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CONFORMATION OF NON-AROMATIC RING COMPOUNDS, Part 62 (1)

NMR SPECTRA AND GEOMETRY OF SOME 1,3-OXATHIANES

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Introduction

The conformational and physical properties (A-values substituents, dipole moments, NMR) of 1,3-dioxanes and -dithianes have been extensively studied (2). X-ray determinations of a 2-(equatorially)-substituted 1,3-dioxane (3) and -dithiane (4) indicate a chair-shaped molecule with ring torsional angles as shown in Fig.1.

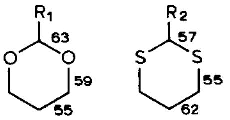


FIG.1. Ring torsional angles (from X-ray analysis) in a 2-substituted 1,3-dioxane and -dithiane (R_1 = p-chlorophenyl, R_2 = phenyl).

On the conformational and geometrical properties of the "mixed" 1,3-diheterocyclic oxathianes thus far only a few papers have been published (5-8). The main conclusions from these studies are:

(i) With the aid of Dreiding models Anteunis et al.(8) found it possible to construct *a priori* two different 1,3-oxathiane chair forms, which are both highly distorted as the result of the large difference in C-S (1.81 Å) and C-O (1.42 Å) distances. In one of these forms, the puckering is largest in the S-side of the ring, in the other one in the O-side. In the latter case a serious synaxial $H_{2a}H_{6a}$ interaction appears to exist.

(ii) From vicinal (5,8) and long-range (6) coupling constants it appeared that slight deformations of the 1,3-oxathiane system are rather easily caused by substitution. In some 2,4,6-trisubstituted and 2,5-disubstituted rings the O-side appeared to be the more puckered one (8).

(iii)A study of the ring inversion rates (7) of 1,3-oxathiane and some geminal dimethyl derivatives reveals that about the same free energies of activation exist ($\Delta G^{\ddagger}_{-70}$ = 9.1 - 9.3 kcal/mole) in the unsubstituted ring and in its 4,4- and 6,6-dimethyl derivatives (For the numbering in this ring system see Table 1). A much lower value (8.0 kcal/mole) was found in the 2,2-dimethyl compound, and a higher value (10.4 kcal/mole) in the 5,5-dimethyl derivative. The differences are probably due to a difference in $\Delta H^{\ddagger}$ and not to a difference in $\Delta S^{\ddagger}$.

At present we are investigating a series of alkyl- and aryl-substituted 1,3-oxathianes with the aid of dipole moments and NMR spectra (9), whereas an X-ray analysis is being carried out (10). In this paper we wish to report the NMR results on the following compounds: 1,3-oxathiane (I), 2,2-dimethyl- (II), 4,4-dimethyl- (III) and 6,6-dimethyl-

1,3-oxathiane (IV). These compounds were prepared as described (7). These rings can be studied by means of the so-called "R-value" method, originally introduced by Lambert (11) and recently extended by one of us (12): For six-membered rings existing in solution as an equilibrium mixture of two equivalent conformers and having a $-CH_2-CH_2-$ or $-CH_2-CHR-$ moiety (from which two vicinal coupling constants, J_{trans} and J_{cis}, can be extracted from the NMR spectrum), the ratio $R = J_{trans}/J_{cis}$ is equated (12) to the ring torsional angle ψ in that moiety by:

$$\cos^2\psi = 3/(2 + 4R) \qquad (1)$$

The results for about 20 compounds (among which the $C_4-C_5-C_6$ part of 1,3-dioxane) indicate (12) that the ψ values calculated from the experimental vicinal coupling constants with the aid of eq.(1) agree with the results from diffraction analyses within about 2°.

Results

The 100 Mc/s NMR spectra were taken with a Varian HA-100 spectrometer from solutions in carbon tetrachloride. The ring protons in the $C_4-C_5-C_6$ moiety yield an AA'BB' spectrum in the case of III and IV; in I and II an AA'BB'CC' spectrum is present with $J_{AB} \simeq J_{AB'} \simeq 0$. As the chemical shifts are rather large with respect to the coupling constants the analysis of the spin-spin splitting pattern is straightforward (13): The results in terms of the chemical shifts with respect to TMS (δ_2 denotes the shift of the protons on C_2, etc.) and the usual coupling parameters in AA'BB' spectra N, L and M (14) are presented in Table 1. The vicinal coupling constants J_{trans} and J_{cis} follow from N and L. K could not be extracted from the spectra, so no values for the geminal couplings can be derived. From recent compilations of geminal coupling constants (15-17) it is seen that in 6-membered rings the geminal coupling constant is about -13 c/s in the $-CH_2-S-$ moiety (thiane), -11.5 c/s in $-O-CH_2-$ (tetrahydropyran), whereas in $-CH_2-CH_2-CH_2-$ (cyclohexane) -13 c/s is found (18). The $M = |J_{AA'} - J_{BB'}|$ values in Table 1 are in good agreement with these figures. In compound IV a rather large long-range coupling exists between the protons on C_4 and C_2: $^4J \simeq 1.1$ c/s. As this coupling is presumably between the equatorial protons on C_2 and C_4 (W rule (19)), it follows that $^4J_{2e4e} \simeq 2.2$ c/s. In compound I this long-range coupling is weaker ($\lesssim$ 1 c/s). Decoupling of the C_2 protons was carried out in this case in order to simplify the multiplet due to the C_4 protons.

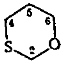
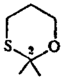
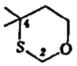
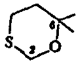
From the ratio of J_{trans} and J_{cis} (R) the ring torsional angle about the C_4-C_5 and / or C_5-C_6 bond was calculated with the aid of eq.(1). The results are also shown in Table 1.

Discussion

Like Anteunis et al.(8) did with Dreiding models (cf.introduction), we constructed the 1,3-oxathiane ring with the aid of another type of models (20) and could confirm the existence of two possibilities for the chair form: one with the largest puckering on the O-side, the other one being most puckered on the S-side. In our opinion no definite conclusion wan be drawn from this feature, as in principle the following possibilities exist:

a. The real chair form is rather rigid with a geometry about intermediate between the two model forms.

TABLE 1. Chemical shifts (ppm from TMS), coupling constants (c/s), R values and torsional angles in compounds I-IV.

Compound						
	I		II		III	IV
δ_2	4.8		-		4.7	4.7
δ_4	2.8		2.8		-	2.7
δ_5	1.8		1.8		1.6	1.7
δ_6	3.7		3.8		3.7	-
	O-side	S-side	O-side	S-side	O-side	S-side
N	10.7	11.5	11.3	11.8	11.3	12.4
L	4.2	5.7	3.6	5.0	4.8	5.3
M	1.9	∽0	1.5	∽0	1.6	∽0
J_{trans}	7.4_5	8.6	7.4_5	8.4	8.0_5	8.8_5
J_{cis}	3.2_5	2.9	3.8_5	3.4	3.2_5	3.5_5
R	2.29	2.97	1.94	2.47	2.48	2.49
ψ_{45}		62°		60°		60°
ψ_{56}	59°		56°		60°	

b. Two chair forms with different geometry and energy separated by a significant energy barrier exist, thus giving rise to a conformational equilibrium between them.

c. The two forms are not separated by a significant barrier, thus yielding a rather flexible chair form in 1,3-oxathiane.

In cases b and c the R-value method yields only average dihedral angles about the 4-5 and 5-6 bonds, whereas substituents may change the situation by changing the energy barrier and/or energy difference between both chair forms.

From Table 1 the following conclusions appear:

(i) In compounds I and II the puckering about bond 4-5 (S-side) is larger than that about bond 5-6 (O-side). In cases b and c (see above) this means that on average the S-side is the more puckered one. This is in agreement with the observation (see introduction) that serious 2,6-synaxial interaction is present in the form with a more puckered O-side.

(ii) The 2,2-dimethyl derivative is significantly less puckered in the C_4-C_5-C_6 moiety than the unsubstituted ring, presumably on account of the synaxial interactions with the 2-methyl group. This difference in geometry is consistent with the large difference in chair-chair inversion rate found for I and II (see introduction).

(iii) In compounds III and IV only one dihedral angle is obtained from the R-value method, so no complete picture is obtained for the puckering in the C_4-C_5-C_6 region. The chair-chair inversion rates (7) are equal to that in the unsubstituted compound, which might be an indication that the puckering is not very different, consistent with the dihedral angle found (60^o).

(iv) The dihedral angles found in compounds I-IV have the expected order of magnitude, as they lie between those in the 1,3-dioxane and -dithiane derivative studied by X-ray analysis (cf.Fig.1). The same situation is found from X-ray analyses (2a) on 1,4-diheterocyclic compounds, in which the puckering of trans-2,3-dichloro-1,4-oxathiane lies between that in the correspondingly substituted dioxane and dithiane.

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