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THE NMR SPECTRA OF SOME 5,5-DISUBSTITUTED-1,3-DIOXANS

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Abstract—The NMR Spectra of 1,3-dioxans substituted at C_5 with an asymmetric group provide clear evidence of coupling, extending over four bonds, between the C_4 and C_6 equatorial protons.

RECENT interest[1,2] in long range couplings in 1,3-dioxans has prompted us to report our observations on the NMR spectra of some 5,5-disubstituted-1,3-dioxans. The NMR Spectra of III (Table 1) in non-aromatic solvents showed a single AB type quartet for the C_4 and C_6 methylene protons (like I in all solvents), each line showing evidence of additional coupling by its slightly broadened appearance. Apparently in these solvents the non-equivalence of the C_4 and C_6 methylene protons caused by the asymmetry of the C_5 group is too small to be completely resolved. However, the spectra of III in aromatic solvents did show the influence of the asymmetry of the C_5 group and two overlapping AB quartets were obtained for the C_4 methylene protons and the C_6 methylene protons. It would appear that the aromatic solvent has increased the effective asymmetry of the C_5 group, consistent with the work of Bhacca and Williams[3] on the chemical shifts induced by benzene in ketones. Thus as shown schematically in IV, an association of the aromatic molecule with the positive partial charge on the carbonyl C atom would increase the differential shielding of the two methylene groups by the asymmetric function. This agrees with the observed shielding of the acetyl methyl and of the C_5-Me in going from carbon tetrachloride as solvent to the aromatic solvents. In this connection it is interesting to note the effect of benzonitrile on the spectrum of III. Although this solvent succeeds in rendering the C_4 and C_6 methylene protons magnetically dissimilar δ_{CDCl_3}–$\delta_{C_6H_5CN}$ for the acetyl methyl and the C_5-Me are only 0·05 and 0·01 ppm compared with δ_{CDCl_3}–$\delta_{C_4H_4S}$ for the same protons of 0·33 and 0·08 ppm respectively. It is tempting to postulate a weaker "complex" between the carbonyl and benzonitrile because of repulsion between the carbonyl and cyanide dipoles. However, the effect of solvent on the NMR of compounds such as in III involves so many variables that these statistical "complexes" (such as IV) must be regarded as schematic only.

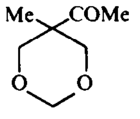
The long range influence of an asymmetric grouping on the equivalence of methylene group protons is to be expected but the real interest of the spectra of III in aromatic solvents was the sharp doublet character of each of the lines composing the two quartets (for example, see Fig 1). The low field part of the AB quartets show a larger long range J(ca. 1·2 c/s) than the high field signals (J = ca. 0·8 c/s). These results do not indicate a coupling between C_{4e} and C_{6e} and between C_{6a} and C_{4a} since the simplicity of the spectrum precludes rigid structures slowly interconverting;

TABLE 1. NMR SPECTRA OF III

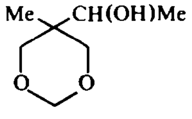
Solvent	Chemical shifts (τ)										Coupling constants (c/s)			
	CHOAc	H_2	$H_{2'}$	H_4	$H_{4'}$	H_6	$H_{6'}$	COMe	CHMe	5-Me	$J_{22'}$	$J_{44'}$*	J_{46}	$J_{4'6'}$
CCl_4	4·99	5·32			6·35	6·61		8·03	8·87	9·08	—	−11·5	—	
$CDCl_3$	4·95	5·20			6·24	6·52		7·97	8·82	9·06	—	−11·5		
CH_3CN	4·86	5·24	5·30		6·26	6·56		—	8·86	9·13	−6	−11·3	—	
C_6H_5CN	4·70	5·20	5·26	6·18	6·52	6·25	6·55	7·98	8·83	9·11	−6	−11·4	1·2	broad signal
Benzene	4·81	5·34		6·35	6·67	6·49	6·76	8·25	8·97	9·19	—	−11·4	1·2	0·8
Thiophen	4·82	5·38		6·38	6·68	6·52	6·78	8·30	9·0	9·21	—	−11·4	1·1	0·8
Furan	4·81	5·32		6·31	6·61	6·42	6·68	8·21	8·94	9·14	—	−11·4	1·2	0·8
Pyrrole	4·82	5·49	5·61	6·47	6·87	6·65	6·95	8·41	9·10	9·39	−6	−11·5	1·5	broad signal

* $J_{44'} = J_{66'}$.

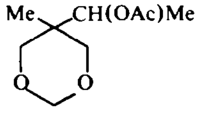
and in all the solvents, except pyrrole, the difference in chemical shift between the C_2 methylene protons is between zero and 0·06 ppm, indicating rapid conformational equilibrium between the two possible chair forms IIIa and IIIb. J_{gem} for the methylene protons adjacent to the oxygen atom is around $-11·5$ c/s, the normal value for 1,3-dioxans.* Compound III is expected to exist as an equilibrium mixture of IIIa and IIIb since the conformational energy differences between Me and —CH(OAc)Me should not be very high. Thus we have in the NMR spectra of compound III in aromatic solvents an unequivocal demonstration of coupling over four bonds of the order of 2 c/s.



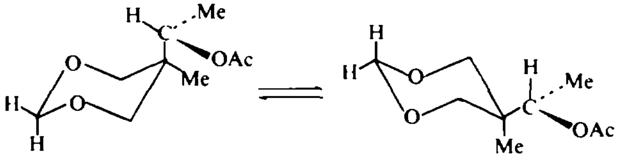
I



II



III



IIIa IIIb

The NMR spectra (Table 2) of the alcohol II shows the same two overlapping quartets for the C_4 and C_6 methylene protons with the low field parts of the quartets showing a long range coupling of 1·4 c/s. The high field parts of the AB quartets also showed evidence of long range coupling by their broadened appearance. In the case of II the C_4 and C_6 methylene protons were non-equivalent in both aromatic and non-aromatic solvents, and the spectra showed only small variations with solvent. The IR spectrum of II in carbon tetrachloride (0·05 M soln) showed a sharp peak at 3620 cm^{-1} arising from a free O—H stretching vibration together with a broad band centred at ca. 3400 cm^{-1} indicative of intermolecular hydrogen-bonding. On dilution to 0·02 M, although the 3620 cm^{-1} absorption had increased in intensity the 3400 cm^{-1} absorption was still strong. This leads one to suppose that it is the intermolecular hydrogen-bonding which renders the C_5 substituent sufficiently asymmetric to produce the observed non-equivalence even in non-aromatic solvents. The non-equivalence of the C_4 and C_6 methylene groups in V at low temperatures has been discussed by Anteunis.[4] The non-equivalence in our compounds is not due to slow interconversion between alternative conformations, because it persisted for III in benzonitrile from $-40°$ to $+180°$.

As an extension of this work on dissymmetric dioxans the NMR spectra of VI (R = benzyl and R = α-methylbenzyl) were compared. The spectrum of VI (R = benzyl) showed a single quartet ($J = -10·8$ c/s) for the C_4 and C_6 methylene protons whereas the spectrum of VI (R = α-methylbenzyl) showed the effect of the asymmetry of the C_2 substituent on these protons. The difference in chemical shift between

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* J_{gem} is assumed negative and the sign of ^4J is unknown.

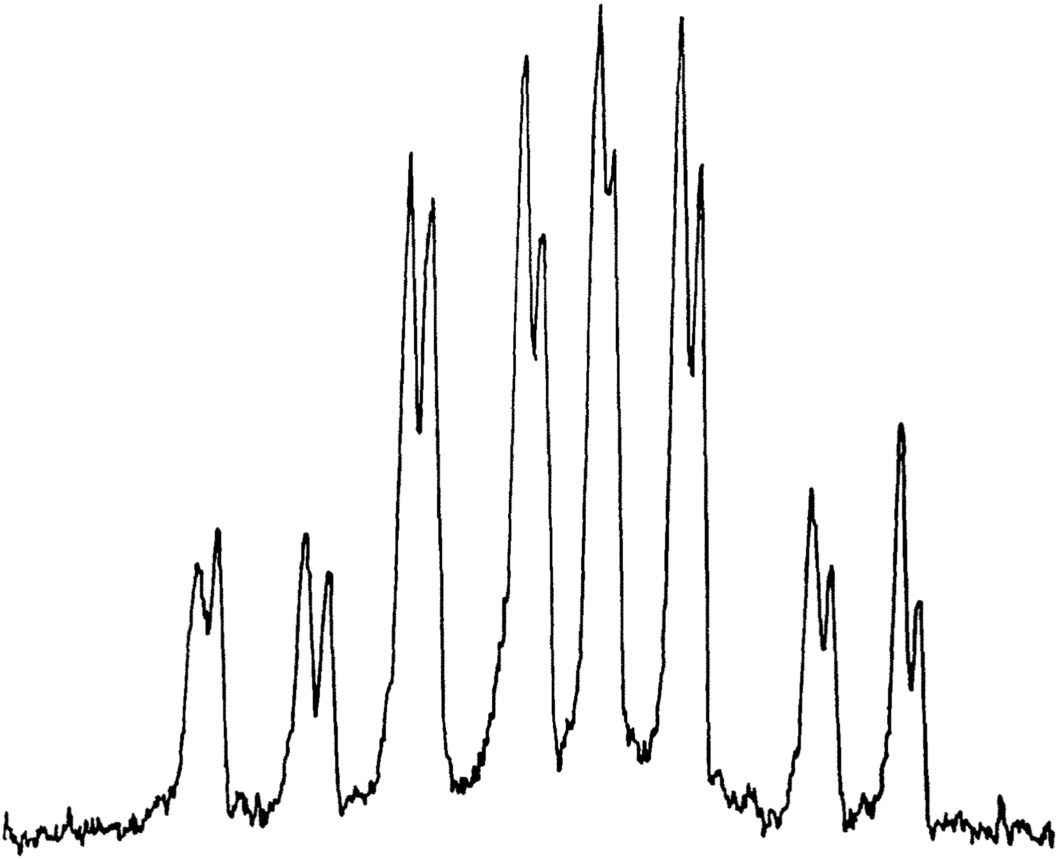
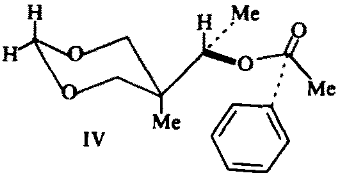
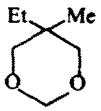


Fig. 1 NMR spectrum of III in furan. The signals from the C_4 and C_6 methylene protons.

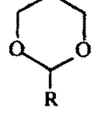
the C_{4a} and C_{6a} protons in this compound was practically zero and that between the C_{4e} and C_{6e} protons only ca. 0·05 ppm in both carbon tetrachloride and benzene solutions. These small differences are to be expected since a substituent at C_2 is one bond further removed from C_4 and C_6 than a C_5-substituent and its influence on the chemical shifts of these protons should therefore be less. However, the splitting of 2 c/s between the C_{4e} and C_{6e} protons was clearly discernable, producing an apparent doublet of triplets.



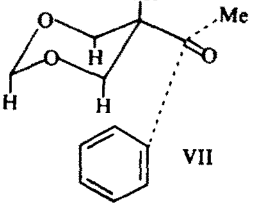
IV



V



VI



VII

TABLE 2. NMR SPECTRA OF II

Solvent	Chemical shifts (τ)								Coupling constants (c/s)		
	H_2	$H_{2'}$	H_4	$H_{4'}$	H_6	$H_{6'}$	CHMe	5-Me	$J_{22'}$	$J_{44'}$*	J_{46}
CCl_4	5·24	5·36	6·06	6·62	6·32	6·66	8·88	9·25	−6	−11·4	1·4
$CDCl_3$	5·18	5·24	6·03	6·51	6·26	6·56	8·87	9·15	−6	−11	1·4
Benzene	5·24	5·38	6·07	6·59	6·46	6·76	9·01	9·28	−5·8	−11·2	1·4
Thiophen	5·27	5·37	6·06	6·60	6·40	6·74	9·0	9·28	−6·0	−11·2	1·4
Furan	5·21	5·31	6·01	6·55	6·32	6·66	8·95	9·23	−6·0	−11·2	1·4
Pyrrole	5·49	5·54	6·32	6·78	6·63	6·91	9·20	9·44	−6·2	−11·2	1·4

* $J_{44'} = J_{66'}$.

TABLE 3. NMR SPECTRA OF I

Solvent	Chemical shifts (τ)						Coupling constants (c/s)	
	H_2	$H_{2'}$	H_4	$H_{4'}$	O=C—Me	5-Me	$J_{22'}$	$J_{44'}$
CCl_4	5·21	5·34	5·84	6·51	7·80	9·05	−6	−11·5
$CDCl_3$	5·14	5·30	5·71	6·47	7·75	9·04	−6	−11·5
CH_3CN	5·17	5·31	5·71	6·44	7·78	9·06	−6	−11·5
Benzene	5·24	5·51	5·91	6·79	8	9·38	−6	−11·5
Thiophen	5·27	5·53	5·93	6·79	8·05	9·39	−6	−11·5
Furan	5·19	5·41	5·80	6·61	7·92	9·22	−6	−11·5
Pyrrole	5·36	5·72	5·94	7·01	8·16	9·58	−6	−11·5

The most significant features of the spectrum of I (Table 3) is the deshielding of the C_4 and C_6 equatorial protons which must be due to the presence of the CO group. The difference in chemical shift between the protons at C_4 is large, being for example 0·68 ppm in carbon tetrachloride solution. The low field signals of the C_2 methylene quartet show long range coupling whereas the high field signals are sharp. The low field signals of the C_4 and C_6 quartet are more complicated in structure than the high field signals which, however, show evidence of further coupling. In compounds of the type VI (R = alkyl) Anderson[5] found that the C_2 axial proton signals were hardly affected by a change in solvent from CCl_4 to benzene. In I however, (Table 4) δ_{CCl_4}–$\delta_{C_6H_6}$ is quite large for the $H_{4'}$ and $H_{6'}$ protons and leads one to postulate a "complex" of the type VII with the aromatic ring tilted towards the C_2 axial protons. In all these "complexes" one can also assume the presence of an interaction between the aromatic solvent and the dipole of the O atoms as suggested by Anderson.[5]

TABLE 4. SOLVENT SHIFTS IN THE NMR SPECTRA OF I

Solvent change	H_2	$H_{2'}$	H_4	$H_{4'}$	$CO\underline{Me}$	5-Me
$\delta_{CCl_4} - \delta_{C_6H_6}$	0·03	0·17	0·07	0·28	0·20	0·33
$\delta_{CDCl_3} - \delta_{C_6H_6}$	0·10	0·21	0·20	0·32	0·25	0·34
$\delta_{CCl_4} - \delta_{C_4H_5N}$	0·15	0·38	0·10	0·50	0·26	0·50

During the writing of the paper another demonstration of a long range coupling of 2·5 c/s between the C_4 and C_6 equatorial protons in 1,3-dioxans was published.[6]

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