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# A Novel, Readily Accessible Lactosaminyl Donor: *N*-Trichloroethoxycarbonyl-hexa-*O*-benzoyl-β-D-lactosaminyl Fluoride

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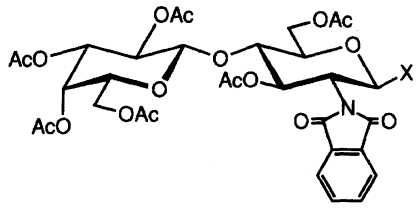
A simple, preparatively satisfactory 10-step sequence is described for converting lactose into a novel, suitably blocked lactosaminyl donor: *N*-Trichloroethoxycarbonyl-β-D-lactosaminyl fluoride (**5**). The key intermediate in this conversion is the particularly well-accessible oxime of lactosulosyl bromide (52% for the 6 steps from lactose), which on α-glycosidation with *p*-methoxybenzyl alcohol, oxime reduction, *N*-protection by Troc chloride, and the anomeric fluorination yields **5** (37% for the 4 steps). The utility of **5** as an effective donor was proved by the β-selective glycosylation of the primary 6-OH of 1,2:3,4-di-*O*-isopropylidene-α-D-galactopyranose (**14**) and the 3-OH of methyl 2,4,6-tri-*O*-benzyl-β-D-galactopyranoside (**16**), both affording the respective trisaccharides **15** and **18** in high yields. The latter, when subjected to *N*-deprotection, *N*-acetylation, and de-*O*-acylation gave, in 42% yield based on donor **5**, β-D-Gal-(1→4)-β-D-GlcNAc-(1→3)-β-D-Gal-(1→Me, a core trisaccharide unit of immunologically important carbohydrate antigens.

*N*-Acetyllactosamine [β-D-Gal*p*-(1→4)-Glc*p*NAc] constitutes a common core unit of complex and hybrid types of *N*-linked glycoproteins.[1] Of special interest are *N*-acetyllactosamine-containing glycolipids of tumor-associated carbohydrate antigens such as SSEA-1,[2] or the carbohydrate ligand of some cell-adhesion molecules, e.g. selectins[3] and N-CAM.[4]

In spite of the usefulness of these oligosaccharides as probes for biomedical research, their isolation from natural sources is laborious and leads only to small amounts of material, so chemical synthesis is necessary. Accordingly, various lactosaminyl donors have been elaborated, either by joining two suitable monosaccharide units,[5] or by modifying lactose via its glycal "lactal" and application of the nitroso halide[6—8] or azidonitration procedure.[8,9] The resulting donors **1**,[7,8] **2**,[9] **3**,[6,10] and **4**[11] have often been utilized in the general assembly of *N*-acetyllactosamine-containing oligosaccharides, yet their accessibility in preparative terms is not satisfactory (Fig. 1).

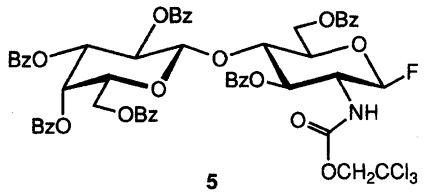



**1** : X = Cl **2** : X = Br
**3** : X = OC(NH)CCl$_3$ **4** : X = SPh

Fig. 1.

The recent syntheses of the lactosaminyl donors as described above have been accomplished mainly through the disaccharide approach which, although quite promising with respect to practicality and overall yield, requires separation of isomers formed either in reduction of the 2-hydroxyimino group to amino group (*gluco*:*manno*=ca. 7:3),[6,7] or in azidonitration of lactal[9,10] forming ca. 10% of the useless *manno* isomer. Another problem arises from the phthalimido group used for *N*-protection, since its removal is usually effected by treatment with hydrazine, which invariably causes removal of *O*-protecting acyl groups; hence in some cases, this group may not applicable to *O*-acylated sugars.

In quest of versatile lactosaminyl donors, we chose a combination of trichloroethoxycarbonyl (Troc) group for *N*-protection and 1-fluoride as the anomeric leaving group, since the Troc group has proved to be useful with respect to facile introduction and deprotection as well as β-selective glycosidation,[12,13] and glycosyl fluorides have been extensively used for their efficiency in glycosylation reactions.[14] We here describe the straightforward preparation of this novel donor, *N*-Troc-lactosaminyl fluoride **5** from lactose (Fig. 2), and its utilization for an efficient generation of a biologically relevant trisaccharide, β-D-Gal*p*-(1→4)-β-D-Glc*p*NAc-(1→3)-β-D-Gal*p*-OMe (**20**).[15,16]




5

Fig. 2.

## Results and Discussion

**Preparation of *N*-Troc Lactosaminyl Fluoride (5).** The conversion of lactose into *N*-acetyllactosamine donor **5** involves the hydroxylactal ester **6**, which is readily transformed in a high-yield 3-step sequence into the (hydroxyimino)lactosulosyl bromide **7**,[17] the key intermediate. The overall yield based on lactose amounts to a satisfactory 57% for the six steps (Scheme 1).

The subsequent conversion of **7** into **5** requires only a simple, preparatively satisfactory 4-step sequence: $\alpha$-selective glycosylation, oxime reduction, liberation of the anomeric OH, and fluorination. Accordingly, the anomeric OH protecting group should be selectively removable just before 1-fluorination; so we selected the *p*-methoxybenzyl residue, inasmuch as it is readily removed under mild, oxidative conditions with 2,3-dichloro-5,6-dicyano-*p*-benzoquinone (DDQ)[18] or ammonium cerium(IV) nitrate (CAN).[19] When glycosyl bromide **7** was simply exposed to a solution of *p*-methoxybenzyl alcohol and *s*-collidine in etherial solvents such as 1,4-dioxane or 1,2-dimethoxyethane for 2 d at ambient temperature in the presence of dessicant (MS-3A), excellent $\alpha$-selective replacement of bromine by benzyl alkoxide could be achieved to yield *p*-methoxybenzyl glycoside **8** in 80—85% yield, the $\alpha:\beta$ selectivity being higher than 10:1. In contrast, $\beta$-glycoside **9** was selectively formed by insoluble silver salt-catalyzed glycosidation of **7** in dichloromethane in a yield of 78%. This $\beta$-glycoside **9** was very helpful to ascertain the respective anomeric configuration of **8** and **9** by comparison of their NMR spectra.

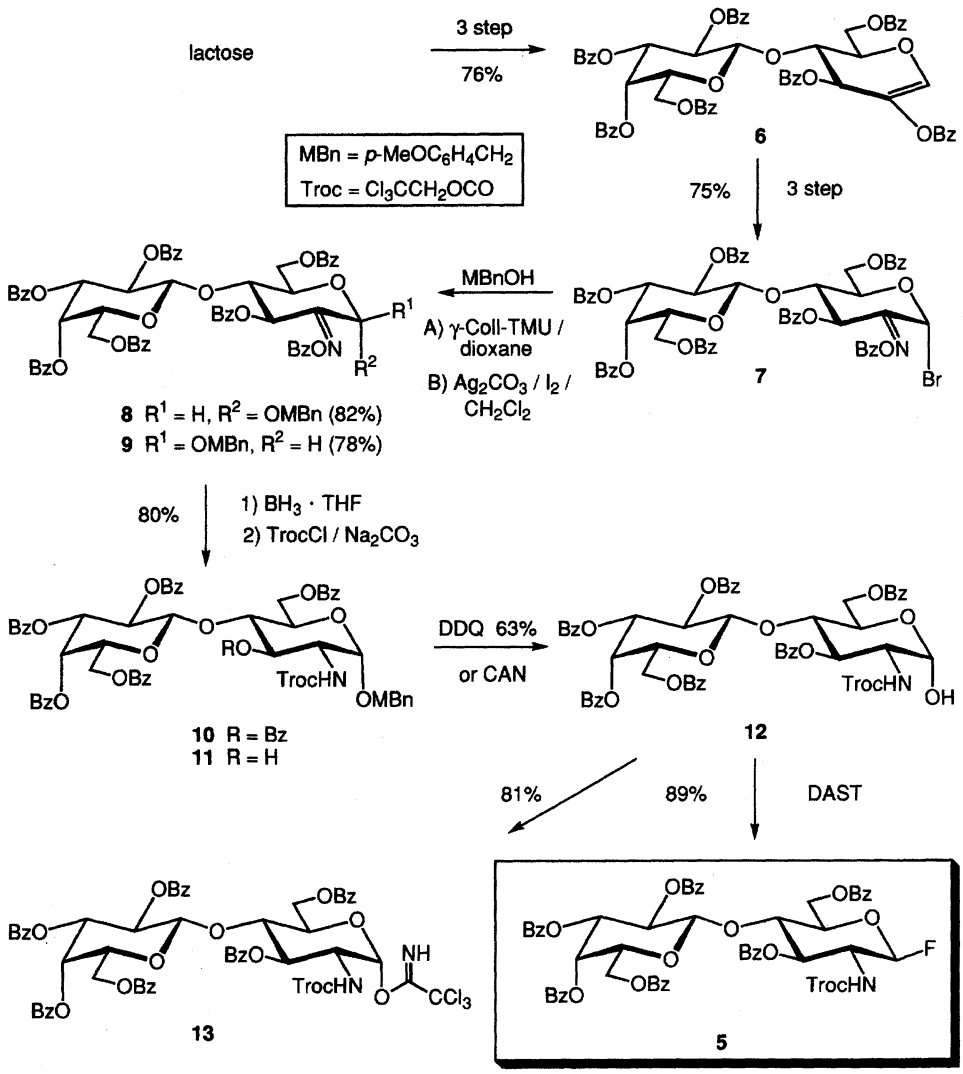
Previous observations[17,20] proved that the acyloxyimino function next to the anomeric center can be stereoselectively reduced with stereoanomeric control such that the hydride attacks the oxime function from the side opposite to the vicinal anomeric substituent. This steric preference leads to the $\alpha$-D-glucosaminide (**10**) from the $\alpha$-D-glycosidulose oxime (**8**). To find the optimum conditions, **8** was exposed to various kinds of borohydride reagents as listed in Table 1. Application of the mixed systems of alkali metal–Lewis acid (Entries 1—4), though adequate for acyloxime reduction,[21—23] proved to be unsuited, invariably resulting in sluggish conversions. The 4-*O*-galactosyl-$\alpha$-D-glucosaminide **10** could be secured by use of borane-tetrahydrofuran ($BH_3$·THF) in THF in 80% yield (Entry 9): Thereby, **8** can be reacted in fairly diluted solution (e.g. 25 mM), under which conditions the formation of the 3-OH-free analog **11** can be prevented (1 M=1 mol dm$^{-3}$). Of course, when **11** has been formed, it can readily be reconverted into **10** by benzoylation (Entries 7 and 9). Aside from the conversion of **11** into **10**, **11** itself may be directly applicable to the synthesis of the trisaccharide component of SSEA-1,[2] $\beta$-D-Gal-(1→4)-[$\alpha$-L-Fuc-(1→3)]-$\beta$-D-GlcNAc; this study is now in progress.

*O*-Demethoxybenzylation, carried out by oxidative C–O bond cleavage with DDQ in dichloromethane/water, readily gave **12** (63%); the use of CAN proved to be less effective, as **12** was obtained in 54% yield only. Consecutive functionalization of the anomeric center of **12** with thionyl chloride–DMF in dichloromethane smoothly gave $\alpha$-chloride (94%), whilst treatment of **12** with (diethylamino)sulfur trifluoride (DAST) in dichloromethane provided the desired fluoride **5** in 89% yield. Displacement of the chlorine atom in the $\alpha$-chloride by fluorine through treatment with silver fluoride also afforded **5** (87%). Considering the good reactivity of glycosyl imidates for glycosylation reaction,[24] we prepared an imidate **13** (81%) from **12** by exposure to a mixture of sodium hydride and trichloroacetonitrile in dichloromethane.

**Utilization of Lactosaminyl Donor 5 for Oligosaccharide Synthesis.** The donor capacity of **5** was first evaluated on the synthesis of a trisaccharide, i.e. $\beta$-D-Gal*p*-(1→4)-$\beta$-D-Glc*p*N-(1→6)-$\alpha$-D-Gal*p* derivative (**15**), with 1,2:3,4-di-*O*-isopropylidene-$\alpha$-D-galactopyranose (**14**)[25] as an acceptor substrate. The glycosylation was more readily effected by fluoride **5** in the presence of silver perchlorate–tin(II) chloride[26] in dichloromethane, to afford the expected trisaccharide **15** in 83% yield. Another lactosaminyl donor, the imidate **13**, upon glycosylation with **14** promoted by 0.1 M $BF_3$·$OEt_2$ complex in dichloromethane, gave **15** in a comparative yield (82%).

Then we tried to examine both donors for glycosylation of the 3-OH in methyl 2,4,6-tri-*O*-benzyl-$\beta$-D-galactopyranoside (**16**).[27] When reacted with the fluoride **5** in dichloromethane and $Cp_2ZrCl_2$–$AgClO_4$[28] as the promotor, the trisaccharide **17** was generated exclusively and could be isolated in a yield of 76% (Scheme 2). The imidate **13**, on the other hand, proved to be less suitable, as it resulted in a mixture of products, conceivably due to decomposition of the educts. The trisaccharide **17** was subsequently subjected to *N*-deprotection (Zn–AcOH) followed by *N*-acetylation ($Ac_2O$) to provide **18** in 71% yield. Zemplén transesterification of **18** readily gave **19** (83%), of which the *O*-benzyl group was removed with Pd–C/$H_2$, to quantitatively give the unprotected trisaccharide **20**. It is of special interest that many cell-surface antigens are composed of this trisaccharide, which serves as an acceptor substrate of glycosyltransferases relevant to a clinically important tumor marker SSEA-1.[2]

**Configurational Assignments.** The anomeric ar-



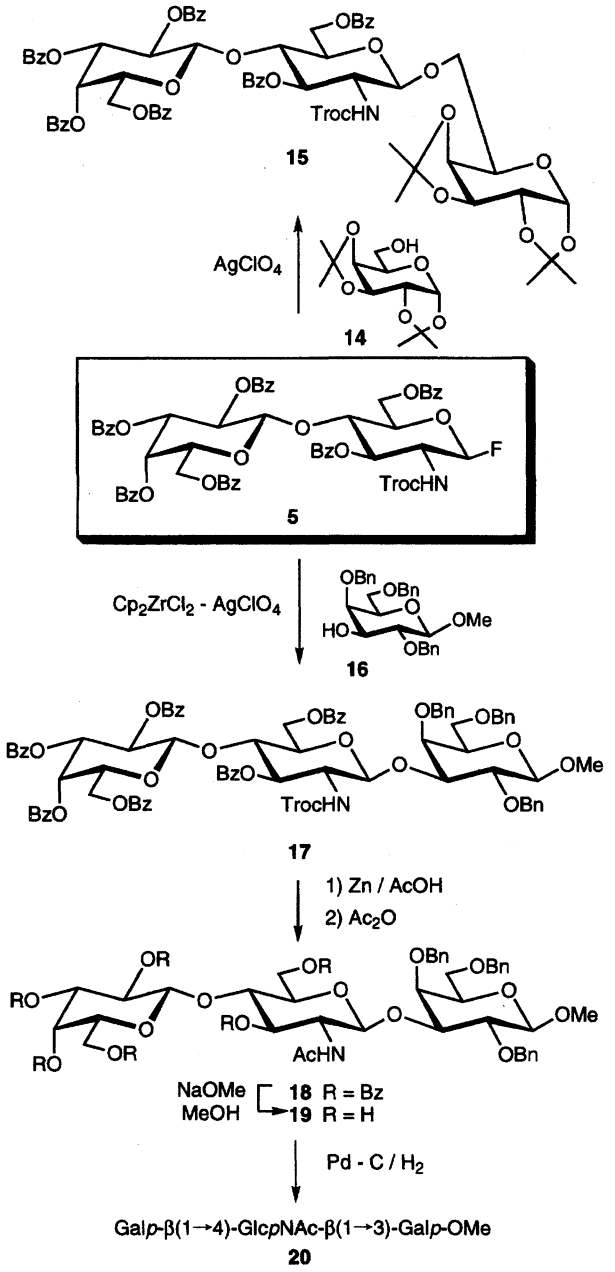

Scheme 1.

Table 1. Reduction of (Benzoyloxyimino)glycoside **8** with Several Reducing Agents[a)]

| Entry | Reducing agent | Solv. | Hydride/**8** | Substrate/Solvent | Yield (%) | | Recovery (%) |
|---|---|---|---|---|---|---|---|
| | | | mol equiv | $M^{-1}$ | **10** | **11** | **8** |
| 1 | $NaBH_4/NiCl_2$[b)] | MeOH | 2 | 0.2 | 7 | — | 86 |
| 2 | $NaBH_4/MoO_3$[b)] | MeOH | 2.5 | 0.125 | 5 | — | 67 |
| 3 | $LiBH_4/Me_3SiCl$[b)] | THF | 5 | 0.5 | 31 | — | — |
| 4 | $LiBH_4/Me_3SiCl$[c)] | THF | 5 | 0.5 | — | — | 86 |
| 5 | $LiBH_4$ | THF | 5 | 0.5 | 3 | 3 | — |
| 6 | $BH_3$·THF | THF | 12 | 0.05 | 42 | 37 | — |
| 7 | $BH_3$·THF | THF | 12 | 0.05 | 77[d)] | — | — |
| 8 | $BH_3$·THF | THF | 12 | 0.025 | 76 | 6 | — |
| 9 | $BH_3$·THF | THF | 12 | 0.025 | 80[d)] | — | — |
| 10 | $BH_3$·THF | THF | 12 | 0.1 | 12 | — | — |

a) The crude reduced products were subsequently *N*-trichloroethoxycarbonylated with Troc Cl. b) Molar ratio of borohydride to additive was 5 : 1. c) Molar ratio of borohydride to $Me_3SiCl$ was 1 : 2. d) The crude reduced product containing **10** and **11** on exposure to benzoyl chloride/pyridine, yielded **10** only.

rangement of the $\alpha$-(acyloxyimino) glycoside **8** was confirmed on the basis of $^1H$ and $^{13}C$ NMR spectroscopy by comparison with those of the counterpart, $\beta$-D-anomer **9**. A relatively large $J_{3,4}$ coupling constant (9.0 Hz) of **8** exhibits $^4C_1$ conformation of the pyranose ring characteristic for $\alpha$-D-anomers of this type of compound,[17,20)]




Scheme 2.

while the corresponding $\beta$-anomer was unequivocally assigned from a small coupling constant ($J_{3,4}$=4.0 Hz) owing to the stereochemical demand, as observed exclusively for 2-(benzoyloxyimino)-$\beta$-D-glycosides.[29—31]

The $\alpha$-D-*gluco*-configuration of the amino sugar portion of the disaccharide **10** was evidenced by the respective coupling constants: $J_{1,2}$, $J_{2,3}$, $J_{3,4}$, and $J_{4,5}$ of 4, 10, 9, and 10 Hz, which cogently reflect the above configuration. The same assignments may be extended to the series of $\alpha$-D-lactosaminide derivatives, **11**, **12**, and **13**, whilst compound **5**, on the basis of its $^1$H and $^{13}$C NMR data, exhibited a $\beta$-D-lactosaminide structure similar to that of the $\beta$-D-glucopyranosyl fluoride.[31]

It should be noted that the $^{13}$C NMR assignments of unprotected trisaccharide **20** are slightly different from the data reported previously (Table 2).[15,16] This may depend on the solvent effect giving rise to $\Delta\delta$=0.5—2 ppm for each carbon chemical shift, which do show the correct interglycosidic linkages as expected for formula **20**.

By way of summary: The results described here disclose facile preparation of *N*-(trichloroethoxycarbonyl)lactosaminyl fluoride **5** as an effective lactosaminyl donor in 19% overall yield form lactose in a simple ten-step sequence. Its utility has been proved for the synthesis of $\beta$-D-Gal*p*-(1→4)-$\beta$-D-Glc*p*NAc-(1→3)-$\beta$-D-Gal*p*-(1→Me (**20**), a core trisaccharide unit of many immunologically relevant glycoproteins and glycolipids. Further application of this methodology is under was to assist the chemical assembly of lactosamine-containing oligosaccharides of biological importance.

## Experimental

Melting Points: Yamato MP-1 and Yanagimoto micro melting point apparatus, uncorrected.

Spectral Measurements: JASCO DIP-180 (rotations); Varian VXR-300, and XL-400 ($^1$H and $^{13}$C NMR); JMS D-100 (MS) instruments. FAB-MS were measured with a matrix (PEG 400 or *m*-NBA) in acetone.

TLC: Merck Silica Gel $F_{254}$, plastic sheets were used to monitor the reactions and to ascertain the purity of the products; solvent systems are given individually and were the same for TLC and column chromatography. The spots were visualized by UV light or by charring with 40% aqueous $H_2SO_4$.

Column Chromatography: Merck Silica Gel 60 (70-230 mesh).

***p*-Methoxybenzyl 3,6-Di-*O*-benzoyl-2-(benzoyloxyimino)-4-*O*-(2,3,4,6-tetra-*O*-benzoyl-$\beta$-D-galactopyranosyl)-$\alpha$-D-*arabino*-hexopyranoside (8).** A mixture of *p*-methoxybenzyl alcohol (2.59 g, 18.7 mmol), molecular sieves (3 Å, powder, 1.80 g), iodine (0.95 g, 3.74 mmol) in dry dioxane (40 ml) was stirred in the dark at room temperature for 1 h. To the mixture were added (benzoyloxyimino)glycosyl bromide **7**[17] (4.29 g, 3.74 mmol) and *s*-collidine (0.54 ml, 4.11 mmol), and stirring was continued for two more days. The resulting mixture was diluted with dichloromethane (200 ml) and filtered through Celite. The filtrate was washed with aqueous 0.1 M $Na_2S_2O_3$ (250 ml), water (250 ml), 0.1 M HCl (250 ml), 5% $NaHCO_3$ (250 ml), and water (3×250 ml). After drying ($Na_2SO_4$) the solvent was removed in vacuo to give a syrup, which was eluted from a silica-gel column with toluene–ethyl acetate (6:1), concentration of the major fraction and the residue solidified from ethyl acetate–ether–pentane afforded 3.70 g (82.1%) of white powder comprising an approximate 10:1 mixture ($^1$H NMR) of **8** and its $\beta$-anomer **9**: Mp 100—102 °C; $[\alpha]_D^{24}$ +107° (*c* 1.0, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=3.74 (s, 3H, OMe), 3.8—4.2 (m, 3H, H-5′, 6′), 4.4—4.7 (m, 3H, H-5, 6), 4.51 (dd, 1H, H-4), 4.59 and 4.77 (each d, 1H, C$\underline{H}_2$Ph), 5.04 (d, 1H, H-1′), 5.48 (dd, 1H, H-3′), 5.78 (dd, 1H, H-2′), 5.82 (d, 1H, H-4′), 6.04 (s, 1H, H-1), 6.45 (d, 1H, H-3), 6.84 (d, 2H, *m*-H or MBn); $J_{3,4}$=9, $J_{1',2'}$=8, $J_{2',3'}$=10.5, $J_{3',4'}$=3.5 Hz; $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=55.1 (OMe), 60.8 (C-6′), 62.0 (C-6), 67.3 (C-4′), 68.5 (Ph$\underline{C}H_2$), 68.9 (C-

Table 2. $^{13}$C NMR Data of Trisaccharide **20** and as Compared to Known Analogs

| Sugar | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $CO\underline{C}H_3$ | $O\underline{C}H_3$ |
|---|---|---|---|---|---|---|---|---|
| | | | | Gal$\beta$1→4GlcNAc$\beta$1→3Gal$\beta$-OCH$_3$(**20**) (in Pyridine-$d_5$) | | | | |
| →3)-$\beta$-D-Gal-OCH$_3$ | 106.09 | 71.42 | 84.02 | 69.77 | 76.75 | 61.91 | | 56.68 |
| →4)-$\beta$-D-GlcNAc-(1→ | 104.04 | 57.77 | 74.11 | 82.73 | 76.58 | 62.14 | 23.64 | |
| $\beta$-D-Gal-(1→ | 105.95 | 72.57 | 75.30 | 70.19 | 77.41 | 62.47 | | |
| | | | | Gal$\beta$1→4GlcNAc$\beta$1→3Gal$\beta$-OCH$_3$(in DMSO-$d_6$)[15] | | | | |
| →3)-$\beta$-D-Gal-OCH$_3$ | 104.00 | 69.27 | 82.39 | 67.12 | 74.75 | 60.30 | | 55.70 |
| →4)-$\beta$-D-GlcNAc-(1→ | 102.00 | 55.46 | 73.73 | 81.21 | 75.48 | 60.41 | 23.02 | |
| $\beta$-D-Gal-(1→ | 103.92 | 70.51 | 71.97 | 68.09 | 74.75 | 60.80 | | |
| | | | | Gal$\beta$1→4GlcNAc$\beta$1→3Gal$\beta$-OCD$_3$(in D$_2$O)[16] | | | | |
| →3)-$\beta$-D-Gal-OCH$_3$ | 104.64 | 70.53 | 83.11 | 68.52 | 75.51 | 61.74 | | |
| →4)-$\beta$-D-GlcNAc-(1→ | 103.49 | 56.08 | 73.04 | 78.95 | 75.41 | 60.67 | 23.02 | |
| $\beta$-D-Gal-(1→ | 103.67 | 71.79 | 73.32 | 67.51 | 76.60 | 61.86 | | |

5), 69.9 (C-2′), 70.4 (C-3), 71.4 (C-5′), 71.6 (C-3′), 77.6 (C-4), 88.6 (C-1), 101.2 (C-1′), 114.0 (*m*-C of MBn), 156.8 (C-2); $J_{C1,H1}$=177, $J_{C1',H1'}$=162 Hz; MS (FAB) *m/z* 1205 $[M+H]^+$, 1227 $[M+Na]^+$. Found: C, 68.54; H, 4.75; N, 1.18%. Calcd for $C_{69}H_{57}NO_{19}$: C, 68.82; H, 4.77; N, 1.16%.

***p*-Methoxybenzyl 3,6-Di-*O*-benzoyl-2-(benzoyloxyimino)-4-*O*-(2,3,4,6-tetra-*O*-benzoyl-$\beta$-D-galactopyranosyl)-$\beta$-D-*arabino*-hexopyranoside (9).** (Benzoyloxyimino)glycosyl bromide **7**[17] (114 mg, 0.1 mmol) was added to a mixture of *p*-methoxybenzyl alcohol (70 mg, 0.5 mmol), silver carbonate (84 mg, 0.3 mmol), and iodine (26 mg, 0.1 mmol) in dry dichloromethane (2 ml) containing molecular sieves 3 Å (100 mg, powder). The mixture was stirred in the dark at room temperature for 2 d. Dilution with dichloromethane (20 ml), filtration through Celite, consecutive washing of the filtrate with 5% $NaHCO_3$ aq (20 ml), and water (3×20 ml), drying ($Na_2SO_4$), and evaporation to dryness in vacuo gave a residue which was eluted from a silica gel column with toluene–ethyl acetate (8 : 1). The major fraction was concentrated and crystallized from diethyl ether–pentane: 94 mg (78%) of **9**; mp 96—98 °C; $[\alpha]_D^{24}$ +22.1° (*c* 0.5, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=3.72 (s, 3H, OMe), 4.0 (m, 1H, H-5), 4.35—4.52 (m, 5H, H-5,5′, 6′), 4.58 (dd, 1H, H-4), 4.71 and 4.81 (each d, 1H, C$\underline{H}_2$Ph), 5.14 (d, 1H, H-1′), 5.60 (dd, 1H, H-3′), 5.81 (dd, 1H, H-2′), 5.92 (s, 1H, H-1), 5.97 (d, 1H, H-4′), 6.36 (d, 1H, H-3), 6.72 (d, 2H, *m*-H of MBn); $J_{3,4}$=4, $J_{4,5}$=7, $J_{1',2'}$=8, $J_{2',3'}$=11.3, $J_{3',4'}$=3.5, $J_{4',5'}$=1 Hz; $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=55.1 (OMe), 61.1 (C-6′), 63.8 (C-6), 67.9 (C-4′), 69.8 (C-2′), 69.9 (Ph$\underline{C}H_2$), 70.4 (C-3), 71.6 (C-3′), 71.8 (C-5′), 72.9 (C-5), 77.2 (C-4), 91.3 (C-1), 102.3 (C-1′), 113.8 (*m*-C of MBn), 157.3 (C-2); $J_{C1,H1}$=171, $J_{C1',H1'}$=159 Hz; MS (FAB) *m/z* 1205 $[M+H]^+$, 1227 $[M+Na]^+$. Found: C, 68.73; H, 4.87; N, 1.13%. Calcd for $C_{69}H_{57}NO_{19}$: C, 68.82; H, 4.77; N, 1.16%.

***p*-Methoxybenzyl 3,6-Di-*O*-benzoyl-4-*O*-(2,3,4,6-tetra-*O*-benzoyl-$\beta$-D-galactopyranosyl)-2-deoxy-2-trichloroethoxycarbonylamino-$\alpha$-D-glucopyranoside (10) and Its 3-OH Free Derivative (11).** A 1 M solution of borane–tetrahydrofuran complex (12 ml) was added to a stirred solution of (benzoyloxyimino)glycoside **8** (1.20 g, 1 mmol) in tetrahydrofuran (38 ml) at −10 °C under an atmosphere of nitrogen. The mixture was stirred for 0.5 h at −10 °C and then allowed to warm to room temperature with further stirring for 2 h. Excess reductant was quenched with methanol (12 ml) at 0 °C; then the mixture was passed through a basic resin (Amberlite IR-45, 15 g) and washed with methanol. The eluate was concentrated in vacuo and the residue was dissolved in dichloromethane (40 ml), treated in an ice-bath with 2,2,2-trichloroetoxycarbonyl chloride (187 µl) and sodium carbonate (240 mg, 2.26 mmol). The mixture was stirred overnight at ambient temperature, then filtered and evaporated to dryness. The residue was dissolved in diethyl ether (100 ml), washed with 1 M HCl (100 ml) and water (2×100 ml). Drying ($Na_2SO_4$) and concentration gave a residue, which was purified by elusion from a silica gel column with toluene–ethyl acetate (5 : 1). The major fraction eluted first was concentrated to give 960 mg (76%) of **10**; $[\alpha]_D^{24}$ +71.5° (*c* 0.69, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=3.80 (3H, s, $OCH_3$), 3.84 (1H, td, H-5′), 3.85 (1H, dd, H-6′a), 3.89 (1H, dd, H-6′b), 4.09 (1H, td, H-5), 4.17 (1H, m H-2), 4.22 (1H, dd, H-4), 4.44 (1H, dd, H-6a), 4.44 (1H, d, C$\underline{H}_2$Ph), 4.47 (1H, d, Troc-$CH_2$), 4.53 (1H, dd, H-6b), 4.63 (1H, d, Troc-$CH_2$), 4.64 (1H, d, C$\underline{H}_2$Ph), 4.90 (1H, d, H-1′), 4.94 (1H, d, H-1), 5.33 (1H, d, NH), 5.38 (1H, dd, H-3′), 5.68 (1H, dd, H-3), 5.70 (1H, dd, H-2′), 5.74 (1H, dd, H-4′); $J_{1,2}$=4, $J_{2,3}$=$J_{2,NH}$=10, $J_{3,4}$=9, $J_{4,5}$=10, $J_{5,6a}$=4, $J_{5,6b}$=2, $J_{6a,6b}$=12, $J_{1',2'}$=8, $J_{2',3'}$=10, $J_{3',4'}$=3.5, $J_{4',5'}$=1, $J_{5',6'a}$=9, $J_{5',6'b}$=5, $J_{6'a,6'b}$=12 Hz; $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=54.27 (C-2), 55.30 ($OCH_3$), 60.88 (C-6′), 62.29 (C-6), 67.40 (C-4), 69.06 (C-5), 69.53 (C$\underline{H}_2$Ph), 69.97 (C-2′), 71.27 (C-5′), 71.63 (C-3), 71.86 (C-3′), 74.32 (Troc-C$\underline{H}_2$), 76.24 (C-4), 95.87 (C-1), 101.18 (C-1′); MS (FAB) *m/z* 1284 $[M+Na]^+$. Found: C, 61.74; H, 4.45; N, 1.03; Cl, 8.47%. Calcd for $C_{65}H_{56}NO_{19}Cl_3$: C, 61.89; H, 4.47; N, 1.11; Cl, 8.43%.

The fraction eluted from the silica-gel column next, i.e. following **10**, gave upon evaporation to dryness and crystallization from ether–pentane 75.0 mg (5.9%) of pentabenzoate **11**, having a free 3-OH group: Mp 99—101 °C; $[\alpha]_D^{24}$ +119° (*c* 0.89, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=3.80 (3H, s, $OCH_3$), 3.81 (1H, dd, H-4), 3.91 (1H, dd, H-2), 4.00 (1H, dd, H-3), 4.01 (1H, td, H-5′), 4.18 (1H, dd, H-6′a), 4.41 (1H, dd, H-6′), 4.45 (1H, d, C$\underline{H}_2$Ph), 4.42—4.50 (3H, m, H-5, 6a, 6b), 4.53, 4.57 (each 1H, d, $CH_2$Ph), 4.83 (1H, d, Troc-$CH_2$), 4.92 (1H, d, H-1), 5.04 (1H, d, H-1′), 5.22 (1H, d, NH), 5.60 (1H, dd, H-3′), 5.91 (1H, dd, H-2′), 5.98 (1H, dd, H-4′); $J_{1,2}$=4, $J_{2,3}$=10, $J_{2,NH}$=$J_{3,4}$=9, $J_{1',2'}$=8, $J_{2',3'}$=10.5, $J_{3',4'}$=3.5, $J_{4',5'}$=1, $J_{5',6'a}$=4, $J_{5',6'b}$=9, $J_{6'a,6'b}$=12 Hz;

$^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=54.74 (C-2), 55.23 ($OCH_3$), 62.22 (C-6′), 62.67 (C-6), 67.94 (C-5′), 67.99 (C-4′), 69.47 (C-2′, $\underline{C}H_2Ph$), 70.87 (C-3), 71.48 (C-3′), 72.38 (C-5), 74.65 (Troc-$\underline{C}H_2$), 82.69 (C-4), 95.96 (C-1), 102.21 (C-1′); MS (FAB) $m/z$ 1189 $[M+Na]^+$; MS (FD) $m/z$ 1158 $[M+1]^+$. Found: C, 60.24; H, 4.49; N, 1.13; Cl, 9.06%. Calcd for $C_{58}H_{52}NO_{18}Cl_3$: C, 60.14; H, 4.61; N, 1.21; Cl, 9.18%.

**3,6-Di-*O*-benzoyl-4-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-2-deoxy-2-trichloroethoxycarbonylamino-α-D-glucopyranose (12). A. With 2,3-Dichloro-5,6-dicyano-*p*-benzoquinone (DDQ):** Water (0.19 ml) and DDQ (55.3 mg, 0.244 mmol) were added to a stirred solution of **10** (240 mg, 0.19 mmol) in dichloromethane (3.8 ml). The mixture was stirred at room temperature overnight, diluted with dichloromethane (50 ml), washed with 5% aqueous $NaHCO_3$ (2×50 ml), and water (3×50 ml), dried ($Na_2SO_4$), and evaporated in vacuo to dryness. The residue was eluted through a silica-gel column with toluene–ethyl acetate (3:1). Concentration of the major fraction gave a syrup which crystallized from diethyl ether-pentane, affording 137 mg (63%) of **12** as colorless crystals; mp 130—132 °C; $[\alpha]_D^{25}$ +56.1° (*c* 0.41, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=3.91 (1H, dd, H-6′a), 3.99 (1H, td, H-5′), 4.09 (1H, dd, H-6′b), 4.2—4.3 (2H, m, H-4, 5), 4.3—4.34 (2H, m, H-6a, 6b), 4.38 (1H, td, H-2), 4.55 (1H, d, Troc-$CH_2$), 4.79 (1H, d, H-1′), 4.82 (1H, d, OH), 4.83 (1H, d, Troc-$CH_2$), 5.53 (1H, d, H-3′), 5.59 (1H, dd, H-1), 5.62 (1H, dd, H-2′), 5.76 (1H, dd, H-4′), 6.28 (1H, dd, H-3); $J_{1,2}$=3.5, $J_{2,3}$=10, $J_{2,NH}$=11, $J_{3,4}$=9, $J_{1',2'}$=7.5, $J_{2',3'}$=10, $J_{3',4'}$=3.5, $J_{4',5'}$=1, $J_{5',6'a}$=7, $J_{5',6'b}$=6, $J_{6'a,6'b}$=10, $J_{1,OH}$=5 Hz; $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=54.38 (C-2), 61.14 (C-6′), 62.49 (C-6), 67.43 (C-4′), 68.85 (C-5), 70.73 (C-2′, 3′), 71.08 (C-3), 71.45 (C-5′), 74.50 (Troc-$\underline{C}H_2$), 75.79 (C-4), 92.15 (C-1), 101.07 (C-1′), 155.22 (Troc-CO), 165.23—165.98 (CO); MS (FAB) $m/z$ 1162 $[M+Na]^+$, 1124 $[M-OH]^+$. Found: C, 60.24; H, 4.23; N, 1.22; Cl, 9.32%.

**B. With Ammonium Cerium(IV) Nitrate (CAN):** To a solution of **10** (126 mg, 0.1 mmol) in acetonitrile (1.8 ml) containing water (0.2 ml) was added 109 mg (0.199 mmol) of CAN. The mixture was stirred at room temp for 20 h, and worked up as described for method A, giving 62.1 mg (54.4%) of **12**.

**3,6-Di-*O*-benzoyl-4-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-2-deoxy-2-trichloroethoxycarbonylamino-β-D-glucopyranosyl Fluoride (5). A. Direct Fluorination of 12 with (Diethylamino)sulfur Trifluoride (DAST):** DAST (24 μl, 0.18 mmol) was added to a cooled (−30 °C), stirred solution of **12** (103 mg, 0.089 mmol) under nitrogen atmosphere. The mixture was stirred at room temperature for 20 h, treated with methanol (20 μl) at −30 °C, and concentrated to dryness. The residue was dissolved in dichloromethane (20 ml), washed with 5% aqueous $NaHCO_3$ (20 ml) and water (3×20 ml), dried ($Na_2SO_4$), and concentrated in vacuo to give a syrup. Elution from a silica-gel column with toluene–ethyl acetate (3:1), and concentration of the fraction containing **5** gave 90 mg (89%) as a colorless syrup, which crystallized from diethyl ether–pentane: Mp 113—116 °C; $[\alpha]_D^{25}$ +53.2° (*c* 0.43, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=4.02 (1H, td, H-5), 4.08—4.16 (3H, m, H-6′b, 5′, 6′a), 4.12 (1H, m, H-2), 4.30 (1H, dd, H-4), 4.51 (1H, dd, H-6a), 4.61 (1H, dd, H-6b), 4.64, 4.72 (1H each, d, Troc-$CH_2$), 4.98 (1H, d, H-1′), 5.47 (1H, d, H-1), 5.50 (1H, dd, H-3′), 5.62 (1H, dd, H-3), 5.74 (1H, dd, H-2′), 5.84 (1H, dd, H-4′), 5.94 (1H, d, NH); $J_{1,2}$=5, $J_{H,F}$=51, $J_{2,3}$=$J_{3,4}$=$J_{4,5}$=7, $J_{5,6a}$=$J_{5,6b}$=7, $J_{6a,6b}$=12, $J_{2,NH}$=9, $J_{1',2'}$=8, $J_{2',3'}$=10, $J_{3',4'}$=3.5, $J_{4',5'}$=1 Hz; $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=53.61 (C-2), 61.50 (C-6′), 62.58 (C-6), 67.59 (C-4′), 69.85 (C-3, 2′), 71.45 (C-3′), 71.83 (C-5′), 73.01 (C-5), 73.99 (C-4), 74.57 (Troc-$\underline{C}H_2$), 95.15 ($CCl_3$), 101.33 (C-1′), 106.67 (C-1); $J_{C1,F}$=220.99, $J_{C2,F}$=29.19, $J_{C5,F}$=3.05 Hz; MS (FAB) $m/z$ 1166 $[M+Na]^+$.

**B. By Chlorination of 12 and Subsequent Halogen Exchange by Fluoride:** To an ice-cooled stirred solution of **12** (96.2 mg, 0.076 mmol) in dry dichloroethane (1.0 ml) were added thionyl chloride (22.8 μl, 0.305 mmol) and dry DMF (3.5 μl, 0.045 mmol). The mixture was stirred at room temperature for 20 h, filtered through a pad of silica gel (100 mg), and concentrated in vacuo to give 82.8 mg (94%) of glycosyl chloride as a colorless syrup: $[\alpha]_D^{24}$ +68.6° (*c* 1.5, $CHCl_3$); MS (FAB) $m/z$ 1182 $[M+Na]^+$. The chloride (65 mg, 0.05 mmol) was dissolved in dry acetonitrile (1.0 ml), treated with silver fluoride (15.9 mg, 0.125 mmol), and stirred at room temperature overnight. After aqueous work-up as described for method A, the fluoride **5** (50.7 mg, 87%) was obtained as colorless crystals.

**3,6-Di-*O*-benzoyl-4-*O*-(2,3,4,6-tetra-*O*-benzoyl-β-D-galactopyranosyl)-2-deoxy-2-trichloroethoxycarbonylamino-α-D-glucopyranosyl Trichloroacetimidate (13).** Trichloroacetonitrile (84.0 μl, 0.84 mmol) and sodium hydride (60% in oil; 23.2 mg, 0.58 mmol) were added to a solution of **12** (104 mg, 0.091 mmol) in dry dichloromethane (1.0 ml). The mixture was stirred at room temperature for 1.5 h and the solvent was removed in vacuo to give a residue, which was eluted through a silica-gel column with toluene–ethyl acetate (4:1). Concentration of the major fraction and crystallization from diethyl ether–pentane gave 94.3 mg (80.8%) of **13** as colorless crystals: Mp 115—117 °C; $[\alpha]_D^{26}$ +68.9° (*c* 0.65, $CHCl_3$); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$=3.84—4.02 (3H, m, H-5′, 6′), 4.18 (1H, td, H-5), 4.52 (1H, dd, H-4), 4.45 (1H, d, H-2), 4.48 (1H, dd, H-6a), 4.54 (1H, dd, H-6b), 4.56, 4.66 (each 1H, d, $CH_2$), 4.95 (1H, d, H-1′), 5.40 (1H, dd, H-3′), 5.42 (1H, d, NH), 5.71 (1H, dd, H-2′), 5.75 (1H, dd, H-3), 5.78 (1H, dd, H-4′), 6.43 (1H, d, H-1); $J_{1,2}$=4, $J_{2,3}$=9.5, $J_{3,4}$=10, $J_{4,5}$=9.5, $J_{5,6a}$=2, $J_{5,6b}$=3.5, $J_{6a,6b}$=12, $J_{2,NH}$=10, $J_{1',2'}$=8, $J_{2',3'}$=10.5, $J_{3',4'}$=3, $J_{4',5'}$=1 Hz; $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$=54.16 (C-2), 60.97 (C-6′), 61.79 (C-6), 67.39 (C-4′), 69.93 (C-2′), 71.02 (C-3), 71.35 (C-5), 71.39 (C-5′), 71.77 (C-3′), 74.45 ($CH_2$), 75.20 (C-4), 94.68 (C-1), 101.23 (C-1′); MS (FAB) $m/z$ 1307 $[M+Na]^+$. Found: C, 54.94; H, 3.70; N, 1.88; Cl, 16.54%. Calcd for $C_{59}H_{48}N_2O_{18}Cl_{16}$: C, 55.11; H, 3.76; N, 2.18; Cl, 16.54%.

***O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-1→4)-*O*-(3,6-di-*O*-benzoyl-2-deoxy-2-trichloroethoxycarbonylamino-β-D-glucopyranosyl)-(1→6)-1,2:3,4-di-*O*-isopropylidene-α-D-galactopyranose (15). A. Glycosylation of Galactopyranose 14 with Lactosaminyl β-Fluoride (5):** To a solution of **5** (71.0 mg, 0.062 mmol) in dry dichloromethane (2 ml) with molecular sieves (3 Å, 200 mg, powder) was added 1,2:3,4-di-*O*-isopropylidene-α-D-galactopyranose (**14**)[25] (19.3 mg, 74.4 μmol), $SnCl_2$ (12.8 mg, 0.068 mmol), and silver perchlorate (14 mg, 0.068 mmol). After stirring in the dark at room temperature overnight, the reaction mixture was di-

luted with dichloromethane (10 ml) and filtered through a pad of Celite. The filtrate was washed with 5% aqueous $NaHCO_3$ (10 ml) and water (3×10 ml), dried ($Na_2SO_4$), and evaporated to dryness. The residue was eluted through a silica-gel column with toluene–ethyl acetate (1:1). Concentration of the major fraction afforded 71.1 mg (82.9%) of **15** as a colorless syrup: Mp 116—120 °C; $[\alpha]_D^{25}$ +23.7° (*c* 1.4, $CHCl_3$); $^1$H NMR (400 MHz, $CDCl_3$) $\delta$=1.28, 1.31, 1.39, 1.51 (each 3H, s, $CH_3$), 3.79 (1H, td, H-5′), 3.80—3.84 (4H, m, H-5′, 6″a, 6a, 6b), 3.85 (1H, td, H-5″), 3.89 (1H, dd, H-6″b), 3.97 (1H, td, H-5), 4.02 (1H, dd, H-2′), 4.12 (1H, dd, H-4), 4.18 (1H, dd, H-4′), 4.29 (1H, dd, H-2), 4.30 4.90 (each 1H, d, $CH_2CCl_3$), 4.44 (1H, dd, H-6′a), 4.54 (1H, dd, H-3), 4.58 (1H, dd, H-6′b), 4.85 (1H, d, H-1″), 4.88 (1H, d, H-1′), 5.31 (1H, d, NH), 5.35 (1H, dd, H-3″), 5.53 (1H, d, H-1), 5.53 (1H, dd, H-3′), 5.68 (1H, dd, H-2″), 5.72 (1H, d, H-4″); $J_{1,2}$=5, $J_{2,3}$=2.5, $J_{3,4}$=8, $J_{4,5}$=2, $J_{5,6a}$=2, $J_{5,6b}$=4, $J_{6a,6b}$=12, $J_{1',2'}$=8, $J_{2',3'}$=10, $J_{3',4'}$=9, $J_{4',5'}$=10, $J_{5',6'a}$=4.5, $J_{5',6'b}$=2, $J_{6'a,6'b}$=12, $J_{1'',2''}$=8, $J_{2'',3''}$=10, $J_{3'',4''}$=3.5, $J_{4'',5''}$=1, $J_{5'',6''a}$=7, $J_{5'',6''b}$=3, $J_{6''a,6''b}$=12 Hz; $^{13}$C NMR (100 MHz, $CDCl_3$) $\delta$=24.29, 24.89, 25.91, 26.01 (4×$CH_3$), 56.25 (C-2), 61.11 (C-6″), 62.58 (C-6), 67.50 (C-4′), 68.40 (C-6′), 68.81 (C-5″), 69.94 (C-2′), 70.21 (C-2″), 70.71 (C-3″), 72.96 (C-5), 73.27 (C-3), 74.25 ($CH_2$), 75.94 (C-4), 95.33 ($CCl_3$), 96.19 (C-1″), 100.93 (C-1), 101.21 (C-1′), 108.73, 109.39 (isopropyridene-C); MS (FAB) *m/z* 1406 $[M+Na]^+$.

**B. With Lactosaminyl Imidate (13):** To a mixture of **13** (90.8 mg, 70.7 μmol) and di-*O*-isopropylidene-galactose **14** (22.1 mg, 85.2 μmol) in dry dichloromethane (2 ml) was added 0.1 M $BF_3$·$OEt_2$ complex (0.16 ml) at −20 °C under nitrogen atmosphere. After being stirred at room temperature for 1.5 h, the mixture was treated with $NaHCO_3$ (powder) and 10% aqueous $NaHCO_3$ at −20 °C, followed by dilution with dichloromethane (10 ml), washing with water (2×10 ml), and drying ($Na_2SO_4$). Removal of the solvent in vacuo gave the residue, which was purified by passing through a silica-gel column with toluene–ethyl acetate (4:1) to give 79.9 mg (81.7%) of **15** as a colorless syrup.

**Methyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-*O*-(3,6-di-*O*-benzoyl-2-deoxy-2-trichloroethoxycarbonylamino-β-D-glucopyranosyl)-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranoside (17).** A solution of fluoride **5** (114.3 mg, 0.1 mmol) in dry dichloromethane (2 ml) was added to a mixture of methyl 2,4,6-tri-*O*-benzyl-β-D-galactopyranoside (**16**)[27] (55.8 mg, 0.12 mmol), dichlorobis ($\eta^5$-cyclopentadienyl)zirconium (29.2 mg, 0.1 mmol), and silver perchlorate (41.4 mg, 0.2 mmol) in dry dichloromethane (2 ml) with molecular sieves (3 Å, 200 mg, powder). The mixture was stirred in the dark at room temperature overnight, and worked up as described for **15** (Method A). Purification of the crude product by elution from a silica-gel column with toluene–ethyl acetate (4:1) provided 120.4 mg (76%) of **17** as a colorless syrup. Crystallization from diethyl ether–pentane gave an amorphous powder: Mp 114—116 °C; $[\alpha]_D^{23}$ +33.4° (*c* 1.1, $CHCl_3$); $^1$H NMR (400 MHz, $CDCl_3$) $\delta$=3.44, (1H, dd, H-6″a), 3.47 (1H, td, H-5″), 3.51 (3H, s, $OCH_3$), 3.55 (1H, dd, H-6″b), 3.61 (1H, td, H-5′), 3.71 (1H, m, H-3), 3.73 (1H, dd, H-2), 3.78 (1H, dd, H-4), 3.8—3.86 (3H, m, H-5, 6), 3.98 (1H, dd, H-2′), 4.15 (1H, dd, H-4′), 4.18 (1H, d, H-1), 4.38 4.41, 4.59, 4.87, 4.95 (each 1H, d, $C\underline{H}_2$Ph), 4.44 (1H, dd, H-6′a), 4.60 (1H, dd, H-6′b), 4.77 (1H, d, H-1′), 4.86 (1H, d, H-1″), 5.22 (1H, dd, H-3′), 5.37 (1H, dd, H-3″), 5.68 (1H, dd, H-2″), 5.73 (1H, dd, H-4″); $J_{1,2}$=7, $J_{2,3}$=9, $J_{3,4}$=3, $J_{4,5}$=1, $J_{1',2'}$=8.5, $J_{2',3'}$=10.5, $J_{3',4'}$=9, $J_{4',5'}$=10, $J_{5',6'a}$=4, $J_{5',6'b}$=2, $J_{6'a,6'b}$=11, $J_{1'',2''}$=8, $J_{2'',3''}$=10, $J_{3'',4''}$=3, $J_{4'',5''}$=1 Hz; $^{13}$C NMR (100 MHz, $CDCl_3$) $\delta$=56.50 (C-2′), 56.91 ($OCH_3$), 60.94 (C-6), 62.09 (C-6′), 67.45 (C-4″), 69.07 (C-6″), 69.96 (C-2″), 71.35 (C-5), 71.78 (C-3″), 72.79 (C-5′), 72.84 (C-3′), 73.46 (Troc-$CH_2$), 73.58 (C-5″), 74.26 74.64, 74.80 ($CH_2$Ph), 75.83 (C-4), 76.07 (C-4′), 79.80 (C-3), 80.12 (C-2), 95.30 ($CCl_3$), 101.04 (C-1″), 101.65 (C-1′), 104.92 (C-1), 154.35 (Troc-CO), 164.79—165.69 (6×CO): MS (FAB) *m/z* 1608 $[M+Na]^+$, 1585 $[M]^+$.

**Methyl *O*-(2,3,4,6-Tetra-*O*-benzoyl-β-D-galactopyranosyl)-(1→4)-*O*-(2-acetamido-3,6-di-*O*-benzoyl-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranoside (18).** A mixture of the trisaccharide **17** (79.3 mg, 50 μmol) and zinc powder (208 mg) in acetic acid (2.9 ml) was stirred at room temperature overnight. The reaction mixture was filtered through a pad of Celite, and concentrated in vacuo to dryness. The residue was dissolved in dichloromethane (10 ml), washed with 1 M HCl (10 ml) and water (20 ml), dried ($Na_2SO_4$), and evaporated in diminished pressure to yield a colorless syrup. A solution of the syrup in dry methanol (3.5 ml) was treated with acetic anhydride (1.7 ml), stirred at ambient temperature for 3 h, and concentrated in vacuo to give the residue, which was eluted through a silica-gel column with toluene–ethyl acetate (3:1), affording 51.6 mg (71.0%) of **18** as a colorless syrup. Crystallization from diethyl ether excess pentane gave an amorphous powder: Mp 110—112 °C; $[\alpha]_D^{23}$ +26.1° (*c* 0.5, $CHCl_3$); $^1$H NMR (400 MHz, $CDCl_3$) $\delta$=1.60, (3H, s, $COCH_3$), 3.38 (1H, dd, H-6″a), 3.46 (1H, td, H-5″), 3.49 (3H, s, $OCH_3$), 3.53 (1H, dd, H-6″b), 3.67 (1H, dd, H-2), 3.69 (1H, td, H-5′), 3.71 (1H, m, H-3), 3.83 (1H, dd, H-4), 3.81—3.86 (3H, m, H-5, 6), 4.18 (1H, d, H-1), 4.19 (1H, dd, H-4′), 4.33 (1H, dd, H-2′), 4.36, 4.85, 4.37, 4.39, 4.58, 4.99 (each 1H, d, $CH_2$Ph), 4.43 (1H, dd, H-6′a), 4.64 (1H, dd, H-6′b), 4.82 (1H, d, H-1′), 4.87 (1H, d, H-1″), 5.30 (1H, dd, H-3′), 5.39 (1H,dd, H-3″), 5.69 (1H,dd, H-2″), 5.74 (1H, dd, H-4″); $J_{1,2}$=7, $J_{2,3}$=8, $J_{3,4}$=2.5, $J_{4,5}$=1, $J_{1',2'}$=8, $J_{2',3'}$=9, $J_{3',4'}$=10, $J_{4',5'}$=9, $J_{5',6'a}$=4, $J_{5',6'b}$=2, $J_{6'a,6'b}$=12, $J_{1'',2''}$=8, $J_{2'',3''}$=10, $J_{3'',4''}$=3, $J_{4'',5''}$=1, $J_{5'',6''a}$=5, $J_{5'',6''b}$=6, $J_{6''a,6''b}$=9 Hz; $^{13}$C NMR (100 MHz, $CDCl_3$) $\delta$=22.74 ($CO\underline{C}H_3$), 54.08 (C-2′), 56.85 ($OCH_3$), 60.89 (C-6″), 62.13 (C-6′), 67.48 (C-4″), 69.22 (C-6″), 70.01 (C-2″), 71.37 (C-5), 71.75 (C-3″), 72.91 (C-5′), 73.45 ($CH_2$Ph), 73.58 (C-3′), 73.66 (C-5″), 74.26, 74.63 (2×$CH_2$Ph), 75.94 (C-4′, 4), 79.45 (C-3), 81.26 (C-2), 101.09 (C-1), 102.31 (C-1′), 104.79 (C-1), 164.89—169.80 (6×CO), 169.80 ($CH_3\underline{C}O$); MS (FAB)*m/z* 1476 $[M+Na]^+$.

**Methyl *O*-β-D-Galactopyranosyl-(1→4)-*O*-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→3)-2,4,6-tri-*O*-benzyl-β-D-galactopyranoside (19).** A methanolic 0.1 M sodium methoxide solution (1 ml) was added to **18** (61.6 mg, 42.4 μmol). The mixture was stirred at ambient temperature for 1 h, neutralized with acidic resin (Dowex 50W×2), and filtered. The filtrate was concentrated in vacuo to give a residue, which was eluted from a silica-gel column with chloroform–methanol (4:1). Concentration of the major fraction gave 29.2 mg (83.1%) of **19** as a colorless

syrup: $[\alpha]_D^{21}$ −18.0° (*c* 0.48, $CHCl_3$): $^1H$ NMR (400 MHz, $CDCl_3$) $\delta$=1.60 (3H, s, $COCH_3$), 3.44 (3H, s, $OCH_3$), 3.74—3.92 (6H, m, H-6, 6′, 6″), 4.21 (1H,d, H-1″), 4.39 (1H, d, H-1), 4.51, 4.52, 4.59, 4.60 4.87, 4.88 (each 1H, d, $CH_2Ph$), 4.69 (1H, d, H-1′); $J_{1,2}$=8, $J_{1',2'}$=8, $J_{1'',2''}$=7, $J_{2',NH}$=8 Hz; $^{13}C$ NMR (100 MHz, $CDCl_3$) $\delta$=23.04 ($CO\underline{C}H_3$), 56.77 (C-2′, $OCH_3$), 61.35 (C-6), 61.40 (C-6″), 61.63 (C-6′), 73.42, 74.22, 74.42 (3×$CH_2Ph$), 79.27 (C-3), 81.34 (C-2), 102.09 (C-1′), 103.04 (C-1″), 104.63 (C-1), 172.35 ($CH_3\underline{C}O$); MS (FAB) *m/z* 852 $[M+Na]^+$. Found: C, 58.43; H, 6.53; N, 1.66%. Calcd for $C_{42}H_{55}NO_{16}\cdot 2H_2O$: C, 58.25; H, 6.86; N, 1.61%.

**Methyl *O*-β-D-Galactopyranosyl-(1→4)-*O*-(2-acetamido-2-deoxy-β-D-glucopyranosyl)-(1→3)-β-D-galactopyranoside (20).** A solution of **19** (24.9 mg, 30 μmol) in methanol–water (4:1, 10 ml) was hydrogenated in the presence of 10% palladium on carbon (25 mg) and acetic acid (0.5 ml) under an atmosphere of hydrogen ($3.45\times10^5$ Pa) for 24 h. The mixture was filtered through Celite and the filtrate was concentrated in vacuo to give a syrup, which was purified by elution from a silica gel column with chloroform–methanol (1:2). The major fraction was concentrated to afford 15.6 mg (93%) of **20** as a colorless syrup: $[\alpha]_D^{22}$ +4.4° (*c* 0.36, MeOH); $^1H$ NMR (400 MHz, pyridine-$d_5$) $\delta$=2.01 (3H, s, $COCH_3$), 3.53 (3H, s, $OCH_3$), 3.86 (1H, td, H-5′), 3.96 (1H, td, H-5), 4.44 (1H, m, H-5″), 4.14 (1H, dd, H-3″), 4.17 (1H, dd, H-3), 4.24 (1H, dd, H-4′), 4.31 (1H, dd, H-6a), 4.35—4.40 (5H, m, H-6b, 6′a, 6′b, 6″a, 6″b), 4.42 (1H, dd, H-3′), 4.45 (1H, dd, H-2′), 4.49 (1H, dd, H-4″), 4.50 (1H, dd, H-2), 4.51 (1H, dd, H-2″), 4.61 (1H, d, H-1), 4.68 (1H, dd, H-4), 5.07 (1H, d, H-1″), 5.55 (1H, d, H-1′), 9.05 (1H, d, NH); $J_{1,2}$=8, $J_{2,3}$=10, $J_{3,4}$=3, $J_{4,5}$=1, $J_{5,6a}$=5, $J_{6a,6b}$=11, $J_{1',2'}$=8, $J_{2',3'}$=10, $J_{3',4'}$=8, $J_{4',5'}$=10, $J_{1'',2''}$=8, $J_{2'',3''}$=10, $J_{3'',4''}$=3, $J_{2',NH}$=7.5 Hz; $^{13}C$ NMR (100 MHz, pyridine) are listed in Table 2; MS (FAB) *m/z* 582 $[M+Na]^+$, 560 $[M]^+$.

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