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CONFORMATIONAL STUDIES OF TRIMETHYLENE SULFITE AND RELATED COMPOUNDS IV

THE CONFORMATIONAL ENERGY OF THE AXIAL S=O BOND

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Several studies have been published on the conformational behaviour of six-membered cyclic sulfites (1-6), which all give evidence for the preferential occurrence of chair forms with axial S=O bond. The available information about the conformational energy of this bond, i.e. the free energy difference between the axial and equatorial orientation, is however rather qualitative at present. By ultrasonic measurements (7) the presence of a two-state unimolecular equilibrium could be detected in trimethylene sulfite and some methyl-derivatives. Although this method does not give details about the structure of the conformers, enthalpy as well as entropy differences could be evaluated for the (supposed chair) equilibria. For the unsubstituted sulfite the quoted values are: ΔH^o = 1.3 Kcal/mole, ΔS^o = -2.5 e.u. This result is slightly at variance with our earlier estimate of $\Delta G^o = 3.5 \pm 1$ Kcal/mole, which was based mainly on measurements of dipole moments in dilute solutions in apolar solvents. An even higher value has been suggested by Overberger c.s. (8).

In order to exclude the uncertainty, due to the possible occurrence of non-chair forms in compounds with unfavourable intramolecular interactions (cf. 4, 9,10,11), we have now investigated two isomeric sulfites derived from trans-2-hydroxymethylcyclohexanol. The latter diol was obtained from cyclohexene by the Prins reaction, which is known to give trans-substituted products (12).

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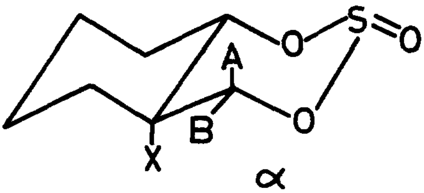
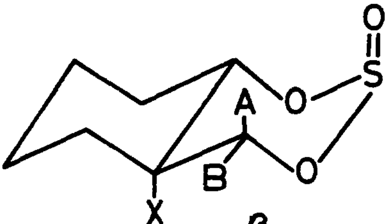
We may expect the trans ring-junction to give a strong bias to the sulfite ring to take up a chair form also in the case of the less stable isomer. This is confirmed by experiment. The NMR spectra of the isolated compounds I and II show vicinal coupling constants J_{AX} and J_{BX} close to 11 and 4 Hz respectively in both isomers.

Other typical properties are shown in Table 1.



α



β

TABLE 1

Properties of isomers of trans-1,3,2-dioxathiadecalin-2-oxide.

Isomer	μ(D) in CCl_4 +)	ν SO (cm^{-1}) in CCl_4	K OH ($l.mole.^{-1}min^{-1}$)	Config. Assignm.	Analysis ++)		
					C	H	S
I b.p.130°/ 22mm	3.85	1190	3.5	β	47.93	7.07	18.15
II m.p.43-46	5.15	1240	2.10^2	α	47.76	6.91	18.25

+) determined at 25°C; ++) Calc.: C 47.73; S 18.18; H 6.82%.

The electric dipole moments and S=O stretching frequencies, as well as the rates of alkaline hydrolysis are in complete agreement with observations made in earlier studies (1,2,9,13) on conformationally mobile sulfites, if structures β and α are assigned to isomers I and II respectively.

By catalytic amounts of acid (HCl, BF_3), equilibria I $\rightleftharpoons$ II could be set up in various solvents. From the equilibrium constants determined by GLC using a polyethyleneglycol succinate column, configurational preferences for the S=O

bond were calculated with the equation: $-\Delta G_{SO} = RT\ln II / I$.
The free energy values thus obtained (Table 2) show an interesting increase with

TABLE 2

Equilibration of isomeric trans-1,3,2-dioxathiadecalin-2-oxides

solvent	temperature	catalyst	K = I/II ++)	ΔG_{SO}(Kcal/mole)
CCl_4	40°	BF_3, $SOCl_2$ +)	25	1.9^5
CCl_4	77°	BF_3	22	2.1
C_6H_6	40°	BF_3, HCl	18.7	1.80
C_6H_6	77°	$SOCl_2$ +)	15.8	1.92
$CHCl_3$	40°	BF_3, HCl	13.9	1.61
CH_3CN	40°	BF_3, HCl	12.9	1.57

+) The small amounts of thionyl chloride probably react with traces of water to give HCl. ++) The values at 40° are average results of $\geqslant 5$ experiments.

decreasing solvent polarity. This effect is the more significant if one considers that the data refer to rather concentrated solutions (~ 20% wt/vol). Therefore, the dielectric constant of the medium surrounding the solute molecules varies only down to $\varepsilon \approx 5$ in the present experiments. The slight increase of ΔG_{SO} with temperature may be due to a similar medium effect.

Two interpretations of this result seem appropriate here:

(a) The preference for the axial orientation of the S=O bond in cyclic sulfites closely resembles the behaviour of "anomeric" substituents in related heterocyclic systems. Although the exact origin of the anomeric effect is still in dispute (14), intramolecular dipolar forces almost certainly make an important contribution to it. These forces are affected by a change in solvent polarity.

(b) A highly polar molecule such as α will be stabilised relative to a less polar one in a surrounding dielectric. As this intermolecular interaction increases with the dielectric constant of the medium, this would decrease the apparent energy content of the more polar structure relative to the less polar one and hence lower the free-energy difference.

At present it seems difficult to differentiate between these two - possibly both contributing - factors. The importance of the electrostatic forces sub (a) is supported by a recent calculation. Yuldasheva c.s. (6) estimated the axial S=O bond in trimethylene sulfite to be 2.15 Kcal./mole more stable than the equatorial bond if $\varepsilon \approx 2$, which is in good agreement with the above experimental results.

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