2-(Trimethylsilyl)ethyl Glycosides.[1] Synthesis, Anomeric Deblocking, and Transformation into 1,2-Trans 1-*O*-Acyl Sugars

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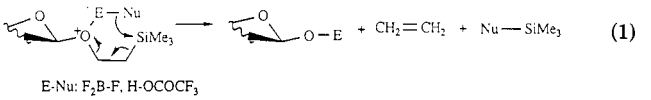
Twenty-seven mono→tetrasaccharidic 2-(trimethylsilyl)ethyl (TMSET) glycosides were synthesized by the Königs–Knorr-type method in combination with a wide range of standard reagents for glycoside synthesis and protecting-group chemistry. Variously protected TMSET glycosides were treated with BF_3·Et_2O (0.7–0.8 equiv) and different carboxylic anhydrides (1.1–15 equiv) in toluene at 22–55 °C, which gave in one step the corresponding protected 1-*O*-acyl sugars. In the majority of cases, the yields of purified compounds exceeded 90% and the anomeric configuration of the starting TMSET glycoside was conserved to a large extent (>95%) in most of the 1-O-acylated products. Unprotected and acetyl-, benzoyl-, benzyl-, dimethyl-*tert*-butylsilyl-, and phthaloyl-protected mono→tetrasaccharidic TMSET glycosides were anomerically deblocked by using trifluoroacetic acid in dichloromethane at 0–22 °C for 10–30 min. The hemiacetal products were isolated in 88–96% yield; all reagents and byproducts were volatile and easily removed.

Anomeric blocking groups are widely used in carbohydrate synthesis. They should be stable against a multitude of reagents, yet amenable to selective removal or transformation by reactions that are mild enough not to break intersaccharidic glycosidic bonds. Anomerically blocked saccharides in general use are alkyl, aryl, benzyl, allyl, and thio glycosides as well as 1-*O*-acyl sugars, ortho esters, and oxazolines. However, none of these are stable under all the various reaction conditions of oligosaccharide synthesis.

The aim of the present paper is to show that 2-(trimethylsilyl)ethyl (TMSET) glycosides[2,3] (Chart I) are compatible with most reaction conditions used in carbohydrate synthesis (Table V). This was demonstrated by submitting TMSET glycosides to numerous reaction conditions (Schemes II–IV) during the build-up of complex oligosaccharide glycosides (to be used in connection with biological investigations) followed by their transformation into 1-*O*-acyl saccharides (Table III) with retention of the anomeric configuration and also into hemiacetal sugars (Table IV). The reaction conditions were carefully designed to be practically useful and to furnish the products in high yields.

Anomeric deblocking of TMSET glycosides as presented here is based on the well-known acid-induced fragmentation of β-substituted organosilicon compounds. In the Peterson olefination reaction[4] the fragmentation of the intermediate (β-hydroxyalkyl)trimethylsilane is considered to yield trimethylsilanol and the desired olefin. Analogously, fragmentation of TMSET glycosides should yield ethylene and the corresponding trimethylsilyl (TMS) glycoside. However, the anomeric oxygen seems to associate with the acid and a positive charge is developed on the oxygen (and hence by induction, on the carbon atom β to silicon). A hard base[5] such as fluoride ion or the anion of a strong acid can react with the hard silicon center and thereby cause the TMSET group to fragment into ethylene, a TMS derivative, and a saccharidic derivative that still carries the anomeric oxygen, now substituted with the remains of the (Lewis) acid that was used (cf. eq 1). The saccharidic derivative can then react with acid anhydrides to give the corresponding 1-*O*-acyl sugar (Scheme I). With proton acids, the saccharidic derivative is a hemiacetal sugar.



(1)

E-Nu: F_2B-F, H-OCOCF$_3$

Our first objective has been to develop methods for the stereospecific transformation of TMSET glycosides into 1,2-trans 1-*O*-acyl saccharides since these are reliable glycosyl donors in Lewis acid induced glycoside synthesis.[6] We therefore carried out a preliminary investigation of the anomeric deblocking of TMSET glycosides using different acidic reagents in the presence of acetic anhydride with the aim of capturing the anomeric oxygen atom in the form of acetate before the intermediate had undergone significant anomerization.

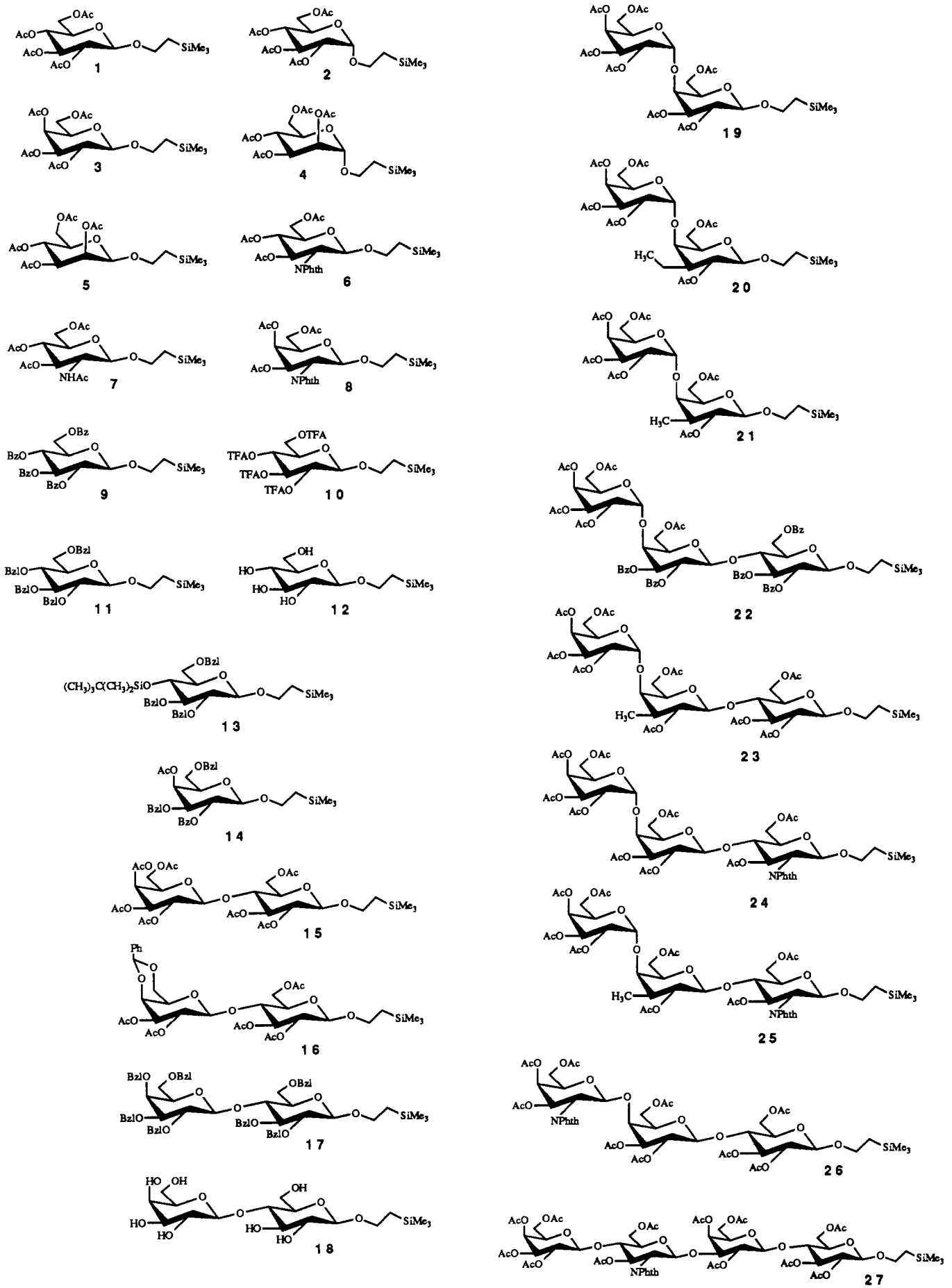
A second objective was to find a generally useful method for the preparation of protected hemiacetal sugars from the corresponding TMSET glycosides. After extensive investigation of different acids and solvents, it was found that trifluoroacetic acid in dichloromethane performs the anomeric deblocking in a very satisfactory manner.

Lipshutz et al.[2] found that $LiBF_4$ in CH_3CN caused anomeric deblocking of TMSET monosaccharide glycosides and suggested that F^-/BF_3 (formed via the equilibrium between $LiBF_4$ and LiF/BF_3) was the active species. Compounds carrying a 2-benzyloxy group were not included in the investigation. We found that addition of a small amount of trifluoroacetic anhydride (TFAA) to the

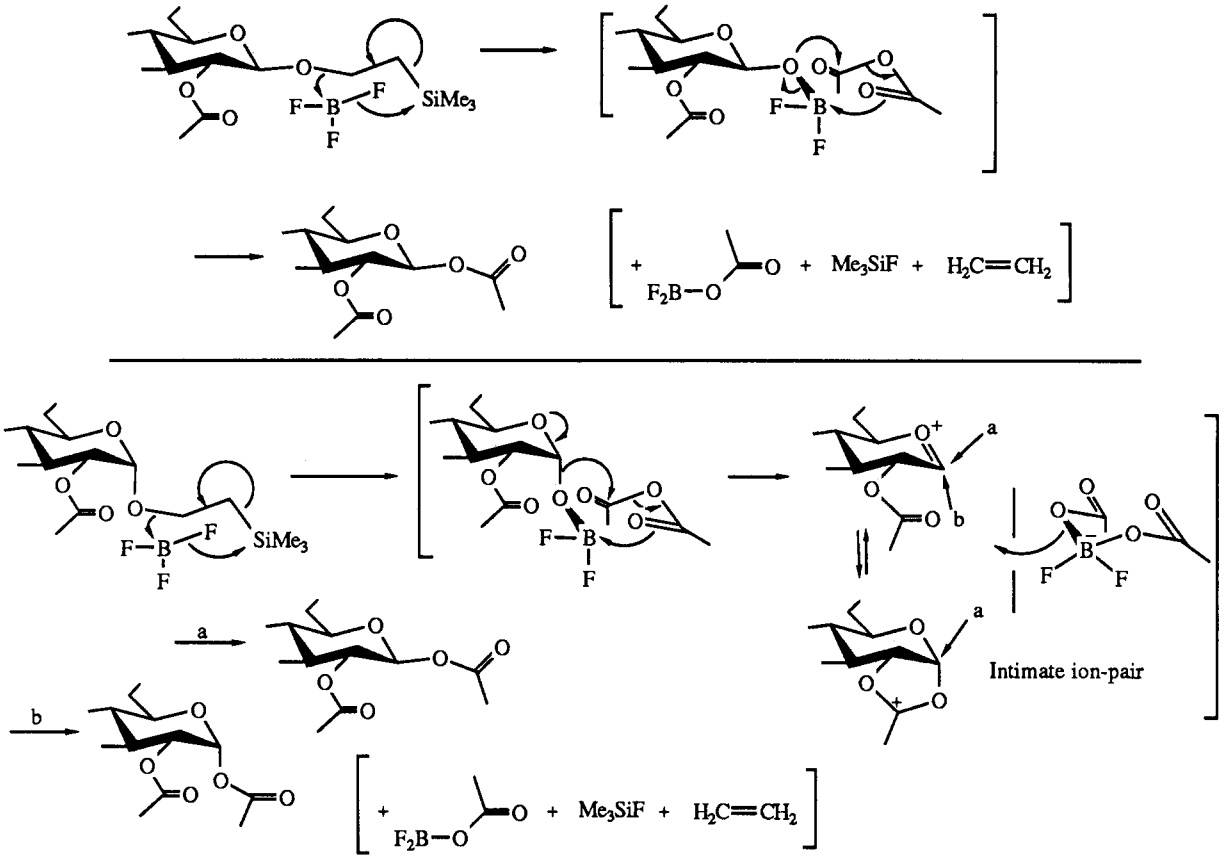
(1) Paper 3. For paper 2 in the series, see: Jansson, K.; Frejd, T.; Kihlberg, J.; Magnusson, G. *Tetrahedron Lett.* **1988**, *29*, 361.
(2) Lipshutz, B. H.; Pegram, J. J.; Morey, M. C. *Tetrahedron Lett.* **1981**, *22*, 4603.
(3) Jansson, K.; Frejd, T.; Kihlberg, J.; Magnusson, G. *Tetrahedron Lett.* **1986**, *27*, 753.
(4) Peterson, D. J. *J. Org. Chem.* **1968**, *33*, 780.
(5) Ho, T.-L. *Hard and Soft Acids and Bases Principle in Organic Chemistry*; Academic Press: New York, 1977.
(6) (a) Lemieux, R. U.; Shyluk, W. P. *Can. J. Chem.* **1953**, *31*, 528. (b) Ingle, T. R.; Bose, J. L. *Carbohydr. Res.* **1970**, *12*, 459. (c) Honma, K.; Nakazima, K.; Uematsu, T.; Hamada, A. *Chem. Pharm. Bull.* **1976**, *24*, 394. (d) Hanessian, S.; Banoub, J. *Carbohydr. Res.* **1977**, *59*, 261. (e) Banoub, B.; Bundle, D. R. *Can. J. Chem.* **1979**, *57*, 2085. (f) Kiso, M.; Anderson, L. *Carbohydr. Res.* **1979**, *72*, c12, c15. (g) Ferrier, R. J.; Furneaux, R. H. *Methods Carbohydr. Chem.* **1980**, *8*, 251. (h) Magnusson, G.; Noori, G.; Dahmén, J.; Frejd, T.; Lave, T. *Acta Chem. Scand., Ser. B* **1981**, *B35*, 213. (i) Dahmén, J.; Frejd, T.; Magnusson, G.; Noori, G. *Carbohydr. Res.* **1982**, *111*, c1; (j) **1983**, *114*, 328. (k) Dahmén, J.; Frejd, T.; Grönberg, G.; Lave, T.; Magnusson, G.; Noori, G. *Ibid.* **1983**, *116*, 303. (l) Dahmén, J.; Frejd, T.; Magnusson, G.; Noori, G.; Carlström, A.-S. *Ibid.* **1984**, *127*, 27. (m) Paulsen, H.; Paal, M. *Ibid.* **1984**, *135*, 53. (n) Ansari, A. A.; Frejd, T.; Magnusson, G. *Ibid.* **1987**, *161*, 225.

0022-3263/88/1953-5629$01.50/0

Chart I. TMSET Glycosides for Transformation into 1-*O*-Acyl Sugars (Chart II and Table III) and Hemiacetal Sugars (Chart III and Table IV)



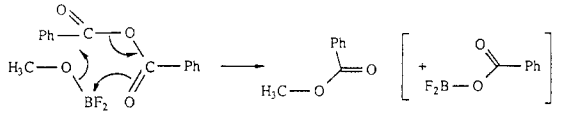
Scheme I. Suggested Reaction Path for the Transformation of TMSET Glycosides into 1-*O*-Acyl Sugars



reaction mixture greatly increased the reaction rate and that boron trifluoride etherate (BF_3·Et_2O) was a more efficient reagent than $LiBF_4$. Lipshutz found a series of reagents to be ineffective. We have investigated some additional reagents and solvents with the aim of finding suitable combinations for both deblocking and transformation of TMSET glycosides into 1-*O*-acyl sugars. The results shown in Table I should be taken as indicative since the reactivities of 1 and 11 were only determined by TLC. Basic solvents such as esters, ethers, alcohols, and amines were found to retard the reaction of 1 and 11, probably because they compete with the anomeric oxygen for the acidic reagents.

BF_3·Et_2O, $ZnCl_2$, $SnCl_4$, and $FeCl_3$ were submitted to further exploratory investigations using the TMSET glucoside 1 and acetic anhydride for the synthesis of glucose pentaacetate (28). The results are shown in Table IIA–D. The conclusion was that BF_3·Et_2O was the optimal Lewis acid since it combines the desired high conservation of the anomeric stereostructure with high reaction rate and solubility in various solvents. Toluene was found to be the optimal solvent because it prevents anomerization of the product (Table IID), it has a boiling point (111 °C) that allows simple variation of the reaction temperature, and also because it is efficient for azeotropic removal of residual water in the starting material.

As indicated in eq 1, the primary product of the reaction between 1 and BF_3·Et_2O is a Glc1O-BF_2 fluoroborate ester. A few $ROBF_2$ derivatives where R is an alkyl group have been reported.[7] These compounds seem to be unstable in solution, entering into an equilibrium that includes the species BF_3, $ROBF_2$, $(RO)_2BF$, and $(RO)_3B$. Similar compounds are most probably formed in the present case where R equals sugar residues. It is difficult to ascertain which of these species really react with the carboxylic anhydrides to form the 1-*O*-acyl sugars. In the discussion below, the notation "Glc1O-BF_2" should therefore be interpreted as an activated, boron-containing sugar derivative, not necessarily having this formula. Indirect evidence for the transient existence of Sugar1O-BF_2 in the formation of 1-*O*-acyl sugars was found by treating $MeOBF_2$[7] with benzoic anhydride. Methyl benzoate was formed (eq 2), probably by an acylation reaction that is similar to the one indicated in Scheme I.



(2)

Preparation of 1-*O*-Acyl Sugars. In the synthesis of oligosaccharides for use in biological evaluations, it is desirable to be able to prepare, from a common precursor, different functional derivatives such as glycolipids, glycoproteins, and simple (e.g. methyl or ethyl) glycosides in addition to the reducing (hemiacetal) oligosaccharide itself. We have reported the synthesis of several mono-, di-, tri-, and tetrasaccharides and their functional derivatives using "pre-spacerarm" glycosides based on the primary alcohols 2-bromoethanol[8] and 3-bromo-2-(bromomethyl)propan-1-ol (DIBOL).[6n] Thiols, optionally carrying added functionalities, then replaced bromine, giving artificial glycolipids and spacerarm glycosides for coupling to proteins and particles.

(7) Köster, R. *Houben-Weil Methoden der Organischen Chemie*; Georg Thieme Verlag: Stuttgart, 1963; Vol. 6/2, p 262.

(8) (a) Dahmén, J.; Frejd, T.; Magnusson, G.; Noori, G.; Carlström, A.-S. *Carbohydr. Res.* **1984**, *129*, 63 and references cited. (b) Magnusson, G. In *Protein-Carbohydrate Interactions in Biological Systems*; Lark, D., Ed.; Academic Press: London, 1986; p 215.

Table I. Treatment of 1 and 11 with Various Reagent-Solvent Combinations[a]

1 → 58		1 → 28		11 → 59		11 → e	
reagent/solvent[f]	reactivity[b]	reagent/solvent[f]	reactivity[b]	reagent/solvent[f]	reactivity[b]	reagent/solvent[f]	reactivity[b]
$BF_3{\cdot}Et_2O/Et_3N$	–	TfOH/Ac_2O	+	TFA/CH_2Cl_2, 2:1	+	70% $HClO_4$/MeCN	+
$BF_3{\cdot}Et_2O$/pyridine	–	H_2SO_4/Ac_2O	+	TFA/MeCN, 1:9	(–)	70% $HClO_4/PrNO_2$	+
$BF_3{\cdot}Et_2O$/DMF	–	$FeCl_3SiO_2/Ac_2O$	+	70% TfOH/PhCN	+	70% $HClO_4/PhNO_2$	+
BF_3Et_2O/EtOH	–	$FeCl_3/Ac_2O$	+	70% $HClO_4$/PhCN	+	70% $HClO_4/PhCH_3$	+
$BF_3{\cdot}Et_2O$/THF	–	$BF_3{\cdot}Et_2O/Ac_2O$	+	70% $HClO_4$/EtCN	(–)	70% $HClO_4/CH_2Cl_2$	+
BF_3Et_2O/EtOAc	–	$SnCl_4/Ac_2O$	+	HCOONa/HCOOH	–	$BF_3{\cdot}Et_2O$/MeCN	+
$BF_3{\cdot}Et_2O/PhCH_3$	(+)	$ZnCl_2/Ac_2O$	(+)	HCl/CH_2Cl_2	–	TMSTf/MeCN	+
$BF_3{\cdot}Et_2O/CH_2Cl_2$	(+)	$ZnBr_2/Ac_2O$	(+)	$HCl/PhCH_3$	–	H_2SO_4/MeCN	+
$BF_3{\cdot}Et_2O$/TFAA	+	$LiBF_4/Ac_2O$		35% HBF_4/PhCN	(–)	$AlCl_3$/MeCN	+
$BF_3{\cdot}Et_2O$/MeCN	+	MeCN/55 h/	(+)	MeCOOH	–	$FeCl_3SiO_2$/MeCN	(–)
$BF_3{\cdot}Et_2O/MeNO_2$	+	70 °C		$LiBF_4$/MeCN/81 h/	(+)[c]	TfOH/CH_2Cl_2	+
$LiBF_4$/MeCN/	+	$TiBr_4/Ac_2O$	*d*	70 °C		TfOH/HOAc/40 °C	+
17 h/70 °C		$TiCl_4/Ac_2O$	*d*	70% $HClO_4$/EtOAc	(–)[c]	TfOH/dioxane	(+)
70% $HClO_4$/MeCN	+	$AlCl_3/Ac_2O$	*d*	70% $HClO_4$/DMSO	–	TfOH/PhCN	+
TMSTf/MeCN	(+)[c]			70% $HClO_4$/DMF	–	HCOOH/60 °C	+
TfOH/MeCN	+[c]			70% $HClO_4$/THF	–		
H_2SO_4/MeCN	+			$ZnCl_2$/MeCN	–		
$TiCl_4$/MeCN	+			HCl/dioxane	–		
$AlCl_3$/MeCN	(+)			HCl(aq)/HOAc/100 °C	(+)[c]		
$FeCl_3$/MeCN	(+)			Nafion-H^+/PhCN	–		
$SnCl_4$/MeCN	(+)			TfOH/EtCOOH/40 °C	–		
$ZnCl_2$/MeCN	–						
Bu_4NBF_4/MeCN	–						
$LiClO_4$/MeCN	–						
TFA/MeCN 1:9	–						
TFA/CH_2Cl_2 2:1	+						
HCl/CH_2Cl_2	–						
TMSTf/CH_2Cl_2	+[c]						
HCOOH/60 °C	+						

[a] Reactions were typically run at 25 °C with 10 mg of 1 and 11 and ca. 1 equiv of the reagent. The reaction mixtures were analyzed by TLC. [b] –, <5% of 1 or 11 was consumed after 2 h; +, >95% of 1 or 11 was consumed after 2 h; (–), >5% but <20% of 1 and 11 was consumed after 2 h; (+), >50% but <95% of 1 and 11 was consumed after 2 h. [c] Byproducts were formed. [d] Insoluble material was formed by reaction of the Lewis acid with acetic anhydride. [e] **59**, trehaloses, and unidentified products were formed. [f] DMF, *N*,*N*-dimethylformamide; THF, tetrahydrofuran; TFAA, trifluoroacetic anhydride; TFA, trifluoroacetic acid; TMSTf, trimethylsilyl trifluoromethanesulfonate; TfOH, trifluoromethanesulfonic acid; DMSO, dimethyl sulfoxide; $PrNO_2$, 1-nitropropane; 70% $HClO_4$, 70% TfOH, and 35% HBF_4 refer to aqueous solutions.

Primary alcohols can normally be efficiently glycosylated by simple treatment with an acetylated sugar in the presence of a Lewis acid.[6] We have used $BF_3{\cdot}Et_2O$ extensively with 2,2,2-trichloroethanol,[6h] 2-bromoethanol,[8] and DIBOL,[6n] whereas others have preferred $SnCl_4$ with various alcohols.[6a-e] In such glycosylations it is in most cases advantageous to use sugar acetates with a 1,2-trans configuration since they react more rapidly than the 1,2-cis isomers and give higher yields and cleaner products.[6m] In fact, preliminary investigations have shown that pure 1,2-cis 1-*O*-acyl sugars as such do not form glycosides in the presence of simple alcohols with 1.5 equiv of $BF_3{\cdot}Et_2O$. We have used many of the 1,2-trans 1-*O*-acetates of Chart II in $BF_3{\cdot}Et_2O$-mediated glycosylations with DIBOL. The yields of isolated glycosides were in the range 50–95%; the higher yields were found, much to our surprise, with the more complex oligosaccharides (e.g. **54–56**, Chart II).[9]

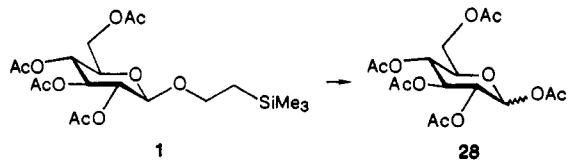
TMSET glycosides having a 1,2-trans configuration are well suited for transformation into 1,2-trans 1-*O*-acyl sugars.[3] Thus, treatment with 0.7–0.8 equiv of $BF_3{\cdot}Et_2O$ and 1.1–15 equiv of a carboxylic anhydride in toluene at 20–60 °C gives the corresponding 1-*O*-acyl sugar in 70–99% yield (Table III). The presumed Sugar1O-BF_2 intermediate (Scheme I) apparently has a high propensity to react with carboxylic anhydrides with conservation of the anomeric stereostructure of the TMSET glycoside. This constitutes an advantage over other methods such as acetolysis or hydrolysis/acetylation of simple glycosides, since these methods normally give α/β mixtures with α dominating. Furthermore, different *O*- and *N*-acyl-protected sugars can be used with a series of carboxylic anhydrides; mixed acyl sugars can thus be efficiently prepared (Table III and Chart II). As demonstrated with several di-, tri-, and tetrasaccharides **15–27**, the reaction is mild enough not to break intersaccharidic bonds. This is especially important in cases where substantial effort has been put into the construction of the oligosaccharide; lengthy synthetic schemes can now be trustfully designed since the final anomeric deblocking gives only the desired 1-*O*-acyl sugar.

Carboxylic anhydrides that do *not* carry bulky or electron-withdrawing substituents react rapidly with 1 to give the 1-*O*-acyl sugar with a high 1,2-trans/1,2-cis ratio (Table III). Bulky substituents (as in pivalic anhydride) seem to retard the formation of the Glc1O-BF_2 intermediate but still allow rapid transformation of the latter into the 1-*O*-acyl sugar. Probably $BF_3{\cdot}Et_2O$ forms a sterically hindered complex with pivalic anhydride, which then reacts with the TMSET glycoside. The reaction requires 9 h at 60 °C to go to completion if pivalic anhydride is present from the beginning of the reaction, whereas the sugar pivalate is formed in ca. 10 min from a preformed Glc1O-BF_2 intermediate. Furthermore, addition of 1 equiv of acetylacetone to the reaction mixture blocks the reaction completely, probably due to strong complexation with $BF_3{\cdot}Et_2O$.

With electron-withdrawing substituents (such as Cl) in the carboxylic anhydride, complex formation with $BF_3{\cdot}Et_2O$ seems to be less pronounced, and the formation of

(9) Unpublished results.

Table II



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A. Comparison between Lewis Acids under Similar Reaction Conditions[a]

Lewis acid	reactn time (min)	yield (%)[b]	28β/28α[c]
BF_3Et_2O	10	88	89/11
$ZnCl_2$	480	81	86/14
$SnCl_4$	10	90	60/40
$FeCl_3$	20	90	22/78

B. Comparison between Different Lewis Acids for the Anomerization of 28β[d]

	Ratio[c] 28β/28α		
reactn time (h)	BF_3·Et_2O	$ZnCl_2$	$FeCl_3$
0.9	99/1	99/1	88/12
17	91/9	99/1	68/32
120	60/40	95/5	20/80

C. Ratio of 28β/28α as a Function of Reaction Time and Amount of BF_3·Et_2O in the Reaction 1 → 28[e]

	Ratio[c] 28β/28α	
BF_3·Et_2O (equiv)	2 h	18 h
1	67/33	45/55
2	20/80	16/84
5	16/84	15/85

D. Anomerization of 28β in Different Solvents[f]

	Ratio[c] 28β/28α			
reactn time (h)	CH_3CN	CH_3NO_2	toluene	CH_2Cl_2
1	95/5	95/5	100/0	100/0
17	94/6	80/20	99/1	99/1
120	93/7	75/25	98/2	99/1

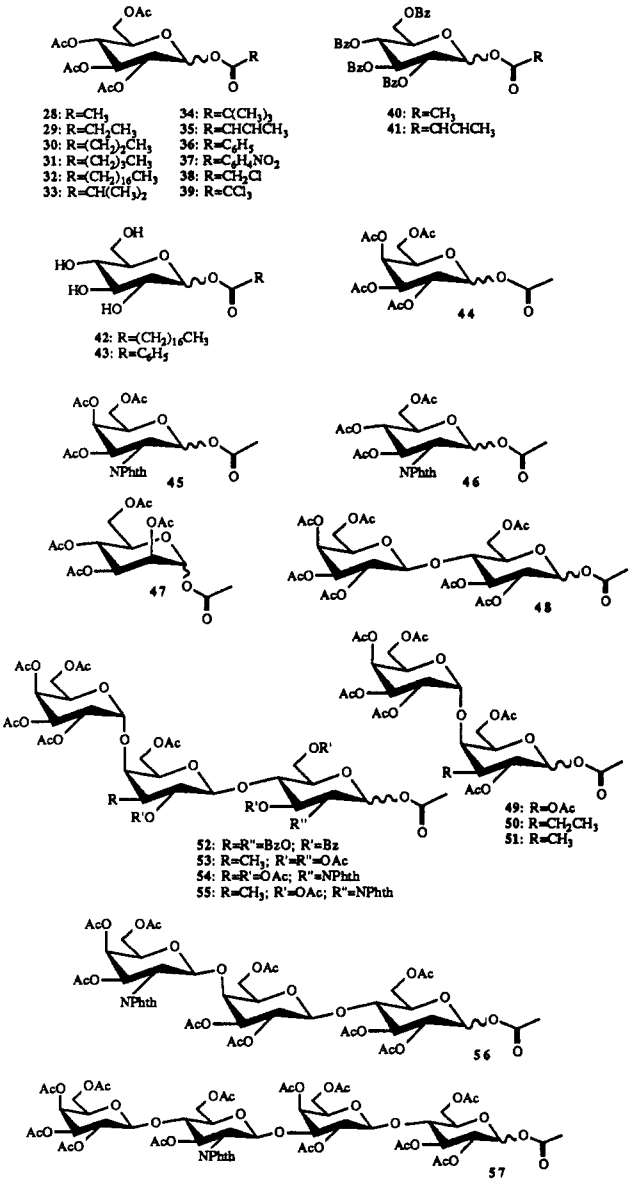
[a] 1 equiv of 1; 0.9 equiv of Lewis acid; Ac_2O (5 mL/mmol of 1); 22 °C. [b] Determined by chromatography. [c] Determined by GC. [d] 1 equiv of 28β; 0.24 equiv of Lewis acid; Ac_2O (5 mL/mmol of 28β); 22 °C. [e] 1 equiv of 1; 15 equiv of Ac_2O; CH_3CN (5 mL/mmol of 1); 22 °C. 1 was consumed within 1 h. [f] 1 equiv of 28β; 0.1 equiv of BF_3·Et_2O; solvent: 5 mL/mmol of 28β; 22 °C.

the Glc1O-BF_2 intermediate is not retarded. However, the reaction of Glc1O-BF_2 with the carboxylic anhydride was slowed down and consequently the former had time to anomerize; the resulting 1-*O*-acylglucose (**38**, **39**) had a low β/α ratio.

Strongly electron withdrawing groups in both of the carboxylic acid residues of the anhydride (e.g. *p*-nitrobenzoic anhydride and trifluoroacetic anhydride) can block the acylation of the Glc1O-BF_2 intermediate completely, whereas unsymmetrical (mixed) anhydrides with only one electron-withdrawing part (mixed *p*-nitrobenzoic–acetic anhydride) will react preferentially to give the product (**37**) that carries the electron-withdrawing acyl functionality. Finally, cyclic anhydrides such as succinic anhydride do not react at all, which probably reflects a need for conformational freedom of the anhydride in its reaction with the Sugar1O-BF_2 species.

These observations lead to a plausible reaction path (Scheme I) where the boron of the Sugar1O-BF_2 intermediate will form a complex with the carbonyl oxygen of the more electron rich part of the anhydride. This complexation will polarize the anhydride enough for the anomeric oxygen to attack the other carbonyl group of the anhydride, resulting in the desired 1-*O*-acyl sugar with conserved anomeric configuration. The (acyloxy)difluoroborane is a probable byproduct.

Chart II. 1-*O*-Acyl Sugars Prepared from the TMSET Glycosides Shown in Chart I. Yields and β/α Ratios Are Shown in Table III



The TMSET β-gluco- and -mannosides (**1** and **5**) react more rapidly than the corresponding α-glycosides (**2** and **4**) with BF_3·Et_2O/acetic anhydride. This may be due to the anomeric effect, which would make the electrons on the anomeric oxygen of the TMSET α-glycosides less accessible for electrophilic attack by BF_3·Et_2O, in line with the well-known rate differences observed in the hydrolysis of β- and α-gluco- and -mannosides.[10] The α-glucoside (**2**) and β-mannoside (**5**) did not show the high degree of conservation of anomeric configuration in the 1-*O*-acetate (**28** and **47**) that did the 1,2-trans glycosides. This indicates the presence of additional mechanistic subleties in the reaction, such as interaction from the 2-*O*-acetyl group in the case of 1,2-trans Sugar1O-BF_2 intermediates and the formation of intimate ion pairs with 1,2-cis compounds. In the α-glycosides, favorable orbital overlap between the ring and anomeric oxygens should facilitate the breaking of the anomeric C–O bond, thus furnishing a cation that

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Table III. Preparation of 1-*O*-Acyl Sugars from TMSET Glycosides

starting material[a]	reactn conditns[b]/time (h)	product[c]	β/α ratio[d]	yield (%)[e]
1	A/1	**28**	97/3	98
1	A/2	**29**	98/2	96
1	A/2	**30**	98/2	99
1	A/2	**31**	97/3	98
1	A/2	**32**	99/1[f]	96
1	A/3	**33**	99/1	98
1	C/9	**34**	97/3	98
1	B/1	**35**	94/6	94
1	B/6	**36**	94/6	98
1	B/1[g]	**37**, **28**	99/1,[f] 95/5	77, 21
1	C/1	**38**	58/42	87
1	D/2	**39**	1/99[f]	80
2	B/6	**28**	39/61	93
3	E/2	**44**	96/4	92
4	B/3	**47**	6/94	92
5	A/1	**47**	50/50	95
6	B/1	**46**	99/1[f]	97
7	F/2	*h*	*h*	90
8	E/3	**45**	97/3	93
9	B/1	**40**	97/3	96
9	B/2	**41**	98/2	97
10	A/4[i]	**42**	*j*	71
10	B/3[i]	**43**	70/30	79
15	E/3	**48**	98/2	95
19	B/1	**49**	86/14	99
20	B/0.5	**51**	20/80	94
21	B/0.5	**50**	20/80	88
22	E/15	**52**	97/3	95
23	B/0.5	**53**	95/5	96
24	E/5	**54**	99/1	95
25	B/0.5	**55**	99/1	78
26	B/2	**56**	97/3	88
27	E/3	**57**	98/2	93

[a] See Chart I. [b] TMSET glycoside (mmol)/carboxylic anhydride (mmol)/BF_3·Et_2O (mmol)/toluene (mL)/temp (°C): A, 0.20/0.22/0.14/1.0/55; B, 0.20/0.30/0.16/1.0/55; C, 0.20/0.60/0.16/1.0/55; D, 0.20/2.0/0.16/1.0/55; E, 0.20/3.0/0.16/1.0/22; F, 0.20/3.0/0.30/1.0/22. [c] See Chart II. [d] Determined by gas chromatography and/or NMR. [e] Isolated by chromatography and/or crystallization; see Experimental Section. [f] Only the major anomer was detected by NMR. [g] Mixed *p*-nitrobenzoic/acetic anhydride (mp 77–80 °C) was used. [h] 1,3,4,6-Tetra-*O*-acetyl-2-acetamido-2-deoxy-β-D-glucopyranose (53%) was formed together with the α acetate (5%) and the corresponding 1,2-oxazoline (32%). [i] Treatment with solid $NaHCO_3$ (0.5 mmol) and methanol (10 mL) removed the trifluoroacetyl groups. [j] β/α ratio not determined; pure **42** was obtained (30%) by recrystallization from methanol.

would react in a nonspecific manner as indicated by routes a and b in Scheme I.

Standard acyl O- and N-protecting groups of carbohydrate chemistry (but not benzyl groups[11]) are compatible with the reaction conditions (Chart II and Table III). This is especially valuable when one needs to discriminate between the anomeric and the other acyl groups. Such "mixed" acyl sugars are potentially useful in the search for optimal 1-*O*-acyl sugars for use as glycosyl donors in Lewis acid induced glycoside synthesis, an area that is currently under investigation in our laboratory. A further example is the preparation of 1-*O*-acyl sugars where the rest of the hydroxyl groups are unprotected (cf. the synthesis of the naturally occurring 1-*O*-stearoyl-β-D-glucopyranose (**42**) and periplanetin (**43**),[12] both prepared via the corresponding trifluoroacetyl derivative **10**). In such cases it is important that the protecting 2-*O*-acyl group will have participating abilities in order to give a high β/α ratio in the reaction of the TMSET glycoside (see discussion above) and that it can be removed selectively together with the rest of the protecting groups. The trifluoroacetyl group fulfills the second criterion in that it can be removed by neutral methanol treatment. However, its participating ability is not optimal, which is reflected in the relatively low β/α ratio (70/30) obtained in the preparation of **43**. Schmidt et al. reported recently an efficient synthetic route to 1-*O*-acyl sugars via trichloroacetimidates.[13]

TMSET glycosides of complex oligosaccharides (e.g. **15**–**27**) were transformed into the corresponding 1-*O*-acetyl sugars in very high yields and with no formation of byproducts according to TLC and NMR analysis. In two cases (**50** and **51**) a low β/α ratio was obtained. This is probably due to a high propensity for Lewis acid induced anomerization of 1-*O*-acyl sugars (and possibly Sugar1O-BF_2 intermediates) carrying electron-donating substituents in the sugar ring or having a reduced number of electron-attracting substituents; here the methyl and ethyl groups play that role.

Anomeric Deblocking of TMSET Glycosides; Hemiacetal Sugars. Protected sugars having a free (hemiacetal) anomeric position are widely used intermediates in the synthesis of oligosaccharides and other chiral natural products. Existing methods for the preparation of these intermediates are based mainly on deblocking of the corresponding glycosides. These methods are, however, frequently connected with low yields, formation of byproducts such as trehaloses,[14] and incompatibility of the anomeric blocking group with many standard reactions of carbohydrate synthesis.

Selective anomeric deblocking of TMSET glycosides was reported by Lipshutz et al.[2] and later by us,[3] using $LiBF_4$ and BF_3·Et_2O, respectively. We consider BF_3 to be the reactive species in both procedures (see above). However, BF_3·Et_2O was not compatible with benzylated sugars because trehaloses were formed. Consequently, alternative procedures were investigated.

Inorganic proton acids in polar solvents (e.g. 1 equiv of 70% aqueous $HClO_4$ in benzonitrile) gave with **11** ca. 65% yield of the hemiacetal sugar **59**, whereas in apolar solvents (e.g. toluene) the corresponding trehaloses were formed in ca. 80% yield. Formic acid, which is highly polar (and should therefore suppress the formation of trehaloses), effected the anomeric deblocking of the acetylated saccharides **1** and **15** at 60 °C in 90 and 93% yield, respectively, whereas the benzylated glycoside **11** gave the α/β-formate mixture as the main product. The benzylated disaccharide **17** gave, however, only a low yield of the hemiacetal **66**, probably due to formolysis of the intersaccharidic bond.

Numerous combinations of acids and solvents were investigated with respect to their efficiency for selective anomeric deblocking of TMSET glycosides (Table I). Trifluoroacetic acid in dichloromethane was the optimal system and anomeric deblocking was performed with both unprotected and protected saccharides that carried a host of different protecting groups (Chart III). It should be noted that the β-glycosides reacted considerably faster than the α-glucoside **88**, which was also the case in the BF_3·Et_2O-mediated transformation of β- and α-gluco- and -mannosides **1**, **2**, **5**, and **4** discussed above. Of the protecting groups tested, the 4,6-*O*-benzylidene group was cleaved almost as rapidly as the TMSET group, whereas

(11) Ganem, B.; Small, V. R., Jr. *J. Org. Chem.* **1974**, *39*, 3728. Kartha, K. P. R.; Dasgupta, F.; Singh, P. P.; Srivastava, H. C. *J. Carbohydr. Chem.* **1986**, *5*, 437. Park, M. H.; Takeda, R.; Nakanishi, K. *Tetrahedron Lett.* **1987**, *28*, 3823.

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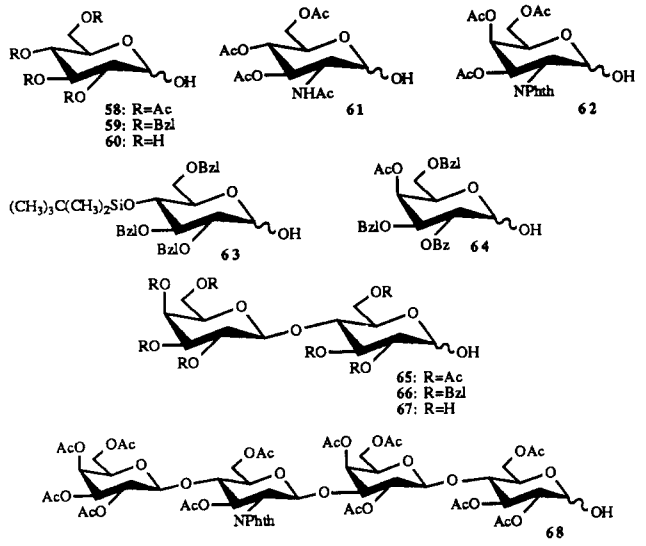
(13) Schmidt, R. R.; Michel, J. *J. Carbohydr. Chem.* **1985**, *4*, 141.

(14) Pavia, A. A.; Rocheville, J.-M.; Ung, S. N. *Carbohydr. Res.* **1980**, *79*, 79.

Chart III. Hemiacetal Sugars Prepared from the TMSET Glycosides Shown in Chart I. Yields Are Shown in Table IV



other protecting groups were stable. The use of 90% aqueous trifluoroacetic acid[15] permitted the selective removal of the 4,6-*O*-benzylidene group of compound **16**, which gave **101** without affecting the TMSET group. Another valuable observation was that the *tert*-butyldimethylsilyl-protected glycoside **13** could be deblocked selectively at 0 °C to give **63** in 93% yield (Chart III), whereas selective removal of the *tert*-butyldimethylsilyl group was effected by tetrabutylammonium fluoride which furnished **79** in 85% yield. An added advantage of the present reaction is that only volatile reaction byproducts are formed; the desired hemiacetal sugars were obtained practically pure by evaporation of the unwanted material. Repeated additions of *n*-propyl acetate and toluene during the evaporation process protected the hemiacetal sugar from high concentrations of trifluoroacetic acid (Table IV).

In summary, the acylation and deblocking reactions presented here are fully compatible with most of the normally used protecting groups of synthetic carbohydrate chemistry. The reactions can be safely applied with mono-, di-, tri-, and tetrasaccharides with no concomitant cleavage of interglycosidic bonds. We feel secure enough to recommend the use of these reactions whenever the overall synthetic effort that is put into a saccharide synthesis motivates the use of TMSET glycosides.

Synthesis of TMSET Glycosides. The first preparation of TMSET glycosides was reported by Lipshutz et al.,[2] who used Königs–Knorr- and Fischer-type methods to produce normal TMSET glycosides and oxymercuration and glycal rearrangement for the 2-deoxy compounds. We have used similar methods for the preparation of the TMSET glycosides 1–8 and 15 of Chart I, including $HgO/HgBr_2$, silver triflate, and bromide ion mediated syntheses with 1-halo sugars, $Hg(CN)_2/HgBr_2$ and $Hg(CN)_2$ mediated syntheses with acetochloro sugars, and *p*-toluenesulfonic acid mediated Fischer-type glycosidation with D-mannose. The remaining monosaccharide and lactose derivatives of Chart I were prepared by straightforward manipulations of the functional groups of the above-mentioned glycosides. The synthesis of compound 8 (Scheme II) deserves, however, some further comments. The configuration at the 4-position of **76** was readily inverted by a nucleophilic displacement of the corresponding benzenesulfonate (**80**) by using cesium acetate. In this way, the two synthetically valuable building blocks **76** and 2-(trimethylsilyl)ethyl 3,6-di-*O*-benzyl-2-deoxy-2-phthalimido-β-D-galactopyranoside were made available via essentially a single synthetic route that starts with D-glucosamine.

Table IV. Preparation of Hemiacetal Sugars from TMSET Glycosides

starting material[a]	reactn conditns[b]	product[c]	yield (%)[d]
1	22 °C; 20 min	**58**	95
11	0 °C; 30 min	**59**	93
12	22 °C; 30 min	**60**	96
7	22 °C; 10 min	**61**	95
8	22 °C; 20 min	**62**	95
13	0 °C; 30 min	**63**	93
14	22 °C; 20 min	**64**	93
15	22 °C; 20 min	**65**	93
17	0 °C; 30 min	**66**	90
18	22 °C; 30 min	**67**	95
27	22 °C; 20 min[e]	**68**	90
88	0 °C; 240 min	**59**	88

[a] See Chart I. [b] TMSET glycoside 0.1 mmol; CF_3COOH 1 mL; CH_2Cl_2 0.5 mL. [c] See Chart III. [d] Isolated product; see Experimental Section. [e] **27** 0.0143 mmol; CF_3COOH 0.6 mL; CH_2Cl_2 0.3 mL.

The remaining compounds of Chart I (**19–27**) were prepared by straightforward glycoside synthesis and protecting group chemistry using the partly protected saccharides **72**, **76**, **79**, **96**, **99**, **103**, **105**, and **121** of Schemes II, III and IV as glycosyl acceptors. Some of the reaction steps for the synthesis of these compounds deserve some further comments. Positions 3, 4, and 6 of 2-(trimethylsilyl)ethyl β-D-galactopyranoside (**69**) were protected in one single step by using 2,2-dimethoxypropane/*p*-toluenesulfonic acid,[16] thus furnishing **89** in 75% yield. Three additional steps gave **92** having 3-OH unprotected. The overall sequence from **69** constitutes an improvement of our earlier method of preparing the methyl glycoside[17] corresponding to **92**. Catalytic hydrogenation of the olefins **94** and **97** gave the 3-deoxy-3-*C*-ethyl and methyl TMSET galactosides **95** and **98**; the corresponding gulosides were not found in the reaction mixtures. This is in accord with our previous findings.[17] Acetobromogalabiose[6k] was used as glycosyl donor in the preparation of **114**. The preparation of the 3′-deoxy-3′-*C*-methyl analogues **116** and **117** required the chloride **115** because of the lability of the corresponding bromide. This is in line with our general observation that the reactivity of the glycosyl donor has to be moderated by the anomeric halogen in response to the presence of electron-donating substituents in the sugar ring; deoxy and *C*-alkyl sugars require anomeric chlorine or fluorine in order to be stable enough for convenient handling.[18] In the synthesis of the tetrasaccharide **122**, the partially protected lactoside **121** permitted a seemingly absolute discrimination between the two potentially reactive positions 3′ and 4′, thus simplifying the protection of the glycosyl acceptor. The preferential glycosylation of the more reactive equatorial hydroxyl group of a similar lactose derivative has been reported.[19]

(15) Christensen, J. E.; Goodman, L. *Carbohydr. Res.* **1968**, *7*, 510.

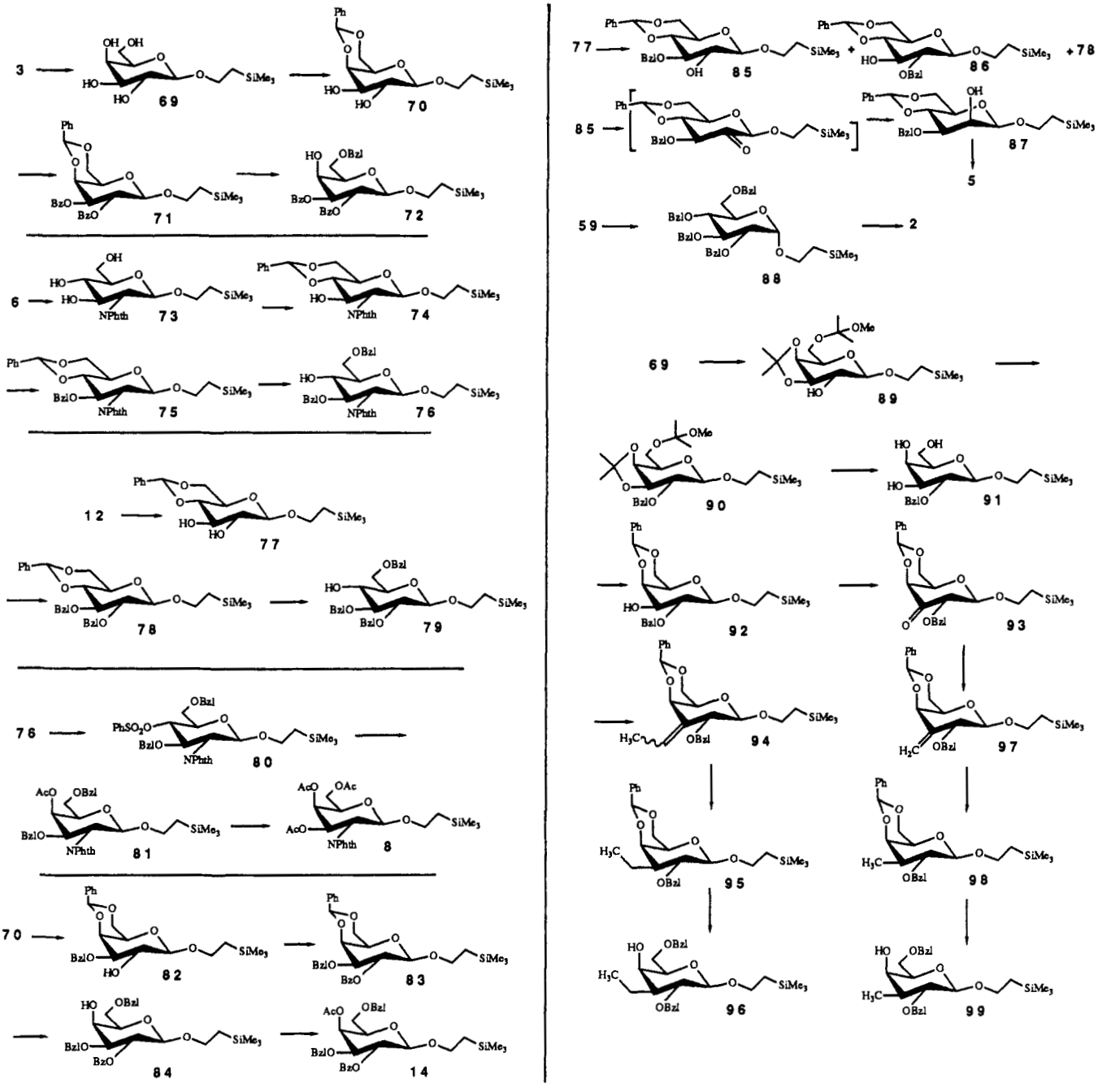
(16) Barili, P. L.; Berti, G.; Catelani, G.; Colonna, F.; Marra, A. *Tetrahedron Lett.* **1986**, *27*, 2307.

(17) Kihlberg, J.; Frejd, T.; Jansson, K.; Magnusson, G. *Carbohydr. Res.* **1986**, *152*, 113.

(18) Kihlberg, J.; Frejd, T.; Jansson, K.; Kitzing, S.; Magnusson, G. *Carbohydr. Res.*, in press.

(19) Paulsen, H.; Paal, M.; Hadamczyk, D.; Steiger, K.-M. *Carbohydr. Res.* **1984**, *131*, c1. Paulsen, H.; Paal, M. *Ibid.* **1985**, *137*, 39. Paulsen, H.; Steiger, K.-M. *Ibid.* **1987**, *169*, 105.

Scheme II. Synthesis of TMSET Monosaccharides. Reaction Conditions are Summarized in Table V and Detailed in the Experimental Section



The remaining reactions of Schemes II–IV are compiled, together with additional observations made during this work, in Table V in a format that will make it possible to evaluate the compatibility of the TMSET group with various reaction conditions and combinations thereof.

Transformation of the di-, tri-, and tetrasaccharide derivatives **48–57** into sugars for biological use (such as unprotected saccharides, artificial glycolipids, and glycoproteins) will be reported separately.

Experimental Section

$BF_3{\cdot}Et_2O$ was distilled and kept in a sealed ampule before use. The β/α ratio of the 1-*O*-acyl sugars was determined by GC using a 9.7-m polyphenylmethylsiloxane (50%) RSL-300 column (**28–31**, **33–36**, **38**, **44**, **47**). TLC was performed on Kieselgel 60 F_{254} (Merck). Column chromatography was performed in the gravity mode on Kieselgel 60 (Merck 230–400 mesh). Melting points are uncorrected. NMR spectra were recorded in $CDCl_3$ with $CHCl_3$ as internal standard unless otherwise stated, using a Varian XL300 spectrometer; chemical shifts are relative to Me_4Si. Optical rotations were measured with a Perkin-Elmer 141 polarimeter.

2-(Trimethylsilyl)ethanol was prepared essentially as described; the reduction step required only half of the reported amount of lithium aluminum hydride.[20]

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranoside (1). 2,3,4,6-Tetra-*O*-acetyl-α-D-glucopyranosyl bromide (39.4 g, 95.9 mmol) was added to a stirred suspension of HgO (20.8 g, 95.9 mmol), $HgBr_2$ (cat.), $CaSO_4$ (26.1 g, 192 mmol), and 2-(trimethylsilyl)ethanol (17.9 g, 144 mmol) in dry chloroform (290 mL; purified by passing through grade 1 alumina). The mixture was stirred in the dark at room temperature for 48 h (the reaction was monitored by TLC: SiO_2, EtOAc/heptane 1:2), filtered (Celite), and washed with saturated aqueous $NaHCO_3$ and water. The organic phase was dried (Na_2SO_4) and concentrated to give a syrup that crystallized on standing. A portion

(20) Fessenden, R. J.; Fessenden, J. S. *J. Org. Chem.* **1967**, *32*, 3535. Gerlach, H. *Helv. Chim. Acta* **1977**, *60*, 3039.

Scheme III. Synthesis of TMSET Disaccharides. Reaction Conditions are Summarized in Table V and Detailed in the Experimental Section

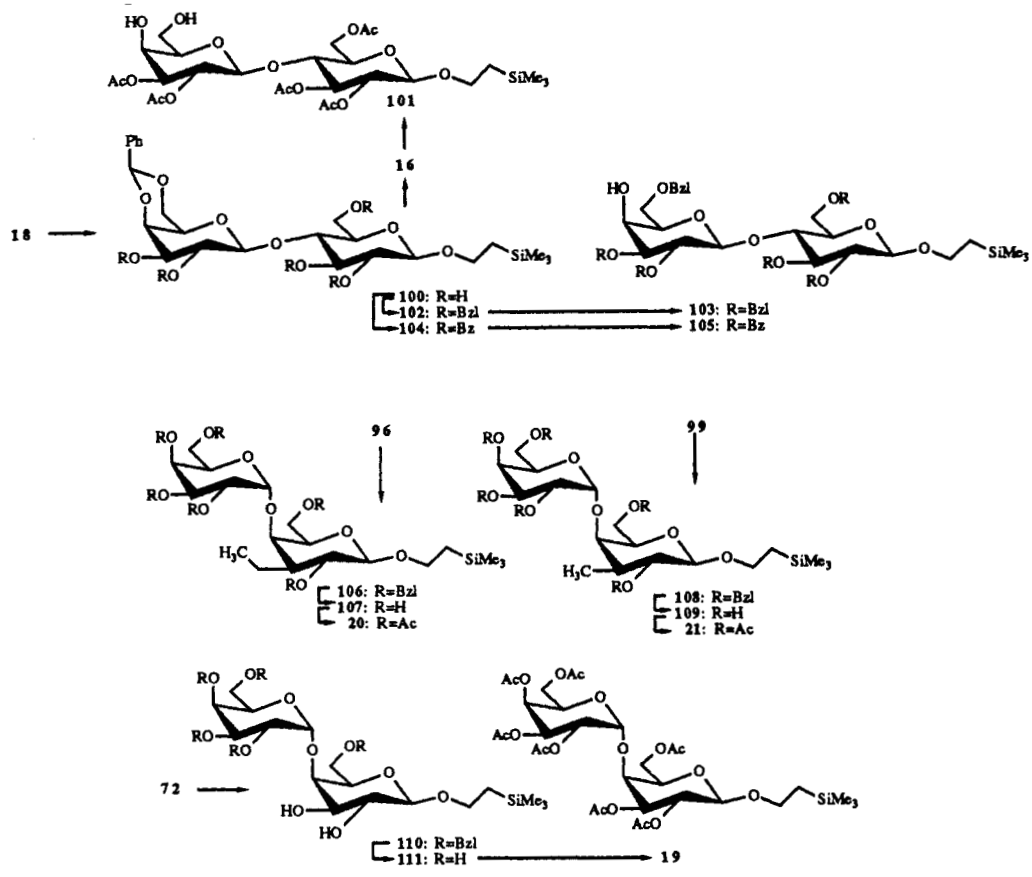


Table V. Reagents That Do Not Affect the TMSET Anomeric Blocking Group

glycoside synthesis: $HgO/HgBr_2$: (1, 3, 15); $Hg(CN)_2/HgBr_2$: (7); TsOH: (4); $Cl_2CHOMe/ZnCl_2$, $Hg(CN)_2$: (6); $AgOSO_2CF_3$/collidine: (8, 106, 108, 110, 112, 118, 122); $AgOSO_2CF_3/Me_2NCONMe_2$: (114, 116, 117); Et_4NBr: (88)
acylation: Ac_2O/pyridine: (2, 4, 5, 8, 14, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27); PhCOCl/pyridine: (9, 71, 83, 104); $(CF_3CO)_2O/CF_3COONa$: (10); $PhSO_2Cl$/pyridine: (80)
deacylation: NaOMe/MeOH: (12, 18, 69, 77, 110)
benzylation: $PhCH_2Cl$/KOH: (11, 17, 78); $PhCH_2Br$/NaH: (75, 90, 102, 120); $PhCH_2Br/Bu_4NBr$/NaOH(aq): (82); $PhCH_2Br/Bu_4NHSO_4$/NaOH(aq): (85, 86)
hydrogenation: H_2/Pd/C: (2, 5, 8, 24, 25, 26, 27, 95, 98, 107, 109, 111, 113)
acetal formation: PhCHO/HCOOH: (70, 92); $PhCH(OMe)_2$/TsOH: (74, 77, 100); $Me_2C(OMe)_2$/TsOH: (89, 119)
acetal hydrolysis: 80% HOAc(aq): (91, 121); 90% CF_3COOH(aq): (101)
silylation: t-$BuMe_2SiCl$/imidazole: (13)
desilylation: Bu_4NF: (79)
hydride reaction: $NaCNBH_3/HCl/Et_2O$: (72, 76, 79, 84, 96, 99, 103, 105); $LiAlH_4$: (87)
oxidation: $Me_2SO/(COCl)_2$: (87, 93)
Wittig olefination: $Ph_3P{=}CHCH_3$: (94); $Ph_3P{=}CH_2$: (97)
nucleophilic substitution: CsOAc/DMF: (81)

(2.14 g) was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **1** (1.72 g, 84%): mp 65–67 °C (ether/hexane); $[\alpha]^{25}_D$ −22° (*c* 1, $CHCl_3$); ^1H NMR δ 5.20 (t, 1 H, J = 9.6 Hz, H-3), 5.09 (t, 1 H, J = 9.6 Hz, H-4), 4.97 (dd, 1 H, J = 9.6, 7.8 Hz, H-2), 4.51 (d, 1 H, J = 7.8 Hz, H-1), 4.26, 4.13 (dd, 1 H each, J = 12.0, 4.8, 2.7 Hz, H-6), 3.97, 3.56 (dq, 1 H each, J = 10.5, 9.6, 5.7, 6.9, 10.5 Hz, OCH_2CH_2), 3.69 (ddd, 1 H, J = 9.6, 4.8, 2.7 Hz, H-5), 2.08, 2.04, 2.02, 2.00 (s, 3 H each, $OCOCH_3$), 0.96, 0.90 (dq, 1 H each, J = 14.0, 9.6, 5.7, 6.9, 10.5 Hz, CH_2Si), 0.01 (s, 9 H, $SiMe_3$); ^{13}C NMR δ 100.2 (C-1), 17.9 (CH_2Si), −1.5 ($SiMe_3$). Anal. Calcd for $C_{19}H_{32}O_{10}Si$: C, 50.9; H, 7.2. Found: C, 50.9; H, 7.3.

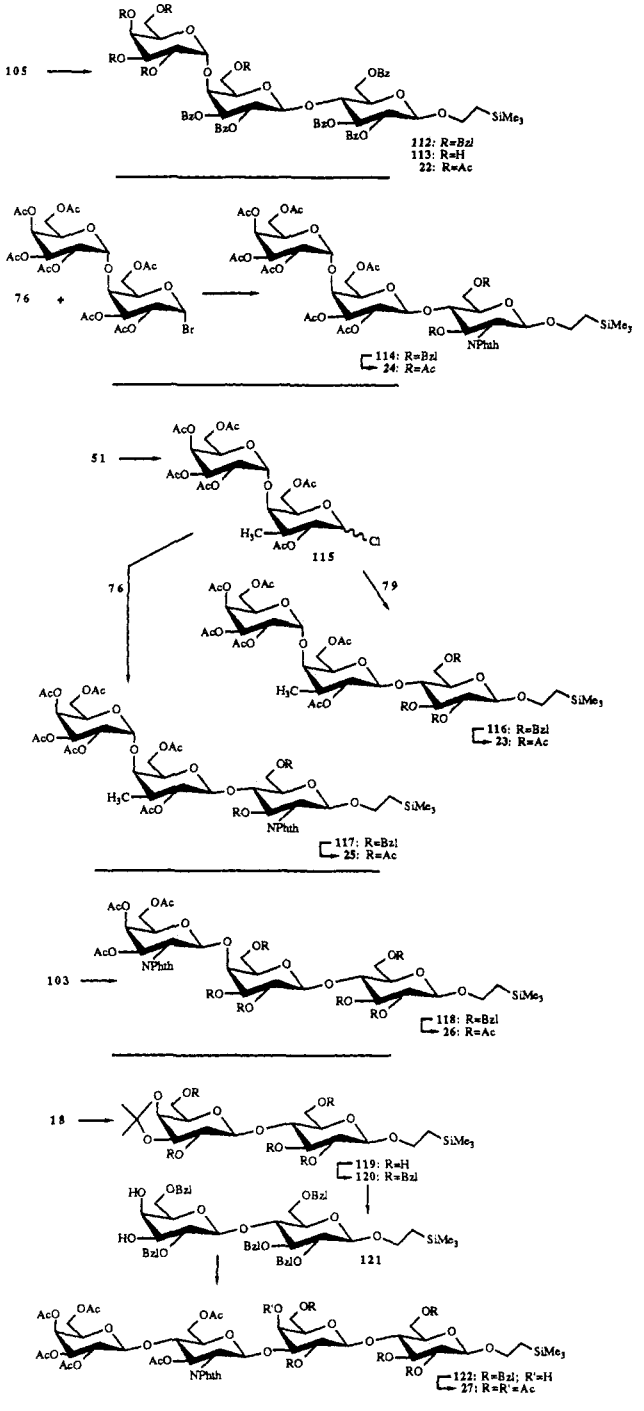
The rest of the crude product was recrystallized from methanol by the dropwise addition of water until cloudiness appeared and then cooling, which gave **1** (ca. 60%).

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-acetyl-α-D-glucopyranoside (2). Compound **88** (100 mg; 0.156 mmol) was hydrogenated (H_2, 1 atm, Pd/C, 10%, 60 mg) in acetic acid (3 mL), the mixture was filtered, and the solvent was removed. The residue was acetylated with acetic anhydride/pyridine (5 mL, 2:3). The volatiles were removed and the residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **2** (61 mg; 86%): mp 58–59 °C (hexane); $[\alpha]^{25}_D$ +111° (*c* 1, $CDCl_3$); ^1H NMR δ 5.49 (dd, 1 H, J = 10.1, 9.4 Hz, H-3), 5.07 (d, 1 H, J = 3.3 Hz, H-1), 5.05 (dd, 1 H, J = 10.3, 9.4 Hz, H-4), 4.86 (dd, 1 H, J = 10.1, 3.3 Hz, H-2), 4.24, 4.09 (dd, 1 H each, J = 12.2, 4.8, 2.3 Hz, H-6), 4.02 (ddd, 1 H, J = 10.3, 4.8, 2.3 Hz, H-5), 0.03 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{19}H_{32}O_{10}Si$: C, 50.9; H, 7.2. Found: C, 50.9; H, 7.1.

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-acetyl-β-D-galactopyranoside (3). 2,3,4,6-Tetra-*O*-acetyl-α-D-galactopyranosyl bromide (10.0 g, 24.3 mmol), was treated as above (**1**) to give crude **3** (9.4 g) as a syrup. A portion (2.16 g) of the crude product was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **3** (1.99 g, 80%): $[\alpha]^{25}_D$ −15° (*c* 1, $CHCl_3$); ^1H NMR δ 5.39 (dd, 1 H, J = 3.3, 1.0 Hz, H-4), 5.20 (dd, 1 H, J = 10.5, 7.8 Hz, H-2), 5.01 (dd, 1 H, J = 10.5, 3.3 Hz, H-3), 4.48 (d, 1 H, J = 7.8 Hz, H-1), 4.20, 4.13 (dd, 1 H each, J = 11.2, 7.2, 6.6 Hz, H-6), 3.99, 3.57 (dq, 1 H each, J = 10.5, 5.7, 9.6 Hz and J = 10.5, 6.9 Hz, OCH_2CH_2), 3.90 (dt, 1 H, J = 6.6, 1.0 Hz, H-5), 0.98, 0.92 (dq, 1 H each, J = 14.0, 6.9, 9.6 Hz and J = 14.0, 10.5, 5.7 Hz, CH_2CH_2Si), 0.01 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{19}H_{32}O_{10}Si$: C, 50.9; H, 7.2. Found: C, 50.8; H, 6.9.

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-acetyl-α-D-mannopyranoside (4). D-Mannose (1.0 g; 5.6 mmol), 2-(trimethylsilyl)ethanol (4.0 g; 34 mmol), and *p*-toluenesulfonic acid monohydrate (16 mg) were stirred for 17 h at 80 °C and then for 1 h at 100 °C. The mixture was cooled to 22 °C and triethylamine (excess) was added. The solvent was removed and the residue was partitioned between ether and water, the organic phase was extracted with water, the combined aqueous extract was washed

Scheme IV. Synthesis of TMSET Tri- and Tetrasaccharides. Reaction Conditions are Summarized in Table V and Detailed in the Experimental Section



with ether, and water was removed to give a residue (0.8 g) that was chromatographed (SiO_2, $CHCl_3$/MeOH/H_2O 65:35:10) to give 2-(trimethylsilyl)ethyl α-D-mannopyranoside (290 mg; 18%), containing 6% of the β anomer. Part of the material (178 mg) was acetylated with acetic anhydride/pyridine and the mixture was concentrated. The residue (269 mg) was crystallized from ether/hexane (1:10) to give **4** (214 mg, 80% from 2-(trimethylsilyl)ethyl α-D-mannopyranoside): mp 60–62 °C (ether/hexane); $[\alpha]^{25}_D$ +47° (*c* 1, $CHCl_3$); ^1H NMR δ 5.36 (dd, 1 H, *J* = 10.0, 3.8 Hz, H-3), 5.26 (t, 1 H, *J* = 10.0 Hz, H-4), 5.21 (dd, 1 H, *J* = 3.5, 1.6 Hz, H-2), 4.83 (d, 1 H, *J* = 2.0 Hz, H-1), 4.26, 4.12 (dd, 1 H each, *J* = 12.2, 6.0, 2.5 Hz, H-6), 4.00 (m, 1 H, H-5), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{19}H_{32}O_{10}Si$: C, 50.9; H, 7.2. Found: C, 50.8; H, 7.1.

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-acetyl-β-D-mannopyranoside (5). Compound **87** (280 mg, 0.61 mmol) was hydrogenated (H_2, 1 atm, Pd/C, 10%, 280 mg) in acetic acid (5 mL) and then acetylated with acetic anhydride/pyridine (10 mL, 2:3). The mixture was concentrated and the residue was chromatographed (SiO_2, EtOAc/heptane 2:5) and crystallized to give **5** (218 mg, 80% from **87**): mp 83–84 °C (ether/hexane); $[\alpha]^{25}_D$ −44° (*c* 1, $CHCl_3$); ^1H NMR δ 5.45 (dd, 1 H, *J* = 3.0, 1.0 Hz, H-2), 5.25 (t, 1 H, *J* = 10.0 Hz, H-4), 5.05 (dd, 1 H, *J* = 10.4, 3.0 Hz, H-3), 4.65 (d, 1 H, *J* = 0.9 Hz, H-1), 4.30, 4.16 (dq, 1 H each, *J* = 12.0, 5.6, 2.7 Hz, H-6), 3.66 (ddd, 1 H, *J* = 10.1, 5.6, 2.7 Hz, H-5), 0.00 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{19}H_{32}O_{10}Si$: C, 50.9; H, 7.2. Found: C, 50.7; H, 7.1.

2-(Trimethylsilyl)ethyl 3,4,6-Tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (6). A solution of **46**[21] (10.1 g, 21.2 mmol) and α,α-dichloromethyl methyl ether (10 mL) in dry dichloromethane (50 mL) was treated with dry $ZnCl_2$ (320 mg) and the mixture was stirred for 2 h at 22 °C. The mixture was diluted with dichloromethane and washed with cold water, cold saturated aqueous $NaHCO_3$, and water, dried (Na_2SO_4), and concentrated. Toluene was added and removed to yield 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-α/β-D-glucopyranosyl chloride (9.6 g; 100%), sufficiently pure for use in the next step. The chloride (16.80 g, 37 mmol), 2-(trimethylsilyl)ethanol (8.74 g, 74 mmol), and $Hg(CN)_2$ (9.35 g, 37 mmol) were heated in 1,2-dichloroethane (200 mL) for 4 h at 70 °C. More 2-(trimethylsilyl)ethanol (1.21 g, 10.3 mmol) and $Hg(CN)_2$ (2.33 g, 9.2 mmol) were added and the mixture was heated for 16 h at 50 °C, then cooled to 22 °C, diluted with dichloromethane, and filtered (Celite). The filtrate was washed with aqueous KI (10%) and water, dried, and concentrated. The crude product was chromatographed (SiO_2, toluene/EtOAc, 10:1) to give **6** (12.6 g, 64%). Crystallization from EtOAc/heptane gave **6**: mp 83–85 °C; $[\alpha]^{25}_D$ +24° (*c* 1, $CHCl_3$); ^1H NMR δ 5.77 (dd, 1 H, *J* = 10.7, 9.0 Hz, H-3), 5.38 (d, 1 H, *J* = 8.6 Hz, H-1), 5.18 (dd, 1 H, *J* = 9.0, 10.5 Hz, H-4), −0.13 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{33}NO_{10}Si$: C, 56.1; H, 6.2; N, 2.6. Found: C, 56.0; H, 6.3; N, 2.5.

2-(Trimethylsilyl)ethyl 2-Acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-β-D-glucopyranoside (7). A mixture of 2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-α-D-glucopyranosyl chloride[22] (22.7 g, 62.1 mmol), 2-(trimethylsilyl)ethanol (11.0 g, 93.2 mmol), $Hg(CN)_2$ (15.7 g, 62.1 mmol), and $HgBr_2$ (2.2 g, 6.1 mmol) in benzene/nitromethane (100 mL, 1:1) was stirred for 1.5 h at 30 °C and 1 h at 50 °C. The solvent was removed and the residue was partitioned between dichloromethane and saturated aqueous NaCl. The aqueous phase was extracted with dichloromethane and the combined organic extracts were washed with saturated aqueous $NaHCO_3$ and water, dried (Na_2SO_4), and concentrated. The residue was crystallized from EtOAc/heptane to give **7** (15.4 g, 56%): mp 184–185 °C; $[\alpha]^{25}_D$ −18° (*c* 1, $CHCl_3$); ^1H NMR δ 5.44 (br d, 1 H, *J* = 8.8 Hz, N*H*Ac), 5.32 (dd, 1 H, *J* = 10.9, 9.3 Hz, H-3), 5.06 (t, 1 H, *J* = 9.7 Hz, H-4), 4.71 (d, 1 H, *J* = 8.3 Hz, H-1), 4.26, 4.12 (dd, 1 H each, *J* = 12.2, 4.9, 2.4 Hz, H-6), 3.76 (dt, 1 H, *J* = 10.9, 8.5 Hz, H-2), 3.69 (ddd, 1 H, *J* = 10.0, 4.9, 2.4 Hz, H-5), 0.00 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{19}H_{33}NO_9Si$: C, 51.0; H, 7.4. Found: C, 50.9; H, 7.4.

2-(Trimethylsilyl)ethyl 3,4,6-Tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-galactopyranoside (8). (a) 3,4,6-Tri-*O*-acetyl-2-deoxy-2-phthalimido-α-D-galactopyranosyl bromide (713 mg, 1.43 mmol) in nitromethane (2 mL) was added to a solution of 2-(trimethylsilyl)ethanol (250 mg, 2 mmol), silver trifluoromethanesulfonate (515 mg, 2 mmol), and 2,4,6-trimethylpyridine (242 mg, 2 mmol) in nitromethane (2 mL) at −30 °C. After 3 h, the cooling bath was removed and after having reached room temperature, the mixture was filtered (Celite) and diluted with dichloromethane. The organic phase was washed with saturated, aqueous $NaHCO_3$, aqueous HCl (3%), and water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **8** (410 mg, 54%): mp 104–108 °C (ether/hexane); $[\alpha]^{25}_D$ −9° (*c* 0.5, $CHCl_3$); ^1H NMR δ 7.86–7.75 (m, 4 H, PhH), 5.78 (dd, 1 H, *J* = 11.4, 3.6 Hz, H-3), 5.48 (dd, 1 H, *J* = 3.6, 1.0 Hz, H-4), 5.34 (d, 1 H, *J* = 8.6 Hz, H-1), 4.54

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(dd, 1 H, J = 11.4, 8.6 Hz, H-2), 4.25, 4.19 (dd, 1 H each, J = 11.2, 7.1 Hz, H-6), 4.08 (dt, 1 H, J = 7.1, 1.0 Hz, H-5), −0.13 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{33}NO_{10}Si$: C, 56.1; H, 6.2; N, 2.6. Found: C, 56.2; H, 6.4; N, 2.5.

(b) Compound **81** (1.10 g, 1.74 mmol) was hydrogenated (H_2, Pd/C, 10%, 0.55 g, 40 psi) in acetic acid (35 mL) for 2 h. The mixture was filtered (Celite) and coconcentrated with toluene. The solid residue was acetylated with acetic anhydride/pyridine (2:3, 25 mL) at 22 °C for 16 h and then coconcentrated with toluene. The residue was dissolved in dichloromethane and washed with saturated aqueous $NaHCO_3$ and water and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:4) to give **8** (827 mg, 88%).

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-benzoyl-β-D-glucopyranoside (9). Compound **12** (1.00 g, 3.57 mmol) was dissolved in pyridine (10 mL) and benzoyl chloride (3.5 mL; 28.5 mmol) was added at room temperature. After 12 h, water (2 mL) was added, and the mixture was stirred for 15 min and then partitioned between dichloromethane and water, hydrochloric acid (1 M), and water. The organic phase was dried (Na_2SO_4) and concentrated and the residue was chromatographed (SiO_2, EtOAc/hexane 1:3) to give **9** (1.95 g, 78%) as a syrup: $[\alpha]^{25}_D$ +18° (c 1, $CHCl_3$); ^1H NMR δ 7.24–8.03 (m, 20 H, PhH) 5.90 (t, 1 H, J = 9.8 Hz, H-3), 5.66 (t, 1 H, J = 9.8 Hz, H-4), 5.52 (dd, 1 H, J = 9.8, 7.8 Hz, H-2), 4.86 (d, 1 H, J = 7.8 Hz, H-1), 4.64, 4.50 (dd, 1 H each, J = 12.0, 5.7, 3.4 Hz, H-6), 4.16 (ddd, 1 H, J = 9.8, 5.7, 3.4 Hz, H-5), −0.08 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{39}H_{40}O_{10}Si$: C, 67.2; H, 5.8. Found: C, 67.0; H, 5.8.

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetrakis-*O*-(trifluoroacetyl)-β-D-glucopyranoside (10). Trifluoroacetic anhydride (5.9 mL, 42 mmol) was added to a mixture of **12** (1.02 g, 3.65 mmol) and sodium trifluoroacetate (0.27 g, 1.94 mmol) at 50 °C. After a 15-min reflux the heating was discontinued and the mixture was repeatedly (3 times) diluted with tetrachloromethane (15 mL) and concentrated at <40 °C. The residue was extracted with hot dichloromethane (3 × 10 mL) and the extract was concentrated to give crude **10** (2.40 g) as a syrup. The crude material was used immediately for the synthesis of **42** and **43**: $[\alpha]^{25}_D$ +3° (c 1, $CHCl_3$); ^1H NMR δ 5.56 (t, 1 H, J = 9.5 Hz, H-3), 5.32 (t, 1 H, J = 9.8 Hz, H-4), 5.21 (dd, 1 H, J = 9.8, 7.8 Hz, H-2), 4.74 (d, 1 H, J = 7.8 Hz, H-1), 4.52 (m, 2 H, H-6), 4.02 (m, 1 H, H-5), 0.01 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{19}H_{20}F_{12}O_{10}Si$: C, 34.4; H, 3.0. Found: C, 32.8; H, 2.7.

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-benzyl-β-D-glucopyranoside (11). Compound **12** (310 mg, 1.11 mmol), benzyl chloride (2.4 mL), and KOH (1 g) were stirred overnight at 130 °C and then cooled. The mixture was partitioned between water and dichloromethane. The organic phase was dried (Na_2SO_4) and concentrated and the residue was chromatographed (SiO_2, EtOAc/hexane 1:12) to give 11 (0.61 g; 86%): mp 105–106 °C (MeOH); $[\alpha]^{25}_D$ +5.5° (c 1, $CHCl_3$); ^1H NMR δ 4.52–5.00 (m, 8 H, $PhCH_2$), 4.41 (d, 1 H, J = 7.8 Hz, H-1), 3.76 (dd, 2 H, J = 10.7, 1.9 Hz, H-6), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{39}H_{48}O_6Si$: C, 73.1; H, 7.6. Found: C, 73.1; H, 7.4.

2-(Trimethylsilyl)ethyl β-D-Glucopyranoside (12). Compound 1 (5 g, 11.1 mmol) was dissolved in methanol (50 mL) and methanolic sodium methoxide (0.1 mL, 1 M) was added. The mixture was stirred for 3 h and then neutralized with Duolite (H^+) resin. Filtration and removal of the solvent gave crude **12** (3.1 g; 99%). Crystallization from ethyl acetate gave **12** (2.82 g, 90%): mp 128–129 °C (EtOAc); $[\alpha]^{25}_D$ −43° (c 1, $CHCl_3$); ^1H NMR (D_2O + 0.2% acetone) δ 4.45 (d, 1 H, J = 7.7 Hz, H-1), 3.89, 3.70 (dd, 1 H each, J = 12.2, 5.3, 2.1 Hz, H-6), 3.22 (dd, 1 H, J = 9.1, 8.1 Hz, H-2), 0.01 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{11}H_{24}O_6Si$: C, 47.1; H, 8.6. Found: C, 47.1; H, 8.6.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-(dimethyl-*tert*-butylsilyl)-β-D-glucopyranoside (13). Compound **79** (123 mg, 0.224 mmol), imidazole (70 mg, 1.03 mmol), and *tert*-butyldimethylsilyl chloride (80 mg, 0.53 mmol) were dissolved in dimethylformamide (1 mL) and the mixture was stirred for 48 h. The mixture was diluted with dichloromethane (10 mL) and washed with aqueous HCl (5 mL, 0.4 M), saturated aqueous $NaHCO_3$ (2 × 5 mL), and water (2 × 5 mL). The organic phase was dried (Na_2SO_4) and concentrated and the residue was chromatographed (SiO_2, toluene) to give **13** (117 mg; 79%): $[\alpha]^{25}_D$ +18° (c 2, $CHCl_3$); ^1H NMR δ 7.24–7.36 (15 H, PhH), 4.52–5.04 (6 H, $PhCH_2$), 4.45 (d, 1 H, J = 7.5 Hz with virtual coupling: entry 4 in ref 24, H-1), 3.78 (dd, 1 H, J = 10.7, 2.0 Hz, H-6), 0.83 (s, 9 H, $SiCMe_3$), 0.04 (s, 9 H, $SiMe_3$), −0.01, −0.03 (s, 3 H each, $SiMe_2$). Anal. Calcd for $C_{38}H_{56}O_6Si_2$: C, 68.6; H, 8.5. Found: C, 69.1; H, 8.8.

2-(Trimethylsilyl)ethyl 4-*O*-Acetyl-2-*O*-benzoyl-3,6-di-*O*-benzyl-β-D-galactopyranoside (14). Compound **84** (9.50 g, 16.8 mmol) was acetylated with acetic anhydride–pyridine (100 mL, 1:1), the solvent was removed, and the residue was chromatographed (SiO_2, EtOAc/heptane, 1:4) to give **14** (9.69 g, 95%) as a syrup: $[\alpha]^{22}_D$ +38° (c 1.0, $CHCl_3$); ^1H NMR δ 5.65 (dd, 1 H, J = 3.4, 0.7 Hz, H-4), 5.38 (dd, 1 H, J = 10.1, 8.0 Hz, H-2), 4.55 (AB q, 2 H, J = 12.7 Hz, $PhCH_2$), 4.54 (AB q, 2 H, J = 11.9 Hz, $PhCH_2$), 4.52 (d, 1 H, J = 8.0 Hz, H-1), 3.79 (m, 1 H, H-5), 2.13 (s, 3 H, OAc), −0.11 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{34}H_{42}O_8Si$: C, 67.3; H, 7.0. Found: C, 67.2; H, 7.0.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranoside (15). 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-α-D-glucopyranosyl bromide (5.00 g, 7.15 mmol) was added to a stirred suspension of HgO (1.55 g, 7.15 mmol), $HgBr_2$ (15 mg), $CaSO_4$ (1.95 g, 14.3 mmol), and 2-(trimethylsilyl)ethanol (1.73 g, 14.3 mmol) in dry chloroform (26 mL; passed through grade 1 alumina). The mixture was stirred for 20 h with protection from light (the reaction was monitored by TLC: SiO_2, EtOAc/heptane 2:1), then filtered (Celite), and washed with saturated aqueous $NaHCO_3$ and water. The organic phase was dried (Na_2SO_4) and concentrated and the residue was dissolved in toluene/nitromethane (56 mL, 1:1) and $HgBr_2$ (69 mg) was added. The mixture was stirred for 24 h at 50 °C (in order to transform the 2-(trimethylsilyl)ethyl orthoacetate into **15**), passed through a column of grade 2 alumina, concentrated, and chromatographed (SiO_2, EtOAc/heptane 1:1) to give **15** (3.1 g; 59%) as a syrup: $[\alpha]^{25}_D$ −16° (c 1, $CHCl_3$); ^1H NMR δ 5.35 (dd, 1 H, J = 3.4, 1.0 Hz, H-4′), 5.19 (t, 1 H, J = 9.3 Hz, H-3), 5.11 (dd, 1 H, J = 10.5, 7.8 Hz, H-2′), 4.95 (dd, 1 H, J = 10.5, 3.4 Hz, H-3′), 4.88 (dd, 1 H, J = 9.5, 7.8 Hz, H-2), 4.48, 4.47 (d, 1 H each, J = 7.8 Hz, H-1,1′), 4.10 (m, 4 H, H-6,6′), 3.94, 3.55 (m, 1 H each, OCH_2CH_2), 3.87 (dt, 1 H, J = 7.6, 1.0 Hz, H-5′), 3.79 (t, 1 H, J = 9.8 Hz, H-4), 3.60 (ddd, 1 H, J = 9.8, 5.1, 2.0 Hz, H-5), 1.97–2.15 (7 s, 3 H each, OAc), 0.91 (m, 2 H, CH_2Si), 0.00 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{31}H_{48}O_{18}Si$: C, 50.5; H, 6.6. Found: C, 50.5; H, 6.6.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3-di-*O*-acetyl-4,6-*O*-benzylidene-β-D-galactopyranosyl)-β-D-glucopyranoside (16). Compound **100** (1.0 g, 1.89 mmol) was acetylated (Ac_2O/pyridine, 24 mL, 9:15; 4-(dimethylamino)pyridine, 5 mg) at 60 °C for 12 h, then poured onto ice, and extracted with dichloromethane. The organic phase was dried (Na_2SO_4), concentrated, and crystallized (EtOAc/heptane) to give **16** (0.91 g, 65%): mp 190–191 °C; $[\alpha]^{25}_D$ +29° (c 1, $CHCl_3$); ^1H NMR δ 7.36–7.48 (5 H, PhH), 5.46 (s, 1 H, PhCH), 5.26 (dd, 1 H, J = 10.6, 7.8 Hz, H-2′), 5.20 (t, 1 H, J = 9.5 Hz, H-3), 4.90 (dd, 1 H, J = 9.7, 7.7 Hz, H-2), 4.87 (dd, 1 H, J = 10.2, 3.7 Hz, H-3′), 4.48, 4.46 (d, 1 H each, J = 7.7 Hz, H-1,1′), 4.32 (d, 1 H, J = 4.0 Hz, H-4′), 3.78 (t, 1 H, J = 9.8 Hz, H-4), 3.60 (m, 1 H, H-5), 3.45 (s, 1 H, H-5′), 0.00 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{34}H_{48}O_{16}Si$: C, 55.1; H, 6.5. Found: C, 55.1; H, 6.7.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranosyl)-β-D-glucopyranoside (17). Compound **18** (2.0 g, 4.5 mmol) was added to a stirred suspension of NaH (2.3 g, 48 mmol, 50% in mineral oil) in dimethylformamide (50 mL) at 0 °C and the mixture was stirred for 10 min. Benzyl bromide (6.13 mL, 48 mmol) was added during

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15 min and the mixture was stirred at 0 °C for 1 h and then at 60 °C for 30 min. The reaction was monitored by TLC (SiO_2, EtOAc/heptane 1:5). Methanol (4 mL) was added and the mixture was stirred for 15 min and then diluted with dichloromethane and washed several times with water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/CH_2Cl_2 1:50) to give **17** (4.00 g, 83%): $[\alpha]^{25}_D$ +8° (*c* 2, $CHCl_3$); ^1H NMR δ 4.45, 4.39 (d, 1 H each, *J* = 8.1, 7.3 Hz, H-1,1′), 0.02 (s, 9 H, $SiMe_3$); ^{13}C NMR δ 102.6, 102.9 (C-1,1′), 18.5 (CH_2Si), −1.4 ($SiMe_3$). Anal. Calcd for $C_{66}H_{76}O_{11}Si$: C, 73.9; H, 7.1. Found: C, 73.7; H, 7.1.

2-(Trimethylsilyl)ethyl 4-*O*-β-D-Galactopyranosyl-β-D-glucopyranoside (18). Compound **15** (6.3 g, 8.55 mmol) was dissolved in methanol (100 mL) and NaOMe/MeOH (3 mL, 0.5 M) was added. The mixture was stirred at 22 °C for 2 h and then neutralized with Duolite (H^+) and the solvent was removed to give **18** (3.7 g, 98%): mp 184–186 °C (EtOAc/MeOH); $[\alpha]^{25}_D$ −18° (*c* 0.7, MeOH); ^1H NMR (D_2O) δ 4.49, 4.44 (d, 1 H each, *J* = 8.1, 7.8 Hz, H-1,1′), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{17}H_{34}O_{11}Si$: C, 46.1; H, 7.7. Found: C, 45.7; H, 7.9.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranoside (19). Compound **111** (94 mg, 0.21 mmol) was acetylated with acetic anhydride–pyridine (6 mL, 1:1) for 16 h. The mixture was concentrated and the residue was chromatographed (SiO_2, EtOAc/heptane 1:1) to give **19** (149 mg; 95%) as a syrup: $[\alpha]^{25}_D$ +63° (*c* 2.4, $CDCl_3$); ^1H NMR δ 5.57 (dd, 1 H, *J* = 3.2, 1.3 Hz, H-4′), 5.39 (dd, 1 H, *J* = 11.0, 3.3 Hz, H-3′), 5.19 (dd, 1 H, *J* = 11.0, 3.7 Hz, H-2′), 5.16 (dd, 1 H, *J* = 10.7, 7.8 Hz, H-2), 5.00 (d, 1 H, *J* = 3.7 Hz, H-1′), 4.81 (dd, 1 H, *J* = 10.7, 2.7 Hz, H-3), 4.54 (br t, 1 H, *J* = 6.7 Hz, H-5 or 5′), 4.48 (d, 1 H, *J* = 7.8 Hz, H-1), 4.48 (dd, 1 H, *J* = 11.1, 6.7 Hz, H-6 or 6′), 4.05 (br d, 1 H, *J* = 2.7 Hz, H-4), 3.78 (br t, 1 H, *J* = 7.0 Hz, H-5 or 5′), 1.98–2.13 (6 s, 3 H each, OAc), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{31}H_{48}O_{18}Si$: C, 50.5; H, 6.6. Found: C, 50.7; H, 6.6.

2-(Trimethylsilyl)ethyl 2,6-Di-*O*-acetyl-3-deoxy-3-*C*-ethyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranoside (20). Compound **107** (320 mg, 0.70 mmol) was acetylated with acetic anhydride/pyridine (1:1), the solvent was removed, and the residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give amorphous **20** (478 mg, 96%): $[\alpha]^{22}_D$ +59° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.52 (dd, 1 H, *J* = 3.0, 1.4 Hz, H-4′), 5.34 (dd, 1 H, *J* = 11.1, 3.0 Hz, H-3′), 5.26 (dd, 1 H, *J* = 11.1, 3.6 Hz, H-2′), 5.09 (d, 1 H, *J* = 3.7 Hz, H-1′), 4.88 (dd, 1 H, *J* = 10.8, 7.6 Hz, H-2), 4.36–4.47 (m, 2 H, H-5,6), 4.38 (d, 1 H, *J* = 7.9 Hz, H-1), 4.21 (dd, 1 H, *J* = 10.9, 6.4 Hz, H-6), 4.12 (dd, 1 H, *J* = 11.3, 7.4 Hz, H-6′), 4.04 (dd, 1 H, *J* = 10.9, 6.4 Hz, H-6′), 3.84 (br s, 1 H, H-4), 3.68 (br t, 1 H, *J* = 6.6 Hz, H-5), 1.40–1.70 (m, 3 H, H-3, CH_2CH_3), 0.82–1.15 (m, 5 H, CH_2CH_3, $OCH_2CH_2SiMe_3$), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{31}H_{50}O_{16}Si$: C, 52.7; H, 7.1. Found: C, 52.7; H, 7.0.

2-(Trimethylsilyl)ethyl 2,6-Di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranoside (21). Crude **109** (from 450 mg of **108**) was acetylated with acetic anhydride/pyridine (1:1) and the crude product was chromatographed (SiO_2, EtOAc/heptane 1:2) to give amorphous **21** (255 mg, 80% from **108**): $[\alpha]^{22}_D$ +56° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.51 (dd, 1 H, *J* = 3.2, 1.3 Hz, H-4′), 5.35 (dd, 1 H, *J* = 11.1, 3.2 Hz, H-3′), 5.27 (dd, 1 H, *J* = 11.1, 3.5 Hz, H-2′), 5.08 (d, 1 H, *J* = 3.5 Hz, H-1′), 4.85 (dd, 1 H, *J* = 11.4, 7.8 Hz, H-2), 4.49 (br t, 1 H, *J* = 6.8 Hz, H-5′), 4.40 (d, 1 H, *J* = 7.7 Hz, H-1), 4.38 (dd, 1 H, *J* = 11.3, 6.8 Hz, H-6), 4.22 (dd, 1 H, *J* = 11.2, 6.2 Hz, H-6), 4.13 (dd, 1 H, *J* = 11.2, 6.7 Hz, H-6′), 4.07 (dd, 1 H, *J* = 11.2, 6.7 Hz, H-6′), 3.71 (br t, 1 H, *J* = 6.6 Hz, H-5), 3.69 (br s, 1 H, H-4), 1.97–2.13 (6 s, 3 H each, OAc), 1.90 (m, 1 H, H-3), 1.11 (d, 3 H, *J* = 7.0 Hz, $CHCH_3$), 0.01 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{30}H_{48}O_{16}Si$: C, 52.0; H, 7.0. Found: C, 51.8; H, 7.3.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzoyl-4-*O*-[6-*O*-acetyl-2,3-di-*O*-benzoyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (22). Compound **113** (0.50 g, 0.44 mmol) was acetylated with acetic anhydride (330 μL, 3.49 mmol) and pyridine (5 mL). The mixture was diluted with dichloromethane (15 mL) and washed with water (20 mL), aqueous H_2SO_4 (20 mL, 2 M), saturated aqueous $NaHCO_3$ (20 mL), and water (20 mL), then dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 2:3) to give **22** (0.53 g, 90%) as a syrup: $[\alpha]^{25}_D$ +93° (*c* 0.9, $CHCl_3$); ^1H NMR δ 7.19–8.04 (m, 25 H, PhH), 5.75 (t, 1 H, *J* = 9.3 Hz, H-3), 5.64 (dd, 1 H, *J* = 11.1, 7.8 Hz, H-2′), 5.47 (dd, 1 H, *J* = 3.4, 1.5 Hz, H-4″), 5.36 (dd, 1 H, *J* = 9.5, 7.8 Hz, H-2), 5.31 (dd, 1 H, *J* = 11.3, 3.5 Hz, H-3′), 5.10 (dd, 1 H, *J* = 10.9, 3.7 Hz, H-2″), 5.04 (dd, 1 H, *J* = 10.8, 2.6 Hz, H-3″), 4.94 (d, 1 H, *J* = 3.7 Hz, H-1″), 4.82 (d, 1 H, *J* = 7.9 Hz, H-1′), 4.69 (d, 1 H, *J* = 7.8 Hz, H-1), −0.15 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{68}H_{74}O_{26}Si$: C, 61.2; H, 5.6. Found: C, 61.1; H, 5.7.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-[2,6-di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (23). Crude **116** (from 1 g of **51**) was debenzylated as described in the preparation of **107** and the crude product was acetylated with acetic anhydride/pyridine (1:1). The solvent was removed and the residue was chromatographed (SiO_2, EtOAc/heptane 1:1) to give amorphous **23** (194 mg, 33% from **51**): $[\alpha]^{22}_D$ +32° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.53 (dd, 1 H, *J* = 3.1, 1.4 Hz, H-4″), 5.53 (dd, 1 H, *J* = 11.1, 3.1 Hz, H-3″), 5.25 (dd, 1 H, *J* = 11.1, 3.5 Hz, H-2″), 5.18 (dd, 1 H, *J* = 9.5, 8.8 Hz, H-3), 5.06 (d, 1 H, *J* = 3.5 Hz, H-1″), 4.89 (dd, 1 H, *J* = 9.4, 7.9 Hz, H-2), 4.79 (dd, 1 H, *J* = 11.5, 7.8 Hz, H-2′), 4.48 (d, 1 H, *J* = 8.0 Hz, H-1), 4.39 (d, 1 H, *J* = 7.9 Hz, H-1′), 1.85 (m, 1 H, H-3), 1.08 (d, 3 H, *J* = 7.0 Hz, $CHCH_3$), 0.003 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{42}H_{64}O_{24}Si$: C, 51.4; H, 6.6. Found: C, 51.0; H, 6.7.

2-(Trimethylsilyl)ethyl 3,6-Di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-[2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (24). Compound **114** (2.5 g, 2.25 mmol) was hydrogenated (H_2, Pd/C, 10%, 1 g, 55 psi) in acetic acid (40 mL) at 22 °C for 24 h, the mixture was filtered (Celite), and the solvent was removed to give the crude debenzylated saccharide (2.70 g). A portion (2.24 g) was acetylated with acetic anhydride/pyridine (1:1), the solvent was removed, and the residue was chromatographed (SiO_2, EtOAc/heptane, 1:1 → 1:2) and then crystallized from methanol to give **24** (1.65 g; 87%): mp 219–220.5 °C; $[\alpha]^{22}_D$ +53° (*c* 1.2, $CHCl_3$); ^1H NMR δ 7.70–7.90 (m, 4 H, PhH), 5.39 (d, 1 H, *J* = 8.5 Hz, H-1), 4.97 (d, 1 H, *J* = 3.5 Hz, H-1″), 4.56 (d, 1 H, *J* = 7.5 Hz, H-1′), 3.99 (br t, 1 H, *J* = 2 Hz, H-4′), −0.14 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{49}H_{65}NO_{26}Si$: C, 52.9; H, 5.9; N, 1.2. Found: C, 52.0; H, 5.9; N, 1.3.

2-(Trimethylsilyl)ethyl 3,6-Di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-[2,6-di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (25). Crude **117** was debenzylated and acetylated as described above (**23**). The crude product was chromatographed (SiO_2, EtOAc/heptane 3:2) to give amorphous **25** (173 mg, 27% from **51**): $[\alpha]^{22}_D$ +43° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.71 (dd with virtual coupling, 1 H, *J* = 10.8, 8.4 Hz, H-3), 5.51 (dd, 1 H, *J* = 3.0, 1.3 Hz, H-4″), 5.38 (d, 1 H, *J* = 8.4 Hz, H-1), 5.32 (dd, 1 H, *J* = 11.2, 3.0 Hz, H-3″), 5.23 (dd, 1 H, *J* = 11.2, 3.5 Hz, H-2″), 5.05 (d, 1 H, *J* = 3.5 Hz, H-1″), 4.81 (dd, 1 H, *J* = 11.7, 7.8 Hz, H-2′), 4.44 (d, 1 H, *J* = 7.7 Hz, H-1′), 4.20 (dd, 1 H, *J* = 10.8, 8.5 Hz, H-2), 1.93–2.13 (8 s, 3 H each, OAc), 1.90 (m, 1 H, H-3′), 1.08 (d, 1 H, *J* = 7.0 Hz, $CHCH_3$), −0.14 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{48}H_{65}NO_{24}Si$: C, 54.0; H, 6.1; N, 1.3. Found: C, 53.8; H, 6.4; N, 1.1.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-[2,3,6-tri-*O*-acetyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (26). Compound **118** (385 mg, 0.275 mmol) was hydrogenated (H_2; 1 atm, Pd/C, 10%, 120 mg) for 6 h in acetic acid (10 mL). The mixture was filtered (Celite) and concentrated and the residue (224 mg) was dissolved in a mixture of 4-(dimethylamino)pyridine (5 mg) in acetic anhydride/pyridine (11 mL, 3:8) and stirred at 100 °C for 15 h. The dark brown mixture was diluted with dichloromethane and the organic phase was washed with aqueous HCl (1 M) and water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane/CH_2Cl_2 1:2:2 → 2:1:1) to give **26** (156 mg; 51%): ^1H NMR δ 7.72–8.00 (m, 4 H, PhH), 5.90 (dd, 1 H, *J* = 11.8, 3.4 Hz, H-3″), 5.46 (dd, 1 H, *J* = 3.4, 1.0 Hz, H-4″), 5.25 (d, 1 H, *J* = 8.7 Hz, H-1″), 5.13 (t, 1 H, *J* = 9.6 Hz, H-3), 4.86 (dd, 1 H, *J* = 9.4, 7.8 Hz, H-2), 4.79 (dd, 1 H, *J* = 10.2, 2.9 Hz, H-3′), 4.43 (d, 1 H, *J* = 7.8 Hz, H-1), 4.28 (d, 1 H, *J* = 7.9 Hz, H-1′), 4.06

(d, 1 H, J = 3.1 Hz, H-4'), 3.70 (t, 1 H, J = 9.5 Hz, H-4), 0.00 (s, 9 H, $SiMe_3$).

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-[2,4,6-tri-*O*-acetyl-3-*O*-[3,6-di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranosyl]-β-D-galactopyranosyl]-β-D-glucopyranoside (27). Compound **122** (1.80 g, 1.14 mmol) was hydrogenated (H_2, Pd/C, 10%, 1.80 g, 50 psi) in acetic acid (50 mL) for 75 min at 22 °C. The catalyst was filtered off (Celite), the filtrate was concentrated, and toluene was added and removed. The residue was acetylated with acetic anhydride/pyridine (35 mL, 3:4) for 3 h at 50 °C and for 16 h at 22 °C. The mixture was coconcentrated with toluene and the residue was dissolved in dichloromethane, washed with saturated aqueous $NaHCO_3$ and water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/toluene 2:3) to give **27** (1.13 g, 83%): $[\alpha]^{25}_D$ +2° (c 0.8, $CHCl_3$); ^1H NMR δ 7.70–7.82 (m, 4 H, PhH), 5.64 (dd, 1 H, J = 10.8, 8.7 Hz, H-3''), 5.34 (d, 1 H, J = 8.2 Hz, H-1''), 5.32 (dd, 1 H, J = 0.9 Hz, H-4'''), 5.29 (br d, 1 H, J = 3.5 Hz, H-4'), 4.58 (d, 1 H, J = 7.8 Hz, H-1'''), 4.39 (d, 1 H, J = 7.9 Hz, H-1), 4.27, (d, 1 H, J = 8.1 Hz, H-1'), 0.03 (s, 9 H, $SiMe_3$); ^{13}C NMR δ 101.1, 100.5, 99.9 (C-1,1',1'''), 97.3 (C-1''), 62.1, 61.5, 60.8, 59.9 (C-6,6',6'',6'''), 54.9 (C-2''), 17.8 (CH_2Si), −1.5 ($SiMe_3$). Anal. Calcd for $C_{61}H_{81}NO_{34}Si$: C, 52.3; H, 5.8; N, 1.0. Found: C, 52.0; H, 5.8; N, 0.9.

General Methods for the Preparation of 1-*O*-Acyl Sugars. The 2-(trimethylsilyl)ethyl glycoside (0.2 mmol) was dissolved in dry toluene (1 mL) and the appropriate carboxylic anhydride (cf. Chart II) was added followed by $BF_3{\cdot}Et_2O$ in the amounts shown below and in Table III. The reaction was monitored by TLC (SiO_2; EtOAc/heptane). The mixture was diluted with dichloromethane (5 mL), washed with saturated aqueous $NaHCO_3$ (5 mL) and water (5 mL), dried (Na_2SO_4), and concentrated. The residue was satisfactory for further synthetic work in the majority of cases. Chromatography (SiO_2, EtOAc/heptane) gave the 1-*O*-acyl sugar as a β/α mixture (cf. Table III); the major anomer was obtained by recrystallization in several cases. Slightly varying reaction conditions (A–F) were used. Methods A and B were applicable with most of the carboxylic anhydrides and are consequently recommended for general use; here, simple filtration through silica can replace the extraction/chromatography procedure described above. Method F employs an excess of $BF_3{\cdot}Et_2O$ to compensate for complexation with the acetamido group of **7**. Methods A–F: carboxylic anhydride (mmol)/$BF_3{\cdot}Et_2O$ (mmol)/temp (°C). A: 0.22/0.14/55; B: 0.3/0.16/55; C: 0.6/0.16/55; D: 2.0/0.16/55; E: 3.0/0.16/22; F: 3.0/0.30/22.

The following 1-*O*-acyl sugars were prepared: 1,2,3,4,6-penta-*O*-acetyl-β/α-D-glucopyranose (**28**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-propionyl-β/α-D-glucopyranose (**29**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-butyryl-β/α-D-glucopyranose (**30**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-valeryl-β/α-D-glucopyranose (**31**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-stearyl-β/α-D-glucopyranose (**32**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-isobutyryl-β/α-D-glucopyranose (**33**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-pivaloyl-β/α-D-glucopyranose (**34**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-crotonyl-β/α-D-glucopyranose (**35**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-benzoyl-β/α-D-glucopyranose (**36**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-(*p*-nitrobenzoyl)-β/α-D-glucopyranose (**37**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-(chloroacetyl)-β/α-D-glucopyranose (**38**), 2,3,4,6-tetra-*O*-acetyl-1-*O*-(trichloroacetyl)-β/α-D-glucopyranose (**39**), 1-*O*-acetyl-2,3,4,6-tetra-*O*-benzoyl-β/α-D-glucopyranose (**40**), 2,3,4,6-tetra-*O*-benzoyl-1-*O*-crotonyl-β/α-D-glucopyranose (**41**), 1-*O*-stearoyl-β/α-D-glucopyranose (**42**), 1-*O*-benzoyl-β/α-D-glucopyranose (**43**), 1,2,3,4,6-penta-*O*-acetyl-β/α-D-galactopyranose (**44**), 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-phthalimido-β/α-D-galactopyranose (**45**), 1,3,4,6-tetra-*O*-acetyl-2-deoxy-2-phthalimido-β/α-D-glucopyranose (**46**), 1,2,3,4,6-penta-*O*-acetyl-β/α-D-mannopyranose (**47**), 1,2,3,6-tetra-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β/α-D-glucopyranose (**48**), 1,2,3,6-tetra-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β/α-D-galactopyranose (**49**), 1,2,6-tri-*O*-acetyl-3-deoxy-3-*C*-ethyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-α/β-D-galactopyranose (**50**), 1,2,6-tri-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-α/β-D-galactopyranose (**51**), 1-*O*-acetyl-2,3,6-tri-*O*-benzoyl-4-*O*-[6-*O*-acetyl-2,3-di-*O*-benzoyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β/α-D-glucopyranose (**52**), 1,2,3,6-tetra-*O*-acetyl-4-*O*-[2,6-di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β/α-D-glucopyranose (**53**), 1,3,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-(2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl)-β/α-D-glucopyranose (**54**), 1,3,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-[2,6-di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β/α-D-glucopyranose (**55**), 1,2,3,6-tetra-*O*-acetyl-4-*O*-(2,3,6-tri-*O*-acetyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-galactopyranosyl)-β-D-galactopyranosyl)-β/α-D-glucopyranose (**56**), 1,2,3,6-tetra-*O*-acetyl-4-*O*-[2,4,6-tri-*O*-acetyl-3-*O*-[3,6-di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranosyl]-β-D-galactopyranosyl]-β,α-D-glucopyranose (**57**).

Full experimental details for the preparation of **28**–**57** are available as supplementary material. Table VI gives selected physical data.

General Method of the Anomeric Deblocking of TMSET Glycosides. The TMSET glycoside (0.1 mmol) was dissolved under nitrogen in dichloromethane (0.5 mL), CF_3COOH (1 mL) was added (at 0 °C with benzylated TMSET glycosides), and the mixture was stirred (see Table IV for reaction time and temperature). *n*-Propyl acetate (3 mL) and toluene (6 mL) were added and then removed at ca. 5 Torr. A second portion of toluene (4 mL) was added and removed, which gave the reducing saccharide sufficiently pure for most synthetic applications. Column chromatography gave the hemiacetal sugars **58**–**68** in 88–95% yield (see Table IV).

The following hemiacetal sugars were prepared: 2,3,4,6-tetra-*O*-acetyl-D-glucopyranose (**58**), 2,3,4,6-tetra-*O*-benzyl-D-glucopyranose (**59**), D-glucose (**60**), 2-acetamido-3,4,6-tri-*O*-acetyl-2-deoxy-D-glucopyranose (**61**), 3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-D-galactopyranose (**62**), 2,3,6-tri-*O*-benzyl-4-*O*-(dimethyl-*tert*-butylsilyl)-D-glucopyranose (**63**), 4-*O*-acetyl-2-*O*-benzoyl-3,6-di-*O*-benzyl-D-galactopyranose (**64**), 2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-D-glucopyranose (**65**), 2,3,6-tri-*O*-benzyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-β-D-galactopyranosyl)-D-glucopyranose (**66**), 4-*O*-β-D-galactopyranosyl-D-glucopyranose (**67**), 2,3,6-tri-*O*-acetyl-4-*O*-[2,4,6-tri-*O*-acetyl-3-*O*-[3,6-di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranosyl]-D-glucopyranose (**68**).

Full experimental details for the preparation of **58**–**68** are available as supplementary material. Table VII gives selected physical data.

2-(Trimethylsilyl)ethyl β-D-Galactopyranoside (69). Compound **3** (20.0 g, 44.6 mmol) was dissolved in methanol (250 mL) and MeONa/MeOH (6 mL, 0.2 M) was added. The mixture was stirred for 3 h, then neutralized with Duolite (H^+) resin, and concentrated to give amorphous **69** (12.1 g; 97%): $[\alpha]^{25}_D$ −20° (c 1, MeOH); ^1H NMR (D_2O) δ 4.36 (d, 1 H, J = 7.9 Hz, H-1), 3.88 (dd, 1 H, J = 3.6, 1.0 Hz, H-4), 3.59 (dd, 1 H, J = 9.9, 3.6 Hz, H-3), 3.44 (dd, 1 H, J = 9.9, 7.9 Hz, H-2), −0.01 (s, 9 H, $SiMe_3$).

2-(Trimethylsilyl)ethyl 4,6-*O*-Benzylidene-β-D-galactopyranoside (70). Compound **69** (19.0 g, 67.9 mmol) was dissolved in formic acid (30 mL), benzaldehyde (30 mL) was added, and the mixture was stirred at 22 °C for 30 min. Heptane (200 mL) was added and the mixture was neutralized with saturated aqueous $NaHCO_3$. The aqueous phase was extracted with dichloromethane (3 × 300 mL), the combined organic extract was washed with saturated aqueous $NaHCO_3$ (300 mL), dried (Na_2SO_4), and concentrated, and the residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **70** (19.8 g, 79%): mp 110–113 °C (EtOAc/heptane); $[\alpha]^{25}_D$ −47° (c 0.9, $CHCl_3$); ^1H NMR ($CDCl_3$, 1 drop of D_2O added) δ 5.52 (s, 1 H, PhCH), 4.31 (dd, 1 H, J = 12.6, 1.3 Hz, H-6), 4.27 (d, 1 H, J = 7.3 Hz, H-1), 4.16 (dd, 1 H, J = 3.6, 0.9 Hz, H-4), 4.05 (dd, 1 H, J = 12.6, 2.0 Hz, H-6), 3.72 (dd, 1 H, J = 9.8, 7.3 Hz, H-2), 3.65 (dd, 1 H, J = 9.8, 3.6 Hz, H-3), 3.42 (br s, 1 H, H-5), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{18}H_{28}O_6Si$: C, 58.7; H, 7.7. Found: C, 58.8; H, 7.8.

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranoside (71). Benzoyl chloride (3.50 g, 24.9 mmol) was added to a solution of **70** (3.66 g, 9.95 mmol) in dry pyridine (40 mL) at 0 °C. After 15 h at 22 °C the mixture was diluted with dichloromethane (150 mL), washed with saturated aqueous $NaHCO_3$ (2 × 50 mL) and water (50 mL), dried

Table VI. Selected Physical Data for the 1-*O*-Acyl Sugars 28–57 (see Chart II)

compd	mp (°C)	$[\alpha]^{25}_D$, deg (*c* 1, $CHCl_3$)	^1H NMR δ/J (Hz) ($CDCl_3/Me_4Si$; anomeric hydrogens only)	Anal. Calcd/Found C	H	N	ref
28β	131–132	+5	5.72/8.4	49.2/49.2	5.7/5.7		23
29β	97–98	+5	5.73/8.0	50.5/50.4	6.0/6.0		
30β	81–82	+4	5.74/8.0	51.7/51.7	6.3/6.3		
31β	61–62	+2	5.72/8.3	52.8/52.8	6.5/6.5		
32β	77–78	+1	5.73/8.4	62.5/62.5	8.9/8.8		12
33β	111–112	+5	5.71/8.0	51.7/51.7	6.3/6.2		
34β	135–136	+7	5.67/7.8	52.8/52.7	6.5/6.6		
35β	93–95	−7	5.78/8.1	51.9/51.9	5.8/5.8		
36β	144–145	−26	5.93/8.6 (virtual coupling: entry 19 in ref 24)	55.8/55.7	5.4/5.3		12
37β	223–225	−33	5.92/8.4 (virtual coupling: entry 19 in ref 24)	50.7/50.7	4.7/4.8	2.8/2.7	
38[a]	107–108	+34	6.40/3.7; 5.77/8.5	45.2/45.2	5.0/4.9		
39α	124–127	+97	6.44/3.7	38.9/39.0	3.9/3.9		
40β	189–191	+58	6.09/8.0	67.7/67.7	4.7/4.9		
41[a]	syrup	+43	6.14/8.0	68.7/68.4	4.9/4.8		
42β	108–111	+1[b]	see ref 12	64.5/64.7	10.4/10.5		12
43β	185–190	−3[b]	see ref 12	54.9/54.9	5.7/5.7		12
44β	139–142	+24	[c]				25
45β	syrup		6.46/9.2				
46β	syrup		6.50/8.9				21
47[a]	syrup		[c]				26
48β	syrup		5.66/8.3; 4.46/7.8				
49β	syrup	+79[d]	5.71/7.8; 5.00/3.5	49.6/49.5	5.6/5.7		
50[a]	amorphous		6.28/3.5; 5.63/8.1	51.9/51.6	6.2/6.3		
51[a]	amorphous		6.29/3.5; 5.64/8.0				
52[a]	syrup	+77	5.92/8.0; 4.94/3.7; 4.82/7.8	61.1/60.8	5.1/5.0		
53β[e]	amorphous	+54[f]	5.68/8.2; 5.07/3.2; 4.38/7.8	50.8/50.7	5.9/6.2		
53α	amorphous		6.24/3.7; 5.08/3.6; 4.38/7.8				
54β	247–248	+72	6.52/9.0; 4.97/3.5; 4.55/7.5	52.4/52.1	5.3/5.3	1.3/1.2	
55[a]	amorphous	+63[g]	6.51/9.0; 5.06/3.5; 4.43/7.6	53.5/53.6	5.5/5.7	1.4/1.2	
56[a]	syrup	−17[h]	5.64/8.1; 5.26/8.3; 4.29/7.6				
57[a]	syrup	+9	5.60/8.1; 5.35/8.2; 4.59/7.9; 4.27/8.1	51.9/51.9	5.3/5.4	1.0/0.9	

[a] For anomeric composition, see Table II. [b] *c* 1, dioxane. [c] Comparative GC using authentic material verified the structure. [d] *c* 1.7, $CHCl_3$; calculated from the β/α ratio using $[\alpha]_D$ +138° for **49α**.[27] [e] A small amount of pure **53β** was obtained by chromatography. [f] *c* 0.5, $CHCl_3$. [g] *c* 0.7, $CHCl_3$. [h] *c* 0.3, $CHCl_3$.

Table VII. Selected Physical Data for the Hemiacetal Sugars 58–68 (see Chart III)

compd	mp (°C)	^{13}C NMR δ ppm ($CDCl_3/Me_4Si$; anomeric carbons only)	Anal. Calcd/Found C	H	ref
58		95.5, 90.0			28
59	151–152	97.5, 91.3	75.5/75.3	6.7/6.7	29
60		98.6, 94.8 (D_2O)			
61		97.4, 91.4			
62		93.1, 92.7			
63	98–99	97.5, 90.8	70.2/70.2	7.9/7.6	
64		^1H NMR: 5.61, 4.48	68.8/69.0	6.0/6.1	
65		101.1, 101.0, 95.1, 90.0			
66		102.8, 97.3, 91.3			
67		105.6, 98.5, 94.5 (D_2O)			
68		101.2, 100.6, 100.4, 97.4, 95.3, 90.1			

(Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:5) to give **71** (5.38 g, 94%): mp 68–71 °C (EtOAc/heptane); $[\alpha]^{25}_D$ +117° (*c* 0.9, $CHCl_3$); ^1H NMR δ 5.86 (dd, 1 H, J = 10.7, 8.2 Hz, H-2), 5.55 (s, 1 H, PhCH), 5.35 (dd, 1 H, J = 10.7, 3.5 Hz, H-3), 4.77 (d, 1 H, J = 8.2 Hz, H-1), 4.59 (dd, 1 H, J = 3.5, 1.0 Hz, H-4), 4.42 (dd, 1 H, J = 12.3, 1.3 Hz, H-6), 4.14 (dd, 1 H, J = 12.3, 1.5 Hz, H-6), 3.67 (br s, 1 H, H-5), −0.07 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{32}H_{36}O_8Si$: C, 66.6; H, 6.3. Found: C, 66.5; H, 6.2.

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzoyl-6-*O*-benzyl-β-D-galactopyranoside (72). Saturated ethereal HCl was added at 22 °C to a mixture of **71** (5.20 g, 9.04 mmol), $NaCNBH_3$ (4.30 g, 68.6 mmol), and powdered molecular sieves (4.5 g, 4 Å) in dry tetrahydrofuran (130 mL).[30] The addition was discontinued when the solution became acidic (pH paper). The reaction was monitored by TLC (SiO_2, EtOAc/heptane 1:1) and, when complete, solid $NaHCO_3$, dichloromethane (250 mL), and saturated aqueous $NaHCO_3$ (100 mL) were added. The mixture was filtered, the organic phase was dried (Na_2SO_4) and concentrated, and the residue was chromatographed (SiO_2, EtOAc/heptane 1:3) to give **72** (4.36 g, 83%): mp 88–89 °C (EtOAc/heptane); $[\alpha]^{25}_D$ +58° (*c* 0.8, $CHCl_3$); ^1H NMR δ 5.74 (dd, 1 H, J = 10.2, 7.7 Hz, H-2), 5.28 (dd, 1 H, J = 10.2, 3.4 Hz, H-3), 4.70 (d, 1 H, J = 7.7 Hz, H-1), 4.62, 4.59 (AB q, 1 H each, J_{AB} = 12.2 Hz, $PhCH_2$), 4.38 (br d, 1 H, J = 3.4 Hz, H-4; acetylation shifted the H-4 signal to 5.70 ppm), 3.77–3.88 (m, 3 H, H-5,6), −0.08 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{32}H_{38}O_8Si$: C, 66.4; H, 6.6. Found: C, 66.2; H, 6.5.

2-(Trimethylsilyl)ethyl 2-Deoxy-2-phthalimido-β-D-glucopyranoside (73). NaOMe/MeOH (0.2 M, 3 mL) was added to a solution of **6** (12.6 g, 23.6 mmol) in dry methanol (150 mL) and the mixture was stirred for 2.5 h at 22 °C, then deionized with Duolite C-26 (H^+), and concentrated to give amorphous **73** (9.26 g, 96%) that was used in the next step without further purification.

2-(Trimethylsilyl)ethyl 4,6-*O*-Benzylidene-2-deoxy-2-phthalimido-β-D-glucopyranoside (74). Compound **73** (9.0 g, 22.0 mmol) was dissolved in dry acetonitrile (150 mL) and α,α-dimethoxytoluene (6.69 g, 44.0 mmol) and *p*-toluenesulfonic acid monohydrate (320 mg) were added. The reaction was monitored by TLC (EtOAc/heptane 2:3). After 45 min, triethylamine (3 mL) was added, the mixture was concentrated, and the residue was chromatographed (SiO_2, EtOAc/heptane 1:3) to give **74** (9.95

(30) Garegg, P. J.; Hultberg, H.; Wallin, S. *Carbohydr. Res.* **1982**, *108*, 97.

g, 91%): $[\alpha]^{22}_D$ −28° (c, 1, $CHCl_3$); ^1H NMR δ 7.35–7.90 (m, 9 H, PhH), 5.58 (s, 1 H, C*H*Ph), 5.31 (d, 1 H, J = 8.1 Hz, H-1). Anal. Calcd for $C_{26}H_{31}NO_7Si$: C, 62.8; H, 6.3; N, 2.8. Found: C, 63.5, H, 6.5; N, 2.6.

2-(Trimethylsilyl)ethyl 3-*O*-Benzyl-4,6-*O*-benzylidene-2-deoxy-2-phthalimido-β-D-glucopyranoside (75). To a solution of **74** (6.10 g, 12.3 mmol) in dry *N,N*-dimethylformamide (50 mL) was added NaH in mineral oil (0.89 g, 18.4 mmol, 50%) and benzyl bromide (44.2 g, 258 mmol). The mixture was stirred for 3 h at 22 °C and then cooled (ice bath) and acetic acid was added (caution!) to destroy excess NaH. The mixture was partitioned between dichloromethane and water, the aqueous layer was extracted with dichloromethane, and the combined extract was washed with saturated aqueous $NaHCO_3$ and water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, heptane → EtOAc/heptane 1:3) to give **75** (5.94 g, 82%): $[\alpha]^{22}_D$ +39° (c 0.7, $CHCl_3$); ^1H NMR δ 6.85–7.88 (m, 14 H, PhH), 5.63 (s, 1 H, C*H*Ph), 5.22 (d, 1 H, J = 8.6 Hz, H-1). Anal. Calcd for $C_{33}H_{37}NO_7Si$: C, 67.4; H, 6.4; N, 2.4. Found: C, 68.3; H, 6.5; N, 2.4.

2-(Trimethylsilyl)ethyl 3,6-Di-*O*-benzyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (76). To a cooled (0 °C), stirred suspension of **75** (339 mg, 0.58 mmol), $NaCNBH_3$ (329 mg, 5.22 mmol), and powdered molecular sieves (3 Å, 260 mg) in dry tetrahydrofuran (10 mL) was added dropwise a saturated solution of HCl in ether (ca. 2.5 mL) until the evolution of gas ceased. The reaction was monitored by TLC (SiO_2, EtOAc/heptane 1:2). After 1 h at 0 °C, ethyl acetate was added, the mixture was filtered (Celite), and the filtrate was washed with saturated aqueous $NaHCO_3$ and water. The organic extract was stirred with SiO_2 (12 g) for 1 h and filtered, and the SiO_2 was washed thoroughly with ethyl acetate. The solution was concentrated and the residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **76** as a syrup (294 mg, 86%): ^1H NMR δ 6.94–7.85 (m, 14 H, PhH), 5.16 (d, 1 H, J = 8.0 Hz, H-1), 4.74, 4.54 (AB q, 1 H each, J_{AB} = 12.3 Hz, CH_2Ph), 4.66, 4.59 (AB q, 1 H each, J_{AB} = 12.1 Hz, CH_2Ph), 2.93 (d, 1 H, J = 2.5 Hz, OH-4).

2-(Trimethylsilyl)ethyl 4,6-*O*-Benzylidene-β-D-glucopyranoside (77). Crude **12** (2.49 g, 8.9 mmol) was dissolved in dry tetrahydrofuran (50 mL), α,α-dimethoxytoluene (2.04 g, 13.4 mmol) and *p*-toluenesulfonic acid monohydrate (170 mg) were added, and the mixture was stirred for 24 h at 22 °C. *p*-Toluenesulfonic acid monohydrate (60 mg) and α,α-dimethoxytoluene (1.02 g, 6.7 mmol) were added, and the mixture was stirred for 3 h and then neutralized with pyridine. The solvent was removed and the residue was chromatographed (SiO_2, $CHCl_3$/EtOAc 7:1) to give **77** (2.71 g, 83%). Crystallization from ether/heptane/EtOAc gave **77**: mp 124–126 °C; $[\alpha]^{25}_D$ −49° (c 2, $CHCl_3$); ^1H NMR δ 7.35–7.52 (m, 5 H, PhH), 5.54 (s, 1 H, C*H*Ph), 4.42 (d, 1 H, J = 7.8 Hz, H-1), 4.36 (dd, 2 H, J = 4.9, 10.4 Hz, H-6), 2.74 (d, 1 H, J = 1.4 Hz, OH), 2.56 (d, 1 H, J = 2.3 Hz, OH). Anal. Calcd for $C_{18}H_{28}O_6Si$: C, 58.7; H, 7.7. Found: C, 58.6; H, 7.9.

2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (78). Compound **77** (250 mg, 0.68 mmol), benzyl chloride (235 μL, 2.04 mmol), and KOH (230 mg, 4.08 mmol) were dissolved in toluene (10 mL) and the mixture was refluxed for 15 h (the reaction was monitored by TLC: SiO_2, EtOAc/hexane 1:6). The mixture was washed with saturated aqueous NaCl, dried (Na_2SO_4), and concentrated and the residue (391 mg) was crystallized from methanol to give **78** (306 mg, 82%): mp 80–81 °C; $[\alpha]^{25}_D$ −31° (c 1, $CHCl_3$); ^1H NMR δ 5.58 (s, 1 H, PhH), 4.52 (d, 1 H, J = 7.7 Hz, H-1), 3.46 (t, 1 H, J = 8.1 Hz, H-3), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{32}H_{40}O_6Si$: C, 70.0; H, 7.4. Found: C, 69.8; H, 7.4.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-β-D-glucopyranoside (79). (a) Compound **78** (274 mg, 0.50 mmol), $NaCNBH_3$ (430 mg, 6.5 mmol), and powdered molecular sieves (3 Å, 1 g) were suspended in dry tetrahydrofuran (7 mL). Saturated ethereal HCl was added dropwise at 22 °C until the gas evolution ceased and TLC (SiO_2, EtOAc/heptane 1:2) showed that **78** had been consumed. The mixture was filtered through silica using ethyl acetate and the eluate was concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **79** (216 mg, 79%): $[\alpha]^{25}_D$ −19° (c 3, $CHCl_3$); ^1H NMR δ 4.43 (d, 1 H, J = 7.3 Hz, H-1), 0.04 (s, 9 H, $SiMe_3$); 4-*O*-acetylated **79** had a signal at 4.95 (t, 1 H, J = 9.8 Hz, H-4). Anal. Calcd for $C_{32}H_{42}O_6Si$: C, 69.8; H, 7.7. Found: C, 69.6; H, 7.8.

(b) Compound **13** (6.7 mg, 0.01 mmol) was dissolved in dry tetrahydrofuran (0.1 mL), tetrabutylammonium fluoride in dry tetrahydrofuran (20 μL, 1 M, 0.02 mmol) was added, and the mixture was stirred for 2 h at 22 °C. The mixture was chromatographed (SiO_2, EtOAc/heptane 1:3) to give **79** (4.7 mg, 85%).

2-(Trimethylsilyl)ethyl 4-*O*-(Phenylsulfonyl)-3,6-di-*O*-benzyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (80). To a solution of **76** (2.31 g, 3.9 mmol) in dry pyridine (20 mL) was added 4-(dimethylamino)pyridine (0.5 g, 4.0 mmol) and benzenesulfonyl chloride (4.84 g, 27.4 mmol), and the mixture was heated for 20 h at 90 °C. Benzenesulfonyl chloride (2.07 g, 11.7 mmol) was added and the heating was continued for 4 h. The mixture was cooled to 22 °C and then partitioned between cold ethyl acetate and cold aqueous HCl (5%). The aqueous phase was extracted with ethyl acetate and the combined organic extract was washed with cold aqueous HCl (10%), water, saturated aqueous $NaHCO_3$, and water, then dried, and concentrated. The residue was chromatographed (SiO_2, toluene/EtOAc 30:1) to give **80** (1.70 g, 60%): $[\alpha]^{22}_D$ +41° (c 2, $CHCl_3$); ^1H NMR δ 6.71–7.95 (m, 19 H, PhH), 5.08 (d, 1 H, J = 8.6 Hz, H-1), 4.84 (dd, 1 H, J = 8.8, 9.8 Hz, H-4), 4.37 (dd, 1 H, J = 8.8, 10.6 Hz, H-3). Anal. Calcd for $C_{39}H_{43}NO_9SSi$: C, 64.2; H, 5.9; N, 1.9. Found: C, 64.1; H, 6.0; N, 1.9.

2-(Trimethylsilyl)ethyl 4-*O*-Acetyl-3,6-di-*O*-benzyl-2-deoxy-2-phthalimido-β-D-galactopyranoside (81). To a solution of **80** (1.60 g, 2.19 mmol) in dry *N,N*-dimethylformamide (30 mL) was added cesium acetate (2.10 g, 10.95 mmol) and powdered molecular sieves (3 Å, 3.2 g) and the mixture was heated for 3.5 h at 130 °C, then cooled to 22 °C, diluted with ethyl acetate, and filtered (Celite). The filtrate was washed with 4 portions of water, dried (Na_2SO_4) and concentrated. The residue was chromatographed (SiO_2, toluene/EtOAc 30:1) to give **81** (1.26 g, 91%): $[\alpha]^{22}_D$ +43° (c 0.7, $CHCl_3$); ^1H NMR δ 6.90–7.87 (m, 14 H, PhH), 5.67 (dd, 1 H, J = 3.4, 0.8 Hz, H-4), 5.16 (d, 1 H, J = 8.4 Hz, H-1), 2.14 (s, 3 H, OAc). Anal. Calcd for $C_{35}H_{41}NO_8Si$: C, 66.5; H, 6.5; N, 2.2. Found: C, 67.1; H, 6.6; N, 2.3.

2-(Trimethylsilyl)ethyl 3-*O*-Benzyl-4,6-*O*-benzylidene-β-D-galactopyranoside (82). Compound **70** (15.0 g, 40.7 mmol), tetrabutylammonium bromide (2.65 g, 8.1 mmol), and benzyl bromide (8.70 mL, 69.2 mmol) were dissolved in toluene (750 mL), aqueous NaOH (5%, 75 mL), was added, and the mixture was stirred vigorously at 60 °C for 24 h. The organic phase was washed with water (300 mL), dried, and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane, 1:2) to give crystalline **82** (11.50 g, 62%): mp 135–136 °C; $[\alpha]^{22}_D$ +21° (c 1.0, $CHCl_3$); ^1H NMR δ 5.46 (s, 1 H, PhC*H*), 4.77 (s, 2 H, PhCH_2), 4.31 (d, 1 H, J = 7.7 Hz, H-1), 4.13 (dd, 1 H, J = 3.6, 0.9 Hz, H-4), 3.50 (dd, 1 H, J = 9.7, 3.6 Hz, H-3), 1.83 (d, 1 H, J = 1.8 Hz, OH), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{27}H_{38}O_5Si$: C, 65.5; H, 7.5. Found: C, 65.3; H, 7.5.

2-(Trimethylsilyl)ethyl 2-*O*-Benzoyl-3-*O*-benzyl-4,6-*O*-benzylidene-β-D-galactopyranoside (83). Compound **82** (10.0 g, 21.8 mmol) was dissolved in pyridine (100 mL), benzoyl chloride (3.8 mL, 32.7 mmol) was added, and the mixture was stirred for 3 h at room temperature. The solution was diluted with dichloromethane (300 mL), washed with water (100 mL) and saturated aqueous $NaHCO_3$ (100 mL), dried, and concentrated. Crystallization from ethyl acetate/heptane gave **83** (10.8 g, 88%): mp 187–188 °C; $[\alpha]^{22}_D$ +42° (c 1.0, $CHCl_3$); ^1H NMR δ 5.62 (dd, 1 H, J = 10.1, 8.0 Hz, H-2), 5.53 (s, 1 H, PhC*H*), 4.64 (AB q, 2 H, J = 13.1 Hz, PhCH_2), 4.59 (d, 1 H, J = 8.0 Hz, H-1), 4.36 (dd, 1 H, J = 12.2, 1.5 Hz, H-6), 4.23 (dd, 1 H, J = 3.5, 0.8 Hz, H-4), 4.07 (dd, 1 H, J = 12.2, 1.8 Hz, H-6), 3.74 (dd, 1 H, J = 10.1, 3.6 Hz, H-3), 3.41 (m, 1 H, H-5), −0.10 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{32}H_{38}O_7Si$: C, 68.3; H, 6.8. Found: C, 68.1; H, 6.8.

2-(Trimethylsilyl)ethyl 2-*O*-Benzoyl-3,6-di-*O*-benzyl-β-D-galactopyranoside (84). Saturated HCl in ether was added dropwise at 22 °C to a mixture of **83** (10.8 g, 19.2 mmol), $NaCNBH_3$ (11.7 g, 177 mmol), and molecular sieves (3 Å, 11 g) in dry tetrahydrofuran (130 mL), until the pH was ~2. The mixture was kept at room temperature for 1.5 h and then solid $NaHCO_3$ was added, and the mixture was diluted with dichloromethane (200 mL) and saturated aqueous $NaHCO_3$ (50 mL) and filtered through Celite. The organic phase was washed with aqueous

$NaHCO_3$ (50 mL), dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane, 1:3) to give **84** (9.54 g, 88%) as a syrup: $[\alpha]^{22}_D$ +17° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.45 (dd, 1 H, *J* = 9.7, 8.0 Hz, H-2), 4.62 (s, 2 H, $PhCH_2$), 4.60 (AB q, 2 H, $PhCH_2$), 4.49 (d, 1 H, *J* = 8.0 Hz, H-1), 4.14 (br s, 1 H, H-4), 3.87 (dd, 1 H, *J* = 9.8, 6.3 Hz, H-6), 3.78 (dd, 1 H, *J* = 9.8, 5.9 Hz, H-6), 3.62 (dd, 1 H, *J* = 9.8, 3.4 Hz, H-3), 2.59 (m, 1 H, H-5), −0.11 (s, 9 H, $SiMe_3$).

2-(Trimethylsilyl)ethyl 3-*O*-Benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (85), 2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (86), and 2-(Trimethylsilyl)ethyl 2,3-Di-*O*-benzyl-4,6-*O*-benzylidene-β-D-glucopyranoside (78). Compound **77** (16.0 g, 43.4 mmol), tetrabutylammonium hydrogen sulfate (2.93 g, 8.6 mmol), and benzyl bromide (12.6 g, 73.7 mmol) were disolved in dichloromethane (700 mL). Aqueous NaOH (58 mL, 1.3 M) was added and the mixture was stirred vigorously at reflux for 48 h. The organic phase was washed three times with water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:8 → 2:3) to give **78** (0.95 g, 4% after crystallization from methanol), **85** (4.77 g, 24%; 3.67 g, 18% after crystallization from methanol/water), **86** (6.8 g, 34%; 5.3 g, 27% after crystallization from pentane), and unreacted **77** (2.6 g, 16%).

85: mp 84–85 °C (heptane); $[\alpha]^{25}_D$ −36° (*c* 1, $CHCl_3$); ^1H NMR δ 5.57 (s, 1 H, PhCH), 4.95, 4.81 (AB q, 1 H each, *J* = 11.5 Hz, $PhCH_2$), 4.40 (d, 1 H, *J* = 7.6 Hz, H-1), 4.35 (dd, 1 H, *J* = 10.4, 5.0 Hz, H-6), 3.80 (t, 1 H, *J* = 10.1 Hz), 3.44 (m, 1 H, H-5), 0.03 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{34}O_6Si$: C, 65.5; H, 7.5. Found: C, 65.8; H, 7.2.

86: mp 90–91 °C (heptane); $[\alpha]^{25}_D$ −23° (*c* 1, $CHCl_3$); ^1H NMR δ 5.51 (s, 1 H, PhCH), 4.95, 4.75 (AB q, 1 H each, *J* = 11.5 Hz, $PhCH_2$), 4.52 (d, 1 H, *J* = 7.6 Hz, H-1), 4.34 (dd, 1 H, *J* = 10.4, 5.0 Hz, H-6), 3.83 (dt, 1 H, *J* = 9.0, 1.5 Hz, H-3; acetylated **86** had the H-3 signal at 5.29), 3.77 (t, 1 H, *J* = 10.4 Hz, H-6), 3.53 (t, 1 H, *J* = 9.0 Hz, H-4), 3.42 (dt, 1 H, *J* = 9.4, 5.0 Hz, H-5), 3.33 (dd, 1 H, *J* = 9.0, 7.6 Hz, H-2), 2.47 (d, 1 H, *J* = 1.8 Hz, OH), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{34}O_6Si$: C, 65.5; H, 7.5. Found: C, 65.5; H, 7.4.

2-(Trimethylsilyl)ethyl 3-*O*-Benzyl-4,6-*O*-benzylidene-β-D-mannopyranoside (87). Compound **85** (1.00 g, 2.18 mmol) was oxidized with methyl sulfoxide as described.[17] The crude product was dissolved in ether (30 mL), $LiAlH_4$ (200 mg) was added, and the mixture was stirred for 2 h. Saturated aqueous K_2CO_3 was added and the mixture was filtered and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:4) to give **87** (560 mg, 56%): $[\alpha]^{25}_D$ −20° (*c* 1, $CDCl_3$); ^1H NMR δ 5.61 (s, 1 H, PhCH), 4.87, 4.79 (AB q, 1 H each, *J* = 12.3 Hz, $PhCH_2$), 4.52 (d, 1 H, *J* = 1.0 Hz, H-1), 4.34 (dd, 1 H, *J* = 10.4, 5.0 Hz, H-6), 4.15 (t, 1 H, *J* = 9.5 Hz, H-4), 4.11 (m, 1 H, *J* = 3.4 Hz, H-2), 3.89 (t, 1 H, *J* = 10.3 Hz, H-6), 3.65 (dd, 1 H, *J* = 9.6, 3.3 Hz, H-3), 3.35 (dt, 1 H, *J* = 10.0, 4.9 Hz, H-5), 2.53 (d, 1 H, *J* = 1.3 Hz, OH), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{34}O_6Si$: C, 65.5; H, 7.5. Found: C, 65.5; H, 7.6.

2-(Trimethylsilyl)ethyl 2,3,4,6-Tetra-*O*-benzyl-α-D-glucopyranoside (88). Compound **59** (250 mg, 0.46 mmol) and dimethylformamide (300 μL) were dissolved in dichloromethane (1.5 mL) and oxalyl chloride (300 μL) was added dropwise (gas evolution). The mixture was stirred for 30 min and rapidly chromatographed (SiO_2, EtOAc/heptane 1:2). The resulting 2,3,4,6-tetra-*O*-benzyl-D-glucopyranosyl chloride was dissolved in dichloromethane (2 mL) and added to a stirred, boiling mixture of tetraethylammonium bromide (107 mg, 0.50 mmol), powdered molecular sieves (4 Å, 0.5 g), 2-(trimethylsilyl)ethanol (60 mg, 0.50 mmol), and dimethylformamide (0.15 mL) in dichloromethane (2 mL). After 48 h, 2-(trimethylsilyl)ethanol (50 mg, 0.42 mmol) and dimethylformamide (0.1 mL) in dichloromethane (1 mL) were added and the mixture was refluxed for 72 h. The mixture was filtered (Celite), diluted with dichloromethane, washed with three portions of water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, CH_2Cl_2/toluene 2:1) to give **88** (155 mg, 52%) and **11** (20 mg, 7%). **88**: $[\alpha]^{25}_D$ +43° (*c* 1, $CDCl_3$); ^1H NMR δ 4.80 (d, 1 H, *J* = 3.6 Hz, H-1), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{39}H_{48}O_6Si$: C, 73.1; H, 7.6. Found: C, 73.2; H, 7.6.

2-(Trimethylsilyl)ethyl 3,4-*O*-Isopropylidene-6-*O*-(2-methoxyisopropyl)-β-D-galactopyranoside (89). Compound **69** (2.50 g, 8.92 mmol) was dissolved in 2,2-dimethoxypropane (180 mL) and the mixture was stirred for 24 h with a catalytic amount of *p*-toluenesulfonic acid. The reaction mixture was quenched with triethylamine and concentrated. Chromatography (SiO_2, EtOAc/heptane, 1:1, +0.1% triethylamine) gave **89** as a syrup (2.65 g, 75%): ^1H NMR (pyridine-d_5) δ 4.74 (d, 1 H, *J* = 8.1 Hz, H-1), 4.60 (dd, 1 H, *J* = 7.2, 5.5 Hz, H-3), 4.43 (dd, 1 H, *J* = 5.5, 1.8 Hz, H-4), 4.06–4.15 (2 H, H-2,6), 4.00 (dd, 1 H, *J* = 9.8, 4.9 Hz, H-6), 3.33 (s, 3 H, CH_3O), 1.52 (s, 3 H, CCH_3), 1.42 (s, 9 H, CCH_3), 0.003 (s, 9 H, $SiMe_3$).

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-3,4-*O*-isopropylidene-6-*O*-(2-methoxyisopropyl)-β-D-galactopyranoside (90). A solution of **89** (2.55 g, 6.50 mmol) in dry *N*,*N*-dimethylformamide (5 mL) was added to NaH (340 mg, 8.50 mmol, 60% in mineral oil) in dry *N*,*N*-dimethylformamide (15 mL), and the mixture was stirred for 1.5 h at 22 °C. Benzyl bromide (1.15 mL, 11.5 mmol) was added dropwise at 0 °C and the mixture was stirred at 22 °C for 3 h, then diluted with water (10 mL) and extracted with ether (3 × 20 mL), dried, and concentrated. the residue was chromatographed (SiO_2, EtOAc/heptane, 1:3, +0.1% triethylamine) to give **90** (2.63 g, 84%): ^1H NMR (pyridine-d_5) δ 5.14, 5.09 (AB q, 2 H, *J* = 12.1 Hz, $PhCH_2$), 4.73 (d, 1 H, *J* = 8.2 Hz, H-1), 4.53 (dd, 1 H, *J* = 6.9, 5.6 Hz, H-3), 4.42 (dd, 1 H, *J* = 5.6, 2.2 Hz, H-4), 4.07 (dd, 1 H, *J* = 9.9, 7.0 Hz, H-6), 3.97 (dd, 1 H, *J* = 9.8, 4.8 Hz, H-6), 3.32 (s, 3 H, CH_3O), 1.46 (s, 3 H, CCH_3), 1.41 (s, 9 H, CCH_3), 0.001 (s, 9 H, $SiMe_3$).

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-β-D-galactopyranoside (91). Compound **90** (2.5 g, 5.18 mmol) was dissolved in 80% aqueous acetic acid (25 mL) and kept at 90 °C for 20 min. The mixture was concentrated and the residue was chromatographed (SiO_2, $CHCl_3$/MeOH, 10:1) to give amorphous **91** (1.88 g, 98%): $[\alpha]^{22}_D$ + 16° (*c* 1, $CDCl_3$); ^1H NMR δ 4.99, 4.68 (AB q, 2 H, *J* = 11.6 Hz, $PhCH_2$), 4.41 (d, 1 H, *J* = 7.6 Hz, H-1), 3.97 (dd, 1 H, *J* = 11.8, 6.1 Hz, H-6), 3.86 (dd, 1 H, *J* = 11.7, 4.5 Hz, H-6), 3.50 (dd, 1 H, *J* = 9.5, 7.5 Hz, H-2), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{18}H_{30}O_6Si$: C, 58.4; H, 8.2. Found: C, 58.2; H, 7.9.

A sample of **91** (100 mg, 0.27 mmol) was acetylated with acetic anhydride/pyridine and the crude product was chromatographed (SiO_2, EtOAc/heptane, 1:1) to give 2-(trimethylsilyl)ethyl 3,4,6-tri-*O*-acetyl-2-*O*-benzyl-β-D-galactopyranoside (127 mg, 95%): ^1H NMR δ 5.35 (dd, 1 H, *J* = 3.5, 0.9 Hz, H-4), 4.97 (dd, 1 H, *J* = 10.2, 3.5 Hz, H-3), 4.89, 4.64 (AB q, 2 H, *J* = 11.7 Hz, $PhCH_2$), 4.48 (d, 1 H, *J* = 7.8 Hz, H-1), 4.19 (dd, 1 H, *J* = 11.2, 6.5 Hz, H-6), 4.09 (dd, 1 H, *J* = 11.1, 7.1 Hz, H-6), 3.86 (br t, 1 H, *J* = 6.8 Hz, H-5), 3.61 (dd, 1 H, *J* = 9.9, 7.7 Hz, H-2), 0.04 (s, 9 H, $SiMe_3$).

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-β-D-galactopyranoside (92). Compound **91** (1.7 g, 4.59 mmol) was dissolved in benzaldehyde/formic acid (15 mL, 1:1). After 5 min, the solution was neutralized with saturated aqueous $NaHCO_3$ (40 mL), the mixture was extracted with dichloromethane (3 × 30 mL), and the organic phase was dried and concentrated. The residue was chromatographed (toluene/EtOAc, 4:1) to give amorphous **92** (1.68 g, 80%): $[\alpha]^{22}_D$ +5° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.56 (s, 1 H, PhC*H*), 5.00, 4.74 (AB q, 2 H, *J* = 11.3 Hz, $PhCH_2$), 4.41 (d, 1 H, *J* = 7.5 Hz, H-1), 4.35 (dd, 1 H, *J* = 12.4, 1.6 Hz, H-6), 4.22 (dd, 1 H, *J* = 3.8, 1.0 Hz, H-4), 4.08 (dd, 1 H, *J* = 12.4, 1.8 Hz, H-6), 3.74 (ddd, 1 H, *J* = 9.6, 7.2, 3.8 Hz, H-3; acetylated **92** had the H-3 signal at 4.91 ppm), 3.62 (dd, 1 H, *J* = 9.6, 7.5 Hz, H-2), 3.45 (m, 1 H, H-5), 2.49 (d, 1 H, *J* = 7.2 Hz, OH), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{34}O_6Si$: C, 65.5; H, 7.5. Found: C, 65.5; H, 7.4.

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-β-D-*xylo*-hexopyranosid-3-ulose (93). Compound **92** (1.5 g, 3.27 mmol) was oxidized with methyl sulfoxide as described.[17] The residue was chromatographed (SiO_2, EtOAc/heptane, 1:4) to give an epimeric mixture of ketones (1.26 g, 85%), containing ≃75% of **93**. An analytical sample of **93** was obtained by crystallization from ethyl acetate/heptane: mp 84–85 °C; $[\alpha]^{22}_D$ −38° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.58 (s, 1 H, PhC*H*), 4.81, 4.74 (AB q, 2 H, *J* = 11.5 Hz, $PhCH_2$), 4.58, 4.52 (AB q, 2 H, *J* = 8.0 Hz, H-1,2), 4.45 (dd, 1 H, *J* = 12.5, 1.5 Hz, H-6), 4.44 (d, 1 H, *J* = 1.2 Hz, H-4), 4.15 (dd, 1 H, *J* = 12.7, 1.8 Hz, H-6), 3.53 (q, 1 H, *J* = 1.6 Hz, H-5), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{25}H_{32}O_6Si$: C, 65.8; H, 7.1. Found: C, 65.8, H, 7.1.

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-3-*C*-ethylidene-β-D-*xylo*-hexopyranoside (94E and 94Z).

n-Butyllithium in hexane (2.3 mL, 1.6 M, 3.68 mmol) was added at 22 °C to a suspension of ethyltriphenylphosphonium bromide (1.38 g, 3.68 mmol) in dry ether (20 mL) under nitrogen. After 1.5 h, a solution of crude **93** (1.2 g, 2.63 mmol) in dry ether (50 mL) was added and the mixture was stirred overnight. Water (30 mL) was added, the mixture was stirred for 2 h, the phases were separated, and the aqueous phase was extracted with ether (3 × 30 mL). The combined ether extract was dried (Na_2SO_4) and concentated. The residue was chromatographed (SiO_2, EtOAc/heptane, 6:1) to give a mixture of the two stereoisomers of **94** (**94E** and **94Z**, 970 mg, 79%). **94E** (500 mg, 41%) was obtained by crystallization from ethyl acetate/heptane: mp 112–113 °C; $[\alpha]^{22}_D$ +36° (*c* 0.6, $CHCl_3$); ^1H NMR δ 6.06 (dq, 1 H, *J* = 7.1, 2.1 Hz, C=C*H*CH_3, 17% NOE on irradiation of C=CHCH_3), 5.62 (s, 1 H, PhC*H*), 4,98, 4.67 (AB q, 2 H, *J* = 11.3 Hz, PhCH_2), 4.81 (d, 1 H, *J* = 1.3 Hz, H-4, 11% NOE on irradiation of C=CHCH_3), 4.36 (dd, 1 H, *J* = 12.5, 1.3 Hz, H-6), 4.34 (d, 1 H, *J* = 7.6 Hz, H-1), 4.18 (dp, 1 H, *J* = 7.7, 2.1 Hz, H-2), 4.14 (dd, 1 H, *J* = 12.2, 2.0 Hz, H-6), 3.40 (q, 1 H, *J* = 1.6 Hz, H-5), 1.79 (dd, 3 H, *J* = 7.1, 2.1 Hz, C=CHCH_3), 0.03 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{27}H_{36}O_5Si$: C, 69.2; H, 7.7. Found: C, 69.3; H, 7.7.

Chromatography of the mother liquor gave crystalline **94Z**: mp 47–49 °C; $[\alpha]^{22}_D$ +16° (*c* 0.6, $CHCl_3$); ^1H NMR δ 5.91 (br q, 1 H, *J* = 7.2 Hz, C=C*H*CH_3), 5.55 (s, 1 H, PhC*H*), 4.85, 4.68 (AB q, 2 H, *J* = 11.3 Hz, PhCH_2), 4.67 (d, 1 H, *J* = 6.4 Hz, H-1), 4.39 (dp, 1 H, *J* = 6.2, 1.6 Hz, H-2), 4.32 (dd, 1 H, *J* = 12.3, 1.5 Hz, H-6), 4.28 (br s, 1 H, H-4, 13% NOE on irradiation of C=C*H*CH_3), 4.06 (dd, 1 H, *J* = 12.4, 2.0 Hz, H-6), 3.58 (q, 1 H, *J* = 1.8 Hz, H-5) 1.88 (dd, 1 H, *J* = 7.2, 1.5 Hz, C=CHCH_3, 4% NOE on irradiation of C=C*H*CH_3), 0.03 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{27}H_{36}O_5Si$: C, 69.2; H, 7.7. Found: C, 69.2; H, 7.7.

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-3-deoxy-3-*C*-ethyl-β-D-galactopyranoside (95). Compound **94** (950 mg, 2.03 mmol) was hydrogenated (H_2, Pd/C, 10%, 0.5 g, 1.8 atm.) in ethyl acetate/MeOH (70 mL, 2:3) containing NaOMe (0.03 M) for 1 h. The mixture was neutralized with acetic acid, filtered (Celite) and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane, 1:5) to give crystalline **95** (889 mg, 93%). Mp 100.5–101.5°, $[\alpha]^{22}_D$ +20° (*c* 1.0, $CHCl_3$). ^1H NMR (C_6D_6) δ 5.27 (s, 1 H, PhC*H*), 5.19, 4.52 (ABq, 2 H, J 11.5 Hz, PhCH_2), 4.44 (d, 1 H, *J* = 7.5 Hz, H-1), 4.16 (dd, 1 H, *J* = 12.1, 1.5 Hz, H-6), 3.59 (dd, 1 H, *J* = 10.6, 7.4 Hz, H-2), 3.48–3.53 (m, 2 H, H-4,6), 2.76 (q, 1 H, *J* = 1.2 Hz, H-5), 2.00, 1.69 (m, 1 H each, CH_2CH_3), 1.47 (m, 1 H, H-3), 0.93 (t, 3 H, *J* = 7.4 Hz, CH_2CH_3), –0.01 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{27}H_{38}O_5Si$: C, 68.9; H, 8.1. Found: C, 68.5; H, 8.0.

2-(Trimethylsilyl)ethyl 2,6-Di-*O*-benzyl-3-deoxy-3-*C*-ethyl-β-D-galactopyranoside (96). Compound **95** (850 mg, 1.81 mmol) was reduced with $NaCNBH_3$ as described in the preparation of **84**. The crude product was chromatographed (SiO_2, EtOAc/heptane 1:6), to give **96** as a syrup (470 mg, 54%): $[\alpha]^{22}_D$ +6° (*c* 1.0, $CHCl_3$); ^1H NMR δ 4.95, 4.56 (AB q, 2 H, *J* = 11.0 Hz, PhCH_2), 4.40 (d, 1 H, *J* = 7.8 Hz, H-1), 3.89 (br s, 1 H, H-4; acetylated **96** had the H-4 signal at 5.30 ppm), 3.76 (dd, 1 H, *J* = 10.2, 5.5 Hz, H-6), 3.70 (dd, 1 H, *J* = 10.0, 5.0 Hz, H-6), 3.24 (dd, 1 H, *J* = 10.1, 7.7 Hz, H-2), 1.76–1.95 (m, 2 H, C$H_2$$CH_3$, OH), 1.37–1.55 (m, 2 H, C$H_2$$CH_3$, H-3), 0.94 (t, 3 H, *J* = 7.2 Hz, CH_2CH_3), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{27}H_{40}O_5Si$: C, 68.6; H, 8.5. Found: C, 68.7; H, 8.4.

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-3-*C*-methylene-β-D-*xylo*-hexopyranoside (97). Crude **93** (3,00 g, 6.57 mmol) was treated with *n*-butyllithium and methyltriphenylphosphonium bromide essentially as described in the preparation of **94**. The crude product was chromatographed (SiO_2, EtOAc/heptane, 5:1) and the purified product was crystallized from ethanol to give **97** (1.73 g, 58%): mp 74–75 °C; $[\alpha]^{22}_D$ +18° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.58 (s, 1 H, PhC*H*), 5.51, 5.31 (2 t, 1 H each, *J* = 1.8 Hz, C=CH_2), 4.98, 4.71 (AB q, 2 H, *J* = 11.5 Hz, PhCH_2), 4.47 (d, 1 H, *J* = 1.2 Hz, H-4), 4.36 (d, 1 H, *J* = 7.8 Hz, H-1), 4.35 (dd, 1 H, *J* = 12.5, 1.5 Hz, H-6), 4.11 (dd, 1 H, *J* = 12.4, 2.0 Hz, H-6), 3.44 (m, 1 H, H-5), 0.03 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{26}H_{34}O_5Si$: C, 68.7; H, 7.5. Found: C, 68.7; H, 7.6.

2-(Trimethylsilyl)ethyl 2-*O*-Benzyl-4,6-*O*-benzylidene-3-deoxy-3-*C*-methyl-β-D-galactopyranoside (98). Compound **97** (1.50 g, 3.30 mmol) was hydrogenated as described in the preparation of **95** and the crude product was chromatographed (SiO_2, EtOAc/heptane, 6:1) to give **98** (1.32 g, 87%): mp 76–77 °C (EtOH); $[\alpha]^{22}_D$ +13° (*c* 1.0, $CHCl_3$); ^1H NMR δ 5.51 (s, 1 H, PhC*H*), 5.00, 4.58 (AB q, 2 H, *J* = 11.0 Hz, PhCH_2), 4.43 (d, 1 H, *J* = 7.7 Hz, H-1) 4.33 (dd, 1 H, *J* = 12.3, 1.4 Hz, H-6), 4.06 (dd, 1 H, *J* = 12.3, 2.0 Hz, H-6), 3.86 (dd, 1 H, *J* = 3.2, 0.8 Hz, H-4), 3.44 (m, 1 H, H-5), 3.40 (dd, 1 H, *J* = 10.7, 7.6 Hz, H-2), 1.87 (m, 1 H, H-3), 1.19 (d, 3 H, *J* = 6.7 Hz, CHCH_3), 0.03 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{26}H_{36}O_5Si$: C, 68.4; H, 7.9. Found: C, 68.3; H, 8.1.

2-(Trimethylsilyl)ethyl 2,6-Di-*O*-benzyl-3-deoxy-3-*C*-methyl-β-D-galactopyranoside (99). Compound **98** (1.14 g, 2.50 mmol) was reduced with $NaCNBH_3$ as described in the preparation of **84**. The crude product was chromatographed (SiO_2, EtOAc/heptane, 1:4) to give **99** (0,69 g, 60%) as a syrup: $[\alpha]^{22}_D$ +13° (*c* 0.7, $CHCl_3$); ^1H NMR δ 4.94, 4.58 (AB q, 2 H, *J* = 11.1 Hz, PhCH_2), 4.61, 4.56 (AB q, 2 H, *J* = 11.8 Hz, PhCH_2), 4.41 (d, 1 H, *J* = 7.6 Hz, H-1), 3.75 (dd, 1 H, *J* = 9.8, 5.4 Hz, H-6), 3.55–3.75 (3 H, H-4,5, OCH_2C$H_2$$SiMe_3$; acetylated **99** had the H-4 signal at 5.18 ppm), 3.69 (dd, 1 H, *J* = 9.9, 4.9 Hz, H-6), 3.23 (dd, 1 H, *J* = 10.9, 7.6 Hz, H-2), 2.26 (d, 1 H, *J* = 7.0 Hz, OH), 1.70 (m, 1 H, H-3), 1.13 (d, 3 H, *J* = 6.7 Hz, CHCH_3), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{26}H_{38}O_5Si$: C, 68.1; H, 8.4. Found: C, 68.6; H, 8.7.

2-(Trimethylsilyl)ethyl 4-*O*-(4,6-*O*-Benzylidene-β-D-galactopyranosyl)-β-D-glucopyranoside (100). Compound **18** (3.0 g, 6.78 mmol) was dissolved in dry acetonitrile (100 mL), then α,α-dimethoxytoluene (2.1 mL, 13.7 mmol) and a catalytic amount of *p*-toluenesulfonic acid were added, and the mixture was stirred at 22 °C overnight. Triethylamine (1 mL) was added, the mixture was concentrated, and the residue was chromatographed (SiO_2, EtOAc–MeOH 15:1) to give **100** (3.27 g, 91%): $[\alpha]^{22}_D$ –40° (*c* 0.6, $CHCl_3$); ^1H NMR δ 7.33–7.50 (m, 5 H, PhH), 5.44 (s, 1 H, PhC*H*), 4.46 (d, 1 H, *J* = 7.8 Hz, H-1), 4.27 (d, 1 H, *J* = 7.5 Hz, H-1′). Anal. Calcd for $C_{24}H_{38}O_{11}Si$: C, 54.3; H, 7.2. Found: C, 54.1; H, 7.2.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-acetyl-4-*O*-(2,3-di-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranoside (101). Compound **16** (74 mg, 0.10 mmol) was dissolved in dichloromethane (2 mL) and the mixture was cooled (0 °C). Aqueous trifluoroacetic acid[15] (90%, 0.2 mL) was added and the mixture was stirred for 90 min at 0 °C then diluted with dichloromethane and washed with water, saturated aqueous $NaHCO_3$, and water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 4:1) to give **101** (50 mg, 77%). Recrystallization (EtOAc/heptane) gave **101** (40 mg, 62%): mp 152–160 °C; $[\alpha]^{25}_D$ –7° (*c* 1, $CHCl_3$); ^1H NMR δ 4.50, 4.48 (d, 1 H each, *J* = 7.8, 7.4 Hz, H-1,1′), 0.00 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{27}H_{44}O_{16}Si$: C, 49.7; H, 6.8. Found: C, 49.2; H, 6.8.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-(2,3-di-*O*-benzyl-4,6-*O*-benzylidene-β-D-galactopyranosyl)-β-D-glucopyranoside (102). Compound **100** (1.5 g, 2.83 mmol) was benzylated according to the procedure used for the preparation of **17**. The crude product was chromatographed (SiO_2, EtOAc/hexane 1:3) to give **102** (1.72 g, 62%): mp 108–109 °C (MeOH); $[\alpha]^{25}_D$ +12° (*c* 1, $CHCl_3$); ^1H NMR δ 5.45 (s, 1 H, PhCH), 4.46, 4.38 (d, 1 H each, *J* = 8.1, 7.8 Hz, H-1,1′), 0.02 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{59}H_{68}O_{11}Si$: C, 72.2; H, 7.0. Found: C, 72.4; H, 7.1.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-(2,3,6-tri-*O*-benzyl-β-D-galactopyranosyl)-β-D-glucopyranoside (103). Compound **102** (1.70 g, 1.73 mmol) was reduced according to the procedure used for the preparation of **72** and **84**. The crude product was chromatographed (SiO_2, EtOAc/heptane 1:3) to give **103** (1.35 g, 80%): mp 100–102 °C (heptane); $[\alpha]^{25}_D$ +18° (*c* 1, $CHCl_3$); ^1H NMR δ 0.02 (s, 9 H, $SiMe_3$); acetylated **103** had 5.56 (dd, 1 H, *J* = 3.0, 1.0 Hz, H-4′). Anal. Calcd for $C_{59}H_{70}O_{11}Si$: C, 72.1; H, 7.2. Found: C, 72.5; H, 7.4.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzoyl-4-*O*-(2,3-di-*O*-benzoyl-4,6-*O*-benzylidene-β-D-galactopyranosyl)-β-D-glucopyranoside (104). Compound **100** (2.8 g, 5.28 mmol) was dissolved in pyridine (15 mL), then benzoyl chloride (6.4 mL, 37.6 mmol) was added dropwise with stirring at 0 °C and the mixture was allowed to attain room temperature. When **100** had been consumed, water (ca 0.5 mL) was added, and the mixture was stirred for 15 min, then diluted with dichloromethane (75 mL), washed with water (75 mL), aqueous H_2SO_4 (50 mL, 2 M), and

saturated aqueous $NaHCO_3$ (50 mL), dried (Na_2SO_4), and concentrated to give **104** (4.2 g, 76%): $[\alpha]^{22}_D$ +110° (*c* 1.3, $CHCl_3$); ^1H NMR δ 7.15–8.19 (m, 30 H, PhH), 5.83 (t, 1 H, *J* = 9.3 Hz, H-3), 5.79 (dd, 1 H, *J* = 10.5, 7.8 Hz, H-2′), 5.32 (dd, 1 H, *J* = 9.2, 7.8 Hz, H-2), 5.29 (s, 1 H, PhC*H*), 5.16 (dd, 1 H, *J* = 10.5, 3.7 Hz, H-3′), 4.84 (d, 1 H, *J* = 8.1 Hz, H-1′), 4.69 (d, 1 H, *J* = 7.8 Hz, H-1), 4.61, 4.37 (dd, 1 H each, *J* = 12.0, 2.0, 4.6 Hz, H-6), 4.30 (d, 1 H, *J* = 3.4 Hz, H-4′), 4.21 (t, 1 H, *J* = 9.5 Hz, H-4). Anal. Calcd for $C_{59}H_{58}O_{16}Si$: C, 67.4; H, 5.6. Found: C, 67.4; H, 5.5.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzoyl-4-*O*-(2,3-di-*O*-benzoyl-6-*O*-benzyl-β-D-galactopyranosyl)-β-D-glucopyranoside (105). Saturated ethereal HCl was added at 22 °C to a solution of **104** (4.30 g, 4.1 mmol), $NaCNBH_3$ (2.58 g, 41 mmol), and powdered molecular sieves (2 g, 4 Å) in dry tetrahydrofuran (70 mL).[30] The addition was discontinued when the solution became acidic. The reaction was monitored by TLC (SiO_2, EtOAc/heptane) and $NaHCO_3$, dichloromethane (60 mL), saturated aqueous $NaHCO_3$ (30 mL), and water (30 mL) were added. The mixture was filtered, the organic phase was dried (Na_2SO_4) and concentrated, and the residue was chromatographed (SiO_2, EtOAc/hexane 1:3) to give **105** (3.14 g, 73%): $[\alpha]^{22}_D$ +44° (*c* 1, $CHCl_3$); ^1H NMR δ 7.18–8.18 (m, 30 H, PhH), 5.71 (dd, 1 H, *J* = 10.0, 9.1 Hz, H-3), 5.69 (dd, 1 H, *J* = 11.6, 8.1 Hz, H-2′), 5.37 (dd, 1 H, *J* = 9.5, 7.8 Hz, H-2), 5.09 (dd, 1 H, *J* = 10.6, 3.1 Hz, H-3′), 4.73 (d, 1 H, *J* = 7.7 Hz, H-1′), 4.67 (d, 1 H, *J* = 7.8 Hz, H-1), 4.57, 4.40 (dd, 1 H each, *J* = 12.0, 1.7, 5.1 Hz, H-6′), 4.21 (d, 1 H, *J* = 3.4 Hz, H-4′; acetylated **105** had the H-4′ signal at 5.48 ppm). Anal. Calcd for $C_{59}H_{60}O_{16}Si$: C, 67.3; H, 5.7. Found: C, 66.9; H, 5.8.

2-(Trimethylsilyl)ethyl 2,6-Di-*O*-benzyl-3-deoxy-3-*C*-ethyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl)-β-D-galactopyranoside (106). Freshly prepared 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl chloride (862 mg, 1.52 mmol) in dry toluene (3 mL) was added to a mixture of **96** (450 mg, 0.95 mmol), silver trifluoromethanesulfonate (410 mg, 1.62 mmol), and 2,4,6-trimethylpyridine (226 μL, 1.71 mmol) in dry toluene (10 mL) under nitrogen at −40 °C. The mixture was kept at room temperature for 1 h, then filtered, and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane, 1:10) to give **106** (804 mg, 85%) as a syrup: ^1H NMR δ 4.38 (d, 1 H, *J* = 7.6 Hz, H-1), 3.29 (dd, 1 H, *J* = 10.6, 7.5 Hz, H-2), 1.81 (m, 1 H, CH_2CH$_3$), 1.40–1.50 (2 H, CH_2CH$_3$, H-3), 0.86 (br t, 3 H, CH$_2$CH_3), 0.04 (s, 9 H, SiMe$_3$).

2-(Trimethylsilyl)ethyl 3-Deoxy-3-*C*-ethyl-4-*O*-α-D-galactopyranosyl-β-D-galactopyranoside (107). Compound **106** (750 mg, 0.75 mmol) was hydrogenated (H_2, Pd/C, 10%, 0.5 g) at 20 psi in acetic acid (70 mL) for 1 h. The mixture was filtered (Celite) and concentrated and the residue was chromatographed (SiO_2, $CHCl_3$/MeOH 8:1) to give amorphous **107** (350 mg 98%): ^1H NMR (CD_3OD) δ 5.00 (d, 1 H, *J* = 3.4 Hz, H-1′) 4.28 (d, 1 H, *J* = 7.6 Hz, H-1), 1.87 (m, 1 H, CH_2CH$_3$), 1.36–1.57 (m, 2 H, CH_2CH$_3$ and H-3), 1.03 (t, 3 H, *J* = 7.3 Hz, CH$_2$CH_3), 0.05 (s, 9 H, SiMe$_3$).

2-(Trimethylsilyl)ethyl 2,6-Di-*O*-benzyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl)-β-D-galactopyranoside (108). Compound **99** (300 mg, 0.65 mmol) was glycosylated with freshly prepared 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl chloride as described in the preparation of **106**, to give **108** (460 mg, 72%) as a syrup: ^1H NMR δ 4.92 (d, 1 H, *J* = 2.6 Hz, H-1′), 4.38 (d, 1 H, *J* = 7.6 Hz, H-1), 1.74 (m, 1 H, H-3), 1.18 (d, 3 H, *J* = 6.8 Hz, CHCH_3), 0.03 (s, 9 H, SiMe$_3$).

2-(Trimethylsilyl)ethyl 3-Deoxy-3-*C*-methyl-4-*O*-α-D-galactopyranosyl-β-D-galactopyranoside (109). Compound **108** (450 mg, 0.46 mmol) was hydrogenated as described in the preparation of **107** to give crude **109**, which was used without further purification for the preparation of **21**.

2-(Trimethylsilyl)ethyl 6-*O*-Benzyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl)-β-D-galactopyranoside (110). A solution of freshly prepared 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl chloride (480 mg, 0.87 mmol) in dry toluene (2 mL) was added to a stirred solution of **72** (250 mg, 0.433 mmol), silver trifluoromethanesulfonate (200 mg, 0.779 mmol), 2,4,6-trimethylpyridine (115 μL, 0.87 mmol), and molecular sieves (0.4 g, 4 Å) in dry toluene (4 mL) at −40 °C with exclusion of light and under nitrogen. The mixture was allowed to attain room temperature, then filtered, and concentrated, and the residue was chromatographed (SiO_2, EtOAc/heptane 1:6) to give crude 2-(trimethylsilyl)ethyl 2,3-di-*O*-benzoyl-6-*O*-benzyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl)-β-D-galactopyranoside (565 mg). The crude product was debenzoylated (0.1 M NaOMe/MeOH–dichloromethane 2:1, 15 mL) at 22 °C for 12 h, the mixture was neutralized with acetic acid (45 μL) and concentrated, and the residue was chromatographed (SiO_2, EtOAc/heptane 45:55) to give **110** (324 mg, 84%) as a syrup: $[\alpha]^{25}_D$ +9.4° (*c* 0.8, $CHCl_3$); ^1H NMR ($CDCl_3$, 1 drop of D_2O added) δ 4.94 (d, 1 H, *J* = 3.9 Hz, H-1′), 4.24 (d, 1 H, *J* = 7.4 Hz, H-1), 3.47 (dd, 1 H, *J* = 9.9, 7.4 Hz, H-2), 3.37 (dd, 1 H, *J* = 9.9, 2.7 Hz, H-3), 3.29 (dd, 1 H, *J* = 9.4, 3.9 Hz, H-2′), 0.08 (s, 9 H, SiMe$_3$). Anal. Calcd for $C_{52}H_{64}O_{11}Si$: C, 69.9; H, 7.2. Found: C, 69.9; H, 7.2.

2-(Trimethylsilyl)ethyl 4-*O*-α-D-Galactopyranosyl-β-D-galactopyranoside (111). Compound **110** (261 mg, 0.293 mmol) was hydrogenated (H_2, Pd/C, 10%, 140 mg, 1 atm) in acetic acid (7.5 mL) for 30 min. The mixture was filtered (Celite) and concentrated and the residue was dissolved in H_2O (5 mL) and lyophilized to give amorphous **111** (115 mg, 89%): $[\alpha]^{25}_D$ +76° (*c* 0.5, H_2O); ^1H NMR [D_2O, sodium 3-(trimethylsilyl)propanesulfonate] δ 4.95 (d, 1 H, *J* = 3.3 Hz, H-1′), 4.45 (d, 1 H, *J* = 7.9 Hz, H-1), 4.34 (br t, 1 H, *J* = 6.5 Hz, H-5′), 3.50 (dd, 1 H, *J* = 10.4, 7.9 Hz, H-2), 0.01 (s, 9 H, SiMe$_3$).

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzoyl-4-*O*-[2,3-di-*O*-benzoyl-6-*O*-benzyl-4-*O*-(2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (112). Compound **105** (2.70 g, 2.56 mmol) was dissolved in dry toluene (60 mL) and silver trifluoromethanesulfonate (1.00 g, 3.89 mmol), 2,4,6-trimethylpyridine (0.49 g, 4.04 mmol), and powdered molecular sieves (2 g, 4 Å) were added. Freshly prepared 2,3,4,6-tetra-*O*-benzyl-α-D-galactopyranosyl chloride (2.1 g, 3.76 mmol) in dry toluene (10 mL) was added dropwise to the mixture at −20 °C under nitrogen with protection from light. The mixture was allowed to attain room temperature while being monitored by TLC, then filtered (Celite), and concentrated. The residue was chromatographed (EtOAc/heptane 2:9) to give **112** (2.82 g, 70%): $[\alpha]^{22}_D$ +64° (*c* 0.5, $CHCl_3$); ^1H NMR δ 5.78 (t, 1 H, *J* = 9.4 Hz, H-3), 5.74 (dd, 1 H, *J* = 11.0, 7.8 Hz, H-2′), 5.31 (dd, 1 H, *J* = 9.7, 7.8 Hz, H-2), 5.06 (dd, 1 H, *J* = 10.9, 3.0 Hz, H-3′), 4.86 (d, 1 H, *J* = 7.9 Hz, H-1′), 4.81 (d, 1 H, *J* = 6.4 Hz), 4.68 (d, 1 H, *J* = 7.9 Hz, H-1), 4.78 (s, 1 H, H-1″). Anal. Calcd for $C_{93}H_{94}O_{21}Si$: C, 70.9; H, 6.0. Found: C, 70.6; H, 5.9.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzoyl-4-*O*-[2,3-di-*O*-benzoyl-4-*O*-α-D-galactopyranosyl-β-D-galactopyranosyl]-β-D-glucopyranoside (113). Compound **112** (3.0 g, 1.90 mmol) was hydrogenated (H_2, Pd/C, 10%, 300 mg, 1 atm) in acetic acid (10 mL). The mixture was filtered (Celite) and concentrated and the residue was chromatographed (SiO_2, EtOAc/EtOH 40:1) to give **113** (1.5 g, 70%): $[\alpha]^{22}_D$ +85° (*c* 1.1, $CHCl_3$); ^1H NMR δ 7.20–8.01 (m, 25 H, PhH), 5.71 (t, 1 H, *J* = 9.6 Hz, H-3), 5.58 (dd, 1 H, *J* = 10.7, 7.8 Hz, H-2′), 5.37 (dd, 1 H, *J* = 9.9, 7.8 Hz, H-2), 5.11 (dd, 1 H, *J* = 10.4, 1.8 Hz, H-3′), 4.82 (d, 1 H, *J* = 3.4 Hz, H-1″), 4.79 (d, 1 H, *J* = 7.8 Hz, H-1′), 4.69 (d, 1 H, *J* = 8.2 Hz, H-1), 4.58, 4.38 (dd, 1 H each, *J* = 12.0, 1.7, 4.3 Hz, H-6), −0.15 (s, 9 H, SiMe$_3$). Anal. Calcd for $C_{58}H_{64}O_{21}Si$: C, 61.9; H, 5.7. Found: C, 61.7; H, 5.8.

2-(Trimethylsilyl)ethyl 3,6-Di-*O*-benzyl-2-deoxy-2-phthalimido-4-*O*-[2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (114). A solution of 2,3,6-tri-*O*-acetyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-α-D-galactopyranosyl bromide[6k] (5.01 g, 7.18 mmol) in dichloromethane (23 mL) was added at −75 °C to a stirred solution of **76** (5.9 g, 10 mmol), silver trifluoromethanesulfonate (3.0 g, 11.6 mmol), and 1,1,3,3-tetramethylurea (1.63 g, 14.0 mmol) in dichloromethane (47 mL) with protection from light. The cooling bath was removed and the mixture was stirred for 15 h at 22 °C, then filtered (Celite), washed with saturated aqueous NaCl and saturated aqueous $NaHCO_3$, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 5:2 → 1:1) to give unreacted **76** (3.2 g), the 1′-α isomer of **114** (0.22 g), and a mixture of the 1′-α isomer and **114** (4.7 g). Crystallization of the latter fraction from MeOH gave pure **114** (2.39 g). Repeated chromatography and crystallization of the remaining material gave an additional amount of pure **114** (0.3 g) and the 1′-α isomer (1.09 g, 20%). Total yield of **114**: 2.69 g (49%, based on reacted **76**): mp 111–112 °C;

$[\alpha]^{22}_D$ +70° (*c*, 1.2, $CHCl_3$); ^1H NMR δ 6.75–7.70 (m, 14 H, PhH), 5.11 (d, 1 H, *J* = 8.0 Hz, H-1), 4.93 (d, 1 H, *J* = 3.5 Hz, H-1″), 4.65 (d, 1 H, *J* = 8.0 Hz, H-1′), 3.97 (dd, 1 H, *J* = 3.0, 0.5 Hz, H-4′), −0.16 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{59}H_{73}NO_{24}Si$: C, 58.7; H, 6.1; N, 1.2. Found: C, 58.3; H, 6.1; N, 1.1.

The 1′-α isomer was an amorphous solid: $[\alpha]^{22}_D$ +126° (*c*, 1.1, $CHCl_3$); ^1H NMR δ 6.75–7.75 (m, 14 H, PhH), 5.58 (d, 1 H, *J* = 2.5 Hz, H-1′), 5.09 (d, 1 H, *J* = 8.5 Hz, H-1), 4.97 (d, 1 H, *J* = 3.5 Hz, H-1″), −0.16 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{59}H_{73}NO_{24}Si$: C, 58.7; H, 6.1; N, 1.2. Found: C, 58.7; H, 6.2; N, 1.1.

2,6-Di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-α/β-D-galactopyranosyl Chloride (115). Compound **51** (1.0 g, 1.58 mmol) was dissolved in 1,1-dichlorodimethyl ether (10 mL), and then acetic anhydride (2 mL) and $ZnCl_2$ (0.5 g) were added. The mixture was stirred for 2 h at 22 °C, then cold dichloromethane (100 mL) and cold saturated aqueous $NaHCO_3$ (50 mL) were added, and the phases were separated. The organic phase was washed with saturated aqueous $NaHCO_3$ (50 mL), dried (Na_2SO_4), and concentrated to give a syrup containing ~75% of **115**. The crude product was used without further purification in the preparation of compounds **116** and **117**.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-[2,6-di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (116). Crude **115** (ca 0.6 mmol) was dissolved in dry dichloromethane (2 mL) and then added to a suspension of **72** (825 mg, 1.5 mmol), silver trifluoromethanesulfonate (262 mg, 1.0 mmol), and 1,1,3,3-tetramethylurea (133 μL, 1.1 mmol) in dry dichloromethane (5 mL) at −78 °C. The mixture was kept at 22 °C for 16 h, then filtered, diluted with dichloromethane (100 mL), washed with saturated aqueous $NaHCO_3$ (30 mL) and water (30 mL), dried (Na_2SO_4), and concentrated to give crude **116**, which was used without purification in the preparation of **23**.

2-(Trimethylsilyl)ethyl 3,6-Di-*O*-benzyl-2-deoxy-2-phthalimido-4-*O*-[2,6-di-*O*-acetyl-3-deoxy-3-*C*-methyl-4-*O*-(2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (117). Crude **115** (ca 0.6 mmol) was treated with **76** (885 mg, 1.5 mmol), essentially as described for the preparation of **116** from **72**, to give crude **117**, which was used without purification in the preparation of **25**.

2-(Trimethylsilyl)ethyl 2,3,6-tri-*O*-benzyl-4-*O*-[2,3,6-tri-*O*-benzyl-4-*O*-(3,4,6-tri-*O*-acetyl-2-deoxy-2-phthalimido-β-D-galactopyranosyl)-β-D-galactopyranosyl]-β-D-glucopyranoside (118) was prepared essentially as described[31] for the 8-(methoxycarbonyl)octyl glycoside. 3,4,6-Tri-*O*-acetyl-2-deoxy-2-phthalimido-D-galactopyranosyl bromide (100 mg, 0.2 mmol) was dissolved in nitromethane (2 mL) and added to a mixture of **103** (167 mg, 0.17 mmol), 2,4,6-trimethylpyridine (24 μL, 0.18 mmol), and silver trifluoromethanesulfonate (60 mg, 0.23 mmol) in dry nitromethane (2.5 mL) at −25 °C. The mixture was stirred for 6 h at −25 °C and for 20 h at 22 °C. Dichloromethane (10 mL) was added, the mixture was filtered, and the filtrate was washed with aqueous $Na_2S_2O_3$, cold water, dilute aqueous HCl, and saturated aqueous $NaHCO_3$, then dried, and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:3) to give **118** (129 mg, 54%): $[\alpha]^{25}_D$ +3° (*c* 0.7, $CDCl_3$); ^1H NMR δ 6.16 (dd, 1 H, *J* = 11.5, 3.7 Hz, H-3″), 5.56 (d, 1 H, *J* = 3.7 Hz, H-4″), 5.38 (d, 1 H, *J* = 8.3 Hz, H-1″), 4.64 (dd, 1 H, *J* = 11.5, 8.3 Hz, H-2″), 0.01 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{79}H_{89}NO_{20}Si$: C, 67.7; H, 6.4; N, 1.0. Found: C, 67.5; H, 6.5; N, 1.0.

2-(Trimethylsilyl)ethyl 4-*O*-(3,4-*O*-Isopropylidene-β-D-galactopyranosyl)-β-D-glucopyranoside (119). To a solution of **18** (8.5 g, 19.2 mmol) and 2,2-dimethoxypropane (30 mL) was added *p*-toluenesulfonic acid monohydrate (1.0 g), and the mixture was stirred overnight at 22 °C and then neutralized with triethylamine. The mixture was concentrated, then dissolved in 80% aqueous acetic acid and acetone (140 mL, 1:1), and stirred for 1 h at 22 °C in order to hydrolyze methoxypropyl groups formed during the isopropylidenation step. The mixture was concentrated (<30 °C), toluene was added and removed, and the residue was chromatographed (SiO_2, EtOAc/MeOH) to give **119** (4.39 g, 50%): $[\alpha]^{22}_D$ +6° (*c* 0.8, MeOH); ^1H NMR (D_2O) δ 4.36 (d, 1 H, *J* = 8.2 Hz, H-1′), 4.30 (d, 1 H, *J* = 8.1 Hz, H-1), 1.45, 1.33 (s, 3 H each, $C(CH_3)_2$), 0.04 (s, 9 H, $SiMe_3$). Anal. Calcd for $C_{20}H_{38}O_{11}Si$: C, 49.8; H, 7.9. Found: C, 49.8; H, 8.1.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-(2,6-di-*O*-benzyl-3,4-*O*-isopropylidene-β-D-galactopyranosyl)-β-D-glucopyranoside (120). To a solution of **119** (1.60 g, 3.3 mmol) in *N*,*N*-dimethylformamide was added NaH (1.58 g, 33.0 mmol, 50% in mineral oil), the mixture was stirred for 10 min at 22 °C, and benzyl bromide (5.64 g, 33.0 mmol) was added. After 4 h, excess NaH was destroyed by addition of MeOH, the mixture was partitioned between ethyl acetate and water, and the organic phase was washed with 4 portions of water, dried (Na_2SO_4), and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:4) to give **120** (2.76 g, 90%): ^{13}C NMR δ 109.7 (CMe_2), 103.2, 101.3 (C-1,1′), 27.9, 26.4 ($C(CH_3)_2$).

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-(2,6-di-*O*-benzyl-β-D-galactopyranosyl)-β-D-glucopyranoside (121). Compound **120** (2.56 g, 2.7 mmol) was dissolved in aqueous acetic acid (50 mL, 80%) and the mixture was heated for 40 min at 100 °C and concentrated. The residue was chromatographed (SiO_2, EtOAc/heptane 1:2) to give **121** (1.81 g, 75%). Trituration with heptane gave crystalline **121**: mp 99.5–101 °C; ^{13}C NMR δ 103.1, 102.6 (C-1,1′), −1.4 ($SiMe_3$). Anal. Calcd for $C_{52}H_{64}O_{11}Si$: C, 69.9; H, 7.2 Found: C, 70.3; H, 7.5.

2-(Trimethylsilyl)ethyl 2,3,6-Tri-*O*-benzyl-4-*O*-[2,6-di-*O*-benzyl-3-*O*-[3,6-di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-β-D-glucopyranosyl]-β-D-galactopyranosyl]-β-D-glucopyranoside (122). To a cooled (−18 °C), stirred mixture of **121** (1.40 g, 1.57 mmol), 3,6-di-*O*-acetyl-2-deoxy-2-phthalimido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-galactopyranosyl)-α/β-D-glucopyranosyl chloride[32] (1.52 g, 2.0 mmol), and powdered molecular sieves (2.95 g, 3 Å) in dry dichloromethane (25 mL) was added (8 min) a solution of silver trifluoromethanesulfonate (0.80 g, 3.14 mmol) and 2,4,6-trimethylpyridine (0.38 g, 3.14 mmol) in dichloromethane/toluene (16 mL, 3:2) with protection from light. The mixture was stirred for 1 h, the cooling bath was removed, and aqueous $Na_2S_2O_7$ (5 mL, 10%) was added. The mixture was stirred for 15 min and filtered (Celite), and the filtrate was washed with aqueous HCl (5%), water, and saturated aqueous $NaHCO_3$, then dried, and concentrated. The residue was chromatographed (SiO_2, EtOAc/toluene 1:3) to give crude **122** (1.88 g, 75%), which contained traces of impurities according to ^1H NMR; it was used for the synthesis of **27** without further purification.

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Supplementary Material Available: General methods for the preparation of 1-*O*-acyl sugars **28–68** (13 pages). Ordering information is given on any current masthead page.

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