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Iodine–sodium cyanoborohydride-mediated reductive ring opening of 4,6-*O*-benzylidene acetals of hexopyranosides ☆

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ABSTRACT

A quick, efficient and convenient method for the regiospecific reductive ring opening of 4,6-*O*-benzylidene acetals of *O*-/*S*-alkyl/aryl glycosides of mono- and disaccharides, leading to the exclusive formation of the corresponding 6-*O*-benzyl ethers, using sodium cyanoborohydride in the presence of molecular iodine, is reported. It has been observed that common protecting groups such as ethers and esters are well tolerated under the conditions studied. The reaction was proved unsuccessful when applied to a glucosamine-derived benzylidene acetal.

Protection of a pair of appropriately oriented 1,2- or 1,3-hydroxyls as cyclic acetals, in particular as the *O*-benzylidene and the *O*-isopropylidene acetals, is one of the most frequently used reactions in the chemistry of polyhydroxylic compounds such as carbohydrates and cyclitols. This is because the acetals are highly stable under alkaline/basic conditions and their removal can be achieved at will using acidic reagents and therefore extremely useful in multi-step synthetic operations involving such substances. Molecular iodine,[2,3] just as many other Lewis (or other) acids, has been known to be of significant use in the formation[2,4] and removal[3,4] of cyclic acetals. Reductive ring opening of benzylidene acetals, another important reaction in this context, has been of great value in the selective manipulations of neighbouring hydroxyls in polyols.[5–19] Most of the reagent systems known for this transformation suffer from various practical limitations being sensitive to either air or moisture.[18] As iodine does not suffer from such limitations in laboratory handling, its use was examined in the reductive ring opening of 4,6-*O*-benzylidene hexosides as necessitated during the synthetic work on-going in our laboratory. The results are summarized below.

When a solution of methyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-α-D-glucopyranoside (**1**) dissolved in anhydrous acetonitrile was treated with sodium cyanoborohydride in the presence of iodine facile reductive cleavage occurred and the product obtained was isolated in 97% yield after aqueous workup and purification by chromatographic filtration (see Scheme 1 and entry 1, Table 1). The reaction was fast (complete within 5 min of the addition of iodine which was carried out over a span of 15 min) and was highly efficient as is evident from the yield of the isolated product. The product was unambiguously characterized as methyl 2,3-di-*O*-acetyl-6-*O*-benzyl-α-D-glucopyranoside (**2**)[9] by NMR spectroscopy. Upon acetylation (Ac_2O in pyridine) compound **2** afforded a tri-*O*-acetate as expected and was unambiguously characterized as methyl 2,3,4-tri-*O*-acetyl-6-*O*-benzyl-α-D-glucopyranoside (**3**)[20] establishing the authenticity of the 6-*O*-benzyl ether **2**. The downfield shift observed in the H-4 chemical shift in the ^{1}H NMR spectrum of compound **3** [δ 4.95 (t, $J_{2,3} = J_{3,4} = 9.6$ Hz, 1H, H-4] in comparison to its precursor **2** [δ 3.65 (t, $J_{2,3} = J_{3,4} = 9.6$ Hz, 1H, H-4] was on the lines expected. The three three-proton singlets observed at δ 2.07, 2.00 and 1.91 were also consistent with the expected result of acetylation of **2** (for which only two three-proton singlets were observed, at δ 2.09 and 2.05). Clearly, addition of iodine to a solution of the benzylidene acetal **1** in acetonitrile must result in the complexation of the halogen with the electron pair on O-4 of the glucose residue as shown in **G1** (Scheme 1). Subsequent cleavage of the *O*-4-benzylidene–carbon bond would give rise to the resonance stabilized (**G3**) intermediate **G2**. Reaction of the hydride moiety at the benzylidene carbon would then lead, after an aqueous work-up, to the 6-*O*-benzyl ether **2** with a free OH group on C-4. The mechanism is analogous to the H^+-mediated reductive ring opening of benzylidene ring reported by Garegg and Hultberg (Table 2, entry 2).[8] Protic acid-catalyzsed reductive ring opening of **1** to give the 6-*O*-benzyl ether **2** has also been reported by others[9,10] but using Et_3SiH as the hydride donor reagent in the presence of either TFA[9] or TfOH[10] (Table 2, entry 3) although it was noted that in the former instance the analogous

☆ See Ref. 1.

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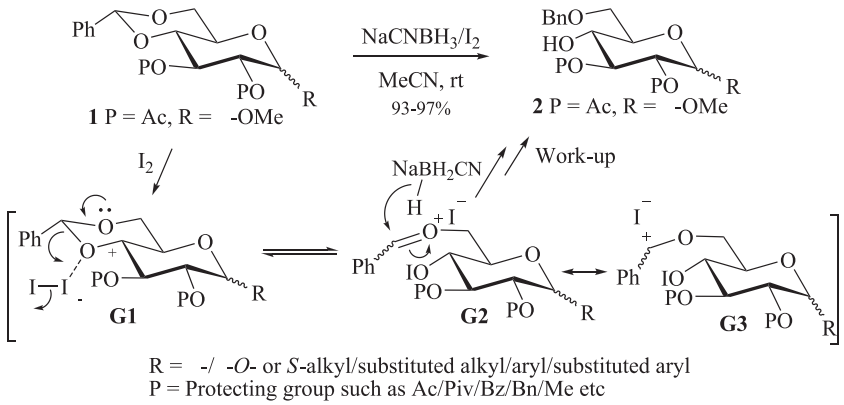
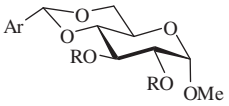
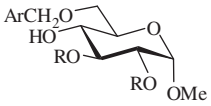
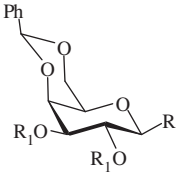
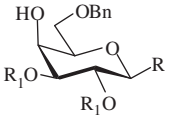
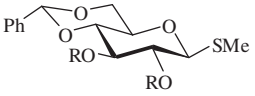
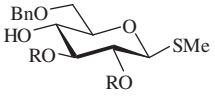
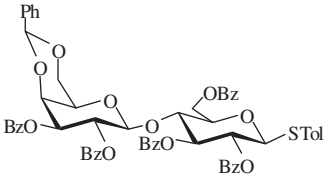
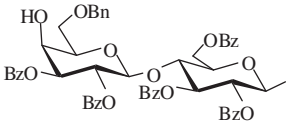
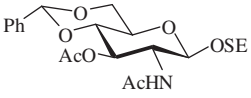


Scheme 1. Regiospecific reductive ring opening of 4,6-*O*-benzylidene glucosides.

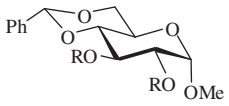
Table 1
Regiospecific reductive ring opening of benzylidene acetals using sodium cyanoborohydride-iodine system[a]

Entry	Substrate	Product	Yield, % (Time, h)[c]	Reference (acetylated product)
				
1	**1**, R = Ac, Ar = Ph	**2**, R = Ac, Ar = Ph	97	9[28]
2	**4**, R = Bn, Ar = Ph	**5**, R = Bn, Ar = Ph	95	12[29]
3	**6**, R = Me, Ar = Ph	**7**, R = Me, Ar = Ph	97	23[30]
4	**8**, R = Bz, Ar = Ph	**9**, R = Bz, Ar = Ph	90	12
5	**10**, R = Piv, Ar = Ph	**11**, R = Piv, Ar = Ph	95	—
6	**12**, R = Ac, Ar = *p*-MeO-Ph	**13**, R = Ac, Ar = *p*-MeO-Ph	93	11[28]
				
7	**14**, R = OMe, R_1 = Ac	**15**, R = OMe, R_1 = Ac	94	9[31]
8	**16**, R = OMe, R_1 = Bn	**17**, R = OMe, R_1 = Bn	95	24[32]
9[b]	**18**, R = O-*p*-O_2N-Ph, R_1 = Ac	**19**, R = O-*p*-O_2N-Ph, R_1 = Ac	94 (2)	25
10	**20**, R = SPh, R_1 = Bz	**21**, R = SPh, R_1 = Bz	87 (1)	26, 33
				
11	**22**, R = Ac	**23**, R = Ac	94	—[27c]
12	**24**, R = Bn	**25**, R = Bn	94	27c[27c]
13[b]	 **26**	 **27**	74 (2)	—
14	 **28**, SE = $CH_2CH_2SiMe_3$	No reaction	Nil	—

[a] Reactions were carried with acetal: $NaBH_3CN/I_2$ in the mole ratio 1:3.5:5 in MeCN at rt.
[b] Reactions were scaled up to 12 g.
[c] Addition of I_2 was carried out over 15 min and the reaction was complete in 5 min thereafter unless otherwise specified.

galactopyranoside-derived acetals failed to react.[9] Likewise, the $BF_3{\cdot}Et_2O$-mediated regioselective reductive ring opening of **1** using Bu_3SnH also has been effective for the regioselective formation of the ether **2** (Table 2, entry 4) although accompanied to some extent by the corresponding 4,6-diol resulting from the partial hydrolytic cleavage of the acetal **1**.

Table 2
Regioselective reductive ring opening of methyl 4,6-*O*-benzylidene glucosides



Entry No	R	Hydride reagent	Acid catalyst	Reaction		Ether obtained
				Time	Yield (%)	
1	H	$LiAlH_4$	$AlCl_3$	6 h	36	4-*O*-Bn:6-*O*-Bn = 4:1; some 4,6-diol also obtained as hydrolytic product[5]
	Bn			40 h	64	4-*O*-Bn only[5]
	Bn			2 h (reflux)	94	4-*O*-Bn only[6]
2	Bn	$NaBH_3CN$	HCl	10 min (0 °C)	81	6-*O*-Bn only[8]
	Bz			–do–	95	6-*O*-Bn only[8]
3[*]	Ac	Et_3SiH	TFA	2–5 h (0 °C→rt)	95	6-*O*-Bn only; the β-D-Gal*p* analogues did not react[9]
	Bn		TFA	–do–	80	6-*O*-Bn only; β-D-Gal*p* analogues did not react[9]
	Ac		TfOH	1–3 h (−78 °C)	90	6-*O*-Bn only[10]
	Bn		$PhBCl_2$	–do–	91	4-*O*-Bn only[10]
	Bn		$Cu(OTf)_2$	15 h	62	6-*O*-Bn only; use of Et_3SiD led to the 4-*O*-CHDPh ether[12]
4	Ac	Bu_3SnH	$BF_3{\cdot}Et_2O$	0.5 h	62	6-*O*-Bn only; some 4,6-diol also obtained as hydrolytic product[11]
5	H	$BH_3{\cdot}THF$	Bu_2BOTf	1 h (0 °C)	91	4-*O*-Bn only[13]
	Bn			–do–	87	4-*O*-Bn only[13]
	Piv			–do–	88	4-*O*-Bn only[13]
	Bn		$V(O)(OTf)_2/M(OTf)_3$ [M = Sc/Pr/Nd/Sm/Eu/Gd]	3 h	94	4-*O*-Bn only[15]
	Bn		$Cu(OTf)_2$	0.75–27 h	70–95	4-*O*-Bn only; use of $BD_3{\cdot}THF$ led to the 4-*O*-CHDPh ether[12]
	Bn		TMSOTf	1 h	96	4-*O*-Bn only[16]
	H		$CoCl_2$	10 min	85	4-*O*-Bn only; some 4,6-diol also obtained as hydrolytic product[17]
	Bn				Quant	4-*O*-Bn only[17]
	Ac				91	4-*O*-Bn only; some 4,6-diol also obtained as hydrolytic product[17]
6	Ac	$NaBH_3CN$	I_2	20 min	97	6-*O*-Bn only
	Bn		(Current method)	–do–	95	6-*O*-Bn only
	Bz			–do–	90	6-*O*-Bn only
	Piv			–do–	95	6-*O*-Bn only
7	Bn	$BH_3{\cdot}NMe_3$	$AlCl_3$ (in THF)	—	71	6-*O*-Bn only[19]
		$BH_3{\cdot}NMe_3$	$AlCl_3$ (in PhMe)	—	50	4-*O*-Bn only[19]

[a] $Et_3SiH–BF_3{\cdot}Et_2O–TFA$ system has been reported to be effective for the conversion of glycosides to anhydroalditols.[21]

Thus it appears that irrespective of the bulkiness of the hydride donor reagent, the use of a relatively small acidic catalyst invariably leads to the formation of the 6-*O*-benzyl ether selectively following a path as depicted in Scheme 1. In contrast, as can be seen from the literature, use of a bulky Lewis acid such as $AlCl_3$,[5,6] $PhBCl_2$,[10] Bu_2BOTf,[13] $V(O)(OTf)_2$,[15] $M(OTf)_3$[15] (where M = Sc/Pr/Nd/Sm/Eu/Gd), $Cu(OTf)_2$,[11] TMSOTf[16] or $CoCl_2$,[17] almost always leads to the selective formation of the 4-*O*-benzyl ether analogue (Table 2, entry 5). Clearly, under these conditions the bulky Lewis acid, owing to a greater steric requirement, complexes with the O-6 (instead of the O-4 as shown in Scheme 1 in the case of I_2) of the hexopyranoside acetal as a consequence of which the cleavage of the *O*-6-benzylidene–carbon bond takes place (in contrast to the *O*-4-benzylidene-carbon bond cleavage depicted in Scheme 1) leading to the formation of the 4-*O*-benzyl ether following the inevitable reaction of the hydride reagent at the benzylidene carbon and the subsequent aqueous work-up. It can also be observed that under such circumstances the size of the reducing agent is not of a significant consequence (as can be seen from the fact that both $LiAlH_4$ and BH_3 give rise to the 4-*O*-benzyl ether selectively (Table 2, entries 1 and 5).

This has been further demonstrated in the mechanistic investigation of the reaction of acetal **4** by Johnsson et al.[19a] wherein they showed that the reductive ring opening by $BH_3{\cdot}NMe_2$ in the presence of $AlCl_3$ (in which the latter acts as an activating agent for the boron complex resulting in BH_3 serving as the actual Lewis acid catalyst in the reaction) gives rise to product **5** (the 6-*O*-Bn ether) in contrast to the formation of the analogous 4-*O*-Bn derivative when performed using the $BH_3{\cdot}THF–AlCl_3$ system,[19a] or alternatively, as had been previously shown, using $BH_3{\cdot}NMe_2$ in the presence of $AlCl_3$ in toluene.[19b] Furthermore, even the bulkiness of the substituent on O-3, in fact, does not seem to be, in contrast to what has been considered during the early works,[6] as important as the factors described above in imparting directive influence on the reductive ring opening of 4,6-*O*-benzylidene acetals of aldohexopyranosides. Thus, on extending the reaction of sodium cyanoborohydride in the presence of iodine to glucopyranoside derivatives **4**, **6**, **8**, and **10** bearing O-3 substituents of varying steric bulk (ranging from methyl to benzyl/benzoyl to pivaloyl) led in all cases to the exclusive formation of the respective 6-*O*-benzyl ethers **5**, **7**, **9**, and **11** in excellent yields (Table 1, entries 2–5). A comparison of the results obtained on the reductive ring opening of compounds **1**, **4**, **8** and **10** in the presence of iodine with those from the literature given in Table 2 shows that the $I_2–NaBH_3CN$ method is both quick and efficient, like many of the methods reported. But unlike the reagents such as anhydrous HCl (a gas), $AlCl_3$, $BF_3{\cdot}Et_2O$, TMSOTf as well as the metal triflates reported (moisture sensitive), iodine is an easy-to-handle reagent and is not moisture sensitive. The applicability of the method to the regioselective ring opening of the *p*-methoxybenzylidene acetals became evident from the reaction of **12** which gave the expected 6-*O*-*p*-methoxybenzyl ether **13**[11] in 93% yield (Table 1, entry 6).

When methyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-β-D-galactopyranoside (**14**), as also its *p*-nitrophenyl analogue **18**, were subjected to the above conditions for the reductive ring opening, the corresponding 6-*O*-Bn ethers **15** and **19** were obtained in excellent yield (94% in each case) after purification (entries 7 and 9, respectively, Table 1). In the latter case, as the product **19** was required as starting material for another synthetic work in progress in our laboratory, the reaction was also scaled up to the preparative scale (12 g) very successfully. Methyl 2,3-di-*O*-benyl-4,6-*O*-benzylidene-β-D-galactopyranoside (**16**) when subjected to the reaction also gave the expected 6-*O*-benzyl galactoside derivative **17** in 95% yield (Table 1, entry 8).

As molecular iodine is known to be capable of activating thioglycoside donors in glycosylation reactions, categories of both 'armed' as well as 'disarmed' thioglycoside-substrates were subjected to the reductive ring opening reaction conditions subsequently. Thus, the benzylidene acetals derived from the phenyl thiogalactoside **20** and the methyl thioglucosides **22** and **24** upon the reaction also yielded the respective 6-*O*-Bn ethers (**21**, **23** and **25**, respectively) in excellent yields proving the reductive conditions to be effective in keeping the integrity of the thioglycoside moiety intact. The signals obtained at δ 4.95 (d, $J_{1,2}$ = 10.0 Hz, 1H, H-1) and 4.59 (s, 2H, CH_2Ph) for **21**; 4.38 (d, $J_{1,2}$ = 9.6 Hz, 1H, H-1) and 2.15 (s, 3H, SCH_3) for **23**; and 4.39 (d, $J_{1,2}$ = 9.4 Hz, 1H, H-1) and 2.23 (s, 3H, SCH_3) for **25** in their respective ^{1}H NMR spectra were diagnostic of the structural elements present in them and along with other signals obtained were indeed confirmatory of the structures shown for the respective compounds.

The result obtained on the application of the reaction to the disaccharide-derived benzylidene acetal **26** was also found to be very satisfactory (Table 1, entry 13). In contrast, when the reductive benzylidene ring opening as described above was extended to the glucosamine derivative **28**, no reaction was observed even after several hours of stirring at rt. One of the noticeable differences in this case was that compound **28** had very poor solubility in acetonitrile (the solvent used for the reaction). In addition, the acetamido (amino nitrogen) functionality also seemed to hamper the reaction. It may be recalled that clear differences in the ease of iodine-catalysed acetylation of D-glucose and *N*-acetyl-D-glucosamine, using acetic anhydride as the acyl donor reagent, had been reported in which the hexose underwent acetylation distinctly faster (about 500 times or more) than its corresponding 2-acetamido-2-deoxy analogue.[22] Thus, further optimization of the reaction conditions would be required if benzylidene acetals such as **28** are to be subjected to the reaction reported here.

1. Experimental

1.1. General

All the reagents used were as purchased without purification. Solvents used for reactions were dried according to standard methods. Reactions were monitored by TLC, which was performed using 0.2 mm Merck pre-coated Silica Gel 60 F254 aluminium sheets. Compounds were detected by dipping the TLC plates in an ethanolic solution of sulphuric acid (5% v/v) and heating them thereafter. Melting points were determined on a Buchi melting point apparatus. Specific rotations were recorded on a Rudolph Research Autopol IV Polarimeter at room temperature (approximately 20–25 °C). NMR spectra were recorded on Bruker Avance DPX (300 or 400 MHz) spectrometer. ^{1}H NMR and ^{13}C NMR spectra were referenced using either residual solvent signals, or tetramethylsilane in the respective deuterated solvents. Coupling constants (*J*) are reported in Hertz. Mass spectra were recorded on MALDI (Bruker Daltonics, Ultraflex TOF/TOF) Spectrometer.

1.2. General procedure for reductive ring opening of 4,6-*O*-benzylidene acetals of hexopyranosides

To a mixture of the 4,6-*O*-benzylidene acetal derivative of the desired sugar glycoside (**1**/**4**/**6**/**8**/**10**/**12**/**14**/**16**/**18**/**20**/**22**/**24**/**26**, 1 mmol), $NaBH_3CN$ (5 mmol) and powdered molecular sieves (4 Å) taken in a round bottomed flask was added MeCN (2 mL per 100 mg of the sugar derivative; in the case of **26** THF was used as the solvent instead of MeCN) and was stirred for 5 min. Iodine (3.5 mmol) was added portion wise over a period of 15 min and the mixture was stirred until the reaction was complete (as shown by monitoring by TLC using EtOAc–hexane, 1:1 as the mobile phase). After completion of the reaction, it was diluted with dichloromethane, filtered through a Celite pad and the filtrate was washed successively with aqueous Na_2CO_3 solution (10%, w/v) and water, dried (Na_2SO_4), and was concentrated under reduced pressure to afford the respective product (**2**/**5**/**7**/**9**/**11**/**13**/**15**/**17**/**19**/**21**/**23**/**25**/**27**) in good yields. The analytically pure product was obtained either by chromatographic purification (silica gel column) or by recrystallization. The spectral data were in accordance with the expected structure and in agreement with literature values (**2**,[9] **5**,[12] **7**,[23] **9**,[12] **11**, **13**,[11] **15**,[9] **17**,[24] **19**[25] and **21**,[26,33] **23**, **25**,[27] **27**); and the data have been reported here only for the compounds for which they have not been reported before. Also, in all the cases the products obtained were subjected to acetylation by acetic anhydride in pyridine and the derived products were further characterized, in particular, to observe the down field shift of the H-4 chemical shift upon the expected O-acetylation to ensure the authenticity of the regioselective product obtained in the reductive ring opening. The literature references for the acetylated products obtained in this study have been given in Table 2.

1.3. Methyl,-2,3-di-*O*-acetyl-6-*O*-benzyl–D-glucopyranoside (2)[9]

δ_H (300 MHz, $CDCl_3$): 7.34 (m, 5H, Ar-H), 5.27 (t, 1H, *J* = 9.3 Hz, H-3), 4.91–4.85 (m, 2H, H-1, H-2), 4.59 (q, 2H, *J* = 12.0 Hz, $ArCH_2$), 3.79–3.68 (m, 4H, H-4, H-5, H-$6_{a,b}$), 3.39 (s, 3H, CH_3), 2.11, 2.08 (2s, 6H, 2 × $COCH_3$).

1.4. Methyl 6-*O*-benzyl-2,3-di-*O*-pivaloyl–D-glucopyranoside (11)

Mp 48.0 °C; $[\alpha]_D$ +46.8 (*c* 1, $CHCl_3$); δ_H (300 MHz, $CDCl_3$): 7.34 (m, 5H, Ar-H), 5.34 (t, 1H, *J* = 9.5 Hz, H-3), 4.92 (d, 1H, *J* = 3.6 Hz, H-1), 4.83 (dd, 1H, *J* = 3.6 Hz, *J* = 10.2, H-2), 4.61 (q, 2H, *J* = 12.0 Hz, $ArCH_2$), 3.82–3.71 (m, 3H, H-4, H-5, H-6), 3.37 (s, 3H, CH_3), 1.19, 1.17 (2s, 18H, 2 × $C(CH_3)_3$). Anal. Calcd for $C_{24}H_{36}O_8$ (452.24): C, 63.70; H, 8.02; Found: C, 63.71; H, 8.02.

1.5. Methyl 2,3-di-*O*-acetyl-6-*O*-(*p*-methoxybenzyl)–D-glucopyranoside (13)[11]

δ_H (300 MHz, $CDCl_3$): 7.29 (d, 2H, *J* = 8.1 Hz, Ar-H), 6.93 (d, 2H, *J* = 8.1 Hz, C_6H_4), 5.33 (t, 1H, *J* = 9.6 Hz, H-3), 4.90–4.78 (m, 2H, H-1, H-2), 4.54 (s, 2H, $ArCH_2$), 3.80–3.53 (m, 5H, H-4, H-5, CH_3), 3.41–3.33 (m, 5H, H-$6_{a,b}$, CH_3), 2.08, 2.06 (2s, 6H, 2 × $COCH_3$).

1.6. Methyl 2,3-di-*O*-acetyl-6-*O*-benzyl–D-galactopyranoside (15)[9]

δ_H (300 MHz, $CDCl_3$): 7.32 (m, 5H, Ar-H), 5.26 (t, 1H, *J* = 9.6 Hz, H-3), 4.95 (dd, 1H, *J* = 2.8 Hz, *J* = 10.2 Hz, H-2), 4.58 (t, *J* = 12.1 Hz, 2H, $ArCH_2$), 4.39 (d, 1H, *J* = 7.9 Hz, H-1), 4.14 (s, 1H, H-4), 3.82–3.67 (m, 3H, H-5, H-$6_{a,b}$), 3.50 (s, 3H, CH_3), 2.11, 2.08 (2s, 6H, 2 × $COCH_3$).

1.7. Methyl 2,3-di-*O*-acetyl-6-*O*-benzyl-1-thio–D-glucopyranoside (23)

Oil, $[\alpha]_D$ −59.5 (c 1, $CHCl_3$); δ_H (300 MHz, $CDCl_3$): 7.33 (m, 5H, Ar-H), 5.09 (t, 1H, *J* = 9.3 Hz, H-3), 5.02 (t, 1H, *J* = 9.6 Hz, H-2),

4.59 (q, J = 11.9 Hz, 2H, $ArCH_2$), 4.38 (d, 1H, J = 9.6 Hz, H-1), 3.85–3.72 (m, 3H, H-5, H-$6_{a,b}$), 3.59 (m, 1H, H-4), 2.15 (s, 3H, SCH_3), 2.09, 2.06 (2s, 6H, $2 \times COCH_3$). Anal. Calcd for $C_{18}H_{24}O_7S$ (384.12): C, 56.24; H, 6.29. Found: C, 56.26; H, 6.30.

1.8. Methyl 2,3,6-tri-*O*-benzyl-1-thio–D-glucopyranoside (25)[27]

δ_H (300 MHz, $CDCl_3$): 7.39–7.25 (m, 15H, Ar-H), 4.94 (d, 1H, J = 11.4 Hz, $ArCH_2$), 4.89 (d, 1H, J = 10.2 Hz, $ArCH_2$), 4.81 (d, 1H, J = 11.7 Hz, $ArCH_2$), 4.72 (d, 1H, J = 10.7 Hz, $ArCH_2$), 4.61 (t, 2H, J = 10.5 Hz, $ArCH_2$), 4.39 (d, 1H, J = 9.4 Hz, H-1), 3.75 (d, 2H, J = 4.5 Hz, H-$6_{a,b}$), 3.64 (t, 1H, J = 9.0 Hz, H-3), 3.56–3.39 (m, 3H, H-2, H-4, H-5), 2.23 (s, 3H, SCH_3).

1.9. 4-Methyl-phenyl 2,3,6-tri-*O*-benzoyl-4-*O*-(2,3-di-*O*-benzoyl-6-*O*-benzyl-β-D-galactopyranosyl)-1-thio-β-D-glucopyranoside (27)

Mp 203 °C; $[\alpha]_D$ −11.2 (c 1 $CHCl_3$); δ_H (300 MHz; $CDCl_3$) 7.96–7.88 (m, 10H, Ar-H), 7.60 (t, J = 7.3 Hz, 1H, Ar-H), 7.52–7.17 (m, 21H, Ar-H, H-2 and H-6 of SPh), 6.86 (d, J = 7.9 Hz, 2H, H-3 and H-5 of SPh), 5.72 (t, J = 9.3 Hz, 1H, H-3), 5.69 (t, J = 9.4 Hz, 1H, H-2′), 5.32 (t, J = 9.7 Hz, 1H, H-2), 5.13 (dd, J = 2.8 Hz, J = 10.3 Hz, 1H, H-3′), 4.83 (d, J = 9.9 Hz, 1H, H-1), 4.72 (d, J = 7.8 Hz, 1H, H-1′), 4.61 (d, J = 10.9 Hz, 1H, H-6_a), 4.31 (dd, J = 4.9 Hz, J = 11.9 Hz, 1H, H-6_b), 4.18 (m, 3H, H-4′, $ArCH_2$), 4.06 (t, J = 9.2 Hz 1H, H-4), 3.85 (m, 1H, H-5), 3.46 (t, J = 5.7 Hz, 1H, H-5′), 3.04–2.93 (m, 2H, H-6′$_{a,b}$), 2.39 (br s, 1H, OH), 2.21 (s, 3H, Ph-CH_3); δ_C (75.47 MHz; $CDCl_3$) 166.2, 165.9, 165.7, 165.6, 138.9, 138.2, 134.4, 133.7, 133.6, 130.3, 130.2, 130.0, 129.8, 129.5, 129.3, 128.9, 128.3, 128.0, 101.9, 86.2, 78.0, 76.8, 75.2, 74.7, 73.7, 73.5, 70.9, 70.5, 67.8, 67.5, 63.1 and 21.7; MALDI-TOF MS calcd m/z 1059.137, found m/z 1098.385 ($M+K^+$), 1082.365 ($M+Na^+$). Compound **27** upon acetylation (Ac_2O/pyridine, 18 h, 27 °C) gave the corresponding 4′-*O*-acetate for which the H-4′ chemical shift was observed at δ_H 5.49 (d, $J_{3',4'}$ = 3.2 Hz).

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