Supplementary Information

'Nonself' sugar mimic of the HIV "glycan shield" shows enhanced antigenicity

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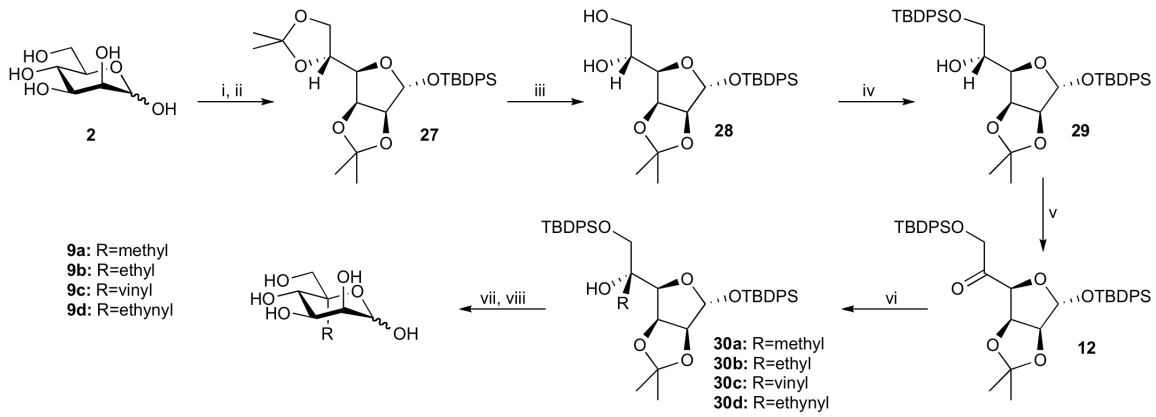
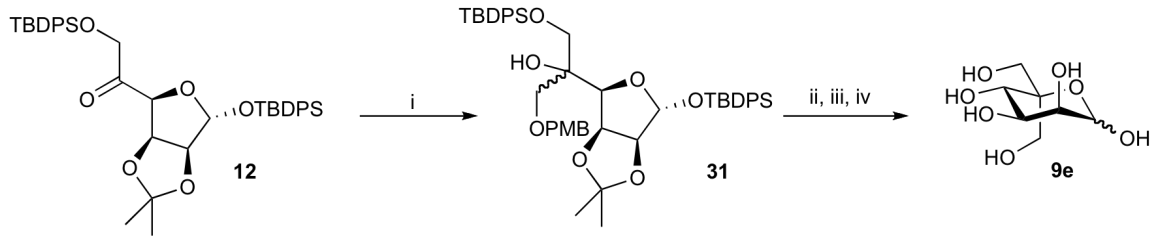
Contents

1. Experimental:

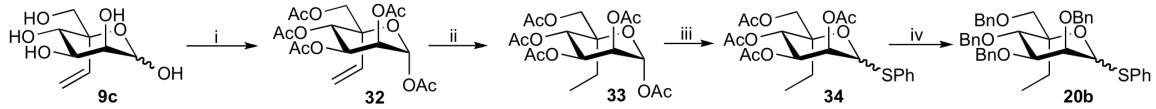
1.1 C-5 substituted monomer synthesis



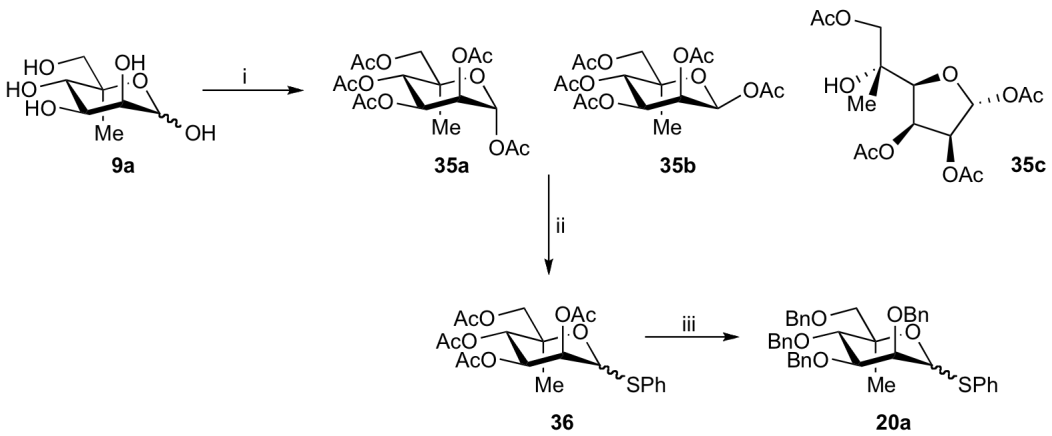
Scheme S1: i) 2,2-dimethyloxypropane, pTsOH, DMF, 73%, ii) TBDPSCl, Imidazole, DCM, 95%, iii) c.HCl, MeOH, 82%, iv) TBDPSCl, Imidazole, DMF, 79%, v) DMSO, $C_2O_2Cl_2$, DCM, -78$^oC \rightarrow$RT, 97%, vi) RMgBr, THF, vii) TBAF, THF, viii) TFA, H_2O.



Scheme S2: i) Bu_3SnCH_2OPMB, BuLi, THF, 76%, ii) CAN, MeCN, H_2O, 69%, iii) TBAF, THF, 94%, iv) TFA, H_2O, 43%.

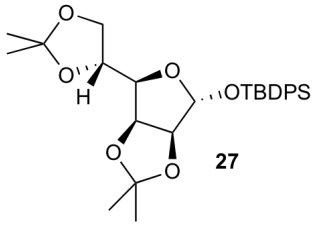


Scheme S3: i) Ac_2O, Pyridine, ii) Thiophenol, $BF_3.OEt_2$, DCM, 0^oC-RT, BnBr, NaH, DMF, iv) Pd/C, H_2, EtOH.



Scheme S4: i) Ac_2O, Pyridine, ii) Thiophenol, $BF_3.OEt_2$, DCM, 0°C-RT, BnBr, NaH, DMF.

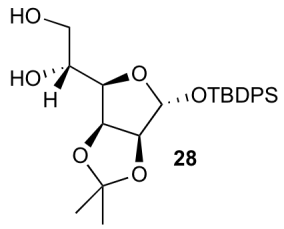
tert-Butyldiphenylsilyl 2,3:5,6-di-*O*-isopropylidene-α-D-mannofuranoside 27



tert-Butyldiphenylchlorosilane (1.1 mL, 4.23 mmol) was added to a solution of 2,3:5,6-di-*O*-isopropylidene-α-D-mannofuranose (1)(1.0 g, 3.85 mmol) and imidazole (1.0 g, 15.4 mmol) in anhydrous DCM. After 16 h, t.l.c. (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.9) with complete consumption of the starting material (R_f 0.2). The reaction mixture was concentrated *in vacuo* and diluted with diethyl ether (200 mL), washed with water (200 mL) and ammonium chloride (200 mL of an saturated aqueous solution). The organic phase was dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (6:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3:5,6-di-*O*-isopropylidene-α-D-mannofuranoside **27** (1.83 g, 95 %) as a colourless oil; $[\alpha]_D^{19}$+67.1 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) no significant data to report; δ_H (400 MHz, $CDCl_3$) 1.12 (9H, s, $C(CH_3)_3$), 1.36, 1.42, 1.44, 1.50 (12H, 4 x s, 4 x Me), 3.88 (1H, dd, $J_{5,6}$ 4.7 Hz, $J_{6,6'}$ 8.7 Hz, H-6), 4.06 (1H, dd, $J_{5,6'}$ 6.3 Hz, H-6'), 4.23 (1H, dd, $J_{3,4}$ 3.6 Hz, $J_{4,5}$ 7.8 Hz, H-4), 4.40 (1H, ddd, H-5), 4.77 (1H, d, $J_{2,3}$ 5.8 Hz, H-2), 4.94 (1H, dd, H-3), 5.38 (1H, s, H-1); δ_C (100 MHz, $CDCl_3$) 19.3 (s, $\underline{C}(CH_3)_3$), 24.6, 25.4, 25.9, 27.0 (4 x q, 4 x CH_3), 26.8 (q, $C(\underline{C}H_3)_3$), 66.9 (t, C-6), 73.1 (d, C-5), 79.7 (d, C-3), 80.6 (d, C-4), 87.1 (d, C-2), 101.8 (d,

C-1), 109.2, 112.6 (2 x s, 2 x $\underline{C}(CH_3)_2$), 127.7, 129.9, 135.5 (3 x d, 3 x Ar-C), 133.5, 134.8 (2 x s, 2 x Ar-C); *m/z* (ESI^+) 557 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{28}H_{38}O_6SiNa$ ($M+Na^+$) 521.2330. Found 521.2319.

tert-Butyldiphenylsilyl 2,3-*O*-isopropylidene-α-D-mannofuranoside 28



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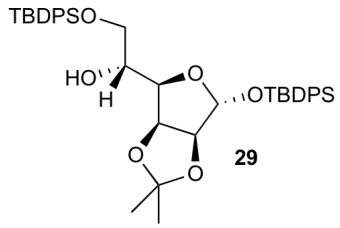
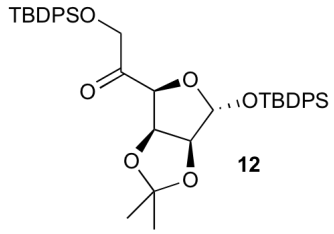
Concentrated hydrogen chloride (5 mL) was added to *tert*-butyldiphenylsilyl 2,3:5,6-di-*O*-isopropylidene-α-D-mannofuranoside **27** (11.4 g, 22.9 mmol) in methanol (25 mL). After 3 h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with complete consumption of the starting material (R_f 0.9). Triethylamine (5 mL) was added to the reaction mixture and then concentrated *in vacuo*. The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-α-D-mannofuranoside **28** (8.6 g, 82 %) as a colourless oil; $[\alpha]_D^{19}$+116.2 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) 3418 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.08 (9H, s, $C(CH_3)_3$), 1.34, 1.43 (6H, 2 x s, 2 x CH_3), 2.36 (2H, bs, 2 x OH), 3.59 (1H, dd, $J_{5,6}$ 6.1 Hz, $J_{6,6'}$ 11.5 Hz, H-6), 3.75 (1H, dd, $J_{5,6'}$ 3.4 Hz, H-6'), 3.95 (1H, ddd, $J_{4,5}$ 8.5 Hz, H-5), 4.15 (1H, dd, $J_{3,4}$ 3.9 Hz, H-4), 4.74 (1H, dd, $J_{2,3}$ 5.9 Hz, H-2), 4.96 (1H, dd, H-3), 5.39 (1H, s, H-1), 7.37-7.68 (10H, m, Ar-H); δ_C (100 MHz, $CDCl_3$) 14.2 (s, $\underline{C}(CH_3)_3$), 24.7, 25.9 (2 x q, 2 x CH_3), 26.8 (q, $C(\underline{C}H_3)_3$), 60.4 (t, C-6), 70.3 (d, C-5), 79.7 (d, C-4), 80.1 (d, C-3), 86.7 (d, C-2), 101.6 (d, C-1), 112.7 (s, $\underline{C}(CH_3)_2$), 127.7, 129.9, 135.6 (3 x d, 3 x Ar-C), 132.9 (s, Ar-C); *m/z* (ESI^+) 517 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{25}H_{34}O_6SiNa$ ($M+Na^+$) 481.2017. Found 481.2004.

tert-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-_tert_-butyldiphenylsilyl-α-D-mannofuranoside 29



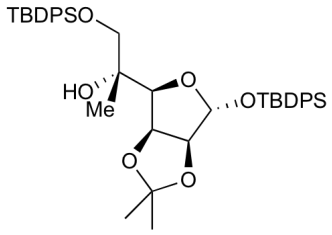
tert-Butyldiphenylchlorosilane (4.89 mL, 18.8 mmol) was added to a solution of *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-α-D-mannofuranoside **28** (8.6 g, 18.8 mmol) and imidazole (5.0 g, 75.2 mmol) in anhydrous DMF. After 16 h, t.l.c. (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.9) with complete consumption of the starting material (R_f 0.1). The reaction mixture was concentrated *in vacuo* and diluted with diethyl ether (300 mL), washed with water (300 mL) and ammonium chloride (300 mL of a saturated aqueous solution). The organic phase was dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (6:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-α-D-mannofuranoside **29** (10.4 g, 79 %) as a colourless oil; $[\alpha]_D^{19}$+28.7 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3444 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.03, 1.09 (18H, 2 x s, 2 x $C(CH_3)_3$), 1.33, 1.41 (6H, 2 x s, 2 x Me), 2.94 (1H, bs, OH), 3.65 (1H, dd, $J_{5,6}$ 7.0 Hz, $J_{6,6'}$ 10.4 Hz, H-6), 3.84 (1H, dd, $J_{5,6'}$ 3.8 Hz, H-6'), 4.05 (1H, atd, J_d 3.8 Hz, J_t 7.1 Hz, H-5), 4.14 (1H, dd, $J_{3,4}$ 3.7 Hz, $J_{4,5}$ 8.0 Hz, H-4), 4.69 (1H, d, $J_{2,3}$ 5.8 Hz, H-2), 4.93 (1H, dd, H-3), 5.32 (1H, s, H-1), 7.19-7.70 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 14.2 (s, 2 x $\underline{C}(CH_3)_3$), 24.7, 25.9 (q, 2 x Me), 26.7, 26.9 (2 x q, 2 x $C(\underline{C}H_3)_3$), 66.8 (t, C-6), 70.5 (d, C-5), 79.3 (d, C-4), 80.3 (d, C-3), 86.8 (d, C-2), 101.6 (d, C-1), 112.5 (s, $\underline{C}(CH_3)_2$), 127.6, 127.7, 129.7, 135.5, 135.6 (5 x d, Ar-C), 132.8, 133.1, 133.2, 133.3 (4 x s, Ar-C); *m/z* (ESI^+) 755 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{41}H_{52}O_6Si_2Na$ ($M+Na^+$) 719.3195. Found 719.3196.

tert-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside 12



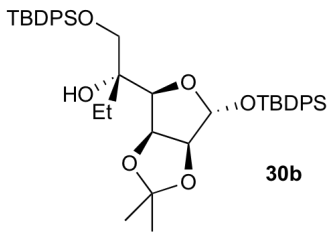
Dimethyl sulfoxide (624 μL, 8.8 mmol) was added dropwise to a solution of oxalyl chloride (561 μL, 4.4 mmol) in anhydrous DCM (10 mL) at -78 ^{o}C. After 1 h, *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-α-D-mannofuranoside **29** (769 mg, 1.1 mmol) in anhydrous DCM (10 mL) was added dropwise to the reaction mixture. After 2 h, triethylamine (1.1 mL, 11.0 mmol) was added and the reaction mixture allowed to warm to room temperature. After 2 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.7) with consumption of the starting material (R_f 0.6). Potassium hydrogensulfate (100 mL of a saturated aqueous solution) was added and the reaction mixture was extracted with DCM (3 x 100 mL). The combined organic layers were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (7:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside **12** (744 mg, 97 %) as a colourless oil; $[\alpha]_D^{19}$+4.9 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1743 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.07, 1.13 (18H, 2 x s, 2 x $C(CH_3)_3$), 1.22, 1.26 (6H, 2 x s, 2 x Me), 4.38, 4.42 (2H, ABq, *J* 18.3 Hz, H-6, H-6'), 4.67 (1H, d, $J_{3,4}$ 5.6 Hz, H-4), 5.03 (1H, d, $J_{2,3}$ 4.3 Hz, H-2), 5.57 (1H, dd, H-3), 5.47 (1H, s, H-1), 7.32-7.71 (20 H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 19.2, 19.3 (2 x s, $\underline{C}(CH_3)_3$), 24.7, 25.6 (2 x q, 2 x Me), 26.6, 26.7 (2 x q, 2 x $C(\underline{C}H_3)_3$), 69.0 (t, C-6), 80.6 (d, C-3), 84.3 (d, C-2), 86.0 (d, C-4), 101.3, (d, C-1), 113.1 (s, $\underline{C}(CH_3)_2$), 127.8, 129.9, 135.5, 135.7 (4 x d, Ar-C), 132.5, 132.7 (2 x s, 2 x Ar-C), 203.7 (s, C=O); *m/z* (ESI^+) 753 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{41}H_{50}O_6Si_2Na$ ($M+Na^+$) 717.3038. Found 717.3037.

tert-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-methyl-α-D-mannofuranoside 30a



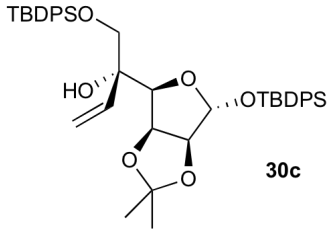
Methyl magnesium bromide (141 μL of a 3M solution in THF, 0.43 mmol) was added to a solution of *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside **12** (59 mg, 0.085 mmol) in anhydrous THF (1 mL). After 1 h, ammonium chloride (1 mL of a saturated aqueous solution) was added followed by extraction with DCM (3 x 25 mL). The combined organic phases were washed with brine (25 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatograpy (8:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-methyl-α-D-mannofuranoside **30a** (56 mg, 93 %) as a colourless oil; $[\alpha]_D^{19}$+42.9 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3508 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.11, 1.13 (18H, 2 x s, 2 x $C(CH_3)_3$), 1.23, 1.35, 1.40 (9H, 3 x s, 3 x Me), 3.65, 3.80 (2H, ABq, *J* 10.0 Hz, H-6, H-6'), 4.53 (1H, d, $J_{2,3}$ 2.1 Hz, H-2), 4.64-4.66 (2H, m, H-3, H-4), 5.43 (1H, s, H-1), 7.35-7.74 (20 H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 19.3 (s, $\underline{C}(CH_3)_3$), 22.9, 24.0, 25.6 (3 x q, 3 x CH_3), 26.7, 26.9 (q, $C(\underline{C}H_3)_3$), 70.2 (t, C-6), 73.8 (s, C-5), 80.2 (d, C-2), 80.7, 87.5 (2 x d, C-3, C-4), 100.5 (d, C-1), 112.5 (s, $\underline{C}(CH_3)_2$), 127.6, 127.7, 127.8, 129.8, 129.9, 134.8, 135.5, 135.8 (8 x d, Ar-C), 132.7, 133.2, 133.4 (s, Ar-C); *m/z* (ESI^+) 769 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{42}H_{54}O_6Si_2Na$ ($M+Na^+$) 733.3351. Found 733.3349.

tert-butyldiphenylsilyl 2,3-_O_-isopropylidene-6-_O_-_tert_-butyldiphenylsilyl-5-_C_-ethyl-α-D-mannofuranoside 30b



Ethyl magnesium bromide (110 μL of a 3 M solution in THF, 0.33 mmol) was added to a solution of *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside **12** (50 mg, 0.065 mmol) in anhydrous THF. After 1 h, ammonium chloride (1 mL of a saturated aqueous solution) was added followed by extraction with DCM (3 x 25 mL). The combined organic phases were washed with brine (25 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatograpy (8:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-ethyl-α-D-mannofuranoside **30b** (51 mg, 99 %) as a colourless oil; $[\alpha]_D^{19}$+40.8 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3507 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 0.89 (3H, t, *J* 7.6 Hz, $CH_2C\underline{H}_3$), 1.11, 1.13 (18H, 2 x s, 2 x $C(CH_3)_3$), 1.19, 1.37 (6H, 2 x s, 2 x Me), 1.72-1.95 (2H, m, CH_2), 3.69, 3.84 (2H, ABq, *J* 10.1 Hz, H-6, H-6'), 4.33 (1H, d, $J_{2,3}$ 2.7 Hz, H-2), 4.51 (1H, dd, $J_{3,4}$ 5.8 Hz, H-3), 4.60 (1H, d, H-4), 5.41 (1H, s, H-1), 7.36-7.74 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 6.8 (q, $CH_2\underline{C}H_3$), 19.3 (s, $\underline{C}(CH_3)_3$), 23.9, 25.5 (2 x q, 2 x Me), 26.7, 27.0 (2 x q, $C(\underline{C}H_3)_3$), 27.4 (t, $\underline{C}H_2CH_3$), 65.8 (t, C-6), 75.1 (s, C-5), 80.1 (d, C-2), 80.8 (d, C-3), 87.3 (d, C-4), 100.4 (d, C-1), 112.4 (s, $\underline{C}(CH_3)_2$), 127.7, 127.8, 129.8, 135.5 ,135.7, 135.8 (6 x d, Ar-C), 132.7, 133.2, 133.4 (3 x s, Ar-C); *m/z* (ESI^+) 783 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{43}H_{56}O_6Si_2Na$ ($M+Na^+$) 747.3058. Found 747.3057.

***tert*-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-vinyl-α-D-mannofuranoside 30c**

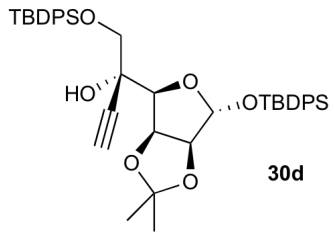


30c

Vinyl magnesium bromide (330 μL of a 1 M solution in THF, 0.33 mmol) was added to a solution of *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside **12** (50 mg, 0.063 mmol) in anhydrous THF. After 1 h, ammonium chloride (1 mL of a saturated aqueous solution) was added followed by

extraction with DCM (3 x 25 mL). The combined organic phases were washed with brine (25 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatograpy (8:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-vinyl-α-D-mannofuranoside **30c** (42 mg, 81 %) as a colourless oil; $[\alpha]_D^{19}$+41.7 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3508 (br, OH), 3072 (w, C=C) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.09, 1.11 (18H, 2 x s, 2 x $C(CH_3)_3$), 1.22, 1.38 (6H, 2 x s, 2 x Me), 3.75, 3.84 (2H, ABq, *J* 9.8 Hz, H-6, H-6'), 4.48 (1H, d, $J_{2,3}$ 3.1 Hz, H-2), 4.63 (1H, d, $J_{3,4}$ 5.7 Hz, H-4), 4.68 (1H, dd, H-3), 5.23 (1H, d, *J* 10.9 Hz, C<u>H</u>H'=CH), 5.40 (1H, s, H-1), 4.58 (1H, d, *J* 17.3 Hz, CH<u>H</u>'=CH), 6.05 (1H, dd, CHH'=C<u>H</u>), 7.34-7.74 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 19.3 (s, <u>C</u>$(CH_3)_3$), 24.0, 25.5 (2 x q, 2 x CH_3), 26.8, 26.9 (2 x q, 2 x C(<u>C</u>$H_3)_3$), 69.7 (t, C-6), 75.6 (s, C-5), 79.7 (d, C-2), 80.6 (d, C-3), 87.2 (d, C-4), 100.5 (d, C-1), 112.6 (s, <u>C</u>$(CH_3)_2$), 114.4 (t, <u>C</u>H_2=CH), 127.7, 127.8, 129.8, 135.7, 135.8, 135.9 (6 x d, Ar-C), 132.6, 133.1, 133.2, 133.3 (4 x s, Ar-C), 139.1 (d, CH_2=<u>C</u>H); *m/z* (ESI^+) 781 (M+MeCN+NH_4^+, 100%); HRMS (ESI^+) calcd. for $C_{43}H_{54}O_6Si_2Na$ (M+Na^+) 745.3351. Found 745.3353.

tert-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-ethynyl-α-D-mannofuranoside 30d

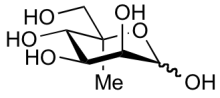


30d

Ethynyl magnesium bromide (2.62 mL of a 0.5 M solution in THF, 1.31 mmol) was added to a solution of *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside **12** (200 mg, 0.26 mmol) in anhydrous THF (2 mL). After 1 h, ammonium chloride (5 mL of a saturated aqueous solution) was added followed by extraction with DCM (3 x 50 mL). The combined organic phases were washed with brine (50 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatograpy (8:1,

petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-ethynyl-α-D-mannofuranoside **30d** (180 mg, 86 %) as a colourless oil; $[\alpha]_D^{18}$+25.1 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3455 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.10, 1.13 (18H, 2 x s, 2 x $C(CH_3)_3$), 1.27, 1.40 (6H, 2 x s, 2 x Me), 2.51 (1H, s, CH), 3.94, 3.98 (2H, ABq, *J* 10.0 Hz, H-6, H-6'), 4.60 (1H, d, $J_{2,3}$ 3.5 Hz, H-2), 4.70 (1H, d, $J_{3,4}$ 5.8 Hz, H-4), 4.85 (1H, dd, H-3), 5.45 (1H, s, H-1), 7.26-7.84 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 19.2, 19.4 (2 x s, 2 x $\underline{C}(CH_3)_3$), 24.1, 25.4 (2 x q, 2 x Me), 26.6, 26.8 (2 x q, 2 x $C(\underline{C}H_3)_3$), 69.2 (t, C-6), 72.9 (s, C-5), 73.8 (d, C≡$\underline{C}$H), 77.0 (s, $\underline{C}$≡CH), 80.1 (d, C-2), 80.4 (d, C-3), 87.2 (d, C-4), 100.7 (d, C-1), 112.9 (s, $\underline{C}(CH_3)_2$), 127.6, 127.7, 127.8, 129.6, 129.8, 135.4, 135.6, 135.9, 136.0 (9 x d, Ar-C), 132.4, 132.7, 132.9, 133.1, 134.8 (5 x s, Ar-C); *m/z* (ESI^+) 779 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{43}H_{56}O_6Si_2N$ ($M+NH_4^+$) 738.3641. Found 738.3635.

5-*C*-Methyl-D-mannopyranose 9a

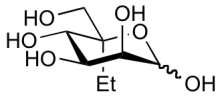


9a

Tetrabutyl ammonium fluoride (879 μL of a 1 M solution in THF) was added to *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-methyl-α-D-mannofuranoside **30a** (150 mg, 0.21 mmol) in THF (3 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.9). The reaction was concentrated *in vacuo* and the residue purified by flash column chromatography (1:1, petrol:ethyl acetate) to afford 2,3-*O*-isopropylidene-5-*C*-methyl-α-D-mannofuranose (47 mg, 95 %) as a colourless oil. Trifluoroacetic acid (1 mL) was added to 2,3-*O*-isopropylidene-5-*C*-methyl-α-D-mannofuranose (47 mg, 0.18 mmol) in water (2 mL) and the reaction mixture stirred. After 18 h, t.l.c (9:1, ethyl acetate:methanol) indicated formation of a product (R_f 0.0) with consumption of the starting material (R_f 0.3). The reaction mixture was concentrated *in vacuo* and co-evaporated with toluene (3 x 20 mL). The residue was purified by reverse phase flash chromatography (C-18, water) to afford 5-*C*-Methyl-D-mannopyranose **9a** (18 mg, 51 %) as a colourless oil; δ_H (500 MHz, D_2O) 1.08 (3H, s,

Meβ), 1.18 (3H, s, Meα), 3.42, 3.52 (2H, ABq, *J* 12.0 Hz, H-6β, H-6'β), 3.46, 3.51, (2H, ABq, *J* 12.0 Hz, H-6α, H-6'α), 3.63 (1H, d, $J_{3,4}$ 10.2 Hz, H-4α), 3.77 (1H, dd, $J_{2,3}$ 3.3 Hz, H-3α), 3.80 (1H, d, $J_{3,4}$ 9.6 Hz, H-4β), 3.83 (1H, dd, $J_{1,2}$ 2.4 Hz, $J_{2,3}$ 3.3 Hz, H-2β), 3.84 (1H, dd, $J_{1,2}$ 1.0 Hz, H-2α), 3.99 (1H, dd, H-3β), 4.97 (1H, d, H-1α), 5.10 (1H, d, H-1β); δ_C (125 MHz, D_2O) 13.1 (q, Meβ), 18.5 (q, Meα), 66.2 (t, C-6β), 66.6 (t, C-6α), 67.2 (d, C-3β), 67.4 (d, C-4α), 68.0 (d, C-4β), 69.8 (d, C-3α), 70.8 (d, C-2β), 71.5 (d, C-2α), 77.1 (s, C-5α), 79.5 (d, C-5β), 89.4 (d, C-1α), 94.8 (d, C-1β); *m/z* (ESI^+) 217 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_7H_{14}O_6Na$ ($M+Na^+$) 217.0683. Found 217.0684.

5-*C*-Ethyl-D-mannopyranose 9b

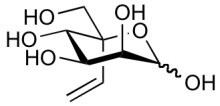


9b

Tetrabutyl ammonium fluoride (840 μL of a 1 M solution in THF) was added to *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-ethyl-α-D-mannofuranoside **30b** (200 mg, 0.28 mmol) in THF (3 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.9). The reaction was concentrated *in vacuo* and the residue purified by flash column chromatography (1:1, petrol:ethyl acetate) to afford 2,3-*O*-isopropylidene-5-*C*-ethyl-α-D-mannofuranose (55 mg, 80 %) as a colourless oil. Trifluoroacetic acid (1 mL) was added to 2,3-*O*-isopropylidene-5-*C*-ethyl-α-D-mannofuranose (55 mg, 0.22 mmol) in water (2 mL) and the reaction mixture stirred. After 18 h, t.l.c (9:1, ethyl acetate:methanol) indicated formation of a product (R_f 0.0) with consumption of the starting material (R_f 0.3). The reaction mixture was concentrated *in vacuo* and co-evaporated with toluene (3 x 20 mL). The residue was purified by reverse phase flash chromatography (C-18, water) to afford 5-*C*-ethyl-D-mannopyranose **9b** (30 mg, 66 %) as a colourless oil; δ_H (500 MHz, D_2O) 0.77-0.83 (9H, m, 3 x CH_3), 1.37-1.83 (6H, m, 3 x CH_2), 3.50, 3.62 (2H, ABq, *J* 12.0 Hz, H-6a, H-6'a), 3.54, 3.66 (2H, ABq, *J* 12.3 Hz, H-6b, H-6'b), 3.61 (2H, d, *J* 17.5 Hz, H-6c, H-6'c), 3.77 (1H, at, *J* 3.5 Hz, H-2b), 3.79 (1H, dd, $J_{2,3}$ 3.4 Hz, $J_{3,4}$ 10.4 Hz, H-3a), 3.84 (1H dd, $J_{1,2}$ 1.2 Hz, H-2a), 3.88 (1H, dd, $J_{3,4}$ 8.6 Hz, $J_{2,3}$ 3.5 Hz, H-3b), 3.90 (1H, d, H-4a), 3.92 (1H, d, H-4b),

3.99 (1H, dd, $J_{1,2}$ 5.5 Hz, $J_{2,3}$ 4.3 Hz, H-2c), 4.12 (1H, d, $J_{3,4}$ 2.8 Hz, H-4c), 4.30 (1H, dd, $J_{3,4}$ 2.8 Hz, $J_{2,3}$ 4.3 Hz, H-3c), 4.90 (1H, d, H-1a), 5.08 (1H, d, $J_{1,2}$ 3.5 Hz, H-1b), 5.22 (1H, d, $J_{1,2}$ 5.5 Hz, H-1c); δ_C (125 MHz, D_2O) 5.8 (q, CH_3a), 6.60 (q, CH_3b, CH_3c), 18.6 (t, CH_2a), 23.5 (t, CH_2b), 26.2 (t, CH_2c), 62.0 (t, C-6b), 62.5 (t, C-6c), 63.5 (t, C-6a), 67.7 (d, C-4a), 68.0 (d, C-4b), 69.7 (d, C-3a), 70.7 (d, C-3b), 71.4 (d, C-2a), 71.8 (d, C-3c), 72.4 (d, C-2b), 76.6 (s, C-5c), 77.8 (d, C-2c), 78.3 (s, C-5a), 79.2 (d, C-4c), 81.7 (s, C-5b), 89.0 (d, C-1a), 93.7 (d, C-1b), 100.3 (d, C-1c); *m/z* (ESI^+) 231 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_8H_{16}O_6Na$ ($M+Na^+$) 231.0839. Found 231.0839.

5-*C*-Vinyl-D-mannopyranose 9c

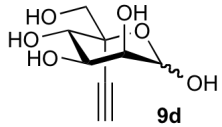


9c

Tetrabutyl ammonium fluoride (690 μL of a 1 M solution in THF) was added to *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-vinyl-α-D-mannofuranoside **30c** (170 mg, 0.23 mmol) in THF (3 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.9). The reaction was concentrated *in vacuo* and the residue purified by flash column chromatography (1:1, petrol:ethyl acetate) to afford 2,3-*O*-isopropylidene-5-*C*-vinyl-α-D-mannofuranose (47 mg, 82 %) as a colourless oil. Trifluoroacetic acid (1 mL) was added to 2,3-*O*-isopropylidene-5-*C*-vinyl-α-D-mannofuranose (47 mg, 0.19 mmol) in water (2 mL) and the reaction mixture stirred. After 18 h, t.l.c (9:1, ethyl acetate:methanol) indicated formation of a product (R_f 0.0) with consumption of the starting material (R_f 0.3). The reaction mixture was concentrated *in vacuo* and co-evaporated with toluene (3 x 20 mL). The residue was purified by RP flash chromatography (C-18, water) to afford 5-*C*-vinyl-D-mannopyranoside **9c** (20 mg, 51%) as a colourless oil; δ_H (400 MHz, D_2O) 3.35, 3.52 (2H, ABq, *J* 12.2 Hz, H-6, H-6'), 3.53 (1H, dd, $J_{2,3}$ 2.9 Hz, $J_{3,4}$ 10.5 Hz, H-3), 3.78 (1H, d, H-2), 3.83 (1H, d, H-4), 3.95 (1H, s, H-1), 5.33 (1H, d, *J* 17.8 Hz, C<u>H</u>H'=CH), 5.40 (1H, d, *J* 11.3 Hz, CH<u>H</u>'=CH), 5.83 (1H, dd, CH_2=CH); δ_C (100 MHz, D_2O) 65.9 (t, C-6), 67.3 (d, C-4), 70.5 (d, C-3), 72.1 (d, C-2), 80.0 (s, C-5), 89.7 (d, C-1), 119.1 (t, <u>C</u>H_2=CH), 131.0 (d, CH_2=<u>C</u>H); *m/z*

(ESI$^-$) 205 (M-H$^+$, 100%); HRMS (ESI$^-$) calcd. for $C_8H_{13}O_6$ (M-H$^+$) 205.0707. Found 205.0709.

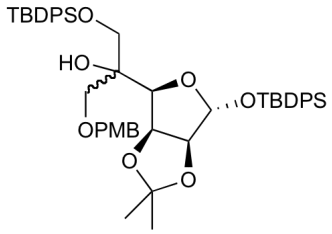
5-*C*-Ethynyl-α-D-mannopyranose 9d



9d

Tetrabutyl ammonium fluoride (800 μL of a 1 M solution in THF) was added to *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-ethynyl-α-D-mannofuranoside **30d** (180 mg, 0.22 mmol) in THF (3 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.1) with consumption of the starting material (R_f 0.9). The reaction was concentrated *in vacuo* and the residue purified by flash column chromatography (1:1, petrol:ethyl acetate) to afford 2,3-*O*-isopropylidene-5-*C*-ethynyl-α-D-mannofuranose (53 mg, 99 %) as a colourless oil. Trifluoroacetic acid (1 mL) was added to 2,3-*O*-isopropylidene-5-*C*-ethynyl-α-D-mannofuranose (53 mg, 0.22 mmol) in water (2 mL) and the reaction mixture stirred. After 18 h, t.l.c (9:1, ethyl acetate:methanol) indicated formation of a product (R_f 0.0) with consumption of the starting material (R_f 0.3). The reaction mixture was concentrated *in vacuo* and co-evaporated with toluene (3 x 20 mL). The residue was purified by reverse phase flash chromatography (C-18, water) to afford 5-*C*-ethynyl-α-D-mannopyranose **9d** (30 mg, 66 %) as a colourless oil; δ_H (400 MHz, D_2O) 2.94 (1H, s, CH), 3.59 (1H, d, $J_{3,4}$ 10.0 Hz, H-4), 3.65, 3.73 (2H, ABq, J 12.0 Hz, H-6, H-6'), 3.82 (1H, dd, $J_{2,3}$ 3.3 Hz, H-3), 3.87 (1H, dd, $J_{1,2}$ 1.1 Hz, H-2), 5.18 (1H, d, H-1); δ_C (100 MHz, D_2O) 65.7 (t, C-6), 67.5 (d, C-4), 70.8 (d, C-3), 71.4 (d, C-2), 76.2 (s, C-5), 78.1 (s, C≡CH), 79.6 (d, C≡CH), 91.9 (d, C-1); *m/z* (ESI$^-$) 203 (M-H$^+$, 100%); HRMS (ESI$^-$) calcd. for $C_8H_{11}O_6$ (M-H$^+$) 203.0550. Found 203.0560.

***tert*-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-6'-*O*-*para*-methoxybenzyl-5-*C*-hydroxymethyl-α-D-mannofuranoside 31**



Butyl lithium (1.14 mL of a 1.6 M solution in hexane) was added to a solution of (*para*-methyoxybenzyloxymethyl)tri-*n*-butylstannane (2-4)(0.97 mL, 2.20 mmol) in anhydrous THF (3 mL) at -78 ^{o}C. A yellow colour change was observed. After 30 min, *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-keto-α-D-mannofuranoside **12** (561 mg, 0.73 mmol) in anhydrous THF (3 mL) was added dropwise. After 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting material (R_f 0.6). Ammonium chloride (5 mL of a saturated aqueous solution) was added followed by extraction with DCM (3 x 50 mL). The combined organic phases were washed with brine (50 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatograpy (8:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-6'-*O*-*para*-methoxybenzyl-5-*C*-hydroxymethyl-α-D-mannofuranoside **31** as a mixture of diastereomers (469 mg, 76 %) as a colourless oil.

Minor diastereomer:

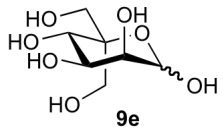
$[\alpha]_D^{18}$+41.5 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3509 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.07, 1.09 (6H, 2 x s, 2 x CH_3), 1.19, 1.37 (18H, 2 x s, 2 x $C(CH_3)_3$), 3.62, 3.68 (2H, ABq, *J* 9.5 Hz, H-6, H-6'), 3.74 (1H, d, *J* 9.9 Hz, C<u>H</u>H'), 3.81 (3H, s, OMe), 4.18 (1H, d, CH<u>H</u>'), 4.34 (1H, d, $J_{2,3}$ 2.0 Hz, H-2), 4.47, 4.55 (2H, ABq, *J* 11.7 Hz, CH_2), 4.61 (2H, as, H-3, H-4), 5.40 (1H, s, H-1), 6.63 (2H, d, *J* 8.7 Hz, 2 x Ar-H $_{PMB}$), 7.23 (2H, d, 2 x Ar-H $_{PMB}$), 7.31-7.72 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 19.2, 19.3 (2 x s, 2 x <u>C</u>$(CH_3)_3$), 24.0, 25.5 (2 x q, 2 x Me), 26.7, 26.9 (2 x q, 2 x C(<u>C</u>$H_3)_3$), 55.3 (q, OMe), 60.0 (t, CH_2), 71.2 (t, C-6), 73.3 (t, CH_2), 75.7 (s, C-5), 77.8 (d, C-2), 81.0, 87.1 (2 x d, C-3, C-4), 100.7 (d, C-1), 112.5 (s, <u>C</u>$(CH_3)_2$), 113.6, 129.3 (2 x d, 2 x Ar-C $_{PMB}$), 127.7, 127.8, 129.7, 129.8, 135.5, 135.7 (6 x d, Ar-C), 130.8, 132.7, 133.2, 133.5 158.9 (5 x s, Ar-C);

m/z (ESI^+) 905 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{50}H_{62}O_8Si_2Na$ ($M+Na^+$) 869.3875. Found 869.3873.

Major diasteromer:

$[\alpha]_D^{18}$+25.2 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3509 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.00, 1.08 (6H, 2 x s, 2 x CH_3), 1.26, 1.39 (18H, 2 x s, 2 x $C(CH_3)_3$), 3.68 (1H, d, *J* 9.1 Hz, C<u>H</u>H'), 3.81, 3.90 (2H, ABq, *J* 10.2 Hz, H-6, H-6'), 3.83 (3H, s, OMe), 3.98 (1H, d, CH<u>H</u>'), 4.33 (1H, d, $J_{2,3}$ 3.2 Hz, H-2), 4.50, 4.59 (2H, ABq, *J* 11.5 Hz, CH_2), 4.63 (1H, d, $J_{3,4}$ 5.8 Hz, H-4), 4.90 (1H, dd, H-3), 5.36 (1H, s, H-1), 6.89 (2H, d, *J* 8.7 Hz, 2 x Ar-H $_{PMB}$), 7.14-7.72 (22H, m, 22 x Ar-H); δ_C (100 MHz, $CDCl_3$) 19.1, 19.4 (2 x s, 2 x <u>C</u>$(CH_3)_3$), 24.1, 25.7 (2 x q, 2 x Me), 26.8, 26.9 (2 x q, 2 x C(<u>C</u>$H_3)_3$), 55.3 (q, OMe), 65.8 (t, CH_2), 71.1 (t, C-6), 73.2 (t, CH_2), 75.5 (s, C-5), 78.5 (d, C-2), 81.2 (d, C-3), 87.0 (d, C-4), 100.1 (d, C-1), 112.5 (s, <u>C</u>$(CH_3)_2$), 113.7, 129.1 (d, 2 x Ar-C $_{PMB}$), 127.6, 127.7, 127.8, 129.5, 129.8, 133.5, 133.7 (7 x d, Ar-C), 130.6, 132.8, 133.1, 133.5, 133.7, 159.1 (6 x s, Ar-C); *m/z* (ESI^+) 905 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{50}H_{62}O_8Si_2Na$ ($M+Na^+$) 869.3875. Found 869.3873.

5-*C*-Hydroxymethyl-α-D-mannopyranose 9e



9e

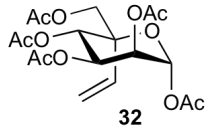
tert-Butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-6'-*O*-*para*-methoxybenzyl-5-*C*-hydroxymethyl-α-D-mannofuranoside **31** (460 mg, 0.54 mmol) and ammonium cerium nitrate (596 mg, 1.09 mmol) were stirred in acetonitrile and water (5 ml of a 9:1 mixture). After 30 min, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.4) with consumption of the starting material (R_f 0.5). The reaction mixture was diluted with DCM (100 mL) and washed with sodium thiosulfate (100 mL of a 0.1 M solution). The aqueous layer was extracted with DCM (2 x 50 mL) and the combined organic layers washed with EDTA (100 mL of a 0.05 M solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatrography (8:1, petrol:ethyl acetate) to afford *tert*-butyldiphenylsilyl 2,3-*O*-

isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-hydroxymethyl-α-D-mannofuranoside (270 mg, 69 %) as a colourless oil.

Tetrabutyl ammonium fluoride (500 μL of a 1 M solution in THF) was added to *tert*-butyldiphenylsilyl 2,3-*O*-isopropylidene-6-*O*-*tert*-butyldiphenylsilyl-5-*C*-hydroxymethyl-α-D-mannofuranoside (170 mg, 0.23 mmol) in THF (2 mL). After 30 min, t.l.c (ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.9). The reaction was concentrated *in vacuo* and the residue purified by flash column chromatography (ethyl acetate) to afford 2,3-*O*-isopropylidene-5-*C*-hydroxymethyl-α-D-mannofuranose (54 mg, 94 %) as a colourless oil.

Trifluoroacetic acid (1 mL) was added to 2,3-*O*-isopropylidene-5-*C*-hydroxymethyl-α-D-mannofuranose (54 mg, 0.22 mmol) in water (2 mL) and the reaction mixture stirred. After 18 h, t.l.c (9:1, ethyl acetate:methanol) indicated formation of a product (R_f 0.0) with consumption of the starting material (R_f 0.3). The reaction mixture was concentrated *in vacuo* and co-evaporated with toluene (3 x 20 mL). The residue was purified by RP flash chromatography (C-18, water) to afford 5-*C*-hydroxymethyl-α-D-mannopyranose **9e** (20 mg, 43 %) as a colourless oil; major structure: δ_H (500 MHz, D_2O) 3.58-3.68 (4H, m, 2 x CH_2), 3.81 (1H, dd, $J_{1,2}$ 1.0 Hz, $J_{2,3}$ 3.3 Hz, H-2), 3.93 (1H, d, $J_{3,4}$ 9.1 Hz, H-4), 4.04 (1H, dd, H-3), 5.07 (1H, d H-1); δ_C (125 MHz, D_2O) 61.6, 62.3 (2 x t, 2 x CH_2), 67.2 (d, C-4), 67.4 (d, C-3), 70.1 (d, C-2), 80.4 (s, C-5), 89.6 (d, C-1); *m/z* (ESI^-) 233 ($M-H^+$, 100%); HRMS (ESI^-) calcd. for $C_7H_{14}O_7$ ($M-H^+$) 233.0631. Found 233.0631.

1,2,3,4,6-Penta-*O*-acetyl-5-*C*-vinyl-α-D-mannopyranose 32

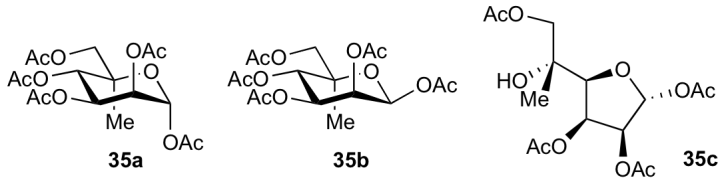


32

5-*C*-Vinyl-α-D-mannopyranose **9c** (152 mg, 0.74 mmol) was stirred in acetic anhydride (5 mL) and pyridine (10 mL). After 18 h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting material (R_f 0.0). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene. The residue was purified by flash column chromatography (1:1, petrol:ethyl acetate) to afford 1,2,3,4,6-penta-*O*-acetyl-5-*C*-vinyl-α-D-mannopyranose **32** (247 mg, 80%) as a

colourless oil; $[\alpha]_D^{19}$-105.5 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1752 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.99, 2.06, 2.10, 2.22 (15H, 4 x s, 5 x OAc), 3.79, 4.19 (2H, ABq, *J* 12.4 Hz, H-6, H-6'), 5.07 (1H, dd, $J_{2,3}$ 3.1 Hz, $J_{3,4}$ 10.8 Hz, H-3), 5.44 (1H, dd, $J_{1,2}$ 1.4 Hz, H-2), 5.63 (1H, d, H-4), 5.65 (1H, dd, *J* 3.4 Hz, *J* 8.5 Hz, CH=C<u>H</u>H'), 5.93-5.96 (2H, m, C<u>H</u>=CH<u>H</u>'), 6.06 (1H, d, H-1); δ_C (100 MHz, $CDCl_3$), 20.5, 20.7, 20.8 (3 x q, 5 x OAc), 65.4 (t, C-6), 65.6 (d, C-4), 68.7 (d, C-2), 68.9 (d, C-3), 78,6 (s, C-5), 86.6 (d, C-1), 122.5 (t, CH=<u>C</u>H_2), 129.1 (d, <u>C</u>H=CH_2), 168.6, 169.3, 169.8, 170.2, 170.5 (5 x s, 5 x C=O); *m/z* (ESI^+) 475 (M+MeCN+NH_4^+, 100%); HRMS (ESI^+) calcd. for $C_{18}H_{24}O_{11}Na$ (M+Na^+) 439.1211. Found 439.1212.

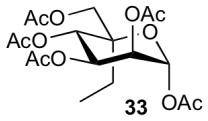
1,2,3,4,6-Penta-*O*-acetyl-5-*C*-methyl-α-D-mannopyranose 35a, 1,2,3,4,6-Penta-*O*-acetyl-5-*C*-methyl-β-D-mannopyranose 35b and 1,2,3,6-tetra-*O*-acetyl-5-*C*-methyl-α-D-mannofuranoside 35c



5-*C*-Methyl-α-D-mannopyranose **9a** (41 mg, 0.21 mmol) was stirred in acetic anhydride (5 mL) and pyridine (10 mL). After 18 h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting material (R_f 0.0). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene. The residue was purified by flash column chromatography to afford an inseparable mixture of 1,2,3,4,6-penta-*O*-acetyl-5-*C*-methyl-α-D-mannopyranose **35a**, 1,2,3,4,6-penta-*O*-acetyl-5-*C*-methyl-β-D-mannopyranose **35b** and 1,2,3,6-tetra-*O*-acetyl-5-*C*-methyl-α-D-mannofuranoside **35c** (67 mg, 79%, 33:17:50) as a colourless oil; δ_H (400 MHz, $CDCl_3$) 1.33, (3H, s, CH_3-c), 1.38 (3H, s, CH_3-β), 1.39 (3H, s, CH_3-α), 2.00, 2.01, 2.04, 2.05, 2.09, 2.10, 2.13, 2.14, 2.16, 2.18, 2.20 (42H, 12 x s, 14 x OAc), 3.55, 4.34 (2H, ABq, *J* 7.7 Hz, H-6c, H-6'c), 3.95, 3.99 (2H, Abq, *J* 11.9 Hz, H-6β, H-6'β), 3.98, 4.09 (2H, ABq, *J* 12.0 Hz, H-6α, H-6'α), 4.89 (1H, d, $J_{3,4}$ 1.8 Hz, H-4c), 4.98 (1H, dd, $J_{2,3}$ 5.6 Hz, H-3c), 5.20 (1H, d, H-2c), 5.19-5.27 (2H, m, H-2β, H-3α), 5.40 (1H, s, H-1c), 5.46 (1H, d, $J_{3,4}$ 10.3 Hz, H-4α), 5.45-5.50 (2H, m, H-2α, H-3β), 5.56 (1H, d, $J_{3,4}$ 10.5 Hz, H-4β),

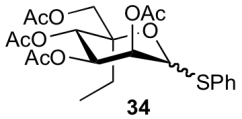
6.05 (1H, d, $J_{1,2}$ 1.4 Hz, H-1α), 6.09 (1H, d, $J_{1,2}$ 2.2 Hz, H-1β); δ_C (100 MHz, $CDCl_3$) 14.9 (q, CH_3-α), 17.9 (q, CH_3-c), 19.2 (q, CH_3-β), 20.5, 20.6, 20.7, 20.7, 20.8, 20.8, 21.1 (7 x q, 14 x OAc), 68.2, 68.4 (2 x d, H-2β, H-4β), 66.5 (d, H-3α), 66.7 (d, C-3c), 67.2 (t, C-6α), 67.2 (t, C-6β), 67.9 (d, C-2c), 68.3, 68.4 (2 x d, C-2α, C-4α), 68.9 (d, C-3β), 71.1 (t, C-6c), 73.0 (d, C-4c), 76.0 (s, C-5α), 78.2 (s, C-5β), 79.6 (s, C-5c), 86.8 (d, C-1α), 91.0 (d, C-1β), 100.4 (d, C-1c), 168.3, 168.6, 169.4, 169.6, 169.7, 169.9, 170.0, 170.2, 170.5, 170.6 (s, 14 x C=O).

1,2,3,4,6-Penta-*O*-acetyl-5-*C*-ethyl-α-D-mannopyranose 33



Palladium on carbon (30 mg) was added to a solution of 1,2,3,4,6-penta-*O*-acetyl-5-*C*-vinyl-α-D-mannopyranose **32** (72 mg, 0.17 mmol) in ethanol (3 mL). The flask was evacuated and refilled with hydrogen five times and the reaction mixture stirred under an atmosphere of hydrogen. After 1 h the reaction mixture was filtered through celite® and concentrated *in vacuo* to afford 1,2,3,4,6-penta-*O*-acetyl-5-*C*-ethyl-α-D-mannopyranose **33** (72 mg, 100 %) as a colourless oil; $[\alpha]_D^{21}$-45.1(*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1750 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 0.99 (3H, t, *J* 7.3 Hz, CH_3), 1.65-1.74 (2H, m, CH_2), 1.98, 2.02, 2.08, 2.09, 2.19 (15H, 5 x s, 5 x OAc), 4.05, 4.11 (2H, ABq, *J* 12.0 Hz, H-6, H-6'), 5.25 (1H, dd, $J_{2,3}$ 3.3 Hz, $J_{3,4}$ 10.4 Hz, H-3), 5.43 (1H, dd, $J_{1,2}$ 1.4 Hz, H-2), 5.58 (1H, d, H-4), 5.99 (1H, d, H-1); δ_C (100 MHz, $CDCl_3$) 6.05 (q, CH_3), 20.5 (t, CH_2), 20.6, 20.7, 20.7, 20.8, 20.8 (5 x q, 5 x OAc), 64.9 (t, C-6), 67.1 (d, C-4), 68.2 (d, C-3), 68.4 (d, C-2), 77.7 (s, C-5), 86.2 (d, C-1), 168.6, 169.3, 169.9, 170.2, 170.5 (5 x s, 5 x C=O); *m/z* (ESI^+) 477 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{18}H_{26}O_{11}Na$ ($M+Na^+$) 441.1373. Found 441.1372.

Phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-ethyl-1-thio-α-D-mannopyranoside 34a and Phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-ethyl-1-thio-β-D-mannopyranoside 34b



34

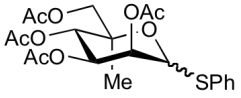
Boron trifluoroetherate (71 μL, 0.56 mmol) was added dropwise to a solution of 1,2,3,4,6-penta-*O*-acetyl-5-*C*-ethyl-α-D-mannopyranose **33** (68 mg, 0.16 mmol) and thiophenol (71 μL, 0.56 mmol) in anhydrous DCM (1 mL) at 0°C. The reaction mixture was allowed to warm to room temperature and stirred under an atmosphere of argon. After 5 h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with complete consumption of the starting material (R_f 0.5). The reaction mixture was quenched with triethylamine (100 μL), diluted with DCM and washed with sodium hydrogencarbonate (50 mL of a saturated aqueous solution). The aqueous phase was extracted with DCM (3 x 30 mL) and the combined organic phases were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-ethyl-1-thio-α-D-mannopyranoside **34a** and phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-ethyl-1-thio-β-D-mannopyranoside **34b** (73 mg, 97 %) as a colourless oil; (2:1, α:β).

α: $[\alpha]_D^{22}$-84.2 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1750 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 0.52 (3H, t, *J* 7.5 Hz, CH_3), 1.55-1.84 (2H, m, CH_2), 1.97, 2.00, 2.11, 2.19 (12H, 4 x s, 4 x OAc), 4.07, 4.10 (2H, ABq, *J* 12.0 Hz, H-6, H-6'), 4.90 (1H, d, $J_{1,2}$ 1.2 Hz, H-1), 5.17 (1H, d, $J_{2,3}$ 3.5 Hz, $J_{3,4}$ 10.7 Hz, H-3), 5.59 (1H, d, H-4), 5.63 (1H, dd, H-2), 7.29-7.60 (5H, m, 5 x Ar-H); δ_C (100 MHz, $CDCl_3$) 5.6 (q, CH_3), 19.2 (t, CH_2), 20.6, 20.7, 20.8, 21.0 (4 x q, 4 x OAc), 65.4 (t, C-6), 67.5 (d, C-4), 69.1 (d, C-3), 70.9 (d, C-2), 78.9 (s, C-5), 80.8 (d, C-1), 128.9, 129.0, 1234.6 (d, Ar-C), 132.2 (s, Ar-C), 169.4, 170.2, 170.3, 170.6 (4 x s, 4 x C=O); *m/z* (ESI^+) 527 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{22}H_{28}O_9SNa$ ($M+Na^+$) 491.1344. Found 491.1346.

β: $[\alpha]_D^{22}$-4.0 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1750 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 0.88 (3H, t, *J* 7.5 Hz, CH_3), 1.58-1.74 (2H, m, CH_2), 2.05, 2.07, 2.10, 2.12 (12H, 4 x s, 4 x OAc), 4.28, 4.41 (2H, ABq, *J* 12.0 Hz, H-6, H-6'), 5.19-5.22 (2H, m, H-2, H-4), 5.30 (1H, d, $J_{1,2}$ 4.1 Hz, H-1), 5.38 (1H, dd, $J_{2,3}$ 3.5 Hz, $J_{3,4}$ 5.6 Hz, H-3), 7.30-7.61 (5H, m, 5 x Ar-H); δ_C (100 MHz, $CDCl_3$) 7.2 (q, CH_3), 20.7, 20.8 (2 x q, 4 x OAc), 25.3 (t, CH_2), 61.2 (t, C-6), 67.2 (d, C-3), 67.9 (d, C-2), 67.9 (d, C-4), 79.5 (s, C-5), 80.5 (d, C-1),

128.0, 128.9 (d, Ar-C), 132.5 (s, Ar-C), 169.2, 169.4, 169.4, 170.4 (4 x s, 4 x C=O); *m/z* (ESI^+) 527 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{22}H_{28}O_9SNa$ ($M+Na^+$) 491.1344. Found 491.1346.

Phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-methyl-1-thio-α-D-mannopyranoside 36

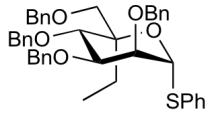


36

Boron trifluoroetherate (280 μL, 2.21 mmol) was added dropwise to a solution of 1,2,3,4,6-penta-*O*-acetyl-5-*C*-methyl-D-mannopyranose **35a**, **35b**, **35c** (253 mg, 0.63 mmol) and thiophenol (193 μL, 1.88 mmol) in anhydrous DCM (4 mL) at 0°C. The reaction mixture was allowed to warm to room temperature and stirred under an atmosphere of argon. After 1.5 h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.7) with complete consumption of the starting material (R_f 0.5). The reaction mixture was quenched with triethylamine (500 μL), diluted with DCM and washed with sodium hydrogencarbonate (100 mL of a saturated aqueous solution). The aqueous phase was extracted with DCM (3 x 50 mL) and the combined organic phases were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-methyl-1-thio-D-mannopyranoside **36** as a mixture of anomers (143 mg, 50%, α:β, 2:1) as a colourless oil and recovered furanose sugar (114 mg, 50%); ν_{max} (thin film) 1750 (s, C=O) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 1.28 (3H, s, Meα), 1.42 (3H, s, Meβ), 1.98, 2.04, 2.07, 2.08, 2.11, 2.13, 2.19 (24H, 7 x s, 8 x OAc), 4.05, 4.13 (2H, ABq, *J* 11.8 Hz, H-6α, H-6'α), 4.16, 2.38 (2H, ABq, *J* 11.8 Hz, H-6β, H-6'β), 5.09 (1H, d, $J_{1,2}$ 1.2 Hz, H-1α), 5.17 (1H, dd, $J_{2,3}$ 3.5 Hz, $J_{3,4}$ 10.7 Hz, H-3α), 5.28-5.30 (2H, m, H-3β, H-4β), 5.33 (1H, d, $J_{1,2}$ 6.5 Hz, H-1β), 5.44 (1H, dd, $J_{2,3}$ 3.3 Hz, H-2β), 5.47 (1H, d, H-4α), 5.64 (1H, dd, H-2α); δ_C (125 MHz, $CDCl_3$) 14.1 (q, Meα, Meβ), 20.2, 20.6, 20.6, 20.7, 20.7, 20.8 (q, 8 x OAc), 65.4 (t, C-6β), 66.6 (d, C-4α), 67.2 (d, C-2β), 67.8 (t, C-6α), 67.9, 68.6 (2 x d, C-3β, C-4β), 69.2 (d, C-3α), 71.1 (d, C-2α), 77.5 (s, C-5α), 77.9 (s, C-5β), 80.6 (d, C-1α), 81.5 (d, C-1β), 128.0, 129.0, 129.2, 131.5, 131.9, 132.4 (d, Ar-C), 132.8, 133.5 (s, Ar-C),

169.4, 169.5, 170.2, 170.4, 170.6 (s, 8 x C=O); *m/z* (ESI^+) 477 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_{21}H_{26}O_9SNa$ ($M+Na^+$) 477.1190. Found 477.1190.

Phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-1-thio-α-D-mannopyranoside 20b

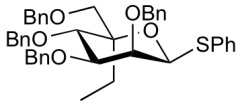


20b

Sodium methoxide (0.5 mL of a 0.1 M solution in methanol) was added to a solution of phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-ethyl-1-thio-α-D-mannopyranoside **34** (102 mg, 0.22 mmol) in methanol (2 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0) with consumption of the starting material (R_f 0.7). The reaction mixture was neutralised with DOWEX®, filtered and concentrated *in vacuo*. The residue was suspended in anhydrous DMF (2 mL) and sodium hydride (53 mg, 1.32 mmol of 60% in mineral oil) added. Benzyl bromide (116 μL, 0.97 mmol) was added dropwise and the reaction mixture stirred under an atmosphere of argon. After 18 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.9) with consumption of the starting material (R_f 0). The reaction mixture was quenched with methanol (1 mL) and concentrated *in vacuo*. The residue was resuspended in diethyl ether (20 mL) and washed with water (20 mL). The aqueous layer was re-extracted with diethyl ether (2 x 20 mL) and the combined organic layers were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-1-thio-α-D-mannopyranoside **20b** (100 mg, 69 %) as a colourless oil; $[\alpha]_D^{22}$-33.0 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (400 MHz, $CDCl_3$) 0.55 (3H, t, *J* 7.5 Hz, CH_3), 1.62-1.75 (2H, m, CH_2), 3.66, 3.70 (2H, ABq, *J* 11.1 Hz, H-6, H-6'), 3.81 (1H, dd, $J_{2,3}$ 2.9 Hz, $J_{3,4}$ 10.1 Hz, H-3), 4.19 (1H, dd, $J_{1,2}$ 1.1 Hz, H-2), 4.51 (1H, d, H-4), 4.56 (1H, d, *J* 11.7 Hz, C<u>H</u>H'), 4.68 (1H, d, *J* 11.1 Hz, C<u>H</u>H'a), 4.75 (1H, d, *J* 12.1 Hz, C<u>H</u>H'b), 4.78 (1H, d, CH<u>H</u>'b), 4.87-4.92 (4H, m, 3 x CH, H-1), 5.13 (1H, d, CH<u>H</u>'a), 7.23-7.65 (25H, m, 25 x Ar-H); δ_C (100 MHz, $CDCl_3$) 6.2 (q, CH_3), 19.5 (t, CH_2), 72.8 (t, C-6), 72.1, 72.8, 73.8, 75.1 (4 x t, 4 x CH_2), 76.7 (d, C-4), 78.4 (d, C-2), 78.6 (d, C-3), 82.0 (s, C-5), 83.6 (d, C-1), 127.2-128.7 (d, Ar-C), 138.3, 138.5, 138.7, 138.8, 138.9 (5 x s, 5 x Ar-C); *m/z* (ESI^+) 719

(M+MeCN+NH_4^+, 100%); HRMS (ESI^+) calcd. for $C_{42}H_{44}O_5SNa$ (M+Na^+) 683.2802. Found 683.2807.

Phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-1-thio-β-D-mannopyranoside 20b

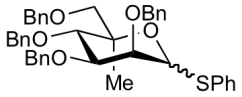


20b

Sodium methoxide (0.5 mL of a 0.1 M solution in methanol) was added to a solution of phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-ethyl-1-thio-β-D-mannopyranoside **34** (74 mg, 0.16 mmol) in methanol (2 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0) with consumption of the starting material (R_f 0.7). The reaction mixture was neutralised with DOWEX®, filtered and concentrated *in vacuo*. The residue was suspended in anhydrous DMF (2 mL) and sodium hydride (38 mg, 0.96 mmol of 60% in mineral oil) added. Benzyl bromide (83 μL, 0.70 mmol) was added dropwise and the reaction mixture stirred under an atmosphere of argon. After 18 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.9) with consumption of the starting material (R_f 0). The reaction mixture was quenched with methanol (1 mL) and concentrated *in vacuo*. The residue was resuspended in diethyl ether (20 mL) and washed with water (20 mL). The aqueous layer was re-extracted with diethyl ether (2 x 20 mL) and the combined organic layers were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (petrol→3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-1-thio-β-D-mannopyranoside **20b** (93 mg, 88 %) as a colourless oil; $[\alpha]_D^{22}$+11.1 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (400 MHz, $CDCl_3$) 0.88 (3H, t, *J* 7.5 Hz, CH_3), 1.80-2.14 (2H, m, CH_2), 3.71, 3.84 (2H, ABq, *J* 9.9 Hz, H-6, H-6'), 3.88 (1H, dd, $J_{1,2}$ 7.5 Hz, $J_{2,3}$ 3.0 Hz, H-2), 3.92 (1H, dd, $J_{3,4}$ 5.4 Hz, H-3), 3.95 (1H, d, H-4), 4.44-4.49 (3H, m, 3 x C<u>H</u>H'), 4.52 (1H, d, *J* 10.8 Hz, C<u>H</u>H'), 4.59 (2H, d, *J* 3.8 Hz, 2 x CH<u>H</u>'), 4.64 (1H, d, *J* 11.9 Hz, CH<u>H</u>'), 4.66 (1H, d, *J* 12.0 Hz, CH<u>H</u>'), 5.45 (1H, d, H-1), 7.19-7.59 (25H, m, 25 x Ar-H); δ_C (100 MHz, $CDCl_3$) 7.5 (q, CH_3), 25.3 (t, CH_2), 68.8 (t, C-6), 72.5, 73.0, 73.3, 73.8 (4 x t, 4 x CH_2), 75.1, 75.4, 75.6 (3 x d, C-2, C-3, C-4), 81.7 (s, C-5), 81.9 (d, C-1), 126.9-131.4 (d, Ar-C), 135.1 (s, Ar-C-S), 138.1, 138.3, 138.4, 138.6 (4 x s, 4 x Ar-

C); *m/z* (ESI$^+$) 719 (M+MeCN+NH_4^+, 100%); HRMS (ESI$^+$) calcd. for $C_{42}H_{44}O_5SNa$ (M+Na^+) 683.2802. Found 683.2807.

Phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-methyl-1-thio-α-D-mannopyranoside 20a

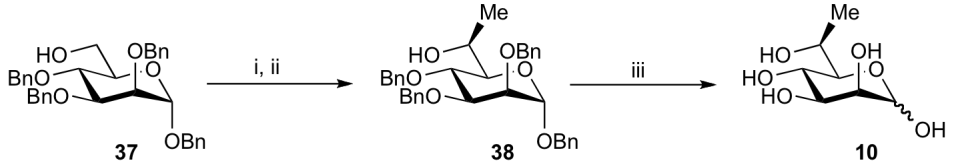


20a

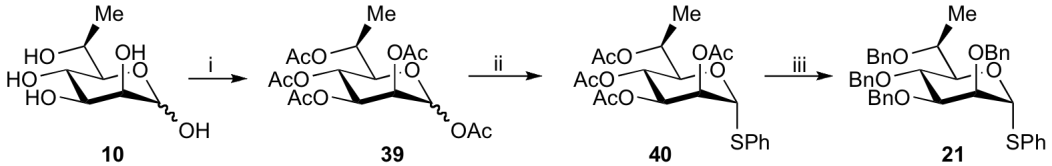
Sodium methoxide (1 mL of a 0.1 M solution in methanol) was added to a solution of phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-methyl-1-thio-α-D-mannopyranoside **36** (171 mg, 0.38 mmol) in methanol (2 mL). After 30 min, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0) with consumption of the starting material (R_f 0.7). The reaction mixture was neutralised with DOWEX®, filtered and concentrated *in vacuo*. The residue was suspended in anhydrous DMF (2 mL) and sodium hydride (90 mg, 2.26 mmol of 60% in mineral oil) added. Benzyl bromide (200 μL, 1.67 mmol) was added dropwise and the reaction mixture stirred under an atmosphere of argon. After 18 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.9) with consumption of the starting material (R_f 0). The reaction mixture was quenched with methanol (1 mL) and concentrated *in vacuo*. The residue was resuspended in diethyl ether (50 mL) and washed with water (50 mL). The aqueous layer was re-extracted with diethyl ether (2 x 30 mL) and the combined organic layers dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (petrol→3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-methyl-1-thio-α-D-mannopyranoside **20a** (135 mg, 55 %) as a mixture of anomers and as a colourless oil; α:β, 2:1; ν_{max} (thin film) no significant peaks; δ_H (400 MHz, $CDCl_3$) 1.23 (3H, s, $CH_3\alpha$), 1.45 (3H, s, $CH_3\beta$), 3.58, 3.73 (1H, ABq, *J* 9.8 Hz, H-6β, H-6'β), 3.62, 3.69 (2H, ABq, *J* 11.1 Hz, H-6α, H-6'α), 3.81 (1H, dd, $J_{2,3}$ 2.9 Hz, $J_{3,4}$ 10.8 Hz, H-3α), 3.91 (1H, dd, $J_{1,2}$ 5.6 Hz, $J_{2,3}$ 3.1 Hz, H-2β), 3.99 (1H, dd, $J_{3,4}$ 7.1 Hz, H-3β), 4.06 (1H, d, H-4β), 4.18 (1H, dd, $J_{1,2}$ 1.0 Hz, H-2α), 4.26 (1H, d, H-4α), 4.45-4.67 (10H, m, 10 x CH), 4.74-4.93 (5H, m, 5 x CH), 5.04 (1H, d, H-1α), 5.11 (1H, d, *J* 11.4 Hz, CH), 5.50 (1H, d, H-1β), 7.18-7.54 (50H, m, 50 x Ar-H); δ_C (100 MHz, $CDCl_3$) 13.8 (q, $CH_3\alpha$), 20.5 (q, $CH_3\beta$), 72.3, 72.7, 73.3 (3 x t, CH_2), 73.6 (t, C-6β), 73.7, 74.3 (2 x t, CH_2), 75.1 (t, C-6α), 75.4 (t,

CH_2), 75.6, 75.6, 75.9, 76.0 (4 x d, C-4α, C-2β, C-3β, C-4β), 78.5 (d, C-2α), 80.6, 80.9 (2 x s, C-5α, C-5β), 80.9 (d, C-3α), 82.8 (d, C-1β), 83.0 (d, C-1α), 126.8-131.5 (d, Ar-C), 134.9-138.8 (s, Ar-C); *m/z* (ESI^+) 705 ($M+MeCN+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{41}H_{46}O_5SN$ ($M+NH_4^+$) 664.3091. Found 664.3092.

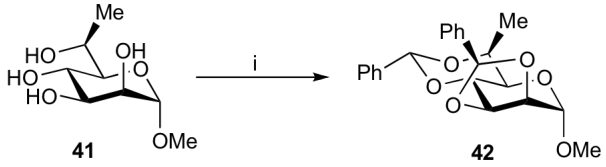
1.2 C-6 substituted monomer synthesis



Scheme S5: i) DMSO, $C_2O_2Cl_2$, DCM, -78°C→RT, ii) MeMgBr, THF, 56% over 2 steps, iii) H_2, Pd/C, MeOH, 95%.

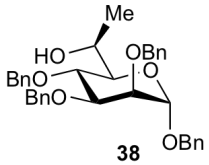


Scheme S6: i) Ac_2O, Pyridine, 92%, ii) Thiophenol, $BF_3.OEt_2$, DCM, 0°C-RT, 80, iii) NaOMe, MeOH then BnBr, NaH, DMF, 74%.



Scheme S7: i) $PhCH(OMe)_2$, *p*TSA, DMF, 50 °C, 27%.

Benzyl 2,3,4-tri-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranoside 38

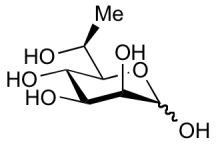


Dimethyl sulfoxide (1090 μL, 15.4 mmol) was added dropwise to a solution of oxalyl chloride (980 μL, 7.7 mmol) in anhydrous DCM (10 mL) at -78 °C. After 1 h, benzyl 2,3,4-tri-*O*-benzyl-6-*O*-trityl-α-D-mannopyranoside **37** (5)(1.04 g, 1.9 mmol) in anhydrous DCM (10 mL) was added dropwise to the reaction mixture. After a further 2 h, triethylamine (2 mL, 19.2 mmol) was added and the reaction mixture allowed to warm to

room temperature. After a further 2 h, t.l.c (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting material (R_f 0.4). Ammonium chloride (30 mL of a saturated aqueous solution) was added and the reaction mixture was extracted with DCM (3 x 50 mL). The combined organic layers were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was used without purification in the following step.

Methyl magnesium bromide (1.28 mL, 3.8 mmol of a 3 M solution in THF) was added to the aldehyde in anhydrous THF (10 mL). After 3 h, ammonium chloride (50 mL) was added to the reaction mixture and the product was extracted into DCM (3 x 50 mL). The combined organic layers were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (4:1, petrol:ethyl acetate → 2:1) to afford benzyl 2,3,4-tri-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranoside **38** (600 mg, 56% over 2 steps) as a colourless oil; $[\alpha]_D^{25}$+34.2 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3383 (O-H, br) cm^{-1}; δ_H (400 MHz, $CDCl_3$)1.32 (3H, d, *J* 6.6 Hz, CH_3), 2.06 (1H, d, *J* 9.6 Hz, OH), 3.51 (1H, dd, $J_{4,5}$ 9.6 Hz, $J_{5,6}$ 1.3 Hz, H-5), 3.84 (1H, dd, $J_{1,2}$ 2.0 Hz, $J_{2,3}$ 2.8 Hz, H-2), 3.98 (1H, dd, $J_{3,4}$ 9.4 Hz, H-3), 4.12-4.17 (2H, m, H-4, H-6), 4.44 (1H, d, *J* 11.9 Hz, CH), 4.63-4.74 (5H, m, 5 x CH), 4.79 (1H, d, *J* 12.4 Hz, CH), 4.95 (1H, d, H-1), 5.99 (1H, d, *J* 10.6 Hz, CH), 7.26-7.38 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 20.3 (q, Me), 65.6 (d, C-6), 68.1, 72.3, 72.8 (3 x t, 3 x CH_2), 74.6 (d, C-2), 74.7 (d, C-5), 75.0 (d, -4), 80.3 (d, C-3), 97.3 (d, C-1), 127.6-128.5 (d, Ar-C), 137.0, 138.2, 138.5, 138.5 (s, Ar-C); *m/z* (ESI^+) 572 ($M+NH_4^+$, 100), 1127 ($2M+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{35}H_{38}NaO_6$ ($M+Na^+$) 577.2561. Found 577.2546.

6-*S*-6-*C*-Methyl-D-mannopyranose 10

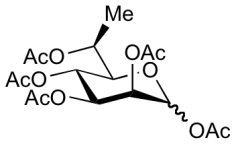


10

Benzyl 2,3,4-tri-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranoside **38** (240 mg, 0.50 mmol) was dissolved in methanol and palladium on carbon was added. Hydrogen gas was

bubbled through the solution and the the reaction mixture was left to stir under hydrogen. After 18 h, the reaction mixture was carefully filtered through celite and concentrated *in vacuo*. The residue was purified by flash column chromatography (2:2:1, ethyl acetate:isopropanol:water) to afford 6-*S*-6-*C*-methyl-D-mannopyranose **10** (93 mg, 95 % over 3 steps, α:β, 2:1); δ_H (400 MHz, D_2O) 1.14 (3H, d, *J* 6.8 Hz, CH_3-α), 1.17 (3H, d, *J* 6.5 Hz, CH_3-β), 3.01 (1H, dd, $J_{5,6}$ 1.5 Hz, $J_{4,5}$ 9.6 Hz, H-5β), 3.43 (1H, ad, *J* 8.6 Hz, H-5α), 3.51 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 9.6 Hz, H-3β), 3.58-3.71 (3H, m, H-3α, H-4α, H-4β), 3.7803.80 (2H, m, H-2α, H-2β), 3.99-4.08 (2H, m, H-6α, H-6β), 4.75 (1H, s, H-1β), 5.07 (1H, s, H-1α); δ_C (100 MHz, D_2O) 19.2 (q, Me-α, Me-β), 64.9 (d, C-6α), 65.0 (d, C-6β), 66.9 (d, C-4β), 67.2 (d, C-4α), 71.0 (d, C-3α, C-2α), 71.6 (d, C-2β), 73.7 (d, C-3β), 74.5 (d, C-5α), 78.3 (d, C-5β), 94.3 (d, C-1β), 94.5 (d, C-1α).

1,2,3,4,6-Penta-*O*-acetyl-6-*S*-6-*C*-methyl-D-mannopyranose 39

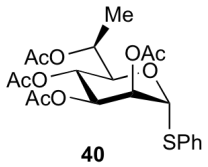


39

6-*S*-6-*C*-Methyl-D-mannopyranose **10** (209 mg, 1.1 mmol) was stirred with acetic anhydride (10 mL) and pyridine (10 mL). After 16 h, t.l.c (1:2, ethyl acetate:petrol) indicated formation of a product (R_f 0.3) with consumption of the starting material (R_f 0). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene. The residue was purified by flash column chromatography (2:1, ethyl acetate:petrol) to afford 1,2,3,4,6-penta-*O*-acetyl-6-*S*-6-*C*-methyl-D-mannopyranose **39** (400 mg, 92 %) as a clear oil; ν_{max} (thin film) 1750 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.24 (3H, d, *J* 6.6 Hz, CH_3-β), 1.29 (3H, d, *J* 6.6 Hz, CH_3-α), 1.96, 1.99, 2.06, 2.13, 2.16 (15H, 5 x s, 5 x OAc-α), 1.96, 2.00, 2.06, 2.08, 2.20 (15H, 5 x s, 5 x OAc-β), 3.53 (1H, dd, $J_{5,6}$ 2.3 Hz, $J_{4,5}$ 10.1 Hz, H-5β), 3.79 (1H, dd, $J_{5,6}$ 2.0 Hz, $J_{4,5}$ 9.6 Hz, H-5α), 4.99-5.05 (2H, m, H-6α, H-6β), 5.08 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 10.1 Hz, H-3β), 5.24 (1H, dd, $J_{1,2}$ 1.7 Hz, $J_{2,3}$ 3.3 Hz, H-2α), 5.26-65.36 (3H, m, H-3α, H-4α, H-4β), 5.47 (1H, dd, $J_{1,2}$ 1.2 Hz, H-2β), 5.79 (1H, d, H-1β), 6.10 (1H, d, H-1α); δ_C (100 MHz, $CDCl_3$) 14.2 (q, Me-β), 15.6 (q, Me-α), 20.5, 20.6, 20.6, 20.8, 20.8, 20.9, 21.0 (q, 5 x OAc-α, 5 x OAc-β), 64.9 (d, C-4β), 65.1 (d, C-

4α), 65.8 (d, C-5β), 66.1 (d, C-5α), 68.3 (d, C-2β), 68.4 (d, C-2α), 69.0 (d, C-3α), 70.9 (d, C-3β), 73.4 (d, C-6α), 76.3 (d, C-6β), 90.8 (d, C-1α), 90.9 (d, C-1β), 167.9, 168.4, 169.4, 169.4, 169.7, 169.8, 170.0, 170.2, 170.4, 170.5 (s, C=O); *m/z* (ESI^+) 422 ($M+NH_4^+$, 100), 826 ($2M+NH_4^+$, 60%); HRMS (ESI^+) calcd. for $C_{17}H_{24}NaO_{11}$ ($M+Na^+$) 427.1211. Found 427.1211.

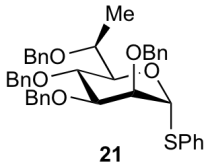
Phenyl 2,3,4,6-tetra-*O*-acetyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside 40



40

Borontrifluoroetherate (235 μL, 1.85 mmol) was added dropwise to a solution of 1,2,3,4,6-penta-*O*-acetyl-6-*S*-6-*C*-methyl-D-mannopyranose **39** (300 mg, 0.74 mmol) and thiophenol (152 μL, 1.48 mmol) in anhydrous DCM (5 mL) at 0 ^oC. After 2 h, t.l.c (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with consumption of the starting material (R_f 0.4). The reaction was quenched with triethylamine (1 mL), diluted with DCM (40 mL) and washed with sodium hydrogen carbonate (50 mL of a saturated aqueous solution). The aqueous phase was extracted with DCM (2 x 30 mL) and the combined organic layers were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-acetyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside **40** (268 mg, 80%) as a clear oil; $[\alpha]_D^{25}$ +73.6 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1711 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.12 (3H, d, *J* 6.6 Hz, Me), 2.00, 2.04, 2.09, 2.17 (12H, 4 x s, 4 x OAc), 4.25 (1H, dd, $J_{4,5}$ 9.6 Hz, $J_{5,6}$ 1.6 Hz, H-5), 5.07 (1H, dq, J_d 2.0 Hz, J_q 6.6 Hz, H-6), 5.30 (1H, dd, $J_{2,3}$ 3.3 Hz, $J_{3,4}$ 10.1 Hz, H-3), 5.38 (1H, at, *J* 9.9 Hz, H-4), 5.53 (1H, dd, $J_{1,2}$ 1.3 Hz, H-2), 5.65 (1H, d, H-1), 7.28-7.47 (5H, m, Ar-H); δ_C (100 MHz, $CDCl_3$) 15.8 (q, Me), 20.6, 20.9, 21.0, 21.1 (4 x q, 4 x Me), 65.7 (d, C-4), 66.3 (d, C-6), 69.6 (d, C-3), 70.9 (d, C-2), 72.5 (d, C-5), 85.8 (d, C-1), 127.9, 129.2, 131.5 (d, Ar-C), 132.4 (s, Ar-C), 169.6, 169.9, 170.0, 170.5 (4 x s C=O); *m/z* (ESI^+) 472 ($M+NH_4^+$, 100); HRMS (ESI^+) calcd. for $C_{21}H_{26}NaO_9S$ ($M+Na^+$) 477.1190. Found 477.1185.

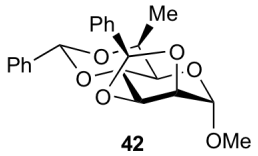
Phenyl 2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside 21



21

Phenyl 2,3,4,6-tetra-*O*-acetyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside **40** (308 mg, 0.68 mmol) was dissolved in methanol (20 mL) and sodium methoxide (20 mg, 0.37 mmol) was added. After 1 h, t.l.c (9:1, ethyl acetate:methanol) indicated formation of a product (R_f 0.1) with consumption of the starting material (R_f 0.9). The reaction mixture was neutralized with acidified DOWEX, filtered and concentrated *in vacuo*. The residue was dissolved in anhydrous DMF (5 mL) and sodium hydride (163 mg, 4.1 mmol of 60% dispersion in mineral oil) and benzyl bromide (300 mL, 3.0 mmol) was added. After 18 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.8) with consumption of the starting material (R_f 0). The reaction mixture was quenched with methanol (10 mL) and concentrated *in vacuo*. The residue was resuspended in diethyl ether (50 mL) and washed with water (50 mL). The aqueous phase was further extracted with diethyl ether (2 x 50 mL). The combined organic layers were washed with brine (50 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (petrol→3:1, petrol:ethyl acetate) to afford phenyl 2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside **21** (325 mg, 74 %) as a colourless oil; $[\alpha]_D^{25}$+75.4 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (400 MHz, $CDCl_3$) 1.22 (3H, d, *J* 6.3 Hz, Me), 3.87 (1H, dd, $J_{2,3}$ 3.0 Hz, $J_{3,4}$ 9.3 Hz, H-3), 3.92 (1H, dd, $J_{4,5}$ 9.6 Hz, $J_{5,6}$ 1.2 Hz, H-5), 4.02 (1H, d, $J_{1,2}$ 1.8 Hz, H-2), 4.08 (1H, dq, J_d 1.2 Hz, J_q 6.3 Hz, H-6), 4.29 (1H, at, *J* 9.4 Hz, H-4), 4.36-4.40 (2H, m, 2 x CH), 4.59 (2H, s, 2 x CH), 4.65 (1H, d, *J* 12.4 Hz, CH), 4.74 (1H, d, *J* 11.9 Hz, CH), 4.81 (1H, d, *J* 12. 4 Hz, CH), 4.91 (1H, d, *J* 10.9 Hz, CH), 5.81 (1H, d, H-1), 7.19-7.46 (25H, m, 25 x Ar-H); δ_C (100 MHz, $CDCl_3$) 15.5 (q, Me), 70.6 (t, CH_2), 71.4 (d, C-6), 71.7, 72.0 (2 x t, 2 x CH_2), 74.7 (d, C-4), 74.9 (t, CH_2), 75.7 (2 x d, C-2, C-5), 80.5 (d, C-3), 85.5 (d, C-1), 127.1-130.9 (d, Ar-C), 134.5, 137.9, 138.1, 138.6, 138.6, (5 x s, 5 x Ar-C); *m/z* (ESI^+) 664 ($M+NH_4^+$, 100), 1310 ($2M+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{41}H_{42}NaSO_5$ ($M+Na^+$) 669.2645. Found 669.2634.

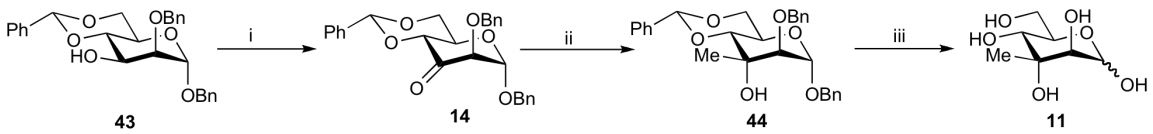
Methyl 2,3:4,6-di-*O*-benzylidene-6-*S*-6-*C*-methyl-α-D-mannopyranoside 42



42

Methyl 6-*S*-6-*C*-methyl-α-D-mannopyranoside **41** (60 mg, 0.29 mmol), *p*TsOH (3 mg, 0.015 mmol) and dimethoxybenzaldehyde (48 μL, 0.32 mmol) in anhydrous acetonitrile (2 mL) were heated at 50 ^{o}C under an atmosphere of argon. After 2 h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of 2 products (R_f 0.4, 0.9) with consumption of the starting material (R_f 0). The reaction mixture was quenched with triethylamine (0.5 mL) and concentrated *in vacuo*. The residue was purified by flash column chromatography (4:1→1:1, petrol:ethyl acetate) to afford methyl 2,3:4,6-di-*O*-benzylidene-6-*S*-6-*C*-methyl-α-D-mannopyranoside **42** (23 mg, 27%) as a colourless oil; R_f 0.9 (1:1, petrol:ethyl aceate); $[\alpha]_D^{23}$ -17.1 (*c*, 0.9 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (500 MHz, $CDCl_3$) 1.56 (3H, d, *J* 7.0 Hz, CH_3), 3.40 (3H, s, OMe), 4.06 (1H, dd, $J_{4,5}$ 10.4 Hz, $J_{5,6}$ 6.0 Hz, H-5), 4.13 (1H, dd, $J_{3,4}$ 5.0 Hz, H-4), 4.15 (1H, d, $J_{2,3}$ 7.6 Hz, H-2), 4.55 (1H, at, *J* 6.6 Hz, H-6), 4.61 (1H, dd, H-3), 5.02 (1H, s, H-1), 5.96 (1H, s, CHPh), 6.30 (1H, s, CHPh), 7.27-7.54 (10H, m, 10 x Ar-H); δ_C (125 MHz, $CDCl_3$) 11.4 (q, CH_3), 55.1 (q, OMe), 62.3 (d, C-5), 70.5 (d, C-6), 70.9 (d, C-4), 75.1 (d, C-2), 76.5 (d, C-3), 94.2 (d, CH), 98.7 (d, C-1), 103.0 (d, CH), 126.0, 126.4, 126.5, 128.2, 128.5, 129.0, 129.1 (d, Ar-C), 137.5, 138.7 (2 x s, Ar-C); *m/z* (ESI^+) 385 ($M+H^+$, 100%); HRMS (ESI^+) calcd. for $C_{22}H_{24}O_6Na$ ($M+ Na^+$) 407.1465. Found 407.1465.

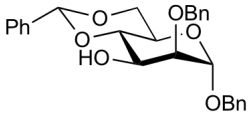
1.3 C-3 substituted monomer synthesis



43 **14** **44** **11**

Scheme S8: i) Ac_2O, DMSO, 76% ii) MeMgBr, THF, 59% iii) H_2, Pd/C, MeOH, 75%.

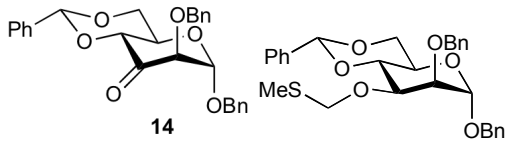
Benzyl 2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside 43



43

DIBAL-H (3.73 mL of a 1.5 M solution in toluene) was added to a solution of benzyl (S),(R)-2,3:4,6-di-*O*-benzylidene-α-D-mannopyranoside **43** (6)(880 mg, 2.0 mmol) in anhydrous toluene (50 mL) at – 40 ^{o}C. After 4 h, t.l.c (4:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.4) with consumption of the starting material (R_f 0.6). The reaction mixture was allowed to warm to room temperature and quenched with ammonium chloride (20 mL of a saturated aqueous solution). Sodium potassium tartrate (40 mL of a saturated aqueous solution) was added and the mixture stirred for 20 min. The mixture was extracted with ethyl acetate (3 x 100 mL) and the combined organic layers were washed with water (100 mL) and brine (100 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (5:1, petrol:ethyl acetate) to afford benzyl 2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (680 mg, 76 %) as a clear oil; $[\alpha]_D^{25}$+34.2 (*c*, 2.0 in $CHCl_3$) [Lit. $[\alpha]_D^{23}$+ 42 (*c*, 0.72 in $CHCl_3$)];(6-8) δ_H (400 MHz, $CDCl_3$) 2.46 (1H, d, *J* 7.9 Hz, OH), 3.83-3.93 (3H, m, H-2, H-5, H-6) 3.97 (1H, at, *J* 9.6 Hz, H-4), 4.14-4.20 (1H, m, H-3), 4.27 (1H, dd, $J_{5,6'}$ 3.3 Hz, $J_{6,6'}$ 8.6 Hz, H-6'), 4.52 (1H, d, *J* 11.9 Hz, CH), 4.68-4.76 (3H, m, 3 x CH), 4.97 (1H, d, $J_{1,2}$ 1.0 Hz, H-1), 5.60 (1H, s, CH), 7.33-7.54 (15H, m, 15 x Ar-H); δ_C (100 MHz, $CDCl_3$) 63.7 (d, C-5), 68.8 (d, C-3), 68.8 (t, C-6), 69.3 (t, CH_2), 73.7 (t, CH_2), 78.5 (d, C-2), 79.5 (d, C-4), 97.6 (d, C-1), 102.1 (d, CH), 126.3-129.1 (d, Ar-C), 136.9, 137.3, 137.6 (s, Ar-C).

Benzyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-ulo-α-D-mannopyranoside 14



14

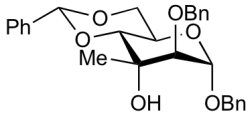
Benzyl 2-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside **43** (600 mg, 1.34 mmol) was stirred with acetic anhydride (8 mL) and DMSO (5 mL). After 24 h, t.l.c (4:1, petrol:ethyl acetate) indicated formation of 2 products (R_f 0.5, 0.6) with complete

consumption of the starting material (R_f 0.4). The pH was adjusted to pH 8 using sodium carbonate followed by extraction with DCM (2 x 100 mL). The combined organic phases were washed with water (2 x 30 mL), dried ($MgSO_4$), filtered and concentrated in vacuo. The residue was purified by flash column chromatography (8:1, petrol:ethyl aceate) to afford sugar top (80 mg, 12%) and benzyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-ulo-α-D-mannopyranoside **14** (350 mg, 59%) both as clear oil.

R_f 0.5 (4:1, petrol:ethyl acetate); $[\alpha]_D^{23}$+62.8 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1748 (C=O, s) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 3.93 (1H, d, $J_{1,2}$ 1.3 Hz, H-2), 3.99 (1H, at, *J* 10.1 Hz, H-6), 4.18 (1H, dat, J_d 4.8 Hz, J_t 10.1 Hz, H-5), 4.33 (1H, dd, $J_{5,6'}$ 4.7 Hz, $J_{6,6'}$ 10.0 Hz, H-6'), 4.50 (1H, d, *J* 12.0 Hz, C<u>H</u>H'a), 4.56 (1H, d, *J* 12.0 Hz, C<u>H</u>H'b), 4.65 (1H, d, CH<u>H</u>'a), 4.73 (1H, d, CH<u>H</u>'b), 4.90 (1H, d, $J_{4,5}$ 9.8 Hz, H-4), 5.17 (1H, d, H-1), 5.61 (1H, s, CH), 7.27-7.53 (15H, m, 15 x Ar-H); δ_C (125 MHz, $CDCl_3$), 64.2 (d, C-5), 66.3 (2 x t, CH_2, C-6), 70.5 (t, CH_2), 81.1 (d, C-4), 82.7 (d, C-2), 101.3 (d, C-1), 102.2 (d, CH), 126.2-129.3 (d, Ar-C), 136.2, 136.2, 136.5 (s, Ar-C), 198.2 (s, C-3); *m/z* (ESI^+) 464 ($M+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{28}H_{30}NaO_7$ ($M+MeOH+Na^+$) 501.1884. Found 501.1884.

R_f 0.6 (4:1, petrol:ethyl acetate); $[\alpha]_D^{23}$+83.5 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (400 MHz, $CDCl_3$) 2.14 (3H, s, Me), 3.87 (1H, dd, $J_{1,2}$ 1.3 Hz, $J_{2,3}$ 3.3 Hz, H-2), 3.90-3.96 (2H, m, H-5, H-6), 4.24 (1H, at, *J* 10.1 Hz, H-4), 4.27 (1H, dd, $J_{5,6'}$ 2.8 Hz, $J_{6,6'}$ 8.1 Hz, H-6'), 4.35 (1H, dd, $J_{3,4}$ 10.1 Hz, H-3), 4.53 (1H, d, *J* 11.9 Hz, CHH'a), 4.72-4.84 (5H, m, CHH'a, CH_2b), CH_2S), 4.93 (1H, d, H-1), 5.64 (1H, s, CH), 7.28-7.52 (15H, m, 15 x Ar-H); δ_C (100 MHz, $CDCl_3$) 13.8 (q, Me), 64.3 (d, C-5), 68.9 (t, C-6), 69.2 (t, C-6), 73.2 (d, C-3), 73.5 (t, CH_2), 75.1 (t, CH_2S), 76.4 (d, C-2), 78.7 (d, C-4), 98.3 (d, C-1), 101.6 (d, CH), 127.9-128.9 (d, Ar-C), 136.9, 137.5, 137.9 (3 x s, 3 x Ar-C); *m/z* (ESI^+) 526 ($M+NH_4^+$, 100%); HRMS (ESI^+) calcd. for $C_{29}H_{32}NaSO_6$ ($M+Na^+$) 531.1812. Found 531.1799.

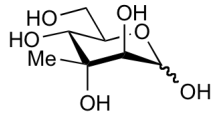
Benzyl 2-*O*-benzyl-3-*C*-methyl-4,6-*O*-benzylidene-α-D-altropyranoside 44



44

Methyl magnesium bromide (458 μL, 1.37 mmol of a 3 M solution in THF) was added to a solution of sugar **14** (320 mg, 0.69 mmol) in anhydrous THF (10 mL) at -78 ^{o}C. After 2 h, t.l.c (6:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.25) with consumption of the starting material (R_f 0.3). The reaction mixture was quenched with ammonium chloride (50 mL of a saturated aqueous solution) and extracted with DCM (3 x 50 mL). The combined organic phases were washed with brine (50 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (6:1, petrol:ethyl acetate) to afford benzyl 2-*O*-benzyl-3-*C*-methyl-4,6-*O*-benzylidene-α-D-altropyranoside **44** (250 mg, 75%) as a colourless oil; $[\alpha]_D^{23}$+29.0 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3507 (O-H, br) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.39 (3H, s, Me), 1.59 (1H, bs, OH), 3.45 (1H, s, H-2), 3.79 (1H, d, $J_{4,5}$ 9.6 Hz, H-4), 3.84 (1H, at, *J* 10.1 Hz, H-6), 4.13 (1H, ddd, $J_{5,6'}$ 5.1 Hz, $J_{5,6}$ 10.1 Hz, H-5), 4.31 (1H, dd, $J_{6,6'}$ 10.1 Hz, H-6'), 4.56 (1H, d, *J* 11.6 Hz, C<u>H</u>H'a), 4.57 (1H, d, *J* 11.9 Hz, C<u>H</u>H'b), 4.63 (1H, d, CH<u>H</u>'a), 4.80 (1H, d, CH<u>H</u>'b), 4.94 (1H, s, H-1), 5.61 (1H, s, CH), 7.27-7.50 (15H, m, 15 x Ar-H); δ_C (125 MHz, $CDCl_3$) 21.2 (q, Me), 60.1 (d, C-5), 69.0 (t, C-6), 71.3 (s, C-3), 69.8, 73.6 (2 x t, 2 x CH_2), 79.9 (d, C-4), 80.4 (d, C-2), 97.4 (d, C-1), 102.0 (d, CH), 126.2, 128.0, 128.1, 128.6, 128.9 (d, Ar-C), 136.3, 137.1, 137.5 (s, Ar-C); *m/z* (ESI$^+$) 480 (M+NH_4^+, 100%); HRMS (ESI$^+$) calcd. for $C_{28}H_{30}NaO_6$ (M+Na^+) 485.1935. Found 485.1933.

3-*C*-Methyl-D-altropyranoside 11

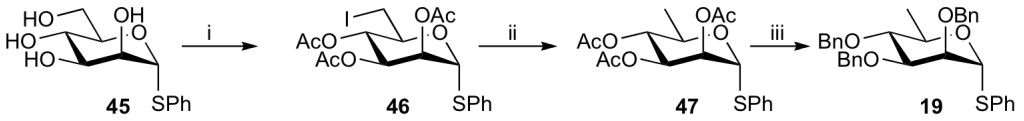


11

Benzyl 2-*O*-benzyl-3-*C*-methyl-4,6-*O*-benzylidene-α-D-altropyranoside **44** (90 mg, 0.16 mmol) was dissolved in methanol (10 mL) and palladium on carbon (10 mg, of 10% loading) was added. The reaction vessel was evacuated and refilled with hydrogen 5 times and then left to stir under an atmosphere of hydrogen. After 24 h, t.l.c (ethyl

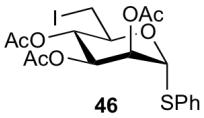
acetate) indicated formation of a product (R_f 0) with consumption of the starting material (R_f 0.9). The reaction mixture was filtered through celite and concentrated *in vacuo*. The residue was purified by flash column chromatography (9:1, ethyl acetate:methanol) to afford 3-*C*-methyl-D-altropyranoside **11** (30 mg, 97%) as a clear oil; δ_H (400 MHz, D_2O) 1.19 (3H, s, Me-β), 1.21 (3H, s, Me-α), 3.32-3.37 (2H, m, H-2α, H-4α), 3.44 (1H, d, $J_{4,5}$ 10.4 Hz, H-5β), 3.50 (1H, s, H-2β), 3.55-3.60 (2H, m, H-6α, H-5α), 3.64 (1H, dd, $J_{5,6}$ 5.8 Hz, $J_{6,6'}$ 12.1 Hz, H-6β), 3.72-3.77 (2H, m, H-6'α, H-6'β), 3.83 (1H, ddd, $J_{5,6'}$ 2.0 Hz, H-5β), 4.94 (1H, s, H-1β), 5.05 (1H, s, H-1α); δ_C (100 MHz, D_2O) 22.2 (q, Me-β), 22.3 (q, Me-α), 61.8 (t, C-6β), 62.0 (t, C-6α), 67.6 (d, C-2β), 67.8 (d, C-2α), 69.4, 72.7 (2 x d, C-4β, C-5β), 73.4 (s, C-3β), 73.6 (s, C-3α), 74.8, 75.0 (2 x d, C-4α, C-5α), 92.2 (d, C-1α), 95.2 (d, C-1β); *m/z* (ESI^+) 217 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_7H_{14}O_6Na$ ($M+Na^+$) 217.0683. Found 217.0685.

1.4 D-Rham monomer synthesis



Scheme S8: I_2, Imidazole, PPh_3, THF, 65°C, then Ac_2O, pyridine, 58% ii) H_2, Pd/C, NEt_3, MeOH, 89% iii, NaOMe, MeOH then BnBr, NaH, DMF, 94%.

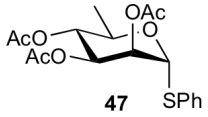
Phenyl 2,3,4-tri-*O*-acetyl-6-deoxy-6-iodo-thio-α-D-mannopyranoside 46



Iodine (1.08 g, 4.2 mmol) was added to a solution of phenyl-1-thio-α-D-mannopyranoside **45** (920 mg, 3.5 mmol), imidazole (474 mg, 7.1 mmol) and triphenylphosphine (1.1 g, 4.2 mmol) in anhydrous THF (20 mL) and the reaction mixture was heated to 70 °C. After 1 h, t.l.c (ethyl acetate) indicated formation of a product (R_f 0.3) with consumption of the starting material (R_f 0). The reaction mixture was concentrated *in vacuo* and the residue was resuspended in acetic anhydride (20 mL) and pyridine (20 mL). After 3 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting material (R_f 0). The reaction mixture

was concentrated *in vacuo*, dissolved in DCM (100 mL) and washed with sodium thiosulfate (100 mL of a 10% aqueous solution) and sodium hydrogen carbonate (100 mL of a saturated aqueous solution). The organic phase was dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (5:1, petrol:ethyl acetate) to afford phenyl 2,3,4-tri-*O*-acetyl-6-deoxy-6-iodo-thio-α-D-mannopyranoside **46** (1.02 g, 58% over 2 steps) as a clear oil; $[\alpha]_D^{25}$+79.7 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) 1750 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 2.01, 2.09, 2.14 (9H, 3 x s, 3 x OAc), 3.20 (1H, dd, $J_{5,6}$ 7.6 Hz, $J_{6,6'}$ 10.9 Hz, H-6), 3.32 (1H, dd, $J_{5,6'}$ 2.5 Hz, H-6'), 4.28 (1H, ddd, $J_{4,5}$ 9.8 Hz, H-5), 5.21 (1H, at, *J* 9.8 Hz, H-4), 5.28 (1H, dd, $J_{2,3}$ 3.0 Hz, $J_{3,4}$ 9.8 Hz, H-3), 5.48 (1H, dd, $J_{1,2}$ 1.5 Hz, H-2), 5.50 (1H, d, H-1), 7.27-7.57 (5H, m, 5 x Ar-H); δ_C (100 MHz, $CDCl_3$) 3.5 (q, C-6), 20.7, 20.8, 20.9 (3 x q, 3 x OAc), 68.9 (d, C-3), 70.1 (d, C-4), 71.0 (d, C-5), 71.1 (d, C-2), 86.0 (d, C-1), 128.1, 129.2, 132.1 (d, Ar-C), 132.8 (s, Ar-C), 169.8, 169.8, 169.9 (3 x s, 3 x C=O); *m/z* (ESI^+) 526 ($M+NH_4^+$, 100); HRMS (ESI^+) calcd. for $C_{18}H_{21}NaO_7SI$ ($M+Na^+$) 530.9945 Found 530.9940.

Phenyl 2,3,4-tri-*O*-acetyl-1-thio-α-D-rhamnopyranoside 47

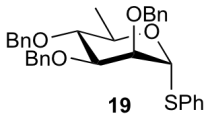


47

Palladium on carbon (10% loading, 50 mg) and triethylamine (1 mL) was added to phenyl 2,3,4-tri-*O*-acetyl-6-deoxy-6-iodo-1-thio-α-D-mannopyranoside **46** (450 mg, 0.9 mmol) in ethanol (20 mL). Hydrogen gas was bubbled through the solution to saturation. After 16 h, the reaction mixture was carefully filtered through celite and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford phenyl 2,3,4-tri-*O*-acetyl-thio-α-D-rhamnopyranoside **47** (300 mg, 89%) as a clear oil; $[\alpha]_D^{25}$+61.1 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) 1711 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.25 (3H, d, *J* 6.3 Hz, CH_3), 2.01, 20.8, 2.14 (9H, 3 x s, 3 x OAc), 4.37 (1H, dq, J_d 9.8 Hz, J_q 6.3 Hz, H-5), 5.15 (1H, at, *J* 9.8 Hz, H-4), 5.28 (1H, dd, $J_{2,3}$ 3.3 Hz, $J_{3,4}$ 10.9 Hz, H-3), 5.41 (1H, d, $J_{1,2}$ 1.5 Hz, H-1), 5.50 (1H, dd, H-2), 7.26-7.48 (5H, m, 5 x Ar-H); δ_C (100 MHz, $CDCl_3$) 17.3 (q, Me), 20.7, 20.8, 20.9 (3 x q, 3 x OAc), 67.7 (d, C-5), 69.4 (d, C-3), 71.1, 71.2 (2 x d, C-2, C-3), 85.7 (d, C-1), 127.9, 129.2,

131.8 (3 x d, Ar-C), 133.2 (s, Ar-C), 169.9, 170.0 (2 x s, 3 x C=O); *m/z* (ESI^+) 405 ($M+Na^+$, 100); HRMS (ESI^+) calcd. for $C_{18}H_{22}NaO_7S$ ($M+Na^+$) 405.0984. Found 405.0988.

Phenyl 2,3,4-tri-*O*-benzyl-thio-α-D-rhamnopyranoside 19

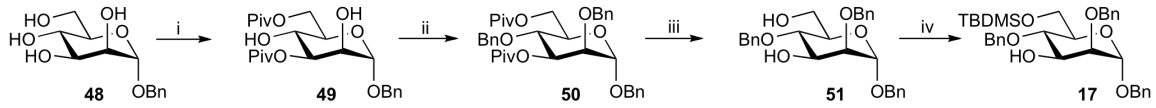


19

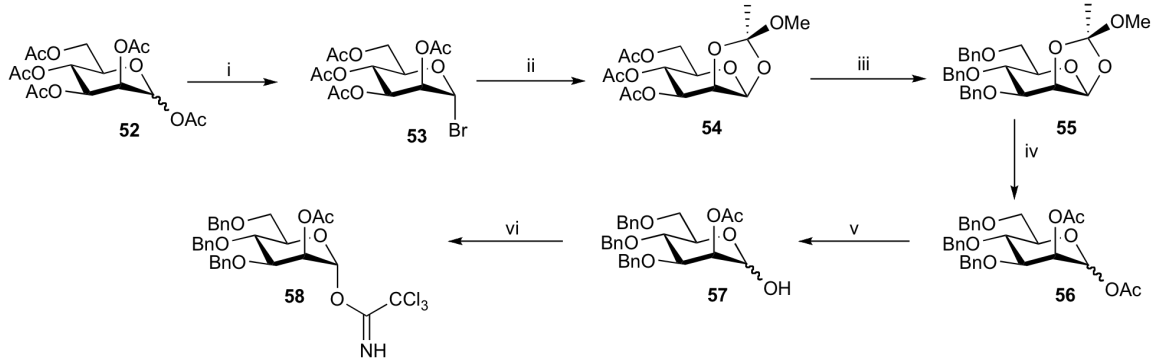
Phenyl 2,3,4-tri-*O*-acetyl-thio-α-D-rhamnopyranoside **47** (250 mg, 0.68 mmol) was dissolved in methanol (20 mL) and sodium methoxide (20 mg, 0.37 mmol) was added. After 1 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0) with consumption of the starting material (R_f 0.7). The reaction mixture was neutralized with acidified DOWEX, filtered and concentrated *in vacuo*. The residue was dissolved in anhydrous DMF (5 mL) and sodium hydride (122 mg, 3.0 mmol of 60% dispersion in mineral oil) and benzyl bromide (268 μL, 2.2 mmol) was added. After 18 h, t.l.c (6:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.8) with consumption of the starting material (R_f 0). The reaction mixture was quenched with methanol (10 mL) and concentrated *in vacuo*. The residue was resuspended in diethyl ether (50 mL) and washed with water (50 mL). The aqueous phase was further extracted with diethyl ether (2 x 50 mL). The combined organic layers were washed with brine (50 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (petrol→3:1, petrol:ethyl acetate) to afford phenyl 2,3,4-tri-*O*-benzyl-thio-α-D-rhamnopyranoside **19** (328 mg, 94 %) as a colourless oil; $[\alpha]_D^{25}$+85.7 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (400 MHz, $CDCl_3$) 1.41 (3H, d, *J* 6.3 Hz, CH_3), 3.74 (1H, at, *J* 9.4 Hz, H-4), 3.89 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 9.3 Hz, H-3), 4.04 (1H, dd, $J_{1,2}$ 1.8 Hz, H-2), 4.21 (1H, dq, J_d 9.4 Hz, J_q 6.3 Hz, H-5), 4.64-4.72 (4H, m, 4 x CH), 4.78 (1H, d, *J* 12.4 Hz, CH), 5.02 (1H, d, *J* 10.8 Hz, CH), 5.55 (1H, d, H-1), 7.27-7.45 (20H, m, 20 x Ar-H); δ_C (100 MHz, $CDCl_3$) 18.0 (q, C-6), 69.4 (d, C-5), 72.1 (t, CH_2), 75.3 (t, CH_2), 76.5 (d, C-2), 80.0 (d, C-3), 80.5 (d, C-4), 85.8 (d, C-1), 127.3, 127.7, 127.8, 128.1, 128.4, 129.1, 131.3 (d, Ar-C), 134.7, 137.9,

138.3, 138.5 (4 x s, 4 x Ar-C); *m/z* (ESI^+) 544 ($M+NH_4^+$, 100); HRMS (ESI^+) calcd. for $C_{33}H_{34}NaSO_6$ ($M+Na^+$) 549.2070. Found 540.2052.

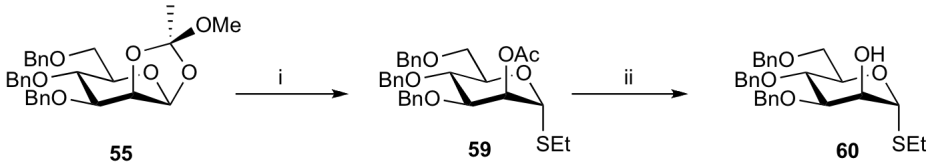
1.5 Tetrasaccharide synthesis



Scheme S9: i) PivCl, Pyridine, 0°C, 73%, ii) benzyl 2,2,2-trichloroacetimidate, TMSOTf, DCM, Cyclohexane, 67%, iii) NaOMe, MeOH, 70°C, 99%, iv) TBDMSCl, imidazole, DMF, 0°C, 90%.

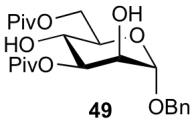


Scheme S10: i) HBr/AcOH, DCM, ii) MeOH, 2,4,6-collidine, DCM, reflux, 98%, iii) NaOMe, MeOH, then BnBr, NaH, DMF, 92% over 2 steps, iv) AcOH, H_2O then Ac_2O, pyridine, 99% over 2 steps, v) $BnNH_2$, THF, 99%, vi) trichloroacetonitrile, DBU, DCM, 4Å sieves, 90%.



Scheme S11: EtSH, $HgBr_2$, MeCN, 4Å sieves, 77%, ii) NaOMe, MeOH, 93%.

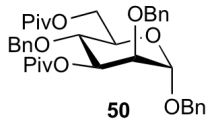
Benzyl 4,6-di-*O*-pivaloyl-α-D-mannopyranoside 49



Trimethylacetyl chloride (11.8 mL, 95.6 mmoL) was added dropwise to a solution of benzyl α-D-mannopyranoside **48** (9) (10.0 g, 37.0 mmol) in anhydrous pyridine (60 mL) at 0°C. After 15 min, t.l.c. (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.4) with complete consumption of the starting material (R_f 0.0). Methanol (10 mL) was added to the reaction mixture which was then concentrated *in vacuo*. The residue was

suspended in ethyl acetate (200 mL) and washed with hydrochloric acid (100 mL of a 1% aqueous solution), brine (100 mL) and sodium hydrogencarbonate (100 mL of a saturated aqueous solution). The organic layer was dried ($MgSO_4$), filtered and concentrated *in vacuo*. Recrystallisation (ethyl acetate/petrol) afforded benzyl 4,6-di-*O*-pivaloyl-α-D-mannopyranoside **49** (11.8 g, 73 %) as a white cystalline solid; m.p. 133-134 ^oC; $[\alpha]_D^{23}$ + 59.9 (*c*, 1.0 in $CHCl_3$); ν_{max} (KBr) 3483 (br, OH), 1730, 1712 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.26 (18H, 1 x s, 2 x $C(CH_3)_3$), 3.85 (1H, at, *J* 9.7 Hz, H-4), 3.90-3.93 (1H, m, H-5), 4.05 (1H, at, *J* 2.1 Hz, H-2), 4.39-4.41 (2H, m, H-6, H-6'), 4.54 (1H, d, *J* 11.9 Hz, C<u>H</u>H'Ph), 4.76 (1H, d, *J* 11.9 Hz, CH<u>H</u>'Ph), 4.91 (1H, d, $J_{1,2}$ 1.4 Hz, H-1), 5.12 (1H, dd, $J_{2,3}$ 3.2 Hz, H-3), 7.28-7.33 (5H, m, 5 x Ar-H); δ_C (100 MHz, $CDCl_3$) 27.2 (q, 6 x CH_3), 38.4 (s, 2 x <u>C</u>$(CH_3)_3$), 65.4 (t, CH_2), 66.6 (d, C-4), 68.4 (t, C-6), 70.7 (d, C-2), 71.5 (d, C-5), 74.3 (d, C-3), 98.3 (d, C-1), 128.1, 128.3 (2 x d, 2 x Ar-C), 136.7 (s, Ar-C), 179.1 (s, C=O); *m/z* (ESI^+) 497 ($M+MeCN+NH_4^+$, 100 %); HRMS (ESI^+) calcd. for $C_{23}H_{35}O_8$ ($M+H^+$) 439.2332. Found 439.2336.

Benzyl 2,4-di-*O*-benzyl-3,6-di-*O*-pivaloyl-α-D-mannopyranoside 50

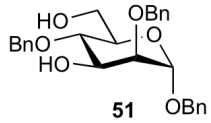


50

Benzyl 4,6-di-*O*-pivaloyl-α-D-mannopyranoside **49** (3.0 g, 6.9 mmol) and benzyl 2,2,2-trichloroacetimidate (5.1 mL, 27.4 mmol) was stirred in DCM (20 mL) and cyclohexane (20 mL) with 4 Å molecular sieves for 30 min. The reaction mixture was cooled to 0 ^oC and trimethylsilyltriflate (72 μL, 0.34 mmol) was added dropwise. After 16 h, t.l.c. (7:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with complete consumption of the starting material (R_f 0.1). Triethylamine was added (2 mL) and the reaction mixture filtered through celite® and concentrated *in vacuo*. The residue was purified by flash column chromatography (7:1, petrol:ethyl acetate) to afford benzyl 2,4-di-*O*-benzyl-3,6-di-*O*-pivaloyl-α-D-mannopyranoside **50** (2.8 g, 67 %) as a colourless oil; $[\alpha]_D^{23}$ + 51.3 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1730 (s, C=O) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.28, 1.29 (18H, 2 x s, 2 x $C(CH_3)_3$), 3.95-4.04 (3H, m, H-2, H-4, H-5), 4.29 (1H, dd, $J_{5,6}$ 5.0 Hz, $J_{6,6'}$ 11.8 Hz, H-6), 4.47-4.63 (5H, m, H-6', 4 x CH), 4.78 (1H, d, *J* 11.9 Hz, CH), 4.85

(1H, d, *J* 10.8 Hz, CH), 4.96 (1H, d, $J_{1,2}$ 1.8 Hz, H-1), 5.42 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 9.1 Hz, H-3), 7.33-7.42 (15H, m, Ar-H); δ_C (100 MHz, $CDCl_3$) 27.3 (q, CH_3), 38.6 (s, $\underline{C}(CH_3)_3$), 63.1 (t, C-6), 68.9 (t, CH_2), 70.4, 73.6, 74.0, 76.4 (4 x d, C-2, C-3, C-4, C-5), 73.2, 74.8 (2 x t, 2 x CH_2), 96.6 (d, C-1), 127.6-128.5 (d, 15 x Ar-C), 137.0, 139.1, 140.4 (s, 3 x Ar-C), 177.9, 178.3 (2 x s, 2 x C=O); *m/z* (ESI^+) 677 ($M+NH_4^+$+MeCN, 100 %); HRMS (ESI^+) calcd. for $C_{37}H_{50}O_8N$ ($M+NH_4^+$) 636.3536. Found 636.3531.

Benzyl 2,4-di-*O*-benzyl-α-D-mannopyranoside 51

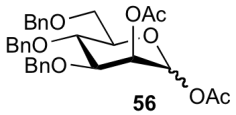


Sodium methoxide (611 mg, 11.3 mmol) was added to a solution of benzyl 2,4-di-*O*-benzyl-3,6-di-*O*-pivaloyl-α-D-mannopyranoside **50** (2.8 g, 4.5 mmol) in methanol (30 mL) and heated to reflux at 70 ^oC. After 16 h, t.l.c. (3:1 , petrol:ethyl acetate) indicated formation of a product (R_f 0.1) with complete consumption of the starting material (R_f 0.4). The reaction mixture was stirred with acidified DOWEX until at pH 8, filtered and concentrated *in vacuo* to afford benzyl 2,4-di-*O*-benzyl-α-D-mannopyranoside **51** (2.0 g, 99 %) as a colourless oil; $[\alpha]_D^{23}$+ 44.3 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 2923 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 3.68-3.85 (5H, m, H-2, H-4, H-5, H-6, H-6'), 4.07 (1H, dd, $J_{2,3}$ 3.8 Hz, $J_{3,4}$ 8.5 Hz, H-3), 4.47 (1H, d, *J* 11.9 Hz, CH), 4.59 (1H, d, *J* 11.8 Hz, CH), 4.67-4.72 (3H, m, 3 x CH), 4.92 (1H, d, *J* 11.1 Hz, CH), 4.97 (1H, d, $J_{1,2}$ 1.8 Hz, H-1), 7.29-7.37 (15H, m, ArH); δ_C (100 MHz, $CDCl_3$) 62.3 (t, C-6), 69.3 (t, CH_2), 71.6, 71.8, 76.5, 78.4 (4 x d, C-2, C-3, C-4, C-5), 73.2, 75.1 (2 x t, 2 x CH_2), 96.4 (d, C-1), 127.9-128.7 (d, Ar-C), 137.1, 137.6, 138.3 (3 x s, 3 x Ar-C); *m/z* (ESI^+) 509 ($M+NH_4^+$+MeCN, 100 %); HRMS (ESI^+) calcd. for $C_{27}H_{34}O_6N$ ($M+NH_4^+$) 468.2386. Found 468.2394.

Benzyl 2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 17A

tert-Butyldimethylsilyl chloride (184 mg, 1.22 mmol) was added to a solution of benzyl 2,4-di-*O*-benzyl-α-D-mannopyranoside **51** (500 mg, 1.11 mmol) and imidazole (297 mg, 4.44 mmol) in DMF (8 mL) at 0 ^{o}C and the reaction mixture stirred under an atmosphere of argon. After 2 h, t.l.c., (3:1, petrol:ethyl acetate), indicated formation of a product (R_f 0.7) with complete consumption of the starting material (R_f 0.1). The reaction mixture was concentrated *in vacuo* and the residue suspended in ethyl acetate (200 mL) and washed with hydrochloric acid (100 mL of a 1 M aqueous solution). The phases were separated and the aqueous layer extracted with ethyl acetate (2 x 100 mL). The combined organic layers were washed with sodium hydrogencarbonate (200 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatograpy (4:1, petrol:ethyl acetate) to afford benzyl 2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **17** (559 mg, 90 %) as a colourless oil; $[\alpha]_D^{22}$ + 24.1 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3420 (br, OH) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 0.12, 0.13 (6H, 2 x s, 2 x CH_3), 0.95 (9H, s, $C(CH_3)_3$), 3.68-3.74 (2H, m, H-4, H-5), 3.80 (1H, dd, $J_{1,2}$ 1.3 Hz, $J_{2,3}$ 3.8 Hz, H-2), 3.89 (2H, ad, *J* 2.9 Hz, H-6, H-6'), 4.06-4.08 (1H, m, H-3), 4.49 (1H, d, *J* 11.9 Hz, C<u>H</u>H'), 4.57 (1H, d, *J* 11.7 Hz, C<u>H</u>H'), 4.66-4.76 (3H, m, C<u>H</u>H', 2 x CH<u>H</u>'), 4.93 (1H, d, *J* 11.1 Hz, CH<u>H</u>'), 5.10 (1H, d, H-1), 7.31-7.39 (15H, m, 15 x Ar-H); δ_C (100 MHz, $CDCl_3$) -5.0, -5.2 (2 x q, 2 x CH_3), 18.4 (s, <u>C</u>$(CH_3)_3$), 26.0 (q, C(<u>C</u>$H_3)_3$), 62.7 (t, C-6), 68.8, 72.8, 75.0 (3 x t, 3 x CH_2), 71.9 (d, C-3), 72.6, 76.7 (2 x d, C-4, C-5), 78.7 (d, C-2), 95.9 (d, C-1), 127.8, 127.9, 128.1, 128.5, 128.6 (5 x d, 15 x Ar-C), 137.4, 138.7, 138.8 (3 x s, 3 x Ar-C); *m/z* (ESI^+) 623 ($M+NH_4^+$+MeCN, 100 %); HRMS (ESI^+) calcd. for $C_{33}H_{48}O_6NSi$ ($M+NH_4^+$) 582.3251. Found 582.3242.

1,2-Di-*O*-acetyl-3,4,6-tri-*O*-benzyl-D-mannopyranose 56

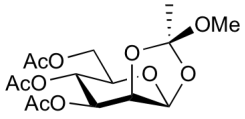


56

Exo-3,4,6-tri-*O*-benzyl-1,2-*O*-(1-methoxyethylidene)-β-D-mannopyranoside **55** (10) (9.7 g, 19.1 mmol) was stirred in water (100 mL) and acetic acid (150 mL). After 4 h, t.l.c. (1:1, ethyl acetate:petrol) indicated formation of two products (R_f 0.5, 0.6) with complete

consumption of the starting material (R_f 0.8). The reaction mixture was diluted with ethyl acetate (400 mL) and the layers separated. The aqueous layer was extracted with ethyl acetate (2 x 100 mL) and the combined organic layers washed with sodium hydrogencarbonate (200 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was coevaporated with toluene and dried *in vacuo*. The residue was suspended in pyridine (100 mL), cooled to 0^oC and acetic anhydride (50 mL) was added dropwise. The reaction mixture was allowed to warm to room temperature. After 16 h, t.l.c. (1:1, ethyl acetate:petrol) indicated formation of a product (R_f 0.8) with complete consumption of the starting materials (R_f 0.5, 0.6). The reaction mixture was concentrated *in vacuo* to afford 1,2-di-*O*-acetyl-3,4,6-tri-*O*-benzyl-D-mannopyranose as a mixture of anomers **56** (10) (α:β, 1:3.5) (10.1 g, 99 %); δ_H (400 MHz, $CDCl_3$) 2.11, 2.21 (6H, 2 x s, 2 x CH_3-β), 2.14, 2.27 (6H, 2 x s, 2 x CH_3-α), 3.62-3.66 (1H, m, H-5α), 3.74-3.97 (7H, m, H-4α, H-4β, H-5β, H-6α, H-6β, H-6'α, H-6'β), 4.04-4.06 (2H, m, H-3α, H-3β), 4.54-4.63 (6H, m, 3 x CH_2α, 3 x CH_3β), 4.70-4.81 (4H, m, 2 x CHH'α, 2 x CHH'β), 4.90-4.94 (2H, m, CHH'α, CHH'β), 5.44 (1H, s, H-2β), 5.68 (1H, d, *J* 3.0 Hz, H-2α), 5.80 (1H, s, H-1α), 6.19 (1H, d, $J_{1,2}$ 1.7 Hz, H-1β), 7.29-7.35 (15H, m, 15 x Ar-H).

Exo-3,4,6-tri-_O_-acetyl-1,2-_O_-(1-methoxyethylidene)-β-D-mannopyranoside 54

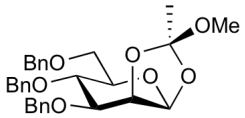


54

2,4,6-Collidine (20 mL, 152 mmol) and anhydrous methanol (9.1 mL, 224 mmol) were added to 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranosyl bromide **53**(10) (47.3g, 115 mmol) in anhydrous DCM (250 mL) and the reaction mixture was heated to reflux. After 16 h, t.l.c. (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with complete consumption of the starting material (R_f 0.7). Water (250 mL) was added to the reaction mixture which was then extracted with DCM (250 mL). The organic layer was washed with brine (200 mL), dried ($MgSO_4$), filtered and concentrated *in vacuo*. Recrystallisation (diethyl ether) afforded *exo*-3,4,6-tri-*O*-acetyl-1,2-*O*-(1-methoxyethylidene)-β-D-

mannopyranoside **54** (45.5 g, 98 %) as a white crystalline solid; $[\alpha]_D^{22}$ – 26.3 (*c*, 1.0 in $CHCl_3$); [Lit. $[\alpha]_D^{24}$ – 28.4 (*c*, 1.5 in $CHCl_3$)];(11) δ_H (400 MHz, $CDCl_3$) 1.74 (3H, s, Me), 2.05, 2.07, 2.12 (9H, 3 x s, 3 x OAc), 3.28 (3H, s OMe), 3.68 (1H, ddd, $J_{4,5}$ 7.5 Hz, $J_{5,6}$ 2.6 Hz, $J_{5,6'}$ 4.9 Hz, H-5), 4.14 (1H, dd, $J_{6,6'}$ 12.1 Hz, H-6), 4.23 (1H, dd, H-6'), 4.61 (1H, dd, $J_{1,2}$ 2.5 Hz, $J_{2,3}$ 4.0 Hz, H-2), 5.14 (1H, dd, $J_{3,4}$ 9.9 Hz, H-3), 5.30 (1H, at, *J* 9.7 Hz, H-4), 5.49 (1H, d, H-1).

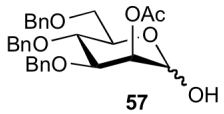
***Exo*-3,4,6-tri-*O*-benzyl-1,2-*O*-(1-methoxyethylidene)-β-D-mannopyranoside 55**



55

Benzyl bromide (36 mL, 304 mmol) was added dropwise to a solution of *exo*-1,2-*O*-(1-methoxyethylidene)-β-D-mannopyranoside **54** and sodium hydride (60 % dispersion in mineral oil, 16.6 g, 415 mmol) in anhydrous DMF (500 mL) and stirred under argon. After 16h, t.l.c. (1:1, ethyl acetate:petrol) indicated formation of a product (R_f 0.8) with complete consumption of the starting material (R_f 0.0). Methanol (75 mL) was added to quench the reaction mixture, which was then concentrated *in vacuo*. The residue was suspended in water (500 mL) and extracted with diethyl ether (2 x 300 mL). The combined organic layers were washed with brine (200 mL), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford *exo*-3,4,6-tri-*O*-benzyl-1,2-*O*-(1-methoxyethylidene)-β-D-mannopyranoside **55** (32 g, 92% over 2 steps) as a white solid; $[\alpha]_D^{22}$ + 25.6 (*c*, 1.0 in $CHCl_3$); [Lit. $[\alpha]_D^{24}$ + 26 (*c*, 1.1 in $CHCl_3$)];(12) δ_H (400 MHz, $CDCl_3$) 1.76 (3H, s, Me),3.30 (3H, s, OMe), 3.44 (1H, ddd, *J* 2.4 Hz, *J* 4.3 Hz, *J* 9.4 Hz, H-5), 3.71-3.79 (3H, m, H-3, H-6, H-6'), 3.94 (1H, at, *J* 9.3 Hz, H-4), 4.41 (1H, dd, $J_{1,2}$ 2.5 Hz, $J_{2,3}$ 3.8 Hz, H-2), 4.55-4.64 (3H, m, 3 x CH), 4.79 (1H, d, *J* 12.4 Hz, CH), 4.81 (1H, d, *J* 11.3 Hz, CH), 4.94 (1H, d, *J* 10.8 Hz, CH), 5.36 (1H, d, H-1), 7.24-7.43 (15H, m, 15 x Ar-H).

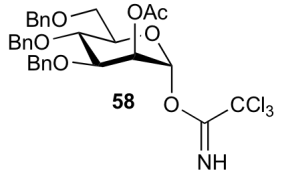
2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranose 57



57

Benzylamine (3.1 mL, 28.5 mmol) was added to a solution of 1,2-di-*O*-acetyl-3,4,6-tri-*O*-benzyl-D-mannopyranose **56** (10.1 g, 19.0 mmol) in THF (100 mL). After 24 h, t.l.c. (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.3) with complete consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo*, dissolved in ethyl acetate (300 mL) and washed with ice cold hydrochloric acid (100 mL of a 1 M aqueous solution) and sodium hydrogencarbonate (100 mL of a saturated aqueous solution). The organic layer was dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate) to afford 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranose **57** (9.3 g, 99 %) as a colourless oil; α anomer: $[\alpha]_D^{22}$+ 17.8 (*c*, 1.0 in $CHCl_3$); [Lit. $[\alpha]_D^{25}$+ 16.7 (*c*, 0.8 in $CHCl_3$)];(13) δ_H (400 MHz, $CDCl_3$) 2.16 (3H, s, OAc), 3.72 (2H, m, H-6, H-6'), 3.78 (1H, at, *J* 9.6 Hz, H-4), 4.04-4.09 (2H, m, H-3, H-5), 4.47 (1H, d, *J* 10.8 Hz, CHH'a), 4.52-4.56 (2H, m, 2 x CH), 4.63 (1H, d, *J* 12.2 Hz, CH), 4.72 (1H, d, *J* 11.2 Hz, CH), 4.87 (1H, d, CHH'a), 5.25 (1H, d, $J_{1,2}$ 1.9 Hz, H-1), 5.39 (1H, dd, $J_{2,3}$ 3.2 Hz, H-2), 7.29-7.35 (15H, m, 15 x Ar-H).

2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl trichloroacetimidate 58

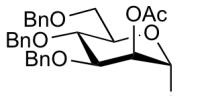


58

2-*O*-Acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranose **57** (1.17 g, 2.38 mmol) and trichloroacetonitrile (2.4 mL, 23.8 mmol) were stirred in DCM (40 mL) with 4 Å molecular sieves for 30 min. 1,8-Diazabicyclo[5.4.0]undec-7-ene (18 μL, 0.12 mmol) was added and the reaction mixture stirred under an atmosphere of argon. After 16 h, t.l.c. (1:1, ethyl acetate:petrol), indicated formation of a product (R_f 0.7) with complete consumption of the starting material (R_f 0.4). Triethylamine (1 mL) was added and the reaction mixture filtered through celite and concentrated *in vacuo*. The residue was purified by flash column chromatography (1:1, ethyl acetate:petrol) to afford 2-*O*-acetyl-

3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl trichloroacetimidate **58** (1.36 g, 90 %) as a colourless oil; $[\alpha]_D^{22}$+ 44.4 (*c*, 1.0 in $CHCl_3$); [Lit. $[\alpha]_D^{20}$ + 45 (*c*, 1.0 in $CHCl_3$)];(14) δ_H (400 MHz, $CDCl_3$) 2.23 (3H, s, CH_3), 3.76 (1H, dd, $J_{5,6}$ 1.4 Hz, $J_{6,6'}$ 11.1 Hz, H-6), 3.89 (1H, dd, $J_{5,6'}$ 1.1 Hz, H-6'), 4.02-4.10 (3H, m, H-3, H-4, H-5), 4.56 (2H, at, *J* 11.1 Hz, 2 x CHH'), 4.63 (1H, d, *J* 11.2 Hz, CHH'a), 4.73 (1H, d, *J* 12.0 Hz, CHH'), 4.78 (1H, d, CHH'a), 4.92 (1H, d, *J* 10.6 Hz, CHH'), 5.54-5.56 (1H, m, H-2), 6.35 (1H, d, $J_{1,2}$ 1.6 Hz, H-1), 7.22-7.39 (15H, m, 15 x Ar-H), 8.73 (1H, bs, NH).

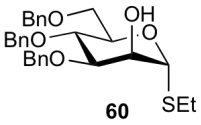
Ethyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-1-thio-α-D-mannopyranoside 59



59

Exo-3,4,6-tri-*O*-benzyl-1,2-*O*-(1-methoxyethylidene)-β-D-mannopyranoside **55** (5.0 g, 9.88 mmol) was stirred in anhydrous acetonitrile (50 mL) and 4Å molecular sieves for 1 h under an atmosphere of Argon. Ethanethiol (2.5 mL, 32.6 mmol) and mercury bromide (356 mg, 0.99 mmol) were added and the reaction mixture heated at 60 °C. After 18 h, t.l.c. (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with consumption of the starting material (R_f 0.4). The reaction mixture was cooled to room temperature and filtered through celite®. The filtrate was diluted with DCM (200 mL) and washed with sodium hydroxide (100 mL of a 1 M aqueous solution). The aqueous phase was extracted with DCM (2 x 100 mL) and the combined organic layers dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:diethyl ether) to afford ethyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-1-thio-α-D-mannopyranoside **59** (4.1 g, 77%) as a colourless oil; $[\alpha]_D^{21}$+78.3 (*c*, 1.0 in $CHCl_3$) [Lit. $[\alpha]_D^{22}$+76 (*c*, 0.7 in $CHCl_3$);];(15) δ_H (400 MHz, $CDCl_3$) 1.31 (3H, t, *J* 7.4 Hz, CH_3), 2.19 (3H, s, Ac), 2.57-2.73 (2H, m, CH_2), 3.71 (1H, dd, $J_{5,6}$ 1.9 Hz, $J_{6,6'}$ 10.8 Hz, H-6), 3.87 (1H, dd, $J_{5,6'}$ 4.2 Hz, H-6'), 3.92-4.00 (2H, m, H-3, H-4), 4.18-4.21 (1H, m, H-5), 4.49-4.57 (3H, m, 3 x CH), 4.70-4.73 (2H, m, 2 x CH), 4.89 (1H, d, *J* 10.8 Hz, CH), 5.36 (1H, d, $J_{1,2}$ 1.7 Hz, H-1), 5.47 (1H, dd, $J_{2,3}$ 2.7 Hz, H-2), 7.18-7.39 (15H, m, 15 x Ar-H).

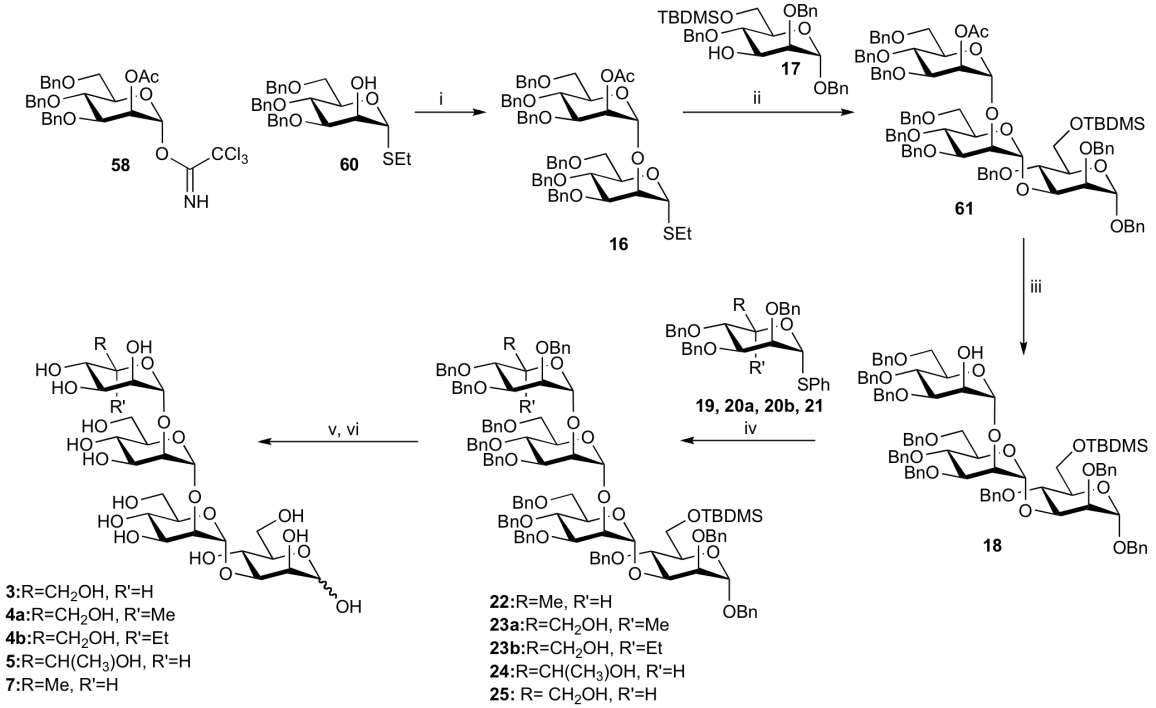
Ethyl 3,4,6-tri-*O*-benzyl-1-thio-α-D-mannopyranoside 60



60

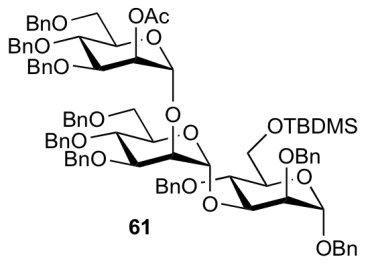
Sodium methoxide (5 mL of a 0.1 M solution in methanol) was added to a solution of ethyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-1-thio-α-D-mannopyranoside **59** (3.2 g, 6.0 mmol) in methanol (50 mL). After 30 min, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting material (R_f 0.7). The reaction mixture was neutralized with DOWEX®, filtered and concentrated *in vacuo* to afford ethyl 3,4,6-tri-*O*-benzyl-1-thio-α-D-mannopyranoside **60** (2.74 g, 93 %) as a colourless oil; $[\alpha]_D^{21}$+91 (*c*, 1.0 in $CHCl_3$) [Lit. $[\alpha]_D^{23.5}$+88 (*c*, 1.0 in $CHCl_3$);];(16) δ_H (400 MHz, $CDCl_3$) 1.30 (3H, t, *J* 7.4 Hz, CH_3), 2.54-2.72 (2H, m, CH_2), 3.70 (1H, dd, $J_{5,6}$ 2.0 Hz, $J_{6,6'}$ 10.8 Hz, H-6), 3.81 (1H, dd, $J_{5,6'}$ 4.5 Hz, H-6'), 3.85 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 9.1 Hz, H-3), 3.92 (1H, at, *J* 9.2 Hz, H-4), 4.11 (1H, dd, $J_{1,2}$ 1.1 Hz, H-2), 4.18 (1H, dd, $J_{4,5}$ 9.6 Hz, H-5), 4.51-4.53 (2H, m, 2 x CH), 4.66-4.69 (3H, m, 3 x CH), 4.84 (1H, d, *J* 10.9 Hz, CH), 5.41 (1H, d, H-1), 7.19-7.37 (15H, m, 15 x Ar-H).

Tetrasaccharide synthesis



Scheme S12: i) TMSOTf, DCM, 78%, ii) Tf_2O, Me_2S_2, TTBP, DCM, 4Å sieves, -78°C→RT, 68%, iii) NaOMe, MeOH, 95%, iv) DMTST, TTBP, DCM, 4Å sieves, -78°C→RT, v) AcOH, H_2O, 50 °C, vi) H_2, Pd/C, MeOH.

Benzyl (2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 61

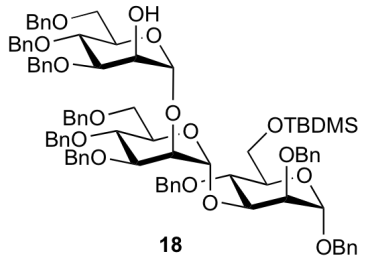


Benzyl 2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside (77 mg, 0.14 mmol), ethyl 2-*O*-acetyl-3,4,6-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-thio-α-D-mannopyranoside **16** (160 mg, 0.16 mmol) and 2,6-di-*tert*-butyl-4-methylpyridine **17** (235 mg, 0.95 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (2 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -78 °C. DCM (2 mL) was added to a flame dried flask containing 4Å molecular sieves and stirred for 1 h then cooled to 0 °C. To this flask was added dimethyldisulfide (73 μL, 0.816 mmol) and trifluoromethylsulfonic anhydride (137 μL, 0.816 mmol). After 2 min, the solution was transferred to the flask containing the flask containing the sugar reagents at -78 °C. The mixture was stirred at -78 °C under an atmosphere of argon. After 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with complete consumption of the starting materials (R_f 0.6, 0.3). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→6:1, petrol:ethyl acetate) to afford benzyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **61** (136 mg, 68%) as a colourless oil.

$[\alpha]_D^{21}$+15.3 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1758 (br, C=O) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 0.06, 0.07 (6H, 2 x s, 2 x CH_3), 0.91 (9H, s, $C(CH_3)_3$), 2.13 (3H, s, Ac), 3.46 (1H, d, *J*

10.5 Hz, H-6a), 3.68-4.00 (14H, m, H-2a, H-3b/c, H-4a/b/c, H-5a/b/c, H-6b/c, H-6'a/b/c), 4.03 (1H, m, H-2b), 4.15 (1H, dd, $J_{2,3}$ 3.1 Hz, $J_{3,4}$ 9.5 Hz, H-3a), 4.31 (1H, d, *J* 12.2 Hz, CH), 4.40 (1H, d, *J* 10.9 Hz, CH), 4.42-4.46 (2H, m, 2 x CH), 4.51 (1H, d, *J* 12.1 Hz, CH), 4.53-4.68 (10H, m, 10 x CH), 4.76 (1H, d, *J* 11.7 Hz, CH), 4.82 (1 H, d, *J* 10.9 Hz, CH), 4.88 (1H, d, *J* 11.2 Hz, CH), 4.90 (1H, d, $J_{1,2}$ 1.4 Hz, H-1a), 5.06 (1H, d, $J_{1,2}$ 1.5 Hz, H-1c), 5.2 (1H, d, $J_{1,2}$ 1.3 Hz, H-1b), 5.54 (1H, at, *J* 2.2 H, H-2c), 7.14-7.36 (45H, m, 45 x Ar-H); δ_C (125 MHz, $CDCl_3$) -5.3, -5.1, (q, 2 x CH_3), 18.4 (s, $\underline{C}(CH_3)_3$), 26.0 (q, $C(\underline{C}H_3)_3$), 62.6 (t, C-6b), 68.4 (t, C-6a), 68.7 (t, CH_2), 68.8 (d, C-2c), 69.5 (C-6c), 71.9, 72.1, 73.2, 73.4, 74.8, 74.9, 75.0 (t, 8 x CH_2), 72.6, 73.4, 74.2, 74.8, 75.1, 77.2, 78.1 (d, C-2a/b, C-3b/c, C-4a/b/c, C-5a/b/c), 78.1 (d, C-3a), 96.1 (d, C-1a), 99.3 (d, C-1c), 100.9 (d, C-1b), 127.3-128.5 (d, 45 x Ar-C), 137.5-138.7 (s, 9 x Ar-C), 170.1 (s, C=O); *m/z* (ESI^+) 1493 ($M+Na^+$, 100 %); ($M+Na^+$) peaks observed: 1451.7 (100%), 1452.7 (98%), 1453.7 (47%), 1454.7 (15%), 1555.7 (5%), peaks calculated: 1451.7 (99%), 1452.7 (100%), 1453.7 (56%), 1454.7 (22%), 1555.7 (7%).

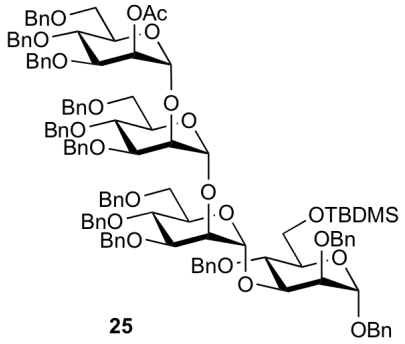
Benzyl (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 18A



Benzyl (2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **61** (40 mg, 0.026 mmol) was dissolved in methanol (2 mL) and sodium methoxide (0.2 mL of a 0.1 M solution in methanol) was added. After 24 h, t.l.c. (3:1, petrol:ethyl acetate) showed formation of a product (R_f 0.3) and complete consumption of the starting material (R_f 0.6). Ammonium chloride (a drop of a saturated aqueous solution) was added followed by sodium hydrogen carbonate (10 mL of a saturated aqueous solution). The mixture was extracted with DCM (3 x 25 mL) and the combined

organic layers dried ($MgSO_4$), filtered and concentrated *in vacuo* to afford benzyl (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18A** (35 mg, 95 %) as a colourless oil; $[\alpha]_D^{21}$+23.9 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3420 (br, OH) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 0.10, 0.11 (6H, 2 x s, 2 x CH_3), 0.95 (9H, s, $C(CH_3)_3$), 3.53 (1H, d, *J* 10.6 Hz, H-6c), 3.66-3.73 (4H, m, H-5a), H-6b, H-6'b, H-6'c), 3.77-3.81 (2H, m, H-6a, H-6'a), 3.82-3.96 (5H, bm, H-3c, H-4a, H-4b, H-4c, H-5c), 3.99 (1H, at, *J* 2.6 Hz, H-2a), 4.02-4.05 (2H, m, H-3b, H-5b), 4.0 (1H, m, H-2b), 4.16 (1H, m, H-2c), 4.20 (1H, dd, $J_{2,3}$ 3.1 Hz, $J_{3,4}$ 9.1 Hz, H-3a), 4.37 (1H, d, *J* 12.4 Hz, CH), 4.47 (1H, d, *J* 12.0 Hz, CH), 4.51 (1H, d, *J* 10.9 Hz, CH), 4.55 (1H, d, *J* 11.8 Hz, CH), 4.58-4.63 (9H, m, 9 x CH), 4.66 (1H, d, *J* 8.7 Hz, CH), 4.71 (1H, d, *J* 11.7 Hz, CH), 4.80 (1H, d, *J* 11.8 Hz, CH), 4.83 (1H, d, *J* 10.9 Hz, CH), 4.90 (1H, d, *J* 11.1 Hz, CH), 4.94 (1H, d, $J_{1,2}$ 0.9 Hz, H-1a), 5.17 (1H, d, $J_{1,2}$ 1.1 Hz, H-1c), 5.30 (1H, s, H-1b), 7.20-7.35 (45H, m, 45 x Ar-H); δ_C (125 MHz, $CDCl_3$) -5.3 (q, 2 x CH_3), 18.4 (s, $\underline{C}(CH_3)_3$), 25.9 (q, $C(\underline{C}H_3)_3$), 62.6 (t, C-6a), 68.5 (t, C-6c), 68.6 (d, C-2c), 68.7 (t, CH_2), 69.5 (t, C-6b), 71.6 (d, C-5c), 71.9, 72.1, 72.2 (3 x t, 3 x CH_2), 72.6 (d, C-5b), 73.2 (t, CH_2), 73.3 (d, C-5a), 73.3 (t, CH_2), 74.2, 74.9, 75.2 (d, C-2b, C-4a, C-4b, C-4c), 74.7, 74.9 (2 x t, 2 x CH_2), 75.2 (d, C-2a), 78.0 (d, C-3b), 79.9 (d, C-3a, C-3c), 96.0 (d, C-1a), 101.0 (d, C-1b, C-1c), 126.0-129.0 (d, Ar-C), 137.4-138.7 (s, Ar-C); *m/z* (ESI^+) 1487 ($M+Na^+$, 100%), ($M+Na^+$) peaks measured: 1452.7 (100%), 1451.7 (95%), 1453.7 (53%), 1454.7 (13%), 1455.7 (2%), peaks calculated: 1452.7 (100%), 1451.7 (99%), 1453.7 (51%), 1454.7 (17%), 1455.7 (6%).

Benzyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 25A

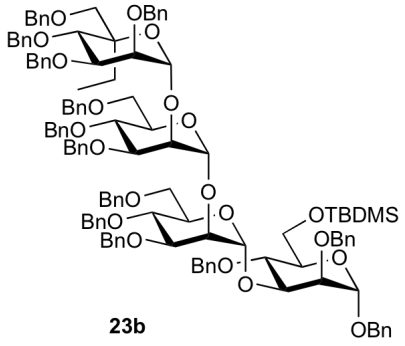


25

Benzyl 2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **5.3.13** (29 mg, 0.051 mmol), ethyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-thio-α-D-mannopyranoside **5.3.106** (60 mg, 0.043 mmol) and 2,6-di-*tert*-butyl-4-methylpyridine (76 mg, 0.30 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (1 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -78 ^{o}C. DCM (1 mL) was added to a flame dried flask containing 4Å molecular sieves and stirred for 1 h then cooled to 0 ^{o}C. To this flask was added dimethyldisulfide (23 μL, 0.26 mmol) and trifluoromethylsulfonic anhydride (44 μL, 0.26 mmol). After 2 min, the solution was transferred to the flask containing the flask containing the sugar reagents at -78 ^{o}C. The mixture was stirred at -78 ^{o}C under an atmosphere of argon. After 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.4) with complete consumption of the starting materials (R_f 0.1, 0.3). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite®. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→6:1, petrol:ethyl acetate) to afford benzyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **25A** (24 mg, 29%) as a colourless oil; $[\alpha]_D^{22}$+30.5 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1744 (s, C=O) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 0.10, 0.10 (6H, 2 x s, 2 x Me), 0.95 (9H, s, $C(CH_3)_3$), 2.19 (3H, s, OAc), 3.47 (1H, dd, $J_{5,6}$ 1.1 Hz, $J_{6,6'}$ 10.5 Hz, H-6d), 3.53 (1H, dd, $J_{5,6}$ 1.0 Hz, $J_{6,6'}$ 10.8 Hz, H-6c), 3.65-3.72 (5H, m, H-5a, H-6b, H-6'b, H-6'c, H-6'd), 3.77-3.78 (2H, m, H-6a, H-6'a), 3.83 (1H, at, *J* 9.6 Hz, H-4b), 3.88-3.94 (3H, m, H-4a, H-5c, H-5d), 3.94-4.04

(6H, m, H-2a, H-3b, H-5b, H-3c, H-4c, H-4d), 4.07 (1H, dd, $J_{2,3}$ 3.3 Hz, $J_{3,4}$ 9.4 Hz, H-3d), 4.10 (1H, at, *J* 2.2 Hz, H-2c), 4.18 (1H, at, *J* 2.2 Hz, H-2b), 4.21 (1H, dd, $J_{2,3}$ 3.1 Hz, $J_{3,4}$ 9.4 Hz, H-3a), 4.26-4.91 (24H, m, 12 x CH_2), 4.94 (1H, $J_{1,2}$ 1.5 Hz, H-1a), 5.16 (1H, d, $J_{1,2}$ 1.5 Hz, H-1d), 5.24 (1H, d, $J_{1,2}$ 1.6 Hz, H-1c), 5.31 (1H, d, $J_{1,2}$ 1.3 Hz, H-1b), 5.63 (1H, dd, H-2d), 7.14-7.43 (60H, m, 60 x Ar-H); δ_C (125 MHz, $CDCl_3$, assigned using HSQC) -5.0 (q, 2 x CH_3), 21.2 (q, OAc), 26.1 (q, C($\underline{C}H_3)_3$), 62.4 (t, C-6a), 68.3 (t, C-6d), 68.6 (t, C-6c), 69.5 (t, C-6b), 68.6, 71.9, 72.0, 73.0, 73.3, 74.7, 75.2 (t, 12 x CH_2), 71.8 (d, C-5c), 72.3 (d, C-5d), 72.5 (d, C-5b), 73.2 (d, C-5a), 74.0 (d, C-4c), 74.5 (d, C-4d), 74.6 (d, C-2b), 74.7 (d, C-4a), 74.8 (d, C-4b), 75.1 (d, C-2c), 77.9 (d, C-2a), 78.2 (d, C-3d), 79.4 (2 x d, C-3b, C-3c), 80.0 (d, C-3a), 95.9 (d, C-1a), 99.3 (d, C-1d), 100.4 (d, C-1c), 101.0 (d, C-1b), 128.0 (d, Ar-C); *m/z* (ESI^+) 1927 ($M+Na^+$, 100%), ($M+Na^+$) peaks measured: 1925.9 (69%), 1926.9 (100%), 1927.9 (63%), 1928.9 (24%), 1929.9 (8%), 1930.9 (2%), calculated peaks: 1925.9 (75%), 1926.9 (100%), 1927.9 (72%), 1928.9 (36%), 1929.9 (15%), 1930.9 (5%).

Benzyl (2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside 23b



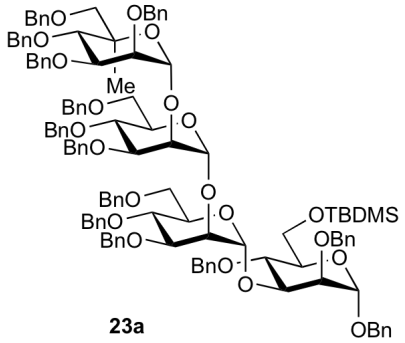
23b

Benzyl (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18** (59 mg, 0.041 mmol), phenyl 2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-1-thio-β-D-mannopyranoside **20b** (31 mg, 0.050 mmol) and 2,4,6-tri-*t*-butylpyrimidine (85 mg, 0.328 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (1 mL) and transferred using a cannula to a flame dried flask containing 4Å

molecular sieves. The mixture was stirred for 1 h and cooled to -78 ^{o}C. DCM (1 mL) was added to a flame dried flask containing 4Å molecular sieves and stirred for 1 h then cooled to 0 ^{o}C. To this flask was added dimethyldisulfide (28 μL, 0.31 mmol) and trifluoromethylsulfonic anhydride (54 μL, 0.31 mmol). After 2 min, the solution was transferred to the flask containing the sugar reagents at -78 ^{o}C. The mixture was stirred at -78 ^{o}C under an atmosphere of argon. After 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with complete consumption of the starting materials (R_f 0.1, 0.7). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite®. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→6:1, petrol:ethyl acetate) to afford benzyl (2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **23b** (16 mg, 20%) as a colourless oil; $[\alpha]_D^{17}$+12.3 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (500 MHz $CDCl_3$) 0.88, 0.93 (6H, 2 x s, 2 x Me), 0.82 (3H, t, *J* 7.3 Hz, $CH_2C\underline{H}_3$), 0.94 (9H, s, $C(CH_3)_3$), 1.73-2.00 (2H, m, $C\underline{H}_2CH_3$), 3.49-3.54 (2H, m, H-6c, H-6d), 3.62-3.67 (2H, m, H-5a, H-6'c), 3.69-3.78 (5H, m, H-6a, H-6'a, H-6b, H-6'b, H-6'd), 3.82-3.94 (6H, m, H-4a, H-3b, H-4b, H-4c, H-5c, H-2d), 3.99 (1H, dd, $J_{1,2}$ 1.9 Hz, $J_{2,3}$ 2.9 Hz, H-2a), 4.04-4.06 (2H, m, H-3c, H-5b), 4.07-4.10 (2H, m, H-2c, H-3d), 4.18 (1H, dd, $J_{3,4}$ 10.2 Hz, H-3a), 4.28 (1H, at, *J* 1.9 Hz, H-2b), 4.36-4.41 (3H, m, H-4d, CH_2), 4.44-4.92 (24H, m, 12 x CH_2), 4.93 (1H, d H-1a), 5.25 (1H, d, $J_{1,2}$ 1.2 Hz, H-1b), 5.36 (1H, d, $J_{1,2}$ 1.2 Hz, H-1c), 5.45 (1H, d, $J_{1,2}$ 3.5 Hz, H-1d), 7.16-7.40 (65H, m, 65 x Ar-H); δ_C (125 MHz, $CDCl_3$, assigned from HSQC) -5.3 (q, Me), 7.5 (q, $CH_2\underline{C}H_3$), 24.8 (t, $\underline{C}H_2CH_3$), 25.4 (q, $C(\underline{C}H_3)_3$), 62.5 (t, C-6a), 68.8 (t, C-6c), 69.5 (t, C-6b), 71.7 (t, C-6d), 68.4, 72.0, 73.0, 73.3, 74.6, 74.9 (t, CH_2), 72.3 (d, C-5c), 72.5 (d, C-5b), 73.2 (d, C-5a), 74.4 (d, C-4c), 74.7 (d, C-2b), 74.8 (d, C-2c), 75.0 (2 x d, C-4a, C-4b), 75.8 (d, C-2d), 76.0 (d, C-4d), 76.4 (d, C-3d), 77.9 (d, C-2a), 78.8 (d, C-3c), 80.4 (d, C-3a), 80.5 (d, C-3b), 95.7 (d, C-1a), 96.6 (d, C-1d), 100.6 (d, C-1b), 101.1 (d, C-1c), 127.3 (d, Ar-C); *m/z* (ESI^+) 2003 ($M+Na^+$, 100%); ($M+Na^+$) measured peaks: 2001.9 (56%), 2002.9 (100%), 2003.9 (65%), 2004.9 (25%), 2005.9 (7%), 2006.9 (2%), 2007.9 (1%), calculated peaks: 2001.9

(71%), 2002.9 (100%), 2003.9 (75%), 2004.9 (40%), 2005.9 (16%), 2006.9 (6%), 2007.9 (2%).

Benzyl (2,3,4,6-tetra-*O*-benzyl-5-*C*-methyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside 23a

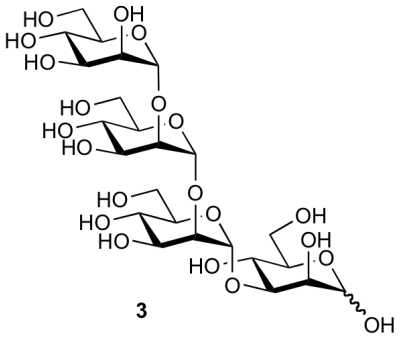


23a

Benzyl (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18** (102 mg, 0.071 mmol), phenyl 2,3,4,6-tetra-*O*-acetyl-5-*C*-methyl-1-thio-D-mannopyranoside **20a** (55 mg, 0.086 mmol) and 2,4,6-tri-*t*-butylpyrimidine (92 mg, 0.36 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (1 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -20 ^{o}C. Dimethylthiosulfonium triflate (710 μL of a 0.4 M solution in DCM was added to the reaction mixuture. After 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with complete consumption of the starting materials (R_f 0.1, 0.7). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite®. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→6:1, petrol:ethyl acetate) to afford benzyl (2,3,4,6-tetra-*O*-benzyl-5-*C*-methyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **23a** (25 mg, 18%) as a colourless oil; $[\alpha]_D^{25}$+21 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (500 MHz, $CDCl_3$) 0.09, 0.09 (6H, 2 x s, 2 x Me), 0.94 (9H, s, $C(CH_3)_3$), 1.30 (3H, s Me),

3.40, 3.48 (2H, ABq, *J* 10.5 Hz, H-6d, H-6'd), 3.51-3.53 (1H, d, H-6c), 3.63-3.72 (4H, m, H-5a, H-6b, H-6'b, H-6'c), 3.77-3.78 (2H, m, H-6a, H-6'a), 3.85-3.94 (6H, m, H-4a, H-3b, H-4b, H-2c, H-4c, H-5c, H-2d), 3.98 (1H, dd, $J_{1,2}$ 2.0 Hz, $J_{2,3}$ 2.9 Hz, H-2a), 4.01-4.06 (3H, m, H-5b, H-2c, H-3c), 4.10 (1H, dd, $J_{2,3}$ 2.8 Hz, $J_{3,4}$ 9.9 Hz, H-3d), 4.18 (1H, d, $J_{3,4}$ 9.4 Hz, H-3a), 4.30 (1H, bs, H-2b), 4.37-4.93 (2H, m, H-4d, CH), 4.45-4.95 (25H, m, 12 x CH_2, CH), 4.93 (1H, d, H-1a), 5.28 (1H, d, $J_{1,2}$ 1.4 Hz, H-1b), 5.29 (1H, s, H-1c), 5.44 (1H, d, $J_{1,2}$ 2.0 Hz, H-1d), 7.14-7.34 (65H, m, 65 x Ar-H); δ_C (125 MHz, $CDCl_3$, assigned using HSQC) -5.3 (q, Me), 25.4 (q, $C(\underline{C}H_3)_3$), 30.0 (q, Me), 62.3 (t, C-6a), 68.4 (C-6c), 68.8, 73.0, 73.6, 74.6 (t, CH_2), 69.1 (t, C-6b), 72.3 (2 x d, C-5b, C-5c), 73.0 (d, C-5a), 74.6 (4 x d, C-4a, C-4b, C-4c, C-2b), 74.9 (d, C-2c), 75.2 (d, C-4d), 75.2 (t, C-6d), 75.6 (d, C-2d), 76.2 (d, C-3d), 77.8 (d, C-2a), 79.1 (d, C-3c), 79.8 (d. C-3a), 80.1 (d, C-3b), 95.6 (d, C-1a), 99.8 (d, C-1d), 100.1 (d, C-1b), 101.1 (d, C-1c), 127.6 (d, Ar-C); *m/z* (ESI^+) 1989 ($M+Na^+$, 100%); ($M+Na^+$) peaks measured: 1987.9 (62%), 1988.9 (100%), 1989.9 (68%), 1990.9 (27%), 1991.9 (9%), peaks calculated: 1987.9 (72%), 1988.9 (100%), 1989.9 (75%), 1990.9 (39%), 1991.9 (16%).

α-D-Mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose 3

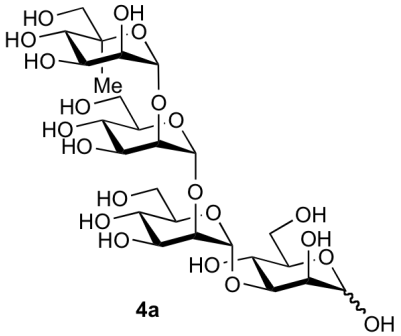


3

Sodium methoxide (1 mL of a 0.1 M solution in methanol) was added to a solution of benzyl 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **25A** (24 mg, 0.013 mmol) in methanol (1 mL). After 18 h the reaction mixture was neutralized with acidified

DOWEX, filtered and concentrated *in vacuo*. The residue was suspended in acetic acid (80% in water) and heated at 50°C. After 24 h, t.l.c (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and passed through a silica plug to afford α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose **3** (5 mg, 60% over 3 steps) as an amorphous white solid; Partial assignment: δ_H (500 MHz, D_2O) 3.54-4.03 (24H, m), 4.82 (1H, s, H-1aβ), 4.97 (1H, d, $J_{1,2}$ 1.2 Hz, H-1), 5.07 (1H, d, $J_{1,2}$ 1.6 Hz, H-1), 5.22 (1H, s, H-1aα), 5.29 (1H, s, H-1); δ_C (125 MHz, D_2O) 60.8, 60.9, 61.0 (3 x t, C-6a, C-6b, C-6c, C-d), 66.0, 66.2, 66.7, 66.8, 66.9, 69.9, 70.0, 70.3, 70.9, 75.9, 78.0, 78.5, 78.6, 80.4 (14 x d, C-2a,b,c,d, C-3a,b,c,d, C-4a,b,c,d, C-5a,b,c,d), 93.5, 94.0, 100.5, 100.6, 102.2 (5 x d, C-1aα,aβ,b,c,d); *m/z* (ESI^+) 689 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_{24}H_{42}O_{21}Na$ ($M+Na^+$) 689.2116. Found 689.2111.

5-*C*-Methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose 4a

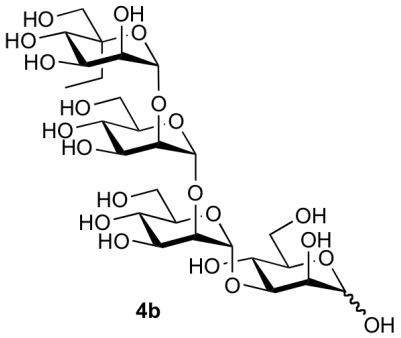


4a

Benzyl (2,3,4,6-tetra-*O*-benzyl-5-*C*-methyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **23a** (25 mg, 0.013 mmol) was suspended in acetic acid (80% in water) and heated at 50°C. After 24 h, t.l.c (3:1,

petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and passed through a silica plug to afford **5**-*C*-methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose **4a** (6 mg, 70% over 2 steps) as an amorphous white solid; Partial assignment: δ_C (500 MHz, D_2O) 1.22 (3H, s, Me), 3.30 (1H, ddd, *J* 2.0 Hz, *J* 6.2 Hz, *J* 8.8 Hz, H-5), 3.44, 3.54 (2H, ABq, *J* 12.0 Hz, H-6d, H-6'd), 3.59-4.08 (20 H, m), 4,82 (1H, s, H-1aβ), 5.06 (1H, d, $J_{1,2}$ 1.9 Hz, H-1), 5.07 (1H, $J_{1,2}$ 1.5 Hz, H-1aα), 5.22 (1H, s, H-1), 5.27 (1H, s, H-1); δ_C (125 MHz, D_2O) 18.3 (q, Me) 60.8 (t, C-6a,b,c), 66.5 (t, C-6d), 66.0, 66.3, 66.8, 67.1, 67.6, 70.1, 70.3, 70.5, 70.9, 72.5, 73.3, 75.9, 77.9, 78.1, 78.2 (16 x d, C-2a,b,c,d, C-3a,b,c,d, 4a,b,c,d, 5a,b,c), 80.4 (s, C-5d), 93.5, 94.0, 100.5, 100.7, 102.9 (5 x d, C-1aα, aβ, b, c, d); *m/z* (ESI^+) 703 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_{25}H_{44}O_{21}Na$ ($M+Na^+$) 703.2267. Found 703.2265.

5-*C*-Ethyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)- D-mannopyranose 4b

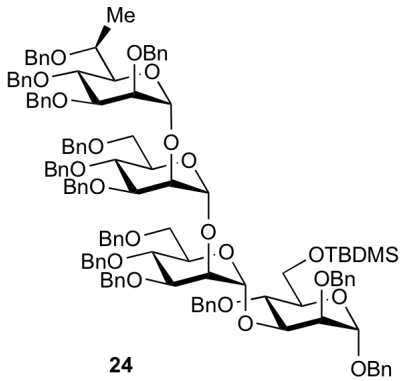


4b

Benzyl (2,3,4,6-tetra-*O*-benzyl-5-*C*-ethyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **23b** (16 mg, 0.008 mmol) was suspended in acetic acid (80% in water) and heated at 50°C. After 24 h, t.l.c (3:1,

petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and passed through a silica plug to afford 5-*C*-ethyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose **4b** (4 mg, 78% over 2 steps) as a white amorphous solid; Partial assignment: δ_H (500 MHz, D_2O) 0.84 (3H, t, *J* 7.5 Hz, CH_3), 1.57-1.76 (2H, m, CH_2), 3.34 (1H, ddd, *J* 2.5 Hx, *J* 6.5 Hz, *J* 9.5 Hz, H-5), 3.53 (1H, d, *J* 11.5 Hz, H-6d), 3.60-4.09 (H, m), 4.83 (1H, s, H-1aβ), 5.04 (1H, d, $J_{1,2}$ 5.5 Hz, H-1), 5.09 (1H, d, $J_{1,2}$ 1.5 Hz, H-1aα), 5.23 (1H, s, H-1), 5.30 (1H, s, H-1); *m/z* (ESI^+) 717 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_{26}H_{46}O_{21}Na$ ($M+Na^+$) 717.2424. Found 717.2424.

Benzyl-(2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside 24A



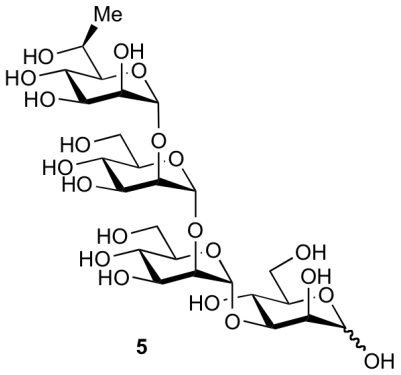
24

Benzyl (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18A** (95 mg, 0.067 mmol), phenyl 2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside **21** (52 mg, 0.080 mmol) and 2,4,6-tri-*t*-butylpyrimidine (87 mg, 0.34 mmol) were dried in a dessicator overnight. The reagents

were dissolved in DCM (1 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -78 ^{o}C. Dimethylthiosulfonium triflate (69 mg, 0.27 mmoL) was added to the reaction mixuture and after 30 min the reaction mixture was allowed to warm to room temperature. After a further 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with complete consumption of the starting materials (R_f 0.1, 0.7). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite®. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→6:1, petrol:ethyl acetate) to afford benzyl-(2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **24A** (65 mg, 55%) as a colourless oil; $[\alpha]_D^{25}$+15 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (700 MHz, $CDCl_3$) 0.04, 0.05 (6H, 2 x s, 2 x Me), 0.90 (9H, s, $CH(CH_3)_3$), 1.13 (3H, d, *J* 6.5 Hz, 6-Me), 3.47 (2H, at, *J* 10.8 Hz, H-6c, H-5d), 3.60-3.74 (6H, m, H-6a, H-6'a, H-6b, H-6'b, H-6c, H-5a), 3.78-3.87 (6H, m, H-2d, H-4a, H-4b, H-4c, H-5c, H-6d), 3.90 (1H, dd, $J_{2,3}$ 2.9 Hz, $J_{3,4}$ 9.4 Hz, H-3d), 3.93 (1H, dd, $J_{2,3}$ 2.5 Hz, $J_{3,4}$ 9.2 Hz, H-3b), 3.96 (1H, dd, $J_{1,2}$ 1.9 Hz, $J_{2,3}$ 2.5 Hz, H-2a), 3.98-4.00 (1H, m, H-5b), 4.00 (1H, d, $J_{2,3}$ 2.5 Hz, $J_{3,4}$ 9.3 Hz, H-3c), 4.14 (1H, at, *J* 2.2 Hz, H-2c), 4.16 (1H, dd, $J_{2,3}$ 3.0 Hz, $J_{3,4}$ 9.5 Hz, H-3a), 4.17-4.20), 2H, m, H-2b, H-4d), 4.31 (2H, d, *J* 12.2 Hz, 2 x CH), 4.35 (1H, d, *J* 11.5 Hz, CH), 4.36-4.67 (20H, m, 20 x CH), 4.77 (1H, d, *J* 11.8 Hz, CH), 4.83 (1H, d, *J* 11.0 Hz, CH), 4.90 (1H, d, $J_{1,2}$ 1.3 Hz, H-1a), 4.92 (1H, d, *J* 11.1 Hz, CH), 5.23 (1H, d, $J_{1,2}$ 1.5 Hz, H-1b), 5.26 (1H, s, H-1c), 5.40 (1H, s, H-1d), 7.13-7.35 (65H, m, 65 x Ar-H); δ_C (175 MHz, $CDCl_3$) 1.0 (q, Me), 15.2 (q, 6-Me), 25.9 (q, $C(CH_3)_3$), 62.4 (t, H-6a), 68.5 (t, CH_2), 68.8 (t, C-6c), 69.2 (t, C-6b), 70.3 (t, CH_2), 71.2 (d, C-6d), 71.5, 71.6, 72.0 (3 x t, CH_2), 72.4 (d, C-5c), 72.6 (d, C-5b), 72.7 (t, CH_2), 73.0 (t, CH_2), 73.1 (d, C-5a), 73.1 (d, C-2c), 73.4 (d, C-2b), 73.9 (d, C-2d), 74.6 (d, C-4d), 74.6 (d, C-4a, C-4b, C-4c), 74.8, 74.8, 74.9 (t, CH_2), 74.9 (d, C-5d), 77.8 (d, C-2a), 79.4 (d, C-3c), 79.9 (d, C-3b), 80.0 (d, C-3d), 80.2 (d, C-3a), 95.7 (d, C-1a), 98.4 (d, C-1d), 99.9 (d, C-1b), 101.0 (d, C-1c); *m/z* (ESI^+) 1988 ($M+Na^+$, 100%); ($M+Na^+$) peaks measured: 1987.9 (67%), 1988.9 (100%), 1989.9

(69%), 1990.9 (35%), 1991.9 (14%), 1992.9 (5%) calculated peaks: 1987.9 (72%), 1988.9 (100%), 1989.9 (75%), 1990.9 (39%), 1991.9 (15%), 1992.9 (5%).

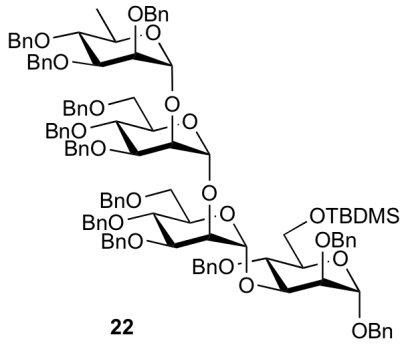
6-*C*-Methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose 5



Benzyl-(2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **24A** (96 mg, 0.049 mmol) was suspended in acetic acid (80% in water) and heated at 50°C. After 48 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.1) with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and passed through a silica plug to afford 6-*C*-methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose **5** (30 mg, 90% over 2 steps) as an amorphous white solid; δ_H (500 MHz, D_2O) 1.23 (3H, d, J 6.7 Hz, CH_3), 3.41-4.11 (23H, m, 23 x CH), 4.61 (1H, s, H-1aβ), 5.01 (1H, s, H-1), 5.06 (1H, s, H-1aα), 5.15 (1H, s, H-1), 5.27 (1H, s, H-1); δ_C (125 MHz, D_2O) 19.0 (q, Me), 60.8, 60.9 (t, C-6a, C-6b, C-6c), 64.7 (d, C-6d), 65.9, 66.2, 66.7, 66.9, 67.0, 69.9, 70.0, 70.1, 70.4, 70.5, 72.5, 73.0, 74.9, 75.9, 77.9, 78.1, 78.8, 80.6 (d, C-2a, C-3a, C-4a, C-5a, C-2b, C-3b, C-4b, C-5b, C-2c, C-3c, C-4c, C-5c, C-2d, C-3d, C-4d, C-5d), 93.5 (d, C-1aβ), 94.0 (d, C-1aα), 100.7 (d, C-1),

100.8(d, C-1), 102.1 (d, C-1); *m/z* (ESI^+) 679 ($M+H^+$, 100%); HRMS (ESI^+) calcd. for $C_{25}H_{43}O_{21}$ ($M+H^+$) 679.2302. Found 679.2302.

Benzyl-(2,3,4-tri-*O*-benzyl-α-D-rhamnopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside 22

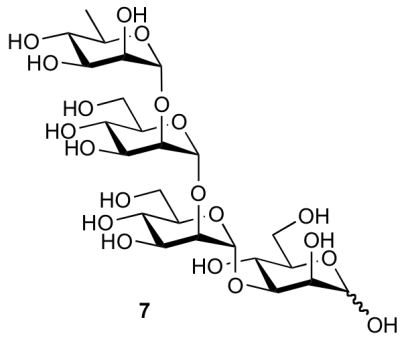


22

Benzyl (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18A** (62 mg, 0.043 mmol), phenyl 2,3,4-tri-*O*-benzyl-thio-α-D-rhamnopyranoside **19** (27 mg, 0.052 mmol) and 2,4,6-tri-*t*-butylpyrimidine (56 mg, 0.22 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (1 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -78 ^oC. Dimethylthiosulfonium triflate (44 mg, 0.17 mmoL) was added to the reaction mixuture and after 30 min the reaction mixture was allowed to warm to room temperature. After a further 1 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with complete consumption of the starting materials (R_f 0.1, 0.7). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite®. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→6:1, petrol:ethyl acetate) to afford benzyl-(2,3,4-tri-*O*-benzyl-α-D-rhamnopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **22** (39 mg, 49%) as a colourless oil; $[\alpha]_D^{25}$ +19 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) no significant peaks; δ_H (700 MHz, $CDCl_3$) 0.06, 0.07 (6H, 2 x s, 2 x Me), 0.91 (9H, s, $C(CH_3)_3$), 1.25 (3H, d, *J* 6.3 Hz,

CH_3), 3.50 (1H, d, *J* 9.9 Hz, H-6c), 3.60-3.63 (2H, m, H-5a, H-4d), 3.66-3.69 (2H, m, H-6'c, H-6b), 3.70-3.77 (3H, m, H-6'b, H-6a, H-6'a), 3.81-3.86 (5H, m, H-2d, H-4a, H-4b, H-4c, H-5d), 3.87-3.90 (3H, m, H-5c, H-3b, H-3d), 3.95 (1H, dd, $J_{1,2}$ 1.9 Hz, $J_{2,3}$ 2.9 Hz, H-2a), 3.98-4.01 (3H, m, H-2c, H-3c, H-5b), 4.15 (1H, dd, $J_{2,3}$ 2.9 Hz, $J_{3,4}$ 9.5 Hz, H-3a), 4.20 (1H, bs, H-2b), 4.34 (1H, d, *J* 12.4 Hz, CH), 4.42-4.67 (17H, m, 17 x CH), 4.74 (1H, d, *J* 11.4 Hz, CH), 4.82 (1H, d, *J* 10.9 Hz, CH), 4.89 (1H, d, *J* 11.5 Hz, CH), 4.90 (1H, s, H-1a), 4.97 (1H, d, *J* 10.9 Hz, CH), 5.15 (1H, d, $J_{1,2}$ 1.3 Hz, H-1b), 5.19 (1H, d, $J_{1,2}$ 1.2 Hz, H-1d), 5.28 (1H, s, H-1c), 7.14-7.34 (60H, m, 60 x Ar-H); δ_C (175 MHz, $CDCl_3$) 1.0 (q, Me), 18.0 (q, Rham Me), 25.6 (q, $C(CH_3)_3$), 62.2 (t, C-6a), 68.3 (d, C-2d), 68.6 (t, CH_2), 68.7 (t, C-6c), 69.4 (t, C-6b), 71.7, 71.9, 72.2 (3 x t, CH_2), 72.2 (d, C-5c), 72.5 (d, C-5b), 72.9, 73.1 (2 x t, CH_2), 73.2 (d, C-5a), 73.8 (d, C-2b), 74.7 (t, CH_2), 74.7 (d, C-4a, C-4b, C-4c, C-5d), 74.9, 75.2 (t, CH_2), 75.1 (d, C-2c), 78.0 (d, C-2a), 79.1 (d, C-3c), 79.5 (d, C-3d), 79.8 (d, C-3b), 80.4 (d, C-3a), 80.6 (d, C-4d), 95.9 (d, C-1a), 98.9 (d, C-1d), 100.8 (d, C-1b), 101.3 (d, C-1c); *m/z* (ESI^+) 1868 ($M+Na^+$, 100%); ($M+Na^+$) peaks measured: 1867.9 (75%), 1868.9 (100%), 1869.9 (81%), 1870.9 (61%), 1871.9 (25%), 1872.9 (7%), 1873.9 (5%); calculated peaks: 1867.9 (74%), 1868.9 (100%), 1869.9 (68%), 1870.9 (61%), 1871.9 (23%), 1872.9 (10%), 1873.9 (5%).

α-D-Rhamnopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose 7

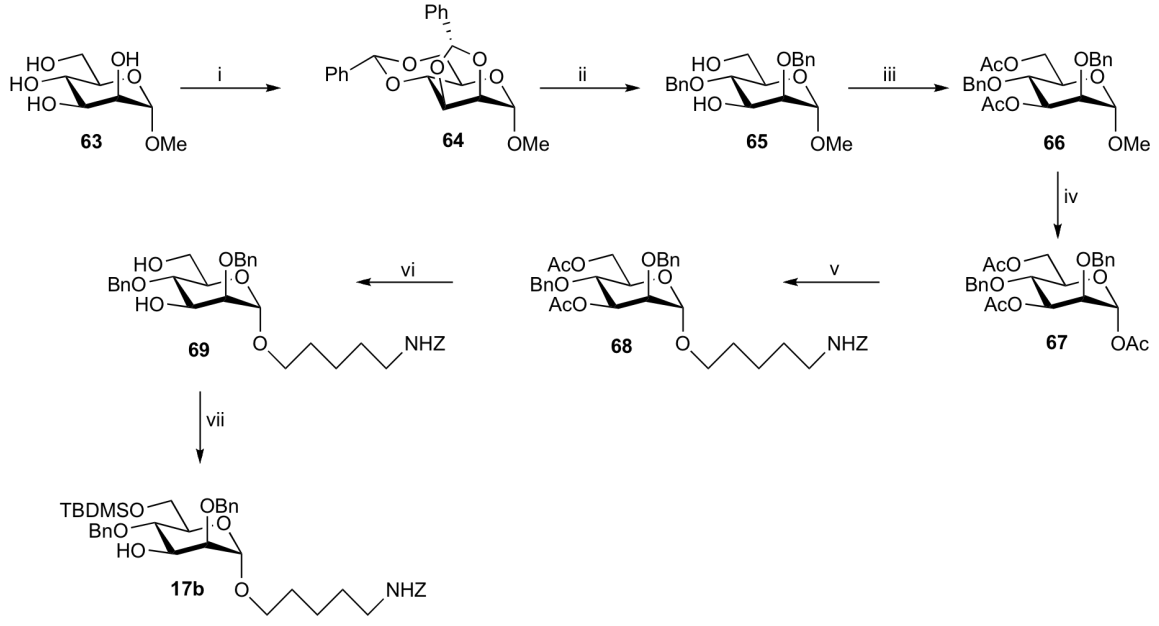


7

Benzyl-(2,3,4-tri-*O*-benzyl-α-D-rhamnopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **22** (110 mg, 0.060 mmol) was suspended in acetic acid (80% in water) and heated at 50°C. After 48 h, t.l.c (4:1,

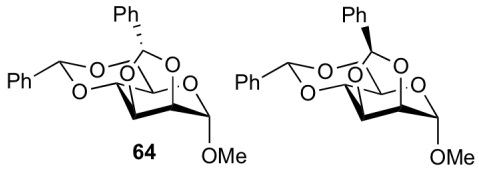
petrol:ethyl acetate) indicated formation of a product (R_f 0.1) with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and passed through a silica plug to afford α-D-rhamnopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-D-mannopyranose **7** (mg, % over 2 steps) as an amorphous white solid; δ_H (500 MHz, D_2O) 1.09 (3H, d, *J* 6.0 Hz, CH_3-β), 1.19 (3H, d, *J* 6.3 Hz, CH_3-α), 3.36 (1H, at, *J* 9.7 Hz, CH), 3.61-4.03 (21H, m, 21 x CH), 4.82 (1H, s, H-1aβ), 4.89 (1H, s, H-1), 5.07 (1H, s, H-1aα), 5.12 (1H, s, H-1), 5.25 (1H, s, H-1); δ_C (125 MHz, D_2O) 16.5 (q, Me), 60.8, 60.9 (2 x t, C-6a, C-6b, C-6c), 66.1, 66.3, 66.7, 66.9, 69.0, 70.0, 70.2, 70.4, 70.9, 72.0, 72.5, 73.3, 75.9, 77.9, 78.1, 78.2, 80.4 (d, C-2a, C-3a, C-4a, C-5a, C-2b, C-3b, C-4b, C-5b, C-2c, C-3c, C-4c, C-5c, C-2d, C-3d, C-4d, C-5d), 93.5 (d, C-1aβ), 93.9 (d, C-1aα), 100.6, 100.8, 102.1 (d, C-1b, C-1c, C-1d); *m/z* (ESI^+) 649 ($M+H^+$, 100%); HRMS (ESI^+) calcd. for $C_{24}H_{41}O_{20}$ ($M+H^+$) 649.2197. Found 649.2199.

1.6 Tetrasaccharide synthesis with linker:



Scheme S13: i) Dimethylacetyl, *p*TsOH, DMF, 75°C, 86%, ii) BH_3.THF, Bu_2BOTf, THF, 0°C, iii) Ac_2O, Pyrindine, 100%, iv) c.H_2SO_4, AcOH, Ac_2O, 0°C, 99%, v) BF_3OEt_2, DCM, Linker, 86%, vi) NaOMe, MeOH, 100%, vii) TBDMSCl, Imidazole, DMF, 0°C, 90%.

Methyl (R),(R)-2,3:4,6-di-*O*-benzylidene-α-D-mannopyranoside and Benzyl (S),(R)-2,3:4,6-di-*O*-benzylidene-α-D-mannopyranoside 64

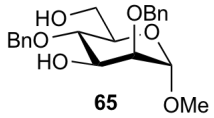


Dimethoxybenzaldehyde (34 mL, 222 mmol) was added to a solution of methyl-α-D-mannopyranoside **63** (20 g, 103 mmol) and *para*-toluenesulfonic acid (703 mg, 3.70 mmol) in anhydrous DMF (100 mL) (17). The reaction mixture was heated to 75 °C on a rotary evaporator at 200 mbar. After 4 h, t.l.c (4:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.9) with consumption of the starting material (R_f 0). The reaction mixture was concentrated *in vacuo* and residue co-evaporated with toluene. The residue was dissolved in DCM (300 mL) and washed with sodium hydrogen carbonate and brine (200 mL each of a saturated aqueous solution). The organic phase was dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was recrystallised (ethyl acetate/methanol) to afford the exo anomer benzyl (S),(R)-2,3:4,6-di-*O*-benzylidene-α-D-mannopyranoside (14 g, 37%) as a white crystalline solid. The mother liquor was purified by flash column chromatography (9:1, petrol:ethyl acetate) and recrystallisation (ethanol) to afford the endo anomer benzyl (R),(R)-2,3:4,6-di-*O*-benzylidene-α-D-mannopyranoside **64** (18.6 g, 48%) as a white crystalline solid.

Exo: $[\alpha]_D^{23}$ -0.5 (*c*, 1.0 in $CHCl_3$), [Lit. $[\alpha]_D$ -1.9 (*c*, 0.76 in $CHCl_3$)](17); δ_H (400 MHz, $CDCl_3$) 3.42 (3H, s, OMe), 3.84-3.94 (3H, m, H-4, H-5, H-6), 4.17 (1H, d, $J_{2,3}$ 5.5 Hz, H-2), 4.38 (1H, d, *J* 5.3 Hz, H-6'), 4.65 (1H, dd, $J_{3,4}$ 7.9 Hz, H-3), 5.03 (1H, s, H-1), 5.66 (1H, s, CHPh), 6.31 (1H, s, CHPh), 7.35-7.56 (10H, m, 10 x Ar-H).

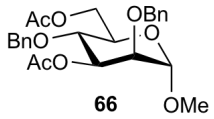
Endo: $[\alpha]_D^{23}$ +0.5 (*c*, 2.0 in $CHCl_3$), [Lit. $[\alpha]_D$ +0.3 (*c*, 0.68 in $CHCl_3$)](17); δ_H (400 MHz, $CDCl_3$) 3.44 (3H, m, H-4, H-5, H-6), 4.31 (1H, d, $J_{2,3}$ 6.3 Hz, H-2), 4.33 (1H, dd, $J_{5,6'}$ 4.2 Hz, $J_{6,6'}$ 9.8 Hz, H-6'), 4.49 (1H, at, *J* 6.5 Hz, H-3), 5.10 (1H, s, H-1), 5.55 (1H, s, CHPh), 5.99 (1H, s, CHPh), 7.33-7.58 (10H, m, 10 x Ar-H).

Methyl 2,4-di-*O*-benzyl-α-D-mannopyranoside 65



(R),(R)-2,3:4,6-Di-*O*-benzylidene-α-D-mannopyranoside **64** (5 g, 13.4 mmol) was dissolved in anhydrous THF (50 mL) and cooled to 0 ºC. Borane.THF complex (77 mL of a 1 M solution in THF) was added to the reaction mixture (18). After 5 min, Bu_2BOTf (10.6 mL of a 1 M solution in DCM) was added slowly to the reaction mixture. After 4 h, t.l.c. (4:1, petrol:ethyl acetate) indicated formation of a product (R_f 0) with consumption of the starting material (R_f 0.8). Triethylamine (2 mL) was added to the reaction mixture followed by slow addition of methanol (10 mL) at 0 ºC. When no more hydrogen was produced the reaction mixture was concentrated *in vacuo* and the residue purified by flash column chromatography (4:1→1:1, petrol:ethyl acetate) to afford methyl 2,4-di-*O*-benzyl-α-D-mannopyranoside **65** (4.5 g, 89%) as a colourless oil; $[\alpha]_D^{23}$ +22.1 (*c*, 2.0 in $CHCl_3$), [Lit. $[\alpha]_D^{23}$ +23.5 (*c*, 0.77 in $CHCl_3$)] (19); ν_{max} (thin film) 3420 (OH, br) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 3.34 (3H, s, OMe), 3.61 (1H, ddd, $J_{5,6'}$ 3.0 Hz, $J_{5,6}$ 4.3 Hz, $J_{4,5}$ 9.6 Hz, H-5), 3.70 (1H, at, *J* 9.4 Hz, H-4), 3.75 (1H, dd, $J_{1,2}$ 1.5 Hz, $J_{2,3}$ 3.7 Hz, H-2), 3.80 (1H, dd, $J_{6,6'}$ 11.9 Hz, H-6), 3.88 (1H, dd, H-6'), 4.01 (1H, dd, $J_{3,4}$ 9.0 Hz, H-3), 4.63 (1H, d, *J* 11.9 Hz, C<u>H</u>H'a), 4.68 (1H, d, *J* 11.1 Hz, C<u>H</u>H'b), 4.74 (1H, d, CH<u>H</u>'a), 4.77 (1H, d, H-1), 4.92 (1H, d, CH<u>H</u>'b), 7.28-7.42 (10H, m, 10 x Ar-H); δ_C (100 MHz, $CDCl_3$) 54.9 (q, OMe), 62.3 (t, C-6), 71.2 (d, C-5), 71.7 (d, C-3), 73.1, 74.9 (t, 2 x CH_2), 76.4 (d, C-4), 78.4 (d, C-2), 98.2 (d, C-1), 127.8-128.6 (d, Ar-C), 137.8, 138.4 (2 x s, 2 x Ar-C); *m/z* (ESI$^+$) 392 (M+NH_4^+, 100%); HRMS (ESI$^+$) calcd. for $C_{21}H_{26}NO_6Na$ (M+Na^+) 397.1619. Found 397.1622.

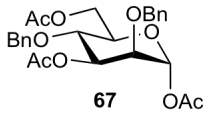
Methyl 2,4-di-*O*-benzyl-3,6-di-*O*-acetyl-α-D-mannopyranoside 66



Methyl 2,4-di-*O*-benzyl-α-D-mannopyranoside **65** (4.5 g, 12.0 mmol) was stirred in acetic anhydride (50 mL) and pyridine (50 mL). After 20 h, t.l.c. (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with consumption of the starting

material (R_f 0.1). The reaction mixture was concentrated *in vacuo* and co-evaporated with toluene. The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate) to afford methyl 2,4-di-*O*-benzyl-3,6-di-*O*-acetyl-α-D-mannopyranoside **66** (5.5 g, 100%) as a colourless oil; $[\alpha]_D^{23}$ +4.1 (*c*, 2.0 in $CHCl_3$), [Lit. $[\alpha]_D$ +12.6 (*c*, 1.36)] (20); ν_{max} (thin film) 1740 (C=O, s) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.99, 2.09 (6H, 2 x s, 2 x OAc), 3.37 (3H, s, OMe), 3.84-3.89 (2H, m, H-2, H-5), 3.95 (1H, at, *J* 9.3 Hz, H-4), 4.31 (1H, dd, $J_{5,6}$ 4.8 Hz, $J_{6,6'}$ 11.9 Hz, H-6), 4.37 (1H, dd, $J_{5,6'}$ 2.2 Hz, H-6'), 4.58 (1H, d, *J* 12.1 Hz, C<u>H</u>H'a), 4.60 (1H, d, *J* 11.1 Hz, C<u>H</u>H'b), 4.68 (1H, d, CH<u>H</u>'b), 4.72 (1H, d, CH<u>H</u>'a), 4.75 (1H, d, $J_{1,2}$ 1.7 Hz, H-1), 5.24 (1H, dd, $J_{2,3}$ 3.3 Hz, $J_{3,4}$ 9.4 Hz, H-3), 7.27-7.37 (10H, m, 10 x Ar-H).

2,4-*O*-Benzyl-1,3,6-tri-*O*-acetyl-α-D-mannopyranose 67

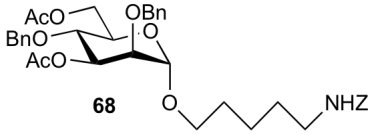


67

Sulfuric acid (1 mL of a concentrated solution) was added to methyl 2,4-di-*O*-benzyl-3,6-di-*O*-acetyl-α-D-mannopyranoside **66** (4.95 g, 10.8 mmol) in acetic anhydride (60 mL) and acetic acid (30 mL) at -10 ºC. After 2 h, sodium acetate (6 g) was added to the reaction mixture which was then concentrated *in vacuo*. The residue was dissolved in ethyl acetate (100 mL) and washed with water (200 mL). The aqueous phase was re-extracted with ethyl acetate (3 x 50 mL) and the combined organic phases were washed with sodium hydrogen carbonate (100 mL of a saturated aqueous solution), dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate) to afford 2,4-*O*-benzyl-1,3,6-tri-*O*-acetyl-α-D-mannopyranose **67** (5.18 g, 99%) as a colourless oil; $[\alpha]_D^{23}$ +10.7 (*c*, 2.0 in $CHCl_3$) [Lit. $[\alpha]_D$ +31.1 (*c*, 0.09)] (20); ν_{max} (thin film) 1742 (C=O, s) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.99, 2.07, 2.10 (9H, 3 x s, 3 x OAc), 3.88 (1H, dd, $J_{1,2}$ 2.0 Hz, $J_{2,3}$ 3.3 Hz, H-2), 3.97 (1H, dd, $J_{5,6'}$ 2.3 Hz, $J_{5,6}$ 4.1 Hz, $J_{4,5}$ 9.9 Hz, H-5), 4.03 (1H, at, *J* 9.3 Hz, H-4), 4.30 (1H, dd, $J_{6,6'}$ 11.6 Hz, H-6), 4.35 (1H, dd, H-6'), 4.57 (1H, d, *J* 12.1 Hz, C<u>H</u>H'a), 4.61 (1H, d, *J* 11.1 Hz, C<u>H</u>H'b), 4.73 (1H, d, CH<u>H</u>'b), 4.74 (1H, d, CH<u>H</u>'a), 5.23 (1H, dd, $J_{3,4}$ 9.4 Hz, H-3),

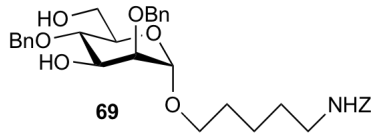
6.19 (1H, d, H-1), 7.28-7.37 (10H, m, 10 x Ar-H); *m/z* (ESI$^+$) 504 (M+NH_4^+, 100%); HRMS (ESI$^+$) calcd. for $C_{26}H_{30}NO_9Na$ (M+Na^+) 509.1780. Found 509.1782.

5-(Benzyloxycarbonylamino)pentyl-3,6-di-*O*-acetyl-2,4-di-*O*-benzyl-α-D-mannopyranoside 68



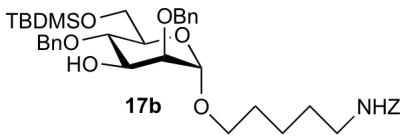
Boron trifluorodiethyletherate (1.45 mL of a 1 M solution in DCM) was added to a solution of 2,4-*O*-benzyl-1,3,6-tri-*O*-acetyl-α-D-mannopyranose **67** (2.2 g, 4.6 mmol) and 5-(Z-amino)-1-pentanol (2.2 g, 9.2 mmol) in anhydrous DCM (25 mL) at 0 ºC. The reaction mixture was allowed to warm to room temperature. After 8 h, t.l.c (2:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.2) with consumption of the starting material (R_f 0.3). Triethylamine (2 mL) was added to the reaction mixture which was then concentrated *in vacuo*. The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate) to afford 5-(benzyloxycarbonylamino)pentyl-3,6-di-*O*-acetyl-2,4-di-*O*-benzyl-α-D-mannopyranoside **68** (2.6 g, 86%) as a colourless oil; $[\alpha]_D^{23}$ +12.4 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) 1740 (C=O, s) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.34-1.40 (2H, m, CH_2-3), 1.49-1.54 (2H, m, CH_2-2), 1.54-1.62 (2H, m, CH_2-4), 2.00, 2.08 (6H, 2 x s, 2 x OAc), 3.17-3.22 (2H, m, CH_2-1), 3.36-3.42 (1H, m, CH_2-5), 3.64-3.70 (1H, m, CH_2-5'), 3.85-3.89 (2H, m, H-2, H-5), 3.95 (1H, at, *J* 9.6 Hz, H-4), 4.31 (1H, dd, $J_{5,6}$ 4.5 Hz, $J_{6,6'}$ 11.9 Hz, H-6), 4.36 (1H, dd, $J_{5,6'}$ 2.5 Hz, H-6'), 4.58 (1H, d, *J* 12.2 Hz, C<u>H</u>H'a), 4.59 (1H, d, *J* 11.1 Hz, C<u>H</u>H'b), 4.67 (1H, d, CH<u>H</u>'a), 4.71 (1H, d, CH<u>H</u>'b), 4.82 (1H, d, $J_{1,2}$ 1.5 Hz, H-1), 4.91 (1H, bs, NH), 5.10 (2H, s, CH_2-Z), 5.26 (1H, dd, $J_{2,3}$ 3.3 Hz, $J_{3,4}$ 9.4 Hz, H-3), 7.27-7.37 (15H, m, 15 x Ar-H); δ_C (100 MHz, $CDCl_3$) 20.9, 21.0 (2 x q, 2 x OAc), 23.5 (t, CH_2-3), 28.9, 29.8 (2 x t, CH_2-2, CH_2-4), 40.9 (t, CH_2-1), 63.4 (t, C-6), 66.5 (t, CH_2-Z), 67.8 (t, CH_2-5), 69.7 (d, C-5), 72.9 (t, CH_2Ph), 73.4 (d, C-3), 73.9 (d, C-4), 74.8 (t, CH_2Ph), 75.9 (d, C-2), 97.7 (d, C-1), 127.8-128.5 (d, Ar-C), 136.7, 137.8, 137.9 (s, Ar-C), 156.4 (s, N-C=O), 170.1, 170.9 (2 x s, O-C=O); *m/z* (ESI$^+$) 681 (M+NH_4^+, 100%); *m/z* (ESI$^+$) 686 (M+Na^+, 100%); HRMS (ESI$^+$) calcd. for $C_{37}H_{45}NO_{10}Na$ (M+Na^+) 686.2936. Found 686.2923.

5-(Benzyloxycarbonylamino)pentyl-2,4-di-*O*-benzyl-α-D-mannopyranoside 69



Sodium methoxide (50 mg, 0.9 mmol) was added to a solution of 5-(benzyloxycarbonylamino)pentyl-3,6-di-*O*-acetyl-2,4-di-*O*-benzyl-α-D-mannopyranoside **68** (2.6 g, 3.9 mmol) in methanol (50 mL). After 4h, t.l.c (1:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.1) with consumption of the starting material (R_f 0.5). The reaction mixture was neutralized with DOWEX, filtered and concentrated *in vacuo* to afford 5-(benzyloxycarbonylamino)pentyl-2,4-di-*O*-benzyl-α-D-mannopyranoside **69** (2.1 g, 98%) as a colourless oil; $[\alpha]_D^{23}$ +15.3 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) 3420 (OH, br), 1703 (C=O, s) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 1.31-1.38 (2H, m, CH_2-3), 1.47-1.57 (4H, m, CH_2-2, CH_2-4), 3.16-3.21 (2H, m, CH_2-1), 3.32-3.37 (1H, m, C<u>H</u>H'-5), 3.58-3.69 (3H, m, CH<u>H</u>'-5, H-5, H-4), 3.73 (1H, dd, $J_{1,2}$ 1.3 Hz, $J_{2,3}$ 3.6 Hz, H-2), 3.78 (1H, dd, $J_{5,6}$ 4.5 Hz, $J_{6,6'}$ 11.9 Hz, H-6), 3.87 (1H, dd, $J_{5,6'}$ 2.8 Hz, H-6'), 4.00 (1H, dd, $J_{3,4}$ 9.6 Hz, H-3), 4.62 (1H, d, *J* 11.6 Hz, C<u>H</u>H'a), 4.67 (1H, d, J 11.1 Hz, C<u>H</u>H'b), 4.74 (1H, d, CH<u>H</u>'a), 4.83 (1H, s, H-1), 4.92 (1H, d, CH<u>H</u>'b), 5.09 (2H, s, CH_2-Z), 7.28-7.41 (15H, m, 15 x Ar-H); δ_C (100 MHz, $CDCl_3$) 23.3 (t, CH_2-3), 28.9, 29.7 (2 x t, CH_2-2, CH_2-4), 40.9 (t, CH_2-1), 62.4 (t, C-6), 67.4 (t, CH_2-5), 71.3 (d, C-5), 71.9 (d, C-3), 73.1, 75.0 (2 x t, 2 x CH_2), 76.6 (d, C-4), 78.5 (d, C-2), 97.1 (d, C-1), 127.8-128.6 (d, Ar-C), 136.6, 137.7, 138.3 (s, Ar-C), 156.9 (s, C=O); *m/z* (ESI^+) 602 ($M+Na^+$, 100%); HRMS (ESI^+) calcd. for $C_{33}H_{41}NO_8Na$ ($M+ Na^+$) 602.2724. Found 602.2718.

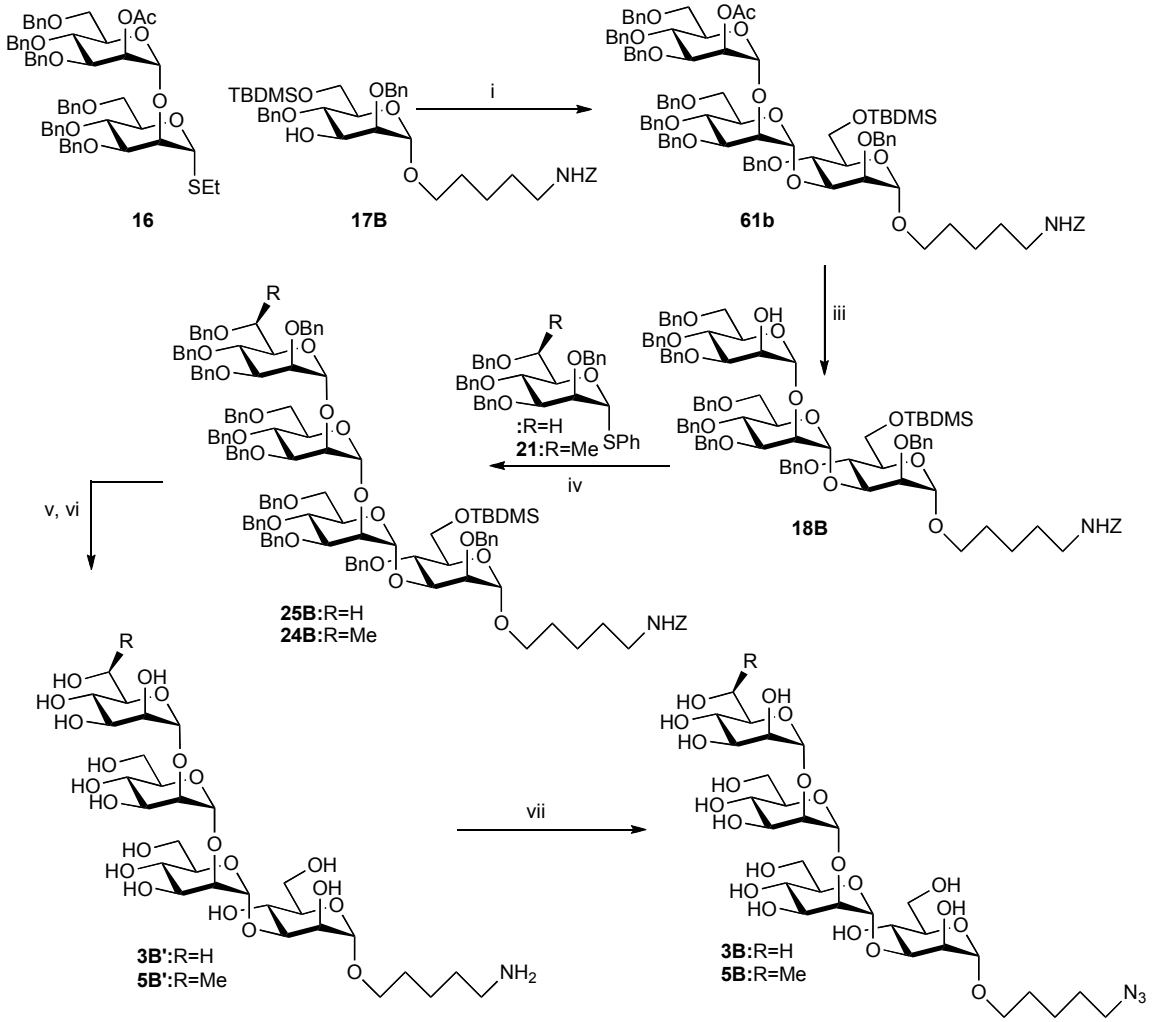
5-(Benzyloxycarbonylamino)pentyl-2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 17B



TBDMSCl (352 mg, 2.34 mmol) was added to a solution of 5-(benzyloxycarbonylamino)pentyl-2,4-di-*O*-benzyl-α-D-mannopyranoside **69** (1.34 g, 2.34

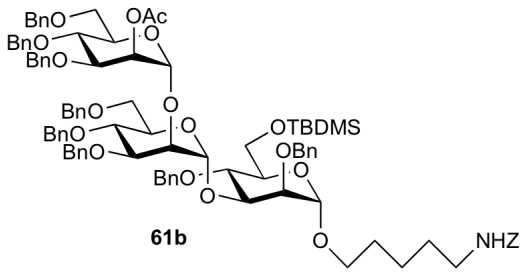
mmol) and imidazole (627 mg, 9.36 mmol) in anhydrous DMF (20 mL) at 0 ºC. After 1 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.3) with consumption of the starting material (R_f 0). Methanol (1 mL) was added to the reaction mixture which was then concentrated *in vacuo*. The residue was suspended in ethyl acetate (100 mL) and washed with ammonium chloride (100 mL of a saturated aqueous solution). The aqueous phase was re-extracted with ethyl acetate (2 x 100 mL) and the combined organic phases were dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (3:1, petrol:ethyl acetate) to afford 5-(benzyloxycarbonylamino)pentyl-2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **17B** (1.45 g, 90 %) as a colourless oil; $[\alpha]_D^{23}$ +14.1 (*c*, 2.0 in $CHCl_3$); ν_{max} (thin film) 3240 (OH, br), 1705 (C=O, s) cm^{-1}; δ_H (400 MHz, $CDCl_3$) 0.10, 0.11 (6H, 2 x s, 2 x Me), 0.93 (9H, s, $C(CH_3)_3$), 1.33-1.39 (2H, m, CH_2-3), 1.48-1.59 (4H, m, CH_2-2, CH_2-4), 2.42 (1H, d, *J* 9.6 Hz, OH), 3.17-3.22 (2H, m, CH_2-1), 3.33-3.38 (1H, m, C<u>H</u>H'-5), 3.55-3.59 (1H, m, CH<u>H</u>'-5), 3.64-3.69 (2H, m, H-4, H-5), 3.72 (1H, dd, $J_{1,2}$ 1.5 Hz, $J_{2,3}$ 3.8 Hz, H-2), 3.84-3.90 (2H, m, H-6, H-6'), 4.01 (1H, dat, J_d 3.8 Hz, J_t 9.4 Hz, H-3), 4.60 (1H, d, *J* 11.8 Hz, C<u>H</u>H'a), 4.66 (1H, d, *J* 10.8 Hz, C<u>H</u>H'b), 4.74 (1H, d, CH<u>H</u>'a), 4.82 (1H, bs, NH), 4.88 (1H, s, H-1), 4.92 (1H, d, CH<u>H</u>'b), 5.11 (2H, s, CH_2-Z), 7.29-7.39 (15H, m, 15 x Ar-H); δ_C (100 MHz, $CDCl_3$) -5.3, -5.1 (2 x q, 2 x Me), 18.3 (s, <u>C</u>$(CH_3)_3$), 23.4 (t, CH_2-3), 25.9 (q, C(<u>C</u>$H_3)_3$), 29.1, 29.8 (2 x t, CH_2-2, CH_2-4), 40.9 (t, CH_2-1), 62.7 (t, C-6), 66.6 (t, CH_2-Z), 67.1 (t, CH_2-5), 71.9 (d, C-3), 72.3 (d, C-4), 72.7 (t, CH_2Ph), 74.9 (t, CH_2Ph), 76.6 (d, C-5), 78.7 (d, C-2), 96.5 (d, C-1), 127.7-128.5 (d, Ar-C), 136.7, 137.9, 138.7 (s, Ar-C), 156.4 (s, C=O).

Synthesis of linker tetrasaccharides



Scheme S14: i) DMTST, TTBP, DCM, -78°C-RT, 4A molecular sieves, 80%, ii) NaOMe, MeOH, 90%, iii) DMTST, TTBP, DCM, -78°C-RT, 4A molecular sieves, **3b:** 44%, **5b:** 49%, v) AcOH, H_2O, 50°C, vi) H_2, Pd/C, MeOH, vii) TfN_3, $CuCl_2$, NH_4HCO_3, DCM, H_2O, **3c:** 77%, **5c:** 91%.

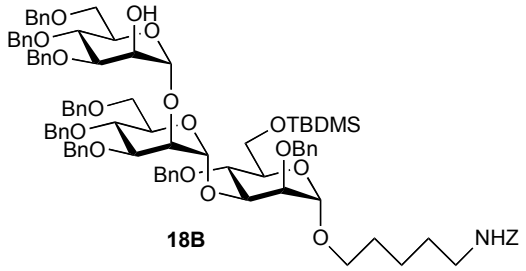
5-(Benzyloxycarbonylamino)pentyl- (2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 61b



5-(Benzyloxycarbonylamino)pentyl 2,4-di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **17B** (90 mg, 0.13 mmol), ethyl 2-*O*-acetyl-3,4,6-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-thio-α-D-mannopyranoside **16** (151 mg, 0.16 mmol) and 2,6-di-*tert*-butyl-4-methylpyridine (168 mg, 0.65 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (2 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -78 ºC. DMTST (134 mg, 0.52 mmol) was added and the mixture was stirred at -78 ºC under an atmosphere of argon and after 30 min the reaction was allowed to warm to room temperature. After 1 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.6) with complete consumption of the starting materials (R_f 0.7, 0.3). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→5:1, petrol:ethyl acetate) to afford 5-(benzyloxycarbonylamino)pentyl- 2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **61b** (145 mg, 80%) as a colourless oil. $[\alpha]_D^{25}$ +25.4 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1743, 1723 (C=O, s) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 0.02, 0.04 (6H, 2 x s, 2 x Me), 0.88 (9H, s, $C(CH_3)_3$), 1.23-1.30 (2H, m, CH_2-3), 1.41-1.51 (4H, m, CH_2-2, CH_2-4), 2.12 (3H, s, OAc), 3.10-3.14 (2H, m, CH_2-1), 3.24-3.29 (1H, m, C<u>H</u>H'-5), 3.45 (1H, ad, *J* 9.8 Hz, H-6c), 3.53 (1H, atd, J_d 9.5 Hz, J_t 3.8 Hz, H-5a), 3.57-3.68 (4H, m, CH<u>H</u>'-5, H-6'c, H-6b, H-6'b), 3.73 (2H, ad, *J* 3.2 Hz, H-6a, H-6'a), 3.79-3.93 (5H, m, H-2a, H-4a, H-4b, H-4c, H-5c), 3.96-4.02 (4H, m, H-2b, H-3b, H-3c, H-5b), 4.07 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 9.5 Hz, H-3a), 4.33 (1H, d, *J* 12.3 Hz, CH), 4.38 (1H, d, *J* 11.0 Hz, CH), 4.42 (1H, d, *J* 11.0 Hz, CH), 4.48-4.65 (10H, m, 10 x CH), 4.73 (1H, d, *J* 11.7 Hz, CH), 4.77 (1H, d, $J_{1,2}$ 0.9 Hz, H-1a), 4.81 (1H, d, *J* 10.8 Hz, CH), 5.08 (3H, d, *J* 2.5 Hz, CH_2-Z, H-1c), 5.20 (1H, d, $J_{1,2}$ 1.3 Hz, H-1b), 5.53 (1H, dd, $J_{2,3}$ 2.8 Hz, H-2c), 7.12-7.36 (45H, m, 45 x Ar-H); δ_C (125 MHz, $CDCl_3$) -5.3, -5.2 (2 x q, 2 x Me), 18.3 (s, $C(CH_3)_3$), 21.2 (q, OAc), 23.4 (t, CH_2-3), 25.9 (q, $C(CH_3)_3$), 28.9, 29.7 (2 x t, CH_2-2, CH_2-4), 40.9 (t, CH_2-1), 62.3 (t, C-6a), 66.5 (t, CH_2-Z), 67.2 (t, CH_2-5), 68.7 (d, C-2c), 69.6 (t, C-6c), 71.8 (t, C-6b), 71.9 (t, CH_2), 71.9 (d, C-5c), 72.1 (t, CH_2), 72.5 (d, C-5b), 73.1 (d, C-5a), 71.2, 73.1 (2 x t, 2 x CH_2), 74.1 (d, C-4a), 74.8 (d, C-4b, C-4c),

74.9 (d, C-2b), 75.0 (t, CH_2), 77.2 (d, C-2a, C-3c), 78.1 (d, C-3b), 79.5 (d, C-3a), 96.8 (d, C-1a), 99.2 (d, C-1c), 101.0 (d, C-1b), 127.30128.4 (d, Ar-C), 136.7, 138.0, 138.6 (s, Ar-C), 156.3, 170.1 (s, C=O); *m/z* (ESI$^+$) 1618 (M+NH_4^+, 100%); (M+Na^+) peaks measured: 1622.7 (94%), 1623.7 (100%), 1624.7 (56%), 1625.7 (21%), 1626.7 (7%), 1627.7 (2%) calculated peaks: 1622.7 (91%), 1623.7 (100%), 1624.7 (61%), 1625.7 (26%), 1626.7 (8%), 1627.7 (2%).

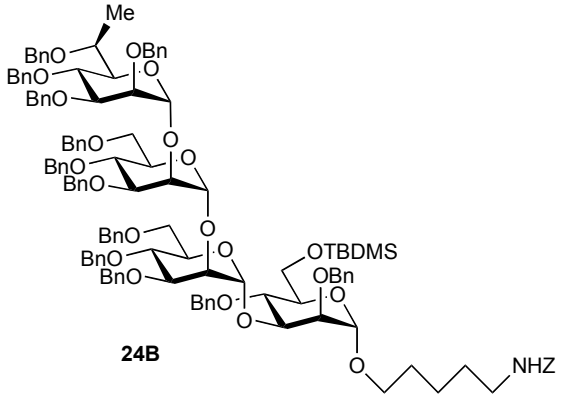
5-(Benzyloxycarbonylamino)pentyl- (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside 18B



5-(Benzyloxycarbonylamino)pentyl- (2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α–D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **17B** (145 mg, 0.091 mmol) was dissolved in methanol (2 mL) and sodium methoxide (0.2 mL of a 0.1 M solution in methanol) was added. After 24 h, t.l.c. (3:1, petrol:ethyl acetate) showed formation of a product (R_f 0.1) and complete consumption of the starting material (R_f 0.4). Ammonium chloride (a drop of a saturated aqueous solution) was added followed by sodium hydrogen carbonate (20 mL of a saturated aqueous solution). The mixture was extracted with DCM (3 x 50 mL) and the combined organic layers dried ($MgSO_4$), filtered and concentrated *in vacuo*. The residue was purified by flash column chromatography (2:1, petrol:ethyl aceate) to afford 5-(benzyloxycarbonylamino)pentyl- (3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18B** (128 mg, 90 %) as a colourless oil; $[\alpha]_D^{23}$ +34.2 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 3424 (OH, br), 1723 (C=O, s) cm^{-1}; δ_H (500 MHz, $CDCl_3$) 0.04, 0.05 (6H, 2 x s, 2 x Me), 0.89 (9H, s, $C(CH_3)_3$), 1.25-

1.31 (2H, m, CH_2-3), 1.41-1.50 (4H, m, CH_2-2, CH_2-4), 3.10-3.14 (2H, m, CH_2-1), 3.26-3.30 (1H, m, C<u>H</u>H'-5), 3.50 (1H, ad, *J* 10.4 Hz, H-6c), 3.54 (1H, atd, *J* 9.4 Hz, *J* 4.1 Hz, H-5a), 3.59-3.69 (4H, m, CH<u>H</u>'-5, H-6b, H-6'b, H-6'c), 3.74 (2H, s, H-6a, H-6'a), 3.78-3.91 (6H, m, H-2a, H-3c, H-4a, H-4b, H-4c, H-5c), 3.98-4.04 (3H, m, H-2b, H-3b, H-5b), 4.08 (1H, dd, $J_{2,3}$ 3.1 Hz, $J_{3,4}$ 9.4 Hz, H-3a), 4.12 (1H, bs, H-2c), 4.28 (1H, d, *J* 12.3 Hz, CH), 4.47 (1H, d, *J* 11.0 Hz, CH), 4.50-4.63 (11H, m, 11 x CH), 4.74 (1H, d, *J* 11.4 Hz, CH), 4.78 (1H, s, H-1a), 4.79 (1H, d, *J* 11.0 Hz, CH), 5.09 (2H, s, CH_2-Z), 5.15 (1H, s, H-1c), 5.24 (1H, d, $J_{1,2}$ 1.3 Hz, H-1b), 7.15-7.37 (45H, m, 45 x Ar-H); δ_C (125 MHz, $CDCl_3$) -5.3, -5.1 (2 x q, 2 x Me), 18.3 (s, <u>C</u>$(CH_3)_3$), 23.4 (t, CH_2-3), 25.9 (q, C(<u>C</u>$H_3)_3$), 29.0, 29.7 (2 x t, CH_2-2, CH_2-4), 40.9 (t, CH_2-1), 62.7 (t, C-6a), 66.5 (t, CH_2-Z), 67.3 (t, CH_2-5), 68.5 (d, C-2c), 68.5 (t, C-6c), 69.6 (t, C-6b), 71.6 (d, C-5c), 71.9, 72.1 (2 x t, 2 x CH_2), 72.3 (d, C-5b), 72.6 (t, CH_2), 73.1 (d, C-5a), 73.2, 73.3 (2 x t, 2 x CH_2), 74.2, 74.7 (2 x d, C-4a, C-4b, C-4c), 74.9, 75.0 (2 x t, 2 x CH_2), 75.2 (d, C-2b), 78.1 (d, C-2a), 79.5 (d, C-3b), 79.9 (2 x d, C-3a, C-3c), 96.8 (d, C-1a), 100.9 (d, C-1c), 101.6 (d, C-1b), 127.3-128.5 (d, Ar-C), 136.7-138.7 (s, Ar-C), 156.3 (s, C=O); *m/z* (ESI^+) 1576 ($M+NH_4^+$, 100%); ($M+Na^+$) peaks measured: 1580.7 (94%), 1581.7 (100%), 1582.7 (59%), 1583.7 (23%), 1584.7 (8%), 1585.7 (2%) calculated peaks: 1580.7 (93%), 1581.7 (100%), 1582.7 (60%), 1583.7 (25%), 1584.7 (8%), 1585.7 (2%).

5-(Benzyloxycarbonylamino)pentyl-(2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside 24B

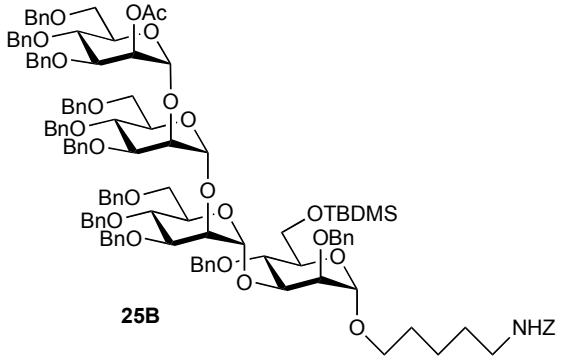


24B

5-(Benzyloxycarbonylamino)pentyl- (2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-(3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→3)-2,4,di-*O*-benzyl-6-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside **18B** (66 mg, 0.042 mmol), phenyl 2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-1-thio-α-D-mannopyranoside **21** (33 mg, 0.051 mmol) and 2,4,6-tri-*t*-butylpyrimidine (54 mg, 0.21 mmol) were dried in a dessicator overnight. The reagents were dissolved in DCM (1 mL) and transferred using a cannula to a flame dried flask containing 4Å molecular sieves. The mixture was stirred for 1 h and cooled to -78 ºC. Dimethylthiosulfonium triflate (43 mg, 0.168 mmoL) was added to the reaction mixture and after 30 min the reaction mixture was allowed to warm to room temperature. After a further 1 h, t.l.c (3:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.5) with complete consumption of the starting materials (R_f 0.2, 0.7). The reaction mixture was quenched with triethylamine (0.5 mL) and filtered through celite®. The filtrate was concentrated *in vacuo* and the residue purified by flash column chromatography (petrol→5:1, petrol:ethyl acetate) to afford 5-(benzyloxycarbonylamino)pentyl-(2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **5B** (43 mg, 49%) as a colourless oil; $[\alpha]_D^{21}$ +16.0 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1720 (s, C=O) cm^{-1}; δ_H (700 MHz, $CDCl_3$) 0.03, 0.04 (6H, 2 x s, 2 x Me), 0.89 (9H, s, $C(CH_3)_3$), 1.15 (3H, d, *J* 6.5 Hz, 6-Me), 1.26-1.33 (2H, m, CH_2-3), 1.43-1.50 (4H, m, CH_2-2, CH_2-4), 3.12-3.15 (2H, m, CH_2-1), 3.27-3.29 (1H, m, CHH'-5), 3.49 (2H, at, *J* 9.9 Hz, H-5d, H-6c), 3.53-3.55 (1H, m, H-5^a), 3.59-3.64 (2H, m, H-6'c, CHH'-5), 3.67-3.68 (2H, m, H-6b, H-6'b), 3.72-3.73 (2H, m, H-6^a, H-6'a), 3.79-3.84 (5H, m, H-2d, H-4c, H-4b, H-5c, H-6d), 3.87 (1H, at, J 9.3 Hz, H-4^a), 3.90-3.92 (2H, m, H-2^a, H-3d), 3.94 (1H, dd, $J_{2,3}$ 2.2 Hz, $J_{3,4}$ 9.2 Hz, H-3b), 4.01-4.04 (2H, m, H-3c, H-5b), 4.10 (1H, dd, $J_{2,3}$ 2.6 Hz, $J_{3,4}$ 9.4 Hz, H-3a), 4.15 (1H, as, H-2c), 4.20 (1H, at, *J* 9.6 Hz, H-4d), 4.22 (1H, as, H-2b), 4.32 (1H, d, *J* 11.8 Hz, CH), 4.36-4.41 (4H, m, 4 x CH), 4.49-4.67 (16H, m, 16 x CH), 4.76 (2H, d, *J* 11.4 Hz, 2 x CH), 4.79 (1H, s, H-1a), 4.85 (2H, d, *J* 11.0 Hz, 2 x CH), 4.93 (1H, d, *J* 10.9 Hz, CH), 5.10 (2H, s, CH_2-Z), 5.25 (2H, s, H-1b, H-1c), 5.41 (1H, s, H-1d), 7.13-7.38 (65H, m, 65 x Ar-H); δ_C (175 MHz, $CDCl_3$) -4.5 (q, Me), 15.4 (q, 6-Me), 23.3 (t, CH_2-3), 25.6 (q, $C(CH_3)_3$), 28.8, 29.6 (2 x t, CH_2-2, CH_2-4), 40.9 (t,

CH_2-1), 62.4 (t, C-6a), 66.4 (t, CH_2-Z), 67.2 (t, CH_2-1), 68.7 (t, C-6c), 69.3 (t, C-6b), 70.3 (t, CH_2), 71.3 (d, C-5d), 71.5, 71.6, 71.7, 72.1 (t, CH_2), 72.4 (d, C-5c), 72.5 (d, C-5b), 72.9 (d, C-5a), 72.9 (t, CH_2), 73.0 (d, C-2c), 73.2 (t, CH_2), 73.4 (d, C-2b), 74.0 (d, C-2d), 74.6 (d, C-4d), 74.7, 74.8 (t, CH_2), 74.7 (d, C-4a), 74.8 (d, C-4b, C-4c), 75.0)d, C-5d), 78.0 (d, C-2a), 79.4 (d, C-3c), 80.0 (d, C-3b), 80.2 (d, C-3d), 80.3 (d, C-3a), 96.6 (d, C-1a), 98.3 (d, C-1d), 100.0 (d, C-1b), 101.1 (d, C-1c); *m/z* (ESI^+) 2118 ($M+Na^+$, 100%); ($M+Na^+$) peaks measured: 2116.9 (64%), 2117.9 (100%), 2118.9 (77%), 2119.9 (40%), 2120.9 (14%), 2121.9 (5%) calculated peaks: 2116.9 (69%), 2117.9 (100%), 2118.9 (78%), 2119.9 (42%), 2120.9 (17%), 2121.9 (6%).

5-(Benzyloxycarbonylamino)pentyl-(2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-a-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside 25B

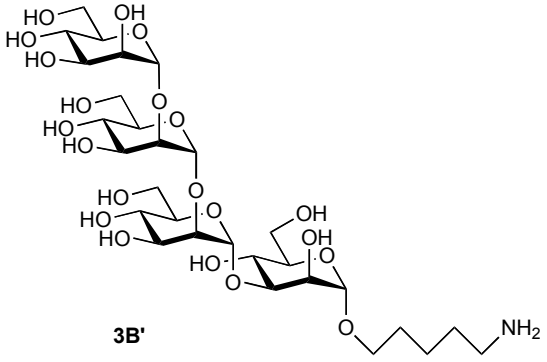


25B

Same as above procedure. Yield 44%; $[\alpha]_D^{21}$ +13.5 (*c*, 1.0 in $CHCl_3$); ν_{max} (thin film) 1751, 1720 (s, C=O) cm^{-1}; δ_H (700 MHz, $CDCl_3$) 0.04, 0.05 (6H, 2 x s, 2 x Me), 0.90 (9H, s, $C(CH_3)_3$), 1.25-1.31 (2H, m, CH_2-3), 1.42-1.49 (4H, m, CH_2-2, CH_2-4), 2.15 (3H, s, OAc), 3.10-3.14 (2H, m, CH_2-1), 3.26-3.28 (1H, m, C<u>H</u>H'-5), 3.45 (1H, d, *J* 9.3 Hz, H-6d), 3.51 (1H, d, *J* 10.0 Hz, H-6c), 3.52-3.55 (1H, m, H-5a), 3.59-3.62 (1H, m, CH<u>H</u>'-5), 3.63 (1H, dd, $J_{5,6}$ 3.1 Hz, $J_{6,6'}$ 10.5 Hz, H-6'd), 3.66-3.69 (3H, m, H-6'c, H-6b, H-6'b), 3.72-3.74 (2H, m, H-6a, H-6'a), 3.78 (1H, at, *J* 9.7 Hz, H-4b), 3.80 (1H, m, H-4a), 3.88-3.90 (2H, m, H-5c, H-5d), 3.92-4.01 (6H, m, H-2a, H-3b, H-3c, H-4c, H-4d, H-5b), 4.03 (1H, dd, $J_{2,3}$ 3.2 Hz, $J_{3,4}$ 9.3 Hz, H-3d), 4.06 (1H, bs, H-2c), 4.10 (1H, dd, $J_{2,3}$ 3.0 Hz, $J_{3,4}$ 9.5 Hz, H-3a), 4.15 (1H, d, *J* 3.1 Hz, H-2b), 4.25 (1H, d, *J* 12.2 Hz, CH), 4.38-4.64 (18H,

m, 18 x CH), 4.69 (1H, d, *J* 10.9 Hz, CH), 4.75 (1H, d, *J* 11.4 Hz, CH), 4.78 (1H, s, H-1a), 4.84-4.88 (3H, m, 3 x CH), 5.10 (2H, s, CH_2-Z), 5.12 (1H, d, $J_{1,2}$ 1.2 Hz, H-1d), 5.22 (1H, s, H-1b), 5.26 (1H, s, H-1c), 5.59 (1H, dd, $J_{1,2}$ 1.9 Hz, $J_{2,3}$ 2.9 Hz, H-2d), 7.10-7.38 (60H, m, 60 x Ar-H); δ_C (175 MHz, $CDCl_3$) -4.5 (q, Me), 23.3 (t, CH_2-3), 21.1 (q, OAc), 25.7 (q, $C(CH_3)_3$), 28.9, 29.7 (2 x t, CH_2-2, CH_2-4), 40.4 (t, CH_2-1), 62.6 (t, C-6a), 66.4 (t, CH_2-Z), 67.1 (t, CH_2-5), 68.4 (t, C-6d), 68.8 (t, C-6c), 69.4 (t, C-6b), 71.8, 71.9 (t, 2 x CH_2), 72.0 (2 x d, C-5c, C-5d), 72.5 (d, C-5b), 72.9 (d, C-5a), 73.0, 73.2, 73.3 (t, CH_2), 74.1 (d, C-4c), 74.4 (d, C-4d), 74.7 (d, C-2b), 74.7 (d, C-4a), 74.8, 74.9 (t, CH_2), 75.0 (d, C-2c), 75.0 (d, C-4b), 78.1 (d, C-2a), 78.3 (d, C-3d), 79.3 (d, C-3c), 79.3 (d, C-3b), 80.1 (d, C-3a), 96.7 (d, C-1a), 99.1 (d, C-1d), 100.4 (d, C-1b), 101.2 (d, C-1c); *m/z* (ESI^+) 2055 ($M+Na^+$, 100%); ($M+Na^+$) peaks measured: 2054.8 (71%), 2055.8 (100%), 2056.8 (72%), 2057.8 (37%), 2058.8 (14%), 2059.8 (5%) calculated peaks: 2054.9 (72%), 2055.9 (100%), 2056.9 (75%), 2057.9 (39%), 2058.9 (15%), 2059.9 (5%).

5-Amino-pentyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-α-D-mannopyranoside 3B'

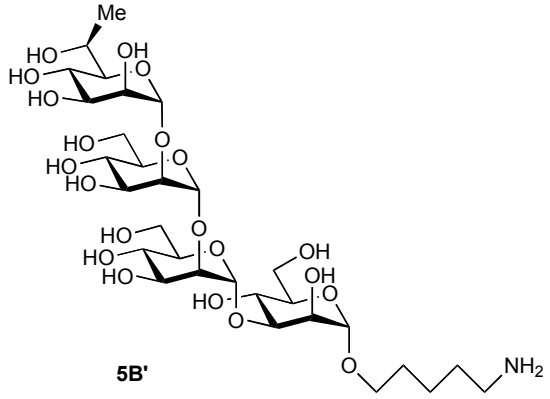


3B'

Sodium methoxide (1 mL of a 0.1 M solution in methanol) was added to a solution of 5-(benzyloxycarbonylamino)pentyl-(2-*O*-acetyl-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl)-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **25B** (50 mg, 0.025 mmol) in methanol (1 mL). After 18 h the reaction mixture was neutralized with acidified DOWEX, filtered and concentrated *in vacuo*. The residue was suspended in was suspended in acetic acid (80% in water) and heated at 50°C. After 48 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a product (R_f 0.1)

with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and purified by reverse phase C-18 chromatography to afford 5-amino-pentyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-α-D-mannopyranoside **3B'** (14 mg, 75% over 2 steps) as an amorphous white solid; δ_H (500 MHz, D_2O) 1.37 (2H, bs, CH_2-3), 1.59 (4H, bs, CH_2-2, CH_2-4), 2.92 (2H, bs, CH_2-1), 3.46-4.02 (26H, m, 24 x CH, CH_2-5), 4.75, 4.96, 5.22, 5.27 (4H, 4 x s, 4 x H-1); δ_C (125 MHz, D_2O) 22.4 (t, CH_2-3), 26.5, 28.0 (2 x t, CH_2-2, CH_2-4), 39.4 (t, CH_2-1), 60.8, 61.0 (t, C-6a, C-6b, C-6c, C-6d), 66.1, 66.9, 67.4, 69.7, 69.9, 70.3, 72.9, 73.2, 73.3, 78.4, 78.5, 78.6 (d, C-2a, C-3a, C-4a, C-5a, C-2b, C-3b, C-4b, C-5b, C-2c, C-3c, C-4c, C-5c, C-2d, C-3d, C-4d, C-5d), 99.6, 100.6, 102.2 (d, C-1a, C-1b, C-1c, C-1d).

5-Amino-pentyl-6-*C*-6-*S*-methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-α-D-mannopyranoside 5B'

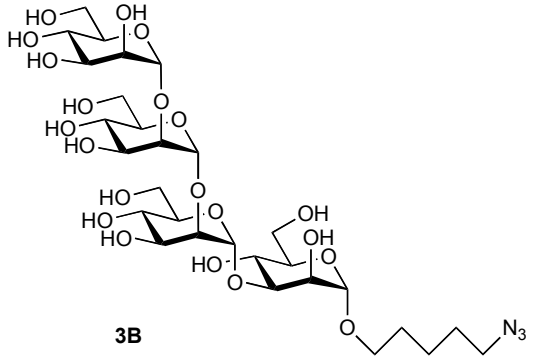


5B'

5-(Benzyloxycarbonylamino)pentyl-(2,3,4,6-tetra-*O*-benzyl-6-*S*-6-*C*-methyl-α-D-mannopyranosyl)-(1→2)- 3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→2)-3,4,6-tri-*O*-benzyl-α-D-mannopyranosyl-(1→3)-2,4-di-*O*-benzyl-6-*O*-tert-butyldimethylsilyl-α-D-mannopyranoside **24B** (43 mg, 0.021 mmol) was suspended in acetic acid (80% in water) and heated at 50ºC. After 48 h, t.l.c (5:1, petrol:ethyl acetate) indicated formation of a

product (R_f 0.1) with consumption of the starting material (R_f 0.6). The reaction mixture was concentrated *in vacuo* and coevaporated with toluene (3 x 10 mL). The residue was purified by flash column chromatography (2:1, petrol:ethyl acetate). The desilylated product was dissolved in ethanol and palladium (10 mg of 10% palladium on carbon) was added. Hydrogen gas was bubbled through the solution until saturated. After 48 h under hydrogen, the reaction mixture was filtered through celite®, concentrated *in vacuo* and purified by reverse phase C-18 chromatography to afford 5-amino-pentyl-6-*C*-6-*S*-methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-α-D-mannopyranoside **5B'** (12 mg, 77% over 2 steps) as an amorphous white solid; δ_H (500 MHz, D_2O) 1.23 (3H, d, *J* 6.6 Hz, 6-Me), 1.34-1.40 (2H, m, CH_2-3), 1.54-1.57 (4H, m, CH_2-2, CH_2-4), 2.85 (1H, at, *J* 7.5 Hz, CH_2-1), 3.41-4.09 (25H, m, CH_2-5, 23x CH), 4.75, 5.01, 5.15, 5.27 (4H, 4 x s, 4 x H-1); δ_C (125 MHz, D_2O) 19.0 (q, Me), 22.5 (t, CH_2-3), 27.4, 28.1 (2 x t, CH_2-2, CH_2-4), 39.6 (t, CH_2-1), 60.8, 61.0, 61.0 (t, C-6a, C-6b, C-6c), 66.9 (t, CH_2-5), 66.0, 66.7, 67.0, 67.5, 69.7, 70.0, 70.1, 70.5, 72.9, 73.3, 73.4, 75.0, 77.9, 78.6, 78.8, 81.7 (d, C-2a, C-3a, C-4a, C-5a, C-2b, C-3b, C-4b, C-5b, C-2c, C-3c, C-4c, C-5c, C-2d, C-3d, C-4d, C-5d, C-6d), 99.5, 100.7, 100.8, 102.1 (d, C-1a, C-1b, C-1c, C-1d).

5-Azido-pentyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-α-D-mannopyranoside 3B



3B

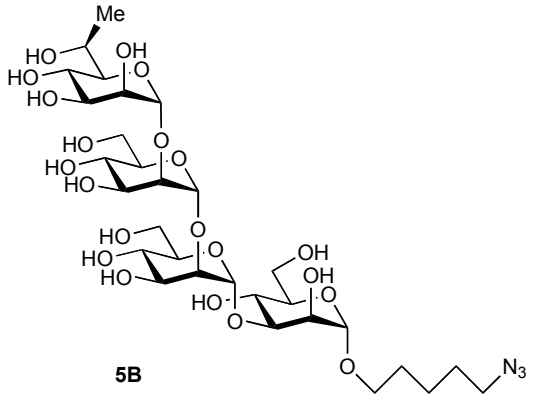
Sodium azide (12mg, 0.186mmol, 20eq) was dissolved in water (2ml) and DCM (2ml). The resulting biphasic mixture was cooled to 0°C and Tf_2O (15.7µl, 0.093mmol, 10eq) was added to the organic layer via syringe. The mixture was stirred at 0°C for 3 hours, after which the aqueous layer was removed and the organic layer washed with water (2 x

1ml), saturated $NaHCO_3$ solution (2ml) and water (3 x 2ml). To this solution of TfN_3 was added NH_4HCO_3 (1.5mg, 0.019mmol, 2eq), $CuCl_2$ (0.1mg, 9.3 x 10^{-4} mmol, 0.1eq), **3B'** (7mg, 9.3 x 10^{-3} mmol, 1eq), and water (1ml). Methanol (~6ml) was added to yield a monophasic solution. The reaction was monitored using TLC (5 ethanol : 3 NH_4OH : 1 water) and HPLC using a Phenomenex Luna NH_2 column (4.6 x 300mm, 5µm) and 1 water : 1 acetonitrile as the mobile phase at flow rate of 1ml/min, with ELS detection of eluants. After 19 hours of reaction, starting material was still present so excess TfN_3 (20eq, solution in 1ml of DCM), prepared using the above protocol, was added to drive the reaction to completion. After a further 25 hours, complete consumption of starting material was detected. The organic solvents were removed *in vacuo* and the aqueous layer washed with ethyl acetate (2 x 15ml). The aqueous layer was lyophilized to remove NH_4HCO_3. The crude solid was dissolved in water (1ml) and Cu^{2+} removed by cation exchange through a column of Dowex 50WX8 (H^+ form), eluted with water as the mobile phase. The product containing fractions were lyophilized and purified by HPLC using a Phenomenex Luna NH_2 column (4.6 x 300mm, 5µm) and 1 water : 3 acetonitrile as the mobile phase at flow rate of 1ml/min, with RI detection of eluants to yield the desired compound as a pale yellow amorphous solid **3B** (5.6mg, 77%).

R_f 0.5 (5 ethanol : 3 NH_4OH : 1 water); ^{1}H NMR (500MHz, D_2O) δ ppm 1.37 (2H, m, H9), 1.51-1.61 (4H, m, H8, H10), 3.26 (2H, t, $J_{H10\text{-}H11}$ 6.8Hz, H11), 3.47 (1H, ddd, $J_{H7\text{-}H7'}$ 9.7Hz, $J_{H7'\text{-}H8}$ 6.1, $J_{H7'\text{-}H8'}$ 5.9Hz, H7'), 3.55 (1H, m, H5a), 3.58 (1H, t, $J_{3a\text{-}4a}$ 9.8Hz, $J_{4a\text{-}5a}$ 9.8Hz, H4a), 3.60 – 3.63 (2H, m, H5b, H5c), 3.63- 3.70 (9H, m, H4b, H4c, H4d, H5d, H6'a, H6'b, H6'c, H6'd, H7'), 3.76 (1H, dd, $J_{H3a\text{-}H4a}$ 9.6Hz, $J_{H2a\text{-}H3a}$ 3.6Hz, H3a),3.78-3.82 (5H, m, H3d, H6a, H6b, H6c, H6d), 3.88 (1H, dd, $J_{H3c\text{-}H4c}$ 9.1Hz, $J_{H2c\text{-}H3c}$ 3.2Hz, H3c), 3.91 (1H, dd, $J_{H3b\text{-}H4b}$ 9.3Hz, $J_{H2b\text{-}H3b}$ 3.3Hz, H3b), 3.97 - 4.01 (3H, m, H2a, H2b, H2d), 4.03 (1H, dd, $J_{H2c\text{-}H3c}$ 3.3Hz, $J_{H1c\text{-}H2c}$ 1.6Hz, H2c), 4.75 (1H, d, $J_{H1d\text{-}H2d}$ 1.3Hz, H1d), 4.97 (1H, d, $J_{H1a\text{-}H2a}$ 1.3Hz, H1a), 5.22 (1H, d, $J_{H1c\text{-}H2c}$ 1.3Hz, H1c), 5.27 (1H, d, $J_{H1b\text{-}H2b}$ 1.3Hz, H1b); ^{13}C NMR (126MHz, D_2O) δ ppm 22.7 (1C, C9), 27.7 (1C, C10), 28.0 (1C, C8), 51.0 (1C, C11), 60.8 (1C, C6d), 60.9 (1C, C6a), 60.9 (1C, C6c), 61.0 (1C, C6b), 66.1 (1C, C5d), 66.8 (1C, C5a), 66.8 (1C, C5c), 66.9 (1C, C5b), 67.6 (1C, C7), 69.7 (1C, C2d), 69.9 (1C, C2a), 70.0 (1C, C3b), 70.0 (1C, C3c), 70.3 (1C, C3a), 72.8 (1C, C4a), 73.2 (1C, C4d), 73.2 (1C, C4c), 73.3 (1C, C4b), 78.4 (1C, C2c), 78.5 (1C, C3d), 78.6 (1C, C2b), 99.6

(1C, C1d), 100.6 (1C, C1c), 100.7 (1C, C1b), 102.2 (1C, C1a); HRMS m/z (ES^+) 800.2902 $[M + Na]^+$ (required 800.2907).

5-Azido-pentyl-6-*C*-6-*S*-methyl-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→2)-α-D-mannopyranosyl-(1→3)-α-D-mannopyranoside 5B



5B

Sodium azide (102mg, 1.57mmol, 150eq) was dissolved in water (3ml) was DCM (3ml). The resulting biphasic mixture was cooled to 0°C and Tf_2O (132µl, 0.79mmol, 75eq) was added to the organic layer via syringe. The mixture was stirred at 0°C for 3 hours, after which the aqueous layer was removed and the organic layer washed with water (2 x 3ml), saturated $NaHCO_3$ solution (3ml) and water (3 x 2ml). To this solution of TfN_3 was added NH_4HCO_3 (2.5mg, 0.031mmol, 3eq), $CuCl_2$ (0.2mg, 1.6 x 10^{-3} mmol, 0.15eq), **5B'** (8mg, 0.01mmol, 1eq), and water (3ml). Methanol (~15ml) was added to yield a monophasic solution. The reaction was monitored using TLC (5 ethanol : 3 NH_4OH : 1 water) and HPLC using a Phenomenex Luna NH_2 column (4.6 x 300mm, 5µm) and 1 water : 1 acetonitrile as the mobile phase at flow rate of 1ml/min, with ELS detection of eluants. After 17 hours of reaction, complete consumption of starting material was detected. The organic solvents were removed *in vacuo* and the aqueous layer washed with ethyl acetate (2 x 15ml). The aqueous layer was lyophilized to remove NH_4HCO_3. The crude solid was dissolved in water (1ml) and Cu^{2+} removed by cation exchange through a column of Dowex 50WX8 (H^+ form), eluted with water as the mobile phase. Lyophilization yielded the desired compound as a white amorphous solid **5B** (7.5mg, 91%).

R_f 0.6 (5 ethanol : 3 NH_4OH : 1 water); ^{1}H NMR (500MHz, D_2O) δ ppm 1.22 (3H, d, J_{H-H6a} 6.6Hz, CH_3), 1.36 (2H, m, ^3J 7.6Hz, H9), 1.54 (4H, quin, ^3J 7.3Hz, H8, H10), 3.25 (2H, t, $J_{H10-H11}$ 6.8Hz, H11), 3.40 (1H, d, $J_{H5a-H4a}$ 9.5Hz, H5a), 3.45 (1H, dt, ^2J 9.8Hz, $J_{H7'-H8'}$ 9.8Hz, $J_{H7'-H8}$ 6.0Hz, H7'), 3.53-3.59 (3H, m, H4b, H5b, H5c), 3.60-3.67 (7H, m, H4c, H4d, H5d, H6'b, H6'c, H6'd, H7), 3.71 (1H, t, $J_{H3a-H4a}$ 9.1Hz, $J_{H4a-H5a}$ 9.1Hz, H4a), 3.75 (1H, dd, $J_{H3a-H4a}$ 8.7Hz, $J_{H2a-H3a}$ 3.3Hz, H3a), 3.77-3.81 (4H, m, H3d, H6b, H6c, H6d), 3.86 (1H, dd, $J_{H3b-H4b}$ 9.3Hz, $J_{H2b-H3b}$ 3.2Hz, H3b), 3.87 (1H, dd, $J_{H3c-H4c}$ 9.3Hz, $J_{H2c-H3c}$ 3.2Hz, H3c), 3.95 (1H, t, $J_{H1a-H2a}$ 1.9Hz, $J_{H2a-H3a}$ 1.9Hz, H2a), 3.97 (1H, t, $J_{H1b-H2b}$ 1.6Hz, $J_{H2b-H3b}$ 1.6Hz, H2b, H2d), 4.04 (1H, t, $J_{H1c-H2c}$ 2.5Hz, $J_{H2c-H3c}$ 2.5Hz, H2c), 4.08 (1H, qd, $J_{H6a-CH3}$ 6.9Hz, $J_{H5a-H6a}$ 1.0Hz, H6a), 4.74 (1H, as, H1d), 5.00 (1H, as, H1a), 5.14 (1H, as, H1c), 5.26 (1H, as, H1b);^{13}C NMR (126MHz, D_2O) δ ppm 18.8 (1C, CH_3), 22.7 (1C, C9), 27.7 (1C, C10), 28.0 (1C, C8), 51.0 (1C, C11), 60.8 (1C, C6d), 60.9 (1C, C6c), 61.0 (1C, C6b), 64.7 (1C, C6a), 66.0 (1C, C5d), 66.7 (1C, C4a), 66.9 (1C, C5c), 66.9 (1C, C5b), 67.6 (1C, C7), 69.7 (1C, C2d), 69.9 (1C, C2a), 70.0 (1C, C3c), 70.1 (1C, C3b), 70.5 (1C, C3a), 72.8 (1C, C4b), 73.3 (1C, C4c), 73.3 (1C, C4d), 75.0 (1C, C5a), 77.9 (1C, C2c), 78.6 (1C, C2b), 78.8 (1C, C3d), 99.5 (1C, C1d), 100.7 (1C, C1c), 100.8 (1C, C1b), 102.1 (1C, C1a); HRMS 790.3097 $[M - H]^-$ (required 790.3099).

2. Modelling data

Modelling experimental

Molecular modelling of the interaction between the synthesised sugars and 2G12 was carried out by Dr. Mark R. Wormald at the Oxford Glycobiology Institute, Department of Biochemistry, University of Oxford. This was performed on a Silicon Graphics Fuel workstation using InsightII and Discover software (Accelrys Inc., San Diego, USA).

The structures of the synthetic monosaccharides and disaccharides were built in Insight and energy minimised. For the disaccharides, the glycosidic linkage conformations were determined using the database of glycosidic linkage conformations. (21)

A single Fab domain of 2G12 was created from the coordinates of the 1.75 Å structure of the complex of 2G12 with Manα1-2Man(22) obtained from the Protein DataBase.(23)

(PDB code 1OP3). The synthetic monosaccharides (Fig. 1) and disaccharides (Fig. 2) were docked into the Fab antigen binding site by overlaying the terminal residue with the terminal Man residue of the Manα1-2Man ligand. The modeled disaccharide complexes were then energy minimized, keeping the peptide backbone and the carbon atoms of the terminal saccharide residue fixed, and the resulting disaccharide conformation compared to the modeled free disaccharide.

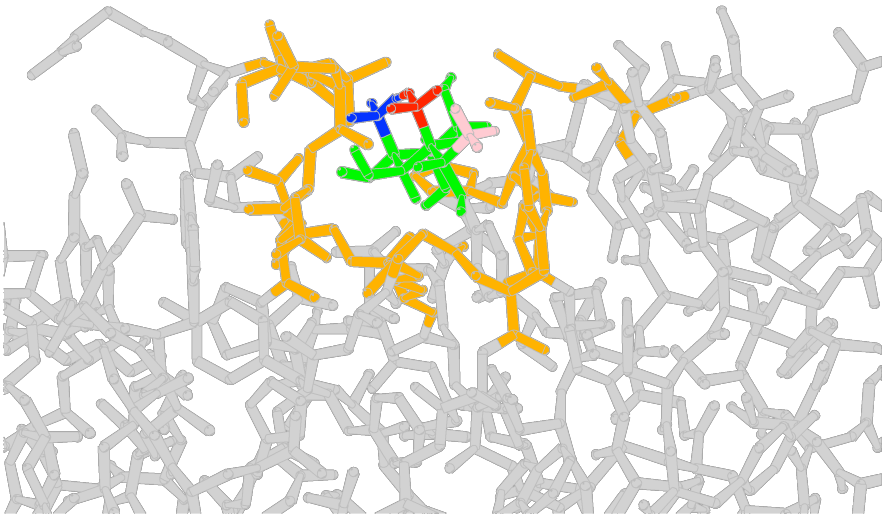


Figure S1: Mannose monosaccharide modeled in Fab 2G12 binding site. Substitutions at C-3 (blue), C-5 (red) and C-6 (pink) added to determine tolerance in binding site.

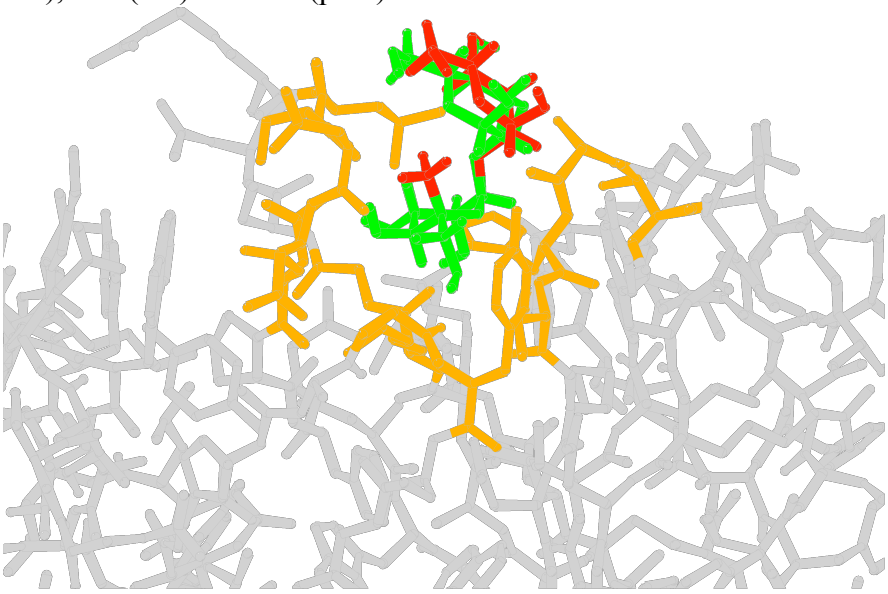


Figure S2: Terminal disaccharide of the D1 arm modeled in the Fab 2G12 binding site. Natural substrate (green) and C-5 modified disaccharide (red).

3. Competition ELISA

Procedure:

Plates (microtiter plate, flat bottom, Costar type 3690; Corning) were coated with 250 ng per well $gp120_{JR\text{-}CSF}$ overnight at 4°C. All subsequent steps were performed at room temperature. The plates were washed four times with PBS/0.05% (vol/vol) Tween 20 (Sigma), blocked for 1 h with 3% (mass/vol) BSA and then emptied but not washed. 2G12 (diluted to 0.5 ug/mL with 1% BSA/0.02% Tween20/PBS (PBS-BT) was added in the presence of serially diluted carbohydrate inhibitors and incubated for 2h. Unbound Ab was removed by washing four times as described above. Bound 2G12 was detected with 50 μL of an peroxidase-conjugated goat anti-human IgG $F(ab')_2$ HRP (Pierce) diluted 1:1,000 in PBS-BT. After 1 h, the wells were washed four times, and bound Ab was visualized with TMB substrate (Sigma, 50 μL of a 1mg/mL solution), quenched with 2M sulphuric acid and monitored at 450 nm.

Monosaccharide IC_{50} values:

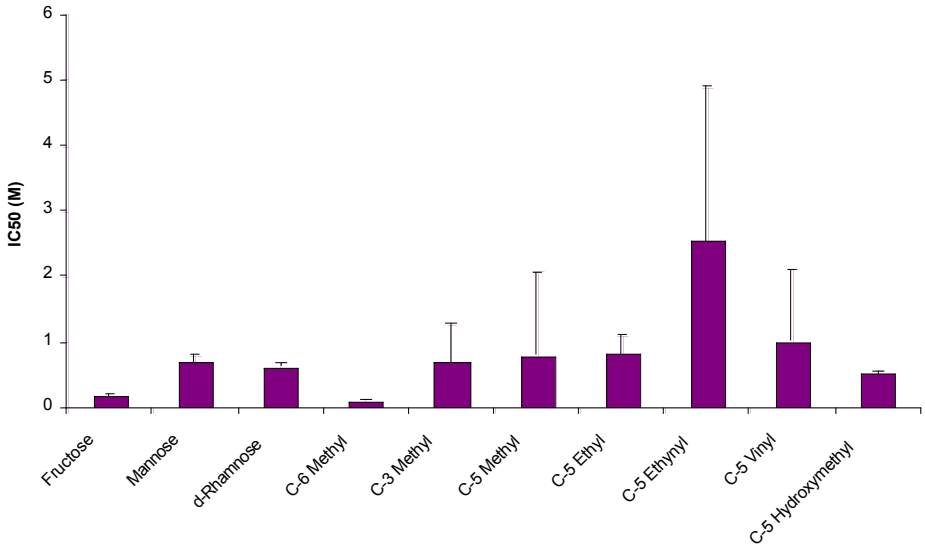


Figure S3: Monosaccharide inhibition.

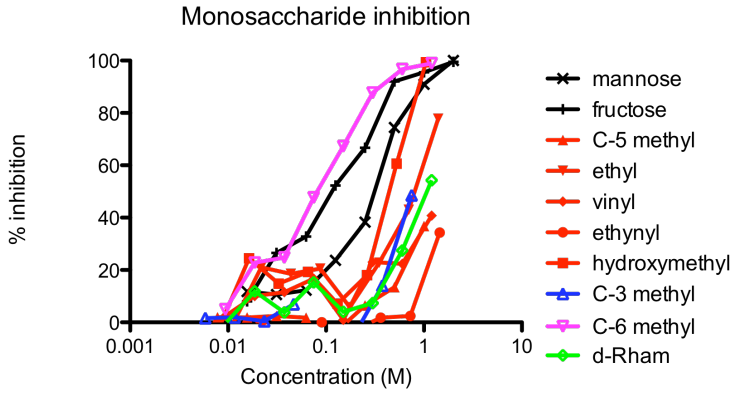


Figure S4: Monosaccharide inhibition curves.

Tetrasaccharide IC_{50} values:

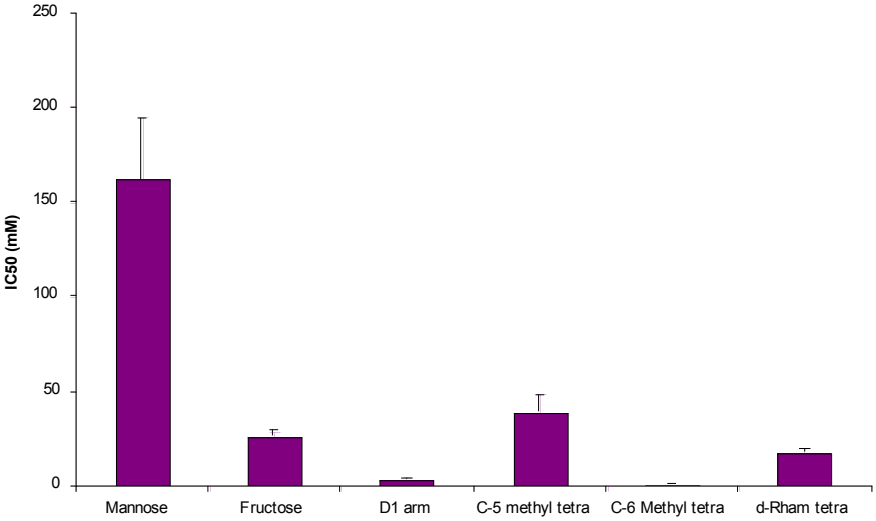


Figure S5: Tetrasaccharide Inhibitions.

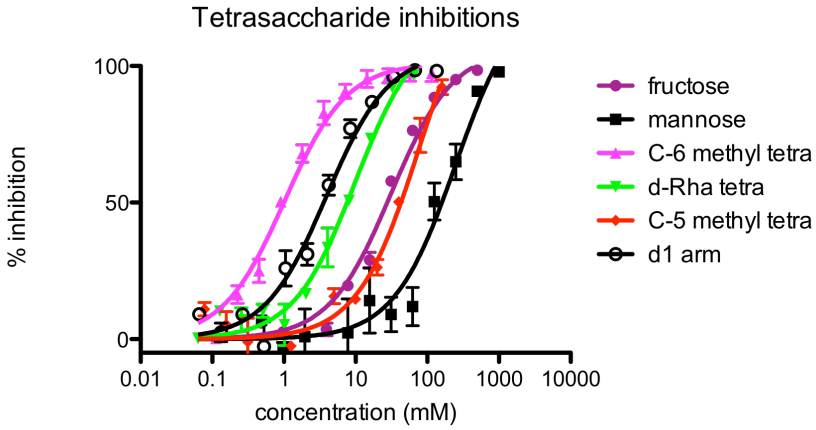


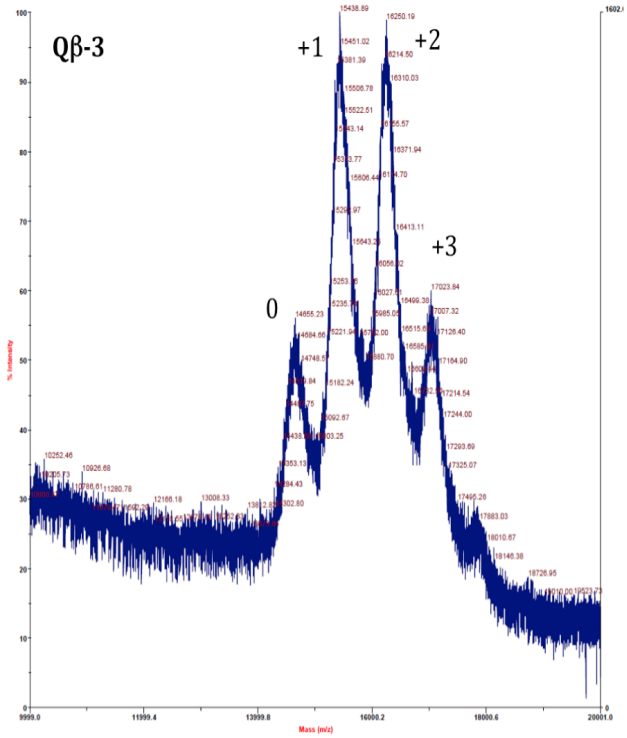
Figure 6: Tetrasaccharide inhibtion curves

4. Protein conjugation:

Conjugation to Qβ particles

Qβ-alkyne: Qβ bearing alkyne at surface-exposed lysine residues was prepared by incubating a 10 mg/mL solution of Qβ with 25 mM of N-(4-Pentynoyloxy) succinimide (35- fold excess with respect to protein subunit) in 0.1 M potassium phosphate buffer (pH 7) with 10% DMSO for 12 hours. The derivatized virus was separated from excess reagent by ultracentrifugation using a 10-40% sucrose gradient.

Carbohydrate conjugation by click chemistry: Tetrasaccharide azides **3c** and **5c** (0.5 mM) was added to Qβ-alkyne (1 mg/ml) in 0.1 M potassium phosphate buffer pH 7. The following reagents were added sequentially: aminoguanidine (AG, 5 mM), mixture of $CuSO_4$:THPTA [tris(3-hydroxypropyltrazolylmethyl)amine] in a molar ratio of 1:5 (0.25 mM $CuSO_4$, 1.25 mM THPTA), and sodium ascorbate (5 mM). The reaction mixture was incubated at room temperature for 1 hrs. Samples Qβ-**3** and Qβ-**5** were analyzed and purified by size-exclusion chromatography (SEC) using a Superose6 column.



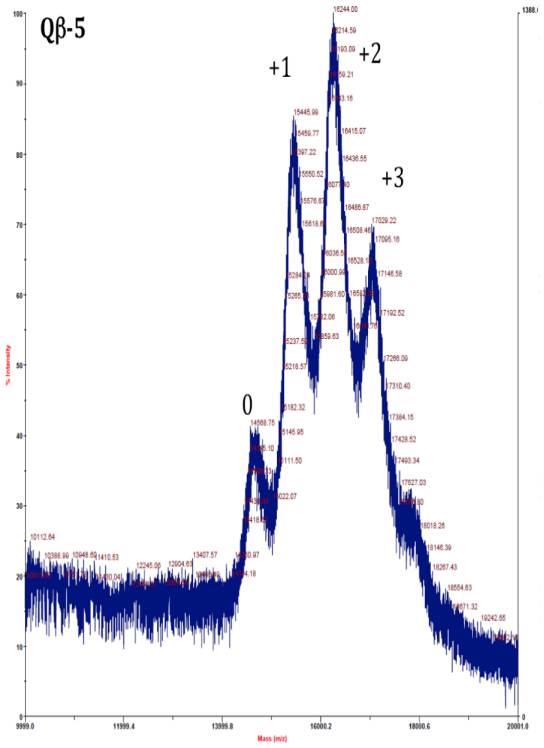


Figure S7a: MALDI spectra confirming modification of Qβ particles. The number above the peaks corresponds to the number of glycans attached to each subunit of the capsid.

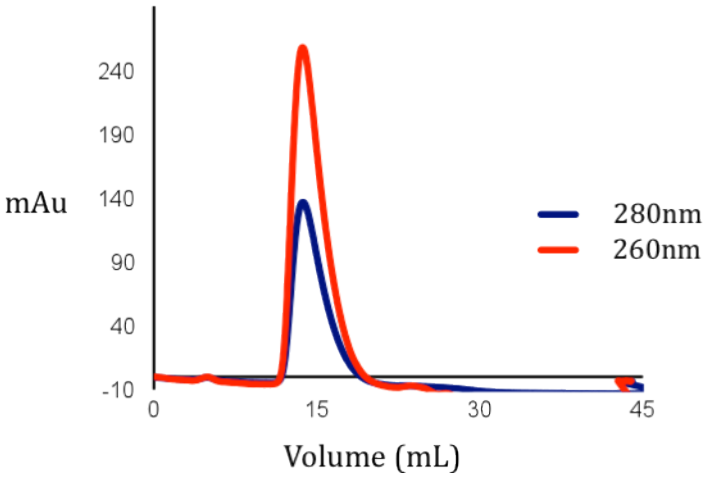


Figure S7b: Size-exclusion FPLC (Superose-6) trace showing the modified Qβ particles to be intact.

5. Serum Analysis:

2G12 binding ELISA to Qβ conjugates

Wells were coated with 250 ng of Qβ glycoconjugate overnight at 4 °C. Plates were

washed four times with PBS/0.05% (vol/vol) Tween 20 (Sigma), blocked for 1 h with 100 μL 5% non-fat milk/PBS/0.05% Tween 20. Serial dilutions of 2G12 in 5% non-fat milk/PBS/0.05% Tween 20 were incubated for 2 h. Unbound Ab was removed by washing four times as described above. Binding was detected with Goat anti-human-Fcγ AP conjugate (1:1000, Jackson ImmunoResearch, West Grove, PA) and *p*-nitrophenol phosphate substrate (Sigma) at 405 nm.

Immunisation protocol

New Zealand white rabbits were immunized at 4 week intervals with 50 μg of conjugate (based on protein content) with the adjuvant Alum in PBS (total of 4 immunisations and 4 rabbits per group). Blood was drawn 8 days after each immunisation. Rabbits 8143-8146 were immunised with Qβ-**3** and rabbits 8151-8154 were immunised with Qβ-**5**.

Serum ELISA

Wells were coated with 250 ng of gp120 JR-FL (Progenics, Tarrytown, NY) or 250 ng of glycoconjugate overnight at 4 °C. Plates were washed four times with PBS/0.05% (vol/vol) Tween 20 (Sigma), blocked for 1 h with 100 μL 5% non-fat milk/PBS/0.05% Tween 20. Serial dilutions of rabbit serum in 5% non-fat milk/PBS/0.05% Tween 20 were incubated for 2 h. Unbound Ab was removed by washing four times as described above. Binding was detected with Goat anti-rabbit-Fcγ AP conjugate (1:1000, Jackson ImmunoResearch, West Grove, PA) and *p*-nitrophenol phosphate substrate (Sigma) at 405 nm. The serum binding titres were calculated as the serum dilution that gave 50% of the maximum binding.

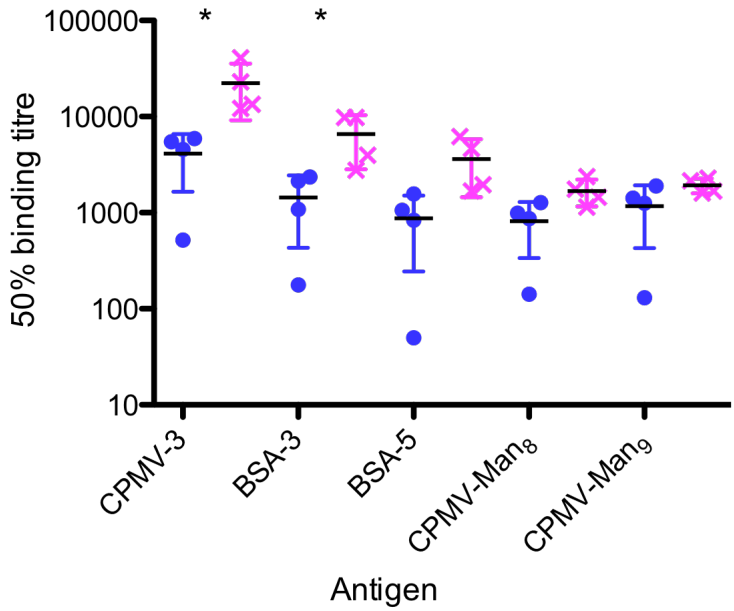


Figure S8a: 50% Maximum binding titre of serum against oligomannose glycocojugates elicited by immunization with Qβ-**3** and Qβ-**5** (measured by ELISA). Blue circles = Qβ-**3** and pink crosses = Qβ-**5**. Each group consists of 4 rabbits. * = $p < 0.05$ in t-test.

gp120 Binding ELISA

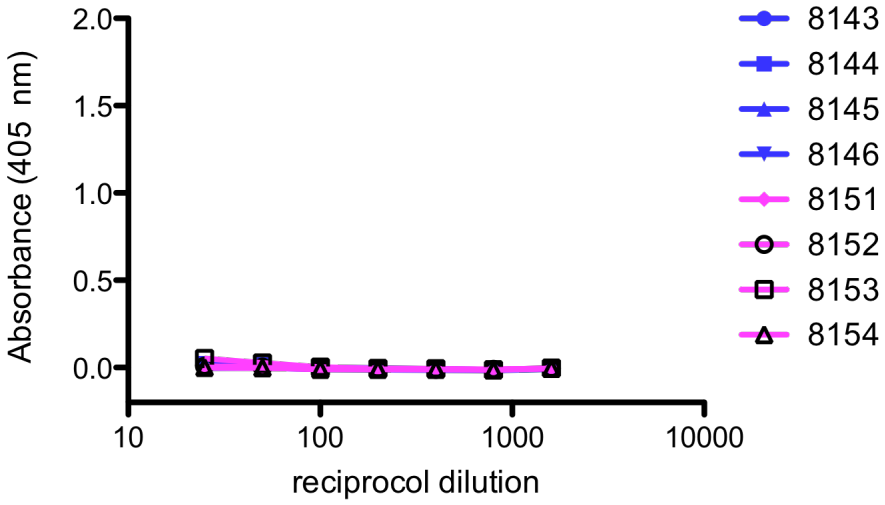


Figure S8: Binding to $gp120_{JR\text{-}FL}$ by rabbit serum from immunisation with glycoconjugates Qβ-**3** (blue) and Qβ-**5** (pink).

Neutralisation Assays

HIV-1 enveloped pseudovirus capable of single round infection was generated by cotransfection of HEK 293T cells with HIV Env expressing plasmid and pSG3ΔEnv as

previously described (24). Virus was harvested after 72 h. Serial dilutions of Ab were incubated with virus for 1h at 37 ºC before being added to TZM-bl cells. After 3 days the TZM-bl cells were lysed and luciferase assay run. Neutralisation activity was measured by reduction in RLU compared to virus only controls.

HIV-1 pseudovirus neutralisation assay:

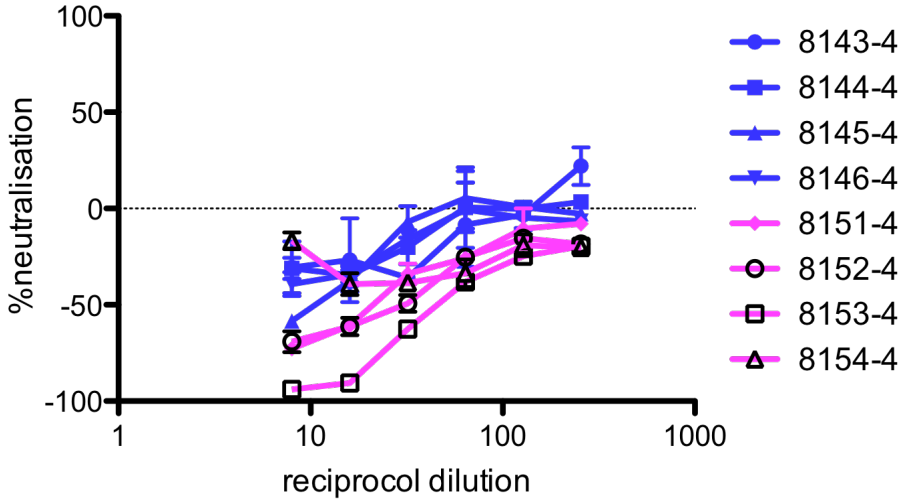


Figure S9: HIV-1 Neutralisation activity of serum from rabbits immunised with Qβ-**3** (blue) and Qβ-**5** (pink).

Time Course of IgG production:

Titres of antibodies against CPMV-**3** were measured by ELISA after each immunisation. Both immunogens have a similar trend in antibody production over the immunisation schedule. However, the non-self immunogen Qβ-**5** does produce overall higher titres of Man_4 specific antibodies.

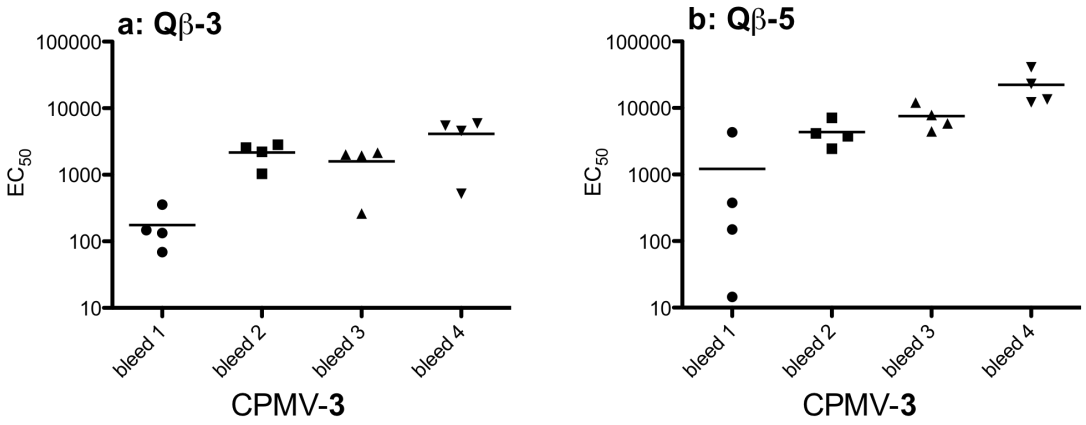


Figure S10: Time course of antibody production against CPMV-**3**.

Linker reactivity:

The CPMV-Man_1 glycoconjugate was used to estimate the antibody titres against the linker joining the carbohydrate to the virus scaffold. The antibody titres against both CPMV-**3** and CPMV-Man_1 were measured by ELISA. Serum was also depleted of linker reactivity by incubating the serum overnight with CPMV-Man_1 glycoconjugates. Antibody titres against both CPMV-**3** and CPMV-Man_1 were then re-assessed by ELISA. The difference in antibody titres against CPMV-**3** for the depleted and undepleted serum were very similar suggesting the CPMV-**3** specific antibodies are not directed against the linker component.

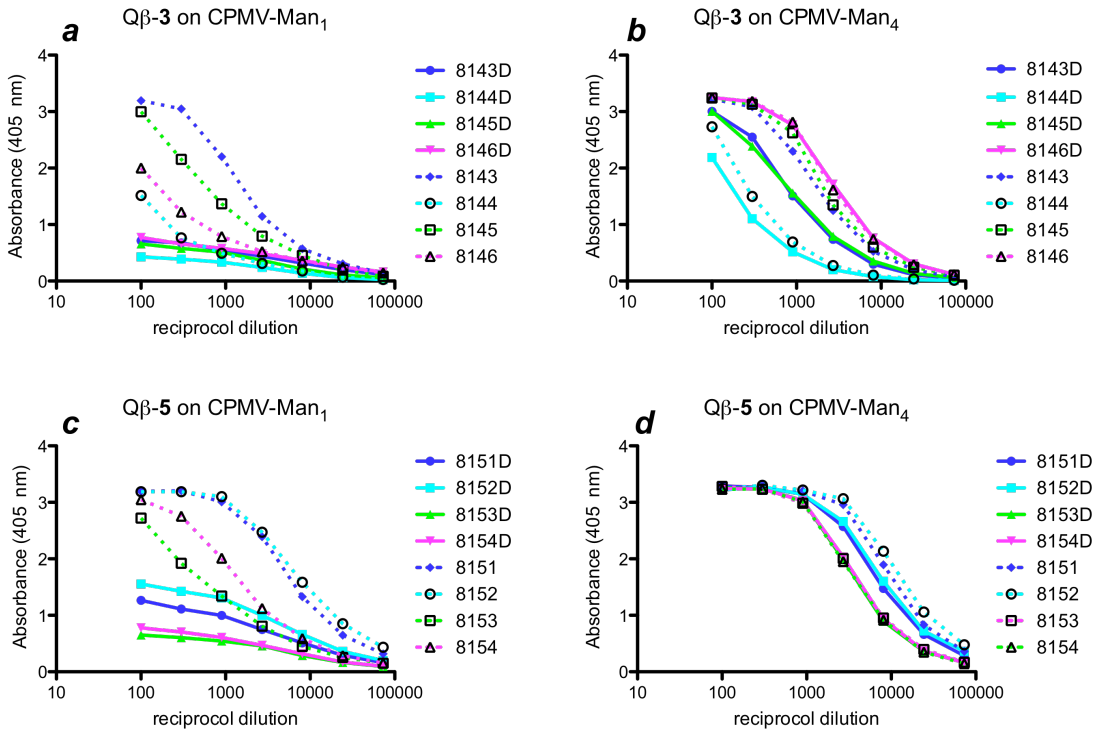


Figure S11: Antibody titres against CPMV-**3** and CPMV-Man$_1$ with and without depletion with CPMV-Man$_1$. a) Qβ-**3** serum on CPMV-Man$_1$; b) Qβ-**3** serum on CPMV-**3**; c) Qβ-**5** serum on CPMV-Man$_1$ and d) Qβ-**5** serum on CPMV-**3**. D= serum depleted with CPMV-Man$_1$.

6. Crystal structure determinations and analyses:

Fab 2G12 fragments were prepared as previously described (22) and concentrated to 20 mg/ml. For each complex, the solid sugar ligand was added to the Fab solution to saturation. For crystallization, equal volumes of protein/sugar and reservoir solution (0.3 μL) were mixed in sitting-drop vapor-diffusion experiments. Fab 2G12/D-fructose crystals were grown with a reservoir solution of 2.5 M sodium malonate (pH 5.5) whereas C-6 methyl monosaccharide **10** cocrystals were grown with 30% polyethylene glycol (PEG) 3350 and 0.5 M ammonium iodide (pH 8.5); and, C-6''' methyl tetrasaccharide **5** cocrystals were grown with 15% PEG 4000 and 0.5 M ammonium formate (pH 7.5). The monosaccharide **10** and tetrasaccharide **5** cocrystals were cryoprotected with 5% and 25% glycerol, respectively, and the D-fructose co-crystals were cryoprotected with 3.4 M sodium malonate. Data were collected at 100 K, at the Advanced Light Source beamlines 5.0.3 and 8.2.1, and Advanced Photon Source

beamline 23IDB (λ ~ 1.0 Å), and indexed, integrated, and scaled using HKL2000 (25). Data collection and refinement results are summarized in Table S1.

The structures were solved by molecular replacement using the 1.75 Å structure of Fab 2G12 ((22) Protein Data Bank ID code 1OP3) as the starting model for Phaser (26). The asymmetric unit of all the cocrystals consisted of two Fab plus sugar complexes. Model building was performed with COOT (27) and refined with Refmac5 using TLS refinement (26, 28) and with Buster (29). The same R_{free} test-set (5%) was maintained throughout the refinement of all the structures. Total B-factors were calculated using TLSANL (26, 30). $F_o - F_c$ simulated annealing omit maps were calculated using CNS (Version 1.1) (31). Molecular topologies for Refmac5, Buster and CNS were generated using PRODRG (32). Potential H bonds were evaluated using the program HBPLUS (33), with some modifications. Buried molecular surface areas and van der Waals contacts were measured using the programs MS (34) and CONTACTSYM (35), respectively, with some modifications (36).

Table S1: Data collection and refinement statistics

	2G12/D-fructose	2G12/C-6 methyl monosaccharide **10**	2G12/C-6 methyl tetrasaccharide **5**
Data collection			
Space group	$P2_12_12_1$	$P2_1$	$P2_12_12_1$
Cell dimensions			
a, *b*, *c* (Å)	77.91, 93.26, 169.60	72.62, 72.09, 84.07	44.74, 131.16, 169.53
α, β, γ(°)	90, 90, 90	90, 95.8, 90	90, 90, 90
Resolution (Å)	50-1.95 (2.02-1.95)*	50-1.75 (1.81-1.75)	50-2.85 (2.95-2.85)
R_{sym}	6.7 (30.0)	8.1 (39.3)	10.3 (44.8)
$I / \sigma I$	15.1 (3.0)	11.3 (2.5)	11.5 (2.4)
Completeness (%)	89.5 (67.5)	98.4 (97.5)	88.4 (61.8)
Redundancy	3.2 (2.6)	3.2 (2.6)	5.1 (5.0)
Refinement			
Resolution (Å)	30-1.95	30-1.75	30-2.85
No. reflections (test)[#]	77,022(4103)	81,209(4297)	21,374(1045)
R_{cryst} / R_{free}	18.2/22.3	17.6/21.8	23.2/28.0
No. atoms			
Protein	6655	6776	6535
Ligand	24	28	92
Water	565	1003	8
B-values			
Protein	47.7	23.3	79.2
Ligand	35.0	22.5	72.8
Water	47.5	24.4	53.6
R.m.s. deviations			
Bond lengths (Å)	0.015	0.013	0.009
Bond angles (°)	1.58	1.51	1.19
Ramachandran statistics[~] (%)			
Most favoured regions	88.8	90.4	87.9
Additional allowed regions	10.6	9.0	11.0
Generously allowed	0.3	0.3	0.8
Disallowed regions[^]	0.3	0.3	0.3
Other			

Data were collected from a single crystal for each structure.
*Values in parentheses are for the highest-resolution shell.
[#]Test set of reflections for calculation of R_{free}.
[~]Calculated using PROCHECK (29). [^]Residue L51 of both Fab molecules in the asymmetric unit is in a well-defined γ turn in almost all other antibody structures, but is incorrectly flagged by PROCHECK as an outlier.

6. References:

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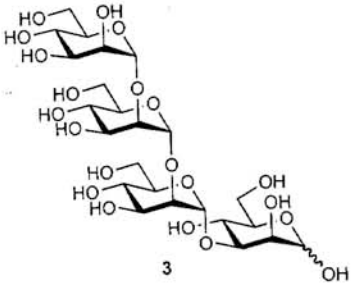

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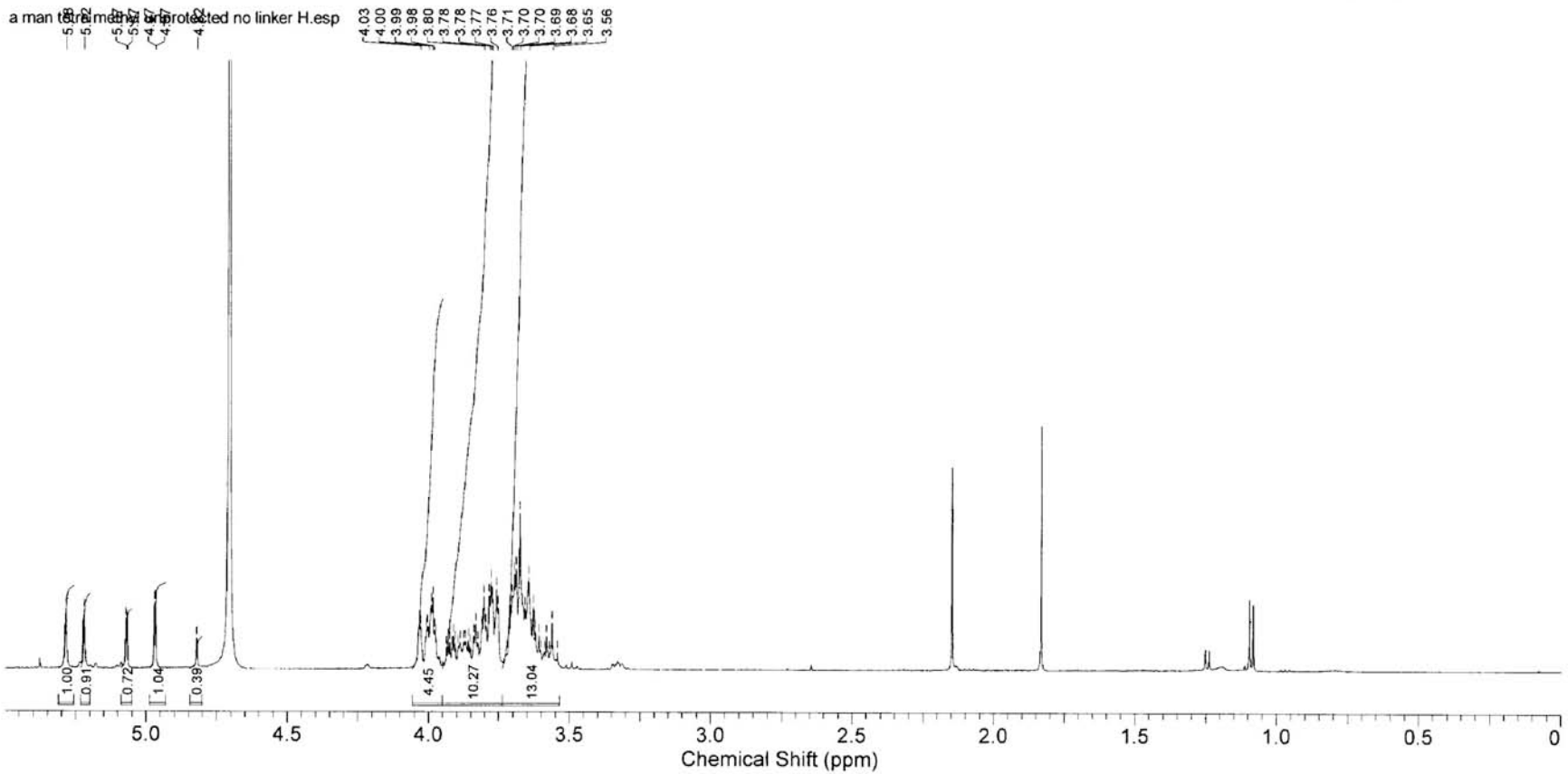

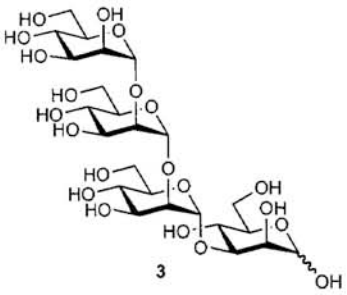

3

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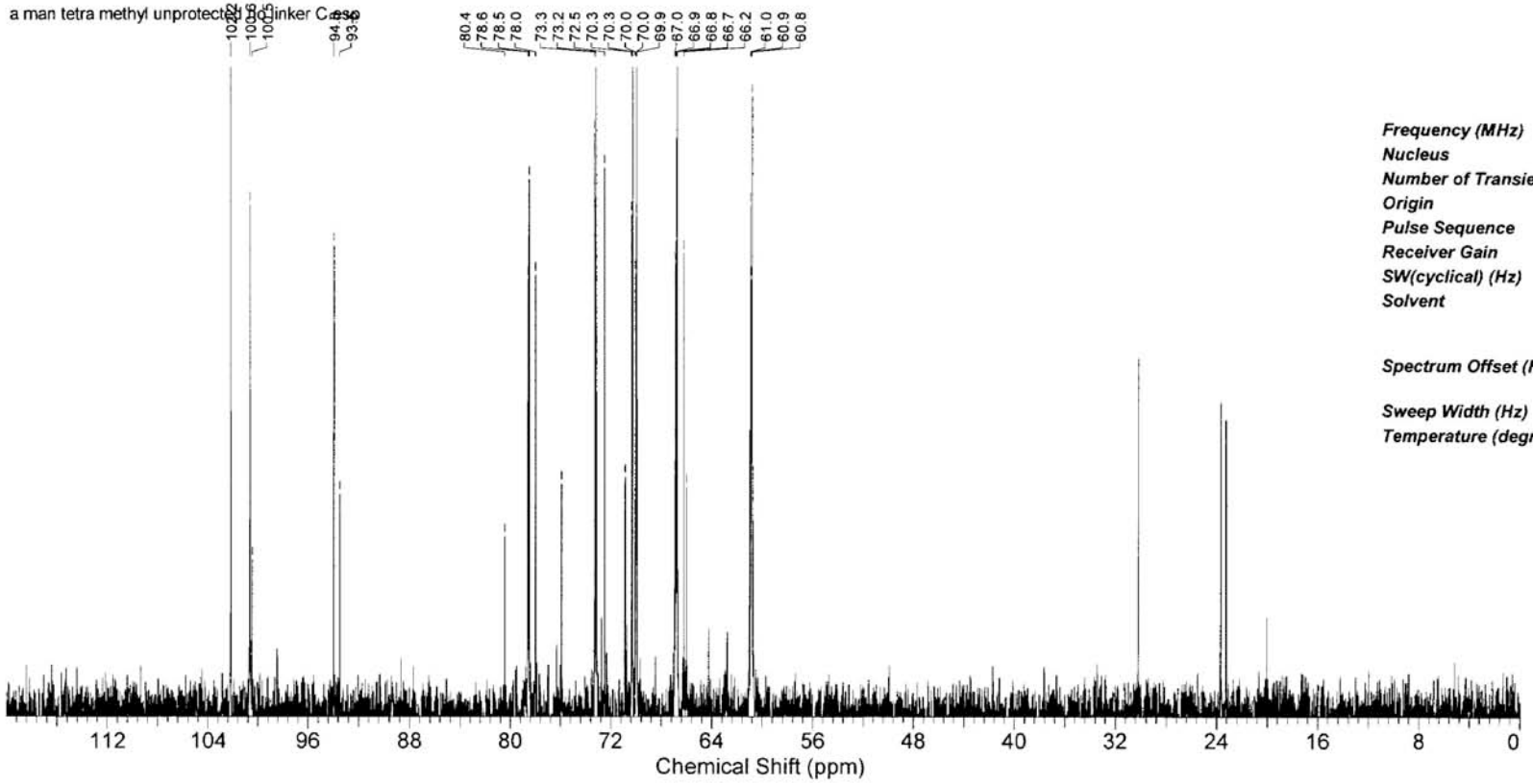

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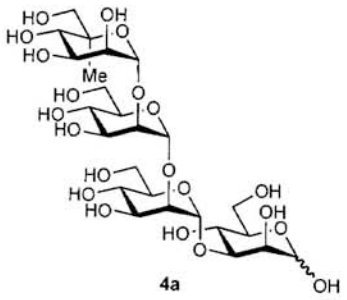

4a

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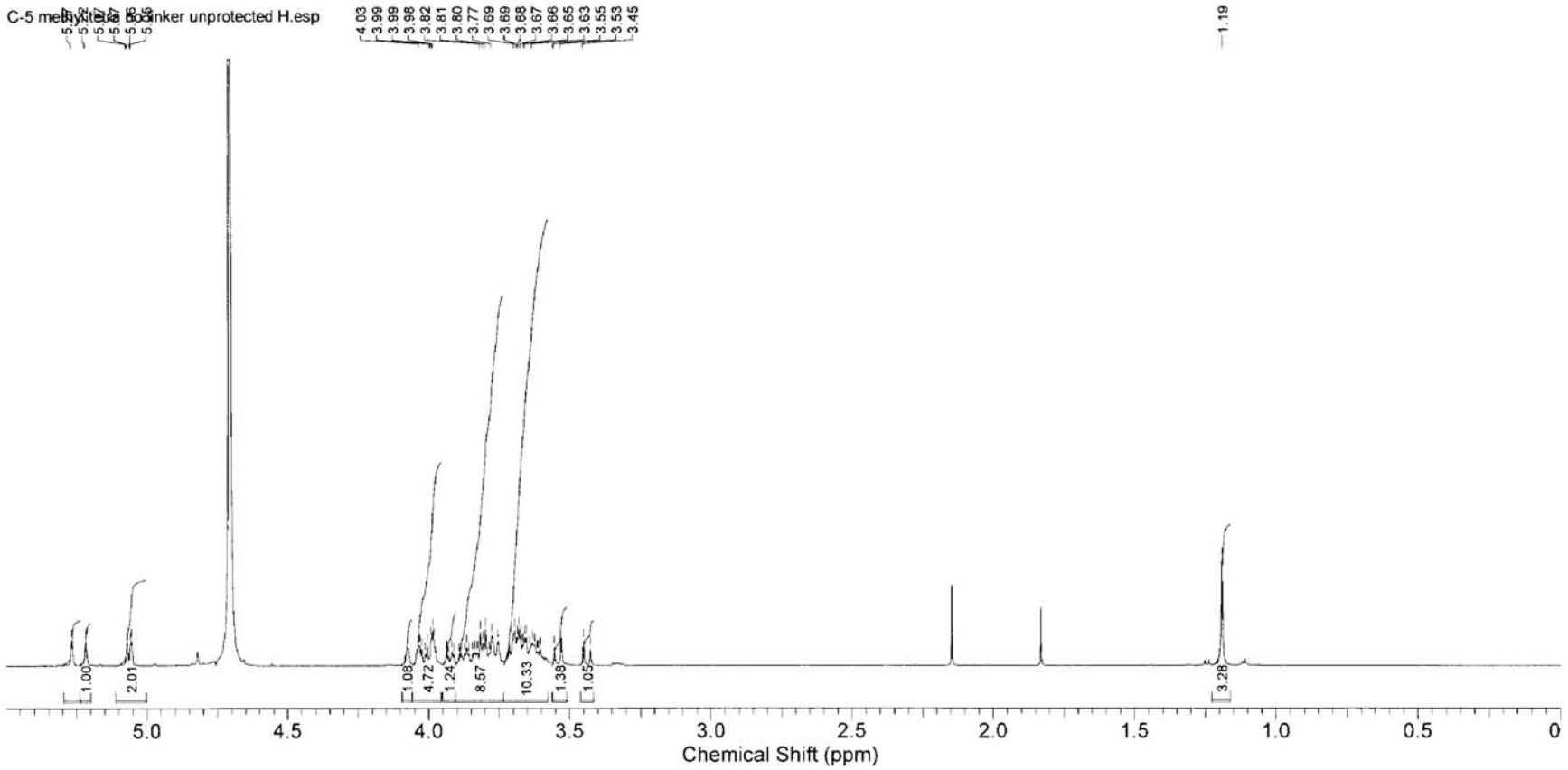

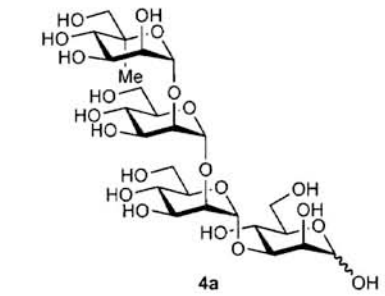

4a

C-5 methyl tetra no linker unprotected C.esp

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78.1
77.9
75.9
73.3
72.5
70.9
70.5
70.3
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66.9
66.8
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66.3
60.9
60.8
18.2

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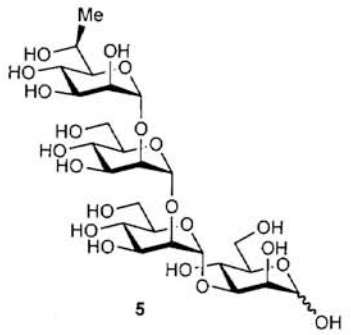
Chemical Shift (ppm)



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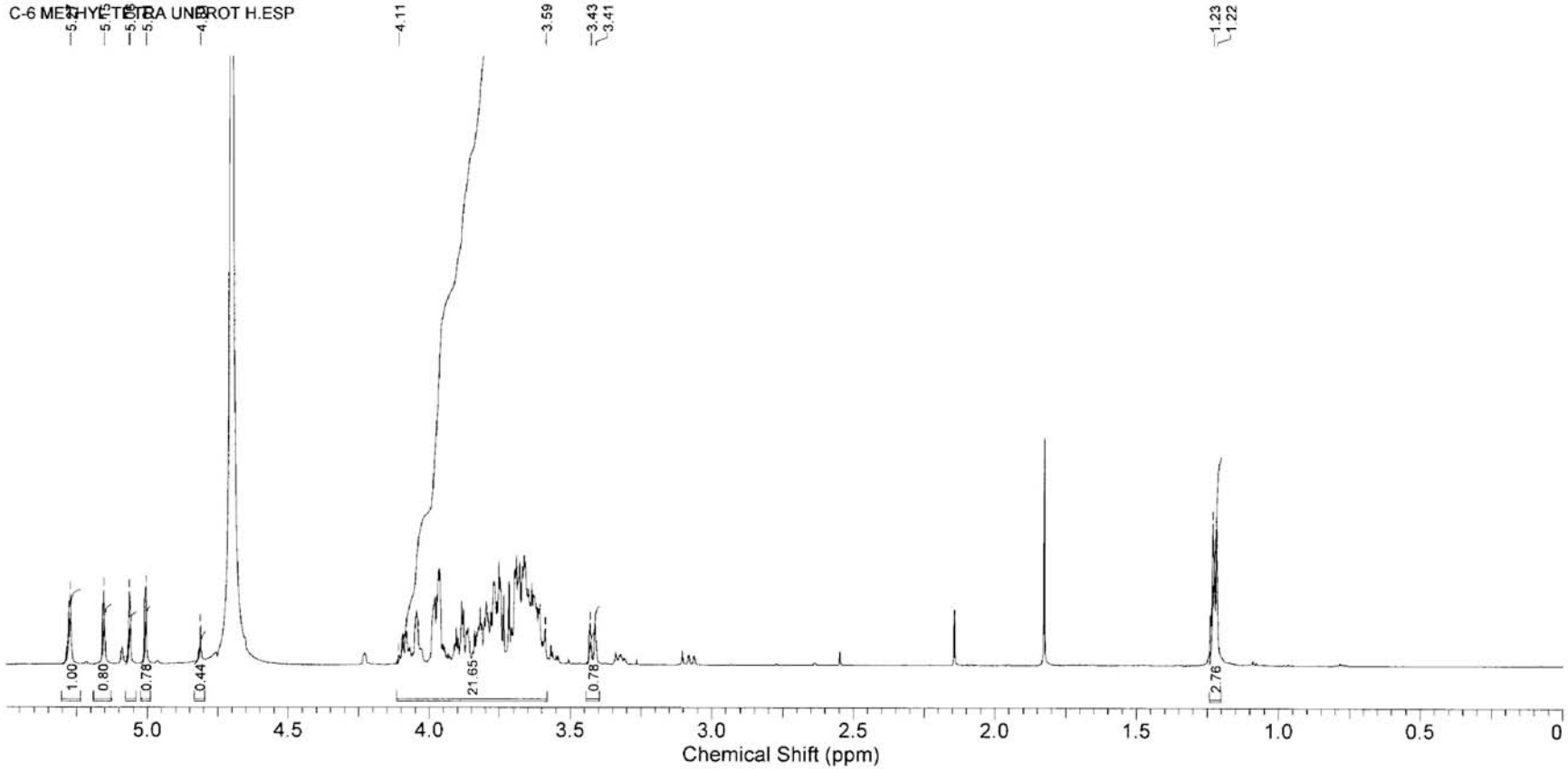
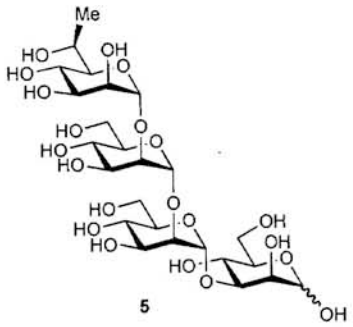
C-6 METHYL TETRA UNEROT H.ESP





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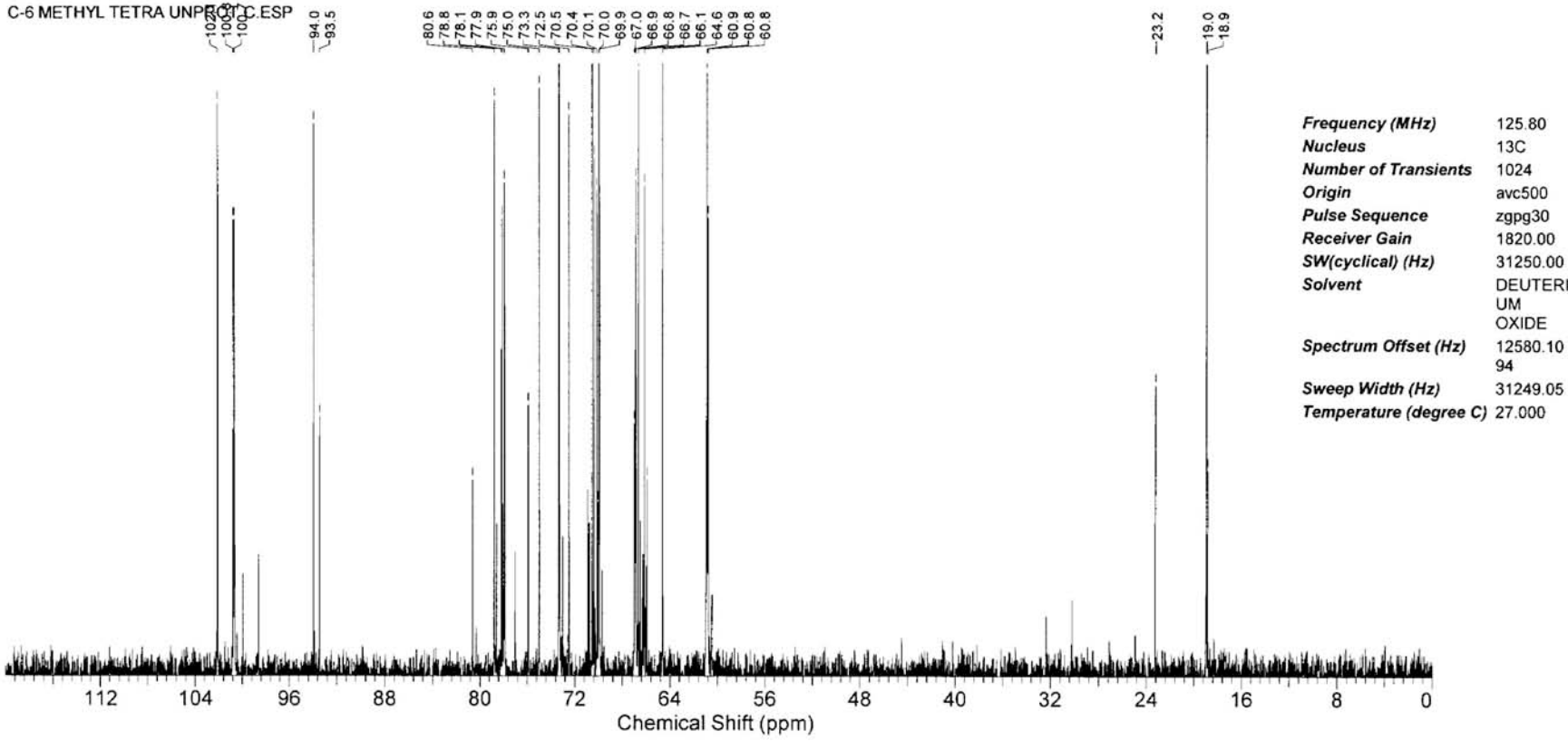

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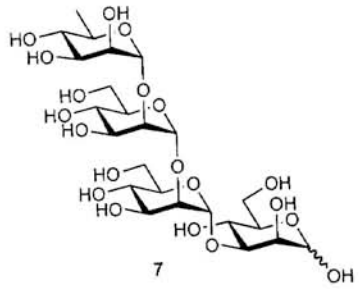

7

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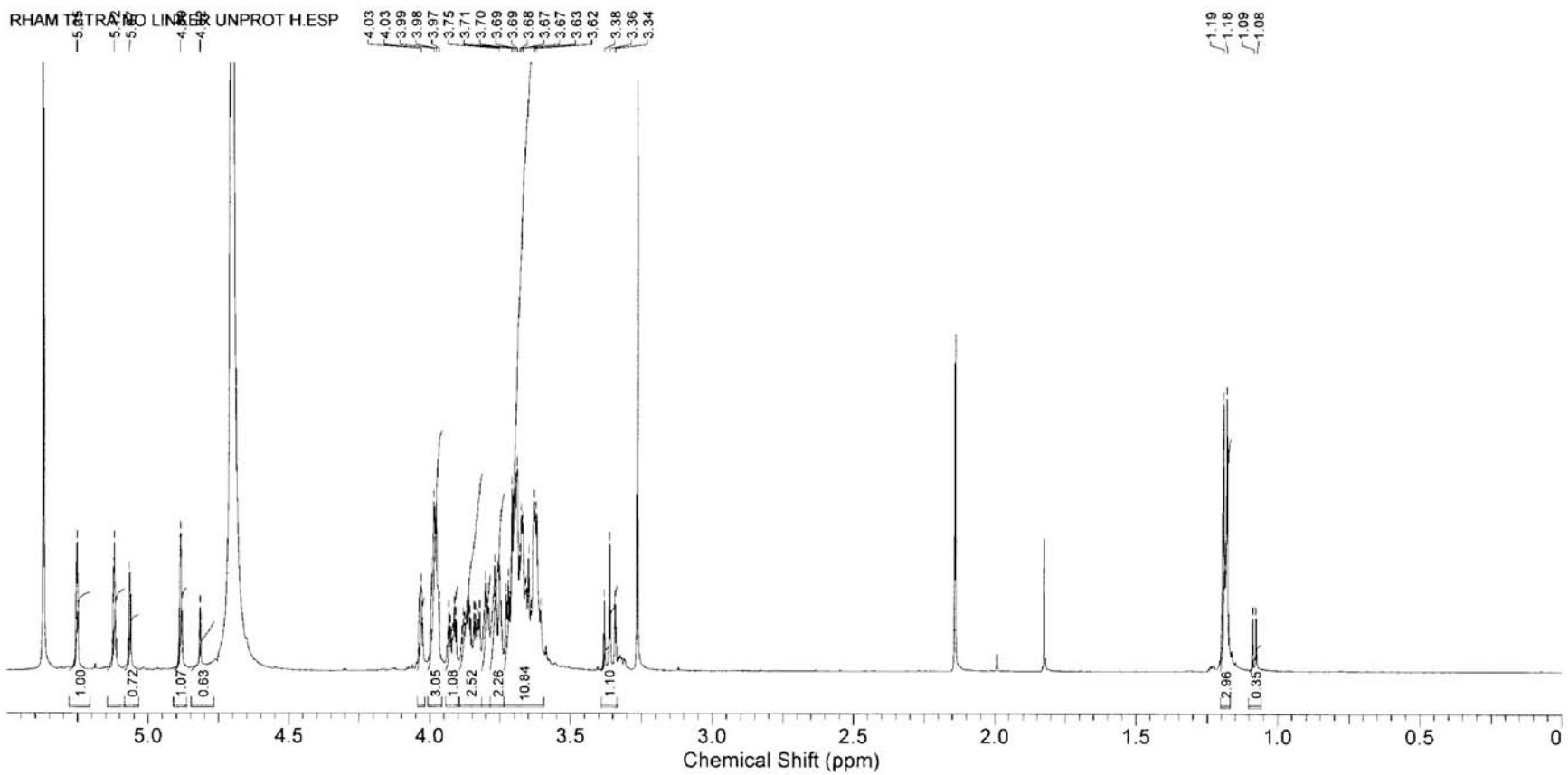
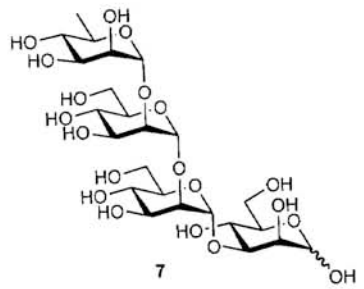
RHAM TETRA NO LINKER UNPROT H.ESP





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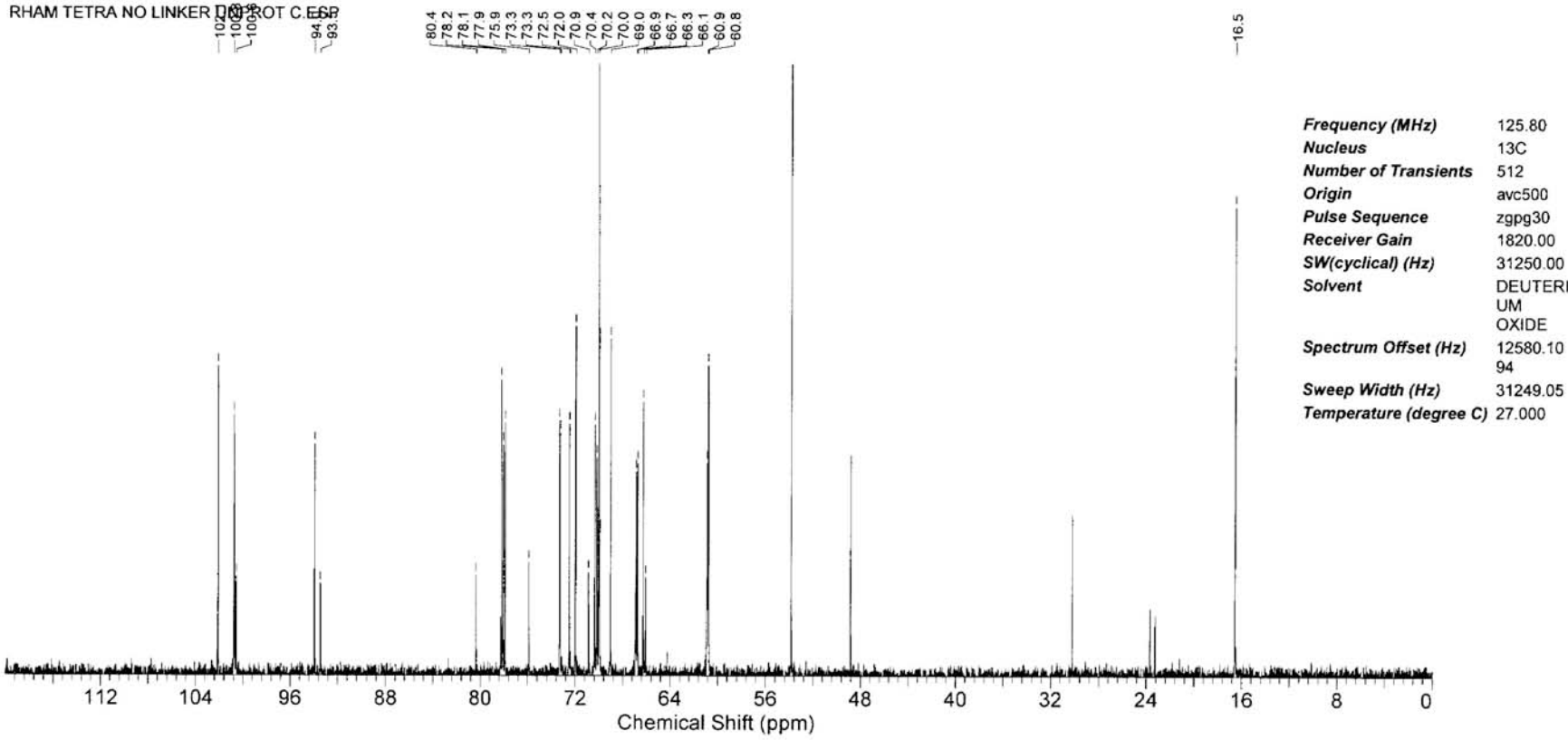

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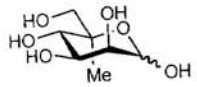

9a

methyl monomer H.esp

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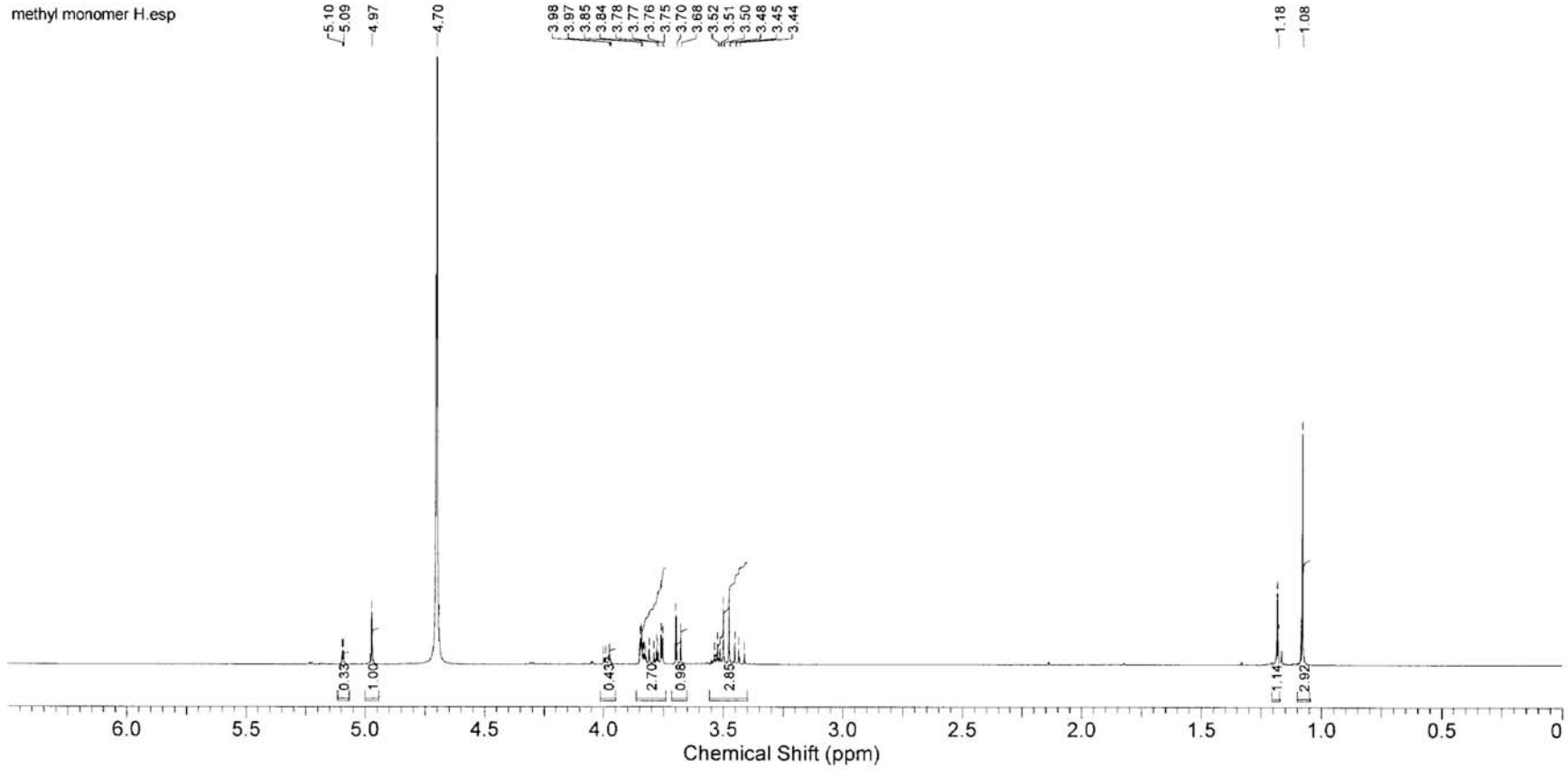

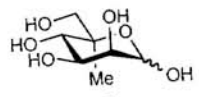

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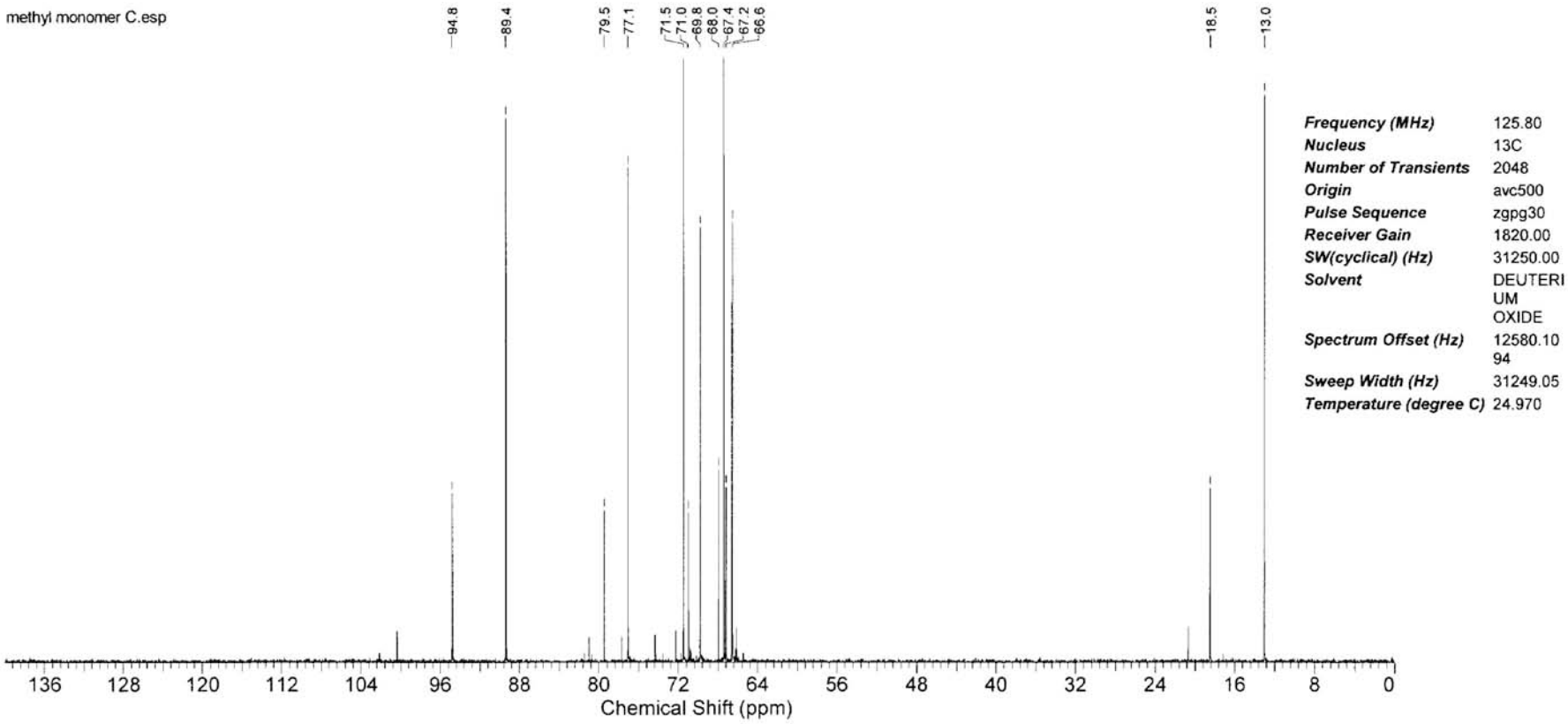
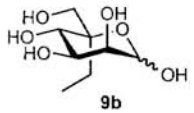
methyl monomer C.esp



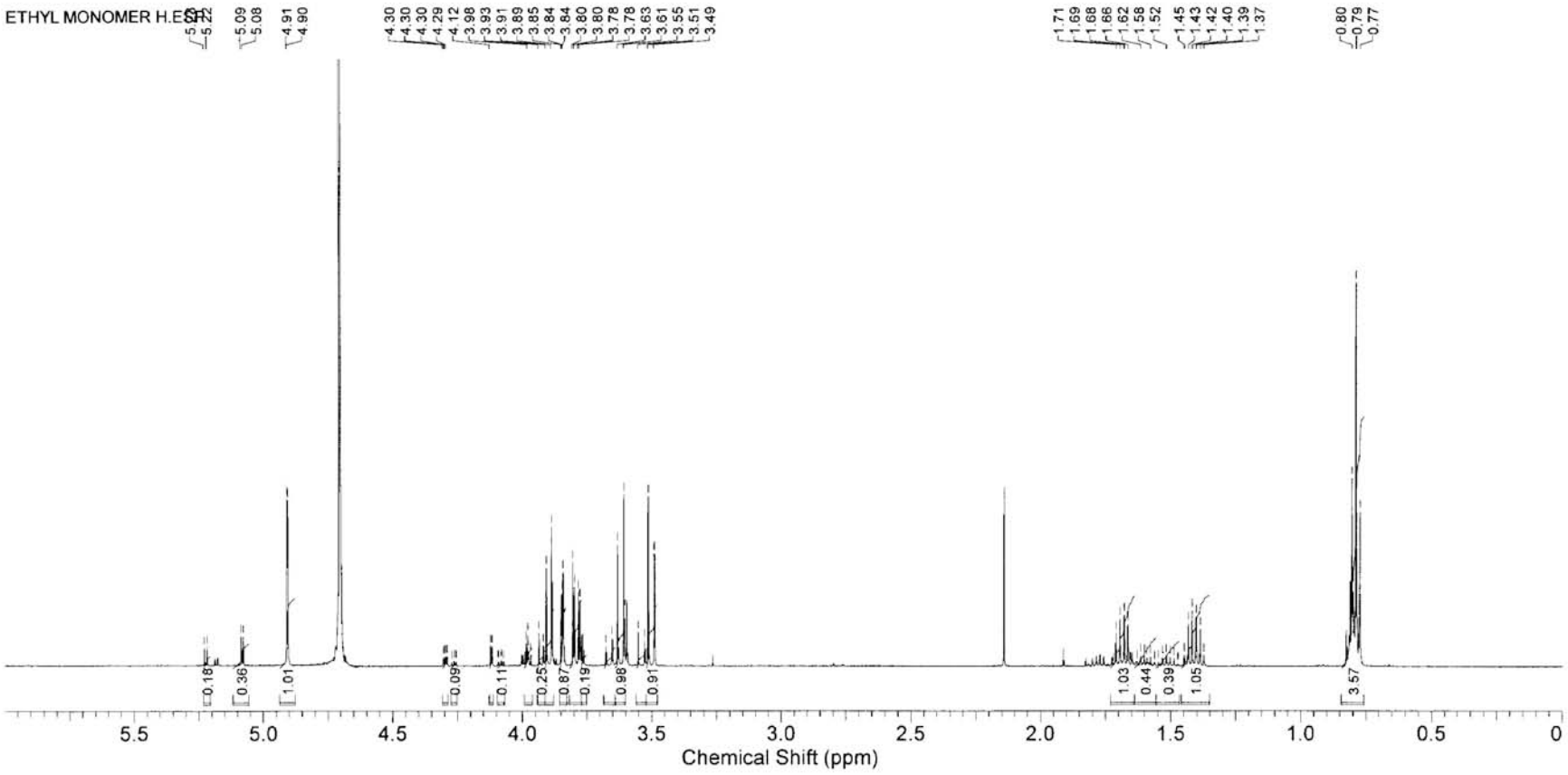
Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	2048
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1820.00
SW(cyclical) (Hz)	31250.00
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	12580.1094
Sweep Width (Hz)	31249.05
Temperature (degree C)	24.970

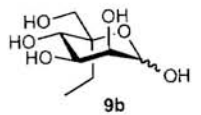
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	3089.6072
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970



9b

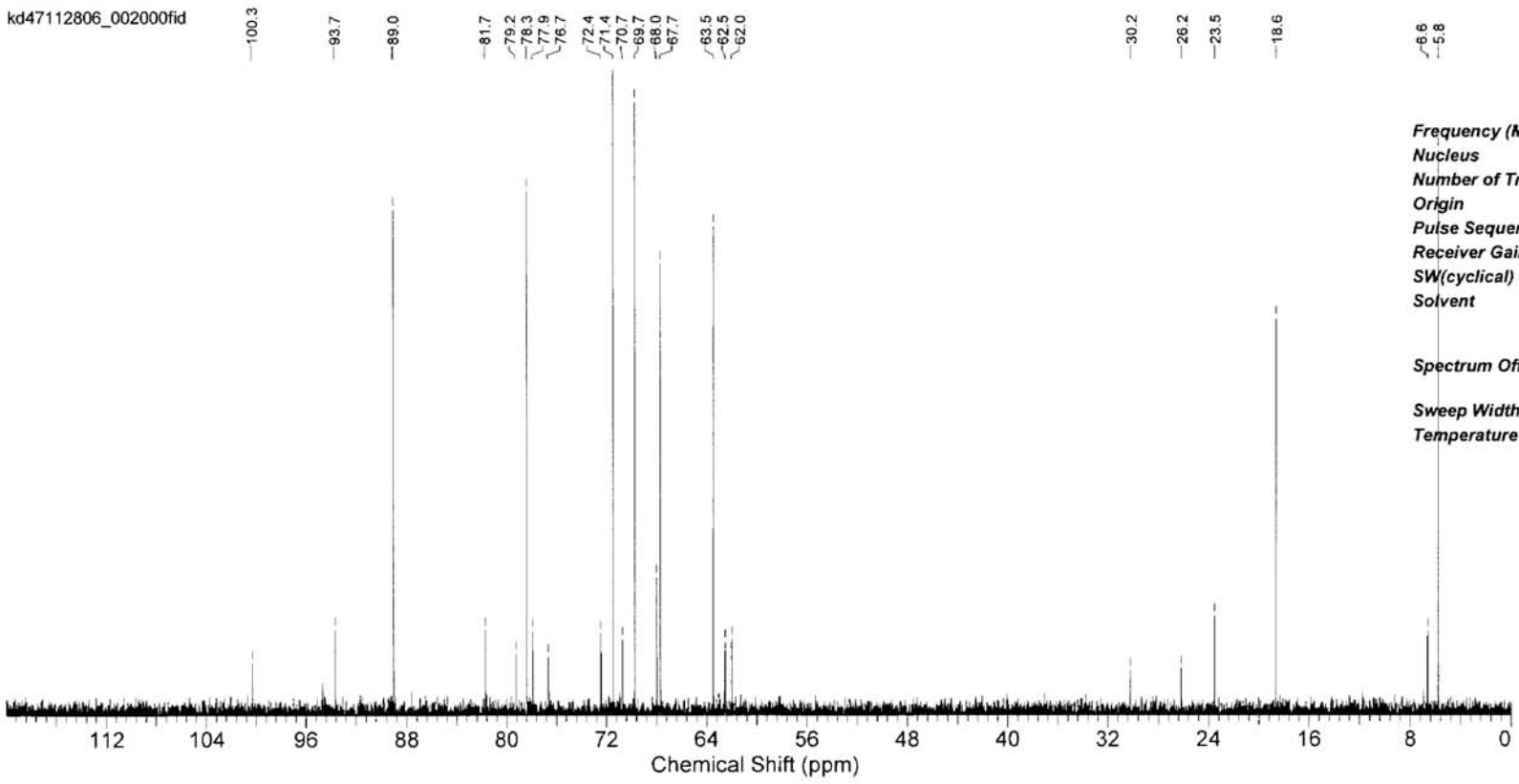
ETHYL MONOMER H.ESR



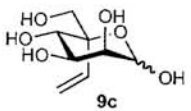


9b

kd47112806_002000fid



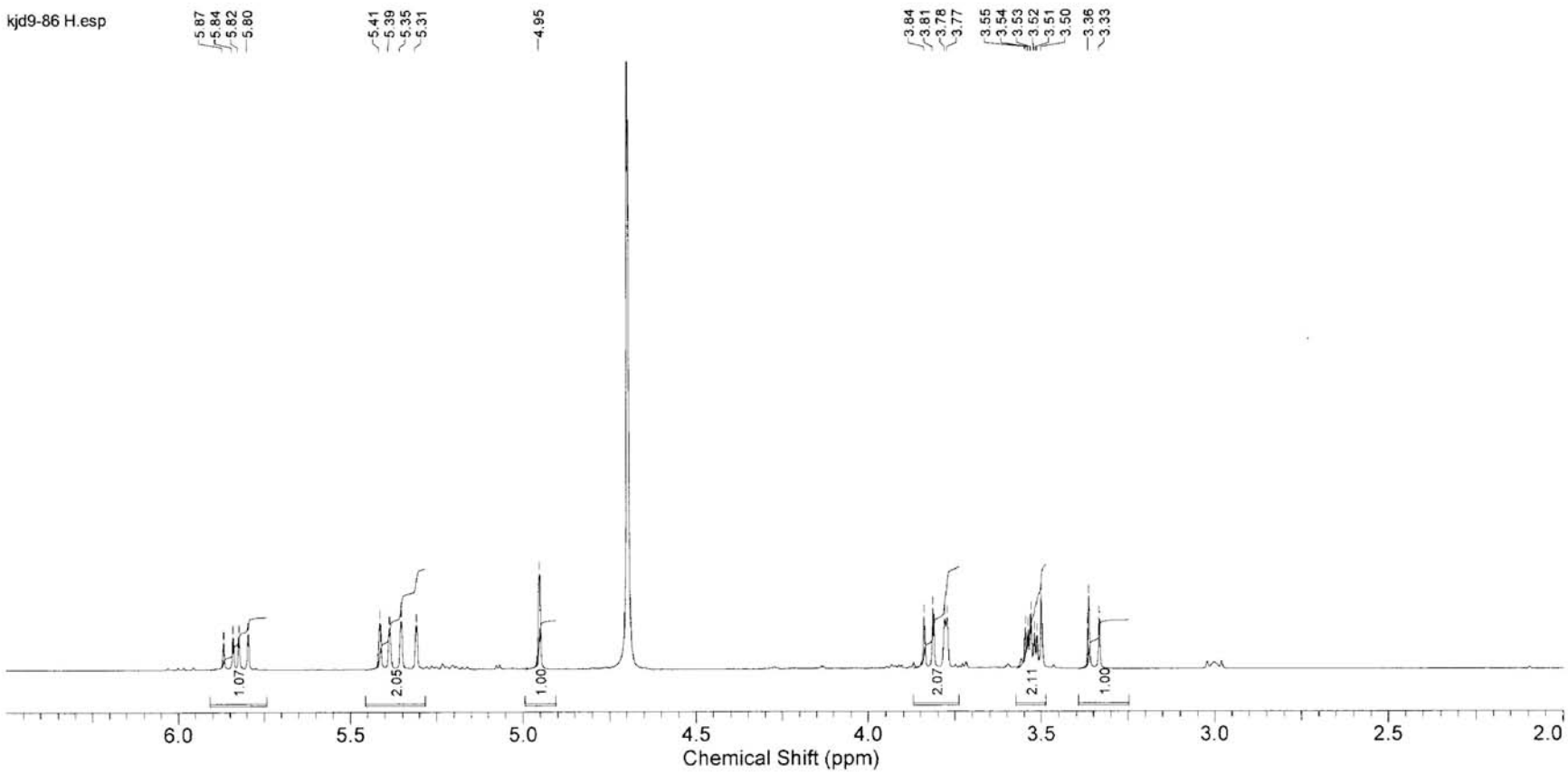
Frequency (MHz)	125.81
Nucleus	13C
Number of Transients	256
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1620.00
SW(cyclical) (Hz)	31250.00
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	12582.9307
Sweep Width (Hz)	31249.05
Temperature (degree C)	24.970

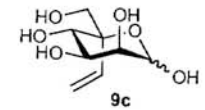


9c

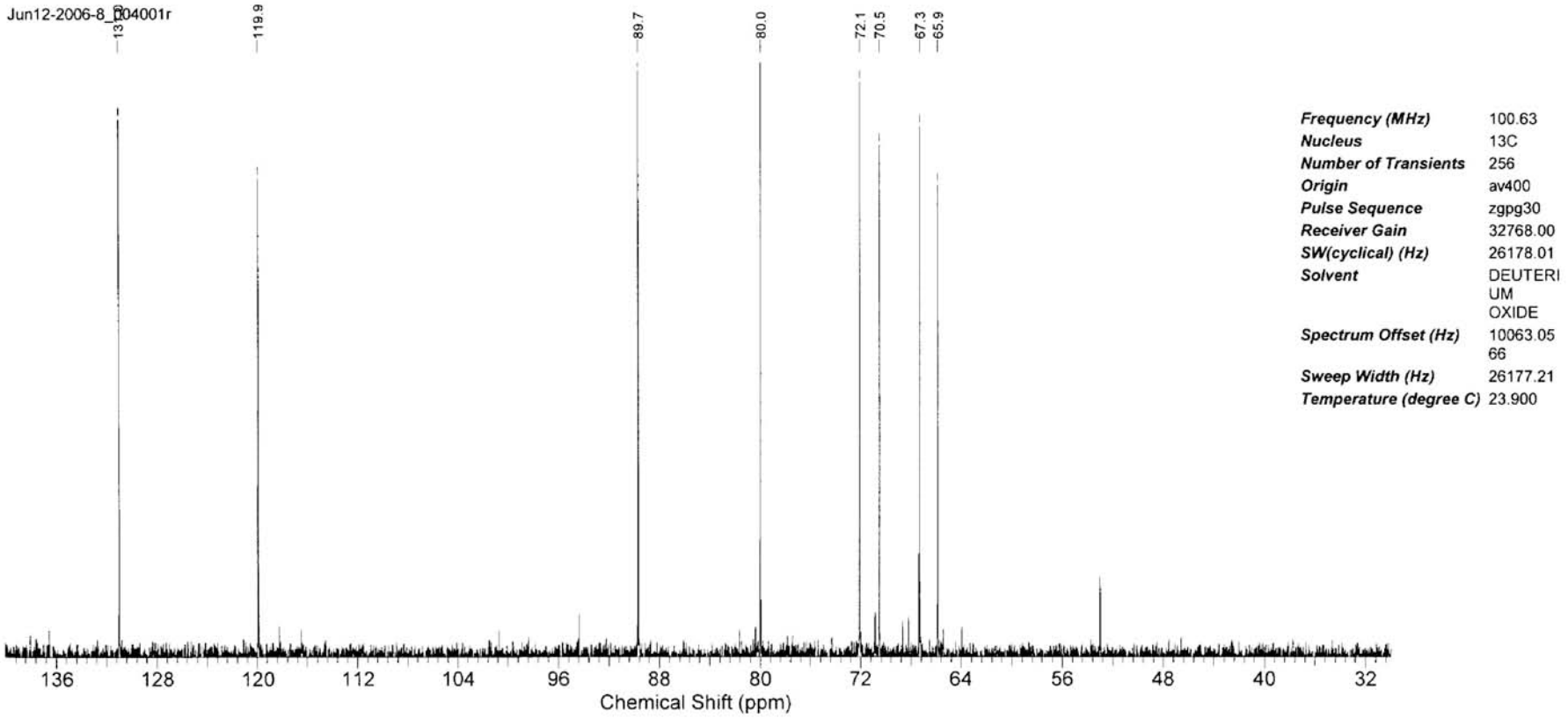
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	2471.3989
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.500

kjd9-86 H.esp

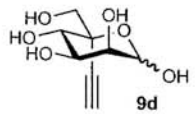




9c



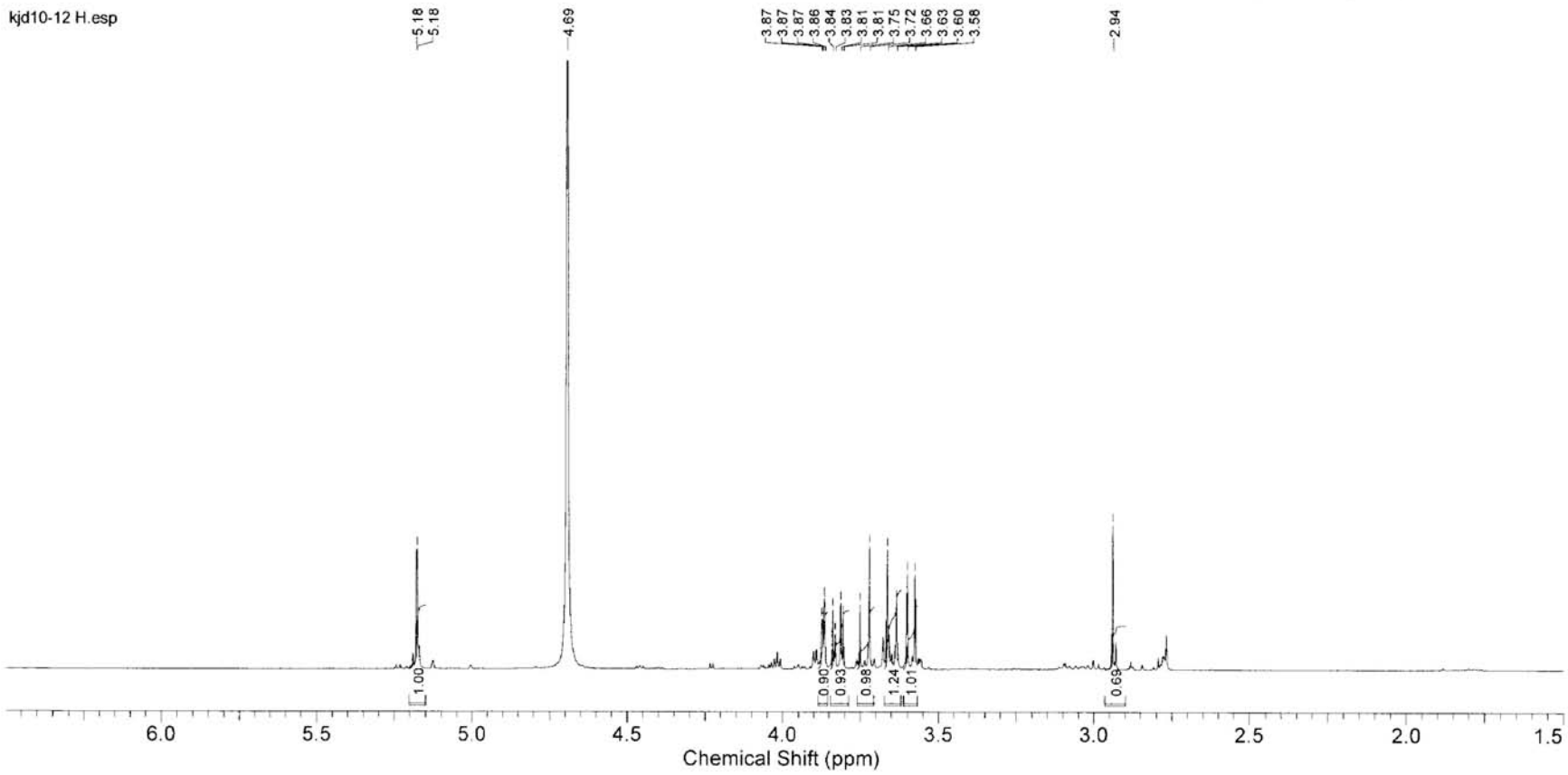
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	10063.0566
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.900

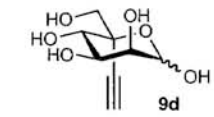


9d

kjd10-12 H.esp

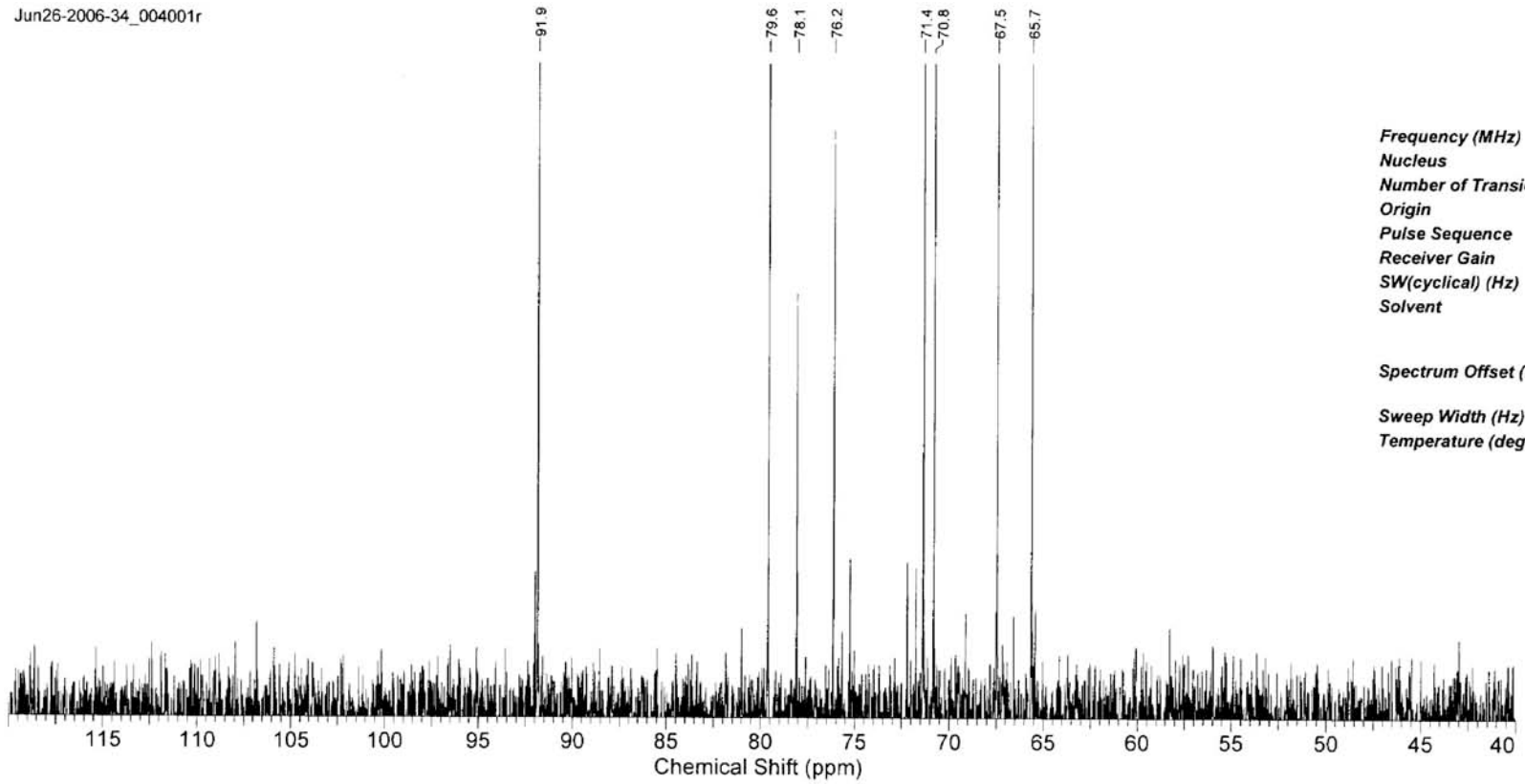
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	143.70
SW(cyclical) (Hz)	8278.15
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	2471.3989
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.100





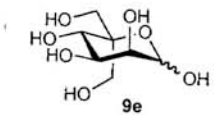
9d

Jun26-2006-34_004001r



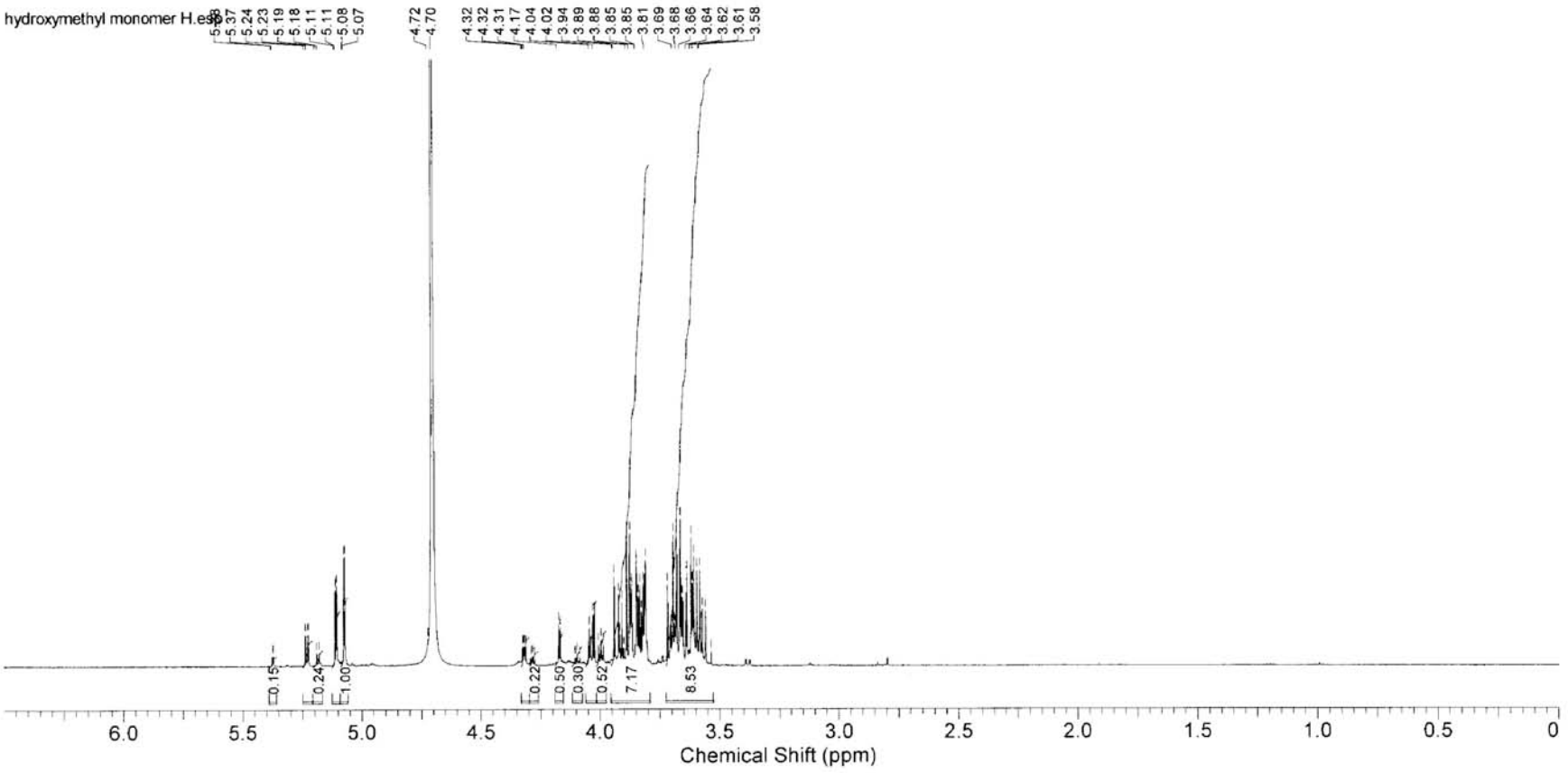
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	10063.0566
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.000

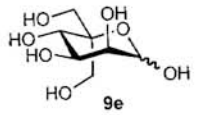
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	3089.6072
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970



9e

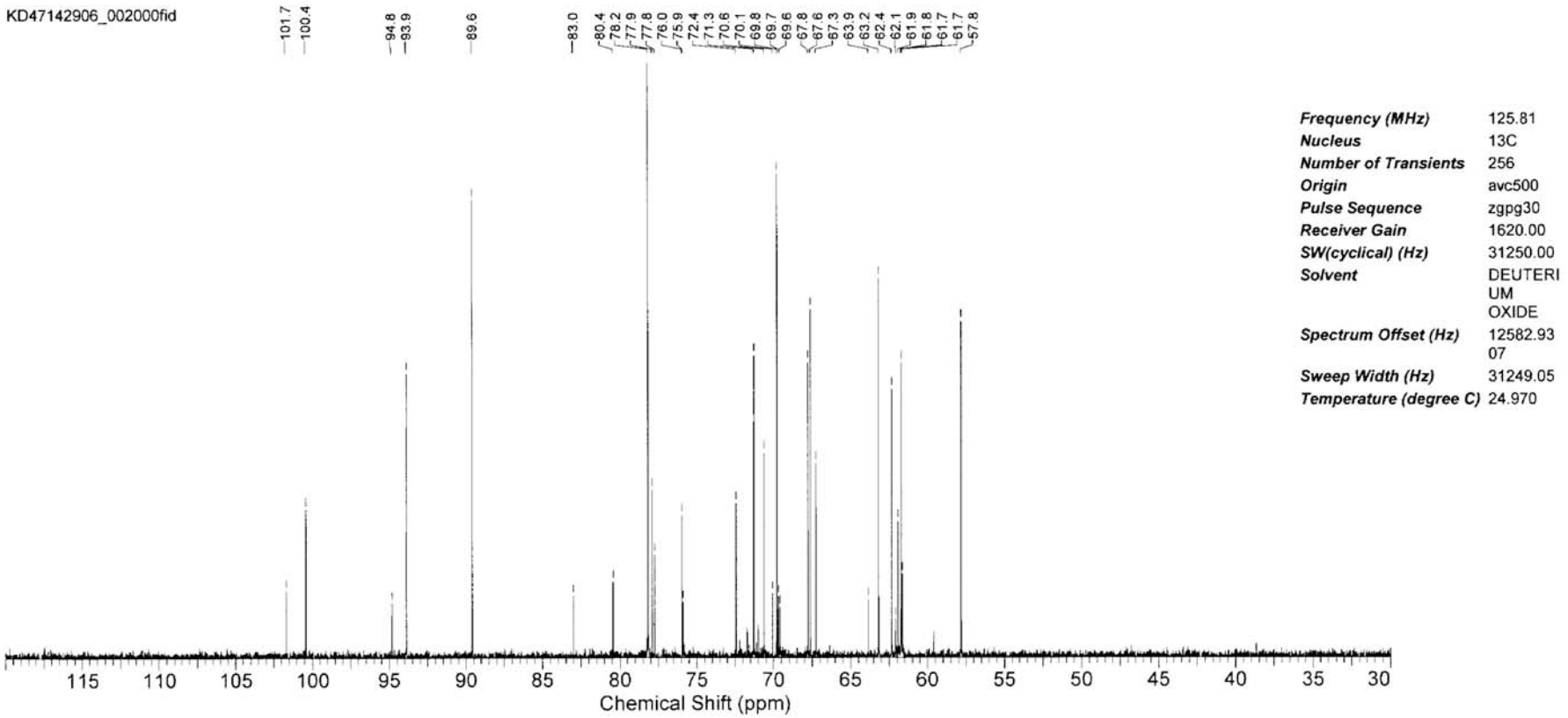
hydroxymethyl monomer H.esp



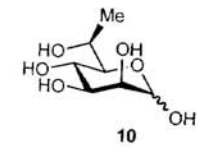


9e

KD47142906_002000fid



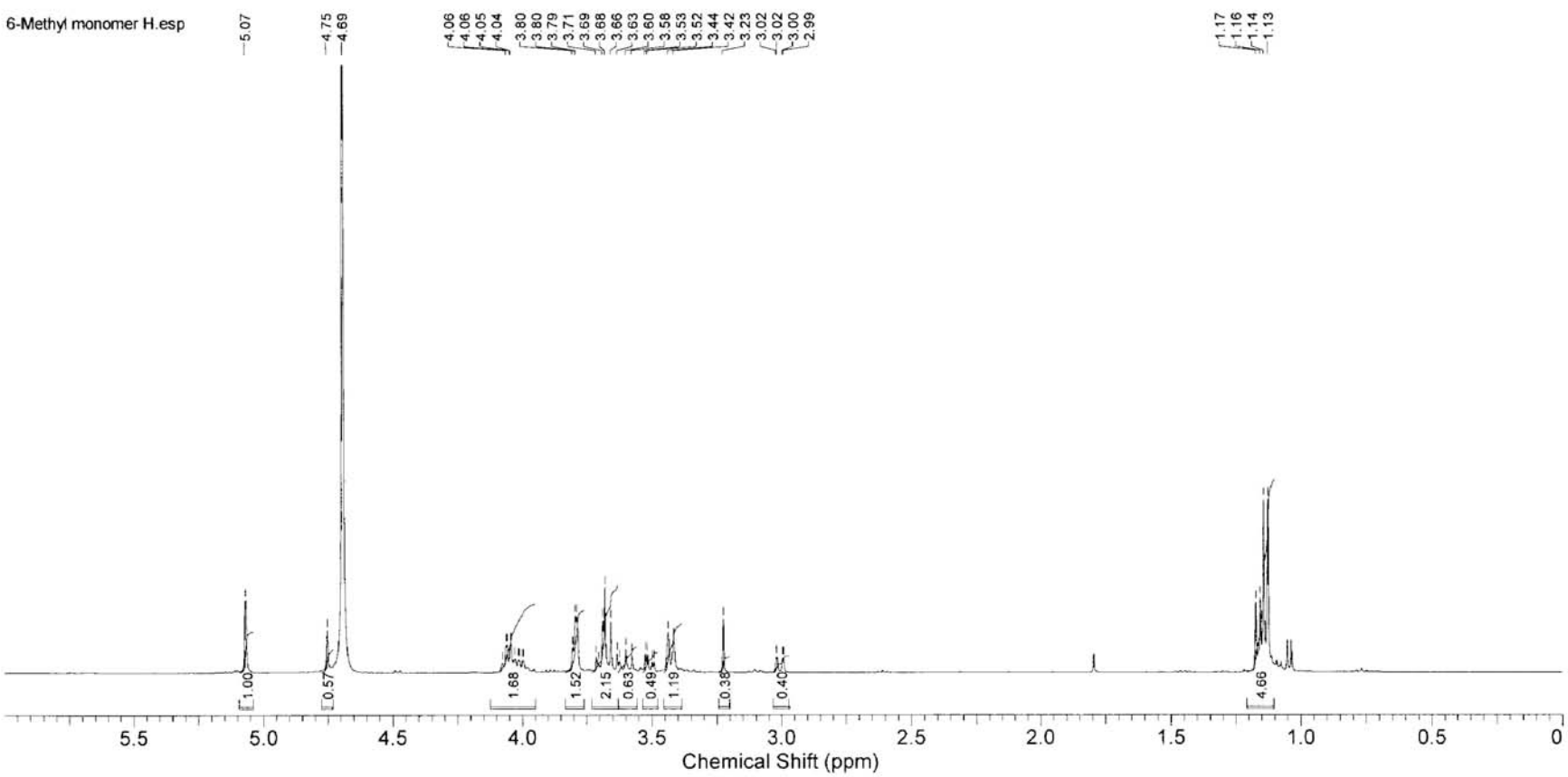
Frequency (MHz)	125.81
Nucleus	13C
Number of Transients	256
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1620.00
SW(cyclical) (Hz)	31250.00
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	12582.9307
Sweep Width (Hz)	31249.05
Temperature (degree C)	24.970

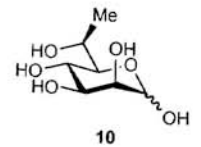


10

6-Methyl monomer H.esp

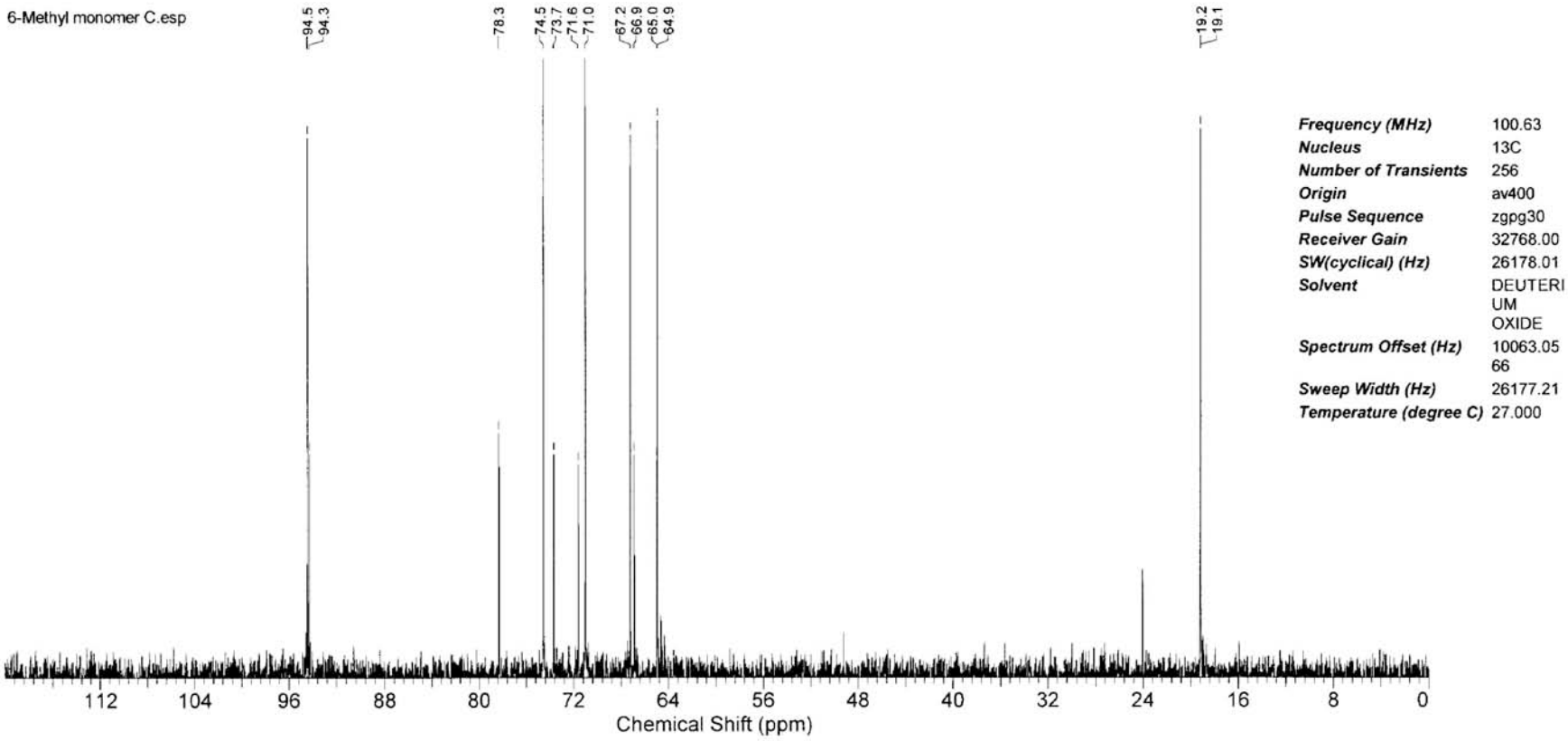
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	40.30
SW(cyclical) (Hz)	8278.15
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	2471.3989
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000



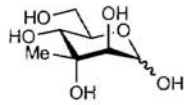


10

6-Methyl monomer C.esp



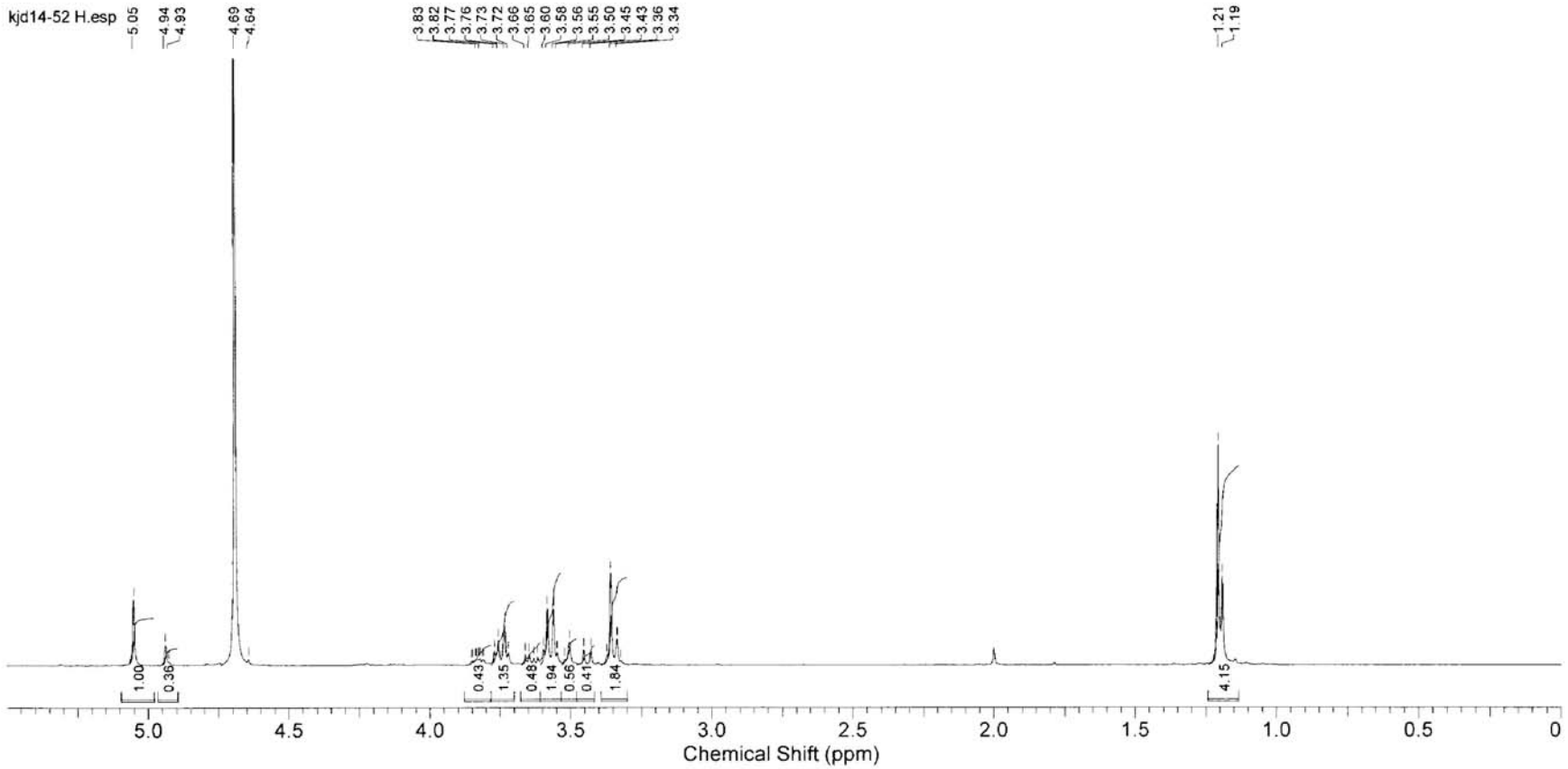
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	10063.0566
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000

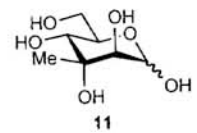


11

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	2471.3989
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000

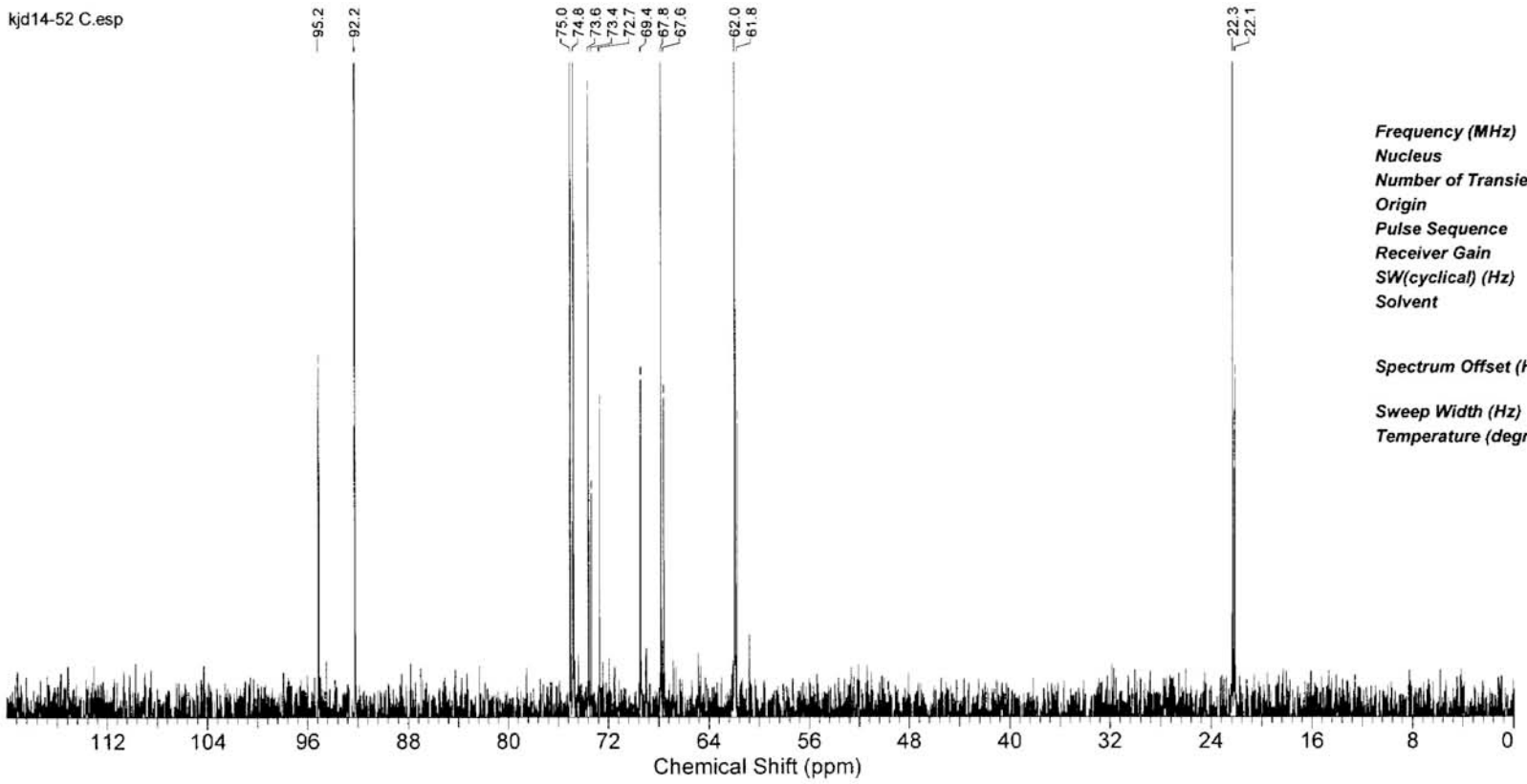
kjd14-52 H.esp



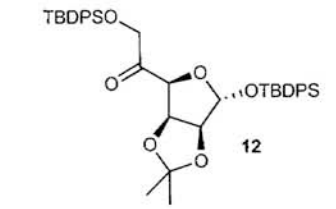


11

kjd14-52 C.esp

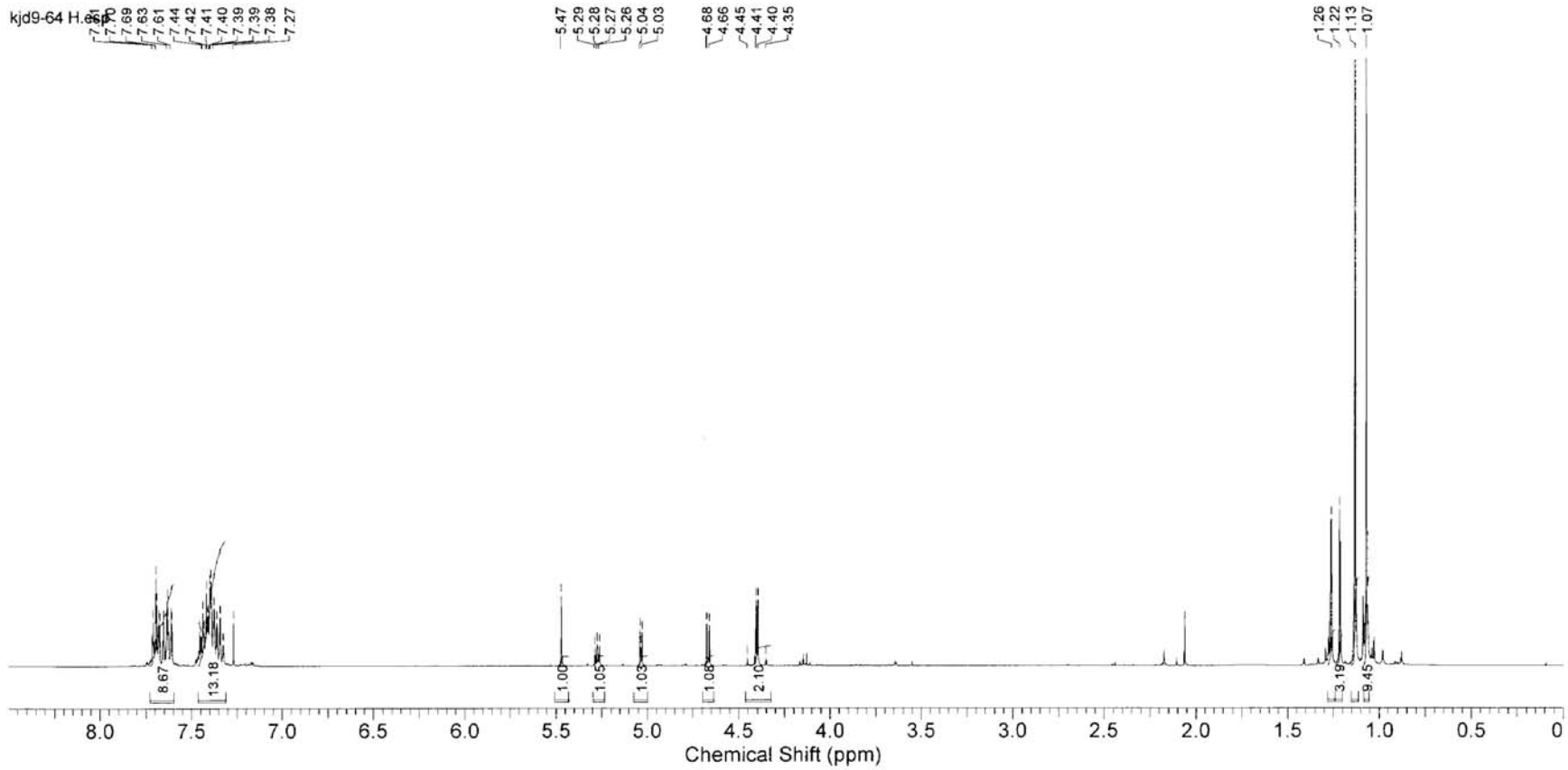


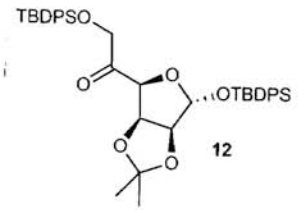
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	10063.0566
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000



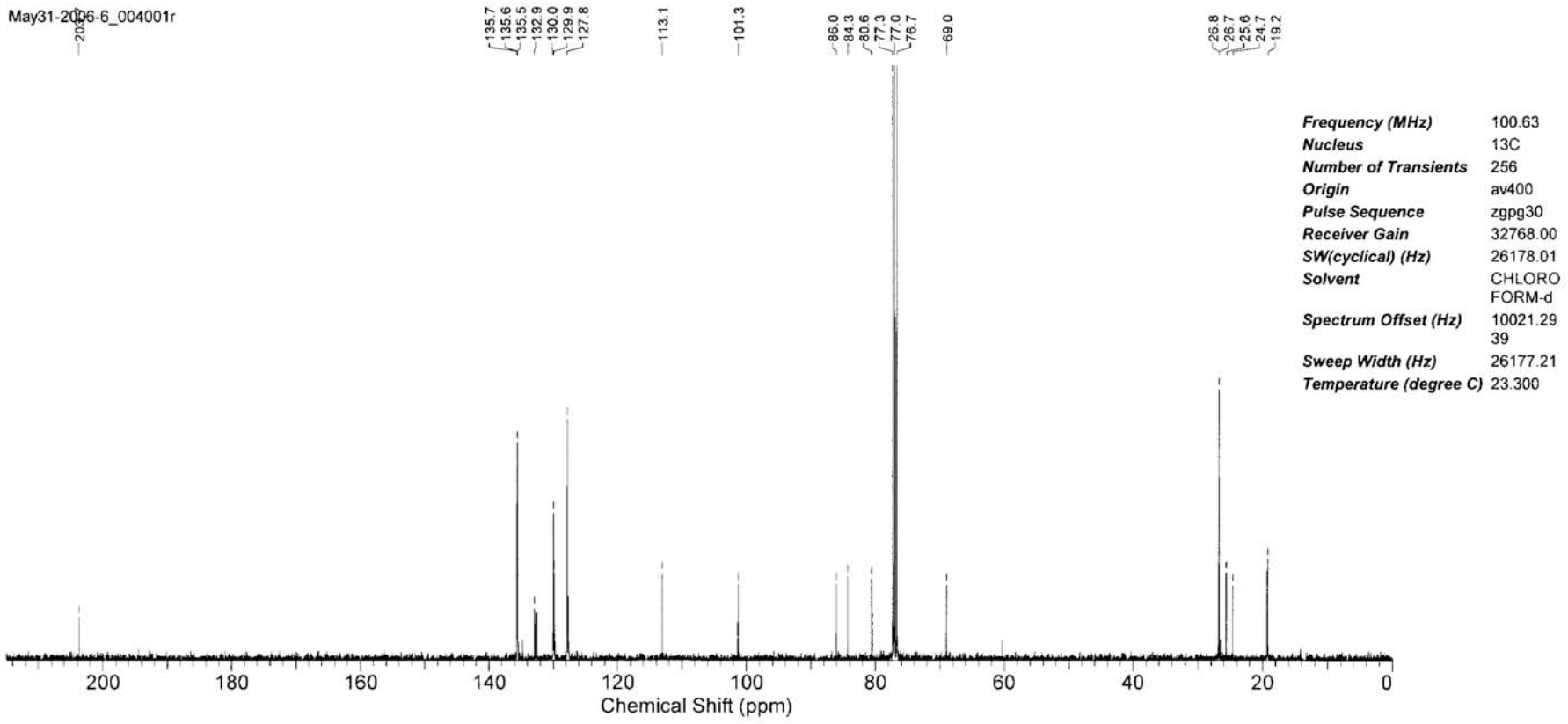
kjd9-64 H.esp

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.300



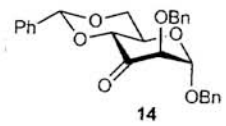


May31-2006-6_004001r



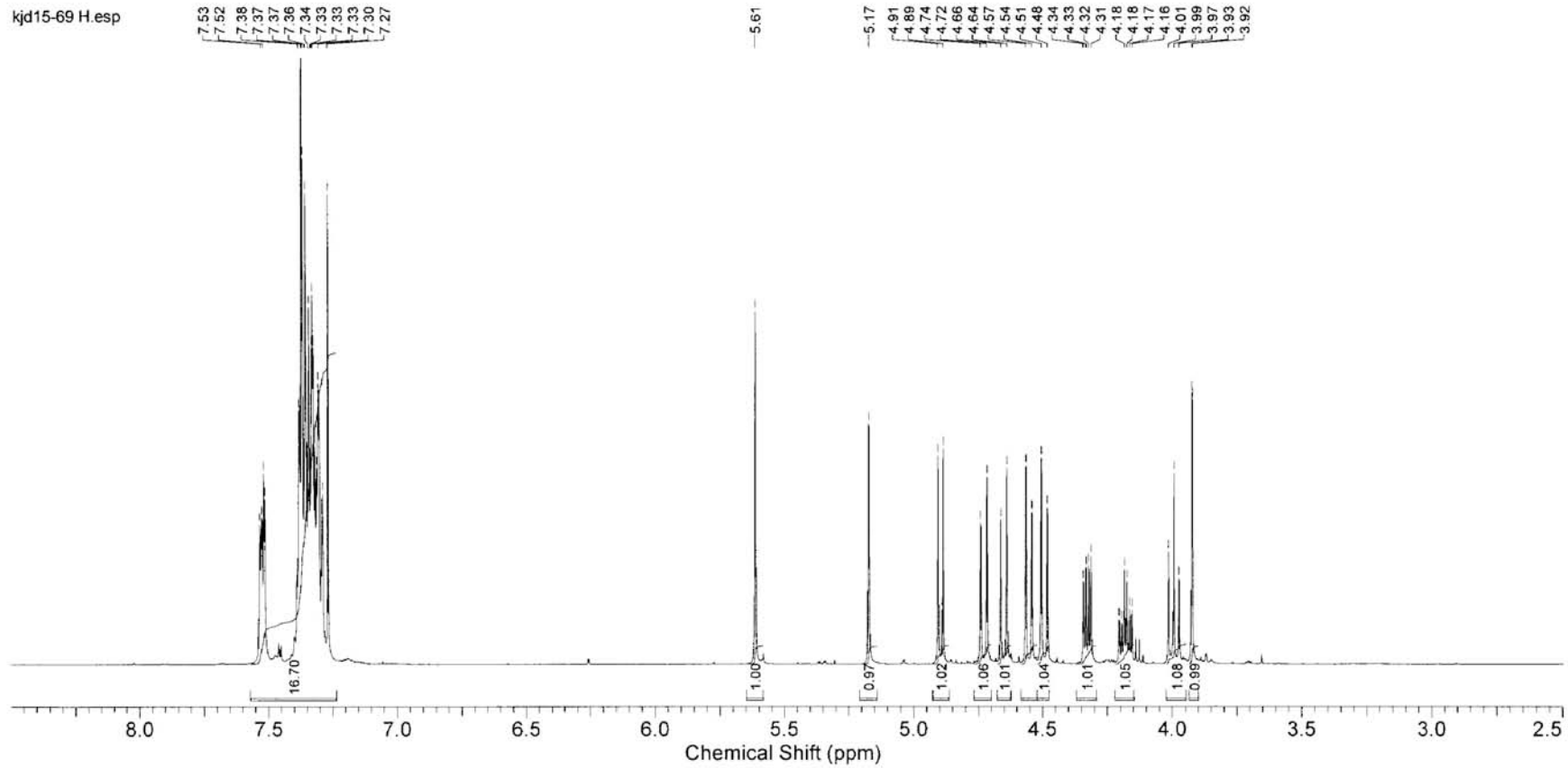
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.300

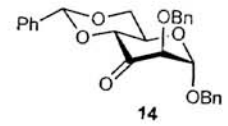
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3065.5417
Sweep Width (Hz)	10330.26
Temperature (degree C)	27.000



14

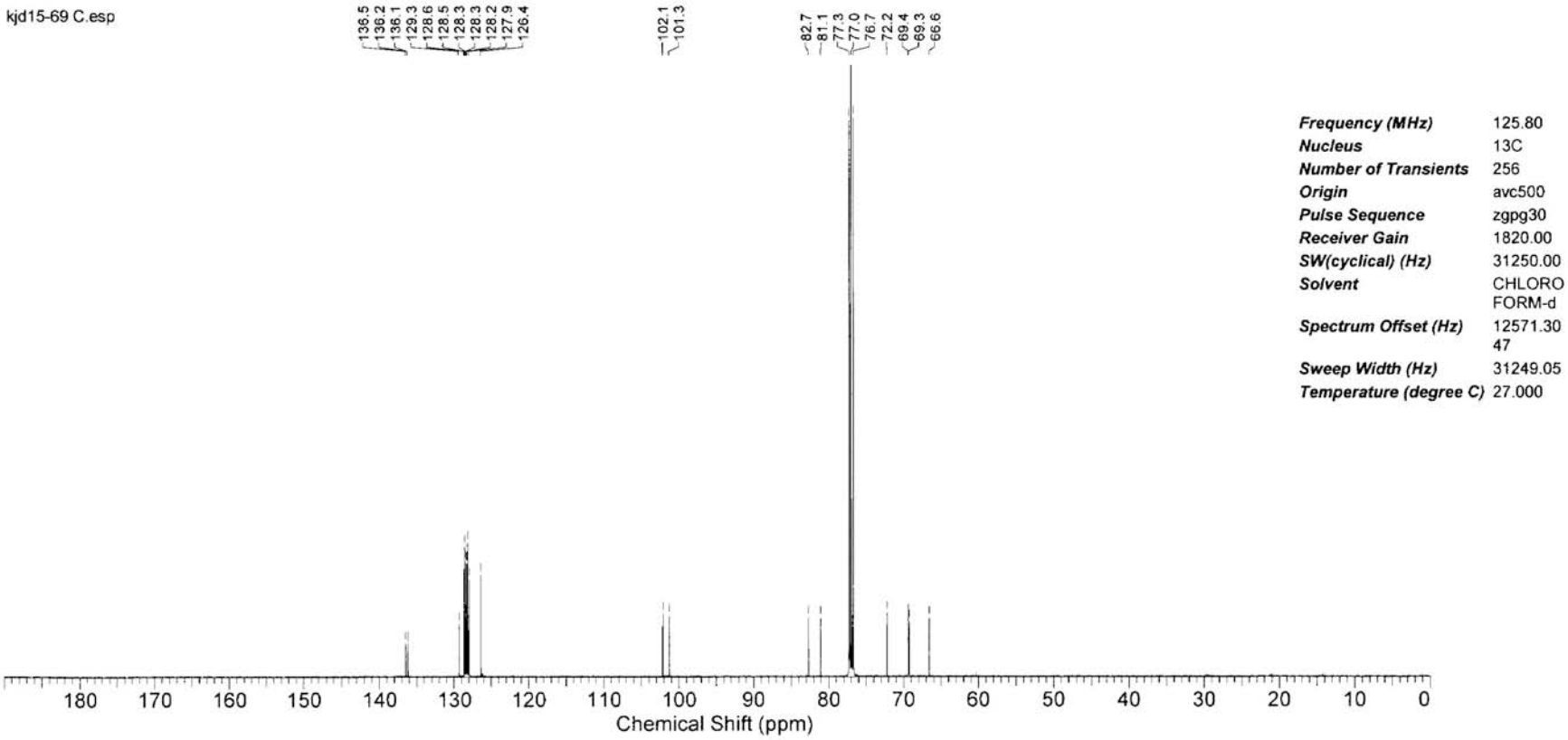
kjd15-69 H.esp



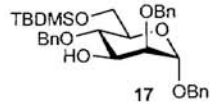


14

kjd15-69 C.esp

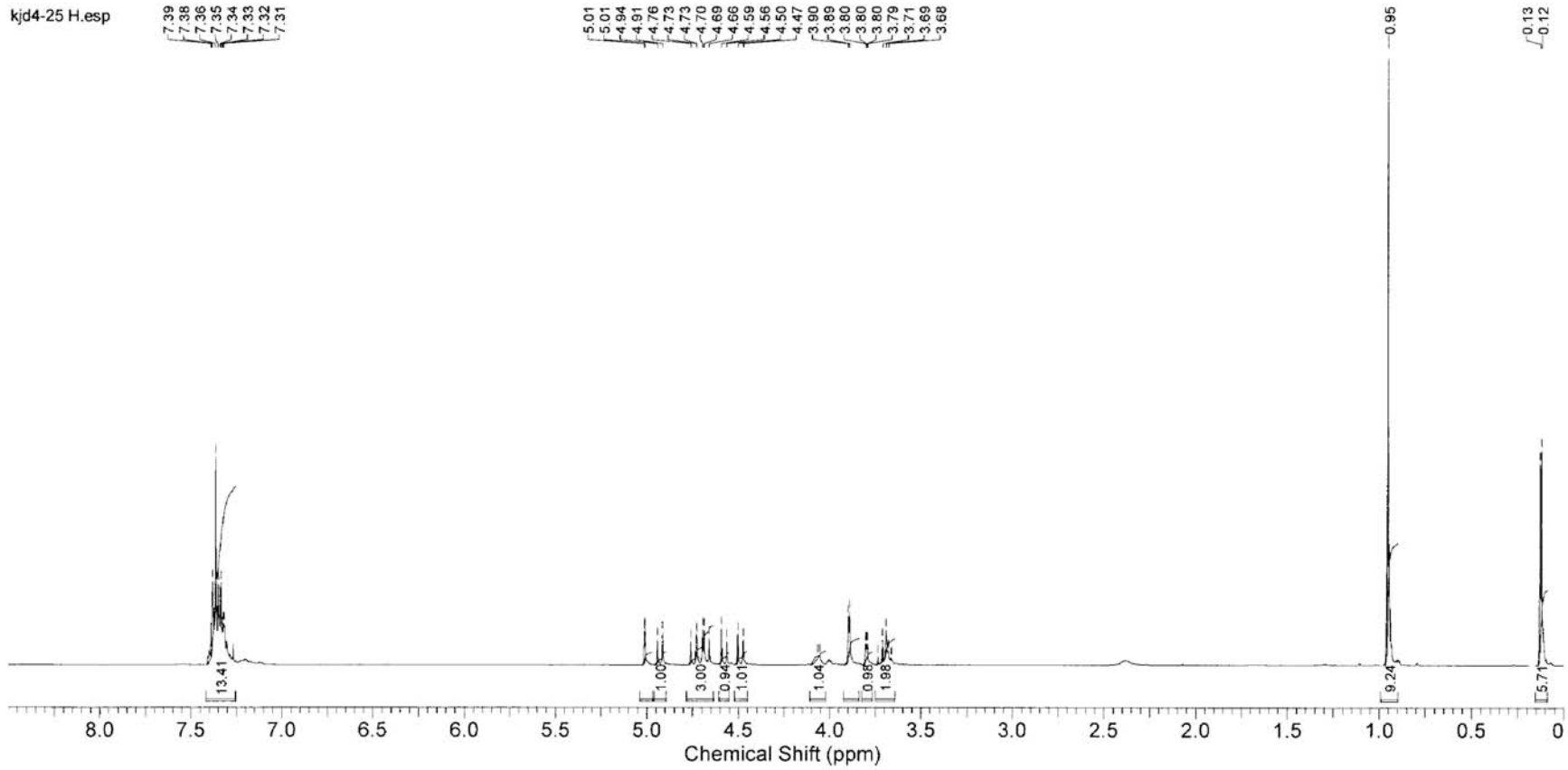


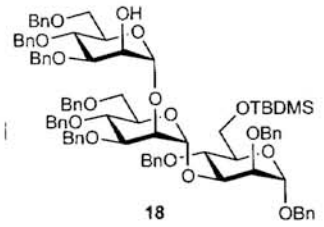
Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	256
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1820.00
SW(cyclical) (Hz)	31250.00
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	12571.3047
Sweep Width (Hz)	31249.05
Temperature (degree C)	27.000



Frequency (MHz)	400.13
Nucleus	1H
Number of Transients	16
Origin	dpx400
Pulse Sequence	zg60
Receiver Gain	32.00
SW(cyclical) (Hz)	5592.84
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	1983.0321
Sweep Width (Hz)	5592.67
Temperature (degree C)	27.000

kjd4-25 H.esp

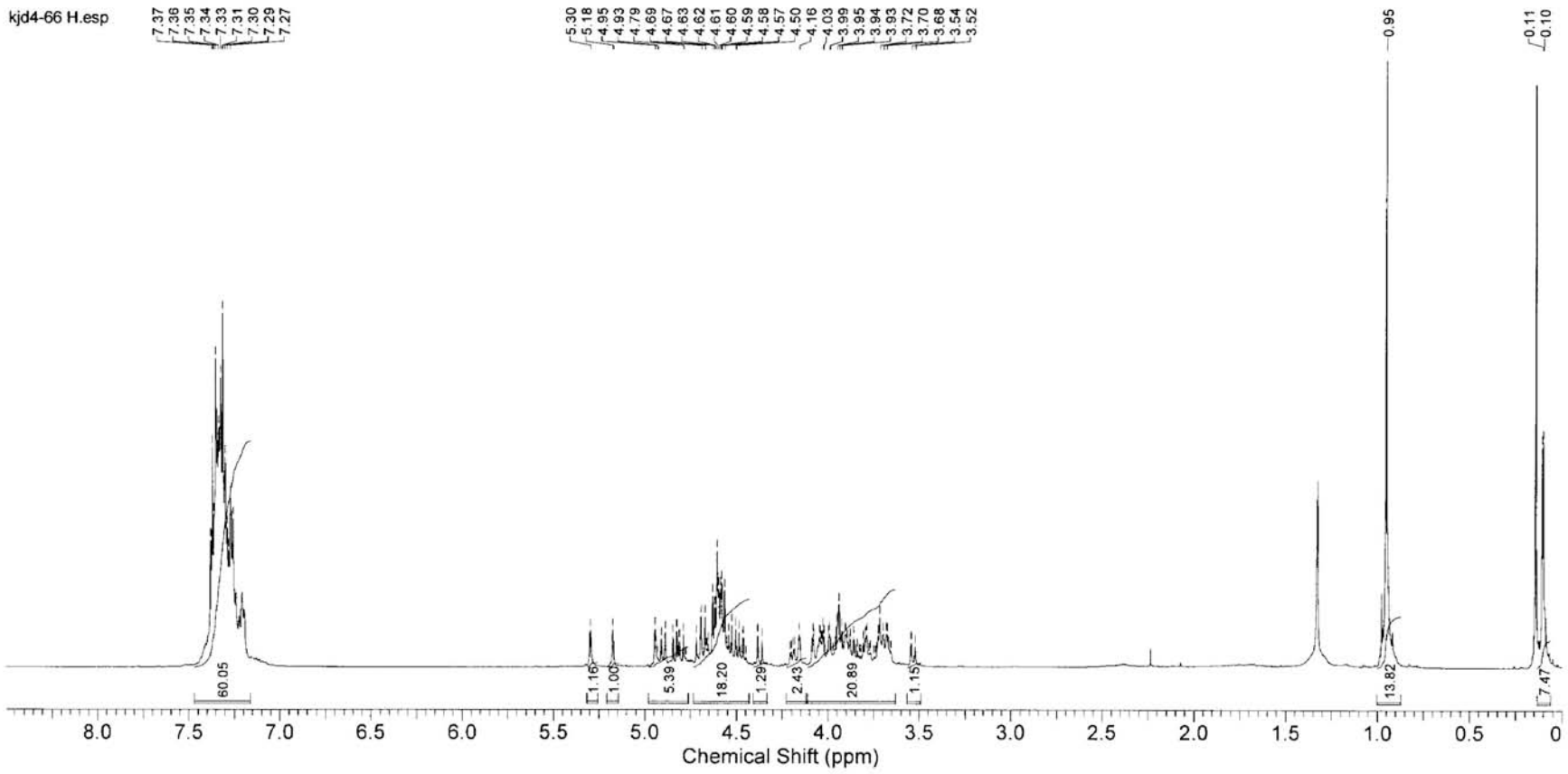


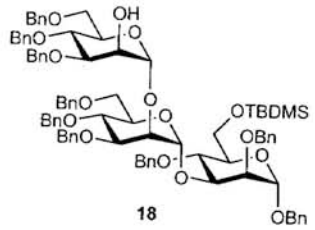


18

Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	6.35
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3089.5557
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.546

kjd4-66 H.esp



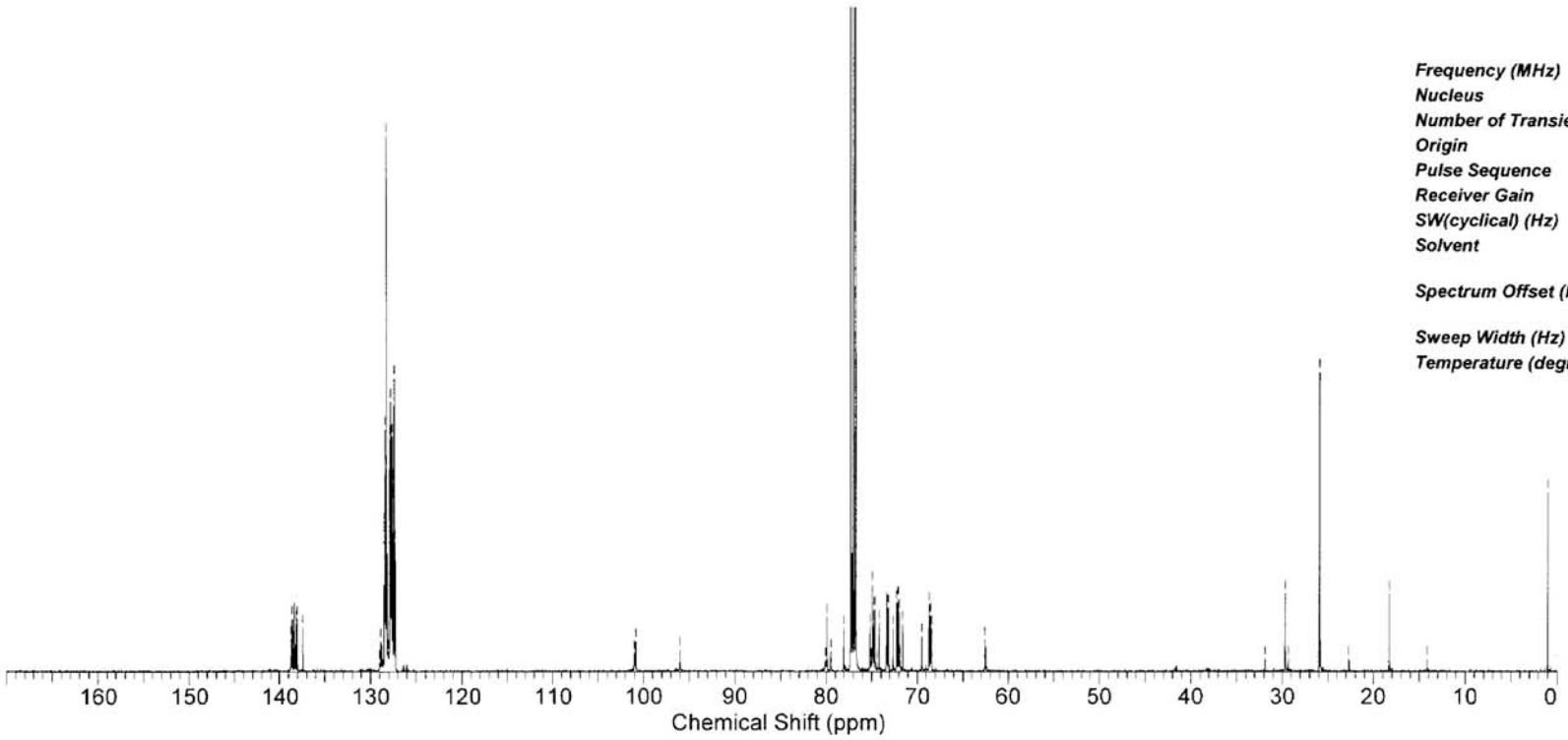


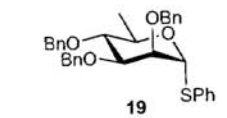
18

kd20320804_002001r

138.7
138.6
138.4
138.3
138.1
128.9
128.4
128.4
128.2
127.9
127.8
127.7
127.6
127.4
101.0
100.9
96.0
79.9
77.3
77.0
76.8
74.9
74.7
73.3
73.3
73.2
72.2
72.1
71.6
68.7
62.6
31.9
29.7
29.4
25.9
22.7
18.3
14.1
1.0

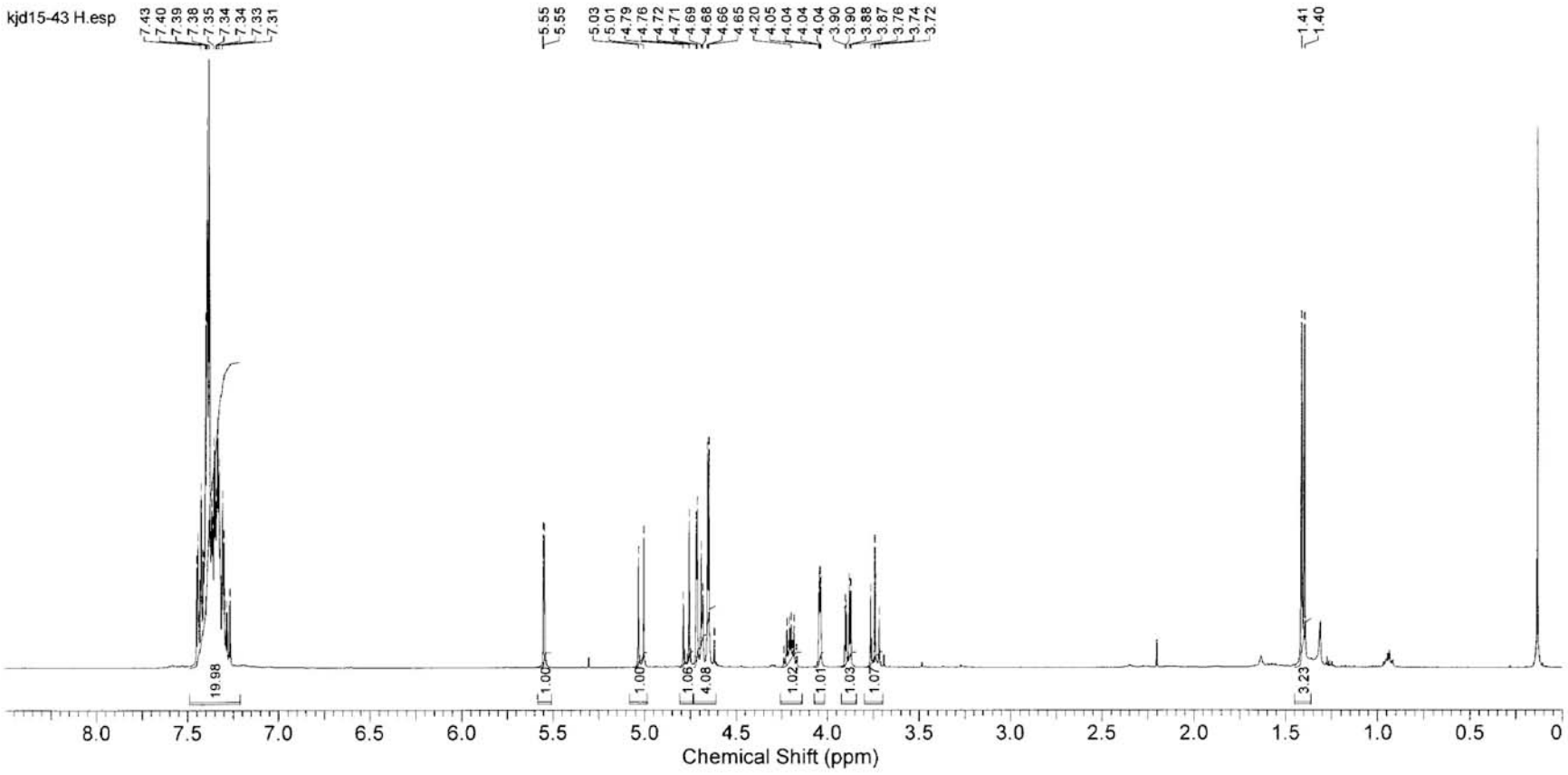
Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	512
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1820.00
SW(cyclical) (Hz)	31250.00
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	12571.3047
Sweep Width (Hz)	31249.05
Temperature (degree C)	24.546

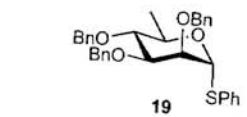




19

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	35.90
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000





19

kjd15-43 C.esp

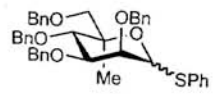
138.6
138.3
137.9
134.7
131.3
129.1
128.4
128.1
127.9
127.8
127.7
85.8
80.5
80.1
77.4
77.1
76.8
76.5
75.5
72.2
69.4
18.0

Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000

180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

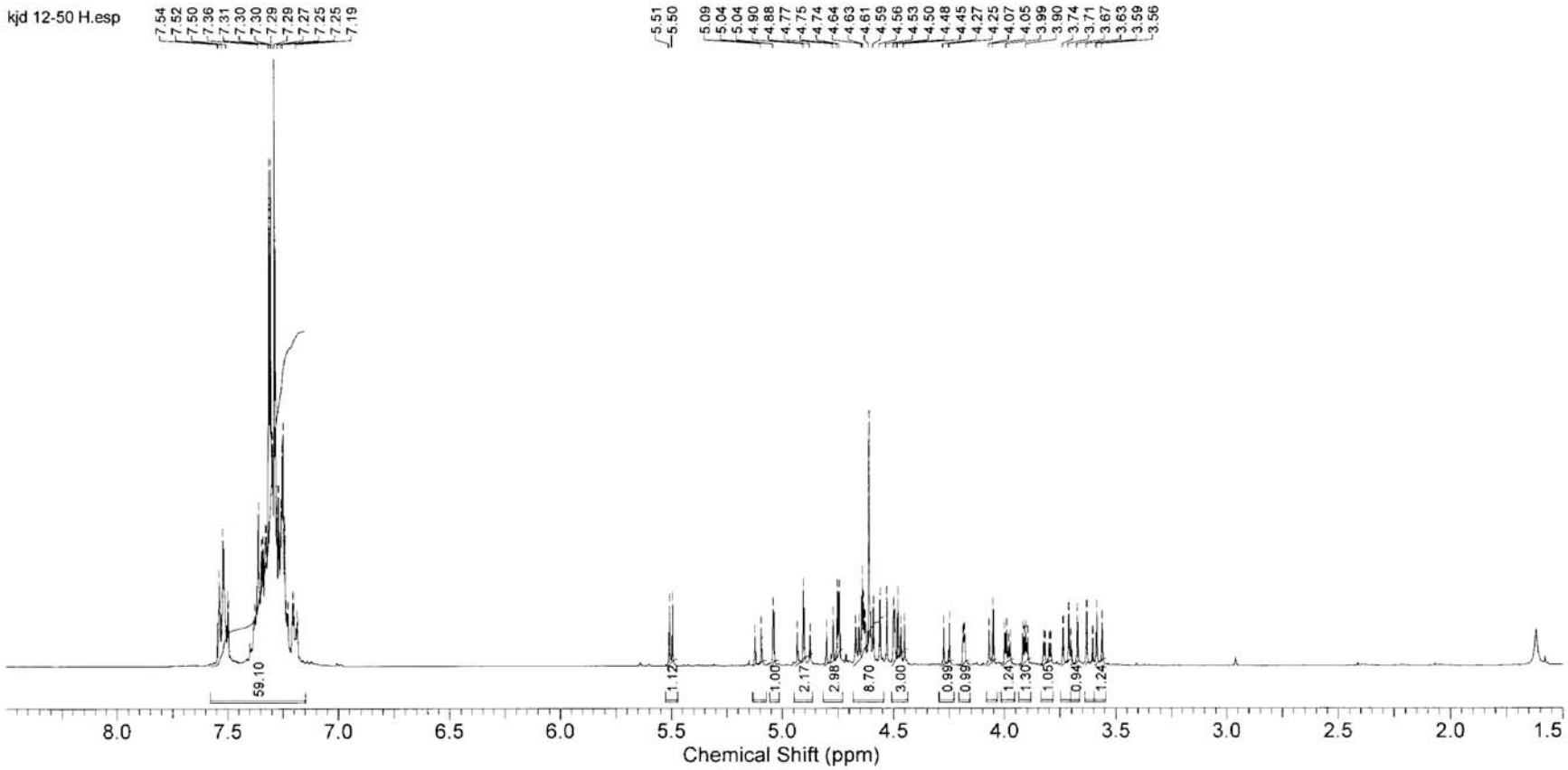
Chemical Shift (ppm)

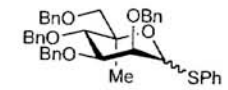
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	22.700



20a

kjd 12-50 H.esp





20a

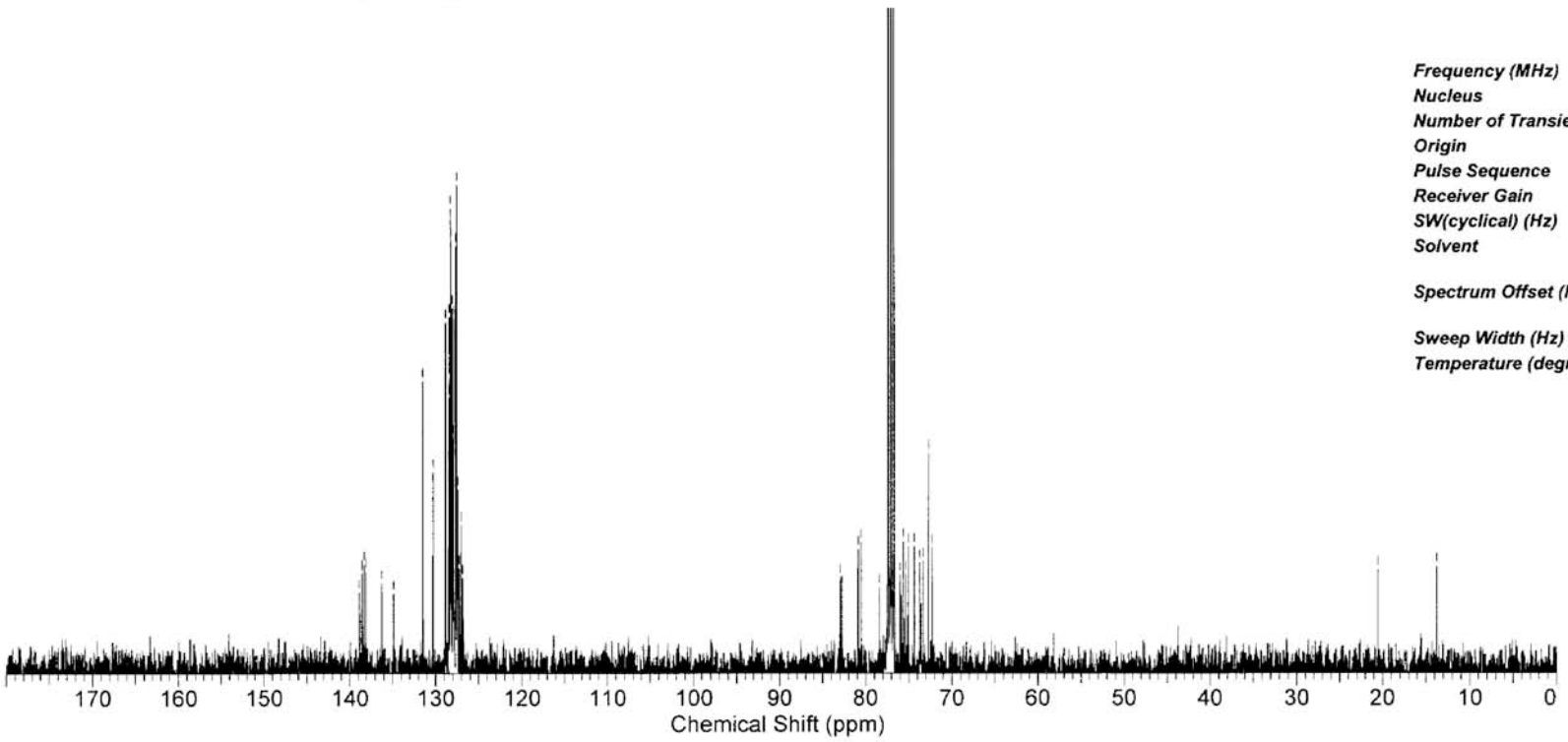
kjd 12-50 C.esp

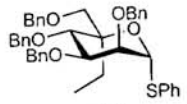
138.8
138.5
138.5
138.3
131.5
128.8
128.4
128.2
128.2
128.0
127.9
127.6
127.5
127.0

83.0
80.9
80.5
77.4
77.0
76.7
75.6
75.1
74.3
73.7
73.3
72.7
72.3

20.5
13.8

Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.100





20b:α

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	40.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.6377
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.100

kjd11-40 H.esp

7.64 7.41 7.39 7.37 7.35 7.33 7.32 7.31 7.30 7.25 7.24

5.14 5.11 4.92 4.91 4.89 4.89 4.87 4.76 4.70 4.60 4.57 4.54 4.52 4.50

3.83 3.82 3.80 3.80 3.72 3.69 3.68 3.65

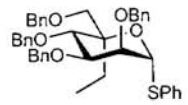
1.77 1.75 1.73 1.71 1.69 1.67 1.66 1.64 1.62

0.57 0.55 0.53

35.62 1.00 3.89 2.01 3.15 1.03 0.93 1.08 1.93 4.06 2.54

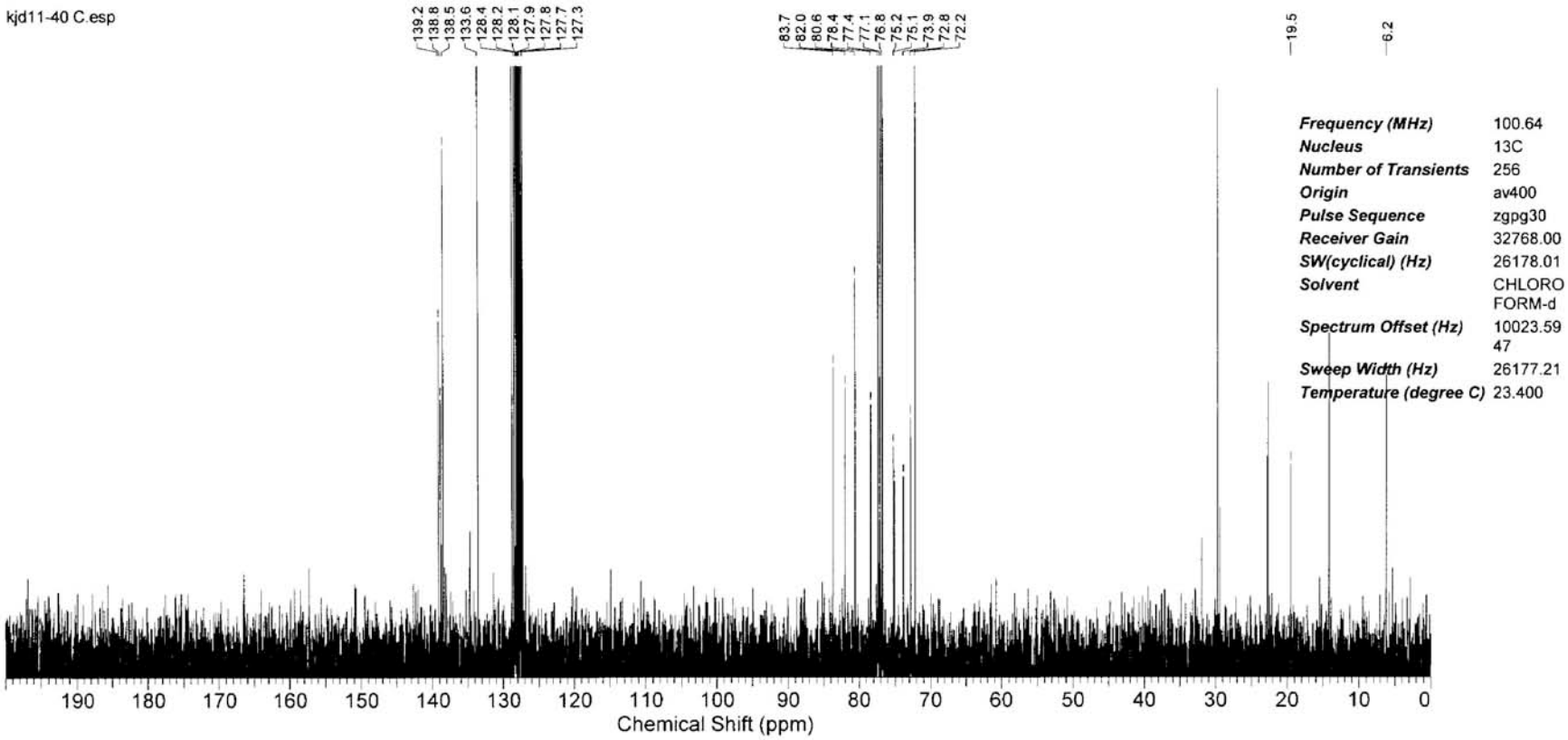
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Chemical Shift (ppm)

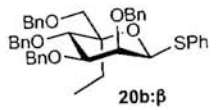


20b:α

kjd11-40 C.esp



Frequency (MHz)	100.64
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10023.5947
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.400



20b:β

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	40.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.000

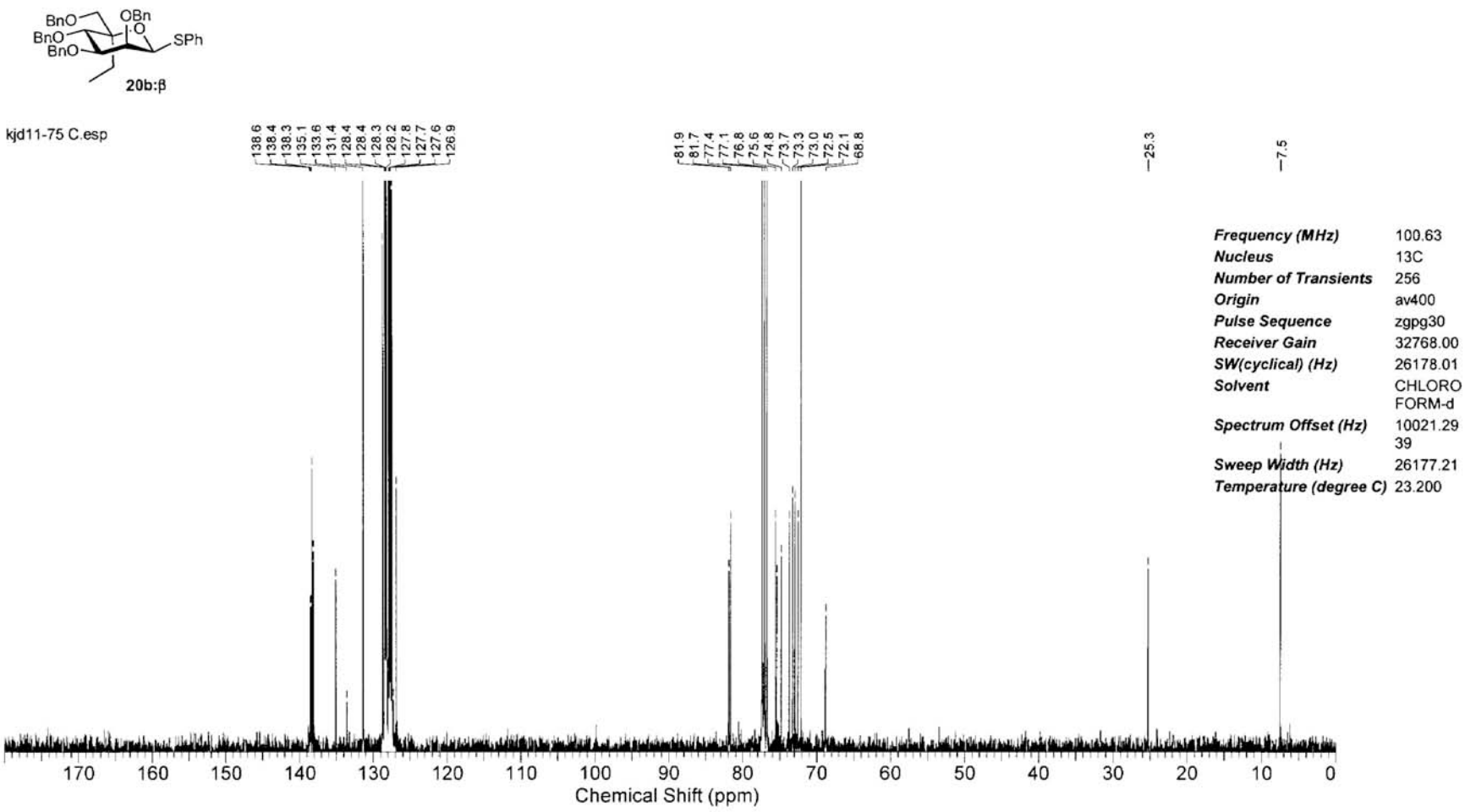
kjd10-75 H.esp

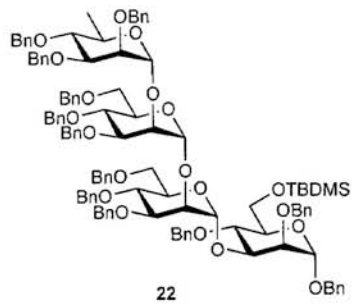
7.59 7.57 7.41 7.40 7.35 7.33 7.32 7.26 7.26 7.25 7.24 5.46 5.44 4.66 4.64 4.63 4.61 4.60 4.53 4.52 4.49 4.48 4.47 3.94 3.93 3.92 3.89 3.87 3.85 3.83 3.73 3.70 2.13 2.12 2.10 2.08 2.06 2.04 1.89 1.87 1.85 1.84 1.82 1.80 0.89 0.88 0.86

36.68 0.99 5.13 4.85 1.97 1.01 1.21 1.04 1.04 3.11

8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

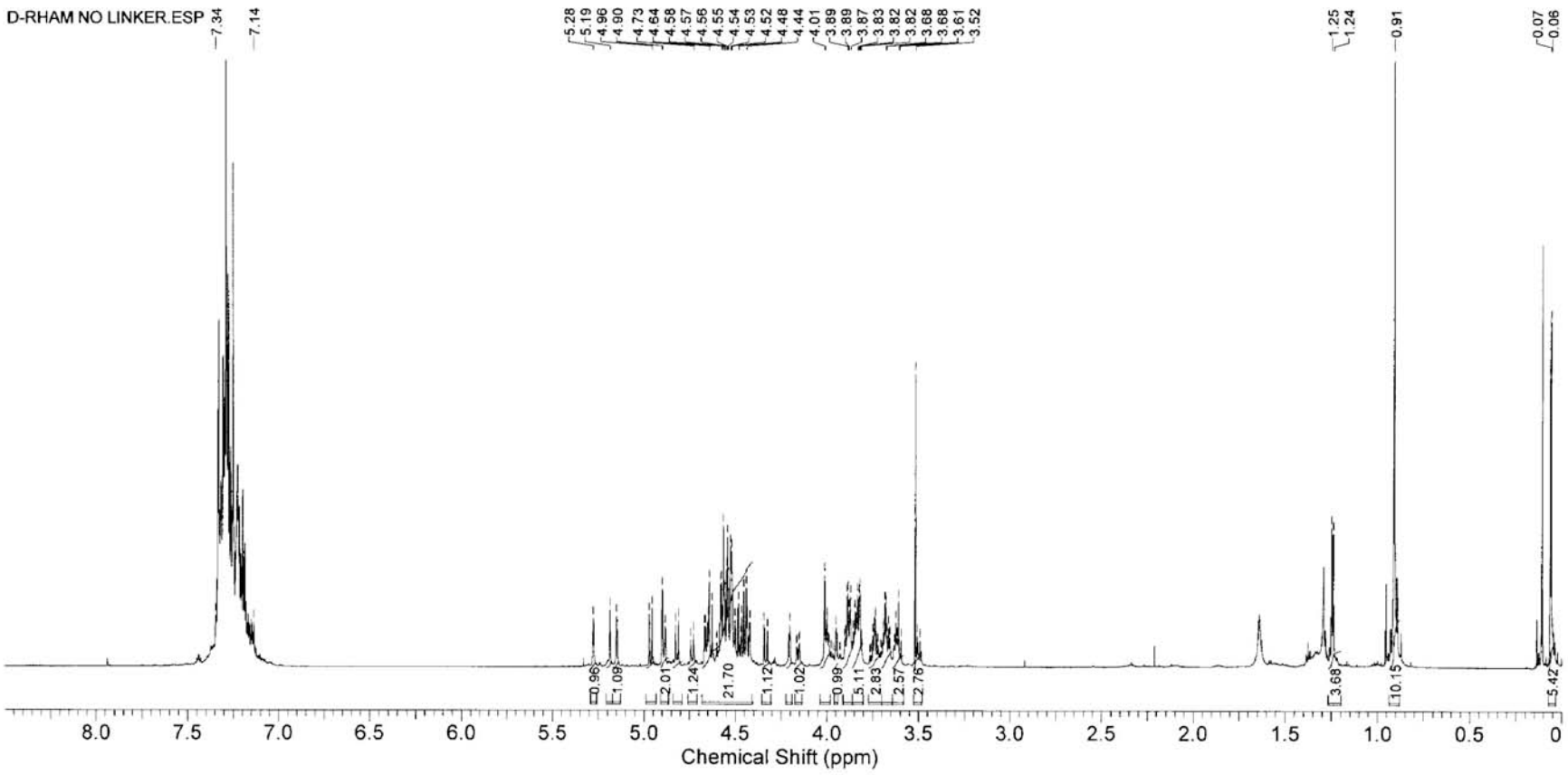
Chemical Shift (ppm)

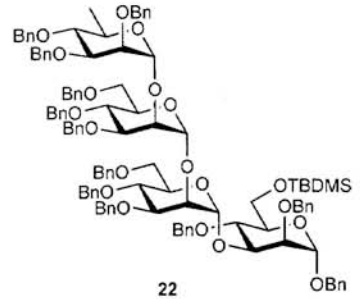

BnO
OBn
BnO
O
SPh
BnO
20b:β
kjd11-75 C.esp
138.6
138.4
138.3
135.1
133.6
131.4
128.4
128.4
128.3
128.2
127.8
127.7
127.6
126.9
81.9
81.7
77.4
77.1
76.8
75.6
74.8
73.7
73.3
73.0
72.5
72.1
68.8
25.3
7.5
Frequency (MHz) 100.63
Nucleus 13C
Number of Transients 256
Origin av400
Pulse Sequence zgpg30
Receiver Gain 32768.00
SW(cyclical) (Hz) 26178.01
Solvent CHLOROFORM-d
Spectrum Offset (Hz) 10021.2939
Sweep Width (Hz) 26177.21
Temperature (degree C) 23.200
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Chemical Shift (ppm)



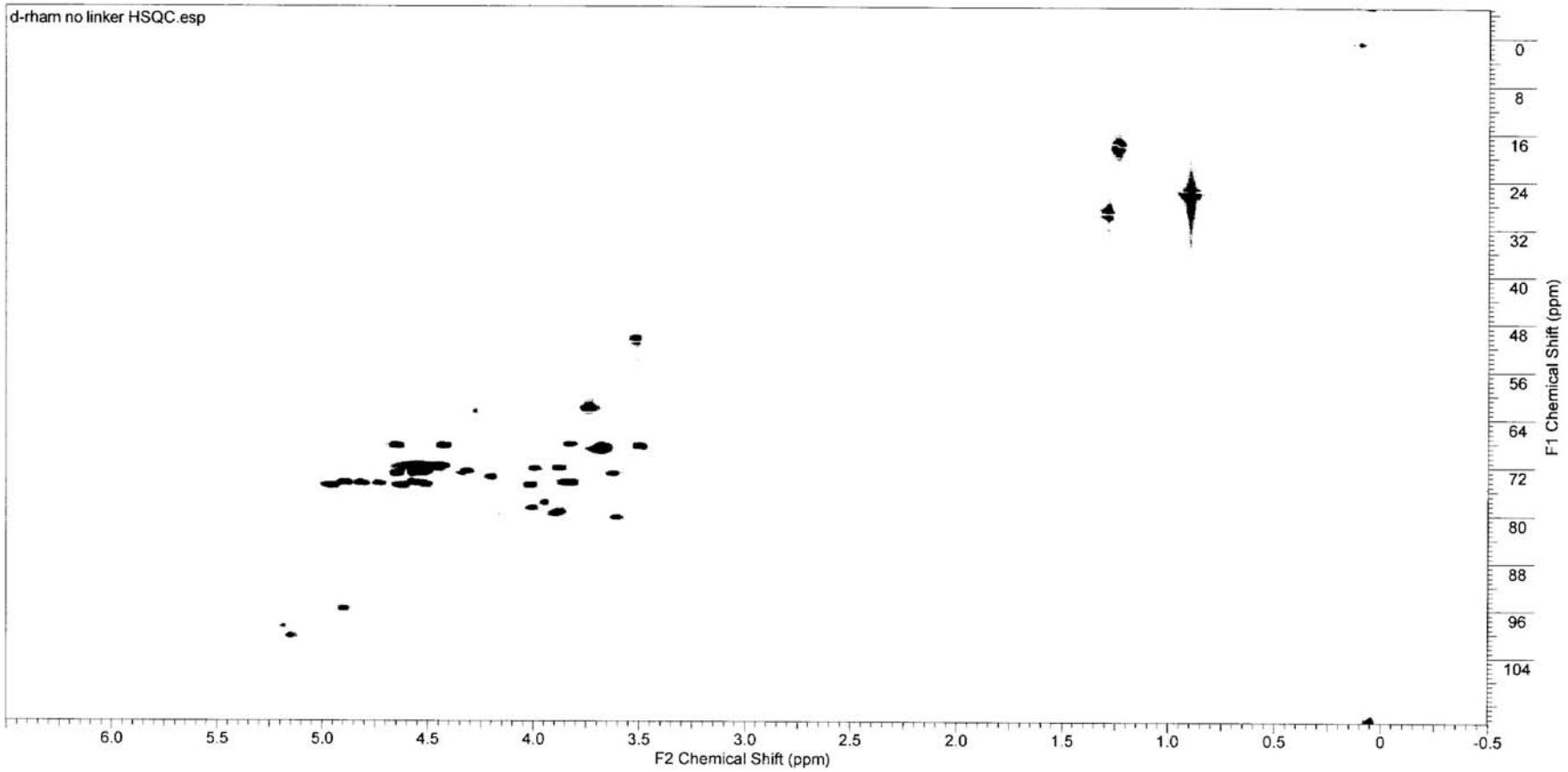
22

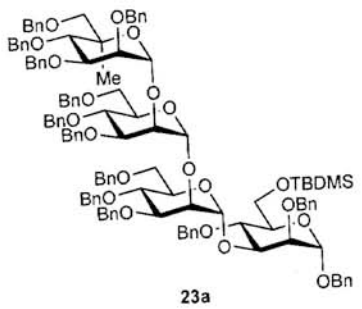
Frequency (MHz)	700.13
Nucleus	1H
Number of Transients	8
Origin	av700
Pulse Sequence	zg60
Receiver Gain	8.00
SW(cyclical) (Hz)	11160.71
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3500.6514
Sweep Width (Hz)	11160.54
Temperature (degree C)	25.000




OBn
BnO
BnO
BnO
BnO
BnO
BnO
BnO
BnO
OTBDMS
OBn
OBn

22

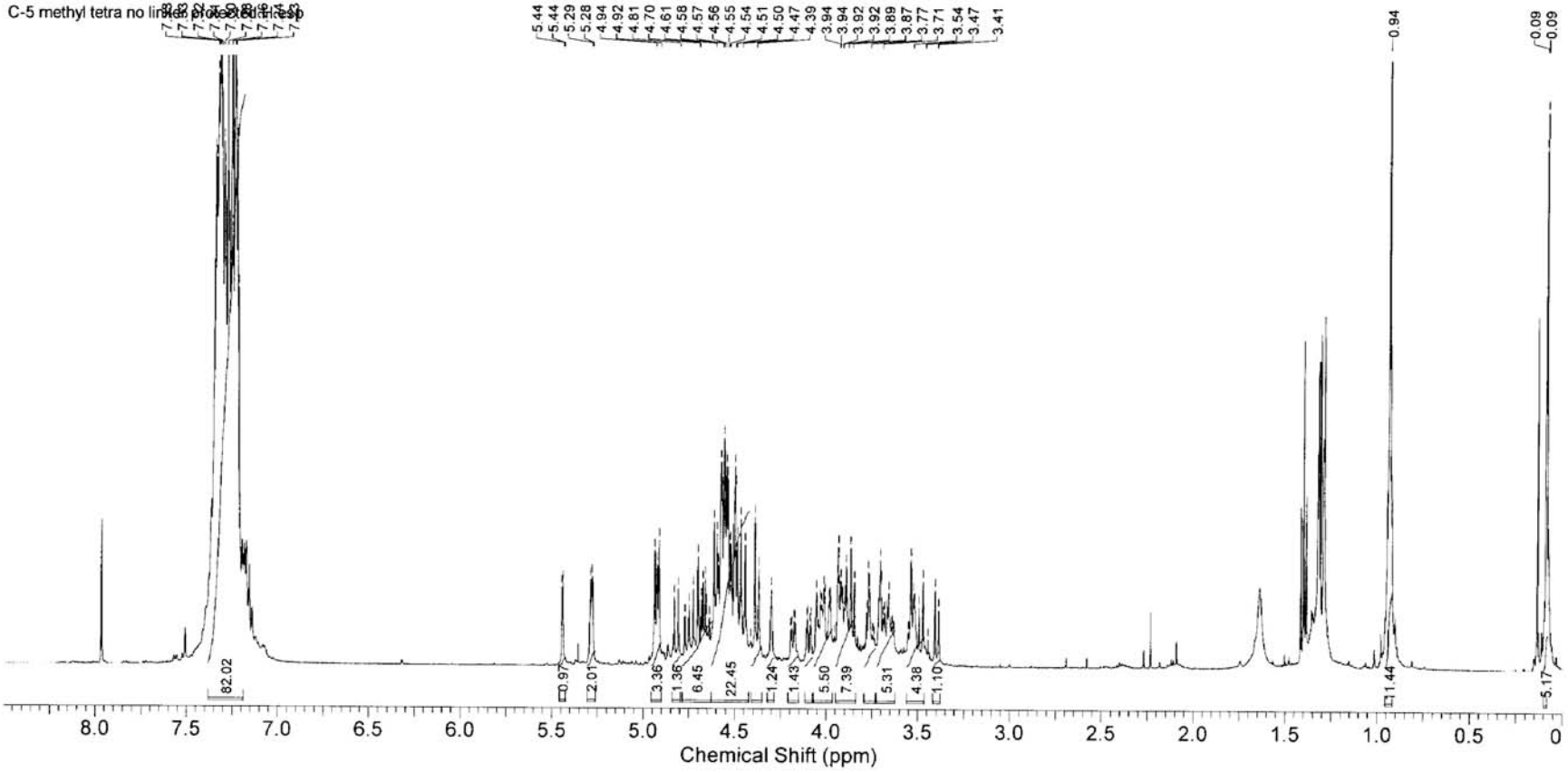

d-rham no linker HSQC.esp
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
F2 Chemical Shift (ppm)
0
8
16
24
32
40
48
56
64
72
80
88
96
104
F1 Chemical Shift (ppm)

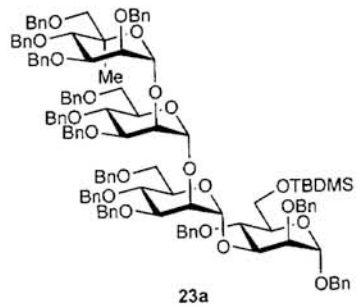


23a

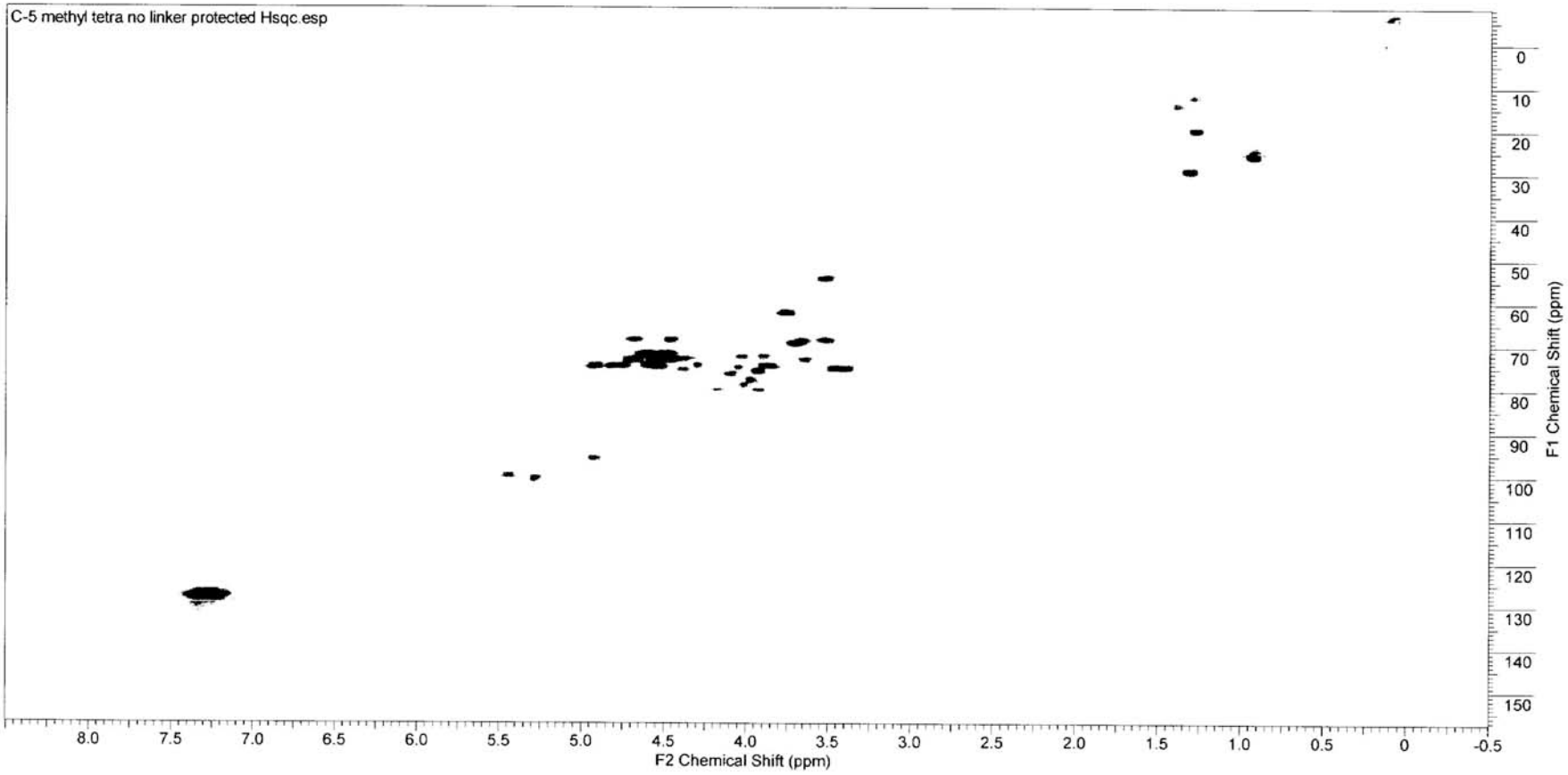
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3089.5557
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970

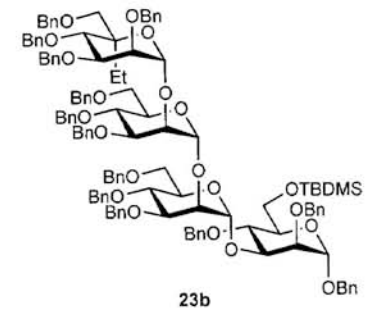
C-5 methyl tetra no linker protected trisaccharide




BnO
OBn
BnO
BnO
Me
BnO
BnO
BnO
BnO
BnO
BnO
OTBDMS
OBn
BnO
OBn

23a

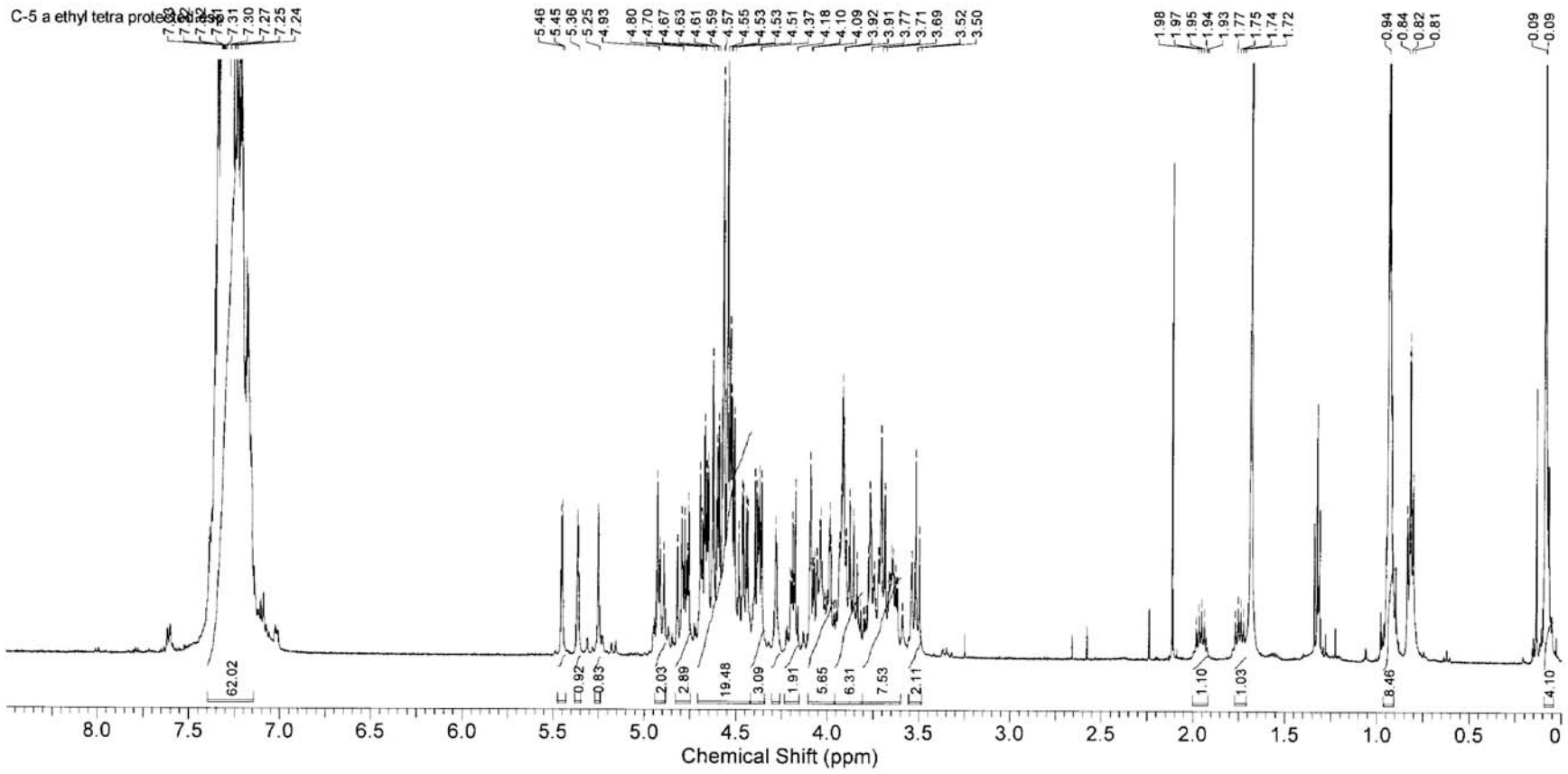

C-5 methyl tetra no linker protected Hsqc.esp
F2 Chemical Shift (ppm)
F1 Chemical Shift (ppm)

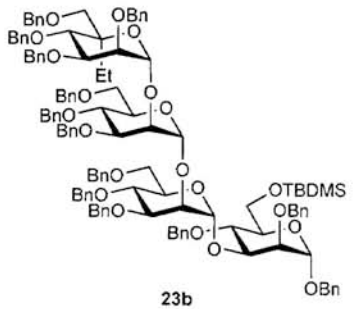


23b

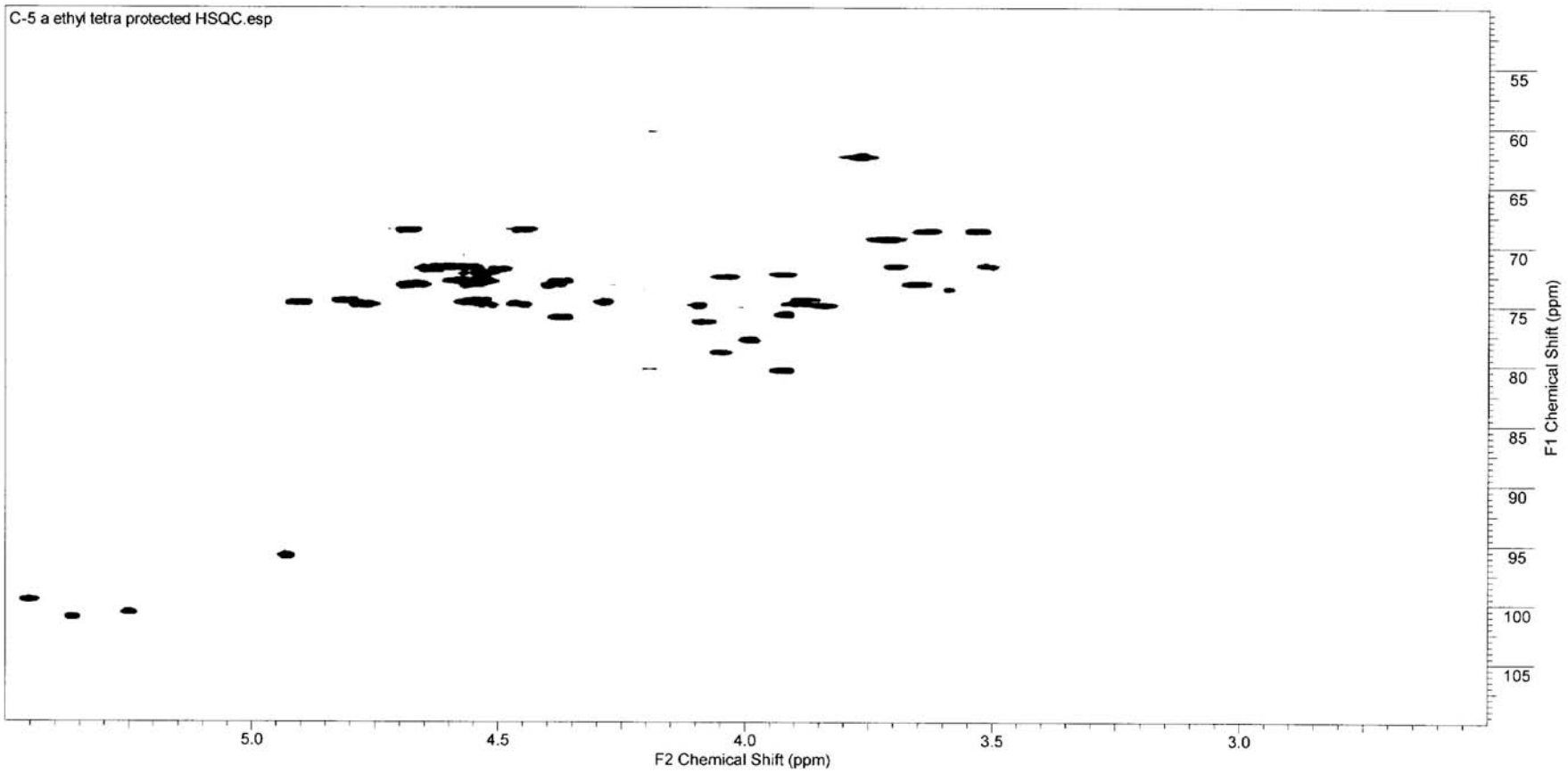
C-5 a ethyl tetra protected sugar

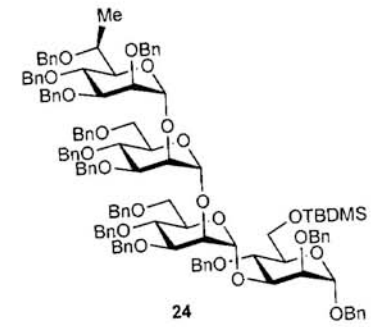
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3089.5557
Sweep Width (Hz)	10330.26
Temperature (degree C)	15.536




BnO
OBn
BnO
BnO
Et
BnO
O
BnO
O
BnO
BnO
O
BnO
O
BnO
BnO
OTBDMS
OBn
BnO
O
O
OBn

23b

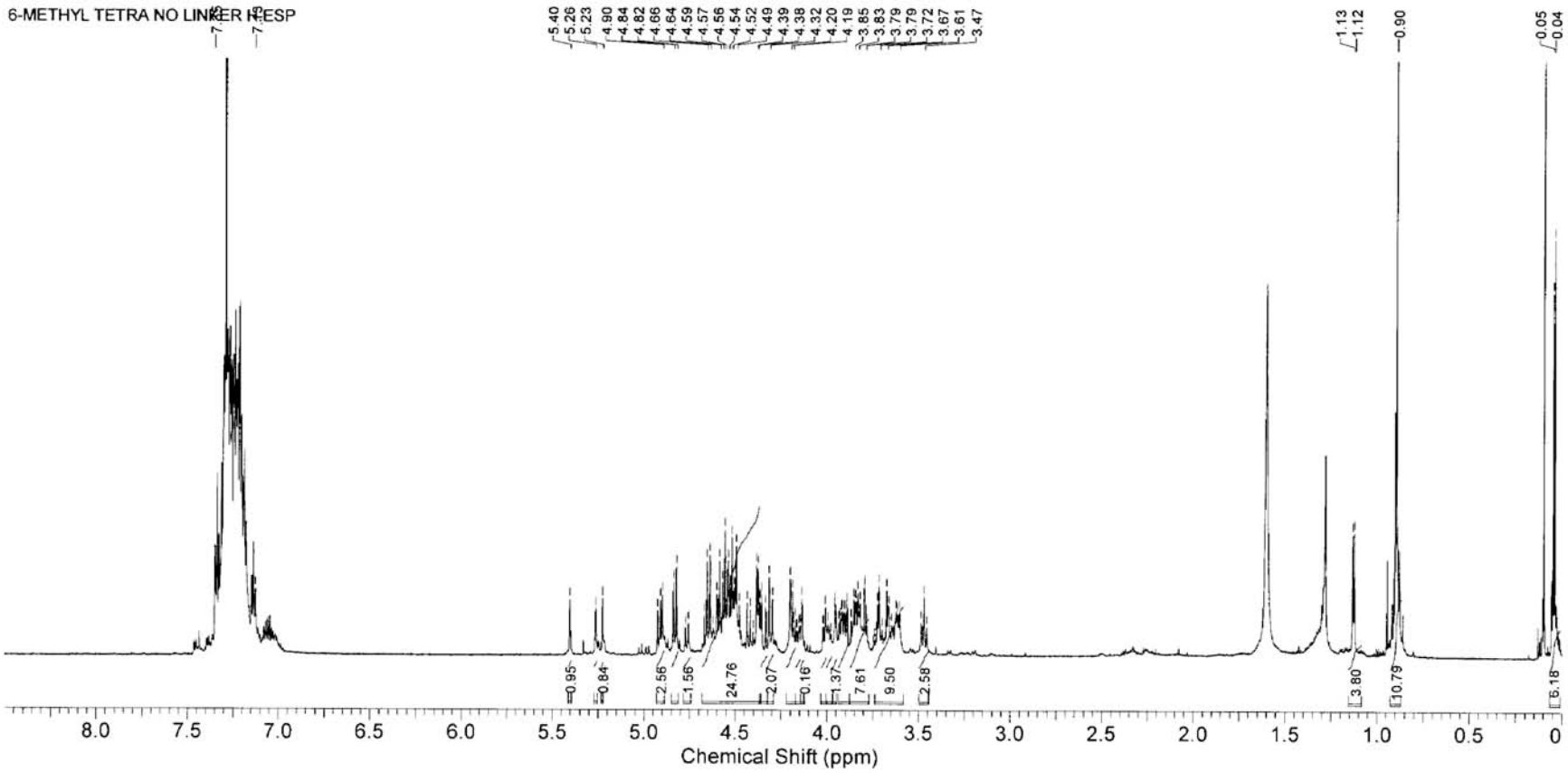

C-5 a ethyl tetra protected HSQC.esp
55
60
65
70
75
80
85
90
95
100
105
F1 Chemical Shift (ppm)
5.0
4.5
4.0
3.5
3.0
F2 Chemical Shift (ppm)

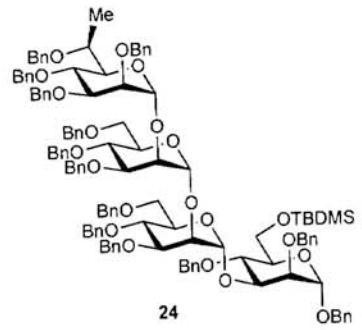


24

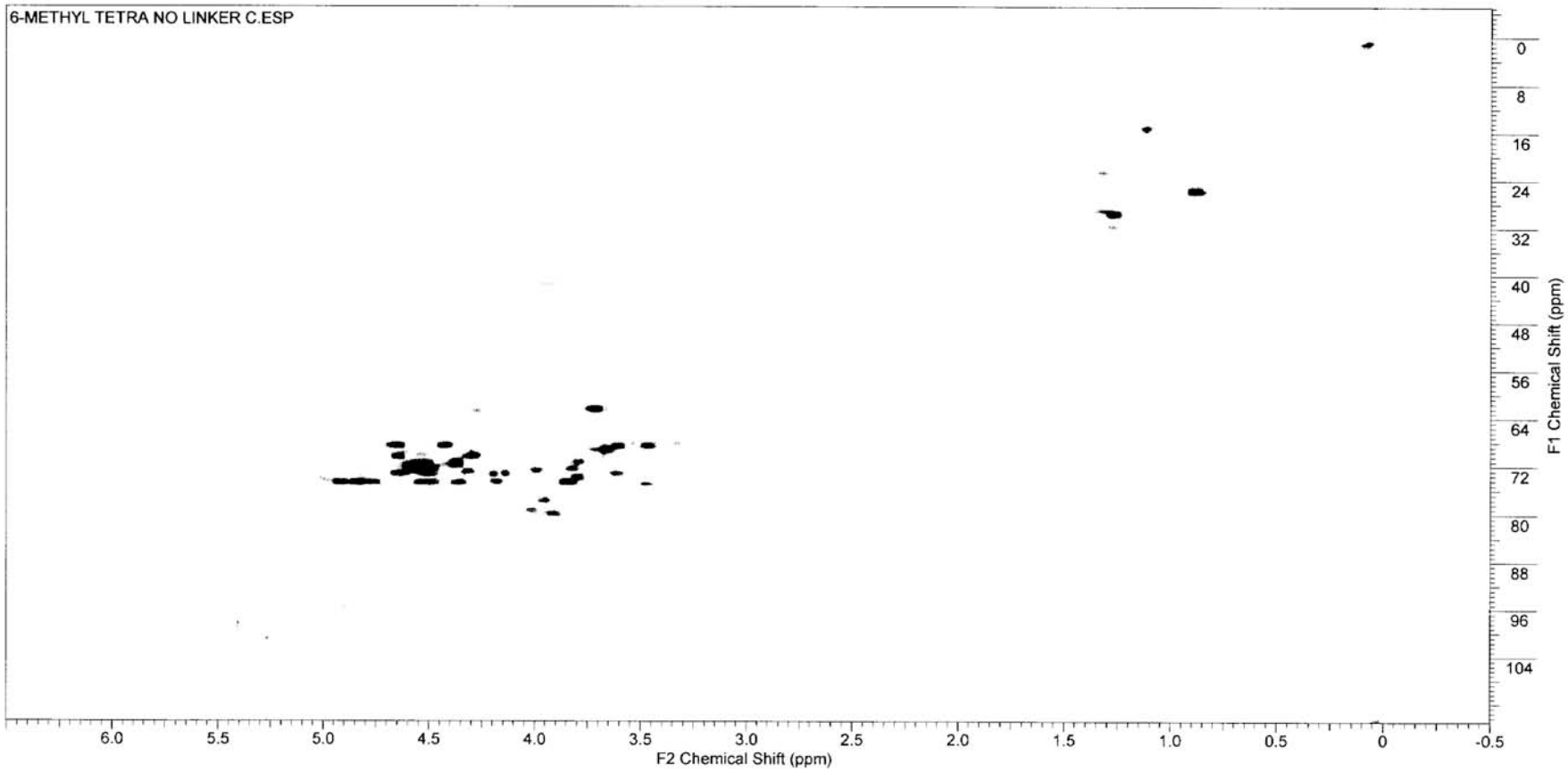
Frequency (MHz)	700.13
Nucleus	1H
Number of Transients	8
Origin	av700
Pulse Sequence	zg60
Receiver Gain	8.00
SW(cyclical) (Hz)	11160.71
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3500.6514
Sweep Width (Hz)	11160.54
Temperature (degree C)	25.000

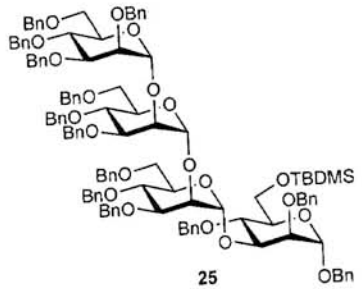
6-METHYL TETRA NO LINKER ESP




Me
BnO
OBn
BnO
BnO
BnO
BnO
BnO
BnO
BnO
BnO
BnO
OTBDMS
OBn
BnO
O
OBn

24

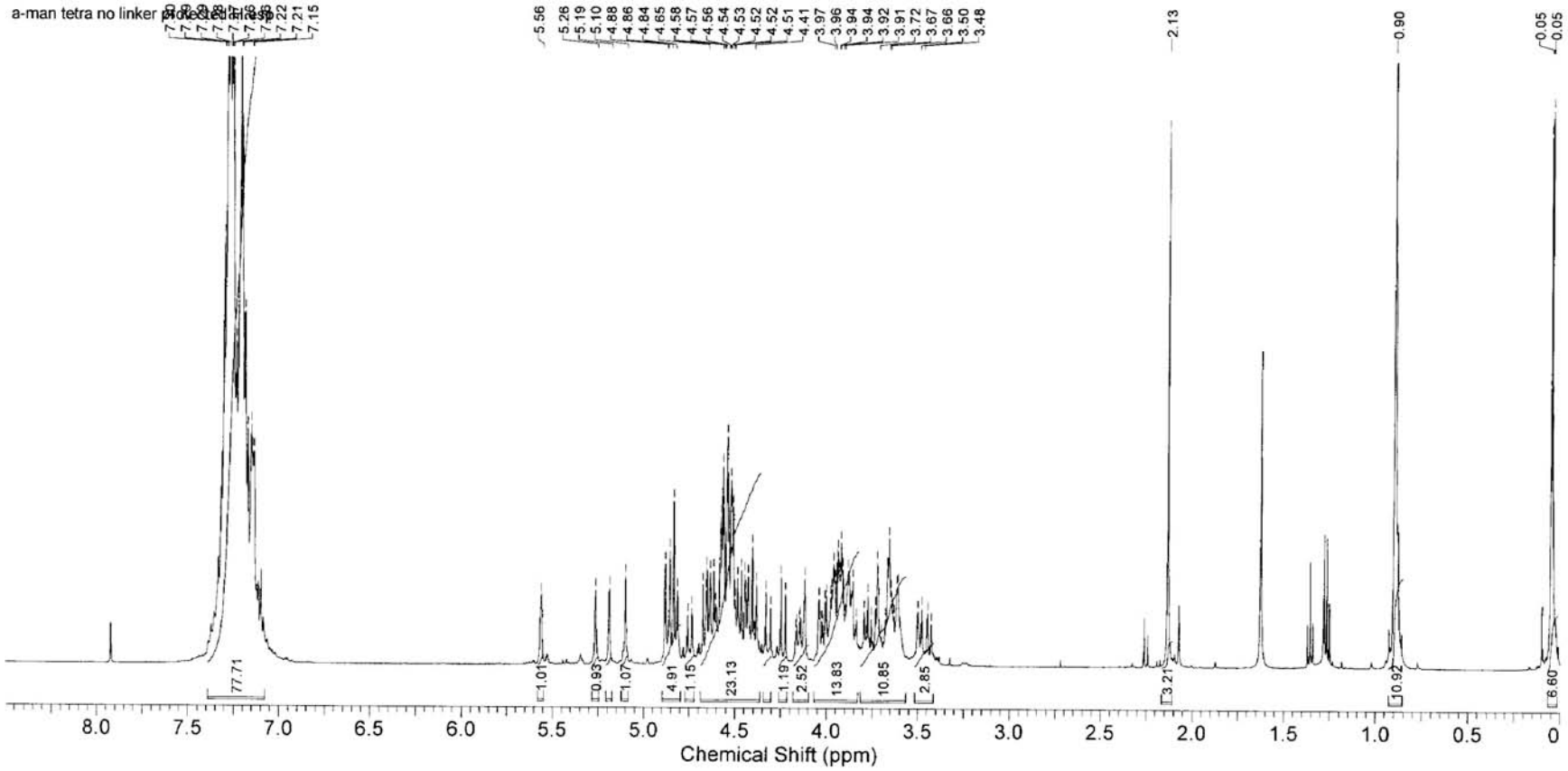

6-METHYL TETRA NO LINKER C.ESP
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
F2 Chemical Shift (ppm)
0
8
16
24
32
40
48
56
64
72
80
88
96
104
F1 Chemical Shift (ppm)

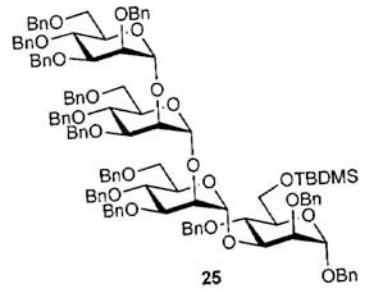


25

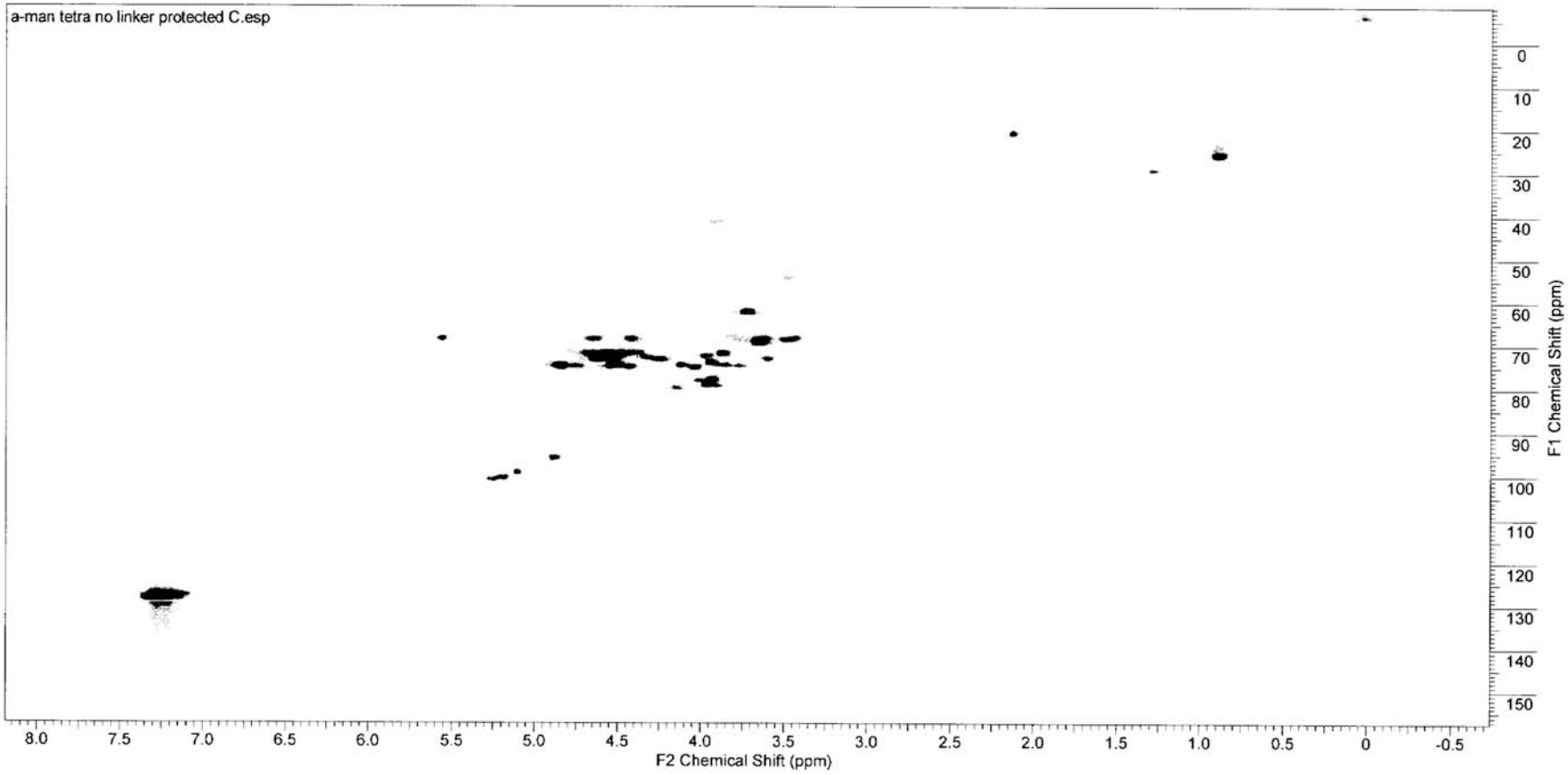
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3065.5417
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970

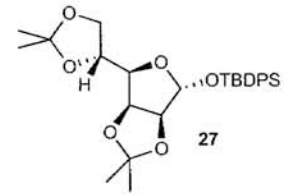
a-man tetra no linker protected mass




BnO
OBn
BnO
BnO
BnO
O
BnO
BnO
BnO
O
BnO
BnO
BnO
O
BnO
OTBDMS
OBn
O
OBn

25


a-man tetra no linker protected C.esp
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
F2 Chemical Shift (ppm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
F1 Chemical Shift (ppm)



27

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	18.00
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.200

kjd9-58H.esp

7.74 7.72 7.71 7.70 7.69 7.67 7.67 7.43 7.43 7.42 7.42 7.41

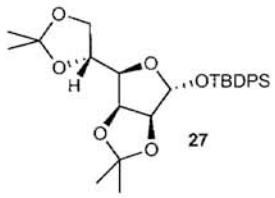
5.38 4.95 4.94 4.93 4.92 4.78 4.76 4.40 4.39 4.39 4.38 4.25 4.24 4.23 4.08 4.06 4.06 4.04 3.90 3.89 3.88

1.50 1.44 1.42 1.36 1.12

6.06 9.17 1.00 1.07 1.11 1.04 1.06 1.08 1.05 13.12 10.31

8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Chemical Shift (ppm)

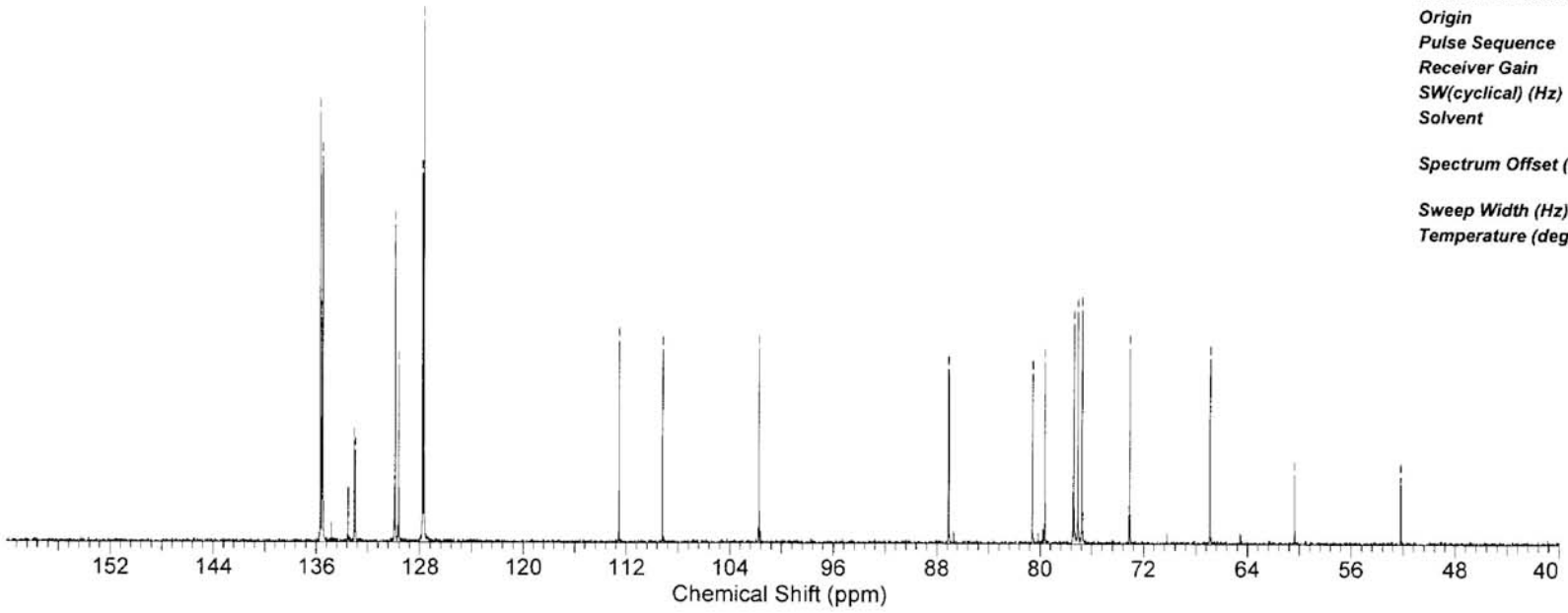


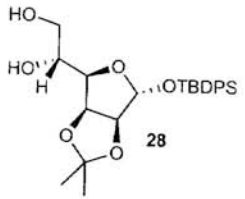
27

kjd9-58 C.esp

135.7
135.6
133.1
133.0
129.9
129.6
127.8
127.7
112.5
109.2
101.8
87.1
80.6
79.7
77.4
77.1
76.8
73.1
66.9
60.4
52.2

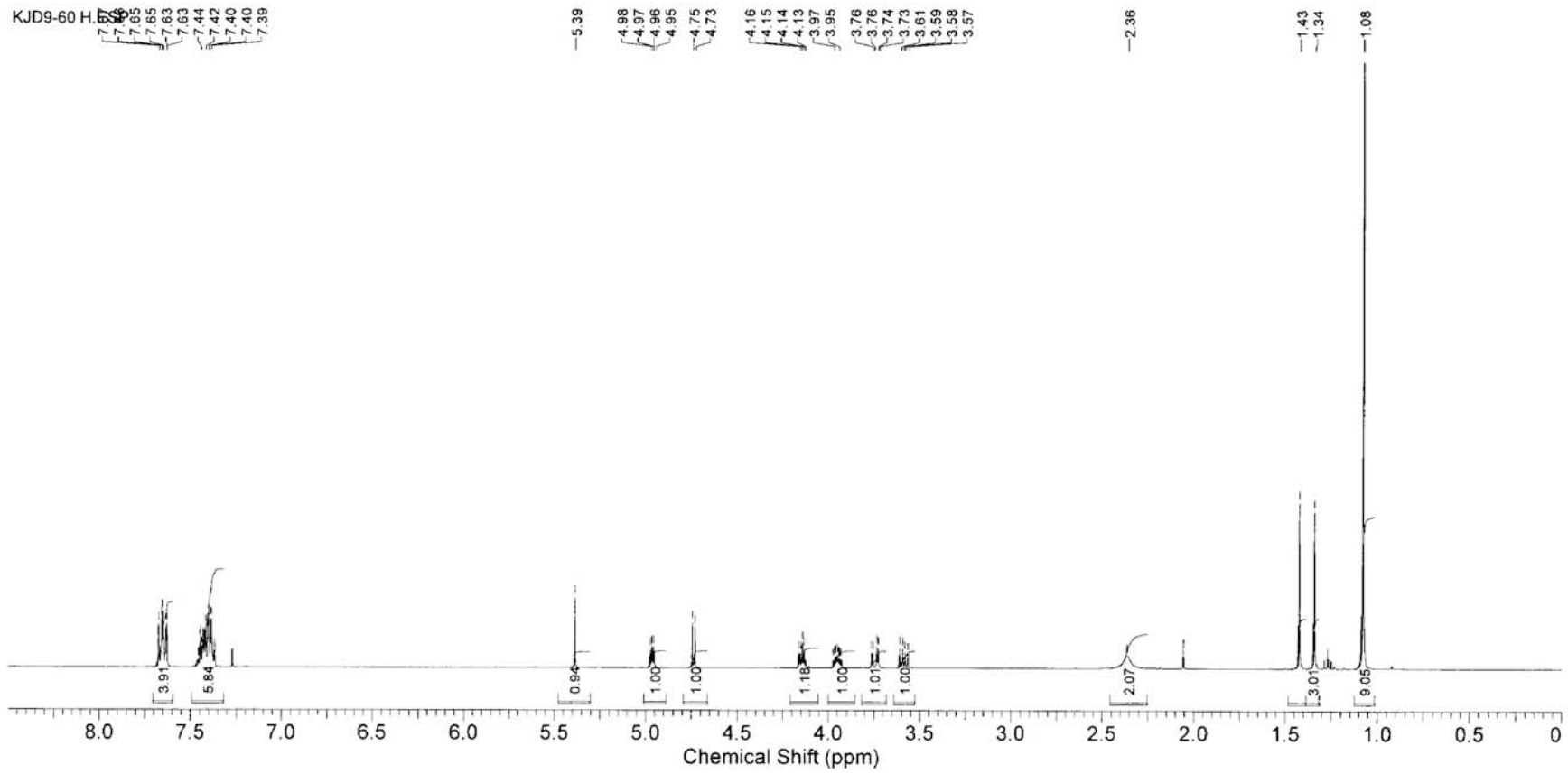
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.900

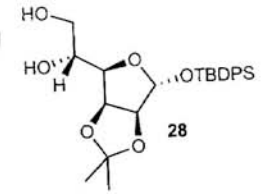




KJD9-60 H.

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	50.80
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.700





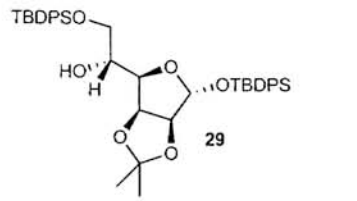
May29-2006-16_004000fid

135.7
135.6
133.0
129.9
127.8
127.7
101.6
86.7
80.2
79.7
77.4
77.1
76.7
70.3
64.5
26.8
25.9
24.7
19.2

Frequency (MHz)	100.64
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10023.5947
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.700

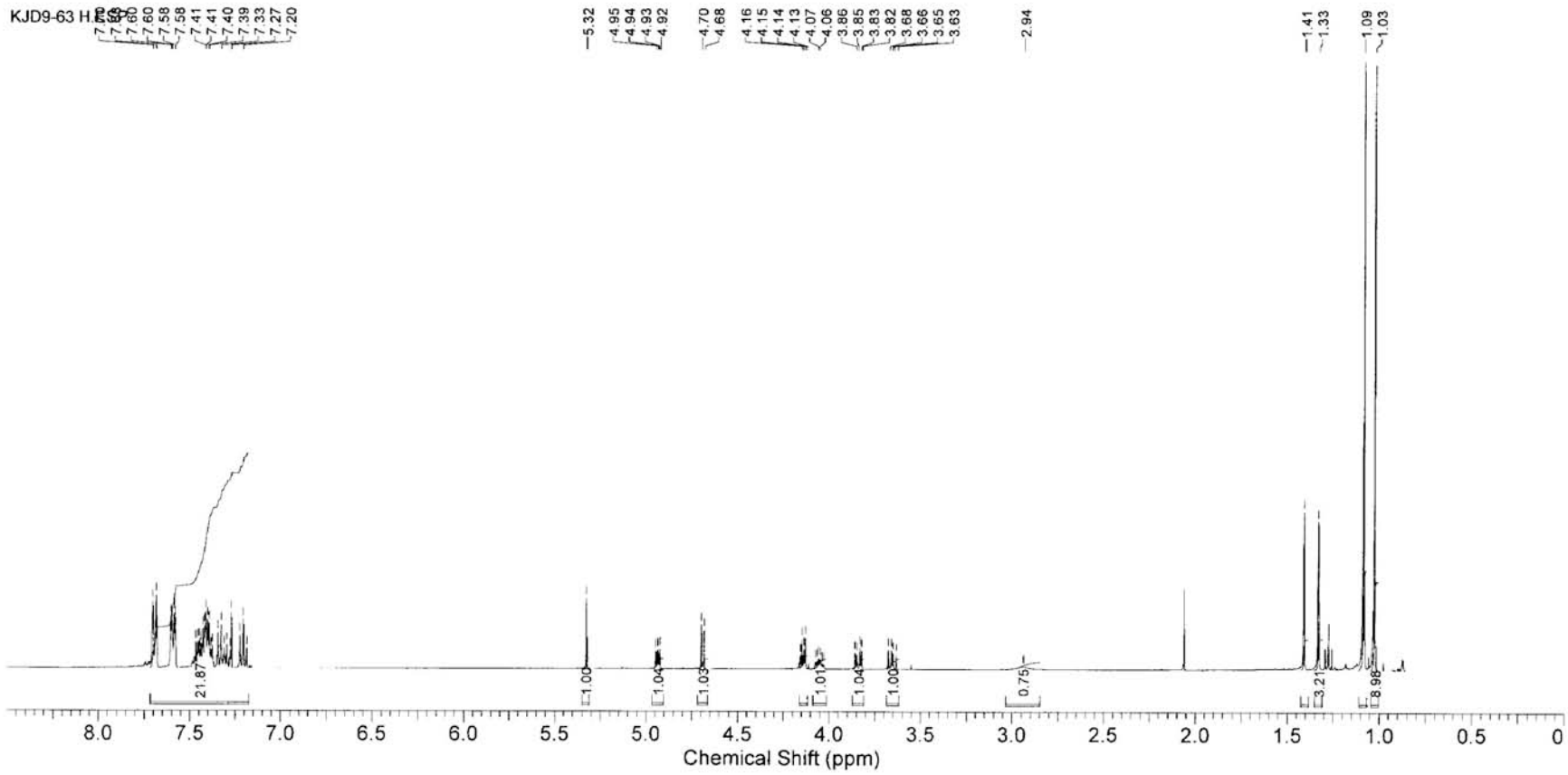
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

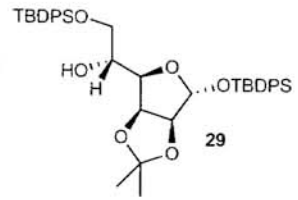
Chemical Shift (ppm)



KJD9-63 H.ESP

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.6377
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.100

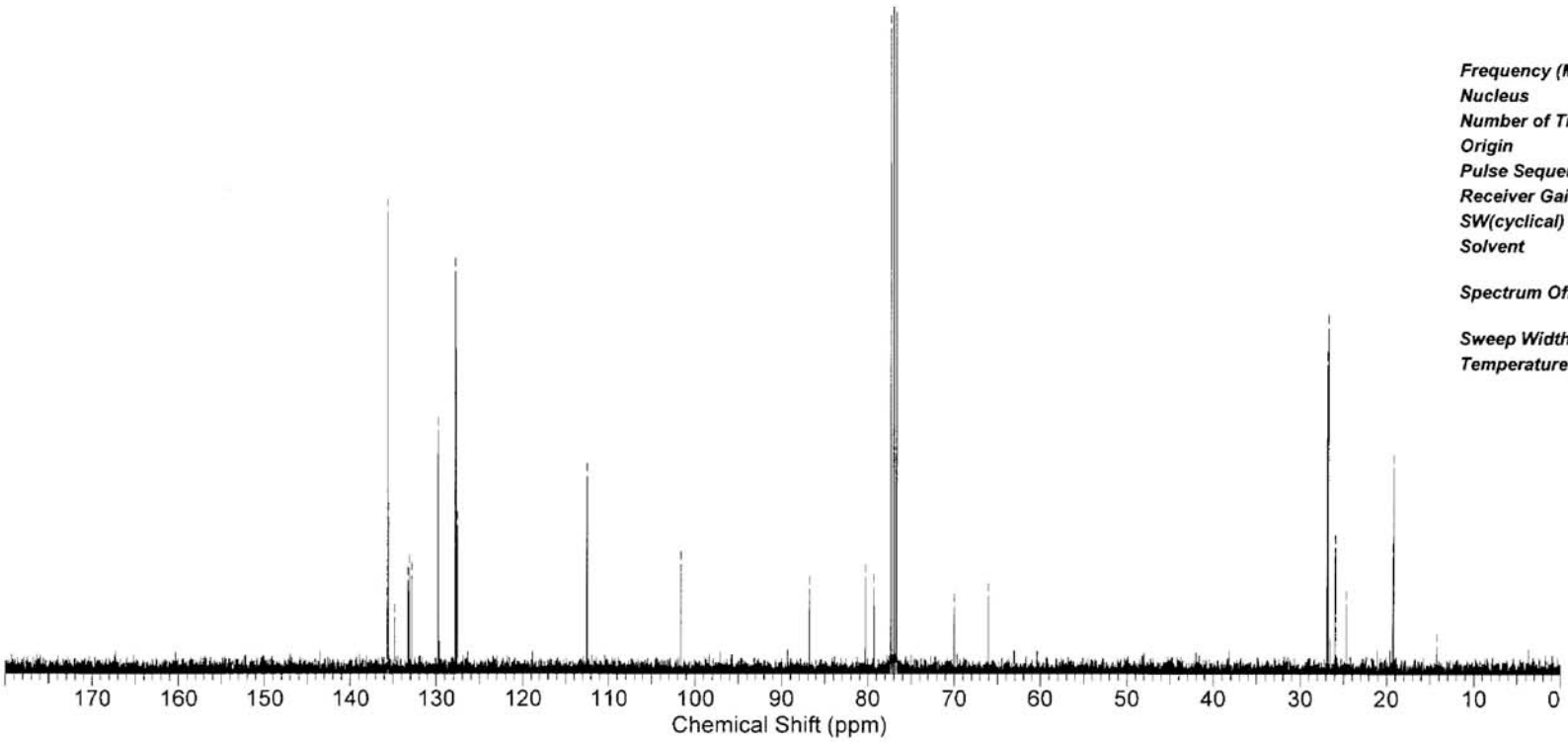


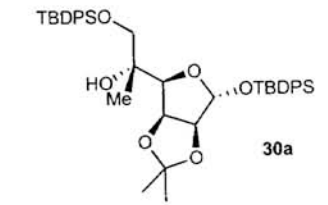


May30-2006-21_004000fid

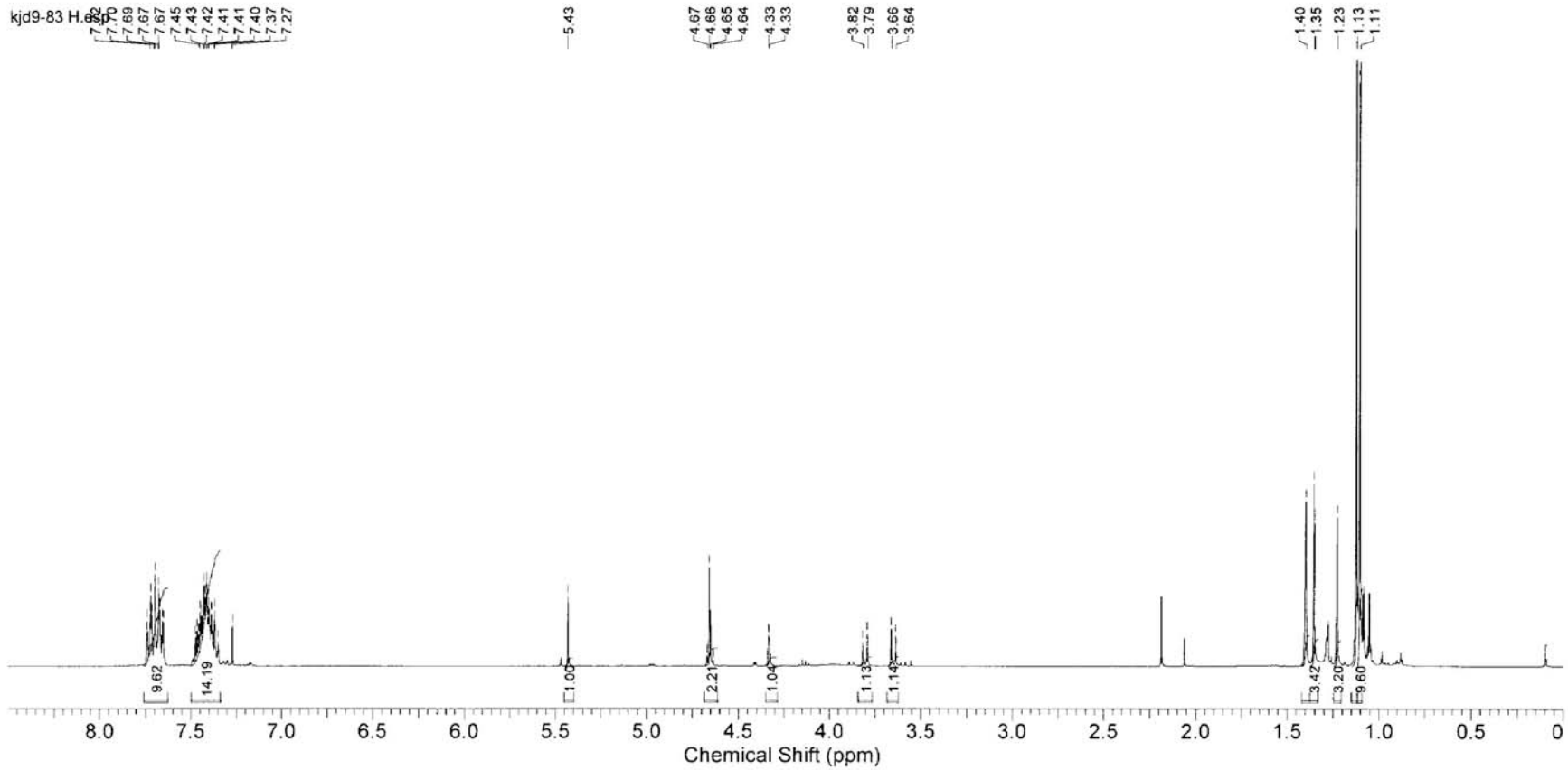
135.6
135.5
134.8
133.3
133.2
133.1
132.9
129.8
127.8
127.6
112.5
101.6
86.8
80.3
79.3
77.4
77.0
76.7
70.0
66.1
26.9
26.8
25.9
24.7
19.3
19.2
14.2

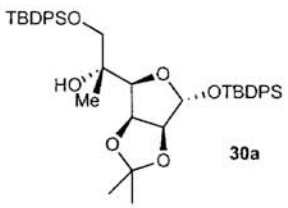
Frequency (MHz)	100.64
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10023.5947
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.900





Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	50.80
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.500



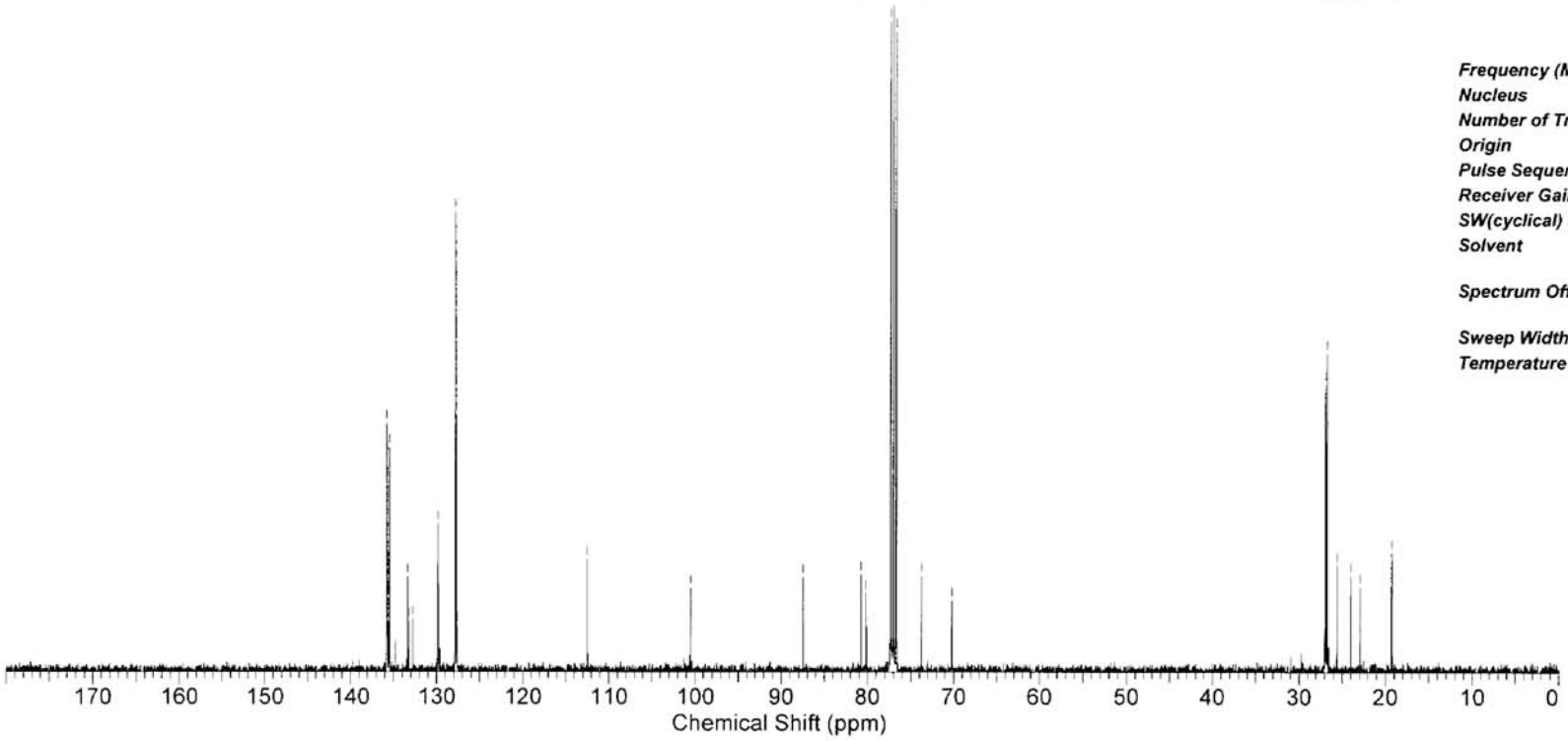


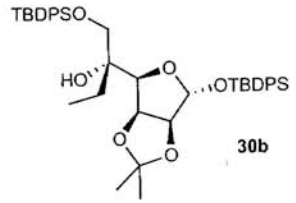
30a

kjd9-83 C.esp

135.8
135.7
135.5
133.3
133.2
132.7
129.8
127.8
127.7
127.6
112.5
100.5
87.5
80.8
80.2
77.3
77.0
76.7
73.7
70.2
26.9
26.7
25.6
24.0
22.9
19.3

Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.500





Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	50.80
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	22.600

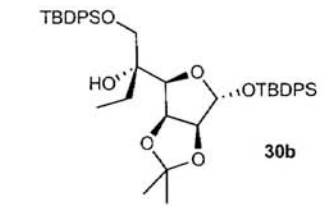
kjd9-72 H.esp

7.72 7.70 7.70 7.69 7.67 7.65 7.45 7.45 7.43 7.42 7.40 7.38 5.41 4.61 4.59 4.52 4.51 4.50 4.50 4.34 4.33 3.85 3.82 3.71 3.68 2.18 1.93 1.92 1.90 1.88 1.86 1.81 1.79 1.77 1.76 1.74 1.37 1.19 1.13 1.10 0.90 0.88 0.87

9.28 14.24 0.96 1.07 1.00 1.00 1.27 1.14 0.70 1.05 0.97 3.10 21.21 4.17

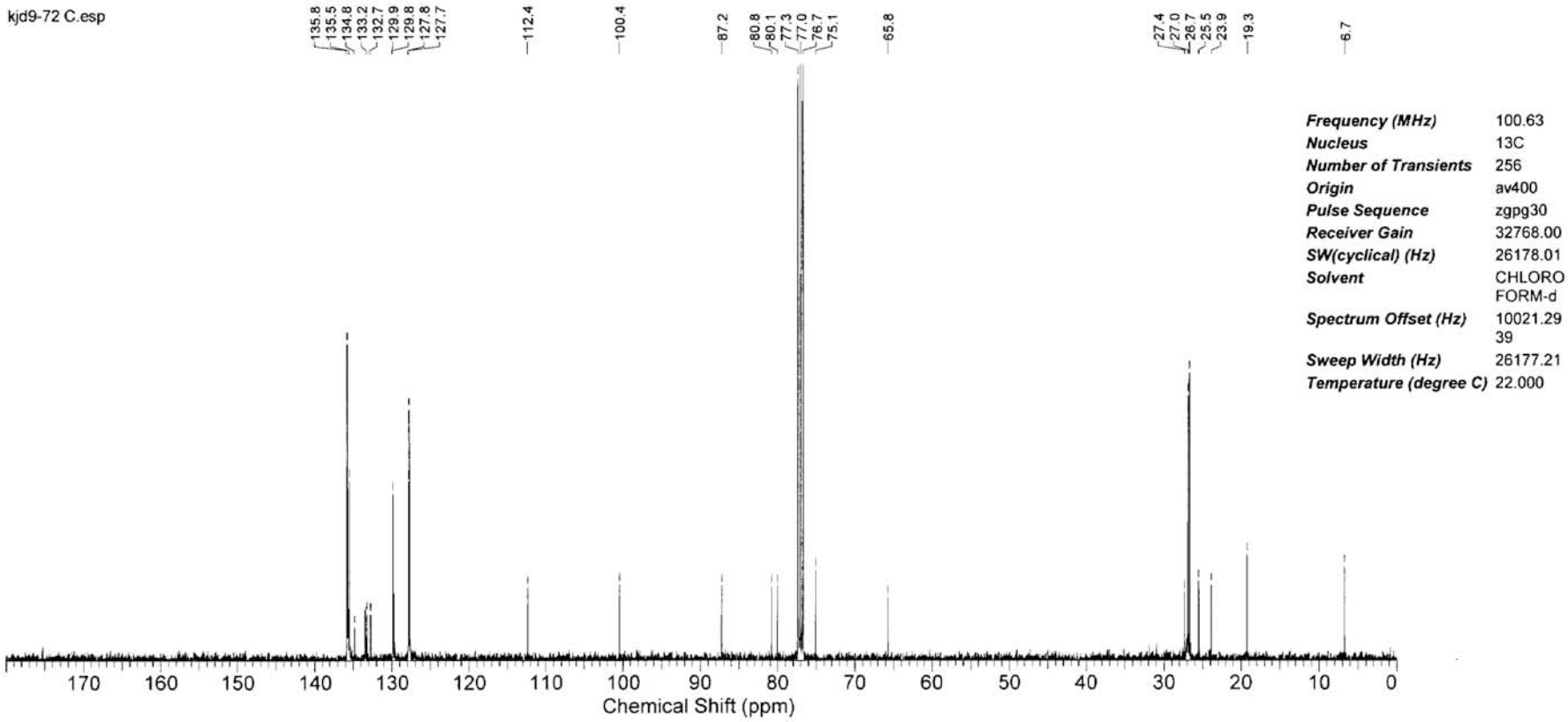
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Chemical Shift (ppm)

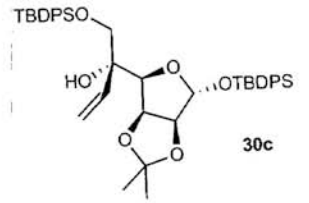


30b

kjd9-72 C.esp

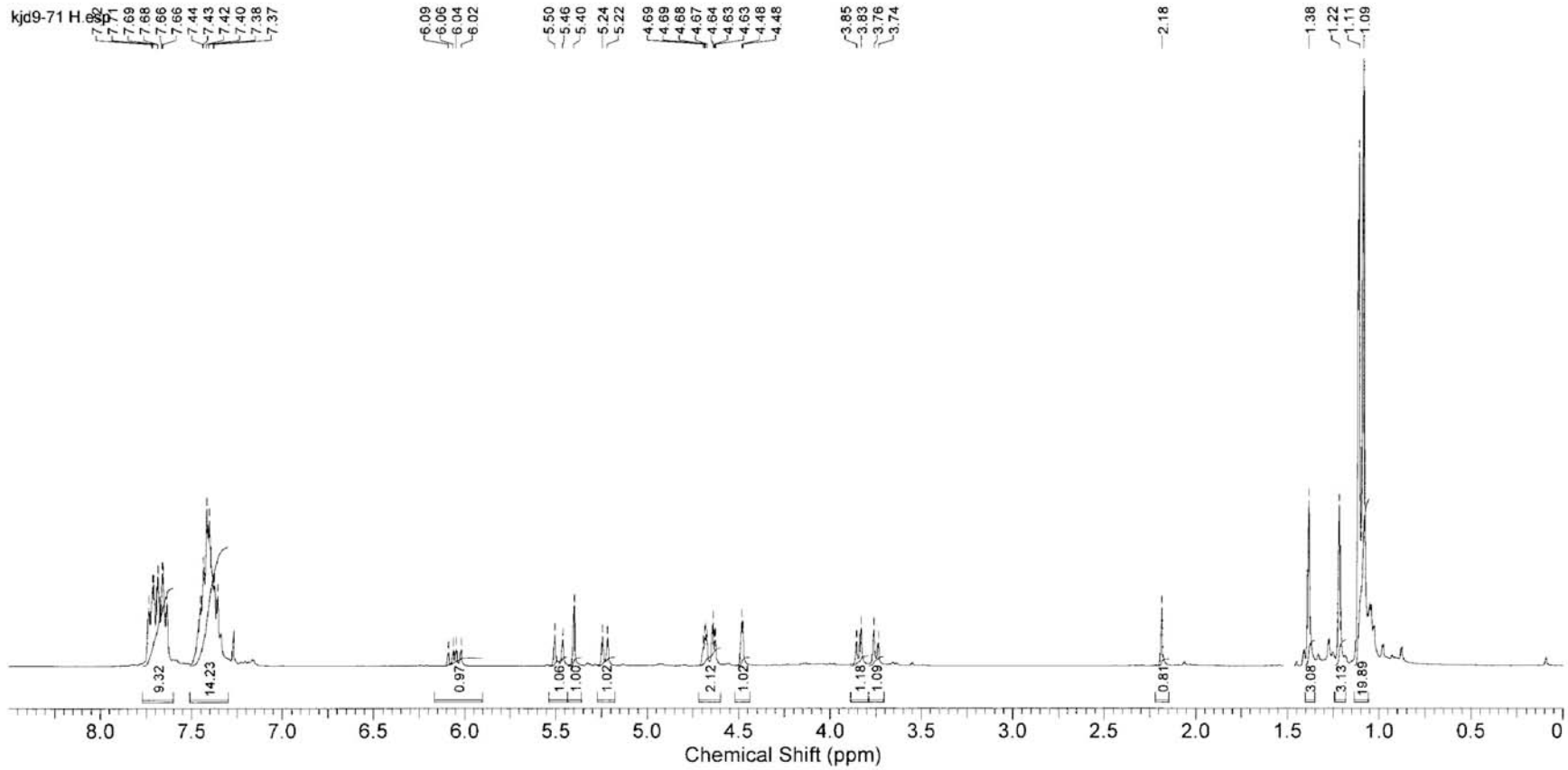


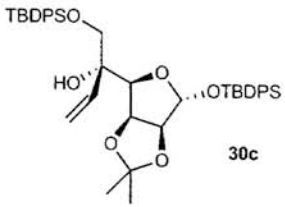
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	22.000



Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	21.900

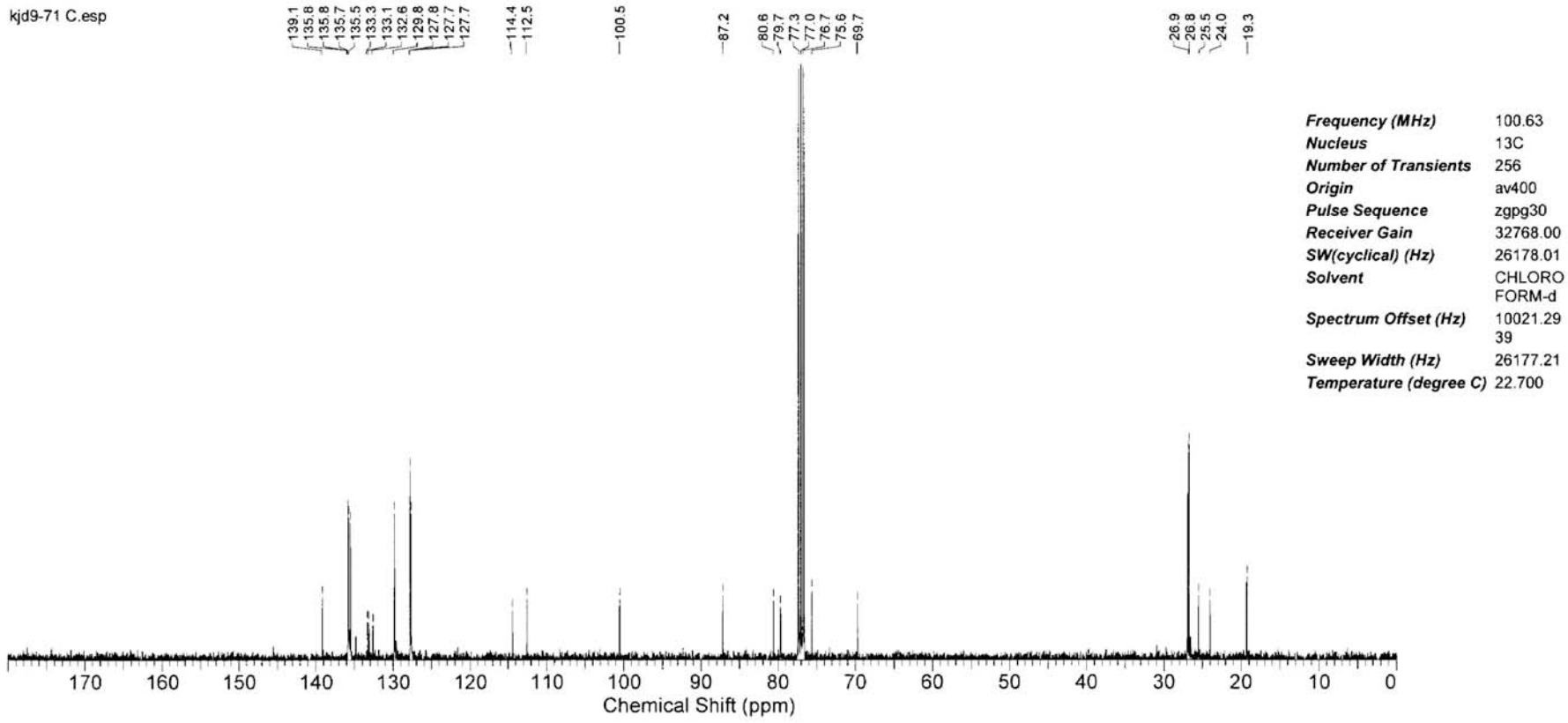
kjd9-71 H.esp



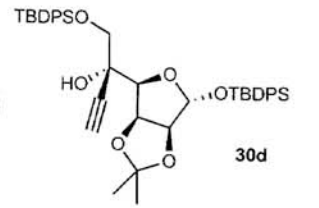


30c

kjd9-71 C.esp



Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	22.700



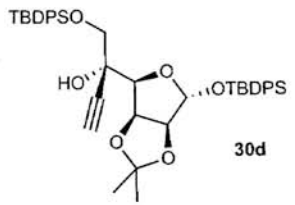
30d

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	40.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	22.600

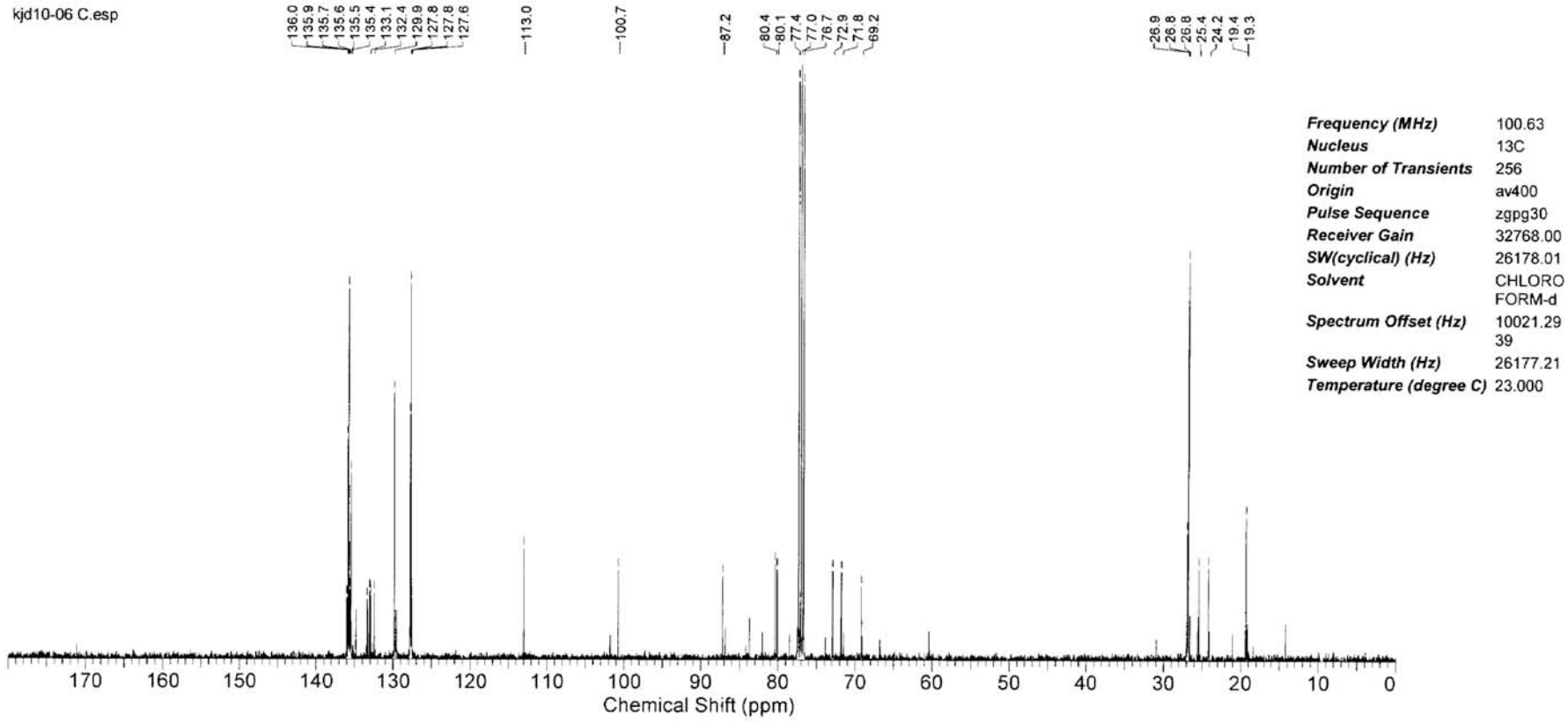
kjd10-06 H 65

7.88 3.39 17.03 1.00 1.04 1.06 2.47 3.10 3.37 21.02

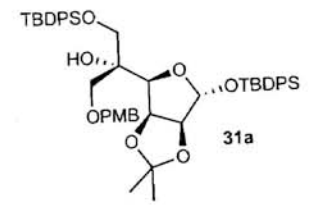
Chemical Shift (ppm)



kjd10-06 C.esp



Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.000



Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.200

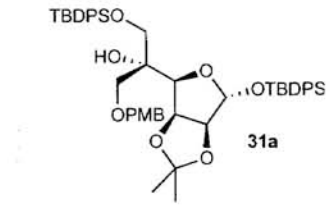
kjd9-90b H esp

7.71 7.70 7.69 7.66 7.40 7.39 7.38 7.36 7.33 7.27 7.24 7.22 6.85 6.83 5.40 4.61 4.56 4.53 4.49 4.46 4.34 4.34 4.19 4.16 3.82 3.81 3.75 3.73 3.69 3.67 3.63 3.61 1.37 1.19 1.09 1.07

8.04 14.73 1.83 0.91 1.94 1.00 1.03 0.96 1.00 1.02 3.05 2.92 17.99

8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

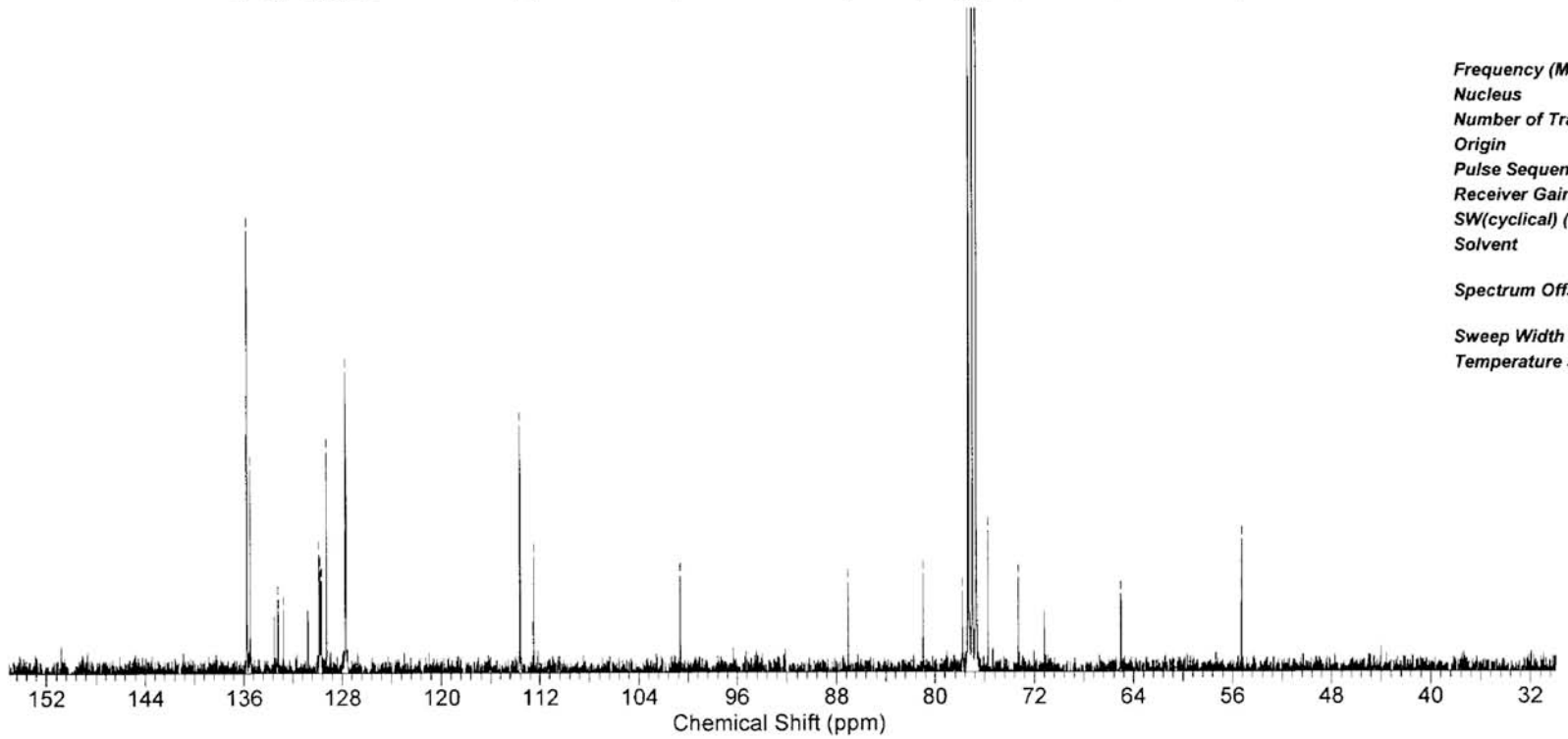
Chemical Shift (ppm)



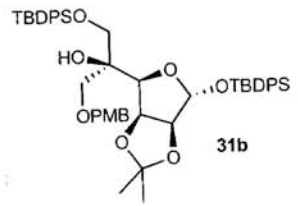
31a

Jun14-2006-11_004001r

135.7
135.4
133.2
132.7
129.9
129.8
129.7
129.7
129.3
127.7
127.7
113.6
112.5
100.7
87.1
81.0
77.8
77.3
77.0
76.7
75.7
73.3
65.0
55.3



Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.600



31b

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	40.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.200

kjd9-90a H.esp

7.92 7.90 7.70 7.68 7.58 7.57 7.36 7.35 7.32 7.30 7.28 7.27 7.26 7.16 6.90 6.88

5.36

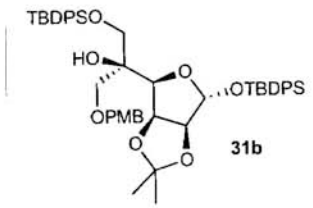
4.91 4.91 4.90 4.89 4.64 4.63 4.60 4.57 4.51 4.48 4.33 4.32 3.99 3.97 3.91 3.88 3.83 3.80 3.69 3.66

1.39 1.26 1.08 1.00

4.36 4.08 13.25 2.00 1.99 1.05 0.97 1.00 1.03 1.00 1.03 4.04 1.13 3.49 3.15 9.19

8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Chemical Shift (ppm)

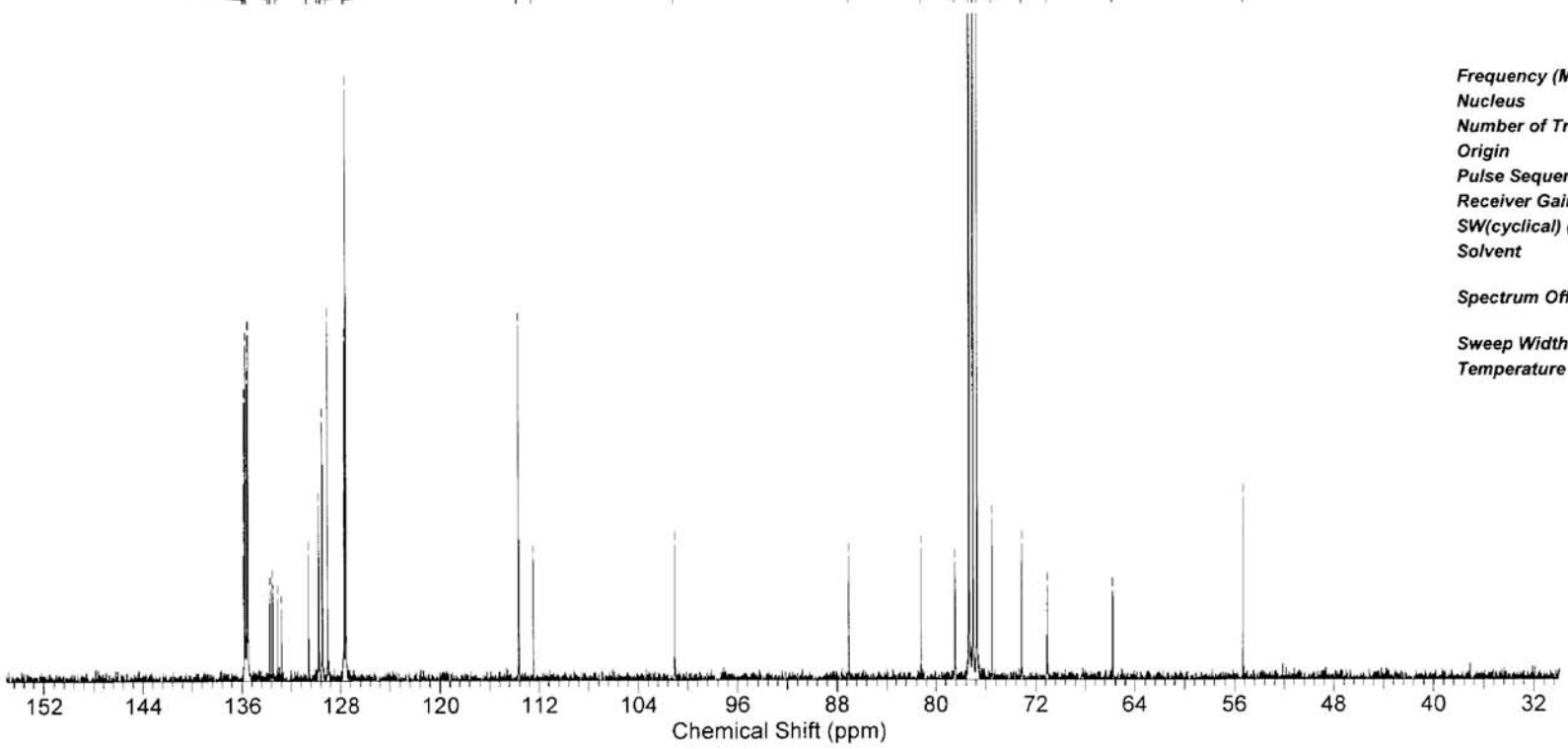


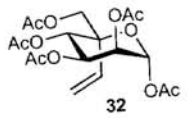
31b

kjd9-90a C.esp

135.8
135.7
135.6
135.5
133.7
133.5
133.1
130.6
129.8
129.5
129.0
127.7
127.6
113.7
112.5
101.0
87.0
81.2
78.5
77.4
77.0
76.7
75.5
73.1
71.1
65.8
55.3

Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.800

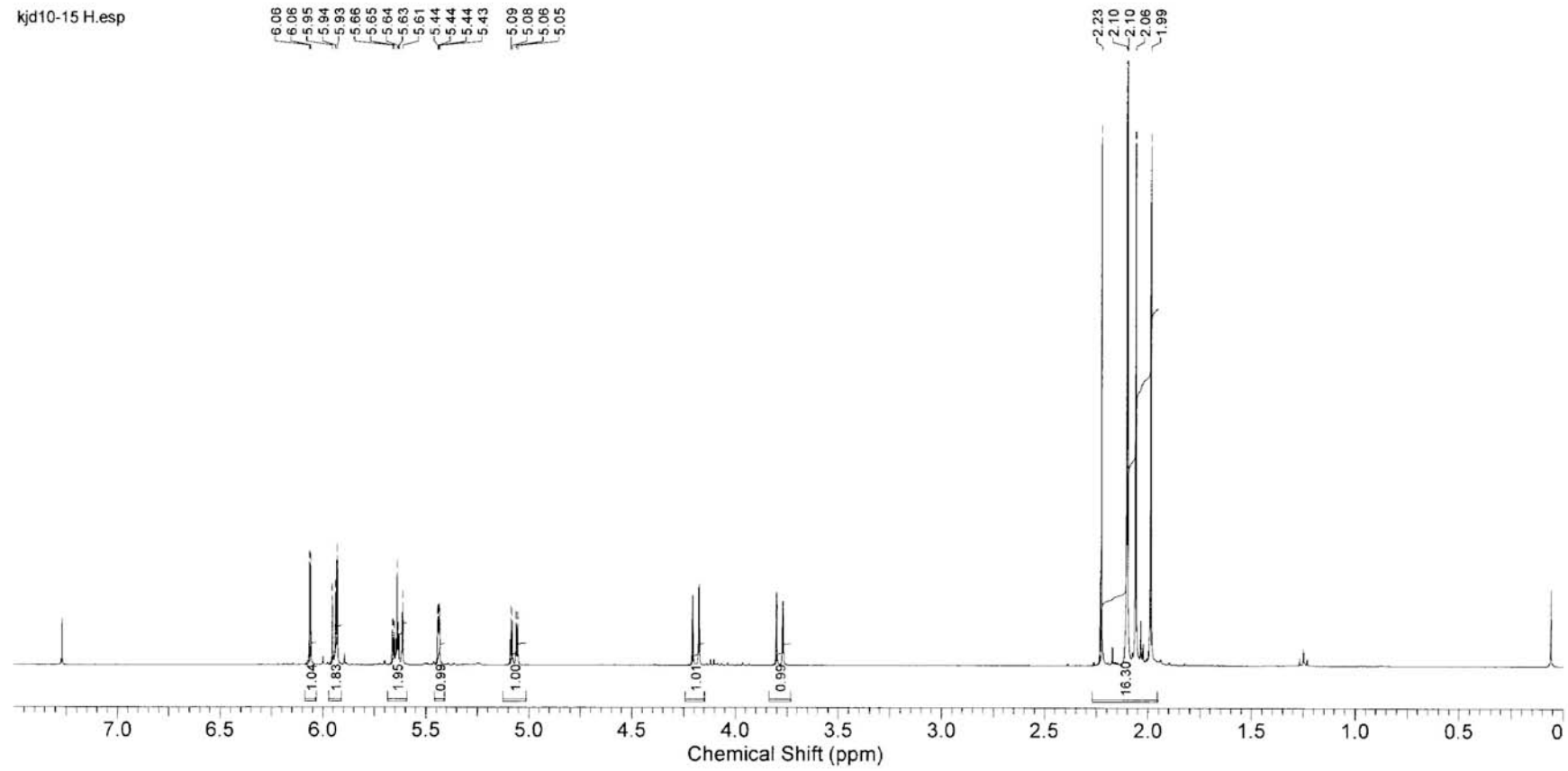


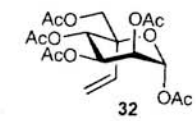


32

kjd10-15 H.esp

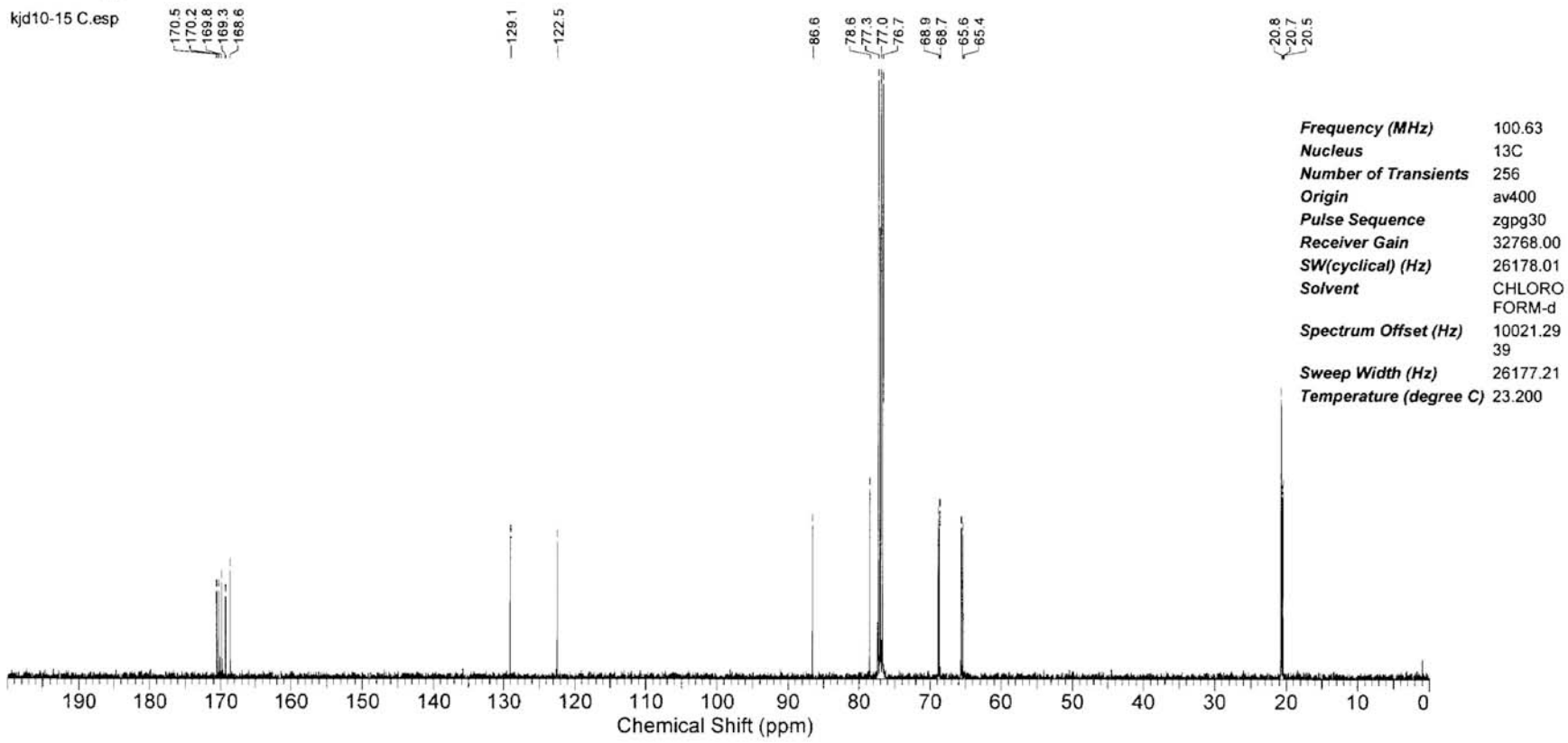
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.200



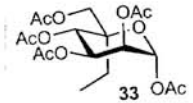


32

kjd10-15 C.esp

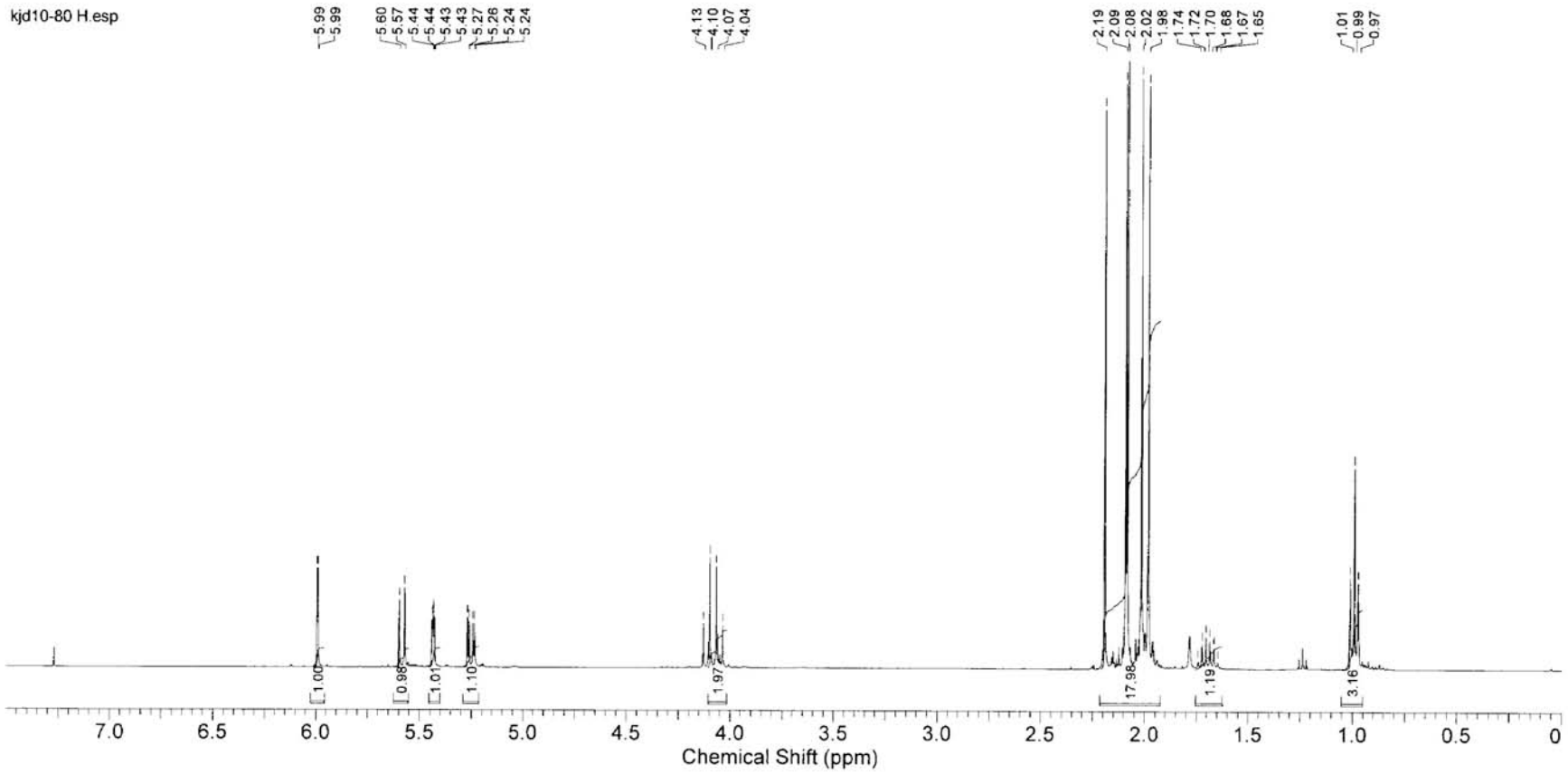


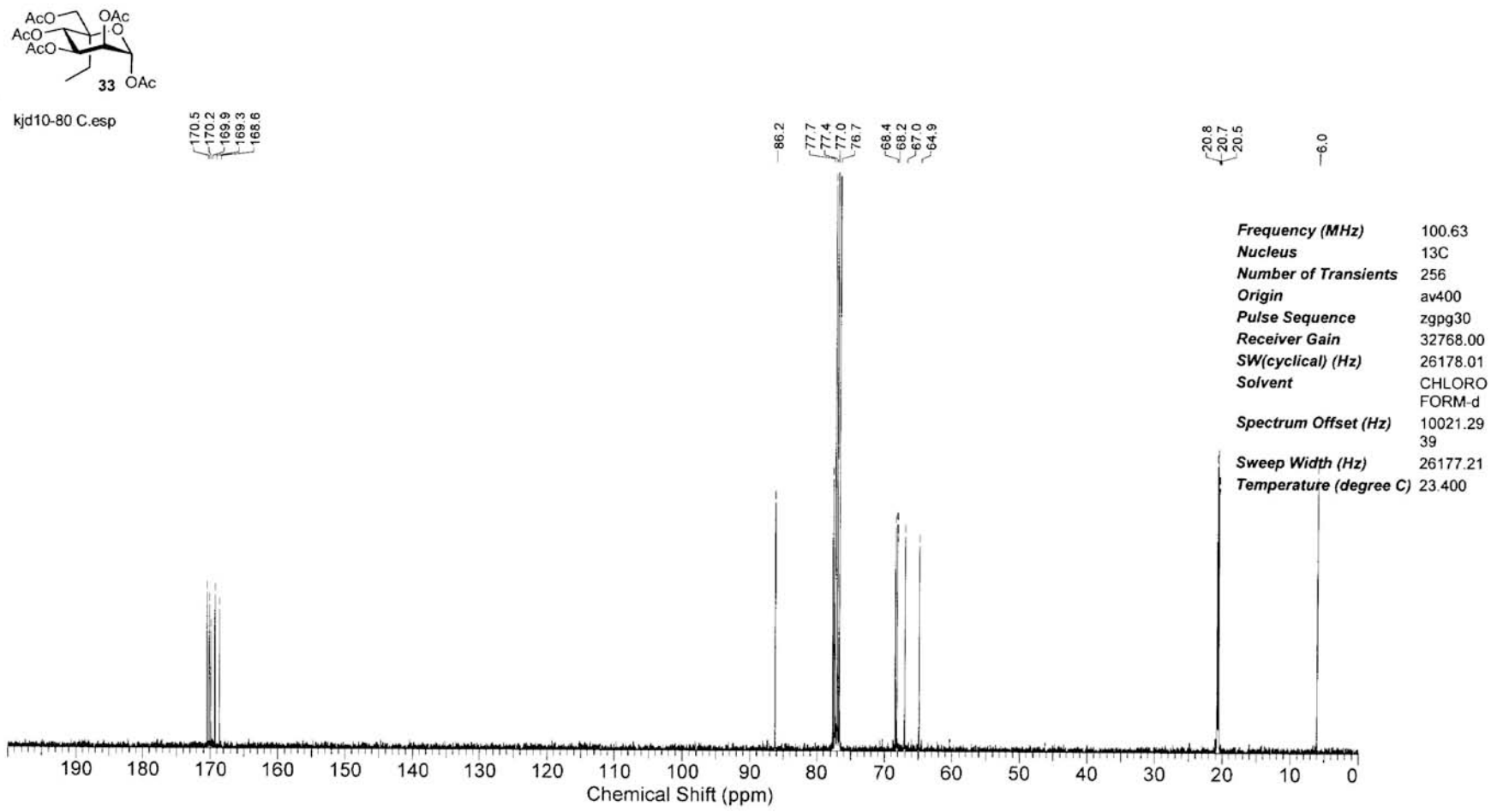
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.200

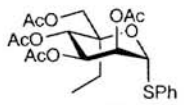


kjd10-80 H.esp

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	45.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.300




AcO
OAc
AcO
O
AcO
33
OAc
kjd10-80 C.esp
170.5
170.2
169.9
169.3
168.8
86.2
77.7
77.4
77.0
76.7
68.4
68.2
67.0
64.9
20.8
20.7
20.5
6.0
Frequency (MHz) 100.63
Nucleus 13C
Number of Transients 256
Origin av400
Pulse Sequence zgpg30
Receiver Gain 32768.00
SW(cyclical) (Hz) 26178.01
Solvent CHLOROFORM-d
Spectrum Offset (Hz) 10021.2939
Sweep Width (Hz) 26177.21
Temperature (degree C) 23.400
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Chemical Shift (ppm)



34α

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.400

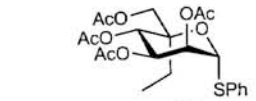
kjd10-97 alpha 1H esp

7.59 7.58 7.57 7.34 7.33 7.31 7.30 7.30 7.27
5.64 5.64 5.63 5.63 5.60 5.57
5.19 5.18 5.17 5.16 4.90 4.90
4.12 4.11 4.09 4.08 4.05
2.19 2.11 2.00 1.97 1.84 1.82 1.80 1.78 1.77 1.75 1.63 1.61 1.59 1.57
0.54 0.52 0.50

1.89 3.26 1.93 1.13 1.00 2.31 6.13 5.91 1.18 1.11 2.98

8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Chemical Shift (ppm)

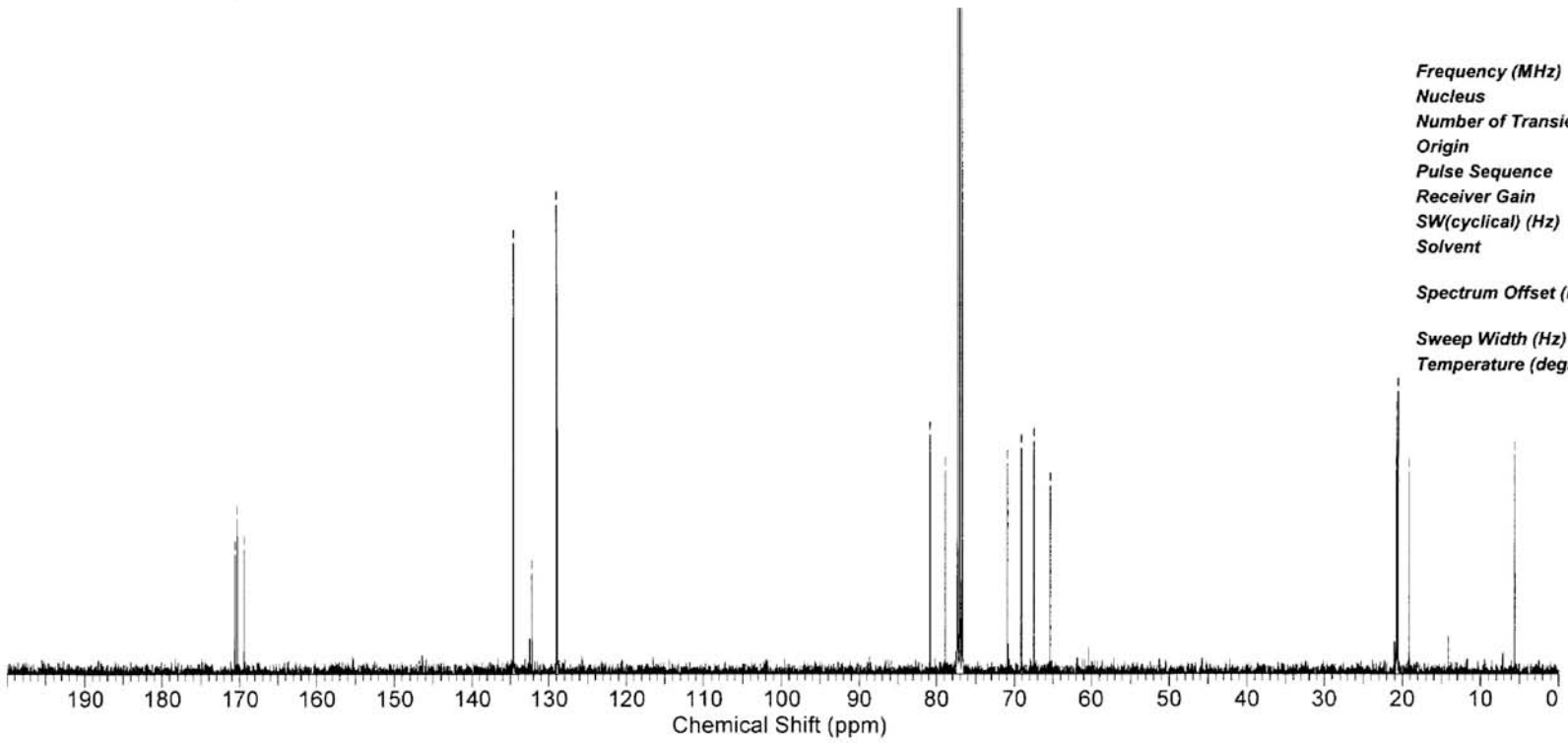


34α

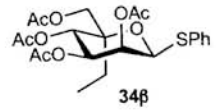
Sep13-2006-49_004001r

170.6
170.3
169.3
134.6
132.2
129.0
80.8
78.9
77.4
77.0
76.7
70.9
69.1
67.5
65.4
20.8
20.7
20.6
19.2
5.6

Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.700

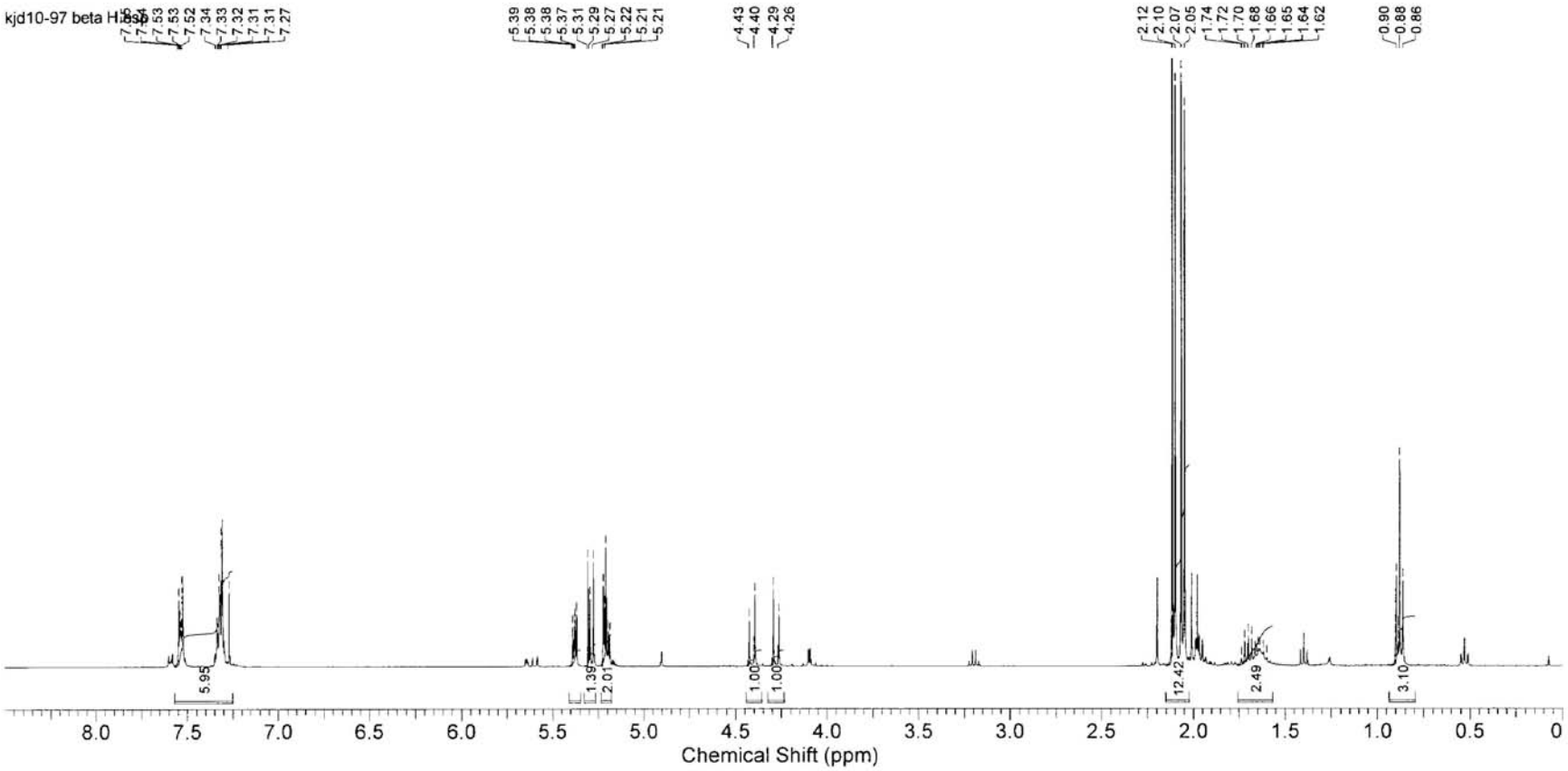


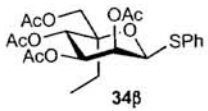
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	161.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	23.100



34β

kjd10-97 beta H.esp



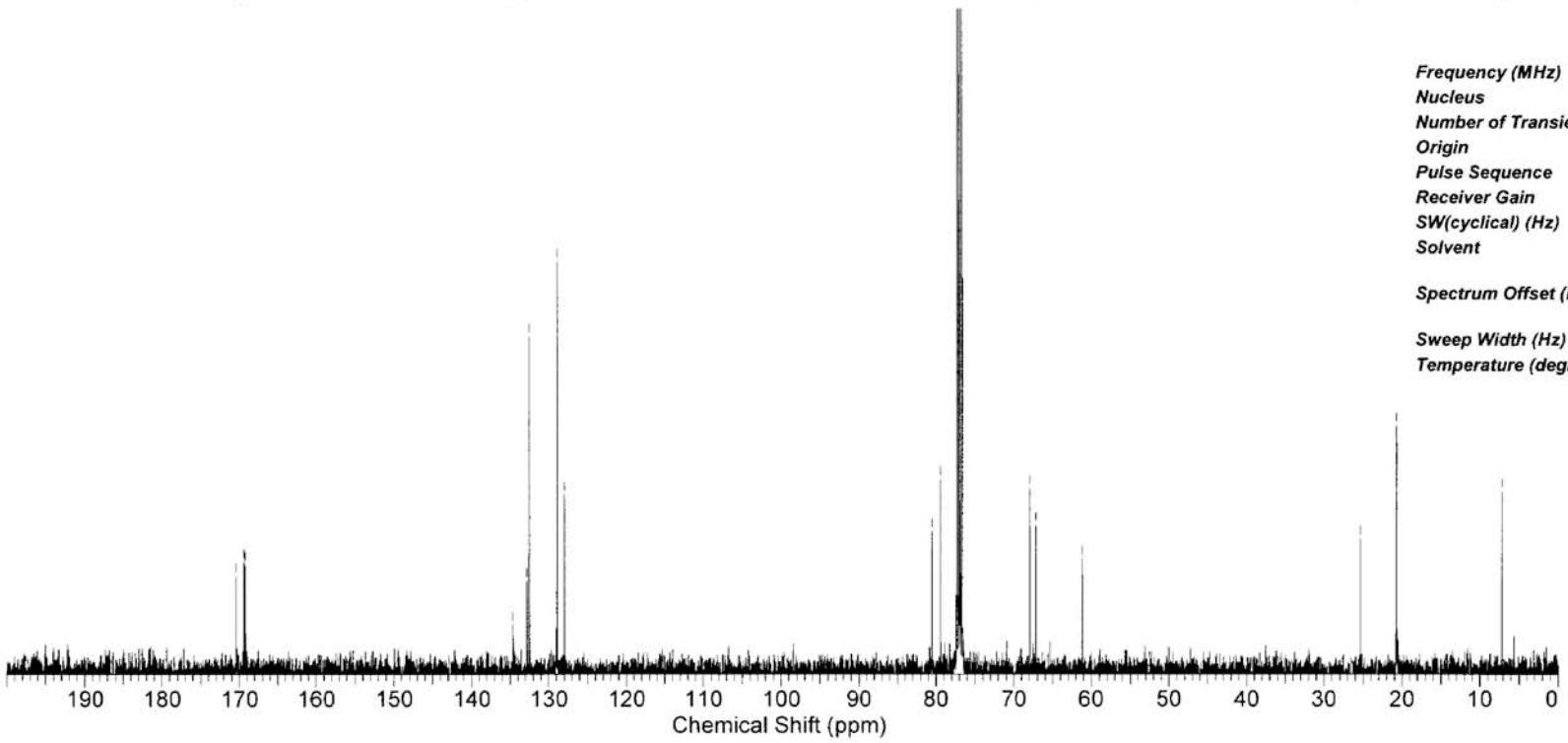


34β

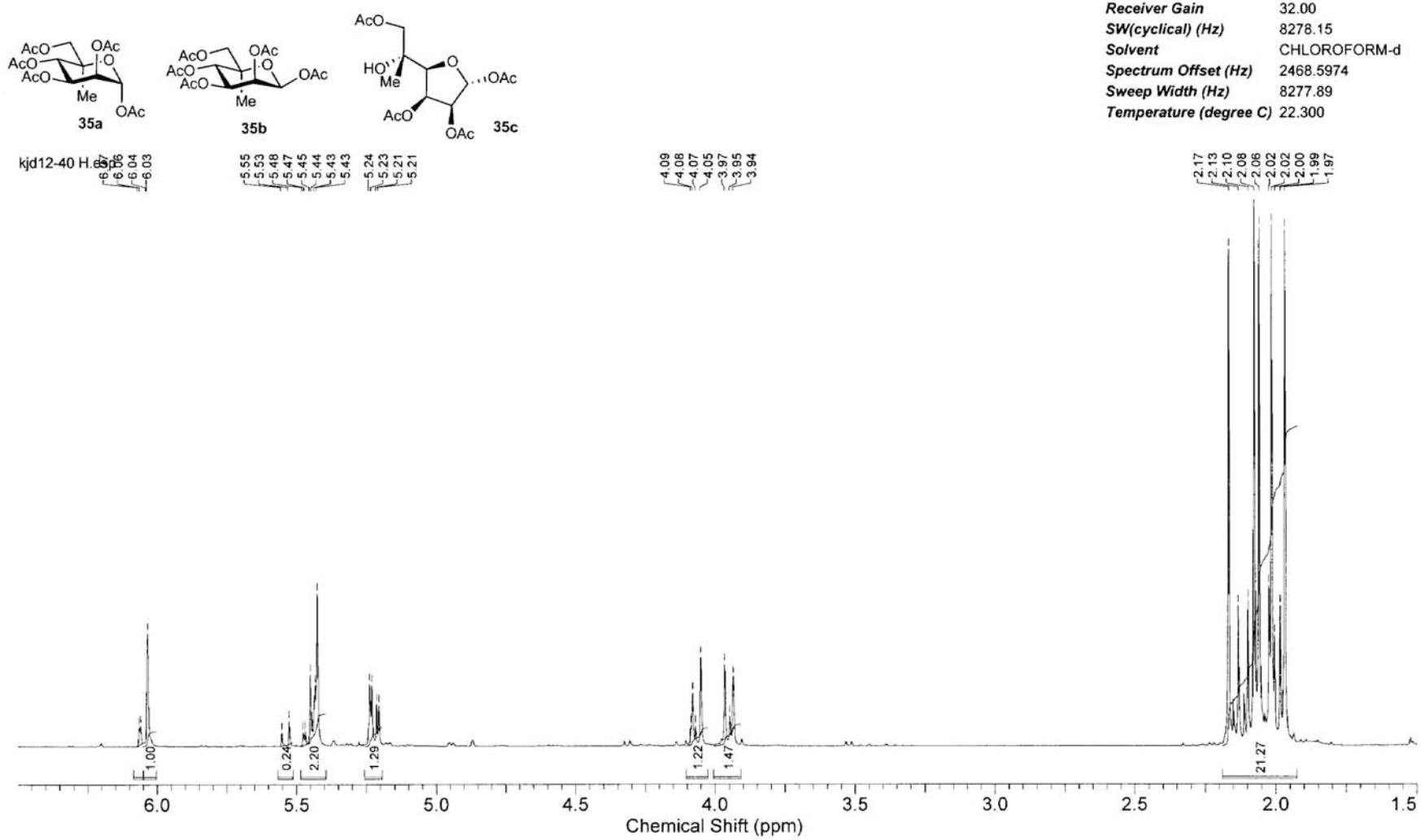
kjd10-97 beta C.esp

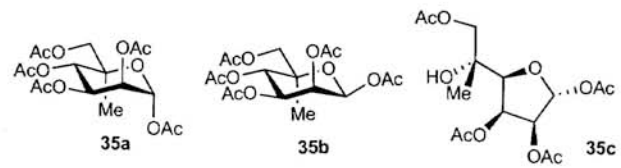
170.4
169.4
169.2
134.6
132.8
132.5
128.9
128.0
80.5
79.4
77.3
77.0
76.7
67.9
67.2
61.2
25.3
20.7
7.2

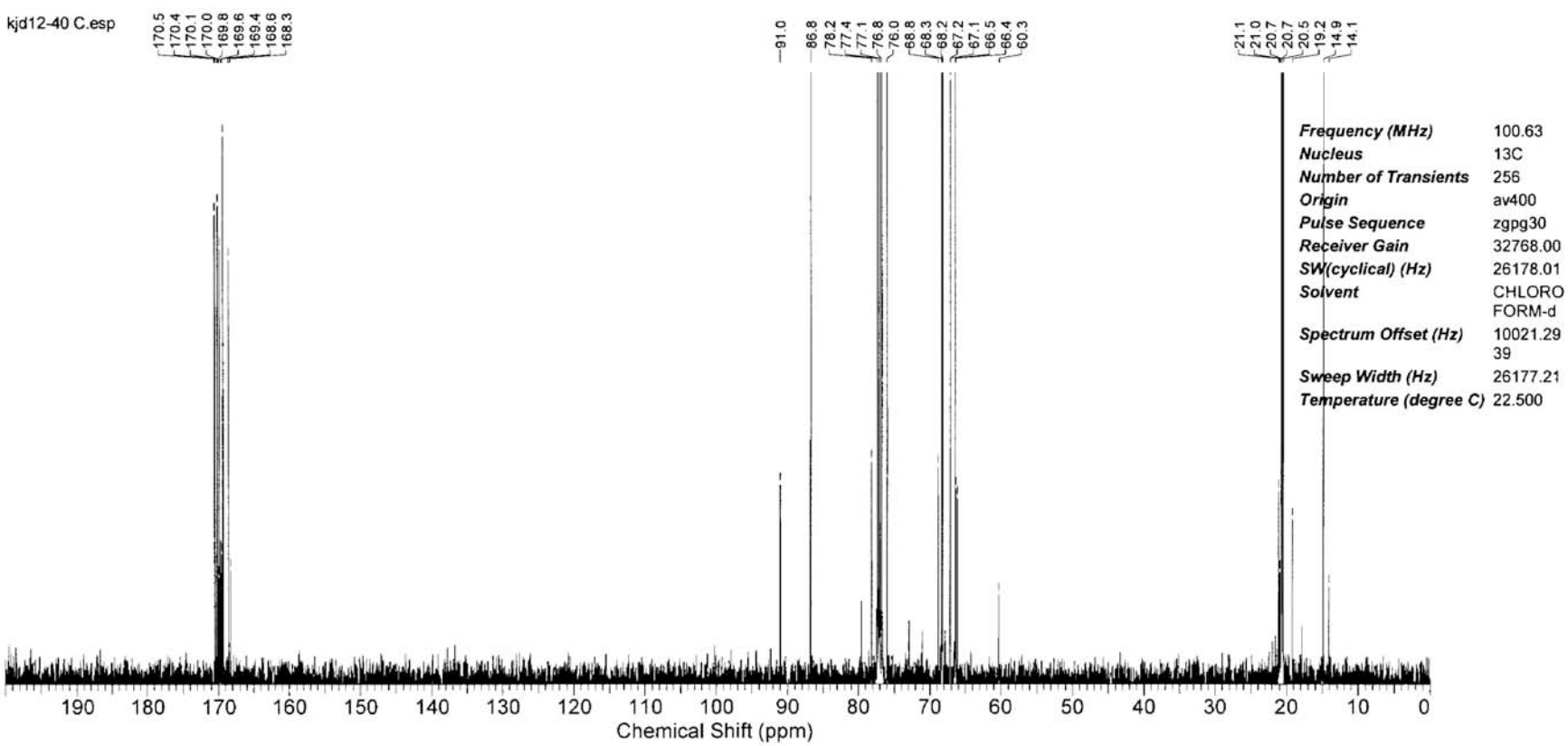
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	23.800

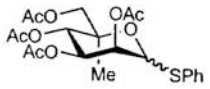


Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	32.00
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	22.300




AcO
OAc
AcO
AcO
Me
OAc
35a
AcO
OAc
AcO
AcO
Me
OAc
35b
AcO
HO
Me
O
OAc
AcO
OAc
35c

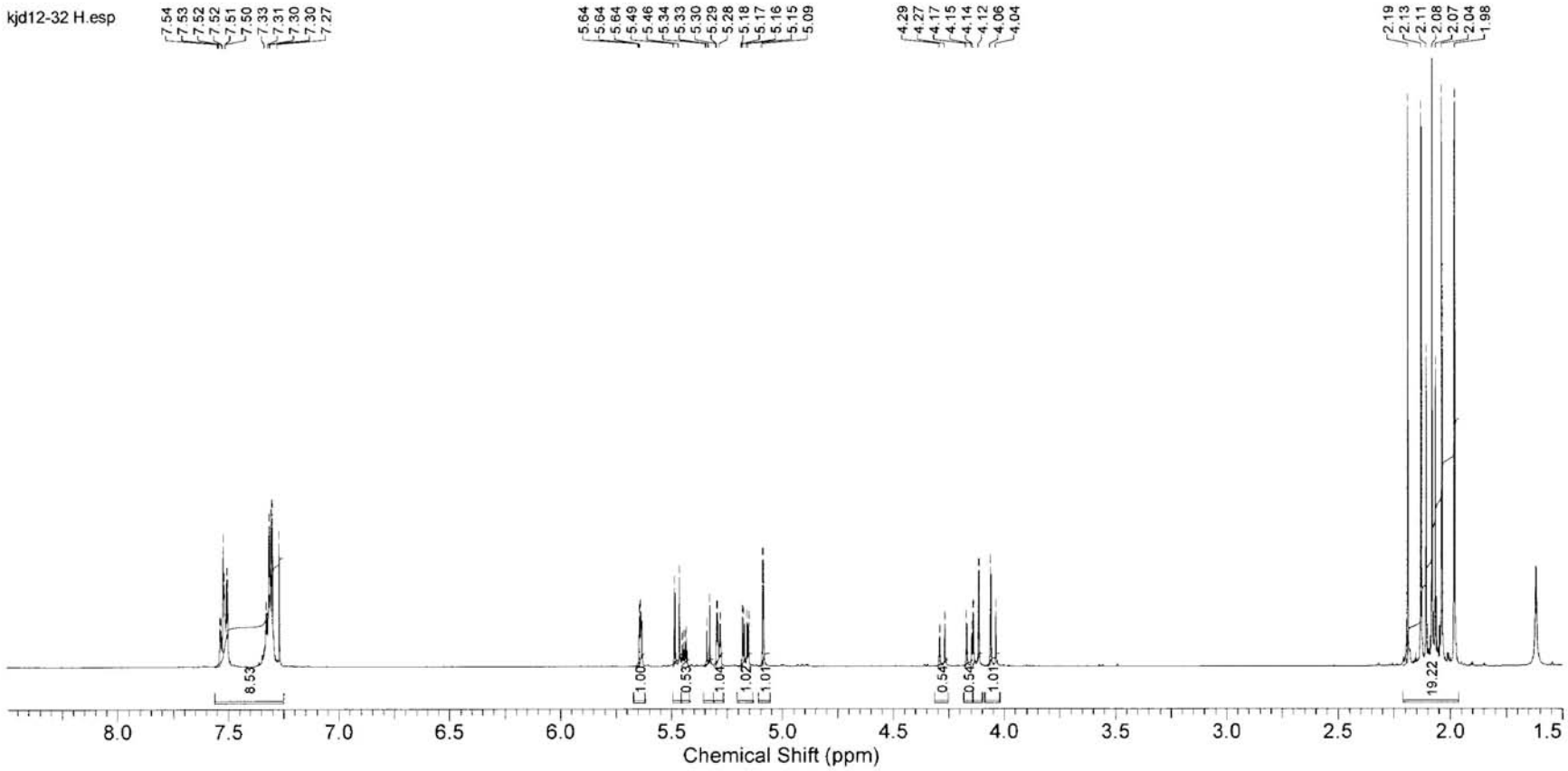

kjd12-40 C.esp
170.5
170.4
170.1
170.0
169.8
169.6
169.4
168.6
168.3
91.0
86.8
78.2
77.4
77.1
76.8
76.0
68.8
68.3
68.2
67.2
67.1
66.5
66.4
60.3
21.1
21.0
20.7
20.7
20.5
19.2
14.9
14.1
Frequency (MHz) 100.63
Nucleus 13C
Number of Transients 256
Origin av400
Pulse Sequence zgpg30
Receiver Gain 32768.00
SW(cyclical) (Hz) 26178.01
Solvent CHLOROFORM-d
Spectrum Offset (Hz) 10021.2939
Sweep Width (Hz) 26177.21
Temperature (degree C) 22.500
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Chemical Shift (ppm)

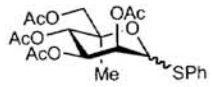


36

Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3065.5417
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970

kjd12-32 H.esp





36

kjd12-32 C.esp

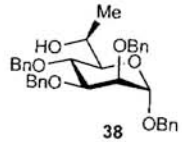
170.6
170.4
170.2
170.2
169.5
169.4
133.5
132.8
132.4
131.9
129.0
128.0
128.0
81.5
80.6
77.9
77.5
77.3
77.0
76.7
71.1
69.2
68.6
67.9
67.8
67.2
66.6
65.4
20.7
20.7
20.6
20.2
14.1

Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	256
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1620.00
SW(cyclical) (Hz)	31250.00
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	12571.3047
Sweep Width (Hz)	31249.05
Temperature (degree C)	24.970

190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

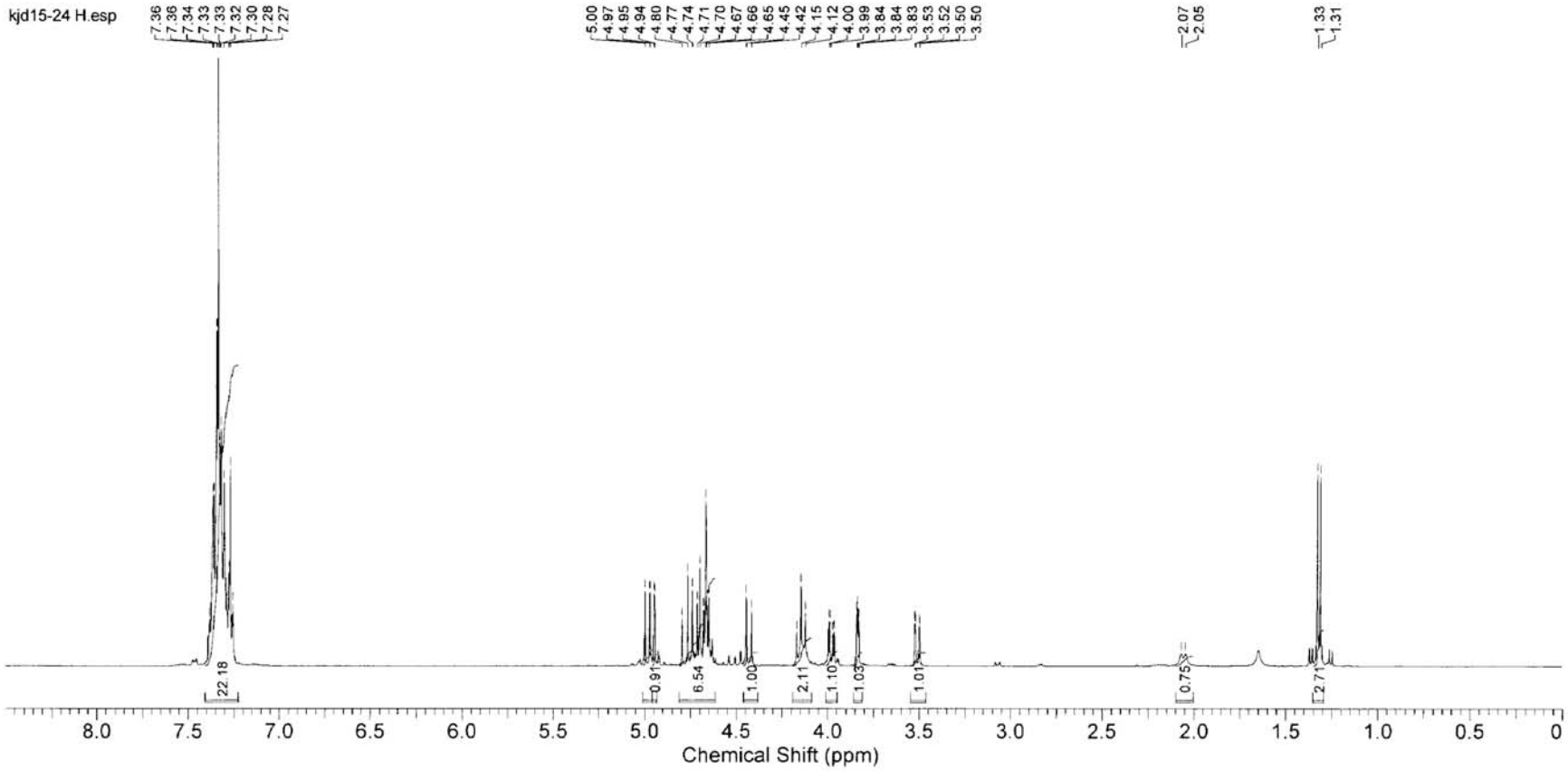
Chemical Shift (ppm)

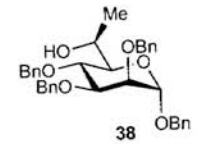
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	90.50
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000



38

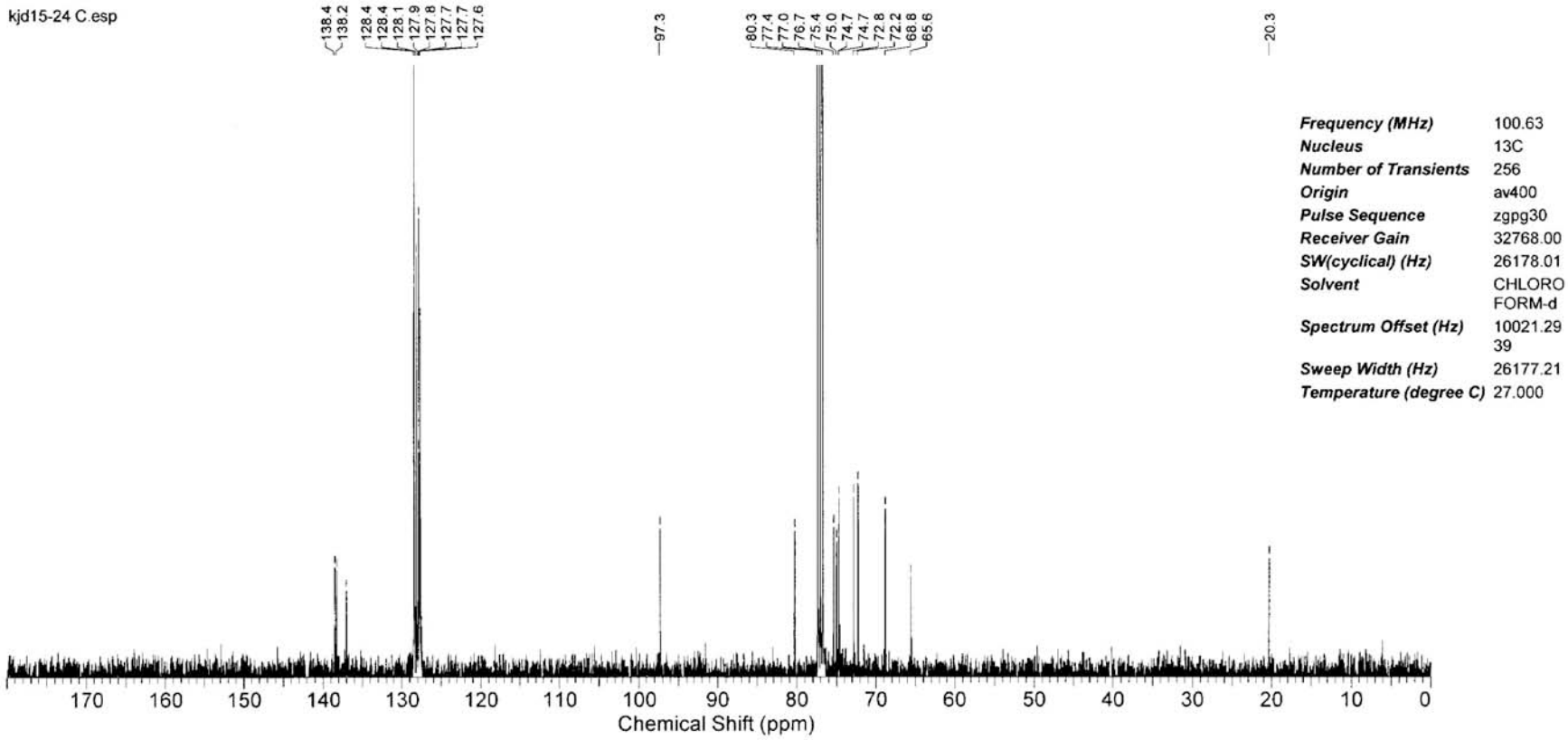
kjd15-24 H.esp



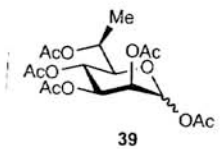


38

kjd15-24 C.esp



Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000



39

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	32.00
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000

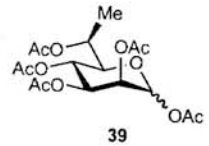
kjd15-19 H-1.esp

6.01 6.00 5.79 5.78 5.48 5.47 5.36 5.33 5.31 5.30 5.29 5.26 5.25 5.24 5.24 5.02 5.02 5.01 5.00 2.20 2.16 2.13 2.08 2.06 2.06 2.00 1.99 1.99 1.96 1.96 1.29 1.28 1.24 1.24 1.23 1.22

1.00 0.32 0.32 3.86 1.79 1.08 0.33 24.45 4.94

6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

Chemical Shift (ppm)



39

kjd15-19 C 5d

170.5
170.4
170.2
170.0
169.8
169.7
169.4
168.4
167.9

90.9
90.8

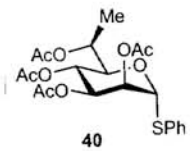
77.4
77.1
76.8
76.3
73.4
70.9
69.0
68.4
68.3
66.1
65.8
65.1
64.9

21.0
20.9
20.8
20.8
20.6
20.5
15.6
14.1

Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000

180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

Chemical Shift (ppm)

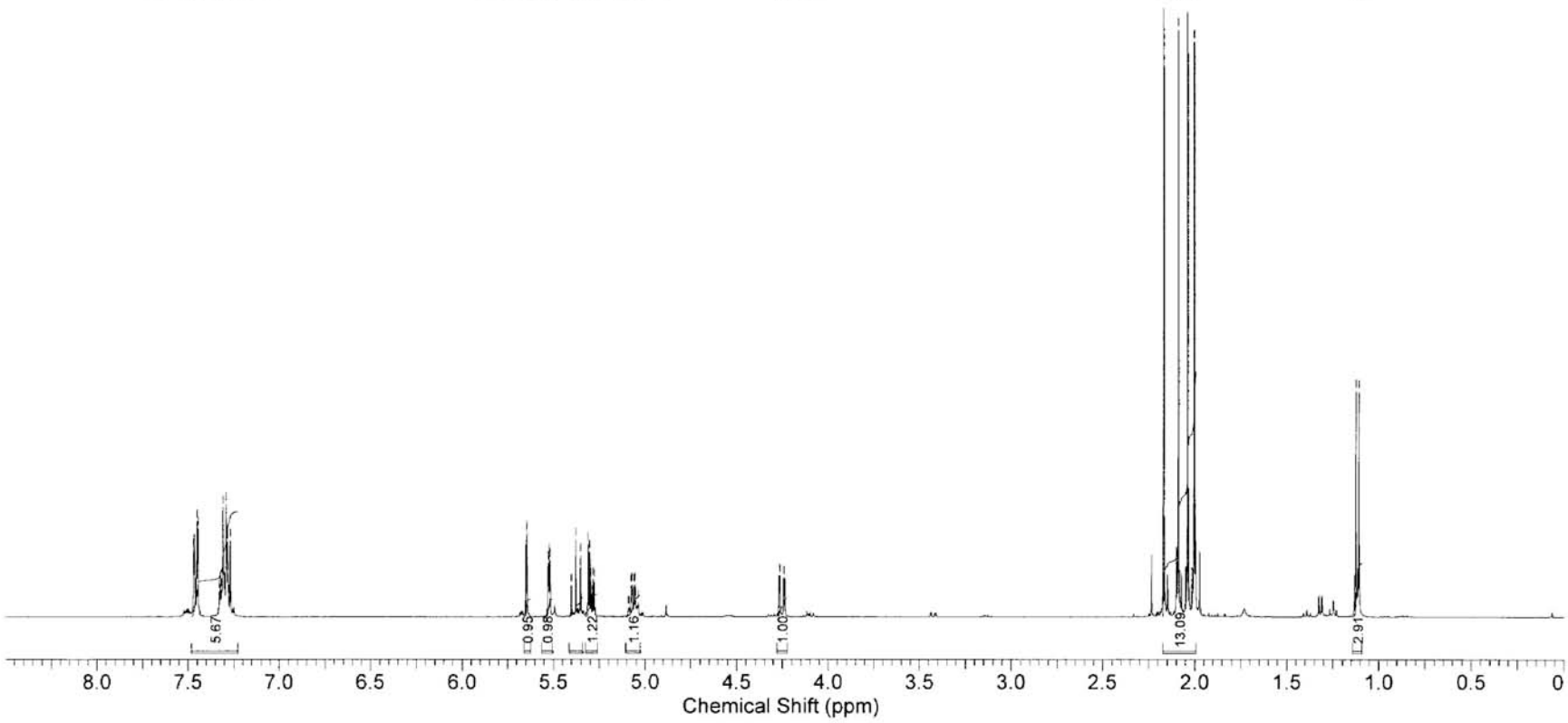


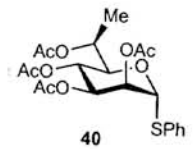
40

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	40.30
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000

kjd15-20 H.esp

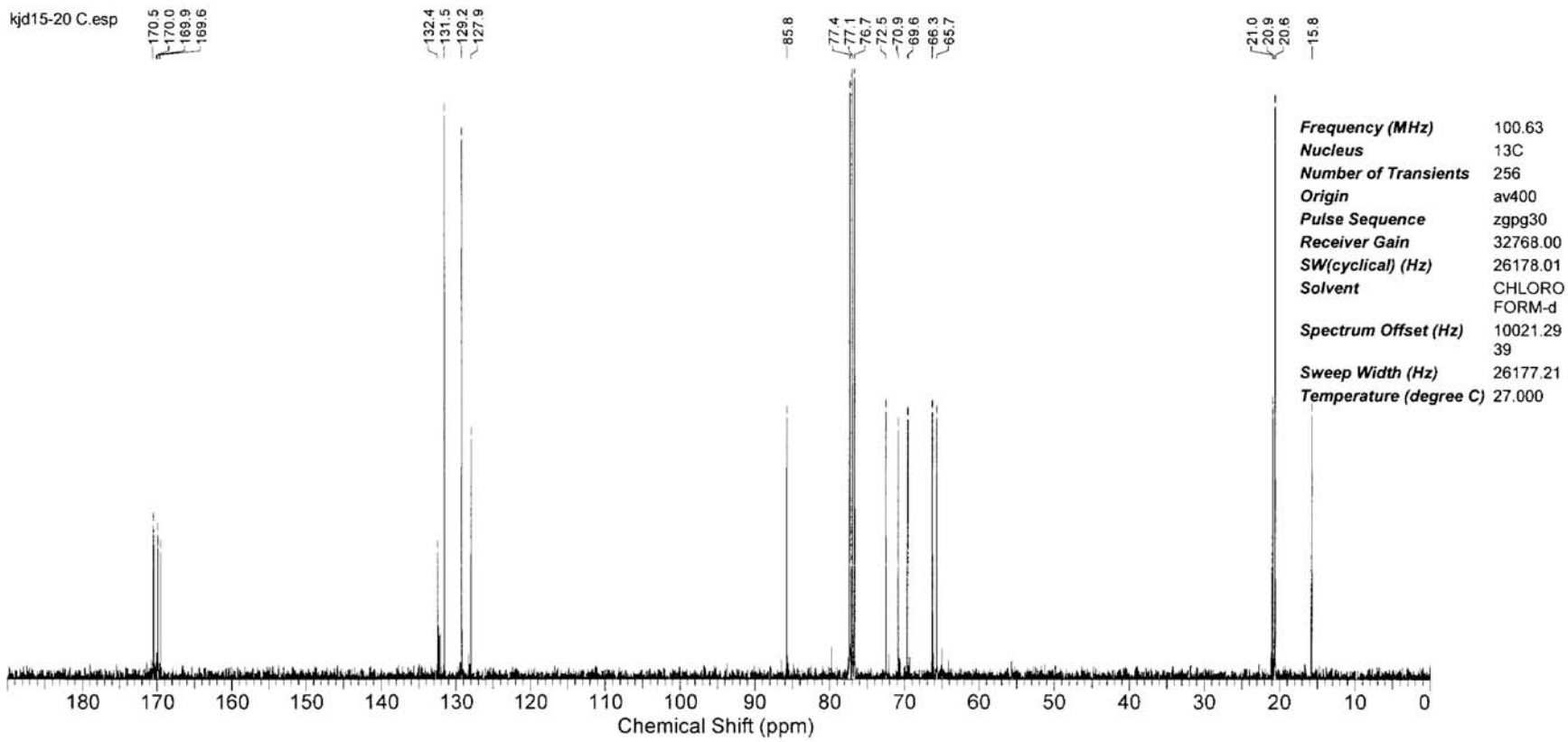
7.47 7.46 7.45 7.44 7.31 7.30 7.29 7.29 7.29 7.29 7.27
5.65 5.64 5.53 5.53 5.52 5.52 5.38 5.35 5.31 5.30 5.28 5.07 5.06 5.05
4.27 4.26 4.24 4.24
2.17 2.09 2.04 2.00
1.13 1.11



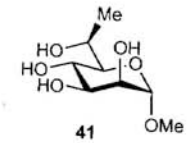


40

kjd15-20 C.esp



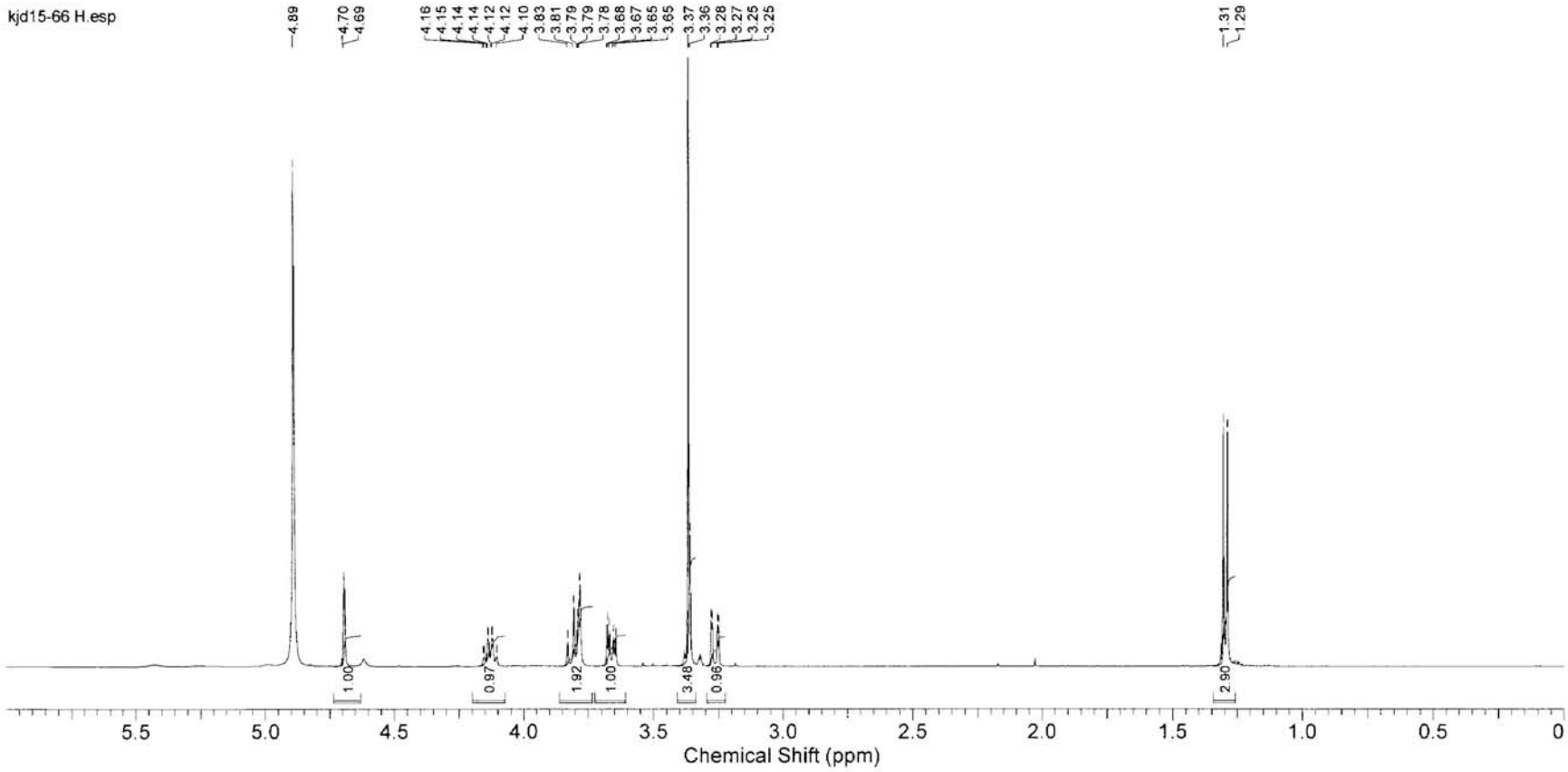
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000

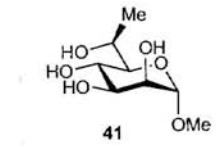


41

kjd15-66 H.esp

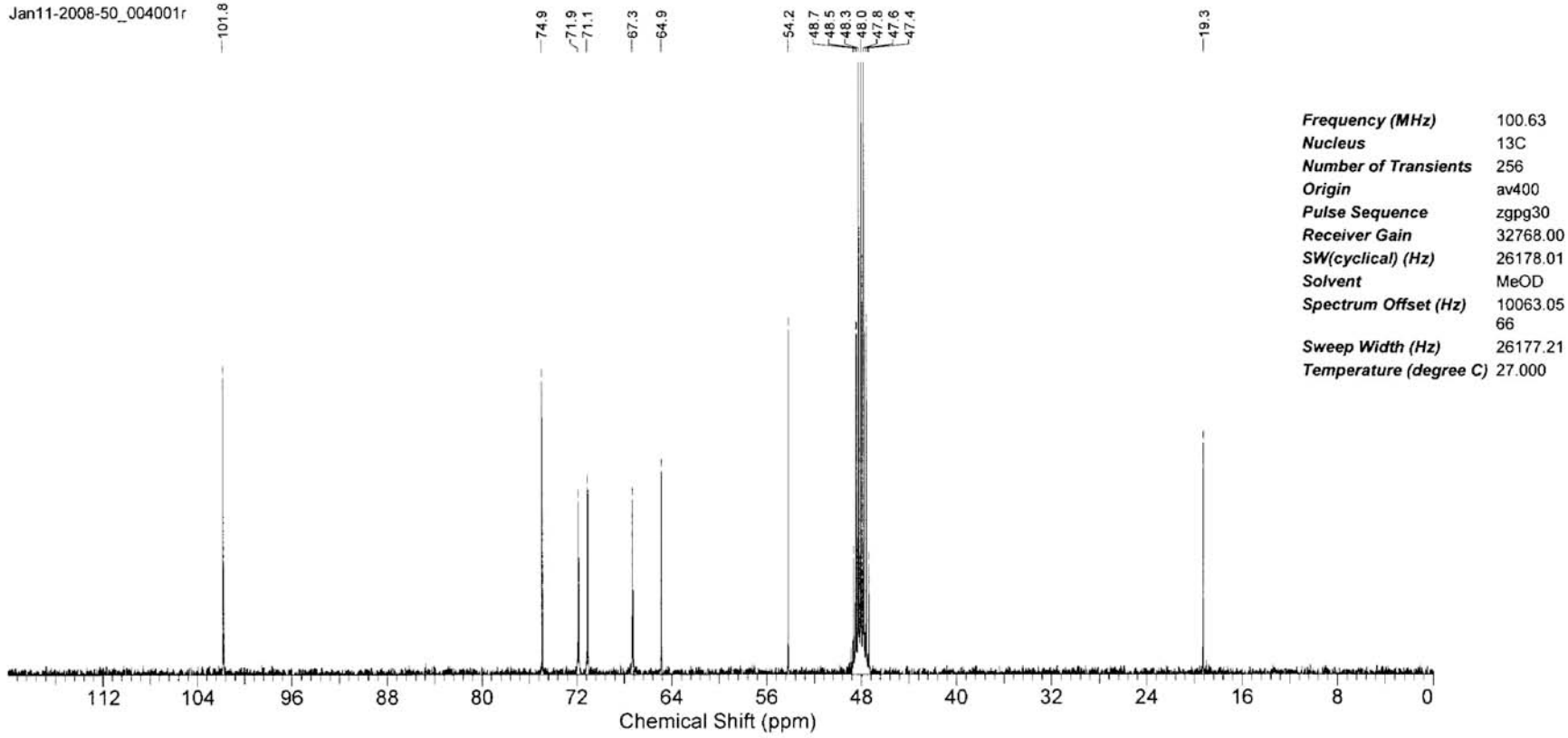
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	32.00
SW(cyclical) (Hz)	8278.15
Solvent	MeOD
Spectrum Offset (Hz)	2471.3989
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000





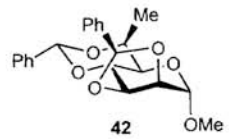
41

Jan11-2008-50_004001r

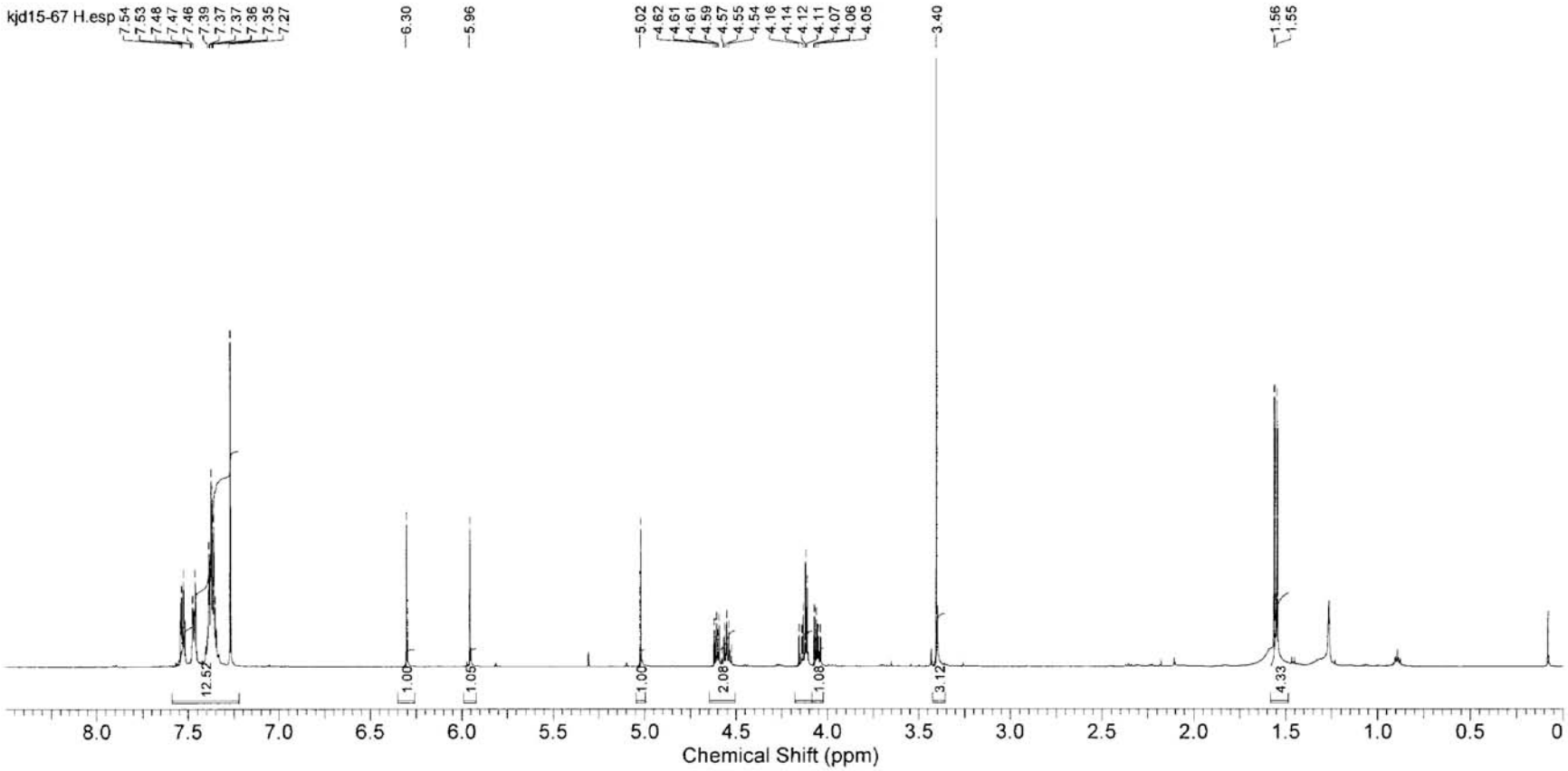


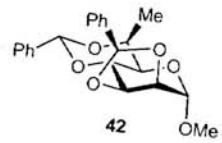
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	MeOD
Spectrum Offset (Hz)	10063.0566
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000

Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3065.5417
Sweep Width (Hz)	10330.26
Temperature (degree C)	27.000



42





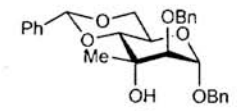
kjd15-67 C.esp

138.6
137.5
129.1
129.0
128.4
128.2
126.4
126.0
103.0
98.7
94.2
77.2
77.0
76.7
76.5
75.1
70.9
70.5
62.3
55.1
11.5

Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	1024
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	912.00
SW(cyclical) (Hz)	31250.00
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	12571.3047
Sweep Width (Hz)	31249.05
Temperature (degree C)	27.000

150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

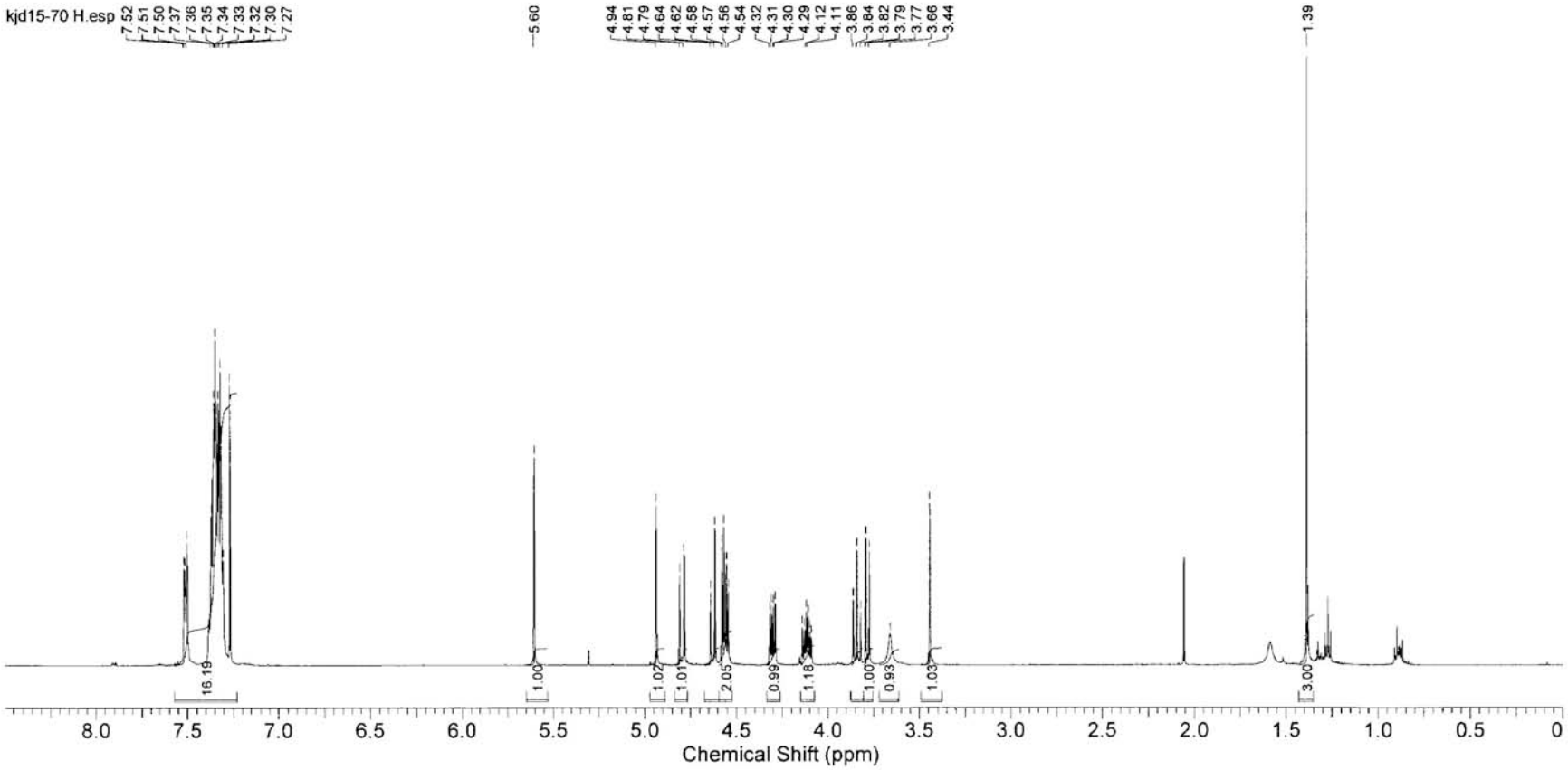
Chemical Shift (ppm)

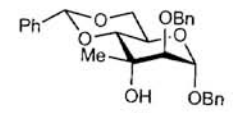


44

Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	3065.5417
Sweep Width (Hz)	10330.26
Temperature (degree C)	27.000

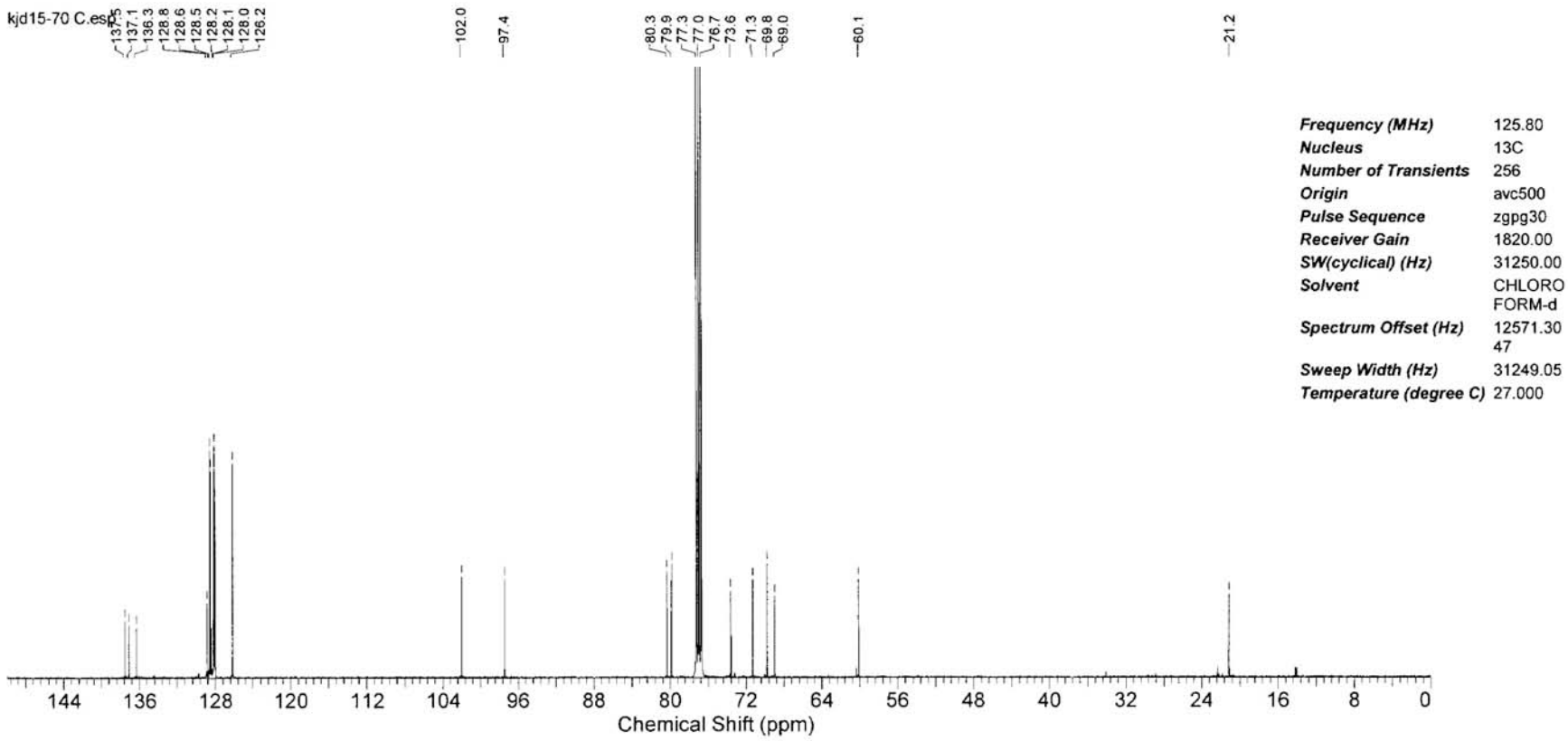
kjd15-70 H.esp





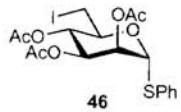
44

kjd15-70 C.esp



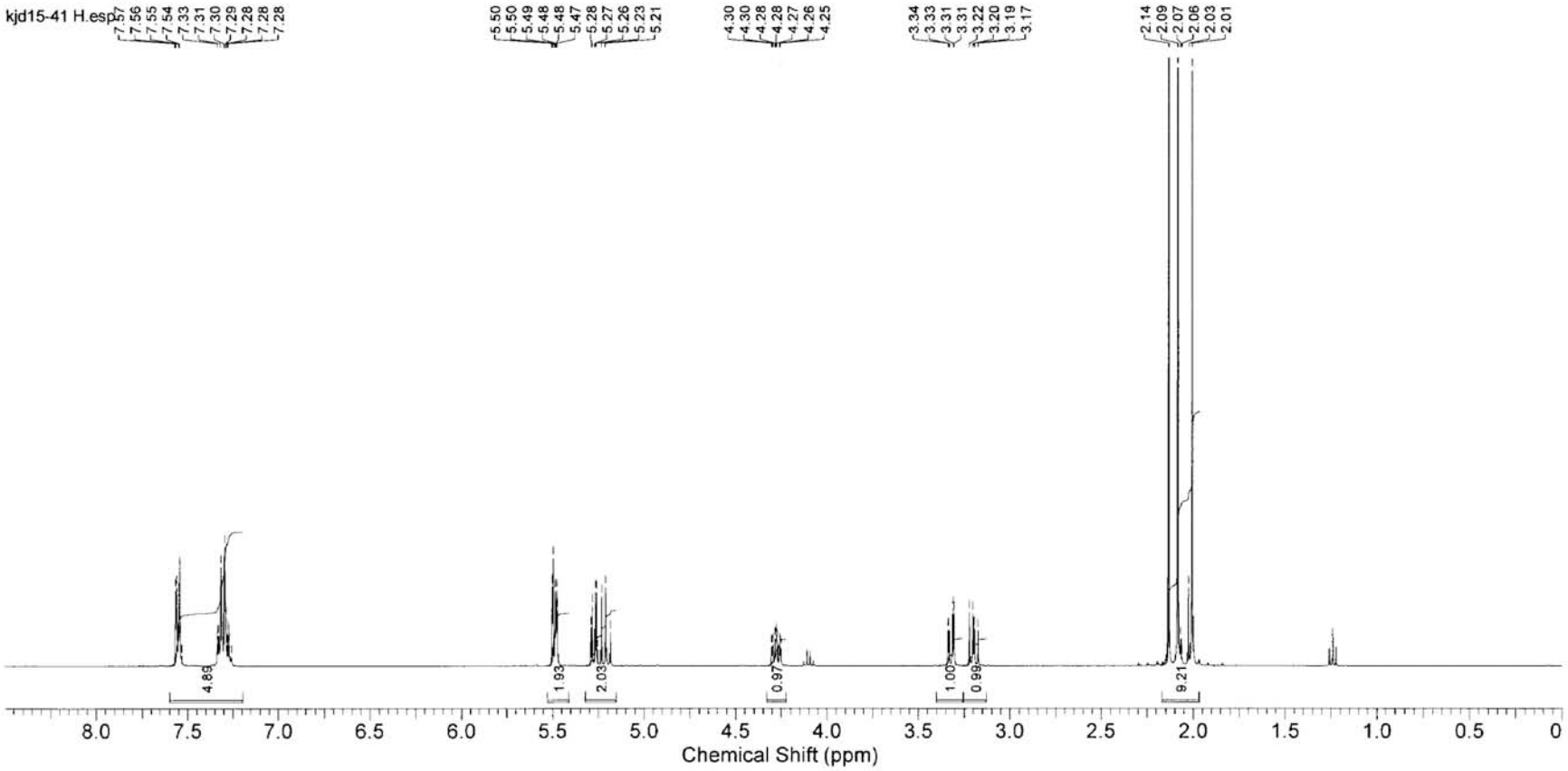
Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	256
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1820.00
SW(cyclical) (Hz)	31250.00
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	12571.3047
Sweep Width (Hz)	31249.05
Temperature (degree C)	27.000

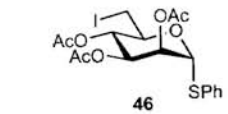
Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	32.00
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	21.500



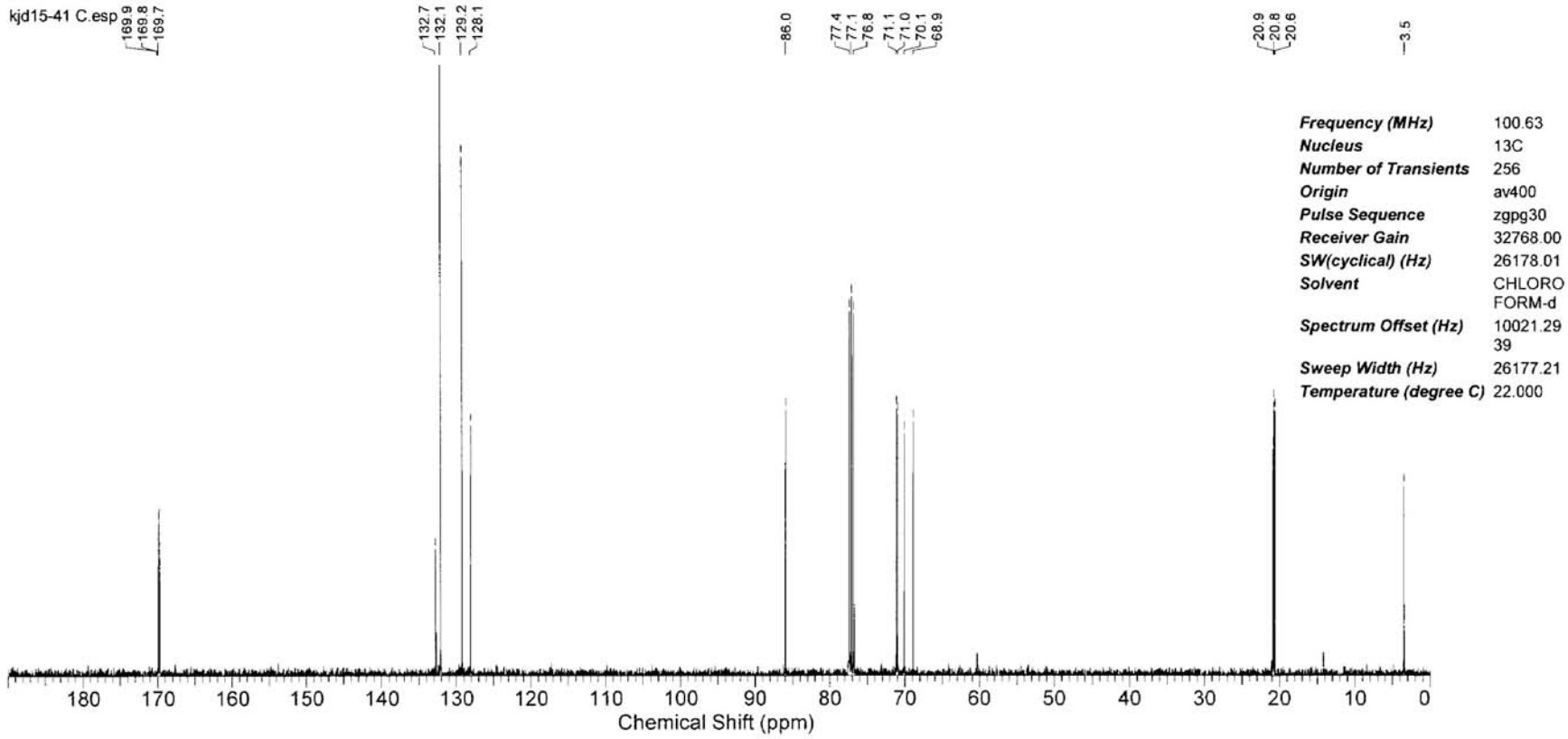
46

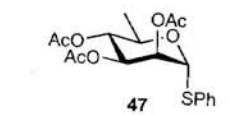
kjd15-41 H.esp




I
OAc
AcO
O
AcO
SPh

46

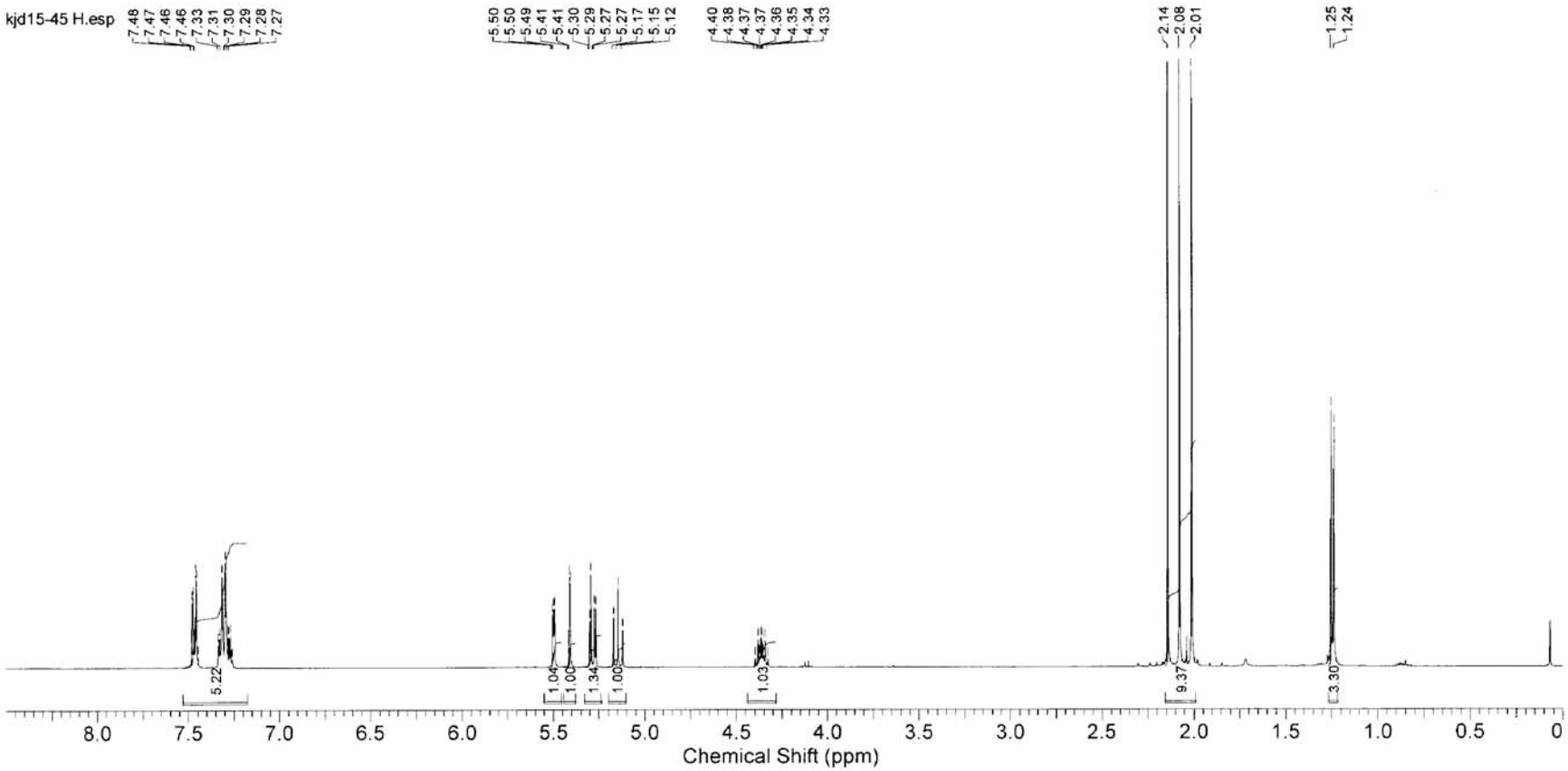

kjd15-41 C.esp
169.9
169.8
169.7
132.7
132.1
129.2
128.1
86.0
77.4
77.1
76.8
71.1
71.0
70.1
68.9
20.9
20.8
20.6
3.5
Frequency (MHz) 100.63
Nucleus 13C
Number of Transients 256
Origin av400
Pulse Sequence zgpg30
Receiver Gain 32768.00
SW(cyclical) (Hz) 26178.01
Solvent CHLOROFORM-d
Spectrum Offset (Hz) 10021.2939
Sweep Width (Hz) 26177.21
Temperature (degree C) 22.000
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
Chemical Shift (ppm)

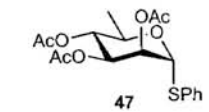


47

Frequency (MHz)	400.20
Nucleus	1H
Number of Transients	16
Origin	av400
Pulse Sequence	zg60
Receiver Gain	35.90
SW(cyclical) (Hz)	8278.15
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2468.5974
Sweep Width (Hz)	8277.89
Temperature (degree C)	27.000

kjd15-45 H.esp



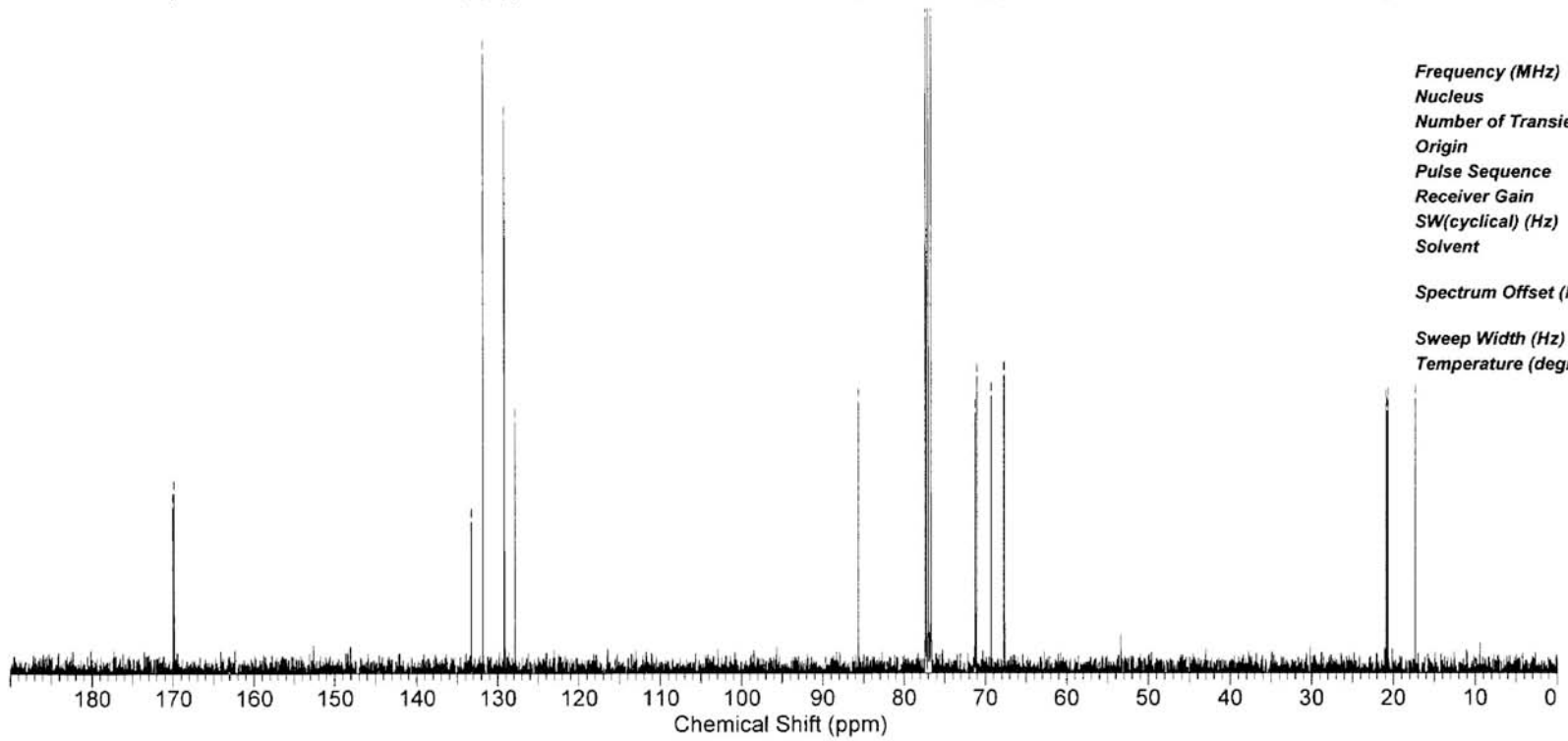


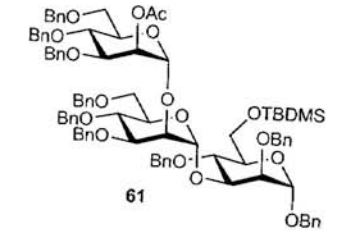
47

kjd15-45 C.esp

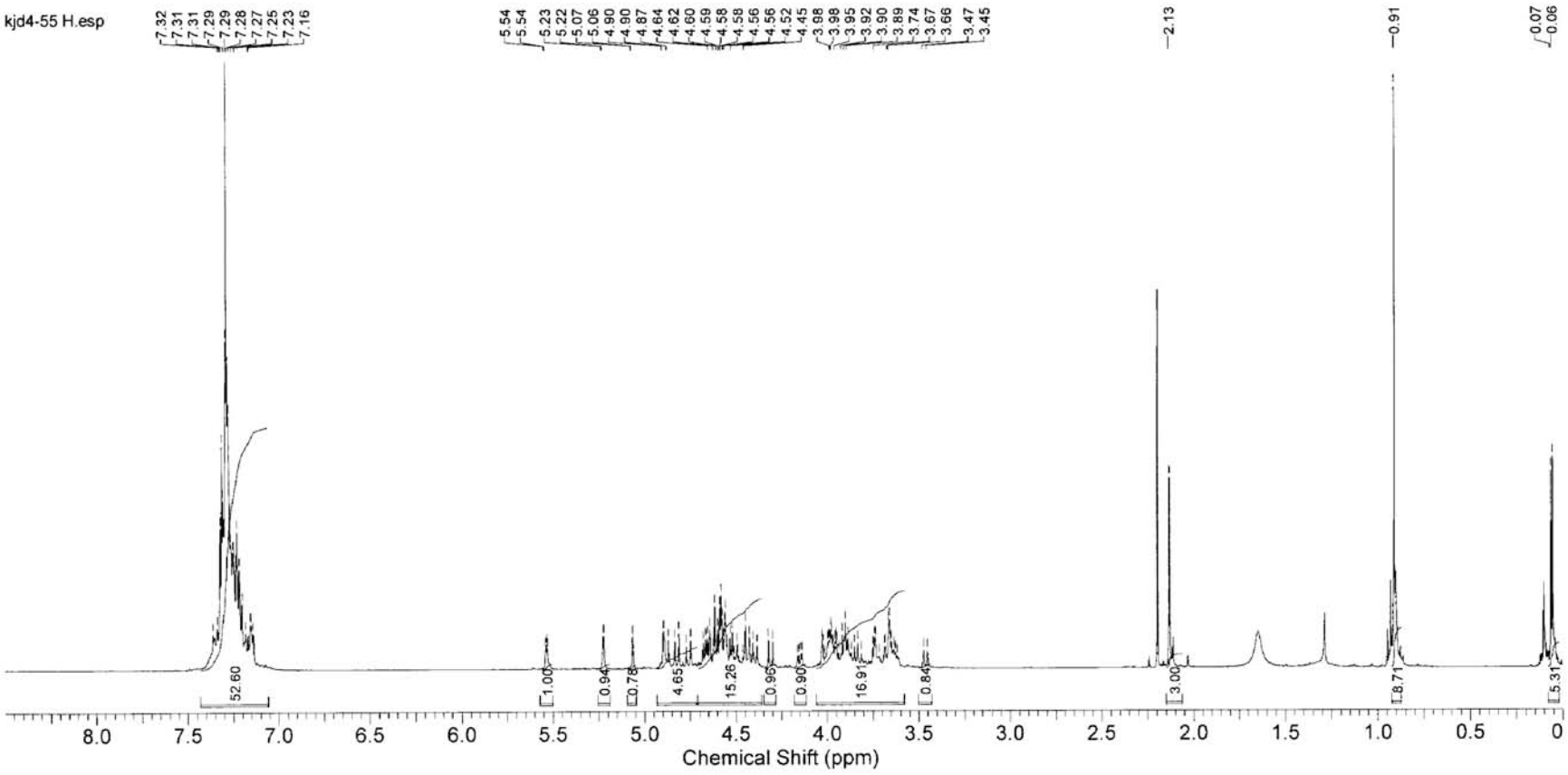
170.0
169.9
133.2
131.8
129.2
127.9
85.7
77.4
77.1
76.7
71.3
71.1
69.4
67.7
20.9
20.8
20.7
17.3

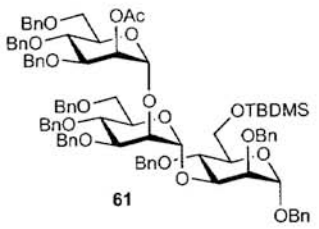
Frequency (MHz)	100.63
Nucleus	13C
Number of Transients	256
Origin	av400
Pulse Sequence	zgpg30
Receiver Gain	32768.00
SW(cyclical) (Hz)	26178.01
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	10021.2939
Sweep Width (Hz)	26177.21
Temperature (degree C)	27.000





Frequency (MHz)	499.98
Nucleus	1H
Number of Transients	16
Origin	avb500
Pulse Sequence	zg30
Receiver Gain	256.00
SW(cyclical) (Hz)	10330.58
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	2499.9995
Sweep Width (Hz)	10330.26
Temperature (degree C)	25.729

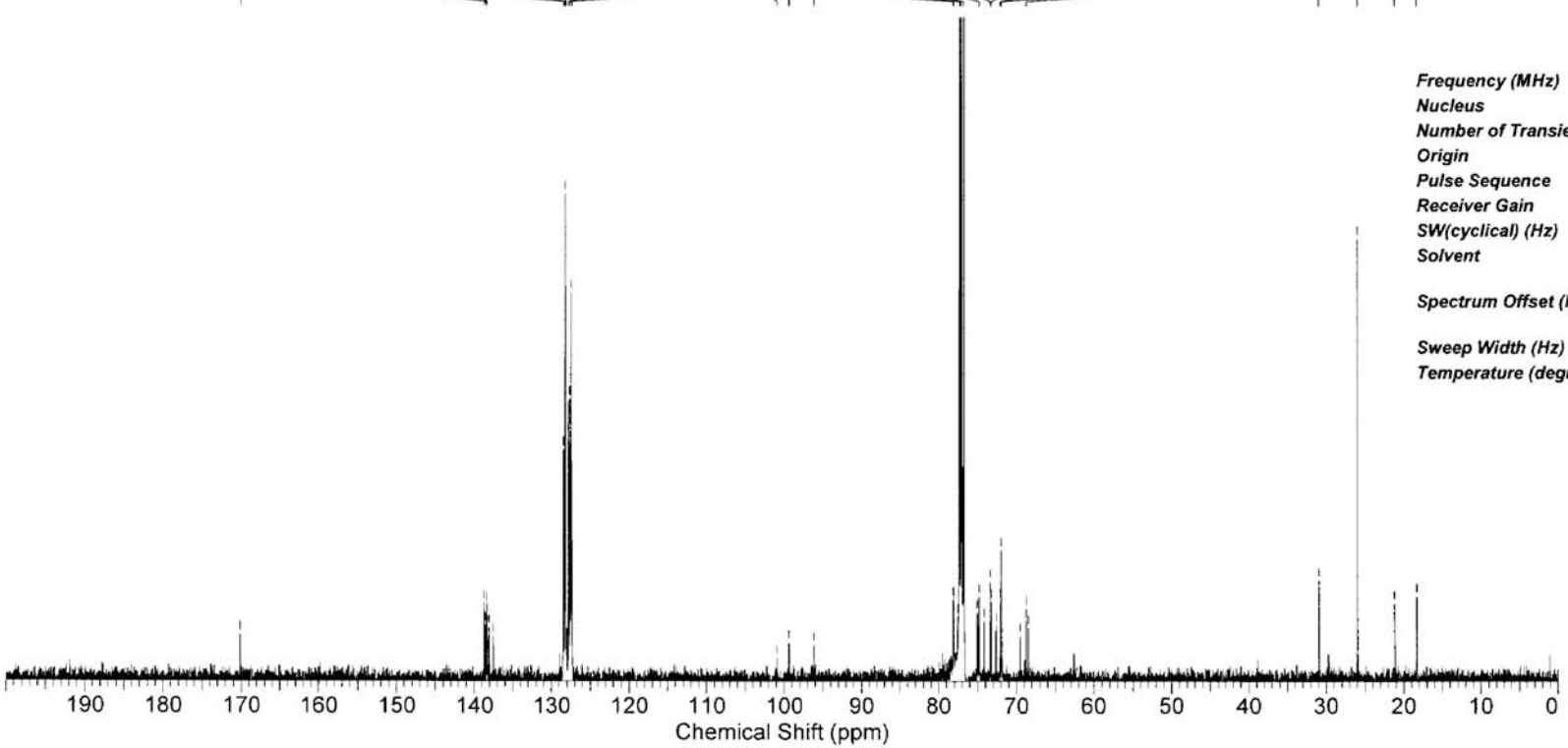




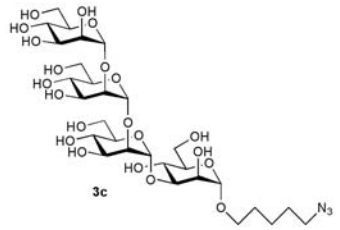
kjd4-55 C.esp

170.1
138.7
138.5
138.4
128.5
128.3
128.2
128.2
127.8
127.7
127.5
127.3
100.9
99.3
96.1
78.1
77.3
77.0
76.8
74.8
73.4
73.2
72.1
72.0
71.9
68.8
68.7
30.9
25.9
21.2
18.3

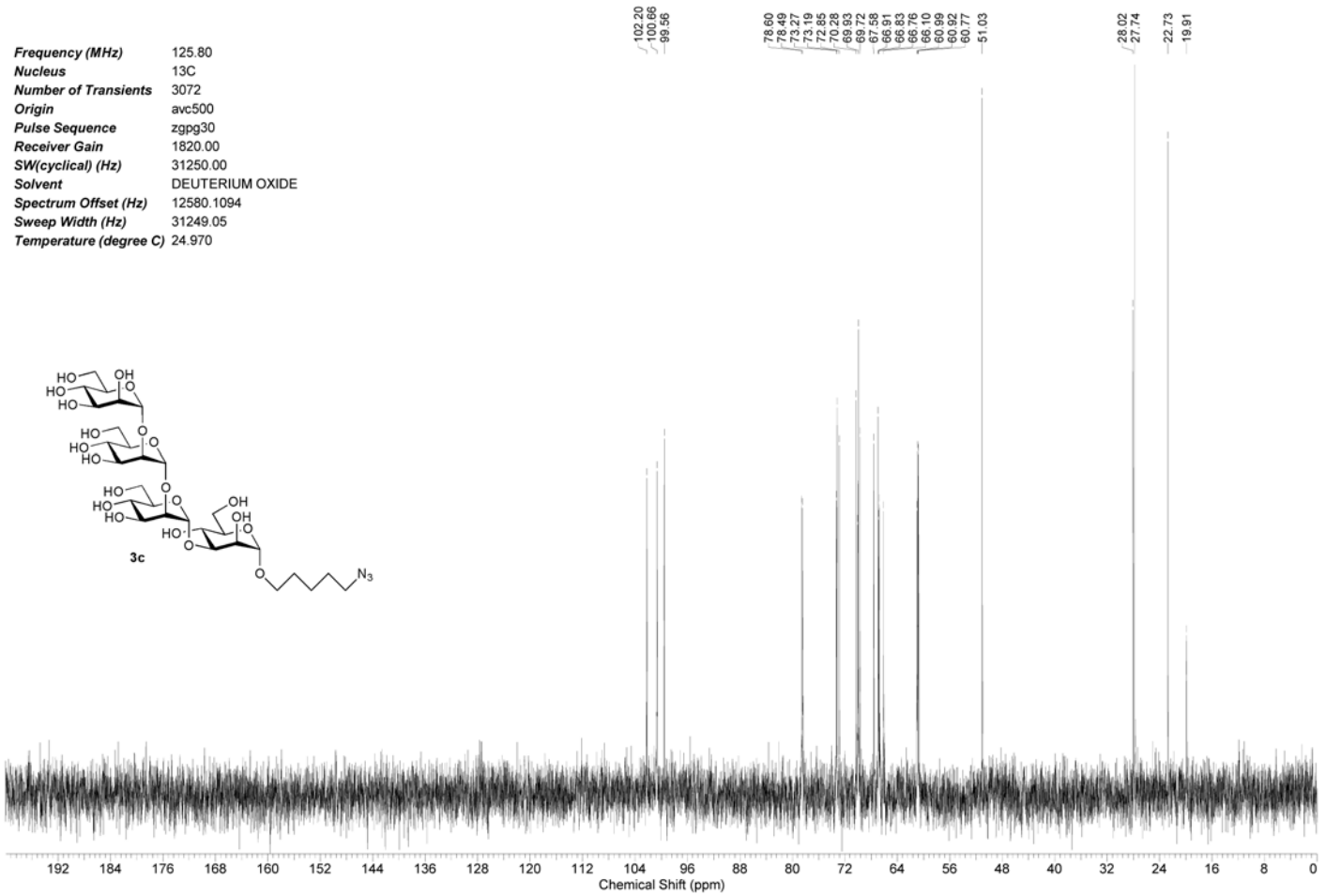
Frequency (MHz)	125.72
Nucleus	13C
Number of Transients	4096
Origin	avb500
Pulse Sequence	zgpg30
Receiver Gain	3640.00
SW(cyclical) (Hz)	31250.00
Solvent	CHLOROFORM-d
Spectrum Offset (Hz)	12572.0127
Sweep Width (Hz)	31249.05
Temperature (degree C)	26.380



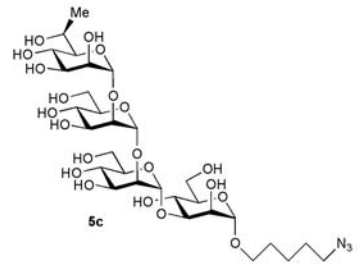
Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	64
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	4.00
SW(cyclical) (Hz)	10330.58
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	3089.5557
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970



3c

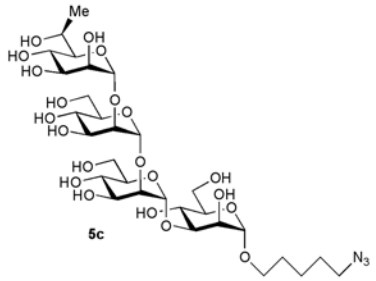

Frequency (MHz) 125.80
Nucleus 13C
Number of Transients 3072
Origin avc500
Pulse Sequence zgpg30
Receiver Gain 1820.00
SW(cyclical) (Hz) 31250.00
Solvent DEUTERIUM OXIDE
Spectrum Offset (Hz) 12580.1094
Sweep Width (Hz) 31249.05
Temperature (degree C) 24.970
102.20
100.66
99.56
78.60
78.49
73.27
73.19
72.85
70.28
69.93
69.72
67.58
66.91
66.83
66.76
66.10
60.99
60.92
60.77
51.03
28.02
27.74
22.73
19.91
3c
N3
192 184 176 168 160 152 144 136 128 120 112 104 96 88 80 72 64 56 48 40 32 24 16 8 0
Chemical Shift (ppm)

Frequency (MHz)	500.30
Nucleus	1H
Number of Transients	16
Origin	avc500
Pulse Sequence	zg30
Receiver Gain	14.20
SW(cyclical) (Hz)	10330.58
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	3089.5557
Sweep Width (Hz)	10330.26
Temperature (degree C)	24.970



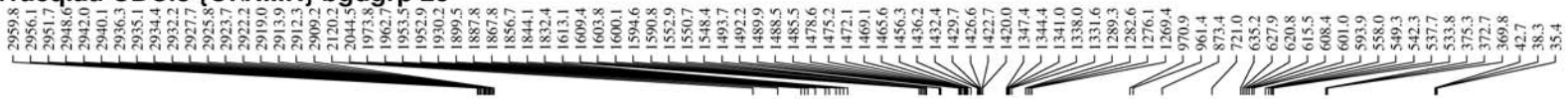
5c

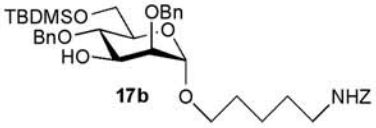
Frequency (MHz)	125.80
Nucleus	13C
Number of Transients	2048
Origin	avc500
Pulse Sequence	zgpg30
Receiver Gain	1820.00
SW(cyclical) (Hz)	31250.00
Solvent	DEUTERIUM OXIDE
Spectrum Offset (Hz)	12580.1094
Sweep Width (Hz)	31249.05
Temperature (degree C)	24.970



5c

Instrument DQX400
Chemist kjd
Group bgd
kjd16-15
h1acq.au CDCl3 {C:\NMR} bgdgrp 23

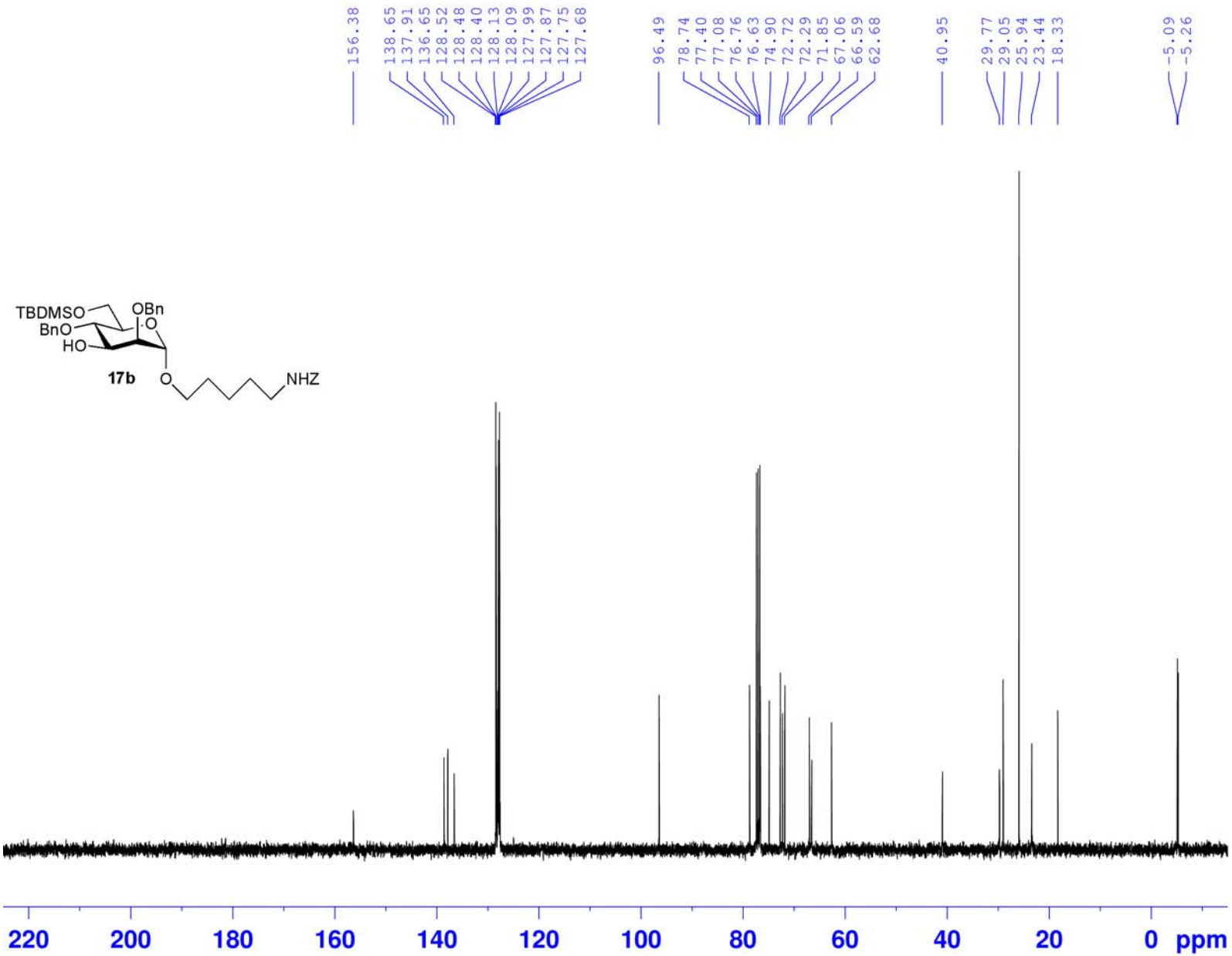




NMR@CHEM.OX

```
Current Data Parameters
NAME       Feb27-2008-23
EXPNO                 1
PROCNO                1

F2 - Acquisition Parameters
Date_          20080228
Time               1.39
INSTRUM           av400
PROBHD   5 mm QNP 1H/13
PULPROG            zg60
TD                65536
SOLVENT           CDCl3
NS                   16
DS                    2
SWH           8278.146 Hz
FIDRES        0.126314 Hz
AQ            3.9584243 sec
RG                   32
DW              60.400 usec
DE               7.50 usec
TE              300.0 K
D1           1.00000000 sec

======== CHANNEL f1 ========
NUC1                 1H
P1                9.00 usec
PL1               0.00 dB
SFO1        400.2024714 MHz

F2 - Processing parameters
SI                32768
SF          400.2000028 MHz
WDW                  EM
SSB                   0
LB                0.30 Hz
GB                    0
PC                 1.00
```

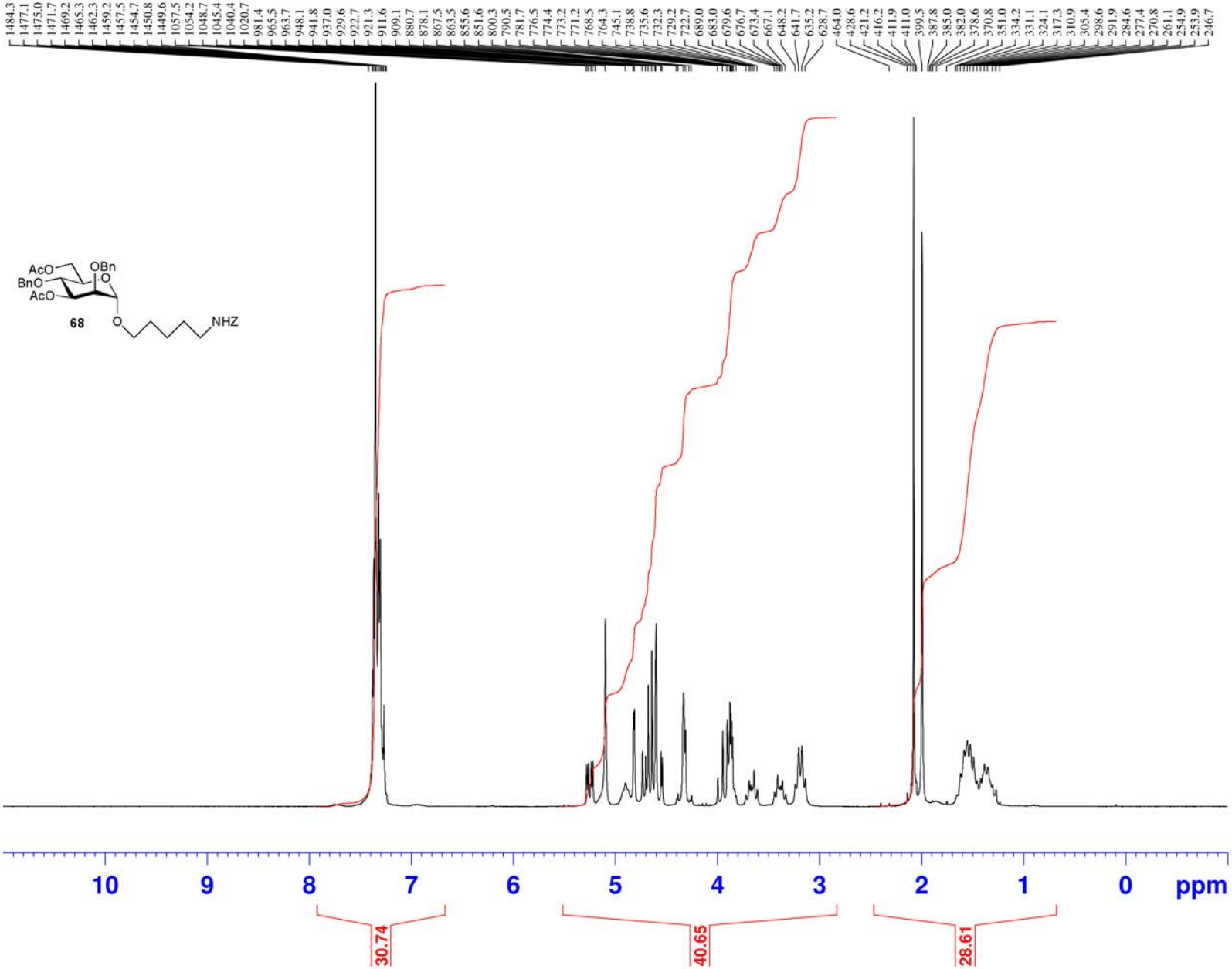
Instrument DQX400
Chemist kjd
Group bgd
kjd16-15
c13acq.au CDCl3 {C:\NMR} bgdgrp 23



NMR@CHEM.OX

```
Current Data Parameters
NAME       Feb27-2008-23
EXPNO                  4
PROCNO                 1

F2 - Acquisition Parameters
Date_           20080228
Time                1.55
INSTRUM            av400
PROBHD   5 mm QNP 1H/13
PULPROG           zgpg30
TD                 32768
SOLVENT            CDCl3
NS                   256
DS                     4
SWH            26178.010 Hz
FIDRES         0.798889 Hz
AQ             0.6259188 sec
RG                 32768
DW                19.100 usec
DE                 7.50 usec
TE                 300.0 K
D1             1.00000000 sec
d11            0.03000000 sec
DELTA          0.89999998 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                 13C
P1                  9.50 usec
PL1                 0.00 dB
SFO1         100.6403931 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                 1H
PCPD2              80.00 usec
PL12               19.00 dB
PL13               25.00 dB
PL2                 0.00 dB
SFO2         400.2016008 MHz

F2 - Processing parameters
SI                 32768
SF           100.6303718 MHz
WDW                  EM
SSB                   0
LB                 1.00 Hz
GB                    0
PC                 1.40
```

Instrument DPX200
Chemist kjd
Group bgd
kjd16-12
h1acq.au CDCl3 {C:\NMR} bgdgrp 2



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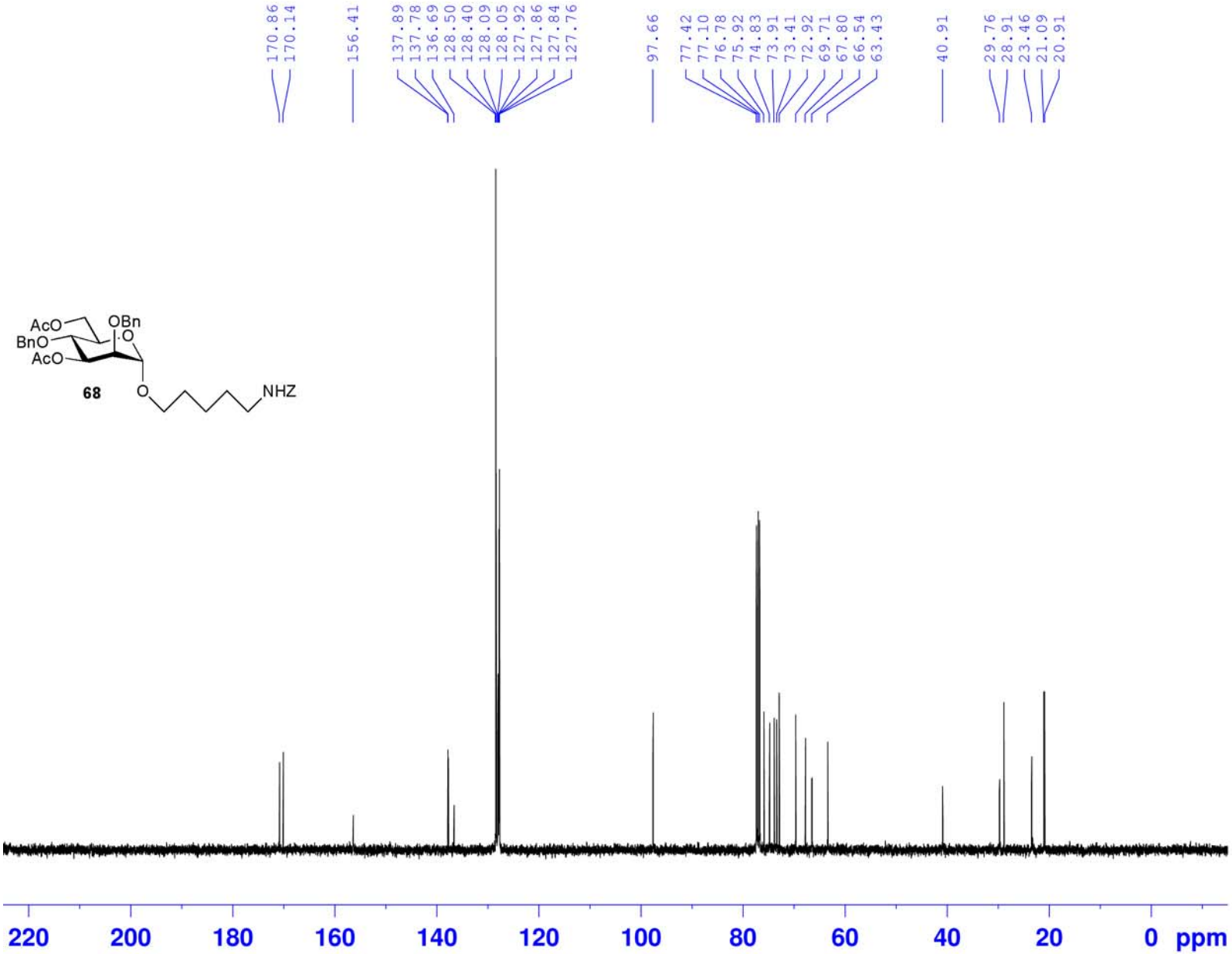
```
Current Data Parameters
NAME        Feb20-2008-2
EXPNO                  1
PROCNO                 1

F2 - Acquisition Parameters
Date_           20080220
Time               18.30
INSTRUM          dpx200
PROBHD   5 mm Dual 13C/
PULPROG             zg60
TD                 16384
SOLVENT             CDCl3
NS                    16
DS                     2
SWH             2796.421 Hz
FIDRES          0.170680 Hz
AQ              2.9295092 sec
RG                  90.5
DW                178.800 usec
DE                  6.00 usec
TE                 300.0 K
D1             1.00000000 sec

======== CHANNEL f1 ========
NUC1                   1H
P1                  7.80 usec
PL1                -3.00 dB
SFO1         200.1310007 MHz

F2 - Processing parameters
SI                 32768
SF           200.1300125 MHz
WDW                   EM
SSB                    0
LB                  0.30 Hz
GB                     0
PC                  1.00
```

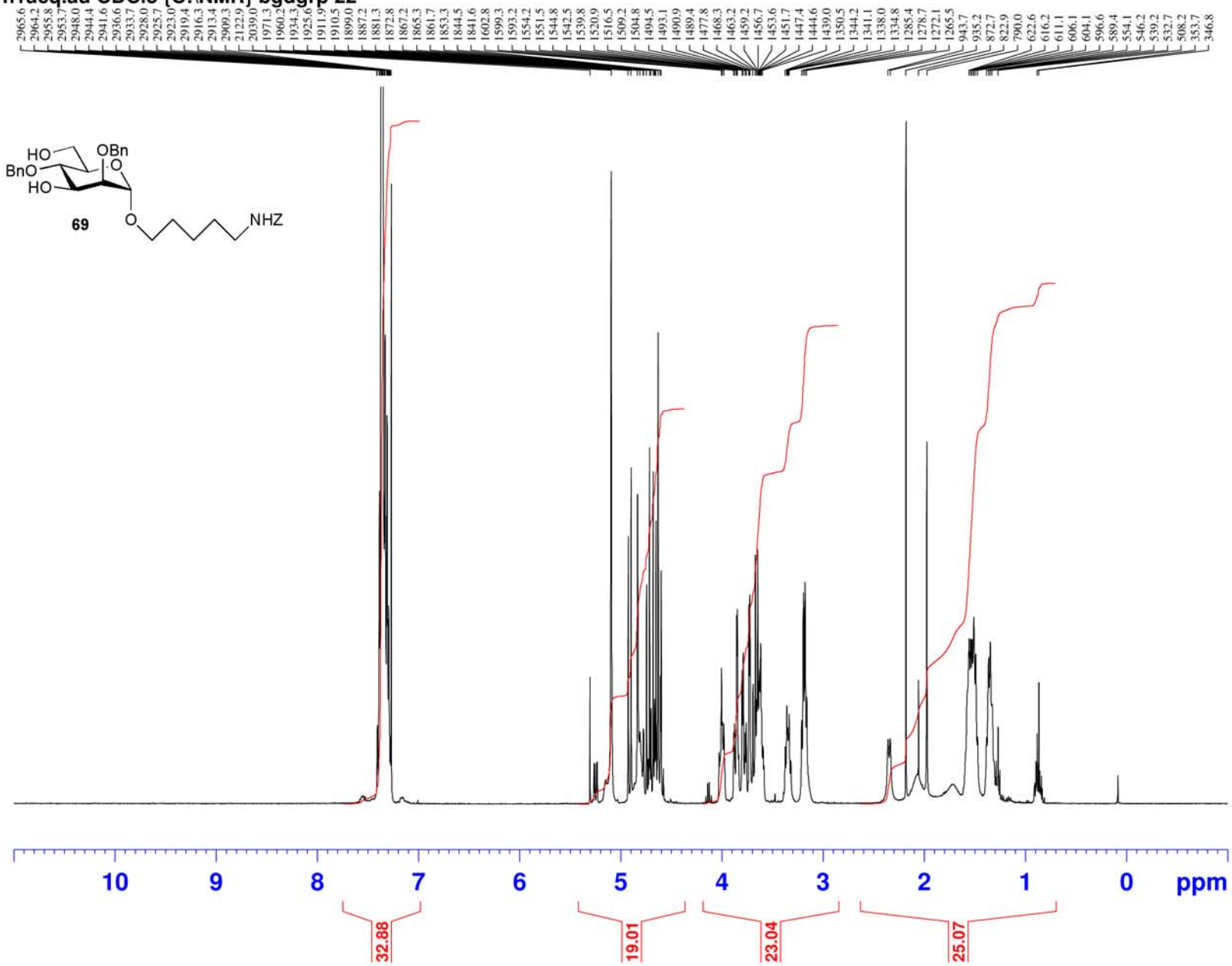
Instrument DQX400
Chemist kjd
Group bgd
kjd16-12
c13acq.au CDCl3 {C:\NMR} bgdgrp 52



NMR@CHEM.OX

```
Current Data Parameters
NAME       Feb21-2008-52
EXPNO                 4
PROCNO                1

F2 - Acquisition Parameters
Date_          20080221
Time              11.54
INSTRUM           av400
PROBHD   5 mm QNP 1H/13
PULPROG         zgpg30
TD                32768
SOLVENT           CDCl3
NS                  256
DS                    4
SWH           26178.010 Hz
FIDRES         0.798889 Hz
AQ             0.6259188 sec
RG                32768
DW               19.100 usec
DE                7.50 usec
TE                300.0 K
D1            1.00000000 sec
d11           0.03000000 sec
DELTA         0.89999998 sec
TD0                   1

======== CHANNEL f1 ========
NUC1                 13C
P1                 9.50 usec
PL1                0.00 dB
SFO1        100.6403931 MHz

======== CHANNEL f2 ========
CPDPRG2          waltz16
NUC2                 1H
PCPD2             80.00 usec
PL12              19.00 dB
PL13              25.00 dB
PL2                0.00 dB
SFO2        400.2016008 MHz

F2 - Processing parameters
SI                32768
SF          100.6303718 MHz
WDW                  EM
SSB                   0
LB                 1.00 Hz
GB                    0
PC                 1.40
```

Instrument DQX400
Chemist kjd
Group bgd
kjd16-14p
h1acq.au CDCl3 {C:\NMR} bgdgrp 22



NMR@CHEM.OX

Current Data Parameters
NAME Feb27-2008-22
EXPNO 1
PROCNO 1

F2 - Acquisition Parameters

Date_	20080228	
Time	1.13	
INSTRUM	av400	
PROBHD	5 mm QNP 1H/13	
PULPROG	zg60	
TD	65536	
SOLVENT	CDCl3	
NS	16	
DS	2	
SWH	8278.146	Hz
FIDRES	0.126314	Hz
AQ	3.9584243	sec
RG	90.5	
DW	60.400	usec
DE	7.50	usec
TE	300.0	K
D1	1.00000000	sec

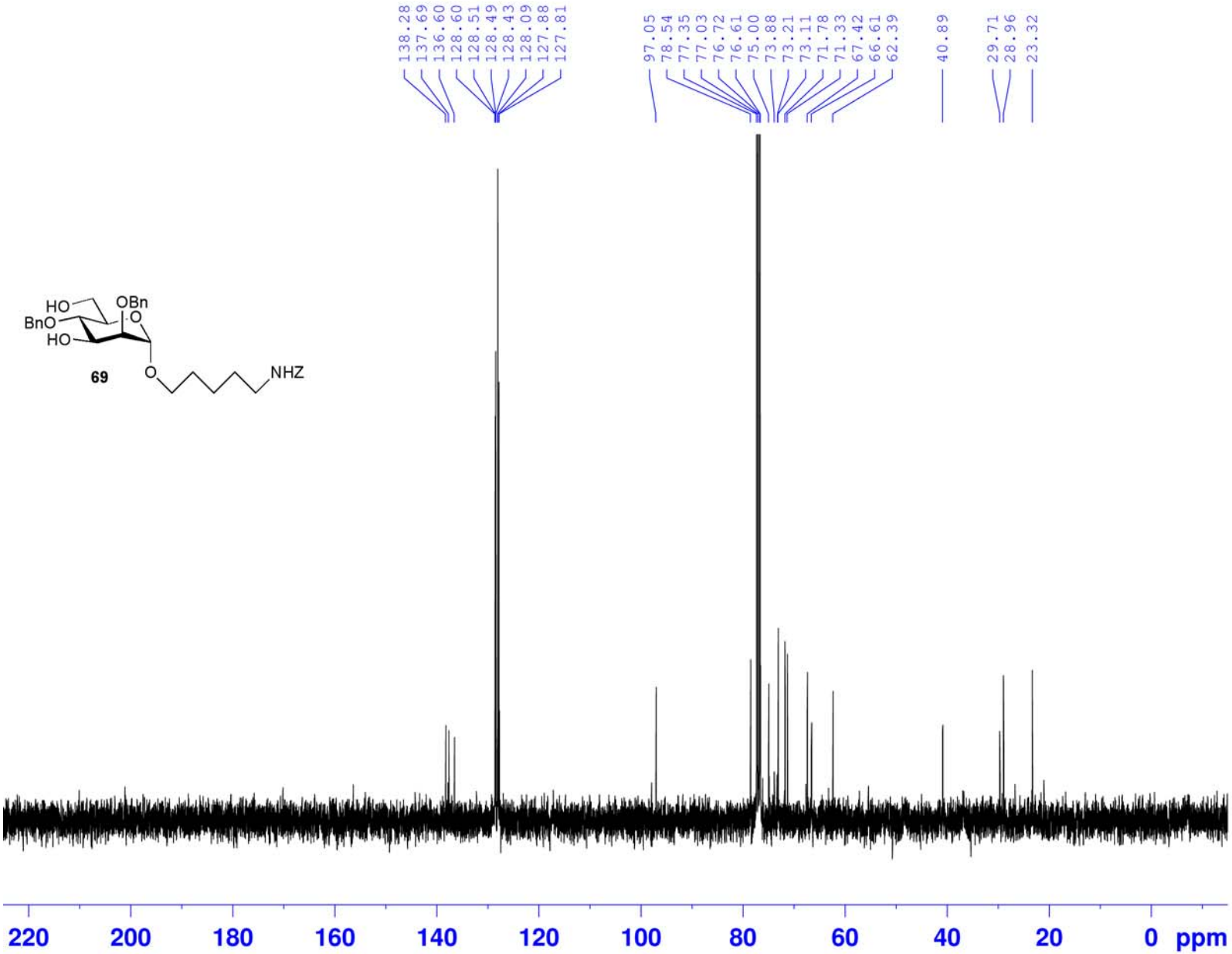
======== CHANNEL f1 ========

NUC1	1H	
P1	9.00	usec
PL1	0.00	dB
SFO1	400.2024714	MHz

F2 - Processing parameters

SI	32768	
SF	400.2000028	MHz
WDW	EM	
SSB	0	
LB	0.30	Hz
GB	0	
PC	1.00	

Instrument DQX400
Chemist kjd
Group bgd
kjd16-14p
c13acq.au CDCl3 {C:\NMR} bgdgrp 22



NMR@CHEM.OX

```
Current Data Parameters
NAME       Feb27-2008-22
EXPNO                  4
PROCNO                 1

F2 - Acquisition Parameters
Date_           20080228
Time                1.29
INSTRUM            av400
PROBHD   5 mm QNP 1H/13
PULPROG           zgpg30
TD                 32768
SOLVENT            CDCl3
NS                   256
DS                     4
SWH            26178.010 Hz
FIDRES          0.798889 Hz
AQ              0.6259188 sec
RG                 32768
DW                19.100 usec
DE                 7.50 usec
TE                300.0 K
D1             1.00000000 sec
d11            0.03000000 sec
DELTA          0.89999998 sec
TD0                    1

======== CHANNEL f1 ========
NUC1                  13C
P1                   9.50 usec
PL1                  0.00 dB
SFO1         100.6403931 MHz

======== CHANNEL f2 ========
CPDPRG2           waltz16
NUC2                  1H
PCPD2              80.00 usec
PL12               19.00 dB
PL13               25.00 dB
PL2                 0.00 dB
SFO2         400.2016008 MHz

F2 - Processing parameters
SI                 32768
SF           100.6303718 MHz
WDW                   EM
SSB                    0
LB                  1.00 Hz
GB                     0
PC                  1.40
```