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CONTRIBUTION OF INTRINSIC DIASTEREOMERISM TO THE MAGNETIC NONEQUIVALENCE OF DIASTEREOMERIC NUCLEI

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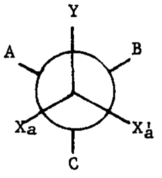
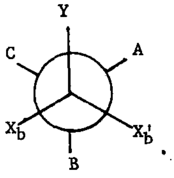
The magnitude of the difference in chemical shift of diastereomeric X groups ($\Delta\nu_{total} = \nu_X - \nu_{X'}$) in compounds of the type CX_2Y-CABC is temperature dependent. Generally the magnitude of the nonequivalence decreases with increasing temperature (2). This decrease has been interpreted as an indication of the change in the relative weights of the three conformers, A, B, and C. It has been argued that if the populations of the conformers were equal, the nonequivalence would be close to zero(3), although it had been pointed out that the X nuclei would remain diastereomeric even under conditions of rapid rotation and equal population of the conformers, and that a nonequivalence should, in principle, result (4).



A



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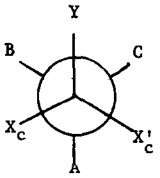

C

The observed nonequivalence will be a weighted average of the nonequivalences in the individual conformers A, B, and C,

$$\Delta\nu_{\text{total}} = \sum_{i}^{n} X_i \Delta\nu_i \tag{1}$$

where X_i is the mole fraction of conformer i, and $\Delta\nu_i = \nu_{X_i} - \nu_{X_i'}$ is the difference in chemical shift (nonequivalence) between X and X' in conformer i. The nonequivalence that would result if all X_i were equal is the contribution of the intrinsic diastereomerism (or intrinsic asymmetry).

$$\Delta\nu_{id} = \sum_{i}^{n} 1/n\ (\Delta\nu_i) \tag{2}$$

From (1) and (2) we can write

$$\Delta\nu_{\text{total}} = \sum_{i}^{n} (X_i - \frac{1}{n})\Delta\nu_i + \sum_{i}^{n} (1/n)\Delta\nu_i \tag{3}$$

or

$$\Delta\nu_{\text{total}} = \Delta\nu_{cp} + \Delta\nu_{id}$$

The first term represents the contribution of the differences in population of the various conformers. As the conformer populations approach equality, as would be expected at high temperatures, $\Delta\nu_{cp}$ should decrease toward its limit of zero. The second term, $\Delta\nu_{id}$, on the other hand, is independent of conformer populations.

The approximation, that $\Delta\nu_{id}$ is close to zero, depends on the judgment that the chemical shifts of X_a, X_b and X_c will be about equal to X_c', X_a' and X_b' respectively, since their environments are similar. If $\nu_{X_a} - \nu_{X_c'}$, $\nu_{X_b} - \nu_{X_a'}$, and $\nu_{X_c} - \nu_{X_b'}$ are all close to zero, their average which equals $\Delta\nu_{id}$ will be close to zero. An attempt has been made to estimate this contribution of intrinsic diastereomerism to the total magnetic nonequivalence from high temperature NMR spectra, although the necessary assumptions leave some doubt about the errors in such approximations (4). Gutowsky obtained a value of $\Delta\nu_{id} = 6.7$ c.p.s. for $CF_2Br\text{-}CFBrCl$(I), in good agreement with the value obtained from the low temperature spectrum (vide infra). Unfortunately, the low value obtained for this compound reinforced the presumption that $\Delta\nu_{id}$ was close to zero in general.

It is possible to calculate $\Delta\nu_{id}$ directly, from low temperature NMR spectra in which the individual spectra of the rotamers can be observed, since $\Delta\nu_{id} = \sum_{i}^{n} 1/n(\Delta\nu_i)$. Such a calculation can be made from the low temperature spectra of I and CF_2Br-CHBrCl(II) (5,6). The values of the observed nonequivalence and the calculated values of the intrinsic diastereomerism term are given in Table 1. Although $\Delta\nu_{id}$ makes up only a minor part of the total in the case of I, it is of considerable importance in the case of II. (7)

Table 1[a]

Compound	$\Delta\nu_{id}$	$\Delta\nu_{total}$ (temperature)
I	5 c.p.s.	95 c.p.s. (27°C.)
II	55 c.p.s.	188 c.p.s. (30°C.)

[a] The values for I are taken or calculated from ref. 6, those for II from ref. 5. All values in the table refer to 56.4 Mc/sec. spectra. Gutowsky's value for I was obtained from 60 Mc/sec. spectra.

Furthermore, although the approximation that $\Delta\nu_{id}$ is close to zero holds for I, examination of the low temperature NMR data (5) indicates that this is fortuitous. The approximation depends on the judgment that $\nu_{X_a} - \nu_{X'_c}$ $\nu_{X_b} - \nu_{X'_a}$, and $\nu_{X_c} - \nu_{X'_b}$ are all close to zero. Although their average is in fact close to zero for I, this is not because the terms themselves are low but is due to the fortuitous canceling of large terms of opposite sign. The values are -420 c.p.s., +280 c.p.s., and +155 c.p.s.; their average is 5 c.p.s.; the average of their absolute values is 285 c.p.s.

Although the conformation population approach leads to an understanding of the usual decrease in magnetic nonequivalence with temperature, we should not lose sight of the fact that the decrease in the conformer population contribution is superimposed over an intrinsic diastereomerism contribution which can be quite large in some cases. Great care should be taken before assuming that two nuclei which are in environments which are on first glance as similar as X_a and X'_c have nearly the same chemical shift.

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7. A referee has suggested that it seems unlikely that $\Delta\nu_{id}$ is temperature independent. However, we feel that the changes with temperature in the n.m.r. spectrum of a single conformer due to changes in solvation, population of vibrational states etc. are so small as to be negligible. The values in Table 1 were calculated using assignments of Newmark and Sederholm (5,6). The referee has also noted that even if these assignments are in error, $\Delta\nu_{id}$ for II can be no lower than 27 ± 4 cps.