

Domino Electrocyclization/Azide-Capture/Schmidt Rearrangement Employing Simple Dienones and Azides

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Supporting Information

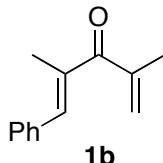
Contents

Experimental Procedures.....	S-1—S-9
References.....	S-9
Copies of ^1H and ^{13}C NMR Spectra.....	S-10—S-53

Experimental Procedures

General Information. Reactions were carried out in flame-dried glassware under a positive nitrogen atmosphere unless otherwise stated. Transfer of anhydrous solvents and reagents was accomplished with oven-dried syringes or cannulae. Solvents were distilled before use: methylene chloride from calcium hydride, tetrahydrofuran, diethylether and benzene from sodium/benzophenone ketyl, toluene from sodium metal. Thin layer chromatography was performed on glass plates precoated with 0.25 mm Kieselgel 60 F₂₅₄ (Merck). Flash chromatography columns were packed with 230-400 mesh silica gel (Silicycle). Proton nuclear magnetic resonance spectra (^1H NMR) were recorded at 400 MHz or 500 MHz and coupling constants (J) are reported in Hertz (Hz). Carbon nuclear magnetic resonance spectra (^{13}C NMR) were recorded at 100 MHz or 125 MHz and are reported (ppm) relative to the center line of the triplet from chloroform-*d* (77.23 ppm). Infrared (IR) spectra were measured with a Mattson Galaxy Series FT-IR 3000 spectrophotometer. Mass spectra were determined on a PerSeptive Biosystems Mariner high-resolution electrospray positive ion mode spectrometer.

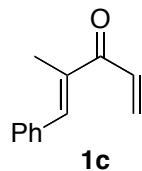
Preparation of Dienones



Preparation of 1b. To a solution of 2-bromopropene (1.3 mL, 15 mmol) in THF (10 mL) was added Mg (0.60 g, 25 mmol). The reaction mixture was refluxed for 30 min. The resulting solution was transferred dropwise to a solution of α -methyl-*trans*-cinnamaldehyde (1.50 g, 10 mmol) in THF (10 mL). The reaction mixture was stirred for 2 h at room temperature. Saturated

NH_4Cl solution (10 mL) was added to quench the reaction. The resulting mixture was then extracted with CH_2Cl_2 (20 mL) and the organic layer was washed with brine (10 mL) and dried over MgSO_4 . The solvent was evaporated under reduced pressure and the residue was purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford the desired dienol as a colorless oil (1.5 g, 80%): R_f 0.54 (5:1 hexanes/EtOAc); IR (thin film) 3375, 1649, 1599, 1491, 1445; ^1H NMR (500 MHz, CDCl_3) δ 7.38-7.12 (m, 5H), 6.64 (s, 1H), 5.17-5.12 (m, 1H), 5.02-4.98 (m, 1H), 4.61 (s, 1H), 2.02 (s, 1H), 1.82 (d, 3H, J = 1.3 Hz), 1.73 (d, 3H, J = 0.7 Hz); ^{13}C NMR (125 MHz, CDCl_3) δ 145.2, 137.9, 137.6, 129.0, 128.1, 126.7, 126.5, 111.6, 81.0, 18.5, 13.5; HRMS (EI) calcd for $\text{C}_{13}\text{H}_{16}\text{O}$ 188.1201, found: m/z 188.1206.

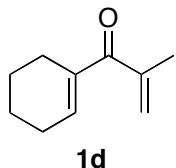
To a solution of the dienol (500 mg, 2.66 mmol) in dichloromethane (25 mL) was added BaMnO_4 (1.4 g, 5.32 mmol). The reaction mixture was stirred for 24 h at room temperature before filtration through celite. The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford dienone **1b** (297 mg, 60%) as a colorless oil: R_f 0.73 (5:1 hexanes/EtOAc); IR (thin film) 1643, 1622, 1574, 1491, 1447; ^1H NMR (400 MHz, CDCl_3) δ 7.42-7.24 (m, 6H), 5.70 (app pentet, 1H, J = 1.5 Hz), 5.59 (app pentet, 1H, J = 1.0 Hz), 2.14 (d, 3H, J = 1.5 Hz), 2.03 (app t, 3H, J = 1.0 Hz); ^{13}C NMR (125 MHz, CDCl_3) δ 200.9, 143.9, 140.1, 136.5, 135.9, 129.7, 128.4, 128.3, 123.5, 19.3, 14.2; HRMS (EI) calcd for $\text{C}_{13}\text{H}_{14}\text{O}$ 186.1044, found: m/z 186.1042.



Preparation of 1c. To a solution of α -methyl-*trans*-cinnamaldehyde (1.5 g, 0.011 mmol) in THF (10 mL) was added vinyl magnesium bromide (Aldrich; 1.0 M in THF; 12 mL, 0.012 mmol). The reaction mixture was stirred for 2 h at room temperature. Saturated NH_4Cl solution (10 mL) was then added to quench the reaction. The resulting mixture was extracted with CH_2Cl_2 (20 mL) and the organic layer was washed with brine (10 mL) and dried over MgSO_4 . The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford the desired dienol as a colorless oil (1.48 g, 85%): R_f 0.53 (5:1 hexanes/EtOAc); IR (thin film) 3363 (broad), 1641, 1600, 1492, 1443 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.39-7.21 (m, 5H), 6.61 (s, 1H), 5.96 (ddd, 1H, J = 5.8, 10.4, 16.7 Hz), 5.38 (dt, 1H, J = 1.4, 16.7 Hz), 5.24 (dt, 1H, J = 1.4, 10.4 Hz), 4.70 (d, 1H, J = 5.8 Hz), 1.88 (d, 1H, J = 1.4 Hz); ^{13}C NMR (125 MHz, CDCl_3) δ 138.9, 138.8, 137.5, 129.0, 128.1, 126.5, 126.0, 115.7, 78.6, 13.9; HRMS (EI) calcd for $\text{C}_{12}\text{H}_{14}\text{O}$ 173.0966, found: m/z 173.0962; Anal. Calcd for $\text{C}_{12}\text{H}_{14}\text{O}$: C, 82.72; H, 8.10. Found: C, 82.71; H, 8.13.

To a solution of the dienol (70.5 mg, 0.402 mmol) in dichloromethane (5 mL) was added BaMnO_4 (412 mg, 1.60 mmol). The reaction mixture was stirred for 24 h at room temperature before filtration through celite. The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford dienone **1c** (44.7 mg, 65%) as colorless oil: R_f 0.82 (5:1 hexanes/EtOAc); IR (thin film) 1720, 1657, 1658, 1605, 1491, 1447 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.54-7.33 (m, 6H), 7.06 (dd, 1H, J = 10.6, 17.0 Hz), 6.33 (dd, 1H, J = 1.8, 17.0 Hz), 5.81 (dd, 1H, J = 1.8, 10.6 Hz), 2.16 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 193.3, 139.8, 137.7, 135.8, 132.2, 129.7, 128.6, 128.47, 128.46, 13.5;

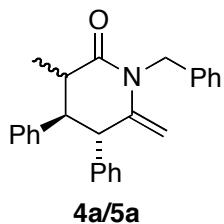
HRMS (EI) calcd for C₁₂H₁₂O 172.0888, found: m/z 172.0882; Anal. Calcd for C₁₂H₁₂O: C, 83.69; H, 7.02. Found: C, 84.10; H, 7.37.



Preparation of 1d. To a solution of 2-bromopropene (1.20 mL, 13.6 mmol) in THF (10 mL) was added Mg (653 mg, 27.2 mmol). The reaction mixture was refluxed for 30 min and the resulting solution was then transferred to a solution of 1-cyclohexene-1-carboxaldehyde (1.0 g, 9.1 mmol) in THF (10 mL). The reaction mixture was stirred for 2 h at room temperature. Saturated NH₄Cl solution (10 mL) was added to quench the reaction. The resulting mixture was further extracted with CH₂Cl₂ (20 mL). Then organic layer was washed with brine (10 mL) and dried over MgSO₄. The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford the desired dienol as a colorless oil (1.15 g, 83%): R_f 0.60 (5:1 hexanes/EtOAc); IR (thin film) 3372, 1650, 1447; ¹H NMR (400 MHz, CDCl₃) δ 5.79-5.75 (m, 1H), 5.05-5.04 (m, 1H), 4.92-4.90 (m, 1H), 4.39-4.38 (m, 1H), 2.12-2.02 (m, 2H), 1.98-1.78 (m, 2H), 1.67-1.54 (m, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 145.5, 137.6, 124.0, 110.7, 79.7, 25.1, 23.6, 22.6, 22.5, 18.5; HRMS (EI) calcd for C₁₀H₁₆O 152.1201, found: m/z 152.1201.

To a solution of the dienol (570 mg, 3.75 mmol) in dichloromethane (20 mL) was added BaMnO₄ (1.92 g, 7.5 mmol). The reaction mixture was stirred for 24 h at room temperature before filtration through celite. The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford dienone **1d** (337 mg, 60%) as a colorless oil: R_f 0.65 (5:1 hexanes/EtOAc); IR (thin film) 1642, 1450, 1435; ¹H NMR (500 MHz, CDCl₃) δ 6.68-6.67 (m, 1H), 5.57-5.56 (m, 1H), 5.42-5.29 (m, 1H), 2.29-2.21 (m, 4H), 1.94-1.93 (m, 3H), 1.70-1.61 (m, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 199.9, 143.7, 141.6, 138.1, 122.3, 25.9, 23.7, 22.0, 21.7, 19.2; HRMS (EI) calcd for C₁₀H₁₄O 150.1044, found: m/z 150.1044.

Trapping of Dienones

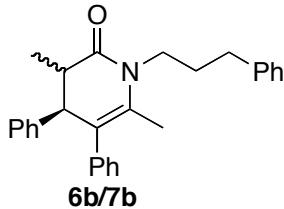


Trapping of 1a with Benzyl Azide 2a: Formation of 6-Methylenepiperidones 4a and 5a. To a solution of dibenzylidenepentanone **1a** (100 mg, 0.038 mmol) and benzyl azide¹ **2a** (100 mg, 0.76 mmol) in CH₂Cl₂ (5 mL) at -78 °C was added BF₃•OEt₂ (0.058 mL, 0.46 mmol). After 15 min, the reaction mixture was stirred at 0 °C for 15 min.; saturated aqueous NaHCO₃ (10 mL) was added and the resulting mixture was allowed to warm to room temperature. The aqueous phase was extracted with CH₂Cl₂ (2 x 20 mL). The combined organic phases were concentrated to give a mixture of two isomeric products by crude NMR. The two products were then separated and purified by flash column chromatography (silica gel; 15:1 hexanes/EtOAc) to give

52 mg of all-*trans* diastereomer **4a** and 50 mg of *cis/trans* diastereomer **5a** as colorless oils in a combined yield of 72%.

4a: R_f 0.1 (15:1 hexanes/EtOAc); ^1H NMR (400 MHz, CDCl_3) δ 7.36-6.90 (m, 15H), 5.13 (d, 1H, J = 15.6 Hz), 5.02 (d, 1H, J = 15.6 Hz), 4.50 (app t, 1H, J = 1.8 Hz), 3.90 (app dt, 1H, J = 11.8, 1.7 Hz), 3.77 (app t, 1H, J = 1.7 Hz), 3.05 (app t, 1H, J = 11.6 Hz), 2.85-2.93 (m, 1H), 1.14 (d, 3H, J = 6.9 Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 172.6, 148.2, 141.4, 141.0, 137.6, 129.3, 128.8, 128.5, 128.2, 128.1, 127.1, 126.9, 126.8, 126.7, 97.4, 53.2, 51.5, 48.2, 44.0, 15.8; HRMS (ESI) [M+H] $^+$ for $\text{C}_{26}\text{H}_{26}\text{NO}$: calcd 368.2008, Found: *m/z* 368.2008.

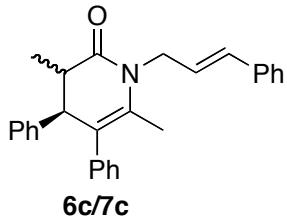
5a: R_f 0.26 (15:1 hexanes/EtOAc); ^1H NMR (400 MHz, CDCl_3) δ 7.35-7.05 (m, 15H), 5.15 (d, 1H, J = 15.2 Hz), 5.12 (d, 1H, J = 15.2 Hz), 4.62 (d, 1H, J = 1.5 Hz), 4.09-4.05 (m, 2H), 3.40 (app t, 1H, J = 5.2 Hz), 2.87 (app dq, 1H, J = 7.1, 5.5 Hz), 1.12 (d, 3H, J = 7.1 Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 172.6, 144.9, 143.3, 140.2, 137.6, 128.82, 128.80, 128.73, 128.72, 127.95, 127.91, 127.4, 127.1, 127.0, 97.6, 50.8, 49.9, 47.4, 37.0, 14.2; HRMS (ESI) [M+H] $^+$ for $\text{C}_{26}\text{H}_{26}\text{NO}$: calcd 368.2008, found: *m/z* 368.2004.



Trapping of 1a with Azide 2b. Dienone **1a** was treated with 1-azido-3-phenylpropane² **2b** following the procedure given in the Experimental Section for **6a/7a**. Purification by column chromatography (silica gel; hexanes/EtOAc 5:1) afforded *trans* isomer **6b** (81.0 mg, 54%) and *cis* isomer **7b** (36.0 mg, 24%) as colorless oils.

6b: R_f 0.49 (5:1 hexanes/EtOAc); IR (film microscope) 1668, 1617, 1495, 1452, 1394 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.34-7.18 (m, 11H), 7.04-6.98 (m, 4H), 4.01 (ddd, 1H, J = 6.2, 9.8, 14.0 Hz), 3.53 (ddd, 1H, J = 5.6, 10.0, 14.3 Hz), 3.51 (d, 1H, J = 7.0 Hz), 3.14 (app pentet, 1H, J = 7.0 Hz), 2.80-2.65 (m, 2H), 2.12-1.98 (m, 2H), 1.88 (s, 3H), 1.07 (d, 3H, J = 7.0 Hz); ^{13}C NMR (125 MHz, CDCl_3) δ 171.6, 141.4, 140.9, 137.6, 132.0, 129.2, 128.7, 128.4, 128.3, 128.3, 128.2, 127.0, 126.6, 126.0, 123.0, 50.3, 42.3, 40.3, 33.5, 30.4, 16.5, 12.8; HRMS (EI) calcd for $\text{C}_{28}\text{H}_{29}\text{ON}$ 395.2249, found: *m/z* 395.2252. Anal. Calcd for $\text{C}_{28}\text{H}_{29}\text{ON}$: C, 82.98; H, 7.60; N, 4.40. Found: C, 82.71; H, 7.63; N, 3.92.

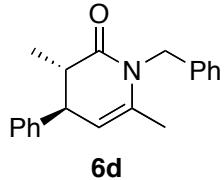
7b: R_f 0.46 (5:1 hexanes/EtOAc); IR (film microscope) 1667, 1599, 1494, 1453, 1394 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.32-7.06 (m, 15H), 4.03 (ddd, 1H, J = 6.5, 9.3, 14.1 Hz), 3.45 (ddd, 1H, J = 6.5, 8.8, 14.1 Hz), 3.44 (app s, 1H), 2.83 (dq, 1H, J = 1.7, 7.2 Hz), 2.71-2.59 (m, 2H), 1.96-1.84 (m, 2H), 1.92 (s, 3H), 1.43 (d, 3H, J = 7.2 Hz); ^{13}C NMR (125 MHz, CDCl_3) δ 172.3, 141.4, 141.3, 140.9, 131.7, 129.2, 128.6, 128.4, 128.3, 128.2, 127.3, 126.8, 126.7, 126.0, 118.5, 51.2, 44.1, 41.6, 33.3, 30.7, 17.6, 16.3; HRMS (EI) calcd for $\text{C}_{28}\text{H}_{29}\text{ON}$ 395.2249, found: *m/z* 395.2245. Anal. Calcd for $\text{C}_{28}\text{H}_{29}\text{ON}$: C, 82.98; H, 7.60; N, 4.40. Found: C, 82.02; H, 7.61; N, 4.03.



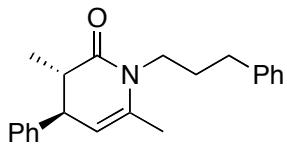
Trapping of 1a with Azide 2c. Dienone **1a** was treated with cinnamyl azide³ **2c** following the procedure given in the Experimental Section for **6a/7a**. Purification by column chromatography (silica gel; hexanes/EtOAc 5:1) afforded *trans* isomer **6c** (85 mg, 57%) and *cis* isomer **7c** (42 mg, 28%) as colorless oils.

6c: R_f 0.28 (5:1 hexanes/EtOAc); IR (cast film) 1667, 1598, 1492, 1431, 1391 cm^{-1} ; ¹H NMR (400 MHz, CDCl₃) δ 7.42-7.01 (m, 15H), 6.63 (d, 1H, *J* = 16.0 Hz), 6.37 (ddd, 1H, *J* = 5.9, 6.9, 16.0 Hz), 4.83 (ddd, 1H, *J* = 1.5, 5.9, 15.4 Hz), 4.34 (ddd, 1H, *J* = 1.2, 6.9, 15.4 Hz), 3.56 (d, 1H, *J* = 7.1 Hz), 3.22 (app pentet, 1H, *J* = 7.0 Hz), 2.04 (d, 3H, *J* = 0.6 Hz), 1.11 (d, 3H, *J* = 7.0 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 171.5, 140.6, 137.3, 136.6, 132.5, 132.1, 129.1, 128.7, 128.5, 128.3, 128.1, 127.6, 126.9, 126.6, 126.3, 125.3, 123.2, 50.2, 44.3, 40.3, 16.6, 12.8; HRMS (EI) calcd for C₂₈H₂₇ON 393.2092, found: m/z 393.2093.

7c: R_f 0.25 (5:1 hexanes/EtOAc); IR (film microscope) 1668, 1599, 1491, 1449, 1392 cm^{-1} ; ¹H NMR (400 MHz, CDCl₃) δ 7.38-7.10 (m, 15H), 6.51 (td, 1H, *J* = 1.5, 16.0 Hz), 6.22 (ddd, 1H, *J* = 5.2, 6.9, 16.0 Hz), 4.85 (ddd, 1H, *J* = 1.6, 5.2, 15.9 Hz), 4.24 (ddd, 1H, *J* = 1.2, 6.8, 15.9 Hz), 3.52 (app s, 1H), 2.91 (dq, 1H, *J* = 1.8, 7.2 Hz), 2.06 (d, 3H, *J* = 0.6 Hz), 1.51 (d, 3H, *J* = 7.2 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 172.2, 141.0, 140.6, 136.5, 131.8, 131.7, 129.1, 128.5, 128.4, 128.1, 127.6, 127.3, 126.7, 126.6, 126.3, 125.5, 118.5, 51.1, 44.0, 43.6, 17.5, 16.4; HRMS (EI) calcd for C₂₈H₂₇ON 393.2092, found: m/z 393.2096.

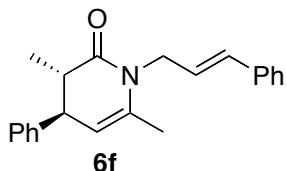


Trapping of 1b with Benzyl Azide 2a. To a solution of dienone **1b** (76.0 mg, 0.41 mmol) and benzyl azide¹ **2a**, (109.2 mg, 0.82 mmol) in dichloromethane (5 mL) was added BF₃•OEt₂ (116 μL , 0.82 mmol) at -78°C (dry ice/acetone bath). The reaction mixture was stirred for 60 min before saturated NaHCO₃ solution (2 mL) was added to quench the reaction. The resulting mixture was extracted with CH₂Cl₂ (20 mL) and the organic layer was washed with brine (10 mL) and dried over MgSO₄. The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford only the *trans* product, **6d** (89.5 mg, 75%): R_f 0.56 (5:1 hexanes/EtOAc); IR (film microscope) 1673, 1670, 1604, 1495, 1452 cm^{-1} ; ¹H NMR (400 MHz, CDCl₃) δ 7.39-7.20 (m, 8H), 7.12-7.04 (m, 2H), 5.22 (dd, 1H, *J* = 1.0, 5.3 Hz), 4.94 (AB, 2H, *J* = 15.7 Hz), 3.65 (qdd, 1H, *J* = 1.3, 5.3, 6.0 Hz), 2.97 (app pentet, 1H, *J* = 7.0 Hz), 2.02 (app t, 3H, *J* = 1.3 Hz), 1.03 (d, 3H, *J* = 7.1 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 173.2, 139.2, 138.3, 136.0, 128.5, 128.3, 128.2, 127.1, 127.0, 126.7, 108.3, 45.2, 42.4, 40.9, 19.5, 12.1; HRMS (EI) calcd for C₂₀H₂₁ON 291.1623, found: m/z 291.1622.



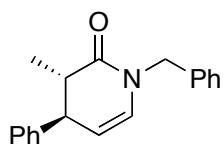
6e

Trapping of 1b with Azide 2b. Dienone **1b** was treated with 1-azido-3-phenylpropane² **2b** following the procedure given above for **6d**. Purification by column chromatography (silica gel; hexanes/EtOAc 5:1) afforded *trans* isomer **6e** (127.6 mg, 80%) as a colorless oil: R_f 0.36 (5:1 hexanes/EtOAc); IR (film microscope) 1665, 1660, 1602, 1551, 1496, 1453 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 7.36-7.12 (m, 10H), 5.22 (qd, 1H, J = 1.1, 5.4 Hz), 3.8 (ddd, 1H, J = 5.8, 9.9, 13.9 Hz), 3.58 (ddd, 1H, J = 5.6, 9.9, 14.0 Hz), 3.54 (dd, 1H, J = 5.4, 7.0 Hz), 2.87 (app pentet, 1H, J = 7.0 Hz), 2.70-2.74 (m, 2H), 2.04-1.84 (m, 2H), 1.97 (app s, 3H), 0.98 (d, 3H, J = 7.1 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 172.7, 141.3, 139.5, 135.6, 128.3, 128.3, 128.2, 128.1, 126.8, 125.9, 108.5, 42.5, 41.7, 40.7, 33.2, 30.5, 19.2, 12.1; HRMS (EI) calcd for C₂₂H₂₅ON 319.1936, found: m/z 319.1931.



6f

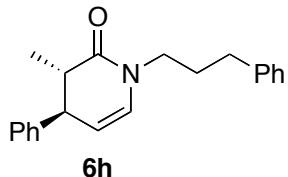
Trapping of 1b with Azide 2c. Dienone **1b** was treated with cinnamyl azide³ **2c** following the procedure given above for **6d**. Purification by column chromatography (silica gel; hexanes/EtOAc 6:1) afforded *trans* isomer **6f** (159.7 mg, 72%) as a colorless oil: R_f 0.33 (6:1 hexanes/EtOAc); IR (film microscope) 1674, 1670, 1600, 1495, 1450, 1389 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.40-7.12 (m, 10H), 6.56 (d, 1H, J = 16.0 Hz), 6.29 (td, 1H, J = 6.1, 16.0 Hz), 5.25 (qd, 1H, J = 1.0, 5.5 Hz), 4.60 (ddd, 1H, J = 1.4, 5.8, 15.8 Hz), 4.37 (ddd, 1H, J = 1.2, 6.2, 15.8 Hz), 3.58 (app t, 1H, J = 5.8 Hz), 2.95 (app pentet, 1H, J = 7.0 Hz), 2.09 (app t, 3H, J = 1.2 Hz), 1.02 (d, 3H, J = 7.0 Hz); ¹³C NMR (125 MHz, CDCl₃) δ 172.8, 139.4, 136.6, 135.9, 132.0, 128.6, 128.4, 128.3, 127.7, 126.9, 126.4, 125.4, 108.7, 43.8, 42.7, 40.8, 19.4, 12.3; HRMS (EI) calcd for C₂₂H₂₃ON 317.1779, found: m/z 317.1764.



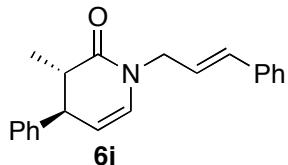
6g

Trapping of 1c with Benzyl Azide 2a: To a solution of dienone **1c** (53.0 mg, 0.31 mmol) and benzyl azide¹ **2a** (82 mg, 0.62 mmol) in dichloromethane (5 mL) was added BF₃•OEt₂ (43 μ L, 0.34 mmol) at room temperature. The reaction mixture was stirred for 15 min before saturated NaHCO₃ solution (2 mL) was added to quench the reaction. The resulting mixture was extracted with CH₂Cl₂ (10 mL) and the organic layer was washed with brine (10 mL) and dried over MgSO₄. The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford only *trans* product, **6g** (53.2 mg, 62%): R_f 0.62 (5:1 hexanes/EtOAc); IR (film microscope) 1668, 1603, 1494, 1453, 1406 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 7.39-7.18 (m, 8H), 7.04-6.98 (m, 2H), 6.23 (dd, 1H, J = 1.1, 7.7

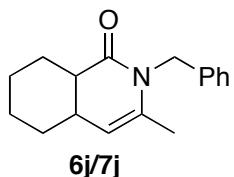
Hz), 5.35 (dd, 1H, J = 5.2, 7.7 Hz), 4.87 (d, 1H, J = 14.7 Hz), 4.62 (d, 1H, J = 14.7 Hz), 3.66 (app t, 1H, J = 7.0 Hz), 2.98 (app pentet, 1H, J = 7.1 Hz), 1.01 (d, 3H, J = 7.1 Hz); ^{13}C NMR (100 MHz, CDCl_3) δ 171.8, 138.9, 137.1, 129.2, 128.7, 128.4, 128.21, 128.20, 127.6, 127.0, 110.1, 49.4, 43.7, 41.0, 12.1; HRMS (EI) calcd for $\text{C}_{19}\text{H}_{19}\text{ON}$ 277.1467, found: m/z 277.1463.



Trapping of 1c with Azide 2b: Dienone **1c** was treated with 1-azido-3-phenylpropane² **2b** following the procedure given above for **6g**. Purification by column chromatography (silica gel; hexanes/EtOAc 5:1) afforded *trans* isomer **6h** (106 mg, 40%) as a colorless oil: R_f 0.38 (5:1 hexanes/EtOAc); IR (film microscope) 1666, 1602, 1495, 1453 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.34-7.12 (m, 10H), 6.17 (dd, 1H, J = 1.2, 7.8 Hz), 5.34 (dd, 1H, J = 5.0, 7.8 Hz), 3.66 (dd, 1H, J = 5.0, 7.0 Hz), 3.64 (ddd, 1H, J = 6.4, 8.1, 13.6 Hz), 3.51 (ddd, 1H, J = 6.5, 8.1, 13.8 Hz), 2.88 (app pentet, 1H, J = 7.0 Hz), 2.69 (t, 2H, J = 8.1 Hz), 2.02-1.94 (m, 2H), 0.97 (app s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 171.7, 141.3, 139.2, 129.6, 128.4, 128.3, 128.2, 128.1, 126.9, 125.9, 109.4, 46.1, 43.5, 40.9, 33.0, 30.0, 11.9; HRMS (EI) calcd for $\text{C}_{21}\text{H}_{23}\text{ON}$ 305.1779, found: m/z 305.1775.



Trapping of 1c with Azide 2c. Dienone **1c** was treated with cinnamyl azide³ **2c** following the procedure given above for **6g**. Purification by column chromatography (silica gel; hexanes/EtOAc 5:1) afforded *trans* isomer **6i** (83.3 mg, 43%) as a colorless oil: R_f 0.35 (6:1 hexanes/EtOAc); IR (film microscope) 1666, 1600, 1578, 1494, 1450, 1405, 1386 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.41-7.10 (m, 10H), 6.60 (td, 1H, J = 1.3, 15.8 Hz), 6.28-6.20 (m, 2H), 5.38 (dd, 1H, J = 5.0, 7.7 Hz), 4.36 (ddd, 1H, J = 1.3, 6.4, 15.1 Hz), 4.29 (ddd, 1H, J = 1.3, 6.4, 15.1 Hz), 3.68 (app t, 1H, J = 7.1 Hz), 2.96 (app pentet, 1H, J = 7.1 Hz), 1.00 (d, 3H, J = 7.1 Hz); ^{13}C NMR (125 MHz, CDCl_3) δ 171.6, 139.1, 136.4, 133.3, 129.1, 128.6, 128.5, 128.2, 127.8, 127.0, 126.5, 124.3, 110.1, 47.8, 43.7, 41.0, 12.1; HRMS (EI) calcd for $\text{C}_{21}\text{H}_{21}\text{ON}$ 303.1623, found: m/z 303.1618.

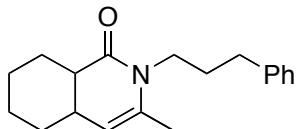


Trapping of 1d with Benzyl Azide 2a. To a solution of dienone **1d** (100 mg, 0.67 mmol) and benzyl azide¹ **2a** (178 mg, 1.34 mmol) in dichloromethane (5 mL) was added $\text{BF}_3\text{-OEt}_2$ (190 μL , 1.34 mmol) at 0 °C (ice-water bath). The reaction mixture was stirred for 60 min before saturated NaHCO_3 solution (2 mL) was added to quench the reaction. The resulting mixture was

extracted with CH_2Cl_2 (20 mL) and the organic layer was washed with brine (10 mL) and dried over MgSO_4 . The solvent was evaporated under reduced pressure and the residue purified by column chromatography (silica gel; hexanes/EtOAc 5:1) to afford the *trans* isomer **6j** (90.5 mg, 53%) and the *cis* isomer **7j** (46.1 mg, 27%) as colorless oils.

6j: R_f 0.55 (5:1 hexanes/EtOAc); IR (film microscope) 1675, 1664, 1605, 1496, 1446 cm^{-1} ; ^1H NMR (500 MHz, CD_3OD) δ 7.32-7.10 (m, 5H), 5.18 (d, 1H, J = 16.3 Hz), 4.94 (app s, 1H), 4.58 (d, 1H, J = 16.3 Hz), 2.25-2.18 (m, 1H), 2.16-2.02 (m, 2H), 1.92-1.82 (m, 2H), 1.82 (app t, 3H, J = 1.4 Hz), 1.80-1.74 (m, 1H), 1.38-1.18 (m, 4H); ^{13}C NMR (125 MHz, CD_3OD) δ 175.3, 139.6, 136.2, 129.7, 128.0, 127.2, 114.1, 46.2, 45.7, 37.0, 33.2, 27.5, 26.7, 26.6, 19.1; HRMS (EI) calcd for $\text{C}_{17}\text{H}_{21}\text{ON}$ 255.1623, found: m/z 255.1628.

7j: R_f 0.54 (5:1 hexanes/EtOAc); IR (film microscope) 1674, 1670, 1605, 1496, 1446 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 7.34-7.16 (m, 5H), 4.93 (d, 1H, J = 16.0 Hz), 4.88 (d, 1H, J = 4.2 Hz), 4.84 (d, 1H, J = 16.0 Hz), 2.64-2.61 (m, 1H), 2.56-2.48 (m, 1H), 2.16-2.02 (m, 1H), 1.85 (app t, 3H, J = 1.6 Hz), 1.60-1.49 (m, 4H), 1.48-1.36 (m, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 173.2, 138.7, 134.9, 128.6, 126.8, 126.4, 109.7, 44.8, 42.3, 32.3, 28.7, 24.6, 23.8, 23.6, 19.4; HRMS (EI) calcd for $\text{C}_{17}\text{H}_{21}\text{ON}$ 255.1623, found: m/z 255.1629.

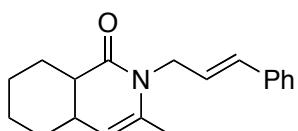


6k/7k

Trapping of 1d with Azide 2b: Dienone **1d** was treated with 1-azido-3-phenylpropane² **2b** following the procedure given above for **6j/7j**. Purification by column chromatography (silica gel; hexanes/EtOAc 5:1) afforded *trans* isomer **6k** (138 mg, 53%) and *cis* isomer **7k** (46 mg, 17%) as colorless oils.

6k: R_f 0.57 (3:1 hexanes/EtOAc); IR (microscope) 1671, 1616, 1496, 1447, 1389; ^1H NMR (500 MHz, C_6D_6) δ 7.16-6.98 (m, 5H), 4.52 (app s, 1H), 3.98-3.92 (m, 1H), 3.11 (ddd, 1H, J = 5.6, 8.9, 14.0 Hz), 2.52-2.40 (m, 3H), 1.90-1.81 (m, 1H), 1.81-1.62 (m, 4H), 1.60-1.48 (m, 2H), 1.45 (dd, 3H, J = 1.4, 2.5 Hz), 1.38-1.35 (m, 1H), 1.16-0.90 (m, 3H); ^{13}C NMR (125 MHz, CDCl_3) δ 172.9, 141.6, 134.4, 128.33, 128.29, 125.9, 112.5, 45.0, 41.3, 35.6, 33.2, 32.1, 30.8, 26.3, 25.7, 25.5, 18.9; HRMS (EI) calcd for $\text{C}_{19}\text{H}_{25}\text{ON}$ 283.1936, found: m/z 283.1934.

7k: R_f 0.53 (3:1 hexanes/EtOAc); IR (microscope) 1672, 1670, 1496, 1446, 1392 cm^{-1} ; ^1H NMR (500 MHz, C_6D_6) δ 7.18-6.98 (m, 5H), 4.61 (d, 1H, J = 5.0 Hz), 3.74 (br s, 1H), 3.32 (br s, 1H), 2.50-2.41 (m, 3H), 2.37 (br s, 1H), 2.04 (br s, 1H), 1.82-1.68 (m, 2H), 1.68-1.58 (m, 1H), 1.51-1.46 (m, 1H), 1.43 (app t, 3H, J = 1.3 Hz), 1.39-1.29 (m, 3H), 1.27-1.19 (m, 1H), 1.15-1.08 (m, 1H); ^{13}C NMR (125 MHz, C_6D_6) δ 171.6, 142.0, 135.0, 128.7, 128.6, 126.2, 109.4, 42.0, 41.3, 33.5, 33.2, 31.4, 29.1, 25.3, 25.1, 23.6, 19.1; HRMS (EI) calcd for $\text{C}_{19}\text{H}_{25}\text{ON}$ 283.1936, found: m/z 283.1933.



6l/7l

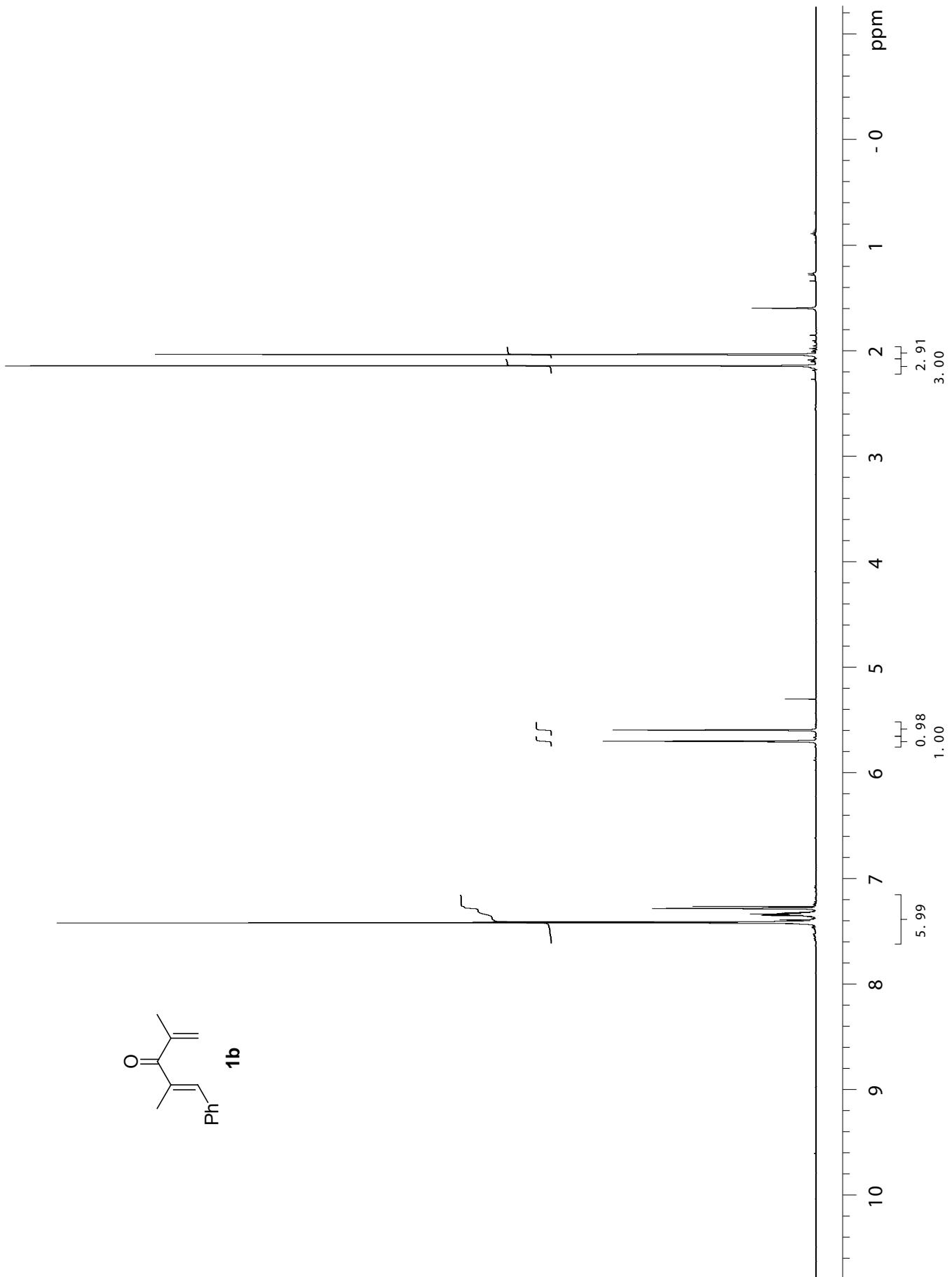
Trapping of **1d with Azide **2c**.** Dienone **1d** was treated with cinnamyl azide³ **2c** following the procedure given above for **6j/7j**. Purification by column chromatography (silica gel; hexanes/EtOAc 4:1) afforded *trans* isomer **6l** (150 mg, 52%) and *cis* isomer **7l** (60 mg, 21%) as colorless oils.

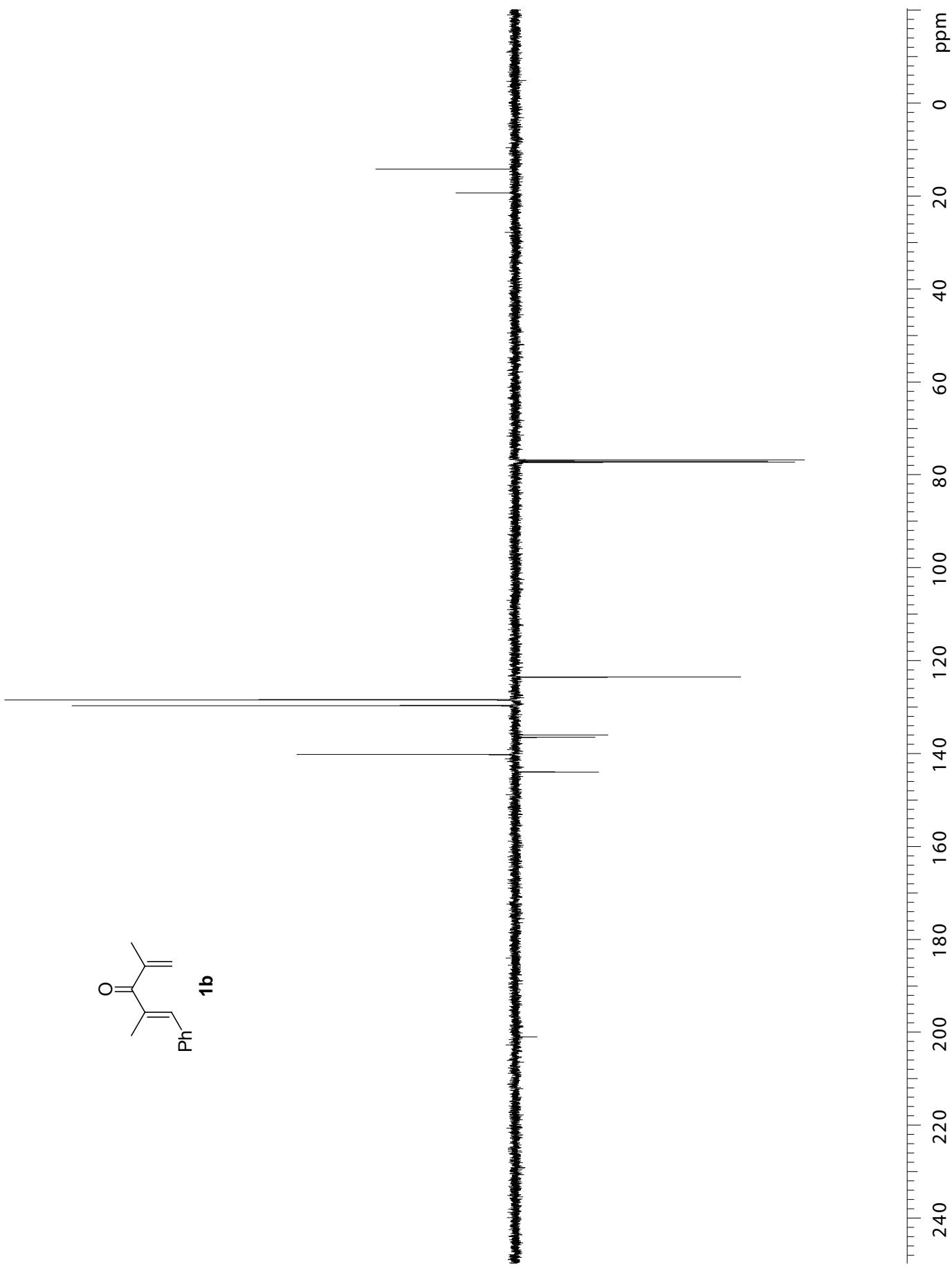
6l: R_f 0.45 (4:1 hexanes/EtOAc); IR (film microscope) 1672, 1494, 1447, 1387 cm⁻¹; ¹H NMR (500 MHz, CD₃OD) δ 7.38-7.16 (m, 5H), 6.41 (td, 1H, *J* = 1.5, 15.8 Hz), 6.18 (td, 1H, *J* = 5.4, 16.0 Hz), 4.94 (app s, 1H), 4.61 (ddd, 1H, *J* = 1.8, 5.0, 16.8 Hz), 4.20 (ddd, 1H, *J* = 1.6, 5.6, 16.8 Hz), 2.21-2.16 (m, 1H), 2.09-2.02 (m, 1H), 2.02-1.96 (m, 1H), 1.97 (dd, 3H, *J* = 1.4, 2.3 Hz), 1.90-1.82 (m, 2H), 1.77-1.72 (m, 1H), 1.31-1.18 (m, 4H); ¹³C NMR (125 MHz, CD₃OD) δ 175.0, 138.1, 136.1, 132.0, 129.6, 128.6, 127.3, 126.6, 113.8, 46.2, 44.3, 37.1, 33.3, 27.4, 26.7, 26.6, 19.0; HRMS (EI) calcd for C₁₉H₂₃ON 281.1779, found: m/z 281.1776.

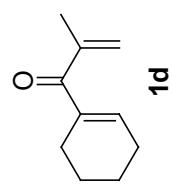
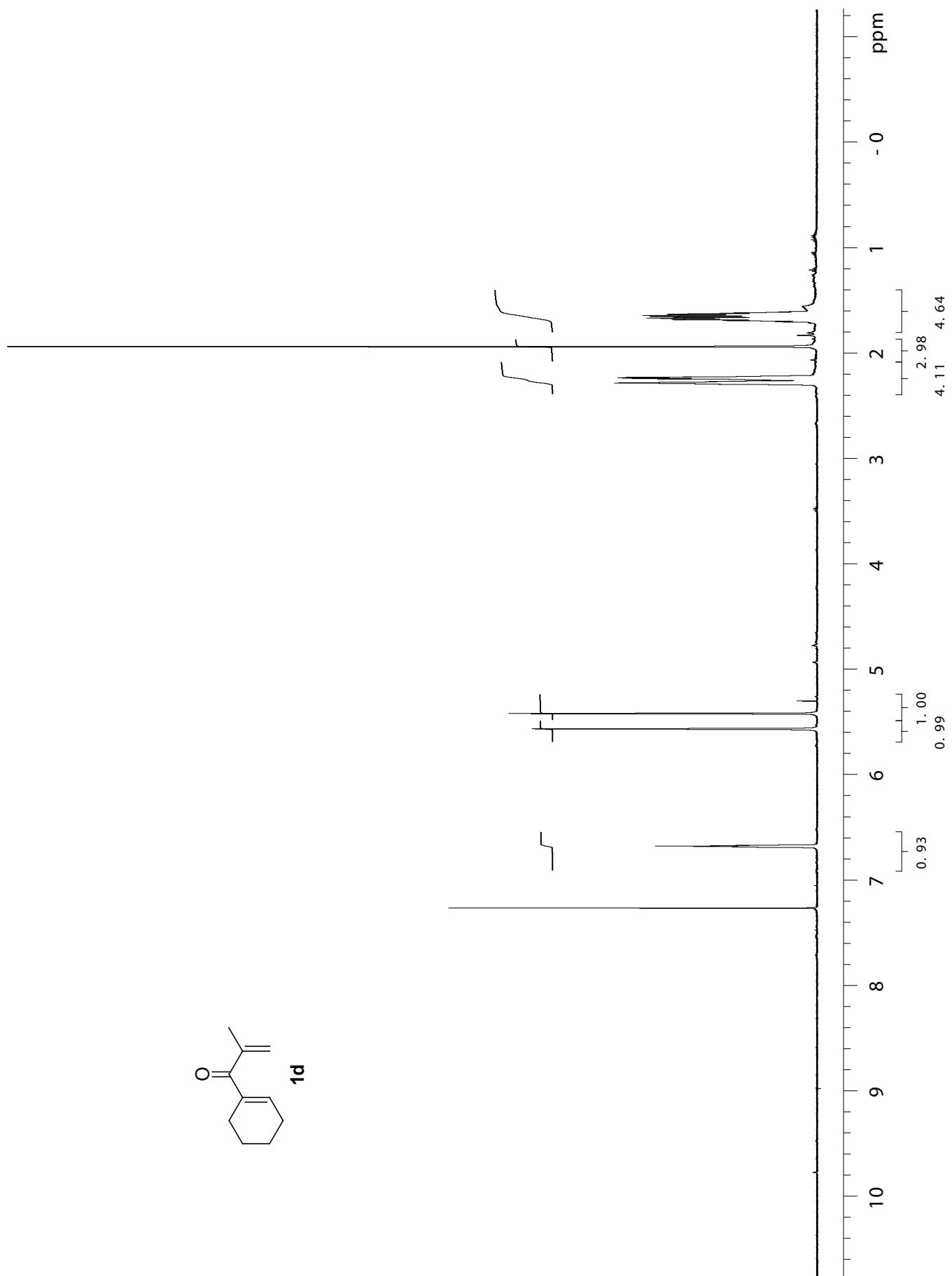
7l: R_f 0.43 (4:1 hexanes/EtOAc); IR (film microscope) 1673, 1670, 1495, 1447, 1390 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 7.38-7.20 (m, 5H), 6.45 (td, 1H, *J* = 1.5, 16.0 Hz), 6.18 (td, 1H, *J* = 5.4, 16.0 Hz), 4.90 (d, 1H, *J* = 4.2 Hz), 4.42 (dd, 1H, *J* = 5.4, 16.8 Hz), 4.37 (dd, 1H, *J* = 5.4, 16.8 Hz), 2.61-2.56 (m, 1H), 2.50-2.42 (m, 1H), 2.10-1.98 (m, 1H), 1.96 (t, 3H, *J* = 1.5 Hz), 1.60-1.42 (m, 4H), 1.42-1.36 (m, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 172.7, 136.7, 134.7, 130.7, 128.4, 127.4, 126.2, 126.0, 109.6, 43.1, 42.1, 32.2, 28.6, 24.5, 23.8, 23.4, 19.1; HRMS (EI) calcd for C₁₉H₂₃ON 281.1779, found: m/z 281.1775.

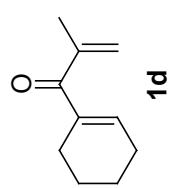
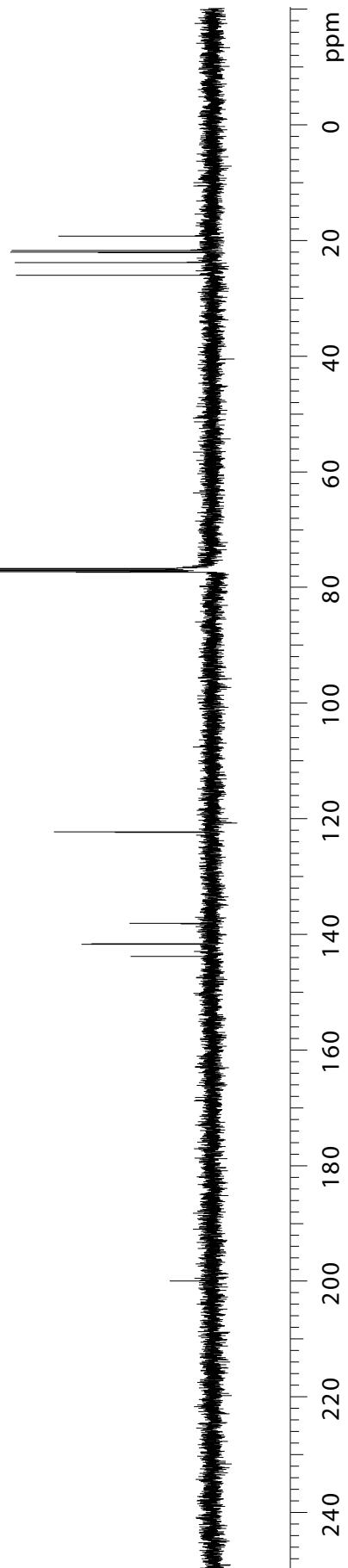
References

- (1) Reddy, D. S.; Judd, W. R.; Aube, J. *Org. Lett.* **2003**, *5*, 3899.
- (2) Koziara, A.; Zwierzak, A. *Synthesis* **1992**, *11*, 1063.
- (3) Alvarez, S. G.; Alvarez, M. T. *Synthesis* **1997**, *4*, 413.



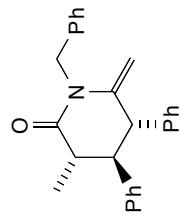




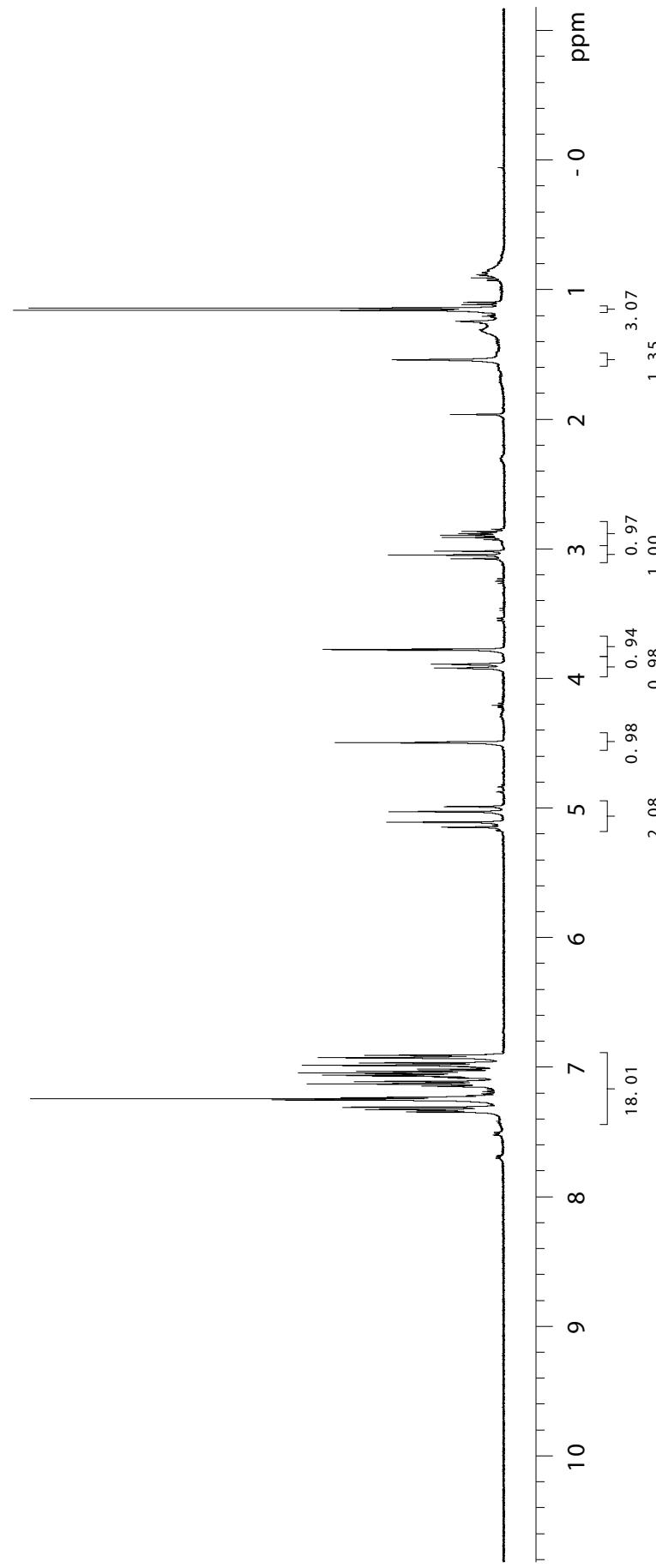


400 MHz 1D in CDCl₃ (ref. to CDCl₃ @ 7.26 ppm), temp 27.0 C -> actual temp = 27.0 C, m#00gz probe
AR-2-157C-exo
date: May 19 2005 sweep width: 4803Hz acq. time: 2.0s relax: 3.0s # scans: 16
spectrometer: i bdw file: /mit/d600/home13/westnmr/nmrdata/Al1/Book2/AR-H-2-157C.fid

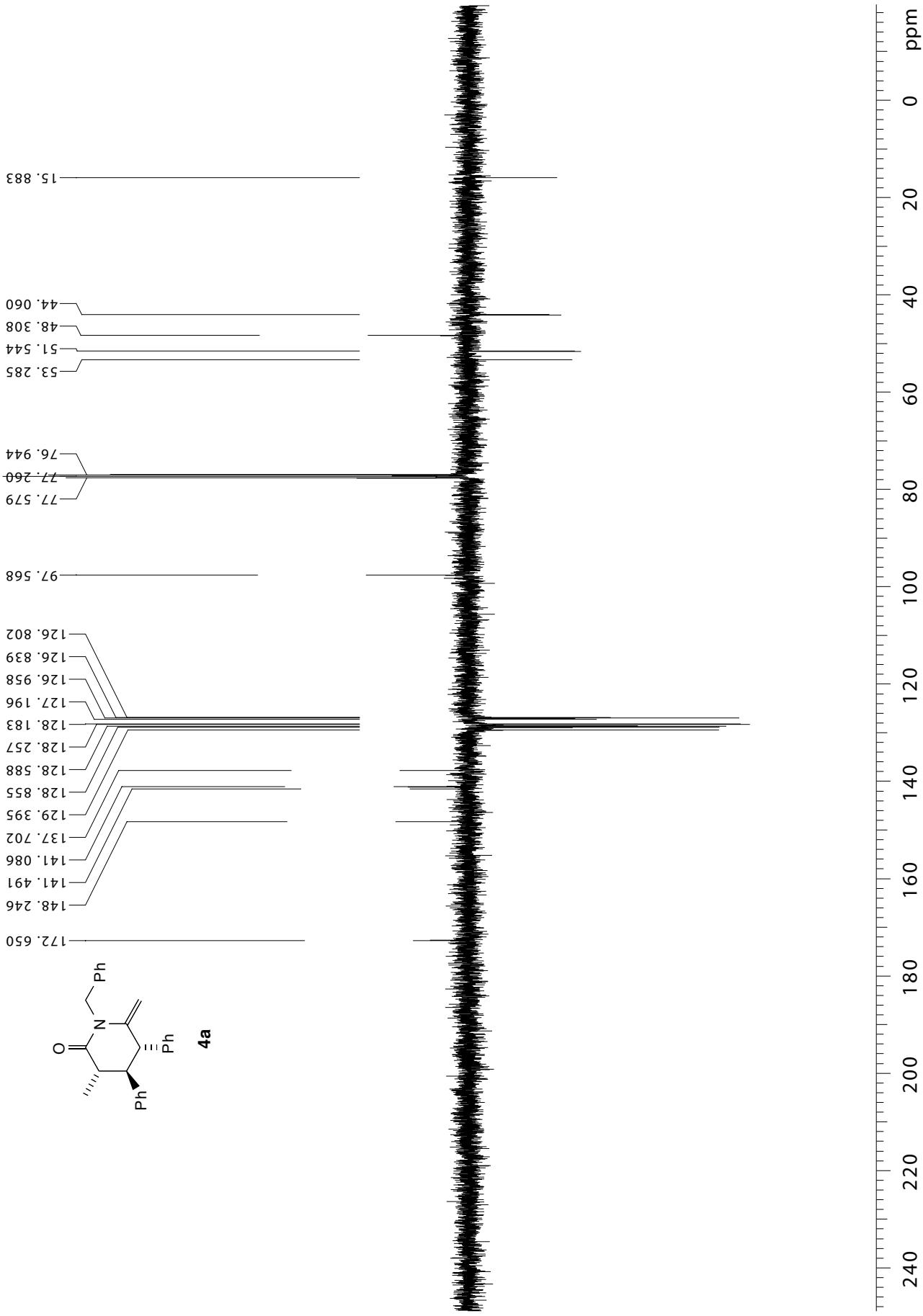
Pulse Sequence: s2pul



4a

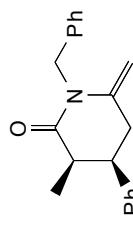


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 C & CH₂ same, CH & CH₃ opposite side of solvent signal
 dptg: 100, zq: 2005, sweep width: 27027 Hz, acq. time: 2.0 s, # scans: 704, di g. res.: 0.4 Hz / pt, hz / mm 112.6
 spectrometer: i baw file: /mmt/d600/home13/westnmr/nmrdata/Al1/Book2/AR-AP1-2-157C.fid

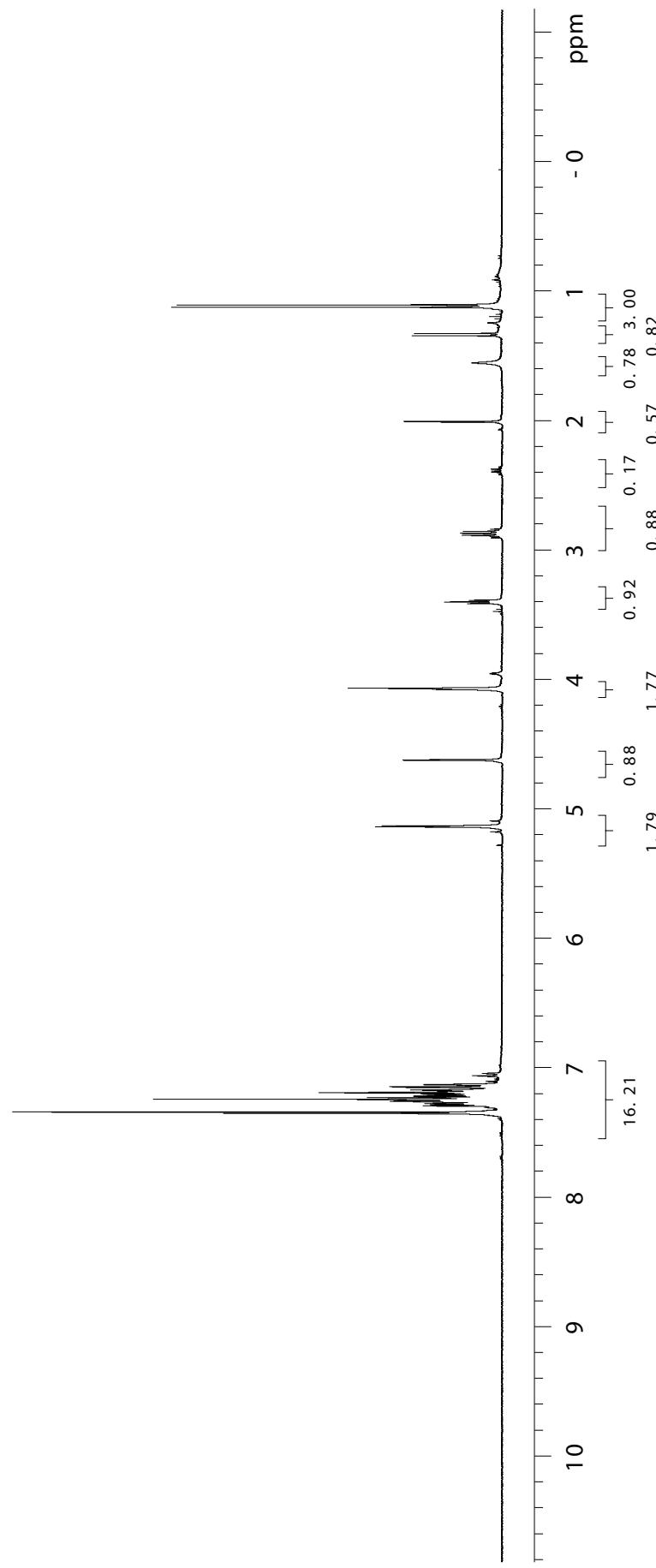


400 MHz 1D in CDCl₃ (ref. to CDCl₃ @ 7.26 ppm), temp 27.0 C -> actual temp = 27.0 C, m#00gz probe
AR-2-157Aexo
date: May 19 2005 sweep width: 4803Hz acq. time: 2.0s relax: 3.0s # scans: 30
spectrometer: i bdw filte: /mt/d600/home13/westnmr/nmrdata/Al1/Book2/AR-H-2-157A.fid

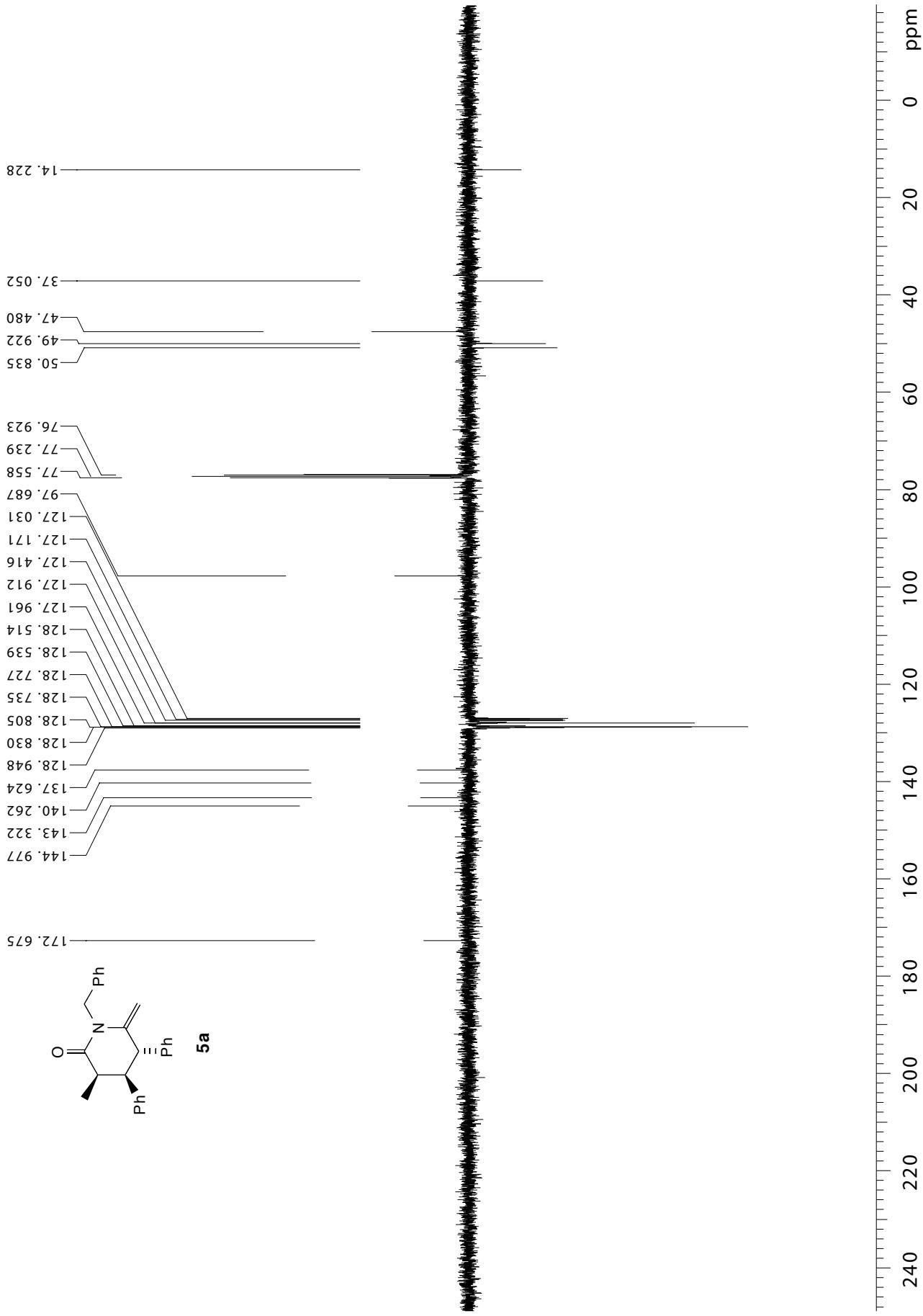
Pulse Sequence: s2pul

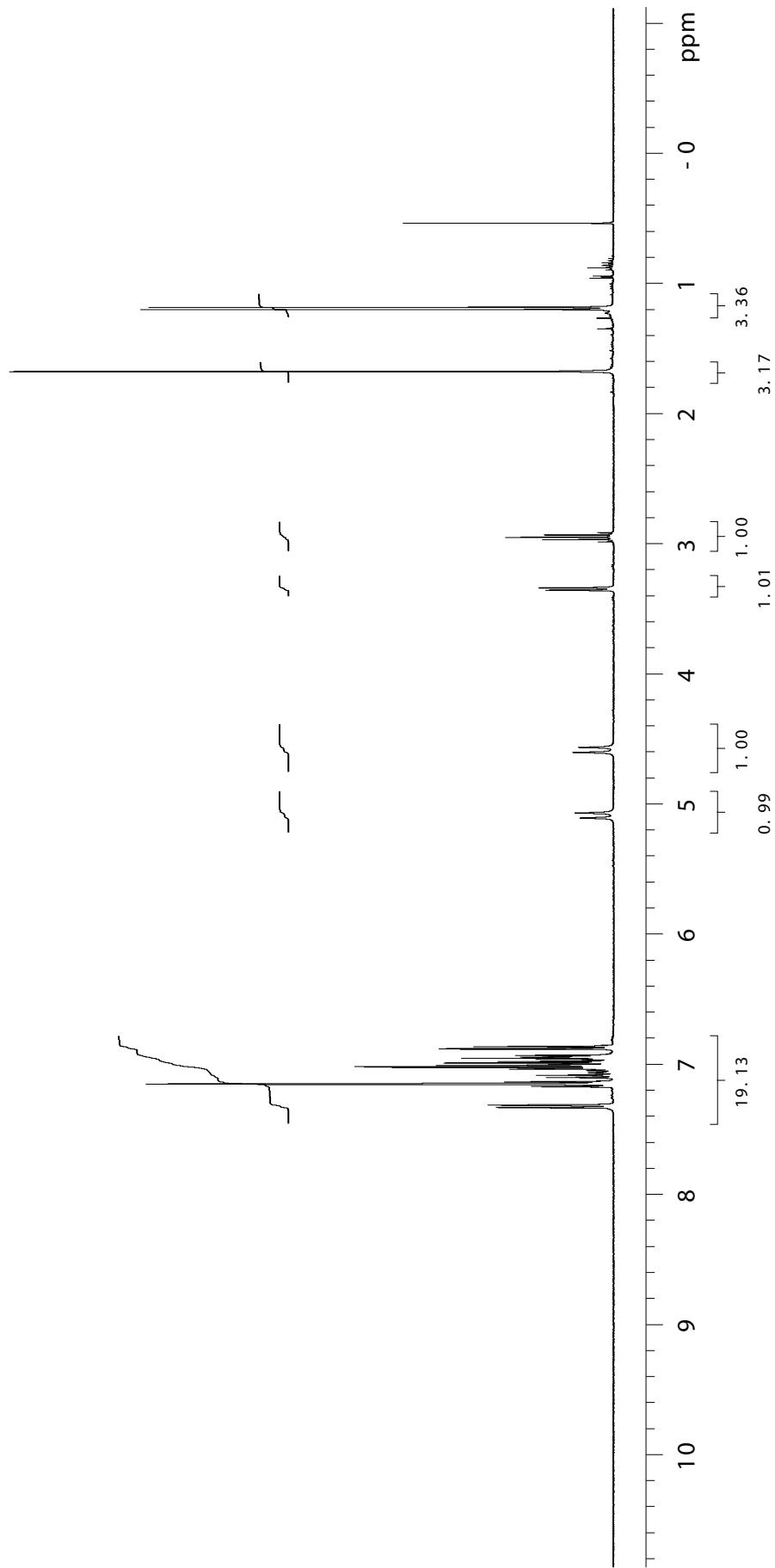
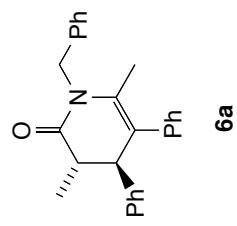


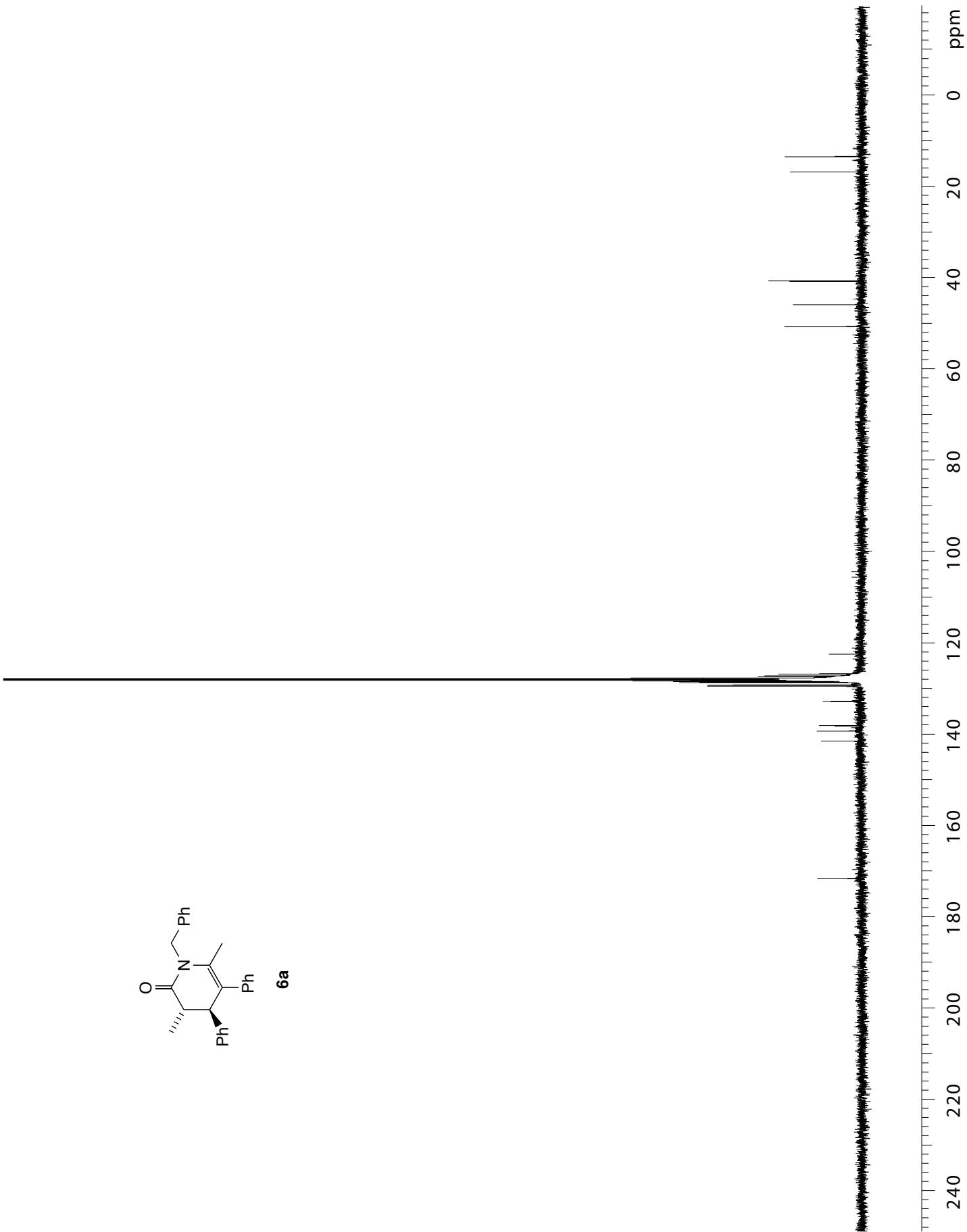
5a

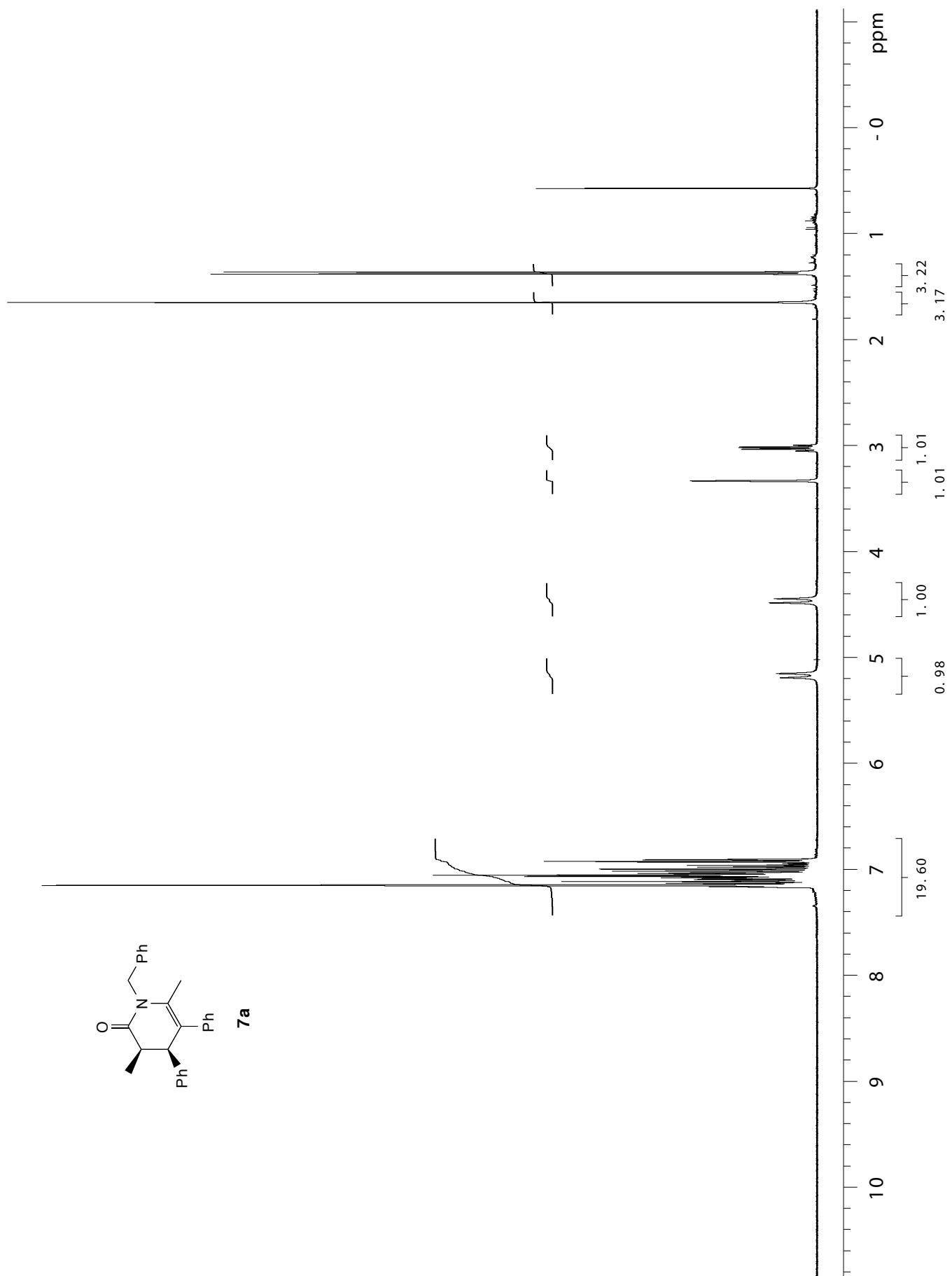


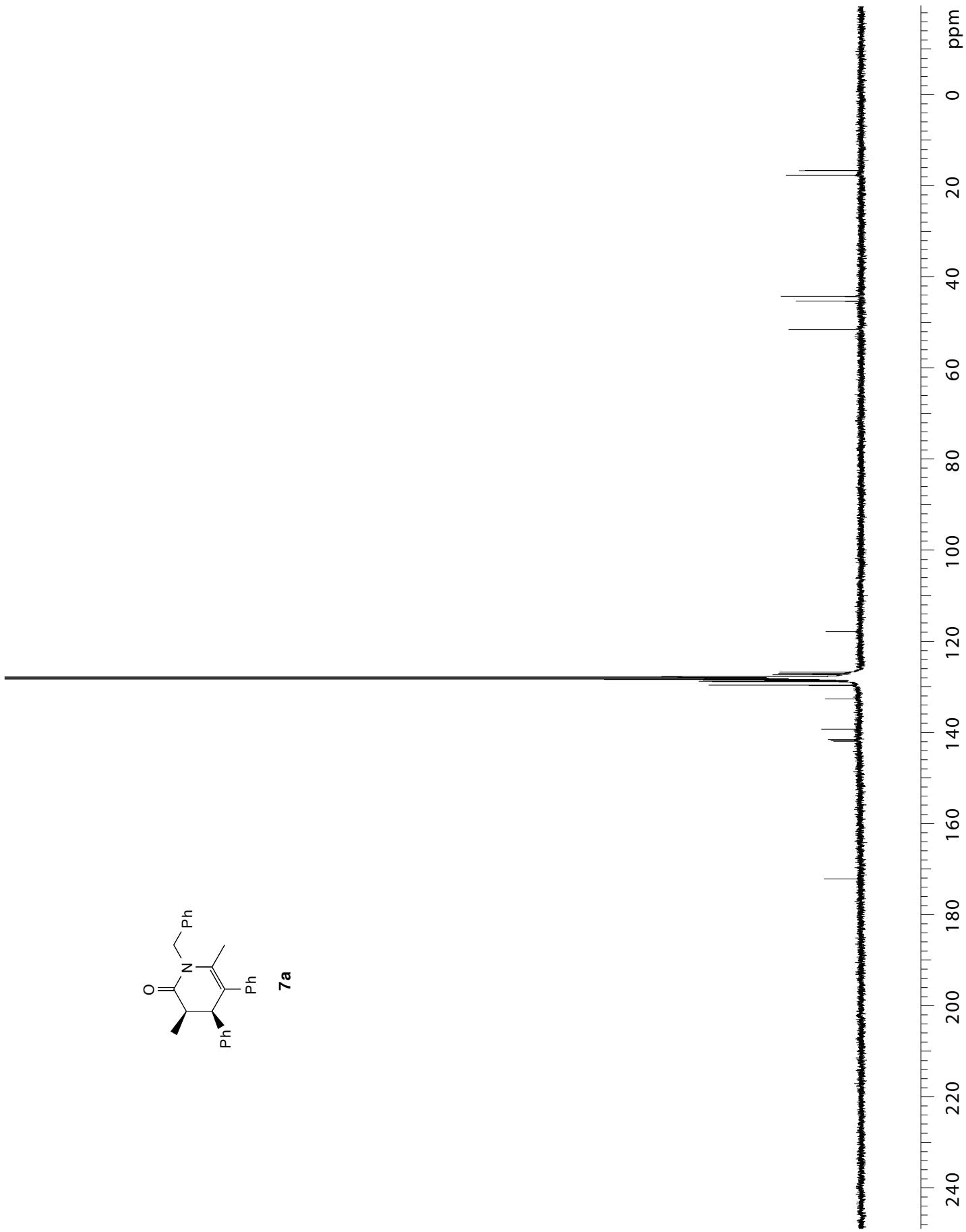
100 MHz APT in CDCl₃ (ref. to CDCl₃ @ 77.0 ppm, temp 27.0 C -> actual temp = 27.0 C, m400gz probe
 C & CH₂ same, CH & CH₃ opposite side of solvent signal
 dpt g: 1.0, dpxg: 2.005, sweep width: 27027 Hz acq. time: 2.0 s rel ax. time: 0.1 s # scans: 600 di g. res.: 0.4 Hz / pt hz / mm 112.6
 spectrometer: i bdw file: /mnt/d600/home13/westnmr/nmrdata/Al1/Book2/AR-APT-2-157A.fid

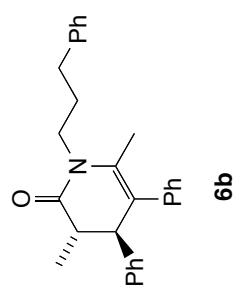




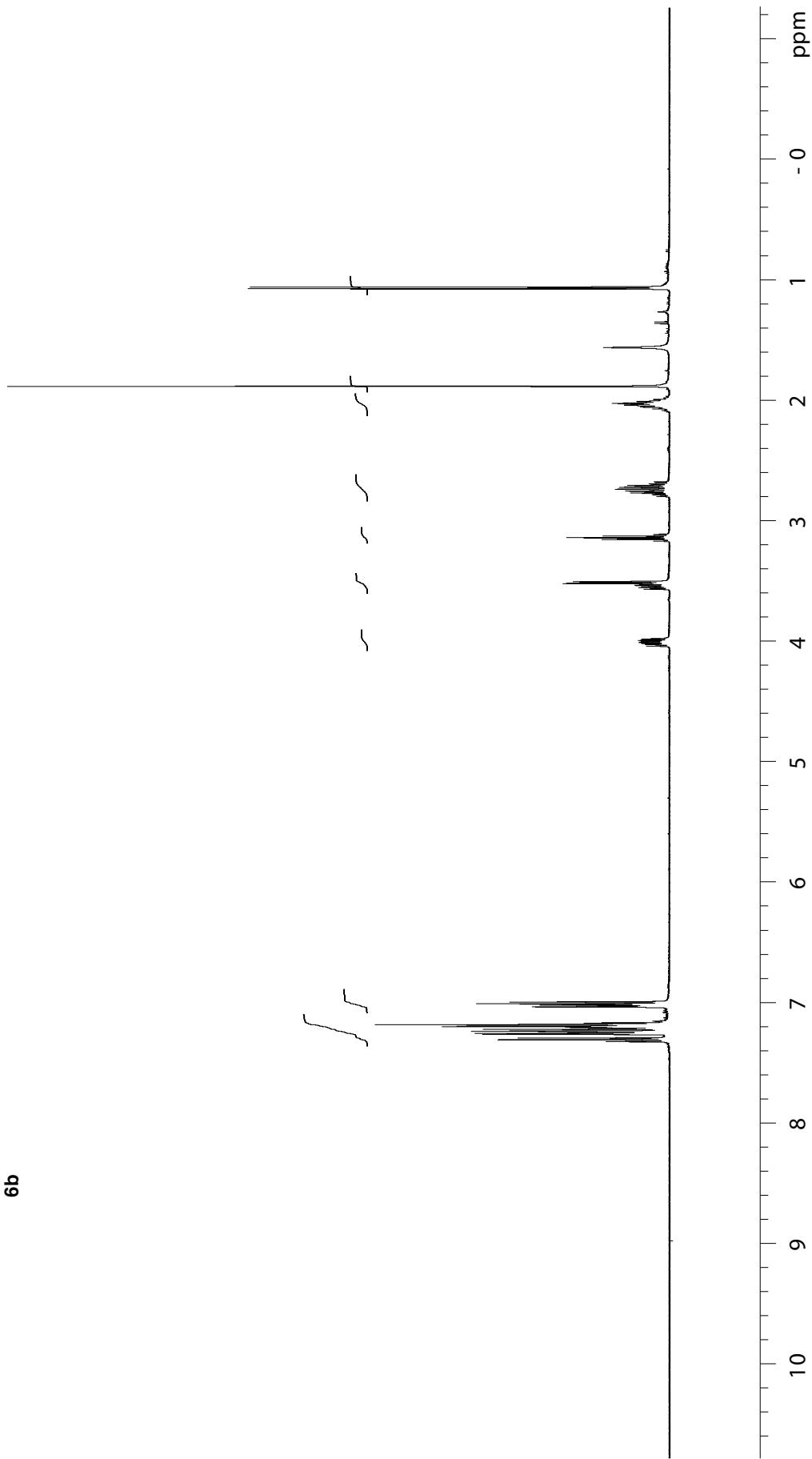


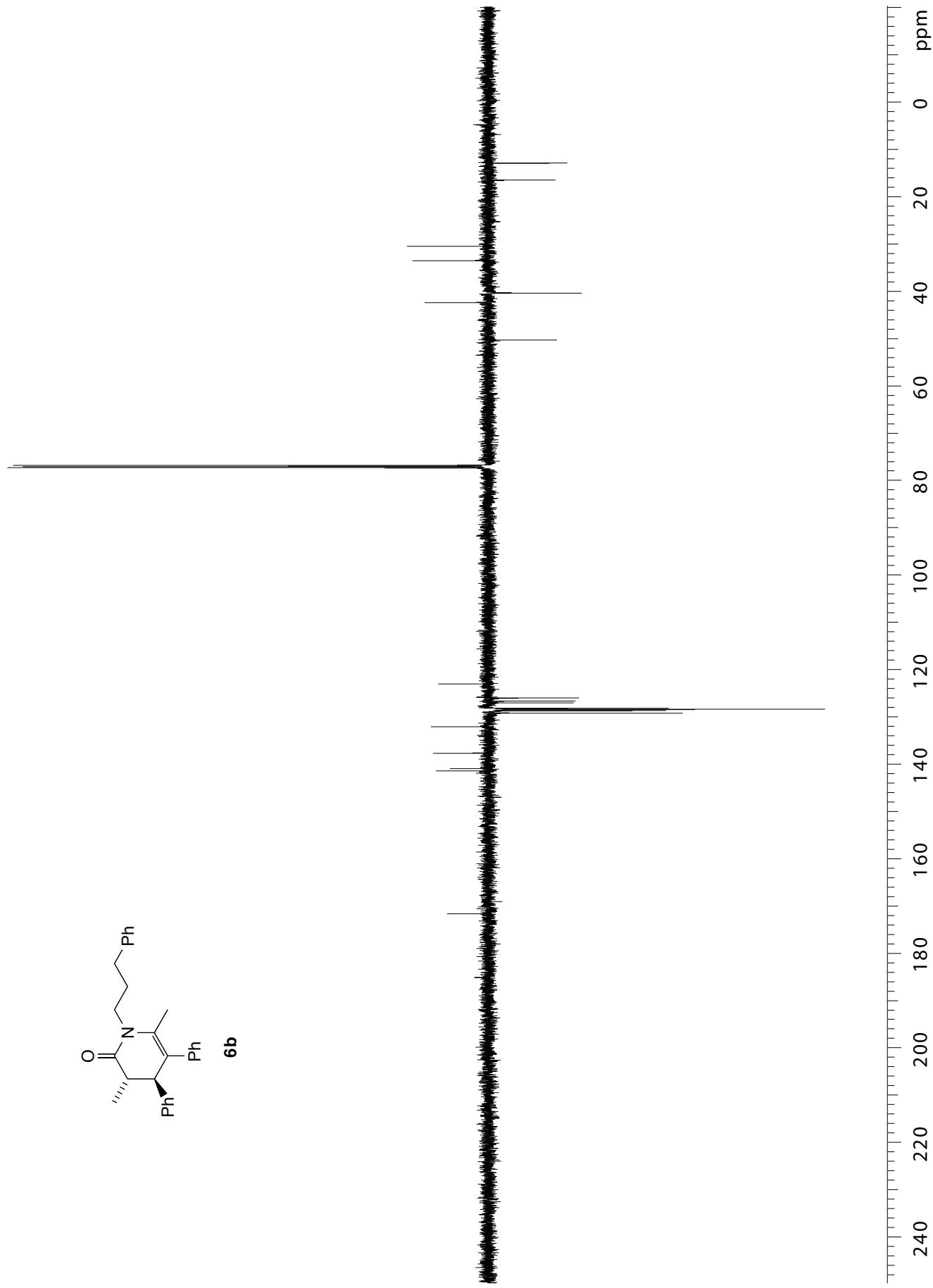


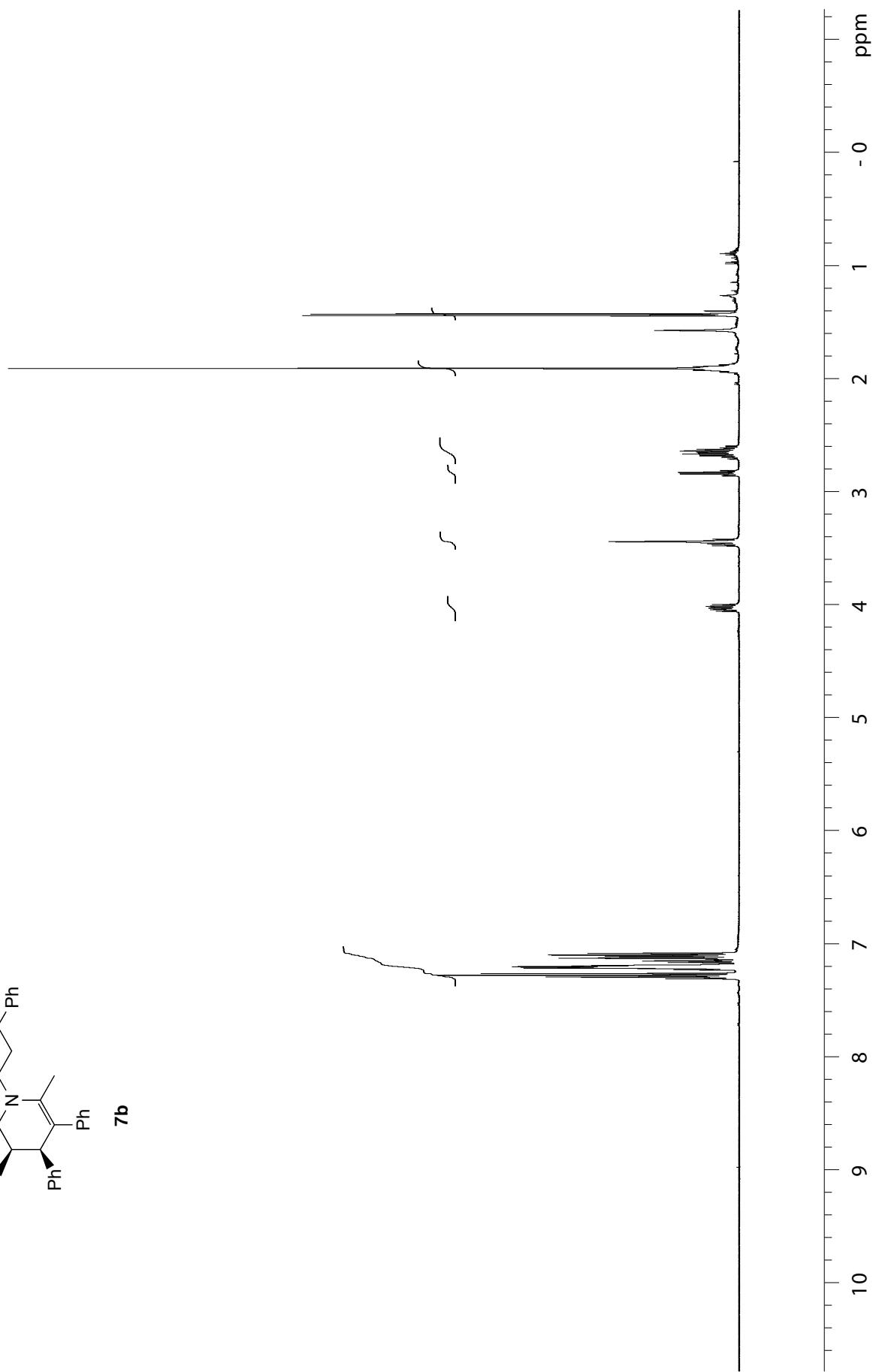
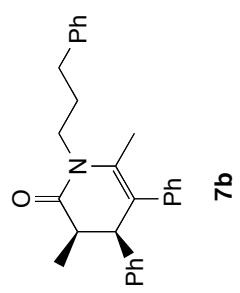


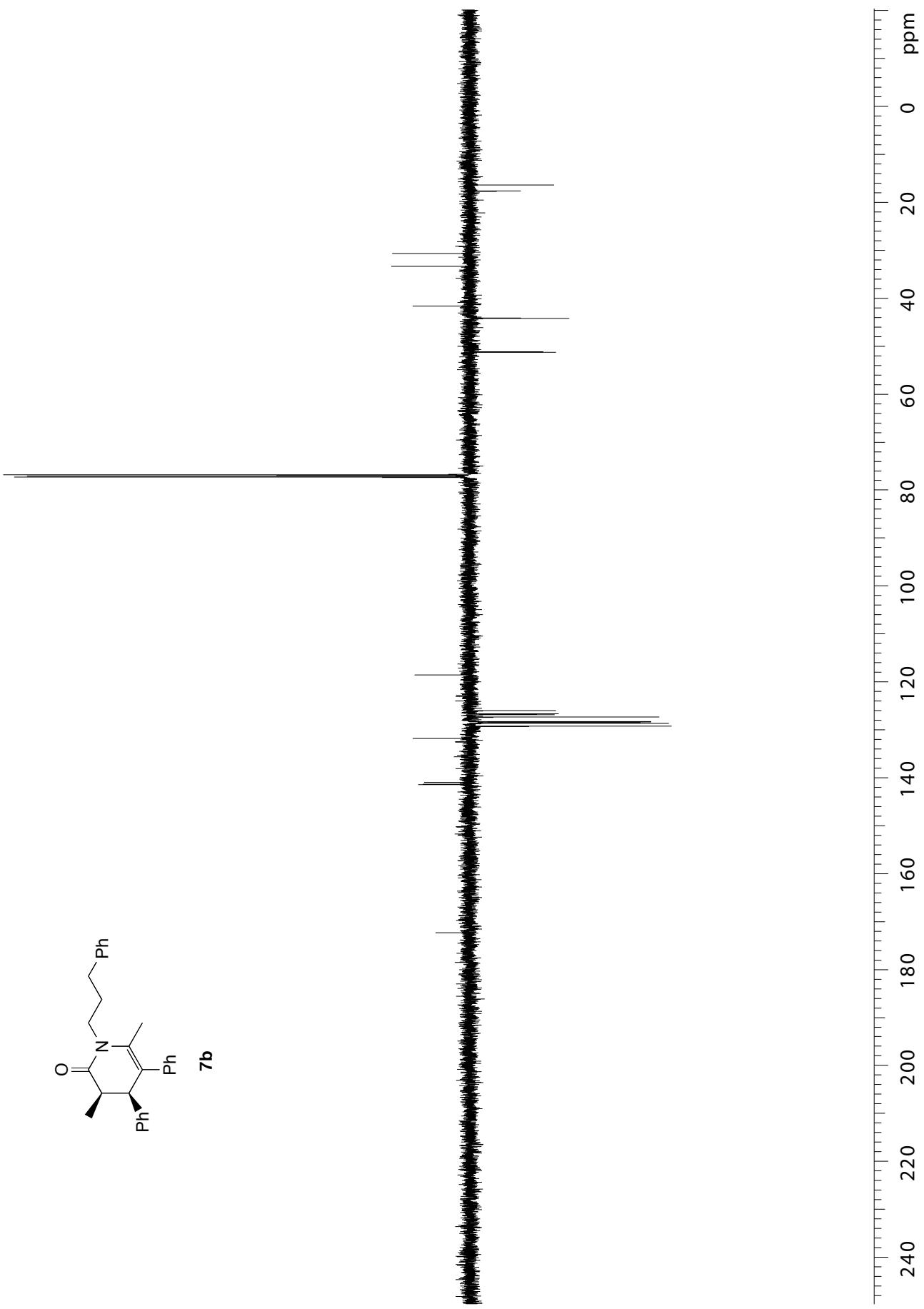
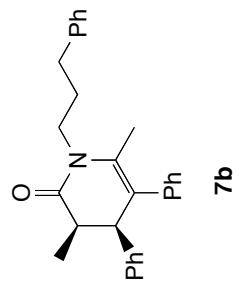


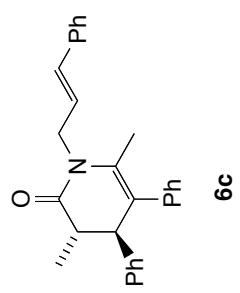
6b



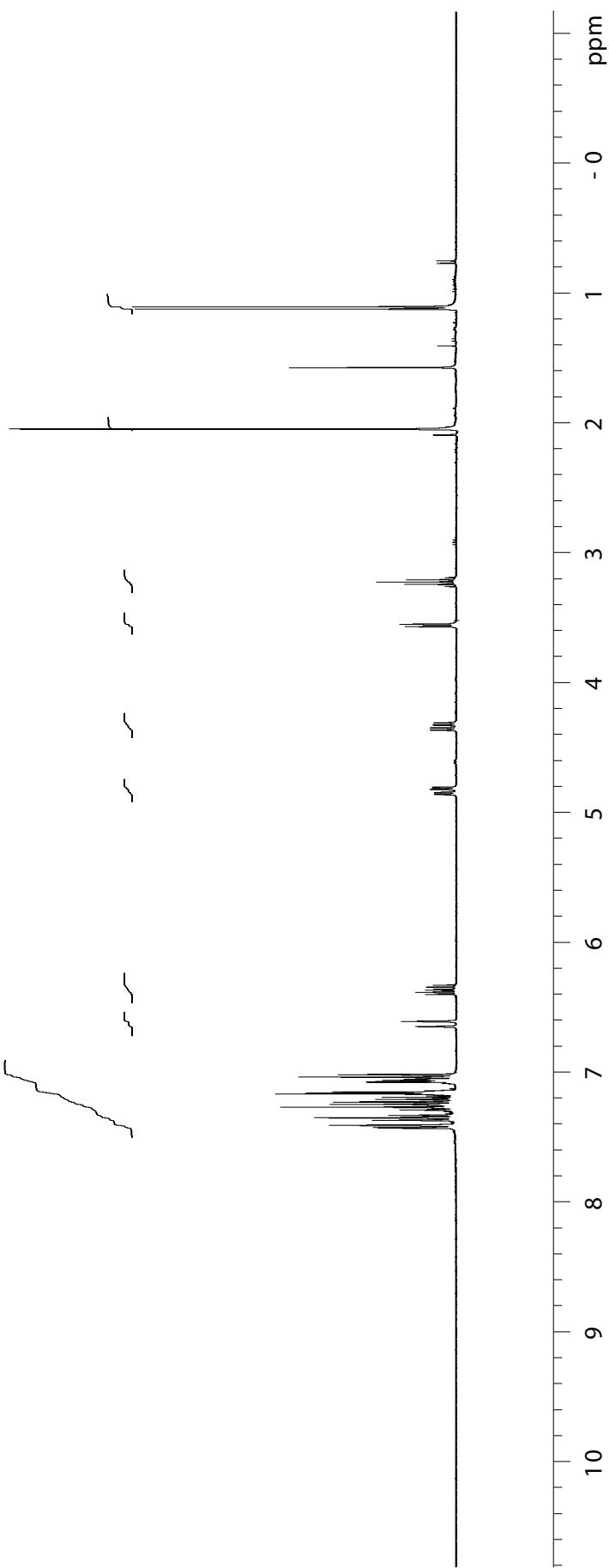


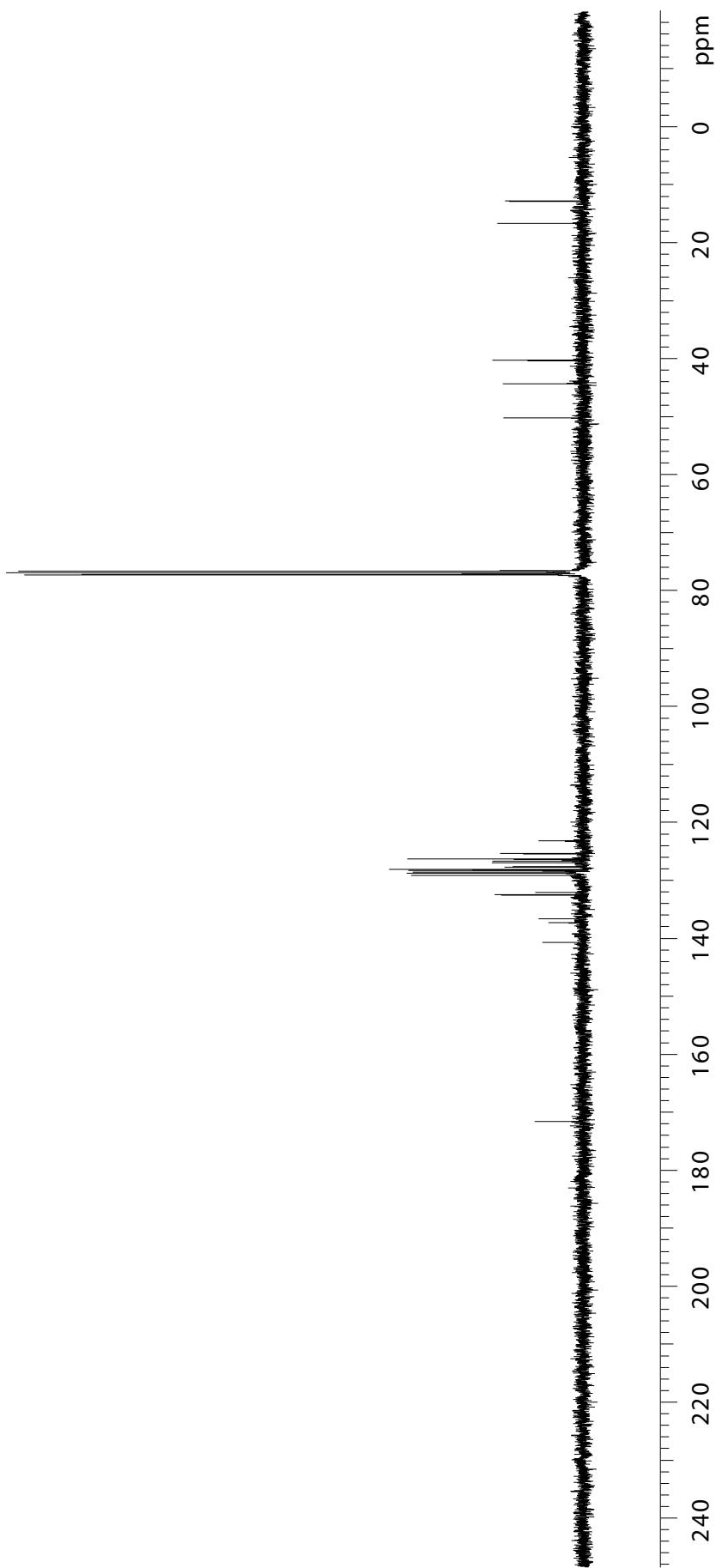
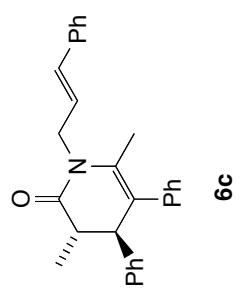


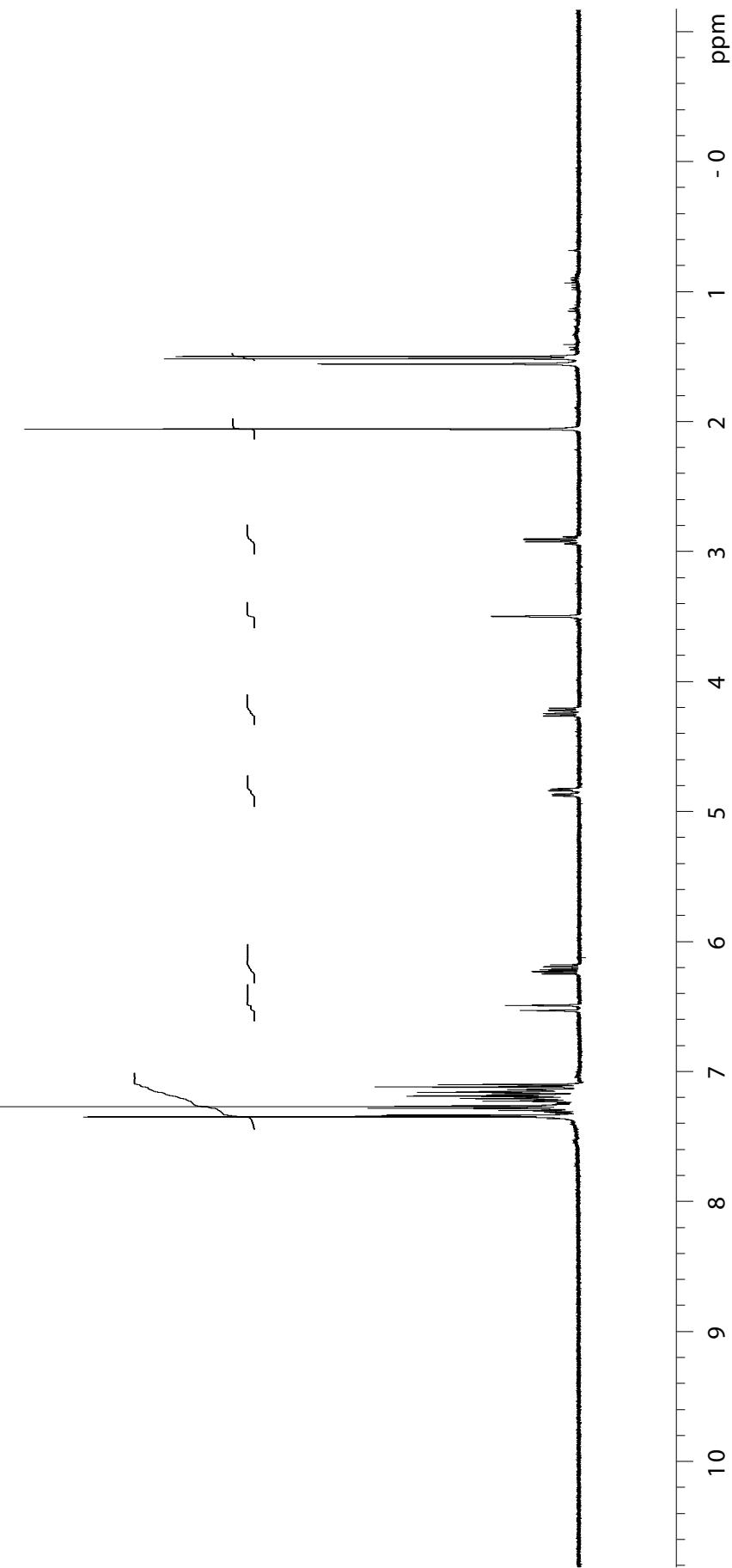
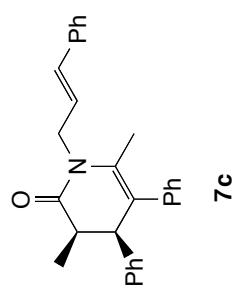


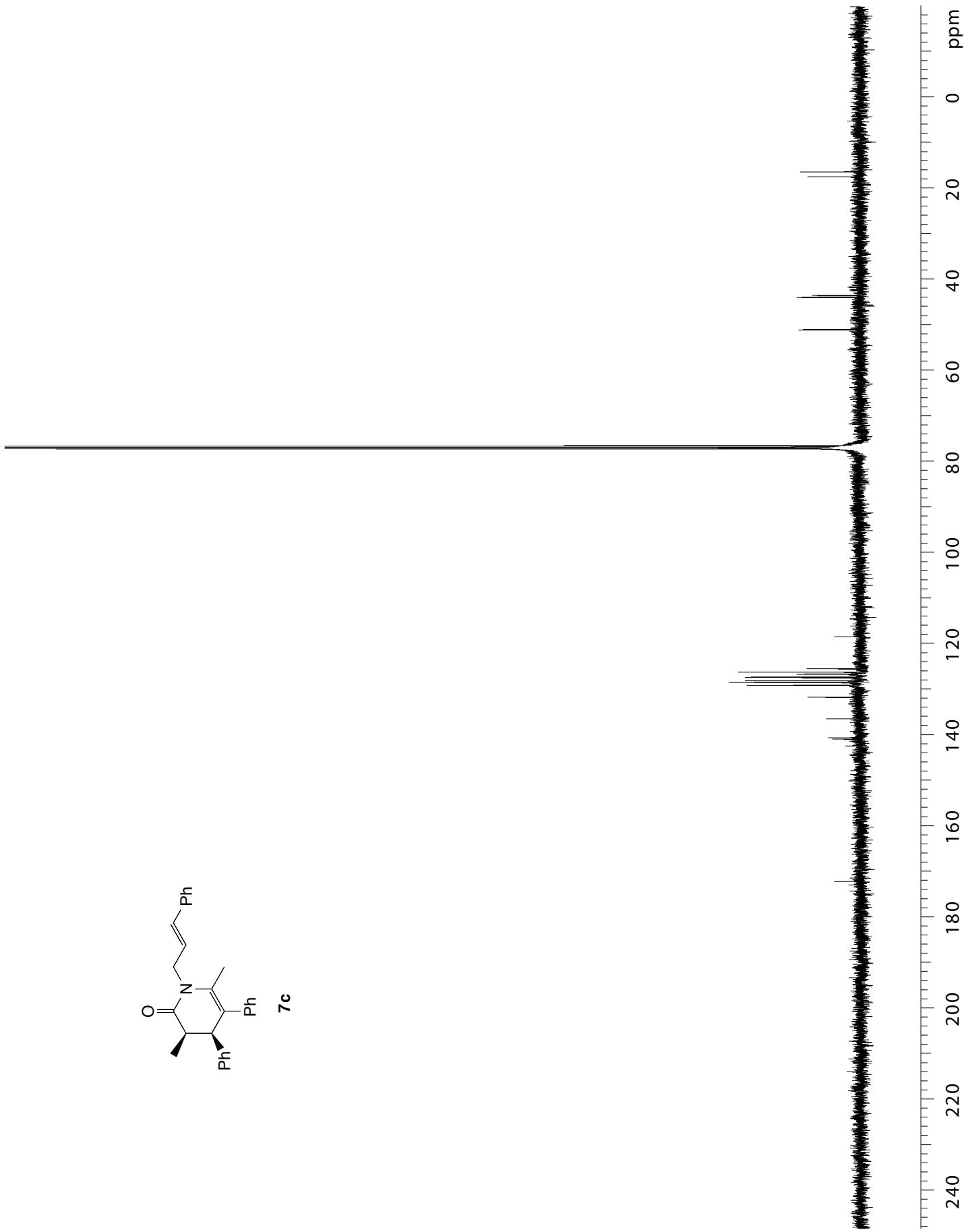


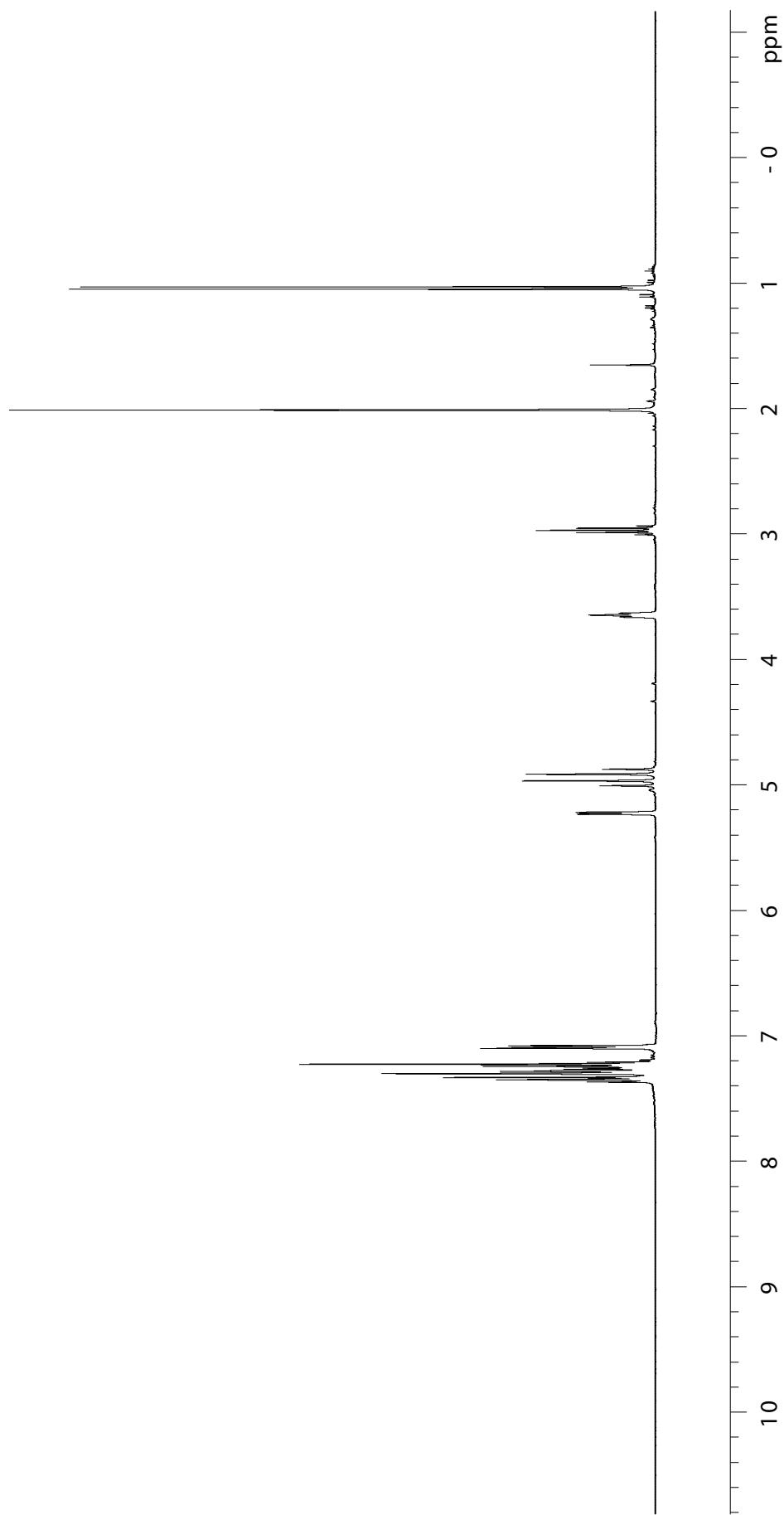
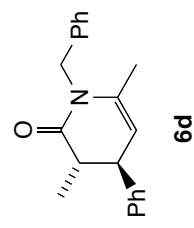
6c

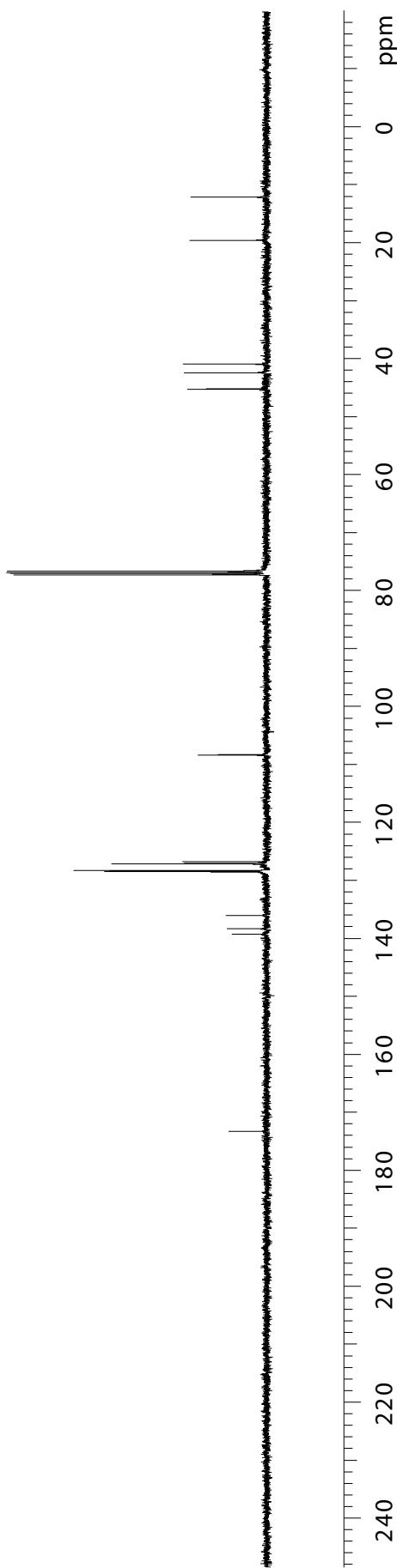
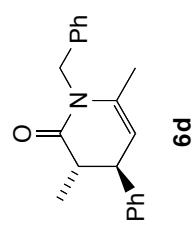


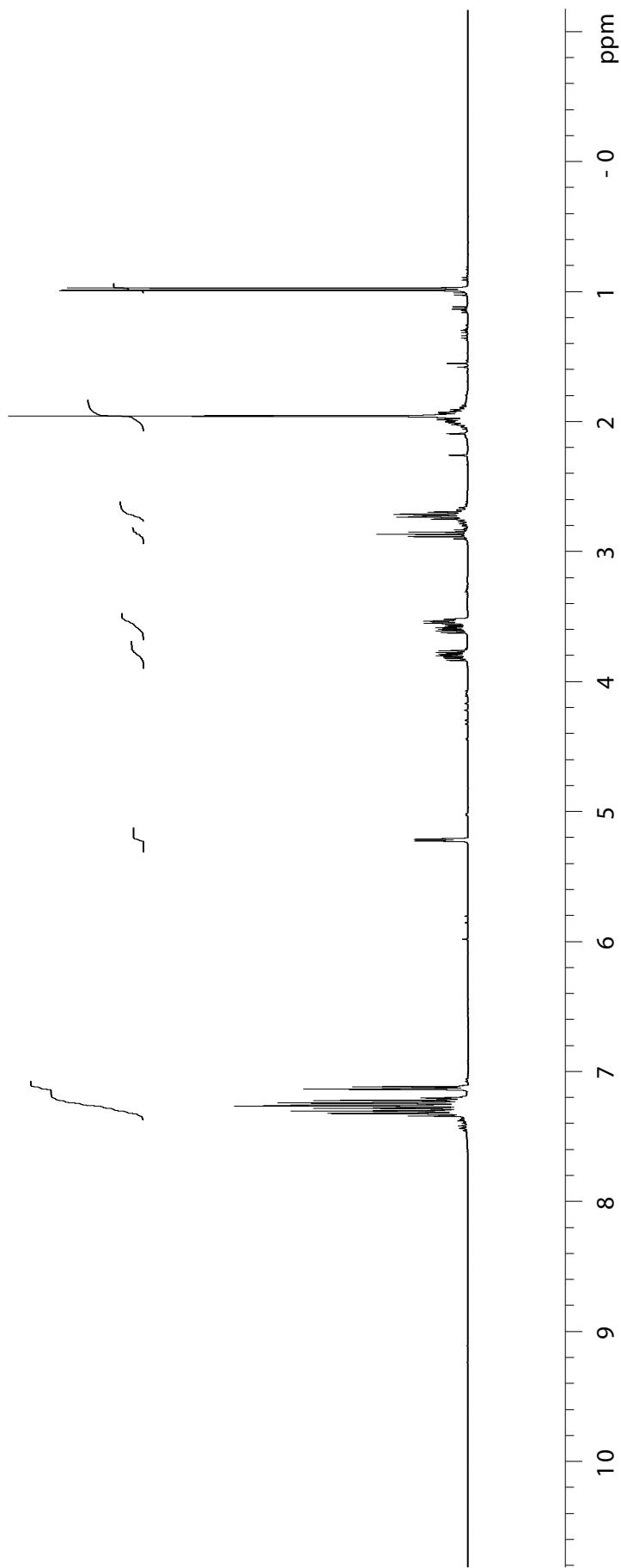
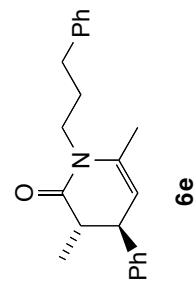


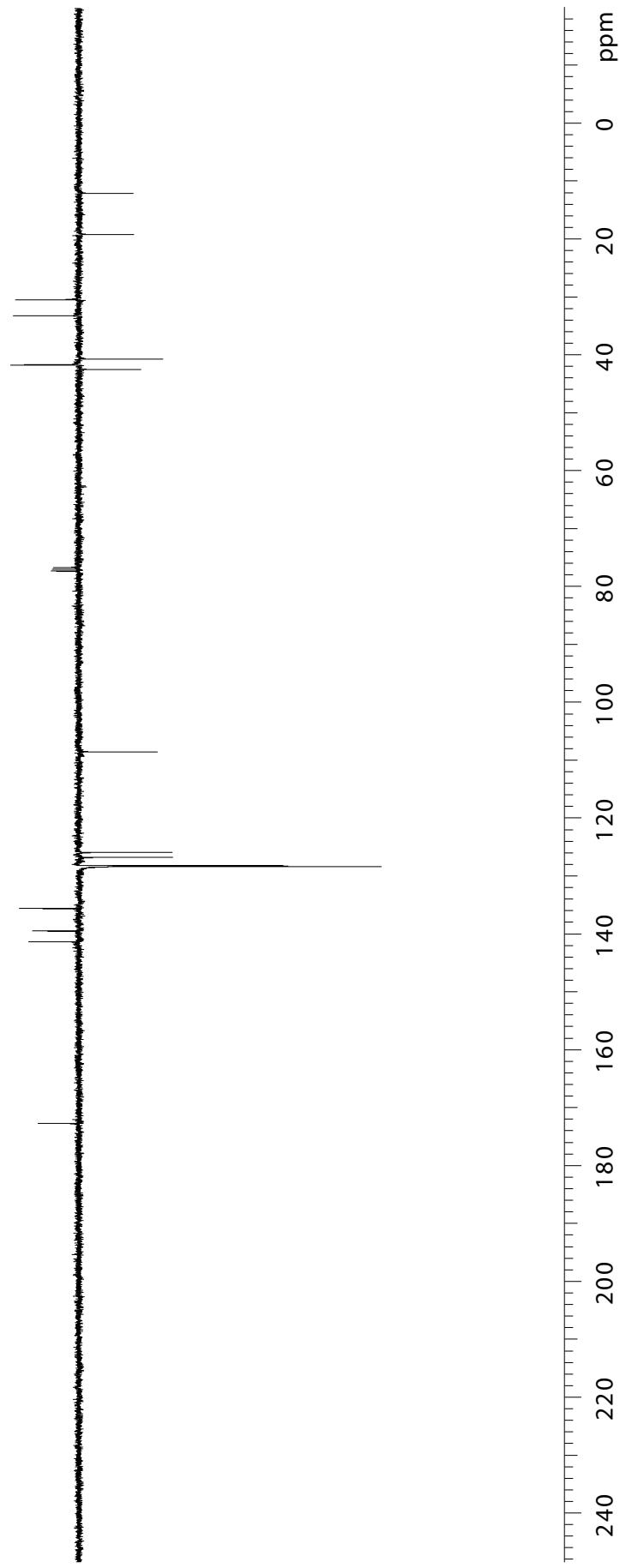
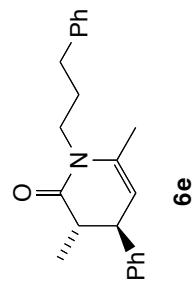


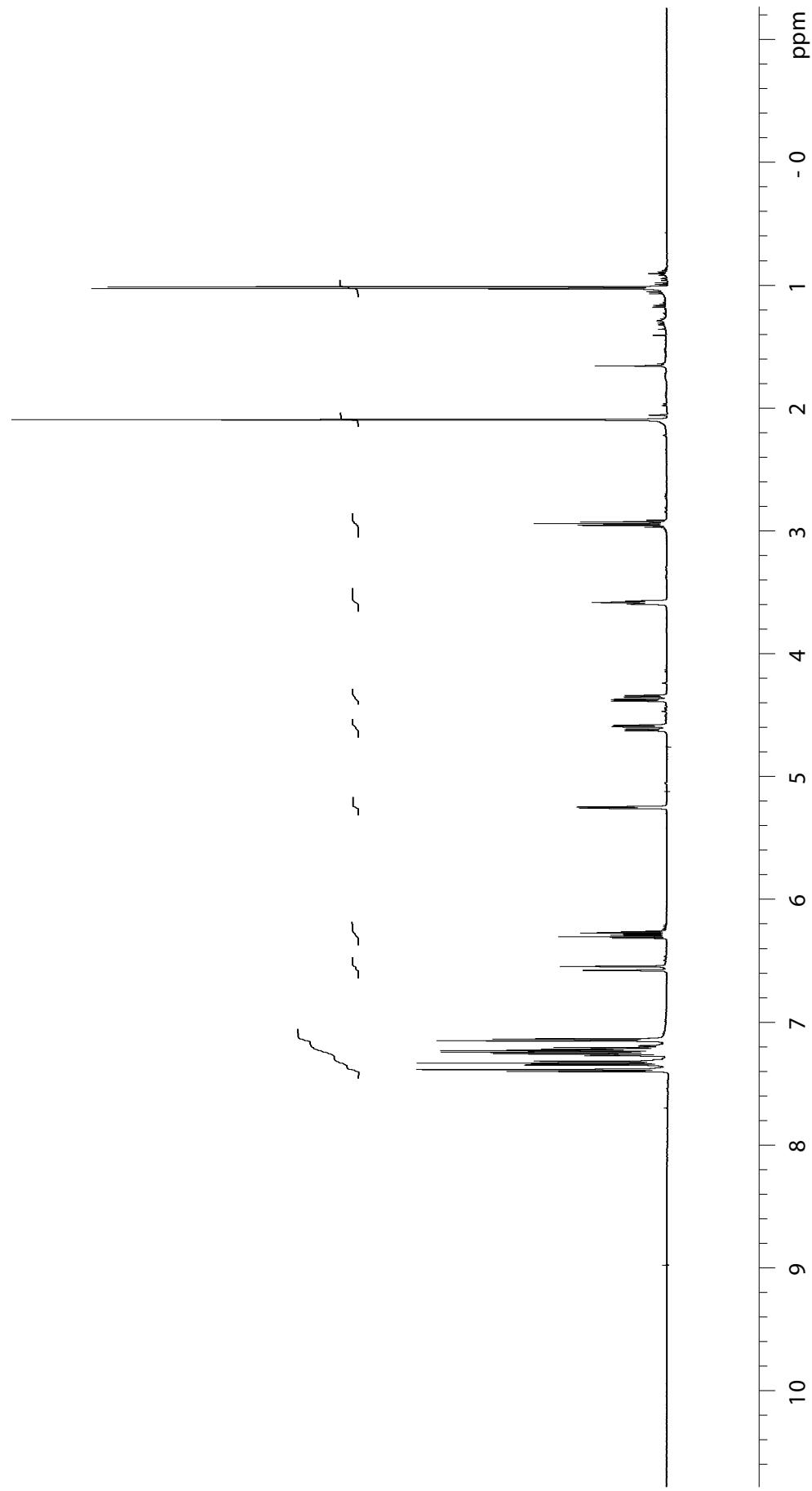
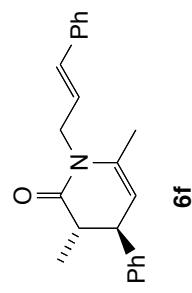




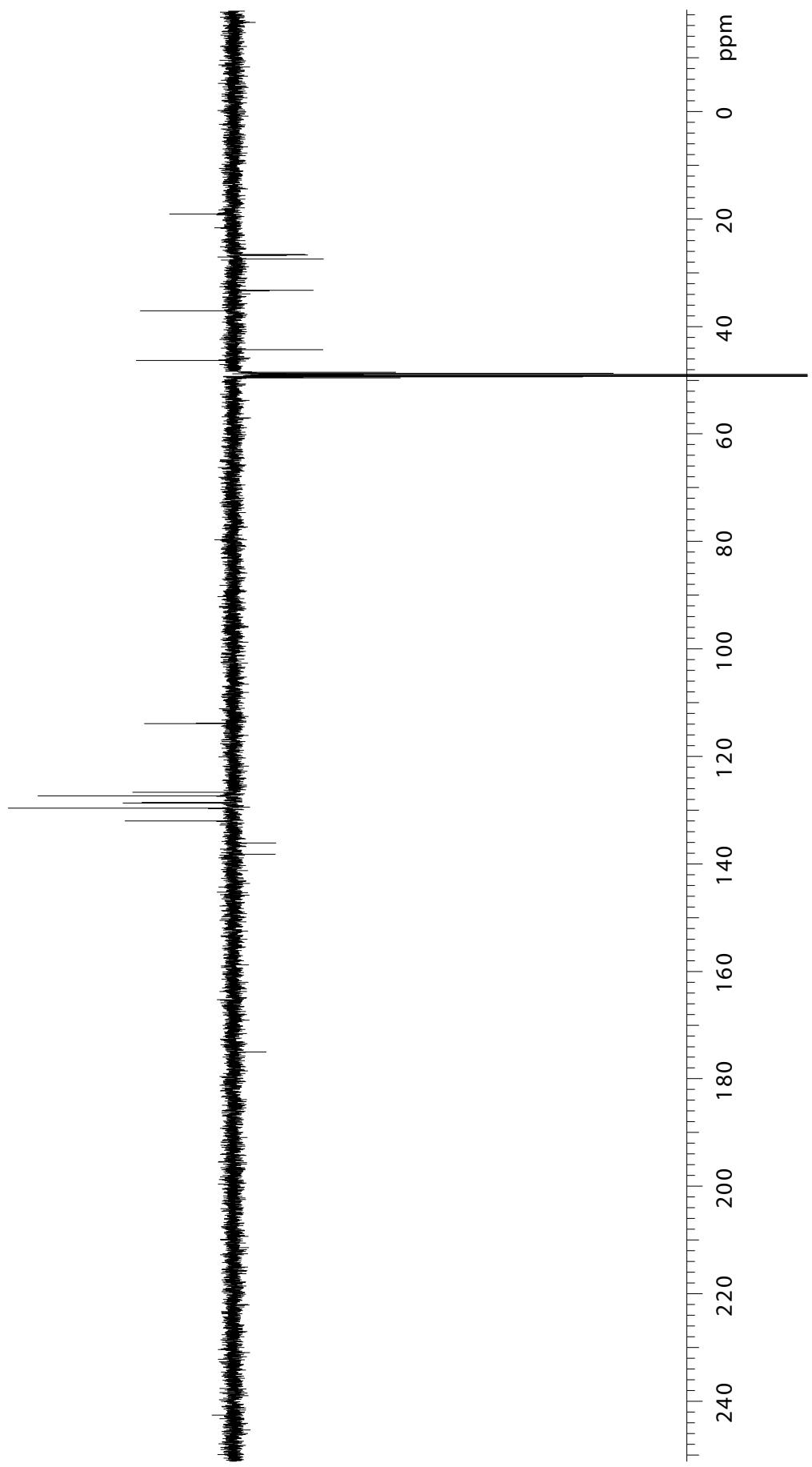
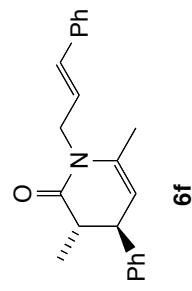


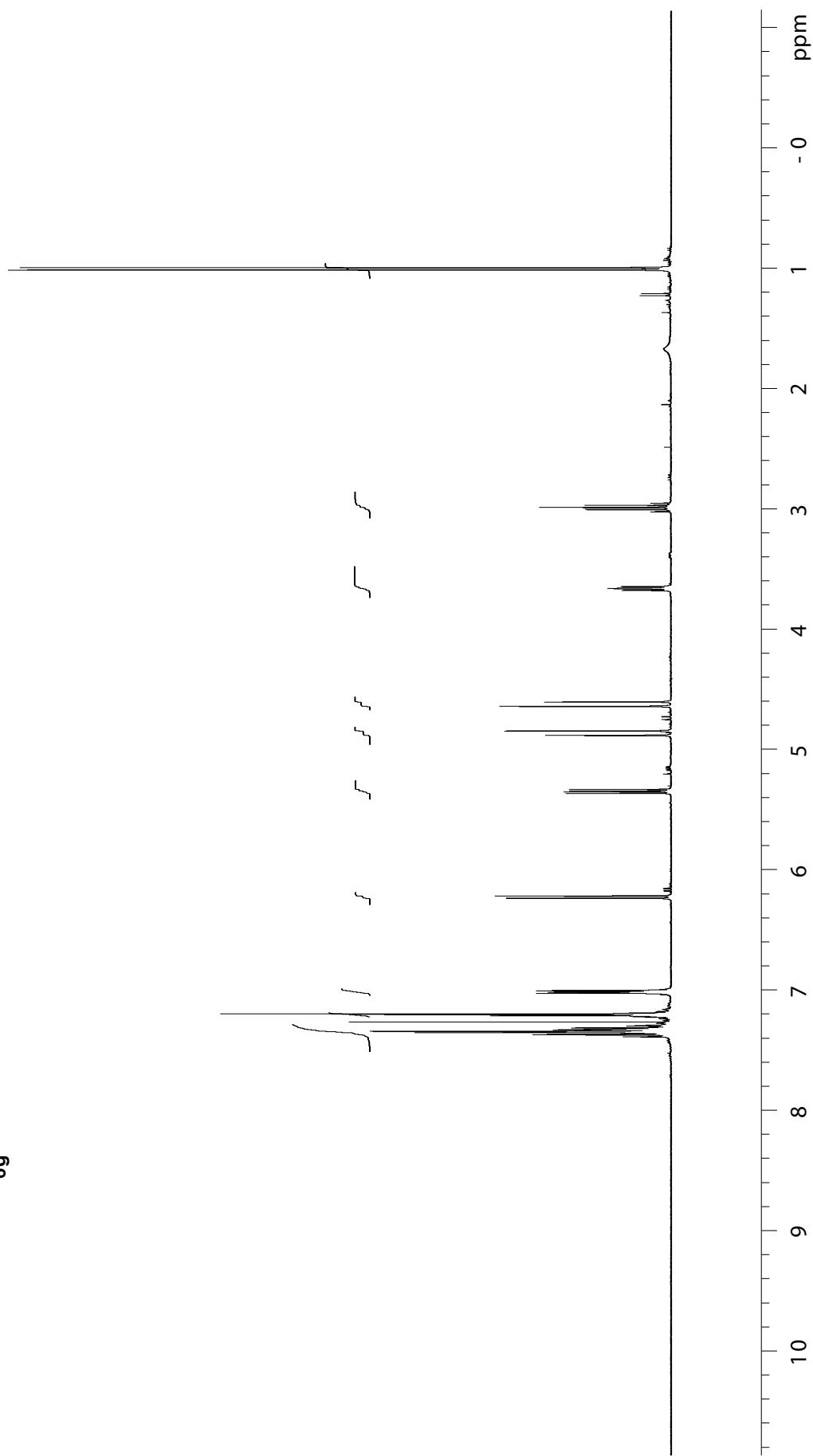
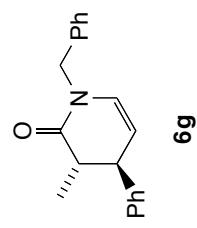


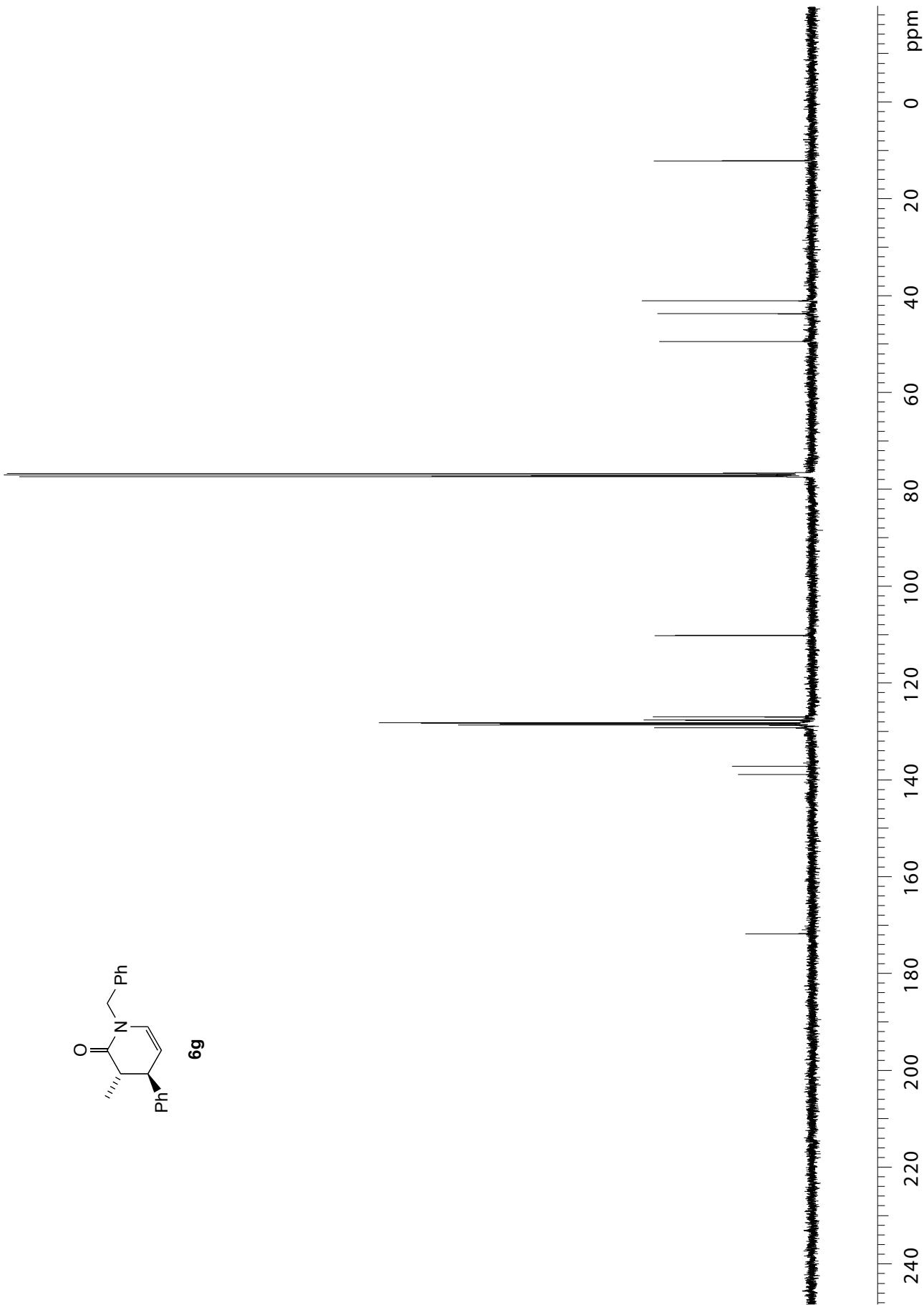


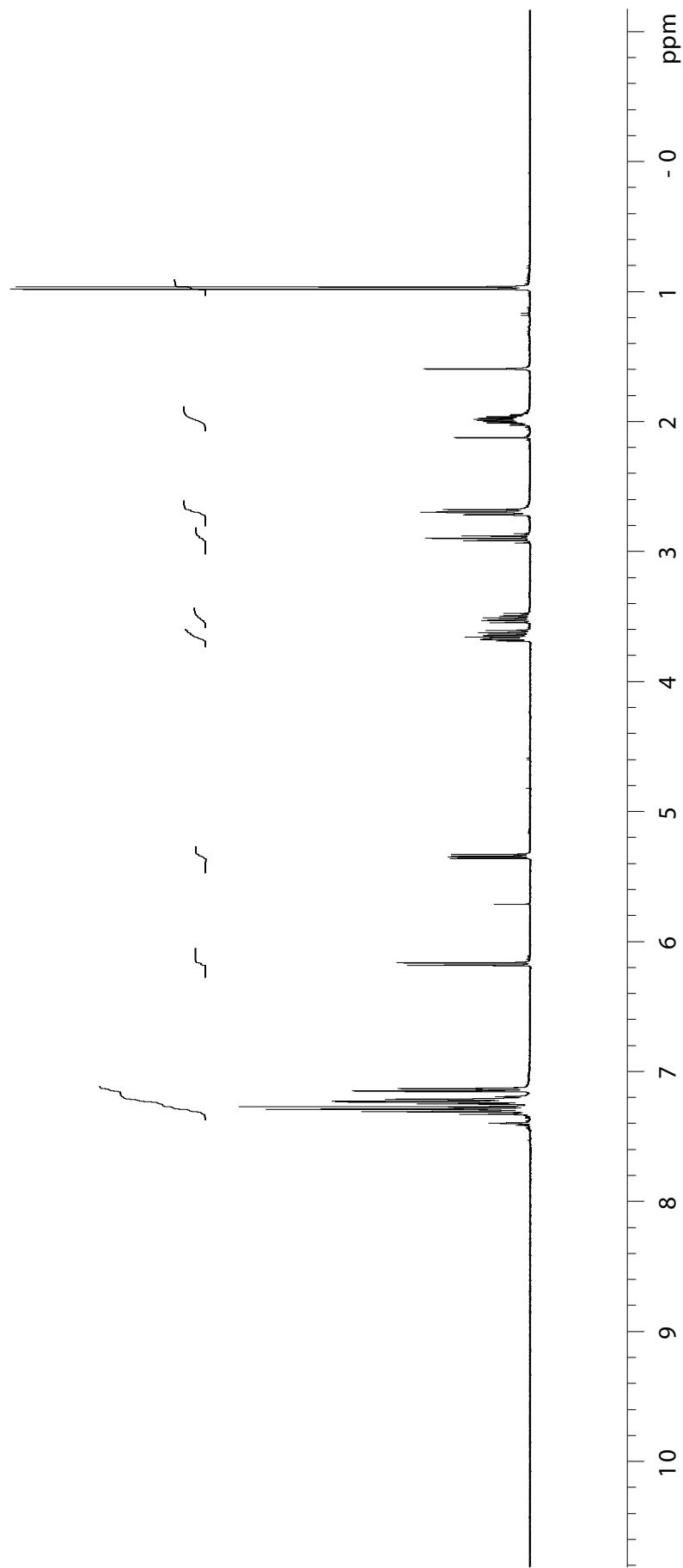
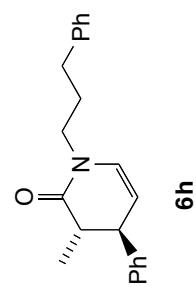


S-34

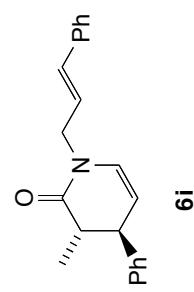


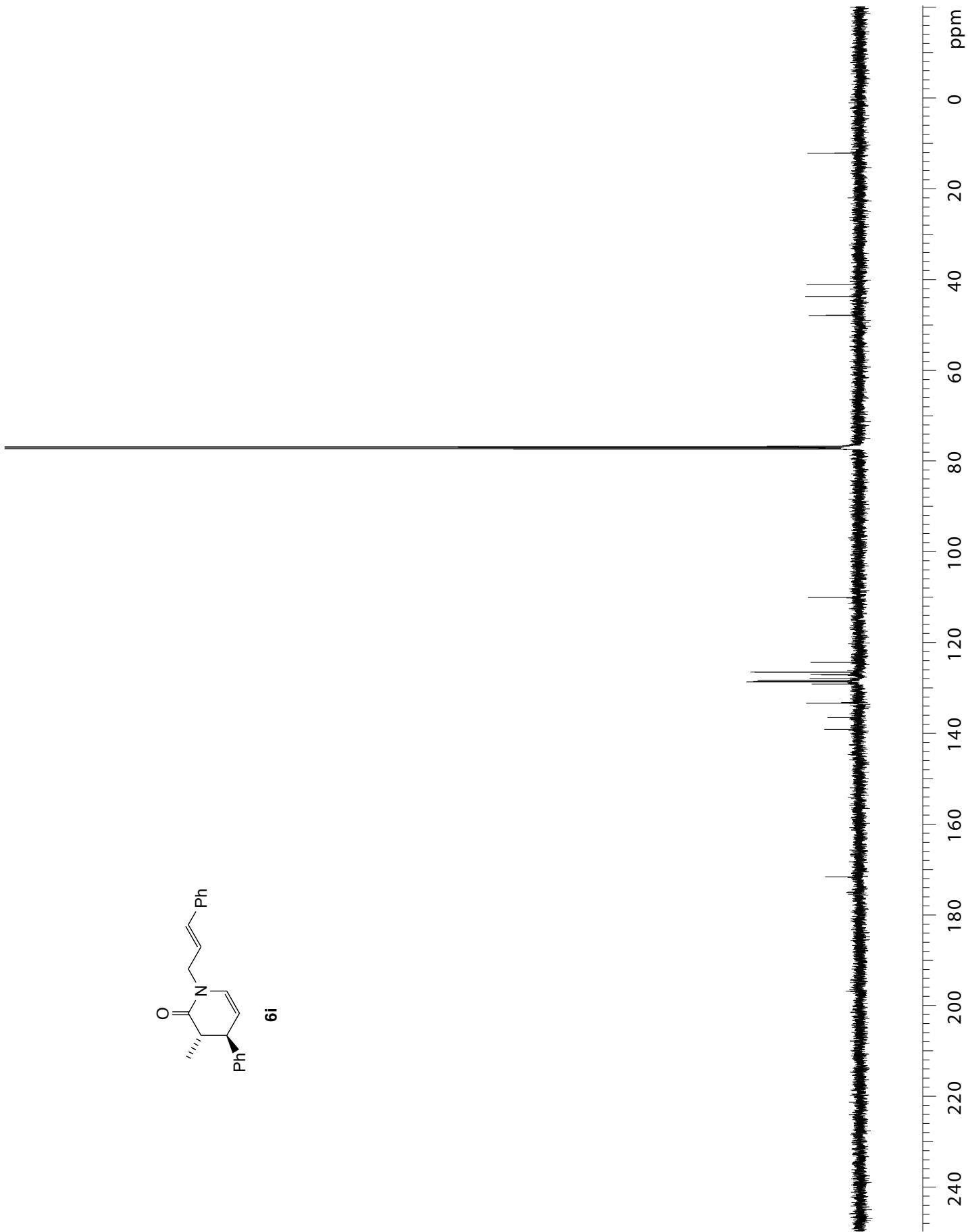


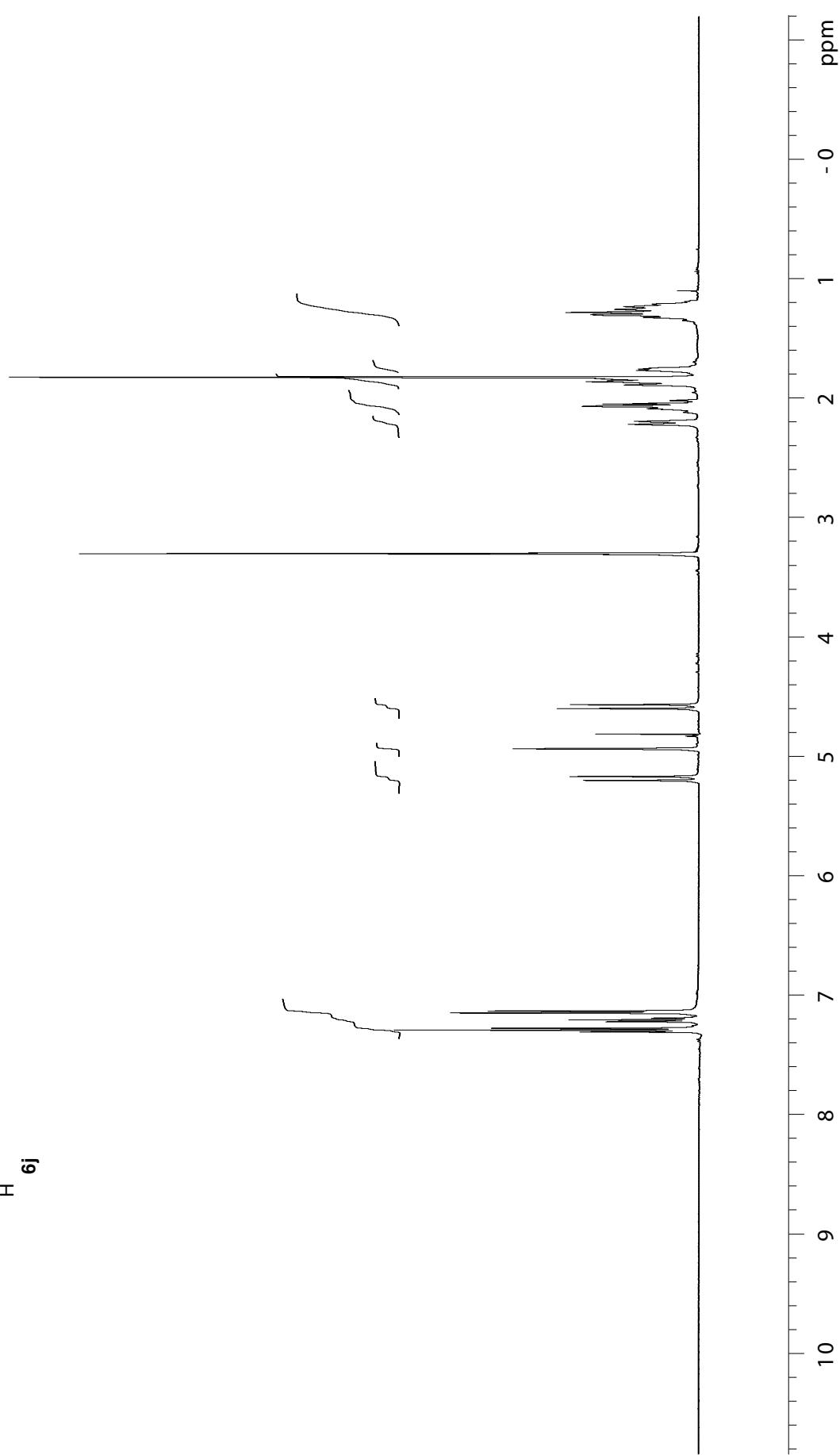
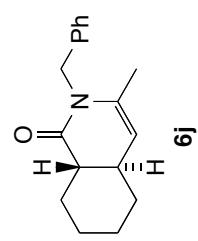


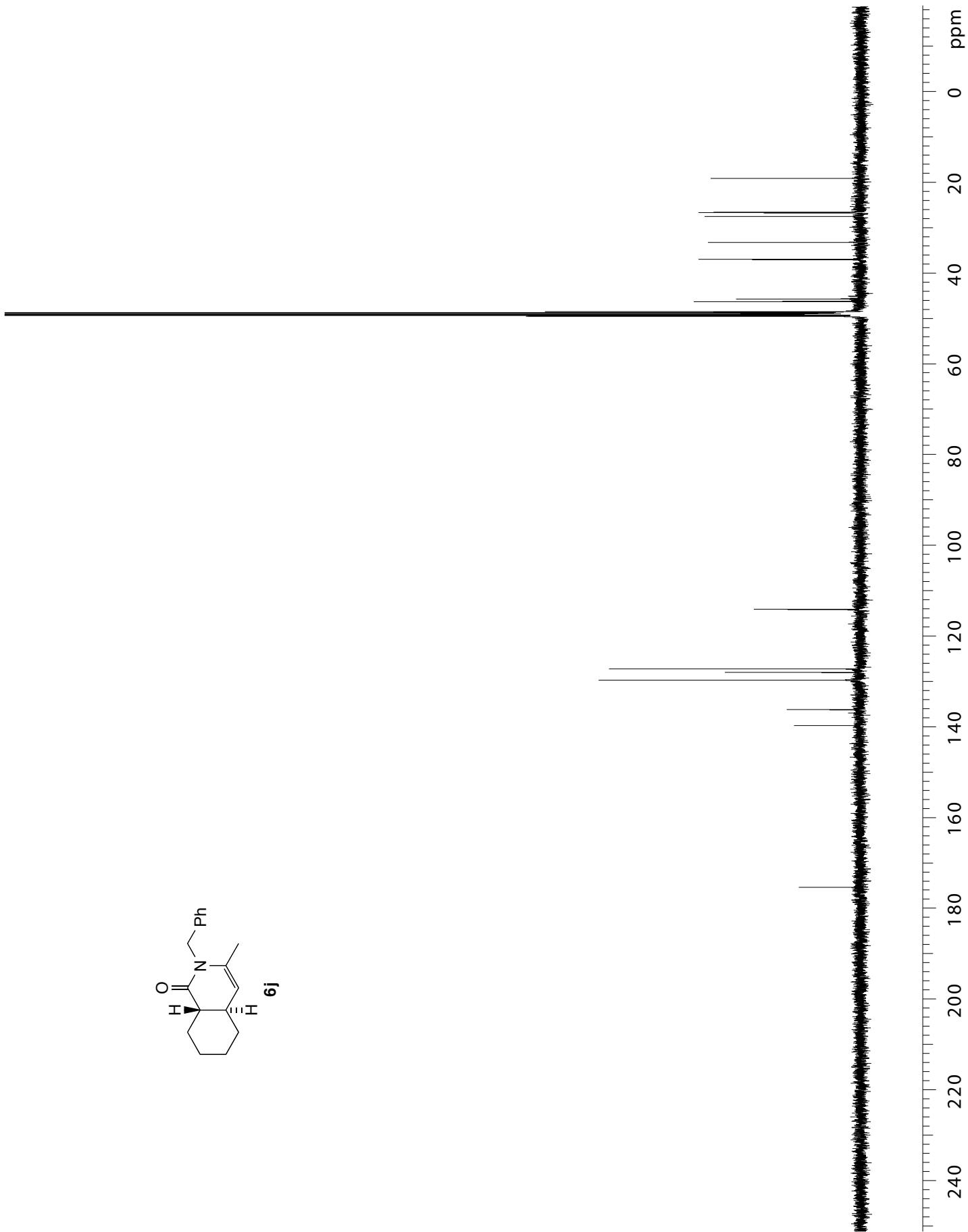


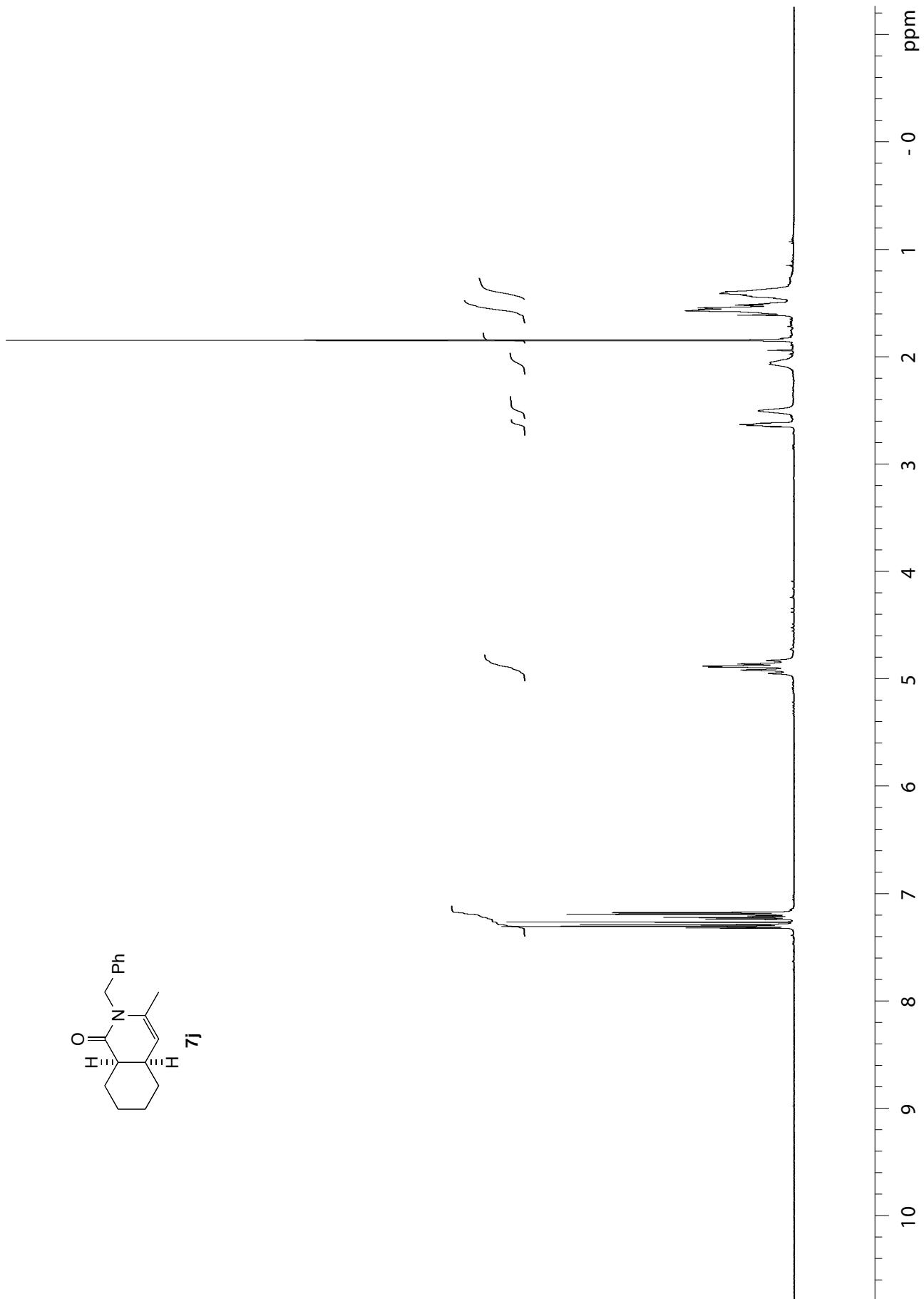


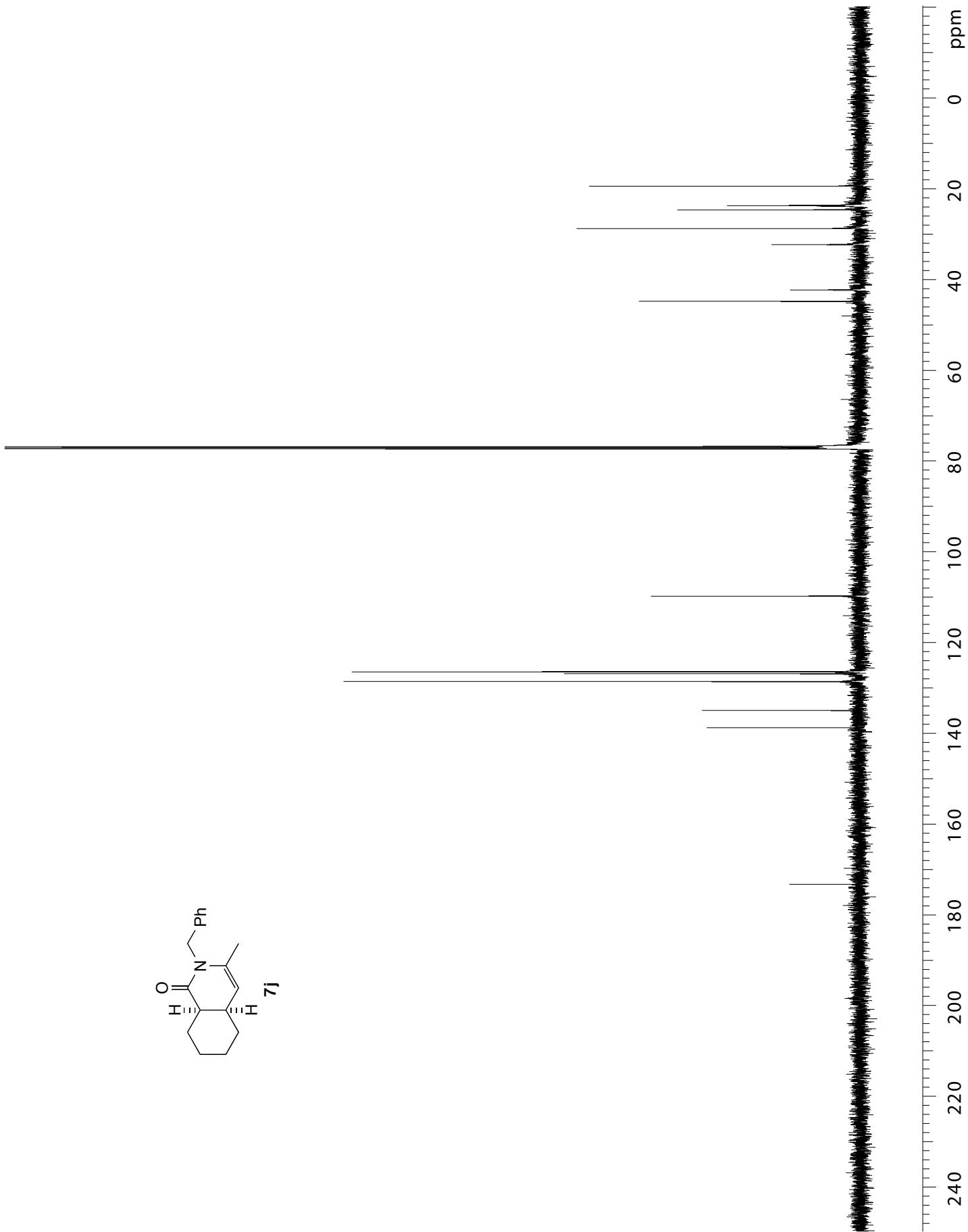


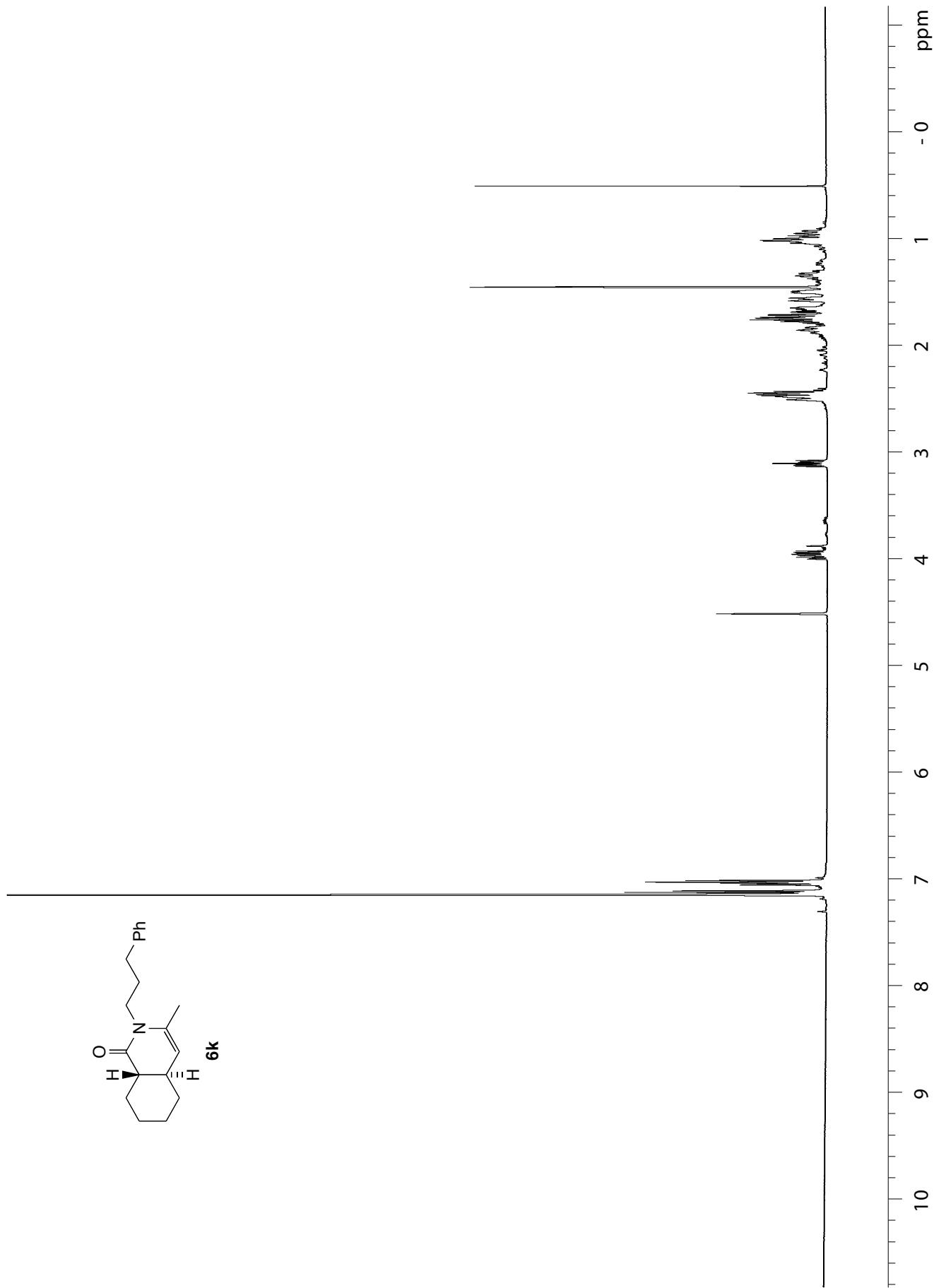


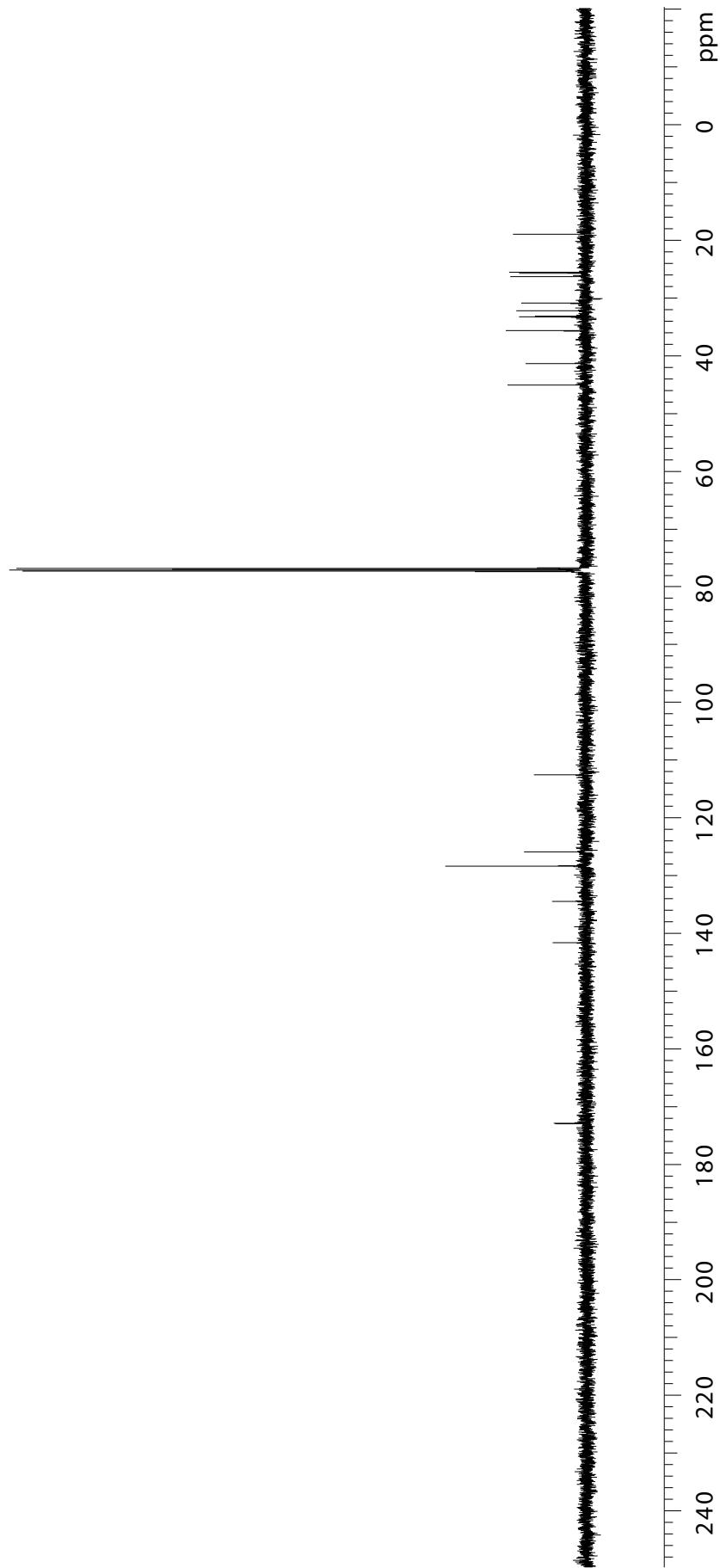
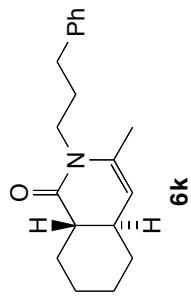


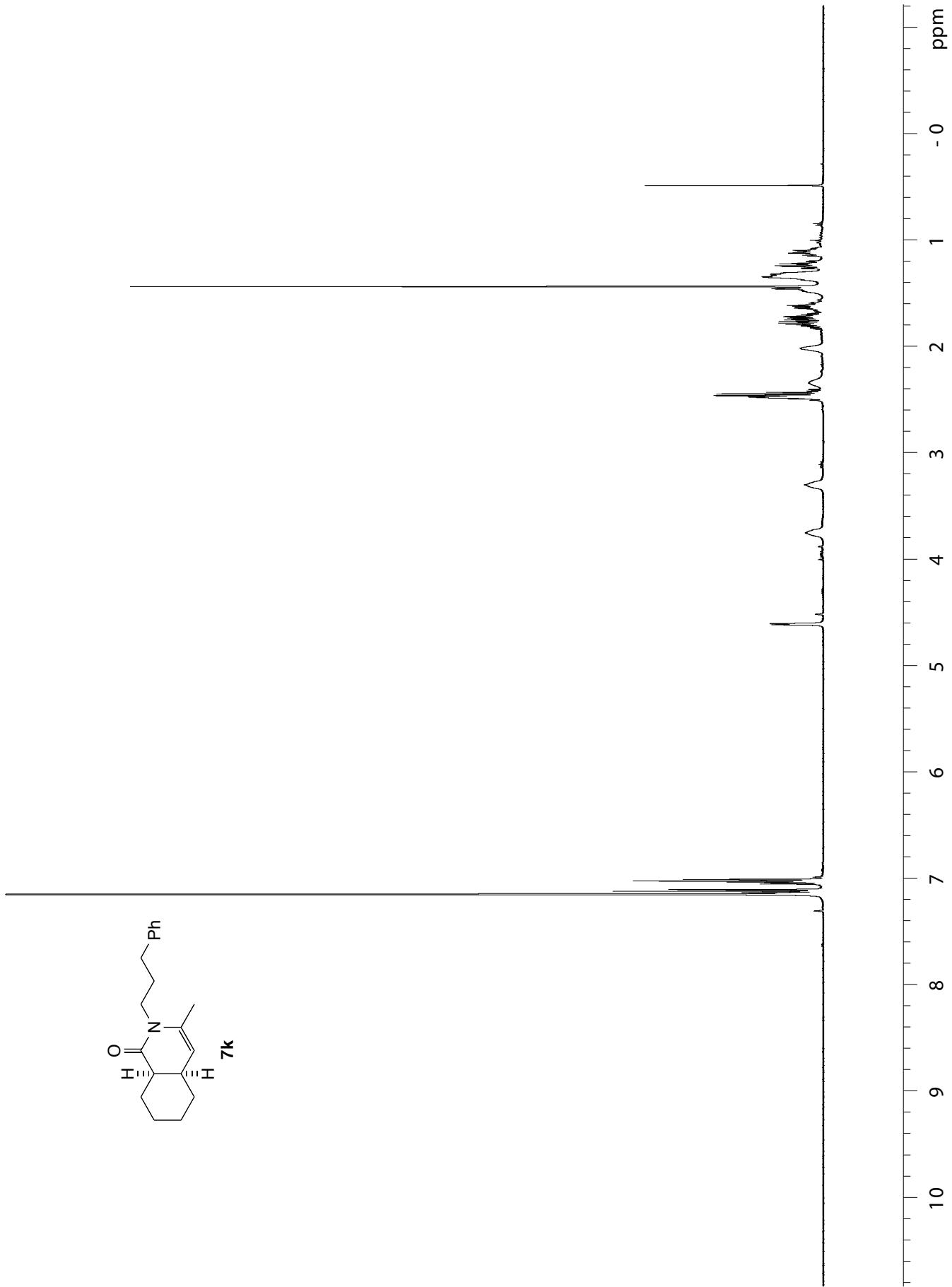


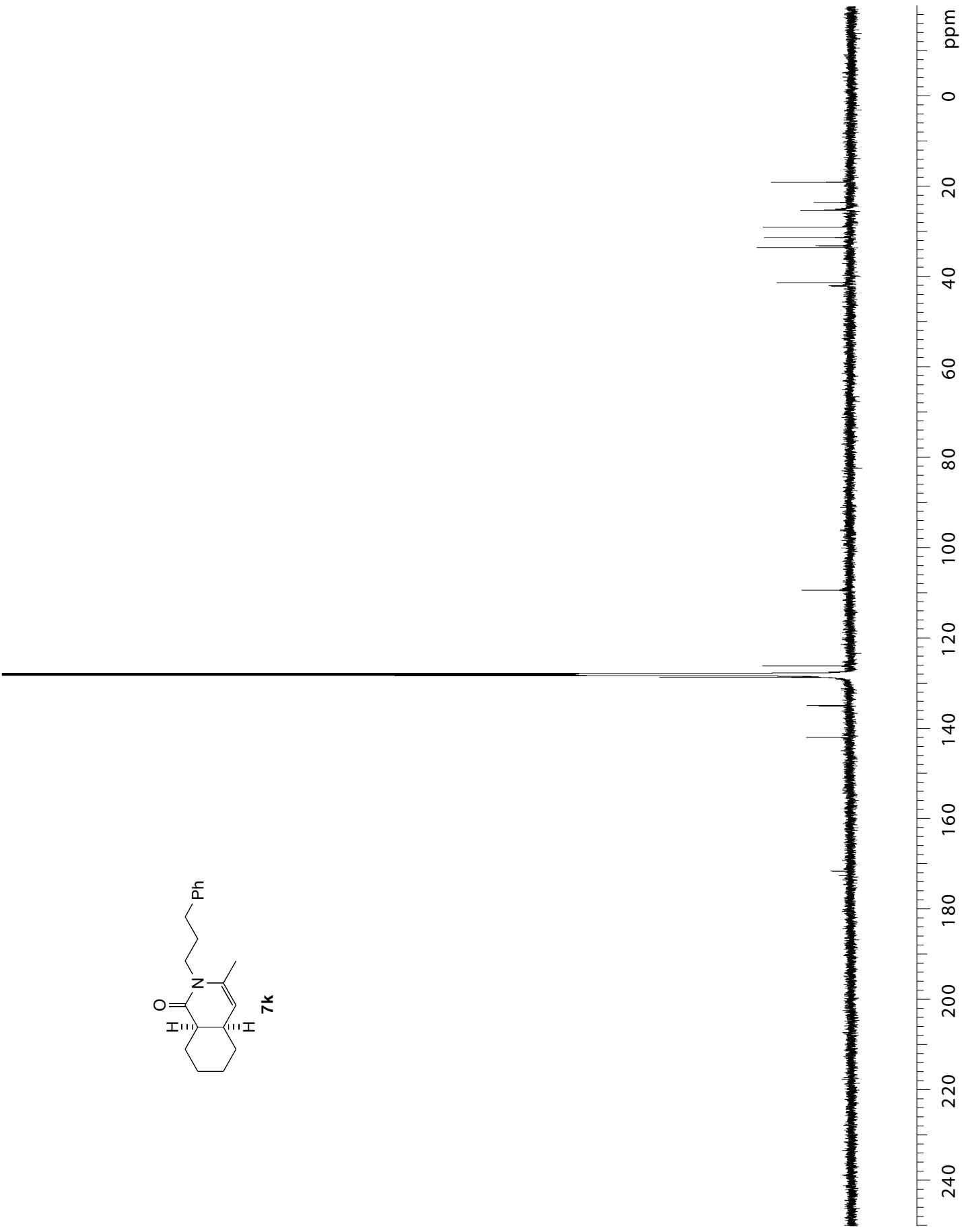


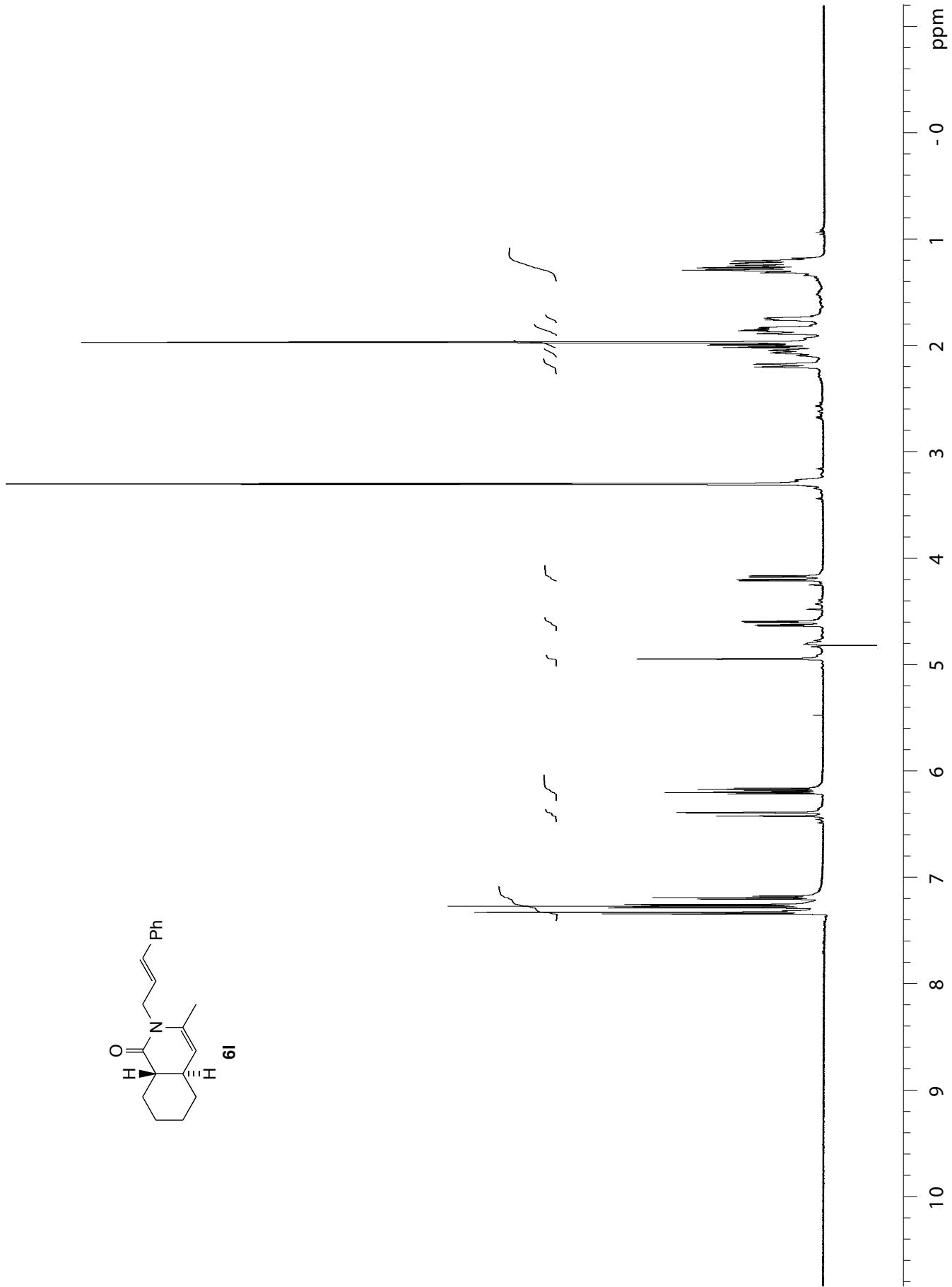


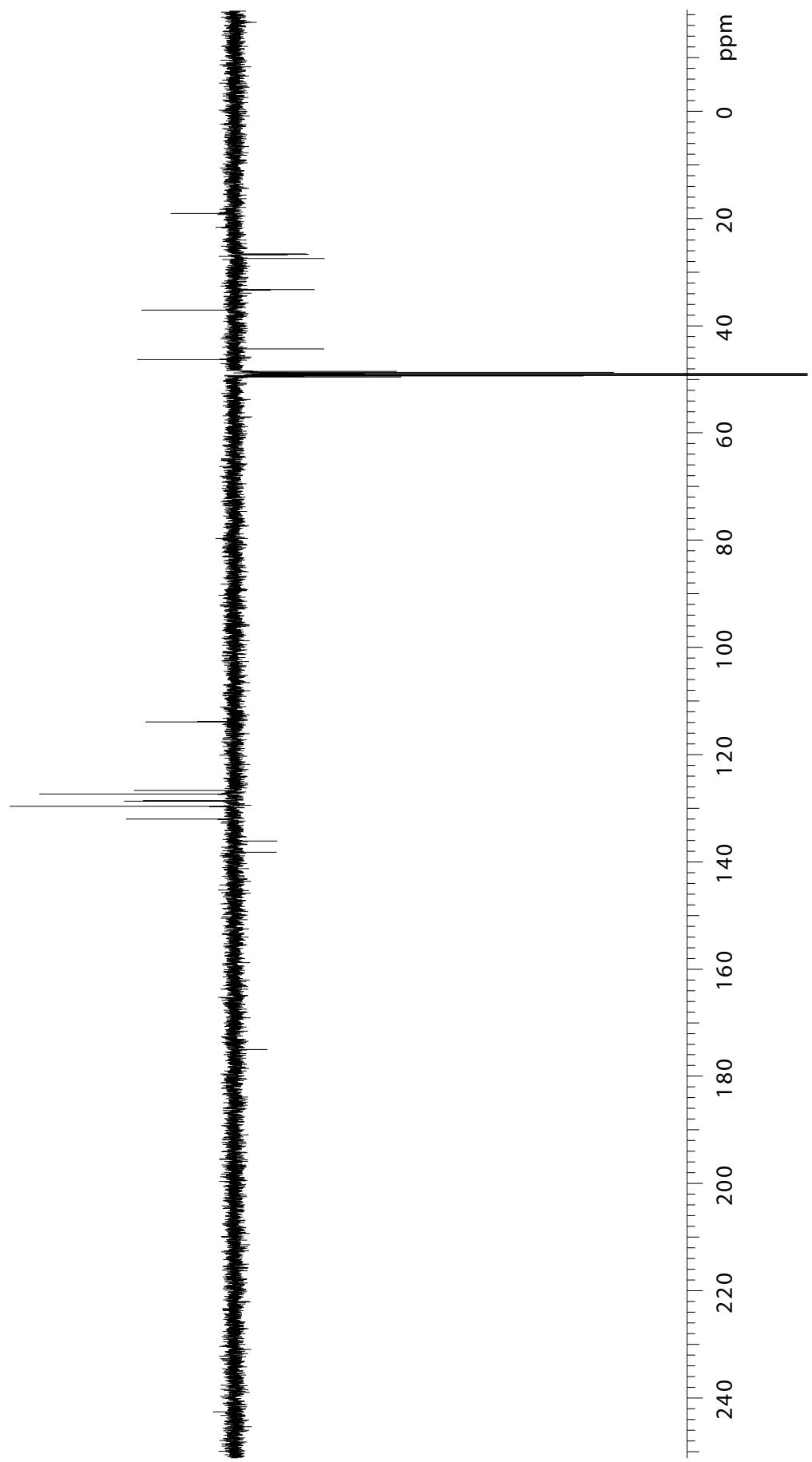
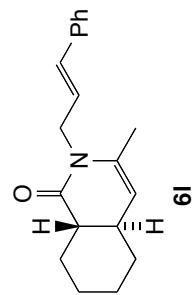




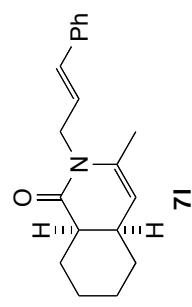








S-51



S-52

