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A convergent synthesis of trisaccharides with α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-β-D-GlcNAc and α-Neu5Ac-(2→3)-β-D-Gal-(1→3)-α-D-GalNAc sequences

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Abstract

The syntheses of three trisaccharides: α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-β-D-GlcNAc→OMe, α-Neu5Ac-(2→3)-β-D-Gal6SO_3Na-(1→4)-β-D-GlcNAc→OMe, and α-Neu5Ac-(2→3)-β-D-Gal-(1→3)-α-D-GalNAc→OBn were accomplished by using either methyl (phenyl 5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-β-D-*glycero*-D-*galacto*-2-nonulopyranoside)onate or methyl (phenyl *N*-acetyl-5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-2-thio-β-D-*glycero*-D-*galacto*-2-nonulopyranoside)onate as the sialyl donor. The *N*,*N*-diacetylamino sialyl donor appears to be more reactive than its parent acetamido sugar when allowed to react with an disaccharide acceptor under the same glycosylation conditions. The trisaccharides, as well as the intermediate products, were fully characterized by 2D DQF ^1H–^1H COSY and 2D ROESY spectroscopy. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Convergent synthesis; 2D DQF-COSY; 2D ROESY; Sialyl donor; Trisaccharide

1. Introduction

Sialic acid (Neu5Ac) frequently terminates the oligosaccharide chains of glycoproteins and glycolipids that play a central role in cell-surface recognition phenomena [1]. Cell-surface sialosides serve as ligands for microbial toxins [2], microbial adhesions that mediate attachment to host cells [3], and lectins that mediate intercellular recognition [4]. Sialic acids are usually found in the terminal positions of oligosaccharides, and the most abundant of these linkages include α-(2→3) to galactose, α-(2→6) to galactose, *N*-acetylglucosamine or *N*-acetylgalactosamine, and α-(2→8) to NeuAc. Sialosides [5] have been the subject of extensive research because of their potential use as therapeutics, and recent reviews describe various approaches to their synthesis [6]. In synthetic carbohydrate chemistry stereoselective α-sialylation, which derives from sialic acid's unique structural features [7], is one of the most difficult problems. Therefore, many synthetic methods have been developed to solve these problems. The most successful method uses a directing auxiliary group (–OH, –SePh, –SPh) in the 3β-position of Neu5Ac [8]. Recently, the *N*,*N*-acyl group of neuraminyl derivatives were used to synthesize sialylated oligosaccharides [9]. This prompted us to prepare the

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relatively inexpensive and the most widely used sialic acid donor **9**, which has been used in our laboratory [10], and its corresponding 5-*N*,*N*-diacetyl neuraminyl derivative, **23**, and examine their properties as sialyl donors with disaccharide acceptors **8** and **20** in the syntheses of three target trisaccharides with the α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-β-D-GlcNAc-→OMe (**1**), α-Neu5Ac-(2→3)-β-D-Gal-(6-SO_3Na)-(1→4)-β-D-GlcNAc→OMe (**2**) and α-Neu5Ac-(2→3)-β-D-Gal-(1→3)-α-D-GalNAc-→OBn (**3**) sequences, which are frequently occurring constitutes of glycoproteins and glycolipids.

2. Results and discussion

Synthesis of disaccharide acceptors: methyl (4,6-O-benzylidene-β-D-galactopyranosyl)-(1→4)-2-deoxy-2-phthalimido-6-O-trimethylacetyl-β-D-glucopyranoside (**8**) *and benzyl (4,6-O-benzylidene-β-D-galactopyranosyl)-(1→3)-2-acetamido-2-deoxy-6-O-trimethylacetyl-α-D-galacopyranoside* (**20**).—In order to synthesize the target trisaccharide molecules **1**–**3** (Fig. 1) the monosaccharide donors **4** [11], **9** [12], **14**, and **23**; monosaccharide acceptors **5** [13], and **15** [14], another disaccharide acceptors **8**, and **20** were prepared (Fig. 2, Schemes 1–3). Having the requisite glycosyl donor and glycosyl acceptors in hand, attention was focused on regioselective glycosylation in order to prepare the β-(1→4)-linked disaccharide **6**. Thus, Sn(II)Cl_2–AgOTf [15] mediated regioselective glycosylation of 2,3,4,6-tetra-*O*-acetyl-β-galactopyranosyl fluoride with the 4-hydroxyl group of **5** in the presence of 3-hydroxyl group opening was first tried. Unfortunately, this protocol resulted in only a modest yield of the β-(1→4)-linked disaccharide **6** after a long reaction time of 12 h at −15 to 25 °C. Attention was

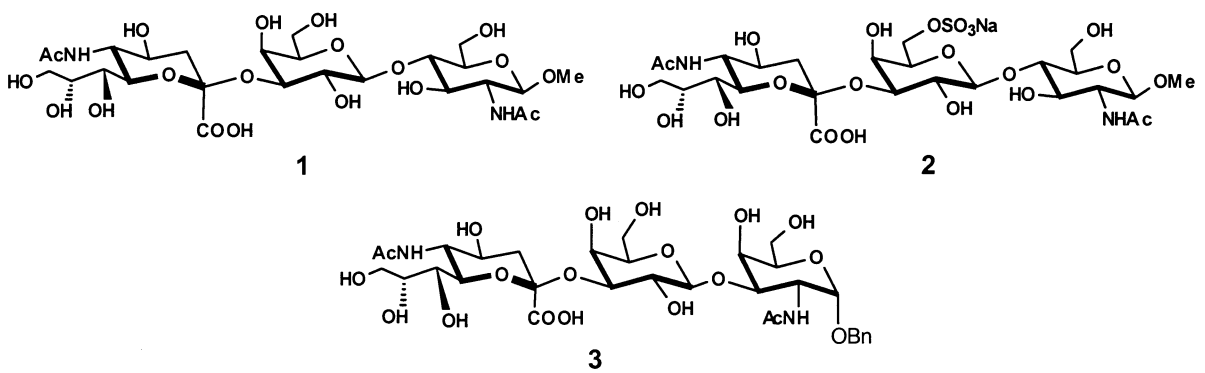


Fig. 1. Targets sialylated and/or sulfated trisaccharides **1**–**3**.

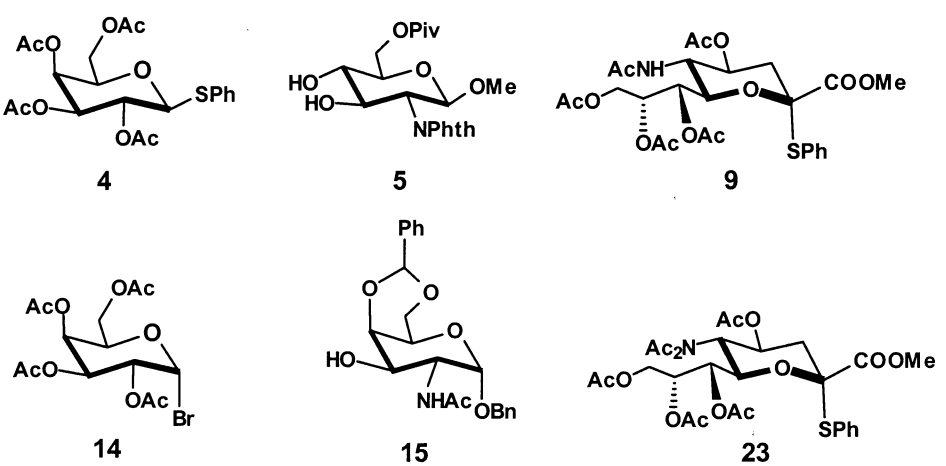
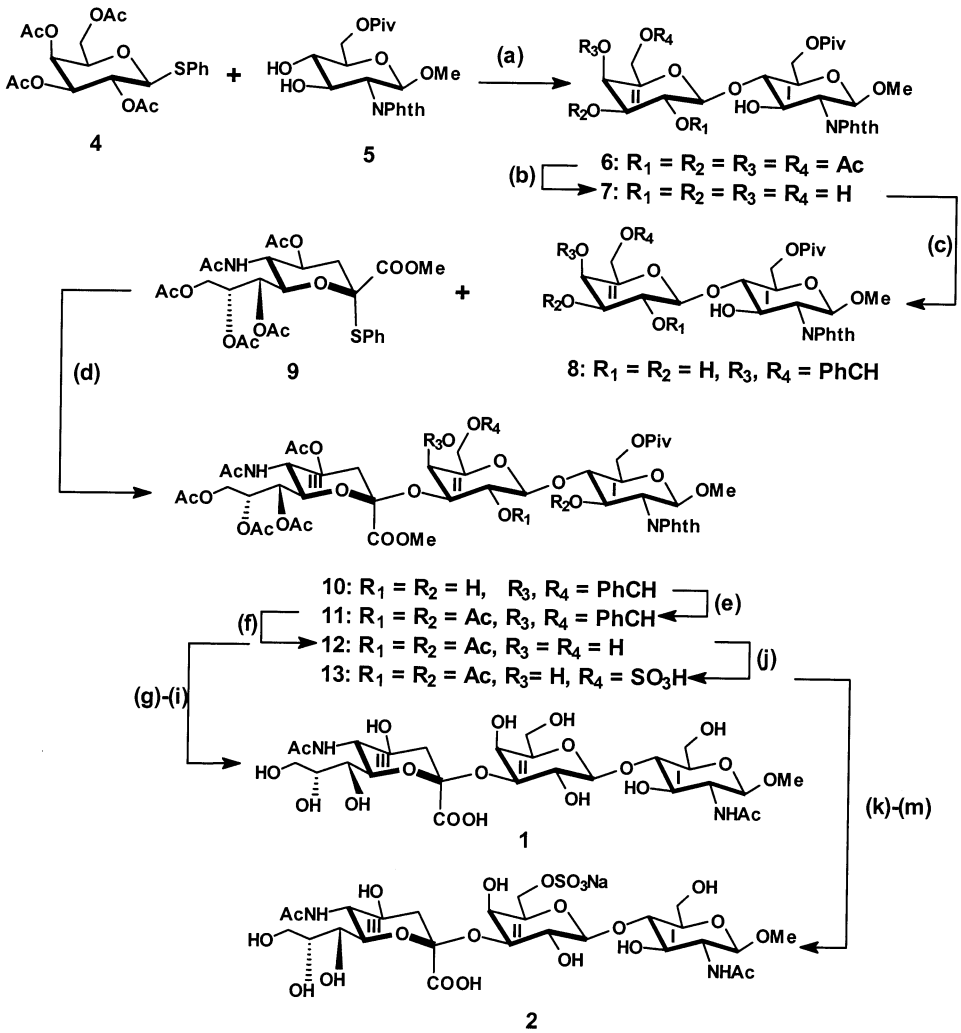


Fig. 2. Key intermediates used in the synthesis of the target trisaccharide molecules.



Scheme 1. (a) NIS–TfOH, 4A-MS, CH_2Cl_2, −45 to −40 °C, 1 h, 75%; (b) CH_3ONa–CH_3OH (1 M), 1:1 CH_2Cl_2–CH_3OH, pH 10, −10 to −5 °C, 20 min, 86%; (c) $PhCH(OCH_3)_2$, *p*-TsOH–CH_3CN, rt, 12 h, 78%; (d) donor **9**, NIS–TfOH, 3A-MS, 3:1 CH_2Cl_2–CH_3CN, −45 to −40 °C, 2 h, 45%; (e) 1:1 pyridine–Ac_2O, DMAP, rt, 12 h; (f) 60% HOAc, 60–65 °C, 4–6 h, 71%; (g) LiI–pyridine, 120–125 °C, 6–8 h; (h) 1:4 $NH_2NH_2{\cdot}H_2O$–EtOH, 80–90 °C, 4–5 h, then, 1:1 pyridine–Ac_2O, DMAP, rt, 12 h; (i) CH_3ONa–CH_3OH (1 M), CH_3OH, rt, 12 h, three steps 15%; (j) SO_3·pyridine–pyridine, 0–5 °C, 12–16 h, 64%; (k) LiI–pyridine, 120–125 °C, 6–8 h; (l) 1:4 $NH_2NH_2{\cdot}H_2O$–EtOH, 80–90 °C, 4–5 h, then, 1:1 pyridine–Ac_2O, DMAP, rt, 12 h; (m) CH_3ONa–CH_3OH (1 M), CH_3OH–H_2O, rt, 12 h, three steps, 36%.

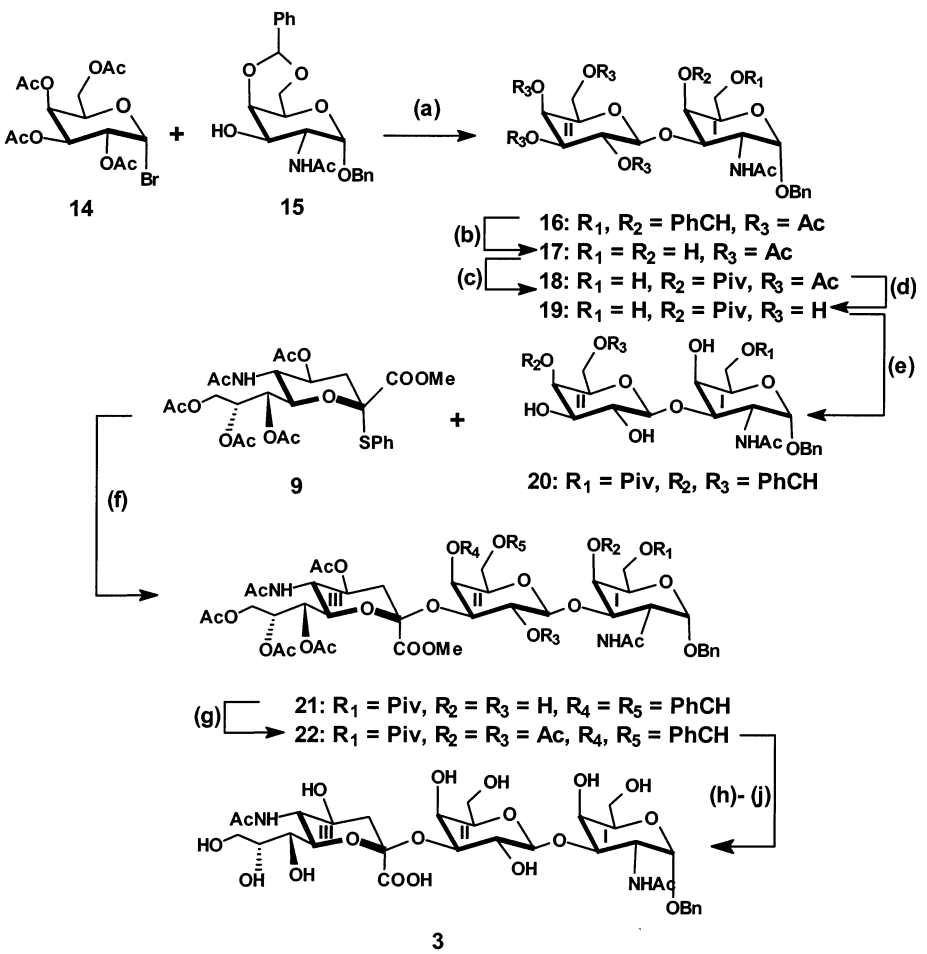
then turned to thioglycosides, which have attracted considerable attention and have been very successfully used in oligosaccharide synthesis. Coupling of phenyl 3,4,6-tetra-*O*-acetyl-1-thio-β-D-galactopyranoside (**4**) with glycosyl acceptor **5** in the presence of the more powerful activator NIS–TfOH at a reasonable reaction temperature (−45 to −40 °C) gave the desired β-(1→4)-linked disaccharide **6** in excellent yield (75%).

The position, connectivity and stereochemistry of the glycosidic linkage in disaccharide **6** was fully confirmed by complete assignment of all the peaks in the spectra with combination of two-dimensional double-quantum filtered ^1H–^1H correlation spectroscopy (2D DQF ^1H–^1H COSY) and D_2O exchange experiments. The value observed for the vicinal coupling constant ($^3J_{1,2}$) between the proton on H-1′ (doublet at δ 4.62) and H-2′ (double doublet at δ 5.23) associated with galactose residue was 8.0 Hz, which confirmed the 1,2-trans configuration (β configuration) of the newly formed linkage. Intersaccharide connectivity, e.g., the β-(1→4) linkage, was unambiguously confirmed by identification of a doublet at δ 4.26 which had a long range coupling ($^3J = 1.6$ Hz) with H-3 of the Glc-

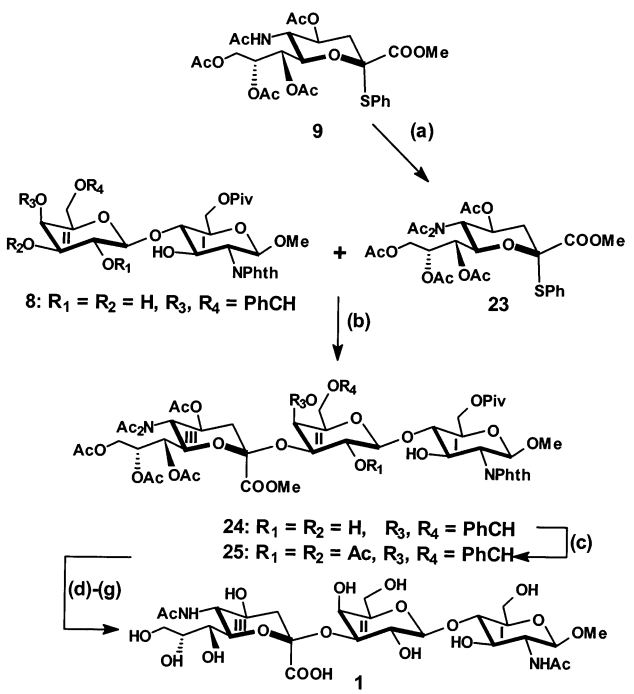
NPthth residue **I** as the proton from HO-3 of the same sugar residue **I** in 2D DQF $^1H-^1H$ COSY spectroscopy (not shown). This assignment was further confirmed by treating disaccharide **6** with D_2O, which caused the doublet peak at δ 4.26 (HO-3) to disappear (Fig. 3).

Selective O-deacetylation of disaccharide **6** in 1:1 $CH_3OH-CH_2Cl_2$ with 1 M sodium methoxide solution at -10 to -5 °C for 20 min provided compound **7** in 86%. The 4,6-*O*-benzylidenated disaccharide acceptor **8** was then obtained in 78% yield by treatment of compound **7** with α,α-dimethoxytoluene at room temperature in dry acetonitrile and in the presence of a catalytic amount of *p*-TsOH.

Condensation of compound **15** with galactosyl bromide **14** (2.0 equivalents) (Scheme 2) in the presence of $Hg(CN)_2$ in 1:1 CH_3NO_2–benzene afforded the desired β-(1→3)-linked disaccharide **16** [16]. The disaccharide **17** was obtained by treatment of disaccharide **16** with 60% HOAc at 60–65 °C for 1.5 h in an excellent yield of 71%. Regioselective protection of the primary hydroxyl group of disaccharide **17** was accomplished by treatment with pivaloyl chloride in the presence of dry pyridine at 0–25 °C to give disaccharide **18** in a high yield of 95%. The *O*-acetyl groups of disaccharide **18** were selectively removed in the presence of the 6-*O*-pivaloyl substituent, as described for the conversion to **7** from **6**, providing compound **19** in 99%. The 4,6-*O*-benzylidenated disaccharide acceptor **20** was then obtained in good yield (73%). Having the requisite glycosyl disaccharide acceptors **8** and **20** and the sialyl donors **9** and **23** in hand, our attention



Scheme 2. (a) 1:1 $Hg(CN)_2-CH_3NO_2$–benzene, 40–45 °C, 16–24 h; (b) 60% HOAc, 60–65 °C, 71%; (c) PivCl–pyridine, 0–25 °C, 12 h, 95%; (d) $CH_3ONa-CH_3OH$ (1 M), pH 10, -10 to -5 °C, 20 min, 99%; (e) $PhCH(OCH_3)_2$, *p*-TsOH, CH_3CN, rt, 3–4 h, 73%; (f) donor **9**, NIS–TfOH, 3:1 $CH_2Cl_2-CH_3CN$, 3A-MS, N_2, -45 to -40 °C, 2–3 h, 42%; (g) 1:1 Ac_2O–pyridine, DMAP, rt, 12 h, 78%; (h) LiI–pyridine, 120–125 °C, 6–8 h, (i) 60% HOAc, 60–65 °C; (j) $CH_3ONa-CH_3OH$ (1 M), CH_3OH, rt, 24 h, three steps, 52%.



Scheme 3. (a) 2-Propenyl acetate–*p*-TsOH·H_2O, 65 °C, 16 h, 99%; (b) donor **23**, NIS–TfOH, 3:1 CH_2Cl_2–CH_3CN, 3A-MS, −45 to −40 °C, 1–1.5 h, 52–55%; (c) pyridine–Ac_2O, rt, 12 h, 78%; (d) LiI–pyridine, 120–125 °C, N_2, 6–8 h, (e) 60% HOAc, 60–65 °C, 4–6 h; (f) 4:1 EtOH–NH_2–NH_2·H_2O, 80–85 °C, 6 h, then, Ac_2O–pyridine, rt, 12 h, (g) CH_3ONa–CH_3OH (1 M), CH_3OH, rt, 24 h, four steps, 12%.

was next focused on their regioselective and stereoselective sialylation.

Regio- and α-stereoselective sialylation of disaccharide acceptors **8** *and* **20** *with sialyl donors* **9** *and* **23**.—Phenylthio-containing sialyl donors **9** and **23** were employed along with *N*-iodosuccinimide (NIS)–trifluoromethanesulfonic acid (TfOH), a powerful glycosyl promoter for thioglycosides [17] and *n*-pentenyl glycosides [18]. Regioselective sialylation of HO-3 of the galactose residue of disaccharide acceptors **8** and **20** was achieved because of its higher nucleophilicity as compared to HO-2. Thus, **8** and **20**, respectively, were reacted with sialyl donor **9** (2.20–3.0 equivalents) in 3:1 dichloromethane–acetonitrile for 2 h at −40 to −45 °C promoted by NIS–TfOH to yield trisaccharides **10** (45%) and **21** (42%) (Schemes 1 and 2). The undesired glycal, a product of elimination of sialyl donor **9**, was observed as a major product. Similarly, trisaccharide **24** was obtained in 50–55% yield from reaction of **8** with new sialyl donor **23** (2.2–3.0 equivalents) (Scheme 3) in the presence of NIS–TfOH in dry 3:1 dichloromethane–acetonitrile for 1 h at −40 to −45 °C. Formation of the undesirable glycal was also observed. An attempt was made to avoid formation of the undesirable glycal by reducing donor excess and using 1.1 equivalent of sialyl donor **23**. The disaccharide acceptor **8**, however, was not completely consumed, and formation of the undesirable glycal could not be avoided. In order to completely consume disaccharide acceptor **8**, another 1.1 equivalents of sialyl donor **23** was added. In comparing sialyl donors **9** and **23** in an identical reaction with **8**, the trivial additional *N*-acetyl group seemingly improved reactivity of glycosyl donor **23** (Scheme 3). Employment of a non-polar (CH_2Cl_2), or polar (CH_3CN, CH_3-CH_2CN, $ClCH_2CH_2Cl$) solvent did not appear to be critical to formation of the thermodynamically unfavored α-glycoside of Neu5Ac [9c,19]. A mixture of dichloromethane and acetonitrile was used to accommodate the respective solubilities of donors **9** and **23**, as well as acceptors **8** and **20**. The proportion of TfOH was found to be very critical for the reaction, and 22–45% of TfOH to the amount of NIS was deemed essential.

The complete structural assignment for compounds **10**, **22** and **24** was accomplished through a combination of 2D DQF ^1H–^1H COSY spectroscopy (Fig. 4: 1D and Fig. 5: 2D DQF-COSY spectra of trisaccharide **24**) and 2D ROESY spectroscopy (not shown). The stereochemistry of the glycosidic linkage for Neu5Ac in trisaccharides **10**, **22** and **24**, was determined to be the α configuration, based on the chemical shifts of H-4″ and H-7″ that were observed at δ 5.00–4.90 (H-4″) and δ 5.32–5.27 (H-7″) for trisaccharide **10**, at 4.85–4.80 (H-4″) and 5.37–5.23 (H-7″) for **22** [20] and similar shifts for trisaccharide **24**. The chemical shift of H-4″ for trisaccharide **24** was downfield at δ 5.48–5.40 because of the electron-withdrawing effect of an additional *N*-acetyl group, while that for H-7″ was at δ 5.23–5.17. The connectivity of α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-β-D-GlcN of trisaccharide **25** was confirmed by 2D ROESY spectroscopy by observation of a strong NOE cross-peak between H-1′ (δ 4.73–4.71) of

sugar residue **II** and H-4 (δ 3.84) of sugar residue **I**, confirming a β-D-Gal-(1→4)-GlcNAc linkage. A similar observation of a weak NOE cross-peak between H-3′ (δ 4.53–4.50) of sugar residue **II** and H-3a″ (δ 1.67–1.61) of sialic acid residue **III** confirmed the Neu5Ac-(2→3)-Gal linkage.

Removal of protective groups to produce target trisaccharides α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-β-D-GlcNAc-(1→O)Me (**1**), *α-Neu5Ac-(2→3)-β-D-Gal-(6-SO_3Na)-(1→4)-β-D-GlcNAc-(1→O)Me* (**2**) *and α-Neu5Ac-(2→3)-β-D-Gal-(1→3)-α-D-GalNAc(1→O)-Bn* (**3**).—Trisaccharide **1** was obtained from

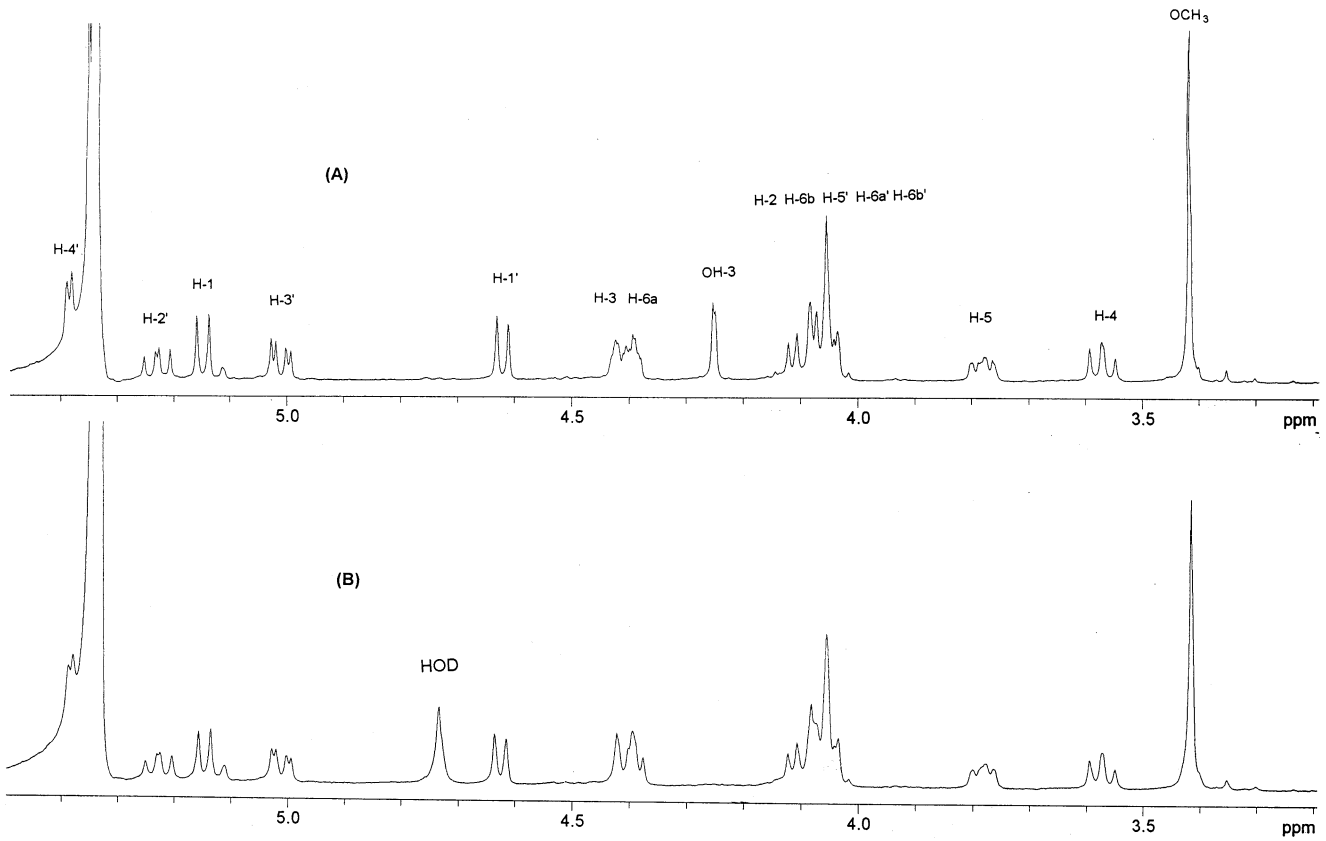


Fig. 3. 400 MHz ^{1}H NMR spectra of disaccharide **6**: (A) recorded in CD_2Cl_2; (B) recorded in $CD_2Cl_2 + D_2O$ at 303.0 K.

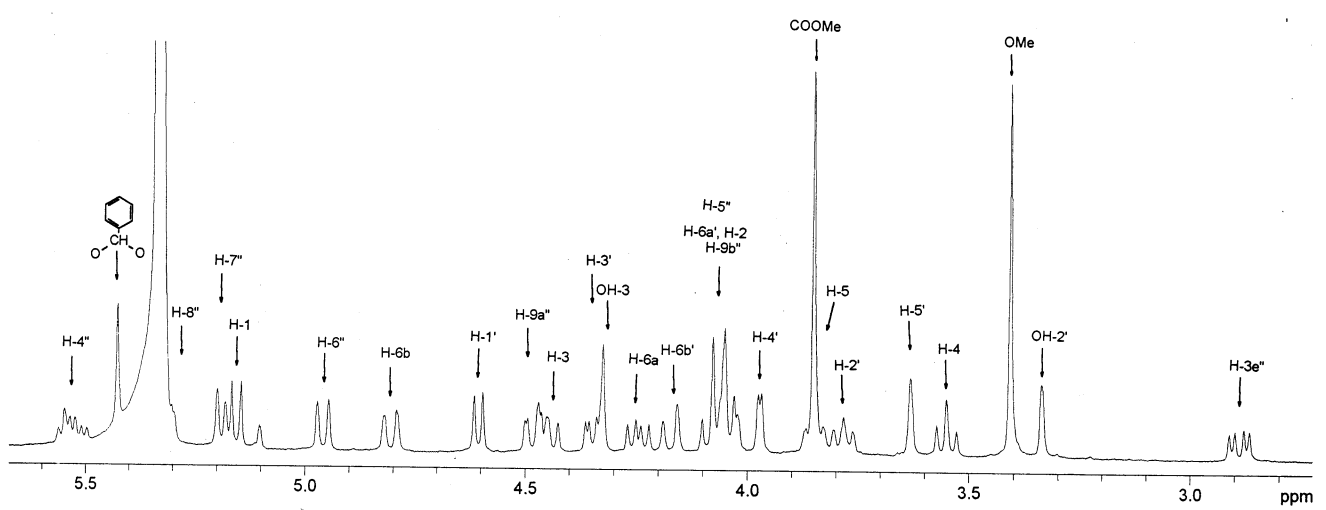


Fig. 4. 400 MHz ^{1}H NMR spectrum of trisaccharide **24** recorded in CD_2Cl_2 at 303.0 K.

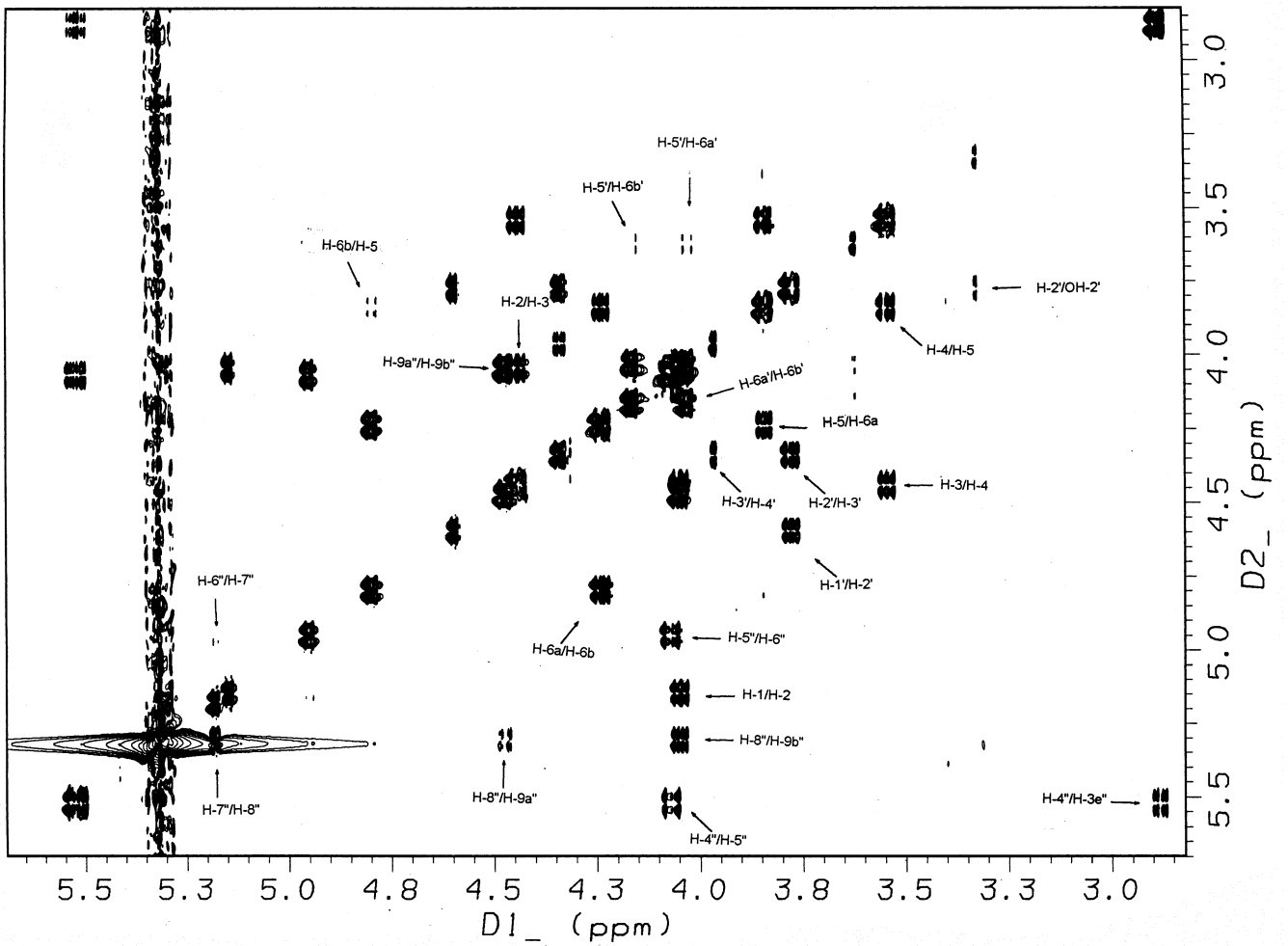


Fig. 5. 600 MHz 2D $^1H-^1H$ DQF-COSY spectrum of trisaccharide **24** recorded in CD_2Cl_2 at 303.0 K.

11 by; (a) removal of the 4,6-*O*-benzylidene group of **11** by treatment with 60% aqueous HOAc at 60–65 °C to give **12**; (b) removal of methyl group by treatment of compound **12** in the presence of a large excess of lithium iodide in dry pyridine at 120–125 °C under dry N_2, (c) removal of the phthalimido group (EtOH–$NH_2NH_2{\cdot}H_2O$, 80–90°C, 4 h), then acetylation with pyridine–Ac_2O, (d) O-deacetylation ($NaOCH_3$–CH_3OH). A protocol employed for preparation of target trisaccharide **2** was similar to that described in the literature [10c]. A similar deprotection procedure was adopted for trisaccharide **22** to afford the target trisaccharide **3**.

The structures of trisaccharide **1**, **2**, and **3** were unambiguously established by a combination of 2D DQF $^1H-^1H$ COSY spectroscopy, 2D ROESY spectroscopy and ^{13}C NMR experiments. For example, in the NMR spectrum of **1**, a weak intersaccharide NOE cross peak was observed between H-3a″ (δ 1.739–1.730) of sialic acid residue **III** and H-3′(δ 4.09–4.02) of galactose residue **II**, which is indicative that the sialic acid residue was attached to C-3 of galactose residue **II**. Similarly, a strong NOE cross peak between H-1′ (at δ 4.44–4.42) to H-4 (at δ 3.60–3.58) of sugar residue **I** (see Figs. 6 and 7) indicated linkage at C-4 of GlcNAc.

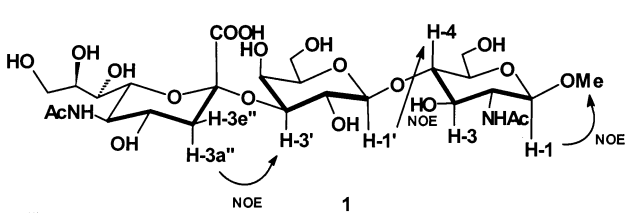


Fig. 6. NOEs of inter- and intrasaccharide residues indicated by the 2D ROESY spectrum.

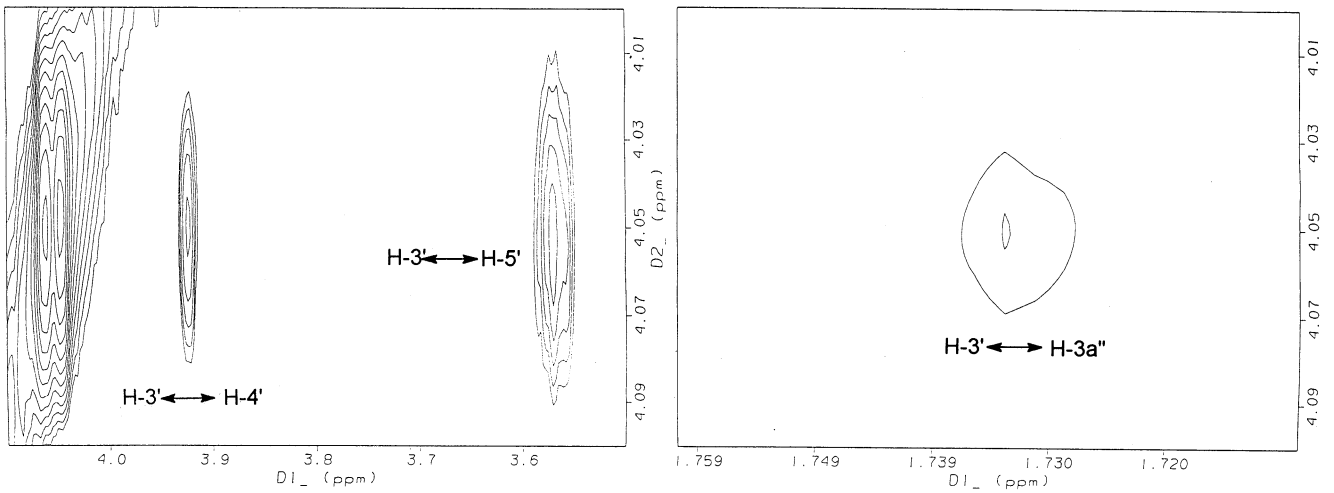


Fig. 7. NOEs of inter- and intrasaccharide residues observed by 2D ROESY spectra.

In summary, the glycosylating capability of sialyl donor **23** was compared with that of its derivative **9** by synthesizing three target trisaccharides, namely, α-Neu5Ac-(2→3)-β-D-Gal-(1→4)-β-D-GlcNAc-(1→O)-Me (**1**), α-Neu5Ac-(2→3)-β-D-Gal6-SO_3Na-(1→4)-β-D-GlcNAc-(1→O)-Me (**2**) and α-Neu5Ac-(2→3)-β-D-Gal-(1→3)-α-D-GalNAc-(1→O)-Bn (**3**). The presence of an additional *N*-acetyl group apparently improved the reactivity of sialyl donor **23** in comparison to that of its parent compound **9**.

3. Experimental

General procedures.—Thin-layer chromatography (TLC) was conducted on glass plates precoated with a 0.25 mm layer of Silica Gel 60 F254 (Analtech GHLF uniplates). The components were visualized either by exposure to UV light or by spraying with 10% H_2SO_4, and 0.2% *p*-anisaldehyde in a solution of EtOH and heating or both. Solutions were concentrated under reduced pressure at < 40 °C. The silica gel used for column chromatography was Baker Analyzed (60–200 mesh). Optical rotations were measured at 25 °C with a Perkin–Elmer 241 polarimeter. ^1H NMR spectra were recorded at 30 °C with either a Bruker AM 400 (400 MHz) or AMX 600 (600 MHz) spectrometer. The values of δ (ppm) are given relative to the signal (δ 0) for internal Me_4Si for solutions in $CDCl_3$, CD_2Cl_2, CD_3OD. ^{13}C NMR spectra were recorded at 303.0 K with a Bruker AM 400 (100.6 MHz) spectrometer using $CDCl_3$ (77.0 ppm), CD_2Cl_2 (54.15 ppm), CD_3OD (49.15 ppm), or acetone-d_6 (206.0 or 29.8) as reference. First-order chemical shifts and coupling constants (J/Hz) were obtained from one-dimensional spectra, and assignments of protons resonance were based on 2D DQF ^1H–^1H COSY and 2D ROESY. Two-dimensional double-quantum filtered phase sensitive ^1H–^1H correlated spectra (DQF ^1H–^1H COSY) and rotating-frame nuclear Overhauser enhancement spectroscopy (ROESY) were recorded at 303.0 K using a Bruker AM 400 (400 MHz) spectrometer and a Bruker AMX 600 (600 MHz) spectrometer. For ROESY experiments, the mixing time was set at 400 ms. All samples submitted for elemental analyses were dried for 48 h under vacuum over P_2O_5 at room temperature (rt). Elemental analyses were performed by Robertson Laboratory, Madison, NJ. *p*-Toluenesulfonic acid monohydrate (*p*-TsOH·H_2O) was co-evaporated (at 80 °C) with anhyd MeCN, then dried under vacuum for 0.5 h before use. CH_2Cl_2,CH_3CN, CH_3OH, and benzene were kept over 4 Å molecule sieves. Pyridine was redistilled over potassium hydroxide, and CH_3NO_2 was freshly distilled over P_2O_5.

Phenyl 2,3,4,6-tetra-O-acetyl-1-thio-β-D-galactopyranoside (**4**).—Compound **4** was prepared according to the literature [11] in quantitative yield as a white solid: TLC R_f =

0.43 (4:1 hexane–EtOAc); $[\alpha]_D$ +12.0° (*c* 1.5, $CHCl_3$); ^1H NMR ($CDCl_3$, 400 MHz): δ 7.50–7.40 (m, 2 H, ArH), 7.32–7.20 (m, 3 H, ArH), 5.40–5.30 (d, 1 H, *J* 2.8 Hz, H-4), 5.20–5.10 (t, 1 H, H-2), 5.10–4.90 (dd, 1 H, $J_{3,4}$ 2.8, $J_{2,3}$ 8.0 Hz, H-3), 4.70–4.60 (d, 1 H, $J_{1,2}$ 9.6 Hz, H-1), 4.20–4.10 (m, 2 H, H-6a, H-6b), 4.00–3.80 (t, 1 H, H-5), 2.05 (s, 3 H, Ac), 2.03 (s, 3 H, Ac), 1.98 (s, 3 H, Ac), 1.91 (s, 3 H, Ac); ^{13}C NMR ($CDCl_3$, 100.6 MHz): δ 132.67, 128.98 128.22, 86.57 (C-1), 74.55, 72.10, 67.41, 61.77, 62.00, 20.93 (Ac), 20.73 (Ac), 20.67 (Ac), 20.63 (Ac).

Methyl 2-deoxy-6-O-trimethylacetyl-2-phthalimido-β-D-glucopyranoside (**5**).—To a cold (0 °C), stirred solution of methyl 2-deoxy-2-phthalimido-β-D-glucopyranoside (25.34 g, 78.45 mmol) in dry pyridine (150 mL), was added trimethylacetyl chloride (11 mL, 86.30 mmol). After 9 h at rt, an additional portion (4 mL, 31.38 mmol) of trimethylacetyl chloride was added again, and stirring was continued for a total of 21 h. The solution was concentrated, and the crude mixture was applied to a column of silica gel and eluted with 20:1 CH_2Cl_2–CH_3OH to give pure compound **5** (30 g, 95%) as an amorphous solid: TLC $R_f = 0.45$ (20:1 CH_2Cl_2–CH_3OH); ^1H NMR ($CDCl_3$, 400 MHz): δ 7.82–7.81 (m, 2 H, ArH), 7.75–7.71 (m, 2 H, ArH), 5.09–5.07 (d, 1 H, $J_{1,2}$ 8.8 Hz, H-1), 4.46–4.44 (dd, 1 H, H-6a), 4.38 (m, 2 H, H-6b, H-3), 4.03–3.98 (dd, 1 H, H-2), 3.64–3.61 (m, 1 H, H-4), 3.41–3.36 (m, 4 H, OCH_3, H-5), 1.25 (s, 9 H, *t*-Bu); ^{13}C NMR ($CDCl_3$, 100.6 MHz): δ 179.19, 133.90, 131.56, 123.27, 99.03 (C-1), 73.91, 73.75, 71.89, 71.32, 63.20, 56.41, 27.00 (3 CH_3).

Methyl (2,3,4,6-tetra-O-acetyl-β-D-galactopyranosyl)-(1→4)-2-deoxy-6-O-trimethylacetyl-2-phthalimido-β-D-glucopyranoside (**6**).—A solution of pheny1 2,3,4,6-tetra-*O*-acetyl-1-thio-β-galactopyranoside (**4**, 12.86 g, 29.23 mmol), methyl 2-deoxy-2-phthalimido-6-*O*-trimethylacetyl-β-D-glucopyranoside (**5**, 13.08 g, 32.14 mmol), NIS (19.72 g, 87.69 mmol) in dry CH_2Cl_2 (238 mL) containing 4A-MS (149 g) was stirred at −45 to −40 °C for 2–3 h in an N_2 atmosphere. TfOH (2.97 mL) was then added, and stirring continued at the same temperature for 1 h. The solution was then neutralized with satd aq $NaHCO_3$, the solids were filtered off, and the organic layer was washed with satd $NaHCO_3$ soln, $Na_2S_2O_3$ (10%) and water, dried with Na_2SO_4 and concentrated. The crude product was purified on a silica gel column using 1:1 hexane–EtOAc as the eluent to give pure compound **6** (13.08 g, 75%) as an amorphous solid: TLC $R_f = 0.43$ (1:1 hexane–EtOAc); $[\alpha]_D$ +14.7° (*c* 1.0, $CHCl_3$); ^1H NMR (CD_2Cl_2, 400 MHz): δ 7.90–7.82 (m, 2 H, ArH), 7.80–7.74 (m, 2 H, ArH), 5.40–5.36 (d, 1 H, $J_{3',4'}$ 3.2 Hz, H-4′), 5.26–5.20 (dd, 1 H, $J_{2',1'}$ 8.4, $J_{2',3'}$ 10.4 Hz, H-2′), 5.18–5.12 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 5.04–4.98 (dd, 1 H, $J_{3',4'}$ 3.6, $J_{2',3'}$ 11.0 Hz, H-3′), 4.64–4.60 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.42–4.38 (m, 2 H, H-3, H-6a), 4.24–4.22 (d, 1 H, *J* 1.6 Hz, OH-3), 4.18–4.00 (m, 5 H, H-2, H-6b, H-5′, H-6a′, H-6b′), 3.82–3.74 (m, 1 H, H-5), 3.60–3.56 (dd, 1 H, H-4), 3.41 (s, 3 H, OCH_3), 2.14 (s, 3 H, Ac), 2.08 (s, 3 H, Ac), 1.97 (s, 3 H, Ac), 1.83 (s, 3 H, Ac), 1.26 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_2Cl_2, 100.6 MHz): δ 177.76, 170.38, 170.23, 170.06, 169.61, 134.36, 132.05, 123.4, 102.31, 99.40 (C-1, C-1′), 83.97, 72.41, 71.80, 71.99, 70.07, 68.90, 67.14, 62.97, 61.97, 55.85, 56.07, 27.26 (3 CH_3), 20.66 (Ac), 20.58 (Ac), 20.52 (Ac), 20.29 (Ac); Anal. Calcd for $C_{34}H_{43}NO_{17}$: C, 55.36; H, 5.89; N, 1.90. Found: C, 55.47; H, 5.95; N, 1.83.

Methyl (β-D-galactopyranosyl)-(1→4)-2-deoxy-6-O-trimethylacetyl-2-phthalimido-β-D-glucopyranoside (**7**).—To a cold (−10 to −5 °C) solution of compound **6** (5.0 g, 6.78 mmol) in 1:1 CH_2Cl_2–CH_3OH (30 mL), was added dropwise a 1 M soln of CH_3ONa in MeOH until the pH of the soln was adjusted to 10, and the stirring was continued at the same temperature for 20 min. The solution was then neutralized with Amberlite IR 120 (H^+) cation-exchange resin, filtered and concentrated. The crude product was applied to a short column of silica gel eluted with 10:1 CH_2Cl_2–CH_3OH to give pure compound **7** (3.31 g, 86%) as an amorphous solid: TLC $R_f = 0.31$ (10:1 CH_2Cl_2–CH_3OH); $[\alpha]_D$ +13.5° (*c* 0.5, CH_3OH); ^1H NMR (CD_2Cl_2, 400 MHz): δ 8.00–7.60 (m, 4 H, ArH), 5.12–5.10 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.70–4.60 (dd, 1 H), 4.50–4.37 (m, 2 H), 4.34–4.32 (d, 1 H, $J_{1',2'}$

7.2 Hz, H-1′), 4.04–3.98 (dd, 1 H), 3.79–3.60 (m, 5 H), 3.60–3.50 (m, 2 H), 3.50–3.40 (dd, 1 H), 3.36 (s, 3 H, OCH_3), 1.25 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_2Cl_2, 100.6 MHz) δ 180.14, 136.07, 133.39, 124.72, 105.71, 100.96 (C-1, C-1′), 81.86, 77.85, 75.26, 74.93, 72.95, 71.52, 70.79, 64.41, 63.12, 58.08, 57.46, 40.4 [$C(CH_3)_3$], 27.95 (CH_3); Anal. Calcd for $C_{26}H_{35}NO_{13}$: C, 54.83; H, 6.21; N, 2.46. Found: C, 54.93; H, 6.21; N, 2.32.

*Methyl (4,6-*O*-benzylidene-β-*D*-galactopyranosyl)-(1→4)-2-deoxy-6-*O*-trimethylacetyl-2-phthalimido-β-*D*-glucopyranoside* (**8**).—To a solution of compound **7** (830 mg, 1.46 mmol), α,α-dimethoxytoluene (0.5 mL, 2.3 mmol) in dry MeCN (20 mL), was added *p*-TsOH·H_2O (191 mg). The mixture was stirred overnight at rt. The acid was then neutralized with Et_3N, and the solution concentrated. The crude product was applied to a short column of silica gel eluted with 20:1 CH_2Cl_2–MeOH to give pure compound **8** (752 mg, 78%) as an amorphous solid: TLC $R_f = 0.44$ (20:1 CH_2Cl_2–CH_3OH) $[\alpha]_D$ + 31.7° (*c* 1.0, $CHCl_3$); ^1H NMR (CD_2Cl_2, 400 MHz): δ 7.90–7.80 (m, 2 H, ArH), 7.80–7.70 (m, 2 H, ArH), 7.50–7.40 (m, 2 H, ArH), 7.40–7.30 (m, 3 H, ArH), 5.52 (s, 1 H, benzylidene proton), 5.15–5.13 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 4.66–4.63 (dd, 1 H, *J* 1.6, J_{gem} 11.6 Hz, H-6a), 4.50–4.40 (dd, 1 H, H-3), 4.38–4.36 (d, 1 H, $J_{1',2'}$ 8.2 Hz, H-1′), 4.30–4.20 (dd, 1 H, *J* 5.6, J_{gem} 12.0 Hz, H-6b), 4.20–4.10 (m, 2 H, H-4′, H-6a′), 4.10–4.00 (m, 2 H, H-2, H-6b′), 3.80–3.70 (m, 2 H, H-5, H-2′), 3.70–3.60 (m, 1 H, H-3′), 3.56 (m, 1 H, H-5′), 3.53–3.49 (t, 1 H, H-4), 3.41 (s, 3 H, OCH_3), 3.30 (d, 1 H, $J_{2',OH'}$ 2.8 Hz, OH-2′), 2.70 (d, 1 H, $J_{3',OH'}$ 8.0 Hz, OH-3′), 1.24 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_2Cl_2, 100.6 MHz): δ 138.05, 134.47, 132.17, 129.50, 128.55, 126.61, 123.58, 104.48, 101.50, 99.50 (C-1, C-1′, benzylidene carbon), 83.12, 75.36, 73.67, 72.99, 71.81, 70.11, 69.14, 67.50, 63.55, 57.00, 56.20, 39.80 [$C(CH_3)_3$], 27.36 (3 CH_3); Anal. Calcd for $C_{33}H_{39}NO_{13}$: C, 60.27; H, 5.99; N, 2.13. Found: C, 60.02; H, 6.15; N, 1.89.

*Methyl [methyl (5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-non-2-ulopyranosyl)onate]-(2→3)-(4,6-*O*-benzylidene-β-*D*-galactopyranosyl)-(1→4)-2-deoxy-2-phthalimido-6-*O*-trimethylacetyl-β-*D*-glucopyranoside* (**10**).—A solution of donor **9** (1.109 g, 1.90 mmol), disaccharide acceptor **8** (500 mg, 0.76 mmol), NIS (1.28 g, 5.7 mmol) in dry 3:1 CH_2Cl_2–MeCN (30 mL) containing 3A-MS (5 g) was cooled (−45 to −40 °C) and stirred in an atmosphere of N_2 for 1.5–2 h. TfOH (0.15 mL) was then added dropwise and the stirring was continued at the same temperature for 1.5 h. More TfOH (40 μL) was then added, and stirring was continued for an additional 1 h. The solution was neutralized with satd aq $NaHCO_3$ soln, the solids were filtered off, and the organic layer was washed with satd $NaHCO_3$ soln, 10% $Na_2S_2O_3$ and water, dried (Na_2SO_4) and concentrated. The crude mixture was placed on a short silica gel column and eluted with 1:5 hexane–EtOAc to give pure compound **10** (430 mg, 0.380 mmol, 45%) as a glass white solid: TLC $R_f = 0.35$ (1:5 hexane–EtOAc); ^1H NMR ($CDCl_3$, 400 MHz) δ 8.00–7.90 (m, 2 H, ArH), 7.90–7.80 (m, 2 H, ArH), 7.60–7.40 (m, 2 H, ArH), 7.40–7.20 (m, 3 H, ArH), 5.46–5.43 (m, 1 H, H-8″), 5.37 (s, 1 H, benzylidene proton), 5.32–5.27 (t, 2 H, H-7″, NHAc″), 5.21–5.19 (d, 1 H, $J_{1,2}$ 8.8 Hz, H-1), 5.00–4.90 (ddd, 1 H, H-4″), 4.85–4.82 (d, 1 H, *J* 2.8 Hz, H-4′), 4.57–4.55 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.48–4.44 (dd, 1 H, *J* 8.8, 10.8 Hz, H-3), 4.41–4.38 (dd, 1 H, *J* 2.2, J_{gem} 12.6 Hz, H-9b″), 4.27–4.19 (m, 3 H, H-3′, H-6a, H-2), 4.16–4.04 (m, 4 H, H-6″, H-6b′, H-9a″, H-6b), 3.98–3.83 (m, 4 H, H-5″, H-2′, H-5′, H-5), 3.68 (s, 3 H, $COOCH_3$), 3.58–3.56 (m, 2 H, H-6a′, H-4), 3.46 (s, 3 H, OCH_3), 2.77–2.72 (dd, 1 H, $J_{3e'',4''}$ 4.4, J_{gem} 12.6 Hz, H-3e″), 2.13 (s, 3 H, Ac), 2.11 (s, 3 H, Ac), 2.02 (s, 3 H, Ac), 2.00 (s, 3 H, Ac), 1.98 (s, 3 H, Ac), 1.97 (t, 1 H, $J_{3a'',3e''}$ 12.6 Hz, H-3a″), 1.25 (s, 9 H, *t*-Bu); ^{13}C NMR ($CDCl_3$, 100.6 MHz) δ 178.25, 171.07, 170.82, 170.46, 170.42, 170.33, 137.90, 134.12, 132.14, 129.19, 128.33, 126.58, 123.48, 104.49, 101.11, 99.24, 97.45 (C-1, C-1′, C-2″, benzylidene carbon), 83.27, 75.05, 73.99, 73.38, 72.86, 70.14, 68.94, 68.65, 68.59, 68.50, 67.30, 66.79, 63.54, 62.85, 56.80, 56.11, 53.20, 50.05, 38.56 (C-3″), 27.43 (3 CH_3) (Ac), 23.40 (Ac), 21.47 (Ac), 21.00 (Ac), 20.93 (Ac); Anal. Calcd for $C_{53}H_{66}N_2O_{25}$: C, 56.28; H, 5.89; N, 2.48. Found: C, 55.95; H, 5.95; N, 2.40.

*Methyl [methyl (5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-*

*non-2-ulopyranosyl)onate]-(2→3)-(2-*O*-acetyl-β-*D*-galactopyranosyl)-(1→4)-2-deoxy-3-*O*-acetyl-2-phthalimido-6-*O*-trimethylacetyl-β-*D*-glucopyranoside* (**12**).—Compound **10** (380 mg, 0.30 mmol) was acetylated with 1:1 Ac_2O–pyridine in the presence of a catalytic amount of DMAP at rt overnight, and the acetylated product of **10** was treated with 60% aq AcOH (20 mL) at 60–65 °C for 6 h. The solution was then concentrated. The crude product was purified in a short column of silica gel with 10:1 CH_2Cl_2–MeOH as the eluent to give compound **12** (220 mg, 71%) as an amorphous solid: TLC $R_f = 0.40$ (10:1 CH_2Cl_2–CH_3OH); ^{1}H NMR (CD_3OD, 400 MHz): δ 8.00–7.80 (m, 2 H, ArH), 7.80–7.60 (m, 2 H, ArH), 5.72–5.68 (dd, 1 H, *J* 8.4, *J* 10.4 Hz, H-3), 5.56–5.50 (m 2 H), 5.24–5.22 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 5.21–5.19 (d, 1 H), 5.00–4.98 (t, 1 H), 4.96–4.93 (ddd, 1 H, H-8″), 4.67–4.65 (d, 1 H, $J_{1',2'}$ 7.6 Hz, H-1′), 4.59–4.56 (d, 1 H, J_{gem} 11.6 Hz, H-9b″), 4.40–4.36 (dd, 1 H, *J* 2.4, *J* 12.4 Hz, H-6a), 4.310–4.29 (dd, 1 H, *J* 2.4, *J* 10.2 Hz), 4.15–3.72 (m 11 H, OCH_3), 3.57 (d, 1 H, H-4′), 3.50–3.49 (t, 1 H, H-5), 3.99 (s, 3 H, OCH_3), 2.67–2.63 (dd, 1 H, *J* 4.4, J_{gem} 11.0 Hz, H-3e″), 2.23 (s, 3 H, Ac), 2.12 (s, 3 H, Ac), 2.08 (s, 3 H, Ac), 2.05 (s, 3 H, Ac), 2.00 (s, 3 H, Ac), 1.99 (s, 3 H, Ac), 1.92 (s, 3 H, Ac), 1.80–1.78 (t, 1 H, J_{gem} 12.3 Hz, H-3a″), 1.25 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_3OD, 100.6 MHz) δ 173.71, 172.49, 172.38, 172.24, 172.14, 171.95, 171.36, 169.86, 135.86, 124.62, 102.73, 102.20 (C-1, C-1′), 98.68 (C-2″), 78.61, 76.55, 75.41, 74.77, 73.47, 73.10, 71.60, 71.12, 69.13, 68.79, 68.24, 64.17, 63.95, 61.42, 57.32, 56.45, 53.72, 50.18, 40.2 [$C(CH_3)_3$], 39.04 (C-3″), 27.83 (3 CH_3), 22.91 (Ac), 21.97 (Ac), 21.82 (Ac), 21.23 (Ac), 21.09 (Ac), 21.00 (Ac), 20.82 (Ac); Anal. Calcd for $C_{50}H_{66}N_2O_{27}$: C, 53.28; H, 5.90; N, 2.48. Found: C, 53.46; H, 5.92; N, 2.39.

*Methyl [methyl (5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-non-2-ulopyranosyl)onate]-(2→3)-(6-*O*-sulfate-β-*D*-galactopyranosyl)-(1→4)-2-deoxy-2-phthalimido-6-*O*-trimethylacetyl-β-*D*-glucopyranoside* (**13**).—To a cold (0–5 °C) stirred solution of compound **12** (220 mg, 0.19 mmol) in dry pyridine (3 mL) was added a SO_3·pyridine complex (36 mg, 0.23 mmol), and stirring was continued at the same temperature for 9 h. The solution was then quenched with MeOH and concentrated. The crude mixture was placed on a short silica gel column and eluted with 10:1 CH_2Cl_2–MeOH to give compound **13** (150 mg, 64%) as a white glass solid: TLC $R_f = 0.16$ (10:1 CH_2Cl_2–CH_3OH); ^{1}H NMR (CD_3OD, 400 MHz): δ 8.00–7.90 (m, 4 H, ArH), 5.76–5.69 (ddd, 1 H, H-8″), 5.67–5.63 (dd, 1 H, *J* 8.4, *J* 10.8 Hz, H-3), 5.40–5.37 (d, 1 H), 5.29–5.27 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 5.05–5.01 (dd, 1 H, *J* 8.0, *J* 9.8 Hz, H-2), 4.80–4.78 (d, 1 H, $J_{1',2'}$ 7.2 Hz, H-1′), 4.69–4.66 (d, 1 H, *J* 9.6 Hz), 4.30–4.29 (m, 2 H), 4.22–4.17 (dd, 1 H), 4.10–3.90 (m, 9 H), 3.84 (s, 3 H, OCH_3), 3.76–3.74 (t, 1 H, H-5), 3.58–3.57 (d, 1 H, *J* 2.4 Hz, H-4′), 3.41 (s, 3 H, OCH_3), 2.75–2.71 (dd, 1 H, *J* 4.0, J_{gem} 12.2 Hz, H-3e″), 2.31 (s, 3 H, Ac), 2.17 (s, 3 H, Ac), 2.07 (s, 6 H, 2 Ac), 1.98 (s, 3 H, Ac), 1.95 (s, 3 H, Ac), 1.82 (s, 3 H, Ac), 1.68–1.60 (t, 1 H, J_{gem} 12.8 Hz, H-3a″), 1.26 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_3OD, 100.6 MHz) δ 174.16, 172.96, 172.84, 172.77, 170.18, 136.40, 125.03, 103.24, 100.64 (C-1, C-1′), 99.18 (C-2″), 79.32, 75.53, 75.21, 74.78, 73.80, 73.55, 71.93, 71.57, 69.55, 69.28, 68.39, 66.82, 64.69, 64.45, 57.73, 56.87, 54.43, 50.61, 39.43 (C-3″), 28.27 (3 CH_3), 23.34 (Ac), 22.39 (Ac), 22.28 (Ac), 21.66 (Ac), 21.54 (Ac), 21.41 (Ac); Anal. Calcd for $C_{50}H_{66}N_2O_{30}S$: C, 49.75; H, 5.51; N, 2.32; S, 2.66. Found: C, 49.77; H, 5.41; N, 2.12; S, 2.66.

*Methyl [(5-acetamido-3,5-dideoxy-*D*-glycero-α-*D*-galacto-non-2-ulopyranosylonic acid)-(2→3)-β-*D*-galactopyranosyl]-(1→4)-2-acetamido-2-deoxy-β-*D*-glucopyranoside* (**1**).—Lithium iodide (LiI, 400 mg, 3.0 mmol) was added to a solution of compound **12** (170 mg, 0.15 mmol) in dry pyridine (3 mL), The mixture was stirred for 6–8 h at 120–125 °C under an N_2 atmosphere. The dark-yellow solution was concentrated, and the residue was co-evaporated with toluene, then dissolved in EtOAc. The solution was washed with satd NaCl, dried (Na_2SO_4), and evaporated to a bright-yellow residue that was directly used for the next step. To the solution of the bright-yellow free acid in MeOH (15 mL) was added NH_2NH_2·H_2O (5 mL) solution. After 3–4 h at 80–85 °C, the mixture was concentrated under vacuum to a crude mixture that was co-evaporated with toluene,

then acetylated with 1:1 Ac_2O–pyridine (8 mL) overnight at rt. The acetylated mixture was concentrated and de-acetylated with 1 M CH_3ONa in MeOH at rt for 24 h and concentrated under vacuum to give a crude mixture that was purified on a short silica gel column by eluting with 3:1:1 *n*-C_3H_7OH–HOAc–water to give compound **1** (16.0 mg, 15%) as an amorphous solid: TLC $R_f = 0.30$ (3:1:1 *n*-C_3H_7OH–HOAc–water); ^1H NMR (CD_3OD, 600 MHz): δ 4.44–4.42 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1′), 4.30–4.28 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 4.04–4.03 (dd, 1 H, *J* 2.4, *J* 8.4 Hz, H-3′), 3.92–3.82 (m, 5 H, H-6b′, H-4′, H-6a′, H-4, H-9b″), 3.73–3.67 (m, 4 H, H-7″, H-4″, H-2, H-6b), 3.65–3.52 (m, 6 H, H-3, H-6″, H-9a″, H-6a, H-2, H-5″), 3.48–3.47 (m, 1 H, H-5), 3.44 (s, 3 H, OCH_3), 3.40–3.39 (m, 2 H, H-8″, H-5′), 2.85–2.83 (dd, 1 H, *J* 4.0, J_{gem} 10.8 Hz, H-3e″), 1.99 (s, 3 H, Ac), 1.94 (s, 3 H, Ac), 1.71 (t, 1 H, H-3a″); ^{13}C NMR (CD_3OD, 100.6 MHz) δ 180.64 (C=O), 175.70 (C=O), 173.82 (C=O), 105.20, 104.07, 102.30 (C-1, C-1′, C-2″), 82.30, 77.84, 77.29, 76.76, 75.14, 74.51, 73.24, 71.08, 70.32, 69.55, 69.28, 64.87, 62.95, 62.20, 61.23, 57.25, 56.66, 54.20, 42.27 (C-3″), 23.13 (Ac), 22.82 (Ac).

Methyl [(5-acetamido-3,5-dideoxy-D-glycero-α-D-galacto-*non-2-ulopyranosylonic acid)-(2→3)-(sodium 6*-O-*sulfo-β*-D-*galactopyranosyl]-(1→4)-2-acetamido-2-deoxy-β*-D-*glucopyranoside* (**2**).—Compound **13** (100 mg, 0.08 mmol) was submitted to an identical reaction sequence as described for **12** to give **1**. The residue dissolved in water and stirred with Amberlite IR 120 cation exchange resin (Na^+) for 4–5 h at rt. The resin was filtered off, the filtrate was concentrated and purified on a column of silica gel by eluting with 1:1:1 *n*-C_3H_7OH–HOAc–water to give compound **2** (25 mg, 36%) as a amorphous solid: TLC $R_f = 0.42$ (1:1:1 *n*-C_3H_7OH–HOAc–H_2O); ^{13}C NMR (D_2O, 100.6 MHz) δ 173.99, 173.37, 172.78, 101.43, 99.85, 98.81, 77.34, 72.29, 66.14, 61.60, 59.66, 56.05, 54.04, 50.68, 38.63 (C-3″), 21.11, 21.02.

Benzyl (2,3,4,6-O-*tetra*-O-*acetyl-β*-D-*galactopyranosyl)-(1→3)-2-acetamido-2-deoxy-α*-D-*galacopyranoside* (**17**).—A stirred mixture of benzyl 2-acetamido-4,6-*O*-benzylidene-2-deoxy-α-D-galactopyranoside (**15**, 2.08 g, 5.21 mmol) and powdered $Hg(CN)_2$ (2.8 g) in 1:1 benzene–nitromethane (100 mL) was boiled until 50 mL of solvent had distilled off. The temperature was then adjusted to 40–45 °C, and 2,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide (3.83 g, 9.34 mmol) was added, and the stirring was continued for 16–24 h at 40–45 °C. The mixture was diluted with benzene and washed with satd aq $NaHCO_3$, 10% aq potassium iodide and water, dried (Na_2SO_4), and concentrated. The crude mixture was taken up in 60% aq AcOH (20 mL) and stirred for 1.5–2 h at 60–65 °C. The AcOH was evaporated under reduced pressure, and the residue was co-evaporated with several added portions of toluene. It was then applied to a short column of silica gel and eluted with 20:1 CH_2Cl_2–CH_3OH to give pure compound **17** (2.37 g, 71%) as a bright-yellow glassy solid: TLC $R_f = 0.41$ (20:1 CH_2Cl_2–CH_3OH); $[\alpha]_D$ +84.3° (*c* 1.0, $CHCl_3$); ^1H NMR (CD_2Cl_2, 400 MHz): δ 7.37–7.36 (m, 5 H, ArH), 5.86–5.84 (d, 1 H, *J* 9.2 Hz, NHAc), 5.36–5.32 (d, 1 H, H-4′), 5.20–5.10 (t, 1 H, H-2′), 5.10–5.00 (dd, 1 H, H-3′), 5.00–4.90 (d, 1 H, H-1), 4.72–4.69 (d, 1 H, J_{gem} 12.0 Hz, OCH_APh, ABq), 4.67–4.65 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.60–4.40 (m, 2 H, OCH_BPh, J_{gem} 11.2 Hz, ABq), 4.20–4.00 (m, 3 H), 4.00–3.90 (m, 1 H), 3.90–3.80 (m, 4 H), 2.13 (s, 3 H, Ac), 2.02 (s, 3 H, Ac), 1.95 (s, 3 H, Ac), 1.92 (s, 3 H, Ac), 1.90 (s, 3 H, Ac); ^{13}C NMR ($CDCl_3$, 100.6 MHz) δ 172.88, 172.03, 171.89, 171.57, 171.47, 135.30, 129.59, 129.47, 128.98, 102.84, 97.98 (C-1, C-1′), 78.37, 72.46, 72.29, 72.01, 70.30, 69.95, 68.88, 49.73, 22.89 (Ac), 20.84 (Ac), 20.65 (Ac), 20.57 (2 Ac); Anal. Calcd for $C_{29}H_{39}NO_{15}$: C, 54.29; H, 6.14; N, 2.18. Found: C, 54.09; H, 6.13; N, 2.12.

Benzyl (2,3,4,6-O-*tetra*-O-*acety-β*-D-*galactopyranosyl)-(1→3)-2-acetamido-2-deoxy-6*-O-*trimethylacetyl*-α-D-*galacopyranoside* (**18**).—To a cold (ice-bath) soln of compound **17** (1.96 g, 3.06 mmol) in dry pyridine (20 mL) was added dropwise trimethylacetyl chloride (0.41 mL, 3.33 mmol), and the stirring was continued for 8 h at 0–25 °C. More trimethylacetyl chloride (0.12 mL) was added at 0 °C, and the stirring was continued for an additional 4–5 h at 0–25 °C. The mixture was concentrated, and the crude product was

passed through a short silica gel column and eluted with 40:1 CH_2Cl_2–MeOH to give pure compound **18** (2.1 g, 95%) as a white solid: TLC $R_f = 0.28$ (40:1 CH_2Cl_2–MeOH); $[\alpha]_D$ + 76.0° (*c* 0.5, $CHCl_3$); ^1H NMR (CD_2Cl_2, 400 MHz): δ 7.60–7.20 (m, 5 H, ArH), 5.53–5.51 (d, 1 H, *J* 9.6 Hz, NHAc), 5.40–5.39 (d, 1 H, $J_{3',4'}$ 2.8 Hz, H-4′), 5.23–5.20 (dd, 1 H, H-2′), 5.02–4.98 (dd, 1 H, H-3′), 4.97–4.96 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1, α form), 4.76–4.73 (d, 1 H, *J* 11.2 Hz, OCH_APh, ABq), 4.64–4.60 (m, 2 H, H-1′, $J_{1',2'}$ 8.0 Hz, H-2), 4.48–4.45 (d, 1 H, J_{gem} 12.0 Hz, OCH_BPh, ABq), 4.41–4.36 (m, 2 H, H-6a′, H-6b′), 4.18–4.09 (m, 4 H, H-4, H-6a, H-5′, H-6b), 4.00–3.92 (t, 1 H, H-5), 3.81–3.78 (dd, 1 H, H-3), 2.05 (s, 3 H, Ac), 2.04 (s, 3 H, Ac), 2.01 (s, 3 H, Ac), 1.98 (s, 3 H, Ac), 1.95 (s, 3 H, Ac), 1.24 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_2Cl_2, 100.6 MHz): δ 178.52, 170.51, 170.36, 170.35, 169.55, 169.51, 137.03, 128.92, 128.68, 128.61, 128.34, 101.89, 97.21 (C-1, C-1′), 78.13, 71.13, 70.85, 69.73, 68.84, 68.77, 68.54, 68.48, 67.08, 64.27, 61.46, 27.42 (3 CH_3), 23.55, 20.85, 20.83, 20.80, 20.75, 20.72; Anal. Calcd for $C_{34}H_{47}NO_{16}$: C, 56.27; H, 6.54; N, 1.93. Found: C, 56.38; H, 6.53; N, 1.90.

*Benzyl (4,6-*O*-benzylidene-β-*D*-galactopyranosyl)-(1→3)-2-acetamido-6-*O*-trimethylacetyl-2-deoxy-α-*D*-galactopyranoside* (**20**).—A solution of compound **18** (2.04 g, 2.81 mmol) in 1:1 CH_2Cl_2–MeOH (20 mL) was cooled to −10 to −5 °C, treated with a 1 M solution of CH_3ONa–CH_3OH until the pH of the solution was equal to 10 (controlled by pH paper), and the stirring was continued at the same temperature for 20 min. The solution was neutralized with Amberlite IR120 (H^+) cation-exchange resin. The resin was filtered off, and the mixture was concentrated. The crude product was applied to a short silica gel column and eluted with 10:1 CH_2Cl_2–MeOH to give quantitatively pure compound **19** (1.56 g, 2.80 mmol), which was dissolved in dry CH_3CN (48 mL) and α,α-dimethoxytoluene (2.31 mL, 4.20 mmol), then treated with *p*-TsOH (461 mg). After 6–8 h at rt the solution was neutralized with Et_3N and concentrated to give a crude product mixture which was passed through a short silica gel column eluted with 10:1 CH_2Cl_2–MeOH to give pure compound **20** (1.31 g, 73%) as a white solid: TLC $R_f = 0.5$ (10:1 CH_2Cl_2–MeOH); ^1H NMR (CD_2Cl_2, 400 MHz): δ 7.56–7.50 (m, 2 H, ArH), 7.40–7.30 (m, 8 H, ArH), 5.60–5.50 (s, 1 H, benzylidene proton), 5.00 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1), 4.80–4.72 (d, 1 H, J_{gem} 12.0 Hz, OCH_APh, ABq), 4.52–4.44 (m, 2 H, OCH_BPh, J_{gem} 11.2 Hz, ABq, H-2), 4.44–4.40 (d, 1 H, $J_{1,2}$ 7.6 Hz, H-1′), 4.32–4.28 (m, 3 H, H-6a, H-6b′, H-6b), 4.24–4.16 (m, 2 H, H-4, H-4′), 4.16–4.08 (m, 2 H, H-5, H-6a′), 3.92–3.84 (dd, 1 H, *J* 2.8, *J* 11.2 Hz, H-3), 3.72–3.64 (dd, 1 H, H-2′), 3.64–3.56 (dd, 1 H, H-3′), 1.96 (s, 3 H, Ac), 1.23 (s, 9 H, *t*-Bu); ^{13}C NMR (CD_2Cl_2, 100.6 MHz): δ 129.40, 128.87, 128.55, 128.49, 128.41, 126.61, 105.67, 101.54, 97.38 (C-1, C-1′, benzylidene carbon), 79.42, 76.35, 72.62, 71.12, 69.77 (2 C), 69.01 (2 C), 67.26, 64.64, 39.80, 27.24 (3 CH_3), 22.75 (Ac); Anal. Calcd for $C_{33}H_{43}NO_{12}$: C, 61.39; H, 6.71; N, 2.17. Found: C, 61.17; H, 6.75; N, 2.17.

*Benzyl [methyl (5-acetamido-4,7,8,9-tetra-*O*-acetyl-3,5-dideoxy-*D*-glycero-α-*D*-galacto-non-2-ulopyranosyl)onate]-(2→3)-(2-*O*-acetyl-4,6-*O*-benzylidene-β-*D*-galactopyranosyl)-(1→4)-3-acetyl-6-*O*-trimethylacetyl-2-acetamido-2-deoxy-α-*D*-galactopyranoside* (**22**).—A solution of donor **9** (470 mg, 0.81 mmol), disaccharide acceptor **20** (220 mg, 0.34 mmol), NIS (547 mg, 2.43 mmol) in dry 3:1 CH_2Cl_2–MeCN (30 mL) containing 3A-MS (6.0 g) was stirred at −45 to −40 °C for 1.5–2 h in an atmosphere of N_2. TfOH (64 μL) was then added dropwise, and the stirring was continued at the same temperature for 1.5 h. Additional TfOH (17 μL) was added, and stirring was continued at the same temperature for 1 h. The mixture was neutralized with satd aq $NaHCO_3$, the solids were filtered off and the organic layer was washed with satd $NaHCO_3$ soln, 10% $Na_2S_2O_3$, water, dried (Na_2SO_4), and concen-trated under diminished pressure to a crude mixture that was passed through a short silica gel column eluted with 1:5 hexane–EtOAc to give pure compound **21** (156 mg, 0.14 mmol, 42.0%) as an amorphous solid. Compound **21** (370 mg, 0.33 mmol) was treated with 1:1 pyridine–Ac_2O (10 mL) overnight at rt. The mixture was concentrated under reduced pressure, and the residue was passed through a short silica gel column

eluted with 20:1 CH_2Cl_2–CH_3OH to give compound **22** (310 mg, 78%) as an amorphous solid: TLC $R_f = 0.64$ (20:1 CH_2Cl_2–CH_3OH); $[\alpha]_D$ +69.6° (*c* 1.65, $CHCl_3$); ^1H NMR ($CDCl_3$, 400 MHz): δ 7.48–7.22 (m 10 H, ArH), 6.50–6.49 (d, 1 H, *J* 6.0 Hz, NHAc), 5.70–5.60 (ddd, 1 H, H-8″), 5.43–5.42 (d, 1 H, *J* 2.8 Hz, H-4), 5.37–5.23 (m, 4 H, NHAc″, H-7″, benzylidene proton, H-2′), 5.18–5.17 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.85–4.80 (ddd, 1 H, H-4″), 4.76–4.74 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.63–4.60 (d, 1 H, J_{gem} 12.0 Hz, OCH_APh, ABq), 4.46–4.43 (d, 1 H, J_{gem} 12.8 Hz, OCH_BPh, ABq), 4.42–4.36 (m, 3 H, H-2, H-3′, H-9b″), 4.27–4.11 (m, 3 H, H-6a, H-6a′, H-6b′), 4.11–4.06 (m, 2 H, H-3, H-5″), 4.00–3.96 (m, 2 H, H-6b, H-5′), 3.91–3.84 (m, 2 H, H-6″, H-9a″), 3.74 (s, 3 H, OCH_3), 3.71–3.70 (d, 1 H, H-4′), 3.48 (m, 1 H, H-5), 2.67–2.65 (dd, 1 H, *J* 4.2 Hz, J_{gem} 12.8 Hz, H-3e″), 2.24 (s, 3 H, Ac), 2.17 (s, 3 H, Ac), 2.10 (s, 6 H, 2 Ac), 2.00 (s, 3 H, Ac), 1.94 (s, 3 H, Ac), 1.87 (s, 3 H, Ac), 1.85 (s, 3 H, Ac), 1.79–1.72 (t, 1 H, *J* 12.8 Hz, H-3a″), 1.22 (s, 9 H, *t*-Bu); ^{13}C NMR ($CDCl_3$, 100.6 MHz): δ 178.51, 171.47, 171.20, 170.90, 170.70, 170.60, 170.34, 170.28, 169.02, 138.04, 137.46, 129.41, 128.83, 128.59, 128.50, 128.39, 126.90, 101.95, 100.53, 97.25, 96.70 (C-1, C-1′, C-2″, benzylidene carbon), 74.51, 72.90, 72.62, 72.58, 69.95, 69.65, 69.33, 69.30, 67.97, 67.92, 67.88, 66.58, 63.53, 53.25, 49.83, 49.49, 38.39 (C-3″), 30.00 [$C(CH_3)_3$], 27.58 (3 CH_3), 23.50 (Ac), 23.33 (Ac), 21.76 (Ac), 21.49 (Ac), 21.17 (Ac), 21.13 (Ac), 20.96 (Ac); Anal. Calcd for $C_{57}H_{74}N_2O_{26}$: C, 56.90; H, 6.21; N, 2.33. Found: C, 56.68; H, 6.36; N, 2.17.

Benzyl [(5-acetamido-3,5-dideoxy-D-glycero-*α*-D-galacto-*non*-2-*ulopyranosylonic acid)-(2→3)-β*-D-*galactopyranosyl]-(1→3)-2-acetamido-2-deoxy-α*-D-*galactopyranoside* (**3**).—To a solution of compound **22** (160 mg, 0.13 mmol) in dry pyridine (3 mL) was added lithium iodide (500 mg, 3.76 mmol). After 6–8 h at 120–125 °C under an N_2 atmosphere, the dark-yellow soln was concentrated under vacuum to a crude product that was co-evaporated with toluene and dissolved in EtOAc, washed with satd aq NaCl, dried (Na_2SO_4) and concentrated to give a bright-yellow solid that was dissolved in 60% aq AcOH and stirred at 60–65 °C for 4–6 h. The mixture was then concentrated, and the residue was dissolved in MeOH (5 mL) and treated with 1 M CH_3ONa and stirred overnight at rt. It was concentrated under reduced pressure, and the crude product was passed through a short silica gel column eluted with 3:1:1 *n*-C_3H_7OH–HOAc–water to give compound **3** (53 mg, 52%) as an amorphous solid: TLC $R_f = 0.46$ (3:1:1 *n*-$CH_3CH_2CH_2OH$–HOAc–water); $[\alpha]_D$ +65.7° (*c* 0.25, CH_3OH); ^1H NMR (CD_3OD, 600 MHz): δ 7.40–7.28 (m, 5 H, ArH), 4.91 (d, 1 H, H-1), 4.77–4.75 (d, 1 H, J_{gem} 12.0 Hz, OCH_APh, ABq), 4.52–4.99 (d, 1 H, J_{gem} 12.0 Hz, OCH_BPh, ABq), 4.49–4.47 (d, 1 H, $J_{1',2'}$ 7.2 Hz, H-1′), 4.43–4.4.41 (dd, 1 H, *J* 9.6 Hz, H-2), 4.20 (s, 1 H, H-4), 4.04–4.02 (dd, 1 H, H-3′), 4.00–3.99 (t, 1 H, H-3), 3.94 (d, 1 H, H-5), 3.90–3.83 (m, 1 H, H-8″), 3.82–3.60 (m, 10 H, H-4″, H-5′, H-9a″, H-9b″, H-6a, H-6b, H-6″, H-6a′, H-5″, H-6b′), 3.60–3.59 (t, 1 H, H-2′), 3.56–3.52 (d, 1 H, H-7″), 2.85–2.81 (dd, 1 H, *J* 4.0, J_{gem} 11.8 Hz, H-3e″), 2.02 (s, 3 H, Ac), 1.96 (s, 3 H, Ac), 1.74 (t, 1 H, H-3a″); ^{13}C NMR (CD_3OD, 100.6 MHz): δ 176.51, 176.18, 175.09, 130.39, 130.28, 129.92, 106.92, 101.50 (C″-2), 99.01, 79.78, 78.56, 77.52, 75.90, 73.92, 73.33, 71.82, 71.34, 70.98, 70.20, 65.27, 63.92, 63.81, 55.01, 51.27, 42.50 (C-3″), 23.93 (Ac), 23.68 (Ac).

Phenyl (methyl 5-acetamido-N-*acetyl-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy-2-thio-β*-D-glycero-D-galacto-*2-nonulopyranoside)onate* (**23**).—A solution of compound **9** (6.64 g, 11.38 mmol) in 2-propenyl acetate (58 mL), was treated with *p*-$TsOH \cdot H_2O$ (108 mg, 0.57 mmol), and the mixture was stirred for 16 h at 60–65 °C. Et_3N was then added, and the mixture was concentrated to give a crude product that was passed through a short silica gel column eluted with 1:1 hexane–EtOAc to give pure **23** as an amorphous solid in quantitative yield: TLC $R_f = 0.53$ (1:1 hexane–EtOAc) $[\alpha]_D$ −58.2° (*c* 1.0, $CHCl_3$); ^1H NMR (CD_2Cl_2, 400 MHz): δ 7.51–7.49 (m, 2 H, ArH), 7.39–7.34 (m, 3 H, ArH), 5.88–5.82 (ddd, 1 H, H-4), 5.65–5.62 (dd, 1 H, *J* 2.0 Hz, *J* 9.8 Hz, H-5), 5.25 (t, 1 H, H-7), 4.90 (m, 1 H, H-8), 4.32–4.29 (dd, 1 H, *J* 1.6, *J* 12.2 Hz, H-9a), 4.14–4.03 (m, 2 H, H-9b, H-6), 3.62 (s, 3 H, $COOCH_3$), 2.80–2.68 (dd, 1 H, $J_{3e,4}$ 4.0, J_{gem}

12.2 Hz, H-3e), 2.39 (s, 3 H, Ac), 2.26 (s, 3 H, Ac), 2.09 (dd, 1 H, H-3a), 2.08 (s, 6 H, 2 Ac), 1.99 (s, 6 H, 2 Ac); ^{13}C NMR (CD_2Cl_2, 100.6 MHz): δ 175.06, 173.74, 170.53, 170.44, 170.36, 169.75, 168.69, 136.63, 130.08, 130.20, 129.46, 89.19 (C-2), 72.28, 70.48, 69.04, 67.08, 62.44, 57.82, 52.85, 38.97 (C-3), 28.15, 25.97, 21.02, 20.99, 20.87; Anal. Calcd for $C_{28}H_{35}NO_{13}S$: C, 53.75; H, 5.64; N, 2.24; S, 5.13. Found: C, 53.73; H, 5.67; N, 2.06; S, 5.12.

Methyl [methyl 5-acetamido-N-*acetyl-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*non-2-ulopyranosyl)onate]-(2→3)-(4,6-O-benzylidene-β-D-galactopyranosyl)-(1→4)-2-deoxy-2-phthalimido-6-O-trimethylacetyl-β-D-glucopyranoside* (**24**)

Procedure A. A solution of donor **23** (544 mg, 0.87 mmol), disaccharide acceptor **8** (520 mg, 0.79 mmol), NIS (587 mg, 2.61 mmol) in dry 3:1 CH_2Cl_2–MeCN (20 mL) containing 3A-MS (6 g) was stirred at −45 to −40 °C for 1.5–2 h under an N_2 atmosphere. TfOH (70 μL) was then added dropwise, and stirring was continued for 1 h at the same temperature. More donor **23** (544 mg, 0.87 mmol) and TfOH (70 μL) were added, and stirring was continued for an additional 1 h. The solution was neutralized with satd aq $NaHCO_3$, solids were filtered off, and the organic layer was washed with satd aq $NaHCO_3$ soln, 10% $Na_2S_2O_3$, water, dried (Na_2SO_4) and concentrated and the crude mixture was passed through a short silica gel column eluted with 1:5 hexane–EtOAc to give pure compound **24** (550 mg, 55.0%) as a white glassy solid.

Procedure B. A solution of donor **23** (713 mg, 1.14 mmol), disaccharide acceptor **8** (300 mg, 0.46 mmol), NIS (770 mg, 3.42 mmol) in dry 3:1 CH_2Cl_2–MeCN (15 mL) containing 3A-MS (4–5 g) was stirred at −45 to −40 °C for 1.5–2 h under an N_2 atmosphere. TfOH (100 μL) was then added dropwise, and stirring was continued for 1 h at the same temperature. The solution was neutralized with satd aq $NaHCO_3$, solids were filtered off, and the organic layer was washed with satd aq $NaHCO_3$, 10% $Na_2S_2O_3$, water, dried (Na_2SO_4), and concentrated under reduced pressure to give a crude mixture that was passed through a short silica gel column eluted with 1:5 hexane–EtOAc to give pure compound **24** (282 mg, 52%) as a glassy white solid: TLC $R_f = 0.35$ (1:5 hexane–EtOAc); ^{1}H NMR (CD_2Cl_2, 600 MHz): δ 8.00–7.90 (m, 2 H, ArH), 7.90–7.80 (m, 2 H, ArH), 7.60–7.40 (m, 2 H, ArH), 7.40–7.20 (m 3 H, ArH), 5.52–5.49 (ddd, 1 H, H-4″), 5.39 (s, 1 H, benzylidene proton), 5.32–5.27 (t, 1 H, H-8″), 5.17–5.15 (dd, 1 H, H-7″), 5.14–5.11 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 4.94–4.92 (dd, 1 H, J 10.4 Hz, H-6″), 4.79–4.76 (dd, 1 H, H-6b), 4.58–4.57 (d, 1 H, $J_{1',2'}$ 7.2 Hz, H-1′), 4.47–4.39 (m, 2 H, H-9a″, H-3), 4.33–4.29 (m, 2 H, H-3′, OH-3), 4.24–4.19 (dd, 1 H, H-6a), 4.16–4.07 (dd, 1 H, H-6b′), 4.07–3.99 (m, 4 H, H-5″, H-2, H-9b″, H-6a′), 3.95–3.94 (d, 1 H, J 2.8 Hz, H-4′), 3.90–3.80 (m, 4 H, H-5, $COOCH_3$), 3.80–3.75 (t, 1 H, H-2′), 3.38 (s, 3 H, OCH_3), 3.31 (d, 1 H, OH-2′), 2.90–2.80 (dd, 1 H, J 4.8, J_{gem} 12.4 Hz, H-3e″), 2.30 (br, 3 H, Ac), 2.11 (s, 3 H, Ac), 2.08 (s, 3 H, Ac), 2.01 (s, 3 H, Ac), 1.93 (s, 3 H, Ac), 1.92–1.86 (t, 1 H, J 12.8 Hz, H-3a″), 1.52 (s, 3 H, Ac), 1.25 (s, 9 H, t-Bu); ^{13}C NMR ($CDCl_3$, 100.6 MHz): δ 171.26, 170.81, 170.78, 168.78, 166.50, 138.55, 134.80, 132.56, 129.78, 128.91, 127.21, 123.57, 104.95, 101.75, 99.76 (C-1, C-1′, benzylidene carbon), 97.14 (C-2″), 83.65, 75.89, 75.12, 73.75, 71.11, 70.59, 69.97, 69.25, 69.03, 6753, 67.36, 66.98, 63.80, 62.83, 57.76, 57.21, 56.70, 39.55 (C-3″), 30.39 [$C(CH_3)_3$], 27.83 (3 CH_3), 21.61 (Ac), 21.34 (Ac), 21.24 (2 Ac), 21.21 (Ac); Anal. Calcd for $C_{55}H_{68}N_2O_{26}$: C, 56.31; H, 5.84; N, 2.39. Found: C, 57.31; H, 6.20; N, 2.59.

Methyl [methyl 5-acetamido-N-*acetyl-4,7,8,9-tetra*-O-*acetyl-3,5-dideoxy*-D-glycero-α-D-galacto-*non-2-ulopyranosy)onate]-(2→3)-(2*-O-*acetyl-4,6*-O-*benzylidene-β*-D-*galactopyranosyl)-(1→4)-2-phthalimido-2*-O-*acetyl-6*-O-*trimethylacetyl-2-deoxy-β*-D-*glucopyranoside* (**25**).—Compound **24** (150 mg) was acetylated with 1:1 pyridine–Ac_2O (8 mL) overnight at rt, and concentrated under vacuum to give a crude product that was passed through a short silica gel column eluting with 1:4 hexane–EtOAc to give compound **25** (134 mg) as a glassy white solid in 78% yield: TLC $R_f = 0.35$ (1:5 hexane–EtOAc); ^{1}H NMR (CD_2Cl_2, 600 MHz): δ 7.85–7.76 (m, 4 H, ArH), 7.60–7.20 (m, 5 H, ArH), 5.78–5.73 (t,

1 H, *J* 8.4 Hz, H-3), 5.55–5.51 (m, 1 H, H-8″), 5.47–5.44 (ddd, 1 H, H-4″), 5.38 (s, 1 H, benzylidene H), 5.28–5.26 (d, 1 H, $J_{1,2}$ 8.4 Hz, H-1), 5.22–5.20 (dd, 1 H, H-7″), 5.10–4.97 (dd, 1 H, H-2′), 4.78–4.75 (dd, 1 H, H-6″), 4.73–4.71 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.67–4.64 (dd, 1 H, H-5), 4.53–4.50 (dd, 1 H, *J* 3.2 Hz, *J* 8.4 Hz, H-3′), 4.41–4.38 (dd, 1 H, H-9a″), 4.27–4.12 (m, 4 H, H-5″, H-6b′, H-6a, H-2), 4.07–3.99 (m, 2 H, H-9b″, H-6a′), 3.86–3.80 (m, 5 H, H-6b, H-4, OCH_3), 3.80–3.79 (d, 1 H, *J* 3.2 Hz, H-4′), 3.48–3.46 (s, 1 H, H-5′), 3.42 (s, 3 H, OCH_3), 2.80–2.72 (dd, 1 H, *J* 4.4 Hz, J_{gem} 13.2 Hz, H-3e″), 2.34 (s, 3 H, Ac), 2.28 (s, 3 H, Ac), 2.24 (s, 3 H, Ac), 2.17 (s, 3 H, Ac), 2.09 (s, 3 H, Ac), 2.05 (s, 3 H, Ac), 1.94 (s, 3 H, Ac), 1.89 (s, 3 H, Ac), 1.67–1.61 (t, 1 H, J_{gem} 12.8 Hz, H-3a″), 1.20 (s, 9 H, *t*-Bu); ^{13}C NMR ($CDCl_3$, 100.6 MHz): δ 178.66, 173.83, 173.63, 170.71, 170.38, 170.13, 169.99, 169.21, 101.89, 101.26, 99.22, 98.17 (C-1, C-1′, benzylidene C, C-2″), 77.77, 74.84, 73.71, 72.46, 71.27, 70.28, 69.73, 69.05, 68.54, 67.61, 66.91, 66.61, 62.92, 62.52, 57.02, 56.64, 55.20, 39.21 (C-2″), 27.30 (3 CH_3), 21.61 (Ac), 21.29 (Ac), 21.15 (Ac), 20.91 (Ac), 20.87 (Ac), 20.82 (Ac), 20.68 (Ac); Anal. Calcd for $C_{59}H_{72}N_2O_{28}$: C, 56.37; H, 5.77; N, 2.28. Found: C, 57.21; H, 6.17; N, 2.15.

Methyl [(5-acetamido-3,5-dideoxy-D-glycero-α-D-galacto-*non-2-ulopyranosylonicacid)-(2→3)-β*-D-*galactopyranosyl]-(1→4)-2-acetamido-2-deoxy-β*-D-*glucopyranoside* (**1**).—To a solution of compound **25** (60 mg, 0.13 mmol) in dry pyridine (2 mL), lithium iodide (300 mg, 1.56 mmol) was added. After 6–8 h at 120–125 °C under N_2 protection, the dark-yellow solution was concentrated under vacuum to give a crude product that was co-evaporated with toluene and dissolved in EtOAc, washed with satd NaCl, dried with anhyd Na_2SO_4, and concentrated to the corresponding carboxylic acid as a bright-yellow solid. To a MeOH solution of the bright-yellow free acid dissolved in MeOH (15 mL) was added $NH_2NH_2{\cdot}H_2O$ (5 mL). After 3–4 h at 80 to 85 °C, the mixture was concentrated under vacuum to a crude mixture that was co-evaporated with toluene and acetylated with 1:1 Ac_2O–pyridine (8 mL) overnight at rt. The acetylated mixture was concentrated. The free acid was dissolved in 60% aq AcOH, stirred at 60–65 °C for 4–6 h, then concentrated to a crude mixture which was dissolved in MeOH (5 mL) and deacetylated with 1 M CH_3ONa overnight at rt, concentrated under vacuum to a crude product that was passed through a short silica gel column eluted with 3:1:1 *n*-C_3H_7OH–HOAc–water to give compound **1** (5 mg) as an amorphous solid in a total yield of 12%.

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