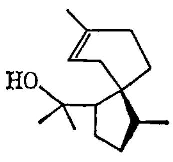

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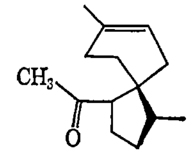

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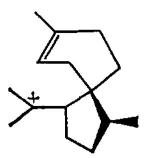

22

cyclization[16] involving carbonium ion **22**. Dissolution of this alcohol in 88% formic acid at 25° resulted in the instantaneous separation of an oily layer (estimated 80% yield), identified as cedrene by comparison of its nmr, ir, and behavior on vpc with natural cedrene.

[16] The defining characteristics of biogenetic-type syntheses are described in; E. E. van Tamelen, *Fortschr. Chem. Org. Naturstoffe*, **19**, 245 (1961).

Terry G. Crandall, Richard G. Lawton
Department of Chemistry, University of Michigan
Ann Arbor, Michigan 48104

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A Detailed Stereochemical Analysis of Electron Impact Induced 1,3 Elimination in Cyclohexanol and Cyclohexyl Chloride

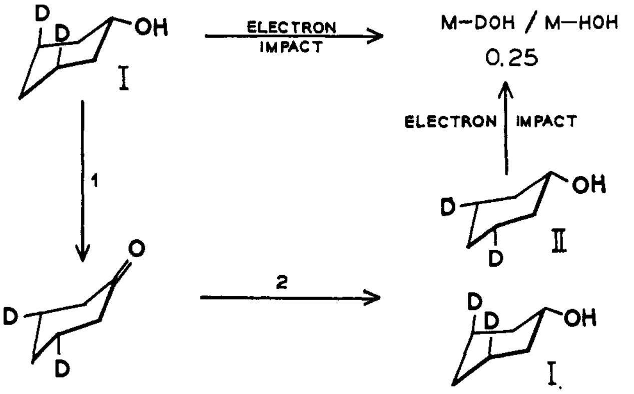
Sir:

Various studies have documented the position of hydrogen abstraction in the electron impact induced elimination reactions of alcohols and chlorides (1). In acyclic hydrocarbon chains, in which the competing hydrogens are all secondary, the loss of water (X = OH in eq 1) involves a highly specific 1,4 elimination[1] while the corresponding chlorides (X = Cl) show a less specifically favored 1,3 elimination.[2] While it has been noted[2,3] that these results point to a dominant heteroatom role in the choice of abstraction site, the similar site selectivities in cyclohexyl chloride[4] and cyclohexanol[4,5] are (*ca.* 70:30, 1,4:1,3 statistically corrected) suggest on the contrary that the structure of the hydrocarbon moiety can be the determining factor. We now report that the 1,3 elimination in cyclohexanol takes place by a rearrangement reaction which is precluded in acyclic alcohols, while the on the surface similar loss of hydrogen chloride from cyclohexyl chloride occurs from an intact molecular ion.

$$(C_nH_qX)\cdot^+ \longrightarrow (C_nH_{q-1})\cdot^+ + HX \qquad (1)$$

Two equivalents of *p*-toluenesulfonyl chloride in pyridine was added slowly to *cis*-1,3,5-trihydroxycyclohexane[6] in cold pyridine. The derived tosylate was treated with lithium aluminum deuteride in ethyl ether to produce, by stereospecific reaction,[7] *cis*-3,5-dideuterio-*trans*-cyclohexanol (I).[8] Oxidation of I with Jones reagent[9] gives rise to *cis*-3,5-dideuteriocyclohexanone which on subsequent reduction with lithium aluminum hydride must give an essentially equal mixture of I and its epimer, *cis*-3,5-dideuterio-*cis*-cyclohexanol (II). Scheme I summarizes these transformations and presents the results of mass spectral analysis of water elimination from I and the mixture of I and II.

Scheme I[a,b]



[a] The mass spectral data were taken near threshold (nominal 9 eV). [b] The ratios for (M − DOH)/(M − HOH) were indistinguishable for I and for the mixture of I and II. The ratio was different (0.40) but still indistinguishable at 70 eV.

If the tosylate displacement leading to I were stereospecific, the results would require that the end result of steps 1 and 2 (Scheme I) be stereochemically equivalent to the impact of 9-V electrons. The following experiment provides unequivocal evidence that this conclusion is correct.

Treatment of I and the mixture of I and II with phosphorus pentachloride in cold chloroform leads, by inversion of configuration,[10] to the respective chlorides[8] III and an equal mixture of III and IV. Scheme II presents these transformations as well as the mass spectral results for the loss of hydrogen chloride from the derived chlorides.

It follows from the divergent results on the loss of hydrogen chloride from III and from the mixture of III and IV that the displacement leading to I is stereospecific. Indeed, the decreased loss of deuterium chloride from the mixture of III and IV points out the necessary *cis* relationship between the abstracted hydrogens and the chlorine in the 1,3 elimination in cyclohexyl chloride. Further, the quantitative ratios for DCl/HCl loss allow the assignment of a lower limit of 84% stereospecificity to the displacement producing I as well as in the *cis* elimination in the derived cyclohexyl chloride molecular ion. These results require that the 1,3 elimination of water in cyclohexanol be

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[1] W. Benz and K. Biemann, *J. Amer. Chem. Soc.*, **86**, 2375 (1964); S. Meyerson and L. C. Leitch, *ibid.*, **86**, 2555 (1964), and references therein.

[2] A. M. Duffield, S. D. Sample, and C. Djerassi, *Chem. Commun.*, 193 (1966).

[3] F. W. McLafferty, "Interpretation of Mass Spectra," W. A. Benjamin, Inc., New York, N. Y., 1966, p 132.

[4] M. M. Green and J. Schwab, *Tetrahedron Lett.*, 2955 (1968).

[5] C. G. MacDonald, J. S. Shannon, and G. Sugowdz, *ibid.*, 807 (1963); H. Budzikiewicz, Z. Pelah, and C. Djerassi, *Monatsh. Chem.*, **95**, 158 (1964).

[6] H. Stetter and K. H. Steinacker, *Chem. Ber.*, **85**, 451 (1952).

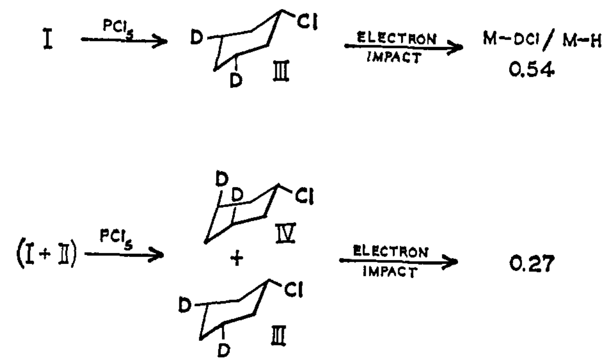
[7] G. K. Helmkamp and B. F. Rickborn, *J. Org. Chem.*, **22**, 479 (1957).

[8] All deuterated materials were found to be identical with authentic protium materials by vapor phase chromatography. In addition, we have oxidized (hot nitric acid) I to adipic acid. The nmr spectrum of the derived dimethyl ester shows multiplets at δ 1.6 (3 H) and 2.3 (3 H) and a singlet at 3.6 (6 H), as required for deuterium incorporation at C-3 and C-5 in the parent cyclohexanol.

[9] L. F. Fieser and M. Fieser, "Reagents for Organic Synthesis," John Wiley & Sons, Inc., New York, N. Y., 1967, p 142.

[10] For a general discussion and leading references see: E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis," Interscience Publishers, New York, N. Y., 1965, pp 91, 92.

Scheme II[a]



[a] See footnote *a* in Scheme I.

nonstereospecific. Cleavage of the carbon–carbon bond adjacent to the hydroxyl group, that is, α cleavage, as a prerequisite for 1,3 elimination is the only plausible mechanism to account for the lack of stereospecificity. This type of bond cleavage is well documented in the mass spectrometry of alcohols,[11] and further it neatly explains the low 1,3 elimination encountered in acyclic alcohols.[1] That is, while α cleavage can precede the formation of an M − 18 ion in ring compounds, it must necessarily preempt such an ion in open-chain counterparts.[12]

Since we have previously demonstrated that the 1,4 elimination in both cyclohexanol and cyclohexyl chloride takes place with high stereospecificity,[4] it is now clear that, whereas unrearranged alcohols show a specific preference for a C-4 hydrogen independent of hydrocarbon structure, the related chlorides may precede directly by both 1,3 and 1,4 elimination according to the structural restrictions imposed by the hydrocarbon grouping. An attractive hypothesis to account for this behavior invokes the variation in bond length encountered in bonds to oxygen and chlorine.[13] In alcohols the shorter radius for bonding would restrict abstractable hydrogens to closer approach than in the case of chlorides, namely from carbon atoms further away along the σ framework. Since the C-4 as well as the C-3 hydrogen distances to the eliminated hydroxyl group in a cyclohexane ring are almost identical with those in an open-chain molecule (by inspection of Dreiding models), it would follow from this argument that hydrogens inaccessible in the acyclic alcohols, namely C-3, should also be inaccessible in cyclohexanol. In the case of chlorides the structure of the hydrocarbon moiety may be expected to play an important role in the choice of abstraction site, since both C-3 and C-4 hydrogens are available for abstraction. Indeed, the entropy of activation in the acyclic chlorides would favor the closure of the smaller ring, that is, hydrogen abstraction from C-3.

In support of this over-all hypothesis it is noteworthy that deuteration studies on acyclic mercaptans[14] show elimination (X = SH, eq 1) from both C-4 and C-3 while data on 1-fluorohexane (X = F, eq 1) demonstrate competitive hydrogen loss from C-5 and C-4.[15]

Further significance for these findings rests in their probable extension to the mass spectrometry of substituted cyclohexanols. Reports have recently appeared describing a large bias against *cis* isomers, for water elimination, from the epimers of both 4- and 3-*t*-butylcyclohexanol.[16,17] These differences have been ascribed to the availability of tertiary hydrogens in the *trans* isomers. In addition, the 4 substituent is at least an order of magnitude more effective in promoting the isomer difference. The present work strongly suggests that α cleavage precedes the elimination of the tertiary hydrogen in the 3-*t*-butylcyclohexanol isomers, thereby explaining, at least in part, the otherwise mysterious specificity change between the 3 and 4 substituents.

Acknowledgment. We are grateful for support of this research to the National Institute of General Medical Sciences (GM-16638-01).

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[11] H. Budzikiewicz, C. Djerassi, and D. H. Williams, "Mass Spectrometry of Organic Compounds," Holden-Day Publishing Co., San Francisco, Calif., 1967, Chapter 2.

[12] Water loss can be observed from an α-cleaved ion from acyclic alcohols if it is not the molecular ion. Such experiments have been carried out. See ref 1 and M. Kraft and G. Spiteller, *Monatsh. Chem.*, **99**, 1839 (1968).

[13] In all cases known oxygen forms stable bonds with shorter bond length than those for chlorine. It is reasonable that this should also be so for the ions of interest here. See L. Pauling, "The Nature of the Chemical Bond," Cornell University Press, Ithaca, N. Y., 1960, Chapters 7 and 12.

[14] A. M. Duffield, W. Carpenter, and C. Djerassi, *Chem. Commun.*, 109 (1967).

[15] W. Carpenter, A. M. Duffield, and C. Djerassi, *ibid.*, 1022 (1967).

[16] C. E. Brion and L. D. Hall, *J. Amer. Chem. Soc.*, **88**, 3661 (1966).

[17] L. Dolejš and V. Hanuš, *Collection Czech. Chem. Commun.*, **33**, 332 (1968). See also M. M. Green, R. J. Cook, W. Rayle, E. Walton, and M. F. Grostic, *J. Chem. Soc., D*, 81 (1969).

[18] National Science Foundation Summer Fellow, 1968.

Mark M. Green, Richard J. Cook[18]
Department of Chemistry, University of Michigan
Ann Arbor, Michigan 48104

Received November 25, 1968

Reactions of Energetic Fluorine-18 Atoms with Fluoromethanes. Formation of CH^{18}F and CF^{18}F

Sir:

Energetic ^{18}F atoms from nuclear recoil react with hydrocarbons and fluorocarbons by both of the substitution pathways shown in (1) and (2),[1-5] using difluoromethane as the example. The experiments reported here have been designed to permit estimation of the energy deposition in such reactions through the observation of secondary decomposition products,[6] in analogy with similar experiments in recoil tritium systems.[7-10] The results, summarized in Table I, have

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[1] N. Colebourne and R. Wolfgang, *J. Chem. Phys.*, 38, 2782 (1963).

[2] N. Colebourne, J. F. T. Todd, and R. Wolfgang, "Chemical Effects of Nuclear Transformations," Vol. 1, International Atomic Energy Agency, Vienna, 1965, p 149.

[3] J. F. J. Todd, N. Colebourne, and R. Wolfgang, *J. Phys. Chem.*, 71, 2875 (1967).

[4] Y.-N. Tang and F. S. Rowland, *ibid.*, **71**, 4576 (1967).

[5] L. Spicer, J. F. J. Todd, and R. Wolfgang, *J. Am. Chem. Soc.*, **90**, 2425 (1968).

[6] Decomposition of monofluorocyclanes following ^{18}F-for-H substitution reactions in cyclanes is reported in ref 4.

[7] Y.-N. Tang and F. S. Rowland, *J. Am. Chem. Soc.*, **88**, 626 (1966).

[8] Y.-N. Tang and F. S. Rowland, *ibid.*, **89**, 6420 (1967).

[9] E. K. C. Lee and F. S. Rowland, *ibid.*, **85**, 897 (1963).

[10] R. Wolfgang, *Progr. Reaction Kinetics*, **3**, 97 (1965).