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Supporting Information

Highly Convergent Synthesis of a β-Mannuronic Acid Alginate Hexadecasaccharide

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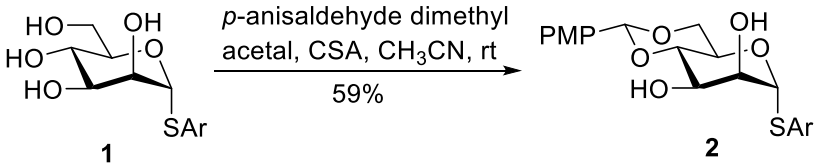
Contents

1. General Information. All reactions were performed with anhydrous solvents in oven-dried glassware with magnetic stirring under argon or nitrogen unless otherwise stated. The chemicals were used as supplied except where noted. Analytical thin layer chromatography (TLC) was conducted on precoated plates of silica gel (0.25-0.3 mm, Shanghai, China). The TLC plates were visualized by exposure to UV light or by staining with a sulfuric acid-ethanol solution. Silica gel column chromatography was performed on silica gel AR (100-200 mesh, Shanghai, China). Optical rotations (OR) were measured with a Rudolph Research Analytical Autopol I automatic polarimeter. NMR spectra were recorded with a Bruker Avance III 400, Bruker Avance III 500 or Bruker Avance III 600 spectrometer. The ^{1}H and ^{13}C NMR spectra were calibrated against the residual proton and carbon signals of the solvents as internal references ($CDCl_3$: δ_H = 7.26 ppm and δ_C = 77.2 ppm; D_2O: δ_H = 4.79). Multiplicities are quoted as singlet (s), broad singlet (br s), doublet (d), triplet (t), quartet (q), doublet of doublets (dd), doublet of triplets (dt), triplet of doublets (td) or multiplet (m). High-resolution mass spectra were recorded on ESI-TOF or MALDI-TOF spectrometers.

2. Experimental details and characterization data of new compounds

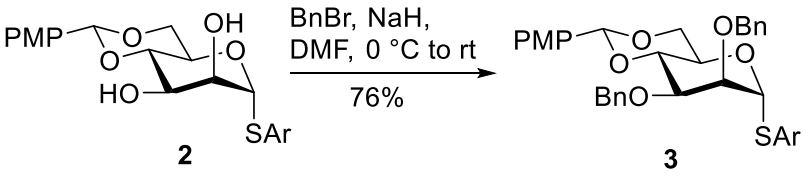
2.1. Synthesis of 2-methyl-5-*tert*-butylphenyl 4,6-*O*-*p*-methoxybenzylidine-1-thio-α-D-mannopyranoside 2



To a solution of thioglycoside **1**[1] (505 mg, 1.48 mmol) in anhydrous CH_3CN (5 mL) was added CSA (34 mg, 0.2 mmol) and *p*-anisaldehyde dimethyl acetal (126 μL, 0.7 mmol, 0.5 eq.) at room temperature. After stirring at room temperature for 1.5 h, *p*-anisaldehyde dimethyl acetal (126 μL, 0.7 mmol, 0.5 eq.) was added and the reaction was stirred at room temperature for another 2 h. TLC indicated that minor starting material **1** remained unreacted, and a small portion of *p*-anisaldehyde dimethyl acetal (75 μL, 0.4 mmol, 0.3 eq.) was added. After stirring at room temperature for another 1 h, the reaction mixture was quenched with Et_3N and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 20:1) to give **2** (400 mg, 59%) as a white

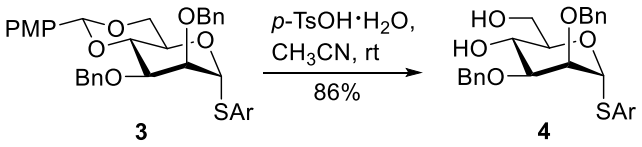
foam: $[\alpha]_D^{20}$ = +207.7 (*c* 0.64, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 2.0 Hz, 1 H), 7.44 (d, *J* = 8.8 Hz, 2 H), 7.23 (dd, *J* = 2.0, 8.0 Hz, 1 H), 7.15 (d, *J* = 8.0 Hz, 1 H), 6.91 (d, *J* = 8.8 Hz, 2 H), 5.53 (s, 1 H), 5.50 (s, 1 H), 4.35 (td, *J* = 4.8, 10.0 Hz, 1 H), 4.27 (d, *J* = 2.4 Hz, 1 H), 4.18 (dd, *J* = 5.2, 10.4 Hz, 1 H), 4.12 (dd, *J* = 2.0, 9.2 Hz, 1 H), 3.99 (t, *J* = 9.6 Hz, 1 H), 3.85–3.80 (m, 4 H), 3.17–3.14 (m, 2 H), 2.41 (s, 3 H), 1.31 (s, 9 H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 160.5, 150.0, 136.8, 132.3, 130.2, 129.9, 129.7, 127.8, 125.2, 113.9, 102.4, 87.9, 79.2, 72.8, 69.2, 68.7, 64.5, 55.5, 34.6, 31.5, 20.4; HRMS (ESI) *m/z* calcd for $C_{25}H_{32}O_6SNa$ $[M + Na]^+$ 483.1817, found 483.1816.

2.2. Synthesis of 2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-4,6-*O*-*p*-methoxy benzylidine-1-thio-α-D-mannopyranoside 3



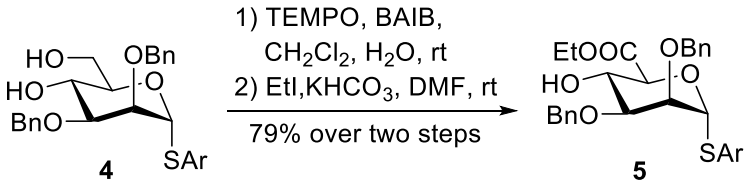
To a solution of **2** (474 mg, 1.03 mmol) in anhydrous DMF (5 mL) was added NaH (165 mg, 60%, 4.1 mmol) and BnBr (367 μL, 3.1 mmol) at 0 ℃. The reaction mixture was warmed to room temperature and then stirred overnight. The reaction was quenched with sat. aq. $NaHCO_3$, diluted with CH_2Cl_2, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 25:1) to give **3** (501 mg, 76%) as a white foam: $[\alpha]_D^{20}$ = +103.9 (*c* 0.38, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, *J* = 2.0 Hz, 1 H), 7.46 (d, *J* = 8.8 Hz, 2 H), 7.38–7.28 (m, 10 H), 7.23 (dd, *J* = 2.0, 8.0 Hz, 1 H), 7.14 (d, *J* = 8.0 Hz, 1 H), 6.92 (d, *J* = 8.8 Hz, 2 H), 5.63 (s, 1 H), 5.43 (d, *J* = 1.2 Hz, 1 H), 4.84 (d-like, *J* = 12.4 Hz, 1 H), 4.75 (s, 2 H), 4.67 (d-like, *J* = 12.0 Hz, 1 H), 4.36–4.30 (m, 2 H), 4.20 (m, 1 H), 4.09 (dd, *J* = 1.2, 3.2 Hz, 1 H), 4.02 (dd, *J* = 3.2, 9.2 Hz, 1 H), 3.90 (t, *J* = 10.0 Hz, 1 H), 3.83 (s, 3 H), 2.32 (s, 3 H), 1.30 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.1, 150.0, 138.6, 137.9, 136.9, 132.6, 130.3, 130.2, 128.6, 128.5, 128.3, 128.1, 127.8, 127.7, 127.6, 125.3, 113.7, 101.7, 87.2, 79.3, 78.3, 76.7, 73.3, 73.2, 68.7, 65.7, 55.5, 34.6, 31.5, 20.4; HRMS (ESI) *m/z* calcd for $C_{39}H_{44}O_6SNa$ $[M + Na]^+$ 663.2756, found 663.2755.

2.3. Synthesis of 2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-mannopyranoside 4



To a solution of **3** (4.15 g, 6.48 mmol) in anhydrous MeCN (40 mL) was added *p*-TsOH·H_2O (2.0 g, 10.6 mmol) at room temperature. After stirring at room temperature for 3 h, the reaction was quenched with Et_3N and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 3:1) to give **4** (2.9 g, 86%) as a white foam: $[\alpha]_D^{20}$ = +24.8 (*c* 0.97, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (d, *J* = 2.0 Hz, 1 H), 7.35–7.21 (m, 11 H), 7.13 (d, *J* = 8.0 Hz, 1 H), 5.46 (d, *J* = 1.2 Hz, 1 H), 4.65 (d-like, *J* = 12.4 Hz, 1 H), 4.58 (d-like, *J* = 12.0 Hz, 2 H), 4.50 (d-like, *J* = 12.0 Hz, 1 H), 4.14 (m, 2 H), 4.03 (dd, *J* = 1.6, 2.8 Hz, 1 H), 3.84 (br s, 2 H), 3.75 (m, 1 H), 2.88 (s, 1 H), 2.33 (s, 3 H), 1.29 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.0, 137.9, 137.8, 136.9, 132.7, 130.3, 130.2, 128.7, 128.6, 128.2, 128.1, 128.0, 125.3, 85.9, 79.9, 75.8, 73.6, 72.4, 72.0, 67.4, 62.8, 34.6, 31.5, 20.4; HRMS (ESI) *m/z* calcd for $C_{31}H_{38}O_5SNa$ $[M + Na]^+$ 545.2338, found 545.2339.

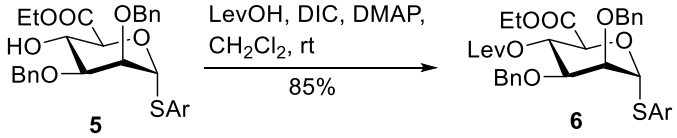
2.4. Synthesis of ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-mannopyranosyl) uronate 5



To a solution of **4** (2.9 g, 5.6 mmol) in dichloromethane and water (2/1, v/v, 60 mL) was added TEMPO (176 mg, 1.1 mmol) and BAIB (4.5 g, 14.1 mmol). After stirring at room temperature for 1 h, the reaction was quenched with sat. aq. $Na_2S_2O_3$, diluted with EtOAc, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure to give the corresponding carboxylic acid. To a solution of the above carboxylic acid in anhydrous DMF (40 mL) was added $KHCO_3$ (2.3 g, 22.6 mmol) and EtI (3.6 mL, 45.2 mmol) at room temperature.

After being stirred at room temperature overnight, the reaction was quenched with acetic acid, diluted with CH_2Cl_2, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 4:1) to give **5** (2.5 g, 79% over two steps) as a white foam: $[\alpha]_D^{20}$ = +38.3 (*c* 0.42, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.60 (s, 1 H), 7.37–7.28 (m, 10 H), 7.23 (dd, *J* = 1.8, 7.8 Hz, 1 H), 7.14 (d, *J* = 7.8 Hz, 1 H), 5.54 (s, 1 H, H-1), 4.76–4.61 (m, 5 H), 4.41 (t, *J* = 9.0 Hz, 1 H), 4.29–4.22 (m, 2 H), 4.02 (m, 1 H), 3.77 (dd, *J* = 3.0, 9.0 Hz, 1 H), 3.12 (s, 1 H), 2.34 (s, 3 H), 1.31 (s, 9 H), 1.29 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 170.4, 150.1, 138.2, 137.8, 136.5, 132.9, 130.1, 129.7, 128.6, 128.5, 128.2, 128.0, 127.9, 125.1, 86.4 (C-1, $^1J_{C1,H1}$ = 167.5 Hz), 78.8, 76.0, 72.7, 72.5, 72.4, 68.8, 62.0, 34.7, 31.5, 20.4, 14.3; HRMS (ESI) *m/z* calcd for $C_{33}H_{40}O_6SNa$ $[M + Na]^+$ 587.2443, found 587.2444.

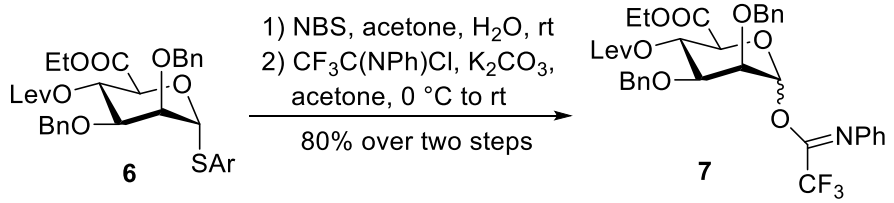
2.5. Synthesis of ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-4-*O*-levulinoyl-1-thio-α-D-mannopyranosyl) uronate 6



To a solution of **5** (1.2 g, 2.13 mmol) in anhydrous CH_2Cl_2 (50 mL) was added LevOH (1.1 mL, 10.7 mmol), DIC (1.7 mL, 10.7 mmol) and DMAP (1.3 g, 10.7 mmol) at room temperature. After stirring at room temperature for 5 h, the reaction was diluted with CH_2Cl_2 and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 3:1) to give **6** (1.2 g, 85%) as a white foam: $[\alpha]_D^{20}$ = +34.8 (*c* 0.28, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (s, 1 H), 7.33–7.26 (m, 10 H), 7.20 (dd, *J* = 2.0, 8.0 Hz, 1 H), 7.11 (d, *J* = 8.0 Hz, 1 H), 5.65 (d-like, *J* = 4.4 Hz, 1 H), 5.60 (t, *J* = 6.4 Hz, 1 H), 4.69 (d-like, *J* = 12.0 Hz, 1 H), 4.61–4.54 (m, 4 H), 4.16–4.08 (m, 1 H), 4.04–3.96 (m, 1 H), 3.87 (m, 2 H), 2.75–2.71 (m, 2 H), 2.58–2.55 (m, 2 H), 2.36 (s, 3 H), 2.19 (s, 3 H), 1.29 (s, 9 H), 1.14 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.4, 171.7, 168.0, 149.9, 137.9, 137.8, 136.5, 132.5, 130.1, 128.5, 128.2, 128.0, 127.9, 125.0, 75.1, 72.6, 69.8,

61.7, 38.0, 34.7, 31.4, 30.1, 28.1, 20.5, 14.1; HRMS (ESI) *m/z* calcd for $C_{38}H_{46}O_8SNa$ $[M + Na]^+$ 685.2811, found 685.2810.

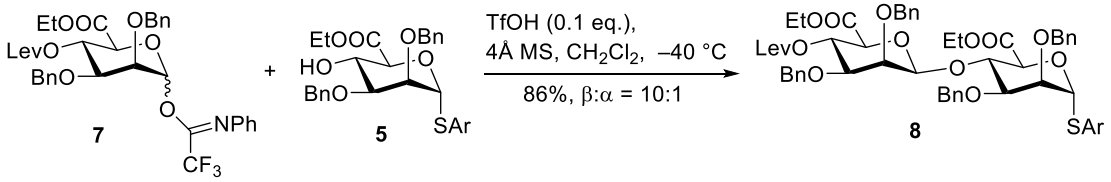
2.6. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-1-*O*-(*N*-phenyl-trifluoro acetimidoyl)-D-mannopyranosyl) uronate 7



To a solution of **6** (2.1 g, 3.17 mmol) in acetone and H_2O (15/1, v/v, 32 mL) was added NBS (2.3 g, 12.8 mmol) at room temperature. After stirring at room temperature for 1 h, the reaction was quenched with sat. aq. $Na_2S_2O_3$, diluted with EtOAc, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give the corresponding hemiacetal as a colorless syrup. To a solution of the resulting hemiacetal in acetone (105 mL) was added *N*-Phenyl-2,2,2-trifluoroacetimidoyl chloride[2] (804 mg, 3.9 mmol) and K_2CO_3 (428 mg, 3.1 mmol) at 0 ℃. The reaction mixture was warmed to room temperature and allowed to stir for 5 h. The mixture was quenched with Et_3N, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 3:1) to give **7** (1.7 g, 80% over two steps) as a white foam: $[\alpha]_D^{20}$ = –10.2 (*c* 0.57, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.25 (m, 12 H), 7.11 (t, *J* = 7.2 Hz, 1 H), 6.78 (d, *J* = 8.0 Hz, 2 H), 6.50 (br s, 1 H), 5.61 (t, *J* = 6.8 Hz, 1 H), 4.70–4.54 (m, 4 H), 4.41 (d, *J* = 6.0 Hz, 1 H), 4.17–4.03 (m, 2 H), 3.91 (dd, *J* = 2.8, 7.2 Hz, 1 H), 3.78 (m, 1 H), 2.76–2.71 (m, 2 H), 2.58 (t, *J* = 6.8 Hz, 2 H), 2.18 (s, 3 H), 1.17 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.3, 171.6, 167.7, 143.5, 142.8, 142.4, 137.6, 137.5, 128.9, 128.5, 128.2, 128.1, 128.0, 124.5, 119.6, 94.4, 74.7, 73.4, 73.3, 73.0, 72.9, 69.1, 62.1, 37.9, 30.0, 28.1, 14.0; HRMS (ESI) *m/z* calcd for $C_{35}H_{36}O_9NF_3Na$ $[M + Na]^+$ 694.2240, found 694.2241.

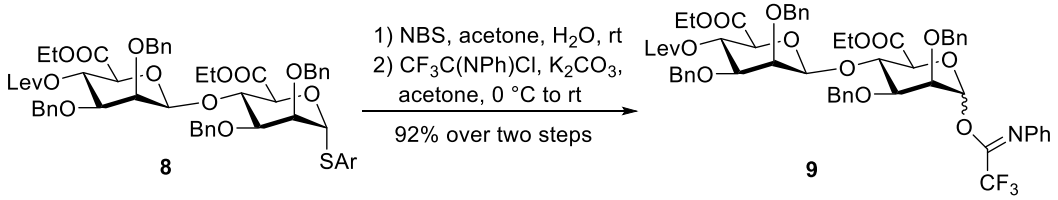
2.7. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-

mannopyranosyl) uronate 8



To a stirred mixture of donor **7** (191 mg, 0.28 mmol), acceptor **5** (107 mg, 0.19 mmol), and 4Å MS (150 mg) in anhydrous CH_2Cl_2 (2 mL) was added TfOH in CH_2Cl_2 (2 M, 10 μL, 0.02 mmol) at –40 ℃. After stirring at –40 ℃ for 1 h, the mixture was quenched with Et_3N, filtered, and concentrated under reduced pressure. The residue was purified by silica gel chromatography (petroleum ether/EtOAc: 4.5:1) to afford **8** (171 mg, 86%, β:α = 10:1) as a white foam. The major β-anomer: $[\alpha]_D^{20}$ = –12.6 (*c* 0.74, $CHCl_3$);^{1}H NMR (500 MHz, $CDCl_3$) δ 7.85 (s, 1 H), 7.49 (d, *J* = 7.5 Hz, 2 H), 7.37–7.21 (m, 19 H), 7.14 (d, *J* = 8.0 Hz, 1 H), 5.73 (br s, 1 H, H-1), 5.61 (t, *J* = 9.5 Hz, 1 H), 4.91 (d-like, *J* = 12.5 Hz, 1 H), 4.83 (d-like, *J* = 12.0 Hz, 1 H), 4.75 (m, 2 H), 4.68–4.58 (m, 6 H), 4.49 (d-like, *J* = 12.5 Hz, 1 H), 4.24–4.18 (m, 2 H), 4.14–4.07 (m, 2 H), 3.99–3.88 (m, 4 H), 3.56 (dd, *J* = 2.5, 9.5 Hz, 1 H), 2.70 (m, 2 H), 2.60 (t, *J* = 6.5 Hz, 2 H), 2.45 (s, 3 H), 2.16 (d-like, *J* = 1.0 Hz, 3 H), 1.36 (s, 9 H), 1.24 (t, *J* = 7.0 Hz, 3 H), 1.12 (t, *J* = 6.5 Hz, 3 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.1, 171.4, 168.9, 167.2, 149.6, 138.4, 138.3, 137.9, 137.8, 136.1, 133.1, 129.7, 129.5, 128.4, 128.3, 128.2, 128.1, 127.9, 127.8, 127.6, 127.5, 127.4, 124.4, 101.3 ($^1J_{C1,H1}$ = 156.5 Hz), 84.0 ($^1J_{C1,H1}$ = 165.5 Hz), 78.3, 76.7, 75.7, 74.2, 74.1, 73.6, 73.0, 72.2, 71.6, 68.9, 61.7, 61.3, 37.8, 34.5, 31.3, 29.8, 27.9, 20.4, 14.0, 13.9; HRMS (ESI) *m/z* calcd for $C_{60}H_{70}O_{14}SNa$ $[M + Na]^+$ 1069.4384, found 1069.4381.

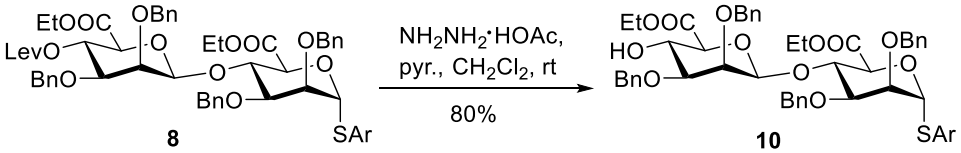
2.8. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-D-mannopyranosyl) uronate 9



To a solution of **8** (1.4 g, 1.34 mmol) in acetone and H_2O (15/1, v/v, 32 mL) was added NBS (942 mg, 5.3 mmol) at room temperature. After stirring at room temperature for 15 min, the reaction was quenched with sat. aq. $Na_2S_2O_3$, diluted with

EtOAc, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give the corresponding hemiacetal as a colorless syrup. To a solution of the resulting hemiacetal in acetone (32 mL) was added *N*-Phenyl-2,2,2-trifluoroacetimidoyl chloride (412 mg, 2.0 mmol) and K_2CO_3 (366 mg, 2.65 mmol) at 0 ℃. The reaction mixture was warmed to room temperature and allowed to stir overnight. The mixture was quenched with Et_3N, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give **9** (1.3 g, 92% over two steps) as a white foam: $[\alpha]_D^{20}$ = –42.3 (*c* 0.70, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40–7.22 (m, 22 H), 7.09 (t, *J* = 7.6 Hz, 1 H), 6.81 (d, *J* = 7.6 Hz, 2 H), 6.53 (br s, 1 H), 5.55 (t, *J* = 9.2 Hz, 1 H), 4.83–4.74 (m, 2 H), 4.69–4.38 (m, 9 H), 4.22–3.97 (m, 5 H), 3.89–3.83 (m, 3 H), 3.48 (dd, *J* = 2.8, 9.6 Hz, 1 H), 2.74–2.70 (m, 2 H), 2.57 (t, *J* = 6.8 Hz, 2 H), 2.17 (s, 3 H), 1.20 (t, *J* = 7.2 Hz, 3 H), 1.09 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.3, 171.6, 168.8, 167.3, 143.8, 143.1, 142.8, 138.3, 138.1, 137.9, 137.8, 128.8, 128.6, 128.5, 128.4, 128.3, 128.2, 128.0, 127.9, 127.8, 127.7, 127.6, 124.3, 119.6, 101.2, 94.3, 78.3, 76.2, 75.5, 74.4, 74.3, 74.2, 73.8, 73.7, 73.3, 72.6, 71.9, 69.0, 61.9, 37.9, 30.0, 28.1, 14.1, 14.0; HRMS (ESI) *m/z* calcd for $C_{57}H_{60}O_{15}NF_3Na$ $[M + Na]^+$ 1078.3813, found 1078.3815.

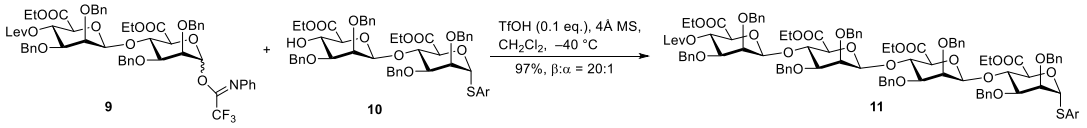
2.9. Synthesis of ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-mannopyranosyl) uronate 10



To a solution of **8** (126 mg, 0.12 mmol) in dichloromethane and pyridine (4/1, v/v, 5 mL) was added H_2NNH_2·HOAc (48 mg, 0.52 mmol) at room temperature. After stirring at room temperature for 4 h, the reaction was quenched with acetone, diluted with CH_2Cl_2, and washed with aq. HCl (1 M) and brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 2:1) to give **10** (91 mg, 80%) as a white foam: $[\alpha]_D^{20}$ = –17.7 (*c* 0.30, $CHCl_3$); ^{1}H NMR (400 MHz,

$CDCl_3$) δ 7.75 (s, 1 H), 7.43 (d, *J* = 6.8 Hz, 2 H), 7.35–7.22 (m, 18 H), 7.17 (dd, *J* = 2.0, 8.0 Hz, 1 H), 7.09 (d, *J* = 8.0 Hz, 1 H), 5.65 (d-like, *J* = 6.0 Hz, 1 H), 4.86 (d-like, *J* = 12.0 Hz, 1 H), 4.74–4.68 (m, 3 H), 4.63–4.52 (m, 7 H), 4.28–4.13 (m, 4 H), 4.06–4.00 (m, 1 H), 3.96–3.90 (m, 2 H), 3.84 (dd, *J* = 2.4, 6.8 Hz, 1 H), 3.72 (d-like, *J* = 9.6 Hz, 1 H), 3.36 (dd, *J* = 2.8, 9.6 Hz, 1 H), 2.99 (d, *J* = 2.4 Hz, 1 H), 2.39 (s, 3 H), 1.28 (s, 9 H), 1.22 (t, *J* = 7.2 Hz, 3 H), 1.05 (t, *J* = 7.2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 169.1, 149.8, 138.7, 138.4, 138.0, 136.3, 133.2, 129.9, 129.7, 128.7, 128.5, 128.4, 128.3, 128.0, 127.9, 127.8, 127.7, 127.6, 124.6, 101.9, 80.3, 76.6, 75.9, 75.2, 74.8, 74.6, 73.2, 72.5, 72.0, 68.3, 61.9, 61.5, 34.7, 31.5, 20.6, 14.2, 14.1; HRMS (ESI) *m/z* calcd for $C_{55}H_{64}O_{12}SNa$ $[M + Na]^+$ 971.4016, found 971.4014.

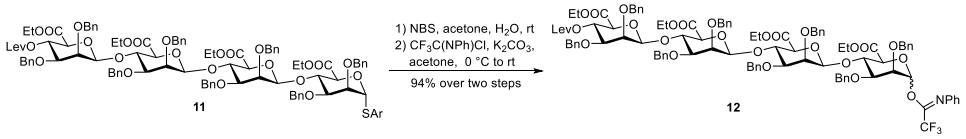
2.10. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-mannopyranosyl) uronate 11



To a stirred mixture of donor **9** (177 mg, 0.17 mmol), acceptor **10** (109 mg, 0.12 mmol), and 4Å MS (300 mg) in anhydrous CH_2Cl_2 (4 mL) was added TfOH in CH_2Cl_2 (1.2 M, 10 μL, 0.012 mmol) at –40 ℃. After stirring at –40 ℃ for 1 h, the mixture was quenched with Et_3N, filtered, and concentrated under reduced pressure. The residue was purified by silica gel chromatography (petroleum ether/EtOAc: 2.5:1) to afford **11** (212 mg, 97%, β:α = 20:1) as a white foam. The major β-anomer: $[\alpha]_D^{20}$ = –26.1 (*c* 1.01, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73 (s, 1 H), 7.45–7.17 (m, 41 H), 7.09 (d, *J* = 8.0 Hz, 1 H), 5.61 (d-like, *J* = 7.0 Hz, 1 H), 5.47 (t, *J* = 9.5 Hz, 1 H), 4.87–4.79 (m, 4 H), 4.76–4.66 (m, 7 H), 4.61–4.33 (m, 12 H), 4.10–3.89 (m, 9 H), 3.84–3.69 (m, 7 H), 3.52–3.42 (m, 3 H), 2.69–2.66 (m, 2 H), 2.53 (t, *J* = 7.0 Hz, 2 H), 2.38 (s, 3 H), 2.14 (s, 3 H), 1.29 (s, 9 H), 1.16–1.04 (m, 12 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.4, 171.6, 169.1, 168.4, 168.2, 167.5, 149.7, 139.0, 138.9, 138.8, 138.7, 138.6, 138.4, 138.0, 137.9, 136.3, 133.1, 129.9, 129.8, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 127.3, 124.6, 102.6 ($^1J_{C1,H1}$ =

156.5 Hz), 102.5 ($^1J_{C1,H1}$ = 157.0 Hz), 101.5 ($^1J_{C1,H1}$ = 157.5 Hz), 84.3 ($^1J_{C1,H1}$ = 166.5 Hz), 79.7, 79.5, 78.7, 77.7, 76.4, 76.1, 75.5, 75.0, 74.8, 74.7, 74.5, 74.4, 73.6, 73.2, 73.0, 72.8, 72.6, 72.4, 71.6, 69.0, 61.6, 61.5, 61.4, 37.9, 34.6, 31.4, 30.0, 28.1, 20.5, 14.2, 14.1, 14.0, 13.9; HRMS (ESI) *m/z* calcd for $C_{104}H_{118}O_{26}SNa$ $[M + Na]^+$ 1837.7530, found 1837.7533.

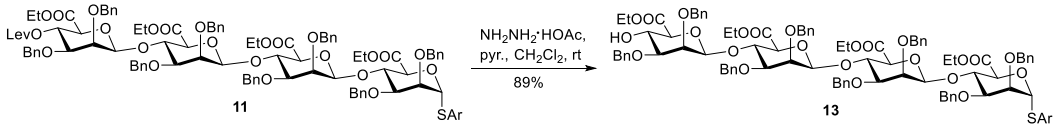
2.11. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-D-mannopyranosyl) uronate 12



To a solution of **11** (3.5 g, 1.93 mmol) in acetone and H_2O (15/1, v/v, 48 mL) was added NBS (1.4 g, 7.7 mmol) at room temperature. After stirring at room temperature for 15 min, the reaction was quenched with sat. aq. $Na_2S_2O_3$, diluted with EtOAc, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give the corresponding hemiacetal as a colorless syrup. To a solution of the resulting hemiacetal in acetone (40 mL) was added *N*-Phenyl-2,2,2-trifluoroacetimidoyl chloride (592 mg, 2.9 mmol) and K_2CO_3 (525 mg, 3.8 mmol) at 0 ℃. The reaction mixture was warmed to room temperature and allowed to stir overnight. The mixture was quenched with Et_3N, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give **12** (3.3 g, 94% over two steps) as a white foam: $[\alpha]_D^{20}$ = –43.7 (*c* 1.06, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45–7.16 (m, 42 H), 7.08 (t, *J* = 7.6 Hz, 1 H), 6.80 (d, *J* = 7.6 Hz, 2 H), 6.52 (br s, 1 H), 5.46 (t, *J* = 9.6 Hz, 1 H), 4.86–4.33 (m, 23 H), 4.23–3.62 (m, 16 H), 3.54 (dd, *J* = 2.8, 8.8 Hz, 1 H), 3.50 (dd, *J* = 2.8, 9.2 Hz, 1 H), 3.42 (dd, *J* = 2.8, 9.6 Hz, 1 H), 2.69–2.65 (m, 2 H), 2.52 (t, *J* = 7.2 Hz, 2 H), 2.13 (s, 3 H), 1.17–1.06 (m, 12 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.4, 171.5, 168.8, 168.3, 168.1, 167.4, 143.7, 139.0, 138.9, 138.8, 138.7, 138.5, 138.0, 137.9, 137.8, 128.7, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 127.3, 124.2, 119.5, 102.6, 102.5, 101.2,

94.2, 79.7, 79.3, 78.6, 77.7, 77.4, 75.9, 75.8, 74.9, 74.8, 74.7, 74.6, 74.5, 74.2, 73.6, 73.2, 72.9, 72.7, 72.6, 71.6, 69.0, 61.8, 61.7, 61.6, 61.5, 37.9, 30.0, 28.0, 14.2, 14.1, 14.0, 13.9; HRMS (ESI) *m/z* calcd for $C_{101}H_{108}O_{27}NF_3Na$ $[M + Na]^+$ 1846.6959, found 1846.6956.

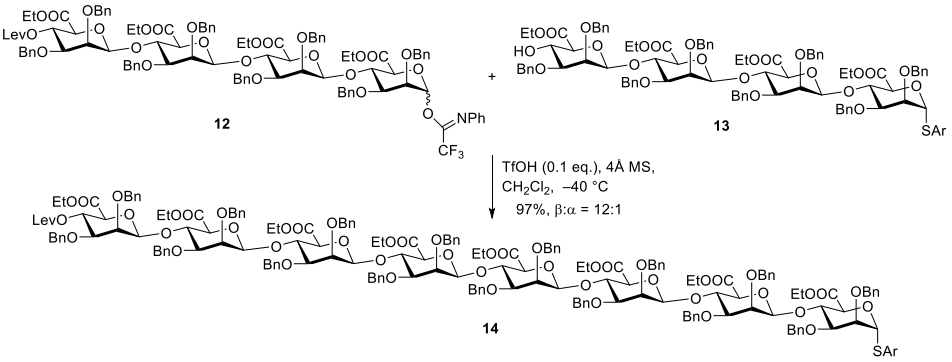
2.12. Synthesis of ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)- ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-mannopyranosyl) uronate 13



To a solution of **11** (2.5 g, 1.38 mmol) in dichloromethane and pyridine (4/1, v/v, 50 mL) was added H_2NNH_2·HOAc (543 mg, 5.9 mmol) at room temperature. After stirring at room temperature for 4 h, the reaction was quenched with acetone, diluted with CH_2Cl_2, and washed with aq. HCl (1 M) and brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give **13** (2.1 g, 89%) as a white foam: $[\alpha]_D^{20}$ = –26.3 (*c* 0.86, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (s, 1 H), 7.45–7.08 (m, 42 H), 5.60 (br s, 1 H), 4.87–4.65 (m, 11 H), 4.59–4.38 (m, 11 H), 4.28–3.78 (m, 17 H), 3.60–3.50 (m, 3 H), 3.30 (dd, *J* = 2.8, 9.6 Hz, 1 H), 2.96 (d, *J* = 2.0 Hz, 1 H), 2.37 (s, 3 H), 1.28 (s, 9 H), 1.17–1.02 (m, 12 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 169.1, 168.4, 168.2, 149.7, 139.0, 138.9, 138.8, 138.4, 138.2, 138.1, 136.4, 133.2, 129.9, 129.8, 128.6, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 124.6, 102.7, 102.6, 101.5, 80.5, 79.9, 79.6, 77.4, 76.4, 76.1, 75.3, 75.0, 74.9, 74.8, 74.7, 74.5, 73.2, 73.0, 72.8, 72.6, 72.5, 71.9, 68.3, 61.7, 61.6, 61.5, 61.4, 34.6, 31.4, 20.5, 14.2, 14.1, 14.0; HRMS (ESI) *m/z* calcd for $C_{99}H_{112}O_{24}SNa$ $[M + Na]^+$ 1739.7162, found 1739.7159.

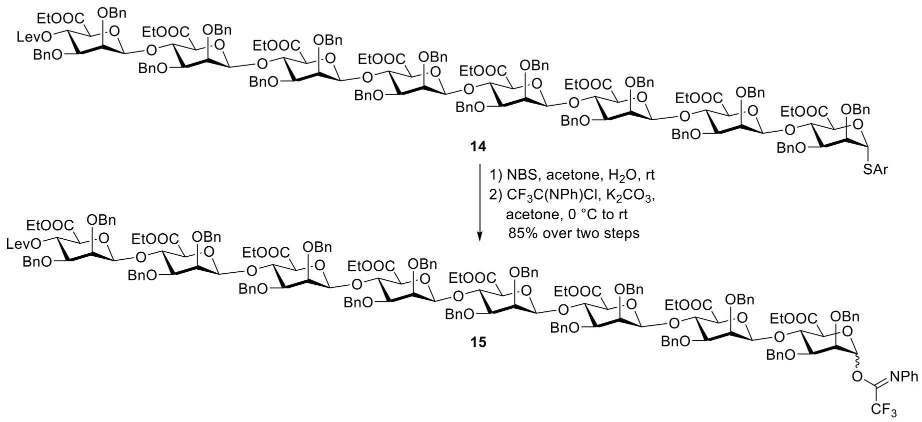
2.13. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-

mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2-methyl-5-*tert*-butylphenyl 2,3-di-*O*-benzyl-1-thio-α-D-mannopyranosyl) uronate 14



To a stirred mixture of donor **12** (252 mg, 0.14 mmol), acceptor **13** (159 mg, 0.093 mmol), and 4Å MS (400 mg) in anhydrous CH_2Cl_2 (5 mL) was added TfOH in CH_2Cl_2 (0.9 M, 10 μL, 0.009 mmol) at –40 ℃. After stirring at –40 ℃ for 0.5 h, the mixture was quenched with Et_3N, filtered, and concentrated under reduced pressure. The residue was purified by silica gel chromatography (petroleum ether/EtOAc: 2:1) to afford **14** (302 mg, 97%, β:α = 12:1) as a white foam. The major β-anomer: $[\alpha]_D^{20}$ = –36.1 (*c* 0.88, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (s, 1 H), 7.39–7.08 (m, 82 H), 5.60 (br s, 1 H), 5.43 (t, *J* = 10.0 Hz, 1 H), 4.85–4.45 (m, 40 H), 4.41–4.29 (m, 7 H), 4.08–3.65 (m, 32 H), 3.49 (dd, *J* = 2.8, 9.2 Hz, 1 H), 3.45–3.39 (m, 6 H), 2.69–2.64 (m, 2 H), 2.51 (t, *J* = 6.8 Hz, 2 H), 2.37 (s, 3 H), 2.13 (s, 3 H), 1.28 (s, 9 H), 1.12–0.99 (m, 24 H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.4, 171.6, 169.1, 168.4, 168.3, 168.2, 167.5, 149.7, 139.0, 138.9, 138.7, 138.4, 138.1, 138.0, 136.4, 133.1, 129.9, 129.8, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 124.6, 102.7 ($^1J_{C1,H1}$ = 156.5, 157.0 Hz), 102.6 ($^1J_{C1,H1}$ = 157.5 Hz), 101.5 ($^1J_{C1,H1}$ = 157.5 Hz), 84.4 ($^1J_{C1,H1}$ = 165.5 Hz), 79.8, 79.7, 79.5, 78.7, 77.7, 77.3, 76.4, 76.3, 76.2, 76.0, 75.5, 75.0, 74.9, 74.7, 74.6, 74.5, 74.4, 73.6, 73.2, 72.9, 72.8, 72.7, 72.5, 72.4, 71.6, 69.0, 61.6, 61.5, 38.0, 34.6, 31.4, 30.0, 28.1, 20.5, 14.2, 14.1, 14.0; MS (MALDI TOF) *m/z* calcd for $C_{192}H_{214}O_{50}SNa$ $[M + Na]^+$ 3374.3821, found 3374.0837.

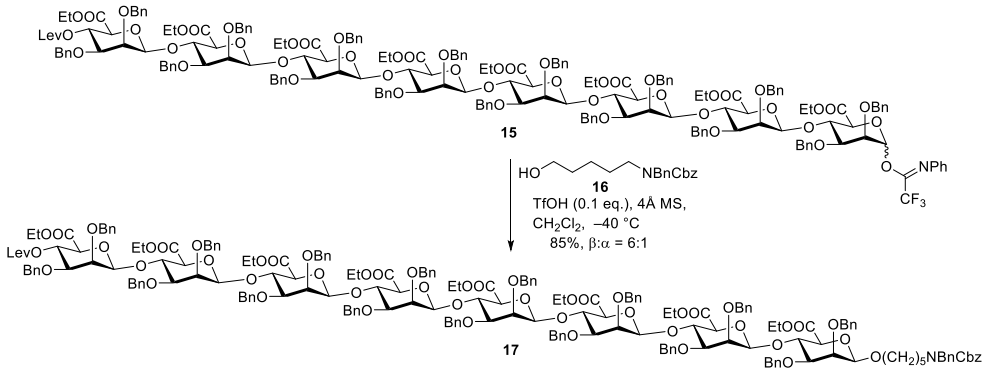
2.14. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-1-*O*-(*N*-phenyl-trifluoroacetimidoyl)-D-mannopyranosyl) uronate 15



To a solution of **14** (500 mg, 0.15 mmol) in acetone and H_2O (15/1, v/v, 10 mL) was added NBS (106 mg, 0.60 mmol) at room temperature. After stirring at room temperature for 15 min, the reaction was quenched with sat. aq. $Na_2S_2O_3$, diluted with EtOAc, and washed with brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give the corresponding hemiacetal as a colorless syrup. To a solution of the resulting hemiacetal in acetone (6 mL) was added *N*-Phenyl-2,2,2-trifluoroacetimidoyl chloride (47 mg, 0.23 mmol) and K_2CO_3 (42 mg, 0.30 mmol) at 0 °C. The reaction mixture was warmed to room temperature and allowed to stir overnight. The mixture was quenched with Et_3N, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give **15** (429 mg, 85% over two steps) as a white foam: $[\alpha]_D^{20}$ = –44.9 (*c* 0.88, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.15 (m, 82 H), 7.08 (t, *J* = 7.2 Hz, 1 H), 6.80 (d-like, *J* = 7.6 Hz, 2 H), 6.51 (br s, 1 H), 5.43 (t, *J* = 9.6 Hz, 1 H), 4.86–4.29 (m, 47 H), 4.13 (m, 1 H), 4.08–3.65 (m, 31 H), 3.53 (dd, *J* = 2.4, 8.8 Hz, 1 H), 3.45–3.39 (m, 6 H), 2.68–2.64 (m, 2 H), 2.51 (t, *J* = 6.8 Hz, 2 H), 2.13 (s, 3 H), 1.15–0.99 (m, 24 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.4, 171.6, 168.8, 168.4, 168.3, 168.1, 167.5, 143.7, 139.0, 138.9, 138.8, 138.5,

138.0, 137.9, 128.8, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 119.5, 102.7, 102.6, 102.5, 94.3, 79.9, 79.7, 78.7, 77.7, 77.4, 76.3, 76.2, 76.0, 75.9, 75.0, 74.9, 74.7, 74.6, 74.5, 74.3, 73.6, 73.2, 73.0, 72.8, 72.7, 72.5, 71.6, 69.0, 61.9, 61.7, 61.6, 61.5, 38.0, 30.0, 28.1, 14.2, 14.1, 14.0; LRMS (ESI) *m/z* calcd for $C_{189}H_{204}O_{51}NF_3Na$ $[M + Na]^+$ 3383.3, found 3383.7.

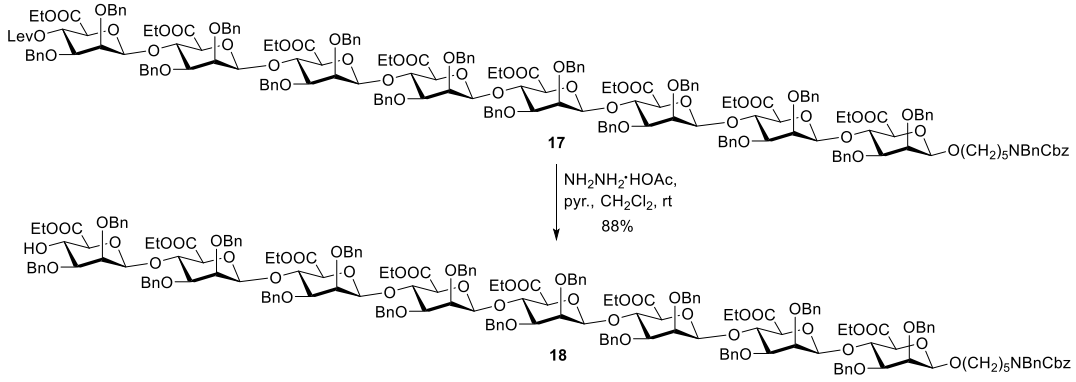
2.15. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (*N*-benzyl–benzyloxycarbonyl-5-aminopentyl 2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate 17



To a stirred mixture of donor **15** (475 mg, 0.14 mmol), linker **16**[3] (93 mg, 0.28 mmol, 2.0 eq.), and 4Å MS (400 mg) in anhydrous CH_2Cl_2 (10 mL) was added TfOH in CH_2Cl_2 (1.4 M, 10 μL, 0.014 mmol) at –40 ℃. After stirring at –40 ℃ for 0.5 h, the mixture was quenched with Et_3N, filtered, and concentrated under reduced pressure. The residue was purified by silica gel chromatography (petroleum ether/EtOAc: 1.75:1) to afford **17** (417 mg, 85%, β:α = 6:1) as a white foam. The major β-anomer: $[\alpha]_D^{20}$ = –53.6 (*c* 0.57, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36–7.15 (m, 90 H), 5.43 (t, *J* = 9.6 Hz, 1 H), 5.16 (d-like, *J* = 10.4 Hz, 2 H), 4.84–4.46 (m, 39 H), 4.41–4.27 (m, 9 H), 4.14–3.64 (m, 33 H), 3.58 (m, 1 H), 3.50–3.39 (m, 8 H), 3.24–3.18 (m, 3 H), 2.68–2.64 (m, 2 H), 2.51 (t, *J* = 6.8 Hz, 2 H), 2.13 (s, 3 H), 1.53 (m, 4 H), 1.29 (m, 2 H), 1.18–0.99 (m, 24 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 206.4, 171.6, 168.4, 168.3, 167.5, 139.0, 138.9, 138.8, 138.6, 138.0, 128.7, 128.6, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 127.3,

102.7 ($^1J_{C1,H1}$ = 155.5 Hz), 102.6 ($^1J_{C1,H1}$ = 157.0 Hz), 102.5 ($^1J_{C1,H1}$ = 156.5 Hz), 102.2 ($^1J_{C1,H1}$ = 154.0 Hz), 101.2 ($^1J_{C1,H1}$ = 158.0 Hz), 79.9, 79.7, 79.6, 78.7, 77.7, 77.4, 76.5, 76.3, 76.2, 75.9, 74.9, 74.8, 74.7, 74.6, 74.5, 74.4, 73.9, 73.6, 72.9, 72.8, 72.5, 71.6, 70.2, 70.1, 69.0, 67.3, 61.7, 61.6, 61.5, 50.6, 50.3, 47.2, 46.3, 38.0, 30.0, 29.5, 29.3, 28.1, 23.4, 14.3, 14.2, 14.1, 14.0; MS (MALDI TOF) *m/z* calcd for $C_{201}H_{223}O_{53}NNa$ $[M + Na]^+$ 3521.4683, found 3521.5762.

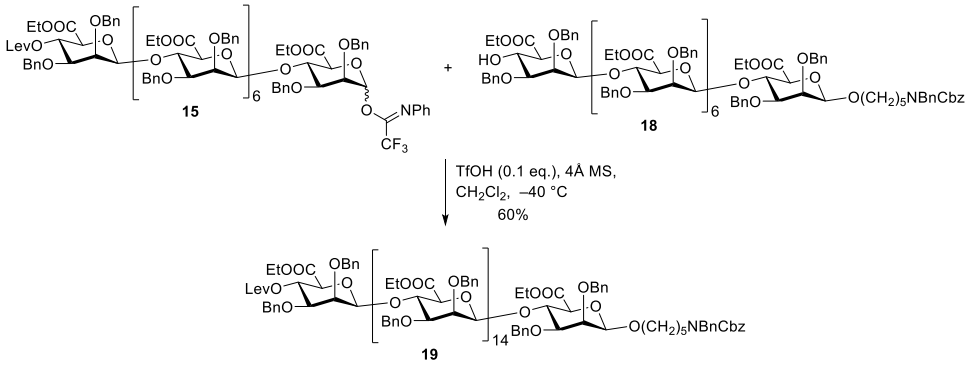
2.16. Synthesis of ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)- ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (*N*-benzyl–benzyl oxycarbonyl-5-aminopentyl 2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate 18



To a solution of **17** (417 mg, 0.12 mmol) in dichloromethane and pyridine (4/1, v/v, 10 mL) was added H_2NNH_2·HOAc (47 mg, 0.51 mmol) at room temperature. After stirring at room temperature for 4 h, the reaction was quenched with acetone, diluted with CH_2Cl_2, and washed with aq. HCl (1 M) and brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give **18** (357 mg, 88%) as a white foam: $[\alpha]_D^{20}$ = –42.2 (*c* 1.47, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37–7.15 (m, 90 H), 5.16 (d-like, *J* = 10.0 Hz, 2 H), 4.85–4.47 (m, 40 H), 4.41–4.30 (m, 8 H), 4.21–3.66 (m, 34 H), 3.56 (d-like, *J* = 9.6 Hz, 1 H), 3.50–3.39 (m, 7 H), 3.30–3.18 (m, 4 H), 2.96 (d, *J* = 1.6 Hz, 1 H), 1.53 (m, 4 H), 1.29 (m, 2 H), 1.18–0.99 (m, 24 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 168.3, 139.0, 138.9, 138.8, 138.7, 138.6, 138.2, 138.0, 128.7, 128.5, 128.3, 128.2, 128.1, 128.0, 127.9,

127.8, 127.7, 127.6, 127.5, 127.4, 127.3, 102.7, 102.6, 102.5, 102.2, 80.4, 79.9, 79.6, 77.4, 76.5, 76.2, 75.9, 75.3, 74.9, 74.8, 74.7, 74.6, 74.4, 73.9, 72.9, 72.8, 72.6, 72.4, 71.8, 70.1, 68.3, 67.3, 61.7, 61.5, 50.6, 50.3, 47.2, 46.3, 29.5, 29.3, 23.4, 14.2, 14.1, 14.0; MS (MALDI TOF) *m/z* calcd for $C_{196}H_{217}O_{51}NNa$ $[M + Na]^+$ 3423.4315, found 3423.5542.

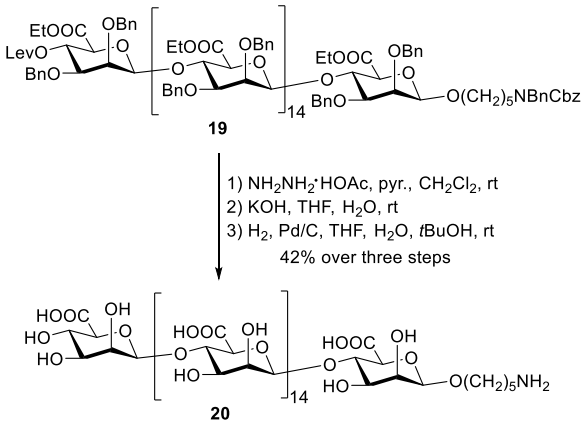
2.17. Synthesis of ethyl (2,3-di-*O*-benzyl-4-*O*-levulinoyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-manno pyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate -(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)- ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-manno pyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate -(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate-(1→4)-ethyl (*N*-benzyl–benzyloxycarbonyl-5-aminopentyl 2,3-di-*O*-benzyl-β-D-mannopyranosyl) uronate 19



To a stirred mixture of donor **15** (65 mg, 0.019 mmol), acceptor **18** (44 mg, 0.013 mmol), and 4Å MS (160 mg) in anhydrous CH_2Cl_2 (2 mL) was added TfOH in CH_2Cl_2 (0.1 M, 10 μL, 0.001 mmol) at –40 ℃. After stirring at –40 ℃ for 0.5 h, the mixture was quenched with Et_3N, filtered, and concentrated under reduced pressure. The residue was purified by silica gel chromatography (petroleum ether/EtOAc: 1.5:1) to afford **19** (51 mg, 60%) as a white foam: $[\alpha]_D^{20}$ = –48.6 (*c* 0.51, $CHCl_3$); ^{1}H NMR

(600 MHz, $CDCl_3$) δ 7.39–7.14 (m, 170 H), 5.43 (t, *J* = 9.6 Hz, 1 H), 5.16 (d-like, *J* = 16.2 Hz, 2 H), 4.84–4.29 (m, 97 H), 4.12–3.65 (m, 66 H), 3.59–3.33 (m, 16 H), 3.28–3.18 (m, 2 H), 2.69–2.61 (m, 2 H), 2.51 (t, *J* = 6.6 Hz, 2 H), 2.13 (s, 3 H), 1.54 (m, 4 H), 1.34–1.29 (m, 2 H), 1.17–0.99 (m, 48 H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 206.4, 171.6, 169.8, 168.5, 168.4, 168.3, 168.2, 167.8, 167.5, 139.1, 139.0, 138.9, 138.8, 138.7, 138.1, 128.7, 128.6, 128.5, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.6, 127.5, 127.4, 127.3, 102.8 ($^1J_{C1,H1}$ = 156.0 Hz), 102.7 ($^1J_{C1,H1}$ = 156.0 Hz), 102.6 ($^1J_{C1,H1}$ = 156.0 Hz), 102.5 ($^1J_{C1,H1}$ = 156.0 Hz), 102.2 ($^1J_{C1,H1}$ = 154.8 Hz), 81.9, 79.9, 79.8, 79.6, 78.7, 77.7, 77.6, 77.3, 76.5, 76.4, 76.3, 76.0, 75.8, 75.0, 74.9, 74.8, 74.7, 74.6, 74.5, 74.4, 73.9, 73.7, 73.1, 73.0, 72.9, 72.8, 72.7, 72.6, 72.5, 71.6, 69.0, 67.3, 61.7, 61.6, 61.5, 50.7, 50.4, 47.3, 46.3, 38.0, 30.0, 29.9, 29.4, 28.1, 23.4, 14.3, 14.2, 14.1, 14.0; MS (MALDI TOF) *m/z* calcd for $C_{377}H_{415}O_{101}NNa$ $[M + Na]^+$ 6594.7266, found 6592.2095.

2.18. Synthesis of hexadecamannuronic acid 20



To a solution of **19** (10 mg, 0.0015 mmol) in CH_2Cl_2 and pyridine (4/1, v/v, 1 mL) at room temperature was added H_2NNH_2·HOAc (1 mg, 0.0065 mmol). After stirring at room temperature for 4 h, the reaction was quenched with acetone, diluted with CH_2Cl_2, and washed with aq. HCl (1 M) and brine. The organic layer was dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/EtOAc = 1:1) to give the corresponding alcohol (8 mg, 83%) as a white solid. MS (MALDI TOF) *m/z* calcd for $C_{372}H_{409}O_{99}NNa$ $[M + Na]^+$ 6501.2618, found 6501.8711. To a solution of the resulting alcohol (25 mg, 0.0039 mmol) in THF (1 mL) was added 1 M aq. KOH (0.5 mL). After stirring at room temperature for 4 h, the mixture was neutralized with

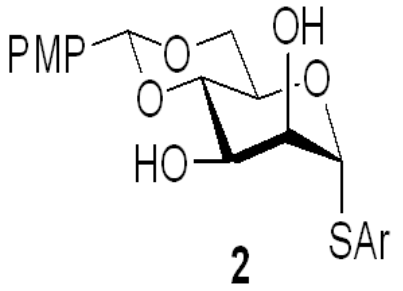
Amberlite IR120 H^+ resin. After filtration, the filtrate was concentrated *in vacuo* to give the corresponding carboxylic acid. A mixture of the resulting carboxylic acid and Pd/C (50 mg, 10%) in THF, water and *t*BuOH (1/1/0.2, v/v/v, 2.2 mL) was stirred under an atmosphere of H_2 at room temperature for 48 h. Filtration, concentration *in vacuo* and elution through Sephadex LH-20 column (H_2O) provided **20** (5.7 mg, 50% over two steps) as a colorless solid: $[\alpha]_D^{20}$ = –68.0 (*c* 0.1, H_2O); ^{1}H NMR (600 MHz, D_2O) δ 4.70– 4.66 (m, 16 H), 4.16–3.63 (m, 66 H), 3.07–2.99 (m, 2 H), 1.75–1.61 (m, 4 H), 1.49–1.40 (m, 2 H); ^{13}C NMR (150 MHz, D_2O) δ 175.5, 175.3, 175.2, 100.1 ($^1J_{C1,H1}$ = 161.4 Hz), 100.0 ($^1J_{C1,H1}$ = 161.4 Hz), 99.8 ($^1J_{C1,H1}$ = 160.8 Hz), 80.7, 78.3, 78.1, 77.9, 77.8, 76.2, 75.8, 73.7, 73.6, 72.5, 71.6, 71.3, 71.2, 71.0, 70.4, 70.0, 69.9, 69.8, 69.6, 68.5, 64.8, 60.8, 47.3, 39.3, 28.0, 26.2, 22.0; MS (MALDI TOF) *m/z* calcd for $C_{101}H_{126}O_{97}NNa_{12}$ $[M + 12Na – 15H]^{3–}$ 1060.1243, found 1059.8368; *m/z* calcd for $C_{101}H_{127}O_{97}NNa_9$ $[M + 9Na – 14H]^{5–}$ 622.4823, found 622.6421.

3. References

(1) S. Picard and D. Crich, *Tetrahedron*, 2013, **69**, 5501.

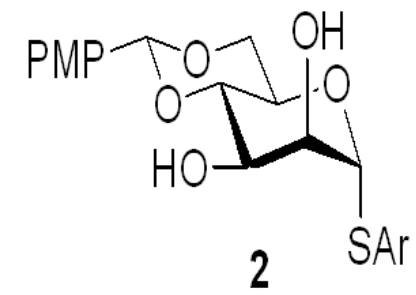
(2) (a) K. Tamura, H. Mizukami, K. Maeda, H. Watanabe and K. Uneyama, *J. Org. Chem.*, 1993, **58**, 32; (b) B. Yu and H. Tao, *Tetrahedron Lett*., 2001, **42**, 2405.

(3) (a) T. K. K. Mong, M. K. Lee, S. G. Duron and C. H. Wong, *Proc. Natl. Acad. Sci. U. S. A.*, 2003, **100**, 797; (b) C. Noti, J. L. de Paz, L. Polito and P. H. Seeberger, *Chem. Eur. J.*, 2006, **12**, 8664.



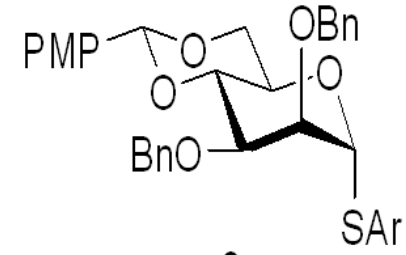
2

(^{1}H NMR, 400 MHz, $CDCl_3$)



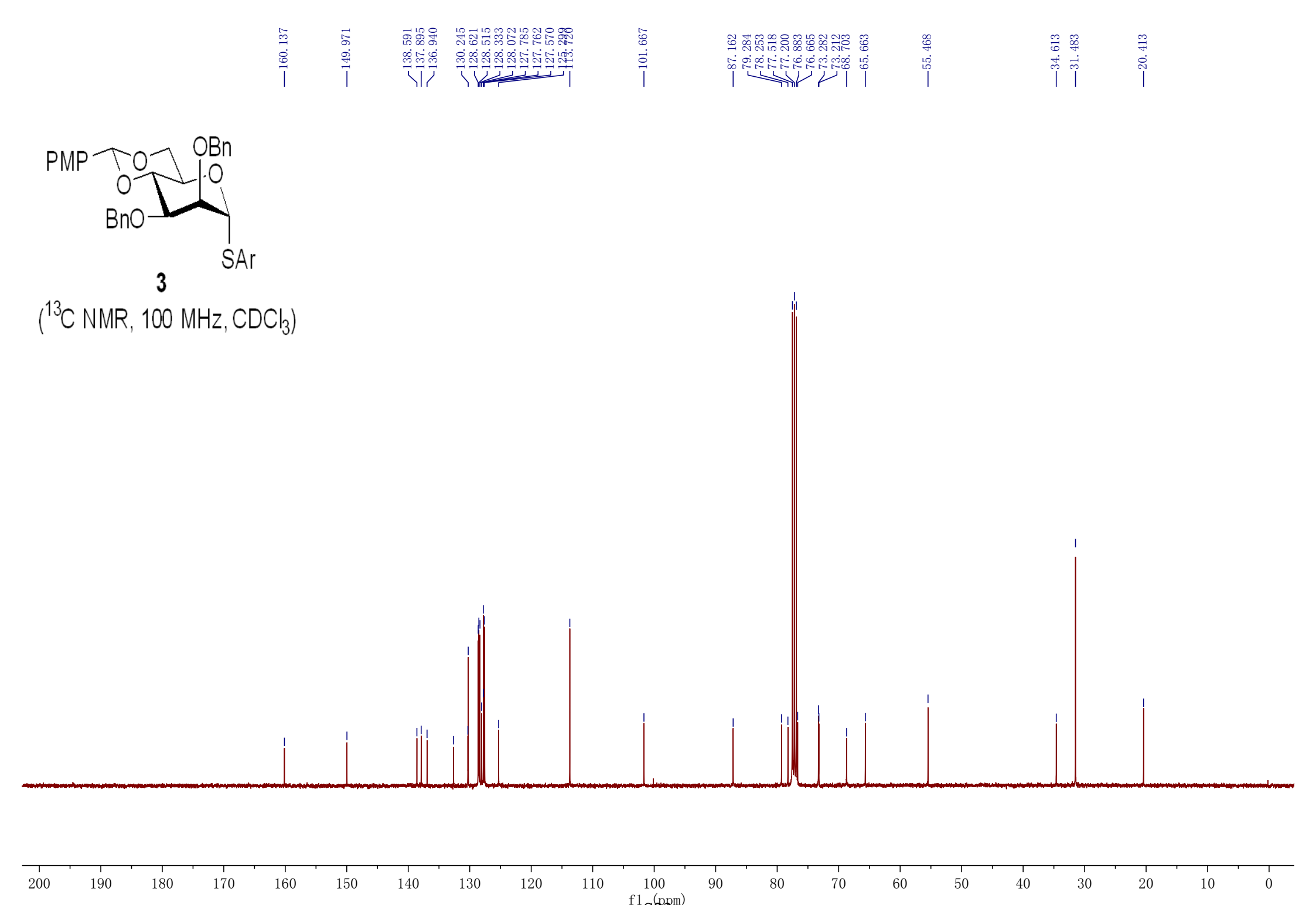
2

(^{13}C NMR, 150 MHz, $CDCl_3$)



3

(^{1}H NMR, 400 MHz, $CDCl_3$)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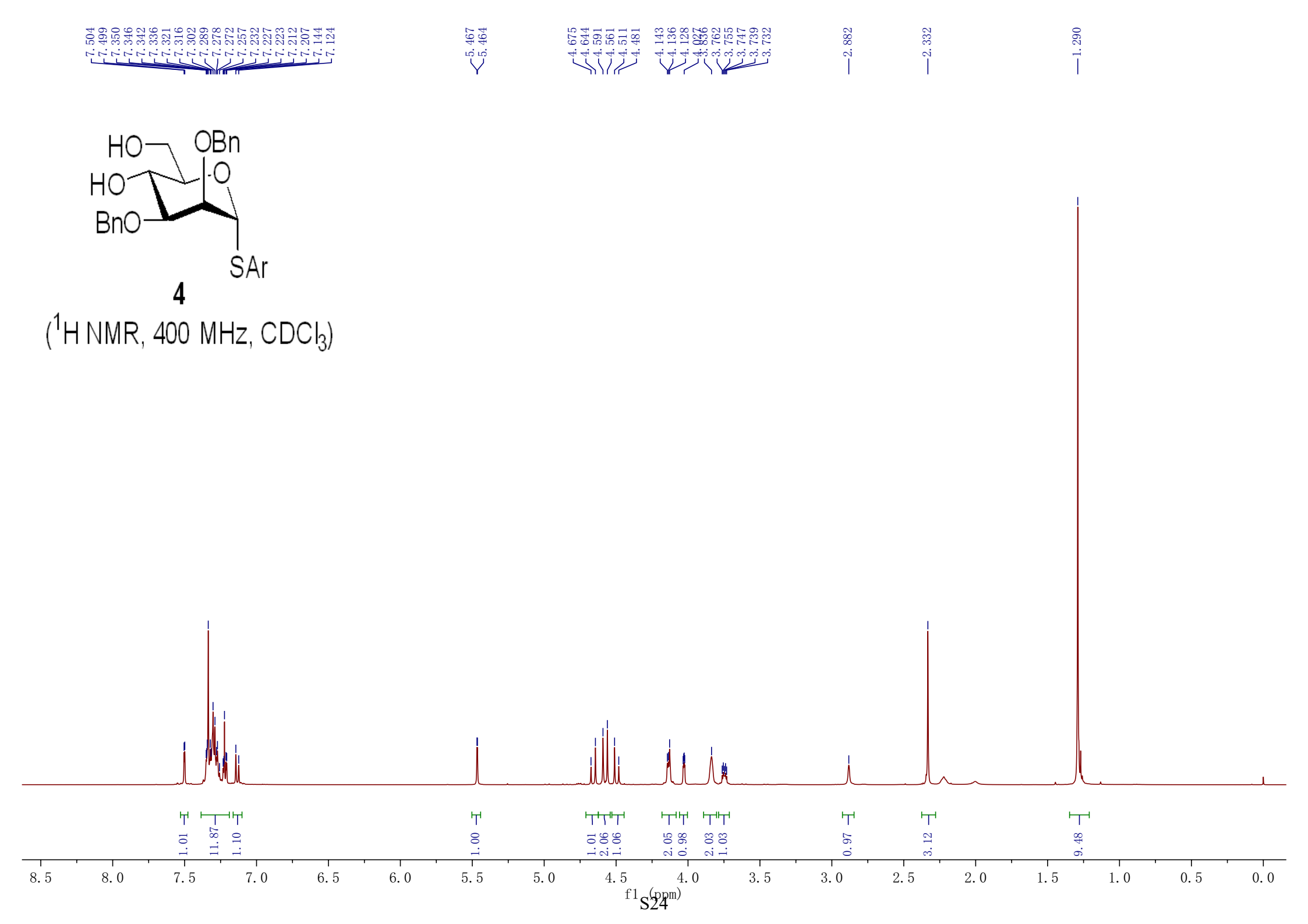
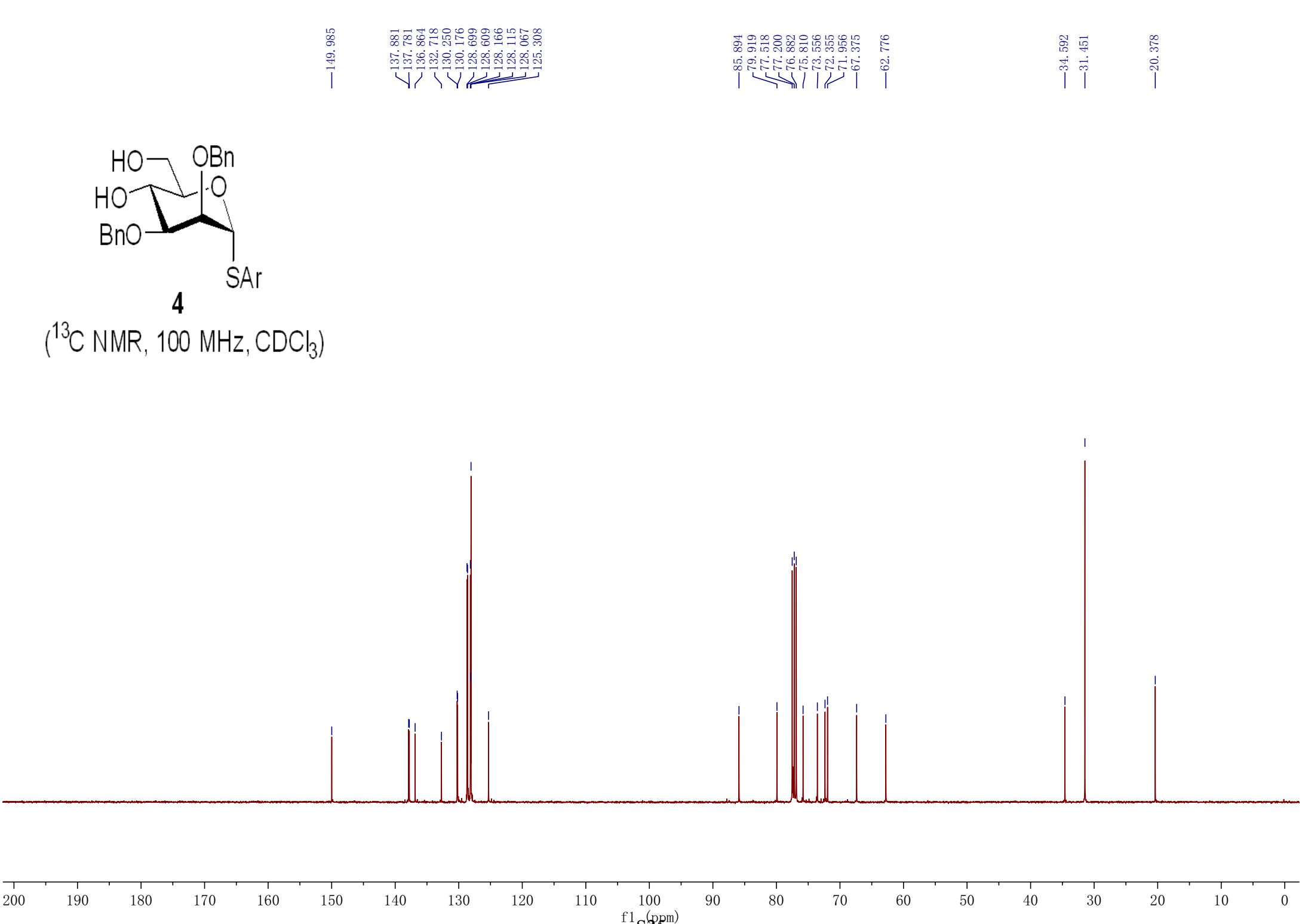
149.971
138.591
137.895
136.940
130.245
128.621
128.515
128.333
128.072
127.785
127.762
127.570
101.667
87.162
79.284
78.253
77.518
77.200
76.883
76.665
73.282
73.212
68.703
65.663
55.468
34.613
31.483
20.413
PMP
OBn
BnO
SAr
3
(^{13}C NMR, 100 MHz, $CDCl_3$)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.504
7.499
7.350
7.346
7.342
7.336
7.321
7.316
7.302
7.289
7.278
7.272
7.257
7.232
7.227
7.223
7.212
7.207
7.144
7.124
5.467
5.464
4.675
4.644
4.591
4.561
4.511
4.481
4.143
4.136
4.128
3.836
3.762
3.755
3.747
3.739
3.732
2.882
2.332
1.290
HO
OBn
HO
O
BnO
SAr
4
(1H NMR, 400 MHz, CDCl3)
1.01
11.87
1.10
1.00
1.01
2.06
1.06
2.05
0.98
2.03
1.03
0.97
3.12
9.48
8.5
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
f1 (ppm)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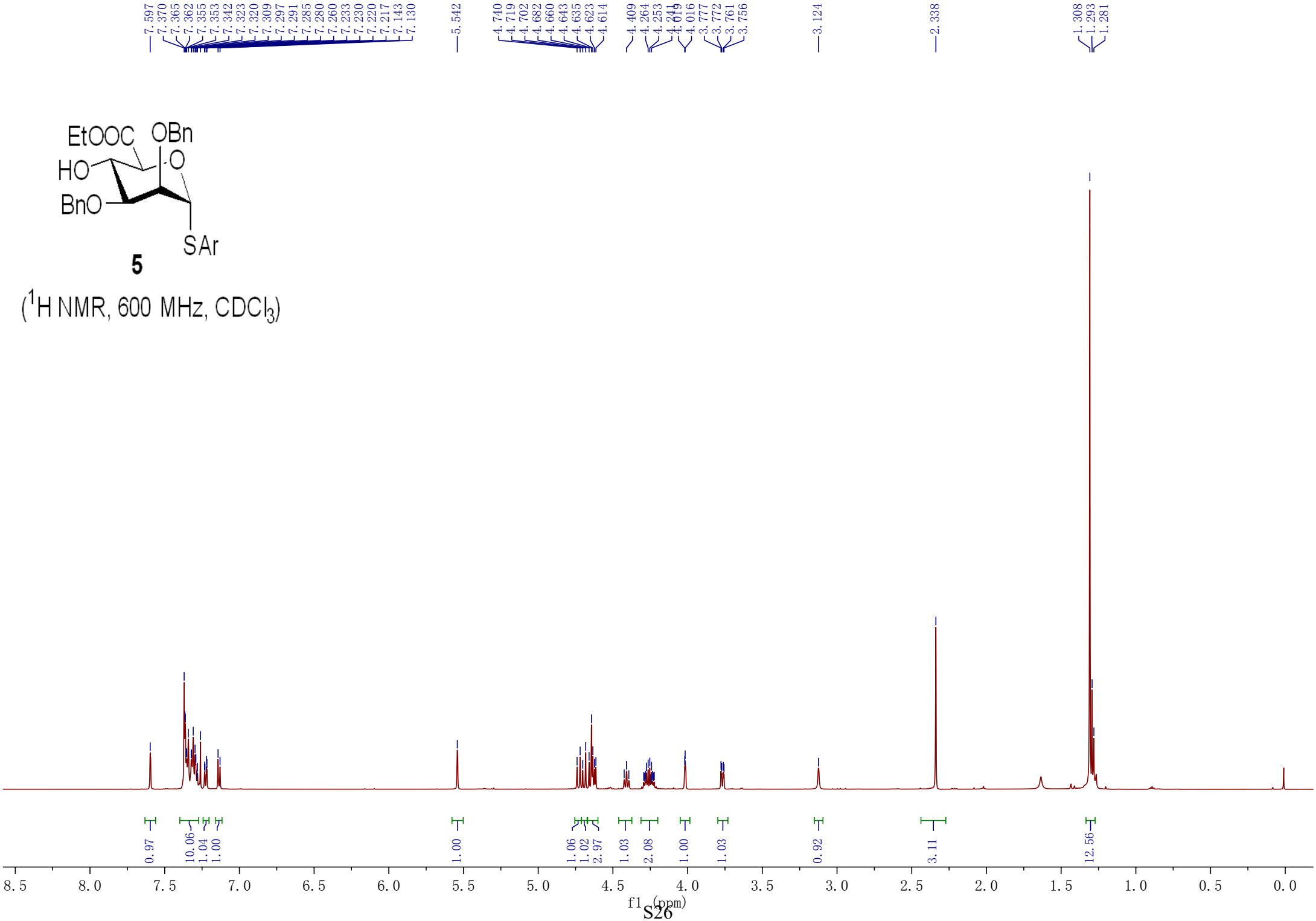
137.881
137.781
136.864
132.718
130.250
130.176
128.699
128.609
128.166
128.115
128.067
125.308
85.894
79.919
77.518
77.200
76.882
75.810
73.556
72.355
71.956
67.375
62.776
34.592
31.451
20.378
HO
OBn
HO
O
BnO
SAr
4
(^{13}C NMR, 100 MHz, $CDCl_3$)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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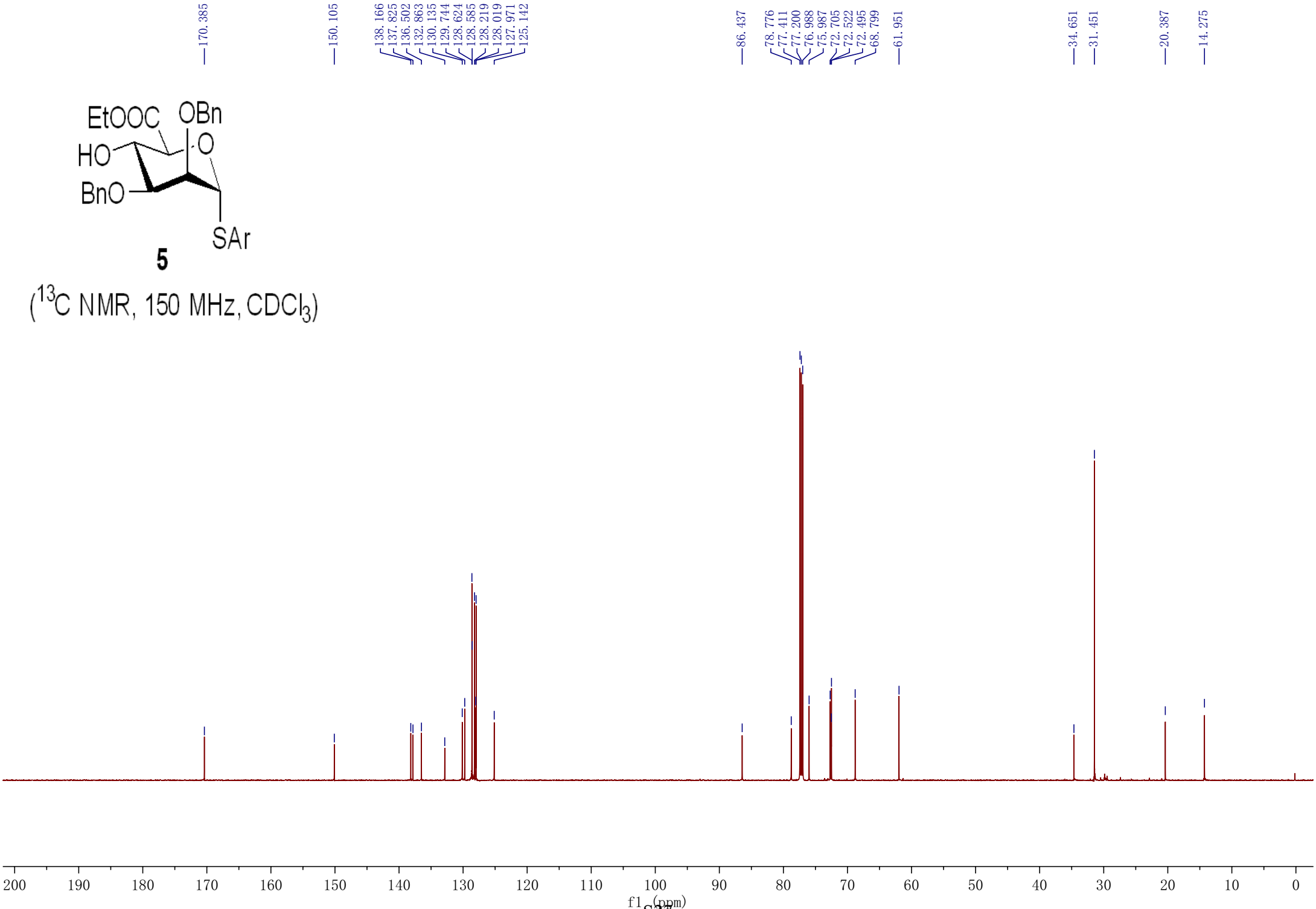
7.365
7.362
7.355
7.353
7.342
7.323
7.320
7.309
7.297
7.291
7.285
7.280
7.260
7.233
7.230
7.220
7.217
7.143
7.130
5.542
4.740
4.719
4.702
4.682
4.660
4.643
4.635
4.623
4.614
4.409
4.264
4.253
4.241
4.016
3.777
3.772
3.761
3.756
3.124
2.338
1.308
1.293
1.281
EtOOC
OBn
HO
O
BnO
SAr
5
(1H NMR, 600 MHz, CDCl3)
0.97
10.06
1.04
1.00
1.00
1.06
1.02
2.97
1.03
2.08
1.00
1.03
0.92
3.11
12.56
8.5
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
f1 (ppm)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150.105
138.166
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136.502
132.863
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129.744
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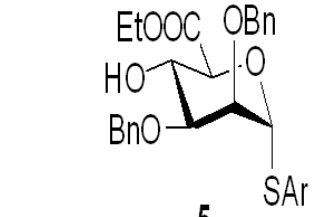
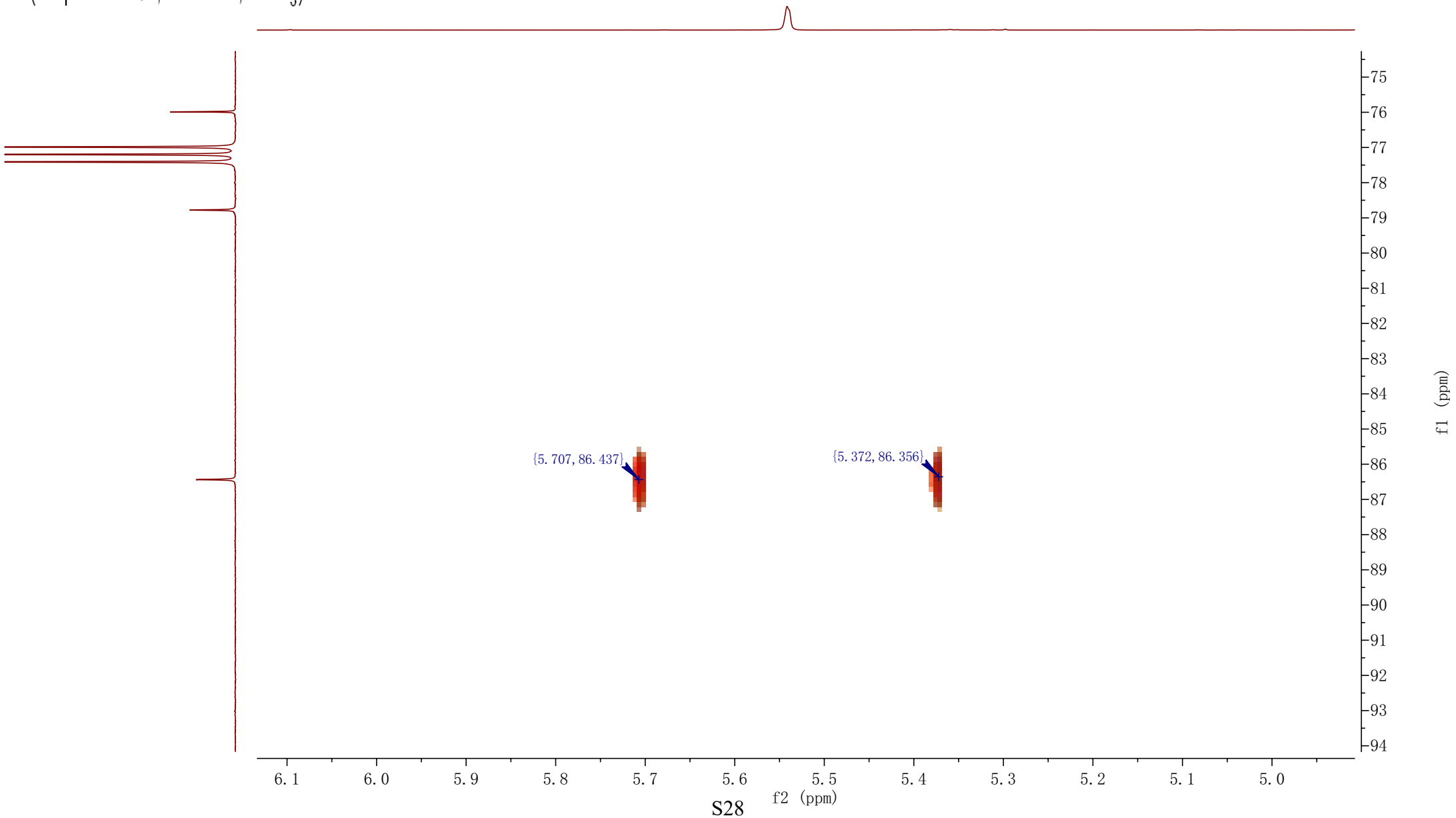
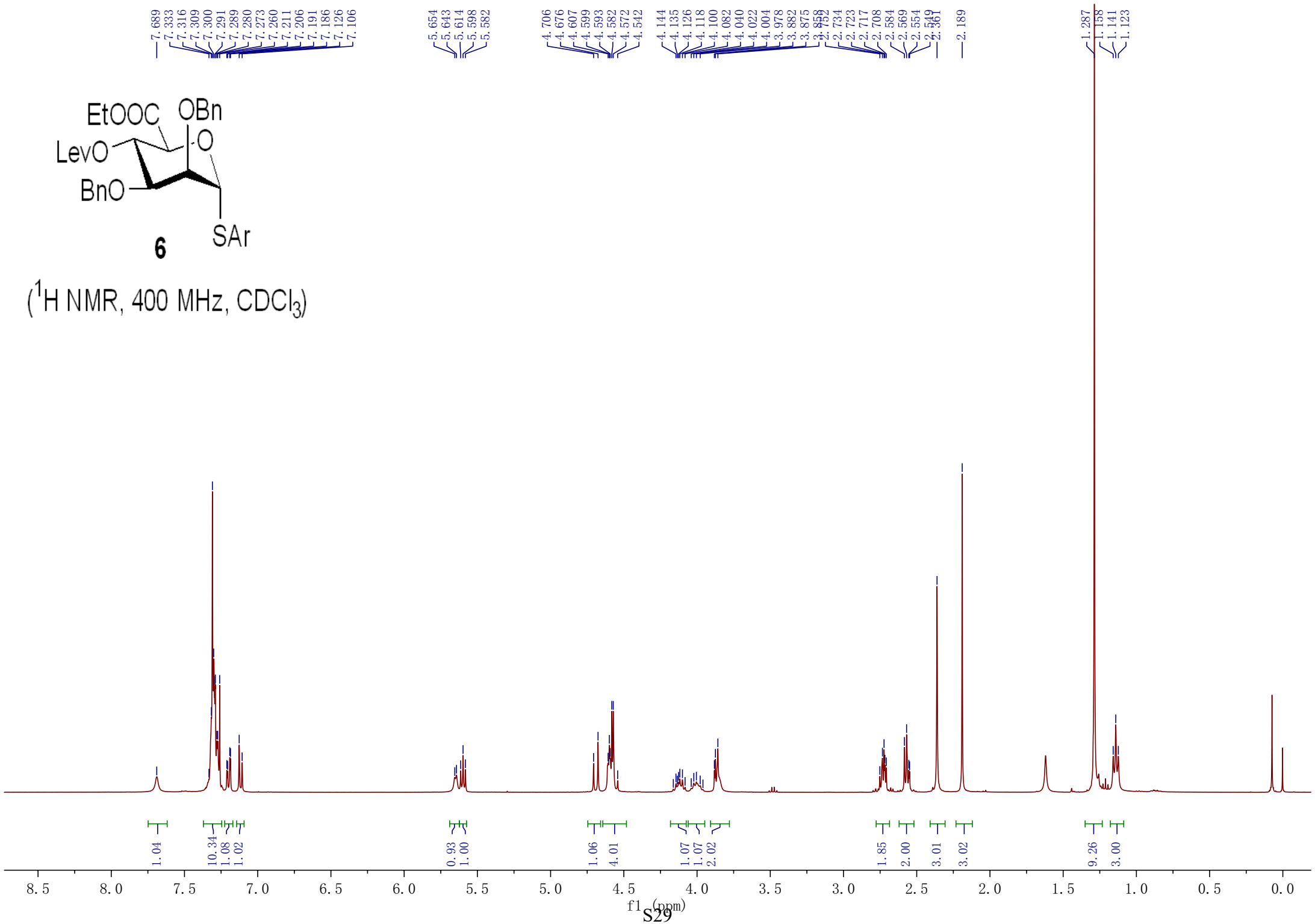
128.585
128.219
128.019
127.971
125.142
86.437
78.776
77.411
77.200
76.988
75.987
72.705
72.522
72.495
68.799
61.951
34.651
31.451
20.387
14.275
EtOOC
OBn
HO
O
BnO
SAr
5
(13C NMR, 150 MHz, CDCl3)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

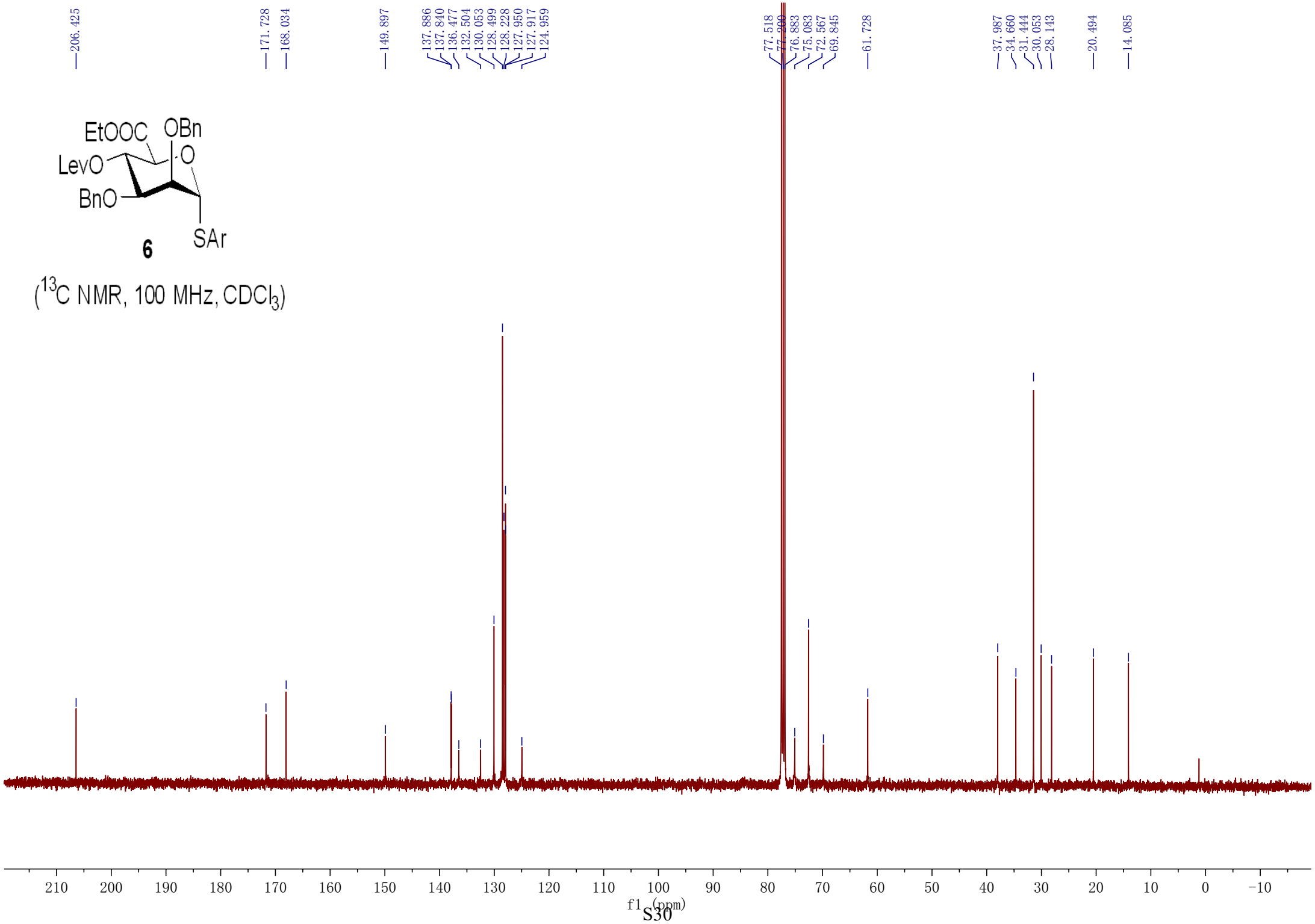


5

(coupled HSQC, 500 MHz, $CDCl_3$)




7.689
7.333
7.316
7.309
7.300
7.291
7.289
7.280
7.273
7.260
7.211
7.206
7.191
7.186
7.126
7.106
5.654
5.643
5.614
5.598
5.582
4.706
4.676
4.607
4.599
4.593
4.582
4.572
4.542
4.144
4.135
4.126
4.118
4.100
4.082
4.040
4.022
4.004
3.978
3.882
3.875
2.734
2.723
2.717
2.708
2.584
2.569
2.554
2.361
2.189
1.287
1.158
1.141
1.123
EtOOC
OBn
LevO
O
BnO
SAr
6
(1H NMR, 400 MHz, CDCl3)
1.04
10.34
1.08
1.02
0.93
1.00
1.06
4.01
1.07
1.07
2.02
1.85
2.00
3.01
3.02
9.26
3.00
8.5
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
f1 (ppm)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137.886
137.840
136.477
132.504
130.053
128.499
128.228
127.950
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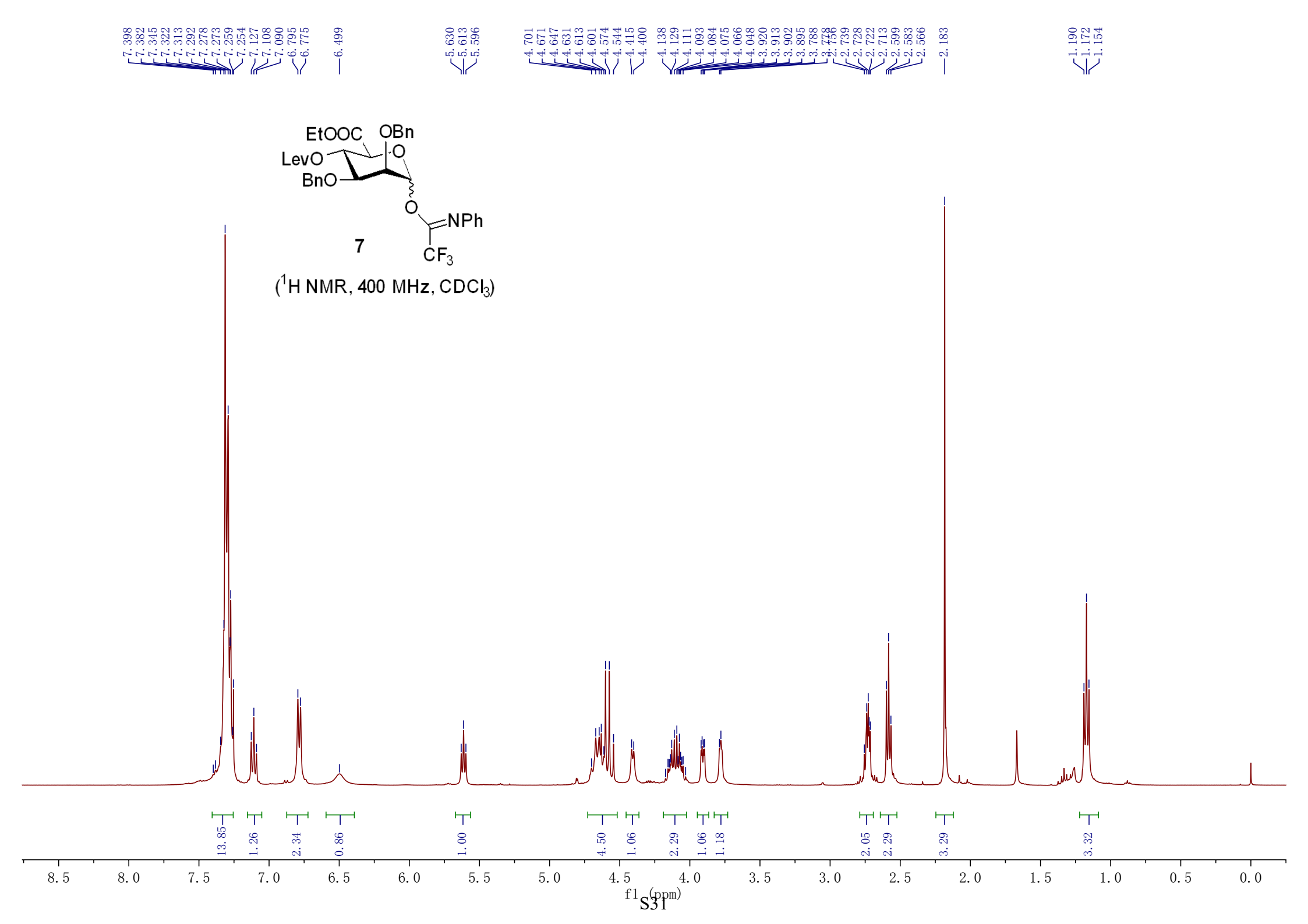
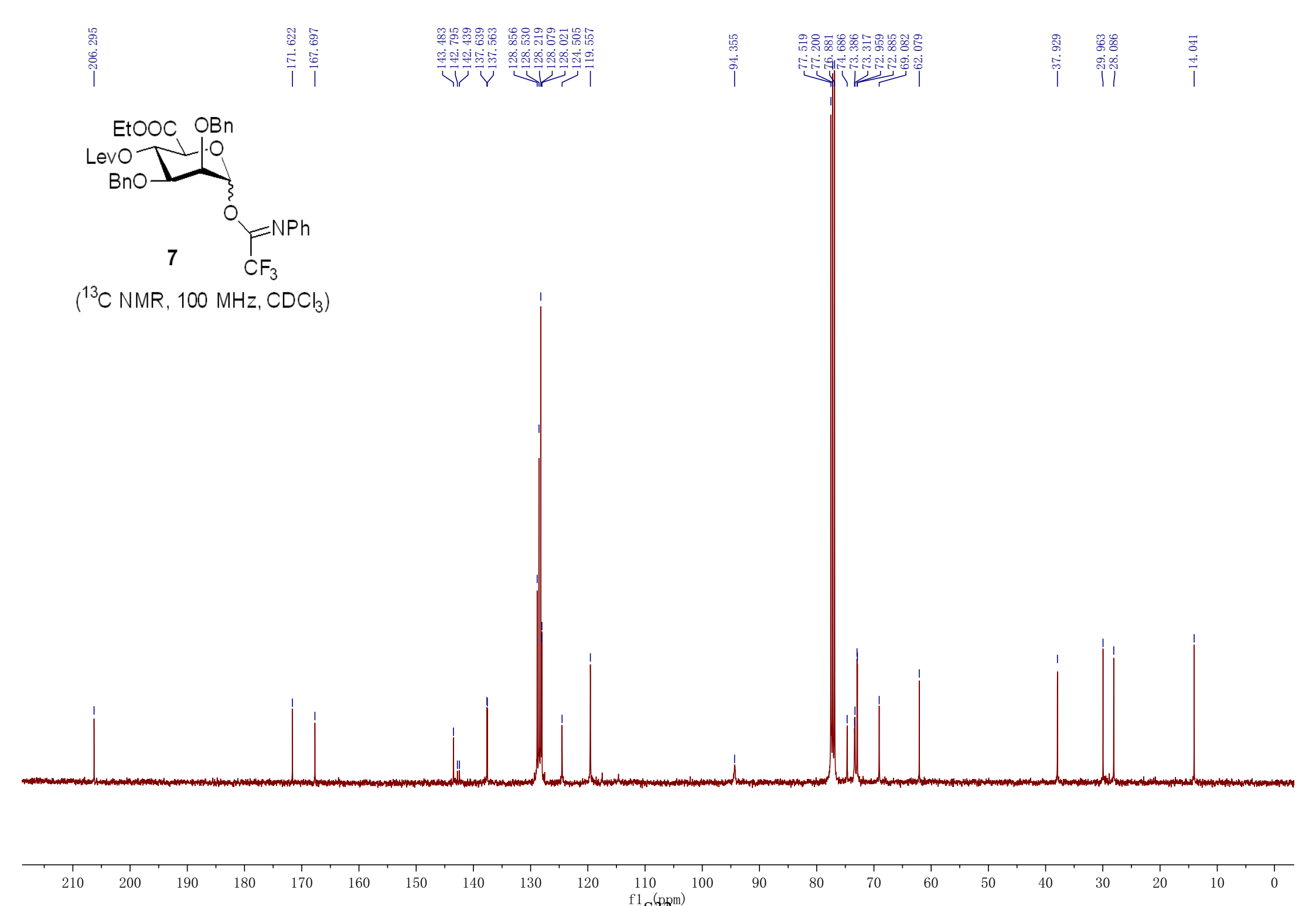
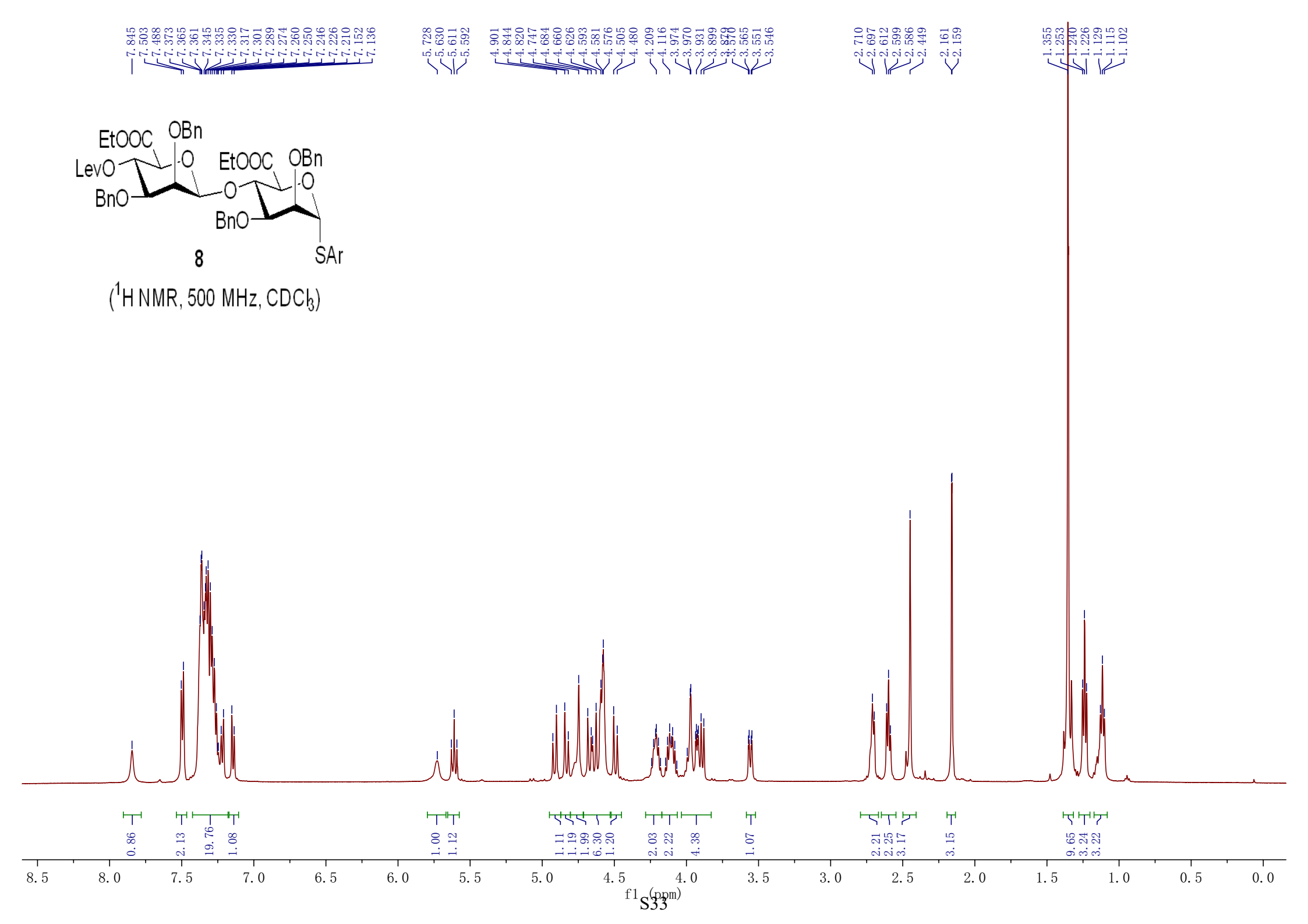
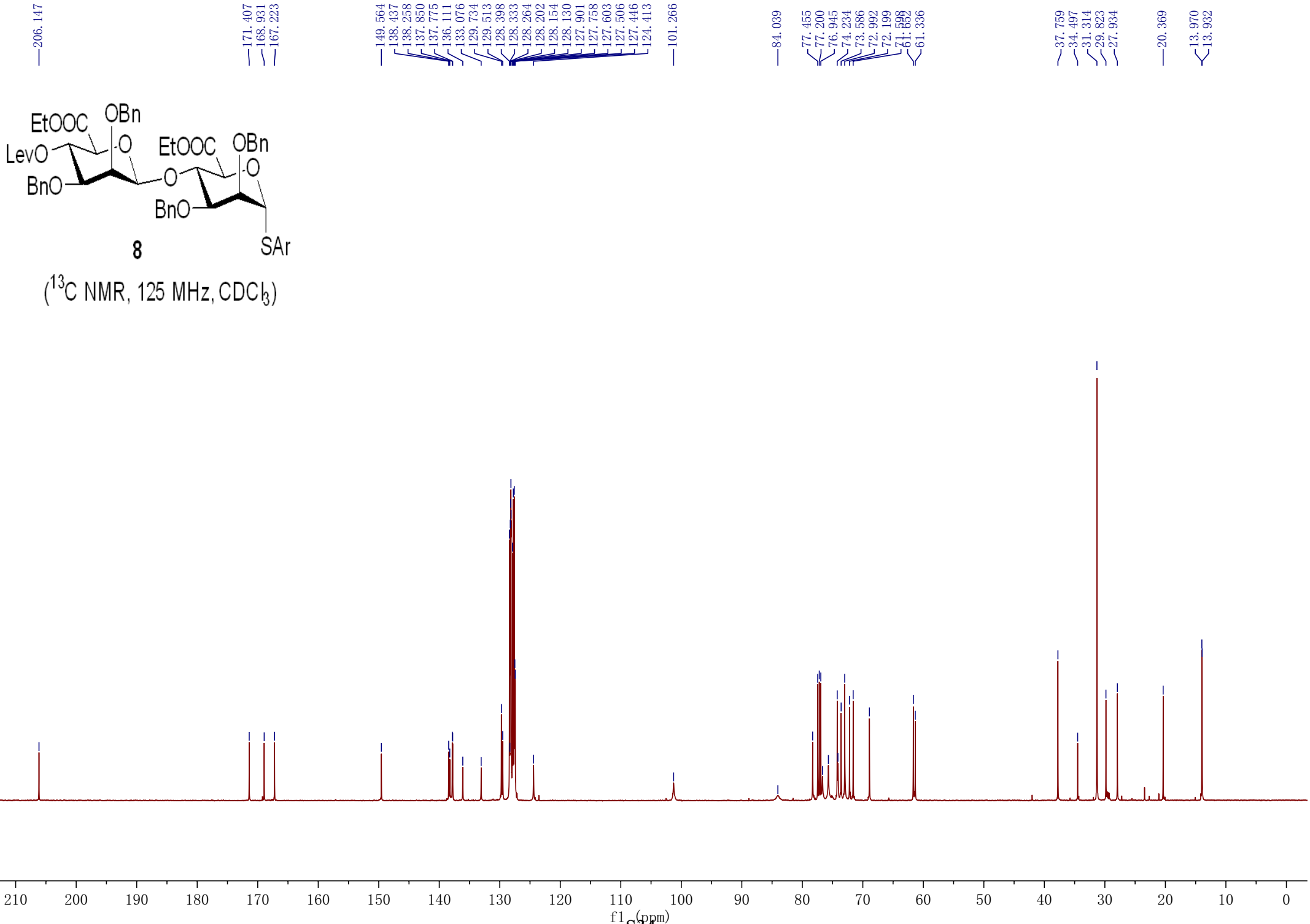
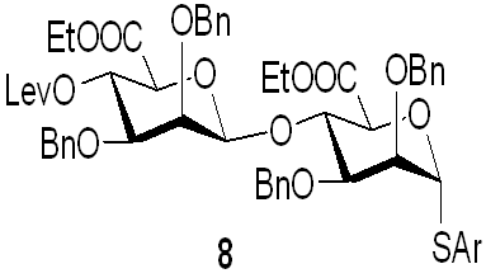
124.959
77.518
77.200
76.883
75.083
72.567
69.845
61.728
37.987
34.660
31.444
30.053
28.143
20.494
14.085
EtOOC
OBn
LevO
O
BnO
SAr
6
(^{13}C NMR, 100 MHz, $CDCl_3$)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−10
f1 (ppm)


7.398
7.382
7.345
7.322
7.313
7.292
7.278
7.273
7.259
7.254
7.127
7.108
7.090
6.795
6.775
6.499
5.630
5.613
5.596
4.701
4.671
4.647
4.631
4.613
4.601
4.574
4.544
4.415
4.400
4.138
4.129
4.111
4.093
4.084
4.075
4.066
4.048
3.920
3.913
3.902
3.895
3.788
2.739
2.728
2.722
2.713
2.599
2.583
2.566
2.183
1.190
1.172
1.154
EtOOC
OBn
LevO
BnO
O
O
NPh
CF3
7
(1H NMR, 400 MHz, CDCl3)
13.85
1.26
2.34
0.86
1.00
4.50
1.06
2.29
1.06
1.18
2.05
2.29
3.29
3.32
8.5
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
f1 (ppm)


206.295
171.622
167.697
143.483
142.795
142.439
137.639
137.563
128.856
128.530
128.219
128.079
128.021
124.505
119.557
94.355
77.519
77.200
76.881
74.686
73.386
73.317
72.959
72.885
69.082
62.079
37.929
29.963
28.086
14.041
EtOOC
OBn
LevO
BnO
O
O
NPh
CF3
7
(13C NMR, 100 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

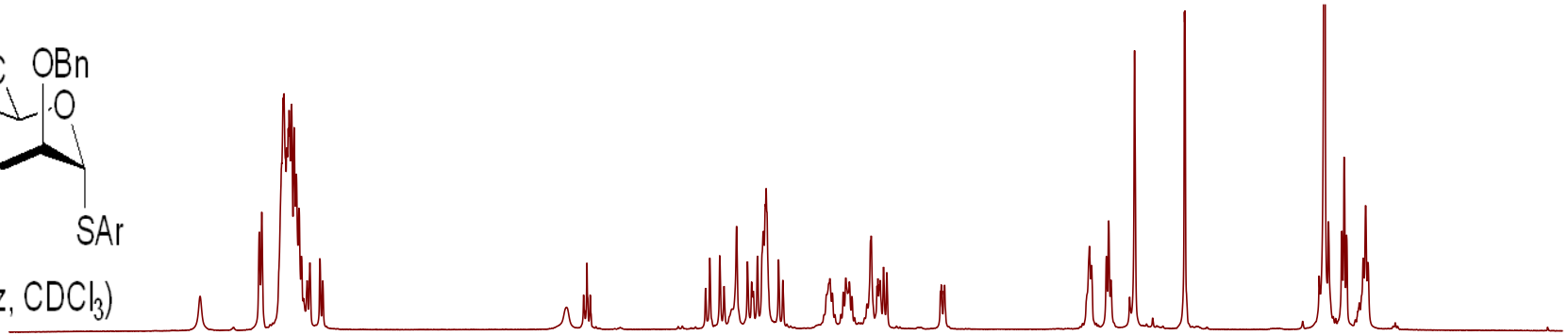

7.845
7.503
7.488
7.373
7.365
7.361
7.345
7.335
7.330
7.317
7.301
7.289
7.274
7.260
7.250
7.246
7.226
7.210
7.152
7.136
5.728
5.630
5.611
5.592
4.901
4.844
4.820
4.747
4.684
4.660
4.626
4.593
4.581
4.576
4.505
4.480
4.209
4.116
3.974
3.970
3.931
3.899
3.565
3.551
3.546
2.710
2.697
2.612
2.599
2.586
2.449
2.161
2.159
1.355
1.253
1.240
1.226
1.129
1.115
1.102
EtOOC
OBn
LevO
BnO
O
EtOOC
OBn
O
BnO
SAr
8
(1H NMR, 500 MHz, CDCl3)
0.86
2.13
19.76
1.08
1.00
1.12
1.11
1.19
1.99
6.30
1.20
2.03
2.22
4.38
1.07
2.21
2.25
3.17
3.15
9.65
3.24
3.22
8.5
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
f1 (ppm)

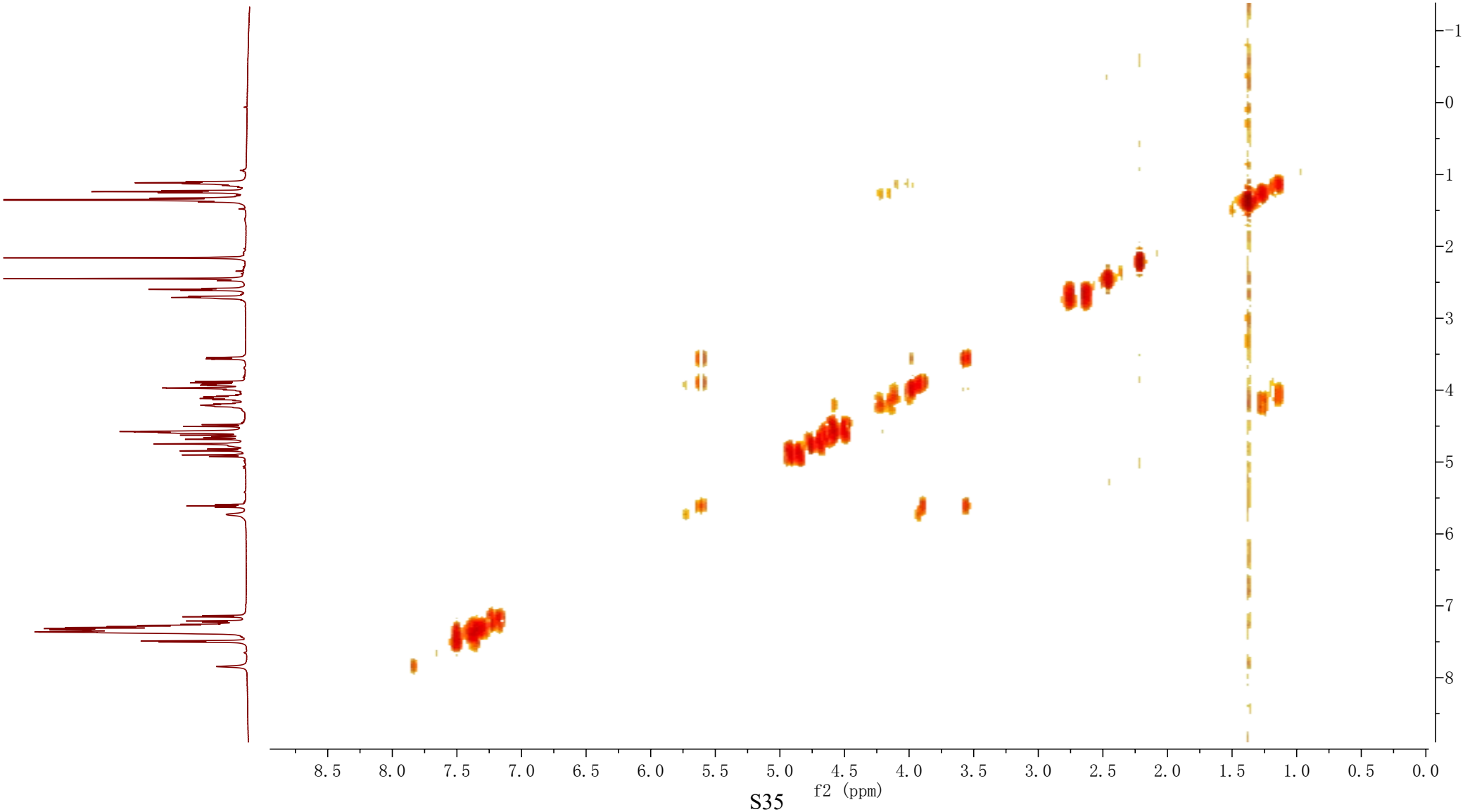

206.147
171.407
168.931
167.223
149.564
138.437
138.258
137.850
137.775
136.111
133.076
129.734
129.513
128.398
128.333
128.264
128.202
128.154
128.130
127.901
127.758
127.603
127.506
127.446
124.413
101.266
84.039
77.455
77.200
76.945
74.234
73.586
72.992
72.199
61.652
61.336
37.759
34.497
31.314
29.823
27.934
20.369
13.970
13.932
EtOOC
OBn
LevO
BnO
O
EtOOC
OBn
BnO
SAr
8
(13C NMR, 125 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

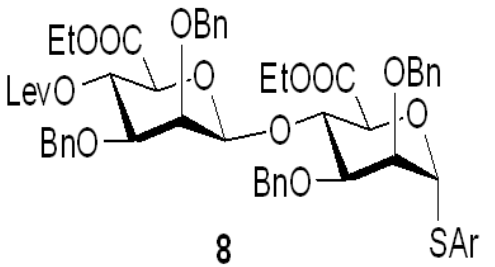


8

(^{1}H-^{1}H COSY, 500 MHz, $CDCl_3$)

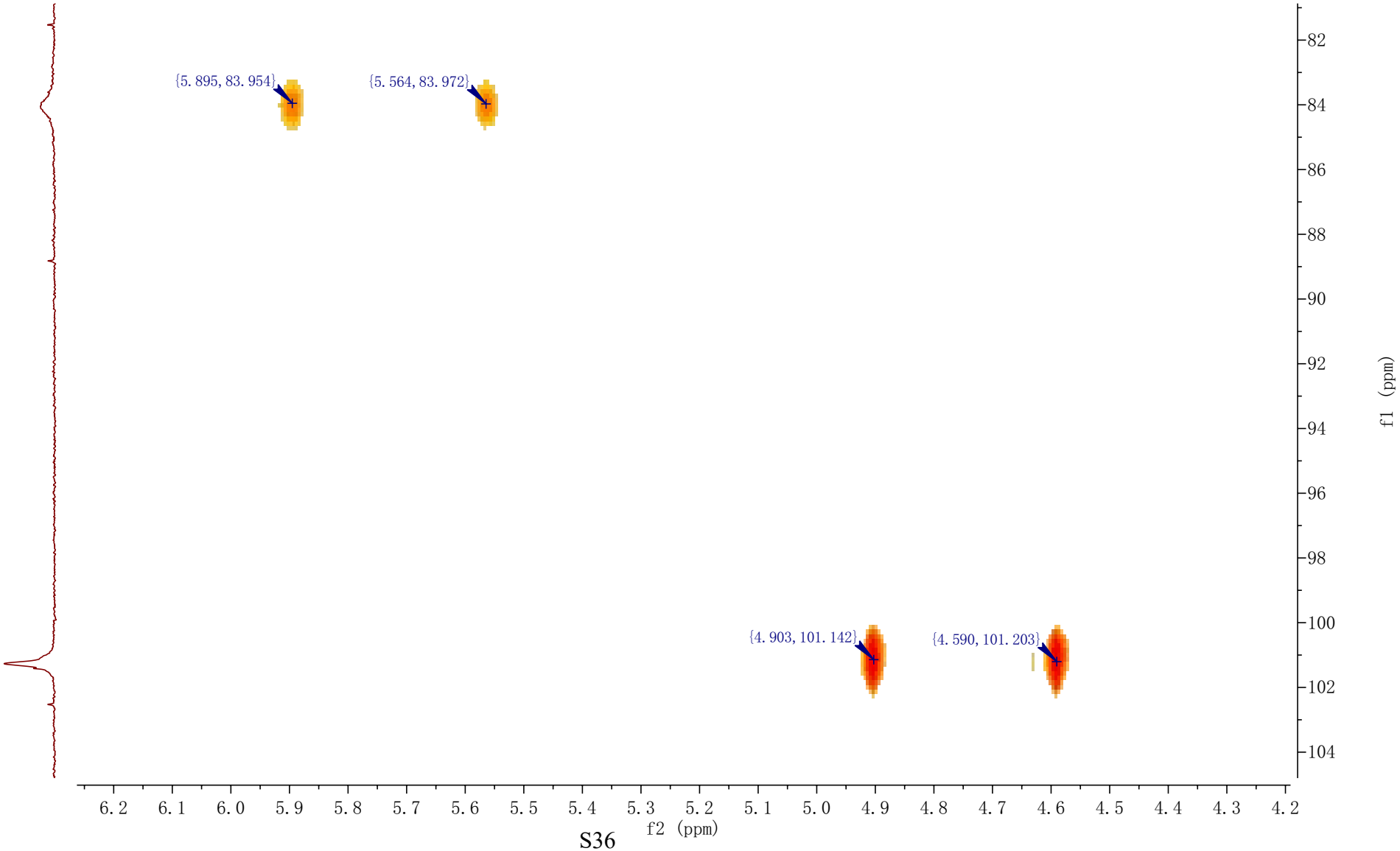


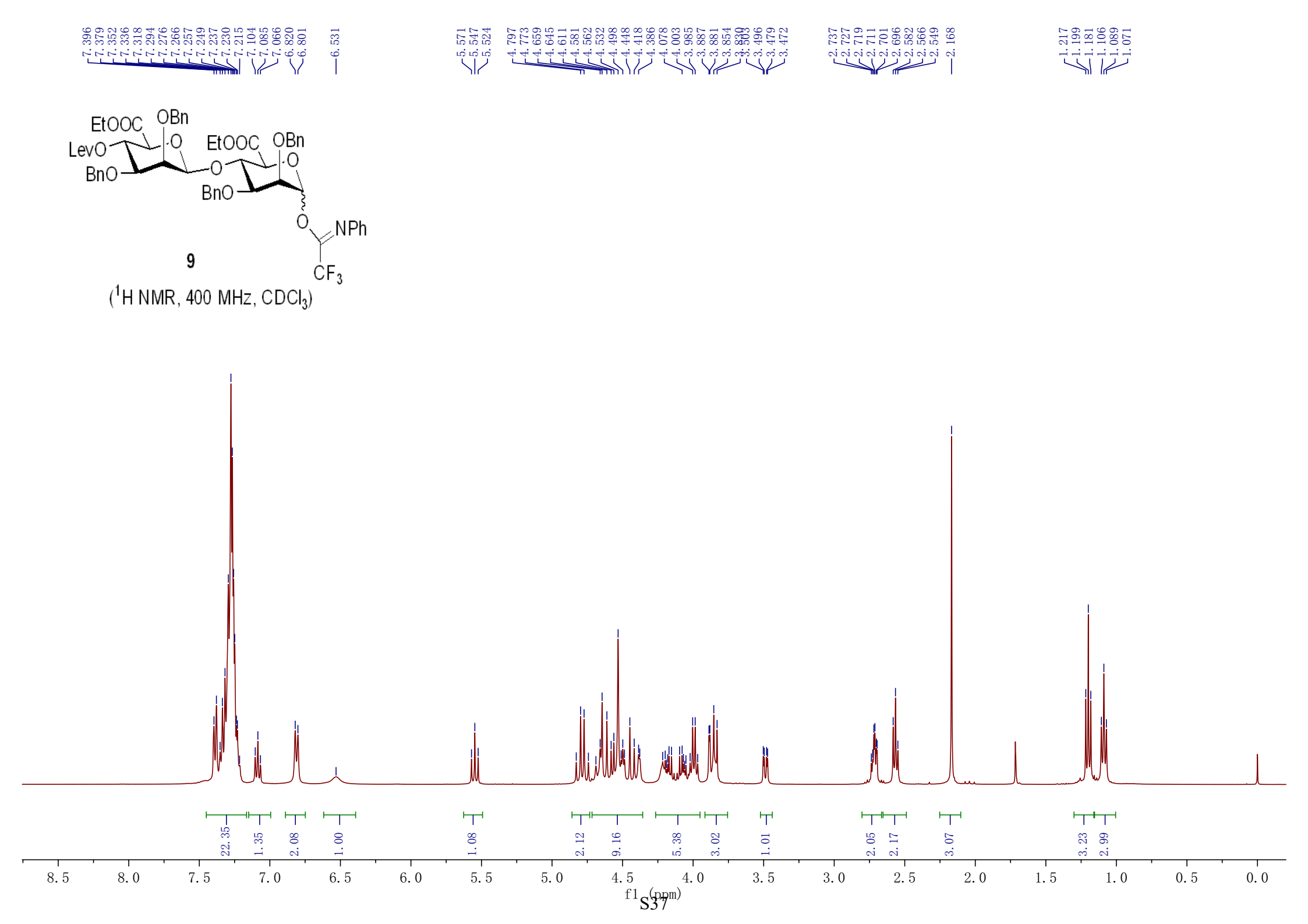


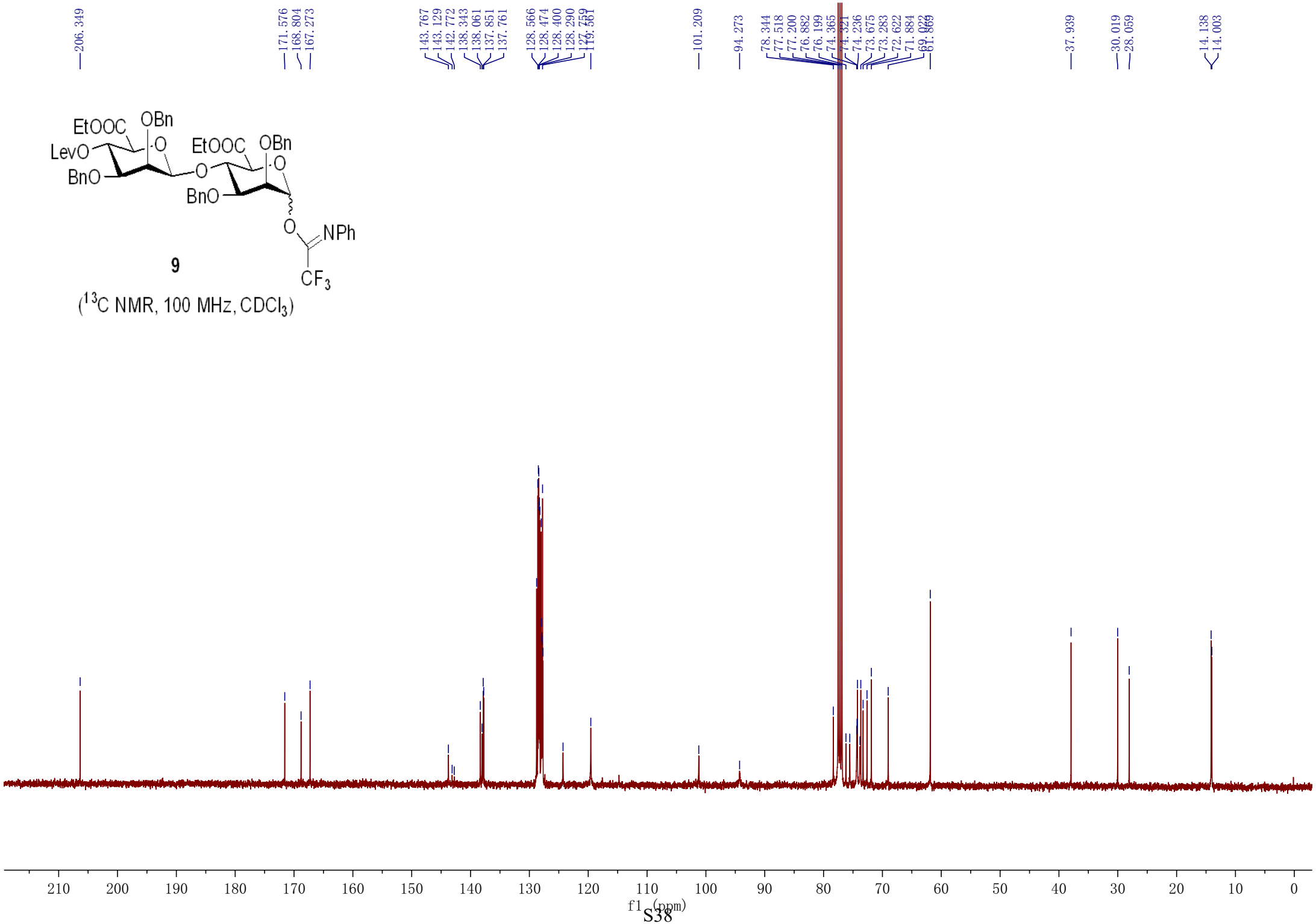


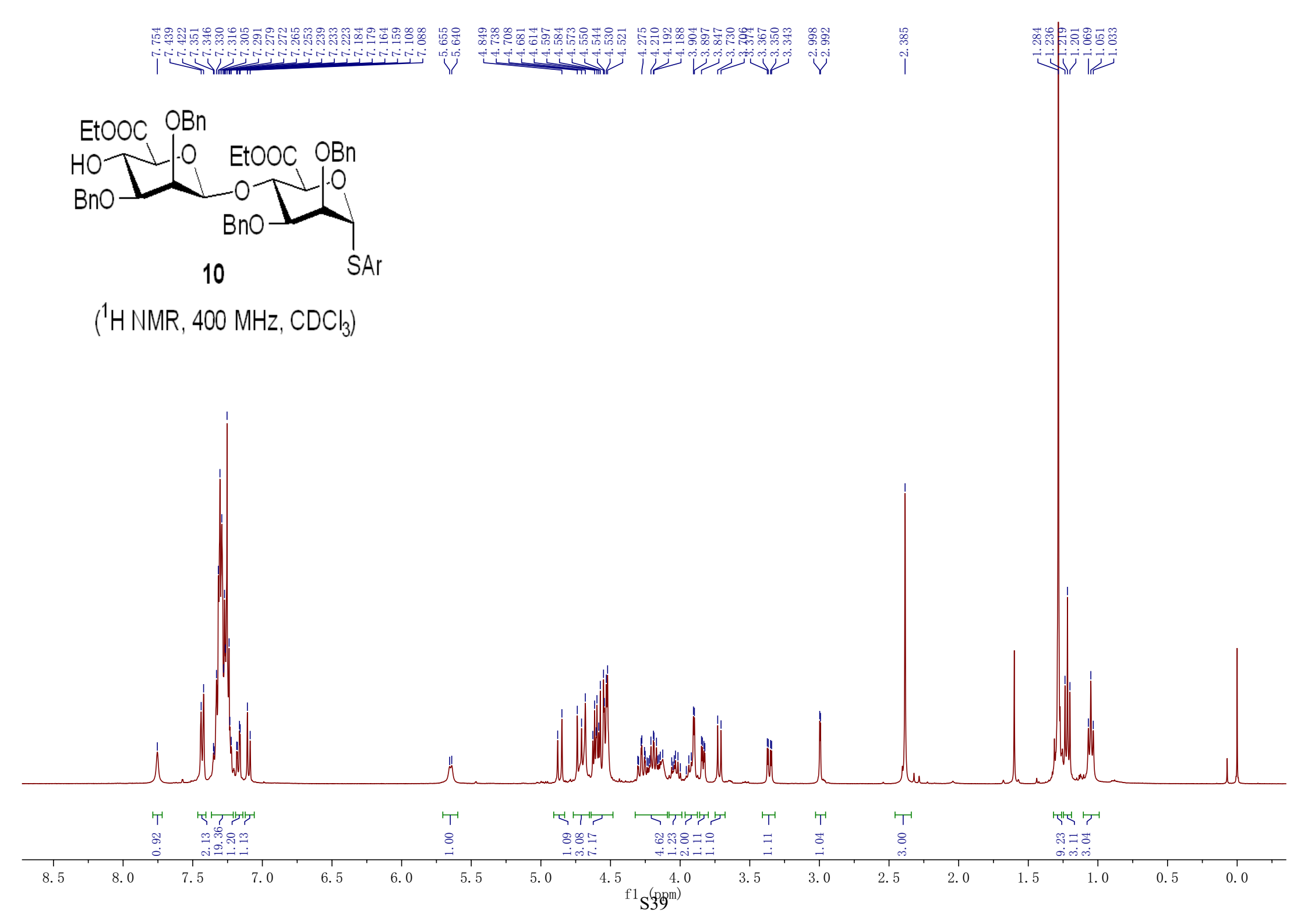
8

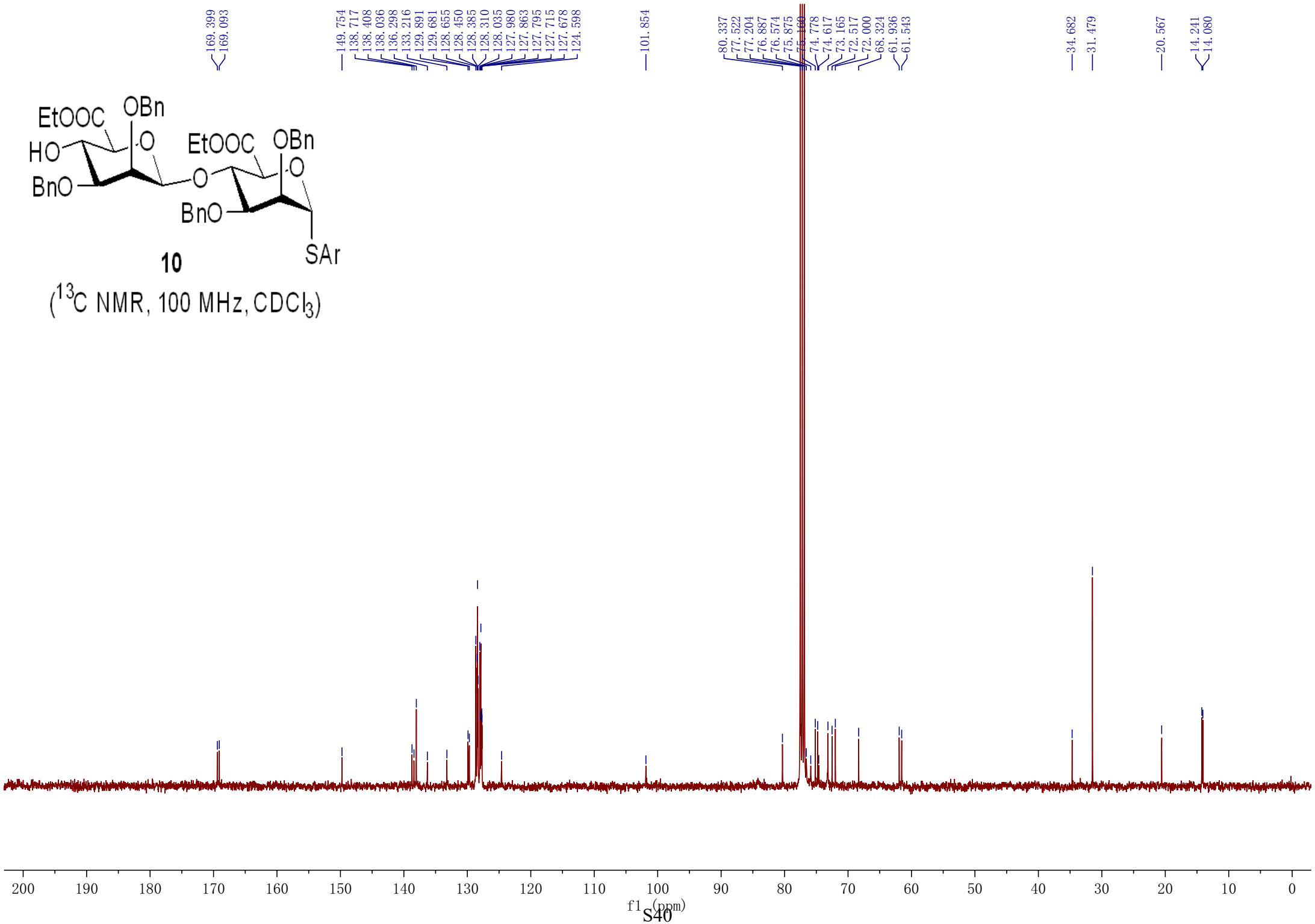
(coupled HSQC, 500 MHz, $CDCl_3$)

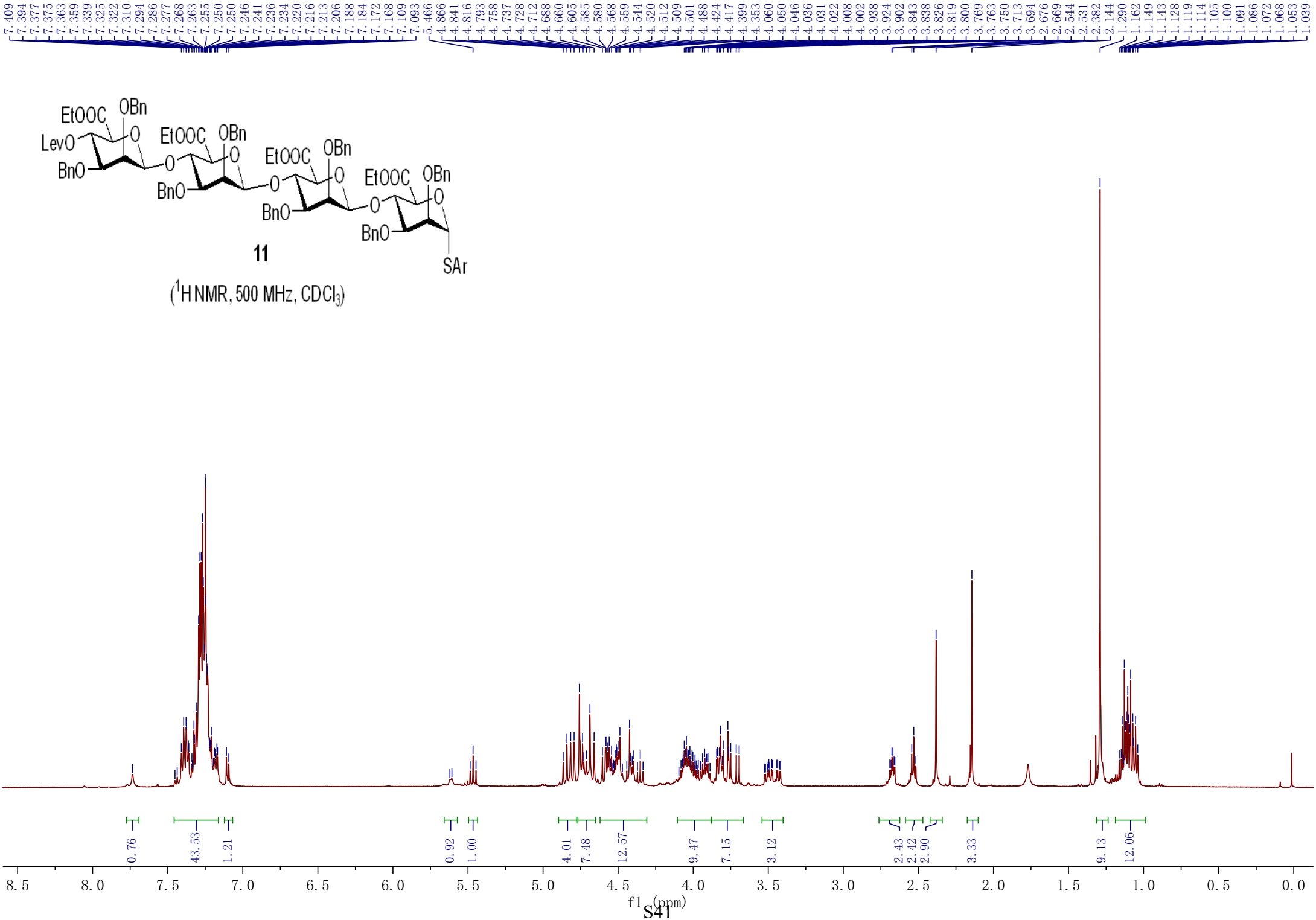


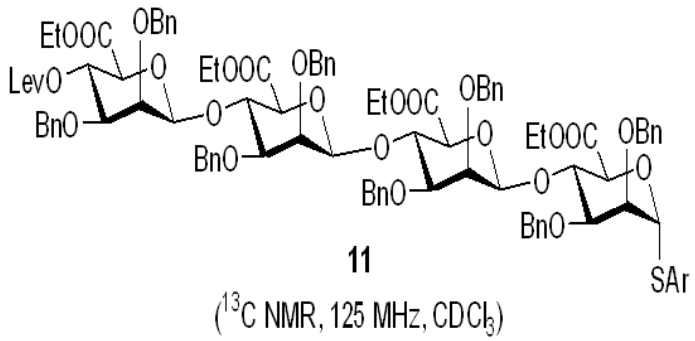

7.396
7.379
7.352
7.336
7.318
7.294
7.276
7.266
7.257
7.249
7.237
7.230
7.215
7.104
7.085
7.066
6.820
6.801
6.531
5.571
5.547
5.524
4.797
4.773
4.659
4.645
4.611
4.581
4.562
4.532
4.498
4.448
4.418
4.386
4.078
4.003
3.985
3.887
3.881
3.854
3.496
3.479
3.472
2.737
2.727
2.719
2.711
2.701
2.696
2.582
2.566
2.549
2.168
1.217
1.199
1.181
1.106
1.089
1.071
EtOOC
OBn
LevO
BnO
EtOOC
OBn
BnO
NPh
CF3
9
(1H NMR, 400 MHz, CDCl3)
22.35
1.35
2.08
1.00
1.08
2.12
9.16
5.38
3.02
1.01
2.05
2.17
3.07
3.23
2.99
8.5
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
f1 (ppm)


206.349
171.576
168.804
167.273
143.767
143.129
142.772
138.343
138.061
137.851
137.761
128.566
128.474
128.400
128.290
101.209
94.273
78.344
77.518
77.200
76.882
76.199
74.365
74.321
74.236
73.675
73.283
72.622
71.884
37.939
30.019
28.059
14.138
14.003
EtOOC
OBn
LevO
BnO
O
EtOOC
OBn
O
BnO
O
NPh
CF3
9
(13C NMR, 100 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


EtOOC
OBn
HO
O
BnO
EtOOC
OBn
O
O
BnO
SAr
10
(1H NMR, 400 MHz, CDCl3)
f1 (ppm)

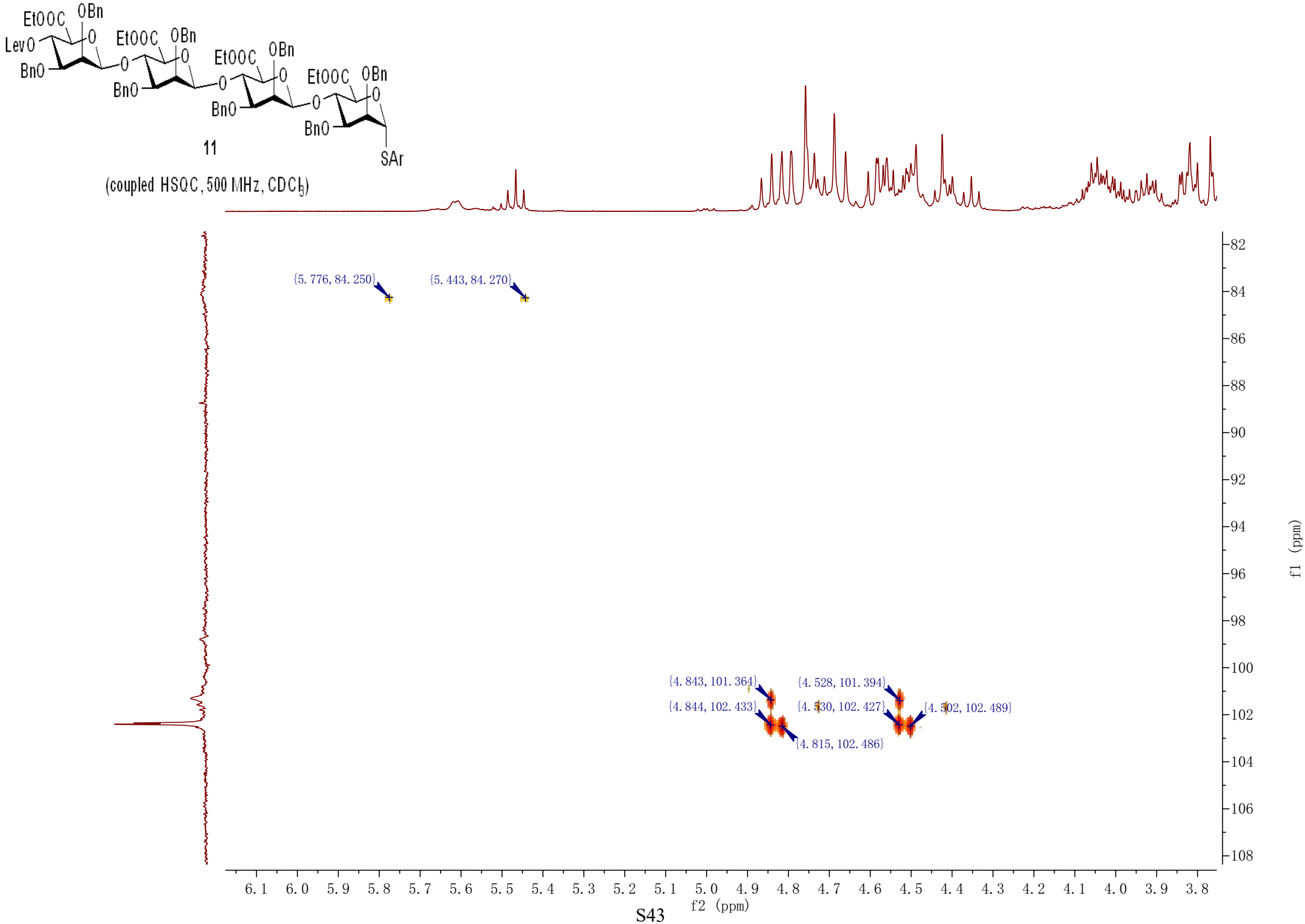

169.399
169.093
149.754
138.717
138.408
138.036
136.298
133.216
129.891
129.681
128.655
128.450
128.385
128.310
128.035
127.980
127.863
127.795
127.715
127.678
124.598
101.854
80.337
77.522
77.204
76.887
76.574
75.875
74.778
74.617
73.165
72.517
72.000
68.324
61.936
61.543
34.682
31.479
20.567
14.241
14.080
EtOOC
OBn
HO
O
BnO
O
EtOOC
OBn
O
BnO
SAr
10
(^{13}C NMR, 100 MHz, $CDCl_3$)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

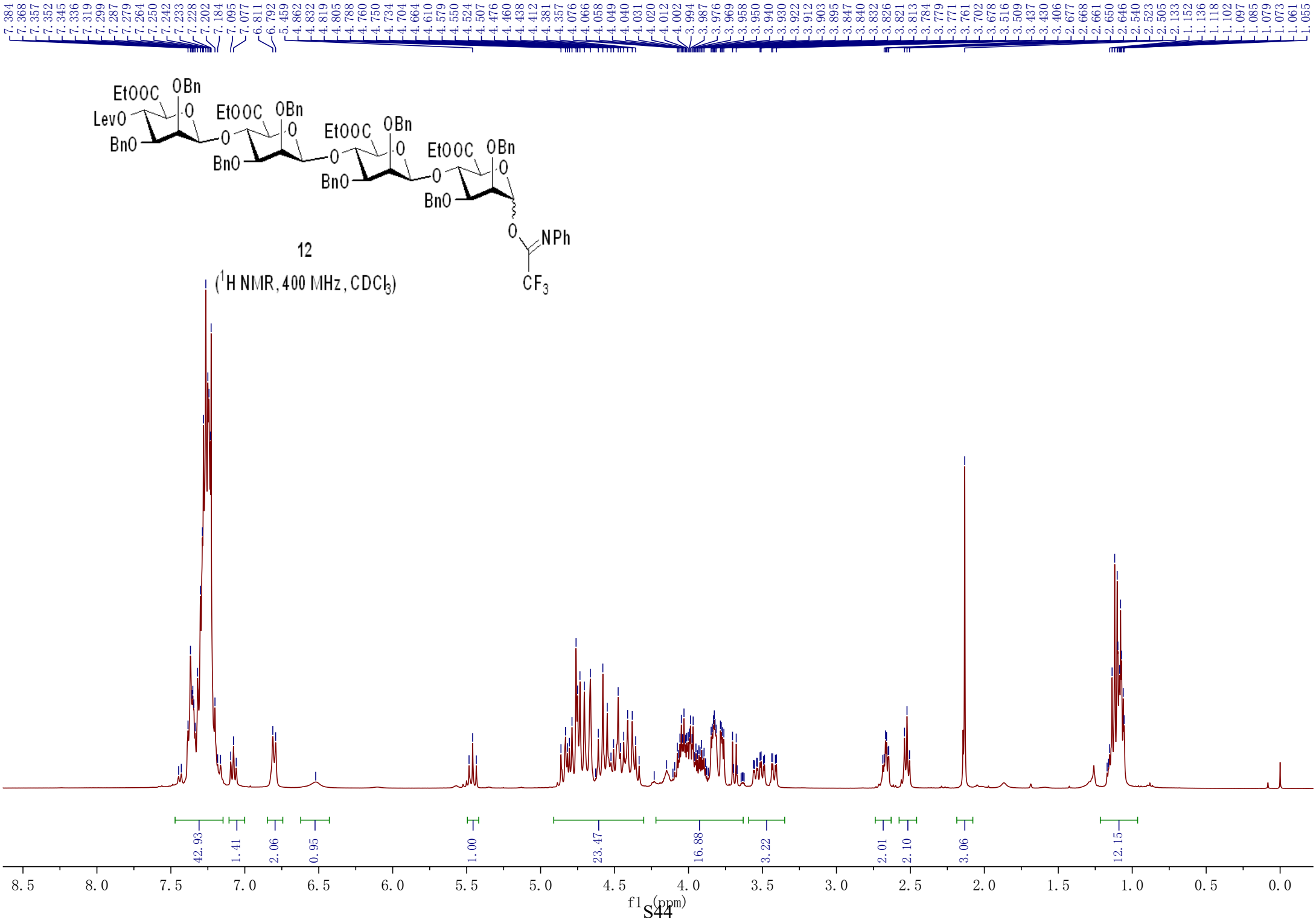

EtOOC
OBn
LevO
BnO
11
SAr
(1H NMR, 500 MHz, CDCl3)
f1 (ppm)

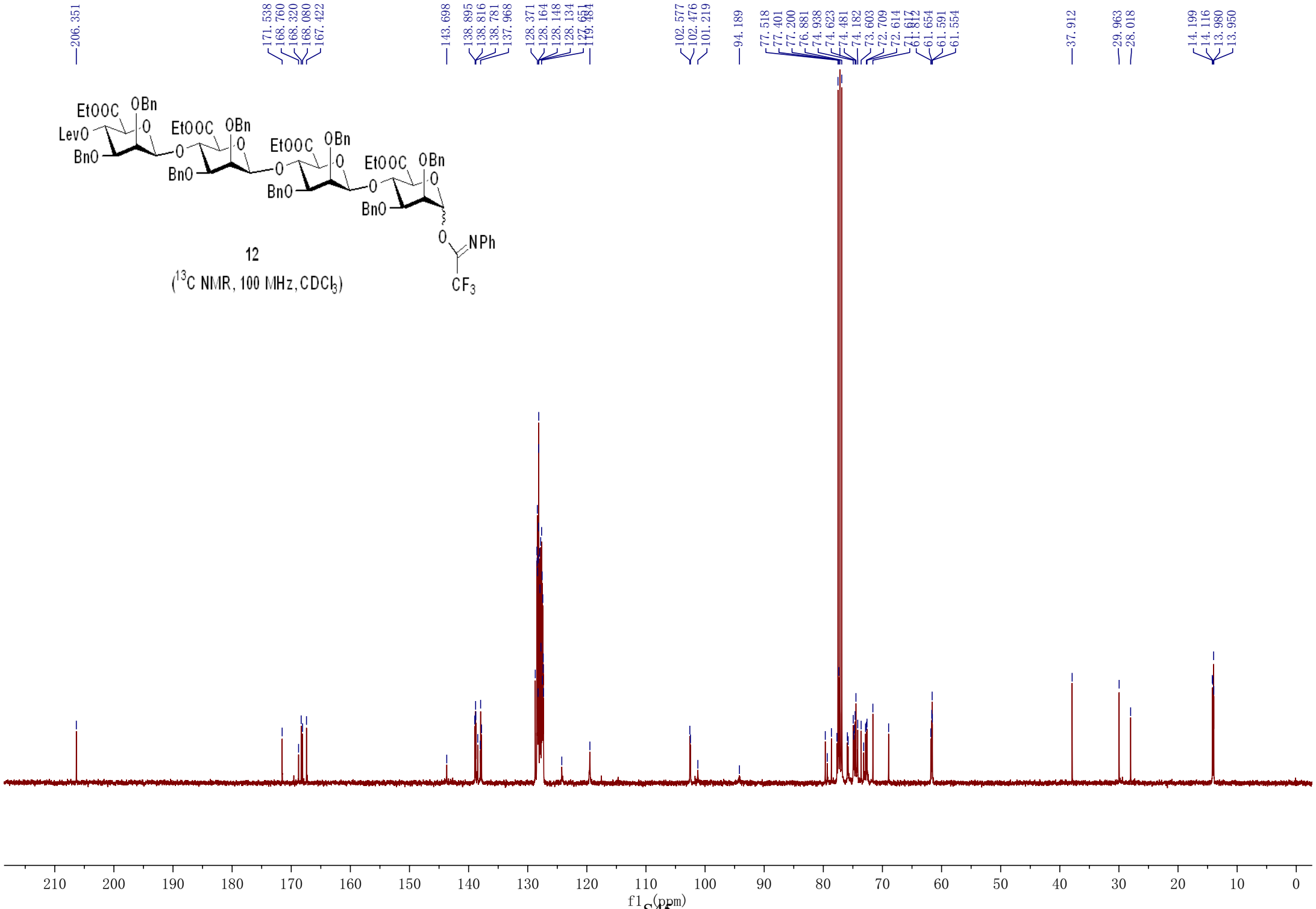


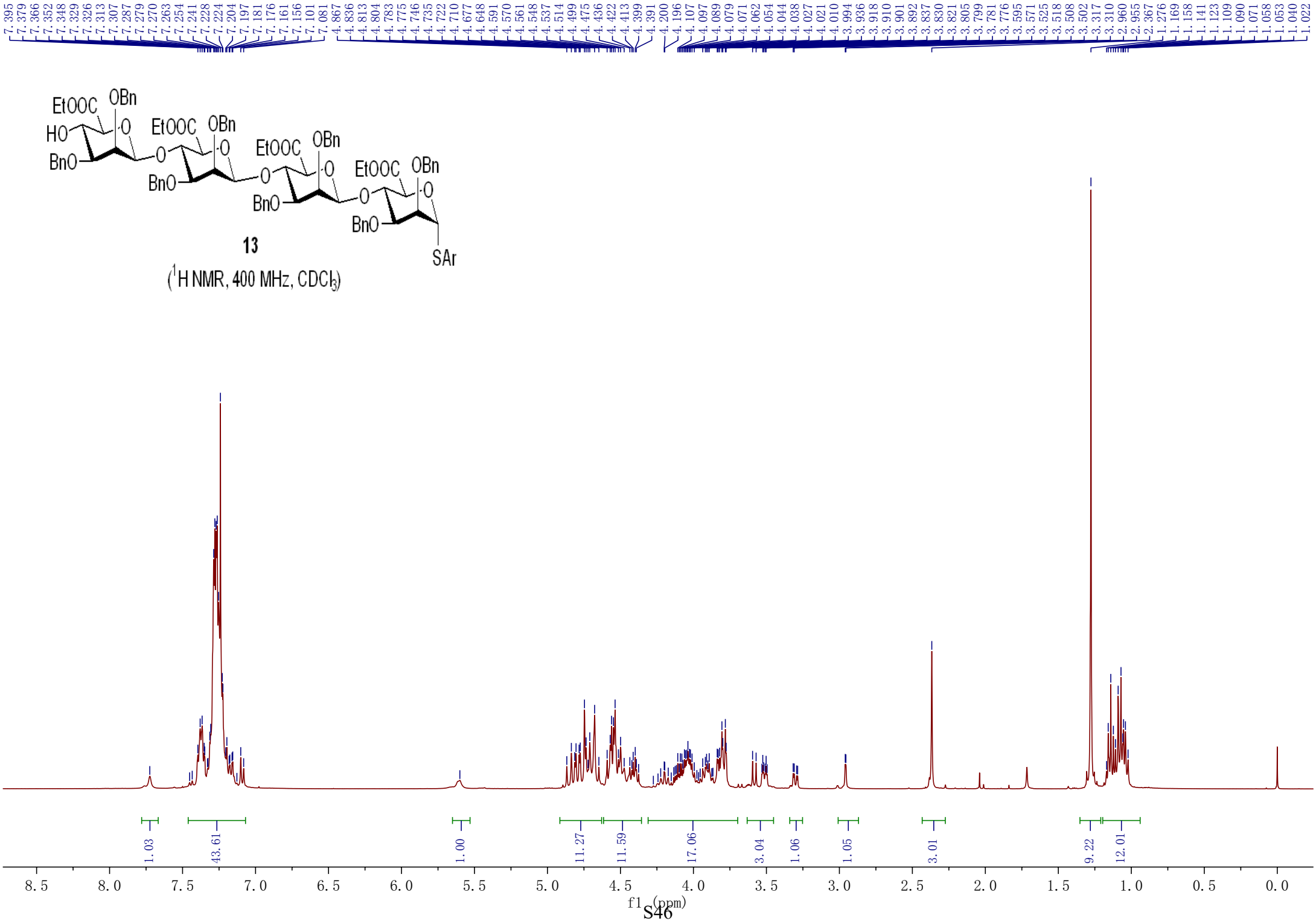
11

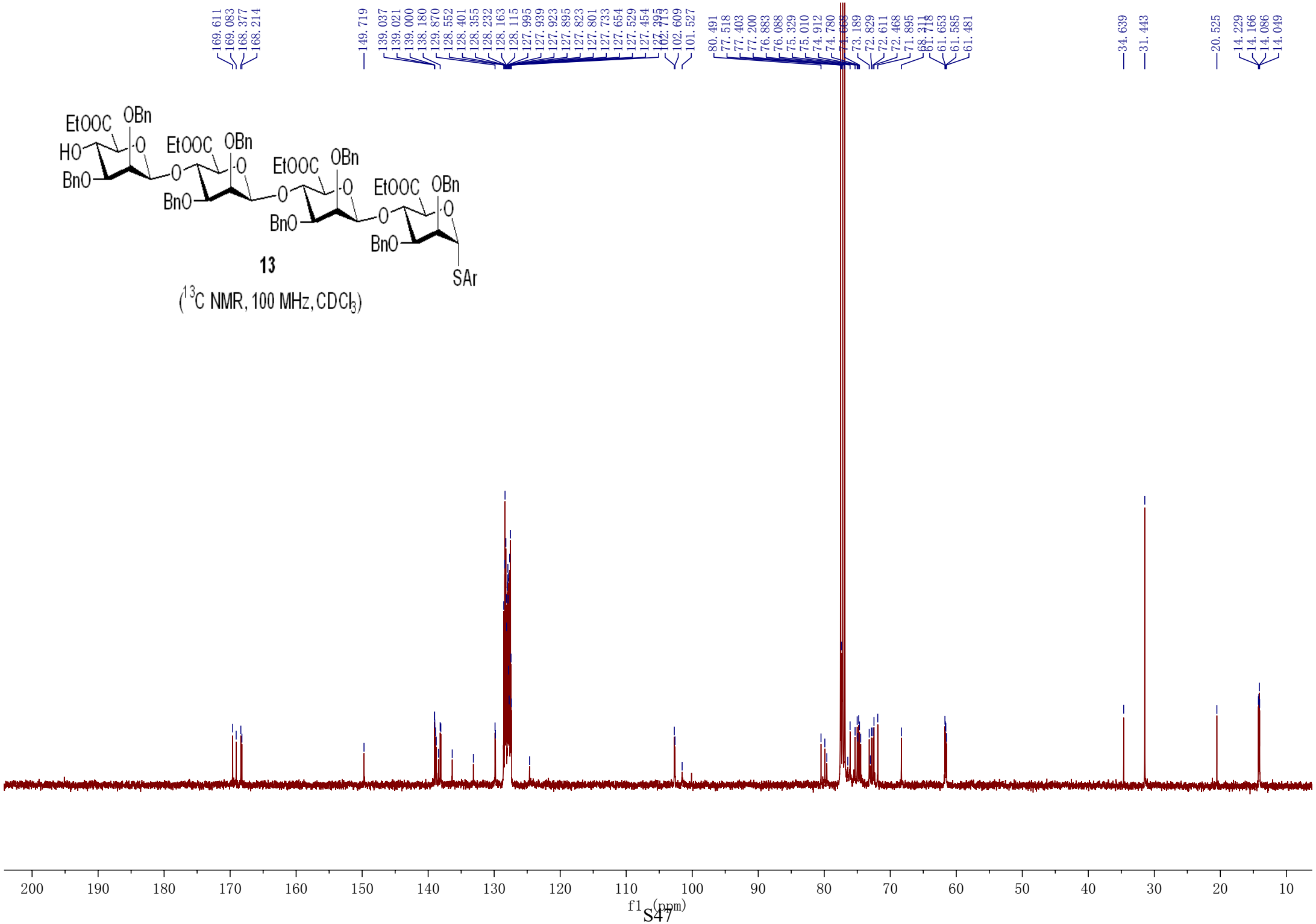
(^{13}C NMR, 125 MHz, $CDCl_3$)

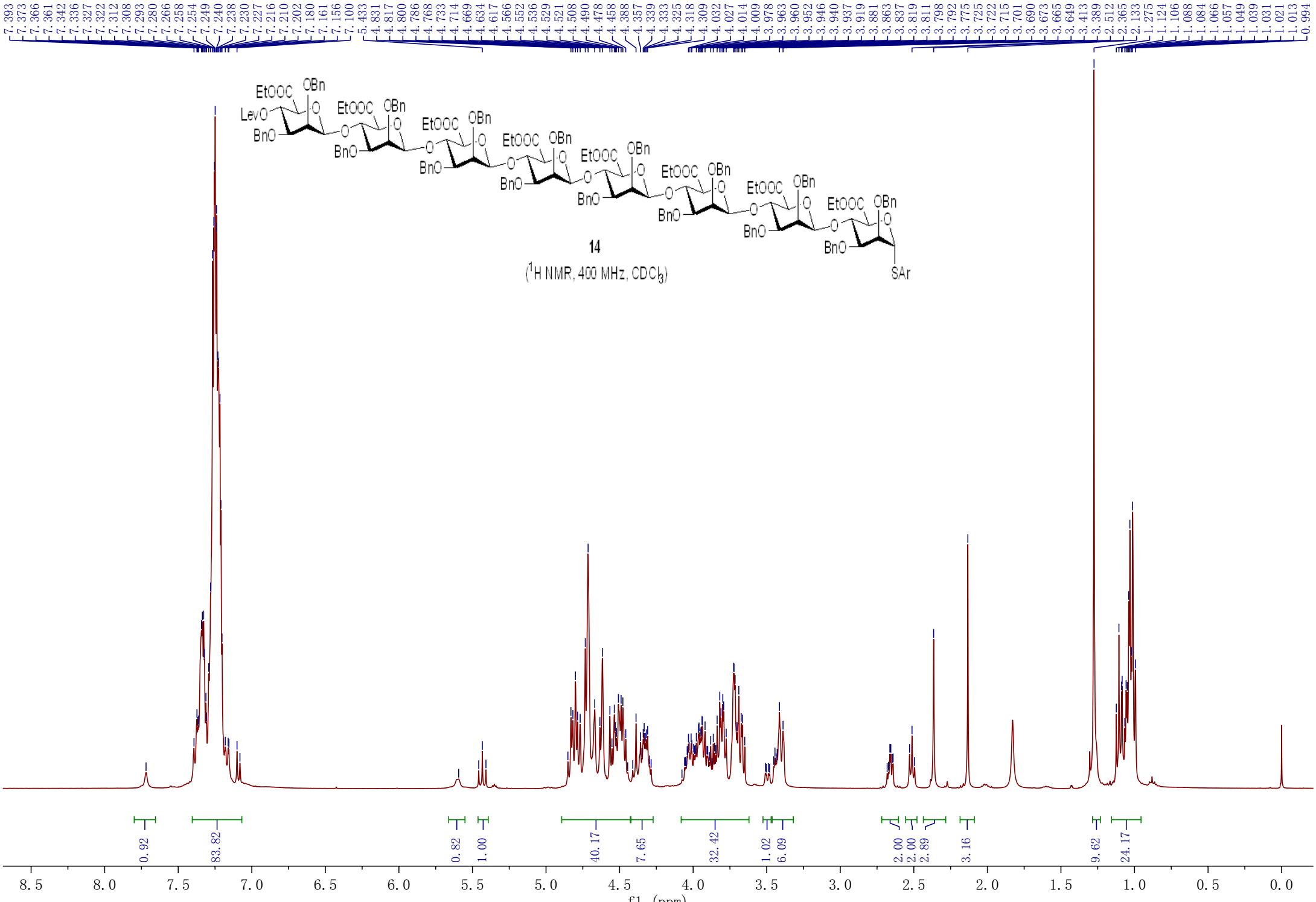

EtOOC
OBn
LevO
BnO
O
SAr
11
(coupled HSQC, 500 MHz, CDCl3)
{5. 776, 84. 250}
{5. 443, 84. 270}
{4. 843, 101. 364}
{4. 844, 102. 433}
{4. 815, 102. 486}
{4. 528, 101. 394}
{4. 530, 102. 427}
{4. 502, 102. 489}
f1 (ppm)
f2 (ppm)

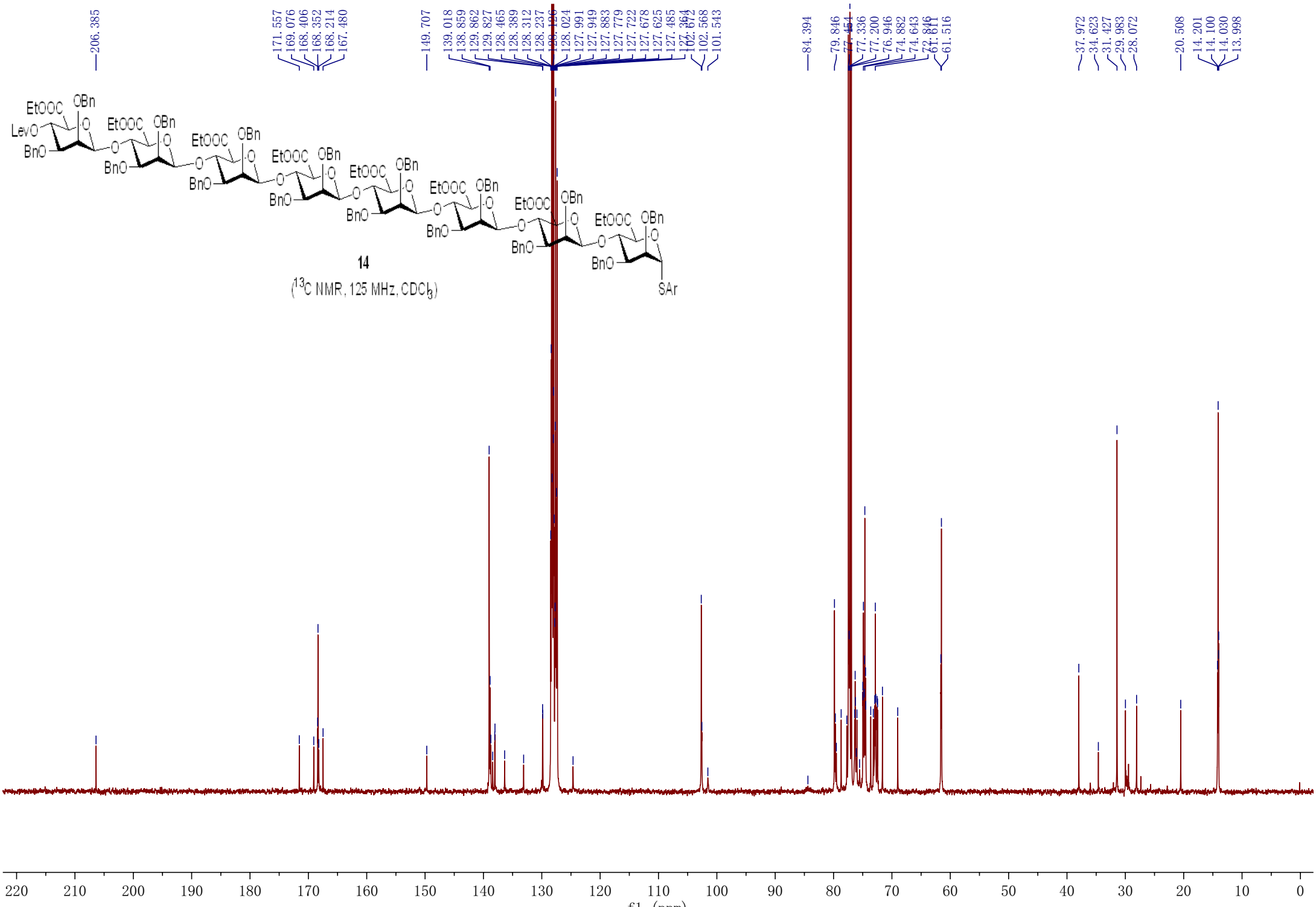

12
(1H NMR, 400 MHz, CDCl3)
f1 (ppm)

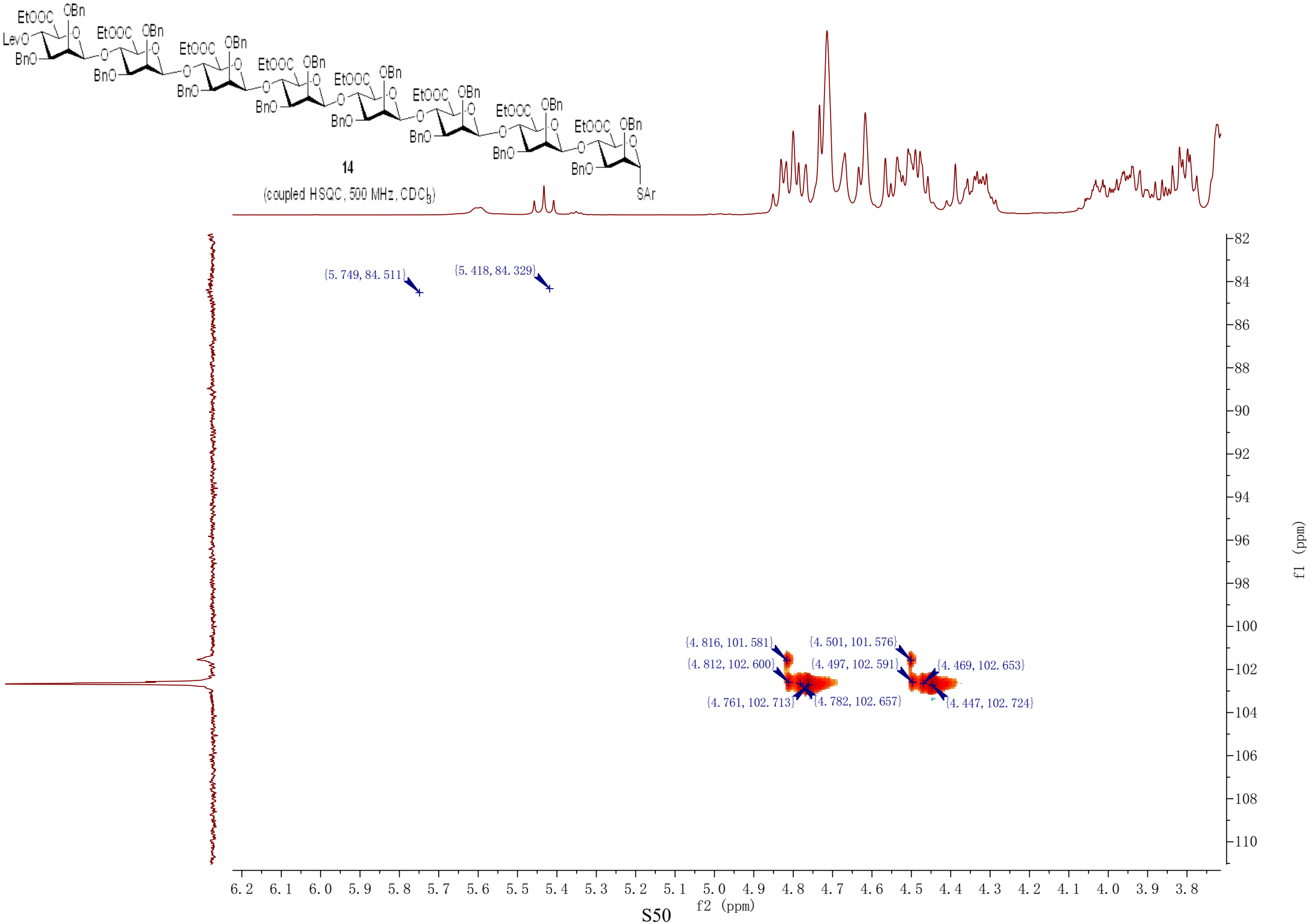

206.351
171.538
168.760
168.320
168.080
167.422
143.698
138.895
138.816
138.781
137.968
128.371
128.164
128.148
128.134
102.577
102.476
101.219
94.189
77.518
77.401
77.200
76.881
74.938
74.623
74.481
74.182
73.603
72.709
72.614
61.654
61.591
61.554
37.912
29.963
28.018
14.199
14.116
13.980
13.950
EtOOC
OBn
LevO
BnO
O
NPh
CF3
12
(13C NMR, 100 MHz, CDCl3)
f1 (ppm)

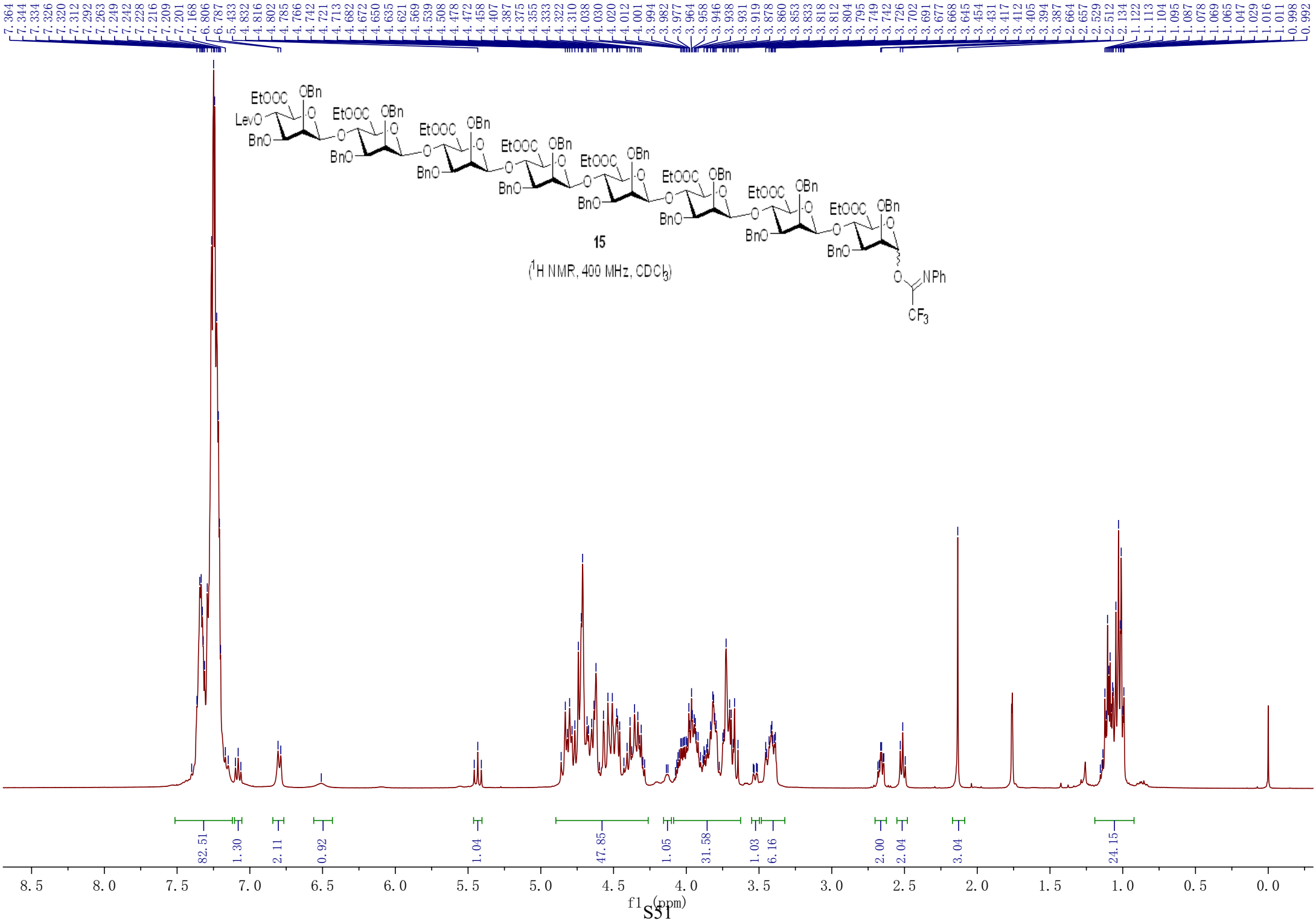

7.395 7.379 7.366 7.352 7.348 7.329 7.326 7.313 7.307 7.287 7.279 7.270 7.263 7.254 7.241 7.228 7.224 7.204 7.197 7.181 7.176 7.161 7.156 7.101 7.081 4.867 4.836 4.813 4.804 4.783 4.775 4.746 4.735 4.722 4.710 4.677 4.648 4.591 4.570 4.561 4.548 4.537 4.514 4.499 4.475 4.436 4.422 4.413 4.399 4.391 4.200 4.196 4.107 4.097 4.089 4.079 4.071 4.062 4.054 4.044 4.038 4.027 4.021 4.010 3.994 3.936 3.918 3.910 3.901 3.892 3.837 3.830 3.821 3.805 3.799 3.781 3.776 3.595 3.571 3.525 3.518 3.508 3.502 3.317 3.310 2.960 2.955 2.367 1.276 1.169 1.158 1.141 1.123 1.109 1.090 1.071 1.058 1.053 1.040 1.022
EtOOC
OBn
HO
BnO
O
13
SAr
(1H NMR, 400 MHz, CDCl3)
1.03
43.61
1.00
11.27
11.59
17.06
3.04
1.06
1.05
3.01
9.22
12.01
8.5 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
f1 (ppm)

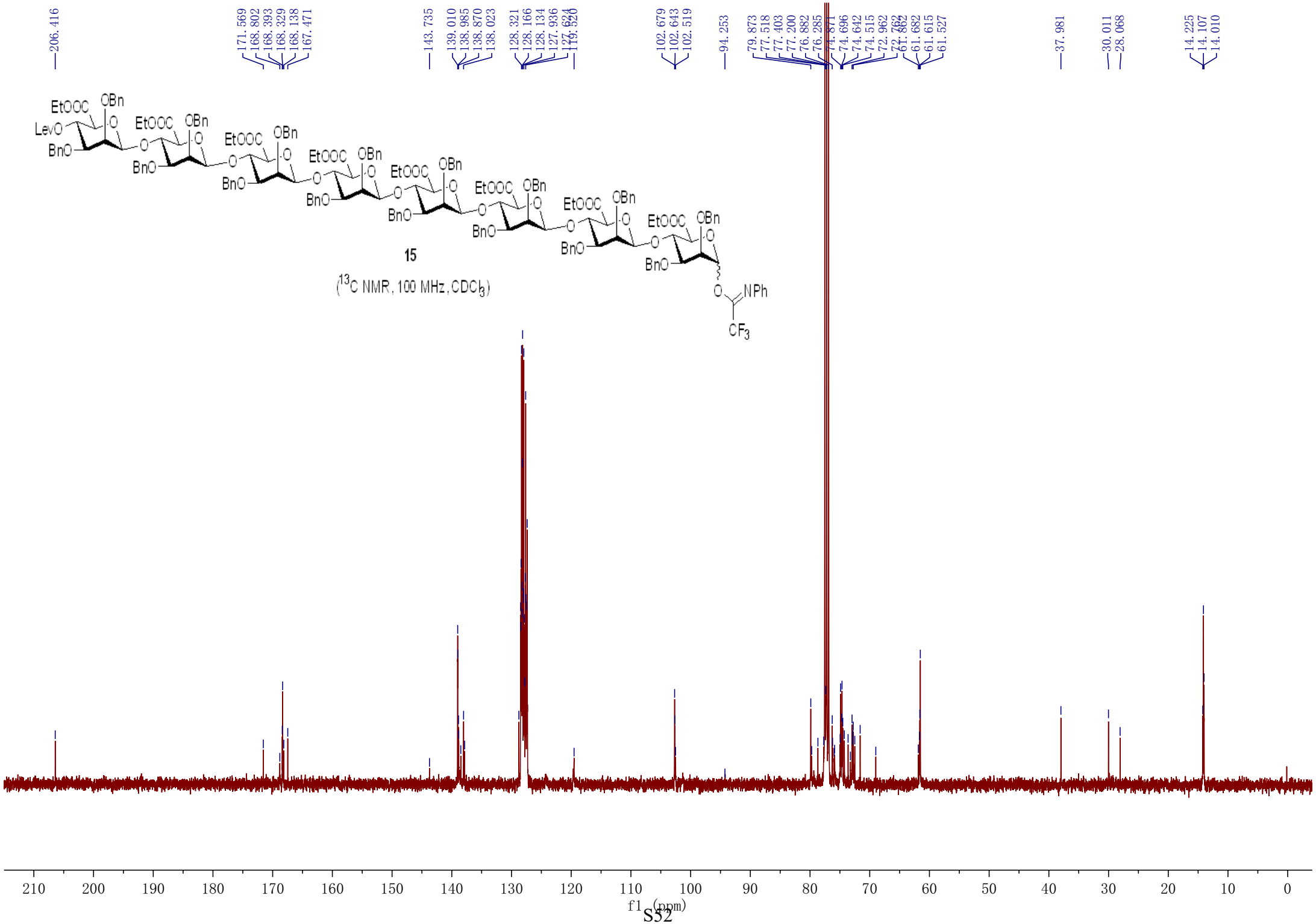

169.611
169.083
168.377
168.214
149.719
139.037
139.021
139.000
138.180
129.870
128.552
128.401
128.355
128.232
128.163
128.115
127.995
127.939
127.923
127.895
127.823
127.801
127.733
127.654
127.529
127.454
102.609
101.527
80.491
77.518
77.403
77.200
76.883
76.088
75.329
75.010
74.912
74.780
73.189
72.829
72.611
72.468
71.895
61.653
61.585
61.481
34.639
31.443
20.525
14.229
14.166
14.086
14.049
EtOOC
OBn
HO
BnO
O
13
SAr
(^{13}C NMR, 100 MHz, $CDCl_3$)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

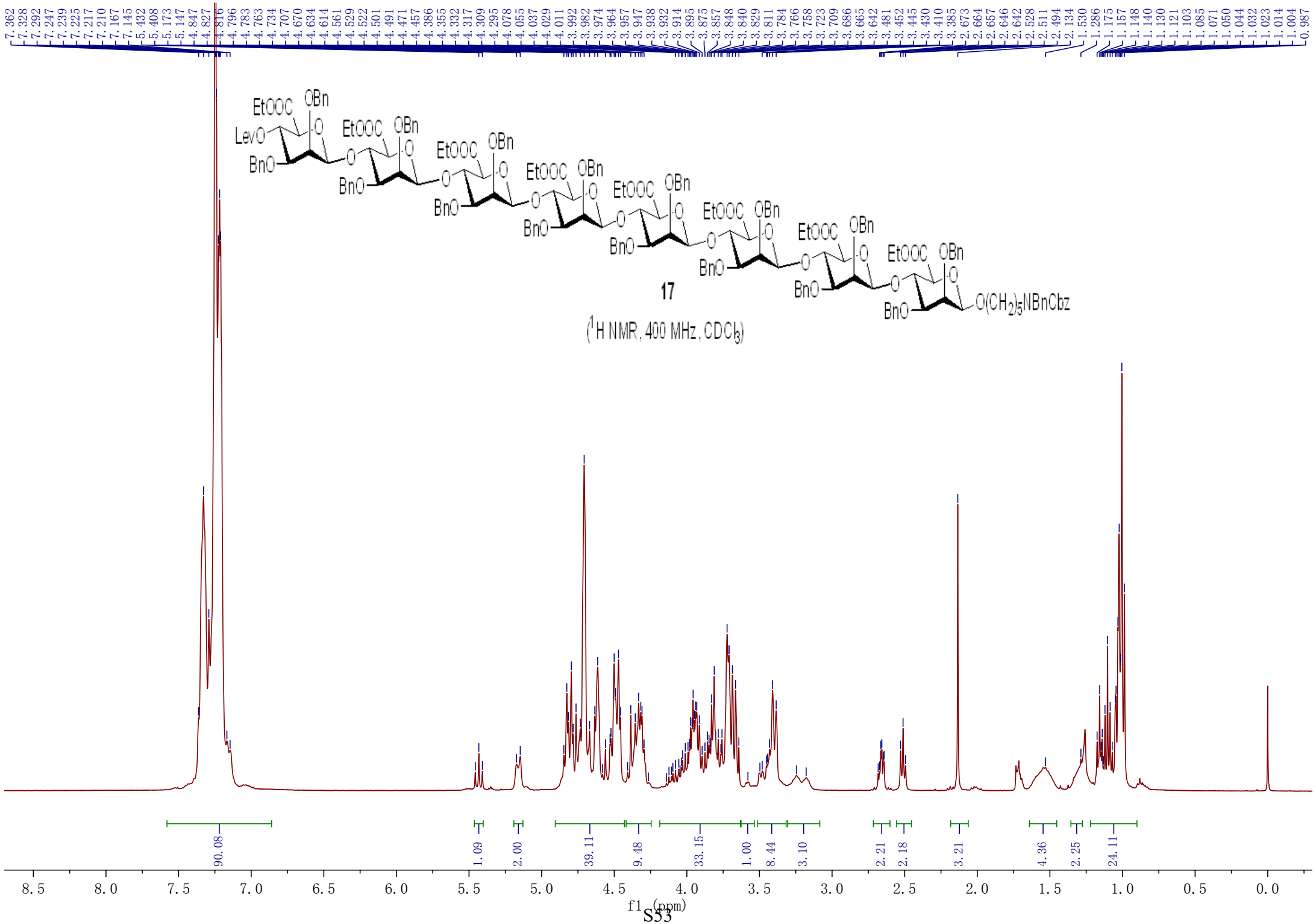

14
(1H NMR, 400 MHz, CDCl3)
f1 (ppm)

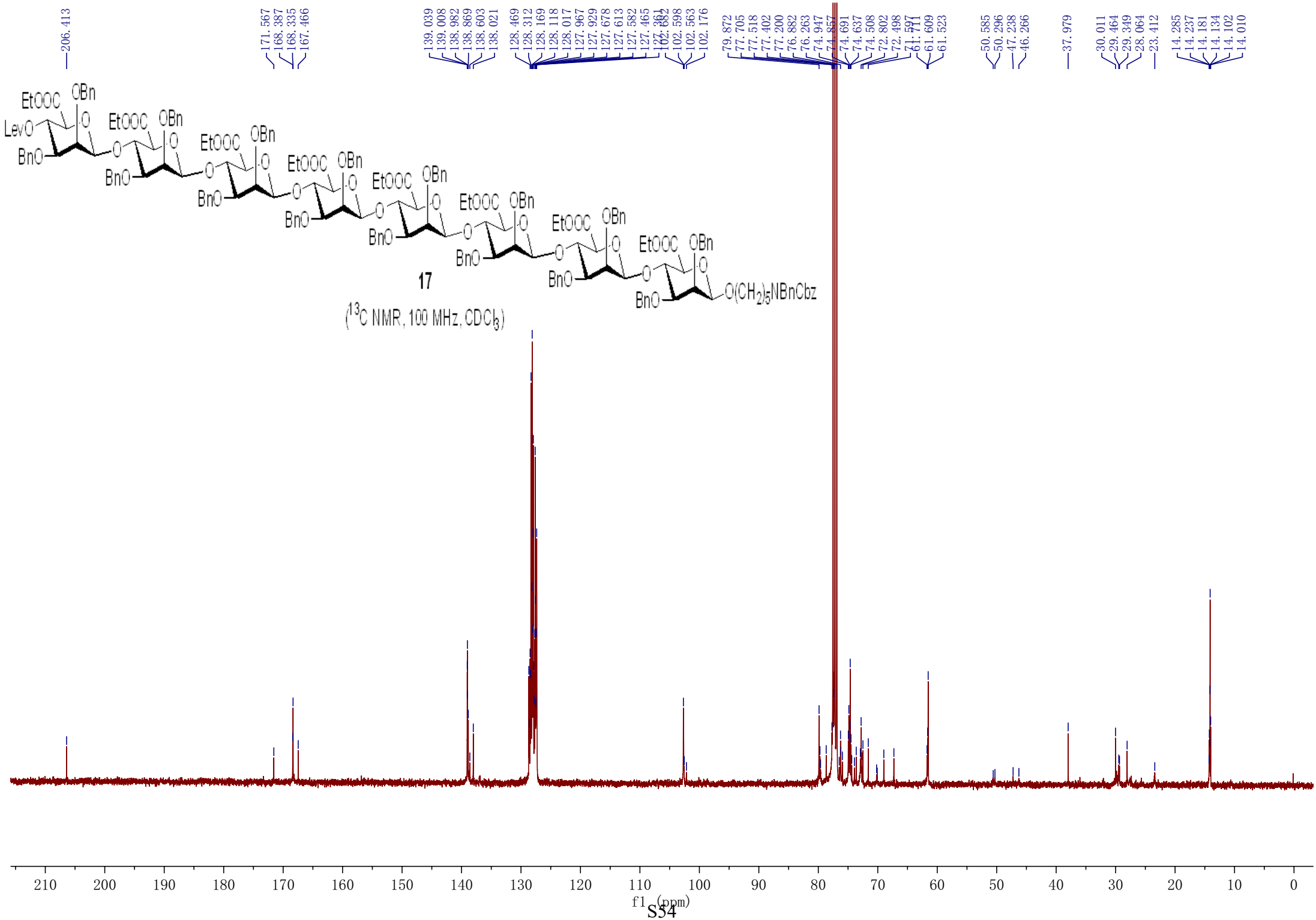

206.385
171.557
169.076
168.406
168.352
168.214
167.480
149.707
139.018
138.859
129.862
129.827
128.465
128.389
128.312
128.237
128.126
128.024
127.991
127.949
127.883
127.779
127.722
127.678
127.625
127.485
102.672
102.568
101.543
84.394
79.846
77.454
77.336
77.200
76.946
74.882
74.643
72.846
61.611
61.516
37.972
34.623
31.427
29.983
28.072
20.508
14.201
14.100
14.030
13.998
EtOOC
OBn
LevO
BnO
SAr
14
(13C NMR, 125 MHz, CDCl3)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

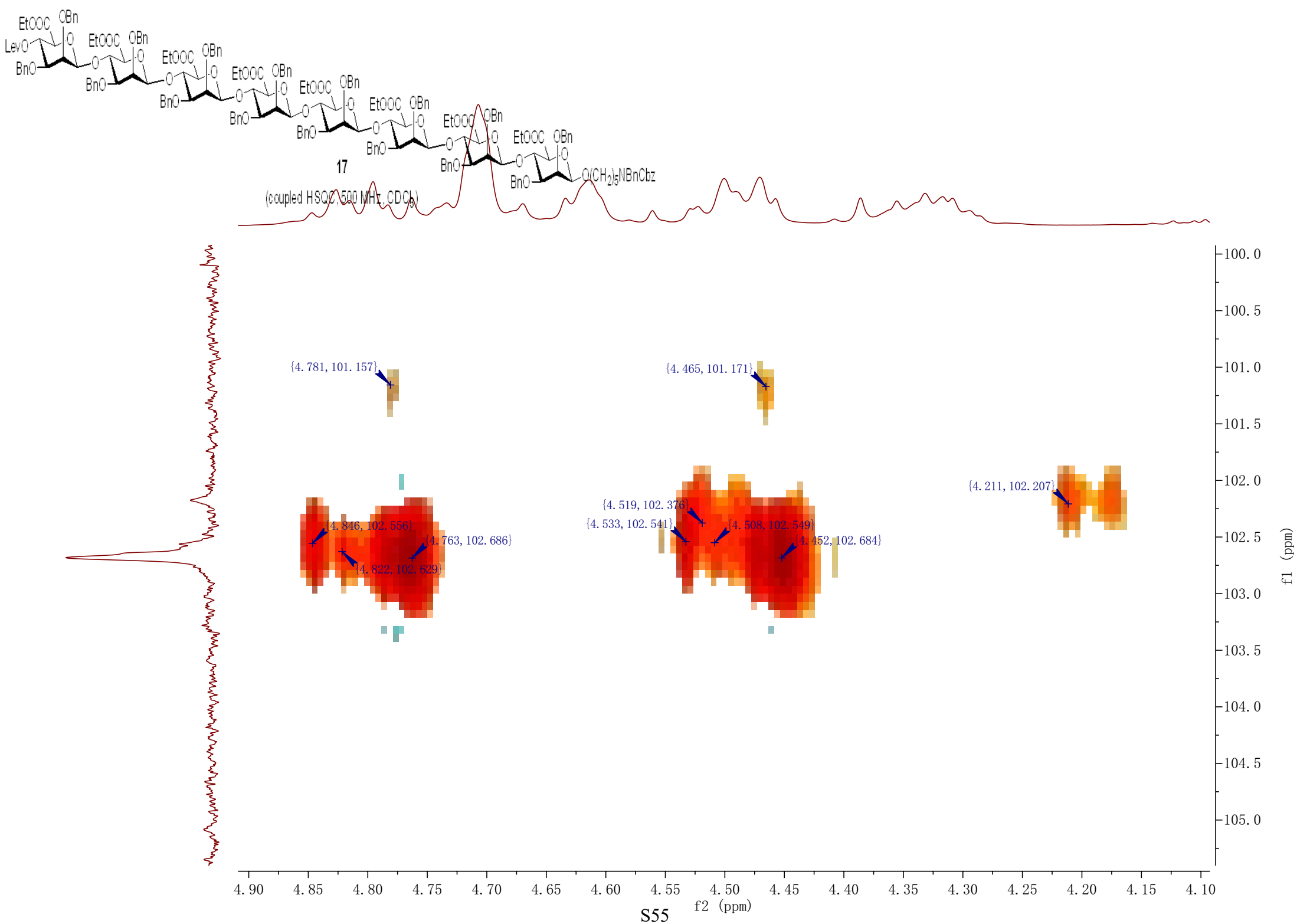

14
(coupled HSQC, 500 MHz, CDCl3)
{5. 749, 84. 511}
{5. 418, 84. 329}
{4. 816, 101. 581}
{4. 812, 102. 600}
{4. 761, 102. 713}
{4. 501, 101. 576}
{4. 497, 102. 591}
{4. 782, 102. 657}
{4. 469, 102. 653}
{4. 447, 102. 724}
f2 (ppm)
f1 (ppm)

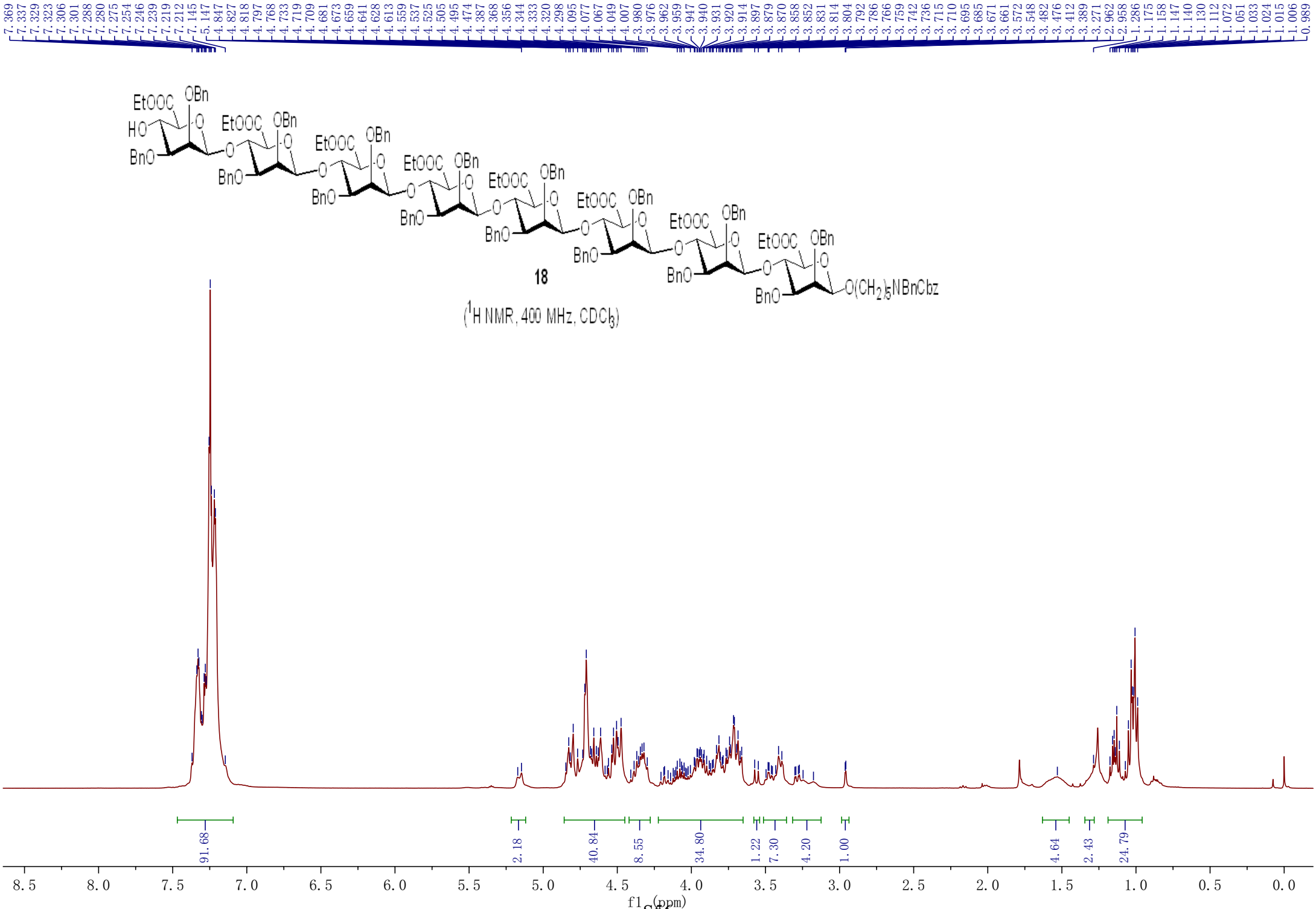

7.364 7.344 7.334 7.326 7.320 7.312 7.292 7.263 7.249 7.242 7.228 7.216 7.209 7.201 7.168 6.806 6.787 5.433 4.832 4.816 4.802 4.785 4.766 4.742 4.721 4.713 4.682 4.672 4.650 4.635 4.621 4.569 4.539 4.508 4.478 4.472 4.458 4.407 4.387 4.375 4.355 4.333 4.322 4.310 4.038 4.030 4.020 4.012 4.001 3.994 3.982 3.977 3.964 3.958 3.946 3.938 3.931 3.919 3.878 3.860 3.853 3.833 3.818 3.812 3.804 3.795 3.749 3.742 3.726 3.702 3.691 3.677 3.668 3.645 3.454 3.431 3.417 3.412 3.405 3.394 3.387 2.664 2.657 2.529 2.512 2.134 1.122 1.113 1.104 1.095 1.087 1.078 1.069 1.065 1.047 1.029 1.016 1.011 0.998 0.992
EtOOC
OBn
LevO
BnO
O
NPh
CF3
15
(1H NMR, 400 MHz, CDCl3)
82.51
1.30
2.11
0.92
1.04
47.85
1.05
31.58
1.03
6.16
2.00
2.04
3.04
24.15
8.5
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
f1 (ppm)

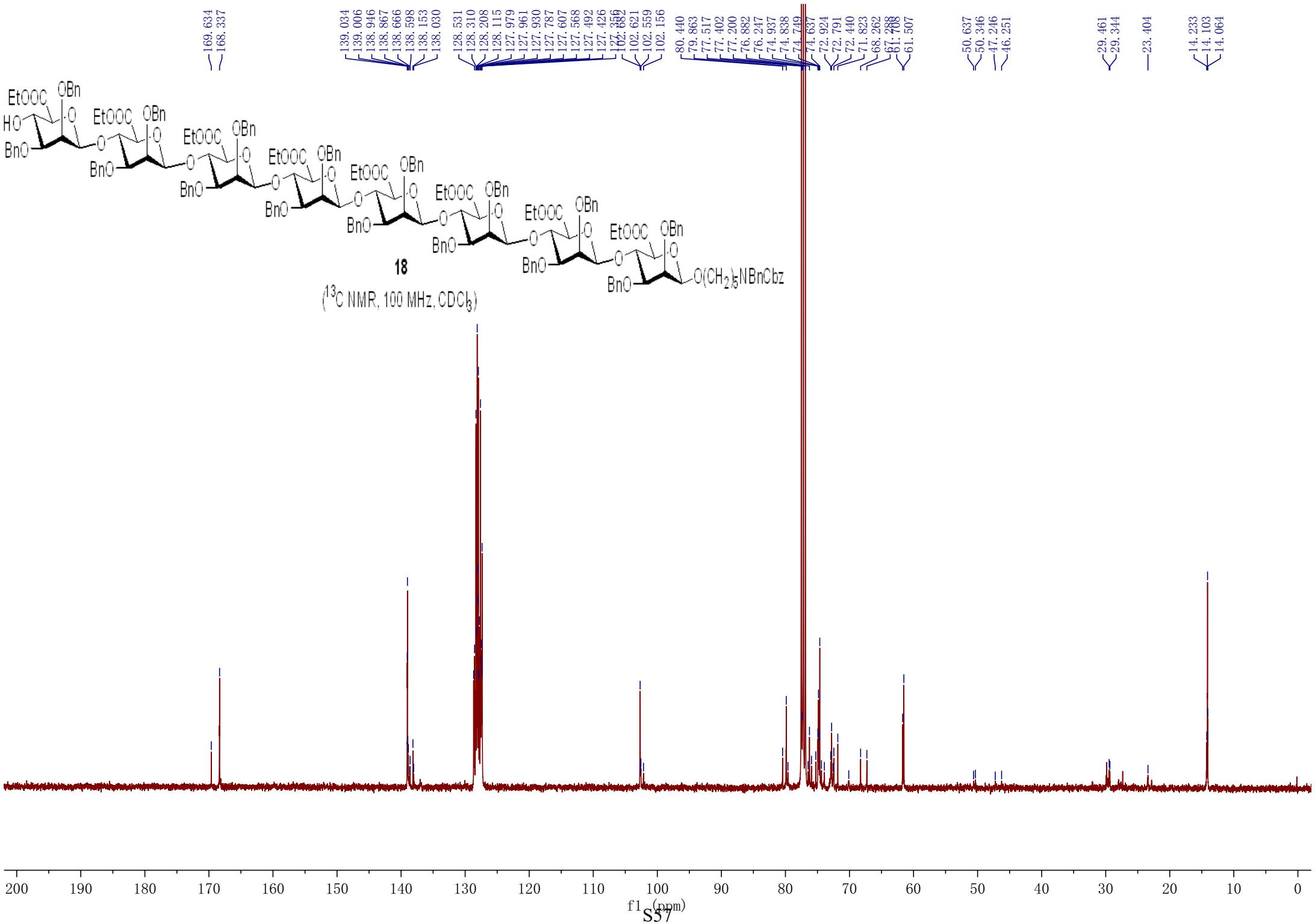

206.416
171.569
168.802
168.393
168.329
168.138
167.471
143.735
139.010
138.985
138.870
138.023
128.321
128.166
128.134
127.936
102.679
102.643
102.519
94.253
79.873
77.518
77.403
77.200
76.882
76.285
74.871
74.696
74.642
74.515
72.962
61.682
61.615
61.527
37.981
30.011
28.068
14.225
14.107
14.010
EtOOC
OBn
LevO
BnO
O
NPh
CF3
15
(13C NMR, 100 MHz, CDCl3)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

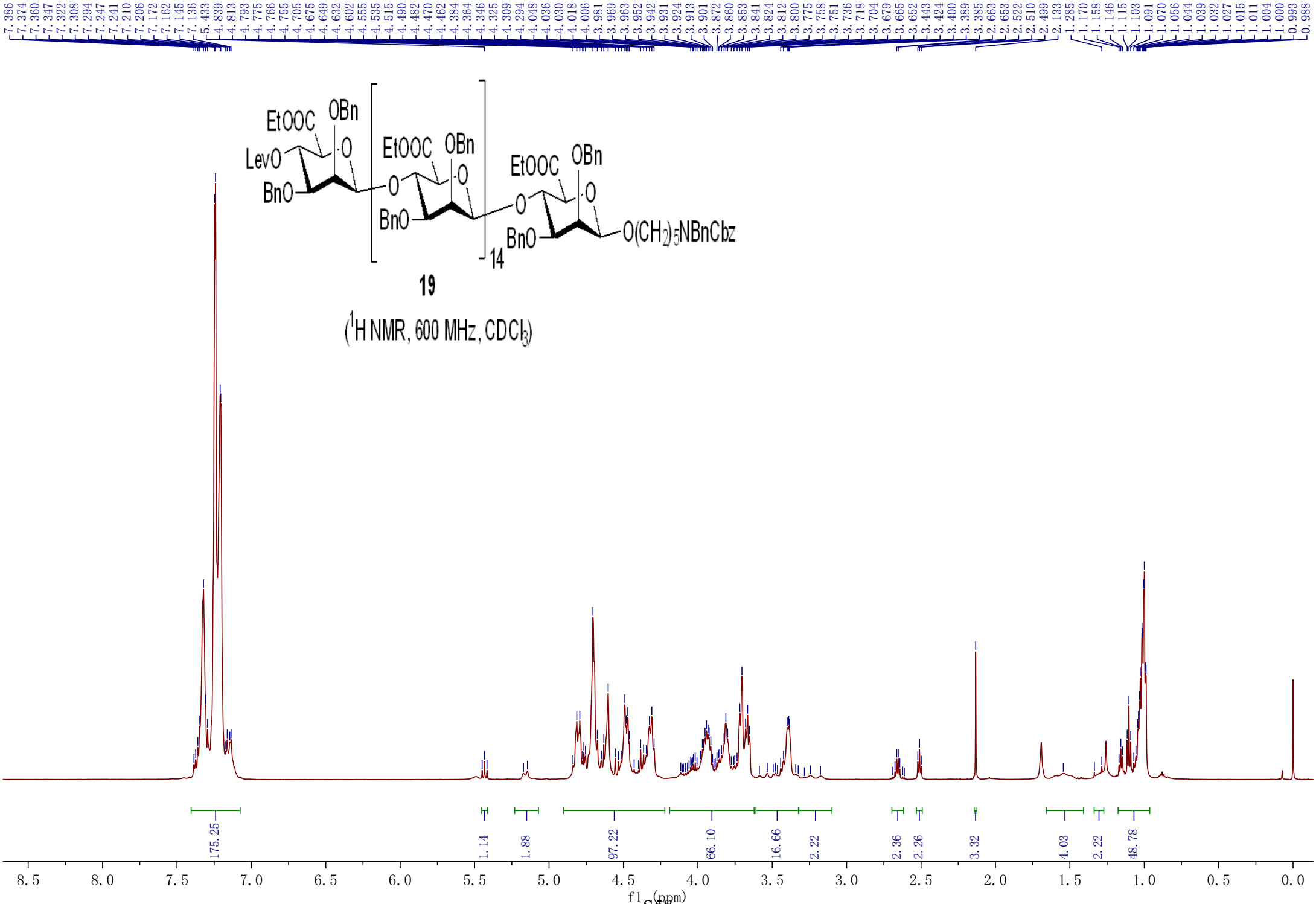

17
(1H NMR, 400 MHz, CDCl3)
f1 (ppm)

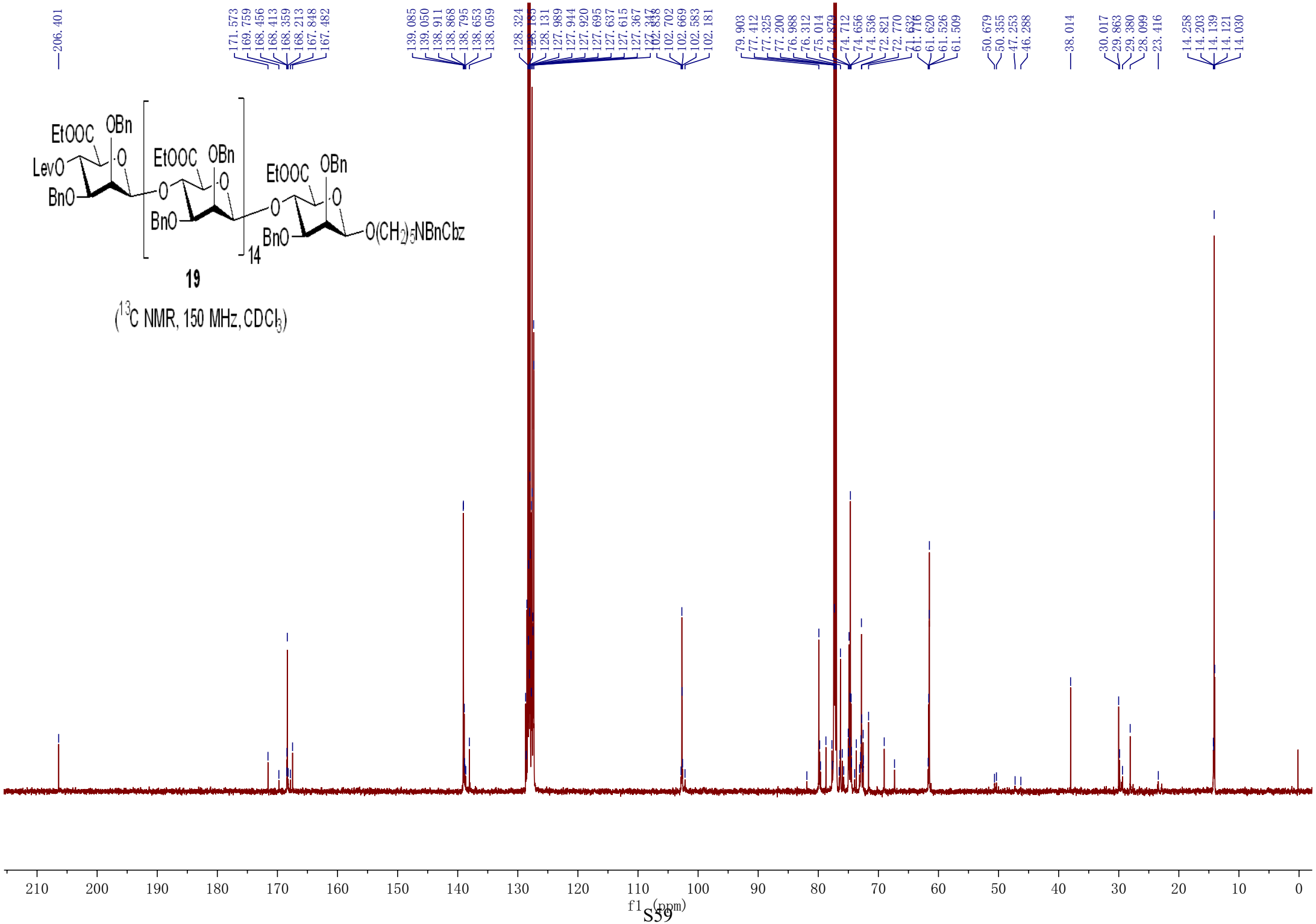

206.413
171.567
168.387
168.335
167.466
139.039
139.008
138.982
138.869
138.603
138.021
128.469
128.312
128.169
128.118
128.017
127.967
127.929
127.678
127.613
127.582
127.465
102.598
102.563
102.176
79.872
77.705
77.518
77.402
77.200
76.882
76.263
74.947
74.691
74.637
74.508
72.802
72.498
61.609
61.523
50.585
50.296
47.238
46.266
37.979
30.011
29.464
29.349
28.064
23.412
14.285
14.237
14.181
14.134
14.102
14.010
EtOOC
OBn
LevO
BnO
O
O(CH2)5NBnCbz
17
(13C NMR, 100 MHz, CDCl3)
f1 (ppm)

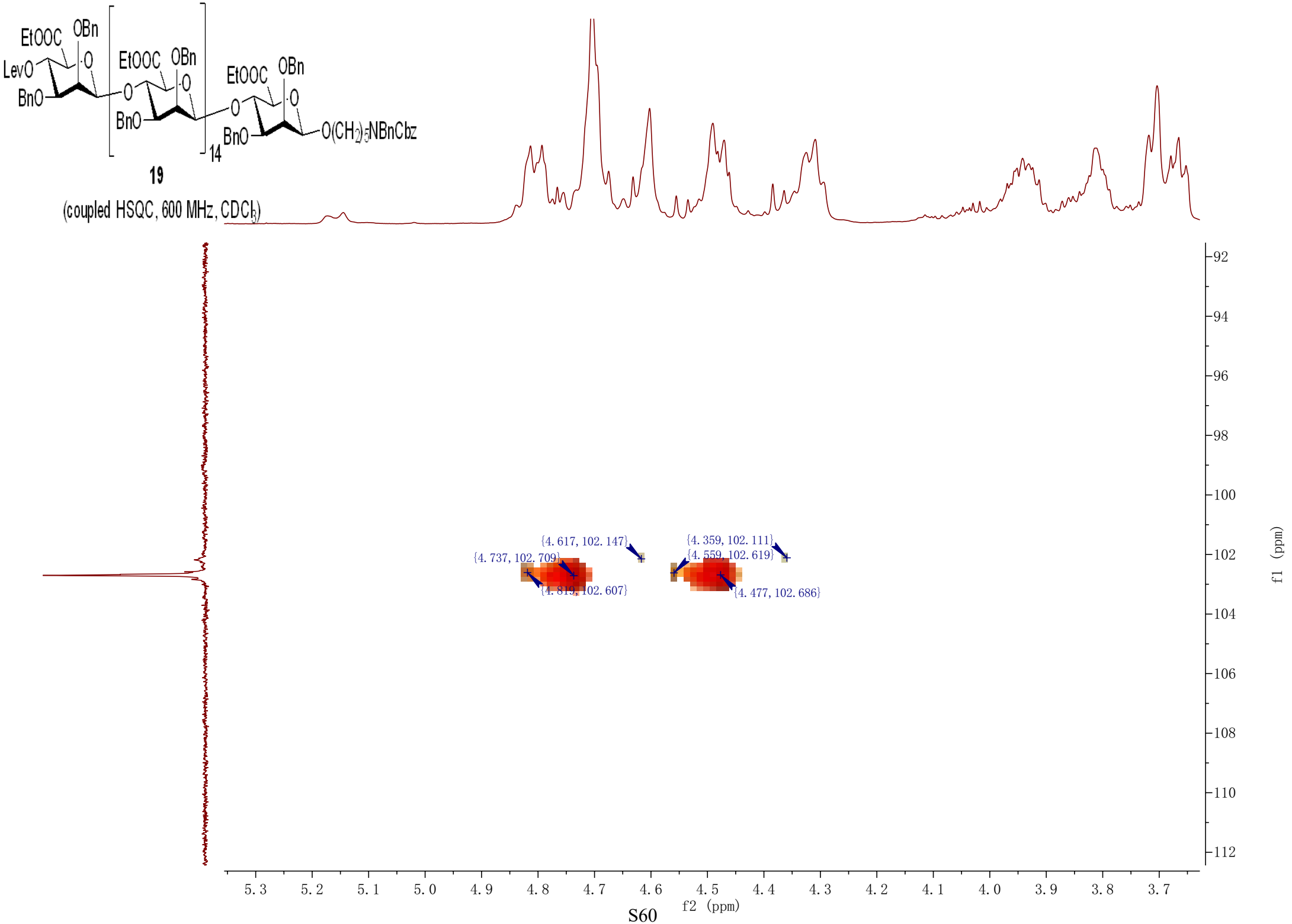

17
(coupled HSQC,500 MHz, CDCl3)
{4.781, 101.157}
{4.465, 101.171}
{4.211, 102.207}
{4.519, 102.376}
{4.533, 102.541}
{4.508, 102.549}
{4.846, 102.556}
{4.763, 102.686}
{4.822, 102.629}
{4.452, 102.684}
f2 (ppm)
f1 (ppm)

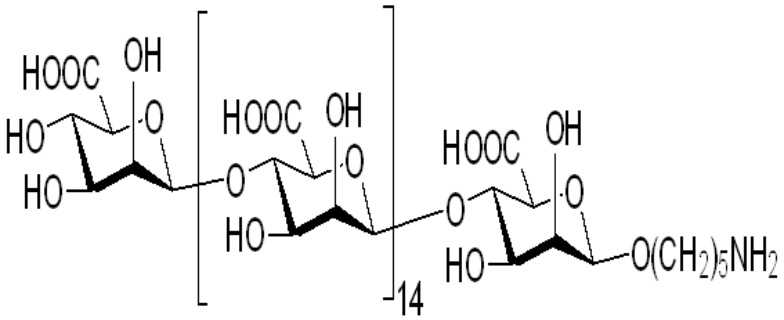

18
(1H NMR, 400 MHz, CDCl3)
f1 (ppm)


169.634
168.337
139.034
139.006
138.946
138.867
138.666
138.598
138.153
138.030
128.531
128.310
128.208
128.115
127.979
127.961
127.930
127.787
127.607
127.568
127.492
127.426
102.682
102.621
102.559
102.156
80.440
79.863
77.517
77.402
77.200
76.882
76.247
74.937
74.838
74.749
74.637
72.924
72.791
72.440
71.823
68.262
61.507
50.637
50.346
47.246
46.251
29.461
29.344
23.404
14.233
14.103
14.064
EtOOC
OBn
HO
BnO
O
18
(13C NMR, 100 MHz, CDCl3)
O(CH2)5NBnCbz
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


EtOOC
OBn
LevO
BnO
O
14
O(CH2)5NBnCbz
19
(1H NMR, 600 MHz, CDCl3)
175.25
1.14
1.88
97.22
66.10
16.66
2.22
2.36
2.26
3.32
4.03
2.22
48.78
f1 (ppm)

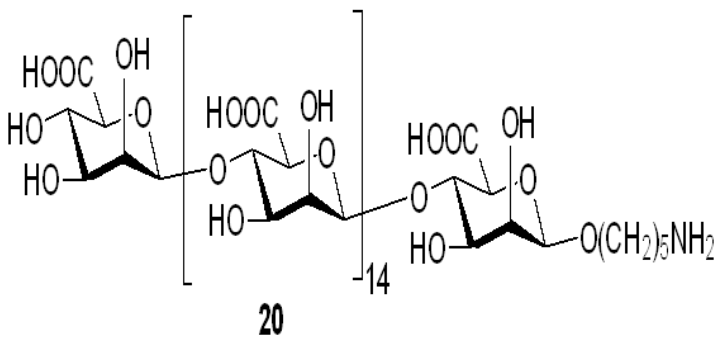

206.401
171.573
169.759
168.456
168.413
168.359
168.213
167.848
167.482
139.085
139.050
138.911
138.868
138.795
138.653
138.059
128.324
128.183
128.131
127.989
127.944
127.920
127.695
127.637
127.615
127.367
127.347
127.338
102.702
102.669
102.583
102.181
79.903
77.412
77.325
77.200
76.988
76.312
75.014
74.879
74.712
74.656
74.536
72.821
72.770
71.632
71.576
61.620
61.526
61.509
50.679
50.355
47.253
46.288
38.014
30.017
29.863
29.380
28.099
23.416
14.258
14.203
14.139
14.121
14.030
EtOOC
OBn
LevO
BnO
O
14
O(CH2)5NBnCbz
19
(13C NMR, 150 MHz, CDCl3)
f1 (ppm)


EtOOC
OBn
LevO
BnO
O
14
O(CH2)5NBnCbz
19
(coupled HSQC, 600 MHz, CDCl3)
{4. 617, 102. 147}
{4. 737, 102. 709}
{4. 819, 102. 607}
{4. 359, 102. 111}
{4. 559, 102. 619}
{4. 477, 102. 686}
f2 (ppm)
f1 (ppm)



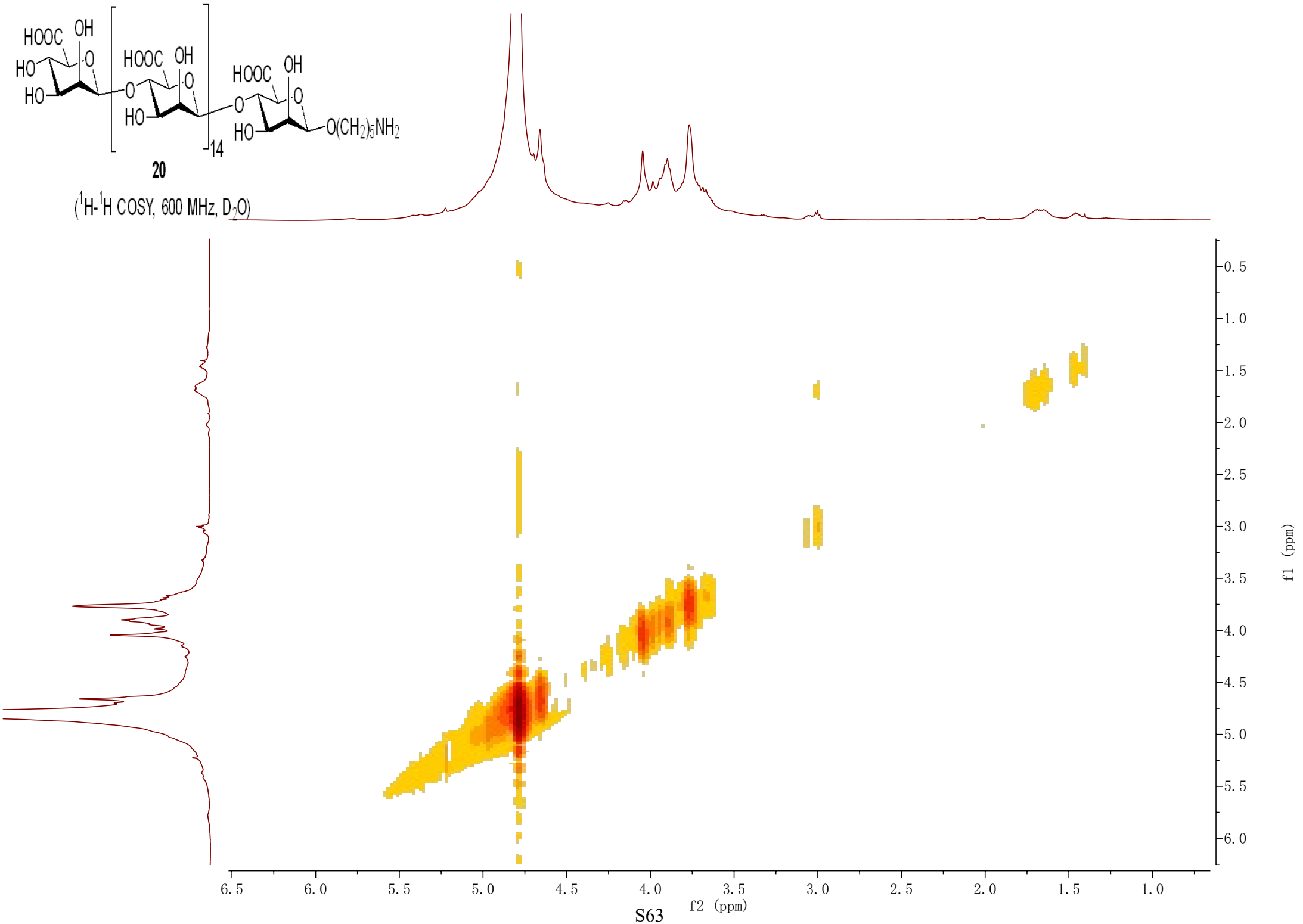
20

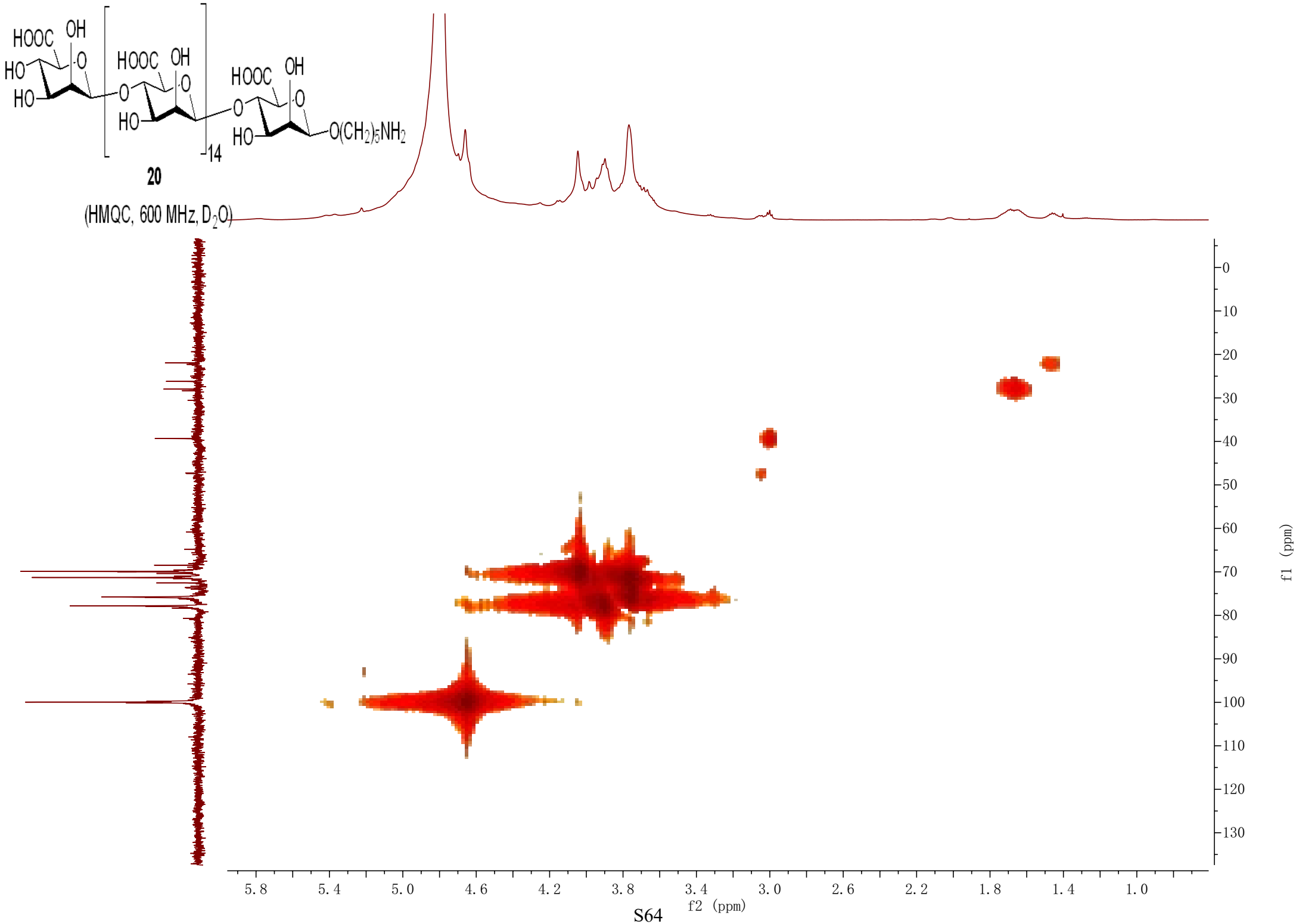
(^{1}H NMR, 600 MHz, D_2O)

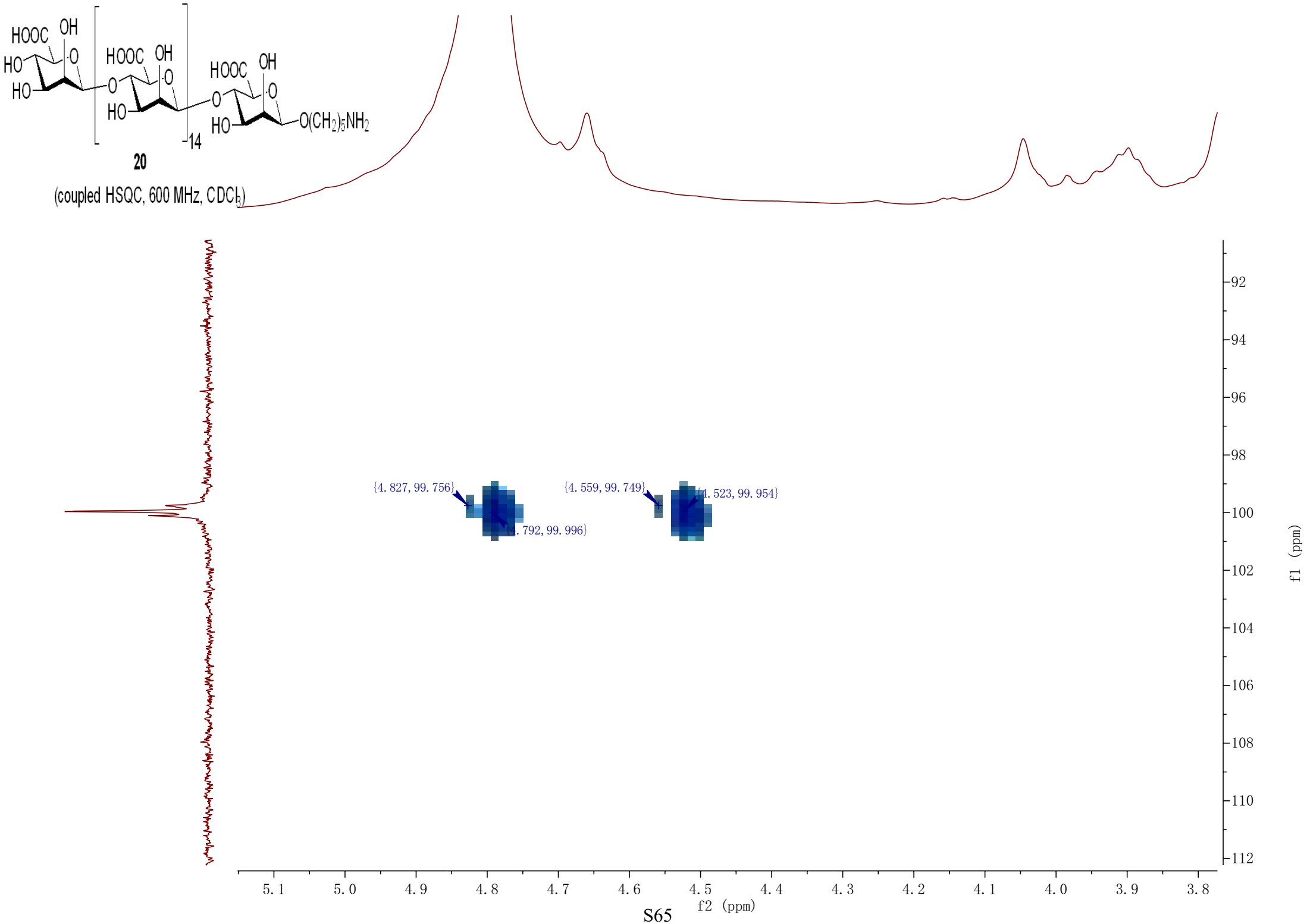


20

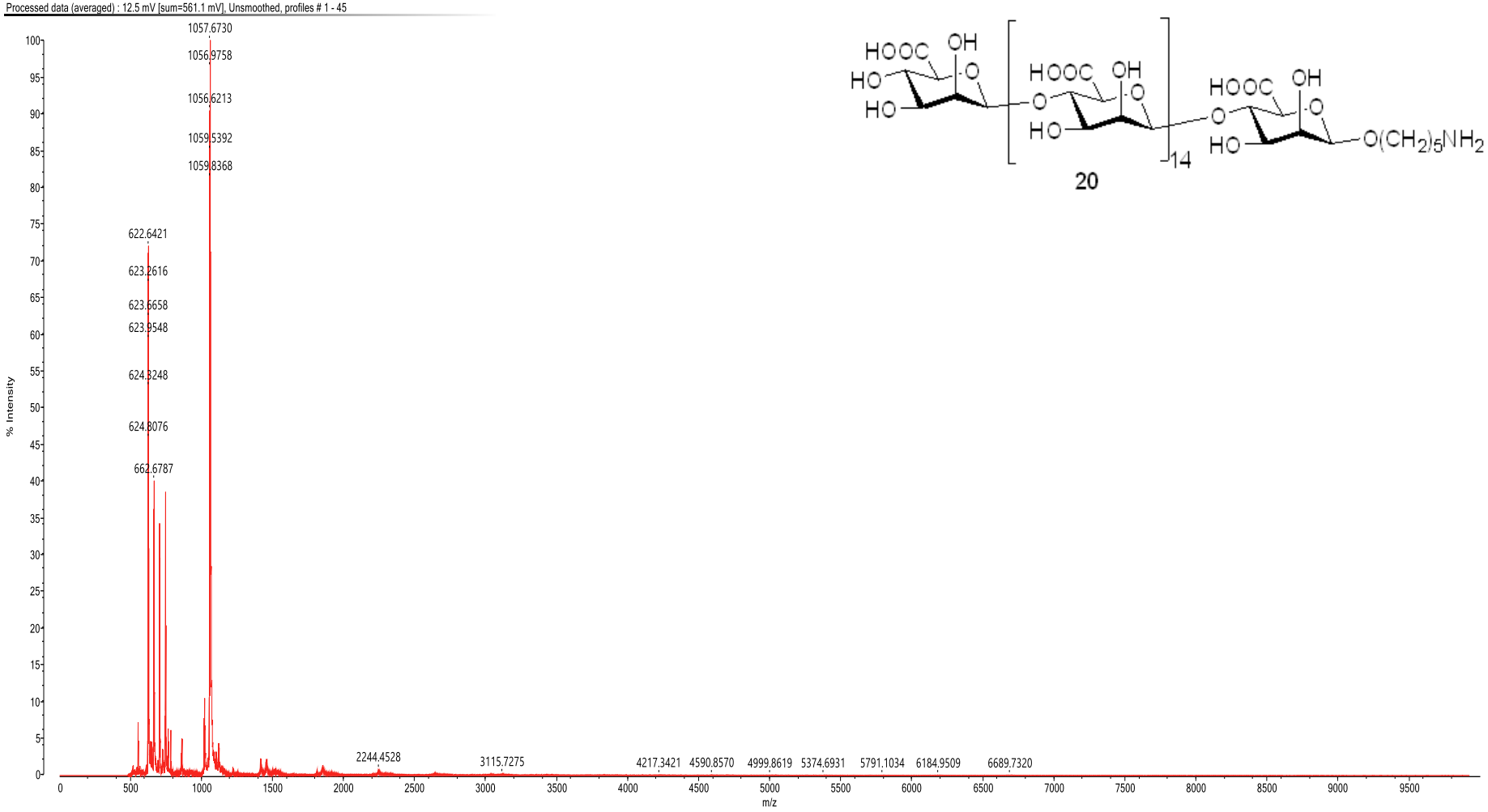
(^{13}C NMR, 150 MHz, D_2O)


HOOC
OH
HO
O
HO
HOOC
OH
O
HO
HOOC
OH
O
HO
O(CH2)5NH2
14
20
(1H-1H COSY, 600 MHz, D2O)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
f1 (ppm)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
f2 (ppm)

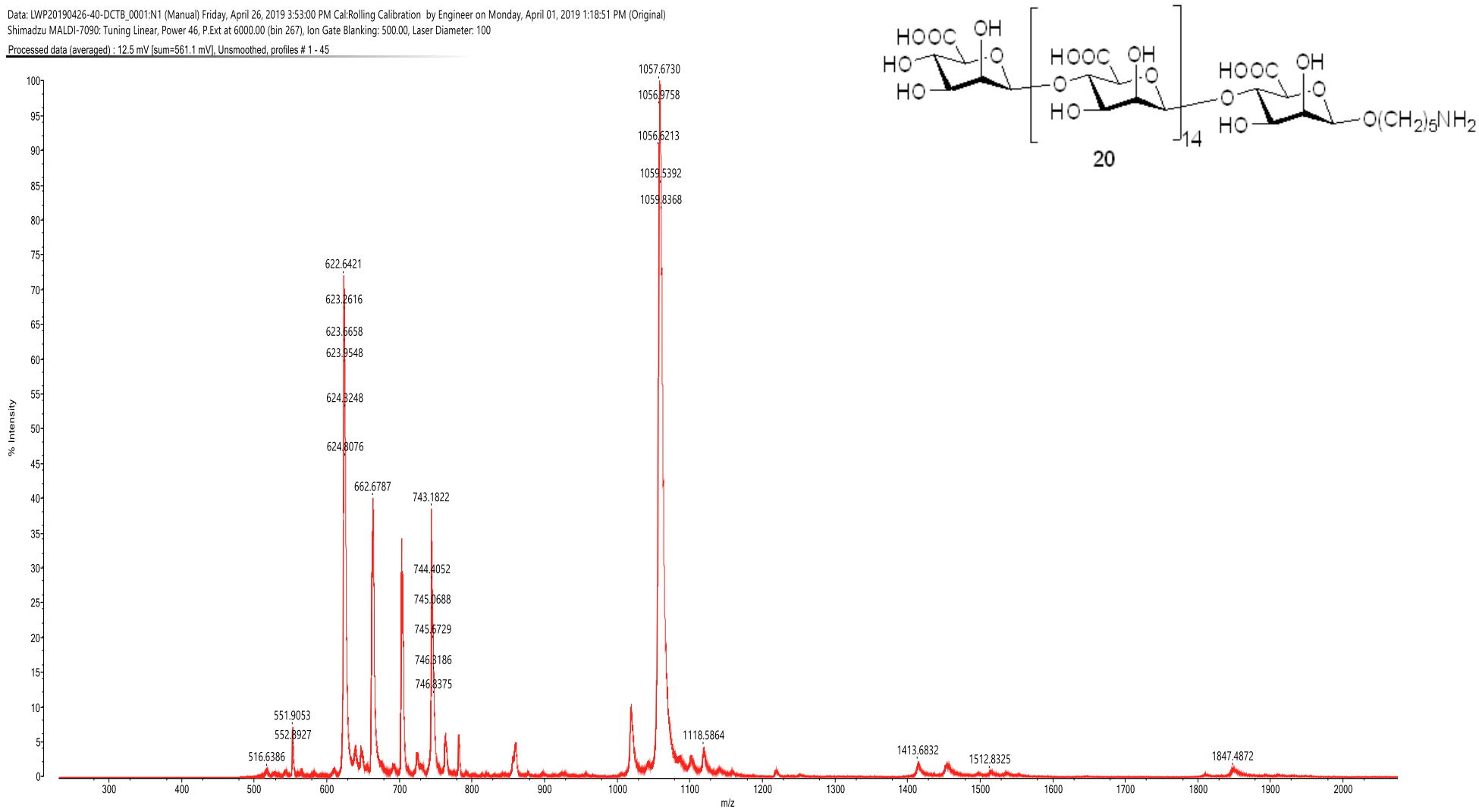

HOOC
OH
HO
O
HO
HOOC
OH
O
HO
14
HOOC
OH
O
HO
O(CH2)5NH2
20
(HMQC, 600 MHz, D2O)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
f1 (ppm)
5.8
5.4
5.0
4.6
4.2
3.8
3.4
3.0
2.6
2.2
1.8
1.4
1.0
f2 (ppm)


HOOC
OH
HO
HO
O
HOOC
OH
O
HO
O
HOOC
OH
O
HO
O(CH2)5NH2
14
20
(coupled HSQC, 600 MHz, CDCl3)
{4. 827, 99. 756}
{4. 792, 99. 996}
{4. 559, 99. 749}
{4. 523, 99. 954}
92
94
96
98
100
102
104
106
108
110
112
f1 (ppm)
5. 1
5. 0
4. 9
4. 8
4. 7
4. 6
4. 5
4. 4
4. 3
4. 2
4. 1
4. 0
3. 9
3. 8
f2 (ppm)

Data: LWP20190426-40-DCTB_0001:N1 (Manual) Friday, April 26, 2019 3:53:00 PM Cal:Rolling Calibration by Engineer on Monday, April 01, 2019 1:18:51 PM (Original)
Shimadzu MALDI-7090: Tuning Linear, Power 46, P.Ext at 6000.00 (bin 267), Ion Gate Blanking: 500.00, Laser Diameter: 100
Processed data (averaged) : 12.5 mV [sum=561.1 mV], Unsmoothed, profiles # 1 - 45



20


Data: LWP20190426-40-DCTB_0001:N1 (Manual) Friday, April 26, 2019 3:53:00 PM Cal:Rolling Calibration by Engineer on Monday, April 01, 2019 1:18:51 PM (Original)
Shimadzu MALDI-7090: Tuning Linear, Power 46, P.Ext at 6000.00 (bin 267), Ion Gate Blanking: 500.00, Laser Diameter: 100
Processed data (averaged) : 12.5 mV [sum=561.1 mV], Unsmoothed, profiles # 1 - 45
% Intensity
m/z
1057.6730
1056.9758
1056.6213
1059.5392
1059.8368
622.6421
623.2616
623.6658
623.9548
624.3248
624.8076
662.6787
743.1822
744.4052
745.0688
745.6729
746.3186
746.8375
551.9053
552.3927
516.6386
1118.5864
1413.6832
1512.8325
1847.4872
HOOC
OH
HO
O
14
O(CH2)5NH2
20