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NMR SPECTRAL STUDIES XI - TITANIUM TETRACHLORIDE - INDUCED SHIFTS ON THE C-13 NMR SPECTRA OF CARBONYL COMPOUNDS[1,2]

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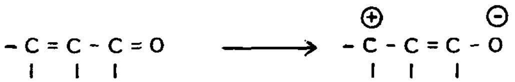
The usefulness of titanium tetrachloride as an nmr shift reagent was recently reported from this laboratory[3]. In a subsequent communication[4], we presented a comparison of the shifts induced by Eu(fod)$_3$ and TiCl$_4$ on the C-13 nmr spectra of some β-lactams and demonstrated that the latter reagent could be conveniently employed for shift studies on the C-13 nmr spectra of carbonyl compounds. In the course of subsequent studies on a number of natural products we have observed interesting shifts for conjugated carbonyl systems. These findings and spectral assignments of a few natural products are described here.

Upon addition of TiCl$_4$ to a CDCl$_3$ - solution of saturated ketones (conveniently in the nmr sample tube), a large downfield shift of the carbonyl carbon and moderate downfield shifts for the adjacent carbons are noticed in the C-13 nmr spectrum[6]; more remote carbon atoms show negligible shifts in either direction. Shifts observed for camphor and fenchone are shown in the Scheme.

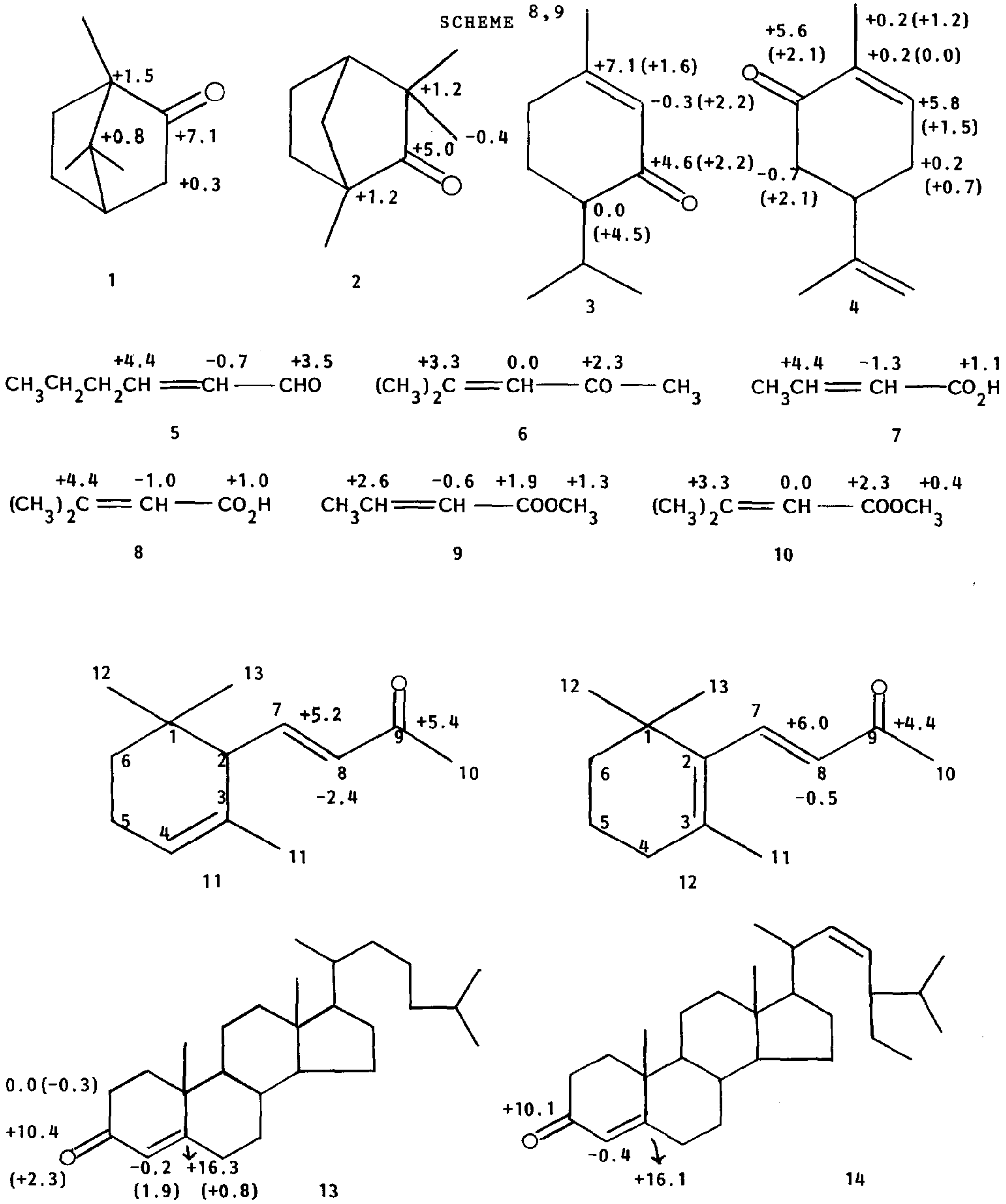
In the case of α,β-unsaturated carbonyl compounds (ketones and aldehydes), addition of TiCl$_4$ caused large downfield shifts for the carbonyl and the β-carbon atoms while the α-carbon atoms showed only very small shifts, in either direction. This could be explained by assuming that upon addition of TiCl$_4$ to solutions of conjugated ketones and aldehydes, the dipolar canonical form (I) makes more significant contribution; consequently a change of distribution of electron density occurs to a great extent at the carbonyl and β-carbon atoms and to a limited extent at the α-carbon:



$$-\underset{|}{C}=\underset{|}{C}-\underset{|}{C}=O \longrightarrow -\overset{\oplus}{\underset{|}{C}}-\underset{|}{C}=\underset{|}{C}-\overset{\ominus}{O}$$

(I)

SCHEME ^{8,9}



1: Camphor; 2: Fenchone; 3: Piperitone; 4: Carvone; 5: 2-Hexenal; 6: Mesityl oxide; 7: Crotonic acid; 8: 2,2-Dimethylacrylic acid; 9: Methyl crotonate; 10: Methyl 2,2-dimethylacrylate; 11: α-Ionone; 12: β-Ionone; 13: 4-Cholesten-3-one; 14: 4,22-Stigmastadien-3-one.

Even α,β-unsaturated acids and esters show large downfield shifts for the β-carbons although the magnitude of the shifts of the carbonyl carbon is considerably reduced probably due to possible chemical reaction of $TiCl_4$ in the case of carboxylic acids and complexing of $TiCl_4$ with the carbonyl as well as alkoxyl group in the case of esters. Shifts observed for a variety of compounds like α, β-unsaturated aldehyde, ketones, acids and esters are given in the Scheme; for the sake of comparison, shifts induced by $Eu(fod)_3$ are also included for three such compounds (piperitone, carvone and 4-cholesten-3-one). It may be noted that $TiCl_4$-induced shifts are larger in magnitude and more diagnostic for the β-carbon atoms. However, in the case of α- and β-ionones, large downfield $TiCl_4$-induced shifts were observed for the α-carbon atoms while smaller upfield shifts were noticed for the β-carbons, on the assumption that the original C-13 chemical shift assignments made by Roberts et al.[5] were correct. That the extended conjugation in these compounds did not materially alter their behaviour towards $TiCl_4$ was proved by the fact that the γ- and δ-carbon atoms showed negligible shift. We therefore reinvestigated the earlier C-13 chemical shift assignments[5] for the C_7 and C_8 of these compounds.

In the proton nmr spectra[7] of α- and β-ionones it was noticed that the C_7 and C_8 protons appeared respectively at 6.60δ and 6.06δ in α-ionone and at 7.28δ and 6.11δ in β-ionone. Single-frequency proton decoupled C-13 nmr spectra of α-ionone showed that upon irradiation of proton frequency at 6.60δ, the signal at 147.8δ was an intensified singlet signal showing it to be due to C_7; irradiation of proton frequency at 6.06δ sharpened and intensified the resonance at 133.08δ proving it to be due to C_8. Similarly, single-frequency proton decoupled C-13 nmr spectra of β-ionone showed that the signals at 142.0δ and 132.4δ corresponded to the C_7 and C_8 carbon atoms respectively. These assignments, which are the reverse of those made by Roberts et al.[5], are in agreement with the predictions made on the basis of $TiCl_4$-induced shifts observed for these compounds.

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REFERENCES

1. For part X, see A.K. Bose, M. Sugiura and Srinivasan, *Tetrahedron Letters,* 000 (1975); (in press); for Part IX, see Ref. 4.
2. Presented partly at the IUPAC Meeting on Natural Products, Ottawa, Canada, June 26-27, 1974.
3. A.K. Bose, P.R. Srinivasan, and G. Trainor, *J. Amer. Chem. Soc., 96,* 3670 (1974).
4. A.K. Bose and P.R. Srinivasan, *J. Magnetic Resonance, 15,* 592 (1974).
5. M. Jautelat, J.B. Grutzner, and J.D. Roberts, *Proc. of National Academy of Sciences (USA), 65,* 288 (1970).
6. C-13 nmr spectra were recorded by Pulse Fourier Transform technique on a Bruker HX-90 NMR Spectrometer employing an internal ^{2}H lock with TMS as internal reference.
7. NMR Spectra Catalog, Varian Associates, U.S.A., 1963,Vol. 2.
8. Shifts (in ppm) upon addition of 25% by weight $TiCl_4$; values in parenthesis are shifts upon addition of 25% by weight $Eu(fod)_3$. Positive numbers denote shift to lower magnetic field; shifts of 0.2 ppm or less have been omitted.
9. C-13 chemical shifts for compounds listed here are to be found in "C-13 NMR Spectroscopy", J.B. Stothers, Academic Press, N.Y., (1972).