Chemical Synthesis of Homogeneous Syndecan-1 Heparan Sulfate Glycopeptide

Supporting Information

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General Experimental Procedures. All reactions were carried out under nitrogen with anhydrous solvents in flame-dried glassware, unless otherwise noted. Glycosylation reactions were performed in the presence of molecular sieves, which were flame–dried right before the reaction under high vaccum. Glycosylation solvents were dried using a solvent purification system and used directly without further drying. Chemicals used were reagent grade as supplied except where noted. Compounds were visualized by UV light (254 nm) and by staining with a yellow solution containing $Ce(NH_4)_2(NO_3)_6$ (0.5 g) and $(NH_4)_6Mo_7O_{24}$ $4H_2O$ (24.0 g) in 6% H_2SO_4 (500mL). Flash column chromatography was performed on silica gel 60 (230-400 Mesh). NMR spectra were referenced using residual $CHCl_3$ (δ ^{1}H-NMR 7.26 ppm, ^{13}C-NMR 77.0 ppm). Peak and coupling constants assignments are based on ^{1}H-NMR, ^{1}H-^{1}H gCOSY and (or) ^{1}H-^{13}C gHMQC and ^{1}H-^{13}C gHMBC experiments.

Characterization of anomeric stereochemistry. The stereochemistries of the newly formed glycosidic linkages were determined by $^3J_{H1,H1}$ through ^{1}H-NMR and/or $^1J_{C1,H1}$ through gHMQC 2-D NMR (without ^{1}H decoupling). Smaller coupling constants of $^3J_{H1,H2}$ (around 3 Hz) indicate α linkages and larger coupling constants $^3J_{H1,H1}$ (7.2 Hz or larger) indicate β linkages. $^1J_{C1,H1}$ around 170 Hz suggests α linkages and 160 Hz suggests β linkages.[1]

General procedure for pre-activation based single-step glycosylation. A solution of donor (60 μmol) and freshly activated molecular sieve MS 4 Å (200 mg) in DCM (2 mL) was stirred at room temperature for 30 minutes, and cooled to −78 °C, which was followed by addition of AgOTf (47 mg, 180 μmol) dissolved in Et_2O (1 mL) without touching the wall of the flask. After 5 minutes, orange colored *p*-TolSCl (9.5 μL, 60 μmol) was added to the solution through a microsyringe. Since the reaction temperature was lower than the freezing point of *p*-TolSCl, *p*-TolSCl was added directly into the reaction mixture to prevent it from freezing on the flask wall. The characteristic yellow color of *p*-TolSCl in the reaction solution dissipated rapidly within a few seconds indicating depletion of *p*-TolSCl. After the donor was completely consumed according to TLC analysis (about 5 minutes at −78 °C), a solution of acceptor (54 μmol) in DCM (0.2 mL) was slowly added dropwise via a syringe together with one equivalent of TTBP. The reaction mixture was warmed to 0 °C under stirring in 2 h. Then the mixture was diluted with DCM (20 mL) and filtered over Celite. The Celite was further washed with DCM until no organic compounds were observed in the filtrate by TLC. All DCM solutions were combined and washed twice with a saturated aqueous solution of $NaHCO_3$ (20 mL) and twice with water (10 mL). The organic layer was collected and dried over Na_2SO_4. After removal of the solvent, the desired oligosaccharide was purified from the reaction mixture via silica gel flash chromatography.

General procedure for protection of 6-OH with Lev. The compound containing 6-OH (1 equiv.) was dissolved in DCM (for 0.5 g of compound, 5 mL), followed by addition of levulinoyl acid (1.4 equiv.), EDC-HCl (1.6 equiv.) and DMAP (0.1 equiv.). The mixture was stirred at room temperature overnight and then was diluted with DCM (100 mL). The organic phase was washed with a saturated aqueous solution of $NaHCO_3$ and then dried

over Na_2SO_4. The solvent was concentrated in vacuo and the compound was purified by silica gel column chromatography.

General procedure for deprotection of Lev. The Lev-protected compound (1 equiv.) was dissolved in DCM/MeOH (for 150 mg of compound, 2.4 mL, 1:1) and acetic acid (0.2 mL). The mixture was cooled to 0 ^{o}C, followed by addition hydrazine monohydrate (5 equiv. for each Lev). The mixture was stirred at 0 °C for 2h and then was quenched by acetone (0.28 mL). The mixture was stirred at room temperature for another 1h and the acetone was evaporated under vaccum. The residue was diluted with EtOAc (50 mL) and washed with a saturated aqueous solution of $NaHCO_3$, 10% HCl and water and the organic phase was dried over Na_2SO_4. The solvent was concentrated in vacuo and the compound was purified by silica gel column chromatography.

General procedure for *O*-sulfation. The mixture of OH-containing compound (for 20 mg of compound, 1 equiv.), DMF (1 mL) and SO_3-NEt_3 (20 equiv. per OH) was stirred at 55 °C for 24 h. The mixture was cooled to room temperature and then diluted with DCM/MeOH (1mL/1mL). The resulting solution was layered on the top of Sephadex LH-20 chromatography column that was eluted with DCM/MeOH (1/1, v/v). The fractions containing product were combined and evaporated to dryness under vacuo without further purification.

General procedure for global debenzylation. The mixture of the Bn/PMB-containing compound (for 3 mg of compound, 1 equiv.), DCM/MeOH (1 mL/1 mL) and Pd/C (15 mg) was stirred under H_2 at room temperature overnight and then filtered via PTFE membrane (pore size 0.22 μm). The filtrate was concentrated to dryness under vacuum and then diluted with H_2O (15 mL). The aqueous phase was further washed with DCM (5 mL × 3) and MeOH (5 mL×3) and then the aqueous phase was dried under vacuum. The crude product was further purified by Sephadex LH-20 chromatography column. The fractions containing product were combined and evaporated to dryness under vacuo without further purification.

General procedure for solid phase peptide synthesis. Amino acids were purchased from Chem-impex. H-Gly-2-CTrt Resin was purchased from Advanced ChemTech (loading level: 0.6 mmol/g). Reaction vessel syringes (10 mL, disposable) and the Domino Block Synthesizer were purchased from Torvig.
(1) Pause Point:
If it is necessary to pause the synthesis, after each coupling-washing procedure, the resin is washed with DCM five times and dried with nitrogen gas at room temperature. The syringe was closed with a plunger and a cap, and stored at < 4 °C. Before resuming the synthesis, the sample was allowed to reach room temperature, and the dry resin was swelled as described in the following.
(2) Select the right syringe:
The optimal available volume for 6 mL syringe is < 4.8 mL;
The optimal available volume for 12 mL syringe is < 8.0 mL;
The concentration of amino acid used for coupling typically is 0.2 ~ 0.4 M;

The final volume of swelling resin, solvent, coupling reagent need to be considered before choosig the right syringe. As an example for 200mg H-Gly-2-ClTrt-Resin with 10 eq amino acid, 9.9 eq HBTU, 20 eq DIPEA, the final reaction volume is about 6 ~ 7 mL. Therefore, the 12 mL syringe should be used.

(3) Reagent:

HBTU: MW 379.24

223 mg (4.9 eq) for 200 mg resin (0.6 mmol/g);

451 mg (9.9 eq) for 200 mg resin (0.6 mmol/g);

DIPEA: MW 129.24 *d* 0.742

0.21 mL (10 eq) for 200 mg resin (0.6 mmol/g);

0.42 mL (20 eq) for 200 mg resin (0.6 mmol/g).

DIPEA usually is 2 eq;

20% piperidine in DMF:

20 mL piperidine + 80 mL DMF 10 mL/ g resin

Capping Reagent:

10 mL Ac_2O + 10 mL DIPEA + 80 mL DMF

Kaiser Reagent:

80% Phenol in EtOH (W/V);

2 mL 0.001M KCN + 98 mL Pyridine;

5% Ninhydrin in EtOH (W/V).

(4) Standard Washing Procedure:

This procedure is performed when Fmoc is removed or the coupling reaction is finished.

(a) Push the plunger to remove the reaction mixture, and then pull it back to the right position;
(b) Put the syringe in the plate;
(c) Fill the syringe with DMF;
(d) Take the plate out of the shaker, carefully wash the plunger and edge of the syringe with DMF, shake for 10s, and remove the solvent by filtration;
(e) Repeat steps a and b three times with DMF;
(f) Repeat steps a and b three times with DCM;
(g) Repeat steps a and b three times with DMF.

Section 1: Resin Swelling

(a) Place the dry resin (200mg) in the syringe;
(b) Fill the reactor with DCM until all the resin beads are immersed;
(c) Shake for 30 min;
(d) Remove DCM by vacuum filtration.

Section 2: Removal of Fmoc

(a) The swelled resin is washed once with DMF;
(b) Fill the syringe with 20% piperidine in DMF (3 ml) and shake for 30 min;
(c) Remove the DMF/piperidine solution by pushing the plunger;
(d) Repeat steps b and c once;
(e) Repeat the standard washing procedure once;

Section 3: Coupling Reaction

(a) Mix the Fmoc protected amino acid (5 eqiv.), DIPEA (10 eqiv.), and HBTU (4.9 eqiv.) with DMF in a dry vial. The reaction mixture is then transferred to syringe when all the compounds are completely dissolved;

(b) Shake the reaction for 2 h;
(c) Repeat standard washing procedure;
(d) Check the resin with Kaiser Method to make sure no free amine is left; Repeat steps a and b if necessary.

Section 4: Capping

(a) Fill the syringe with the capping reagent, and shake for 15 min;
(b) Remove the capping solution by pushing the plunger and repeat step a for 15 min;
(c) Repeat the standard washing procedure;

Section 5: Final Cleavage

(a) Weigh the resin and place it in a round bottom flask. When the resin is dry, swell it as described in section 1;
(b) Add 10 mL of cleavage cocktail (TFA/H_2O/Phenol/TIPS 8.5/0.5/0.5/0.5) per 100mg of resin, stir gently for 2h;
(c) Filter the resin and wash it twice with fresh cleavage cocktail. Recover the filtrate in a rounD-bottom flask;
(d) Concentrate the cleavage cocktail in vacuum to approximately ¼ of its original volume;
(e) Under vigorous stirring, add cold MTBE to precipitate the peptide. At least 10 times the initial TFA volume of MTBE should be added to precipitate the unprotected peptide. When the peptide does not precipitate, concentrate the solution in vacuum and go directly to step 8;
(f) Filter out the precipitate;
(g) Triturate and wash by filtration the precipitated peptide three times with MBTE;
(h) Solubilize the peptide in CH_3CN/H_2O/TFA 50/50/0.1 and lyophilize. Solvent used for this step can be changed to increase solubility. The crude peptide is used for HPLC analysis.

General procedure for HPLC analysis

(1) Preparation of Sample:

(a) Transfer a sample containing ~ 1- 2 mg dry peptide-resin to a small syringe (2 ml);
(b) Add 300 µl of the cleavage cocktail to the dried peptide resin, stir for 3h;
(c) Collect the solution in a small HPLC vial, dilute with 400 µl ACN/H_2O 1/1 and mix;
(d) At this point, the solution can be analyzed in an analytical HPLC system (inject 20 µl) and /or further diluted (1/10) to be injected (2 µl) in liquid chromatograph-mass spectrometer.

(2) Preparation of HPLC Solvent:

(a) Eluent A: weak mobile phase solvent.
Case A: 0.1% TFA in H_2O (1 ml TFA + 1 L H_2O)
Case B: 0.12 % TFA in H_2O (1.2 ml TFA + 1 L H_2O)
(b) Eluent B: strong mobile phase solvent.
Case A: 80% ACN / 0.1% TFA
or 0.085% TFA/ACN (v/v)
Case B: 1.0 mL TFA + 700 ml ACN + 300 ml H_2O

(3) Choice of HPLC Column:

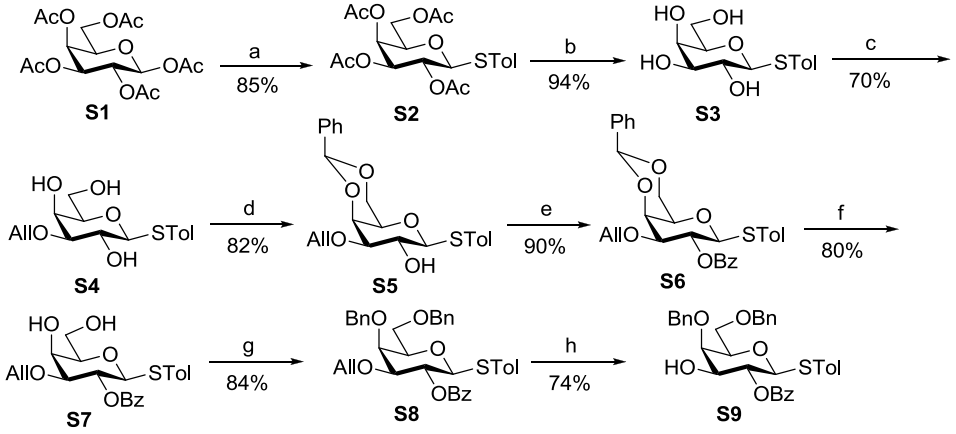
(a) low picomole amount of peptide: 0.21 cm × 25 cm , 0.3 ml/min

(b) < 1 mg peptide: 0.46 cm × 25 cm , 1.0-1.5 ml/min
(c) 1.0-10.0 mg peptide: 1.0 cm × 25 cm , 2.0 ml/min
(d) >10 mg peptide: 2.2 cm × 25 cm , 6.0-10.0 ml/min

(4) Column Preparation:
(a) Eluent B, 2 ml/min, 20 min;
(b) Decrease Eluent B to 0% over 10 min using a linear gradient;
(c) Increase Eluent B to 100% over 10 min using a linear gradient;
(d) Repeat 2;
(e) Equilibrate the column with Eluent A for 20 min.

(5) Detector: 220 nm

Building block preparation

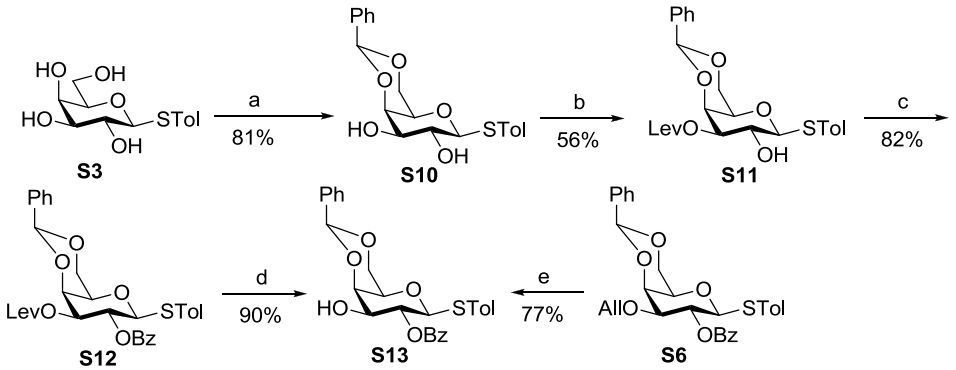


Synthesis of galactose building block **S9**. Reagents and conditions: (a) BF_3/Et_2O, *p*-TolSH, r.t.; (b) NaOMe, DCM/MeOH, r.t.; (c) Bu_2SnO, toluene/THF, reflux, 3 h, then AllBr, Bu_4NBr, THF, reflux; (d) benzaldehyde dimethyl acetal, CSA, CH_3CN; (e) BzCl, DMAP, pyridine, 50 ^oC; (f) *p*-TsOH, DCM/MeOH, r.t.; (g) NaH, BnBr, DMF; (h) $[Ir(COD)(PMePh_2)_2PF_6]$, THF, then H_2O, I_2, H_2, 0 ^oC-r.t..

p-Tolyl 2-O-benzoyl-4,6-di-O-benzyl-1-thio-β-D-galactopyranoside (**S9**). *β*-D-Galactopyranosyl pentaacetate **S1** (10 g, 25.64 mol), *p*-toluenethiol (3.62 g, 29 mmol) were dissolved in DCM (100 mL) and boron trifluoride etherate (10.1 mL, 75 mmol) was added dropwise at room temperature. The mixture was stirred under N_2 at room temperature for 20 hours and then diluted with DCM (200 mL). The organic phase was washed with a saturated aqueous solution of $NaHCO_3$ until the pH reached 7 and then dried over Na_2SO_4, filtered and concentrated to afford crude product **S2**, which was recrystalized from hexanes/EtOAc. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.95 (s, 3 H, COCH_3), 2.02 (s, 3 H, COCH_3), 2.07 (s, 3 H, COCH_3), 2.09 (s, 3 H, COCH_3), 2.32 (S, 3 H, SPhCH_3), 3.86-3.90 (m, 1 H), 4.07-4.18 (m, 2 H), 4.62 (d, 1 H, $J_{1,2}$ = 10 Hz, H-1), 5.00-5.03 (m, 1 H), 5.19 (t, 1 H, $J_{1,2}$ = 10 Hz), 5.38 (dd, 1 H, J = 1 Hz, J = 3.5 Hz), 7.09-7.11 (m, 2 H), 7.38-7.40 (m, 2 H). Compound **S2** (9.89 g) was dissolved in MeOH (50 mL) and DCM (50 mL). 5.4 M NaOMe (19 mL, 0.1 mol) was added and the mixture was stirred at room temperature overnight. The mixture was neutralized by conc. HCl until the pH was around 7 and then concentrated and dried under vacuum. Silica gel column chromatography (9:1

DCM–MeOH) afforded *p*-tolyl 1-thio-*β*-D-galactopyranoside **S3** as white solid (5.86 g, 94%). ^{1}H-NMR (500 MHz, CD_3OD): δ 2.29 (s, 3 H, SPhCH_3), 3.45-3.48 (m, 1 H), 3.51-3.53 (m, 1 H), 3.56 (t, 1 H, J = 4.5 Hz), 3.67-3.76 (m, 2 H), 3.87 (dd, 1 H, J = 1 Hz, J = 3.5 Hz), 4.49 (d, 1 H, $J_{1,2}$ = 9.5 Hz), 7.09-7.11 (m, 2 H), 7.43-7.45 (m, 2 H). Compound **S3** with dibutyltin oxide (6.12 g, 24.6 mmol) in a flask equipped with a Dear-Stark device in anhydrous toluene and THF (200 mL) for 3 h and then concentrated. After cooling the reaction mixture down to room temperature, anhydrous THF (100 mL) was added followed by addition of Bu_4NBr (3.42 g, 22.5 mmol) and AllBr (2.69 mL, 22.5 mmol). The mixture was stirred for 4 h under reflux. After the reaction was complete, THF was removed under reduced pressure. The resulting residue was purified by silica gel column (1:1, hexanes-EtOAc) to afford *p*-tolyl 3-*O*-allyl-1-thio-*β*-D-galactopyranoside **S4** (4.67 g, 70%). ^{1}H-NMR (500 MHz, CD_3OD): δ 2.30 (s, 3 H, SPhCH_3), 3.13-3.34 (m, 1 H), 3.65-3.78 (m, 3 H, H-2, H-6a, H-6b), 4.06-4.07 (m, 1 H, H-4), 4.13-4.25 (m, 2 H, CH_2CHCH_2O), 4.52 (d, 1 H, $J_{1,2}$ = 9.5 Hz, H-1), 5.14-5.17 (m, 1 H, CH_2CHCH$_2$O), 5.30-5.35 (m, 1 H, CH_2CHCH$_2$O), 5.96-6.01 (m, 1 H, CH$_2$CHCH$_2$O), 7.10-7.12 (m, 2 H), 7.44-7.46 (m, 2 H). ^{13}C-NMR (125 MHz, CD_3OD): δ 13.8, 20.8, 21.1, 26.8, 54.1, 62.6, 67.3, 70.0, 71.8, 80.3, 83.5, 90.5, 117.3, 130.5, 131.8, 133.0, 136.4, 138.4. HRMS: $C_{16}H_{22}O_5S$ $[M+NH_4]^+$ calcd: 344.1532, obsd: 344.1542. Compound **S4** (4.67 g, 14.34 mmol) was dissolved in CH_3CN (100 mL) followed by addition of camphorsulfonic acid (CSA, 999 mg, 4.302 mmol) and benzaldehyde dimethyl acetal (3.24 mL, 21.51 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was quenched by Et_3N and diluted with EtOAc (100 mL) and the organic phase was extracted by sat. $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, the residue was purified by silica gel column (5:1:1, hexanes-DCM-EtOAc) to afford *p*-tolyl 3-*O*-allyl-4,6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside **S5** (4.87 g, 82%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.31 (s, 3 H, SPhCH_3), 2.43 (d, 1 H, J = 1.5 Hz, OH), 3.44-3.47 (m, 2 H, H-3, H-5), 3.81 (dt, 1 H, J = 1.5 Hz, J = 9.5 Hz, H-2), 3.98-4.01 (m, 1 H, H-6a), 4.13-4.21 (m, 3 H, H-4, CH$_2$CHCH_2O), 4.34-4.37 (m, 1 H, H-6b), 4.56 (d, 1 H, J = 9.5 Hz, H-1), 5.15-5.18 (m, 1 H, CH_2CHCH$_2$O), 5.25-5.29 (m, 1 H, CH_2CHCH$_2$O), 5.47 (s, 1 H, PhCH), 5.86-5.93 (m, 1 H, CH$_2$CHCH$_2$O), 7.02-7.04 (m, 2 H), 7.29-7.38 (m, 5 H), 7.55-7.57 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.4, 67.3, 69.7, 70.3, 71.1, 73.6, 80.3, 87.4, 101.4, 118.0, 126.8, 126.9, 128.2, 129.2, 129.9, 134.6, 135.0, 138.1, 138.6. HRMS: $C_{23}H_{26}O_5S$ $[M+NH_4]^+$ calcd: 432.1845, obsd: 432.1831. Compound **S5** (4.87 g, 11.76 mmol) was dissolved in dry pyridine (100 mL) followed by addition of DMAP (143 mg, 1.176 mmol) and benzoyl chloride (2.05, 17.64 mmol). The resulting mixture was stirred under 50 ^{o}C overnight. After cooling down to room temperature, the reaction mixture was diluted with DCM and extracted with 10% HCl solution. The combined organic phase was washed with sat. $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, the residue was purified by silica gel column (5:1:1, hexane-DCM-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-3-*O*-allyl-4, 6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside **S6** (5.48 g, 90%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.30 (s, 3 H, SPhCH_3), 3.52-3.54 (m, 1 H, H-5), 3.75 (dd, 1 H, J = 3.5 Hz, J = 9.5 Hz, H-3), 3.97-4.08 (m, 3 H, H-6a, CH$_2$CHCH_2O), 4.28 (dd, 1 H, J = 1 Hz, J = 3.5 Hz, H-4), 4.37-4.40 (m, 1 H, H-6b), 4.78 (d, 1 H, J = 9.5 Hz, H-1), 5.02-5.05 (m, 1 H, CH_2CHCH$_2$O), 5.11-5.15 (m, 1 H, CH_2CHCH$_2$O), 5.43 (t, 1 H, J = 9.5 Hz, H-2), 5.67-5.76 (m, 1 H, CH$_2$CHCH$_2$O), 7.01-7.03 (m, 2 H), 7.30-7.34 (m, 3 H), 7.39-7.48 (m, 6 H), 7.55-7.59 (m, 1 H), 8.04-8.06 (m, 2H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.2, 69.3, 69.3, 70.1,

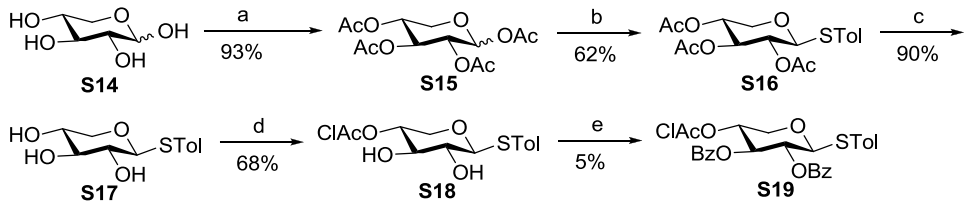
70.7, 73.8, 78.4, 85.5, 101.2, 117.4, 126.6, 127.5, 128.0, 128.3, 128.9, 129.4, 129.7, 130.3, 132.9, 134.4, 134.6, 137.6, 138.1, 164.8. HRMS: $C_{30}H_{30}O_6S$ $[M+NH_4]^+$ calcd: 536.2107, obsd: 530.2036. Compound **S6** (5.48 g, 10.58 mmol) was dissolved in DCM/MeOH (1:1. 100 mL) followed by addition of *p*-TsOH (685 mg, 3.98 mmol). The reaction mixture was kept under room temperature overnight and quenched with Et_3N. After concentration, the resulting residue was purified by silica gel column (2:1:2, hexanes-DCM-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-3-*O*-allyl-1-thio-*β*-D-galactopyranoside **S7** (3.64 g, 80%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.10-2.13 (m, 1 H, O*H*), 2.29 (s, 3 H, SPhCH_3), 2.60 (br, 1 H, O*H*), 3.59-3.65 (m, 2 H, H-3, H-5), 3.79-3.85 (m, 1 H, H-6a), 3.96-4.03 (m, 2 H, CH_2CHCH_2O), 4.07-4.11 (m, 2 H, H-4, H-6b), 4.72 (d, 1 H, J = 10 Hz, H-1), 5.06-5.09 (m, 1 H, CH_2CHCH_2O), 5.13-5.17 (m, 1 H, CH_2CHCH_2O), 5.40 (t, 1 H, J = 10 Hz, H-2), 5.66-5.73 (m, 1 H, CH_2CHCH_2O), 7.04-7.06 (m, 2 H), 7.32-7.34 (m, 2 H), 7.43-7.47 (m, 2 H), 7.56-7.59 (m, 1 H), 8.04-8.06 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.2, 62.6, 67.2, 69.3, 69.8, 71.0, 78.4, 79.5, 86.8, 118.1, 128.4, 129.0, 129.6, 129.8, 129.9, 132.9, 133.1, 133.9, 138.1, 165.2. HRMS: $C_{23}H_{26}O_6S$ $[M+H]^+$ calcd: 431.1528, obsd: 431.1508. Freshly activated MS AW 300 (2 g) was mixed with compound **S7** (3.64 g, 8.47 mmol) in dry DMF. Under N_2, the resulting mixture was stirred under room temperature for 30 minutes, followed by addition of NaH (485 mg, 20.38 mmol) and BnBr (4.03 mL, 33.88 mmol). After the reaction was complete, it was quenched by 10% HCl and diluted with DCM. The organic phase was extracted with sat. $NaHCO_3$ and dried over Na_2SO_4. After concentration, the residue was purified by silica gel column (4:1, hexanes-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-3-*O*-allyl-4,6-di-*O*-benzyl-1-thio-*β*-D-galactopyranoside **S8** (4.33 g, 84%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.26 (s, 3 H, SPhCH_3), 3.62-3.69 (m, 4 H, H-3, H-5, H-6a, H-6b), 3.94-3.99 (m, 2 H, CH_2CHCH_2O, H-4), 4.05-4.10 (m, 1 H, CH_2CHCH_2O), 4.40-4.47 (m, 2 H, CH_2Ph), 4.56-4.59 (m, 1 H, CH_2Ph), 4.73 (d, 1 H, *J* = 10 Hz, H-1), 4.95-4.97 (m, 1 H, CH_2Ph), 5.03-5.05 (m, 1 H, CH_2CHCH_2O), 5.13-5.17 (m, 1 H, CH_2CHCH_2O), 5.59 (t, 1 H, *J* = 10 Hz, H-2), 5.67-5.72 (m, 1 H, CH_2CHCH_2O), 6.97-6.99 (m, 2 H), 7.24-7.34 (m, 12 H), 7.43-7.46 (m, 2 H), 7.54-7.58 (m, 1 H), 8.05-8.07 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.2, 68.8, 70.6, 71.3, 73.1, 73.6, 74.3, 77.7, 81.4, 87.2, 117.2, 127.4, 127.9, 128.0, 128.1, 128.3, 128.4, 129.4, 129.7, 130.2, 132.6, 132.9, 134.3, 137.5, 137.9, 138.5, 165.2. HRMS: $C_{37}H_{38}O_6S$ $[M+NH_4]^+$ calcd: 628.2733, obsd: 628.2721. Compound **S8** (4.33 g, 7.11 mmol) wais dissolved in THF (50 mL), followed by addition of 222 mg $[Ir(COD)(Ph_2MeP)_2]PF_6$. The resulting mixture was stirred under H_2 for 3 h, followed by addition of H_2O (60 mL) and I_2 (3.5 g). After the reaction was complete, the mixture was diluted with EtOAc and extracted with H_2O. The combined organic phase was dried over Na_2SO_4. After concentration, the residue was purified by silica gel column (4:1, hexane-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-4, 6-di-*O*-benzyl-1-thio-*β*-D-galactopyranoside **S9** (3 g, 74%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.29 (s, 3 H, SPhCH_3), 2.47 (d, 1 H, *J* = 9.5 Hz, O*H*), 3.68-3.81 (m, 4 H, H-3, H-5, H-6a, H-6b), 3.95-3.96 (m, 1 H, H-4), 4.46-4.53 (m, 2 H, CH_2Ph), 4.68-4.73 (m, 3 H, CH_2Ph, H-1, *J* = 9.5 Hz), 5.20 (t, 1 H, *J* = 9.5 Hz, H-2), 7.00-7.02 (m, 2 H), 7.26-7.34 (m, 12 H), 7.42-7.45 (m, 2 H), 7.54-7.58 (m, 1 H), 8.03-8.05 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.4, 68.6, 72.5, 73.8, 74.6, 75.5, 77.7, 86.5, 127.8, 128.0, 128.1, 128.6, 128.7, 128.7, 129.1, 129.8, 130.0, 130.2, 133.3, 133.4, 137.9, 138.2, 138.4, 165.5. HRMS: $C_{34}H_{34}O_6S$ $[M+NH_4]^+$ calcd: 588.2420, obsd: 588.2412.



Synthesis of galactose building block **S13**. Reagents and conditions: (a) *p*-methoxybenzylidene dimethyl acetal, CSA, CH_3CN; (b) DCC, LevOH, DMAP, DCM; (c) BzCl, DMAP, DCM, 50 ^oC; (d) NH_2NH_2, HOAc, DCM/MeOH; (e) $[Ir(COD)(PMePh_2)_2PF_6]$, H_2, THF, then H_2O, I_2, 0 ^oC-r.t..

p-Tolyl 2-O-benzoyl-4,6-di-O-benzylidene -1-thio-β-D-galactopyranoside (**S13**).[2] *p*-Tolyl 1-thio-*β*-D-galactopyranoside **S3** (5 g, 17.48 mmol) was dissolved in CH_3CN (100 mL) followed by addition of camphorsulfonic acid (1.21 g, 5.24 mmol) and benzaldehyde dimethyl acetal (3.95 mL, 26.22 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was quenched by Et_3N and diluted with EtOAc (100 mL) and the organic phase was extracted by sat. $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, the residue was recrystalized from EtOH to afford *p*-tolyl 4, 6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside **S10** (5.3 g, 81%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.34 (s, 3 H, SPhCH_3), 2.45-2.49 (m, 2 H), 3.53 (br, 1 H), 3.59-3.69 (m, 2 H), 3.99-4.02 (m, 2 H, CH_2Ph), 4.18-4.19 (m, 1 H), 4.35-4.37 (m, 1 H), 4.44 (d, 1 H, J = 9 Hz, H-1), 5.48 (s, 1 H, PhC*H*), 7.08-7.10 (m, 2 H), 7.33-7.38 (m, 5 H), 7.55-7.57 (m, 2 H). Compound **S10** (5.3 g, 14.16 mmol) was dissolved in dry DCM (100 mL), followed by addition of dicyclohexylcarbodiimide (DCC) (4.53 g, 21.24 mmol), DMAP (878 mg, 7.1 mmol) and LevOH (1.98 g, 17 mmol). The resulting mixture was stirred under room temperature for 3 h. The reaction was diluted with DCM and washed with 10% HCl solution and saturated aqueous $NaHCO_3$ solution sequentially. The combined organic phase was dried over Na_2SO_4 and purified by silica gel column (3:1. hexanes-EtOAc) to afford *p*-tolyl 3-*O*-levulinoyl-4,6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside **S11** (3.74 g, 56%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.04 (s, 3 H, CH_3COCH$_2$CH$_2$O), 2.32 (s, 3 H, SPhCH_3), 2.47 (d, 1 H, O*H*), 2.55-2.57 (t, 2 H, J = 6.5 Hz, CH$_3$COCH_2CH$_2$O), 2.68-2.71 (t, 2 H, J = 6.5 Hz, CH$_3$COCH$_2$CH_2O), 3.56 (br, 1 H), 3.85-3.91 (m, 1 H), 3.97-4.00 (m, 1 H), 4.28-4.36 (m, 2 H), 4.52 (d, 1 H, J = 9.5 Hz, H-1), 4.92 (dd, 1 H, J = 3.5 Hz, J = 10 Hz), 5.44 (s, 1 H, PhC*H*), 7.05-7.07 (m, 3 H), 7.32-7.38 (m, 5 H), 7.55-7.57 (m, 2 H). Compound **S11** (3.74 g, 7.93 mmol) was dissolved in dry DCM (100 mL) followed by addition of DMAP (97 mg, 0.793 mmol) and benzoyl chloride (1.38, 11.9 mmol). The resulting mixture was stirred under 50 ^{o}C overnight. After cooling down to room temperature, the reaction mixture was diluted with DCM and extracted with 10% HCl solution. The combined organic phase was washed with a saturated aqueous $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, the residue was purified by silica gel column (5:1:1, hexanes-DCM-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-3-*O*-levulinoyl-4, 6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside **S12** (3.74 g,

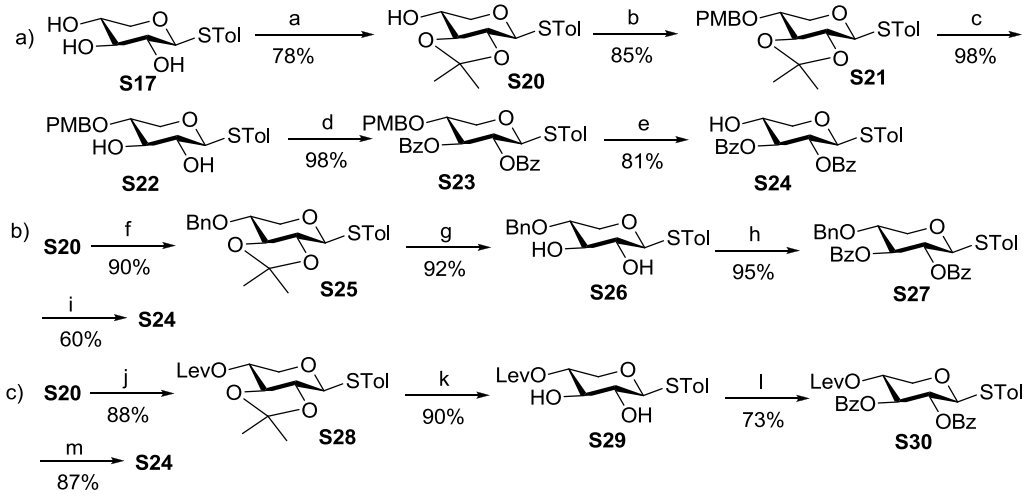
82%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.84 (s, 3 H, CH_3COCH$_2$CH$_2$O), 2.31 (s, 3 H, SPhCH_3), 2.38-2.55 (m, 4 H, CH$_3$COCH_2CH_2O), 3.62 (br, 1 H), 4.01-4.04 (m, 1 H), 4.36-4.39 (m, 2 H), 4.79 (d, 1 H, J = 9.5 Hz, H-1), 5.15 (dd, 1 H, J = 3.5 Hz, J = 10 Hz), 5.46 (s, 1 H, PhCH), 5.15 (t, 1 H, J = 9.5 Hz, H-2), 7.03-7.05 (m, 2 H), 7.32-7.46 (m, 9 H), 7.55-7.58 (m, 1 H), 8.00-8.02 (m, 2 H). Compound **S12** (3.74 g, 6.5 mmol) was dissolved in DCM/MeOH (1:1, 100 mL), followed by addition of HOAc (30 mL) and NH_2NH_2-H_2O (4 mL). The resulting reaction mixture was stirred under room temperature overnight and quenched by acetone, diluted with DCM. The organic phase was extracted with a saturated aqueous $NaHCO_3$ solution. After drying over Na_2SO_4 and concentration, the resulting rsidue was purified by silica gel column (4:1, hexanes-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-4, 6-*O*-benzylidene-1-thio-*β*-D-galactopyranoside **S13** (2.8 g, 90%). Compound **S6** (1 g, 1.93 mmol) wais dissolved in THF (30 mL), followed by addition of 60 mg [Ir(COD)(Ph_2MeP)$_2$]PF_6. The resulting mixture was stirred under H_2 for 3 h, followed by addition of H_2O (15 mL) and I_2 (948 mg). After the reaction was complete, the mixture was diluted with EtOAc and extracted with H_2O. The combined organic phase was dried over Na_2SO_4. After concentration, the residue was purified by silica gel column (4:1, hexanes-EtOAc) to afford *p*-tolyl 2-*O*-benzoyl-4,6-di-*O*-benzyl-1-thio-*β*-D-galactopyranoside **S13** (710 mg, 77%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.32 (s, 3 H, SPhCH_3), 2.54-2.56 (m, 1 H, OH), 3.59 (br, 1 H, H-5), 3.84-3.89 (m, 1 H, H-3), 4.03-4.06 (m, 1 H, H-6a), 4.23-4.25 (m, 1 H, H-4), 4.39-4.42 (m, 1 H, H-6b), 4.75 (d, 1 H, J =10 Hz, H-1), 5.17 (t, 1 H, J = 9.5 Hz, H-2), 5.51 (s, 1 H, PhCH), 7.05-7.07 (m, 2 H), 7.35-7.46 (m, 9 H), 7.55-7.59 (m, 1 H), 8.05-8.07 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.3, 69.1, 69.9, 70.7, 73.0, 75.7, 84.8, 101.5, 126.6, 126.9, 128.1, 128.3, 129.3, 129.5, 129.9, 133.1, 134.6, 137.4, 138.4, 165.5.



Synthesis of xylose building block **S19**. Reagents and conditions: (a) Ac_2O, pyridine; (b) BF_3/Et_2O, *p*-TolSH, r.t.; (c) NaOMe, DCM/MeOH, r.t.; (d) Bu_2SnO, dioxane, then ClAcCl, DCM; (e) BzCl, DMAP, DCM, r.t..

p-Tolyl 2,3-di-O-benzoyl-4-chloroacetyl-1-thio-β-D-xylopyranose (**S19**). A solution of D-xylose **S14** (10 g, 66.67 mmol) in dry pyridine (50 mL) was added Ac_2O (44 mL, 457.6 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was diluted by DCM and washed with 10% HCl solution. The combined organic phase was further extracted with a saturate acquous solution of $NaHCO_3$ and dried over Na_2SO_4. After concentration, the crude product **S15** (19.7 g, 93%) was directly used for next step without further purification. D-Xylopyranosyl tetraacetate **S15** (19.7 g, 62 mol), *p*-toluenethiol (8.75 g, 70.4 mmol) were dissolved in DCM (100 mL) and boron trifluoride etherate (24.5 mL) was added dropwise at room temperature. The mixture was stirred under N_2 at room temperature for 20 hours and then diluted with DCM (200 mL). The organic phase was washed with saturated aqueous solution of $NaHCO_3$

until the pH is 7 and then dried over Na_2SO_4, filtered and concentrated to afford crude product **S16** (14.7 g, 62%), which was recrystalized from hexanes/EtOAc. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.04 (s, 3 H, COC*H*$_3$), 2.05 (s, 3 H, COC*H*$_3$), 2.11 (s, 3 H, COC*H*$_3$), 2.36 (s, 3 H, SPhC*H*$_3$), 3.40 (dd, 1 H, *J* = 9 Hz, *J* = 11.5 Hz, H-5a), 4.27 (dd, 1 H, *J* = 5 Hz, *J* = 7 Hz, H-5b), 4.73 (d, 1 H, *J* = 8.5 Hz, H-1), 4.90-4.95 (m, 2 H, H-2, H-4), 5.18 (t, 1 H, *J* = 8.5 Hz, H-3), 7.13-7.15 (m, 2 H), 7.37-7.39 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 20.6, 20.6, 20.7, 21.1, 65.3, 68.4, 69.8, 72.2, 86.4, 128.1, 129.7, 133.4, 138.5, 169.2, 169.7, 169.9. HRMS: $C_{18}H_{22}O_7S$ $[M+NH_4]^+$ calcd: 400.1430, obsd: 400.1442. Compound **S16** (14.7 g, 38.44 mmol) was dissolved in MeOH (50 mL) and DCM (50 mL). Freshly prepared NaOMe solution in MeOH was added to maintain pH above 12 and the mixture was stirred at room temperature overnight. The mixture was neutralized by conc. HCl until the pH is around 7 and then concentrated and dried under vacuum to afford *p*-tolyl 1-thio-*β*-D-xylopyranose **S17** as white solid (8.86 g, 90%) which was directly used without further purification. ^{1}H-NMR (500 MHz, CD_3OD): δ 2.38 (s, 3 H, SPhC*H*$_3$), 3.15-3.22 (m, 2 H, H-2, H-5a), 3.32-3.35 (m, 1 H, H-5b), 3.42-3.47 (m, 1 H, H-4), 3.91-3.94 (dd, 1 H, *J* = 5 Hz, *J* = 11.5 Hz, H-3), 4.46 (d, 1 H, *J* = 9 Hz, H-1), 7.12-7.14 (m, 2 H), 7.40-7.42 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 20.8, 70.4, 70.9, 73.6, 79.2, 90.3, 130.5, 130.8, 133.9, 139.0. HRMS: $C_{12}H_{16}O_4S$ $[M+H]^+$ calcd: 257.0848, obsd: 257.0857. Compound **S17** (1 g, 3.91 mmol) was dissolved dixoane, followed by addition of Bu_2SnO (1.4 g, 5.62 mmol). The resulting mixture was boiled under reflux for 2 h and then was evaporated to dryness. The resulting residue was dissolved in 40 mL DCM, and a solution of chloroacetyl chloride (ClAcCl) (336 μL, 4.15 mmol) in DCM (4 mL) was added while stirring. After 80 minutes, the reaction was diluted with DCM and washed with sat. $NaHCO_3$ and dried over Na_2SO_4. After, concentration, the residue was purified by silica gel column (1:1, hexane-EtOAc) to afford *p*-tolyl 4-chloroacetyl-1-thio-*β*-D-xylopyranose **S18** (882 mg, 68%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.33 (s, 3 H, SPhC*H*$_3$), 2.74-2.94 (m, 2 H, O*H*), 3.27-3.35 (m, 2 H, H-2, H-5a), 3.72 (dd, 1 H, *J* = 9 Hz, H-3), 4.03-4.16 (m, H-5b, ClC*H*$_2$CO), 4.41 (d, 1 H, *J* = 9 Hz, H-1), 4.82-4.87 (m, 1 H, H-4), 7.11-7.13 (m, 2 H), 7.39-7.41 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 40.6, 66.1, 71.9, 72.3, 74.9, 88.5, 126.9, 129.9, 133.7, 138.9, 166.8. HRMS: $C_{14}H_{17}ClO_5S$ $[M+Na]^+$ calcd: 355.0383, obsd: 355.0309. Compound **S18** (882 mg, 2.66 mmol) was dissolved in DCM (20 mL), followed by addition of DMAP (32 mg, 0.266 mmol) and benzoyl chloride (464 μL, 3.99 mmol). The resulting mixture was stirred under room temperature overnight and diluted with DCM. After extraction with 10% HCl solution, the combined organic phase was further washed with a saturated acquous solution of $NaHCO_3$ and dried over Na_2SO_4. Silica gel column (4:1, hexanes/EtOAc) purification afforded *p*-Tolyl 2, 3-di-*O*-benzoyl-4-chloroacetyl-1-thio-*β*-D-xylopyranose **S19** (72 mg, 5%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.36 (s, 3 H, SPhC*H*$_3$), 3.69-3.73 (m, 2 H, H-5a, H-5b), 3.97-4.05 (m, 2 H, ClC*H*$_2$CO), 4.12-4.16 (m, 1 H, H-4), 5.10 (d, 1 H, *J* = 6.5 Hz, H-1), 5.39 (t, 1 H, *J* = 7 Hz, H-2), 5.60 (t, 1 H, *J* = 7 Hz, H-3), 7.13-7.15 (m, 2 H), 7.40-7.44 (m, 6 H), 7.55-7.58 (m, 3 H), 8.01-8.03 (m, 3 H).



Synthesis of xylose building block **S24**. Reagents and conditions: (a) 2-methoxypropene, CSA, DMF, 60 ^{o}C; (b) NaH, PMBCl, DMF; (c) CSA, DCM/MeOH; (d) BzCl, DMAP, DCM, reflux; (e) DDQ, DCM/H_2O; (f) NaH, BnBr, DMF; (g) CSA, DCM/MeOH; (h) BzCl, DMAP, DCM, reflux; (i) DDQ, DCM/H_2O, reflux; (j) LevOH, EDC-HCl, DMAP, DCM; (k) CSA, DCM/MeOH; (l) BzCl, DMAP, DCM, reflux; (m) NH_2NH_2, HOAc, DCM/MeOH.

p-Tolyl 2, 3-di-O-benzoyl-4-p-methoxybenzyl-1-thio-β-D-xylopyranose (**S23**). A solution of *p*-tolyl 1-thio-*β*-D-xylopyranose **S17** (7 g, 27.34 mmol) in dry DMF (50 mL) was added camphorsulfonic acid (953 mg, 4.1 mmol). The resulting mixture was stirred under 60 ^{o}C. 2-Methoxy propene (7.85 mL, 82.02 mmol) was added into the reaction mixture in portions. The reaction was stirred for another 2 h. After the reaction was complete, it was cooled back to room temperature and quenched with Et_3N. The resulting mixture was concentrated and purified by silica gel column (4:1:1, hexanes-DCM-EtOAc) to afford *p*-tolyl 2, 3-isopropylidene-1-thio-*β*-D-xylopyranose **S20** (6.3 g, 78%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.41 (s, 3 H, C(CH_3)$_2$), 1.46 (s, 3 H, C(CH_3)$_2$), 2.31 (s, 3 H, SPhCH_3), 2.53 (d, 1 H, *J* = 4 Hz, O*H*), 3.16-3.20 (m, 2 H, H-2, H-5a), 3.48 (t, 1 H, J = 9 Hz, H-3), 3.89-4.62 (m, 1 H, H-4), 4.06-4.10 (m, 1 H, H-5b), 4.69 (d, 1 H, *J* = 9.5 Hz, H-1), 7.09-7.11 (m, 2 H), 7.42-7.44 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 26.4, 26.6, 68.9, 69.8, 75.0, 82.8, 85.5, 111.1, 127.7, 129.6, 133.6, 138.4. HRMS: $C_{15}H_{20}O_4S$ $[M+H]^+$ calcd: 297.1161, obsd: 297.1160. Compound **S20** (6.3 g, 21.33 mmol) was dissolved in 40 mL DMF, followed by addition of NaH (1 g, 25.6 mmol) and PMBCl (3.76 mL, 27.73 mmol). After stirring under room temperature overnight, the reaction was quenched by 10% HCl solution and diluted with DCM. The organic phase was extracted with sat. $NaHCO_3$ and dried over Na_2SO_4. Silica gel column (4:1, hexane/EtOAc) purification afforded *p*-Tolyl 2, 3-isopropylidene-4-*p*-methoxybenzyl-1-thio-*β*-D-xylopyranose **S21** (7.54 g, 85%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.43 (s, 3 H, C(CH_3)$_2$), 1.47 (s, 3 H, C(CH_3)$_2$), 2.31 (s, 3 H, SPhCH_3), 3.16-3.21 (m, 2 H, H-2, H-5a), 3.59 (t, 1 H, J = 9 Hz, H-3), 3.67-3.72 (m, 1 H, H-4), 3.77 (s, 3 H, CH_3OPhCH$_2$O), 4.01-4.04 (m, 1 H, H-5b), 4.47-4.49 (m, 1 H, CH$_3$OPhCH_2O), 4.69 (d, 1 H, *J* = 9.5 Hz, H-1), 4.69-4.71 (m, 1 H, CH$_3$OPhCH_2O), 6.83-6.86 (m, 2 H), 7.08-7.10 (m, 2 H), 7.22-7.24 (m, 2 H), 7.42-7.44 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 26.5, 26.7, 55.2, 68.4, 71.8, 75.2, 75.3, 82.4, 85.4, 111.0, 113.8, 127.9, 129.4, 129.5, 130.0, 133.5, 138.3, 159.3. HRMS: $C_{23}H_{28}O_5S$ $[M+H]^+$ calcd: 417.1736, obsd: 417.1725.

Compound **S21** (7.54 g, 18.1 mmol) was dissolved in DCM/MeOH (1:1, 60 mL), followed by addition of camphorsulfonic acid (4.23 g, 18.1 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was quenched by Et_3N and concentrated. The residue was purified by silica gel column (1:1, hexanes-EtOAc) to afford *p*-tolyl 4-*p*-methoxybenzyl-1-thio-*β*-D-xylopyranose **S22** (6.68 g, 98%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.32 (s, 3 H, SPhCH_3), 2.64 (br, 2 H, O*H*), 3.19-3.24 (m, 1 H, H-5a), 3.05-3.35 (m, 1 H, H-2), 3.39-3.44 (m, 1 H, H-4), 3.60-3.65 (m, 1 H, H-3), 3.78 (s, 3 H, CH_3OPhCH$_2$O), 4.01-4.04 (m, 1 H, H-5b), 4.44 (d, 1 H, J = 9 Hz, H-1), 4.53-4.59 (m, 2 H, CH$_3$OPhCH_2O), 6.83-6.86 (m, 2 H), 7.09-7.11 (m, 2 H), 7.21-7.23 (m, 2 H), 7.38-7.40 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 55.2, 67.1, 71.8, 72.6, 88.8, 113.9, 127.9, 129.4, 129.7, 129.9, 133.2, 138.4, 159.4. HRMS: $C_{20}H_{24}O_5S$ $[M+NH_4]^+$ calcd: 394.1688, obsd: 394.1669. Compound **S22** (6.68 g, 17.77 mmol) and DMAP (2.17 g, 17.77 mmol) were dissolved in DCM (100 mL). Benzoyl chloride (4.95 mL, 42.65 mmol) was added into the reaction mixture while stirring and the reaction was left under reflux overnight. After the reaction was complete, it was diluted with DCM and washed with 10% HCl solution. The combined organic phase was extracted with a saturate acquous solution of $NaHCO_3$ and dried over Na_2SO_4. Silica gel column (2:1, hexanes/EtOAc) purification afforded *p*-tolyl 2,3-di-*O*-benzoyl-4-*p*-methoxybenzyl-1-thio-*β*-D-xylopyranose **S23** (10.2 g, 98%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.30 (s, 3 H, SPhCH_3), 3.48-3.52 (m, 1 H, H-5a), 3.70-3.74 (m, 1 H, H-4), 3.73 (s, 3 H, CH_3OPhCH$_2$O), 4.21-4.25 (m, 1 H, H-5b), 4.47-4.52 (m, 2 H, CH$_3$OPhCH_2O), 4.91 (d, 1 H, J = 8 Hz, H-1), 5.28 (t, 1 H, J = 8 Hz, H-2), 5.55 (t, 1 H, J = 8 Hz, H-3), 6.68-6.71 (m, 2 H), 7.06-7.11 (m, 4 H), 7.32-7.39 (m, 6 H), 7.47-7.52 (m, 2 H), 7.92-7.96 (m, 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 55.1, 66.4, 70.5, 72.3, 73.7, 73.9, 87.1, 113.8, 128.3, 128.3, 129.1, 129.4, 129.4, 129.6, 129.7, 129.8, 129.9, 133.0, 133.1, 138.2, 159.3, 165.2, 165.5. HRMS: $C_{34}H_{32}O_7S$ $[M+NH_4]^+$ calcd: 602.2212, obsd: 602.2203.

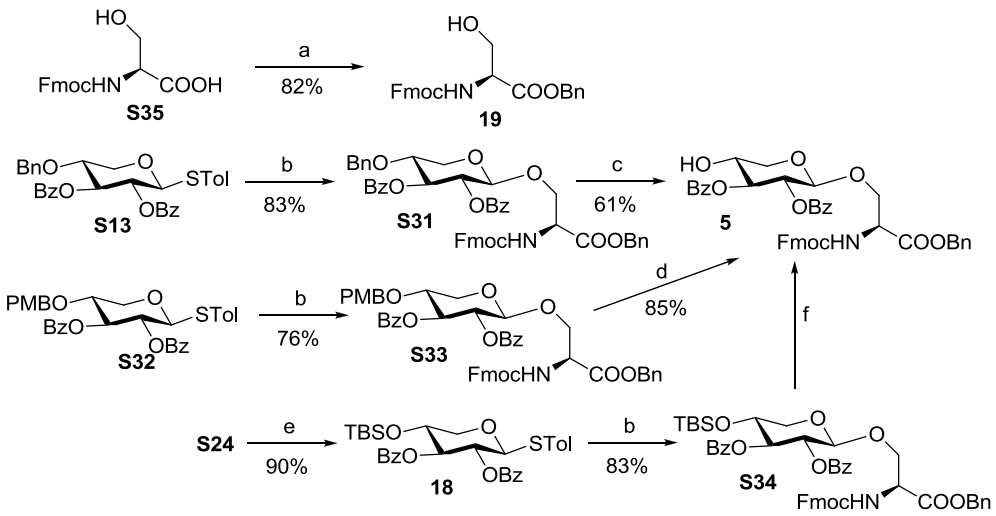
p-Tolyl 2,3-di-O-benzoyl-4-O-benzyl-1-thio-β-D-xylopyranose (**S27**). *p*-Tolyl 2, 3-isopropylidene-1-thio-*β*-D-xylopyranose **S20** (600 mg, 2.03 mmol) was dissolved in 10 mL DMF, followed by addition of NaH (95 mg, 2.44 mmol) and BnBr (314 μL, 2.64 mmol). After stirring under room temperature overnight, the reaction was quenched by 10% HCl solution and diluted with DCM. The organic phase was extracted with a saturate aqueous solution of $NaHCO_3$ and dried over Na_2SO_4. Silica gel column (4:1, hexanes/EtOAc) purification afforded *p*-tolyl 2,3-isopropylidene-4-benzyl-1-thio-*β*-D-xylopyranose **S25** (703 mg, 90%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.48 (s, 3 H, C(CH_3)$_2$), 1.53 (s, 3 H, C(CH_3)$_2$), 2.34 (s, 3 H, SPhCH_3), 3.22-3.29 (m, 2 H, H-2, H-4), 3.67 (t, 1 H, J = 9 Hz, H-3), 3.72-3.78 (m, 1 H, H-5a), 4.09-4.12 (m, 1 H, H-5b), 4.57-4.60 (m, 1 H, PhCH_2O), 4.75 (d, 1 H, J = 9.5 Hz, H-1), 4.80-4.83 (m, 1 H, PhCH_2O), 7.11-7.13 (m, 2 H), 7.26-7.35 (m, 5 H), 7.49-7.51 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 20.8, 26.3, 26.5, 68.0, 71.7, 75.0, 75.3, 82.2, 85.0, 113.2, 127.4, 127.4, 127.6, 129.3, 133.3, 137.7, 138.0. HRMS: $C_{22}H_{26}O_4S$ $[M+Na]^+$ calcd: 410.1528, obsd: 410.1547. Compound **S25** (703 mg, 1.82 mmol) was dissolve in DCM/MeOH (1:1, 10 mL), followed by addition of camphorsulfonic acid (423 mg, 1.82 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was quenched by Et_3N and concentrated. The residue was purified by silica gel column (1:1, hexanes-EtOAc) to afford *p*-tolyl 4-benzyl-1-thio-*β*-D-xylopyranose **S26** (581 mg, 92%). ^{1}H-NMR (500 MHz,

$CDCl_3$): δ 2.34 (s, 3 H, SPhCH_3), 3.22-3.27 (m, 1 H, H-5a), 3.42-3.53 (m, 2 H, H-2, H-4), 3.71-3.75 (m, 1 H, H-3), 3.97-3.99 (m, 1 H, O*H*), 4.03-4.06 (m, 1 H, H-5b), 4.18 (br, 1 H, O*H*), 4.54 (d, 1 H, J = 9 Hz, H-1), 4.61-4.76 (m, 2 H, PhCH_2), 7.11-7.13 (m, 2 H), 7.29-7.36 (m, 5 H), 7.46-7.48 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.4, 67.1, 72.1, 73.0, 77.4, 88.8, 127.8, 127.9, 128.4, 128.6, 129.7, 133.0, 138.0. HRMS: $C_{19}H_{22}O_4S$ $[M+NH_4]^+$ calcd: 364.1583, obsd: 364.1582. Compound **S26** (581 mg, 1.68 mmol) and DMAP (205 mg, 1.68 mmol) were dissolved in DCM (10 mL). Benzoyl chloride (468 μL, 4.03 mmol) was added into the reaction mixture while stirring and the reaction was left under reflux overnight. After the reaction was complete, it was diluted with DCM and washed with 10% HCl solution. The combined organic phase was extracted with a saturated aqueous solution of $NaHCO_3$ and dried over Na_2SO_4. Silica gel column (2:1, hexanes/EtOAc) purification afforded *p*-tolyl 2,3-di-*O*-benzoyl-4-*p*-methoxybenzyl-1-thio-*β*-D-xylopyranose **S27** (881 mg, 95%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.31 (s, 3 H, SPhCH_3), 3.53-3.57 (m, 1 H, H-5a), 3.74-3.78 (m, 1 H, H-4), 4.27-4.31 (m, 1 H, H-5b), 4.56-4.60 (m, 2 H, PhCH_2), 4.95 (d, 1 H, J = 9 Hz, H-1), 5.28-5.32 (m, 1 H, H-2), 5.58-5.62 (m, 1 H, H-3), 7.07-7.09 (m, 2 H), 7.19-7.24 (m, 5 H), 7.32-7.40 (m, 6 H), 7.47-7.53 (m, 2 H), 7.93-7.98 (m, 4 H). HRMS: $C_{33}H_{30}O_6S$ $[M+NH_4]^+$ calcd: 572.2107, obsd: 572.2096.

p-Tolyl 2, 3-di-O-benzoyl-4-O-levulinoyl-1-thio-β-D-xylopyranose (**S30**). *p*-Tolyl 2, 3-isopropylidene-1-thio-*β*-D-xylopyranose **S20** (500 mg, 1.69 mmol) was dissolved in 10 mL DMF, followed by addition of LevOH (205 μL, 2.03 mmol), DMAP (206 mg, 1.69 mmol) and EDC-HCl (389 mg, 2.03 mmol). After stirring under room temperature overnight, the reaction was quenched by 10% HCl solution and diluted with DCM. The organic phase was extracted with sat. $NaHCO_3$ solution and dried over Na_2SO_4. Silica gel column (3:1, hexanes/EtOAc) purification afforded *p*-tolyl 2, 3-isopropylidene-4-levulinoyl-1-thio-*β*-D-xylopyranose **S28** (586 mg, 88%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.40 (s, 3 H, C(CH_3)$_2$), 1.46 (s, 3 H, C(CH_3)$_2$), 2.15 (s, 3 H, CH_3COCH$_2$CH$_2$CO), 2.32 (s, 3 H, SPhCH_3), 2.51-2.81 (m, 4 H, CH$_3$COCH_2CH_2CO), 3.21-3.28 (m, 2 H, H-2, H-5a), 3.69-3.73 (m, 1 H, H-3), 4.20-4.24 (m, 1 H, H-5b), 4.76 (d, 1 H, J = 9.5 Hz, H-1), 4.91-4.96 (m, 1 H, H-4), 7.09-7.11 (m, 2 H), 7.42-7.44 (m, 2 H). HRMS: $C_{20}H_{26}O_6S$ $[M+NH_4]^+$ calcd: 412.2522, obsd: 412.2529. Compound **S28** (586 mg, 1.49 mmol) was dissolved in DCM/MeOH (1:1, 8 mL), followed by addition of camphorsulfonic acid (346 mg, 1.49 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was quenched by Et_3N and concentrated. The residue was purified by silica gel column (1:1, hexane-EtOAc) to afford *p*-tolyl 4-benzyl-1-thio-*β*-D-xylopyranose **S29** (475 mg, 90%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.16 (s, 3 H, CH_3COCH$_2$CH$_2$CO), 2.31 (s, 3 H, SPhCH_3), 2.53-2.57 (m, 3 H, O*H*, CH$_3$COCH$_2$CH_2CO), 2.75-2.78 (m, 2 H, CH$_3$COCH_2CH$_2$CO), 2.87 (br, 1 H, O*H*), 3.26-3.37 (m, 2 H, H-2, H-5a), 3.68-3.72 (m, 1 H, H-3), 4.08-4.12 (m, 1 H, H-5b), 4.42 (d, 1 H, J = 9.5 Hz, H-1), 4.77-4.82 (m, 1 H, H-4), 7.10-7.13 (m, 2 H), 7.40-7.42 (m, 2 H). HRMS: $C_{17}H_{22}O_6S$ $[M+NH_4]^+$ calcd: 372.1481, obsd: 372.1489. Compound **S29** (475 mg, 1.34 mmol) and DMAP (163 mg, 1.34 mmol) were dissolved in DCM (8 mL). Benzoyl chloride (373 μL, 3.21 mmol) was added into the reaction mixture while stirring and the reaction was left under reflux overnight. After the reaction was complete, it was diluted with DCM and washed with 10% HCl solution. The combined organic phase was extracted with a saturated aqueous solution of $NaHCO_3$ and dried over Na_2SO_4. Silica gel column (3:1, hexanes/EtOAc)

purification afforded *p*-tolyl 2,3-di-*O*-benzoyl-4-*O*-levulinoyl-1-thio-*β*-D-xylopyranose **S30** (550 mg, 73%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.04 (s, 3 H, CH_3COCH_2CH_2CO), 2.31 (s, 3 H, SPhCH_3), 2.41-2.67 (m, 4 H, CH_3COCH_2CH_2CO), 3.59-3.63 (m, 1 H, H-5a), 4.43-4.46 (m, 1 H, H-5b), 5.03 (d, 1 H, J = 6 Hz, H-1), 5.08-5.11 (m, 1 H, H-4), 5.34 (t, 1 H, J = 6.5 Hz, H-2), 5.57 (t, 1 H, J = 6.5 Hz, H-3), 7.08-7.10 (m, 2 H), 7.36-7.39 (m, 6 H), 7.49-7.53 (m, 2 H), 7.97-7.99 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 20.9, 21.0, 27.7, 29.5, 37.6, 60.2, 64.3, 68.4, 69.9, 71.5, 86.6, 128.3, 128.3, 128.6, 128.8, 129.2, 129.6, 129.7, 129.8, 133.2, 133.2, 133.3, 138.3, 164.9, 165.2, 171.5, 205.8. HRMS: $C_{31}H_{30}O_8S$ $[M+NH_4]^+$ calcd: 580.2005, obsd: 580.2008.

p-Tolyl 2, 3-di-O-benzoyl-1-thio-β-D-xylopyranose (**S24**). *p*-Tolyl 2, 3-di-*O*-benzoyl-4-*O*-*p*-methoxybenzyl-1-thio-*β*-D-xylopyranose **S23** (10.2 g, 17.41 mmol) was dissolved in DCM/H_2O (10:1, 50 mL), followed by addition of DDQ (5.9 g, 26.11 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was diluted with DCM, washed with a saturate aqueous solution of $NaHCO_3$, dried over Na_2SO_4. Silica gel column (4:1, hexanes/EtOAc) purification afforded *p*-tolyl 2, 3-di-*O*-benzoyl-1-thio-*β*-D-xylopyranose **S24** (6.54 g, 81%). *p*-Tolyl 2,3-di-*O*-benzoyl-4-*O*-benzyl-1-thio-*β*-D-xylopyranose **S27** (881 mg, 1.59 mmol) was dissolved in DCM/H_2O (10:1, 10 mL), followed by addition of DDQ (543 mg, 2.39 mmol). The resulting mixture was stirred under reflux overnight. After the reaction was complete, it was diluted with DCM, washed with a saturated aqueous solution of $NaHCO_3$, dried over Na_2SO_4. Silica gel column (4:1, hexanes/EtOAc) purification afforded *p*-tolyl 2,3-di-*O*-benzoyl-1-thio-*β*-D-xylopyranose **S24** (444 mg, 60%). *p*-Tolyl 2, 3-di-*O*-benzoyl-4-*O*-benzyl-1-thio-*β*-D-xylopyranose **S30** (550 mg, 0.98 mmol) was dissolved in DCM/MeOH (1:1, 8 mL), followed by addition of HOAc (6 mL) and NH_2NH_2-H_2O (570 μL). The resulting mixture was stirred under reflux overnight. After the reaction was complete, it was diluted with DCM, washed with a saturated aqueous solution of $NaHCO_3$, dried over Na_2SO_4. Silica gel column (4:1, hexanes/EtOAc) purification afforded *p*-tolyl 2,3-di-*O*-benzoyl-1-thio-*β*-D-xylopyranose **S24** (396 mg, 87%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.32 (s, 3 H, SPhCH_3), 3.02 (br, 1 H, OH), 3.53-3.58 (m, 1 H, H-5a), 3.94-3.98 (m, 1 H, H-4), 4.38-4.41 (m, 1 H, H-5b), 4.98 (d, 1 H, J = 7 Hz, H-1), 5.29 (t, 1 H, J = 7.5 Hz, H-3), 5.38 (t, 1 H, J = 7.5 Hz, H-2), 7.09-7.11 (m, 2 H), 7.36-7.40 (m, 6 H), 7.51-7.54 (m, 2 H), 7.96-8.02 (m, 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.2, 67.6, 68.2, 70.1, 76.0, 86.8, 128.4, 128.4, 128.7, 128.8, 129.2, 129.7, 129.7, 129.9, 133.2, 133.3, 133.5, 138.3, 165.0, 166.8. HRMS: $C_{26}H_{24}O_6S$ $[M+NH_4]^+$ calcd: 482.1637, obsd: 482.1657.



Screening donor-acceptor pairs for Xylose-Serine synthesis. Reagents and conditions: (a) $KHCO_3$, BnBr, Bu_4NI, DMSO; (b) AgOTf, *p*-TolSCl, DCM, -78 ^oC, then **19**, TTBP, -78 ^oC-r.t.; (c) DDQ, DCM/H_2O, reflux; (d) DDQ, DCM/H_2O; (e) TBSOTf, 2, 6-lutidine, -40 ^oC-0 ^oC; (f) *p*-TsOH, THF/H_2O, 70% or HF/Pyridine, 72% or Tf_2O, THF/H_2O, 80%.

Fmoc-Ser-OBn (**19**).[3] Dry DMSO (6 mL) was added to a 25 mL flask under nitrogen containing compound **S35** (0.962 g, 2.94 mmol), $KHCO_3$ (0.442 g, 4.40 mmol), and tetrabutylammonium iodide (0.1086 g, 0.294 mmol). The resulting white suspension was stirred under room temperature until a homogeneous solution was obtained. BnBr (1.048 mL, 8.80 mmol) was added to the reaction mixture and the reaction was kept for 8 h under room temperature. After the reaction was complete indicated by TLC, it was quenched by water and the mixture was extracted by EtOAc. The combined organic layer was washed by a saturated aqueous solution of $NaHCO_3$, saturate solution of $Na_2S_2O_3$ and brine sequentially. After drying over Na_2SO_4, the solution was concentrated to give yellow oil. The oil was cooled to -78 ^oC and triturated with hexanes. The obtained yellow solid was filtered and washed with hexanes under suction until a white solid was obtained (1 g, 82%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.95 (br, 1 H), 3.91-4.03 (m, 2 H), 4.20 (t, 1 H, J = 7 Hz), 4.39-4.49 (m, 3 H), 5.17-5.25 (m, 2 H), 5.64-5.68 (m, 1 H), 7.26-7.39 (m, 9 H), 7.57-7.59 (m, 2 H), 7.74-7.76 (m, 2 H).

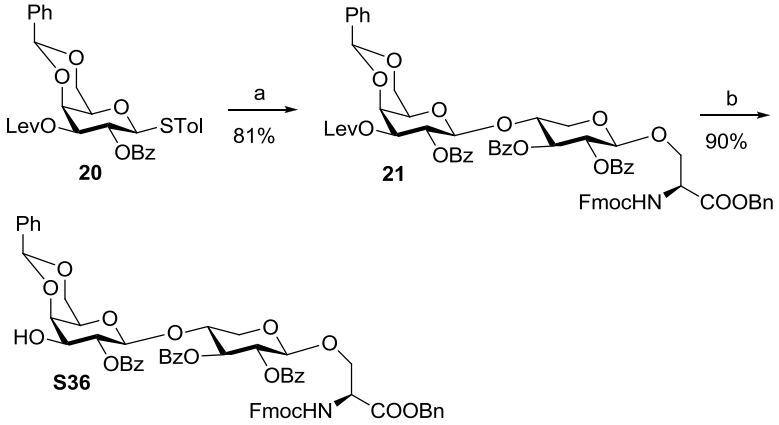
N-Fluorenylmethyloxycarbonyl-O-(2, 3-di-O-benzoyl-4-O-benzyl -β-D-xylopyranosyl)-L-serine benzyl ester (**S31**). Compound **S31** was synthesized from donor **S13** and acceptor **19** in 83% yield following the general procedure of single step glycosylation. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 3.37-3.42 (m, 1 H, H-5a), 3.64-3.70 (m, 1 H, H-4), 3.79-3.82 (m, 1 H, OCH_2CH), 3.89-3.92 (m, 1 H, H-5b), 4.11-4.14 (m, 1 H), 4.19-4.23 (m, 1 H), 4.28-4.35 (m, 2 H), 4.50-4.55 (m, 1 H, OCH$_2$CH), 4.59 (br, 2 H, PhCH_2), 4.64 (d, 1 H, J = 5.5 Hz, H-1), 5.08-5.22 (m, 3 H, H-2, PhCH_2), 5.55-5.59 (m, 2 H), 7.18-7.29 (m, 14 H), 7.35-7.42 (m, 5 H), 7.51-7.55 (m, 3 H), 7.74-7.76 (m, 2 H), 7.92-7.97 (m, 4 H). ^{13}C-NMR (150 MHz, $CDCl_3$): δ 47.3, 54.5, 60.6, 62.6, 67.4, 67.6, 69.2, 71.0, 72.1, 72.7, 74.0, 76.1, 101.2, 120.1, 125.4, 127.3, 127.9, 127.9, 128.0, 128.1, 128.5, 128.5, 128.6, 128.6, 128.7, 129.4, 129.6, 130.0, 130.1, 133.4, 133.5, 135.4, 137.6, 141.4, 143.9, 144.1, 156.1, 165.5, 165.7, 169.7. HRMS: $C_{51}H_{45}NO_{11}$ $[M+NH_4]^+$ calcd: 865.3336, obsd: 865.3331.

N-Fluorenylmethyloxycarbonyl-O-(2,3-di-O-benzoyl-4-O-p-methoxybenzyl-β-D-xylopyranosyl)-L-serine benzyl ester (**S33**). Compound **S33** was synthesized from donor **S32** and acceptor **19** in 76% yield following the general procedure of single step glycosylation. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 3.32-3.28 (m, 1 H), 3.62-3.67 (m, 1 H), 3.73 (s, 1 H, C*H*$_3$OPh), 3.79-3.82 (m, 1 H), 3.86-3.91 (m, 1 H), 4.10-4.14 (m, 1 H), 4.18-4.22 (m, 1 H), 4.28-4.34 (m, 2 H), 4.49-4.54 (m, 2 H), 4.61 (d, 1 H, J = 6 Hz, H-1), 5.08-5.21 (m, 3 H), 5.52-5.59 (m, 2 H), 6.71-6.73 (m, 2 H), 7.11-7.14 (m, 2 H), 7.23-7.28 (m, 8 H), 7.35-7.42 (m, 6 H), 7.50-7.55 (m, 3 H), 7.74-7.76 (m, 2 H), 7.90-7.96 (m, 4 H). HRMS: $C_{52}H_{47}NO_{12}$ $[M+NH_4]^+$ calcd: 895.3442, obsd: 895.3451.

N-Fluorenylmethyloxycarbonyl-O-(2,3-di-O-benzoyl-4-O-tert-butyldimethylsilyl-β-D-xylopyranosyl)-L-serine benzyl ester (**S34**). Compound **S24** (400 mg, 0.86 mmol) in DCM (5 mL) was cooled down to –40 °C, followed by sequential addition of 2, 6-lutidine (203 µL, 1.74 mmol) and TBSOTf (299 µL, 1.3 mmol). The resulting solution was warmed up very slowly to room temperature. The mixture was quenched by Et_3N and then diluted with DCM (100 mL). The organic phase was washed with a saturated aqueous solution of $NaHCO_3$ and then dried over Na_2SO_4, filtered and the solvents were removed in vacuo. Silica gel column chromatography (Hexanes–EtOAc) afforded *p*-Tolyl 2, 3-di-*O*-benzoyl-4-*O*-*tert*-butyldimethylsilyl-1-thio-*β*-D-xylopyranoside **18** as white solid (448 mg, 90%) (HRMS: $C_{32}H_{38}O_6SSi$ $[M+NH_4]^+$ calcd: 596.2502, obsd: 596.2480) which was used as donor to couple to acceptor **19** to produce compound **S34** in 83% yield following the general procedure of single step glycosylation. ^{1}H-NMR (600 MHz, $CDCl_3$): δ -0.12 (s, 3 H, Si(C*H*$_3$)$_2$C(CH$_3$)$_3$), 0.02 (s, 3 H, Si(C*H*$_3$)$_2$C(CH$_3$)$_3$), 0.76 (s, 9 H, Si(CH$_3$)$_2$C(C*H*$_3$)$_3$), 3.31-3.35 (m, 1 H), 3.83-3.96 (m, 3 H), 4.10-4.13 (m, 1 H), 4.18-4.20 (m, 1 H), 4.30-4.34 (m, 2 H), 4.49-4.52 (m, 1 H), 4.57 (d, 1 H, J = 6.5 Hz, H-1), 5.11-5.17 (m, 2 H, PhC*H*$_2$), 5.22-5.25 (m, 1 H), 5.46-5.49 (m, 1 H), 5.54-5.56 (m, 1 H), 7.22-7.40 (m, 14 H), 7.47-7.55 (m, 3 H), 7.75-7.77 (m, 2 H), 7.90-7.95 (m, 4 H). ^{13}C-NMR (150 MHz, $CDCl_3$): δ -5.0, -4.7, 17.7, 25.4, 47.0, 54.3, 65.9, 67.1, 67.3, 68.9, 69.1, 71.5, 74.7, 101.6, 119.9, 119.9, 125.1, 127.0, 127.6, 127.7, 128.1, 128.3, 128.3, 128.5, 129.2, 129.5, 129.7, 129.7, 133.0, 133.1, 135.2, 141.2, 141.2, 143.7, 143.8, 155.9, 165.3, 165.5, 169.4. HRMS: $C_{50}H_{53}NO_{11}Si$ $[M+NH_4]^+$ calcd: 889.3732, obsd: 889.3686.

N-Fluorenylmethyloxycarbonyl-O-(2,3-di-O-benzoyl-β-D-xylopyranosyl)-L-serine benzyl ester (**5**). Compound **S31** (300 mg, 0.354 mmol) was dissolved in 6 mL DCM/H_2O (10:1) and cooled down to 0 ^{o}C, followed by addition of 804 mg DDQ. The resulting mixture was stirred under reflux overnight. After cooling down to room temperature, the reaction mixture was diluted with DCM and washed with sat. $NaHCO_3$. The combined organic phase was dried over Na_2SO_4 and concentrated. Silica gel column purification afforded compound **5** (163 mg, 61%). Compound **S33** (3 g, 3.42 mmol) was dissolved in 50 mL DCM/H_2O (10:1) and cooled down to 0 ^{o}C, followed by addition of 1.55 g DDQ. The resulting mixture was stirred under room temperature overnight. After cooling down to room temperature, the reaction mixture was diluted with DCM and washed with sat. $NaHCO_3$. The combined organic phase was dried over Na_2SO_4 and concentrated. Silica gel column purification afforded compound **5** (2.2 g, 85%). Compound **S34** (1 g, 1.15 mmol) was dissolved in 20 mL DCM/H_2O (10:1) and cooled down to 0 ^{o}C, followed by dropwise addition of 290 µL Tf_2O. The resulting mixture was stirred under room temperature for another 2 h. After the reaction was complete, it was diluted with DCM and washed with sat. $NaHCO_3$. The combined organic phase was dried over Na_2SO_4 and concentrated.

Silica gel column purification afforded compound **5** (696 mg, 80%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 3.05 (d, 1 H, J = 5 Hz, O*H*), 3.38-3.45 (m, 4 H), 3.83 (dd, 1 H, J = 2.5 Hz, J = 8.5 Hz), 3.88-3.93 (m, 1 H), 4.05-4.14 (m, 2 H), 4.22-4.26 (m, 1 H), 4.30-4.35 (m, 2 H), 4.53-4.55 (m, 1 H), 4.65 (d, 1 H, J = 4.5 Hz, H-1), 5.08-5.18 (m, 2 H, PhCH_2), 5.24-5.32 (m, 2 H), 5.57 (d, 1 H, J = 7 Hz), 7.25-7.46 (m, 14 H), 7.51-7.55 (m, 3 H), 7.73-7.76 (m, 2 H), 7.94-7.99 (m, 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 47.0, 54.2, 54.3, 64.0, 64.1, 67.1, 67.3, 67.4, 67.6, 68.3, 68.4, 69.0, 69.1, 70.2, 70.3, 75.0, 75.1, 100.6, 100.7, 119.9, 120.0, 124.7, 125.1, 125.1, 127.1, 127.7, 128.2, 128.4, 128.5, 128.5, 128.8, 129.0, 129.7, 129.8, 129.9, 130.0, 132.6, 133.4, 133.4, 133.6, 133.7, 135.1, 141.2, 143.7, 143.8, 155.9, 165.1, 165.5, 167.0, 169.5. HRMS: $C_{44}H_{39}NO_{11}$ $[M+NH_4]^+$ calcd: 775.2867, obsd: 775.2867.



Synthesis of trisaccharide **S36**. Reagents and conditions: (a) AgOTf, *p*-TolSCl, DCM, -78 ^{o}C, then **5**, TTBP, -78 ^{o}C-0 ^{o}C; (b) NH_2NH_2-H_2O, HOAc, DCM/MeOH.

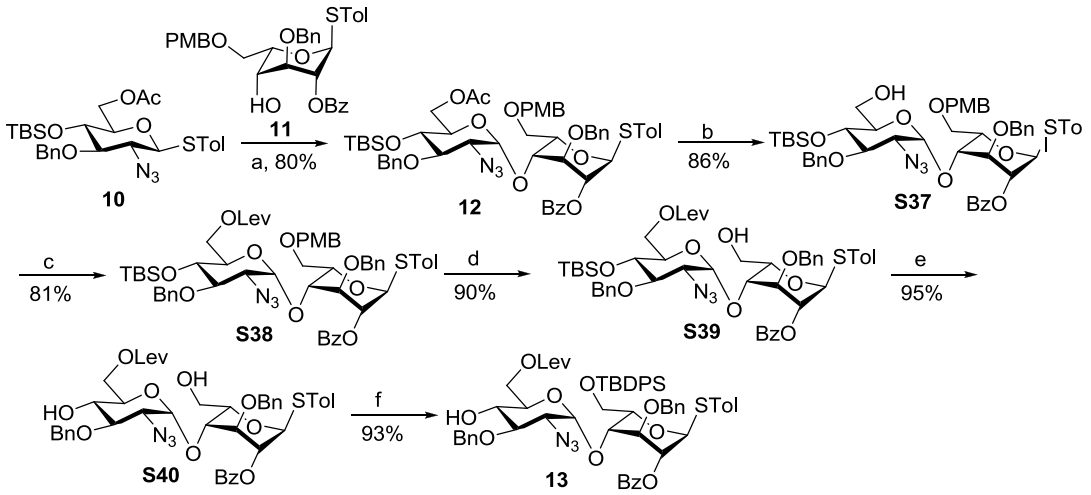
N-Fluorenylmethyloxycarbonyl-O-[2-O-benzoyl-3-O-levulinoyl-4, 6-O-benzylidene -β-D-galactopyranosyl-(1→4)-2,3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**21**). Compound **21** was synthesized from donor **20** and acceptor **5** in 81% yield following the general procedure of single step glycosylation. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.87 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.41-2.61 (m, 4 H, CH$_3$COCH_2CH_2), 3.23-3.31 (m, 2 H), 3.71-3.83 (m, 4 H), 3.90-3.95 (m, 1 H), 4.09-4.13 (m, 1 H), 4.20-4.24 (m, 3 H), 4.29-4.33 (m, 1 H), 4.45-4.51 (m, 1 H), 4.55 (d, 1 H, J = 6 Hz), 4.76 (d, 1 H, J = 8 Hz), 5.00-5.17 (m, 4 H), 5.35 (s, 1 H, PhC*H*), 5.53-5.62 (m, 3 H), 7.20-7.48 (m, 21 H), 7.51-7.56 (m, 3 H), 7.74-7.76 (m, 2 H), 7.94-7.98 (m, 6 H). ^{13}C-NMR (150 MHz, $CDCl_3$): δ 28.4, 29.6, 37.9, 38.1, 47.3, 54.5, 62.5, 66.9, 67.4, 67.5, 68.5, 69.2, 69.3, 69.6, 71.0, 72.0, 72.1, 73.4, 76.2, 91.5, 100.8, 101.2, 102.3, 120.2, 125.4, 126.5, 126.7, 127.3, 127.3, 127.9, 127.9, 128.2, 128.3, 128.4, 128.5, 128.5, 128.6, 128.6, 128.7, 128.8, 129.1, 129.3, 129.6, 129.7, 129.8, 130.0, 130.1, 130.1, 133.3, 133.6, 135.3, 137.7, 141.4, 143.9, 144.0, 156.1, 165.1, 165.3, 165.7, 169.6, 172.3, 206.3. HRMS: $C_{69}H_{63}NO_{19}$ $[M+NH_4]^+$ calcd: 1227.4338, obsd: 1227.3872.

N-Fluorenylmethyloxycarbonyl-O-[2-O-benzoyl-4,6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S36**). Compound **S36** was synthesized from compound **21** in 90% yield following the general procedure of Lev deprotection. ^{1}H-NMR (600 MHz, $CDCl_3$): δ 2.60 (d, 1 H, J = 9.5 Hz, O*H*), 3.26-3.34 (m, 2 H), 3.74-3.86 (m, 5 H), 3.93-3.97 (m, 1 H), 4.09-4.13 (m, 2 H), 4.21-4.33 (m, 2 H), 4.48-4.50 (m, 1 H), 4.57 (d, 1 H, J = 5 Hz), 4.71 (d, 1 H, J = 7 Hz), 5.02-5.10 (m, 2 H, COOCH_2Ph), 5.16-5.19 (m, 1 H), 5.27-5.30 (m, 1 H), 5.40 (s, 1 H, PhC*H*), 5.56 (d, 1 H, J

= 7.5 Hz), 5.61 (t, 1 H, *J* = 6 Hz), 7.21-7.47 (m, 23 H), 7.52-7.54 (m, 3 H), 7.74-7.76 (m, 2 H), 7.95-8.01 (m, 5 H). ^{13}C-NMR (150 MHz, $CDCl_3$): δ 47.0, 54.2, 62.2, 66.8, 67.2, 67.3, 68.3, 69.0, 70.7, 71.6, 71.8, 73.0, 75.3, 75.7, 100.5, 101.4, 101.7, 119.9, 125.1, 126.2, 126.5, 127.0, 127.7, 127.7, 127.9, 128.1, 128.2, 128.3, 128.3, 128.4, 128.4, 128.4, 128.5, 129.1, 129.1, 129.5, 129.6, 129.8, 129.9, 133.1, 133.2, 135.1, 137.2, 141.2, 143.7, 143.8, 155.9, 165.1, 165.5, 165.9, 169.4. HRMS: $C_{64}H_{57}NO_{17}$ $[M+NH_4]^+$ calcd: 1129.3970, obsd: 1129.3920.

p-Tolyl 2,3-di-O-levulinoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-1-thio-β-D-galactopyranoside (**24**). Compound **24** was synthesized from donor **22**[2] and acceptor **23** in 85% yield following the general procedure of single step glycosylation. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.95 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.00 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.28 (s, 3 H, SPhC*H*$_3$), 2.10-2.69 (m, 8 H, CH$_3$COC*H*$_2$C*H*$_2$), 3.35 (br, 1 H), 3.52 (br, 1 H), 3.95-4.03 (m, 2 H), 4.13-4.19 (m, 3 H), 4.33-4.36 (m, 1 H), 4.43 (d, 1 H, J = 3 Hz), 4.65-4.68 (m, 2 H), 4.72 (d, 1 H, *J* = 9.5 Hz), 5.24-5.28 (m, 1 H), 5.42 (s, 1 H, PhC*H*), 5.48-5.53 (m, 1 H), 5.54 (s, 1 H, PhC*H*), 6.98-7.00 (m, 2 H), 7.29-7.34 (m, 6 H), 7.41-7.48 (m, 8 H), 7.57-7.61 (m, 1 H), 8.01-8.04 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 27.5, 28.1, 29.5, 29.5, 37.7, 37.7, 66.4, 68.2, 68.7, 69.0, 69.4, 70.3, 71.7, 73.1, 75.9, 86.1, 100.7, 100.8, 100.9, 126.3, 126.5, 127.9, 128.1, 128.2, 128.5, 128.7, 129.0, 129.4, 129.6, 130.0, 133.2, 133.7, 137.4, 137.8, 137.9, 164.7, 171.2, 172.1, 206.5, 206.6.

"3+2+3" assembly of octasaccharide 27



Synthesis of disaccharide **13**. Reagents and conditions: (a) AgOTf, *p*-TolSCl, DCM, -78 ^{o}C, then **11**, TTBP, -78 ^{o}C-0 ^{o}C; (b) $Mg(OMe)_2$, DCM, -20 ^{o}C-0 ^{o}C; (c) LevOH, EDC-HCl, DMAP, DCM; (d) DDQ, DCM/H_2O; (e) HF/Pyridine; (f) TBDPSCl, imidazole, DCM.

p-Tolyl 2-azido-3-O-benzyl-4-O-tert-butyl-dimethylsilyl-6-O-acetyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-p-methoxybenzyl-1-thio-α-L-idopyranoside (**12**). Compound **12** was synthesized from donor **10** and acceptor **11** in 80% yield following the general procedure of single step glycosylation. The identity of the compound was confirmed by comparison with literature data.[4]

p-Tolyl 2-azido-3-O-benzyl-4-O-tert-butyl-dimethylsilyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-p-methoxybenzyl-1-thio-α-L-idopyranoside (**S37**). Compound **12** (2.2 g, 2.13 mmol) was dissolved in 50 mL dry DCM and cooled down to -20 °C. Fresh methanolic $Mg(OMe)_2$ solution (8%) (21 mL) was added to the reaction mixture. The resulting mixture was left under N_2 and monitored by TLC. After the reaction was complete, it was neutralized by 1 M HOAc to pH 5 and diluted with DCM. After washing with saturated aqueous $NaHCO_3$ solution and drying over Na_2SO_4, the solution was concentrated and purified by silica gel column to afford compound **S37** (1.81 g, 86%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ -0.14 (s, 3 H, Si(CH_3)$_2$), -0.01 (s, 3 H, Si(CH_3)$_2$), 0.85 (s, 9 H, C(CH_3)$_3$), 1.70-1.73 (m, 1 H), 2.28 (s, 3 H, SPhCH_3), 3.18 (m, 1 H, J = 3.5 Hz, J = 10 Hz), 3.31-3.35 (m, 1 H), 3.44-3.48 (m, 1 H), 3.53-3.66 (m, 4 H), 3.73-3.75 (m, 2 H), 3.79 (s, 3 H, CH_3OPh), 3.99-4.02 (m, 1 H, CH_2Ph), 4.12-4.14 (m, 1 H), 4.24-4.27 (m, 1 H), 4.49 (s, 2 H), 4.58 (d, 1 H, J = 4.0 Hz), 4.70-4.73 (m, 1 H, CH_2Ph), 4.88-4.91 (m, 1 H), 4.92-4.94 (m, 1 H, CH_2Ph), 5.31-5.33 (m, 1 H), 5.53 (br, 1 H), 6.85-6.87 (m, 2 H), 7.00-7.02 (m, 2 H), 7.08-7.10 (m, 2 H), 7.20-7.29 (m, 7 H), 7.32-7.36 (m, 4 H), 7.38-7.45 (m, 4 H), 8.08-8.10 (m, 2 H). HRMS: $C_{54}H_{65}N_3O_{11}SSi$ $[M+NH_4]^+$ calcd: 1009.4453, obsd: 1009.4430.

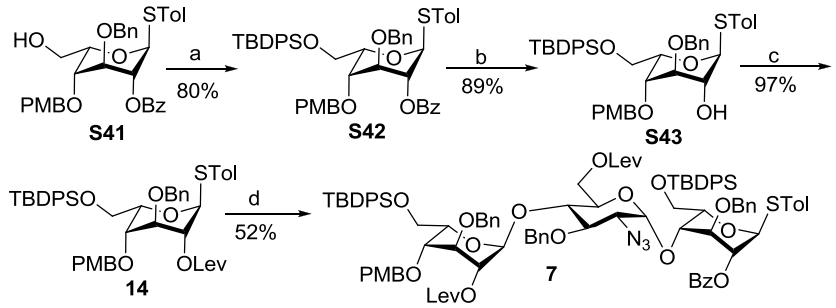
p-Tolyl 2-azido-3-O-benzyl-4-O-tert-butyl-dimethylsilyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-p-methoxybenzyl-1-thio-α-L-idopyranoside (**S38**). Compound **S38** was synthesized from compound **S37** in 81% yield following the general procedure for protecting 6-OH with Lev. ^{1}H-NMR (500 MHz, $CDCl_3$): δ -0.09 (s, 3 H, Si(CH_3)$_2$), -0.01 (s, 3 H, Si(CH_3)$_2$), 0.88 (s, 9 H, C(CH_3)$_3$), 2.14 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.31 (s, 3 H, SPhCH_3), 2.55-2.76 (m, 4 H, CH$_3$COCH_2CH_2), 3.27-3.29 (m, 1 H), 3.35-3.39 (m, 1 H), 3.50-3.54 (m, 1 H), 3.73-3.86 (m, 7 H), 4.02-4.15 (m, 2 H), 4.17 (br, 1 H), 4.24-4.27 (m, 1 H), 4.31-4.34 (m, 1 H), 4.50-4.56 (m, 2 H), 4.68-4.69 (m, 1 H), 4.75-4.77 (m, 1 H), 4.94-4.97 (m, 2 H), 5.37 (br, 1 H), 5.58 (br, 1 H), 6.88-6.90 (m, 2 H), 7.03-7.05 (m, 2 H), 7.14-7.16 (m, 2 H), 7.24-7.30 (m, 6 H), 7.34-7.39 (m, 4 H), 7.43-7.49 (m, 5 H), 8.12-8.14 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ -4.9, -3.9, 14.1, 17.8, 21.0, 25.8, 27.6, 29.7, 37.6, 55.1, 60.2, 62.9, 64.4, 67.1, 69.1, 70.0, 70.8, 71.2, 71.7, 72.5, 72.8, 74.4, 74.7, 80.4, 86.3, 98.2, 113.6, 126.9, 127.2, 127.8, 127.9, 128.0, 128.3, 128.3, 129.1, 129.5, 129.7, 129.8, 130.0, 131.7, 132.2, 133.1, 137.3, 137.4, 137.6, 159.0, 165.5, 172.3, 206.0. HRMS: $C_{59}H_{71}N_3O_{13}SSi$ $[M+NH_4]^+$ calcd: 1107.4821, obsd: 1107.4768.

p-Tolyl 2-azido-3-O-benzyl-4-O-tert-butyl-dimethylsilyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-1-thio-α-L-idopyranoside (**S39**). Compound **S38** (1.6 g, 1.48 mmol) was dissolved in DCM/H_2O (10:1, 30 mL), followed by addition of DDQ (500 mg, 2.25 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was diluted with DCM, washed with sat. $NaHCO_3$ solution, dried over Na_2SO_4. Silica gel column purification afforded compound **S39** (1.29 g, 90%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ -0.17 (s, 3 H, Si(CH_3)$_2$), -0.03 (s, 3 H, Si(CH_3)$_2$), 0.84 (s, 9 H, C(CH_3)$_3$), 2.14 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.31 (s, 3 H, SPhCH_3), 2.57-2.72 (m, 4 H, CH$_3$COCH_2CH_2), 3.22-3.25 (m, 2 H), 3.35-3.39 (m, 1 H), 3.68 (br, 1 H), 3.76-3.98 (m, 6 H), 4.06-4.10 (m, 1 H), 4.15 (br, 1 H), 4.40 (br, 1 H, J = 10.5 Hz), 4.52 (s, 1 H), 4.73-4.75 (m, 1 H, CH_2Ph), 4.82-4.85 (m, 1 H), 4.95-4.97 (m, 1 H, CH_2Ph), 5.36 (s, 1 H), 5.56 (s, 1 H), 7.03-7.10 (m, 4 H), 7.18-7.48 (m, 13 H), 8.10-8.12 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ -4.8, -3.9, 14.0, 17.8, 21.0, 25.7, 27.5, 29.7, 37.6,

61.3, 63.3, 64.4, 67.8, 69.7, 71.0, 71.1, 71.6, 72.3, 74.2, 75.9, 80.3, 86.3, 99.2, 126.7, 127.1, 127.9, 128.1, 128.2, 128.4, 129.6, 129.6, 129.9, 131.6, 132.2, 133.1, 137.2, 137.5, 137.6, 165.4, 172.3, 206.4. HRMS: $C_{51}H_{63}N_3O_{12}SSi$ $[M+NH_4]^+$ calcd: 987.4245, obsd: 987.4199.

p-Tolyl 2-azido-3-O-benzyl-4-O-tert-butyl-dimethylsilyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-1-thio-α-L-idopyranoside (**S40**). Compound **S39** (1.29 g, 1.33 mmol) was dissolved in pyridine (10 mL) in a plastic flask followed by addition of 65-70% HF-pyridine solution (15 mL) under 0 ^oC. The solution was stirred overnight until complete disappearance of starting material as judged by TLC analysis. The reaction mixture was quenched by solid $NaHCO_3$ and diluted with DCM. The aqueous phase was extracted with DCM twice. The combined organic phase was further washed with a saturated aqueous solution of $NaHCO_3$ and dried over Na_2SO_4. Column purification afforded compound **S40** (1.08 g, 95%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.13 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.26-2.29 (m, 1 H), 2.31 (s, 3 H, SPhCH_3), 2.54-2.72 (m, 4 H, CH$_3$COCH_2CH_2), 2.92 (br, 1 H), 3.21 (dd, 1 H, J = 3.5 Hz, J = 10 Hz), 3.31-3.35 (m, 1 H), 3.39-3.44 (m, 1 H), 3.69-3.71 (m, 1 H), 3.75-3.79 (m, 1 H), 3.85-3.90 (m, 2 H), 4.04-4.07 (m, 1 H, CH_2Ph), 4.12-4.14 (m, 1 H), 4.21 (dd, 1 H, J = 2 Hz, J = 12 Hz), 4.26-4.28 (m, 1 H, CH_2Ph), 4.35 (dd, 1 H, J = 5.5 Hz, J = 12 Hz), 4.55 (d, 1 H, J = 4 Hz), 4.73-4.76 (m, 1 H, CH_2Ph), 4.80-4.83 (m, 1 H), 4.95-4.98 (m, 1 H, CH_2Ph), 5.38 (s, 1 H), 5.55 (s, 1 H), 7.10-7.16 (m, 4 H), 7.24-7.30 (m, 4 H), 7.34-7.47 (m, 9 H), 8.13-8.15 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 20.9, 21.0, 27.6, 29.7, 37.7, 60.3, 61.4, 63.2, 63.3, 68.0, 69.7, 70.5, 71.1, 71.2, 72.4, 74.8, 74.9, 80.2, 86.3, 98.6, 127.8, 127.9, 128.1, 128.3, 128.3, 128.4, 129.7, 129.9, 131.6, 132.4, 133.1, 137.2, 137.6, 137.7, 165.6, 173.1, 206.8. HRMS: $C_{45}H_{49}N_3O_{12}S$ $[M+NH_4]^+$ calcd: 873.3381, obsd: 873.3345.

p-Tolyl 2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-tert-butyl-diphenylsilyl-1-thio-α-L-idopyranoside (**13**). Compound **S40** (1.08 g, 1.26 mmol) was dissolved in 10 mL DCM, followed by addition of imidazole (102 mg, 1.5 mmol) and TBDPSCl (487 μL, 1.88 mmol). The resulting mixture was stirred under room temperature overnight and diluted with DCM. The solution was washed with 10% HCl solution, sat. $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, column purification afforded compound **13** (1.28 g, 93%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.08 (s, 9 H, C(CH_3)$_3$), 2.13 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.29 (s, 3 H, SPhCH_3), 2.47-2.69 (m, 4 H, CH$_3$COCH_2CH_2), 2.76 (d, 1 H, J = 4.5 Hz), 3.24 (dd, 1 H, J = 3.5 Hz, J = 10 Hz), 3.31-3.36 (m, 1 H), 3.41-3.45 (m, 1 H), 3.56-3.61 (m, 2 H), 3.75 (br, 1 H), 3.89-3.97 (m, 2 H), 4.14-4.17 (m, 1 H, CH_2Ph), 4.22-4.23 (m, 1 H), 4.33-4.36 (m, 1 H), 4.40-4.43 (m, 1 H, CH_2Ph), 4.68 (d, 1 H, J = 3.5 Hz), 4.75-4.81 (m, 2 H), 4.95-4.97 (m, 1 H, CH_2Ph), 5.39-5.41 (m, 1 H), 5.58-5.59 (m, 1 H), 6.99-7.01 (m, 2 H), 7.18-7.20 (m, 2 H), 7.26-7.50 (m, 19 H), 7.69-7.76 (m, 4 H), 8.12-8.15 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 19.1, 21.0, 26.8, 27.6, 29.6, 37.8, 60.3, 62.5, 63.3, 63.5, 69.3, 69.4, 70.2, 70.3, 70.9, 72.5, 72.7, 74.9, 75.0, 79.9, 86.7, 98.5, 127.7, 127.7, 127.8, 127.9, 127.9, 128.3, 128.3, 128.4, 129.5, 129.7, 129.8, 129.9, 131.6, 132.7, 132.8, 132.9, 133.1, 135.5, 135.6, 137.5, 137.5, 137.8, 165.6, 173.4, 206.4. HRMS: $C_{61}H_{67}N_3O_{12}SSi$ $[M+NH_4]^+$ calcd: 1111.4558, obsd: 1111.4517.



Synthesis of trisaccharide **7**. Reagents and conditions: (a) TBDPSCl, imidazole, DCM; (b) NaOMe, DCM/MeOH; (c) LevOH, EDC-HCl, DMAP, DCM; (d) AgOTf, *p*-TolSCl, DCM, -78 ^{o}C, then **13**, TTBP, -78 ^{o}C-0 ^{o}C.

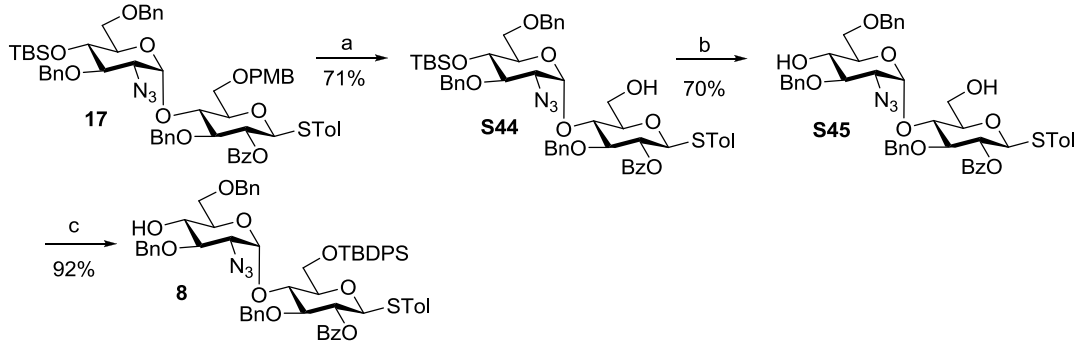
p-Tolyl 2-O-benzoyl-3-O-benzyl-4-O-p-methoxybenzyl-6-O-tert-butyl-diphenylsilyl-1-thio-α-L-idopyranoside (**S42**). Compound **S41**[5] (1.3 g, 2.16 mmol) was dissolved in 10 mL DCM, followed by addition of imidazole (176 mg, 2.59 mmol) and TBDPSCl (840 μL, 3.24 mmol). The resulting mixture was stirred under room temperature overnight and diluted with DCM. The solution was washed with 10% HCl solution, sat. $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, column purification afforded compound **S42** (1.45 g, 80%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.13 (s, 9 H, C(CH_3)$_3$), 2.31 (s, 3 H, SPhCH_3), 3.74-3.76 (m, 1 H), 3.79 (s, 3 H, CH_3OPh), 3.96-4.05 (m, 2 H, H-6a, H-6b), 4.10-4.12 (m, 1 H, H-3), 4.36-4.48 (m, 2 H, PhCH_2), 4.73-4.76 (m, 2 H, H-5, PhCH_2), 4.92-4.95 (m, 1 H, PhCH_2), 5.48-5.49 (m, 1 H, H-2), 5.60 (dd, 1 H, J = 2.5 Hz, H-1), 6.72-6.74 (m, 2 H), 7.02-7.05 (m, 4 H), 7.32-7.53 (m, 16 H), 7.72-7.78 (m, 4 H), 8.02-8.04 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 19.1, 21.0, 26.8, 55.1, 63.0, 69.4, 70.1, 72.2, 72.4, 72.6, 73.7, 86.2, 113.5, 127.6, 127.7, 127.7, 128.1, 128.3, 129.3, 129.4, 129.6, 129.7, 129.9, 129.9, 131.8, 132.4, 132.9, 133.1, 133.2, 135.5, 135.6, 137.2, 137.6, 159.0, 165.5. HRMS: $C_{51}H_{54}O_7SSi$ $[M+NH_4]^+$ calcd: 856.3703, obsd: 856.3743.

p-Tolyl 3-O-benzyl-4-O-p-methoxybenzyl-6-O-tert-butyl-diphenylsilyl-1-thio-α-L-idopyranoside (**S43**). Compound **S42** (2.7 g, 3.22 mmol) was dissolved in DCM/MeOH (1:1, 20 mL) and was added freshly prepared NaOMe in MeOH (5 M) to maintain the pH above 12. After the reaction was complete, the reaction was diluted with 10% HCl solution until the pH was around 6. The solution was washed with 10% HCl solution, a saturated aqueous $NaHCO_3$ solution and the organic phase was dried over Na_2SO_4. After concentration, column purification afforded compound **S43** (2.1 g, 89%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.11 (s, 9 H, C(CH_3)$_3$), 2.30 (s, 3 H, SPhCH_3), 3.71-3.73 (m, 1 H, OH), 3.79 (s, 1 H, CH_3OPh), 3.82-3.84 (m, 1 H), 3.85-3.87 (m, 2 H), 4.03-4.10 (m, 2 H), 4.39-4.42 (m, 1 H), 4.52-4.55 (m, 1 H), 4.57-4.60 (m, 1 H), 4.75-4.81 (m, 2 H), 5.39 (br, 1 H, H-1), 6.80-6.82 (m, 2 H), 7.01-7.03 (m, 2 H), 7.09-7.11 (m, 2 H), 7.34-7.47 (m, 13 H), 7.70-7.73 (m, 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 19.1, 20.9, 26.8, 55.1, 62.6, 67.9, 69.4, 71.7, 71.9, 72.6, 73.4, 89.7, 113.8, 127.6, 127.6, 127.7, 128.4, 128.9, 129.4, 129.6, 129.6, 129.7, 131.9, 133.0, 133.1, 133.3, 135.5, 135.5, 136.9, 137.6, 159.4. HRMS: $C_{44}H_{50}O_6SSi$ $[M+NH_4]^+$ calcd: 752.3441, obsd: 752.3485.

p-Tolyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-6-O-tert-butyl-diphenylsilyl-1-thio-α-L-idopyranoside (**14**). Compound **S43** (2.1 g, 2.86 mmol) was dissolved in 10 mL DCM, followed by addition of LevOH (347 μL, 3.43 mmol), DMAP (348 mg, 2.86 mmol) and EDC-HCl (657 mg, 3.43 mmol). After stirring under room temperature overnight, the

reaction was quenched by 10% HCl solution and diluted with DCM. The organic phase was extracted with a saturated aqueous $NaHCO_3$ solution and dried over Na_2SO_4. Silica gel column purification afforded compound **14** (2.3 g, 97%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.05 (s, 9 H, C(C*H*$_3$)$_3$), 2.13 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.27 (s, 3 H, SPhC*H*$_3$), 2.52-2.75 (m, 4 H, CH$_3$COC*H*$_2$C*H*$_2$), 3.59-3.61 (m, 1 H, H-4), 3.77 (s, 1 H, C*H*$_3$OPh), 3.88-3.91 (m, 3 H, H-3, H-6a, H-6b), 4.30-4.32 (m, 1 H), 4.45-4.47 (m, 1 H), 4.61-4.64 (m, 2 H), 4.82-4.85 (m, 1 H), 5.16-5.18 (m, 1 H, H-2), 5.42 (d, 1 H, J = 2.5 Hz, H-1), 6.75-6.77 (m, 2 H), 6.97-6.99 (m, 2 H), 7.05-7.07 (m, 2 H), 7.31-7.43 (m, 13 H), 7.64-7.69 (m, 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 19.0, 20.9, 20.9, 26.7, 28.0, 29.7, 37.6, 55.1, 60.2, 62.9, 69.3, 70.0, 71.9, 72.5, 73.3, 86.0, 113.6, 127.6, 127.7, 127.8, 128.3, 129.4, 129.4, 129.5, 129.9, 131.8, 132.0, 133.1, 133.2, 135.5, 135.5, 137.1, 137.7, 159.1, 165.4, 171.7, 206.1. HRMS: $C_{49}H_{56}O_8SSi$ $[M+NH_4]^+$ calcd: 850.3809, obsd: 850.3805.

p-Tolyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-6-O-tert-butyl-diphenylsilyl-α-L-idopyranosyl-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-tert-butyl-diphenylsilyl-1-thio-α-L-idopyranoside (**7**). Compound **7** was synthesized from donor **14** and acceptor **13** in 52% yield following the general procedure of single step glycosylation. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.03 (s, 9 H, C(C*H*$_3$)$_3$), 1.06 (s, 9 H, C(C*H*$_3$)$_3$), 2.01 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.02 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.27 (s, 3 H, SPhC*H*$_3$), 2.31-2.68 (m, 8 H, CH$_3$COC*H*$_2$C*H*$_2$), 3.23 (dd, 1 H, J = 4 Hz, J = 10.5 Hz), 3.41 (t, 1 H, J = 9 Hz), 3.53-3.55 (m, 1 H), 3.66-3.71 (m, 2 H), 3.77 (s, 1 H, C*H*$_3$OPh), 3.82-3.95 (m, 7 H), 3.98-4.02 (m, 3 H), 4.15-4.17 (m, 1 H), 4.23 (d, 1 H, J = 10.5 Hz), 4.29-4.31 (m, 1 H), 4.33-4.36 (m, 1 H), 4.58-4.62 (m, 4 H), 4.78-4.83 (m, 2 H), 4.87-4.89 (m, 2 H), 4.93-4.95 (m, 1 H), 5.37 (t, 1 H, J = 4.5 Hz), 5.58 (d, 1 H, J = 3.5 Hz), 6.73-6.75 (m, 2 H), 6.96-6.99 (m, 4 H), 7.12-7.17 (m, 6 H), 7.22-7.40 (m, 23 H), 7.45-7.49 (m, 1 H), 7.56-7.61 (m, 4 H), 7.65-7.67 (m, 2 H), 7.72 (m 2 H), 8.06-8.08 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 19.1, 19.1, 21.0, 26.8, 26.9, 27.7, 27.9, 29.5, 29.6, 29.6, 34.6, 37.6, 55.2, 60.3, 62.9, 63.9, 64.0, 70.1, 70.4, 70.8, 71.4, 72.2, 73.0, 73.6, 74.3, 74.9, 75.2, 75.4, 75.6, 75.9, 78.9, 86.4, 97.9, 98.7, 113.6, 113.9, 127.1, 127.6, 127.6, 127.7, 127.7, 127.7, 127.8, 127.8, 128.0, 128.1, 128.2, 128.3, 128.6, 129.4, 129.4, 129.5, 129.6, 129.7, 129.7, 129.8, 129.8, 129.9, 131.3, 132.0, 132.8, 132.9, 133.1, 133.3, 135.6, 135.6, 135.6, 135.6, 137.5, 137.7, 137.9, 138.1, 159.2, 165.3, 171.7, 172.1, 206.0, 206.2. MALDI-MS: $C_{103}H_{115}N_3O_{20}SSi_2$ $[M+Na]^+$ calcd: 1826.26, obsd: 1826.33.



Synthesis of disaccharide **8**. Reagents and conditions: (a) DDQ, DCM/H_2O; (b) HF/Pyridine; (c) TBDPSCl, imidazole, DCM.

p-Tolyl 2-azido-3,6-di-O-benzyl-4-O-tert-butyl-dimethylsilyl-2-deoxy-β-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-1-thio-β-D-glucopyranoside (**S44**). Compound **17** (300 mg, 0.277 mmol) was dissolved in DCM/H_2O (10:1, 5 mL), followed by addition of DDQ (95 mg, 0.42 mmol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was diluted with DCM, washed with sat. $NaHCO_3$, dried over Na_2SO_4. Silica gel column purification afforded compound **S44** (189 mg, 71%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ -0.10 (s, 3 H, Si(CH_3)$_2$), -0.08 (s, 3 H, Si(CH_3)$_2$), 0.78 (s, 9 H, C(CH_3)$_3$), 2.30 (s, 3 H, SPhCH_3), 3.04 (d, 1 H, J = 6 Hz), 3.15 (dd, 1 H, J = 5.5 Hz, J = 8.5 Hz), 3.40 (dd, 1 H, J = 5.5 Hz, J = 8.5 Hz), 3.46-3.52 (m, 2 H), 3.61-3.65 (m, 2 H), 3.70-3.72 (m, 1 H), 3.88-3.94 (m, 2 H), 4.02 (t, 1 H, J = 7.5 Hz), 4.11 (t, 1 H, J = 7.5 Hz), 4.45-4.47 (m, 1 H), 4.62-4.81 (m, 6 H), 5.31 (t, 1 H, J = 8 Hz), 5.61 (d, 1 H, J = 3.5 Hz), 7.06-7.08 (m, 2 H), 7.11-7.18 (m, 5 H), 7.23-7.35 (m, 12 H), 7.54-7.57 (m, 1 H), 8.05-8.07 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ -4.8, -3.9, 14.0, 17.8, 21.0, 21.0, 25.7, 60.2, 61.3, 63.2, 68.5, 71.3, 72.6, 73.0, 73.1, 73.3, 74.4, 74.8, 79.1, 80.2, 84.9, 86.5, 97.9, 114.2, 127.1, 127.3, 127.4, 127.5, 127.7, 127.8, 128.1, 128.1, 128.3, 128.3, 128.8, 129.5, 129.6, 129.7, 133.1, 133.1, 137.2, 137.3, 137.7, 138.0, 164.9. HRMS: $C_{53}H_{63}N_3O_{10}SSi$ $[M+NH_4]^+$ calcd: 979.4347, obsd: 979.4371.

p-Tolyl 2-azido-3,6-di-O-benzyl-4-O-tert-butyl-dimethylsilyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-1-thio-β-D-glucopyranoside (**S45**). Compound **S44** (1.3 g, 1.35 mmol) was dissolved in pyridine (10 mL) in a plastic flask followed by addition of 65-70% HF-pyridine solution (15 mL) under 0 ^{o}C. The solution was stirred overnight until complete disappearance of starting material as judged by TLC analysis. The reaction mixture was quenched by solid $NaHCO_3$ and diluted with DCM. The aqueous phase was extracted with DCM twice. The combined organic phase was further washed with a saturated aqueous solution of $NaHCO_3$ and dried over Na_2SO_4. Column purification afforded compound **S45** (800 mg, 70%). ^{1}H-NMR (600 MHz, $CDCl_3$): δ 2.31 (s, 3 H, SPhCH_3), 2.43-2.46 (m, 1 H), 2.51-2.53 (m, 1 H), 3.16-3.19 (m, 1 H), 3.50-3.53 (m, 1 H), 3.58-3.66 (m, 3 H), 3.72-3.77 (m, 2 H), 3.79-3.83 (m, 1 H), 3.90-3.94 (m, 1 H), 4.00-4.06 (m, 2 H), 4.50-4.58 (m, 2 H, CH_2Ph), 4.67-4.69 (m, 1 H, CH_2Ph), 4.74-4.81 (m, 3 H), 4.88-4.90 (m, 1 H), 5.30 (t, 1 H, J = 7.5 Hz), 5.58-5.59 (m, 1 H), 7.07-7.09 (m, 2 H), 7.12-7.20 (m, 5 H), 7.26-7.39 (m, 12 H), 7.43-7.47 (m, 2 H), 7.56-7.59 (m, 1 H), 8.07-8.09 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 21.1, 21.1, 60.3, 61.7, 62.4, 69.4, 71.0, 72.0, 72.3, 73.0, 73.6, 74.6, 75.0, 78.9, 79.6, 84.9, 86.5, 97.8, 113.7, 127.6, 127.7, 127.8, 127.8, 128.0, 128.2, 128.4, 128.5, 128.6, 128.7, 129.6, 129.8, 133.1, 133.3, 137.3, 137.3, 137.9, 138.3, 165.1, 171.7, 172.1, 206.0, 206.2. HRMS: $C_{47}H_{49}N_3O_{10}S$ $[M+NH_4]^+$ calcd: 865.3482, obsd: 865.3478.

p-Tolyl 2-azido-3,6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-tert-butyl-diphenylsilyl-1-thio-β-D-glucopyranoside (**8**). Compound **S45** (800 mg, 0.945 mmol) was dissolved in 10 mL DCM, followed by addition of imidazole (102 mg, 1.5 mmol) and TBDPSCl (487 μL, 1.88 mmol). The resulting mixture was stirred under room temperature overnight and diluted with DCM. The solution was washed with 10% HCl solution, a saturated aqueous $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, column purification afforded compound **8** (930 mg, 92%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.09 (s, 9 H, C(CH_3)$_3$), 2.28 (s, 3 H, SPhCH_3), 2.31-2.32 (m, 1 H), 3.13-3.19 (m, 2 H), 3.25-3.28 (m, 1 H), 3.43-3.47 (m, 1 H), 3.60-3.67 (m, 3 H), 3.92-3.97 (m, 2 H), 4.00-4.04 (m, 2 H), 4.20-4.35 (m, 2 H, CH_2Ph), 4.68-4.76 (m, 2 H, CH_2Ph),

4.82-4.87 (m, 3 H), 5.34-5.38 (m, 1 H), 5.59 (d, 1 H, J = 3.5 Hz), 6.98-7.00 (m, 2 H), 7.12-7.20 (m, 7 H), 7.27-7.41 (m, 16 H), 7.44-7.47 (m, 2 H), 7.56-7.59 (m, 1 H), 7.70-7.72 (m , 4 H), 8.08-8.10 (m, 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 19.3, 21.0, 26.9, 62.4, 63.8, 69.0, 70.8, 72.0, 72.9, 73.1, 73.5, 74.4, 74.9, 79.2, 79.6, 85.0, 87.3, 97.6, 127.6, 127.7, 127.7, 127.8, 127.9, 127.9, 128.2, 128.3, 128.4, 128.5, 129.6, 129.6, 129.7, 129.8, 130.4, 131.9, 133.1, 133.3, 133.6,235.5, 135.8, 137.3, 137.5, 137.5, 138.0, 165.2. HRMS: $C_{63}H_{67}N_3O_{10}SSi$ $[M+NH_4]^+$ calcd: 1103.4660, obsd: 1103.4486.

N-Fluorenylmethyloxycarbonyl-O-[2,3-di-O-levulinoyl-4,6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4,6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2,3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**25**). Compound **25** was synthesized from donor **24** and acceptor **5** in 43% yield following the general procedure of single step glycosylation. ^{1}H-NMR (600 MHz, $CDCl_3$): δ 1.96 (s, 3 H, CH_3COCH_2CH_2), 2.02 (s, 3 H, CH_3COCH_2CH_2), 2.13-2.40 (m, 3 H, CH$_3$COCH_2CH_2), 2.51-2.70 (m, 5 H, CH$_3$COCH_2CH_2), 3.19 (s, 1 H), 3.23-3.27 (m, 1 H), 3.35 (s, 1 H), 3.70-3.76 (m, 3 H), 3.80-3.83 (m, 1 H, CH_2Ph), 3.88-3.92 (m, 1 H), 3.95-3.98 (m, 1 H), 4.08-4.13 (m, 2 H), 4.16-4.24 (m, 4 H), 4.29-4.33 (m, 2 H), 4.46-4.48 (m, 1 H), 4.53 (d, 1 H, J = 6.0 Hz), 4.68-4.71 (m, 3 H), 4.99-5.08 (m, 2 H, CH_2Ph), 5.12-5.15 (m, 1 H), 5.26-5.30 (m, 1 H), 5.52-5.44 (m, 2 H), 5.51-5.60 (m, 3 H), 7.15-7.47 (m, 27 H), 7.51-7.57 (m, 3 H), 7.74-7.76 (m, 2 H), 7.93-8.01 (m , 6 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 27.4, 28.1, 29.5, 29.6, 37.6, 37.7, 47.0, 54.2, 60.3, 62.3, 66.4, 67.1, 67.1, 67.2, 68.2, 68.2, 68.7, 69.0, 70.8, 71.2, 71.6, 71.6, 73.1, 75.5, 75.6, 75.7, 100.5, 100.6, 100.9, 102.2, 119.9, 125.1, 126.3, 126.3, 127.0, 127.0, 127.6, 127.7, 127.8, 128.1, 128.2, 128.3, 128.3, 128.3, 128.4, 128.5, 128.7, 129.0, 129.1, 129.4, 129.5, 129.7, 129.9, 133.0, 133.1, 133.4, 135.1, 137.4, 137.7, 141.2, 141.2, 143.6, 143.8, 155.8, 164.6, 165.1, 165.5, 169.4, 171.1, 172.1, 206.5, 206.5. HRMS: $C_{87}H_{83}NO_{26}$ $[M+NH_4]^+$ calcd: 1576.5625, obsd: 1576.5555.

N-Fluorenylmethyloxycarbonyl-O-[2,3-di-O-levulinoyl-4,6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4,6-O-benzylidene-α-D-galactopyranosyl-(1→4)-2,3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**25a**). Compound **25a** was a side product generated in 45% yield during the synthesis of compound **25**. ^{1}H-NMR (600 MHz, $CDCl_3$): δ 1.94 (s, 3 H, CH_3COCH_2CH_2), 1.95 (s, 3 H, CH_3COCH_2CH_2), 1.96-2.15 (m, 3 H, CH$_3$COCH_2CH_2), 2.41-2.66 (m, 5 H, CH$_3$COCH_2CH_2), 3.44 (s, 1 H), 3.46-3.49 (m, 1 H), 3.77 (s, 1 H), 3.81-3.84 (m, 1 H), 3.96-4.12 (m, 6 H), 4.14-4.17 (m, 1 H), 4.23-4.36 (m, 6 H), 4.50-4.52 (m, 2 H), 4.61 (d, 1 H, J = 5.5 Hz), 4.68 (dd, 1 H, J = 3 Hz, J = 8.5 Hz), 4.73 (d, 1 H, J = 6.5 Hz), 5.10-5.17 (m, 3 H), 5.25-5.29 (m, 1 H), 5.40-5.41 (m, 1 H), 5.45-5.49 (m, 2 H), 5.54-5.61 (m, 3 H), 7.14-7.46 (m, 26 H), 7.50-7.55 (m, 6 H), 7.66-7.68 (m, 2 H), 7.73-7.76 (m , 2 H), 7.85-7.87 (m 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 20.9, 27.1, 28.0, 29.5, 29.5, 37.5, 37.6, 47.0, 54.2, 60.3, 63.8, 64.0, 66.4, 67.2, 67.3, 68.3, 68.8, 68.9, 70.0, 71.6, 71.7, 72.0, 72.8, 73.2, 75.1, 76.2, 98.6, 100.4, 100.8, 101.2, 101.3, 119.9, 125.1, 126.1, 126.2, 127.0, 127.0, 127.6, 127.6, 128.0, 128.1, 128.1, 128.2, 128.2, 128.3, 128.3, 128.5, 128.6, 128.8, 128.9, 129.0, 129.4, 129.4, 129.6, 133.0, 133.1, 133.2, 135.1, 137.4, 137.6, 141.2, 141.2, 143.6, 143.7, 155.8, 165.1, 165.2, 165.3, 169.3, 170.9, 172.0, 206.2, 206.5. ESI-MS: $C_{87}H_{83}NO_{26}$ calcd: $[M+NH_4]^+$ calcd: 1575.5, obsd: 1575.9. HRMS: $[M+NH_4]^+$ calcd: 1575.5625, obsd: 1575.5486.

N-Fluorenylmethyloxycarbonyl-O-[4,6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4,6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2,3-di-O-benzoyl-β-D-

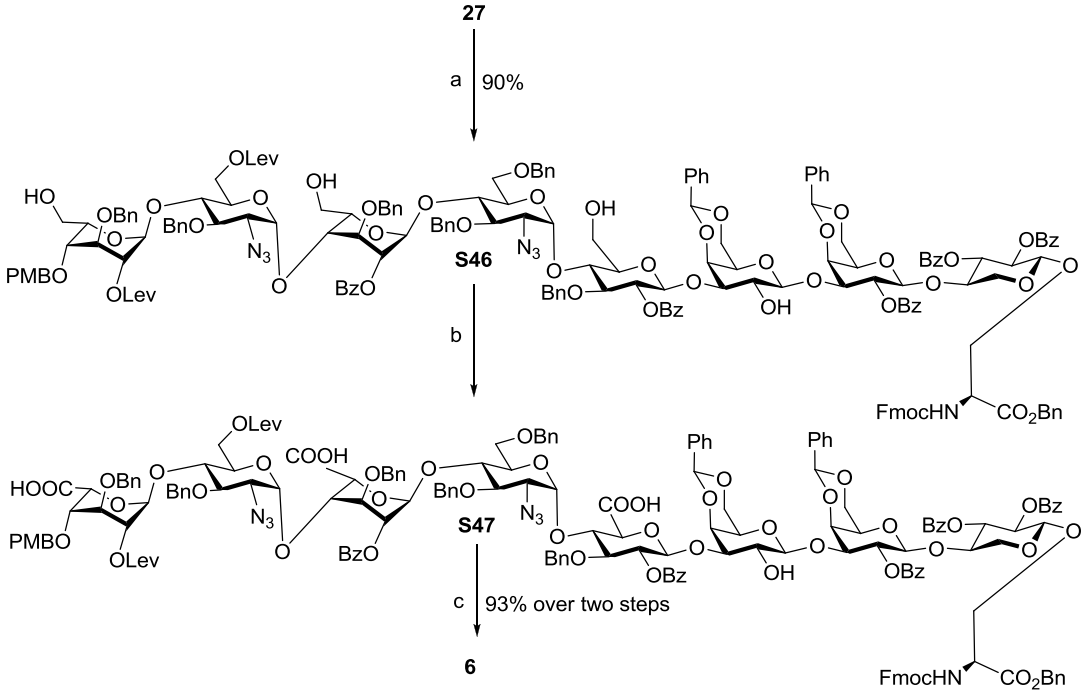
xylopyranosyl]-L-serine benzyl ester (**9**). Compound **9** was synthesized from compound **25** in 72% yield following the general procedure for Lev deprotection. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.53-2.55 (m, 1 H), 2.77 (s, 1 H), 3.25-3.36 (m, 4 H), 3.64-3.68 (m, 1 H), 3.73-3.76 (m, 2 H), 3.80-3.84 (m, 2 H), 3.95-4.06 (m, 4 H), 4.10-4.14 (m, 1 H), 4.17-4.34 (m, 6 H), 4.48-4.50 (m, 1 H), 4.56 (d, 1 H, J = 5.5 Hz), 4.78 (d, 1 H, J = 8 Hz), 5.01-5.09 (m, 2 H, CH_2Ph), 5.15-5.18 (m, 1 H), 5.44-5.47 (m, 2 H), 5.54-5.63 (m, 3 H), 7.20-7.54 (m, 29 H), 7.73-7.76 (m, 2 H), 7.94-7.97 (m, 6 H), 8.33-8.37 (m 1 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 47.0, 54.2, 62.2, 66.7, 67.0, 67.2, 67.3, 68.3, 69.0, 70.7, 71.0, 71.3, 71.5, 72.0, 75.0, 75.5, 75.9, 77.9, 100.4, 101.1, 101.2, 101.9, 104.1, 119.9, 125.1, 126.2, 126.6, 127.0, 127.0, 127.6, 127.7, 128.0, 128.2, 128.2, 128.3, 128.3, 128.4, 128.4, 128.5, 128.7, 128.8, 129.1, 129.2, 129.5, 129.5, 129.6, 129.8, 129.9, 130.8, 133.1, 133.1, 133.2, 135.1, 137.4, 137.6, 141.2, 141.2, 143.6, 143.8, 155.9, 165.1, 165.5, 165.6, 169.4. MALDI-MS: $C_{77}H_{71}NO_{22}$ $[M+Na]^+$ calcd: 1385.38, obsd: 1385.57.

p-Tolyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-6-O-tert-butyl-diphenylsilyl-α-L-idopyranosyl-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-tert-butyl-diphenylsilyl-α-L-idopyranosyl-(1→4)-2-azido-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-6-O-tert-butyl-diphenylsilyl-1-thio-β-D-glucopyranoside (**26**). Compound **26** was synthesized from donor **7** and acceptor **8** in 93% yield following the general procedure of single step glycosylation. ^{1}H-NMR (600 MHz, $CDCl_3$): δ 0.99 (s, 9 H, C(CH_3)$_3$), 1.00 (s, 9 H, C(CH_3)$_3$), 1.04 (s, 9 H, C(CH_3)$_3$), 2.00 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.01 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.25 (s, 3 H, SPhCH_3), 2.30-2.65 (m, 8 H, CH_3COCH$_2$CH$_2$), 3.05-3.10 (m, 1 H), 3.13-3.15 (m, 2 H), 3.18-3.20 (m, 1 H), 3.40-3.44 (m, 2 H), 3.47-3.59 (m, 3 H), 3.64-3.69 (m, 2 H), 3.72-3.76 (m, 6 H), 3.82-4.03 (m, 10 H), 4.08-4.20 (m, 6 H), 4.28-4.31 (m, 2 H), 4.53-4.57 (m, 2 H), 4.60-4.64 (m, 2 H), 4.69-4.79 (m, 6 H), 4.84-4.89 (m, 2 H), 4.97 (d, 1 H, J = 9.5 Hz), 5.16-5.19 (m, 2 H), 5.27-5.31 (m, 1 H), 5.46-5.48 (m, 1 H), 6.71-6.73 (m, 2 H), 6.93-6.97 (m, 4 H), 7.02-7.38 (m, 52 H), 7.42-7.49 (m, 4 H), 7.53-7.76 (m, 12 H), 8.03-8.06 (m 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 19.2, 19.2, 19.2, 21.0, 26.8, 26.9, 27.0, 27.7, 27.9, 29.6, 29.6, 37.6, 55.2, 62.2, 62.6, 63.0, 63.0, 63.7, 63.9, 68.1, 69.6, 69.9, 70.6, 70.9, 71.9, 72.0, 72.9, 73.2, 73.2, 74.2, 74.3, 74.5, 74.6, 74.7, 74.9, 74.9, 75.0, 78.4, 78.9, 79.7, 84.6, 87.0, 97.7, 97.7, 98.3, 113.6, 127.1, 127.3, 127.4, 127.5, 127.6, 127.6, 127.7, 127.7, 127.8, 127.8, 127.9, 128.0, 128.0, 128.1, 128.2, 128.2, 128.3, 128.3, 128.4, 128.6, 129.4, 129.6, 129.6, 129.6, 129.7, 129.7, 129.8, 129.8, 129.9, 130.3, 132.0, 132.9, 133.2, 133.3, 133.5, 135.6, 135.6, 135.6, 135.6, 135.7, 137.4, 137.5, 137.5, 137.8, 137.8, 138.1, 138.2, 159.2, 165.2, 165.3, 171.7, 172.1, 206.1, 206.1. MALDI-MS: $C_{159}H_{174}N_6O_{30}SSi_3$ $[M+Na]^+$ calcd: 2768.43, obsd: 2790.93.

Octasaccharide **27**: A mixture of donor **26** (39 mg, 0.014 mmol) and freshly activated molecular sieves 4Å (200 mg) in CH_2Cl_2 (2 mL) was stirred at room temperature for 30 minutes and then cooled to -78 °C, which was followed by the addition of AgOTf (11 mg, 0.042 mmol) dissolved in acetonitrile (0.02 mL) without touching the wall of the flask. After 5 minutes, orange coloured *p*-TolSCl (2.2 μL, 0.014 mmol) was added through a microsyringe. Since the reaction temperature was lower than the freezing point of *p*-TolSCl, *p*-TolSCl was added directly into the reaction mixture to prevent it from freezing on the flask wall. The characteristic yellow colour of *p*-TolSCl in the reaction solution

dissipated rapidly within a few seconds indicating its depletion. After the donor was completely consumed according to TLC analysis (about 5 minutes at −78 °C), a solution of acceptor **9** (19 mg, 0.014 mmol) and TTBP (3.5 mg, 0.01 mmol) in CH_2Cl_2 (1 mL) was slowly added dropwise via a syringe. The reaction mixture was stirred for 1.5 h until the temperature reached 0 °C, at which point sat. $NaHCO_3$ solution was added to quench the reaction. The reaction mixture was diluted with CH_2Cl_2 (50 mL) and filtered through Celite. The Celite was washed extensively with CH_2Cl_2 until TLC showed no products in the filtrate. The filtrate was combined and extracted with a saturate $NaHCO_3$ solution and dried with Na_2SO_4. After filtration, the reaction mixture was purified by flash column chromatography (hexanes : EtOAc = 1 : 1) to give compound **27** (47 mg, 83%).^{1}H-NMR (600 MHz, $CDCl_3$): δ 0.92 (s, 9 H, C(CH_3)$_3$), 1.00 (s, 9 H, C(CH_3)$_3$), 1.03 (s, 9 H, C(CH_3)$_3$), 1.99 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.00 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.20 (s, 1 H), 2.27-2.66 (m, 8 H, CH_3COCH$_2$CH$_2$), 3.02-3.06 (m, 2 H), 3.09-3.15 (m, 2 H), 3.18-3.22 (m, 2 H), 3.30-3.46 (m, 5 H), 3.47-3.49 (m, 1 H), 3.53-3.57 (m, 1 H), 3.64-3.87 (m, 19 H), 3.94-4.33 (m, 18 H), 4.48-4.77 (m, 12 H), 4.84-4.88 (m, 2 H), 4.96-5.03 (m, 3 H), 5.14-5.18 (m, 3 H), 5.22-5.27 (m, 1 H), 5.31 (s, 2 H), 5.42-5.44 (m, 1 H), 5.47-5.51 (m, 1 H), 5.53-5.55 (m, 1 H), 5.58-5.62 (m, 1 H), 6.71-6.73 (m, 2 H), 6.94-6.96 (m, 4 H), 7.01-7.03 (m, 2 H), 7.04-7.07 (m, 3 H), 7.11-7.38 (m, 78 H), 7.43-7.64 (m, 18 H), 7.42-7.46 (m, 2 H), 7.94-8.02 (m 10 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 19.2, 19.2, 19.3, 26.7, 26.7, 26.9, 27.0, 27.6, 27.9, 29.6, 29.6, 29.6, 37.6, 47.0, 54.2, 55.2, 62.2, 62.3, 62.6, 62.9, 62.9, 63.7, 64.2, 66.8, 67.0, 67.2, 67.3, 68.0, 68.2, 69.0, 69.5, 68.7, 69.9, 70.6, 70.7, 71.3, 71.5, 71.8, 72.0, 73.2, 73.2, 73.3, 73.9, 74.1, 74.2, 74.3, 74.4, 74.7, 74.8, 74.9, 75.0, 75.0, 75.2, 75.5, 75.5, 75.8, 76.5, 78.1, 78.4, 78.9, 83.3, 97.6, 97.7, 98.3, 100.1, 100.5, 101.0, 101.4, 102.0, 104.0, 113.6, 119.9, 125.1, 126.0, 126.6, 127.0, 127.1, 127.3, 127.4, 127.5, 127.6, 127.7, 127.8, 127.8, 127.8, 127.9, 127.9, 127.9, 128.0, 128.0, 128.1, 128.2, 128.2, 128.3, 128.3, 128.3, 128.4, 128.5, 128.6, 128.7, 129.1, 129.4, 129.5, 129.6, 129.6, 129.7, 129.7, 129.9, 130.0, 132.9, 133.1, 133.1, 133.1, 133.2, 133.2, 133.3, 133.5, 135.1, 135.4, 135.4, 135.6, 135.6, 135.6, 137.5, 137.5, 137.6, 137.7, 138.1, 138.2, 141.2, 143.6, 143.8, 155.9, 159.1, 165.1, 165.2, 165.3, 165.3, 165.5, 169.4, 171.7, 172.1, 206.1, 206.2. MALDI-MS: $C_{222}H_{231}N_7O_{25}Si_3$: $[M+NH_4]^+$ calcd: 3931.48, obsd: 3930.60.

Synthesis of syndecan-1 glycopeptide 1

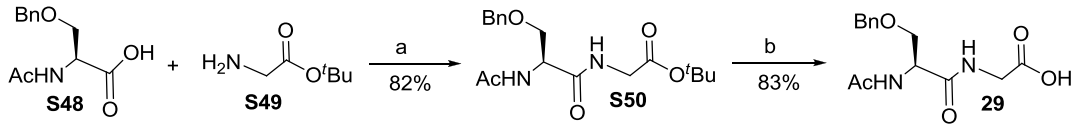


Synthesis of octasaccharide **6**. Reagents and conditions: (a) HF/Pyridine; (b) TEMPO, BAIB, DCM, H_2O, *t*-BuOH; (c) MeI, K_2CO_3, DMF.

N-Fluorenylmethyloxycarbonyl-O-[2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyl-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-α-L-idopyranosyl-(1→4)-2-azido-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S46**). Compound **27** (715 mg, 0.178 mmol) was dissolved in pyridine (6 mL) in a plastic flask followed by addition of 65-70% HF-pyridine solution (4.2 mL) under 0 °C. The solution was stirred overnight until complete disappearance of starting material as judged by TLC analysis. The reaction mixture was quenched by solid $NaHCO_3$ and diluted with DCM. The aqueous phase was extracted with DCM twice. The combined organic phase was further washed with sat. $NaHCO_3$ and dried over Na_2SO_4. Column purification afforded compound **S46** (520 mg, 90%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.11 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.14 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.43-2.78 (m, 8 H, CH_3COCH$_2$CH$_2$), 3.20-3.32 (m, 7 H), 3.36-3.42 (m, 2 H), 3.46-3.53 (m, 3 H), 3.56-3.64 (m, 4 H), 3.68-4.35 (m, 41 H), 4.41-4.44 (m, 1 H), 4.47-4.53 (m, 4 H), 4.56-4.58 (m, 1 H), 4.63-4.65 (m, 1 H), 4.69-4.93 (m, 11 H), 5.02-5.11 (m, 4 H), 5.16-5.20 (m, 2 H), 5.25-5.29 (m, 1 H), 5.35-5.40 (m, 2 H), 5.52-5.64 (m, 4 H), 6.81-6.84 (m, 2 H), 7.12-7.47 (m, 66 H), 7.53-7.58 (m, 2 H), 7.96-8.01 (m, 8 H), 8.07-8.09 (m 2 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.1, 20.9, 27.7, 27.8, 29.6, 29.7, 37.6, 37.7, 46.9, 54.1, 55.1, 60.3, 60.8, 61.1, 61.6, 62.2, 62.3, 63.3, 63.6, 66.7, 66.9, 67.1, 67.2, 67.5, 68.0, 68.1, 68.7, 69.0, 69.2, 69.3, 69.8, 69.9, 70.0, 70.6, 71.3, 71.5, 71.8, 72.1, 72.3, 72.7, 72.8, 73.1, 73.4, 73.8, 74.1, 74.6, 74.8, 75.0, 75.1, 75.3, 75.4,

75.6, 76.5, 78.7, 78.8, 83.2, 97.0, 97.3, 97.5, 97.5, 100.1, 100.4, 100.9, 101.8, 103.8, 113.7, 119.9, 125.0, 125.8, 126.5, 127.0, 127.0, 127.5, 127.6, 127.6, 127.7, 127.7, 127.8, 127.8, 127.9, 128.0, 128.0, 128.1, 128.1, 128.2, 128.2, 128.2, 128.3, 128.3, 128.4, 128.4, 128.5, 128.7, 129.0, 129.4, 129.5, 129.5, 129.6, 129.7, 129.7, 129.8, 129.8, 133.0, 133.1, 133.1, 133.2, 135.0, 137.1, 137.4, 137.4, 137.5, 137.6, 137.8, 141.1, 141.1, 143.6, 143.7, 155.8, 159.3, 165.0, 165.1, 165.3, 165.4, 165.7, 169.4, 171.0, 171.8, 172.1, 206.7, 206.8. MALDI-MS: $C_{181}H_{183}N_7O_{52}$ $[M+Na]^+$ calcd: 3311.41, obsd: 3311.30.

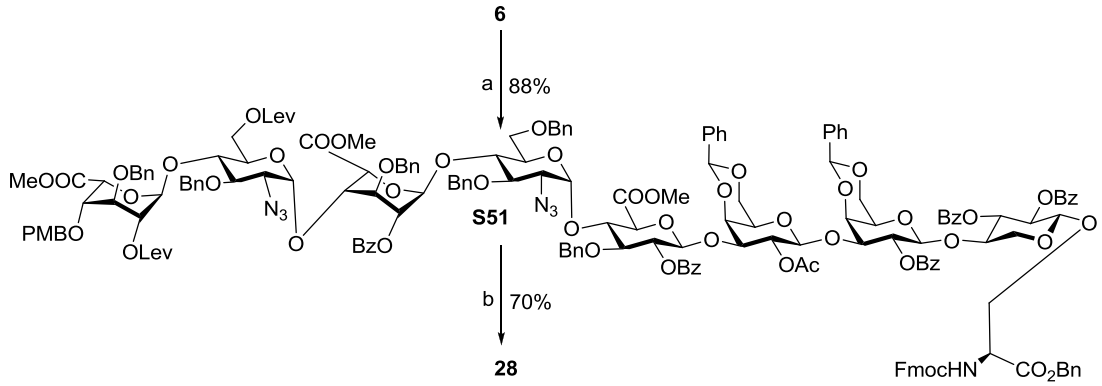
N-Fluorenylmethyloxycarbonyl-O-[methyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-methyl 2-O-benzoyl-3-O-benzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester **(6)**. Compound **S46** (115 mg, 0.035 mmol) was dissolved in DCM/*t*BuOH/H_2O (4:4:1, 4.5 mL), followed by addition of TEMPO (4 mg) and BAIB (90 mg). The resulting mixture was stirred under room temperature overnight. After the reaction was complete indicated by TLC analysis, it was neutralized by 1 M HCl solution to adjust pH around 6. The solution was first diluted with DCM, then extracted with H_2O. The combined organic phase was dried over Na_2SO_4. After concentration, the crude product **S47** was confirmed by MALDI-MS analysis. MALDI-MS: $C_{181}H_{177}N_7O_{55}$ calcd: $[M+Na]^+$ calcd: 3351.00, obsd: 3351.13. The crude compound was dissolved in dry DMF (5 mL), to which was added MeI (17 μL, 0.263 mmol) and K_2CO_3 (73 mg, 0.525 mmol). The resulting mixture was stirred under room temperature overnight. The reaction mixture was diluted with DCM and H_2O. The aqueous phase was extracted with DCM twice. The combined organic phase was further washed with sat. $NaHCO_3$ and dried over Na_2SO_4. Column purification afforded compound **6** (110 mg, 93%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.04 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.11 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.43-2.74 (m, 8 H, C*H*$_3$COCH$_2$CH$_2$), 3.18-3.59 (m, 17 H), 3.62-3.99 (m, 19 H), 4.06-4.25 (m, 11 H), 4.29-4.78 (m, 19 H), 4.85-4.89 (m, 2 H), 4.93-4.95 (m, 1 H), 5.02-5.09 (m, 2 H), 5.13-5.17 (m, 2 H), 5.21-5.28 (m, 2 H), 5.33-5.38 (m, 2 H), 5.45-5.61 (m, 4 H), 6.76-6.81 (m, 1 H), 7.09-7.48 (m, 68 H), 7.51-7.56 (m, 2 H), 7.74-7.76 (m, 1 H), 7.85-7.89 (m, 2 H), 7.93-7.99 (m, 7 H), 8.07-8.09 (m 1 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 14.0, 21.4, 22.6, 27.7, 27.8, 27.9, 29.3, 29.5, 29.6, 29.7, 31.8, 37.6, 37.9, 47.0, 51.7, 51.9, 52.1, 54.2, 55.2, 61.9, 62.2, 62.7, 63.0, 66.8, 66.9, 67.1, 67.3, 68.2, 68.7, 69.0, 69.8, 69.9, 70.2, 70.7, 70.8, 71.2, 71.3, 71.5, 72.3, 73.1, 73.4, 73.7, 73.8, 74.2, 74.4, 74.6, 75.0, 75.4, 75.4, 75.5, 75.7, 77.8, 77.9, 82.6, 97.2, 97.7, 97.9, 99.2, 100.0, 100.5, 100.6, 101.0, 101.8, 103.8, 113.7, 119.9, 125.1, 125.2, 125.8, 126.6, 127.0, 127.0, 127.3, 127.4, 127.6, 127.6, 127.7, 127.7, 127.8, 127.8, 127.9, 127.9, 128.0, 128.0, 128.1, 128.1, 128.2, 128.2, 128.3, 128.3, 128.3, 128.4, 128.6, 128.8, 129.0, 129.0, 129.2, 129.3, 129.4, 129.5, 129.6, 129.6, 129.7, 129.8, 133.1, 133.2, 133.4, 135.1, 137.2, 137.4, 137.4, 137.6, 137.6, 137.8, 137.9, 141.2, 143.6, 143.8, 155.8, 159.3, 164.9, 165.1, 165.1, 165.4, 165.5, 168.9, 169.4, 169.4, 169.9, 171.8, 172.3, 206.1, 206.5. MALDI-MS: $C_{184}H_{183}N_7O_{55}$ $[M+Na]^+$ calcd: 3395.44, obsd: 3395.40.



Synthesis of dipeptide **29**. Reagents and conditions: (a) BOP, DIPEA, DCM/THF; (b) TFA, DCM.

N-(Acetyl)-O-(benzyl)-L-serglycine-t-butyl-ester (**S50**). Serine **S48** (1.329 g, 5.6 mmol), glycine **S49** (940 mg, 5.6 mmol) were dissolved in DCM/THF (1:1, 20 mL), followed by addition of BOP (4.95 g, 11.2 mmol) and DIPEA (1.85 mL, 11.2 mol). The resulting mixture was stirred under room temperature overnight. After the reaction was complete, it was diluted with DCM. The solution was washed with 10% HCl solution, sat. $NaHCO_3$ solution and dried over Na_2SO_4. After concentration, column purification afforded compound **S50** (2.05 g, 82%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.44 (s, 9 H, C(C*H*$_3$)$_3$), 1.99 (s, 3 H, C*H*$_3$CONH), 3.52 (dd, 1 H, J = 7 Hz, J = 9.5 Hz), 3.86-3.90 (m, 3 H), 4.51-4.60 (m, 3 H), 6.44-6.45 (m, 1 H, N*H*), 6.95-6.98 (m, 1 H, N*H*), 7.13-7.23 (m, 1 H), 7.24-7.33 (m, 4 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 23.1, 27.9, 42.1, 52.3, 69.1, 73.4, 82.2, 125.2, 127.8, 127.9, 128.1, 128.4, 128.9, 137.3, 168.4, 170.0, 170.2. HRMS: $C_{18}H_{26}N_2O_5$ $[M+H]^+$ calcd: 351.1920, obsd: 351.1895.

N-(Acetyl)-O-(benzyl)-L-serglycine (**29**). Compound **S50** (2.05 g, 1.86 mmol) was dissolved in 4 mL DCM, followed by addition of TFA (4 mL). The resulting mixture was stirred under room temperature until the reaction was complete indicated by TLC analysis. The solution was concentrated to dryness to afford compound **29** which was used directly for next step without further purification. ^{1}H-NMR (500 MHz, CD_3OD): δ 2.00 (s, 3 H, C*H*$_3$CONH), 3.70-3.77 (m, 2 H), 3.91-3.93 (m, 2 H), 4.52-4.57 (m, 2 H), 6.63 (t, 1 H, J = 4.5 Hz), 7.24-7.27 (m, 1 H), 7.29-7.34 (m, 4 H), 8.21-8.24 (m, 1 H, COO*H*). ^{13}C-NMR (125 MHz, CD_3OD): δ 22.5, 41.9, 54.7, 70.7, 74.2, 128.7, 128.9, 128.9, 129.3, 139.2, 172.5, 173.4. HRMS: $C_{14}H_{18}N_2O_5$ $[M+H]^+$ calcd: 295.1294, obsd: 295.1287.



Synthesis of octasaccharide **28**. Reagents and conditions: (a) Ac_2O, pyridine, 50 ^{o}C; (b) piperidine, DCM.

N-Fluorenylmethyloxycarbonyl-O-[methyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-methyl 2-O-benzoyl-3-O-benzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-

(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-2-O-acetyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S51**). Compound **6** (30 mg, 0.0089 mmol) was dissolved in 2 mL pyridine, followed by addition of 1 mL Ac_2O. The resulting mixture was stirred under 50 ^oC overnight. After cooling back to room temperature, it was diluted with DCM, washed with 10% HCl, sat. $NaHCO_3$. The combined organic phase was dried over Na_2SO_4. Column purification afforded compound **S51** (27 mg, 88%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.04 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.11 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.33 (s, 3 H, COC*H*$_3$), 2.44-2.75 (m, 8 H, C*H*$_3$COCH$_2$CH$_2$), 3.10-3.36 (m, 9 H), 3.44-3.57 (m, 9 H), 3.65-3.97 (m, 18 H), 4.06-4.22 (m, 10 H), 4.27-4.42 (m, 4 H), 4.45-4.70 (m, 13 H), 4.74-4.79 (m, 3 H), 4.84-4.89 (m, 3 H), 4.99-5.07 (m, 2 H), 5.11-5.15 (m, 3 H), 5.17-5.22 (m, 2 H), 5.27-5.33 (m, 3 H), 5.36-5.38 (m, 1 H), 5.44-5.48 (m, 1 H), 5.52-5.58 (m, 3 H), 6.79-6.81 (m, 2 H), 7.07-7.55 (m, 69 H), 7.73-7.77 (m, 2 H), 7.88-8.00 (m, 9 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 20.1, 21.4, 27.8, 27.9, 29.5, 29.7, 37.6, 37.9, 47.0, 51.7, 51.9, 52.1, 54.2, 55.2, 62.3, 62.7, 63.0, 66.7, 67.0, 67.1, 67.2, 68.1, 69.0, 69.8, 70.8, 70.9, 71.2, 71.3, 71.3, 71.7, 72.3, 72.9, 73.4, 73.7, 73.8, 73.9, 74.5, 74.7, 75.0, 75.2, 75.4, 75.4, 75.7, 77.9, 82.6, 97.2, 97.7, 97.9, 99.2, 100.1, 100.4, 100.5, 102.2, 113.7, 119.9, 125.1, 125.2, 126.0, 126.4, 127.0, 127.0, 127.4, 127.6, 127.6, 127.6, 127.7, 127.7, 127.8, 127.8, 127.9, 127.9, 128.0, 128.0, 128.0, 128.1, 128.2, 128.2, 128.3, 128.3, 128.3, 128.4, 128.4, 128.5, 128.6, 128.7, 129.0, 129.1, 129.2, 129.3, 129.5, 129.5, 129.7, 129.9, 129.9, 133.1, 133.4, 135.1, 137.0, 137.3, 137.5, 137.7, 137.8, 137.8, 137.9, 141.2, 143.6, 143.8, 155.9, 159.3, 164.5, 164.6, 165.0, 165.1, 165.5, 168.8, 168.9, 169.4, 169.9, 171.8, 172.3, 206.1, 206.5. MALDI-MS: $C_{186}H_{185}N_7O_{56}$ $[M+Na]^+$ calcd: 3435.18, obsd: 3435.70.

N-(Acetyl)-O-(benzyl)-L-seryl-glycyl-O-[methyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-methyl 2-O-benzoyl-3-O-benzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-2-O-acetyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**30**). Compound **S51** (31 mg, 0.009 mmol) was dissolved in DCM (0.6 mL), followed by addition of 46 μL piperidine. After 3 h, the mixture was diluted with DCM and extracted with H_2O. The combined organic phase was dried over Na_2SO_4. Column purification afforded compound **28** (20 mg, 70%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 2.04 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.11 (s, 3 H, C*H*$_3$COCH$_2$CH$_2$), 2.33 (s, 3 H, COC*H*$_3$), 2.43-2.77 (m, 8 H, CH$_3$COC*H*$_2$C*H*$_2$), 3.07 (br, 1 H), 3.16-3.19 (m, 2 H), 3.22-3.34 (m, 8 H), 3.45-3.58 (m, 10 H), 3.64-4.02 (m, 20 H), 4.04-4.20 (m, 8 H), 4.35-4.42 (m, 3 H), 4.45-4.78 (m, 16 H), 4.84-4.88 (m, 3 H), 4.98 (s, 2 H), 5.09-5.15 (m, 3 H), 5.17-5.22 (m, 2 H), 5.31 (d, 1 H, J = 11 Hz), 5.36-5.38 (m, 1 H), 5.41-5.46 (m, 1 H), 5.52-5.57 (m, 2 H), 6.79-6.81 (m, 2 H), 7.07-7.54 (m, 62 H), 7.88-7.98 (m, 10 H). Compound **28** (22 mg, 0.0069 mmol) and compound **29** (4 mg, 0.0138 mmol) were dissolved in 0.6 mL DMF, followed by addition of HATU (5.2 mg, 0.0138 mmol) and DIPEA (4.8 μL, 0.0276 mmol). The resulting mixture was stirred under room temperature overnight and diluted with DCM. The solution was washed with 10% HCl, sat. $NaHCO_3$. The combined organic phase was dried

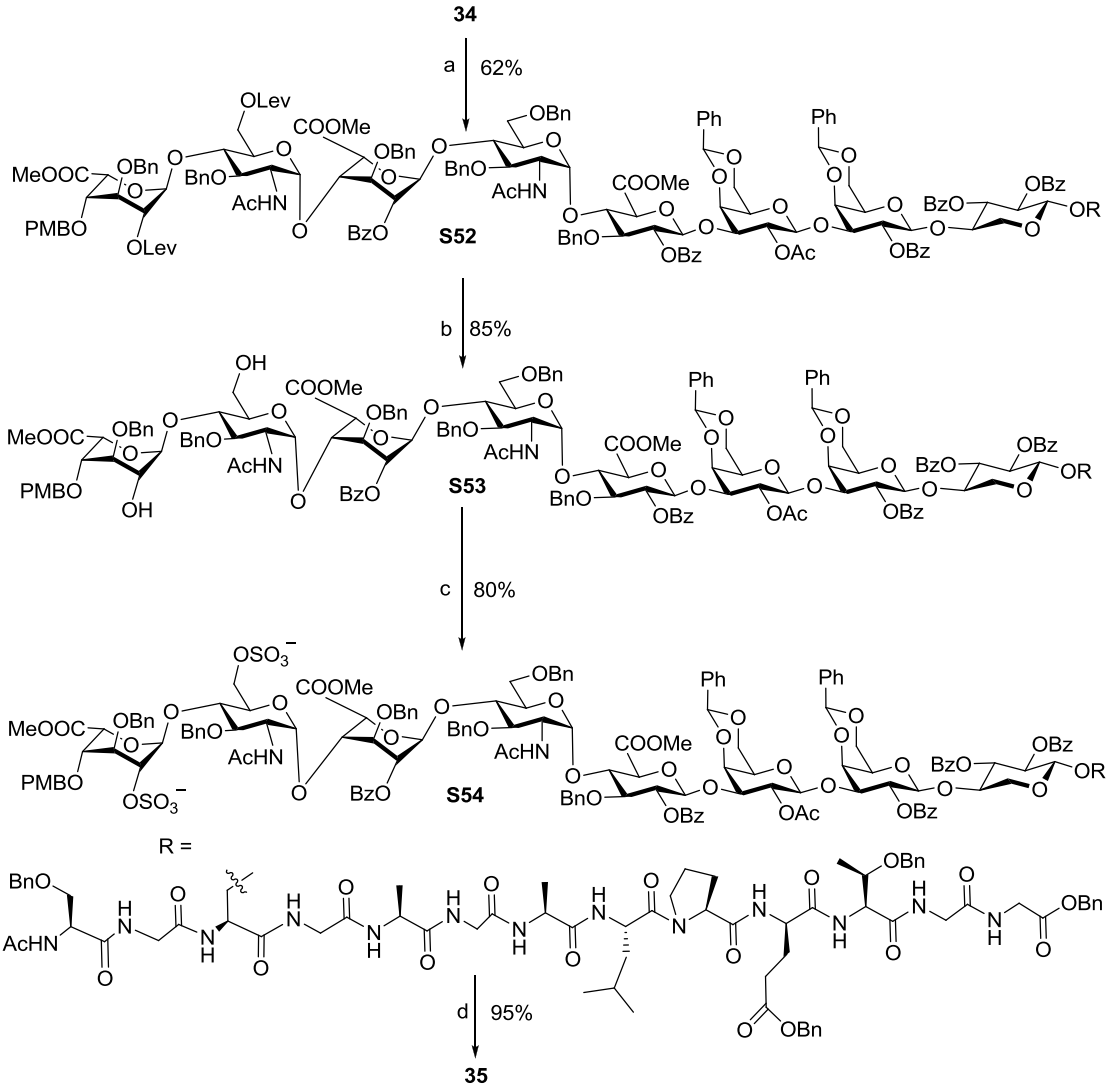
over Na_2SO_4. Column purification afforded compound **30** (18 mg, 77%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.95 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.04 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.33 (s, 3 H, COCH_3), 2.37-2.73 (m, 8 H, CH_3COCH$_2$CH$_2$), 2.78-2.93(m, 6 H), 3.12-3.38 (m, 8 H), 3.44-3.57 (m, 8 H), 3.69-3.97 (m, 18 H), 3.06-4.20 (m, 9 H), 4.38-4.89 (m, 23 H), 4.95-5.27 (m, 7 H), 5.30-5.55 (m, 6 H), 6.45-6.47 (m, 1 H), 6.67-6.71 (m, 1 H), 6.79-6.81 (m, 2 H), 6.93-6.96 (m, 1 H), 7.09-7.54 (m, 67 H), 7.88-7.99 (m, 10 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 20.1, 21.4, 23.0, 27.8, 27.9, 29.5, 29.7, 37.6, 37.9, 38.5, 42.8, 51.7, 51.9, 52.1, 52.5, 52.7, 55.2, 61.9, 62.2, 62.8, 63.1, 66.7, 67.1, 67.3, 68.3, 69.1, 69.1, 69.8, 70.8, 71.0, 71.2, 71.3, 71.5, 72.3, 72.9, 73.3, 73.4, 73.6, 73.7, 73.8, 74.5, 74.5, 74.6, 75.0, 75.3, 75.4, 75.4, 75.5, 75.5, 77.8, 77.9, 82.6, 97.2, 97.7, 98.0, 99.2, 100.1, 100.1, 100.4, 100.5, 102.2, 113.7, 125.2, 126.0, 126.3, 127.3, 127.4, 127.6, 127.6, 127.7, 127.7, 127.8, 127.8, 127.8, 127.9, 127.9, 127.9, 128.0, 128.0, 128.1, 128.2, 128.2, 128.2, 128.3, 128.3, 128.3, 128.4, 128.4, 128.5, 128.6, 128.7, 128.9, 129.0, 129.2, 129.3, 129.3, 129.5, 129.5, 129.5, 129.7, 129.7, 129.9, 130.0, 133.1, 133.1, 133.3, 133.4, 135.0, 137.0, 137.3, 137.4, 137.5, 137.7, 137.7, 137.8, 137.8, 137.8, 138.0, 159.4, 164.5, 164.6, 165.0, 165.1, 165.7, 168.3, 168.8, 169.0, 169.3, 169.9, 170.3, 170.4, 171.8, 172.3, 206.1, 206.5. MALDI-MS: $C_{185}H_{191}N_9O_{58}$ $[M+Na]^+$ calcd: 3489.23, obsd: 3489.22.

N-(Acetyl)-O-(benzyl)-L-seryl-glycyl-O-[methyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-methyl 2-O-benzoyl-3-O-benzyl-α-L-idopyranosyluronate-(1→4)-2-azido-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-2-O-acetyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine (**31**). Compound **30** (32 mg, 0.009 mmol) was dissolved in DCM/MeOH (1:1, 2 mL), followed by addition of Pd/C (3 mg) and NH_4OAc (3 mg, 0.032 mmol). The resulting mixture was stirred under H_2 atomosphere. The reaction was carefully monitored by TLC. After the complete disappearance of starting material, the reaction was diluted with DCM and filtered. After concentration, the residue was purified by silica gel column to afford compound **31** (25 mg, 82%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.14 (s, 3 H), 1.18 (s, 3 H), 1.97 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.03 (s, 3 H, CH_3COCH$_2$CH$_2$), 2.38-2.63 (m, 8 H, CH_3COCH$_2$CH$_2$), 3.12-3.18 (m, 5 H), 3.20 (s, 3 H), 3.24-3.27 (m, 6 H), 3.29 (s, 3 H), 3.35-3.42 (m, 9 H), 3.54-3.58 (m, 4 H), 3.63-3.72 (m, 8 H), 3.75-4.19 (m, 20 H), 4.24-4.69 (m, 22 H), 4.76-4.78 (m, 3 H), 4.91-4.96 (m, 2 H), 5.01-5.10 (m, 3 H), 5.20-5.28 (m, 4 H), 5.39-5.44 (m, 2 H), 6.71-6.73 (m, 2 H), 6.96-7.23 (m, 48 H), 7.25-7.49 (m, 14 H), 7.75-7.88 (m, 10 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 27.6, 29.2, 29.4, 37.7, 51.6, 55.0, 55.1, 70.8, 72.1, 73.1, 73.6, 74.5, 75.3, 76.5, 97.6, 100.4, 113.5, 113.6, 125.7, 125.9, 126.1, 127.6, 127.7, 128.2, 128.9, 129.0, 129.2, 129.4, 129.5, 129.5, 133.3, 136.8, 137.1, 137.2, 137.4, 137.5, 137.6, 137.7, 159.2, 164.6, 164.9, 165.2, 165.3, 166.0, 168.7, 169.3, 169.8, 171.8, 172.3, 206.6, 207.2. MALDI-MS: $C_{178}H_{185}N_9O_{58}$ $[M+Na]^+$ calcd: 3401.40, obsd: 3401.65.

Peptide **32**: Compound **32** was synthesized following the general procedure for solid phase peptide synthesis. MALDI-MS: $C_{63}H_{78}N_{10}O_{16}$ $[M+Na]^+$ calcd: 1254.35, obsd: 1254.80.
Peptide **33**: Compound **32** (6 mg, 0.00488 mmol) was dissolved in 1 mL dry DMF, followed by addition of BnBr (1.2 μL, 0.00975 mmol) and DIPEA (1.7 μL, 0.00975

mmol). The resulting mixture was stirred under room temperature overnight. The product was precipitated from *tert*-butyl methyl ether and purified by silica gel column to afford benzylated compound (4 mg, 60%). MALDI-MS: $C_{70}H_{84}N_{10}O_{16}$ $[M+Na]^+$ calcd: 1344.47, obsd: 1344.10. This compound was dissolved in 0.5 mL DMF, followed by addition of 13 μL piperidine. The resulting mixture was stirred under room temperature for 2 h and the product was precipitated from *tert*-butyl methyl ether and used directly for next step without further purification. MALDI-MS: $C_{55}H_{74}N_{10}O_{14}$ $[M+H]^+$ calcd: 1099.54, obsd: 1099.90.

Glycopeptide **34**: Peptide **33** (13 mg, 0.011 mmol) and glycopeptide **31** (13 mg, 0.00385 mmol) were dissolved in 0.6 mL dry DMF, to which were added 2.2 mg HATU. The resulting mixture was stirred under room temperature overnight and diluted with DCM. The solution was washed with a saturated aqueous $NaHCO_3$ solution. The combined organic phase was dried over Na_2SO_4 and concentrated, purified by silica gel column to afford compound **34** (14 mg, 75%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 0.75-0.94 (m, 15 H), 1.91 (br, 37 H), 2.04 (s, 3 H), 2.11 (s, 3 H), 2.46-2.74 (m, 8 H, C*H*$_3$COCH$_2$CH$_2$), 3.19-3.34 (m, 8 H), 3.44-3.62 (m, 15 H), 3.68-3.98 (m, 23 H), 4.09-4.23 (m, 10 H), 4.35-4.78 (m, 22 H), 4.85-4.89 (m, 3 H), 5.02-5.21 (m, 6 H), 5.33-5.39 (m, 2 H), 5.54-5.57 (m, 1 H), 6.79-6.81 (m, 3 H), 7.01-7.48 (m, 80 H), 7.79-8.01 (m, 6 H). MALDI-MS: $C_{233}H_{257}N_{19}O_{71}$ $[M+Na]^+$ calcd: 4479.71, obsd: 4479.45.



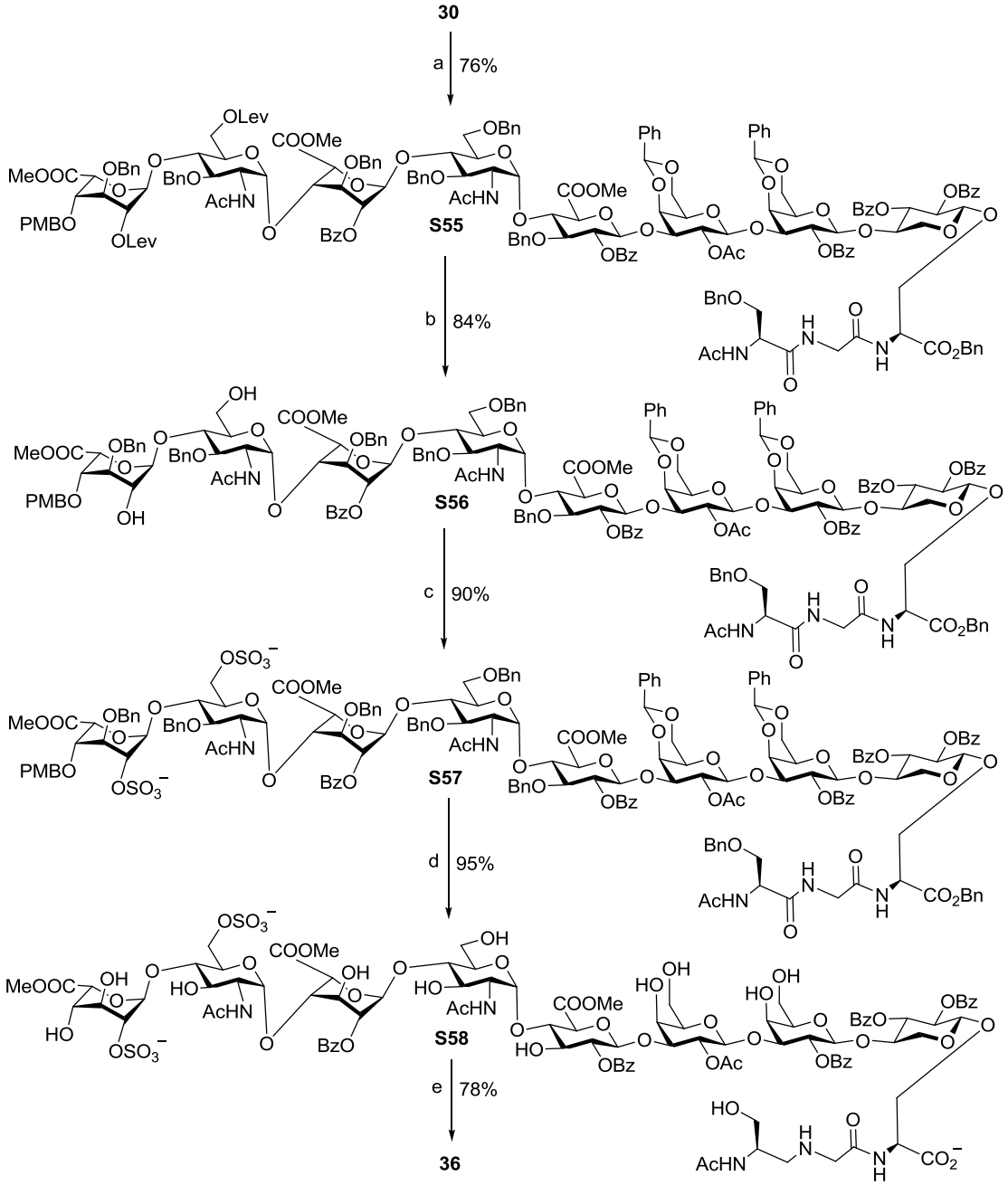
Synthesis of glycopeptide **35**. Reagents and conditions: (a) Zn, $CuSO_4$ (sat.), Ac_2O/THF/HOAc; (b) NH_2NH_2-H_2O, HOAc, DCM/MeOH; (c) SO_3-Et_3N, DMF, 55 ^oC. (d) H_2, Pd/C, DCM/MeOH.

Glycopeptide **S52**: Compound **34** (7 mg, 0.0016 mmol) was dissolved in THF/Ac_2O/HOAc (3:2:1, 1.5 mL), followed by addition of Zn (100 mg), $CuSO_4$ (saturated solution, 10 μL). The resulting mixture was stirred under room temperature overnight. After filtration, the mixture was diluted with DCM and washed with sat. $NaHCO_3$. The combined organic phase was dried over Na_2SO_4 and purified by silica gel column to afford compound **S52** (5 mg, 62%). MALDI-MS: $C_{237}H_{265}N_{15}O_{73}$ $[M+Na]^+$ calcd: 4514.70, obsd: 4514.91.

Glycopeptide **S53**: Compound **S53** was synthesized from compound **S52** following the general procedure for Lev deprotection. MALDI-MS: $C_{227}H_{253}N_{15}O_{69}$ $[M+Na]^+$ calcd: 4318.50, obsd: 4318.75.

Glycopeptide **S54**: Compound **S54** was synthesized from compound **S53** following the general procedure for *O*-sulfation. ESI-MS: $C_{227}H_{251}N_{15}O_{75}S_2^{2-}$ $[M+Li-3H]^{2-}$ calcd: 2228.28, obsd: 2228.35.

Glycopeptide **35**: Compound **35** was synthesized from compound **S116** following the general procedure for global debenzylation. ESI-MS: $C_{135}H_{173}N_{15}O_{74}S_2^{2-}$ $[M-3H]^{3-}$ calcd: 1084.32, obsd: 1084.93, $[M-4H]^{4-}$ calcd: 812.99, obsd: 813.22.



Synthesis of Glycopeptide **36**. Reagents and conditions: (a) Zn, $CuSO_4$ (sat.), Ac_2O/THF/HOAc; (b) NH_2NH_2-H_2O, HOAc, DCM/MeOH; (c) SO_3-Et_3N, DMF, 55 °C; (d) Pd/C, H_2, DCM/MeOH; (e) NaOMe, MeOH, pH = 9.5.

N-(Acetyl)-O-(benzyl)-L-seryl-glycyl-O-[methyl 2-O-levulinoyl-3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyluronate-(1→4)-2-N-acetyl-3-O-benzyl-6-O-levulinoyl-2-deoxy-α-D-glucopyranosyl-(1→4)-methyl 2-O-benzoyl-3-O-benzyl-α-L-

idopyranosyluronate-(1→4)-2-N-acetyl-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-2-O-acetyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S55**). Compoud **30** (33 mg, 0.0095 mmol) was dissolved in THF/Ac_2O/HOAc (3:2:1, 6 mL), followed by addition of Zn (480 mg), $CuSO_4$ (saturated solution, 30 μL). The resulting mixture was stirred under room temperature overnight. After filtration, the mixture was diluted with DCM and washed with sat. $NaHCO_3$. The combined organic phase was dried over Na_2SO_4 and purified by silica gel column to afford compound **S55** (25 mg, 76%). ^{1}H-NMR (600 MHz, $CDCl_3$): δ 1.28 (s, 3 H), 1.30 (s, 3 H), 1.34 (s, 3 H), 1.92 (s, 3 H, $CH_3COCH_2CH_2$), 2.09 (s, 3 H, $CH_3COCH_2CH_2$), 2.41-2.72 (m, 8 H, $CH_3COCH_2CH_2$), 2.74 (s, 3 H), 2.82 (br, 1 H), 2.90 (br, 1 H), 3.12 (br, 1 H), 3.17-3.24 (m, 3 H), 3.26-3.93 (m, 66 H), 3.97-4.65 (m, 43 H), 4.72-4.78 (m, 2 H), 4.89-4.97 (m, 5 H), 5.02-5.07 (m, 5 H), 5.14-5.19 (m, 1 H), 5.24-5.30 (m, 5 H), 5.37-5.42 (m, 2 H), 5.49-5.52 (m, 1 H), 6.74-6.76 (m, 2 H), 6.97-7.51 (m, 66 H), 7.80-7.95 (m, 11 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 19.9, 20.6, 22.2, 22.6, 27.8, 29.5, 29.6, 36.5, 37.6, 37.8, 38.4, 42.4, 51.6, 51.9, 52.4, 52.6, 53.3, 55.1, 62.0, 65.0, 66.5, 66.9, 67.2, 68.2, 68.5, 69.2, 69.6, 70.1, 70.7, 71.2, 71.5, 72.0, 72.8, 72.9, 73.1, 73.2, 73.2, 73.9, 74.5, 74.9, 75.5, 78.3, 81.6, 97.6, 97.8, 98.6, 100.0, 100.4, 102.1, 113.6, 125.9, 126.2, 126.9, 127.1, 127.5, 127.6, 127.7, 127.7, 127.7, 127.8, 127.9, 128.0, 128.0, 128.1, 128.2, 128.2, 128.3, 128.3, 128.4, 128.4, 128.8, 129.4, 129.6, 129.8, 133.1, 133.3, 134.9, 136.1, 136.9, 137.3, 137.5, 137.6, 137.7, 138.2, 159.2, 162.9, 164.6, 165.1, 165.8, 168.3, 168.7, 169.0, 169.1, 169.6, 170.4, 170.8, 171.0, 171.9, 172.3, 174.5, 206.7, 207.1. MALDI-MS: $C_{189}H_{199}N_5O_{60}$ $[M+Na]^+$ calcd: 3523.60, obsd: 3523.87.

N-(Acetyl)-O-(benzyl)-L-seryl-glycyl-O-[methyl 3-O-benzyl-4-O-p-methoxybenzyl-α-L-idopyranosyluronate-(1→4)-2-N-acetyl-3-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-methyl 2-O-benzoyl-3-O-benzyl-α-L-idopyranosyluronate-(1→4)-2-N-acetyl-3, 6-di-O-benzyl-2-deoxy-α-D-glucopyranosyl-(1→4)-2-O-benzoyl-3-O-benzyl-β-D-glucopyranosyl-(1→4)-2-O-acetyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→3)-2-O-benzoyl-4, 6-O-benzylidene-β-D-galactopyranosyl-(1→4)-2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S56**). Compound **S56** was synthesized from compound **S55** in 84% yield following the general procedure of Lev deprotection. ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.22 (s, 3 H), 1.28 (s, 3 H), 1.37 (s, 3 H), 2.00 (s, 3 H), 2.39-2.48 (m, 2 H), 3.13-3.43 (m, 21 H), 3.50-3.61 (m, 10 H), 3.65-3.88 (m, 30 H), 3.97-4.12 (m, 12 H), 4.19-4.70 (m, 38 H), 4.76-4.86 (m, 3 H), 4.88-4.90 (m, 1 H), 4.92-5.01 (m, 5 H), 5.03-5.21 (m, 8 H), 5.27-5.33 (m, 5 H), 5.40-5.54 (m, 3 H), 6.58-6.60 (m, 1 H), 6.76-6.79 (m, 3 H), 6.99-7.54 (m, 61 H), 7.84-7.97 (m, 14 H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ 17.8, 19.9, 22.3, 22.7, 22.8, 24.8, 25.8, 42.5, 51.7, 51.8, 52.0, 52.4, 52.4, 52.6, 55.2, 61.0, 62.0, 66.5, 67.0, 67.2, 68.1, 68.2, 68.5, 69.1, 70.1, 70.7, 71.2, 71.4, 72.2, 72.5, 72.6, 72.8, 72.9, 73.1, 73.2, 73.5, 74.0, 74.4, 74.6, 74.8, 75.2, 75.4, 75.5, 75.7, 78.0, 78.6, 81.5, 96.1, 97.8, 98.8, 100.0, 100.4, 100.9, 102.1, 113.7, 125.9, 126.3, 126.6, 126.9, 127.0, 127.1, 127.5, 127.6, 127.7, 127.8, 127.8, 127.9, 128.0, 128.0, 128.1, 128.1, 128.2, 128.3, 128.3, 128.4, 128.4, 128.5, 128.7, 128.8, 128.9, 129.0, 129.3, 129.4, 129.5, 129.6, 129.7, 129.8, 133.2, 133.4, 133.7, 134.9, 136.1, 136.8, 137.3, 137.3, 137.4, 137.6, 137.8, 138.1, 138.2, 159.4, 164.5, 164.6, 165.1, 165.8, 168.2,

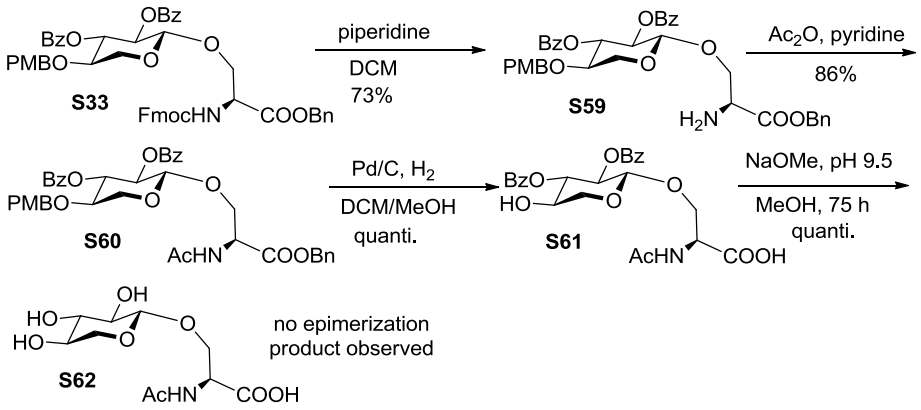
168.5, 169.0, 169.1, 169.6, 170.0, 170.2, 170.5, 170.7. MALDI-MS: $C_{179}H_{187}N_5O_{56}$ $[M+Na]^+$ calcd: 3327.40, obsd: 3327.95.

Glycopeptide **S57.** Compound **S57** was synthesized from compound **S56** in 90% yield following the general procedure of *O*-sulfation. ESI-MS: $C_{179}H_{185}N_5O_{62}S_2^{2-}$ $[M-2H]^{2-}$ calcd: 1730.05, obsd: 1730.84.
Glycopeptide **S58.** Compound **S58** was synthesized from compound **S57** in 95% yield following the general procedure of global debenzylation. ESI-MS: $C_{101}H_{120}N_5O_{61}S_2^{3-}$ $[M-2H]^{2-}$ calcd: 1221.79, obsd: 1222.28, $[M-3H]^{3-}$ calcd: 814.19, obsd: 814.58.
Glycopeptide **36**: Compound **S58** (1 mg) was dissolved in freshly dried MeOH (0.5 mL). 0.5 M NaOMe in MeOH was freshly prepared and added dropwisely to the reaction to maintian pH around 9.5. The reaction was left under N_2 atomosphere for 50 h and quenched by 1 M HOAc. The mixture was loaded onto LH-20 column. Glycopeptide containing fractions were combined and concentrated to afford compound **36**. ESI-MS: $C_{59}H_{90}N_3O_{52}S_2^{3-}$ $[M-2H]^{2-}$ calcd: 868.69, obsd: 868.68.

Glycopeptide **37**: Peptide **33** (4 mg, 0.004 mmol) and compound **36** (4 mg) were dissolved in 0.5 mL dry DMF, to which were added 2 mg HATU and 2 μL 2, 4, 6-collidine. The resulting mixture was stirred under room temperature overnight. The solution was loaded onto LH-20 column. Glycopeptide containing fractions were combined and concentrated to afford compound **37**. ESI-MS: $C_{119}H_{171}N_{15}O_{68}S_2^{2-}$ $[M-2H]^{2-}$ calcd: 1480.99, obsd: 1481.28.
Glycopeptide **1**: Compound **37** was treated following the general procedure for global debenzylation. ESI-MS: $C_{98}H_{151}N_{15}O_{68}S_2^{4-}$ $[M-3H]^{3-}$ calcd: 896.94, obsd: 897.30. $[M-4H]^{4-}$ calcd: 672.45, obsd: 672.99. The product was dissolved in MeOH/H_2O (1:1, 0.5 mL), to which 0.5 M NaOH solution was added to maintain pH around 9.5. The resulting mixture was left under room temperature for 3 h. The solution was loaded onto LH-20 column. Glycopeptide containing fractions were combined and concentrated to afford compound **1**. ^{1}H-NMR (600 MHz, D_2O): δ 0.88-0.94 (m, 10 H), 1.24-1.43 (m, 20 H), 1.51-1.79 (m, 13 H), 2.03 (s, 3 H), 2.06 (s, 3 H), 2.11 (s, 3 H), 2.12-2.38 (m, 14 H), 3.32-4.69 (m, 63 H), 5.12-5.42 (m, 11 H). ESI-MS: $C_{95}H_{142}N_{15}O_{68}S_2^{7-}$ $[M-6H+2NH_4]^{4-}$ calcd: 666.19, obsd: 665.45. $[M-4H+NH_4]^{4-}$ calcd: 888.58, obsd: 888.19.

Probing the possibility of epimerization of glycosylated serine

A potential concern is the possible epimerization[6] of the glycosylated serine in compound **31** during the most basic step in the synthesis, i.e., transesterification. Due to the complexity of **31**, it was extremely challenging to test whether epimerization occurred during this step. To probe this possibility, we carried out a model reaction using xylosylserine **S61** containing two *O*-benzoyl groups. **S61** was subjected to the same transesterification condition (pH 9.5, NaOMe/MeOH). Even after 75 hours, no epimerization product of **S62** was detected, which suggests the epimerization of **31** likely did not occur to a significant extent.



N-O-[2, 3-di-O-benzoyl-4-O-p-methoxybenzyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S59**). Compound **S33** (101 mg, 0.115 mmol) was dissolved in DCM (4 mL), followed by addition of 471 μL piperidine. After 3 h, the mixture was diluted with DCM and extracted with H_2O. The combined organic phase was dried over Na_2SO_4. Column purification afforded compound **S59** (55 mg, 73%). ESI-MS: $C_{37}H_{37}NO_{10}$ $[M+H]^+$ calcd: 656.24, obsd: 656.14.

N-Acetyl-O-[2,3-di-O-benzoyl-4-O-p-methoxybenzyl-β-D-xylopyranosyl]-L-serine benzyl ester (**S60**). Compound **S59** (106 mg, 0.162 mmol) was dissolved in pyridine (3 mL), followed by addition of 153 μL Ac_2O. After overnight, the mixture was diluted with DCM and extracted with 10% HCl, sat. $NaHCO_3$ solution and dried over Na_2SO_4. Column purification afforded compound **S60** (97 mg, 86%). ^{1}H-NMR (500 MHz, $CDCl_3$): δ 1.71 (s, 3 H, NHCH_3), 3.34-3.38 (m, 1 H), 3.63-3.67 (m, 1 H), 3.72-3.73 (m, 1 H), 3.74 (s, 3 H, PhOCH_3), 3.88-3.91 (m, 1 H), 4.29 (dd, 1 H, J = 2.5 Hz, J = 10 Hz), 4.47-4.53 (m, 2 H), 4.58 (d, 1 H, J = 6.5 Hz), 4.73-4.76 (m, 1 H), 5.09-5.18 (m, 3 H), 5.52 (t, 1 H, J = 8 Hz), 6.14 (d, 1 H, J = 8.5 Hz), 6.71-6.73 (m, 2 H), 7.11-7.13 (m, 2 H), 7.29-7.42 (m, 9 H), 7.48-7.54 (m, 2 H), 7.92-7.95 (m, 4 H).

N-Acetyl-O-[2, 3-di-O-benzoyl-β-D-xylopyranosyl]-L-serine (**S61**). Synthesis of **S61** from compound **S60** was achieved in quantitative yield followed the general procedure of global debenzylation. ^{1}H-NMR (500 MHz, CD_3OD): δ 1.59 (s, 3 H, NHCH_3), 3.36-3.38 (m, 1 H), 3.50-3.55 (m, 1 H), 3.94-4.01 (m, 2 H), 4.06-4.11 (m, 1 H), 4.14-4.18 (m, 1 H), 4.34-4.37 (m, 1 H), 4.79 (d, 1 H, J = 7.5 Hz), 5.17-5.21 (m, 1 H), 5.45-5.59 (m, 1 H), 7.39-7.45 (m, 4 H), 7.53-7.57 (m, 2 H), 7.93-7.96 (m, 4 H). ^{13}C-NMR (125 MHz, CD_3OD): 22.4, 55.8, 66.8, 69.3, 70.4, 73.4, 76.9, 78.9, 79.2, 79.4, 102.0, 102.1, 129.4, 129.5, 130.6, 130.6, 130.7, 130.8, 134.3, 134.5, 166.8, 167.4, 172.7, 176.8. ESI-MS: $C_{24}H_{25}NO_{10}$ $[M-H]^+$ calcd: 486.15, obsd: 486.00.

N-Acetyl-O-β-D-xylopyranosyl-L-serine (**S62**). Compound **S61** (4 mg) was dissolved in 1 mL dry MeOH followed by addition of freshly prepared 0.1 M NaOMe until the pH was 9.5. The resulting solution was stirred under room temperature for 75 h and quenched by 1 M HOAc. The mixture was concentrated in vacuo to afford compound **S62** in quantitative yield. ^{1}H-NMR (500 MHz, D_2O): δ 2.08 (s, 3 H, NHCH_3), 3.39-3.38 (m, 2 H), 3.46 (t, 1 H, J = 9 Hz), 3.61-3.67 (m, 1 H), 3.89-3.93 (m, 1 H), 3.96-4.00 (m, 1 H), 4.18-4.22 (m, 1 H), 4.40-4.45 (m, 2 H). ESI-MS: $C_{10}H_{17}NO_8$ $[M-H]^+$ calcd: 278.10, obsd: 278.10.

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[1] K. Bock, C. Pedersen, *J. Chem. Soc., Perkin Trans. 2* **1974**, 293.
[2] X. Ye, Y. Wang, L. Zhang, (Peking University, Peop. Rep. China). Chinese Patent Application: CN, **2006**, CN 1715286 A20060104, p. 18 pp.
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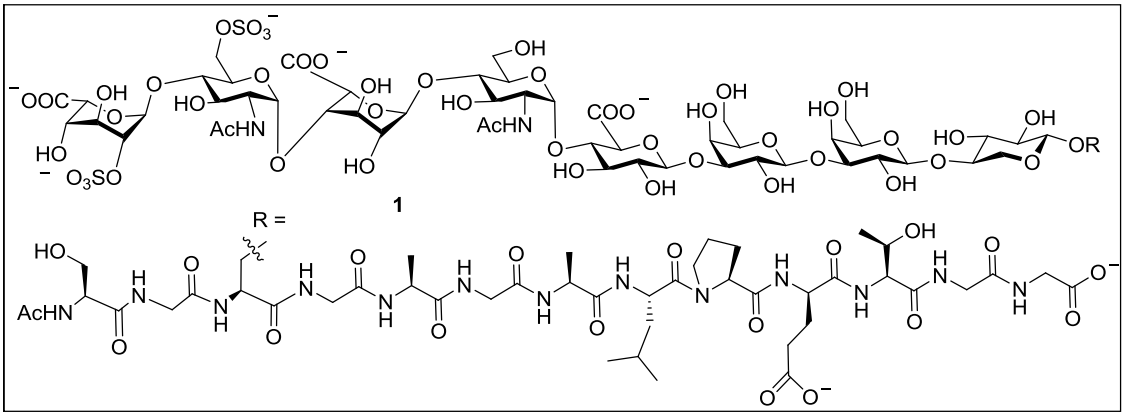
[4] G. Tiruchinapally, Z. Yin, M. El-Dakdouki, Z. Wang, X. Huang, *Chem. Eur. J.* **2011**, *17*, 10106.
[5] Z. Wang, Y. Xu, B. Yang, G. Tiruchinapally, B. Sun, R. Liu, S. Dulaney, J. Liu, X. Huang, *Chem. Eur. J.* **2010**, *16*, 8365.
[6] Y. Zhang, S. M. Muthana, D. Farnsworth, O. Ludek, K. Adams, J. J. Barchi, J. C. Gildersleeve, *J. Am. Chem. Soc.* **2012**, *134*, 6316-6325.

ESI-MS of **1**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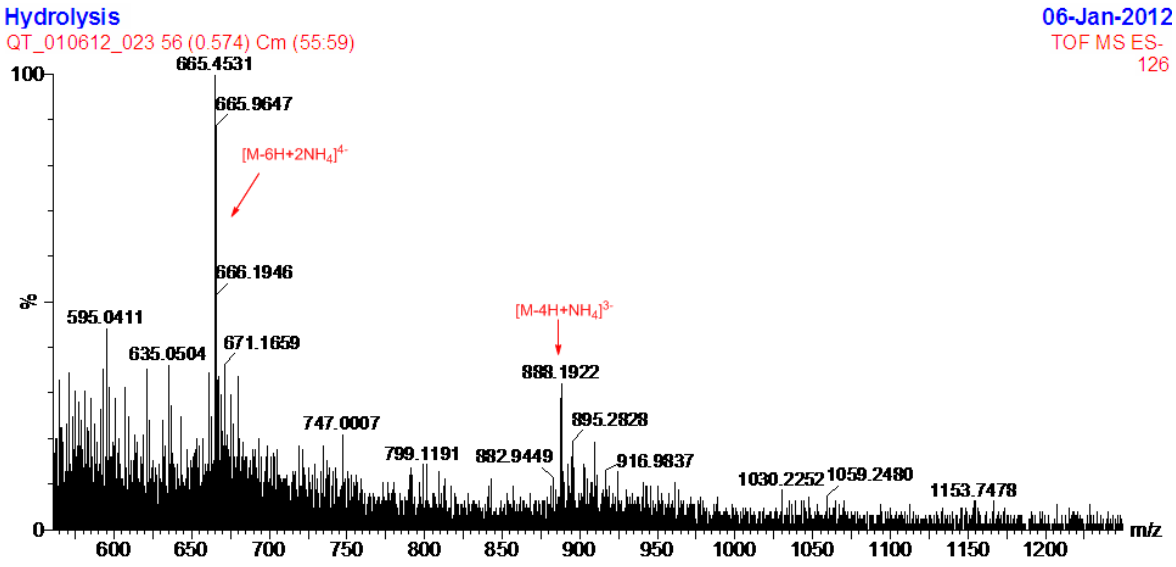
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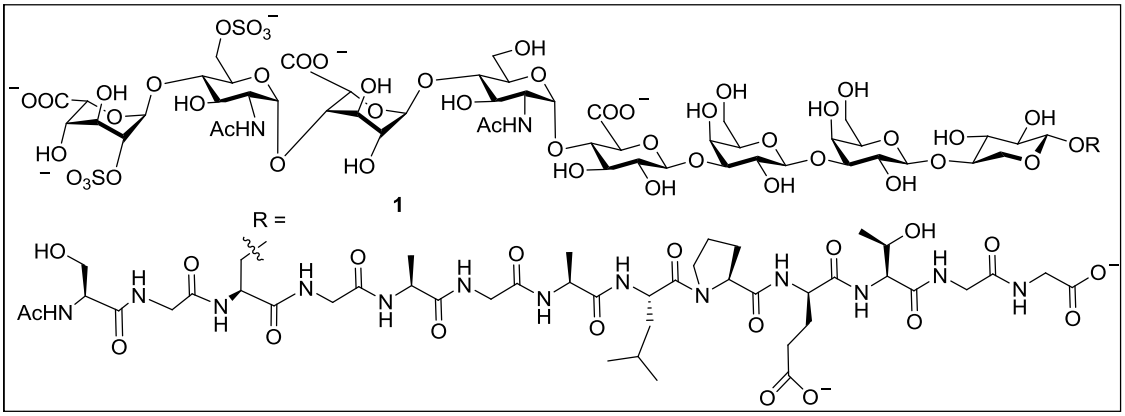
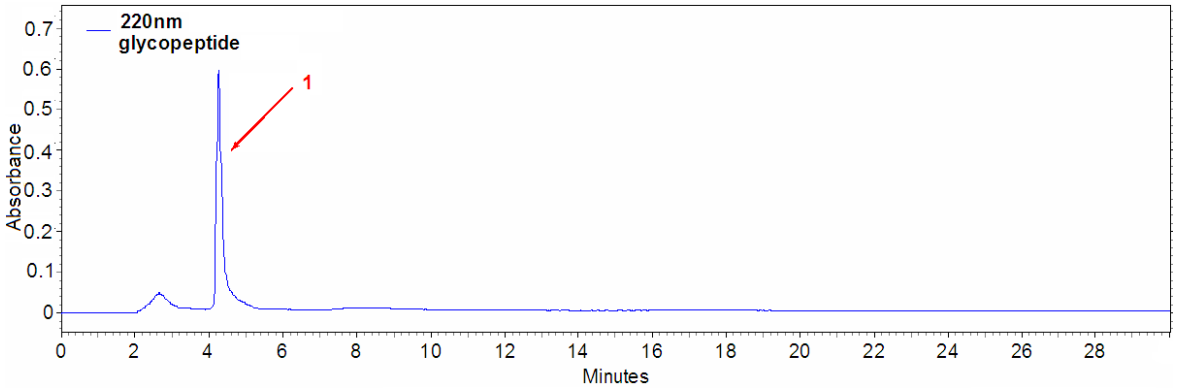
%
m/z

HPLC Chromatogram of glycopeptide **1**

HPLC mobile phase: gradient 40% to 100% B in A over 30 min (solvent A: H_2O; solvent B: CH_3CN). Flow rate: 1 mL/min. Detection Wavelength: 220 nm. HPLC column: SupelCOSIL LC-18, 25 cm x 4.6 mm, 5 µm particle size.





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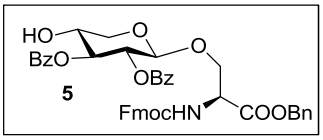

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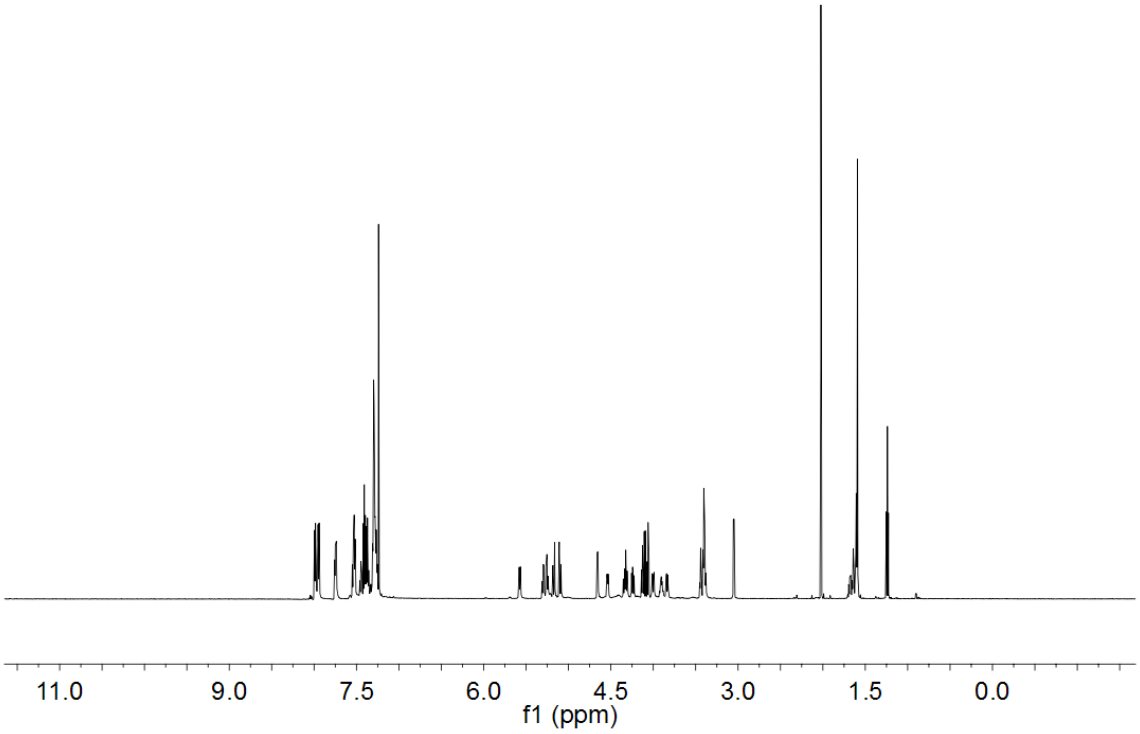

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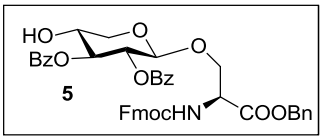

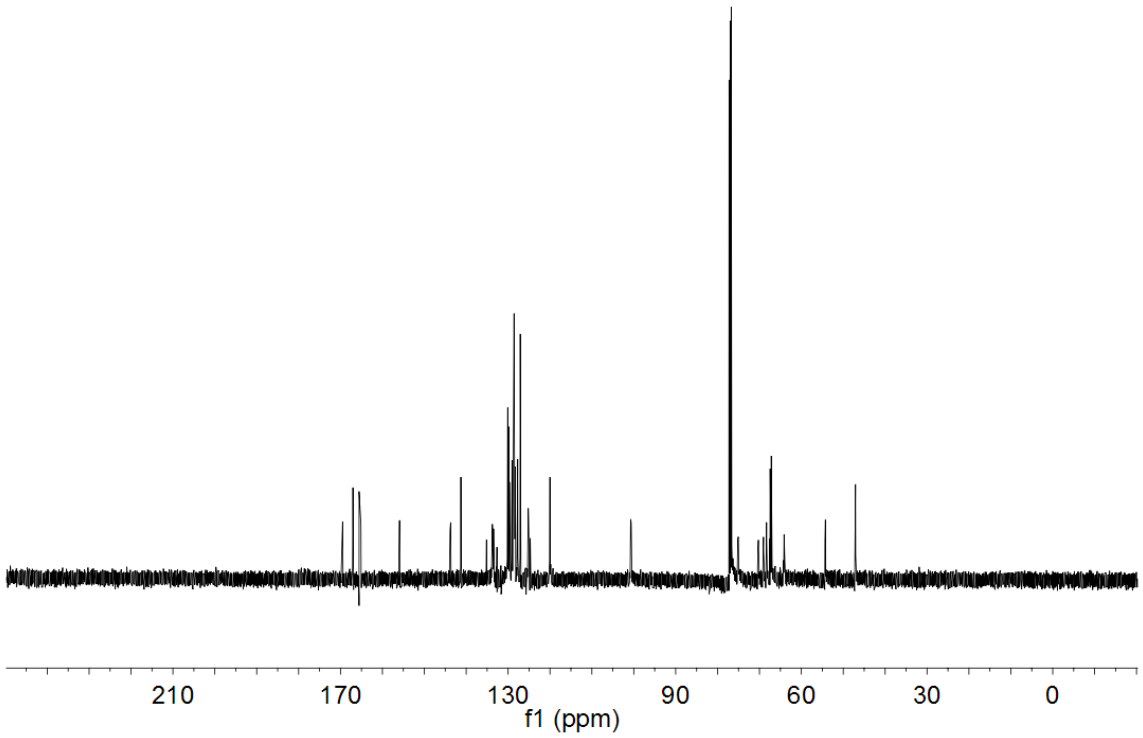

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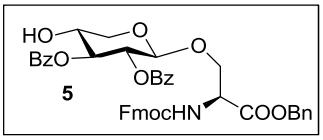

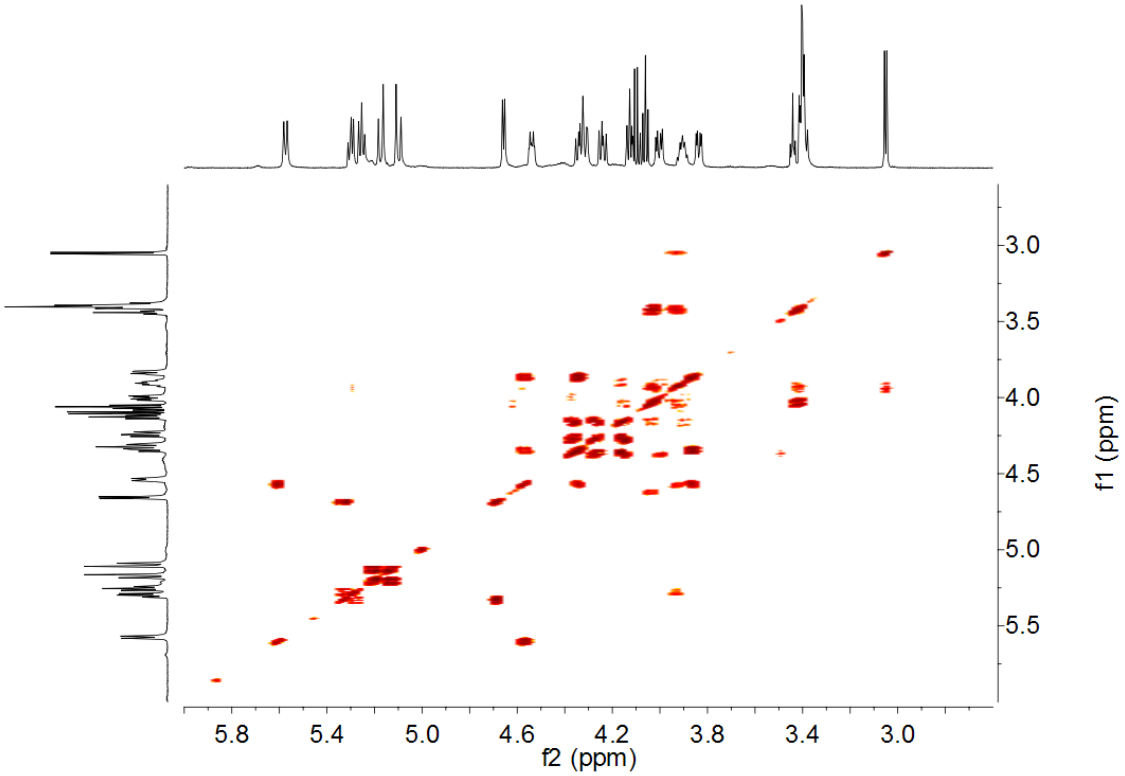

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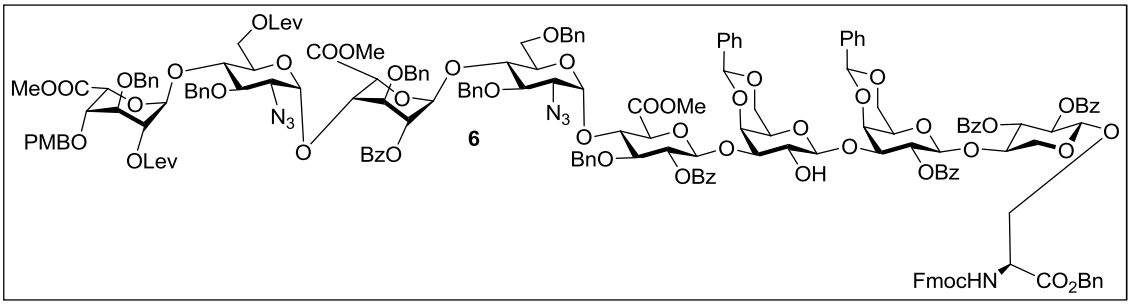

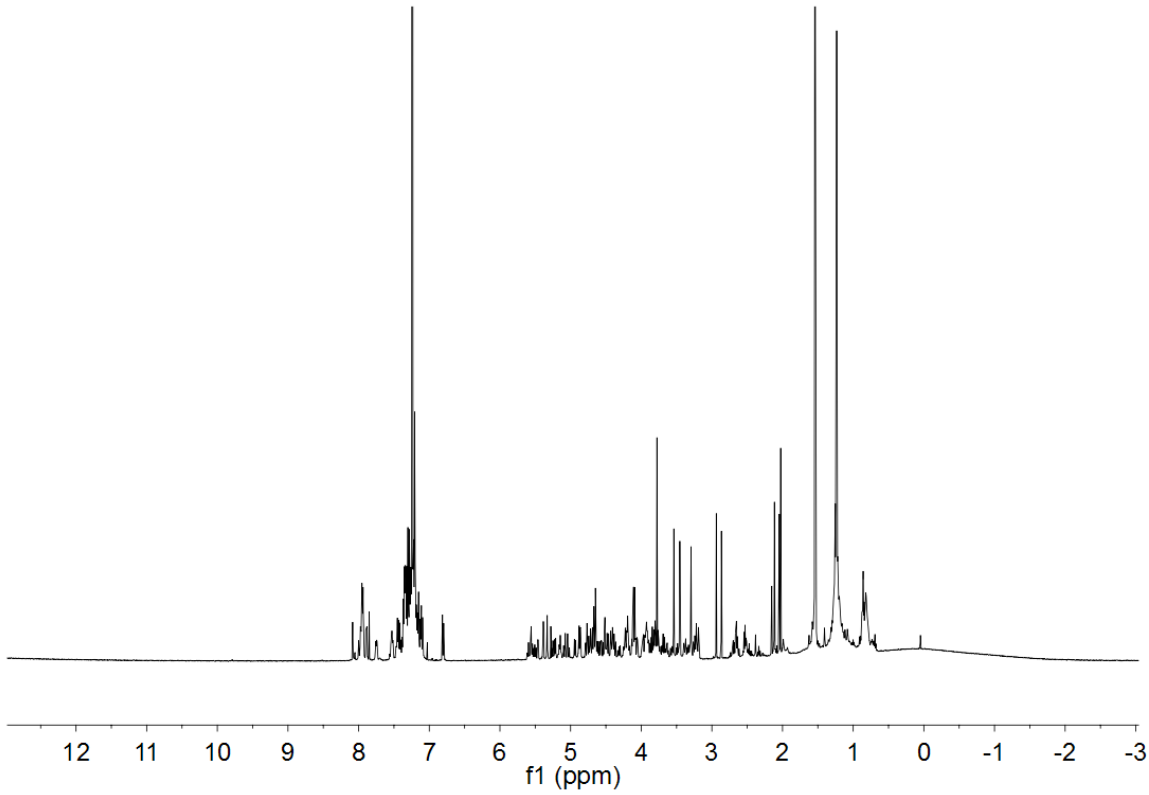

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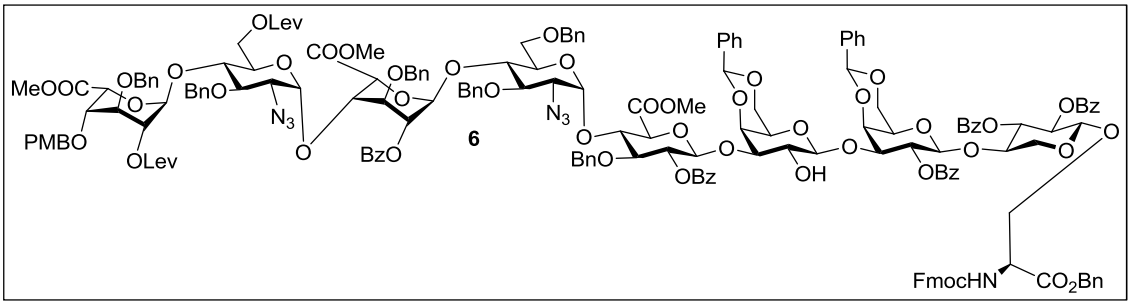

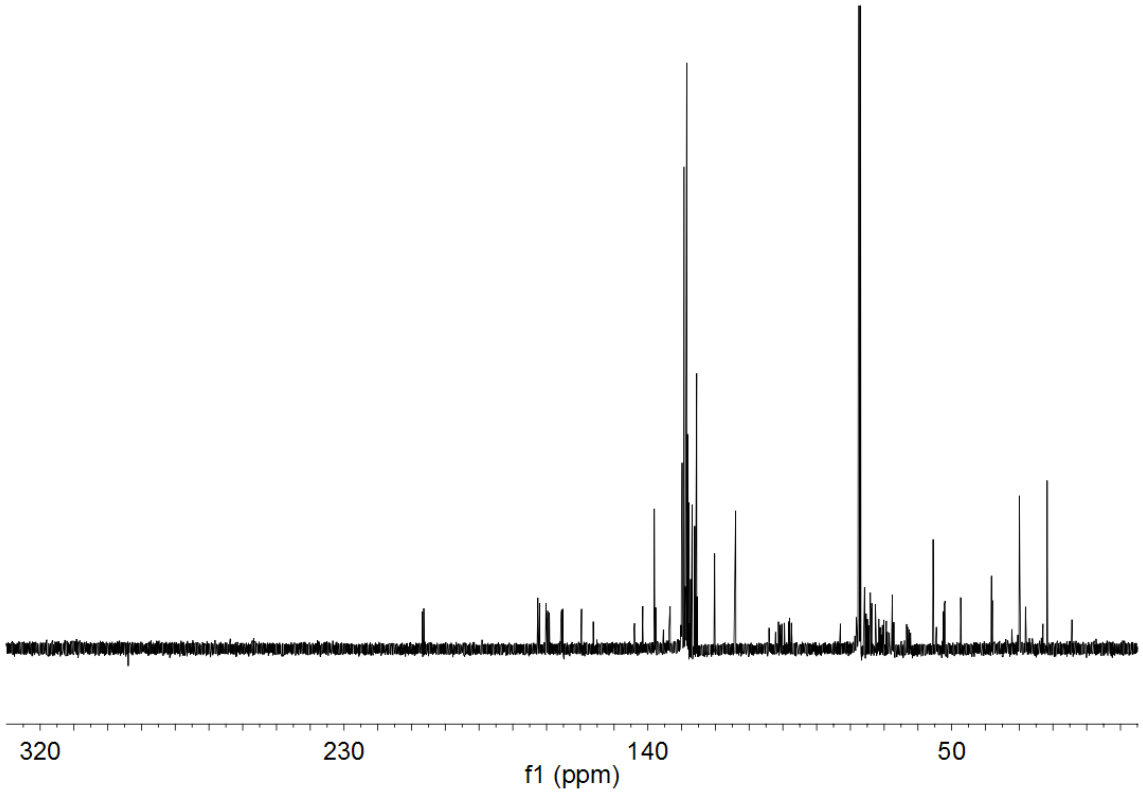

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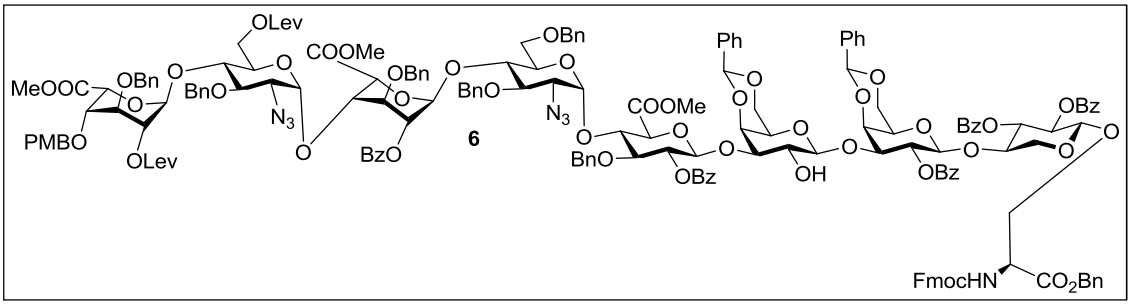

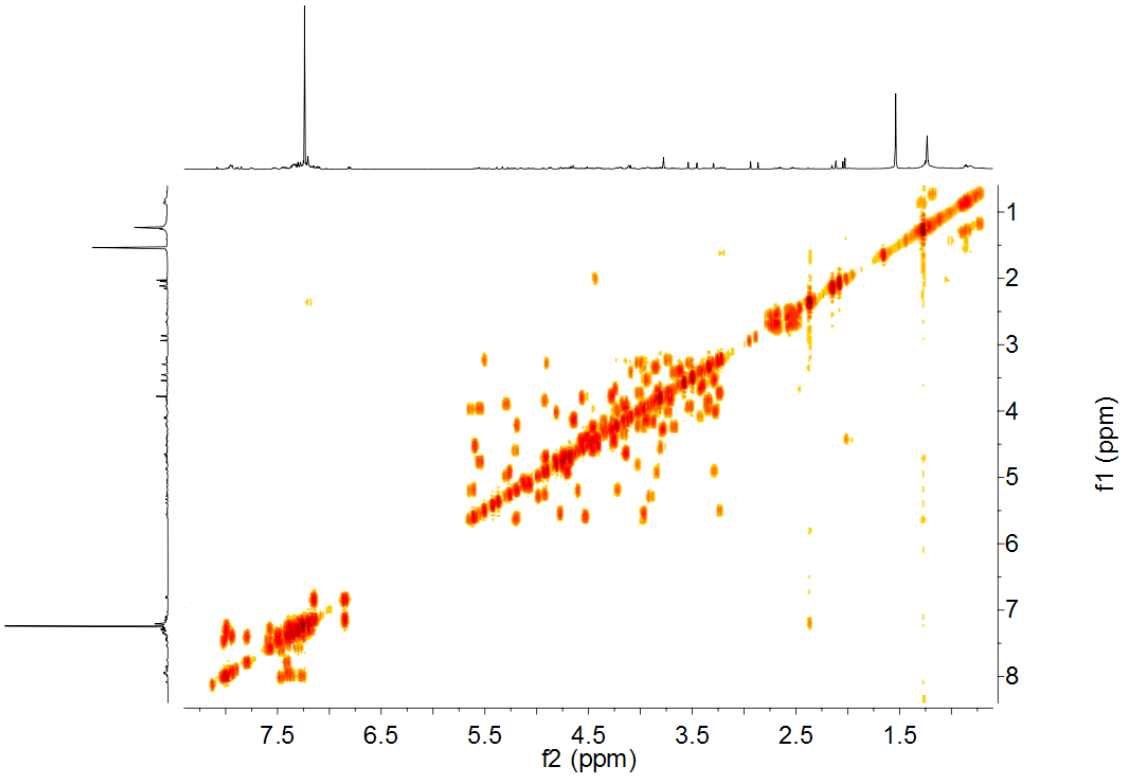

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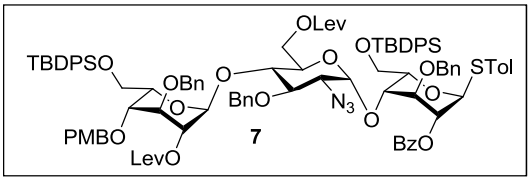
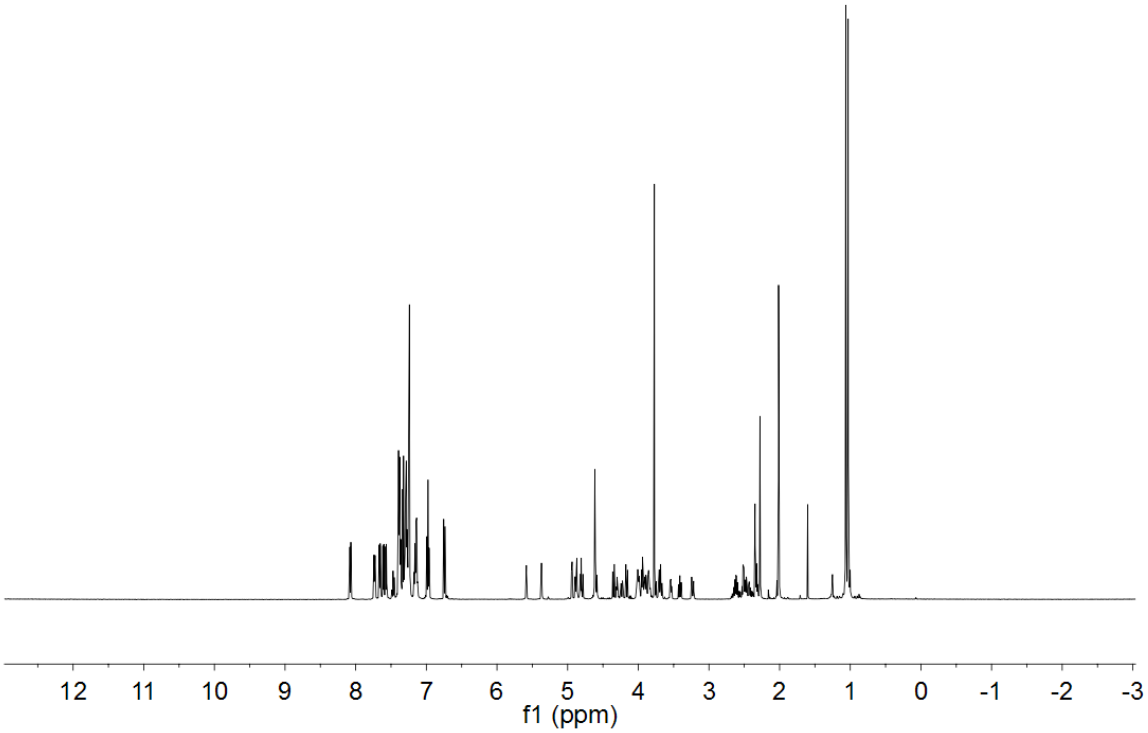
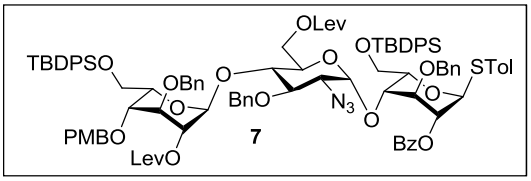
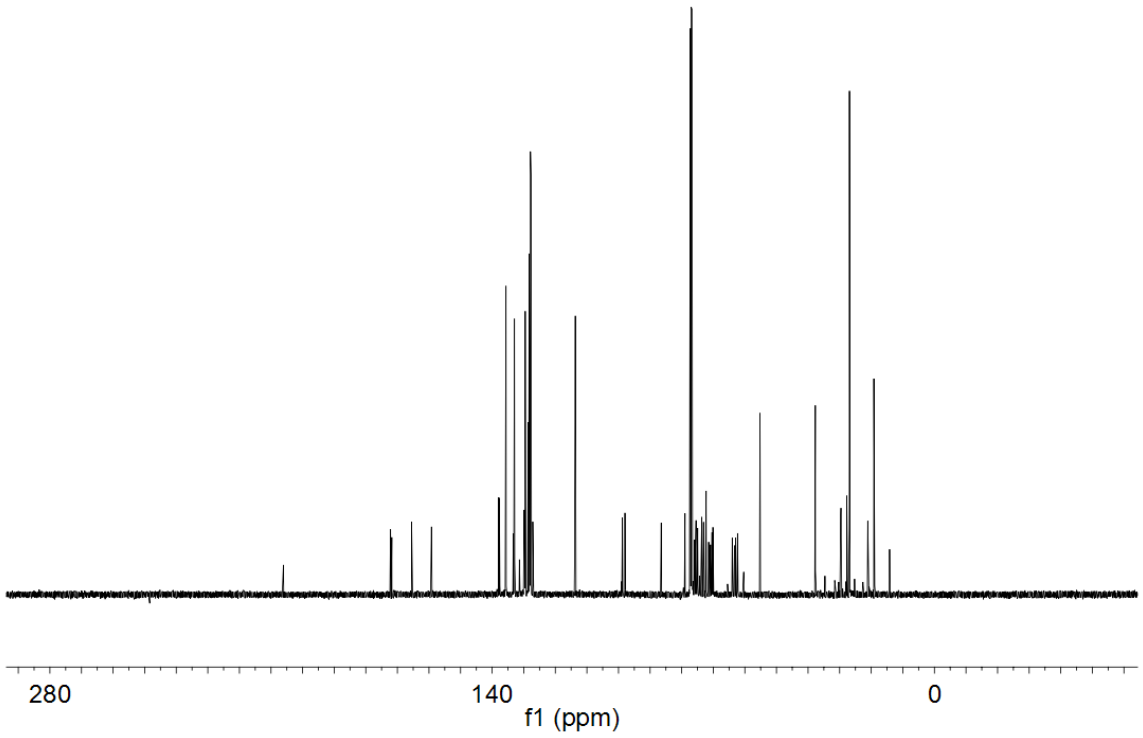




^{13}C-NMR ($CDCl_3$, 125 MHz) of **7**





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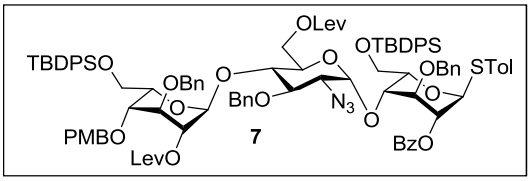
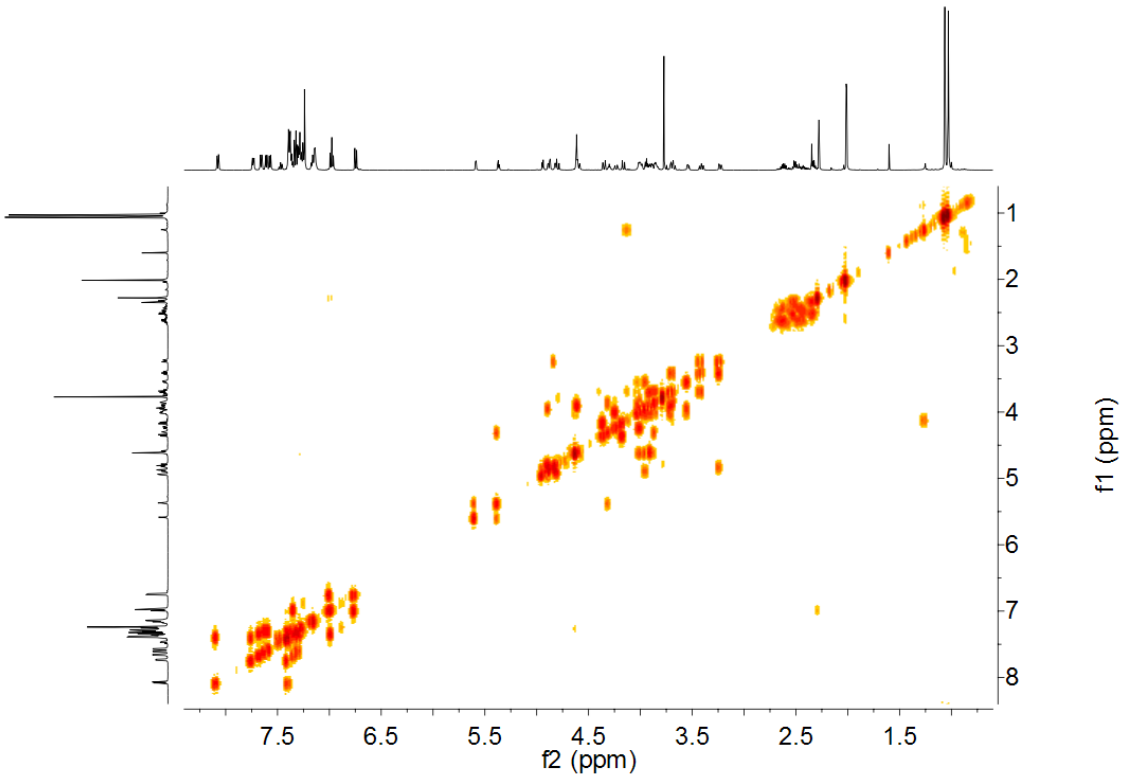
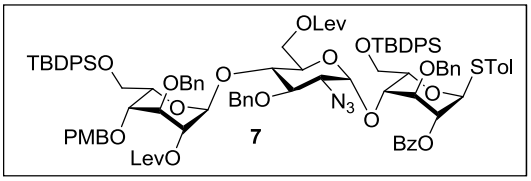
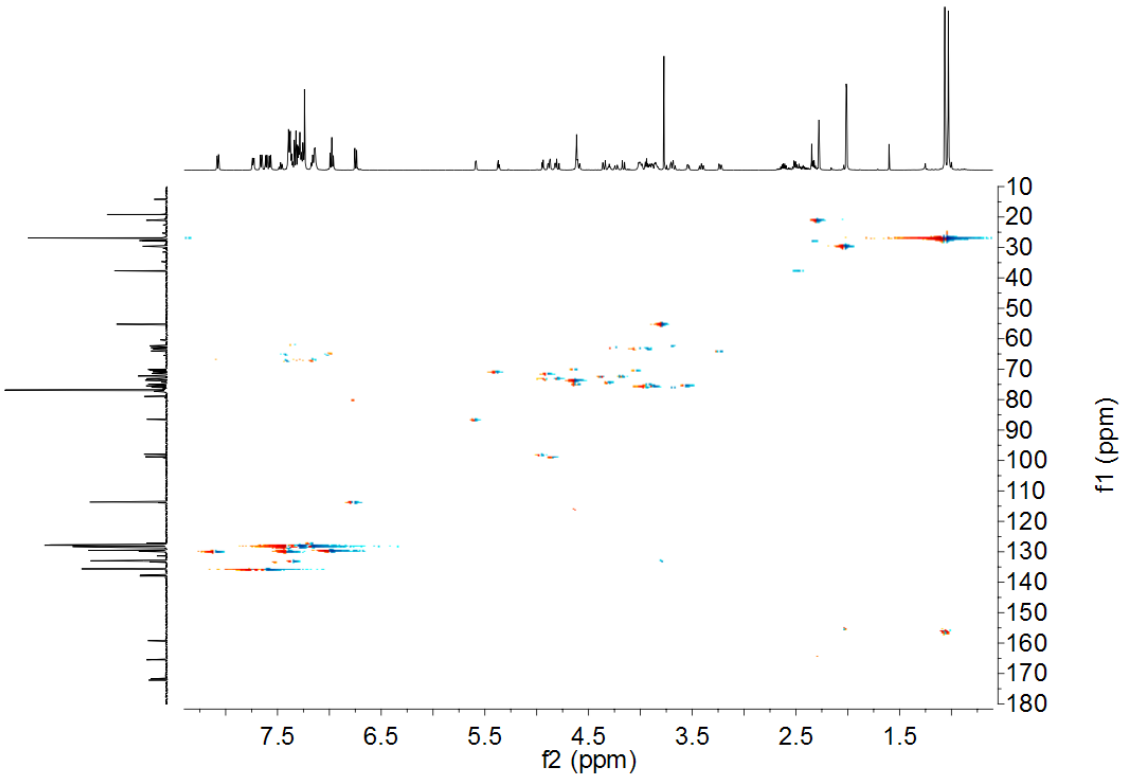


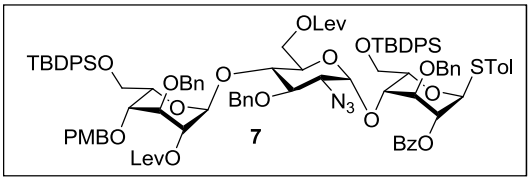


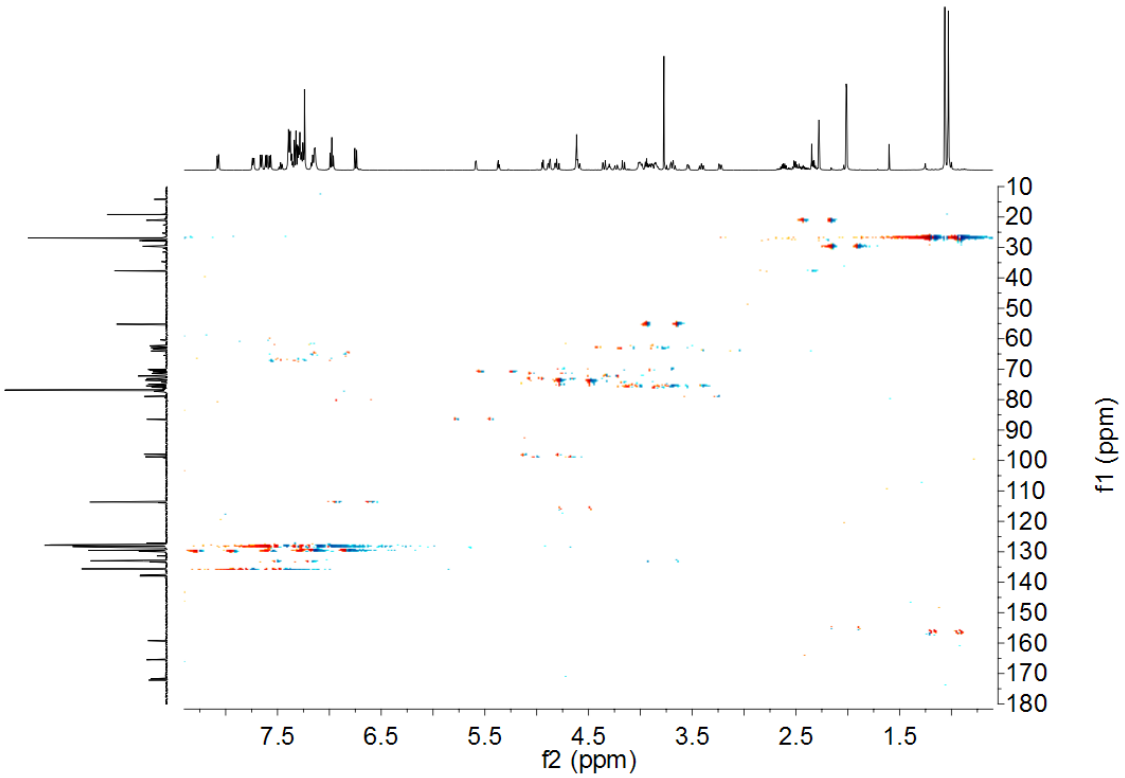
gHMQC ($CDCl_3$, 500 MHz) of **7**



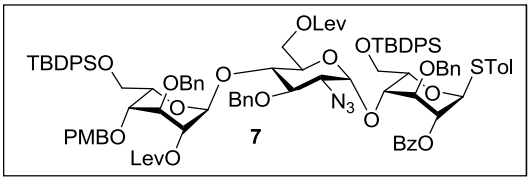


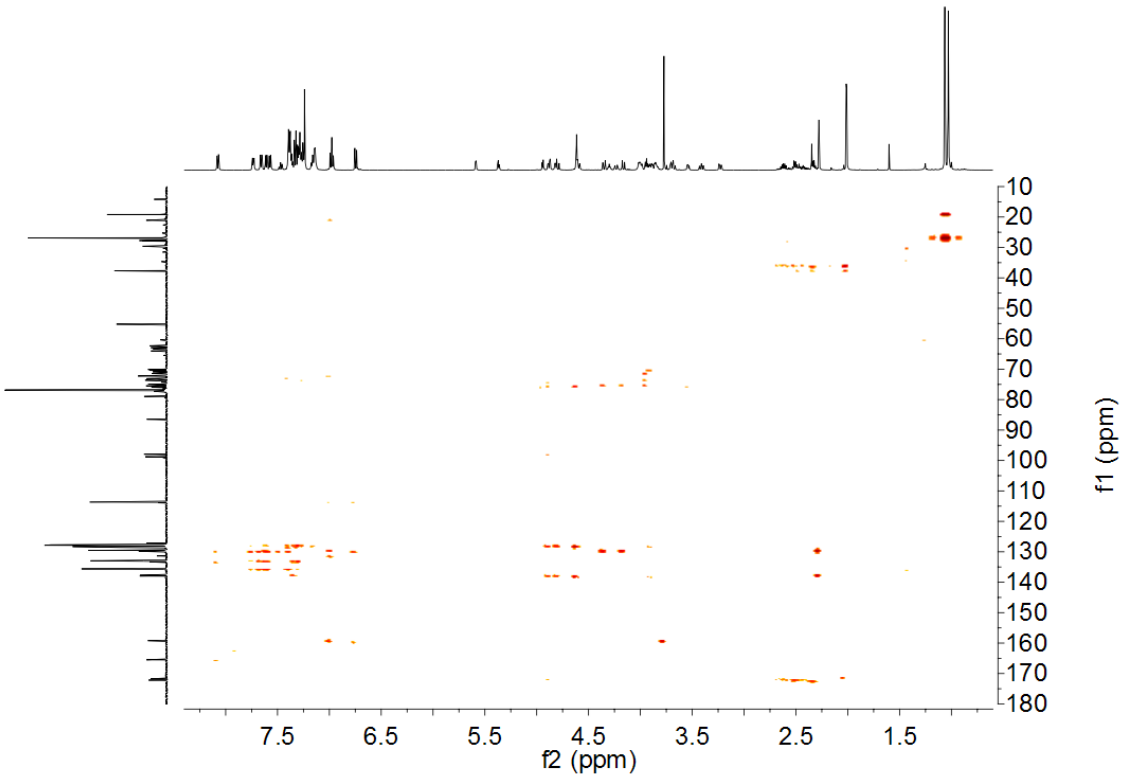
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 500 MHz) of **7**



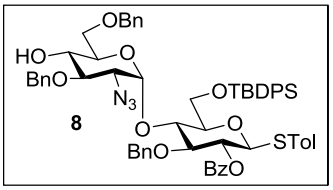


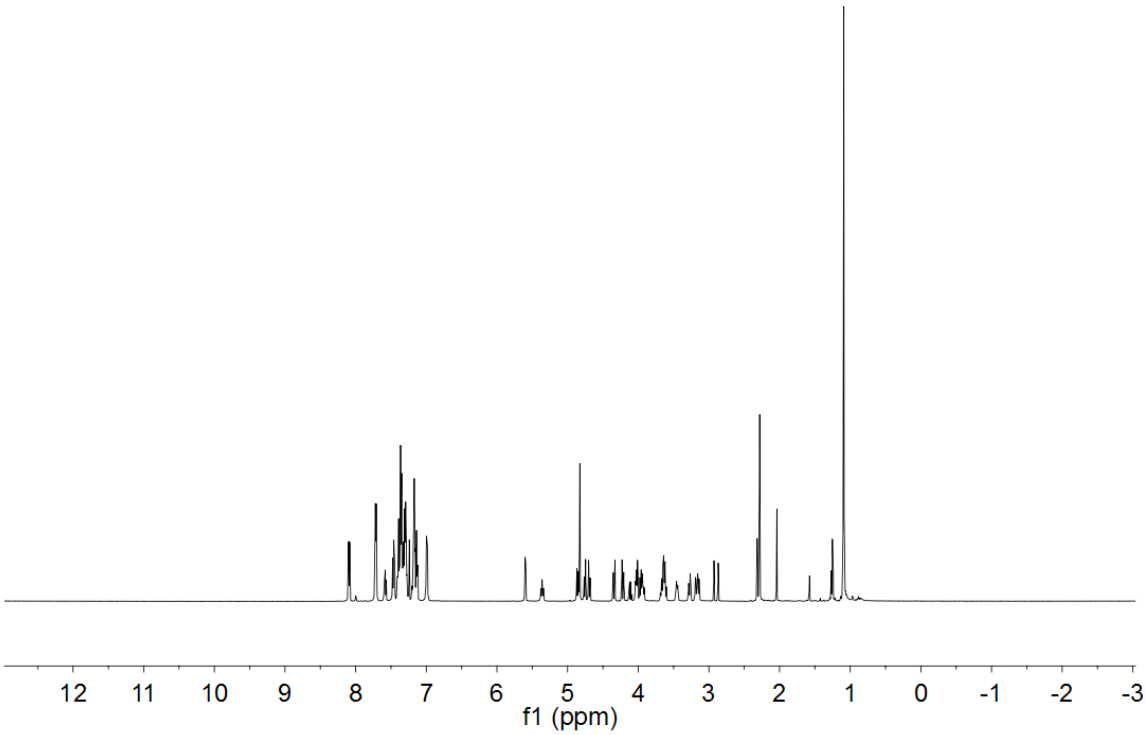
gHMBC ($CDCl_3$, 500 MHz) of **7**



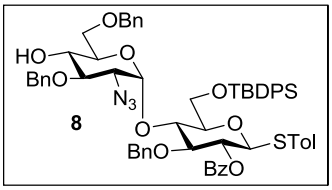


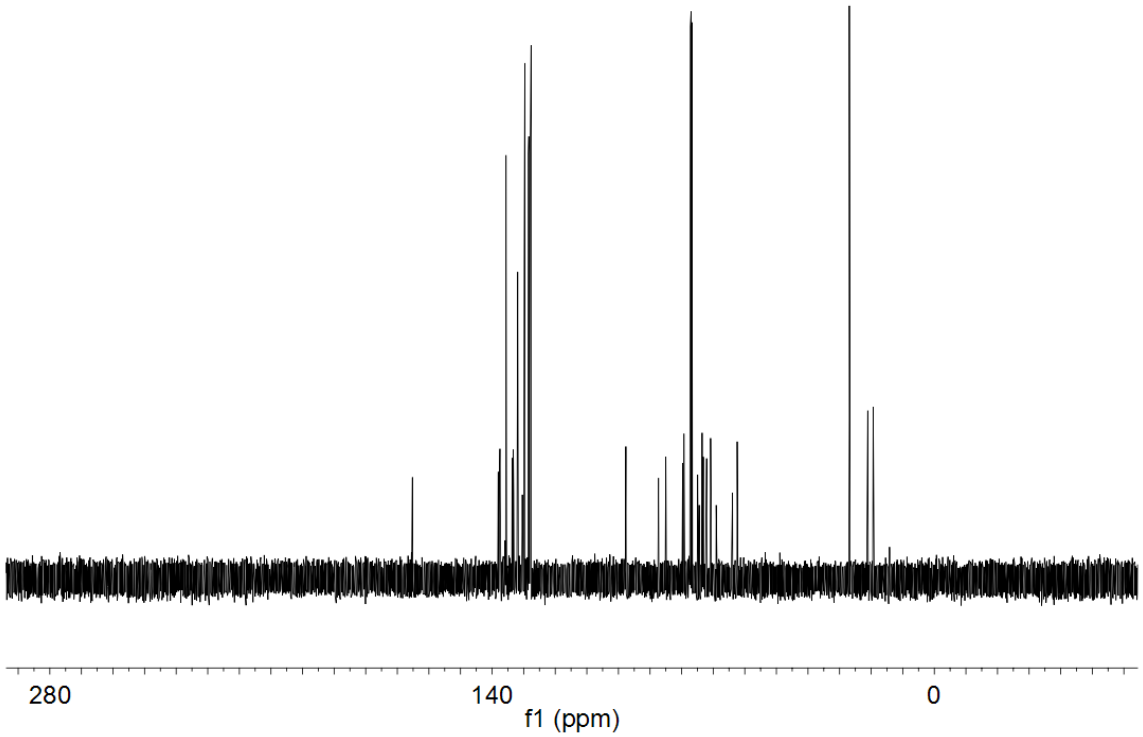
^{1}H-NMR ($CDCl_3$, 500 MHz) of **8**



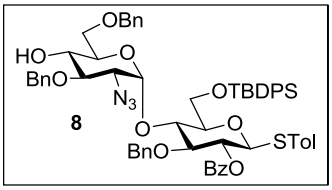


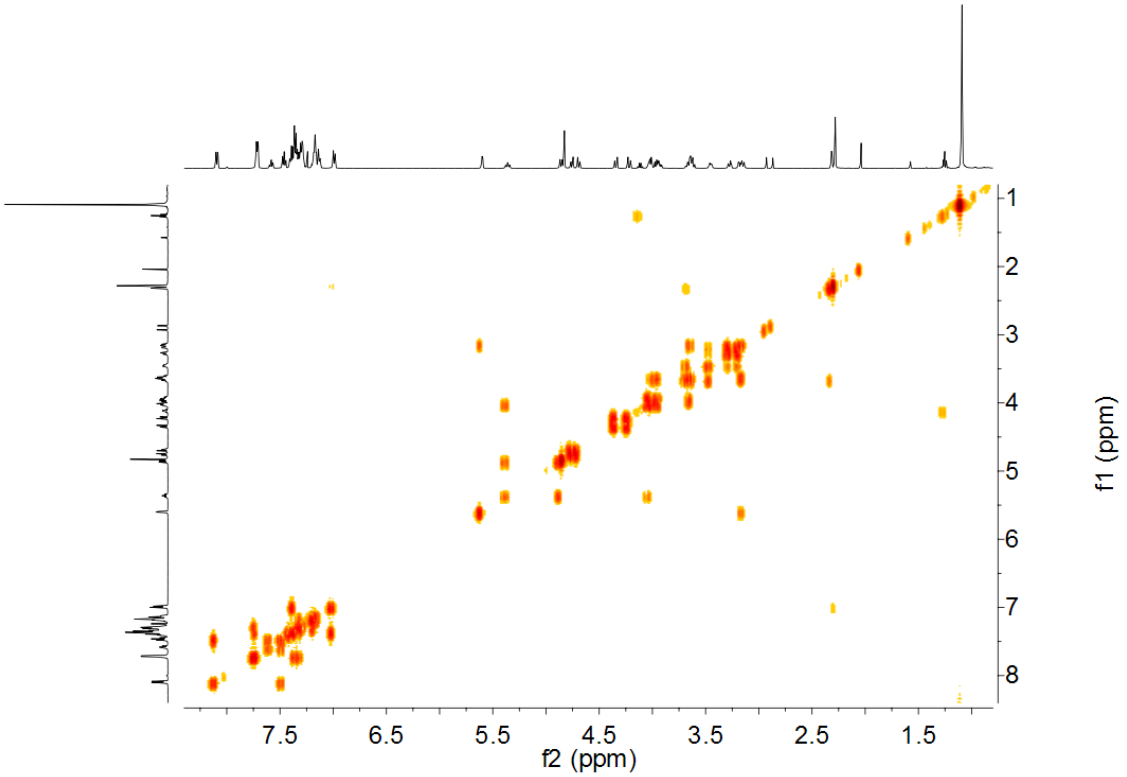
^{13}C-NMR ($CDCl_3$, 125 MHz) of **8**



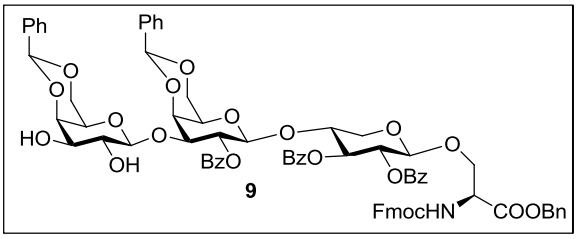


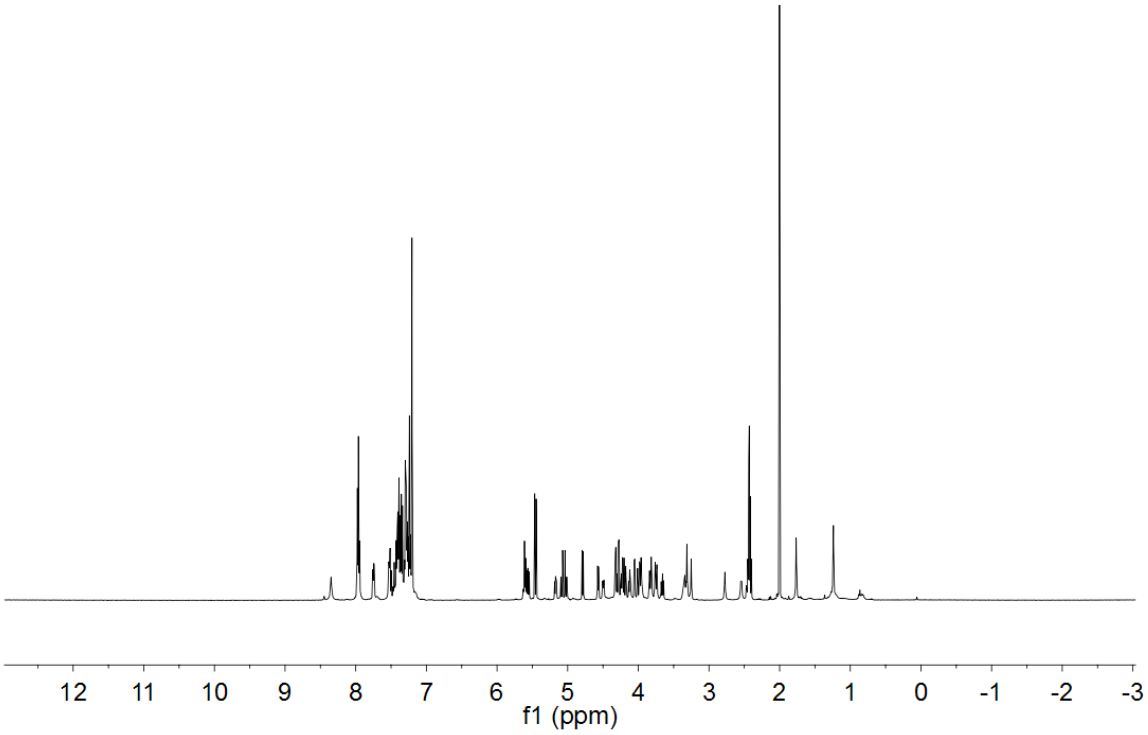
gCOSY ($CDCl_3$, 500 MHz) of **8**



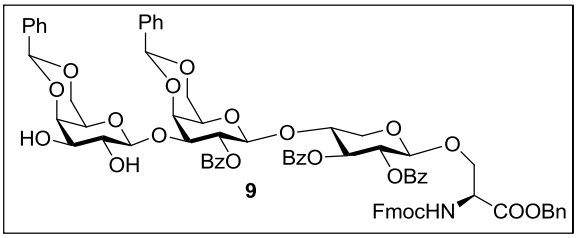


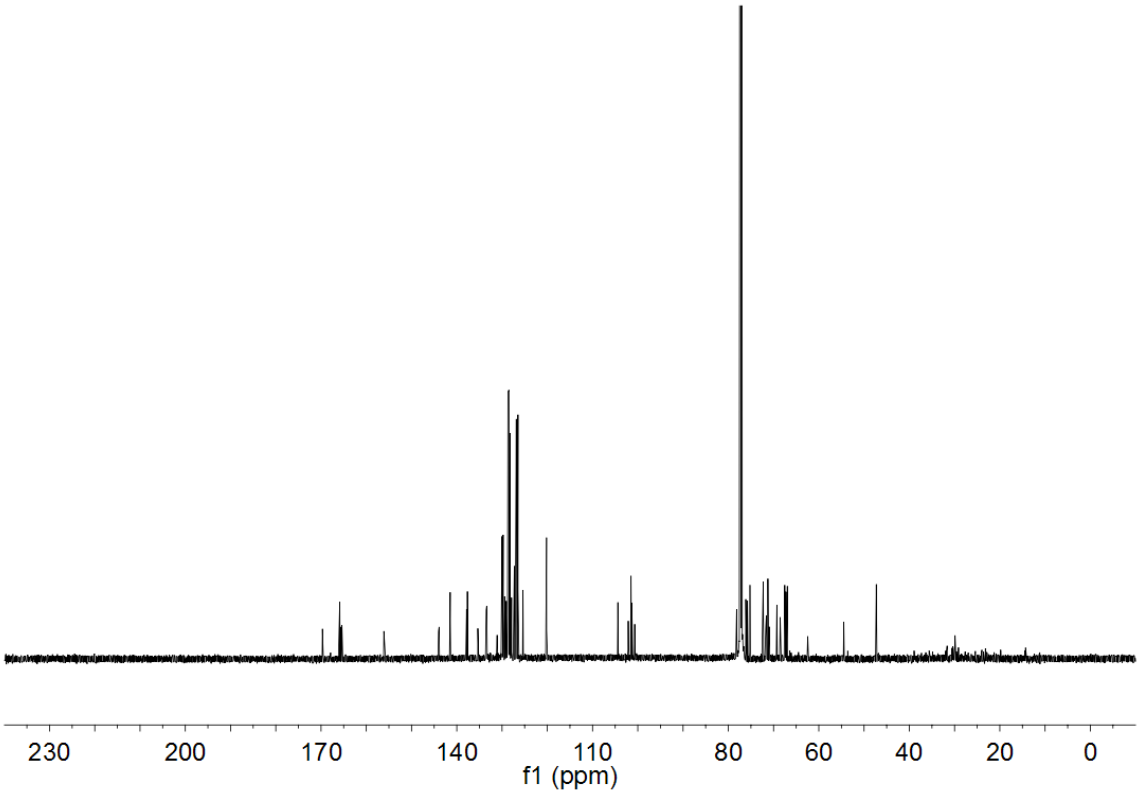
^{1}H-NMR ($CDCl_3$, 500 MHz) of **9**



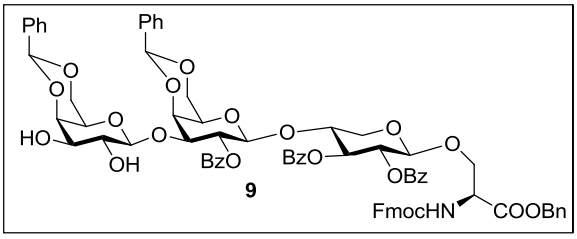


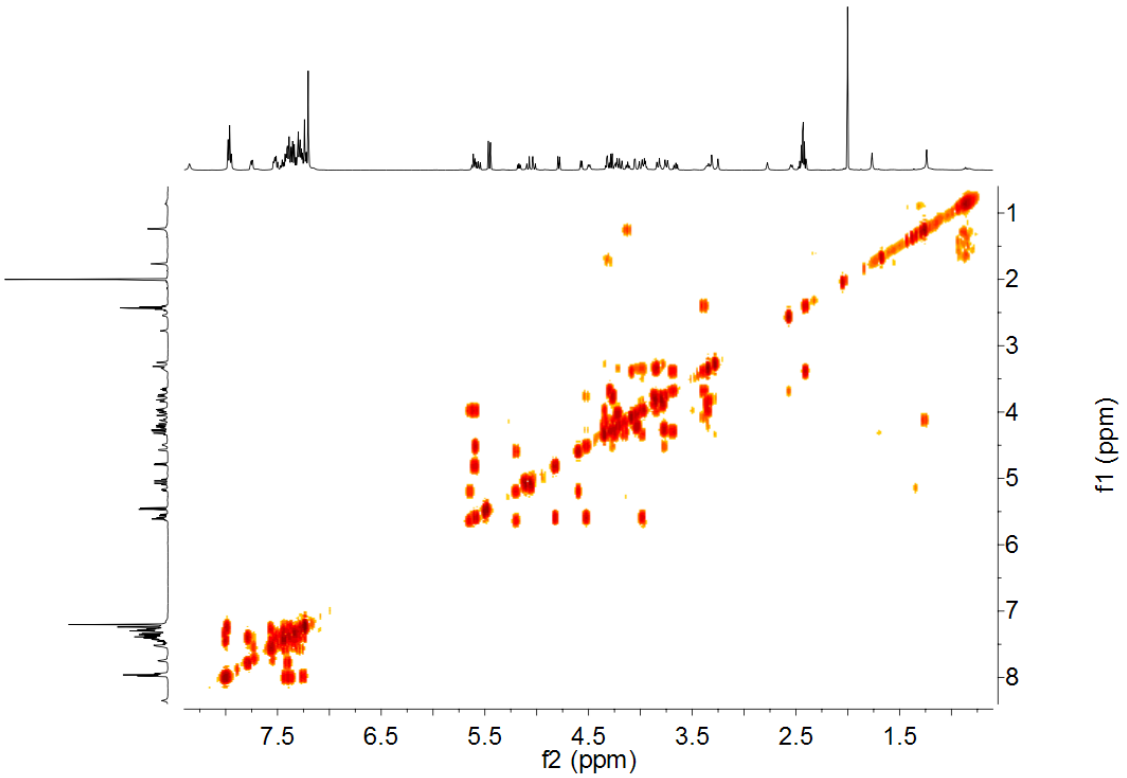
^{13}C-NMR ($CDCl_3$, 150 MHz) of **9**



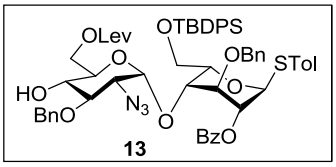


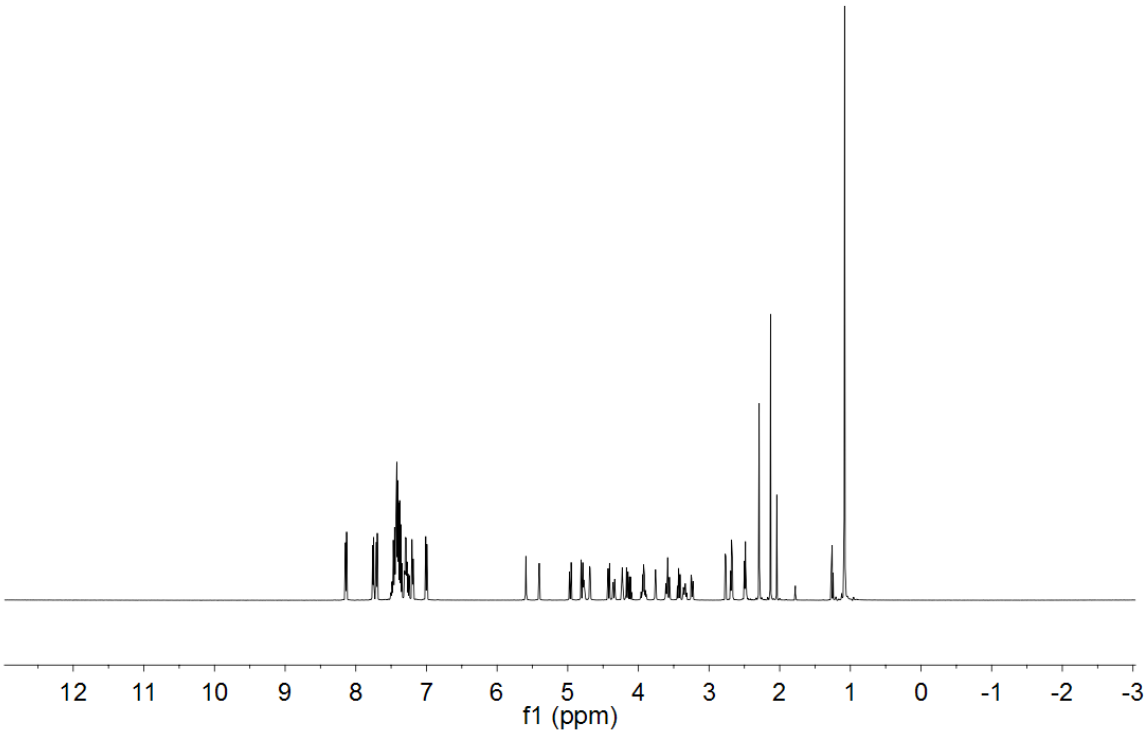
gCOSY ($CDCl_3$, 500 MHz) of **9**



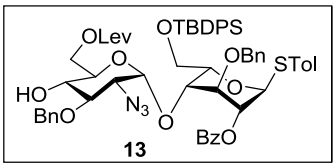


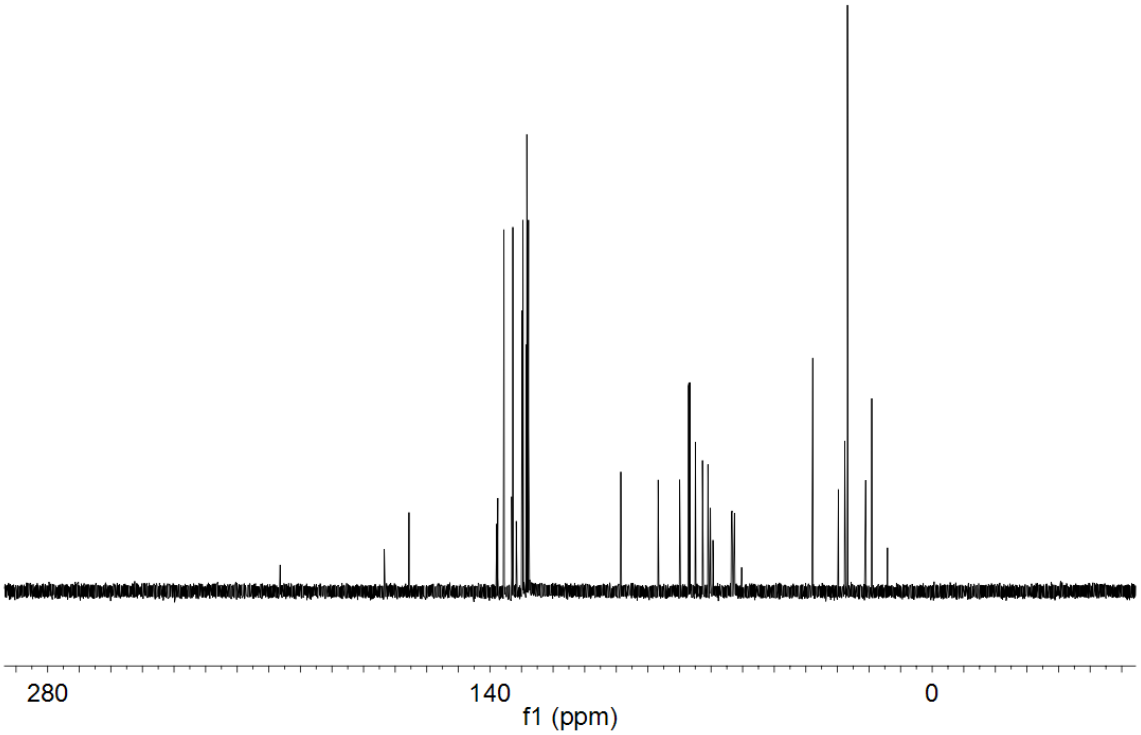
^{1}H-NMR ($CDCl_3$, 500 MHz) of **13**



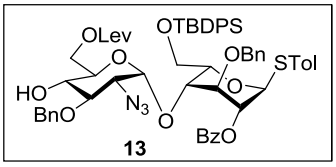


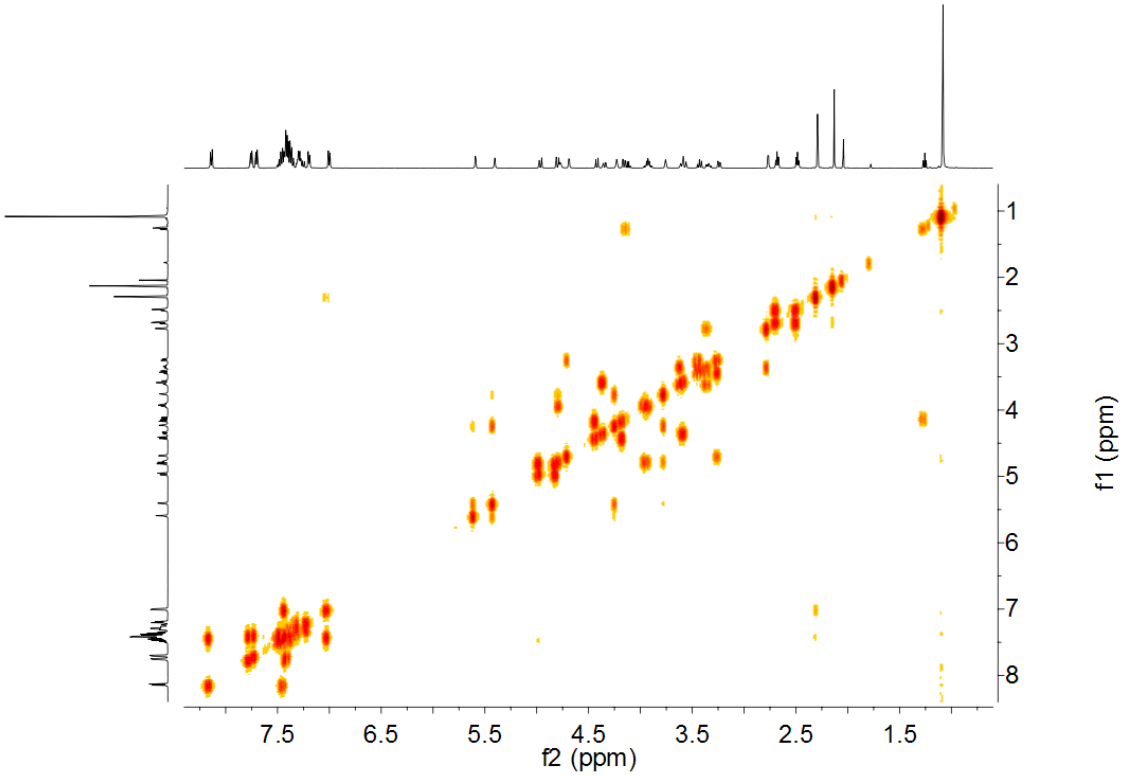
^{13}C-NMR ($CDCl_3$, 125 MHz) of **13**



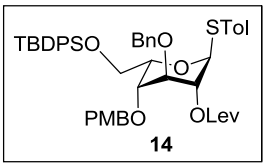


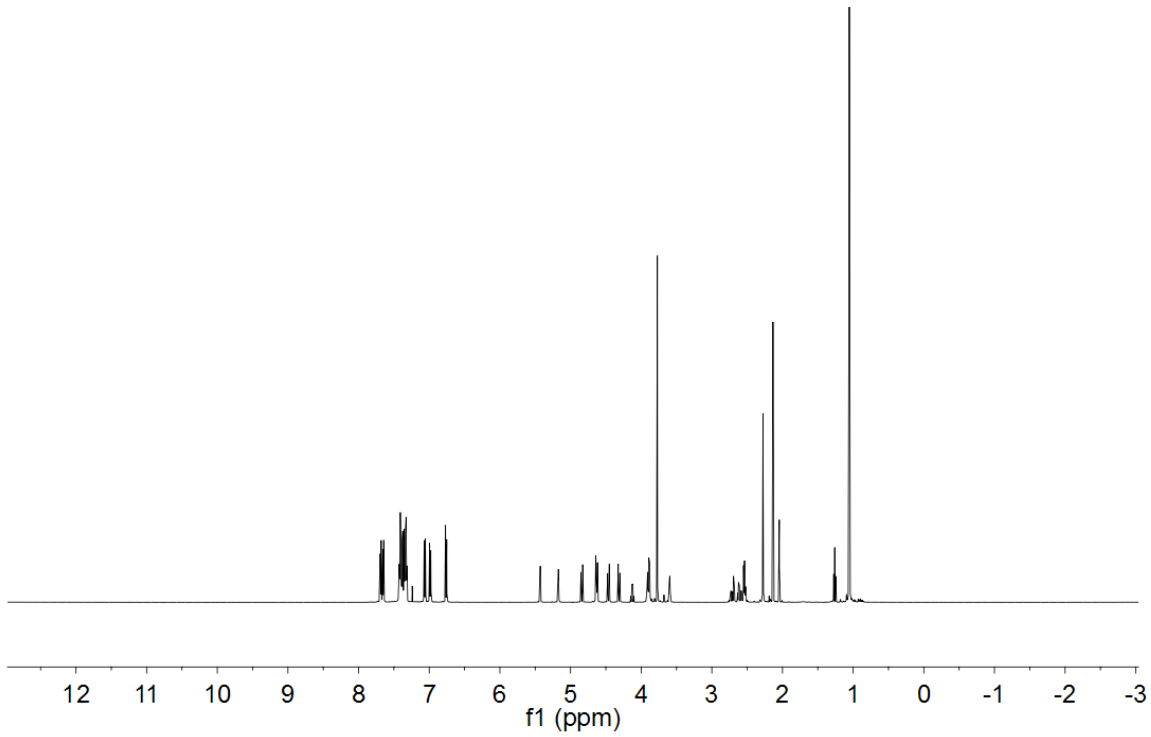
gCOSY ($CDCl_3$, 500 MHz) of **13**



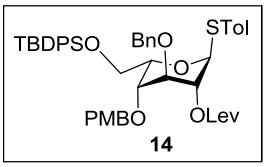


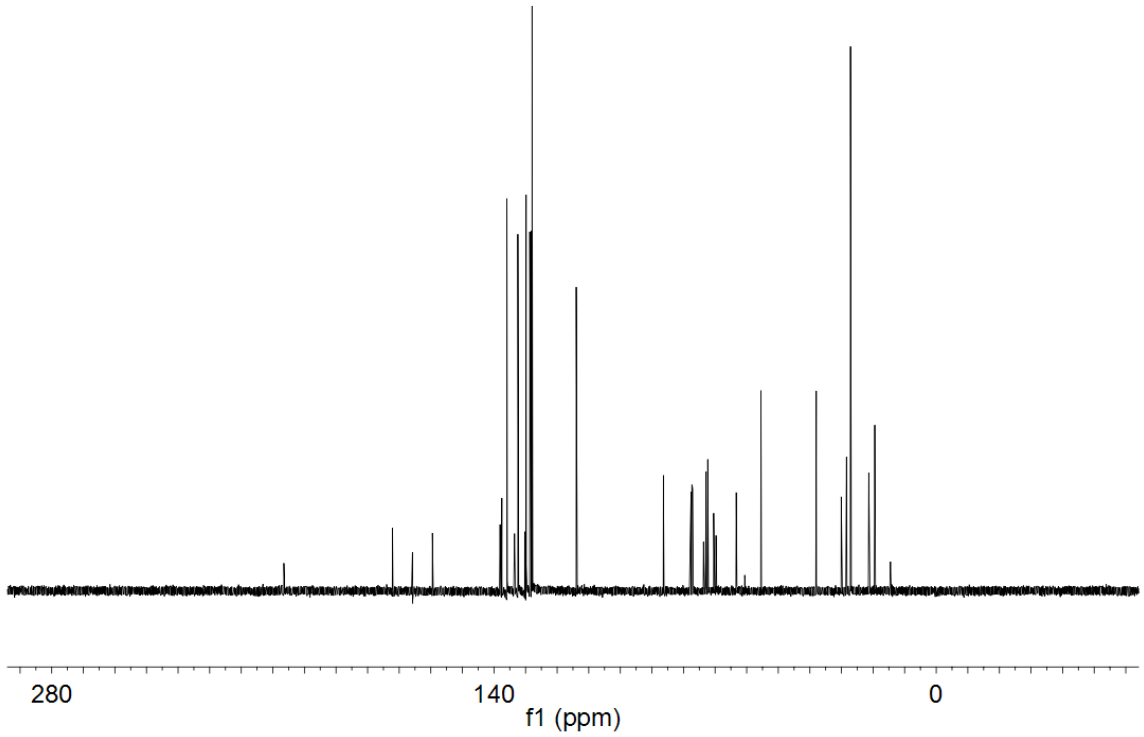
^{1}H-NMR ($CDCl_3$, 500 MHz) of **14**



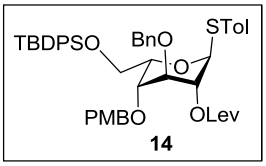


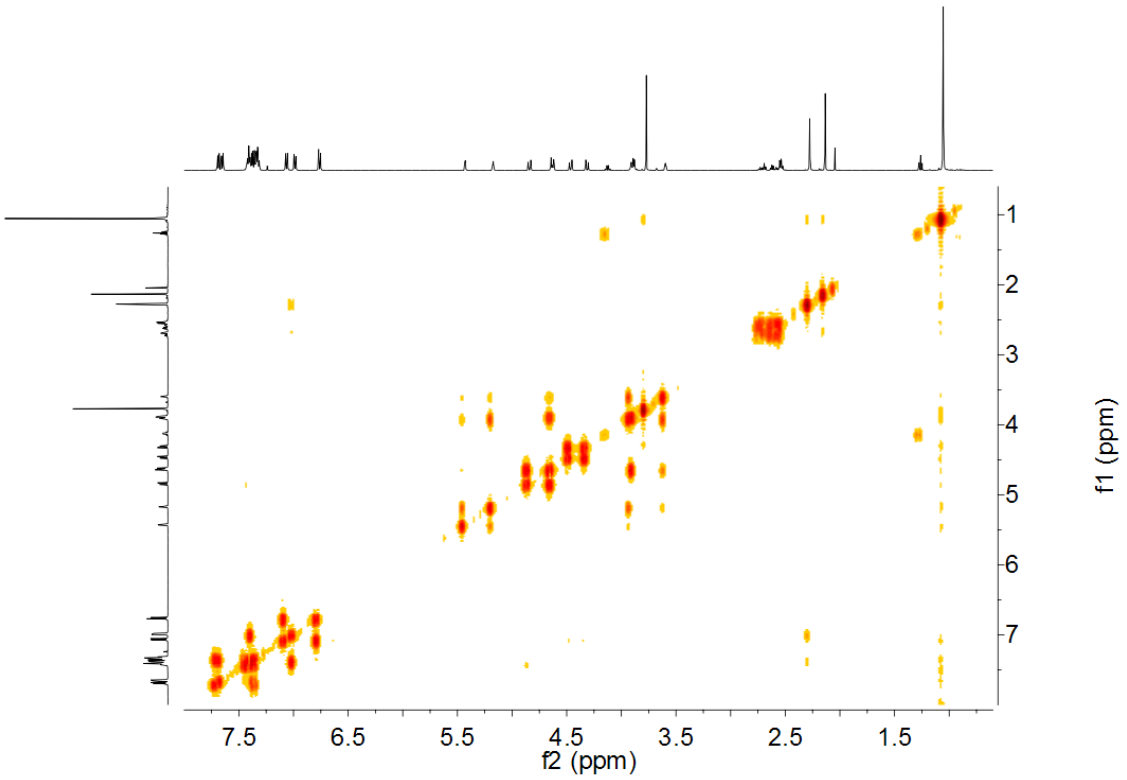
^{13}C-NMR ($CDCl_3$, 125 MHz) of **14**



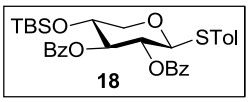


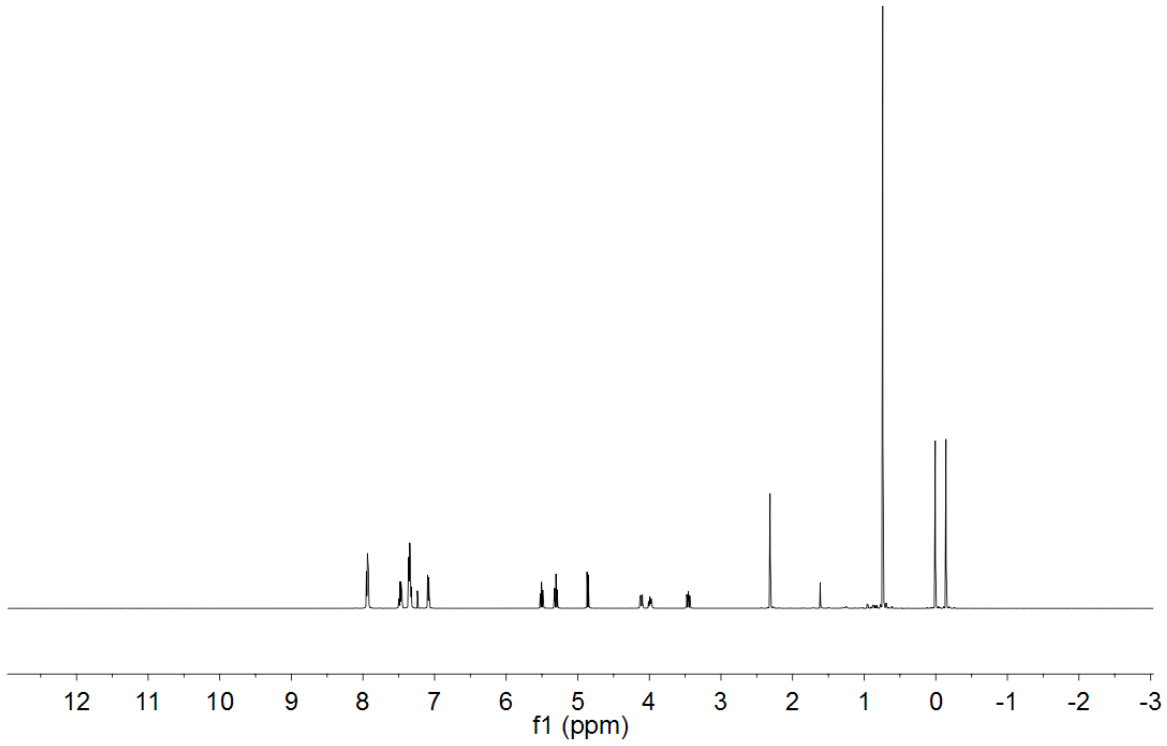
gCOSY ($CDCl_3$, 500 MHz) of **14**



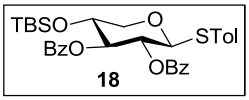


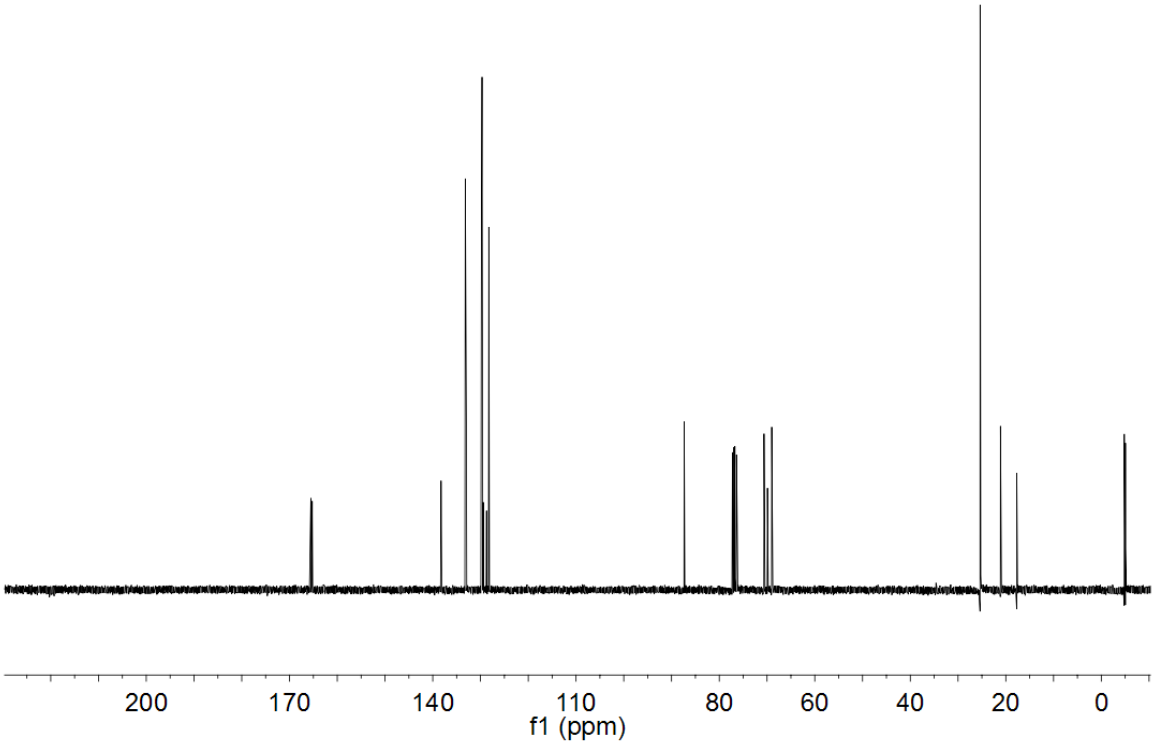
^{1}H-NMR ($CDCl_3$, 500 MHz) of **18**



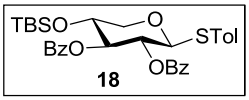


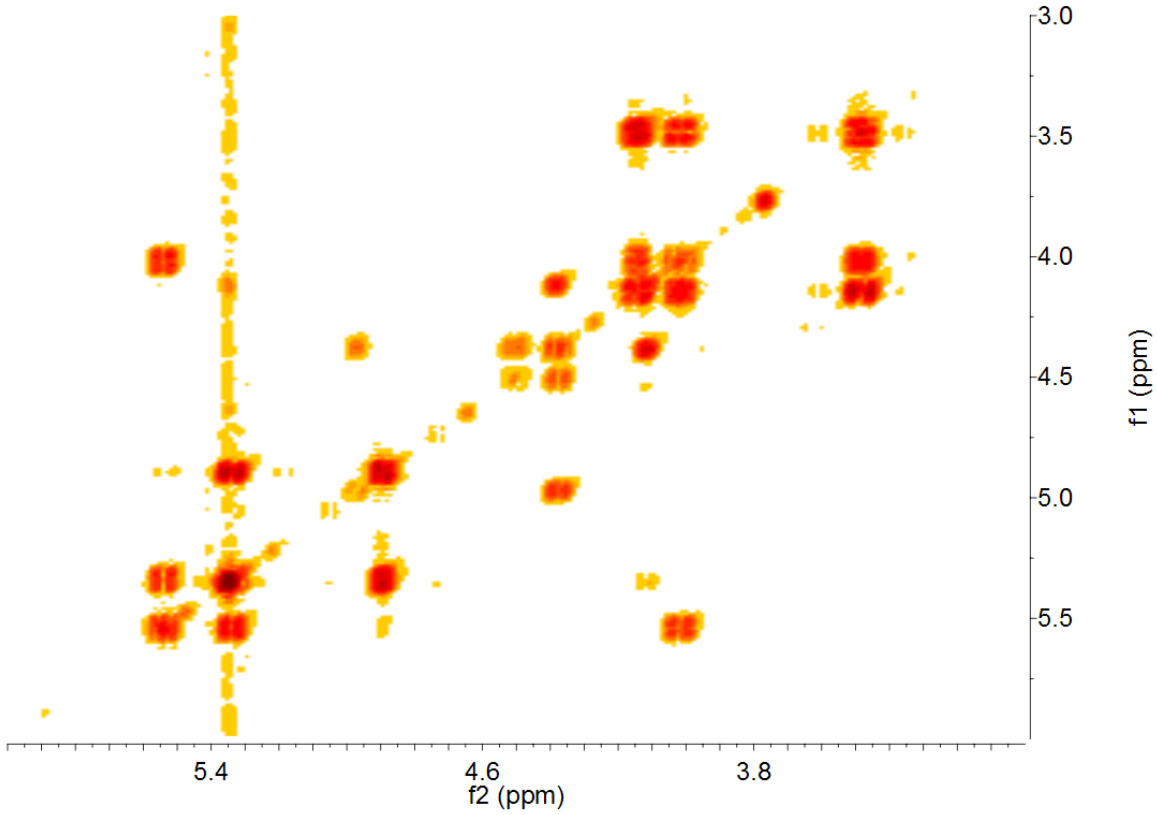
^{13}C-NMR ($CDCl_3$, 125 MHz) of **18**



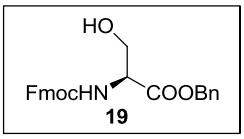


gCOSY ($CDCl_3$, 500 MHz) of **18**





^{1}H-NMR ($CDCl_3$, 500 MHz) of **19**



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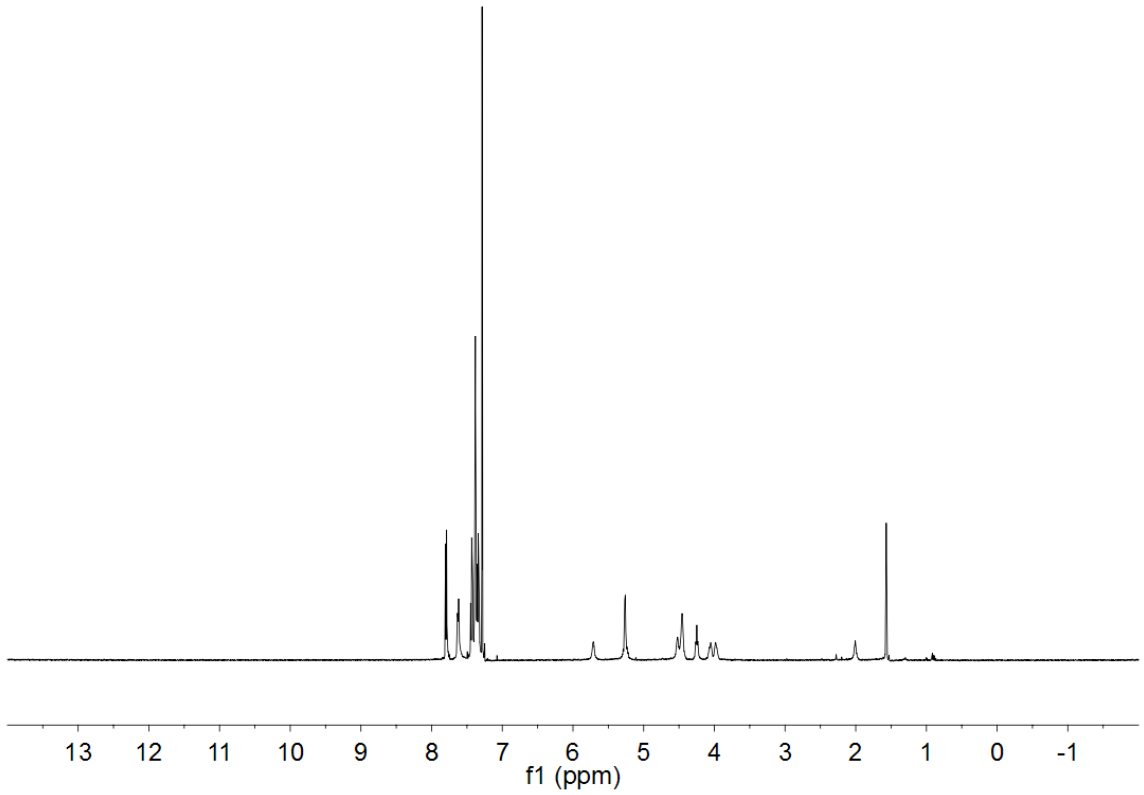
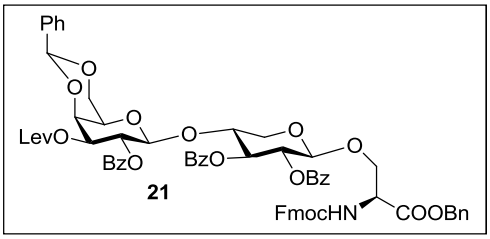
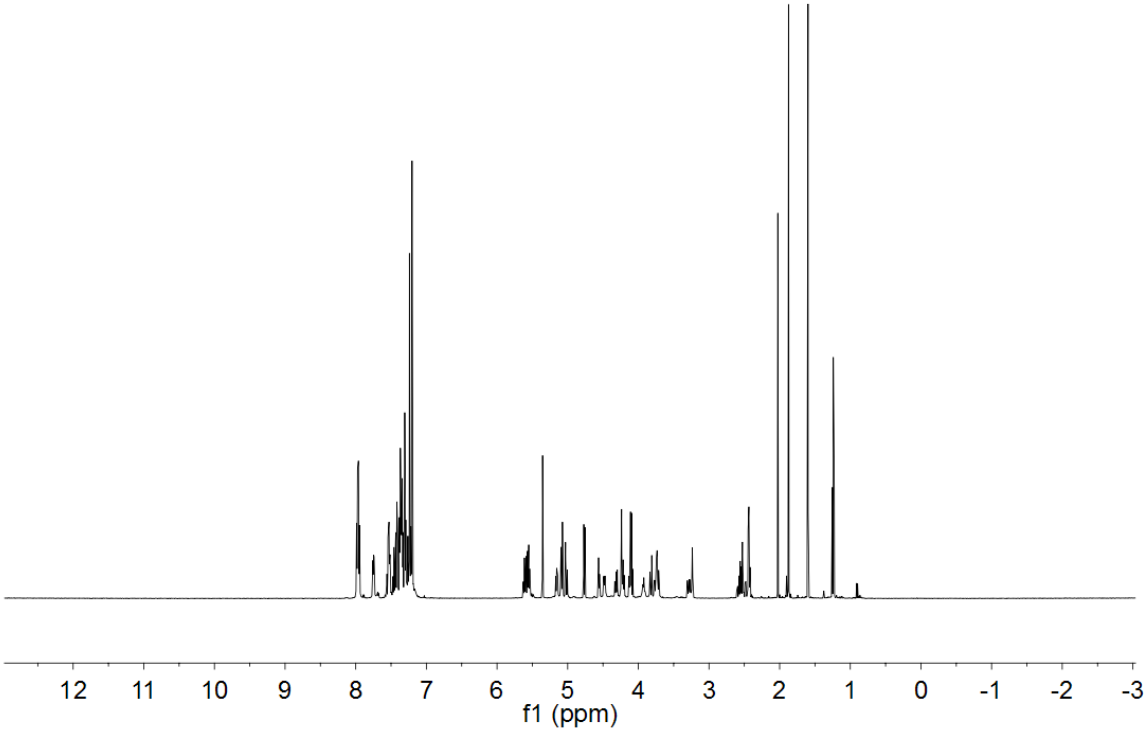
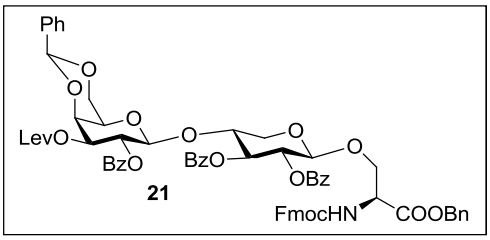


^{1}H-NMR ($CDCl_3$, 500 MHz) of **21**





^{13}C-NMR ($CDCl_3$, 150 MHz) of **21**



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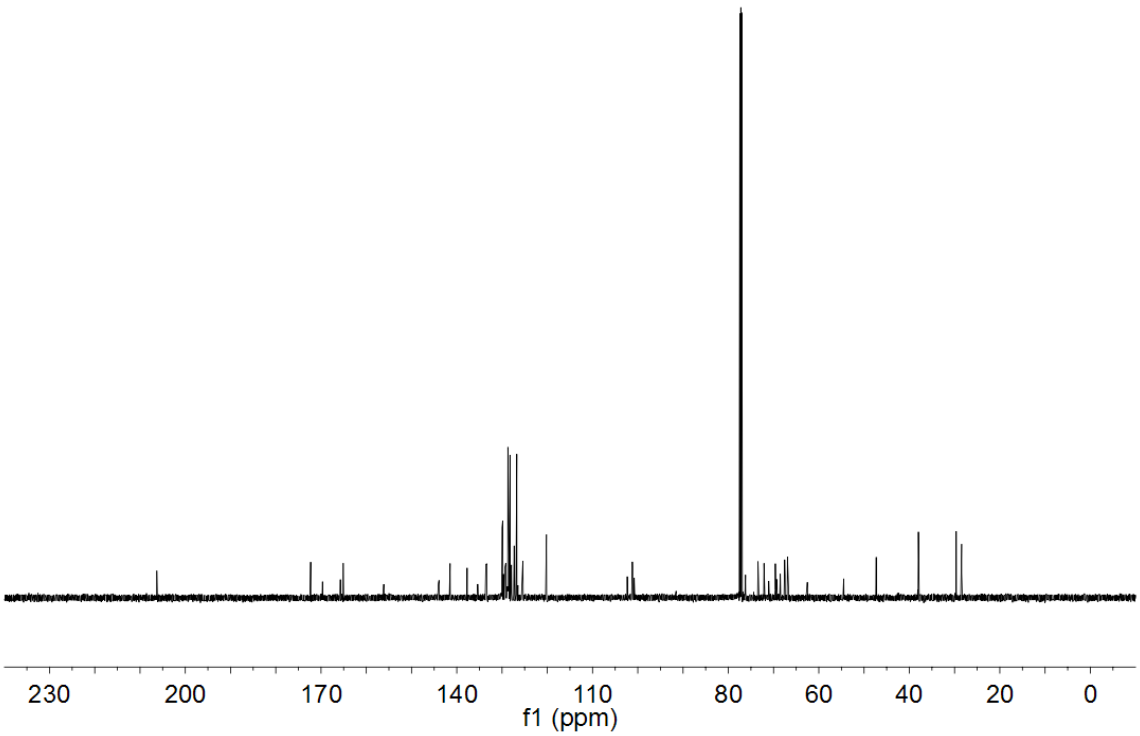
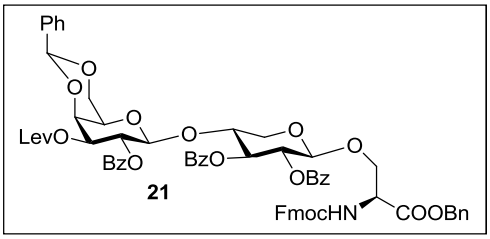


gCOSY ($CDCl_3$, 600 MHz) of **21**



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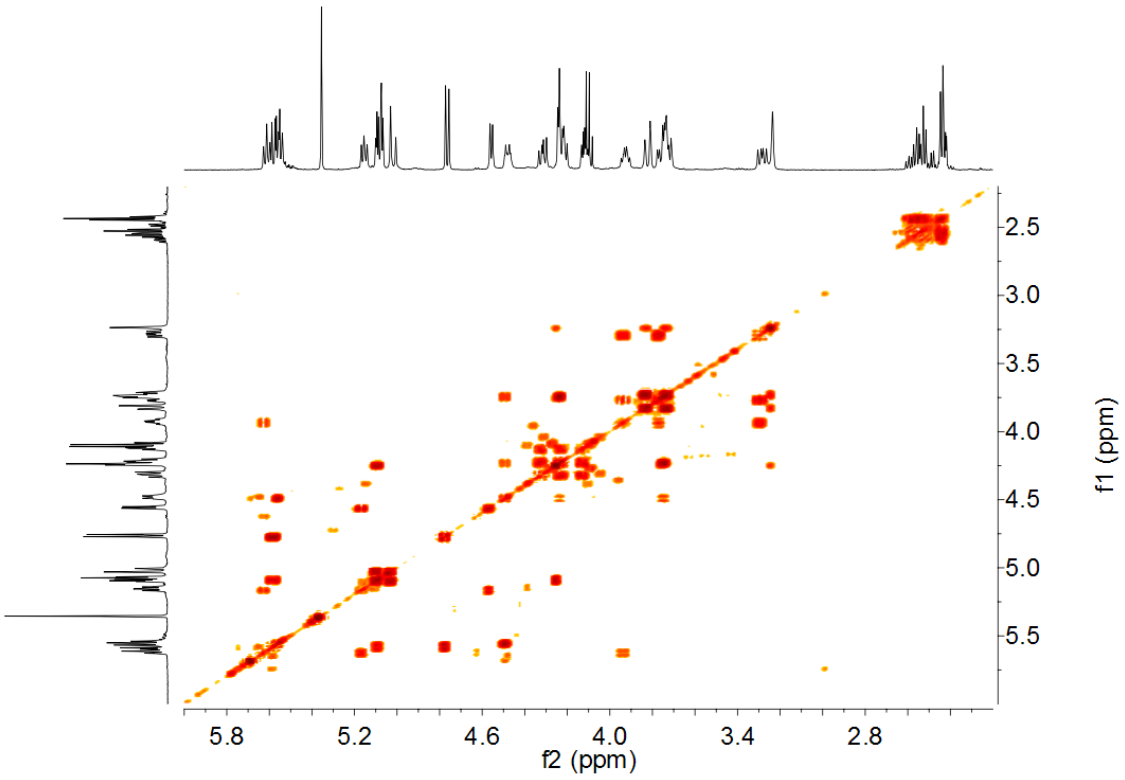
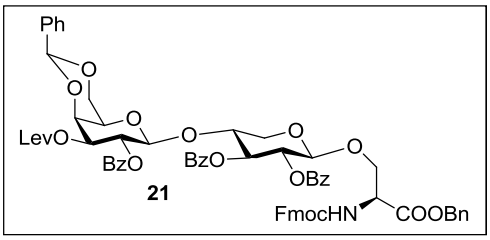
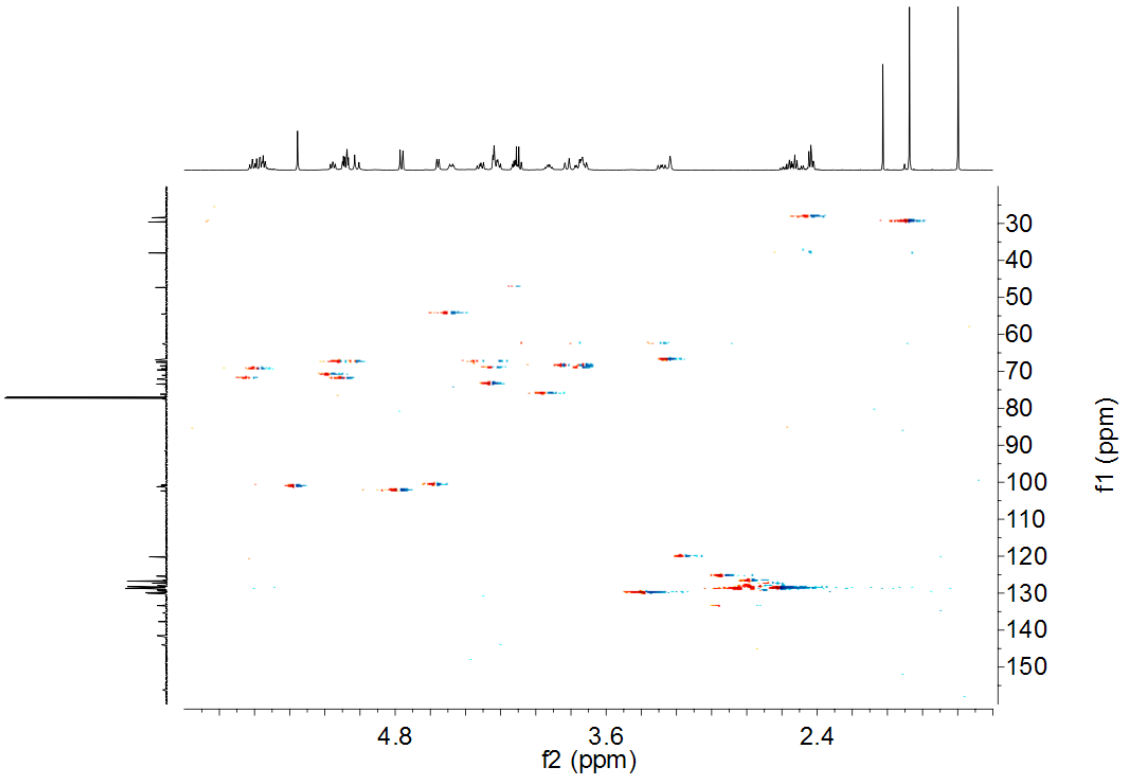


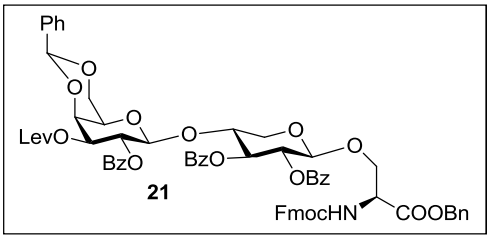
gHMQC ($CDCl_3$, 600 MHz) of **21**



21



gHMQC (without ^{1}H decoupling) ($CDCl_3$, 600 MHz) of **21**



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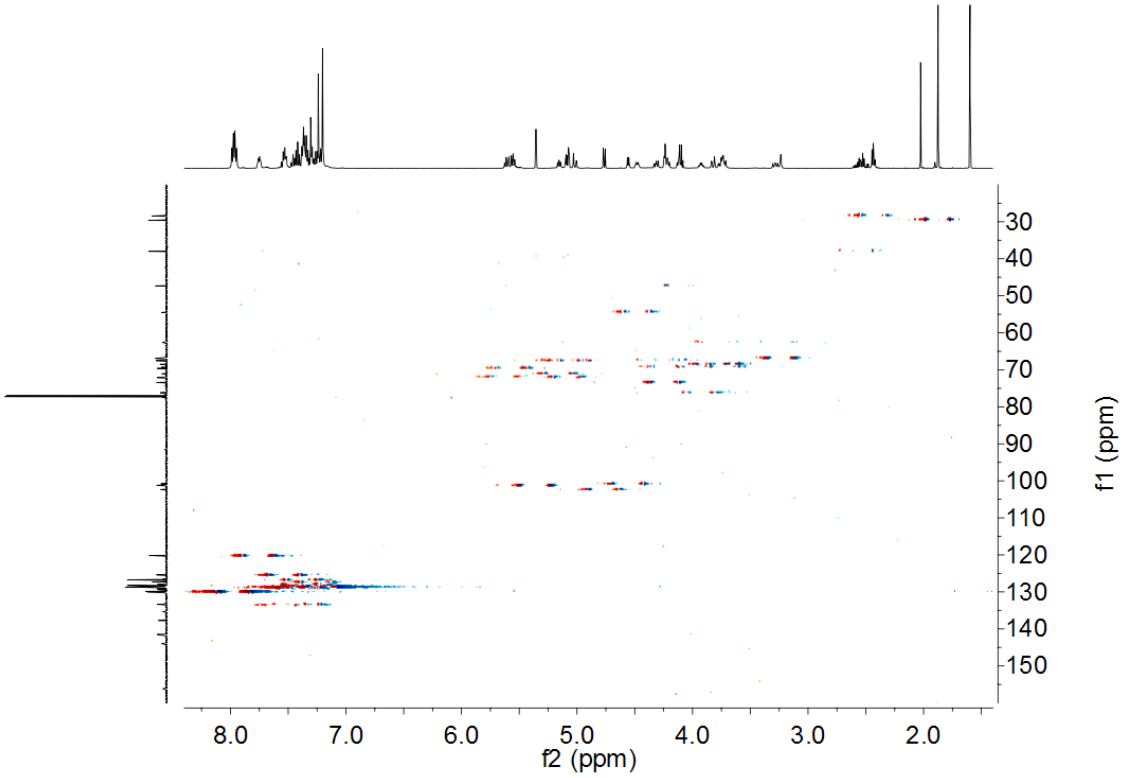
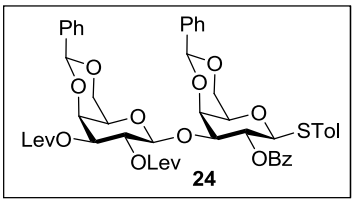
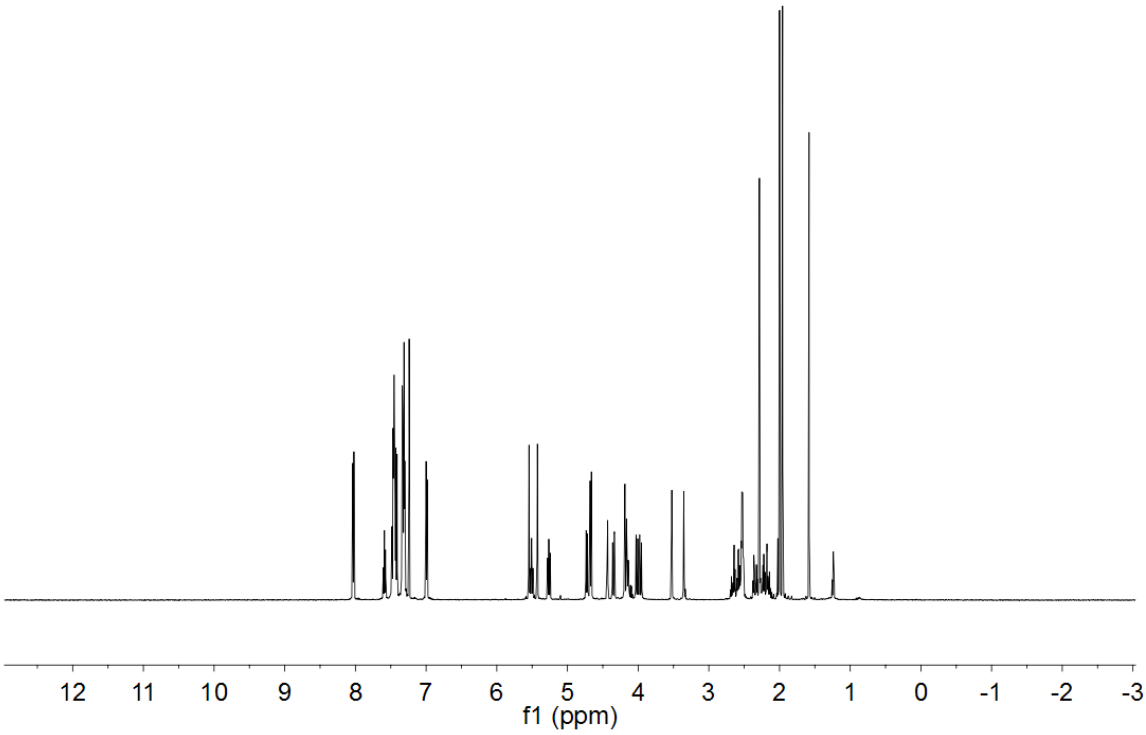
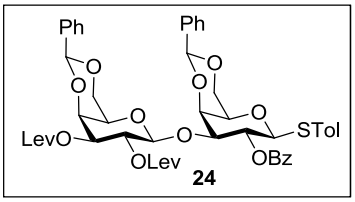


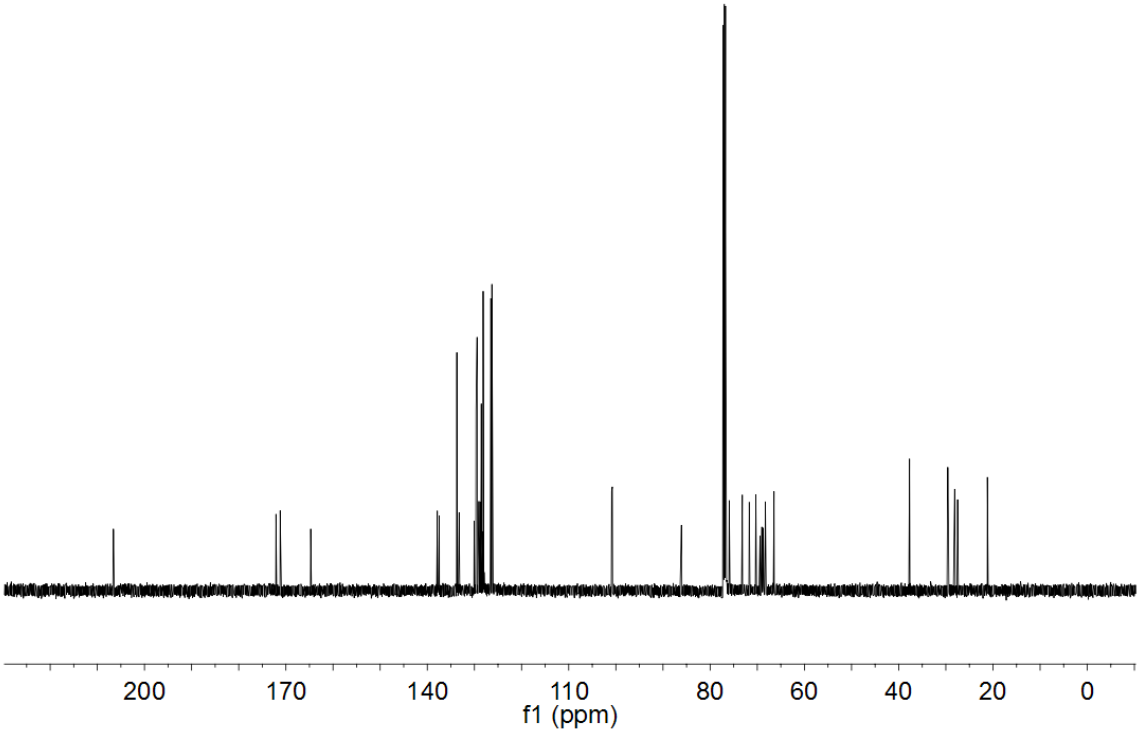
^{1}H-NMR ($CDCl_3$, 500 MHz) of **24**



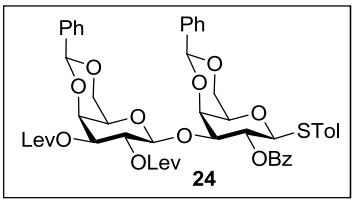


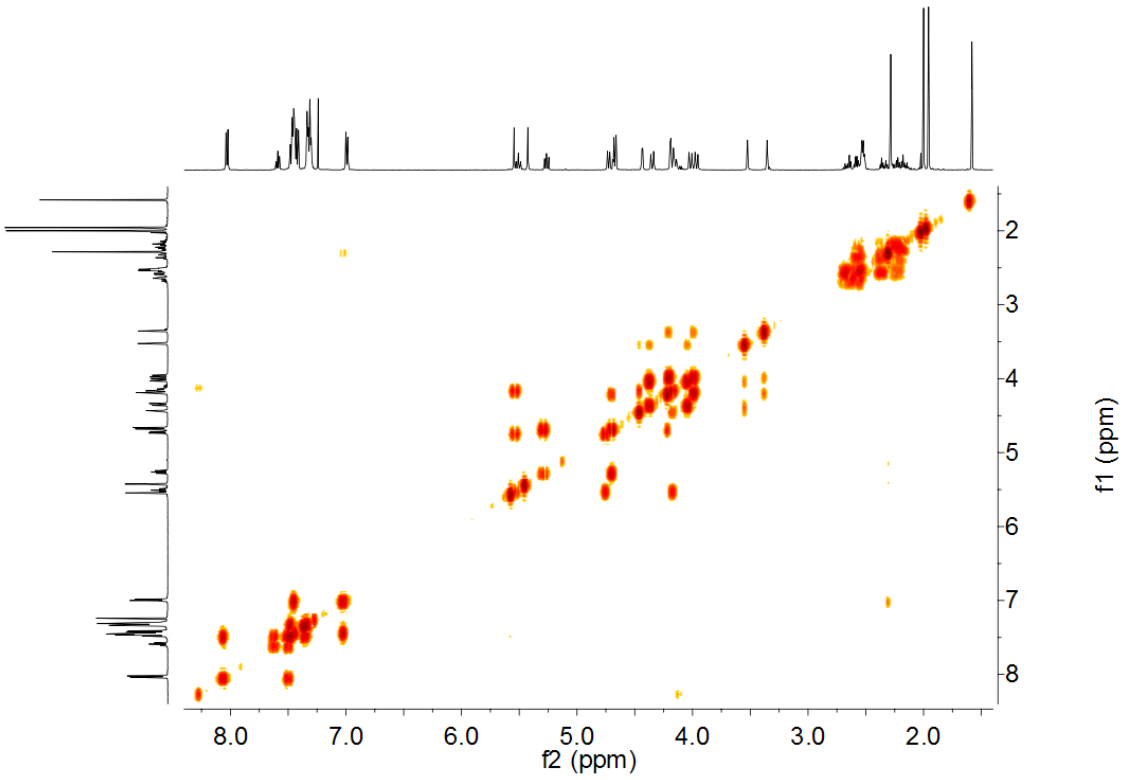
^{13}C-NMR ($CDCl_3$, 125 MHz) of **24**



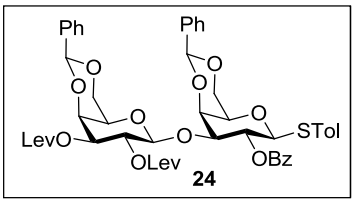


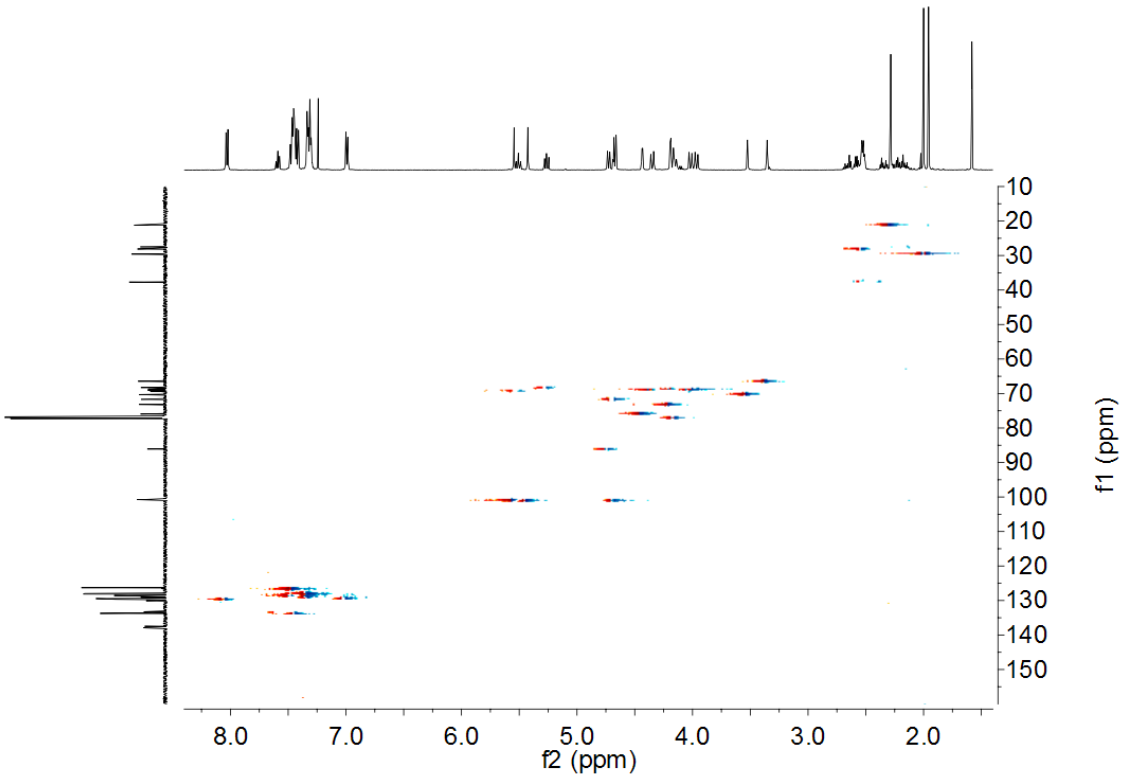
gCOSY ($CDCl_3$, 500 MHz) of **24**



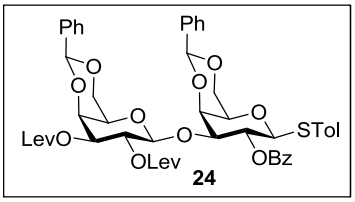


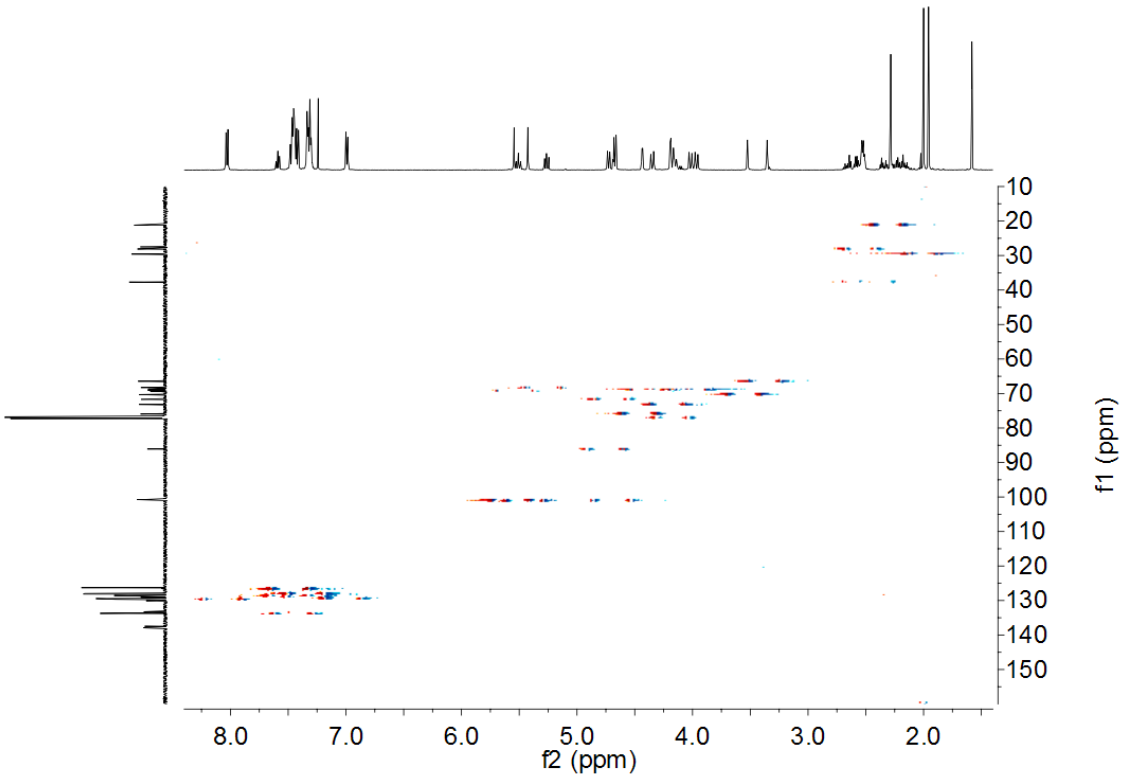
gHMQC ($CDCl_3$, 500 MHz) of **24**



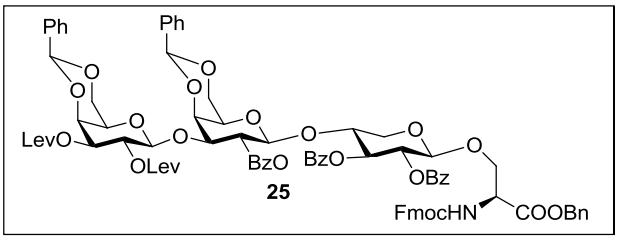


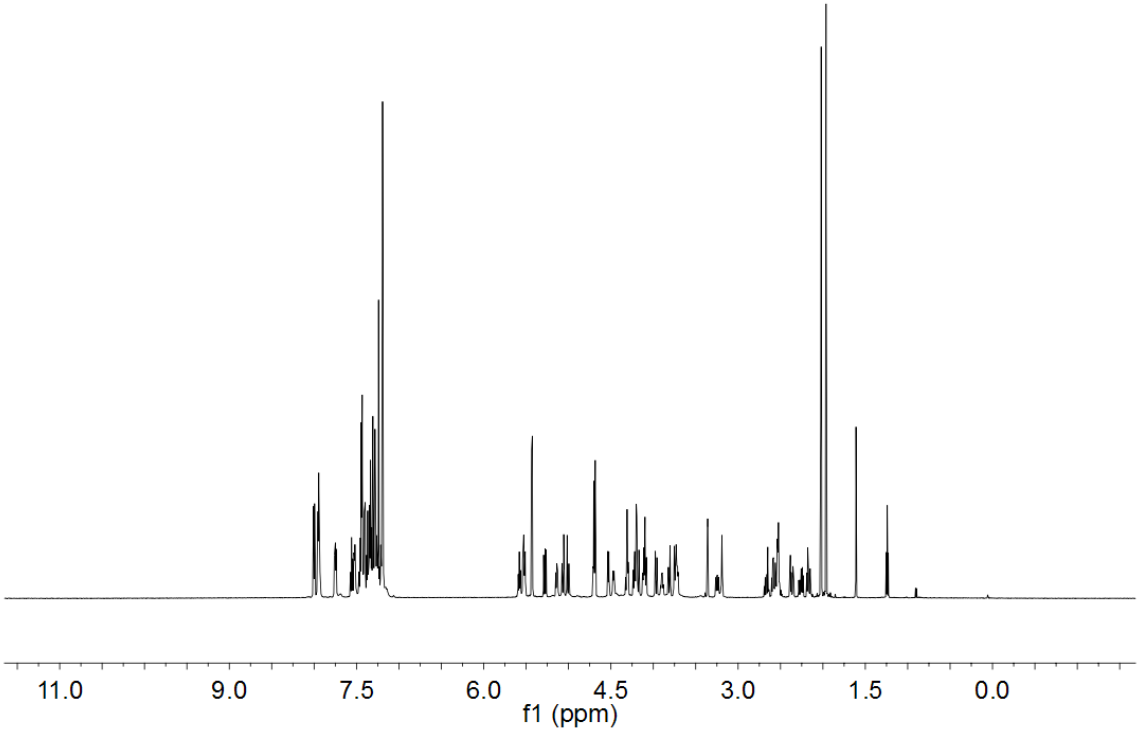
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 500 MHz) of **24**



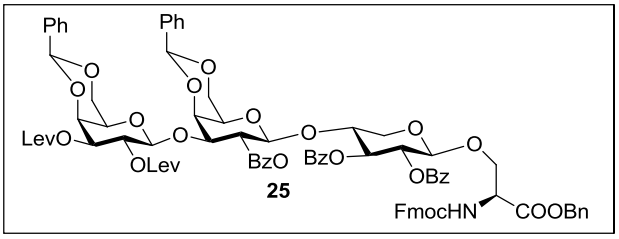


^{1}H-NMR ($CDCl_3$, 600 MHz) of **25**

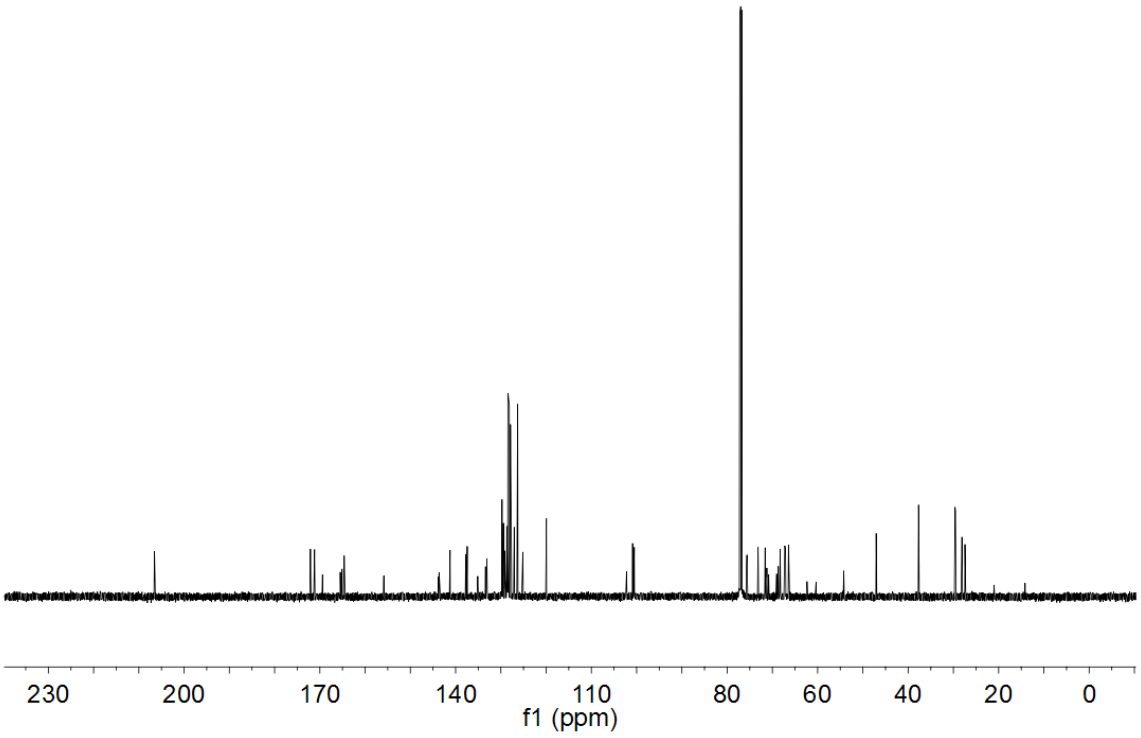




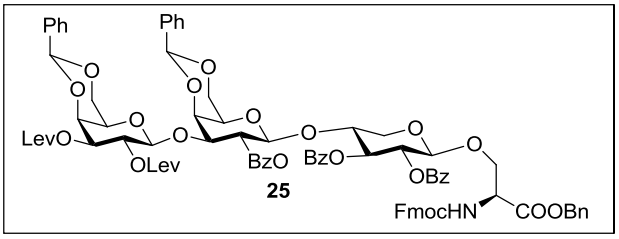
^{13}C-NMR ($CDCl_3$, 150 MHz) of **25**

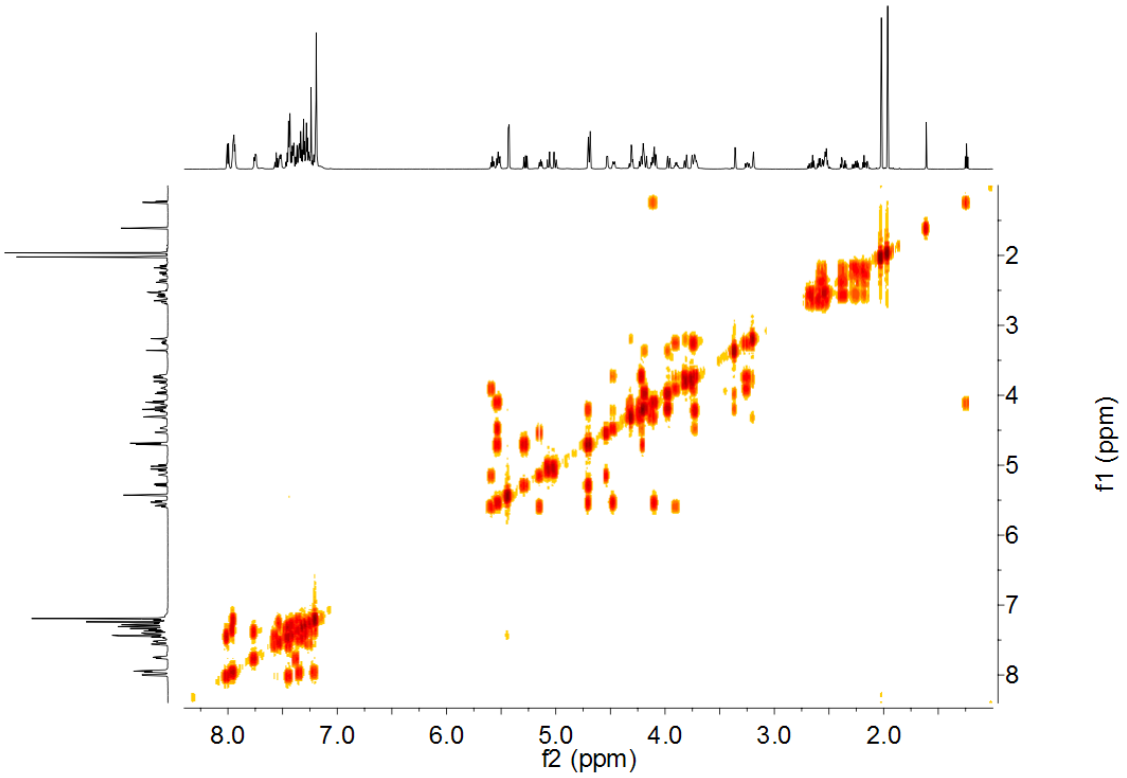


25

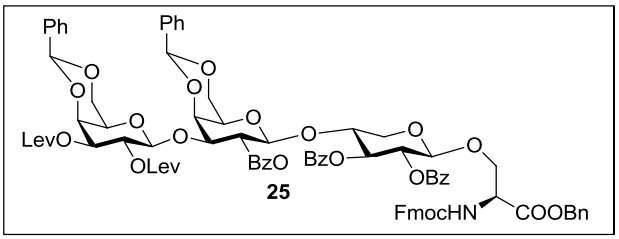


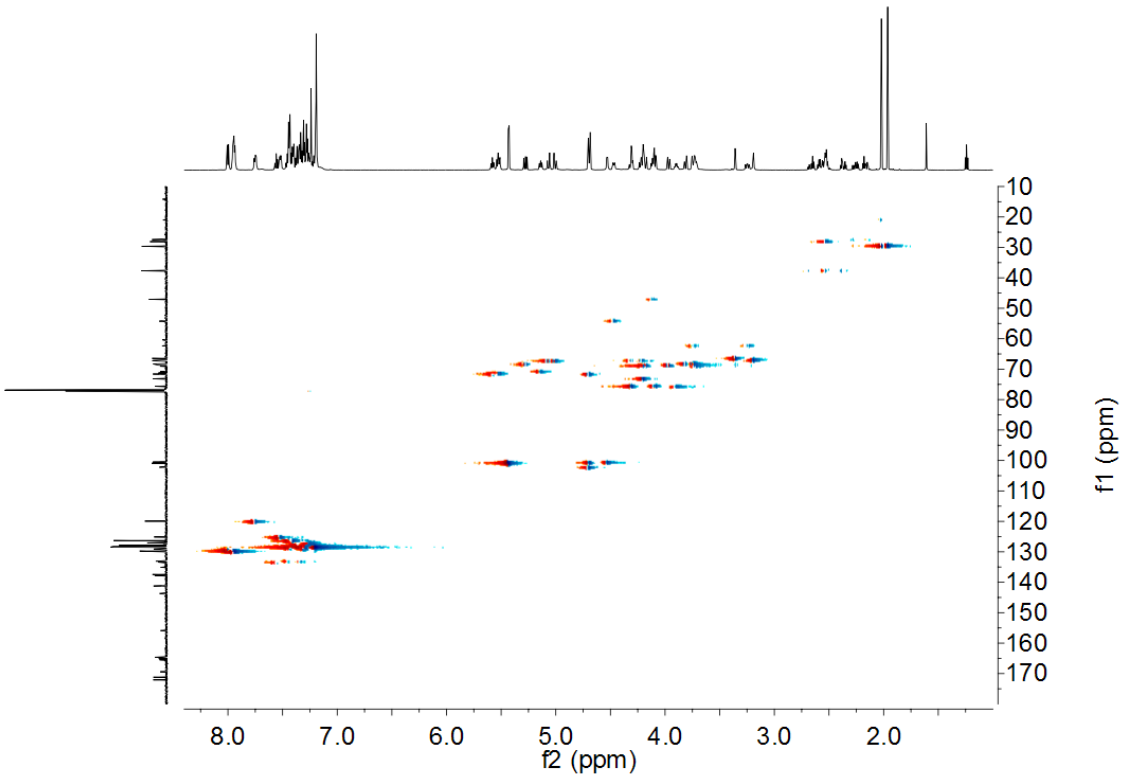
gCOSY ($CDCl_3$, 600 MHz) of **25**



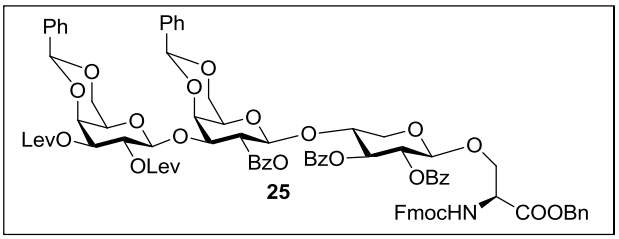


gHMQC ($CDCl_3$, 600 MHz) of **25**





gHMQC (without ^{1}H decoupling) ($CDCl_3$, 600 MHz) of **25**



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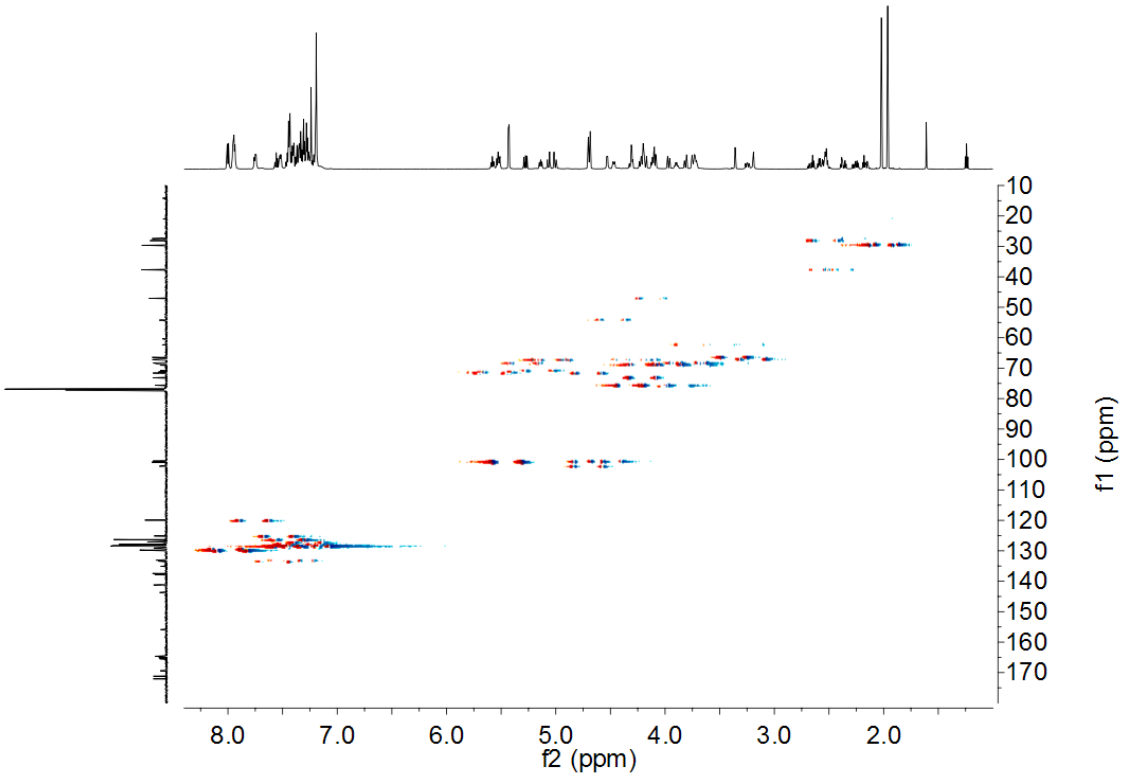
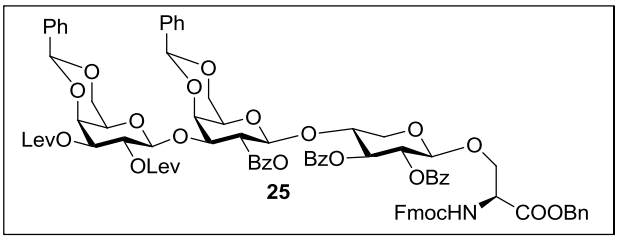
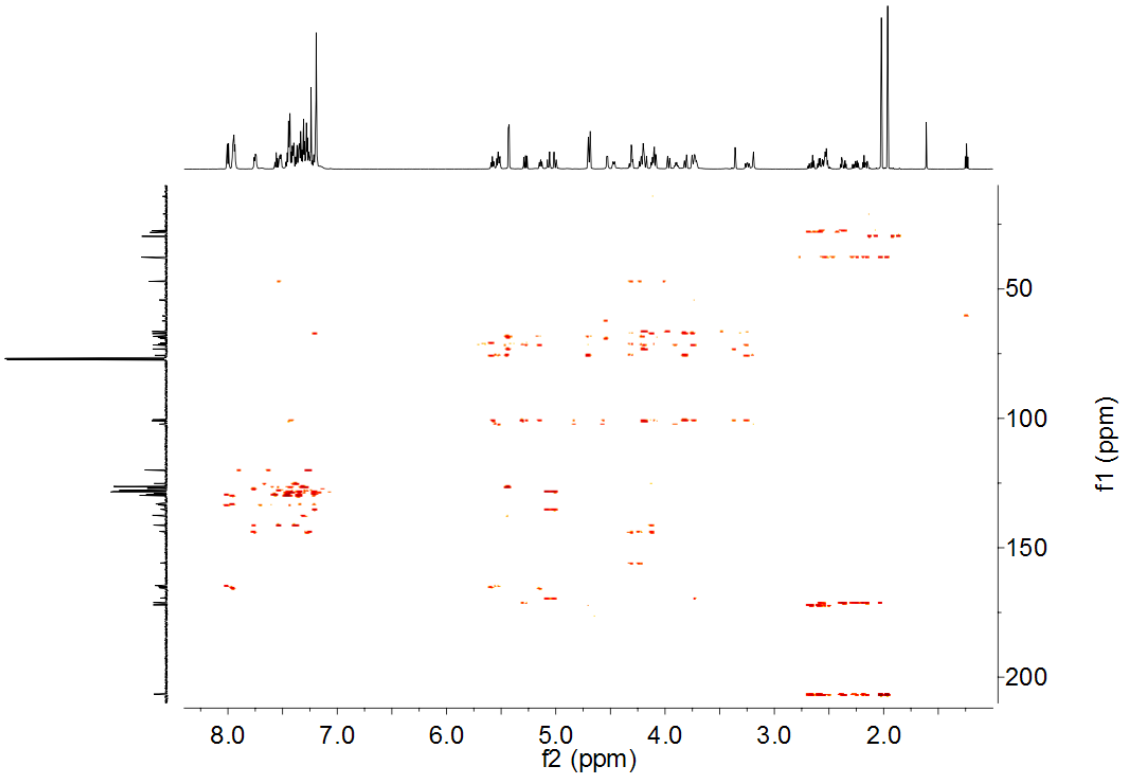
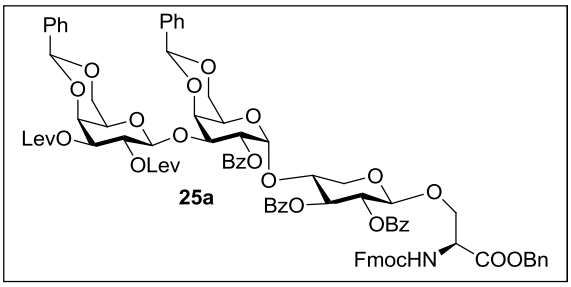


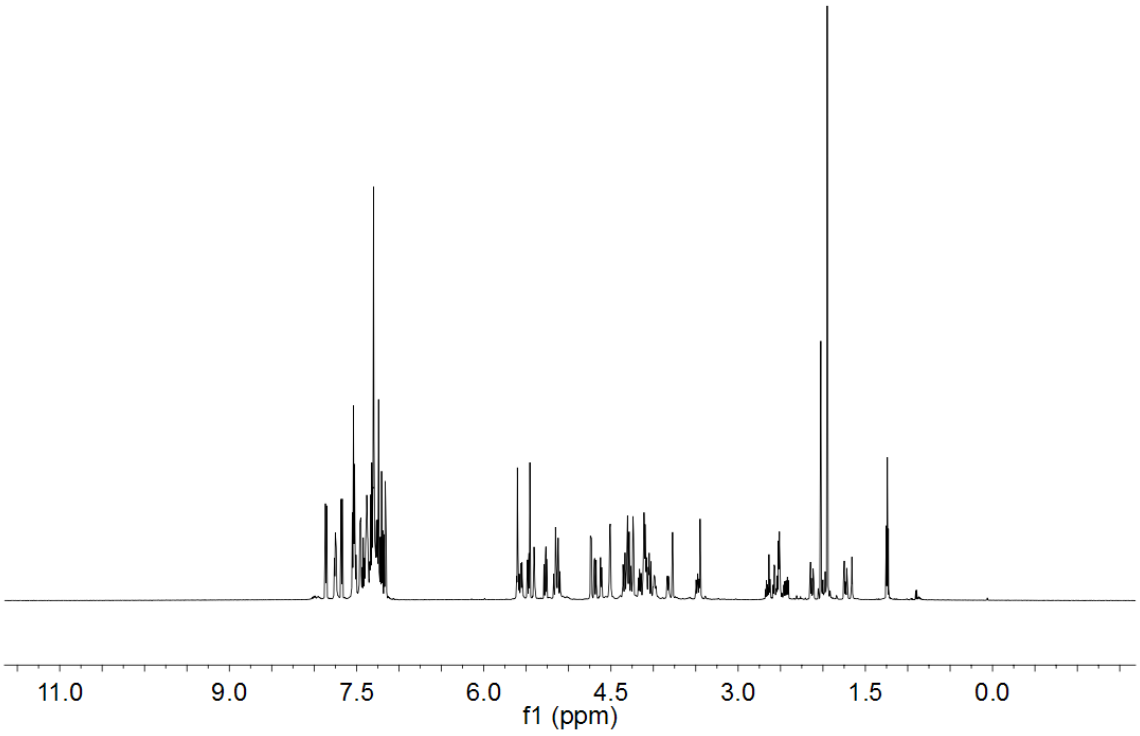
gHMBC ($CDCl_3$, 600 MHz) of **25**



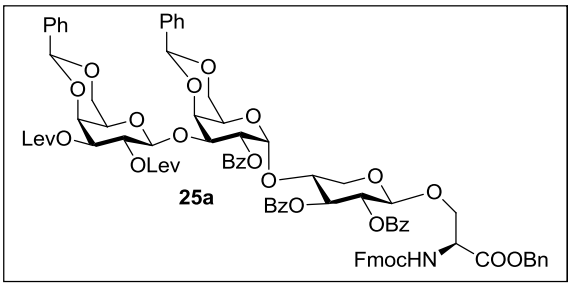


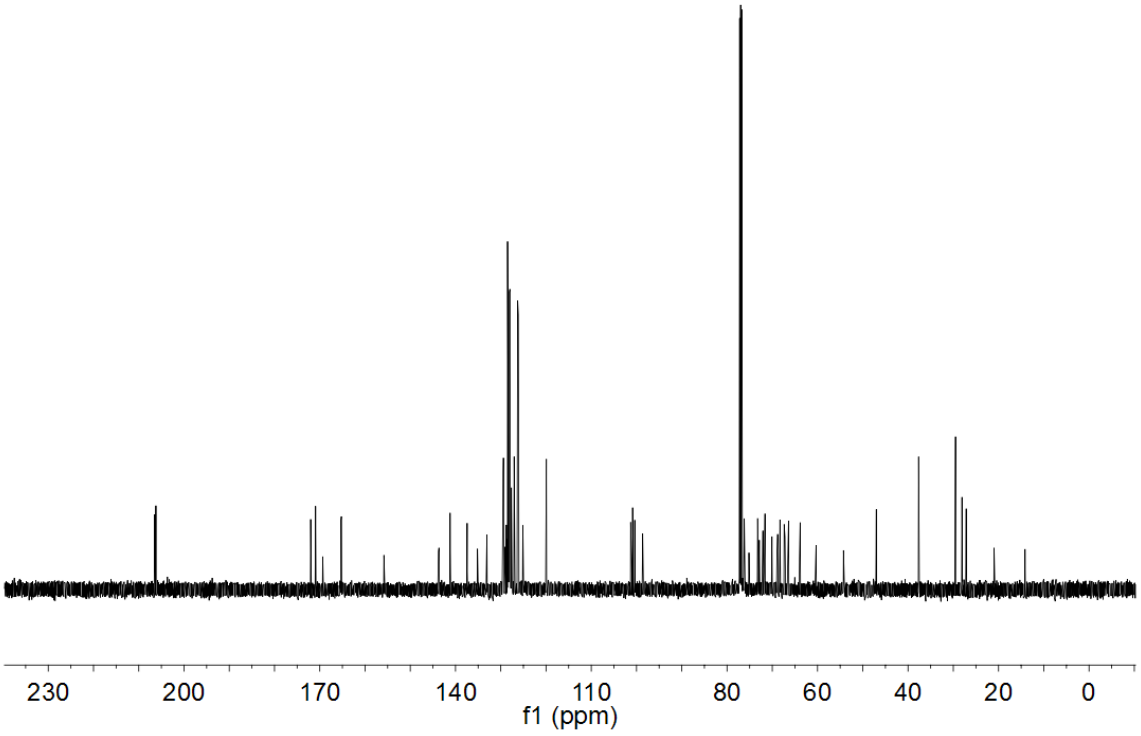
^{1}H-NMR ($CDCl_3$, 600 MHz) of **25a**



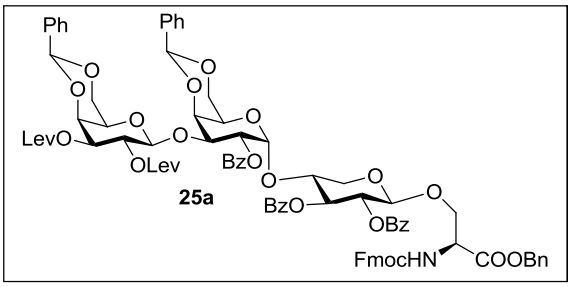


^{13}C-NMR ($CDCl_3$, 150 MHz) of **25a**

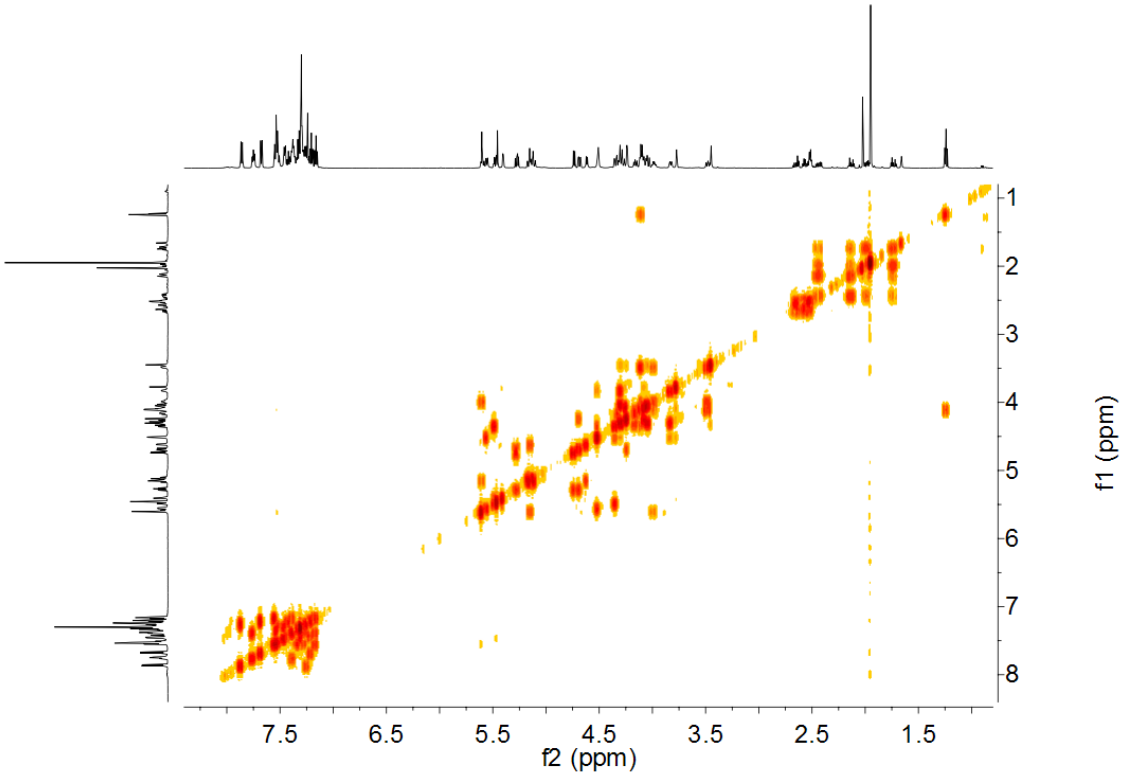




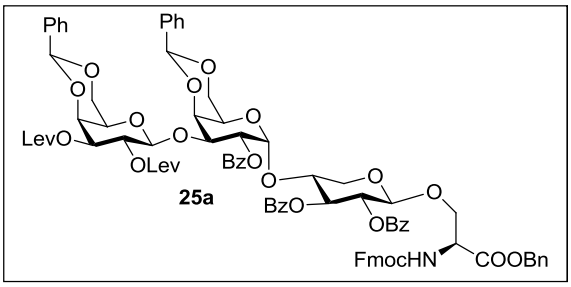
gCOSY ($CDCl_3$, 600 MHz) of **25a**



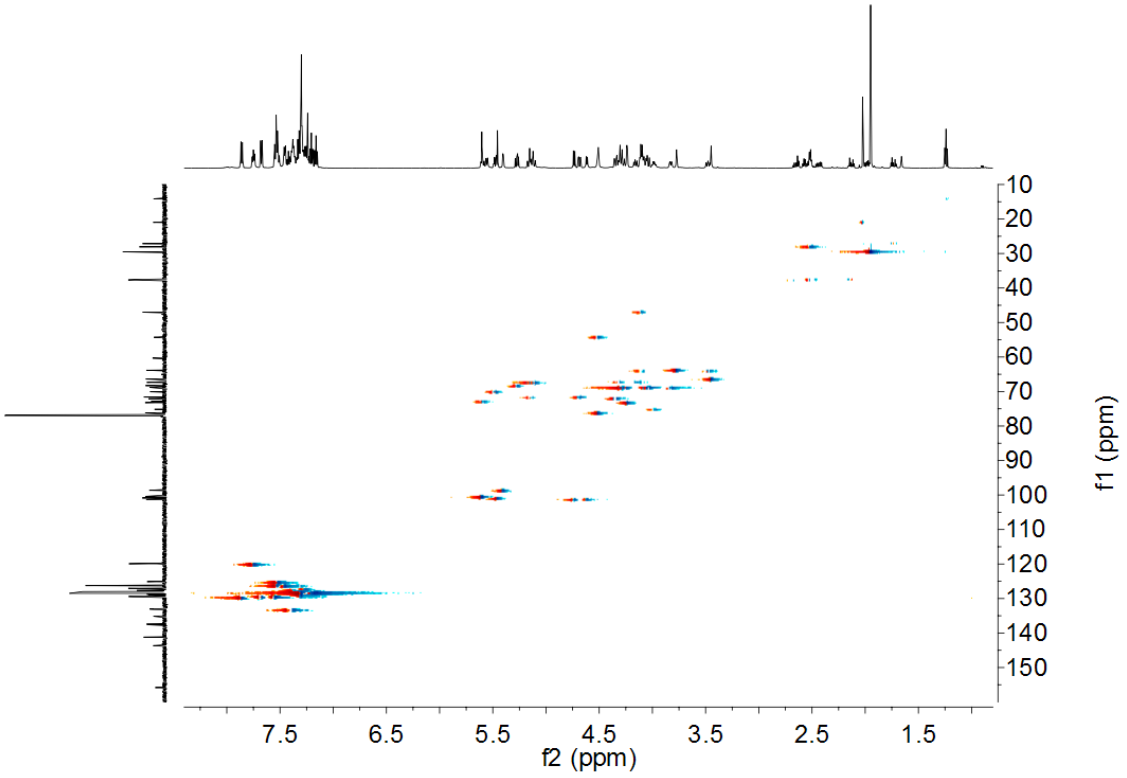
25a



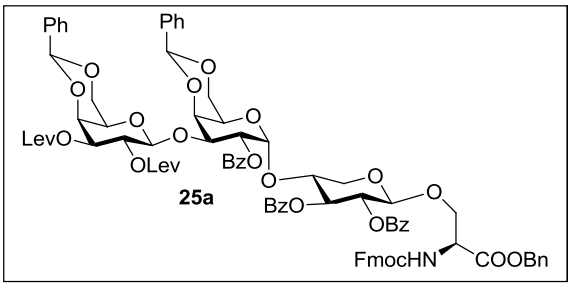
gHMQC ($CDCl_3$, 600 MHz) of **25a**



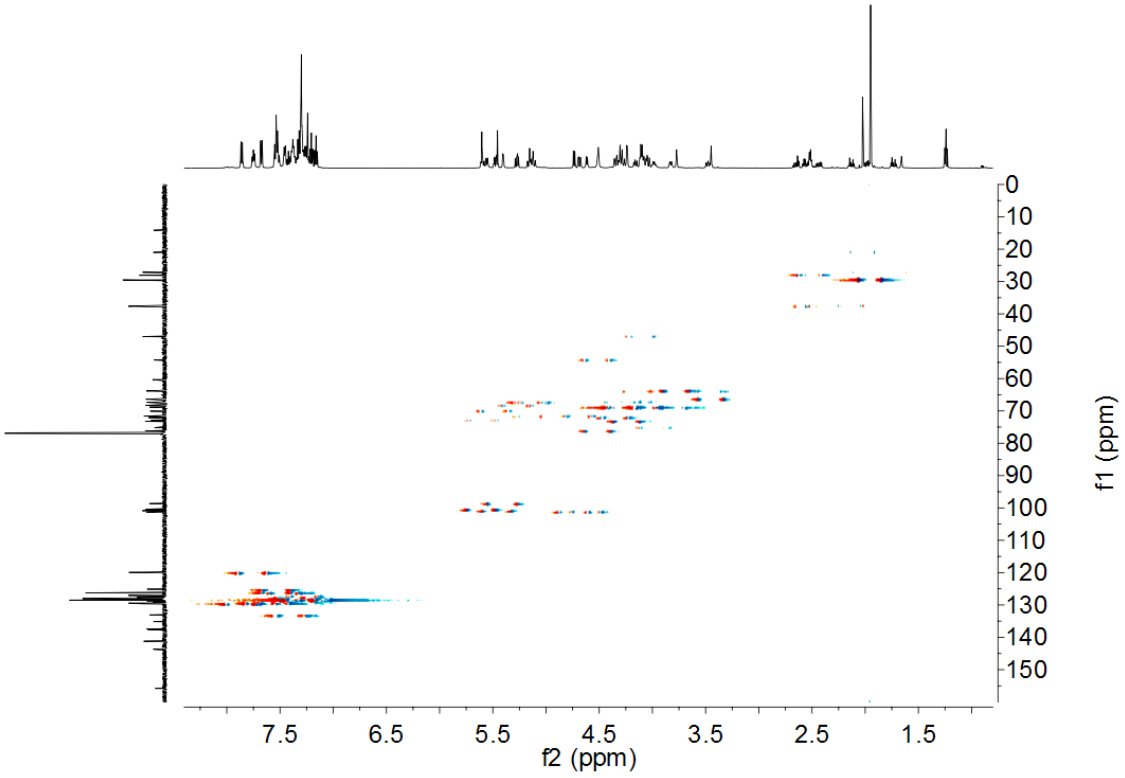
25a



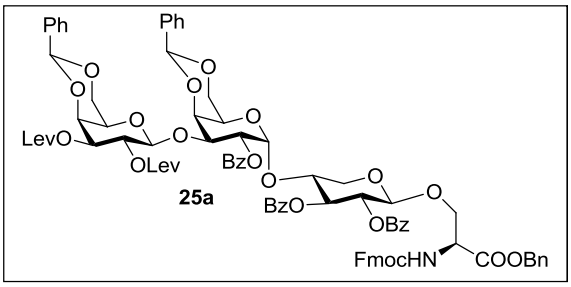
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 600 MHz) of **25a**

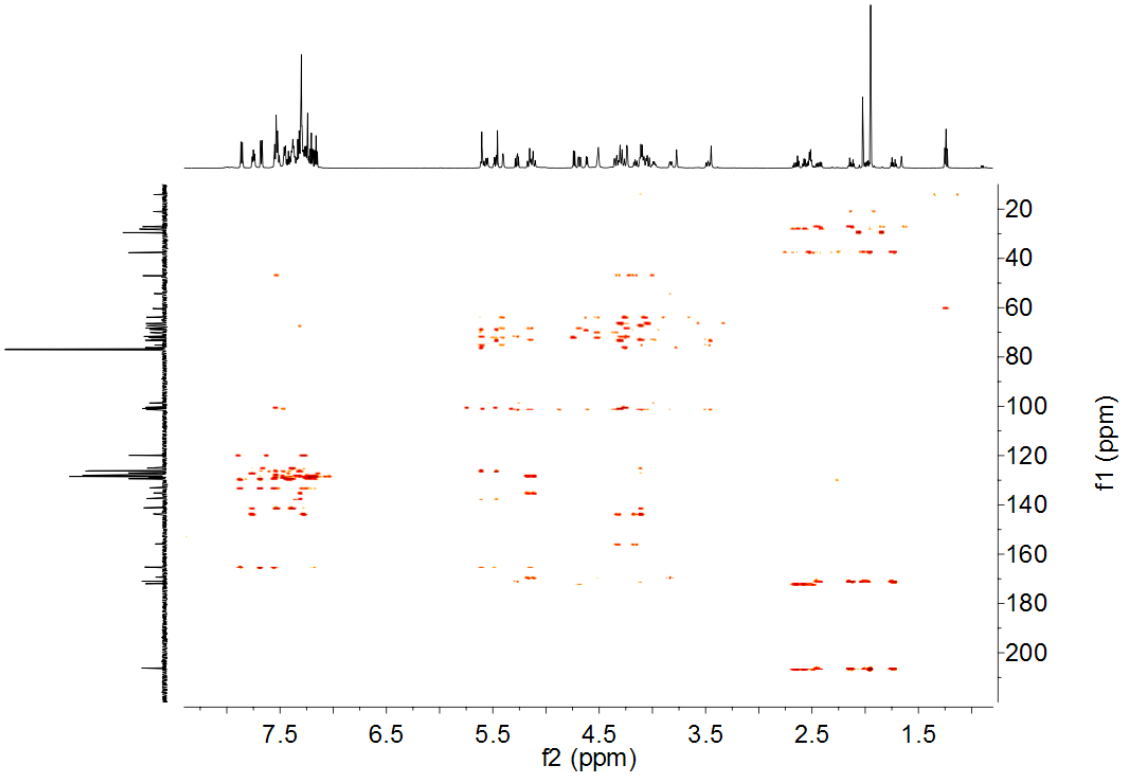


25a

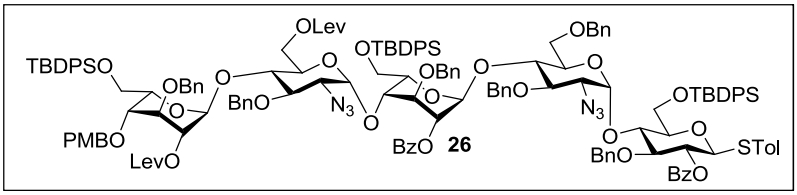


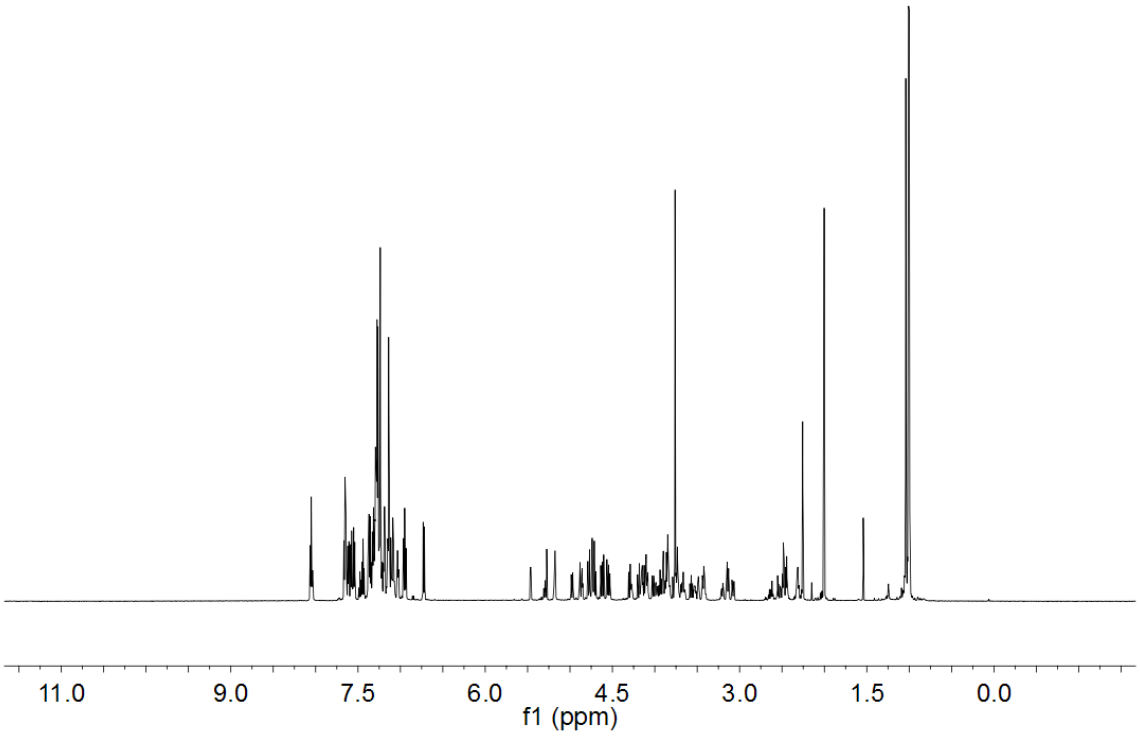
gHMBC ($CDCl_3$, 600 MHz) of **25a**



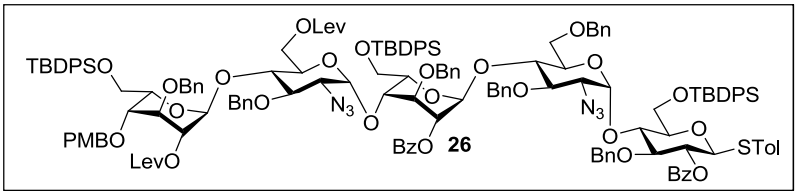


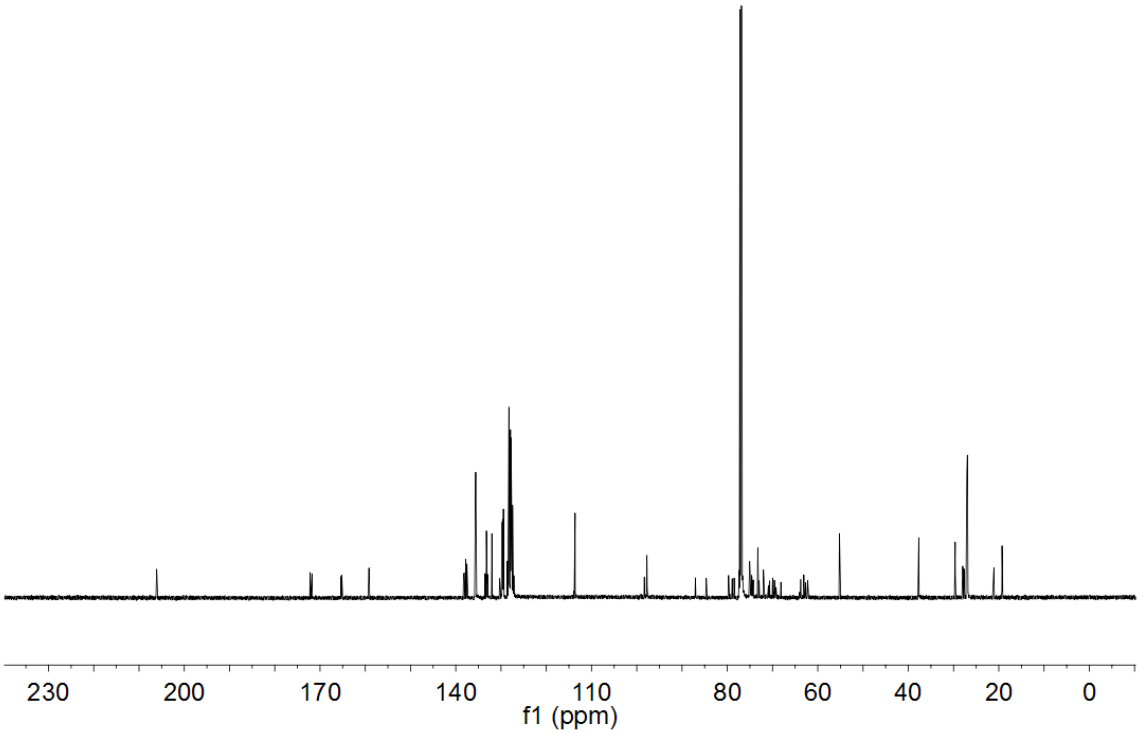
^{1}H-NMR ($CDCl_3$, 600 MHz) of **26**



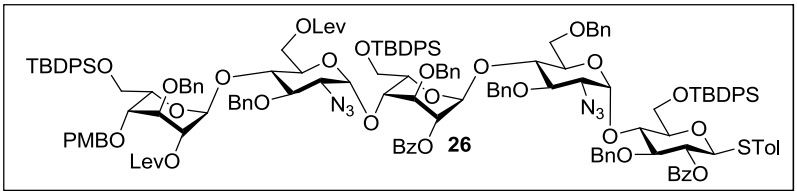


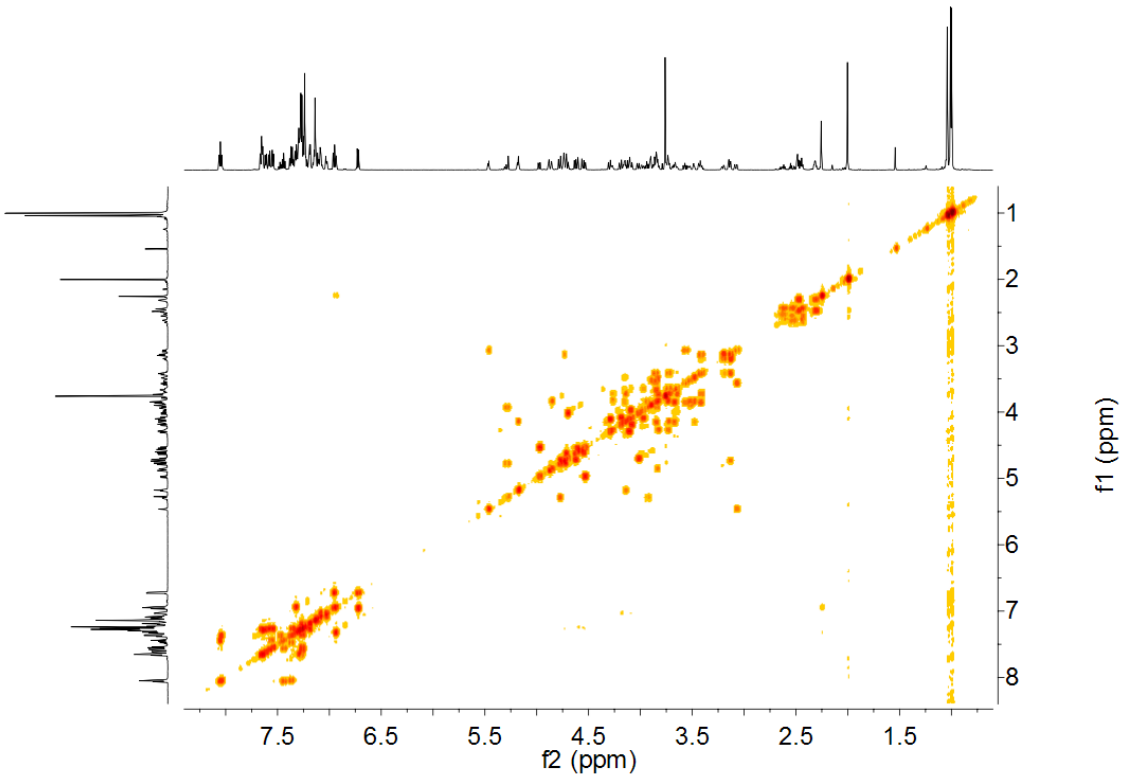
^{13}C-NMR ($CDCl_3$, 150 MHz) of **26**



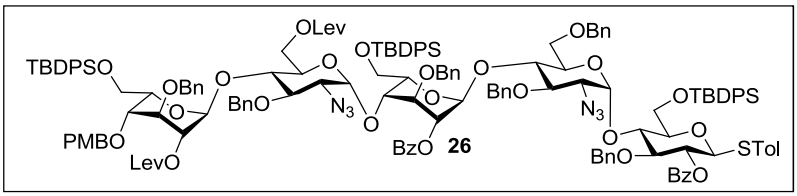


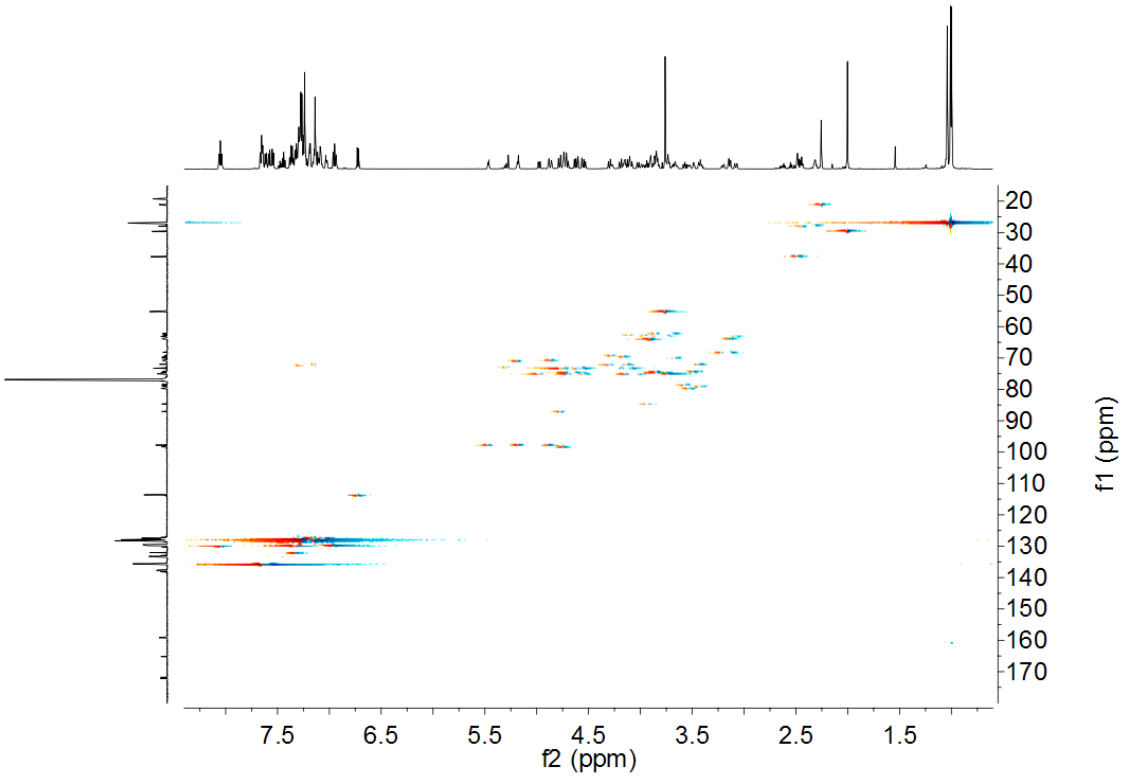
gCOSY ($CDCl_3$, 600 MHz) of **26**



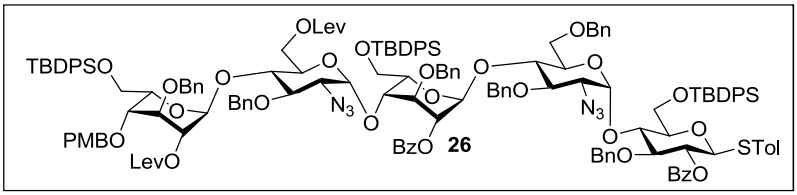


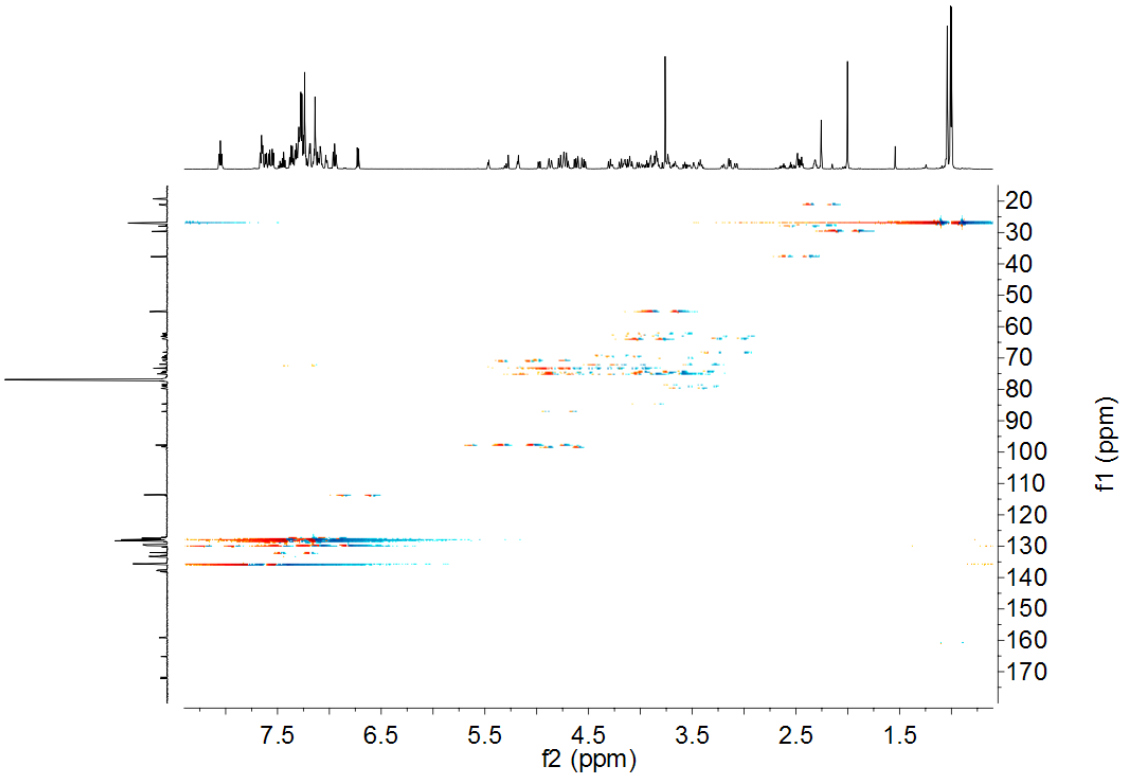
gHMQC ($CDCl_3$, 600 MHz) of **26**



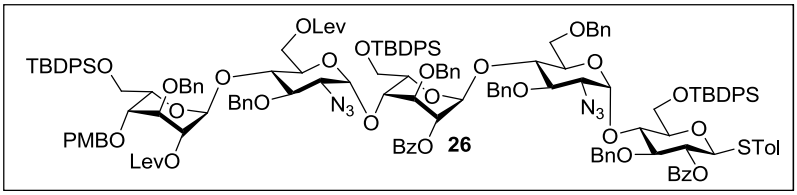


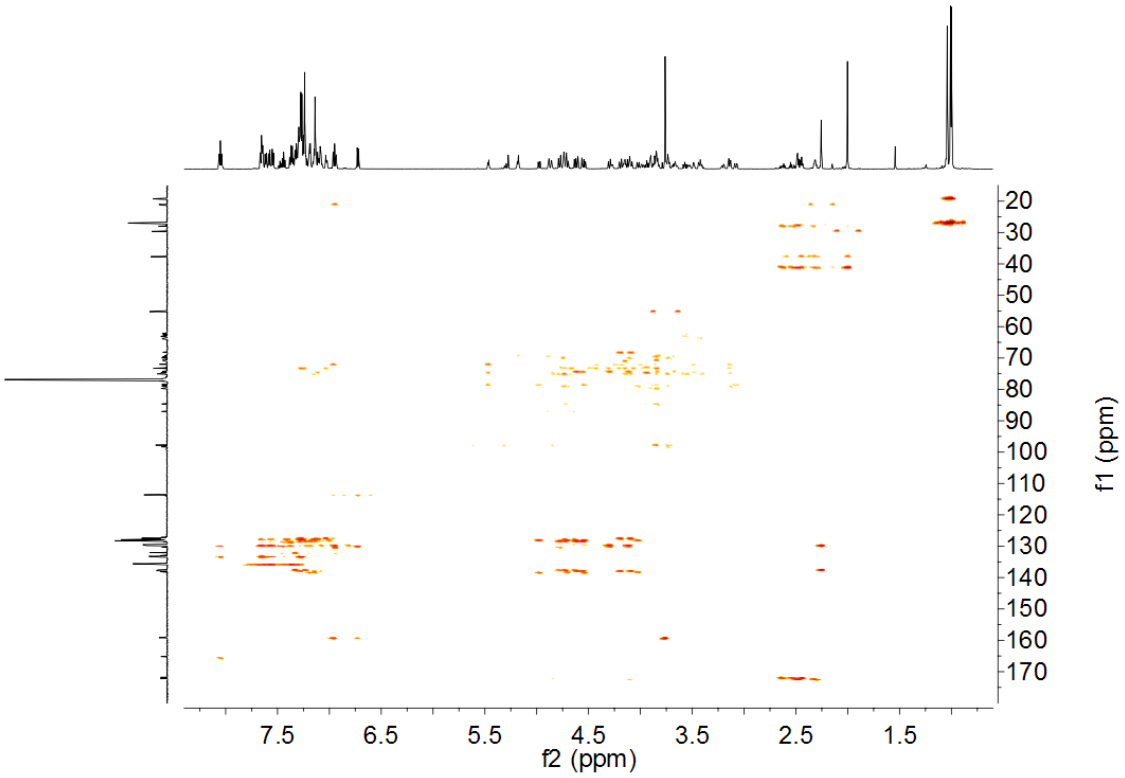
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 600 MHz) of **26**



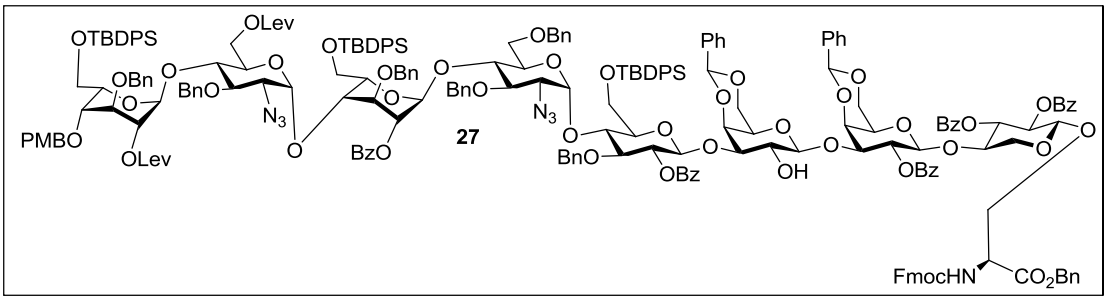


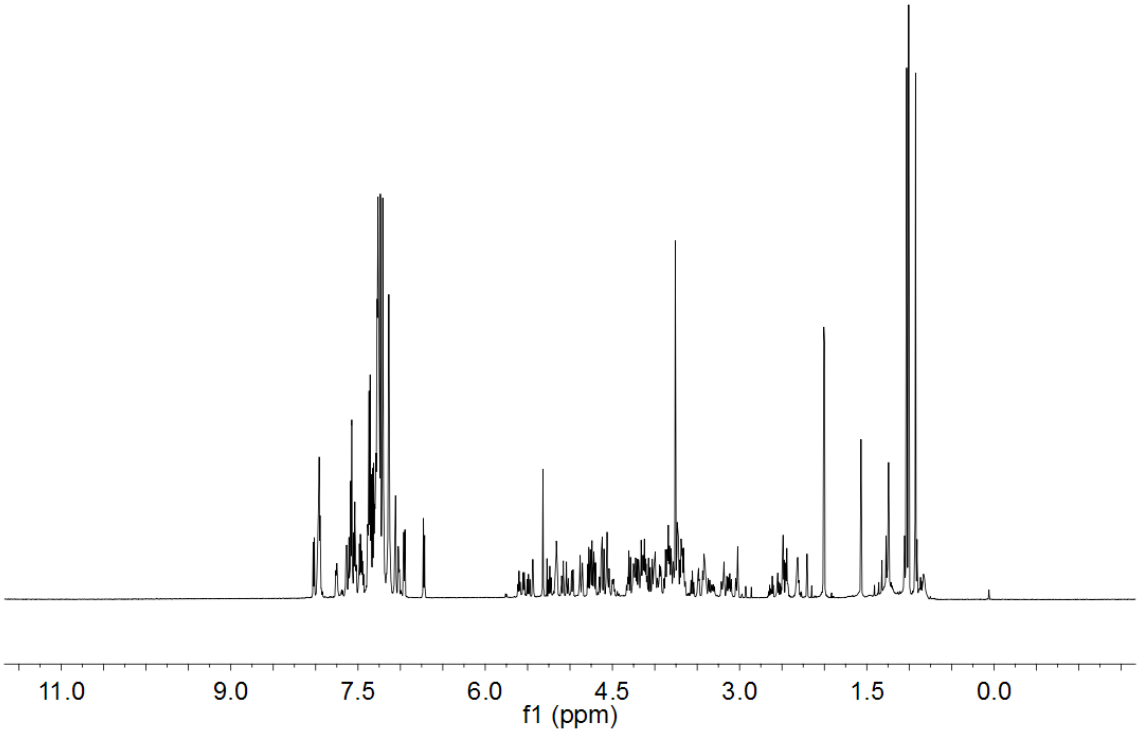
gHMBC ($CDCl_3$, 600 MHz) of **26**



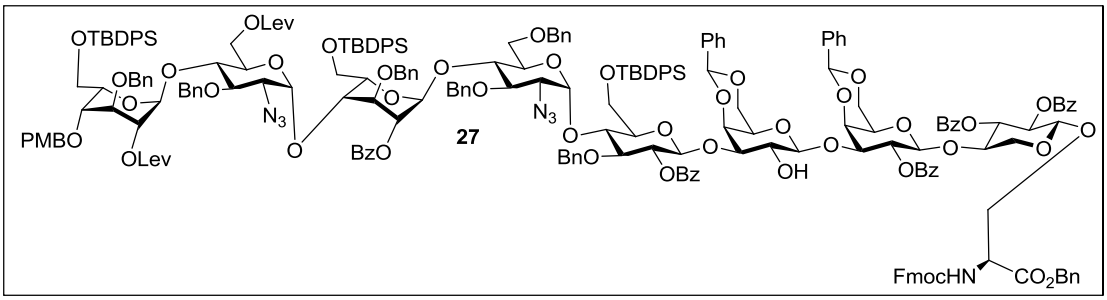


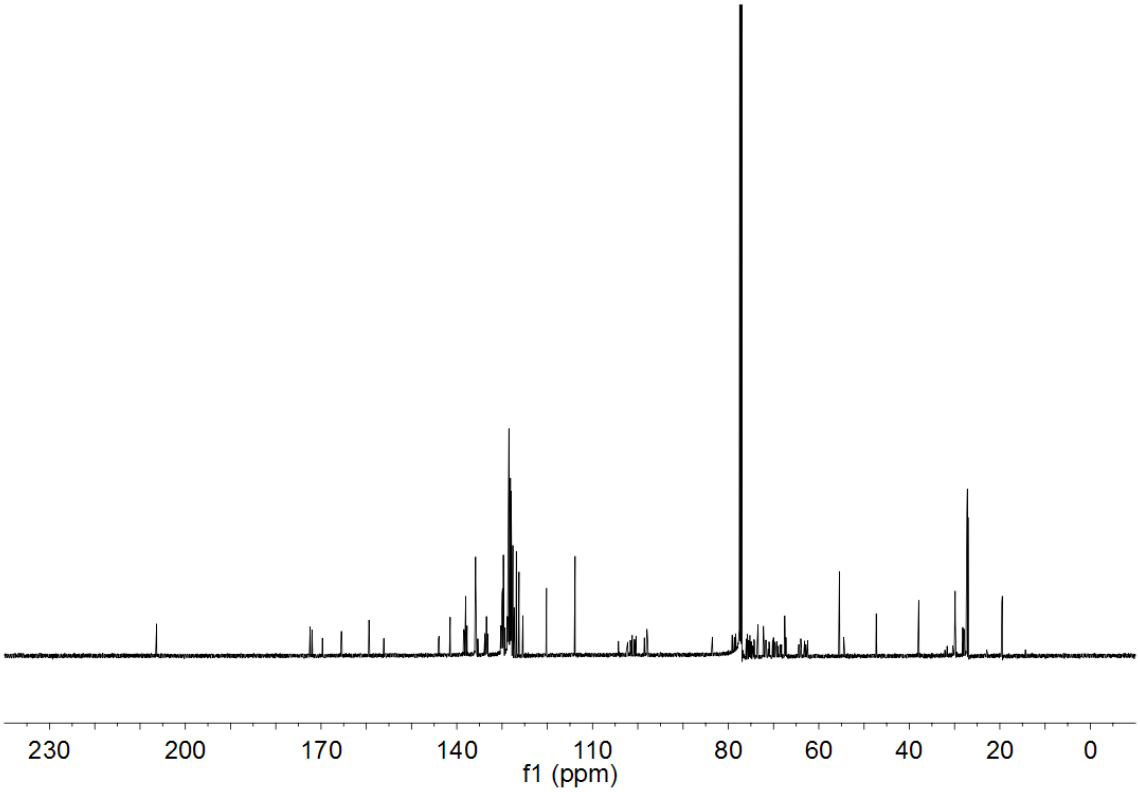
^{1}H-NMR ($CDCl_3$, 600 MHz) of **27**



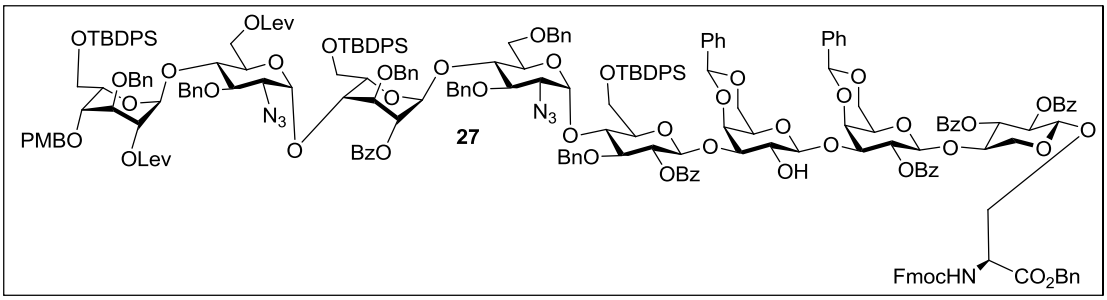


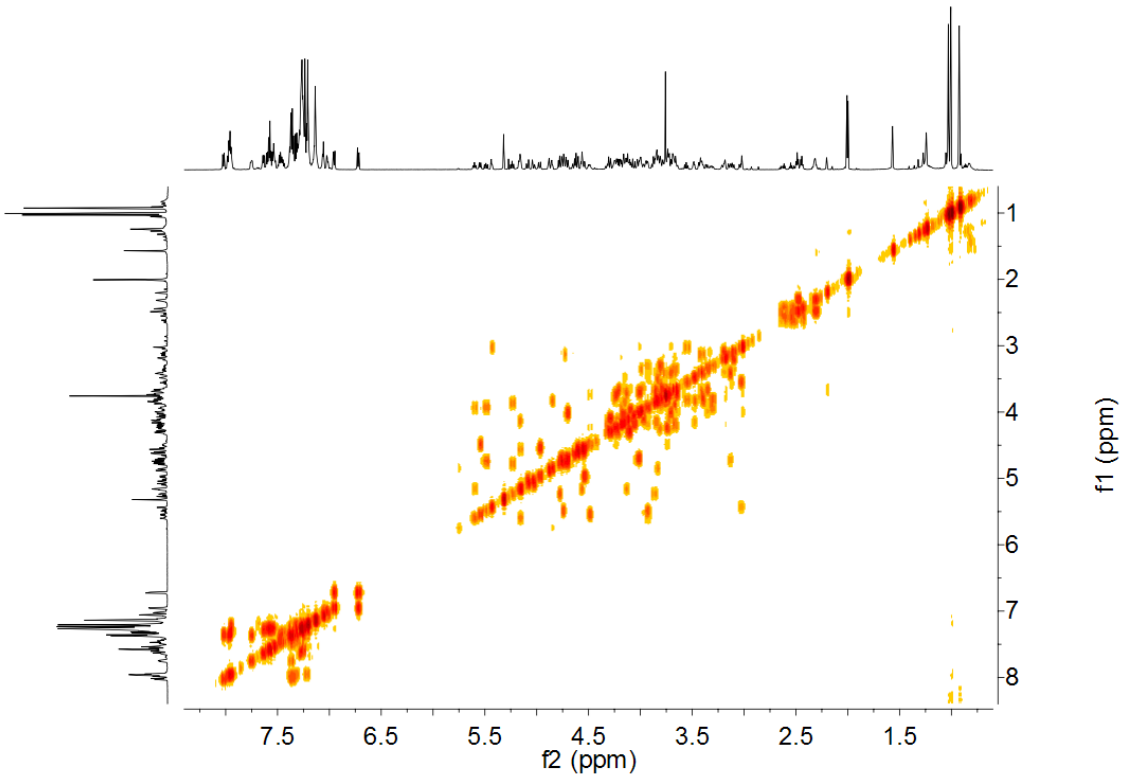
^{13}C-NMR ($CDCl_3$, 150 MHz) of **27**



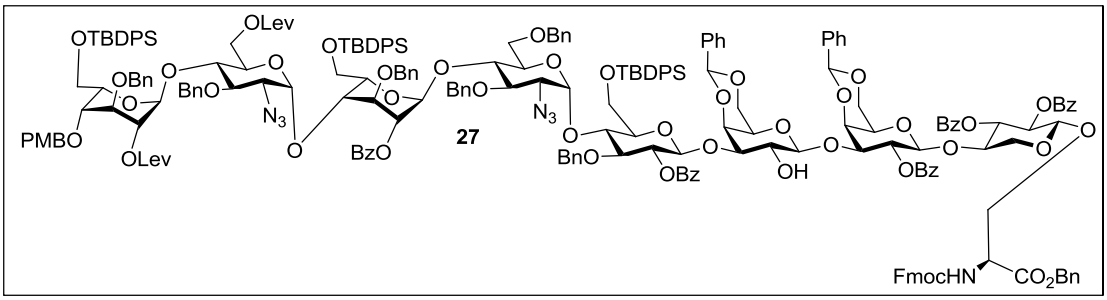


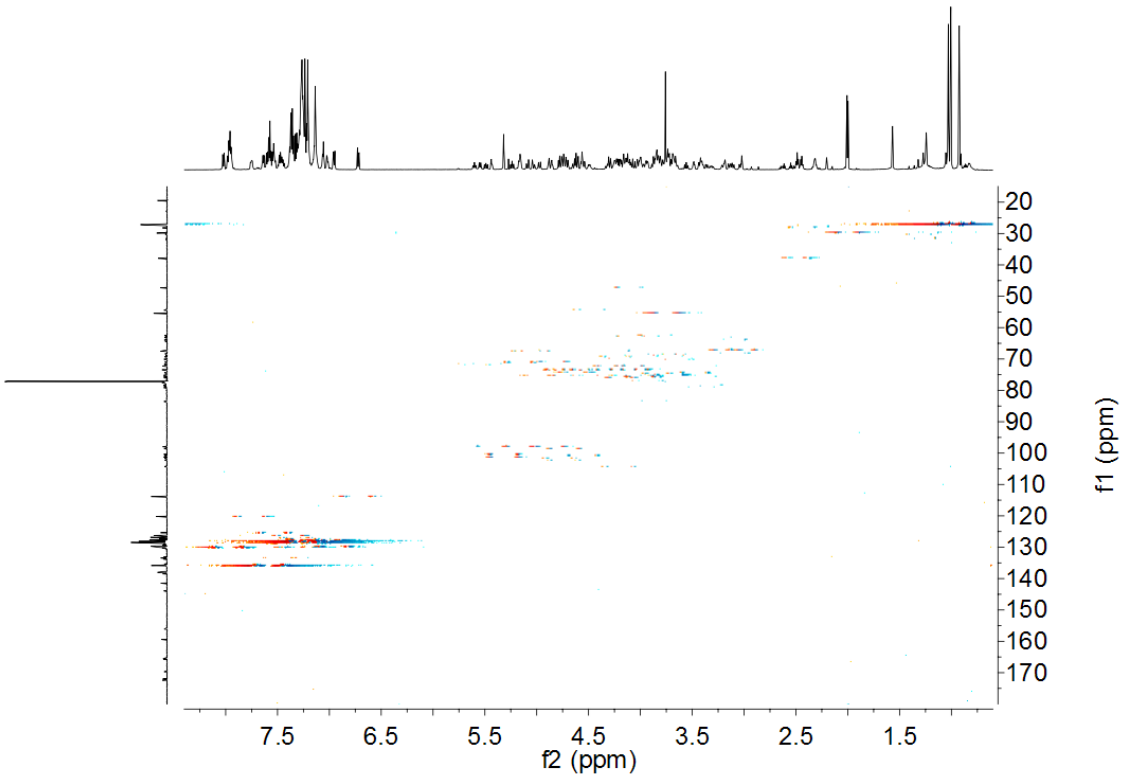
gCOSY ($CDCl_3$, 600 MHz) of **27**



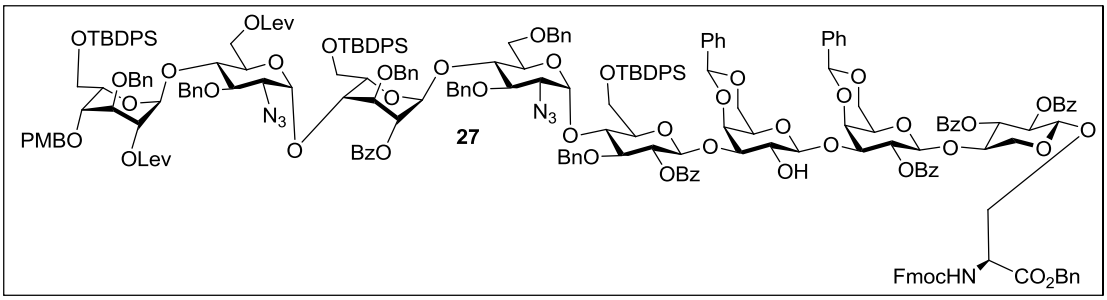


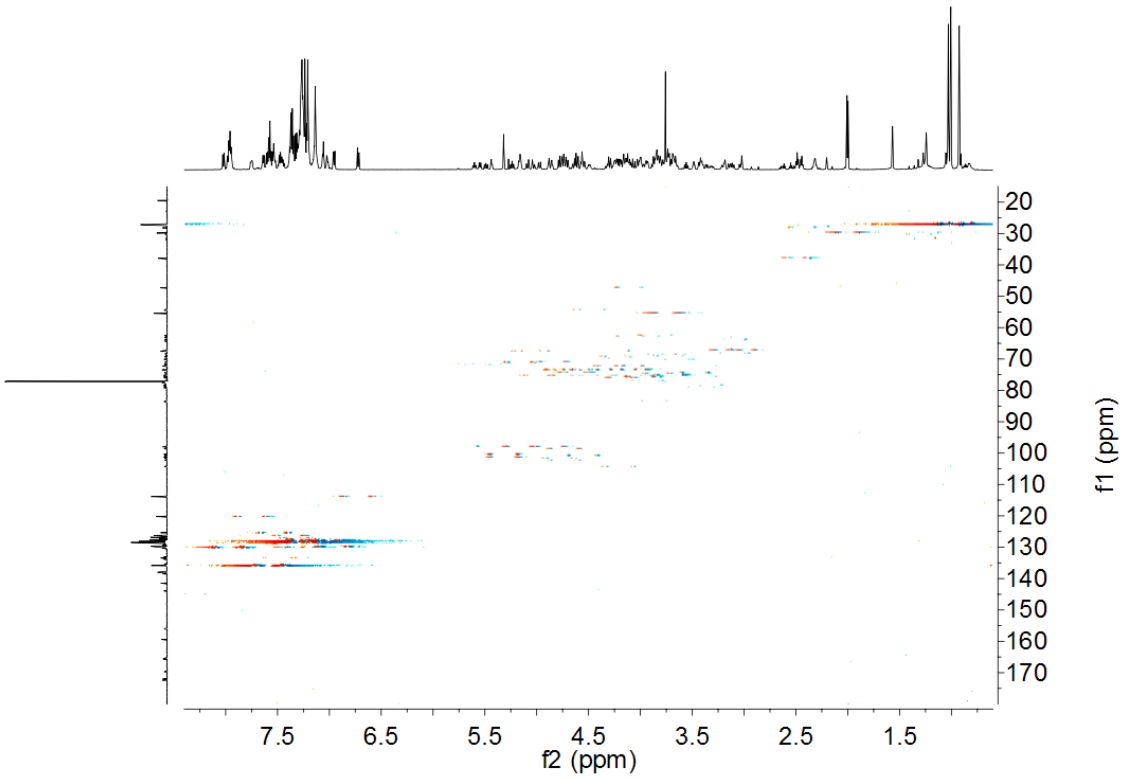
gHMQC ($CDCl_3$, 500 MHz) of **27**



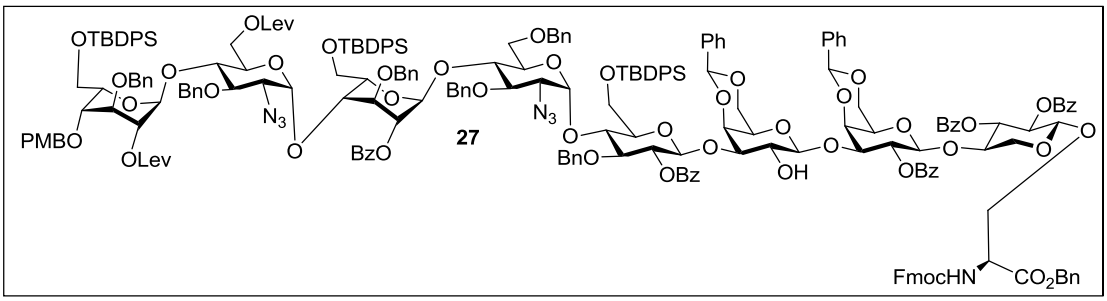


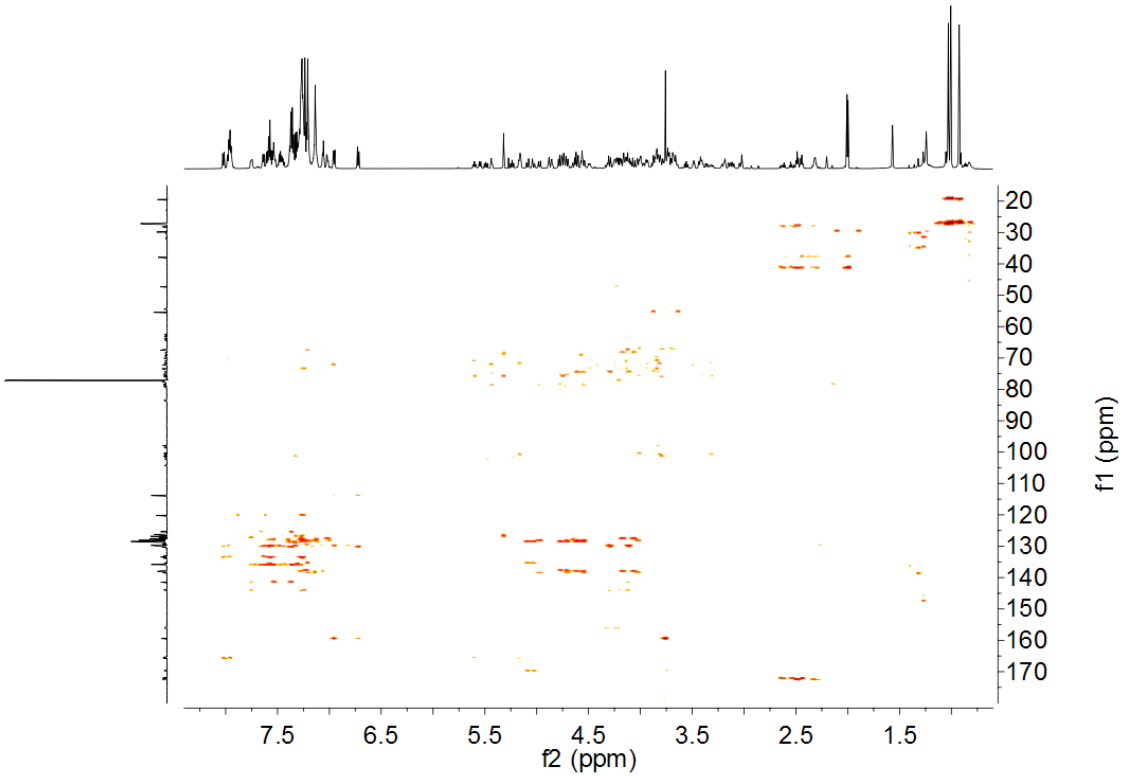
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 500 MHz) of **27**



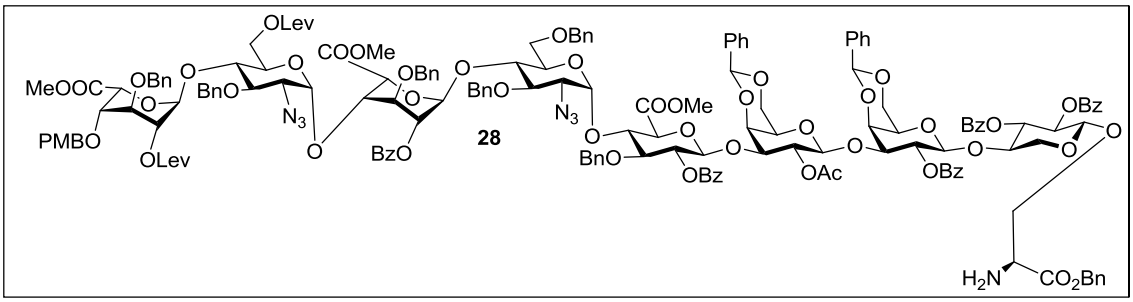


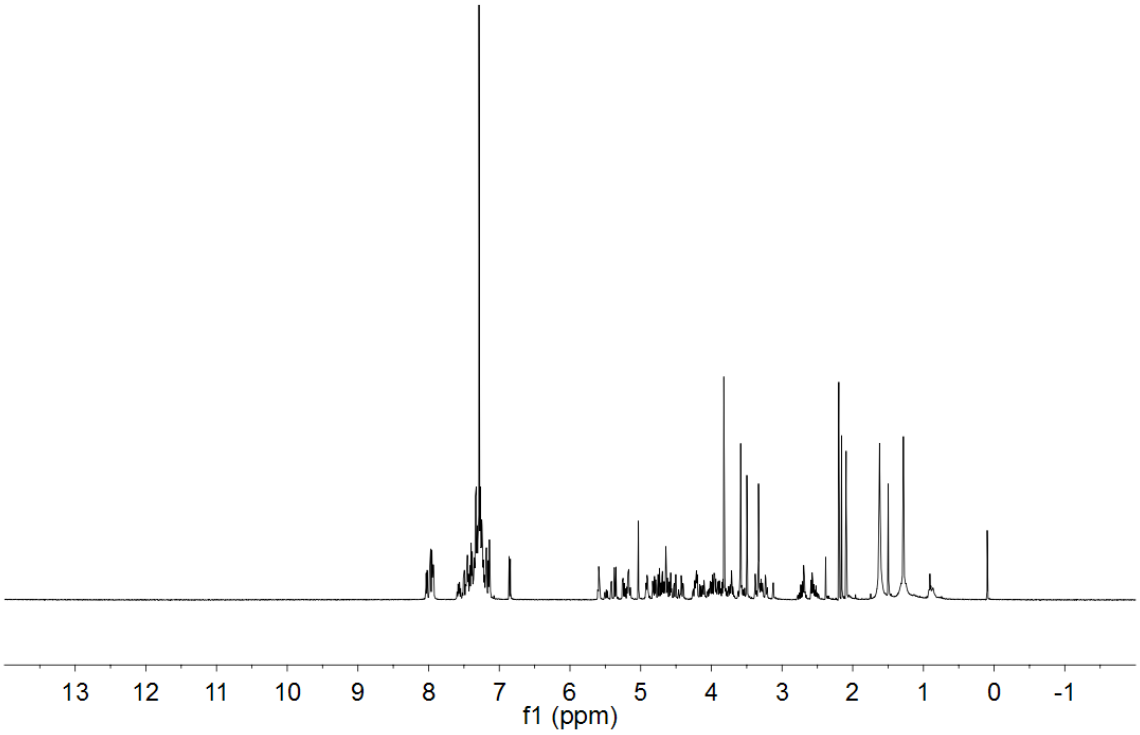
gHMBC ($CDCl_3$, 500 MHz) of **27**



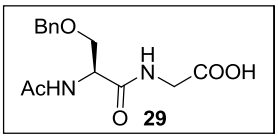


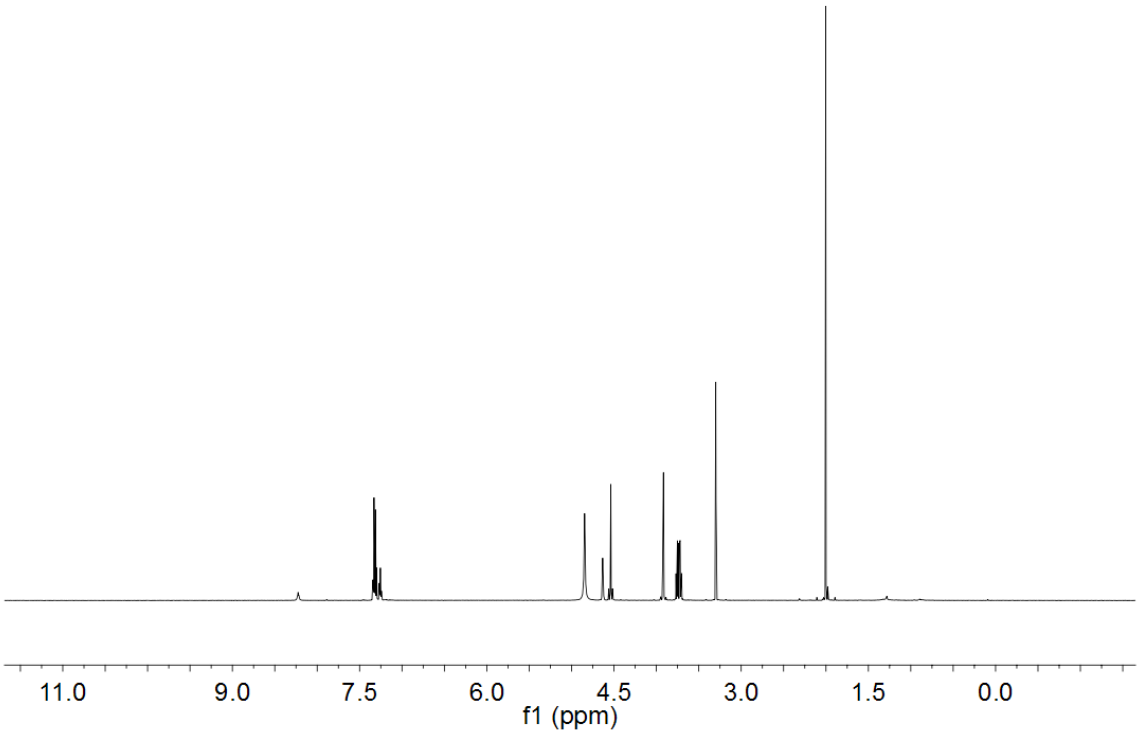
^{1}H-NMR ($CDCl_3$, 500 MHz) of **28**



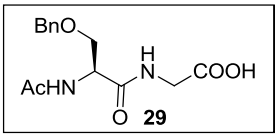


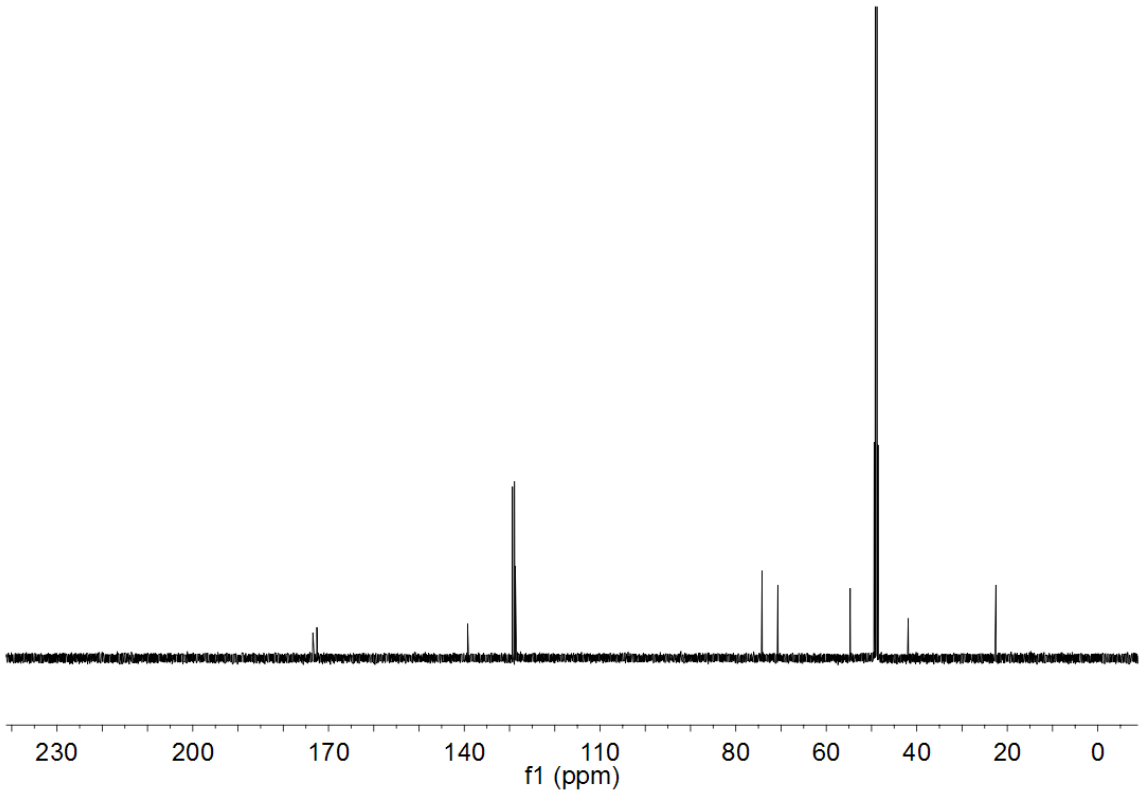
^{1}H-NMR ($CDCl_3$, 500 MHz) of **29**



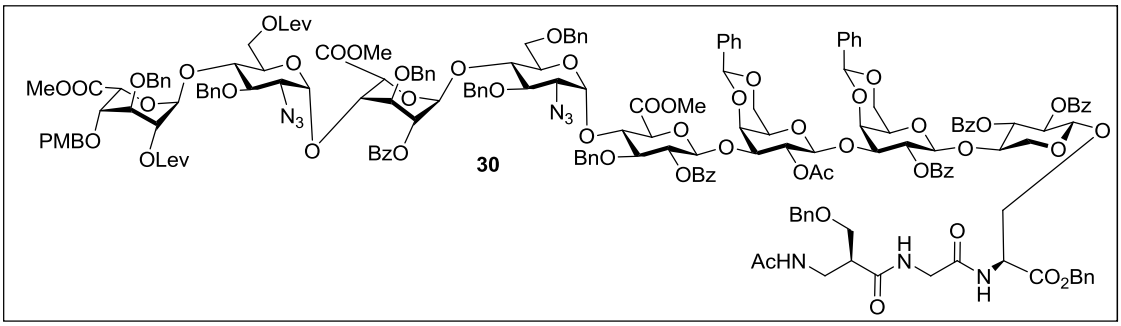


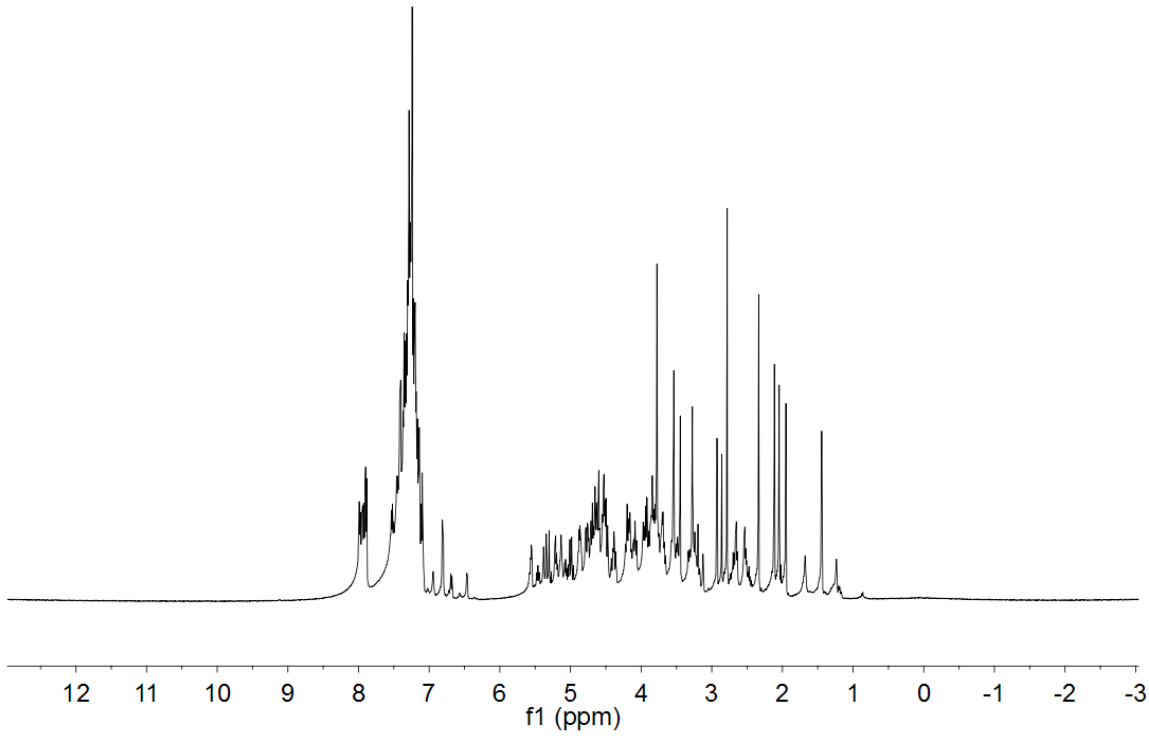
^{13}C-NMR ($CDCl_3$, 125 MHz) of **29**



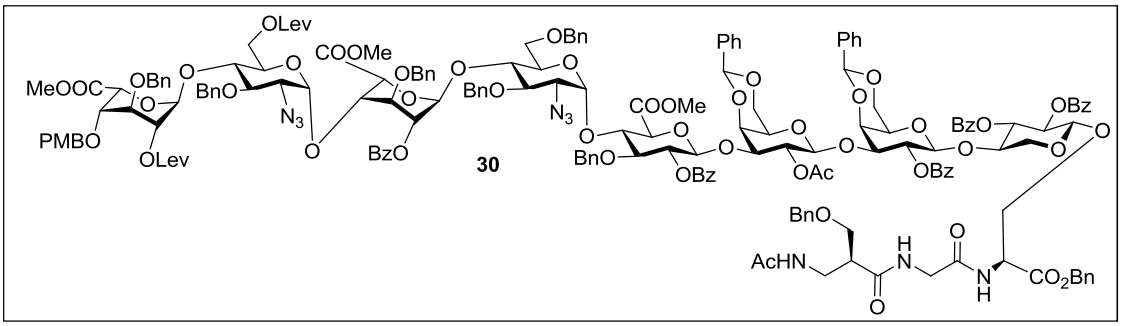


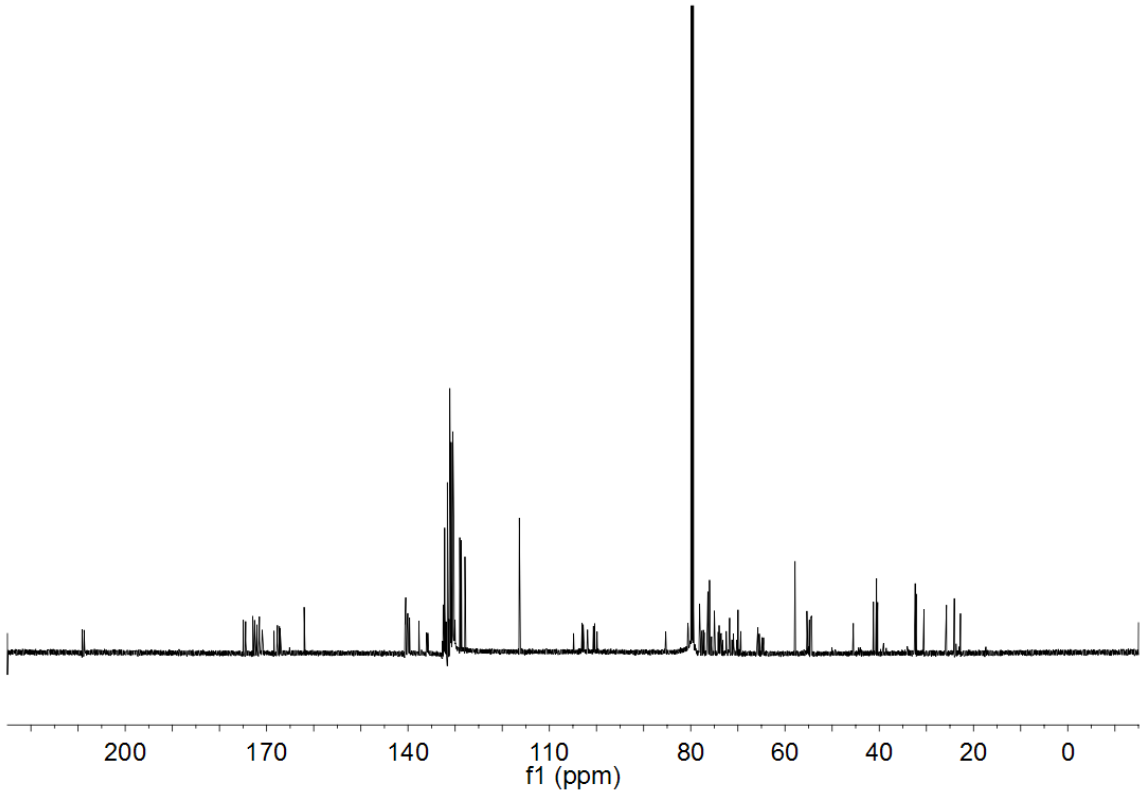
^{1}H-NMR ($CDCl_3$, 500 MHz) of **30**



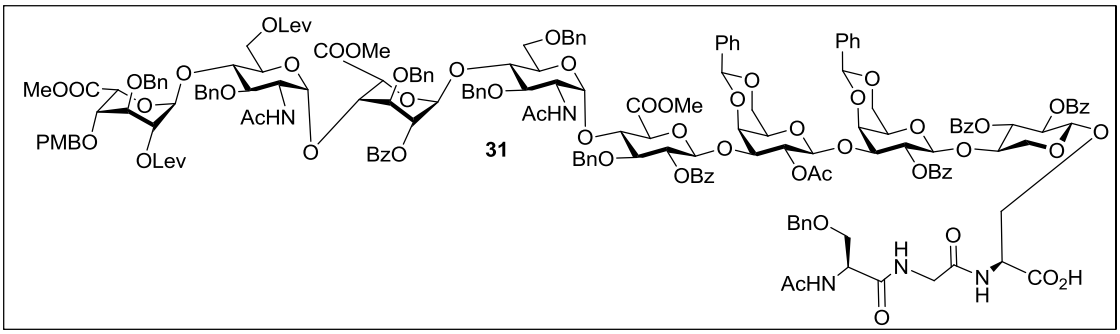


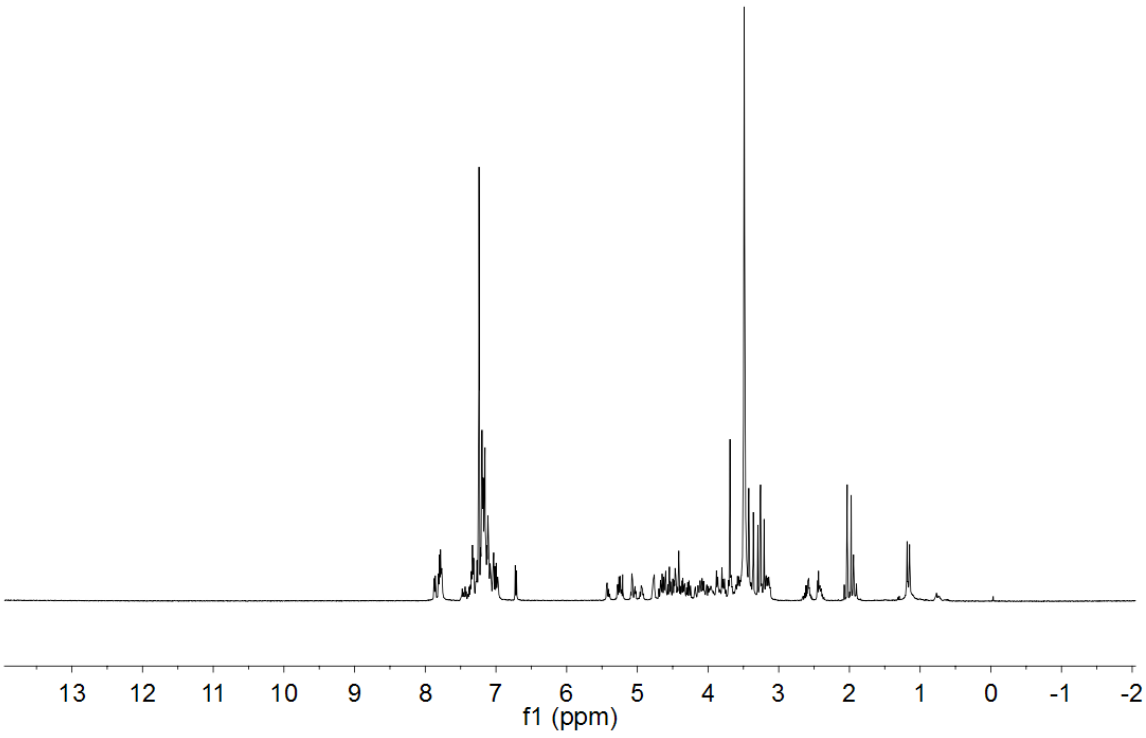
^{13}C-NMR ($CDCl_3$, 125 MHz) of **30**



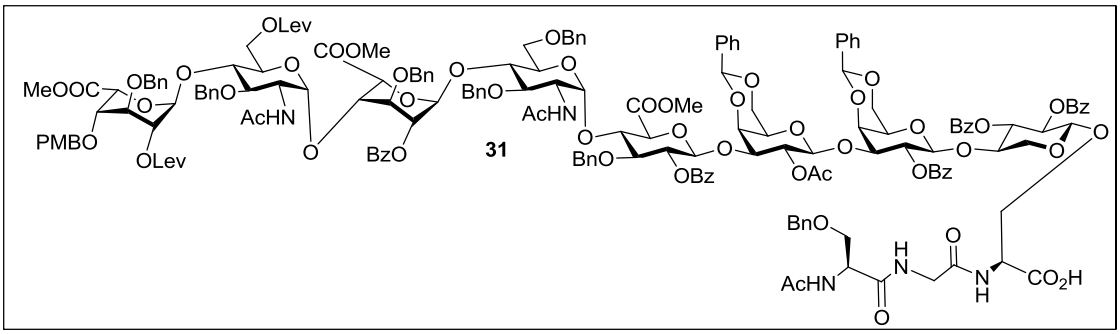


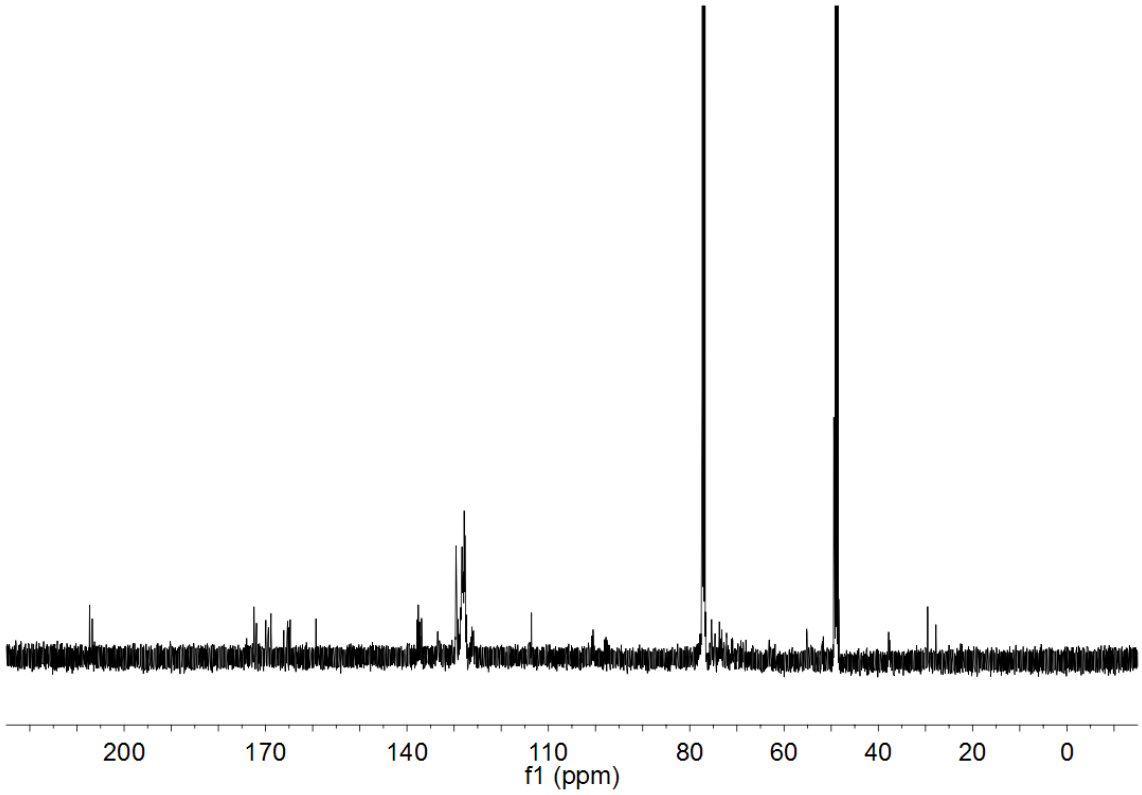
^{1}H-NMR ($CDCl_3$, 500 MHz) of **31**





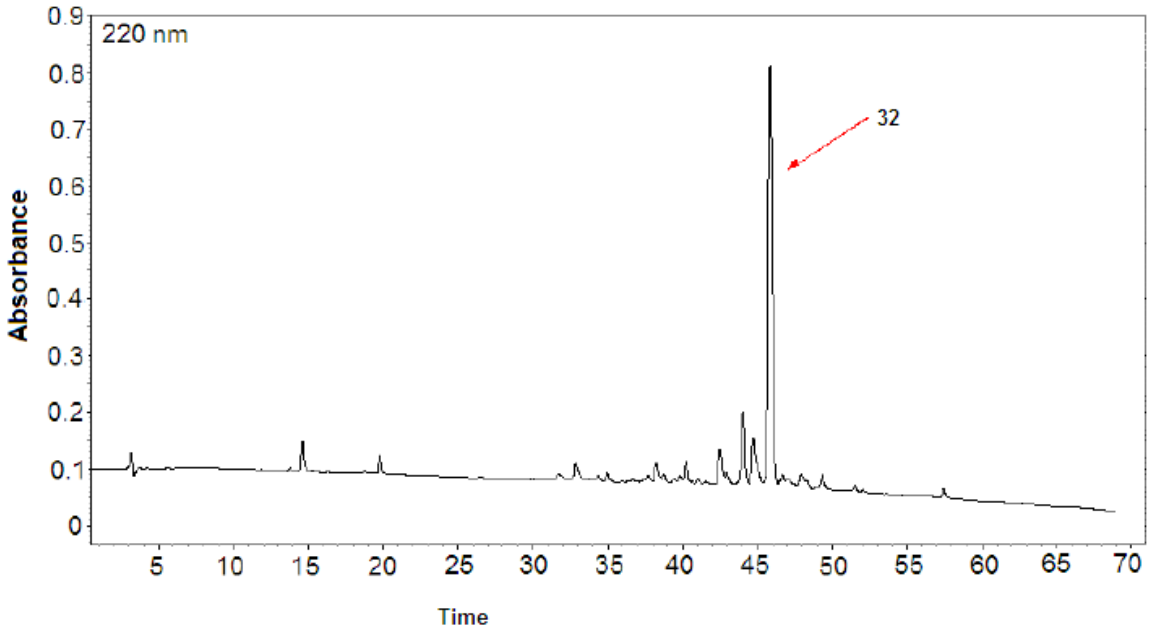
^{13}C-NMR ($CDCl_3$, 125 MHz) of **31**



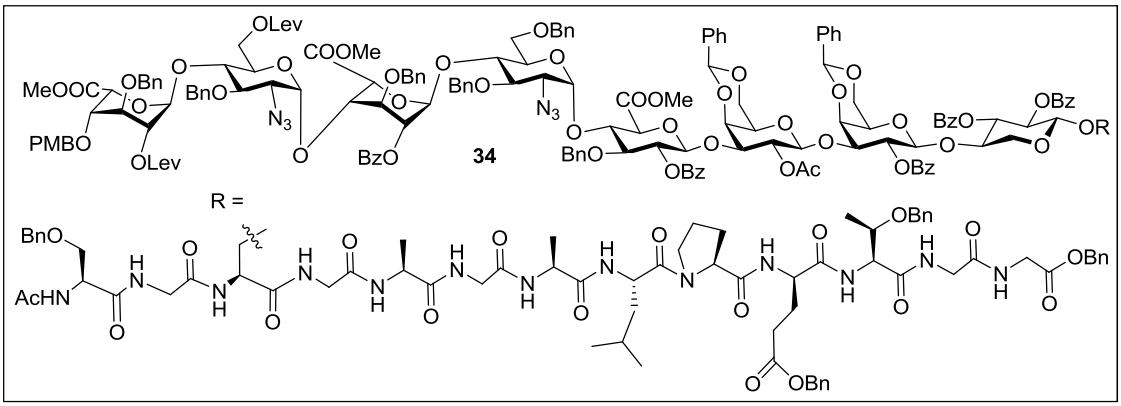


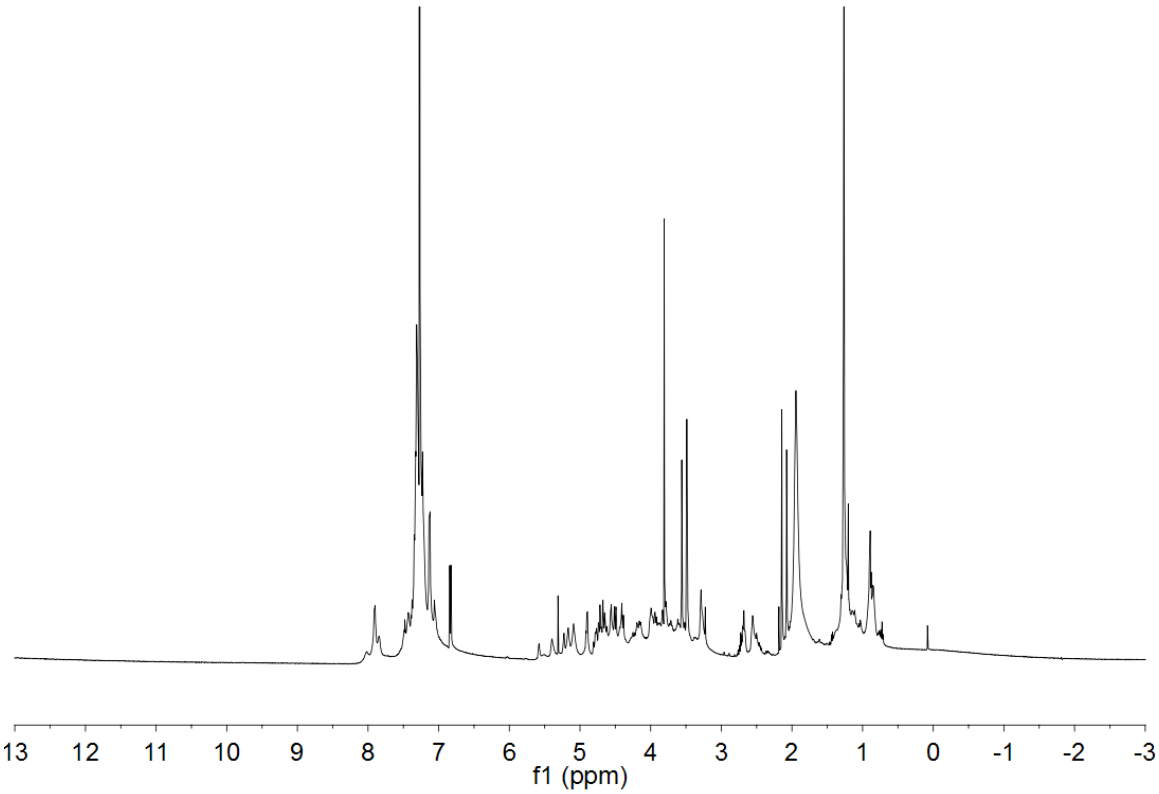
HPLC Chromatogram of crude peptide **32**

HPLC mobile phase: gradient 5% to 100% B in A over 60 min (solvent A: 0.1% TFA in H_2O; solvent B: 0.1% TFA in CH_3CN). Flow rate: 1 mL/min. Detection Wavelenth: 220 nm. HPLC column: SupelCOSIL LC-18, 25 cm x 4.6 mm, 5 µm particle size.

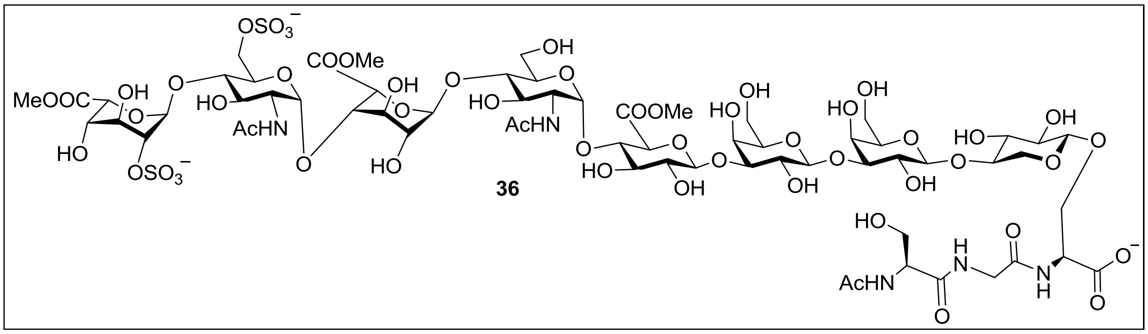


^{1}H-NMR ($CDCl_3$, 500 MHz) of **34**

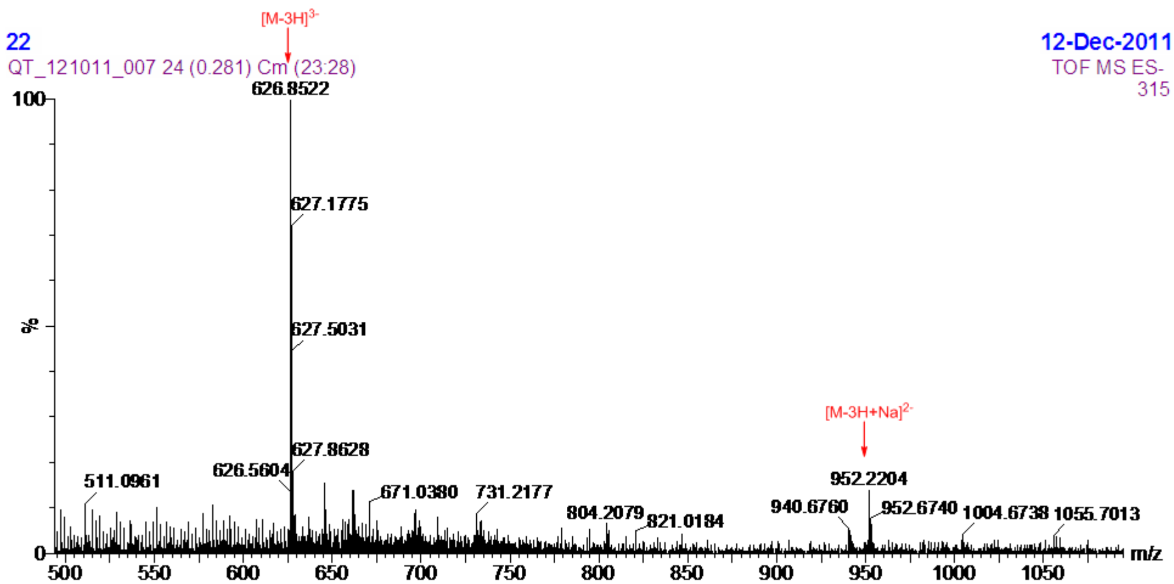




ESI-MS of **36**

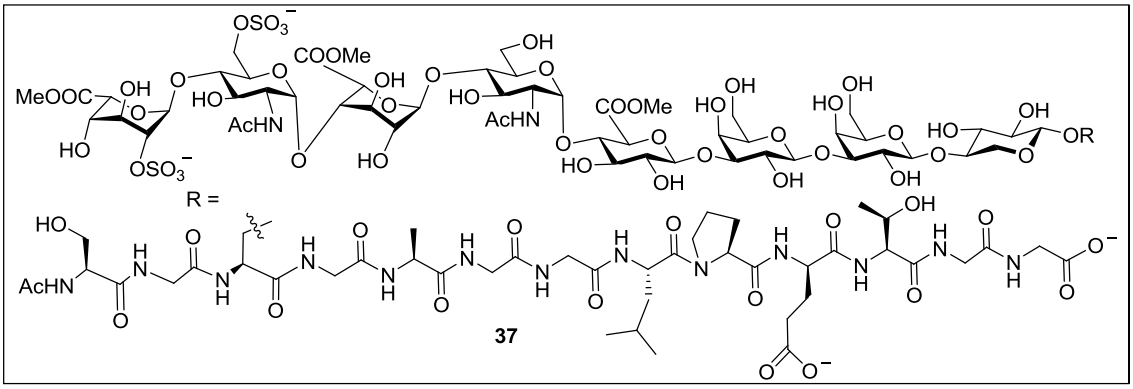


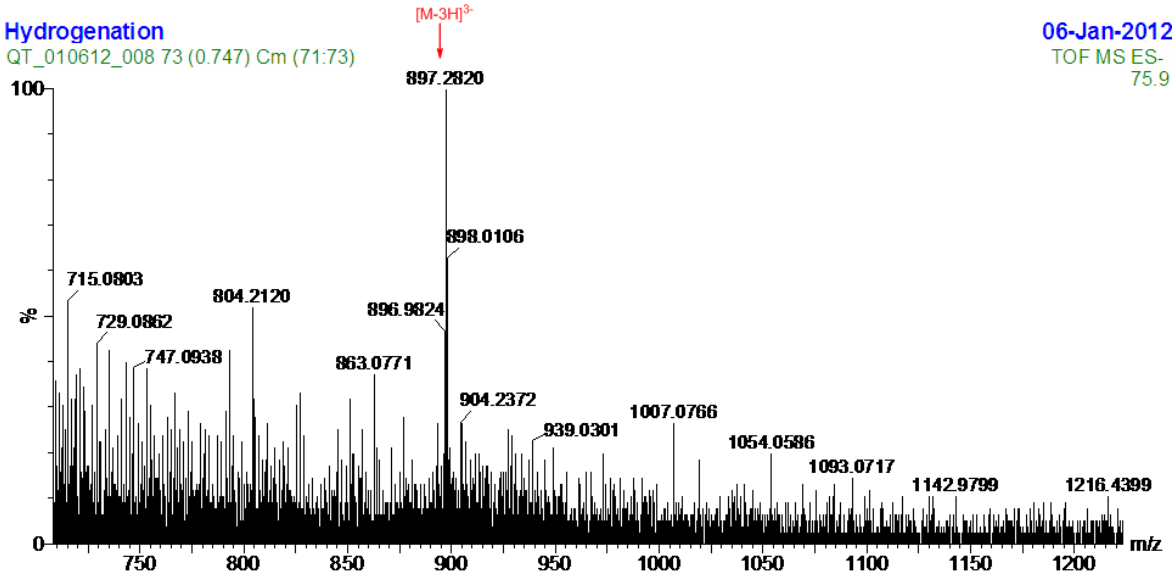
36



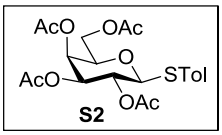
[M-3H]3-
22
QT_121011_007 24 (0.281) Cm (23:28)
12-Dec-2011
TOF MS ES-
315
626.8522
627.1775
627.5031
627.8628
626.5604
511.0961
671.0380
731.2177
804.2079
821.0184
[M-3H+Na]2-
952.2204
940.6760
952.6740
1004.6738
1055.7013
%
m/z

ESI-MS of **37**

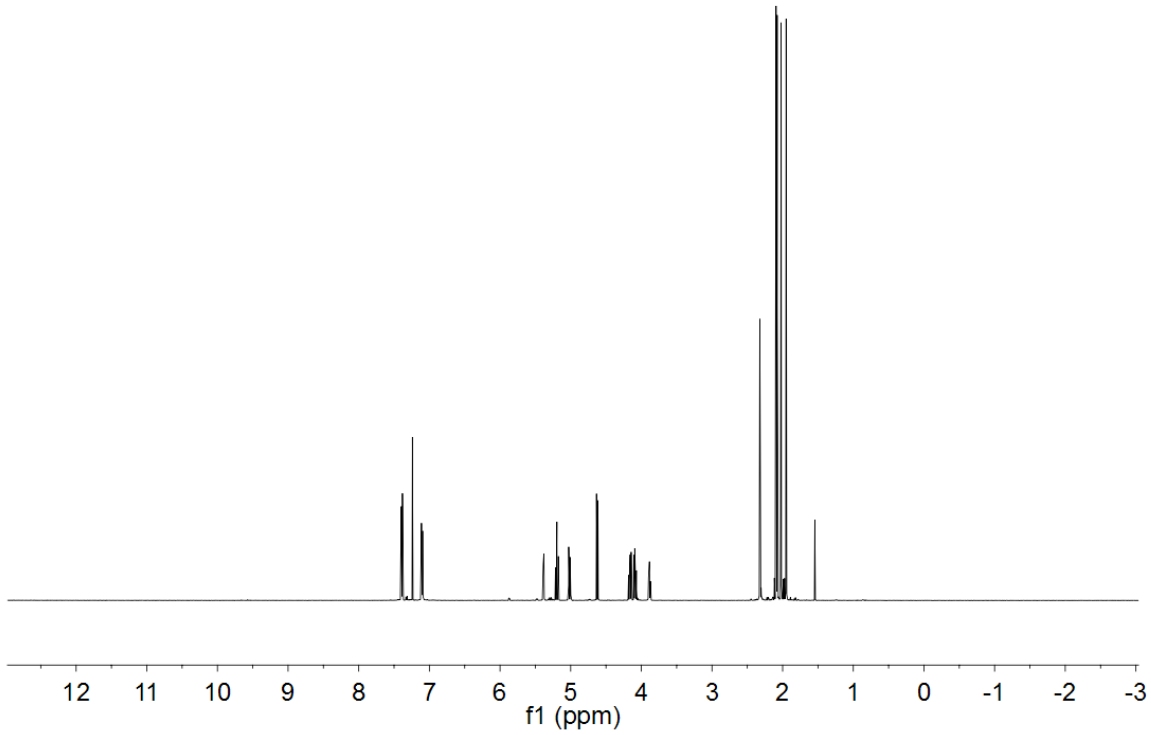

R =
37


Hydrogenation
QT_010612_008 73 (0.747) Cm (71:73)
[M-3H]3-
06-Jan-2012
TOF MS ES-
75.9
100
%
0
897.2820
898.0106
715.0803
804.2120
729.0862
896.9824
747.0938
863.0771
904.2372
939.0301
1007.0766
1054.0586
1093.0717
1142.9799
1216.4399
750
800
850
900
950
1000
1050
1100
1150
1200
m/z

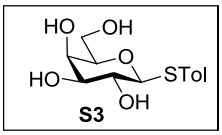
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S2**

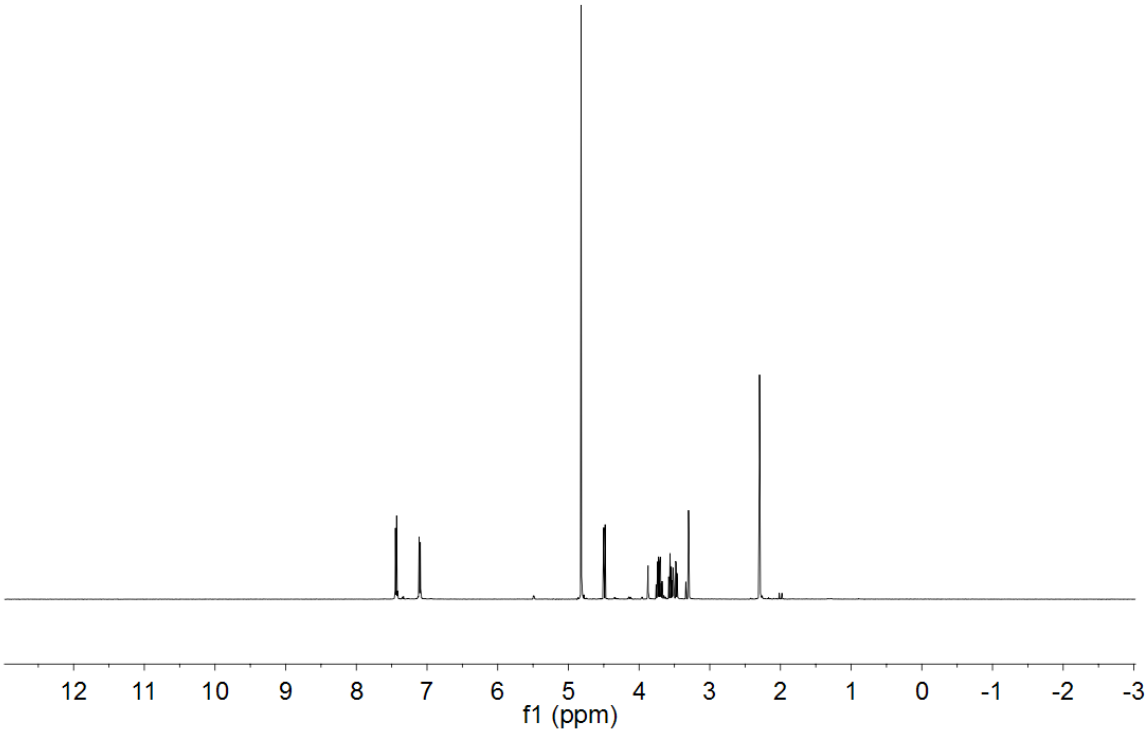


S2

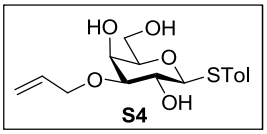


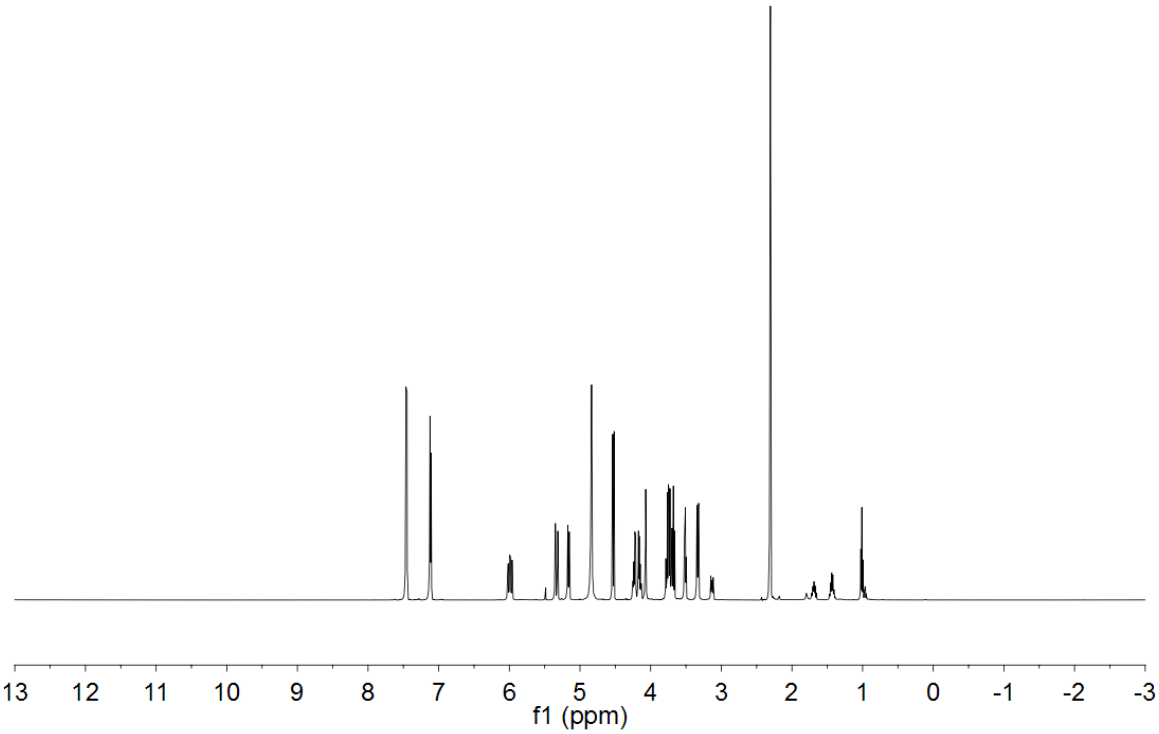
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S3**



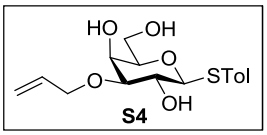


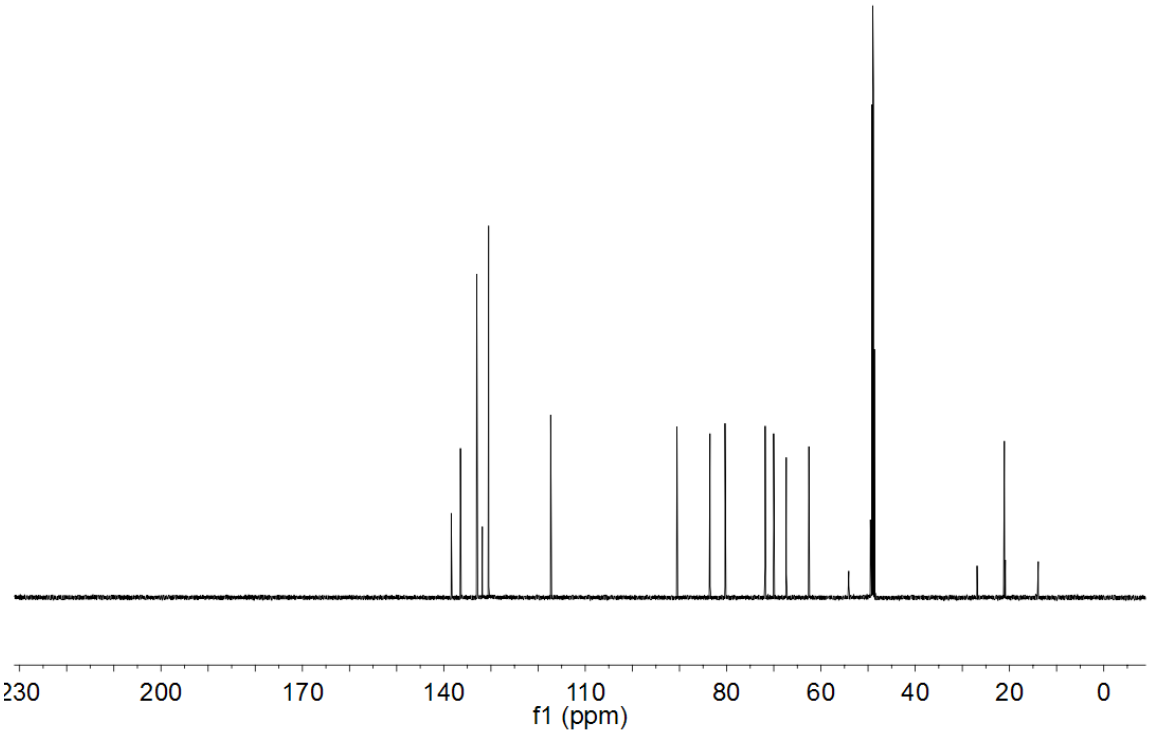
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S4**



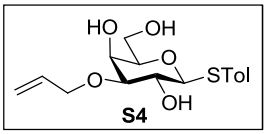


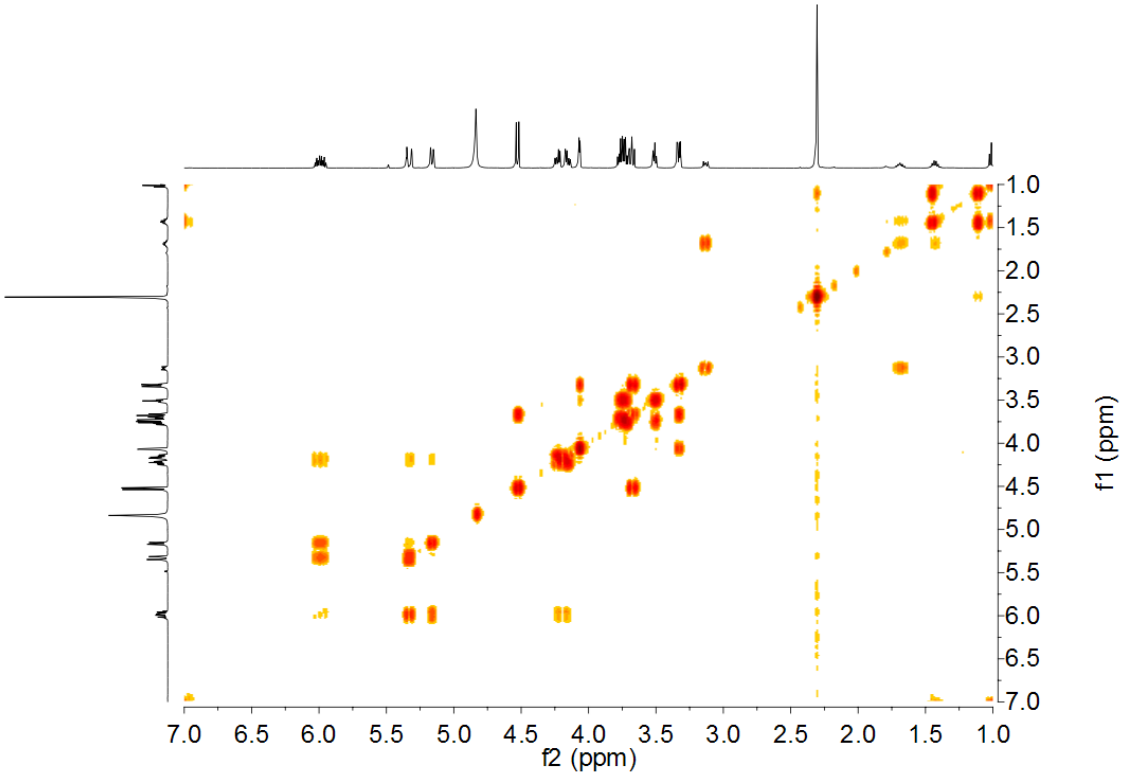
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S4**



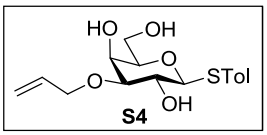


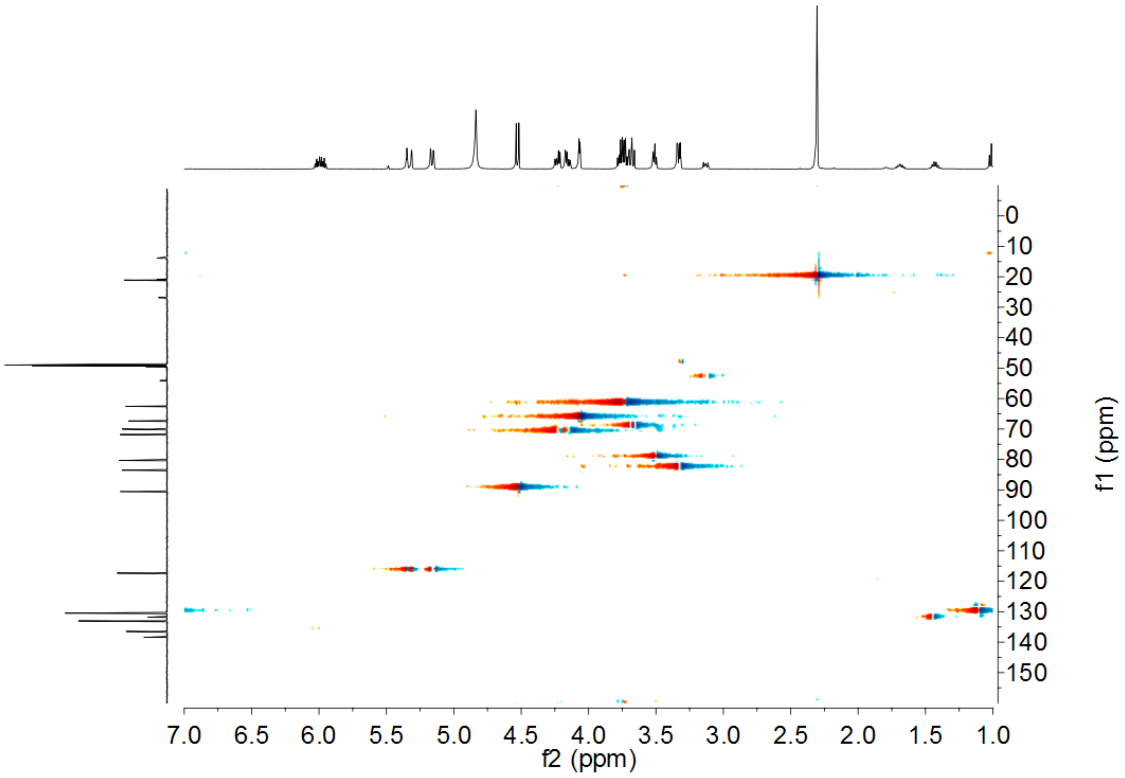
gCOSY ($CDCl_3$, 500 MHz) of **S4**



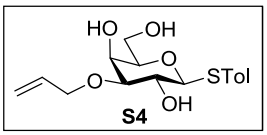


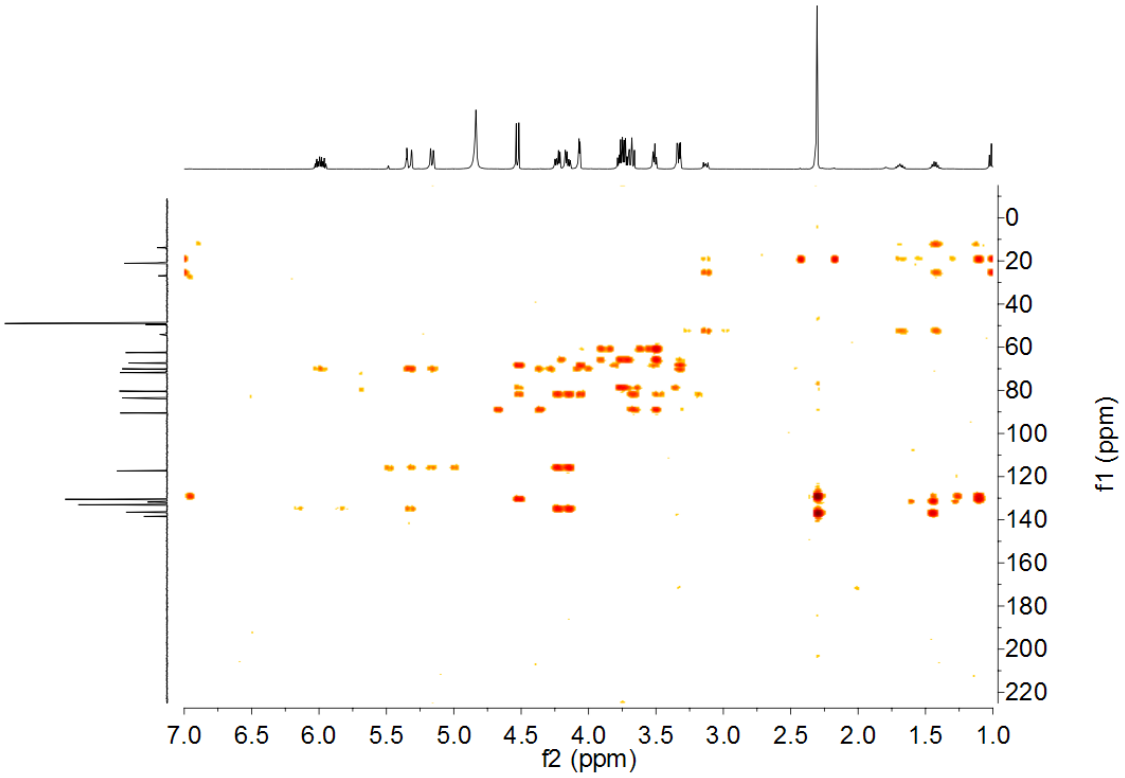
gHMQC ($CDCl_3$, 500 MHz) of **S4**



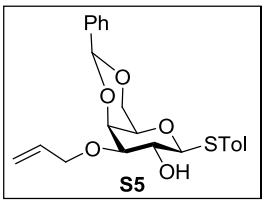


gHMBC ($CDCl_3$, 500 MHz) of **S4**

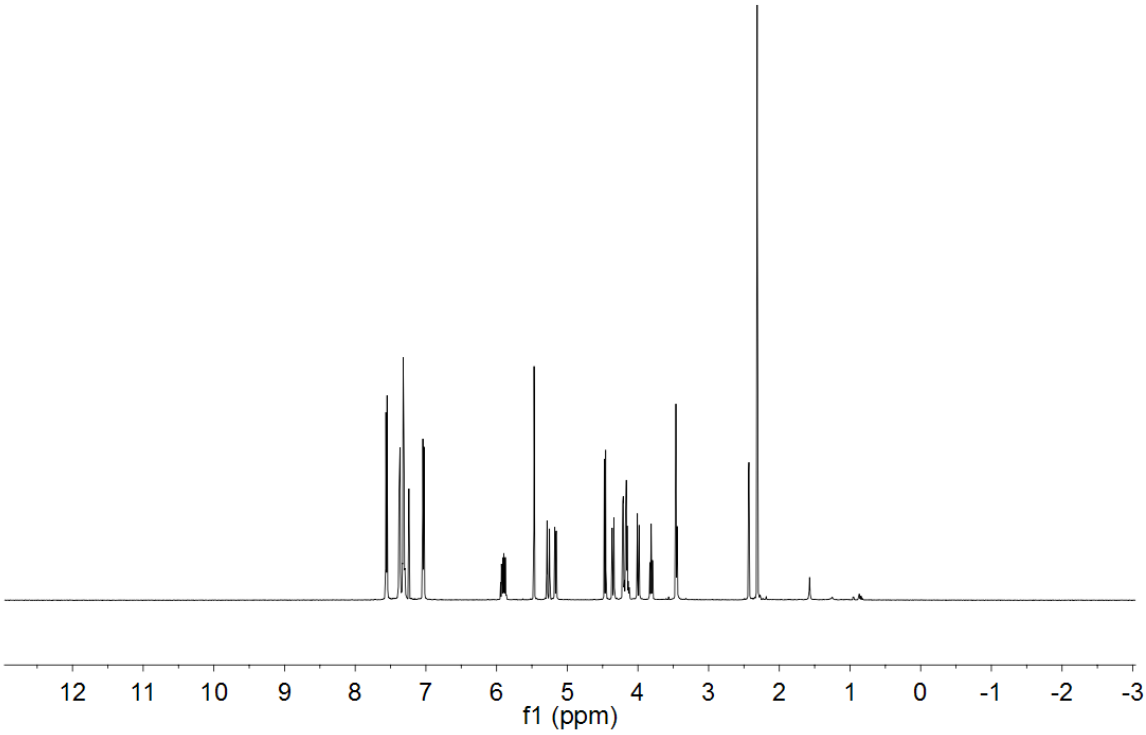




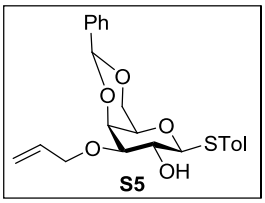
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S5**

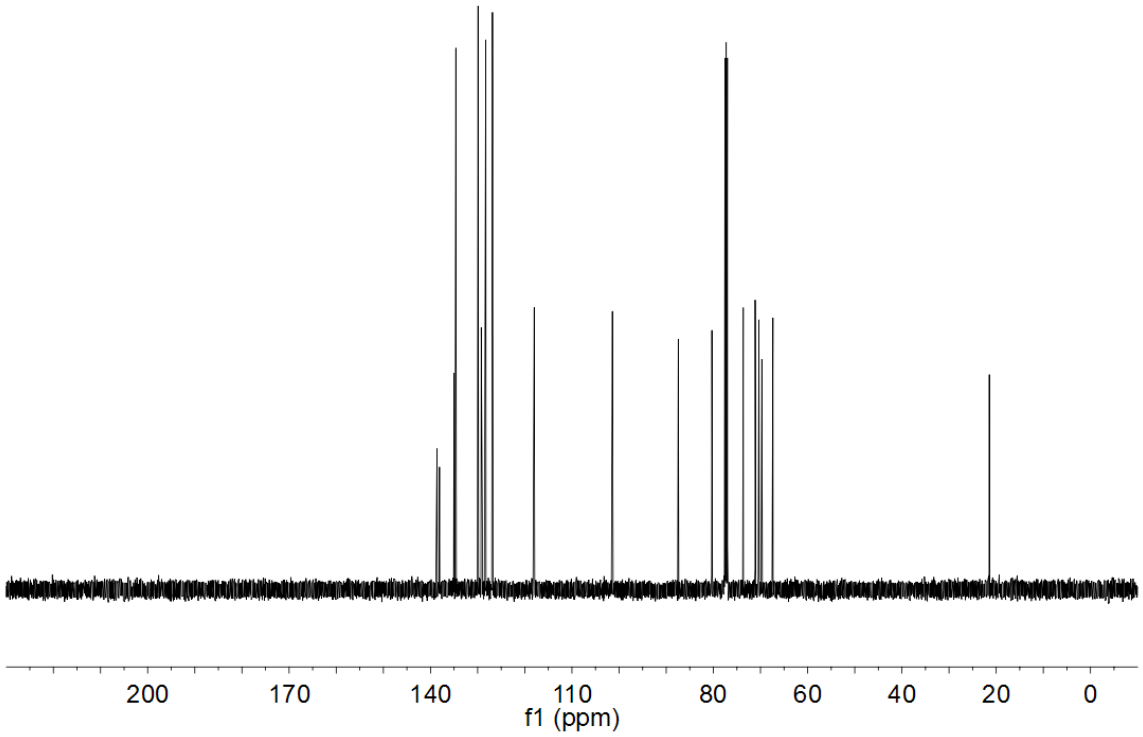


S5

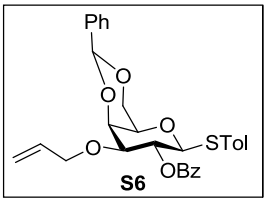


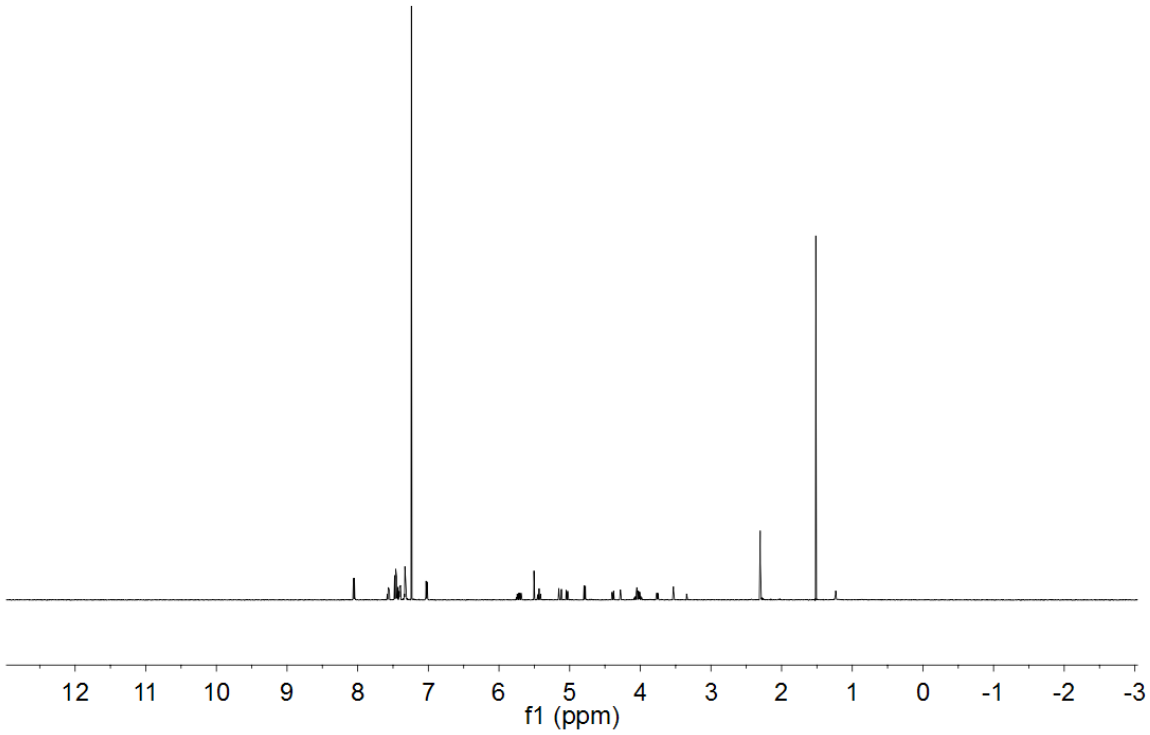
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S5**



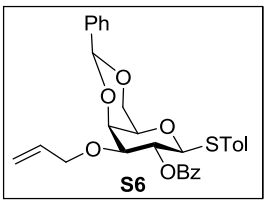


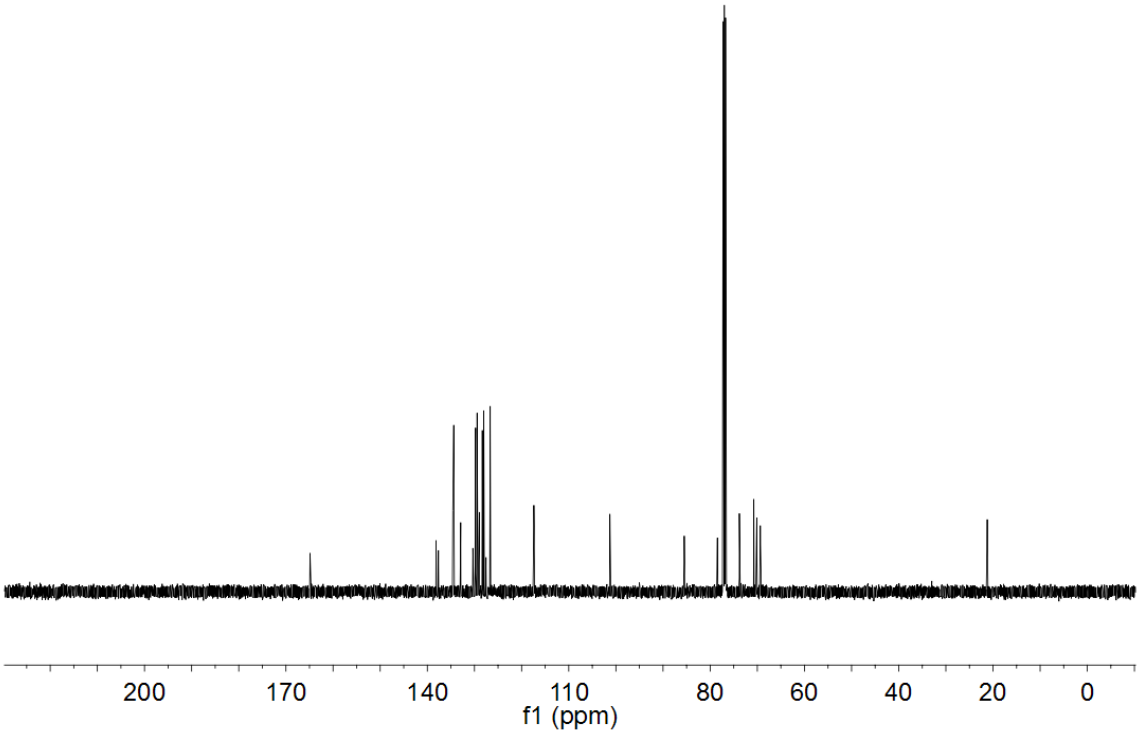
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S6**



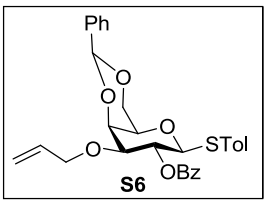


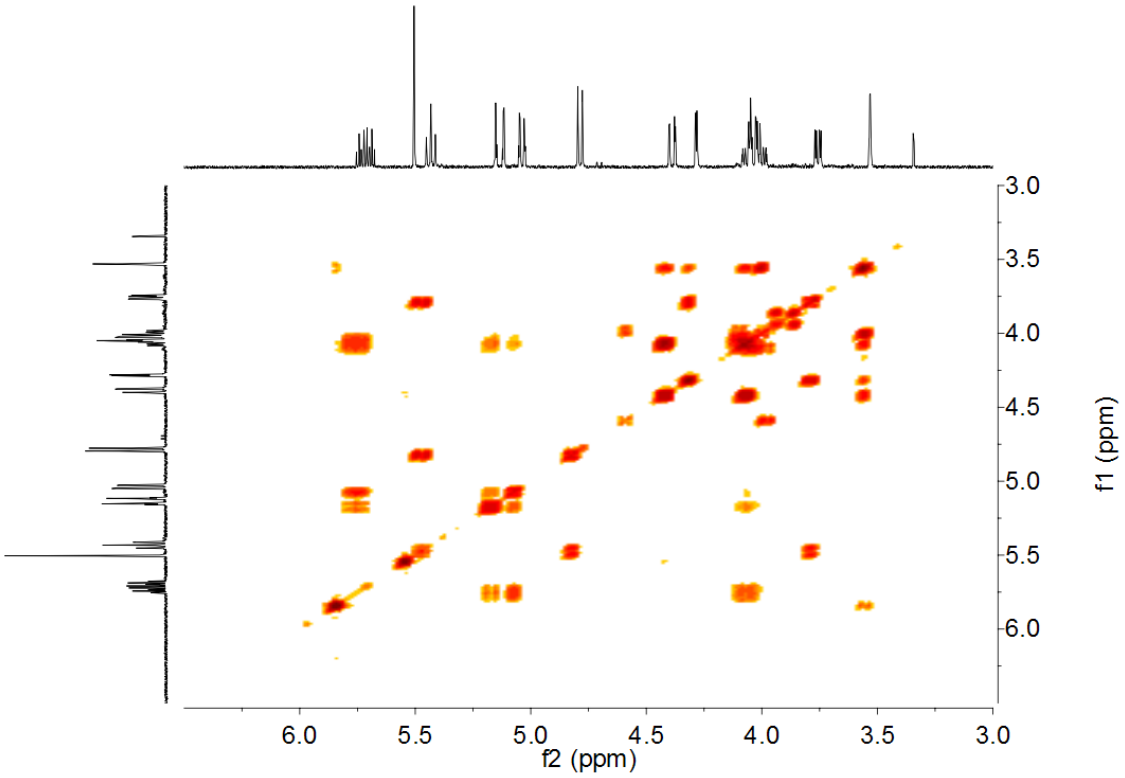
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S6**



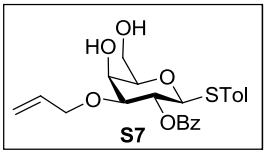


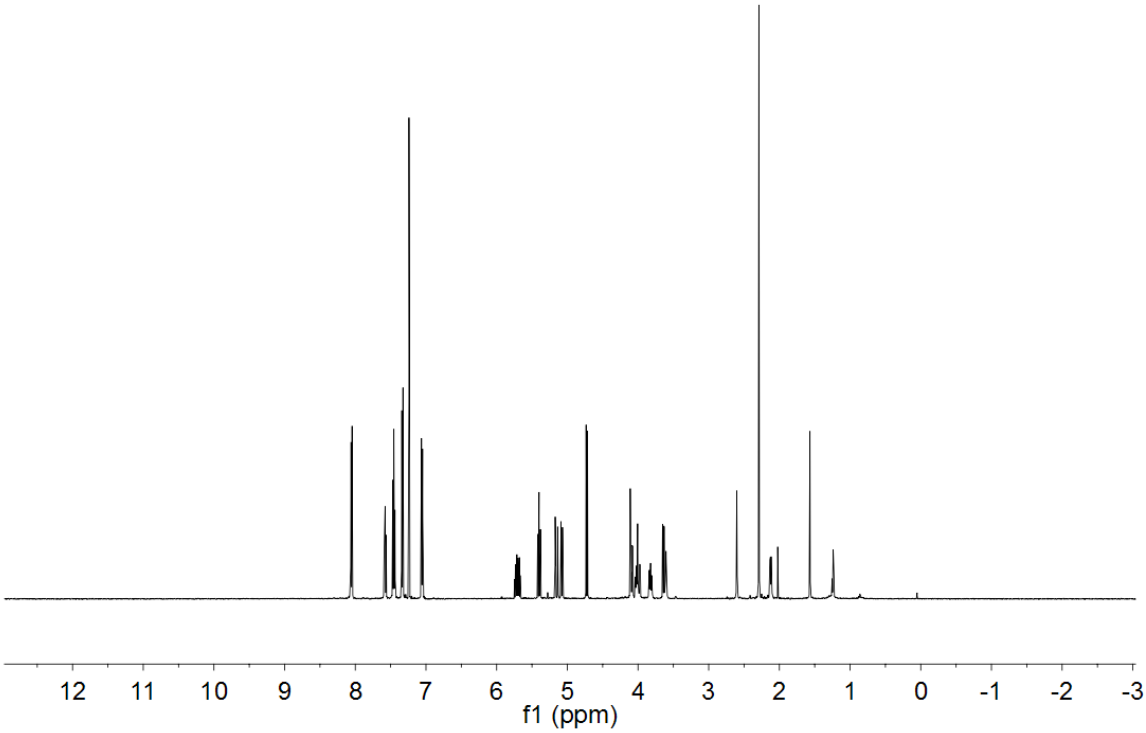
gCOSY ($CDCl_3$, 500 MHz) of **S6**



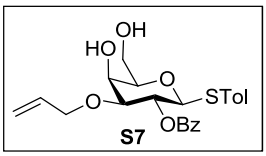


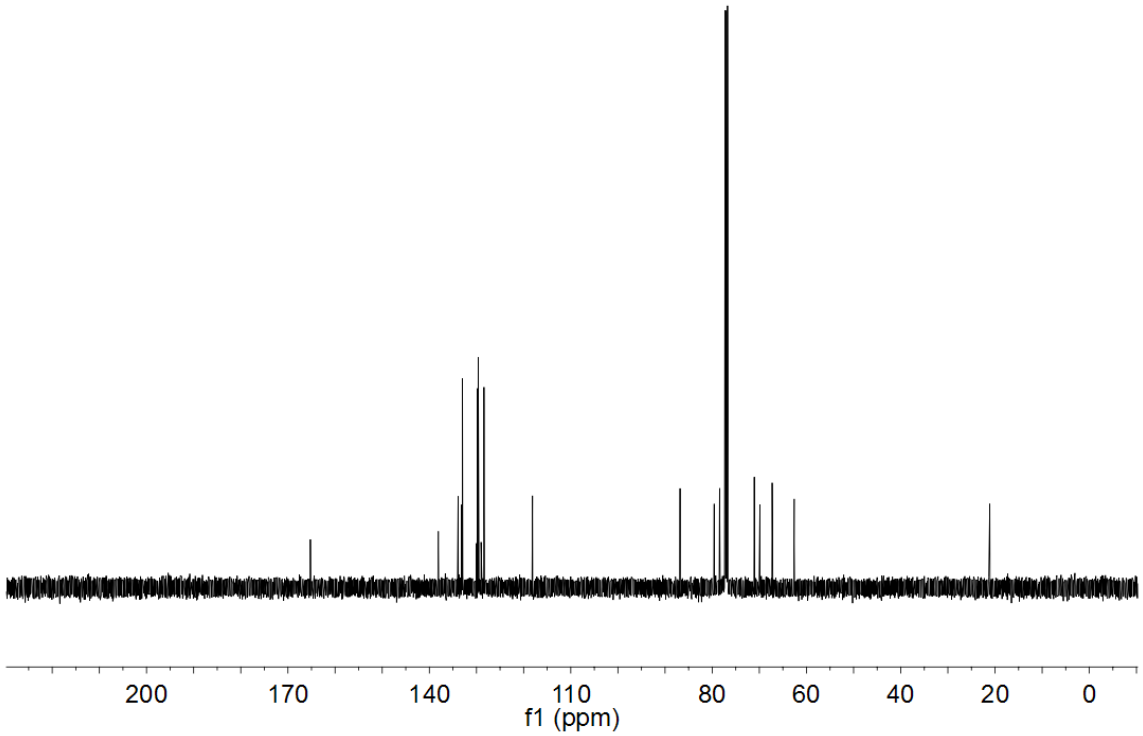
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S7**



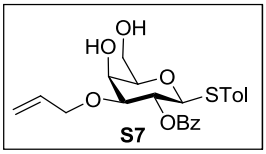


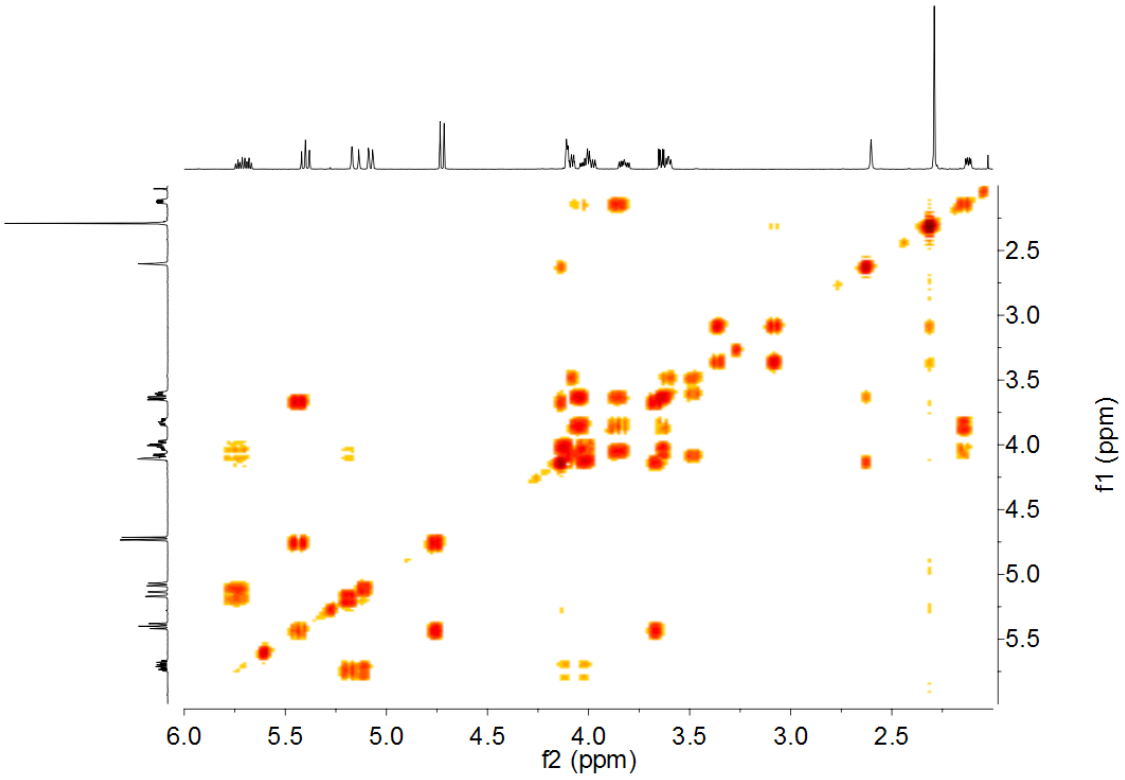
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S7**



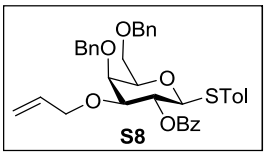


gCOSY ($CDCl_3$, 500 MHz) of **S7**

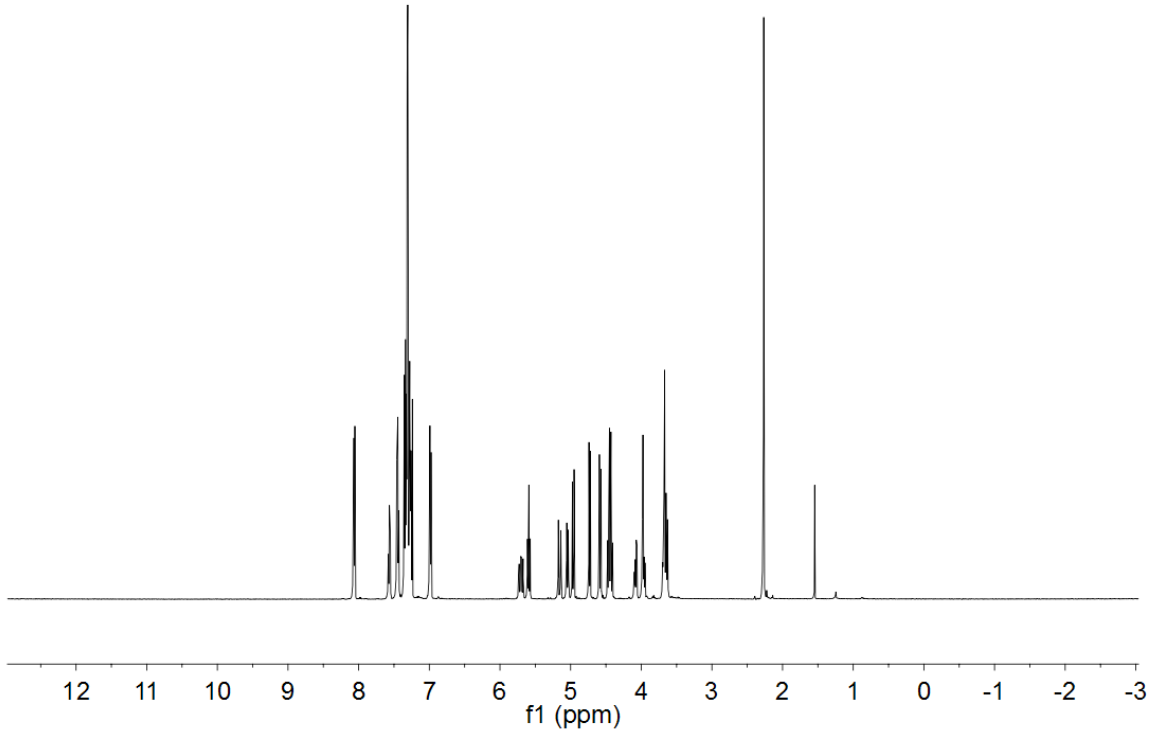




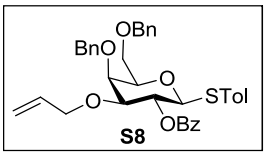
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S8**

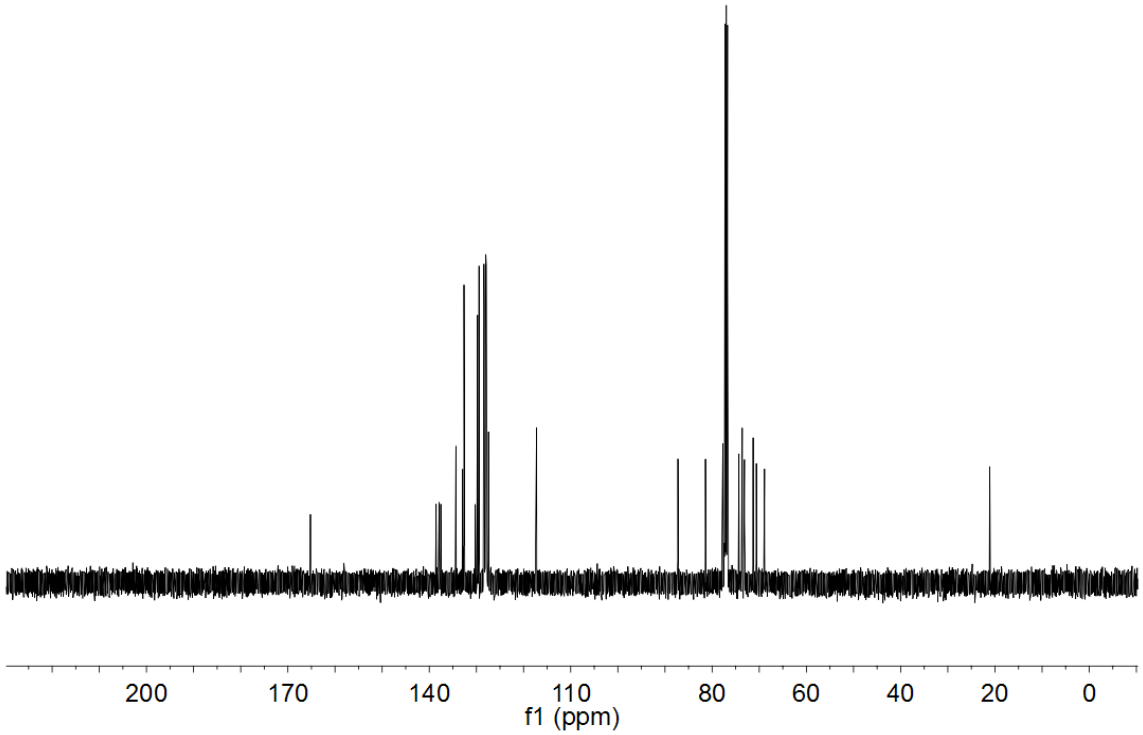


S8

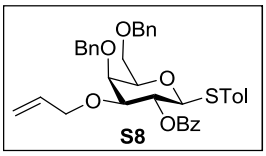


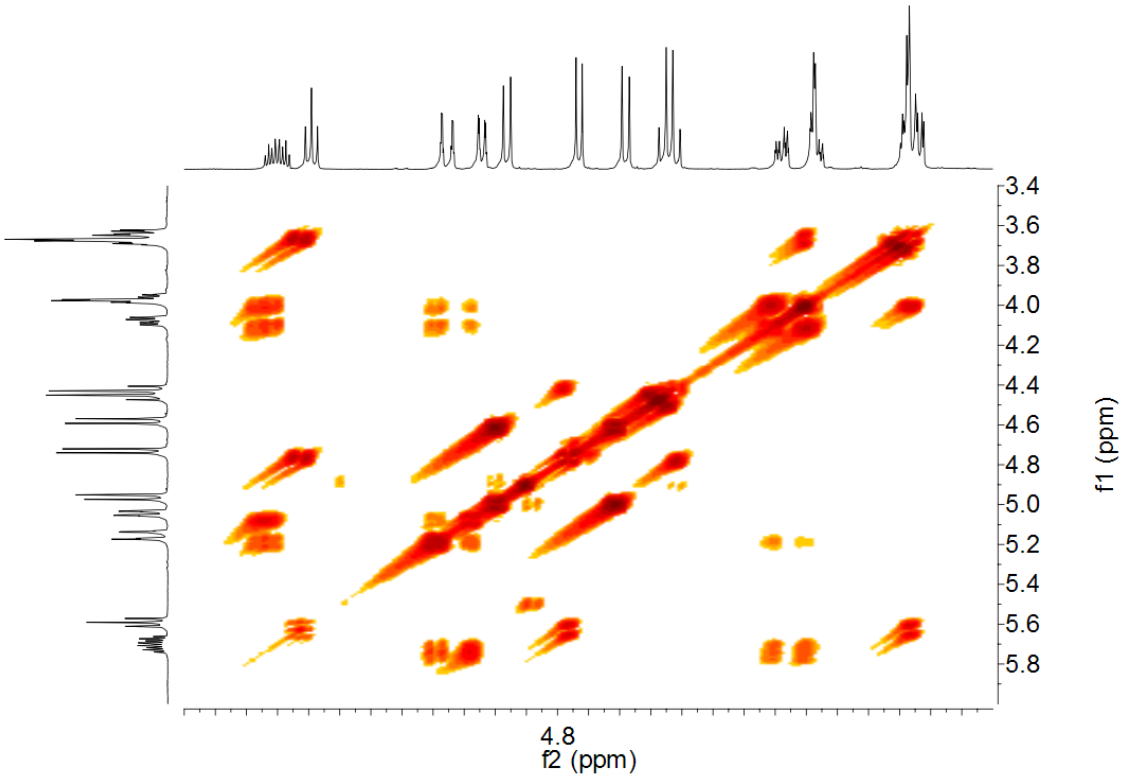
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S8**



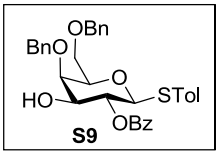


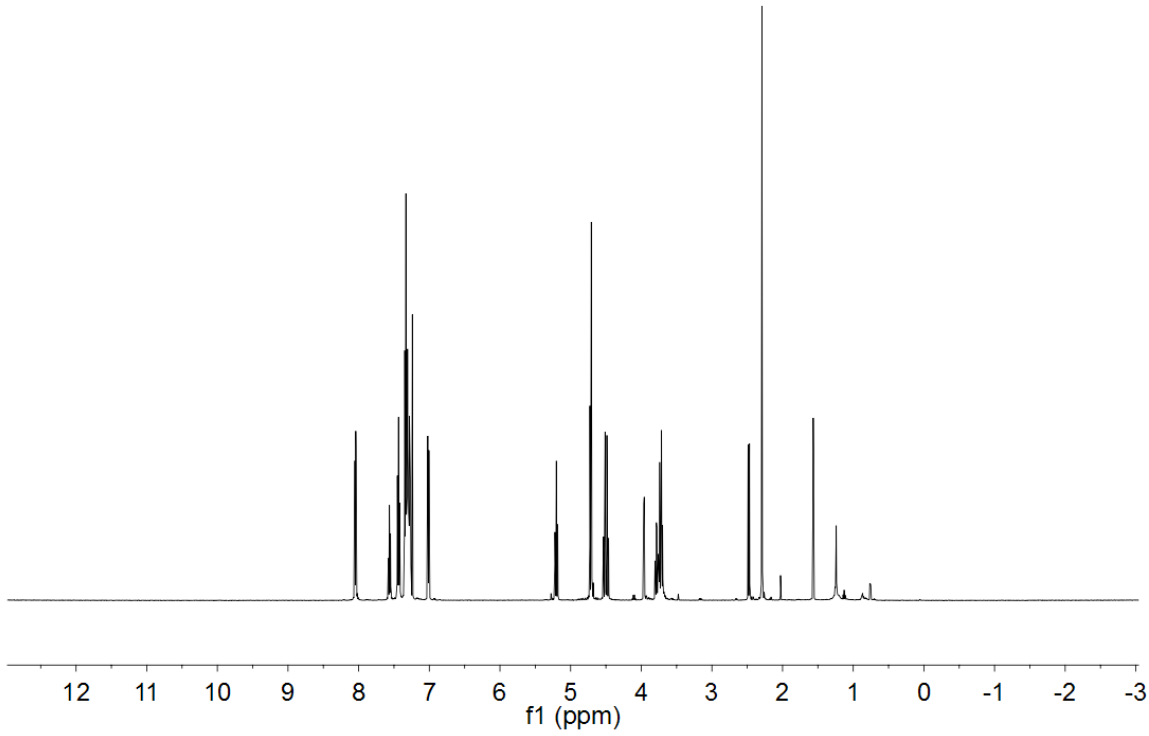
gCOSY ($CDCl_3$, 500 MHz) of **S8**



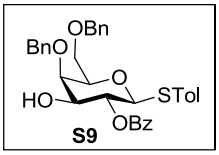


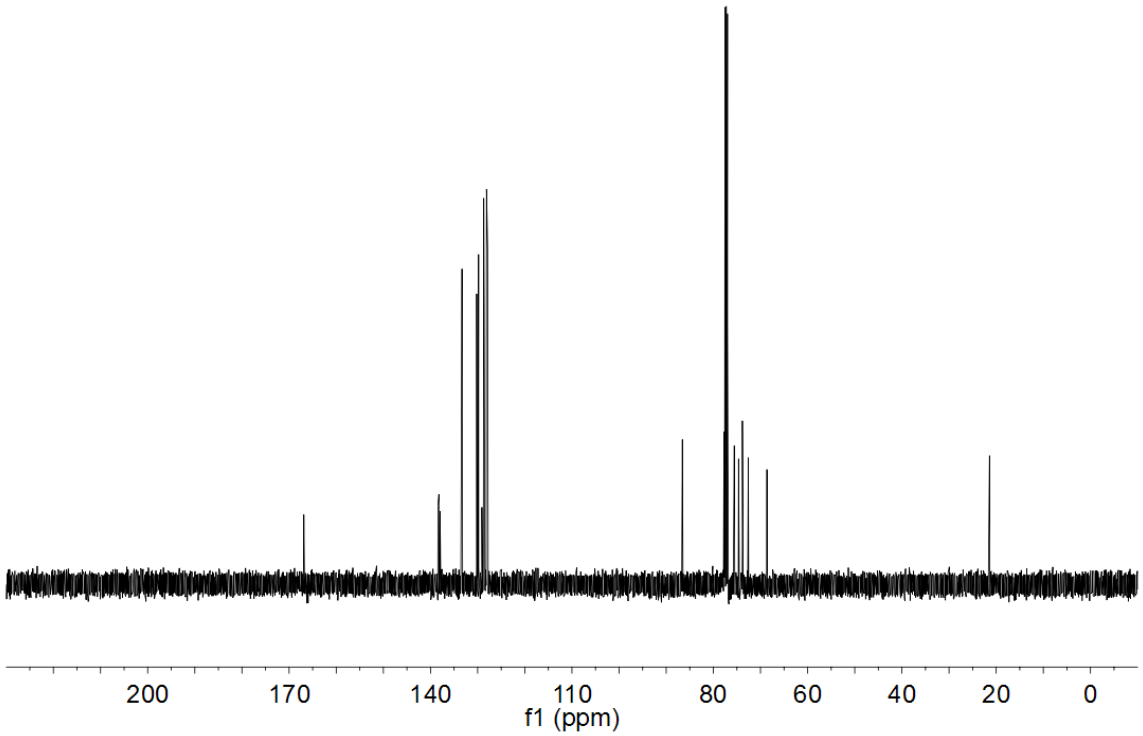
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S9**



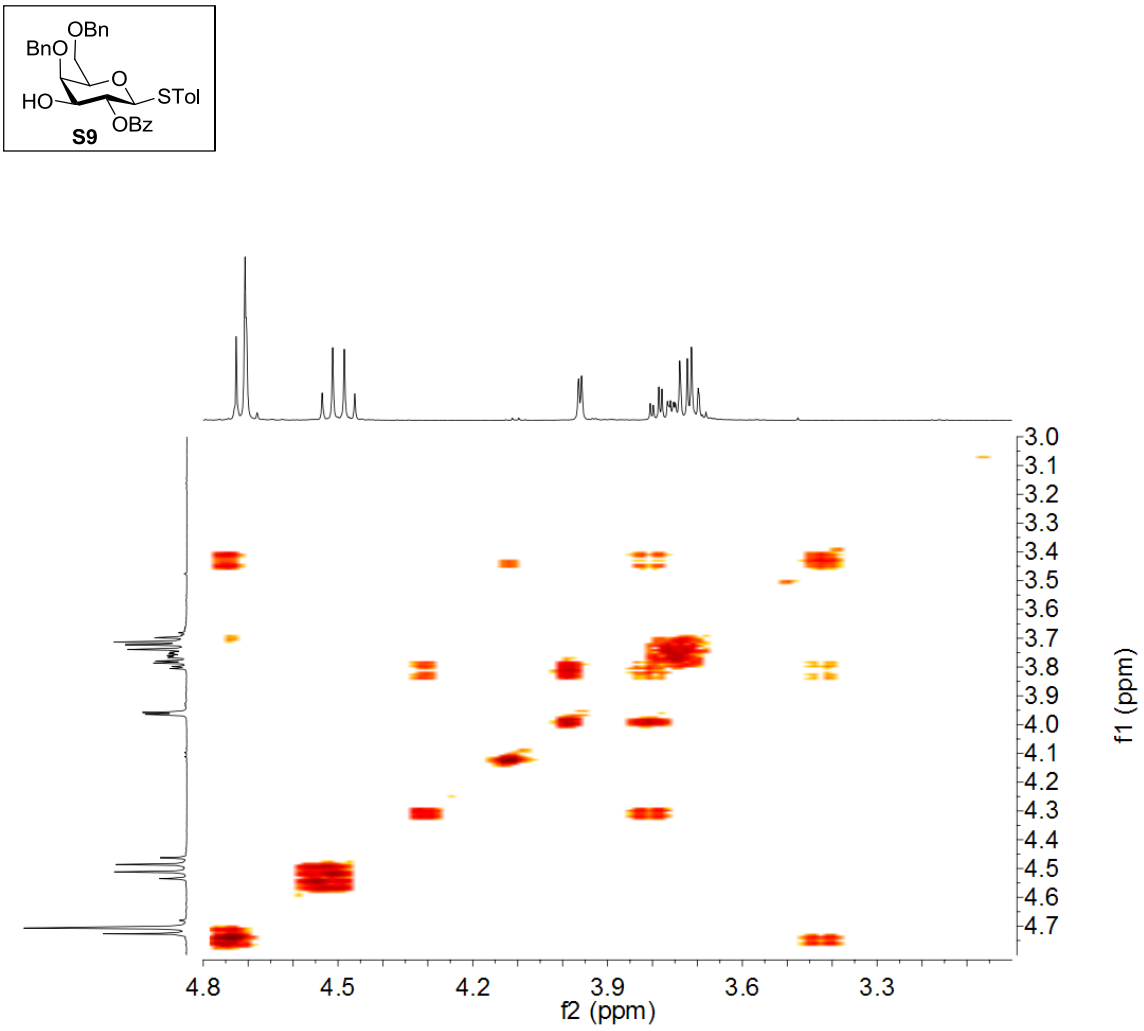


^{13}C-NMR ($CDCl_3$, 125 MHz) of **S9**

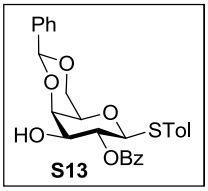


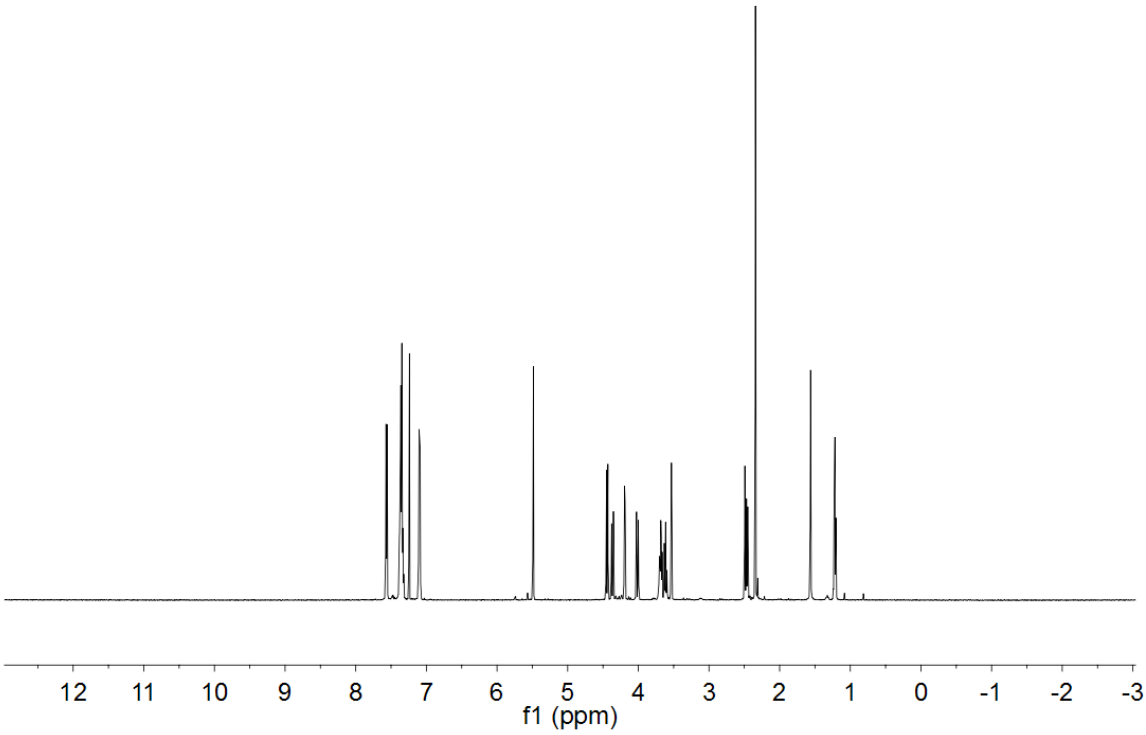


gCOSY ($CDCl_3$, 500 MHz) of **S9**

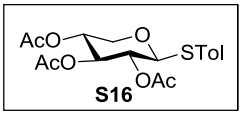


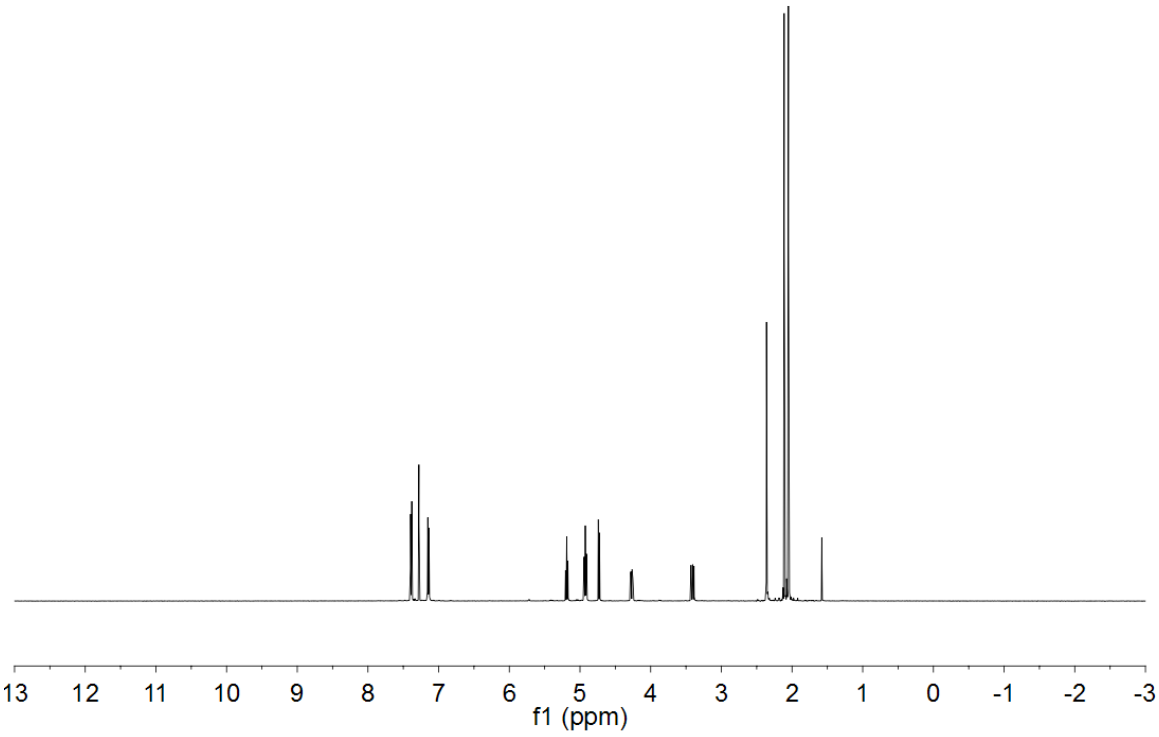
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S13**



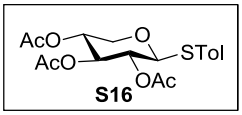


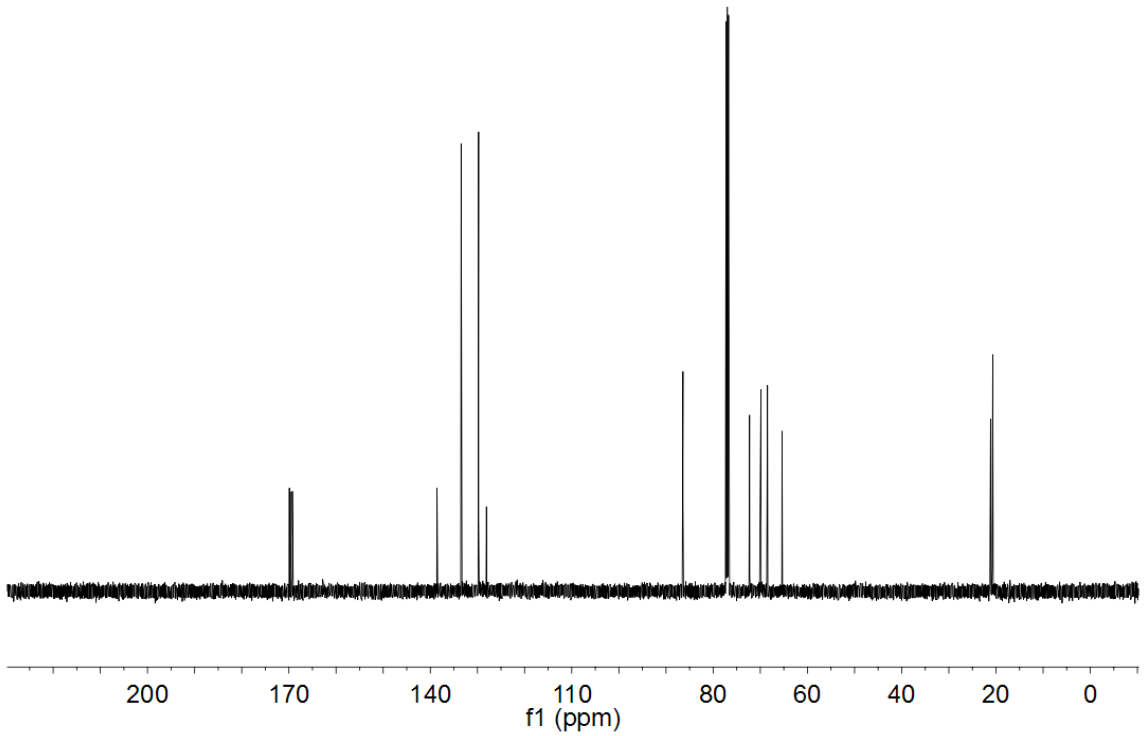
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S16**



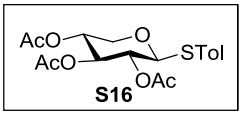


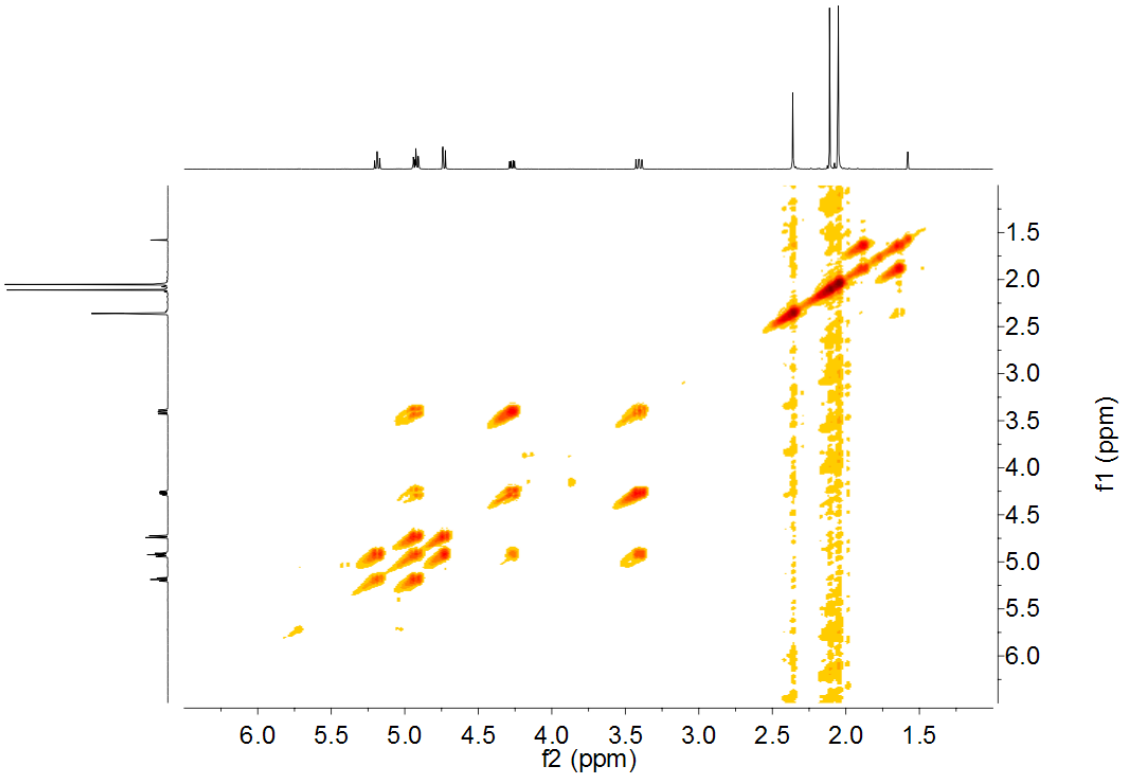
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S16**



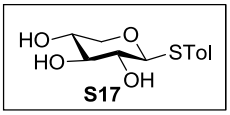


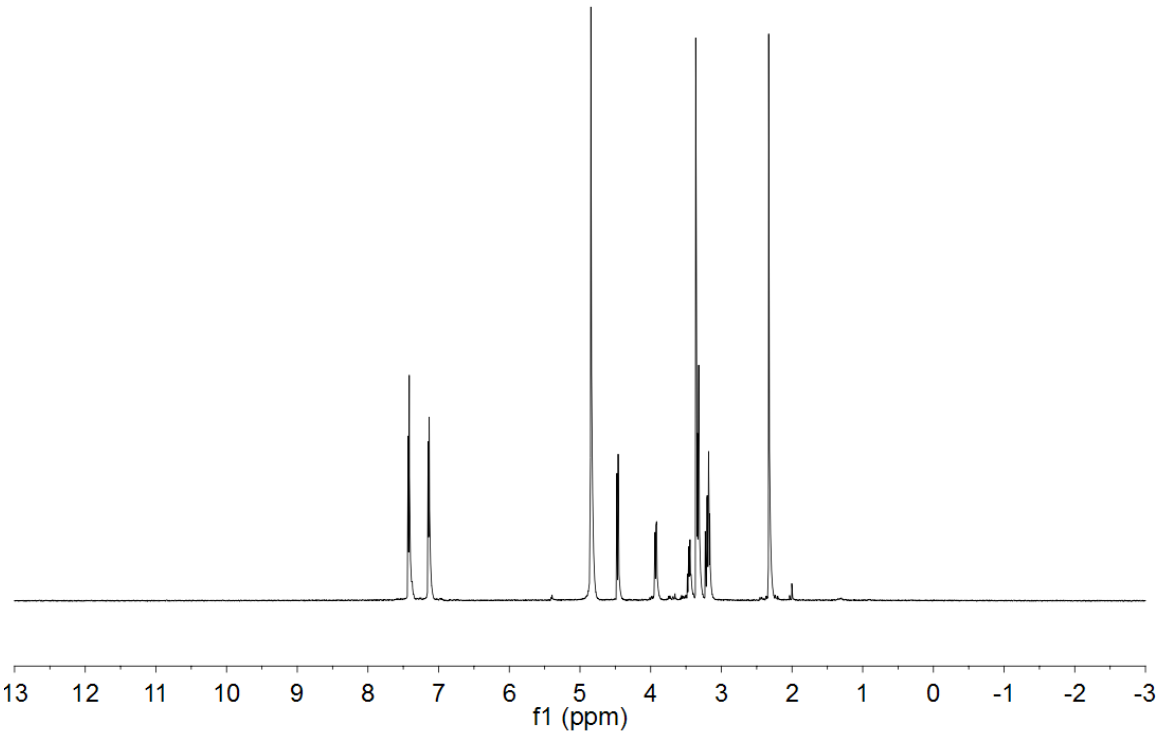
gCOSY ($CDCl_3$, 500 MHz) of **S16**



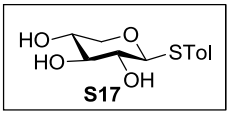


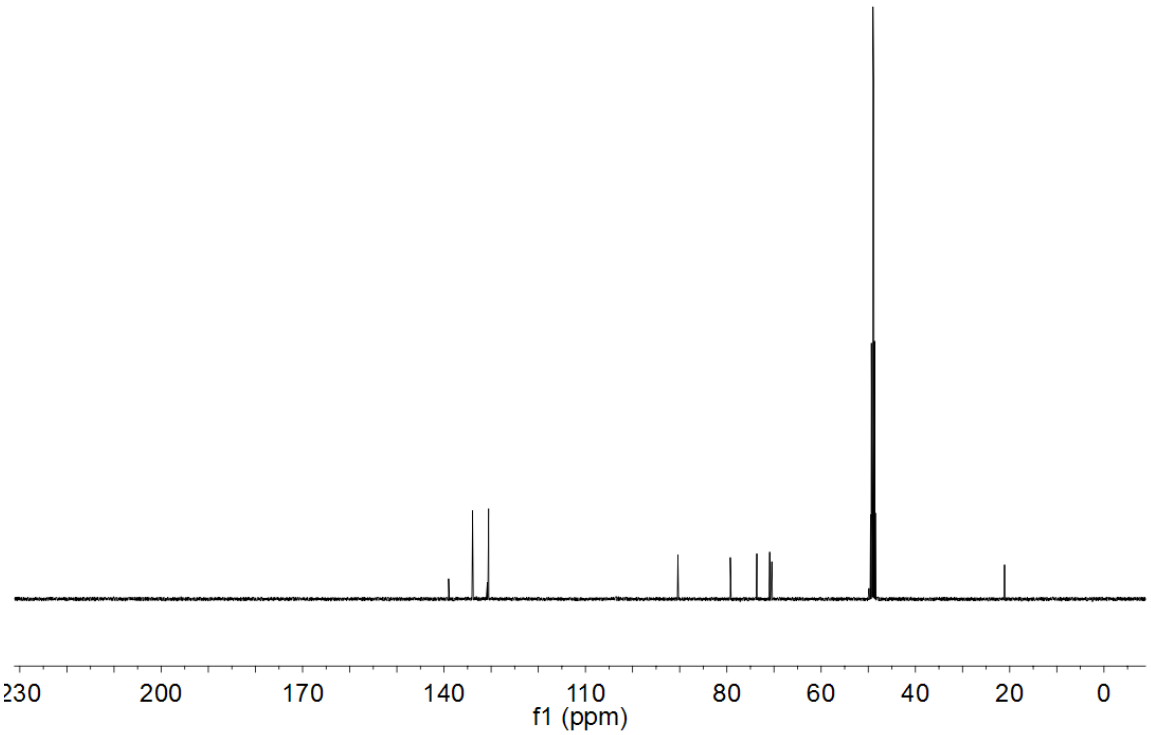
^{1}H-NMR (CD_3OD, 500 MHz) of **S17**



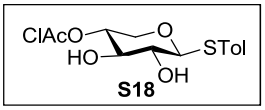


^{13}C-NMR (CD_3OD, 125 MHz) of **S17**

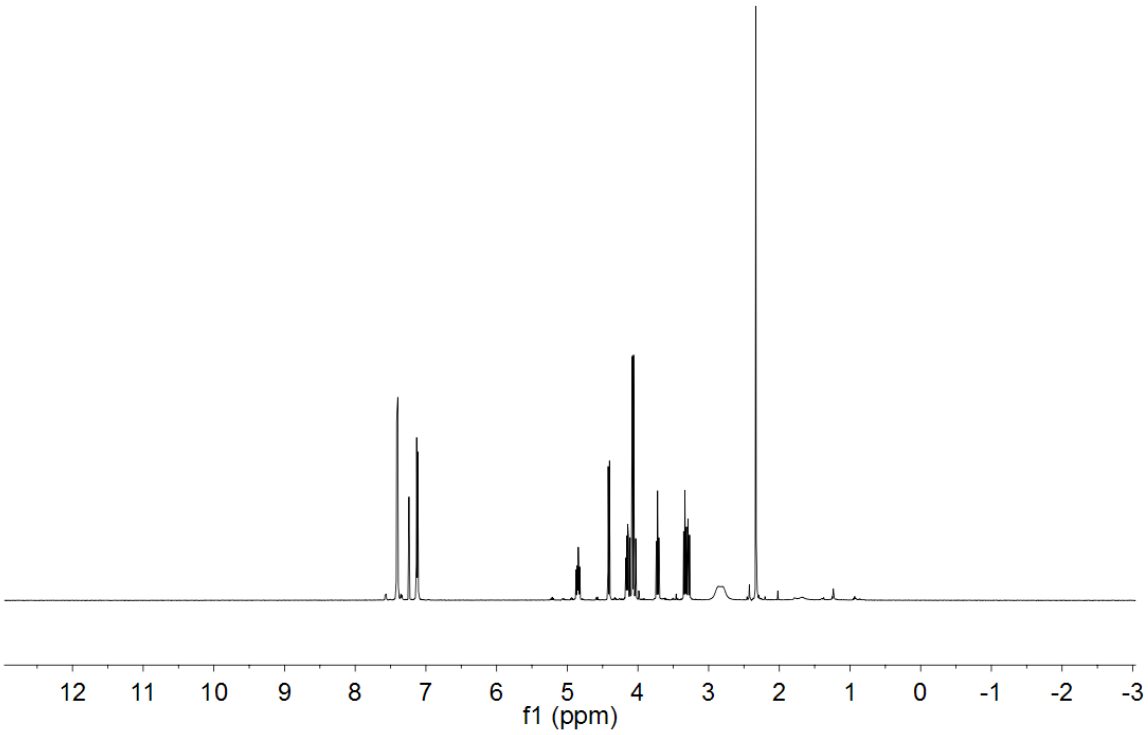




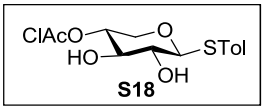
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S18**

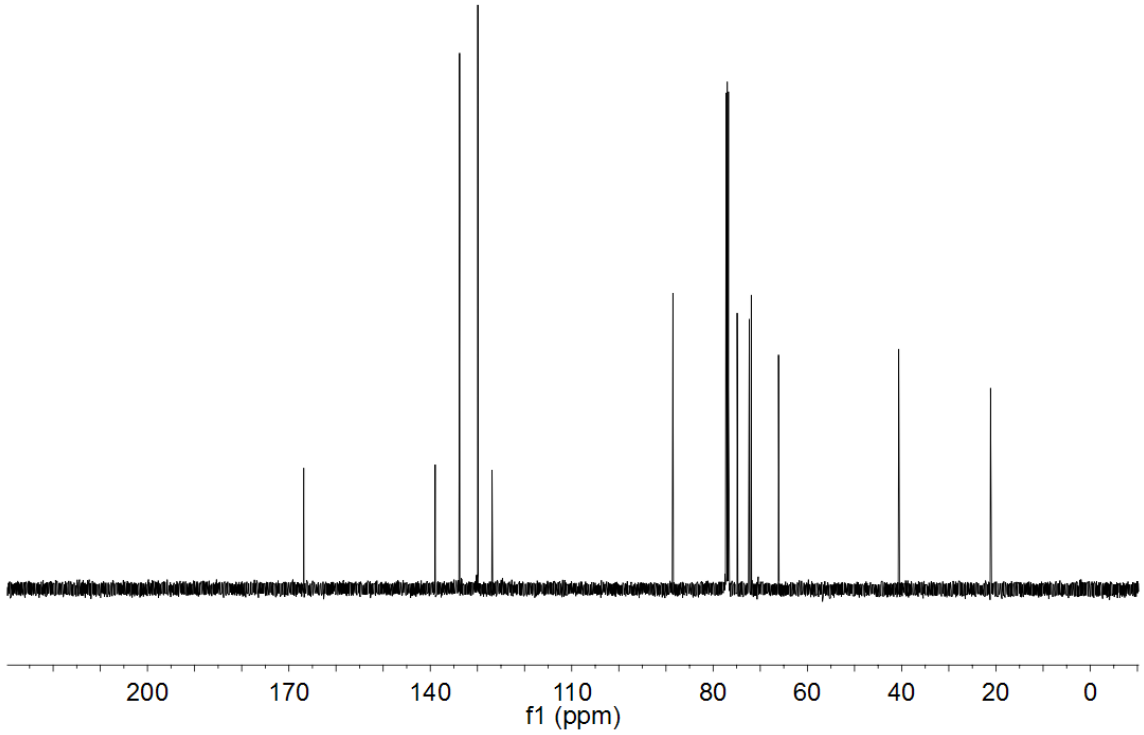


S18

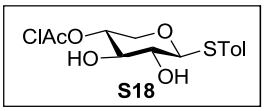


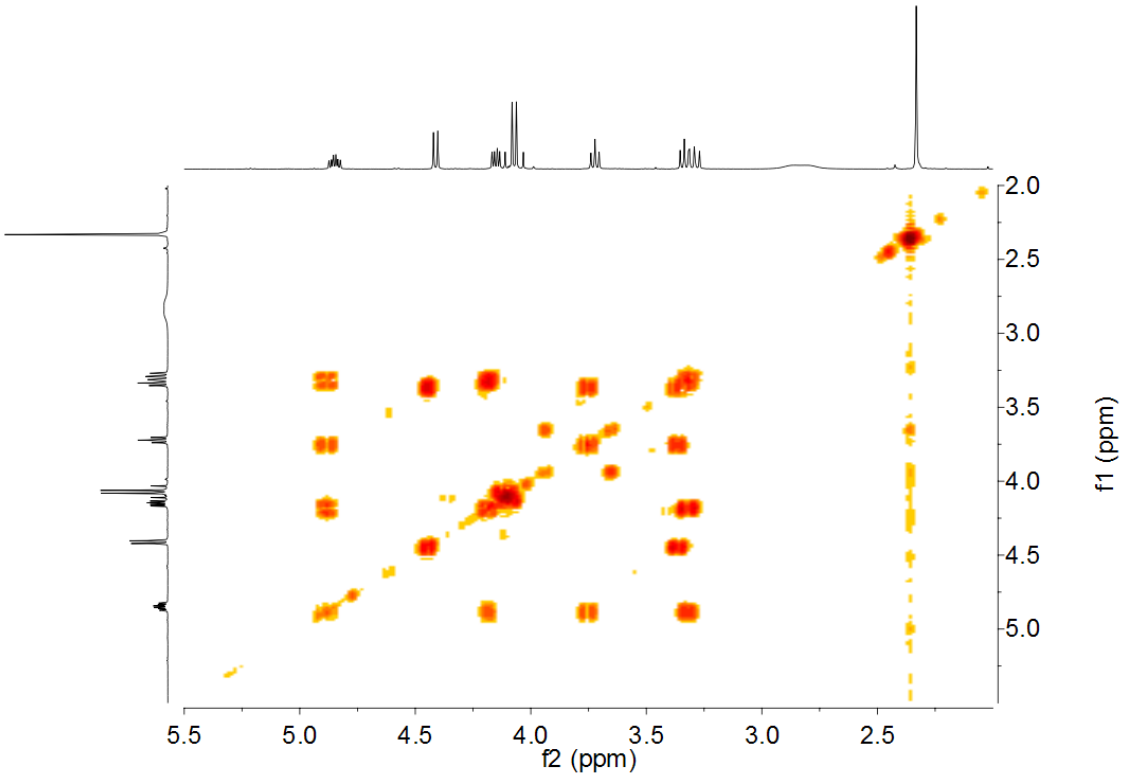
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S18**



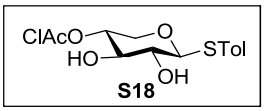


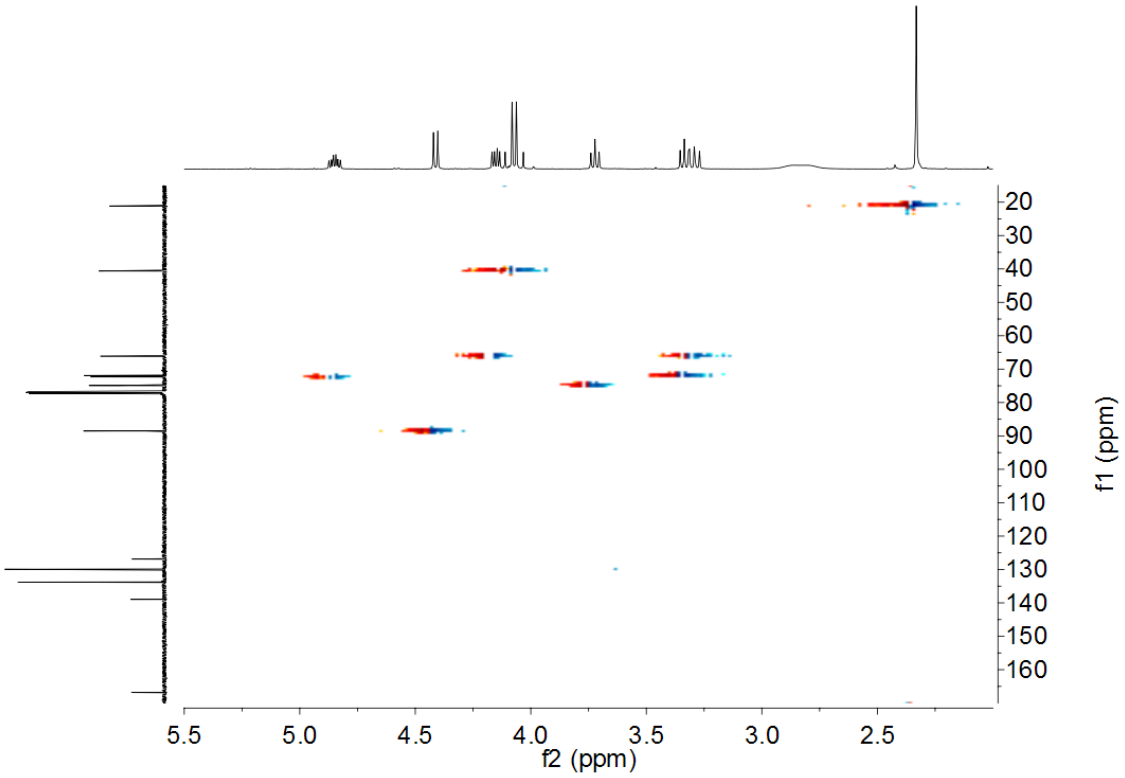
gCOSY ($CDCl_3$, 500 MHz) of **S18**



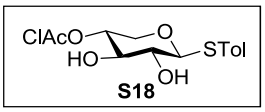


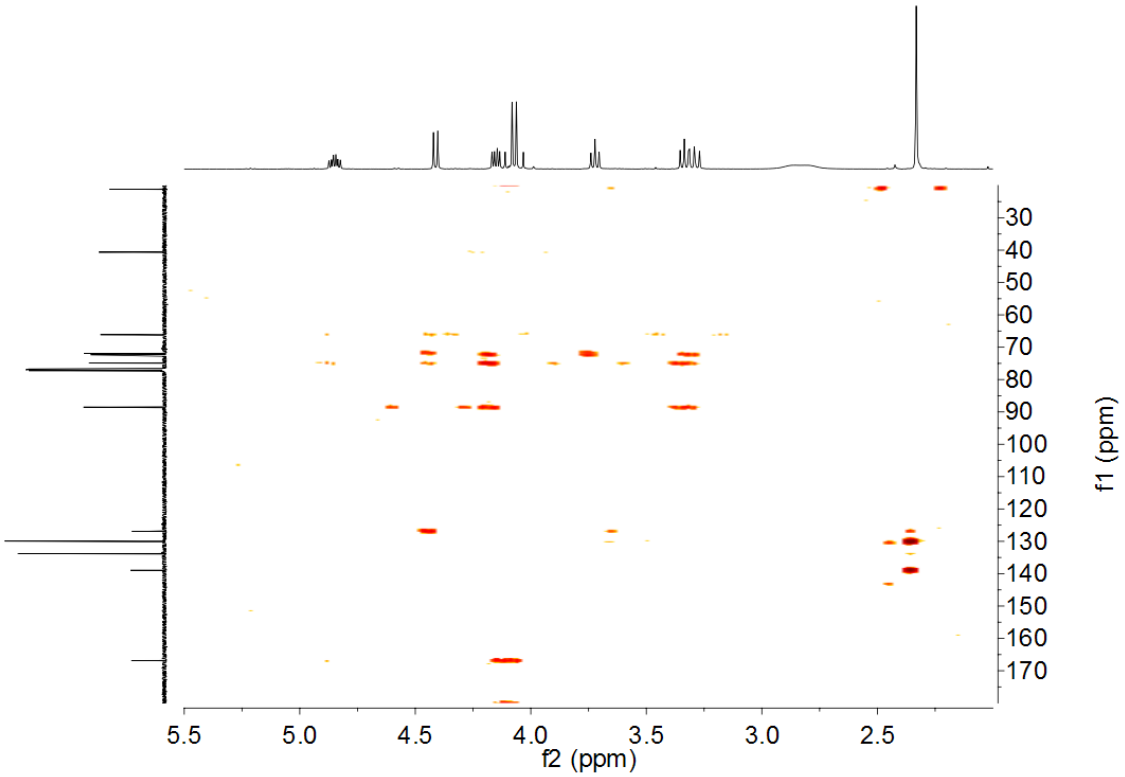
gHMQC ($CDCl_3$, 500 MHz) of **S18**



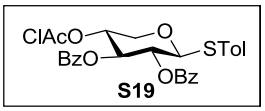


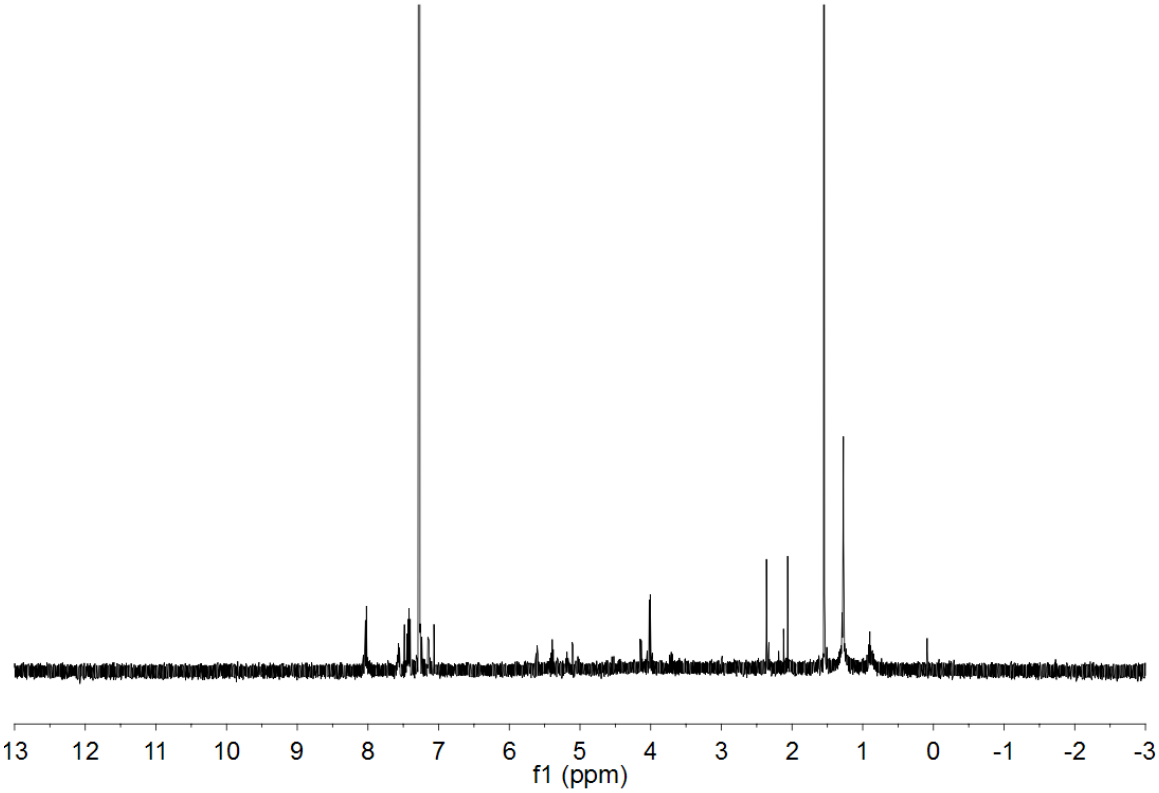
gHMBC ($CDCl_3$, 500 MHz) of **S18**



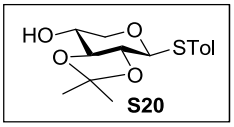


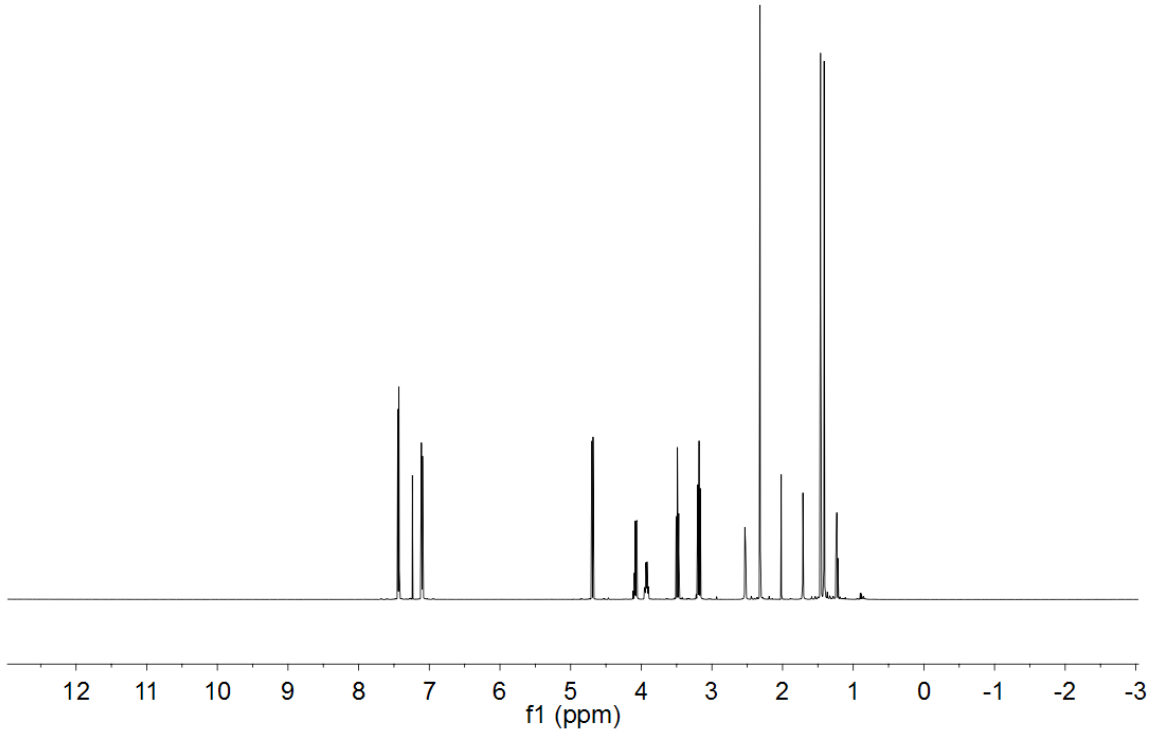
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S19**



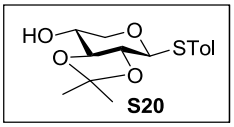


^{1}H-NMR ($CDCl_3$, 500 MHz) of **S20**

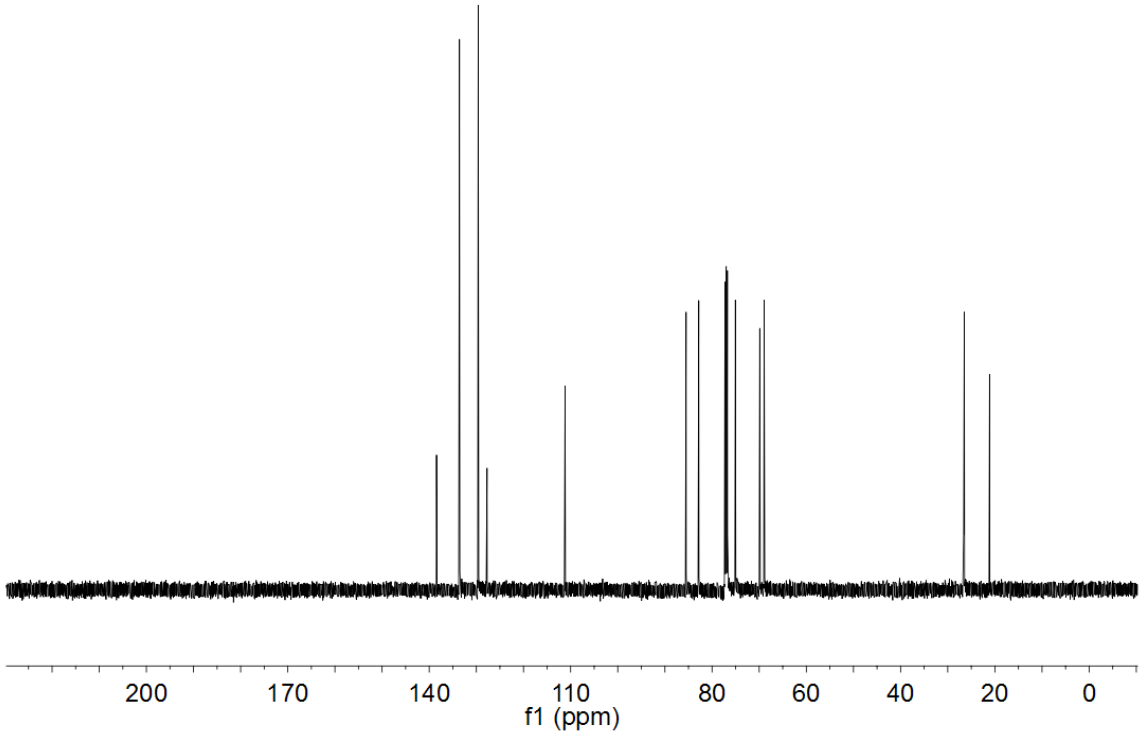




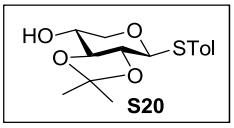
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S20**

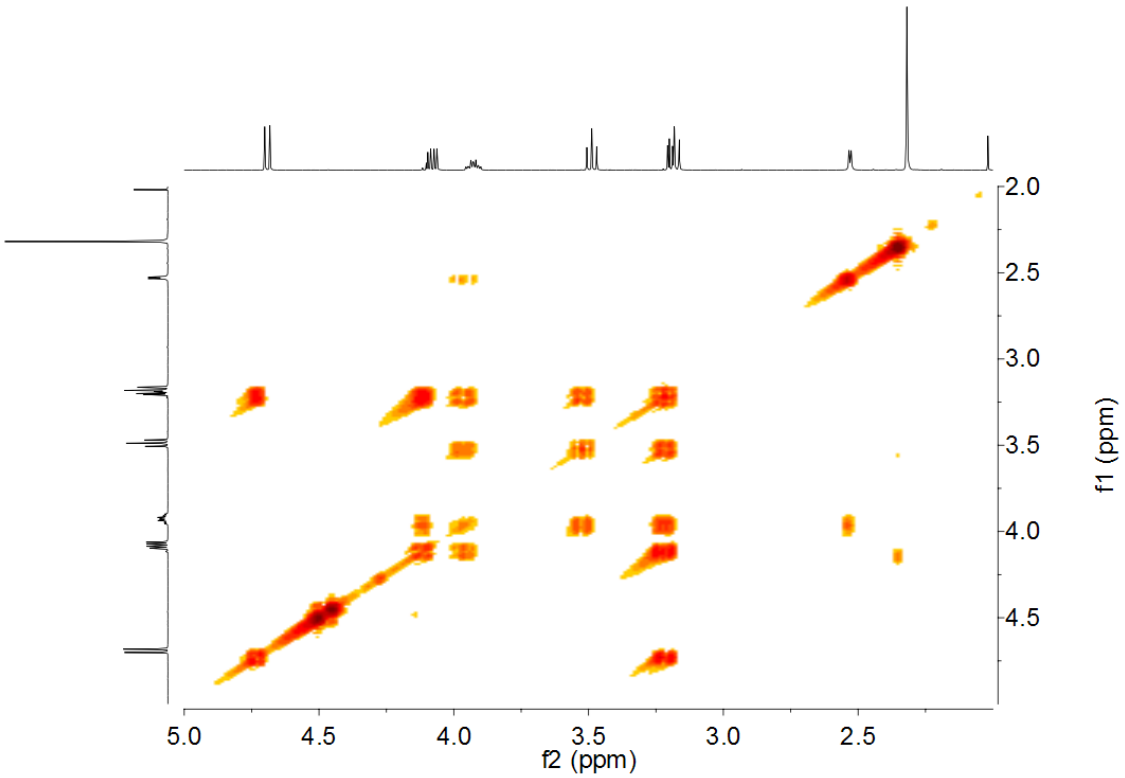


S20

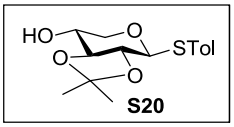


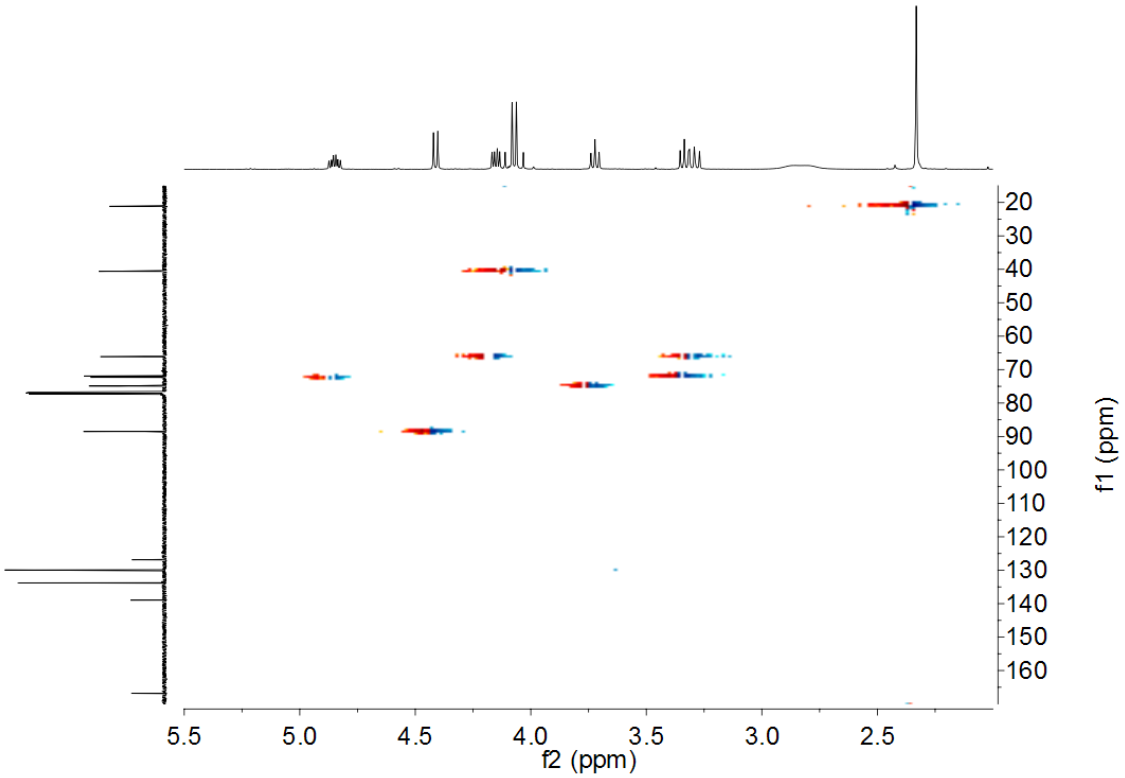
gCOSY ($CDCl_3$, 500 MHz) of **S20**



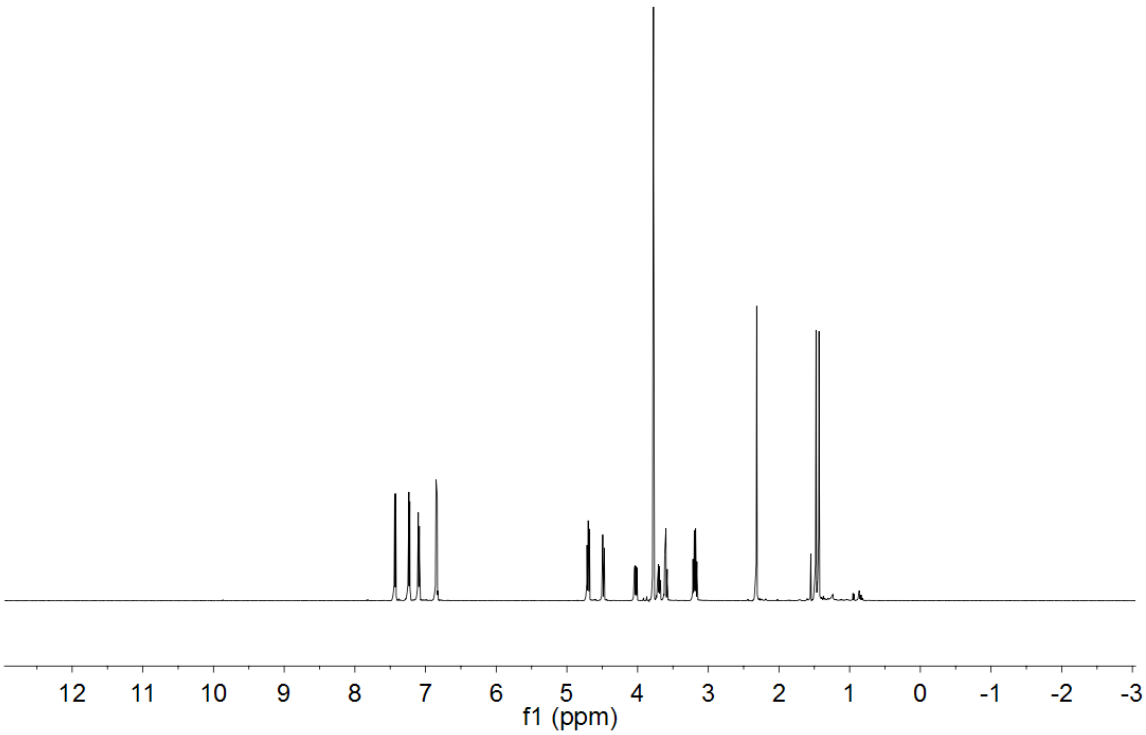


gHMQC ($CDCl_3$, 500 MHz) of **S20**

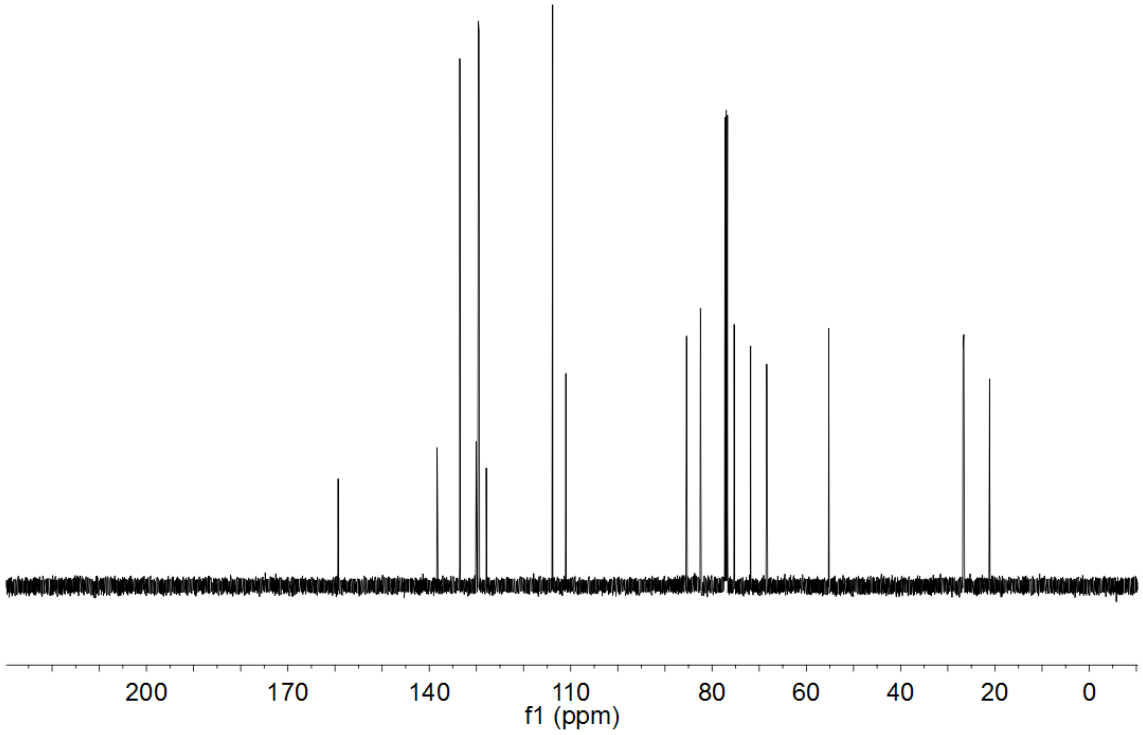




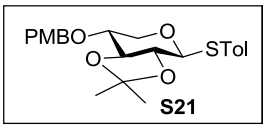
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S21**

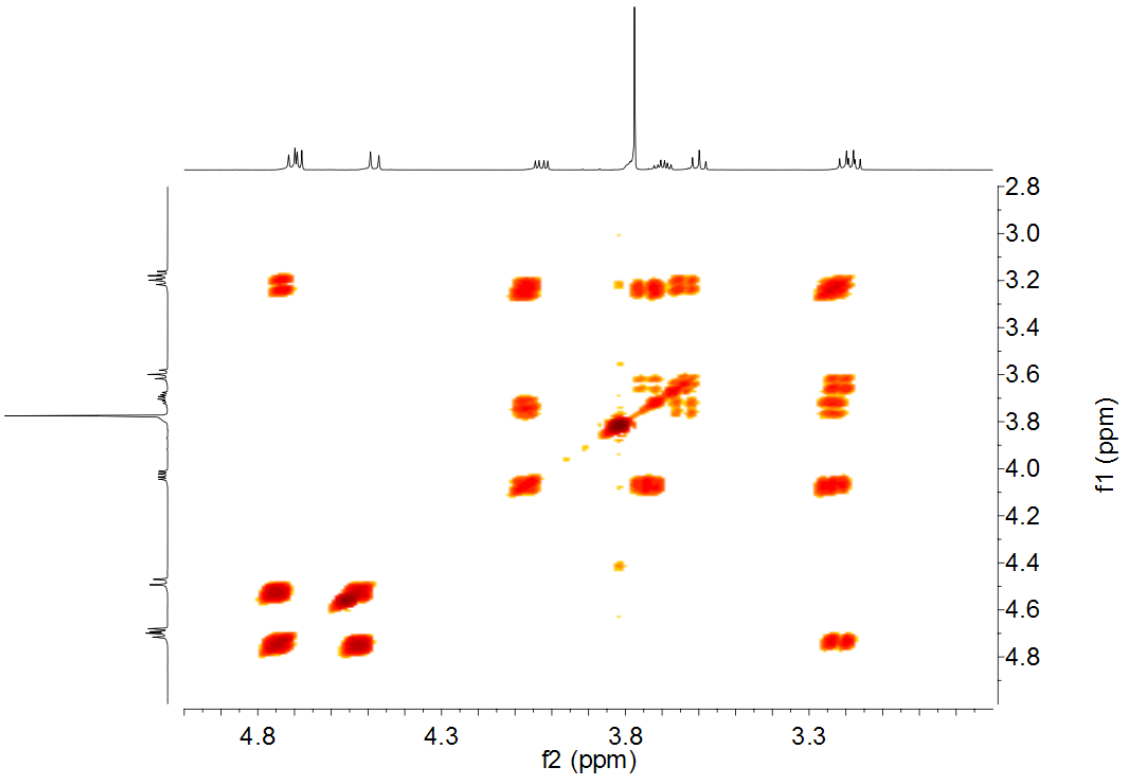


^{13}C-NMR ($CDCl_3$, 125 MHz) of **S21**

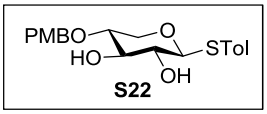


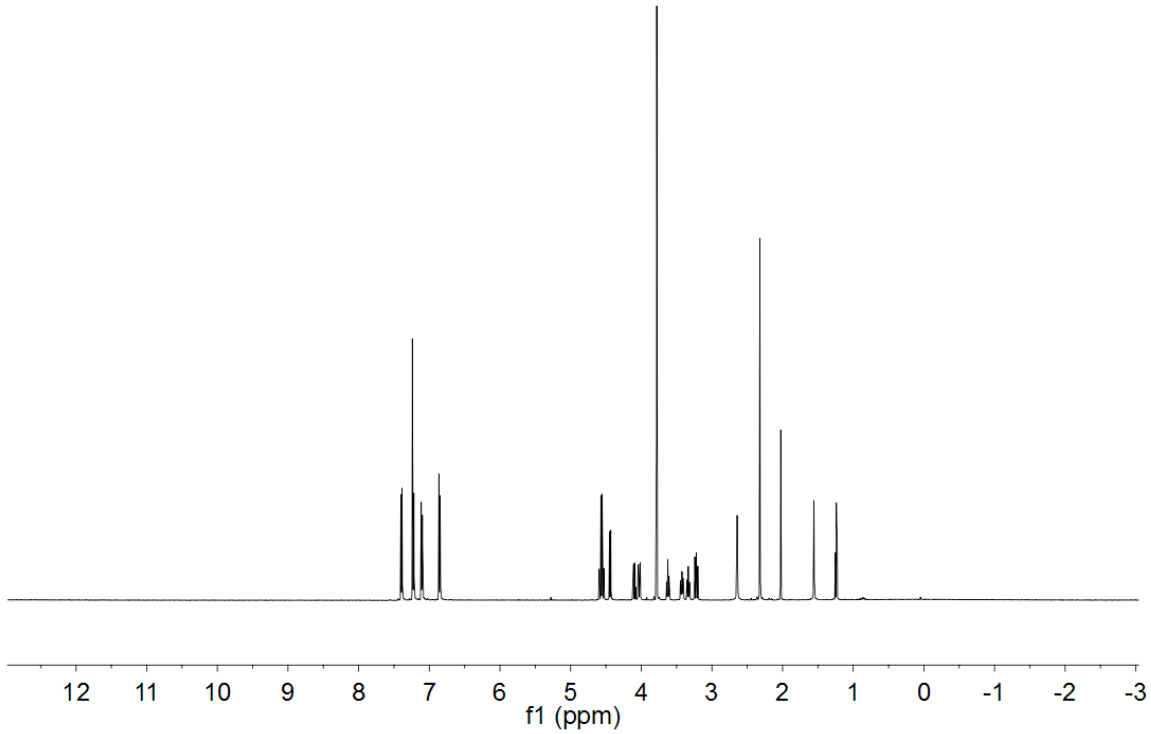
gCOSY ($CDCl_3$, 500 MHz) of **S21**



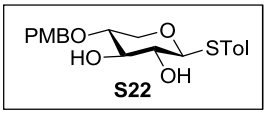


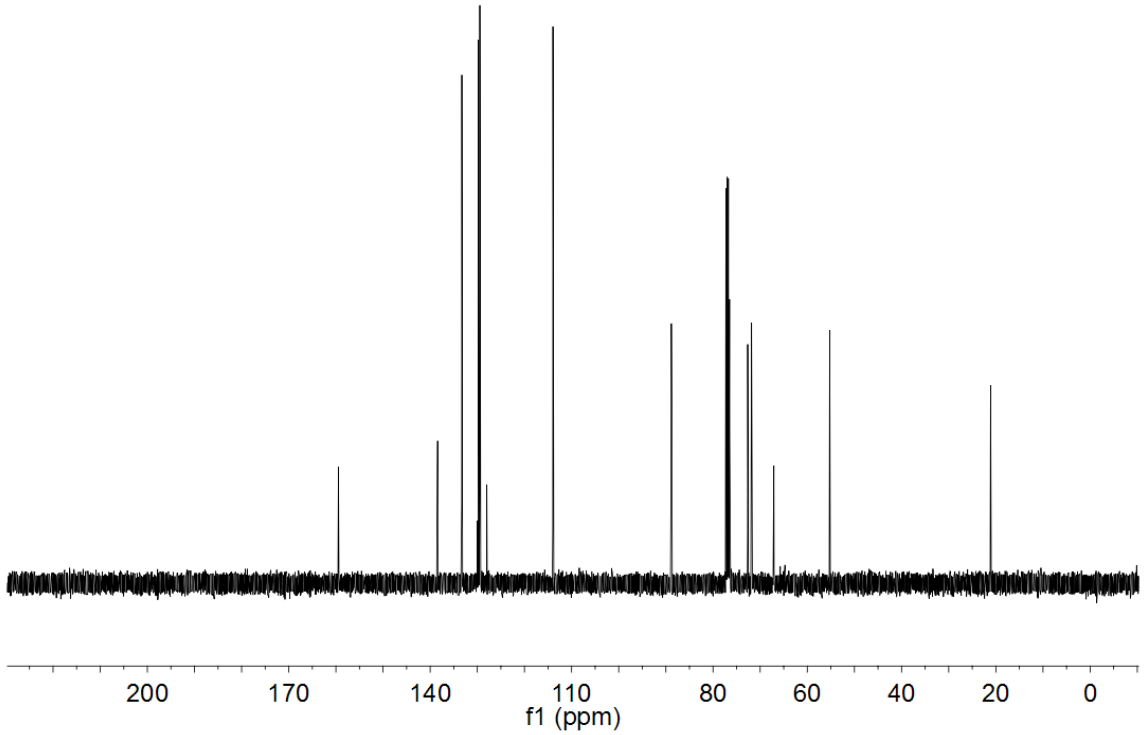
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S22**



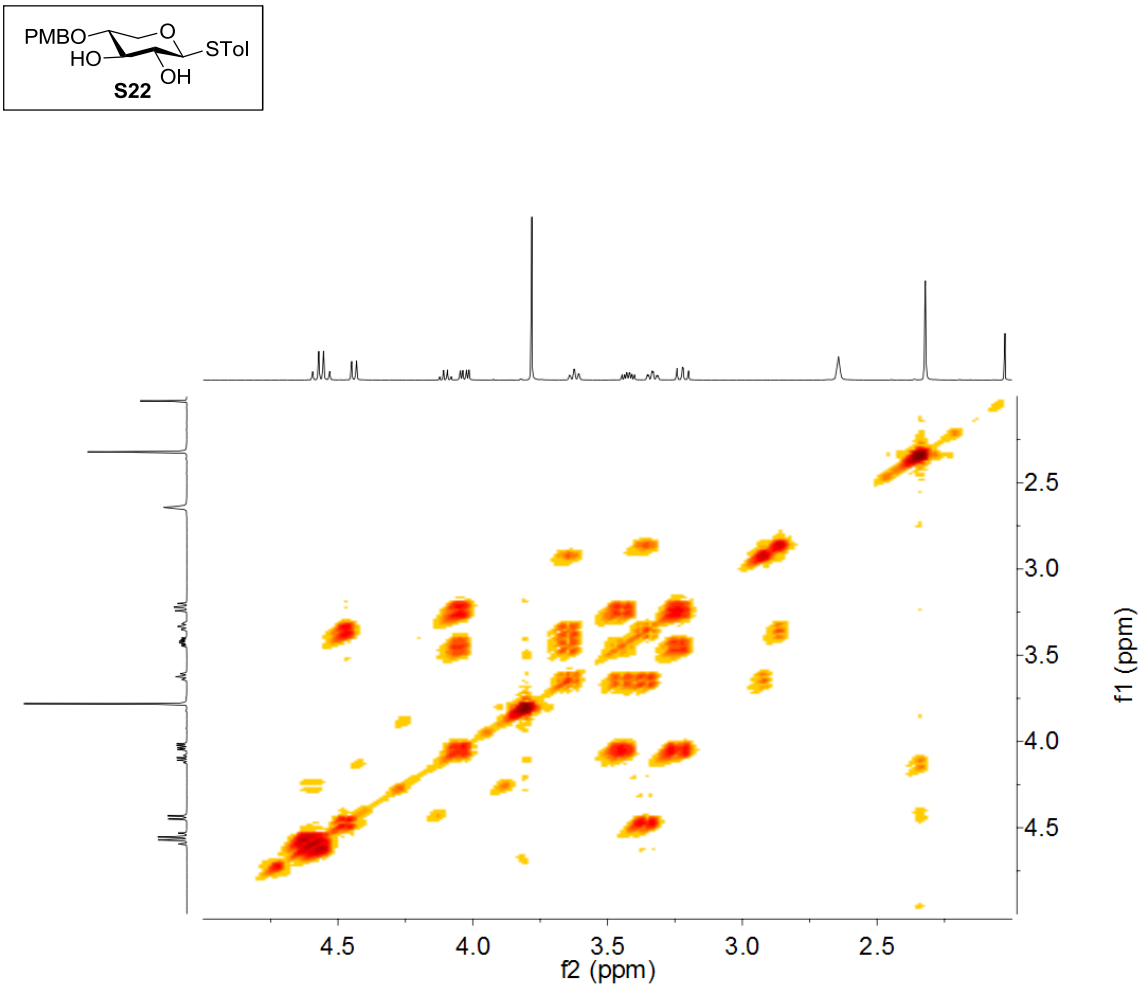


^{13}C-NMR ($CDCl_3$, 125 MHz) of **S22**

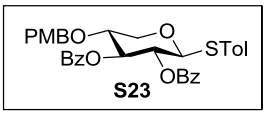




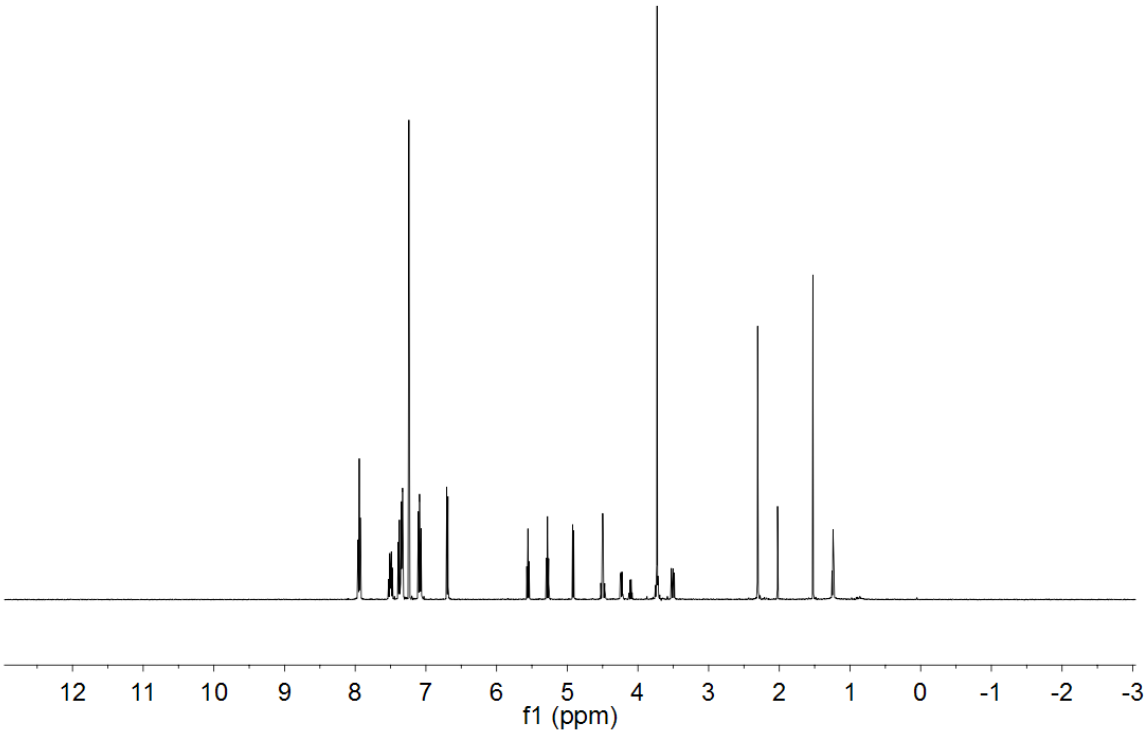
gCOSY ($CDCl_3$, 500 MHz) of **S22**



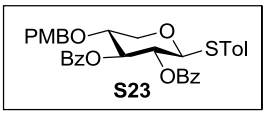
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S23**

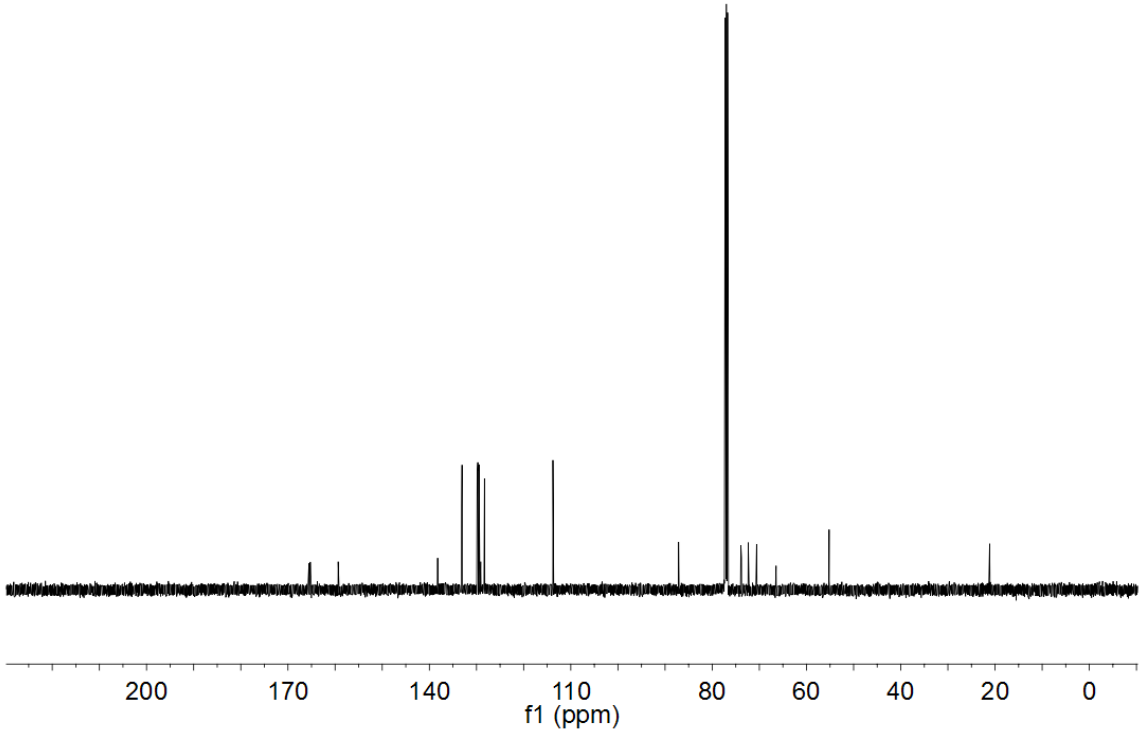


S23

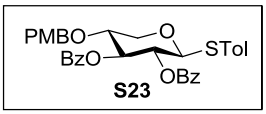


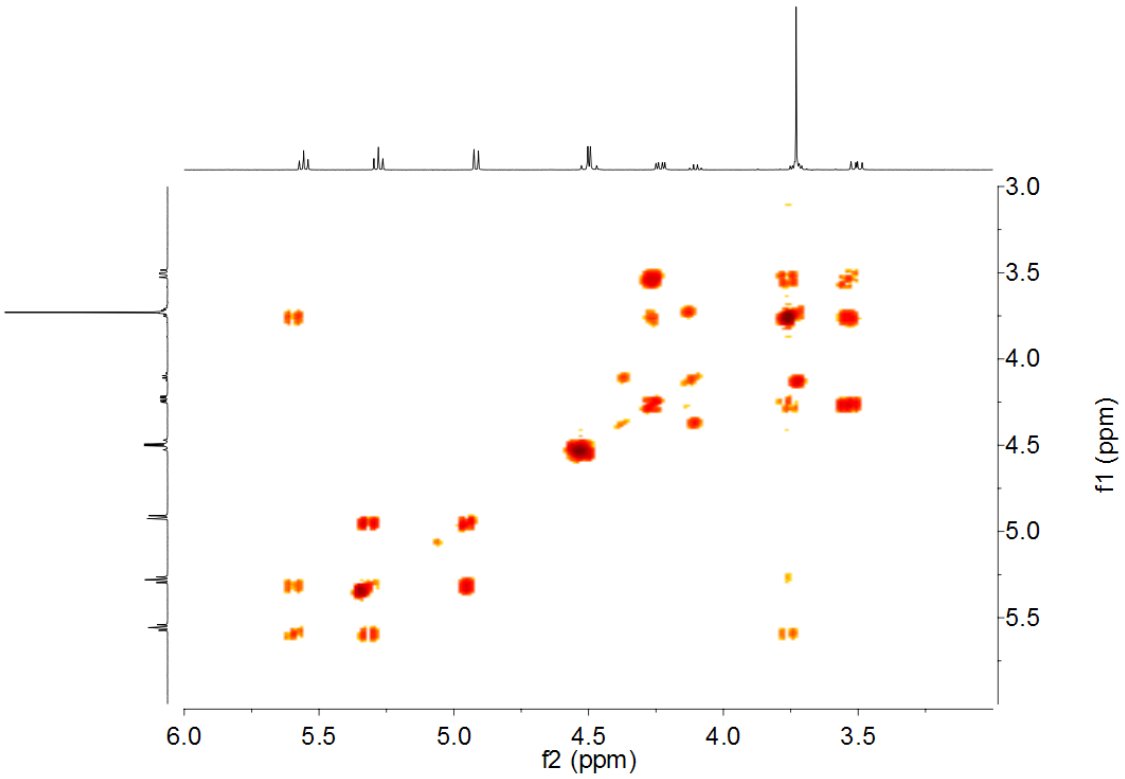
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S23**



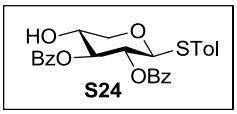


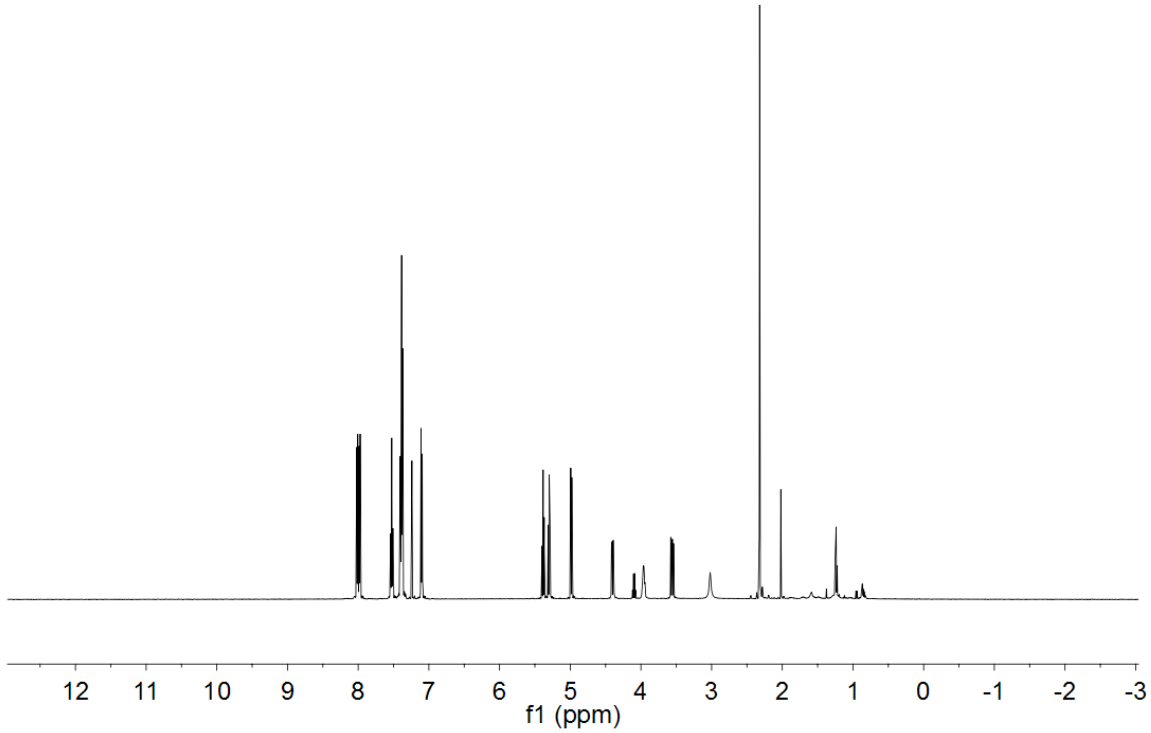
gCOSY ($CDCl_3$, 500 MHz) of **S23**



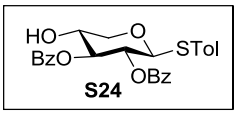


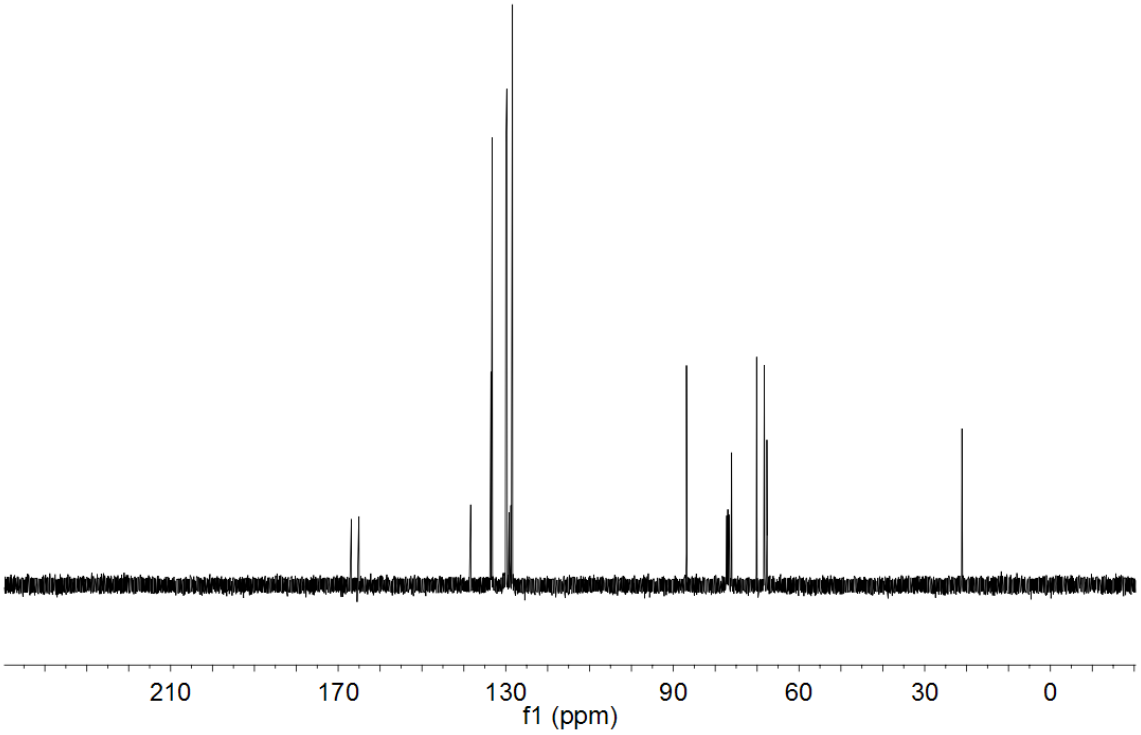
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S24**



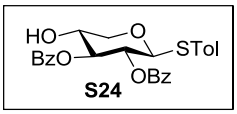


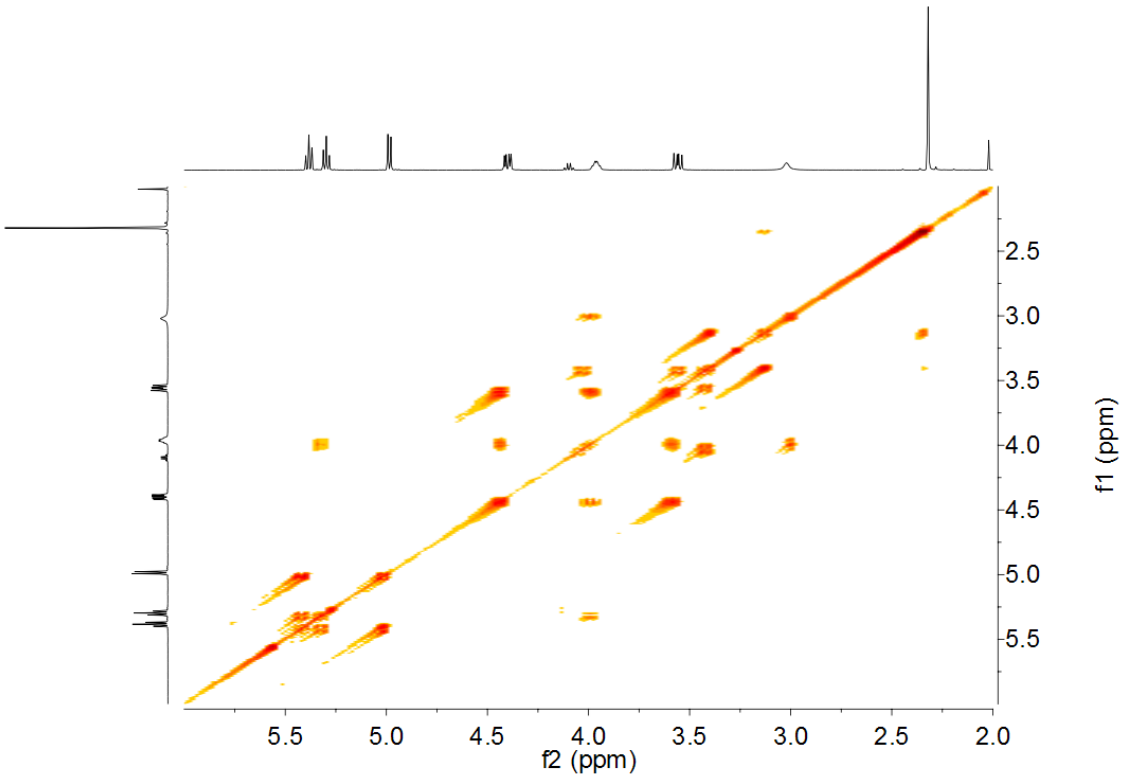
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S24**



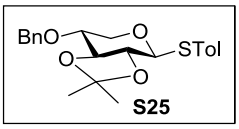


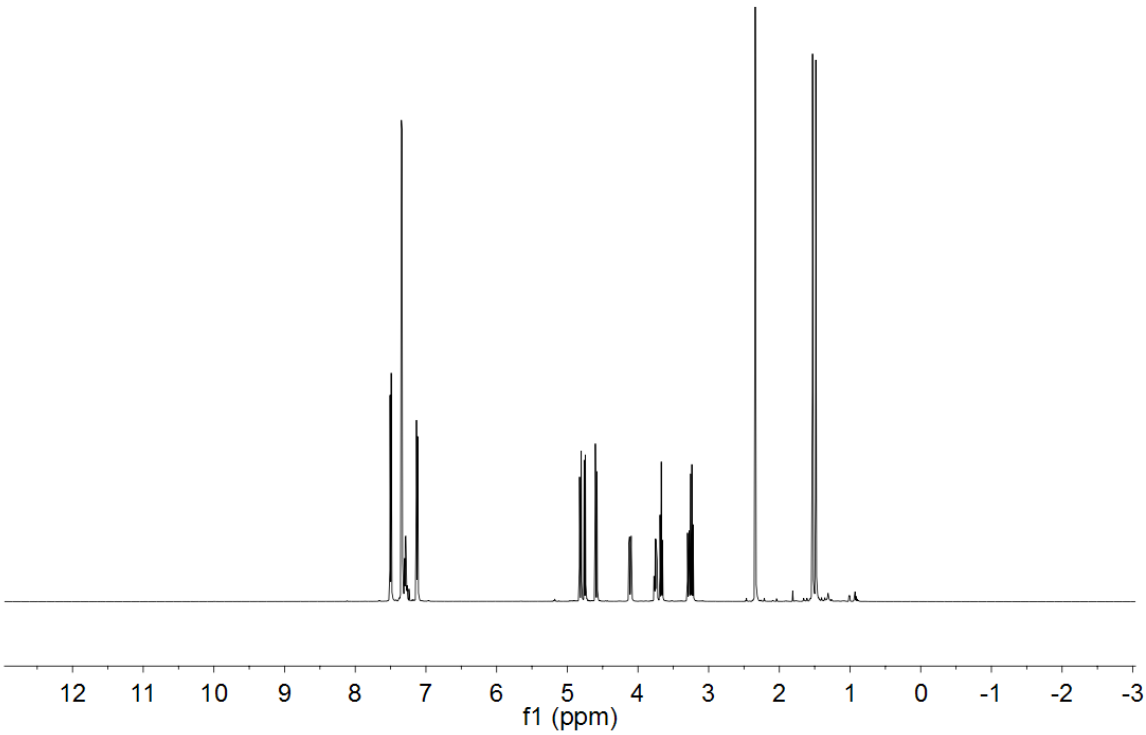
gCOSY ($CDCl_3$, 500 MHz) of **S24**



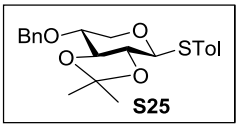


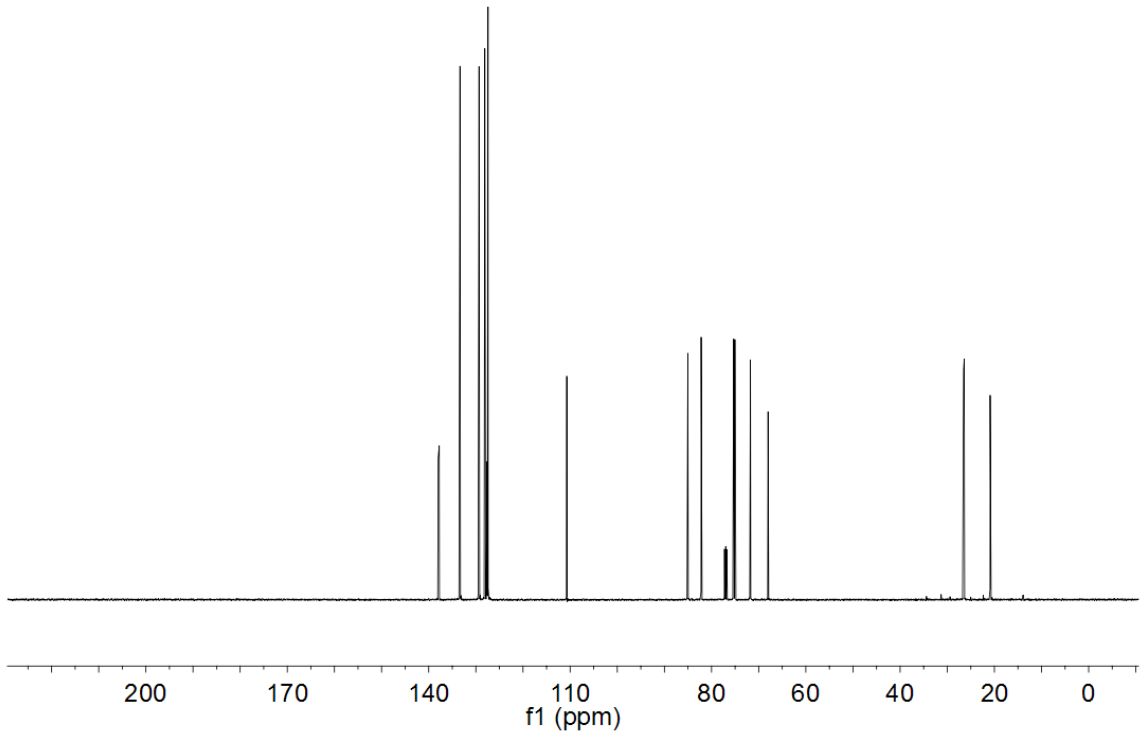
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S25**



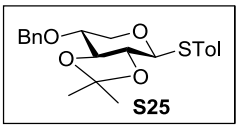


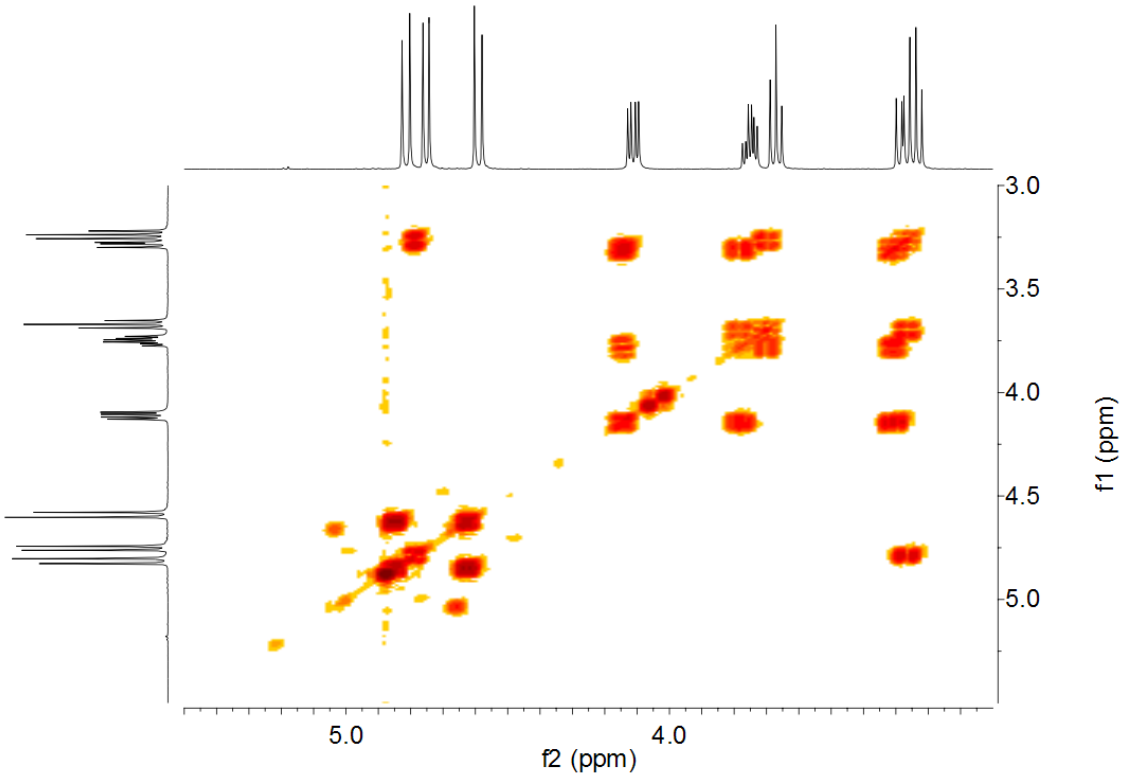
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S25**



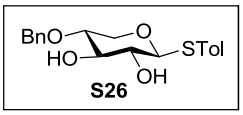


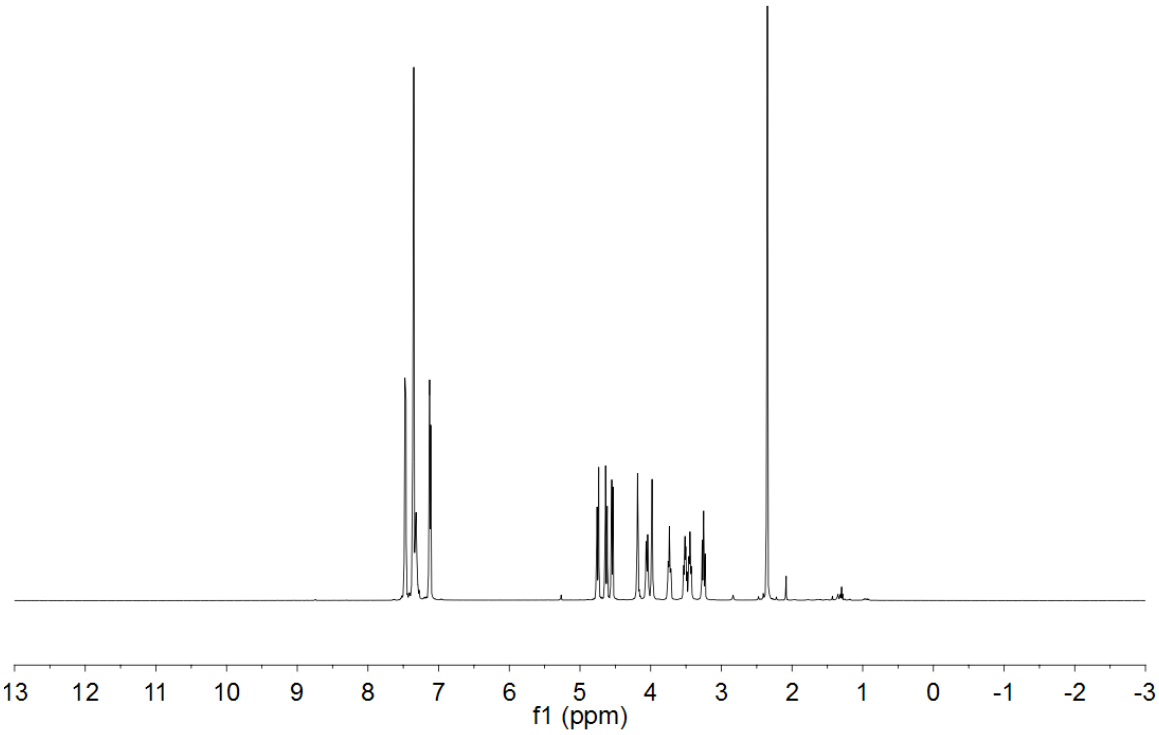
gCOSY ($CDCl_3$, 500 MHz) of **S25**



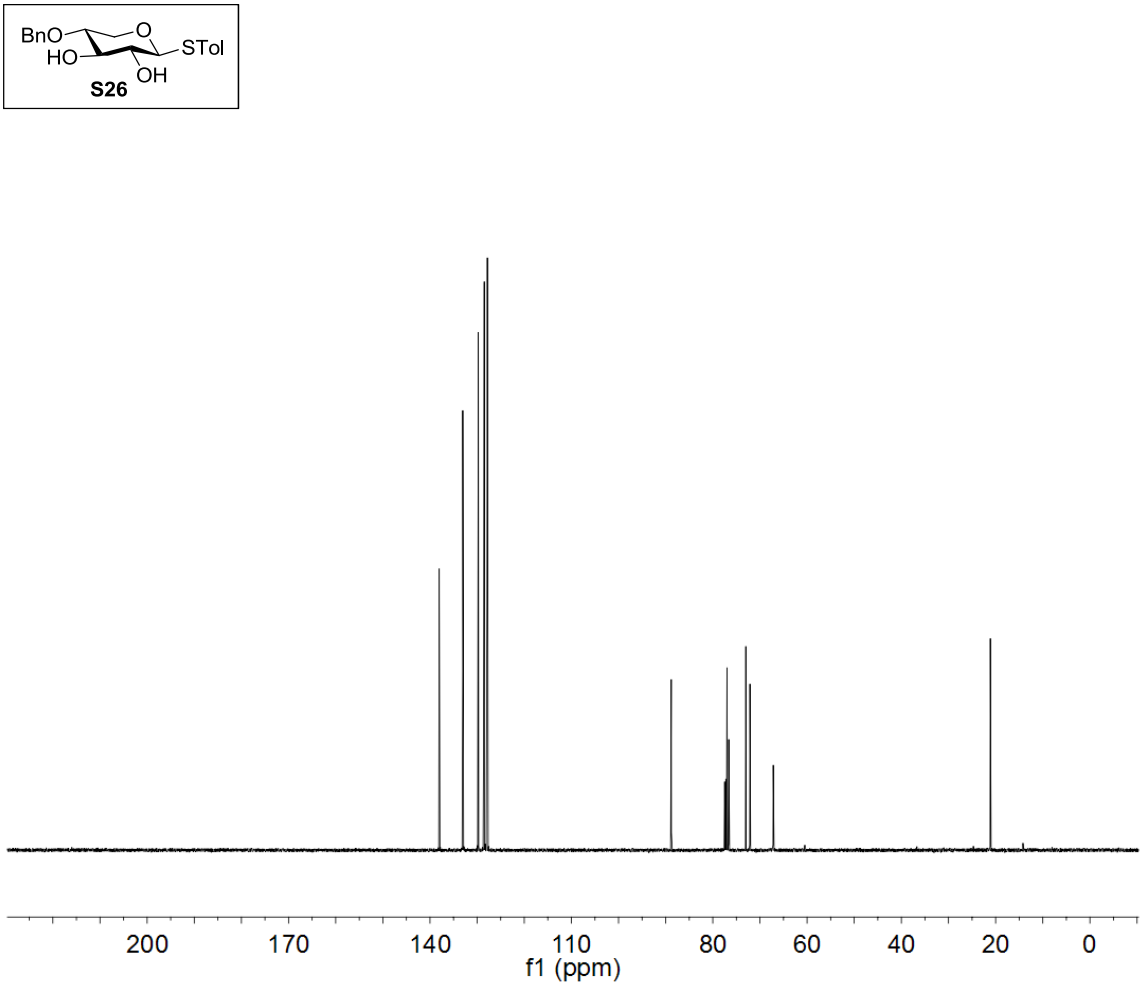


^{1}H-NMR ($CDCl_3$, 500 MHz) of **S26**

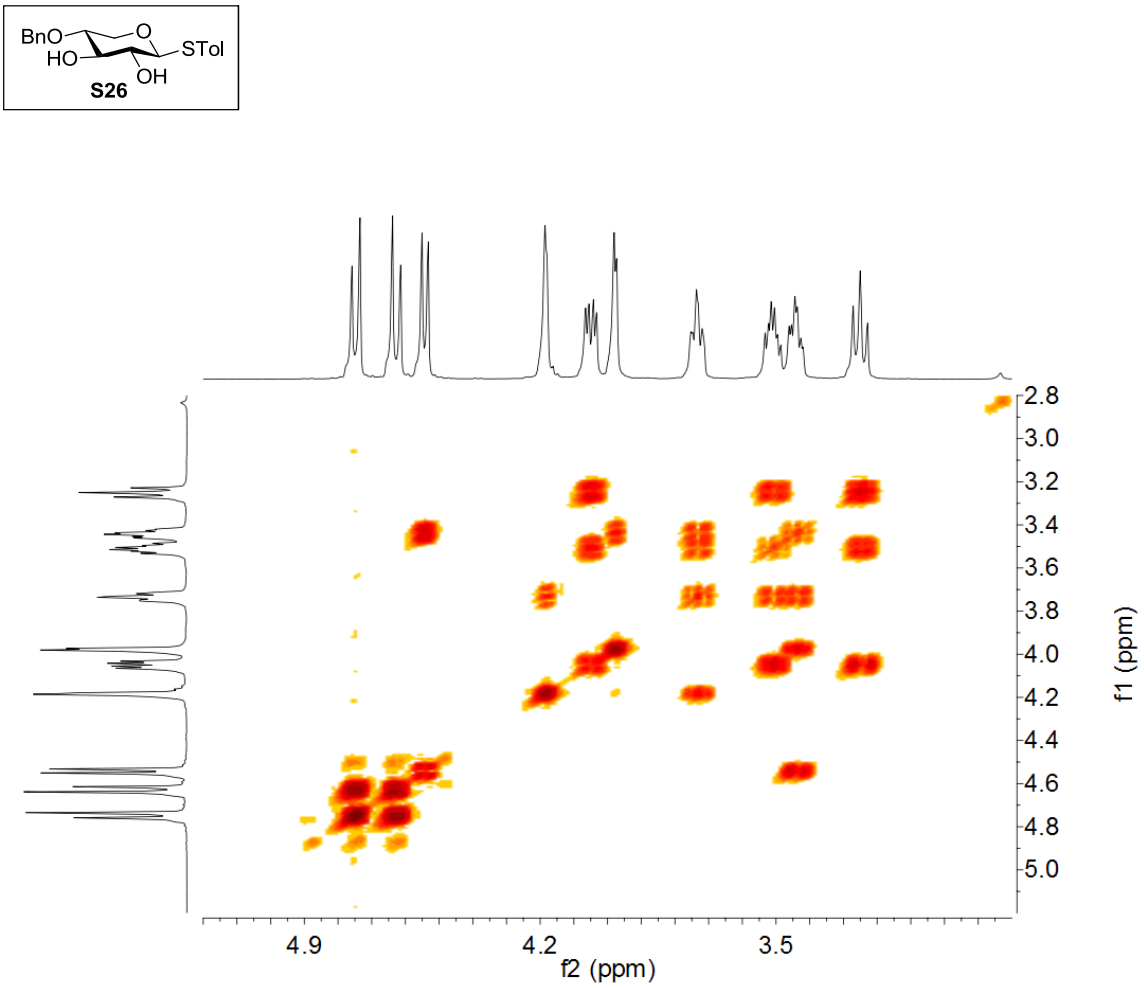




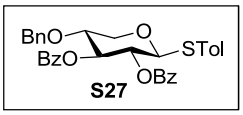
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S26**

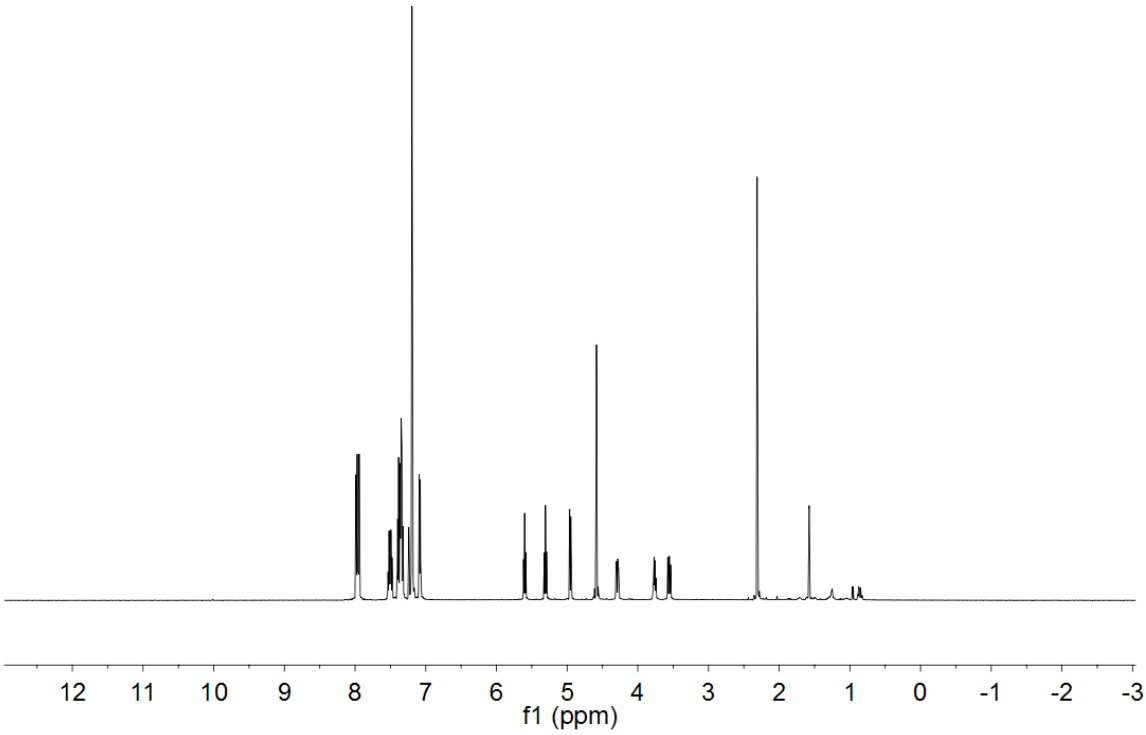


gCOSY ($CDCl_3$, 500 MHz) of **S26**

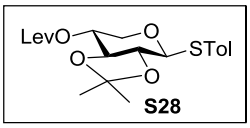


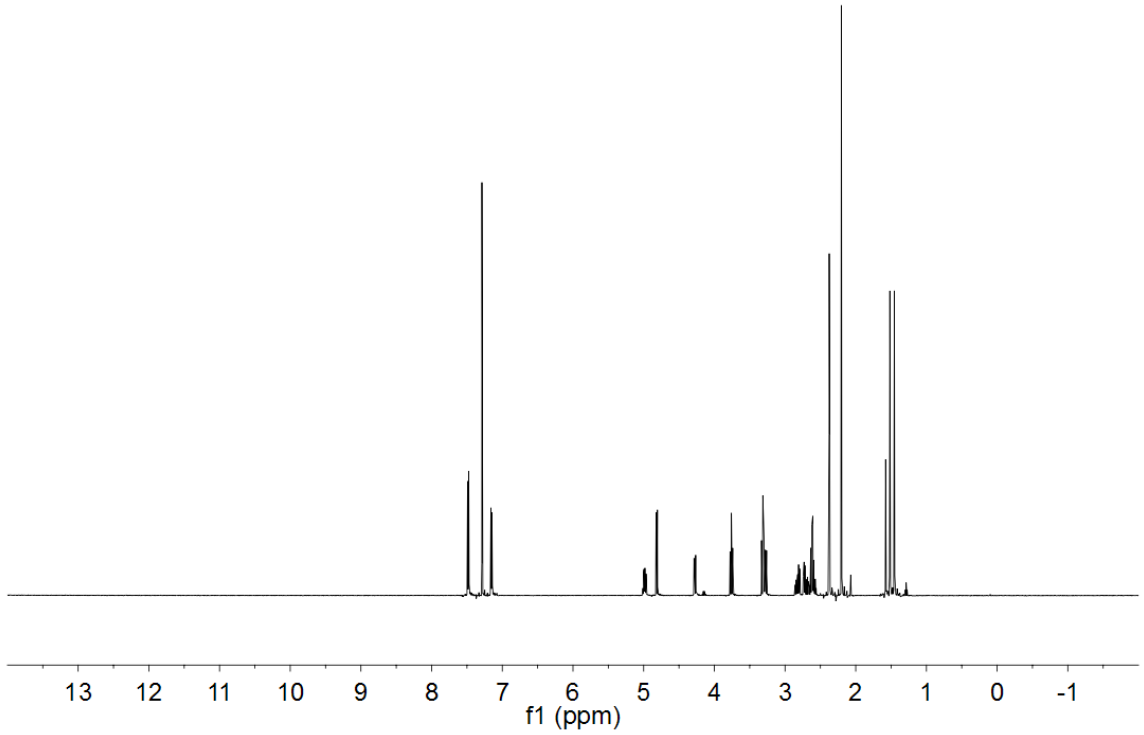
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S27**



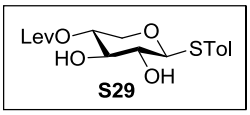


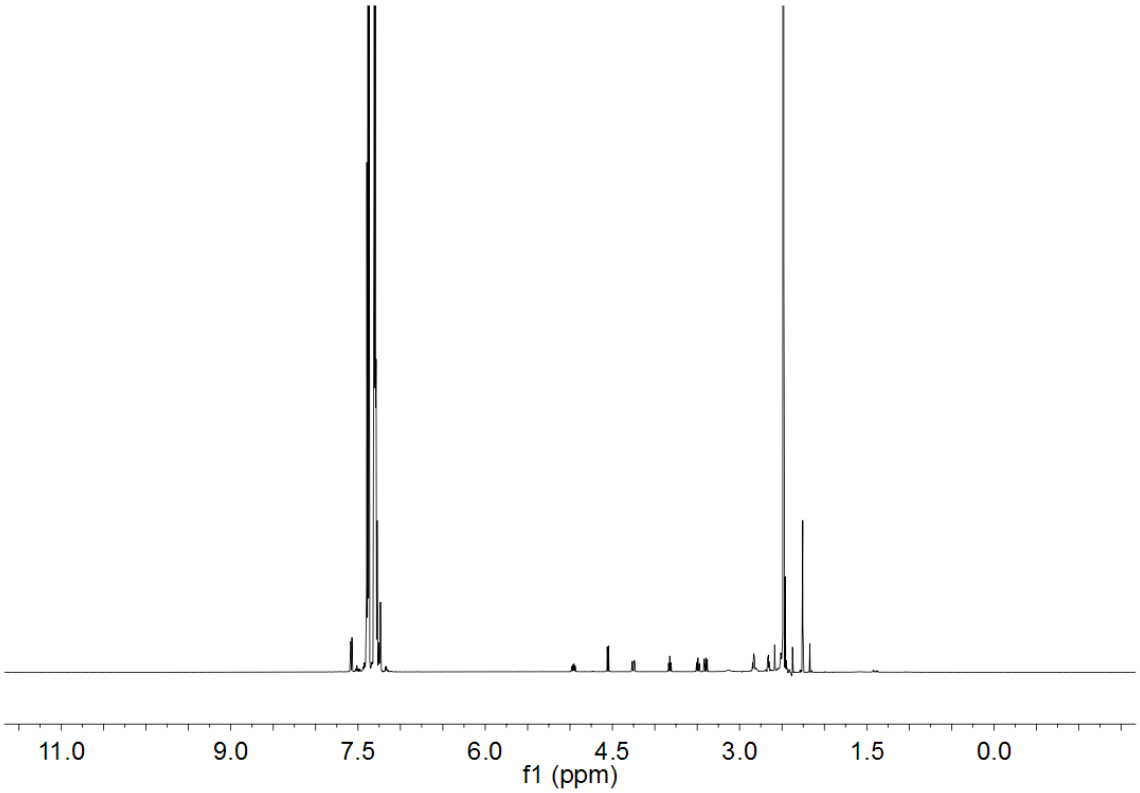
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S28**



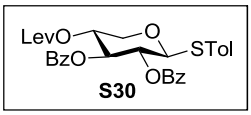


^{1}H-NMR ($CDCl_3$, 500 MHz) of **S29**

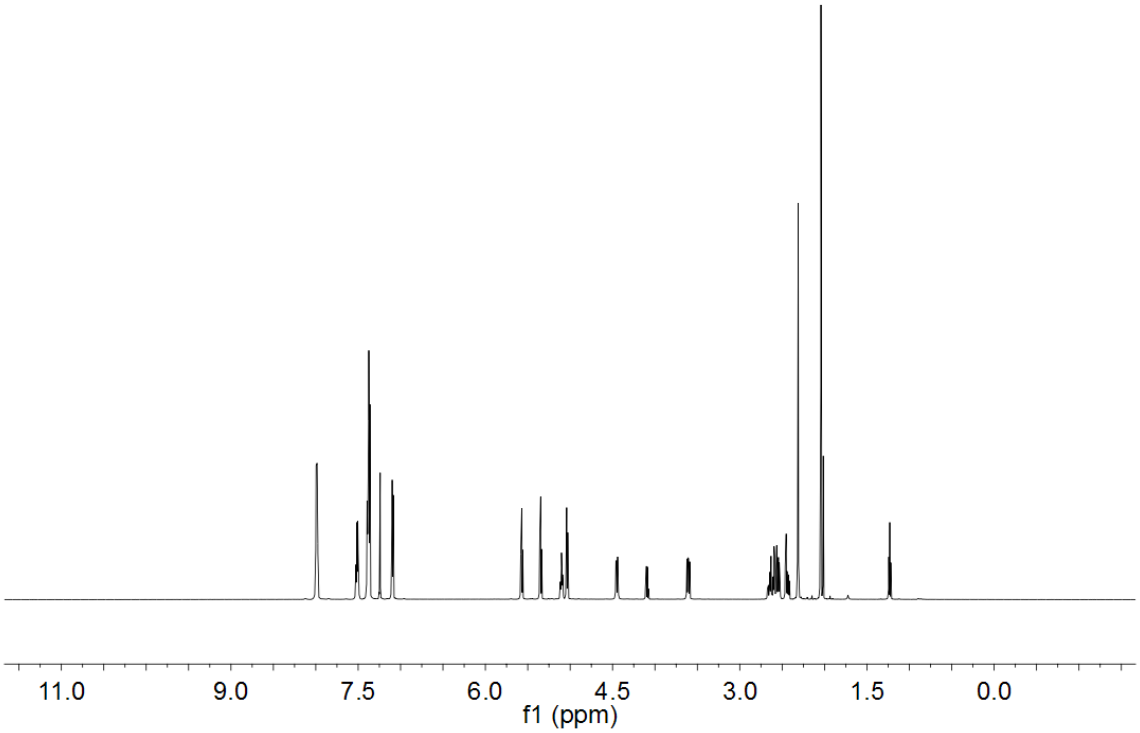




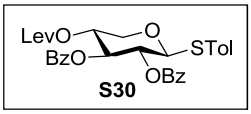
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S30**



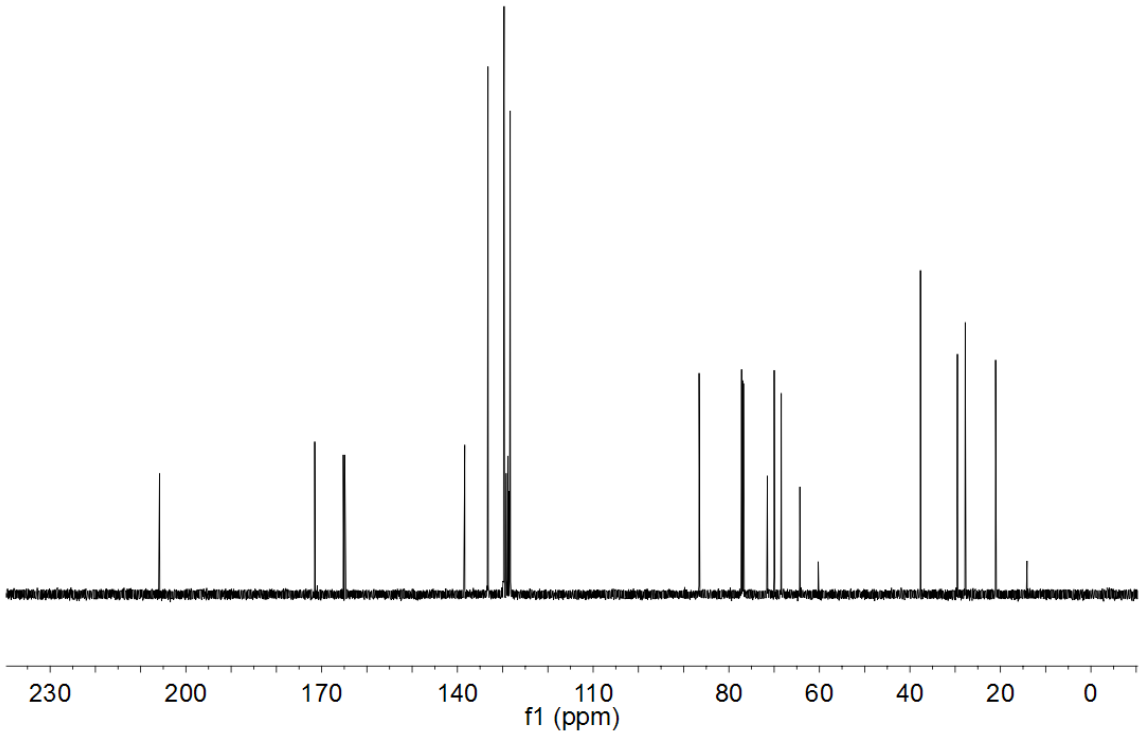
S30



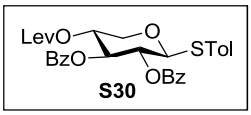
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S30**



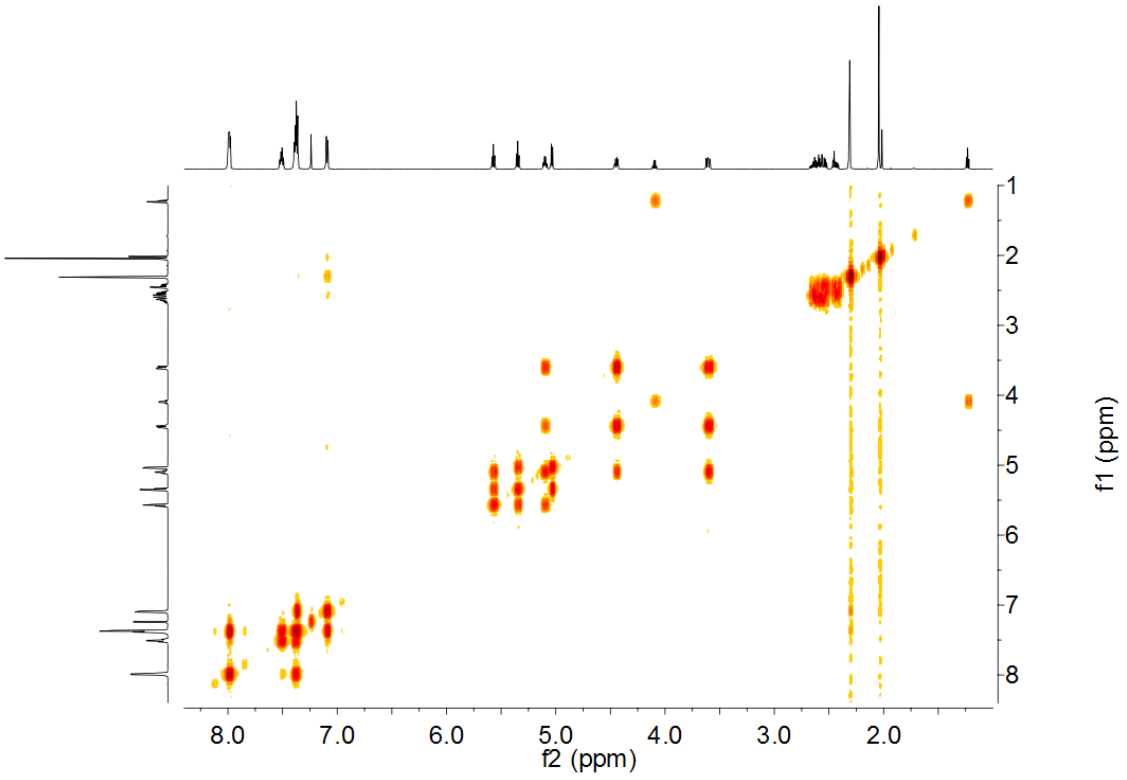
S30



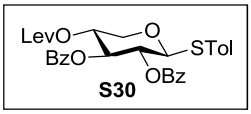
gCOSY ($CDCl_3$, 500 MHz) of **S30**

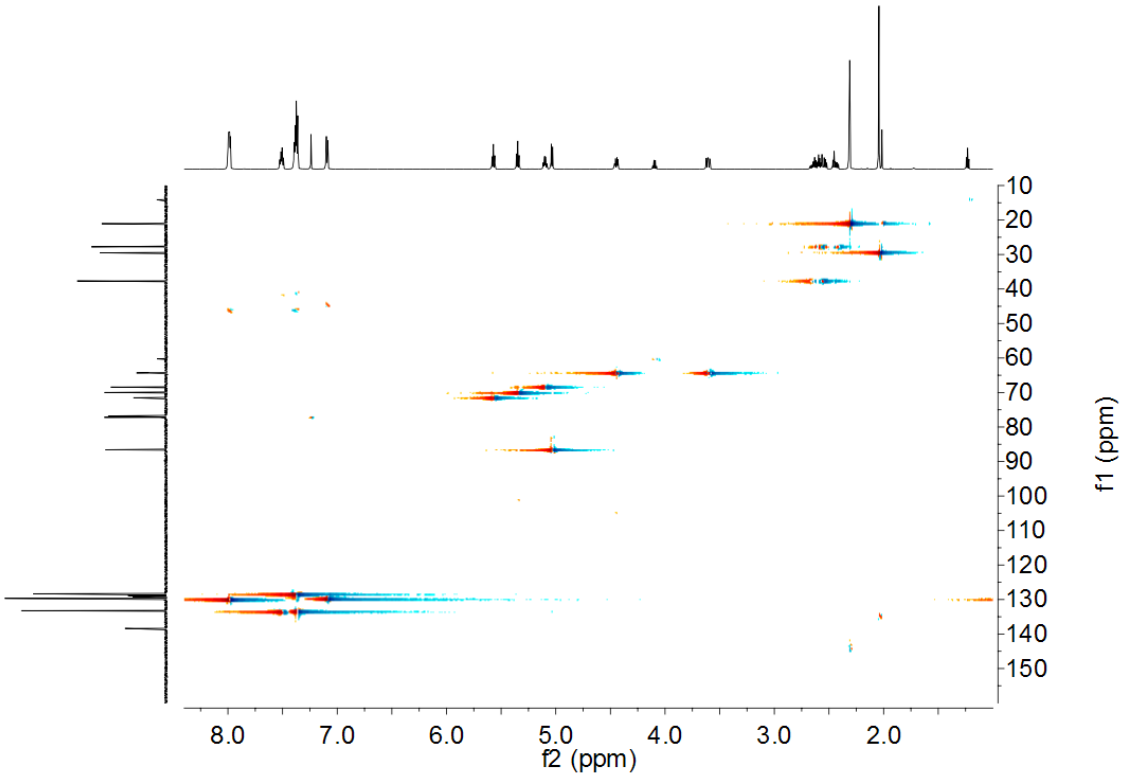


S30

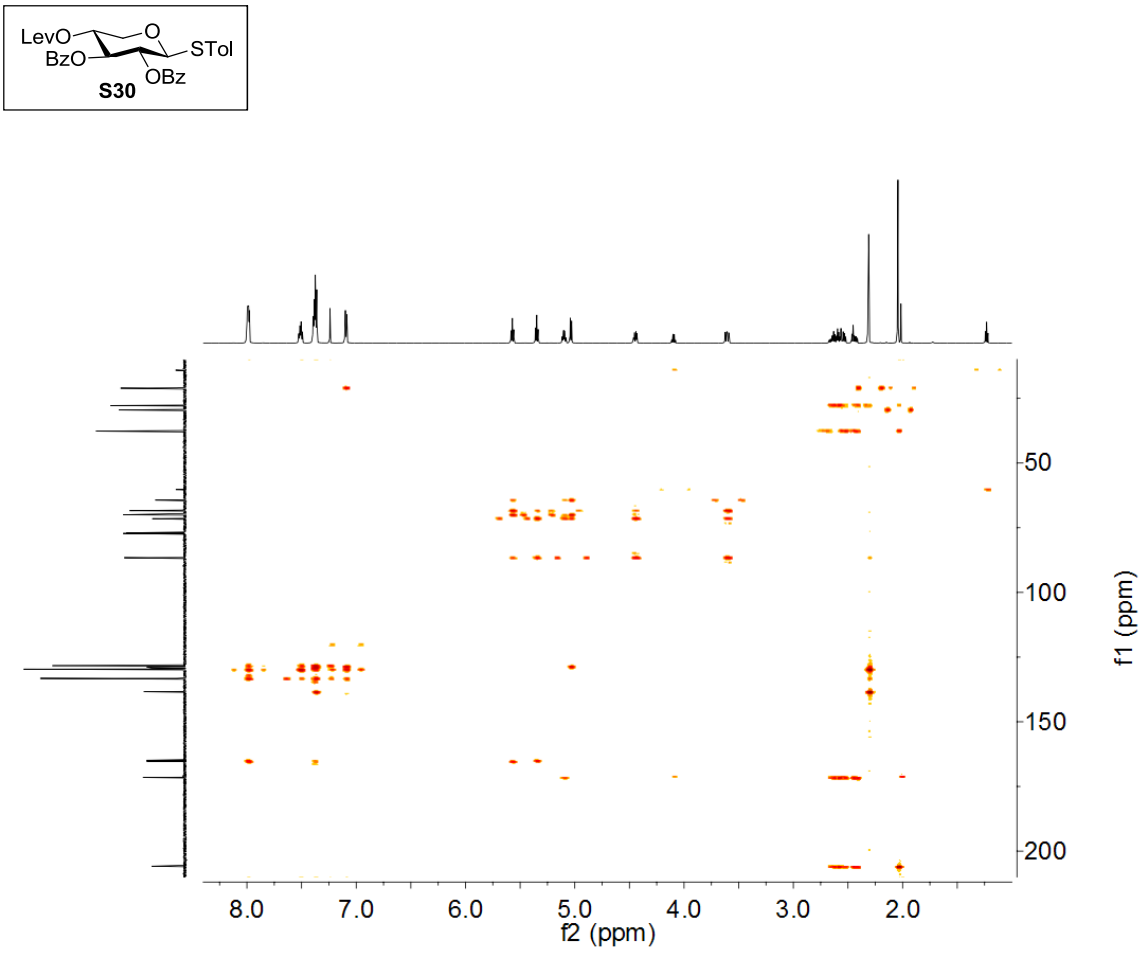


gHMQC ($CDCl_3$, 500 MHz) of **S30**

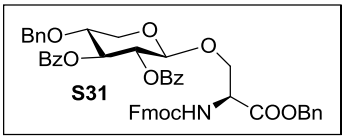


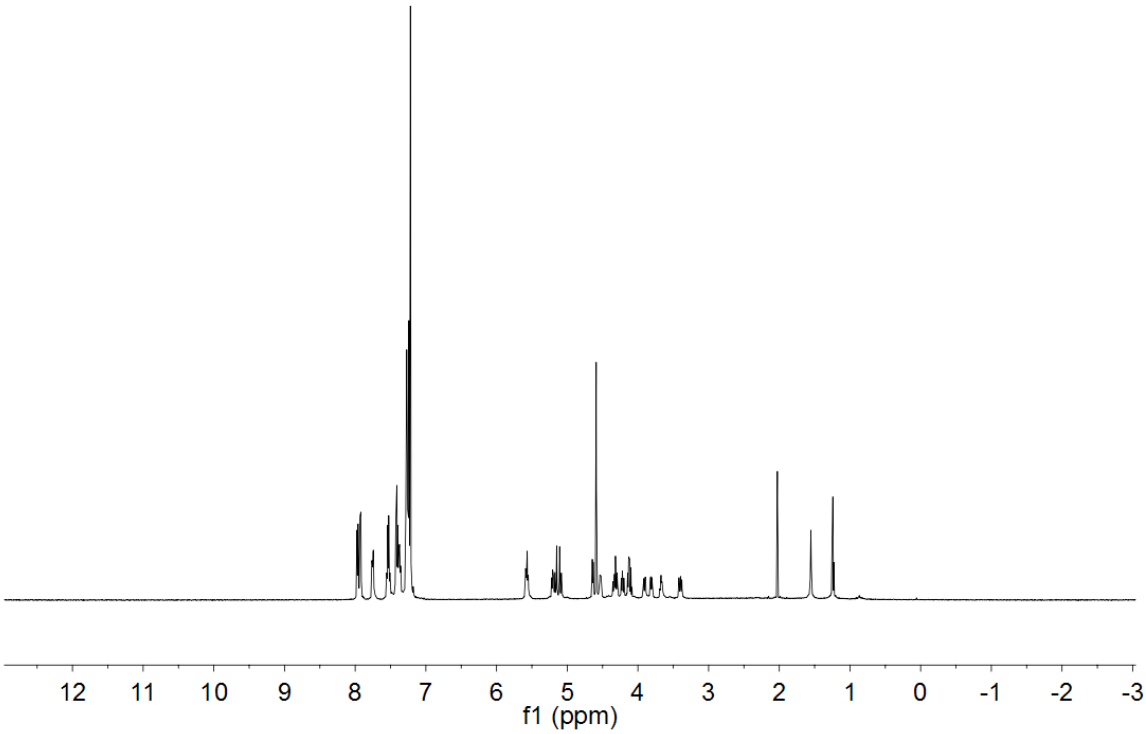


gHMBC ($CDCl_3$, 500 MHz) of **S30**

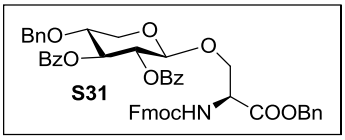


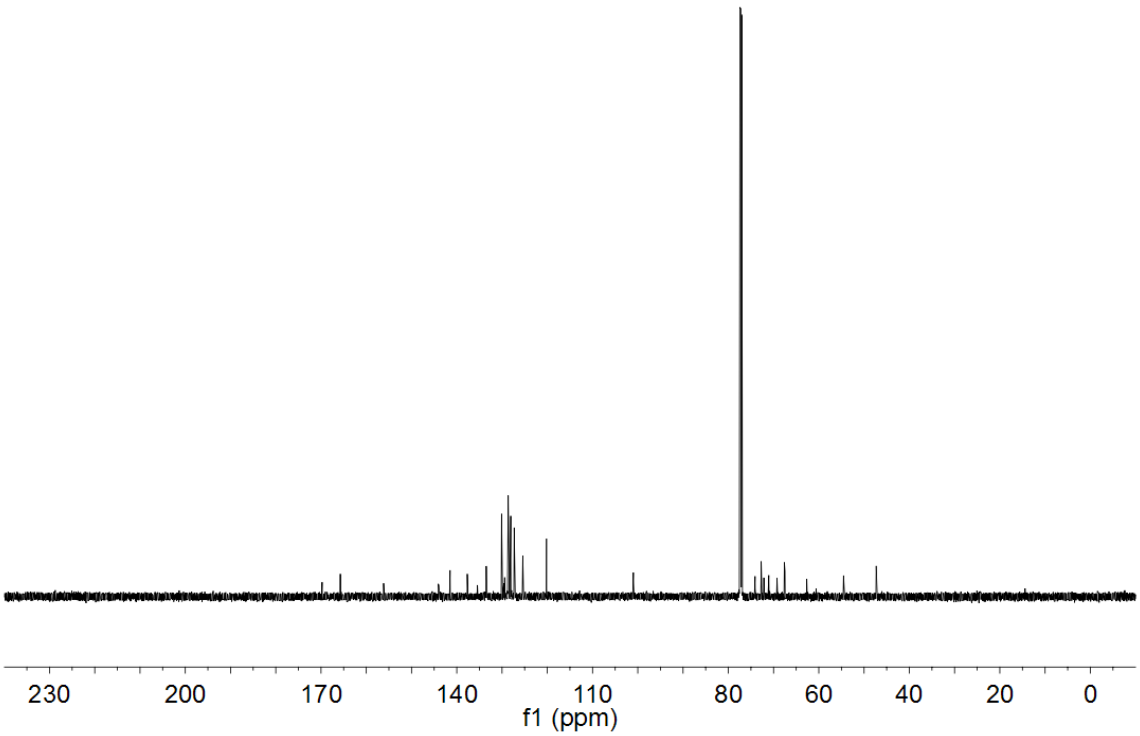
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S31**



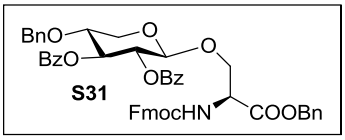


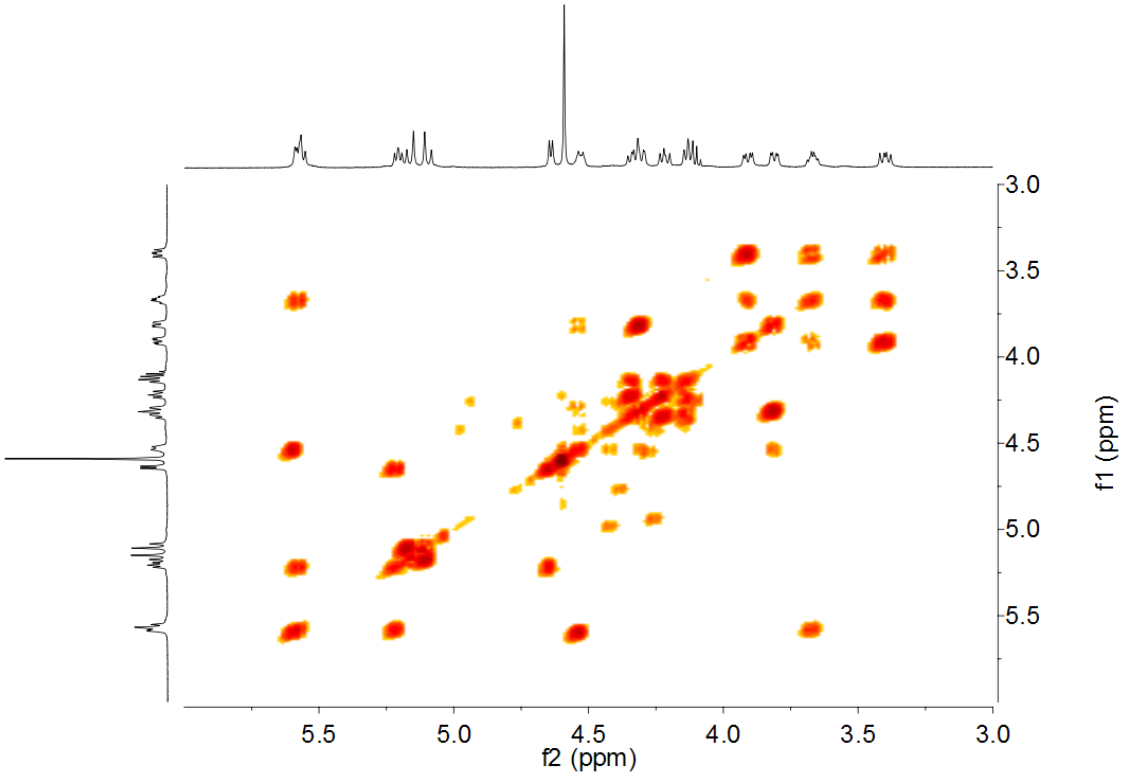
^{13}C-NMR ($CDCl_3$, 150 MHz) of **S31**



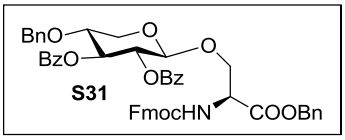


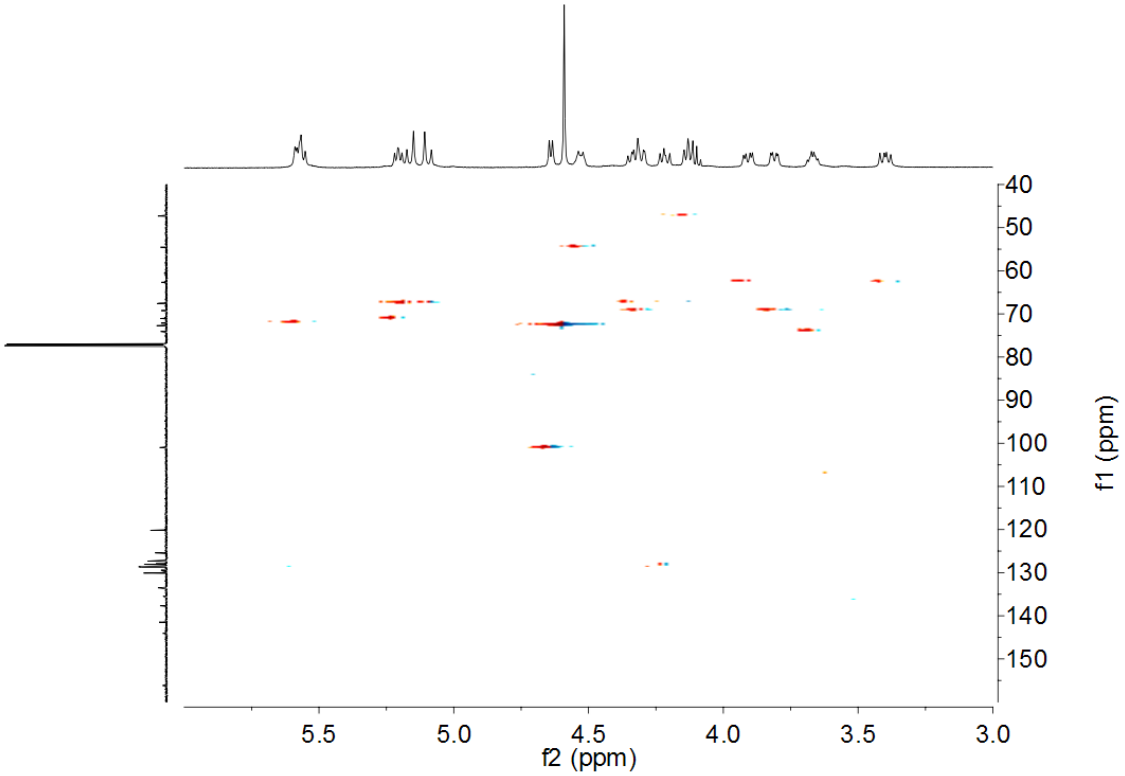
gCOSY ($CDCl_3$, 500 MHz) of **S31**



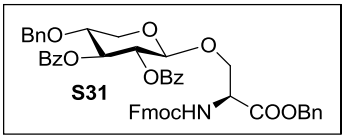


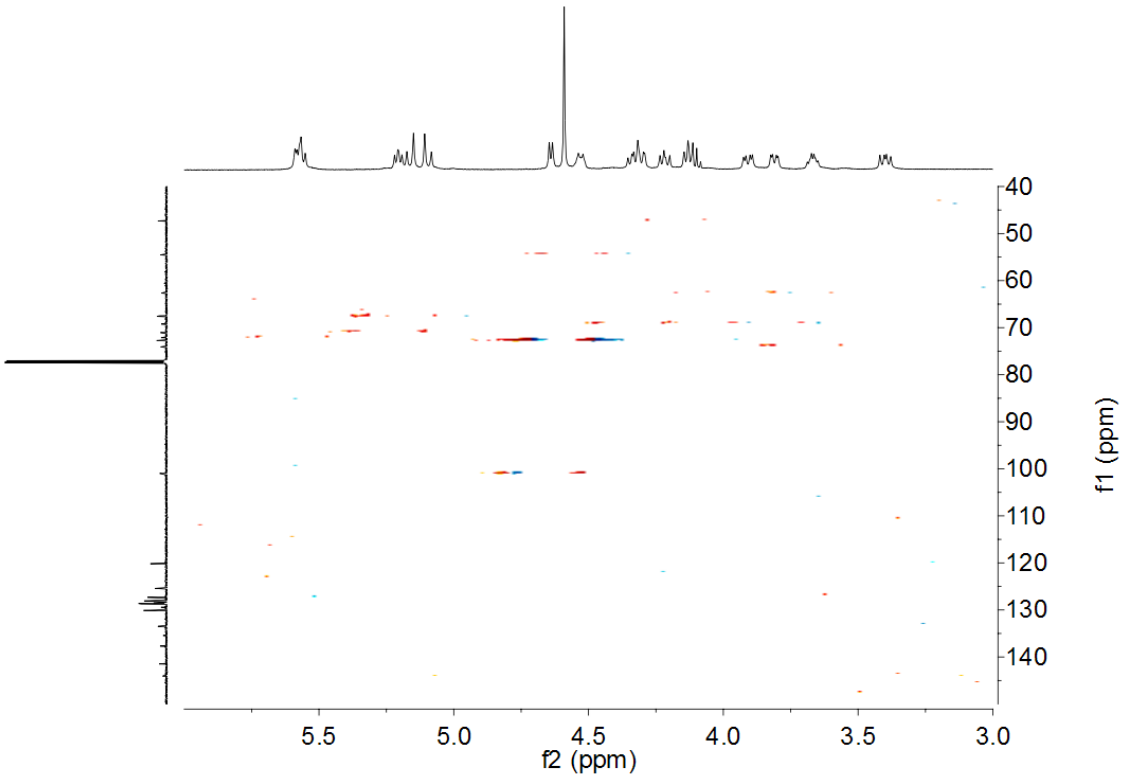
gHMQC ($CDCl_3$, 600 MHz) of **S31**



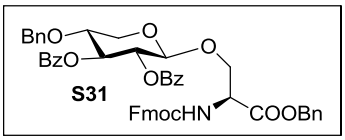


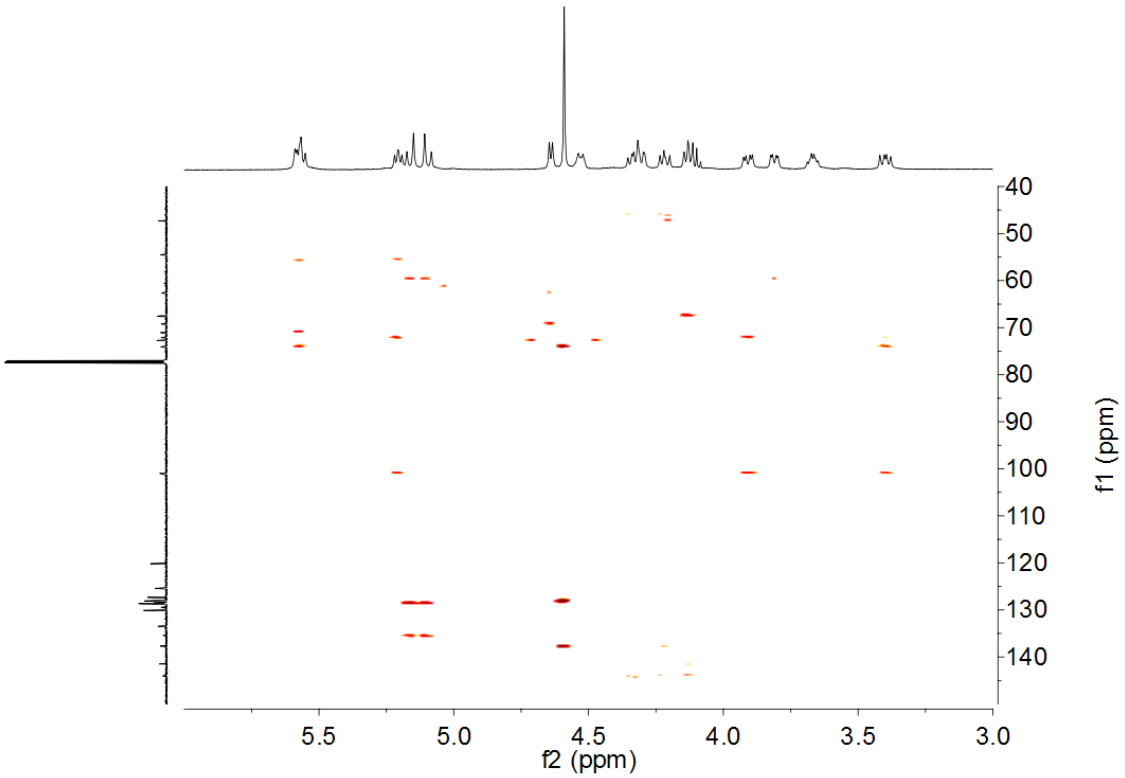
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 600 MHz) of **S31**



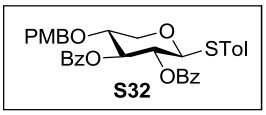


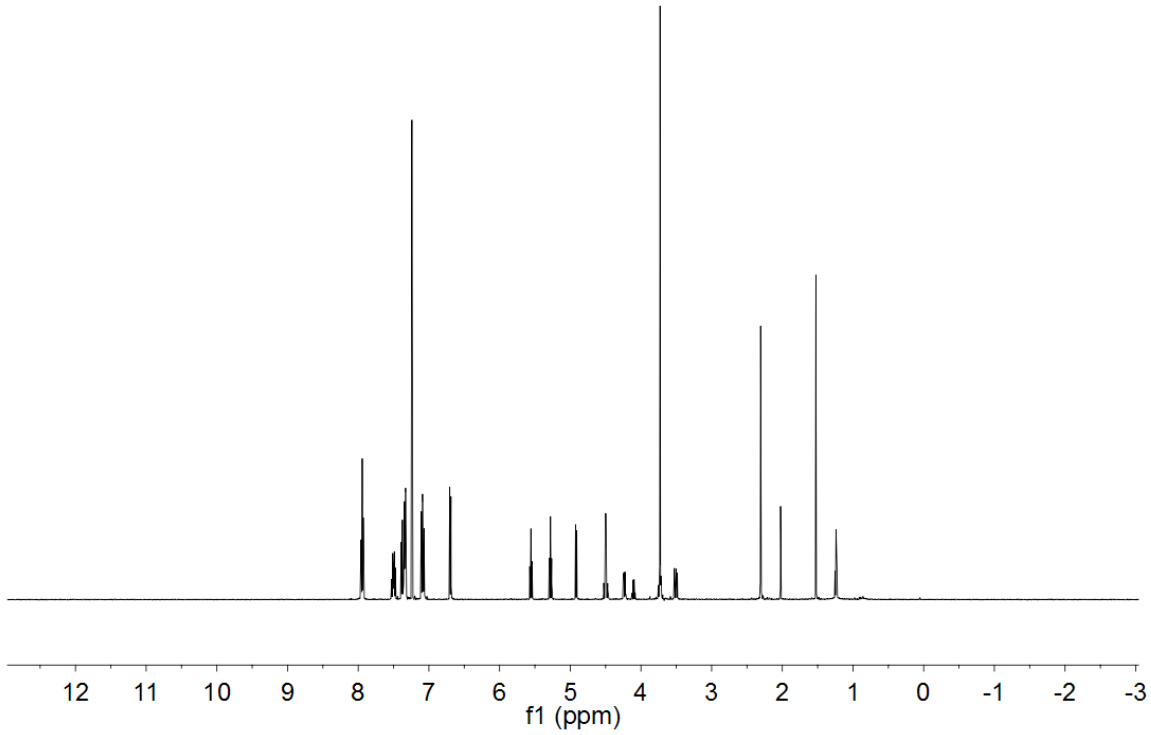
gHMBC ($CDCl_3$, 600 MHz) of **S31**



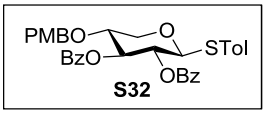


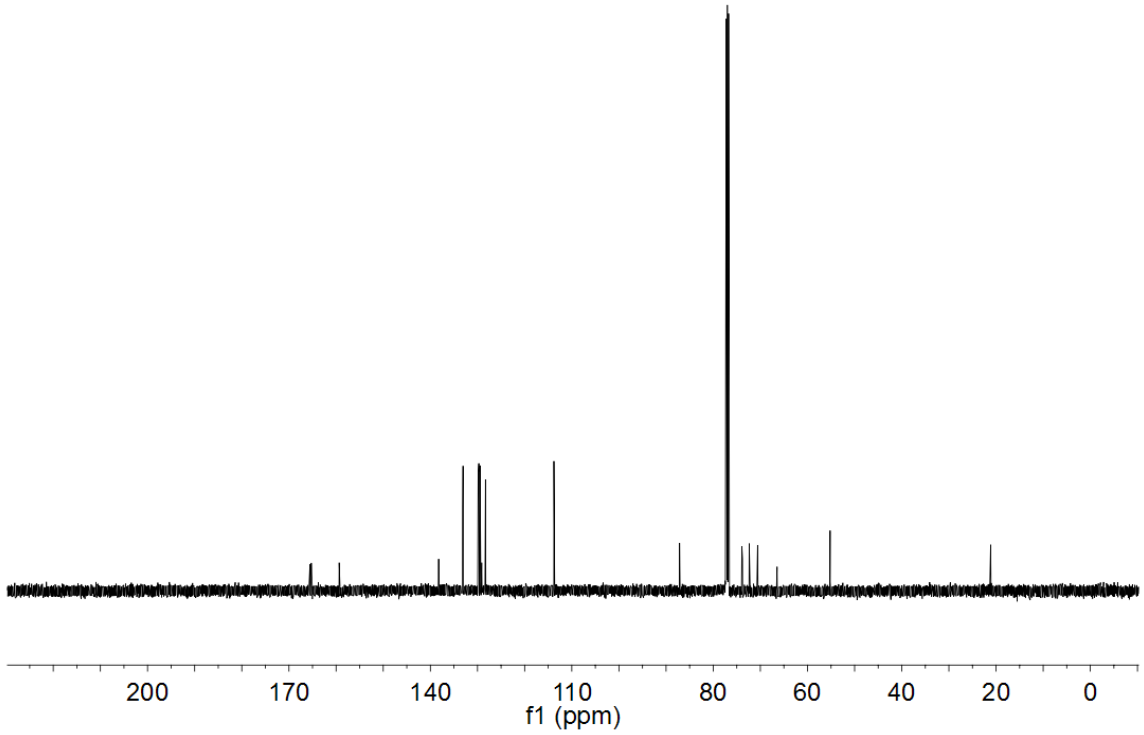
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S32**



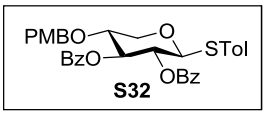


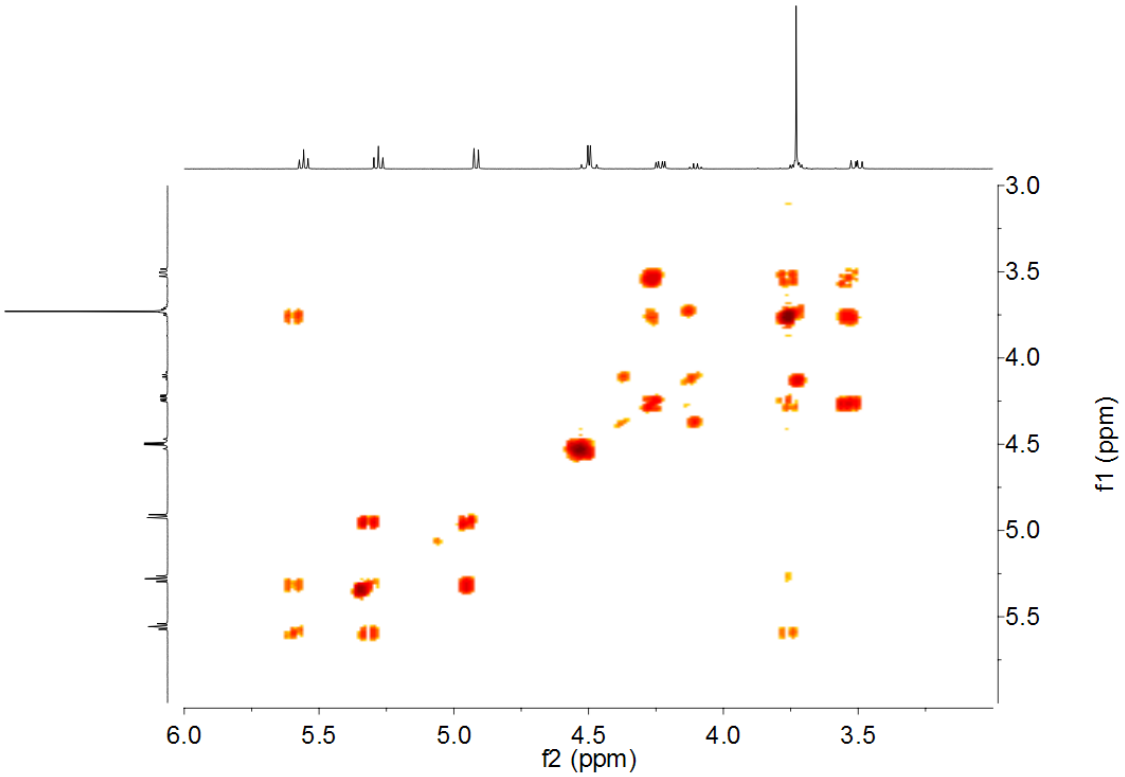
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S32**



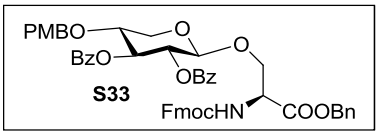


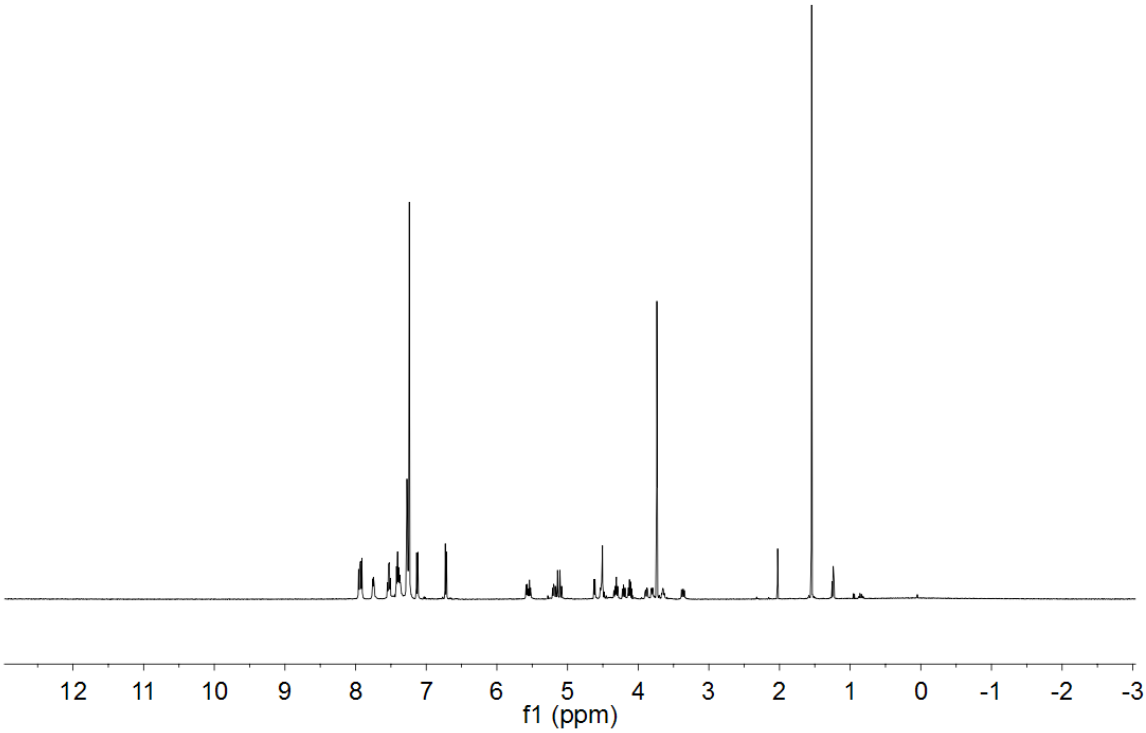
gCOSY ($CDCl_3$, 500 MHz) of **S32**


PMBO
O
STol
BzO
OBz
S32

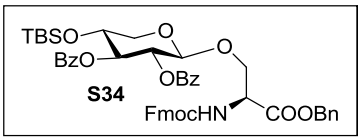

3.0
3.5
4.0
4.5
5.0
5.5
f1 (ppm)
6.0
5.5
5.0
4.5
4.0
3.5
f2 (ppm)

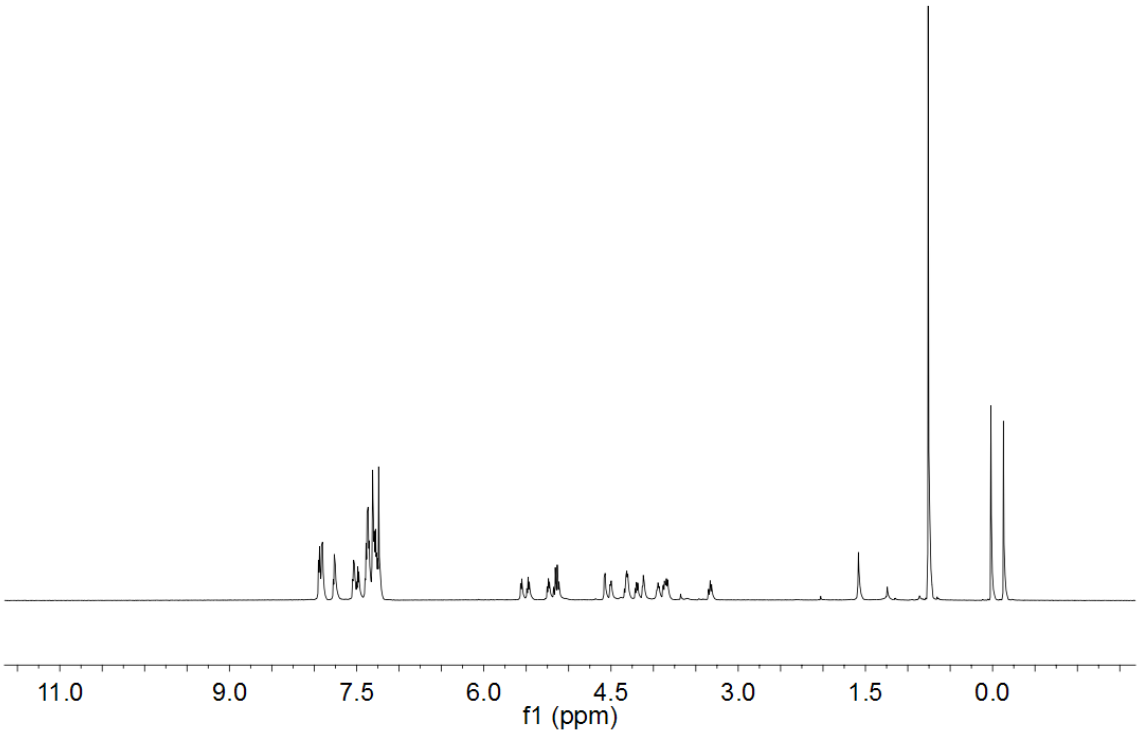
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S33**



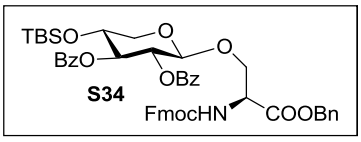


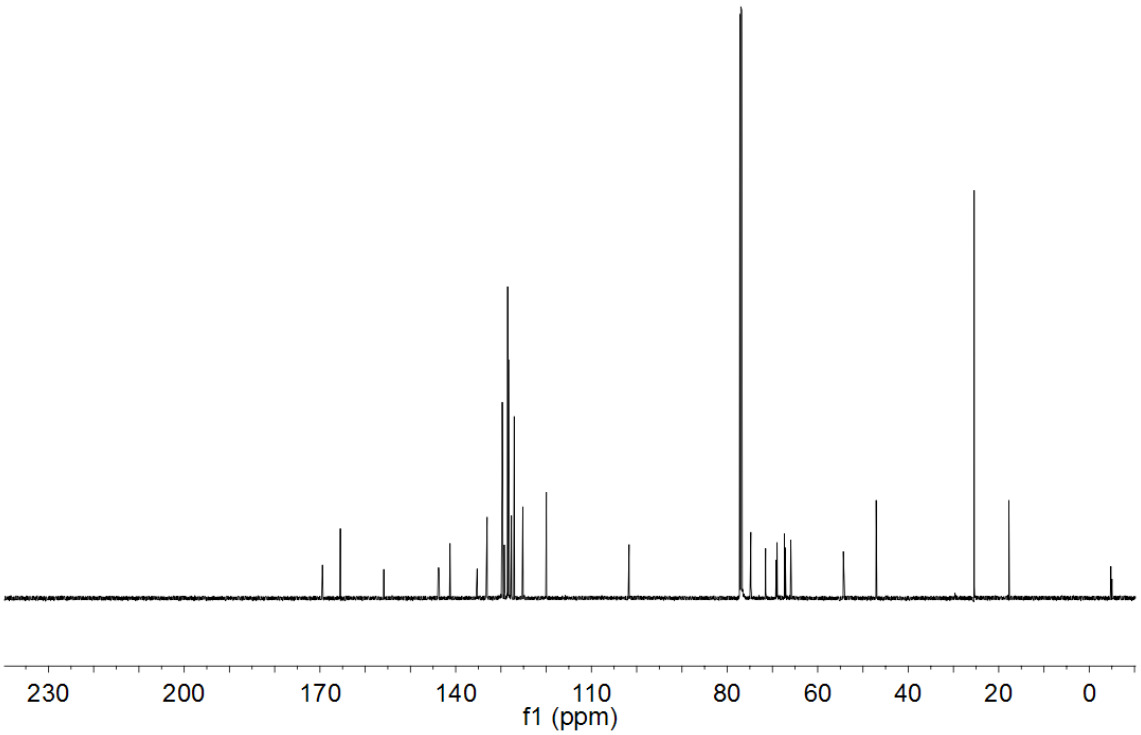
^{1}H-NMR ($CDCl_3$, 600 MHz) of **S34**



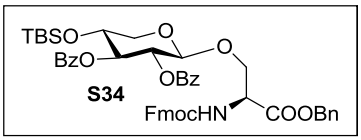


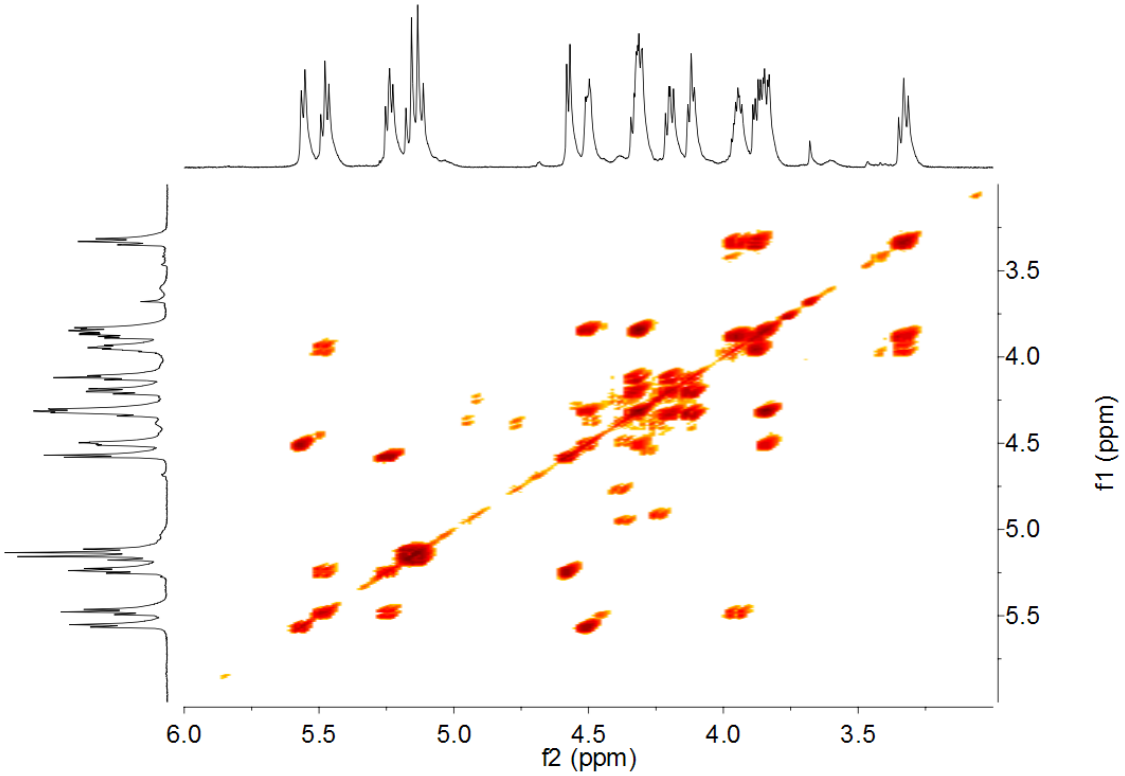
^{13}C-NMR ($CDCl_3$, 150 MHz) of **S34**



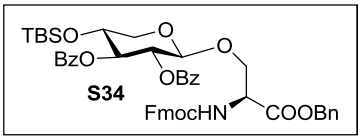


gCOSY ($CDCl_3$, 600 MHz) of **S34**

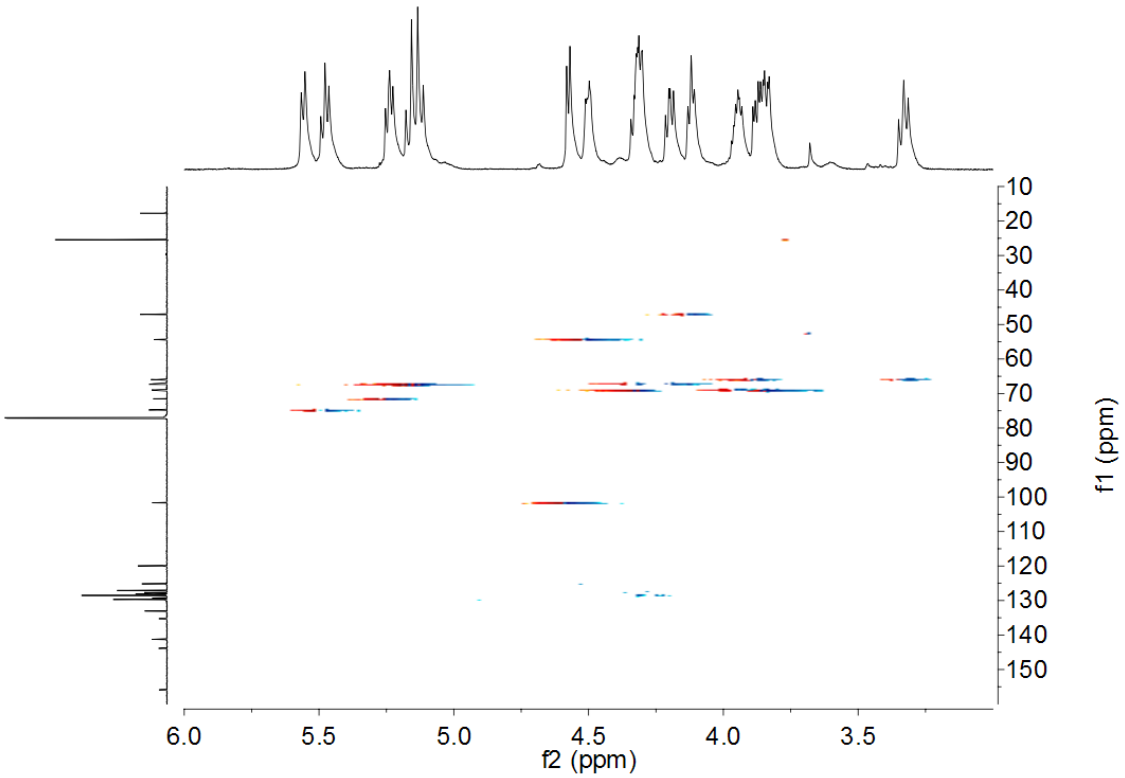




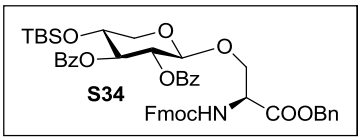
gHMQC ($CDCl_3$, 600 MHz) of **S34**

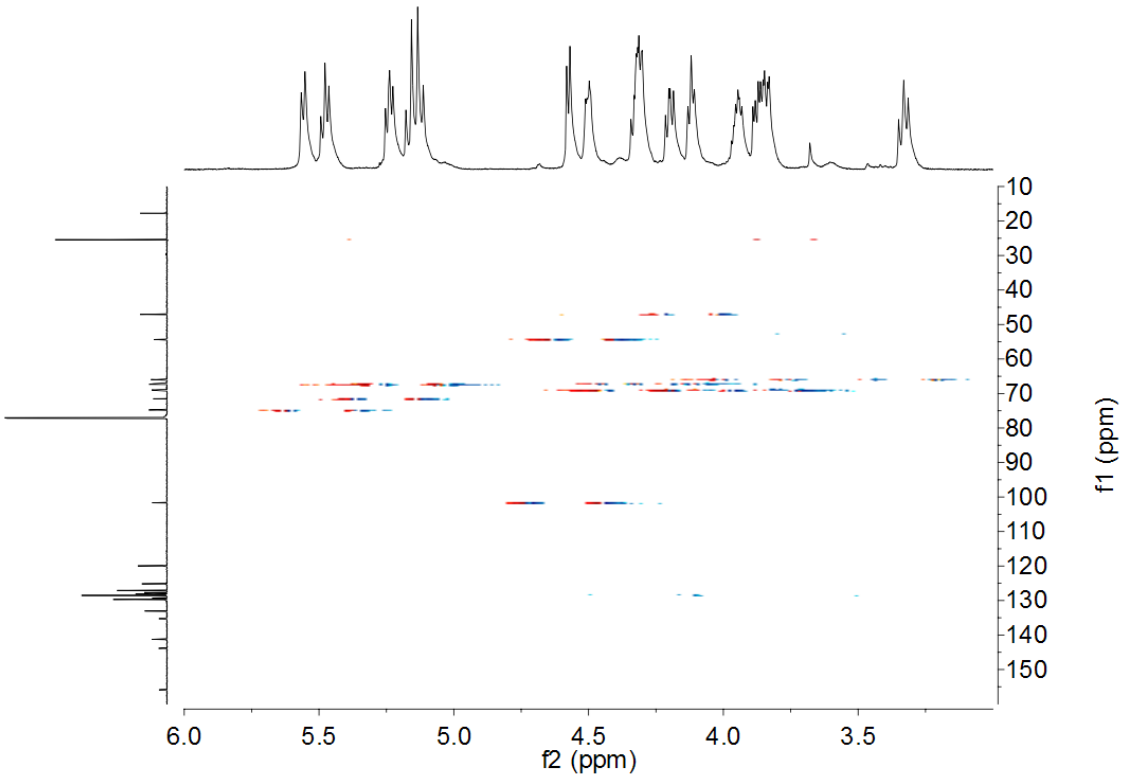


S34

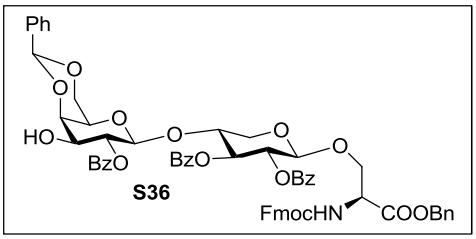


gHMQC (without ^{1}H decoupling) ($CDCl_3$, 600 MHz) of **S34**

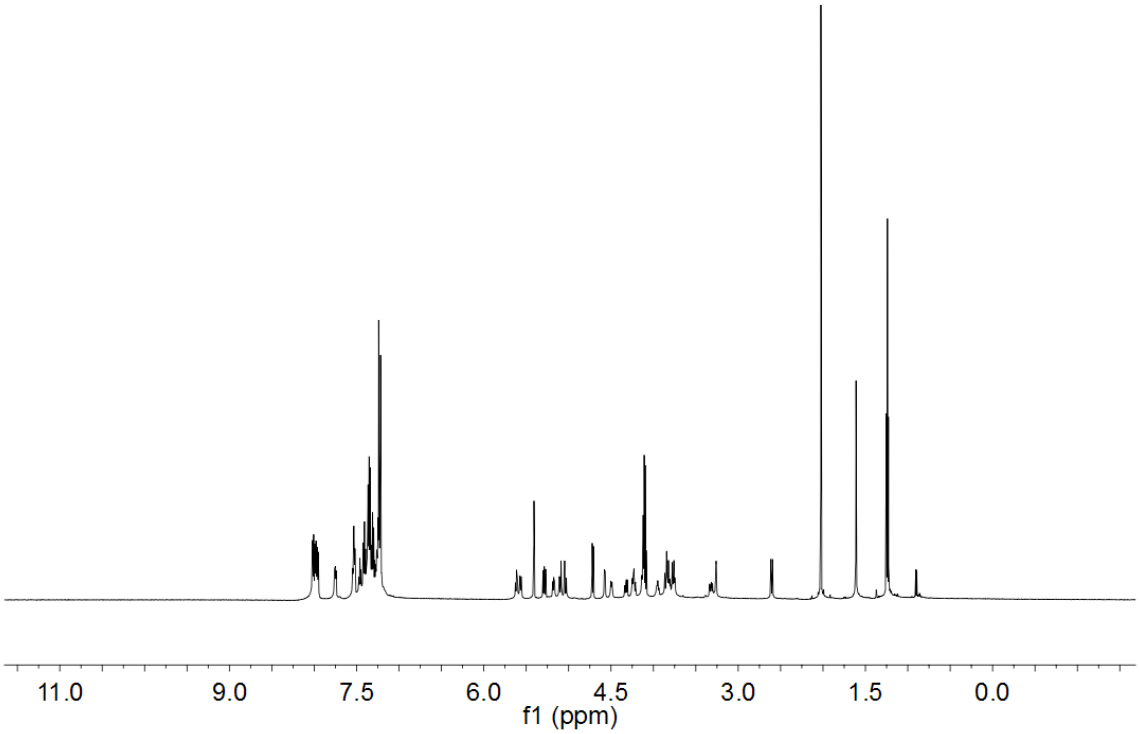




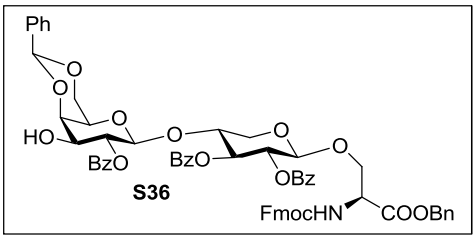
^{1}H-NMR ($CDCl_3$, 600 MHz) of **S36**



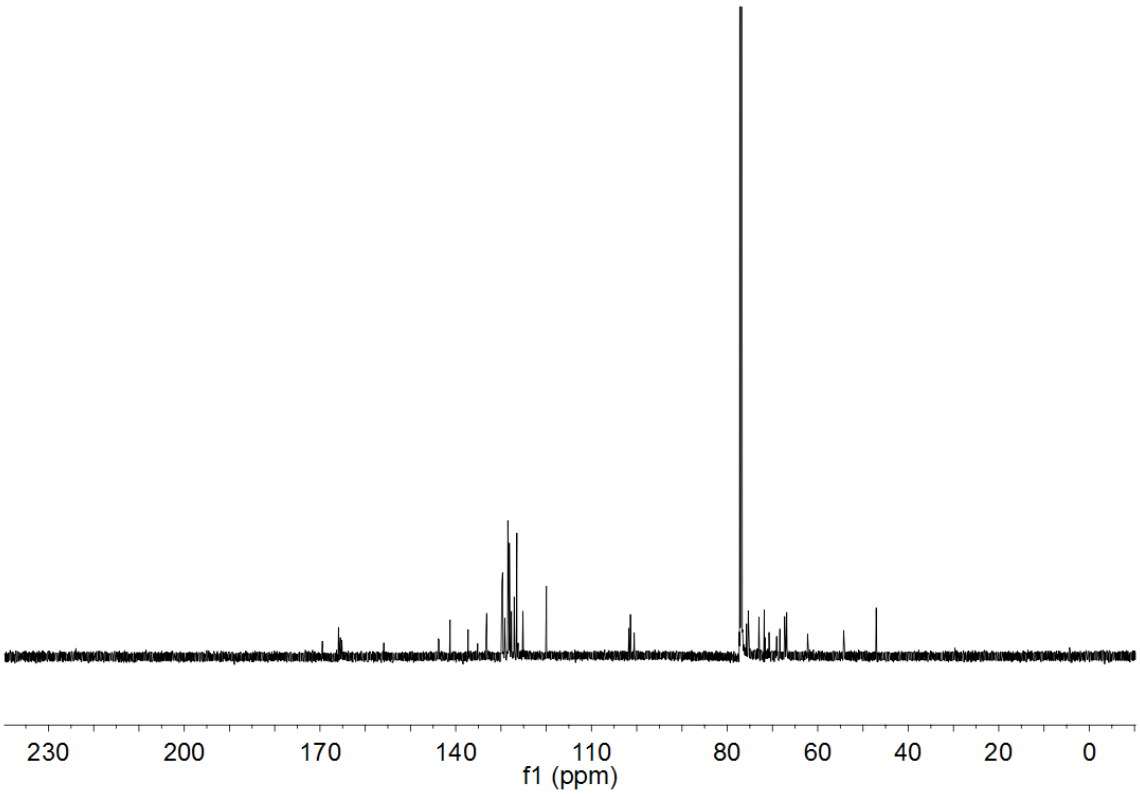
S36



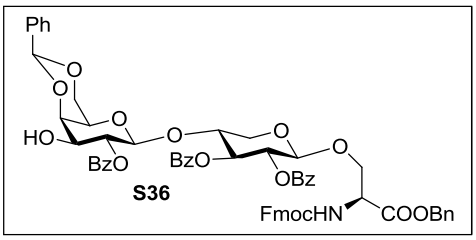
^{13}C-NMR ($CDCl_3$, 150 MHz) of **S36**



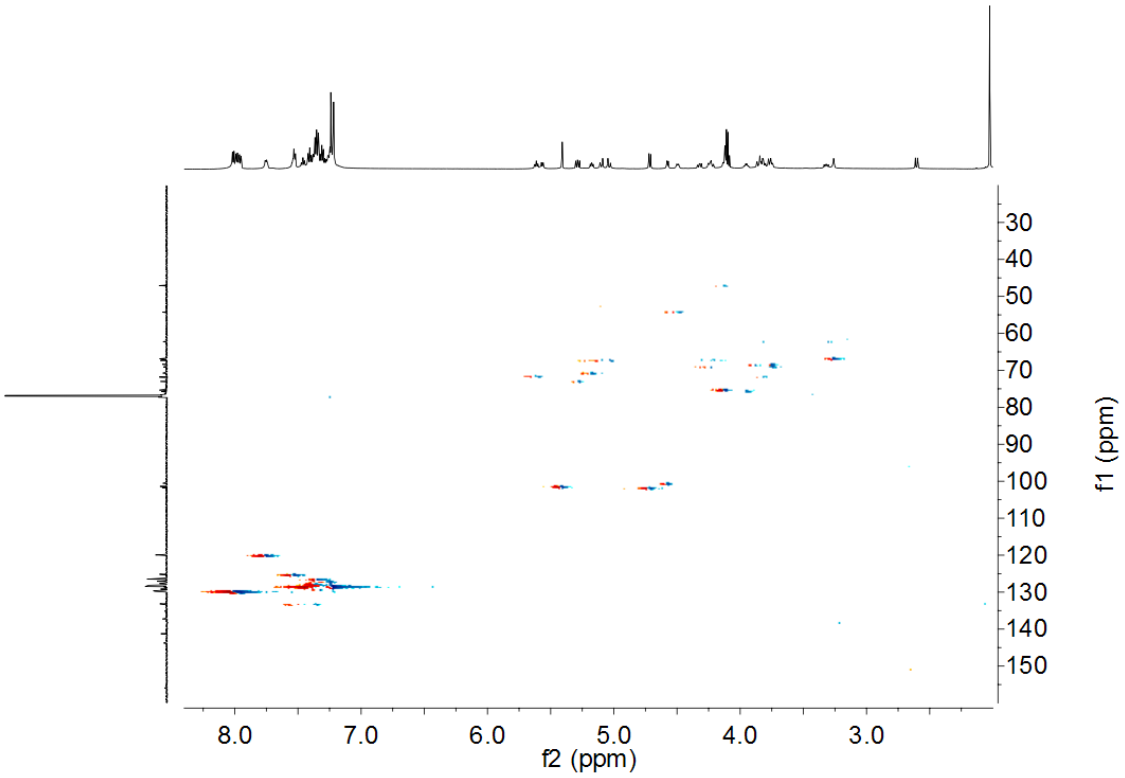
S36



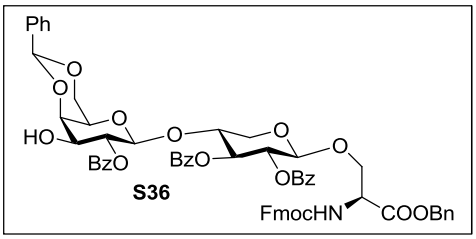
gHMQC ($CDCl_3$, 600 MHz) of **S36**



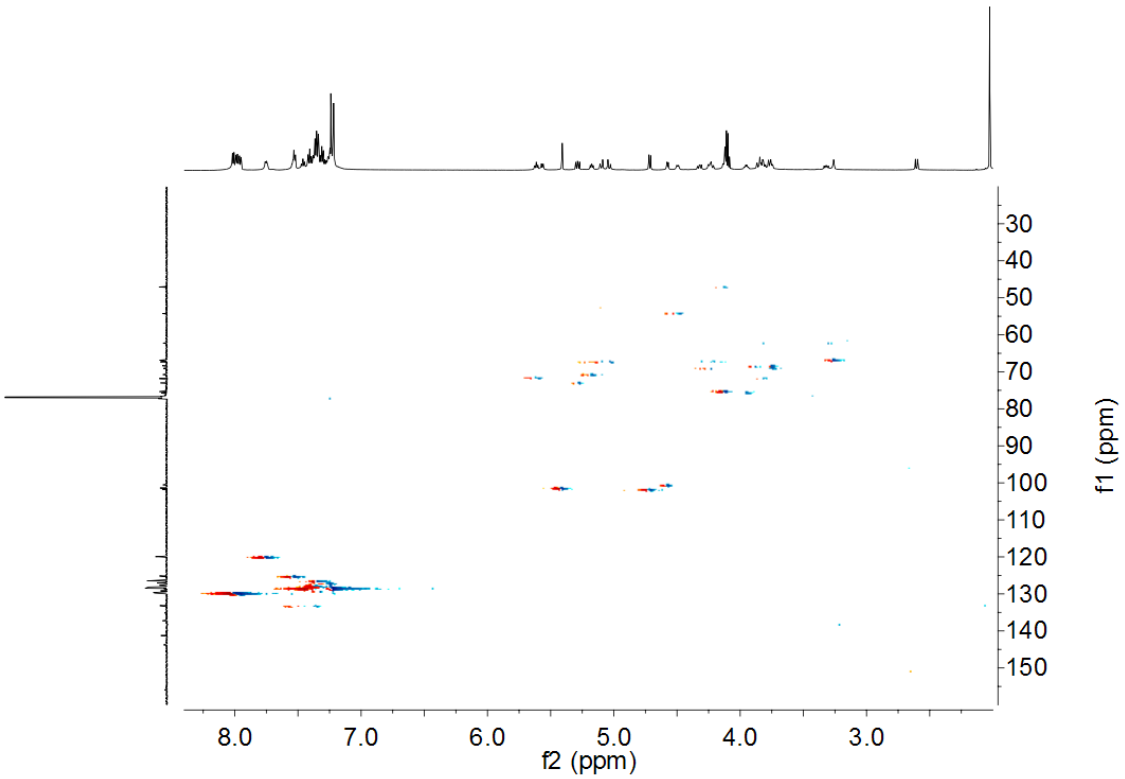
S36



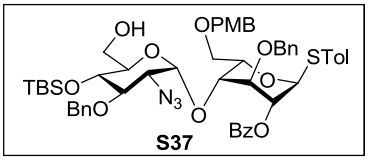
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 500 MHz) of **S36**

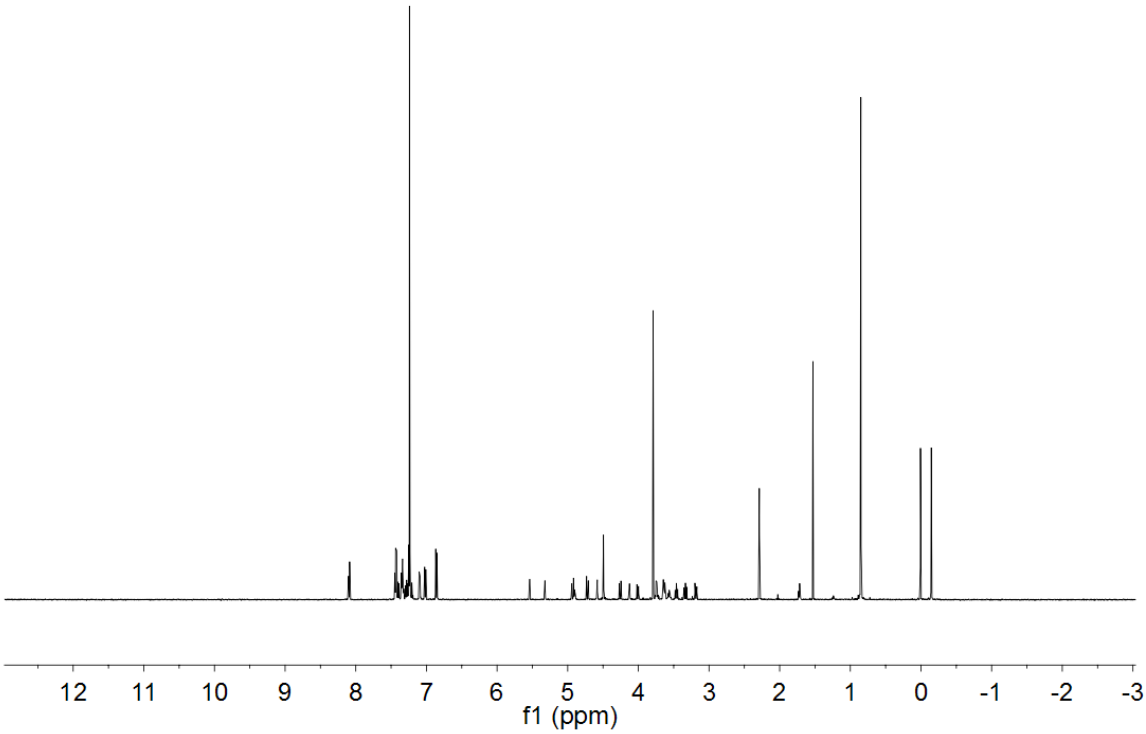


S36

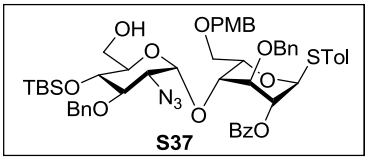


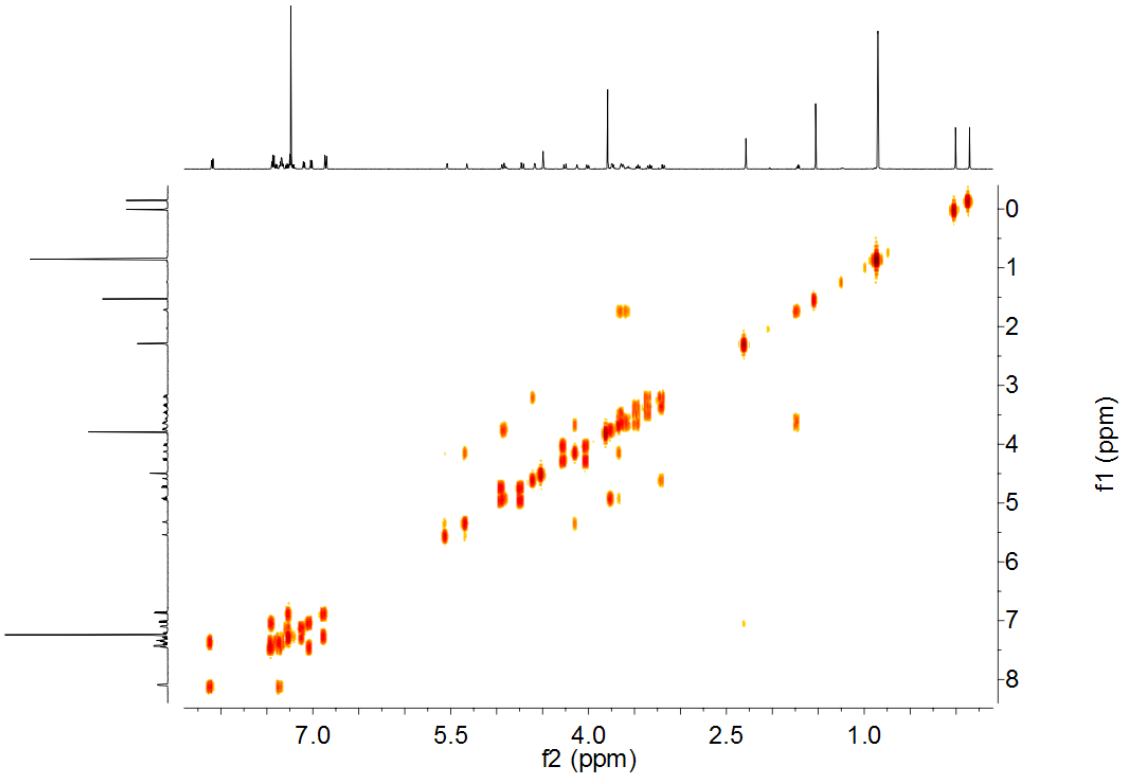
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S37**



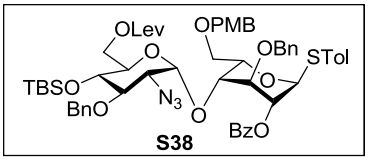


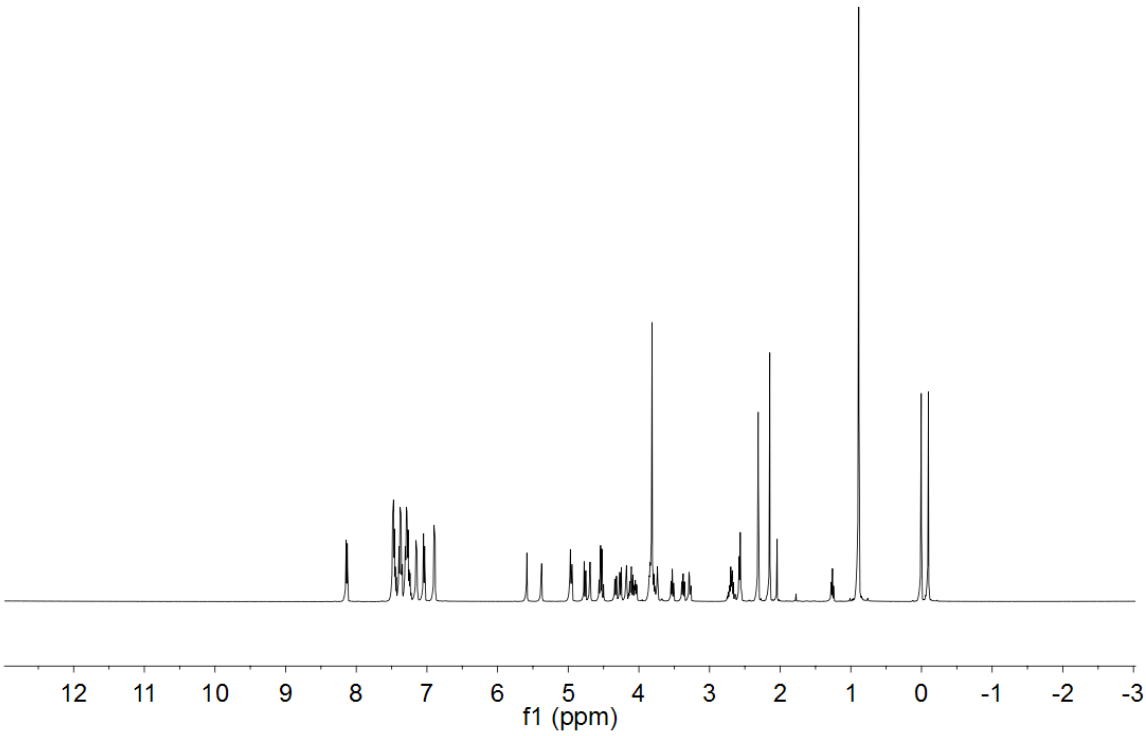
gCOSY ($CDCl_3$, 500 MHz) of **S37**



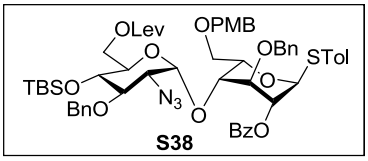


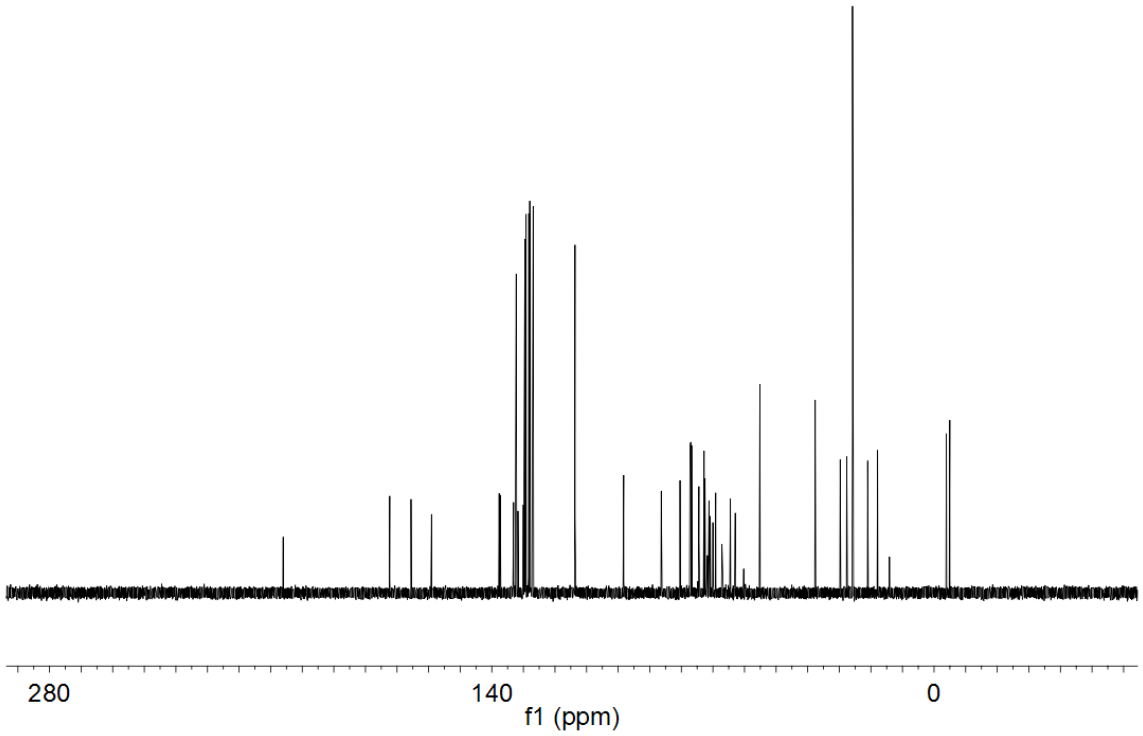
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S38**



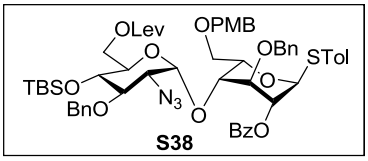


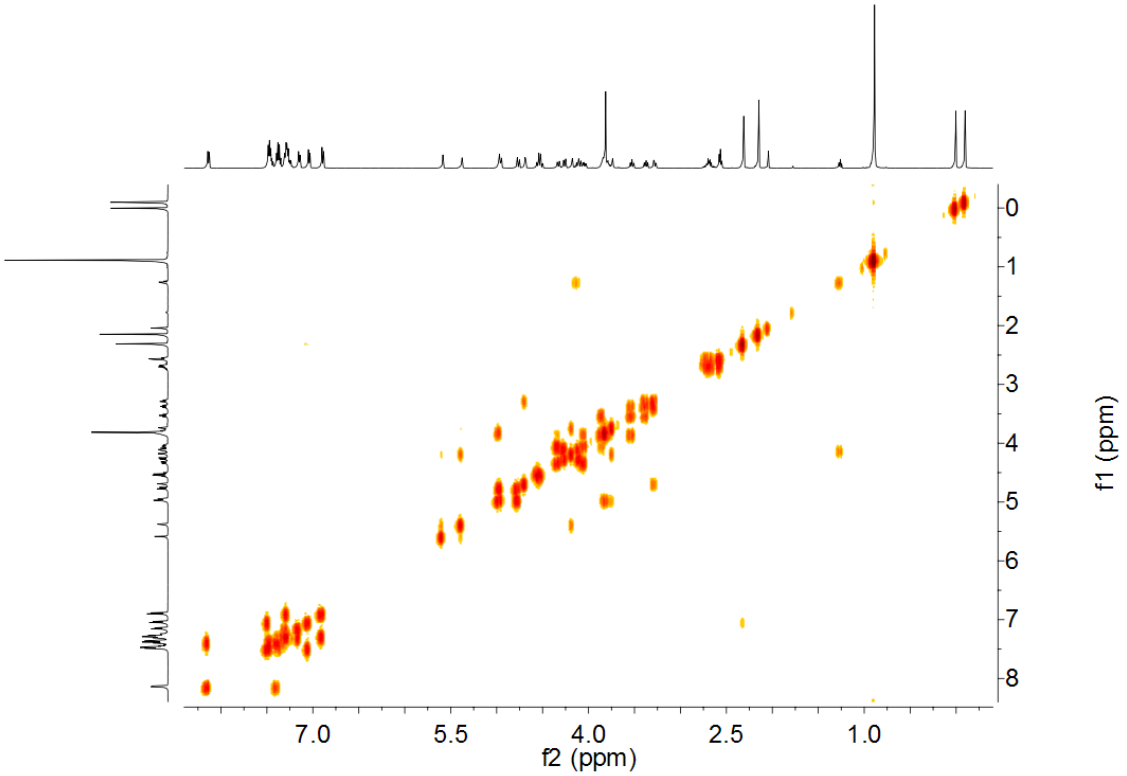
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S38**



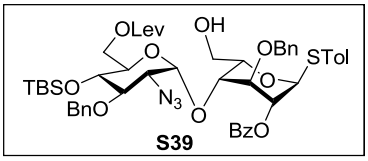


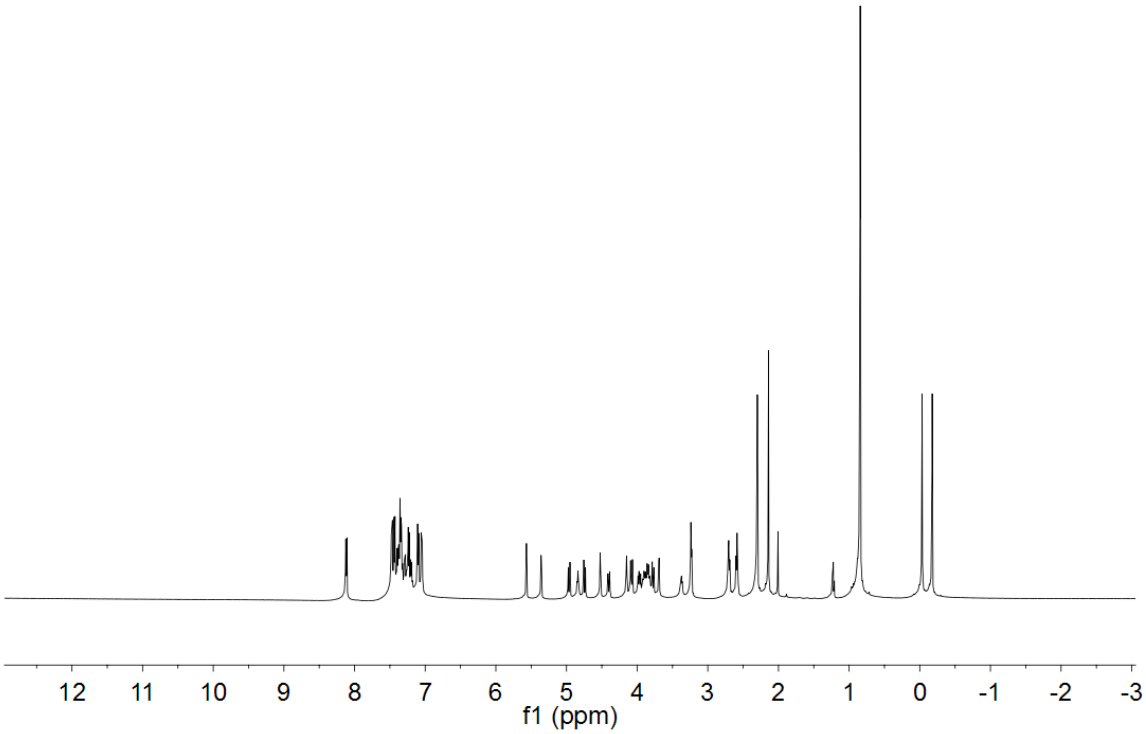
gCOSY ($CDCl_3$, 500 MHz) of **S38**



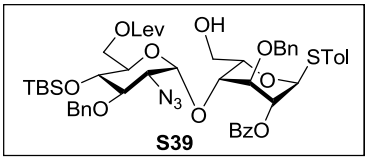


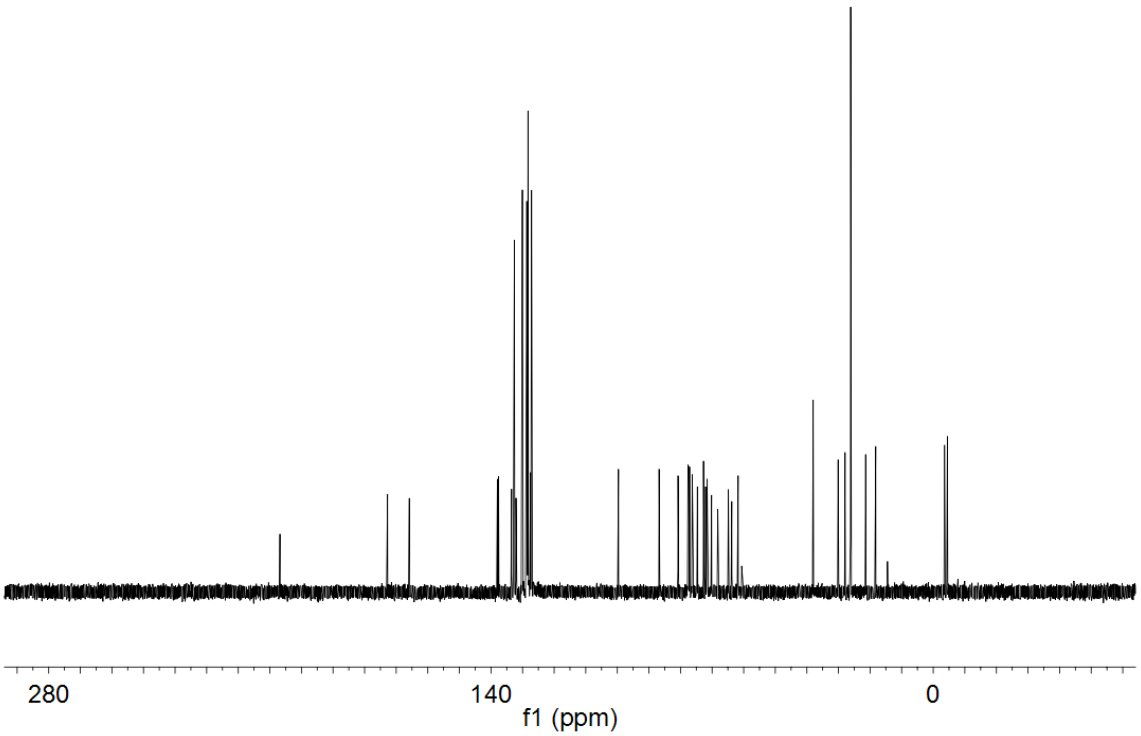
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S39**



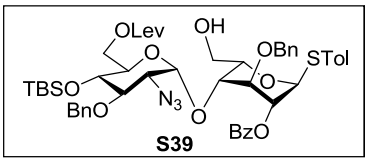


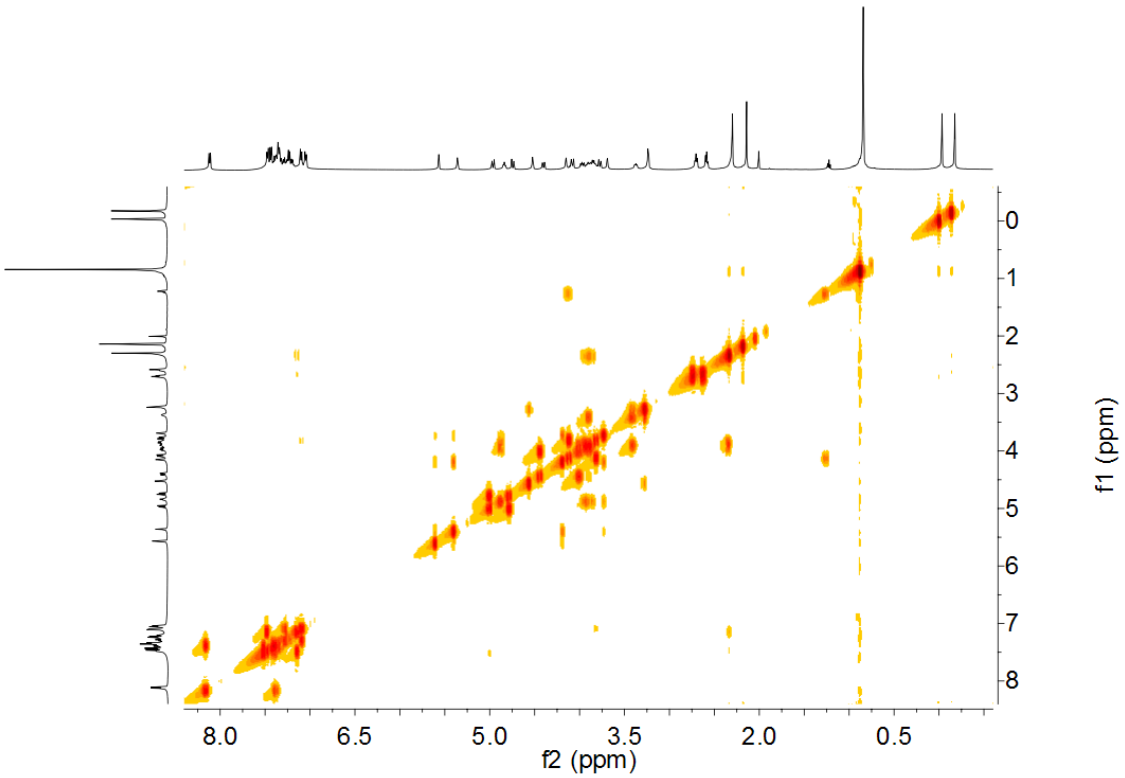
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S39**



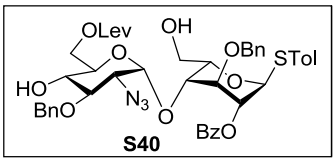


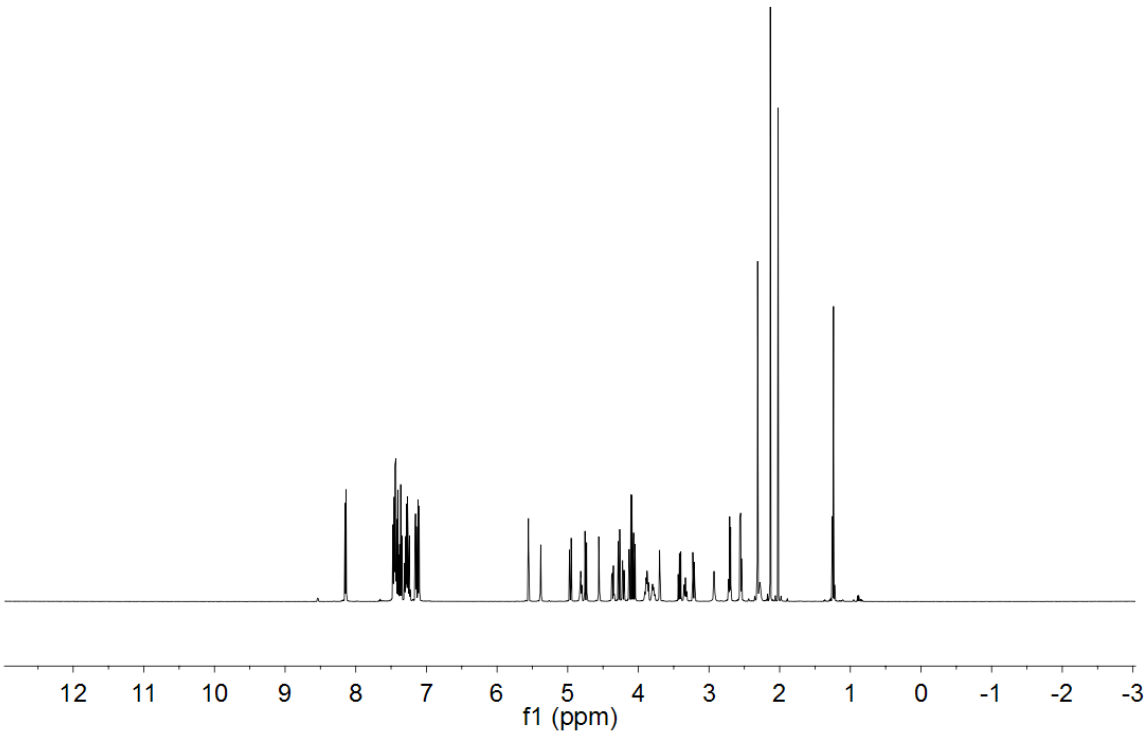
gCOSY ($CDCl_3$, 500 MHz) of **39**



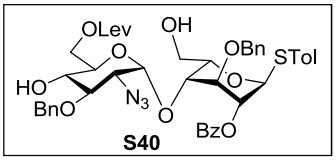


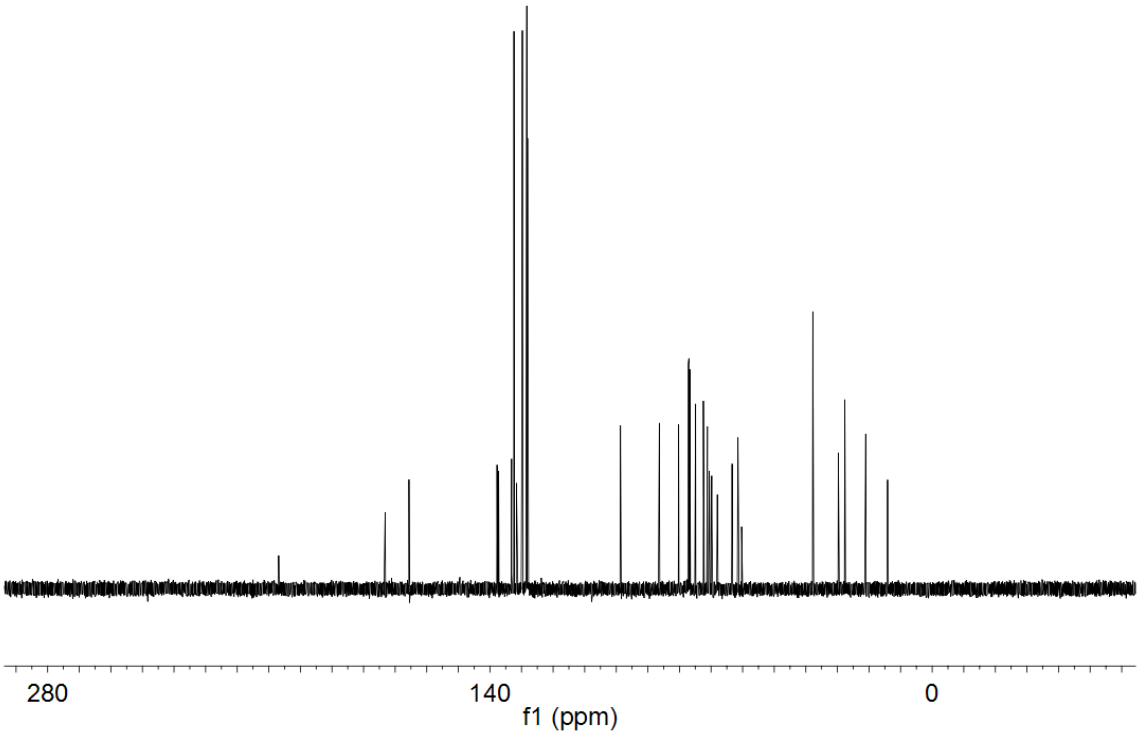
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S40**



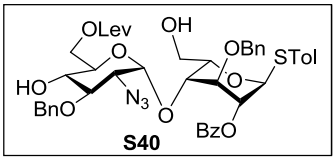


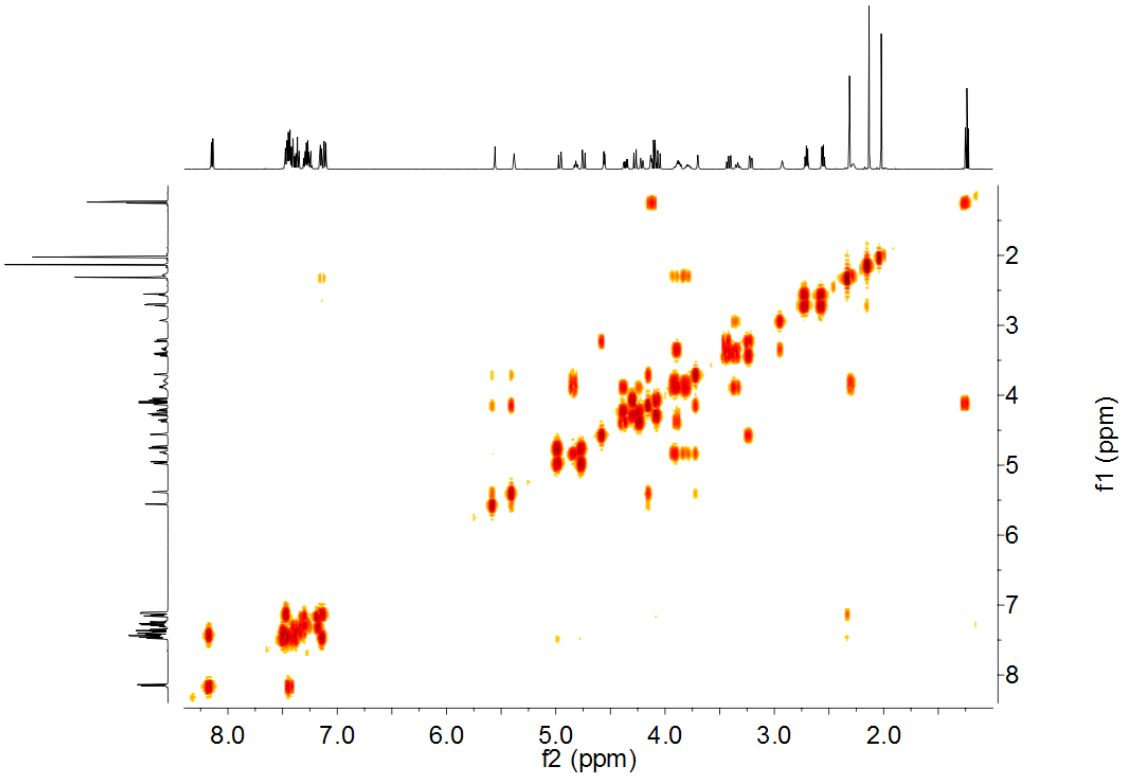
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S40**



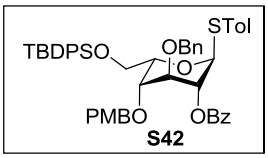


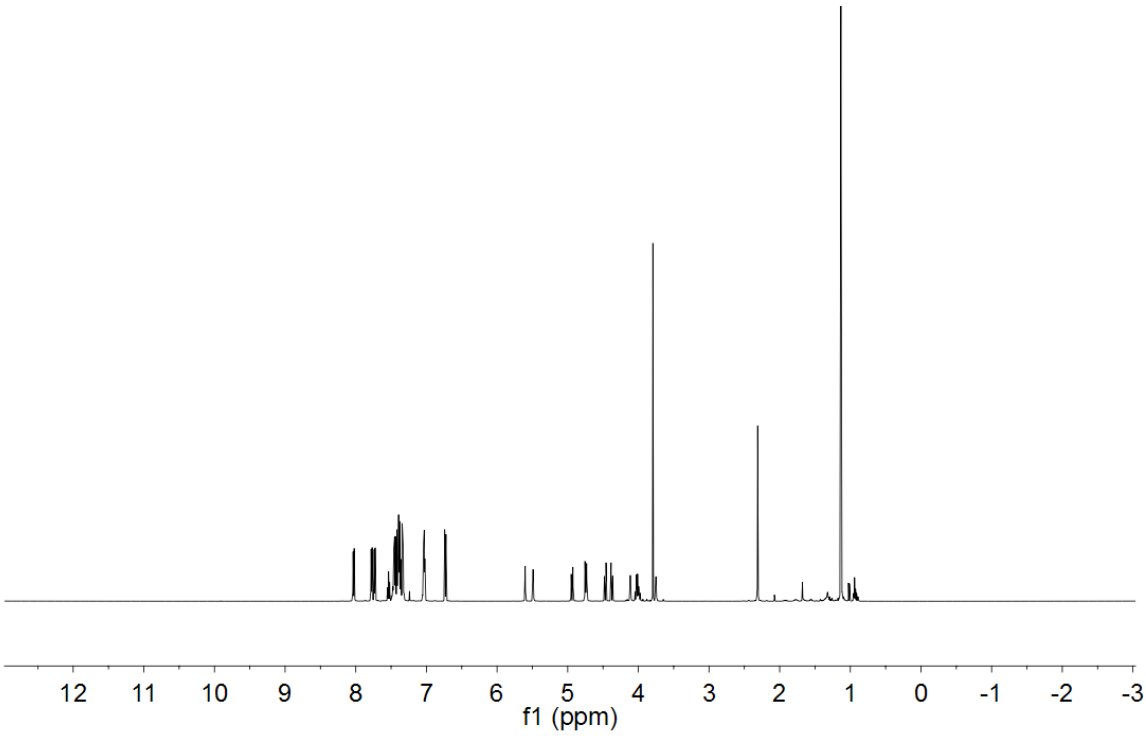
gCOSY ($CDCl_3$, 500 MHz) of **S40**



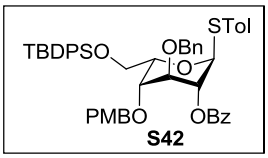


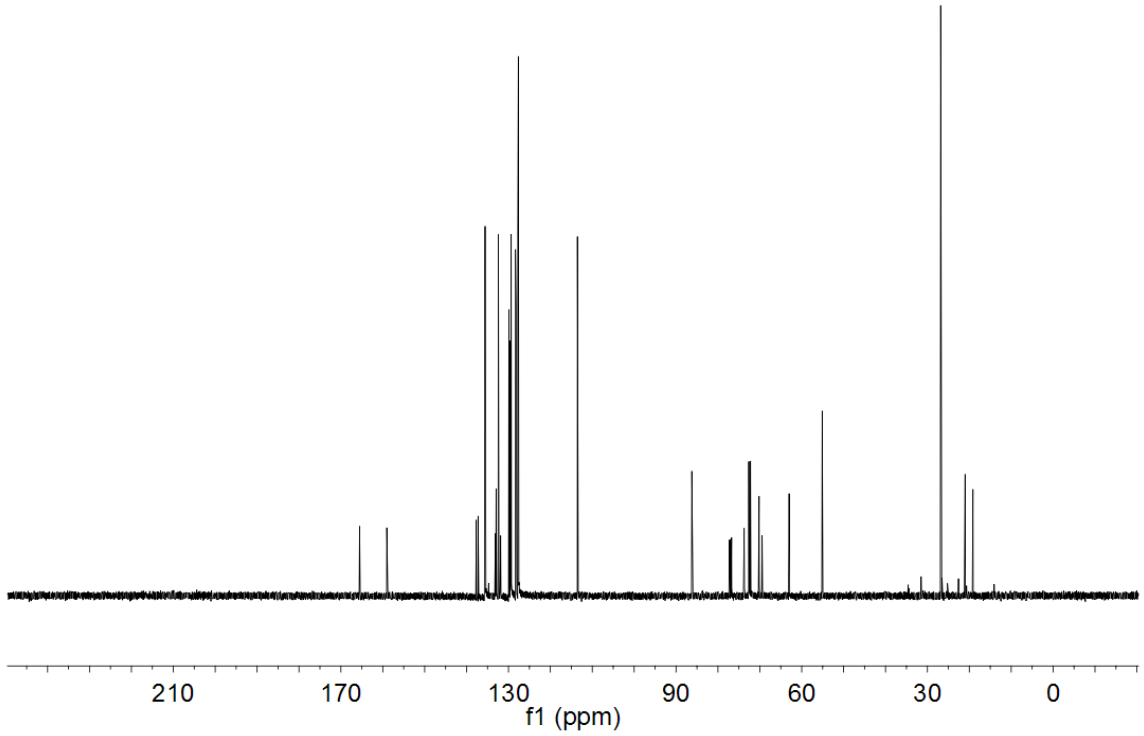
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S42**



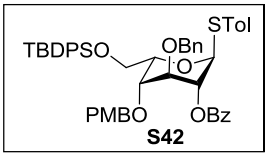


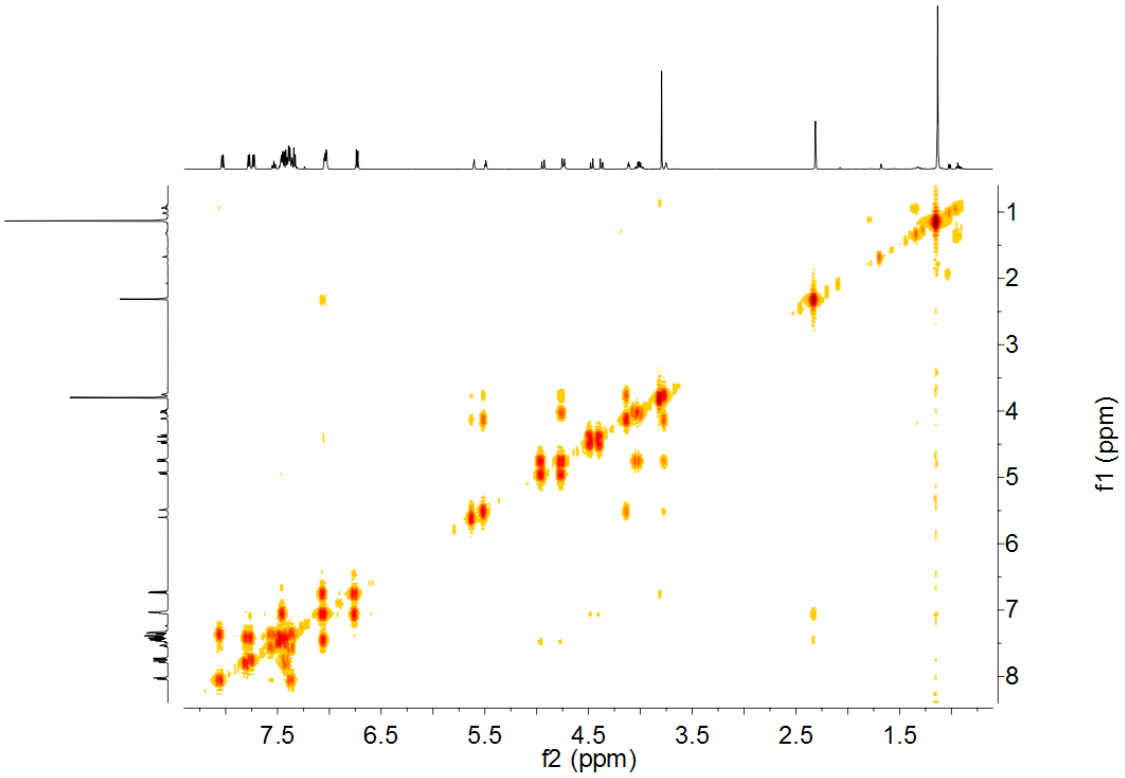
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S42**



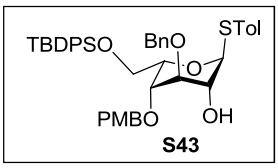


gCOSY ($CDCl_3$, 500 MHz) of **S42**

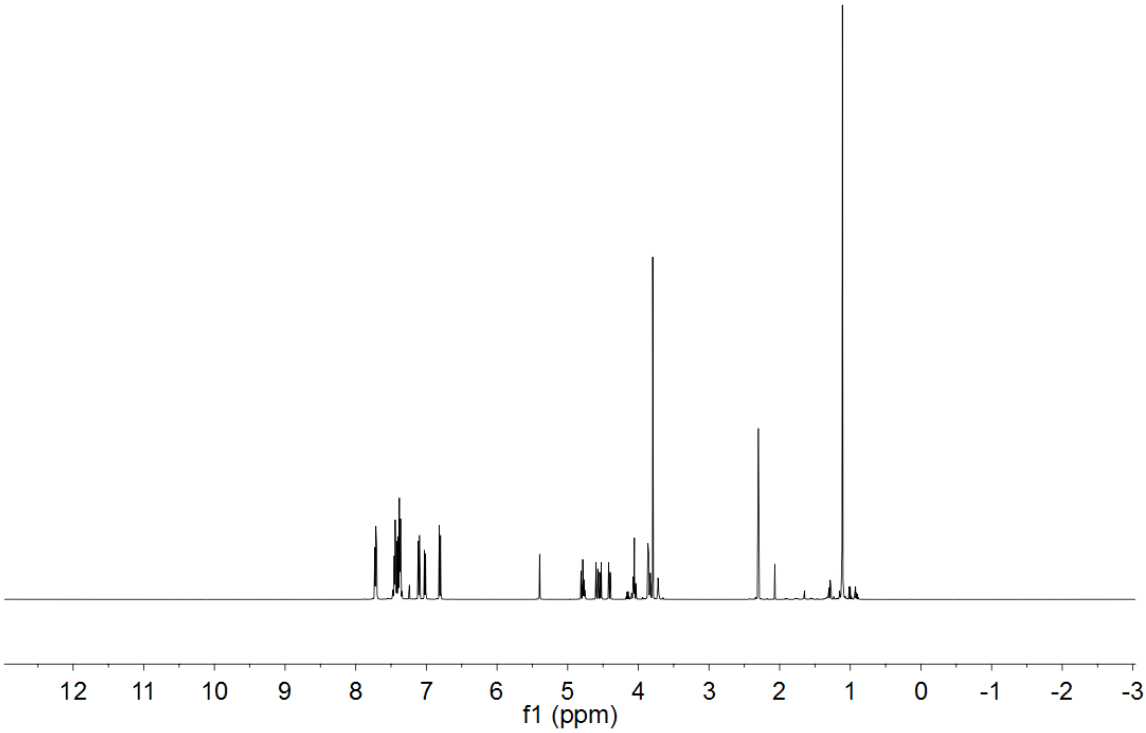




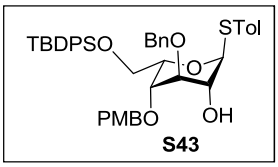
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S43**

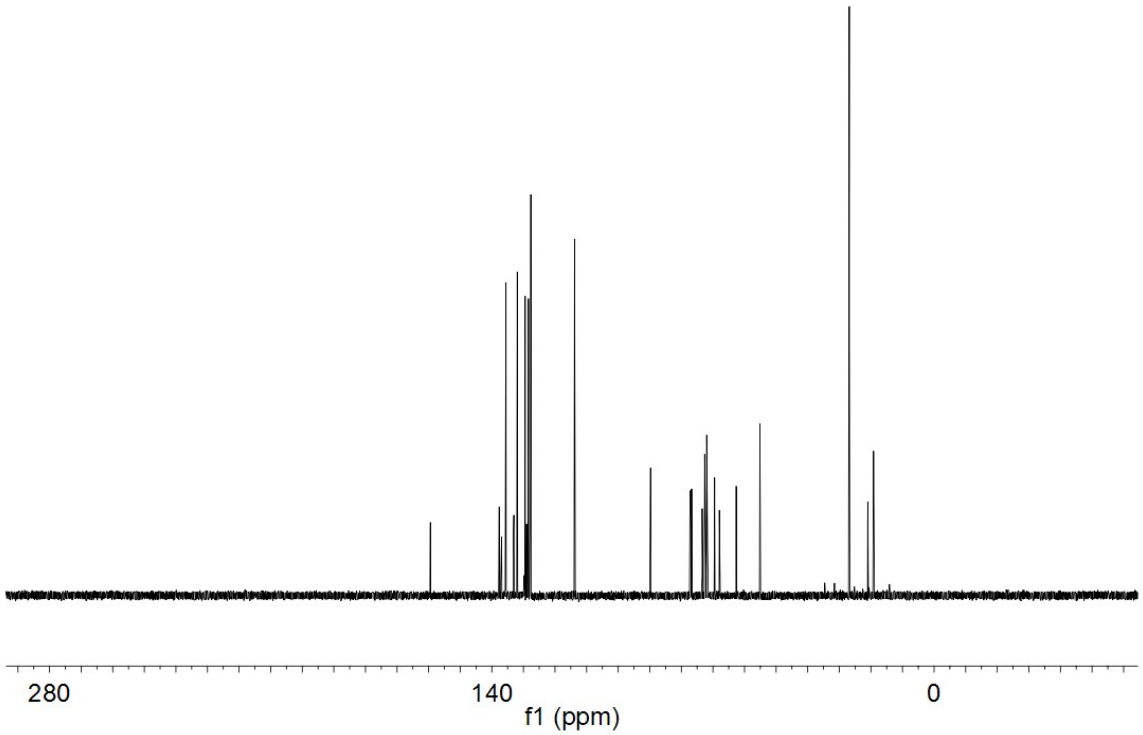


S43

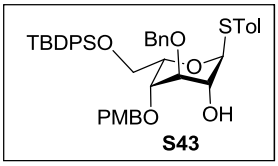


^{13}C-NMR ($CDCl_3$, 125 MHz) of **S43**

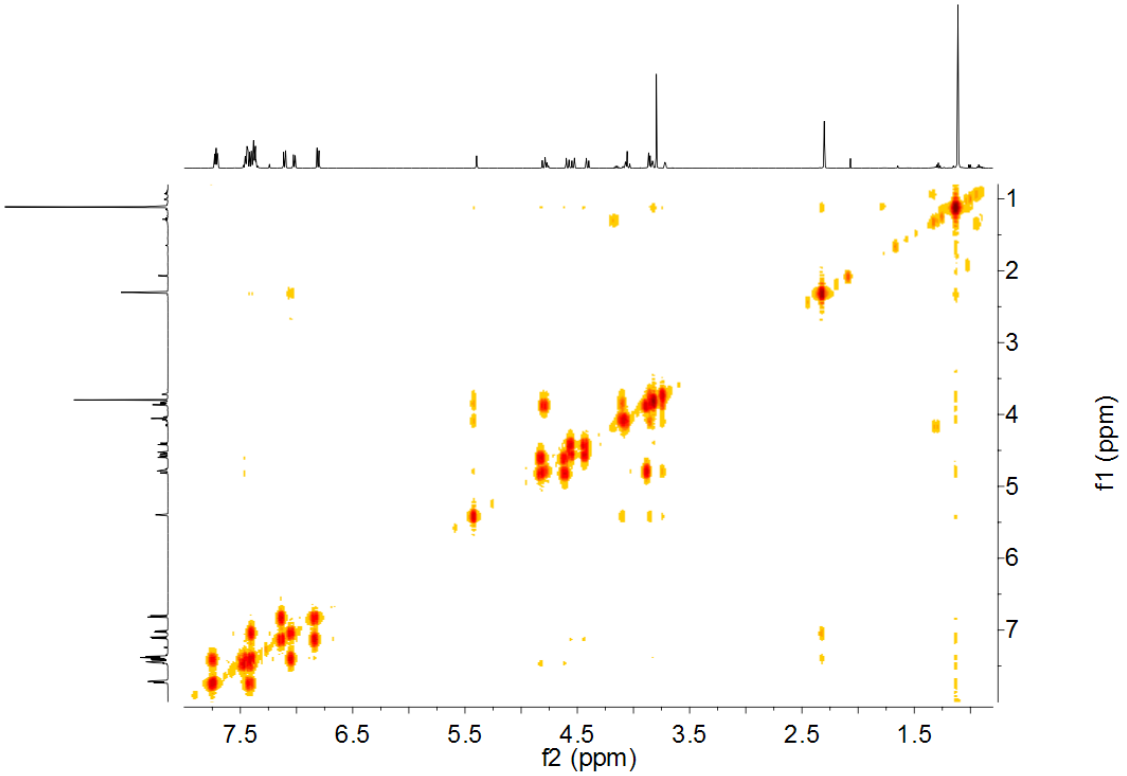




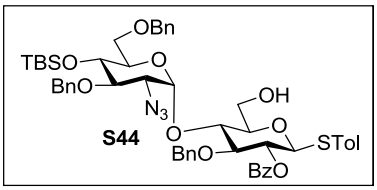
gCOSY ($CDCl_3$, 500 MHz) of **S43**

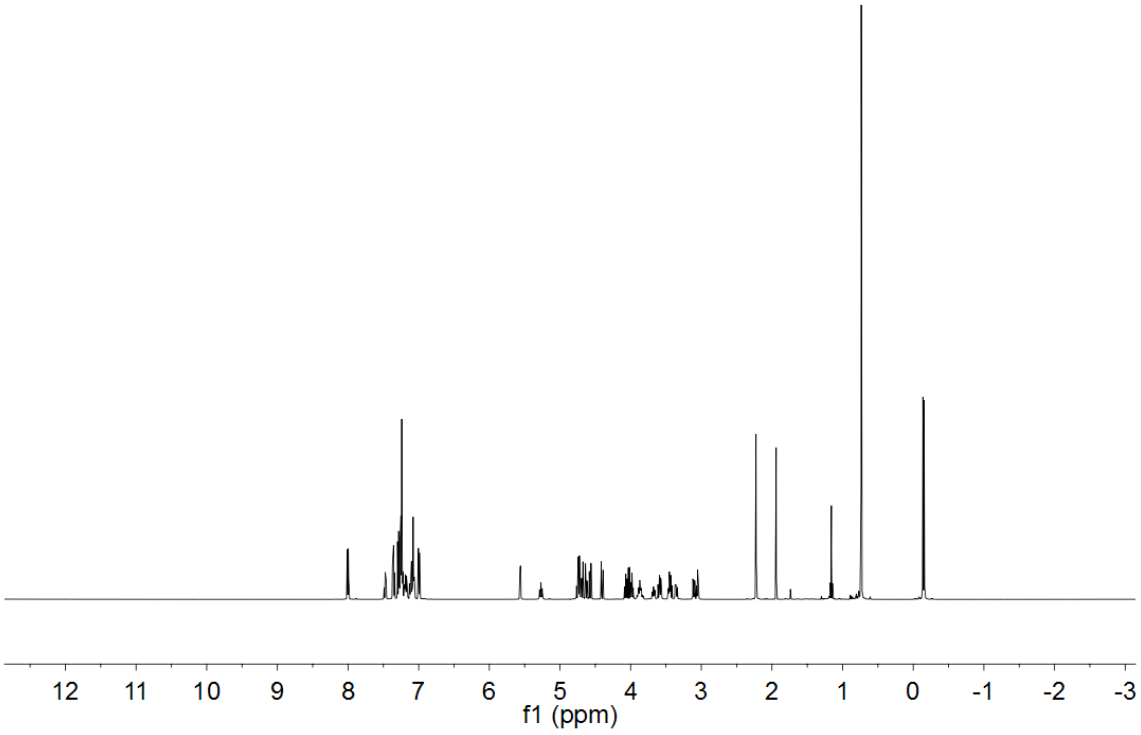


S43

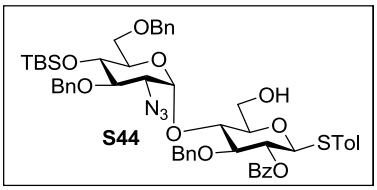


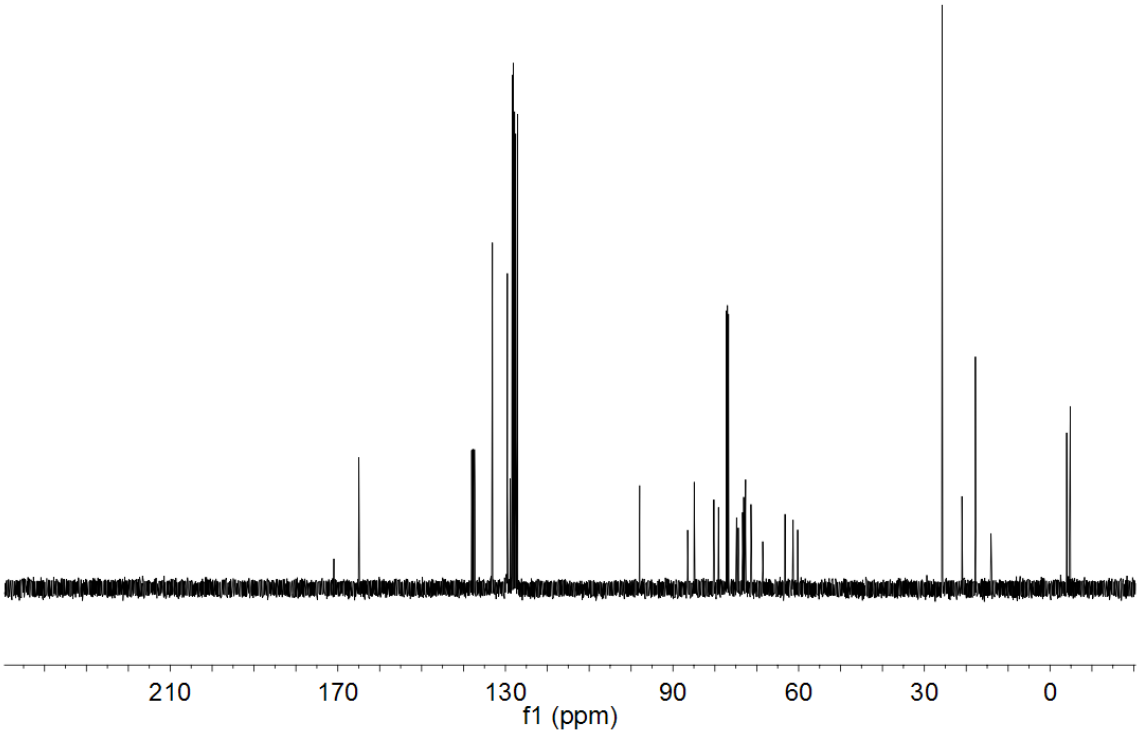
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S44**



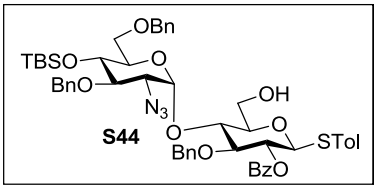


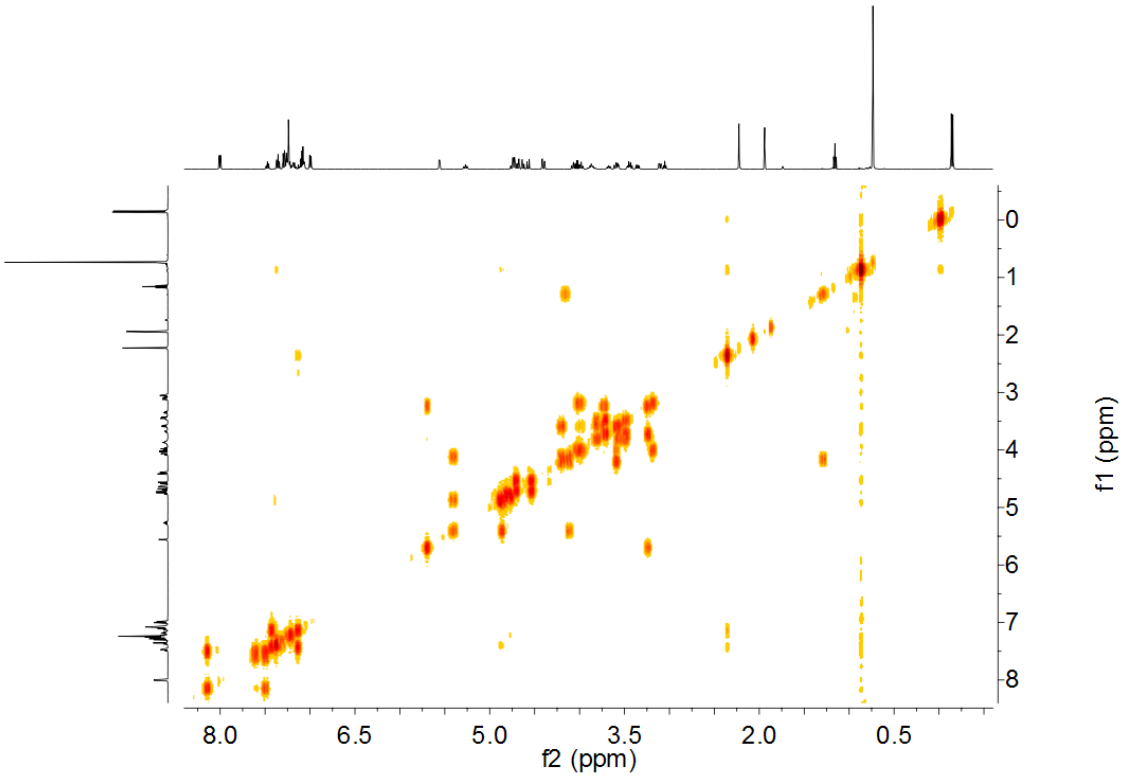
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S44**



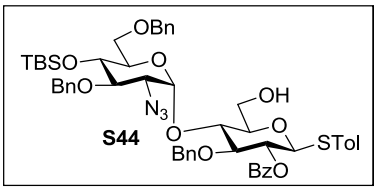


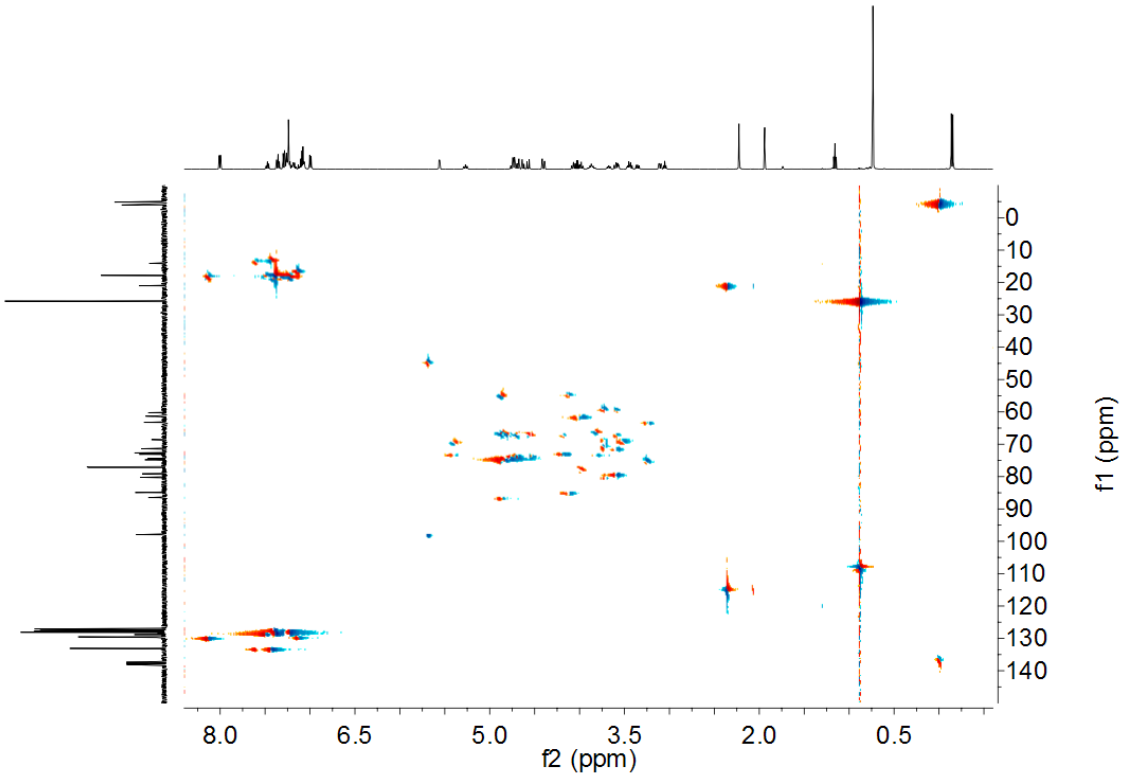
gCOSY ($CDCl_3$, 500 MHz) of **S44**



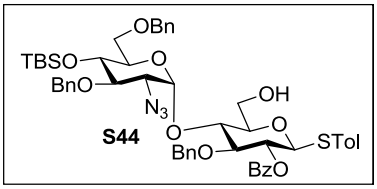


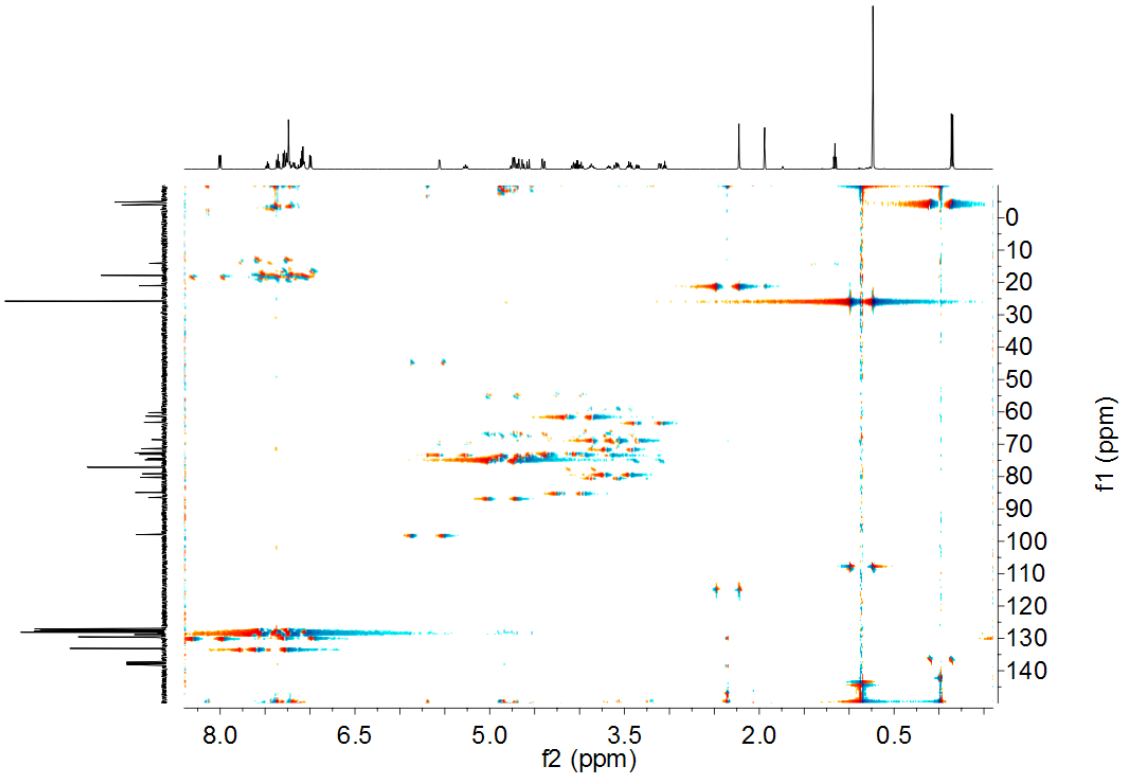
gHMQC ($CDCl_3$, 500 MHz) of **S44**



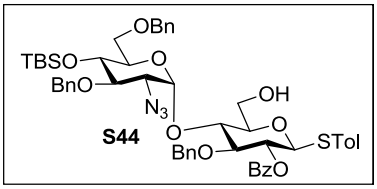


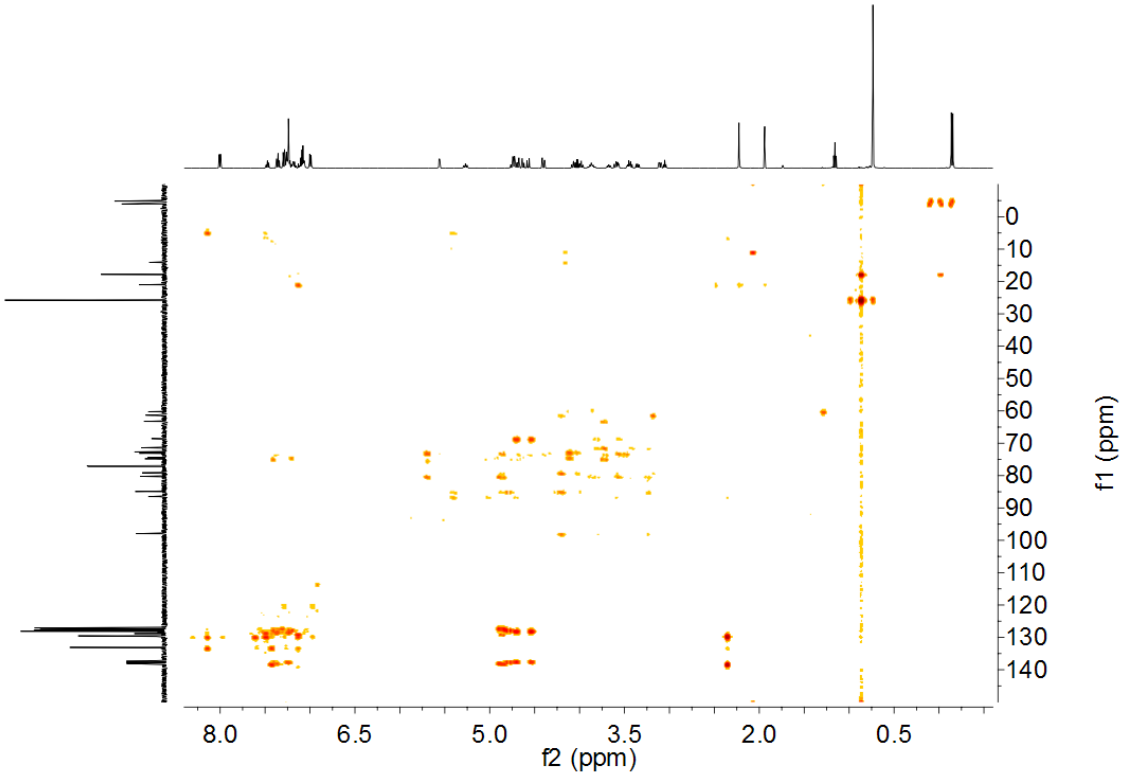
gHMQC (without ^{1}H decoupling) ($CDCl_3$, 500 MHz) of **S44**



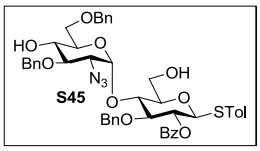


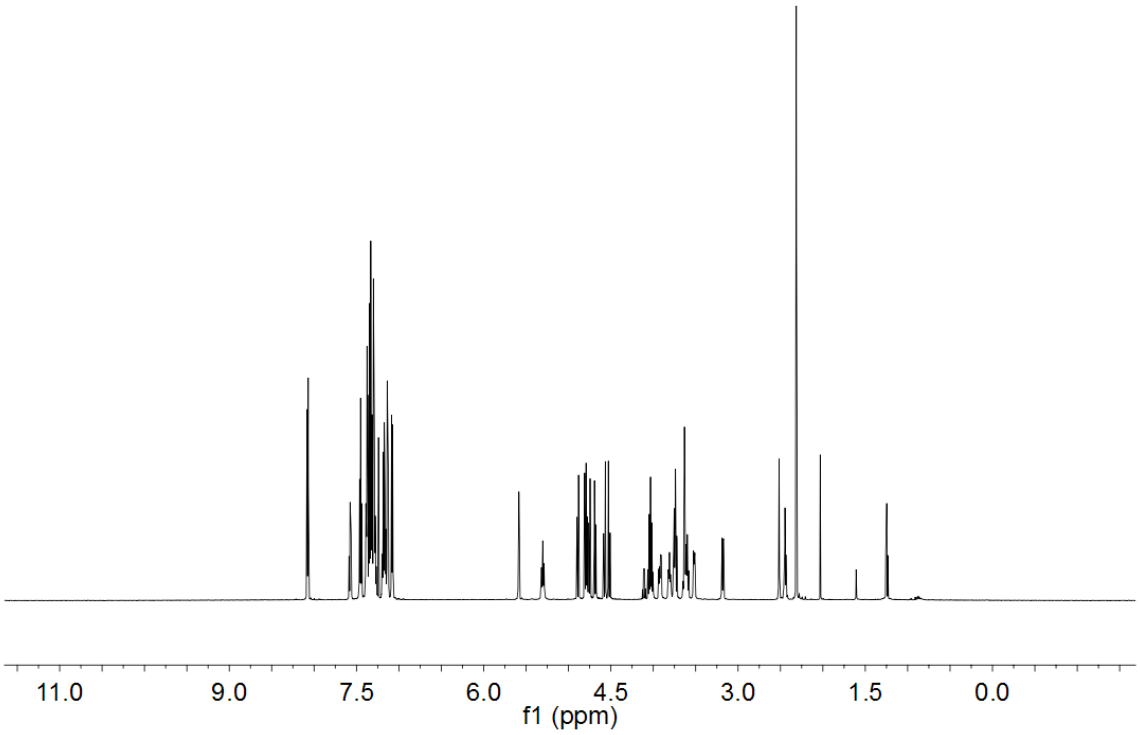
gHMBC ($CDCl_3$, 500 MHz) of **S44**



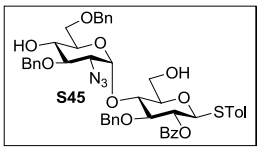


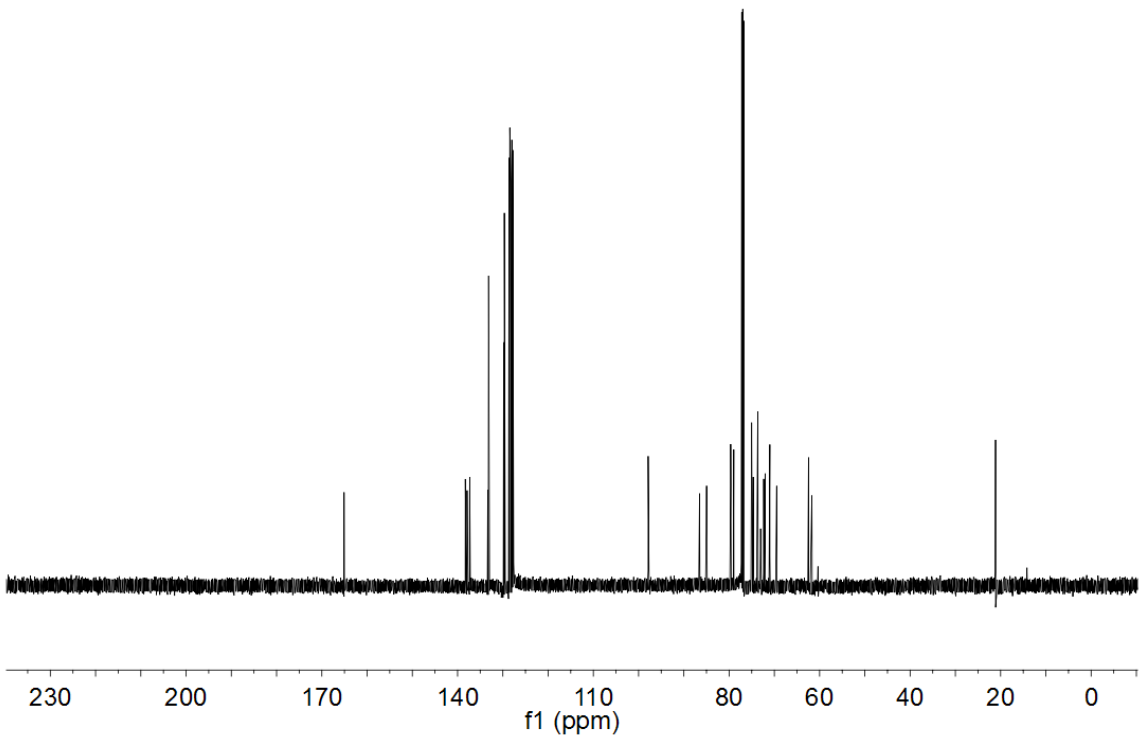
^{1}H-NMR ($CDCl_3$, 600 MHz) of **S45**



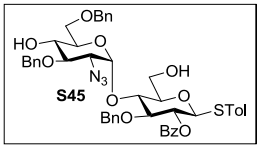


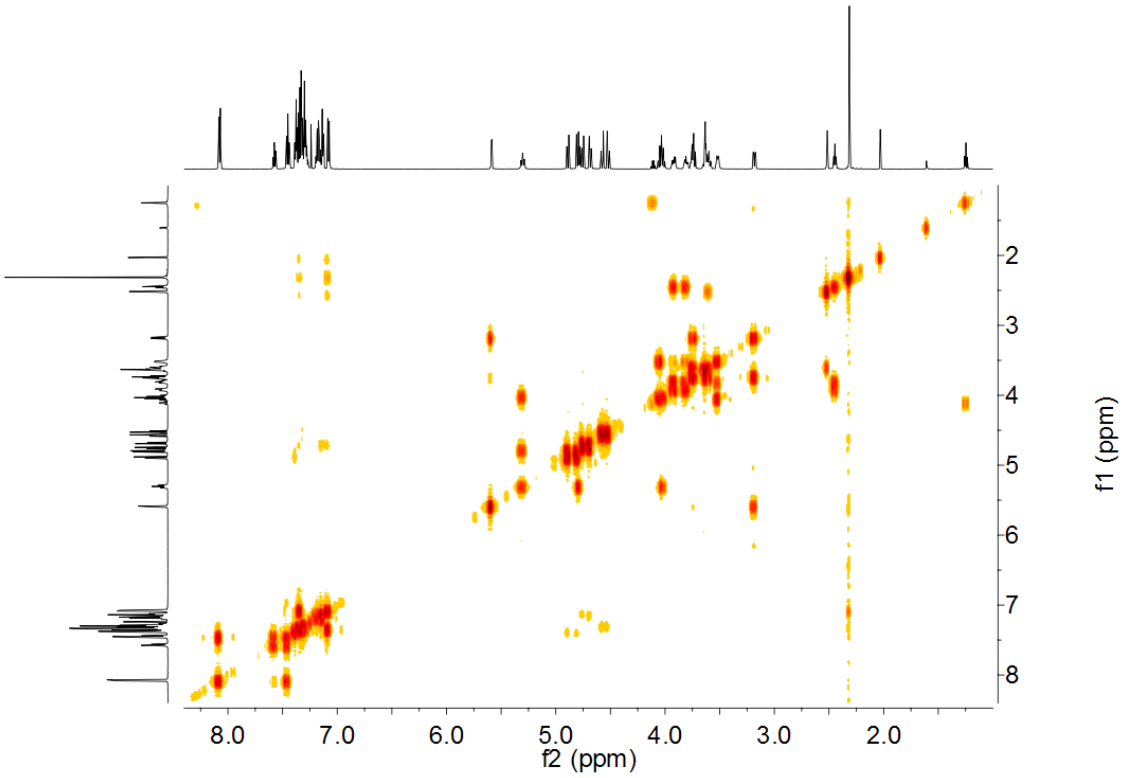
^{13}C-NMR ($CDCl_3$, 150 MHz) of **S45**



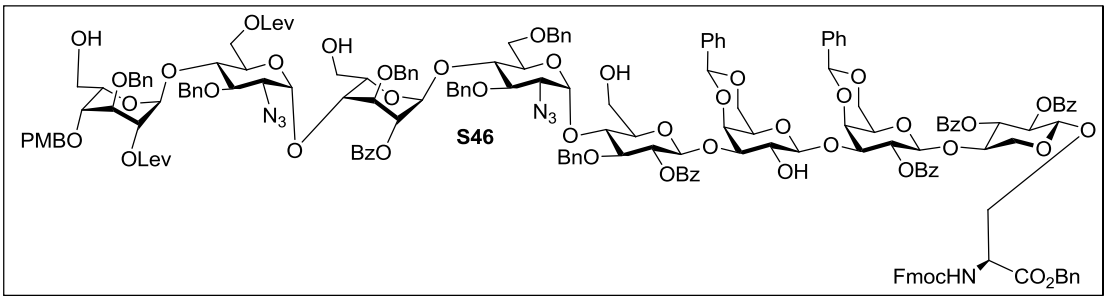


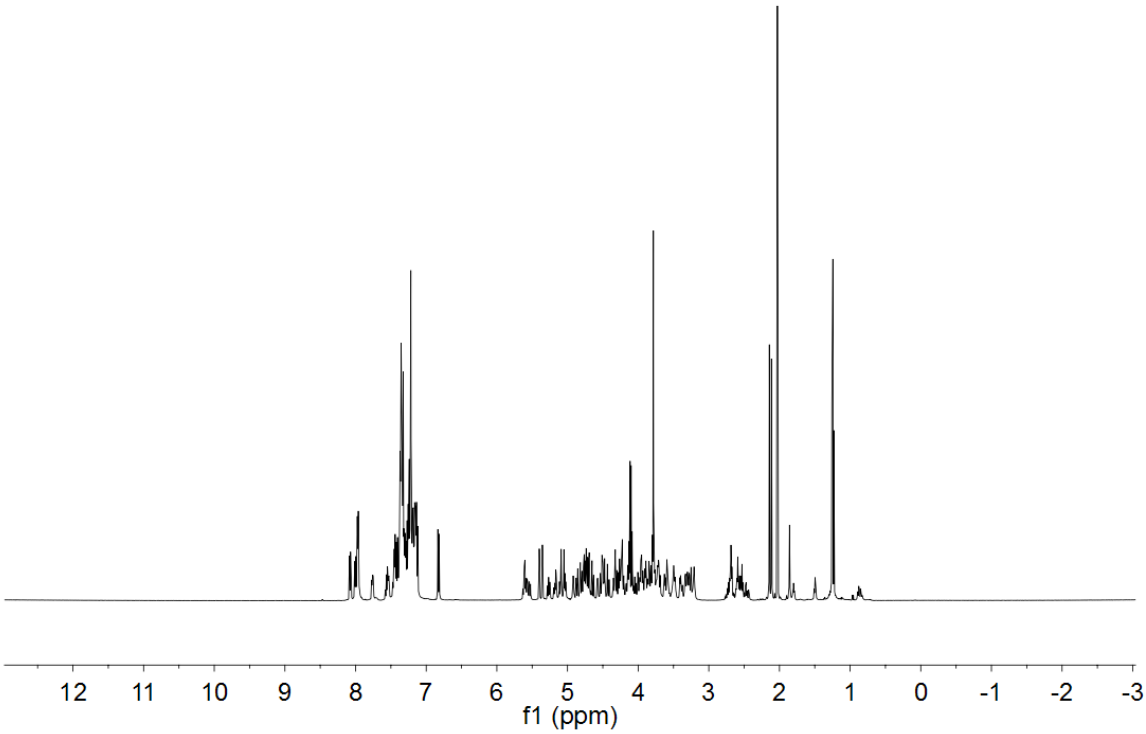
gCOSY ($CDCl_3$, 600 MHz) of **S45**



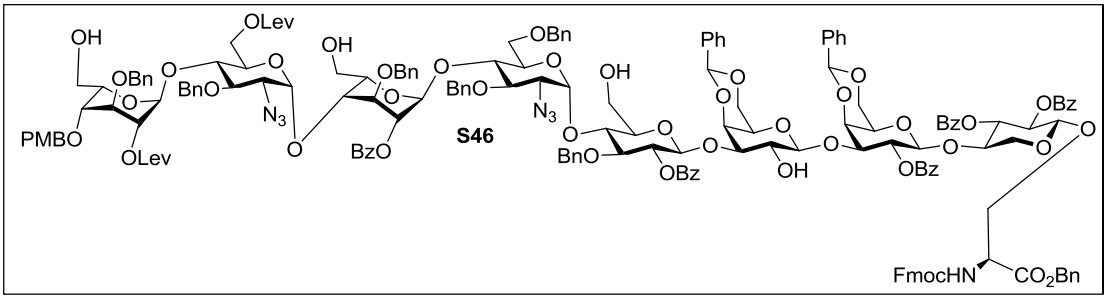


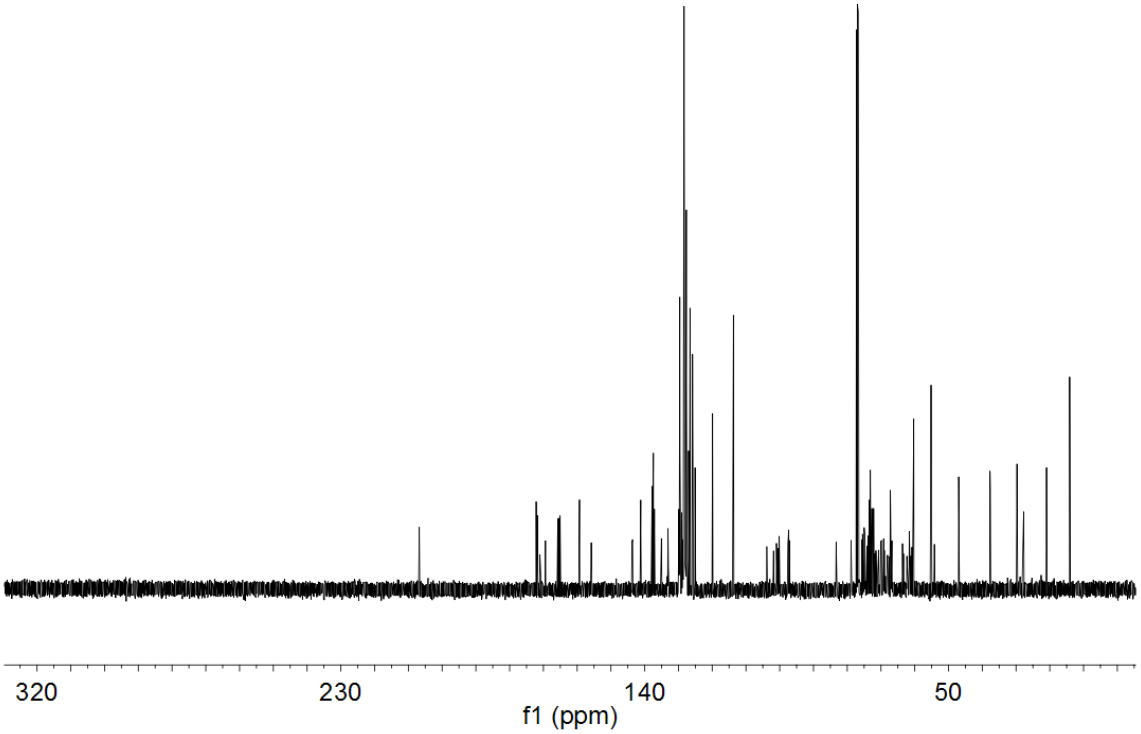
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S46**



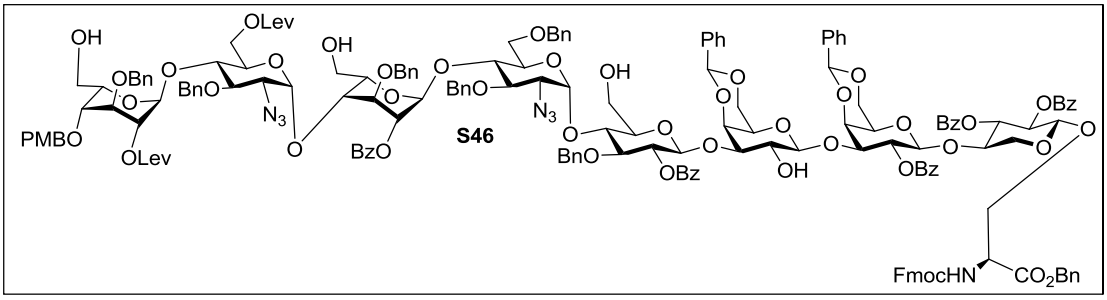


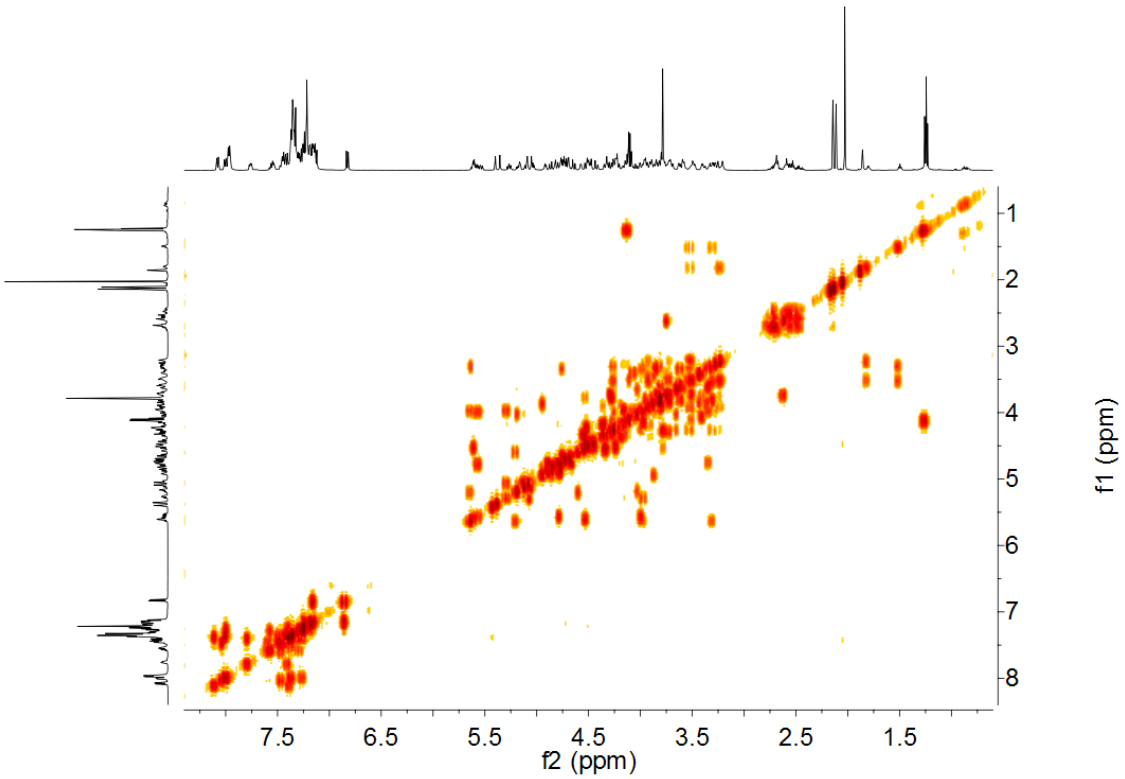
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S46**



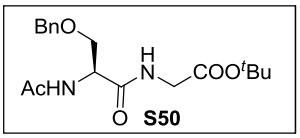


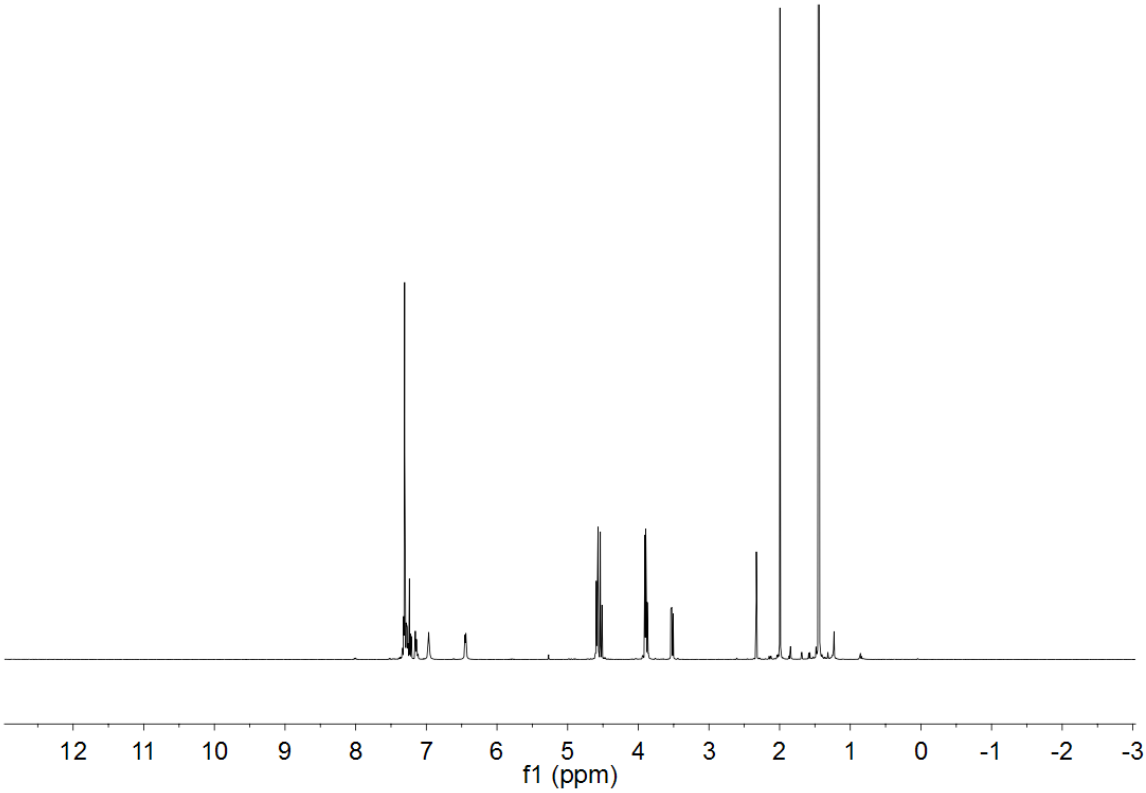
gCOSY ($CDCl_3$, 500 MHz) of **S46**



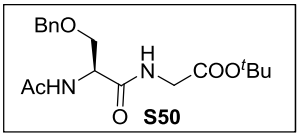


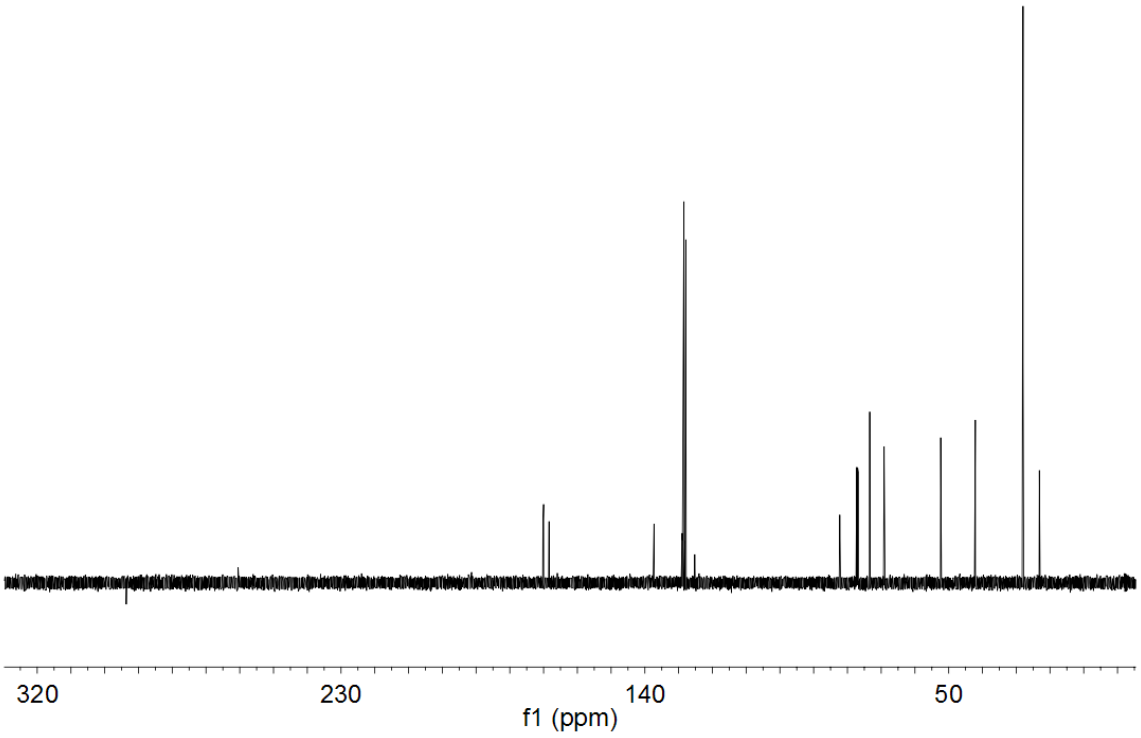
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S50**



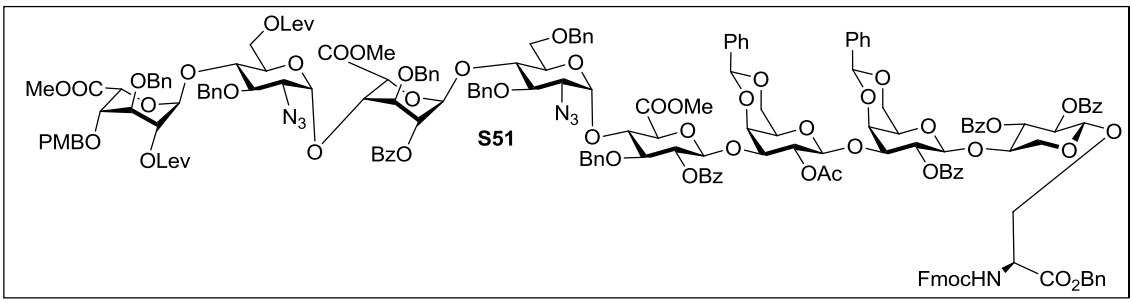


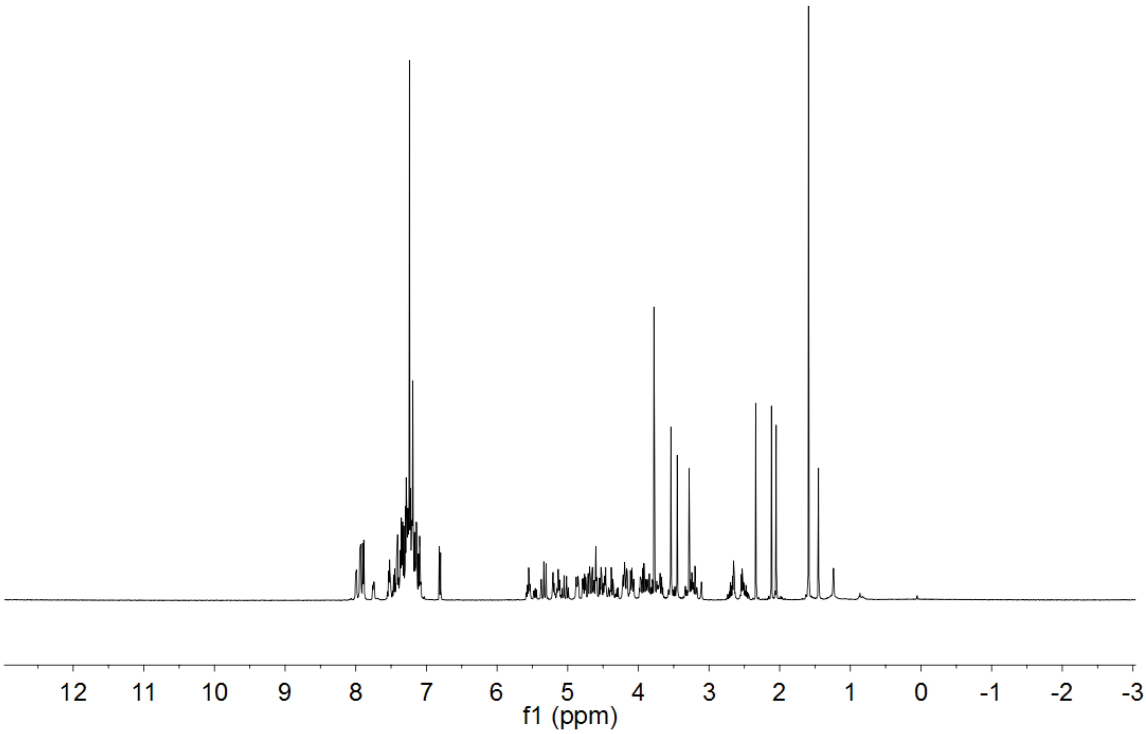
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S50**



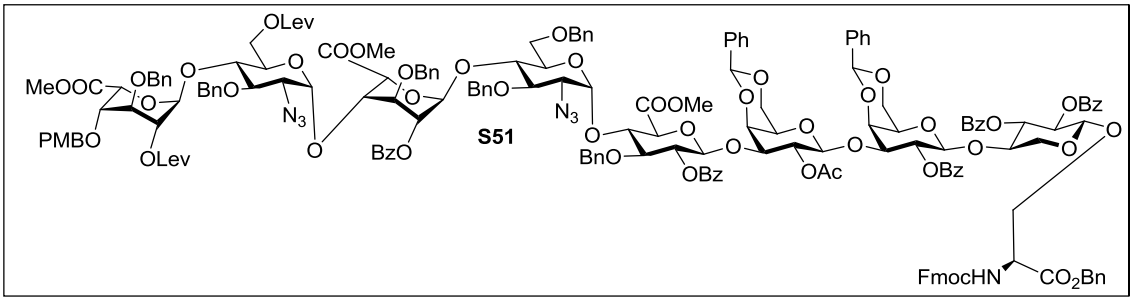


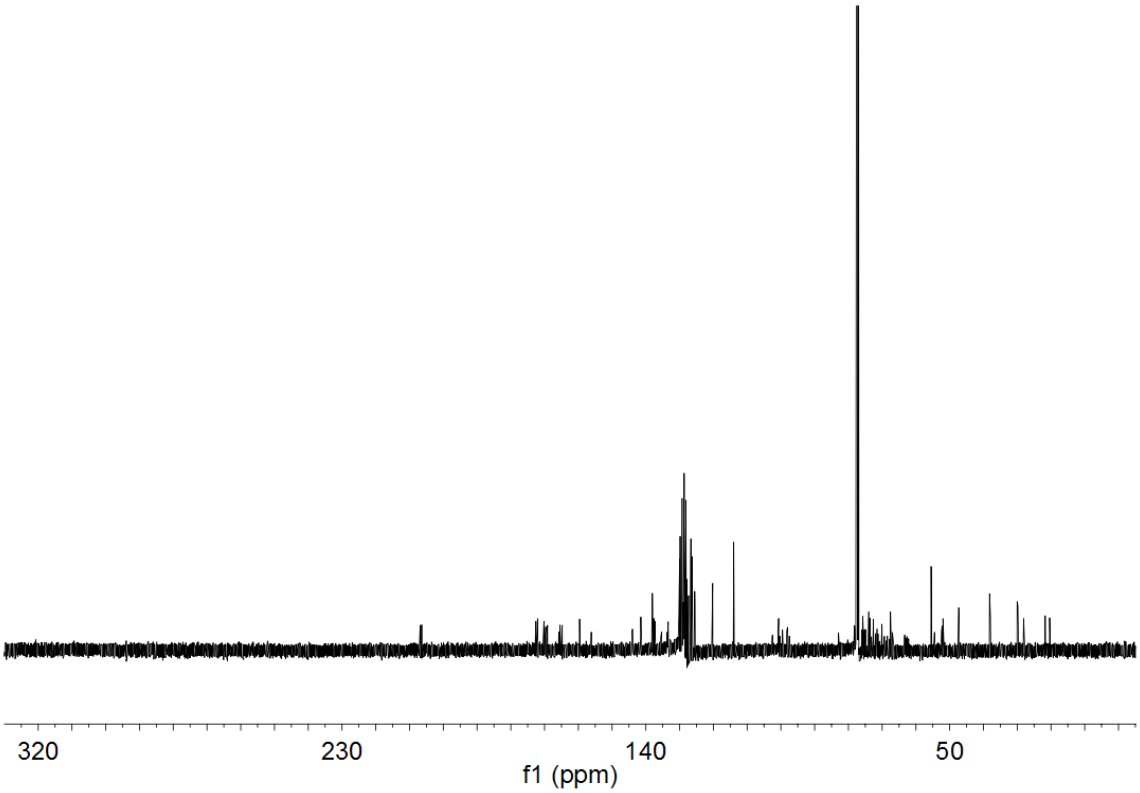
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S51**



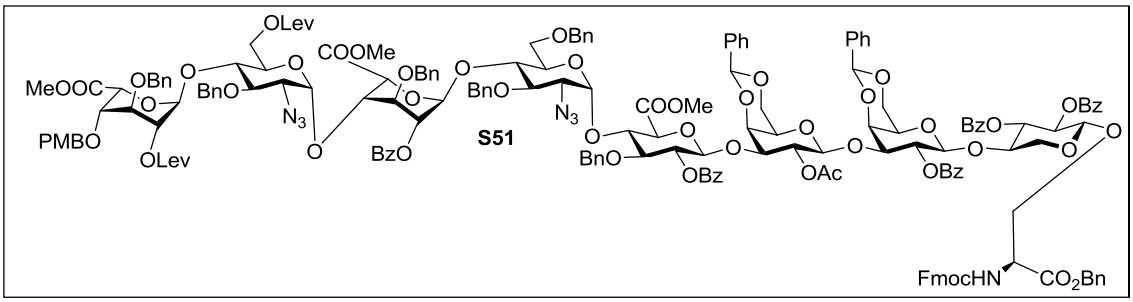


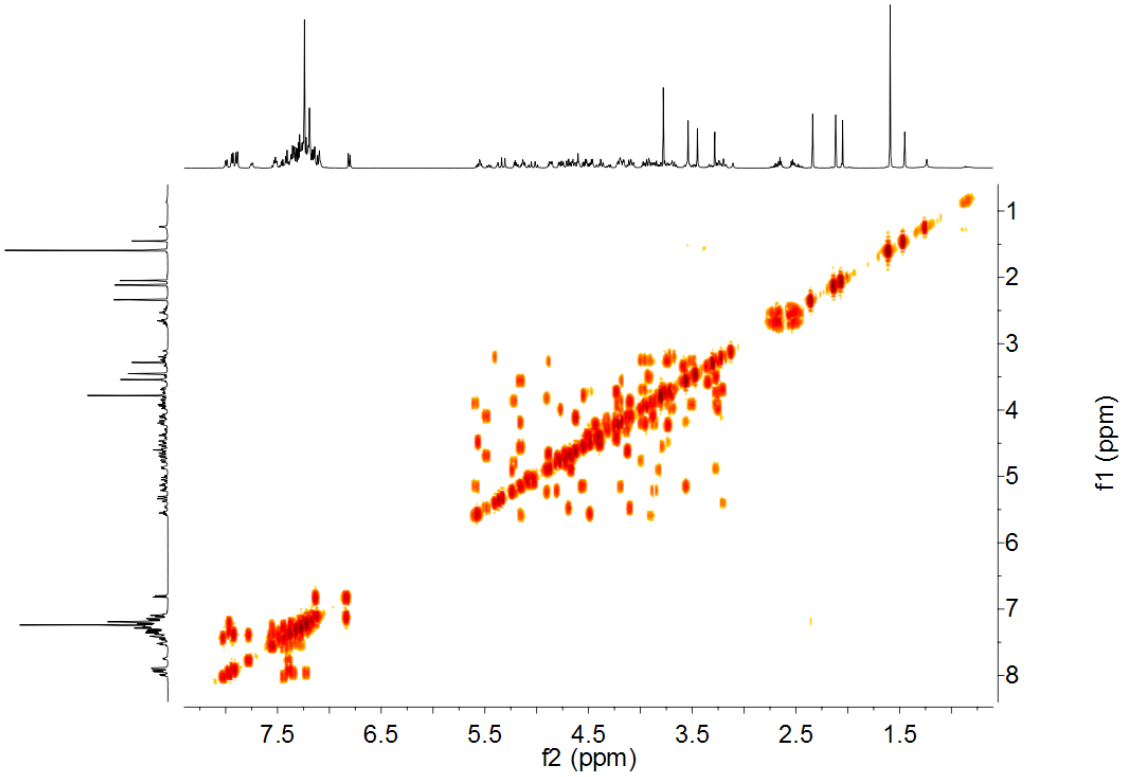
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S51**



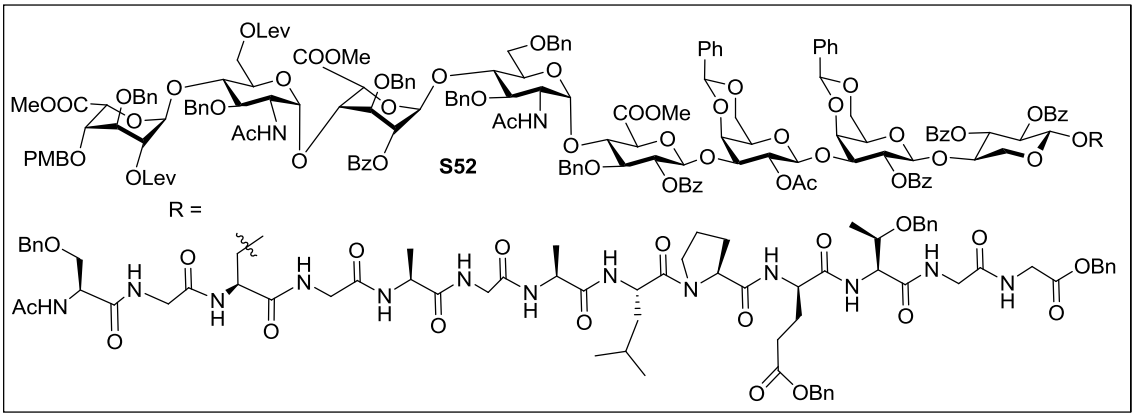


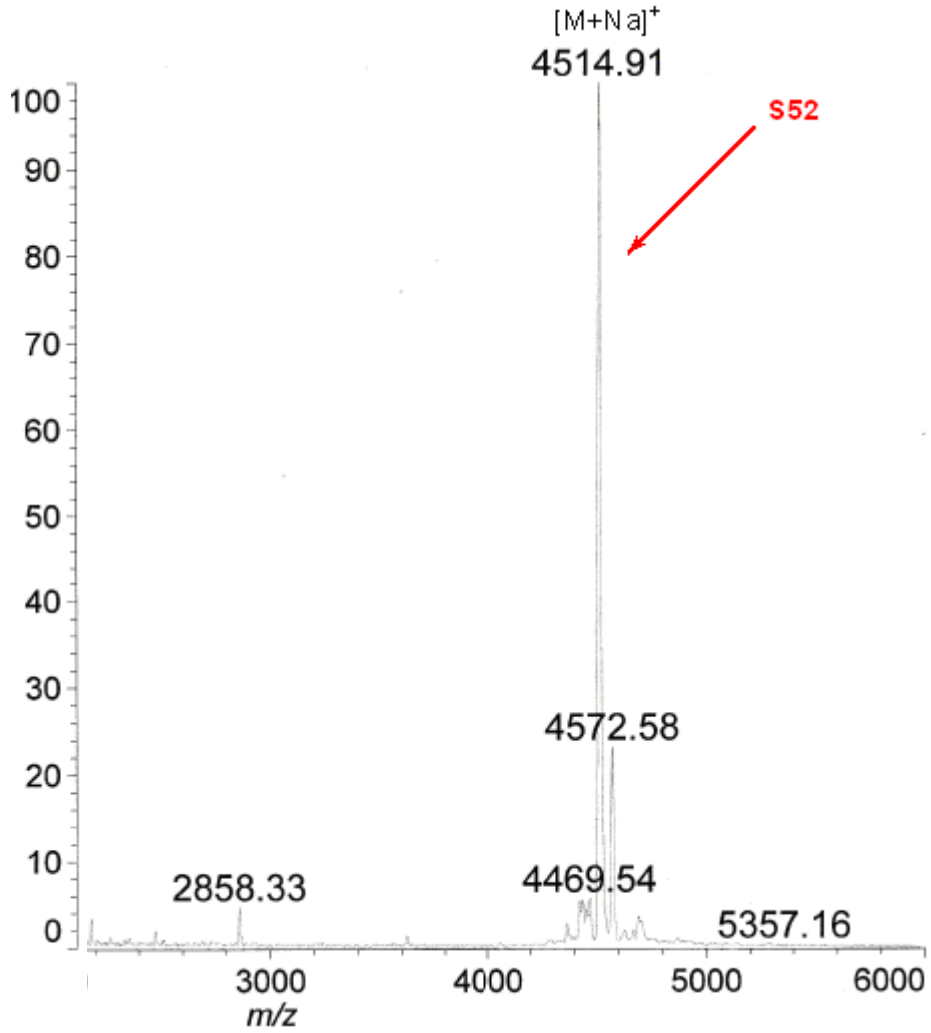
gCOSY ($CDCl_3$, 500 MHz) of **S51**



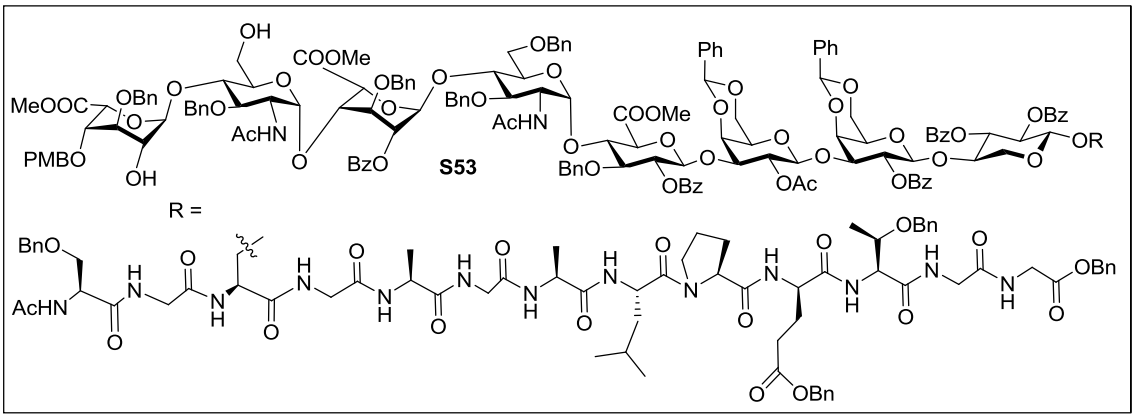


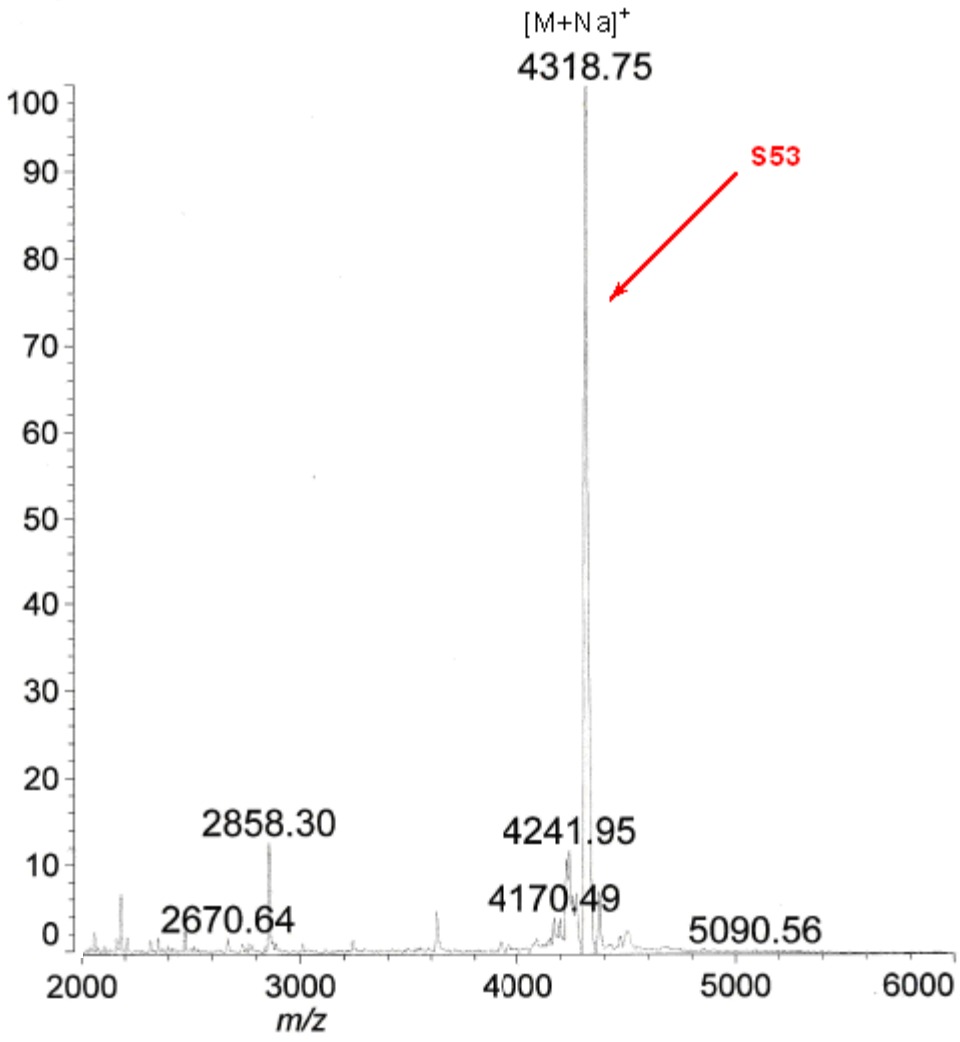
MALDI-MS of **S52**



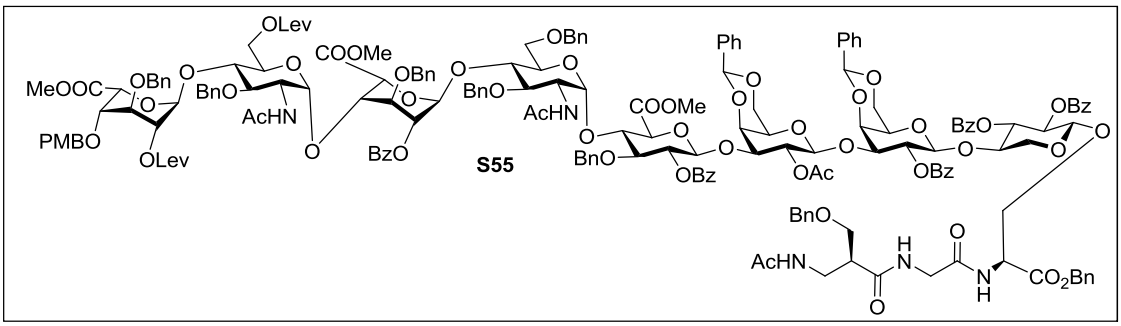


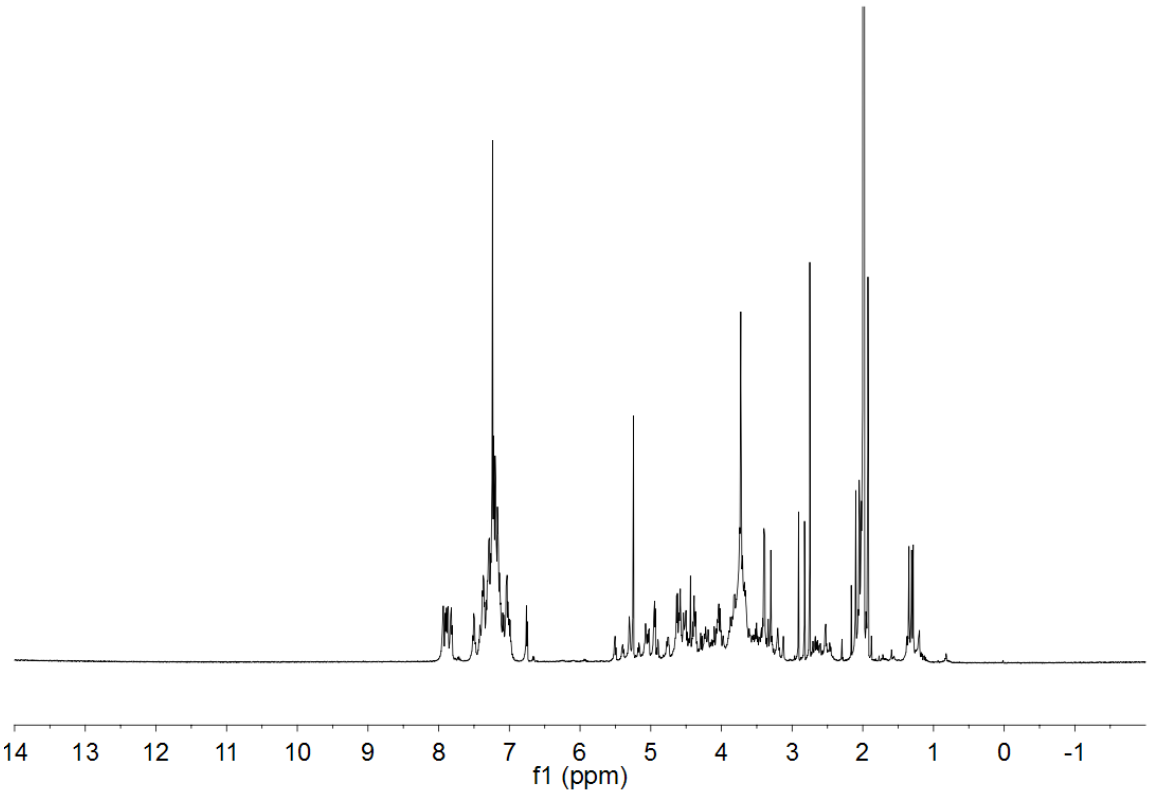
MALDI-MS of **S53**



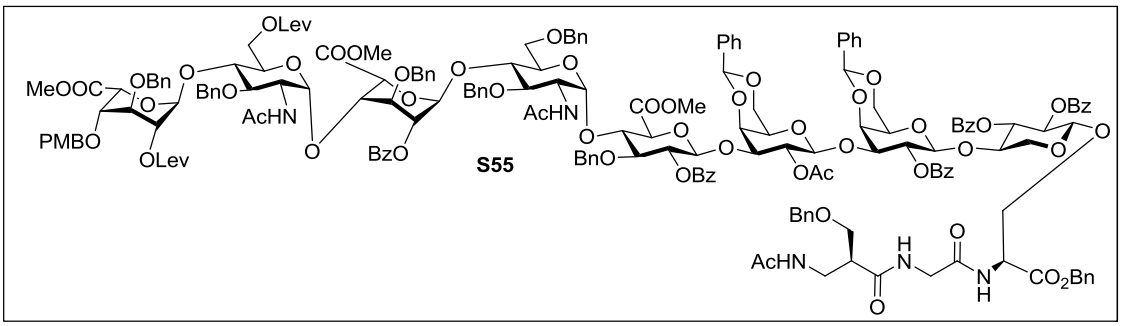


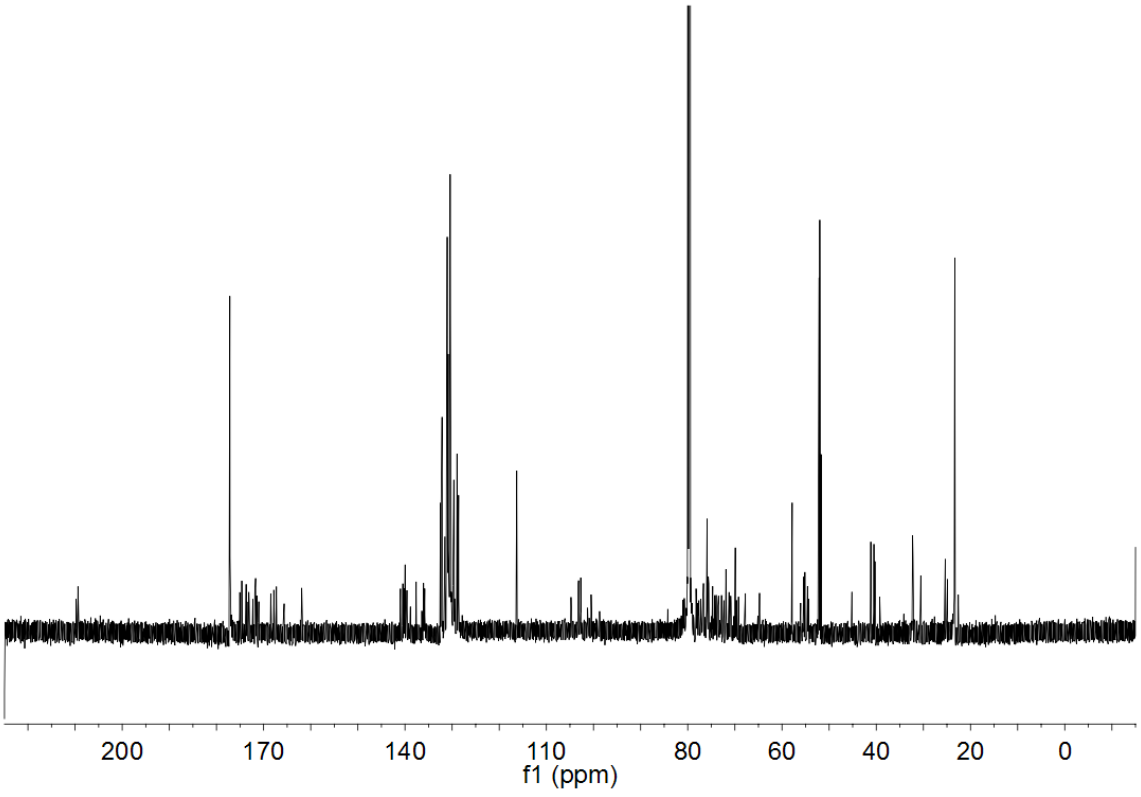
^{1}H-NMR ($CDCl_3$, 600 MHz) of **S55**



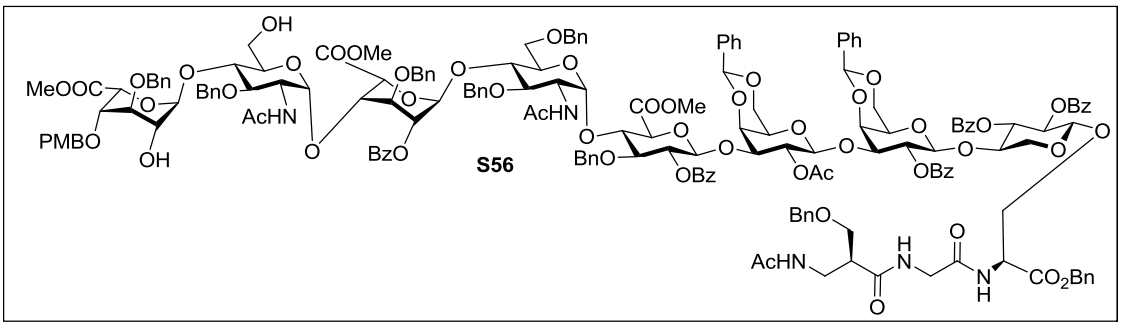


^{13}C-NMR ($CDCl_3$, 150 MHz) of **S55**

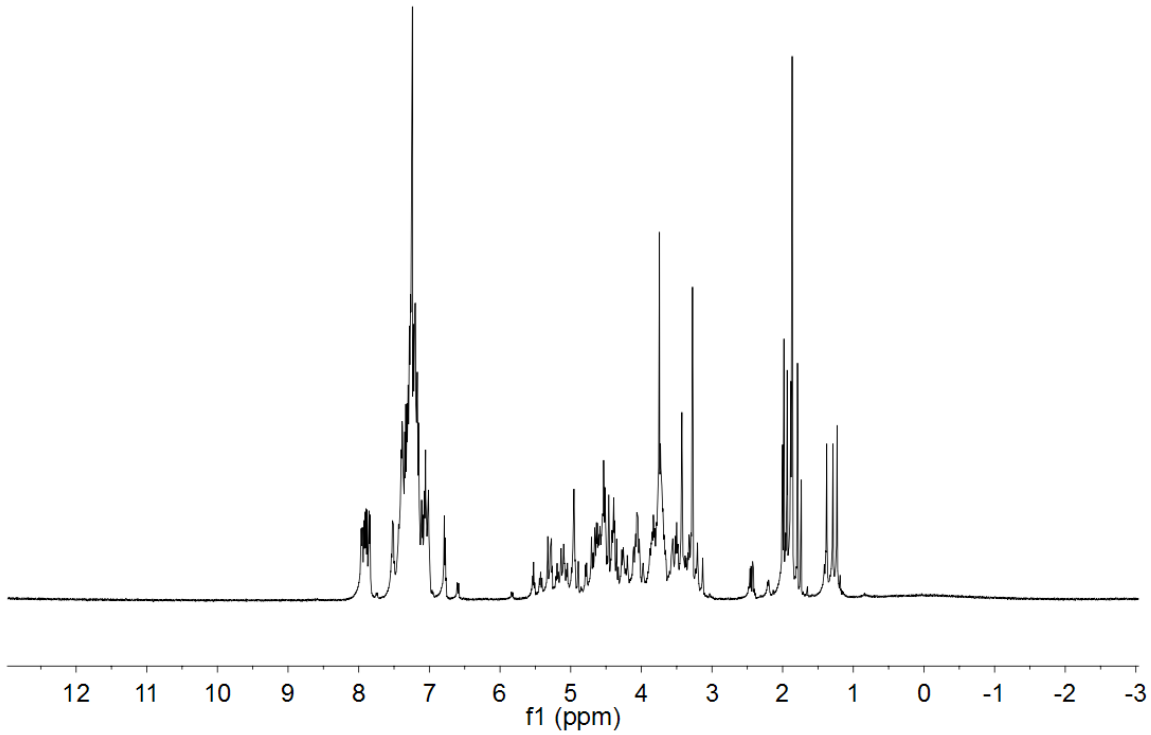




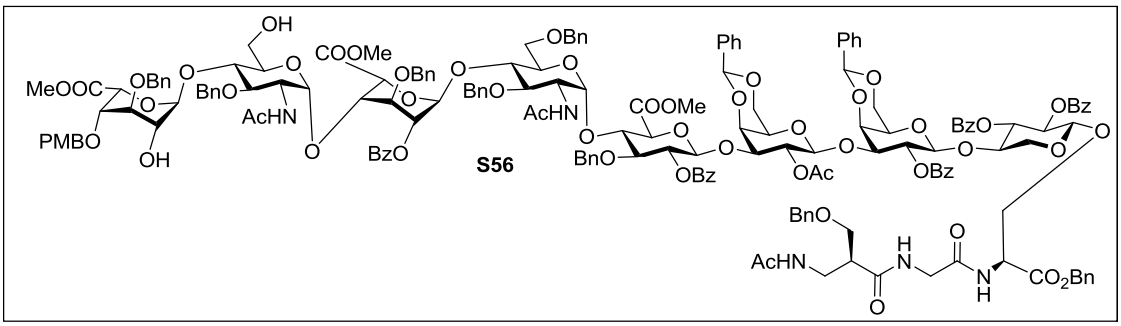
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S56**

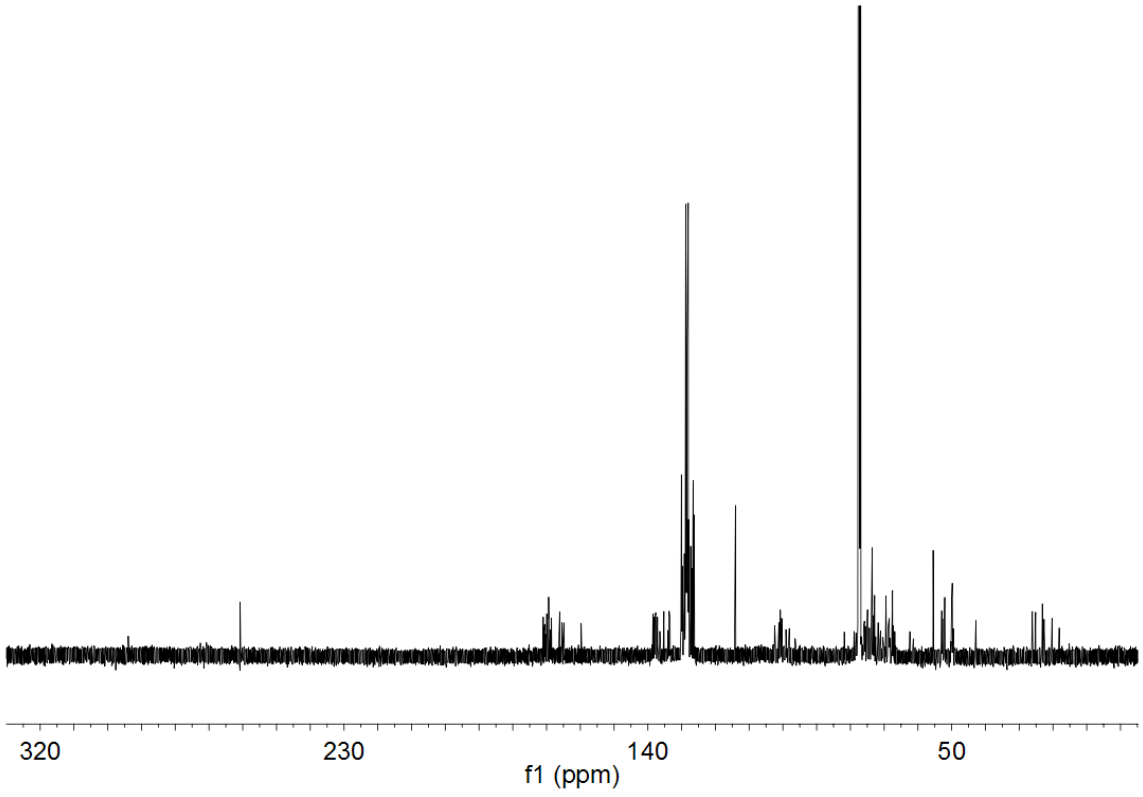


S56

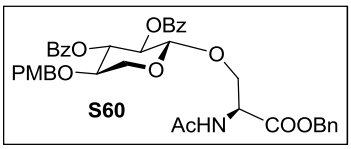


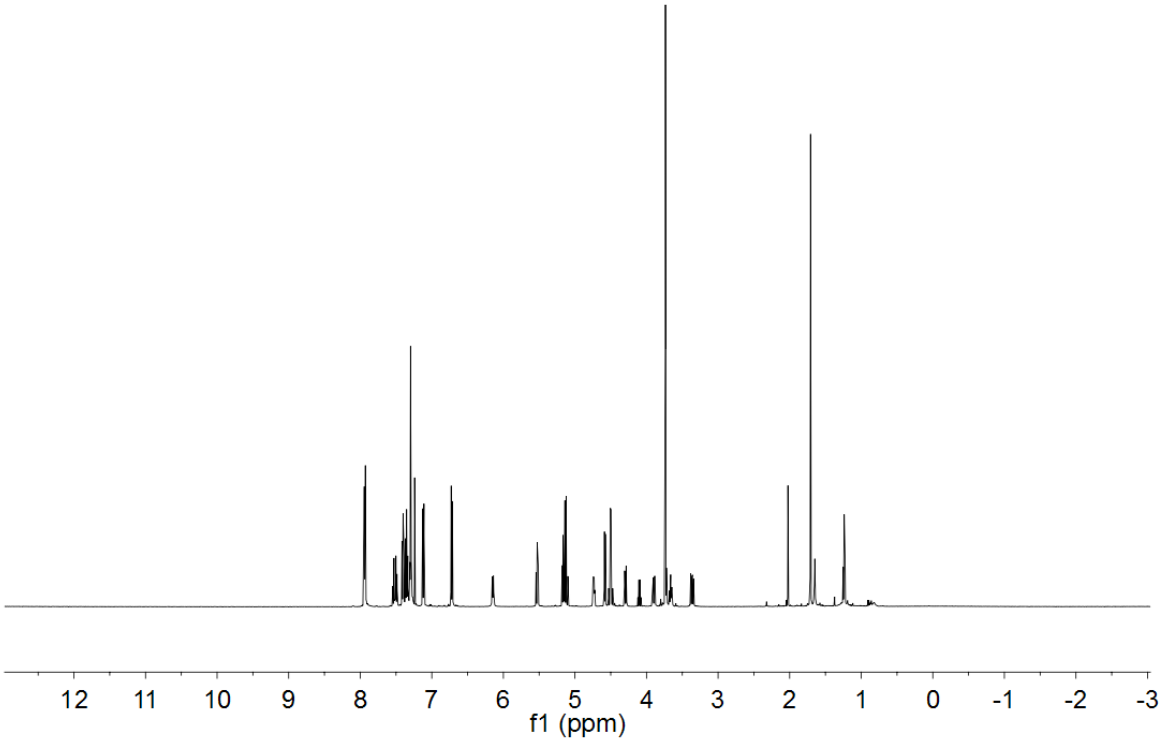
^{13}C-NMR ($CDCl_3$, 125 MHz) of **S56**



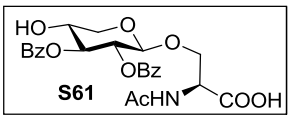


^{1}H-NMR ($CDCl_3$, 500 MHz) of **S60**

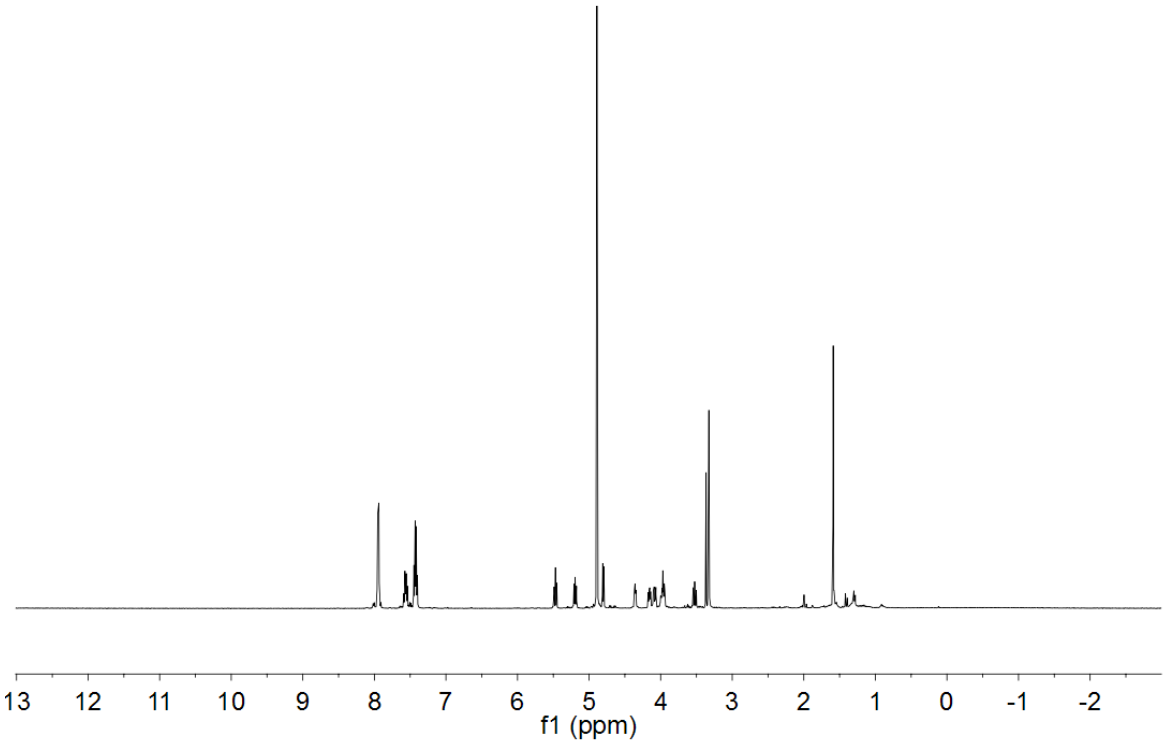




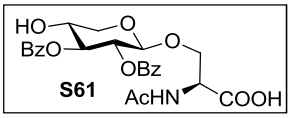
^{1}H-NMR ($CDCl_3$, 500 MHz) of **S61**

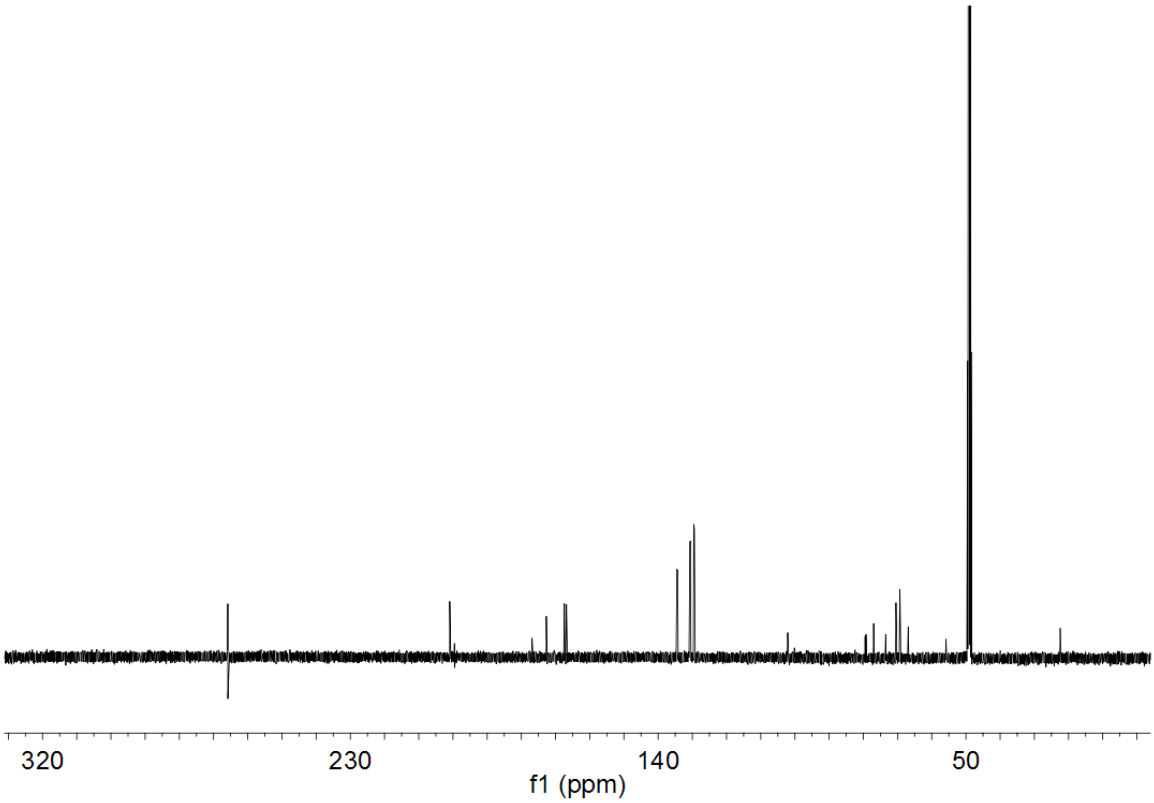


S61



^{13}C-NMR ($CDCl_3$, 125 MHz) of **S61**





^{1}H-NMR ($CDCl_3$, 500 MHz) of **S62**