Nuclear Magnetic Resonance Studies of Rate Processes and Conformations.[1] Ring Inversion in Two Nitrogen-containing Heterocyclic Systems

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CONFORMATIONAL rate processes have been reported for several heterocyclic systems.[2] In particular studies have been made recently of ring inversions in several substituted tetrahydropyridazines.[1,3–5]

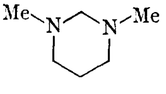
We present here our results concerning two other nitrogen-containing systems which display temperature-dependent n.m.r. spectra.

During the course of a current investigation of the hexahydropyrimidine system,[6] the n.m.r. spectrum of 1,3-dimethylhexahydropyrimidine

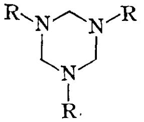
(I) was found to be temperature dependent. The C-2 methylenic protons display a single band at 32°, which, on lowering the temperature, broadens and splits into an AB quartet ($J_{AB} = 8{\cdot}9$ c./sec.) below the coalescence temperature ($T_C = -29 \pm 4°$)

This observation led us to examine the series of symmetrical hexahydrotriazines (II a,b,c,d). At 32° these compounds present a single band for the three equivalent ring-methylene groups in addition to the expected signals for the substituents on the nitrogen atoms. In all four derivatives this band broadens as the temperature is lowered and eventually it separates into a spectrum of the AB type ($J_{AB} = 10{\cdot}2 \pm 0{\cdot}2$ c./sec. in all four derivatives). All other signals remain unchanged. By comparison with systems of known conformation the low- and high-field doublets may be attributed to the equatorial and axial protons respectively. The Table lists the chemical shift differences $\Delta\nu_{AB}$ of the AB spectra and the coalescence temperatures T_C in both deuterochloroform and methylcyclohexane.

In these systems (I, II) two types of rate process should be considered: nitrogen inversion and ring inversion. Nitrogen inversion is known to be a fast rate process (on the n.m.r. time scale), except in certain special cases.[8,9] The observed temperature-dependence of the spectra described here is easily accounted for by slow ring inversion between two equivalent chair forms, in which fast nitrogen inversion between axial and equatorial positions leads to a time averaged signal for the *N*-alkyl groups. In the unlikely event of slow nitrogen inversion being the observed rate process, one would expect less simple spectra than those obtained.[10]



(I)



(II) a; R=Me. b; R=Et
c; R=Pr^i. d; R=Bu^t

The free energies of activation $\Delta G^\ddagger_C$ at the

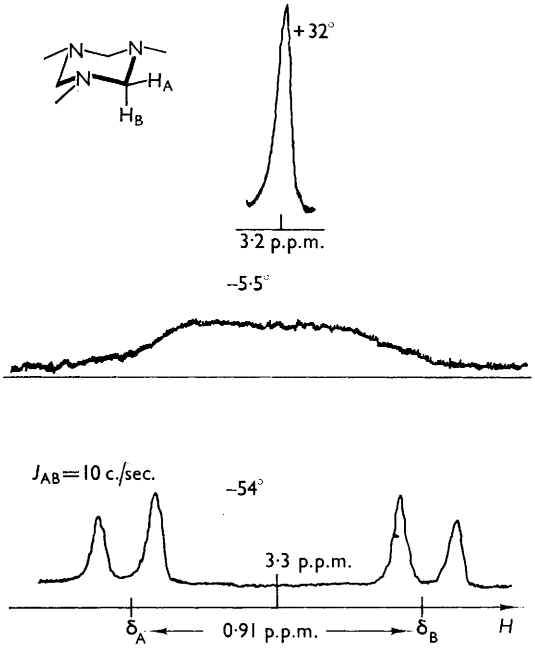


FIGURE. *Ring methylene signal in the spectrum of compound* (IIa) *at different temperatures.*

TABLE

Spectral parameters for ring (C-2) *methylene groups at* 60 *Mc./sec.**

Compound	Solvent	Chemical shift difference $\Delta\nu_{AB}$ (at T°) in c./sec.	Coalescence temperature T_c	Activation energy $\Delta G^\ddagger_C$ at T_c (kcal./mole)
(I)	$CDCl_3$	75·4 ± 2 (−73°)	−29 ± 4°	11·3 ± 0·4
(IIa)	$CDCl_3$	54·7 ± 2 (−54)	− 5 ± 2°	12·6 ± 0·2
	Me·C_6H_{11}†	52·3 ± 2 (−60)	−20 ± 2°	11·9 ± 0·2
(IIb)	$CDCl_3$	63·2 ± 2 (−54)	−17 ± 2°	12·0 ± 0·2
	Me·C_6H_{11}	61·9 ± 2 (−75)	−30 ± 2°	11·4 ± 0·2
(IIc)	$CDCl_3$	53·2 ± 2 (−69)	−32 ± 2°	11·3 ± 0·2
	Me·C_6H_{11}	52·2 ± 3 (−69)	−45 ± 2°	10·7 ± 0·3
(IId)	$CDCl_3$§	—	—	—
	Me·C_6H_{11}	69·3 ± 3 (−80)	−57 ± 2°	10·0 ± 0·3

* The spectra were measured on a Varian A-60 Spectrometer
† Methylcyclohexane
§ This compound decomposed rapidly in deuterochloroform

coalescence temperatures were calculated using the following formula:

$$\Delta G_{\mathrm{C}}^{\ddagger} = 4{\cdot}57\, T_{\mathrm{C}}\left[9{\cdot}67 + \log \frac{T_{\mathrm{C}}}{(\Delta\nu_{\mathrm{AB}}^{2} + 6J_{\mathrm{AB}}^{2})^{\frac{1}{2}}}\right]$$

which incorporates a transmission coefficient of $\frac{1}{2}$.[11]

The barriers found for the ring inversions are listed in the Table. They present an interesting stepwise decrease of *ca.* 0·6—0·7 kcal./mole when going along the series of compounds (II) from R = methyl to R = t-butyl.

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[1] Previous paper: J. C. Breliere and J. M. Lehn, *Chem. Comm.*, 1965, 426.

[2] J. E. Anderson *Quart. Rev.*, 1965, **19**, 426.

[3] B. Price, R. O. Sutherland, and F. G. Williamson, to be published.

[4] R. Daniels and K. Roseman, *Tetrahedron Letters*, 1966, 1335.

[5] J. E. Anderson and J. M. Lehn, to be published.

[6] F. G. Riddell unpublished results.

[7] H. P. Hamlow, S. Okuda, and N. Nakagawa, *Tetrahedron Letters*, 1964, 2553.

[8] A. T. Bottini and J. D. Roberts, *J. Amer. Chem. Soc.*, 1958, **80**, 5203.

[9] A. T. Bottini, R. L. Van Etten, and A. J. Davidson, *J. Amer. Chem. Soc.*, 1965, **87**, 755.

[10] A detailed discussion of this point will be given in the final account.

[11] J. E. Anderson and J. C. D. Brand, *Trans. Faraday Soc.*, 1966, **62**, 517.