Iridium-Catalysed Condensation of Alcohols and Amines as a Method for Aminosugar Synthesis

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Electronic Supplementary Information

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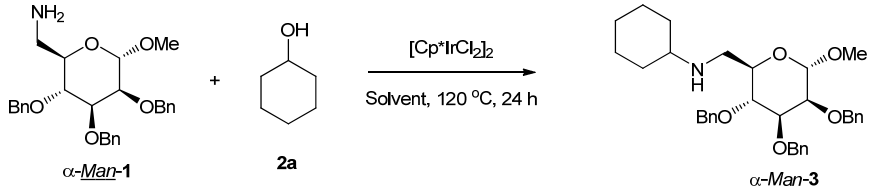
1. General Information

All reactions were carried out under a dry argon atmosphere – running the reactions under nitrogen gave unsatisfactory results – in flame-dried glassware. The sealable tubes used were Biotage microwave vials (5 mL). Reagents were of analytical grade, obtained from commercial suppliers and used without further purification. Carbohydrate alcohols and amines used as starting materials have been prepared before in the literature (α-*Man*-**1**;[1] β-*Glc*-**4**;[2] α-*Man*-**6**;[3] α-*Glc*-**12**;[4] α-*Man*-**10**;[5] α-*Glc*-**13**;[6] α-*Man*-**15**; [7] β-*Glc*-**18**[8]), except for β-*Man*-**5**, which was prepared from methyl 3-azido-4,6-*O*-benzylidene-3-deoxy-β-D-glucopyranoside[2] by the following sequence: triflation of OH-2, displacement of triflate by lithium benzoate, methanolysis of the 2-*O*-benzoyl group and hydrogenolysis of the 3-azide over palladium. Anhydrous toluene was obtained using a VAC solvent purifier system. Products were isolated using flash column chromatography carried out on 60 Å (40–60 μm) silica gel. ^{1}H, COSY, and HSQC NMR spectra were recorded at 400 MHz, and ^{13}C spectra at 100 MHz, on a Bruker Avance 400 spectrometer; ^{1}H NMR spectra at 500 MHz were recorded on a Bruker Avance 500 spectrometer. Chemical shifts (δ) are reported in ppm, using the residual solvent peak in $CDCl_3$ (δ_H 7.26; δ_C 77.00) or in MeOD (δ_H 3.32; δ_C 47.56) as internal reference; coupling constants (*J*) are given in Hz. High resolution mass spectra (HRMS) were recorded on a Bruker MicroTOF ESI–TOF mass spectrometer. Optical rotations were recorded on a Perkin–Elmer 241 polarimeter with a path length of 1 dm.

2. Optimisation of reaction conditions

Table 1: Alkylation of amine α-*Man*-**1** with cyclohexanol (**2a**).[a]



Entry	Solvent	$[Cp^*IrCl_2]_2$ (mol%)	$NaHCO_3$ (mol%)	α-*Man*-**3**[b] (%)
1	Water	5	25	-
2	Toluene	5	25	85
3	Toluene	3	-	90
4	Toluene	1	-	90
5	Toluene	0.5	-	34

[a]A mixture of α-*Man*-**1** (46 mg, 0.1 mmol), cyclohexanol (**2a**, 53 μL, 0.5 mmol) and $[Cp^*IrCl_2]_2$ in water or toluene (0.5 mL), with or without $NaHCO_3$ was heated at 120 °C for 24 h under Ar. [b] Isolated yield.

3. General procedures for the $[Cp^*IrCl_2]_2$ catalysed alkylation reaction

General procedure for alkylation of *O*-protected or partially *O*-protected aminosugars with alcohols (Method A; Scheme 1 and 2)

A flame-dried sealable tube equipped with a magnetic stirrer bar was charged with aminosugar (0.1 mmol) and $[Cp^*IrCl_2]_2$ (1 mol%). The tube was sealed and flushed with argon, then alcohol (0.5 mmol) (0.3 mmol for Scheme 1) and dry toluene (0.5 mL) were added. The reaction mixture was stirred under an argon atmosphere at 120 °C. The progress of the reaction was monitored by TLC. After completion of the reaction, the mixture was concentrated *in vacuo* and the product was isolated by flash column chromatography with the appropriate eluent.

General procedure for alkylation of an *O*-unprotected aminosugar with alcohols (Method B; Scheme 3)

A flame-dried sealable tube equipped with a magnetic stirrer bar was charged with aminosugar (0.1 mmol) and $[Cp^*IrCl_2]_2$ (1 mol%). The tube was sealed and flushed with argon, then alcohol (250 µL) was added. The reaction mixture was stirred under an argon atmosphere at 120 °C. The progress of the reaction was monitored by TLC. After completion of the reaction, the mixture was concentrated *in vacuo* and the product was isolated by flash column chromatography with the appropriate eluent.

General procedure for amination of sugar alcohols (Method C; Schemes 4 and 5)

A flame-dried sealable tube equipped with a magnetic stirrer bar was charged with aminosugar (0.1 mmol), sugar alcohol (0.3 mmol), $[Cp^*IrCl_2]_2$ (3 mol%) and Cs_2CO_3 (25 mol%). The tube was sealed and flushed with argon, then dry toluene (0.5 mL) was added. The reaction mixture was stirred under an argon atmosphere at 120 °C. The progress of the reaction was monitored by TLC. After completion of the reaction, the mixture was concentrated *in vacuo* and the product was isolated by flash column chromatography with the appropriate eluent.

4. Characterisation data of products

Methyl 6-amino-2,3,4-tri-*O*-benzyl-6-*N*-cyclohexyl-6-deoxy-α-D-mannopyranoside (α-*Man*-3)

The title compound was synthesised from methyl 6-amino-2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranoside α-*Man*-**1** (46 mg, 0.10 mmol) and cyclohexanol (**2a**, 53 μL, 0.50 mmol) according to general synthetic method A. The product α-*Man*-**3** was isolated by flash column chromatography (pentane–EtOAc–MeOH, 5:4:1) as a yellow oil (49 mg, 90%); $[\alpha]_D^{23}$ = +29.6 (*c*, 1.0 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.40–7.29 (m, 15 H, Ar-H), 4.96 (d, *J* = 11.2 Hz, 1 H, PhCHH'), 4.79, 4.72 (2 × d, *J* = 12.4 Hz, 2 H, PhCH_2), 4.70 (d, $J_{1,2}$ = 1.7 Hz, 1 H, H-1), 4.67–4.64 (m, 3 H, PhCH_2, PhCHH'), 3.90 (dd, $J_{2,3}$ = 3.0 Hz, $J_{3,4}$ = 8.7 Hz, 1 H, H-3), 3.85–3.76 (m, 3 H, H-2, H-4, H-5), 3.34 (s, 3 H, OCH_3), 3.07 (dd, $J_{5,6'}$ = 2.8 Hz, $J_{6,6'}$ = 12.1 Hz, 1 H, H-6'), 2.79 (dd, $J_{5,6}$ = 7.4 Hz, $J_{6,6'}$ = 12.1 Hz, 1 H, H-6), 2.47 (m, 1 H, CHNH), 1.89–1.80 (m, 2 H, cyclohexyl-H), 1.79–1.27 (m, 2 H, cyclohexyl-H), 1.64 (m, 1 H, cyclohexyl-H), 1.28–1.17 (m, 5 H, cyclohexyl-H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.9, 138.4, 138.2 (3 x Ar-C), 128.4, 128.4, 128.1, 127.9, 127.7, 127.6, 127.6, (Ar-C), 99.2 (C-1), 75.0, 72.9, 72.2 (3 x PhCH_2), 80.2, 77.0, 74.6, 69.8 (C-2, C-3, C-4, C-5), 56.8 (CHNH), 55.2 (OCH3), 47.4 (C-6), 32.3, 32.1, 25.8, 24.9, 24.1 (cyclohexyl-C); HRMS–ESI calcd. for $C_{34}H_{44}NO_5$ (MH^+) 546.3214; found 546.3214.

Methyl 3-amino-4,6-*O*-benzylidene-3-*N*-cyclohexyl-3-deoxy-β-D-glucopyranoside (β-*Glc*-7a)

The title compound was synthesised from methyl 3-amino-4,6-*O*-benzylidene-3-deoxy-β-D-glucopyranoside β-*Glc*-**4** (28 mg, 0.10 mmol) and cyclohexanol (**2a**, 53 μL, 0.50 mmol) according to general synthetic method A. The product β-*Glc*-**7a** was isolated by flash column chromatography (pentane–EtOAc–MeOH, 5:4:1) as a white solid (31 mg, 86%); m.p. 172–173 °C; $[\alpha]_D^{23}$ = –41.5 (*c*, 1.0 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.50-7.37 (m, 5 H, Ar-H), 5.57 (s, 1H, PhCH), 4.38-4.34 (m, 2H, H-1, H-6'), 3.80 (at, J = 10.2 Hz, 1 H, H-6), 3.60 (s, 3H, OCH3), 3.52-3.48 (m, 2 H, H-5, H-4), 3.32 (dd, $J_{1,2}$ = 7.9 Hz, $J_{2,3}$ = 9.6 Hz, 1 H, H-2), 2.98 (at, *J* = 9.6 Hz, 1 H, H-3), 2.90 (m, 1 H, CHNH), 2.47 (br s, 2 H, OH, NH), 2.06-1.93 (m, 2 H, cyclohexyl-H), 1.79-1.72 (m, 2 H, cyclohexyl-H), 1.59 (m, 1 H, cyclohexyl-H), 1.31–1.03 (m, 5 H, cyclohexyl-H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.3 (Ar-C), 128.9, 128.2, 125.8 (Ar-C), 104.8 (C-1), 101.1 (PhCH), 73.3 (C-2), 68.8 (C-6), 81.8, 68.0 (C-4, C-5), 59.3 (C-3), 57.3 (OCH_3), 55.1 (CHNH), 34.8, 33.7, 25.9, 25.2,

24.9 (cyclohexyl-C); HRMS–ESI calcd for $C_{20}H_{29}NNaO_5$ (MNa^+) 386.1949; found 386.1938.

Methyl 3-amino-4,6-*O*-benzylidene-3-*N*-benzyl-3-deoxy-β-D-glucopyranoside (β-*Glc*-7b)

The title compound was synthesised from methyl 3-amino-4,6-*O*-benzylidene-3-deoxy-β-D-glucopyranoside β-*Glc*-**7b** (28 mg, 0.10 mmol) and benzyl alcohol (**2b**, 52 μL, 0.50 mmol) according to general synthetic method A. The product β-*Glc*-**7c** was isolated by flash column chromatography (pentane–EtOAc–MeOH, 5:4:1) as a white solid (35 mg, 94%); m.p. 165–166 °C; $[\alpha]_D^{23}$ = –29.3 (*c*, 1.0 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.53–7.24 (m, 10 H, Ar-H), 5.58 (s, 1 H, C<u>H</u>Ph), 4.38–4.35 (m, 2 H, H-1, H-6'), 4.13, 4.00 (2 × d, *J* = 13.1 Hz, 2 H, NHC<u>H</u>$_2$Ph), 3.81 (at, *J* = 10.2 Hz, 1 H, H-6), 3.63 (at obs, *J* = 9.3 Hz, 1 H, H-4), 3.60 (s, 3 H, OCH_3), 3.52 (m, 1 H, H-5), 3.42 (dd, $J_{1,2}$ = 7.7 Hz, $J_{2,3}$ = 9.7 Hz, 1 H, H-2), 2.97 (at, *J* = 9.7 Hz, 1 H, H-3); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 140.4, 137.3 (2 × Ar-C), 129.0, 128.5, 128.3, 128.2, 127.0, 126.0 (Ar-CH), 104.7 (C-1), 101.5 (Ph<u>C</u>H), 81.5 (C-4), 73.2 (C-2), 68.8 (C-6), 67.7 (C-5), 61.0 (C-3), 57.4 (OCH_3), 52.2 (CH_2NH); HRMS–ESI calcd for $C_{21}H_{26}NO_5$ (MH^+) 372.1805; found 372.1813.

Methyl 3-amino-4,6-*O*-benzylidene-3-*N*-cyclohexyl-3-deoxy-β-D-mannopyranoside (β-*Man*-8)

The title compound was synthesised from methyl 3-amino-4,6-*O*-benzylidene-3-deoxy-β-D-mannopyranoside β-*Man*-**5** (28 mg, 0.10 mmol) and cyclohexanol (**2a**, 53 μL, 0.50 mmol) according to general synthetic method A. The product β-*Man*-**8** was isolated by flash column chromatography (pentane–EtOAc–MeOH, 5:4:1) as a white solid (33 mg, 90%); m.p. 162–164 °C; $[\alpha]_D^{23}$ = –73.8 (*c*, 1.0 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.50–7.38 (m, 5 H, Ar-H), 5.54 (s, 1 H, C<u>H</u>Ph), 4.53 (d, $J_{1,2}$ = 1.2 Hz, 1 H, H-1), 4.35 (dd, $J_{5,6'}$ = 5.0 Hz, $J_{6,6'}$ = 10.5 Hz, 1 H, H-6'), 3.96 (dd, $J_{1,2}$ = 1.0 Hz, $J_{2,3}$ = 3.3 Hz, 1 H, H-2), 3.86 (at, *J* = 10.3 Hz, 1 H, H-6), 3.73 (at, *J* = 9.6 Hz, 1 H, H-4), 3.60 (s, 3 H, OCH_3), 3.48 (m, 1 H, H-5), 3.11 (dd, $J_{2,3}$ = 3.4 Hz, $J_{3,4}$ = 9.8 Hz, 1 H, H-3), 2.54 (m, 1 H, NHC<u>H</u>), 1.99 –1.78 (m, 2 H, cyclohexyl-H), 1.76–1.62 (m, 5 H, OH, NH, cyclohexyl-H), 1.30–1.03 (m, 5 H, cyclohexyl-H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.4 (Ar-C), 129.0, 128.3, 126.0, (Ar-CH), 102.2 (C-1), 101.8 (Ph<u>C</u>H), 77.4 (C-4), 68.8 (C-2), 67.9 (C-5), 67.8 (C-6), 57.5 (C-3), 57.3 (OCH_3), 53.7, 34.8, 33.3, 25.8, 25.3, 25.0 (cyclohexyl-C), HRMS–ESI calcd for $C_{20}H_{30}NO_5$ (MH^+) 364.2118; found 364.2125.

Methyl 3-amino-4,6-*O*-benzylidene-3-*N*-cyclohexyl-3-deoxy-α-D-mannopyranoside (α-*Man*-9)

The title compound was synthesised from methyl 3-amino-4,6-*O*-benzylidene-3-deoxy-α-D-mannopyranoside α-*Man*-**6** (28 mg, 0.10 mmol) and cyclohexanol (**2a**, 53 µL, 0.50 mmol) according to general synthetic method A. The product α-*Man*-**9a** was isolated by flash column chromatography (pentane–EtOAc–MeOH, 5:4:1) as a white solid (28 mg, 78%); m.p. 163–165 °C; $[\alpha]_D^{23}$ = –48.5 (*c*, 1.0 in $CHCl_3$) ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.50–7.38 (m, 5 H, Ar-H), 5.57 (s, 1 H, PhC<u>H</u>), 4.81 (d, $J_{1,2}$ = 1.0 Hz, 1 H, H-1), 4.29 (dd, $J_{5,6'}$ = 3.0 Hz, $J_{6,6'}$ = 8.8 Hz, 1 H, H-6'), 3.93–3.80 (m, 4 H, H-2, H-4, H-5, H-6), 3.42 (s, 3 H, OCH_3), 3.36 (dd, $J_{2,3}$ = 3.3 Hz, $J_{3,4}$ = 9.6 Hz, 1 H, H-3), 2.96 (br s, 2 H, OH, NH), 2.64 (m, 1 H, NHC<u>H</u>), 2.08–1.91 (m, 2 H, cyclohexyl-H), 1.76–1.60 (m, 3 H, cyclohexyl-H), 1.31–1.80 (m, 5 H, cyclohexyl-H); ^{13}C NMR (100 MHz, $CDCl_3$): δ =137.4 (Ar-C), 129.0, 128.2, 126.1 (Ar-CH), 101.9 (C-1), 100.5 (Ph<u>C</u>H), 76.8, 69.0, 67.9 (C-2, C-4, C-5), 67.8 (C-6), 63.1 (C-3), 55.1 (OCH_3), 54.7, 32.7, 25.6, 25.1, 24.9 (cyclohexyl-C); HRMS–ESI calcd for $C_{20}H_{30}NO_5$ (MH^+) 364.2118; found 364.2123.

Methyl 6-amino-6-*N*-cyclohexyl-6-deoxy-α-D-mannopyranoside (α-*Man*-11a)

The title compound was synthesised from methyl 6-amino-6-deoxy-α-D-mannopyranoside α-*Man*-**10** (19 mg, 0.10 mmol) and cyclohexanol (**2a**, 250 µL) according to general synthetic method B. The product α-*Man*-**11a** was isolated by flash column chromatography ($CHCl_3$–MeOH–$NH_{3\ (aq)}$, 4:6:0.2) as a yellow oil (24 mg, 87%); $[\alpha]_D^{23}$= +57 (*c*, 1.0 in $CHCl_3$); ^{1}H NMR (400 MHz, CD_3OD): δ = 4.64 (d, $J_{1,2}$ = 1.6 Hz, 1 H, H-1), 3.80 (dd, $J_{1,2}$ = 1.7 Hz, $J_{2,3}$ = 3.4 Hz, 1 H, H-2), 3.66 (dd, $J_{2,3}$ = 3.4 Hz, $J_{3,4}$ = 9.3 Hz, 1 H, H-3), 3.60 (m, 1 H, H-5), 3.50 (at, *J* = 9.5 Hz, 1 H, H-4), 3.39 (s, 3 H, OCH_3), 3.08 (dd, $J_{5,6'}$ = 3.2 Hz, $J_{6,6'}$ = 12.2 Hz, 1 H, H-6'), 2.78 (dd, $J_{5,6}$ = 8.1 Hz, $J_{6,6'}$ = 12.2 Hz, 1 H, H-6), 2.53 (m, 1 H, C<u>H</u>NH), 1.96–1.93 (m, 2 H, cyclohexyl-H), 1.80–1.77 (m, 2 H, cyclohexyl-H), 1.69-1.66 (m, 1 H, cyclohexyl-H), 1.37–1.09 (m, 5 H, cyclohexyl-H); ^{13}C NMR (100 MHz, CD_3OD): δ = 101.5 (C-1), 70.9 (C-3), 70.6 (C-2), 70.4 (C-5), 69.5 (C-4), 56.5 (CHNH), 54.1 (OCH_3), 47.5 (C-6), 32.3, 32.2, 25.7, 24.7, 24.7 (cyclohexyl-C),; HRMS–ESI calcd for $C_{13}H_{26}NO_5$ (MH^+) 276.1805; found 276.1804.

Methyl 6-amino-6-*N*-cyclopentyl-6-deoxy-α-D-mannopyranoside (α-*Man*-11c)

The title compound was synthesised from methyl 6-amino-6-deoxy-α-D-mannopyranoside α-*Man*-**10** (19 mg, 0.10 mmol) and cyclopentanol (**2c**, 250 µL) according to general synthetic method B.

The product α-*Man*-**11c** was isolated by flash column chromatography ($CHCl_3$–MeOH–$NH_{3\ (aq)}$, 4:6:0.2) as a yellow oil (16 mg, 62%); $[\alpha]_D^{23}$ = +41.4 (*c*, 0.5 in $CHCl_3$); ^{1}H NMR (400 MHz, CD_3OD): δ = 4.63 (d, $J_{1,2}$ = 1.6 Hz, 1 H, H-1), 3.79 (dd, $J_{1,2}$ = 1.7 Hz, $J_{2,3}$ = 3.4 Hz, 1 H, H-2), 3.68–3.60 (m, 2 H, H-3, H-5), 3.50 (at, *J* = 9.5 Hz, 1 H, H-4), 3.39 (s, 3 H, OCH_3), 3.14 (m, 1 H, NHC<u>H</u>), 3.01 (dd, $J_{5,6'}$ = 3.2 Hz, $J_{6,6'}$ = 12.2 Hz, 1 H, H-6'), 2.78 (dd, $J_{5,6}$ = 8.1 Hz, $J_{6,6'}$ = 12.2 Hz, 1 H, H-6), 1.97–1.89 (m, 2 H, cyclopentyl-H), 1.76–1.72 (m, 2 H, cyclopentyl-H), 1.62–1.57 (m, 2 H, cyclopentyl-H), 1.43–1.37 (m, 2 H, cyclopentyl-H); ^{13}C NMR (100 MHz, CD_3OD): δ = 101.5 (C-1), 70.9 (C-3), 70.6 (C-2), 70.3 (C-5), 69.4 (C-4), 59.3 (CHNH), 54.1 (OCH_3), 49.3 (C-6), 31.8, 31.7, 23.6 (cyclopentyl-C),; HRMS–ESI calcd for $C_{12}H_{23}NNaO_5$ (MNa^+) 284.1468; found 284.1469.

Methyl 6-amino-6-deoxy-6-di-*N*,*N*-(*n*-pentyl)-α-D-mannopyranoside (α-*Man*-11d)

The title compound was synthesised from methyl 6-amino-6-deoxy-α-D-mannopyranoside α-*Man*-**10** (19 mg, 0.10 mmol) and *n*-pentanol (**2d**, 250 µL) according to general synthetic method B. The product α-*Man*-**11d** was isolated by flash column chromatography ($CHCl_3$–MeOH–$NH_{3\ (aq)}$, 4:6:0.2) as a yellow oil (27 mg, 82%); $[\alpha]_D^{23}$ = +12.9 (*c*, 1.0 in $CHCl_3$); ^{1}H NMR (400 MHz, CD_3OD): δ = 4.61 (d, $J_{1,2}$ = 1.6 Hz, 1 H, H-1), 3.77 (dd, $J_{1,2}$ = 1.7 Hz, $J_{2,3}$ = 3.4 Hz, 1 H, H-2), 3.68–3.62 (m, 2 H, H-3, H-5), 3.53 (at, *J* = 9.3 Hz, 1 H, H-4), 3.41 (s, 3 H, OCH_3), 2.96 (dd, $J_{5,6'}$ = 5.2 Hz, $J_{6,6'}$ = 13.4 Hz, 1 H, H-6'), 2.72–2.48 (m, 5 H, 2 × C<u>H</u>$_2$, H-6), 1.62–1.46 (m, 4 H, 2 × CH_2), 1.42–1.26 (m, 8 H, 4 × CH_2), 0.94 (t, *J* = 7.0 Hz, 6 H, 2 × CH_3), ^{13}C NMR (100 MHz, CD_3OD): δ = 101.6 (C-1), 71.0, 70.7, 70.3 (C-2, C-3, C-5), 68.5 (C-4), 56.4 (C-6), 54.6 ($N(CH_2)_2$), 54.3 (OCH_3), 29.4, 25.9, 22.2, 13.0 (pentyl-C); HRMS–ESI calcd for $C_{17}H_{36}NO_5$ (MH^+) 334.2588; found 334.2573.

Bis(methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl)amine (*Glc,Glc*-14) [9]

The title compound was synthesised from methyl 6-amino-2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranoside α-*Glc*-**12** (46 mg, 0.10 mmol) and methyl 2,3,4-tri-*O*-benzyl-α-D-glucopyranoside α-*Glc*-**13** (138 mg, 0.30 mmol) according to general synthetic method C at 120 °C. The product ***Glc,Glc*-14** was isolated by flash column chromatography (Pentane–EtOAc, 1:3) as a yellow oil (71 mg, 78%); $[\alpha]_D^{23}$ = +31.2 (*c*, 0.5 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36–7.28 (m, 30 H, Ar-H), 5.00–4.61 (m, 12 H, 6 × PhC<u>H</u>$_2$), 4.53 (d, $J_{1,2}$ = 3.4 Hz, 2 H, H-1), 3.99

(at, J = 9.2 Hz, 2 H, H-3), 3.74 (at, J = 7.7 Hz, 2 H, H-5), 3.47 (dd, $J_{1,2}$ = 3.4 Hz, $J_{2,3}$ = 9.6 Hz, 2 H, H-2), 3.40 (at, J = 9.2 Hz, 2 H, H-4), 3.34 (s, 6 H, OCH_3), 2.86 (dd, $J_{5,6'}$ = 1.8 Hz, $J_{6,6'}$ = 12.3 Hz, 2 H, H-6'), 2.72 (dd, $J_{5,6}$ = 7.0 Hz, $J_{6,6'}$ = 12.3 Hz, 2 H, H-6), 1.65 (br s, 1 H, NH), ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.8, 138.3, 138.2 (6 × Ar-C), 128.5, 128.5, 128.4, 128.1, 128.0, 127.9, 127.7, 127.6 (Ar-CH), 97.8 (C-1), 82.1 (C-3), 80.2 (C-2), 79.6 (C-4), 75.8, 75.0, 73.3 (6 × Ph<u>C</u>H_2), 69.9 (C-5), 55.1 (OCH_3), 50.6 (C-6); HRMS–ESI calcd for $C_{56}H_{63}NO_{10}$ (MH^+) 910.4525; found 910.4529.

Bis(methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranosid-6-yl)amine (*Man,Man*-16)

The title compound was synthesised from methyl 6-amino-2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranoside α-*Man*-**1** (46 mg, 0.10 mmol) and methyl 2,3,4-tri-*O*-benzyl-α-D-mannopyranoside α-*Man*-**15** (138 mg, 0.30 mmol) according to general synthetic method C at 120 °C. The product ***Man,Man*-16** was isolated by flash column chromatography (Pentane–EtOAc, 1:3) as a yellow oil (40 mg, 44%); $[\alpha]_D^{23}$ = +33.4 (*c*, 0.5 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.35–7.28 (m, 30 H, Ar-H), 4.93 (d, J = 11.0 Hz, 2 H, PhCH<u>H</u>'), 4.74–4.61 (m, 12 H, H-1, Ph<u>C</u>H_2, PhC<u>H</u>H'), 3.89–3.70 (m, 8 H, H-2, H-3, H-4, H-5), 3.24 (s, 6 H, OCH_3), 2.98 (dd, $J_{5,6'}$ = 2.4 Hz, $J_{6,6'}$ = 12.0 Hz, 2 H, H-6'), 2.85 (dd, $J_{5,6}$ = 7.9 Hz, $J_{6,6'}$ = 12.0 Hz, 2 H, H-6), 1.80 (br s, 1 H, NH); ^{13}C NMR (100 MHz, $CDCl_3$): δ =139.7, 138.6, 138.4 (Ar-C), 128.4, 128.3, 127.9, 127.6, 127.5 (Ar-CH), 98.9 (C-1), 75.1, 72.8, 72.2 (3 × Ph<u>C</u>H_2), 80.3, 76.9, 74.9, 70.9 (C-2, C-3, C-4, C-5), 54.6 (OCH_3), 50.7 (C-6); HRMS–ESI calcd for $C_{56}H_{63}NO_{10}$ (MH^+) 910.4525; found 910.4525.

(Methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl) (methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranosid-6-yl)amine (*Glc,Man*-17)

From manno *amine and* gluco *alcohol:* The title compound was synthesised from methyl 6-amino-2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranoside α-*Man*-**1** (46 mg, 0.10 mmol) and methyl 2,3,4-tri-*O*-benzyl-α-D-glucopyranoside α-*Glc*-**13** (138 mg, 0.30 mmol) according to general synthetic method C at 120 °C. The product ***Glc,Man*-17** was isolated by flash column chromatography (Pentane–EtOAc, 1:3) as a yellow oil (43 mg, 47%); $[\alpha]_D^{23}$ = +30.6 (*c*, 0.5 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.36–7.27 (m, 30 H, Ar-H), 4.99–4.61 (m, 13 H, 6 × Ph<u>C</u>H_2, H-1^{II}), 4.53 (d, J = 3.6 Hz, 1 H, H-1^{I}), 3.98 (at, J = 9.3 Hz, 1 H, H-3^{I}), 3.89–3.68 (m, 5 H, H-2^{II}, H-3^{II}, H-4^{II}, H-5^{II}, H-5^{I}), 3.48 (dd, $J_{1,2}$ = 3.6 Hz, J = 9.6 Hz, 1 H, H-2^{I}), 3.42 (at, J = 9.4 Hz, 1 H, H-4^{I}), 3.31, 3.27

(2 × s, 6 H, 2 × OCH_3), 2.96–2.88 (m, 2 H, H-6'^{I}, H-6'^{II}), 2.83 (dd, $J_{5,6}$ = 7.8 Hz, $J_{6,6}$ 12.0 Hz, 1 H, H-6^{II}), 2.73 (dd, $J_{5,6}$ = 7.2 Hz, $J_{6,6'}$ = 12.3 Hz, 1 H, H-6^{I}), 1.68 (br s, 1 H, NH); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.8, 138.6, 138.5, 138.4, 138.3, (Ar-C), 128.4, 128.4, 128.3, 128.3, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 126.6, 127.5, (Ar-CH), 98.9 (C-1^{II}), 97.7 (C-1^{I}), 82.1 (C-3^{I}), 80.2 (C-2^{I}), 80.1 (C-4^{I}), 79.7, 77.2, 76.8, 75.8, 75.1, 74.8, 73.3, 72.8, 72.1, 70.9, 69.8 (C-2^{II}, C-3^{II}, C-4^{II}, C-5^{II}, C-5^{I}, 6 × Ph<u>C</u>H_2), 54.9, 54.6 (2 × OCH_3), 50.9 (C-6^{II}), 50.3 (C-6^{I}); HRMS–ESI calcd for $C_{56}H_{63}NO_{10}$ (MH^+) 910.4525; found 910.4507.

The I and II descriptors refer to α-D-glucose and α-D-mannose residues respectively.

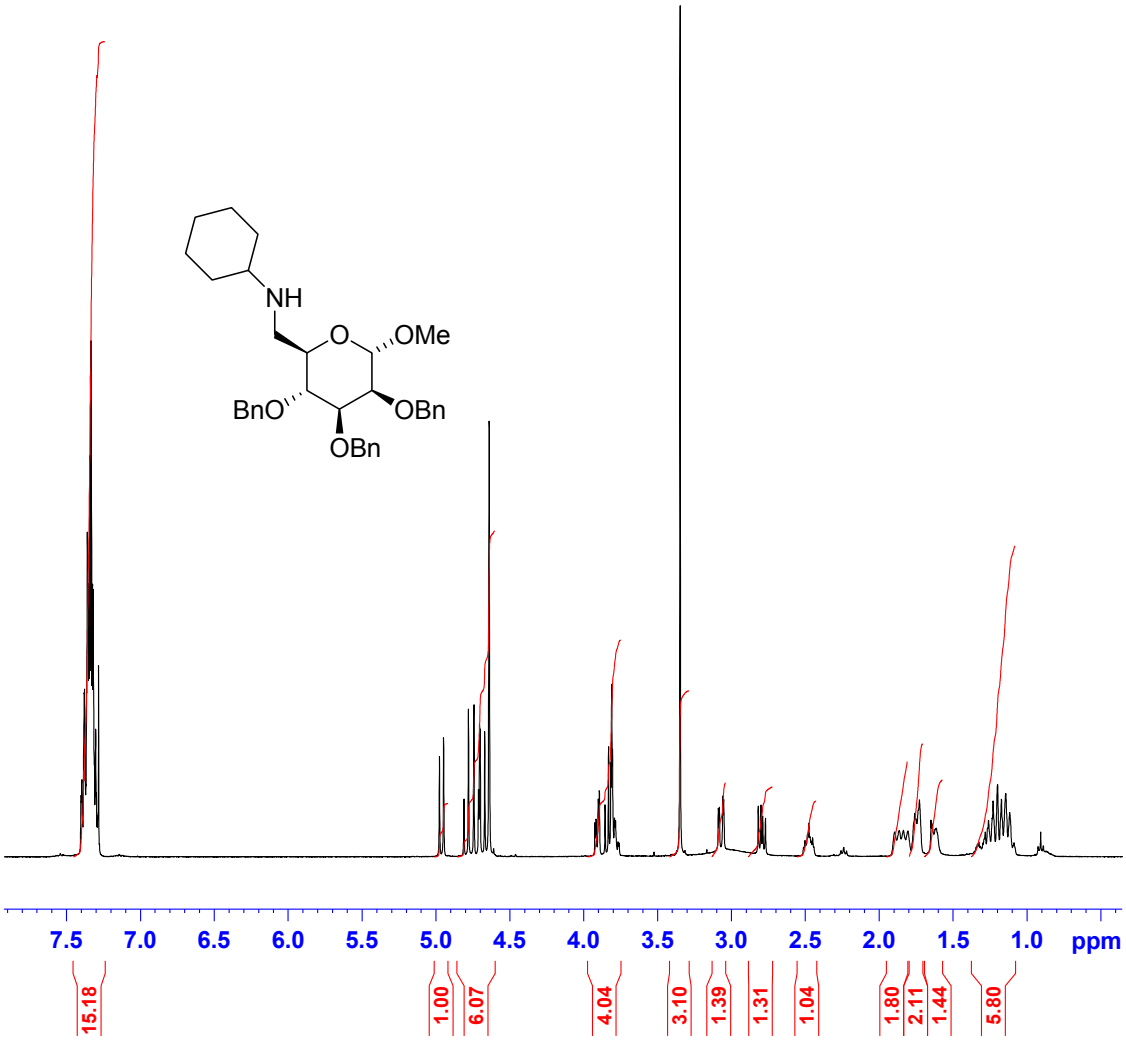
From gluco *amine and* manno *alcohol:* The title compound was synthesised from methyl 6-amino-2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranoside α-*Glc*-**12** (46 mg, 0.1 mmol) and methyl 2,3,4-tri-*O*-benzyl-α-D-mannopyranoside α-*Man*-**15** (138 mg, 0.3 mmol) according to general synthetic method C. The product ***Glc,Man*-17** was isolated by flash column chromatography (Pentane–EtOAc, 1:3) as a yellow oil (44 mg, 48%) identical to that described above.

(Methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl) (methyl 2,3,-di-*O*-benzyl-6-deoxy-β-D-glucopyranosid-6-yl)amine (*Glc,Glc*-19)

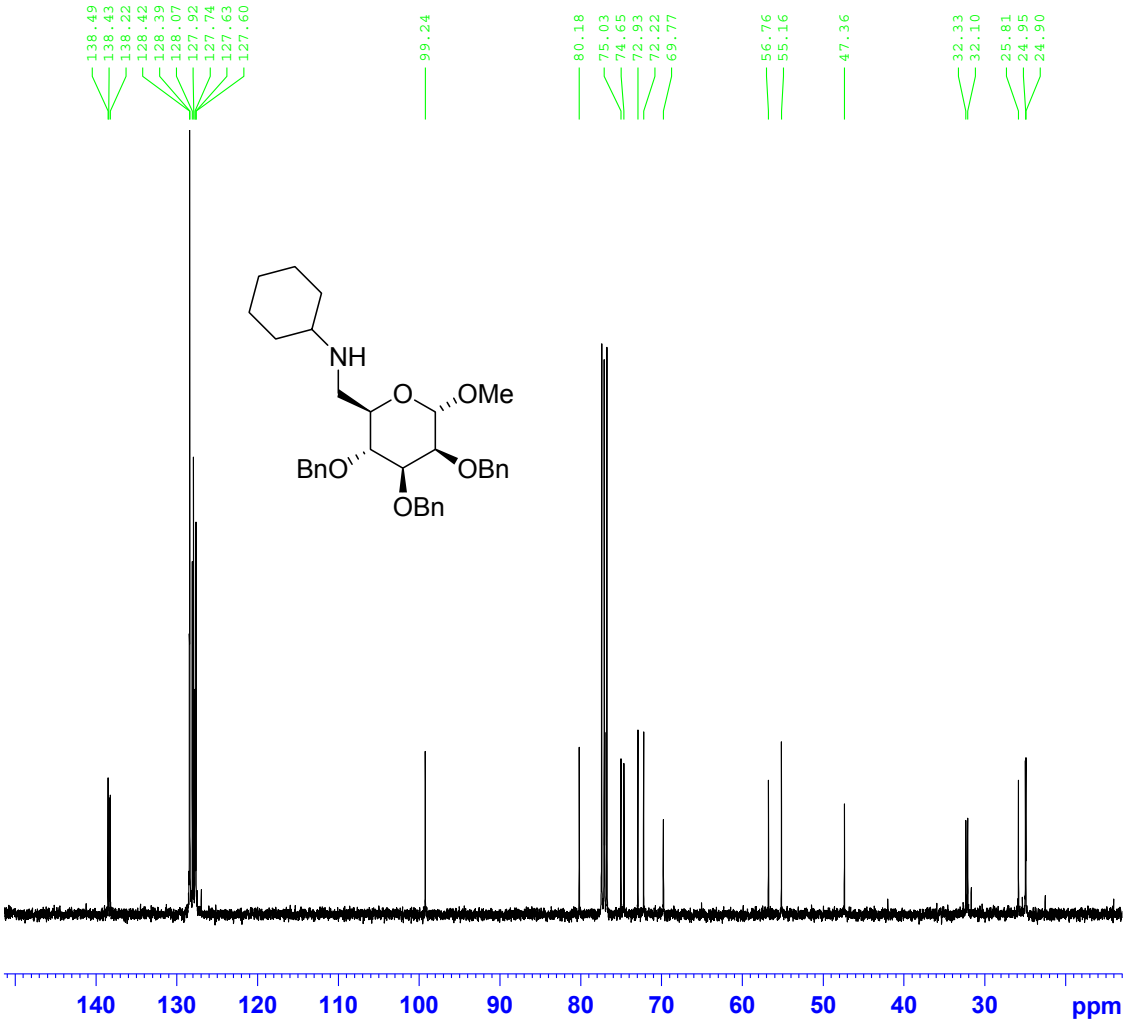
The title compound was synthesised from methyl 6-amino-2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranoside α-*Glc*-**12** (46 mg, 0.1 mmol) and methyl 2,3-di-*O*-benzyl-β-D-glucopyranoside β-*Glc*-**18** (112 mg, 0.3 mmol) according to general synthetic method C. The product ***Glc,Glc*-19** was isolated by flash column chromatography (EtOAc) as a yellow oil (58 mg, 71%); $[\alpha]_D^{23}$ = +29.6 (*c*, 0.5 in $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.39–7.29 (m, 25 H, Ar-H), 5.01–4.60 (m, 10 H, 5 × PhC<u>H</u>$_2$), 4.54 (d, $J_{1,2}$ = 3.6 Hz, 1 H, H-1^{I}), 4.31 (d, $J_{1,2}$ = 7.7 Hz, 1 H, H-1^{II}), 3.99 (at, J = 9.2 Hz, 1 H, H-3^{I}), 3.74 (m, 1 H, H-5^{I}), 3.60–3.34 (m, 11 H, 2 × OCH_3, H-2^{I}, H-4^{I}, H-2^{II}, H-3^{II}, H-4^{II}), 3.27 (m, 1 H, H-5^{II}), 2.98–2.83 (m, 3 H, H-6'^{I}, H-6^{II}, H-6'^{II}), 2.70 (dd, $J_{5,6}$ = 6.6 Hz, $J_{6,6'}$ = 12.4 Hz, 1 H, H-6^{I}), ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.8, 138.7, 138.5, 138.2, 138.1 (Ar-C), 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.6 (Ar-CH), 104.8 (C-1^{II}), 98.0 (C-1^{I}), 82.0 (C-3^{I}), 84.0, 81.6, 80.0, 79.4, 77.2, 75.7, 75.2, 75.0, 74.8, 73.4 (C-2^{II}, C-3^{II}, C-4^{II}, C-2^{I}, C-4^{I}, 5 × Ph<u>C</u>H_2), 72.0 (C-5^{II}), 69.3 (C-5^{I}), 57.1, 55.3 (2 × OCH_3), 52.7 (C-6^{II}), 50.5 (C-6^{I}); HRMS–ESI calcd for $C_{49}H_{57}NO_{10}$ (MH^+) 820.4055; found 820.4082.

The I and II descriptors refer to α-D- and β-D-glucose residues respectively.

5. ^{1}H and ^{13}C NMR spectra



Methyl 6-amino-2,3,4-tri-*O*-benzyl-6-*N*-cyclohexyl-6-deoxy-α-D-mannopyranoside (α-*Man*-3)



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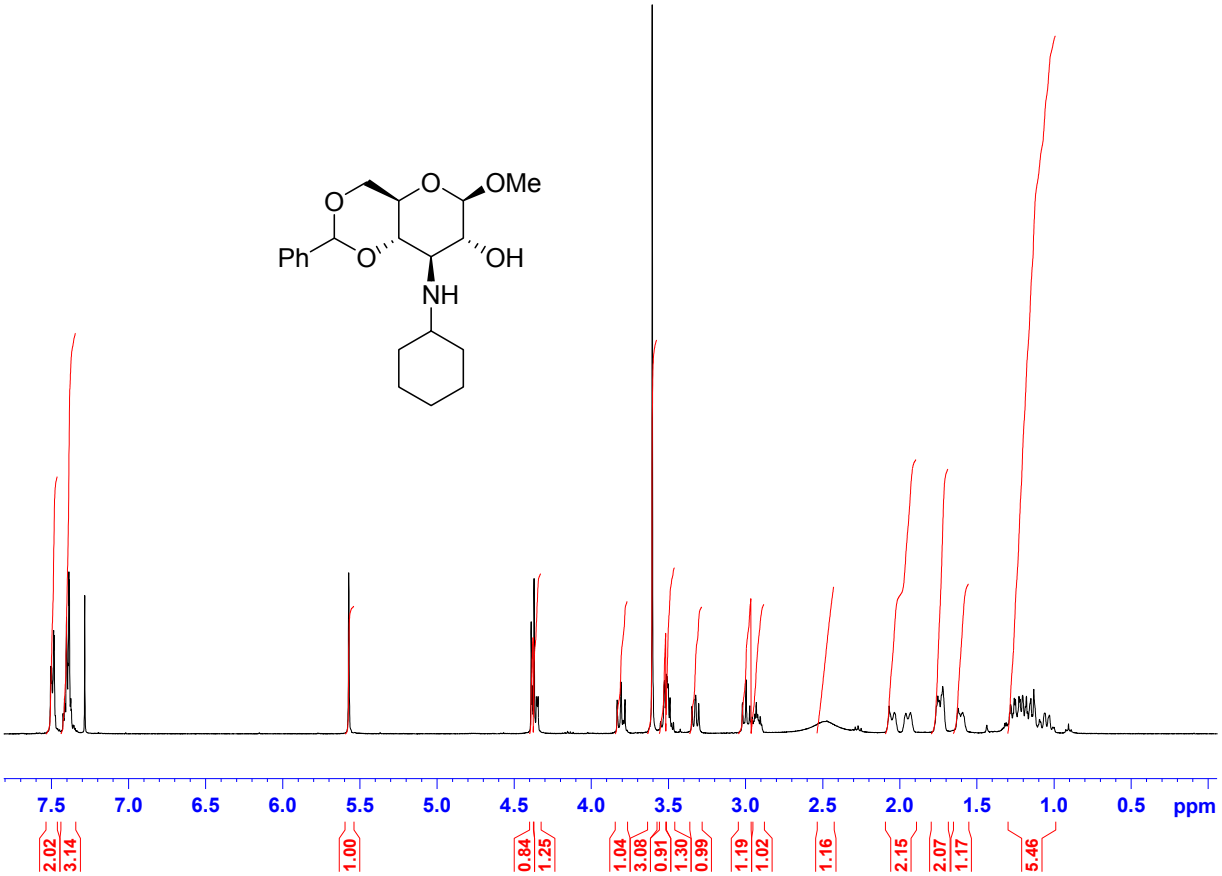
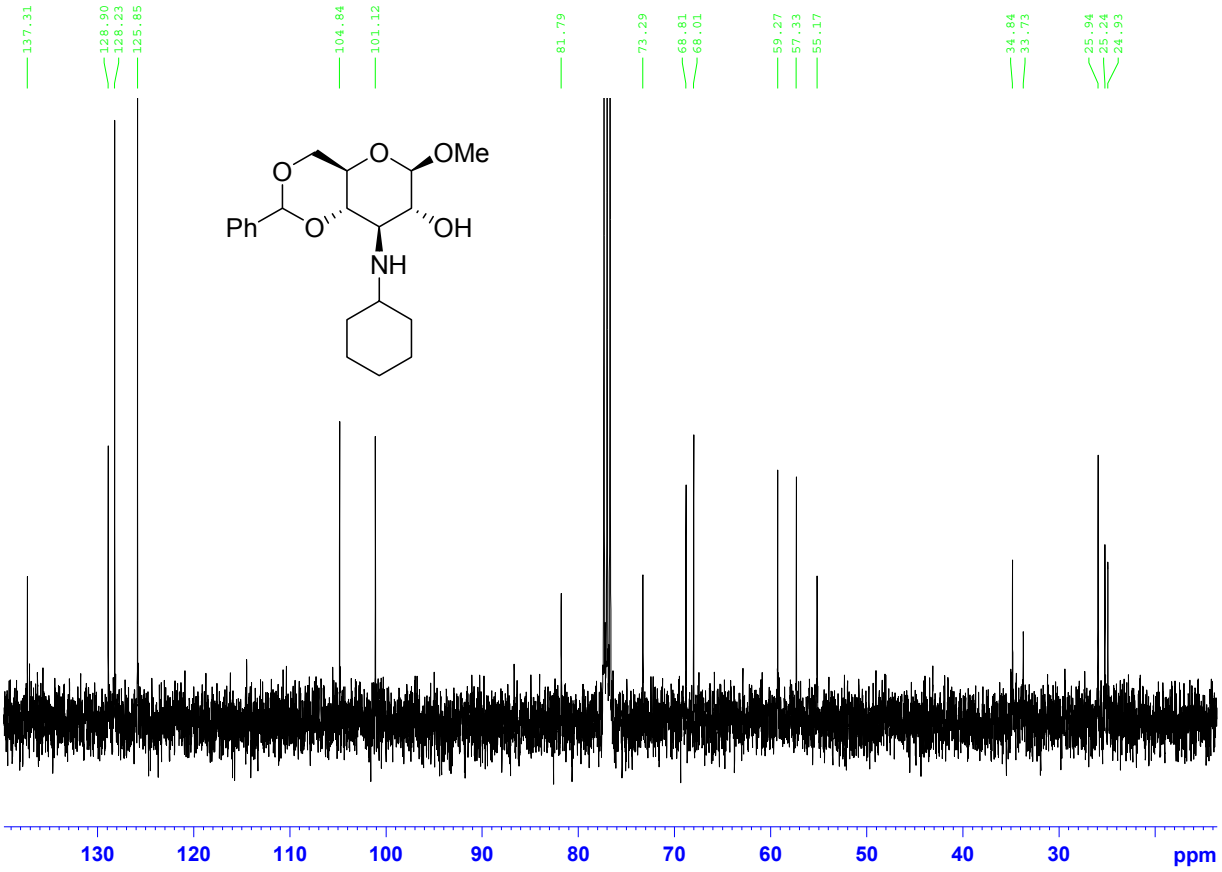


Methyl 3-amino-4,6-*O*-benzylidene-3-*N*-cyclohexyl-3-deoxy-β-D-glucopyranoside (β-*Glc*-7a)



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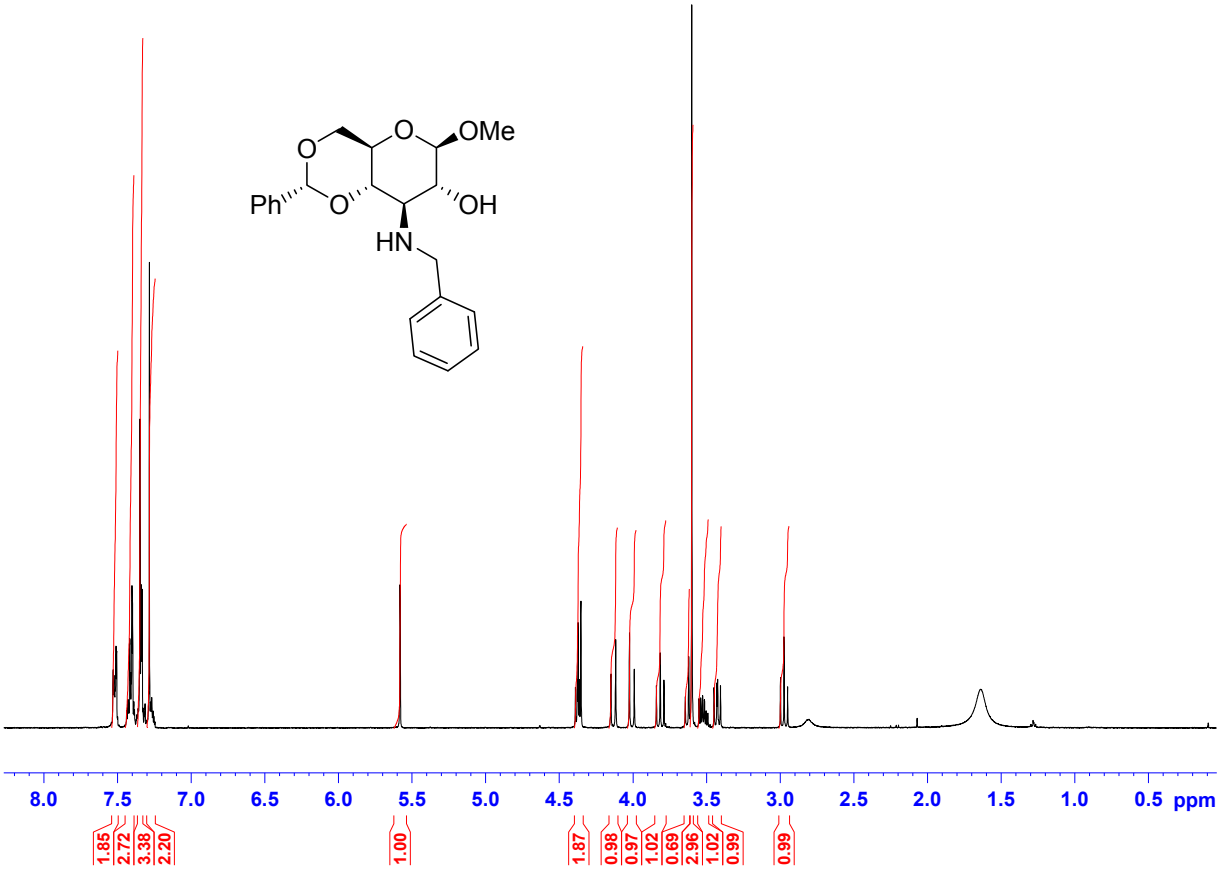

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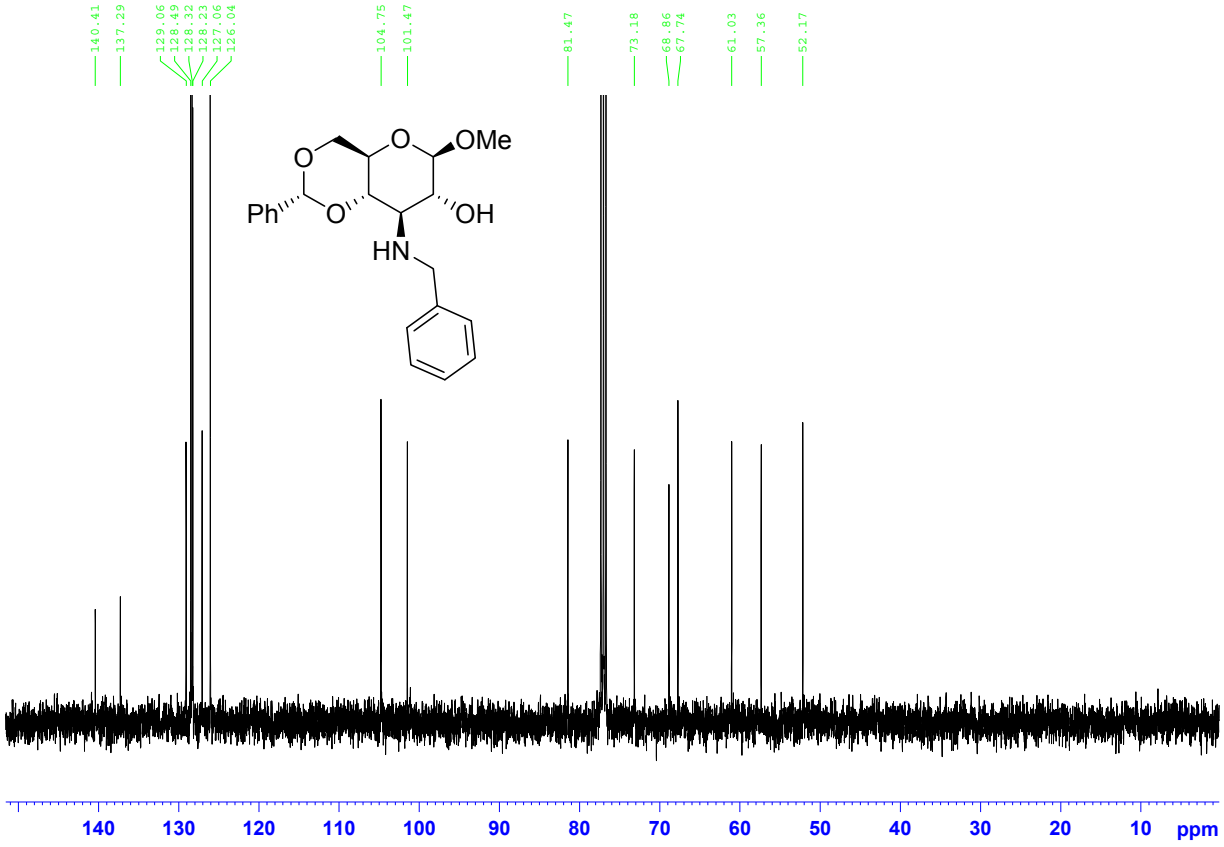

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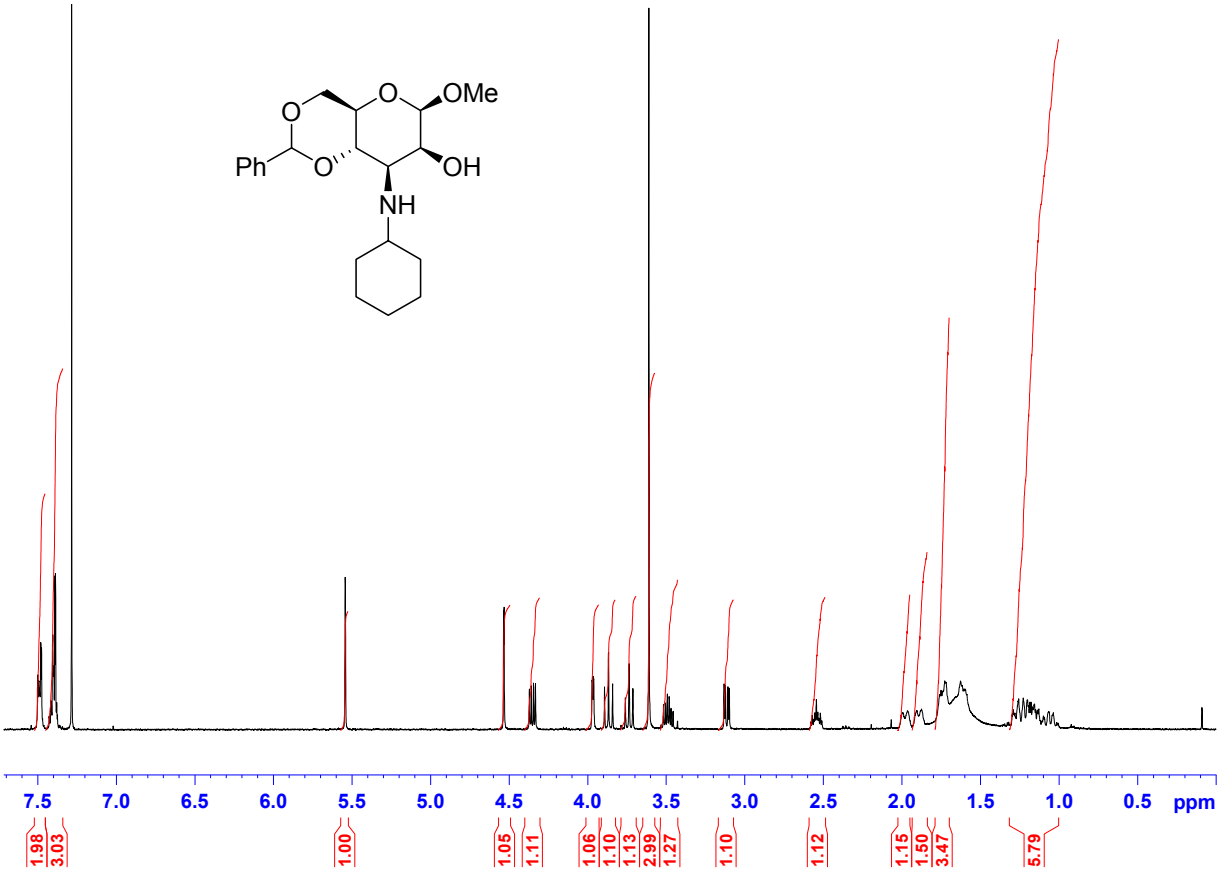
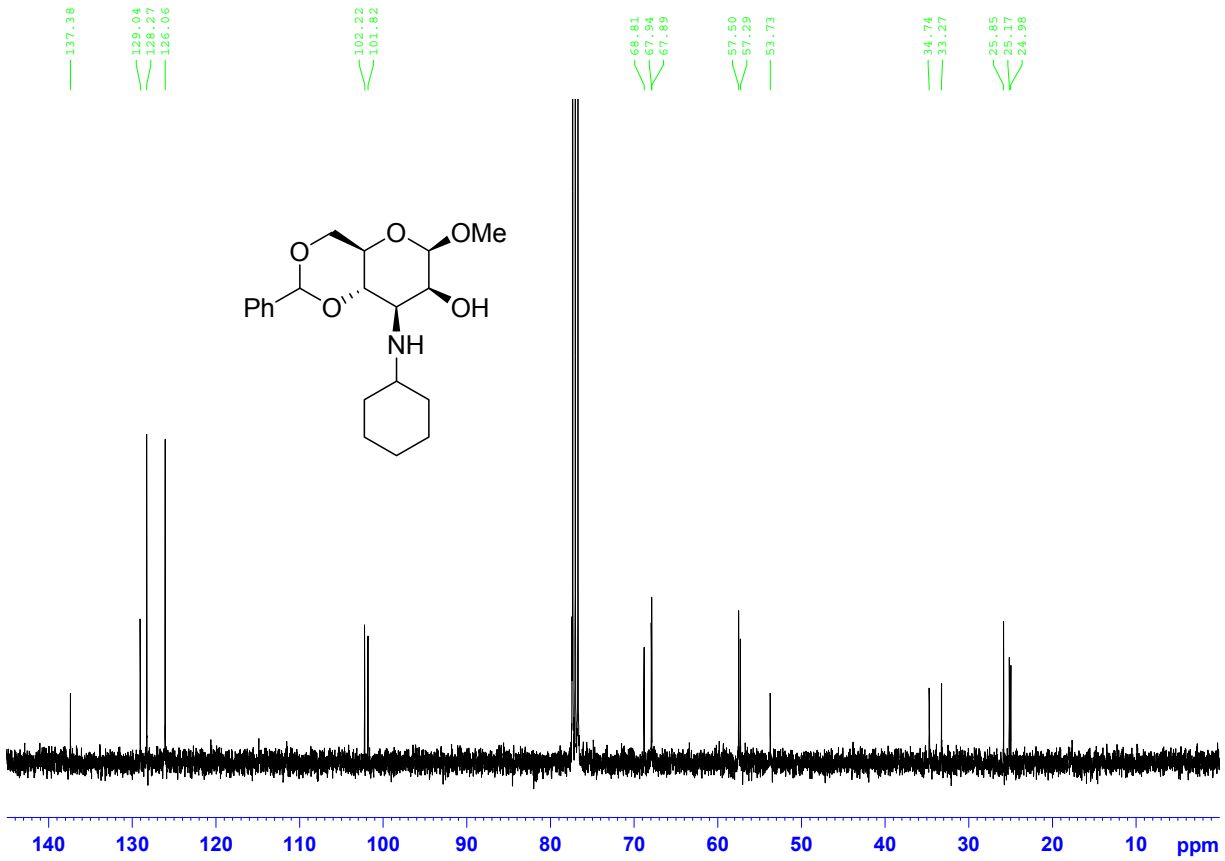


Methyl 3-amino-4,6-*O*-benzylidene-3-*N*-cyclohexyl-3-deoxy-β-D-mannopyranoside (β-*Man*-8)



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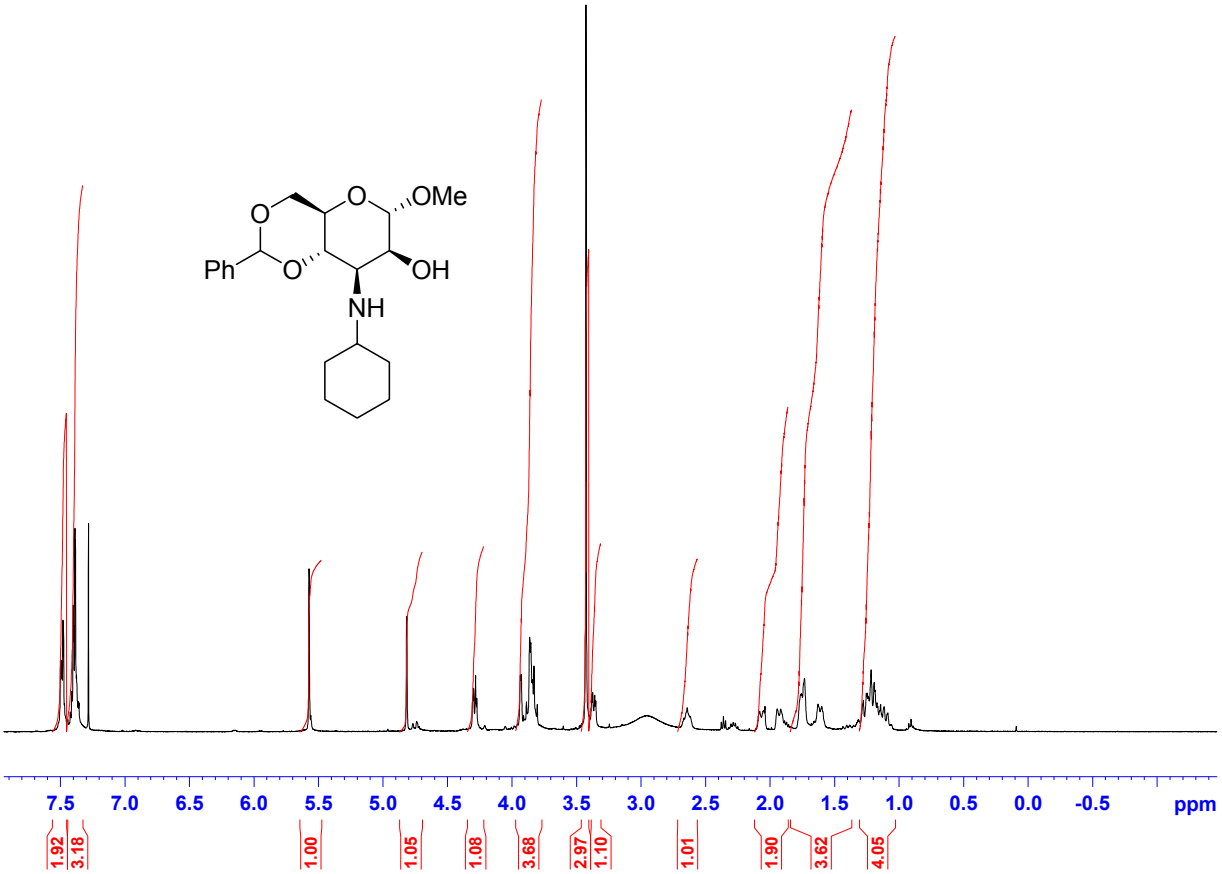

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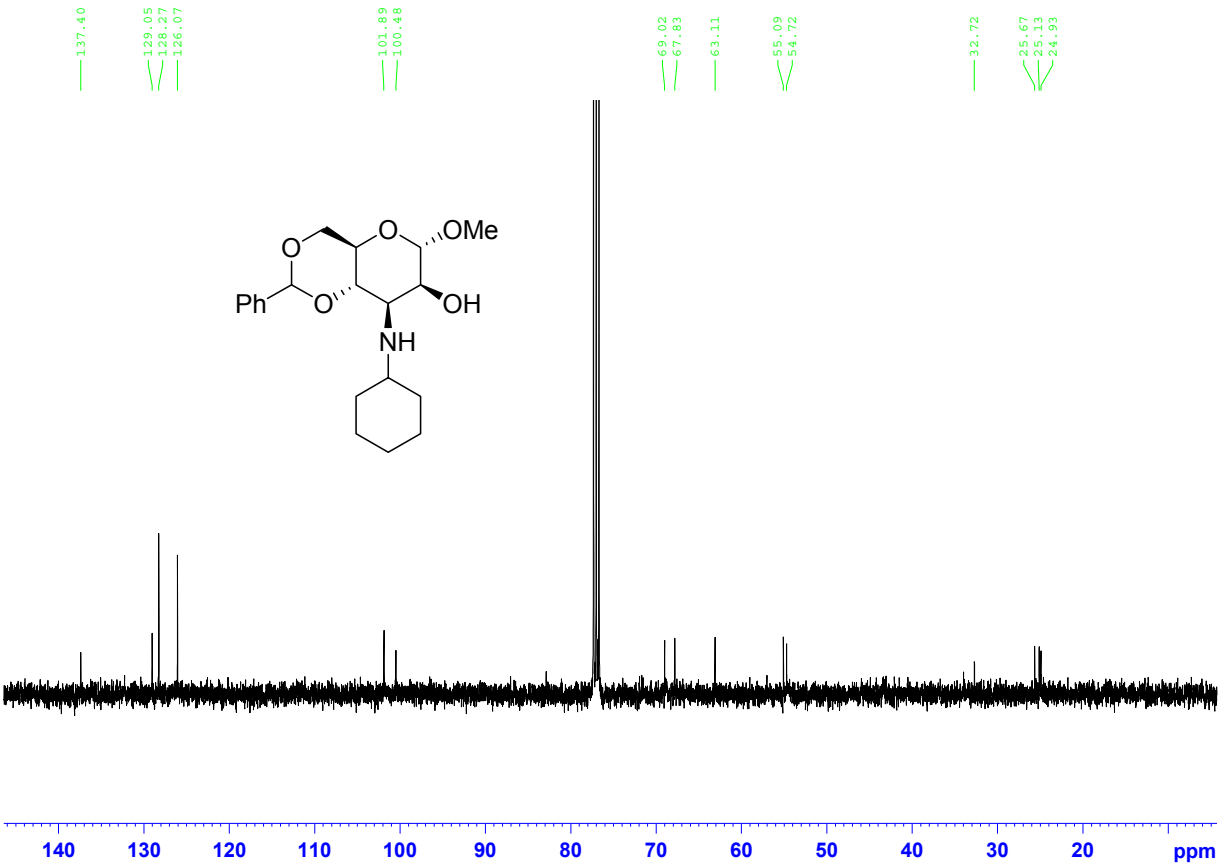

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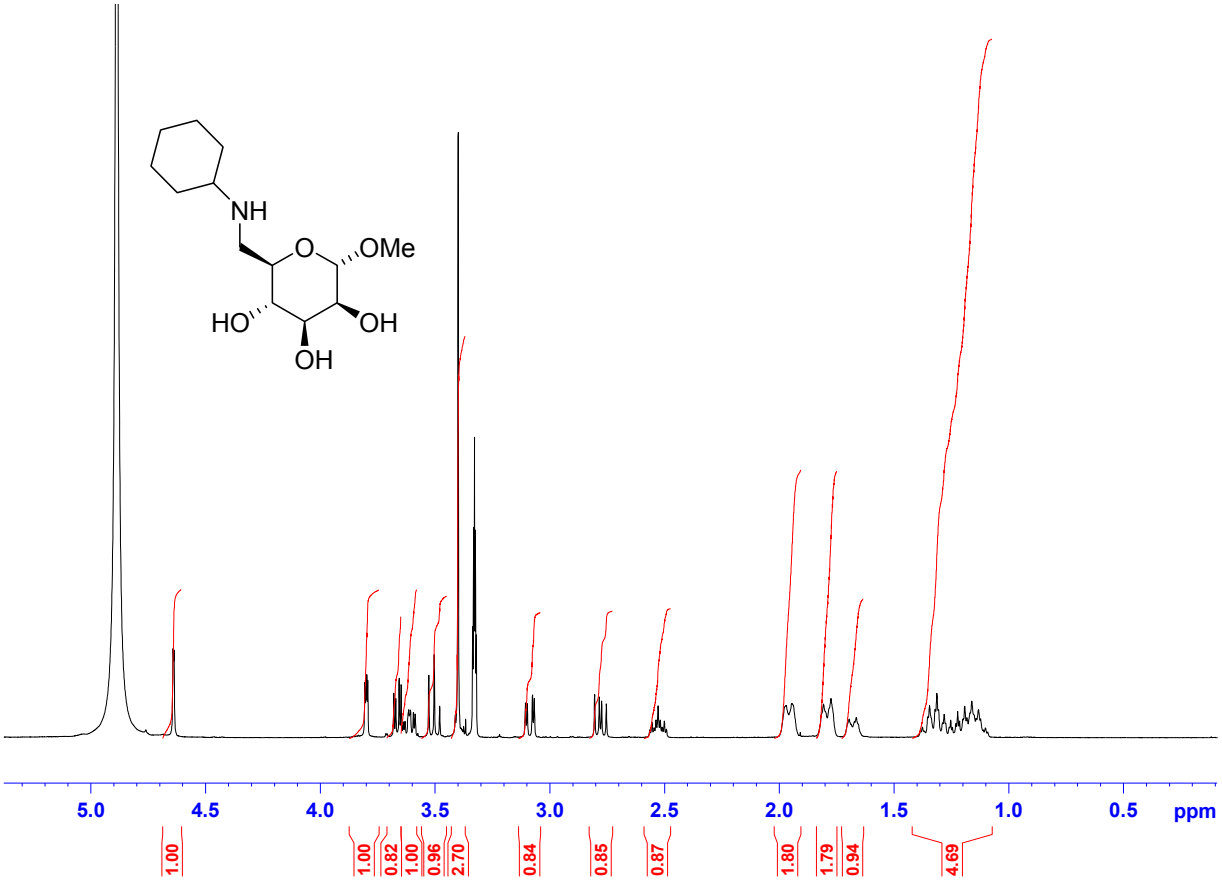
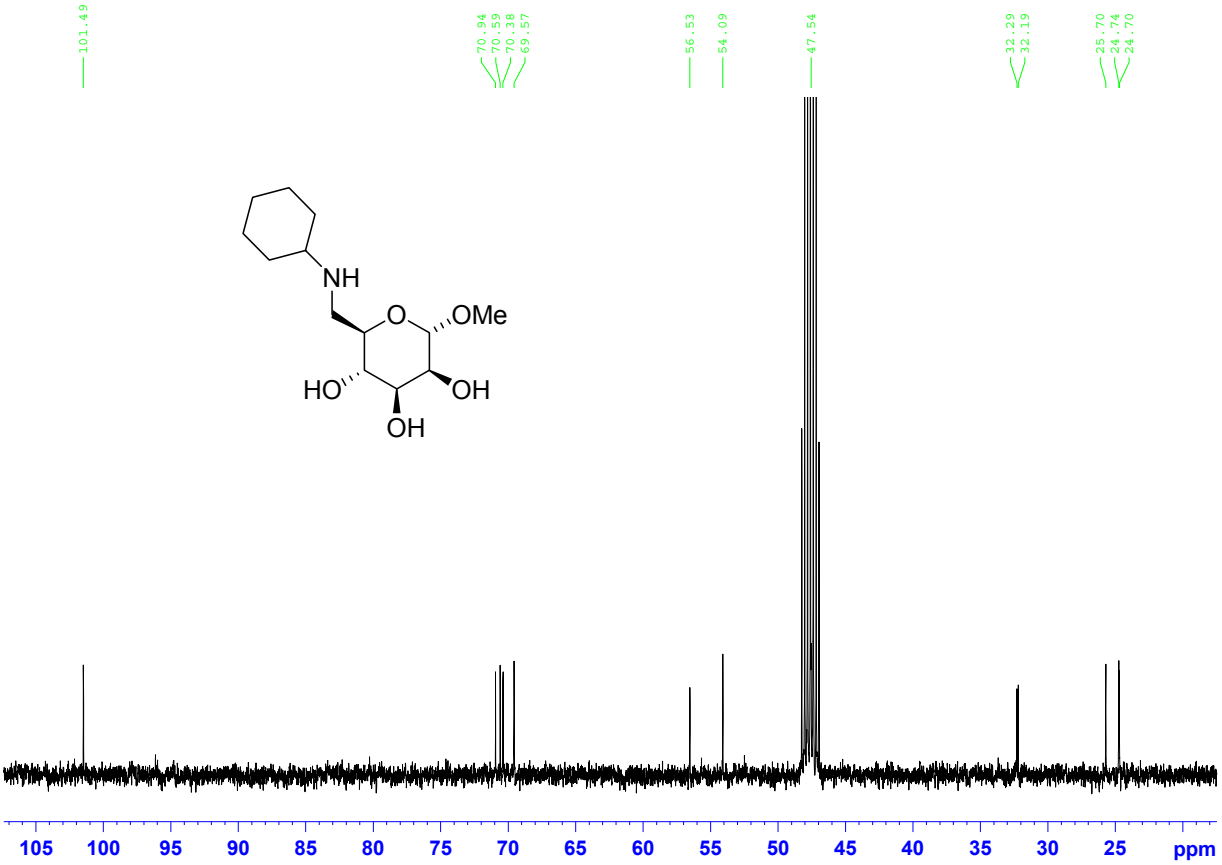
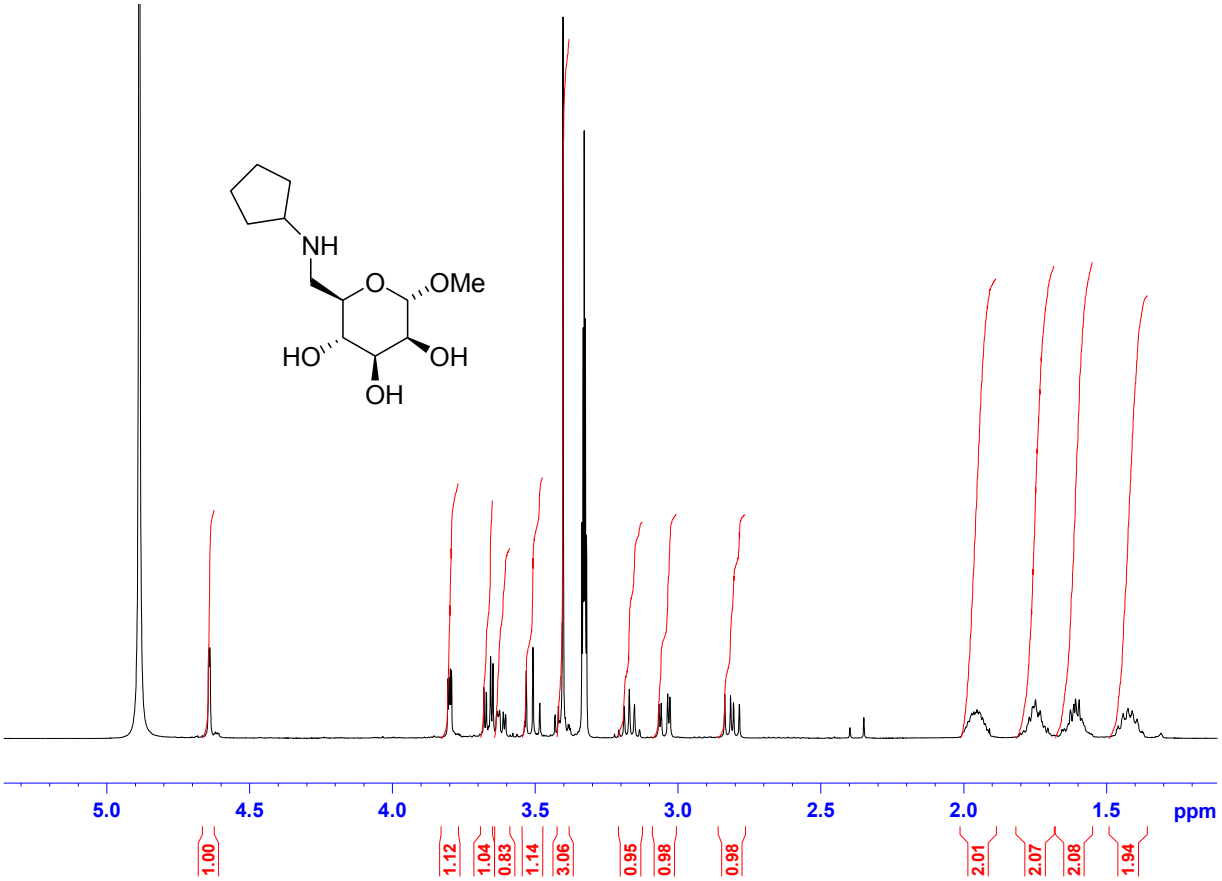


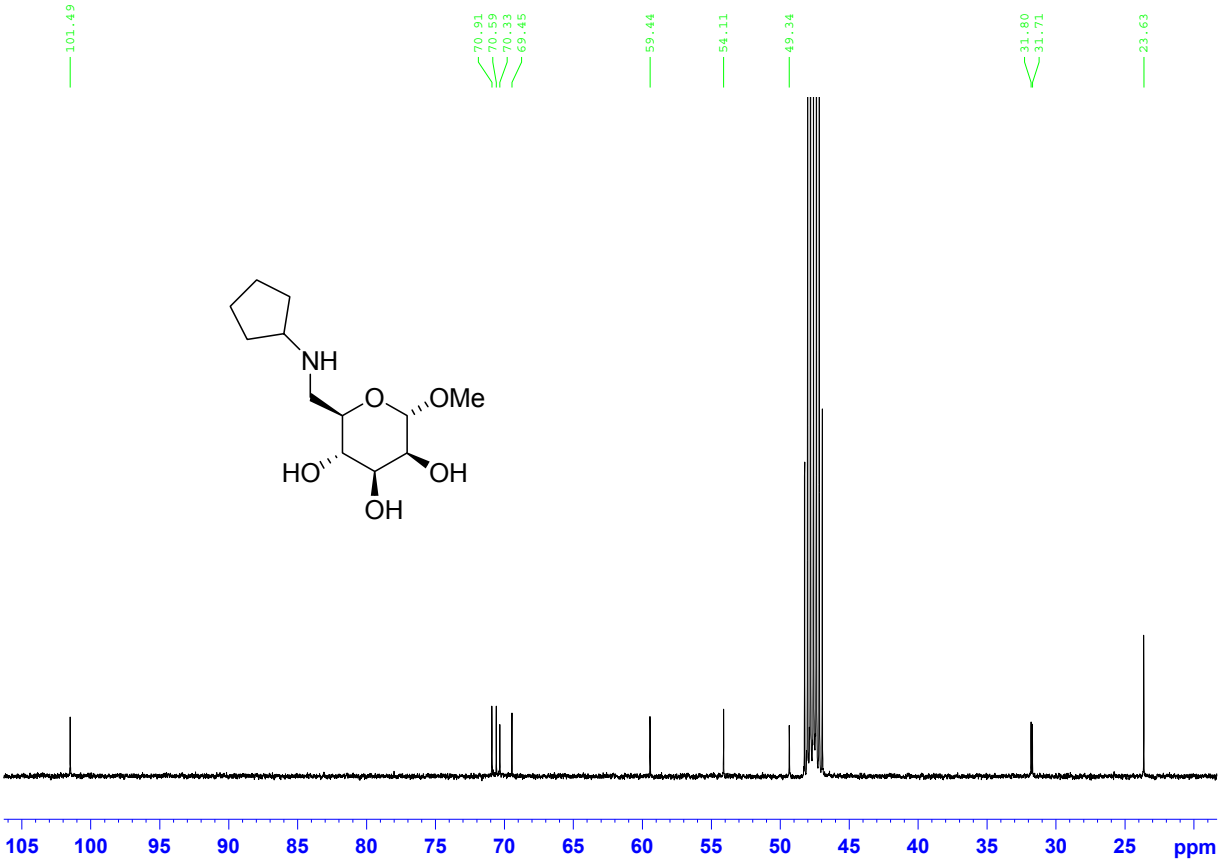
Methyl 6-amino-6-*N*-cyclohexyl-6-deoxy-α-D-mannopyranoside (α-*Man*-11a)



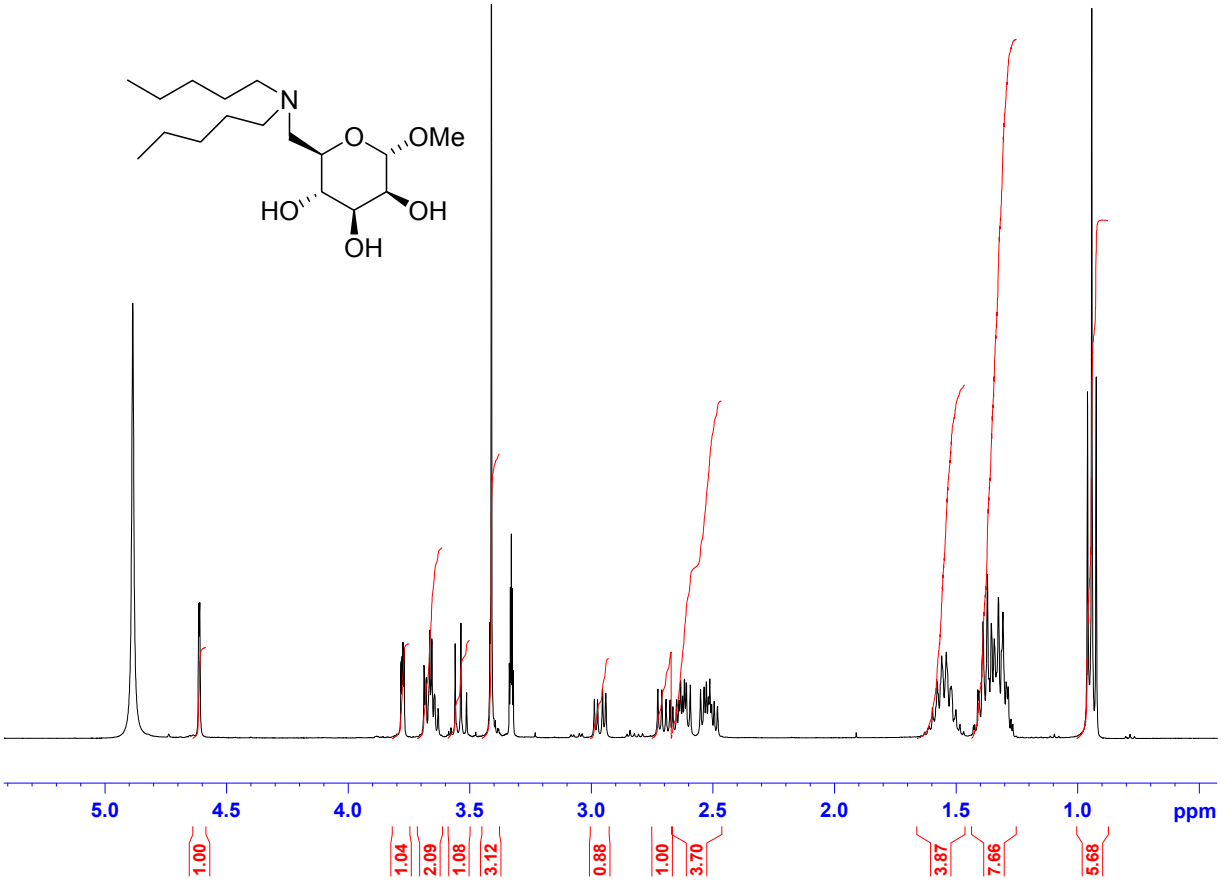
Methyl 6-amino-6-*N*-cyclohexyl-6-deoxy-α-D-mannopyranoside (α-*Man*-11a)



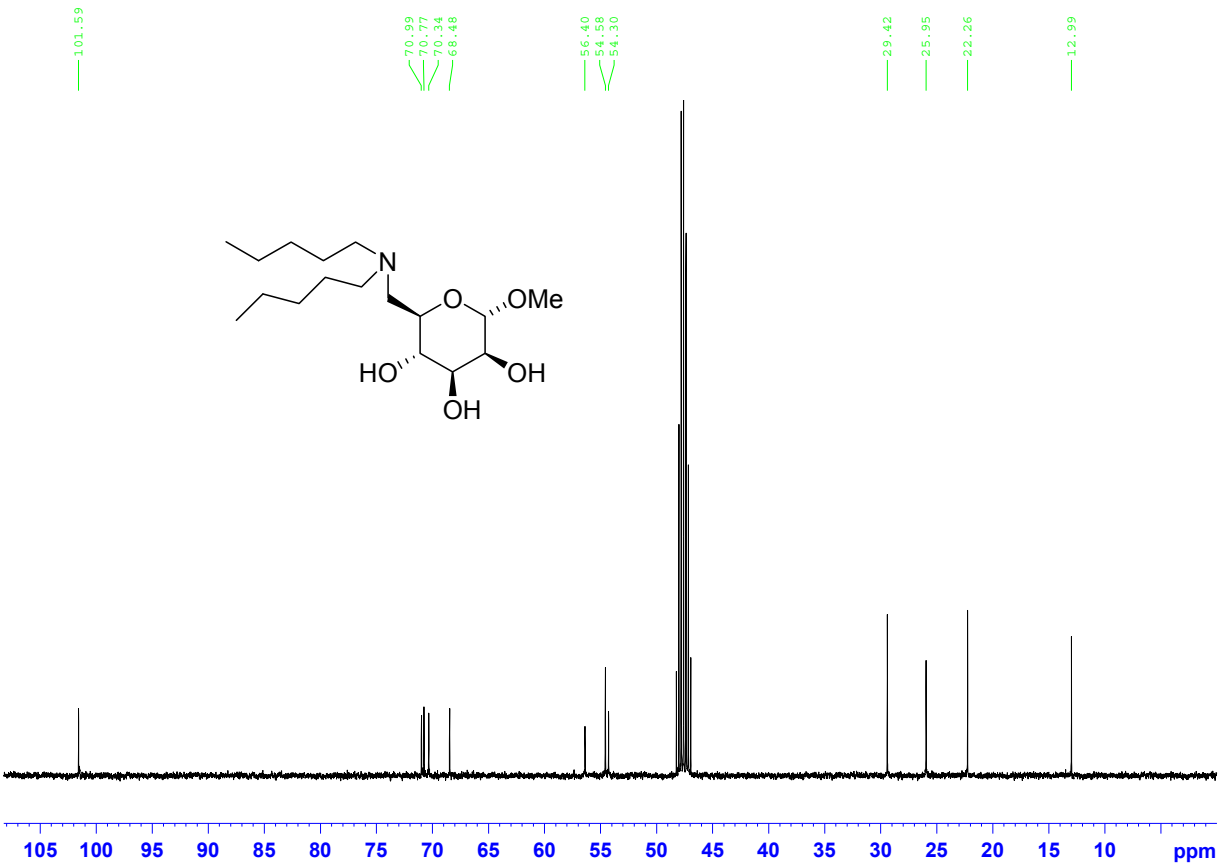
Methyl 6-amino-6-*N*-cyclopentyl-6-deoxy-α-D-mannopyranoside (α-*Man*-11c)



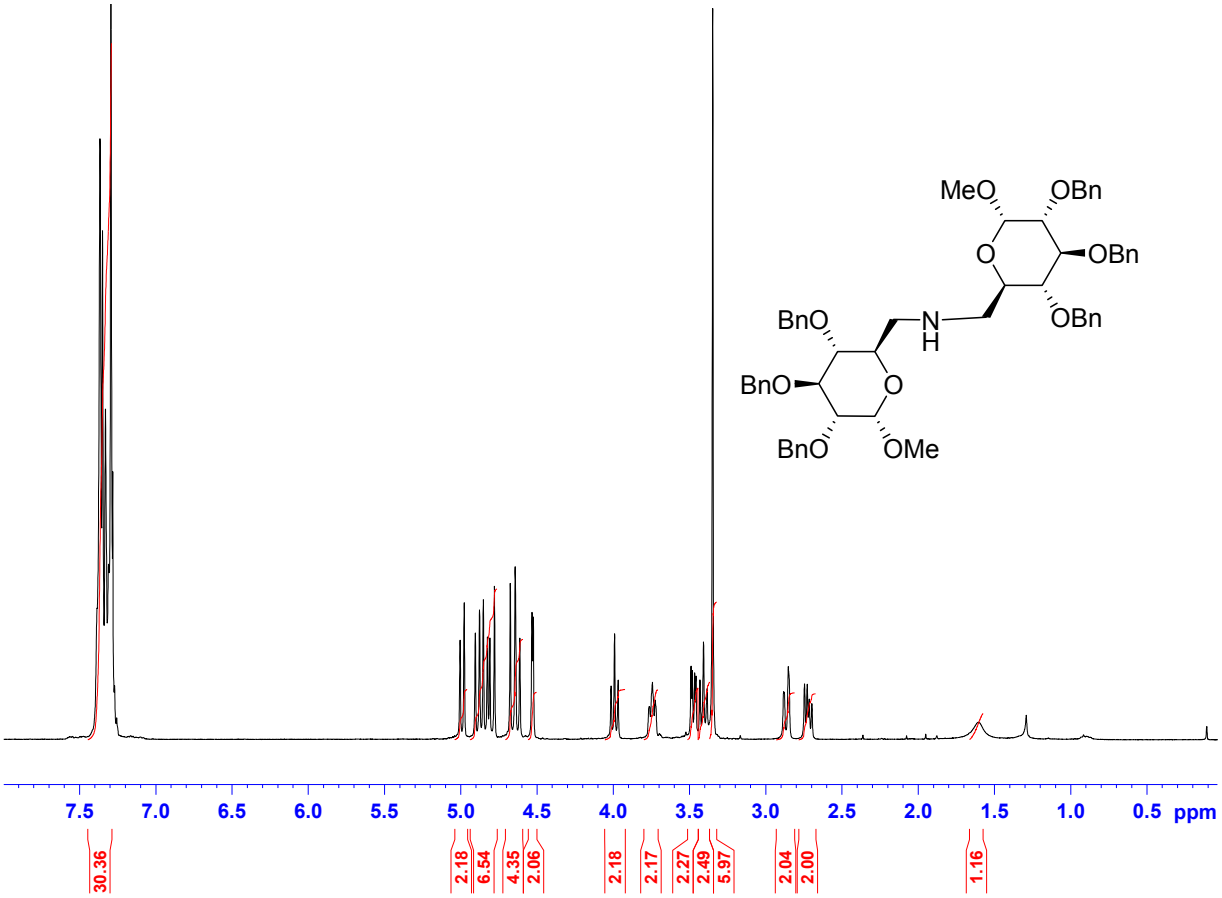
Methyl 6-amino-6-*N*-cyclopentyl-6-deoxy-α-D-mannopyranoside (α-*Man*-11c)



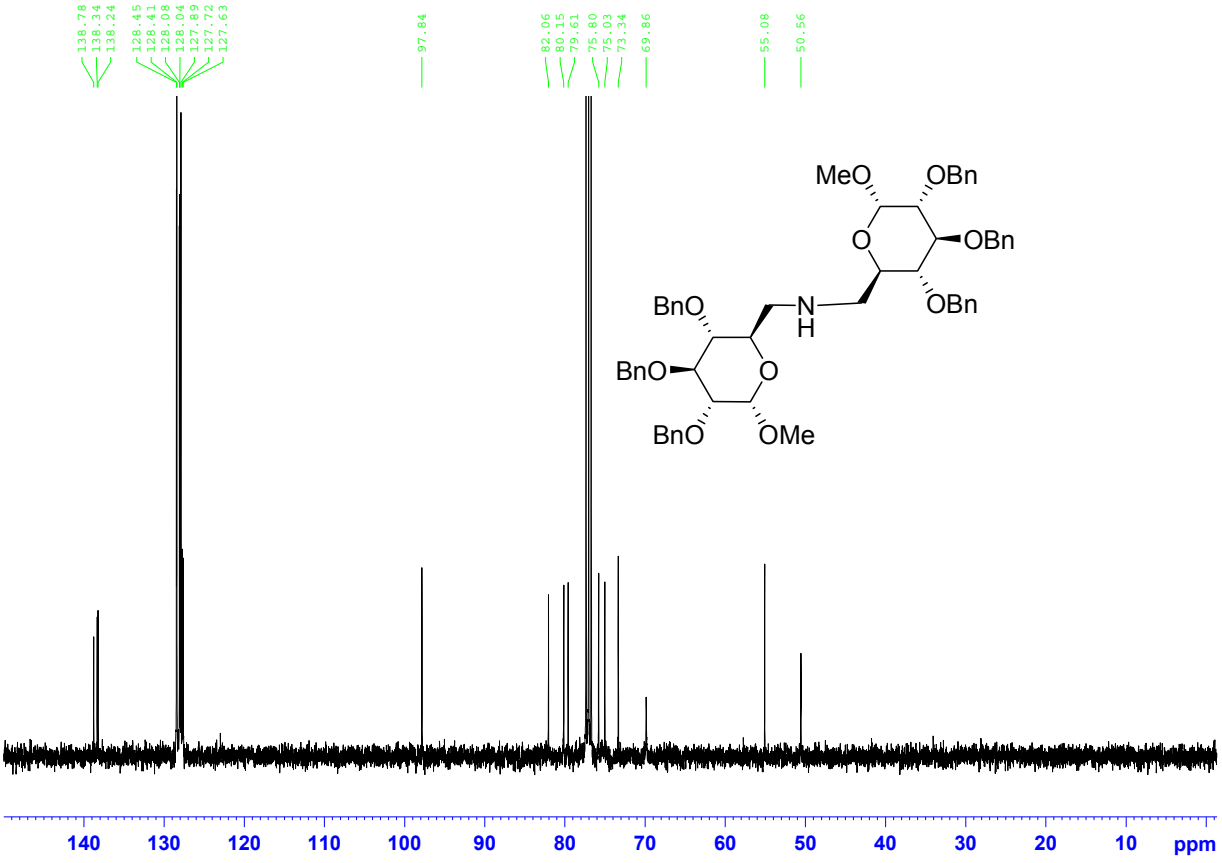
Methyl 6-amino-6-deoxy-6,6-di-*N*,*N*-(*n*-pentyl)-α-D-mannopyranoside (α-*Man*-11d)



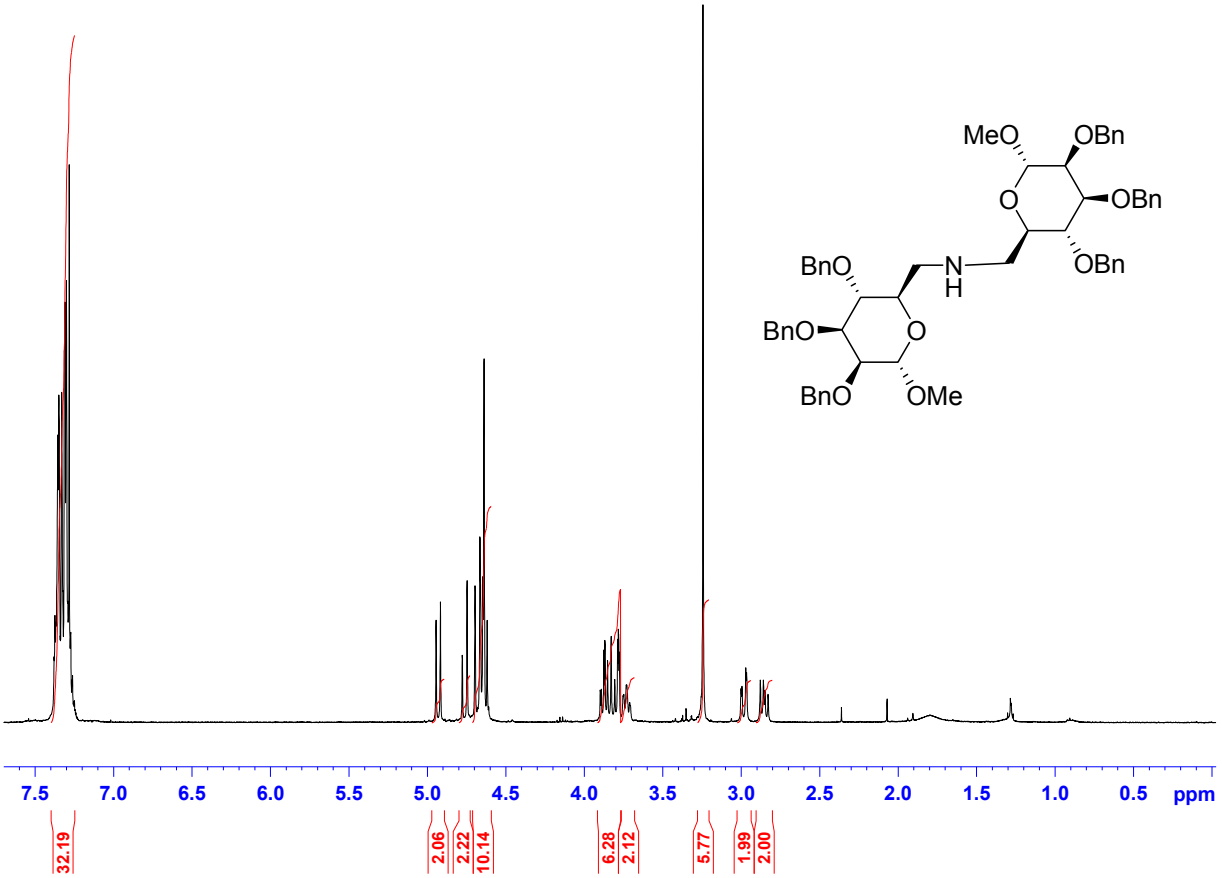
Methyl 6-amino-6-deoxy-6,6-di-*N*,*N*-(*n*-pentyl)-α-D-mannopyranoside (α-*Man*-11d)



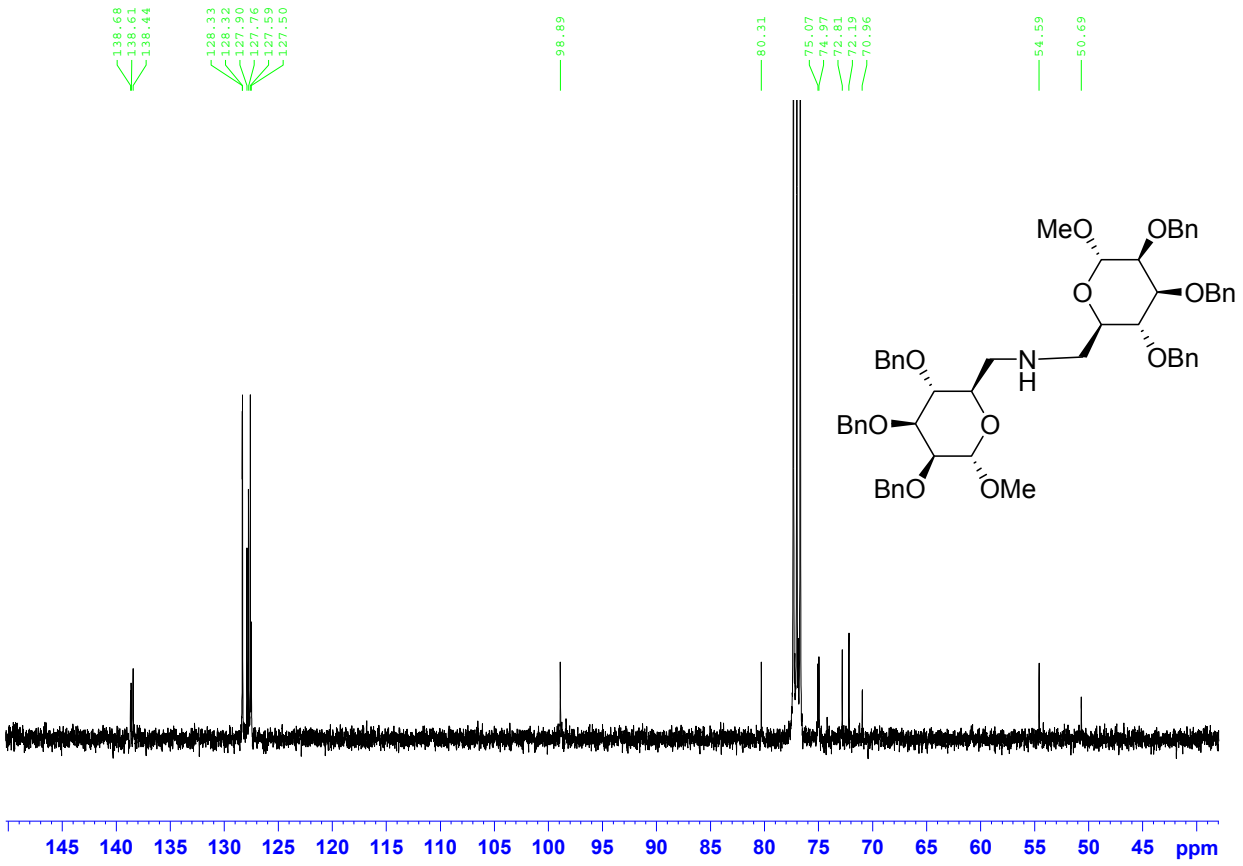
Bis(methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl)amine (*Glc,Glc*-14)



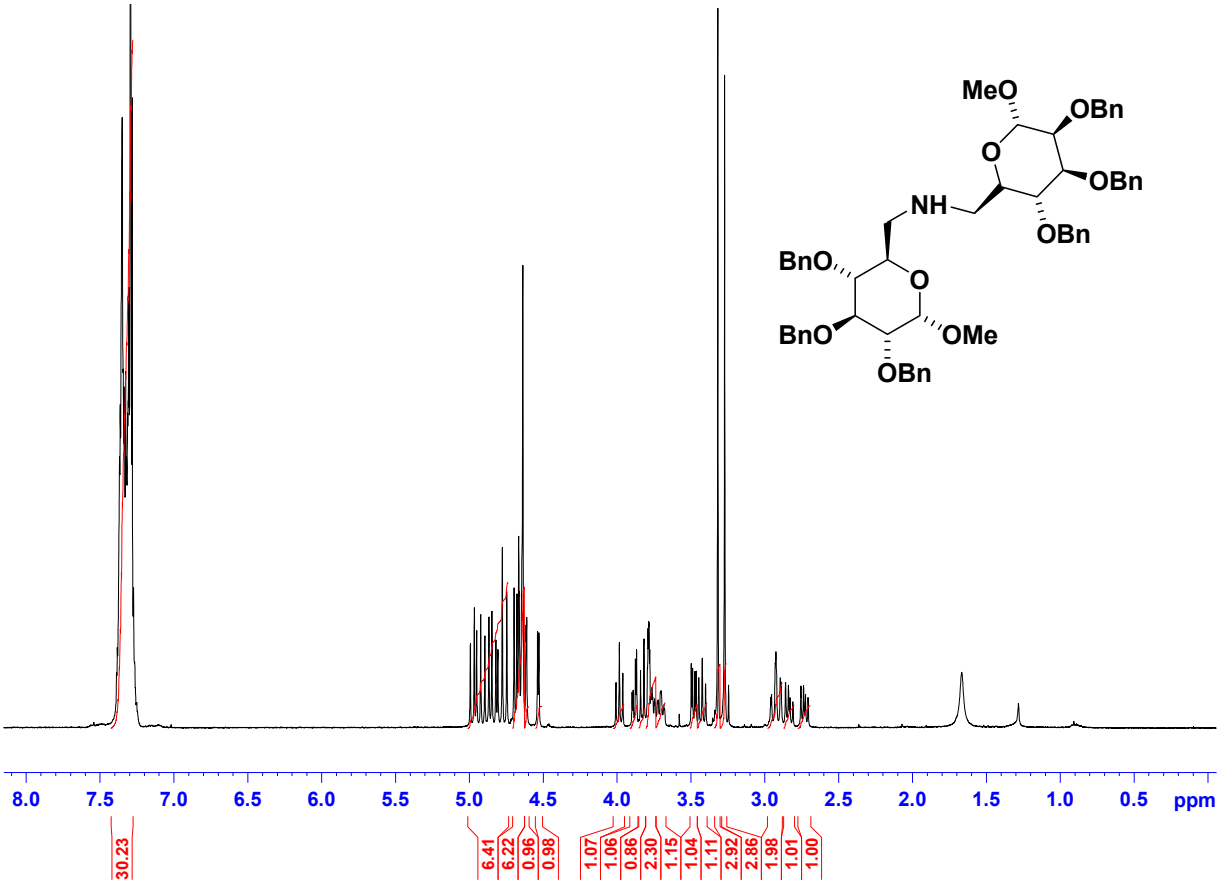
Bis(methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl)amine (*Glc,Glc*-14)



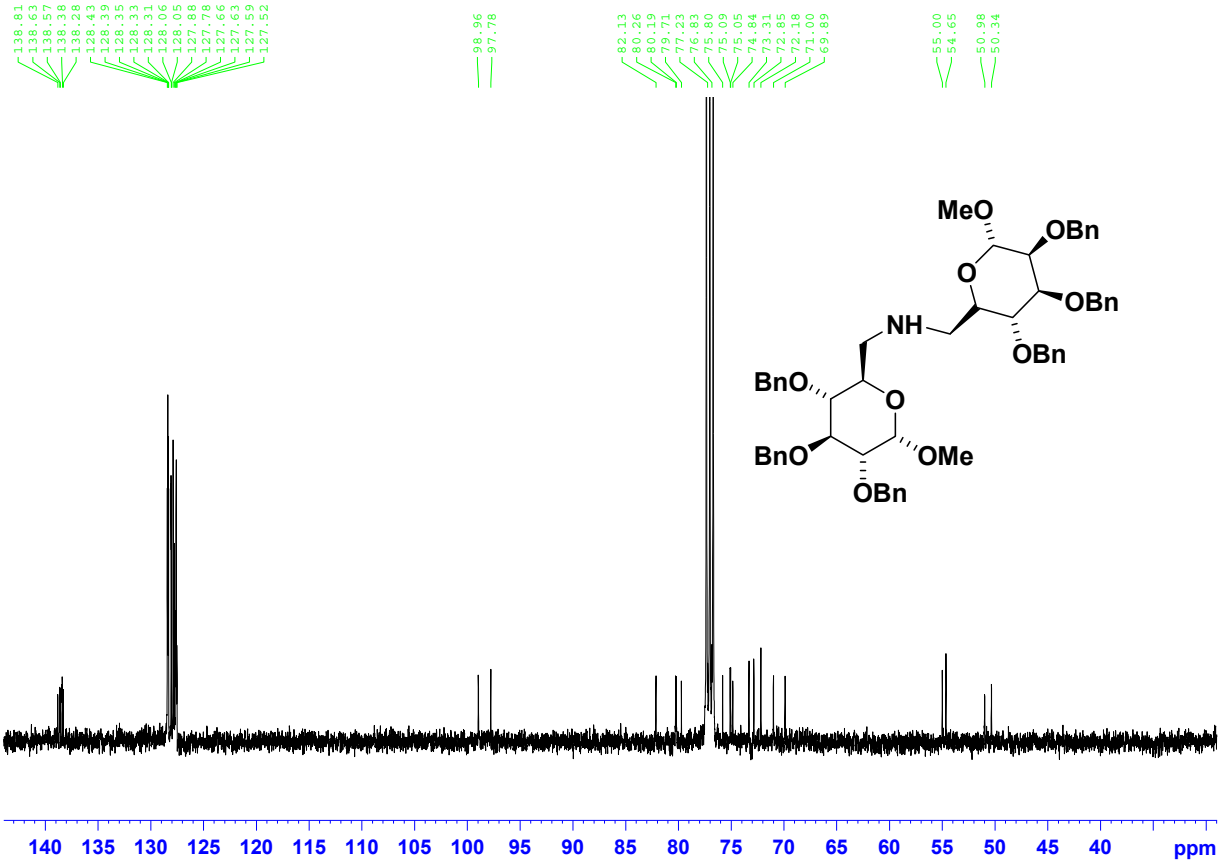
Bis(methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranosid-6-yl)amine (*Man,Man*-16)



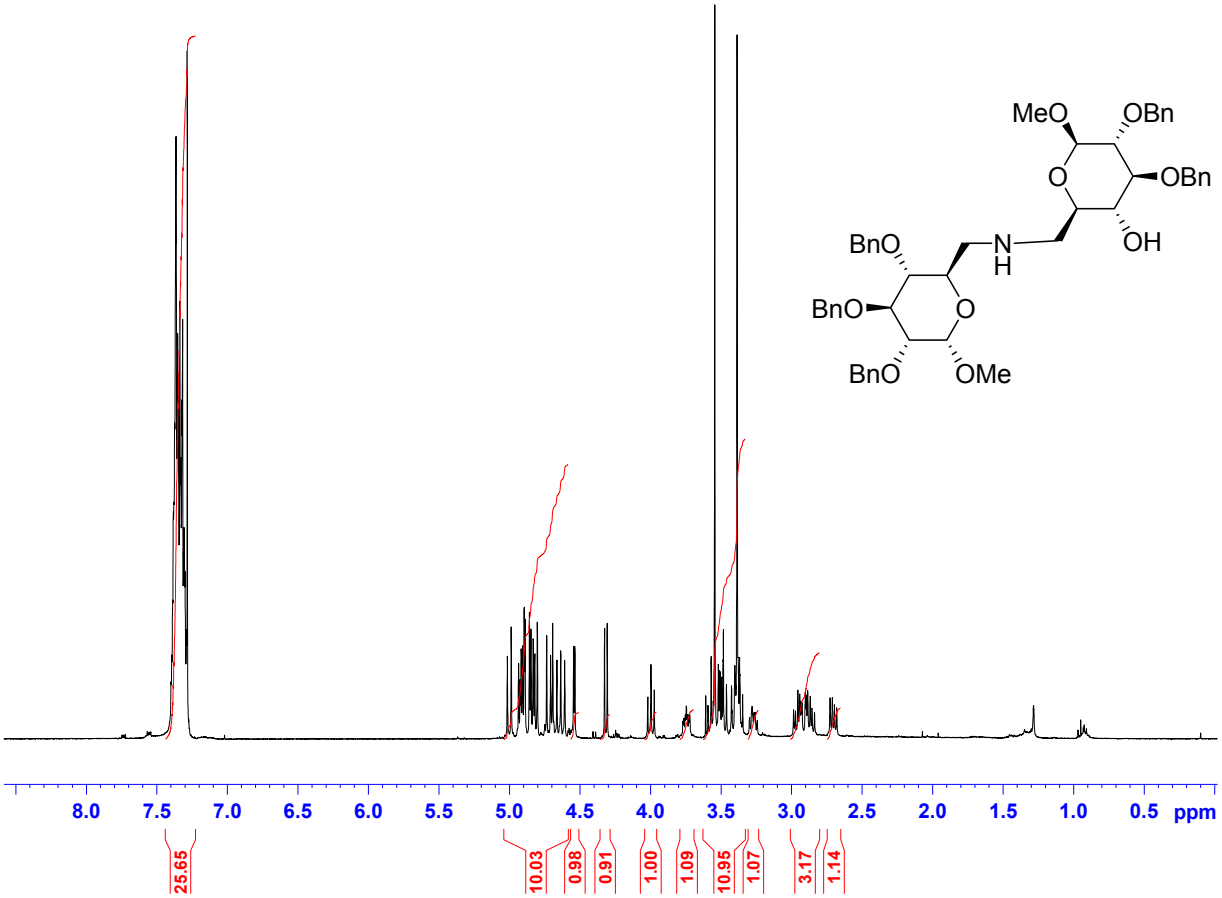
Bis(methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranosid-6-yl)amine (*Man,Man*-16)



(Methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl) (methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranosid-6-yl)amine (*Glc,Man*-17)



(Methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-glucopyranosid-6-yl) (methyl 2,3,4-tri-*O*-benzyl-6-deoxy-α-D-mannopyranosid-6-yl)amine (*Glc,Man*-17)



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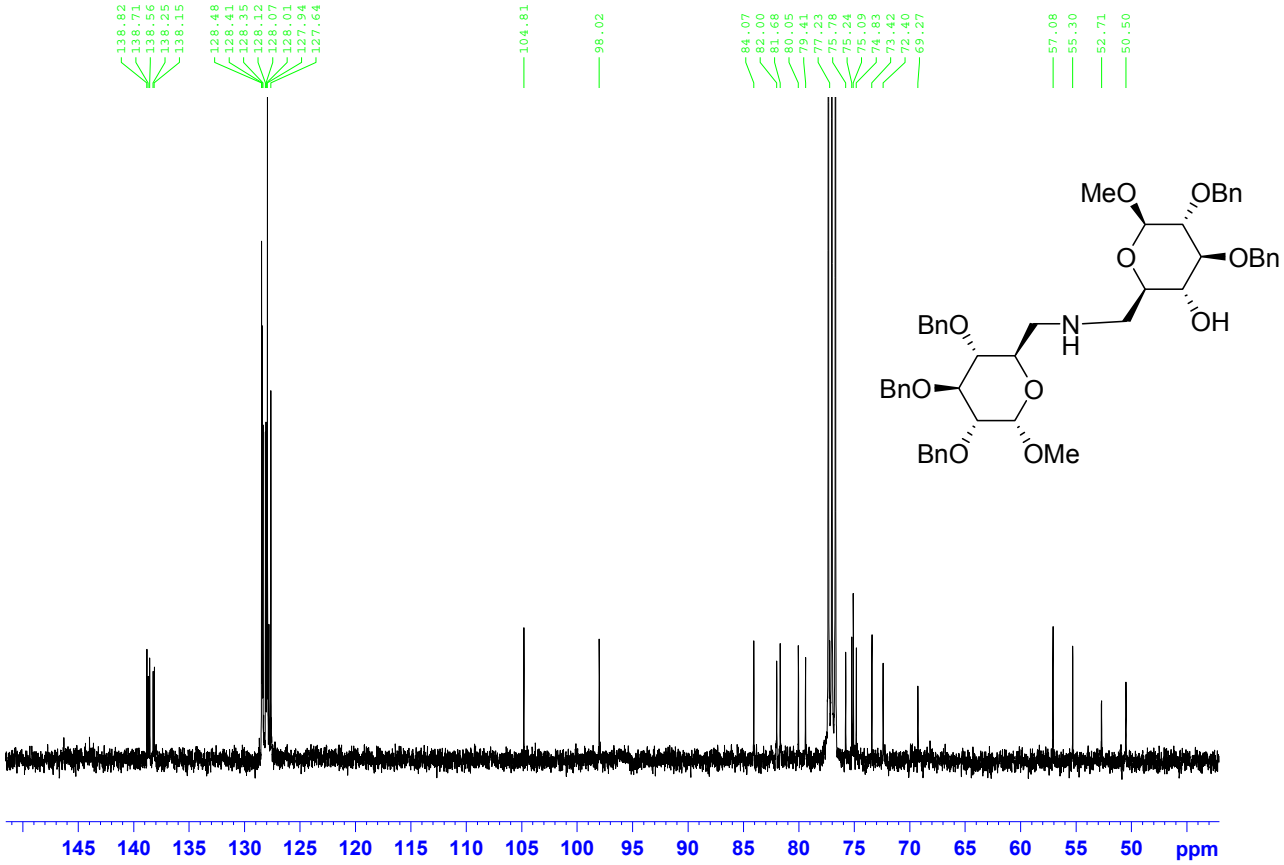

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