Carbohydrate Research, 105 (1982) 258–265
Elsevier Scientific Publishing Company, Amsterdam – Printed in The Netherlands

Note

N.m.r. spectra of methyl *O*-methyl-α-L-rhamnopyranosides in their complexes with tin(II) chloride

JURAJ ALFÖLDI, RUDOLF TOMAN, AND CYRIL PECIAR
Institute of Chemistry, Slovak Academy of Sciences, 809 33 Bratislava, Dúbravská cesta (Czechoslovakia)

(Received March 13th, 1981; accepted for publication in revised form, September 12th, 1981)

Recent years have witnessed an ever-increasing application of organotin compounds in carbohydrate chemistry[1,2] especially in connection with the search for new and selective reactions that may be applied to predetermined sugar hydroxyl groups. Di- and tri-butylstannyl ethers of carbohydrates[3–7] and nucleosides[8,9] have been found useful as intermediates in such reactions, as the organotin groups serve to activate the hydroxyl groups rather than to protect them. In particular, 2,3-*O*-(dialkylstannylene)glycopyranosides and 2′,3′-*O*-(dialkylstannylene)nucleosides have been synthesised and characterised by spectroscopic methods, from which the occurrence of the 2-stanna-1,3-dioxolane ring has been inferred for these compounds[8,10–12].

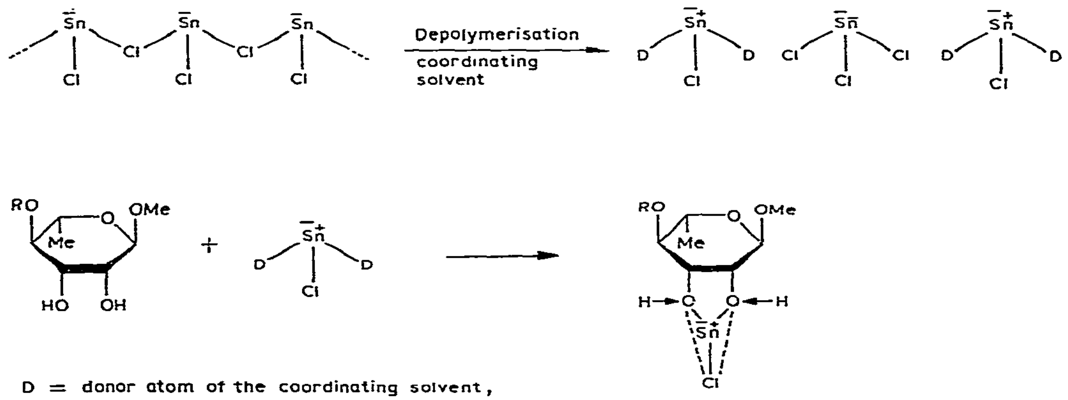
Tin(II) chloride has also been utilised frequently for the selective alkylation of suitable diol groups in nucleosides[13,14] and carbohydrates[15,16], but it is not known for certain how tin is involved in the catalysis of the alkylation reactions, although a tin(II)–sugar intermediate has been proposed[1]. More recently, however, activation of the 2,3-diol of a ribofuranose residue *via* a 2-stanna-1,3-dioxolane structure has been proposed in the *O*-methylation of a nucleoside by diazomethane in the presence of tin(II) chloride[17].

Our detailed studies on regioselective benzylation[18] and alkylation[19] of methyl α-L-rhamnopyranoside (**1**) and its derivatives as catalysed by tin(II) chloride have provided new information on the mode of complexation of tin(II) chloride with methyl glycosides. By this hypothesis, two molecules of solvent, coordinated weakly to a tin(II) atom in *cis*-disposition, may be displaced by two favourably disposed, vicinal, hydroxyl groups, preferentially in the C-2 and C-3 positions of the sugar moiety (Scheme 1).

Thus, the formation of a disubstituted complex between a suitable diol group and the catalyst is a requirement for the aforementioned reactions. A similar conclusion has also been made by Chittenden[16]. Therefore, it seemed of interest to monitor this complexation by ^{1}H-, ^{13}C-, and ^{119}Sn-n.m.r. techniques in order to complement and, where possible, to broaden the present knowledge of this subject.

The ^{1}H-n.m.r. data for **1** and its complex with tin(II) chloride are given in Table I. The ^{1}H spectrum of **1** in acetone-d_6 has been assigned previously[15]. The chemical shifts and coupling constants observed for **1** are typical for the $^1C_4$ conformation and are in good agreement with the theoretical values of coupling constants given in the work of Altona *et al.*[20]. In addition to the signals assigned to the tin(II) chloride–methyl glycoside complex, the ^{1}H spectrum of an equimolar solution of **1** and tin(II) chloride also revealed signals of the parent compound **1**. Integration of the H-1 signals of both compound **1** and also the complex revealed that the complex comprised ~70% of the equilibrium mixture. When compared with **1**, all proton signals of the complex appeared at lower field. The greatest downfield shift (1.62 p.p.m.) of the OH groups may be attributed to O→Sn coordination, which might lead to deshielding of the respective oxygen atoms and a consequent shift to low field. It is well known[20] that the distortion of a pyranose ring by 1° of the torsion angle is characterised by a 5–6% increase of the coupling constant. The $J_{a,e}$ and $J_{e,e}$ values are substantially more sensitive to this change than $J_{a,a}$. With reference to these findings, we may assume that the changes of $J_{1,2}$ and especially $J_{2,3}$ after complexation of **1** with tin(II) chloride, indicate a local C-2–C-3 flattening of the pyranose ring by ~10°, induced by the tendency of the intermediate five-membered ring, involving a tin(II) atom, to approach coplanarity (Scheme 1). Nevertheless, the observed distortions are much smaller than those encountered for example, in complexation of aldoses with ammonium molybdate, where the original $^4C_1$ conformation is reinversed[21] to $^1S_5$ or $^5S_1$.

The ^{1}H-n.m.r. data obtained were supplemented by ^{13}C-n.m.r. measurements. As in the preceding case, the ^{13}C spectra of solutions containing various proportions of tin(II) chloride and **1** revealed both the signals of the complex and those of the parent compound **1** (Fig. 1). It was found from the ratio of the integrated signal intensities of the anomeric carbon atoms of the fully relaxed spectra that the highest



D = donor atom of the coordinating solvent,
for instance of acetone

R = H or Me

Scheme 1

TABLE I

^{1}H-N.M.R. DATA FOR **1** AND ITS COMPLEX WITH TIN(II) CHLORIDE

Compound	*Chemical shifts*[a] *(δ) p.p.m.*								*Coupling constants (Hz)*				
	H-1	*H-2*	*H-3*	*H-4*	*H-5*	*Me*	*OMe*	*OH*	$J_{1,2}$	$J_{2,3}$	$J_{3,4}$	$J_{4,5}$	J_{5,CH_3}
1	4.58d	3.81dd	3.30	—	3.75m	1.24d	3.31s	4.13bs	1.5	3.0	[c]	[c]	5.6
Complex[b]	4.84d	4.04t	3.95	—	4.0m	1.26d	3.39s	5.75bs	~0.6	5.5	[c]	[c]	5.6

[a] Key: bs, broad singlet; d, doublet; dd, doublet of doublets; m, multiplet; s, singlet; and t, triplet. [b] Equimolar solution of **1** and tin(II) chloride. [c] A first-order spectrum was not observed.

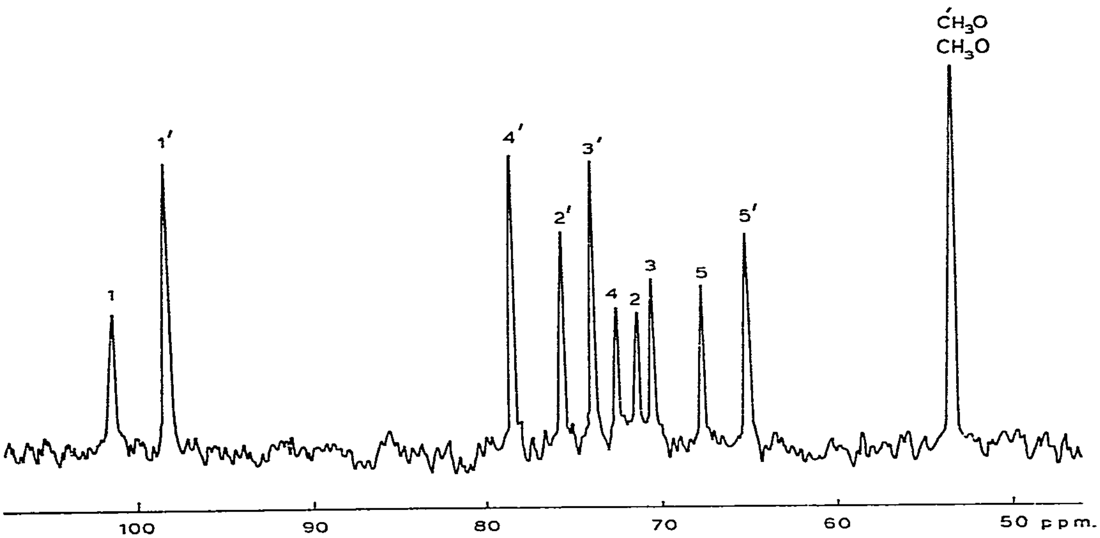


Fig. 1. ^{13}C-F.-t.n.m.r. spectrum, showing the ring-carbon region, of **1** and its complex with tin(II) chloride in equilibrium. Numbers indicate the signals assigned to the respective carbon atoms. Those primed refer to the complex.

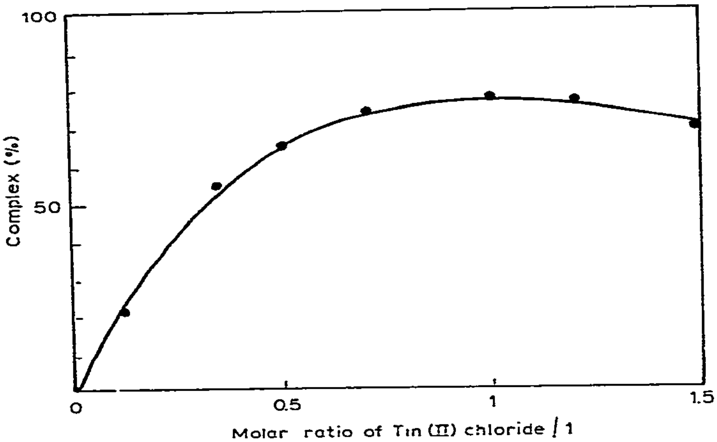


Fig. 2. Dependence of complex formation on the molar ratio of tin(II) chloride to **1**.

content of the complex (~78%) was present in a solution containing an equimolar amount of tin(II) chloride and **1** (Fig. 2).

In Table II, the ^{13}C chemical shifts of **1** and methyl 2-, 3-, and 4-*O*-methyl-α-L-rhamnopyranosides (**2**, **3**, and **4**), before and after addition of an equimolar amount of tin(II) chloride, are listed. The signals for compounds **1**–**4** were assigned on the basis of data published previously[22]. Downfield shifts of the original C-2, C-3, and C-4 signals are apparent for the formation of the complex: 3.90, 3.09, and 5.69 p.p.m. for compound **1** and 6.88, 4.72, and 0.49 for compound **4**, respectively. These shifts

TABLE II

^{13}C-N.M.R. DATA FOR **1**–**4** AND THEIR COMPLEXES WITH TIN(II) CHLORIDE

Compound	*Chemical shifts (δ) p.p.m.*									
	C-1	*C-2*	*C-3*	*C-4*	*C-5*	*Me*	*MeO-1*	*MeO-2*	*MeO-3*	*MeO-4*
1	101.84	72.93	71.95	73.90	68.87	17.86	54.74			
Complex[a]	98.92	76.83	75.04	79.59	66.43	17.86	54.74			
2[b]	98.50	81.21	72.64	74.07	68.87	18.06	54.84	58.60		
3[b]	101.94	68.98	82.13	72.23	67.85	18.18	54.86		57.13	
4	101.34	72.30	72.03	83.81	67.87	18.27	54.82			59.53
Complex[c]	98.84	79.18	76.75	84.30	64.97	18.02	54.82			59.53

[a]Equimolar solutions of **1** with tin(II) chloride. [b]Chemical shifts remained unchanged after addition of an equimolar amount of tin(II) chloride. [c]As [a], but with **4** instead of **1**.

are most probably due to coordination of **1** and **4** to a tin(II) atom whereby the *cis*-disposed OH groups act as suitable electron-pair donors for two empty p orbitals[23]. Similar downfield shifts of signals have been observed in complexation of saccharides with other acceptors[24,25]. Significant effects were also observed at the carbon atoms adjacent to the site of complexation. For example, the shift of 5.69 p.p.m. for the C-4 signal in **1** contrasts with that of −2.92 p.p.m. for C-1 which, among other things, might be influenced by the anomeric effect and the β-effect induced by complexation at HO-2 and HO-3. With **4**, there is an insignificant shift (0.49 p.p.m.) for C-4, which presumably results from a complex shielding-effect in the methyl glycoside. It should be noted that the complexation with **4**, proceeded even more readily than with **1**, as the spectrum of the former revealed $\sim$90% of the complex in solution.

The signals observed for compounds **2** and **3** were consistent with those previously published[22], even in the presence of tin(II) chloride in the solute, thereby indicating that the complexation did not take place. For compound **3**, this result is in agreement with the aforementioned results, which have shown that a prerequisite for effective complexation is the presence of two vicinal *cis*-hydroxyl groups. The complex is then preferentially formed between HO-2 and HO-3, whereas the complexation between HO-3 and HO-4 appears sterically less favourable and is of minor importance[18,19]. This interpretation could be a plausible explanation of the fact that no changes occurred in the spectrum of **2** under the experimental conditions given.

In neither of the spectra recorded could ^{119}Sn satellites be observed. Their appearance has mainly been used as an essential aid for assignment of the position of substitution in di- and tri-butylstannyl ethers in carbohydrates[25]. This lack of satellites is probably because of an entirely different mechanism and character of complexation of **1** and **4** with tin(II) chloride, whereby only an intermediate complex resulting in activation of the respective OH groups is assumed.

Unfortunately, no conclusions can be drawn as to the site of complexation in **1** from measurements of relaxation times (T_1) of C-1–C-5 (Table III). The T_1

TABLE III

SPIN–LATTICE RELAXATION TIMES (T_1) FOR THE RING-CARBON ATOMS OF **1** AND ITS COMPLEX WITH TIN(II) CHLORIDE

Compound	*T_1[a] values (s)*				
	C-1	*C-2*	*C-3*	*C-4*	*C-5*
1	1.66	1.33	1.65	1.46	1.68
Complex[b]	2.31	2.48	2.36	2.49	2.77

[a]Values were measured in an equilibrium mixture of **1** and the complex. [b]Molar ratio of **1** and tin(II) chloride was 3:1.

values are, on the average, 1.4–1.9 times higher for the complex than those of the original **1**. This fact is rather surprising and we have no explanation for it thus far.

It is generally accepted[25,26] that the chemical shift of a ^{119}Sn signal in a complex depends among other things, on the changes in electronegativity around the tin atom, and the stability, composition, and spatial arrangement of the individual complexes. The observed displacement of the ^{119}Sn signal from its original value [—191.10, (A)] to —225.64 p.p.m. in the complex (B), indicates complexation between tin(II) chloride and **1** (Fig. 3). However, insufficient data are available to indicate a relationship between the chemical shift and position of coordination at the sugar residue. In preliminary measurements of the ^{119}Sn spectra, we have found a remarkable influence of the solvents used in the complexation reaction on the chemi-

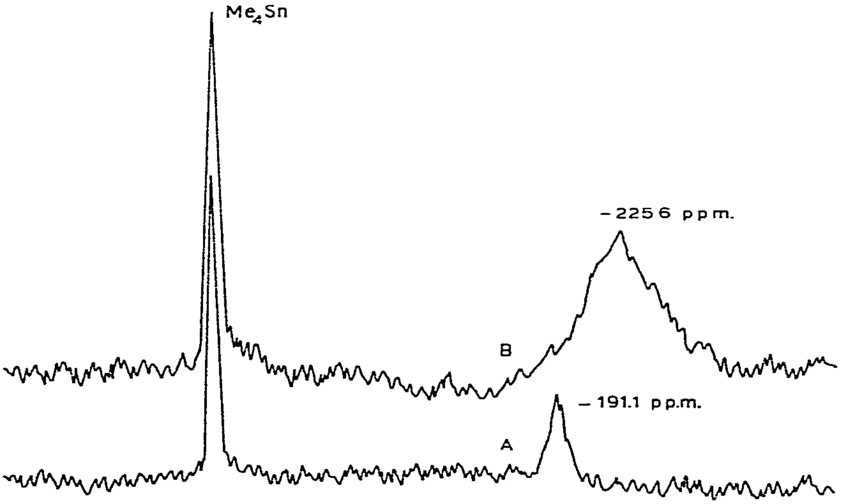


Fig. 3. ^{119}Sn-N.m.r. spectra of tin(II) chloride (A) and of an equimolar amount of tin(II) chloride and **1** (B) in acetone-d_6.

cal shifts of ^{119}Sn. Investigation of the latter effect, as well as the stability of complexes in various solvents, will be the subject of future studies.

In conclusion, the potential value of the multinuclear approach as a complementary method for elucidation of the mechanism of complexation of tin(II) chloride with **1** and its methyl ethers **2**–**4** has been demonstrated. Because of the complex nature of the effects influencing the chemical shifts, investigations on suitable model compounds coordinating with tin(II) chloride in various solvents are in progress in order to obtain more-detailed information on the problems discussed in this paper.

EXPERIMENTAL

N.m.r. spectra. — All n.m.r. measurements were performed on solutions in acetone-d_6 at 22° after ~3 h, when an equilibrium between the methyl glycoside and its complex with tin(II) chloride had been achieved. The ^{1}H spectra were recorded at 80 MHz (internal Me_4Si) with a CW Tesla BS-487-B spectrometer. Proton-signal assignments were made by the INDOR technique. The ^{13}C spectra were measured with the Fourier-transform (F.t.) n.m.r. spectrometers JEOL FX-60 and FX-100 by using noise, off-resonance, and selective decoupling modes. Chemical shifts are referenced to internal Me_4Si, the repetition time was 3 s, the pulse width 4 μs (45° flip angle), and a 2500-Hz sweep width (4k real data points) was used. The T_1 values were recorded with the same apparatus, using the inversion-recovery technique. The pulse delay was 20 s. The ^{119}Sn spectra were recorded with a multi-nuclear F.t.-n.m.r. spectrometer (JEOL FX-100) with Me_4Si as the external standard. Recording of ^{119}Sn and some ^{13}C spectra was performed under conditions supressing the nuclear Overhauser effect.

REFERENCES

1 P. J. Smith, *Chem. Ind. (London)*, (1976) 1025–1029.
2 T. Ogawa, *Kagaku To Seibutsu*, 14 (1976) 654–657.
3 M. A. Nashed and L. Anderson, *Tetrahedron Lett.*, (1976) 3503–3506.
4 V. K. Handa, C. F. Piskorz, J. J. Barlow, and K. L. Matta, *Carbohydr. Res.*, 74 (1979) c5–c7.
5 S. S. Rana, J. J. Barlow, and K. L. Matta, *Carbohydr. Res.*, 85 (1980) 313–317.
6 T. Ogawa and M. Matsui, *Carbohydr. Res.*, 56 (1977) c1–c6; 62 (1978) c1–c4.
7 T. Ogawa, K. Katano, and M. Matsui, *Carbohydr. Res.*, 64 (1978) c3–c9.
8 D. Wagner, J. P. H. Verheyden, and J. G. Moffatt, *J. Org. Chem.*, 39 (1974) 24–30.
9 M. Ikehara and T. Maruyama, *Tetrahedron*, 31 (1975) 1369–1372.
10 R. M. Munavu and H. H. Szmant, *J. Org. Chem.*, 41 (1976) 1832–1836.
11 L. Pellerito, G. Ruisi, R. Barbieri, and M. T. Lo Giudice, *Inorg. Chim. Acta*, 21 (1977) L33–L35.
12 S. David, C. Pascard-Billy, and M. Cesario, *Nouv. J. Chim.*, 3 (1979) 63–68.
13 L. F. Christensen and A. D. Broom, *J. Org. Chem.*, 37 (1972) 3398–3401.
14 M. J. Robins, A. S. K. Lee, and F. A. Norris, *Carbohydr. Res.*, 41 (1975) 304–307, and references cited therein.
15 R. Toman, Š. Karácsonyi, and R. Palovčík, *Carbohydr. Res.*, 56 (1977) 191–194.
16 G. J. F. Chittenden, *Carbohydr. Res.*, 91 (1981) 85–88, and references cited therein.
17 L. Dudycz, A. Kotlicki, and D. Shugar, *Carbohydr. Res.*, 91 (1981) 31–37.
18 R. Toman, J. Rosík, and M. Zikmund, *Carbohydr. Res.*, in press.
19 R. Toman, F. Janeček, I. Tvaroška, and M. Zikmund, *Carbohydr. Res.*, submitted.

20 C. ALTONA AND C. A. G. HAASNOOT, *Org. Magn. Reson.*, 13 (1980) 417–429.

21 J. ALFÖLDI, L. PETRUŠ, AND V. BÍLIK, *Collect. Czech. Chem. Commun.*, 43 (1978) 1476–1480.

22 J. ALFÖLDI, P. KOČIŠ, AND R. TOMAN, *Chem. Zvesti*, 34 (1980) 514–517.

23 J. D. DONALDSON, *Progr. Inorg. Chem.*, 8 (1967) 287–356.

24 J. ALFÖLDI, V. BILÍK, AND L. PETRUŠ, *Collect. Czech. Chem. Commun.*, 45 (1980) 123–126.

25 S. J. BLUNDEN, P. J. SMITH, P. J. BEYNON, AND D. G. GILLIES, *Carbohydr. Res.*, 88 (1981) 9–18.

26 R. K. HARRIS AND B. E. MANN, *NMR and the Periodic Table*, Academic Press, London, 1978, pp. 343–349.