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CARBON-13 CHEMICAL SHIFTS OF ISOPRENOID-β-D-GLUCOPYRANOSIDES AND -β-D-MANNOPYRANOSIDES. STEREOCHEMICAL INFLUENCES OF AGLYCONE ALCOHOLS

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As already mentioned in our previous papers[1,2], application of C-13 NMR spectroscopy has been promising in the field of chemistry of isoprenoid glycosides. In 1974, Lemieux and Koto[3] reported C-13 NMR of α- and β-glucopyranosides of cyclohexanol and its C-methyl homologues in connection with conformational analysis of glucosyl linkages. As expansion of their study, the present authors prepared following β-D-glucopyranosides and explored β-D-glucosylation effects on carbon chemical shifts of both glucose and aglycone moieties, demonstrating that their stereochemical argument[3] can be applied to C-13 NMR for the glucosides of the more complex isoprenoid-aglycones; β-D-glucopyranosides of n-PrOH:1-G, iso-PrOH:2-G, trans-4-tert-Bu-cyclohexanol:3-G, 5α-cholestan-3β-ol(4):4-G, 5α-cholestan-3α-ol:5-G, cholesterol:6-G, l-menthol:7-G, d-menthol:8-G, 3-epi-dammaranediol-I:9-G(3-O-β-D-glucopyranosyl), dammarenediol-I(10):10-G(3-O-β-D-glucopyranosyl) and tert-BuOH:11-G. In order to accumulate more examples of β-glucosides of chiral secondary alcohols, β-L-glucopyranosides of 4 and 10(3-O-β-L-glucopyranosyl) were also prepared, both of which should exhibit the same spectra as those of β-D-glucopyranosides of the corresponding enantiomers of 4 and 10, being designated as ent-4-G and ent-10-G, respectively in the present study. Of a number of dammarane-type glycosides isolated recently by Yahara et al. of our research group, ginsenoside-F_1(12-G, from Ginseng leaves)[4], ginsenoside-Rh_1(13-G, from Ginseng roots)[5] and chikusetsu-saponin-L_{10}(14-G, from leaves of Panax japonicum)[5] also afforded additional examples of spectra for chiral alcoholic mono-β-D-glucosides. All spectra were recorded in C_5D_5N and compared with those of methyl β-D-glucopyranoside(15-G) and the corresponding aglycones[6] taken in the same solvent(Table I).

Carbon Chemical Shifts of Glucosyl Moiety. It has been reported in our previous papers that the anomeric carbon(C-1') signal of tertiary alcoholic β-D-glucosides(steviol-monoside (16-G)[1] and paeoniflorin(17-G)[2] etc.) appears at significantly higher field than those of 15-G and 1-G. The present study further disclosed that the C-1' signal is deshielded in the decreasing order of methyl(δ 105.5), primary(δ 104.4), secondary(δ 102.0-102.5) and tertiary (δ 98.0-100.5) alcoholic β-D-glucopyranosides.

With regard to β-D-glucosides of secondary alcohols having at least one equatorial alkyl substituent on one of its β-carbons (abbrev.: subst-sec-OH type), a C-1' resonance of glucosides of S-alcohols such as 8-G, 10-G and 13-G is exceptionally deshielded, appearing at δ 106.4 ±0.5.

Chemical shift differences of other glucosyl carbons(C-2'~6') between each glucoside are less than 0.7 ppm, being not appreciable for discussion about the correlation with stereochemistry of aglycone alcohols.

Carbon Chemical Shifts of Aglycone Moiety. In general, carbinyl carbon(α-carbon) signals of aglycone alcohols are displaced by +7.0 ±0.6 ppm on the glucosylation. However, the more remarkable deshielding of α-carbon signal(by ca. +10-11 ppm) is observed in the spectra of β-

Table I. C-13 Chemical Shifts (δ ppm from TMS in C_5D_5N)

compound (chirality of alcohol)	C-1'($\Delta\delta_a$)	α-carbon($\Delta\delta_b$)	β-carbon(position and $\Delta\delta_b$)	
15-G (*)	105.5 (0)	56.7 (+7.3)		
1-G (*)	104.4 (-1.1)	71.2 (+7.3)	23.3 (-3.3)	
2-G (*)	102.4 (-3.1)	71.0 (+7.6)	23.8 (β -1.8)	22.0 (β'-3.6)
3-G (*)	102.4 (-3.1)	77.7 (+7.4)	34.5 (C- 2 β -2.2)	32.8 (C- 6 β'-3.9)
4-G (S)	102.0 (-3.5)	77.2 (+6.7)	29.9 (C- 2 β -2.5)	34.8 (C- 4 β'-4.4)
ent-4-G (R)	102.4 (-3.1)	77.7 (+7.2)	28.3 (C- 2 β'-4.1)	36.5 (C- 4 β -2.7)
5-G ax (R)	102.4 (-3.1)	73.0 (+7.5)	25.5 (C- 2 β'-4.3)	34.9 (C- 4 β -1.9)
6-G (S)	102.5 (-3.0)	78.1 (+7.0)	30.2 (C- 2 β -2.3)	39.3 (C- 4 β'-4.0)
7-G (R)	101.5 (-4.0)	77.0 (+6.4)	41.2 (C- 2 -4.9)	48.5 (C- 4 -2.1)
8-G (S)	105.9 (+0.4)	70.6 (+10.5)	44.3 (C- 2 -1.8)	49.5 (C- 4 -1.1)
9-G ax (R)	102.2 (-3.3)	82.1 (+6.8)	22.8 (C- 2 -3.7)	37.5 (C- 4 -0.6)
10-G (S)	106.9 (+1.4)	88.8 (+10.3)	26.8 (C- 2 -1.2)	39.7 (C- 4 +0.3)
ent-10-G (R)	102.3 (-3.2)	84.8 (+6.9)	23.8 (C- 2 -4.2)	38.6 (C- 4 -0.8)
13-G (S)	105.9 (+0.4)[7]	78.0 (+10.4)	45.2 (C- 7 -2.2)	61.4 (C- 5 -0.3)
14-G (R)	100.4 (-5.1)[7]	78.3 (+7.4)	27.9 (C-11 -4.0)	46.2 (C-13 -1.9)
11-G (*)	98.9 (-6.6)	75.3 (+7.5)	29.0 (-2.6)	
12-G (S)	98.0 (-7.5)	83.2 (+10.3)	22.3 (C-21 -4.6)	35.9 (C-22 +0.2)
			51.6 (C-17 -3.0)	
16-G (S)	99.4 (-6.1)	86.4 (+6.6)	38.4 (C-12 -2.3)	44.6 (C-14 -2.8)
			153.7 (C-16 -3.9)	
Rd (3-S)	105.9 (+0.4)	88.9 (+11.0)	26.7 (C- 2 -1.5)	39.6 (C- 4 +0.1)
(20-S)	98.2 (+7.3)	83.3 (+10.4)	22.4 (C-21 -4.5)	36.0 (C-22 +0.2)
			51.7 (C-17 -3.0)	
15-M (*)	102.7 (0)	56.5 (+7.1)		
1-M (*)	101.8 (-0.9)	71.0 (+7.1)	23.3 (-3.3)	
3-M (*)	99.4 (-3.3)	77.1 (+6.8)	34.5 (C- 2 β -2.2)	32.7 (C- 6 β'-4.0)
4-M (S)	99.2 (-3.5)	76.9 (+6.4)	29.9 (C- 2 β -2.5)	34.8 (C- 4 β'-4.4)
8-M (S)	103.6 (+0.9)	81.4 (+10.8)	44.0 (C- 2 -2.1)	49.1 (C- 4 -1.5)
10-M (S)	104.2 (+1.5)	88.8 (+10.8)	26.4 (C- 2 -1.7)	39.4 (C- 4 -0.1)
11-M (*)	96.2 (-6.5)	75.3 (+7.5)	28.8 (-2.8)	

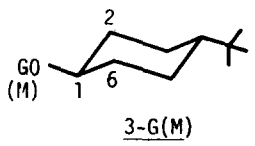
$\Delta\delta_a$: δ(glycoside) - δ(15-G or 15-M). $\Delta\delta_b$: δ(glycoside) - δ(aglycone). β: pro R. β': pro S. (*): achiral. ax: axial OH.

Spectra taken with JEOL JNM-PFT-100 NMR spectrometer (25.15 MHz) at 25° with the concentration of 0.15-0.4 mM/ml using 10 mm tubes. FT measurement condition are as follows: spectral width, 4 KHz; pulse flipping angle, 45°; acquisition time, 0.4 sec; number of data points, 4096 transient time, 1-3 sec; number of transients, 600-10000.

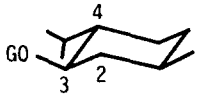
D-glucosides of the S-alcohols of subst-sec-OH type(8-G, 10-G and 13-G) as in the case of the C-1' signal. It is notable that in contrast to the S-alcohols, the D-glucosylation effect on C-1' and α-carbon of the R-alcohols of subst-sec-OH type(7-G, 9-G, ent-10-G and 14-G) is quite similar to that on the corresponding carbons of less hindered secondary alcohols(3-G etc.) except for C-1' signal of 14-G[7].

The effect of D-glucosylation on β-carbon resonances of aglycone alcohols can be generally expressed to be shielding in character, the magnitude of which also depends on the chirality of aglycone alcohols. Inspection of the spectra of β-D-glucosides of achiral secondary alcohols (2-G and 3-G) as well as those of chiral alcohols having two β-methylene groups(4-G, 5-G and ent-4-G) revealed that signals of the pro S-carbon or its equivalent, i.e., C-4 of 4 (β'-C) are always more shielded (by -3.6~4.4 ppm) than those of the pro R-carbon or its equivalent, i.e., C-2 of 4 (β-C) (-1.8~2.7 ppm) on D-glucosylation.

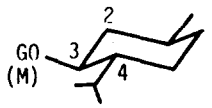
In the spectra of subst-sec-OH type alcoholic β-D-glucosides, D-glucosylation shifts of β-carbon signals of the R-alcohols(7-G, 9-G, ent-10-G and 14-G: methylene: -3.7~4.9 ppm being similar to that of β'-C in the case of 4-G, 5-G and ent-4-G, methine: -1.9~2.1 ppm and quaternary: -0.6~0.8 ppm) are more remarkable than those of the corresponding signals of the S-alcohols(8-G, 10-G and 13-G: methylene: -1.2~2.2 ppm being similar to that of β-C in the case of 4-G, 5-G and ent-4-G, methine: -0.3~1.1 ppm and quaternary: +0.3 ppm).



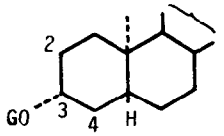
3-G(M)



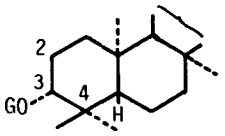
7-G



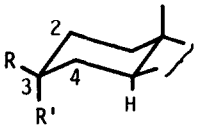
8-G(M)



ent-4-G

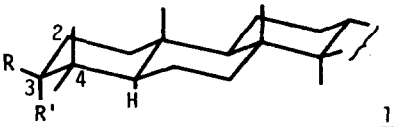


ent-10-G



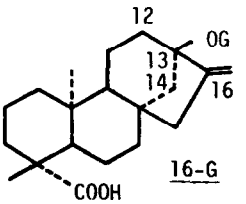
4-G(M): R=OG(OM), R'=H

5-G R=H, R'=OG

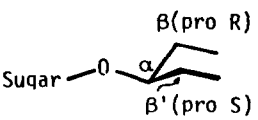


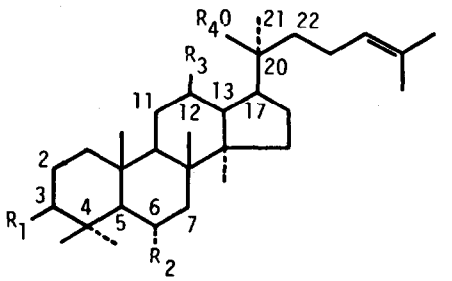
9-G : R=H, R'=OG

10-G(M): R=OG(OM), R'=H

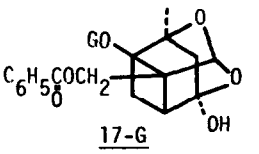


16-G

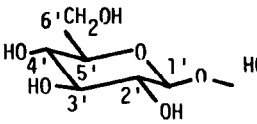


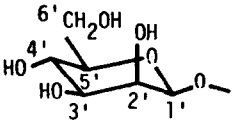


	R_1	R_2	R_3	R_4
12-G:	OH	OH	OH	G
13-G:	OH	OG	OH	H
14-G:	OH	OH	OG	H
R_d:	$OG^{2}\!-\!G$	H	OH	G



17-G





G: β-D-glucopyranosyl M: β-D-mannopyranosyl

It should be noted that the D-glucosylation shifts in the present study mainly depend on the chirality of aglycone alcohols and seem to be independent on their axial-equatorial configuration as indicated in the spectra of 5-G and 9-G. It is also of interest that the similar D-glucosylation shifts to those for 10-G were observed in the case of a 3-[O-β-D-glucopyranosyl (1→2)-β-D-glucopyranoside], ginsenoside-Rd[8]. The glucosylation shifts of γ-carbons of aglycone alcohols are less than 0.7 ppm, being not diagnostic for the structural determination.

β-D-Mannosylation Shifts. In view of the extension of the above study, several β-D-mannopyranosides, 1-M, 3-M, 4-M, 8-M, 10-M and 11-M were also prepared and their spectra in C_5D_5N were compared with those of methyl β-D-mannopyranoside(15-M) and the corresponding aglycone alcohols in C_5D_5N in the same way as that for β-D-glucopyranosides. As shown in Table I, the relationship between the chirality of the aglycone alcohols and the shifts of C-1', α- and β-carbon signals on D-mannosylation was proved to be quite similar to that of the case of the D-glucosylation, suggesting that this effect must be independent on the configuration of the C-2'-hydroxyl group of the sugar moiety.

Studies on C-13 NMR of α- and β-D-mannosides and α- and β-L-rhamnosides in detail are in progress .

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