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## Note

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# Anomalous α-effects, due to esterification, in $^{13}$C-n.m.r. spectra of derivatives of D-mannitol

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Esterification shifts in carbon resonances have been investigated extensively. In general, it is admitted that, on acylation, a carbinyl carbon (α-C) is somewhat deshielded, whereas a β-carbon resonance is displaced upfield[1].

In $^{13}$C-n.m.r. spectroscopy, the effects on chemical shifts caused by acetylation have frequently been applied to $^{13}$C signal-assignments in natural-products chemistry[2]. However, the acetylation shift-effects for sugar moieties are not very regular, varying from deshielding by a few p.p.m. to increased shielding by a similar amount[3–5].

According to Terui *et al.*[6], deshielding effects on α-carbon chemical-shifts by (methoxycarbonyl)ation and methanesulfonylation of simple alcohols are about two, and four, times as strong as those produced by acetylation, although the effects on β-carbon shifts are almost equal. The authors expressed the opinion that benzoylation and *p*-toluenesulfonylation shifts are very similar to the aforementioned acylation shifts, but no data were reported.

On the other hand, Ball and co-workers[7] reported that, on benzoylation of methyl 3,6-anhydro-α-D-glucopyranoside to afford methyl 3,6-anhydro-2,4-di-*O*-benzoyl-α-D-glucopyranoside, the $^{13}$C chemical-shift of C-2 is shifted 2.3 p.p.m. upfield, and that of C-4, 0.7 p.p.m. upfield, in relation to those of the parent compound. They also found that acetylation and benzoylation of O-2, and O-2 and O-4, of 3,6:1′,4′:3′,6′-trianhydrosucrose cause the same pattern in the $^{13}$C-n.m.r. spectra, namely, a small increase in shielding of the α-carbons.

In contrast to these findings, di-*p*-toluenesulfonylation of the compound causes a downfield shift of 2.7 p.p.m. for the C-2 resonance, and a downfield shift of 0.8 p.p.m. for the C-4 resonance. Also, a deshielding effect, due to *p*-toluenesulfonylation, of ~7 p.p.m. was found in the α-carbon resonances of 1,5-anhydro-3,4-di-*O*-*p*-tolylsulfonyl-D-mannitol[8]. It therefore seems that regularities of esterifi-

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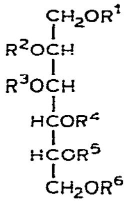

1 $R^1 = R^2 = R^5 = R^6 = H$; $R^3 = R^4 = Ts$
2 $R^2 = R^5 = H$; $R^1 = R^3 = R^4 = R^6 = Ts$
3 $R^2 = R^5 = Ac$; $R^1 = R^3 = R^4 = R^6 = Ts$
4 $R^1 = R^2 = R^3 = R^4 = R^5 = R^6 = Ts$
5 $R^1 = R^2 = R^5 = R^6 = Ac$, $R^3 = R^4 = Ts$
6 $R^1 = R^2 = R^5 = R^6 = Bz$; $R^3 = R^4 = Ts$
7 $R^1 = R^6 = Bz$; $R^2 = R^5 = H$; $R^3 = R^4 = Ts$

Ts = $SO_2C_6H_4Me$-*p*, Bz = PhCO, Ac = MeCO

TABLE I

$^{13}$C CHEMICAL-SHIFT DATA (IN p.p.m.)

| *Carbon atoms* | *Compounds* 1 | 2 | 3 | 4 | 5 | 6 | 7 | D-*Mannitol* |
|---|---|---|---|---|---|---|---|---|
| C-1,6 | 75.09 | 72.36 | 66.92 | 66.89 | 61.61 | 62.39 | 66.60 | 76.3 |
| C-2,5 | 76.08 | 67.53 | 70.03 | 77.55 | 70.50 | 71.36 | 68.06 | 75.3 |
| C-3,4 | 88.39 | 77.63 | 75.89 | 77.70 | 76.27 | 76.45 | 78.62 | 73.6 |
| $C_6H_4$-$CH_3$ | 21.00 | 21.30 | 21.10 | 21.39 | 21.28 | 21.37 | 21.28 | |
| CO-$CH_3$ | | | 20.51 | | 20.69, 20.42 | | | |

cation shifts cannot be claimed for α-carbon signals, although the effects on β-carbon resonances are quite consistent.

In relation to our work on sulfonyl derivatives of alditols[9], the $^{13}$C-n.m.r. spectra of derivatives (**1**–**7**) of D-mannitol were studied, and Table I summarizes our results.

Because of the group configuration of D-mannitol, the C-1,6 and C-2,5, as well as the C-3,4, atom pairs have identical chemical-shifts for the derivatives studied. Consequently, only three lines appear in the $^{13}$C-n.m.r. spectra in the carbohydrate zone. The resonances of C-1,6 were assigned from the off-resonance decoupled spectra.

For compound **1**, assignment of the signal at 75.09 p.p.m. to C-1 and C-6 is straightforward. Of the remaining two resonances, the signal at higher field is assigned to C-2 and C-5, considering that they undergo a β-shift, which has always been found to be a shielding effect. This implies that the deshielding effect on C-3 and C-4 due to *p*-toluenesulfonylation is quite remarkable (~15 p.p.m.), in accordance with the findings of Terui and co-workers[6].

The effect of acylation on the primary alcoholic groups of 3,4-di-*O*-*p*-tolylsulfonyl-D-mannitol, was, however, quite unexpected. *p*-Toluenesulfonylation, as well as benzoylation, respectively shift the C-1,6 resonances by 3.73 and 9.49 p.p.m. upfield. The magnitude of the β-effect on the same carbon atoms is unusually large: acetylation of compound **2** gives **3**, with its C-1,6 resonance shifted 5.44 p.p.m. upfield. The effect is very similar if **2** is *p*-toluenesulfonylated, giving **4** ($\Delta\delta$ −5.47).

The combination of α- and β-effects on C-1,6 is more striking when **1** is fully acetylated, giving **5** (Δδ −13.48), or is benzoylated, giving **6** (Δδ −12.70).

Esterification by acetyl groups produces the largest effect on the chemical shifts of α- and β-carbon atoms in this series. Thus, the "anomalous" behavior found in this work cannot be explained simply by a steric effect.

## EXPERIMENTAL

$^{13}$C-N.m.r. spectra were recorded with a CFT-20 spectrometer, operating in the deuterio-lock mode, for solutions (10–15%) of the compounds in pyridine-$d_5$. Chemical shifts are given on the δ scale, relative to that of internal tetramethylsilane. The spectra were recorded both with complete proton-decoupling and with off-resonance decoupling. Resonances for D-mannitol ($D_2O$) were taken from the literature[10].

Compound **1**, **4**, **5**, and **6** were synthesized according to the literature[11,12]. Syntheses of compounds **2**, **3**, and **7** were conducted as described[9,13].

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