

Supporting Information for

Stereodivergent Allylation of Azaaryl Acetamides and Acetates by Synergistic Iridium and Copper Catalysis

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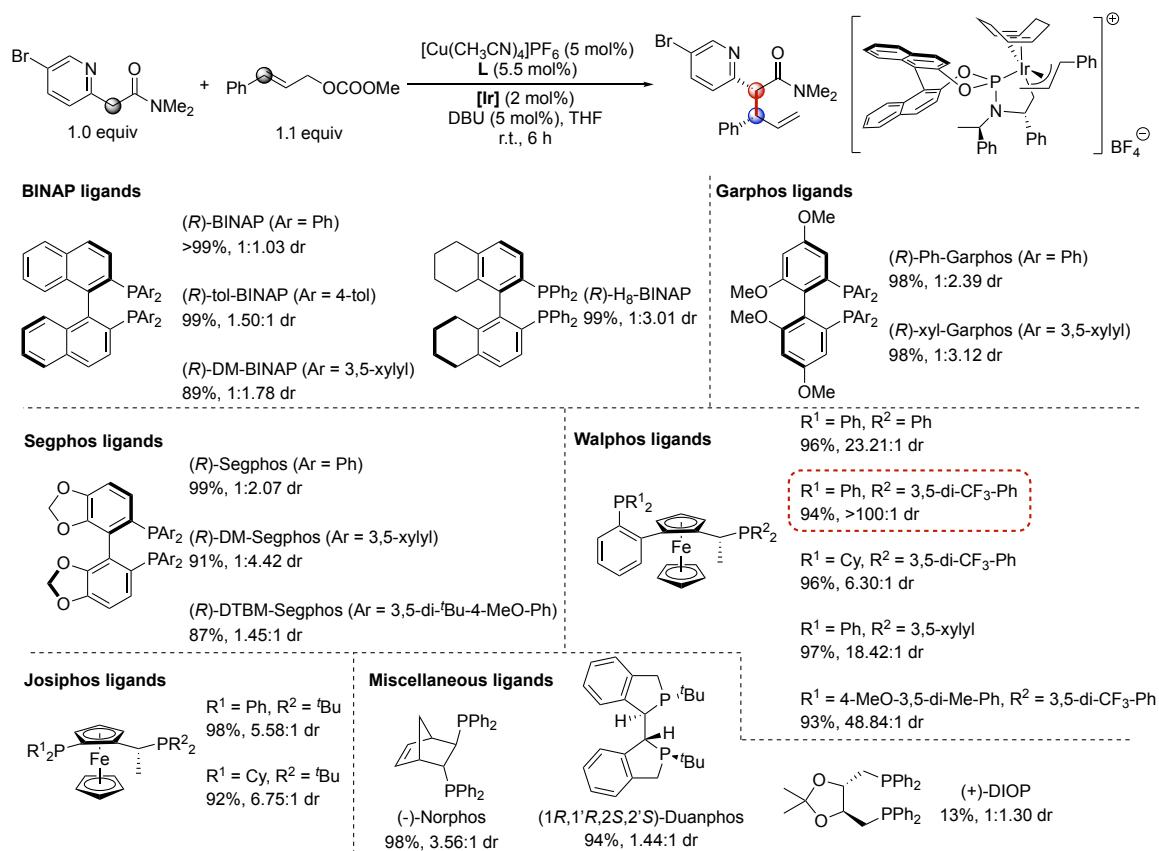
General Experimental Details

Air-sensitive manipulations were conducted under inert atmosphere in a nitrogen-filled glovebox or by standard Schlenk techniques. Tetrahydrofuran (THF) was purified by passing it through a column composed of activated A-1 alumina and degassing by freeze-pump-thaw method. $[\text{Ir}(\text{cod})\text{Cl}]_2$ was obtained from Johnson-Matthey and used without further purification.

Chiral supercritical fluid chromatography (SFC) analysis was conducted on a JASCO SF-2000 integrated analytical SFC system. Proton nuclear magnetic resonance (^1H NMR) spectra were acquired on commercial instruments (300, 400, 500 and 600 MHz) at the NMR facility of University of California, Berkeley. Carbon-13 nuclear magnetic resonance (^{13}C NMR) spectra were acquired at 100, 126 and 151 MHz. Fluorine-19 nuclear magnetic resonance (^{19}F NMR) spectra were acquired at 376 MHz. The proton signal for the residual non-deuterated solvent (δ 7.26 for CDCl_3 , δ 7.16 for C_6D_6) was used as an internal reference for ^1H NMR spectra. For ^{13}C NMR spectra, chemical shifts are reported relative to the δ 77.16 resonance of CDCl_3 and relative to the δ 128.06 resonance of C_6D_6 . For ^{19}F NMR spectra, chemical shifts are reported relative to the δ -113.15 resonance of PhF as an external reference. Coupling constants are reported in Hz. Optical rotations were measured on a Perkin Elmer 241 Automatic Polarimeter. The high-resolution mass spectra were obtained on a high-resolution mass spectrometer at the QB3/Chemistry Mass Spectrometry Facility at UC Berkeley and on the Perkin Elmer AxION2 TOF MS operated by the LBNL Catalysis Facility.

Analytical thin layer chromatography (TLC) was performed on Kieselgel 60 F₂₅₄ glass plates pre-coated with a 0.25 mm thickness of silica gel. The TLC plates were visualized with UV light and/or by staining with KMnO_4 . For the purification of allylation products, column chromatography was generally performed on a Teledyne Isco CombiFlash® R_f system with RediSep Gold™ columns. SiliaFlash® T60 silica gel (particle size 5-20 μm) was used to fill the cartridge for the CombiFlash® system. For the purification of substrates, column chromatography was generally performed using Kieselgel 60 (230-400 mesh) silica gel, typically with a 50-100:1 weight ratio of silica gel to the crude products.

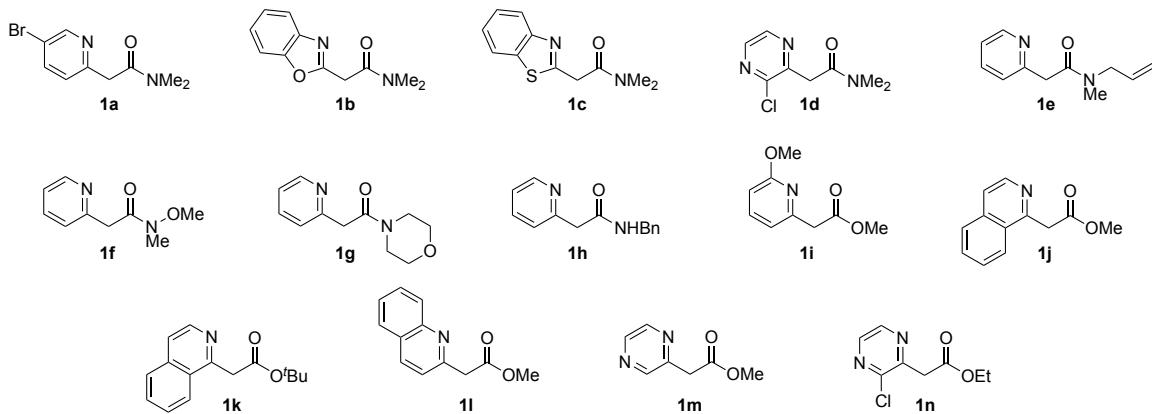
Table S1. Study of the Effects of Ligands on Yield and Diastereoselectivity^a



^aYields were determined by ^1H NMR analysis of the crude reaction mixtures as combined yields of two diastereomers of the branched product with mesitylene as an internal standard. Diastereoselectivity was determined by ^1H NMR analysis of the crude reaction mixtures.

In general, reactions conducted with ligands derived from Walphos afforded the product in high yield with high diastereoselectivity. The ligand circled in a red dash line was chosen for further studies on substrate scope.

Synthesis of Azaaryl Acetamides and Acetates

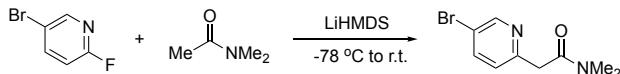


1c, **1d** and **1k** were synthesized following a published procedure.^[1]

1m was purchased from Combi-Blocks.

1n was synthesized following a published procedure.^[2]

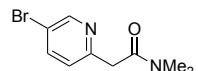
1a was synthesized by the following procedure:



In a 100-mL round-bottom flask containing a magnetic stir bar were added 5-bromo-2-fluoropyridine (0.51 mL, 5.0 mmol, 1.0 equiv), dimethylacetamide (DMAc, 0.51 mL, 5.5 mmol, 1.1 equiv) and THF (10 mL). The mixture was cooled to -78 °C. LiHMDS (1.0 M solution in THF, 11.0 mL, 11.0 mmol, 2.2 equiv) was then added dropwise to the reaction mixture. Thereafter, the reaction mixture was slowly warmed to r.t. and stirred at r.t. overnight.

The reaction mixture was quenched with a sat. aqueous NH₄Cl solution (50 mL) and then diluted with EtOAc (100 mL). The organic layer was separated and washed with brine (50 mL). After evaporation of the solvent under vacuum, the crude mixture was purified by flash column chromatography (0 to 10% MeOH in DCM) to give **1a** (756 mg, 3.11 mmol, 62%) as a yellow solid.

2-(5-bromopyridin-2-yl)-N,N-dimethylacetamide (**1a**)

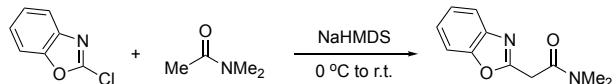


¹H NMR (500 MHz, CDCl₃) δ 8.58 (dd, J = 2.4, 0.7 Hz, 1H), 7.77 (dd, J = 8.3, 2.4 Hz, 1H), 7.26 (d, J = 8.3 Hz, 1H), 3.86 (s, 2H), 3.09 (s, 3H), 2.97 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 169.6, 154.5, 150.3, 139.2, 125.3, 119.0, 43.0, 37.9, 35.7.

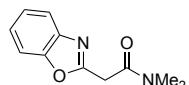
HRMS (ESI): *m/z* for C₉H₁₂BrN₂O [M+H]⁺ calcd.: 243.0128, found: 243.0126.

1b was synthesized by the following procedure:



To the solution of 2-chlorobenzoxazole (0.46 mL, 4.0 mmol, 1.0 equiv) and dimethylacetamide (1.12 mL, 12.0 mmol, 3.00 equiv) in toluene (20 mL) at 0 °C was added NaHMDS (1.0 M in THF, 12.0 mmol, 3.0 equiv) over 2 min. After stirring the mixture at 0 °C for 5 h, the reaction mixture was warmed to r.t. and stirred for another 18 h before it was quenched with sat. aqueous NH_4Cl solution (50 mL) and diluted with EtOAc (100 mL). The organic layer was separated and washed with brine (50 mL). After evaporation of the solvent under vacuum, the crude mixture was purified by flash column chromatography (40% to 75% hexanes in EtOAc) to give **1b** (376 mg, 1.84 mmol, 46%) as a yellow solid.

2-(benzo[d]oxazol-2-yl)-N,N-dimethylacetamide (1b)

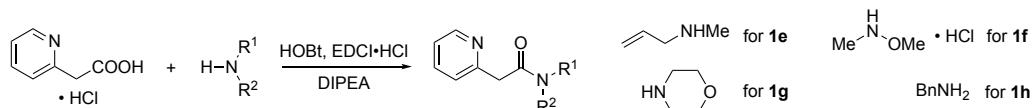


$^1\text{H NMR}$ (600 MHz, CDCl_3) δ 7.72 – 7.67 (m, 1H), 7.54 – 7.48 (m, 1H), 7.35 – 7.29 (m, 2H), 4.07 (s, 2H), 3.14 (s, 3H), 3.02 (s, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 166.2, 160.8, 151.3, 141.3, 125.1, 124.4, 120.0, 110.8, 38.0, 35.92, 35.32.

HRMS (ESI): m/z for $\text{C}_{11}\text{H}_{13}\text{N}_2\text{O}_2$ [$\text{M}+\text{H}]^+$ calcd.: 205.0972, found: 205.0973.

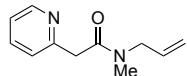
1e, 1f, 1g and **1h** were synthesized by the following procedure:



In a 100-mL round-bottom flask containing a magnetic stir bar were added 2-pyridylacetic acid hydrochloride (0.87 g, 5.0 mmol, 1.0 equiv), the corresponding amine (5.0 mmol, 1.0 equiv), 1-hydroxybenzotriazole (HOBr, 0.68 g, 5.0 mmol, 1.0 equiv), *N,N*-diisopropylethylamine (DIPEA, for **1e**, **1g** and **1h**, 1.74 mL, 10.0 mmol, 2.00 equiv; for **1f**, 2.61 mL, 15.0 mmol, 3.00 equiv) and DCM (20 mL). The mixture was cooled to 0 °C. Then *N*-(3-dimethylaminopropyl)-*N'*-ethylcarbodiimide hydrochloride (EDCl·HCl, 0.96 g, 5.0 mmol, 1.0 equiv) was added in one portion to the reaction mixture. The reaction mixture was slowly warmed to r.t. and stirred at r.t. overnight.

The reaction mixture was diluted with EtOAc (100 mL) and washed with water (50 mL), sat. aqueous NaHCO_3 solution (50 mL) and brine (50 mL). After evaporation of the solvent under vacuum, the crude mixture was purified by flash column chromatography to give the corresponding amide.

N-allyl-*N*-methyl-2-(pyridin-2-yl)acetamide (1e)



0 to 5% MeOH in DCM for flash column chromatography. The title compound was isolated (455 mg, 2.39 mmol, 48%) as a yellow oil.

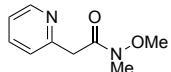
Compound **1e** exists as a mixture of two rotomers (1:1 ratio).

¹H NMR (600 MHz, C₆D₆) δ 8.43 – 8.35 (m, 1H), 7.31 (dd, *J* = 7.9, 1.1 Hz, 0.5H), 7.27 (dd, *J* = 7.8, 1.1 Hz, 0.5H), 7.08 – 6.95 (m, 1H), 6.62 – 6.53 (m, 1H), 5.62 – 5.53 (m, 0.5H), 5.36 – 5.24 (m, 0.5H), 4.93 – 4.83 (m, 2H), 3.81 (q, *J* = 2.3, 1.5 Hz, 2H), 3.79 – 3.75 (m, 1H), 3.69 – 3.60 (m, 1H), 2.69 (s, 1.5H), 2.54 (s, 1.5H).

¹³C NMR (151 MHz, C₆D₆) δ 169.6, 169.2, 157.1, 157.0, 149.4, 149.4, 136.1, 136.1, 133.8, 133.6, 124.0, 123.9, 121.6, 121.6, 116.6, 115.9, 52.4, 50.0, 44.2, 44.1, 34.8, 33.3.

HRMS (ESI): *m/z* for C₁₁H₁₅N₂O [M+H]⁺ calcd.: 191.1179, found: 191.1178.

***N*-methoxy-*N*-methyl-2-(pyridin-2-yl)acetamide (1f)**



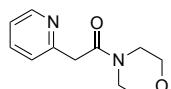
0 to 10% MeOH in DCM for flash column chromatography. The title compound was isolated (conducted at 10-mmol scale, 780 mg, 4.32 mmol, 43%) as brown crystals.

¹H NMR (500 MHz, CDCl₃) δ 8.55 (ddd, *J* = 5.0, 1.9, 0.9 Hz, 1H), 7.64 (td, *J* = 7.7, 1.9 Hz, 1H), 7.32 (d, *J* = 7.8 Hz, 1H), 7.17 (ddd, *J* = 7.5, 4.9, 1.1 Hz, 1H), 4.00 (s, 2H), 3.69 (s, 3H), 3.23 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.3, 155.4, 149.3, 136.3, 123.9, 121.7, 61.3, 41.8, 32.1.

HRMS (ESI): *m/z* for C₉H₁₃N₂O₂ [M+H]⁺ calcd.: 181.0972, found: 181.0975.

1-morpholino-2-(pyridin-2-yl)ethan-1-one (1g)



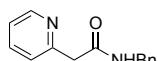
0 to 10% MeOH in DCM for flash column chromatography. The title compound was isolated (113 mg, 0.55 mmol, 11%) as a yellow oil.

¹H NMR (500 MHz, CDCl₃) δ 8.52 (ddd, *J* = 4.9, 1.8, 0.9 Hz, 1H), 7.66 (td, *J* = 7.7, 1.9 Hz, 1H), 7.45 – 7.31 (m, 1H), 7.18 (ddd, *J* = 7.6, 4.9, 1.1 Hz, 1H), 3.92 (s, 2H), 3.73 – 3.59 (m, 6H), 3.58 – 3.37 (m, 2H).

¹³C NMR (151 MHz, CDCl₃) δ 168.8, 155.7, 149.5, 136.9, 123.7, 122.1, 66.9, 66.8, 46.8, 43.8, 42.3.

HRMS (ESI): *m/z* for C₁₁H₁₅N₂O₂ [M+H]⁺ calcd.: 207.1128, found: 207.1128.

***N*-benzyl-2-(pyridin-2-yl)acetamide (1h)**



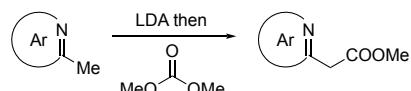
0 to 6% MeOH in DCM for flash column chromatography. The title compound was isolated (922 mg, 4.07 mmol, 81%) as a white solid.

¹H NMR (500 MHz, CDCl₃) δ 8.56 – 8.46 (m, 1H), 7.72 (br s, 1H), 7.66 (td, *J* = 7.7, 1.8 Hz, 1H), 7.34 – 7.11 (m, 7H), 4.47 (d, *J* = 5.8 Hz, 2H), 3.78 (s, 2H).

¹³C NMR (151 MHz, CDCl₃) δ 169.3, 155.8, 149.3, 138.5, 137.3, 128.7, 127.6, 127.4, 124.2, 122.2, 45.4, 43.6.

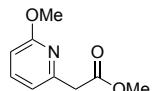
HRMS (ESI): *m/z* for C₁₄H₁₅N₂O [M+H]⁺ calcd.: 227.1179, found: 227.1176.

1i, 1j and 1l were synthesized by the following procedure:



To a solution of diisopropylamine (2.1 mL, 15.0 mmol, 3.0 equiv) in THF (20 mL) was added ⁷BuLi (2.5 M in hexanes, 6.0 mL, 15.0 mmol, 3.0 equiv) at 0 °C. The reaction mixture was stirred at 0 °C for 15 min. A solution of the corresponding methyl azaarene (5.0 mmol, 1.0 equiv) in THF (10 mL) was then added dropwise to the LDA solution at -78 °C. The reaction mixture was stirred at -78 °C for 2 h. Thereafter, dimethyl carbonate (0.50 mL, 6.0 mmol, 1.2 equiv) was added quickly to the mixture. After stirring at -78 °C for 15 min, the reaction was quenched by water (5 mL) at -78 °C and warmed to r.t.. The mixture was diluted with water (50 mL) and extracted with EtOAc (100 mL). The organic layer was separated, washed with brine (50 mL) and dried over Na₂SO₄. After evaporation of the solvent under vacuum, the crude mixture was purified by flash column chromatography to give the corresponding ester.

methyl 2-(6-methoxypyridin-2-yl)acetate (1i)



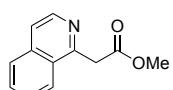
0 to 10% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (277 mg, 1.53 mmol, 31%) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ 7.52 (dd, *J* = 8.3, 7.2 Hz, 1H), 6.83 (d, *J* = 7.2 Hz, 1H), 6.63 (d, *J* = 8.3 Hz, 1H), 3.90 (s, 3H), 3.75 (s, 2H), 3.72 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.3, 163.8, 152.0, 139.1, 116.3, 109.1, 53.4, 52.1, 43.6.

HRMS (EI): *m/z* for C₉H₁₁NO₃ [M]⁺ calcd.: 181.0739, found: 181.0732.

methyl 2-(isoquinolin-1-yl)acetate (1j)



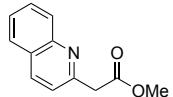
0 to 20% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (985 mg, 4.90 mmol, 98%) as a yellow powder.

¹H NMR (500 MHz, CDCl₃) δ 8.48 (d, *J* = 5.7 Hz, 1H), 8.12 – 8.05 (m, 1H), 7.89 – 7.83 (m, 1H), 7.74 – 7.67 (m, 1H), 7.67 – 7.56 (m, 2H), 4.37 (s, 2H), 3.72 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.0, 154.6, 142.2, 136.5, 130.3, 127.7, 127.5, 125.2, 120.6, 52.4, 42.2.

HRMS (EI): *m/z* for C₁₂H₁₂NO₂ [M]⁺ calcd.: 202.0863, found: 202.0862.

methyl 2-(quinolin-2-yl)acetate (1l)



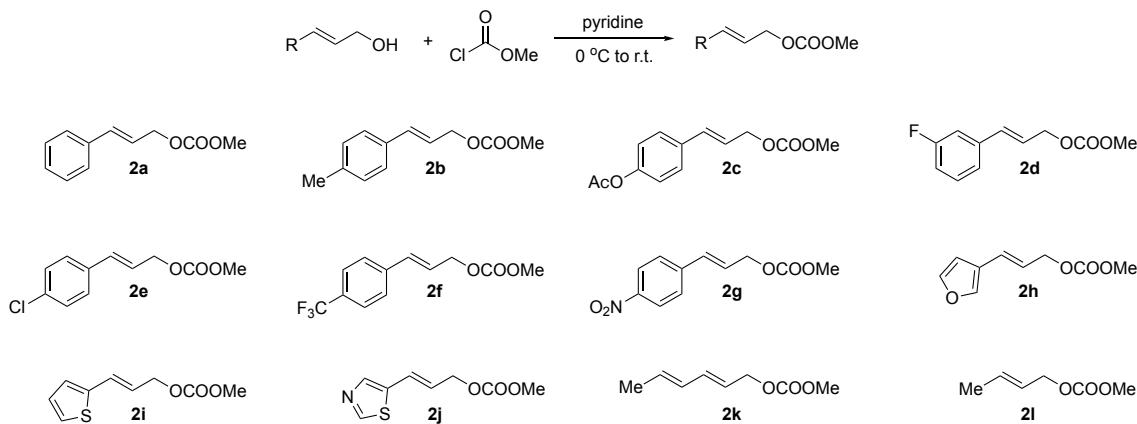
0 to 25% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (310 mg, 1.54 mmol, 31%) as a colorless oil.

¹H NMR (500 MHz, CDCl₃) δ 8.14 (dd, *J* = 8.5, 0.8 Hz, 1H), 8.10 – 8.04 (m, 1H), 7.81 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.71 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.53 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 7.44 (d, *J* = 8.4 Hz, 1H), 4.06 (s, 2H), 3.74 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.0, 154.8, 148.0, 136.8, 129.8, 129.3, 127.7, 127.2, 126.6, 121.8, 52.3, 44.8.

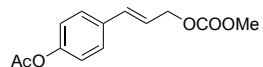
HRMS (EI): *m/z* for C₁₂H₁₂NO₂ [M]⁺ calcd.: 202.0863, found: 202.0862.

Synthesis of Allylic Methyl Carbonates



Allylic methy carbonates were synthesized from the allylic alcohols^[3] following a published procedure^[4]. To a mixture of pyridine (0.73 mL, 9.0 mmol, 3.0 equiv), the allylic alcohol (3.0 mmol, 1.0 equiv) and DCM (6 mL) was added methyl chloroformate (0.46 mL, 6.0 mmol, 2.0 equiv) dropwise at 0°C . The reaction mixture was allowed to warm to r.t. and stirred overnight (monitored by TLC). The mixture was then quenched with water (50 mL) and diluted with EtOAc (100 mL). The organic layer was separated and washed with an aqueous HCl solution (1M, 50 mL; for **2j**, this step was not performed) and brine (50 mL). After evaporation of the solvent under vacuum, the crude mixture was purified by flash column chromatography to give the allylic methyl carbonate.

(E)-4-((methoxycarbonyl)oxy)prop-1-en-1-yl phenyl acetate (2c)



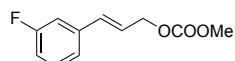
0 to 20% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (starting from 2.0 mmol of the corresponding allylic alcohol; 486 mg, 1.94 mmol, 97%) as a white solid.

$^1\text{H NMR}$ (500 MHz, CDCl_3) δ 7.40 (d, $J = 8.5$ Hz, 2H), 7.05 (d, $J = 8.6$ Hz, 2H), 6.71 – 6.62 (m, 1H), 6.25 (dt, $J = 15.8, 6.4$ Hz, 1H), 4.78 (dd, $J = 6.4, 1.4$ Hz, 2H), 3.81 (s, 3H), 2.30 (s, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 169.4, 155.7, 150.6, 133.9, 133.8, 127.8, 122.8, 121.9, 68.4, 68.4, 54.9, 21.2.

HRMS (EI): m/z for $\text{C}_{13}\text{H}_{14}\text{O}_5 [\text{M}]^+$ calcd.: 250.0841, found: 250.0842.

(E)-3-(3-fluorophenyl)allyl methyl carbonate (2d)



0 to 10% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (starting from 3.0 mmol of the corresponding allylic alcohol; 580 mg, 2.76 mmol, 92%) as a colorless oil.

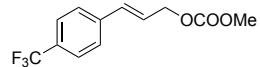
¹H NMR (600 MHz, CDCl₃) δ 7.29 (td, *J* = 8.0, 6.0 Hz, 1H), 7.15 (dt, *J* = 7.7, 1.3 Hz, 1H), 7.09 (dt, *J* = 10.0, 2.1 Hz, 1H), 6.96 (tdd, *J* = 8.4, 2.6, 0.9 Hz, 1H), 6.65 (d, *J* = 15.9 Hz, 1H), 6.30 (dt, *J* = 15.9, 6.3 Hz, 1H), 4.79 (dd, *J* = 6.3, 1.4 Hz, 2H), 3.82 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 163.2 (d, *J* = 245.8 Hz), 155.7, 138.5 (d, *J* = 7.7 Hz), 133.4 (d, *J* = 2.7 Hz), 130.2 (d, *J* = 8.3 Hz), 124.1, 122.7 (d, *J* = 2.8 Hz), 115.1 (d, *J* = 21.4 Hz), 113.2 (d, *J* = 21.7 Hz), 68.1, 55.0.

¹⁹F NMR (376 MHz, CDCl₃) δ -113.4 – -113.6 (m).

HRMS (EI): *m/z* for C₁₁H₁₁FO₃ [M]⁺ calcd.: 210.0692, found: 210.0695.

(E)-methyl (3-(4-(trifluoromethyl)phenyl)allyl) carbonate (2f)



0 to 10% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (starting from 5.5 mmol of the corresponding allylic alcohol; 1.06 g, 4.07 mmol, 74%) as a white solid.

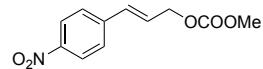
¹H NMR (600 MHz, CDCl₃) δ 7.58 (d, *J* = 8.1 Hz, 2H), 7.48 (d, *J* = 7.9 Hz, 2H), 6.71 (dt, *J* = 15.9, 1.5 Hz, 1H), 6.38 (dt, *J* = 15.9, 6.2 Hz, 1H), 4.82 (dd, *J* = 6.2, 1.4 Hz, 2H), 3.82 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 155.7, 139.6, 133.0, 130.1 (q, *J* = 32.4 Hz), 127.0, 125.7 (q, *J* = 3.8 Hz), 125.4, 124.2 (d, *J* = 271.8 Hz), 68.0, 55.1.

¹⁹F NMR (376 MHz, CDCl₃) δ -62.7 (s).

HRMS (EI): *m/z* for C₁₂H₁₁F₃O₃ [M]⁺ calcd.: 260.0660, found: 260.0661.

(E)-methyl (3-(4-nitrophenyl)allyl) carbonate (2g)



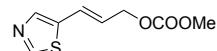
0 to 20% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (starting from 5.0 mmol of the corresponding allylic alcohol; 1.13 g, 4.76 mmol, 95%) as a yellow solid.

¹H NMR (500 MHz, CDCl₃) δ 8.18 (d, *J* = 8.8 Hz, 2H), 7.52 (d, *J* = 8.8 Hz, 2H), 6.74 (dt, *J* = 16.2, 1.7 Hz, 1H), 6.46 (dt, *J* = 16.0, 5.9 Hz, 1H), 4.83 (dd, *J* = 6.0, 1.5 Hz, 2H), 3.82 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 155.6, 147.4, 142.6, 131.8, 127.6, 127.3, 124.2, 67.6, 55.2.

HRMS (EI): *m/z* for C₁₁H₁₁NO₅ [M]⁺ calcd.: 237.0637, found: 237.0634.

(E)-methyl (3-(thiazol-5-yl)allyl) carbonate (2j)



0 to 40% EtOAc in hexanes was used for flash column chromatography. The title compound was isolated (starting from 2.0 mmol of the corresponding allylic alcohol; 149 mg, 0.80 mmol, 40%) as a yellow solid.

¹H NMR (500 MHz, CDCl₃) δ 8.67 (s, 1H), 7.78 (s, 1H), 6.97 – 6.80 (m, 1H), 6.14 (dt, *J* = 15.6, 6.2 Hz, 1H), 4.76 (dd, *J* = 6.2, 1.4 Hz, 2H), 3.82 (s, 3H).

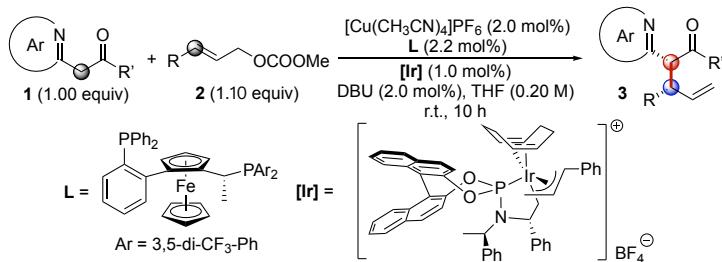
¹³C NMR (151 MHz, CDCl₃) δ 155.6, 152.3, 142.5, 136.2, 126.0, 124.1, 67.6, 55.1.

HRMS (ESI): m/z for $\text{C}_8\text{H}_{10}\text{NO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd.: 200.0376, found: 200.0376.

Synthesis of Iridium Catalysts

Iridium catalysts were synthesized following published procedures.^[5] Catalyst **[Ir]** was synthesized from the corresponding (*R_a,R,R*)-phosphoramidite ligand. Catalyst *ent*-**[Ir]** was prepared from the corresponding (*S_a,S,S*)-phosphoramidite ligand.

General Procedure for Allylations of Azaaryl Acetamides and Acetates



In a nitrogen-filled dry-box, a 1-dram (4 mL) vial equipped with a magnetic stir bar was charged with $[\text{Cu}(\text{CH}_3\text{CN})_4]\text{PF}_6$ (3.7 mg, 0.010 mmol), **L** (10.2 mg, 0.0110 mmol) and THF (1.0 mL). The vial was sealed with a cap containing PTFE/silicone septa. The mixture was stirred at room temperature for 30 min to prepare the Walphos-ligated copper complex (solution **A**). This solution was used within 10 min.

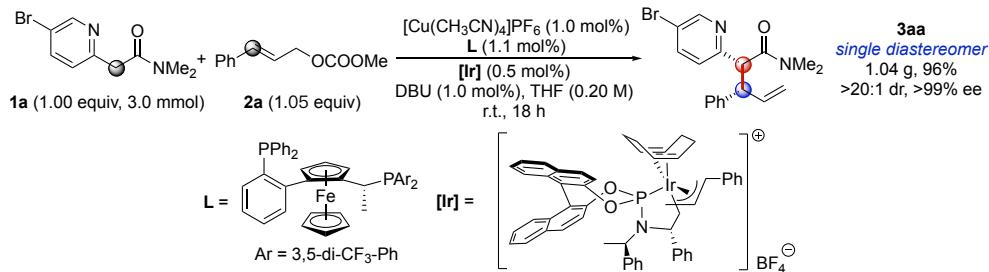
In a nitrogen-filled dry-box, a 1-dram (4 mL) vial equipped with a magnetic stir bar was charged with azaaryl acetamide or acetate **1** (0.100 mmol, 1.00 equiv) and methyl carbonate **2** (0.110 mmol, 1.10 equiv). To the vial was added 0.20 mL of solution **A** (0.0020 mmol, 2.0 mol % of the copper complex). The vial was sealed with a cap containing PTFE/silicone septa. The mixture was stirred at room temperature for 5 min. A stock solution of DBU in THF (0.10 mL, 0.30 mg, 0.0020 mmol, 2.0 mol %) and a stock solution of **[Ir]** in THF (prepared freshly with **[Ir]** in solid state and used within 10 min, 0.20 mL, 1.1 mg, 0.0010 mmol, 1.0 mol %) were then added sequentially to the vial. The vial was then removed from the dry box. The mixture was stirred at room temperature for 10 h.

The reaction mixture was diluted with 2 mL of hexanes, and the resulting solution was filtered through a 0.5-inch plug of silica gel (eluting with 1:1 hexanes:EtOAc, 8 mL; for polar compounds such as **3fa**, **3ga** and **3aj**, pure EtOAc was used). After evaporation of the solvent under vacuum, the crude mixture was purified by column chromatography on a Teledyne Isco CombiFlash® R_f system with RediSep Gold™ columns (4-gram silica gel column). The diastereoselectivity was determined by ¹H NMR analysis of the crude reaction mixture.

If the compound was not isolated as a single diastereomer by flash column chromatography on a Teledyne Isco CombiFlash® R_f system, a preparative TLC separation was performed to remove the minor diastereomer in the product.

For the synthesis of allylation product **3fa**, **3ga**, **3ha**, **3ia**, **3la**, **3ma** and **3na**, 5 mol % of the copper complex (5.0 mol % of $[\text{Cu}(\text{CH}_3\text{CN})_4]\text{PF}_6$ and 5.5 mol % of **L** in 0.20 mL of THF), 2 mol % of **[Ir]** (in 0.20 mL of THF) and 5 mol % of DBU (in 0.10 mL of THF) were used.

Gram-Scale Synthesis of **3aa**



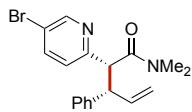
In a nitrogen-filled dry-box, a 1-dram vial (4 mL, **vial A**) equipped with a magnetic stir bar was charged with $[\text{Cu}(\text{CH}_3\text{CN})_4]\text{PF}_6$ (11.2 mg, 0.0300 mmol, 1.00 mol%), **L** (30.7 mg, 0.0330 mmol, 1.10 mol%) and THF (3.0 mL). The vial was sealed with a cap containing PTFE/silicone septa. The mixture was stirred at room temperature for 30 min to prepare the Walphos-ligated copper complex. This solution was used within 10 min. A 1-dram vial (4 mL, **vial B**) equipped with a magnetic stir bar was charged with iridium complex **[Ir]** (16.4 mg, 0.0150 mmol, 0.50 mol%) and THF (3.0 mL). The vial was sealed with a cap containing PTFE/silicone septa. The mixture was stirred at room temperature for 1 min. This solution was used within 10 min.

In a nitrogen-filled dry-box, a 20 mL vial (**vial C**) equipped with a magnetic stir bar was charged with azaaryl acetamide **1a** (729 mg, 3.00 mmol, 1.00 equiv). The solution of the copper complex in **vial A** was added into **vial C** via syringe. **Vial A** was rinsed with THF (1 mL x 3) and the resulting solution was added to **vial C**. The mixture in **vial C** was stirred at r.t. for 5 min. Thereafter, a stock solution of DBU in THF (3.0 mL, 4.6 mg, 0.030 mmol, 1.0 mol %), methyl carbonate **2a** (605 mg, 3.15 mmol, 1.05 equiv) and the solution of the iridium complex in **vial B** were then added sequentially to **vial C**. **Vial B** was rinsed with THF (1 mL x 3) and the resulting solution was added to **vial C**. **Vial C** was sealed partially (CO_2 gas generated during the reaction) with a cap containing PTFE/silicone septa. The mixture in **vial C** was stirred at room temperature for 18 h.

After the reaction, the vial was removed from the dry box. The reaction mixture was diluted with 15 mL of hexanes, and the resulting solution was filtered through a 0.5-inch plug of silica gel (eluting with 1:1 hexanes:EtOAc, 100 mL). After evaporation of the solvent under vacuum, the crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) on a Teledyne Isco Combiflash® R_f system with RediSep Gold™ columns (24-gram silica gel column) to give **3aa** as a white solid (single diastereomer, 1.04 g, 2.89 mmol, 96%). The diastereoselectivity was determined by ^1H NMR analysis of the crude reaction mixture to be >20:1. The enantiomeric excess was determined by SFC analysis to be >99%. See the next section for detailed characterizations of **3aa**.

Scope of Azaaryl Acetamides and Acetates

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (3aa)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 35.0 mg, 0.0974 mmol, 97%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 1.76$ min (major) and $t_R = 1.42$ min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

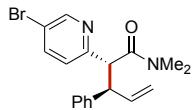
$[\alpha]_D^{25} = -97.1^\circ$ (c 0.14, CH₂Cl₂).

¹H NMR (600 MHz, CDCl₃) δ 8.56 (s, 1H), 7.80 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 1H), 7.34 – 7.28 (m, 4H), 7.23 – 7.19 (m, 1H), 5.84 – 5.74 (m, 1H), 4.85 – 4.80 (m, 2H), 4.59 (d, *J* = 11.3 Hz, 1H), 4.22 (dd, *J* = 11.3, 8.7 Hz, 1H), 2.91 (s, 3H), 2.67 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.8, 157.2, 149.8, 142.1, 139.6, 138.6, 128.7, 128.0, 126.9, 124.7, 119.5, 117.0, 55.8, 53.6, 37.5, 35.9.

HRMS (ESI): *m/z* for C₁₈H₂₀BrN₂O [M+H]⁺ calcd.: 359.0754, found: 359.0754.

(2*R*,3*R*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (4aa)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 45% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 30.0 mg, 0.0835 mmol, 84%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.00$ min (major) and $t_R = 1.63$ min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

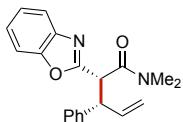
$[\alpha]_D^{25} = -71.0^\circ$ (c 0.42, CH₂Cl₂).

¹H NMR (600 MHz, CDCl₃) δ 8.34 – 8.30 (m, 1H), 7.59 (dd, *J* = 8.5, 2.4 Hz, 1H), 7.36 (d, *J* = 8.5 Hz, 1H), 7.13 (t, *J* = 7.5 Hz, 2H), 7.11 – 7.03 (m, 3H), 6.08 (ddd, *J* = 17.3, 10.4, 7.0 Hz, 1H), 5.13 – 5.02 (m, 2H), 4.59 (d, *J* = 11.1 Hz, 1H), 4.32 (dd, *J* = 11.1, 7.1 Hz, 1H), 3.17 (s, 3H), 2.95 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.1, 156.6, 149.7, 140.3, 139.7, 139.1, 128.8, 128.4, 126.6, 124.5, 119.0, 116.0, 55.0, 52.7, 37.7, 36.2.

HRMS (ESI): *m/z* for C₁₈H₂₀BrN₂O [M+H]⁺ calcd.: 359.0754, found: 359.0756.

(2*R*,3*S*)-2-(benzo[*d*]oxazol-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (3ba)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be 15:1.

The crude mixture was purified by column chromatography (0 to 55% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 30.1 mg, 0.0939 mmol, 94%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 4.93$ min (major) and $t_R = 4.46$ min (minor) [OD-H, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

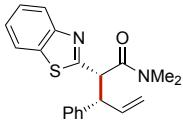
$[\alpha]_D^{25} = -54.5^\circ$ (c 0.40, CH₂Cl₂).

¹H NMR (600 MHz, CDCl₃) δ 7.76 – 7.66 (m, 1H), 7.60 – 7.54 (m, 1H), 7.38 – 7.30 (m, 6H), 7.25 – 7.21 (m, 1H), 5.94 (ddd, *J* = 16.8, 10.2, 8.5 Hz, 1H), 5.08 – 4.99 (m, 1H), 4.87 (d, *J* = 10.2 Hz, 1H), 4.81 (d, *J* = 11.3 Hz, 1H), 4.60 (dd, *J* = 11.3, 8.5 Hz, 1H), 2.99 (s, 3H), 2.73 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 166.8, 162.5, 151.2, 141.0, 140.9, 137.8, 128.8, 128.0, 127.2, 125.1, 124.5, 120.0, 117.2, 111.1, 50.9, 48.7, 37.6, 36.1.

HRMS (ESI): *m/z* for C₂₀H₂₁N₂O₂ [M+H]⁺ calcd.: 321.1598, found: 323.1593.

(2*S*,3*S*)-2-(benzo[*d*]thiazol-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (3ca)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 45% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 32.7 mg, 0.0972 mmol, 97%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.91$ min (major) and $t_R = 2.00$ min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

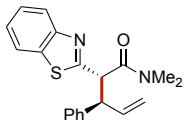
$[\alpha]_D^{25} = -112.0^\circ$ (c 0.25, CH₂Cl₂).

¹H NMR (600 MHz, CDCl₃) δ 8.00 (d, *J* = 8.1 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.48 – 7.43 (m, 1H), 7.39 – 7.30 (m, 5H), 7.26 – 7.21 (m, 1H), 5.99 (ddd, *J* = 16.8, 10.2, 8.7 Hz, 1H), 5.01 – 4.92 (m, 2H), 4.86 (d, *J* = 10.2 Hz, 1H), 4.25 (dd, *J* = 11.1, 8.8 Hz, 1H), 2.85 (s, 3H), 2.70 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 169.7, 169.0, 152.0, 141.3, 137.3, 136.2, 128.7, 128.0, 127.2, 125.9, 125.1, 122.9, 121.9, 117.7, 55.3, 53.8, 37.6, 36.0.

HRMS (ESI): *m/z* for C₂₀H₂₁N₂OS [M+H]⁺ calcd.: 337.1369, found: 337.1372.

(2*S*,3*R*)-2-(benzo[*d*]thiazol-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (4ca)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be 20:1.

The crude mixture was purified by column chromatography (0 to 55% EtOAc in hexanes) to give the title compound as a white solid (28.4 mg, 0.0844 mmol, 84%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 5.90$ min (major) and $t_R = 4.97$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

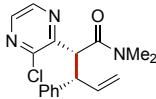
$[\alpha]_D^{25} = -28.5^\circ$ (c 0.20, CH₂Cl₂).

¹H NMR (600 MHz, CDCl₃) δ 7.84 – 7.81 (m, 1H), 7.78 – 7.74 (m, 1H), 7.37 – 7.33 (m, 1H), 7.30 – 7.26 (m, 1H), 7.24 – 7.20 (m, 2H), 7.18 – 7.14 (m, 2H), 7.09 – 7.05 (m, 1H), 6.13 (ddd, $J = 17.4, 10.3, 7.5$ Hz, 1H), 5.13 – 5.07 (m, 2H), 5.02 (d, $J = 10.6$ Hz, 1H), 4.38 (dd, $J = 10.6, 7.5$ Hz, 1H), 3.19 (s, 3H), 2.99 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 169.8, 168.2, 152.0, 139.7, 138.7, 135.8, 128.6, 128.5, 127.0, 125.7, 124.9, 122.8, 121.7, 116.9, 54.2, 52.8, 37.9, 36.3.

HRMS (ESI): *m/z* for C₂₀H₂₁N₂OS [M+H]⁺ calcd.: 337.1369, found: 337.1368.

(2*R*,3*S*)-2-(3-chloropyrazin-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (3da)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 70% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 26.8 mg, 0.0849 mmol, 85%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.18$ min (major) and $t_R = 1.93$ min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

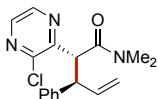
$[\alpha]_D^{25} = -26.0^\circ$ (c 0.45, CH₂Cl₂).

¹H NMR (600 MHz, CDCl₃) δ 8.63 (d, $J = 2.3$ Hz, 1H), 8.25 (d, $J = 2.3$ Hz, 1H), 7.40 – 7.36 (m, 2H), 7.34 – 7.29 (m, 2H), 7.25 – 7.21 (m, 1H), 5.91 (ddd, $J = 16.9, 10.3, 8.6$ Hz, 1H), 5.00 (d, $J = 10.9$ Hz, 1H), 4.86 – 4.77 (m, 2H), 4.55 (dd, $J = 10.9, 8.6$ Hz, 1H), 2.77 (s, 3H), 2.69 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 168.8, 152.5, 148.9, 143.1, 142.1, 141.5, 137.9, 128.6, 128.4, 127.1, 117.0, 52.3, 50.2, 37.2, 36.0.

HRMS (ESI): *m/z* for C₁₇H₁₉ClN₃O [M+H]⁺ calcd.: 316.1211, found: 316.1211.

(2*R*,3*R*)-2-(3-chloropyrazin-2-yl)-*N,N*-dimethyl-3-phenylpent-4-enamide (4da)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 70% EtOAc in hexanes) to give the title compound as a colorless gel (22.8 mg, 0.0722 mmol, 72%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 4.42$ min (major) and $t_R = 4.76$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

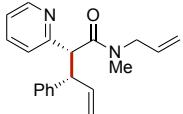
$[\alpha]_D^{25} = +61.4^\circ$ (c 0.14, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.49 (d, $J = 2.4$ Hz, 1H), 8.06 (d, $J = 2.4$ Hz, 1H), 7.17 – 7.10 (m, 4H), 7.10 – 7.01 (m, 1H), 6.12 (ddd, $J = 17.5, 10.0, 7.6$ Hz, 1H), 5.18 – 5.11 (m, 2H), 5.06 (d, $J = 10.8$ Hz, 1H), 4.61 (dd, $J = 10.9, 7.5$ Hz, 1H), 3.23 (s, 3H), 2.99 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 169.3, 151.9, 148.5, 142.8, 141.9, 140.2, 138.9, 128.6, 128.4, 126.8, 116.8, 52.0, 49.8, 37.8, 36.4.

HRMS (ESI): *m/z* for C₁₇H₁₉ClN₃O [M+H]⁺ calcd.: 316.1211, found: 316.1211.

(2*R*,3*S*)-*N*-allyl-*N*-methyl-3-phenyl-2-(pyridin-2-yl)pent-4-enamide (3ea)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 50% EtOAc in hexanes) to give the title compound as a colorless gel (isolated as a single diastereomer, 28.5 mg, 0.0930 mmol, 93%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 6.57$ min (major) and $t_R = 6.19$ min (minor) [OD-H, 2.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

$[\alpha]_D^{25} = -110.2^\circ$ (c 0.16, CH₂Cl₂).

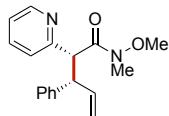
Compound 3ea exists as a mixture of two rotamers (1.2:1 ratio).

¹H NMR (600 MHz, CDCl₃) δ 8.56 – 8.46 (m, 1H), 7.74 – 7.57 (m, 2H), 7.42 – 7.24 (m, 4H), 7.23 – 7.11 (m, 2H), 5.89 – 5.73 (m, 1H), 5.44 (ddd, $J = 17.1, 10.1, 4.9$ Hz, 0.45H), 5.33 – 5.22 (m, 0.55H), 4.97 (dd, $J = 10.3, 1.4$ Hz, 0.45H), 4.87 – 4.83 (m, 0.55H), 4.83 – 4.72 (m, 2H), 4.70 – 4.61 (m, 1H), 4.58 – 4.52 (m, 0.55H), 4.46 (d, $J = 11.2$ Hz, 0.45H), 4.35 – 4.24 (m, 1.45H), 4.02 – 3.94 (m, 0.55H), 3.62 – 3.54 (m, 0.45H), 3.51 – 3.45 (m, 0.55H), 2.91 (s, 1.65H), 2.66 (s, 1.35H).

¹³C NMR (151 MHz, CDCl₃) δ 171.0, 171.0, 158.7, 158.5, 148.9, 148.8, 142.6, 142.4, 138.9, 137.0, 132.6, 132.4, 128.6, 128.5, 128.4, 128.2, 126.8, 126.6, 123.2, 123.0, 122.4, 122.4, 116.7, 116.5, 116.4, 116.3, 57.0, 56.7, 53.7, 53.5, 51.9, 50.3, 35.3, 33.8.

HRMS (ESI): *m/z* for C₂₀H₂₃N₂O [M+H]⁺ calcd.: 307.1805, found: 307.1804.

(2*R*,3*S*)-*N*-methoxy-*N*-methyl-3-phenyl-2-(pyridin-2-yl)pent-4-enamide (3fa)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be 12:1.

The crude mixture was purified by column chromatography (0 to 70% EtOAc in hexanes) to give the title compound as a colorless gel (28.6 mg, 0.0965 mmol, 96%).

The **enantiomeric excess** was determined by SFC analysis to be 97% with $t_R = 7.65$ min (major) and $t_R = 7.23$ min (minor) [IC, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

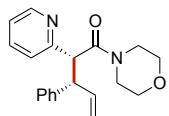
$[\alpha]_D^{25} = -181.0^\circ$ (c 0.12, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.56 (d, *J* = 4.6 Hz, 1H), 7.73 – 7.59 (m, 2H), 7.40 – 7.35 (m, 2H), 7.31 (dd, *J* = 8.5, 6.9 Hz, 2H), 7.23 – 7.12 (m, 2H), 5.81 (ddd, *J* = 16.3, 10.8, 8.6 Hz, 1H), 4.90 (d, *J* = 11.7 Hz, 1H), 4.82 – 4.73 (m, 2H), 4.25 (dd, *J* = 11.7, 8.5 Hz, 1H), 3.50 (s, 3H), 2.92 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 172.4, 158.2, 149.1, 142.2, 139.0, 136.8, 128.6, 128.3, 126.8, 123.6, 122.4, 116.5, 61.8, 55.0, 53.2, 32.2.

HRMS (ESI): *m/z* for C₁₈H₂₁N₂O₂ [M+H]⁺ calcd.: 297.1598, found: 297.1598.

(2*R*,3*S*)-1-morpholino-3-phenyl-2-(pyridin-2-yl)pent-4-en-1-one (3ga)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (30% to 90% EtOAc in hexanes) to give the title compound as a white solid (29.9 mg, 0.0927 mmol, 93%).

The **enantiomeric excess** was determined by SFC analysis to be 99% with $t_R = 2.74$ min (major) and $t_R = 2.43$ min (minor) [OJ-H, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

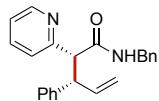
$[\alpha]_D^{25} = -94.1^\circ$ (c 0.16, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.49 (dt, *J* = 5.0, 1.3 Hz, 1H), 7.75 – 7.58 (m, 2H), 7.38 – 7.29 (m, 4H), 7.25 – 7.15 (m, 2H), 5.81 (ddd, *J* = 16.9, 10.5, 8.5 Hz, 1H), 4.89 – 4.74 (m, 2H), 4.57 (d, *J* = 11.4 Hz, 1H), 4.30 (dd, *J* = 11.3, 8.5 Hz, 1H), 3.59 – 3.46 (m, 2H), 3.44 – 3.28 (m, 3H), 3.28 – 3.18 (m, 2H), 3.18 – 3.07 (m, 1H).

¹³C NMR (151 MHz, CDCl₃) δ 169.8, 158.3, 148.9, 142.4, 138.7, 137.0, 128.8, 128.2, 126.9, 123.3, 122.5, 116.8, 66.8, 66.7, 56.1, 53.3, 46.5, 42.6.

HRMS (ESI): *m/z* for C₂₀H₂₃N₂O₂ [M+H]⁺ calcd.: 323.1754, found: 323.1755.

(2*R*,3*S*)-*N*-benzyl-3-phenyl-2-(pyridin-2-yl)pent-4-enamide (3ha)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 65% EtOAc in hexanes) to give the title compound as a white solid (30.0 mg, 0.0876 mmol, 88%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 15.12$ min (major) and $t_R = 14.34$ min (minor) [OD-H, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

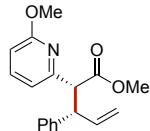
$[\alpha]_D^{25} = +12.5^\circ$ (c 0.24, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.51 (dd, *J* = 5.0, 1.7 Hz, 1H), 7.66 (td, *J* = 7.7, 1.8 Hz, 1H), 7.42 (d, *J* = 7.8 Hz, 1H), 7.35 – 7.29 (m, 4H), 7.29 – 7.24 (m, 1H), 7.22 – 7.13 (m, 4H), 7.13 – 7.05 (m, 1H), 6.83 – 6.77 (m, 2H), 5.82 (ddd, *J* = 16.9, 10.3, 8.2 Hz, 1H), 4.86 – 4.76 (m, 2H), 4.29 – 4.21 (m, 2H), 4.15 (dd, *J* = 15.1, 5.6 Hz, 1H), 4.07 (d, *J* = 11.0 Hz, 1H).

¹³C NMR (151 MHz, CDCl₃) δ 170.6, 157.9, 149.0, 141.3, 138.7, 138.3, 136.9, 128.8, 128.5, 128.4, 127.5, 127.1, 127.0, 124.4, 122.5, 116.6, 61.6, 54.0, 43.4.

HRMS (ESI): *m/z* for C₂₃H₂₃N₂O [M+H]⁺ calcd.: 343.1805, found: 343.1802.

methyl (2*R*,3*S*)-2-(6-methoxypyridin-2-yl)-3-phenylpent-4-enoate (3ia)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be 10:1.

The crude mixture was purified by column chromatography (0 to 10% EtOAc in hexanes) to give the title compound as a colorless gel (28.7 mg, 0.0965 mmol, 97%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.97$ min (major) and $t_R = 3.20$ min (minor) [OJ-H, 1.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

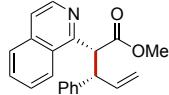
$[\alpha]_D^{25} = +73.5^\circ$ (c 0.16, CH₂Cl₂).

¹H NMR (400 MHz, CDCl₃) δ 7.35 – 7.29 (m, 1H), 7.17 – 7.02 (m, 5H), 6.72 (dd, *J* = 7.3, 0.7 Hz, 1H), 6.44 (dd, *J* = 8.2, 0.7 Hz, 1H), 6.10 (ddd, *J* = 17.1, 10.3, 7.7 Hz, 1H), 5.17 (dt, *J* = 17.2, 1.3 Hz, 1H), 5.10 (dt, *J* = 10.3, 1.1 Hz, 1H), 4.30 (dd, *J* = 11.4, 7.6 Hz, 1H), 4.17 (d, *J* = 11.4 Hz, 1H), 3.83 (s, 3H), 3.69 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 172.4, 163.3, 153.8, 140.8, 139.7, 138.7, 128.4, 128.3, 126.5, 116.2, 115.9, 109.0, 58.4, 53.4, 52.2, 51.9.

HRMS (ESI): *m/z* for C₁₈H₂₀NO₃ [M+H]⁺ calcd.: 298.1438, found: 298.1437.

methyl (2*R*,3*S*)-2-(isoquinolin-1-yl)-3-phenylpent-4-enoate (3ja)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 20% EtOAc in hexanes) to give the title compound as a yellow gel (31.3 mg, 0.0986 mmol, 99%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 4.25$ min (major) and $t_R = 3.38$ min (minor) [OJ-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

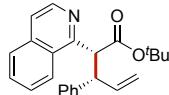
$[\alpha]_D^{25} = -95.7^\circ$ (c 0.39, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.63 (d, $J = 5.6$ Hz, 1H), 8.44 – 8.39 (m, 1H), 7.90 – 7.83 (m, 1H), 7.74 – 7.65 (m, 2H), 7.60 (dd, $J = 5.6$, 1.0 Hz, 1H), 7.49 – 7.42 (m, 2H), 7.37 (dd, $J = 8.4$, 6.9 Hz, 2H), 7.29 – 7.22 (m, 1H), 5.73 (ddd, $J = 17.1$, 10.3, 7.5 Hz, 1H), 5.17 (d, $J = 11.3$ Hz, 1H), 4.80 (dd, $J = 11.3$, 7.6 Hz, 1H), 4.75 (dt, $J = 17.0$, 1.4 Hz, 1H), 4.68 (dt, $J = 10.4$, 1.3 Hz, 1H), 3.39 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.2, 156.0, 142.4, 141.8, 138.8, 136.7, 130.1, 128.7, 128.6, 128.1, 127.8, 127.8, 127.0, 124.8, 120.4, 116.3, 54.0, 52.2, 51.1.

HRMS (ESI): *m/z* for C₂₁H₂₀NO₂ [M+H]⁺ calcd.: 318.1489, found: 318.1487.

tert-butyl (2*R*,3*S*)-2-(isoquinolin-1-yl)-3-phenylpent-4-enoate (3ka)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 10% EtOAc in hexanes) to give the title compound as a white solid (35.0 mg, 0.0973 mmol, 97%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 5.16$ min (major) and $t_R = 5.44$ min (minor) [OD-H, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

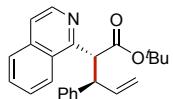
$[\alpha]_D^{25} = -92.2^\circ$ (c 0.27, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.63 (d, $J = 5.6$ Hz, 1H), 8.48 – 8.44 (m, 1H), 7.88 – 7.81 (m, 1H), 7.73 – 7.63 (m, 2H), 7.58 (dd, $J = 5.7$, 0.9 Hz, 1H), 7.52 – 7.45 (m, 2H), 7.39 – 7.31 (m, 2H), 7.29 – 7.23 (m, 1H), 5.77 (ddd, $J = 17.3$, 10.4, 7.1 Hz, 1H), 5.06 (d, $J = 11.4$ Hz, 1H), 4.85 – 4.79 (m, 1H), 4.74 (dt, $J = 17.1$, 1.4 Hz, 1H), 4.70 (dt, $J = 10.3$, 1.4 Hz, 1H), 1.05 (s, 9H).

¹³C NMR (151 MHz, CDCl₃) δ 169.8, 156.4, 142.3, 142.0, 139.5, 136.7, 129.9, 129.1, 128.5, 128.1, 127.7, 127.5, 126.8, 125.1, 120.1, 115.8, 81.1, 54.8, 50.6, 27.7.

HRMS (ESI): *m/z* for C₂₄H₂₆NO₂ [M+H]⁺ calcd.: 360.1958, found: 360.1957.

tert-butyl (2*R*,3*R*)-2-(isoquinolin-1-yl)-3-phenylpent-4-enoate (4ka)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 15% EtOAc in hexanes) to give the title compound as a colorless gel (36.0 mg, 0.0100 mmol, >99%).

The **enantiomeric excess** was determined by SFC analysis to be 96% with $t_R = 2.37$ min (major) and $t_R = 1.65$ min (minor) [OJ-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

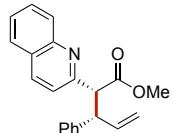
$[\alpha]_D^{25} = +59.6^\circ$ (c 0.25, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.45 (d, *J* = 5.6 Hz, 1H), 8.28 (dd, *J* = 8.6, 1.3 Hz, 1H), 7.73 – 7.66 (m, 1H), 7.56 (dddd, *J* = 18.2, 8.3, 6.8, 1.4 Hz, 2H), 7.38 (dd, *J* = 5.6, 0.9 Hz, 1H), 7.15 – 7.11 (m, 2H), 7.02 – 6.96 (m, 2H), 6.92 – 6.86 (m, 1H), 6.24 (ddd, *J* = 17.1, 10.3, 8.0 Hz, 1H), 5.29 (dt, *J* = 17.1, 1.3 Hz, 1H), 5.17 (ddd, *J* = 10.2, 1.5, 0.8 Hz, 1H), 5.04 (d, *J* = 11.2 Hz, 1H), 4.78 (dd, *J* = 11.2, 8.0 Hz, 1H), 1.33 (s, 9H).

¹³C NMR (151 MHz, CDCl₃) δ 170.4, 156.1, 142.0, 141.6, 140.0, 136.4, 129.6, 128.4, 128.0, 127.7, 127.4, 127.2, 126.1, 124.8, 119.8, 116.0, 81.4, 54.4, 50.8, 28.1.

HRMS (ESI): *m/z* for C₂₄H₂₆NO₂ [M+H]⁺ calcd.: 360.1958, found: 360.1958.

methyl (2*R*,3*S*)-3-phenyl-2-(quinolin-2-yl)pent-4-enoate (3la)



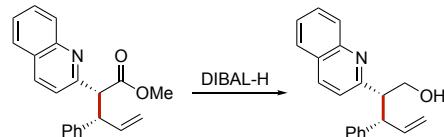
Prepared according to the general procedure as described above.

The diastereomeric ratio of the crude mixture was determined to be 6:1.

The crude mixture was purified by column chromatography (0 to 20% EtOAc in hexanes) to give the title compound as a yellow gel (30.7 mg, 0.0967 mmol, 97%). However, the diastereomeric ratio of the product after purification was determined to be 2.4:1, indicating that **3la** epimerized on silica gel.

HRMS (ESI): *m/z* for C₂₁H₂₀NO₂ [M+H]⁺ calcd.: 318.1489, found: 318.1489.

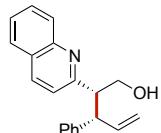
For characterizations, the crude mixture of **3la** was reduced by DIBAL-H after filtering off metal salts:



To the crude mixture of **3la** in THF (0.5 mL) was added DIBAL-H solution (1M in hexanes, 0.40 mL, 0.40 mmol, 4.0 equiv) dropwise under -20 °C. After stirred at -20 °C for 1 h, the mixture was warmed to r.t. and

quenched with aqueous Rochelle salt solution (3 mL). The mixture was stirred at r.t. for 30 min until a clear solution was obtained, and then extracted with EtOAc (6 mL x 4). After evaporation of the solvent under vacuum, the crude mixture was purified by flash column chromatography (0 to 35% EtOAc in hexanes) to give **5** (isolated a single diastereomer, 20.0 mg, 0.0691 mmol, 69%) as a yellow gel.

(2*R*,3*S*)-3-phenyl-2-(quinolin-2-yl)pent-4-en-1-ol (5**)**



The **enantiomeric excess** was determined by SFC analysis to be 99% with $t_R = 4.18$ min (major) and $t_R = 3.78$ min (minor) [AD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

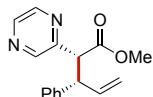
$[\alpha]_D^{25} = +124.0^\circ$ (c 0.30, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.02 (dd, $J = 8.3, 1.1$ Hz, 1H), 7.75 (dd, $J = 8.5, 0.7$ Hz, 1H), 7.70 – 7.64 (m, 2H), 7.50 – 7.43 (m, 1H), 7.11 – 7.06 (m, 2H), 7.06 – 6.99 (m, 3H), 6.68 (d, $J = 8.5$ Hz, 1H), 6.24 (ddd, $J = 17.0, 10.1, 9.1$ Hz, 1H), 5.33 (dt, $J = 16.9, 1.3$ Hz, 1H), 5.21 (dd, $J = 10.1, 1.6$ Hz, 1H), 4.23 (dd, $J = 11.1, 4.0$ Hz, 1H), 4.18 – 4.05 (m, 2H), 3.26 (ddd, $J = 10.9, 4.1, 2.3$ Hz, 1H).

¹³C NMR (151 MHz, CDCl₃) δ 164.0, 147.1, 142.8, 139.5, 135.8, 129.6, 129.0, 128.4, 128.1, 127.6, 126.8, 126.3, 126.2, 122.8, 117.0, 63.4, 52.9, 52.3.

HRMS (ESI): *m/z* for C₂₀H₂₀NO [M+H]⁺ calcd.: 290.1539, found: 290.1537.

methyl (2*R*,3*S*)-3-phenyl-2-(pyrazin-2-yl)pent-4-enoate (3ma)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be 10:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (27.0 mg, 0.101 mmol, >99%).

The **enantiomeric excess** was determined by SFC analysis to be 95% with $t_R = 3.41$ min (major) and $t_R = 3.24$ min (minor) [OD-H, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

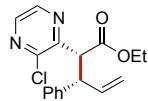
$[\alpha]_D^{25} = -66.3^\circ$ (c 0.35, CH₂Cl₂).

¹H NMR (400 MHz, CDCl₃) δ 8.70 (d, $J = 1.5$ Hz, 1H), 8.63 – 8.55 (m, 1H), 8.49 (d, $J = 2.5$ Hz, 1H), 7.38 – 7.30 (m, 4H), 7.25 – 7.21 (m, 1H), 5.86 – 5.61 (m, 1H), 4.92 – 4.73 (m, 2H), 4.37 – 4.20 (m, 2H), 3.44 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.0, 152.8, 145.5, 144.4, 143.7, 141.0, 138.0, 128.8, 128.0, 127.2, 117.4, 57.1, 52.3.

HRMS (ESI): *m/z* for C₁₆H₁₇N₂O₂ [M+H]⁺ calcd.: 269.1285, found: 269.1285.

ethyl (2*R*,3*S*)-2-(3-chloropyrazin-2-yl)-3-phenylpent-4-enoate (3na)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be 16:1.

The crude mixture was purified by column chromatography (0 to 20% EtOAc in hexanes) to give the title compound as a colorless gel (30.5 mg, 0.0963 mmol, 96%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.70$ min (major) and $t_R = 2.60$ min (minor) [OJ-H, 3.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

$[\alpha]_D^{25} = -46.9^\circ$ (c 0.35, CH₂Cl₂).

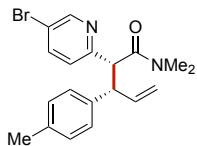
¹H NMR (400 MHz, CDCl₃) δ 8.63 (d, $J = 2.4$ Hz, 1H), 8.33 (d, $J = 2.4$ Hz, 1H), 7.46 – 7.35 (m, 4H), 7.33 – 7.25 (m, 1H), 5.98 – 5.78 (m, 1H), 4.95 – 4.79 (m, 3H), 4.47 (dd, $J = 11.3, 8.6$ Hz, 1H), 3.94 (qd, $J = 7.1, 2.0$ Hz, 2H), 0.97 (t, $J = 7.1$ Hz, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 169.5, 151.9, 149.8, 142.7, 142.4, 141.1, 138.0, 128.7, 128.3, 127.2, 116.9, 61.3, 53.9, 51.9, 13.9.

HRMS (ESI): *m/z* for C₁₇H₁₈ClN₂O₂ [M+H]⁺ calcd.: 317.1051, found: 317.1051.

Scope of Allylic Methyl Carbonates

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(*p*-tolyl)pent-4-enamide (3ab)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 34.9 mg, 0.0935 mmol, 94%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with t_R = 2.32 min (major) and t_R = 2.00 min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

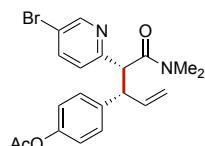
$[\alpha]_D^{25} = -107.5^\circ$ (c 0.52, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.55 (d, J = 2.4 Hz, 1H), 7.79 (dd, J = 8.4, 2.4 Hz, 1H), 7.58 (d, J = 8.5 Hz, 1H), 7.20 (d, J = 8.2 Hz, 2H), 7.11 (d, J = 7.8 Hz, 2H), 5.76 (ddd, J = 17.4, 9.8, 8.7 Hz, 1H), 4.88 – 4.76 (m, 2H), 4.56 (d, J = 11.3 Hz, 1H), 4.18 (dd, J = 11.3, 8.7 Hz, 1H), 2.92 (s, 3H), 2.69 (s, 3H), 2.31 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.8, 157.3, 149.8, 139.5, 139.1, 138.9, 136.3, 129.4, 127.8, 124.6, 119.5, 116.6, 55.8, 53.2, 37.5, 35.9, 21.2.

HRMS (ESI): *m/z* for C₁₉H₂₂BrN₂O [M+H]⁺ calcd.: 373.0910, found: 373.0916.

4-((3*S*,4*R*)-4-(5-bromopyridin-2-yl)-5-(dimethylamino)-5-oxopent-1-en-3-yl)phenyl acetate (3ac)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 55% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 38.5 mg, 0.0923 mmol, 92%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with t_R = 2.47 min (major) and t_R = 1.76 min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

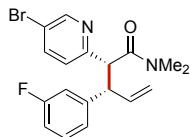
$[\alpha]_D^{25} = -103.1^\circ$ (c 0.59, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.55 (d, J = 2.3 Hz, 1H), 7.79 (dd, J = 8.4, 2.2 Hz, 1H), 7.56 (d, J = 8.5 Hz, 1H), 7.32 (d, J = 8.5 Hz, 2H), 7.03 (d, J = 8.6 Hz, 2H), 5.76 (ddd, J = 16.8, 10.4, 8.6 Hz, 1H), 4.86 – 4.76 (m, 2H), 4.52 (d, J = 11.3 Hz, 1H), 4.23 (dd, J = 11.2, 8.6 Hz, 1H), 2.89 (s, 3H), 2.68 (s, 3H), 2.28 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.6, 169.5, 157.0, 149.8, 149.5, 139.7, 139.6, 138.2, 129.0, 124.6, 121.6, 119.5, 117.2, 56.0, 52.8, 37.5, 35.9, 21.3.

HRMS (ESI): m/z for $C_{20}H_{22}BrN_2O_3 [M+H]^+$ calcd.: 417.0808, found: 417.0805.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-3-(3-fluorophenyl)-*N,N*-dimethylpent-4-enamide (3ad)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 34.2 mg, 0.0906 mmol, 91%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.05$ min (major) and $t_R = 1.89$ min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

$[\alpha]_D^{25} = -106.7^\circ$ (c 0.49, CH_2Cl_2).

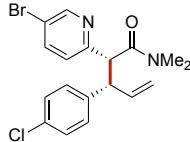
$^1\text{H NMR}$ (500 MHz, CDCl_3) δ 8.56 (d, $J = 2.4$ Hz, 1H), 7.80 (dd, $J = 8.4, 2.3$ Hz, 1H), 7.54 (d, $J = 8.4$ Hz, 1H), 7.30 – 7.22 (m, 1H), 7.10 (dt, $J = 7.8, 1.2$ Hz, 1H), 7.02 (dt, $J = 10.0, 2.1$ Hz, 1H), 6.95 – 6.87 (m, 1H), 5.73 (ddd, $J = 16.9, 10.2, 8.6$ Hz, 1H), 4.91 – 4.74 (m, 2H), 4.54 (d, $J = 11.3$ Hz, 1H), 4.23 (dd, $J = 11.3, 8.7$ Hz, 1H), 2.95 (s, 3H), 2.71 (s, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 170.5, 163.0 (d, $J = 245.6$ Hz), 156.8, 150.0, 144.9 (d, $J = 7.0$ Hz), 139.6, 138.0, 130.1 (d, $J = 8.1$ Hz), 124.5, 123.7 (d, $J = 2.8$ Hz), 119.6, 117.4, 114.8 (d, $J = 21.6$ Hz), 113.8 (d, $J = 21.3$ Hz), 55.7, 53.1, 37.5, 36.0.

$^{19}\text{F NMR}$ (376 MHz, CDCl_3) δ -112.8 – -113.1 (m).

HRMS (ESI): m/z for $C_{18}H_{19}BrFN_2O [M+H]^+$ calcd.: 377.0659, found: 377.0665.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-3-(4-chlorophenyl)-*N,N*-dimethylpent-4-enamide (3ae)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 35.9 mg, 0.0912 mmol, 91%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 4.18$ min (major) and $t_R = 3.88$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

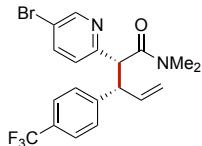
$[\alpha]_D^{25} = -114.8^\circ$ (c 0.50, CH_2Cl_2).

¹H NMR (500 MHz, CDCl₃) δ 8.42 (d, *J* = 2.3 Hz, 1H), 7.65 (dd, *J* = 8.4, 2.3 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 1H), 7.14 – 7.04 (m, 4H), 5.68 – 5.51 (m, 1H), 4.74 – 4.55 (m, 2H), 4.37 (d, *J* = 11.4 Hz, 1H), 4.07 (dd, *J* = 11.3, 8.6 Hz, 1H), 2.79 (s, 3H), 2.56 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.4, 156.8, 149.9, 140.8, 139.7, 138.2, 132.6, 129.4, 128.8, 124.4, 119.6, 117.3, 55.9, 52.8, 37.5, 36.0.

HRMS (ESI): *m/z* for C₁₈H₁₉BrClN₂O [M+H]⁺ calcd.: 393.0364, found: 393.0365.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(4-(trifluoromethyl)phenyl)pent-4-enamide (3af)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 38.8 mg, 0.0908 mmol, 91%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with t_R = 5.83 min (major) and t_R = 5.16 min (minor) [OD-H, 2.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

[*α*]_D²⁵ = -103.6° (c 0.55, CH₂Cl₂).

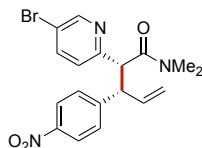
¹H NMR (500 MHz, CDCl₃) δ 8.58 (d, *J* = 2.3 Hz, 1H), 7.81 (dd, *J* = 8.4, 2.2 Hz, 1H), 7.57 (d, *J* = 8.0 Hz, 2H), 7.53 (d, *J* = 8.4 Hz, 1H), 7.44 (d, *J* = 8.0 Hz, 2H), 5.74 (ddd, *J* = 17.2, 10.2, 8.6 Hz, 1H), 4.88 – 4.77 (m, 2H), 4.56 (d, *J* = 11.3 Hz, 1H), 4.31 (dd, *J* = 11.2, 8.7 Hz, 1H), 2.95 (s, 3H), 2.70 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.2, 156.6, 150.1, 146.5, 139.7, 137.9, 129.1 (d, *J* = 32.5 Hz), 128.4, 125.7 (q, *J* = 3.8 Hz), 124.3, 124.3 (q, *J* = 271.8 Hz), 119.7, 117.6, 55.8, 53.3, 37.5, 36.0.

¹⁹F NMR (376 MHz, CDCl₃) δ -62.5 (s).

HRMS (ESI): *m/z* for C₁₉H₁₉BrF₃N₂O [M+H]⁺ calcd.: 427.0627, found: 427.0632.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(4-nitrophenyl)pent-4-enamide (3ag)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (isolated as a single diastereomer, 37.2 mg, 0.0920 mmol, 92%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with t_R = 3.24 min (major) and t_R = 2.82 min (minor) [OJ-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

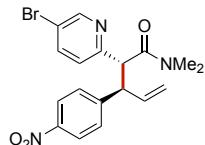
$[\alpha]_D^{25} = -168.0^\circ$ (c 0.49, CH_2Cl_2).

$^1\text{H NMR}$ (500 MHz, CDCl_3) δ 8.59 (dd, $J = 2.3, 0.7$ Hz, 1H), 8.21 – 8.13 (m, 2H), 7.81 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.58 – 7.45 (m, 3H), 5.83 – 5.65 (m, 1H), 4.88 (dt, $J = 10.2, 0.9$ Hz, 1H), 4.82 (dt, $J = 16.9, 1.1$ Hz, 1H), 4.55 (d, $J = 11.3$ Hz, 1H), 4.36 (dd, $J = 11.3, 8.6$ Hz, 1H), 2.96 (s, 3H), 2.70 (s, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 169.9, 156.2, 150.2, 146.9, 139.8, 137.2, 128.9, 124.2, 124.0, 119.8, 118.2, 55.9, 53.2, 37.5, 36.0.

HRMS (ESI): m/z for $\text{C}_{18}\text{H}_{19}\text{BrN}_3\text{O}_3$ [$\text{M}+\text{H}]^+$ calcd.: 404.0604, found: 404.0605.

(2*R*,3*R*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(4-nitrophenyl)pent-4-enamide (4ag)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 60% EtOAc in hexanes) to give the title compound as a colorless gel (isolated as a single diastereomer, 36.5 mg, 0.0903 mmol, 90%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 3.78$ min (major) and $t_R = 3.25$ min (minor) [OD-H, 10.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

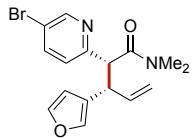
$[\alpha]_D^{25} = -103.6^\circ$ (c 0.30, CH_2Cl_2).

$^1\text{H NMR}$ (500 MHz, CDCl_3) δ 8.40 – 8.27 (m, 1H), 8.06 – 7.92 (m, 2H), 7.62 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.33 (dd, $J = 8.4, 0.8$ Hz, 1H), 7.28 – 7.19 (m, 2H), 6.13 – 5.98 (m, 1H), 5.15 (dt, $J = 10.4, 1.1$ Hz, 1H), 5.06 (dt, $J = 17.2, 1.2$ Hz, 1H), 4.57 (d, $J = 11.1$ Hz, 1H), 4.48 (dd, $J = 11.0, 6.9$ Hz, 1H), 3.16 (s, 3H), 2.96 (s, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 170.3, 155.7, 150.1, 148.2, 146.7, 139.5, 138.4, 129.8, 124.1, 123.6, 119.5, 117.3, 54.8, 52.4, 37.7, 36.3.

HRMS (ESI): m/z for $\text{C}_{18}\text{H}_{19}\text{BrN}_3\text{O}_3$ [$\text{M}+\text{H}]^+$ calcd.: 404.0604, found: 404.0605.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-3-(furan-3-yl)-*N,N*-dimethylpent-4-enamide (3ah)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a colorless gel (isolated as a single diastereomer, 28.9 mg, 0.0828 mmol, 83%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 2.87$ min (major) and $t_R = 2.40$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

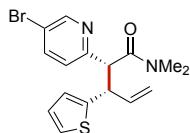
$[\alpha]_D^{25} = -87.5^\circ$ (c 0.44, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.54 (d, $J = 2.4$ Hz, 1H), 7.77 (dd, $J = 8.5, 2.3$ Hz, 1H), 7.50 (d, $J = 8.5$ Hz, 1H), 7.35 (t, $J = 1.7$ Hz, 1H), 7.31 – 7.28 (m, 1H), 6.36 – 6.32 (m, 1H), 5.67 (ddd, $J = 17.0, 10.2, 8.6$ Hz, 1H), 4.95 – 4.79 (m, 2H), 4.35 (d, $J = 11.1$ Hz, 1H), 4.20 (dd, $J = 11.1, 8.6$ Hz, 1H), 3.00 (s, 3H), 2.82 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 171.0, 156.8, 149.9, 143.0, 139.5, 139.5, 137.6, 125.9, 124.4, 119.5, 117.1, 109.9, 55.9, 44.0, 37.6, 36.1.

HRMS (ESI): *m/z* for C₁₆H₁₈BrN₂O₂ [M+H]⁺ calcd.: 349.0546, found: 349.0545.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(thiophen-2-yl)pent-4-enamide (3ai)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a colorless gel (isolated as a single diastereomer, 30.8 mg, 0.0843 mmol, 84%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 4.49$ min (major) and $t_R = 3.41$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

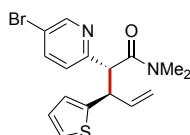
$[\alpha]_D^{25} = -123.1^\circ$ (c 0.41, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.55 (d, $J = 2.3$ Hz, 1H), 7.78 (dd, $J = 8.5, 2.4$ Hz, 1H), 7.52 (d, $J = 8.4$ Hz, 1H), 7.16 (dd, $J = 4.7, 1.6$ Hz, 1H), 6.93 – 6.88 (m, 2H), 5.74 (ddd, $J = 16.9, 10.1, 8.5$ Hz, 1H), 4.94 – 4.79 (m, 2H), 4.58 (dd, $J = 11.1, 8.5$ Hz, 1H), 4.51 (d, $J = 11.2$ Hz, 1H), 3.00 (s, 3H), 2.79 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.6, 156.6, 150.0, 145.4, 140.0, 138.2, 126.9, 124.7, 124.4, 123.9, 119.6, 117.2, 56.9, 48.5, 37.6, 36.1.

HRMS (ESI): *m/z* for C₁₆H₁₈BrN₂OS [M+H]⁺ calcd.: 365.0318, found: 365.0318.

(2*R*,3*R*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(thiophen-2-yl)pent-4-enamide (4ai)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 50% EtOAc in hexanes) to give the title compound as a slightly yellow solid (isolated as a single diastereomer, 34.6 mg, 0.0947 mmol, 95%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 4.68$ min (major) and $t_R = 3.46$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

$[\alpha]_D^{25} = -56.1^\circ$ (c 0.41, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.41 (d, $J = 2.4$ Hz, 1H), 7.66 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.38 (d, $J = 8.5$ Hz, 1H), 7.02 (dd, $J = 5.1, 1.1$ Hz, 1H), 6.75 (dd, $J = 5.1, 3.5$ Hz, 1H), 6.62 (dd, $J = 3.5, 1.1$ Hz, 1H), 6.09 (ddd, $J = 17.3, 10.3, 7.2$ Hz, 1H), 5.18 – 5.07 (m, 2H), 4.60 (dd, $J = 10.8, 7.1$ Hz, 1H), 4.49 (d, $J = 10.7$ Hz, 1H), 3.14 (s, 3H), 2.93 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.6, 156.4, 149.9, 143.8, 139.2, 139.2, 126.6, 125.5, 124.3, 124.2, 119.3, 116.4, 56.4, 47.7, 37.7, 36.2.

HRMS (ESI): *m/z* for C₁₆H₁₈BrN₂OS [M+H]⁺ calcd.: 365.0318, found: 365.0319.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-(thiazol-5-yl)pent-4-enamide (3aj)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (30 to 100% EtOAc in hexanes) to give the title compound as a colorless gel (isolated as a single diastereomer, 27.7 mg, 0.0756 mmol, 76%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 1.42$ min (major) and $t_R = 1.24$ min (minor) [OD-H, 20.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

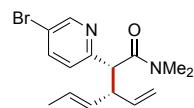
$[\alpha]_D^{25} = -98.1^\circ$ (c 0.40, CH₂Cl₂).

¹H NMR (500 MHz, CDCl₃) δ 8.69 (s, 1H), 8.57 (d, $J = 2.3$ Hz, 1H), 7.79 (dd, $J = 8.5, 2.4$ Hz, 1H), 7.71 (s, 1H), 7.46 (dd, $J = 8.5, 0.7$ Hz, 1H), 5.73 (ddd, $J = 17.2, 9.9, 8.7$ Hz, 1H), 4.98 – 4.81 (m, 2H), 4.64 (dd, $J = 10.9, 8.8$ Hz, 1H), 4.46 (d, $J = 11.0$ Hz, 1H), 3.01 (s, 3H), 2.82 (s, 3H).

¹³C NMR (151 MHz, CDCl₃) δ 170.1, 156.0, 152.3, 150.2, 140.7, 139.8, 137.3, 124.1, 119.8, 118.2, 57.0, 45.7, 37.5, 36.1.

HRMS (ESI): *m/z* for C₁₅H₁₇BrN₃OS [M+H]⁺ calcd.: 366.0270, found: 366.0263.

(2*R*,3*R*,*E*)-2-(5-bromopyridin-2-yl)-*N,N*-dimethyl-3-vinylhex-4-enamide (3ak)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be >20:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (28.4 mg, 0.0879 mmol, 88%).

The **enantiomeric excess** was determined by SFC analysis to be 97% with $t_R = 1.84$ min (major) and $t_R = 1.65$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

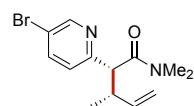
$[\alpha]_D^{25} = -60.0^\circ$ (c 0.37, CH_2Cl_2).

$^1\text{H NMR}$ (500 MHz, CDCl_3) δ 8.51 (d, $J = 2.4$ Hz, 1H), 7.73 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.42 (d, $J = 8.5$ Hz, 1H), 5.62 – 5.38 (m, 3H), 4.86 – 4.78 (m, 2H), 4.12 (d, $J = 10.4$ Hz, 1H), 3.65 – 3.55 (m, 1H), 3.09 (s, 3H), 2.91 (s, 3H), 1.65 (d, $J = 5.6$ Hz, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 171.2, 157.2, 149.8, 139.3, 138.2, 130.9, 127.2, 124.6, 119.3, 116.5, 55.1, 50.3, 37.7, 36.1, 18.3.

HRMS (ESI): m/z for $\text{C}_{15}\text{H}_{20}\text{BrN}_2\text{O}$ [$\text{M}+\text{H}]^+$ calcd.: 323.0754, found: 323.0753.

(2*R*,3*S*)-2-(5-bromopyridin-2-yl)-*N,N*-trimethylpent-4-enamide (3al)



Prepared according to the general procedure as described above.

The diastereomeric ratio was determined to be 9:1.

The crude mixture was purified by column chromatography (0 to 40% EtOAc in hexanes) to give the title compound as a white solid (27.4 mg, 0.0922 mmol, 92%).

The **enantiomeric excess** was determined by SFC analysis to be 98% with $t_R = 1.82$ min (major) and $t_R = 1.63$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

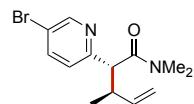
$[\alpha]_D^{25} = -63.5^\circ$ (c 0.11, CH_2Cl_2).

$^1\text{H NMR}$ (500 MHz, CDCl_3) δ 8.51 (d, $J = 2.5$ Hz, 1H), 7.74 (dd, $J = 8.5, 2.4$ Hz, 1H), 7.41 (dd, $J = 8.4, 0.7$ Hz, 1H), 5.49 (ddd, $J = 17.0, 10.3, 8.3$ Hz, 1H), 4.97 – 4.66 (m, 2H), 3.93 (d, $J = 10.6$ Hz, 1H), 3.11 (s, 3H), 3.09 – 3.03 (m, 1H), 2.94 (s, 3H), 1.11 (d, $J = 6.5$ Hz, 3H).

$^{13}\text{C NMR}$ (151 MHz, CDCl_3) δ 171.6, 157.7, 149.8, 140.8, 139.4, 124.3, 119.2, 115.3, 56.7, 42.0, 37.8, 36.1, 19.5.

HRMS (ESI): m/z for $\text{C}_{13}\text{H}_{18}\text{BrN}_2\text{O}$ [$\text{M}+\text{H}]^+$ calcd.: 297.0597, found: 297.0596.

(2*R*,3*R*)-2-(5-bromopyridin-2-yl)-*N,N*-trimethylpent-4-enamide (4al)



Prepared according to the general procedure as described above (*ent*-[Ir] was used instead of [Ir]).

The diastereomeric ratio was determined to be 6:1.

The crude mixture was purified by column chromatography (0 to 50% EtOAc in hexanes) to give the title compound as a white solid (27.9 mg, 0.0939 mmol, 94%).

The **enantiomeric excess** was determined by SFC analysis to be >99% with $t_R = 1.98$ min (major) and $t_R = 1.78$ min (minor) [OD-H, 5.0% MeOH, 2.5 mL/min, 220 nm, 40 °C].

$[\alpha]_D^{25} = -30.6^\circ$ (c 0.13, CH_2Cl_2).

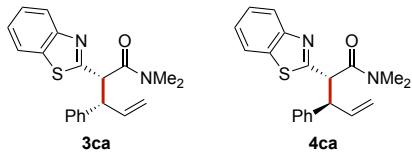
^1H NMR (500 MHz, CDCl_3) δ 8.55 (d, $J = 2.3$ Hz, 1H), 7.78 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.49 (dd, $J = 8.5, 0.7$ Hz, 1H), 5.86 (ddd, $J = 17.3, 10.4, 7.1$ Hz, 1H), 5.10 (dt, $J = 17.3, 1.4$ Hz, 1H), 5.01 (dt, $J = 10.4, 1.2$ Hz, 1H), 3.92 (d, $J = 10.4$ Hz, 1H), 3.12 – 3.00 (m, 4H), 2.91 (s, 3H), 0.80 (d, $J = 6.9$ Hz, 3H).

^{13}C NMR (151 MHz, CDCl_3) δ 171.6, 157.6, 149.9, 141.6, 139.6, 124.0, 119.4, 114.7, 56.7, 40.9, 37.7, 36.0, 17.4.

HRMS (ESI): m/z for $\text{C}_{13}\text{H}_{18}\text{BrN}_2\text{O} [\text{M}+\text{H}]^+$ calcd.: 297.0597, found: 297.0598.

Determination of Absolute Configuration

The structure and absolute configuration of allylation product **3ca** and its diastereomer **4ca** were determined by X-ray diffraction analysis. Single crystals suitable for X-ray diffraction were obtained by slow vapor diffusion of pentane into saturated solutions of **3ca** and **4ca** in diethyl ether.

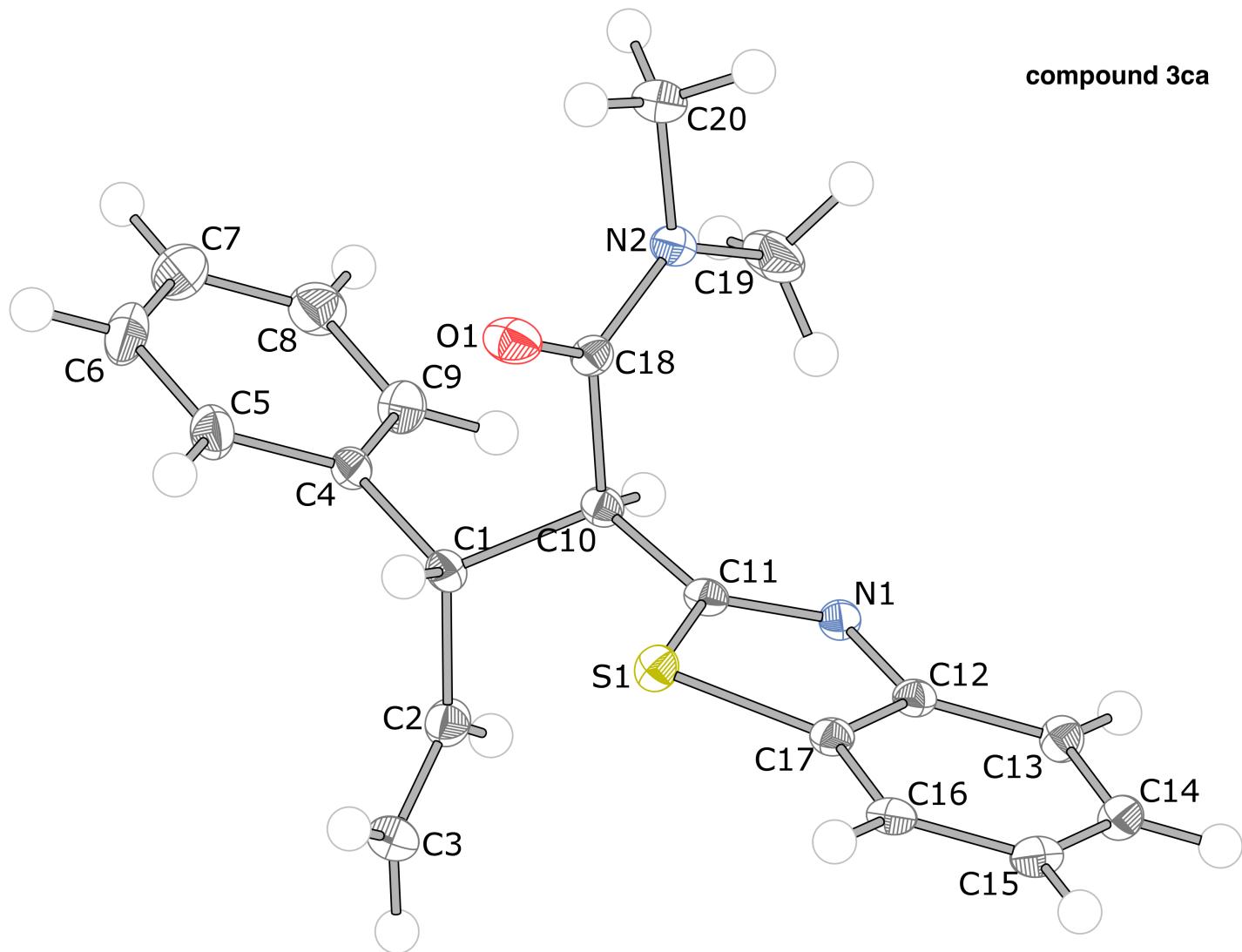


The absolute configurations of all other products shown in this paper were assigned by analogy.

References

- [1] Fallan, C.; Lam, H. W. *Chem. Eur. J.* **2012**, *18*, 11214.
- [2] Chekmarev, D. S.; Shorshnev, S. V.; Stepanov, A. E.; Kasatkin, A. N. *Tetrahedron* **2006**, *62*, 9919.
- [3] The parent allylic alcohols for **2a**, **2g**, **2k** and **2l** are commercially available. The parent allylic alcohols for other allylic methyl carbonates were synthesized following published procedures: (a) Jiang, X.; Beiger, J. J.; Hartwig, J. F. *J. Am. Chem. Soc.* **2017**, *139*, 87; (b) Jiang, X.; Hartwig J. F. *Angew. Chem. Int. Ed.* **2017**, *56*, 8887.
- [4] Matsubara, R.; Jamison, T. F. *J. Am. Chem. Soc.* **2010**, *132*, 6880.
- [5] For the synthesis of the ligands, see: Polet, D.; Alexakis, A. *Org. Lett.* **2005**, *7*, 1621. For the synthesis of the catalysts, see: Liu, W.-B.; Zheng, C.; Zhuo, C.-X.; Dai, L.-X.; You, S.-L. *J. Am. Chem. Soc.* **2012**, *134*, 4812. AgBF₄ was employed instead of AgOTf.

compound 3ca



3ca

A colorless rod 0.20 x 0.10 x 0.10 mm in size was mounted on a Cryoloop with Paratone oil. Data were collected in a nitrogen gas stream at 100(2) K using scans. Crystal-to-detector distance was 40 mm and exposure time was 50 seconds per frame using a scan width of 2.0°, fast scan was added and used to replace overloaded reflections. Data collection was 99.1% complete to 26.73° in θ. A total of 11627 reflections were collected covering the indices, -15 ≤ h ≤ 14, -7 ≤ k ≤ 7, -16 ≤ l ≤ 15. 3624 reflections were found to be symmetry independent, with an R_{int} of 0.0552. Indexing and unit cell refinement indicated a primitive, monoclinic lattice. The space group was found to be P2₁ (No. 4). The data were integrated using the Bruker SAINT software program and scaled using the SADABS software program. Solution by iterative methods (SHELXT-2016) produced a complete heavy-atom phasing model consistent with the proposed structure. All non-hydrogen atoms were refined anisotropically by full-matrix least-squares (SHELXL-2016). All hydrogen atoms were placed using a riding model. Their positions were constrained relative to their parent atom using the appropriate HFIX command in SHELXL-2016. Absolute stereochemistry was unambiguously determined to all chiral centers.

Table S2 Crystal data and structure refinement for 3ca.

| | |
|-------------------------------------|---|
| Identification code | 3ca |
| Empirical formula | C ₂₀ H ₂₀ N ₂ OS |
| Formula weight | 336.44 |
| Temperature/K | 100(2) |
| Crystal system | monoclinic |
| Space group | P2 ₁ |
| a/Å | 11.935(2) |
| b/Å | 5.9402(10) |
| c/Å | 12.713(2) |
| α/° | 90 |
| β/° | 105.332(7) |
| γ/° | 90 |
| Volume/Å ³ | 869.2(3) |
| Z | 2 |
| ρ _{calc} g/cm ³ | 1.285 |
| μ/mm ⁻¹ | 0.195 |
| F(000) | 356.0 |
| Crystal size/mm ³ | 0.2 × 0.1 × 0.1 |
| Radiation | MoKα (λ = 0.71073 Å) |
| 2θ range for data collection/° | 5.458 to 53.304 |
| Index ranges | -15 ≤ h ≤ 14, -7 ≤ k ≤ 7, -16 ≤ l ≤ 15 |
| Reflections collected | 11627 |
| Independent reflections | 3624 [R _{int} = 0.0552, R _{sigma} = 0.0575] |
| Completeness to theta = 26.73° | 99.1% |
| Absorption correction | Multi-scan |
| Max. and min. transmission | 0.4296 and 0.3131 |
| Refinement method | Full-matrix least-squares on F ² |
| Data/restraints/parameters | 3624/1/220 |

| | |
|---|-------------------------------|
| Goodness-of-fit on F^2 | 1.069 |
| Final R indexes [$I \geq 2\sigma(I)$] | $R_1 = 0.0326, wR_2 = 0.0797$ |
| Final R indexes [all data] | $R_1 = 0.0375, wR_2 = 0.0815$ |
| Largest diff. peak/hole / e Å ⁻³ | 0.29/-0.23 |
| Flack parameter | 0.01(4) |

Table S3 Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters (Å² $\times 10^3$) for 3ca. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{ij} tensor.

| Atom | x | y | z | U(eq) |
|------|------------|-----------|------------|-----------|
| S1 | 1720.5(4) | 8173.2(8) | 3496.0(4) | 17.06(15) |
| O1 | 4000.2(13) | 7253(3) | 2469.8(14) | 24.1(4) |
| N1 | 2253.2(15) | 4384(3) | 4524.7(14) | 15.4(4) |
| N2 | 4891.1(16) | 4268(3) | 3435.2(15) | 18.8(4) |
| C12 | 1824.3(17) | 5786(3) | 5200.6(17) | 15.0(4) |
| C17 | 1468.7(16) | 7931(4) | 4774.3(16) | 15.3(4) |
| C16 | 1010.5(17) | 9513(4) | 5352.9(18) | 17.3(4) |
| C4 | 2592.6(17) | 3578(4) | 793.4(16) | 16.5(4) |
| C2 | 777.3(19) | 3800(4) | 1421.3(17) | 20.6(5) |
| C18 | 3942.9(18) | 5401(4) | 2875.7(17) | 15.4(4) |
| C13 | 1727.6(19) | 5226(4) | 6243.2(18) | 17.8(4) |
| C11 | 2249.3(17) | 5405(3) | 3624.1(17) | 14.7(4) |
| C20 | 6032.8(19) | 5234(4) | 3503(2) | 25.0(5) |
| C15 | 912.3(19) | 8917(4) | 6376.2(19) | 19.7(5) |
| C1 | 1993.6(18) | 4696(4) | 1580.7(17) | 15.9(4) |
| C10 | 2740.6(17) | 4355(3) | 2768.8(16) | 15.0(4) |
| C14 | 1273(2) | 6795(4) | 6816.3(19) | 19.9(5) |
| C5 | 2687(2) | 4721(4) | -131.1(18) | 23.4(5) |
| C6 | 3273(2) | 3761(5) | -833(2) | 30.6(6) |
| C9 | 3069(2) | 1440(4) | 989(2) | 22.0(5) |
| C3 | -169.8(19) | 5035(5) | 1070.5(19) | 26.2(5) |
| C7 | 3761(2) | 1642(5) | -616(2) | 30.8(6) |
| C8 | 3656(2) | 484(4) | 292(2) | 27.2(5) |
| C19 | 4890(2) | 2099(4) | 3968(2) | 30.6(6) |

Table S4 Anisotropic Displacement Parameters (Å² $\times 10^3$) for 3ca. The Anisotropic displacement factor exponent takes the form: -
 $2\pi^2[h^2a^{*2}U_{11}+2hka^{*}b^{*}U_{12}+\dots]$.

| Atom | U ₁₁ | U ₂₂ | U ₃₃ | U ₂₃ | U ₁₃ | U ₁₂ |
|------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| S1 | 19.5(3) | 14.2(2) | 18.6(3) | 2.7(2) | 6.96(18) | 2.4(2) |

| | | | | | | |
|-----|----------|----------|----------|----------|----------|----------|
| O1 | 19.4(8) | 18.2(8) | 33.7(9) | 7.2(7) | 5.2(7) | -1.5(7) |
| N1 | 14.1(8) | 16.5(9) | 15.5(8) | 0.5(7) | 3.6(6) | -1.8(7) |
| N2 | 14.2(9) | 21.9(9) | 19.9(9) | 3.0(8) | 3.8(7) | 1.6(8) |
| C12 | 12.1(9) | 16.2(10) | 16.4(10) | -1.1(8) | 3.0(7) | -1.5(8) |
| C17 | 12.4(9) | 16(1) | 17.3(9) | -0.4(9) | 3.3(7) | -2.3(8) |
| C16 | 11.8(9) | 16.8(10) | 23.0(11) | 0.9(9) | 3.8(8) | 0.4(8) |
| C4 | 14.8(9) | 19.9(11) | 13.9(9) | -0.7(8) | 2.1(7) | -2.2(8) |
| C2 | 20.2(10) | 24.3(11) | 17.6(10) | -1.5(8) | 5.5(8) | -4.9(8) |
| C18 | 15.4(10) | 15.7(9) | 15.8(10) | -1.1(8) | 5.5(8) | 1.3(8) |
| C13 | 17.8(10) | 17.4(10) | 18.3(10) | 2.2(8) | 4.8(8) | -1.4(8) |
| C11 | 11.8(9) | 13.6(9) | 17.9(10) | 0.6(8) | 2.7(7) | -0.5(8) |
| C20 | 15.7(10) | 31.6(13) | 27.0(12) | 0.6(10) | 4.4(9) | 0.6(9) |
| C15 | 15.7(10) | 20.4(11) | 23.8(11) | -4.1(9) | 6.7(8) | 0.3(8) |
| C1 | 16.4(10) | 15.1(9) | 15.4(10) | 2.4(8) | 2.7(7) | 0.7(8) |
| C10 | 14.1(9) | 13.9(10) | 16.3(10) | 0.5(8) | 3.1(7) | 0.3(8) |
| C14 | 18.7(11) | 23.5(11) | 18.4(11) | -1.0(9) | 6.6(9) | -1.0(8) |
| C5 | 25.6(11) | 25.6(12) | 18.4(11) | 4.6(9) | 4.9(9) | 4.0(9) |
| C6 | 36.8(14) | 39.1(15) | 18.6(11) | 4(1) | 12.3(10) | 2.4(11) |
| C9 | 24.7(11) | 20.9(12) | 20.6(11) | -0.3(9) | 6.4(9) | -0.4(9) |
| C3 | 16.4(11) | 36.9(15) | 23.6(12) | 1.7(10) | 2.5(9) | -1.2(10) |
| C7 | 28.0(13) | 41.3(15) | 25.5(13) | -8.4(11) | 11.6(11) | 3.6(11) |
| C8 | 26.8(12) | 26.8(12) | 27.4(12) | -4.6(10) | 6.3(10) | 4.9(10) |
| C19 | 23.8(12) | 25.7(12) | 38.7(15) | 12.9(12) | 2.1(11) | 5.8(11) |

Table S5 Bond Lengths for 3ca.

| Atom | Atom | Length/Å | Atom | Atom | Length/Å |
|------|------|----------|------|------|----------|
| S1 | C17 | 1.735(2) | C4 | C5 | 1.387(3) |
| S1 | C11 | 1.754(2) | C4 | C9 | 1.386(3) |
| O1 | C18 | 1.225(3) | C2 | C1 | 1.509(3) |
| N1 | C12 | 1.388(3) | C2 | C3 | 1.322(3) |
| N1 | C11 | 1.294(3) | C18 | C10 | 1.536(3) |
| N2 | C18 | 1.347(3) | C13 | C14 | 1.379(3) |
| N2 | C20 | 1.460(3) | C11 | C10 | 1.501(3) |
| N2 | C19 | 1.456(3) | C15 | C14 | 1.400(3) |
| C12 | C17 | 1.406(3) | C1 | C10 | 1.551(3) |
| C12 | C13 | 1.401(3) | C5 | C6 | 1.393(3) |
| C17 | C16 | 1.391(3) | C6 | C7 | 1.384(4) |
| C16 | C15 | 1.383(3) | C9 | C8 | 1.388(3) |
| C4 | C1 | 1.527(3) | C7 | C8 | 1.377(4) |

Table S6 Bond Angles for 3ca.

| Atom | Atom | Atom | Angle/° | Atom | Atom | Atom | Angle/° |
|------|------|------|---------|------|------|------|---------|
|------|------|------|---------|------|------|------|---------|

| | | | | | | | |
|-----|-----|-----|------------|-----|-----|-----|------------|
| C17 | S1 | C11 | 89.00(10) | N2 | C18 | C10 | 118.66(18) |
| C11 | N1 | C12 | 110.54(18) | C14 | C13 | C12 | 118.8(2) |
| C18 | N2 | C20 | 118.42(19) | N1 | C11 | S1 | 116.00(16) |
| C18 | N2 | C19 | 125.7(2) | N1 | C11 | C10 | 122.39(19) |
| C19 | N2 | C20 | 115.84(19) | C10 | C11 | S1 | 121.48(15) |
| N1 | C12 | C17 | 115.37(18) | C16 | C15 | C14 | 120.8(2) |
| N1 | C12 | C13 | 125.4(2) | C4 | C1 | C10 | 109.47(16) |
| C13 | C12 | C17 | 119.21(19) | C2 | C1 | C4 | 111.04(17) |
| C12 | C17 | S1 | 109.07(15) | C2 | C1 | C10 | 111.70(17) |
| C16 | C17 | S1 | 128.98(17) | C18 | C10 | C1 | 108.45(16) |
| C16 | C17 | C12 | 121.94(19) | C11 | C10 | C18 | 107.62(17) |
| C15 | C16 | C17 | 117.9(2) | C11 | C10 | C1 | 114.67(17) |
| C5 | C4 | C1 | 119.95(19) | C13 | C14 | C15 | 121.3(2) |
| C9 | C4 | C1 | 121.45(19) | C4 | C5 | C6 | 120.6(2) |
| C9 | C4 | C5 | 118.6(2) | C7 | C6 | C5 | 120.1(2) |
| C3 | C2 | C1 | 123.8(2) | C4 | C9 | C8 | 120.9(2) |
| O1 | C18 | N2 | 122.6(2) | C8 | C7 | C6 | 119.7(2) |
| O1 | C18 | C10 | 118.73(18) | C7 | C8 | C9 | 120.2(2) |

Table S7 Hydrogen Atom Coordinates ($\text{\AA} \times 10^4$) and Isotropic Displacement Parameters ($\text{\AA}^2 \times 10^3$) for 3ca.

| Atom | x | y | z | U(eq) |
|------|------|-------|-------|-------|
| H16 | 773 | 10956 | 5054 | 21 |
| H2 | 687 | 2259 | 1582 | 25 |
| H13 | 1970 | 3792 | 6550 | 21 |
| H20A | 6491 | 4172 | 3197 | 37 |
| H20B | 6434 | 5532 | 4268 | 37 |
| H20C | 5940 | 6645 | 3090 | 37 |
| H15 | 596 | 9961 | 6786 | 24 |
| H1 | 1941 | 6348 | 1424 | 19 |
| H10 | 2839 | 2704 | 2917 | 18 |
| H14 | 1204 | 6429 | 7524 | 24 |
| H5 | 2349 | 6171 | -287 | 28 |
| H6 | 3337 | 4561 | -1461 | 37 |
| H9 | 2993 | 620 | 1608 | 26 |
| H3A | -106 | 6581 | 903 | 31 |
| H3B | -914 | 4377 | 986 | 31 |
| H7 | 4167 | 990 | -1090 | 37 |
| H8 | 3987 | -975 | 441 | 33 |
| H19A | 4191 | 1969 | 4229 | 46 |
| H19B | 5581 | 1980 | 4586 | 46 |
| H19C | 4898 | 889 | 3446 | 46 |

Refinement model description

Number of restraints - 1, number of constraints - unknown.

Details:

1. Fixed Uiso

At 1.2 times of:

All C(H) groups, All C(H,H) groups

At 1.5 times of:

All C(H,H,H) groups

2.a Ternary CH refined with riding coordinates:

C1(H1), C10(H10)

2.b Aromatic/amide H refined with riding coordinates:

C16(H16), C2(H2), C13(H13), C15(H15), C14(H14), C5(H5), C6(H6), C9(H9),
C7(H7), C8(H8)

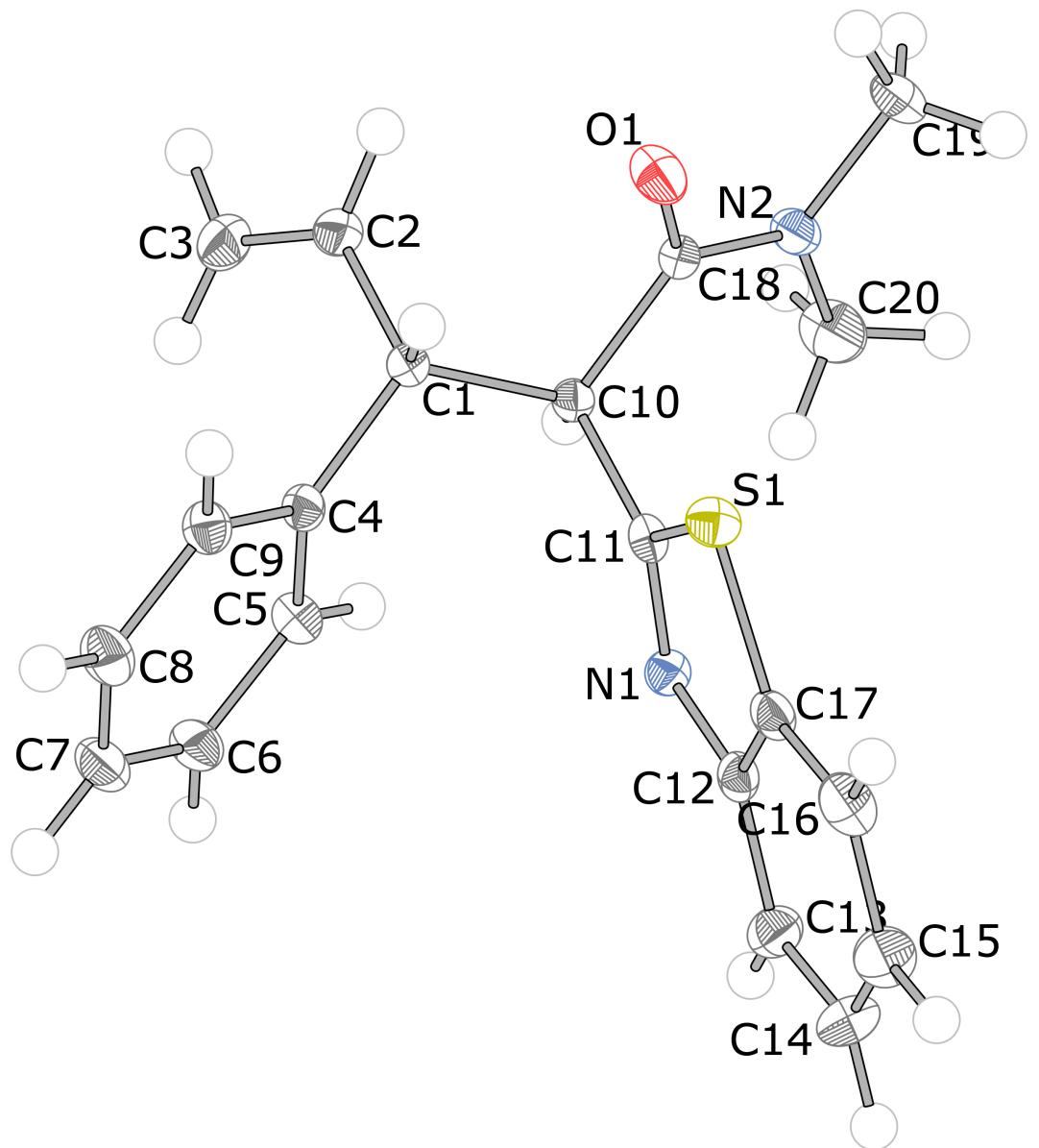
2.c X=CH2 refined with riding coordinates:

C3(H3A,H3B)

2.d Idealised Me refined as rotating group:

C20(H20A,H20B,H20C), C19(H19A,H19B,H19C)

This report has been created with Olex2, compiled on 2017.08.10 svn.r3458 for OlexSys. Please [let us know](#) if there are any errors or if you would like to have additional features.



compound 4ca

4ca

A colorless rod 0.50 x 0.20 x 0.10 mm in size was mounted on a Cryoloop with Paratone oil. Data were collected in a nitrogen gas stream at 100(2) K using and scans. Crystal-to-detector distance was 50 mm and exposure time was 15 seconds per frame using a scan width of 0.4°, fast scan was added and used to replace overloaded reflections. Data collection was 99.6% complete to 27.48° in θ. A total of 15255 reflections were collected covering the indices, -8 ≤ h ≤ 8, -11 ≤ k ≤ 11, -40 ≤ l ≤ 40. 3972 reflections were found to be symmetry independent, with an R_{int} of 0.0275. Indexing and unit cell refinement indicated a primitive, monoclinic lattice. The space group was found to be P2₁2₁2₁ (No. 19). The data were integrated using the Bruker SAINT software program and scaled using the SADABS software program. Solution by iterative methods (SHELXT-2016) produced a complete heavy-atom phasing model consistent with the proposed structure. All non-hydrogen atoms were refined anisotropically by full-matrix least-squares (SHELXL-2016). All hydrogen atoms were placed using a riding model. Their positions were constrained relative to their parent atom using the appropriate HFIX command in SHELXL-2016. Absolute stereochemistry was unambiguously determined to all chiral centers.

Table S8 Crystal data and structure refinement for 4ca.

| | |
|-------------------------------------|--|
| Identification code | 4ca |
| Empirical formula | C ₂₀ H ₂₀ N ₂ OS |
| Formula weight | 336.44 |
| Temperature/K | 100(2) |
| Crystal system | orthorhombic |
| Space group | P2 ₁ 2 ₁ 2 ₁ |
| a/Å | 6.3339(5) |
| b/Å | 8.7346(7) |
| c/Å | 31.364(3) |
| α/° | 90 |
| β/° | 90 |
| γ/° | 90 |
| Volume/Å ³ | 1735.2(2) |
| Z | 4 |
| ρ _{calc} g/cm ³ | 1.288 |
| μ/mm ⁻¹ | 0.176 |
| F(000) | 712.0 |
| Crystal size/mm ³ | 0.5 × 0.2 × 0.1 |
| Radiation | MoKα ($\lambda = 0.71073\text{\AA}$) |
| 2θ range for data collection/° | 4.84 to 55.042 |
| Index ranges | -8 ≤ h ≤ 8, -11 ≤ k ≤ 11, -40 ≤ l ≤ 40 |
| Reflections collected | 15255 |
| Independent reflections | 3972 [$R_{\text{int}} = 0.0275$, $R_{\text{sigma}} = 0.0246$] |
| Completeness to theta = 27.48° | 99.6% |
| Absorption correction | Multi-scan |
| Max. and min. transmission | 0.4305 and 0.3724 |
| Refinement method | Full-matrix least-squares on F ² |

| | |
|---|---|
| Data/restraints/parameters | 3972/0/220 |
| Goodness-of-fit on F ² | 1.128 |
| Final R indexes [I>=2σ (I)] | R ₁ = 0.0256, wR ₂ = 0.0707 |
| Final R indexes [all data] | R ₁ = 0.0261, wR ₂ = 0.0711 |
| Largest diff. peak/hole / e Å ⁻³ | 0.29/-0.22 |
| Flack parameter | -0.001(13) |

Table S9 Fractional Atomic Coordinates ($\times 10^4$) and Equivalent Isotropic Displacement Parameters (Å $^2 \times 10^3$) for 4ca. U_{eq} is defined as 1/3 of the trace of the orthogonalised U_{IJ} tensor.

| Atom | x | y | z | U(eq) |
|------|------------|------------|-----------|-----------|
| S1 | 4538.4(6) | 5127.3(4) | 3069.4(2) | 19.49(11) |
| O1 | 6506.2(19) | 8067.8(14) | 3542.1(4) | 25.4(3) |
| N1 | 1266(2) | 4739.9(15) | 3559.7(4) | 16.6(3) |
| N2 | 3252(2) | 9091.8(15) | 3614.6(5) | 20.6(3) |
| C18 | 4673(3) | 7966.4(17) | 3668.5(5) | 16.1(3) |
| C11 | 3065(2) | 5438.0(17) | 3535.4(5) | 15.1(3) |
| C12 | 928(3) | 3861.0(18) | 3193.4(5) | 17.3(3) |
| C9 | 6947(3) | 3007.1(19) | 4241.7(5) | 20.0(3) |
| C4 | 5357(3) | 4100.5(17) | 4274.3(4) | 16.7(3) |
| C16 | 2398(3) | 3153(2) | 2498.5(6) | 26.6(4) |
| C17 | 2542(3) | 3936.4(17) | 2886.9(5) | 18.8(3) |
| C1 | 5813(2) | 5721.7(17) | 4122.5(5) | 16.3(3) |
| C6 | 3103(3) | 2180(2) | 4598.3(5) | 23.1(3) |
| C13 | -854(3) | 2957.2(19) | 3117.5(6) | 23.2(3) |
| C7 | 4687(3) | 1099.5(19) | 4560.3(5) | 25.2(4) |
| C10 | 3930(2) | 6463.9(17) | 3880.8(5) | 14.9(3) |
| C14 | -993(3) | 2171(2) | 2733.2(6) | 29.9(4) |
| C5 | 3424(3) | 3673.0(19) | 4455.4(5) | 20.0(3) |
| C2 | 6469(3) | 6783.1(19) | 4481.7(6) | 23.3(3) |
| C3 | 6160(3) | 6567(2) | 4892.7(6) | 27.7(4) |
| C8 | 6612(3) | 1511(2) | 4382.6(6) | 24.8(4) |
| C19 | 3915(3) | 10518(2) | 3410.8(6) | 28.3(4) |
| C20 | 1024(3) | 9002(2) | 3731.5(7) | 33.1(4) |
| C15 | 609(4) | 2279(2) | 2427.2(6) | 32.1(4) |

**Table S10 Anisotropic Displacement Parameters ($\text{\AA}^2 \times 10^3$) for 4ca. The Anisotropic displacement factor exponent takes the form: -
 $2\pi^2[h^2a^{*2}U_{11} + 2hka^*b^*U_{12} + ...]$.**

| Atom | U ₁₁ | U ₂₂ | U ₃₃ | U ₂₃ | U ₁₃ | U ₁₂ |
|------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| S1 | 20.54(19) | 19.46(18) | 18.47(18) | 0.14(13) | 5.43(15) | -1.10(15) |
| O1 | 17.4(6) | 24.1(6) | 34.8(7) | 9.7(5) | 5.3(5) | -0.4(5) |
| N1 | 16.2(6) | 16.6(6) | 16.9(6) | 0.0(5) | -0.4(5) | 0.0(5) |
| N2 | 17.4(6) | 16.3(6) | 28.0(7) | 4.9(5) | -1.2(6) | -0.4(5) |
| C18 | 16.8(7) | 16.0(6) | 15.7(6) | 1.9(5) | -3.0(6) | -1.5(6) |
| C11 | 15.5(7) | 15.4(7) | 14.3(6) | 2.7(5) | 0.5(5) | 2.7(5) |
| C12 | 20.9(8) | 13.8(6) | 17.1(7) | 0.8(5) | -2.7(6) | 3.3(6) |
| C9 | 20.4(8) | 21.1(8) | 18.5(7) | 1.5(6) | 1.0(6) | 0.9(6) |
| C4 | 20.6(7) | 16.1(7) | 13.5(6) | 0.4(5) | -1.7(6) | -0.4(6) |
| C16 | 41.0(11) | 20.2(8) | 18.6(8) | -1.6(6) | 4.1(7) | 2.9(8) |
| C17 | 25.1(8) | 12.7(7) | 18.5(7) | 1.2(5) | -1.2(6) | 2.1(6) |
| C1 | 15.2(7) | 16.3(7) | 17.4(7) | 2.4(5) | -2.1(5) | -0.5(5) |
| C6 | 24.7(8) | 22.8(8) | 21.8(8) | 4.5(6) | 1.9(6) | -4.6(7) |
| C13 | 20.8(8) | 22.3(8) | 26.5(8) | -2.4(6) | -3.1(6) | -0.5(6) |
| C7 | 34.0(9) | 17.0(7) | 24.7(8) | 3.2(6) | 0.3(7) | -1.4(7) |
| C10 | 14.3(7) | 14.7(7) | 15.6(6) | 1.5(5) | -0.6(5) | -0.7(5) |
| C14 | 33(1) | 25.6(9) | 30.9(9) | -6.4(7) | -9.0(8) | -3.6(7) |
| C5 | 20.6(8) | 18.7(7) | 20.7(7) | 2.2(6) | 1.4(6) | 1.1(6) |
| C2 | 23.7(8) | 17.7(7) | 28.5(8) | 0.4(6) | -8.5(7) | -2.7(7) |
| C3 | 33.1(10) | 25.0(8) | 25.1(8) | -2.7(7) | -9.3(7) | 0.2(7) |
| C8 | 29.2(9) | 18.5(8) | 26.7(8) | 1.2(6) | 0.9(7) | 5.7(7) |
| C19 | 31.3(9) | 17.7(8) | 35.7(9) | 10.1(7) | -2.8(7) | -0.3(7) |
| C20 | 17.2(8) | 28.2(9) | 53.9(12) | 6.7(9) | 2.2(8) | 4.8(7) |
| C15 | 50.6(12) | 23.2(8) | 22.4(8) | -8.3(6) | -5.7(9) | 0.4(9) |

Table S11 Bond Lengths for 4ca.

| Atom | Atom | Length/ \AA | Atom | Atom | Length/ \AA |
|------|------|----------------------|------|------|----------------------|
| S1 | C11 | 1.7551(15) | C9 | C8 | 1.395(2) |
| S1 | C17 | 1.7344(17) | C4 | C1 | 1.522(2) |
| O1 | C18 | 1.230(2) | C4 | C5 | 1.401(2) |
| N1 | C11 | 1.295(2) | C16 | C17 | 1.400(2) |
| N1 | C12 | 1.3983(19) | C16 | C15 | 1.384(3) |
| N2 | C18 | 1.343(2) | C1 | C10 | 1.555(2) |
| N2 | C19 | 1.461(2) | C1 | C2 | 1.517(2) |
| N2 | C20 | 1.460(2) | C6 | C7 | 1.383(3) |
| C18 | C10 | 1.545(2) | C6 | C5 | 1.394(2) |
| C11 | C10 | 1.509(2) | C13 | C14 | 1.390(2) |
| C12 | C17 | 1.405(2) | C7 | C8 | 1.388(3) |
| C12 | C13 | 1.398(2) | C14 | C15 | 1.400(3) |
| C9 | C4 | 1.392(2) | C2 | C3 | 1.317(3) |

Table S12 Bond Angles for 4ca.

| Atom | Atom | Atom | Angle/ [°] | Atom | Atom | Atom | Angle/ [°] |
|------|------|------|---------------------|------|------|------|---------------------|
| C17 | S1 | C11 | 88.86(8) | C15 | C16 | C17 | 117.60(17) |
| C11 | N1 | C12 | 110.18(13) | C12 | C17 | S1 | 109.44(12) |
| C18 | N2 | C19 | 119.08(14) | C16 | C17 | S1 | 128.90(14) |
| C18 | N2 | C20 | 125.21(15) | C16 | C17 | C12 | 121.65(16) |
| C20 | N2 | C19 | 115.68(14) | C4 | C1 | C10 | 113.25(13) |
| O1 | C18 | N2 | 122.62(14) | C2 | C1 | C4 | 112.86(13) |
| O1 | C18 | C10 | 119.17(13) | C2 | C1 | C10 | 108.50(13) |
| N2 | C18 | C10 | 118.15(14) | C7 | C6 | C5 | 120.34(16) |
| N1 | C11 | S1 | 116.37(11) | C14 | C13 | C12 | 118.56(16) |
| N1 | C11 | C10 | 123.85(13) | C6 | C7 | C8 | 119.68(15) |
| C10 | C11 | S1 | 119.78(11) | C18 | C10 | C1 | 109.31(12) |
| N1 | C12 | C17 | 115.15(14) | C11 | C10 | C18 | 107.79(12) |
| C13 | C12 | N1 | 125.01(15) | C11 | C10 | C1 | 112.40(12) |
| C13 | C12 | C17 | 119.84(15) | C13 | C14 | C15 | 121.00(17) |
| C4 | C9 | C8 | 120.59(17) | C6 | C5 | C4 | 120.47(16) |
| C9 | C4 | C1 | 118.56(15) | C3 | C2 | C1 | 126.75(16) |
| C9 | C4 | C5 | 118.66(14) | C7 | C8 | C9 | 120.25(17) |
| C5 | C4 | C1 | 122.75(14) | C16 | C15 | C14 | 121.33(16) |

Table S13 Hydrogen Atom Coordinates ($\text{\AA} \times 10^4$) and Isotropic Displacement Parameters ($\text{\AA}^2 \times 10^3$) for 4ca.

| Atom | x | y | z | U(eq) |
|------|-------|-------|------|-------|
| H9 | 8273 | 3281 | 4122 | 24 |
| H16 | 3488 | 3218 | 2291 | 32 |
| H1 | 7023 | 5662 | 3918 | 20 |
| H6 | 1789 | 1903 | 4722 | 28 |
| H13 | -1946 | 2882 | 3324 | 28 |
| H7 | 4459 | 80 | 4655 | 30 |
| H10 | 2780 | 6701 | 4089 | 18 |
| H14 | -2194 | 1551 | 2677 | 36 |
| H5 | 2323 | 4406 | 4481 | 24 |
| H2 | 7175 | 7699 | 4402 | 28 |
| H3A | 5461 | 5669 | 4989 | 33 |
| H3B | 6636 | 7308 | 5092 | 33 |
| H8 | 7705 | 773 | 4357 | 30 |
| H19A | 5449 | 10506 | 3370 | 42 |
| H19B | 3527 | 11386 | 3592 | 42 |
| H19C | 3214 | 10617 | 3134 | 42 |
| H20A | 588 | 7927 | 3744 | 50 |
| H20B | 175 | 9542 | 3518 | 50 |

| | | | | |
|------|-----|------|------|----|
| H20C | 814 | 9478 | 4011 | 50 |
| H15 | 465 | 1743 | 2165 | 38 |

Refinement model description

Number of restraints - 0, number of constraints - unknown.

Details:

1. Fixed Uiso

At 1.2 times of:

All C(H) groups, All C(H,H) groups

At 1.5 times of:

All C(H,H,H) groups

2.a Ternary CH refined with riding coordinates:

C1(H1), C10(H10)

2.b Aromatic/amide H refined with riding coordinates:

C9(H9), C16(H16), C6(H6), C13(H13), C7(H7), C14(H14), C5(H5), C2(H2),

C8(H8),

C15(H15)

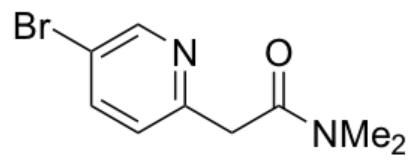
2.c X=CH₂ refined with riding coordinates:

C3(H3A,H3B)

2.d Idealised Me refined as rotating group:

C19(H19A,H19B,H19C), C20(H20A,H20B,H20C)

This report has been created with Olex2, compiled on 2017.08.10 svn.r3458 for OlexSys. Please [let us know](#) if there are any errors or if you would like to have additional features.



-169.66

-154.54

-150.37

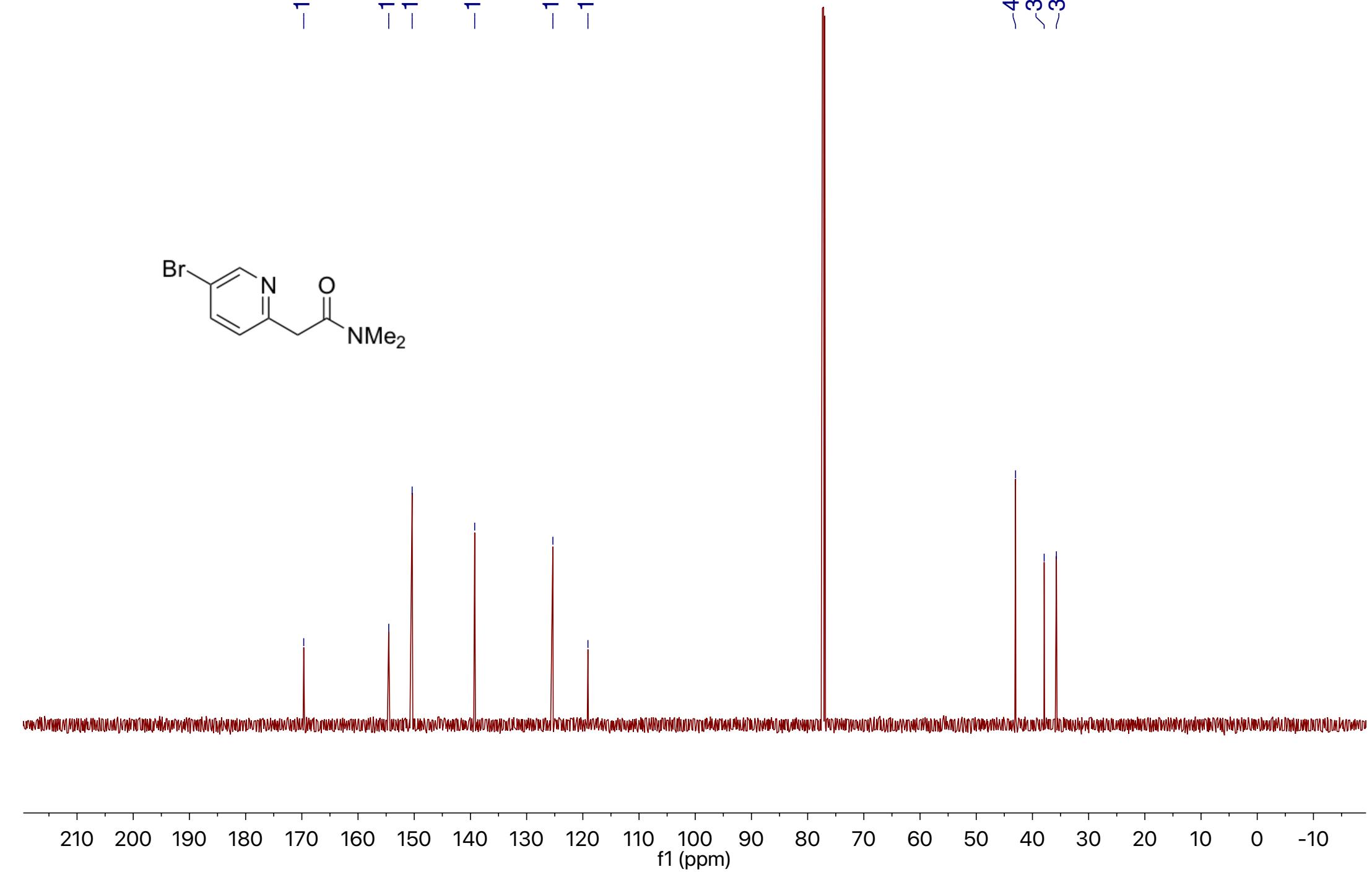
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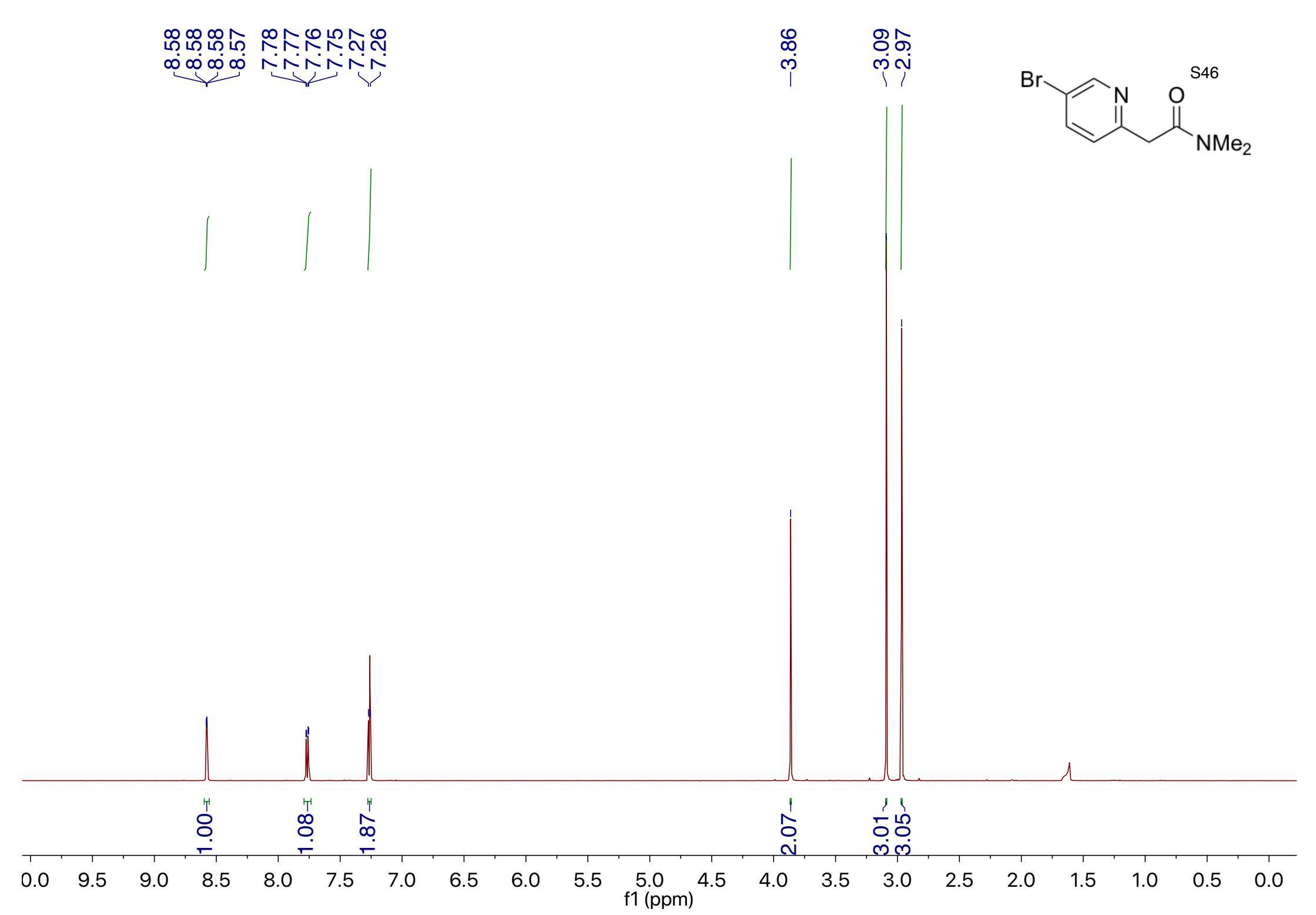
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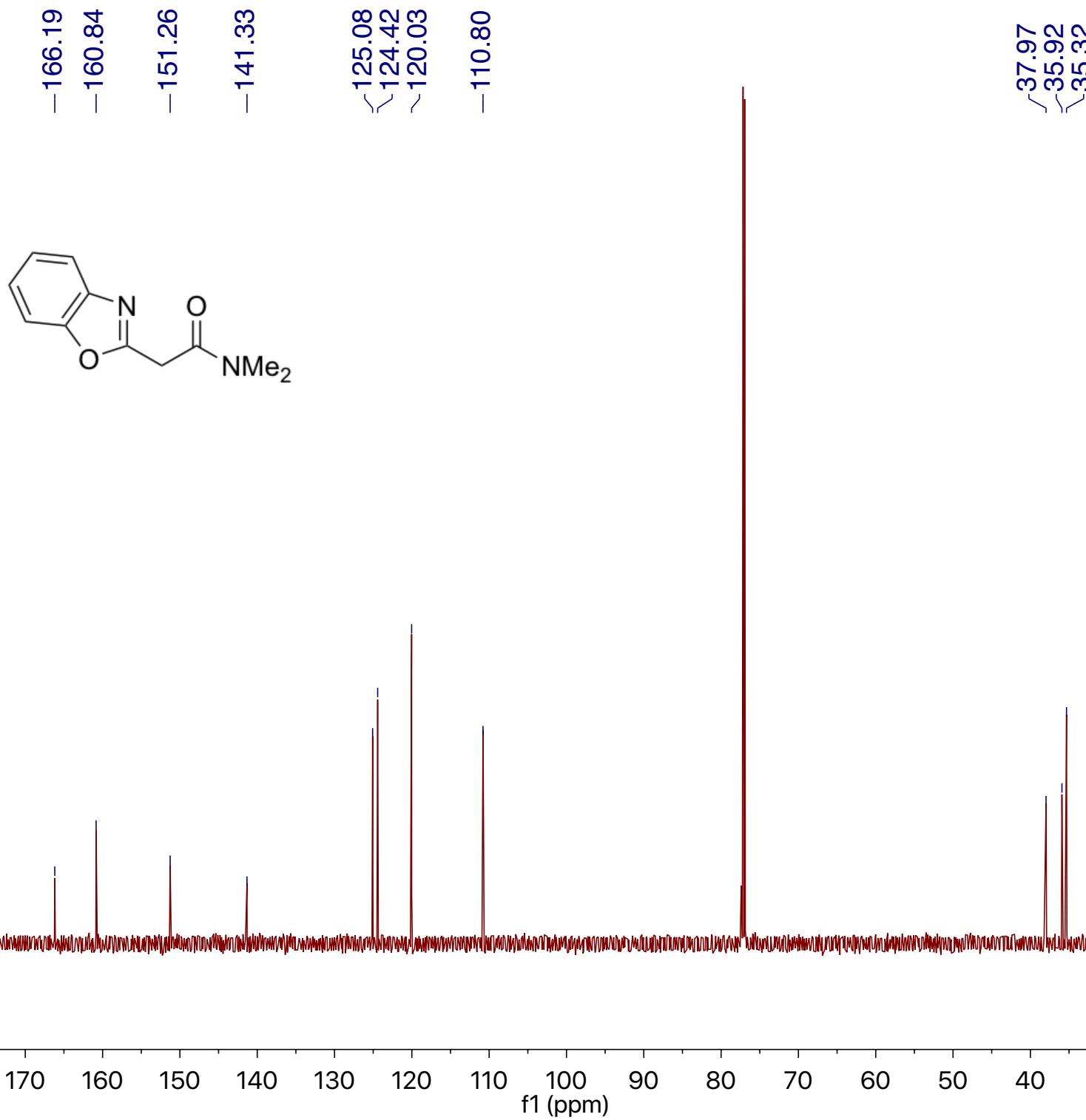
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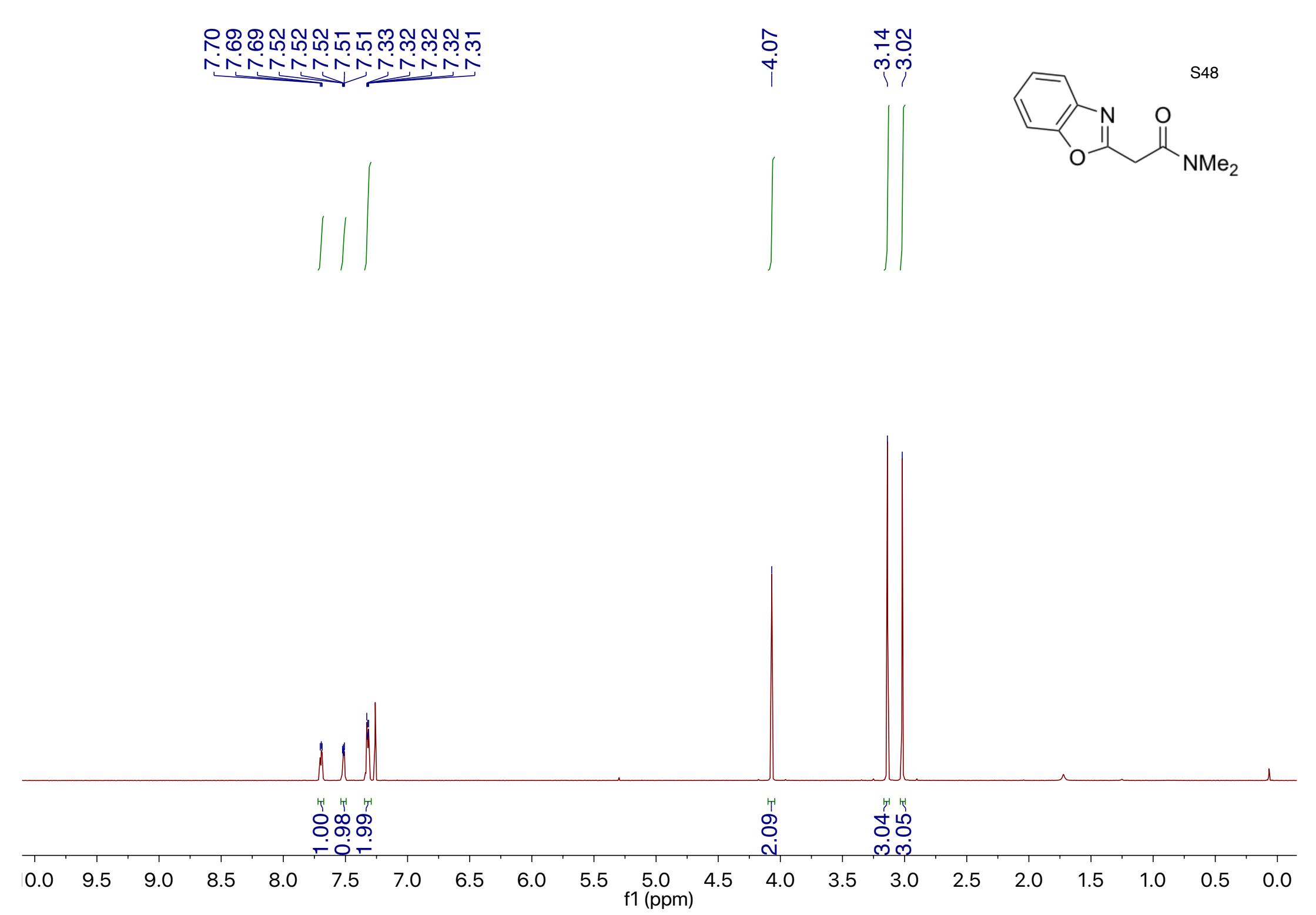
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-35.74

S45

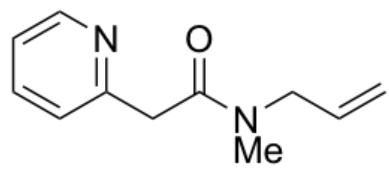




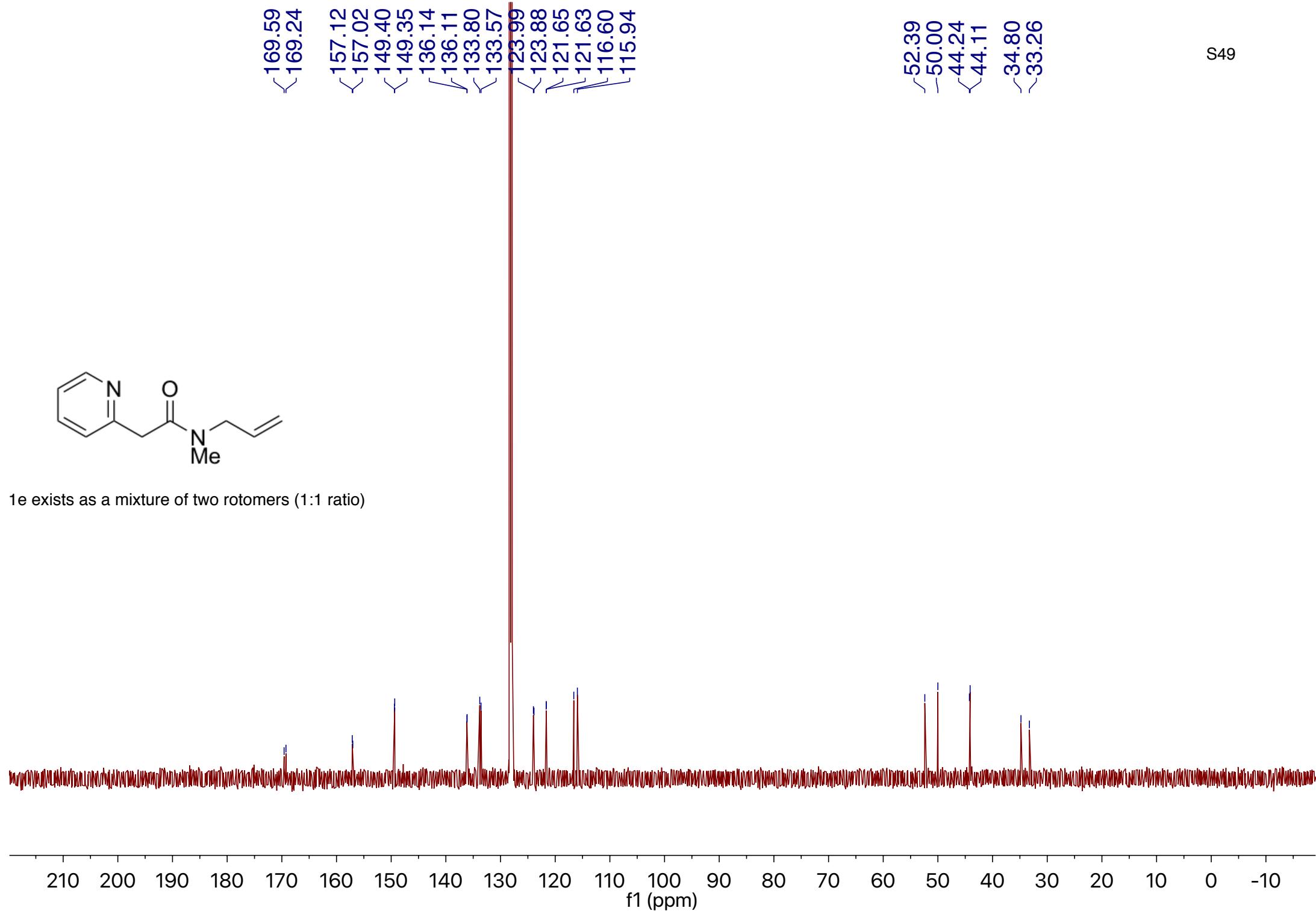




S48

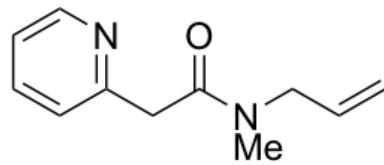


1e exists as a mixture of two rotomers (1:1 ratio)

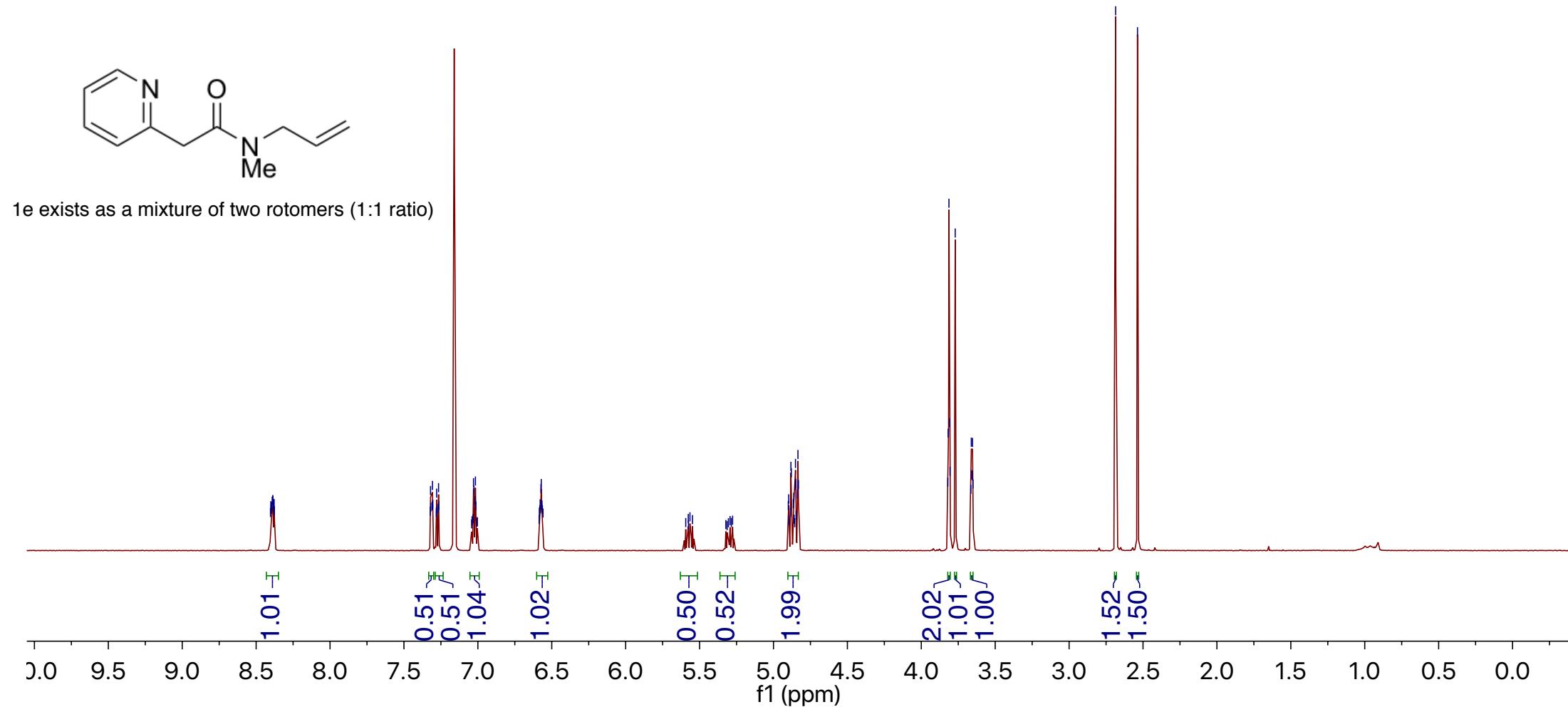


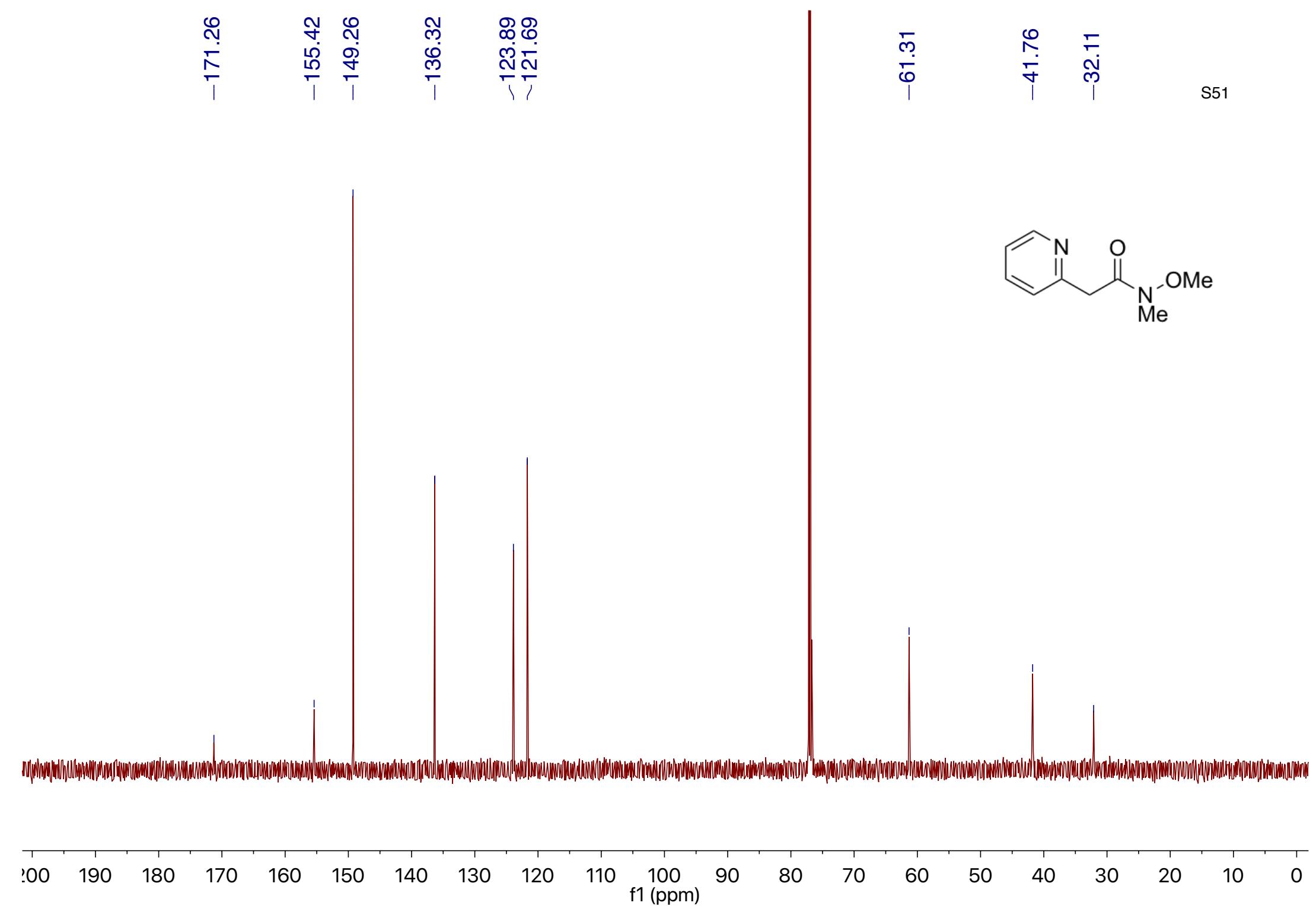
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7.31
7.28
7.27
7.27
7.26
7.03
7.03
7.02
7.02
7.01
6.58
6.58
6.58
6.58
6.57
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6.56
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4.88
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4.84
3.82
3.82
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2.54

S50



1e exists as a mixture of two rotomers (1:1 ratio)





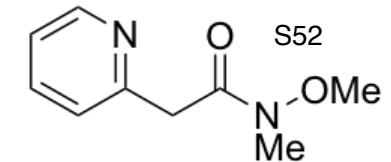
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7.17
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7.16
7.15



0.97
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1.00
1.01

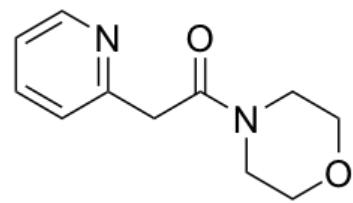
-4.00
3.69
-3.23

2.00
3.00
3.04



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f1 (ppm)

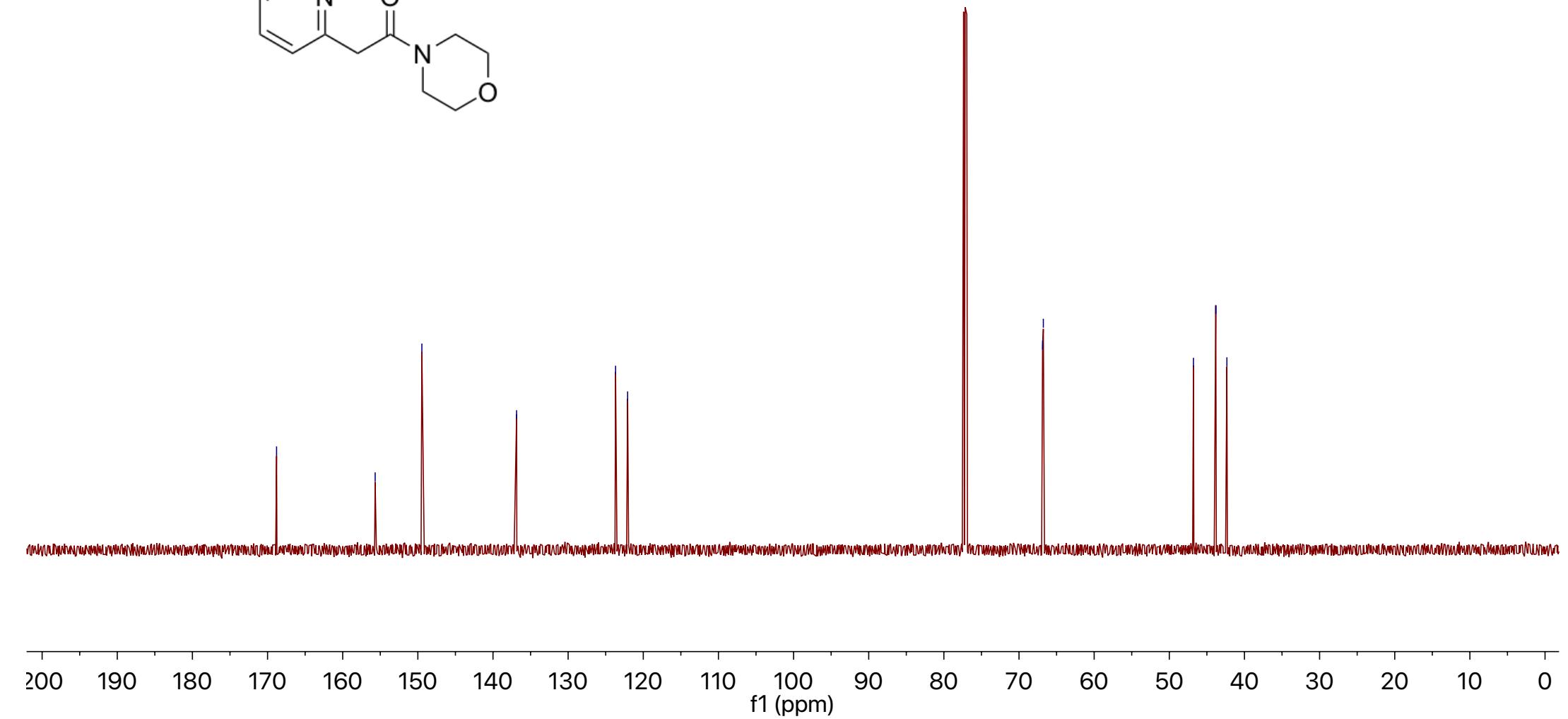


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-149.46
-136.86

~123.69
~122.08

66.86
66.76

~46.79
~43.81
~42.34

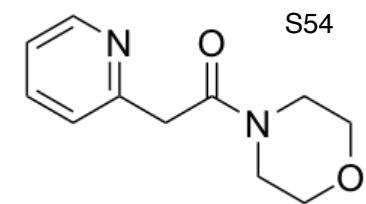


8.53
8.53
8.52
8.52
8.52
8.51
8.51
7.68
7.67
7.66
7.66
7.64
7.64
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7.36
7.35
7.34
7.19
7.18
7.18
7.17
7.17

∫ ∫ ∫ ∫

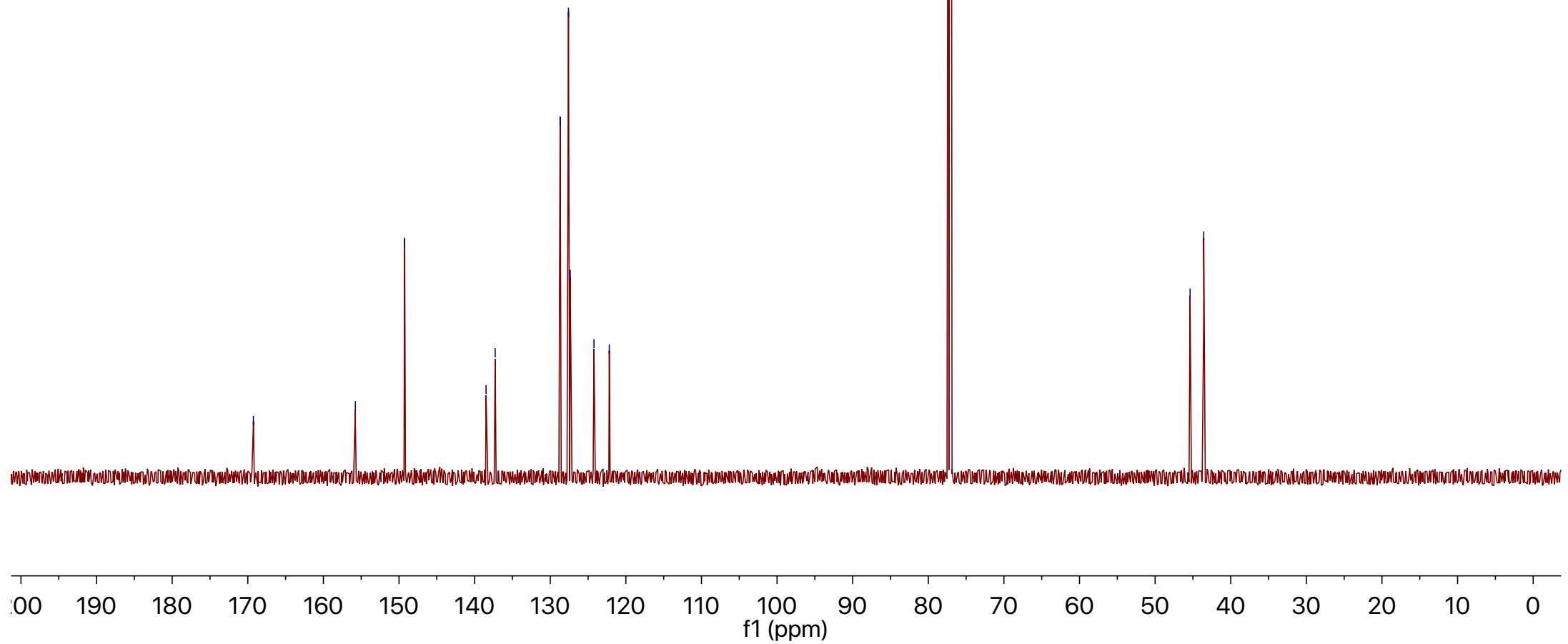
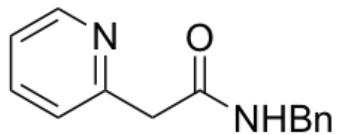
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3.61
3.55
3.55
3.54
3.54

2.09
6.03
2.07



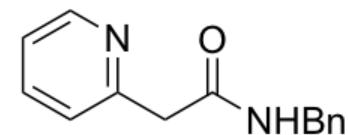
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f1 (ppm)



8.52
8.51
8.51
8.51
8.50
8.50
7.72
7.68
7.67
7.66
7.64
7.31
7.31
7.31
7.30
7.30
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7.29
7.29
7.28
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7.22
7.20
7.19
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7.19
7.18
7.18
4.47
4.46
3.78

S56



1.00

0.81

1.08

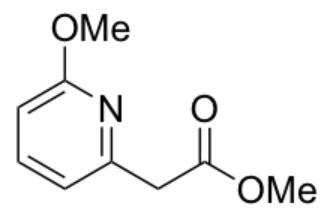
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2.08

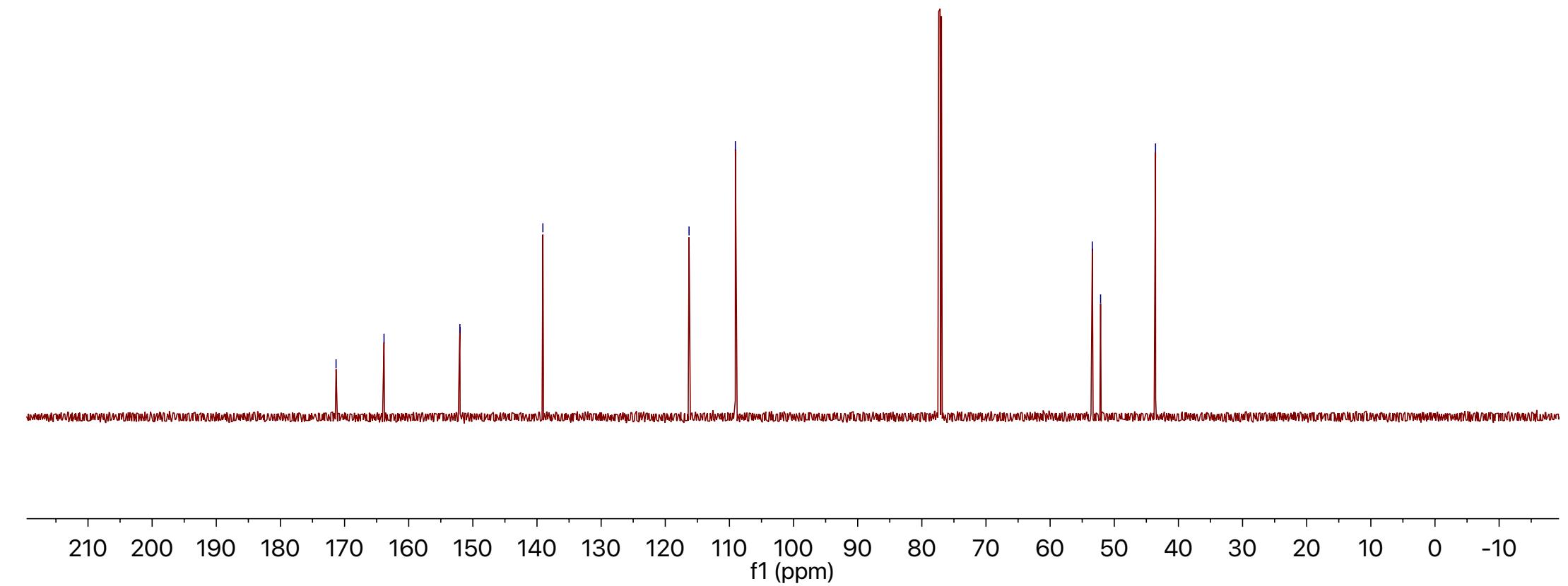
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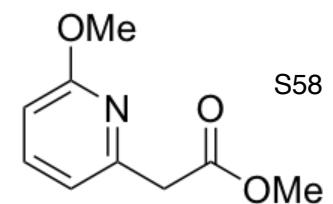
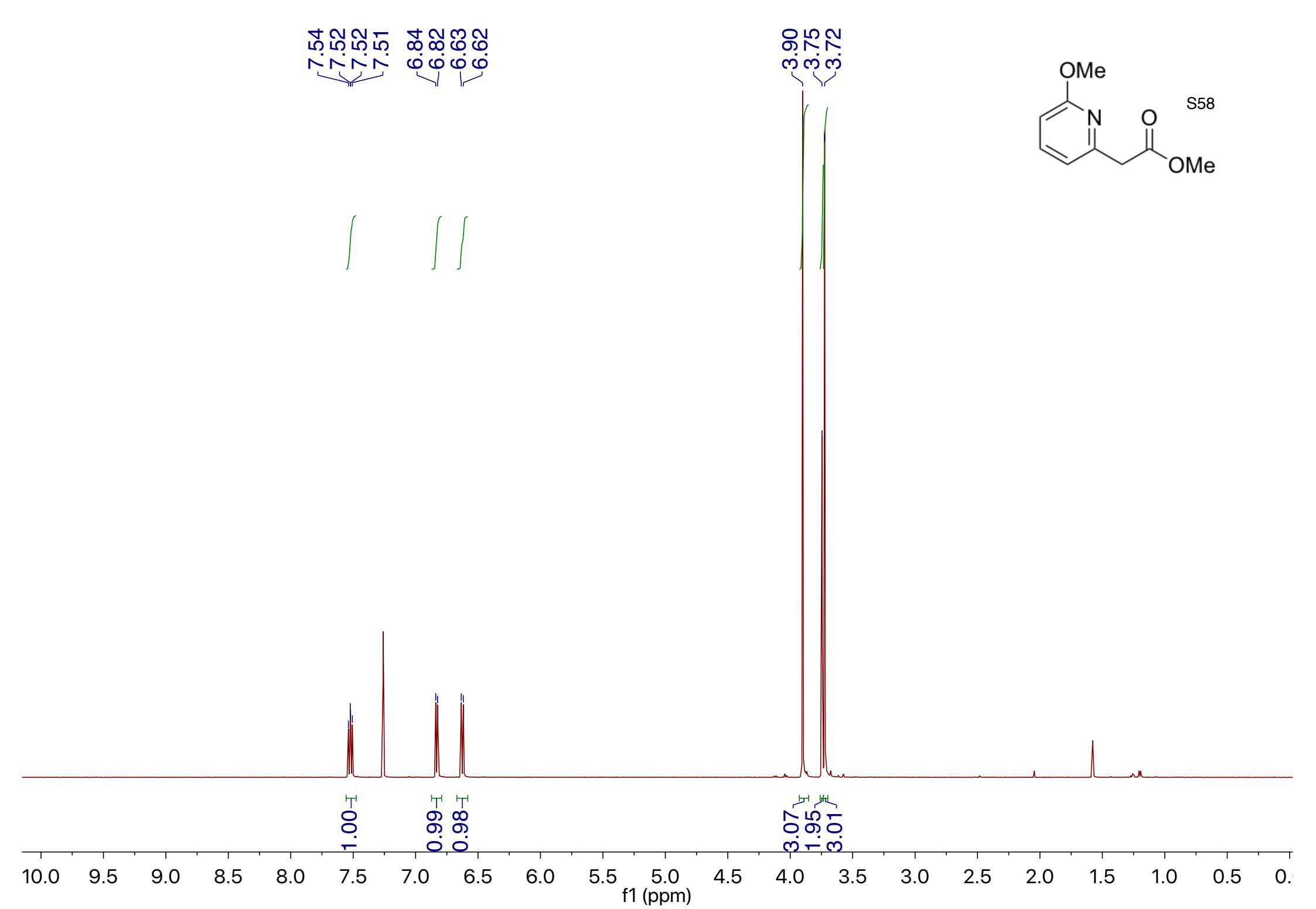
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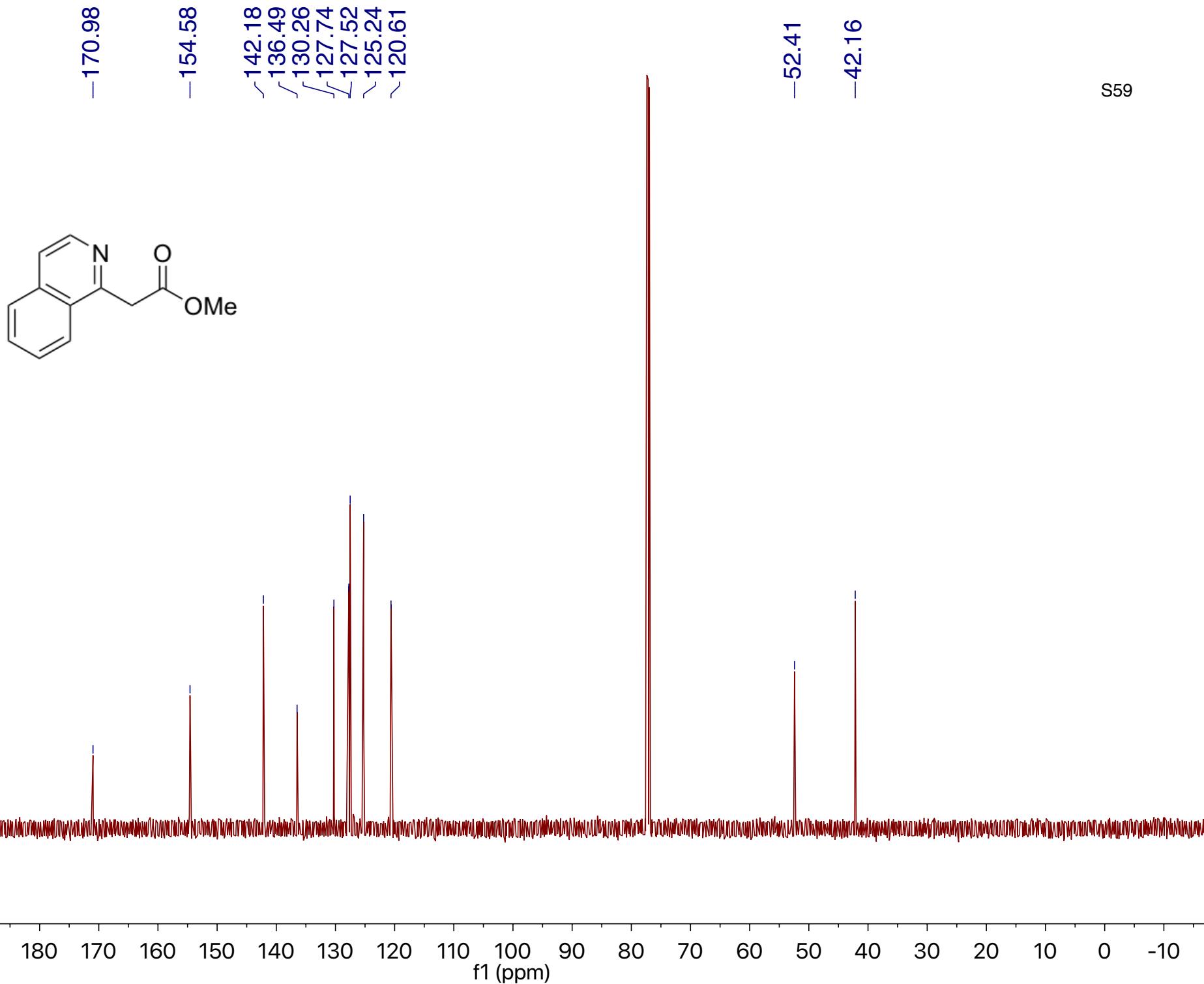
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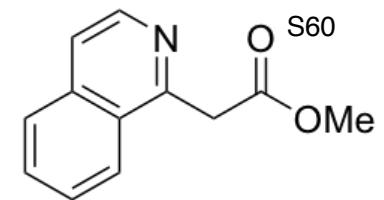
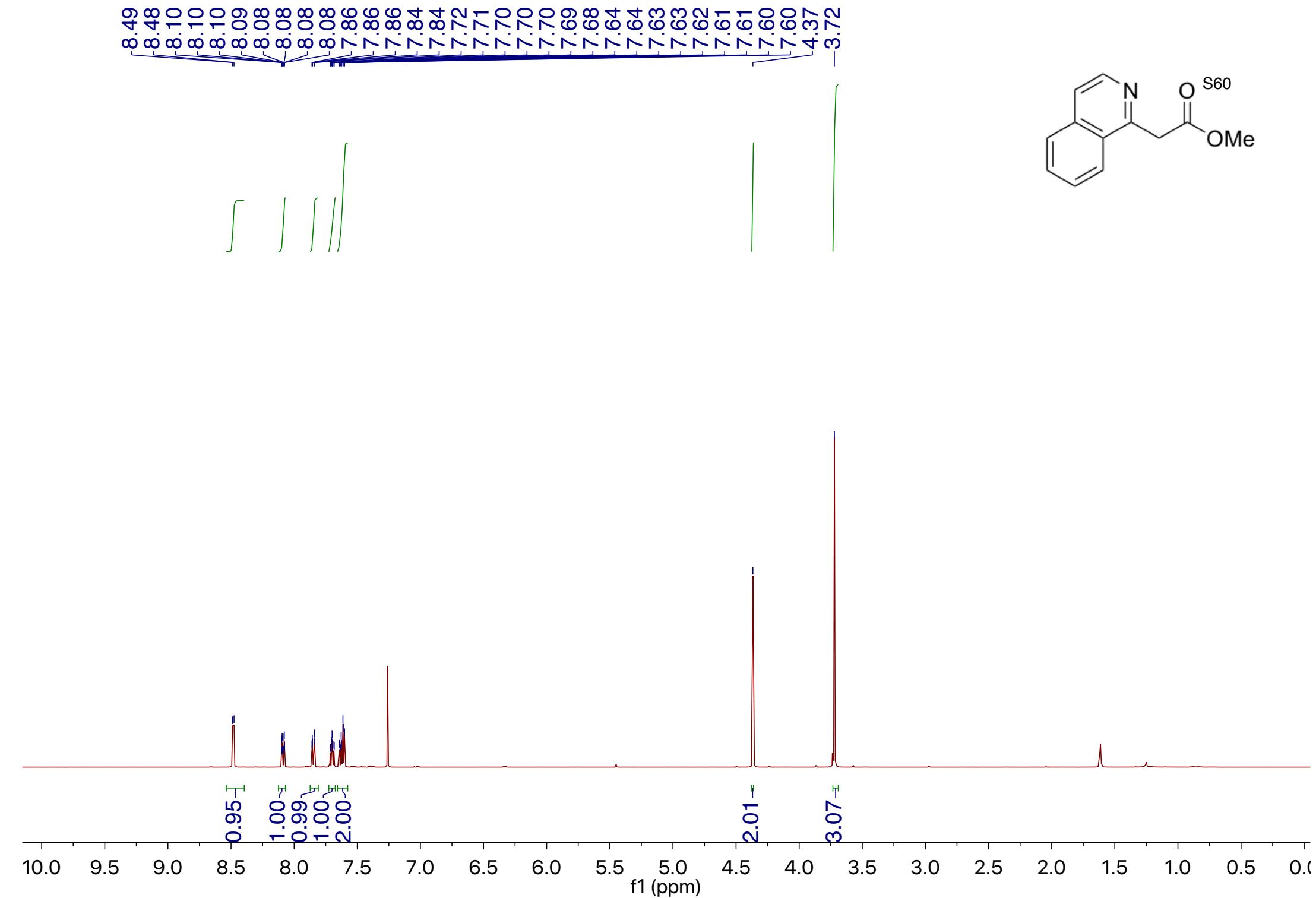


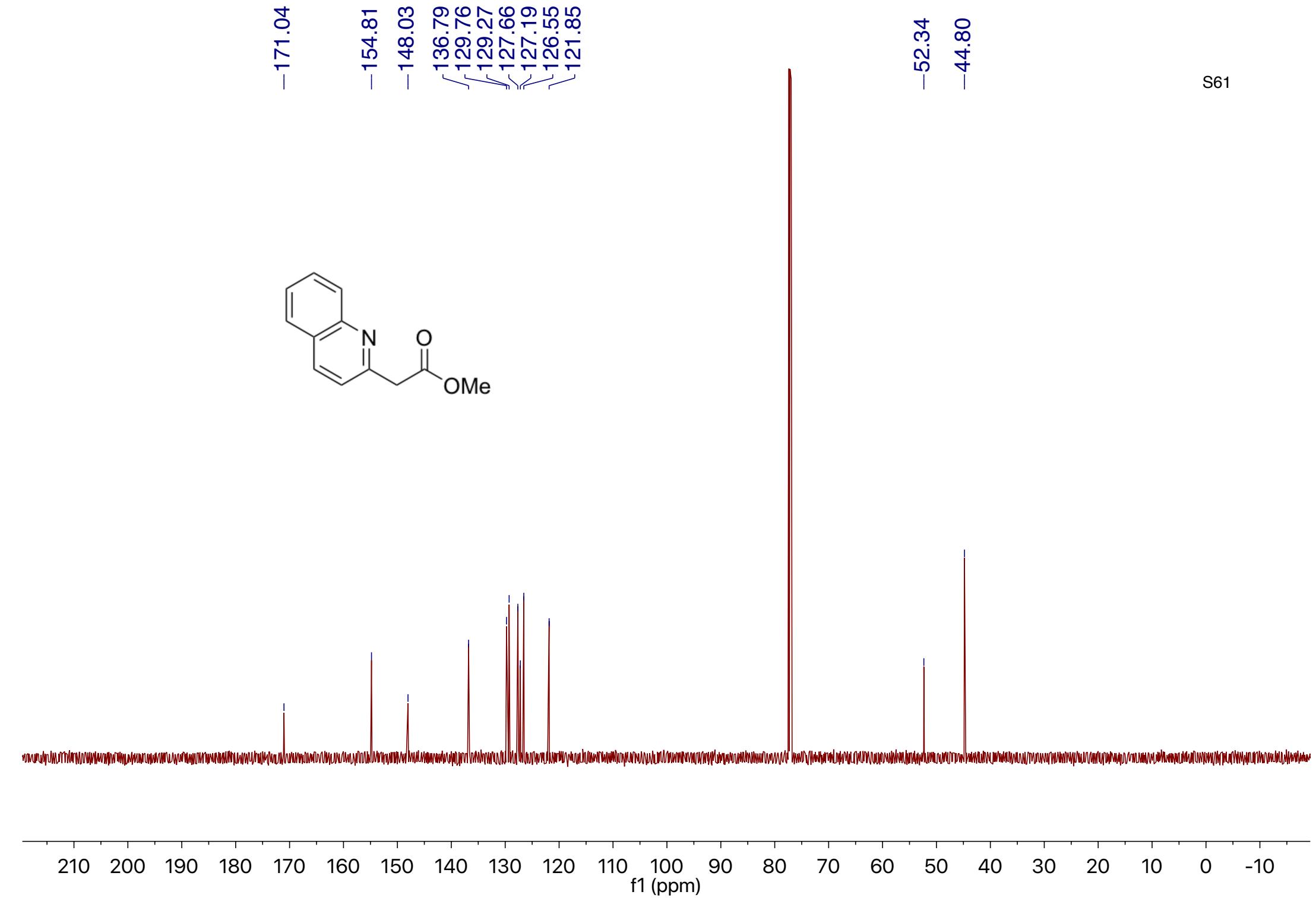
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-152.02
-139.08
-116.29
-109.07
53.42
52.13
-43.57

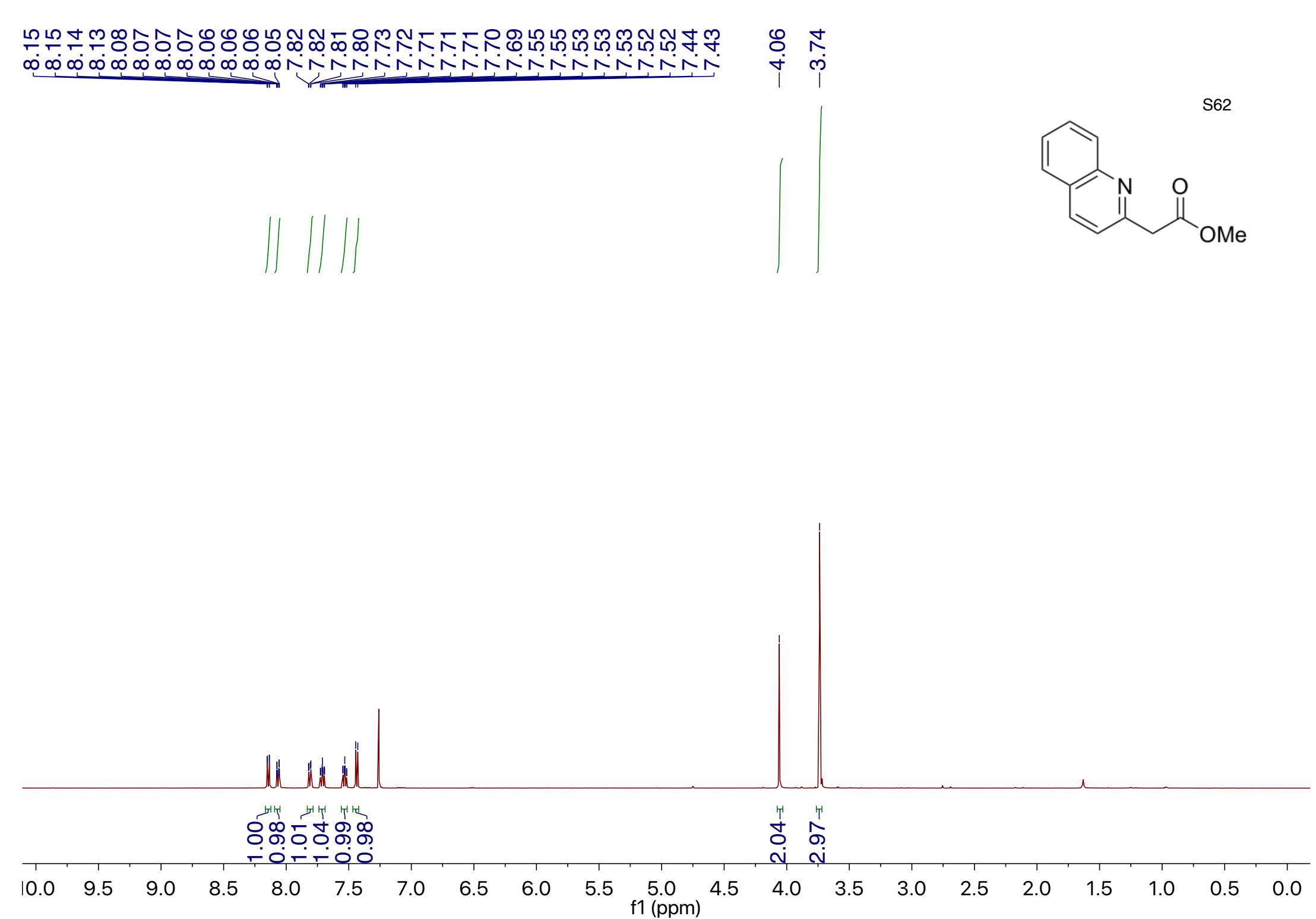




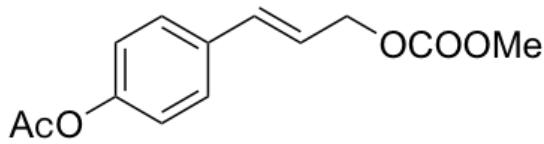








S62



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-150.60

<133.93

<133.81

-127.77

<122.80

<121.86

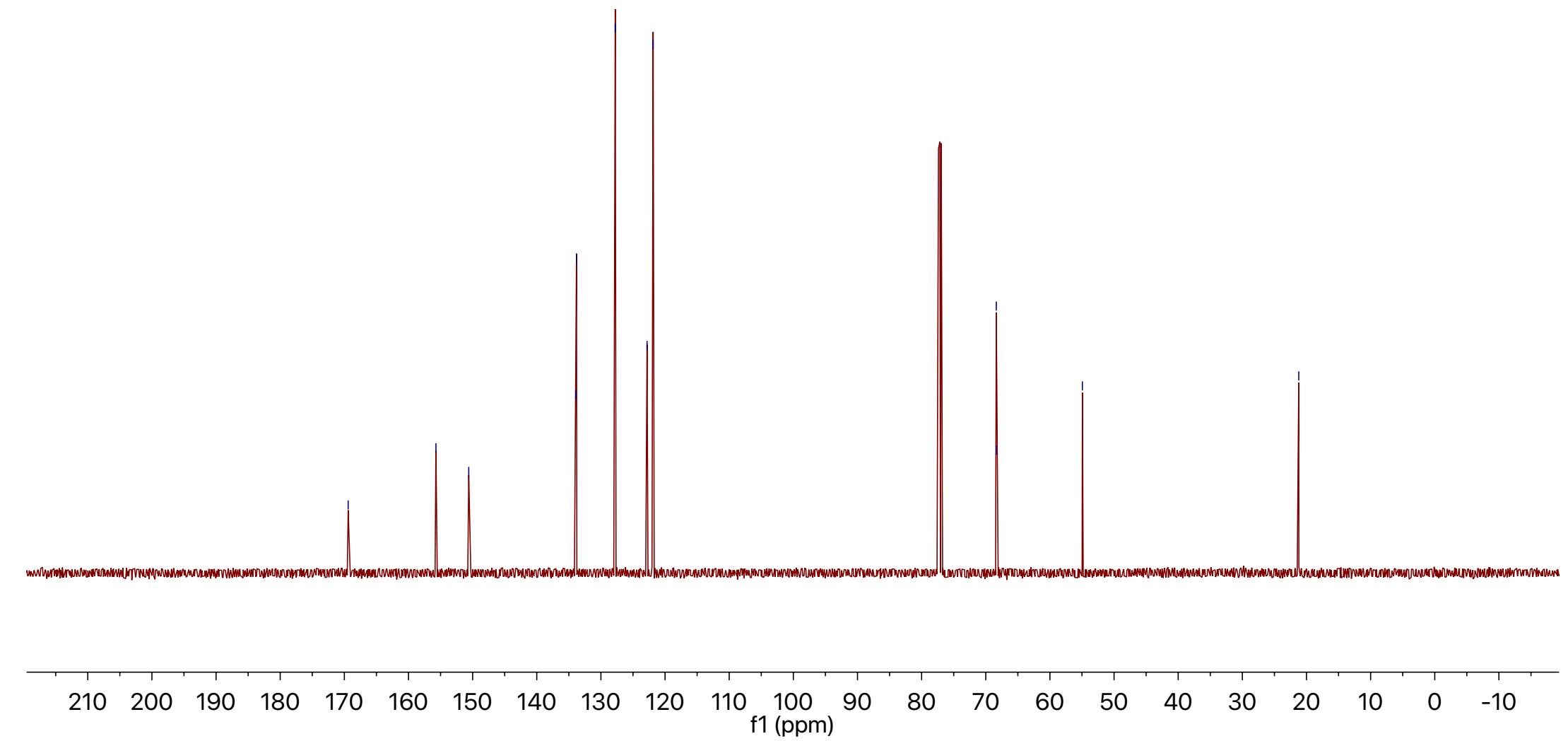
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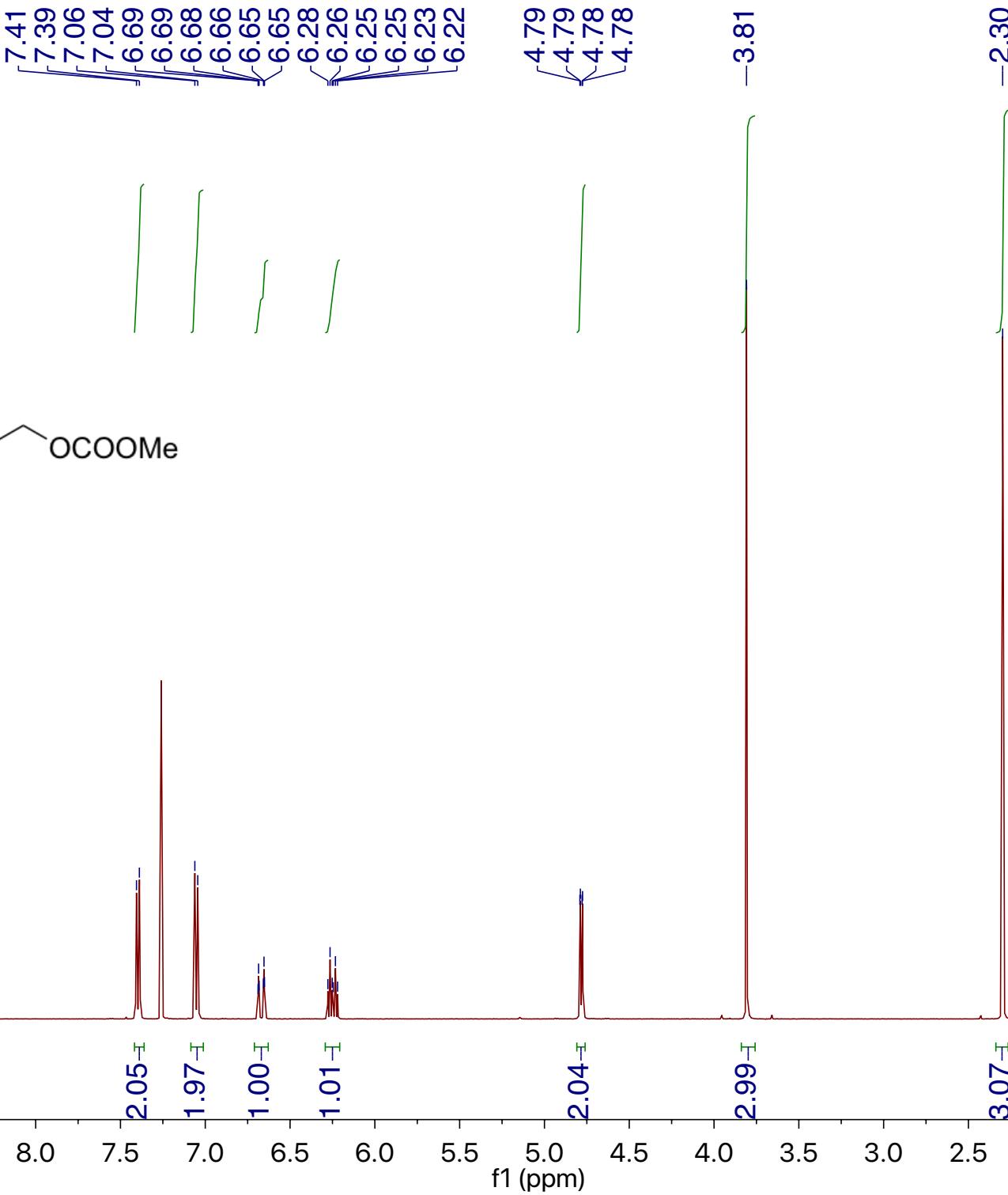
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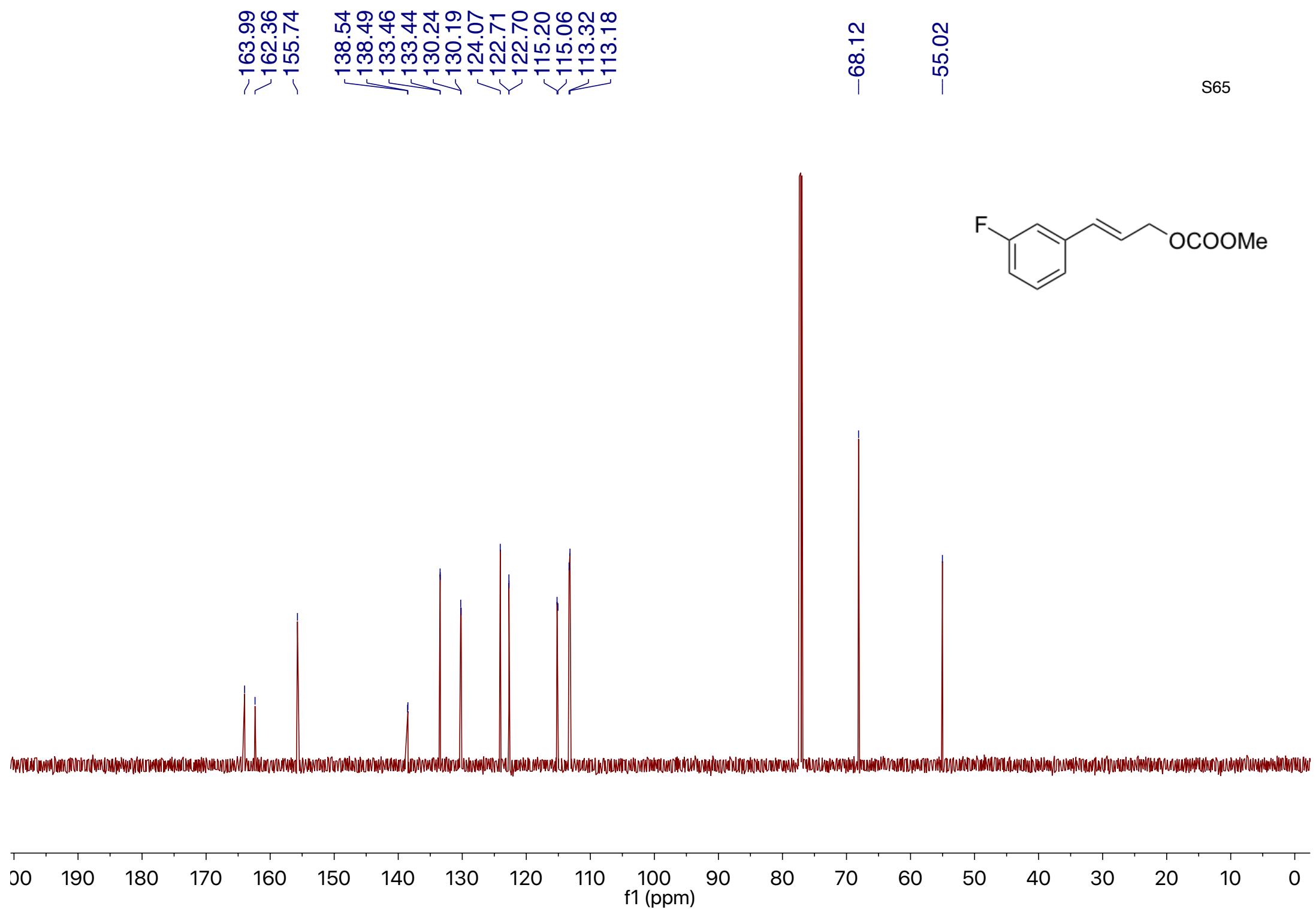
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S63

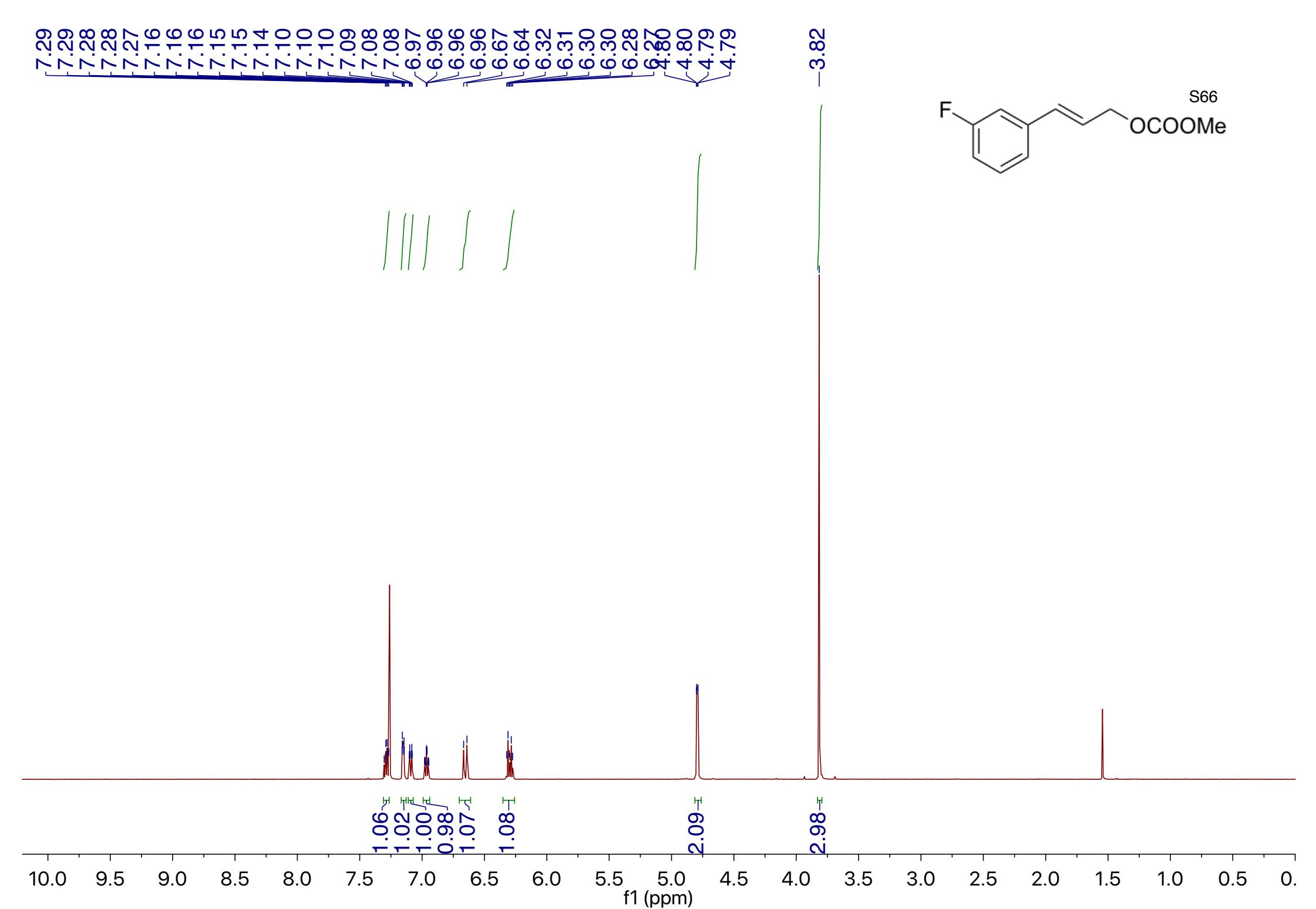


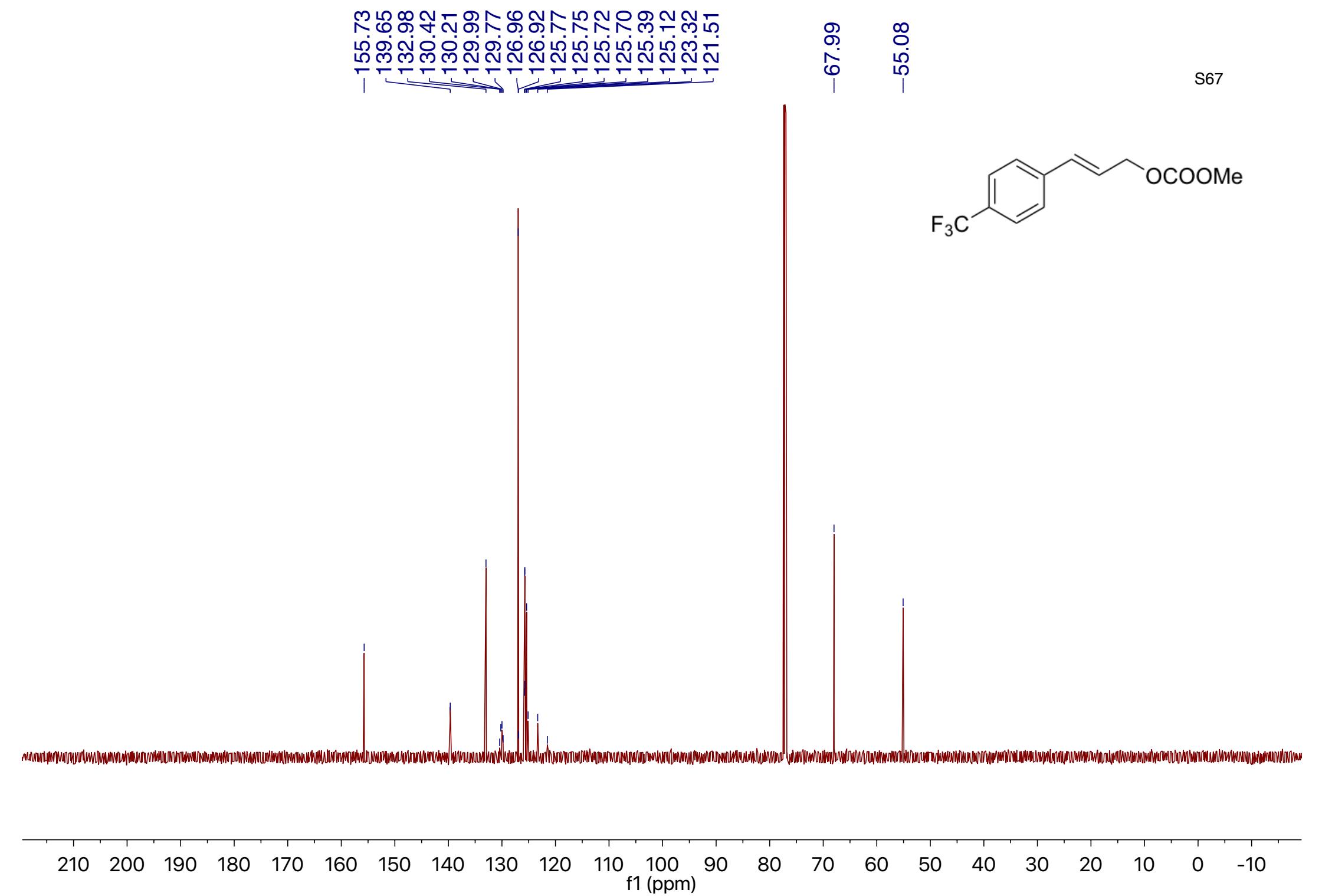


S64



S65

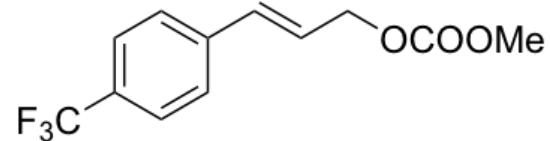




7.59
7.57
7.49
7.48
7.48
6.73
6.73
6.73
6.70
6.70
6.41
6.40
6.39
6.38
6.37
6.36
4.82
4.82
4.81
4.81

3.82

S68



1.99
2.05

1.00
1.01

2.02

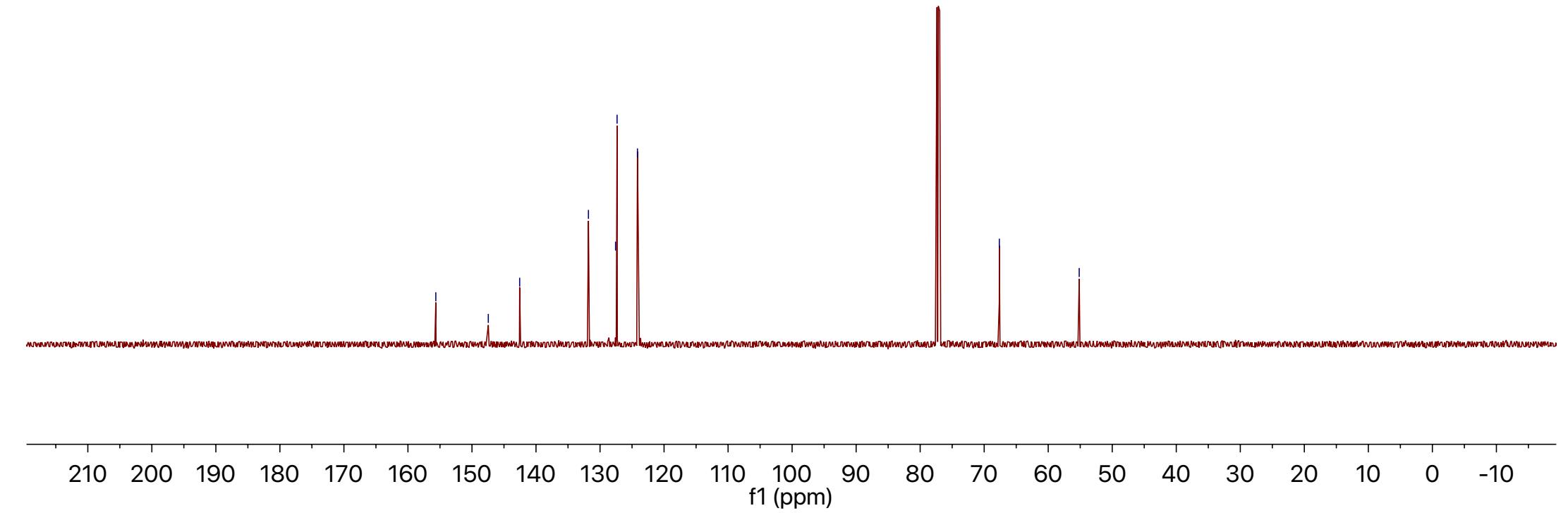
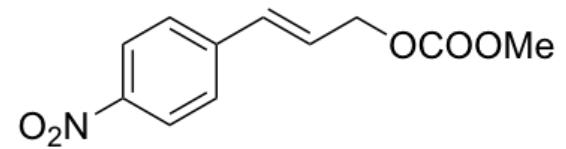
3.02

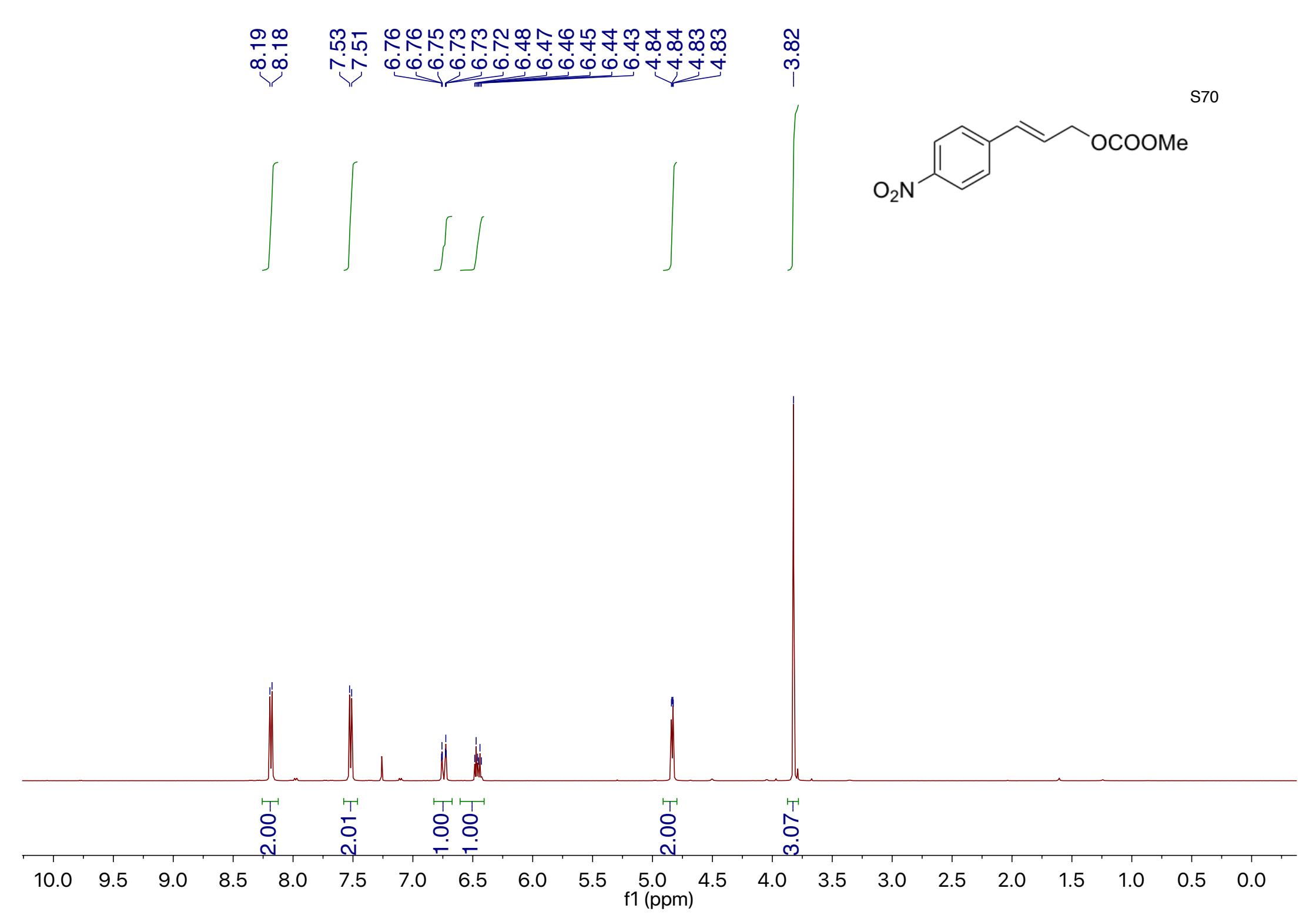
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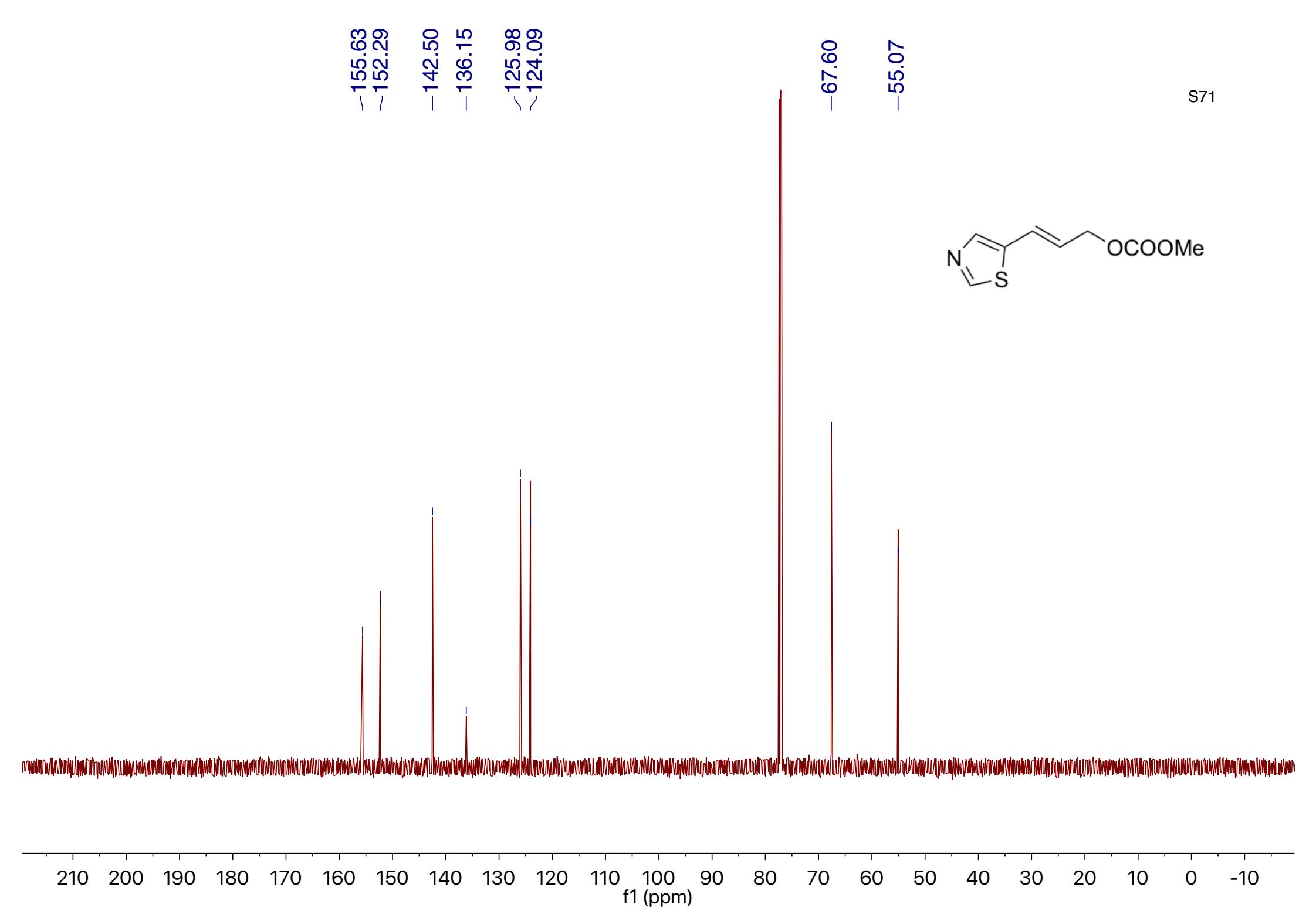
f1 (ppm)

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-67.64
-55.16

131.81
127.58
127.34
124.15



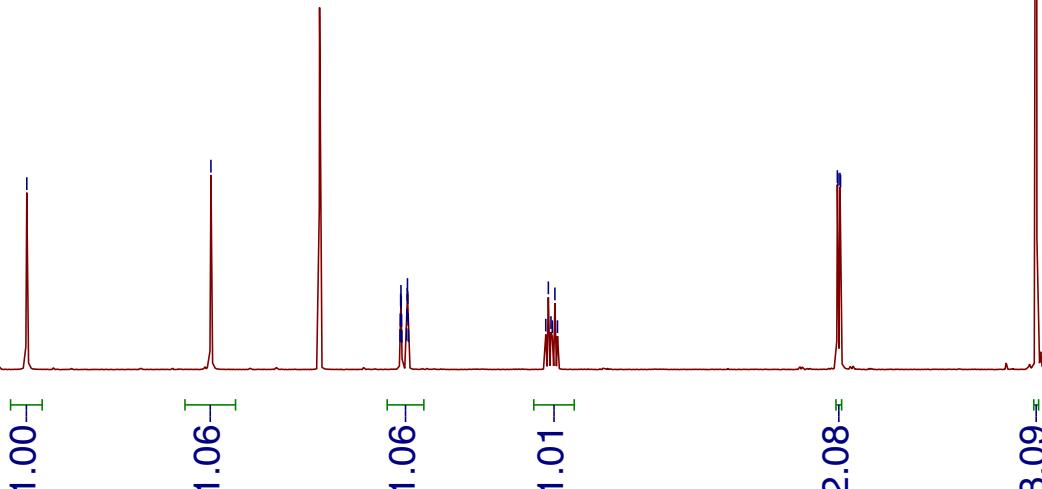
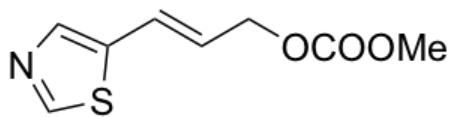




8.67 7.78
6.87 6.87
6.87 6.87
6.87 6.87
6.87 6.87
6.84 6.84
6.84 6.84
6.84 6.84
6.83 6.83
6.17 6.16
6.15 6.14
6.13 6.12
4.77 4.77
4.76 4.76
4.76

3.82

S72

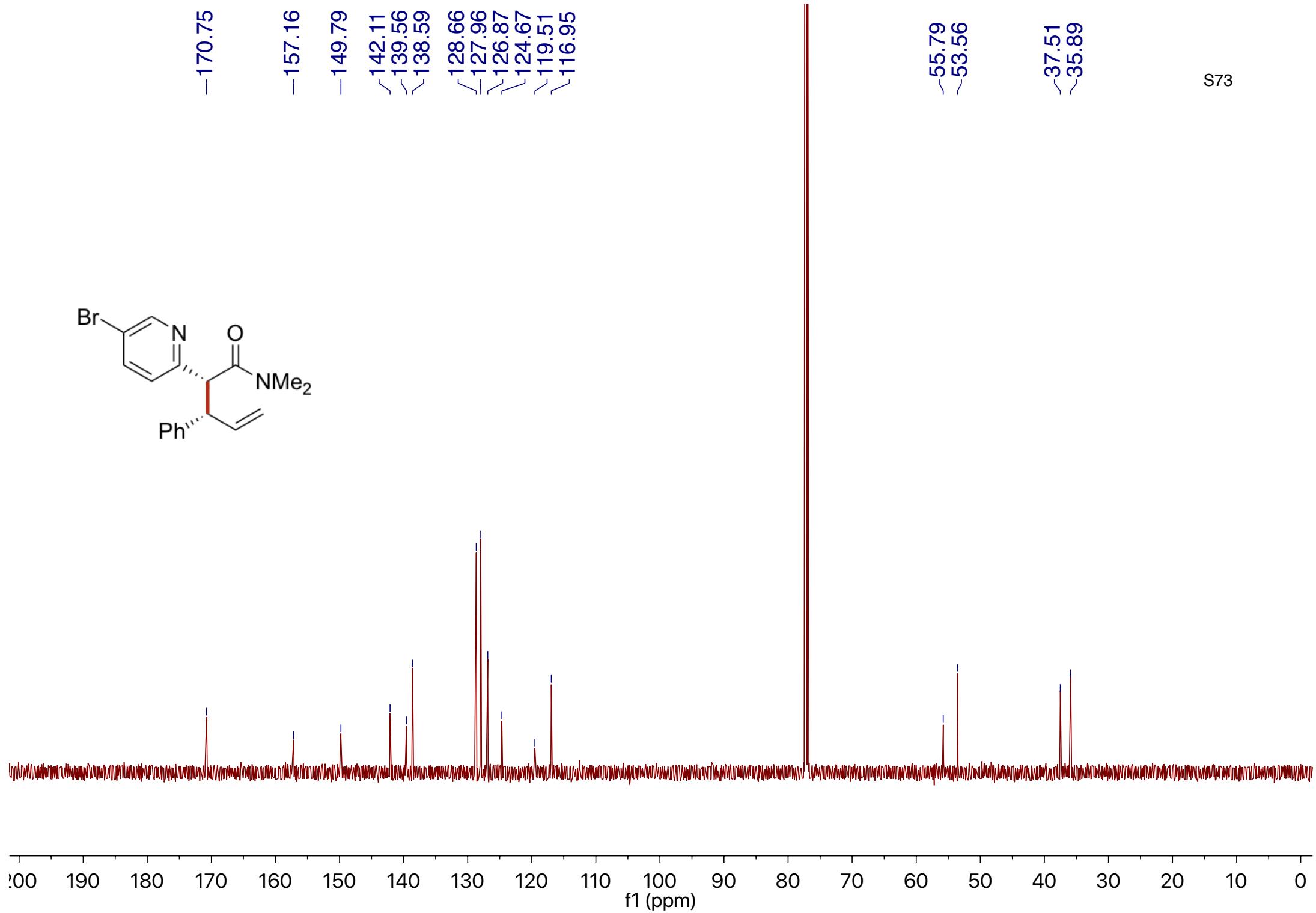
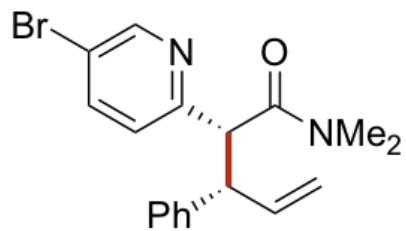


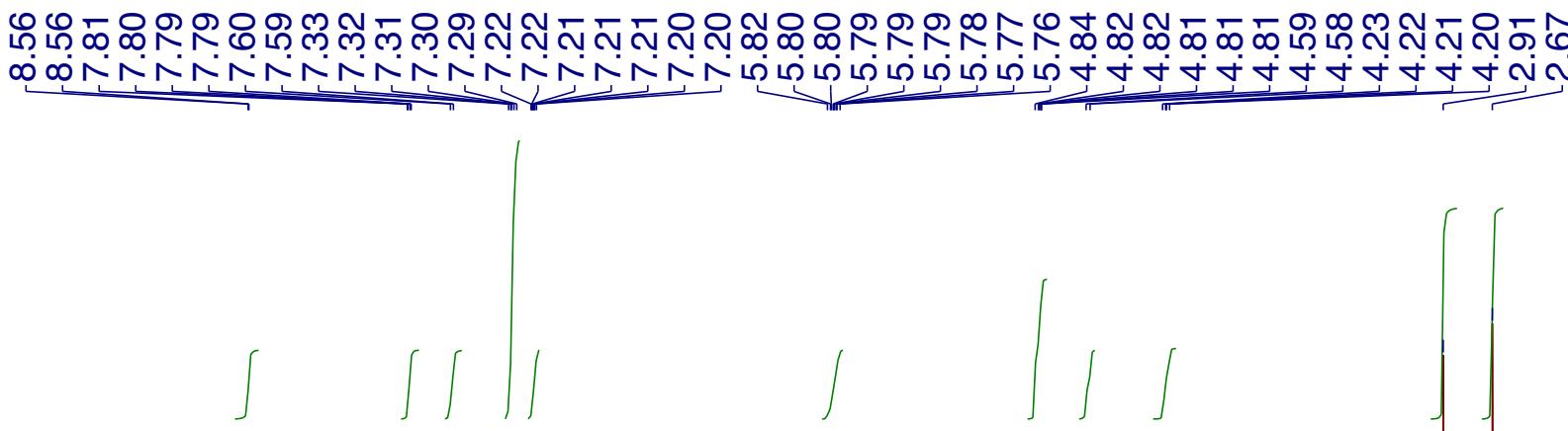
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

f1 (ppm)

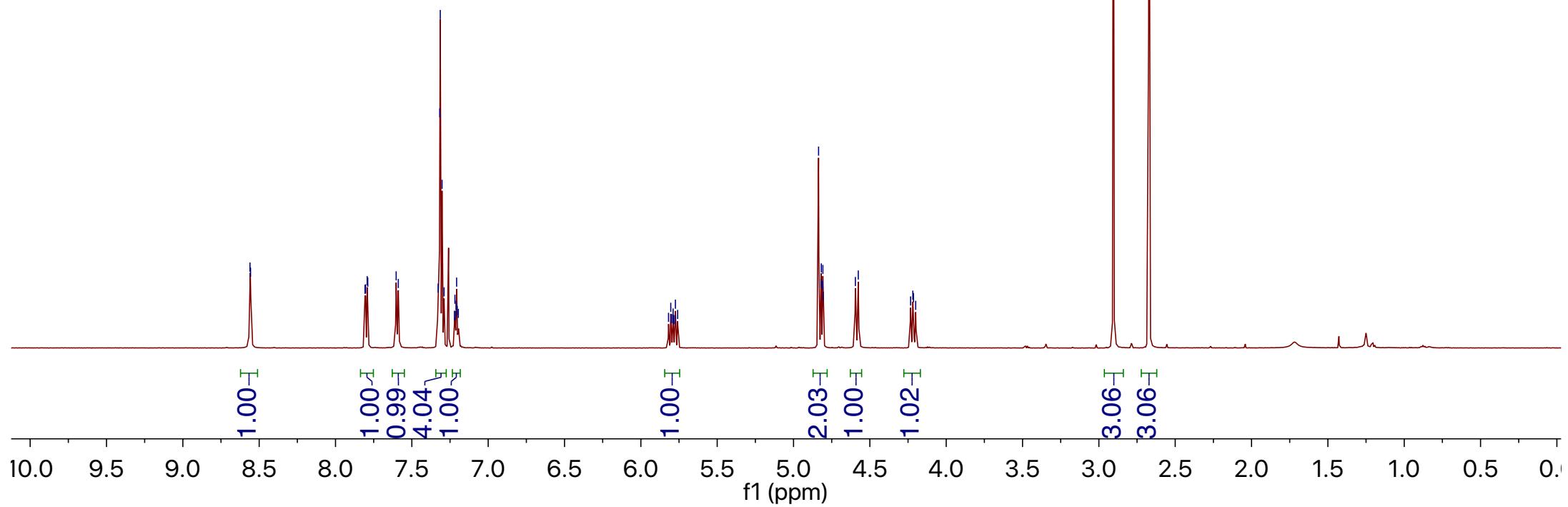
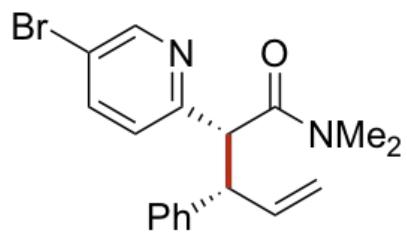
\sim 170.75
 \sim 157.16
 \sim 149.79
 \sim 142.11
 \sim 139.56
 \sim 138.59
 \sim 128.66
 \sim 127.96
 \sim 126.87
 \sim 124.67
 \sim 119.51
 \sim 116.95
 \sim 55.79
 \sim 53.56
 \sim 37.51
 \sim 35.89

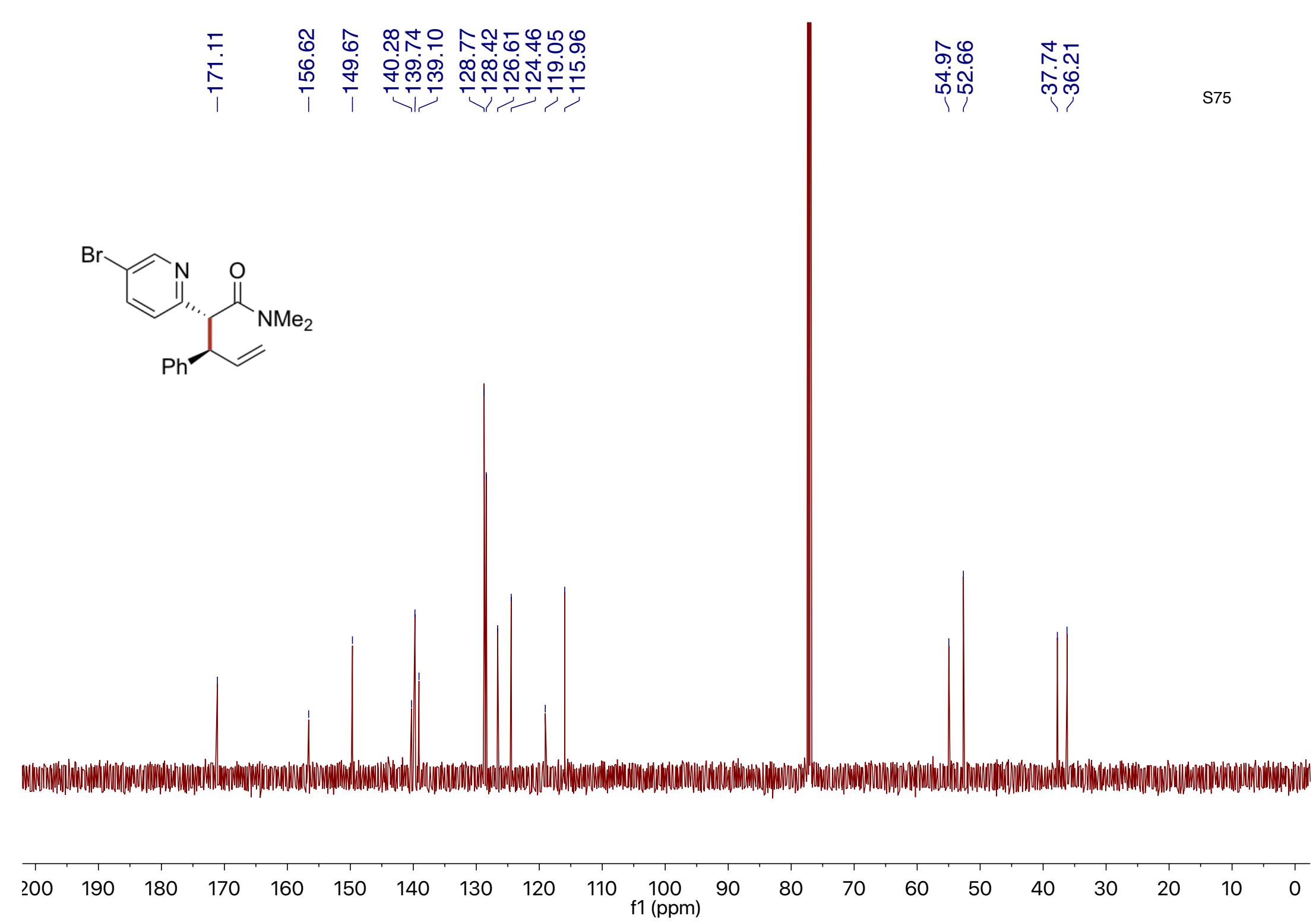
S73



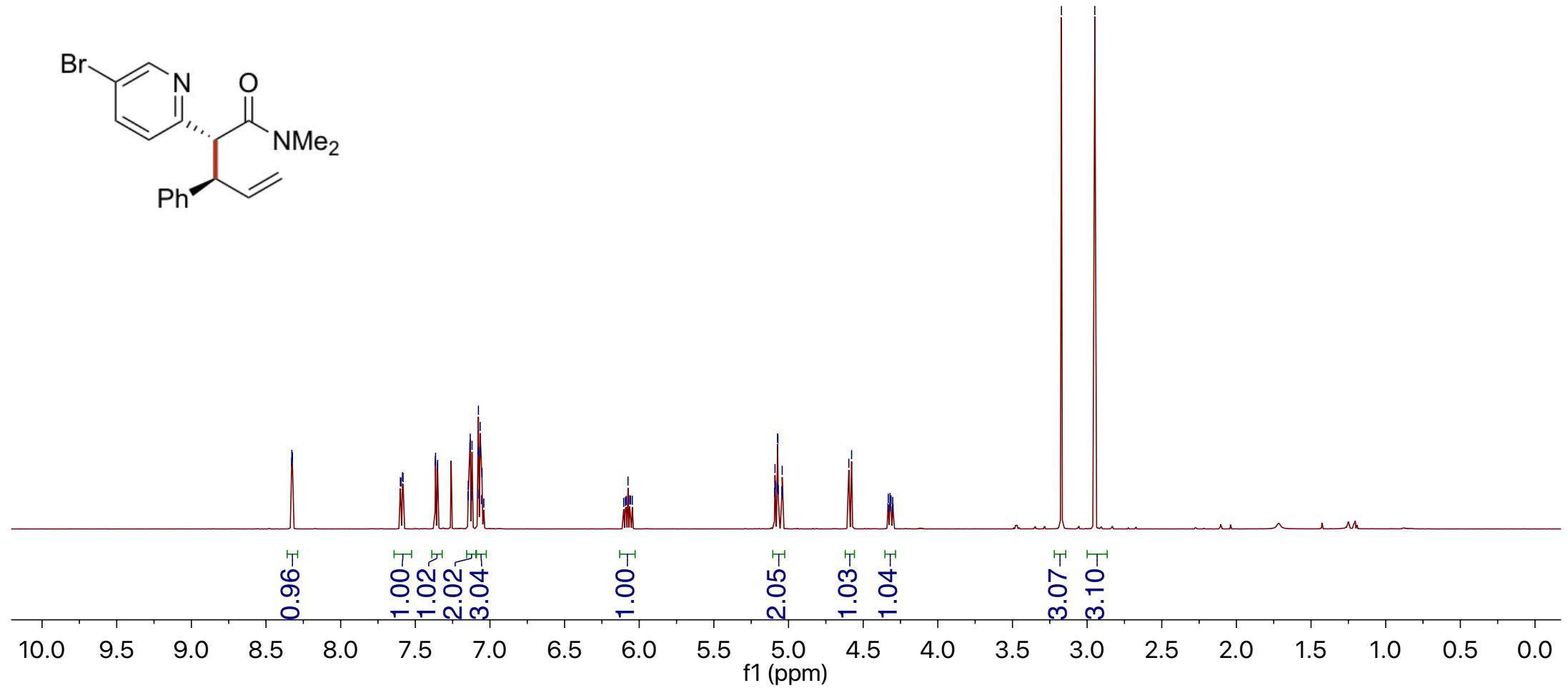
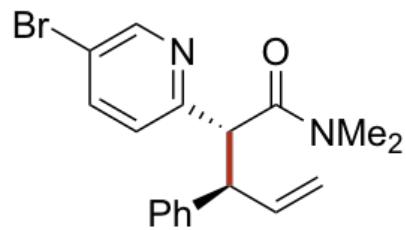
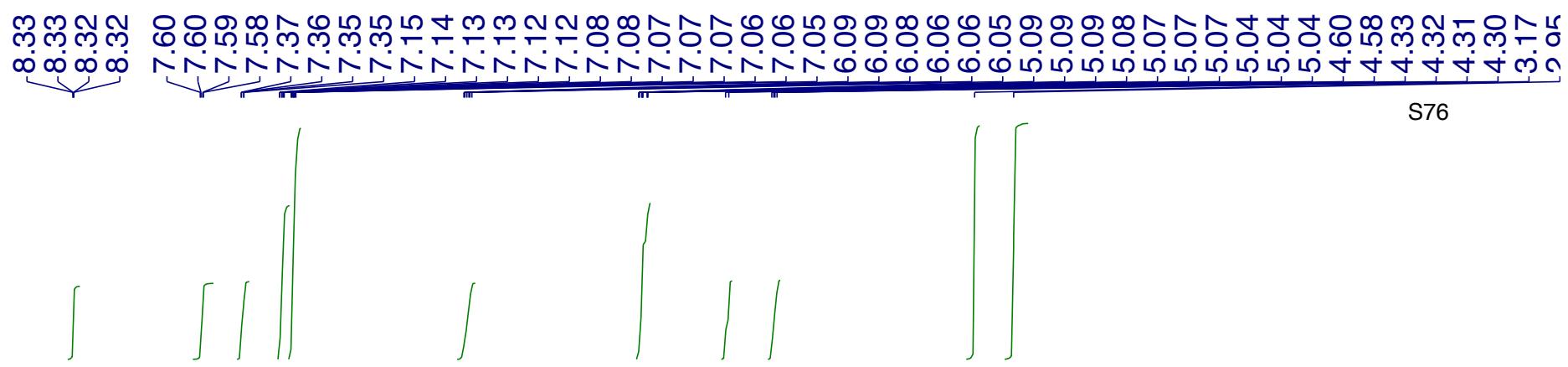


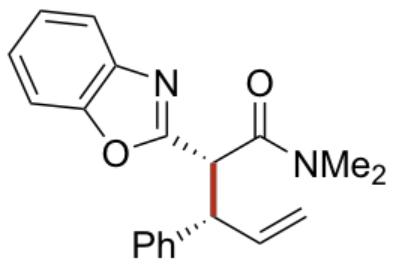
S74





S75





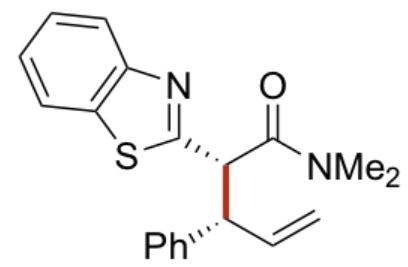
-166.82
-162.46
-151.24

140.96
140.86
137.82
128.80
128.02
127.17
125.14
124.48
120.02
117.17
111.10

50.92
48.68
37.62
36.14

f1 (ppm)

S77

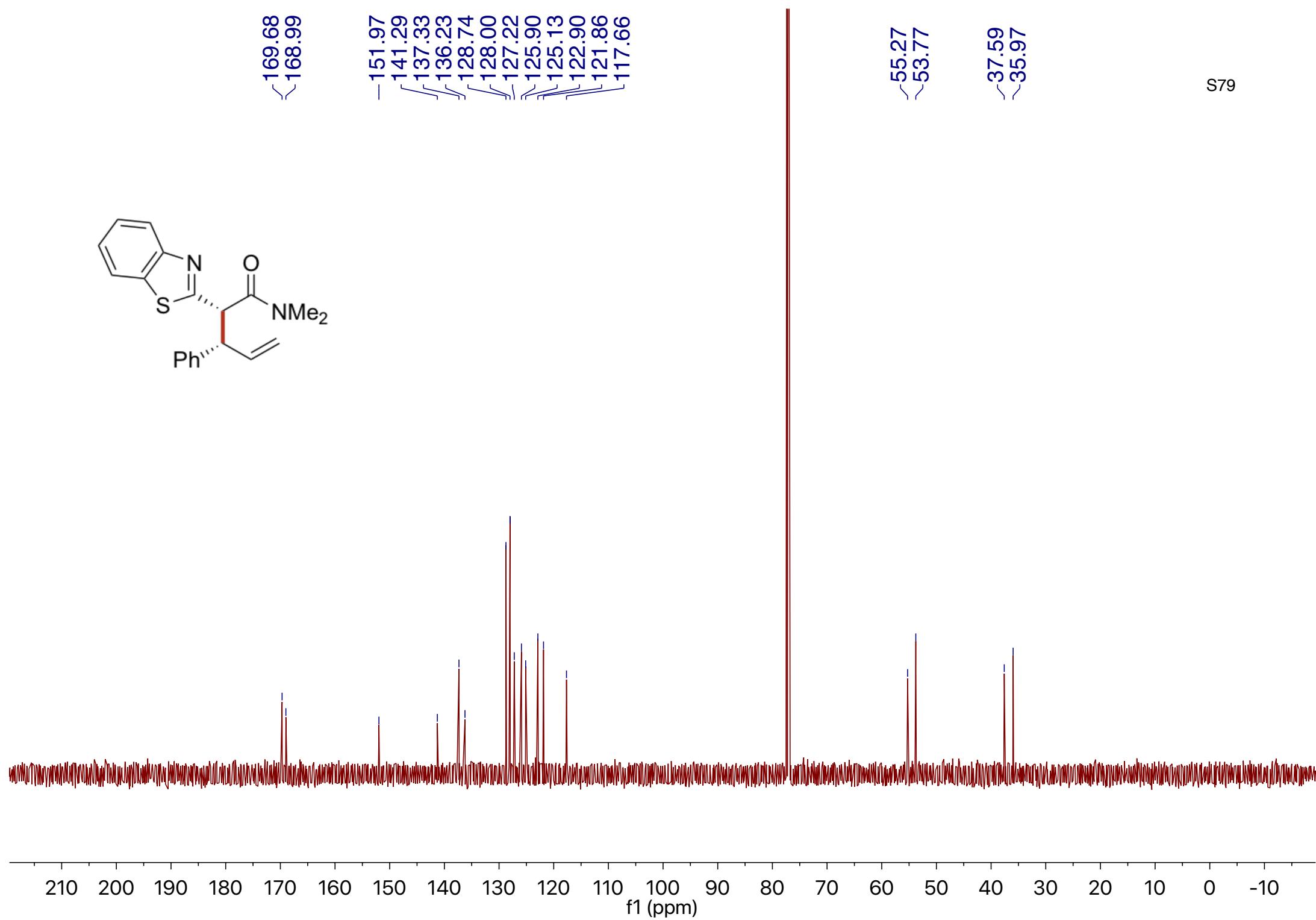


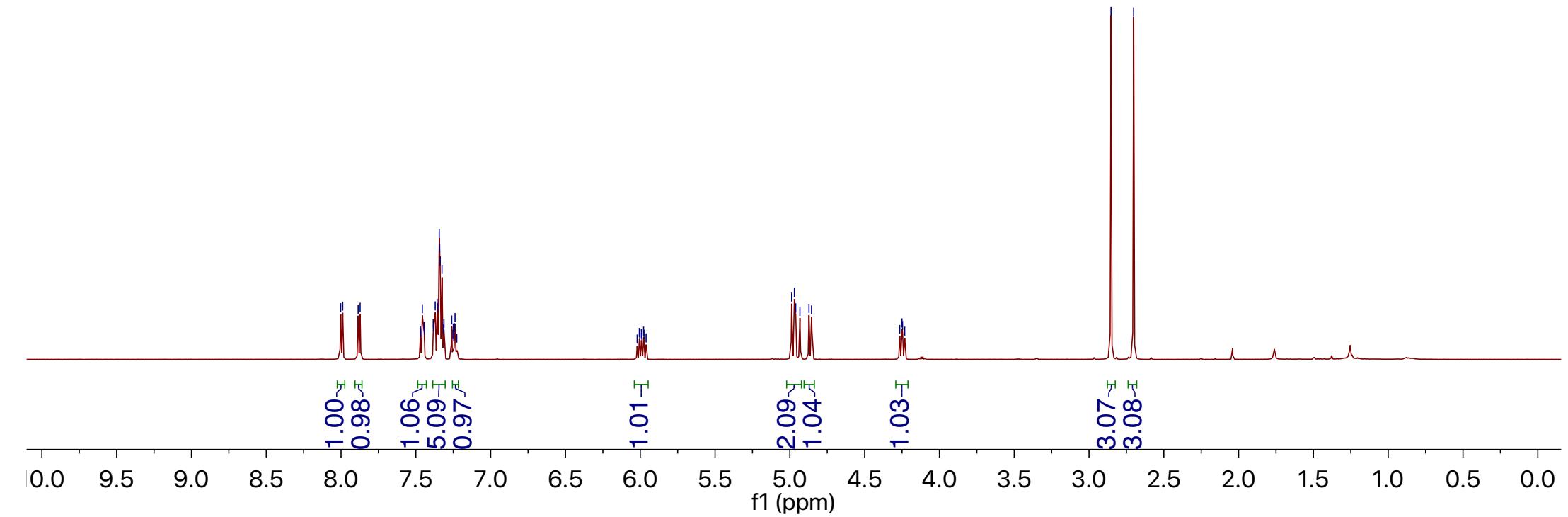
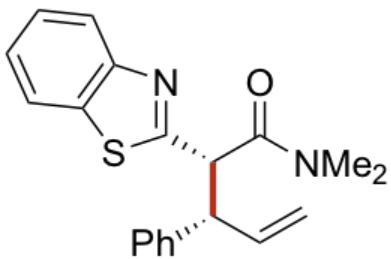
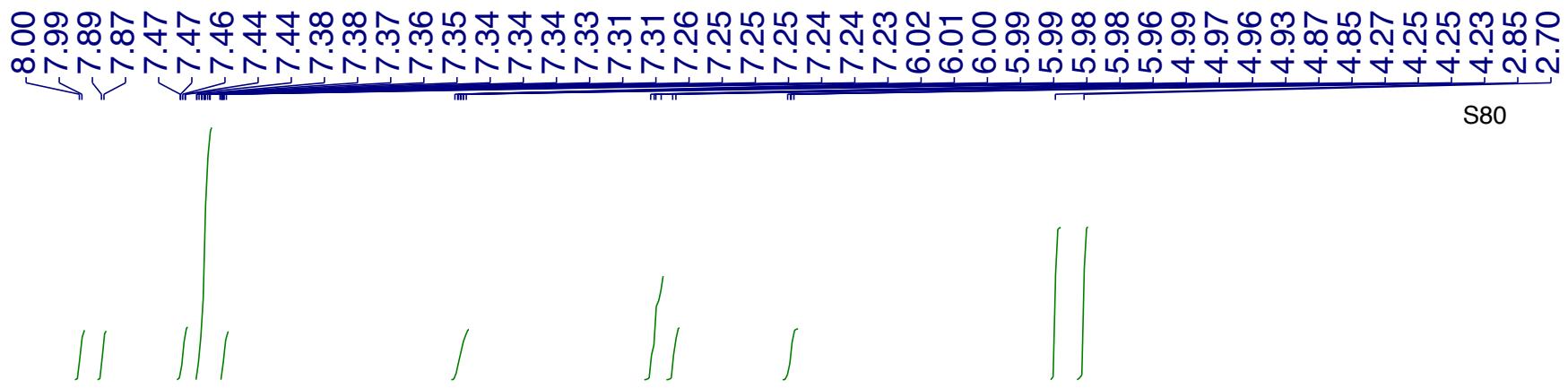
169.68
168.99

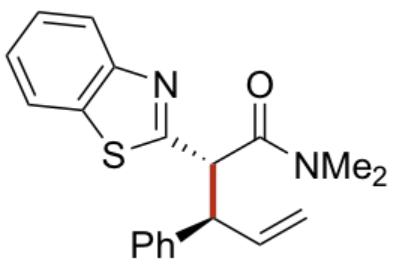
151.97
141.29
137.33
136.23
128.74
128.00
127.22
125.90
125.13
122.90
121.86
117.66

55.27
53.77

37.59
35.97







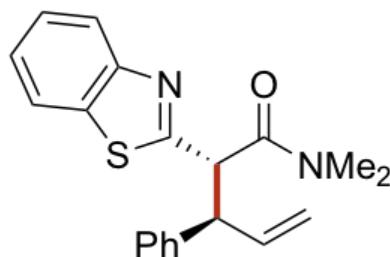
~169.80
~168.24

-152.02
-139.71
-138.67
-135.79
-128.62
-128.54
-126.96
-125.72
-124.91
-122.76
-121.67
-116.90

54.24
52.77
~37.90
~36.34

7.83
7.83
7.82
7.82
7.81
7.76
7.76
7.76
7.75
7.75
7.75
7.75
7.36
7.36
7.35
7.35
7.34
7.34
7.29
7.29
7.28
7.28
7.27
7.27
7.26
7.26
7.23
7.23
7.22
7.22
7.21
7.21
7.17
7.17
7.16
7.16
7.15
7.15
7.14
7.14
7.07
7.07
7.06
7.06
6.13
6.13
6.12
6.12
5.12
5.12
5.12
5.12
5.11
5.11
5.10
5.10
5.08
5.08
5.07
5.07
5.03
5.03
5.01
5.01
4.39
4.39
4.38
4.38
4.36
4.36
3.19
3.19
2.99

S82



1.00
1.01
1.07
1.09
2.00
2.07
1.01

1.05

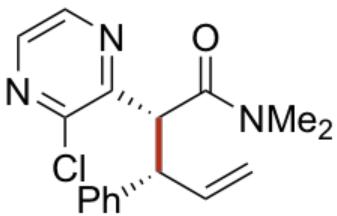
2.08
1.01

1.05

3.04
3.08

10.0 9.5 9.0 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

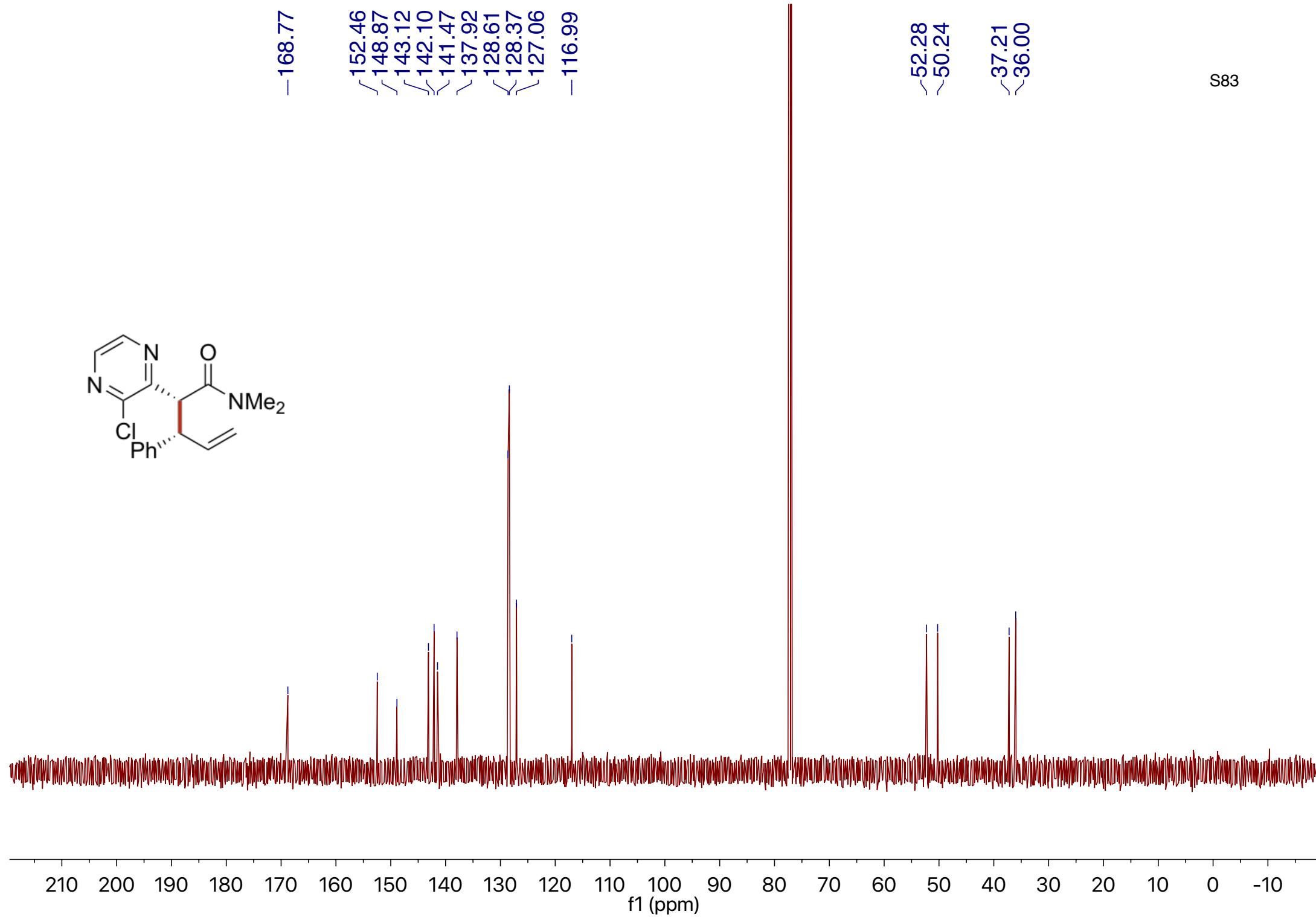
f1 (ppm)

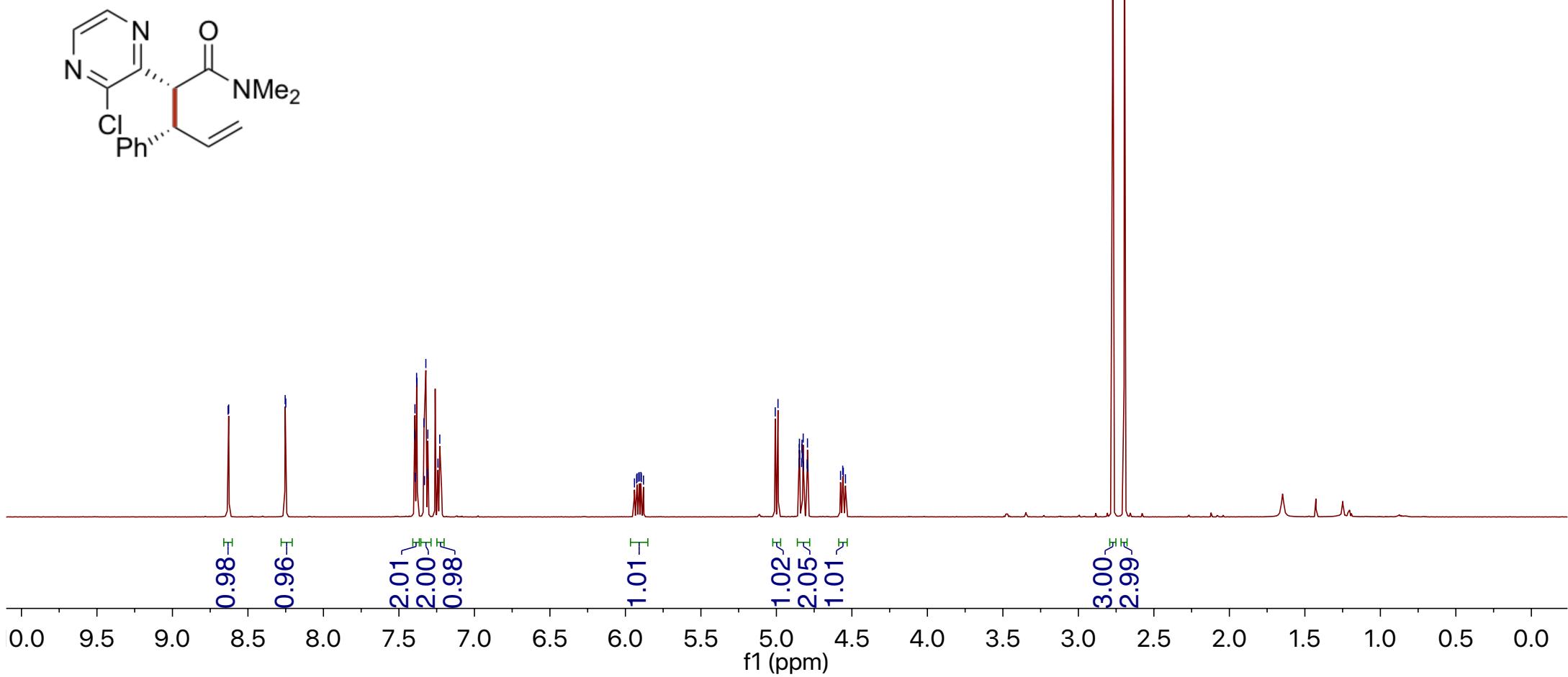
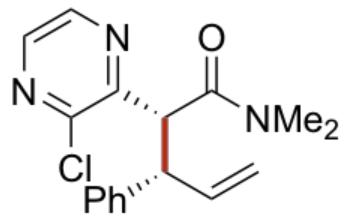
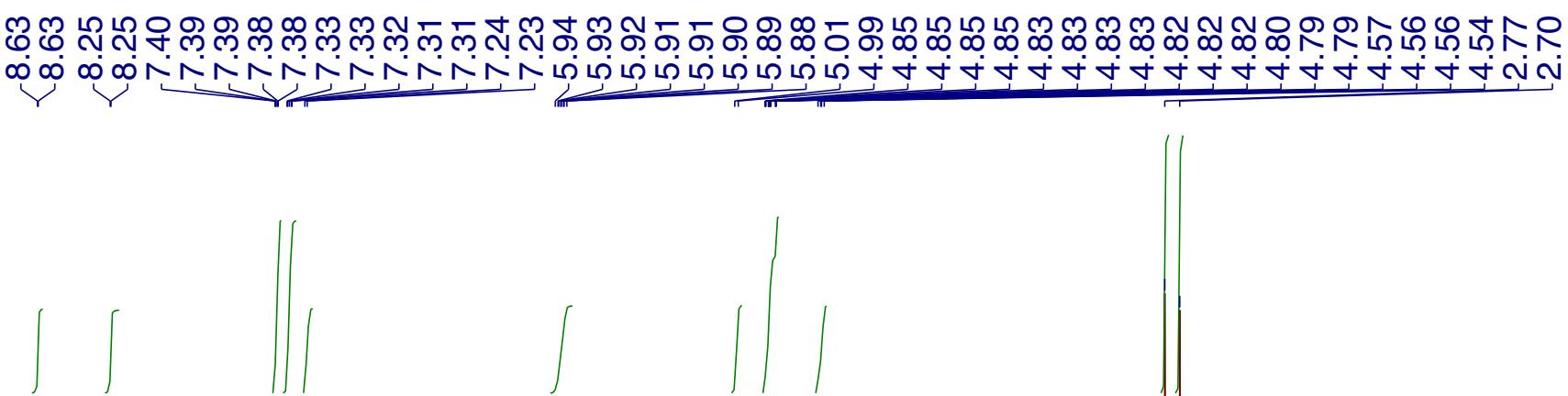


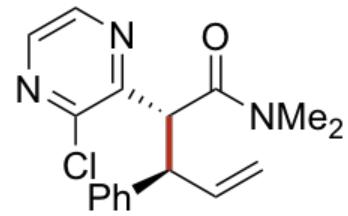
-168.77

152.46
148.87
143.12
142.10
141.47
137.92
128.61
128.37
127.06
-116.99

52.28
50.24
37.21
36.00







-169.33

151.88
148.52
142.76
141.88
140.23
138.87
128.60
128.35
126.80
-116.75

52.02
~49.78
37.76
~36.39

S85

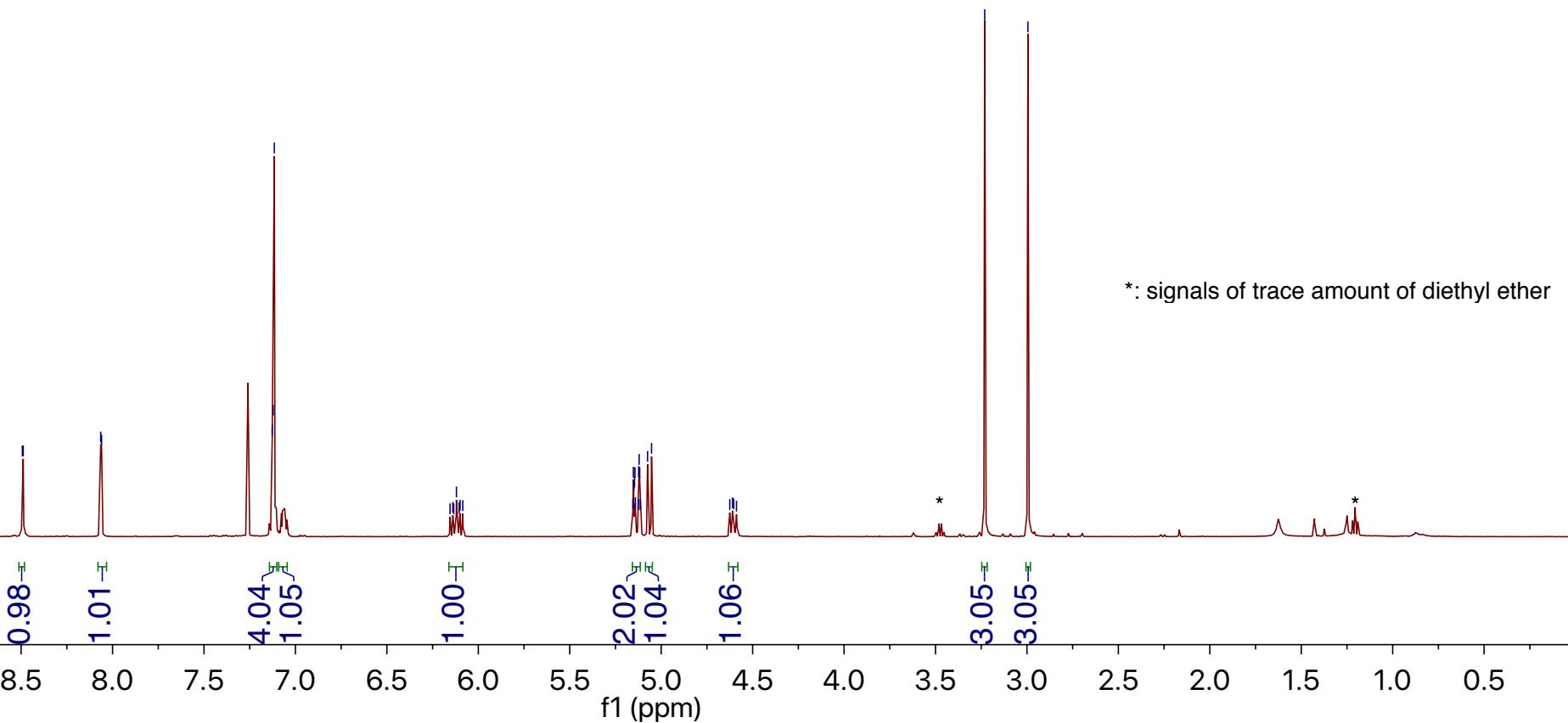
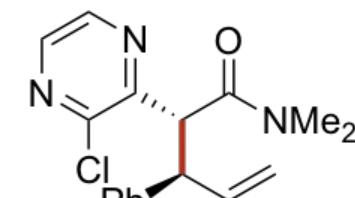
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

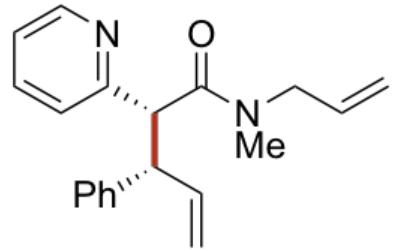
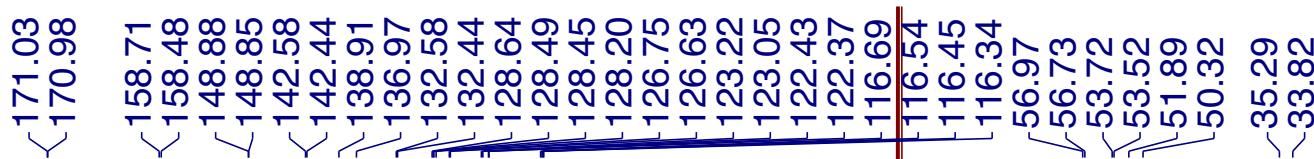
f1 (ppm)

8.49
8.49
8.06
8.06

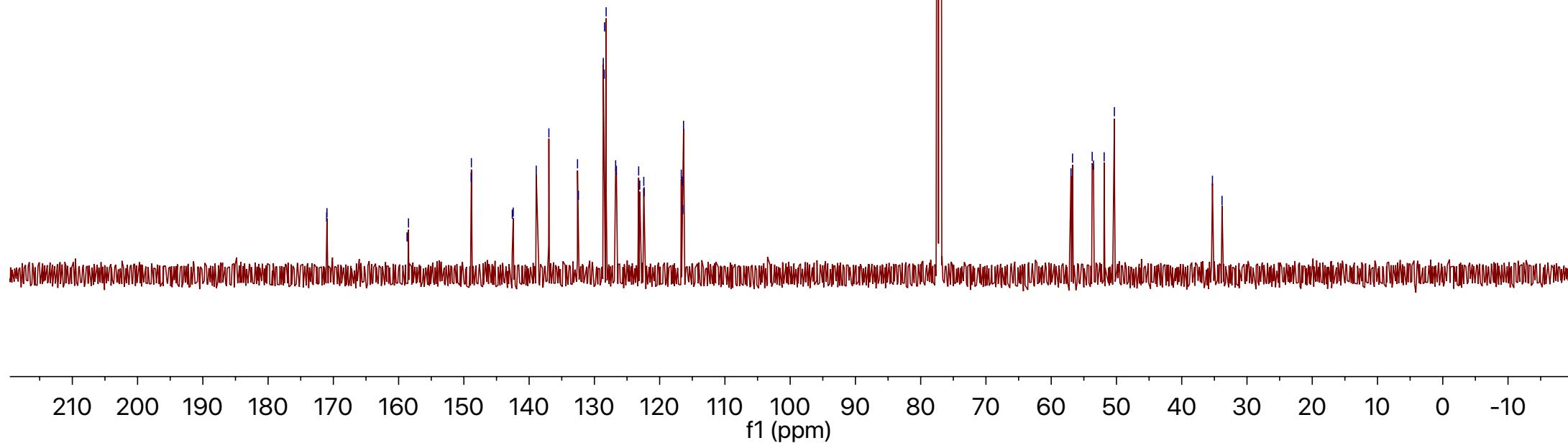
7.13
7.12
7.12
6.15
6.14
6.13
6.12
6.10
6.10
6.08
5.15
5.15
5.14
5.14
5.13
5.12
5.12
5.11
5.07
5.07
4.63
4.61
4.60
4.59
3.23
2.99

S86



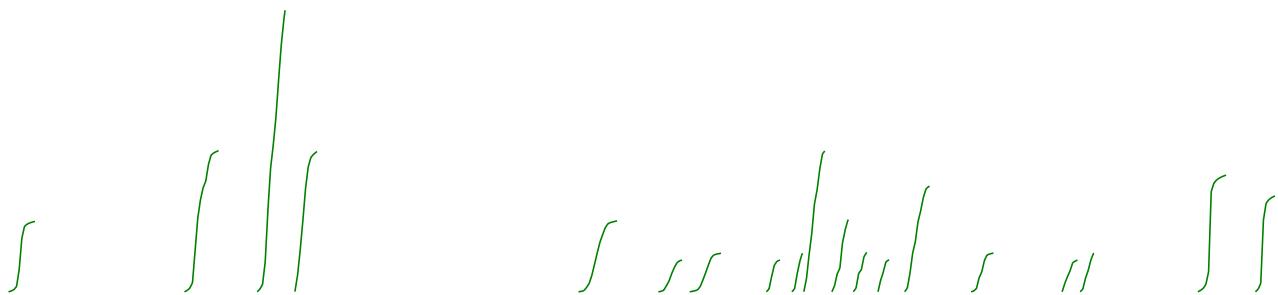


3ea exists as a mixture of two rotomers (1.2:1 ratio, or 55:45 ratio)

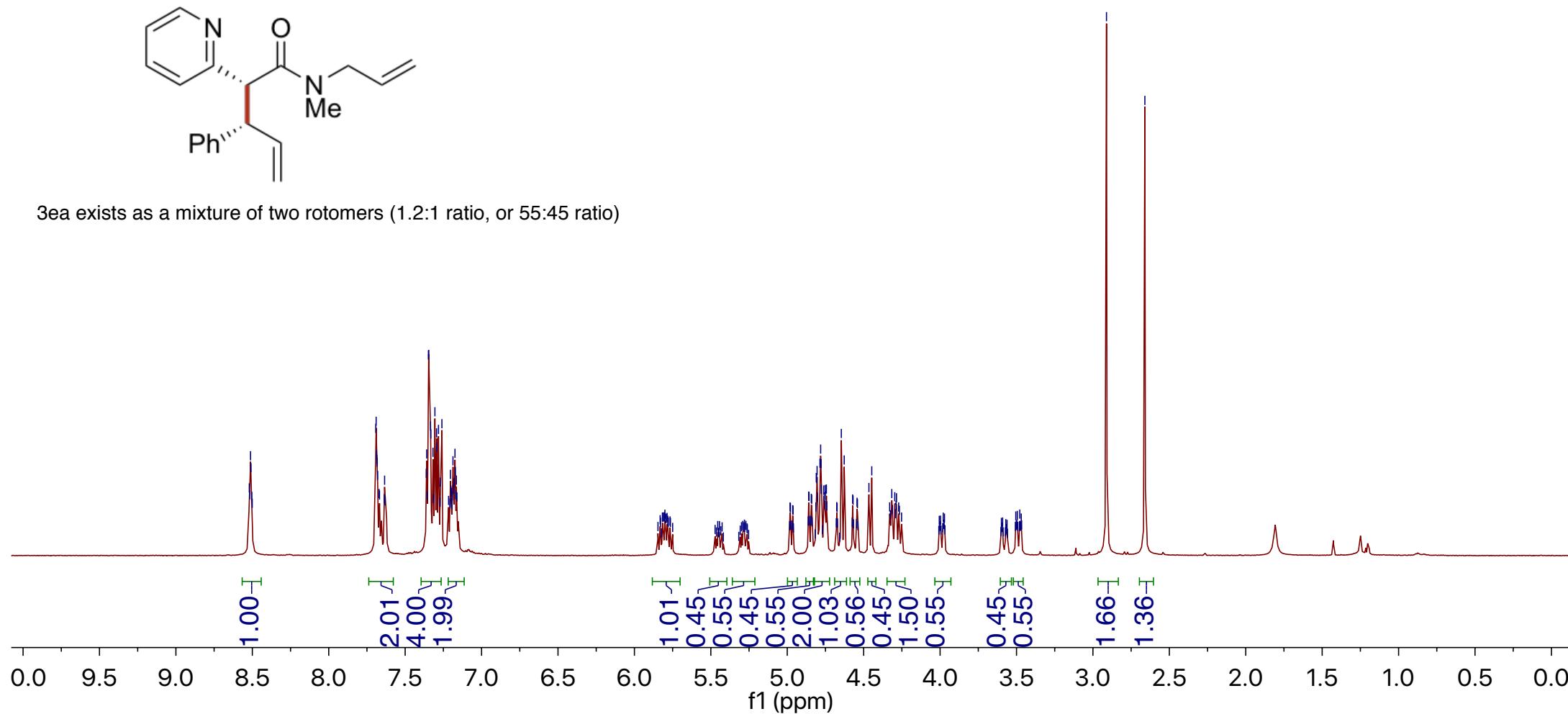


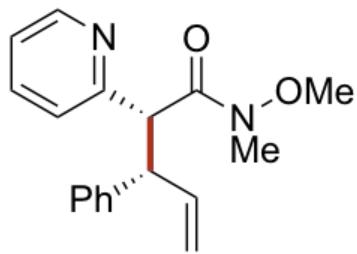
8.52
8.51
8.51
8.50
7.69
7.69
7.69
7.68
7.68
7.67
7.67
7.63
7.36
7.36
7.35
7.35
7.33
7.33
7.32
7.31
7.29
7.29
7.28
7.27
7.26
7.20
7.20
7.19
7.19
7.18
7.18
7.17
7.17
7.16
4.86
4.81
4.80
4.79
4.78
4.78
4.75
4.75
4.65
4.63
4.47
4.45
4.32
2.91
2.66

S88



3ea exists as a mixture of two rotomers (1.2:1 ratio, or 55:45 ratio)





-172.36

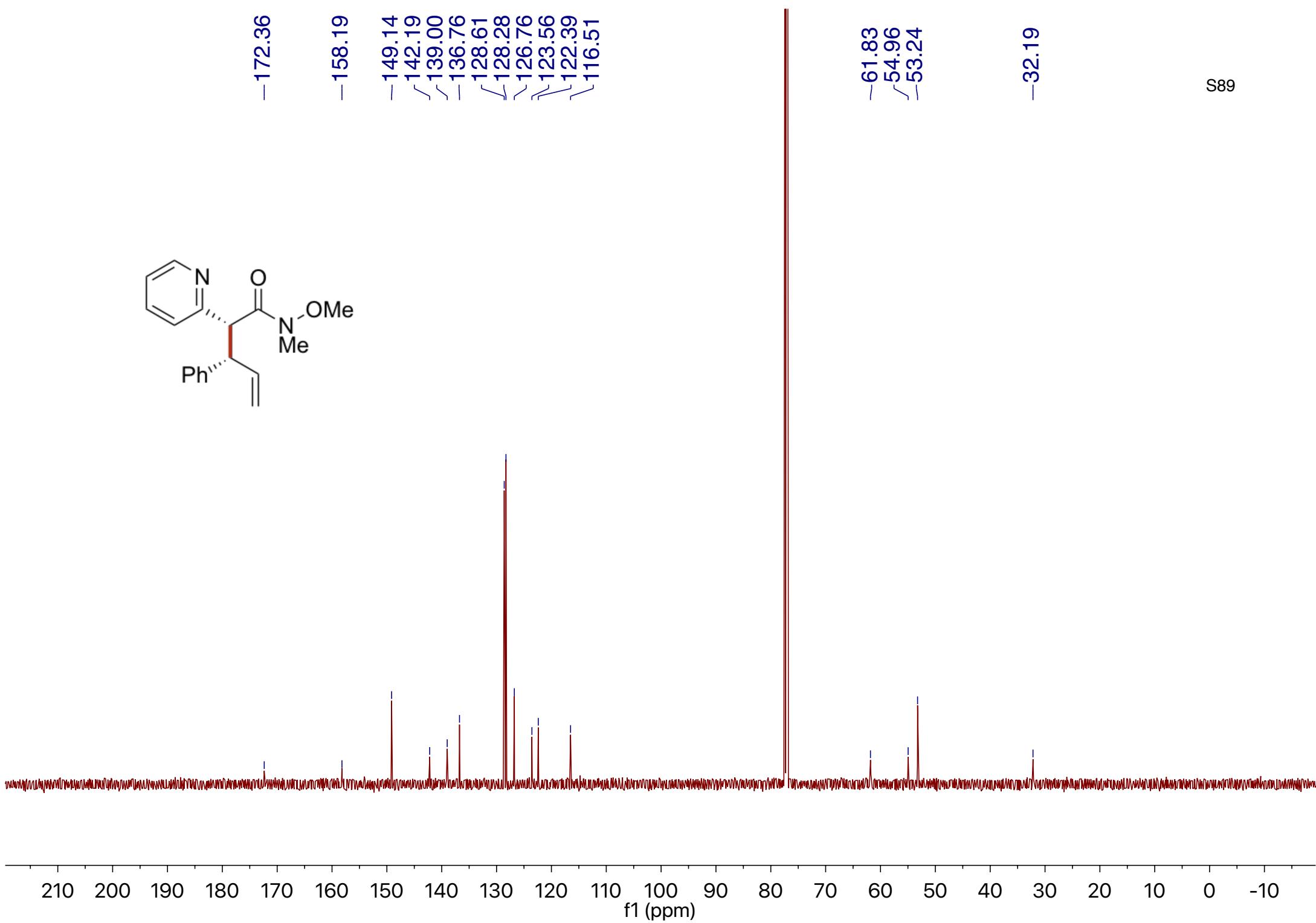
-158.19

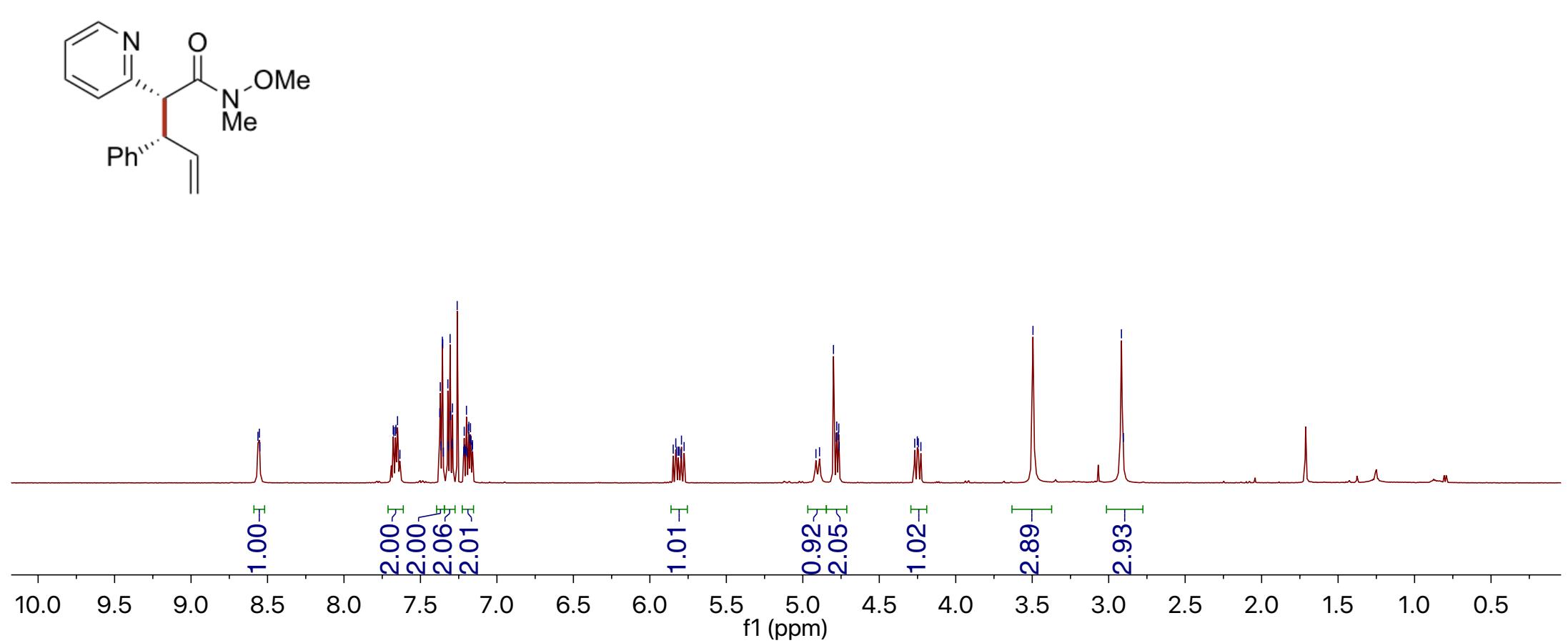
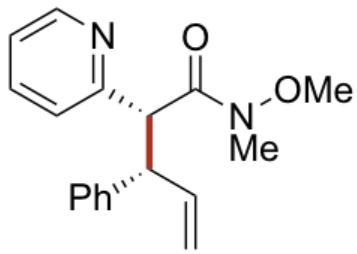
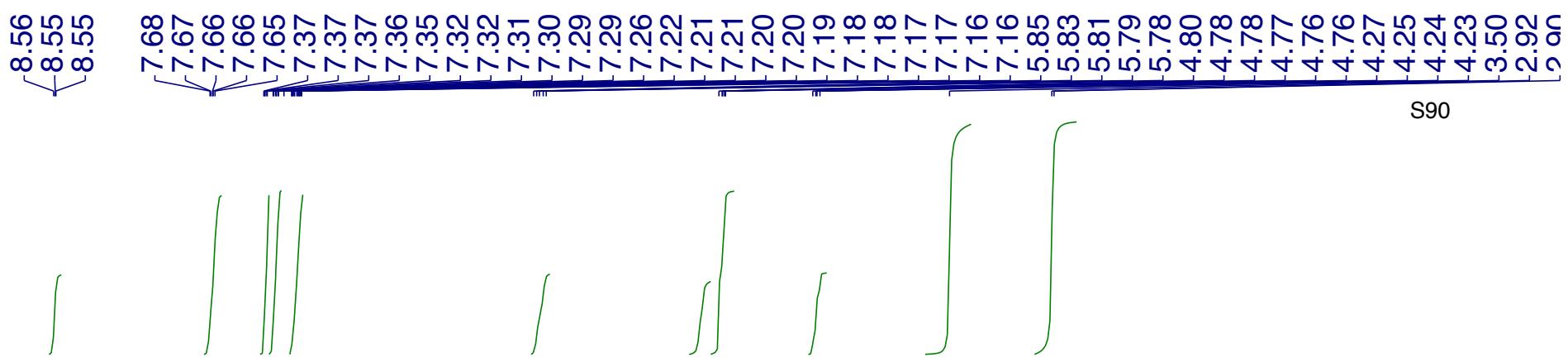
-149.14
-142.19
-139.00
-136.76
-128.61
-128.28
-126.76
-123.56
-122.39
-116.51

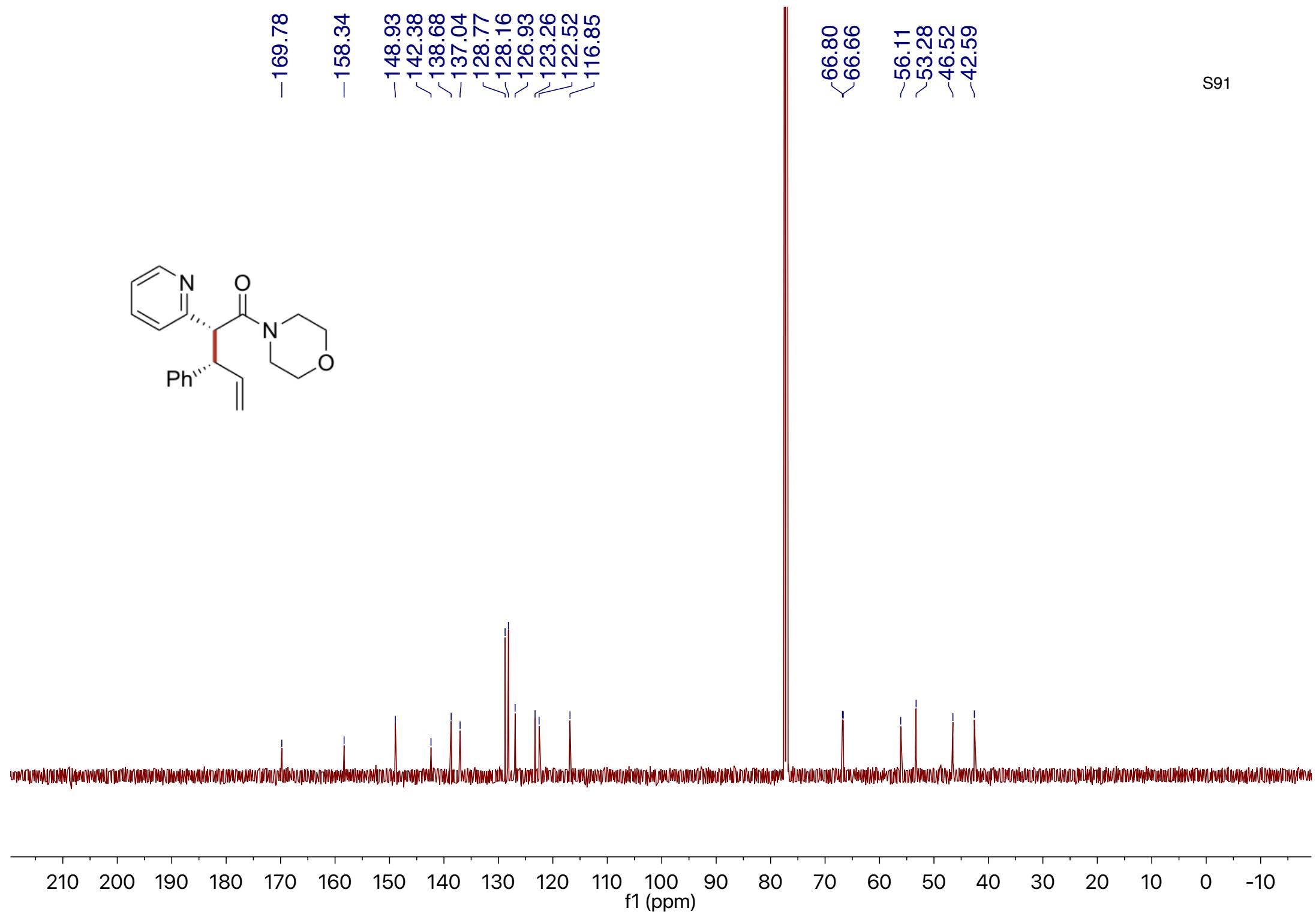
-61.83
-54.96
-53.24

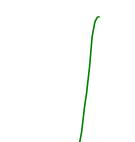
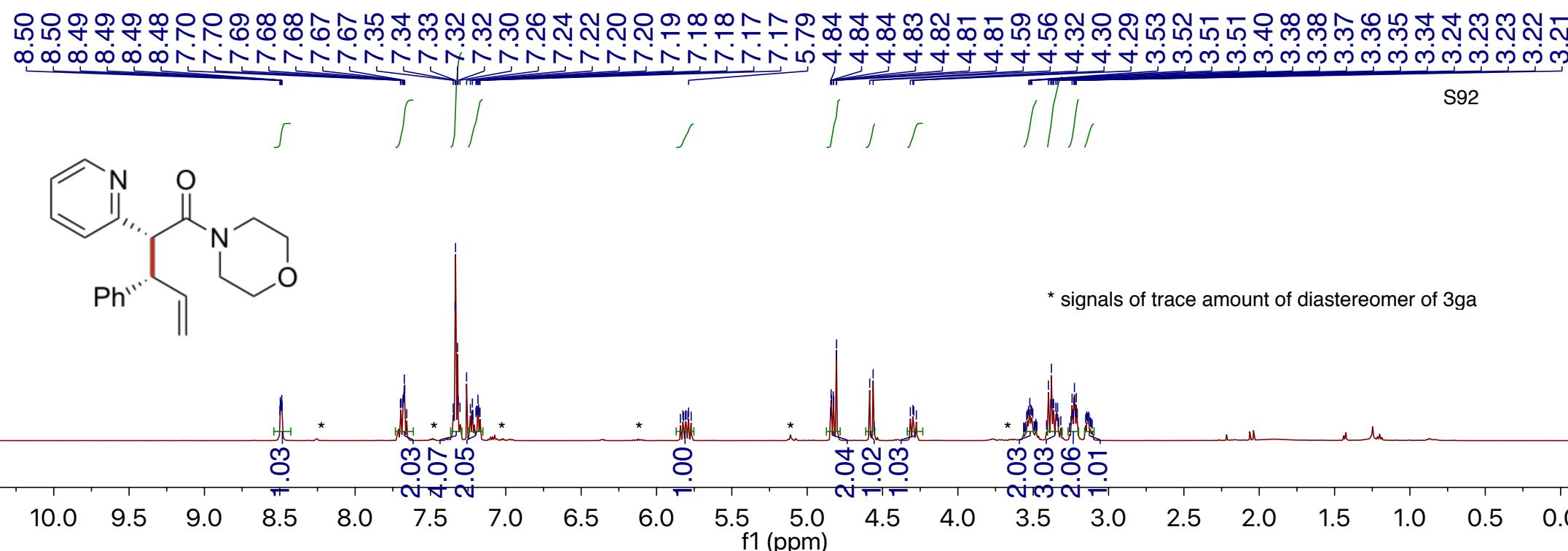
-32.19

S89

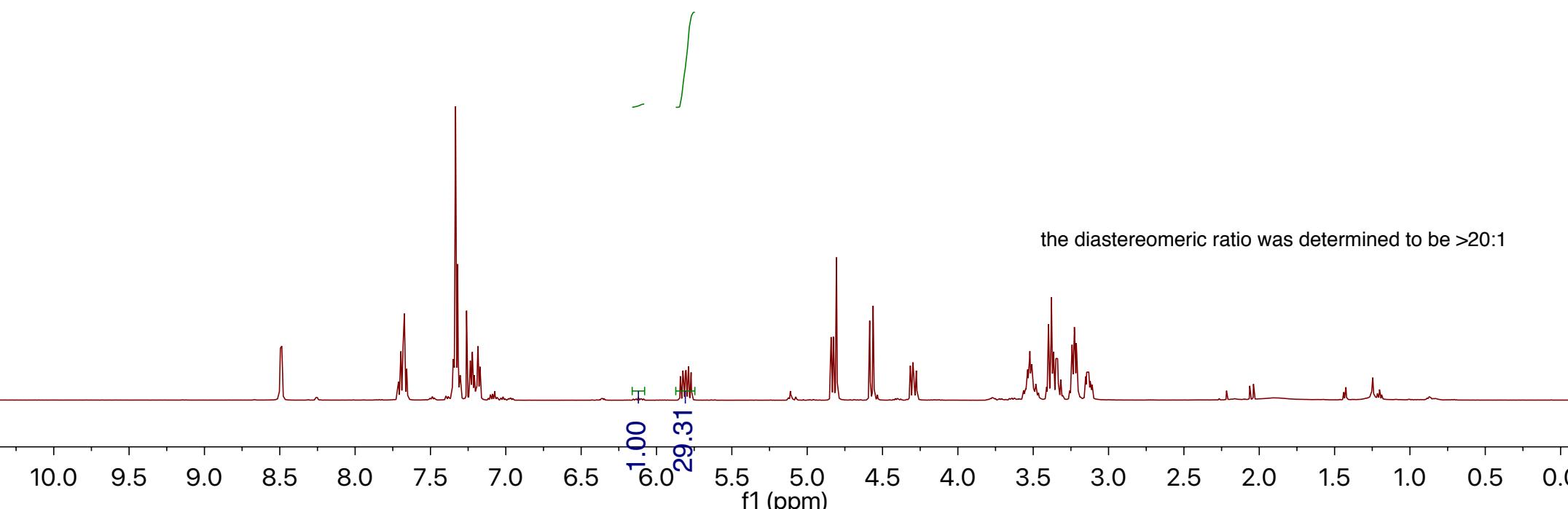


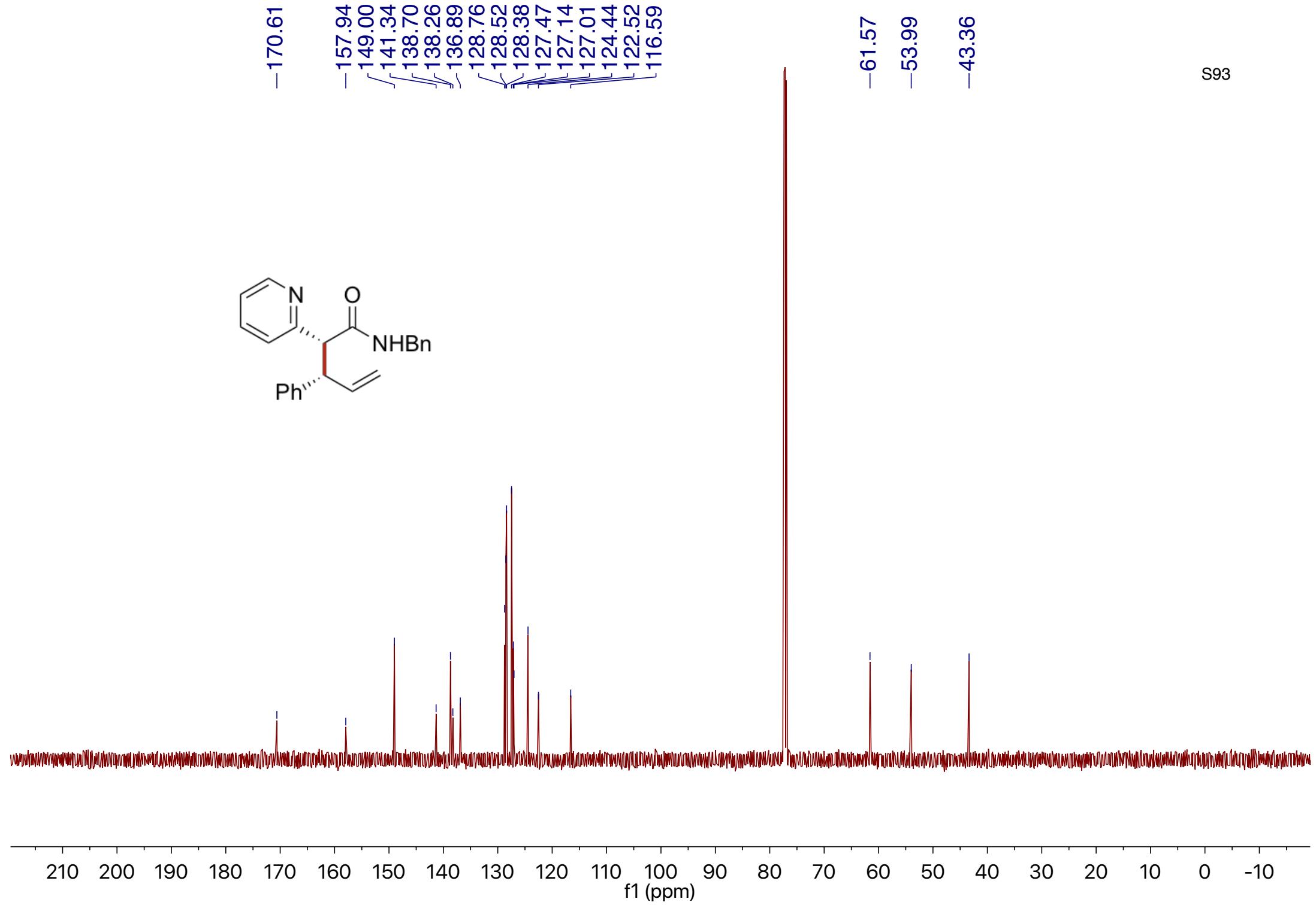




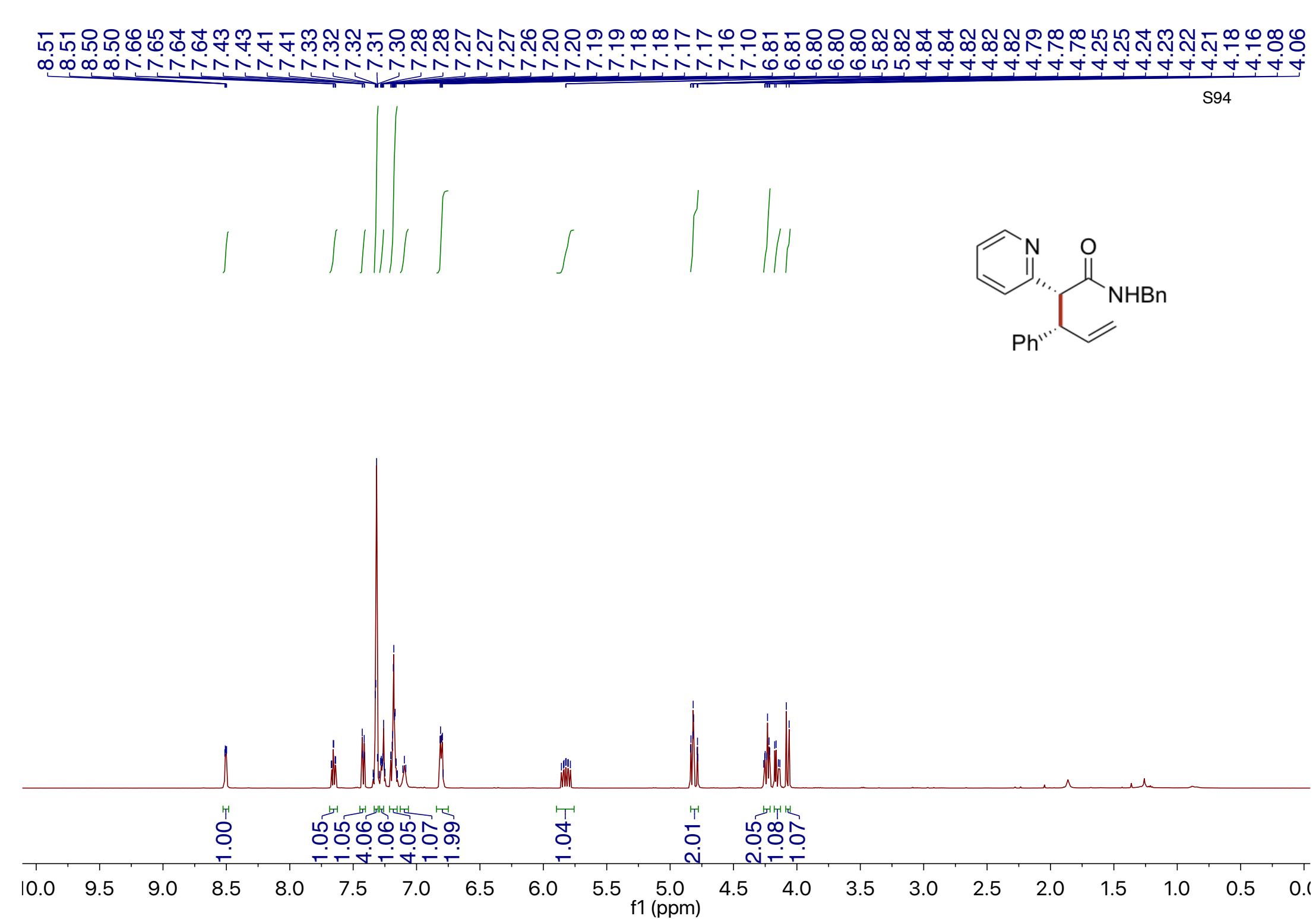


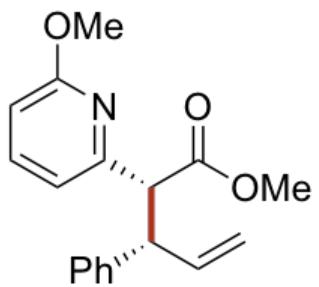
the diastereomeric ratio was determined to be >20:1





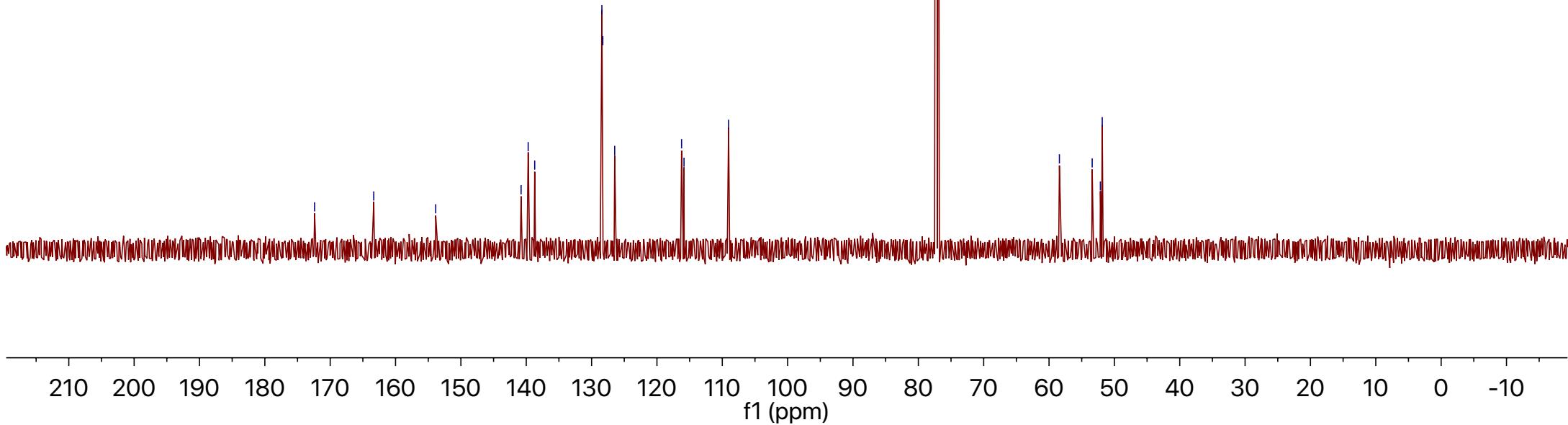
S93

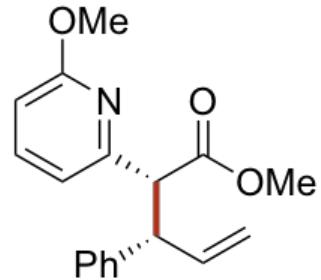
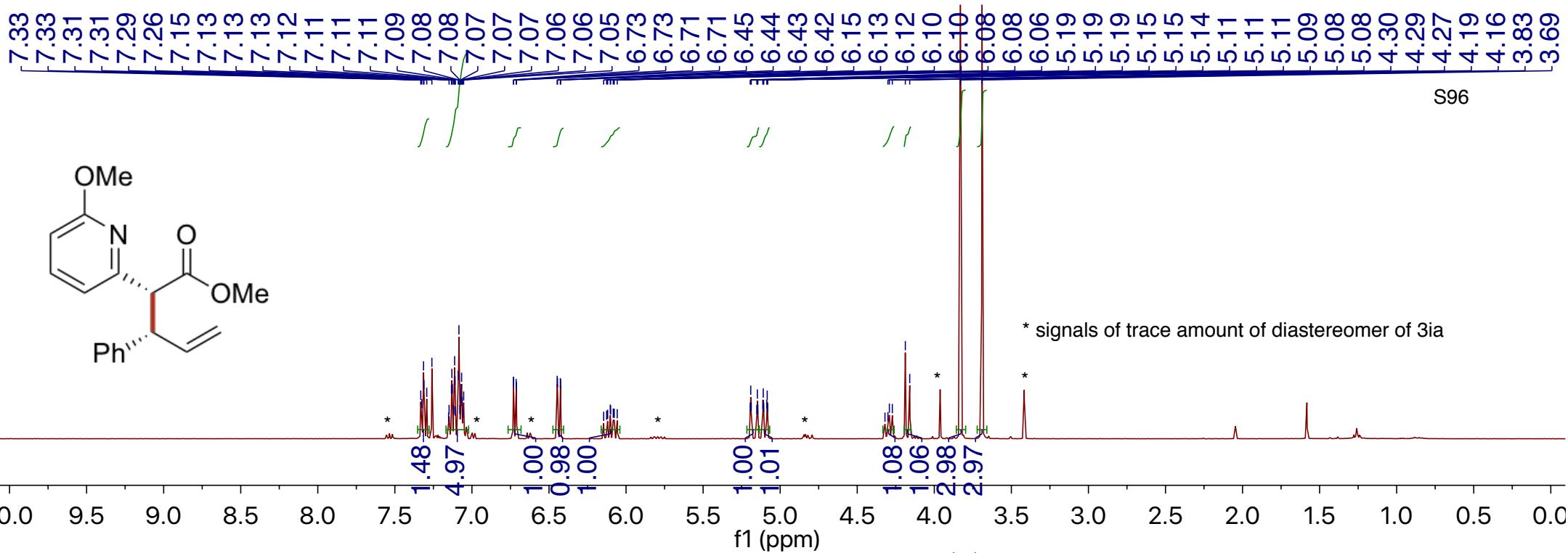




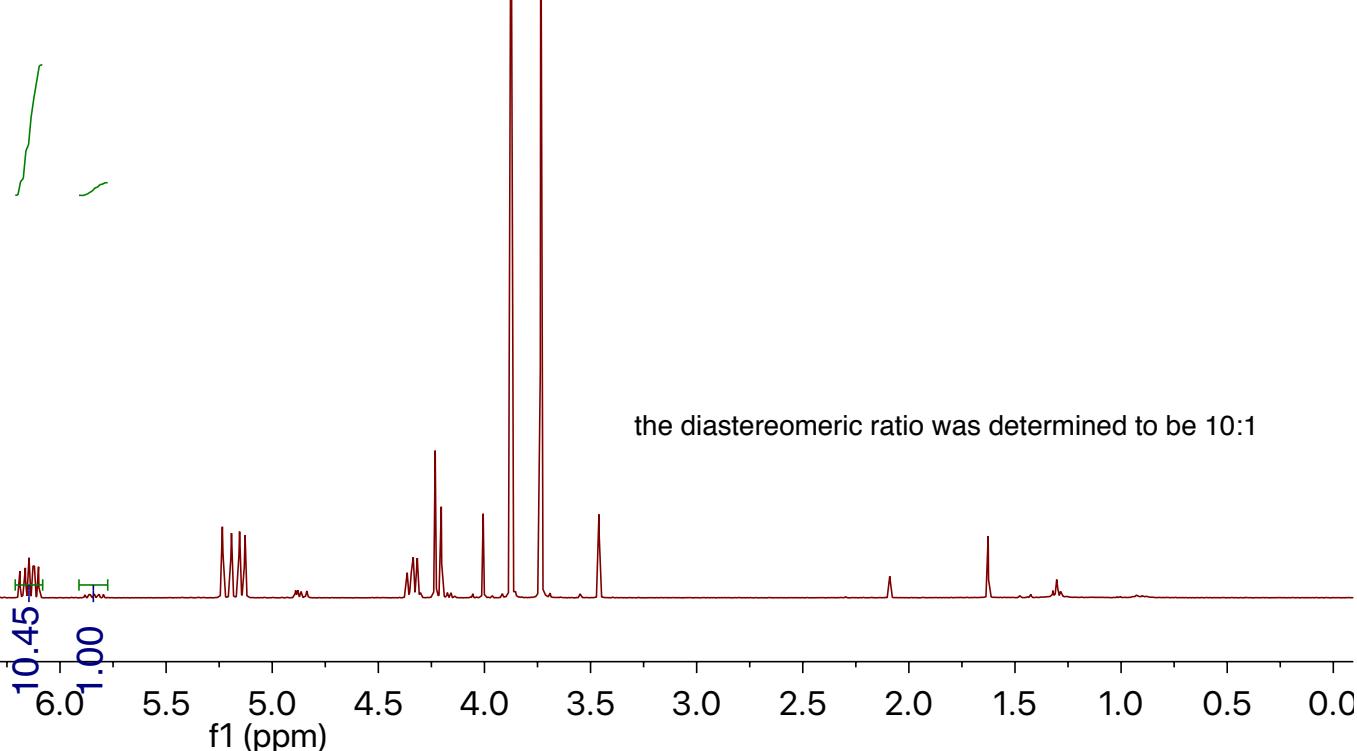
Peak list for the ¹³C NMR spectrum:

| | | |
|---------|----------|----------|
| -172.39 | -163.33 | -153.85 |
| ~140.79 | / 139.70 | \ 138.71 |
| | / 128.43 | \ 128.28 |
| | / 126.47 | \ 126.47 |
| | ~116.23 | \ 115.86 |
| | ~115.86 | \ 115.86 |
| | ~109.04 | |





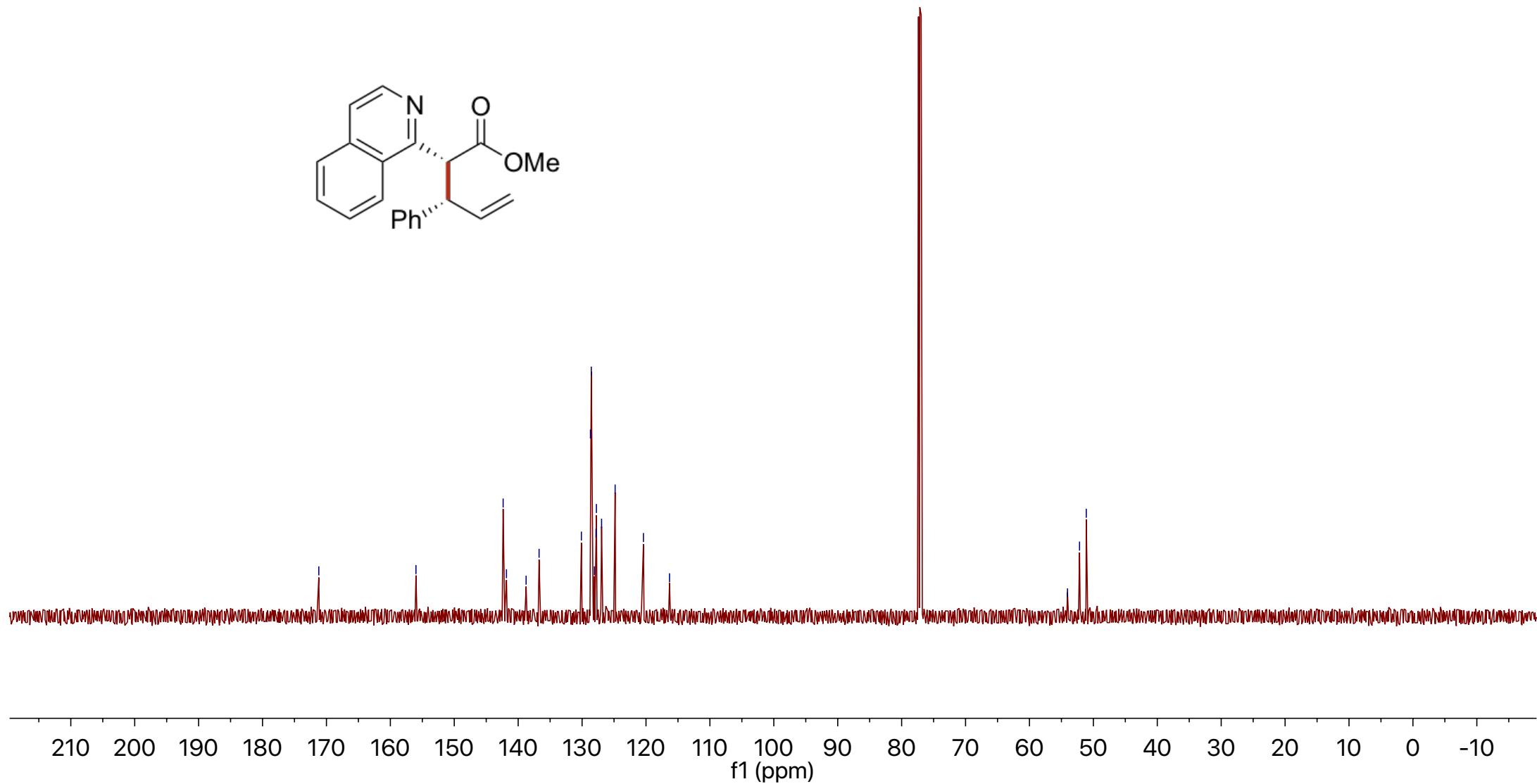
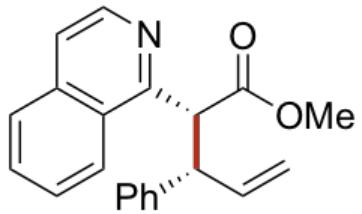
* signals of trace amount of diastereomer of 3ia

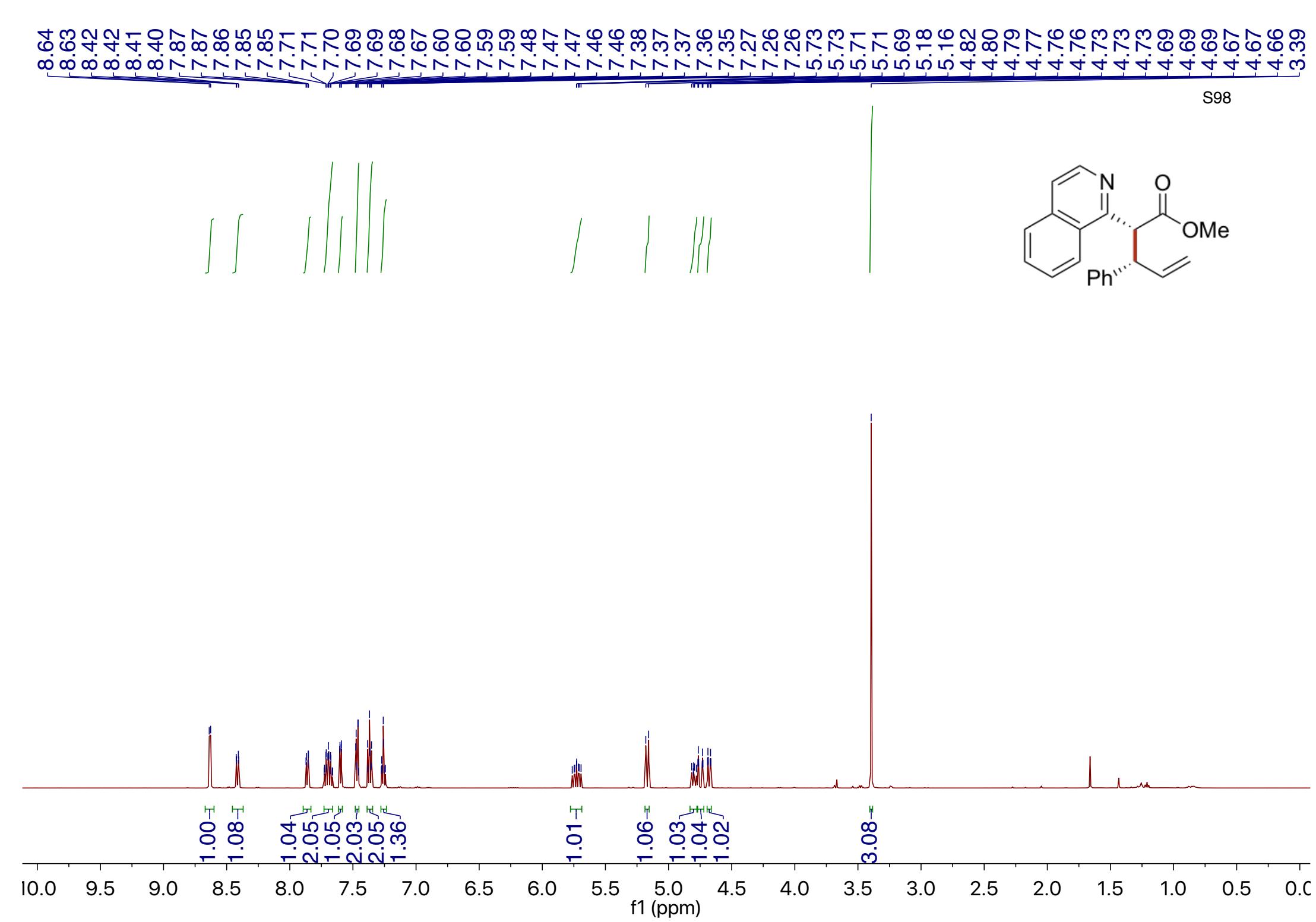


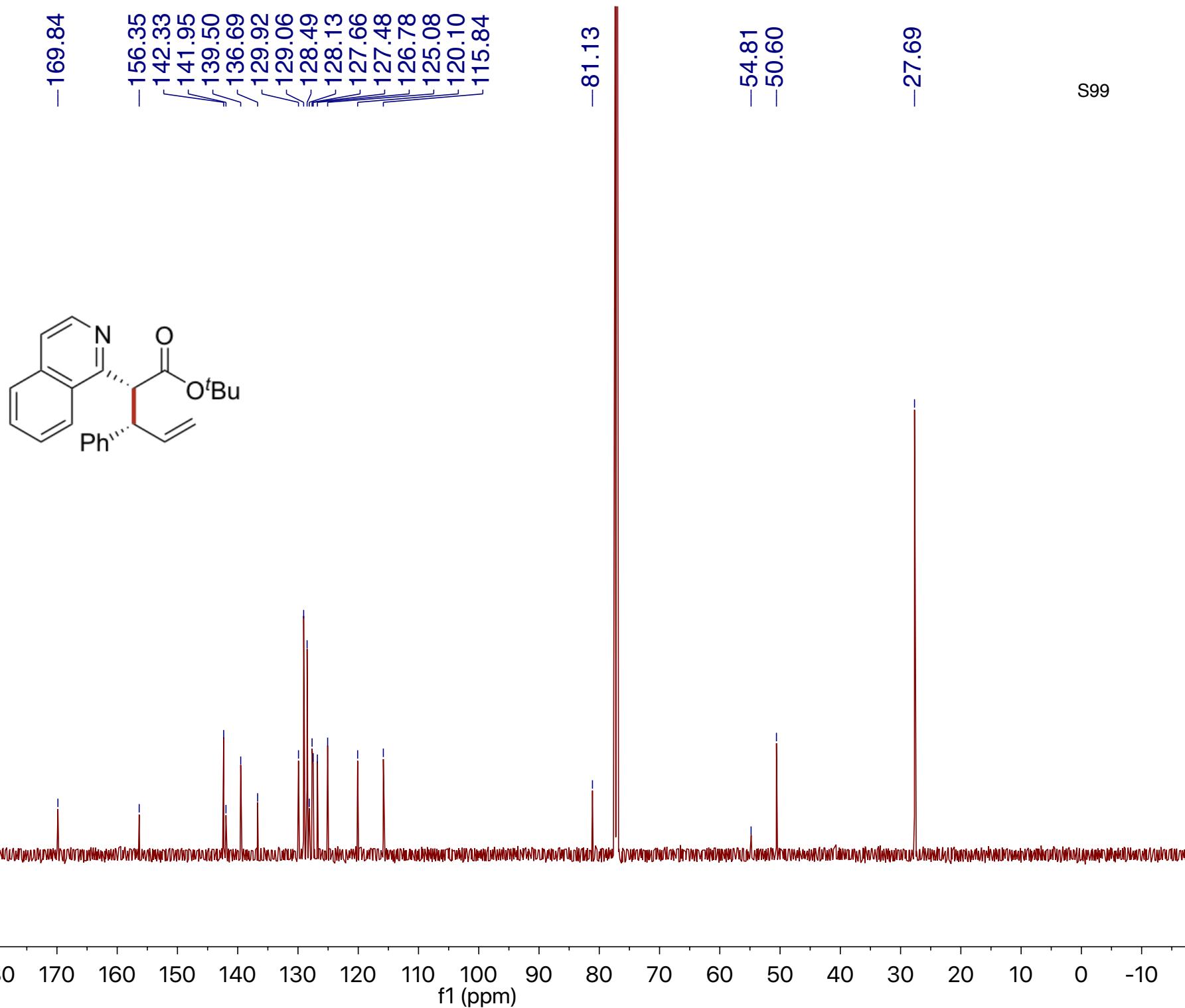
-171.19

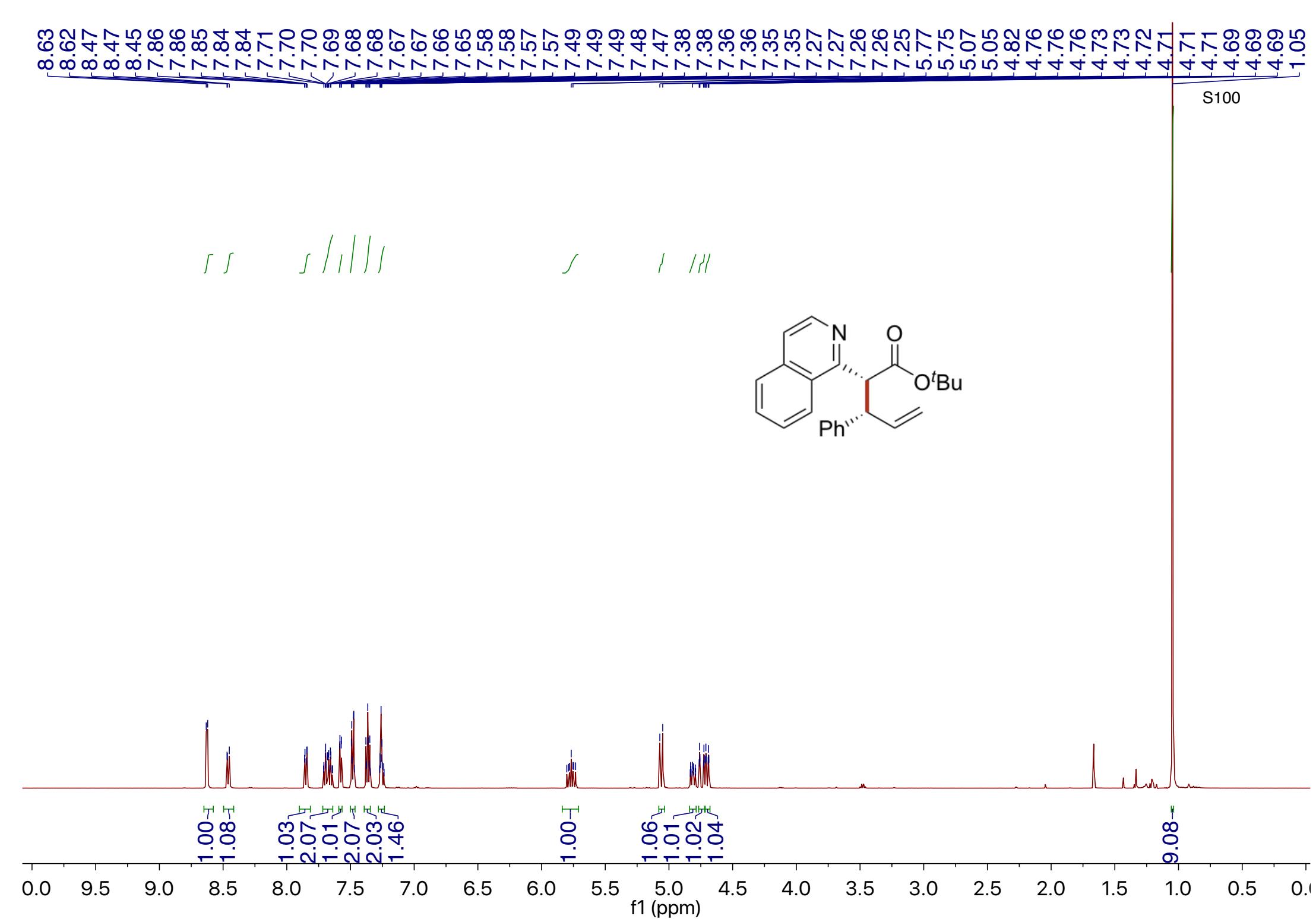
-155.99
-142.35
-141.83
-138.76
-136.73
-130.11
-128.69
-128.56
-128.07
-127.82
-127.76
-126.95
-124.83
-120.40
-116.32

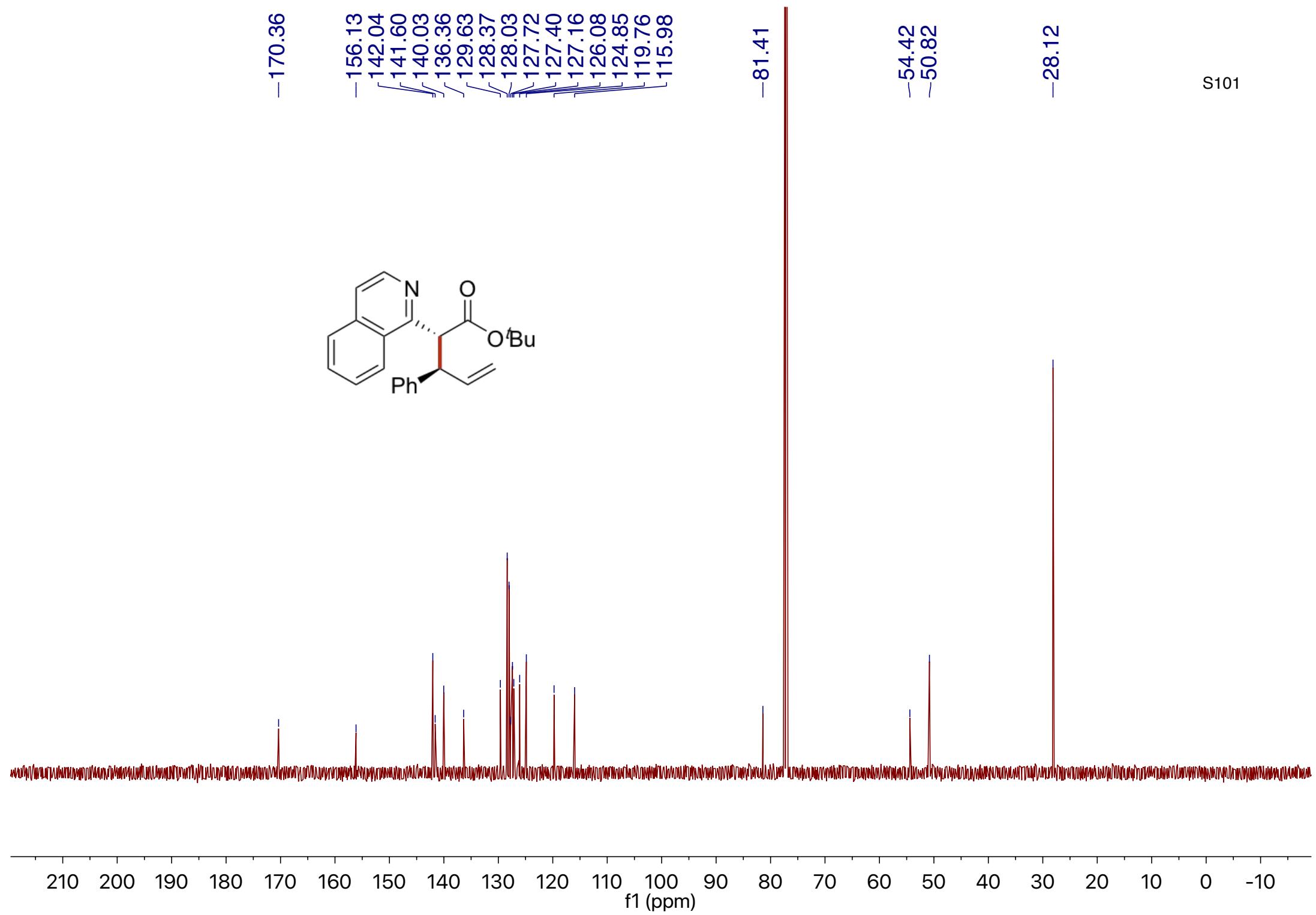
54.05
52.16
51.11



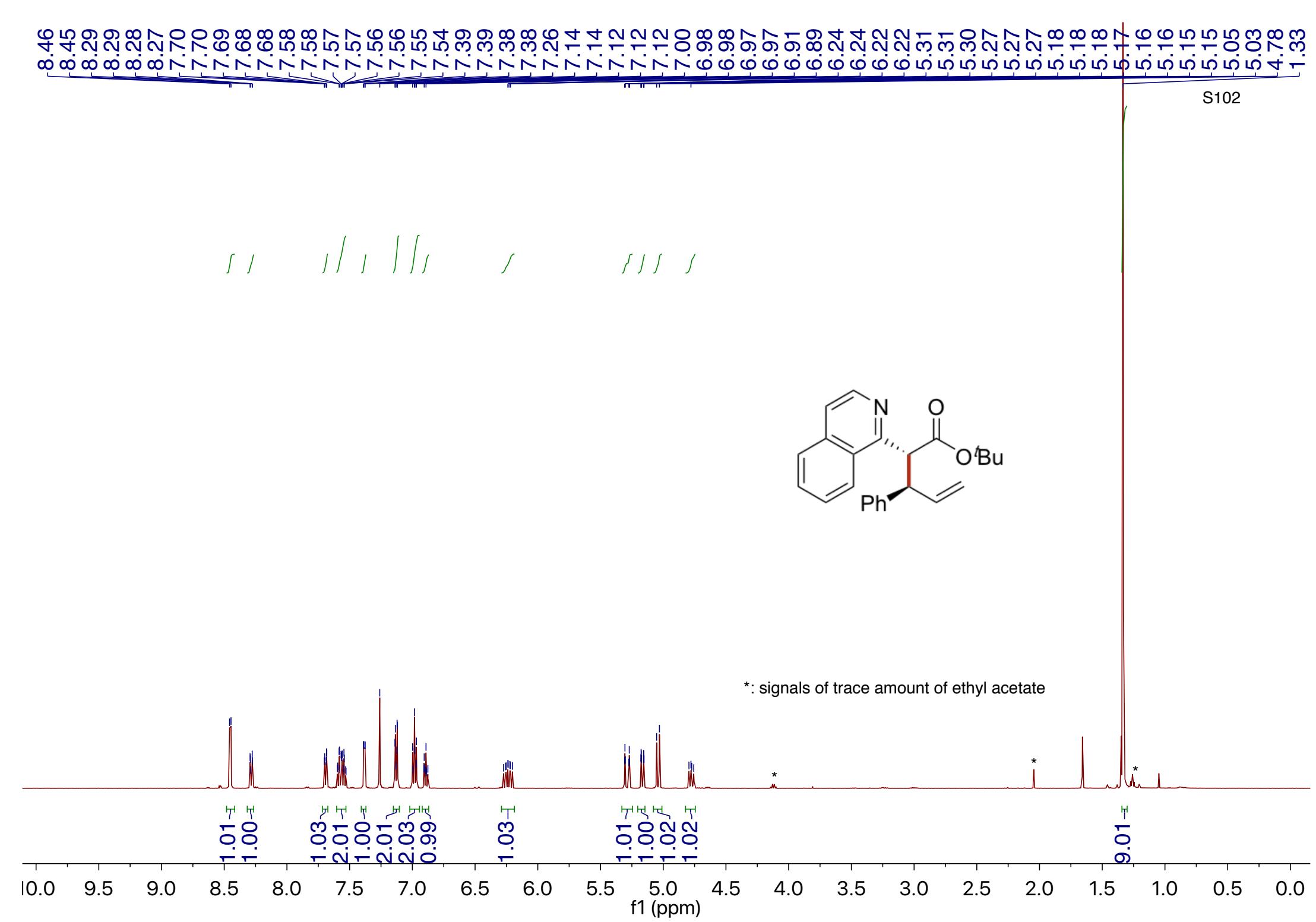


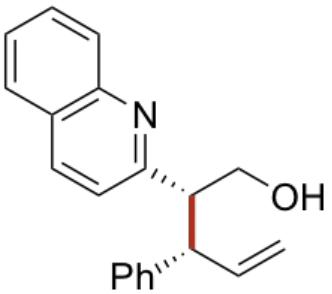






S101

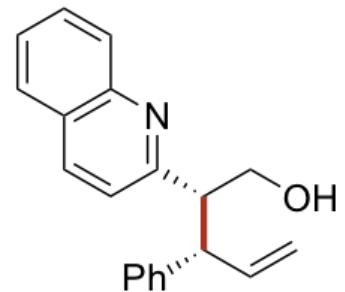
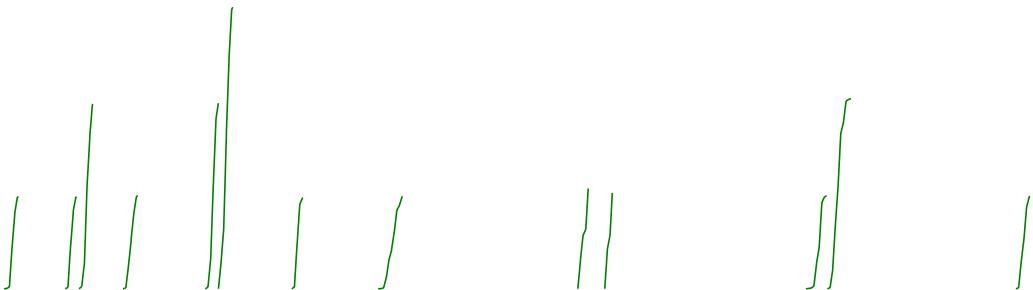




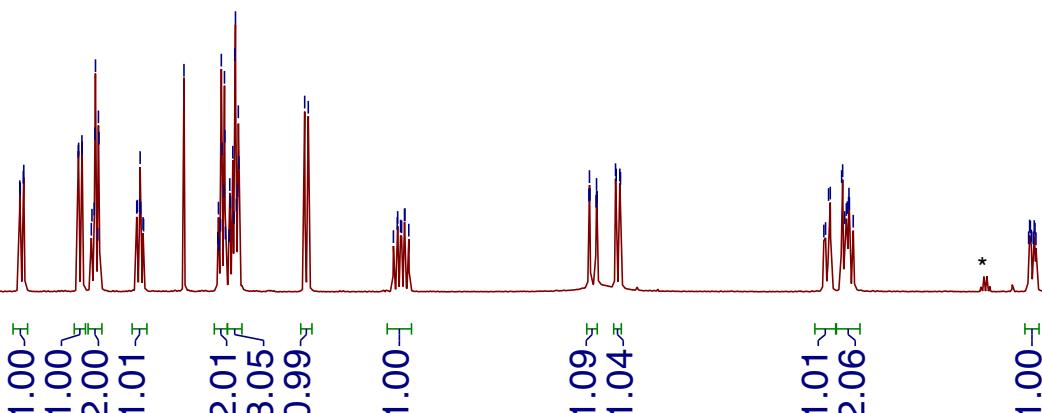
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

8.03
8.02
8.02
7.76
7.76
7.74
7.74
7.69
7.68
7.68
7.66
7.66
7.48
7.47
7.47
7.46
7.26
7.10
7.08
7.07
7.07
7.07
7.08
7.07
7.07
7.03
7.02
7.02
7.01
7.01
6.69
6.67
6.67
6.22
6.22
5.35
5.35
5.32
5.31
5.23
5.22
4.21
4.21
4.16
4.15
4.14
4.13
4.12
4.12

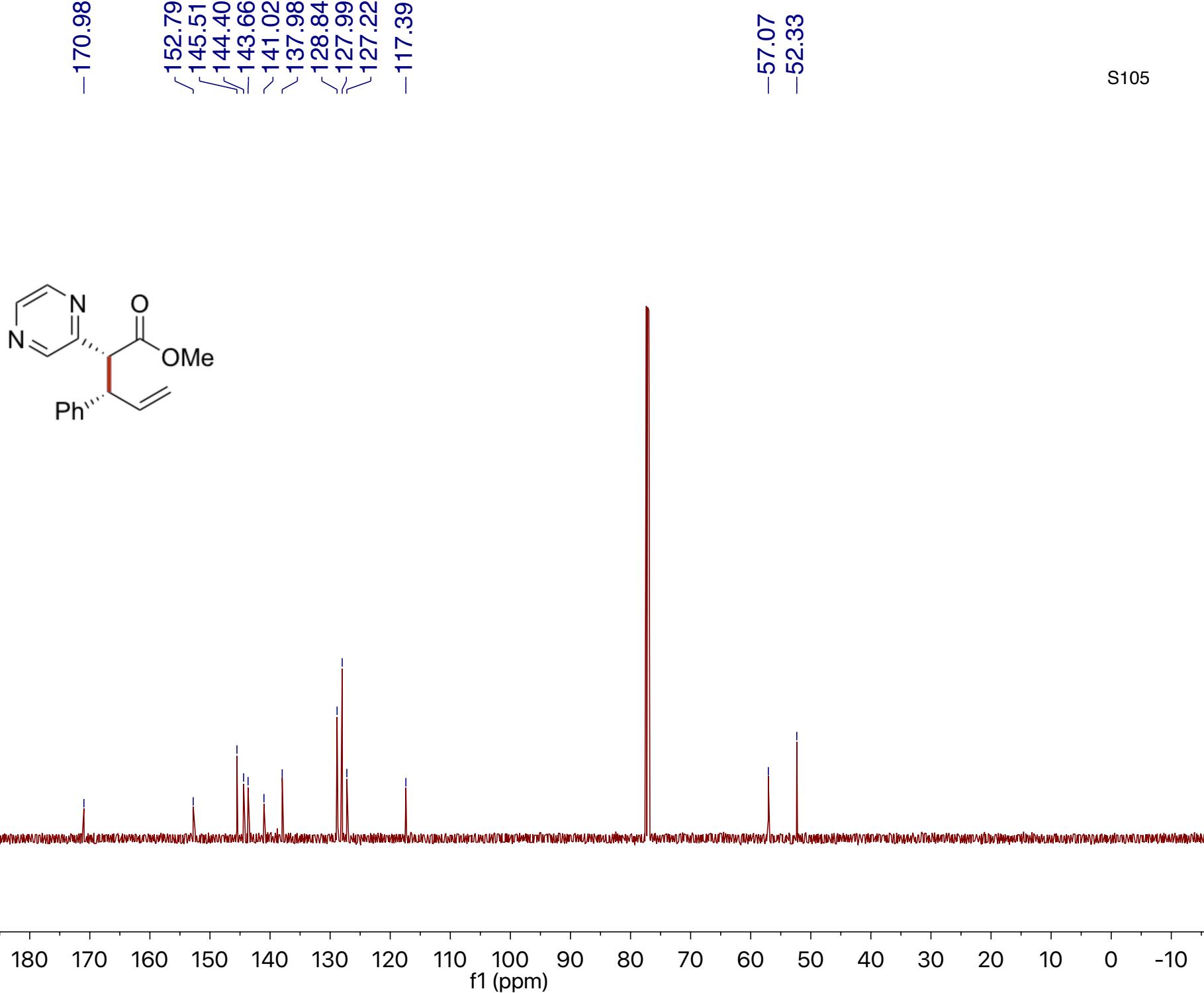
S104

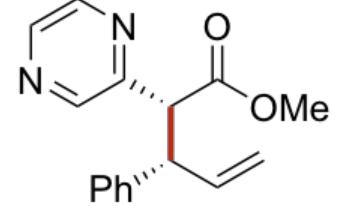
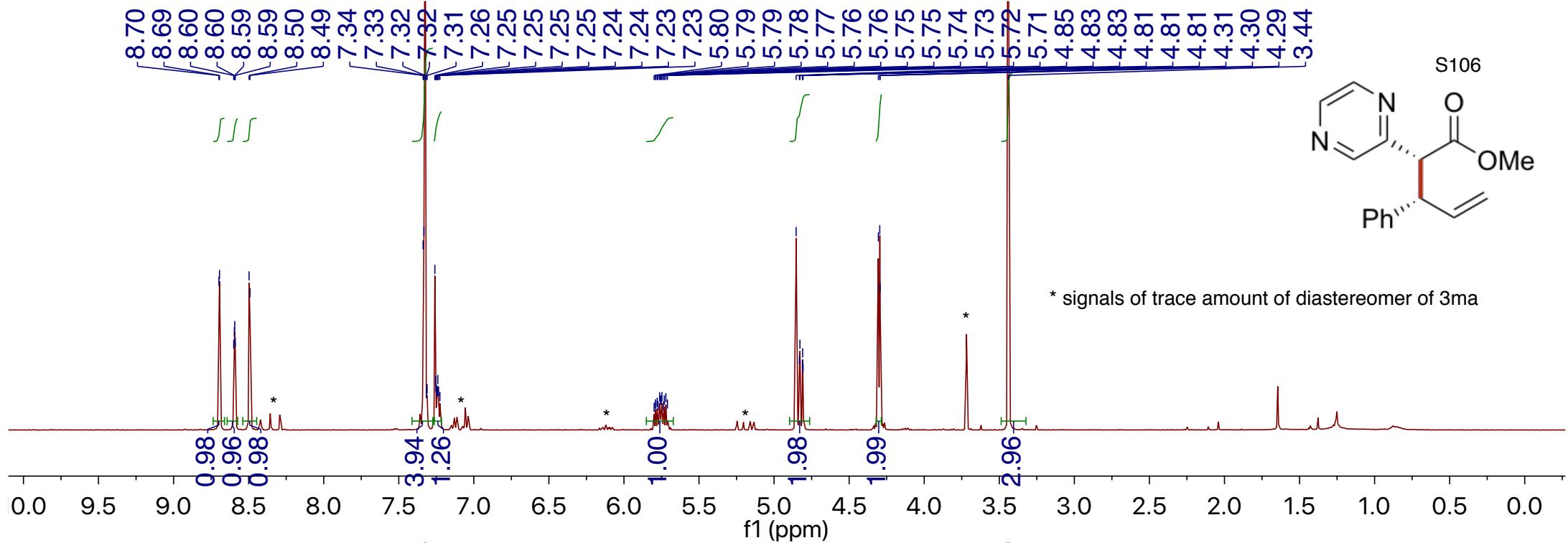


*: signals of trace amount of diethyl ether

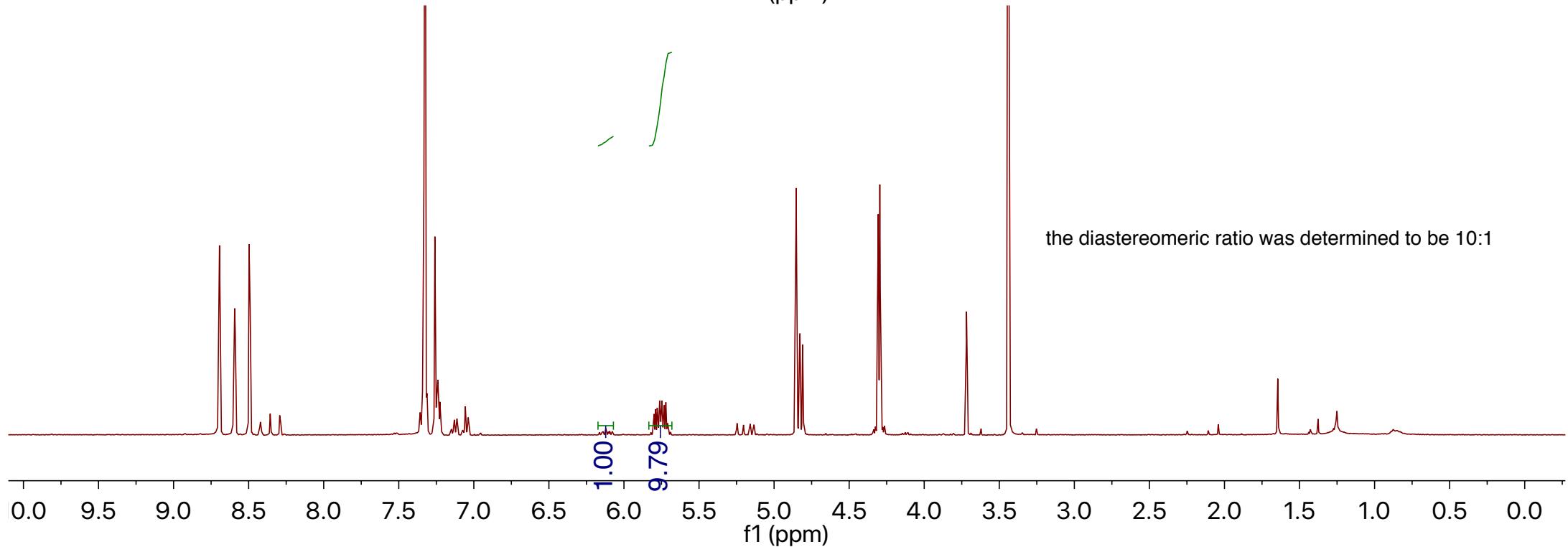


1.00
1.00
2.00
1.01
2.01
3.05
0.99
0.99
1.00
1.09
1.04
1.01
2.06
1.00





* signals of trace amount of diastereomer of 3ma



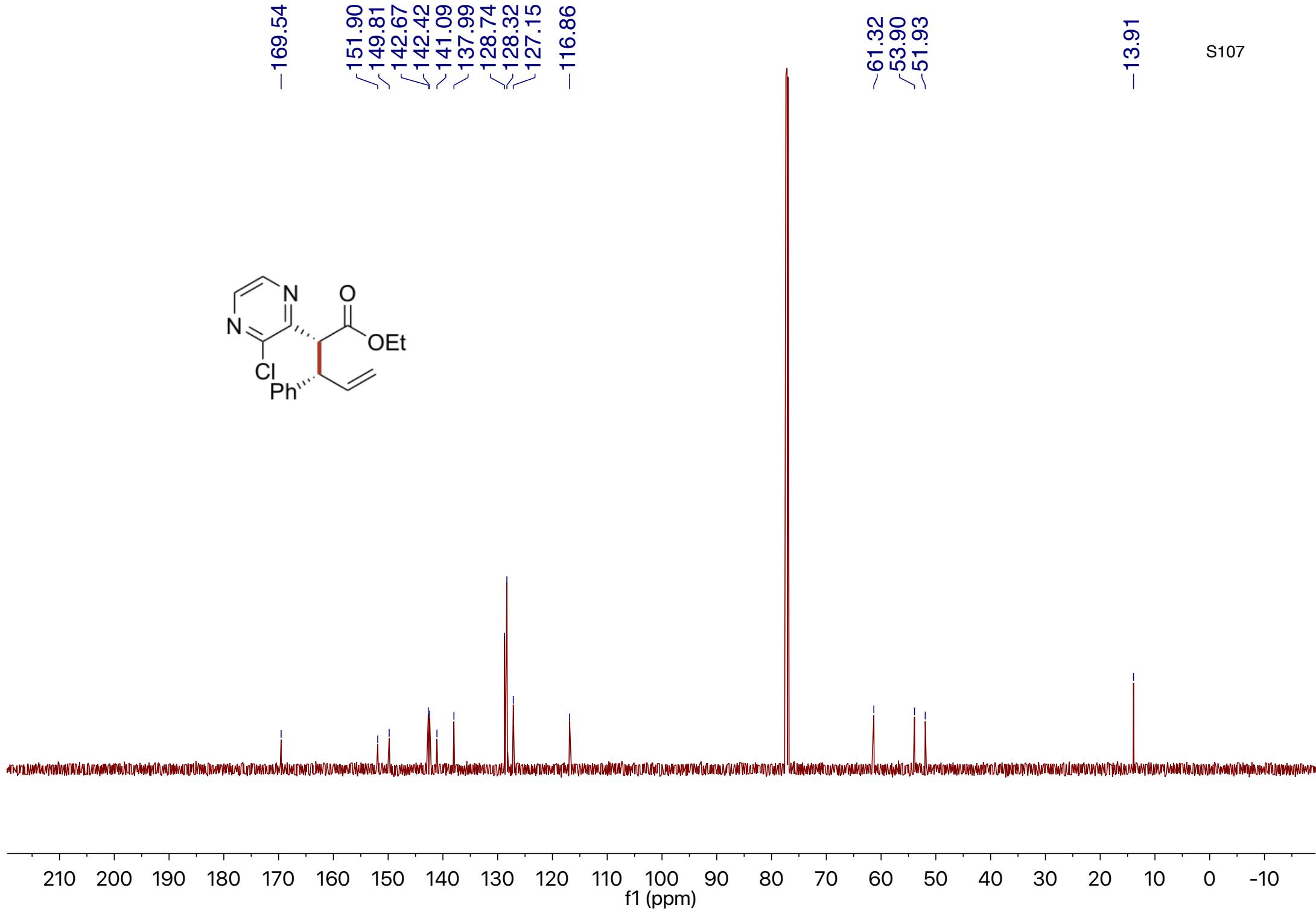
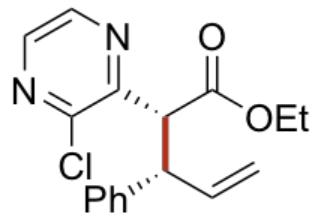
-13.91

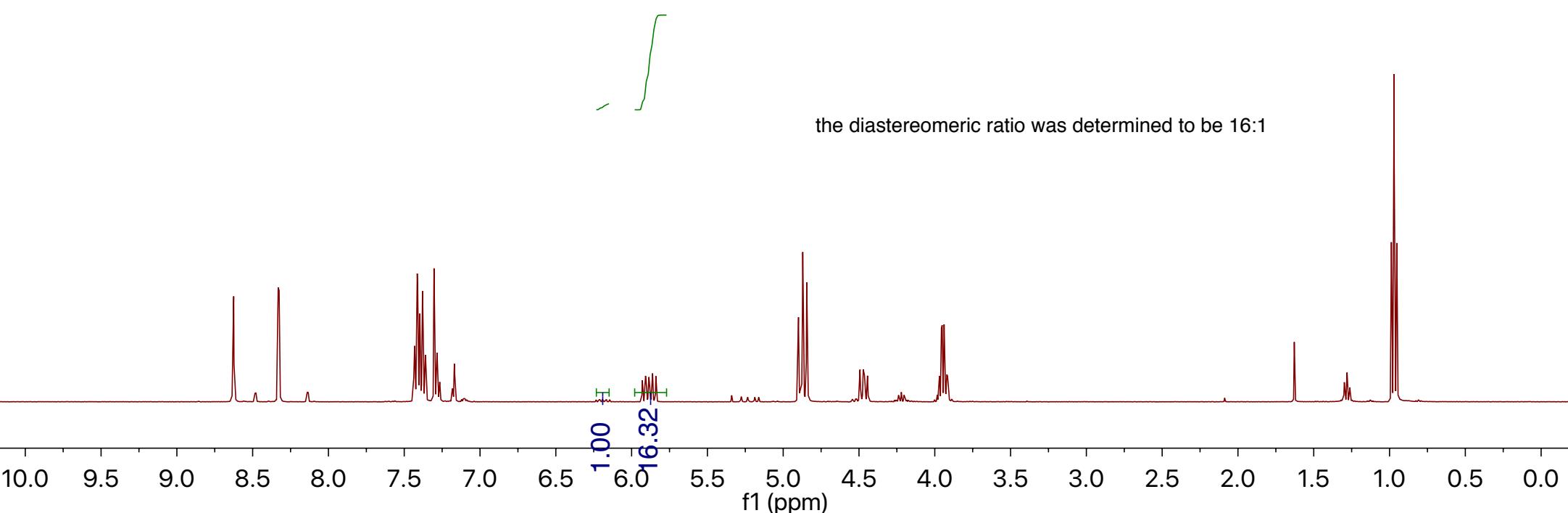
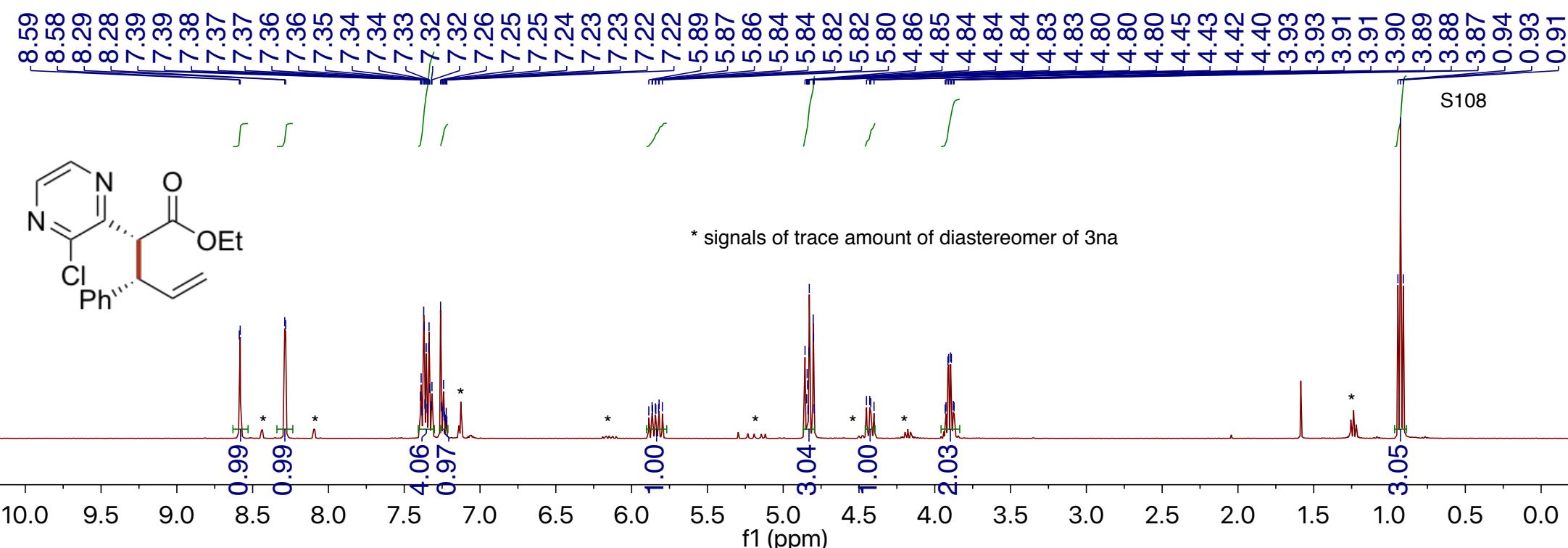
 \sim 61.32
 $\sqrt{53.90}$
 $\sqrt{51.93}$

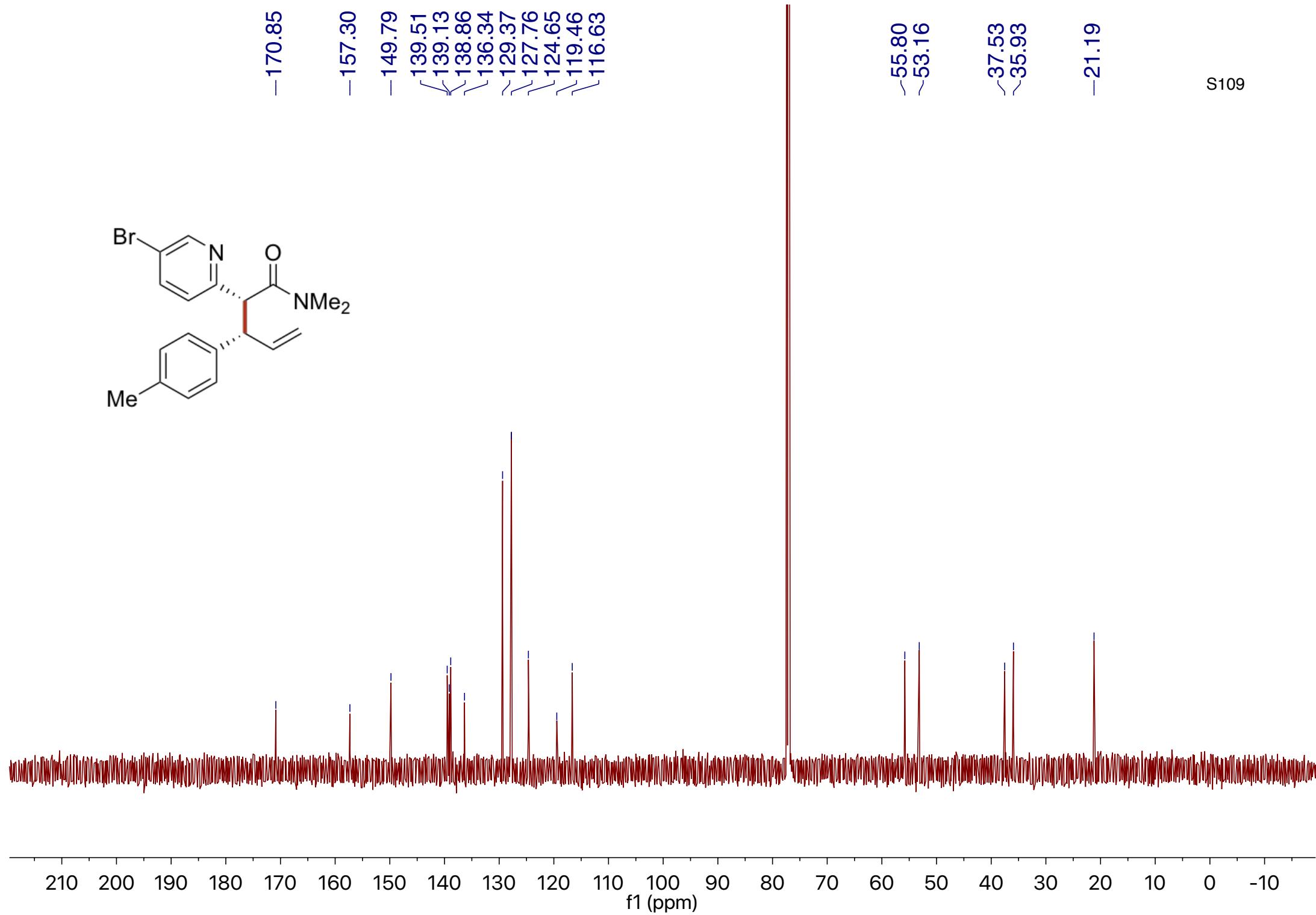
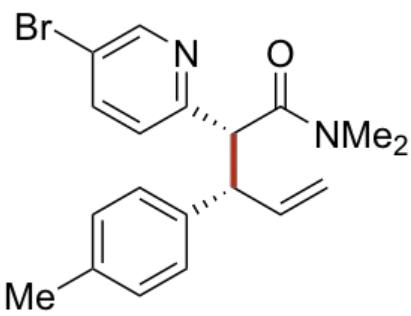
-116.86

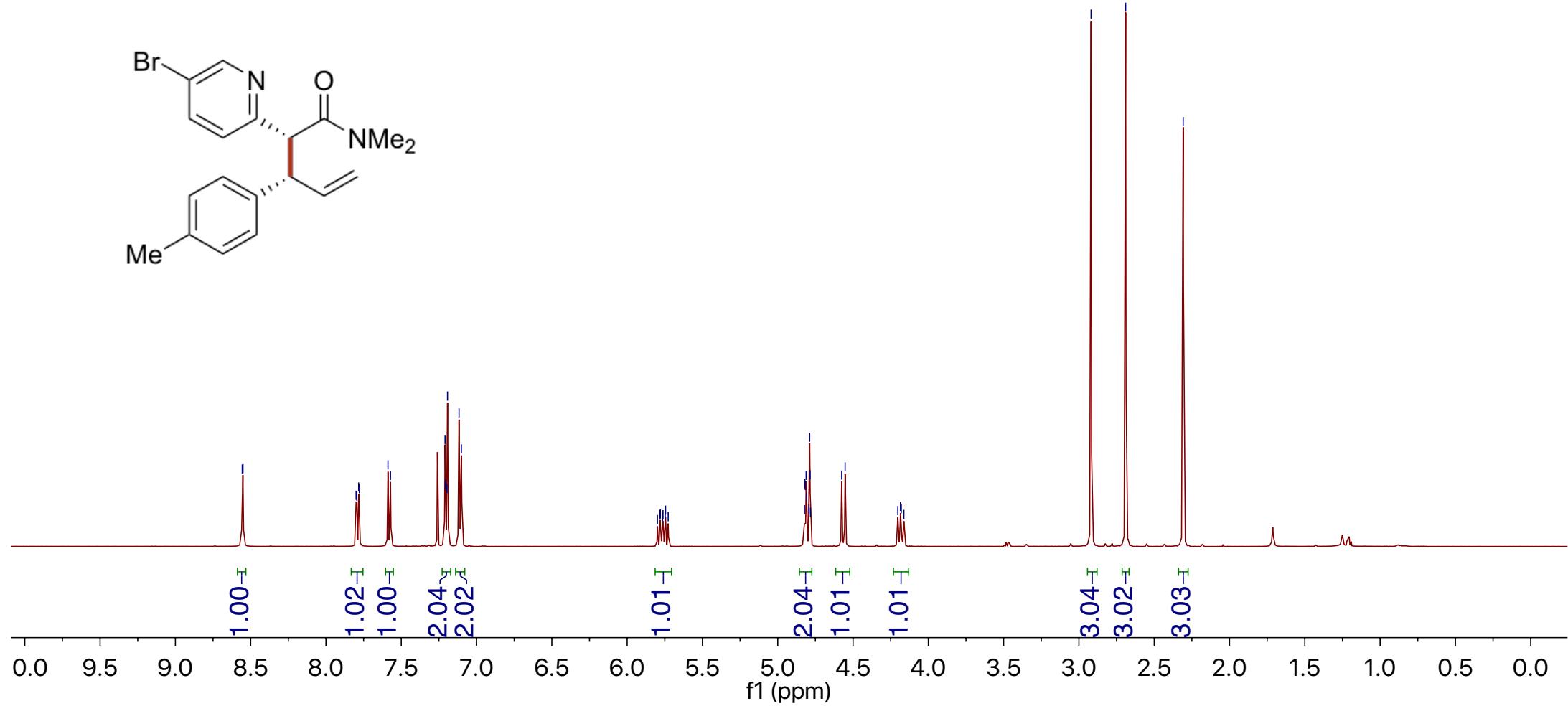
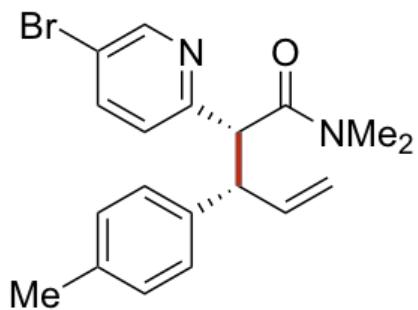
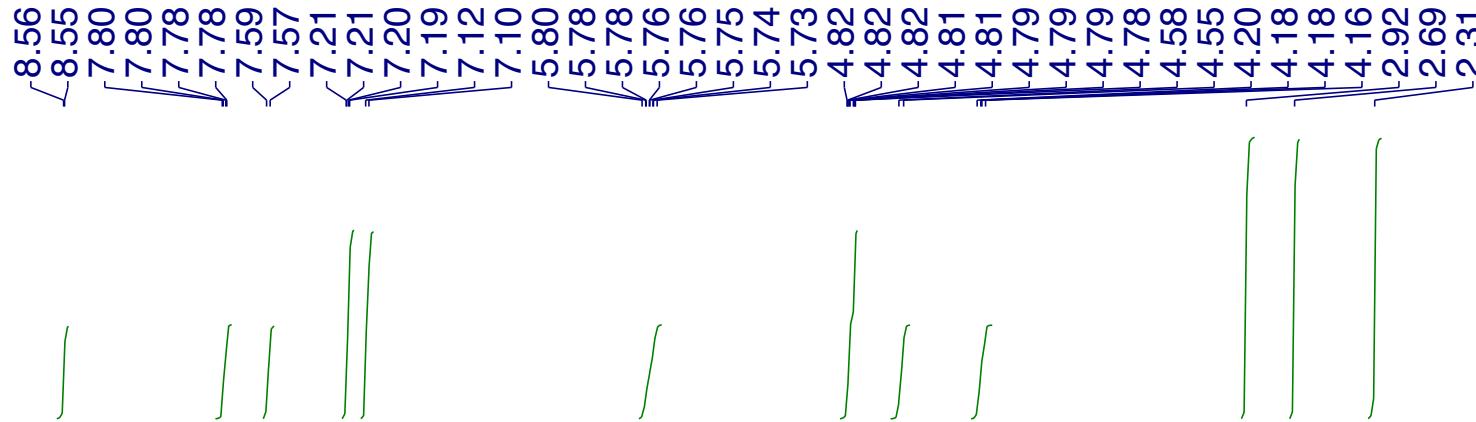
151.90
149.81
142.67
142.42
141.09
137.99
128.74
128.32
127.15

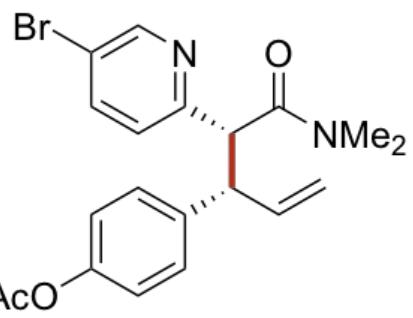
-169.54











170.60
169.50
156.99
149.85
149.52
139.68
139.55
138.24
128.98
124.59
121.65
119.54
117.18

-56.02
-52.83
37.50
35.89
-21.28

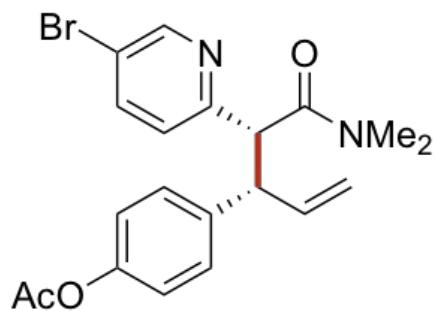
S111

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)

8.55
8.55
7.80
7.80
7.78
7.78
7.57
7.55
7.33
7.33
7.32
7.32
7.03
7.03
7.02
7.02
5.79
5.78
5.77
5.76
5.76
5.74
5.74
5.72
5.72
4.84
4.84
4.84
4.83
4.83
4.82
4.82
4.80
4.80
4.80
4.80
4.53
4.53
4.51
4.51
4.25
4.23
4.22
4.21
2.89
2.68
2.28

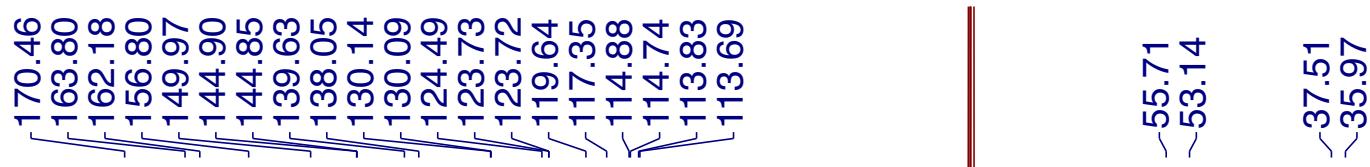
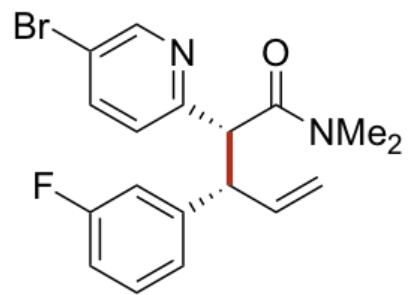
S112



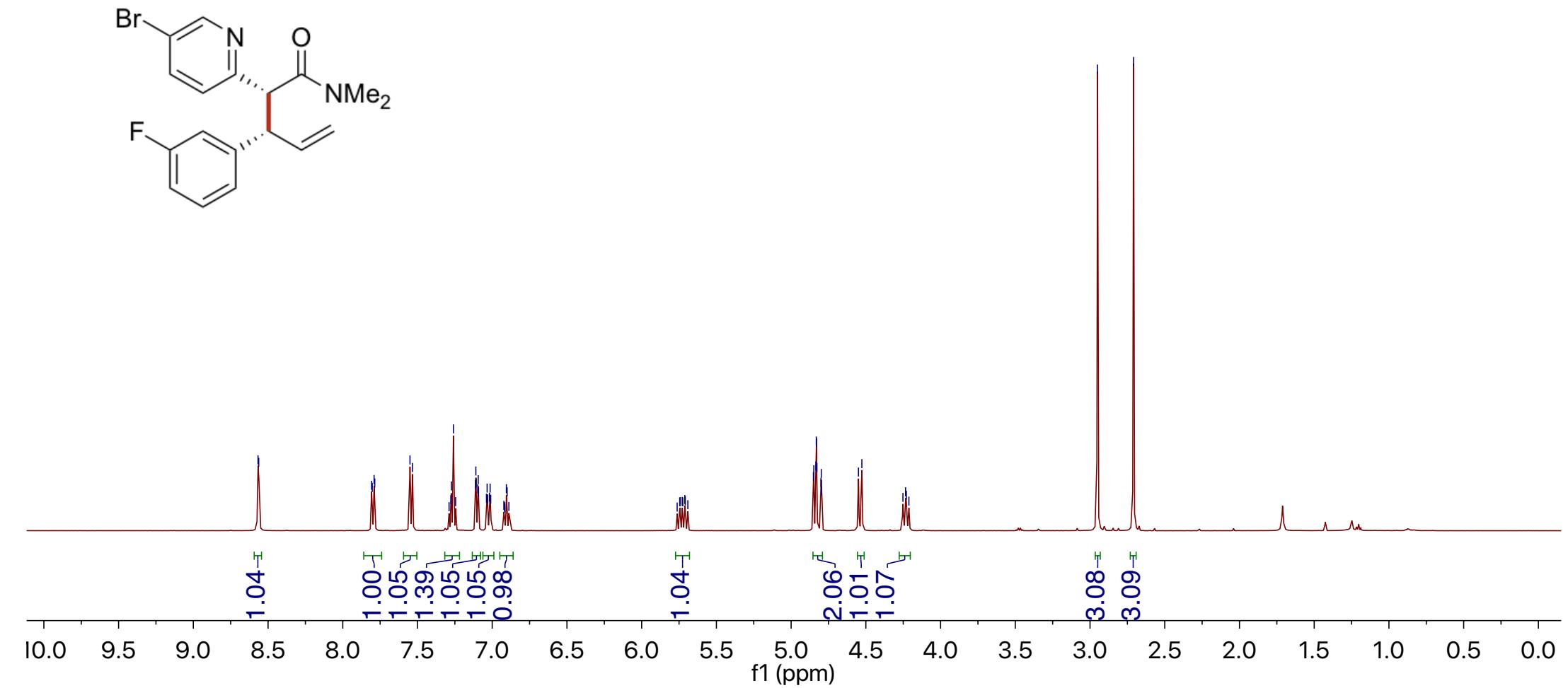
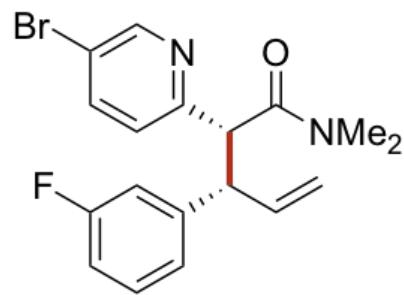
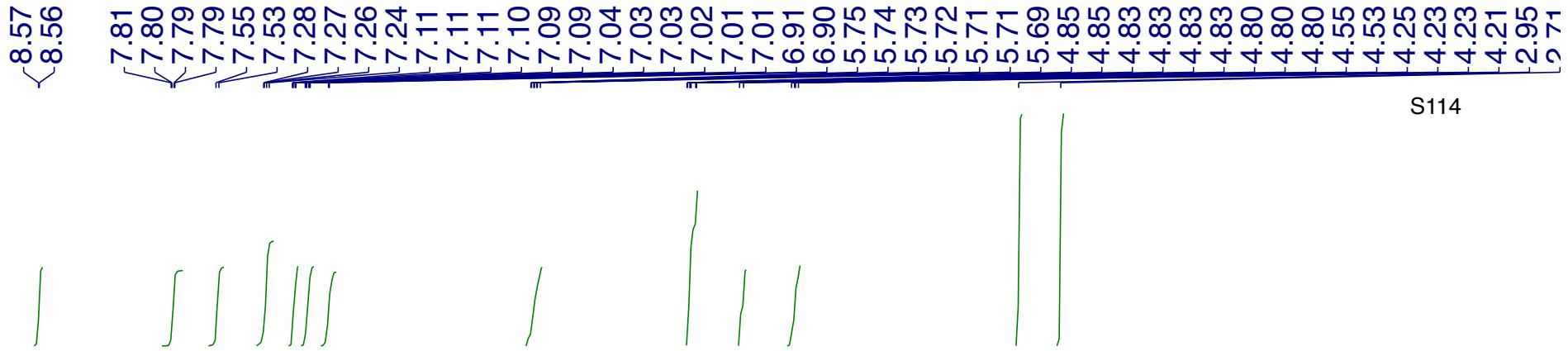
1.00
0.99
1.02
2.03
1.99
1.01
2.04
1.00
1.01
3.02
3.03
3.03

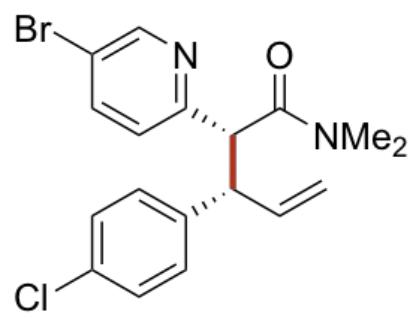
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

f1 (ppm)



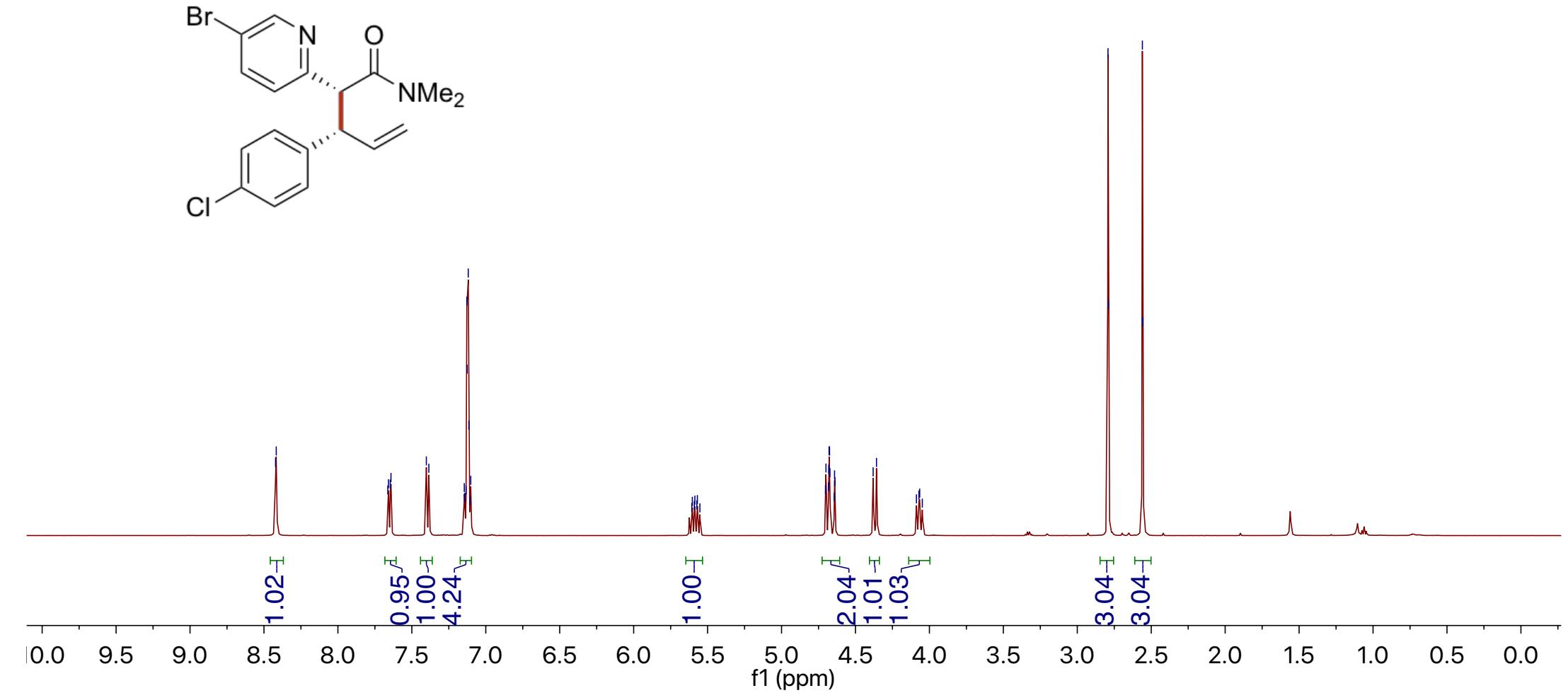
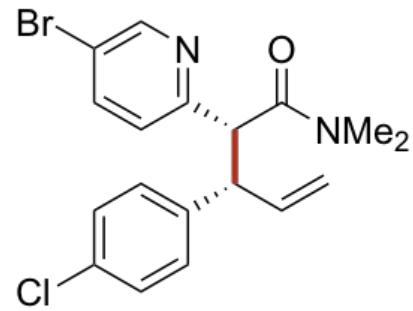
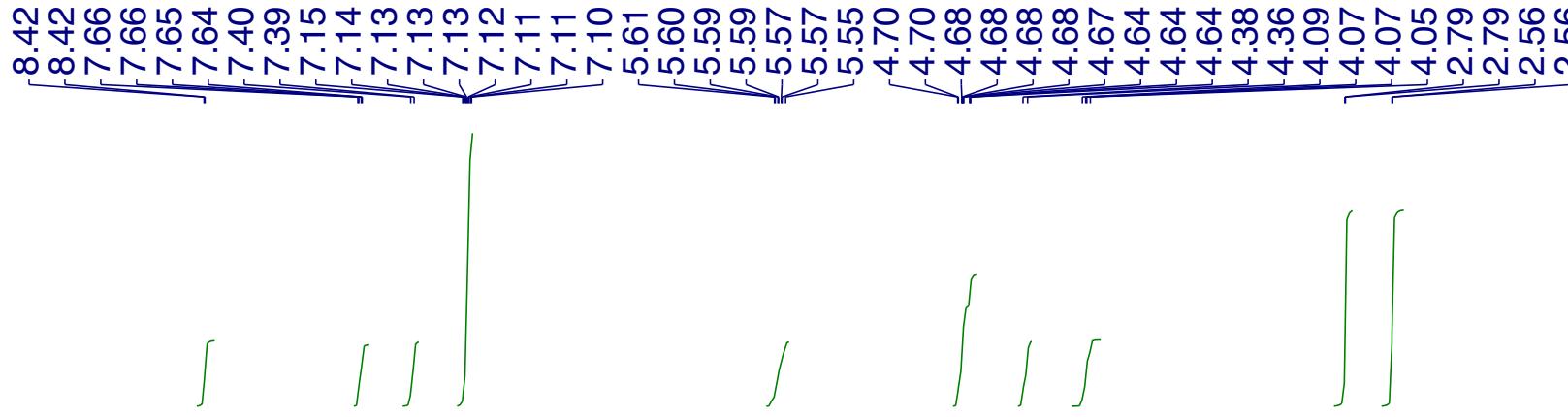
S113

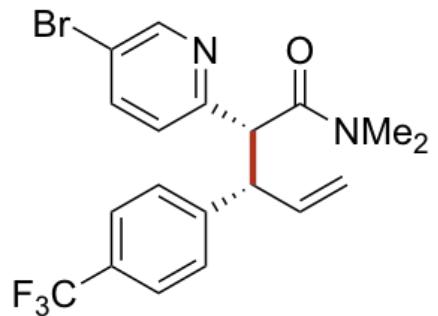




210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)



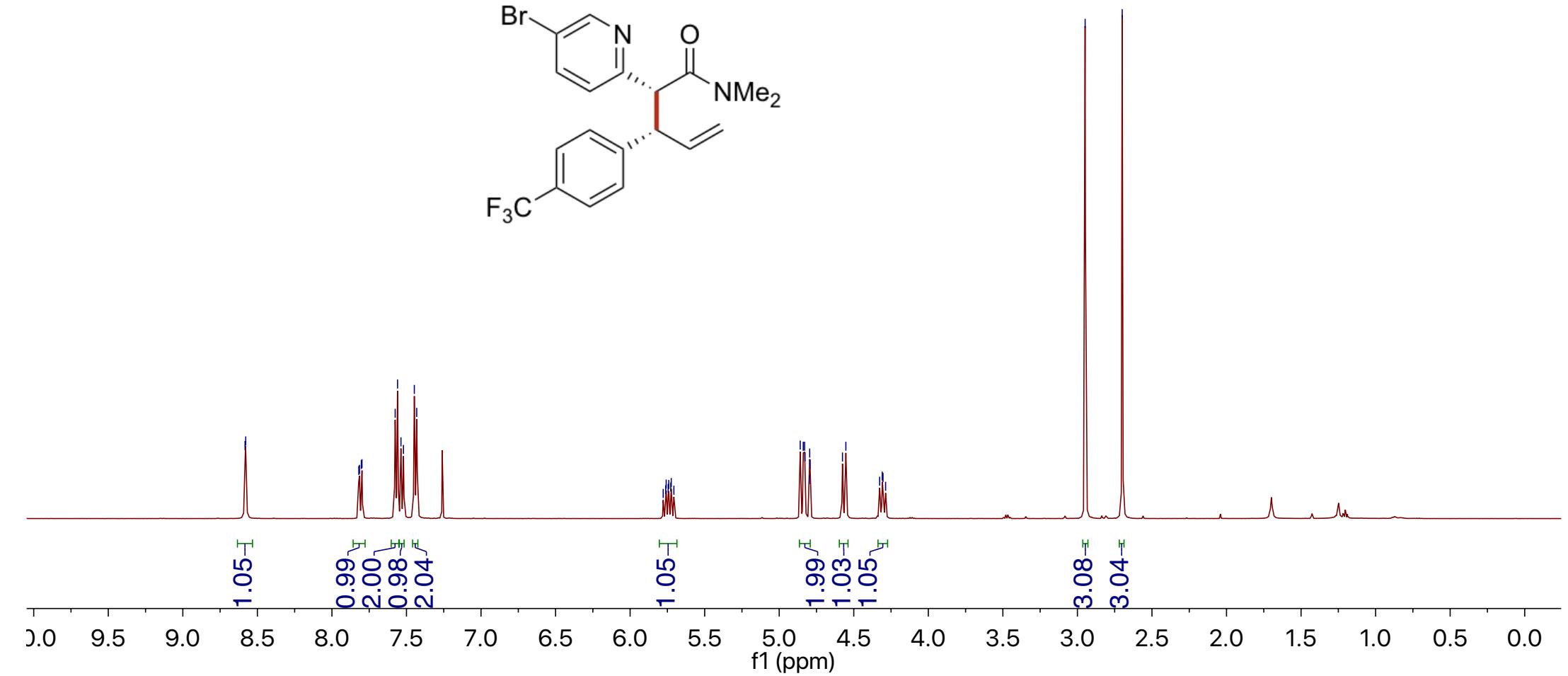
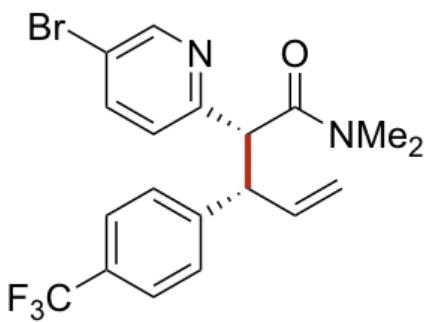
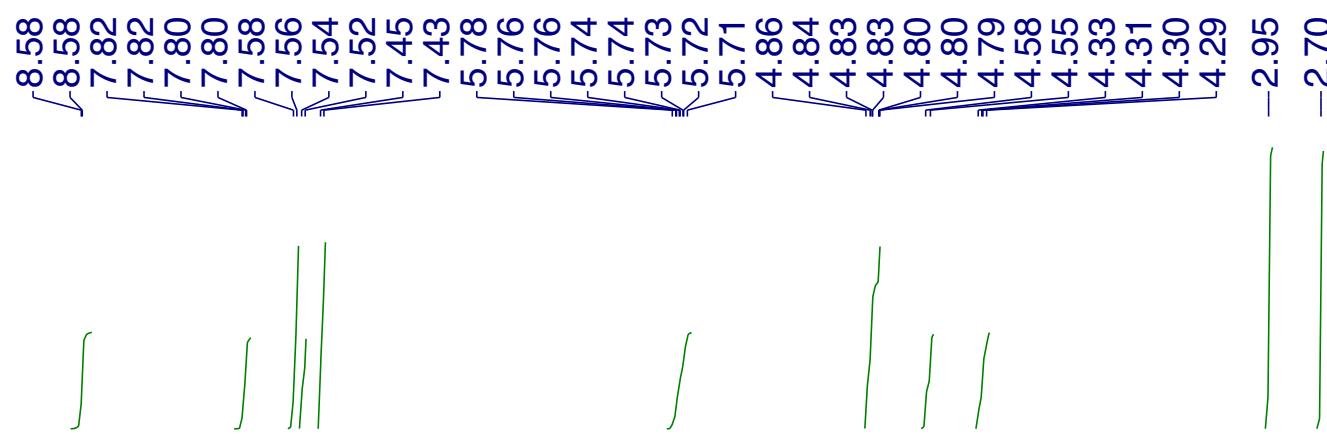


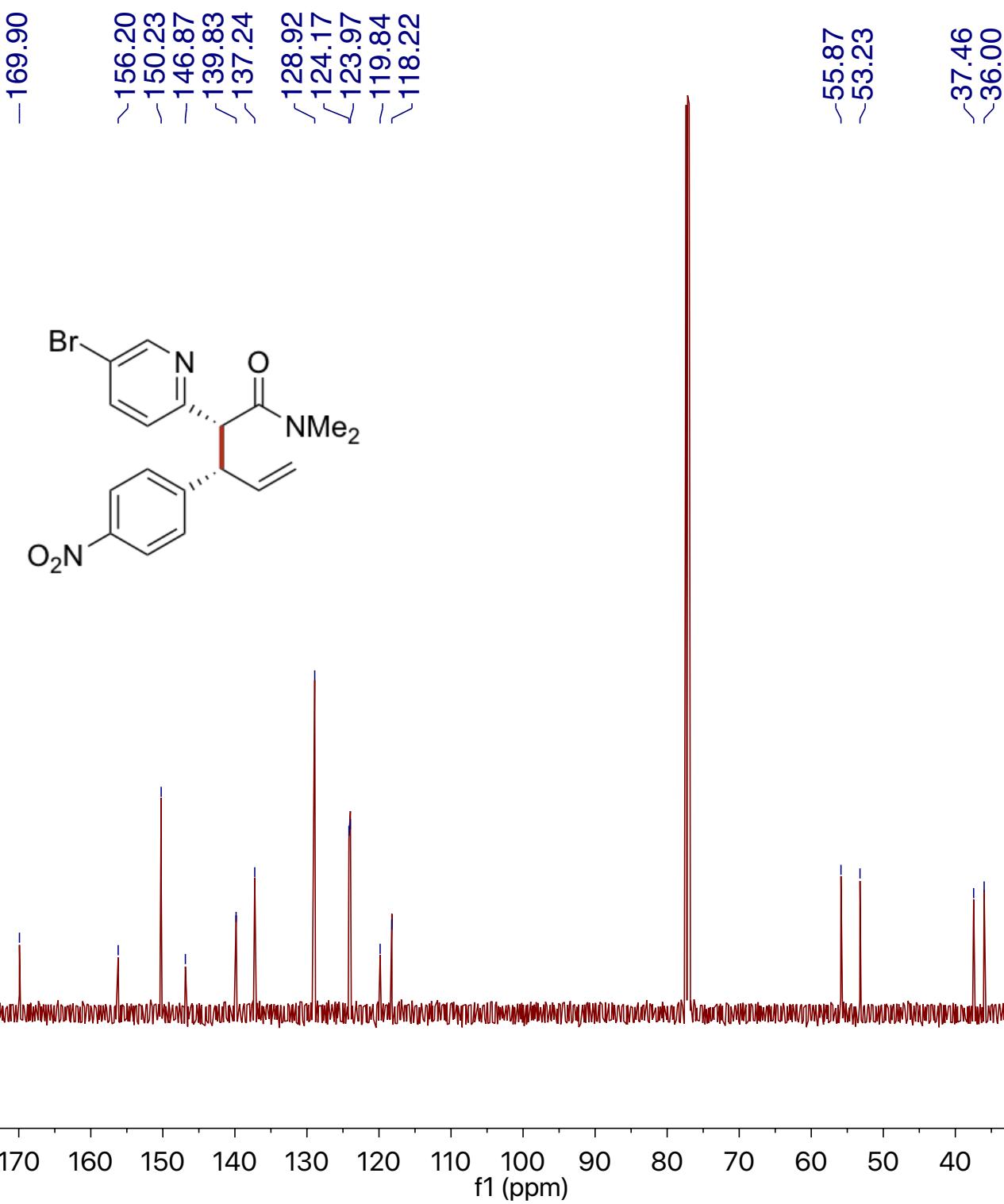
-170.24

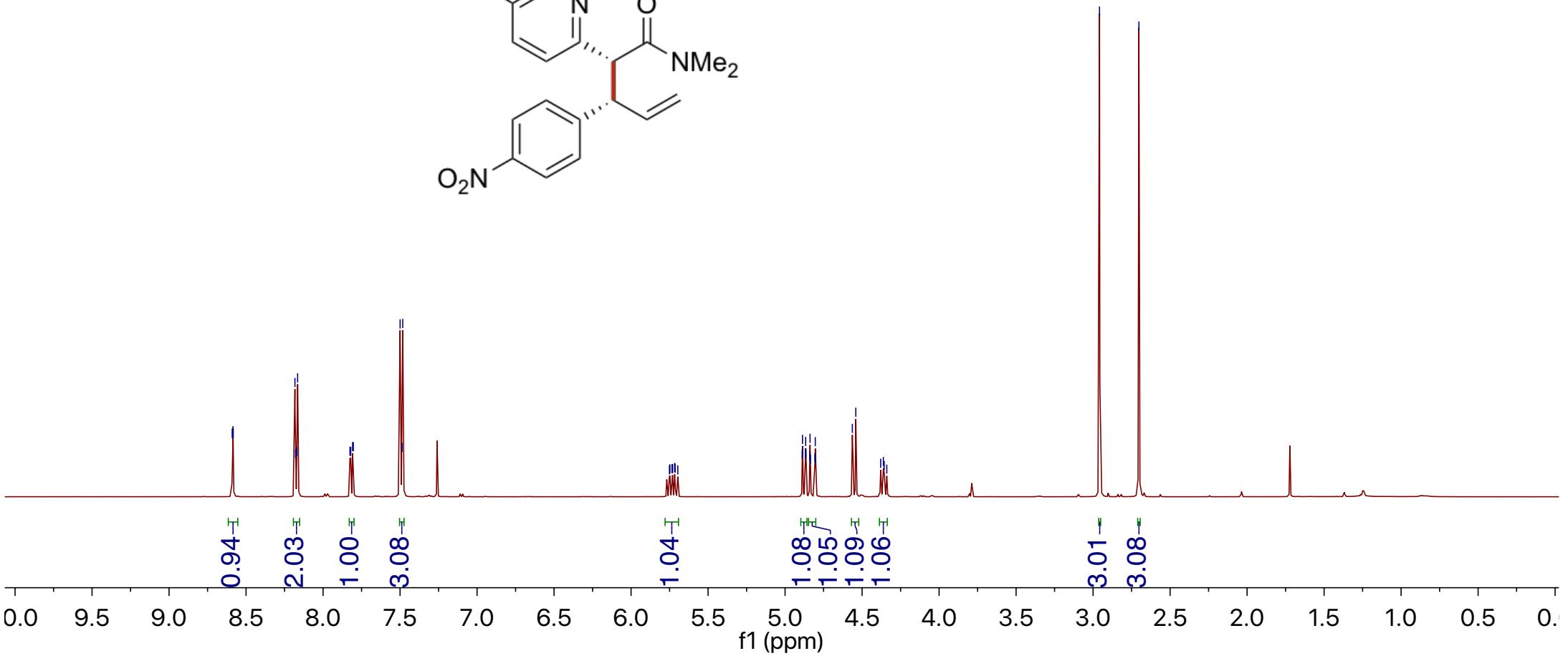
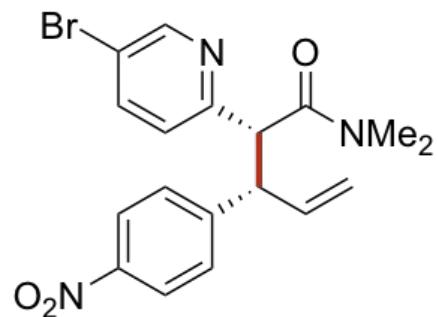
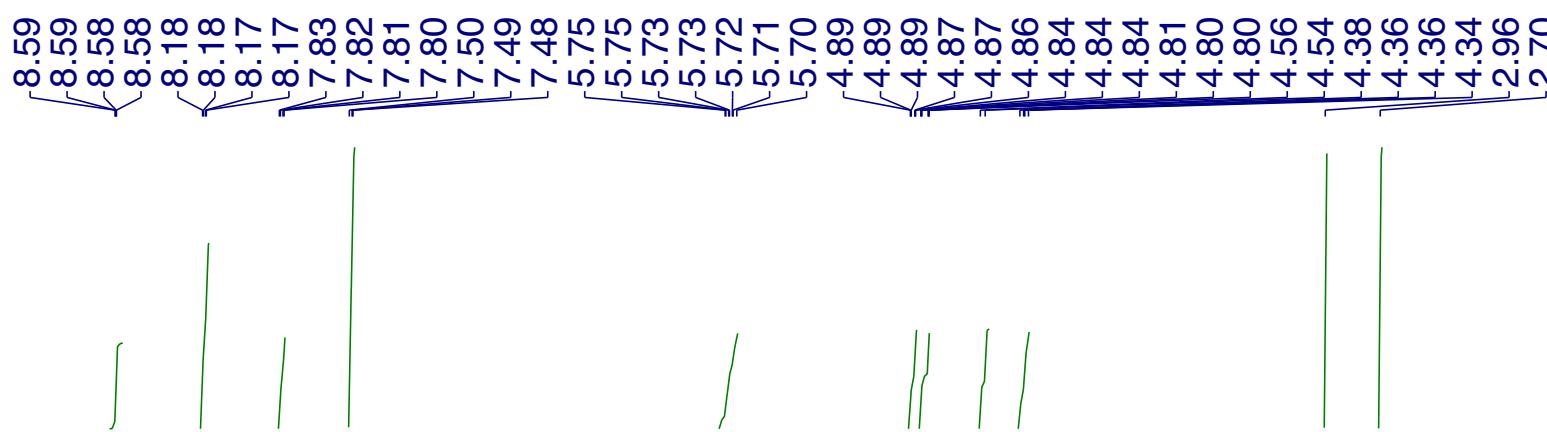
~55.81
~53.26

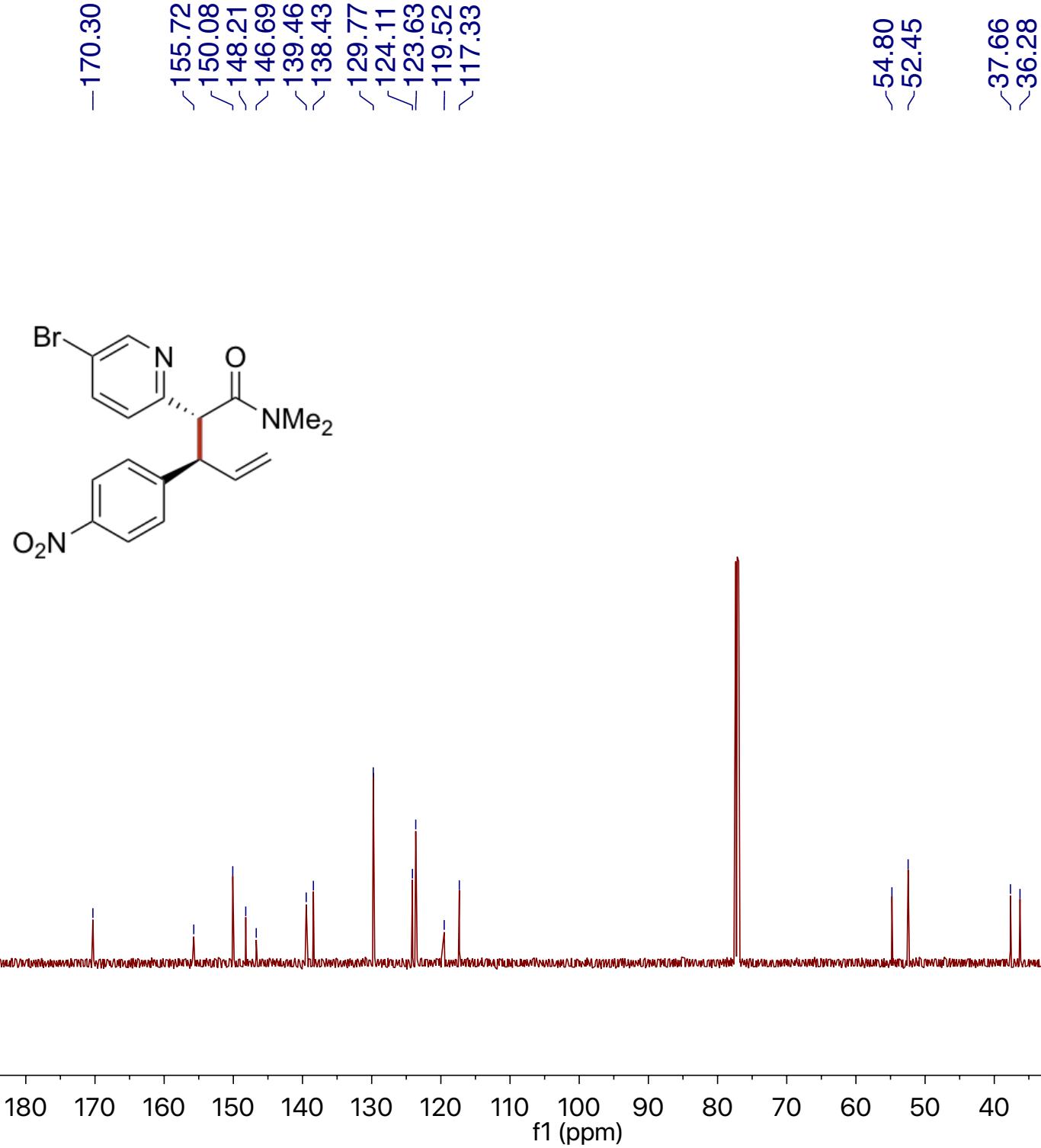
37.48
35.97

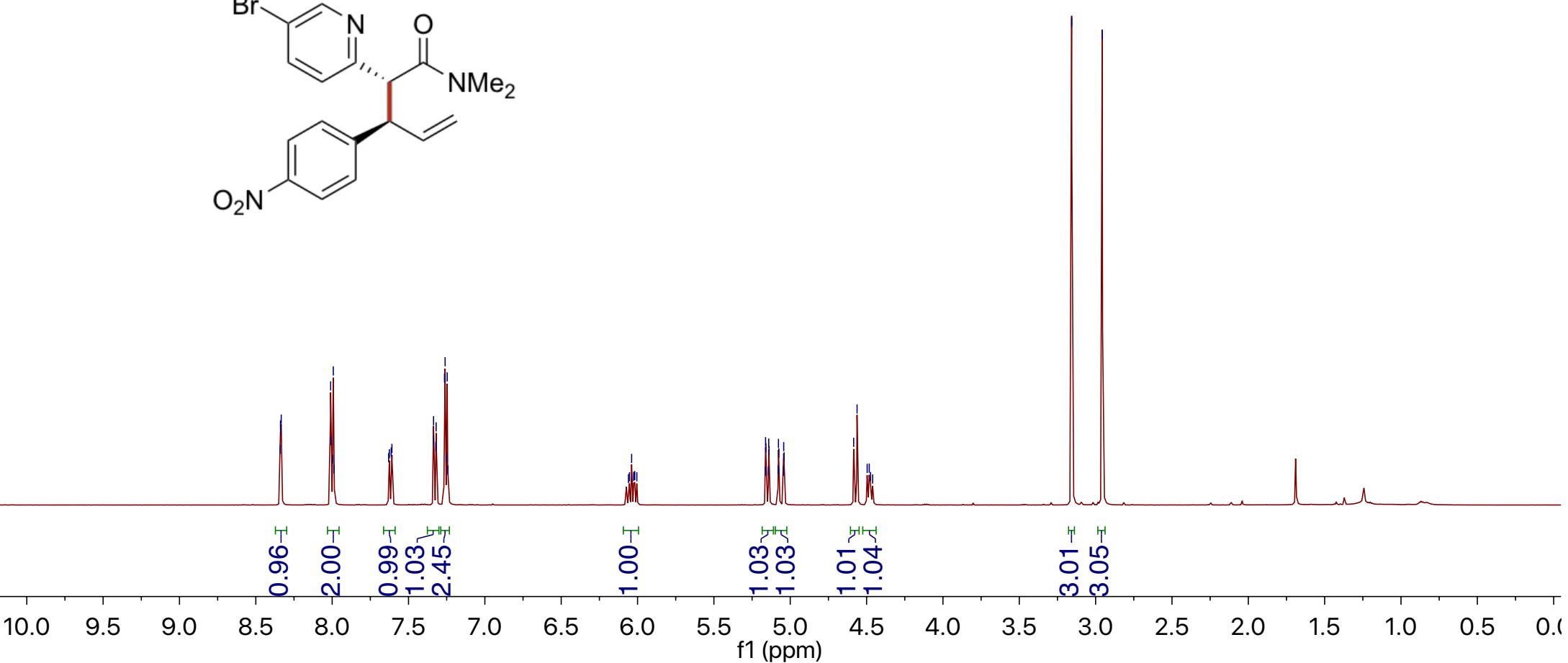
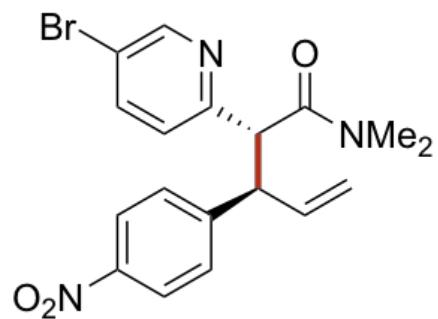
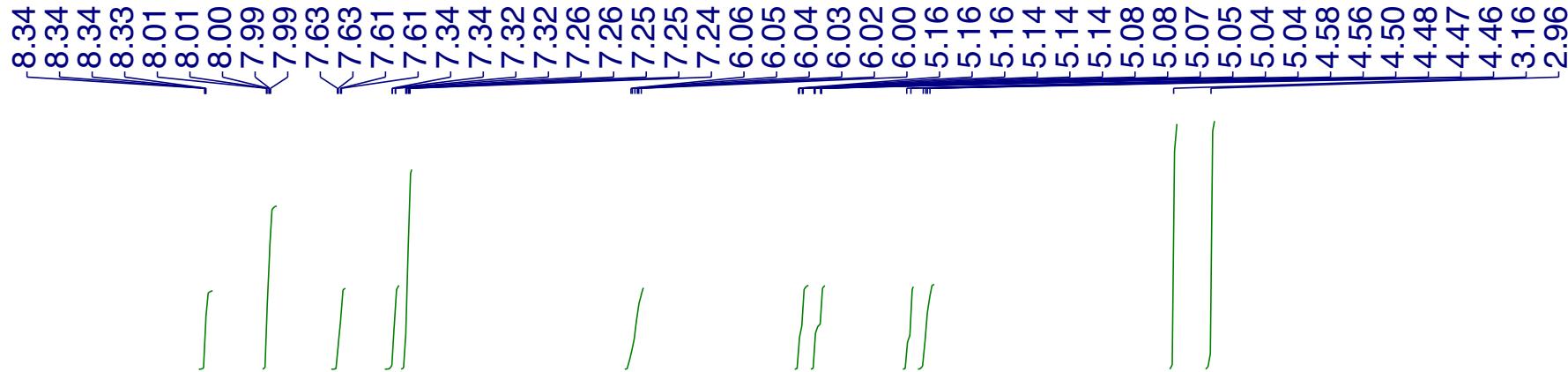
S117

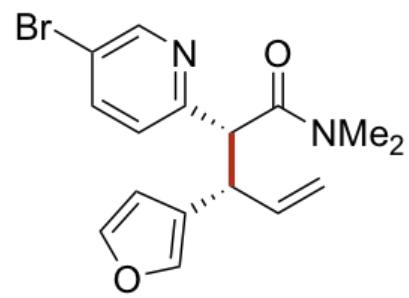












-171.00

-156.85
-149.91
-142.98
-139.54
-139.51
-137.65

-125.88
-124.41
-119.54
-117.09
-109.93

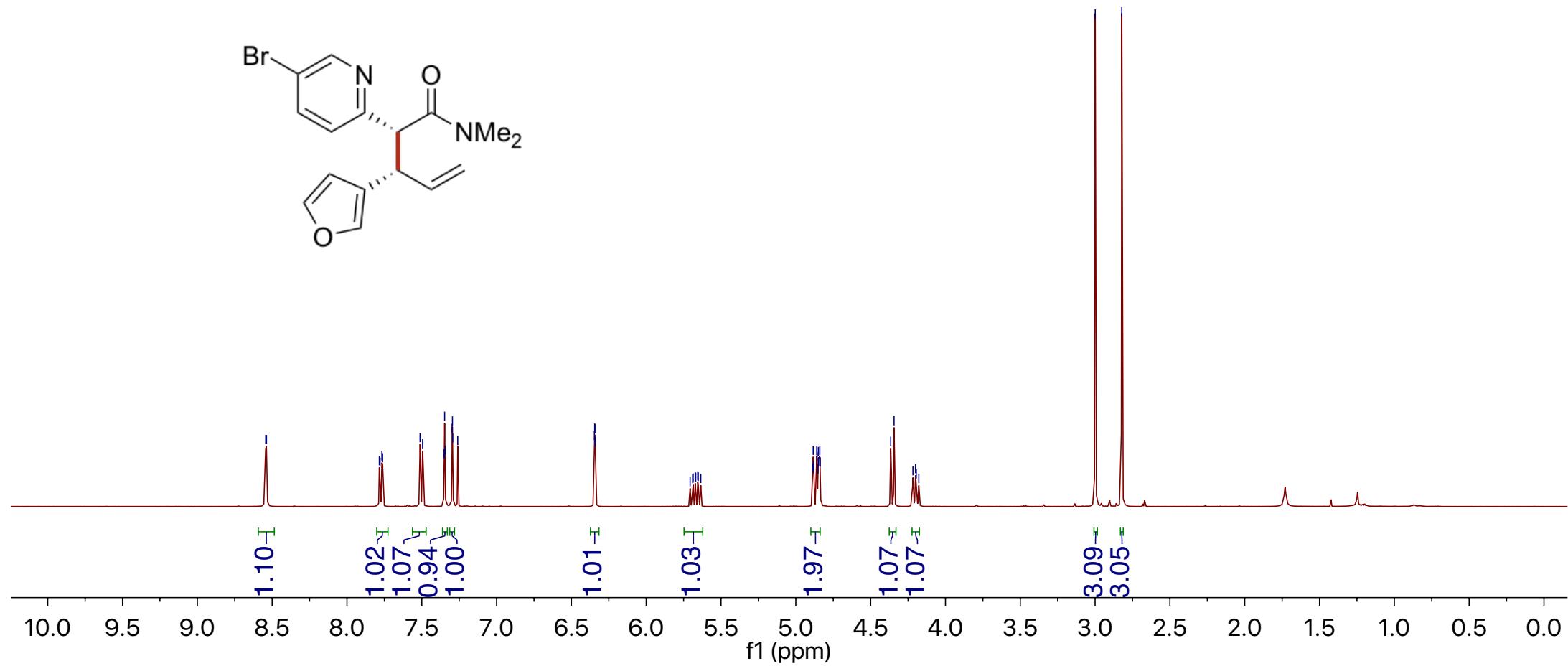
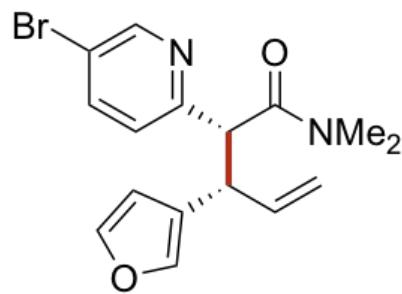
-55.89

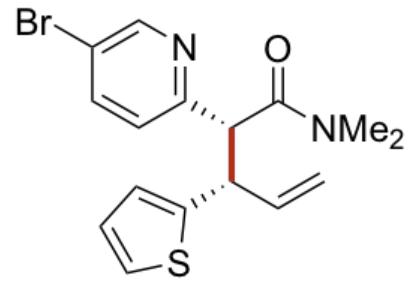
-43.97
-37.59
-36.07

S123

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)





-170.62

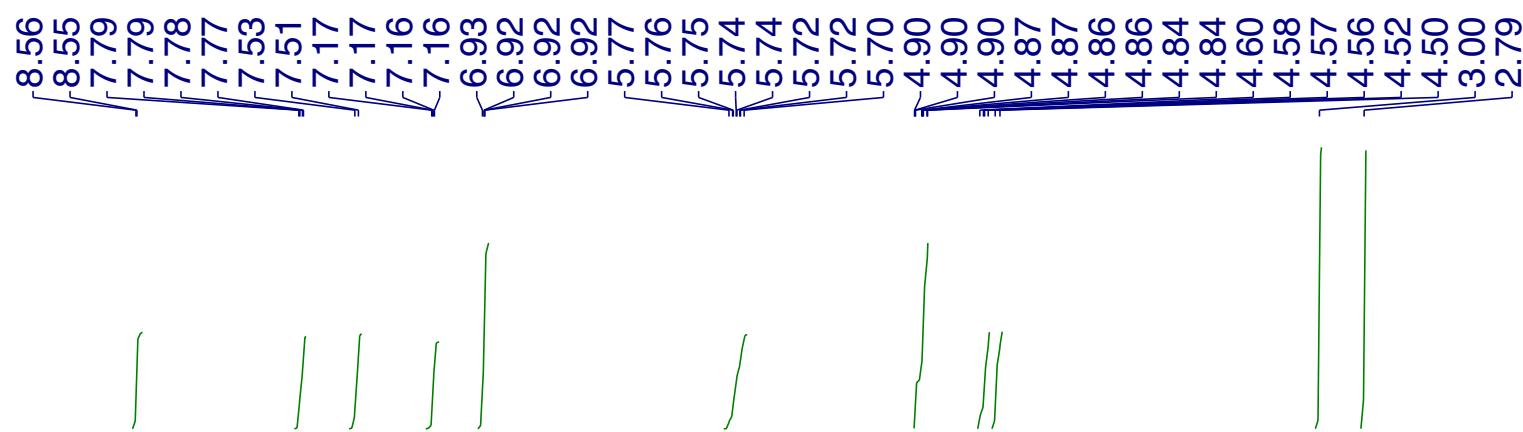
~156.59
~149.97
~145.45
~139.58
~138.21
126.91
124.70
124.43
123.86
119.63
117.24

-56.91
-48.50
~37.56
~36.08

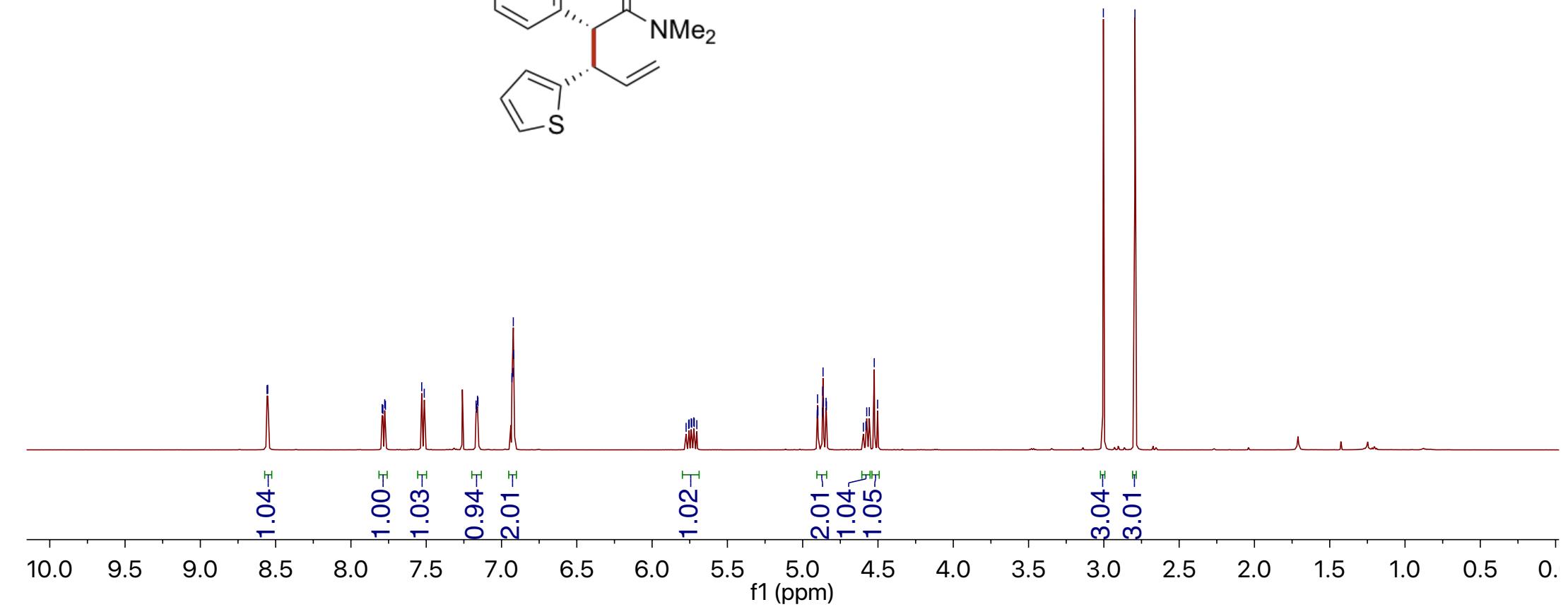
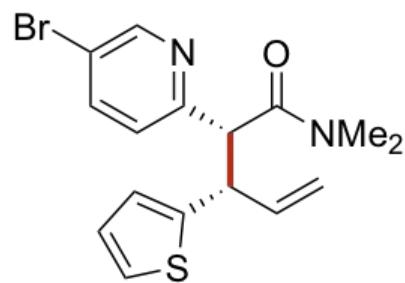
S125

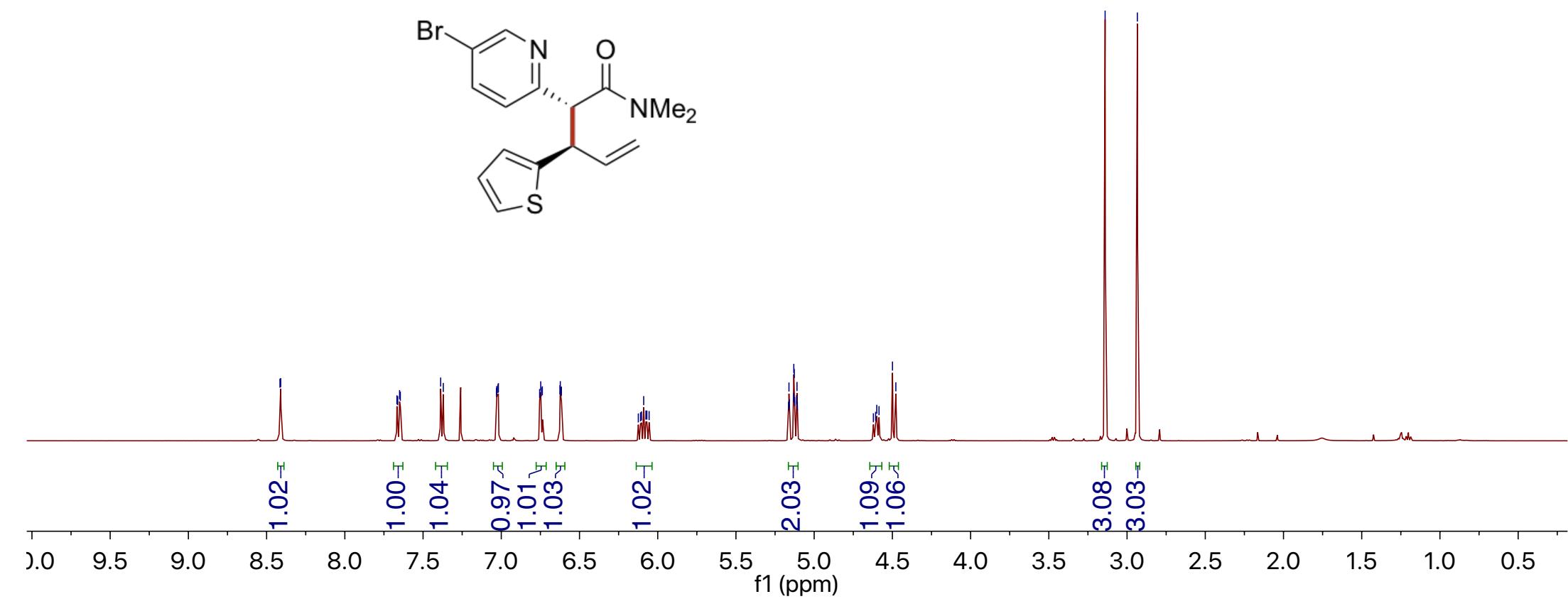
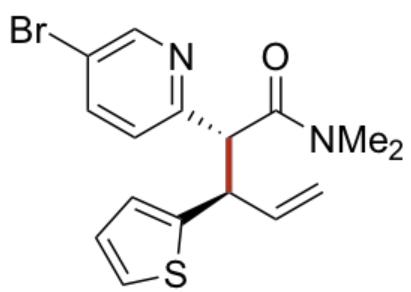
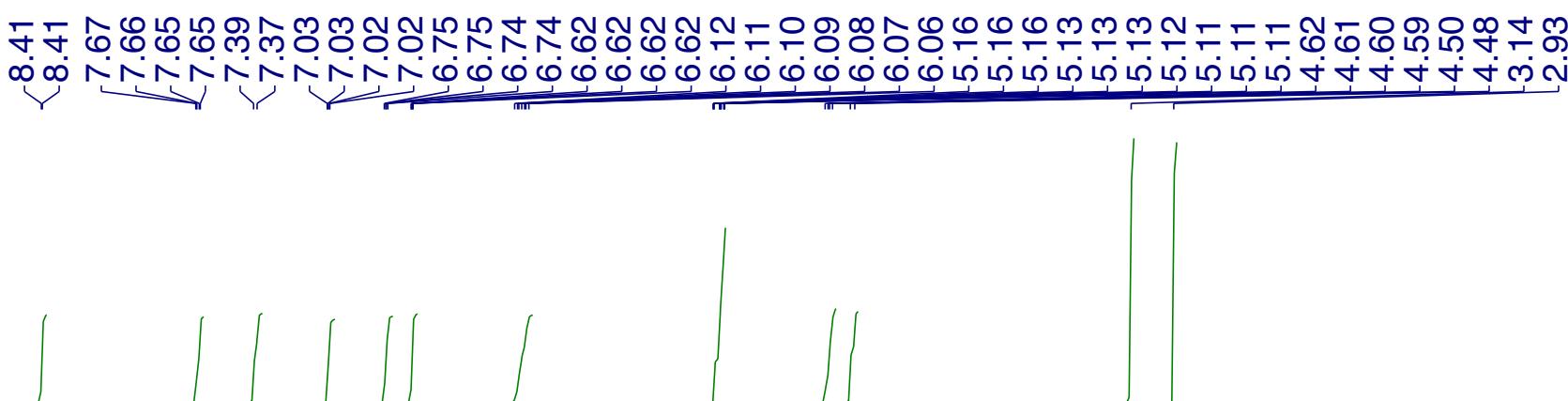
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

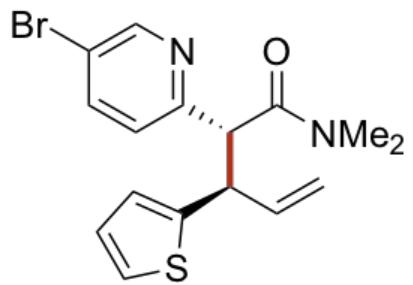
f1 (ppm)



S126





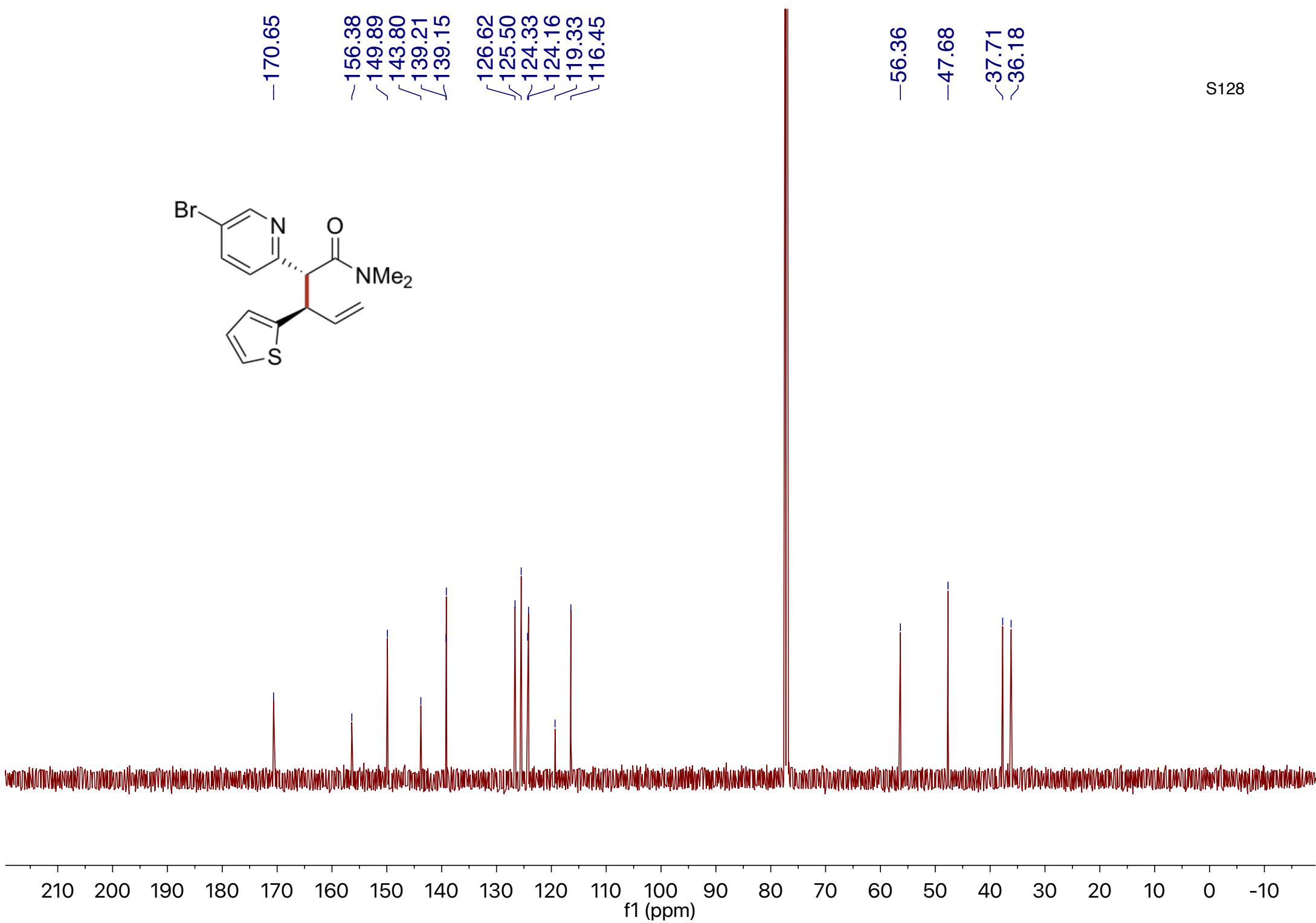


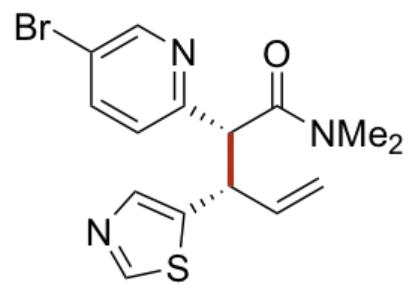
—170.65

—156.38
—149.89
—143.80
—139.21
—139.15

126.62
125.50
124.33
124.16
119.33
116.45

—56.36
—47.68
—37.71
—36.18





-170.10

~155.97
~152.26
~150.20
~140.74
~139.76
~137.31

~124.13
~119.84
~118.16

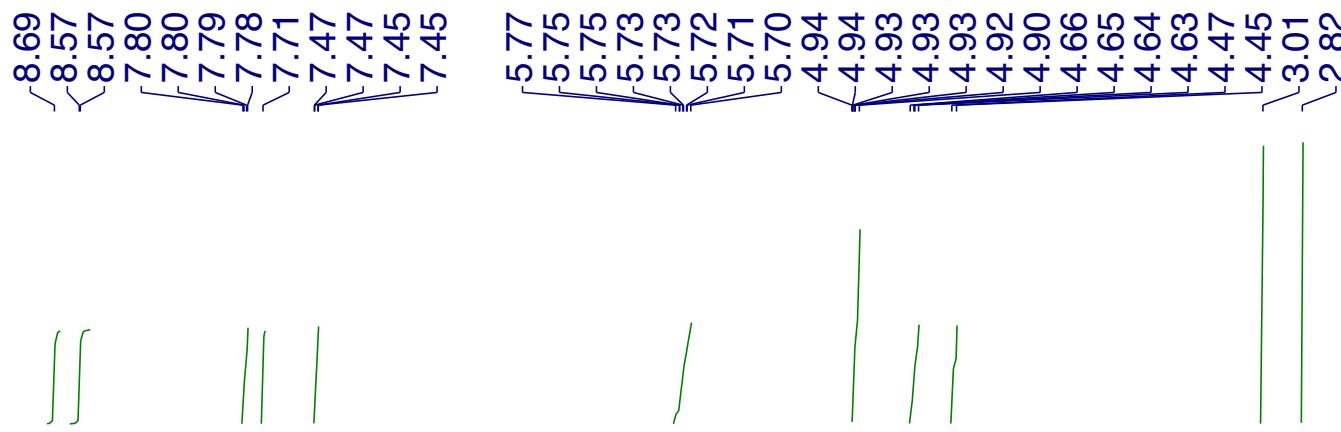
-56.99

-45.69
~37.50
~36.14

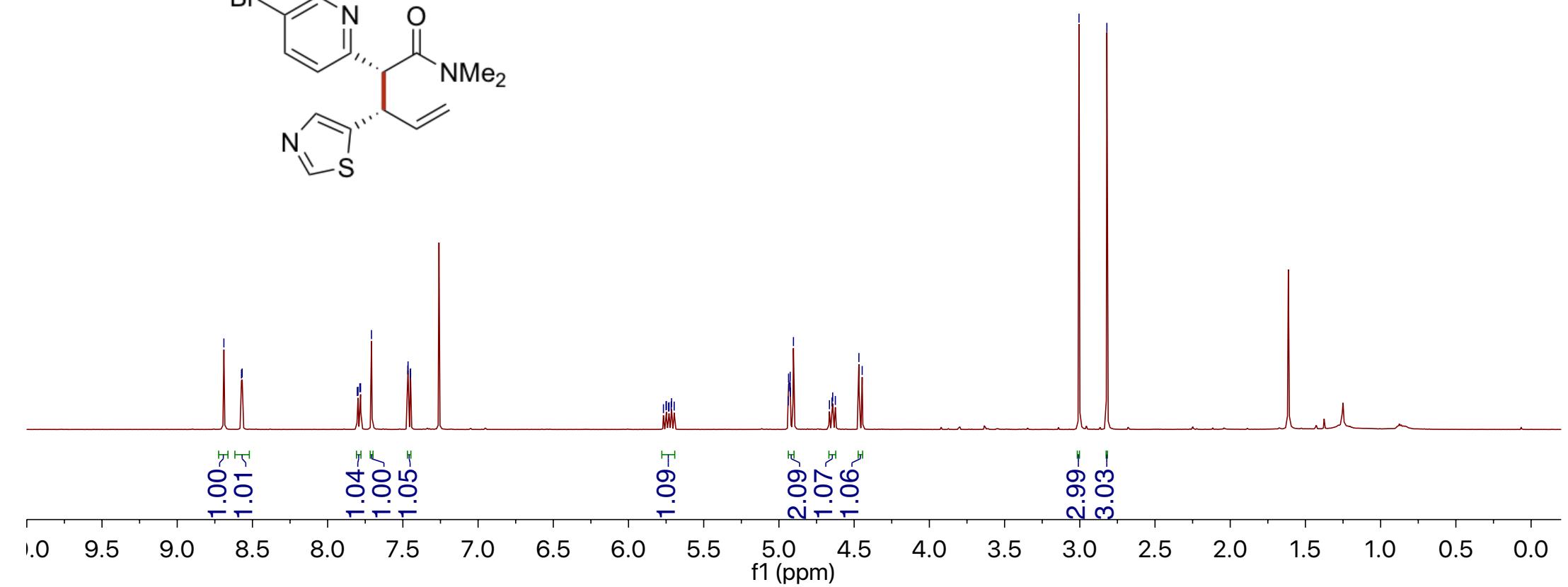
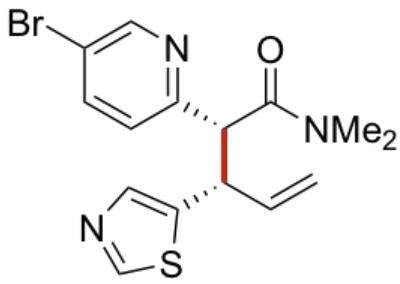
S129

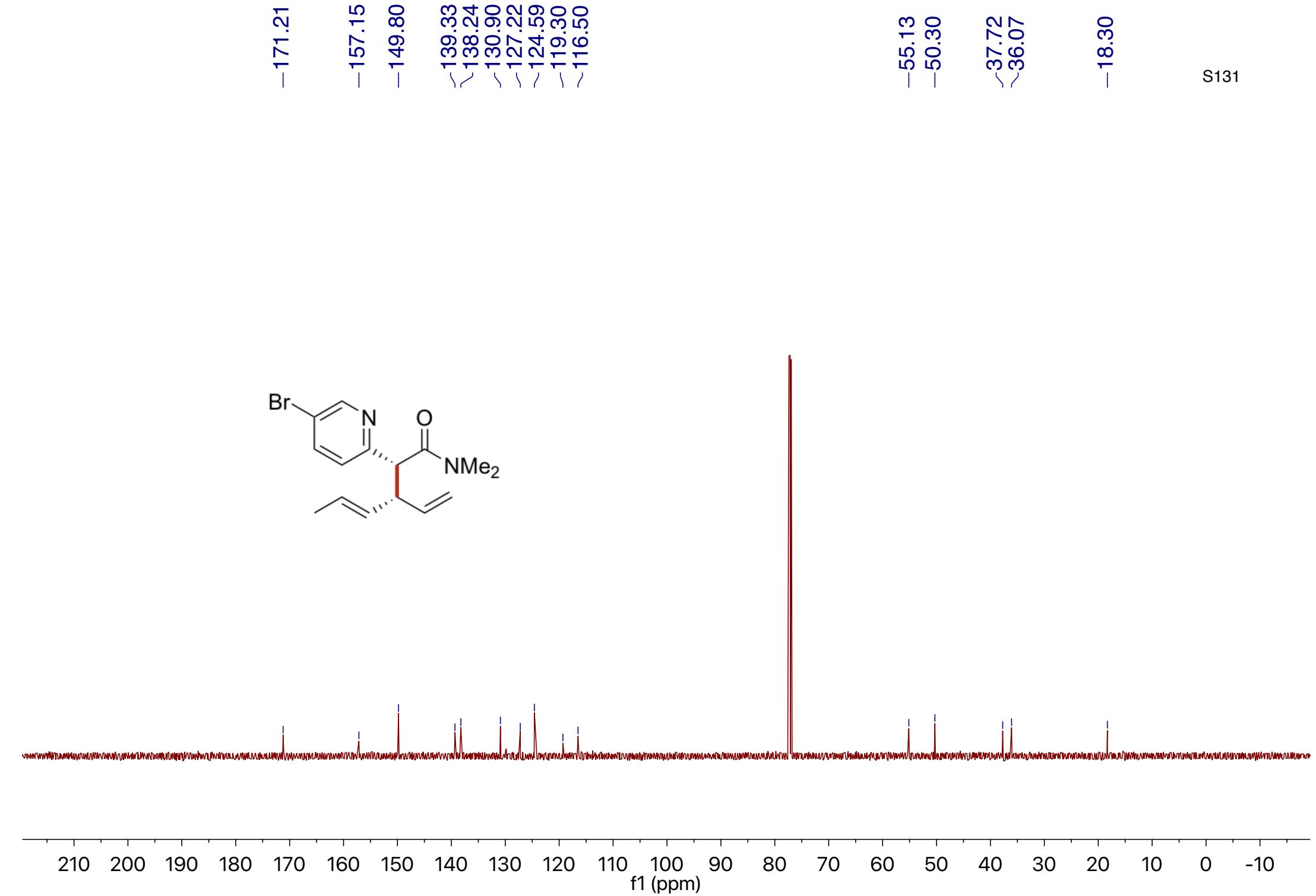
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

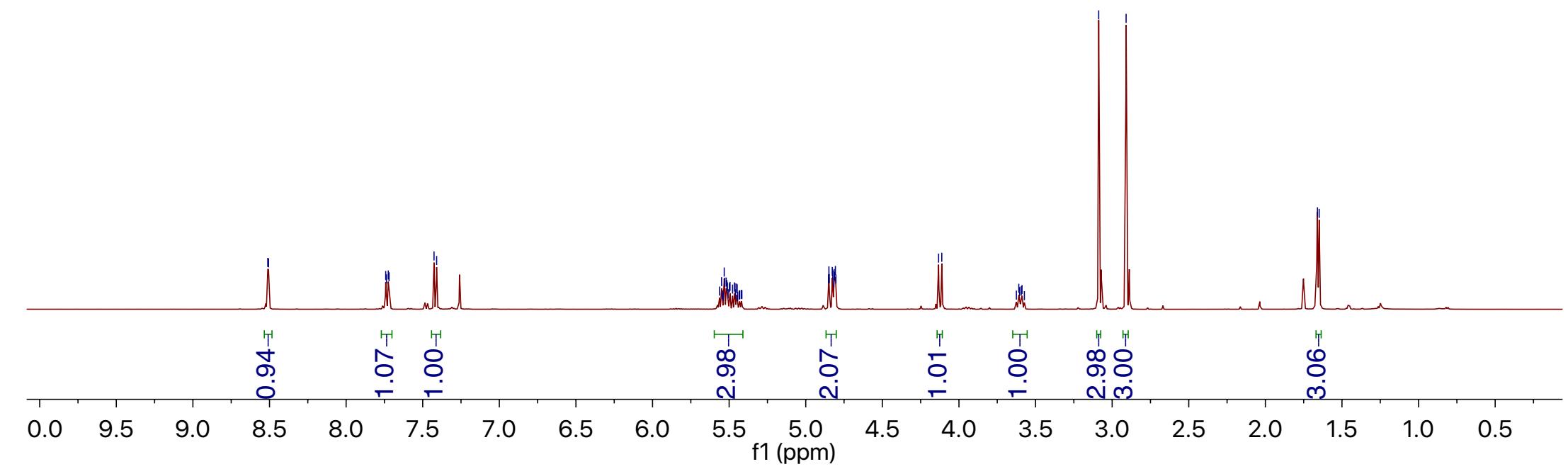
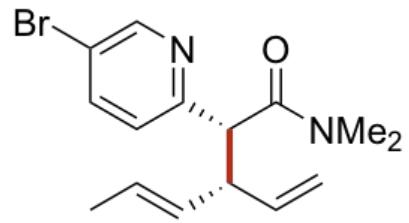
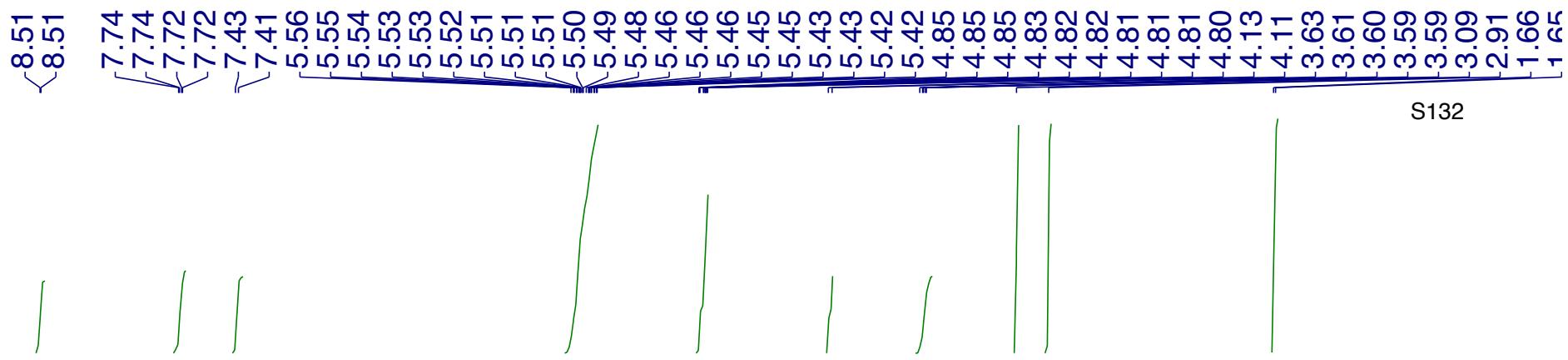
f1 (ppm)

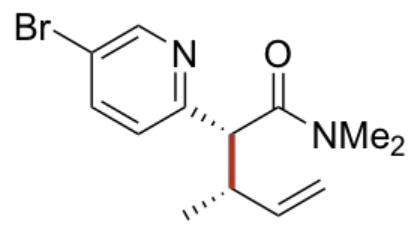


S130

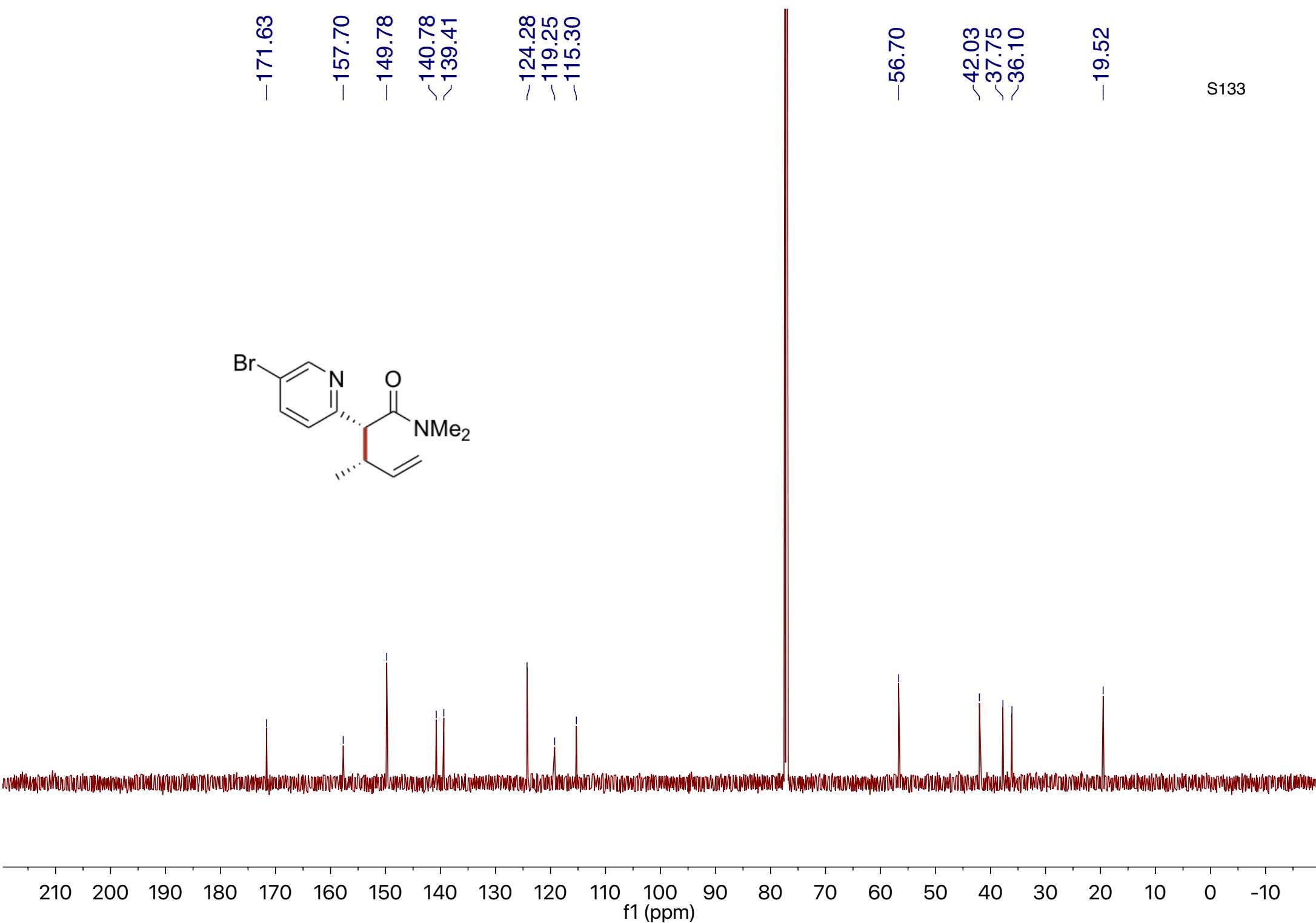


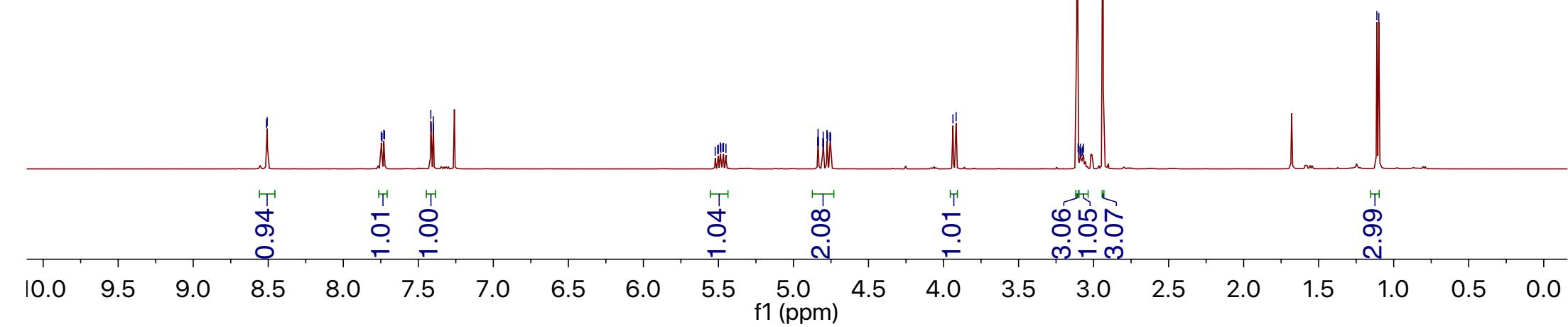
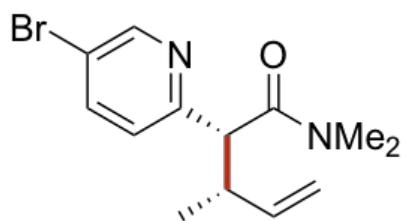
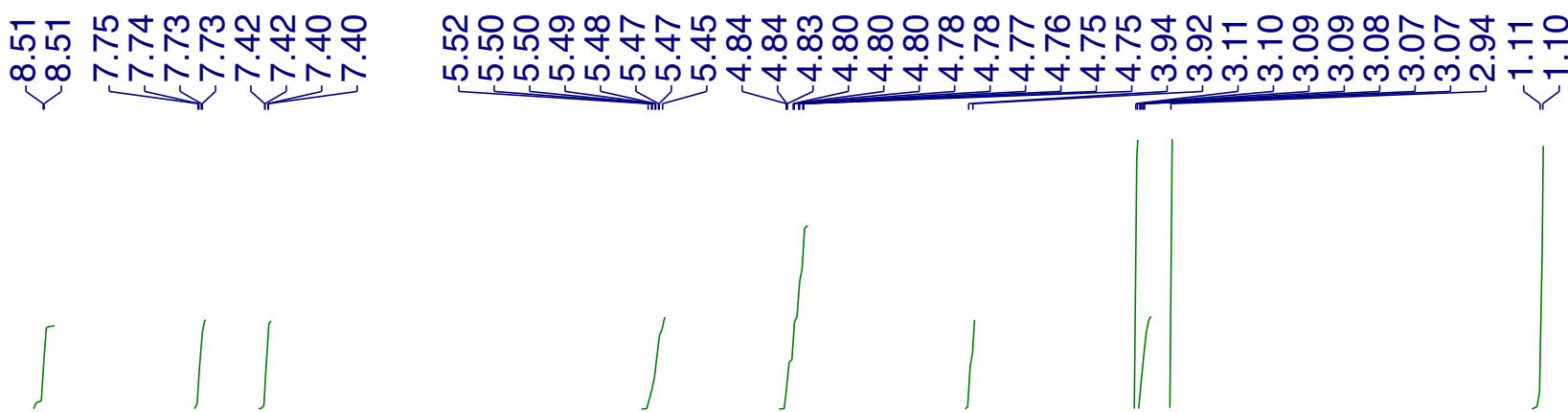


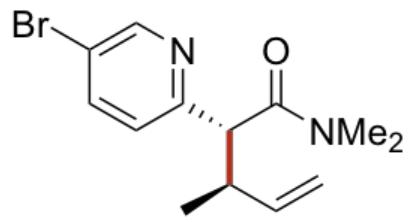




-171.63
-157.70
-149.78
-140.78
-139.41
-124.28
-119.25
-115.30
-56.70
-42.03
-37.75
-36.10
-19.52







-171.63

-157.61

-149.94

<141.56
~139.59

~124.02
-119.43
-114.74

-56.69

~40.88
~37.70
~36.02

-17.41

S135

