Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

A bidirectional synthesis of spiroacetals via Rh(II)-catalysed C–H insertion

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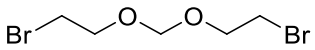
General Experimental Details

All reactions were performed under an atmosphere of nitrogen unless otherwise indicated. Temperatures quoted as -78 °C, -60 °C, -40 °C and -20 °C were obtained by cooling the reaction vessel in bath of dry ice/acetone/water. Anhydrous solvents were dried on molecular sieves prior to use. All other reagents and solvents were used as purchased from commercial suppliers unless otherwise noted. Reaction progress was monitored by thin layer chromatography (TLC) on aluminum backed silica gel plates, visualising with UV light, and plates were developed using vanillin or potassium permanganate. Flash chromatography was performed using silica gel (230 – 400 mesh). NMR spectra were acquired on Varian INOVA or Bruker Avance III HD NMR spectrometers at 500 MHz and 125 MHz for ^{1}H and ^{13}C respectively. ^{1}H NMR spectra were referenced to the residual forms of the solvent with one less deuterium than the perdeuterated solvent ($CHCl_3$ = 7.26 ppm) ^{13}C NMR spectra were referenced to the internal perdeuterated solvent resonance ($CDCl_3$ = 77.16 ppm & C_6D_6 = 128.06 ppm). Coupling constants (*J*) are in Hz. The multiplicities of the signals are described using the following abbreviations: s = singlet, d = doublet, t = triplet q=quadruplet, br = broad. Low resolution electrospray mass spectra (LRESIMS) were recorded on an Agilent 6120 quadrupole LCMS system. High resolution mass spectra (HRMS) were acquired on a Bruker Bruker QTOF MaXis II ETD.

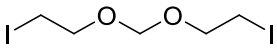
Experimental Procedures and Charcterisation Data

1-bromo-2-[(2-bromoethoxy)methoxy]ethane (8)[1]



2-Bromoethanol (17.0 mL, 240 mmol, 2 eq) and paraformaldehyde (3.60 g, 120 mmol, 1 eq) were dissolved in toluene (20 mL) in a round-bottom flask equipped with a Dean-Stark apparatus. Concentrated sulfuric acid (1 drop, cat.) was added and the mixture was refluxed for 1.5h, until approximately the expected amount of water has been collected. After cooling, sodium bicarbonate (approx. 2 g) was added and the mixture was filtered. The filtrate was directly purified by flash chromatography (95:5, PS/EtOAc) to provide **8** (24.10 g, 92 mmol, 77%) as a colourless oil: R_f 0.60 (95:5 PS/Et_2O); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.78 (2H, s, $OC\underline{H}_2O$), 3.92 (4H, t, *J* = 6.0 Hz, $BrCH_2C\underline{H}_2O$), 3.51 (4H, t, *J* = 6.0 Hz, $BrC\underline{H}_2CH_2O$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 95.60 ($O\underline{C}H_2O$), 68.29 ($BrCH_2\underline{C}H_2O$), 30.82 ($BrCH_2\underline{C}H_2O$).

1-iodo-2-[(2-iodoethoxy)methoxy]ethane (9)

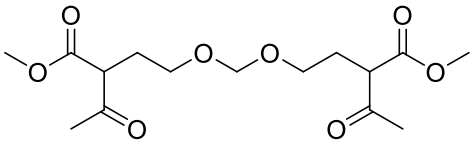


1-bromo-2-[(2-bromoethoxy)methoxy]ethane (16.0 g, 61 mmol, 1 eq) and sodium iodide (18.8 g, 122 mmol, 2.05 eq) were dissolved in acetone (40 mL) and heated to reflux for 3 h. Acetone was evaporated under vacuum, water/Et_2O (1:1 v/v) was added and layers were separated. Organic layer was washed with brine and dried over magnesium sulfate. Organic layer was filtered and solvent was evaporated, to yield **9** (20.04 g, 56.3 mmol, 92%) as an orange-brown oil: R_f 0.60 (95:5 PS/Et_2O); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.77 (2H, s, OC$\underline{H}_2$O), 3.86 (4H, t, *J* = 6.5 Hz, ICH$_2$C$\underline{H}_2$O), 3.29 (4H, t, *J* = 6.5 Hz, IC$\underline{H}_2$CH$_2$O); ^{13}C NMR (126 MHz, $CDCl_3$) δ 95.26 (O$\underline{C}$H$_2$O), 69.12 (ICH$_2\underline{C}$H$_2$O), 3.14 (I$\underline{C}$H$_2$CH$_2$O).

General Procedure for nucleophilic substitution

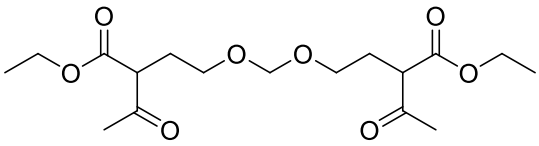
Diiodo compound (1eq) and alkyl acetoacetate sodium salt (3.5 eq) were dissolved in DME (0.75-1 M) and then heated to reflux for 16 h (overnight). The reaction was quenched with sat. NH_4Cl(aq)/water (1:1 v/v) and extracted with ethyl acetate (3 times). The organic layer was washed with brine and dried over magnesium sulfate, then filtered and solvent was removed *in vacuo*. The crude residue was purified by flash chromatography (90:10, PS/EtOAc) to yield the desired compound.

Methyl 2-{2-[(3-acetyl-4-methoxy-4-oxobutoxy)methoxy]ethyl}-3-oxobutanoate (11a)



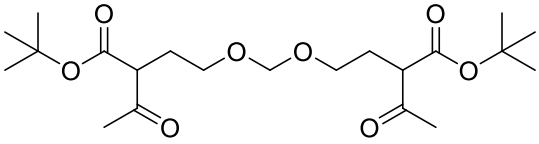
Reaction of 1,7-diiodo-3,5-dioxaheptane (6.00 g, 16.85 mmol) and methyl acetoacetate sodium salt (8.28 g, 60 mmol) in DME (15 mL) according to the General Procedure, provided the title compound (5.797 g, 11.44 mmol, 68%) as a yellow oil: R_f 0.15 (90:10 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.54 (2H, s, OC$\underline{H}_2$O), 3.72 (6H, s, C$\underline{H}_3$OC(O)), 3.64 (2H, t, *J* = 6.9 Hz, OCH$_2$CH$_2$C$\underline{H}$), 3.50 (4H, m, OC$\underline{H}_2$CH$_2$CH), 2.23 (6H, s, (CO)C$\underline{H}_3$), 2.11 (4H, m, CH$_2$C$\underline{H}_2$CH); ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.78 ($\underline{C}$(O)CH$_3$), 170.19 ($\underline{C}$(O)OMe), 95.35 (O$\underline{C}$H$_2$O), 65.35 (O$\underline{C}$H$_2$CH$_2$CH), 56.58 ($\underline{C}$H$_3$OC(O)), 52.60 (OCH$_2$CH$_2\underline{C}$H), 29.26 (OCH$_2\underline{C}$H$_2$CH), 28.32 (C(O)$\underline{C}$H$_3$); MS (ESI +) *m/z* 355.14 ([M + Na]$^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{15}H_{24}NaO_8$ 355.1363, found 355.1363.

Ethyl 2-{2-[(3-acetyl-4-ethoxy-4-oxobutoxy)methoxy]ethyl}-3-oxobutanoate (11b)



Reaction of 1,7-diiodo-3,5-dioxaheptane (6.00 g, 16.85 mmol) and ethyl acetoacetate sodium salt (8.97 g, 60 mmol) in DME (20 mL) according to the General Procedure, provided the title compound (4.604 g, 12.79 mmol, 76%) as a yellow oil: R_f 0.29 (90:10 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.53 (2H, s, OC<u>H</u>$_2$O), 4.19 (4H, app dtt, J_1 = 10.8 Hz, J_2 = 6.6 Hz, J_3 = 3.7 Hz, CH_3C<u>H</u>$_2CO_2$), 3.62 (2H, t, J = 7.1 Hz, CH_2CH_2C<u>H</u>), 3.51 (4H, app hept, J_1 = 5.2 Hz, J_2 = 4.5 Hz, OC<u>H</u>$_2CH_2CH$), 2.25 (6H, s, (CO)C<u>H</u>$_3$), 2.12 (4H, dt, J_1 = 11.3 Hz, J_2 = 6.2 Hz, OCH_2C<u>H</u>$_2CH$), 1.27 (6H, t, J = 7.4 Hz, C<u>H</u>$_3CH_2CO_2$)); ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.70 (<u>C</u>(O)CH_3), 169.51 (<u>C</u>(O)OEt), 95.14 (O<u>C</u>H_2O), 65.19 (O<u>C</u>H_2CH_2CH), 61.39 (CH_3<u>C</u>H_2OC(O)), 56.61 (OCH_2CH_2<u>C</u>H), 29.03 (OCH_2<u>C</u>H_2CH), 28.07 (C(O)<u>C</u>H_3), 14.04 (<u>C</u>H_3CH_2OC(O)); MS (ESI +) *m/z* 383.16 ([M + Na]$^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{17}H_{28}NaO_8$ 383.1676, found 383.1680.

***tert*-Butyl 2-(2-{[3-acetyl-4-(*tert*-butoxy)-4-oxobutoxy]methoxy}ethyl)-3-oxobutanoate (11c)**

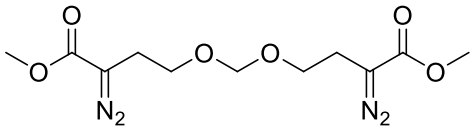


Reaction of 1,7-diiodo-3,5-dioxaheptane (6.00g, 16.85mmol) and *tert*-butyl acetoacetate sodium salt (10.8g, 60mmol) in DME 15(mL) according to the General Procedure, provided the title compound (3.636 g, 8.74 mmol, 52%) as a yellow oil: R_f 0.44 (90:10 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.56 (2H, s, OC<u>H</u>$_2$O), 3.54-3.50 (3H, m, CH_2CH_2C<u>H</u>, C<u>H</u>$_2CH_2CH$), 2.24 (6H, s, (CO)C<u>H</u>$_3$), 2.08 (4H, app p, J = 6.7 H , CH_2C<u>H</u>$_2CH$), 1.46 (9H, s, (C<u>H</u>$_3$)$_3$COC(O)); ^{13}C NMR (126 MHz, $CDCl_3$) δ 203.22 (<u>C</u>(O)CH_3), 168.82 (<u>C</u>(O)O*t*-Bu), 95.31 (O<u>C</u>H_2O), 82.09 (C(O)O<u>C</u>$(CH_3)_3$), 65.46 (O<u>C</u>H_2CH_2CH), 57.93 (OCH_2CH_2<u>C</u>H), 29.15 (OCH_2<u>C</u>H_2CH), 28.19 (C(O)<u>C</u>H_3), 28.06 (C(O)OC(<u>C</u>H_3)$_3$); MS (ESI +) *m/z* 408.92 ([M + Na - 30]$^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{21}H_{36}NaO_8$ 439.2302, found 439.2307.

General Procedure for Diazo Transfer

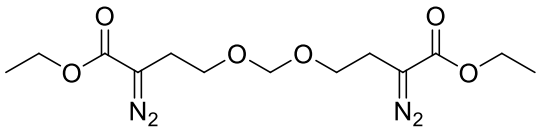
The bis β-ketoester (1 eq) and *p*ABSA (2.4 eq) were dissolved in acetonitrile (0.15 M). The mixture was cooled to 0 ^{o}C (ice bath) and DBU (2.4 eq) was added dropwise. The reaction was allowed to warm to room temperature and stirred for 24 h. The reaction was quenched with Et_2O/water (1:1 v/v) and extracted with ethyl acetate (3 times). The organic layer was washed with brine and dried over magnesium sulfate, then filtered and solvent was evaporated under vacuum. The crude residue was purified by flash chromatography (90:10, PS/EtOAc) to yield the desired compound.

Methyl 2-diazo-4-[(3-diazo-4-methoxy-4-oxobutoxy)methoxy]butanoate (12a)



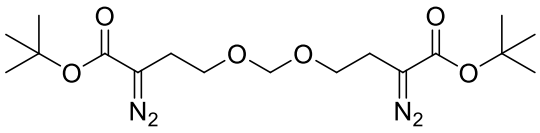
The bis β-ketoester **11a** (2.70 g, 8.10 mmol) with *p*-ABSA (4.66 g, 19.4 mmol) in acetonitrile (80 mL) according to the diazo transfer procedure provided the title compound (1.388 g, 4.63 mmol, 57%) as a bright yellow oil: R_f 0.68 (70:30 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.66 (2H, s, OC<u>H</u>$_2$O), 3.77 (6H, s, (CO)OC<u>H</u>$_3$), 3.68 (4H, t, *J* = 5.9 Hz, OC<u>H</u>$_2$CH$_2$C(N$_2$)), 2.56 (4H, t, *J* = 5.9 Hz, OCH$_2$C<u>H</u>$_2$C(N$_2$)); ^{13}C NMR (126 MHz, $CDCl_3$) δ 95.57 (CH_2), 66.28 (CH_2), 52.09 (CH_3), 24.34 (CH_2), O<u>C</u>(O)C(N$_2$) and OC(O)<u>C</u>(N$_2$) not detected.

Ethyl 2-diazo-4-[(3-diazo-4-ethoxy-4-oxobutoxy)methoxy]butanoate (12b)



The bis β-ketoester **11b** (3.50 g, 8.4 mmol) with *p*-ABSA (4.84 g, 20.16 mmol) in acetonitrile (85 mL) according to the diazo transfer procedure provided the title compound (1.560 g, 4.06 mmol, 48%) as a bright yellow oil: R_f 0.53 (85:15 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.66 (2H, s, OC<u>H</u>$_2$O), 4.22 (4H, t, *J* = 7.1 Hz, (CO)OC<u>H</u>$_2$CH$_3$), 3.68 (4H, t, *J* = 5.9 Hz, OC<u>H</u>$_2$CH$_2$C(N$_2$)), 2.56 (4H, t, *J* = 5.9 Hz, OCH$_2$C<u>H</u>$_2$C(N$_2$)), 1.27 (6H, t, *J* =7.1 Hz, (CO)OC<u>H</u>$_2$CH$_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 95.61 (CH_2), 66.32 (CH_2), 60.97 (CH_2), 24.35 (CH_2), 14.67 (CH_3), O<u>C</u>(O)C(N$_2$) and OC(O)<u>C</u>(N$_2$) not detected.

***Tert*-butyl 4-{[4-(*tert*-butoxy)-3-diazo-4-oxobutoxy]methoxy}-2-diazobutanoate (12c)**



The bis β-ketoester (**11c**) (2.70 g, 8.1 mmol) with *p*-ABSA (4.66 g, 19.4 mmol) in acetonitrile (80 mL) according to the diazo transfer procedure provided the title compound (1.388 g, 4.63 mmol, 57%) as a bright yellow oil: R_f 0.45 (95:5 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.66 (2H, s, OC$\underline{H}_2$O), 3.67 (4H, t, *J* = 6.0 Hz, OC$\underline{H}_2$CH$_2$C(N$_2$)), 2.51 (4H, t, *J* = 6.0 Hz, OCH$_2$C$\underline{H}_2$C(N$_2$)), 1.48 (18H, s, (CO)OC(C$\underline{H}_3$)$_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 95.41 (CH_2), 81.19 (C_{quat}), 66.15 (CH_2), 28.39 (CH_3), 24.15 (CH_2), O$\underline{C}$(O)C(N$_2$) and OC(O)$\underline{C}$(N$_2$) not detected.

Rhodium-catalysed C-H insertion reaction

Diazo compound (1 eq) was dissolved in dry toluene (0.1 M) under argon atmosphere, then the solution was degassed by bubbling argon under vigorous stirring at -78 ^{o}C (dry ice in acetone). Rhodium catalyst (0.5 mol%) was added quickly. The mixture was progressively warmed until 0 °C was reached. The solvent was removed *in vacuo* and the crude mixture was purified by flash chromatography (85:15, PS/EtOAc) to yield the desired compounds.

13a: ^{1}H NMR (500 MHz, Chloroform-*d*) δ 4.05 (2H, td, *J* = 8.5, 3.8 Hz), 3.77 (2H, td, *J* = 8.4, 7.3 Hz), 3.73 (6H, s), 3.59 (2H, dd, *J* = 10.3, 9.1 Hz), 2.53 (2H, ddt, *J* = 12.4, 10.4, 8.7 Hz), 2.12 (2H, dddd, *J* = 12.6, 9.0, 7.3, 3.9 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.21 (C_{carbox}), 112.45 (C_{spiro}), 66.99 (CH_2), 52.11 (CH_3), 49.58 (CH), 26.50 (CH_2); MS (ESI +) *m/z* 267.15 ([M + Na]$^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{11}H_{16}NaO_6$ 267.0839, found 267.0836.

14a: ^{1}H NMR (500 MHz, Chloroform-*d*) δ 4.04 – 3.96 (2H, m), 3.93 – 3.86 (2H, m), 3.76 (3H, s), 3.66 (3H, s), 3.54 (1H, dd, *J* = 9.7, 8.1 Hz), 3.23 (1H, dd, *J* = 8.0, 6.5 Hz), 2.54 (1H, dtd, *J* = 12.5, 8.2, 6.2 Hz), 2.35 (1H, dtd, *J* = 12.4, 7.8, 6.5 Hz), 2.23 – 2.12 (2H, m); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.63 (C_{carbox}), 170.40 (C_{carbox}), 114.01 (C_{spiro}), 66.90 (CH_2), 65.92 (CH_2), 52.26 (CH_3), 51.99 (CH_3), 51.87 (CH), 47.82 (CH), 27.96 (CH_2), 27.53 (CH_2); MS (ESI +) *m/z* 267.15 ([M + Na]$^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{11}H_{16}NaO_6$ 267.0839, found 267.0836.

13b: ^{1}H NMR (Chloroform-*d*, 500 MHz) δ 4.24 (2H, q, *J* = 7.1 Hz), 4.16 (2H, q, *J* = 7.1 Hz), 4.05 (2H, td, *J* = 8.6, 4.0 Hz), 3.77 (2H, td, *J* = 8.3, 7.3 Hz), 3.59 (2H, dd, *J* = 10.3, 9.0 Hz), 2.53 (2H, ddt, *J* = 12.5, 10.4, 8.7 Hz), 2.11 (2H, dddd, *J* = 12.6, 9.0, 7.3, 3.9 Hz), 1.27 (6H, t, *J* = 7.1 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.77 (C_{carbox}), 112.63 (C_{spiro}), 67.04 (CH_2) , 60.87 (CH_2), 49.74 (CH), 26.51 (CH_2), 14.45 (CH_3); MS (ESI +) *m/z* 295.11 ($[M + Na]^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{13}H_{20}NaO_6$ 295.1152, found 295.1152.

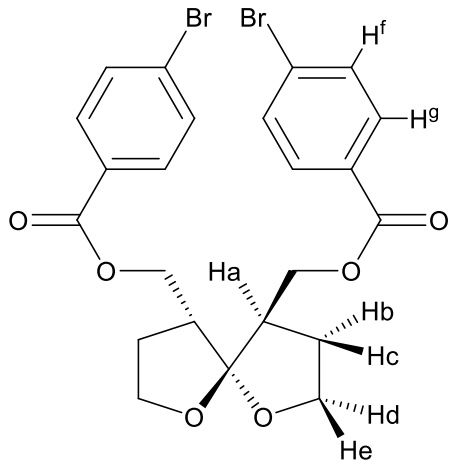
14b: ^{1}H NMR (500 MHz, Chloroform-*d*) δ 4.22 (2H, q, *J* = 7.2 Hz), 4.18 – 4.07 (2H, m), 3.99 (2H, td, *J* = 8.4, 5.5 Hz), 3.89 (2H, dtd, *J* = 8.7, 7.7, 7.1, 5.6 Hz), 3.56 (1H, dd, *J* = 9.7, 7.9 Hz), 3.22 (1H, t, *J* = 7.6 Hz), 2.54 (1H, dtd, *J* = 12.0, 8.0, 6.2 Hz), 2.36 (1H, dq, *J* = 12.3, 7.8 Hz), 2.22 – 2.08 (2H, m), 1.31 (3H, t, *J* = 7.1 Hz), 1.23 (3H, t, *J* = 7.1 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.00 (C_{carbox}), 170.04 (C_{carbox}), 114.10 (C_{spiro}), 66.80 (CH_2), 65.92 (CH_2), 61.14 (CH_2), 60.87 (CH_2), 52.00 (CH), 49.90 (CH), 28.12 (CH_2), 27.55 (CH_2), 14.31 (CH_3), 14.22 (CH_3); MS (ESI +) *m/z* 295.11 ($[M + Na]^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{13}H_{20}NaO_6$ 295.1152, found 295.1152.

13c: ^{1}H NMR (Chloroform-*d*, 500 MHz) δ 4.04 (2H, td, *J* = 8.5, 4.1 Hz), 3.77 (2H, q, *J* = 8.2 Hz), 3.49 (2H, dd, *J* = 10.1, 9.1 Hz), 2.49 (2H, ddt, *J* = 12.6, 10.3, 8.6 Hz), 2.05 (2H, dddd, *J* = 11.7, 9.1, 7.3, 4.1 Hz), 1.47 (18H, s); ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.85 (C_{carbox}), 112.95 (C_{spiro}), 80.87 (C_q) , 66.83 (CH_2) , 50.40 (CH), 28.13 (CH_2), 26.36 (CH_3); MS (ESI +) *m/z* 351.10 ($[M + Na]^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{17}H_{28}NaO_6$ 351.1778, found 351.1769.

14c: ^{1}H NMR (500 MHz, Chloroform-*d*) δ 3.98 (1H, td, *J* = 8.2, 6.3 Hz), 3.95 (1H, td, *J* = 8.1, 1.9 Hz), 3.88 (1H, td, *J* = 8.0, 6.1 Hz), 3.84 (1H, ddd, *J* = 10.9, 8.3, 5.6 Hz), 2.53-2.45 (1H, m), 2.32 (1H, dtd, *J* = 12.2, 10.7, 7.9 Hz), 2.13-2.02 (2H, m), 1.50 (9H, s), 1.45 (9H, s); ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.75.00 (C_{carbox}), 169.40 (C_{carbox}), 114.19 (C_{spiro}), 81.20 (C_q), 81.07 (C_q), 66.31 (CH_2), 66.03 (CH_2), 53.04 (CH), 49.02 (CH), 29.70 (CH_2), 28.65 (CH_2), 28.20 (CH_3), 27.50 (CH_3); MS (ESI +) *m/z* 351.10 ($[M - 200]^+$, 100); HRMS (ESI +) *m/z* calculated for $C_{17}H_{28}NaO_6$ 351.1778, found 351.1769.

{(4*R*,9*R*)-9-[(4-bromobenzoyloxy)methyl]-1,6-dioxaspiro[4.4]nonan-4-yl}methyl 4-bromobenzoate (16)

A mixture of spiroacetals **13b**, **14b** and **15b** was dissolved in dry THF (0.15 M) under argon atmosphere. Lithium aluminium hydride powder (8 eq) was dissolved in the same volume of dry THF under argon atmosphere. Both solutions were cooled to 0 ^{o}C and the spiroacetal solution was added dropwise to the $LiAlH_4$ solution with vigorous stirring. The resultant mixture was allowed to warm to room temperature and stirred overnight. The reaction was quenched with Na_2SO_4•$10H_2O$, filtered and solvent was removed *in vacuo*. The residue was dissolved in DCM (0.05 M), cooled to 0 ^{o}C, and *p*-bromobenzoic acid (4 eq), DMAP (cat.) and EDC (2.2 eq) were added. The mixture was allowed to warm to room temperature and stirred overnight. The reactionmicture was quenched with saturated $NaHCO_3$/water (1:1 v/v) and extracted with ethyl acetate (3 times). The organic layers were combined, dried over $MgSO_4$, the solvent removed *in vacuo* and the crude residue was purified by flash chromatography (95:5 to 85:15, PS/EtOAc), to yield the title compound.



R_f 0.43 (85:15 PS/EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (4H, dt, *J* = 8.6, 1.9 Hz, H^g), 7.55 (4H, dt, *J* = 8.6, 1.9 Hz, H^f), 4.49 (2H, dd, *J* = 11.1, 7.1 Hz, H^d or H^e), 4.42 (2H, dd, *J* = 11.1, 6.6 Hz, H^d or H^e), 4.05 (2H, td, *J* = 8.8, 3.3 Hz), 3.83 (2H, dt, *J* = 8.5, 7.4 Hz), 2.74 (2H, ddt, *J* = 11.1, 8.4, 6.8 Hz), 2.17 (2H, dddd, *J* = 11.9, 8.4, 7.3, 3.3 Hz), 1.95 (2H, ddt, *J* = 12.0, 11.1, 8.9 Hz); ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.75 (ArC(O)O), 131.94 (C_{Ar}), 131.15 (C_{Ar}), 129.11 (C_{Ar}), 128.33 (C_{Ar}), 112.69 (C_{spiro}), 66.23 (CH_2), 64.74 (CH_2), 43.51 (CH), 28.66 (CH_2); HRMS (ESI +) *m/z* calculated for $C_{23}H_{22}Br_2NaO_6$ 574.9675, found 574.9664.

X-ray Crystallography

Intensity data were collected with an Oxford Diffraction SuperNova CCD diffractometer using Cu- Kα radiation, the temperature during data collection was maintained at 130.0(1) using an Oxford Cryosystems cooling device. The structure was solved by direct methods and difference Fourier synthesis.[2] Thermal ellipsoid plots were generated using the program ORTEP-3[3] integrated within the WINGX[4] suite of programs.

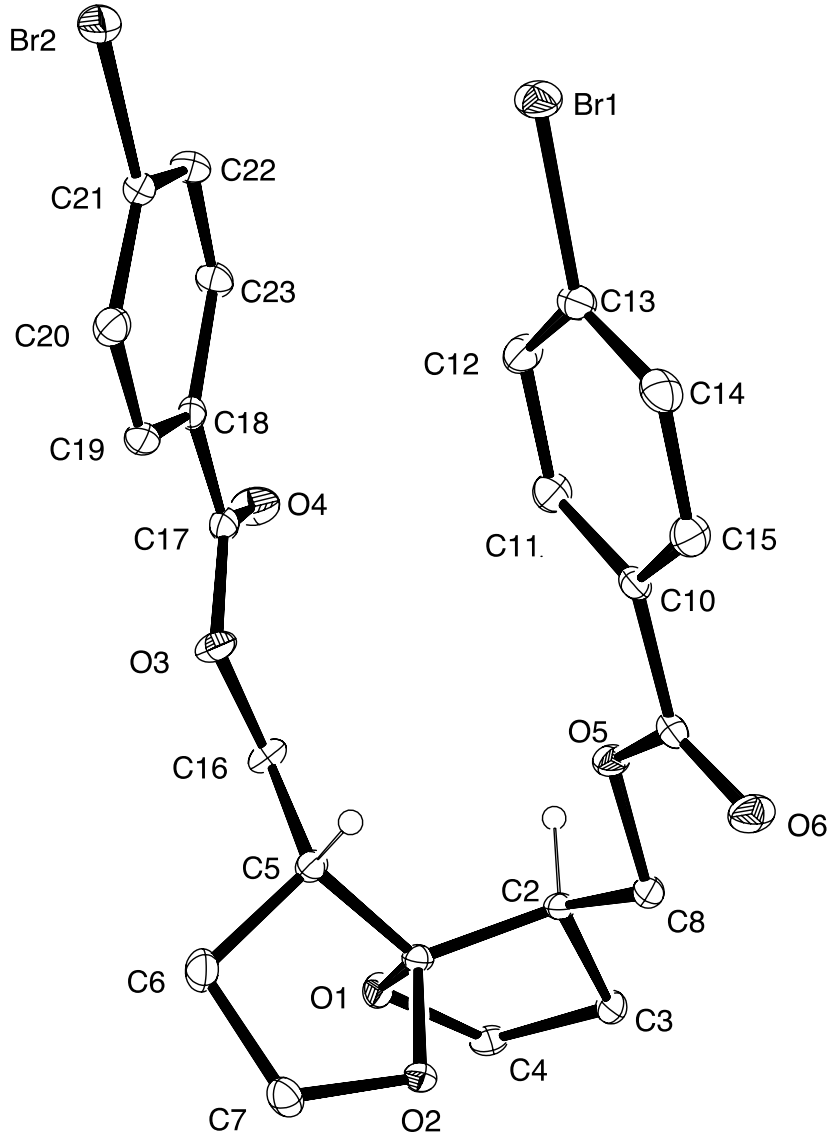
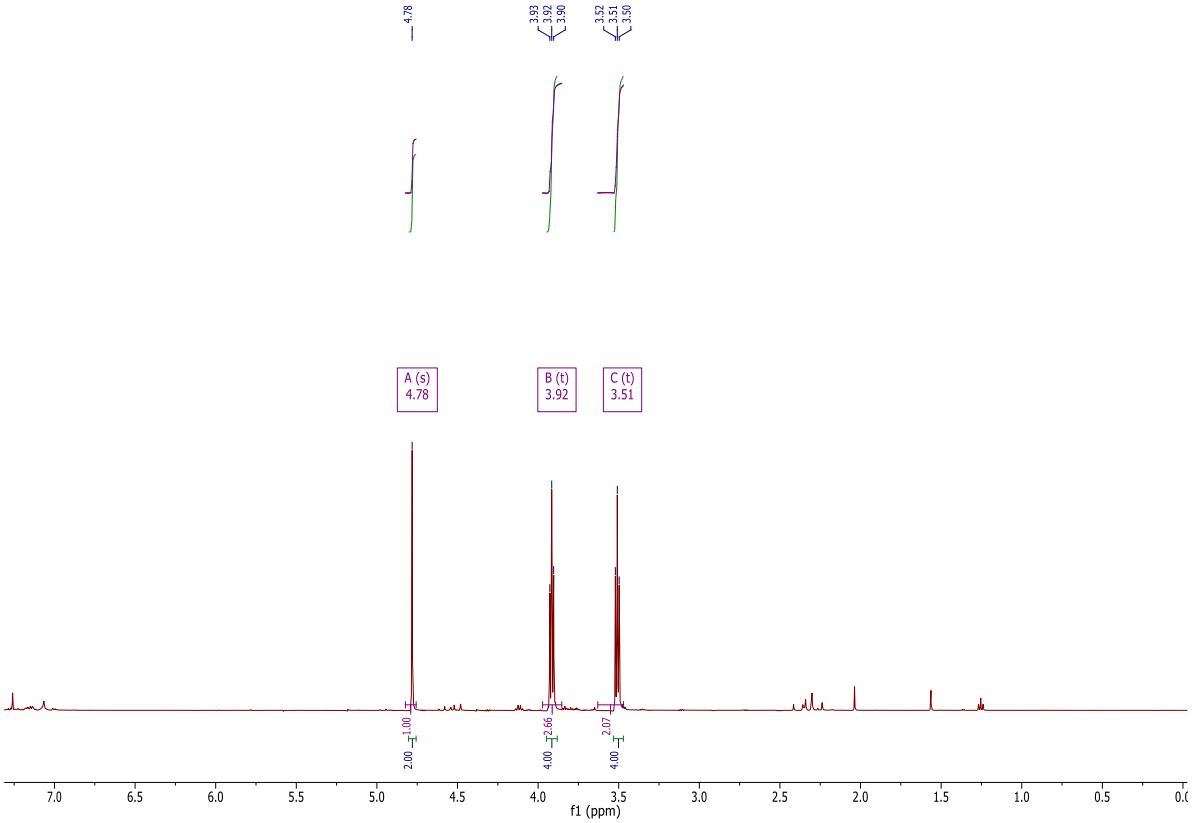


Figure S1. Thermal ellipsoid plot for **16**. Ellipsoids are at the 30% probability level.

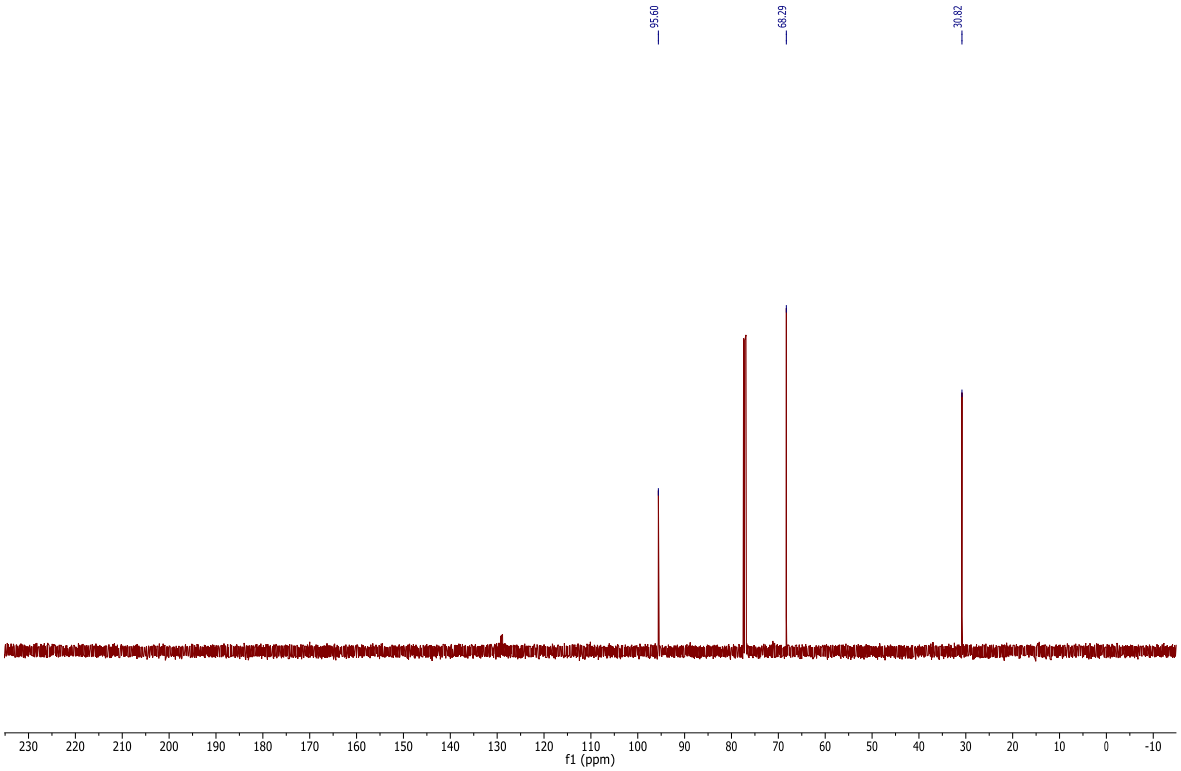
Crystal data for **16**. $C_{23}H_{22}Br_2O_6$, M = 554.22, T = 130.0 K, λ = 1.54184, Orthorhombic, space group P $2_12_12_1$, a = 6.0088(1) b = 14.4880(1), c =25.2409(2) *Å*, V = 2197.36(2) $Å^3$, Z = 4 , D_c = 1.675 mg M^{-3} μ(Cu-Kα) 5.007 mm^{-1}, F(000) =1112, crystal size 0.55 x 0.27 x 0.22 mm^3, 15254 reflections measured, 4594 independent reflections [R(int) = 0.0272], the final R was 0.0259[I > 2σ(I)] and wR(F^2) was 0.0703 (all data), Flack parameter -0.012(7). CCDC deposit code 1519781.

NMR Spectra

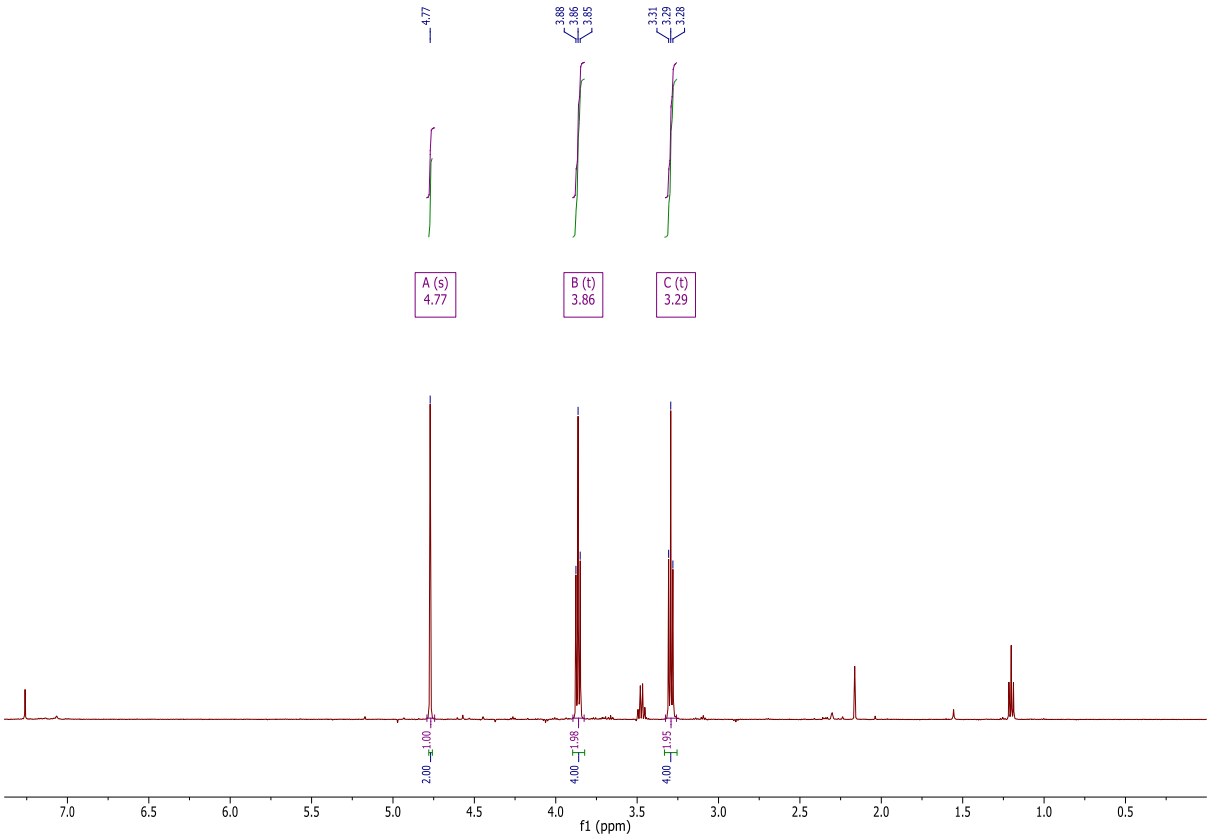
^{1}H NMR spectrum (500 MHz) of **8** in $CDCl_3$



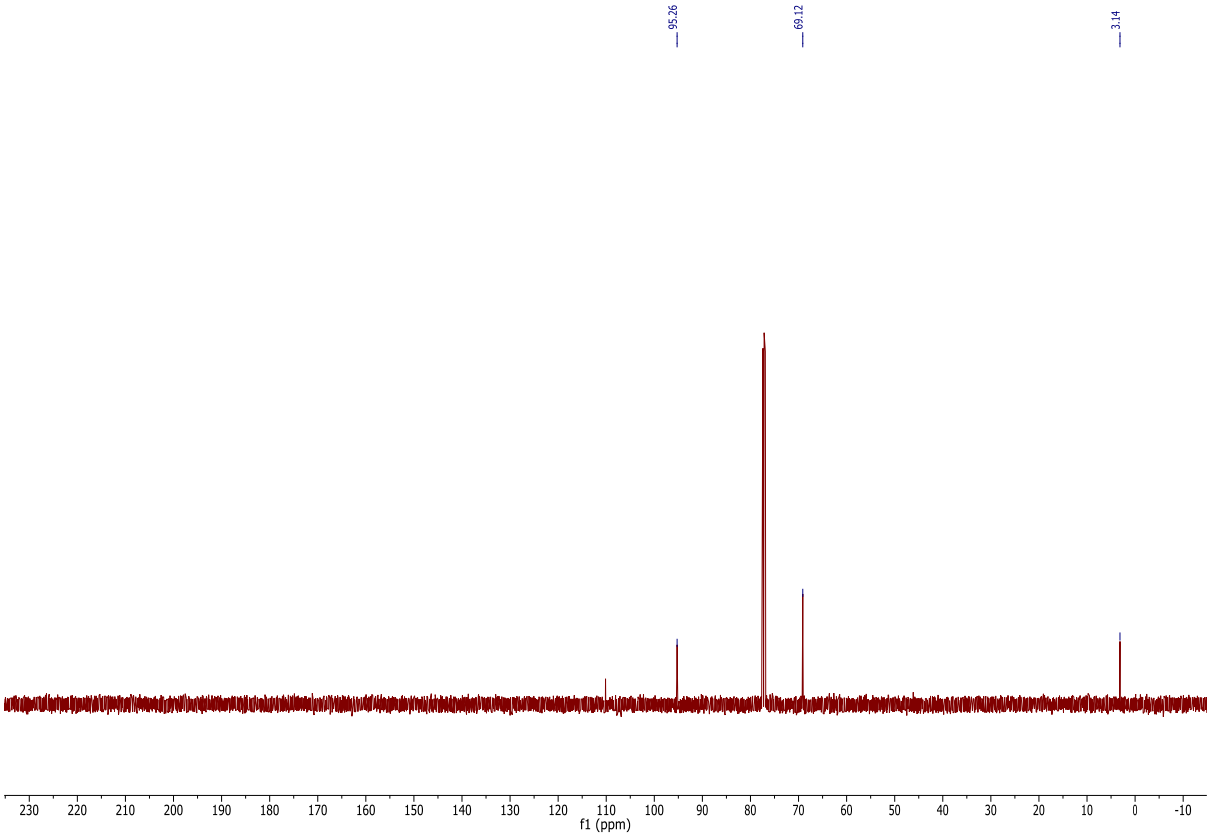
^{13}C NMR spectrum (125 MHz) of **8** in $CDCl_3$



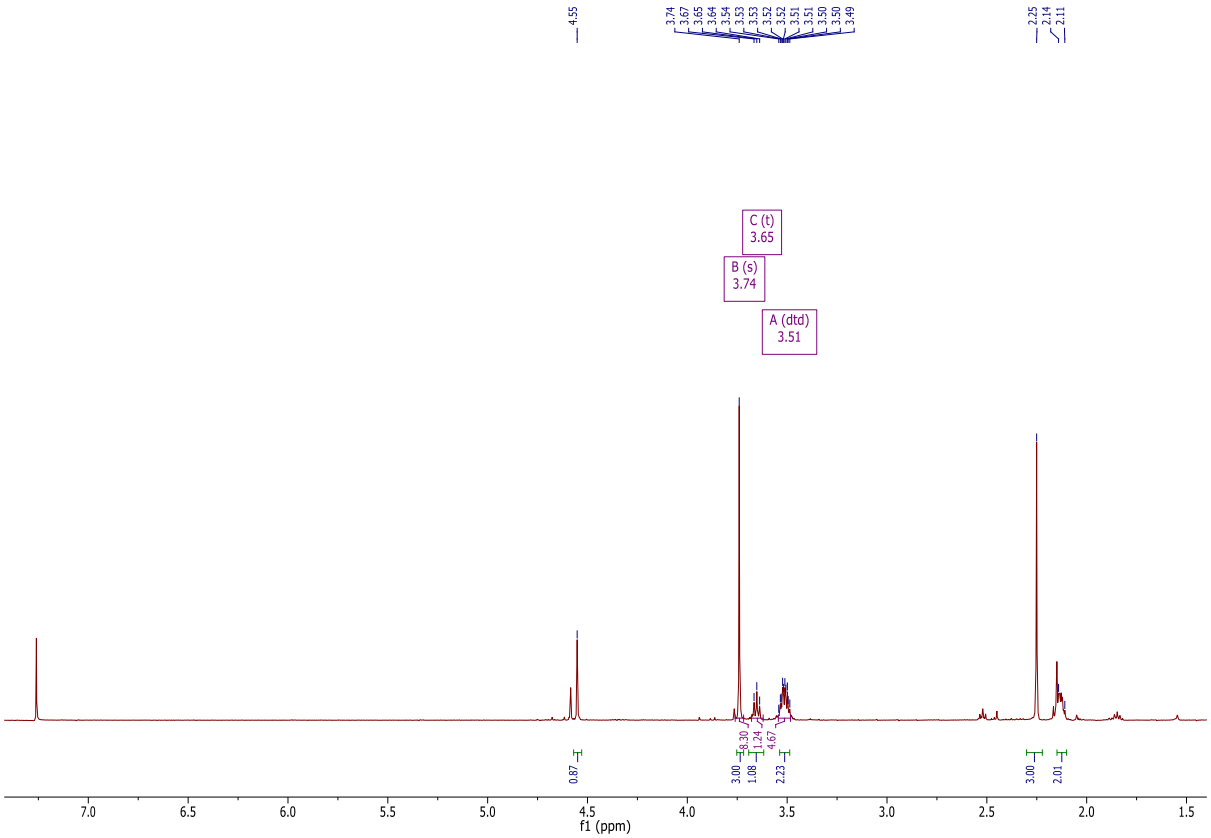
^{1}H NMR spectrum (500 MHz) of **9** in $CDCl_3$



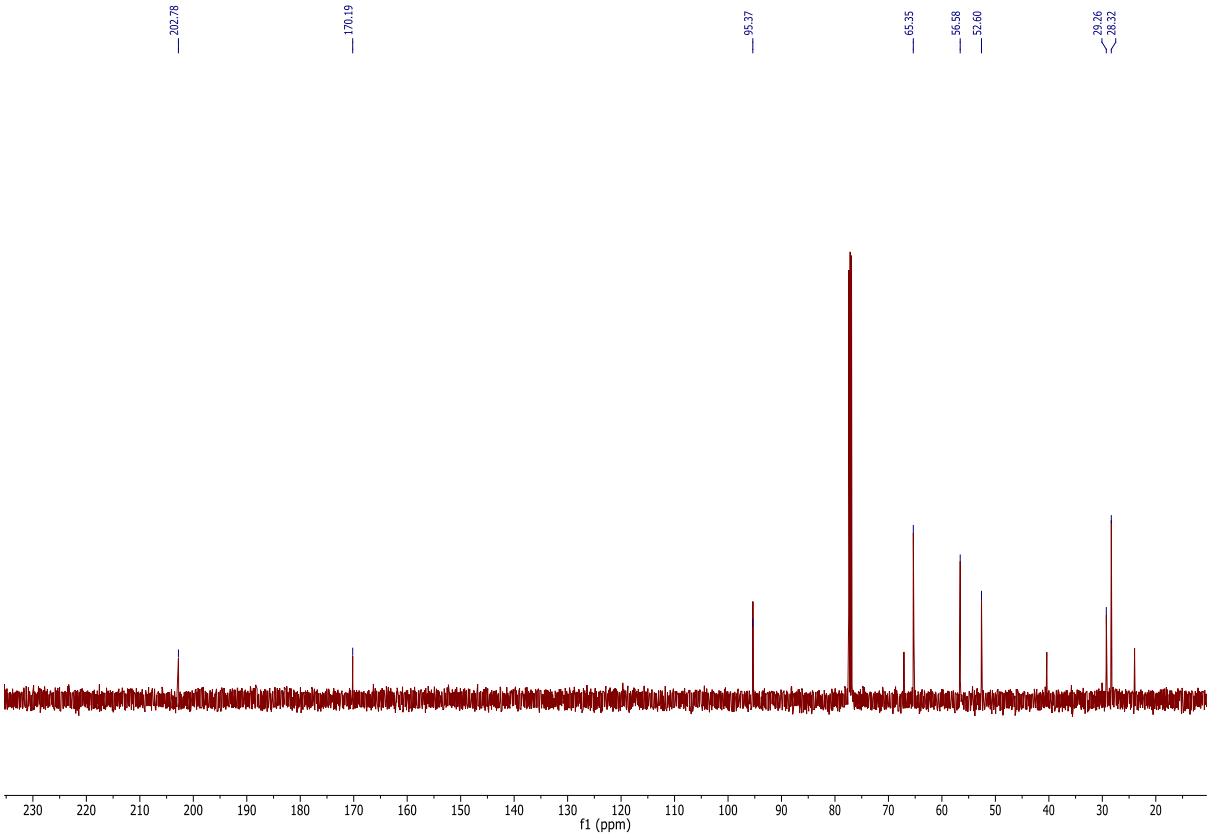
^{13}C NMR spectrum (125 MHz) of **9** in $CDCl_3$



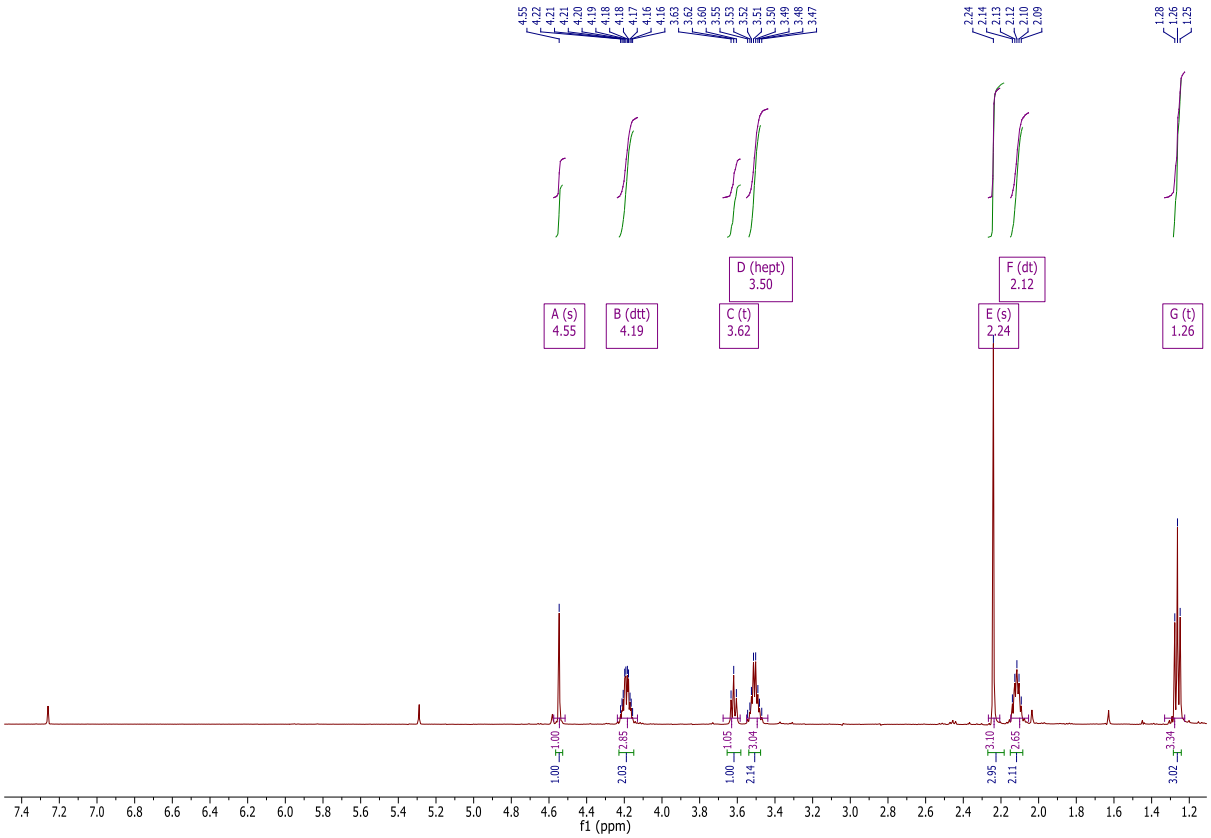
^{1}H NMR spectrum (500 MHz) of **11a** in $CDCl_3$



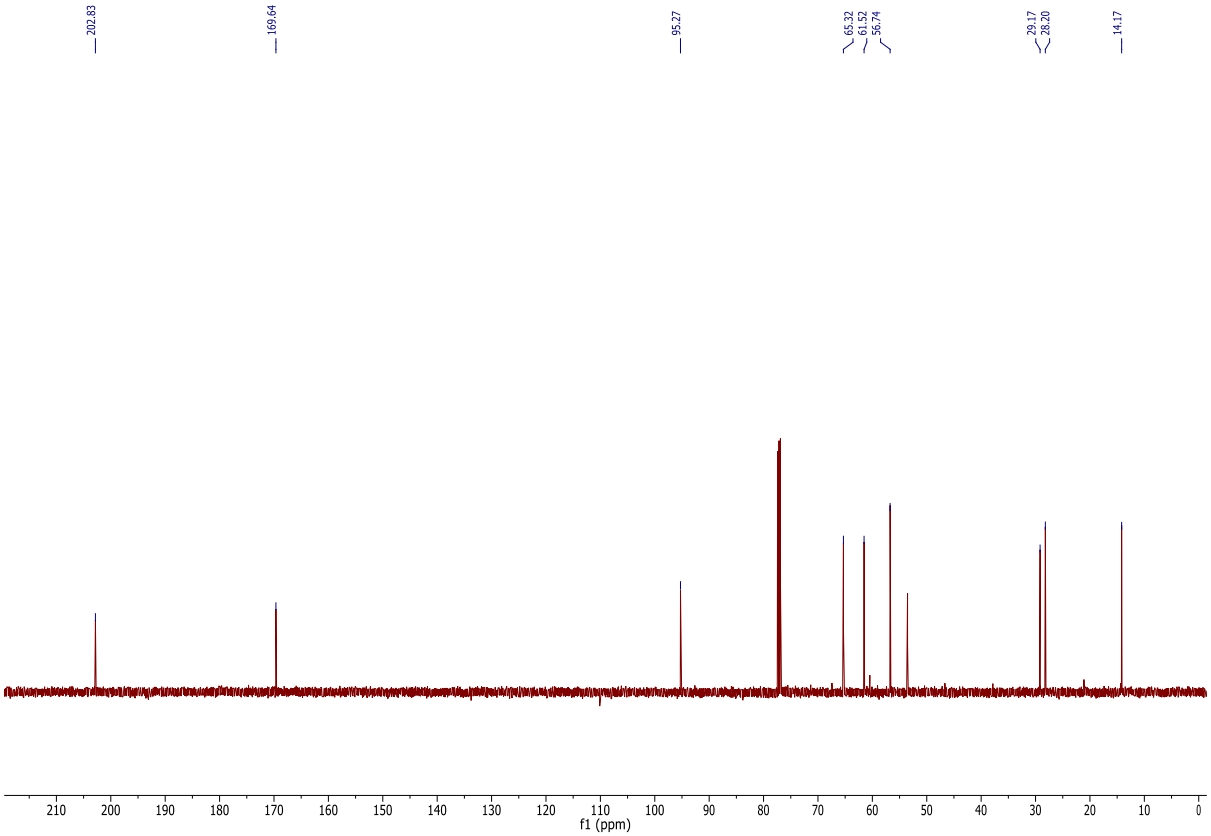
^{13}C NMR spectrum (125 MHz) of **11a** in $CDCl_3$



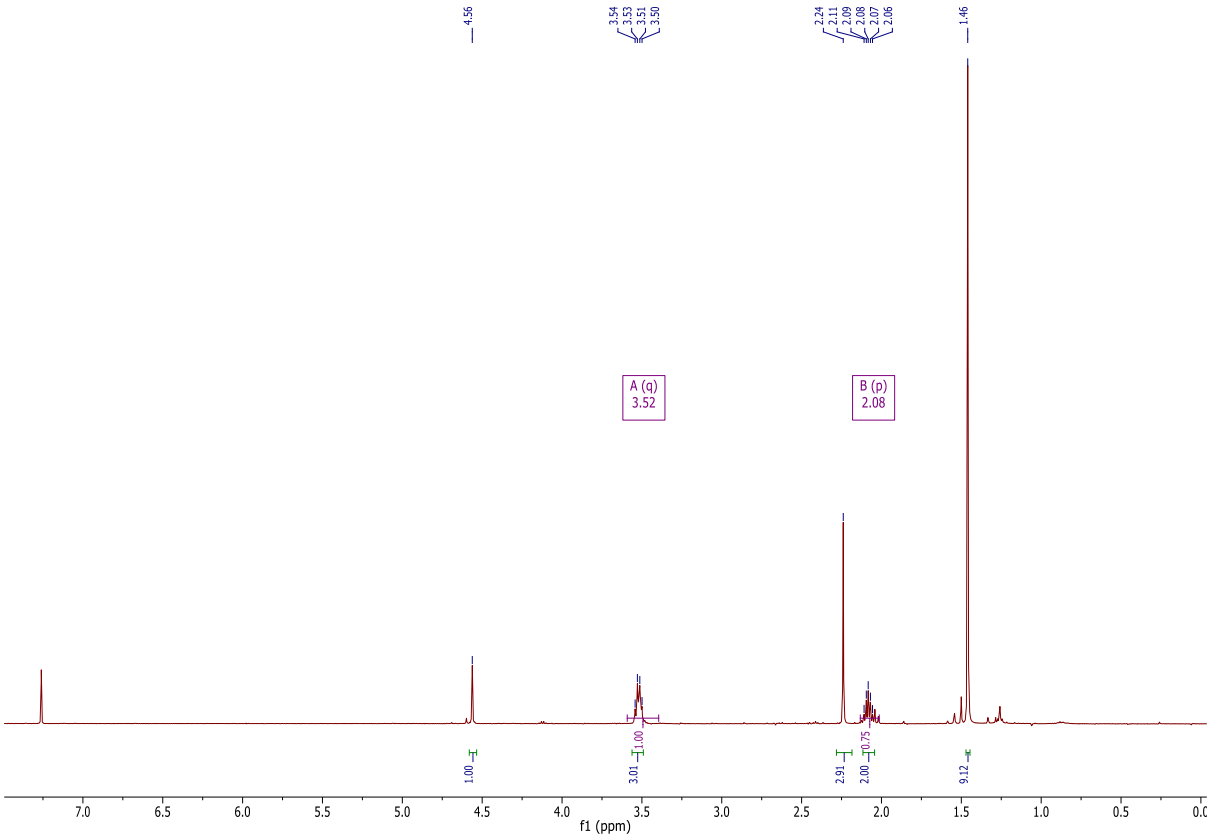
^{1}H NMR spectrum (500 MHz) of **11b** in $CDCl_3$



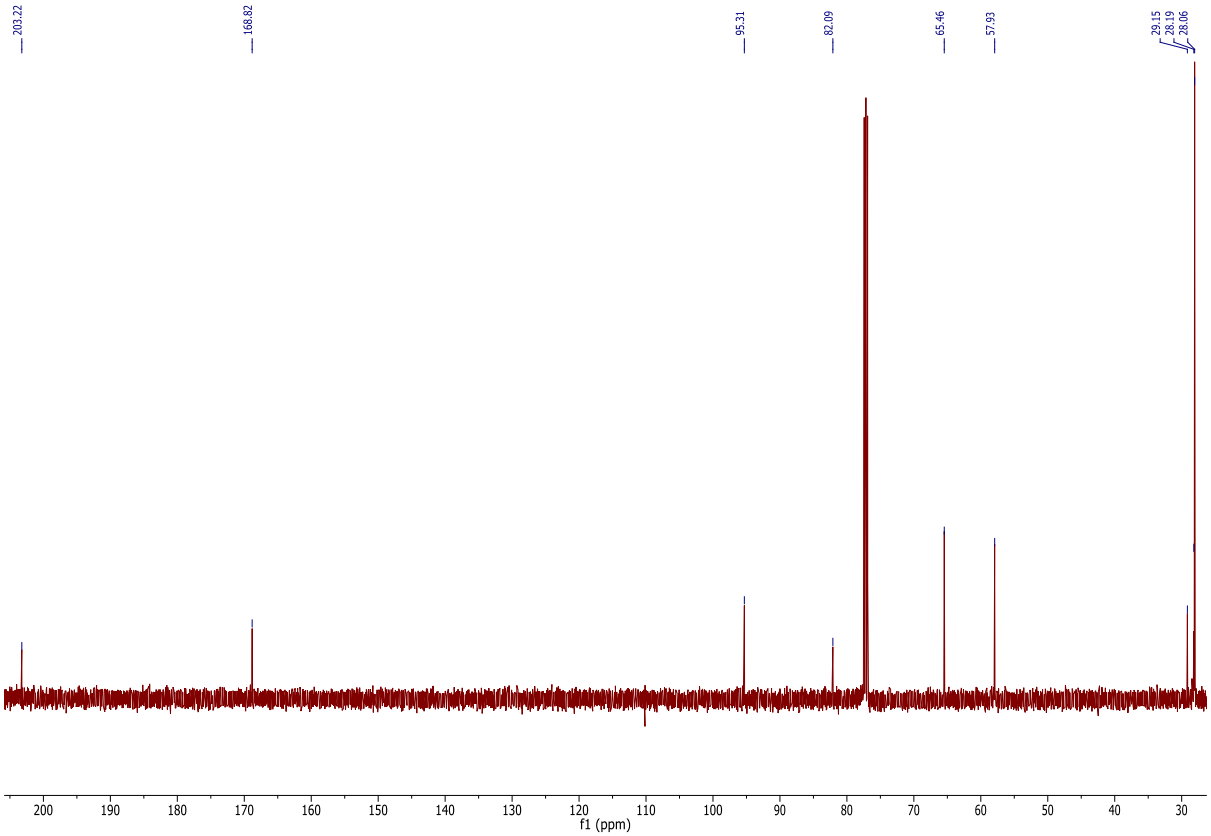
^{13}C NMR spectrum (125 MHz) of **11b** in $CDCl_3$



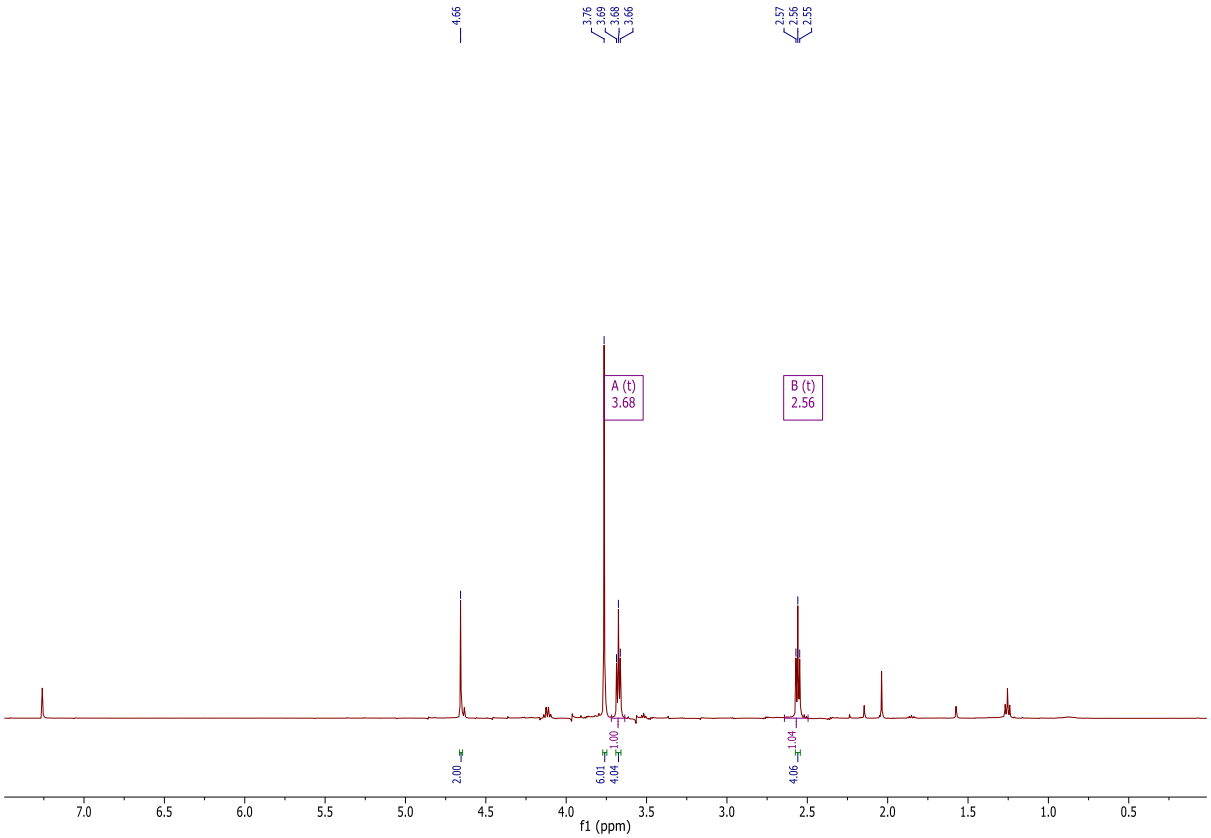
^{1}H NMR spectrum (500 MHz) of **11c** in $CDCl_3$



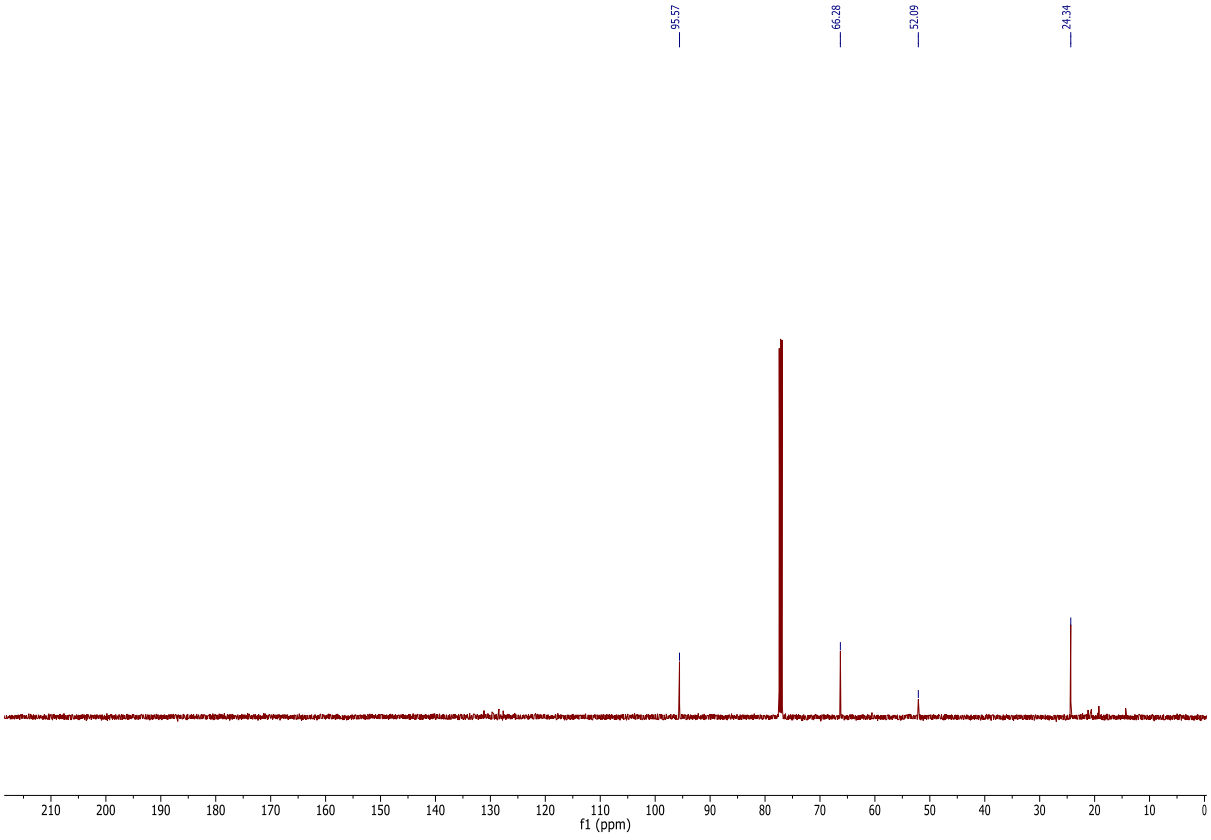
^{13}C NMR spectrum (125 MHz) of **11c** in $CDCl_3$



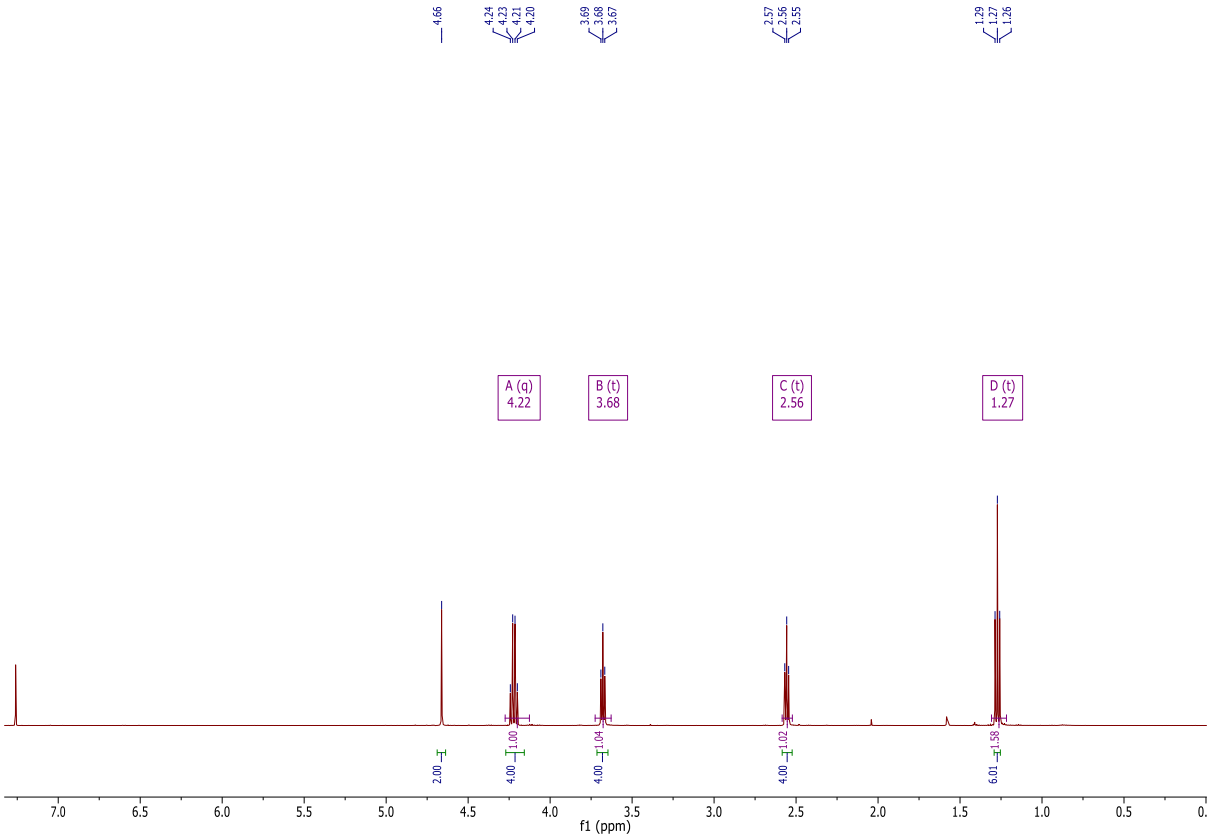
^{1}H NMR spectrum (500 MHz) of **12a** in $CDCl_3$



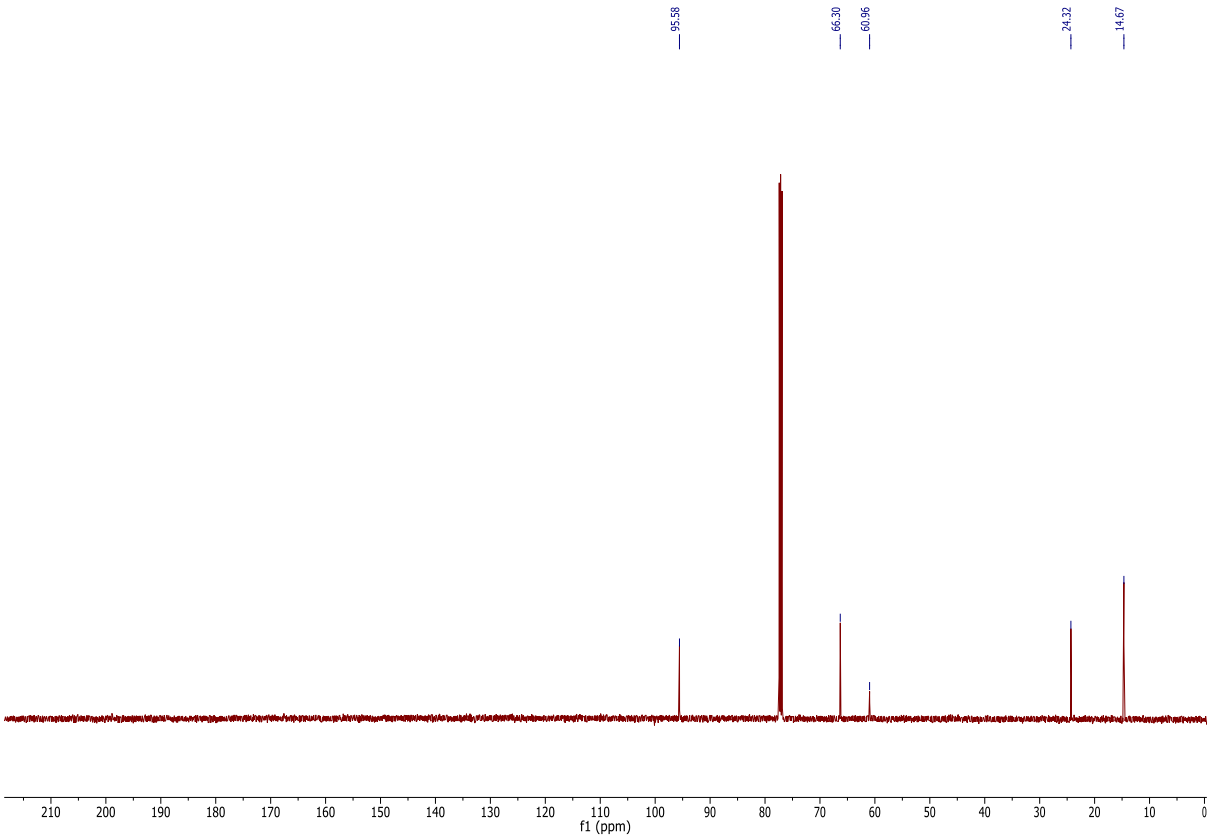
^{13}C NMR spectrum (125 MHz) of **12a** in $CDCl_3$



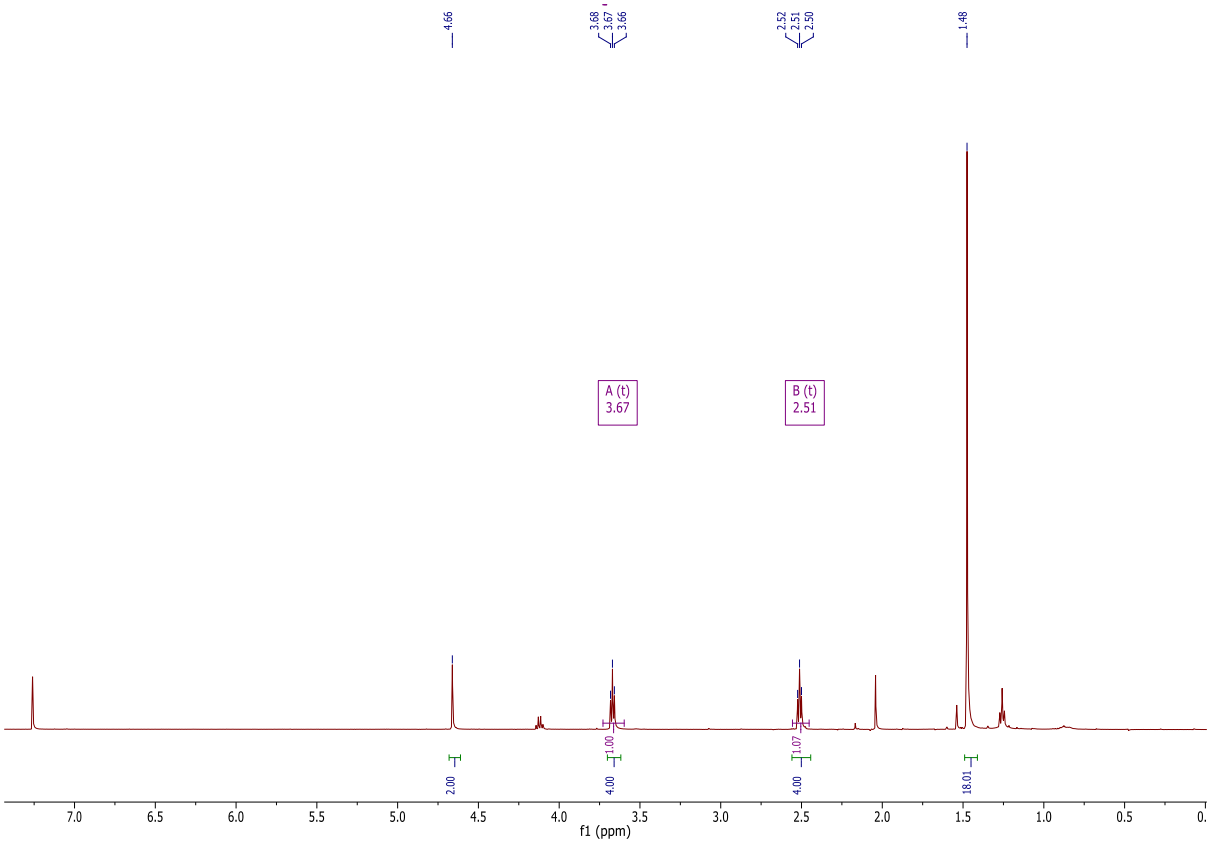
^{1}H NMR spectrum (500 MHz) of **12b** in $CDCl_3$



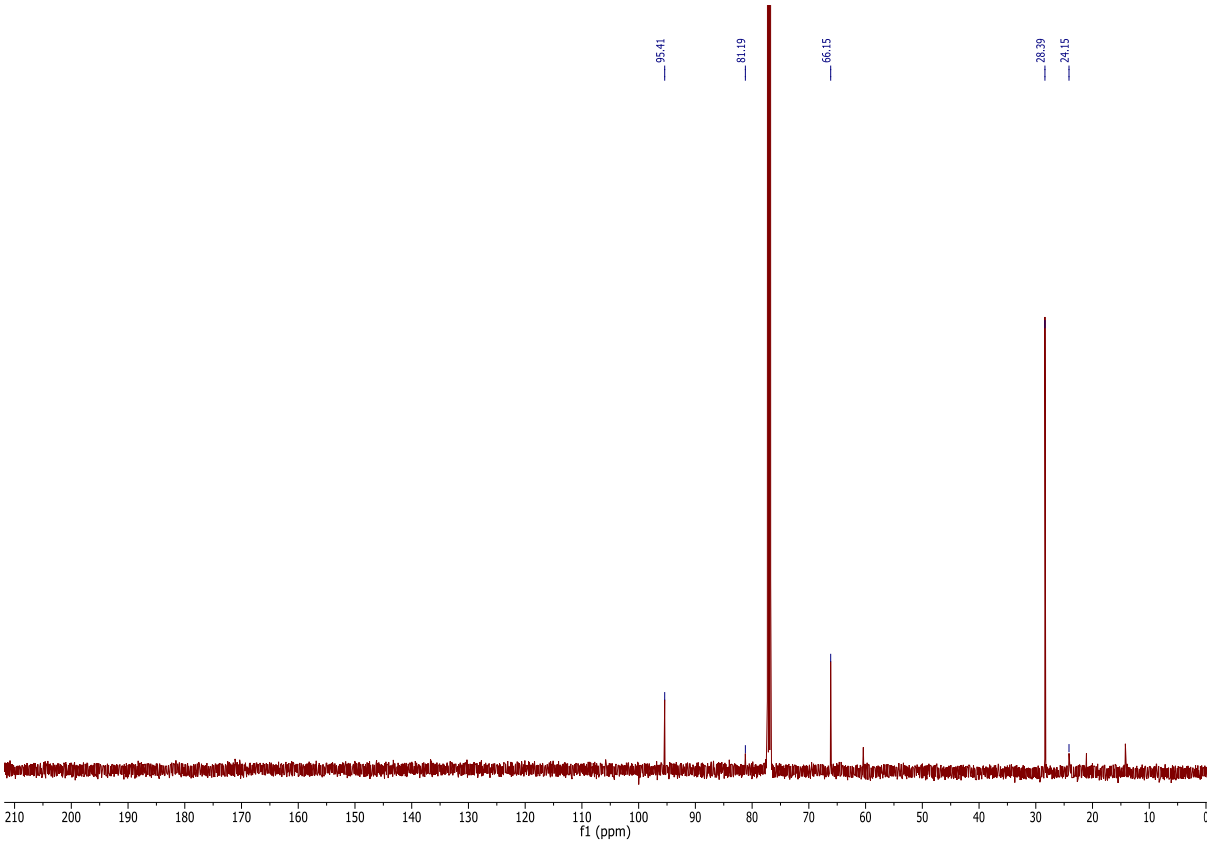
^{13}C NMR spectrum (125 MHz) of **12b** in $CDCl_3$



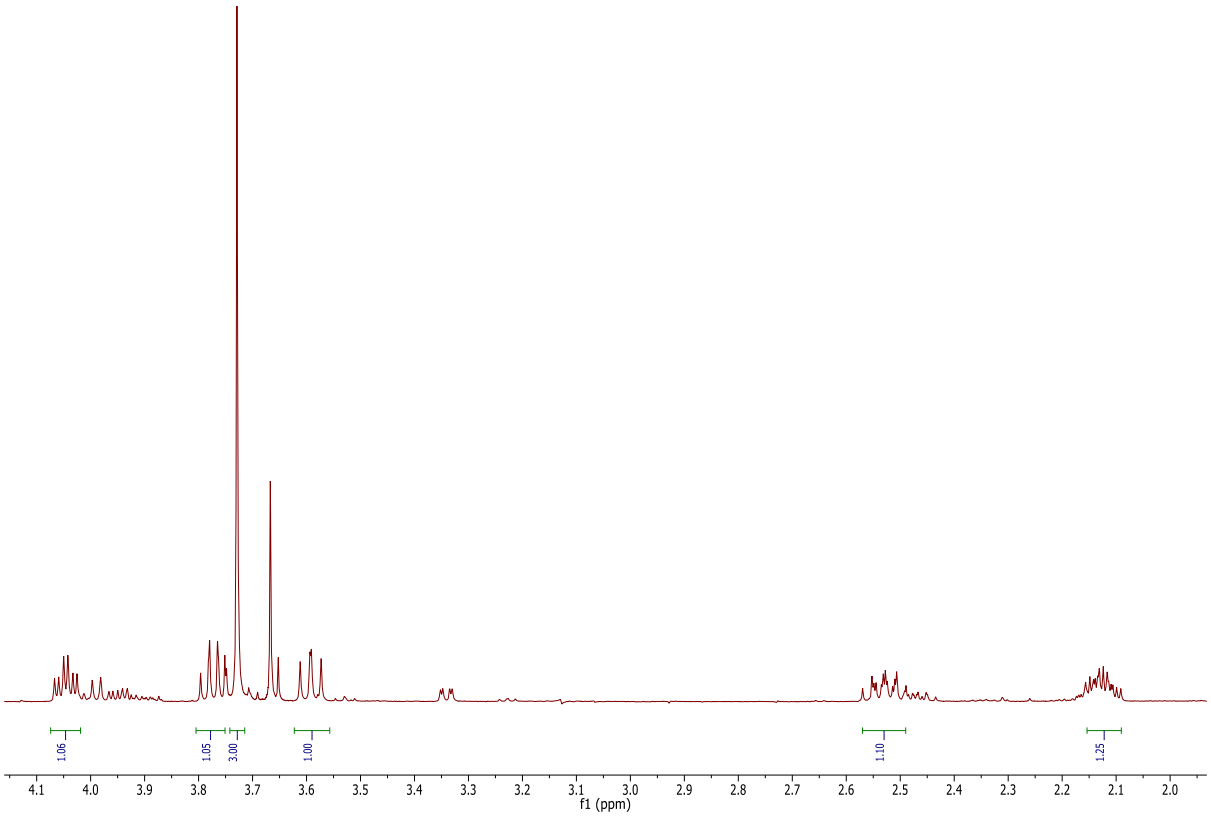
^{1}H NMR spectrum (500 MHz) of **12c** in $CDCl_3$



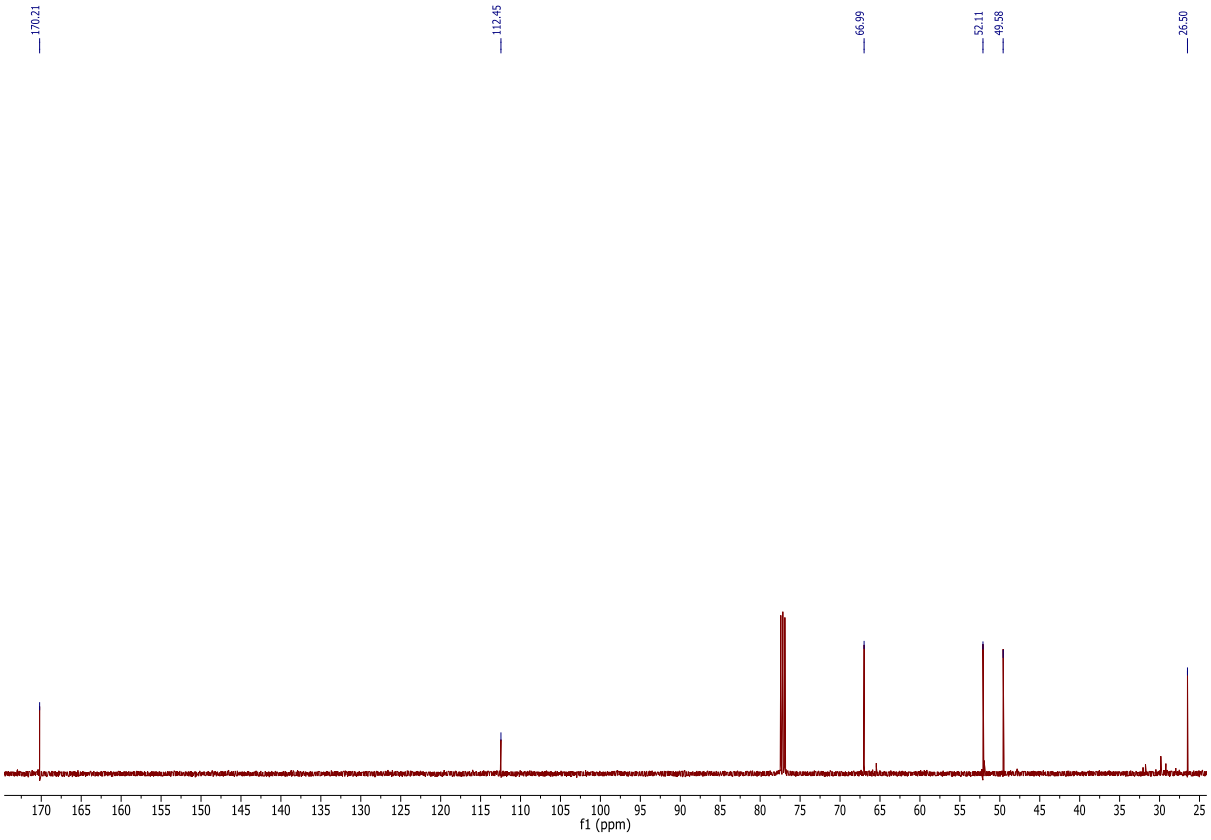
^{13}C NMR spectrum (125 MHz) of **12c** in $CDCl_3$



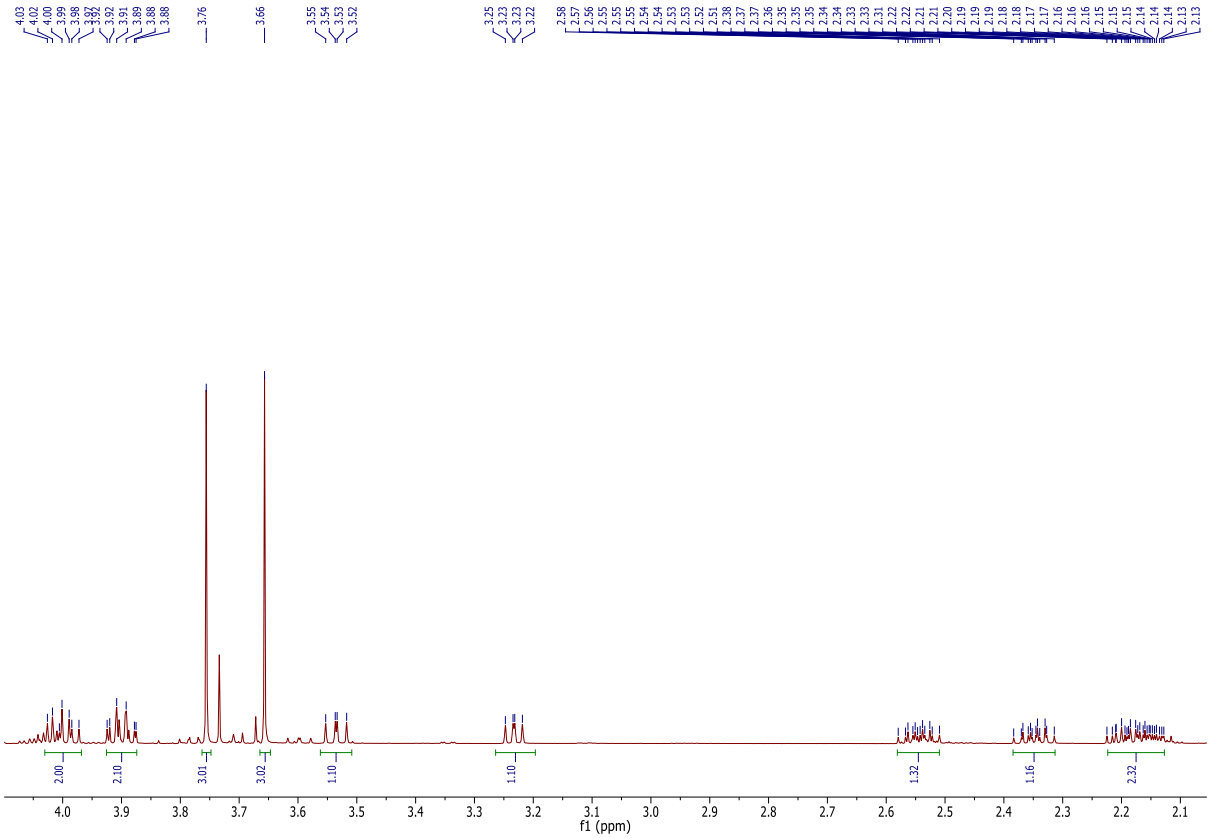
^{1}H NMR spectrum (500 MHz) of **13a** in $CDCl_3$



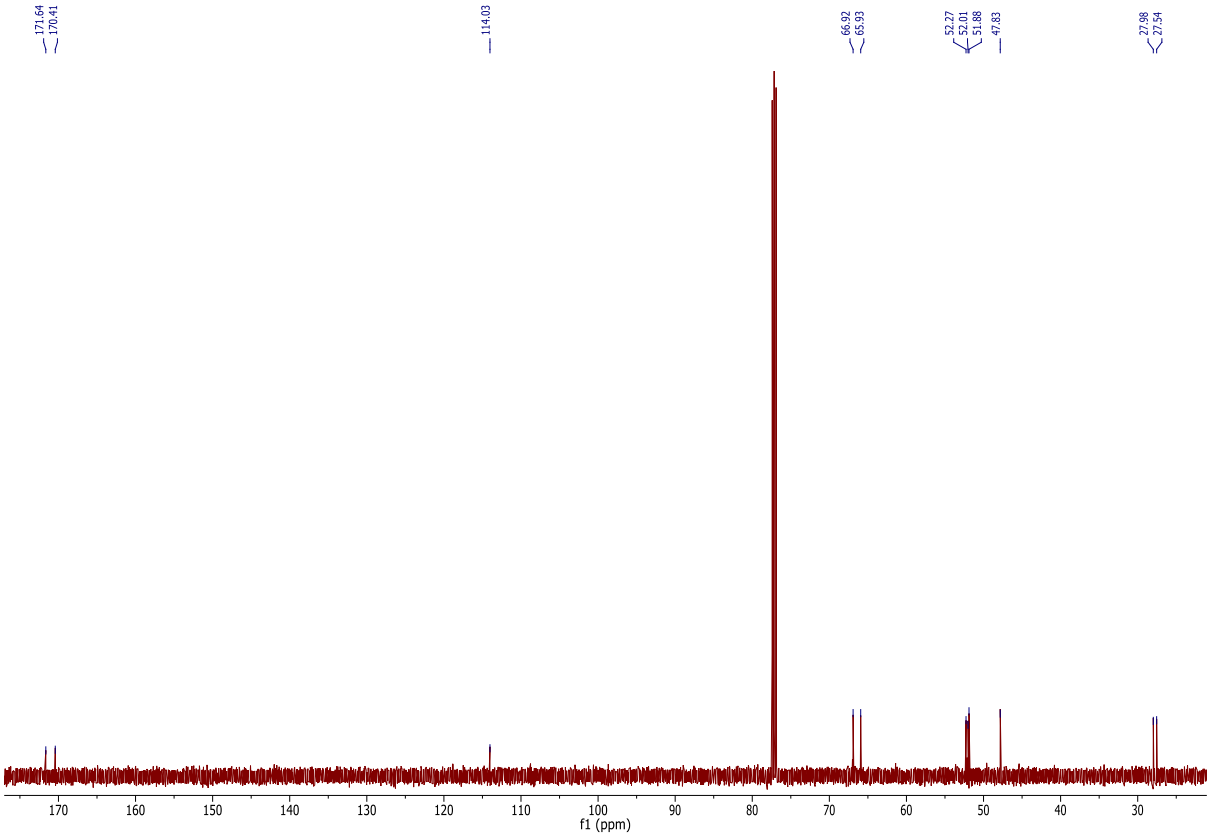
^{13}C NMR spectrum (125 MHz) of **13a** in $CDCl_3$



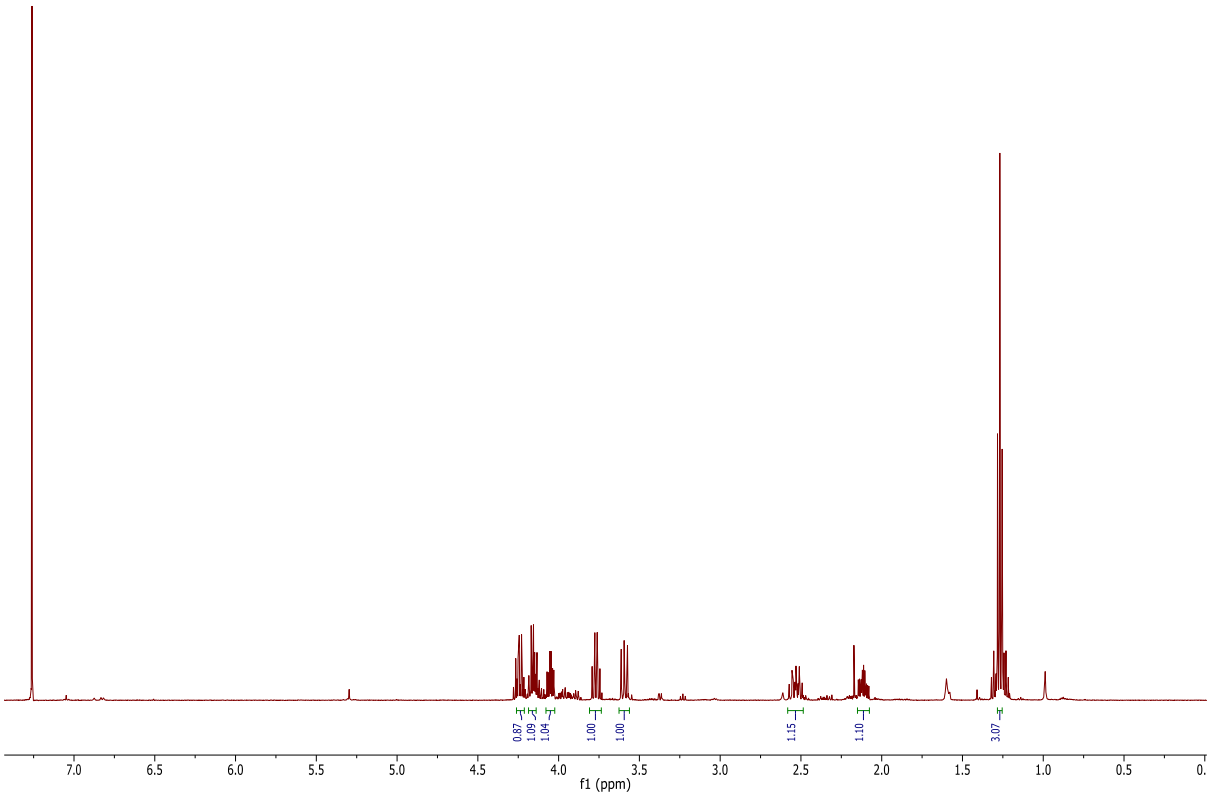
^{1}H NMR spectrum (500 MHz) of **14a** in $CDCl_3$



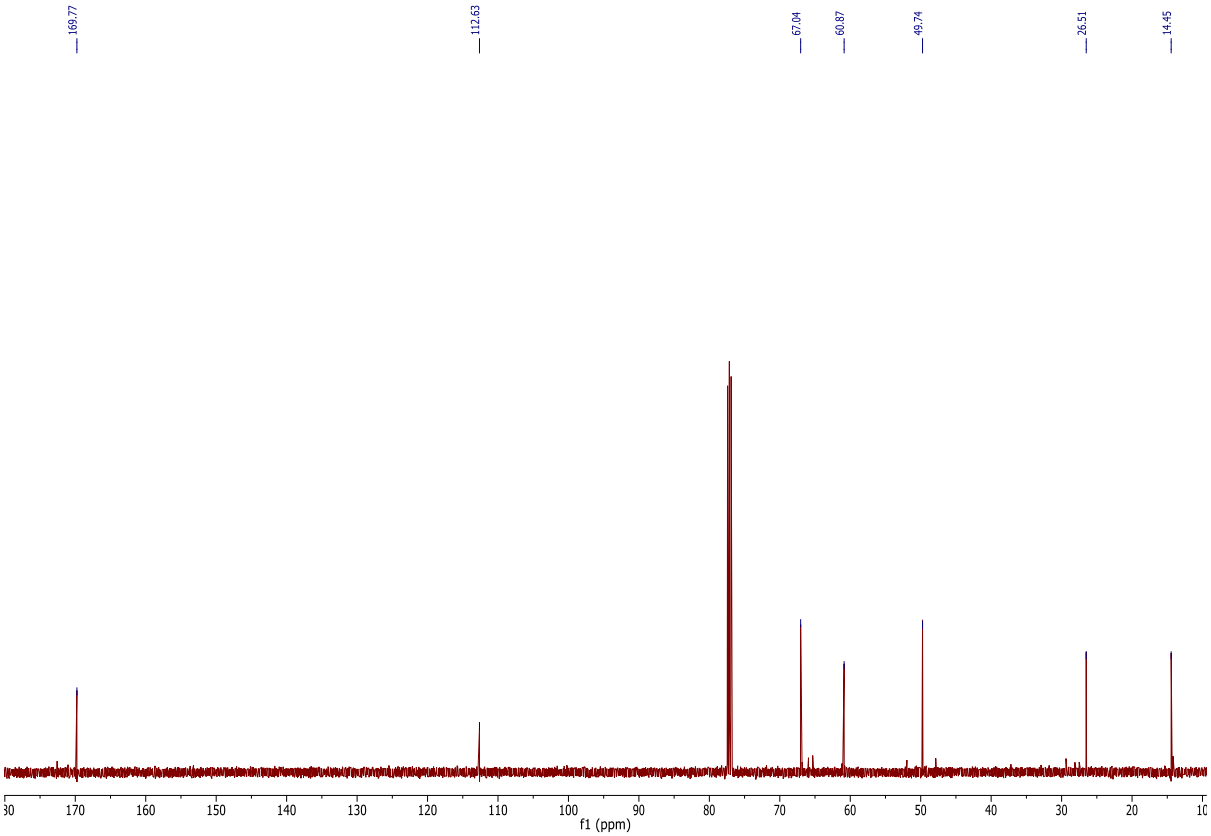
^{13}C NMR spectrum (125 MHz) of **14a** in $CDCl_3$



^{1}H NMR spectrum (500 MHz) of **13b** in $CDCl_3$



^{13}C NMR spectrum (125 MHz) of **13b** in $CDCl_3$



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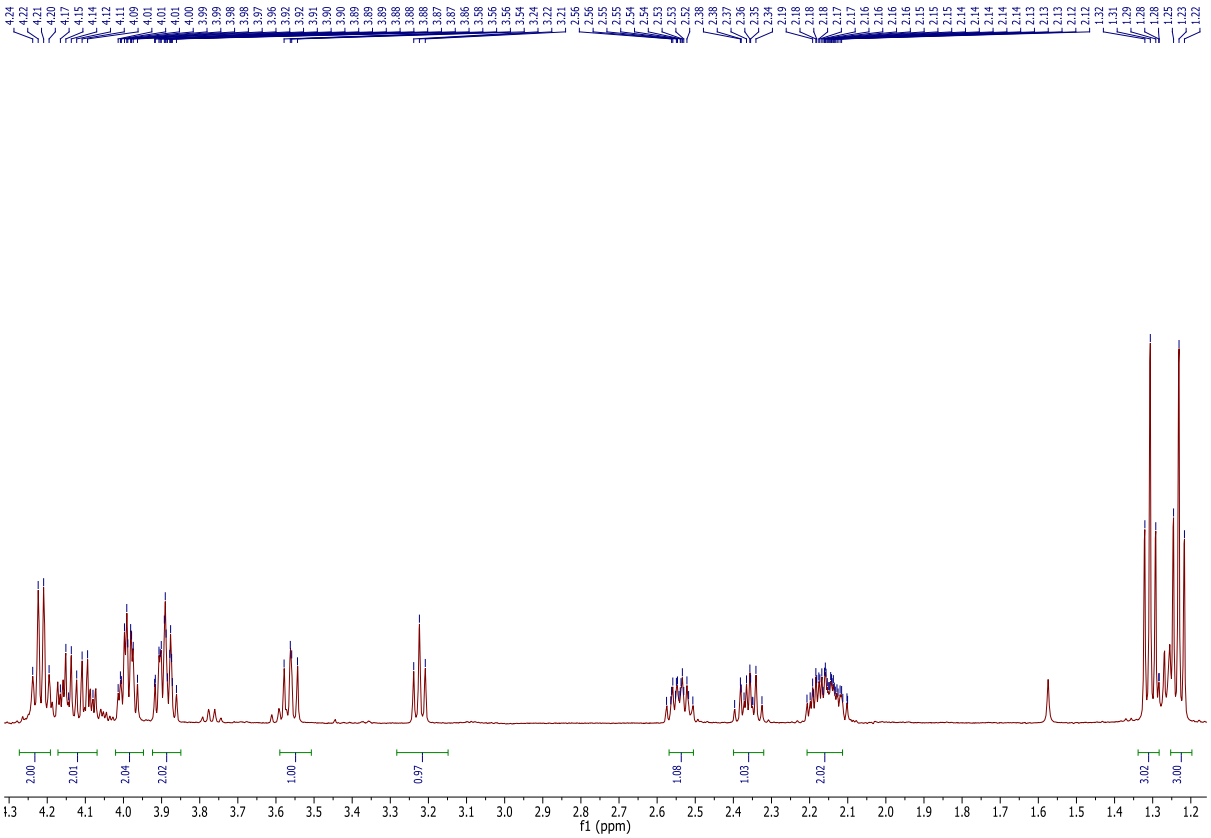

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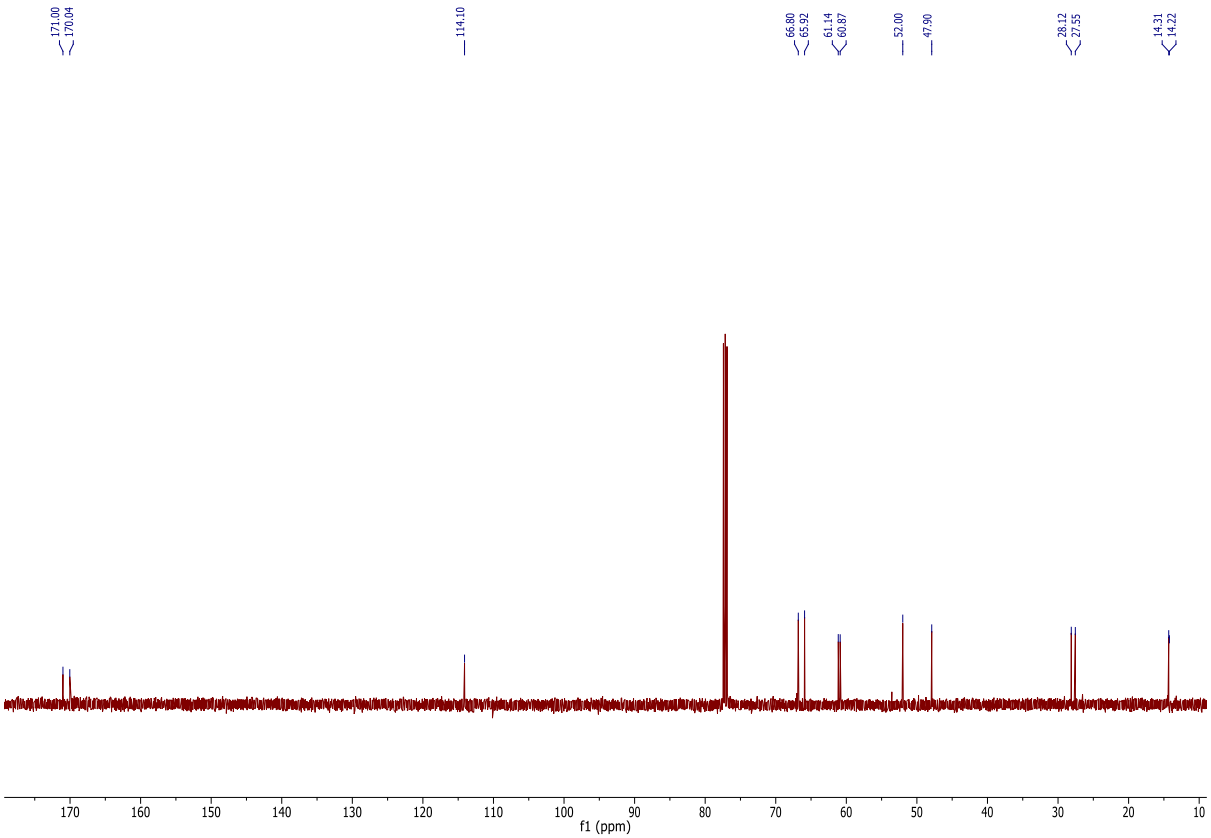
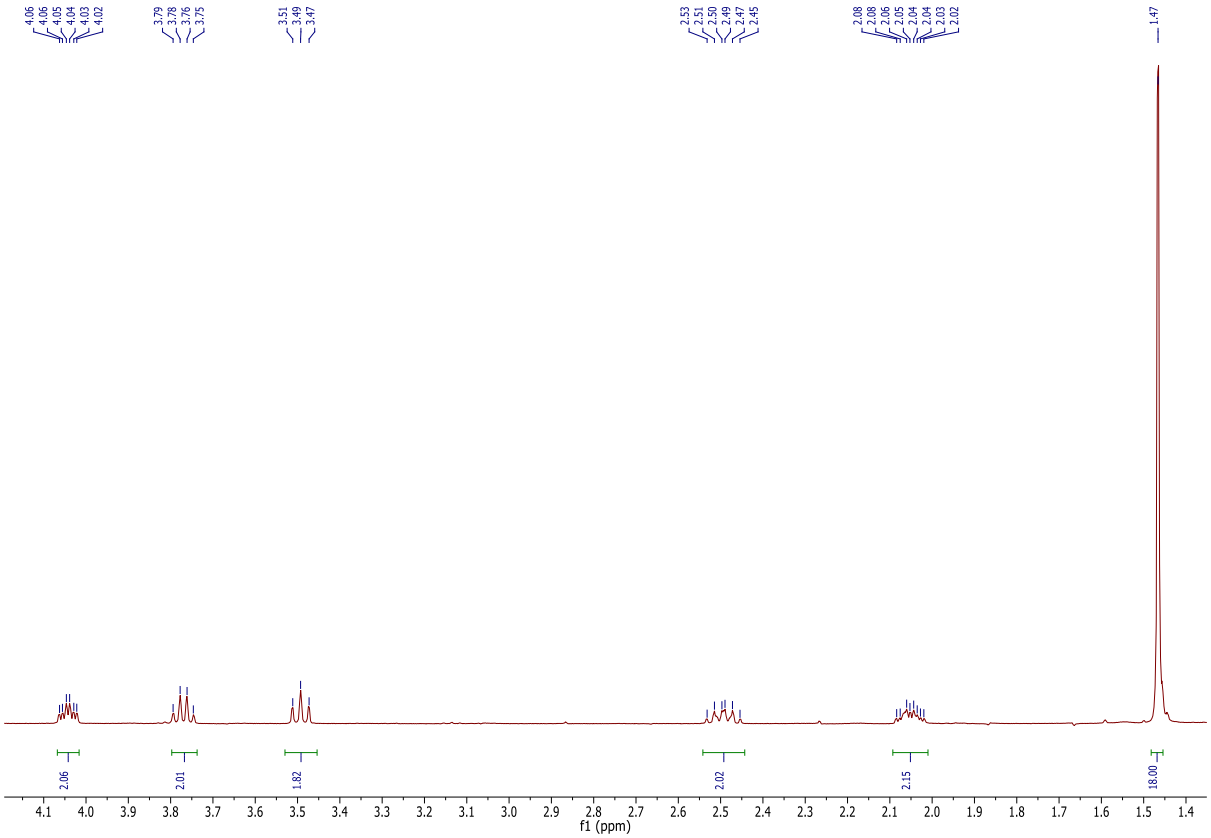
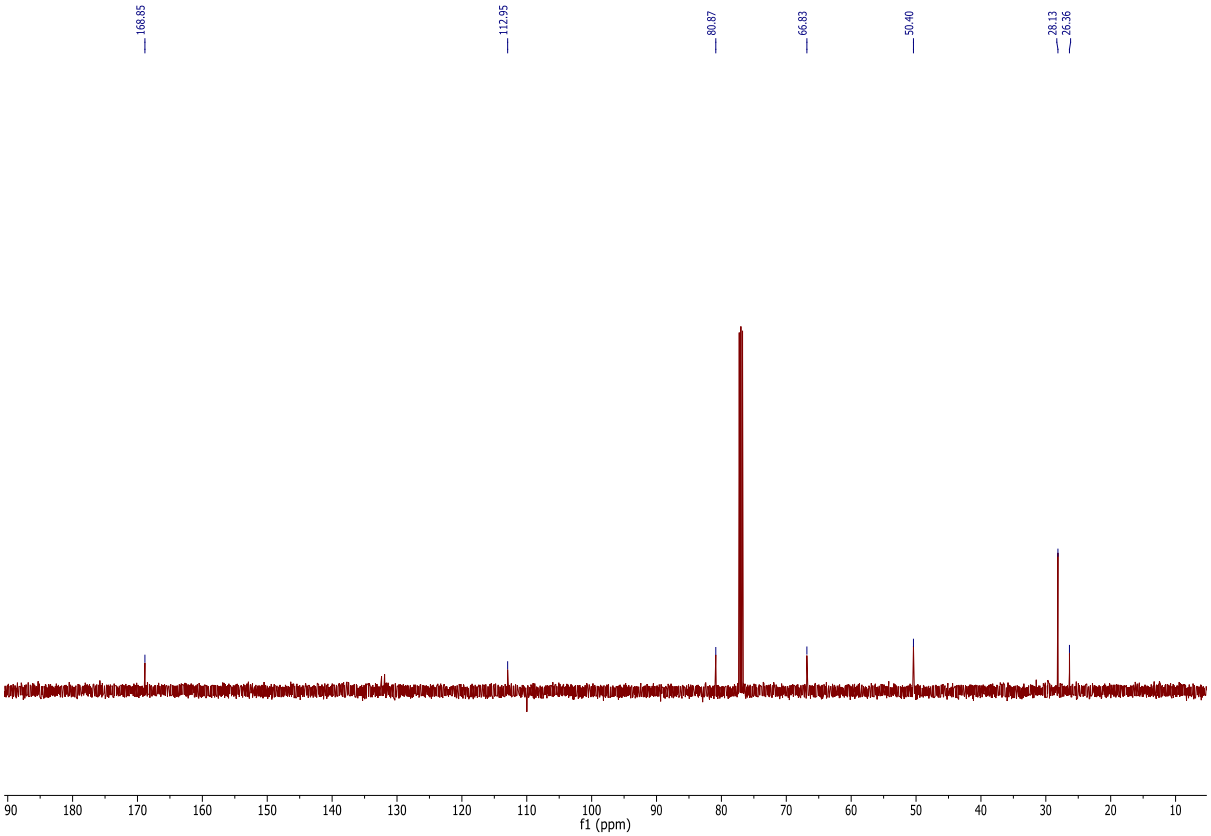


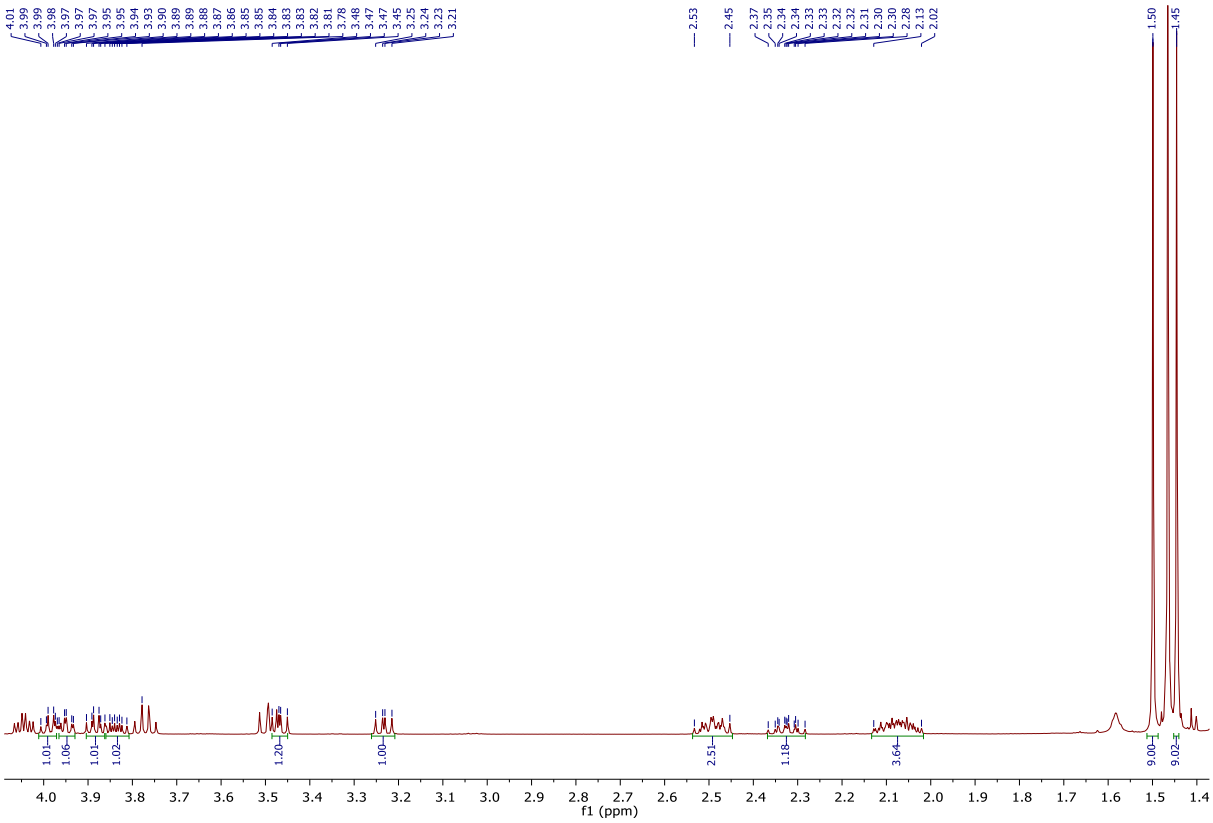
^{1}H NMR spectrum (500 MHz) of **13c** in $CDCl_3$



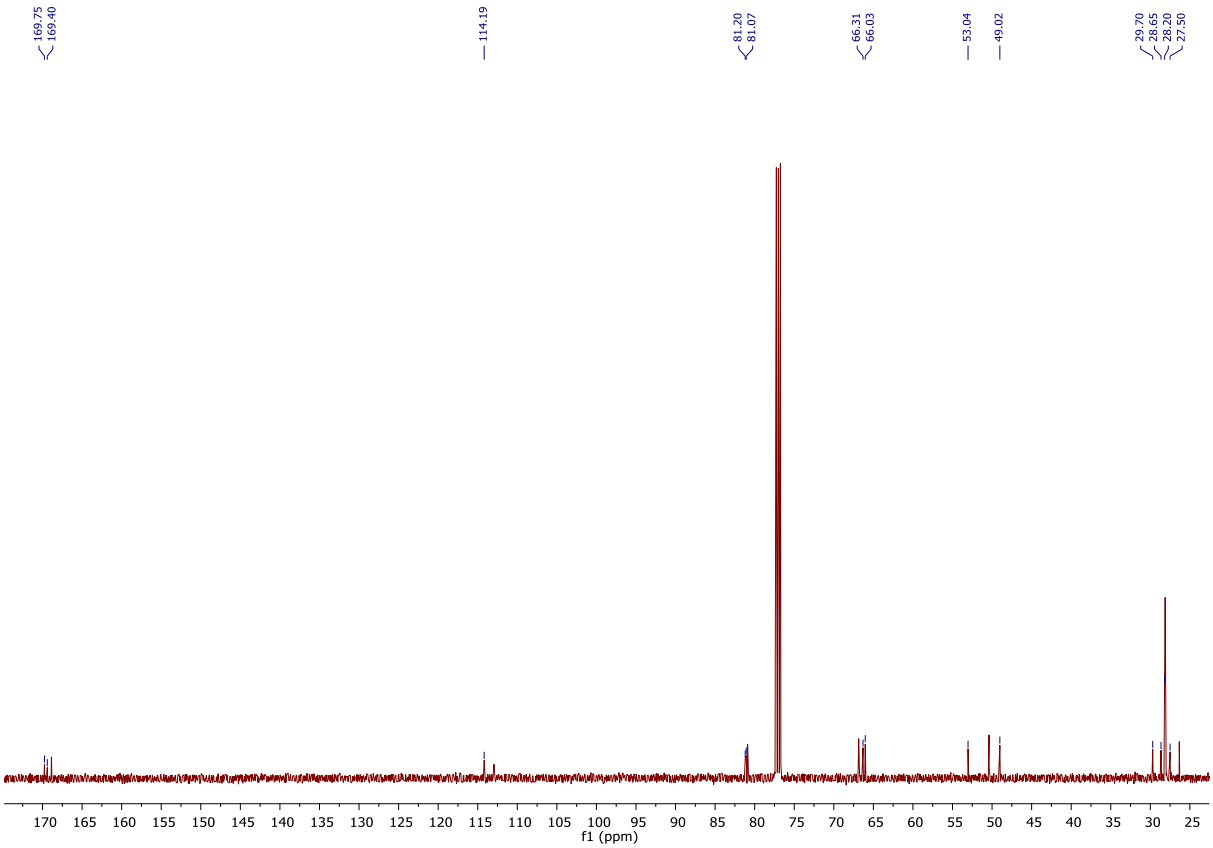
^{13}C NMR spectrum (125 MHz) of **13c** in $CDCl_3$



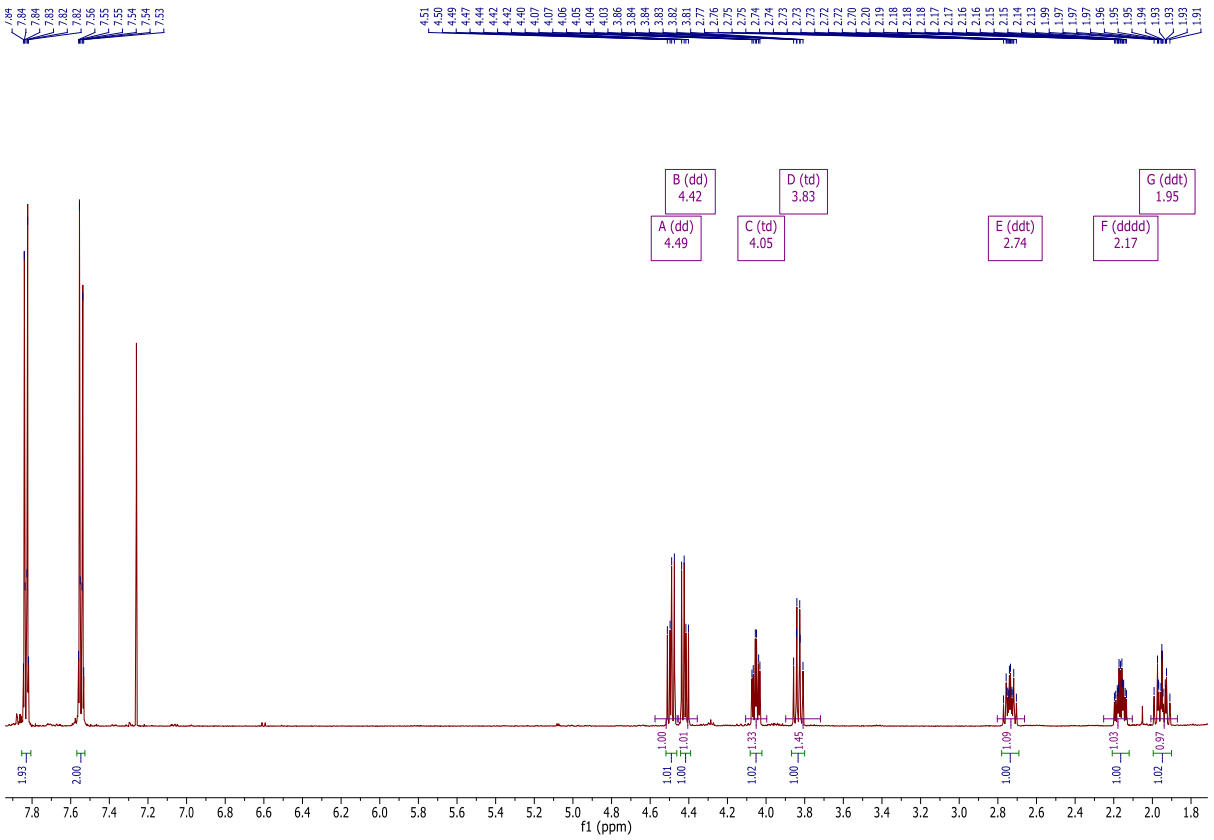
^{1}H NMR spectrum (500 MHz) of a mixture of **14c** and **13c** in $CDCl_3$



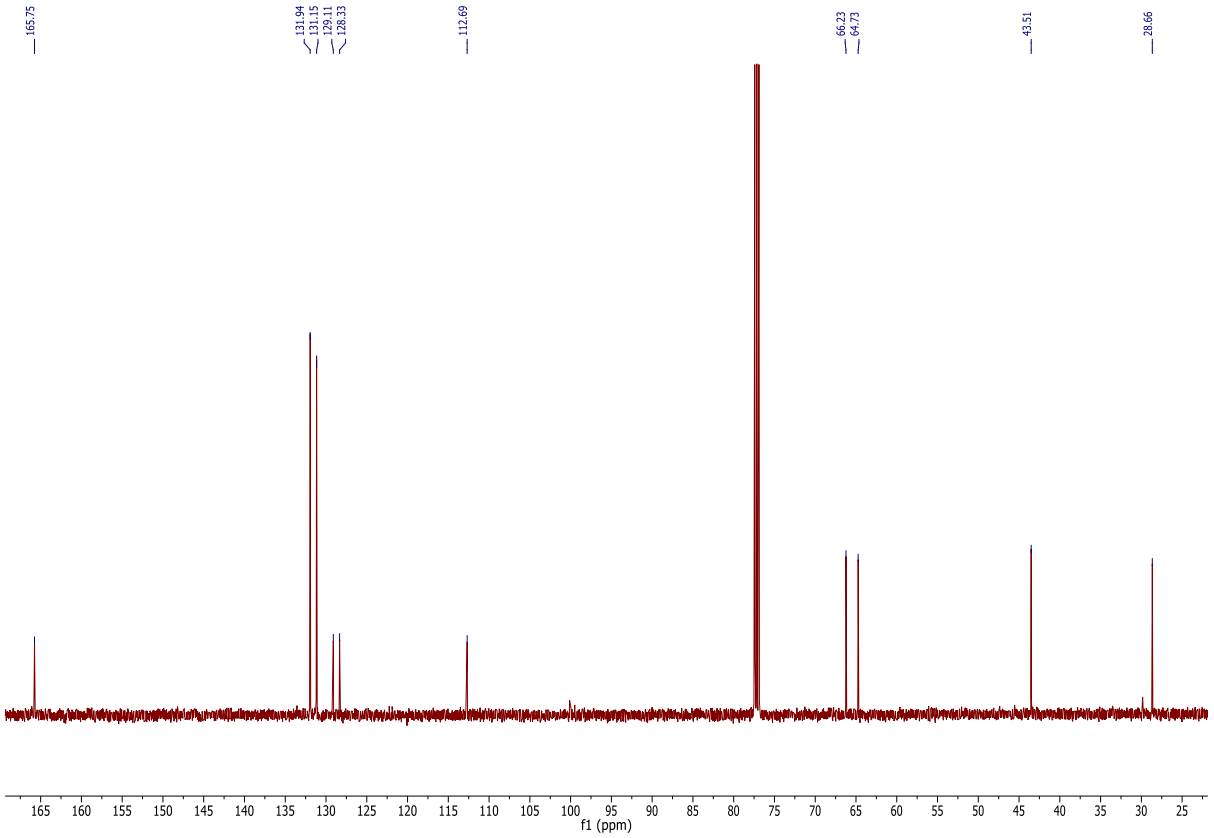
^{13}C NMR spectrum (125 MHz) of a mixture of **14c** and **13c** in $CDCl_3$



^{1}H NMR spectrum (500 MHz) of **16** in $CDCl_3$



^{13}C NMR spectrum (125 MHz) of **16** in $CDCl_3$.



Chiral HPLC traces for 16

From Rh_2(*S*-DOSP)$_4$ reaction (Table 1, entry 7)

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                                                  Inj Volume : 5.0 µl
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    Last changed    : 6/7/2016 4:41:35 PM by Sam
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    Last changed    : 6/7/2016 3:48:13 PM by Sam
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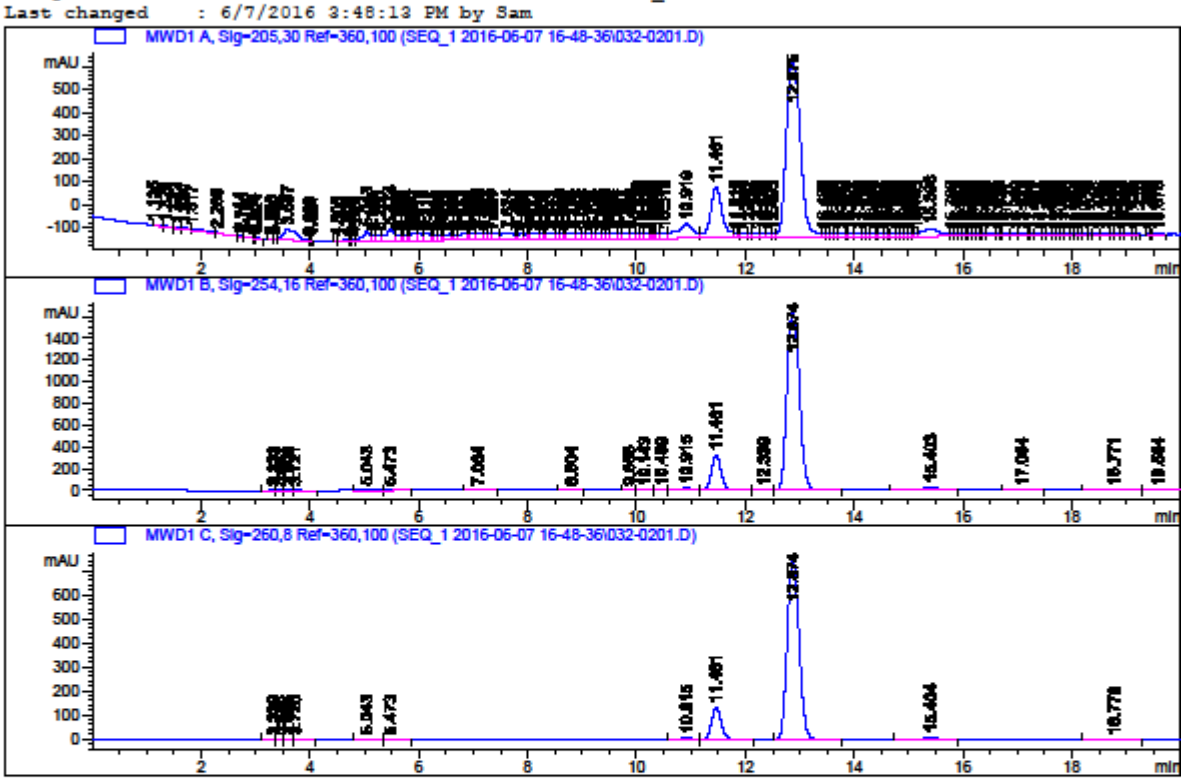


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    ======================================================================

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    Dilution:                     :      1.0000
    Use Multiplier & Dilution Factor with ISTDs


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       2   1.329 VV    0.1474   55.71087    4.72935   0.1665
       3   1.543 VV    0.1183   55.03669    6.95596   0.1645
       4   1.680 VV    0.1146   61.96097    6.65387   0.1851

Instrument 1 7/14/2016 3:22:55 PM Sam                          Page   1 of 5
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From Rh_2(*S*-PTAD)$_4$ reaction (Table 1, entry 8)

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                                                   Inj Volume : 5.0 µl
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    Last changed    : 6/7/2016 4:41:35 PM by Sam
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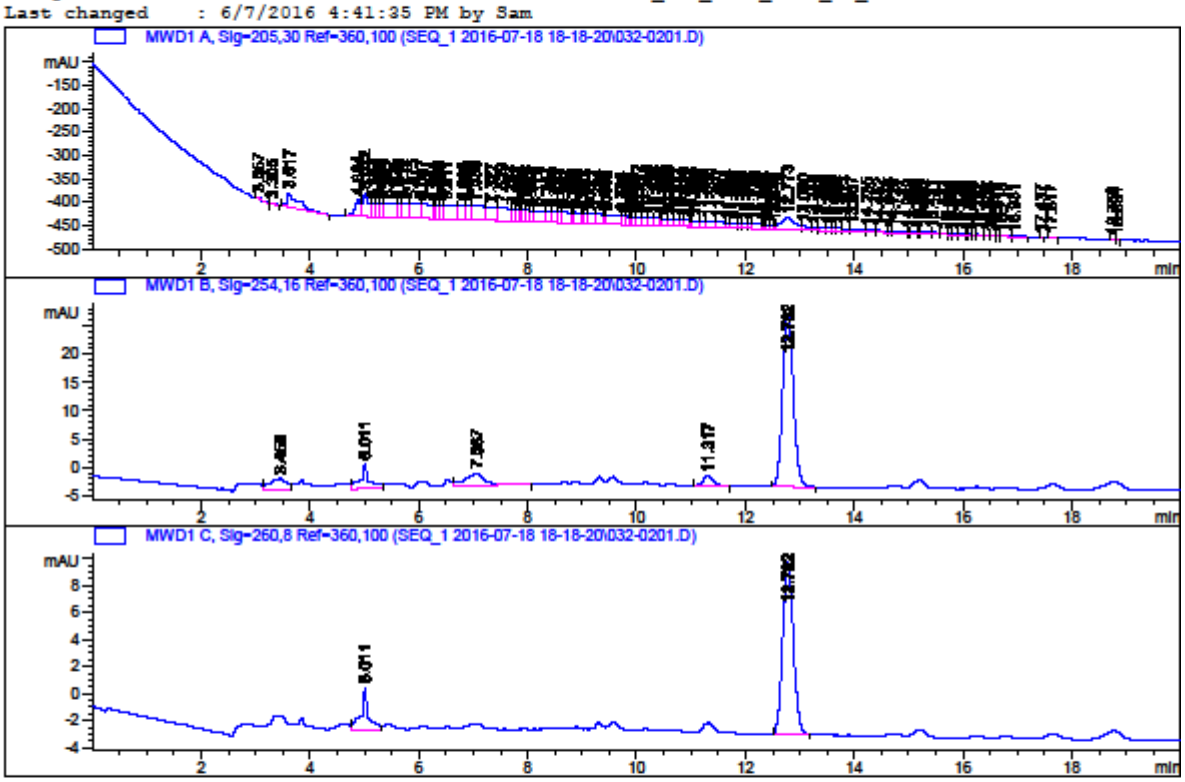


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    Use Multiplier & Dilution Factor with ISTDs


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       2   3.305 VV    0.1102   15.18383    1.84152   0.1254
       3   3.617 VV    0.1837  438.73016   30.15430   3.6226
       4   4.884 VV    0.1016  265.28647   35.33908   2.1905

Instrument 1 7/18/2016 7:04:06 PM Sam                          Page   1 of 4
```

References

(1) Mazurek, W. and Moritz, A.G. *Macromolecules*, **1991**, *24*, 3261.

(2) Sheldrick, G.M., *Acta Cryst.* **2008**, *A64*, 112.

(3) Farrugia, L. J.; *J. Appl. Cryst.* **1997**, *30*, 565.

(4) Farrugia, L. J.; *J. Appl. Cryst.* **1999**, *32*, 837.