Ring Inversion in 1,4-Dioxan

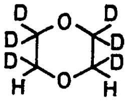
By F. A. L. ANET* and J. SANDSTROM

(*Department of Chemistry, University of California, Los Angeles, California* 90024)

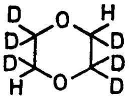
Summary. The free energy barrier ($\Delta G^{\ddagger}$) for ring inversion in hexadeuteriodioxan was determined by low-temperature ^{1}H n.m.r. measurements and found to be 9.7 kcal/mole at −97°.

THE kinetics of ring inversion have been studied by n.m.r. in numerous six-membered carbocyclic and heterocyclic rings, and generally show consistent features.[1] In the case of 1,4-dioxan, however, it has been reported that the n.m.r.

spectrum is apparently temperature-independent[2,3] and it has been suggested that the barrier for ring inversion of this compound should be lower than that of cyclohexane.[4] Since it has also been predicted that the axial–equatorial chemical shift difference in the chair form of 1,4-dioxan should be small, we decided to examine the temperature dependence of the proton spectrum of a partially deuteriated 1,4-dioxan. The deuteriated compound desired must have only CD_2 and CHD groups, for the presence of a large coupling constant in a CH_2 group tends to collapse the spectrum to a single line when the chemical shift difference between the CH_2 protons is much smaller than the coupling constant. An ideal compound is $[^2H_7]$-1,4-dioxan, but because this compound is difficult to synthesize, we chose to examine a mixture of $[^2H_6]$-1,4-dioxan isotopic isomers consisting of the *cis*- and *trans*-forms of (I) and (II) and prepared as follows: ethyl glyoxylate was reduced with lithium aluminium deuteride to $[^2H_3]$-ethylene glycol, which was then dehydrated with sulphuric acid to a mixture of diastereomers of (I) and (II).



(I)



(II)

The product, which was isolated by preparative g.l.c., gave a mass spectrum consistent with its assigned structure. The ^1H n.m.r. spectrum (100 MHz), with deuterons decoupled, gave an apparent single line, which, however, under careful scrutiny proved to be at least a doublet of very small separation (*ca.* 0·2 Hz) as shown by the presence of wiggle-beats under conditions where the tetramethylsilane reference line gave rise to an exponentially decaying ringing pattern. Thus the protons in the diastereomers of (I) and (II) do not all have the same chemical shifts, as a result of a small stereochemical isotope effect. Nevertheless, the isotopic mixture is entirely satisfactory for the n.m.r. experiments described below. The proton spectrum of the deuteriated dioxan broadened considerably below −90° and separated into two lines at −97°. At −116° (Figure) two well-resolved lines were observed with a chemical shift difference of 1·6 Hz or 0·016 p.p.m. The free energy of activation ($\Delta G^{\ddagger}$) for the chair–chair ring inversion is calculated to be 9·7 kcal/mole. The value of $\Delta G^{\ddagger}$ for the chair-to-boat (or chair-to-twist-boat) process is 9·4 kcal/mole. Unfortunately, the very small chemical shift in 1,4-dioxan precludes an accurate determination of $\Delta H^{\ddagger}$ and $\Delta S^{\ddagger}$.

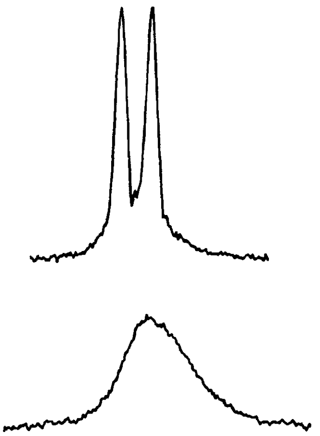


FIGURE. ^1H *n.m.r. spectra* (100 MHz) *of a mixture of diastereomers of deuteriated dioxan* (I *and* II) *at* −110° *in* $CHCl_2F$–$CHClF_2$ *as solvent: top, with deuterons decoupled: bottom without deuterium decoupling.*

A recent calculation,[5] based on vibrational frequencies in the ground state of 1,4-dioxan, gave a $\Delta G^{\ddagger}$ for the chair-to-boat process of 10·1 kcal/mole, a little higher than the experimental value. This discrepancy is not unexpected, as the same kind of calculation for cyclohexane also gave an appreciably higher calculated than observed barrier to inversion.[5]

We have also investigated the n.m.r. spectrum of undeuteriated 1,4-dioxan under the same conditions as described above for (I) and (II). The spectrum, as expected, remained a single line down to −150°.

This work was supported by the National Science Foundation. One of us (J. S.) thanks the Swedish National Sciences Research Council for a travelling grant and the Sweden–America Foundation for a Zorn Scholarship.

(*Received, October* 15*th*, **1971**; *Com.* 1784.)

[1] H. Booth, *Progr. Nuclear Magnetic Resonance Spectroscopy*, 1969, **5**, 149.
[2] B. Pederson and J. Schaug, *Acta Chem. Scand.*, 1968, **22**, 1705.
[3] R. K. Harris and R. A. Spragg, *Chem. Comm.*, 1966, 314.
[4] R. K. Harris and R. A. Spragg, *J. Chem. Soc.* (*B*), 1968, 684.
[5] H. M. Pickett and H. L. Strauss, *J. Amer. Chem. Soc.*, 1970, **92**, 7281.