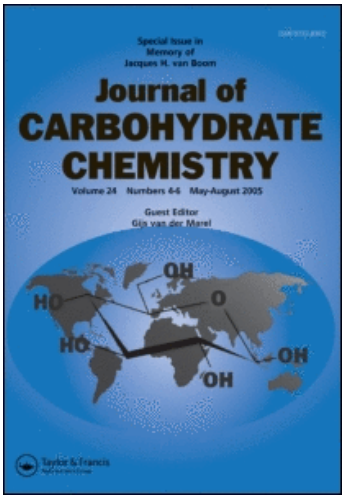


Journal of Carbohydrate Chemistry

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713617200

^{1}H NMR Study of Methyl O-Acetyl-α-and-β-D-Xylopyranosides Conformational Studies and Non Additivity of ^{1}H-Shift Increments

André De Bruyn[a]; Marc Anteunis[a]; Ronan van Rijsbergen[a]; Marc Claeyssens[b]; Pavol Kováč[cd]
[a] Laboratorium vr. Organische Scheikunde, GENT, Belgium [b] Laboratorium vr. Biochemie, GENT, Belgium [c] Institute of Chemistry, Slovak Academy of Sciences, Bratislava, Czechoslovakia [d] Bachem Inc., Torrance, California, U.S.A.

To cite this Article De Bruyn, André , Anteunis, Marc , van Rijsbergen, Ronan , Claeyssens, Marc and Kováč, Pavol(1982) '^{1}H NMR Study of Methyl O-Acetyl-α-and-β-D-Xylopyranosides Conformational Studies and Non Additivity of ^{1}H-Shift Increments', Journal of Carbohydrate Chemistry, 1: 3, 301 — 309
To link to this Article: DOI: 10.1080/07328308208085102
URL: http://dx.doi.org/10.1080/07328308208085102

J. CARBOHYDRATE CHEMISTRY, 1(3), 301-309 (1982-83)

^{1}H NMR STUDY OF METHYL O-ACETYL-α- AND -β-D-XYLOPYRANOSIDES CONFORMATIONAL STUDIES AND NON ADDITIVITY OF ^{1}H-SHIFT INCREMENTS

André De Bruyn,[a] Marc Anteunis,[a] Ronan van Rijsbergen,[a]
Marc Claeyssens,[b] and Pavol Kováč[c+]

[a] Laboratorium vr. Organische Scheikunde, Rijksuniversiteit-Gent, Krijgslaan 281 (S-4bis), B-9000 GENT (Belgium).

[b] Laboratorium vr. Biochemie, Rijksuniversiteit-Gent, K.L. Ledeganckstraat 35, B-9000 GENT (Belgium)

[c] Institute of Chemistry, Slovak Academy of Sciences, 842 38 Bratislava (Czechoslovakia).

Received November 30, 1982

ABSTRACT

^{1}H NMR spectra of the complete series of fully and partially acetylated methyl α- and β-D-xylopyranosides have been studied. The α-anomers occur exclusively in $^4C_1$ chairs but the $^1C_4$ chair becomes increasingly populated in the β-forms especially when the OH-3 is not acetylated. Increments used for the prediction of the chemical shifts of ring protons are discussed and compared with the literature data. The predictability for changes in shifts upon acetylation is poor.

+ Present address: Bachem Inc., 3132 Kashiwa St., Torrance, California 90505 (U.S.A.)

INTRODUCTION

The complete series of the present mono-, di- and tri-acetylated methyl α- and β-D-xylopyranosides has been synthesized by Kováč and co-workers.[1-4] The ^{13}C NMR data for some of these compounds, together with those for some of the benzylated derivatives have been published.[1-5] The ^{13}C NMR assignments were made on the basis of increments as provided in the studies of Utille and Vottero.[6] These authors have studied the ^{13}C NMR data of some partially and fully acetylated α- and β-D-xylopyranoses. It was explicitely accepted that in all the compounds the pyranose rings occur in the $^4C_1$ conformation. In the present study it is shown that such a premise, as could be predicted by the results of Durette and Horton,[7] does not hold for the β-anomers. Recently McEwan and co-workers have investigated the ^1H and ^{13}C-NMR shifts of a series acetylated methyl α- and β-D-xylopyranosides, again without taking into consideration the conformational differences.[8] It must be pointed out that in some of these studies other solvents were used, where of course the pyranose ring can occur in another conformation. However, for the studies described here, we only talk about $CDCl_3$ solutions.

RESULTS AND DISCUSSION.

We have run the ^1H NMR spectra of the complete series of fully and partially acetylated methyl α- and β-D-xylopyranosides (1 - 14) at 360 MHz in $CDCl_3$ solution (TMS internal). The extracted parameters are listed in Table 1.
Compounds 1, 2, 3, 4 and 11 display complex spin-systems of higher order. Reported coupling constants were obtained from simulations. For the other compounds the data of first order analyses fit perfectly with the simulated spectra. Utille has reported the ^1H-NMR data of some fully and partially acetylated α- and β-D-xylopyranoses in his Ph.D. thesis.[9,10] Thus, for 1,2,3-tri-O-acetyl-α-D-xylopyranose he has reported 2.5 Hz for $^3J(4,5eq)$, 12.5 Hz for $^3J(4,5ax)$ and 12.5 Hz for $^2J(5eq,5ax)$. For 1,2,3,4-tetra-O-acetyl-

TABLE 1.

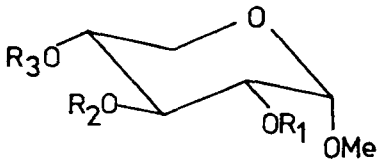
^{1}H NMR -Parameters of the Title Compounds in $CDCl_3$ Solution (TMS internal) at 360 MHz.

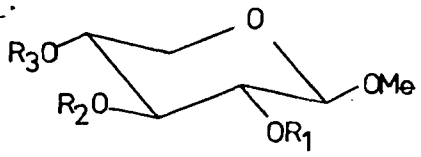
	H-1	H-2	H-3	H-4	H-5A	H-5B	OMe	OAc	$^3J(1,2)$	$^3J(2,3)$	$^3J(3,4)$	$^3J(4,5A)$	$^3J(4,5B)$	$^3J(5A,5B)$	Approx. % $^{14}C_1$
α-Series															
1	4.84	4.67	3.89	3.73	3.69	3.51	3.39	2.16	3.6	9.8	9.2	5.6	10.7	10.7	100
2	4.72	3.57	3.96	3.74	3.74	3.57	3.46	2.17	3.6	9.7	9.1	5.7	10.6	-10.6	100
3	4.74	3.57	3.84	4.79	3.74	3.48	3.42	2.10	3.6	9.7	9.1	5.8	10.6	-10.7	100
4	4.85	4.82	5.21	3.80	3.73	3.53	3.40	2.00, 2.11	3.6	9.7	9.0	5.6	10.6	-10.6	100
5	4.87	4.74	4.04	4.86	3.78	3.52	3.39	2.10, 2.16	3.6	9.8	9.0	5.8	10.5	-10.7	100
6	4.75	3.64	5.23	4.91	3.77	3.54	3.44	2.04, 2.10	3.6	9.8	9.3	5.8	10.5	-10.7	100
7	4.89	4.83	5.47	4.97	3.80	3.56	3.40	2.03(2x), 2.11	3.5	10.0	9.2	5.9	10.6	-10.6	100
β-Series															
8	4.37	4.74	3.60	3.70	4.04	3.34	3.47	2.13	6.2	7.8	7.6	4.6	8.0	-11.9	73
9	4.25	3.49	4.82	3.77	4.05	3.33	3.54	2.17	7.2	8.7	8.6	5.2	9.3	-11.6	86
10	4.33	3.49	3.73	4.84	4.10	3.38	3.52	2.12	5.9	7.4	7.4	4.4	7.3	-11.9	68
11	4.37	4.93	4.93	3.81	4.09	3.37	3.47	2.08, 2.10	7.0	8.4	8.6	5.0	8.8	-11.7	82
12	4.52	4.84	3.81	4.83	4.14	3.46	3.45	2.13, 2.14	4.8	6.4	6.2	3.9	5.9	-12.4	57
13	4.25	3.52	5.10	4.95	4.09	3.34	3.54	2.05, 2.10	7.1	8.9	8.9	5.2	9.2	-11.6	86
14	4.40	4.91	5.18	4.92	4.12	3.37	3.47	2.04, 2.05, 2.06	6.8	8.6	8.6	4.8	8.6	-11.8	77

1 R_1 = Ac, R_2 = R_3 = H
2 R_2 = Ac, R_1 = R_3 = H
3 R_3 = Ac, R_1 = R_2 = H
4 R_1 = R_2 = Ac, R_3 = H
5 R_1 = R_3 = Ac, R_2 = H
6 R_2 = R_3 = Ac, R_1 = H
7 R_1 = R_2 = R_3 = Ac

8 R_1 = Ac, R_2 = R_3 = H
9 R_2 = Ac, R_1 = R_3 = H
10 R_3 = Ac, R_1 = R_2 = H
11 R_1 = R_2 = Ac, R_3 = H
12 R_1 = R_3 = Ac, R_2 = H
13 R_2 = R_3 = Ac, R_1 = H
14 R_1 = R_2 = R_3 = Ac

FIG. 1.





α-D-xylopyranose he has reported 6.4 Hz for $^3J(4,5eq)$, 11.5 Hz for $^3J(4,5ax)$ and 11.5 Hz for $^2J(5eq,5ax)$. These data are not in agreement with those provided in an other publication.[10,11] They also differ from data of the corresponding methyl glycosides that we discuss now.

There are two main regions of absorption for the protons in the present compounds. In the region δ 4.25/5.47 we find the glycosidic proton as well as the protons geminal to an acetylated site. In the region δ 3.40/4.14 we find the protons on C-5 and other ring protons. The glycosidic proton is found at 4.72/4.89 for methyl α-D-xylopyranosides and at δ 4.25/4.52 for compounds of the β-series. Characteristic patterns are observed for each ring proton. Thus H-3 appears as a quasi triplet; H-4 forms an eight line pattern since it is the X-part of an ABX subspectral spin-system, further splitted by an additional coupling with H-3; H-2 appears as a doublet of doublets. For the α-anomers $^3J(1,2)$ is consistently close to 3.6 Hz; for the β-anomers it varies from 4.8 to 7.2 Hz, indicating conformational nonhomogeneity. H-5A appears at δ 3.69/3.80 in α-anomers, and at δ 4.04/4.14 in β-forms, while H-5B of α- and a β-species are found at δ 3.34/3.46 and δ 3.35/3.36, respectively.

Coupling Constants and Conformational Preferences.

When the coupling constants $^3J(4,5eq)$ = 5.8 Hz and $^3J(4,5ax)$ = 10.8 Hz are taken as diagnostic for D-xylopyranoses in a $^4C_1$ conformation,[12] it becomes clear that the pyranose ring of all α-derivatives studied herein take this form but that each β-derivative occurs in a different $^1C_4 \rightleftharpoons {}^4C_1$ equilibrium. The approximate percentage[15] of the $^4C_1$ chair is given in Table 1. The conformational nonhomogeneity is manifested also by the values of the geminal coupling $^2J(5eq,5ax)$. Furthermore, the conformational equilibrium is shifted towards the $^1C_4$ conformation, the more negative the value of the geminal coupling constant. It seems that the geminal coupling constants are not as sensitive as the vicinal couplings, but the observed trend is unambiguously present. Since all the α-anomers occur in a nearly perfect $^4C_1$ conformation, they show also the most positive coupling $^2J(5eq,5ax)$ (∿-10.6 Hz). Taking these findings into consideration, the above-mentioned data provided by Utille should be revised.

It follows from Table 1 that the tendency towards the $^1C_4$ conformation in the β-series is most pronounced with compounds having OH-3 unsubstituted (8, 10 and 12). We presume that this phenomenon results from a hydrogen bond between OH-3 and the anomeric methoxyl group. It is interesting to note that the 2,4-diacetyl derivative (12) shows the most pronounced tendency towards the $^1C_4$ conformation, although in this conformational modification the two acetyl groups are closest to a synaxial disposition.

Acetylation and Shift Increments on Adjacent Protons.

It has been established that proton chemical shifts on a molecule are influenced by substituents on the molecule and by the conformation of the molecule. Small conformational changes may result in important changes in the chemical shifts.[13] In addition, rotameric changes of acetoxy substituents may further appreciably influence shift locations. The pronounced deviation of the present β-series from a unique population of a $^4C_1$ conformation a tendency

which could have been assessed from the ^{1}H NMR data of the acetylated β-D-xylopyranoses,[8,10] renders the claimed[6] general applicability of the increments for the ^{13}C NMR shifts (and for which the occurence of the β-anomers in a $^{4}C_{1}$ conformation was explicitly assumed[6]) doubtful.

In order to define increments caused by acetoxy groups, we have considered only the conformationally more homogeneous α-series. In 1965-1966 Lemieux and Stevens[14,15] reported on the chemical shifts observed for the ring protons in the spectra of peracetylated aldohexopyranoses. They found that only the shifts of H-1 and H-5 were predictable, whereas useful increments could be set up for all the ring-protons in the corresponding unsubstituted sugars.[13,15] Considering the present α-series, we first looked into the effect of acetylation on the shifts of H-2, H-3 and H-4 (Table 2). On vicinal acetylation ("α-substitution") an increment of +0.14 ppm is found, except for H-5ax. Substitution at a β-position has an effect of +0.07 ppm. Where it is usually found that single effects are additive, as in the case of unsubstituted sugars,[12,16] the additivity is now rather bad (we find +0.16/+0.18 ppm experimentally, where +0.21/+0.22 ppm is expected from additivity). When we consider effects on H-1, the α-substitution causes nearly the same effect as on H-2 and H-4, although the substituent is trans disposed. The β-effect, however, disappears almost completely, and the summed effects are in agreement with the expectations from additivity. A trans disposition is also the case for a C-4 acetylation with respect to H-5ax, but now the α-increment is +0.09 ppm and is not substantial for H-5eq (a cis-disposition). Thus, even in the α-series with a constant ring conformation no monotonous increments for acetylation can be proposed in order to predict the ^{1}H NMR shifts, although reliable increments can be proposed for an OH and OMe group.[12,16] We assume that increments for an acetyl group are largely dependent on the anisotropy of the carbonyl bond and concomittantly the rotameric disposition of the OAc groupings. In polyacetylated derivatives there may occur stereochemical dispositions other than in monoacetylated (model)

TABLE 2.

Increments.

α-Substitution :

Proton	Reference Compound	Considered Compound	Effect
H-2	1	4	+0.15
H-4	3	6	+0.14
H-1	4	5	+0.13
H-1	2	4	+0.12
H-1	6	7	+0.14
H-5A	1	5	+0.09
H-5B	1	5	+0.01

β-Substitution :

Proton	Reference Compound	Considered Compound	Effect
H-2	1	5	+0.07
H-4	3	5	+0.07
H-1	4	6	+0.01
H-1	1	4	+0.01
H-5A	1	4	+0.04
H-5B	1	4	+0.02

α + β Substitution :

Proton	Reference Compound	Considered Compound	Effect
H-2	1	7	+0.16
H-4	3	7	+0.18
H-1	4	7	+0.15

γ-Substitution :

Proton	Reference Compound	Considered Compound	Effect
H-1	1	5	+0.03
H-1	2	6	+0.03

compounds. This statement may throw some further doubts on the validity of the ^{13}C NMR increments as proposed by Utille and Vottero.[6]

We should like to point out that it is expected that H-5A (equatorial in the $^4C_1$ chair, but axial in the $^1C_4$ chair) should be found at a lower field in the β-series, since in the $^1C_4$ conformation this proton is affected by the strong effects causing a downfield shift, namely the synaxial disposition of the substituent on C-3 and the antiperiplanar disposition of the substituent on C-4. It is, however, unsafe to propose a quantitative treatment of the chemical shift of H-5a, considering the unpredictable behaviour of the OAc group. Qualitatively it is interesting to note that in the compound 12, with the highest $^1C_4$ population, H-5A is indeed found at δ 4.14, while in 9 and 11 it appears at δ 4.05 and δ 4.09, respectively (cf. δ 3.78 for the α-series). The shift values of H-5A for the other four compounds in the β-series are between these values.

EXPERIMENTAL.

Compounds 1-14 were prepared according to references 1-5. The ^1H NMR spectra were recorded on a Bruker WH360 MHz apparatus (∿2 % solutions in $CDCl_3$, 18°C, F.T. mode, pulse width 2 μsec., quadrature detection, resolution 0.208 Hz/point. The simulations were performed using the Bruker PANIC programme.

ACKNOWLEDGMENT.

We thank Dr. L. Spiessens for the simulations and Mr. G. Verhegge for running the ^1H NMR spectra.

REFERENCES.

1) E. Petráková and P. Kováč, Carbohyd. Res., 101, 141-147 (1982).

2) P. Kováč and R. Palovčík, Chem. Zvesti, 31, 98-105 (1977).

3) P. Kováč and J. Alföldi, Chem. Zvesti, 32, 519-523 (1978).

4) P. Kováč and J. Alföldi, Chem. Zvesti, 33, 785-791 (1979).

5) P. Kováč and J. Hirsch, Carbohyd. Res., 100, 177-193 (1982).

6) J.-P. Utille and P.J.A. Vottero, Carbohyd. Res., 85, 289-297 (1980).

7) P.L. Durette and D. Horton; Carbohyd. Res., 10, 565-577 (1965).

8) T. McEwan, A.G. McInnes and D.G. Smith, Carbohyd. Res., 104, 161-168 (1982).

9) J.-P. Utille, Ph.D. Thesis, Université de Grenoble, France (1979).

10) J.-P. Utille and D. Gagnaire, Carbohyd. Res., 106, 53-57 (1982).

11) J.-P. Utille and P. Vottero, Bull. Soc. Chim. France, 280-287 (1976).

12) A. De Bruyn, M. Anteunis, M. Claeyssens and E. Saman, Bull. Soc. Chim. Belges, 85, 605-615 (1976) and references herein.

13) A. De Bruyn, M. Anteunis and J. Van Beeumen, Bull. Soc. Chim. Belges, 86, 259-265 (1977) and references herein.

14) R.U. Lemieux and J.D. Stevens, Can. J. Chem., 43, 2059-2072 (1965).

15) R.U. Lemieux and J.D. Stevens, Can. J. Chem., 44, 249-262 (1966).

16) A. De Bruyn, M. Anteunis and P. Kováč, Collect. Czech. Chem. Comm., 42, 3057-3068 (1977).