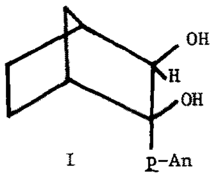
Tetrahedron Letters No.5, pp. 347-350, 1969. Pergamon Press. Printed in Great Britain.

EPOXIDES AS INTERMEDIATES IN ORGANIC REACTIONS. I

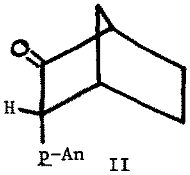
D. C. Kleinfelter and J. H. Long
Department of Chemistry, University of Tennessee
Knoxville, Tennessee, 37916, U.S.A.

(Received in USA 18 October 1968; received in UK for publication 24 December 1968)

Kleinfelter and Dye(1) reported that the rearrangement of 2-p-anisylnorbornane-2,3-cis-exo-diol(I) in conc. H_2SO_4 at 0° gave 40-50% yield of 3-endo-p-anisyl-2-norbornanone(II). Since this yield was an optimum percentage (generally ca. 25% was obtained) we attempted improvement by employing other solvent systems known to effect pinacol rearrangements(2): (1) 98-100% formic acid; (2) 20% acetic acid - 80% H_2SO_4; (3) 1% $HClO_4$ in tetrahydrofuran (THF); (4) 30% HCl in THF; (5) 70% $HClO_4$. The desired improvement, ca. 90% yield, resulted from system 5. Ketone yields were low in systems 1-3, but small amounts, 5-30%, of an isomeric compound ($C_{14}H_{16}O_2$, mp 194-195°) was obtained. System 4 afforded a 60% yield of this compound, which proved to be 2-p-anisylnorbornene-2,3-exo-oxide(III). Reported herein are some observations of this epoxide's unusual stability and its characterization by its unique spectral properties.



I



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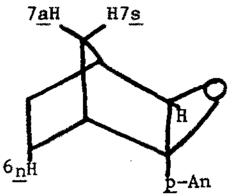

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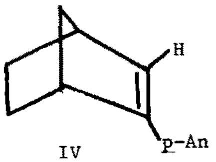

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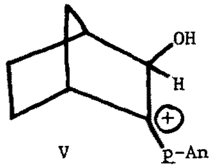

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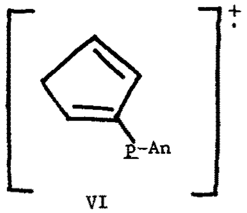

VI

The isolation of III and its chemical reactivity are important with respect to two research problems on which attention has been focused.

(1) Presumably III is not an intermediate in the peracid oxidation of 2-p-anisylnorbornene(IV). Reaction of IV in chloroform solution with buffered peracetic acid at -20° gave only hydroxyacetate. Treatment of III in chloroform solution with buffered and unbuffered peracetic acid at 30° for 24 hours gave only quantitative recovery of starting material. Where relatively stable carbonium ions may be generated, the initial step of the reaction may be attack of the double bond on the electrophilic peracid hydroxyl to produce a β-hydroxy-substituted carbonium ion. In weakly nucleophilic solvents this ion, as generated from I, could collapse to give the epoxide. The involvement of an aryl participation mechanism(3) to explain the stereochemistry of the peracid reaction of IV is obviated by these results.

(2) The 3-exo-hydroxy-2-p-anisylnorbornyl cation(V) formed initially in the rearrangement of I to II is stabilized by resonance with the p-methoxy substituent. The reversible formation of epoxide and this cation competes successfully in the lesser acidic media(4) with rearrangement to the epimeric 3-endo-hydroxy cation, the precursor of II, since the two intervening intermediate ions are secondary ones without p-anisyl stabilization. Attempts to isolate epoxide from similar treatments with the phenyl and p-chlorophenyl analogs of I were unsuccessful. That no endo epoxide forms from the endo-hydroxy cation, but that III forms from V, can be explained on the basis of Schleyer's torsional effect rationale(5) and the known greater propensity for exo hydrogen migration(6).

The characterization of III was accomplished by virtue of its spectral properties, which may also be considered somewhat unique to this aryl substituted norbornane epoxide.

In the aromatic proton region of III's NMR spectrum one o-proton (meta to OCH_3) appears at 7.49 ppm while the other is at 6.92 ppm, each as a doublet of quartets. The m-proton pair absorbs at 6.48 ppm(7). The 7-anti(7a) and 7-syn(7s) protons of norbornene-exo-oxide are observed at 0.70 and 1.35 ppm (J = 8.8 cps), respectively, their separation (0.65 ppm) being attributed to the "ring current" of the epoxide ring(8). The same protons in III appear at 0.74 and 2.62 ppm (J = 9.3 cps). The incorporation of the p-anisyl ring causes a remarkable downfield shift of 1.27 ppm for the 7-syn hydrogen relative to the same hydrogen of norbornene-exo-oxide. The conjugative effect of the p-anisyl ring may increase the oxirane's ability to electrostatically and/or anisotropically deshield the syn hydrogen atom. The 3-endo proton of III absorbs at 3.53 ppm as an apparent unresolved triplet, presumably due to very small coupling with the 4 and 7n protons. This proton is deshielded by 0.37 ppm relative to the unsubstituted epoxide due to the ring current effect of the 2-*endo* *p*-anisyl ring.

The molecular ion (M$^+$216) in III's mass spectrum was only *ca.* 1% as intense as the base peak (m/e 200), corresponding to the 2-*p*-anisylnorbornene radical cation, suggesting extensive atomic oxygen expulsion (9). Although minor amounts of oxygen expulsion from epoxides are know (10), no mention of such extensive oxygen expulsion has appeared in the mass spectra of alicyclic or aromatic epoxides (11). A retrograde Diels-Alder process with loss of ethylene may produce VI, the *p*-anisylcyclopentadiene radical cation (m/e 172, relative intensity 70%), or an analogous species. The m/e 135 peak in III (13% relative intensity), apparently due to the *p*-methoxybenzoyl cation, is absent in IV's spectrum. Otherwise, except for relative intensity differences, the spectra are markedly similar.

The UV spectrum (λ max 229, 277, 284 mμ; log ε 4.05, 3.19, 3.16, 95% EtOH) closely resembles that of *p*-methoxystyrene oxide (12). Further studies of the intermediacy of epoxides and their spectral properties have been initiated.

Acknowledgement - We gratefully acknowledge the National Aeronautics and Space Administration for financial support via a traineeship for Dr. Long, 1966-1968.

Footnotes and References

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2. C. J. Collins, *Quart. Rev.*, *14*, 357 (1960).
3. D. C. Kleinfelter and P. von R. Schleyer, *J. Am. Chem. Soc.*, *83*, 2329 (1961).
4. In 70% $HClO_4$, III gives II in quantitative yield. This reaction assists in the structure proof of III.
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6. J. Berson in "Molecular Rearrangements" P. de Mayo, Ed., Interscience Publishers, Inc., New York, N. Y., 1963, Chapter 3, p 159.
7. The aromatic proton patterns in the NMR spectra of the numerous *p*-anisyl substituted compounds, bicyclic, monocyclic, and acyclic, that we have studied are typical A,A',B,B' systems with the lone exception of III. This unique pattern for III may be due to restricted rotation of the *p*-anisyl ring caused by a steric interaction between the 6-*endo* hydrogen and an *o*-hydrogen.
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9. The mass spectrum was run on an Associated Electrical Industries Ltd. MS 702 instrument, solid sample probe at 70 ev, maintained at 125°. This probe temperature precludes thermal loss of oxygen.

10. F. W. McLafferty, Interpretation of Mass Spectra, W. A. Benjamin, Inc., New York, N.Y., 1966, p 216.

11. H. Budzikiewicz, C. Djerassi, and D. H. Williams, Mass Spectrometry of Organic Compounds, Holden-Day, Inc., San Francisco, Calif., 1967, p 459-462.

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