72. Glycosylidene Carbenes

Part 16

Glycosidation of Methyl 6-*O*-Trityl-α-D-altropyranoside

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Hydrogen bonding of the triol **4** in chlorinated solvents was studied by IR (CH_2Cl_2 and CCl_4) and ^{1}H-NMR spectroscopy ($CDCl_3$), and the regioselectivity of the glycosidation of the triol **4** by the diazirine **1** is predicted on the basis of two assumptions: preferred protonation of the intermediate glycosylidene carbene by the OH group involved in the weakest intramolecular H-bond, and attack in the π-plane of the thereby generated oxycarbenium cation either by the reoriented oxy anion, or by a properly oriented vicinal OH group. Glycosidation led to the disaccharides **5**–**10** (*Scheme*) which were separated and characterized as their acetates **11**–**16**, to the lactone azines **17** and to the 2-(benzyloxy)glucal **18**. In agreement with the predictions, glycosidation in non-coordinating solvents gave the 1,2-, 1,3-, and 1,4-linked disaccharides in decreasing relative amounts. Glycosidation in THF proceeded with a lower degree of regioselectivity and led preferentially to the β-D-anomers, except for the minor, 1,4-linked disaccharides, where THF had only a weak influence on stereoselectivity at room temperature and led to a slight increase of the α-D-anomer at −80°.

Introduction. – In the glycosidation of alcohols by glycosylidene-derived diazirines, the intermediate alkoxy(alkyl)carbenes are protonated by the OH group involved in the weakest intramolecular H-bond, to generate an ion pair where the oxy anion is initially located in the σ-plane of the oxycarbenium cation. Combination of these ions yields glycosides. For this, the ions must reorient themselves, so that the oxy anion can attack in the π-plane of the oxycarbenium cation [1–3]. Alternatively, the oxycarbenium ion can be attacked by another, suitably oriented oxy-anion group, generated by H-transfer from a second OH group to the initially generated oxy anion. This alternative appears to be realized in the glycosidation by the diazirine **1** of the α-D-allopyranoside **2** [1]. In chlorinated solvents, this diol forms the two H-bonded tautomers **2a** and **2b** in a ratio of *ca.* 1:1. Its glycosidation in non-coordinating solvents is unusual; regioselectivity does not reflect the relative strength of the H-bonds and the ratio of the tautomers, and the stereoselectivity differs from the one which has been observed for all other alcohols so far investigated. This result was explained by a preferred protonation of the carbene by HO–C(2) in **2a** and HO–C(3) in **2b**, involved in the weakest H-bonds. Protonation by HO–C(3) leads to glycosidation by the oxy anion derived from the same OH group, but protonation by HO–C(2) is followed by H-transfer from HO–C(3) to $^-$O–C(2) and glycosidation by $^-$O–C(3), located in the π-plane of the cation. One can, however, argue that the regioselectivity is due to a more rapid protonation of the intermediate carbene by

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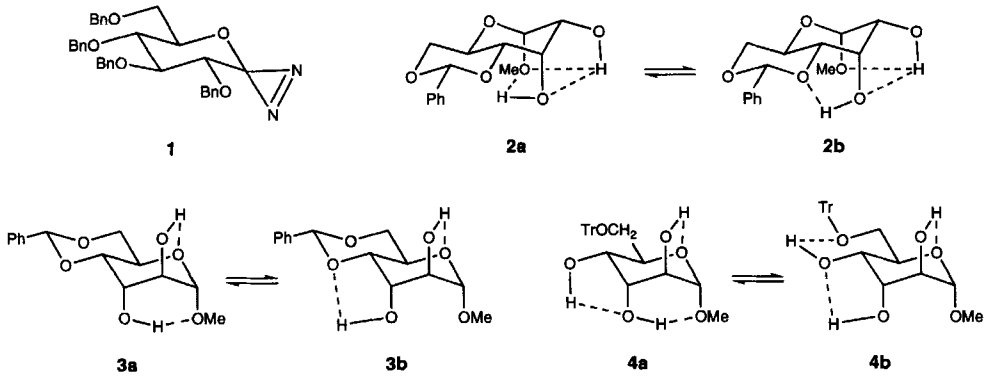

1 2a 2b 3a 3b 4a 4b

Figure. *Glycosyl donor* **1** *and acceptors* **2**–**4**. Intramolecular hydrogen bonding (in chlorinated solvents) of **2**–**4**.

the tautomer **2b**, as HO–C(3) of **2a** is sterically hindered. For this reason and in view of the projected use of aziglyoses as tools for the investigation of H-bonds in more complex hydroxy compounds, we investigated a number of other diols and triols where the regioselectivity of the protonation of the carbene is expected to differ from the one of the formation of the glycosidic bond. We report the glycosidation of the altrotriol **4** by the diazirine **1**. The intramolecular H-bonds in **4** were thought to be suitable for testing the validity of the above formulated explanation, particularly when comparing the glycosidation of **4** to the one of the diol **3** [4], where the 1,2- and 1,3-linked disaccharides were formed in a ratio of *ca.* 9:1, as the kinetic acidity of OH–C(3) is suppressed by H-donation to O–C(1) or O–C(4).

Results and Discussion. – *Hydrogen Bonds of the* α-D-*Altropyranoside* **4**. The IR spectra of **4** in CH_2Cl_2 (0.05, 0.01, and 0.005M) and in CCl_4 solution (0.01 and 0.005M) were compared with those of **3** in the same solvents [1] [4–6]. The IR spectrum of a 0.05M solution of **4** in CH_2Cl_2 shows four strong bands of similar intensity at 3504, 3545, 3577, and 3600 cm^{-1} and a weak shoulder (3500–3300 cm^{-1}). The band at 3600 cm^{-1} is due to the very weak H-bond C(2)–OH···O–C(5) (**3**: 3598 cm^{-1}) and the one at 3577 cm^{-1} to a H-bond in a *cis*-annulated 5-membered ring, *i.e.* C(4)–OH···O–C(3) of **4a** (*Fig.*) or C(3)–OH···O–C(4) of **4b**[2]). The bands at 3545 and 3504 cm^{-1} are indicative of intramolecular H-bonds in a 6-membered ring and/or intermolecular H-bonds. As shown by the concentration dependence of the spectra of **4** (0.01M and 0.005M: same bands accompanied by a slight decrease of the band at 3504 cm^{-1} and the absence of the shoulder between 3500 and 3300 cm^{-1}), the band at 3504 cm^{-1} is mainly due to an intramolecular H-bond. As an anomeric OR group is a relatively poor H-bond acceptor, the absorption at 3545 cm^{-1} is assigned to the C(3)–OH···O–C(1) bond of **4a** (**3**: 3520 cm^{-1}) and the one at 3504 cm^{-1} to the C(4)–OH···O–C(6) bond of **4b**. In CCl_4 solution, the bands for the intramolecular H-bonds are shifted to higher wave numbers (**4**: 3515, 3550, 3580, and 3620 cm^{-1}; **3**: 3554, 3602, and 3630 cm^{-1}). A broad band of **4** at *ca.* 3450 cm^{-1} decreases upon dilution, but is still present for the 0.005M solution. This indicates the presence of di-

[2]) In the solid state, the only intramolecular H-bond of methyl α-D-altropyranoside is between *H*O–C(3) and O–C(4) [7], whereas **3** lacks any intramolecular H-bond [4].

or oligomeric clusters of **4** in CCl_4, even at high dilution. The osmometrically determined molecular weight of **4** (M_r 436.50) in dioxane at a concentration of *ca.* 0.06M (546) shows the tendency of **4** to form aggregates (solvates?) at higher concentrations.

The ^{1}H-NMR spectrum of **4** in $CDCl_3$ (0.05M) shows sharp *d*'s for HO–C(3) and HO–C(4) at 3.18 (J = 9.2 Hz) and 2.51 ppm (J = 8.5 Hz) and a broad *d* for HO–C(2) at 2.02 ppm ($J \approx 7.5$ Hz). The large vicinal J(H,OH) (*Table 1*) indicate the antiperiplanar arrangement of the corresponding C–H and O–H bonds. This arrangement is found in the tautomer **4a** (*Fig.*). In **4b**, J(3,OH) and J(4,OH) should be smaller than *ca.* 2 Hz

Table 1. *^{1}H-NMR* (400 MHz, $CDCl_3$) *Chemical Shifts* [ppm] *and Coupling Constants* [Hz] *for the OH Groups of* **4**

Solvent	OH–C(2)	OH–C(3)	OH–C(4)	J(2,OH)	J(3,OH)	J(4,OH)
$CDCl_3$	2.02 (br.)	3.18	2.51	*ca.* 7.5	9.2	8.5
(D_6)DMSO	5.06	4.32	4.25	4.4	5.0	7.4

(*cf.* [2]); J(4,OH) indicates the presence of *ca.* 10% of **4b**, and the participation of **4b** in the tautomeric equilibrium is qualitatively confirmed by the IR spectra. In (D_6)DMSO solution, HO–C(2) (J = 4.4 Hz) and HO–C(3) (J = 5.0 Hz) are mostly H-bonded to the solvent. Surprisingly, the five-membered ring formed by the H-bond C(4)–OH$\cdots$ $\cdots$O–C(3) is more resistant in (D_6)DMSO than the six-membered ring formed by the H-bond C(3)–OH$\cdots$O–C(1), as indicated by J(4, OH) = 7.4 Hz. This value suggests that at the least about half of the molecules still possess the five-membered intramolecular H-bond[3]). No signals for isotopomers nor even line broadening of the OH signals are observed upon 50% deuteration of a (D_6)DMSO solution of **4** with CD_3OD (see [1] and ref. cit. therein).

Glycosidation of the α-D-*Altropyranoside* **4** *with the Diazirine* **1**. The rate of protonation of the intermediate glycosylidene carbene should be highest for OH–C(2) which forms the weakest H-bond in both tautomers of **4**. There is no neighbouring OH group to interfere with the reorientation of the thereby formed ion pair; protonation by HO–C(2) will lead to formation of the 1,2-linked glycosides, and these should be the main products. In non-coordinating solvents, the β-D-configurated disaccharide should be slightly preferred: THF as a coordinating solvent is expected to strongly increase this tendency [8]. One expects a competing protonation of the carbene by the OH groups in the second weakest H-bonds, *i.e.* by HO–C(4) in **4a** and by HO–C(3) in the minor tautomer **4b**. Protonation by HO–C(4) is expected to lead to an oxycarbenium ion in the vicinity of the intramolecularly H-bonded HO–C(3), which is properly oriented to attack the cation in the π-plane. One predicts that 1,3-linked disaccharides are the second most important products. Their configuration will depend on the orientation of the oxycarbenium cation, which may either depend on steric interactions between the carbene of the oxycarbenium cation and the glycosyl acceptor, or, if rotation around the C(1)–C(4) axis of the oxycarbenium ion is possible, on the activation energies associated with axial or equatorial attack. Finally, for analogous reasons as those detailed above, protonation by HO–C(3) of **4b** should lead to 1,4-linked disaccharides.

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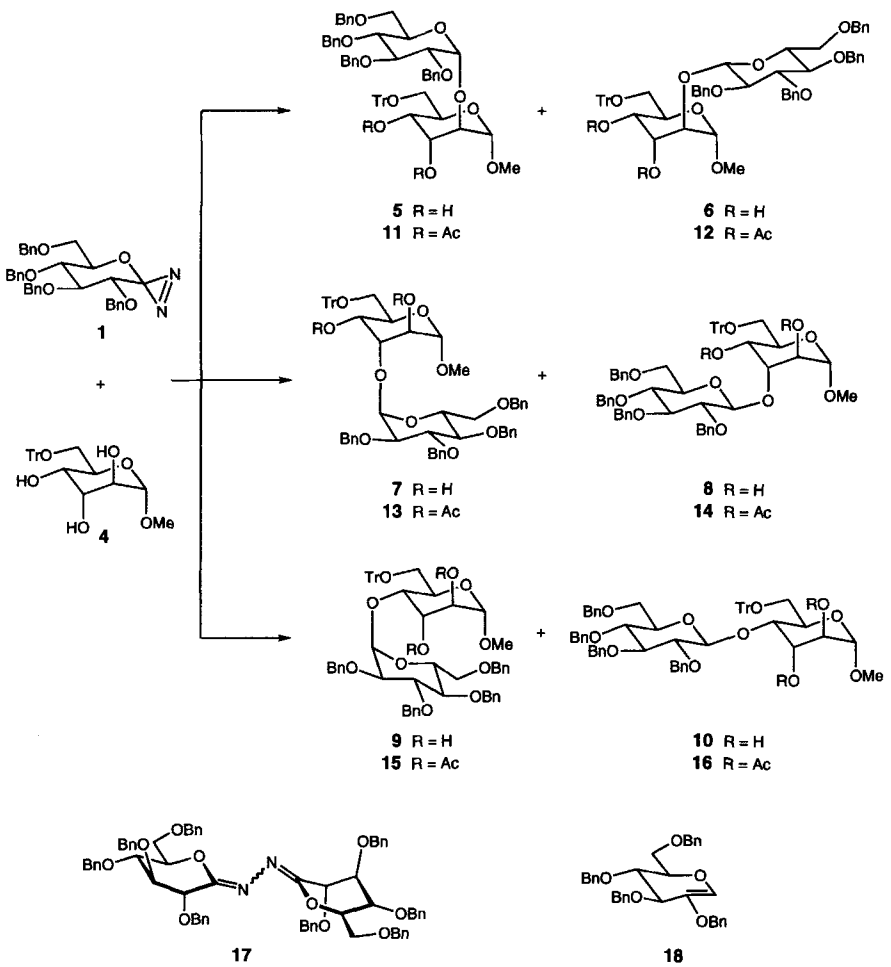
[3]) The J(5,6) values (see *Exper. Part, Table 3*), however, indicate that the *gt*-conformer of **4a** is strongly favoured in (D_6)DMSO.

The diazirine **1** reacted with **4** under various conditions to yield mixtures of the 1,2-, 1,3-, and 1,4-linked disaccharides (*Scheme* and *Table 2*). The ratio of the disaccharides were determined by anal. HPLC of the mixtures of disaccharides obtained after separation of starting material **4** and by-products. The disaccharides **5**–**10** were separated by repeated flash chromatographies and characterized as the diacetates **11**–**16**. The azines **17** [9], and the benzylated 2-(benzyloxy)glucal **18** [9] [10] were obtained as by-products. Attempts to isolate other by-products, particularly demethylated saccharides as they were observed in the glycosidation of **3** [4], trisaccharides, or epoxides failed[4]).

Scheme



[4]) The absence of demethylated products of **4** correlates with the *cis*-orientation of $^{-}$O–C(4) and the protonated RO–C(3) group allowing an intramolecular H^{+}-transfer, which may be facilitated by the conformational flexibility of the altropyranose ring.

Table 2. *Glycosidation of* **4** *with the Diazirine* **1**

Conditions	Total yield [%]	Regioselectivity[a]) RO–C(2)/RO–C(3)/RO–C(4) (**5**/**6**:**7**/**8**:**9**/**10**)	Stereoselectivity[a]) (α-D/β-D) for		
			RO–C(2) (**5**/**6**)	RO–C(3) (**7**/**8**)	RO–C(4) (**9**/**10**)
$ClCH_2CH_2Cl$, 24°	57	55:31:14	43:57	45:55	61:39
CH_2Cl_2, 24°	53	57:30:13	49:51	46:54	64:36
CH_2Cl_2, −80°, *hv*	38	55:27:17	35:65	74:26	69:31
Toluene, 24°	48	48:36:16	41:59	59:41	83:17
Dioxane, 24°	49	50:37:13	62:38	36:64	54:46
THF, 24°	54	47:39:13	49:51	28:72	50:50
THF, −80°, *hv*	50	43:52: 5	9:91	13:87	84:16
DME, 24°	39	36:46:16	52:48	59:41	79:21

[a]) Determined by anal. HPLC of the mixture **5**/**6**/**7**/**8**/**9**/**10** obtained by flash chromatography.

Selected ^{1}H- and ^{13}C-NMR data of the acetates **11**–**16** are given in *Tables 3* and *4* (see *Exper. Part*). The presence of two AcO groups in all products indicates exclusive monoglycosidation. H–C(2), H–C(3), and H–C(4) of the α-D-altrosyl moiety show characteristic signals: H–C(2) a *dd* with J = 0.8–2.3 and 3.8–4.8 Hz, H–C(3) a broadened *t* with $J \approx 3.5$ Hz, and H–C(4) a *dd* with J = 3.0–3.7 and 8.5–9.6 Hz. The assignment of regioisomers is thus readily deduced from the two signals at low field (5.0–5.5 ppm, *Table 3*). The configuration of the new anomeric centre is revealed by the chemical shifts of H–C(1′) and C(1′) and by J(1′,2′) (*Tables 3* and *4*). A strong upfield shift is observed for C(1′) of **15** appearing at 92.5 ppm (shielding by AcO–C(3)?). Otherwise, the chemical-shift values of the H- and C-atoms of the glucopyranosyl residues of **11**–**16** agree well with those of related disaccharides [2] [4].

The regioselectivity of the glycosidation of **4** in non-coordinating solvents is qualitatively as predicted. The major products are the 1,2-linked disaccharides **5** and **6**, with a slight preference of the β-D-anomer, followed by the 1,3- and the 1,4-linked isomers. The relative amounts of the 1,2-linked disaccharides are significantly lower and those of the 1,3-linked disaccharides significantly higher than what resulted from the glycosidation of the altrodiol **3**, although the strength of the intramolecular H-bond between OH–C(3) and O–C(1) is only slightly weaker in the triol **4**, as judged from the IR spectra. The assumption that protonation and glycoside-bond formation is effected by the same OH group requires that OH–C(3) of the minor tautomer **4b** is reacting at a higher rate than OH–C(4) of the major one, and that the major tautomer is transformed into the minor one at a sufficiently high rate. Although one cannot see why **4b** should be protonated more rapidly than **4a** (same frequency of their OH bands in the IR spectra), this explanation cannot be rigorously excluded.

The regioselectivity decreases in THF at room temperature, and at −80°, there is a slight preference for the 1,3-linked products **7** and **8**. This and the lowered yield of the 1,4-isomers **9** and **10** are thought to reflect the influence of THF on H-bonding in the triol. The preponderant formation in THF of the β-D-configurated **8** is in keeping with the preferred axial solvation of the oxycarbenium cation [3] [8]. The anomeric selectivity in the formation of the 1,3-linked disaccharides in non-coordinating solvents is weak. Again, THF leads to a preponderance of the β-D-anomer **8**, particularly at −80°. Surprisingly, CH_2Cl_2 at −80° has the opposite effect, leading mostly to the α-D-glycoside **7**. Unfortunately, these conditions also lead to lower yields. In the 1,4-linked disaccharides **9** and **10**, there is a consistent preference for the α-D-anomer in non-coordinating solvents, particularly in toluene, and this tendency is increased for glycosidations in

1,2-dimethoxyethane (DME) at room temperature and in THF at −80°, reflecting a strong bias for a specific orientation of the carbene and/or the oxycarbenium cation relative to the glycosyl acceptor.

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Experimental Part

General. See [4]. High-performance liquid chromatography (HPLC): anal. 250 × 4.0 mm cartridge with *Merck LiChrosorb Si60* for **5**–**10** (hexane/AcOEt 2:1 and CH_2Cl_2/AcOEt 92:8, 1.5 ml/min).

Typical Glycosidation of **4** *with* **1** *under Thermal Conditions.* Under N_2, solid diazirine **1** [11] (220 mg, 0.4 mmol) was added to a soln. of **4** [12] [13] (158 mg, 0.36 mmol) in $ClCH_2CH_2Cl$ (7.2 ml). The mixture was stirred for 5 h at 24° when **1** was totally consumed. Evaporation and FC (8 g of SiO_2, hexane/AcOEt 2:1) gave 196.8 mg (57%) of **5**/**6**/**7**/**8**/**9**/**10** 24:31:14:17:9:5 (HPLC). The amounts of **4** and the by-products **17** and **18** were not determined. Another FC (hexane/AcOEt 2:1) afforded **5**/**6**/**7**/**8** (166.1 mg), **9** (16.4 mg), and **10** (10.3 mg). FC (CH_2Cl_2/AcOEt 98:2) of **5**/**6**/**7**/**8** gave **5** (44.0 mg), **6** (58.1 mg), and **7**/**8** (62.1 mg), which were separated by another FC (hexane/AcOEt 2:1) giving **7** (27.0 mg) and **8** (33.1 mg). The diols **5**–**10** were acetylated separately in pyridine/Ac_2O 2:1 for 12 h at r.t. Dilution with CH_2Cl_2, washing with 1M aq. Na_2CO_3 and H_2O, and processing of the org. layer as usual afforded **11**–**16**. For analogous reactions under different conditions, see *Table 2*. R_f (hexane/AcOEt 2:1) 0.26 (**5**), 0.24 (**7**), 0.22 (**6**), 0.20 (**8**), 0.14 (**9**), 0.09 (**10**). R_f (CH_2Cl_2/AcOEt 98:2) 0.13 (**5**), 0.10 (**6**), 0.04 (**7**, **8**).

Typical Glycosidation of **4** *with* **1** *under Photolytic Conditions.* Under N_2, a soln. of **4** (43.7 mg, 0.1 mmol) in THF (2 ml) was added to the solid diazirine **1** (60.6 mg, 0.11 mmol). The mixture was stirred and irradiated (*HPK-125-Philips* high-pressure Hg lamp, *Solidex* glass filter) for 1 h at −80°. Evaporation and FC (hexane/AcOEt 2:1) gave 48 mg (50%) of **5**/**6**/**7**/**8**/**9**/**10** 4:39:45:7:4:1 (HPLC).

*Methyl 3,4-Di-*O*-acetyl-2-*O*-(2,3,4,6-tetra-*O*-benzyl-α-*D*-glucopyranosyl)-6-*O*-(triphenylmethyl)-α-*D*-altropyranoside* (**11**). R_f (hexane/AcOEt 2:1) 0.45. $[\alpha]_D^{25} = +45.8$ ($c = 1.57$, $CHCl_3$). IR ($CHCl_3$): 3060*w*, 3000*m*, 2930*m*, 2870*w*, 1742*s*, 1495*m*, 1450*m*, 1370*m*, 1320*w* (br.), 1250*s*, 1195*w* (sh), 1140*s*, 1100*s* (sh), 1085*s* (sh), 1070*s*, 1040*s*, 1028*s* (sh), 995*w*, 900*w*, 700*s*, 670*w*, 648*w*, 632*m*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.49–7.12 (*m*, 35 arom. H); 5.36 (br. *t*, $J \approx 4.3$, H–C(3)); 5.33 (*dd*, $J = 3.7, 8.2$, H–C(4)); 5.06 (*d*, $J = 3.6$, H–C(1′)); 4.99 (*d*, $J = 10.9$, PhC*H*); 4.84 (*d*, $J = 10.8$, PhC*H*); 4.84 (*d*, $J = 2.3$, H–C(1)); 4.81 (*d*, $J = 11.1$, PhC*H*); 4.74 (*d*, $J = 12.0$, PhC*H*); 4.70 (*d*, $J = 12.1$, PhC*H*); 4.62 (*d*, $J = 12.1$, PhC*H*); 4.49 (*d*, $J \approx 10.5$, PhC*H*); 4.46 (*d*, $J = 11.9$, PhC*H*); 4.16 (*ddd*, $J = 2.7, 5.7, 8.0$, H–C(5)); 4.01 (*t*, $J \approx 9.3$, H–C(3′)); 3.91 (br. *ddd*, $J \approx 2, 3.5, 10$, H–C(5′)); 3.89 (*dd*, $J = 2.3, 4.8$, H–C(2)); 3.75 (*dd*, $J = 3.6, 10.7$, H_A–C(6′)); 3.67 (*dd*, $J = 1.9, 10.6$, H_B–C(6′)); 3.65 (*t*, $J \approx 9.6$, H–C(4′)); 3.58 (*dd*, $J = 3.6, 9.6$, H–C(2′)); 3.41 (*s*, MeO); 3.26 (*dd*, $J = 5.8, 10.1$, H_A–C(6)); 3.20 (*dd*, $J = 2.7, 10.1$, H_B–C(6)); 2.01 (*s*, Ac); 1.83 (*s*, Ac). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.99 (*s*); 169.18 (*s*); 143.80 (3*s*); 138.84 (*s*); 138.21 (*s*);138.16 (*s*); 137.93 (*s*); 128.68–126.89 (several *d*); 100.29 (*d*); 97.56 (*d*); 86.62 (*s*); 81.61 (*d*); 79.42 (*d*); 77.57 (*d*); 75.58 (*t*); 75.10 (*t*); 74.22 (*d*); 73.42 (*t*); 72.68 (*t*); 70.95 (*d*); 68.54 (*d* and *t*); 67.64 (*d*); 66.23 (*d*); 63.15 (*t*); 55.33 (*q*); 20.84 (*q*); 20.57 (*q*). Anal. calc. for $C_{64}H_{66}O_{13}$ (1043.22): C 73.69, H 6.38; found: C 73.85, H 6.43.

*Methyl 3,4-Di-*O*-acetyl-2-*O*-(2,3,4,6-tetra-*O*-benzyl-β-*D*-glucopyranosyl)-6-*O*-(triphenylmethyl)-α-*D*-altropyranoside* (**12**). R_f (hexane/AcOEt 2:1) 0.40. $[\alpha]_D^{25} = +26.0$ ($c = 1.99$, $CHCl_3$). IR ($CHCl_3$): 3060*w*, 3030*w* (sh), 3010*w*, 2910*w*, 2870*w*, 1745*s*, 1495*w*, 1450*m*, 1370*m*, 1250*s*, 1195*w* (sh), 1145*s* (sh), 1070*s*, 1030*s*, 950*w*, 900*w*, 700*s*, 648*w* (sh), 632*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.50–7.18 (*m*, 35 arom. H); 5.50 (br. *t*, $J \approx 3.9$, H–C(3)); 5.35 (*dd*, $J = 3.6, 9.1$, H–C(4)); 5.01 (*d*, $J = 10.8$, PhC*H*); 4.94 (*d*, $J = 11.1$, PhC*H*); 4.82 (*d*, $J = 10.9$, PhC*H*); 4.80 (*d*, $J = 10.9$, PhC*H*); 4.79 (*d*, $J = 1.7$, H–C(1)); 4.73 (*d*, $J = 10.8$, PhC*H*); 4.65 (*d*, $J = 12.2$, PhC*H*); 4.58 (*d*, $J = 12.0$, PhC*H*); 4.55 (*d*, $J = 12.4$, PhC*H*); 4.50 (*d*, $J = 7.7$, H–C(1′)); 4.19 (*ddd*, $J = 2.9, 5.0, 9.0$, H–C(5)); 3.97 (*dd*, $J = 1.9, 4.4$, H–C(2)); 3.76 (*dd*, $J = 2.3, 11.3$, H_A–C(6′)); 3.73 (*dd*, $J = 3.9, 11.2$, H_B–C(6′)); 3.68–3.60 (*m*, H–C(3′), H–C(4′)); 3.51 (*t*, $J \approx 8.1$, H–C(2′)); 3.44 (*s*, MeO); 3.45–3.42 (*m*, H–C(5′)); 3.27 (*dd*, $J = 5.2, 10.3$, H_A–C(6)); 3.23 (*dd*, $J = 3.0, 10.3$, H_B–C(6)); 2.05 (*s*, Ac); 1.77 (*s*, Ac). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.87 (*s*); 168.99 (*s*); 143.64 (3*s*); 138.60 (*s*); 138.42 (*s*); 138.23 (*s*); 138.11 (*s*); 128.63–126.84 (several *d*); 103.47 (*d*); 99.86 (*d*); 86.53 (*s*); 84.50 (*d*); 81.84 (*d*); 77.55 (*d*); 75.47 (*t*); 75.33 (*d*); 75.26 (*d*); 74.87 (*t*); 74.83 (*t*); 73.54 (*t*); 68.83 (*d* and *t*); 66.99 (*d*); 65.80 (*d*); 62.84 (*t*); 55.26 (*q*); 20.81 (*q*); 20.47 (*q*). Anal. calc. for $C_{64}H_{66}O_{13}$ (1043.22): C 73.69, H 6.38; found: C 73.81, H 6.48.

Methyl 2,4-Di-O-acetyl-3-O-(2,3,4,6-tetra-O-benzyl-α-D-glucopyranosyl)-6-O-(triphenylmethyl)-α-D-altropyranoside (**13**). R_f (CH_2Cl_2/AcOEt 98:2) 0.46. $[\alpha]_D^{25}$ = +65.1 (*c* = 1.86, $CHCl_3$). IR ($CHCl_3$): 3060*w*, 3030*w* (sh), 3005*w*, 2930*w*, 2870*w*, 1740*s*, 1495*w*, 1450*m*, 1370*m*, 1260*m*, 1235*m*, 1195*w*, 1145*s*, 1090*s*, 1070*s*, 1045*s* (sh), 1030*w*, 950*w*, 900*w*, 860*w*, 700*s*, 630*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.50–7.12 (*m*, 35 arom. H); 5.21 (*dd*, *J* = 3.6, 8.7, H–C(4)); 5.16 (*dd*, *J* = 1.8, 4.2, H–C(2)); 5.09 (*d*, *J* = 3.4, H–C(1′)); 4.97 (*d*, *J* = 10.9, PhC*H*); 4.83 (*d*, *J* = 11.1, PhC*H*); 4.80 (*d*, *J* = 12.2, PhC*H*); 4.79 (*d*, *J* = 10.9, PhC*H*); 4.74 (*d*, *J* = 1.6, H–C(1)); 4.64 (*d*, *J* = 11.9, PhC*H*); 4.54 (*d*, *J* = 12.1, PhC*H*); 4.47 (*d*, *J* = 11.1, PhC*H*); 4.39 (*d*, *J* = 12.1, PhC*H*); 4.32–4.28 (*m*, H–C(5)); 4.13 (br. *t*, *J* ≈ 3.8, H–C(3)); 3.98 (*t*, *J* ≈ 9.2, H–C(3′)); 3.71 (br. *td*, *J* ≈ 2.4, 9.9, H–C(5′)); 3.65 (*dd*, *J* = 3.2, 10.6, H_A–C(6′)); 3.64 (*t*, *J* ≈ 9.4, H–C(4′)); 3.56 (*dd*, *J* = 3.4, 9.6, H–C(2′)); 3.51 (*dd*, *J* = 1.6, 10.5, H_B–C(6′)); 3.36 (*s*, MeO); 3.29 (*dd*, *J* = 2.6, 10.2, H_A–C(6)); 3.21 (*dd*, *J* = 5.1, 10.2, H_B–C(6)); 2.10 (*s*, Ac); 1.77 (*s*, Ac). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.91 (*s*); 169.71 (*s*); 143.88 (3*s*); 138.90 (*s*); 138.59 (2*s*); 137.97 (*s*); 128.80–127.02 (several *d*); 99.38 (*d*); 96.26 (*d*); 86.64 (*s*); 81.42 (*d*); 79.92 (*d*); 77.43 (*d*); 75.47 (*t*); 74.85 (*t*); 73.49 (*t*); 72.26 (*d*); 72.20 (*t*); 70.99 (*d*); 69.33 (*d*); 68.35 (*t*); 67.65 (*d*); 67.10 (*d*); 63.06 (*t*); 55.39 (*q*); 21.01 (*q*); 20.83 (*q*). Anal. calc. for $C_{64}H_{66}O_{13}$ (1043.22): C 73.69, H 6.38; found: C 73.66, H 6.25.

Table 3. *Selected ^{1}H-NMR* (400 MHz, $CDCl_3$) *Chemical Shifts* [ppm] *and Coupling Constants* [Hz] *for* **4** *and* **11–16**

H or *J*	**4**	**4**[a])	**11**[b])	**12**[b])	**13**	**14**	**15**	**16**
H–C(1)	4.72	4.47	4.84	4.79	4.74	4.74	4.73	4.69
H–C(2)	3.95	3.59	3.89	3.97	5.16	5.27	5.01	5.09
H–C(3)	3.90	3.56	5.36	5.50	4.13	4.24	5.36	5.18
H–C(4)	3.78	3.44	5.33	5.35	5.21	5.18	4.14	4.35
H–C(5)	3.71	3.95	4.16	4.19	4.30	4.34	4.42–4.38	4.23
H_A–C(6)	3.50	3.25	3.26	3.27	3.29	3.29	3.50	3.52
H_B–C(6)	3.42	3.03	3.20	3.23	3.21	3.18	3.18	3.30
H–C(1′)			5.06	4.50	5.09	4.34	5.00	4.30
H–C(2′)			3.58	3.51	3.56	3.49	3.45	3.24
H–C(3′)			4.01	3.68–3.60	3.98	3.64	3.57–3.52	3.36
H–C(4′)			3.65	3.68–3.60	3.64	3.57	3.57–3.52	3.525
H–C(5′)			3.91	3.45–3.42	3.71	3.38	3.57–3.52	3.28–3.23
H_A–C(6′)			3.75	3.76	3.65	3.73	3.35	3.68–3.61
H_B–C(6′)			3.67	3.73	3.51	3.73	3.31	3.68–3.61
MeO	3.51	3.39	3.41	3.44	3.36	3.46	3.47	3.42
AcO			2.01	2.05	2.10	2.11	2.10	2.07
			1.83	1.77	1.77	1.66	1.93	2.00
J(1,2)	1.7	1.6	2.3	1.8	1.7	1.3	0.8	1.8
J(2,3)	3.8	4.1	4.8	4.4	4.2	3.8	3.8	4.7
J(3,4)	3.5	3.3	3.7	3.6	3.5	3.5	3.0	3.5
J(4,5)	9.9	9.5	8.2	9.0	8.7	9.7	9.6	8.5
J(5,6*A*)	3.0	1.8	5.8	5.1	2.6	2.3	2.1	2.6
J(5,6*B*)	6.1	7.8	2.7	3.0	5.1	5.1	5.5	5.0
J(6*A*,6*B*)	10.2	9.6	10.1	10.3	10.2	10.1	10.1	10.0
J(1′,2′)			3.6	7.7	3.4	7.5	3.6	7.7
J(2′,3′)			9.6	8.5	9.6	8.6	9.1	9.1
J(3′,4′)			9.0	[c])	9.0	9.0	[c])	9.1
J(4′,5′)			10.0	[c])	9.8	9.6	[c])	9.4
J(5′,6′*A*)			3.6	2.3	3.2	3.0	1.4	[c])
J(5′,6′*B*)			1.9	3.9	1.6	3.0	2.0	[c])
J(6′*A*,6′*B*)			10.7	11.2	10.5	[c])	10.6	[c])

[a]) In (D_6)DMSO.

[b]) Assignment corroborated by selective homonuclear decoupling experiments.

[c]) Not determined.

Table 4. *Selected* ^{13}C*-NMR* (50 MHz, $CDCl_3$) *Chemical Shifts* [ppm] *for* **4** *and* **11**–**16**

Compound	**4**[a])	**11**	**12**	**13**	**14**	**15**	**16**
C(1)	100.7	100.29	99.86	99.38	99.07	98.43	98.71
C(2)	69.1	74.22	75.26[b])	69.33	71.24	69.31[b])	70.15[b])
C(3)	70.9	68.54[b])	68.83[c])	72.26	73.30	66.77[b])	69.76[b])
C(4)	65.0	66.23	65.80	67.10[b])	66.14	65.99[b])	69.49[b])
C(5)	68.5	67.64[b])	66.99[c])	67.65[b])	67.10	65.28[b])	68.29[b])
C(6)	64.2	63.15	62.84	63.06	62.61	63.67	62.72
C(1′)		97.56	103.47	96.26	104.35	92.51	102.54
C(2′)		79.42	81.84	79.92	81.47	78.79	81.64
C(3′)		81.61	84.50	81.42	84.38	81.78	84.37
C(4′)		77.57	77.55	77.43	77.43	77.38	77.59
C(5′)		70.95	75.33[b])	70.99	75.12	70.63	74.88
C(6′)		68.54	68.83	68.35	68.76	68.17	68.70
MeO	55.8	55.33	55.26	55.39	55.24	55.16	55.31
AcO		169.99	169.87	169.91	169.83	170.24	170.27
		169.18	168.99	169.71	169.33	169.30	169.38
		20.84	20.81	21.01	20.92	20.89	20.97
		20.57	20.47	20.83	20.54	20.81	20.78

[a]) Assignments based upon ^1H,^{13}C HMQC spectrum.
[b])[c]) Assignments may be interchanged.

*Methyl 2,4-Di-*O*-acetyl-3-*O*-(2,3,4,6-tetra-*O*-benzyl-β-*D*-glucopyranosyl)-6-*O*-(triphenylmethyl)-α-*D*-altropyranoside* (**14**). R_f (CH_2Cl_2/AcOEt 2:1) 0.32. $[\alpha]_D^{25} = +45.7$ ($c = 1.99$, $CHCl_3$). IR ($CHCl_3$): 3060*w*, 3010*w*, 2930*w*, 2870*w*, 1740*s*, 1495*w*, 1453*m*, 1373*m*, 1360*m* (sh), 1305*w*, 1235*m*, 1195*w*, 1145*s*, 1095*s*, 1070*s*, 1030*s*, 1005*m* (sh), 950*w*, 905*w*, 700*s*, 635*w*. ^1H-NMR (400 MHz, $CDCl_3$): 7.48–7.15 (*m*, 35 arom. H); 5.27 (*dd*, $J = 1.3, 3.8$, H–C(2)); 5.18 (*dd*, $J = 3.5, 9.7$, H–C(4)); 4.95 (*d*, $J = 11.3$, PhC*H*); 4.91 (*d*, $J = 11.1$, PhC*H*); 4.78 (*d*, $J = 10.5$, PhC*H*); 4.76 (*d*, $J = 10.8$, PhC*H*); 4.74 (*d*, $J = 11.2$, PhC*H*); 4.74 (br. *s*, H–C(1)); 4.64 (*d*, $J = 12.1$, PhC*H*); 4.57 (*d*, $J = 10.9$, PhC*H*); 4.54 (*d*, $J = 12.1$, PhC*H*); 4.34 (*d*, $J = 7.5$, H–C(1′)); 4.36 (*ddd*, $J = 2.2, 5.0, 9.6$, H–C(5)); 4.24 (br. *t*, $J \approx 3.6$, H–C(3)); 3.73 (*d*, $J = 3.0$, 2 H–C(6′)); 3.64 (*t*, $J \approx 8.9$, H–C(4′)); 3.57 (*t*, $J \approx 8.9$, H–C(3′)); 3.49 (*dd*, $J = 7.6, 8.5$, H–C(2′)); 3.46 (*s*, MeO); 3.38 (*td*, $J \approx 3.0, 9.6$, H–C(5′)); 3.29 (*dd*, $J = 2.3, 10.1$, H_A–C(6)); 3.18 (*dd*, $J = 5.1, 10.1$, H_B–C(6)); 2.11 (*s*, Ac); 1.66 (*s*, Ac). ^{13}C-NMR (50 MHz, $CDCl_3$): 169.83 (*s*); 169.33 (*s*); 143.76 (3*s*); 138.64 (*s*); 138.44 (*s*); 138.39 (*s*); 138.09 (*s*); 128.64–126.88 (several *d*); 104.35 (*d*); 99.07 (*d*); 86.33 (*s*); 84.38 (*d*); 81.47 (*d*); 77.43 (*d*); 75.39 (*t*); 75.12 (*d*); 74.85 (*t*); 74.11 (*t*); 73.62 (*t*); 73.30 (*d*); 71.24 (*d*); 68.76 (*t*); 67.10 (*d*); 66.14 (*d*); 62.61 (*t*); 55.24 (*q*); 20.92 (*q*); 20.54 (*q*). Anal. calc. for $C_{64}H_{66}O_{13}$ (1043.22): C 73.69, H 6.38; found: C 73.64, H 6.52.

*Methyl 2,3-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-α-*D*-glucopyranosyl)-6-*O*-(triphenylmethyl)-α-*D*-altropyranoside* (**15**). R_f (hexane/AcOEt 2:1) 0.43. $[\alpha]_D^{25} = +41.9$ ($c = 1.77$, $CHCl_3$). IR ($CHCl_3$): 3060*w*, 3030*w* (sh), 3010*w*, 2930*m*, 2870*w*, 1745*s*, 1495*w*, 1455*m*, 1370*m*, 1245*m*, 1235*s*, 1198*w* (sh), 1145*s*, 1100*s* (sh), 1088*s* (sh), 1070*s* (sh), 1045*s*, 1030*s* (sh), 950*w*, 905*w*, 860*w*, 700*s*, 635*w*. ^1H-NMR (400 MHz, $CDCl_3$): 7.51–7.06 (*m*, 35 arom. H); 5.36 (*t*, $J \approx 3.3$, H–C(3)); 5.01 (*dd*, $J = 0.8, 3.8$, H–C(2)); 5.00 (*d*, $J = 3.6$, H–C(1′)); 4.80 (*d*, $J = 10.9$, PhC*H*); 4.76 (*d*, $J = 10.8$, PhC*H*); 4.73 (br. *s*, H–C(1)); 4.68 (*d*, $J = 10.9$, PhC*H*); 4.62 (*d*, $J = 12.1$, PhC*H*); 4.57 (*d*, $J = 12.1$, PhC*H*); 4.51 (*d*, $J = 12.1$, PhC*H*); 4.40 (*d*, $J = 10.7$, PhC*H*); 4.42–4.38 (*m*, H–C(5)); 4.35 (*d*, $J = 12.1$, PhC*H*); 4.14 (*dd*, $J = 3.0, 9.6$, H–C(4)); 3.57–3.52 (*m*, H–C(3′), H–C(4′), H–C(5′)); 3.50 (*dd*, $J = 2.1, 10.1$, H_A–C(6)); 3.47 (*s*, MeO); 3.45 (*dd*, $J = 3.5, 9.1$, H–C(2′)); 3.35 (*dd*, $J = 1.4, 10.6$, H_A–C(6′)); 3.31 (*dd*, $J = 2.0, 10.6$, H_B–C(6′)); 3.18 (*dd*, $J = 5.5, 10.1$, H_B–C(6)); 2.10 (*s*, Ac); 1.93 (*s*, Ac). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.24 (*s*); 169.30 (*s*); 144.02 (3*s*); 138.88 (*s*); 138.44 (*s*); 137.99 (*s*); 137.80 (*s*); 128.82–126.84 (several *d*); 98.43 (*d*); 92.51 (*d*); 86.74 (*s*); 81.78 (*d*); 78.79 (*d*); 77.38 (*d*); 75.52 (*t*); 75.09 (*t*); 73.44 (*t*); 72.83 (*t*); 70.63 (*d*); 69.31 (*d*); 68.17 (*t*); 66.77 (*d*); 65.99 (*d*), 65.28 (*d*); 63.67 (*t*); 55.16 (*q*, MeO); 20.89 (*q*); 20.81 (*q*). Anal. calc. for $C_{64}H_{66}O_{13}$ (1043.22): C 73.69, H 6.38; found: C 73.56, H 6.58.

*Methyl 2,3-Di-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-β-*D*-glucopyranosyl)-6-*O*-(triphenylmethyl)-α-*D*-altropyranoside* (**16**). R_f (hexane/AcOEt 2:1) 0.51. $[\alpha]_D^{25} = +18.6$ ($c = 0.70$, $CHCl_3$). IR ($CHCl_3$): 3060*w*, 3000*w*,

2920*w* (br.), 2870*w*, 1740*s*, 1600*w*, 1495*w*, 1450*m*, 1370*m*, 1305*w*, 1248*s*, 1145*s*, 1095*s* (sh), 1070*s*, 1030*s* (sh), 1015*s* (sh), 970*w* (sh), 950*w*, 900*w*, 700*s*, 665*w*, 645*w*, 630*w*. ^{1}H-NMR (400 MHz, $CDCl_3$): 7.47–7.10 (*m*, 35 arom. H); 5.18 (br. *t*, $J \approx 4.1$, H–C(3)); 5.09 (*dd*, $J = 1.8, 4.7$, H–C(2)); 4.81 (*d*, $J = 11.0$, PhC*H*); 4.76 (*d*, $J = 10.9$, PhC*H*); 4.71 (*d*, $J = 11.1$, PhCH); 4.69 (br. *s*, H–C(1)); 4.60 (*d*, $J = 12.3$, PhC*H*); 4.54 (*d*, $J = 12.4$, 2 PhC*H*); 4.51 (*d*, $J = 12.6$, PhC*H*); 4.45 (*d*, $J = 11.3$, PhC*H*); 4.35 (*dd*, $J = 3.5, 8.5$, H–C(4)); 4.30 (*d*, $J = 7.7$, H–C(1′)); 4.23 (*ddd*, $J = 2.6, 4.8, 8.5$, H–C(5)); 3.68–3.61 (*m*, 2 H–C(6′)); 3.525 (*t*, $J = 9.4$, H–C(4′)); 3.52 (*dd*, $J \approx 2.8, 10.0$, H_A–C(6)); 3.42 (*s*, MeO); 3.36 (*t*, $J = 9.1$, H–C(3′)); 3.30 (*dd*, $J = 5.0, 10.0$, H_B–C(6)); 3.28–3.23 (*m*, H–C(5′)); 3.24 (*dd*, $J = 7.8, 9.1$, H–C(2′)); 2.07 (*s*, Ac); 2.00 (*s*, Ac). ^{13}C-NMR (50 MHz, $CDCl_3$): 170.27 (*s*); 169.38 (*s*); 143.82 (3*s*); 138.67 (*s*); 138.45 (*s*); 138.23 (*s*); 138.19 (*s*); 128.75–127.02 (several *d*); 102.54 (*d*); 98.71 (*d*); 86.52 (*s*); 84.37 (*d*); 81.64 (*d*); 77.59 (*d*); 75.37 (*t*); 74.88 (*t* and *d*); 74.31 (*t*); 73.26 (*t*); 70.15 (*d*); 69.76 (*d*); 69.49 (*d*); 68.70 (*t*); 68.29 (*d*); 62.72 (*t*); 55.31 (*q*); 20.97 (*q*); 20.78 (*q*). Anal. calc. for $C_{64}H_{66}O_{13}$ (1043.22): C 73.69, H 6.38; found: C 73.40, H 6.52.

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