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CHEMICAL SHIFTS INDUCED BY PYRIDINE IN KETONES

Dudley H. Williams
University Chemical Laboratory, Lensfield Road, Cambridge.

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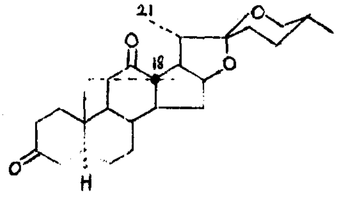
It has recently been shown that Δ values ($\delta_{CDCl_3}-\delta_{C_6H_6}$) for protons in ketones can be utilised to indicate the axial or equatorial nature of a hydrogen atom or methyl group adjacent to carbonyl (1,2) and to locate protons in front or behind a carbonyl group (3,4,5). Results are now reported which indicate that solvent shifts induced by pyridine in ketones can also be utilised in a similar empirical correlation.

In the present study, carbon tetrachloride has been employed as reference solvent (6) and the solvent shift ($\Delta^{CCl_4}_{C_6H_5N}$) is defined as $\delta_{CCl_4}-\delta_{C_5H_5N}$. The $\Delta^{CCl_4}_{C_5H_5N}$ values for some proton resonances in 7 ketones (I-VII) and 4α,β-unsaturated ketones (VIII-XI) are recorded in Table 1. The 3 angular methyl resonances of 7-ketototarol acetate (V) cannot be specifically assigned to a given peak, but all move upfield in pyridine relative to carbon tetrachloride. The 2-H and 4-H resonances of VII have been differentiated from the spectrum of 2,2-d_2-α-tetralone (VIIa). In Table 2 are tabulated, for comparison purposes, the corresponding shifts induced by benzene relative to deuterochloroform ($\delta_{CDCl_3}-\delta_{C_6H_6}$) in compounds VI, VII and IX-XI.



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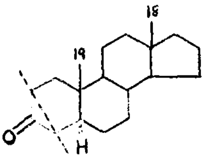

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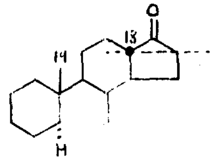

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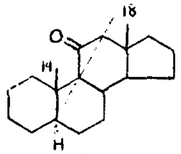

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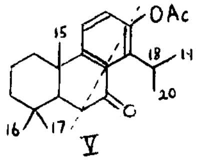

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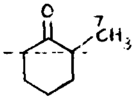

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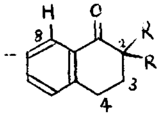
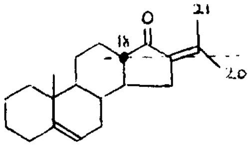
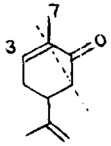


VII, R=H

VIIα, R=D



VIII



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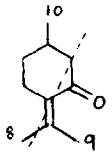
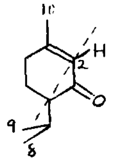


X



XI

TABLE 1

Solvent Shifts ($\Delta^{CCl_4}_{C_5H_5N} = \delta_{CCl_4} - \delta_{C_5H_5N}$ p.p.m.) for some Proton Resonances of Ketones (I-VII) and α,β-Unsaturated Ketones (VIII-XI)

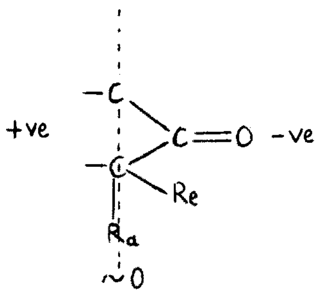
COMPOUND		NEGATIVE OR ZERO			POSITIVE		
I	RESONANCE	18-H	21-H				
	Δ	-0.08	-0.34				
II	RESONANCE				18-H	19-H	
	Δ				+0.06	+0.13	
III	RESONANCE				18-H	19-H	
	Δ				+0.06 OR +0.04	+0.06 OR +0.04	
IV	RESONANCE	19-H			18-H		
	Δ	-0.14			+0.05		
V	RESONANCE	18-H	19-H	20-H	15-H	16-H	17-H
	Δ	-0.53	-0.17	-0.23	(+)	(+)	(+)
VI	RESONANCE	7-H					
	Δ	-0.03					
VII	RESONANCE	8-H			2-H	3-H	4-H
	Δ	-0.27			+0.09	+0.31	+0.12
VIII	RESONANCE	18-H	21-H		20-H		
	Δ	-0.01	-0.13		+0.08		
IX	RESONANCE	7-H			3-H		
	Δ	-0.07±0.02			+0.07		
X	RESONANCE	9-H			8-H	10-H	
	Δ	-0.08			+0.11	+0.15	
XI	RESONANCE	2-H	8-H	9-H	10-H		
	Δ	-0.16	-0.01	0.00	+0.17		

TABLE 2

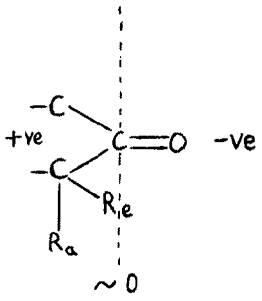
Solvent Shifts ($\Delta^{CDCl_3}_{C_6H_6} = \delta_{CDCl_3} - \delta_{C_6H_6}$ p.p.m.) for some Proton Resonances of Ketones (VI, VII) and α,β-Unsaturated Ketones (IX-XI)

COMPOUND		NEGATIVE OR ZERO	POSITIVE			
VI	RESONANCE			7-H		
	Δ			+0.05		
VII	RESONANCE	8-H		2-H	3-H	4-H
	Δ	-0.16		+0.32	+0.62	+0.53
IX	RESONANCE	7-H		3-H		
	Δ	0.00		+0.51		
X	RESONANCE	9-H		8-H	10-H	
	Δ	-0.03		+0.22	+0.19	
XI	RESONANCE		2-H	8-H	9-H	10-H
	Δ		+0.01	+0.02	+0.03	+0.37

It is evident from the results presented in Table 1 for ketones I-XI that protons located in front of the carbonyl group are deshielded (-0.53 to -0.03 p.p.m.) in pyridine relative to carbon tetrachloride. The solvent shift ($\Delta^{CCl_4}_{C_5H_5N}$) is zero or small (+0.06 to -0.08 p.p.m.) for protons approximately located in a plane drawn perpendicular to the C=O double bond and passing through the α-carbon atoms (see XII; carbonyl group located in a five- or six-membered ring). Protons lying behind this plane have positive $\Delta^{CCl_4}_{C_5H_5N}$ values (+0.05 to 0.31 p.p.m.) i.e., they are shielded in pyridine relative to carbon tetrachloride. The correlation is not sufficiently accurate to predict the sign of $\Delta^{CCl_4}_{C_5H_5N}$ for protons lying very near the reference plane and may of course be modified by polar substituents in the proximity of the carbonyl group. However, the fairly consistent behaviour of these saturated ketones (I-IV, VI), aromatic conjugated ketones (V, VII) and α,β-unsaturated ketones (VIII-XI) is very encouraging. For example, the vinylic α-methyl group of the α,β-unsaturated ketone IX has a negative $\Delta^{CCl_4}_{C_5H_5N}$ value, whereas the corresponding β-methyl group of XI has a positive $\Delta^{CCl_4}_{C_5H_5N}$ value. Similarly, the α-vinyl proton at C-2 in XI moves downfield in pyridine, while the β-vinyl proton at C-3 in IX moves upfield in pyridine.



XII, SIGN OF $\Delta^{CCl_4}_{C_5H_5N}$



XIII, SIGN OF $\Delta^{CDCl_3}_{C_6H_6}$

The corresponding correlation for $\Delta^{CDCl_3}_{C_6H_6}$ values is illustrated pictorially in XIII. It is noteworthy that the differing positions of the approximately located reference planes for the two solvent effects (see XII and XIII) means that whereas α-axial methyl groups have a large positive $\Delta^{CDCl_3}_{C_6H_6}$ value ($\sim$0.3 p.p.m.), the corresponding $\Delta^{CCl_4}_{C_5H_5N}$ value is much smaller (see shifts for 18-H in I, III, and VIII). On the other hand, the pseudo-equatorial proton (2-H) of XI and the pseudo-equatorial methyl group (7-H) of IX have very small $\Delta^{CDCl_3}_{C_6H_6}$ values, but appreciable negative $\Delta^{CCl_4}_{C_5H_5N}$ values.

Apparently, if one is studying a molecule containing a carbonyl group which is distant from other polar functional groups, the location of protons relative to the carbonyl group is greatly facilitated by a study of solvent shifts. It is possible that by the use of additional aromatic solvents, that the molecule may be cut into a number of "slices". Indeed, the results already available for pyridine and benzene solutions indicate that a valuable new method for assisting in the structure elucidation of ketones is available.

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