nance of 3-alkylated products can then be understood, since the n–π^* state has greatest odd electron density at the 3 position.[19] The major pathway for step ii involves a 1,4-hydrogen transfer leading to **1**, a process which has been reported for diradical systems.[20,21] The ratio of **1** to **2** is explicable in terms of strain in the transition state for hydrogen transfer, a 1,4 process being more rapid than the corresponding 1,3.[22]

We are presently investigating mechanistic aspects of this alkylation reaction.

Acknowledgment. We wish to thank the National Research Council of Canada for financial support of this work.

[19] The coefficient of π_3^* (HMO) at C_3 is at least three times that at C_2 for acrolein-like systems. See, *e.g.*, C. A. Coulson and A. Streitwieser, "Dictionary of π-Electron Calculations," W. H. Freeman and Co., San Francisco, Calif., 1965, p 227.

[20] (a) A. S. Gordon and J. R. McNesby, *J. Chem. Phys.*, **31**, 853 (1959); **33**, 1882 (1960); (b) 1,4-hydrogen shifts occur in the photolysis of cyclopentanone: R. Srinivasan, *J. Am. Chem. Soc.*, **81**, 1546 (1959).

[21] A referee has pointed out that since 1,4 ionic hydrogen shifts have not been reported, this argues against a zwitterionic intermediate undergoing step ii.

[22] The 1:1 ratio of **3** and **4** may be a result of their formation from a highly reactive intermediate, with corresponding loss in selectivity.

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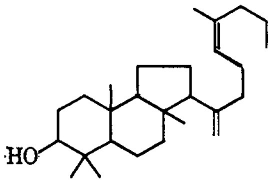
Received September 24, 1966

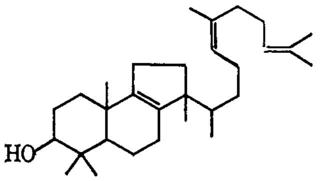
Nonenzymic Laboratory Cyclization of Squalene 2,3-Oxide

Sir:

In view of the utilization of squalene 2,3-oxide (I) in the biosynthesis of lanosterol and cholesterol,[1] the behavior of this new transformation product in nonenzymic cyclizations becomes of more than routine interest, particularly since such chemistry may help identify the molecular areas of enzymatic importance. Herein we describe the preparation and characterization of the tricyclic substances IIa and IIb, produced from epoxide I under mildly acidic, laboratory conditions.



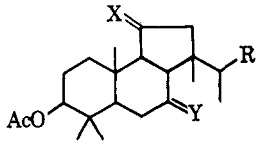
IIa



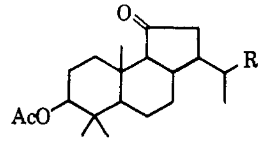
IIb

Squalene 2,3-oxide was obtained from squalene[2] by the selective terminal oxidation method, as previously described.[1,3] Cyclization of I was carried out by means of 0.2 mole of stannic chloride in benzene at 10° for 5 min. In addition to hydrocarbon, some ketonic material, and a product apparently of the previously observed bicyclic type,[4] there were generated in comparatively major amounts two tricyclic components, separated from congeners by chromatography over silica gel–silver nitrate and silica gel–water.

Although in itself an oil, the alcohol IIb formed a crystalline 3,5-dinitrobenzoate (mp 151–153°). On catalytic reduction the acetate of alcohol IIb provided, after chromatography, pure (tlc) tetrahydroacetate (IIIa, X = Y = H_2).[5] Chromium trioxide–acetic acid[6] oxidation of the latter gave rise to ketones IIIb (X = O, Y = H_2)[5] and IIIc (X = H_2, Y = O),[5] separable by chromatography. Lithium–ammonia reduction of IIIb yielded saturated keto acetate IV. The ultraviolet and infrared spectral behavior of the ketonic functions in IIIb ($\nu_{max}^{CCl_4}$ 1690 cm^{-1}; λ_{max}^{EtOH} 240 mμ (ϵ 10,000)), IIIc ($\nu_{max}^{CCl_4}$ 1665 cm^{-1}; λ_{max}^{EtOH} 253 mμ (ϵ 7000)), and IV ($\nu_{max}^{CCl_4}$ 1725 cm^{-1}; λ_{max}^{EtOH} 240 mμ (ϵ 100)) denoted the designated size of the ketonic rings.



III



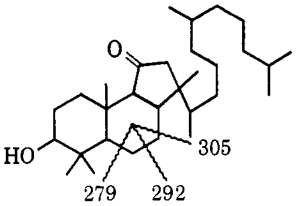
IV

R = $(CH_2)_3CH(CH_3)(CH_2)_3CH(CH_3)_2$

Conclusive evidence for the assigned structures was found by mass spectral means. The mass spectrum of IIIa shows the expected molecular ion at *m/e* 472 (mol wt 472.77). Loss of the side chain gives rise to the major fragment at *m/e* 289. The loss of acetic acid, followed by the retro-Diels–Alder fragmentation in the A ring, results in two major ions at *m/e* 229 and 147.

The two unsaturated ketones IIIb and IIIc have molecular ions at *m/e* 486, the molecular ion of IIIb being more intense than that of IIIa. Cleavage of the side chain leads to major fragmentation in both cases. In IIIb this occurs at *m/e* 304, while in IIIc a hydrogen migration takes place, giving an ion at *m/e* 303. Loss of acetic acid from the major fragment occurs in both cases giving ions at *m/e* 244 and 243, respectively.

The saturated ketone IV has the expected molecular ion at *m/e* 446. It shows the fragmentation pattern characteristic of 11-keto steroids[7] and gives rise to three major fragments at *m/e* 305, 292, and 279. Cleavage of the side chain, followed by loss of water, accounts for the remaining major fragments at *m/e* 263 and 245. These mass spectral data are completely consistent with the assigned structures and are incompatible with all other possibilities. The second tricyclic alcohol, IIa, has been studied less thoroughly, but by similar spectral means its constitution was clarified. For example,



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[1] E. E. van Tamelen, J. D. Willett, R. B. Clayton, and K. E. Lord, *J. Am. Chem. Soc.*, **88**, 4752 (1966).

[2] Squalene was purified by sequential (a) chromatography on active silica gel, (b) chromatography on alumina, (c) distillation through a Vigreaux column, and (d) conversion to the thiourea complex, followed by regeneration with aqueous petroleum ether.

[3] E. E. van Tamelen and T. J. Curphey, *Tetrahedron Letters*, No. 3, 121 (1962).

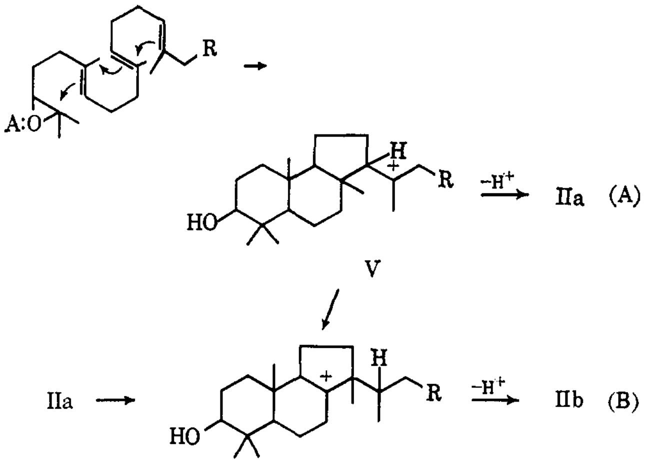
[4] E. E. van Tamelen, A. Storni, E. J. Hessler, and M. Schwartz, *J. Am. Chem. Soc.*, **85**, 3295 (1963).

[5] Nmr spectral data are consistent with the assigned structure.

[6] L. Ruzicka, E. Rey, and A. C. Muler, *Helv. Chim. Acta*, **27**, 472 (1944).

[7] H. Budzikiewicz, C. Djerassi, and D. H. Williams, "Structure Elucidation of Natural Products by Mass Spectrometry," Vol. II, Holden-Day Inc., San Francisco, Calif., 1964, p 81.

the nmr spectrum revealed four saturated methyls (δ 0.82, 0.72, 0.92, and 0.97), two separated olefinic H_A (δ 5.08), and two olefin hydrogens in a methylene group $H_{A,B}$ (δ 4.52, 4.82). In the mass spectrum there were observed *inter alia m/e* 207, 189, and 107, indicating loss of side chains followed by dehydration and retro-Diels-Alder reaction of the bicyclic molecular ion.



From the nature of the structures involved, it is evident that IIa is formed more directly from squalene oxide than IIb (route A), and that IIb must arise by further reaction of IIa or carbonium ion V (route B). Nonenzymic, chemical cyclization of a terpene terminal epoxide leads to the proper structure and configuration of the 3-hydroxylated A-B ring system;[4,8] however, direct enzymatic control is obviously necessary for the prevention of the purely chemical tendency for five-membered ring C formation, and for emergence of the biologically required six-membered C ring.

Acknowledgment. The authors are grateful to the National Science Foundation and the National Institutes of Health for financial support.

(8) (a) E. van Tamelen and E. J. Hessler, *Chem. Commun.*, 13, 411 (1966); (b) E. van Tamelen, M. A. Schwartz, E. J. Hessler, and A. Storni, *ibid.*, 13, 409 (1966); (c) E. van Tamelen and R. M. Coates, *ibid.*, 13, 413 (1966).

(9) National Institutes of Health Postdoctoral Fellow.

(10) National Science Foundation Predoctoral Fellow.

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Received September 30, 1966

Book Reviews

Chemistry of the Rare-Earth Elements. By N. E. Topp (deceased), Principal Scientific Officer, National Chemical Laboratory, Teddington, Middlesex, Great Britain. American Elsevier Publishing Co., 52 Vanderbilt Ave., New York, N. Y. 1965. xi + 164 pp. 14 × 21.5 cm. $10.00.

This is Monograph No. 4 in a series of Inorganic and General Chemistry and appears thanks to the detailed and scholarly work by Topp in getting the manuscript to page-proof form, and also thanks to three anonymous colleagues who saw the manuscript through to final form after Topp's unfortunate death in 1964.

When the study of the rare earth elements began to expand in the 1930's and 1940's, there was no single book then available on the chemistry of these elements. Perhaps the best collection of information on rare earths available in the late 1930's and early 1940's was Chapter 6 of B. S. Hopkins's book, "Chapters in the Chemistry of the Less Familiar Elements," and this was sought out by the scientist starting out to look at these elements with more than a cursory glance.

A more widely available book on the rare earths was that of Yost, Russell, and Garner, which appeared in 1947. This was after the wartime Manhattan Project had resulted in a significant amount of additional information on these elements, particularly their nuclear properties.

The availability of rare earth oxides for the past 20 years in high purity and large quantity has been the impetus responsible for the very large amount of new information on these elements. Topp's monograph comes at an opportune time, for, although it is not the last such book that will ever be written on the subject, it comes after a very large amount of new information on the rare earths has been published as the more easily skimmed "research cream" from this milky way. Topp has written in the lucid scholarly style of the English and has done a fine job. The history of the discoveries of the rare earths is well done; the information on the abundances is condensed, and comparisons with abundances of more familiar elements are good; the role of the f electrons in the magnetic phenomena of these elements is described and given more than perfunctory treatment. The large-scale separation of the elements is discussed at somewhat more length than I think is merited in a volume this size, but this was a subject of prime interest to Topp and, knowing this, it is certainly not a biased apportionment. Since Topp assembled the information in Chapter 7 on compounds of the rare earths with elements from groups III, IV, and V, a number of reports have appeared on such studies that are not included in this volume, but this is the inevitable result of "hysteresis" in publishing such information. Chapter 10 on the analytical chemistry of the rare earths is skimpy in spots considering the amount of material that has appeared, but well-chosen references seem to make up for this minor defect. As fast as developments are coming in the electromagnetic phenomena of the rare earths, Topp's Chapter 12 on "Applications" appears satisfyingly current with few omissions; perhaps the major omission is his failure to to note that the ruddy red glow of the cheeks of television's Ben Cartwright is due to the europium and yttrium phosphors being used in the color-television industry!

It is regreted that this monograph does not cover scandium, which is not likely to be included with other elements in other monographs, and certainly does not warrant a volume by itself at the present. It is a very fine monograph on yttrium and the rare earths and will serve well as a current summary of the information on these elements.

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