidine as a buffer have first-order rate constants of 8×10^{-6} and $\sim 9 \times 10^{-6}$(6)sec^{-1}, respectively (7). These rates are nearly as large as the hydrolysis rate ($17 \times 10^{-6} sec^{-1}$) of t-butyl 3,5-dinitrobenzoate under the same conditions. It seems certain that the rearrangement of secondary 1b is accelerated; if allowance is made for a rate-depressing effect on ionization, probably of 10 or more, that might be anticipated (8) for the inductive effect of the oxygen, it is possible that even the rearrangement of tertiary 1a is modestly accelerated (9).

Acceleration could be due to participation (Scheme 1) by the neighboring oxirane group during ionization, or to acceleration of ionization (Scheme 2) by a conjugative effect of an oxirane ring similar in nature to that exhibited by a cyclopropyl ring (10), or to a combination of these factors. The observation that the rearrangement rates of tertiary 1a and secondary 1b are nearly identical probably is more consistent with neighboring group participation in the rate-~~deter~~mining step as indicated in Scheme 1 (11). A tertiary:secondary rate ratio of $\sim 10^3$ would instead be expected if ionization to an unrearranged cation, as shown in Scheme 2a, was the



rate-determining step, though a smaller ratio would be conceivable if, as shown in Scheme 2b, the subsequent cyclization in the tertiary system was comparable in rate to a reversible ionization.

It may be significant that solvolysis in collidine of the *p*-toluenesulfonate ester of 3β-hydroxy-4β, 5β-epoxycholestane furnished products that must not have formed from a 1-oxabicyclobutonium ion intermediate (12). The *cis* relationship of leaving group and oxirane oxygen in this compound precludes participation by oxygen during ionization.

Rearrangements during solvolyses of thirane (13) and aziridine (14) analogs of oxirane **1** to form sulfur and nitrogen analogs of **3** have been reported. The rates of these rearrangements also seem to be accelerated by the three-membered rings.

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REFERENCES

1. Tetramethyl-3-oxetanone, one product of the epoxidation of tetramethylallene [J.K. Crandall and W. H. Machleder, *Tetrahedron Letters*, 6037 (1966)], may arise from acid catalyzed opening of the diepoxide of tetramethylallene, a reaction process that would be related to the rearrangements reported in this communication.
2. Information about oxetanes has been reviewed [S. Searles, Jr., in "The Chemistry of Heterocyclic Compounds," Vol. 19, A. Weissberger, Ed., Interscience Publishers, New York, 1964, Chapter 9]. Preparations by photochemical methods have since been described [P. Yates and A. G. Szabo, *Tetrahedron Letters*, 485 (1965); R.B. LaCount and C. E. Griffin, *ibid.*, 1549 (1965)].
3. Ester **1b** was a mixture of two diastereoisomers and **3b** a mixture of *cis* and *trans* isomers. Establishing the stereochemical fate of each diasteroisomer will be of great value in establishing the detailed mechanism of the rearrangement.

4. Ester **1c** seemed to be a single diastereoisomer and **3c** a single isomer.

5. The elemental analyses and ir and nmr spectra of new compounds (**1a**-**c** and **2a**-**d**) were in accord with the structures assigned to them. Analytical samples of **1a** always contained at least one mole of water.

6. This number is the average of the rate constants exhibited by the two diastereoisomers.

7. Rates were determined from areas of absorptions due to starting materials in nmr spectra of aliquots Deuterated acetone and water were used to avoid strong solvent absorptions.

8. Studies of effects of 2-alkoxyl or 2-hydroxyl substituents on solvolysis rates of esters and halides include the following: S. Winstein, E. Grunwald, and L. L Ingraham, *J. Amer. Chem. Soc.*, **70**, 821 (1948); S. Winstein and E. Grunwald, *ibid.*, **70**, 828 (1948); H. Böhme and K. Sell, *Chem. Ber.*, **81**, 123 (1948); W. Klemperer, L. McCabe, and B. Sindler, *J. Amer. Chem. Soc.*, **74**, 3425 (1952); S. Winstein, E. Allred, R. Heck, and R. Glick, *Tetrahedron*, **3**, 1 (1958); D. Gagnaire, *Bull. Soc. Chim. France*, 1813 (1960).

9. It would be most appropriate to compare the actual rates of ionization of **1a**, **1b**, and *t*-butyl 3,5-dinitrobenzoate. In the discussion it is assumed that the rearrangement rates of **1a** and **1b** and the hydrolysis rate of *t*-butyl 3,5-dinitrobenzoate are each related to the corresponding ionization rate by approximately the same factor.

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11. B. Capon, *Quart. Rev.* (London), **18**, 45 (1964).

12. J. M. Coxon, R. P. Garland, M. P. Hartshorn, and G. A. Lane, *Chem. Commun.*, 1506 (1968). One product was not identified, however.

13. J. C. Martin and D. J. Anderson, Abstracts, 139th National Meeting of The American Chemical Society, St. Louis, Mo., March 1961, Abstract 31-0.

14. J. A. Deyrup and C. L. Moyer, *Tetrahedron Letters*, 6179 (1968).