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Note

A concise synthesis of 4-nitrophenyl 2-azido-2-deoxy- and 2-acetamido-2-deoxy-D-mannopyranosides

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Abstract—4-Nitrophenyl 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-α- and β-D-mannopyranosides were prepared from methyl 4,6-*O*-benzylidene-α-D-glucopyranoside and 1,3,4,6-tetra-*O*-acetyl-α-D-glucopyranose, respectively. Chemoselective reduction of both azides with hydrogen sulfide readily afforded 4-nitrophenyl 2-acetamido-4,6-di-*O*-acetyl-2-deoxy-α-D- and -β-D-mannopyranosides in higher yields than reduction with triphenylphosphine or a polymer-supported triarylphosphine. Subsequent de-*O*-acetylation yielded 4-nitrophenyl 2-acetamido-2-deoxy-α-D-mannopyranoside and 4-nitrophenyl 2-acetamido-2-deoxy-β-D-mannopyranoside in 20% and 44% overall yields, respectively.

Keywords: 2-Azido-2-deoxymannoside; 2-Acetamido-2-deoxymannopyranoside; 4-Nitrophenyl glycoside; Migration of acetyl group

2-Acetamido-2-deoxy-D-mannopyranose (ManNAc) unis are integral parts of a number of bacterial polysaccharides and lipopolysaccharides.[1–4] Recently, ManNAc was identified as a strong ligand[5] for the natural killer cell activating protein NKR-P1 and it is, inter alia, an intermediate in the biosynthesis of *N*-acetyl D-neuraminic acid.[6] The ManNAc repeating unit has been identified in bacterial polysaccharides[7] and oligosaccharides containing ManNAc were found to possess immunostimulation activity.[8] Moreover, mannose-binding lectin, a pattern recognition molecule of the innate immune system, was proved to interact with a range of sugars including ManNAc.[9] The stereoselective introduction of the ManNAc moiety into an oligosaccharide chain still represents a crucial step in the preparation of potential carbohydrate-based therapeutics.[10] Generally, a variety of 4-nitrophenyl D-hexopyranosides has been exploited as efficient chromogenic glycosyl donors for chemoenzymic synthesis of oligosaccharides. In contrast, both 4-nitrophenyl 2-acetamido-2-deoxy-α-mannopyranoside (**1**) and 4-nitrophenyl 2-acetamido-2-deoxy-β-D-mannopyranoside (**2**) have not yet been utilized as enzyme substrates although their syntheses were already described. Glycoside **1** was prepared in 2% yield from 2-acetamido-2-deoxy-D-glucose 30 years ago.[11] A synthesis of **2** from 4-nitrophenyl β-D-glucopyranoside via 4-nitrophenyl 3-*O*-benzoyl-4,6-benzylidene-β-D-glucopyranoside[12] was published only in 2003.[13] Nevertheless, the laborious pathway with 10 steps prevents a gram scale application.

We now wish to report our synthetic strategy in this area that follows the idea of respective 2-azido-2-deoxy precursors.[14] This permits us to start from D-glucose taking advantage of S_N2 inversion of the configuration at the C-2 atom.

Initially, we attempted to synthesize 4-nitrophenyl 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-α-D-mannopyranoside (**3**) from 1,3,4,6-tetra-*O*-acetyl-α-D-glucopyranose (**4**) that is readily available by a one-pot reaction starting from D-glucose.[15] Tetra-*O*-acetate **4** was isolated by a simple crystallization in 25% yield and it was coupled with trifluoromethanesulfonic anhydride to give 1,3,4,6-tetra-*O*-acetyl-2-*O*-trifluoromethanesulfonyl-α-D-glucopyranose (**5**) in 66% yield. Compound **5** was then subjected to the attack of sodium azide[16] but all attempts to prepare 1,3,4,6-tetra-*O*-acetyl-2-azido-2-deoxy-α-D-mannopyranose (**6**) in a yield higher than 10% failed

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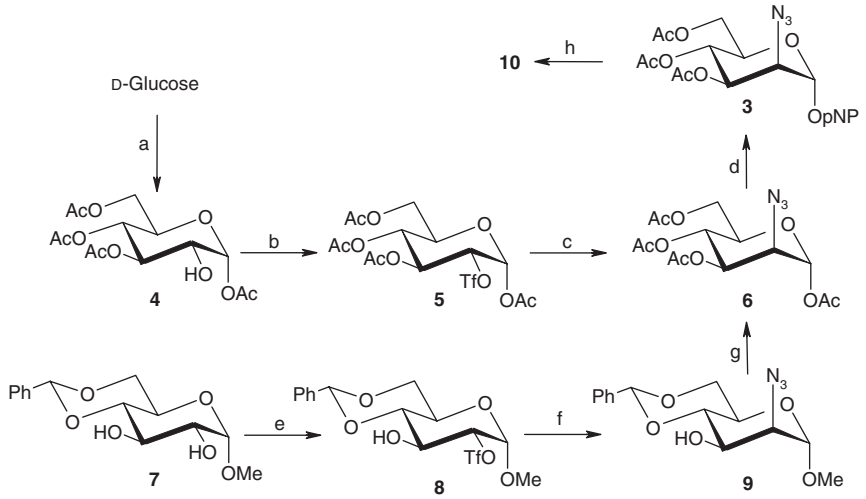
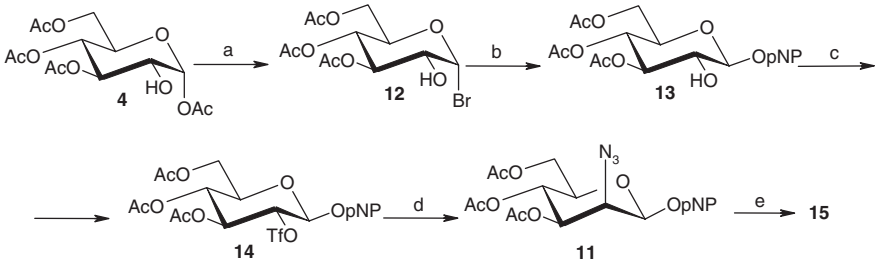
(Scheme 1).[16] In subsequent approach (Scheme 1), treatment of commercially available methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (**7**) with trifluoromethanesulfonic anhydride gave methyl 4,6-*O*-benzylidene-2-*O*-trifluoromethanesulfonyl-α-D-glucopyranoside (**8**).[17] In our hands, the reported yield[17] of selective monotriflation was not reproducible. Under optimized conditions, we were able to obtain 2-*O*-triflate **8** in the yield of 50% only if trifluoromethanesulfonic anhydride diluted with dichloromethane was slowly added to a solution of **7** at 3 °C. In addition to **8**, resulting mixture contained small amount of methyl 4,6-*O*-benzylidene-2,3-di-*O*-trifluoromethanesulfonyl-α-D-glucopyranoside whereas about 35% of the starting glucoside **7** was recovered. In contrast to the paper,[18] azidation of **8** was accelerated by heating and methyl 2-azido-4,6-*O*-benzylidene-2-deoxy-α-D-mannopyranoside (**9**) was prepared in 95% yield within 4.5 h at 70 °C instead of 3 d at room temperature. Acetolysis of **9** gave tetra-*O*-acetate **6** in 75% yield and, finally, stereoselective glycosylation was performed directly without any activation step by melting of tetra-*O*-acetate **6** with 4-nitrophenol in the presence of anhydrous zinc chloride.[19] α-Mannopyranoside **3** was the only product formed (70% yield) thus giving the overall yield of 25% from **7**. Zemplén deacetylation of **3** afforded 4-nitrophenyl 2-azido-2-deoxy-α-D-mannopyranoside (**10**).

For the synthesis of the target 4-nitrophenyl 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-β-D-mannopyranoside (**11**) (Scheme 2), 1,3,4,6-tetra-*O*-acetyl-α-D-glucopyranose (**4**) was converted into 3,4,6-tri-*O*-acetyl-α-D-glucopyranosyl bromide (**12**) according to the procedure described for 3,4,6-tri-*O*-acetyl-α-D-galactopyranosyl bromide.[20] Pure bromide **12** was obtained in 65% yield after purification by flash chromatography on silica gel and characterized by ^{1}H NMR spectral data, which were in accord with those published.[21] The relative instability of **12** necessitated immediate reaction of the crude **12** with 4-nitrophenol in the presence of potassium carbonate.[20] These conditions stereoselectively afforded 4-nitrophenyl 3,4,6-tri-*O*-acetyl-β-D-glucopyranoside (**13**) in 78% overall yield after column chromatography. This procedure was less time-consuming than that described[22] for 3,4,6-tri-*O*-acetyl-α-D-glucopyranosyl chloride and sodium 4-nitrophenoxide apart from a slightly higher yield of **13**. Then, the activation of the 2-OH group in glucoside **13** was carried out by esterification



Scheme 1. Reagents and conditions: (a) (1) Ac_2O, $HClO_4$, rt, 1 h, (2) PBr_3, H_2O, rt, 1.5 h, (3) NaOAc, rt, 2 h 25%; (b) Tf_2O, py, CH_2Cl_2, 3 °C, then rt, 1.5 h, 66%; (c) NaN_3, DMF, 60 °C, 5 h, 10%; (d) *p*-NPOH, $ZnCl_2$, 120 °C, reduced pressure, 25 min, 70%; (e) Tf_2O, py, CH_2Cl_2, 3 °C, 1.5 h, 50%; (f) NaN_3, DMF, 70 °C, 4.5 h, 95%; (g) 3% H_2SO_4 in Ac_2O, rt, 35 min, 75%; (h) MeONa, MeOH, rt, 20 min, 94%.



Scheme 2. Reagents and conditions: (a) HBr, CH_2Cl_2, 3 °C, 3 h; (b) *p*-NPOH, K_2CO_3, acetone, rt, 16 h, 78% from **4**; (c) Tf_2O, py, CH_2Cl_2, 3 °C, then rt, 1.5 h, 84%; (d) NaN_3, DMF, rt, 18 h, 84%; (e) MeONa, MeOH, rt, 20 min, 96%.

with trifluoromethanesulfonic anhydride in a dichloromethane-pyridine mixture.[23] Pure 4-nitrophenyl 3,4,6-tri-*O*-acetyl-2-*O*-trifluoromethanesulfonyl-β-D-glucopyranoside (**14**) was isolated in 84% yield after column chromatography. The use of a crude glucoside **14** in the subsequent nucleophilic displacement with sodium azide afforded 4-nitrophenyl 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-β-D-mannopyranoside (**11**) in 84% yield ($[\alpha]_D^{20}$ −117.6 (*c* 0.9, $CHCl_3$); IR: 2116 (N_3)). Zemplén deacetylation of **11** lead to 4-nitrophenyl 2-azido-2-deoxy-β-D-mannopyranoside (**15**, mp 116–118 °C ($CHCl_3$–MeOH); $[\alpha]_D^{20}$ −1.7 (*c* 1.0, EtOH); IR: 2119 (N_3)). ^1H and ^{13}C NMR data for **15** (CD_3OD) and **11** were in agreement with those published.[13]

For the chemoselective reduction of an azido group in the presence of nitro group, a triphenylphosphine–water system was tested first.[13,24,25] Thus, the azido group in both mannosides **3** and **11** was smoothly reduced (Scheme 3) affording a single product identified as 4-nitrophenyl 2-acetamido-4,6-di-*O*-acetyl-2-deoxy-α-D-mannopyranoside (**16**) and 4-nitrophenyl 2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-mannopyranoside (**17**), respectively. The exclusive formation of the acetamido compounds **16** and **17** bearing free 3-OH group could result from O-3 → N-2 acetyl migration; to our knowledge, this is the first example of acetyl transfer observed under conditions of the Staudinger reaction. A deeper mechanistic study forms a part of our ongoing work in this area. The isolated yield of mannosides **16** and **17** was only 65% although almost quantitative conversion was achieved. The purification of the desired product in particular from triphenylphosphine oxide was tedious. To avoid this problem, we replaced triphenylphosphine by a commercially available polystyryl diphenylphosphine resin but the reduction of **3** in dioxane proceeded slowly, providing **16** in a modest yield after 5 days. Considering the preparative limitation of this reduction method, the use of hydrogen sulfide[26] as alternative reducing agent was next investigated. In this way both azides **3** and **11** were efficiently reduced to mannosides **16** and **17**, respectively, in 86% yield after a simple chromatographic separation. Compounds **16** and **17** were finally de-*O*-acetylated using the Zemplén procedure to afford expected glycosides **1** (mp 130–131 °C (H_2O); $[\alpha]_D^{20}$ +60.9 (*c* 1.0, EtOH)) and **2** (mp 108–110 °C (EtOH), $[\alpha]_D^{20}$ −93.3 (*c* 0.9, MeOH)) in almost quantitative yields. ^1H and ^{13}C NMR data (D_2O) of **1** and **2** were in agreement with those published.[13]

In conclusion, a combination of nucleophilic substitution and glycosylation represents an easy synthetic route to 4-nitrophenyl 2-azido-2-deoxy-D-mannopyranosides in a gram scale and high-overall yield. Subsequent selective reduction with hydrogen sulfide readily provides respective 4-nitrophenyl 2-acetamido-4,6-di-*O*-acetyl-D-mannopyranosides. These selectively protected compounds could be useful tool for *N*-acetyl mannosamine-containing oligosaccharides synthesis.

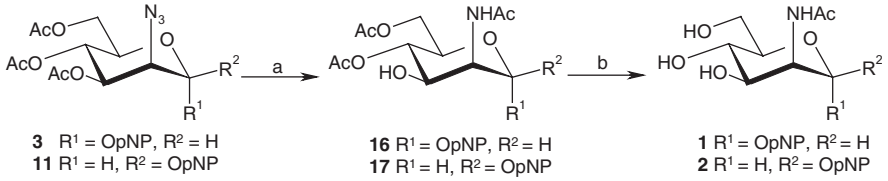
1. Experimental

1.1. General methods

Optical rotations were measured on a Jasco Model DIP-370 polarimeter and are given in 10^{-1} deg cm^2 g^{-1}. Melting points were determined with a Kofler hot block and are uncorrected. NMR spectra were recorded on a Bruker Avance DRX-500 (500.1 MHz for ^1H, 125.7 MHz for ^{13}C) at 25 °C in $CDCl_3$ solution unless otherwise specified. Chemical shifts are expressed in parts per million downfield from Me_4Si. Assignments of ^{13}C and ^1H signals are based on APT, HMQC and COSY experiments. IR spectra (wave numbers in cm^{-1}) were measured on a FT IR Nicolet 740 spectrometer in $CHCl_3$ solutions or KBr pellets. MS spectra of MeOH solution were recorded on a Q-TOF Micro spectrometer (Waters-Micromass) with electrospray ionization in positive mode. Elementary analysis was performed on CHN-Perkin–Elmer-2400. Reactions were followed on TLC on silica gel (10–40 μm, Merck) and column chromatography was carried out on silica gel (100–160 μm, Merck). Compounds on TLC plates were visualized by spraying with 1% cerium(IV)sulfate in 10% sulfuric acid and subsequent mineralization or iodine vapors were used for monitoring of triphenylphosphine oxide. All solvents were dried prior to distillation and stored over molecular sieves. Solvents were removed under reduced pressure below 45 °C.

1.2. 1,3,4,6-Tetra-*O*-acetyl-2-*O*-trifluoromethanesulfonyl-α-D-glucopyranose (5)

Triflic anhydride (1.1 mL, 6.75 mmol) was slowly added to a stirred soln of 1,3,4,6-tetra-*O*-acetyl-α-D-glucopyranose (**4**)[15] (1.96 g, 5.62 mmol) in 1:2 pyridine–dichloromethane mixture (60 mL) at 3 °C. After 1.5 h the reaction was complete, the reaction mixture was concentrated under



3 R¹ = OpNP, R² = H
11 R¹ = H, R² = OpNP
16 R¹ = OpNP, R² = H
17 R¹ = H, R² = OpNP
1 R¹ = OpNP, R² = H
2 R¹ = H, R² = OpNP

Scheme 3. Reagents and conditions: (a) H_2S, py, water, rt, 3.5 h; 86%; (b) MeONa, MeOH, rt, 20 min, 93%.

reduced pressure and the residue was evaporated twice with toluene. Purification on silica gel (3:1 petroleum ether–ethyl acetate) afforded **5** (1.79 g, 66%); mp 86–87 °C (diethyl ether); $[\alpha]_D^{20}$ +99.6 (*c* 1.0, $CHCl_3$); TLC (1:1 petroleum ether–ethyl acetate): R_f 0.81. ^{1}H NMR: δ 6.47 (d, 1H, $J_{1,2}$ 3.6 Hz, H-1), 5.58 (dd, $J_{2,3}$ 9.8 Hz, $J_{3,4}$ 9.8 Hz, 1H, H-3), 5.16 (dd, 1H, $J_{4,5}$ 9.8 Hz, H-4), 4.93 (dd, 1H, H-2), 4.31 (dd, 1H, $J_{5,6b}$ 3.7, $J_{6a,6b}$ 12.5 Hz, H-6b), 4.13–4.12 (m, 1H, H-5), 4.09 (dd, 1H, $J_{6a,5}$ 8.2 Hz, H-6a), 2.30 (s, 3H, CH_3CO), 2.09 (s, 6H, CH_3CO), 2.05 (s, 3H, CH_3CO); ^{13}C NMR: δ 170.41, 169.65, 169.22, 168.97 (4 × CH_3CO), 118.28 (q, $J_{C,F}$ 319.5 Hz, CF_3), 88.05 (C-1), 79.48 (C-2), 69.66 (C-5), 69.07 (C-3), 67.64 (C-4), 60.97 (C-6), 20.58, 20.56, 20.41, 20.30 (4 × CH_3CO). Anal. Calcd for $C_{15}H_{19}F_3O_{12}S$: C, 37.51; H, 3.99; S, 6.67. Found: C, 37.62; H, 4.08; S, 6.48.

1.3. Methyl 4,6-*O*-benzylidene-2-*O*-trifluoromethanesulfonyl-α-D-glucopyranoside (8)

^{1}H NMR data for **8** were in agreement with those published;[17] ^{13}C NMR: δ 136.58 (quaternary C-arom), 129.49 (2C-arom), 128.43 (2C-arom), 126.22 (C-arom), 118.45 (q, $J_{C,F}$ 319.6 Hz, CF_3), 102.15 (C-acetal), 97.57 (C-1), 84.01 (C-2), 81.04 (C-4), 68.60 (C-6), 68.19 (C-3), 61.95 (C-5), 55.87 (OCH_3).

1.4. Methyl 2-azido-4,6-*O*-benzylidene-2-deoxy-α-D-mannopyranoside (9)

^{1}H NMR data for **9** were in agreement with those published;[17] ^{13}C NMR: δ 137.06 (quaternary C-arom), 129.31 (C-arom), 128.37 (2C-arom), 126.24 (2C-arom), 102.28 (C-acetal), 100.07 (C-1), 79.00 (C-4), 68.90 (C-3), 68.66 (C-6), 63.63 (C-2), 63.29 (C-5), 55.17 (OCH_3).

1.5. 1,3,4,6-Tetra-*O*-acetyl-2-azido-2-deoxy-α-D-mannopyranose (6)

A solution of methyl 2-azido-4,6-*O*-benzylidene-2-deoxy-α-D-mannopyranoside (**9**) (2.50 g, 8.06 mmol) in the sulfuric acid-Ac_2O mixture (48 mL, 3% v/v) was stirred at rt for 40 min. Then, the reaction mixture was diluted with satd aq $NaHCO_3$-soln and ethyl acetate. The organic layer was washed with water, dried ($MgSO_4$) and concentrated. The residue was purified by column chromatography (3:1 petroleum ether–ethyl acetate) to afford **6** (2.27 g, 6.05 mmol, 75%); $[\alpha]_D^{20}$ +61.8 (*c* 1.1, $CHCl_3$). ^{1}H and ^{13}C NMR data were in agreement with those published.[13]

1.6. 4-Nitrophenyl 3,4,6-tri-*O*-acetyl-2-azido-2-deoxy-α-D-mannopyranoside (3)

Tetraacetate **6** (0.59 g, 1.58 mmol) was melted with 4-nitrophenol (0.66 g, 5.37 mmol) at 120 °C under reduced pressure. Freshly fused $ZnCl_2$ (0.60 g, 3.61 mmol) was added to the liquid mixture and heating was continued under reduced pressure for 25 min. Brown mass was then diluted with $CHCl_3$ under reflux, silica gel was added and solvent was slowly evaporated. Coated silica gel was then put on a top of column and elution with 4:1 petroleum ether–ethyl acetate yielded compound **3** (0.50 g, 1.11 mmol, 70%); mp 131–132 °C ($CHCl_3$–petroleum ether); $[\alpha]_D^{20}$ +113.5 (*c* 1.2, $CHCl_3$); IR: 2115 (N_3). ^{1}H NMR and ^{13}C NMR spectra were in agreement with those published.[13]

1.7. 4-Nitrophenyl 2-azido-2-deoxy-α-D-mannopyranoside (10)

Compound **3** (122 mg, 0.27 mmol) was deacetylated in MeOH (3 mL) with MeONa (0.1 M, 1 mL). After stirring at rt for 20 min, the mixture was neutralized with AcOH and concentrated. Flash chromatography of the residue afforded **10** (83 mg, 94%); mp 105–107 °C (EtOH), $[\alpha]_D^{20}$ +84.6 (*c* 0.8, EtOH). ^{1}H NMR (CD_3OD): δ 8.23 (d, 2H, *J* 9.1 Hz, H-arom), 7.21 (d, 2H, H-arom), 5.54 (d, 1H, $J_{1,2}$ < 1 Hz, H-1), 4.15 (dd, 1H, $J_{2,3}$ 3.4 Hz, H-2), 3.90 (dd, 1H, $J_{5,6b}$ 1.3 Hz, $J_{6a,6b}$ 12.0 Hz, H-6b), 3.78 (dd, 1H, $J_{3,4}$ 9.2 Hz, H-3), 3.69 (dd, 1H, $J_{6a,5}$ 5.3 Hz, H-6a), 3.55 (dd, $J_{4,5}$ 9.4 Hz, 1H, H-4), 3.45 (m, 1H, H-5); ^{13}C NMR (CD_3OD): δ 126.5 (2C, C-arom), 117.2 (2C, C-arom), 98.0 (C-1), 78.8 (C-5), 73.7 (C-3), 67.9 (C-4), 66.4 (C-2), 62.1 (C-6). Anal. Calcd for $C_{12}H_{14}N_4O_7$: C, 44.18; H, 4.33; N, 17.17. Found: C, 43.81; H, 4.60; N, 17.35.

1.8. 4-Nitrophenyl 2-acetamido-4,6-di-*O*-acetyl-2-deoxy-α-D-mannopyranoside (16)

Compound **3** (161 mg, 0.356 mmol) was dissolved in 1:1 pyridine–water mixture (10 mL) and H_2S was bubbled through the solution for 5 min. The mixture was left at rt for 3.5 h, then the solvents were evaporated. Column chromatography (toluene–ethyl acetate 2:1) of the residue afforded **16** (131 mg, 0.307 mmol, 86%); $[\alpha]_D^{20}$ +49.3 (*c* 1.2, $CHCl_3$). ^{1}H NMR: δ 8.15 (d, 2H, *J* 9.2 Hz, H-arom), 7.10 (d, 2H, H-arom), 6.02 (d, 1H, $J_{N,2}$ 7.3 Hz, N*H*COCH$_3$), 5.64 (d, 1H, $J_{1,2}$ 1.2 Hz, H-1), 4.94 (dd, 1H, $J_{3,4}$ 10.0 Hz, $J_{4,5}$ 10.0 Hz, H-4), 4.58 (m, 1H, H-2), 4.34 (dd, 1H, $J_{3,2}$ 5.0 Hz, H-3), 4.20 (dd, 1H, $J_{6b,5}$ 5.1 Hz, $J_{6a,6b}$ 12.3 Hz, H-6b), 3.96 (dd, 1H, $J_{6a,5}$ 2.0 Hz, H-6a), 3.86 (m, 1H, H-5), 2.94 (br s, 1H, OH), 2.07 (s, 3H, COCH_3), 2.05 (s, 3H, COCH_3), 1.95 (s, 3H, COCH_3); ^{13}C NMR (CD_3OD): δ 171.90, 170.93 (2 × CH_3CO), 160.37 (quaternary C-arom), 143.00 (quaternary C-arom), 125.81 (2C, C-arom), 116.38 (2C, C-arom), 96.69 (C-1), 69.14 (C-5), 68.90 (C-4), 67.91 (C-3), 62.12 (C-6), 52.92 (C-2), 23.34, 20.87, 20.68 (3 × C_3CO). Anal. Calcd for $C_{18}H_{22}N_2O_{10}$: C, 50.71; H, 5.20; N, 6.57. Found: C, 50.99; H, 5.01; N, 6.38.

1.9. 4-Nitrophenyl 3,4,6-tri-*O*-acetyl-β-D-glucopyranoside (13)

Tetra-*O*-acetate **4** (4.00 g, 11.85 mmol) was converted[21] into bromide **12** that was immediately glycosylated with 4-nitrophenol in the presence of potassium carbonate.[20] Column chromatography (1:1 toluene–ethyl acetate) yielded glucopyranoside **13** (3.84 g, 8.97 mmol, 78%). ^{1}H NMR data are in agreement with those published;[22] ^{13}C NMR: δ 178.88, 170.50, 169.60 ($3\times CH_3CO$), 161.40 (quaternary C-arom), 143.16 (quaternary C-arom), 125.72 (2C, C-arom), 116.67 (2C, C-arom), 100.13 (C-1), 74.50 (C-3), 72.32, 71.93 (C-2 and C-5), 68.08 (C-4), 62.01 (C-6), 20.71, 20.63, 20.54 ($3\times CH_3CO$).

1.10. 4-Nitrophenyl 3,4,6-tri-*O*-acetyl-2-*O*-trifluoromethanesulfonyl-β-D-glucopyranoside (14)

Triflic anhydride (0.5 mL, 3.07 mmol) was slowly added at 5 °C to a stirred solution of **13**, (0.881 g, 2.056 mmol) in dichloromethane–pyridine (2:1, 37 mL). The mixture was kept at 3 °C for 30 min, and then allowed to attain rt. After another 30 min, the reaction was complete (TLC petroleum ether, ethyl acetate 1:1, R_f 0.82) and it was quenched by addition of water (1.5 mL). The organic phase was separated and concentrated, and toluene was evaporated twice from the residue that was dried in vacuum. The product was purified by column chromatography (3:1 petroleum ether–ethyl acetate) to yield **14** (0.97 g, 1.72 mmol, 84%); mp 100–101 °C (petroleum ether–ether); $[\alpha]_D^{20}$ −24.2 (*c* 1.1, $CHCl_3$). ^{1}H NMR: δ 8.24 (d, 2H, *J* 9.1 Hz, H-arom), 7.14 (d, 2H, H-arom), 5.48 (dd, 1H, $J_{3,2}$ 9.5 Hz, $J_{3,4}$ 9.5 Hz, H-3), 5.28 (d, 1H, $J_{1,2}$ 7.8 Hz, H-1), 5.17 (dd, 1H, $J_{4,5}$ 9.7 Hz, H-4), 5.01 (dd, 1H, H-2), 4.31 (dd, 1H, $J_{6b,5}$ 5.3 Hz, $J_{6a,6b}$ 12.5 Hz, H-6b), 4.21 (dd, 1H, $J_{6a,5}$ 1.5 Hz, H-6a), 4.00 (ddd, 1H, H-5); ^{13}C NMR: δ 170.30, 169.56, 169.25 ($3\times CH_3CO$), 160.47 (quaternary C-arom), 143.68 (quaternary C-arom), 125.89 (2C, C-arom), 118.53 (q, $J_{F,C}$ 315.3, CF_3), 116.89 (2C, C-arom), 97.31 (C-1), 80.93 (C-2), 72.66 (C-5), 70.95 (C-3), 68.12 (C-4), 61.39 (C-6), 20.60, 20.42, 20.26 ($3\times CH_3CO$). Anal. Calcd for $C_{19}H_{20}F_3N_2O_{13}$: C, 40.79; H, 3.60; N, 2.50; S, 5.73. Found: C, 40.65; H, 3.87; N, 2.35; S, 5.70.

1.11. 4-Nitrophenyl 2-acetamido-4,6-di-*O*-acetyl-2-deoxy-β-D-mannopyranoside (17)

Starting from compound **11** (140 mg, 0.306 mmol) and using a procedure described for **16**, mannoside **17** was prepared (112 mg, 0.263 mmol, 86%); mp 117–118 °C (toluene–ethyl acetate); $[\alpha]_D^{20}$ −117.5 (*c* 1.1, $CHCl_3$). ^{1}H NMR: δ 8.21 (d, 2H, *J* 9.2 Hz, H-arom), 7.09 (d, 2H, H-arom), 6.25 (d, 1H, $J_{NH,2}$ 7.3 Hz, N*H*COCH$_3$), 5.45 (d, 1H, $J_{1,2}$ 2.3 Hz, H-1), 5.02 (dd, 1H, $J_{4,5}$ 7.9 Hz, $J_{4,3}$ 7.9 Hz, H-4), 4.74 (dd, 1H, $J_{2,3}$ 2.3 Hz, H-2), 4.30 (dd, 1H, $J_{5,6b}$ 6.6 Hz, $J_{6a,6b}$ 12.3 Hz, H-6b), 4.23 (dd, 1H, $J_{6a,5}$ 3.5 Hz, H-6a), 4.04 (dd, 1H, H-3), 3.96–3.89 (m, 1H, H-5), 2.15 (s, 3H, COC*H*$_3$), 2.15 (s, 3H, COC*H*$_3$), 1.98 (s, 3H, COC*H*$_3$); ^{13}C NMR: δ 172.65 (2C, CH_3CO), 170.38 (CH_3CO), 160.96 (quaternary C-arom), 143.11 (quaternary C-arom), 128.59 (2C, C-arom), 116.58 (2C, C-arom), 96.04 (C-1), 72.84 (C-5), 70.87 (C-3), 69.45 (C-4), 62.71 (C-6), 51.90 (C-2), 23.28, 20.90, 20.61 ($3\times CH_3CO$). Anal. Calcd for $C_{18}H_{22}N_2O_{10}$: C, 50,71; H, 5.20; N, 6,57. Found: C, 50.78; H, 5.05; N, 6.87.

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