Carbohydrate Research, 26 (1973) 271–273
© Elsevier Scientific Publishing Company, Amsterdam – Printed in Belgium

Preliminary communication

Shifts induced by lanthanide ions in the n.m.r. spectra of carbohydrates in aqueous solution

S.J. ANGYAL
School of Chemistry, The University of New South Wales, Kensington, N.S.W. 2033 (Australia)

(Received December 11th, 1972; accepted for publication, January 2nd, 1973)

In a few instances, use has been made of paramagnetic shift reagents, such as Eu(dpm)$_3$, for the elucidation of the n.m.r. spectra of carbohydrate derivatives[1–4]. The spectra of these compounds were obtained for solutions in chloroform or carbon tetrachloride, but free sugars and glycosides are not soluble in these solvents and the shift reagents are unsuitable for work in aqueous solutions. It is now reported that salts of the lanthanides (europium and praseodymium chlorides and nitrates) cause differential shifts in the spectra of polyols in aqueous solution, provided that the polyols possess a steric arrangement suitable for complex formation, such as an axial–equatorial–axial sequence of oxygen atoms on a six-membered ring[5]. In the absence of such a steric arrangement, substantial changes were not observed in the n.m.r. spectra.

So far, there are very few described examples[6–9] of the use of lanthanide ions in aqueous solution for the purpose of modifying n.m.r. spectra. Hart *et al.*[7], who studied the spectra of hydroxy- and amino-acids, noted that the europium ion shifted the signals upfield, and the praseodymium ion downfield, that is, in a direction opposite to that caused by the respective complex shift-reagents in organic solvents.

The n.m.r. spectrum (Fig. 1) of methyl β-D-hamamelopyranoside[10] (2-*C*-hydroxymethyl-β-D-ribopyranoside) serves as a good example. By analogy with other examples[5], complexing with the metal ion is assumed to occur at O-2, O-3, and O-4. In the n.m.r. spectrum of methyl β-D-hamamelopyranoside (25 mg in 0.4 ml of deuterium oxide), only the anomeric proton and the methoxyl group appear as distinct signals; the signals for the other six protons overlap. Addition of 10 mg (0.22 molar equivalent) of $PrCl_3 \cdot 6H_2O$, as a 20% solution, produces a spectrum (Fig. 1) in which every signal can be identified and the coupling constants can be determined. The signals of the two protons of the hydroxymethyl group coincide; however, on addition of further amounts of praseodymium chloride, the two signals separate, and extrapolation back to the original spectrum allows their detection there as an AB pattern (Fig. 1). The two signals shift to a different extent and at one stage they cross over.

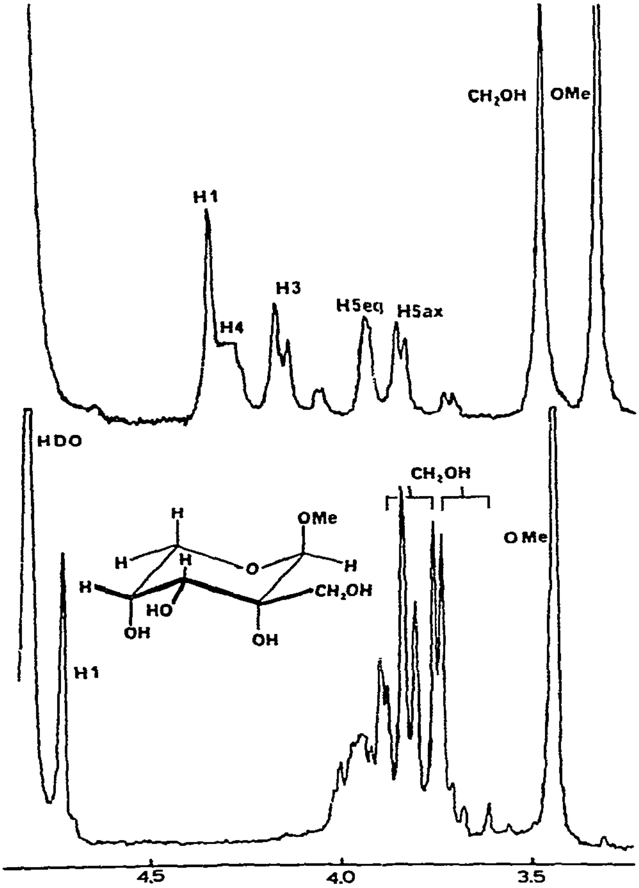

Fig. 1. The 100-MHz n.m.r. spectrum of methyl β-D-hamamelopyranoside in deuterium oxide at 30°. The upper trace shows the spectrum after the addition of 0.22 equivalent of praseodymium chloride. The shifts are measured from the signal of DSS.

Extrapolation gives the following n.m.r. data: δ 3.415 (OMe), 3.71, 3.735 (CH_2OH), 3.76 (H-5*ax*), 3.91 (H-5*eq*), ~3.94 (H-4), 3.80 (H-3), 4.715 (H-1); $J_{3,4}$ 3.5, $J_{4,5eq}$ 1.5, $J_{4,5ax}$ 2.2, $J_{5,5}$ −12.5, J_{CH_2OH} −12 Hz. The extent of the change in chemical shifts, after 0.67 equivalent of praseodymium salt has been added, is H-1 −0.90, H-3 0.89, H-4 0.89, H-5*eq* 0.16, H-5*ax* 0.09, CH_2OH −0.60, −0.65, and OMe −0.23 p.p.m (upfield shifts are negative).

The spectrum of methyl β-D-hamameloside can be elucidated also by the addition of europium nitrate; however, in this case, several additions are necessary before all the signals can be identified. During their gradual changes, several signals coincide at various stages. The extent of change in chemical shifts, after 0.67 equivalent of europium nitrate has been added, is H-1 0.57, H-3 −2.14, H-4 −0.36, H-5*eq* −0.59, H-5*ax* 0.07, CH_2OH 0.23, 0.25, and OMe 0.11 p.p.m.

It is noteworthy that some of the signals shift upfield and others shift downfield; the direction and the magnitude of the changes do not seem to be related to the equation $\Delta\delta = K(3\cos^2 \phi - 1)/r^3$ usually employed for the calculation of pseudocontact shifts[11]. Williams and his co-workers[6] have noted a similar instance: on addition of europium ions to an aqueous solution of methyl 2-acetamido-2-deoxy-β-D-glucopyranoside, the acetamido and glycosidic methyl-signals shift in opposite directions. This seems to be generally true for lanthanide ion-induced shifts in aqueous solution; in none of the cases investigated have we observed a shifting of all signals in the same direction. The direction and magnitude of the lanthanide ion-induced shifts are not understood at present but are being further studied.

ACKNOWLEDGEMENTS

This work was supported by a grant from the Australian Research Grant Committee. The author thanks Professor H. Paulsen for a gift of methyl β-D-hamamelopyranoside, and Miss Hildegard Hufnagel for running the n.m.r. spectra.

REFERENCES

1 D. Horton and J.K. Thomson, *Chem. Commun.*, (1971) 1389.
2 I. Armitage and L.D. Hall, *Can. J. Chem.*, 49 (1971) 2770.
3 J. Yoshimura, K. Kobayashi, K. Sato, and M. Funabashi, *Bull. Chem. Soc. Japan*, 25 (1972) 1806.
4 R.F. Butterworth, A.G. Pernet, and S. Hanessian, *Can. J. Chem.*, 49 (1971) 981.
5 S.J. Angyal and K.P. Davies, *Chem. Commun.*, (1971) 500.
6 K.G. Morallee, E. Nieboer, F.J.C. Rossotti, R.J.P. Williams, and A.V. Xavier, *Chem. Commun.*, (1970) 1132.
7 F.A. Hart, G.P. Moss, and M.L. Staniforth, *Tetrahedron Lett.*, (1971) 3389.
8 C. Reyes-Zamora and C.S. Tsai, *Chem. Commun.*, (1971) 1047.
9 J.K.M. Sanders, S.W. Hanson, and D.H. Williams, *J. Amer. Chem. Soc.*, 94 (1972) 5325.
10 H. Paulsen, V. Sinnwell, and P. Stadler, *Chem. Ber.*, 105 (1972) 1978.
11 H.M. McConnell and R.E. Robertson, *J. Chem. Phys.*, 29 (1958) 1361.