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SPIN DENSITY DISTRIBUTION IN 7-AZABICYCLOHEPTYL-N-OXYL DERIVATIVES

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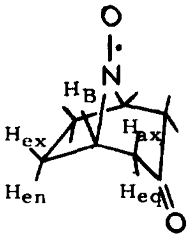
Several EPR studies have been reported over the past several years designated to elucidate the mechanisms of long-range electron and spin density transmission in organic free radicals.[1-4] Particular interest has centered on the EPR spectral characteristics of rigid bi- and tricyclic radical systems, notably semiquinones,[1] semidiones,[2] and semifuraquinones.[3] More recently, stable, bicyclic nitroxide molecules have enabled the determination of the signs of the electron-nuclear spin-spin interactions, thus providing the basis for comparison of experimental data with theoretical calculations.[5,6] It is becoming clear that through-bond spin delocalization and through-space electron delocalization are both efficient means of transmitting spin density, but that their relative importance varies from system to system.

As emphasized by Rassat and Ronzaud,[6] very substantive and stereoselective *electron* delocalization occurs in nitroxide I, corresponding to the W-plan arrangement first recognized by Russell.[7] As suggested by Russell, electron delocalization is envisaged to occur via "homohyperconjugation".

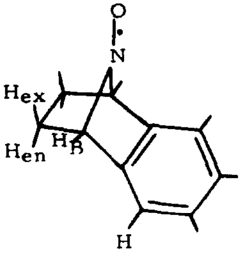


I

$a_N = 20.0$
$a_{H_B} = 5.75$
$a_{H_{ex}} = 0.1$
$a_{H_{en}} = 0.2$
$a_{H_{ax}} = 1.25$
$a_{H_{eq}} = 2.5$

Results are presented in this communication on a new series of bicyclic nitroxides, azabicycloheptyl-N-oxyl derivatives, which confirm the relative importance of electron, rather than spin, delocalization in the heterobicyclic radicals.

Radicals II - V were prepared via m-chloroperbenzoic acid oxidation of the amines in ether. The amines, which had appropriate physical-chemical properties, were obtained from the appropriate benzyne and t-butyl pyrrole-1-carboxylate, followed by hydrogenation at low pressure (PtO_2), treatment with anhydrous HCl and neutralization.[8,9] The nitroxides are refractory to separation and purification, although dilute (1×10^{-4}M) solutions are stable at -20° for hours. The radicals were generated in situ in the thermoregulated (-20°) cavity of a Varian E-9 X-band spectrometer. Linewidths were ca. 0.15 gauss.

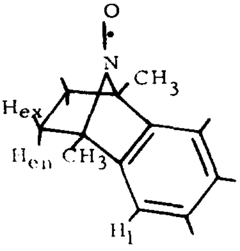


II

a_N = 22.7

$a_{H_{en}}$ = 1.44 (2H)

a_{H_1} = 0.77 (4H)

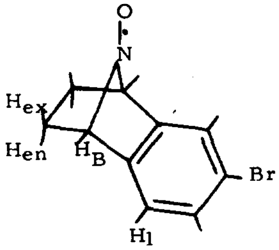


III

a_N = 21.9

$a_{H_{en}}$ = 1.50 (2H)

a_{H_1} = 0.75 (4H)

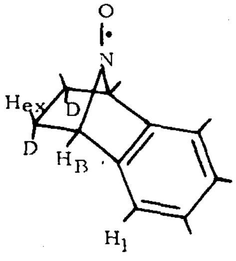


IV

a_N = 22.3

$a_{H_{en}}$ = 1.42 (2H)

a_{H_1} = 0.5 - 0.8 (3H) (poorly resolved)



V

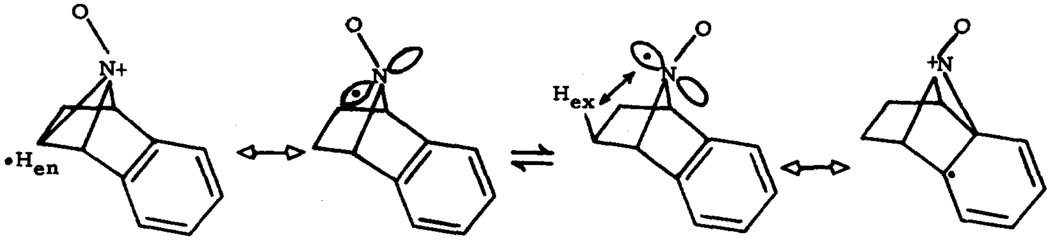
a_N = 22.6

$a_{H_{en}}$ residual, due to non-stereo-specific reduction

a_{H_1} = 0.75 (4H)

The assignments of the coupling constants (in gauss) listed under the structures derive from comparison of the spectra for the four nitroxides. Despite the slight ambiguity of results from IV and V, there is little doubt of the correctness of the assignments for compound II. Comparison of these data to that for I, a 3.2.1 bicyclic ketone, indicates a marked difference in the conformation of several loci in the molecules. No bridgehead hydrogen or methyl group couplings are observed and the coupling for H_{en} is larger at the expense of little coupling to H_{ex}. All of these differences are related to the orientation of the N-O bond.

Two extreme orientations of this bond are possible, syn and anti (relative to the benzene ring). As illustrated in IIb the former (axial in I) leads to an enhanced H_{ex} coupling (as observed) via through-space spin polarization. The latter, IIa, (equatorial in I) allows for valence-bond structures (homohyperconjugation) as described for I,[6] and large H_{en} couplings. The absence of $a_{H_{ex}}$ for compounds II - V and the magnitude of H_{en} would suggest that the preferred conformation for the N-O bond is anti (equatorial in I).



IIa II IIb IIc

However, the lack of bridgehead hydrogen coupling in II, IV and V, which is large in I, indicates that this nucleus is in the nodal plane of the spin-containing orbital. Through-space interactions fall to zero when nuclei are in this plane.[10] Furthermore, when compared to carbon, nitrogen must be much poorer at transmitting spin density via sigma-bond polarization.[11] Thus, the N-O bond cannot be far from co-linearity with the bridgehead carbon-bridging nitrogen bond.[12]

In such a conformation, the couplings to the aromatic protons, as indicated by valence-bond structure IIc, and H_{en} are reasonable and must not represent the maximal couplings possible. Also, if the increase in $a_{H_{en}}$ in II relative to the analogous coupling in I corresponds to a proportional decrease in $a_{H_{ex}}$, the absence of significant coupling to H_{ex} is explicable.

The difference in the hybridization of the nitrogen in II relative to I is also noted. This is indicated by the increase in a_N of ca 2-3 gauss, as determined in ether (and thus does not indicate the larger difference expected if determined in water).[13] The concurrent increases in the s-character of the spin-containing orbital and p-character of the nitrogen sigma bonds must alter the magnitude and method of spin transmission relative to I in an, as yet, undefined way. The basicities of the parent amines should reflect these changes in hybridization and their determination is proceeding.

Since these radicals appear to dimerize, nuclear contact shifts cannot be determined.

Consequently, only a qualitative description of the electronic structure of these nitroxides is possible. However, efforts are being made to stabilize such molecules, thus enabling the quantitative characterization of the electron distribution of the heterobicyclic system.

Acknowledgement.--Acknowledgement is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, and of the General Research Funds of the Departments of Dentistry and Medicine, SUNY at Buffalo, for support of this research.

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