Supporting Information

A versatile approach to the synthesis of glycans containing mannuronic acid residues

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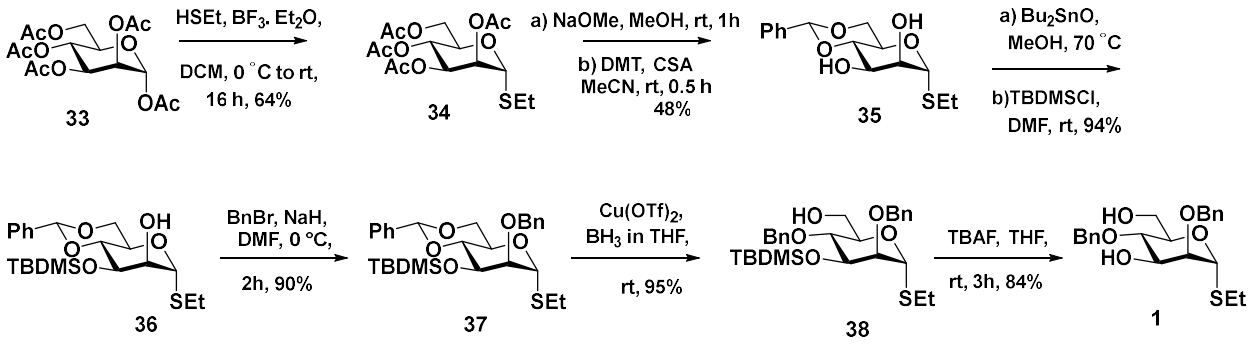
Synthesis of Intermediate 1



Ethyl 2,3,4,6-tetra-*O*-acetyl-1-thio-α-D-mannopyranoside (34). A solution of 1,2,3,4,6-penta-*O*-acetyl-D-mannopyranose (**33**, 15.24 g, 39.04 mmol) and ethane thiol (3.42 mL, 46.85 mmol) in CH_2Cl_2 (150 mL) was cooled to 0 °C. Boron trifluoride diethyl etherate (19.8 mL, 156.2 mmol) was added dropwise, the external cooling was removed, and the resulting mixture was stirred under argon for 16 h at rt. After that, the reaction mixture was diluted with CH_2Cl_2 (~200 mL) and washed with water (100 mL), sat. aq. $NaHCO_3$ (100 mL), and water (2 x 100 mL). The organic layer was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by crystallization from CH_2Cl_2-diethyl ether-hexane to afford the title compound as white crystals in 64% yield (10.25 g, 26.12 mmol). Analytical data for **34** were in agreement with those previously reported.[1,2]

Ethyl 4,6-*O*-benzylidene-1-thio-α-D-mannopyranoside (35). A freshly prepared 1 N solution of NaOMe in MeOH (~10 mL) was added to a solution of compound **34** (10.25 g, 26.12 mmol) in MeOH (80 mL) until pH ~ 9, and the resulting mixture was stirred for 1 h at rt. After that, the reaction mixture was neutralized with Dowex (H^+), the resin was filtered-off, and rinsed successively with MeOH (7 x 20 mL). The combined filtrate (~220 mL) was concentrated under reduced pressure and the residue was dried *in vacuo*. The crude residue containing deacetylated mannosyl derivative (5.49 g, 24.50 mmol) was dissolved in MeCN (60 mL), benzaldehyde dimethyl acetal (DMT, 7.38 mL, 48.96 mmol) and camphorsulfonic acid (CSA, 284 mg, 1.23 mmol) were added, and the resulting mixture was stirred for 0.5 h at rt. After that, the reaction mixture was neutralized with triethylamine (~ 7 mL) and the volatiles were removed under reduced pressure. The residue was diluted with CH_2Cl_2 (~150 mL) and washed with water (50 mL), sat. aq. $NaHCO_3$ (50 mL) and water (2 x 50 mL). The organic layer was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was precipitated using CH_2Cl_2 and hexane to afford the title compound as a colorless amorphous solid in 48% yield (3.67 g, 11.75 mmol). Analytical data for **35** were in agreement with those previously reported.[3]

Ethyl 4,6-*O*-benzylidene-3-*O*-*tert*-butyldimethylsilyl-1-thio-α-D-mannopyranoside (36). Dibutyltin(IV) oxide (Bu_2SnO, 1.73 g, 6.95 mmol) was added to a solution of compound **35** (2.17 g, 6.95 mmol) in CH_3OH (~100 mL), and the resulting mixture was refluxed for 30 min. During this time, the reaction mixture becomes clear. The reaction mixture was allowed to cool to rt, the volatiles were removed under reduced pressure, and the residue was dried in *vacuo*. The resulting residue was dissolved in dry *N,N*-dimethylformamide (25 mL), *tert*-butyldimethylsilyl chloride (1.36 g, 9.02 mmol) was added, and the reaction mixture was stirred under argon for 2 h at rt. After

that, the reaction mixture was diluted with toluene (~100 mL) and washed with water (2 x 25 mL). The organic layer was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-toluene gradient elution) to afford the title compound as a white amorphous solid in 94% yield (2.79 g, 6.54 mmol). Analytical data for **36**: R_f = 0.65 (ethyl acetate/hexane, 2/3, v/v); $[\alpha]_D^{21}$ +125.1 (*c* = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.48 (m, 2H, aromatic), 7.38-7.34 (m, 3H, aromatic), 5.55 (s, 1H, C*H*Ph), 5.41 (s, 1H, H-1), 4.25-4.18 (m, 2H, H-5, 6a), 4.06 (dd, 1H, $J_{3,4}$ = 9.3 Hz, H-3), 3.96 (dd, 1H, $J_{2,3}$ = 3.5 Hz, H-2), 3.93-3.85 (m, 2H, H-4, 6b), 2.99 (s, 1H, OH), 2.63 (m, 2H, SC*H*$_2$CH$_3$), 1.29 (t, 3H, *J* = 7.4 Hz, SCH$_2$C*H*$_3$), 0.87 (s, 9H, Si*t*Bu), 0.10, 0.05 (2 s, 6H, SiMe$_2$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 137.6, 129.0, 128.3 (x2), 126.3 (x2), 102.0, 83.8, 79.4, 73.6, 70.3, 68.8, 63.8, 25.9 (x3), 25.0, 18.3, 15.0, -4.3, -4.9 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{15}H_{20}O_5SNa^+$ 335.0929; found 335.0907. Partial analytical data for **36** were previously reported.[4]

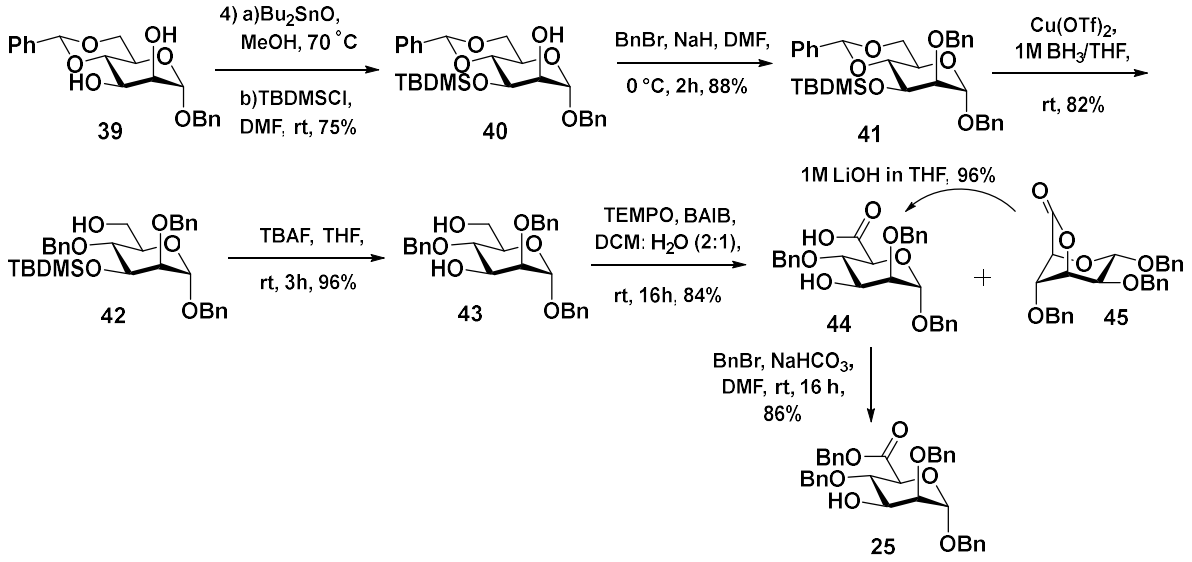
Ethyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-*tert*-butyldimethylsilyl-1-thio-α-D-mannopyranoside (37). NaH (60% in mineral oil, 0.50 g, 12.44 mmol) and benzyl bromide (0.99 mL, 8.30 mmol) were added to a solution of compound **36** (1.77 g, 4.15 mmol) in *N,N*-dimethylformamide (15.0 mL), and the resulting mixture was stirred under argon for 2 h at 0 °C. After that, the reaction mixture was poured into ice-water (10 mL), stirred for 30 min, and extracted with diethyl ether (3 × 30 mL). The combined organic extract (~100 mL) was washed with cold water (3 × 15 mL). The organic phase was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 90% yield (1.93 g, 3.74 mmol). Analytical data for **37** were in agreement with those previously reported.[5]

Ethyl 2,4-di-*O*-benzyl-3-*O*-*tert*-butyldimethylsilyl-1-thio-α-D-mannopyranoside (38). Copper(II) trifluoromethanesulfonate (80 mg, 0.222 mmol) was added to a solution containing compound **37** (1.15 g, 2.22 mmol) and a 1.0 M solution of borane-THF complex in tetrahydrofuran (11.09 mL, 11.09 mmol), and the resulting mixture was stirred under argon for 2 h at rt. The reaction mixture was then cooled to 0 °C and triethylamine (~2 mL) was added until neutral pH. After that, CH_3OH (~5 mL) was added dropwise, and the volatiles were removed under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 95% yield (1.09 g, 2.11 mmol). Analytical data for **38**: R_f = 0.65 (ethyl acetate/hexane, 2/3, v/v); $[\alpha]_D^{22}$ +126.7 (*c* = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.45-7.35 (m, 10H, aromatic), 5.31 (d, 1H, $J_{1,2}$ = 1.5 Hz, H-1), 4.75 (dd, 2H, ^2J = 11.3 Hz, C*H*$_2$Ph), 4.75 (dd, 2H, ^2J = 11.9 Hz, C*H*$_2$Ph), 4.12 (dd, 1H, $J_{3,4}$ = 9.0 Hz, H-3), 4.02 (m, 1H, H-5), 3.94 (m, 1H, H-4), 3.83-3.77 (m, 3H, $J_{2,3}$ = 3.0 Hz, H-2, 6a, 6b), 2.68-2.58 (m, 2H, SC*H*$_2$CH$_3$), 1.96-1.87 (m, 1H, OH), 1.30 (t, 3H, *J* = 7.2 Hz, SCH$_2$C*H*$_3$), 1.00 (s, 9H, Si*t*Bu), 0.16, 0.15 (2 s, 6H, SiMe$_2$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 138.5, 138.4, 128.5 (x4), 127.8 (x5), 127.7, 82.9, 81.1, 75.9, 75.3, 73.9, 73.4, 72.9, 62.4, 26.1 (x3), 25.5, 18.2, 15.0, -4.3, -4.6 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{22}H_{28}O_5SNa^+$ 427.1555; found 427.1563. Partial analytical data for **38** were previously reported.[5]

Ethyl 2,4-di-*O*-benzyl-1-thio-α-D-mannopyranoside (1). A 1.0 M solution of tetrabutylammonium fluoride in THF (4.56 mL, 4.56 mmol) was added to a solution of **38** (1.98 g, 3.80 mmol) in THF (20 mL), and the resulting mixture was stirred under argon for 3 h at rt. After that, the reaction mixture was neutralized with triethylamine (~2 mL) and the volatiles were

removed under reduced pressure. The residue was diluted with CH_2Cl_2 (~50 mL) and washed with water (15 mL), sat. aq. $NaHCO_3$ (15 mL) and water (2 x 15 mL). The organic layer was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 84% yield (1.29 g, 3.19 mmol). Analytical data for **1** were in agreement with those previously reported.[6]

Synthesis of Mannuronic Acid Acceptor 25



Benzyl 4,6-*O*-benzylidene-3-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside (40). To a solution of benzyl 4,6-*O*-benzylidene-α-D-mannopyranoside[7,8] (**39**, 1.71 g, 4.78 mmol) in CH_3OH (~75 mL), dibutyltin(IV) oxide (Bu_2SnO, 1.12 g, 4.78 mmol) was added and the solution was refluxed at 70 °C for 30 min. During this time, the reaction mixture becomes clear. The reaction mixture was allowed to cool to rt, the volatiles were removed under reduced pressure, and the residue was dried in *vacuo*. The resulting residue was dissolved in dry *N,N*-dimethylformamide (25 mL), *tert*-butyldimethylsilyl chloride (0.94 g, 6.21 mmol) was added, and the reaction mixture was stirred under argon for 2 h at rt. After that, the reaction mixture was diluted with toluene (~100 mL) and washed with water (2 x 25 mL). The organic layer was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-toluene gradient elution) to afford the title compound as a white amorphous solid in 75% yield (1.70 g, 3.60 mmol). Analytical data for **40**: R_f = 0.60 (ethyl acetate/toluene, 1/4, v/v); $[\alpha]_D^{22}$ +52.8 (*c* = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.51-7.44 (m, 2H, aromatic), 7.42-7.30 (m, 8H, aromatic), 5.55 (s, 1H, C*H*Ph), 4.98 (d, 1H, $J_{1,2}$ = 1.0 Hz, H-1), 4.63 (dd, 2H, ^2J = 11.9 Hz, CH_2Ph), 4.24 (dd, 1H, $J_{5,6a}$ = 2.6, $J_{5,6b}$ = 8.5 Hz, H-6a), 4.12 (dd, 1H, $J_{3,4}$ = 8.6, H-3), 3.87 (m, 4H, $J_{2,3}$ = 3.7 Hz, H-2, 4, 5, 6b), 2.85 (s, 1H, OH), 0.87 (s, 9H, Si^{t}Bu), 0.10, 0.05 (2 s, 6H, $SiMe_2$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 137.6, 137.1, 129.0, 128.7 (x2), 128.3 (x4), 128.2, 126.2 (x2), 102.0, 99.0, 79.3, 72.1, 69.9, 69.5, 69.0, 63.4, 25.9 (x3), 18.3, -4.2, -4.9 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{20}H_{22}O_6Na^+$ 381.1314; found 381.1327.

Benzyl 2-*O*-benzyl-4,6-*O*-benzylidene-3-*O*-*tert*-butyldimethylsilyl-α-D-mannopyranoside (41). NaH (60% in mineral oil, 0.15 g, 3.70 mmol) and benzyl bromide (0.29 mL, 2.47 mmol) were added to a solution of compound **40** (0.58 g, 1.23 mmol) in *N,N*-dimethylformamide (15.0 mL), and the resulting mixture was stirred under argon for 2 h at 0 °C. After that, the reaction mixture was poured into ice-water (10 mL), stirred for 30 min, and extracted with diethyl ether (3 × 30 mL). The combined organic extract (~100 mL) was washed with cold water (3 × 15 mL). The organic phase was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 88% yield (0.61g, 1.08 mmol). Analytical data for **41**: R_f = 0.80 (ethyl acetate/hexane, 2/3, v/v); $[\alpha]_D^{22}$ +62.8 (*c* = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.49 (m, 2H, aromatic), 7.36-7.24 (m, 13H, aromatic), 5.58 (s, 1H, C*H*Ph), 4.85 (d, 1H, $J_{1,2}$ = 1.2 Hz, H-1), 4.79 (dd, 2H, ^2J = 12.1 Hz, CH_2Ph), 4.58 (dd, 2H, ^2J = 12.1 Hz, CH_2Ph), 4.22 (m, 2H, H-3, 6a), 4.08-4.00 (m, 1H, H-4), 3.85 (m, 2H, H-5, 6b), 3.72 (dd, 1H, $J_{2,3}$ = 3.1 Hz, H-2), 0.89 (s, 9H, Si^{t}Bu), 0.09, 0.04 (2 s, 6H, $SiMe_2$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 138.4, 137.7, 137.2, 129.0, 128.6 (x2), 128.5 (x2), 128.2 (x2), 128.0 (x5), 127.8, 126.3 (x2), 102.0, 99.1, 79.4, 79.2, 74.4, 70.8, 69.2, 69.0, 64.6, 26.0 (x3), 18.5, -4.3, -4.7 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{33}H_{42}O_6SiNa^+$ 586.2682; found 586.2704.

Benzyl 2,4-di-*O*-benzyl-3-*O*-*tert*-butyldimethlsilyl-α-D-mannopyranoside (42). Copper(II) trifluoromethanesulfonate (39 mg, 0.11 mmol) was added to a solution containing compound **41** (0.61 g, 1.10 mmol) and a 1.0 M solution of borane-THF complex in tetrahydrofuran (5.41 mL, 5.41 mmol), and the resulting mixture was stirred under argon for 2 h at rt. The reaction mixture was then cooled to 0 °C and triethylamine (~2 mL) was added until neutral pH. After that, CH_3OH (~5 mL) was added dropwise, and the volatiles were removed under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 82% yield (0.50 g, 0.88 mmol). Analytical data for **42**: R_f = 0.65 (ethyl acetate/hexane, 2/3, v/v); $[\alpha]_D^{22}$ +73.1 (*c* = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.37-7.23 (m, 15H, aromatic), 4.80 (dd, 2H, ^2J = 11.6 Hz, CH_2Ph), 4.84 (d, 1H, $J_{1,2}$ = 1.4 Hz, H-1), 4.72-4.55 (m, 3H, 3 x C*H*Ph), 4.45 (d, 1H, ^2J = 12.2 Hz, C*H*Ph), 4.18 (dd, 1H, $J_{3,4}$ = 9.2 Hz, H-3), 3.87 (dd, 1H, H-4), 3.81-3.57 (m, 4H, $J_{2,3}$ = 2.9 Hz, H-2, 5, 6a, 6b), 1.93 (t, 1H, *J* = 6.5 Hz, OH), 0.96 (s, 9H, Si^{t}Bu), 0.12 (s, 6H, $SiMe_2$) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 138.6, 138.5, 137.4, 128.5 (x8), 127.9 (x3), 127.8 (x4), 97.9, 79.3, 75.9, 75.3, 73.8, 73.4, 72.7, 69.1, 62.4, 26.2 (x3), 18.2, -4.2, -4.6 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{33}H_{44}O_6SiNa^+$ 587.2805; found 587.2814.

Benzyl 2,4-di-*O*-benzyl-α-D-mannopyranoside (43). A 1.0 M solution of tetrabutylammonium fluoride in THF (1.10 mL, 1.10 mmol) was added to a solution of **42** (0.50 g, 0.88 mmol) in THF (10 mL), and the resulting mixture was stirred under argon for 3 h at rt. After that, the reaction mixture was neutralized with triethylamine (~1 mL), and the volatiles were removed under reduced pressure. The residue was diluted with CH_2Cl_2 (~30 mL) and washed with water (10 mL), sat. aq. $NaHCO_3$ (10 mL) and water (2 x 10 mL). The organic layer was separated, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 96% yield (0.38 g, 0.84 mmol). Analytical data for **43**: R_f = 0.40 (ethyl acetate/hexane, 2/3, v/v); $[\alpha]_D^{22}$ +60.6 (*c* = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.40-7.22 (m, 15H, aromatic), 4.95 (br s, 1H, H-1), 4.79 (dd, 2H, ^2J = 11.1 Hz, CH_2Ph), 4.62 (dd, 2H, ^2J = 11.8 Hz, CH_2Ph), 4.57 (dd,

2H, ^2J = 11.9 Hz, CH_2Ph), 4.09-4.01 (m, 1H, H-3), 3.92-3.62 (m, 5H, H-2, 4, 5, 6a, 6b), 2.32 (d, 1H, J = 9.3 Hz, OH), 1.95 (m, 1H, OH) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 138.4, 137.6, 137.1, 128.7 (x2), 128.6 (x3), 128.2 (x4), 128.0 (x4), 127.9 (x2), 96.5, 78.5, 76.5, 75.1, 73.2, 71.8, 71.7, 69.3, 62.3 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{27}H_{30}O_6Na^+$ 473.1940; found 473.1967. Partial analytical data for **43** were previously reported.[9]

Benzyl 2,4-di-*O*-benzyl-α-D-mannopyranosiduronic acid (44) and benzyl 2,4-di-*O*-benzyl-α-D-mannopyranosidurono-6,3-lactone (45). (2,2,6,6-Tetramethylpiperidin-1-yl)oxyl (TEMPO, 26 mg, 0.17 mmol) and bis(acetoxy)iodobenzene (BAIB, 0.68 g, 2.11 mmol) were added to a solution of compound **43** (0.38 g, 0.84 mmol) in CH_2Cl_2/H_2O (15 mL, 2/1, v/v), and the resulting mixture was stirred for 16 h at rt. The reaction was quenched with aq. $Na_2S_2O_3$ (~2 mL) and the volatiles were removed under reduced pressure. The residue was diluted with EtOAc (~20 mL) and washed with water (2 x 5 mL). The aqueous layer was separated and extracted with EtOAc (2 x 20 mL). The organic extracts were combined, dried with Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (CH_3OH-CH_2Cl_2 gradient elution) to give lactone **45** (0.21 g, 0.46 mmol) and acid **44** (0.13 g, 0.28 mmol). Analytical data for **45**: R_f = 0.85 (CH_3OH/CH_2Cl_2, 1/9, v/v) or R_f = 0.75 (ethyl acetate/hexane, 1/1, v/v); $[\alpha]_D^{22}$ +34.9 (c = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.39-7.28 (m, 15H, aromatic), 4.98 (d, 1H, ^2J = 11.8 Hz, CHPh), 4.89 (d, 1H, $J_{1,2}$ = 6.7 Hz, H-1), 4.64 (m, 6H, H-3, 5 x CHPh), 4.26 (d, 1H, $J_{4,5}$ = 2.6 Hz, H-5), 3.99-3.93 (m, 2H, H-2, 4) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 173.1, 137.5, 137.4, 136.9, 128.7 (x5), 128.6 (x2), 128.3 (x2), 128.2 (x4), 128.1 (x2), 96.6, 77.4, 77.2, 74.7, 73.3, 71.1, 70.6, 70.2 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{27}H_{26}O_6Na^+$ 469.1627; found 469.1630.
Lactone **45** (0.21 g, 0.46 mmol) was dissolved in THF (5.0 mL), a 1 M aq. solution of LiOH (5.0 mL) was added and stirred for 4 h at rt. After that, a 1 N aq. solution of HCl was added to pH ~3, and the volatiles were removed under reduced pressure. The residue was diluted with EtOAc (~20 mL) and washed with water (10 mL). The aqueous layer was separated and extracted with EtOAc (3 x 20 mL). The organic extracts were combined, dried with Na_2SO_4, and concentrated under reduced pressure to give acid **44** as a colorless syrup in 96% yield (0.20 g, 0.43 mmol), a combined yield of 84% from **43**. Analytical data for **44**: R_f = 0.40 (CH_3OH/CH_2Cl_2, 1/9, v/v) or R_f = 0.10 (ethyl acetate/hexane, 1/1, v/v); $[\alpha]_D^{22}$ +38.7 (c = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.28 (m, 15H, aromatic), 5.15 (br s, 1H, H-1), 4.86-4.67 (m, 4H, 2 x CH_2Ph), 4.59-4.48 (m, 2H, CH_2Ph), 4.29 (d, 1H, $J_{4,5}$ = 8.4 Hz, H-5), 4.06 (m, 1H, H-3), 3.94 (m, 1H, H-4), 3.75 (dd, 1H, H-2) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 175.4, 138.4, 137.6, 137.3, 129.0, 128.6 (x3), 128.4 (x4), 128.1 (x2), 128.0 (x2), 127.7 (x2), 126.1, 97.8, 78.3, 77.4, 73.3, 73.2, 70.5, 70.0, 69.9 ppm; HR FAB MS $[M+Na]^+$ calcd for $C_{27}H_{28}O_7Na^+$ 487.1733; found 487.1739.

Benzyl (benzyl 2,4-di-*O*-benzyl-α-D-mannopyranosid)uronate (25). Benzyl bromide (0.85 mL, 7.12 mmol) and $NaHCO_3$ (0.36 g, 4.27 mmol) were added to a solution of compound **44** (0.33 g, 0.71 mmol) in *N,N*-dimethylformamide (10 mL), and the resulting mixture was stirred for 16 h at rt. The reaction mixture was diluted with EtOAc (~50 mL) and washed with water (2 x 10 mL). The aqueous layer was separated and extracted with EtOAc (2 x 35 mL). The organic extracts were combined, dried over Na_2SO_4, and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (ethyl acetate-hexane gradient elution) to give the title compound as a colorless syrup in 86% yield (0.34 g, 0.61 mmol). Analytical data for **25**: R_f = 0.60 (ethyl acetate/hexane, 2/3, v/v); $[\alpha]_D^{22}$ +20.3 (c = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$): δ

7.35-7.20 (m, 20H, aromatic), 5.26-5.16 (m, 2H, CH_2Ph), 5.11 (d, 1H, $J_{1,2}$ = 2.4 Hz, H-1), 4.81-4.68 (m, 3H, 3 x C*H*Ph), 4.53 (m, 3H, 3 x C*H*Ph), 4.31 (d, 1H, $J_{4,5}$ = 7.8 Hz, H-5), 4.07-3.94 (m, 2H, H-3, 4), 3.75 (dd, 1H, H-2), 2.37 (d, 1H, J = 7.4 Hz, OH) ppm; ^{13}C NMR (75 MHz, $CDCl_3$): δ 169.6, 138.1, 137.6, 137.0, 135.4, 128.7 (x4), 128.6 (x4), 128.5 (x3), 128.2, 128.1 (x5), 128.0 (x2), 127.9, 96.8, 77.7, 77.4, 74.5, 73.2, 71.6, 71.0, 70.0, 67.3 ppm; HR FAB MS $[M+H]^+$ calcd for $C_{34}H_{34}O_7Na^+$ 577.2202; found 577.2238.

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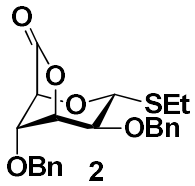
NMR Spectra



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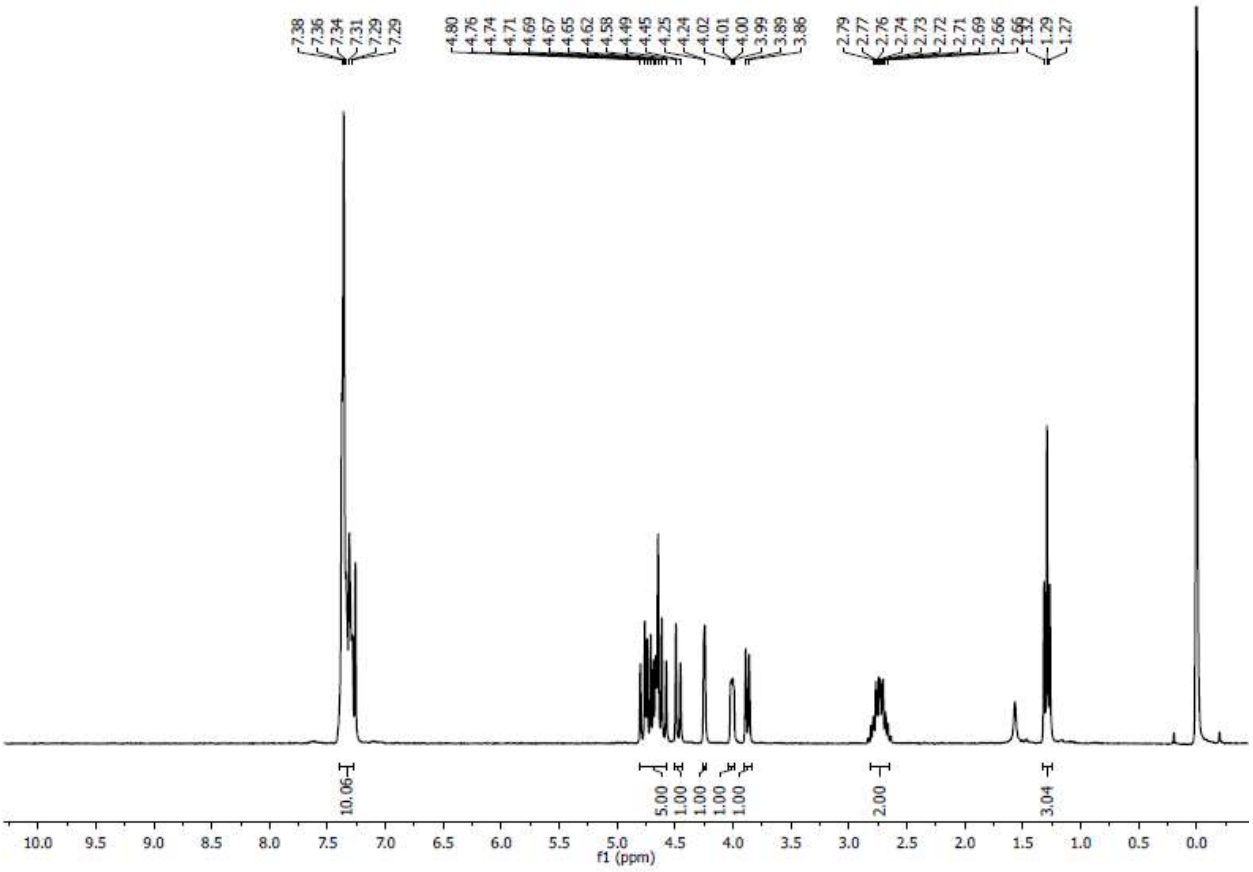

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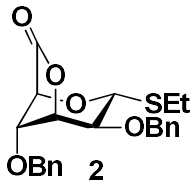

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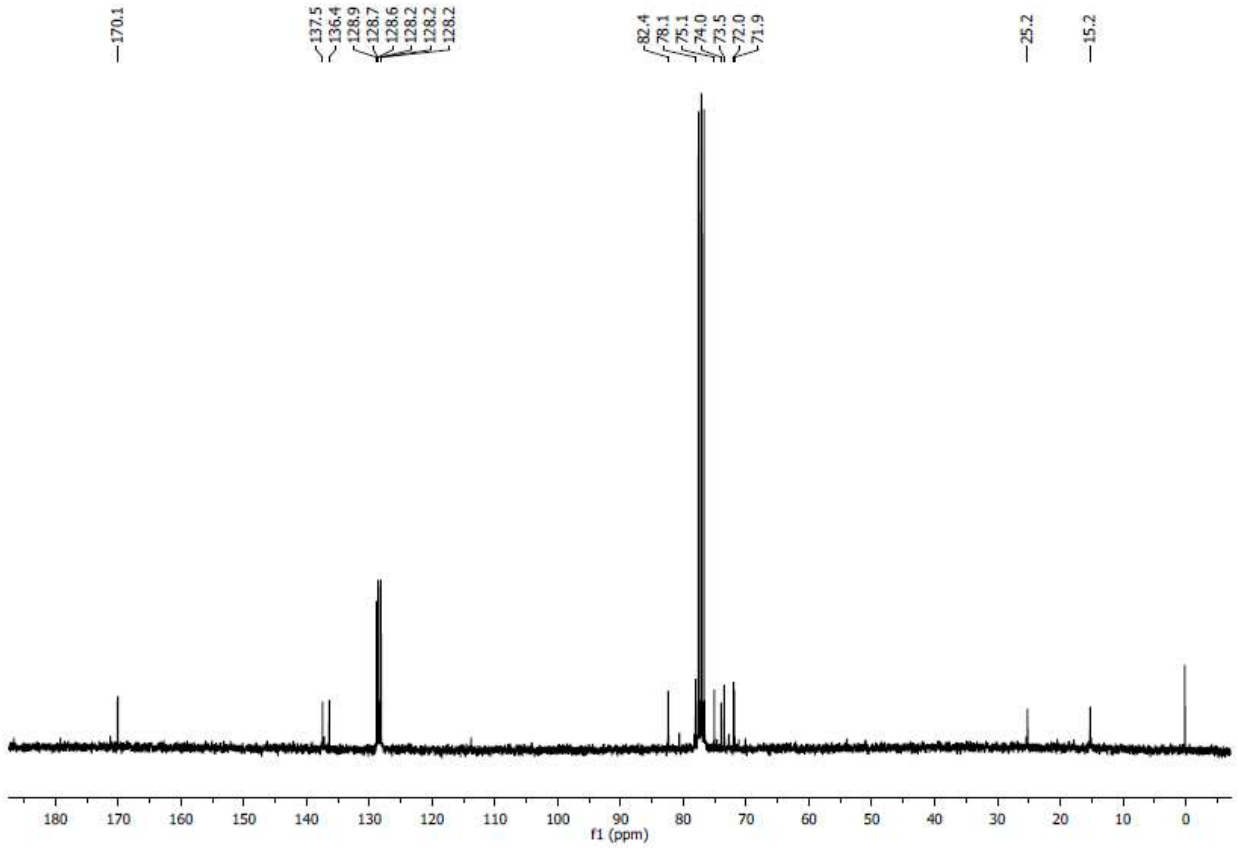

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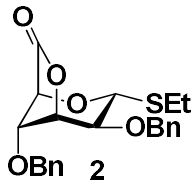

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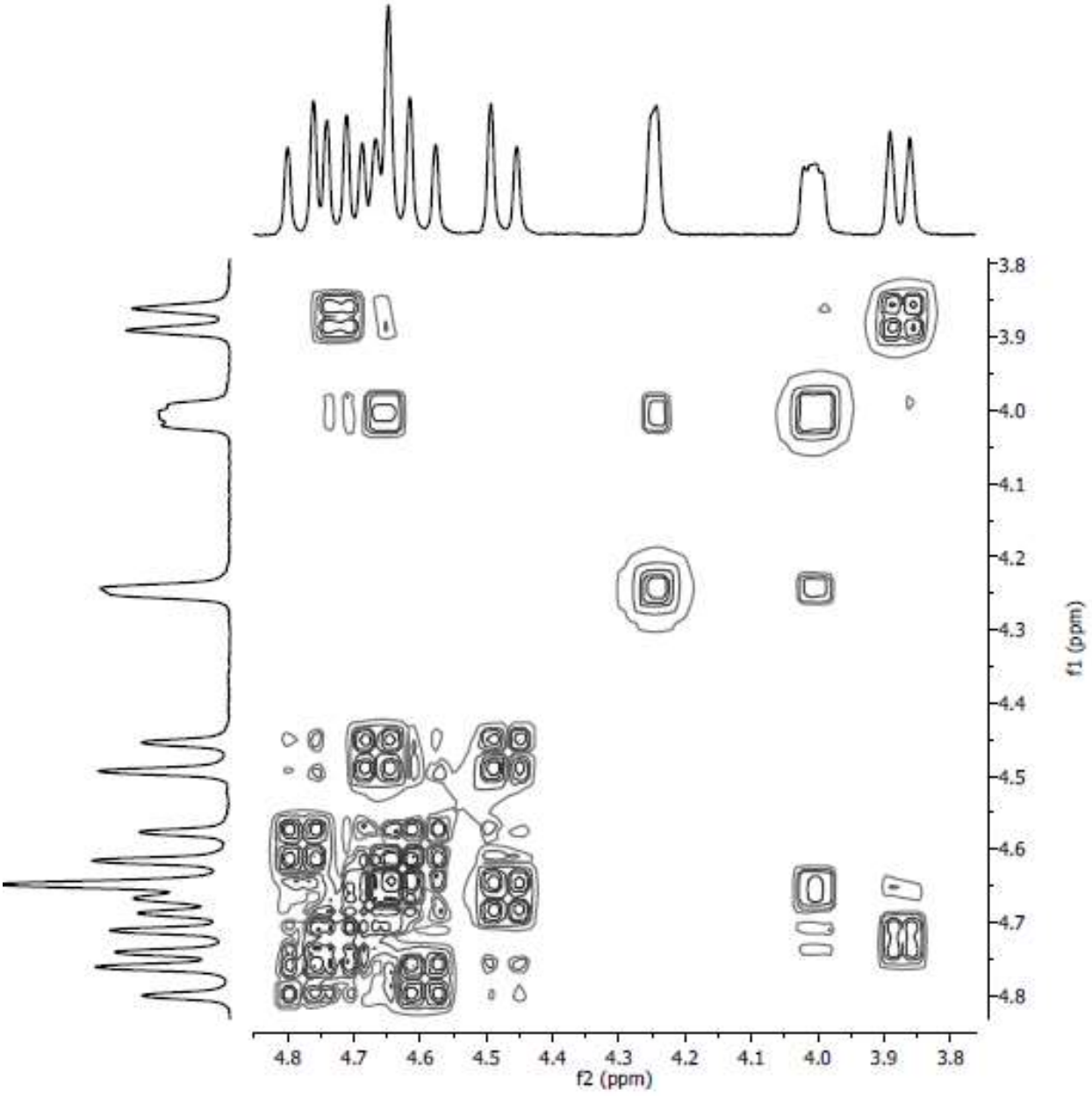

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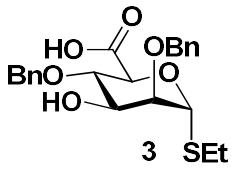

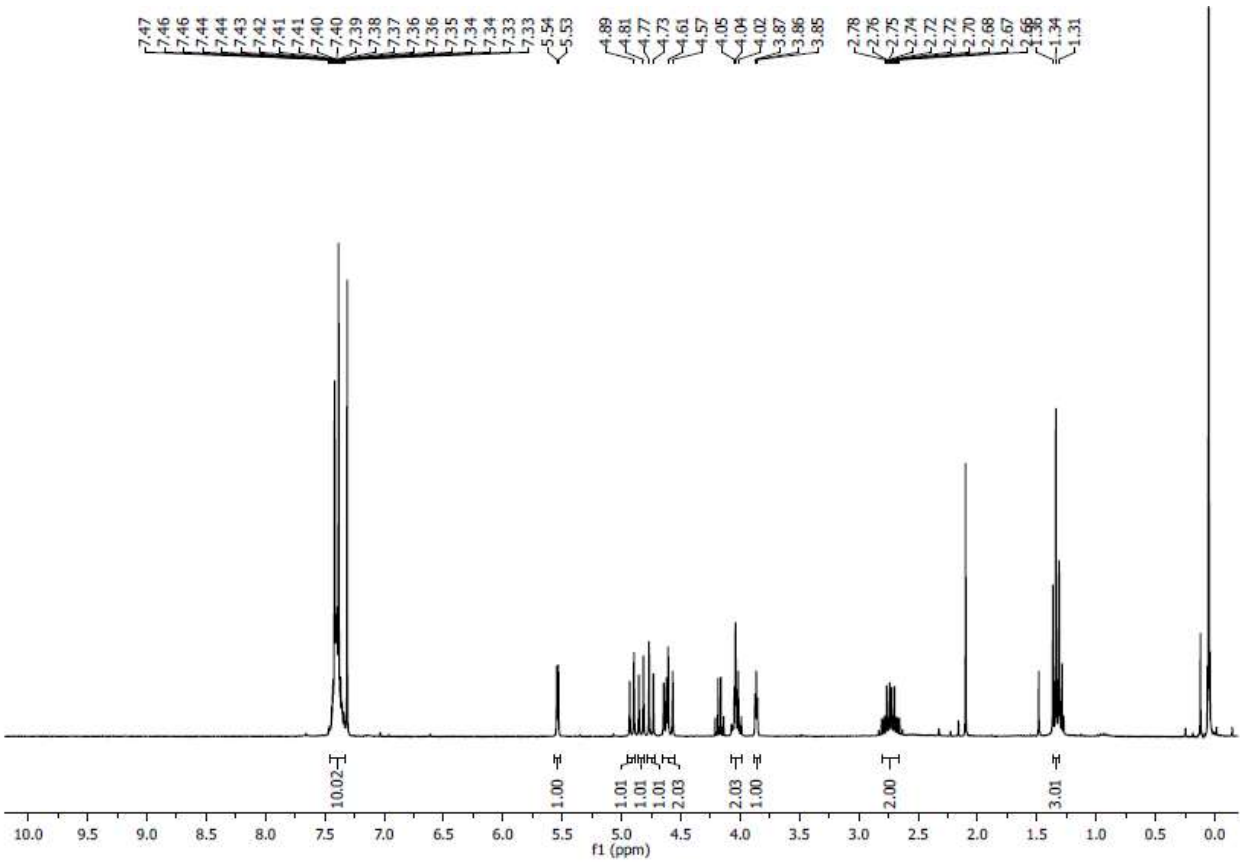

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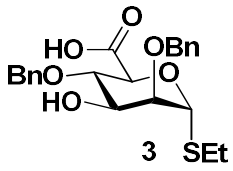
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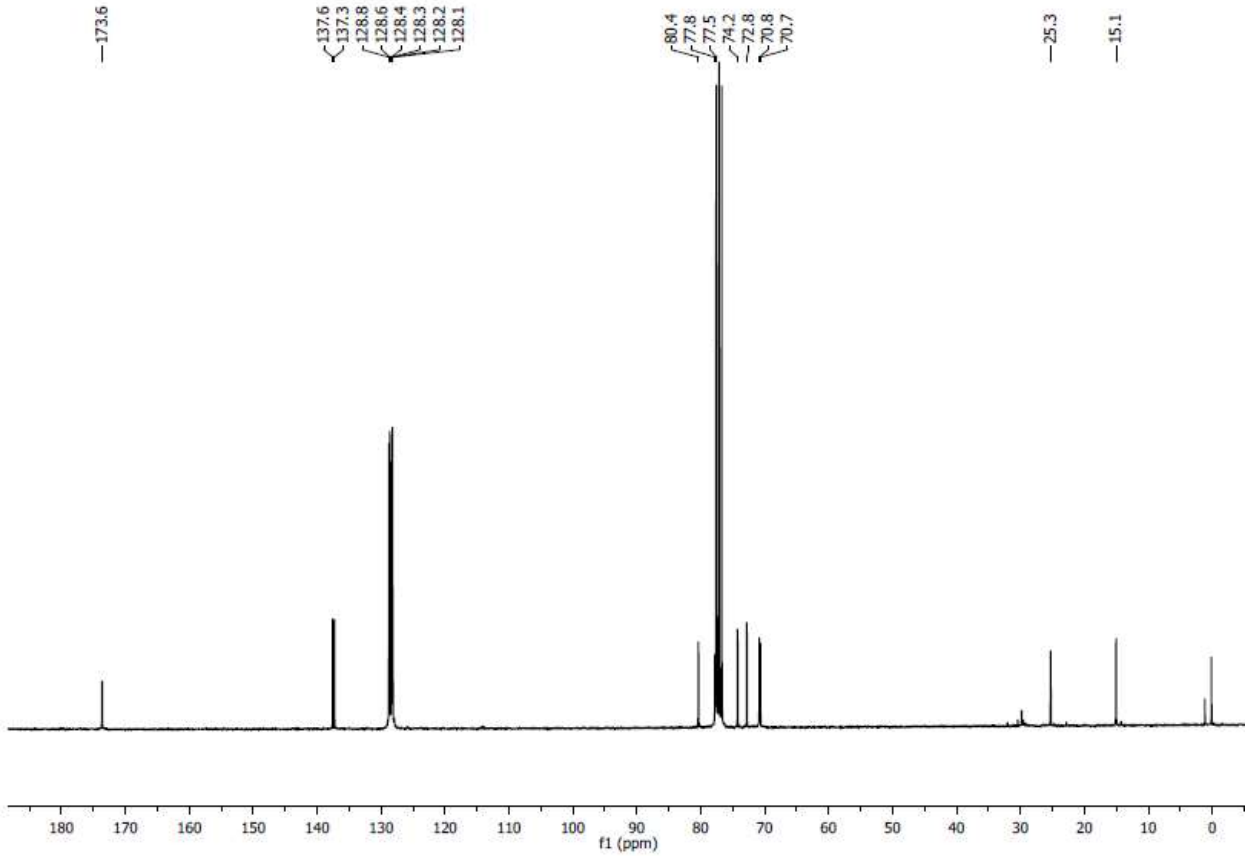
HO
OBn
BnO
O
HO
3
SEt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80.4
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72.8
70.8
70.7
25.3
15.1
180
170
160
150
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f1 (ppm)

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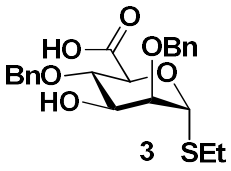

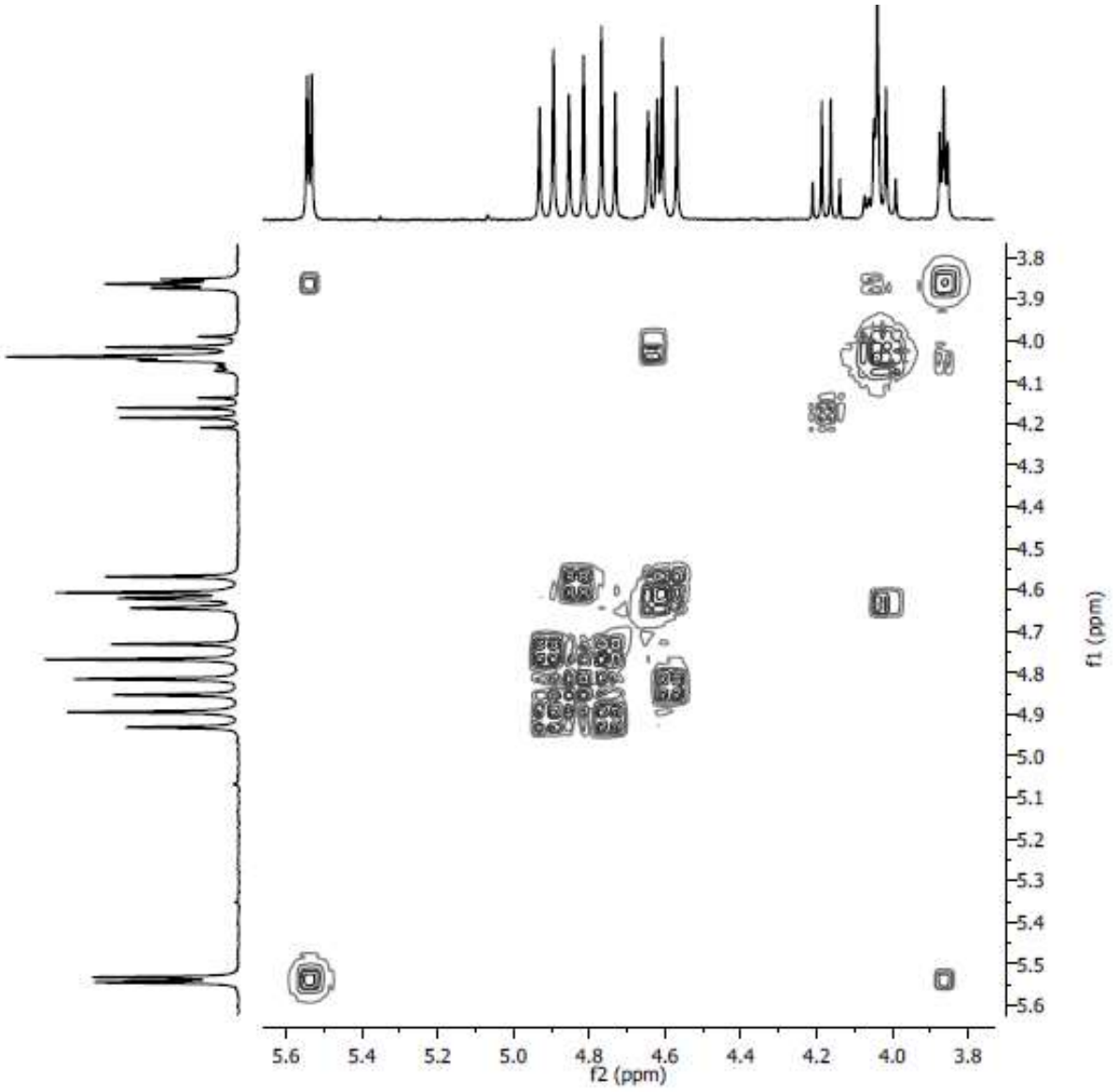

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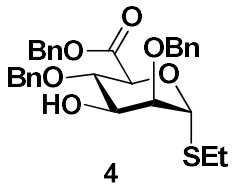

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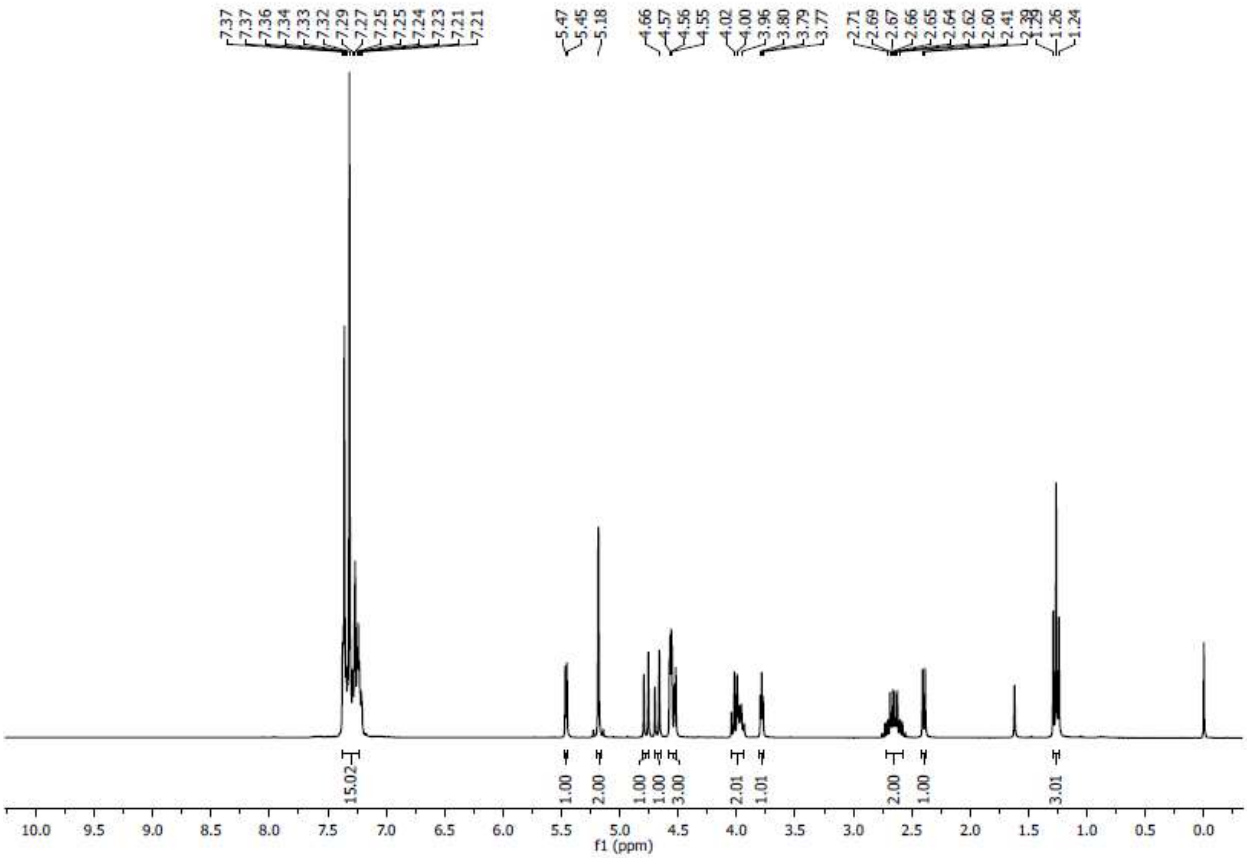

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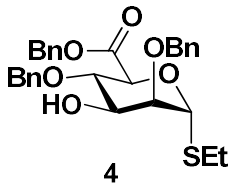

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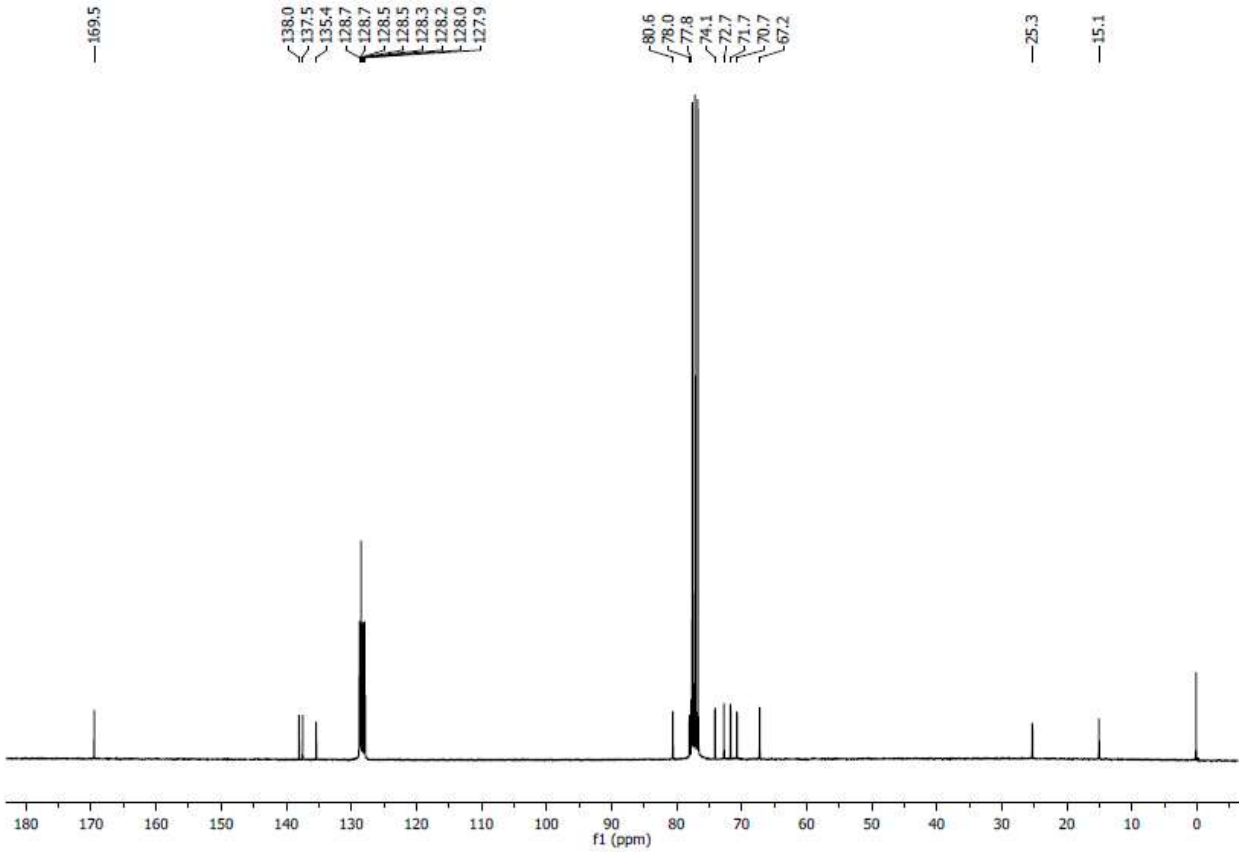

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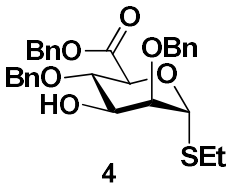

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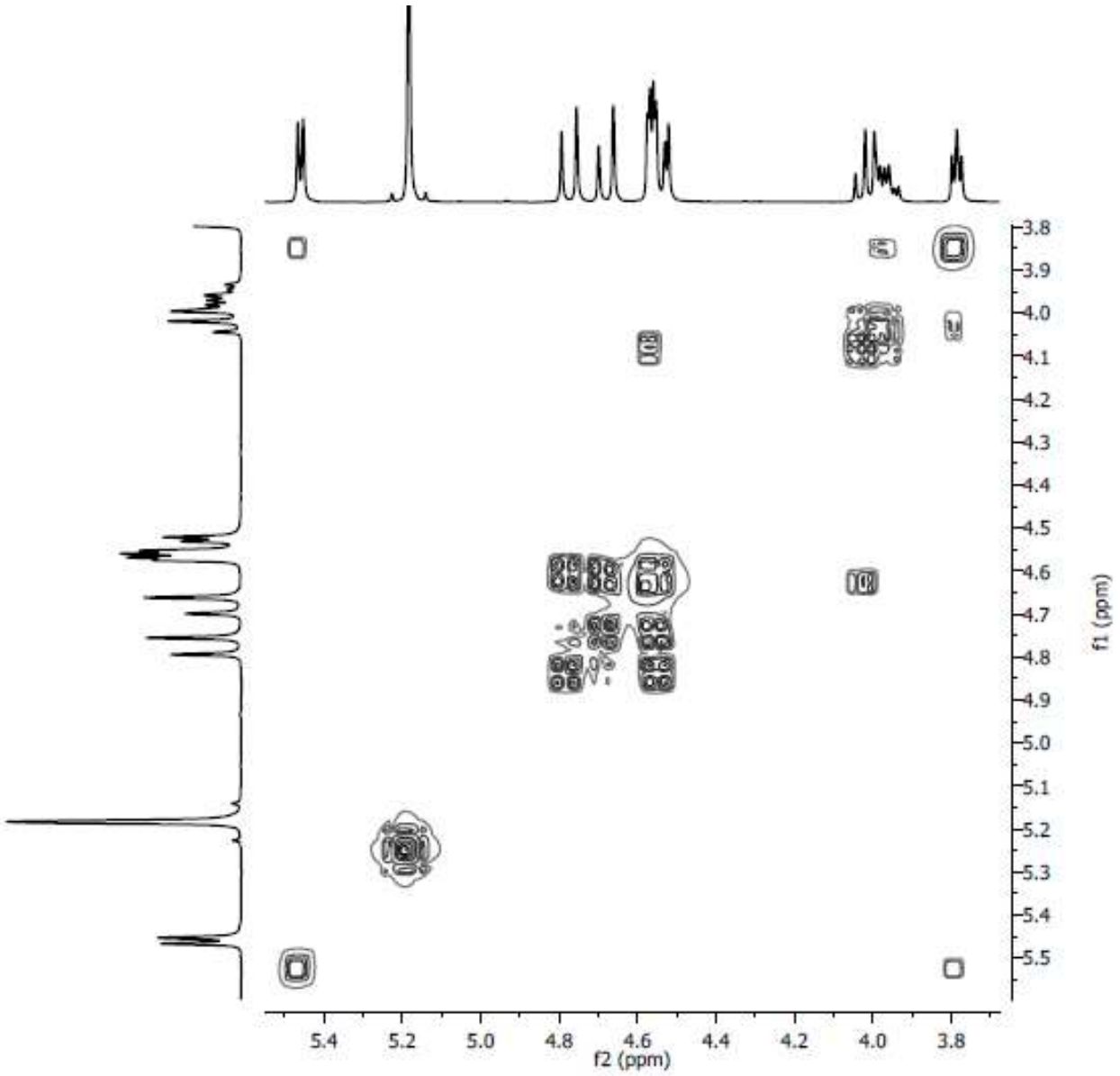

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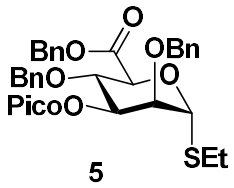

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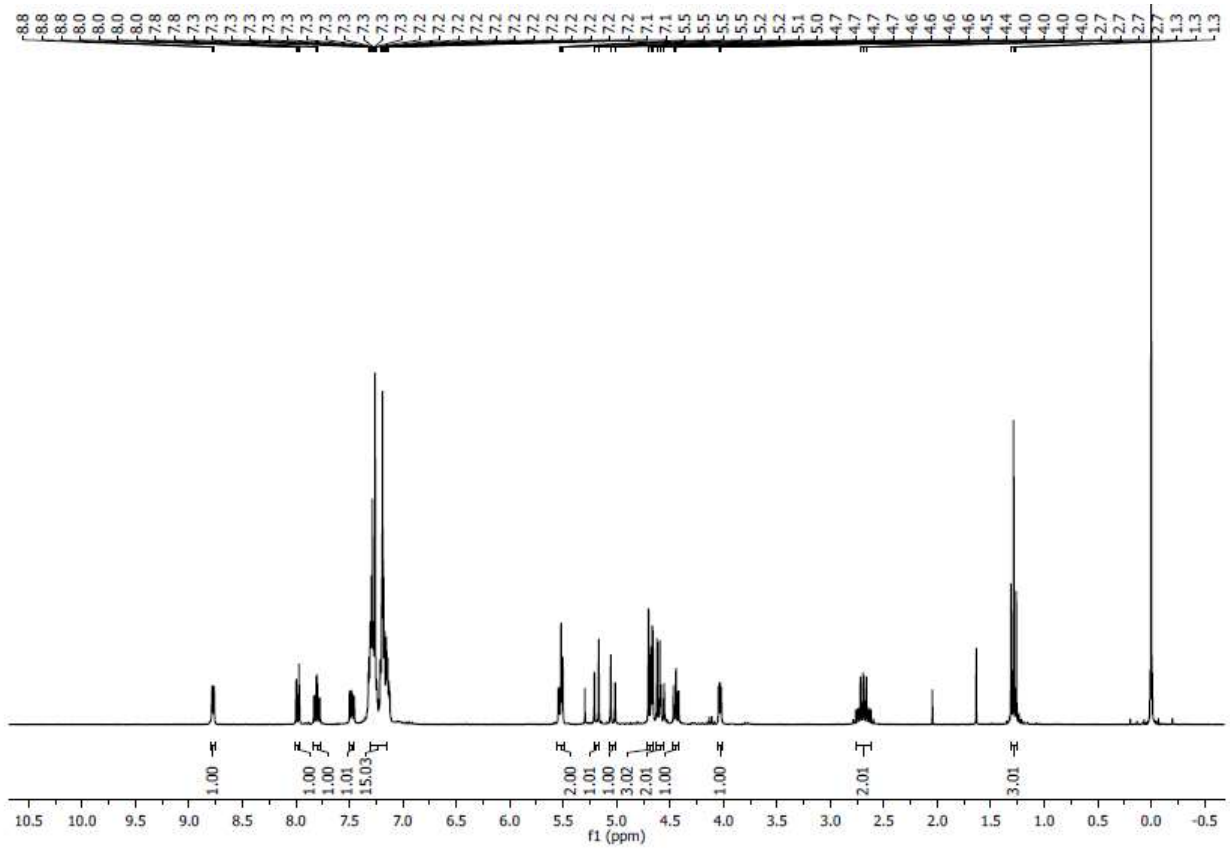

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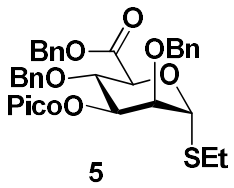

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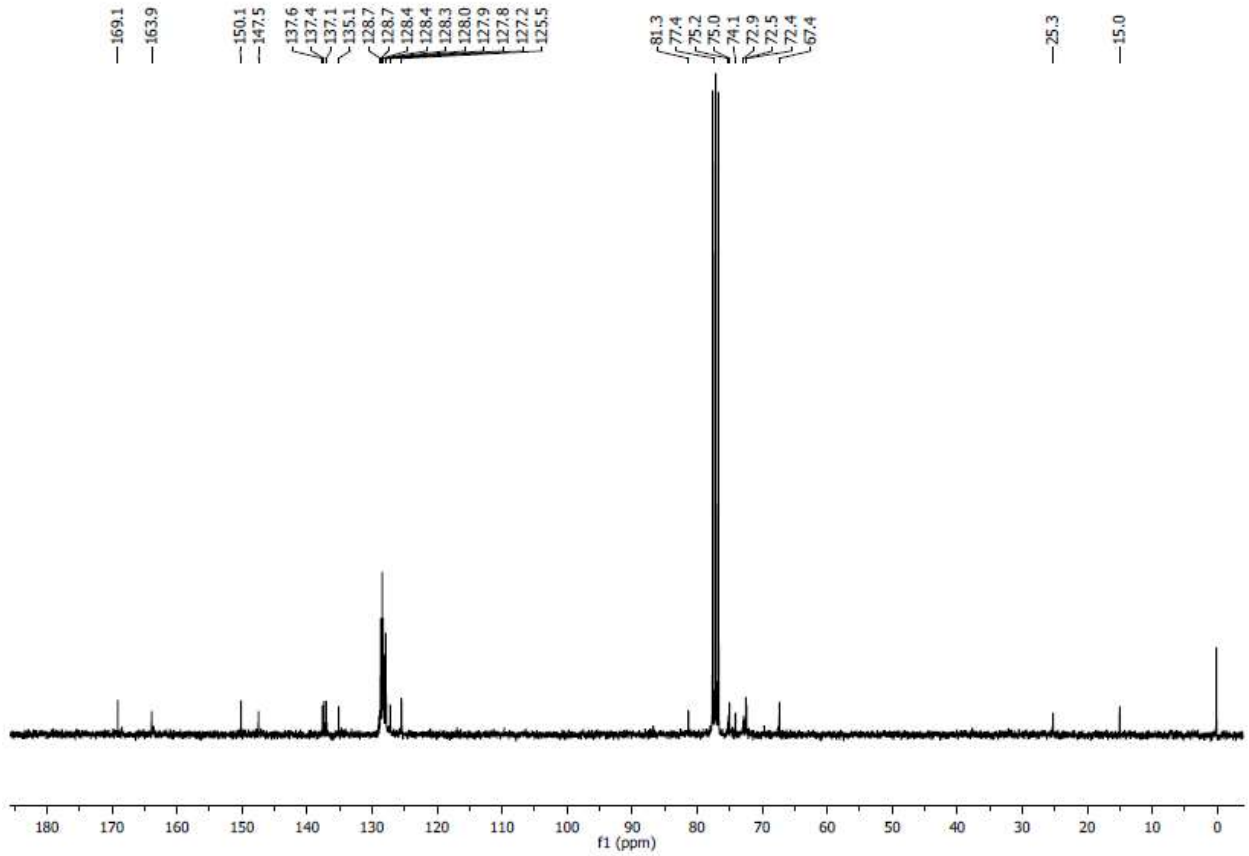

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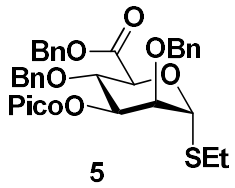

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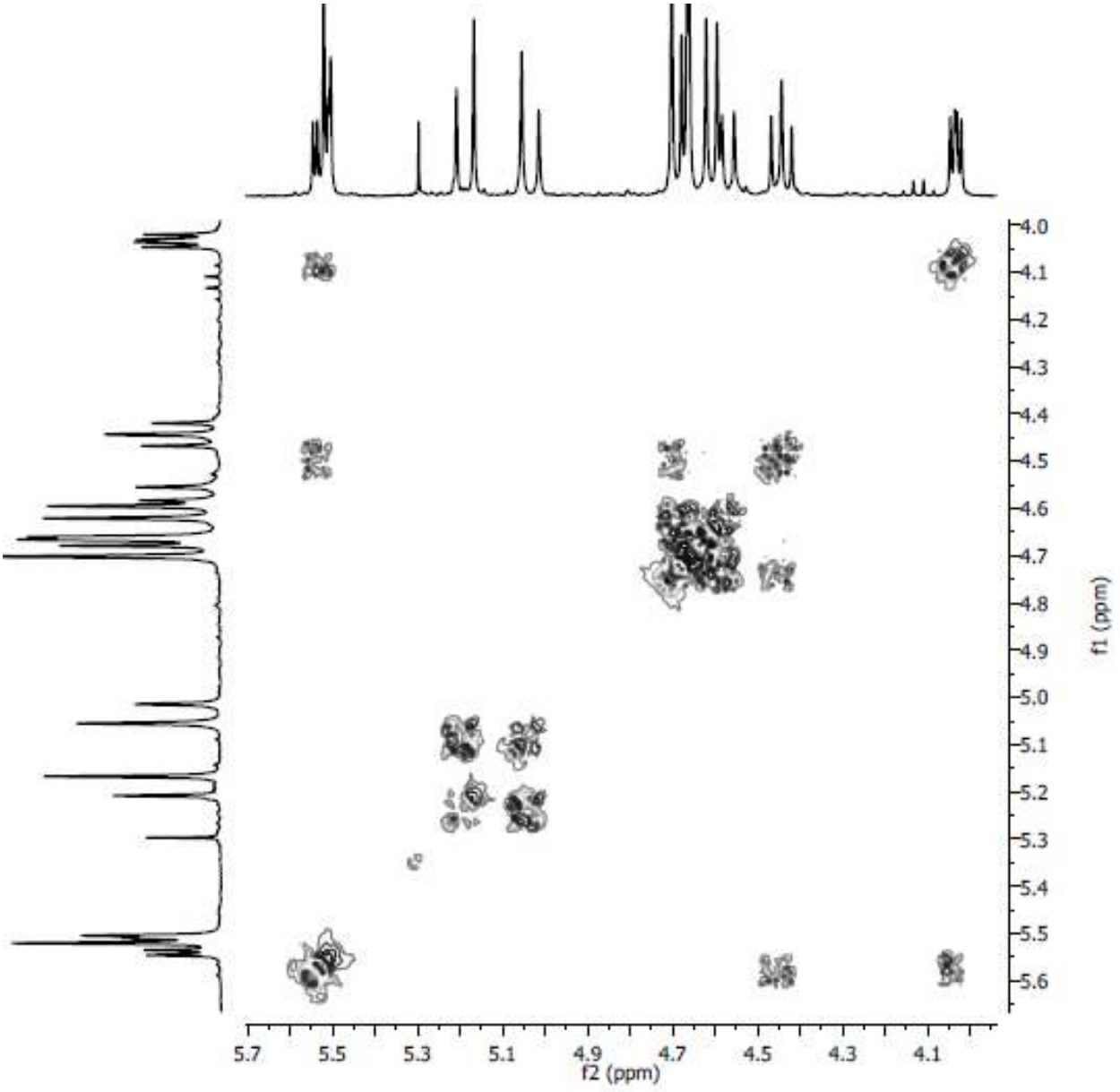

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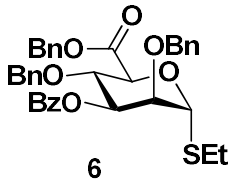

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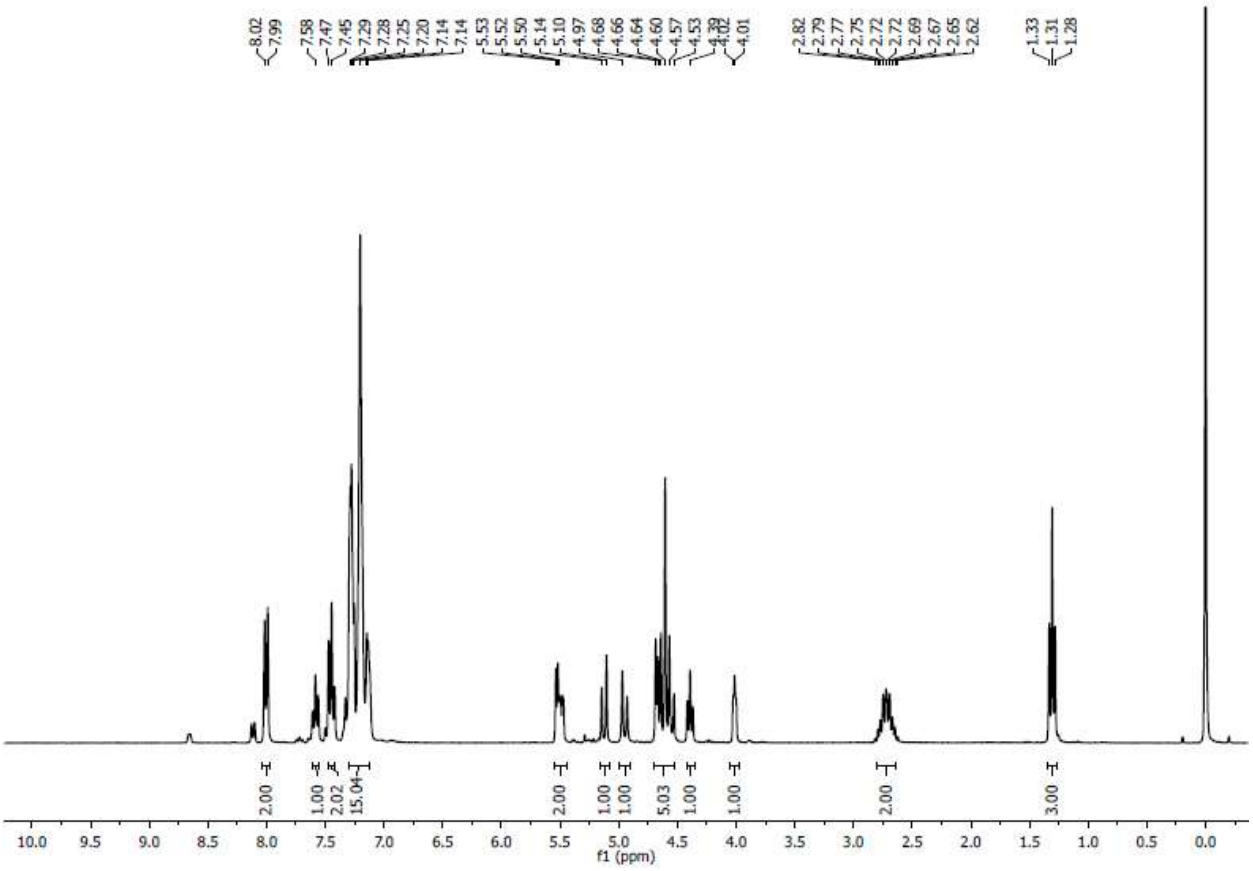

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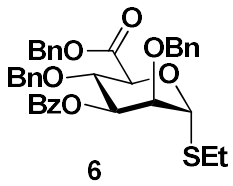

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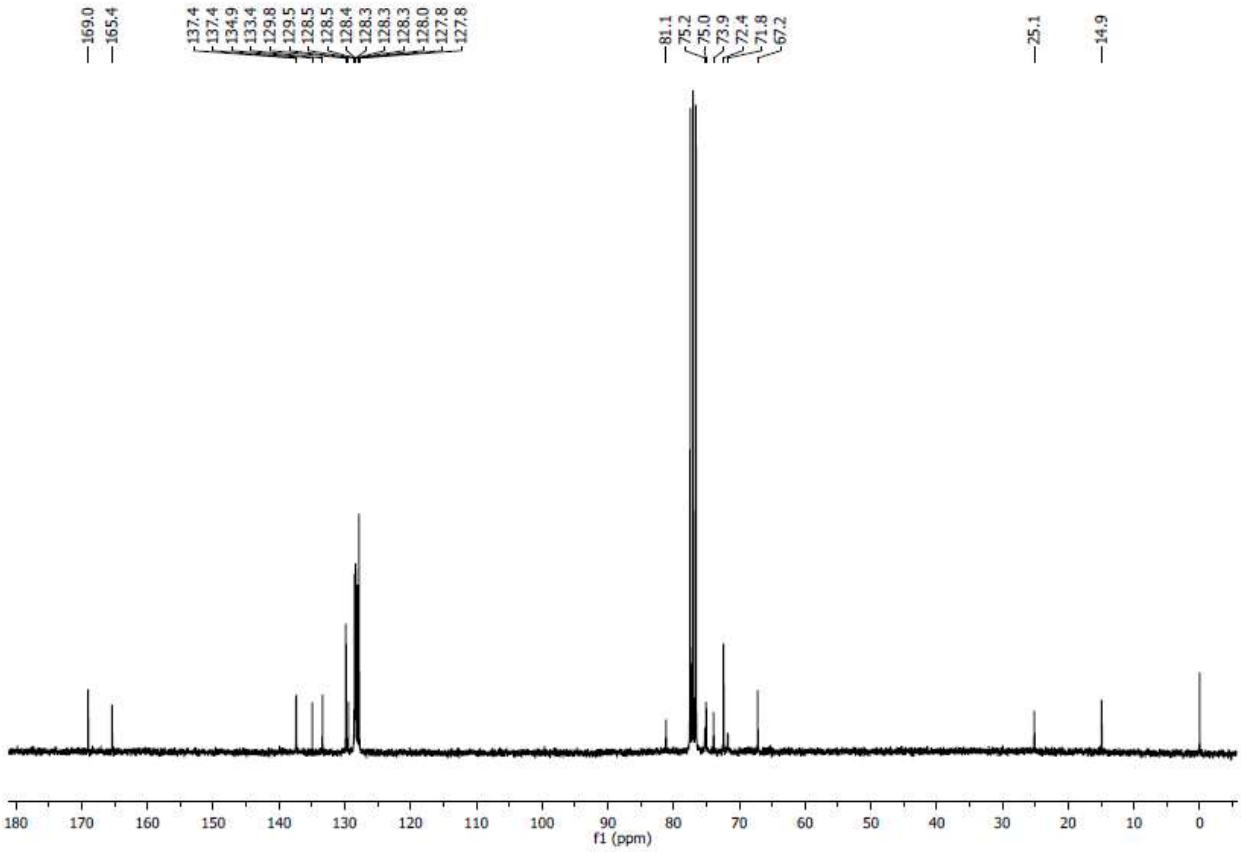

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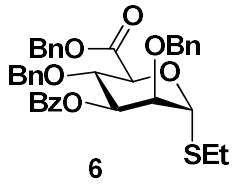

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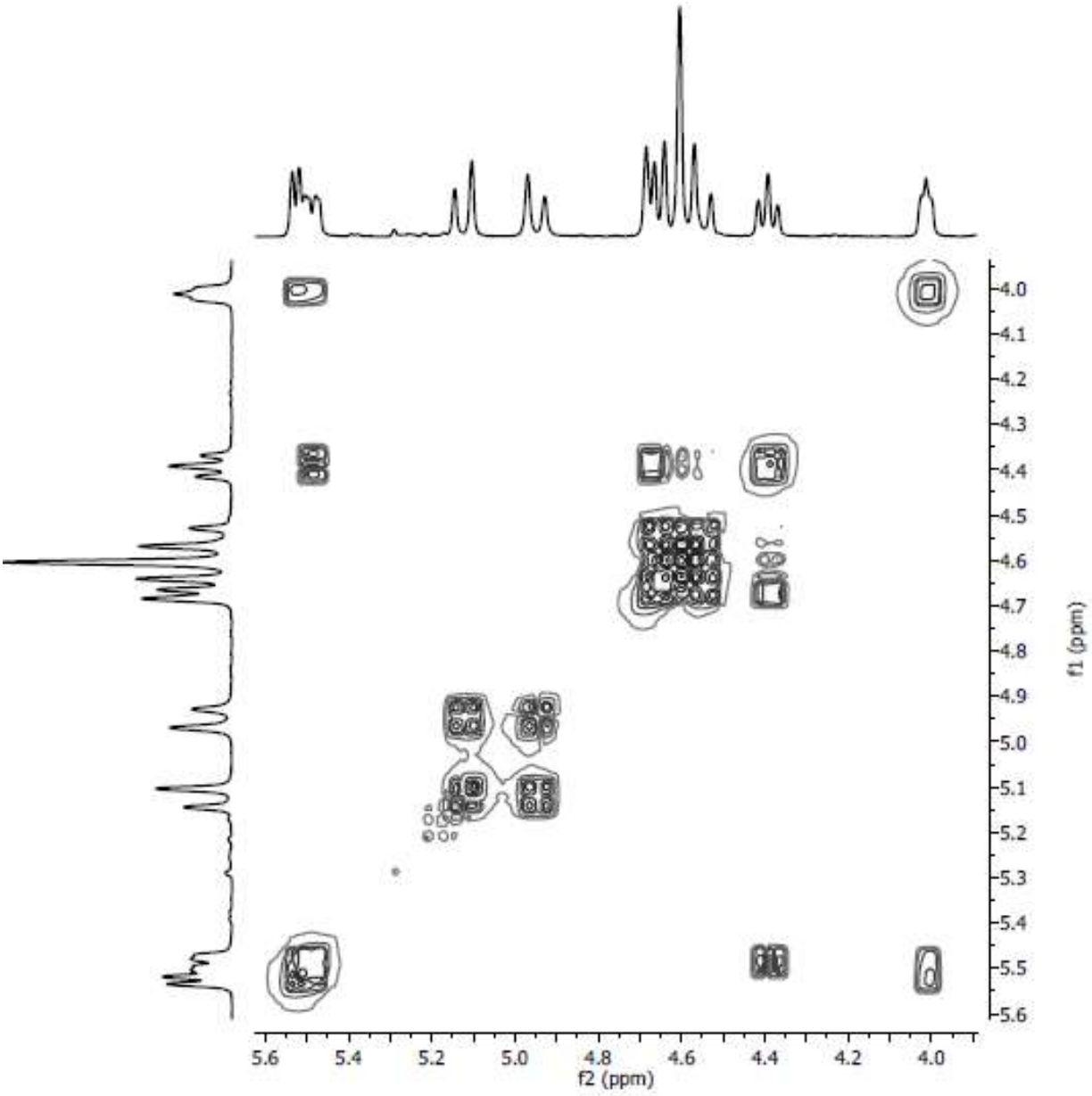

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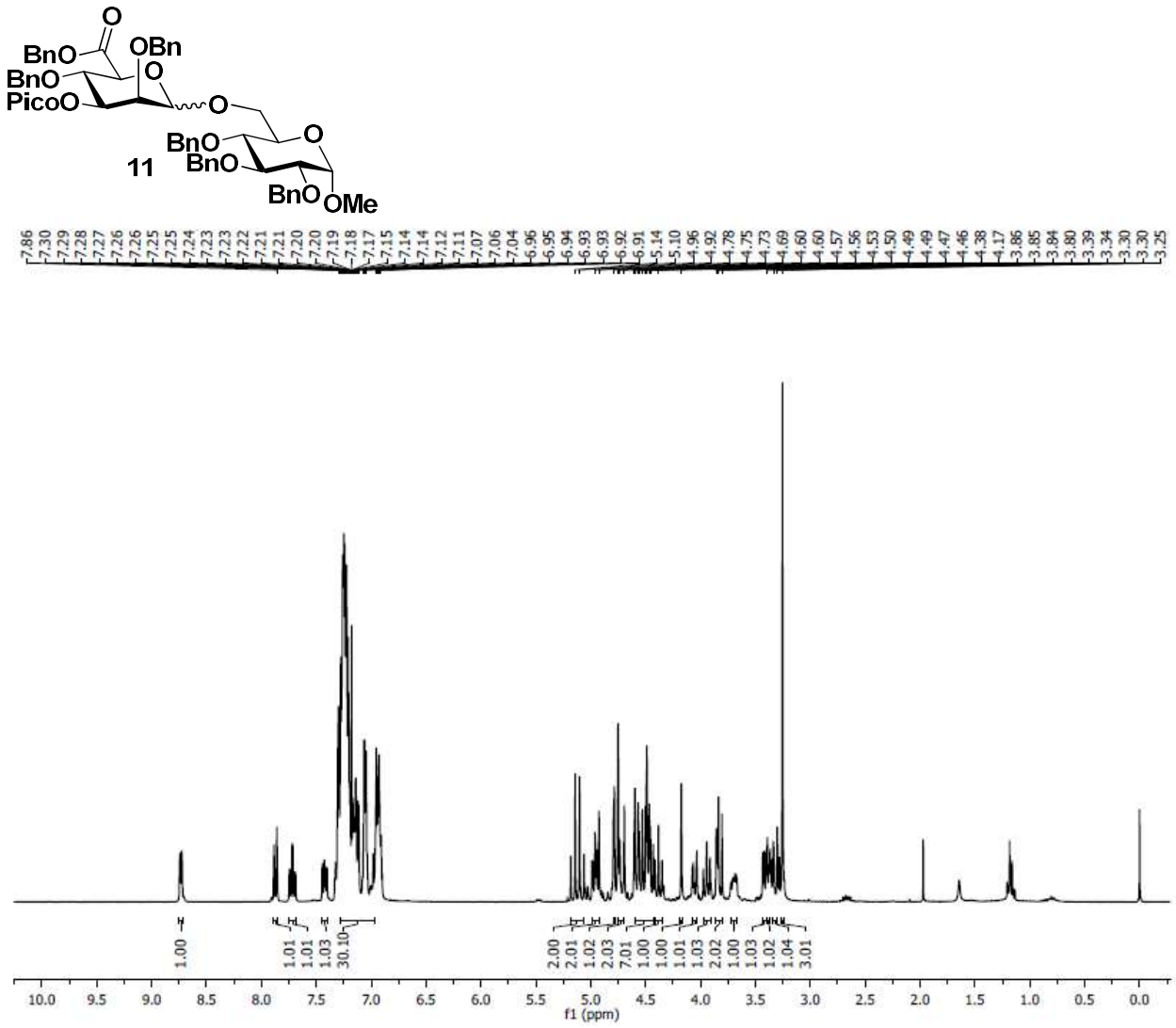

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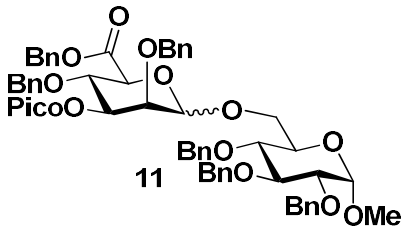

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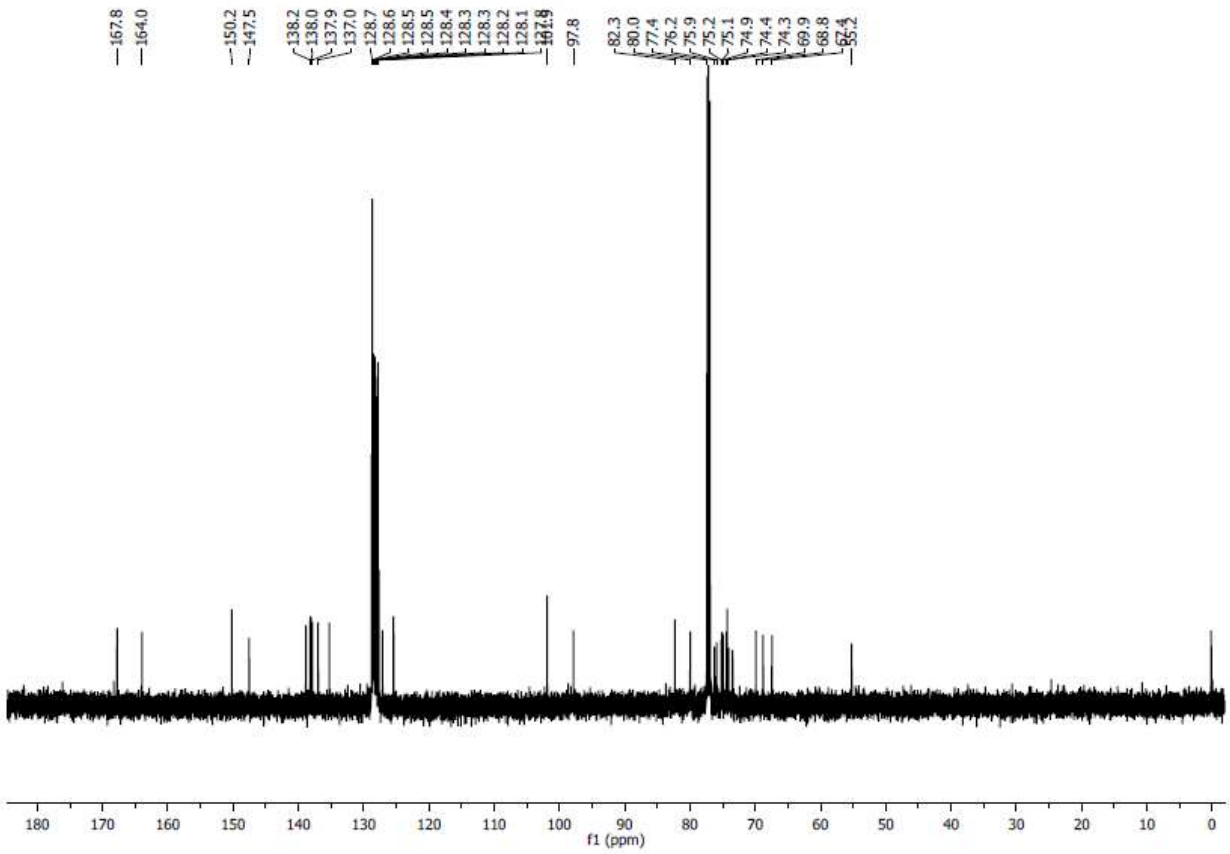

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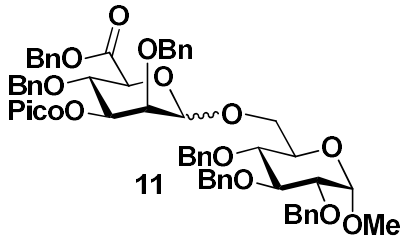

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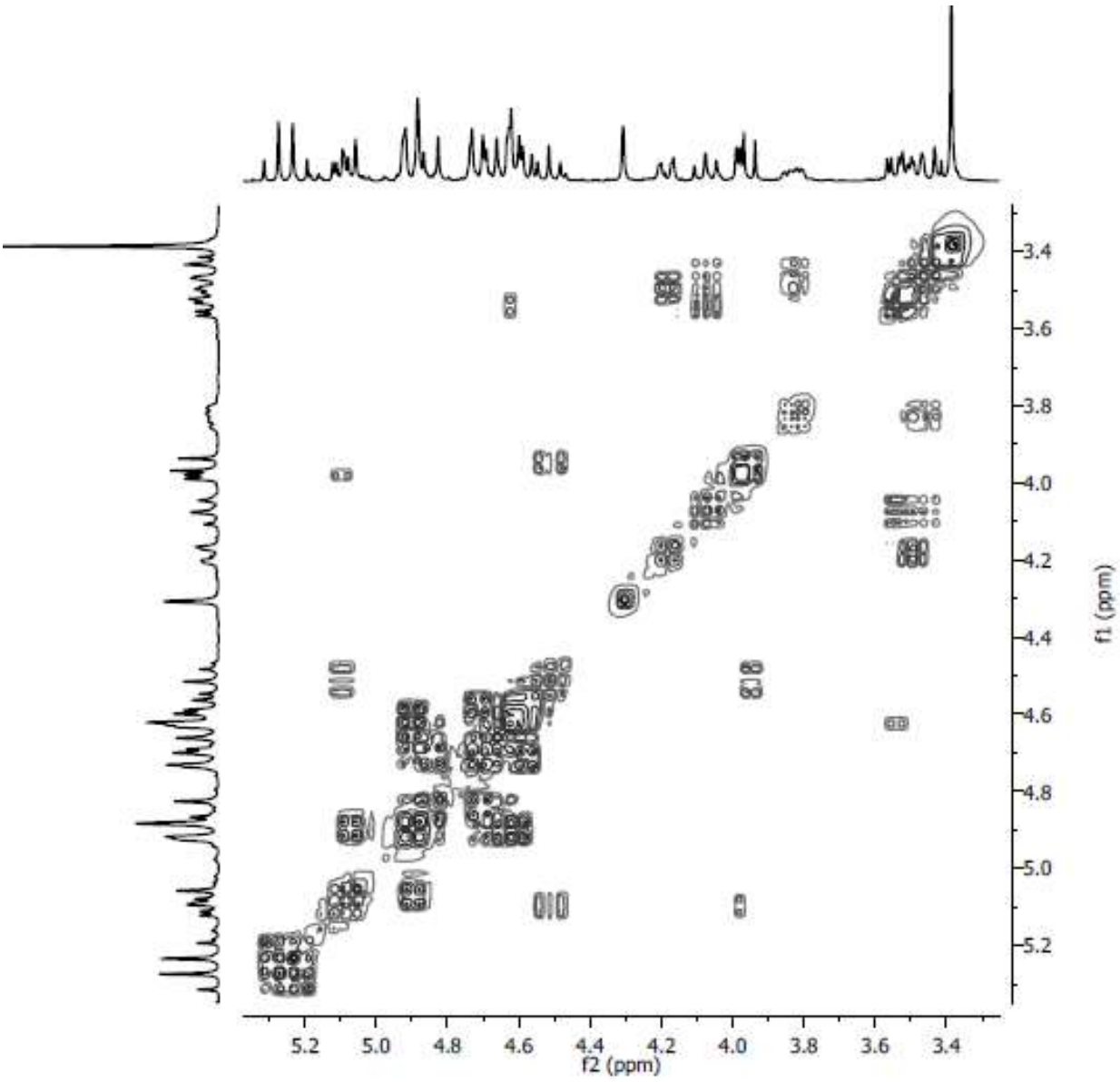

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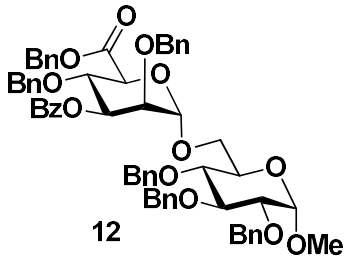

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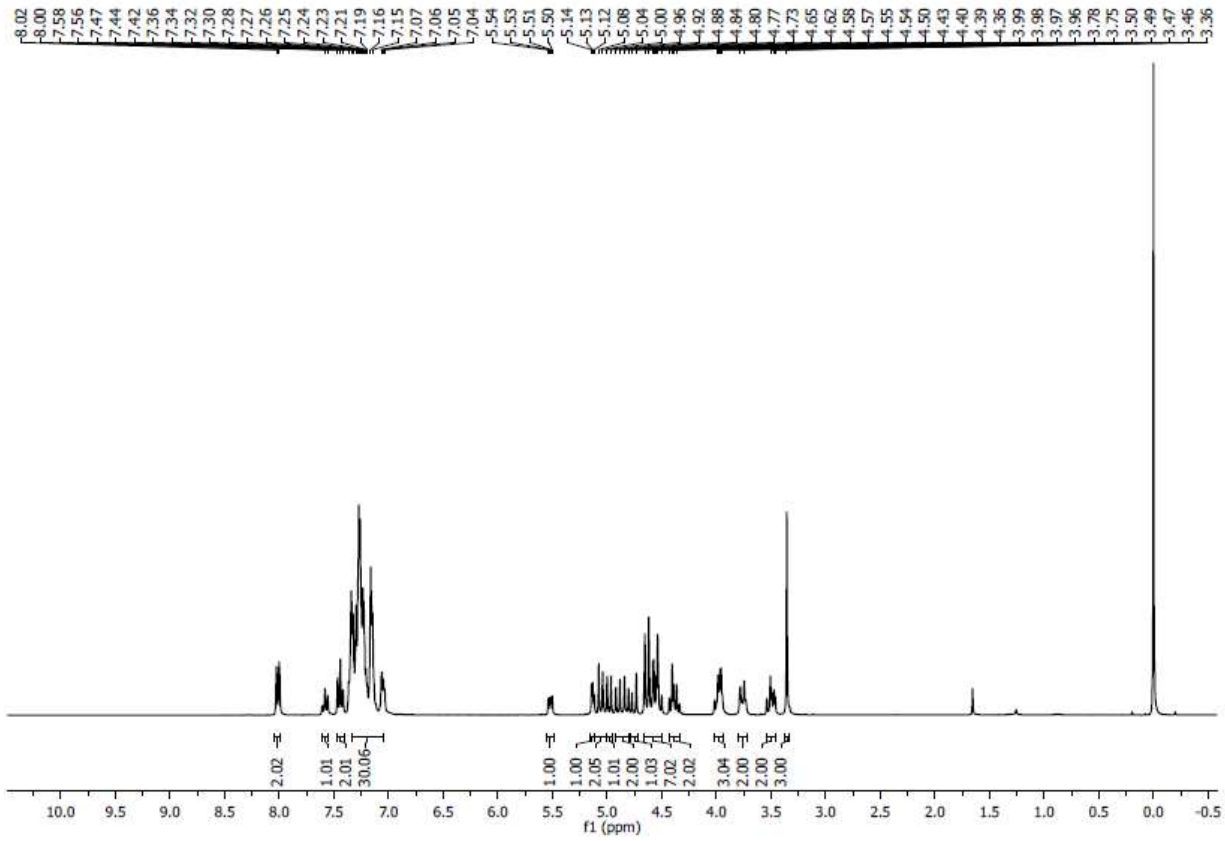

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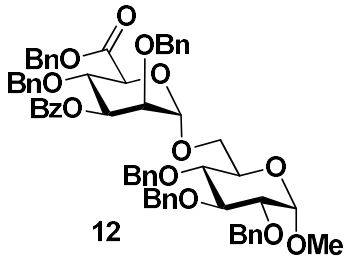

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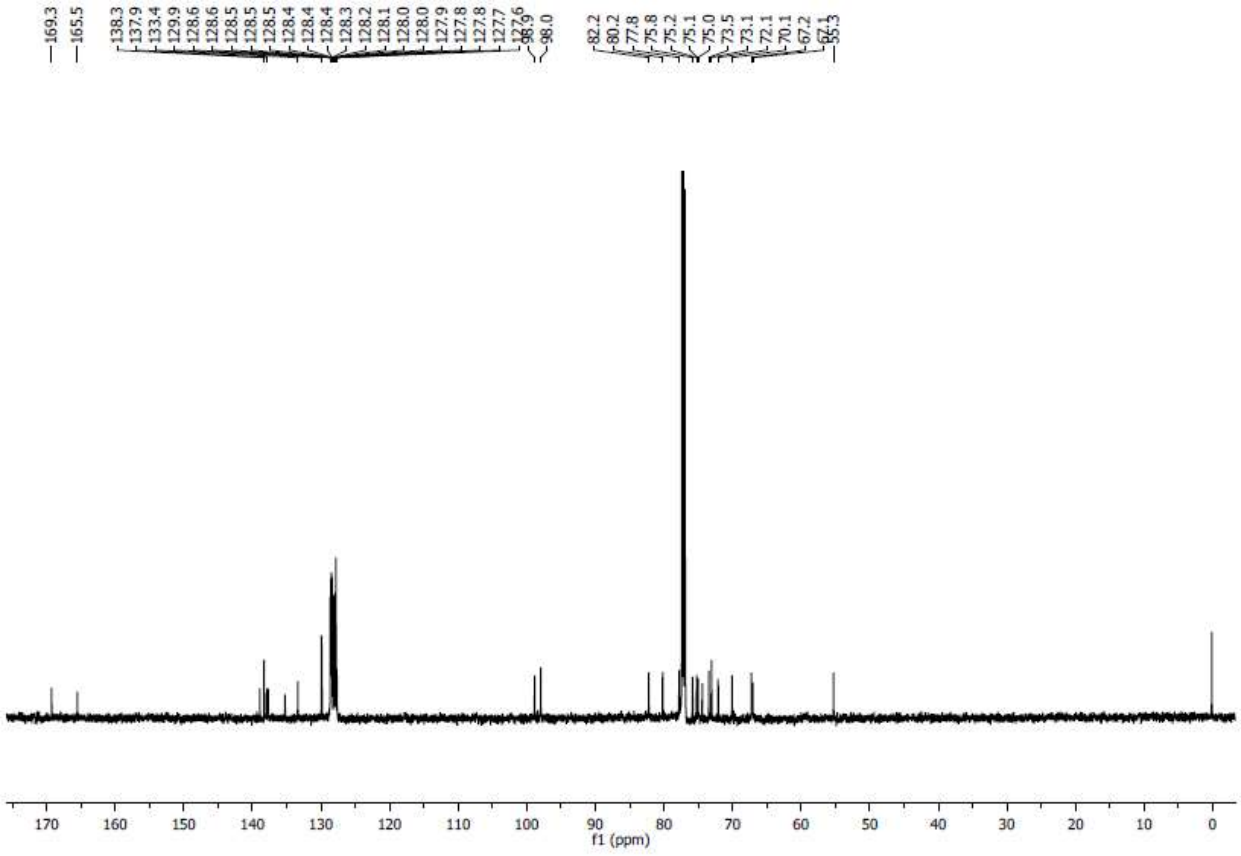

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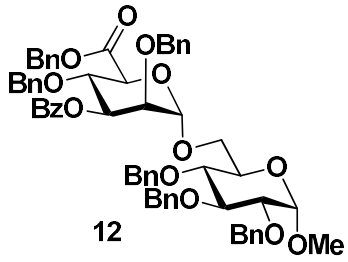

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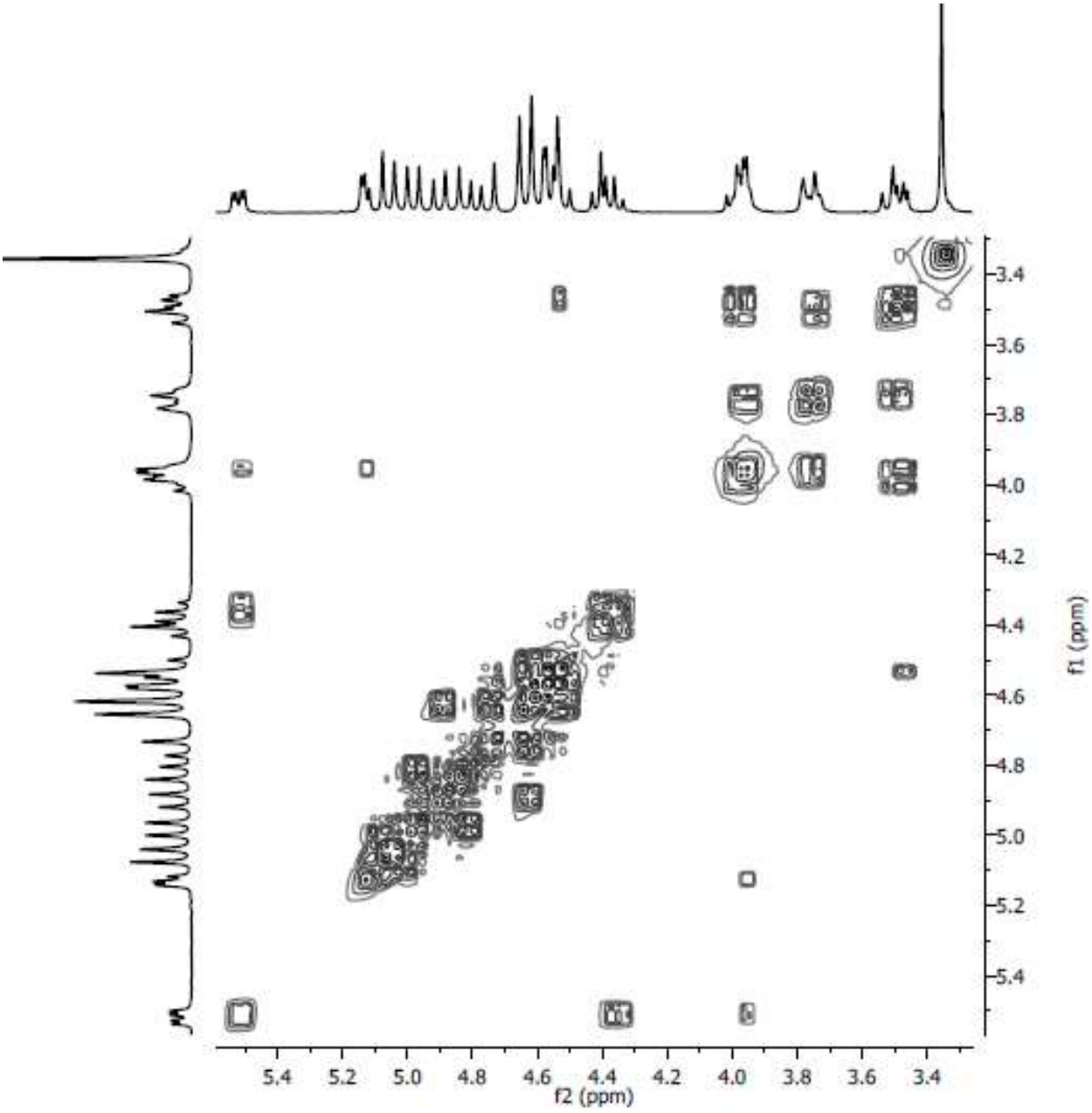

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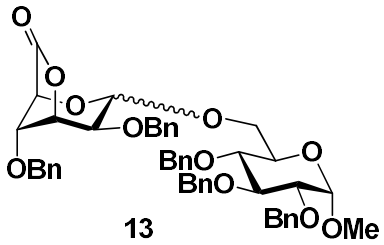

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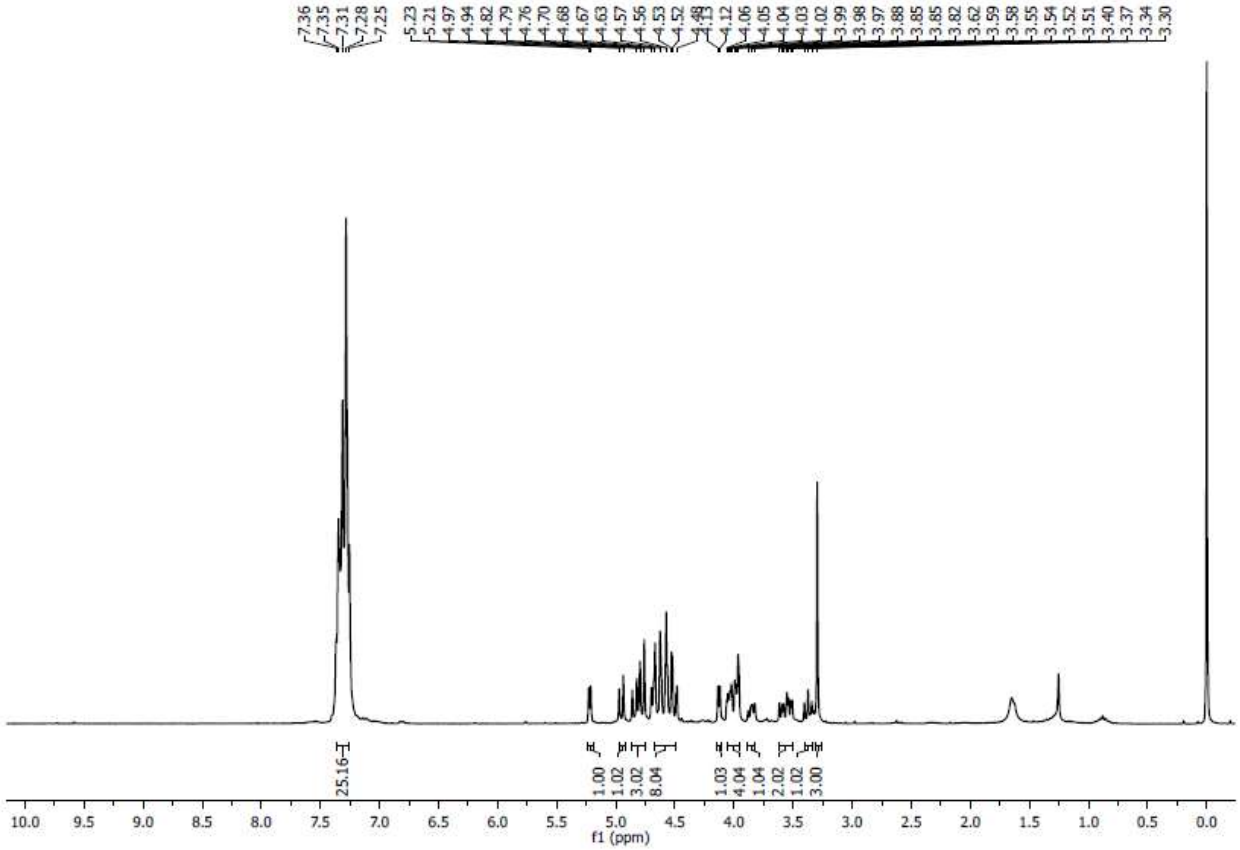

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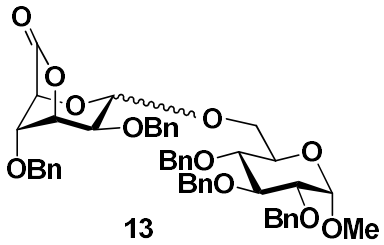

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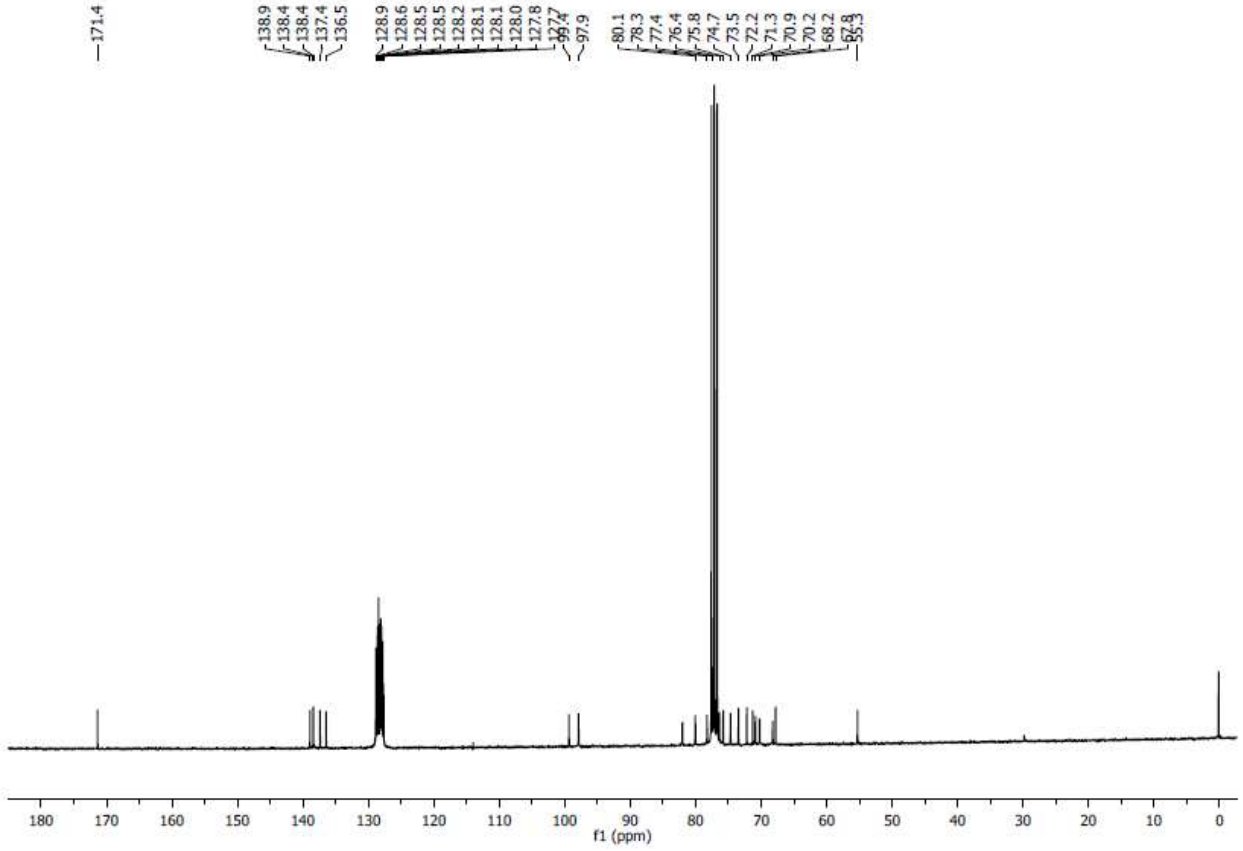

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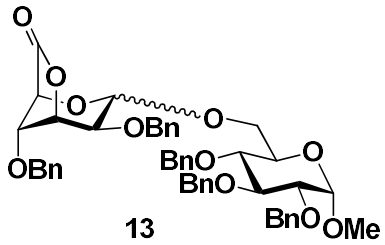

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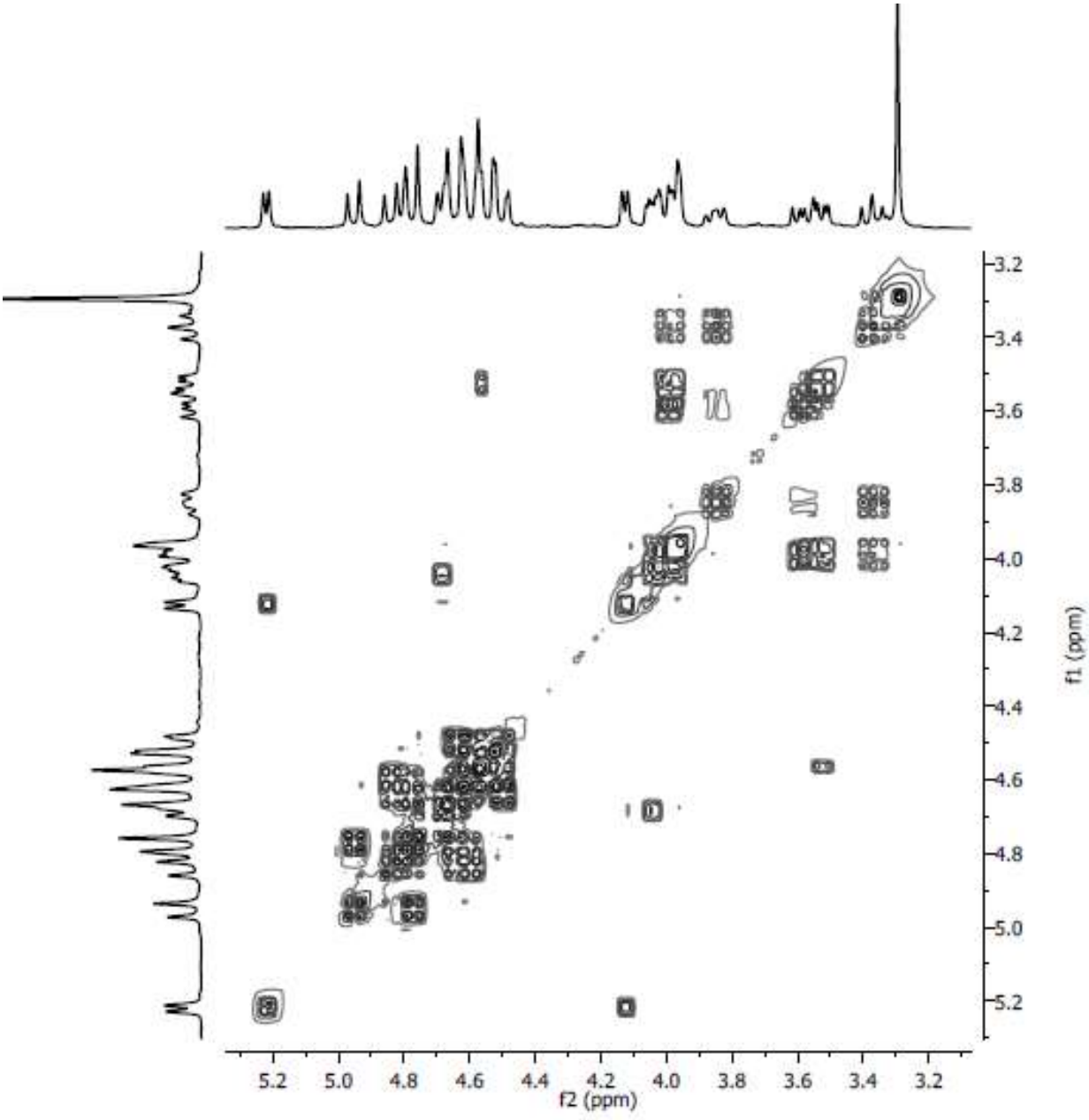

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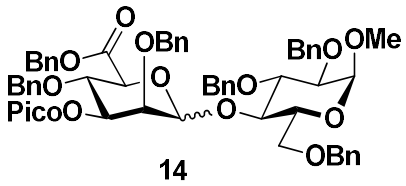

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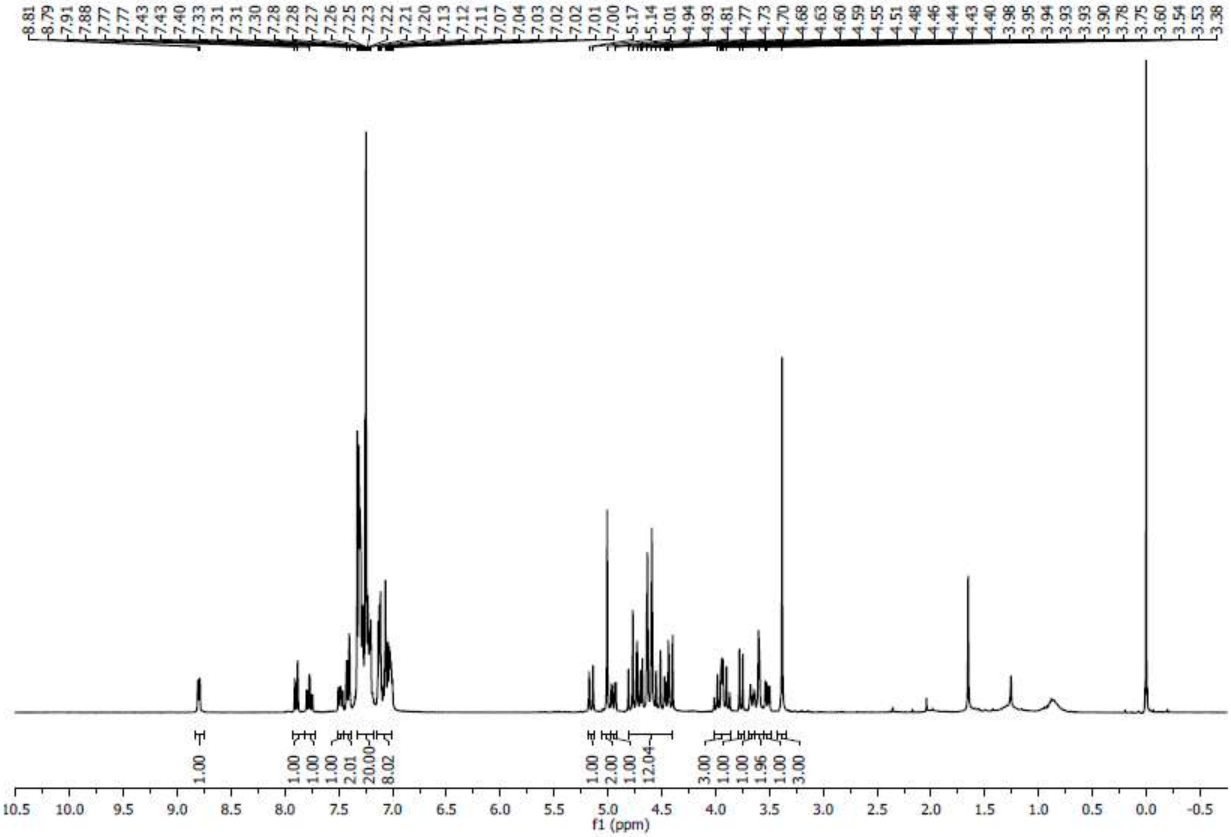

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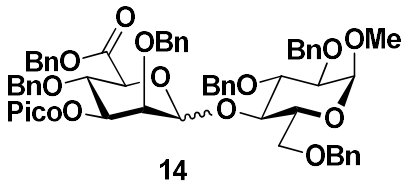

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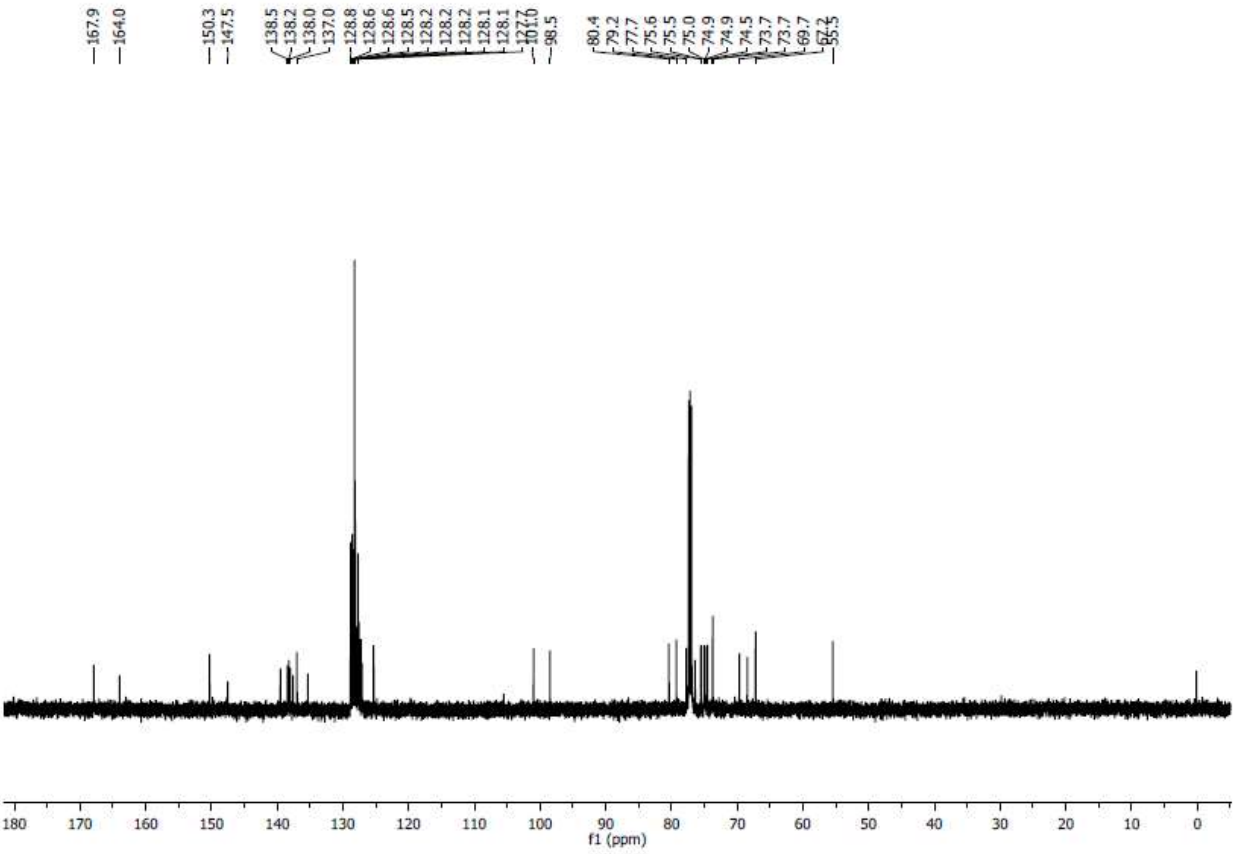

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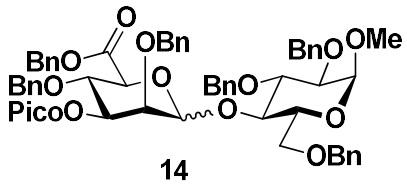

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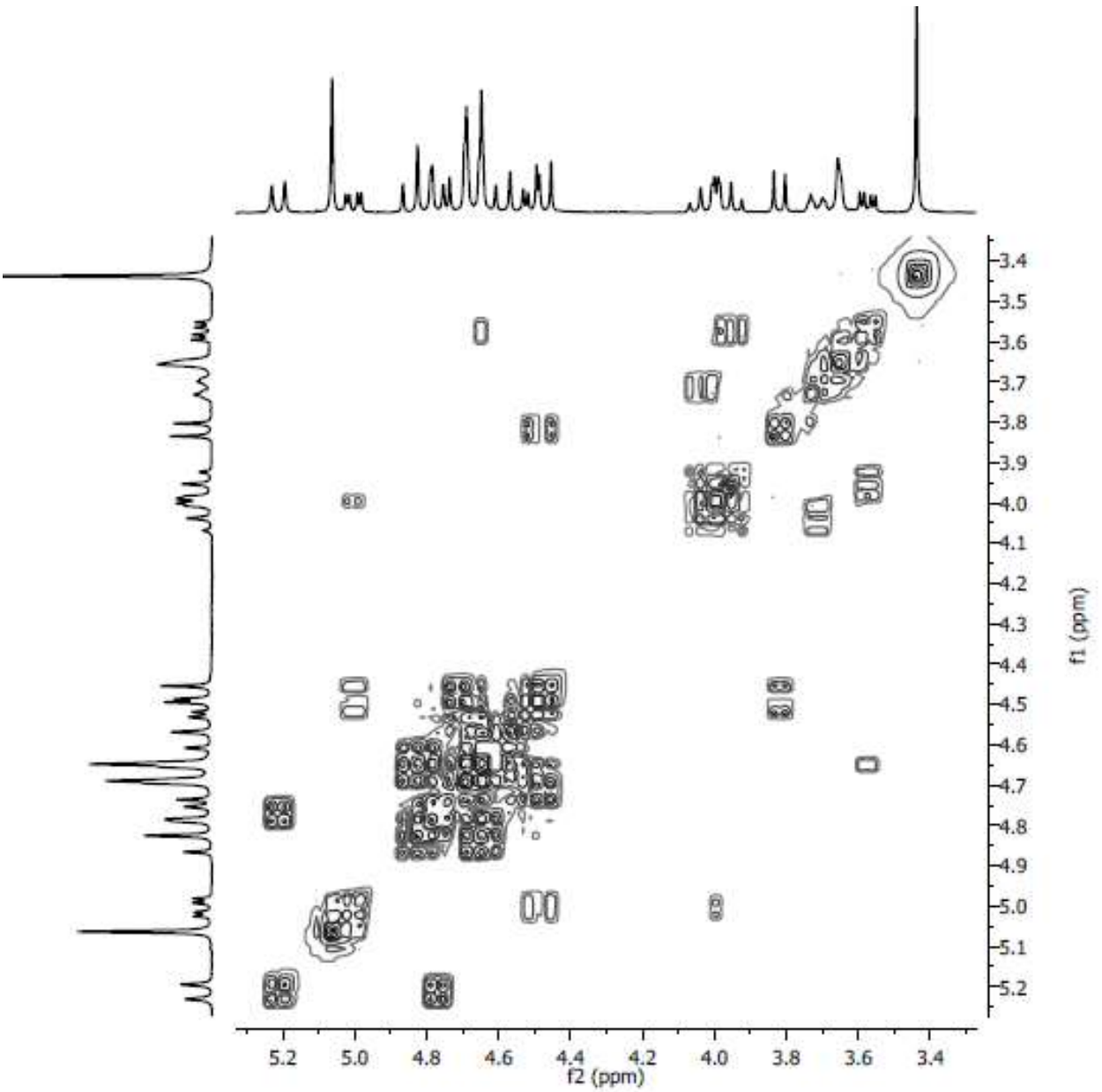

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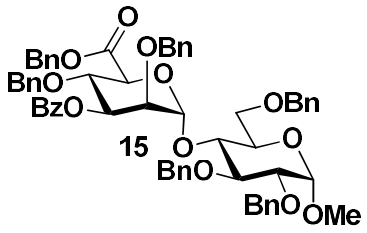

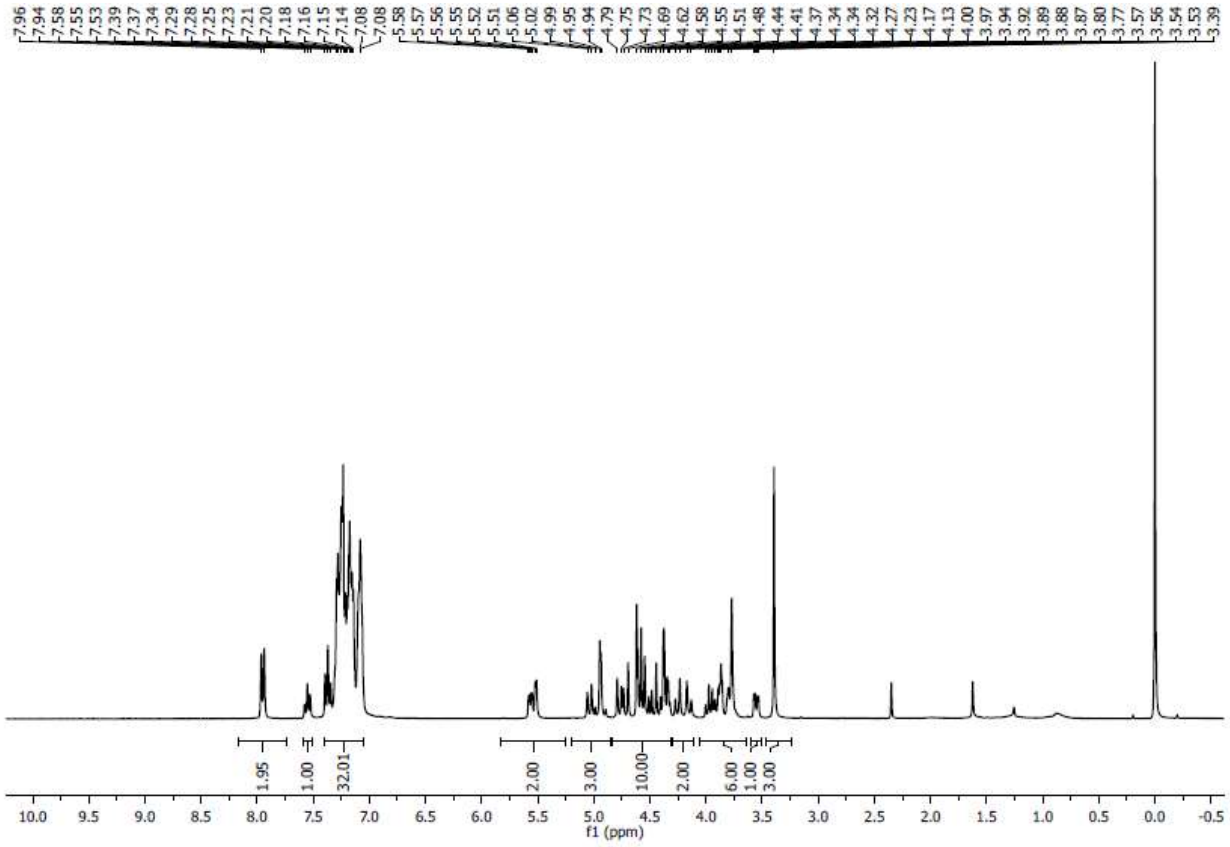

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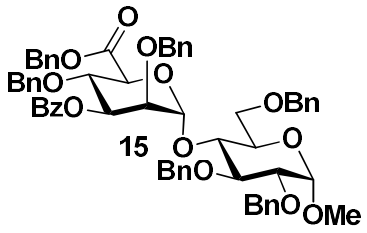
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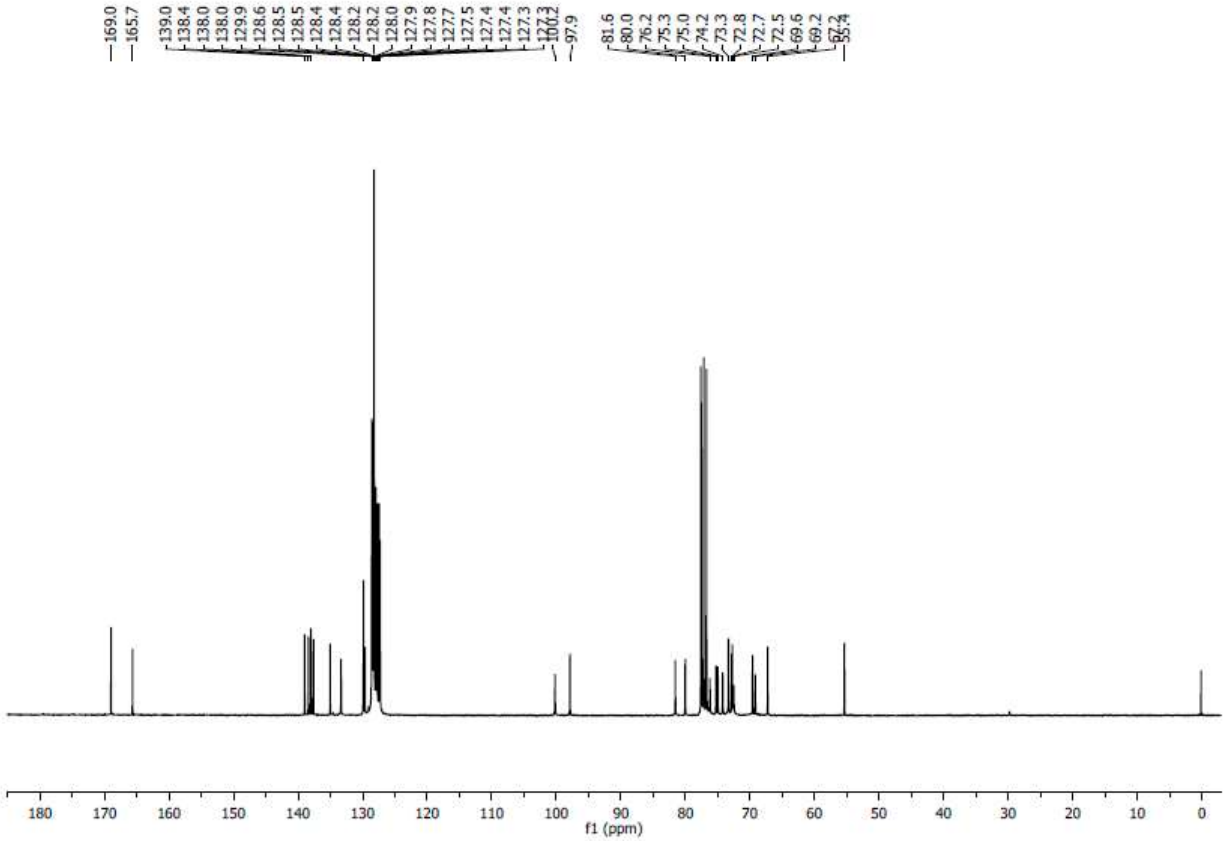
BnO
OBn
BnO
O
BzO
OBn
15
O
O
BnO
BnO
OMe


169.0
165.7
139.0
138.4
138.0
138.0
129.9
128.6
128.5
128.5
128.4
128.4
128.2
128.2
128.0
127.9
127.8
127.7
127.5
127.4
127.4
127.3
127.3
100.2
97.9
81.6
80.0
76.2
75.3
75.0
74.2
73.3
72.8
72.7
72.5
69.6
69.2
67.2
55.4
180
170
160
150
140
130
120
110
100
90
80
70
60
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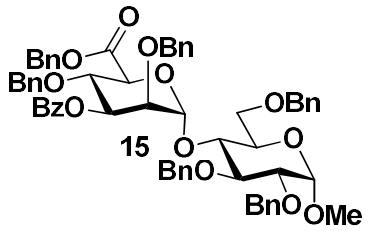
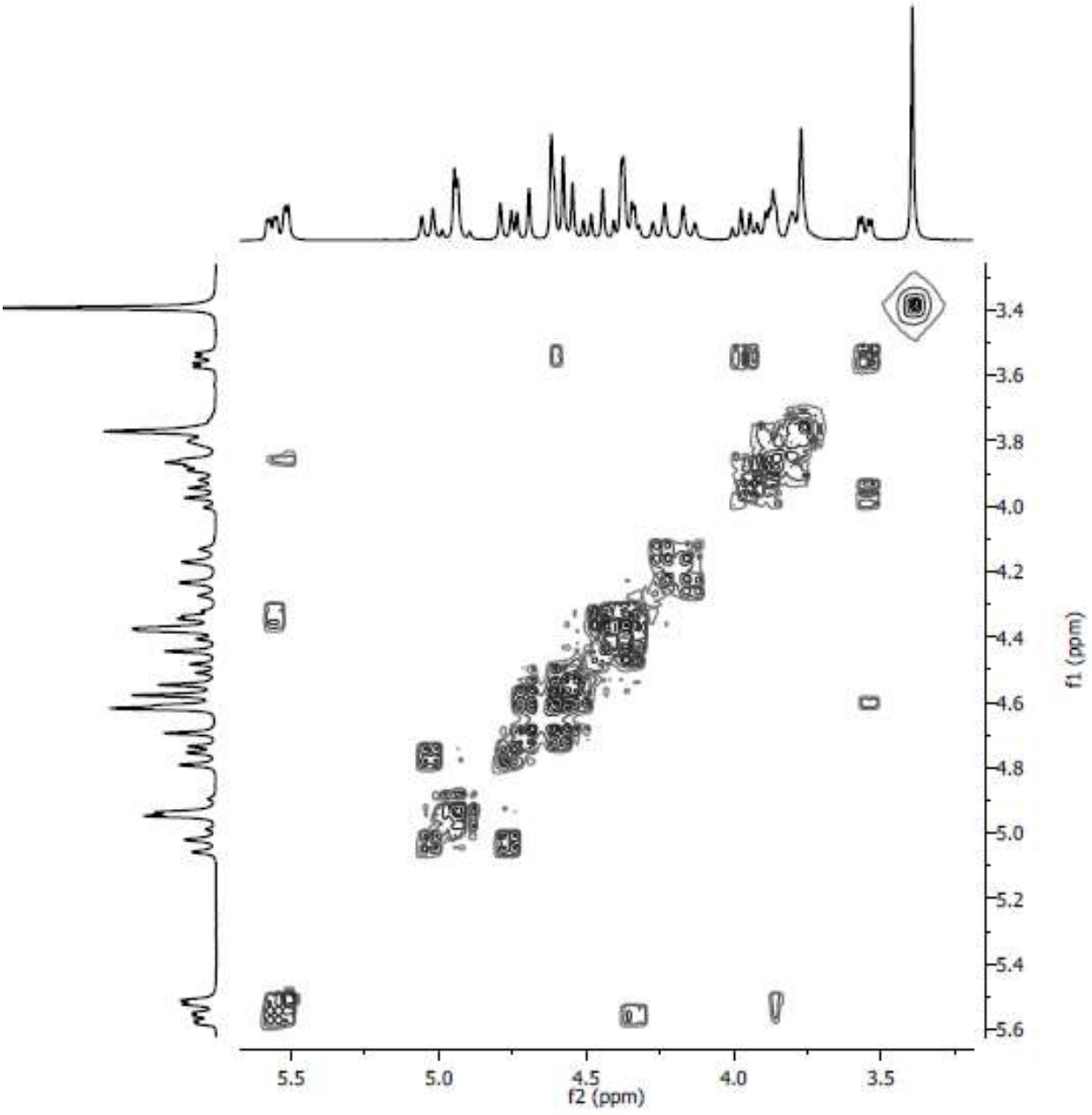
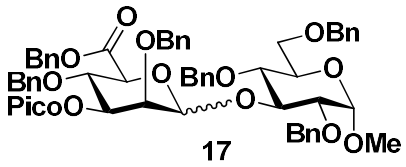
40
30
20
10
0
f1 (ppm)

$CDCl_3$ 75MHz

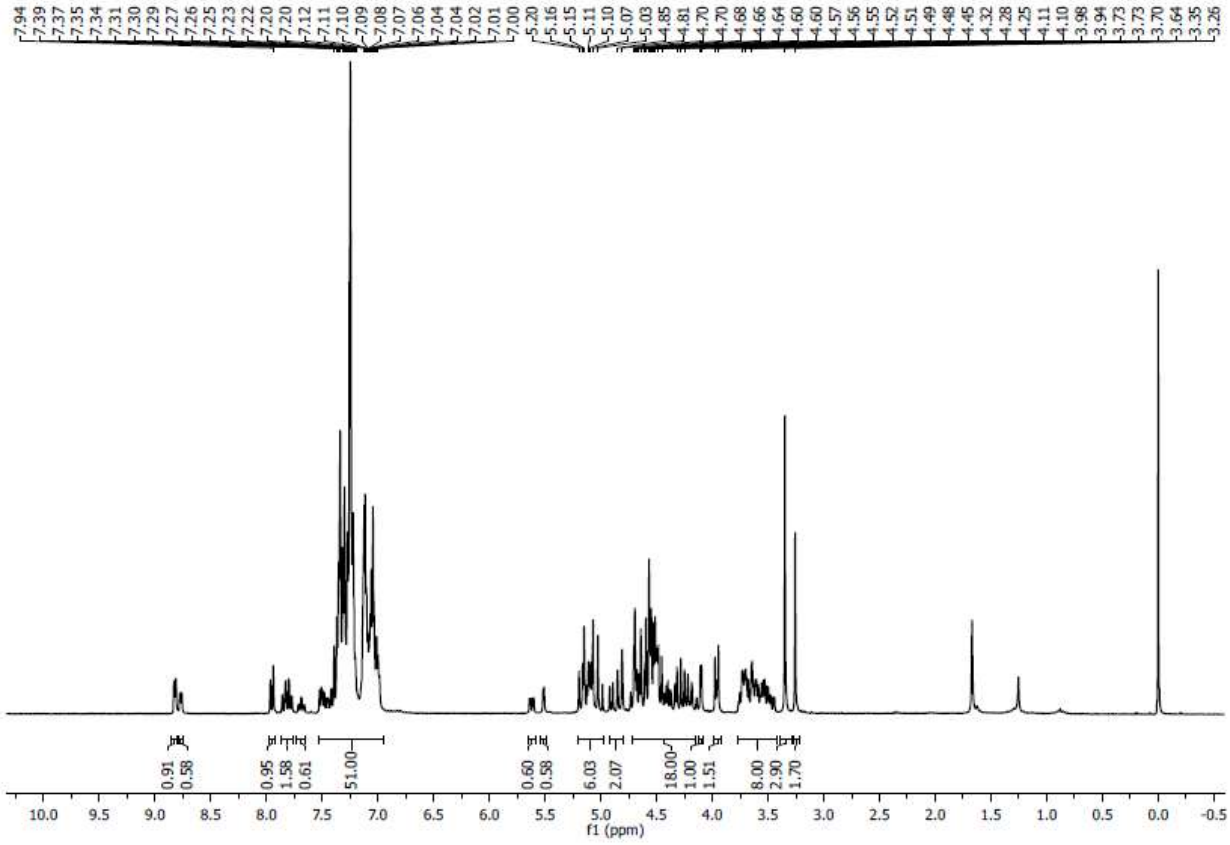




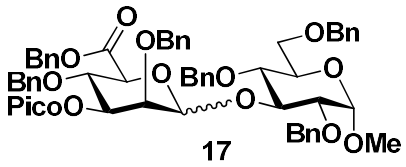
$CDCl_3$ 300MHz



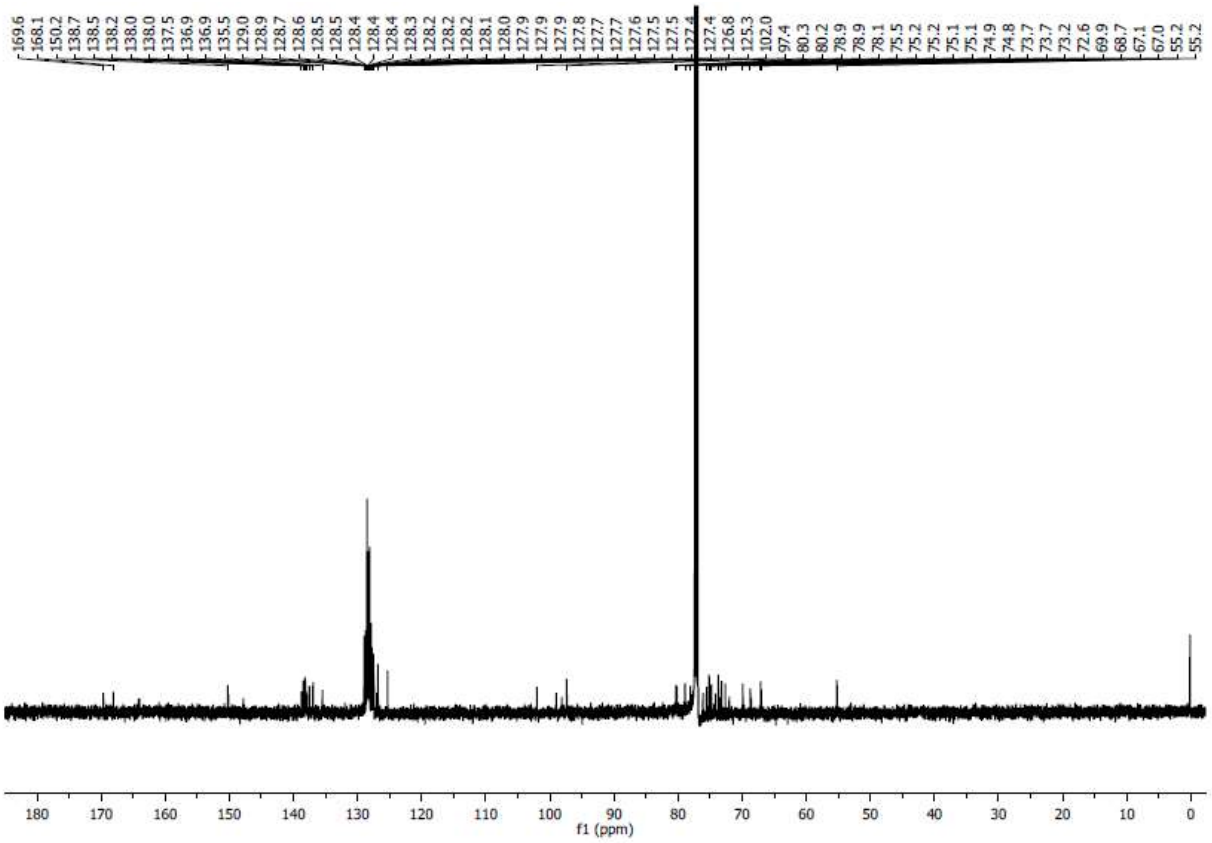
17



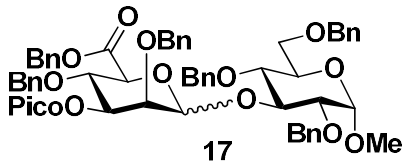
$CDCl_3$ 300MHz



17



$CDCl_3$ 151MHz



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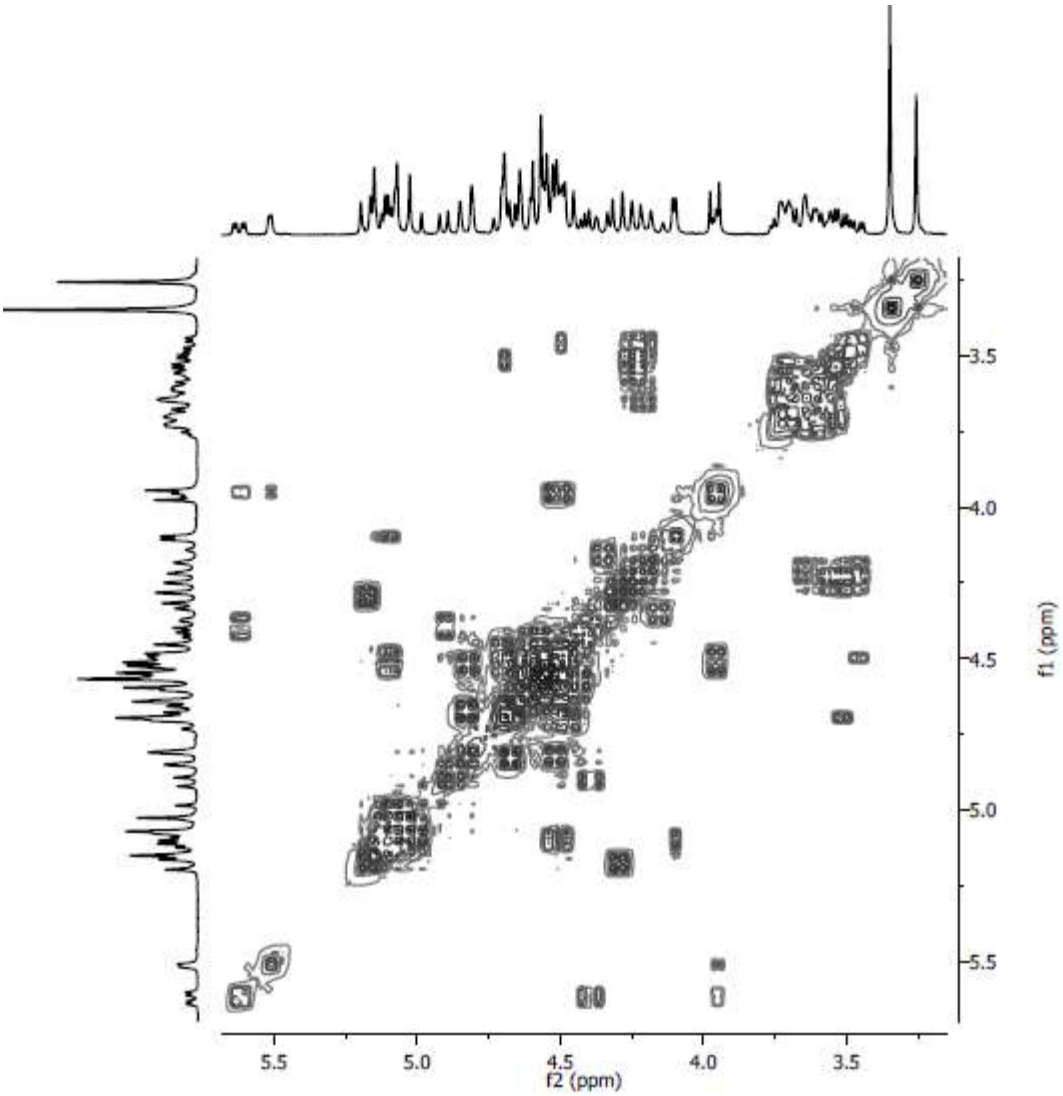
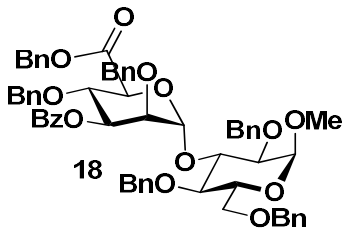
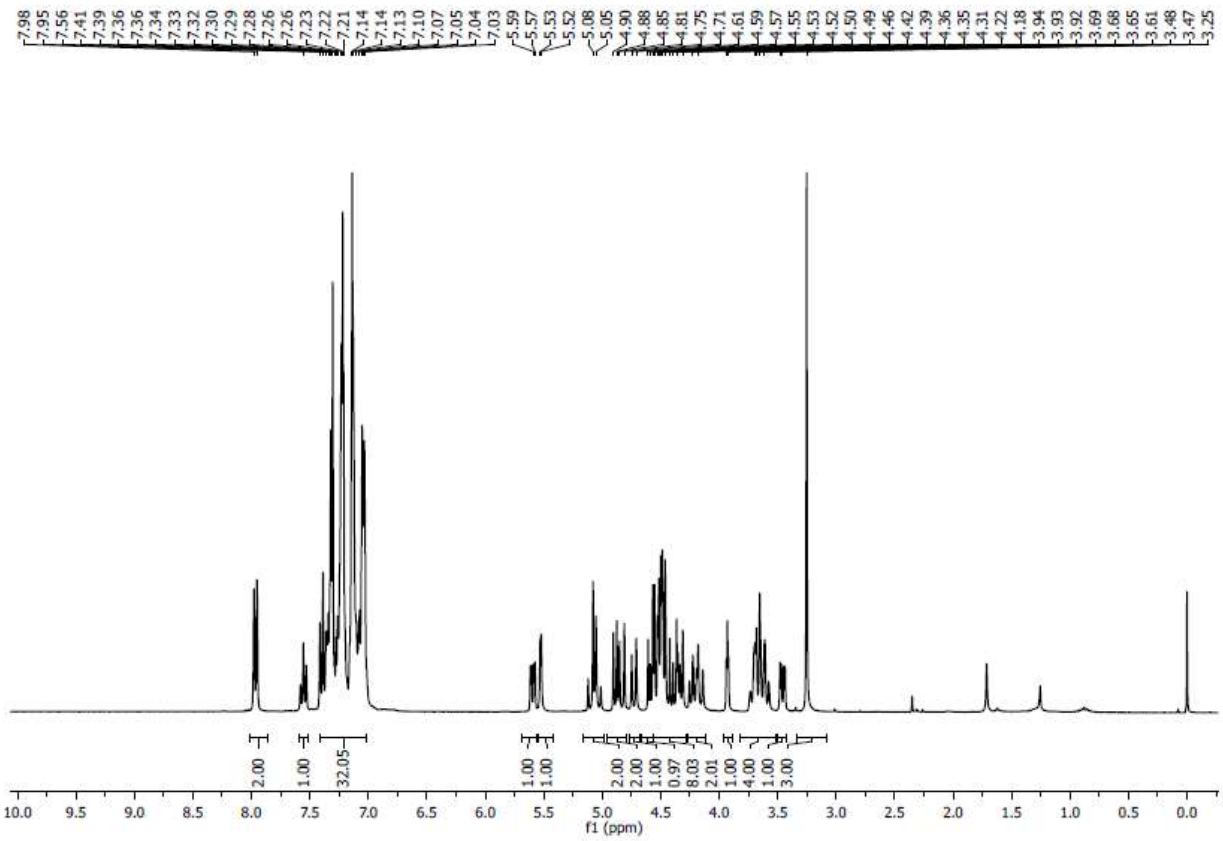
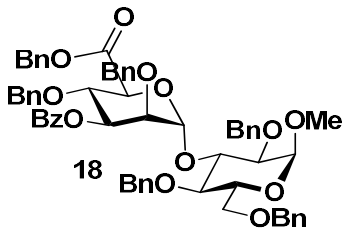


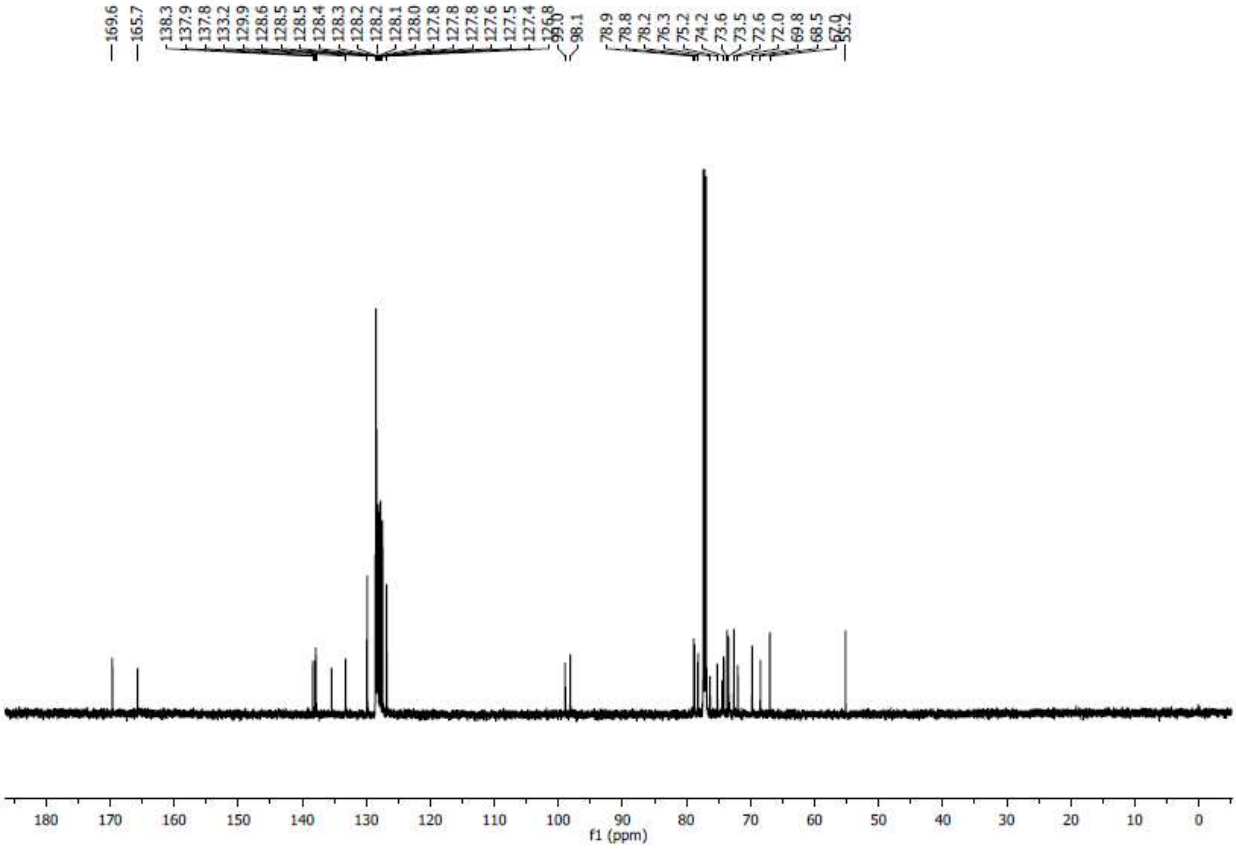
$CDCl_3$ 300MHz



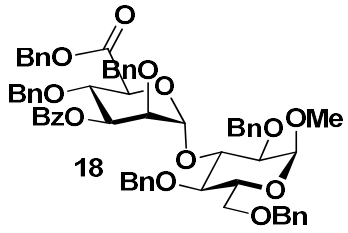


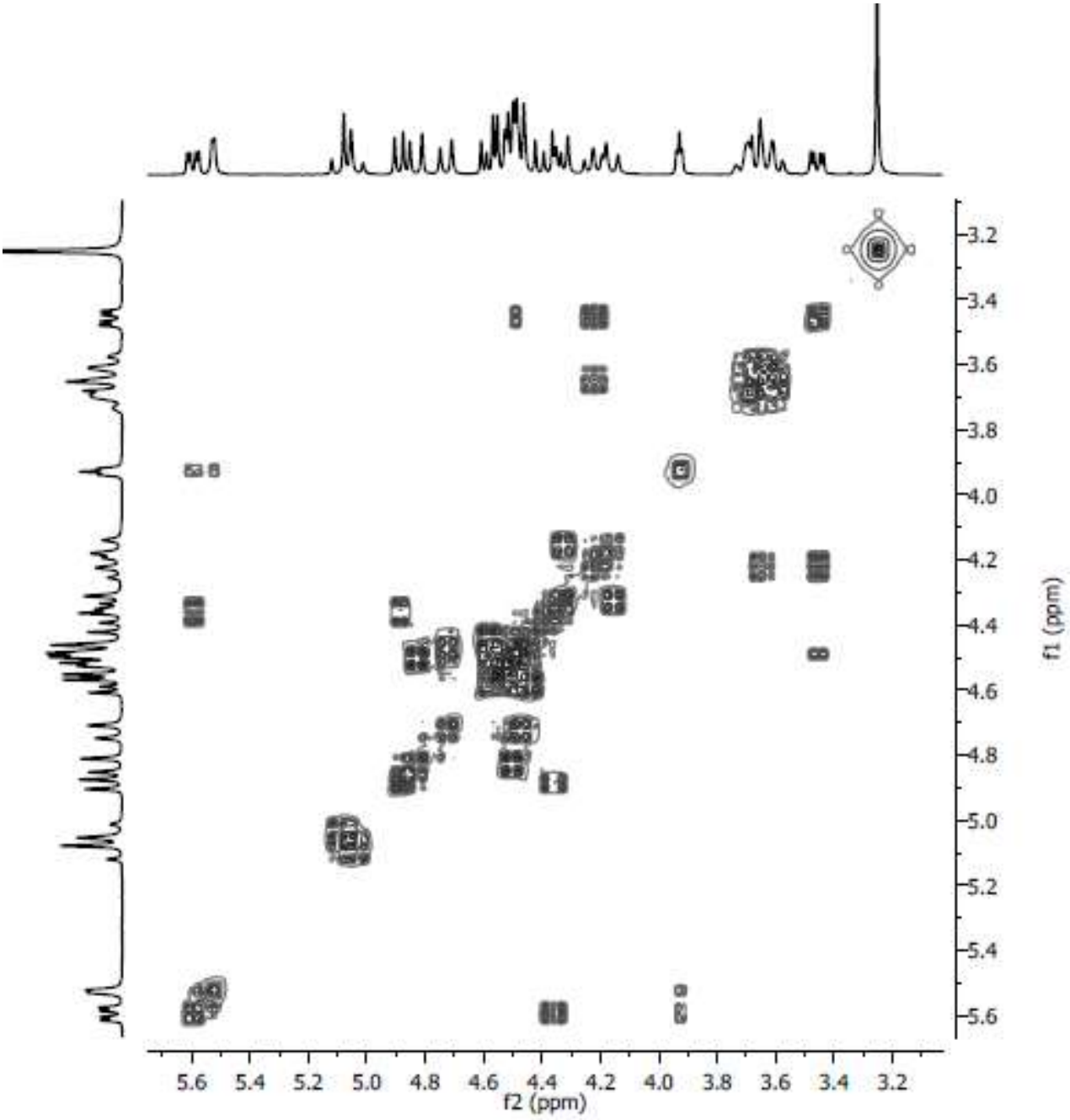
$CDCl_3$ 300MHz



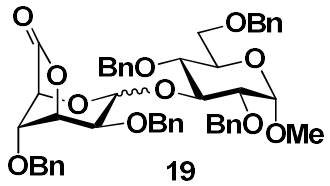


$CDCl_3$ 151MHz

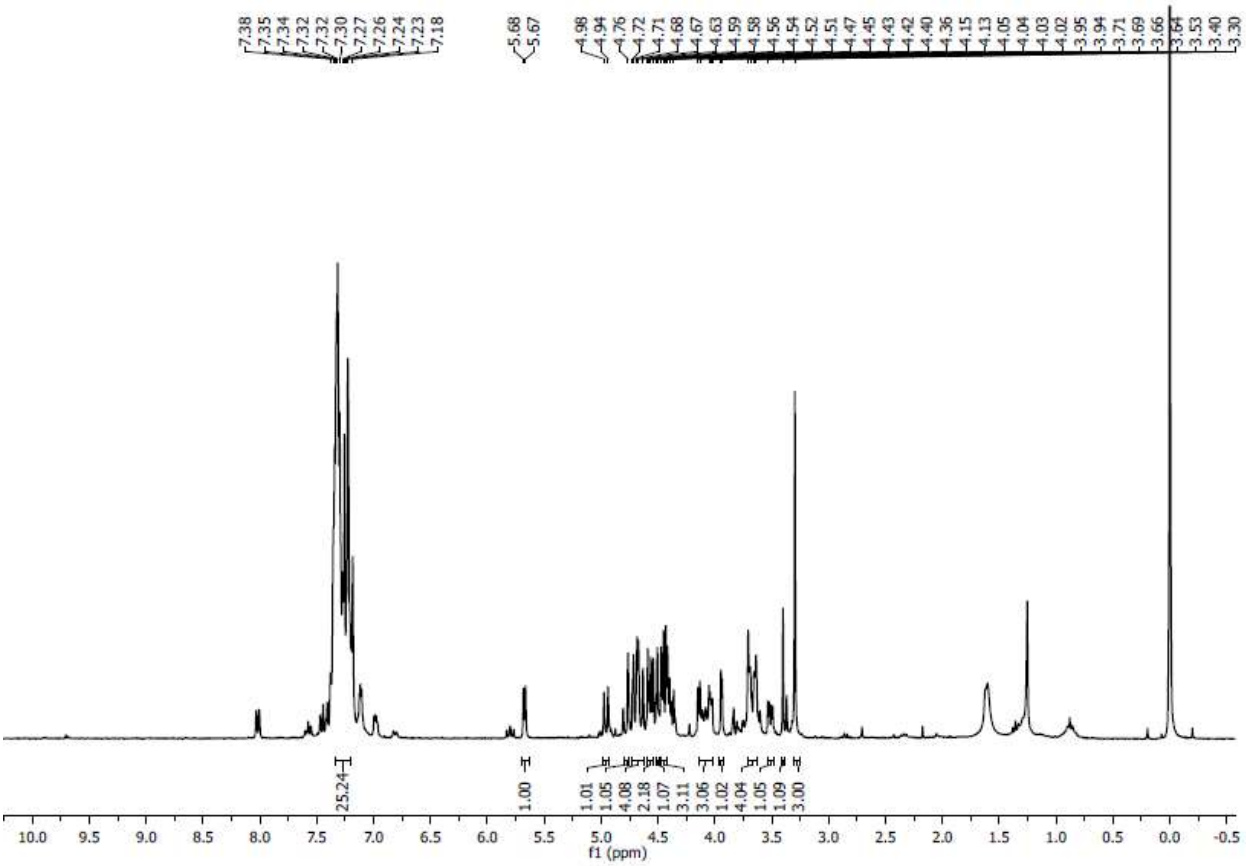




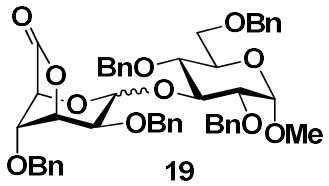
$CDCl_3$ 300MHz



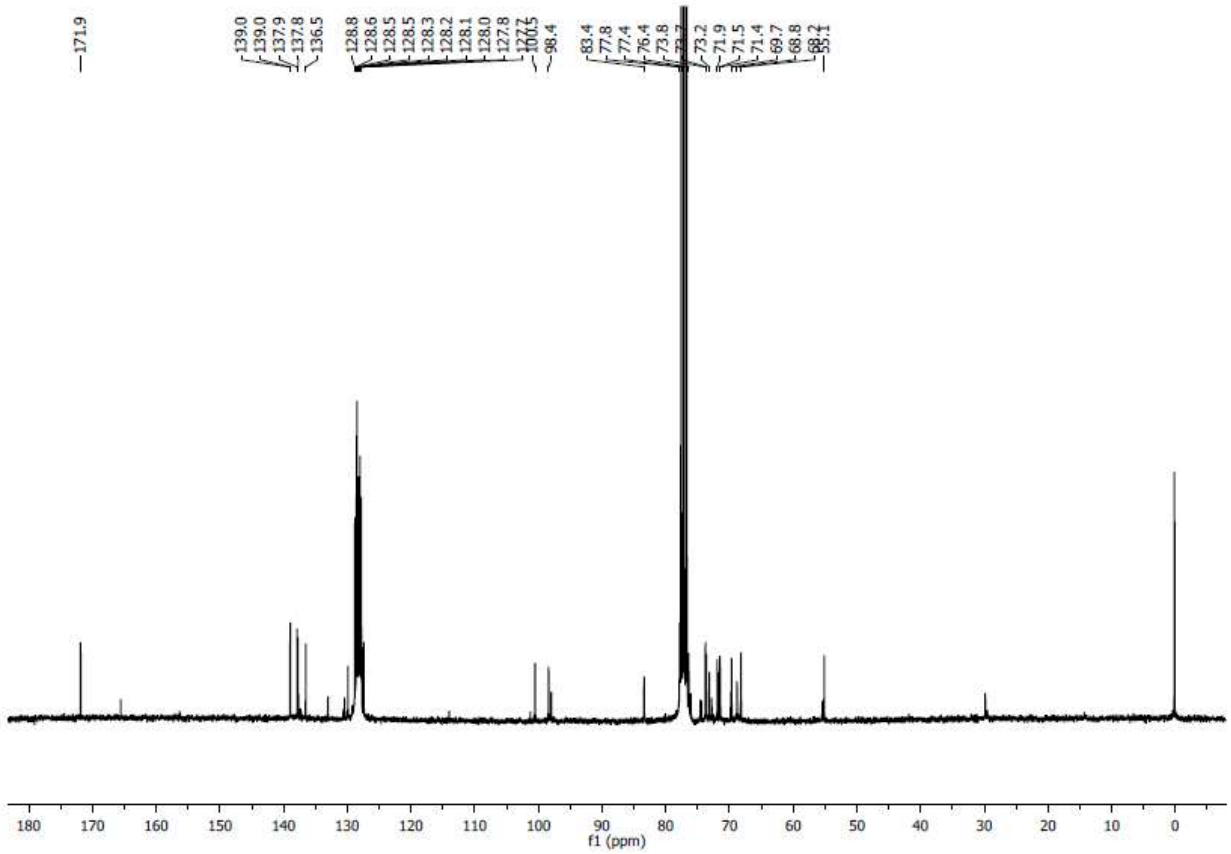
19



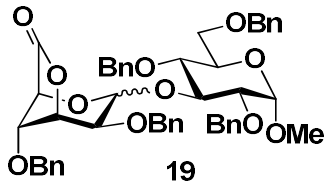
$CDCl_3$ 300MHz



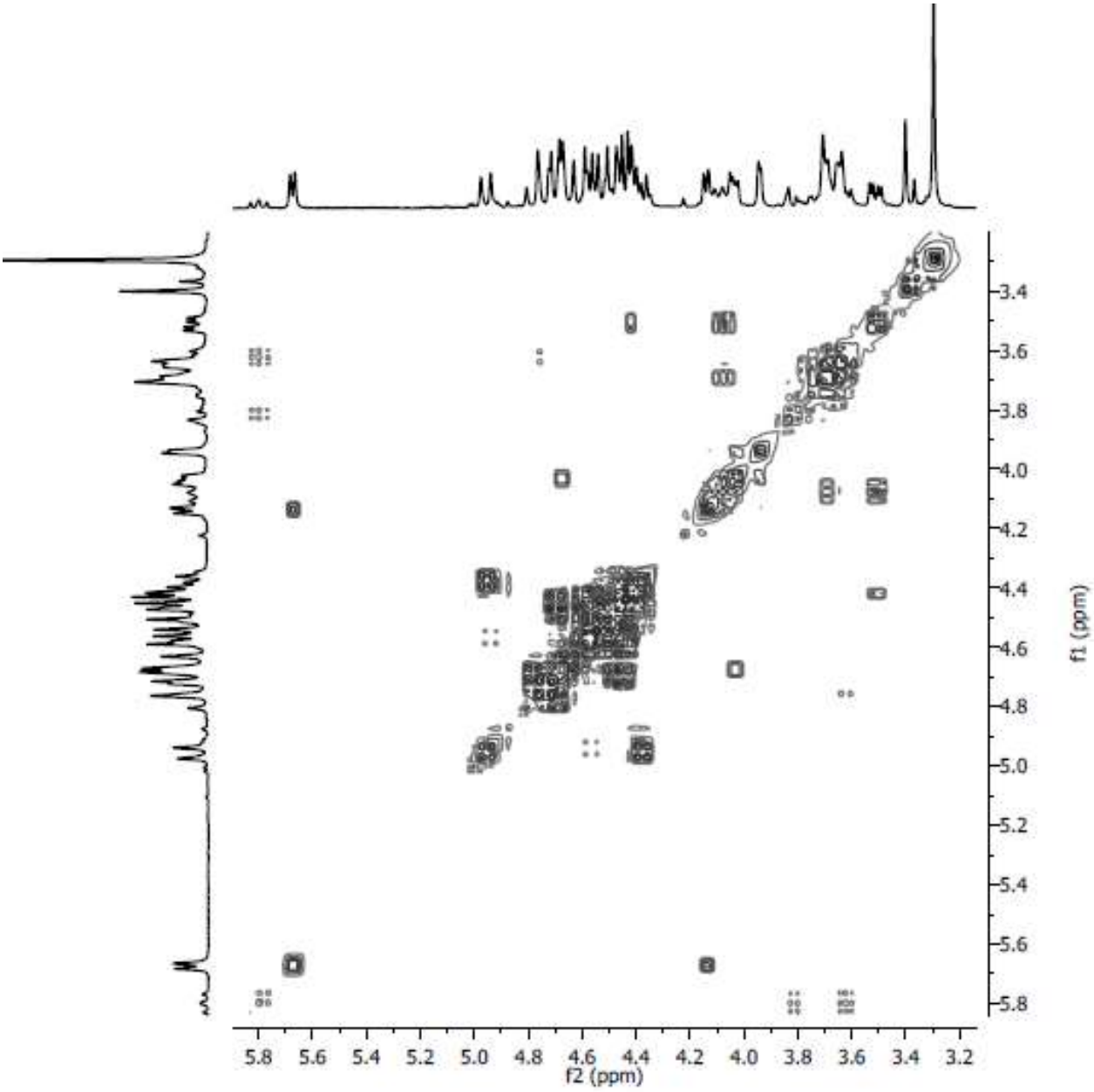
19



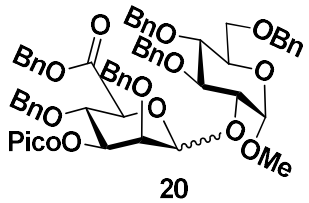
$CDCl_3$ 75MHz



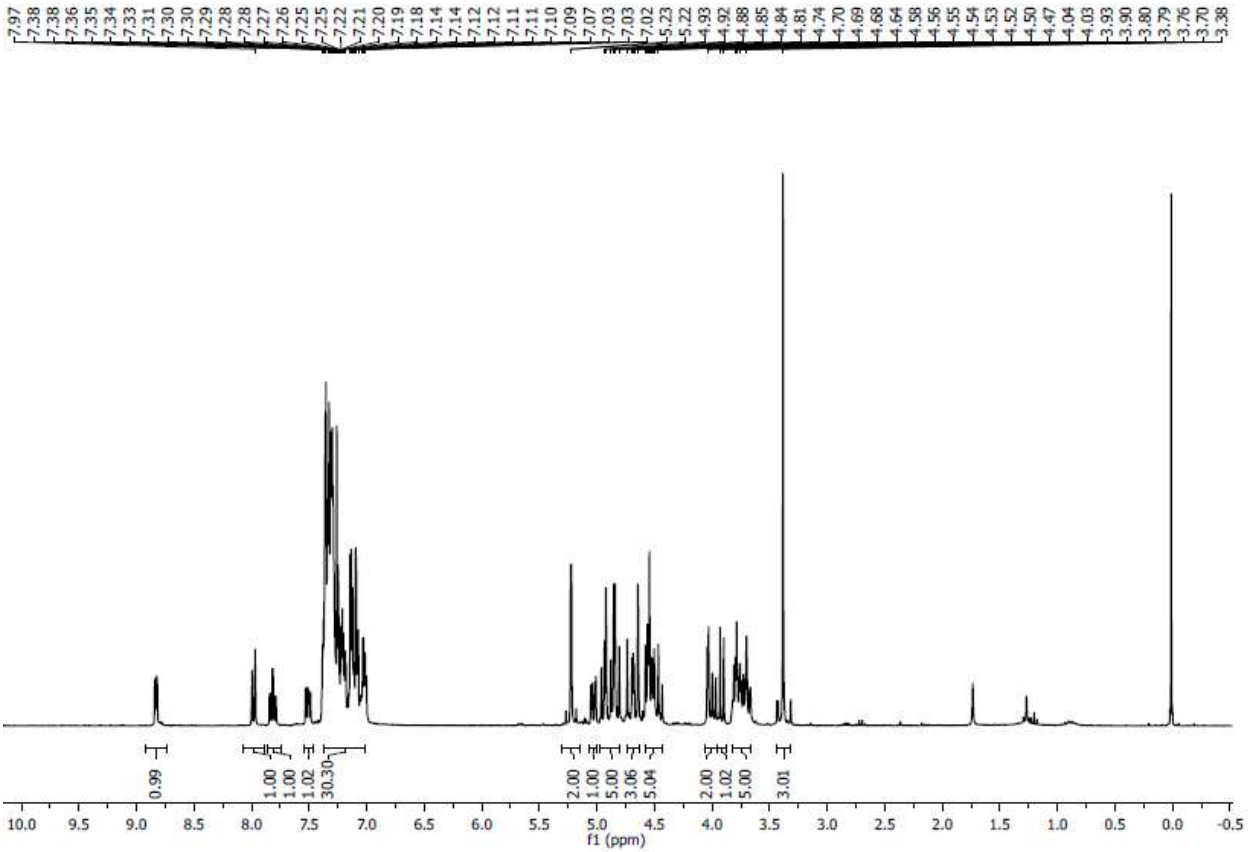
19



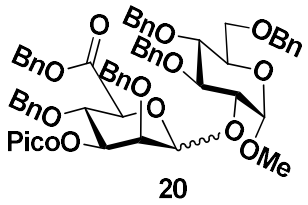
$CDCl_3$ 300MHz



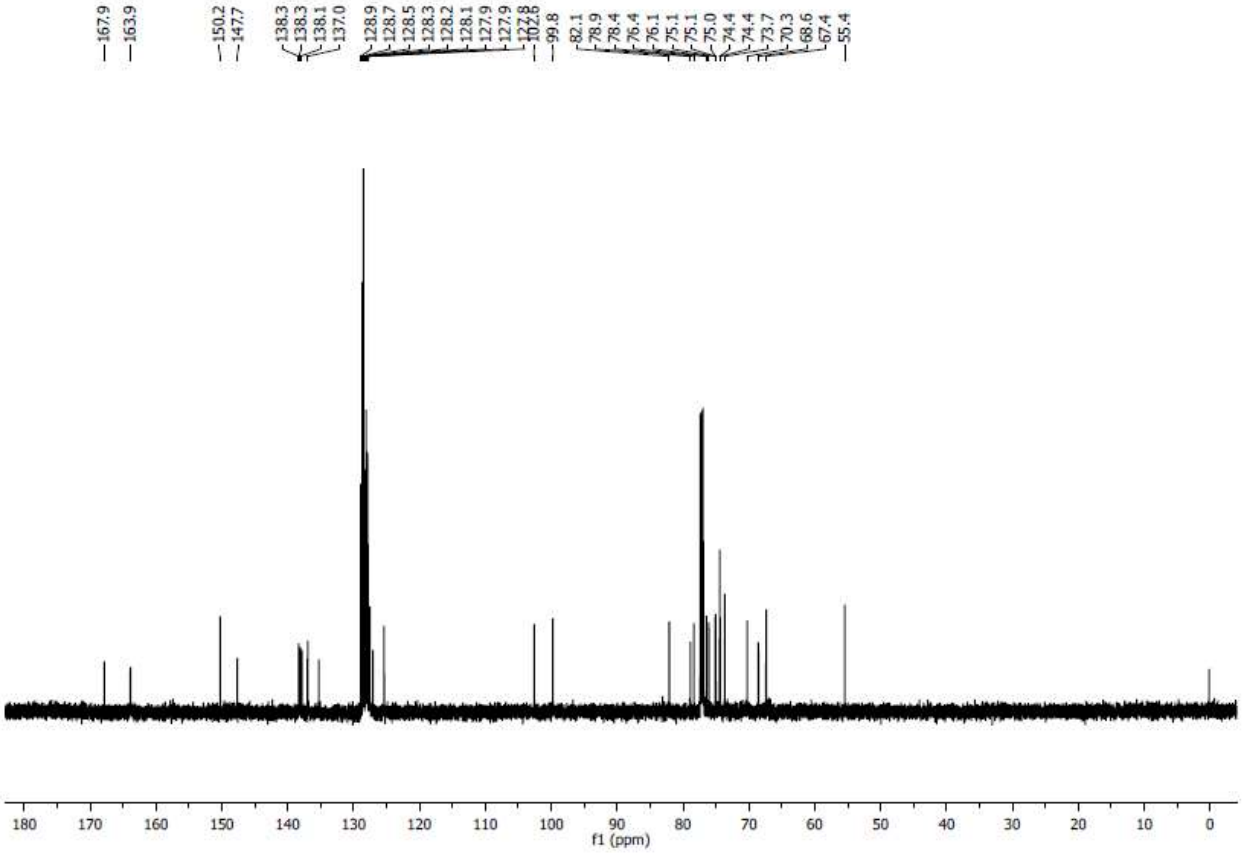
20



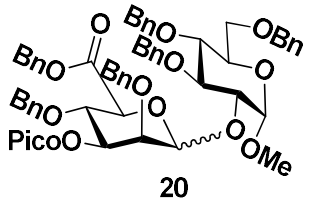
$CDCl_3$ 300MHz



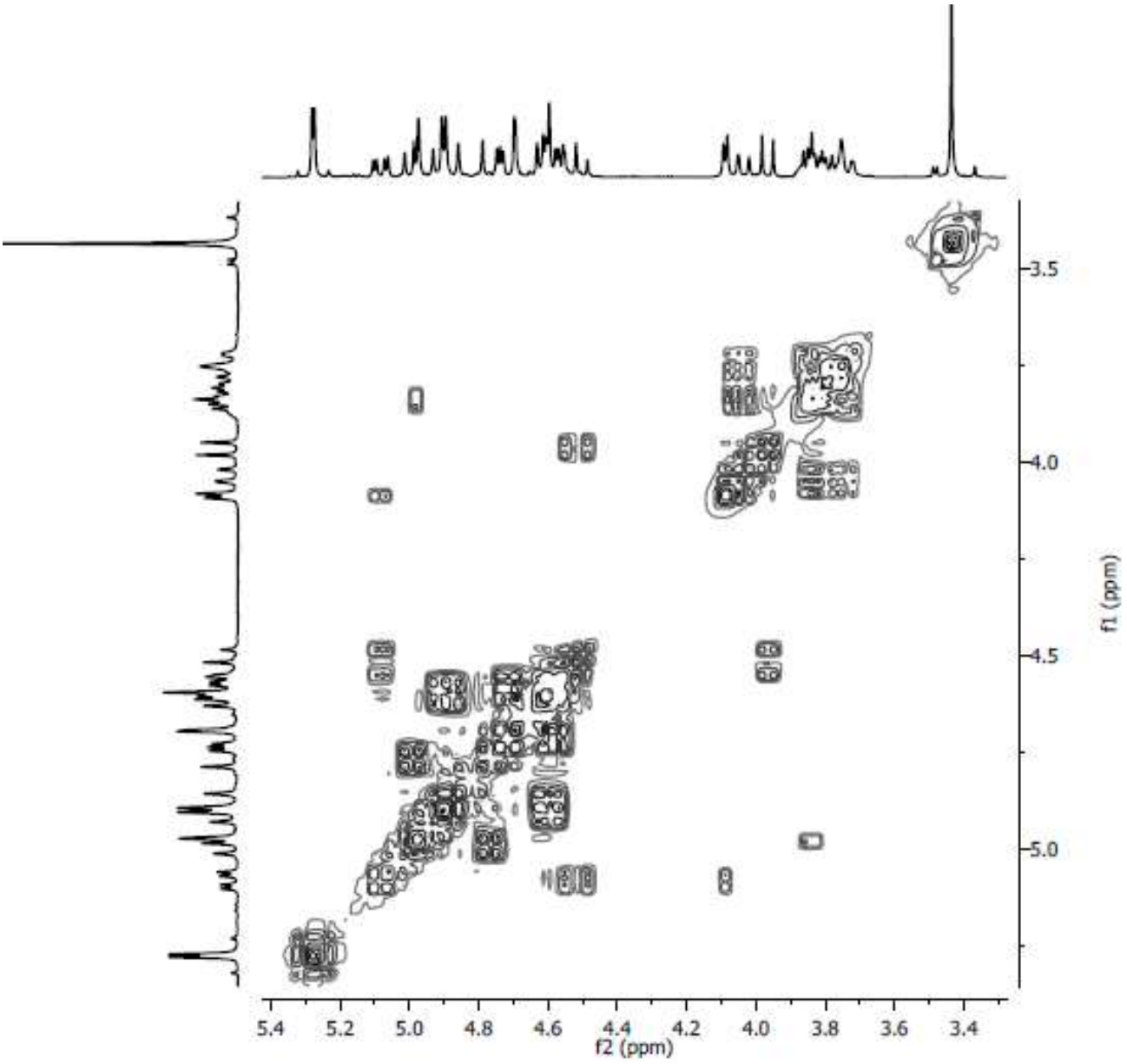
20



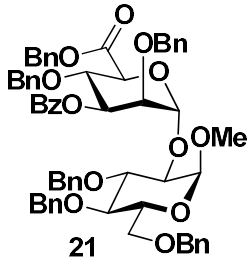
$CDCl_3$ 151MHz



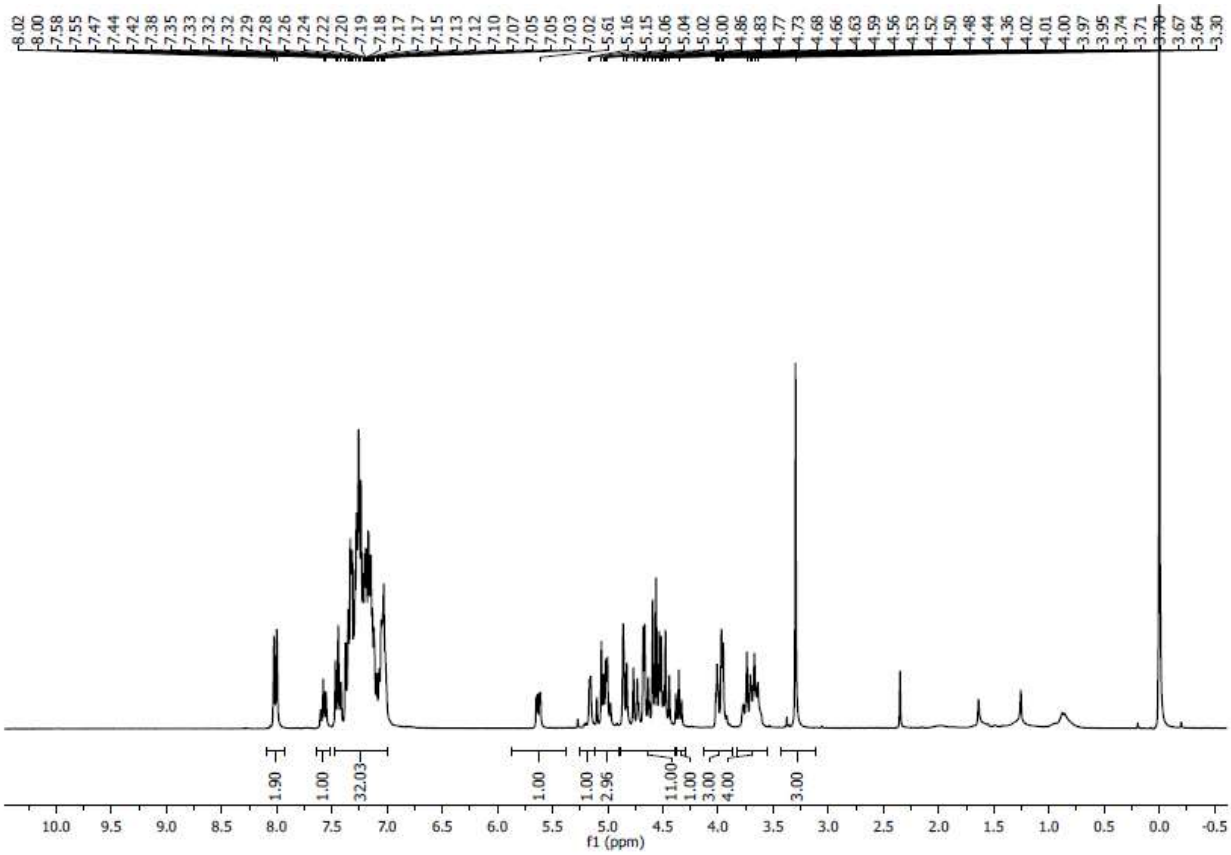
20



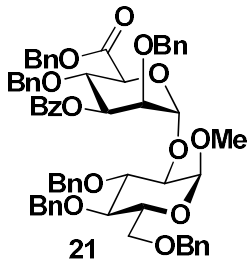
$CDCl_3$ 300MHz

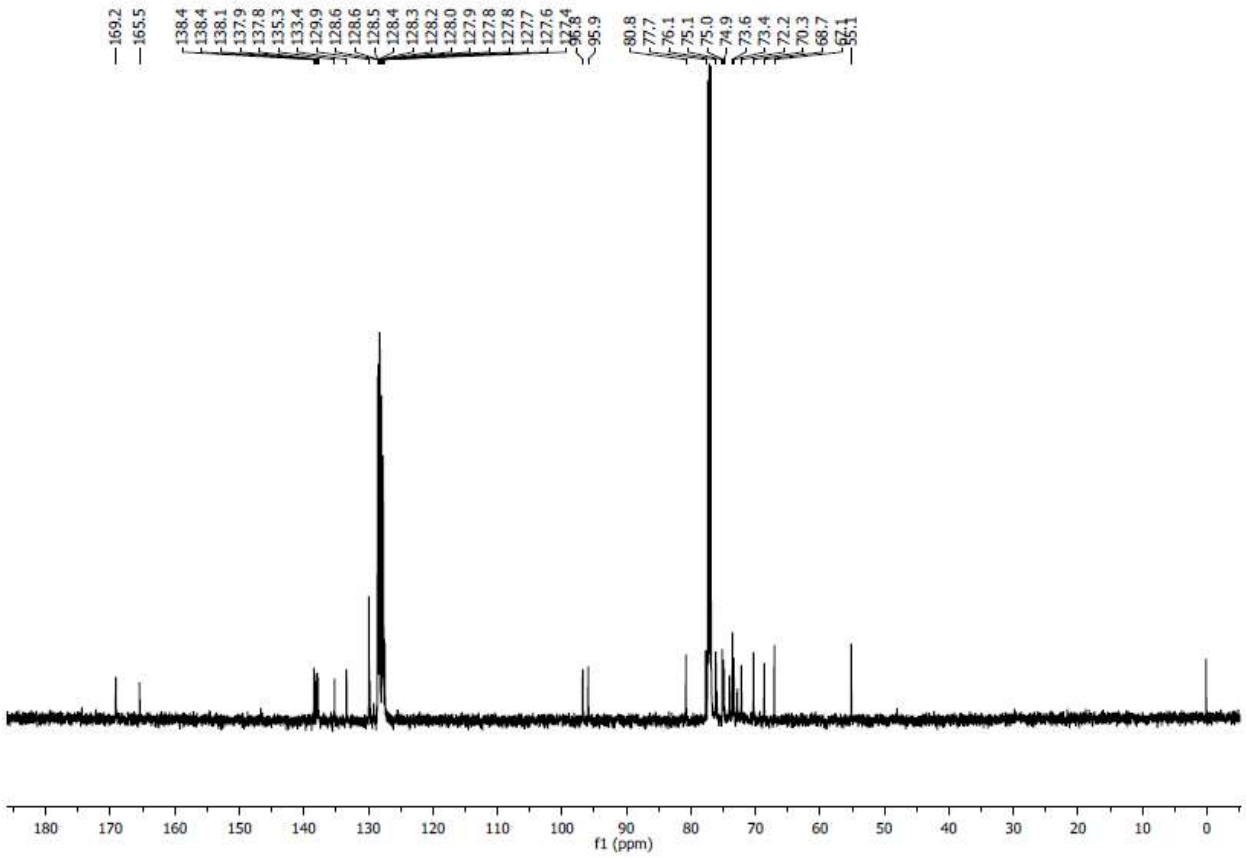


21

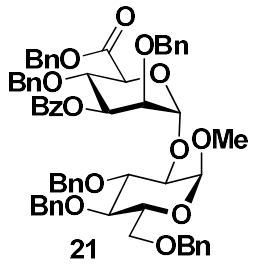


$CDCl_3$ 300MHz

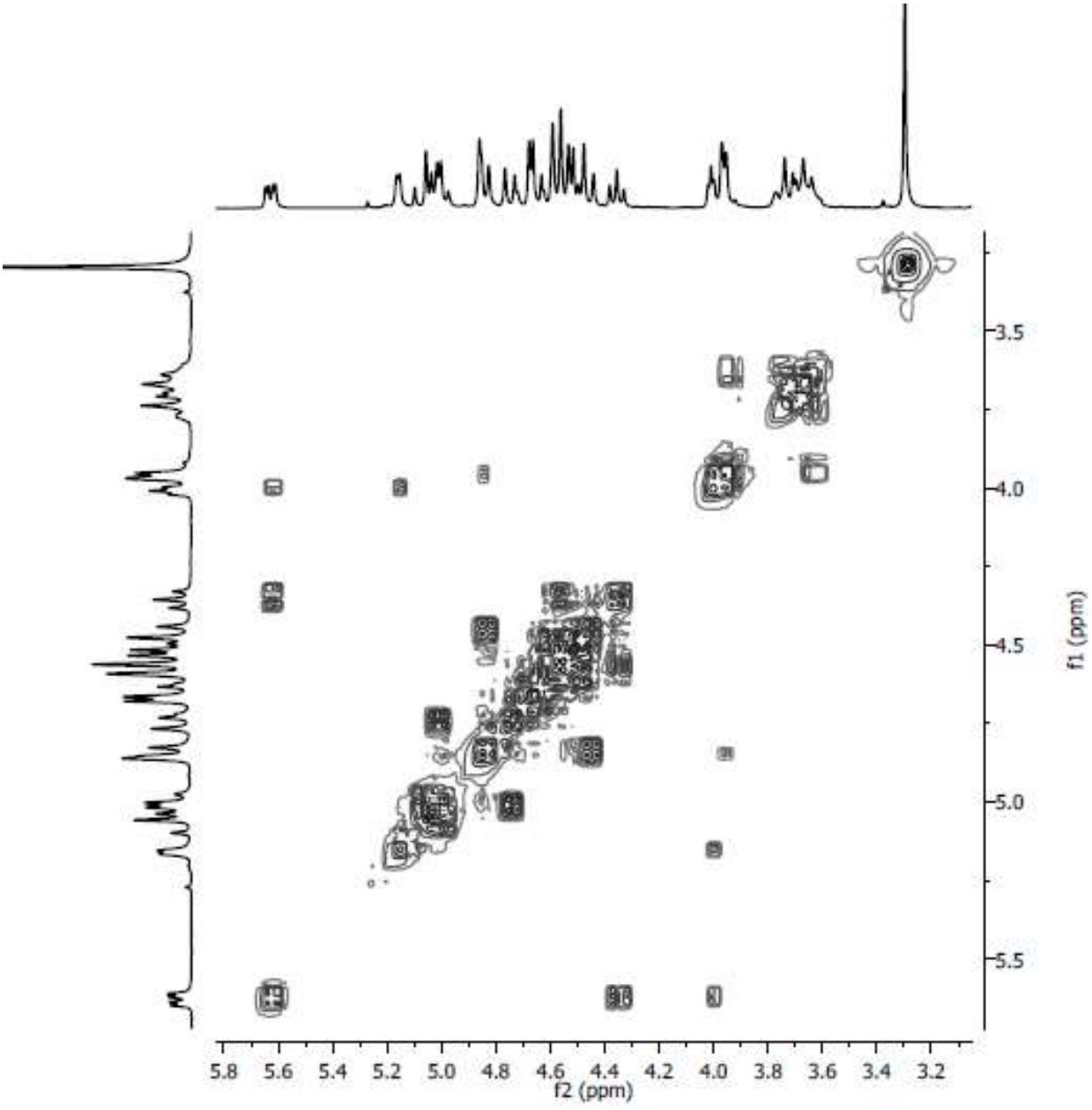




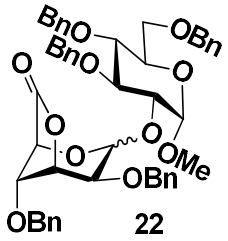
$CDCl_3$ 151MHz



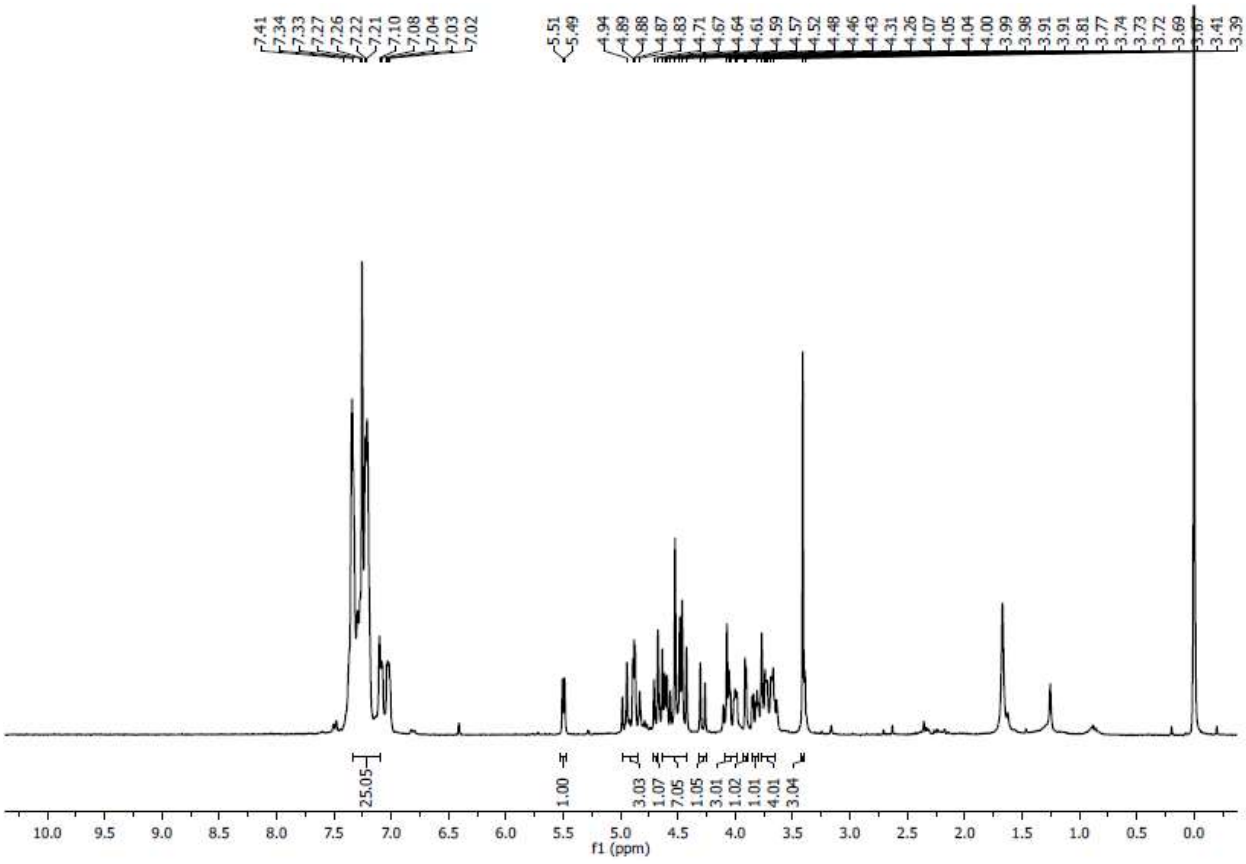
21



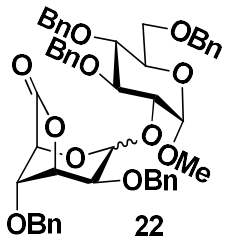
$CDCl_3$ 300MHz



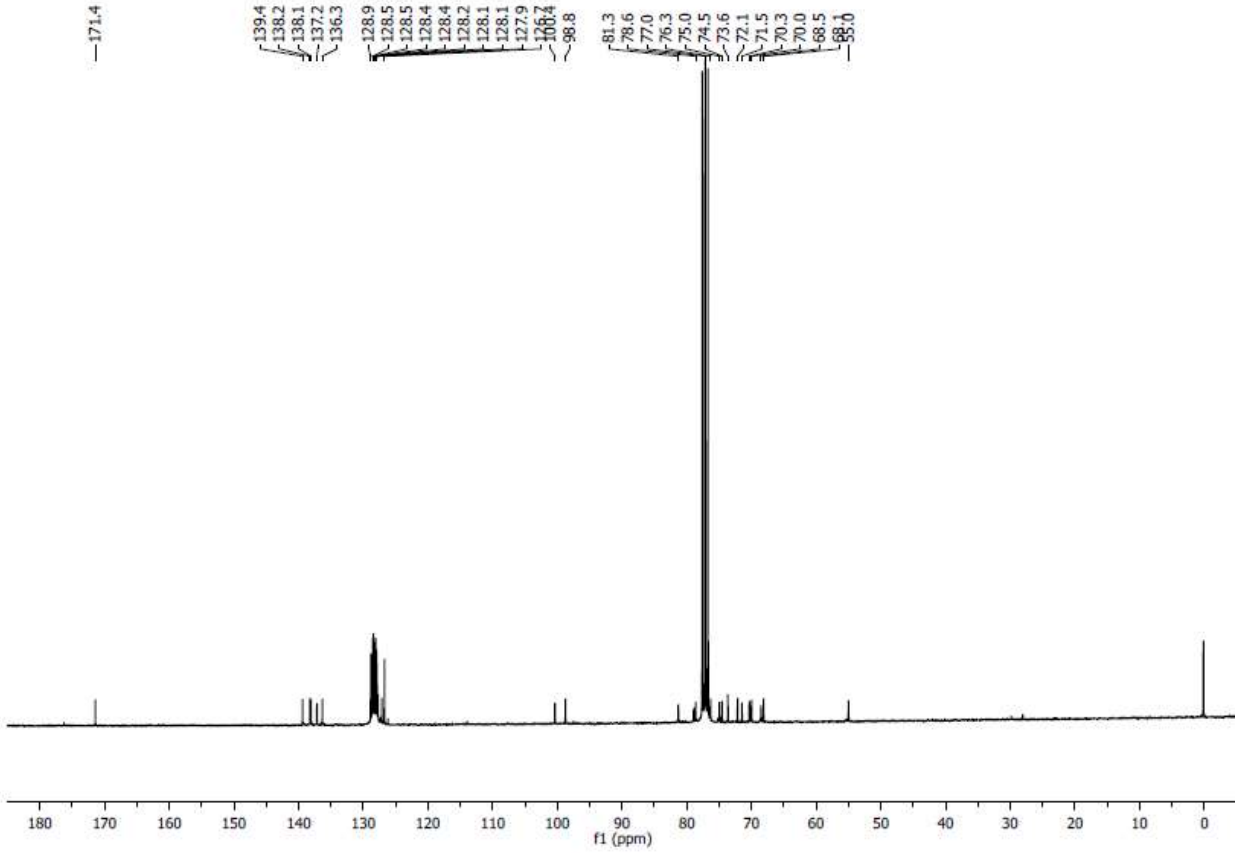
22



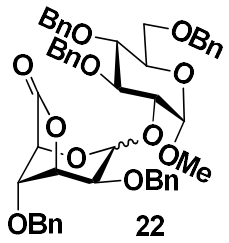
$CDCl_3$ 300MHz



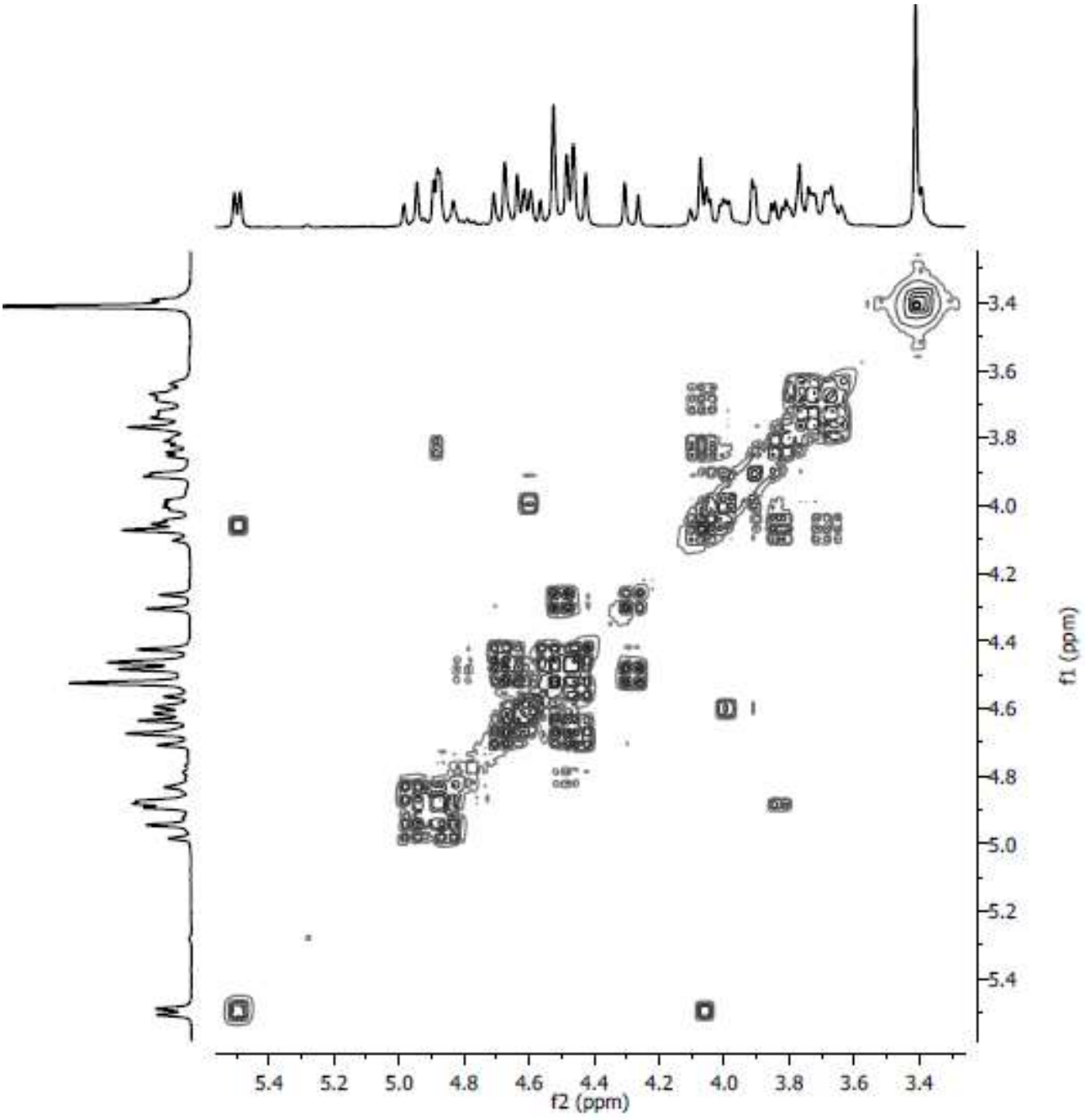
22



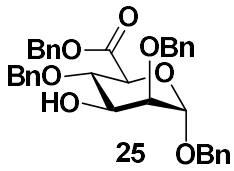
$CDCl_3$ 75MHz

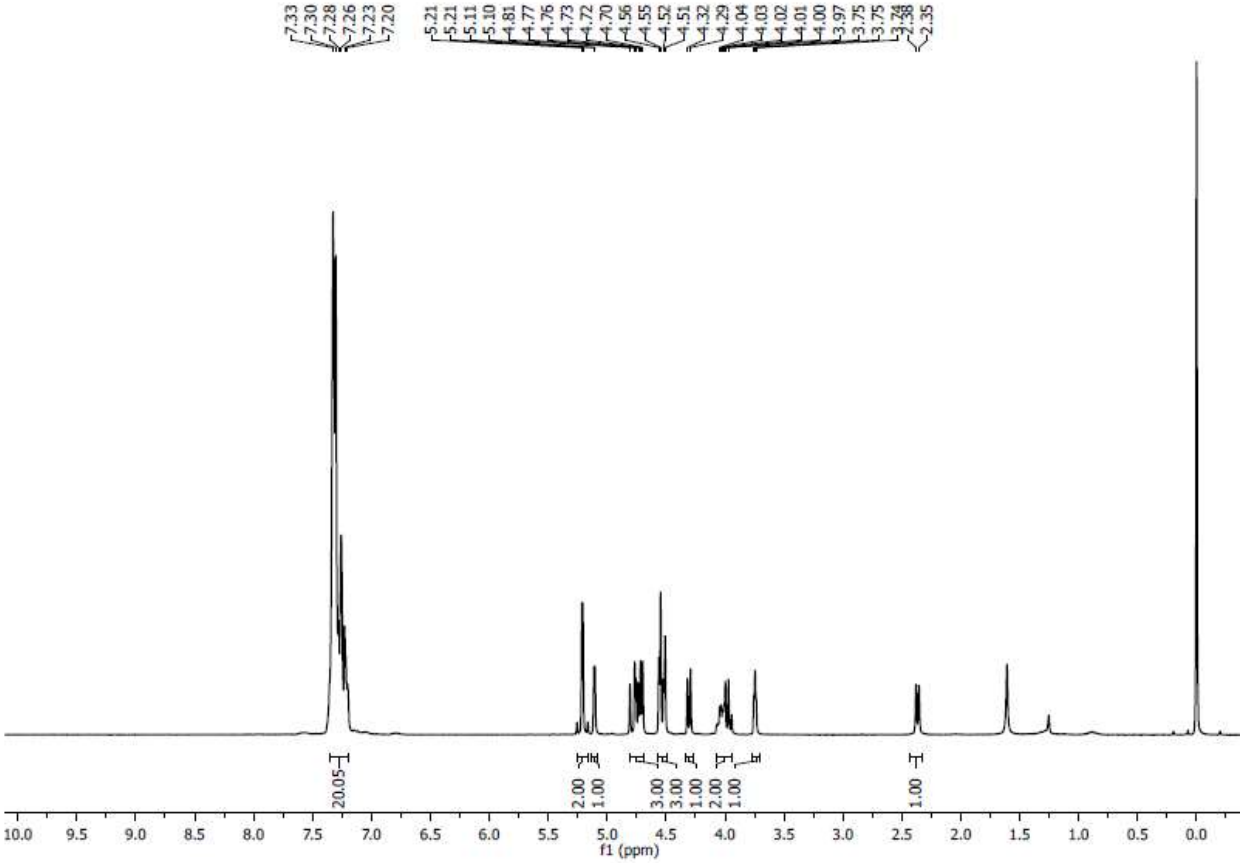


22

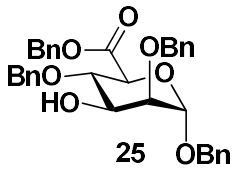


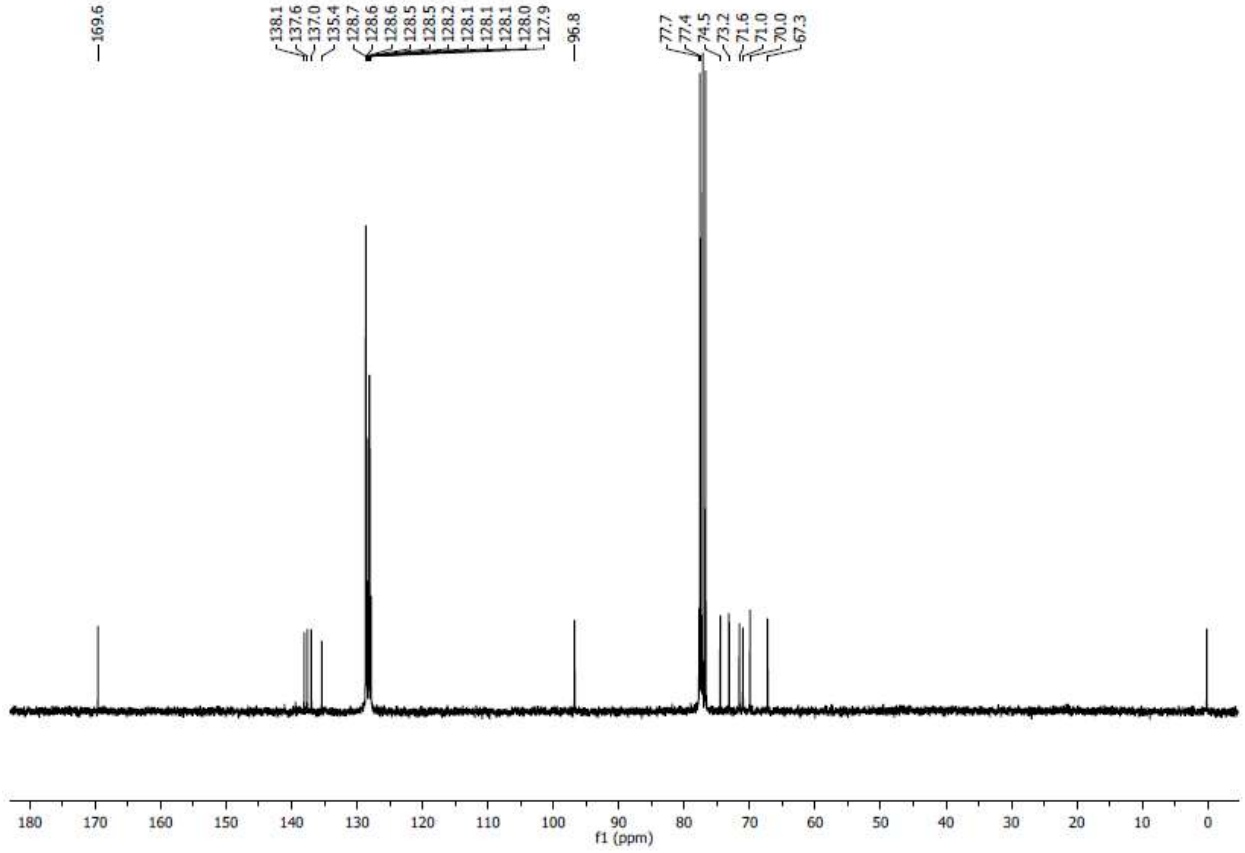
$CDCl_3$ 300MHz



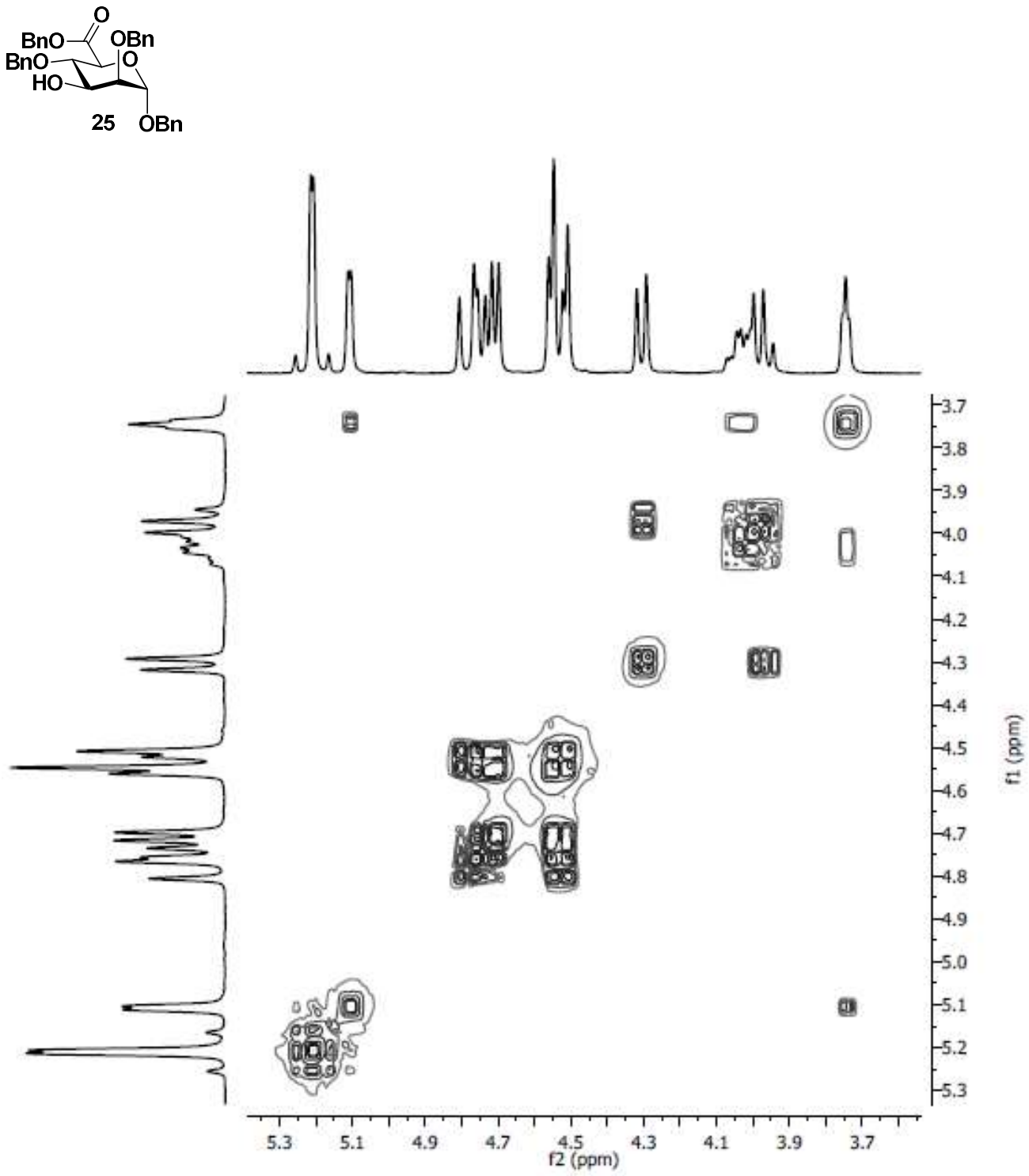


$CDCl_3$ 300MHz

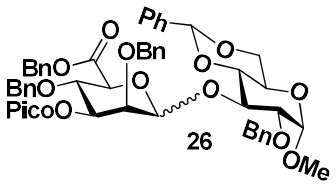

O
BnO
OBn
BnO
O
HO
25
OBn

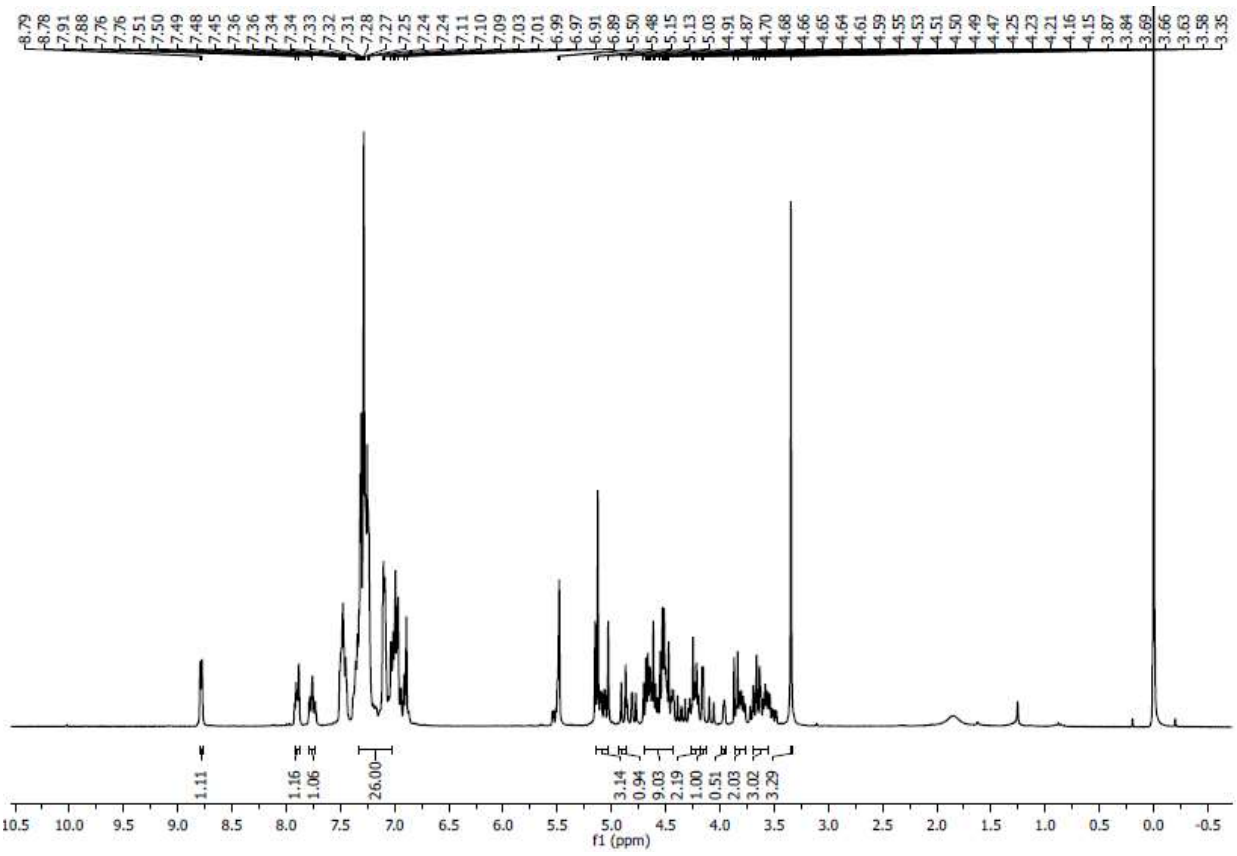

169.6
138.1
137.6
137.0
135.4
128.7
128.6
128.6
128.5
128.5
128.2
128.1
128.1
128.1
128.0
127.9
96.8
77.7
77.4
74.5
73.2
71.6
71.0
70.0
67.3
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

$CDCl_3$ 75MHz

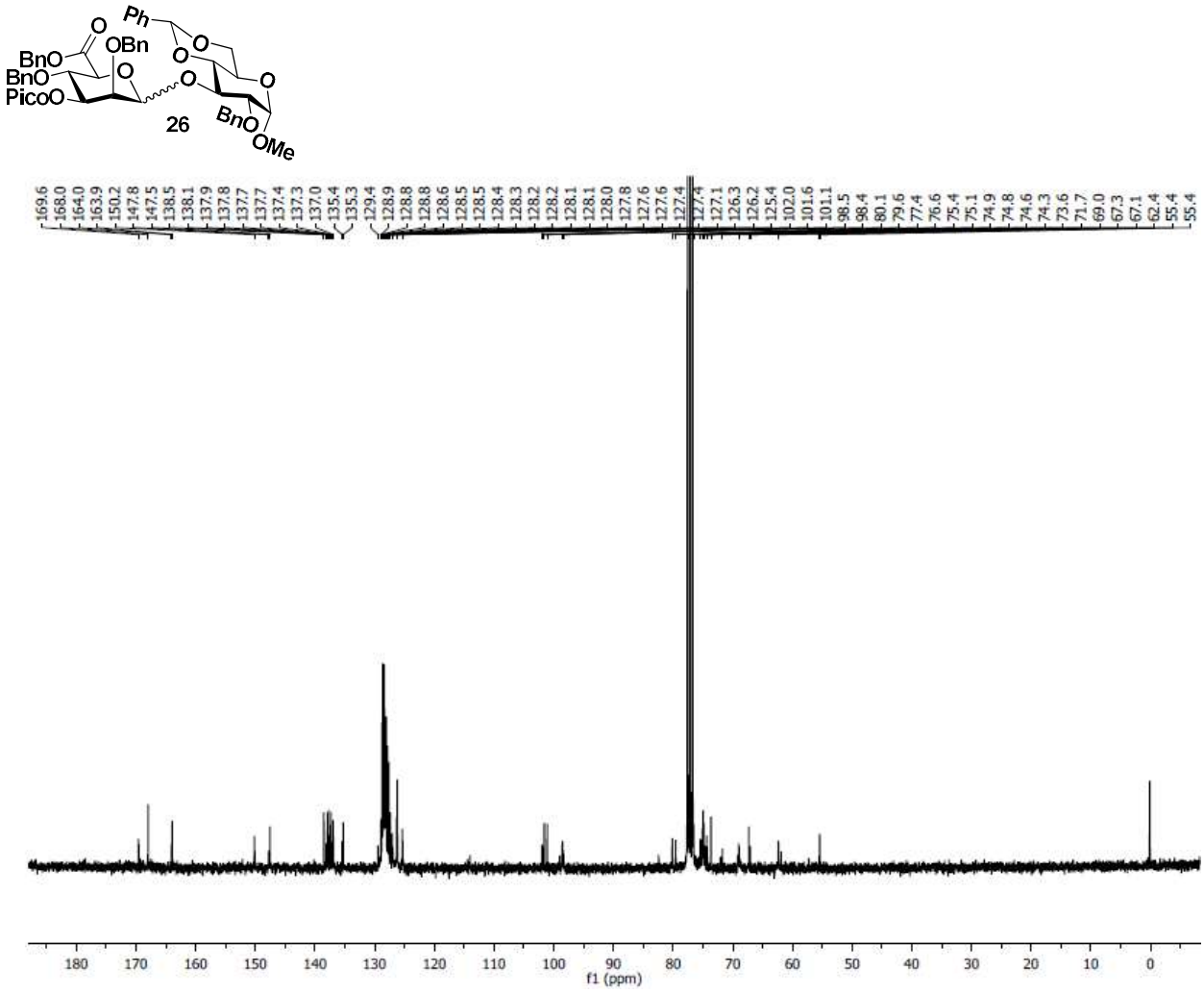


$CDCl_3$ 300MHz

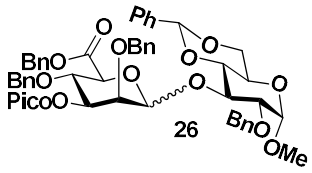


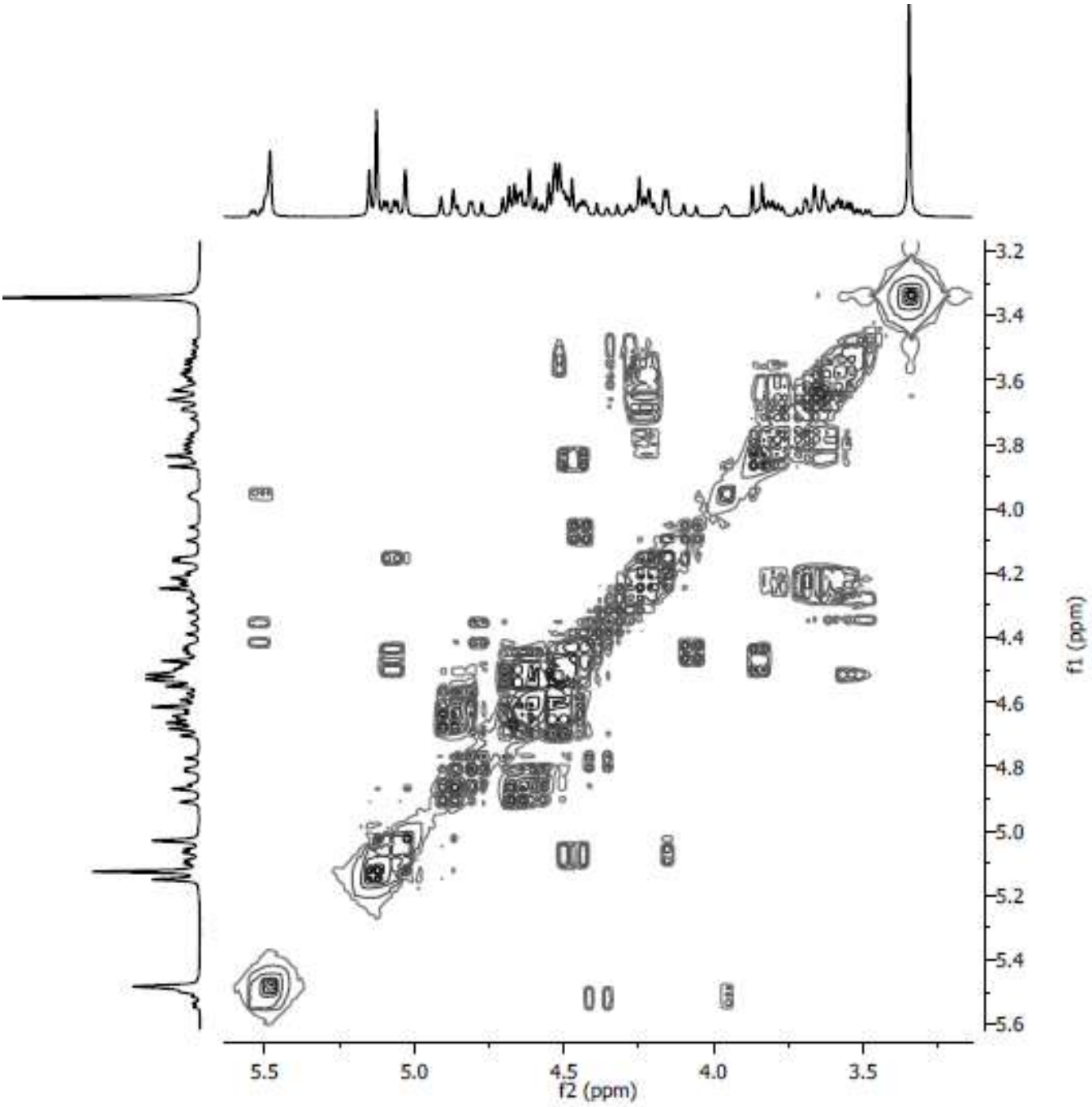


$CDCl_3$ 300MHz

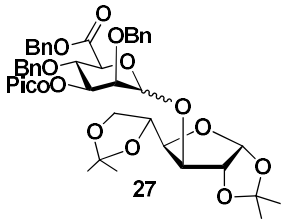

Ph
O
OBn
BnO
BnO
PicoO
26
BnO
OMe
169.6
168.0
164.0
163.9
150.2
147.8
147.5
138.5
138.1
137.9
137.8
137.7
137.7
137.4
137.3
137.0
135.4
135.3
129.4
128.9
128.8
128.8
128.6
128.5
128.5
128.4
128.3
128.2
128.2
128.1
128.1
128.0
127.8
127.6
127.6
127.4
127.4
127.1
126.3
126.2
125.4
102.0
101.6
101.1
98.5
98.4
80.1
79.6
77.4
76.6
75.4
75.1
74.9
74.8
74.6
74.3
73.6
71.7
69.0
67.3
67.1
62.4
55.4
55.4
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

$CDCl_3$ 75MHz

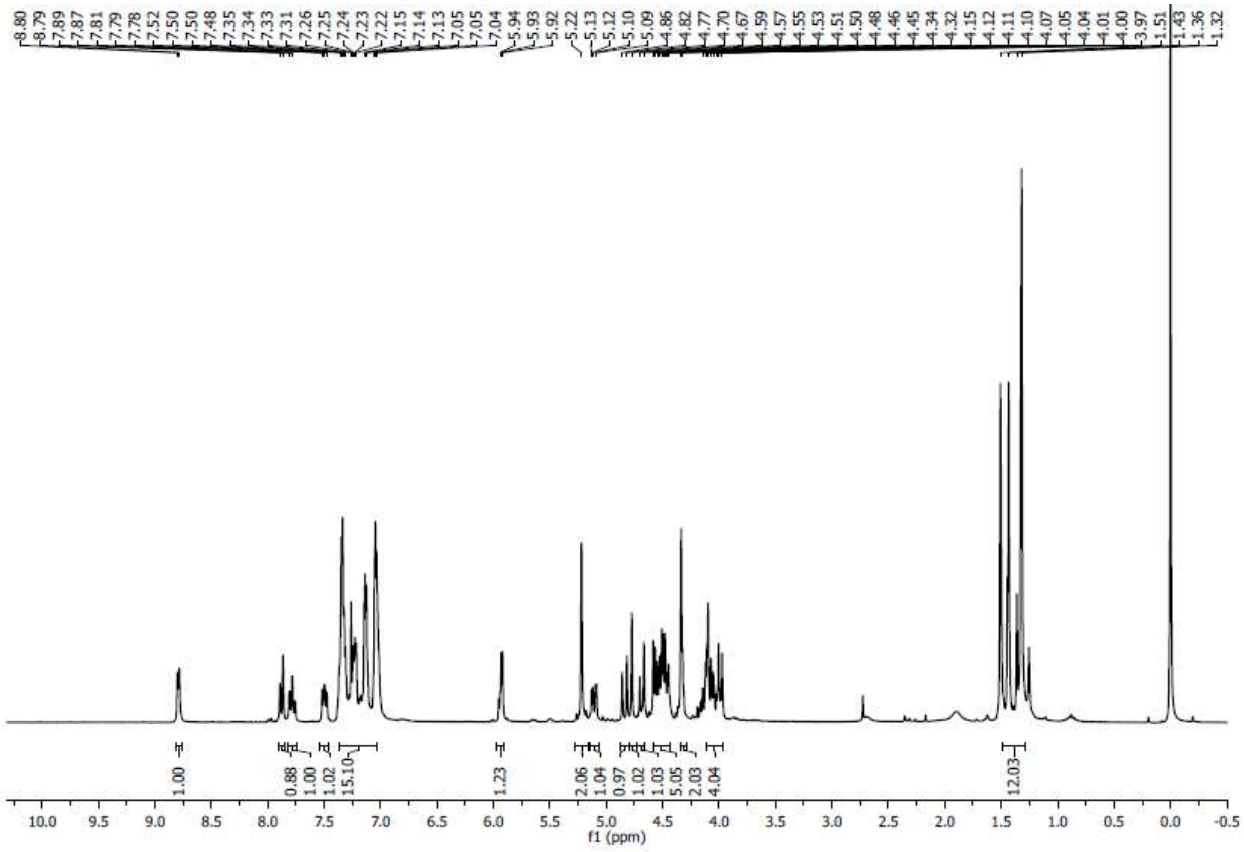




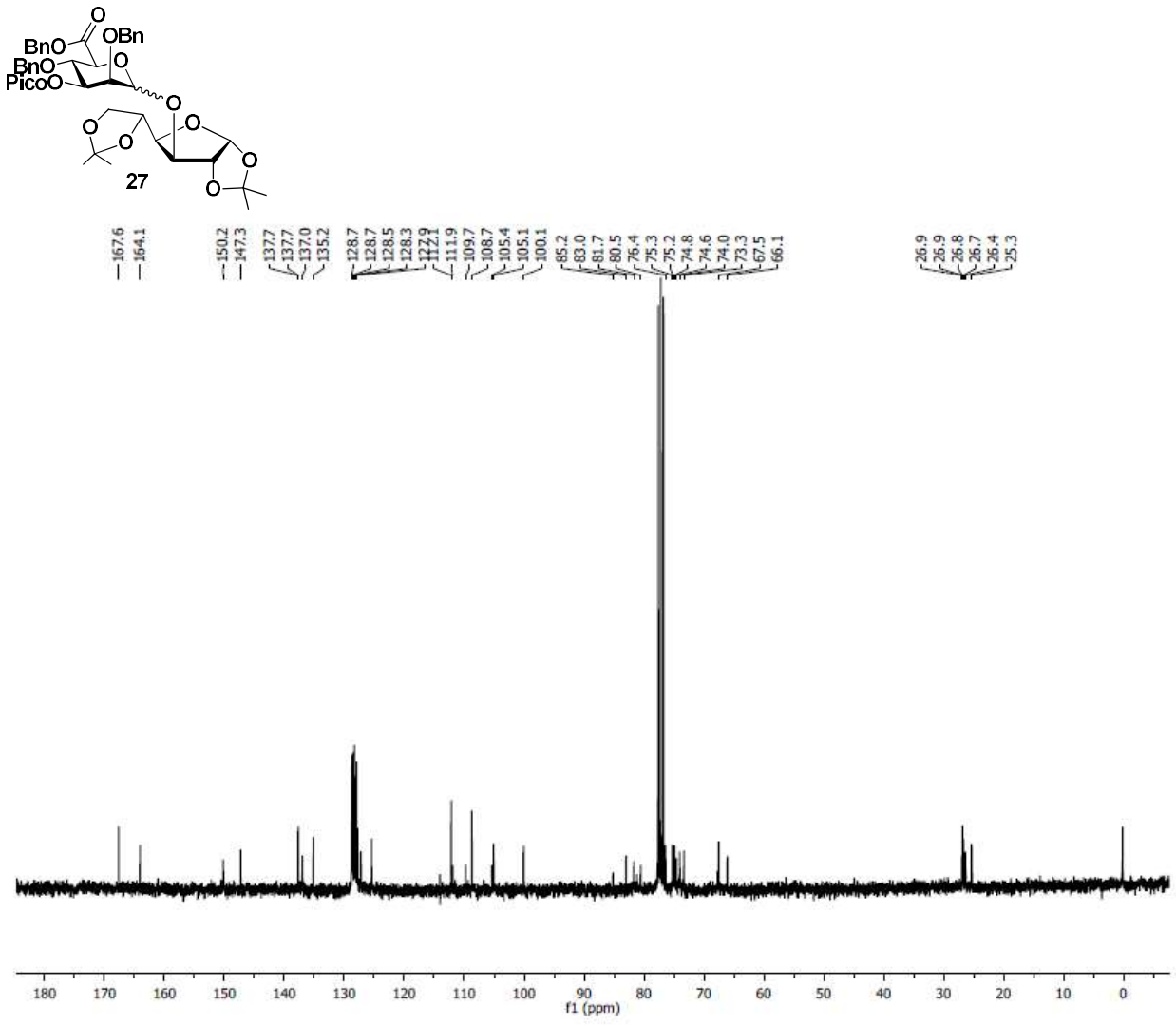
$CDCl_3$ 300MHz



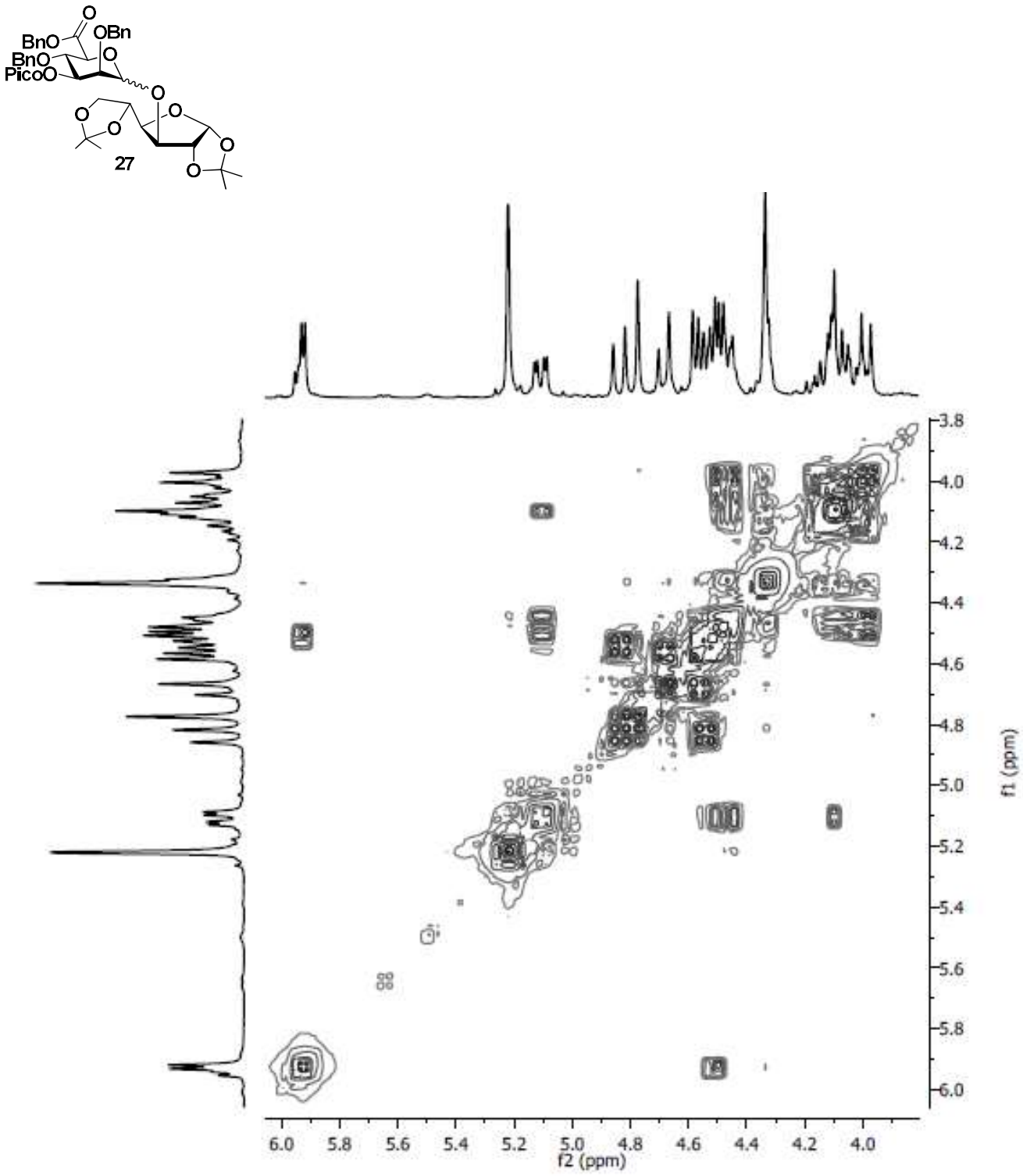
27



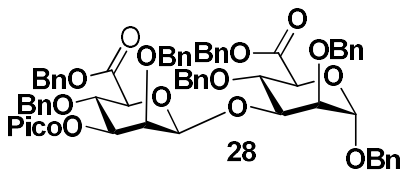
$CDCl_3$ 300MHz

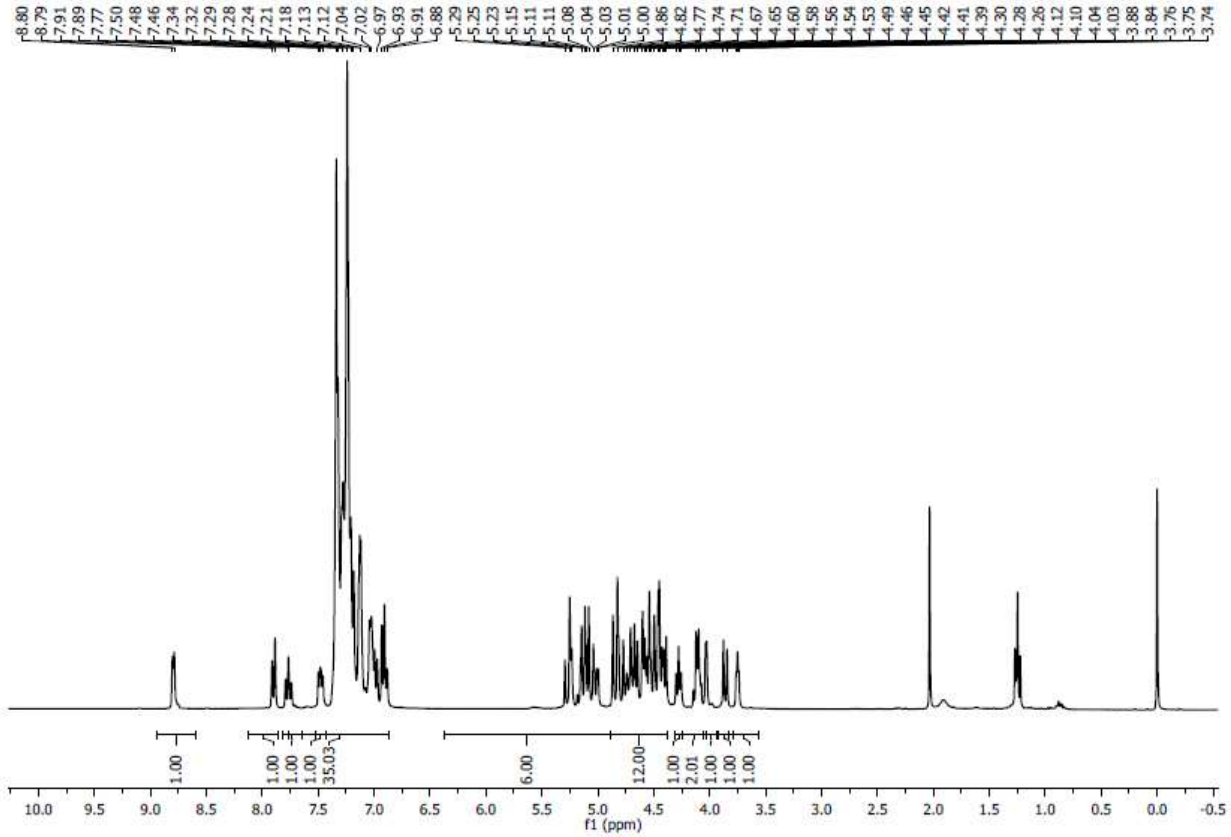

BnO
OBn
BnO
PicoO
O
27
167.6
164.1
150.2
147.3
137.7
137.7
137.0
135.2
128.7
128.7
128.5
128.3
127.9
122.1
111.9
109.7
108.7
105.4
105.1
100.1
85.2
83.0
81.7
80.5
76.4
75.3
75.2
74.8
74.6
74.0
73.3
67.5
66.1
26.9
26.9
26.8
26.7
26.4
25.3
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

$CDCl_3$ 75MHz

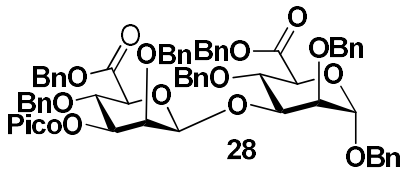


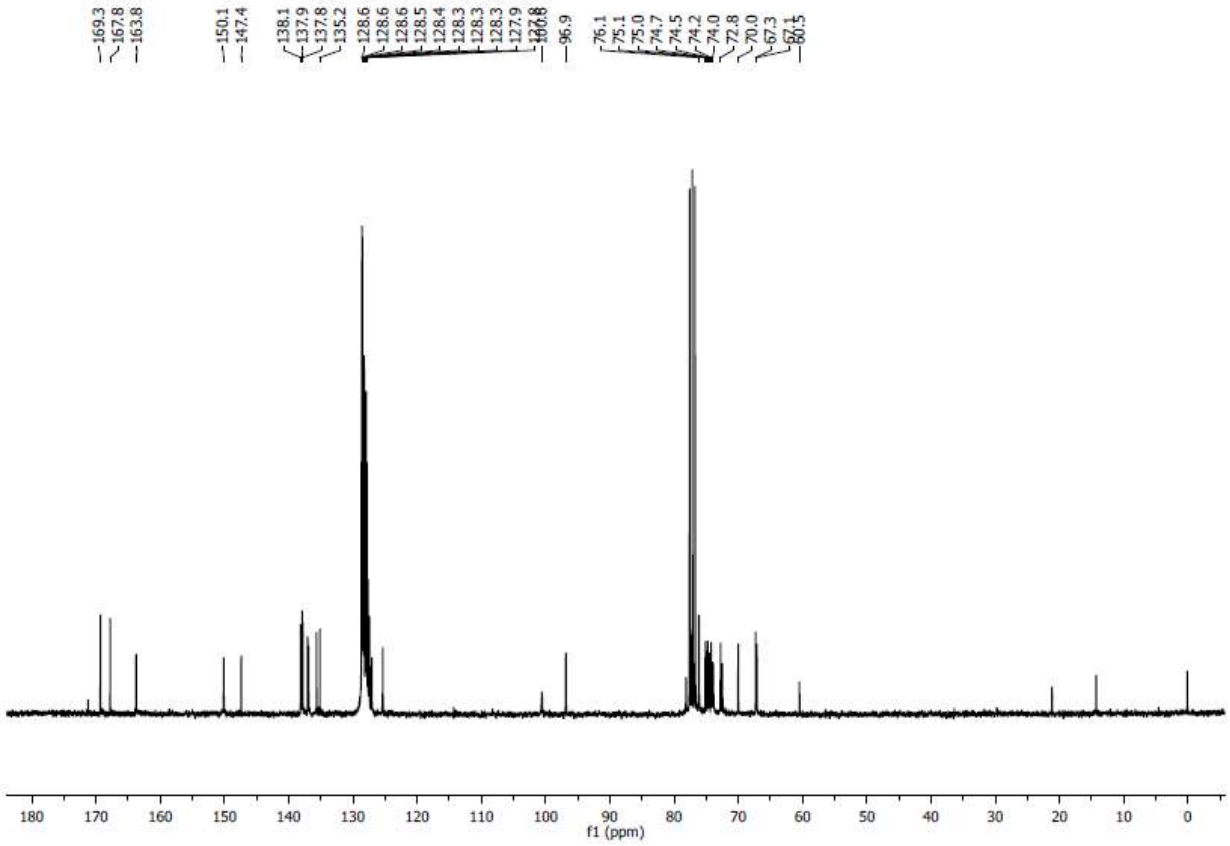
$CDCl_3$ 300MHz



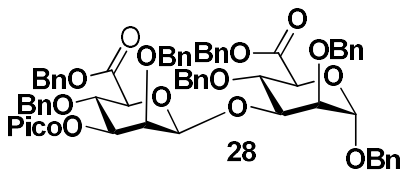


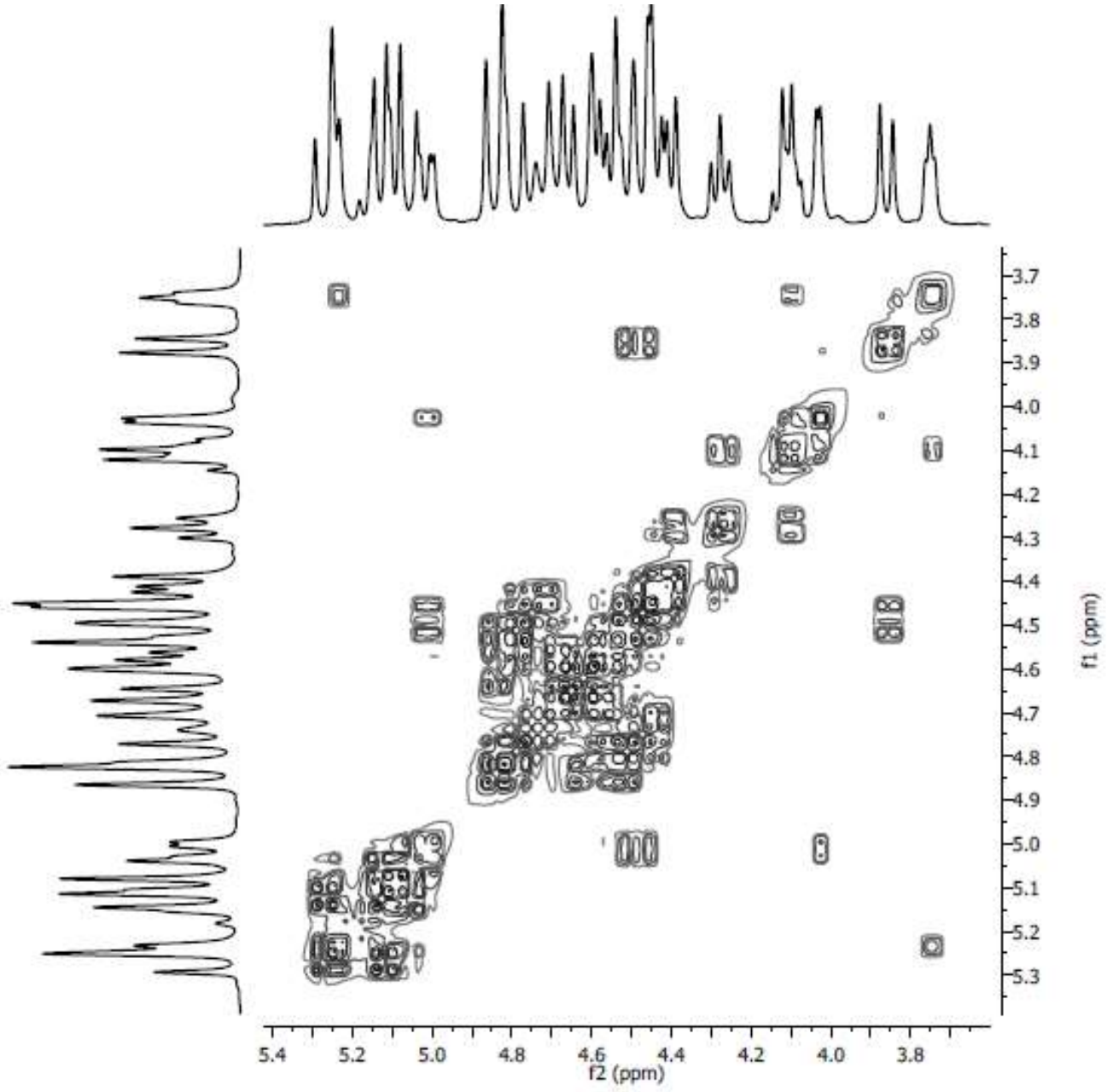
$CDCl_3$ 300MHz


BnO
OBn
BnO
BnO
OBn
BnO
PicoO
O
O
O
O
OBn
28

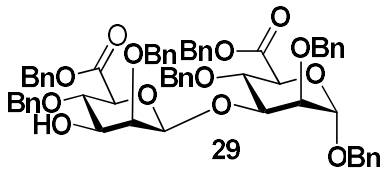

169.3
167.8
163.8
150.1
147.4
138.1
137.9
137.8
135.2
128.6
128.6
128.6
128.5
128.4
128.3
128.3
128.3
127.9
96.9
76.1
75.1
75.0
74.7
74.5
74.2
74.0
72.8
70.0
67.3
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

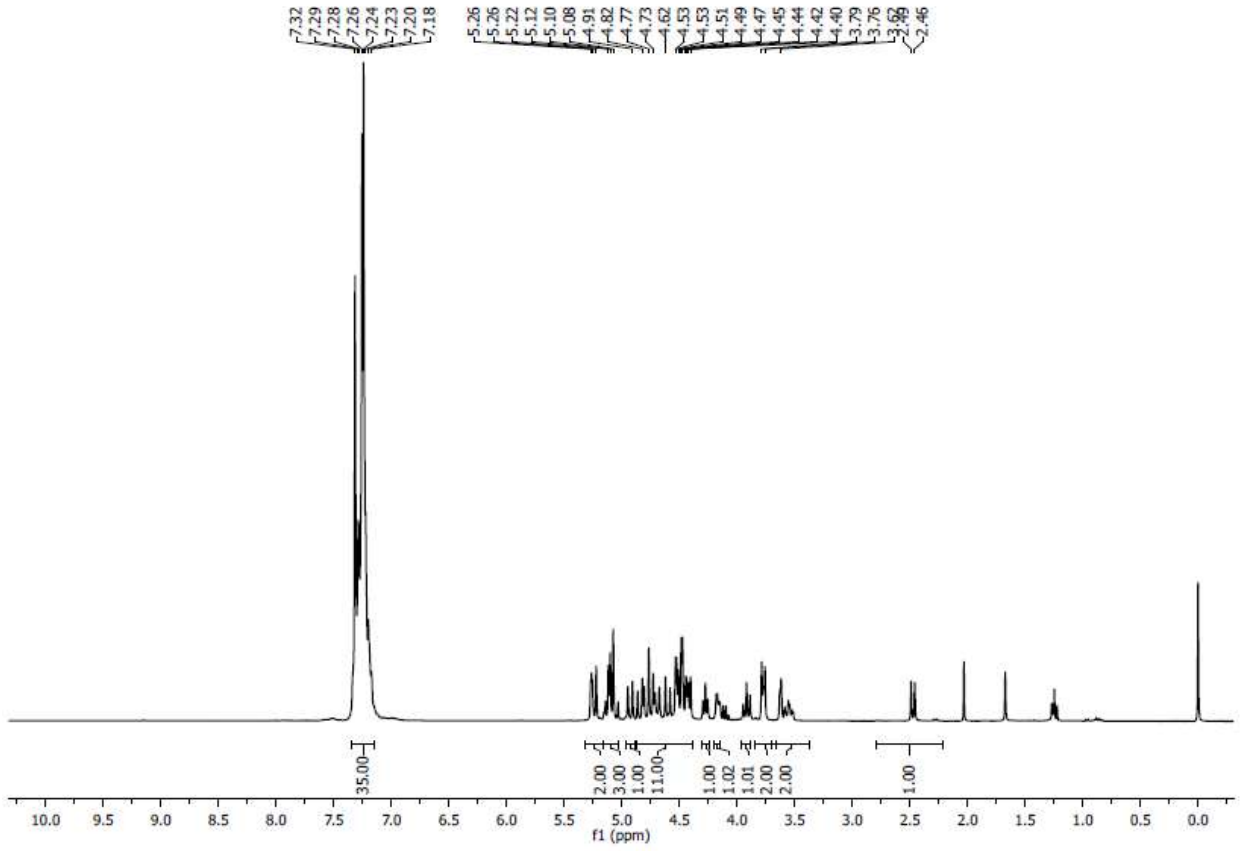
$CDCl_3$ 75MHz



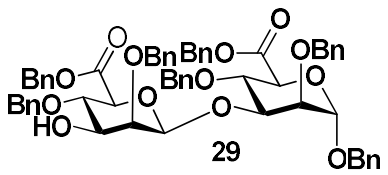


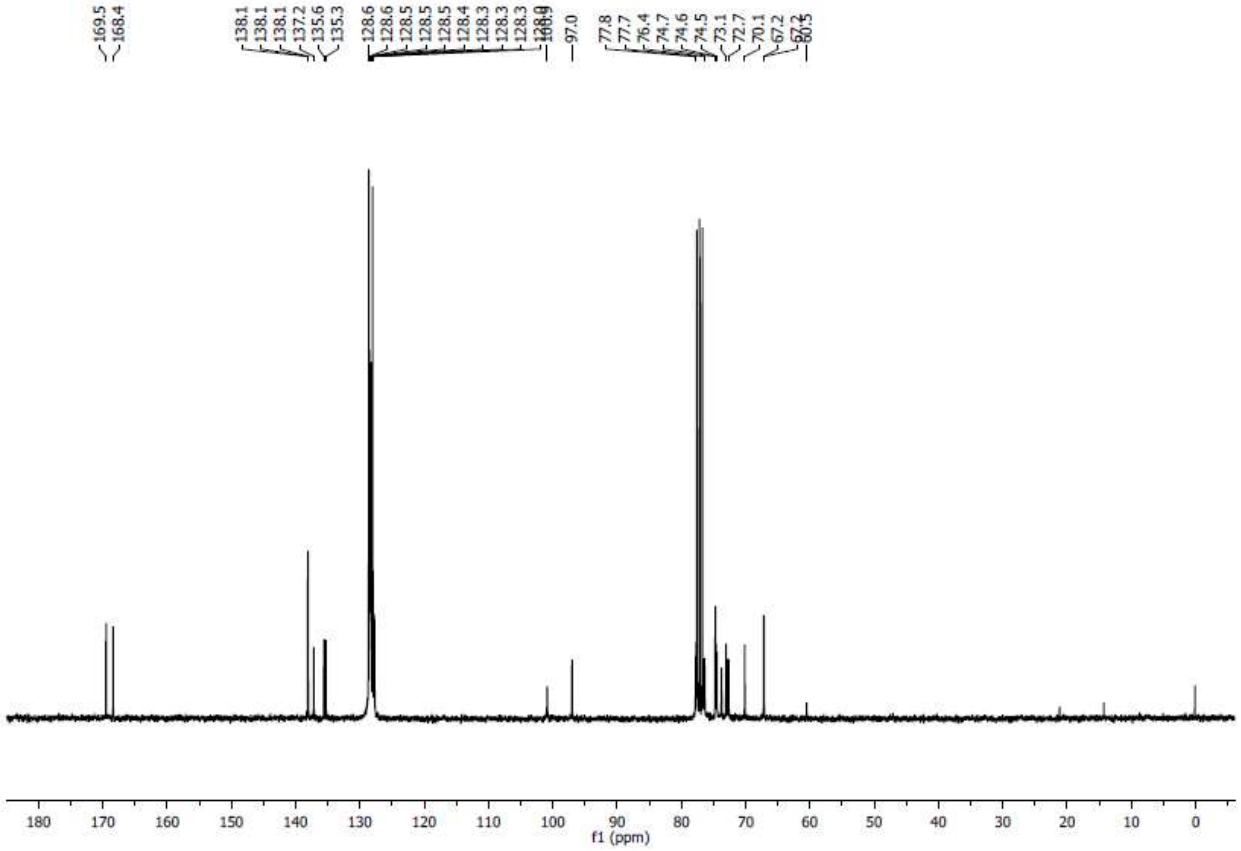
$CDCl_3$ 300MHz



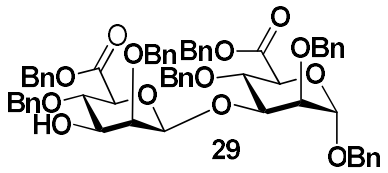


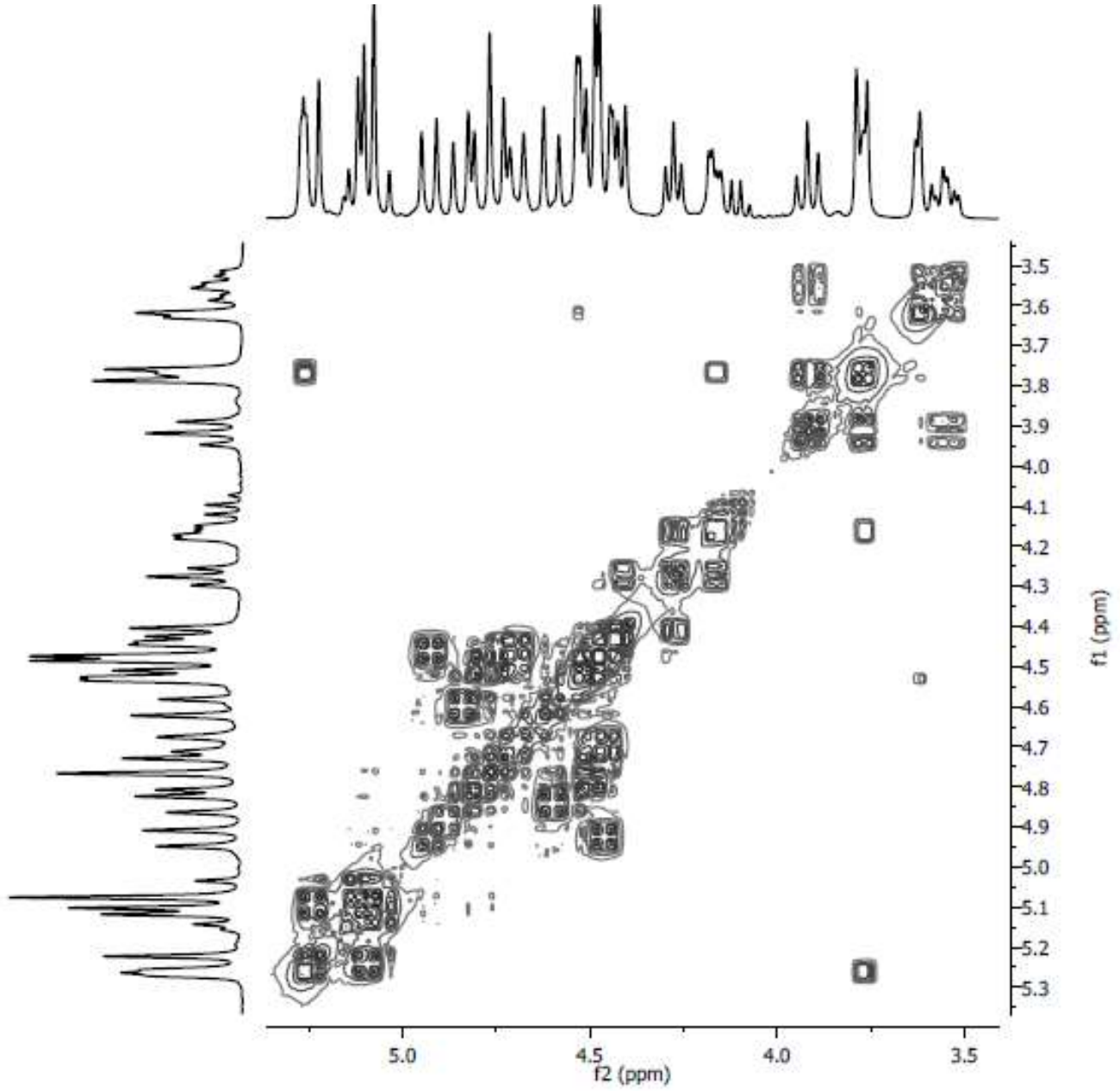
$CDCl_3$ 300MHz


BnO
OBn
BnO
OBn
BnO
BnO
O
HO
O
O
O
OBn
29

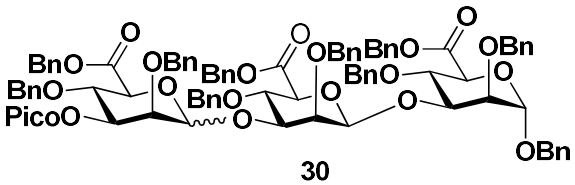

169.5
168.4
138.1
138.1
138.1
137.2
135.6
135.3
128.6
128.6
128.5
128.5
128.5
128.4
128.3
128.3
128.3
97.0
77.8
77.7
76.4
74.7
74.6
74.5
73.1
72.7
70.1
67.2
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

$CDCl_3$ 75MHz

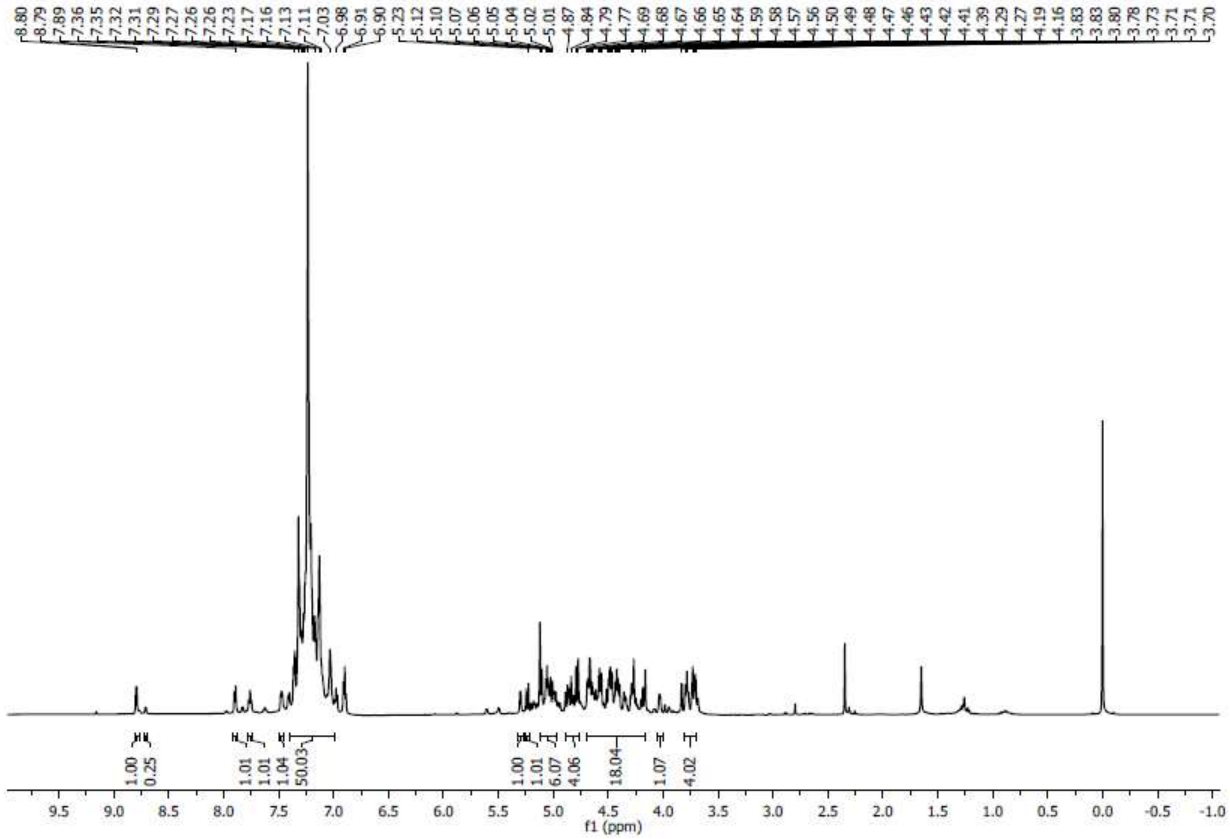




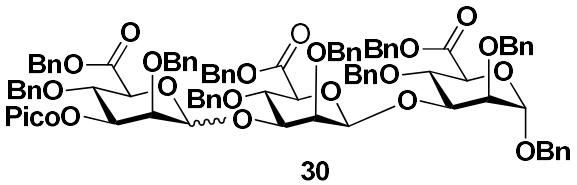
$CDCl_3$ 300MHz



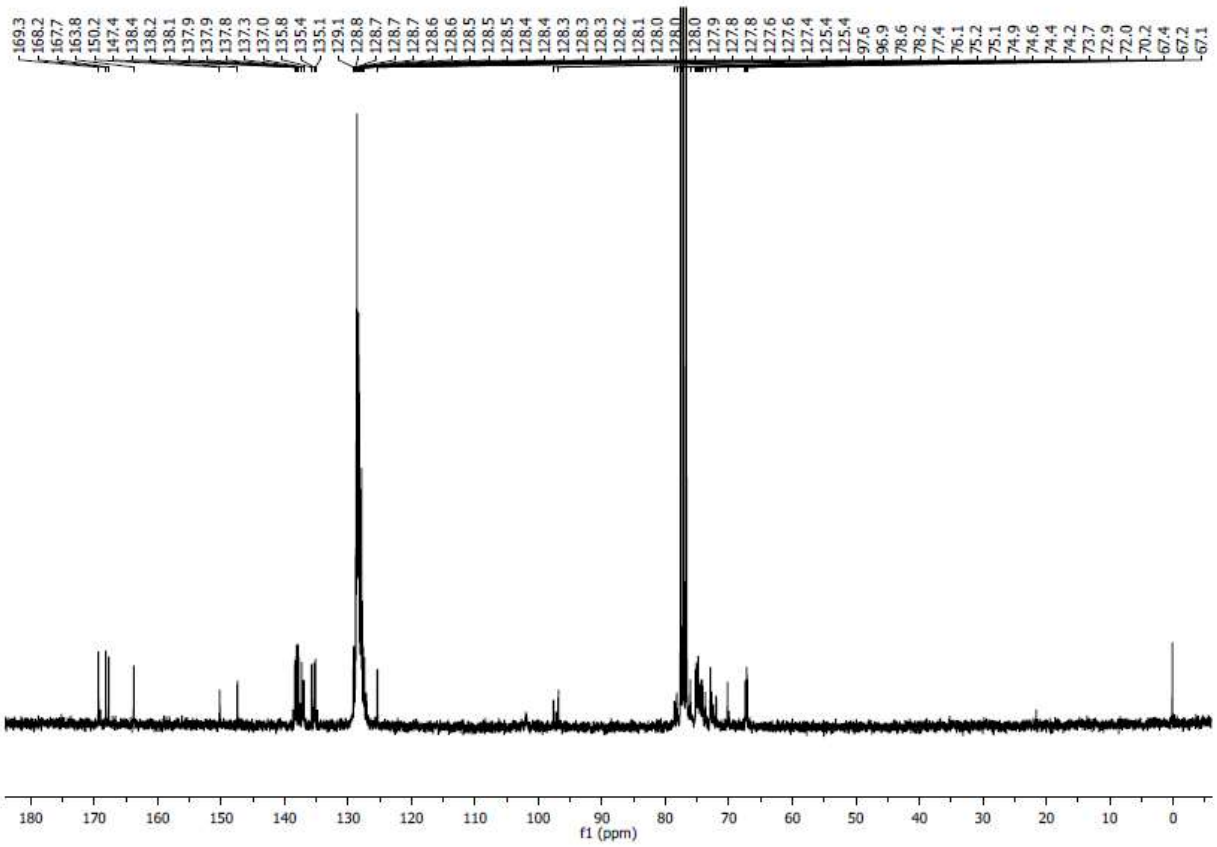
30



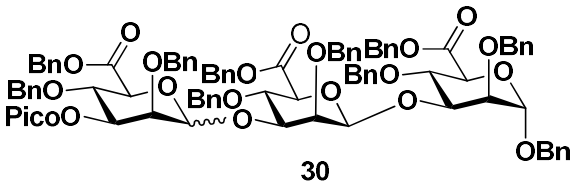
$CDCl_3$ 600MHz



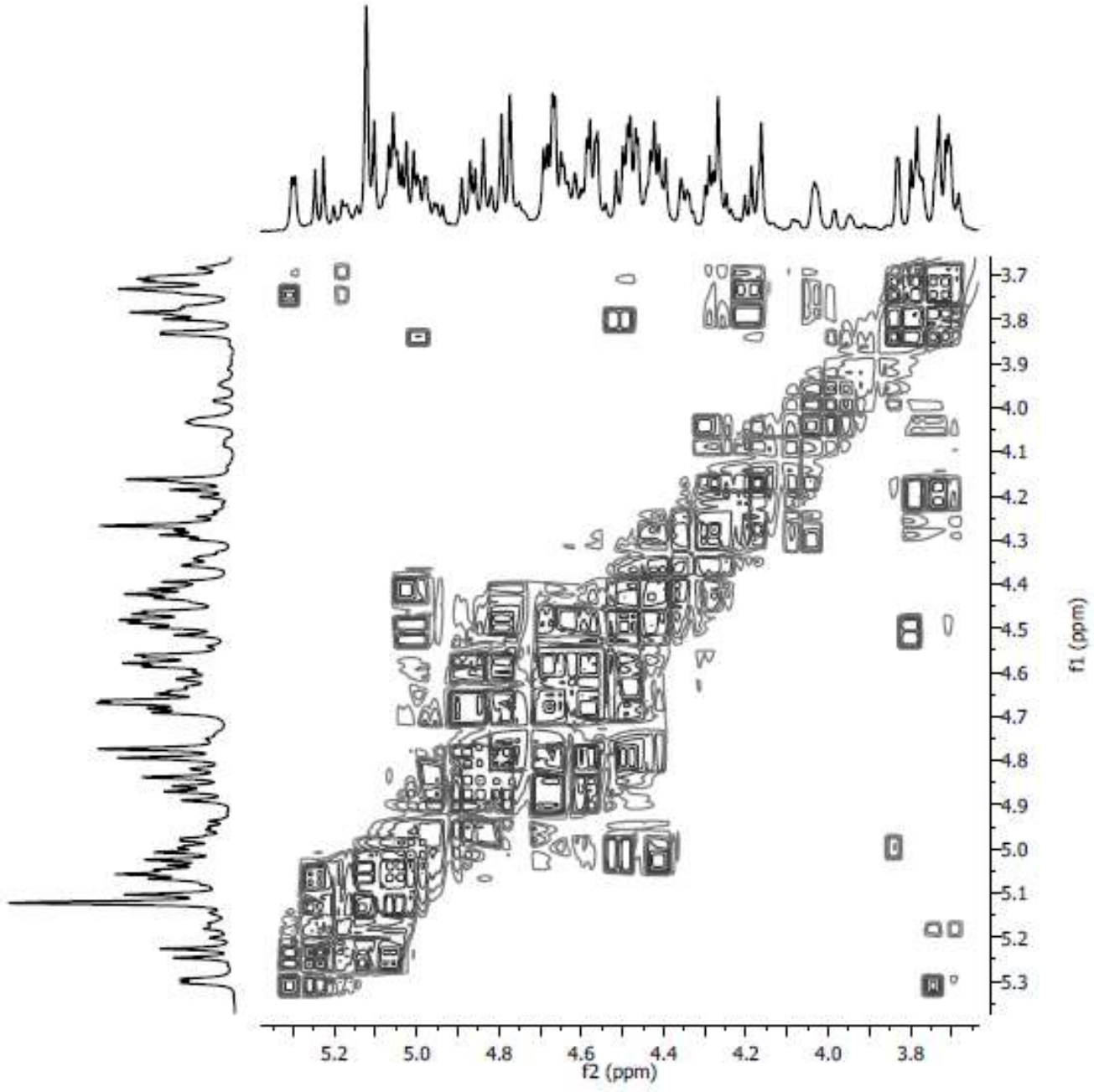
30



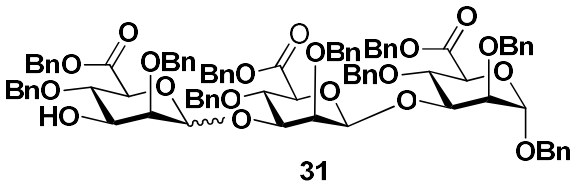
$CDCl_3$ 75MHz



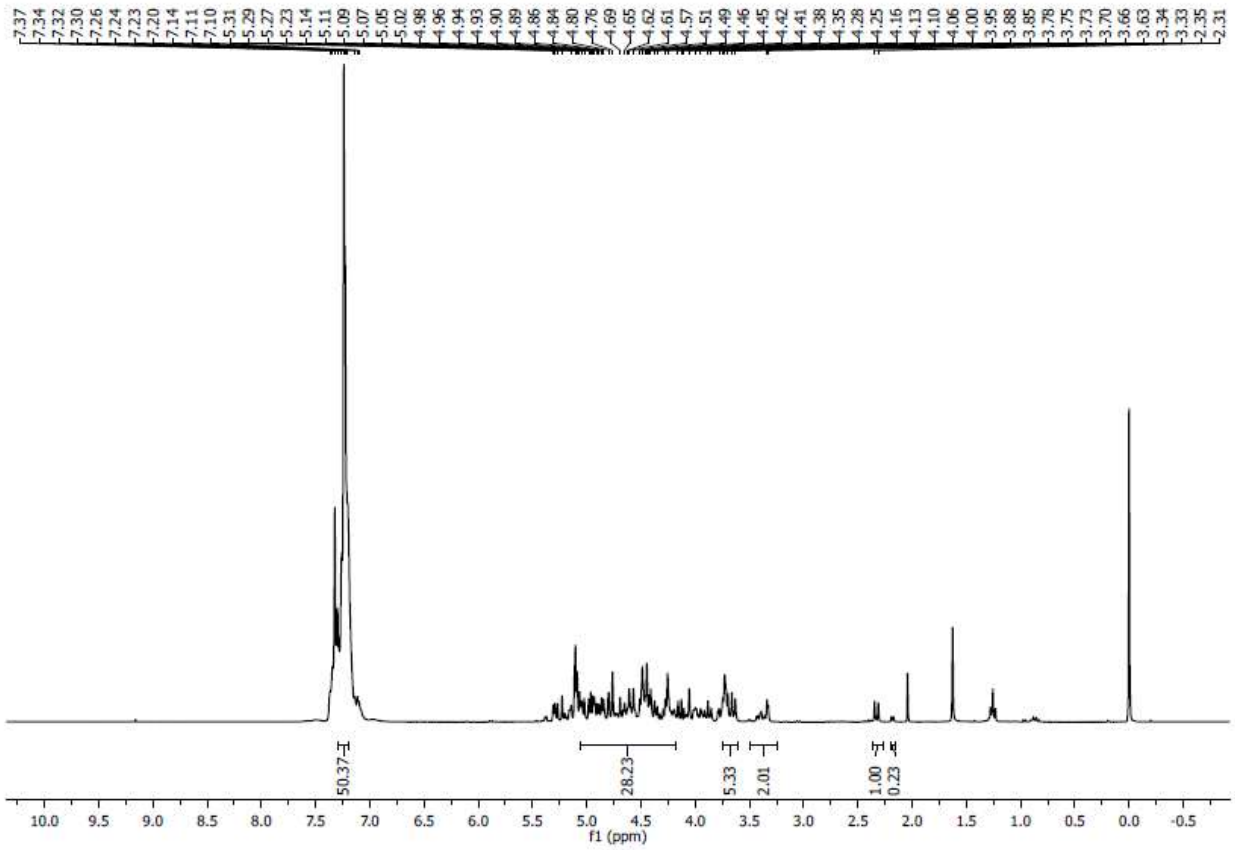
30



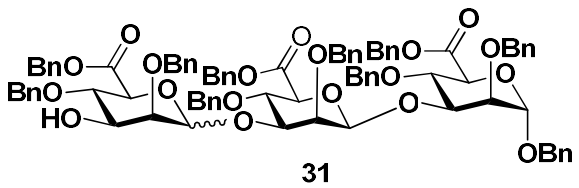
$CDCl_3$ 600MHz



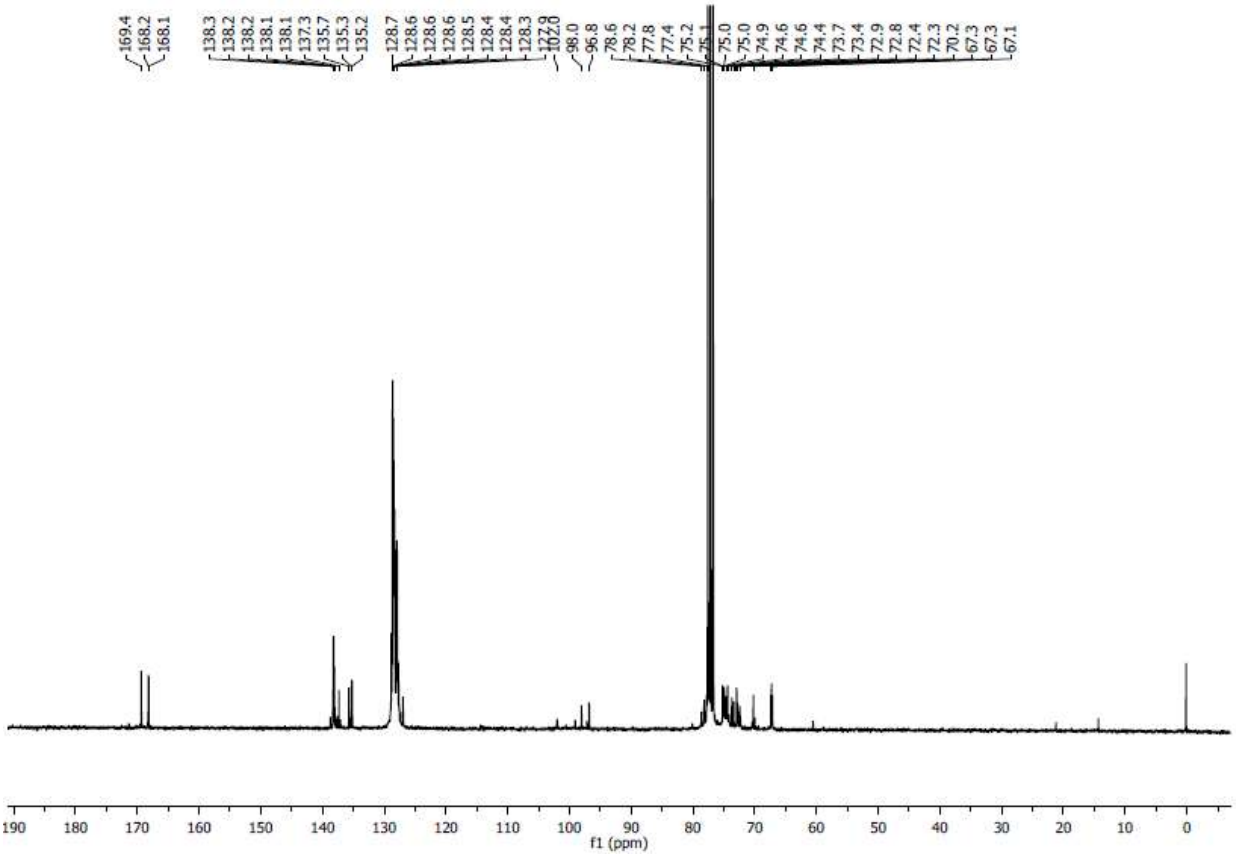
31



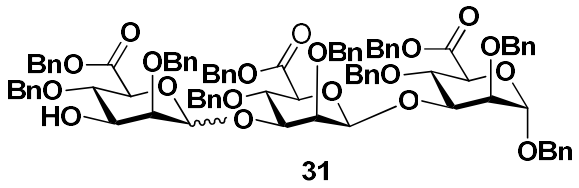
$CDCl_3$ 300MHz



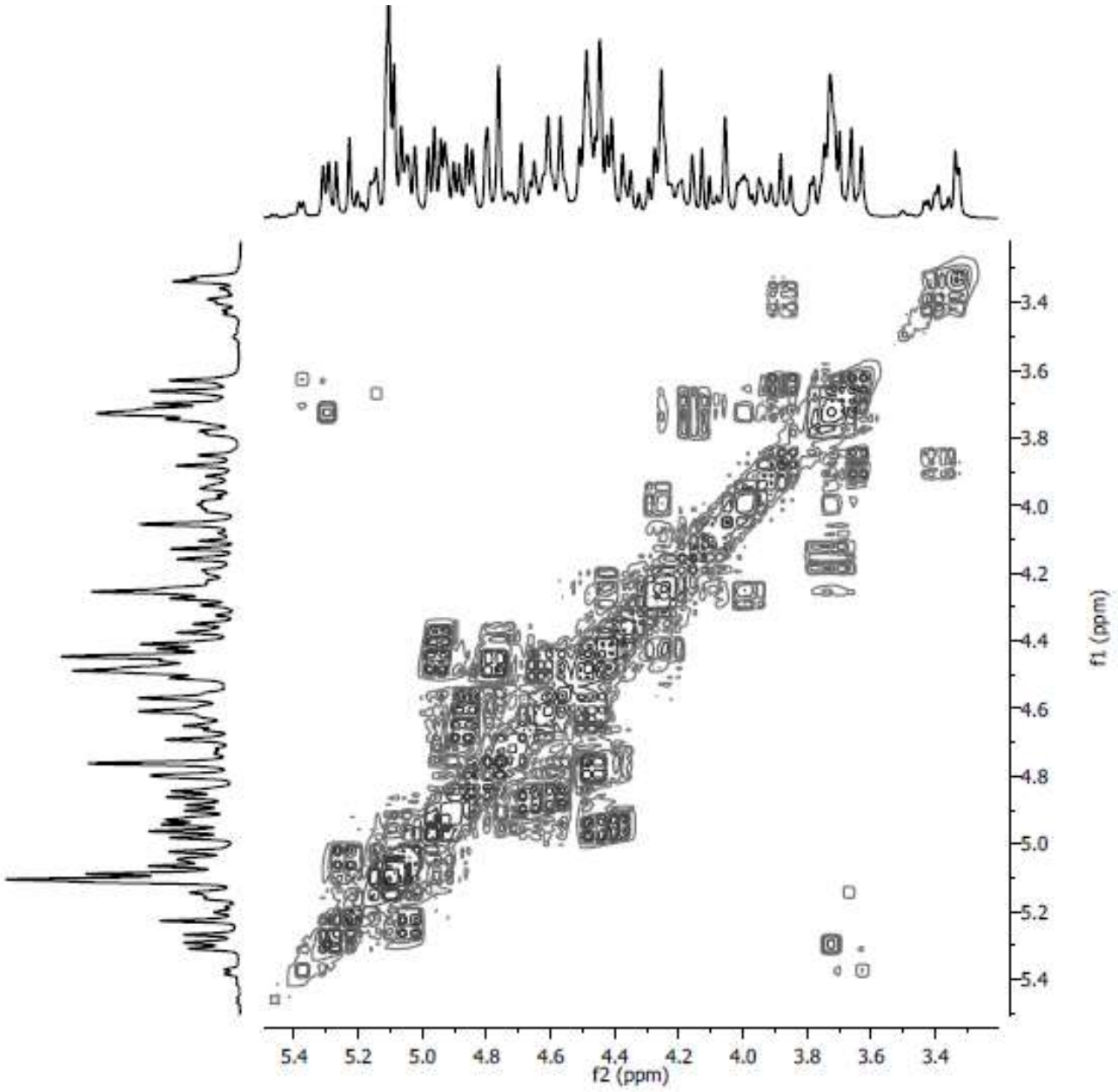
31



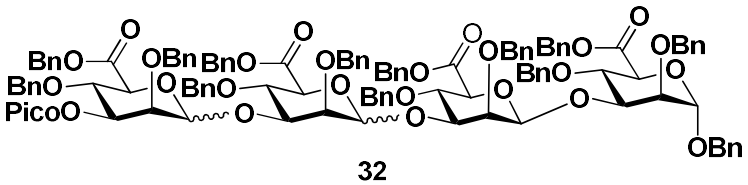
$CDCl_3$ 75MHz



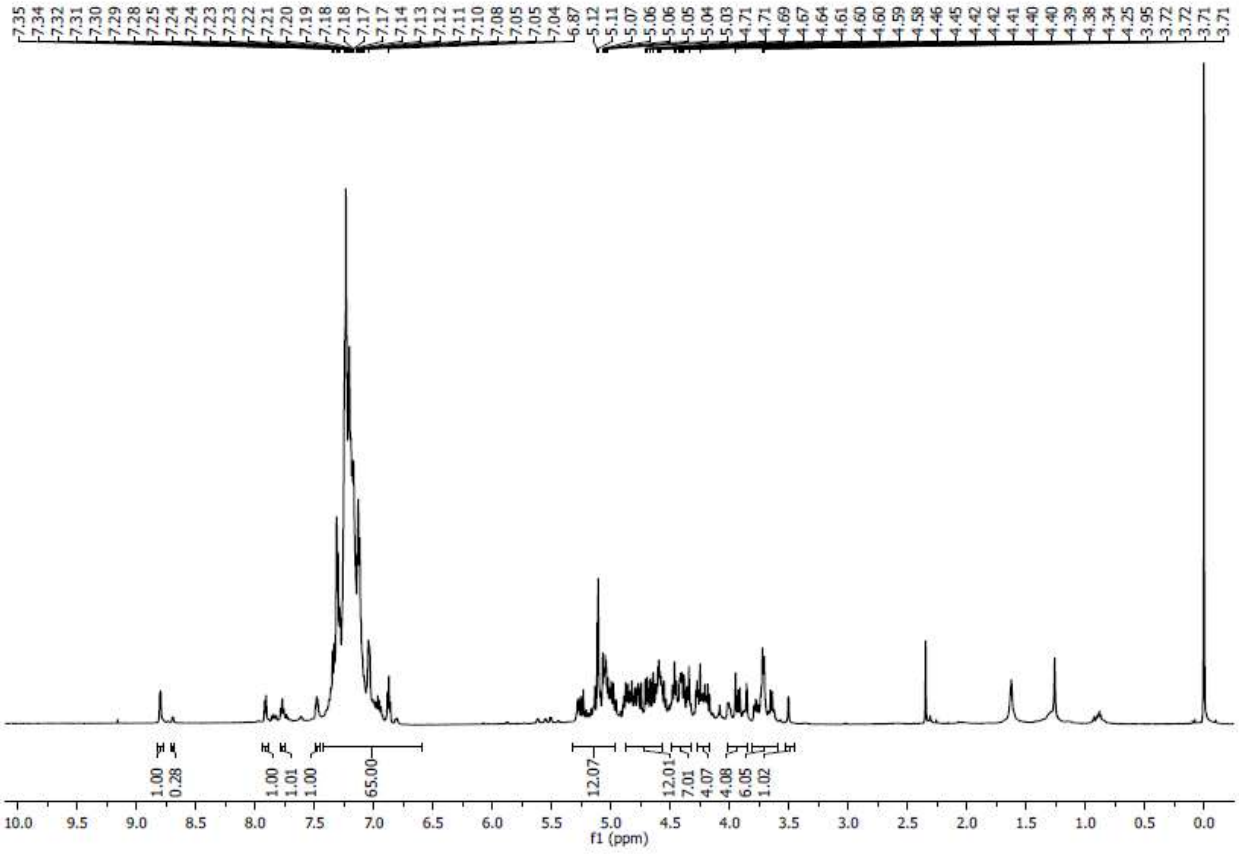
31



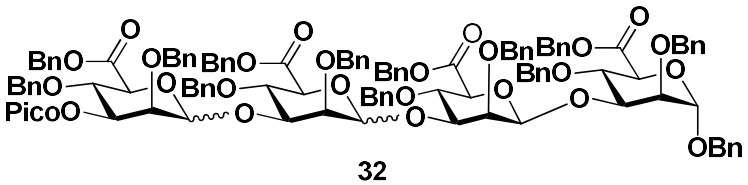
$CDCl_3$ 300MHz



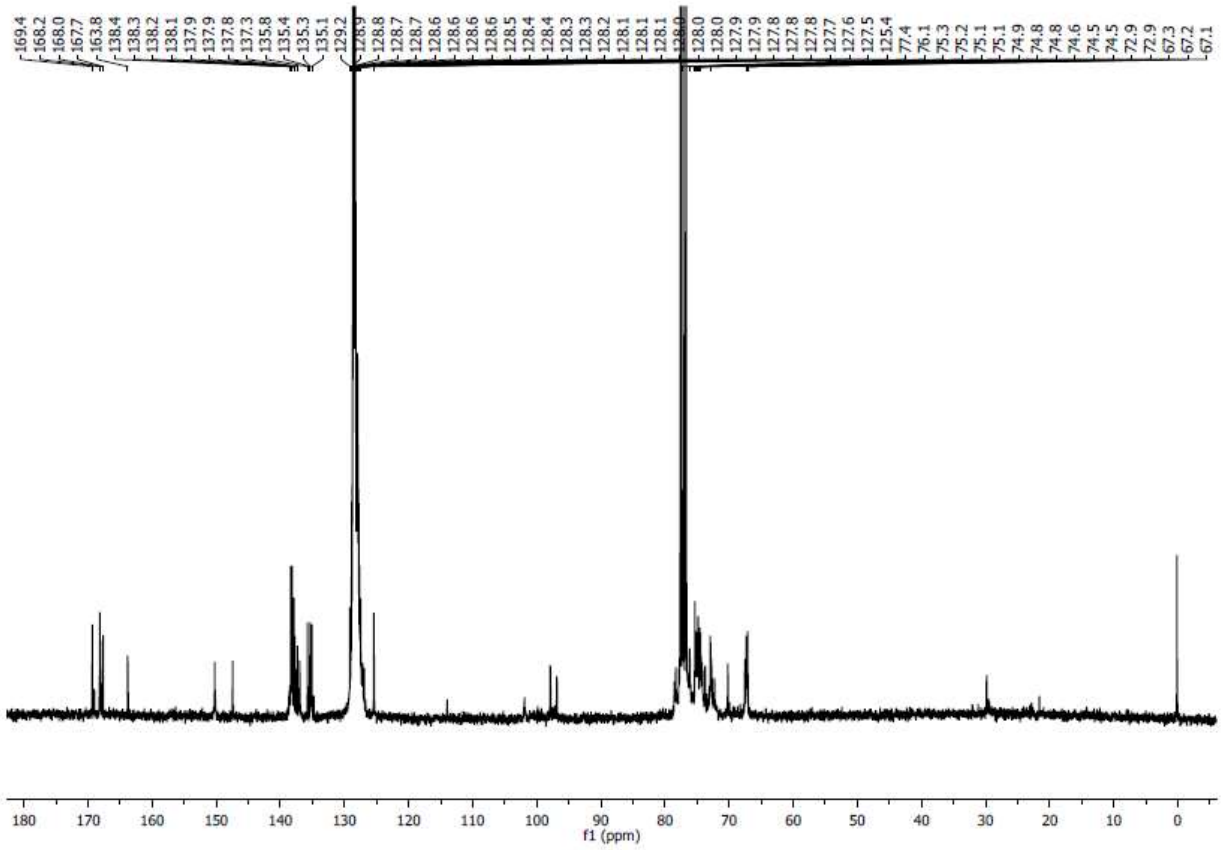
32



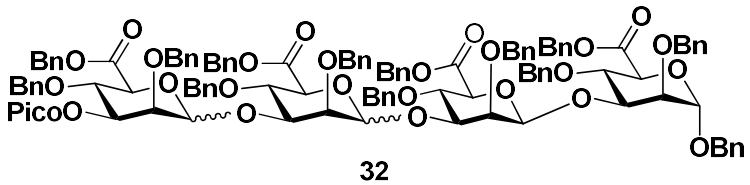
$CDCl_3$ 600MHz



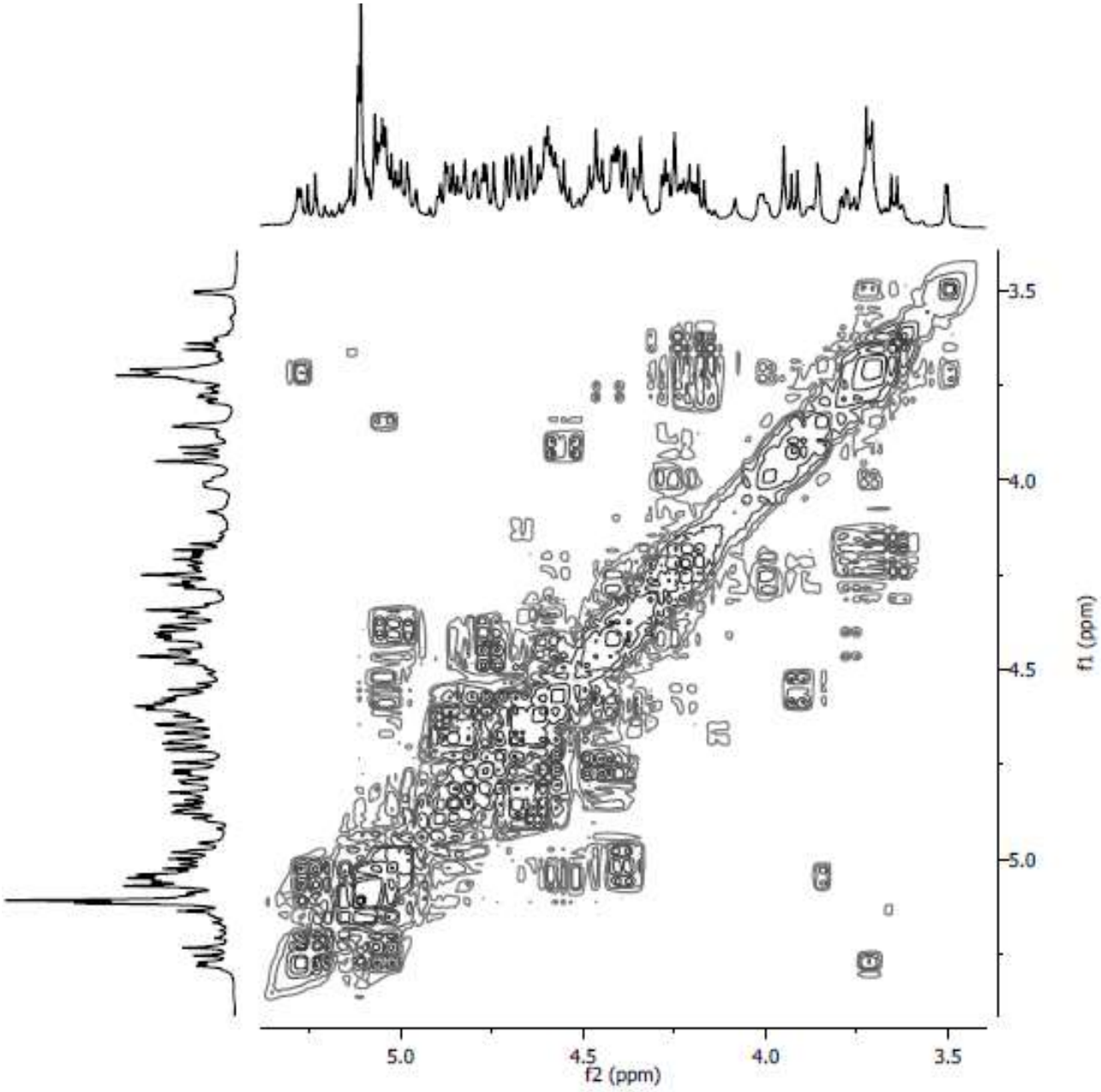
32



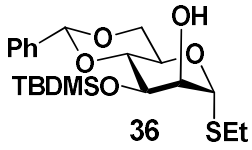
$CDCl_3$ 75MHz

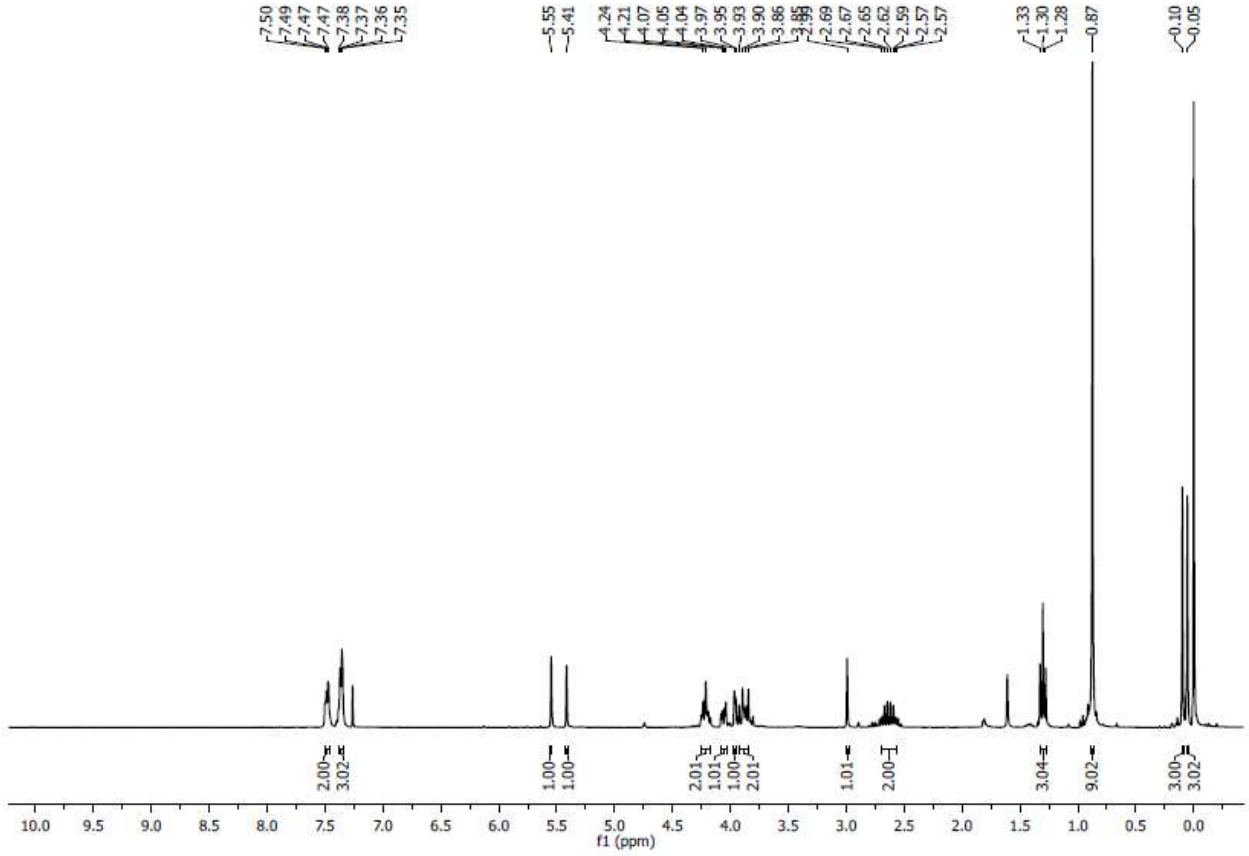


32

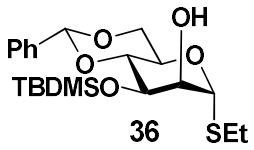


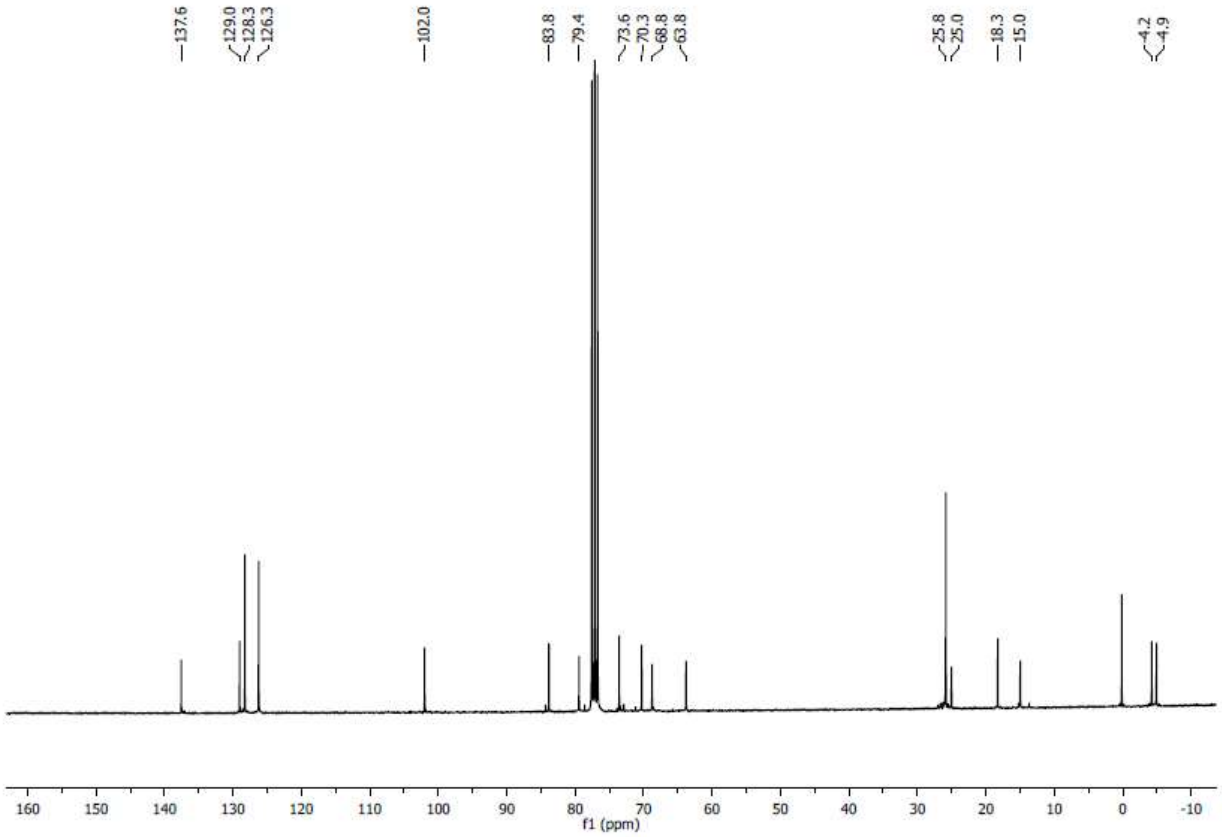
$CDCl_3$ 600MHz



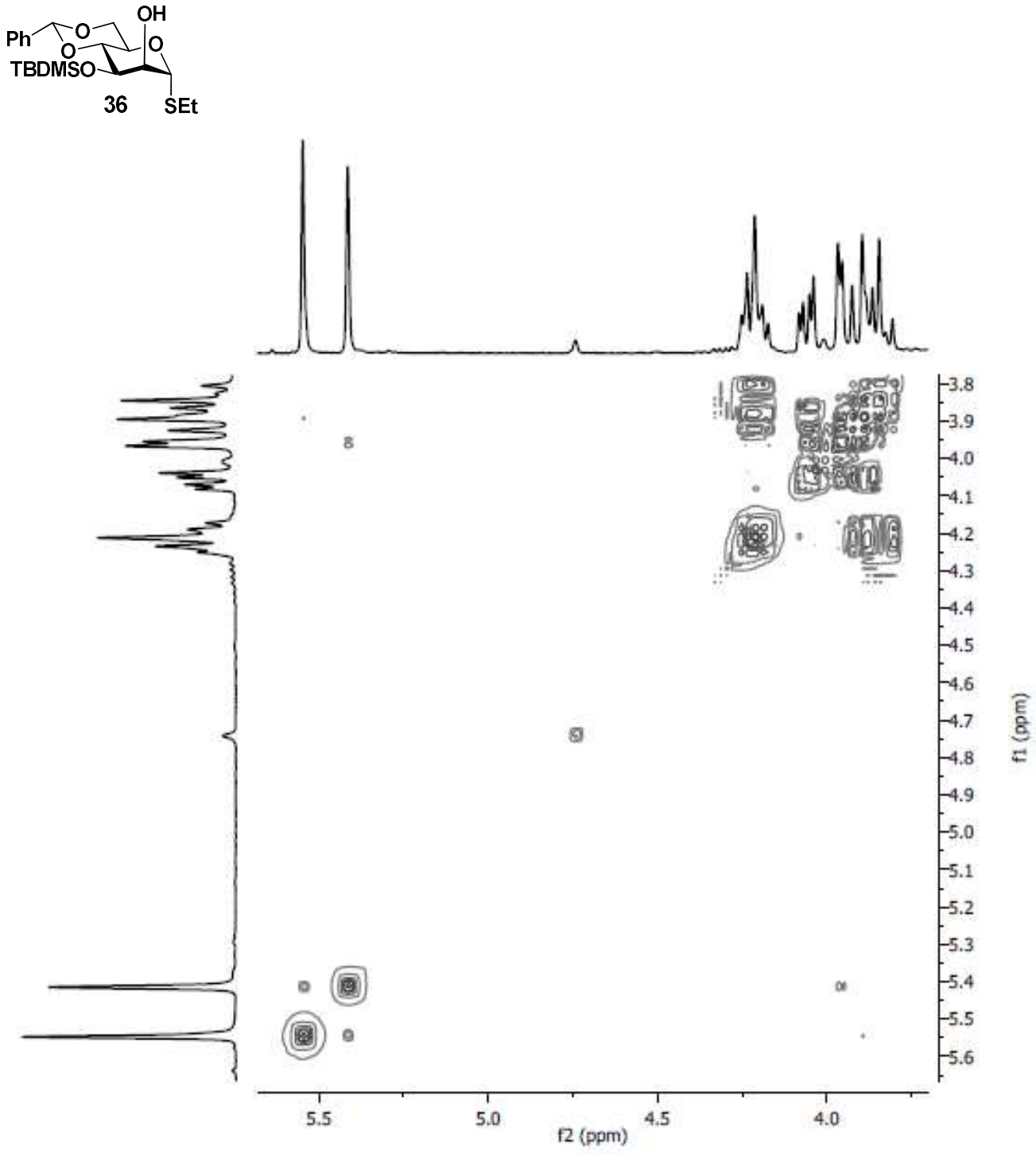


$CDCl_3$ 300 MHz

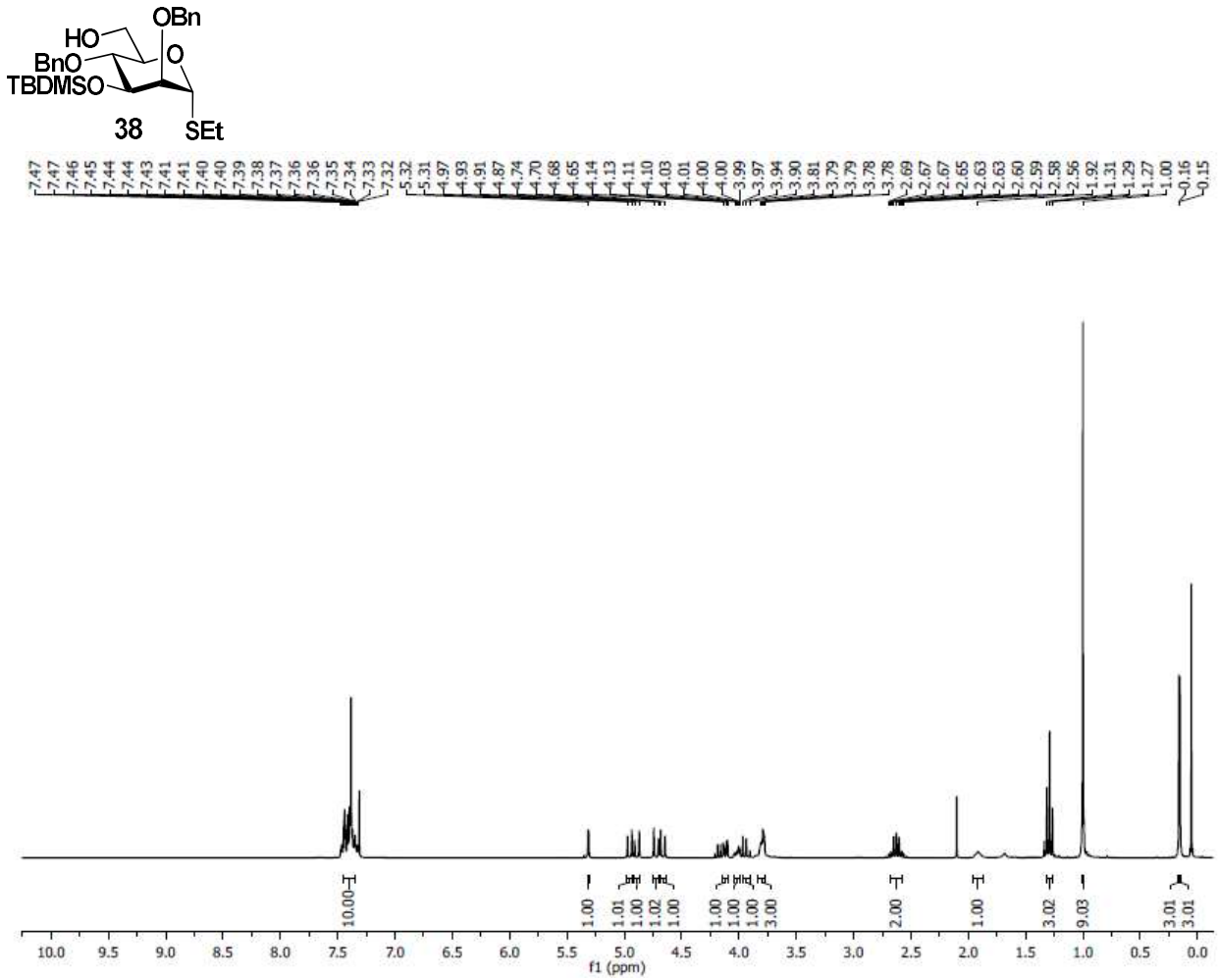

OH
Ph
O
O
O
TBDMSO
36
SEt


137.6
129.0
128.3
126.3
102.0
83.8
79.4
73.6
70.3
68.8
63.8
25.8
25.0
18.3
15.0
-4.2
-4.9
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

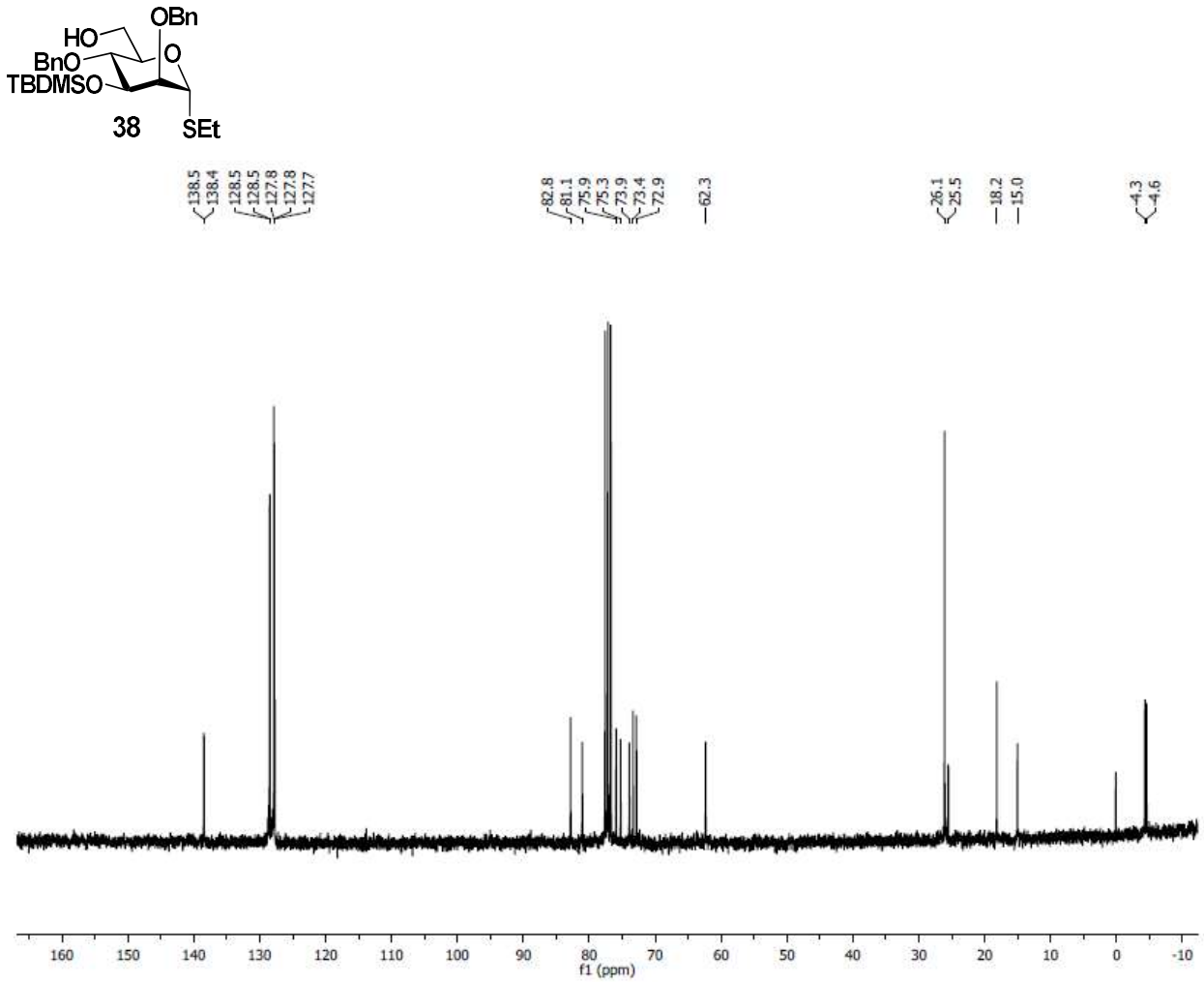
$CDCl_3$ 75 MHz



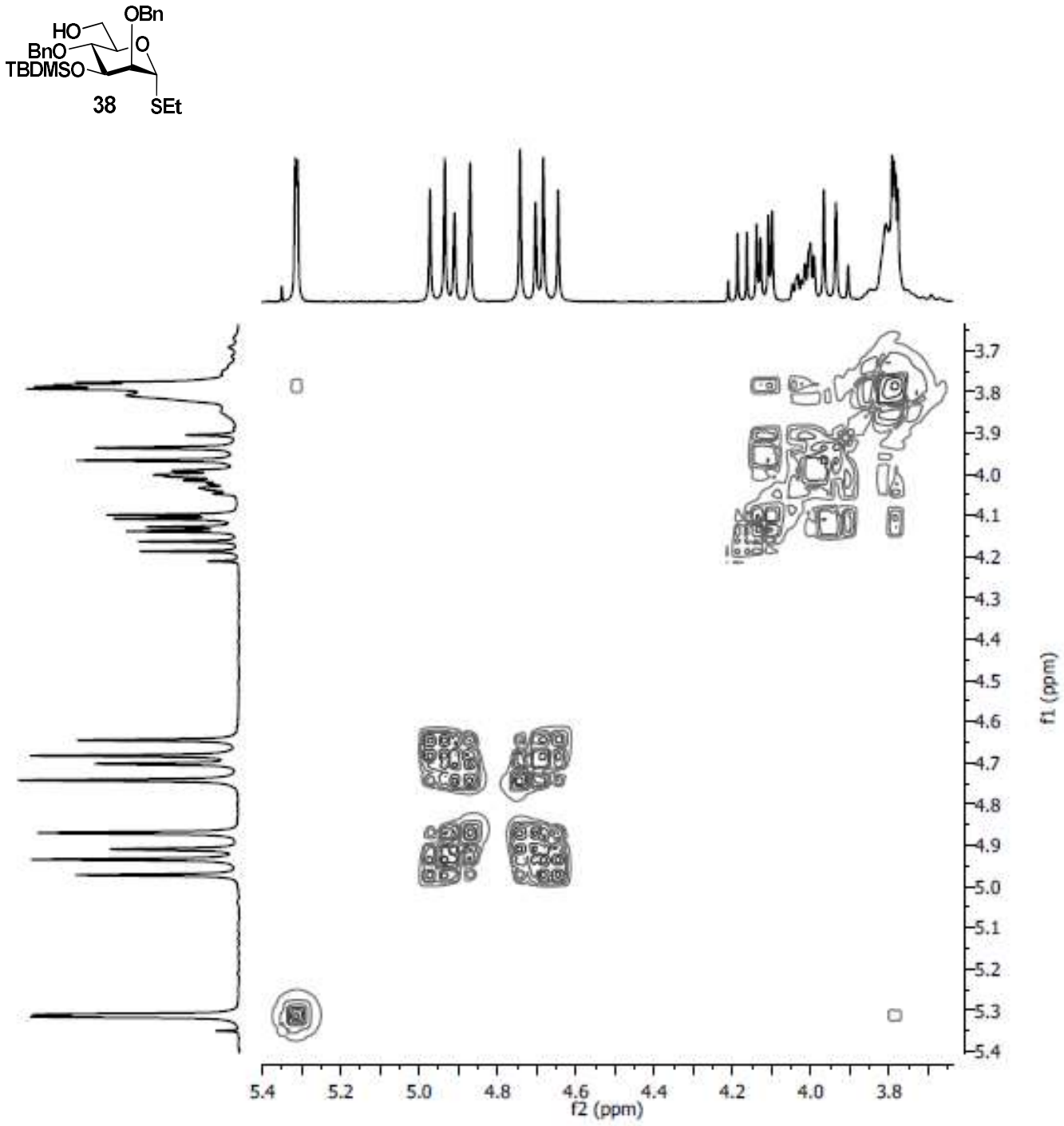
$CDCl_3$ 300 MHz



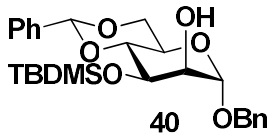
$CDCl_3$ 300MHz

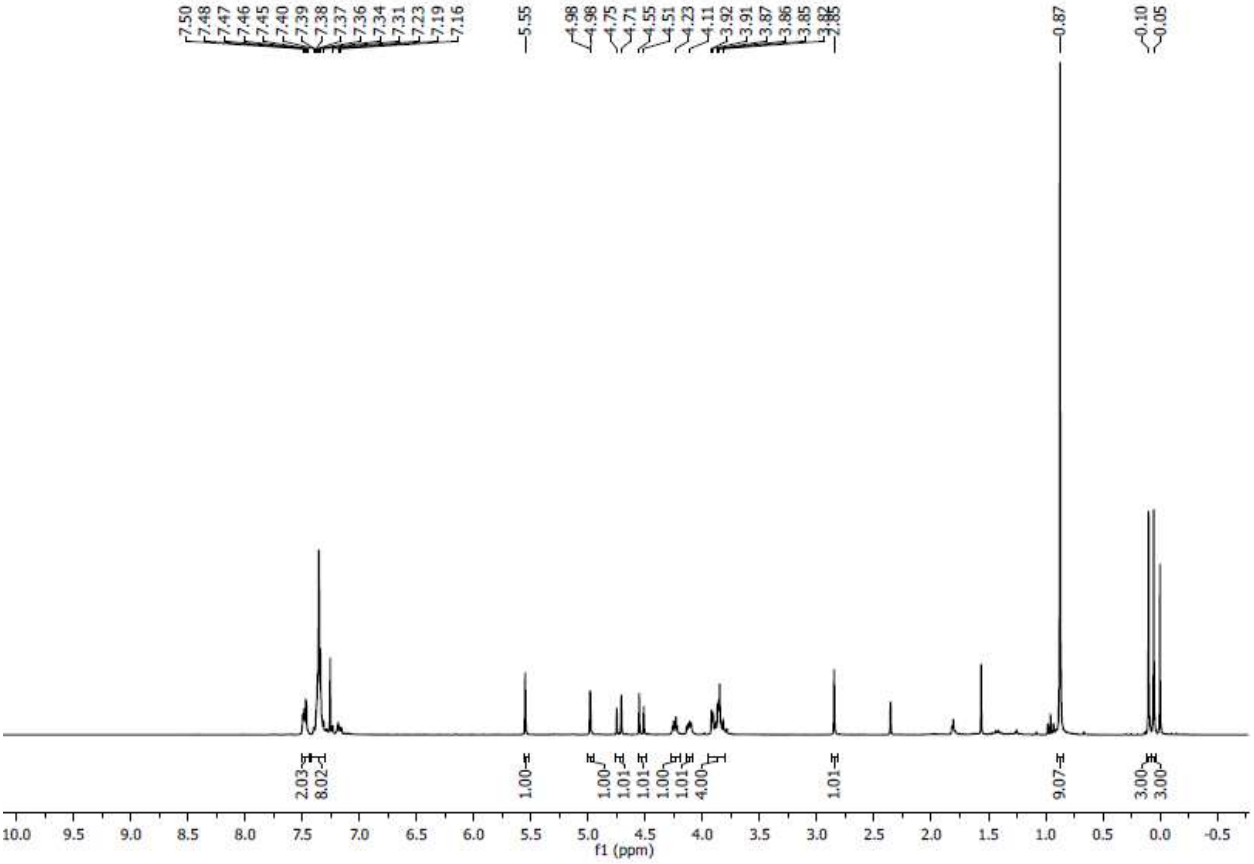

OBn
HO
O
BnO
TBDMSO
38
SEt
138.5
138.4
128.5
128.5
127.8
127.8
127.7
82.8
81.1
75.9
75.3
73.9
73.4
72.9
62.3
26.1
25.5
18.2
15.0
-4.3
-4.6
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

$CDCl_3$ 75MHz

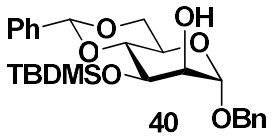


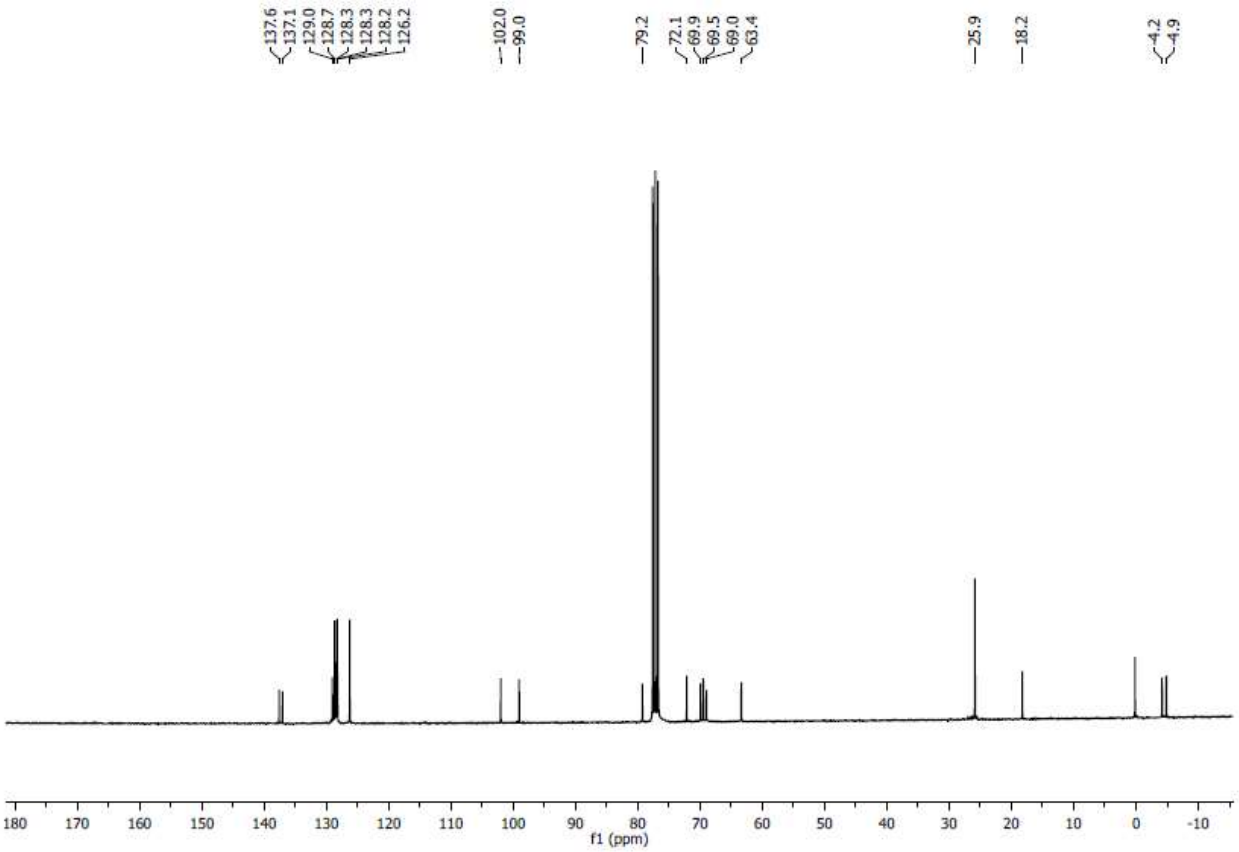
$CDCl_3$ 300MHz



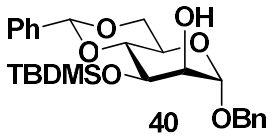


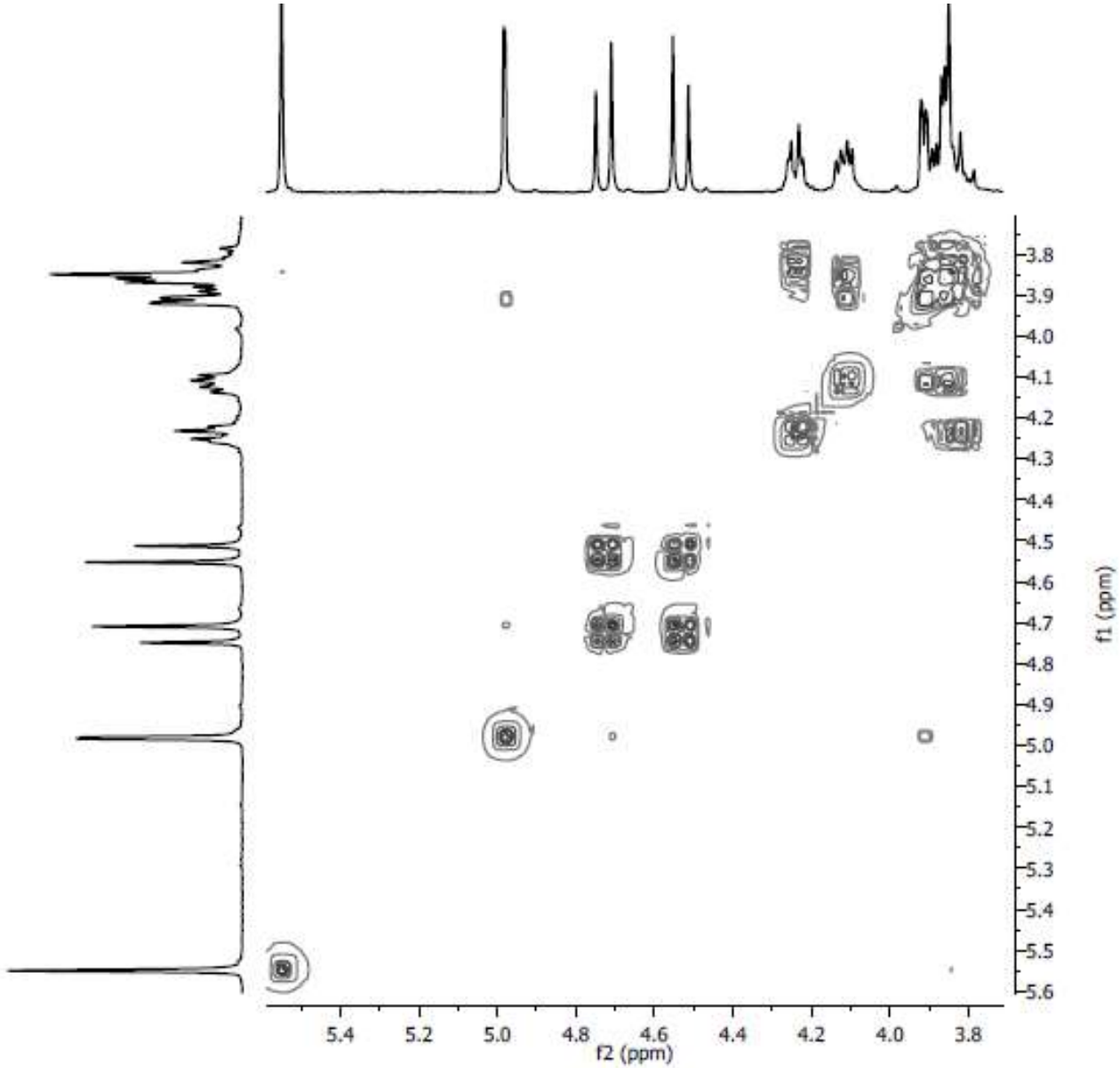
$CDCl_3$ 300MHz


Ph
O
O
OH
O
TBDMSO
40
OBn

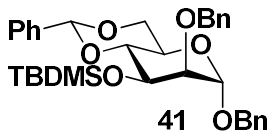

137.6
137.1
129.0
128.7
128.3
128.3
128.2
126.2
102.0
99.0
79.2
72.1
69.9
69.5
69.0
63.4
25.9
18.2
-4.2
-4.9
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

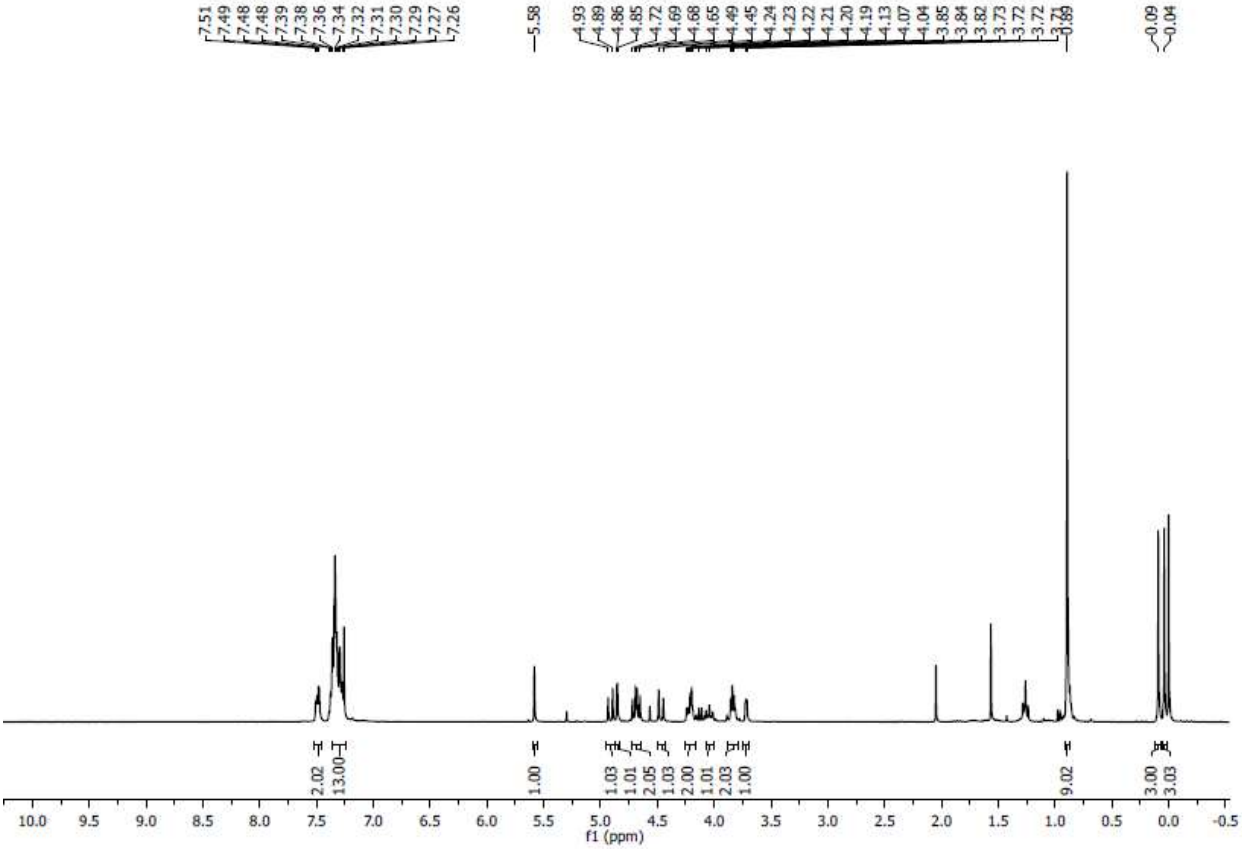
$CDCl_3$ 75MHz



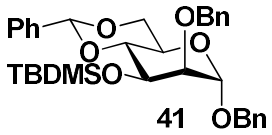


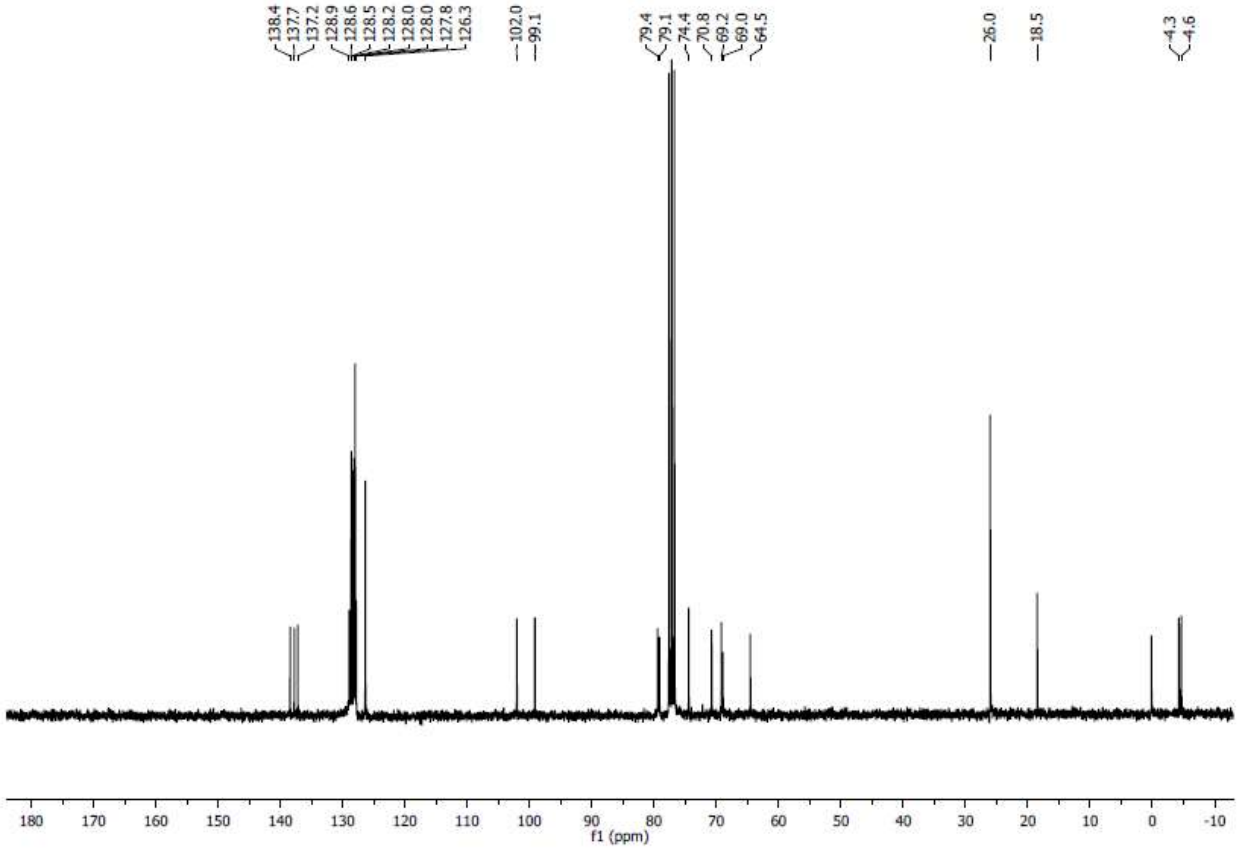
$CDCl_3$ 300MHz



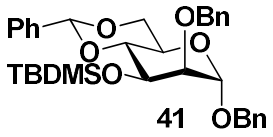


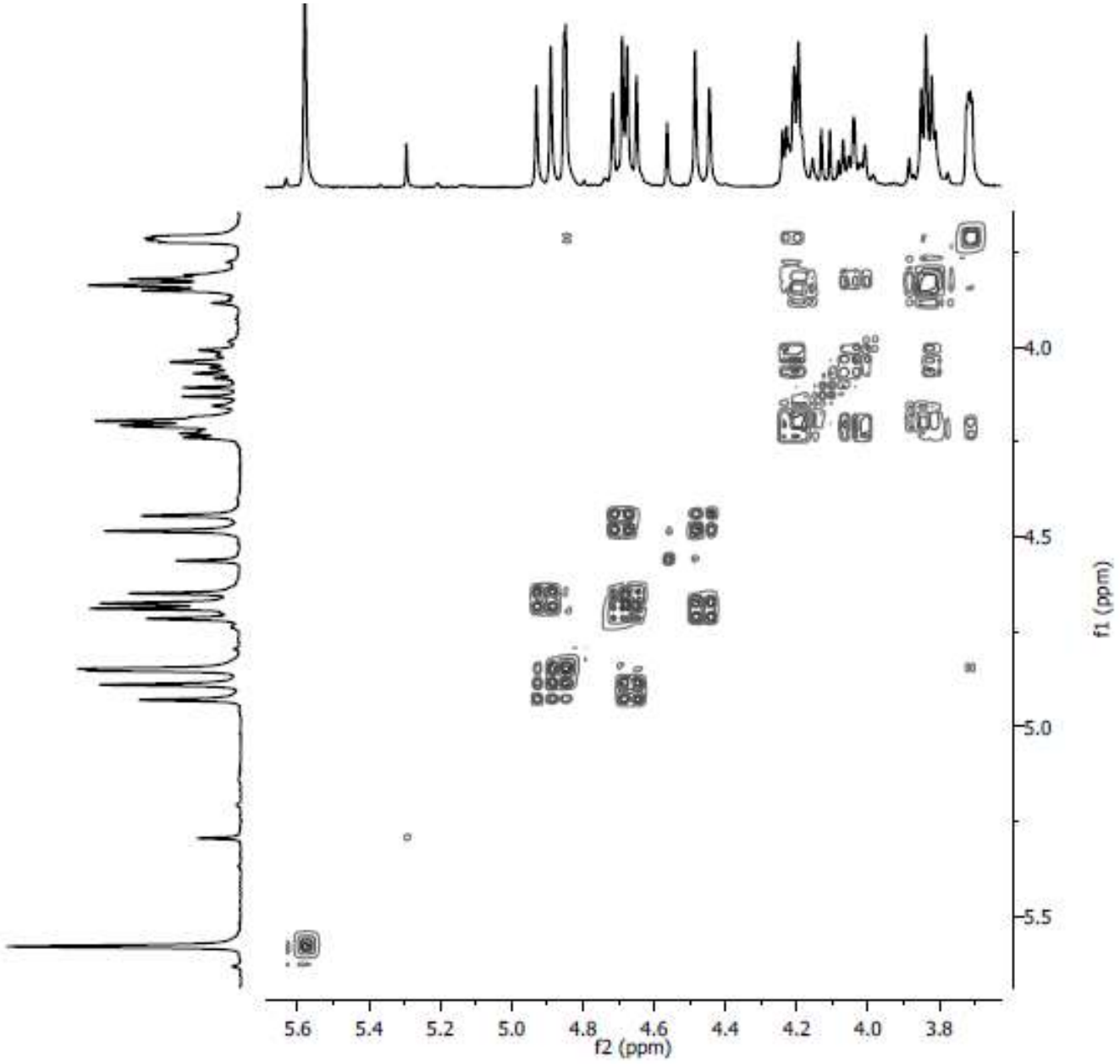
$CDCl_3$ 300MHz


Ph
O
OBn
O
O
TBDMSO
41
OBn

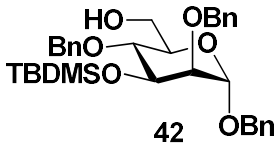

138.4
137.7
137.2
128.9
128.6
128.5
128.2
128.0
128.0
127.8
126.3
102.0
99.1
79.4
79.1
74.4
70.8
69.2
69.0
64.5
26.0
18.5
4.3
-4.6
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

$CDCl_3$ 75MHz

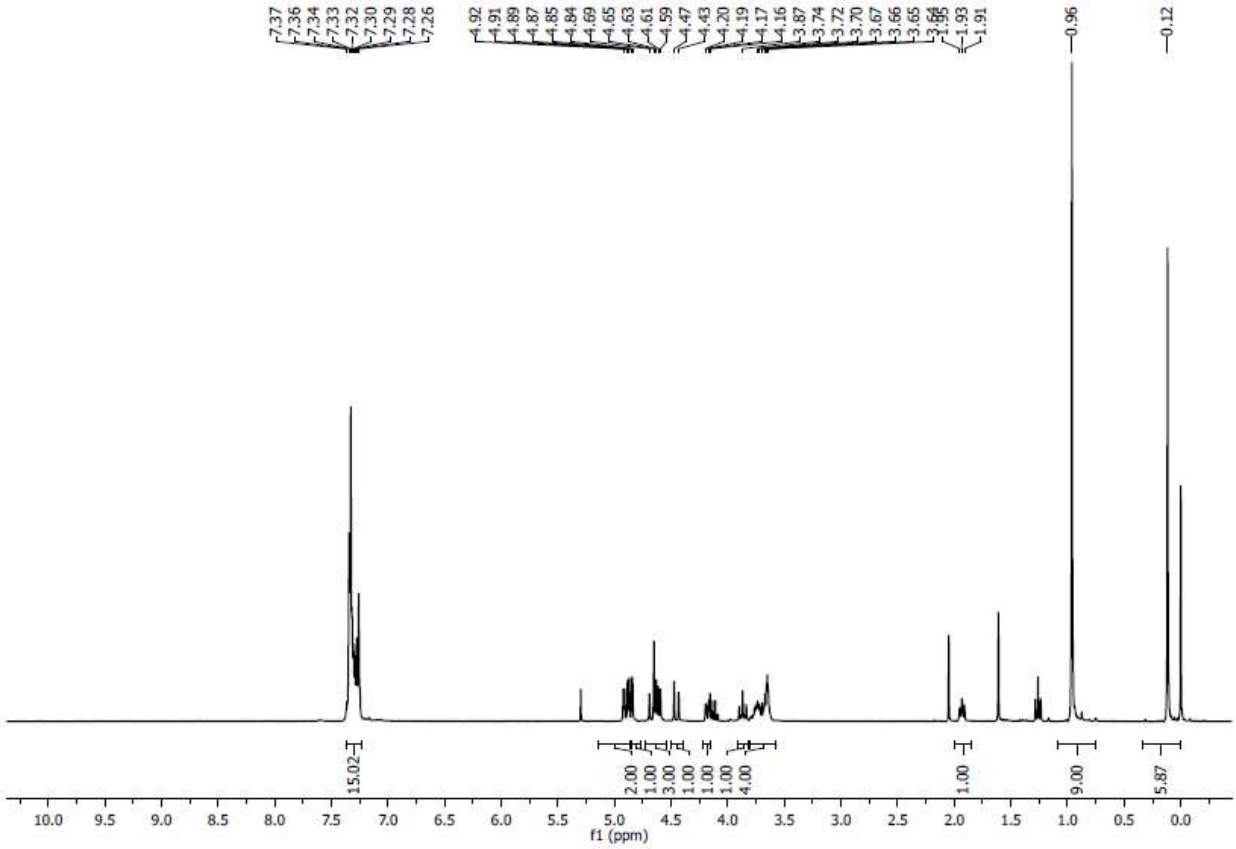




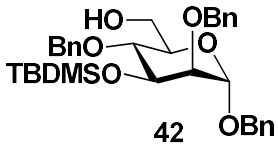
$CDCl_3$ 300MHz



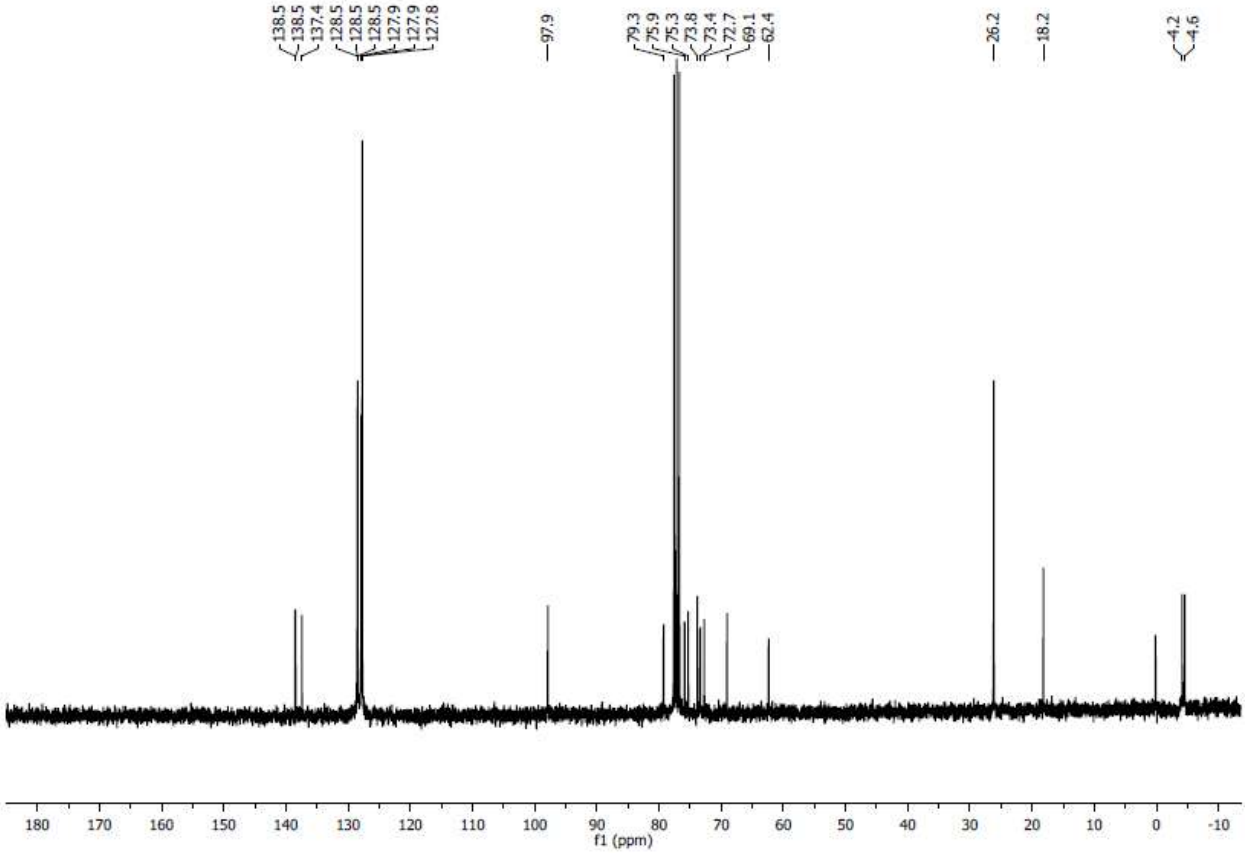
42



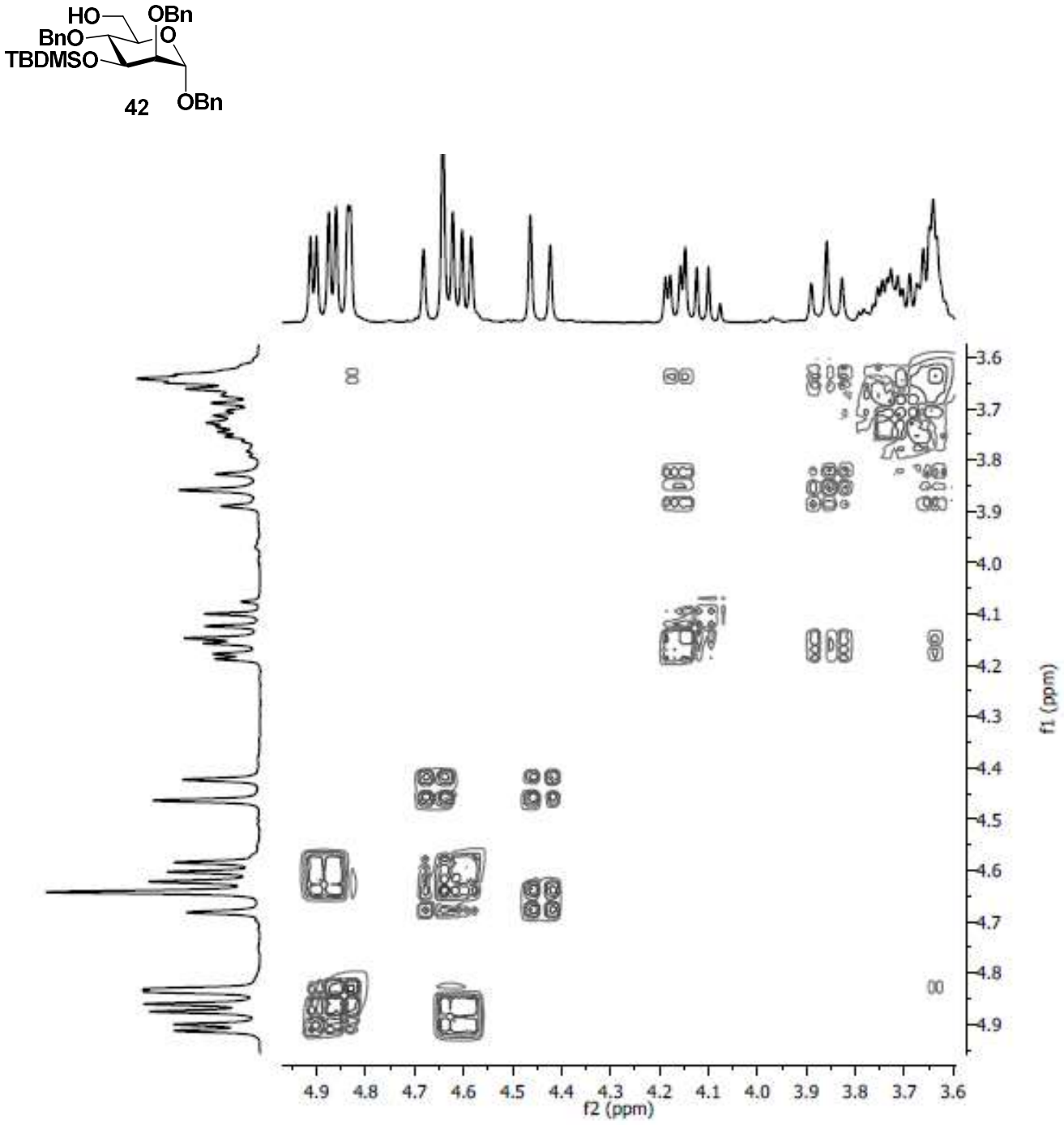
$CDCl_3$ 300MHz



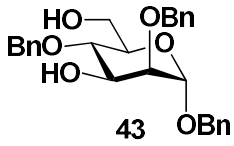
42

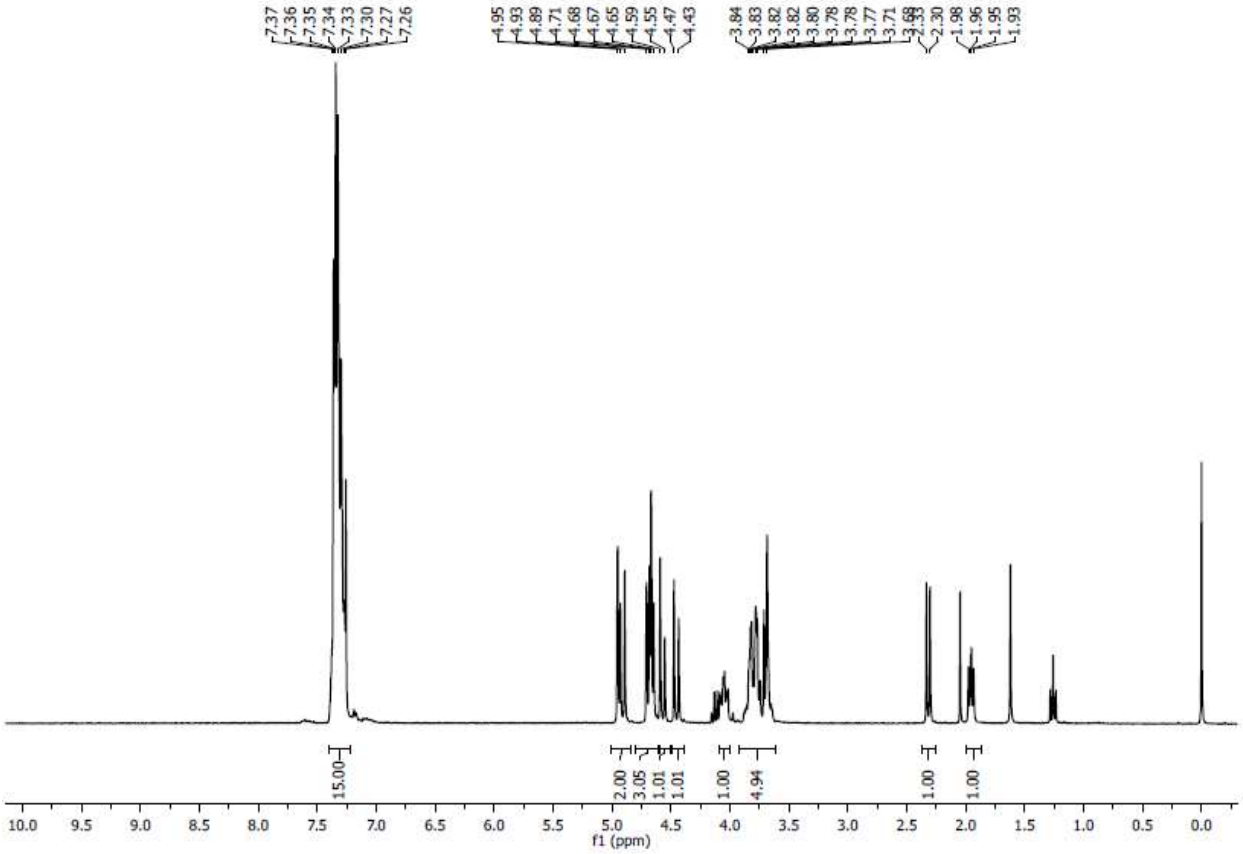


$CDCl_3$ 75MHz

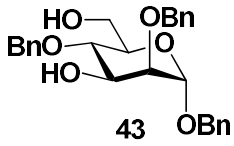


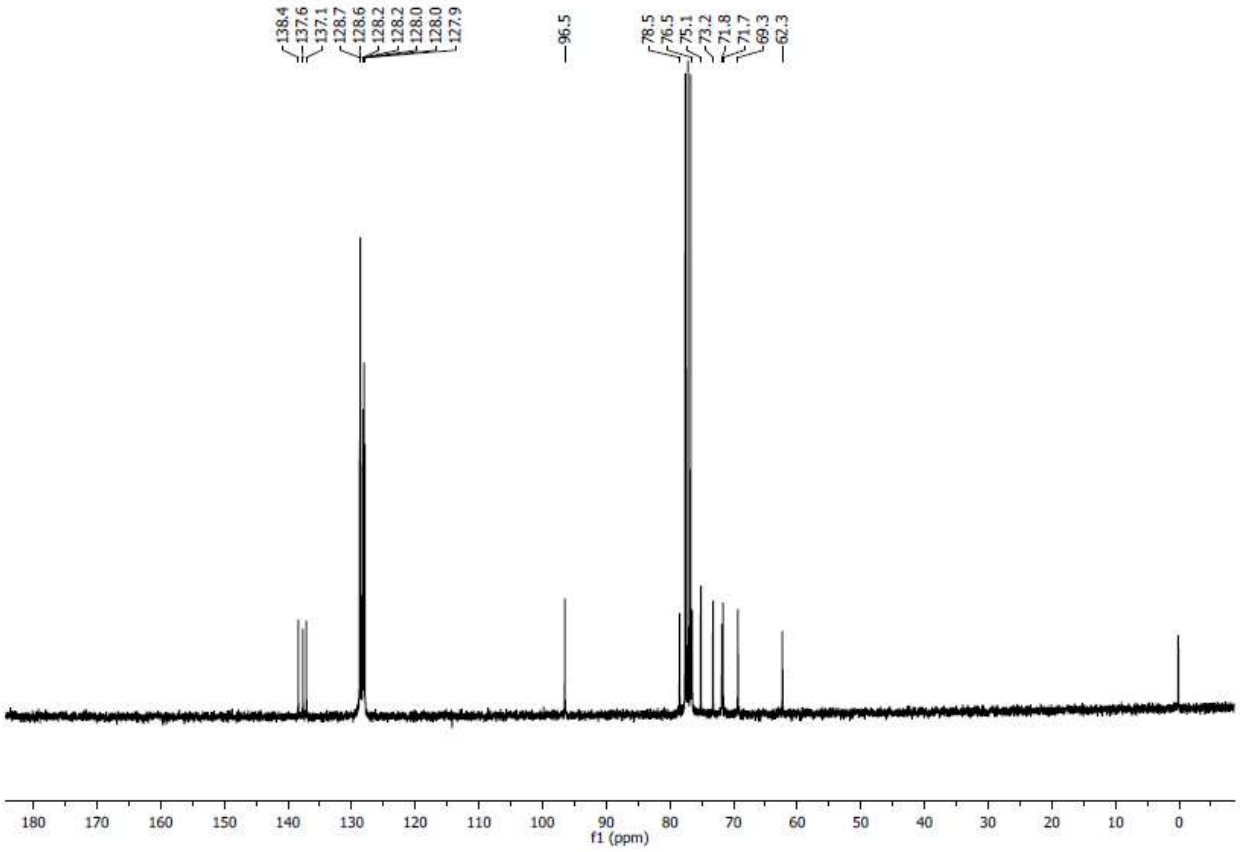
$CDCl_3$ 300MHz



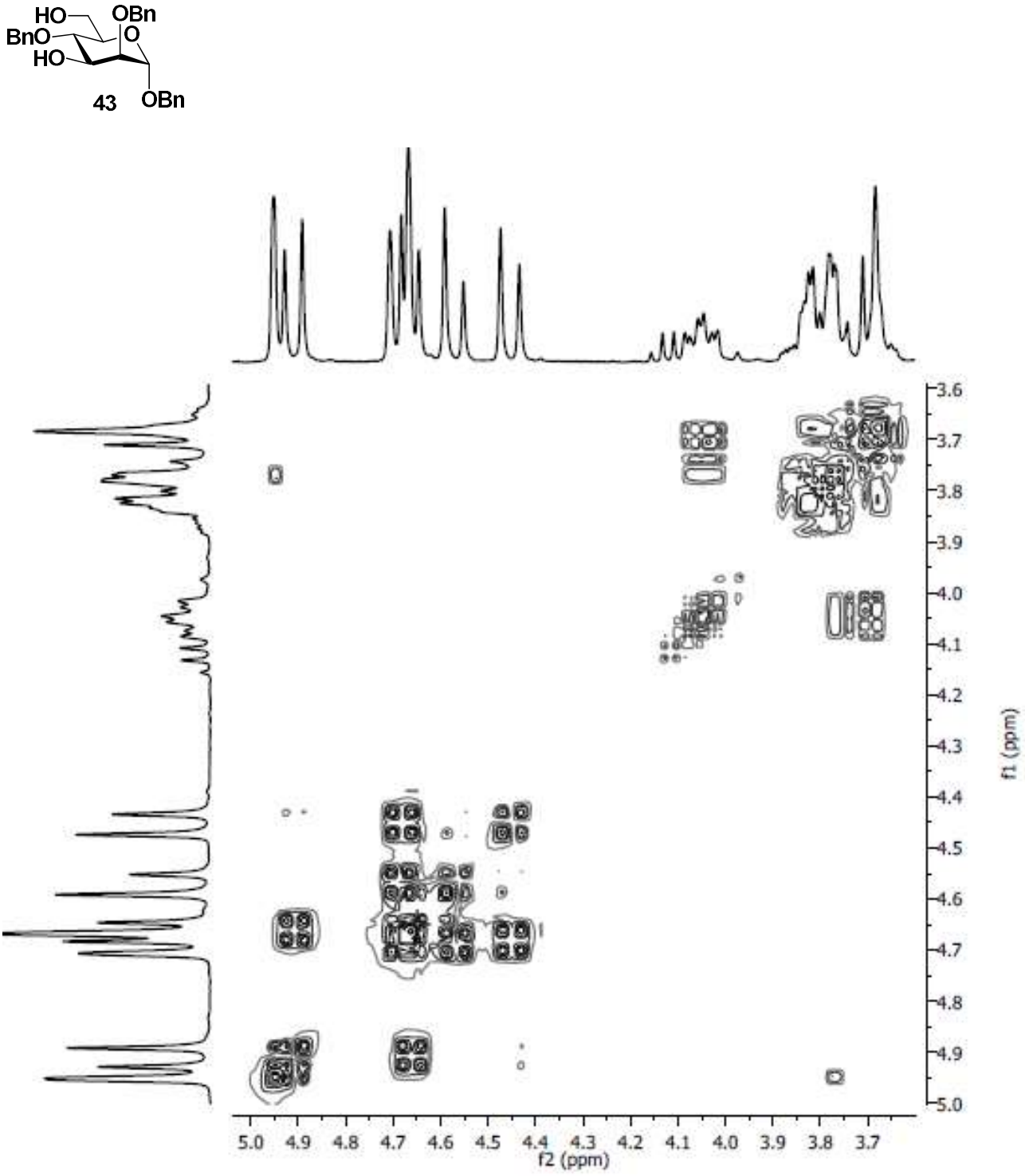


$CDCl_3$ 300MHz

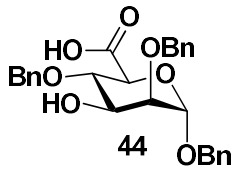

HO
OBn
BnO
O
HO
43
OBn

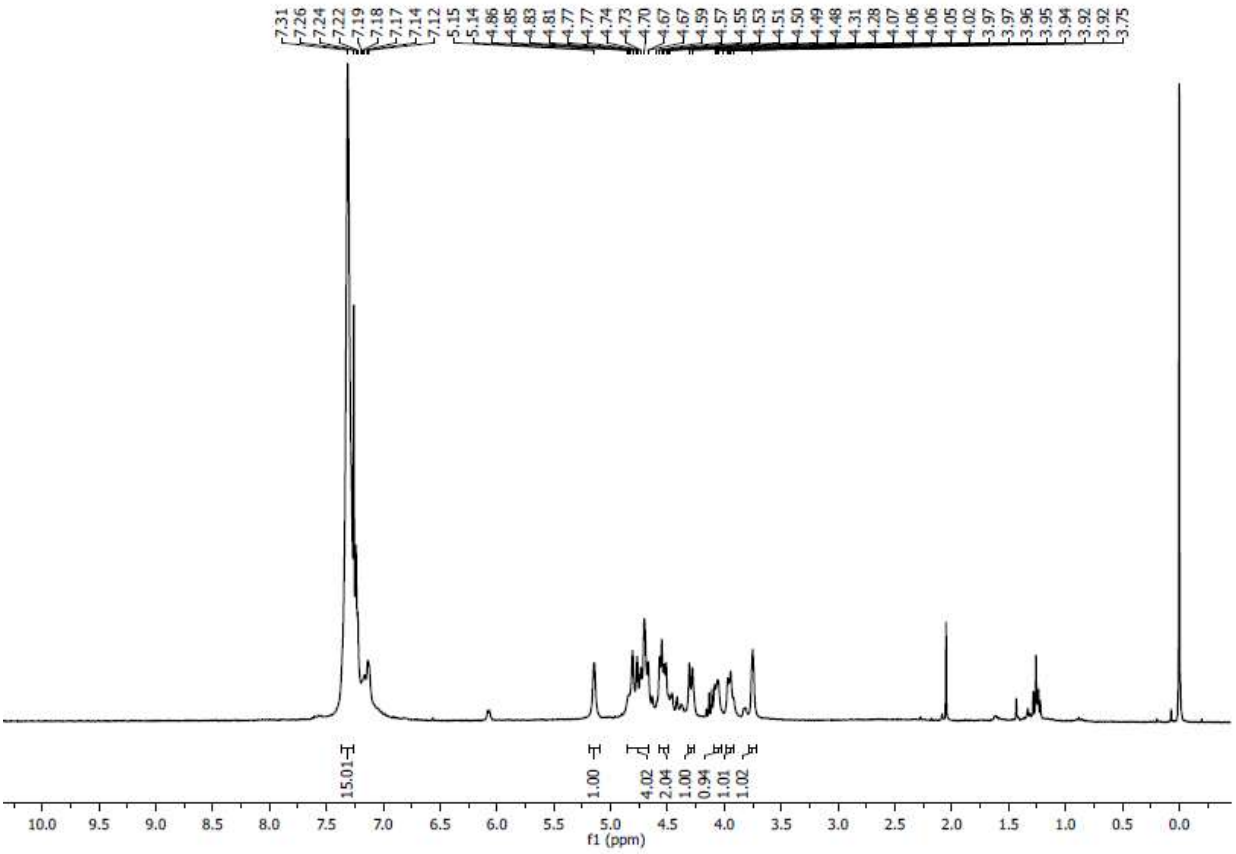

138.4
137.6
137.1
128.7
128.6
128.2
128.2
128.0
128.0
127.9
96.5
78.5
76.5
75.1
73.2
71.8
71.7
69.3
62.3
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

$CDCl_3$ 75MHz

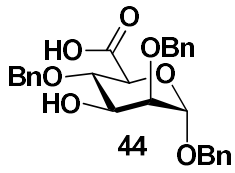


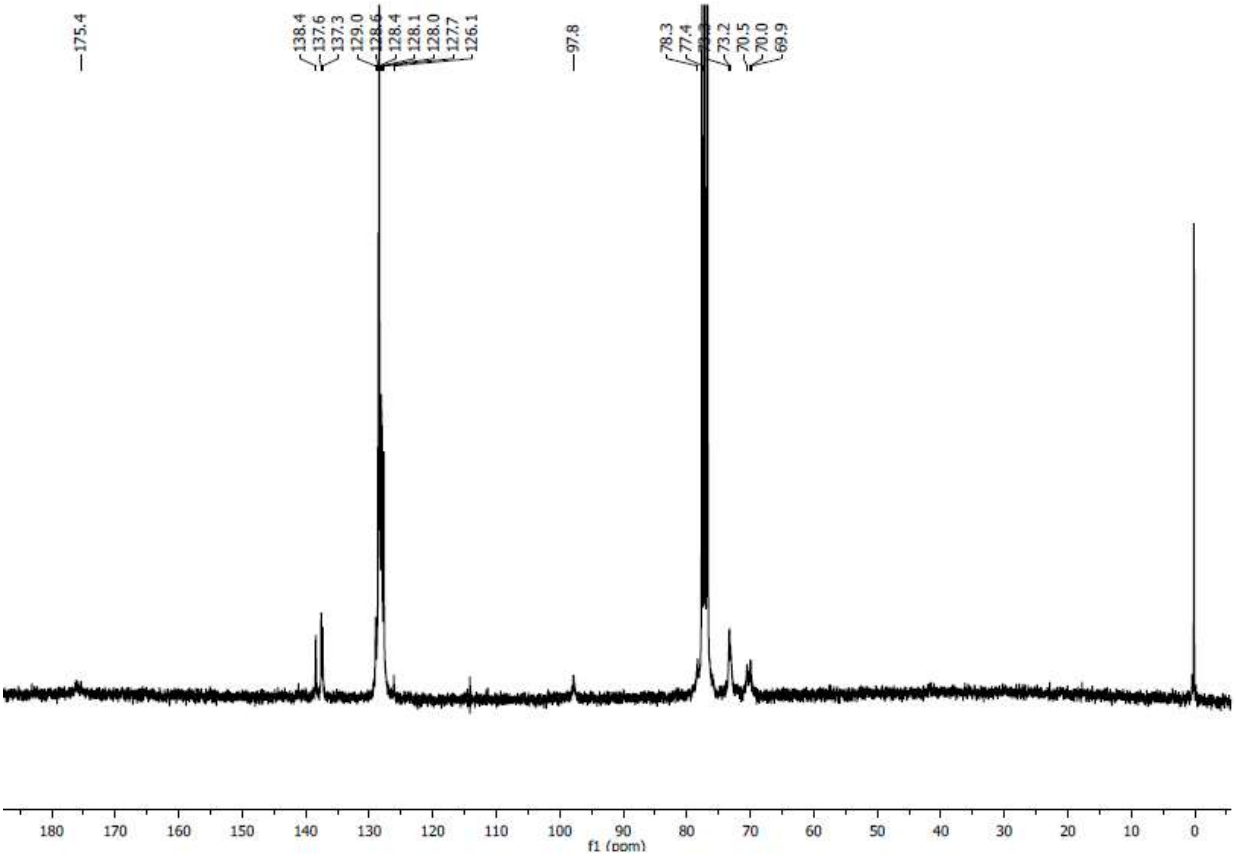
$CDCl_3$ 300MHz



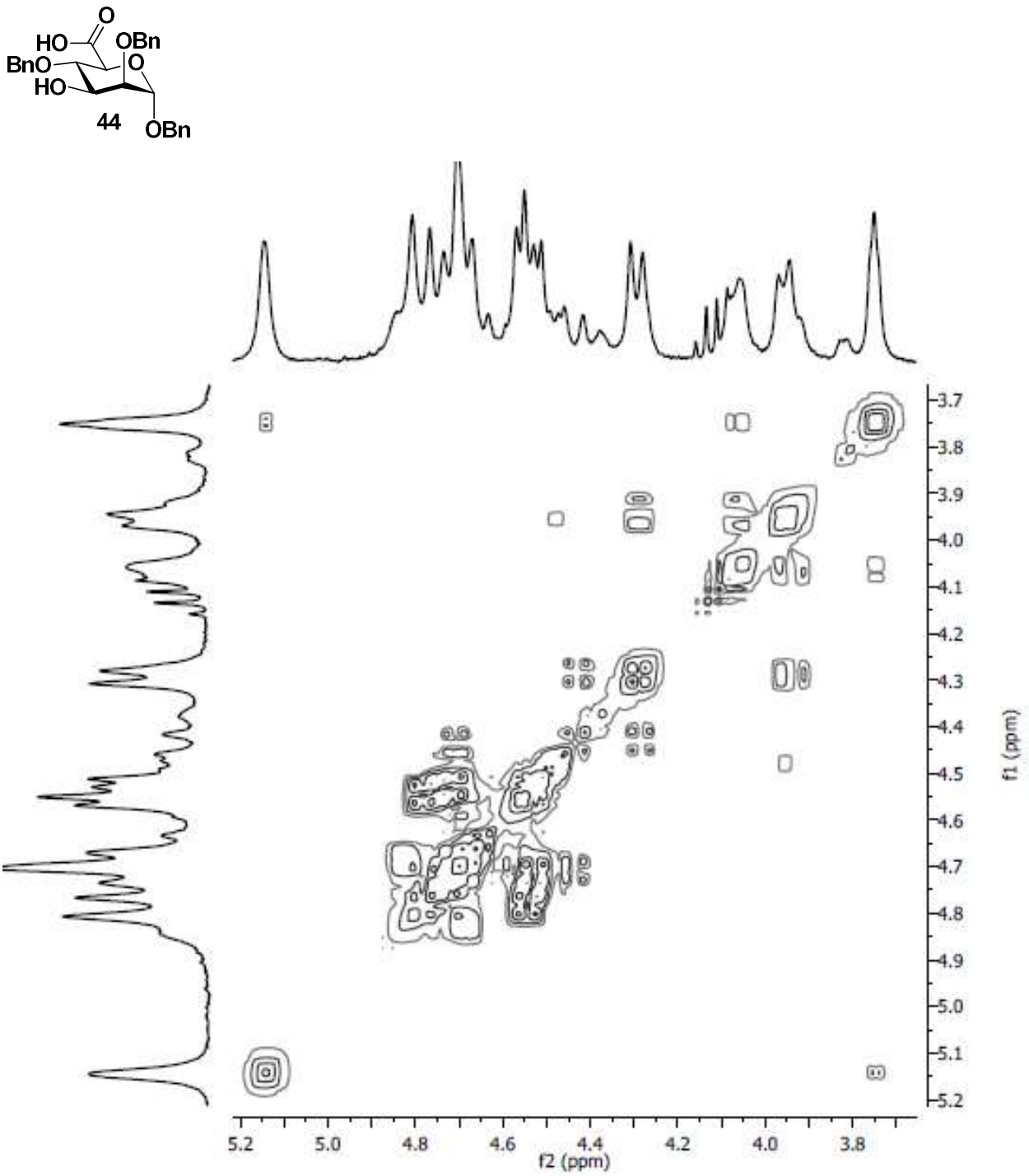


$CDCl_3$ 300MHz

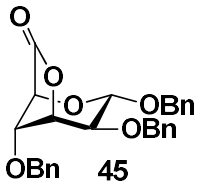

O
HO
OBn
BnO
O
HO
44
OBn


175.4
138.4
137.6
137.3
129.0
128.6
128.4
128.1
128.0
127.7
126.1
97.8
78.3
77.4
73.2
70.5
70.0
69.9
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

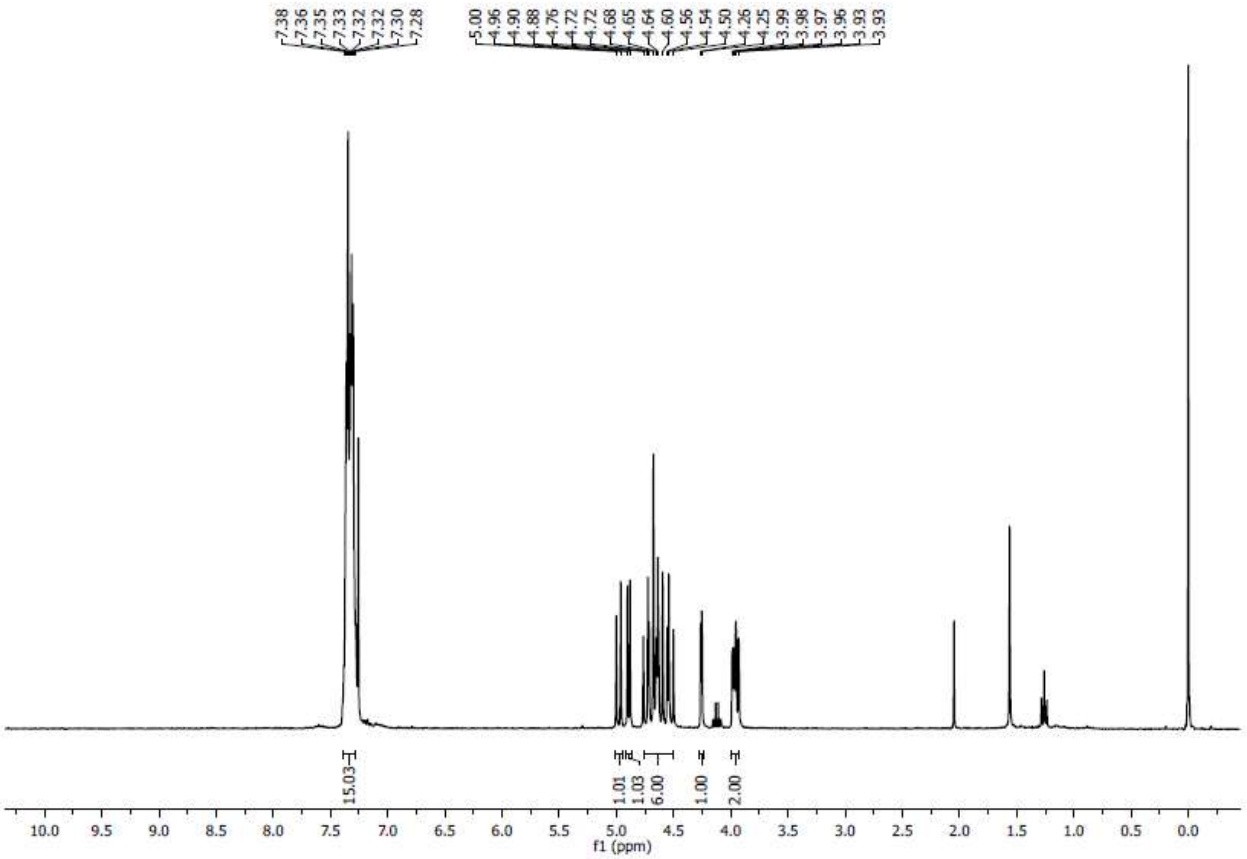
$CDCl_3$ 75MHz



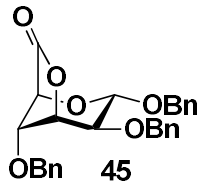
$CDCl_3$ 300MHz



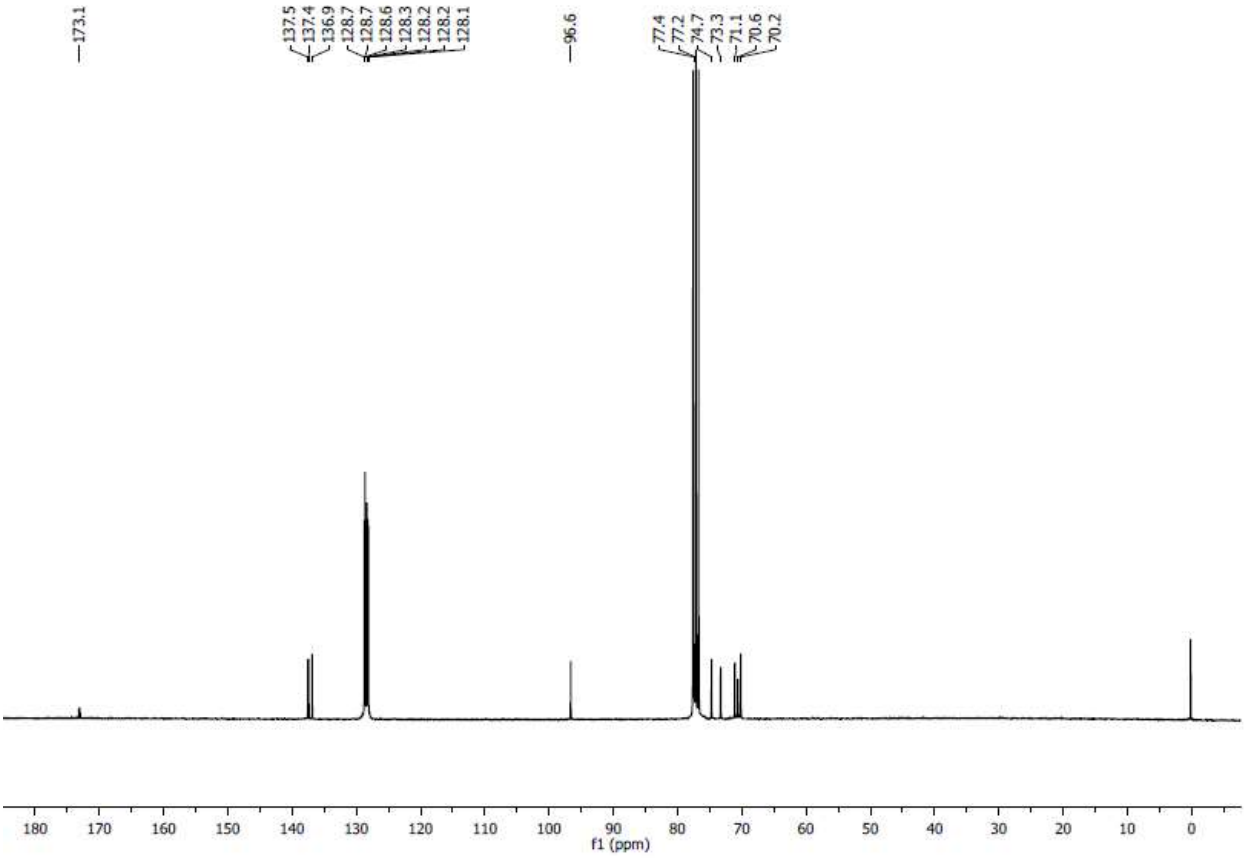
45



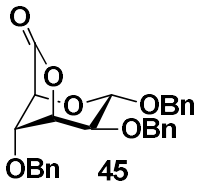
$CDCl_3$ 300MHz



45



$CDCl_3$ 75MHz



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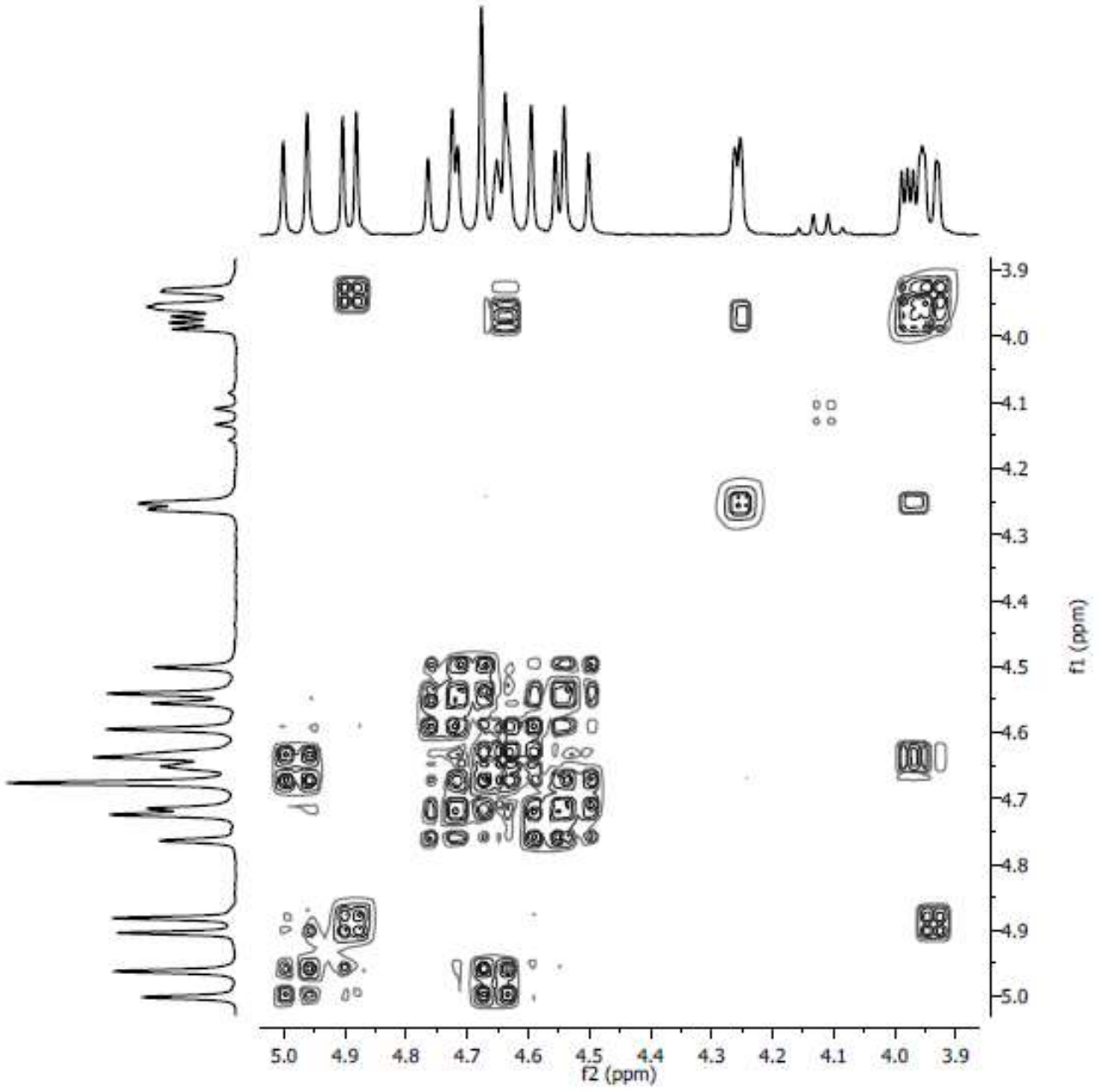

$CDCl_3$ 300MHz