Since triplet transfer to either isomer is diffusion controlled, the excitation ratio, $k_2/k_1$, should be unity for high-energy sensitizers so that the isomer ratio in the photostationary state is a direct measure of the decay ratio, $k_3/k_4$. This provides a means for comparison of the mechanisms of the direct and sensitized reactions. If excitation by direct absorption of light is followed by quantitative crossing into the triplet system, the decay ratio should be the same for the two processes. Since the excitation ratio for direct irradiation is just the ratio of the molar extinction coefficients for the two isomers, the photostationary state relationship becomes

$$\frac{[trans]_s}{[cis]_s} = \frac{\epsilon_{cis}k_3}{\epsilon_{trans}k_4}$$

The predicted relationship was found to hold in the case of the olefinic substrates studied previously,[5] but does not hold for the azobenzenes. The value of $k_3/k_4$ measured by photosensitization is about 60. Zimmerman[6] measured the decay ratio for azobenzenes as a function of wave length and found a value of 4 for $\pi$–$\pi^*$ excitation and a value of 2 for n–$\pi^*$ excitation. The difference between the two numbers is itself an indication that crossing to triplets is not the sole fate of excited singlets. The very large difference between the decay factor for the sensitized reaction and either number for the direct process shows clearly that decay from singlets does not involve passage through the lowest triplet state of the system. The difference between the results also seems to rule out the possibility that *both* singlet and triplet electronically excited states decay by way of highly vibrationally excited forms of the electronic ground states. Since the sum of the quantum yields for the *cis* → *trans* and *trans* → *cis* processes is high,[6] the results cannot be explained by a mechanism involving inefficient inter-system crossing with isomerization occurring only in those molecules that become triplets. Most of the reaction probably involves isomerization of excited singlets themselves, either while they are excited or during the act of internal conversion to ground singlets. Mechanisms involving crossing of excited singlets to higher triplets are unattractive because of the speed with which such species would be expected to decay the lowest triplet.

*Acknowledgment.* This study was supported by the National Science Foundation.

(6) G. Zimmerman, L. Chow, and U. Paik, *J. Am. Chem. Soc.*, 80, 3528 (1958).

(7) National Science Foundation Postdoctoral Fellow, 1964.

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## Classification of Alcohols by Nuclear Magnetic Resonance Spectroscopy. A Cautionary Note

*Sir:*

A recent communication described a clever method for classification of alcohols by nuclear magnetic resonance spectroscopy.[1] The authors reported that in "dimethyl sulfoxide solution strong hydrogen bonding to the solvent shifts the hydroxyl resonance downfield ($\tau$ 6.0 or lower) and reduces the rate of proton exchange sufficiently to permit observation of hydroxyl proton splitting." Although the communication reported that strong acids and bases remove the hydroxyl splitting, traces of acids, which catalyze exchange in the common n.m.r. solvents and are otherwise undetected, are clearly not expected to complicate the n.m.r. data with dimethyl sulfoxide (DMSO) solutions.

Attempting to apply this method to some substituted alcohols of interest to us,[2] we have found it unreliable for a number of alcohols with strong electron-withdrawing substituents close to the hydroxyl group. In the absence of special treatment of these alcohols with solid sodium or potassium carbonate,[4] and sometimes in spite of it, the n.m.r. spectra of DMSO solutions of these alcohols show loss of multiplicity of both hydroxyl and methylene resonances.

The alcohols used were freshly distilled; contamination in them was not revealed by gas chromatography. Those alcohols which failed to give the expected multiplet signals for O*H* were stored over solid carbonate for about 1 hr., with frequent shaking, and then used to prepare fresh DMSO solutions.

Alcohols of unequivocal structure which we have examined, together with chemical shifts (in p.p.m.) for hydroxyl proton,[5] include: (A) those giving expected multiplicity without special treatment: 2-ethoxyethanol (−4.55), allyl alcohol (−4.71), and *trans*-2-chlorocyclooctanol[6] (−4.92). (B) those giving expected multiplicity only after prior treatment with carbonate: 2-chloroethanol (−5.05) and 2-bromoethanol (−5.10) (freshly prepared DMSO solutions of 2-bromoethanol which gave the expected triplet signal deteriorated with time and after 1–2 hr. gave a broad singlet for hydroxyl proton (−5.10)). (C) those for which only sharp singlet (s) or smooth broad (b) signals for O*H* were obtained, even after treatment with carbonate: 2-cyanoethanol (−4.21, b), *trans*-2-bromocyclooctanol[6,7] (−4.60, s), ethyl lactate (−5.22, b), and 2,2,2-trichloroethanol (−5.71, s).[8]

The relative chemical shifts of the O*H* resonances in the various alcohols suggest a fair correlation with the relative electron-attracting power of the substituent. A comparison of relative positions for the 2-haloethanols with those for the 2-halocyclooctanols, however,

(1) O. L. Chapman and R. W. King, *J. Am. Chem. Soc.*, 86, 1256 (1964).

(2) Correspondence initiated by Dr. Gordon H. Whitham, of the University of Birmingham, England, about the identity of methylenecyclohexene bromohydrin[3] prompted the investigation reported here. We acknowledge appreciatively the exchange of information and ideas with Dr. Whitham, who has written that he has confirmed our observations that the hydroxyl proton signal is a singlet with DMSO solution of ethylene bromohydrin.

(3) J. G. Traynham and O. S. Pascual, *Tetrahedron*, 7, 165 (1959).

(4) Professor O. L. Chapman, serving as a referee for this communication, suggested the treatment with solid potassium carbonate to remove traces of acids.

(5) All spectra were obtained for dimethyl sulfoxide solutions approximately 10–30 vol. % in alcohol with a Varian Associates HA-60 spectrometer. Some dependence of chemical shift on concentration and on age of solutions was noted. Chemical shifts reported are for freshly prepared 10 vol. % solutions and are in p.p.m. relative to internal tetramethylsilane.

(6) J. G. Traynham and J. Schneller, *J. Am. Chem. Soc.*, 87, 2398 (1965).

(7) This compound was available in sufficient quantity for one experiment only; it was not treated with carbonate.

(8) Ethyl lactate, 2-cyanoethanol, and 2,2,2-trichloroethanol were also stored over potassium carbonate for 3 days. The O*H* signals recorded with DMSO solutions of these samples were shifted slightly from those obtained with samples treated for 1 hr. with carbonate, but the signals were little changed in appearance.

indicates that structure and perhaps geometry are important as well as electronegativity.

(9) NASA Trainee, 1963–1965.

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## Synthetic Routes to Emetine. Revised Structure of a Lactonic Intermediate

*Sir:*

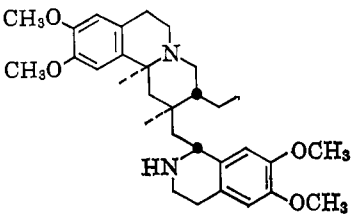
Considerable synthetic activity[1] has been devoted to emetine (I), a useful compound in treatment of amebiasis.[2] One of the earliest syntheses of this compound and some of the subsequent procedures[3] involved a lactonic intermediate (A), assigned structure II. Reinvestigation in our laboratories has raised some question as to the accuracy of these reports.[3] Our findings are described below.[4]

Repetition of the lengthy sequence[3b] yielded a crystalline product, m.p. 100–102° (lit.[3b] m.p. 102.5–103.5°), corresponding to A, in addition to an oil (as reported[3b]). This crystalline substance exhibits a split carbonyl at 5.68 and 5.83 $\mu$ and aliphatic carboxylic acid absorption at 2.8–4.0 $\mu$. Its n.m.r. shows two primary methyl triplets, at $\delta$ 0.97 and 1.01, and two tertiary methyl singlets, at $\delta$ 1.26 and 1.38. Integration shows the same number of hydrogens for the combined triplets and singlets. The singlets and absence of bands in the $\delta$ 4–4.5 region ascribable to $-CH_2OC(=O)-$ absorption are clearly not in accord with structure II. Further indication is provided by O-alkyl and C-methyl determinations which show two C–$CH_3$ groups and absence of O-alkyls. Fractional crystallization (ether) of A yielded A′, m.p. 106–108°, 82%; additional material, m.p. 104–107°, 6%; and an amorphous residue. A′ has spectral and combustion values essentially identical with those of A. However, its n.m.r. spectrum shows only one singlet at $\delta$ 1.26 (and one triplet of equal intensity at 1.01); the n.m.r. of the residue retains two singlets with the 1.38 peak intensified.

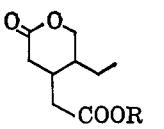
The syntheses of A make use of elaborate sequences to IIIa[3b] or IIIb[5]; these routes involve unambiguous transformations. Further, the n.m.r. spectrum of IIIb[5] shows only one C–$CH_3$ peak at $\delta$ 0.95 (triplet, 3 H) and absorption for the $CH_3OCH_2$ protons at $\delta$ 3.35 (singlet, doublet, 5 H), compatible with the indicated structure; analysis confirms the presence of a single C–$CH_3$. Completion of the synthesis is reportedly accomplished by acid cleavage of the primary alkyl ether one carbon removed from the tertiary center, a reaction often known to occur with rearrangement *via* the tertiary carbonium ion and thence to the thermodynamically most stable lactone.[6] Such a rearrangement of IIIa or IIIb would give the $\gamma$-lactone IVa. On the basis of structure IV the anomalous finding, namely, the n.m.r. singlets in the crude product at $\delta$ 1.26 and 1.38, is then explained by the tertiary methyls in the diastereomeric forms of IVa.

Compound A′ yielded ($CH_2N_2$) the corresponding lactonic methyl ester IVb, m.p. 61–63°; $\lambda_{max}$ 5.64 and 5.74 $\mu$; $\delta$ 1.01 (triplet, 3 H) and 1.26 (singlet, 3 H); a *p*-bromoanilide, m.p. 154–156°; $\lambda_{max}$ 5.66 and 5.91 $\mu$; $\delta$ 1.00 (triplet, 3 H) and 1.30 (singlet, 3 H); and a homoveratryl amide, m.p. 96–98°; $\lambda_{max}$ 5.65 and 6.00 $\mu$; $\delta$ 1.15 (triplet, 3 H) and 1.37 (singlet, 3 H) [*cf.* 5-methyl-5-ethylbutyrolactone,[7] exhibiting carbonyl absorption at 5.66 $\mu$ and n.m.r. peaks at $\delta$ 0.97 (triplet) and 1.38 (singlet)]. These data suffice to establish the structure of A′ as IVa (stereochemistry unspecified) rather than the earlier assignment IIa. Recently[5] other workers reported preparation of a substance reputed to be IIa, m.p. 104.5–106°, by a similar sequence. This substance was identical with A′ (melting point, mixture melting point, infrared, and n.m.r. comparison).

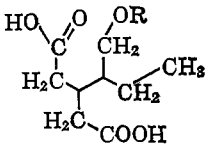
The oil[8] from the acid-cleavage rearrangement of IIIa



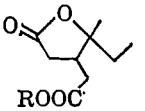
I



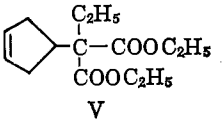
IIa, R=H
b, R=CH3



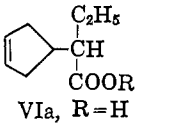
IIIa, R=$C_2H_5$
b, R=$CH_3$
c, R=$COCH_3$
d, R=H



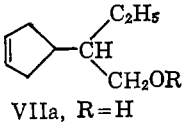
IVa, R=H
b, R=$CH_3$



V



VIa, R=H
b, R=$C_2H_5$



VIIa, R=H
b, R=$COCH_3$

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(4) Satisfactory analyses were obtained for all compounds; infrared spectra were taken in chloroform and n.m.r. spectra in deuteriochloroform. We are indebted to J. Bordner and M. E. Flaugh (University of California, Berkeley, Calif.) for the n.m.r. spectra.

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(8) In most experiments[3] this oil was obtained. Zymalkowski and Frohm[5] report "nahezu quantitativer ausbeute" of A′ (IVa), thus eliminating any possibility for isolation of II.