The Barrier to Ring Inversion in 2,2,5,5-Tetramethylcyclohexanone

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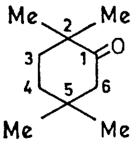
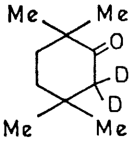
Summary 2,2,5,5-Tetramethylcyclohexanone has a much higher barrier (8·1 kcal/mole) to ring inversion than cyclohexanone (< 5 kcal/mole).

RECENTLY, the free-energy barrier to ring inversion in cyclo-hexanone was reported to be too small to be determined by variable-temperature ^{1}H n.m.r. spectroscopy and an upper limit of 5 kcal/mole was estimated.[1] We report the first, to our knowledge, and surprisingly high barrier to ring inversion in a cyclohexanone derivative, 2,2,5,5-tetramethylcyclohexanone (I).†



(I)



(II)

The Figure shows the 100 MHz ^{1}H n.m.r. spectra of (I) and (II) at several temperatures. The spectrum at +24° shows four singlets at 0·92 (two methyl groups), 1·06 (two methyl groups), 1·63 (two methylene groups), and 2·16 p.p.m. (methylene groups at C-6). A spectral change takes place at low temperatures such that at −130° four methyl peaks (0·80, 0·98, 1·04, 1·14 p.p.m.) are observed. The high-temperature peak at 1·63 p.p.m. has changed into a complex ABCD pattern while the singlet at 2·16 p.p.m. has split into an AB quartet whose low-field doublet is readily identified. Since the high-field doublet overlaps with the ABCD lines, it could only be identified with certainty by comparison with the spectrum of 6,6-dideuterio-2,2,5,5-tetramethylcyclohexanone (II) at the same temperature (Figure, d). The labelled lines in the Figure, c, therefore represent the AB quartet with a chemical-shift difference of 67·6 Hz and a coupling constant equal to 13·5 Hz; its coalescence temperature (T_c) was found to be about −101°.

The rate constant (k, in s^{-1}) at T_c for the process of conformational interconversion responsible for the spectral change was obtained from the relationship given by Kurland and his co-workers.[2] From $k = 157$ s^{-1}, a free energy of activation ($\Delta F^{\ddagger}$) equal to 8·1 kcal/mole was calculated using the Eyring equation with a transmission coefficient of 1.

It is known that cyclohexanone[1] and 3,3,5,5-tetramethylcyclohexanone (III)[3] exist in a chair conformation. Since methyl non-bonded interactions should be less for (I) than for (III), it seems highly probable that its most stable conformation is also a chair.

It is known that 1,1,4,4-tetramethylcyclohexane (IV)[4] has a higher free-energy barrier for ring inversion than cyclohexane[5] (11·1 and 10·2 kcal/mole, respectively). This increase may be attributed to greater torsional and non-bonded strain during rotation around the ring carbon–carbon bonds next to the quaternary carbon in the "ring flip" to reach the transition state. This behaviour is analogous to the barrier difference to methyl-group rotation in propane and 2,2-dimethylpropane (3·4 and 5·2 kcal/mole, respectively[6]).

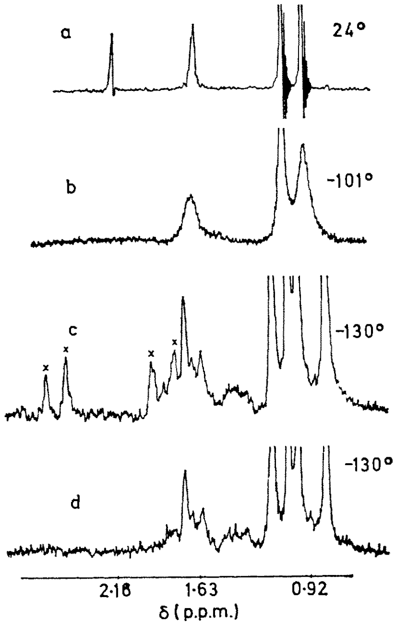


FIGURE. *The* 100 *MHz* ^{1}H *n.m.r. spectra of* (I) (a, b, *and* c) *and* (II) (d) *at several temperatures. The concentrations are* 3% (v : v) *in a mixture of vinyl chloride and chlorodifluoromethane* (85 : 15). *The peak positions in p.p.m. are relative to internal* Me$_4$Si.

The presence of the 1,1,4,4-tetramethyl groups on the cyclohexanone skeleton raises the barrier by at least 3 kcal/mole. Here also the difference may be rationalized in terms of higher torsional and non-bonded strain.

A complete line-shape analysis of the methyl region of the spectrum is planned and we hope to obtain additional information which will enable a precise description of the interconversion mechanism.

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† This compound was prepared by Dr. M. Forest, Master's Thesis, Université de Montréal, 1967.

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