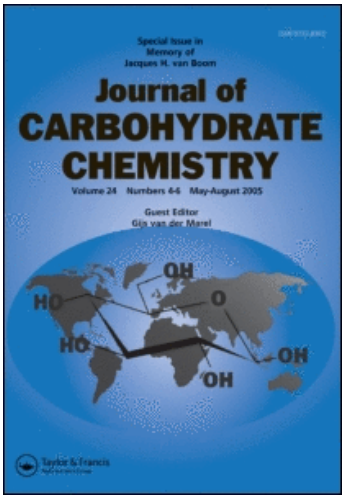

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Stereoselective Synthesis of a Dimer Containing an α-Linked 2-Acetamido-4-Amino-2,4,6-Trideoxy-D-Galactopyranose (Sug*p*) Unit

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STEREOSELECTIVE SYNTHESIS OF A DIMER CONTAINING AN α-LINKED 2-ACETAMIDO-4-AMINO-2,4,6-TRIDEOXY-D-GALACTOPYRANOSE (SUG*p*) UNIT

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ABSTRACT

Ethyl 1-thio-α-D-mannopyranoside **5** was converted to properly protected 2-acetamido-4-amino-2,4,6-trideoxy-D-galactopyranose (Sug*p*) glycosyl donors **1-3**, which could be used to glycosylate 1,6-anhydro-2-azido-3-*O*-benzyl-2-deoxy-ß-D-galactopyranose **23**, leading to the highly stereoselective formation of dimer **24**. Complete deblocking of **24** was accomplished in three steps giving the target disaccharide 1,6-anhydro-2-acetamido-2-deoxy-4-*O*-(2-acetamido-4-amino-2,4,6-trideoxy-α-D-galactopyranosyl)-ß-D-galactopyranose (**4**).

INTRODUCTION

Structure elucidation[1,2] of a cell-wall associated polysaccharide antigen of the complex polysaccharide (*i.e.* the C-substance) from *Streptococcus pneumoniae* type 1 (see Figure 1) revealed that the polysaccharide contains the rare sugar 2-acetamido-4-amino-2,4,6-trideoxy-D-galactopyranose (Sug*p*). It can be seen in Figure 1 that the C-1 and C-3 positions of the Sug*p* moiety are α-and ß-linked to the C-4 and C-1 positions of *N*-acetyl-D-galactosamine and D-glucose, respectively. In an earlier study from this laboratory the

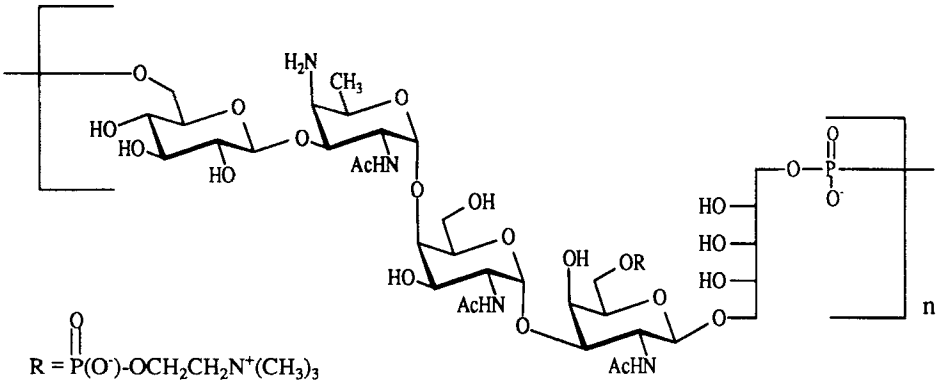
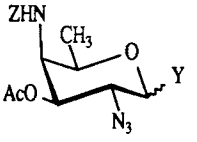


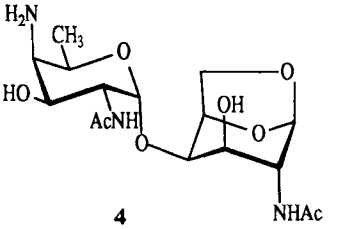
Figure 1. Repeating unit of the subcapsular polysaccharide C-substance from Streptococcus *Pneumoniae* type 1.

synthesis of the Sug*p* derivative benzyl 2,4-diacetamido-2,4,6-trideoxy-α(β)-D-galactopyranoside was disclosed.[3] However, the latter and previously reported[4,5] Sug*p* derivatives were not suitable, due to the presence of a participating acetamido group at C-2, for the introduction of the requisite 1,2-*cis* interglycosidic linkage between Sug*p* and Gal*p*NAc.

As part of a program to study in detail the immunological properties of well-defined C-substance fragments, we report here an approach to the preparation of the Sug*p* donors **1-3** and their application towards the stereoselective synthesis of the Sug*p* containing disaccharide **4**.



1 Y = OC(=NH)CCl$_3$ (α/β)
2 Y = SPh (β)
3 Y = SC(=S)OEt (β)

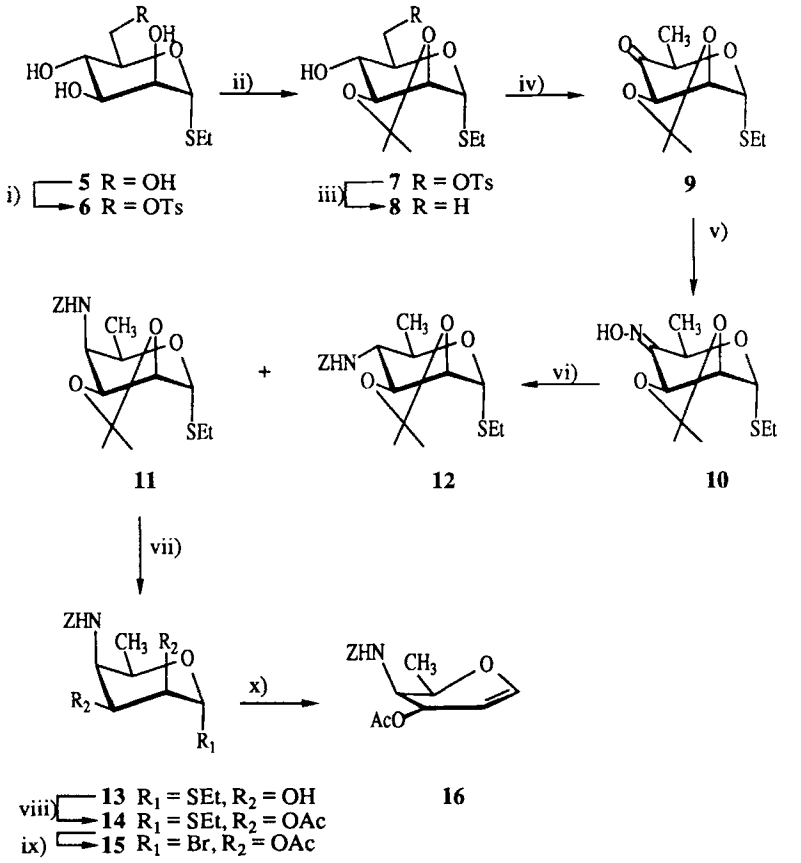


4

RESULTS AND DISCUSSION

A crucial element in a successful synthetic route to the target dimer **4** is the availability of a Sug*p* donor suitable for the introduction of the requisite 1,2-*cis*-linkage. The strategy we adopted to achieve our goal commences, as depicted in Scheme 1, with

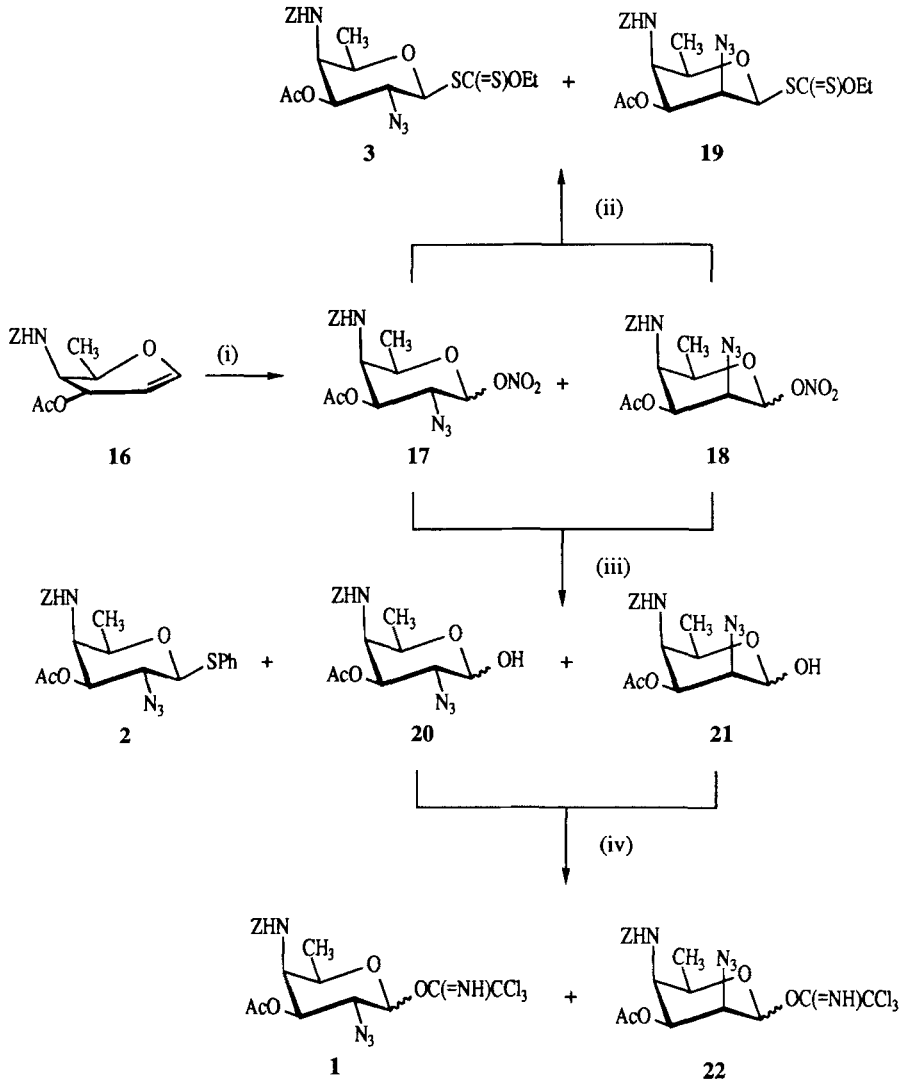
Scheme 1[a]



[a] Key : (i) TsCl/pyr, 16 h, (86%); (ii) 2,2-Dimethoxypropane/acetone/TsOH, 2 h, (75%); (iii) $LiAlH_4$/diethyl ether, reflux, 2 h (62%); (iv) Swern oxidation (100%); (v) $HONH_2(HCl)$/pyr/H_2O, 1 h, (97%); (vi) $NaCNBH_3$/NH_4OAc/$TiCl_3$ in acidified (HCl) MeOH, 40 h, then Benzyloxycarbonylchloride (Z-Cl)/$NaHCO_3$/dioxane/H_2O, 1 h, (75% based on **10**); (vii) Trifluoroacetic acid/H_2O, 9/1, v/v, 5 min.; (viii) Ac_2O/pyr, 16 h, (76%); (ix) Br_2/CH_2Cl_2, 30 min; (x) Activated Zn dust/NaI/AcOH/Ac_2O, 0 °C, 1 h, (93% based on **14**)

the synthesis of the D-galactal derivative **16**. Thus, easily accessible[6] ethyl 1-thio-α-D-mannopyranoside **5** was regioselectively tosylated to give, after acetonation of **6**, the partially protected 6-*O*-tosyl derivative **7**. Reduction of **7** with lithium aluminium hydride[7] gave ethyl 6-deoxy-2,3-*O*-isopropylidene-1-thio-α-D-mannopyranoside **8**. Swern oxidation of **8** (→**9**) and subsequent treatment of the ketone with hydroxylamine hydrochloride furnished oxime **10**. Reduction of the oxime function to the required D-talopyranoside

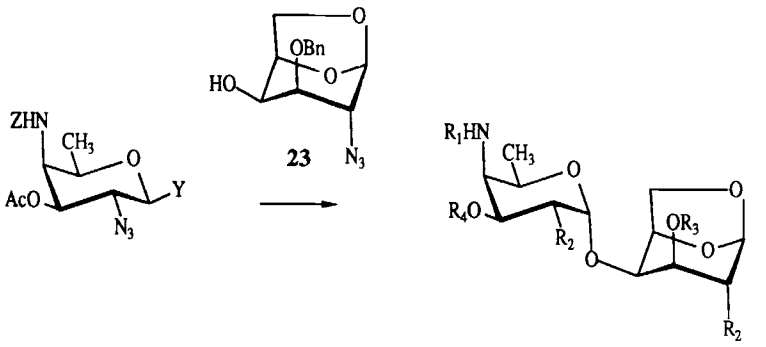
Scheme 2[a]



[a] Key : (i) NaN_3, $(NH_4)_2Ce(NO_3)_6$, CH_3CN, -15 °C, 2 h (71%); (ii) KSC(=S)OEt, CH_3CN, 16 h, (58%); (iii) PhSH, DIPEA, 30 min, (**2**, 22%; **20/21**, 65%); (iv) K_2CO_3, Cl_3CCN, CH_2Cl_2, 4 h, (**1**, α/β, 1/9, 60%);

derivative **11** was realized most effectively *via* the method of Leeds *et al.*[8] Thus, treatment of **10** with sodium cyanoborohydride in the presence of titanium trichloride and subsequent benzyloxycarbonylation of the generated amino function afforded the 4-(benzyloxy-carbonyl)-amino-D-talopyranoside **11** which was contaminated with a small amount (≤ 5%)

Scheme 3



1 Y = OC(=NH)CCl_3 (α/β, 1/9)
2 Y = SPh
3 Y = SC(=S)OEt

i) → **24** R_1 = Z, R_2 = N_3, R_3 = Bn, R_4 = Ac
ii) → **25** R_1 = Z, R_2 = NHAc, R_3 = Bn, R_4 = Ac
ii) → **26** R_1 = Z, R_2 = NHAc, R_3 = Bn, R_4 = H
iii) → **4** R_1 = R_3 = R_4 = H, R_2 = NHAc

Reagents: i) Thioacetic acid, 3 days, RT (84%);
ii) NaOMe, MeOH, 30 min, RT (83%); iii) H_2/Pd/C
in *t*BuOH/AcOH/H_2O, 4 h, 40 °C (80%).

of the tentatively assigned D-mannopyranoside derivative **12**. The latter impurity was separated from the D-talopyranoside isomer by the following procedure. Acidic hydrolysis of the acetonide function (**11** → **13**) followed by acetylation and silica gel chromatography furnished homogeneous **14**, the ^{1}H NMR data (*e.g.* $J_{NH,4}$ = 10.6 Hz, $J_{3,4}$ = 4.2 Hz and $J_{4,5}$ = 2 Hz) of which were in full accord with the proposed structure. Finally, reaction of **14** with bromine[9] and treatment of the resulting bromide **15** with activated zinc dust[10] furnished the key D-galactal precursor **16** in 20% overall yield (based on **5**).

At this stage, we turned our attention to the transformation of the D-galactal **16** into the Sug*p* donors **1-3**. The first step comprised the azidonitration[11,12] of **16**, as outlined in Scheme 2, resulting in the formation of the major Sug*p* derivative **17** and the minor talopyranoside **18** which could not be purified by column chromatography or crystallization. Denitration of the anomeric nitrates was then executed in two different ways. Firstly, compounds **17** and **18** were transformed according to Sinaÿ *et al.*,[13] into the corresponding *S*-xanthates by using *O*-ethyl-*S*-potassium dithiocarbonate to replace the anomeric nitrate group. Work-up and purification gave, as corroborated by NMR spectroscopy, the β-Sug*p*-*S*-xanthate **3** in a reasonable yield. On the other hand, the minor *talo*-derivative **19** could not be obtained in a pure form. Secondly, denitration of **17** and

Table 1. Glycosylation of acceptor 23 with Sug*p* donors 1-3

Donor	Promoter	Yield (%)	α/β Ratio
1	TMSOTf[a]	75	1 : 0
2	NIS/TfOH(cat)[b]	64	1 : 0
3	NIS/TfOH(cat)[b]	16	1 : 0
3	$Cu(OTf)_2$[c]	23	1 : 0

(a)-30°C, CH_2Cl_2, 3 h. (b) RT, Et_2O/1,2-DCE, 16 h. (c) RT, CH_2Cl_2, 3 days;

18 with thiophenol in the presence of *N,N*-diisopropylethylamine revealed, in contrast with expectation,[13,14] the presence of an interesting side-product. Thus, purification of the denitrated mixture resulted in the isolation of the expected products **20-21** (65% combined yield) and a minor product (22% yield), the structure of which was in agreement with the phenyl 1-thio-β-Sug*p* donor **2**. The third Sug*p* donor (*i.e.* **1**) was readily accessible by converting **20-21** into the corresponding trichloroacetimidates *via* the well-established method of Schmidt *et al.*[15] Work-up and separation of the resulting trichloroacetimidates **1** and **22** gave homogeneous donor **1** (α/β mixture) in 60% yield.

Having the glycosyl donors in hand, we explored the glycosylating properties of the individual Sug*p* donors **1-3**. To this end, the known[16] acceptor 1,6-anhydro-2-azido-3-*O*-benzyl-2-deoxy-β-D-galactopyranose (**23**) was glycosylated with the individual donors in the presence of an appropriate promoter [*i.e.* trimethylsilyltriflate[17], *N*-iodosuccinimide (NIS) and catalytic trifluoromethanesulfonic acid (TfOH cat.)[18,19] or copper(II) triflate[13]]. The outcome of these glycosylations are summarized in Table 1. It can be seen that each glycosidation resulting in disaccharide **24** proceeded as expected[17,20] with a high degree of stereoselectivity, with only formation of 1,2-*cis* linkages as gauged by TLC analysis and NMR spectroscopy. It is also evident from the Table that the glycosylation of **23** by the donors **1-2** afforded dimer **24** in acceptable yields. However, it is also clear that the condensation of the reactive equatorial hydroxyl group in acceptor **23** with the *S*-xanthate donor **3** is rather ineffective. In this respect it is of interest to note that the low-yielding glycosylation of **23** with **3** is in sharp contrast with the reported[13] excellent glycosylation capacity of *S*-xanthate donors in the presence of the promoter $Cu(OTf)_2$.

Complete deblocking of **24** could be effected by consecutively executing the following three steps. Reduction of the azido groups and acetylation of the generated

amino functions were performed *via* the one-pot thioacetic procedure of Chu *et al.*[21] Deacetylation of the resulting purified dimer **25** followed by hydrogenolysis of the benzyl (Bn) and benzyloxycarbonyl (Z) groups in **26** furnished crude fully deprotected dimer **4**. Purification of the latter by Sephadex LH-20 chromatography gave homogeneous **4**, the identity of which was firmly established by NMR spectroscopy.

The successful synthesis of dimer **4** reported in this paper may open the way to other valuable synthetic fragments of the C-substance from *Streptococcus pneumoniae* type 1.

EXPERIMENTAL

General Procedures. Dioxane and pyridine were dried by refluxing with CaH_2 (5 g/L) for 6 h and then distilled. Dichloromethane, 1,2-dichloroethane and toluene were distilled from P_2O_5. *N,N*-Dimethylformamide was stirred with CaH_2 at room temperature for 16 h and distilled under reduced pressure. Diethyl ether was distilled from $LiAlH_4$. Dioxane, pyridine and *N,N*-dimethylformamide were stored over molecular sieves 4 Å (Aldrich). Toluene and diethyl ether were stored over sodium wire, dichloromethane and 1,2-dichloroethane over alumina. Schleicher and Schüll DC Fertigfolien F1500 LS 254 were used for TLC analysis. The following eluents were used: System A (dichloromethane/methanol, 9/1, v/v), System B (diethyl ether/hexane, 2/1, v/v), System C (dichloromethane/acetone, 97/3, v/v), System D (dichloromethane/acetone/triethylamine, 96/3/1, v/v/v), System E (ethyl acetate/methanol/water, 5/3/2, v/v/v). Compounds were detected by charring with 20% sulfuric acid in methanol. Optical rotations were recorded at 20 °C with a Perkin-Elmer 241 polarimeter. Column chromatography was performed on silica gel 60, 70-230 mesh (Merck). Gel filtration was performed on Sephadex LH-20 (Pharmacia). NMR spectra were recorded with a JEOL JNM-FX 200 (^{13}C, 50.1 MHz, internal standard chloroform or methanol [respectively 77 and 49 ppm relative to Me_4Si]) and a Bruker WM-300 spectrometer equipped with an Aspect-2000 computer (^1H, 300 MHz, internal standard Me_4Si).

Ethyl 6-*O*-*p*-Toluenesulfonyl-1-thio-α-D-mannopyranoside (6). Ethyl 1-thio-α-D-mannopyranoside **5** (29 g, 129.4 mmol) was dissolved in pyridine (300 mL) and a solution of *p*-toluenesulfonyl chloride (27.3 g, 143 mmol) in pyridine (200 mL) was added dropwise at 0 °C. The mixture was stirred for 3 h at 0 °C and 16 h at 20 °C, when TLC analysis (System A) revealed the reaction to be complete. Water (20 mL) was added and the mixture was concentrated. The residue was co-evaporated with toluene (3 x 100 mL) to give an oil which was purified by silica gel chromatography (eluent: dichloromethane/methanol, 9/1, v/v) giving compound **6** (42.4 g, 86%) as an oil; Rf 0.5 (System A).

Ethyl 2,3-*O*-Isopropylidene-6-*O*-*p*-toluenesulfonyl-1-thio-α-D-mannopyranoside (7). Compound **6** (42.4 g, 112.1 mmol) was dissolved in a mixture of 2,2-dimethoxypropane (85 mL), acetone (125 mL) and *p*-toluenesulfonic acid monohydrate (2.1 g, 11 mmol). After stirring for 2 h at room temperature, TLC analysis (System B) showed complete reaction. The mixture was neutralized with triethylamine (10 mL) and concentrated. The residue was dissolved in dichloromethane (400 mL) and the solution was washed with water (200 mL) and aq. $NaHCO_3$ (7.5 %, 150 mL). The organic layer was dried ($MgSO_4$) and concentrated to an oil, which was purified on silica gel (eluent: diethyl ether/hexane, 1/1 to 2/1, v/v) to give pure **7** (35 g, 75 %) as an oil, which solidified upon standing; mp 81 °C; Rf 0.52 (System B); $[\alpha]_D^{20}$ +87.1 (*c* 1, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 132.3, 144.4 (C-quat., *p*-tosyl), 127.4, 129.3 (C-arom.), 109.1 (C-quat., isopropylidene), 67.7-78.7 (C-1, C-2, C-3, C-4, C-5), 68.7 (C-6), 25.7, 27.5 (2 x CH_3, isopropylidene), 23.5 (CH_2, SEt), 21.1 (CH_3, *p*-tosyl), 13.8 (CH_3, SEt), ^1H NMR ($CDCl_3$) δ 7.7 (d, 2H, *p*-tosyl), 7.35 (d, 2H, *p*-tosyl), 5.5 (bs, 1H, H-1), 4.32 (dd, 1H, $J_{5,6}$ = 5.1 Hz, $J_{6,6'}$ = 11 Hz, H-6), 4.26 (dd, 1H, $J_{5,6'}$ = 2.3 Hz, $J_{6,6'}$ = 11 Hz, H-6'), 4.14 (dd, 1H, $J_{1,2}$ = 0.6 Hz, $J_{2,3}$ = 5.7 Hz, H-2), 4.03-4.12 (m, 1H, H-5), 4.07 (dd, 1H, $J_{3,4}$ = 7.6 Hz, H-3), 3.67 (dd, 1H, $J_{4,5}$ = 10.3 Hz, H-4), 2.9 (bs, 1H, OH), 2.4-2.6 (m, 2H, CH_2, SEt), 2.45 (s, 3H, CH_3, *p*-tosyl), 1.33, 1.51 (2 x s, 6H, 2 x CH_3, isopropylidene), 1.26 (t, 3H, CH_3, SEt).

Anal. Calcd for $C_{18}H_{26}O_7S_2$: C, 51.66, H, 6.26. Found: C, 51.33, H, 6.11%.

Ethyl 6-Deoxy-2,3-*O*-isopropylidene-1-thio-α-D-mannopyranoside (8). Compound **7** (27.7 g, 66.2 mmol) was co-evaporated with toluene (2 x 75 mL) and subsequently dissolved in dry diethyl ether (300 mL). At 0 °C, lithium aluminium hydride (3.8 g, 100 mmol) was added and the mixture was refluxed for 2 h, when TLC analysis (System B) indicated complete reaction. Excess $LiAlH_4$ was destroyed (at 0 °C, vigorous reaction) with aq. oxalic acid (1 M, 10 mL). After filtration over Celite, the organic layer was washed with water (2 x 200 mL), dried ($MgSO_4$) and concentrated. Purification on silica gel (eluent: diethyl ether/hexane, 2/1 to 3/1, v/v) gave compound **8** (10.2 g, 62 %) as an oil; Rf 0.6 (System B); $[\alpha]_D^{20}$ +168.0 (*c* 1, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 108.6 (C-quat., isopropylidene), 65.4-78.7 (C-1, C-2, C-3, C-4, C-5), 25.8, 27.5 (2 x CH_3, isopropylidene), 23.7 (CH_2, SEt), 16.7 (C-6), 14.1 (CH_3, SEt), ^1H NMR ($CDCl_3$) δ 5.52 (bs, 1H, H-1), 4.17 (dd, 1H, $J_{1,2}$ = 0.6 Hz, $J_{2,3}$ = 5.6 Hz, H-2), 4.05 (dd, 1H, $J_{3,4}$ = 7.6 Hz, H-3), 3.96 (ddd, 1H, H-5), 3.4-3.48 (ddd, 1H, $J_{3,4}$ = 7.6 Hz, $J_{4,OH}$ = 4 Hz, H-4), 2.88 (d, 1H, $J_{4,OH}$ = 4 Hz, OH), 2.4-2.6 (m, 2H, CH_2, SEt), 1.28-1.54 (m, 12H, 4 x CH_3: isopropylidene, CH_3-SEt, C-6).

Anal. Calcd for $C_{11}H_{20}O_4S$: C, 53.2, H, 8.12. Found: C, 53.48, H, 8.20%.

Ethyl 4,6-Dideoxy-4-hydroximino-2,3-*O*-isopropylidene-1-thio-α-D-*lyxo*-hexopyranoside (10). To a cooled (-70 °C) solution of oxalyl chloride (1.76 mL, 20 mmol) in dichloromethane (65 mL) was added methyl sulfoxide (1.92 M in dichloromethane, 20 mL) and the mixture was stirred for 5 min, when a solution of compound **8** (3.65 g, 14.7 mmol) in dichloromethane (20 mL) was added dropwise. After stirring for 30 min at -70 °C, triethylamine (11 mL, 79 mmol) was added and the solution was allowed to reach room temperature. The mixture was concentrated and co-evaporated with toluene (2 x 40 mL) to give crude **9** as an oil (Rf 0.9, System B). Compound **9** was dissolved in tetrahydrofuran (75 mL) and methanol (25 mL). To this mixture was added a solution of hydroxylamine hydrochloride (5.1 g, 73.4 mmol) in pyridine/water, 1/1, v/v (50 mL). After stirring for 1 h, TLC analysis (System B) showed that the reaction was complete. The mixture was concentrated, redissolved in dichloromethane (150 mL) and washed with water (2 x 100 mL). The organic layer was dried ($MgSO_4$) and concentrated to an oil, which was purified on silica gel (eluent: diethyl ether/hexane, 1/1 to 2/1, v/v) to give **10** (3.75 g, 97%) as a mixture of *cis-trans* isomers; Rf 0.75 (System B); ^{13}C NMR ($CDCl_3$) δ 153.4, 152.5 (C-4), 110.3, 110.2 (C-quat., isopropylidene), 81.1, 79.9 (C-1), 77.6, 75.6, 72.9, 66.7, 64.1, 63.7 (C-2, C-3, C-5).

Ethyl 4-(Benzyloxycarbonyl)amino-4,6-dideoxy-2,3-*O*-isopropylidene-1-thio-α-D-talopyranoside (11). Compound **10** (4.35 g, 16.6 mmol) was co-evaporated with toluene (2 x 50 mL) and redissolved in methanol (100 mL). To the mixture was added ammonium acetate (2.56 g, 33.2 mmol), sodium cyanoborohydride (10.43 g, 166 mmol) and a solution of titanium(III) chloride (15 wt. % solution in 20-30 wt. % solution hydrochloric acid, 4.7 mL). After 16 h and 24 h another portion of the $TiCl_3$ solution (4.7 mL) was added and stirring was continued for 16 h at 20 °C. The reaction mixture was neutralized with $NaHCO_3$(s) and concentrated. The residue was dissolved in dioxane/water, 1/1, v/v (60 mL). To this solution was added $NaHCO_3$(s) (2.8 g, 33.3 mmol) and benzyl chloroformate (Z-Cl, 3.1 mL, 21.7 mmol). After stirring for 1 h, the reaction mixture was concentrated and the residue was redissolved in dichloromethane (100 mL), washed with water (2 x 30 mL), dried ($MgSO_4$) and again concentrated. The remaining oil was purified on silica gel (eluent: diethyl ether/hexane, 1/1 to 2/1, v/v) to give unreacted **10** (0.4 g, 9 %) and **11** (4.7 g, 75 %); compound **11**: Rf 0.58 (System B); $[\alpha]_D^{20}$ + 74.6 (*c* 1.48, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 156.5 (C=O, Z), 136.2 (C-quat., Z), 126.4-128.2 (C-arom., Z), 108.9 (C-quat., isopropylidene), 79.4 (C-1), 73.2, 71.7 (C-2, C-3), 66.6 (CH_2, Z), 63.7 (C-5), 50.7 (C-4), 25.2, 25.4 (2 x CH_3, isopropylidene) 24.1 (CH_2, SEt), 16.7 (C-6), 14.3 (CH_3, SEt), ^1H NMR ($CDCl_3$) δ 7.1-7.25 (m, 5H, H-arom.), 5.47 (bs, 1H, H-1), 5.06-5.18 (AB, 2H, CH_2,

Z), 5.1 (d, 1H, $J_{4,NH}$ = 10.2 Hz, NH), 4.27-4.3 (t, 1H, $J_{2,3}$ = 6 Hz, $J_{3,4}$ = 6 Hz, H-3), 4.16-4.25 (dq, 1H, H-5), 4.0 (dd, 1H, $J_{1,2}$ = 1 Hz, $J_{2,3}$ = 6.0 Hz, H-2), 3.87-3.94 (ddd, 1H, $J_{4,NH}$ = 10.2 Hz, $J_{4,5}$ = 1.8 Hz, $J_{3,4}$ = 6 Hz, H-4), 2.5-2.7 (m, 2H, CH_2, SEt), 1.1-1.4 (m, 12H, 3 x H-6, 6H isopropylidene, CH_3, SEt).

Anal. Calcd for $C_{19}H_{27}O_5NS$: C, 59.82, H, 7.13, N, 3.67. Found: C, 60.22, H, 7.26, N, 3.44%.

Ethyl 4-(Benzyloxycarbonyl)amino-4,6-dideoxy-1-thio-α-D-talopyranoside (13). Compound **11** (5.0 g, 13.1 mmol) was dissolved in a mixture of trifluoroacetic acid/water, 9/1, v/v (35 mL) and the mixture was stirred for 5 min at room temperature, when TLC analysis (System B) revealed complete conversion of **11** to one product. The solution was diluted with toluene (50 mL) and concentrated. The residue was co-evaporated with toluene (2 x 50 mL) and ethanol (2 x 50 mL) to give crude **13**, which was used in the next step without further purification; ^{13}C NMR ($CDCl_3$) δ 157.6 (C=O, Z), 136.1 (C-quat., Z), 127.5-128.1 (C-arom., Z), 84.5 (C-1), 70.8, 66.2, 65.8 (C-2, C-3, C-5), 66.7 (CH_2, Z), 54.7 (C-4), 24.7 (CH_2, SEt), 16.4 (C-6), 14.6 (CH_3, SEt).

Ethyl 2,3-Di-*O*-acetyl-4-(benzyloxycarbonyl)amino-4,6-dideoxy-1-thio-α-D-talopyranoside (14). Crude **13** was dissolved in a mixture of pyridine/acetic anhydride, 2/1, v/v (45 mL) and the mixture was stirred overnight at 20 °C, when TLC analysis (System C) showed complete reaction. The mixture was concentrated and the residue was co-evaporated with toluene (3 x 50 mL). The residue was purified on silica gel (eluent: diethyl ether/hexane, 1/1 to 2/1, v/v), to give homogeneous **14** (4.25 g, 76% based on **11**), compound **14**: Rf 0.75 (System C); mp 66.5-67.5 °C; $[\alpha]_D^{20}$ + 128.9 (*c* 1, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 168.5, 168.8 (C-quat., acetyl), 156.2 (C=O, Z), 136.5 (C-quat., Z), 127.1-127.9 (C-arom., Z), 82.1 (C-1), 69.7, 66.3, 65.5 (C-2, C-3, C-5), 65.8 (CH_2, Z), 51.4 (C-4), 24.7 (CH_2, SEt), 19.9, 20.2 (2 x CH_3, acetyl), 16.1 (C-6), 14.3 (CH_3, SEt); ^1H NMR ($CDCl_3$) δ 7.3-7.4 (m, 5H, H-arom.), 5.44 (d, 1H, $J_{NH,H-4}$ = 10.6 Hz, NH), 5.05-5.25 (m, 5H, CH_2-Z, H-1, H-2, H-3), 4.46-4.53 (dq, 1H, $J_{4,5}$ = 2.0 Hz, $J_{5,6}$ = 6.4 Hz, H-5), 4.05-4.11 (ddd, 1H, $J_{3,4}$ = 4.2 Hz, $J_{4,5}$ = 2 Hz, $J_{NH,H-4}$ = 10.6 Hz, H-4), 2.54-2.69 (m, 2H, CH_2, SEt), 2.09, 1.9 (2 x s, 6H, CH_3, acetyl), 1.26-1.31 (t, 3H, CH_3, SEt), 1.22 (d, 3H, $J_{5,6}$ = 6.4 Hz, H-6).

Anal. Calcd for $C_{20}H_{27}O_7NS$: C, 56.46, H, 6.40, N, 3.29. Found: C, 56.51, H, 6.17, N, 3.31%.

3-*O*-Acetyl-4-(benzyloxycarbonyl)amino-4,6-dideoxy-D-galactal (16). To a solution of compound **14** (4.25 g, 10 mmol) in diethyl ether (100 mL) was added bromine (0.8 mL, 15.5 mmol) and the mixture was stirred for 30 min under a blanket of nitrogen at

room temperature, when TLC analysis (Rf 0.7, System C) showed the reaction to be complete. The solution was concentrated and the residue was co-evaporated with toluene (2 x 40 mL) to give crude **15** as an oil. Compound **15** was dissolved at 0 °C in a mixture of acetic acid (20 mL) and acetic anhydride (3 mL). To this solution was added sodium iodide (3.4 g, 22.7 mmol) and activated zinc dust (6.5 g, 100 mmol). The reaction mixture was stirred for 1 h at 0 °C, when TLC analysis (System D) revealed the formation of one product. The solution was diluted with diethyl ether (100 mL), filtered over Celite, washed with water (3 x 50 mL), dried ($MgSO_4$) and concentrated. The residue was purified by silica gel chromatography (eluent: dichloromethane/acetone/triethylamine, 97/2/1, v/v/v) to give pure **16** (2.85 g, 93 %) as an oil; Rf 0.7 (System D); $[\alpha]_D^{20}$ + 12.9 (*c* 1, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 170.0 (C-quat., acetyl), 156.8 (C-quat., Z), 146.1 (C-1), 136.8 (C-quat., arom), 127.9-128.3 (C-arom.), 99.4 (C-2), 72.6, 66.4, 66.1 (C-3, C-5), 66.4 (CH_2, Z), 48.2 (C-4), 20.5 (CH_3, acetyl), 16.5 (C-6), ^1H NMR ($CDCl_3$) δ 7.3-7.4 (m, 5H, H-arom.), 6.41 (dd, 1H, $J_{1,2}$ = 6.4 Hz, $J_{1,3}$ = 1.9 Hz, H-1), 5.5 (ddd, 1H, H-3), 5.05-5.2 (AB, 2H, CH_2, Z), 4.96 (bd, 1H, $J_{NH,H-4}$ = 10.2 Hz, NH), 4.6-4.7 (dt, 1H, $J_{1,2}$ = 6.4 Hz, $J_{2,3}$ = 3.7 Hz, $J_{2,4}$ = 1.8 Hz, H-2), 4.18-4.26 (m, 2H, H-4, H-5), 1.93 (s, 3H, CH_3, acetyl), 1.29 (d, 3H, $J_{5,6}$.5 Hz, H-6).

3-*O*-Acetyl-2-azido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-D-galactopyranosyl nitrate (17). Compound **16** (2.85 g, 9.34 mmol) was co-evaporated with toluene (2 x 30 mL) and redissolved in acetonitrile (30 mL). To the cooled (-25 °C) solution was added sodium azide (1.25 g, 19.2 mmol) and ammonium cerium(IV) nitrate (20.5 g, 37.4 mmol). After stirring for 2 h at -15 °C under a blanket of nitrogen, the mixture was diluted with diethyl ether (75 ml), filtered over Celite, washed with ice water (30 mL), dried ($MgSO_4$) and concentrated. The residue was purified on silica gel (eluent: diethyl ether/hexane, 1/1 to 2/1, v/v) to give **17** and **18** (2.7 g, 71 %), a mixture which could not be separated on silica gel or *via* crystallization procedures; Rf 0.6 (System B); IR film ν_{max}: 2100 cm^{-1} (N_3), 1600 cm^{-1} (ONO_2); ^{13}C NMR ($CDCl_3$) δ 98.1, 97.0 (C-1), 57.0, 56.6, 55.7 (C-2), 51.9, 51.4, 50.6 (C-4).

***O*-Ethyl *S*-(3-*O*-Acetyl-2-azido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-ß-D-galactopyranosyl) dithiocarbonate (3).** A mixture of **17** and **18** (170 mg, 0.42 mmol) was dissolved in acetonitrile (5 mL) and potassium ethyl dithiocarbonate (142 mg, 0.88 mmol) was added. After the reaction mixture was stirred for 16 h, the solution was diluted with dichloromethane (30 mL), washed with water (2 x 25 mL), dried ($MgSO_4$), filtered and concentrated. The residue was eluted from a column of silica gel (eluent: dichloromethane/acetone/triethylamine, 96/3/1, v/v/v) to give **3** (115 mg, 58%) as an oil and a

mixture of more polar components, which could not be identified by NMR spectroscopy; Compound **3**: Rf 0.65 (System D); $[\alpha]_D^{20}$ +35.7 (*c* 0.4, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 209.0 (C=S), 169.8 (C-quat., acetyl), 156.4 (C-quat., Z), 136.0 (C-quat., arom.), 127.7-128.2 (C-arom., Z), 86.3 (C-1, $J_{C,H}$ = 155 Hz), 74.8, 74.3 (C-3, C-5), 70.4 (CH_2, OEt), 66.7 (CH_2, Z), 58.1 (C-2), 51.8 (C-4), 20.4 (CH_3, acetyl), 16.4 (C-6), 13.4 (CH_3, OEt).

3-*O*-Acetyl-2-azido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-D-galactopyranose (20). To a solution of **17** and **18** (1.09 g, 2.67 mmol) in thiophenol (7 mL) was added *N,N*-diisopropylethylamine (0.47 mL, 2.7 mmol). After stirring for 30 min at room temperature, the solution was co-evaporated with toluene (2 x 25 ml) and the residue was chromatographed on silica gel (eluent: dichloromethane/acetone, 99/1 to 97/3, v/v) resulting in the isolation of pure **2** (275 mg, 22.5%) and a mixture of galactopyranose **20** and talopyranose **21** (635 mg, 65%); compound **2**: Rf 0.7 (System C); $[\alpha]_D^{20}$ -8.4 (*c* 1, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 169.9 (C-quat., acetyl), 156.4 (C-quat., Z), 136.0 (C-quat., arom.), 132.9 (C-arom., SPh), 131.5 (C-quat., SPh), 127.6-129 (C-arom., Z, SPh), 86.4 (C-1, $J_{C,H}$ = 156.2 Hz), 74.4, 73.4 (C-3, C-5), 66.7 (CH_2, Z), 59.5 (C-2), 51.8 (C-4), 20.5 (CH_3, acetyl), 16.7 (C-6), ^1H NMR ($CDCl_3$) δ 7.25-7.65 (m, 10H, H-arom.), 5.02-5.15 (AB, 2H, CH_2, Z), 4.83 (bd, 1H, $J_{NH,H-4}$ = 9.7 Hz, NH), 4.78 (dd, 1H, $J_{2,3}$ = 10.2 Hz, $J_{3,4}$ = 3.8 Hz, H-3), 4.45 (d, 1H, $J_{1,2}$ = 10.3 Hz, H-1), 4.11-4.16 (ddd, 1H, $J_{4,5}$ = 1.5 Hz, $J_{3,4}$ = 3.8 Hz, $J_{NH,H-4}$ = 10 Hz, H-4), 3.72-3.78 (dq, 1H, $J_{4,5}$ = 1.5 Hz, $J_{5,6}$ = 6.4 Hz, H-5), 3.36 (t, 1H, $J_{1,2}$ = 10.3 Hz, $J_{2,3}$ = 10.2 Hz, H-2), 1.97 (s, 3H, CH_3 acetyl), 1.24 (d, 3H, $J_{5,6}$ = 6.4 Hz, CH_3); compounds **21** and **22**: Rf 0.1 (System C), ^{13}C NMR ($CDCl_3$) δ 96.0, 93.2, 92.7, 91.7 (α,ß-mixture of **21** and **22**).

3-*O*-Acetyl-2-azido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-ß-D-galactopyranosyl trichloroacetimidate (1). To a solution of **20** and **21** (630 mg, 1.73 mmol) in dichloromethane (10 mL) and trichloroacetonitrile (0.88 mL, 8.77 mmol) was added thoroughly dried potassium carbonate (890 mg, 6.4 mmol). The mixture was stirred for 4 h at 20 °C, when the solution was diluted with dichloromethane (40 mL) and the dichloromethane solution was washed with water (3 x 30 mL), dried ($MgSO_4$) and concentrated. The residue was chromatographed on silica gel (eluent: diethyl ether/hexane, 1/1 to 2/1, v/v) resulting in the isolation of three products. The first product collected was talopyranoside **22** ß (60 mg, 7 %, Rf 0.75, System B), followed by Sug(*p*) derivative **1** (α/ß, 1/9, 528 mg, 60 %, Rf 0.5, System B). The third fraction was identified as the α-isomer of **22** (75 mg, 8 %, Rf 0.2, System B). Finally, unreacted **20** and **21** were recovered (100 mg, 15.9 %); Compound **22ß**: ^{13}C NMR ($CDCl_3$) δ 96.2 (C-1, $J_{C,H}$ = 156.7 Hz), 58.0 (C-2), 51.2 (C-4); ^1H NMR ($CDCl_3$) δ 8.7 (s, 1H, C=NH), 6.2 (d, 1H, $J_{1,2}$ = 1 Hz, H-1), 5.32 (t, 1H,

$J_{2,3}$ = $J_{3,4}$ = 4 Hz, H-3), 4.2 (ddd, 1H, $J_{3,4}$ = 4 Hz, $J_{4,NH}$ = 10 Hz, $J_{4,5}$ = 2 Hz, H-4); compound **22α**: ^{13}C NMR ($CDCl_3$) δ 95.6 (C-1, $J_{C,H}$ = 168.7 Hz), 59.8 (C-2), 50.7 (C-4); ^1H NMR ($CDCl_3$) δ 8.7 (s, 1H, C=NH), 5.87 (d, 1H, $J_{1,2}$ = 1,5 Hz, H-1), 5.02 (dd, 1H, $J_{2,3}$ = 3.8 Hz, $J_{3,4}$ = 4.4 Hz, H-3), 4.11 (ddd, 1H, $J_{4,5}$ = 2 Hz, $J_{3,4}$ = 3.9 Hz, $J_{4,NH}$ = 10.5 Hz, H-4); compound **1ß**: $[\alpha]_D^{20}$ +5.5 (*c* 1, $CHCl_3$); ^{13}C NMR ($CDCl_3$) δ 169.8 (C-quat., acetyl), 160.3 (C=NH, imidate), 156.3 (C-quat., Z), 136.0 (C-quat., arom.), 127.7-128.3 (C-arom.), 96.7 (C-1, $J_{C,H}$ = 155.1 Hz), 72.6, 70.4 (C-3, C-5), 66.8 (CH_2, Z), 60.2 (C-2), 51.6 (C-4), 20.4 (CH_3, acetyl), 16.2 (C-6); ^1H NMR ($CDCl_3$) δ 8.76 (s, 1H, C=NH), 7.26-7.39 (m, 5H, H-arom.), 5.6 (d, 1H, $J_{1,2}$ = 8.5 Hz, H-1), 5.12 (d, 1H, $J_{4,NH}$ = 9.7 Hz, NH), 5.05-5.20 (AB, 2H, CH_2, Z), 4.8 (dd, 1H, $J_{2,3}$ = 10.7 Hz, $J_{3,4}$ = 3.9 Hz, H-3), 4.18-4.23 (ddd, $J_{4,NH}$ = 9.7 Hz, $J_{3,4}$ = 3.9 Hz, $J_{4,5}$ = 1.5 Hz, H-4), 3.88-3.95 (dq, 1H, $J_{5,6}$ = 6.4 Hz, $J_{4,5}$ = 1.5 Hz, H-5), 3.75 (dd, 1H, $J_{1,2}$ = 8.5 Hz, $J_{2,3}$ = 10.8 Hz, H-2), 2.0 (s, 3H, CH_3-acetyl), 1.27 (d, 3H, $J_{5,6}$ = 6.4 Hz, 3 x H-6).

Anal. Calcd for $C_{18}H_{20}O_6N_5Cl_3$ **1**: C, 42.5, H, 3.96, N, 13.77. Found: C, 41.74, H, 3.96, N, 13.15%.

1,6-Anhydro-2-azido-3-*O*-benzyl-2-deoxy-4-*O*-(3-*O*-acetyl-2-azido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-α-D-galactopyranosyl)-ß-D-galactopyranose (24).

Method A. To a thoroughly dried mixture of **1** (125 mg, 0.25 mmol) and **23** (75 mg, 0.27 mmol) in dichloromethane (4 mL) were added molecular sieves 4 Å (0.5 g). After stirring for 1 h under a blanket of nitrogen, the mixture was cooled to -30 °C. To the cooled solution was added a catalytic amount of trimethylsilyl triflate (0.1 M in CH_2Cl_2, 0.09 mL). After stirring for 3 h at -30 °C, TLC analysis (System C) indicated the reaction to be complete. The solution was diluted with dichloromethane (50 mL) and filtered. The dichloromethane solution was washed with 10% aq. $NaHCO_3$ (25 mL) and water (2 x 50 mL). The organic layer was dried ($MgSO_4$), concentrated and the residue was purified by LH-20 chromatography to yield pure **24** (116 mg, 75%);

Method B. To a solution of compound **2** (155 mg, 0.34 mmol) and **23** (118 mg, 0.43 mmol) in diethyl ether (3 mL) and 1,2-dichloroethane (3 mL) were added molecular sieves 4 Å (0.5 g). After the mixture was stirred for 1 h, *N*-iodosuccinimide (96 mg, 0.43 mmol) and trifluoromethanesulfonic acid (3 µL, 0.034 mmol) were added. The mixture was stirred for 16 h at room temperature, when the solution was diluted with diethyl ether (25 mL) and filtered, washed with 10% aq. $Na_2S_2O_3$ (2 x 15 mL), 10% aq. $NaHCO_3$ (15 mL) and water (2 x 15 mL). The organic layer was dried ($MgSO_4$), concentrated and the residue was purified by LH-20 chromatography (eluent: dichloromethane/methanol, 1/1, v/v) to give homogeneous **24** (136 mg, 64 %);

Method C. To a solution of compound **3** (138 mg, 0.29 mmol) and **23** (97 mg, 0.35 mmol) in diethyl ether (3 mL) and 1,2-dichloroethane (3 mL) were added molecular sieves 4 Å (0.5 g). After the mixture was stirred for 1 h, *N*-iodosuccinimide (90 mg, 0.4 mmol) and trifluoromethanesulfonic acid (2.5 μL, 0.028 mmol) were added. The mixture was stirred for 16 h at 20 °C, when a second portion of trifluoromethanesulfonic acid (2.5 μL) was added and stirring was continued for 8 h. The solution was diluted with diethyl ether (25 mL) and filtered, washed with 10% aq. $Na_2S_2O_3$ (2 x 15 mL), 10% aq. $NaHCO_3$ (15 mL) and water (2 x 15 mL). The organic layer was dried ($MgSO_4$), concentrated and the residue was purified by LH-20 chromatography (eluent: dichloromethane/methanol, 1/1, v/v) to yield pure **24** (29 mg, 16 %);

Method D. To a solution of compound **3** (118 mg, 0.25 mmol) and **23** (83.8 mg, 0.3 mmol) in dichloromethane (3 mL) were added molecular sieves 4 Å (0.4 g). After the mixture was stirred for 1 h, copper(II) triflate (361.7 mg, 1 mmol) was added. The mixture was stirred for 3 days at 20 °C under a blanket of nitrogen. The solution was diluted with diethyl ether/diisopropylamine, 9/1, v/v (10 mL), filtered and concentrated. The residue was purified by LH-20 chromatography to yield pure **24** (35 mg, 22%); compound **24**: Rf 0.35 (System C); $[\alpha]_D^{20}$ +132.3 (*c* 1, $CHCl_3$); mp 108 °C; ^{13}C NMR ($CDCl_3$) δ 170.1 (C-quat., acetyl), 156.6 (C-quat., Z), 136.8, 136.7 (C-quat., arom.), 127.8-128.6 (C-arom.), 99.9 (C-1), 97.6 (C'-1), 75.5 (C-3), 72.3 (CH_2, benzyl), 72.2, 71.2 (C-4, C-5), 69.1 (C'-3), 66.9 (CH_2, Z), 65.1 (C'-5), 64.7 (C-6), 60.2 (C-2), 57.2 (C'-2), 52.5 (C'-4), 20.5 (CH_3, acetyl), 16.2 (C'-6), ^1H NMR ($CDCl_3$) δ 7.2-7.5 (m, 10H, H-arom.), 5.46 (t, 1H, $J_{1,2}$ = 3.2 Hz, H-1), 5.2 (dd, 1H, $J_{2,3}$ = 11.2 Hz, $J_{3,4}$ = 3.9 Hz, H'-3), 5.02-5.17 (AB, 2H, CH_2, Z), 5.05 (bd, 1H, $J_{NH,H'-4}$ = 9.6 Hz, NH), 4.94 (d, 1H, $J_{1,2}$ = 3.9 Hz, H'-1), 4.73-4.78, 4.40-4.44 (AB, 2H, CH_2, benzyl), 4.6 (d, 1H, $J_{6,6\#}$ = 7.3 Hz, H-6#), 4.48 (t, 1H, H-4), 3.98-4.04 (ddd, 1H, $J_{4,5}$ = 1.8 Hz, $J_{3,4}$ = 3.8 Hz, $J_{NH,H-4}$ = 9.8 Hz, H'-4), 3.96 (t, 1H, H-5), 3.6-3.8 (m, 4H, H-6, H-2, H-3, H'-5), 3.35 (dd, 1H, $J_{1,2}$ = 3.9 Hz, $J_{2,3}$ = 11.2 Hz, H'-2), 2.0 (s, 3H, CH_3, acetyl), 0.93 (d, 1H, $J_{5,6}$ = 6.5 Hz, CH_3).

Anal. Calcd for $C_{29}H_{33}O_9N_7$: C, 55.85, H, 5.33, N, 15.72. Found: C, 55.05, H, 5.37, N, 15.30%.

1,6-Anhydro-2-acetamido-3-*O*-benzyl-2-deoxy-4-*O*-(3-*O*-acetyl-2-acetamido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-α-D-galactopyranosyl)-ß-D-galactopyranose (25). Compound **24** (300 mg, 0.48 mmol) was dissolved in thioacetic acid (1 mL) and the solution was stirred for 3 days at 20 °C, when TLC analysis (System A) showed the formation of one major product, which could be isolated from some faster running side products by chromatographing the mixture on a column of silica gel (eluent: dichloro-

methane/methanol, 97/3 to 9/1, v/v). Compound **25** (267 mg, 84%) was isolated as an oil, which solidified upon standing; Rf 0.64 (System A); mp 199.5-200.5 °C; ^{13}C NMR ($CD_3OD/CDCl_3$) δ 173.8 (2 x C-quat., NHAc), 170.1 (C-quat., acetyl), 156.4 (C-quat., Z), 136.7 (C-quat., arom.), 127.4-128.6 (C-arom.), 100.2 (C-1), 95.6 (C'-1), 75.2, 71.2, 69.3, 68.6, 64.4 (C-3, C'-3, C-4, C-5, C'-5), 70.7 (CH_2, benzyl), 66.3 (CH_2, Z), 63.8 (C-6), 51.9, 50.1, 47.3 (C-2, C'-2, C'-4), 21.9 (2 x CH_3, NH-acetyl), 20.1 (CH_3, acetyl), 15.9 (C'-6).

1,6-Anhydro-2-acetamido-3-*O*-benzyl-2-deoxy-4-*O*-(2-acetamido-4-(benzyloxycarbonyl)amino-2,4,6-trideoxy-α-D-galactopyranosyl)-ß-D-galactopyranose (26). To a solution of compound **25** (322 mg, 0.49 mmol) in methanol (5 mL) was added sodium methoxide (5 mg) and the mixture was stirred for 30 min at 20 °C, when TLC analysis (System A) revealed the reaction to be complete. The solution was neutralized with Dowex 50W (H^+ form), filtered, concentrated and co-evaporated with toluene (2 x 20 mL). The residue was purified on silica gel (eluent: dichloromethane/methanol, 95/5 to 9/1, v/v) to give pure **26** (249 mg, 83%) as a white solid; Rf 0.54 (System A); mp 123-124 °C; $[\alpha]_D^{20}$ +8.6 (*c* 1, $CHCl_3$); ^{13}C NMR (CD_3OD) δ 172.7, 171.8 (2 x C-quat., NHAc), 158.9 (C-quat., Z), 138.1, 137.1 (2 x C-quat., arom.), 128.2-129.0 (C-arom.), 101.0 (C-1), 96.9 (C'-1), 76.8, 72.4, 70.7, 67.2, 66.1 (C-3, C'-3, C-4, C-5, C'-5), 71.8 (CH_2, benzyl), 67.3 (CH_2, Z), 64.8 (C-6), 56.0, 51.3, 51.1 (C-2, C'-2, C'-4), 22.6 (CH_3, acetyl), 16.8 (C'-6); ^{1}H NMR (CD_3OD) δ 7.2-7.5 (m, 10H, H-arom.), 6.1 (2 x d, 2H, C-2-NH), 5.7 (bd, 1H, $J_{4,NH}$ = 9.5 Hz, C-4-NH), 5.35 (s, 1H, H-1), 5.05 (d, 1H, $J_{1,2}$ = 3.4 Hz, H'-1), 4.35 (m, 1H, H-4), 4.0 (ddd, 1H, $J_{1,2}$ = 3.4 Hz, $J_{2,3}$ = 10.8 Hz, $J_{2,NH}$ = 7.5 Hz, H'-2), 2.0, 1.9 (2 x s, 6H, 2 x CH_3, acetyl), 0.9 (d, 3 H, $J_{5,6}$ = 6.4 Hz, CH_3).

1,6-Anhydro-2-acetamido-2-deoxy-4-*O*-(2-acetamido-4-amino-2,4,6-trideoxy-α-D-galactopyranosyl)-ß-D-galactopyranose (4). To a degassed solution of compound **26** (150 mg, 0.24 mmol) in *tert*-butyl alcohol/acetic acid/water, 4/1/1, v/v/v (6 mL) was added palladium on charcoal (150 mg) and the mixture was stirred under a gentle stream of hydrogen. TLC analysis (System E), after 4 h at 40 °C, revealed the complete conversion of **26** to one product. The reaction mixture was degassed, filtered and co-evaporated with toluene (3 x 20 mL). The residue was purified on a Sephadex LH-20 column (eluent: methanol/water, 1/1, v/v) to give compound **4** (75 mg, 79%) as a very hygroscopic solid; Rf 0.25 (System E); $[\alpha]_D^{20}$ +68.0 (*c* 0.15, CH_3OH); ^{13}C NMR (D_2O/CD_3OD) δ 174.7, 173.8 (C-quat., NHAc), 101.1 (C-1), 97.0 (C'-1), 72.5 (C-4), 70.6, 70.5 (C-3, C-5), 68.5 (C'-3), 67.9 (C'-5), 65.2 (C-6), 56.4 (C-2), 55.2 (C'-4), 51.6 (C'-2), 22.8, 22.6 (CH_3, NHAc), 16.9 (C'-6), ^{1}H NMR (D_2O) δ 5.35 (s, 1H, H-1), 5.1 (d, 1H, $J_{1,2}$ = 3.4 Hz, H'-1), 4.56

(t, 1H, $J_{5,6\#}$ = 4.35 Hz, $J_{4,5}$ = 4.35, H-5), 4.45 (d, 1H, $J_{6,6\#}$ = 7.3 Hz, H-6), 4.23 (dt, 1H, $J_{5,6}$ = 6.4 Hz, $J_{4,5}$ = 1.5 Hz, H'-5), 3.9-4.1 (m, 6H, H-2, H'-2, H-3, H'-3, H-4), 3.67 (t, 1H, H-6#), 3.35 (dd, 1H, H'-4), 2.0 (s, 3H, CH_3, acetyl), 0.93 (d, 3H, $J_{5,6}$ = 6.5 Hz, CH_3).

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