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SOLVOLYTIC REARRANGEMENT AND STABLE CARBONIUM IONS FROM TETRACYCLO[4.3.0.0^{3,8}.0^{7,9}]NONAN-2-OL AND RELATED COMPOUNDS

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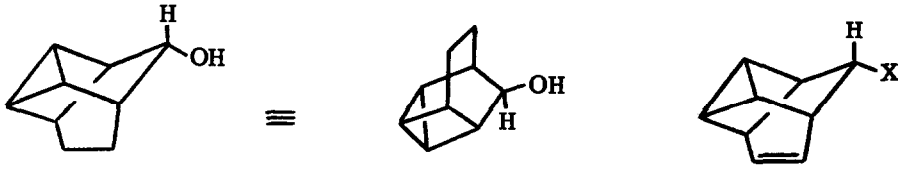
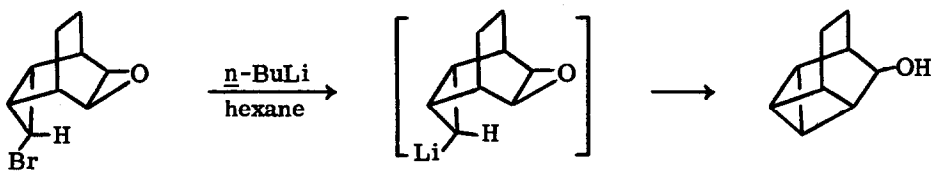
In connection with previous investigations on homocyclopropane participation in solvolysis reactions,[1,2] we considered that the behavior of tetracyclo[4.3.0.0^{3,8}.0^{7,9}]nonan-2-ol (1-OH) and its derivatives would be of interest. This compound is also significant as a 4,5-dihydro derivative of 2-X, a member of the $[CH]_9X$ family,[3] the methyl ether of which (2-OCH_3) has recently been prepared by Magid and Whitehead.[4] In this communication we wish to report the synthesis of 1-OH, the reactivity and degenerate rearrangements associated with the solvolysis of 1-OTs, and nmr spectral data for the stable carbonium ions generated from 1-OH and 2-OCH_3.



1-OH 2-X

Bromo epoxide 3 (mp 60-60.5°), the key intermediate in the synthesis of 1-OH, was prepared from bicyclo[2.2.2]octa-2,5-diene by a three step reaction sequence consisting of dibromocarbene addition (57%), partial reduction with tri-n-butyltin hydride (70%), and epoxidation with metachloroperoxybenzoic acid (86%).[6] The anti stereochemistry of the bromine atom follows from the magnitude of the coupling interaction between the cyclopropane ring hydrogens (δ 3.20, t, J = 2 Hz, CHBr)[7] and is in agreement with the stereochemistry of similar bridged ring compounds containing halocyclopropanes.[8]

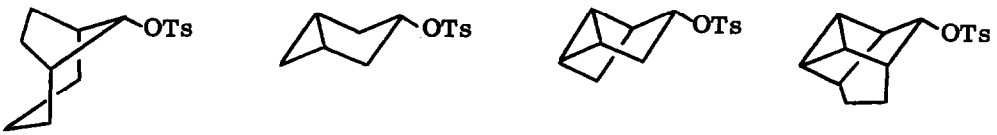
The reaction of the bromo epoxide with 12 equivalents of butyllithium in hexane for 3 days affords a tetracyclic alcohol (84%) which is characterized by the following data: mp 196-198°; ir (KBr), 3400 cm^{-1} (OH); nmr δ 3.94 (2d, J = 2, 6 Hz, CHOH), 2.81 (s, OH), 2.0-2.5 (br m, H_1, H_3, H_6), 1.9-2.1 (m, 7H); mass spectrum: m/e 136 (M^+); p-nitrobenzoate, mp 130-131°. Additional support for the proposed tetracyclic structure 1-OH derives from the identification of the corresponding methyl ether (1-OCH_3) with the ether prepared independently by Magid and Whitehead through reduction of the double bond in 2-OCH_3.[4]



3 4 1-OH

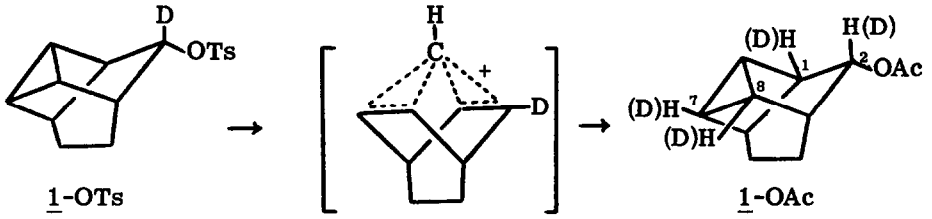
In view of the anti stereochemistry of bromo epoxide 3 and the well-established precedent for halogen-metal exchange between bromo cyclopropanes and organolithium reagents with retention of configuration,[9] we surmise that the cyclization 3 → 1-OH proceeds through lithiated cyclopropane 4.[10] Whether the apparent inversion of stereochemistry on the three-membered ring occurs prior to or concerted with ring closure is, at present, a matter for conjecture.

The solvolysis of 1-OTs (mp 47.5-49°) in acetic acid buffered with 0.024 M sodium acetate at 25° followed first order kinetics through two half lives with a rate constant $k = 1.05 \pm 0.01 \times 10^{-4}$ sec^{-1}.[11] A comparison of the solvolytic reactivity of 1-OTs with that of the model compound endo-8-bicyclo[3.2.1]octyl tosylate (5-OTs)[12] indicates a considerable rate enhancement presumably associated with cyclopropane participation. The solvolysis rate of 1-OTs is approximately 100 times greater than either cis-3-bicyclo[3.1.0]hexyl tosylate (6-OTs)[13] or exo-2-tricyclo[3.2.0.0^{4,6}]heptyl tosylate (7-OTs),[14] both of which undergo heterolysis with involvement of the three-membered ring.



	5-OTs	6-OTs	7-OTs	1-OTs
$k_{rel}^{25^0}$	(1.0)	2.9×10^5	2.0×10^5	2.0×10^7

The sole product formed in the acetolysis of 1-OTs is the corresponding acetate 1-OAc which was reduced with lithium aluminum hydride to alcohol 1-OH (100%, isolated yield). The occurrence of a degenerate rearrangement was revealed by solvolysis of 1-OTs labelled with deuterium at the 2 position. The location of the deuterium label was determined by inspection of the proton nmr spectrum in the presence of the shift reagent $Eu(fod)_3$ and found distributed equally among four positions, the carbinyl carbon (C-2, 0.25 ± 0.05 D) and three others (~0.25 D each), two of which were superimposed in the spectrum. This conclusion is supported by the deuterium nmr spectrum which showed three peaks in the ratio 1 : 1 : 2. On the basis of the chemical shifts for the positions bearing deuterium (δ 4.0, ~0.25 D; 2.3, ~0.25 D, 1.6, ~0.50 D) and their sensitivity to increasing concentrations of shift reagent, we infer that the label is most likely situated at C-1, C-2, C-7, and C-8.

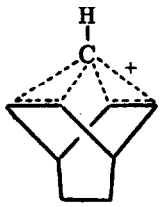


1-OTs 8 1-OAc

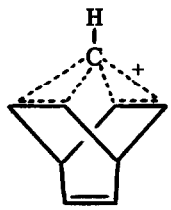
The deuterium scrambling is consistent with the formation of either the ethano-bridged pyramidal carbonium ion 8 or alternatively two identical trishomocyclopropenium ions which interconvert rapidly through a transition state corresponding to 8. Similar pyramidal carbonium ions have previously been postulated as intermediates in solvolytic rearrangements and cyclizations of various strained polycyclic compounds.[15]

Stable carbonium ions were generated from 1-OH and 2-OCH_3 by extraction of methylene chloride solutions with SbF_5-$ClSO_2F$ at -100° to -130°. The proton and carbon-13 nmr spectral data for the ion from 1-OH shown below are consistent with the static pyramidal structure 8. The assignments follow from the relative intensities of the peaks and the diminished intensity of the pmr signal at δ 4.15 in the mono-deuterated ion. The unsaturated ion 9, a new $[CH]_9^+$ species, was similarly generated from 2-OCH_3.[4] Although the pmr spectrum of this ion was partly superimposed upon a broad absorption from presumed decomposition products, an excellent cmr spectrum was secured on the same sample.[16] Ethers 1-OCH_3 and 2-OCH_3 are obtained upon quenching of the carbonium ion solutions with $NaOCH_3/CH_3OH$ at -100°.

NMR Chemical Shifts and (Approximate Relative Intensities)[a]



8

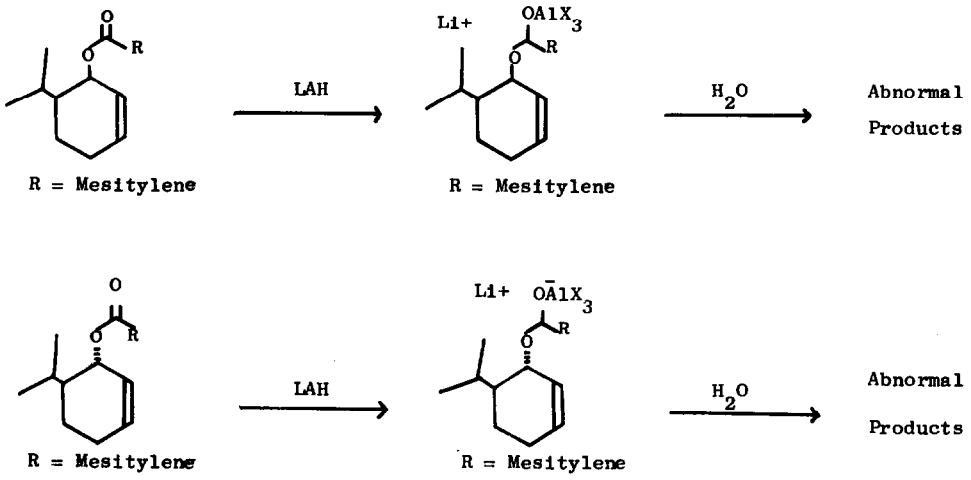


9

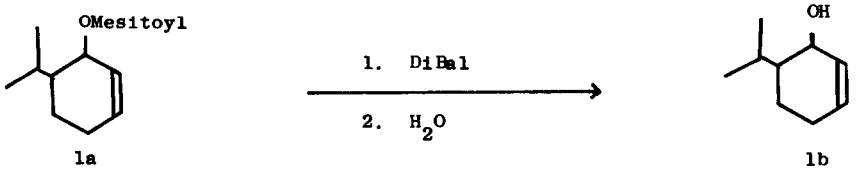
position	δ_H	δ_C	δ_H	δ_C
apical	1.20 (1)	-27.9 (1)	1.12 (1)	-33.6 (1)
basal	4.15 (4)	37.7 (4)	4.33 (4)	35.3 (4)
bridgehead	2.68 (2)	14.9 (2)	3.65 (2)	17.5 (2)
bridge	1.38 (4)	14.2 (2)	6.22 (2)	129.9 (2)

[a]Chemical shifts were measured from internal CH_2Cl_2 for ^1H nmr and CD_2Cl_2 for ^{13}C nmr.

Reduction of the corresponding en-one, 4, with LAH, followed by aqueous workup, is known to give no allylic rearrangement products.[1] Therefore we envision that the anomolous products result from a metallohemiacetal which is stable to LAH but which is susceptible, upon addition of water, to attack by hydroxide (Scheme 1).



Reaction of pure 1a with MeLi, followed by aqueous workup, gave only 1b, but in low yield. However, reaction of pure 1a with 3 equivalents of diisobutylaluminum hydride (DiBAl) for one hour at room temperature, followed by aqueous workup, gave pure 1a in 81% yield.[7] Therefore, in order to avoid anomolous reduction products in the reduction of hindered allylic esters, we recommend the use of DiBAl.



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References

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7. Yields were determined by G.C. using cyclohexanol as an internal standard.

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