Enantioselective Synthesis of α-Quaternary Mannich Adducts by Palladium-Catalyzed Allylic Alkylation: Total Synthesis of (+)-Sibirinine

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Table of Contents

Materials and Methods

Unless otherwise stated, reactions were performed in flame-dried glassware under an argon or nitrogen atmosphere using dry, deoxygenated solvents. Solvents were dried by passage through an activated alumina column under argon.[1] Reaction progress was monitored by thin-layer chromatography (TLC) or Agilent 1290 UHPLC-LCMS. TLC was performed using E. Merck silica gel 60 F254 precoated glass plates (0.25 mm) and visualized by UV fluorescence quenching, *p*-anisaldehyde, or $KMnO_4$ staining. Silicycle Silia*Flash*® P60 Academic Silica gel (particle size 40–63 nm) was used for flash chromatography. Melting points were measured with BÜCHI Melting Point B-545. ^1H and ^{13}C NMR spectra were recorded on a Varian Inova 500 (500 MHz and 126 MHz, respectively) and a Varian Mercury 300 spectrometer (300 MHz and 76 MHz, respectively) and are reported in terms of chemical shift relative to $CHCl_3$ (δ 7.26 and δ 77.16, respectively). ^{19}F NMR spectra were recorded on a Varian Mercury 300 MHz (282 MHz). ^{19}F NMR spectra were reported relative to $CFCl_3$ (δ 0.0 ppm). Data for ^1H NMR are reported as follows: chemical shift (δ ppm) (multiplicity, coupling constant (Hz), integration). Multiplicities are reported as follows: s = singlet, d = doublet, t = triplet, q = quartet, p = pentet, sept = septuplet, m = multiplet, br s = broad singlet, br d = broad doublet, br t = broad triplet, app = apparent. Data for ^{13}C NMR are reported in terms of chemical shifts (δ ppm). IR spectra were obtained by use of a Perkin Elmer Spectrum BXII spectrometer using thin films deposited on NaCl plates and reported in frequency of absorption (cm^{-1}). Optical rotations were measured with a Jasco P-2000 polarimeter operating on the sodium D-line (589 nm), using a 100 mm path-length cell and are reported as: $[a]_D^T$ (concentration in g/100 mL, solvent). Analytical HPLC was performed with an Agilent 1100 Series HPLC utilizing a Chiralpak (AD-H or AS) or Chiralcel (OD-H, OJ-H, or OB-H) columns (4.6 mm x 25 cm) obtained from Daicel Chemical Industries, Ltd. Analytical SFC was performed with a Mettler SFC supercritical CO_2 analytical chromatography system utilizing Chiralpak (AD-H, AS-H or IC) or Chiralcel (OD-H, OJ-H, or OB-H) columns (4.6 mm x 25 cm) obtained from Daicel Chemical Industries, Ltd. High resolution mass spectra (HRMS) were obtained from the Caltech Mass Spectral Facility using a JEOL JMS-600H High Resolution Mass Spectrometer in

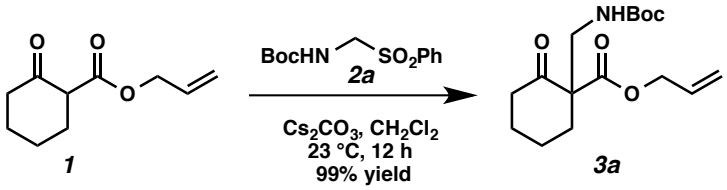
fast atom bombardment (FAB+) or electron ionization (EI+) mode, or Agilent 6200 Series TOF with an Agilent G1978A Multimode source in electrospray ionization (ESI+), atmospheric pressure chemical ionization (APCI+), or mixed ionization mode (MM: ESI/APCI).

Reagents were purchased from Sigma-Aldrich, Acros Organics, Strem, or Alfa Aesar and used as received unless otherwise stated. Et_3N was distilled from calcium hydride prior to use. MeOH was distilled from magnesium methoxide immediately prior to use. (*S*)-$(CF_3)_3$-*t*-BuPHOX,[2] tris(4,4'-methoxydibenzylideneacetone)dipalladium(0) $Pd_2(pmdba)_3$,[3] sulfonyl carbamates **2a**–**g**[4], and 1,3-dicarbonyl compound **1**[5], **5a**–**h**[6] were prepared by known methods.

List of Abbreviations:

Ac – acetyl, Cbz – benzyloxycarbonyl, Cy – cyclohexyl, Boc – *t*-butoxycarbonyl, Bz – benzoyl, DMAP – 4-(dimethylamino)pyridine, DIBAL – diisobutylaluminium hydride, ee – enantiomeric excess, HPLC – high-performance liquid chromatography, *m* – meta, Ms – methanesulfonyl, SFC – supercritical fluid chromatography, TLC – thin-layer chromatography, THF – tetrahydrofuran, Ts – *p*-toluenesulfonyl

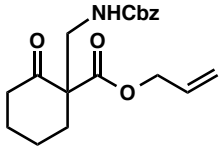
General Procedure A: α-Aminomethyl 1,3-dicarbonyl Substrate Synthesis



Allyl 1-(((*tert*-butoxycarbonyl)amino)methyl)-2-oxocyclohexane-1-carboxylate (3a). To a stirred solution of β-keto ester **1** (0.91 g, 5.0 mmol, 1 equiv) in CH_2Cl_2 (25 mL) was added sulfonylmethyl carbamate **2a** (1.63 g, 6.0 mmol, 1.2 equiv) in one portion at ambient temperature. After stirring for 5 min, Cs_2CO_3 (4.70 g, 12.5 mmol, 2.5 equiv) was added in one portion. After 12 h, full consumption of starting material was determined by TLC analysis. Saturated aqueous ammonium chloride was added slowly, and the biphasic mixture was stirred at ambient temperature for 20 min and extracted with CH_2Cl_2 (3 x 25 mL). The combined organic layers were dried over Na_2SO_4, filtered, and concentrated *in vacuo*. Flash column chromatography (SiO_2, 10% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3a** (1.55 g, 99% yield) as a faintly yellow oil. R_f = 0.55 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.91 (ddt, *J* = 16.5, 10.4, 5.8 Hz, 1H), 5.33 (m, 1H), 5.25 (m, 1H), 5.17 (m, 1H), 4.63 (m, 2H), 3.54 (dd, *J* = 13.9, 7.7 Hz, 1H), 3.40 (dd, *J* = 13.9, 5.7 Hz, 1H), 2.59–2.41 (m, 3H), 1.99 (m, 1H), 1.81 (m, 1H), 1.73–1.51 (m, 3H), 1.40 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.0, 171.0, 156.0, 131.6, 119.2, 79.4, 66.4, 62.4, 44.4, 40.9, 33.9, 28.5, 27.3, 22.2; IR (Neat Film, NaCl) 3461, 3404, 2976, 2939, 2867, 1713, 1501, 1452, 1366, 1247, 1229, 1168, 1141 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{16}H_{26}NO_5$ $[M+H]^+$: 312.1811, found 312.1824.

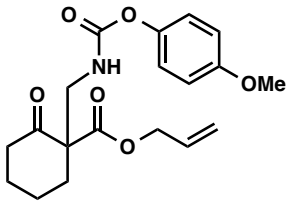
Spectroscopic Data for 3b–g and 6a–i

Allyl 1-(benzyloxycarbonylaminomethyl)-2-oxocyclohexane-1-carboxylate (3b).



The reaction was conducted according to general procedure A. Keto ester **1** (1.66 g, 9.09 mmol); sulfonylmethyl carbamate **2b** (3.33 g, 10.9 mmol); Cs_2CO_3 (7.40 g, 22.7 mmol). The reaction mixture was stirred for 18 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3b** (2.95 g, 8.54 mmol, 94% yield) as a colorless oil. R_f = 0.27 (20% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38–7.28 (m, 5H), 5.86 (ddt, *J* = 16.6, 10.5, 5.9 Hz, 1H), 5.41 (m, 1H), 5.32 (m, 1H), 5.23 (m, 1H), 5.11–5.01 (m, 2H), 4.63–4.52 (m, 2H), 3.62 (dd, *J* = 13.8, 7.7 Hz, 1H), 3.46 (dd, *J* = 13.8, 5.6 Hz, 1H), 2.59–2.42 (m, 3H), 2.00 (m, 1H), 1.81 (m, 1H), 1.72–1.53 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.8, 170.7, 156.5, 136.6, 131.5, 128.6, 128.2, 128.1, 119.3, 66.8, 66.4, 62.2, 44.8, 40.9, 33.9, 27.2, 22.1; IR (Neat Film, NaCl) 3450, 3394, 2943, 1724, 1711, 1509, 1453, 1265 1219, 1141, 981 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{19}H_{24}NO_5$ $[M+H]^+$: 346.1649, found 346.1634.

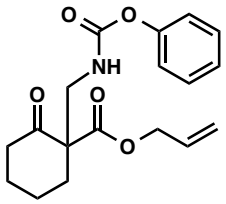
Allyl 1-((4-methoxyphenoxy)carbonylaminomethyl)-2-oxocyclohexane-1-carboxylate (3c).



The reaction was conducted according to general procedure A. Keto ester **1** (182 mg, 1.00 mmol); sulfonylmethyl carbamate **2c** (386 mg, 1.20 mmol); Cs_2CO_3 (910 mg, 2.50 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3c** (265 mg, 0.733 mmol, 73% yield) as a colorless oil. R_f = 0.18 (20% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.01–6.97 (m, 2H), 6.88–6.82 (m, 2H), 5.91 (m, 1H), 5.67 (m, 1H), 5.34 (m, 1H), 5.26 (m, 1H), 4.67–4.64 (m, 2H), 3.78 (s, 3H), 3.67 (dd, *J* = 13.9, 7.7 Hz, 1H), 3.53

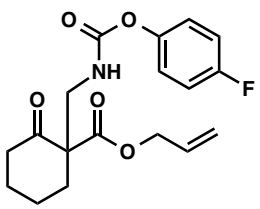
(dd, J = 13.9, 5.6 Hz, 1H), 2.62–2.46 (m, 3H), 2.03 (m, 1H), 1.84 (m, 1H), 1.76–1.58 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.9, 170.7, 157.0, 155.3, 144.7, 131.5, 122.4, 119.4, 114.4, 66.5, 62.2, 55.7, 45.0, 40.9, 34.0, 27.2, 22.1; IR (Neat Film, NaCl) 3377, 2943, 1742, 1732, 1709, 1498, 1201, 1055 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{19}H_{24}NO_6$ $[M+H]^+$: 362.1598, found 362.1601.

Allyl 1-(phenoxycarbonylaminomethyl)-2-oxocyclohexane-1-carboxylate (3d).



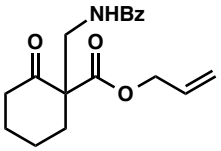
The reaction was conducted according to general procedure A. Keto ester **1** (182 mg, 1.00 mmol); sulfonylmethyl carbamate **2d** (350 mg, 1.20 mmol); Cs_2CO_3 (910 mg, 2.50 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3d** (310 mg, 0.936 mmol, 94% yield) as a colorless oil. R_f = 0.25 (20% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37–7.29 (m, 2H), 7.18 (m, 1H), 7.12–7.05 (m, 2H), 5.92 (ddt, J = 17.3, 10.5, 5.9 Hz, 1H), 5.71 (m, 1H), 5.34 (m, 1H), 5.26 (m, 1H), 4.71–4.62 (m, 2H), 3.68 (dd, J = 13.9, 7.8 Hz, 1H), 3.53 (dd, J = 13.9, 5.6 Hz, 1H), 2.64–2.47 (m, 3H), 2.04 (m, 1H), 1.84 (m, 1H), 1.77–1.58 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.9, 170.7, 154.8, 151.1, 131.5, 129.3, 125.4, 121.6, 119.5, 66.5, 62.1, 45.0, 40.9, 34.0, 27.3, 22.1; IR (Neat Film, NaCl) 3377, 2943, 1745, 1728, 1709, 1514, 1489, 1202, 1143 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{18}H_{22}NO_5$ $[M+H]^+$: 332.1492, found 332.1483.

Allyl 1-((4-fluorophenoxy)carbonylaminomethyl)-2-oxocyclohexane-1-carboxylate (3e).



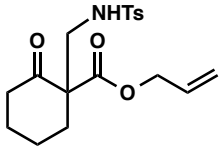
The reaction was conducted according to general procedure A. Keto ester **1** (182 mg, 1.00 mmol); sulfonylmethyl carbamate **2e** (371 mg, 1.20 mmol); Cs_2CO_3 (910 mg, 2.50 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3e** (278 mg, 0.796 mmol, 80% yield) as a colorless oil. R_f = 0.28 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.08–6.98 (m, 4H), 5.91 (ddt, *J* = 17.2, 10.5, 5.9 Hz, 1H), 5.72 (m, 1H), 5.34 (m, 1H), 5.26 (m, 1H), 4.68–4.60 (m, 2H), 3.67 (dd, *J* = 13.9, 7.8 Hz, 1H), 3.52 (dd, *J* = 13.9, 5.5 Hz, 1H), 2.64–2.46 (m, 3H), 2.04 (m, 1H), 1.83 (m, 1H), 1.76–1.57 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.9, 170.7, 160.0 (*J* = 243 Hz), 154.8, 147.0 (*J* = 4 Hz), 131.4, 123.0 (*J* = 9 Hz), 119.5, 115.9 (*J* = 23 Hz), 66.6, 62.1, 45.1, 40.9, 34.0, 27.3, 22.1; IR (Neat Film, NaCl) 3377, 2944, 1746, 1732, 1711, 1497, 1219, 1193, 1147 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{18}H_{21}FNO_5$ $[M+H]^+$: 350.1398, found 350.1392.

Allyl 1-(benzamidomethyl)-2-oxocyclohexane-1-carboxylate (3f).



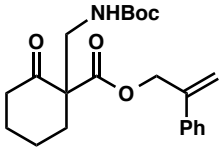
The reaction was conducted according to general procedure A. Keto ester **1** (182 mg, 1.00 mmol); sulfonylmethyl carbamate **2f** (413 mg, 1.50 mmol); Cs_2CO_3 (977 mg, 3.0 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3f** (250 mg, 0.793 mmol, 79% yield) as a white amorphous solid. R_f = 0.30 (40% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.72 – 7.67 (m, 2H), 7.49 – 7.44 (m, 1H), 7.42 – 7.36 (m, 2H), 6.96 – 6.87 (m, 1H), 5.83 (ddt, *J* = 17.2, 10.4, 6.0 Hz, 1H), 5.27 (dq, *J* = 17.1, 1.4 Hz, 1H), 5.18 (dq, *J* = 10.4, 1.2 Hz, 1H), 4.65 – 4.52 (m, 2H), 3.96 (dd, *J* = 13.6, 7.7 Hz, 1H), 3.65 (dd, *J* = 13.6, 5.2 Hz, 1H), 2.61 – 2.49 (m, 3H), 2.05 – 1.97 (m, 1H), 1.87 – 1.81 (m, 1H), 1.75 – 1.58 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.5, 170.8, 167.4, 134.4, 131.6, 131.4, 128.6, 127.0, 119.5, 66.6, 62.2, 43.3, 40.9, 34.2, 27.2, 22.1; IR (Neat Film, NaCl) 3447, 3356, 3061, 3028, 2943, 2866, 1712, 1667, 1651, 1602, 1580, 1519, 1488, 1450, 1307, 1280, 1203, 1142 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{18}H_{22}NO_4$ $[M+H]^+$: 316.1543, found 316.1559.

Allyl 1-(((4-methylphenyl)sulfonamido)methyl)-2-oxocyclohexane-1-carboxylate (3g).



The reaction was conducted according to general procedure A. Keto ester **1** (182 mg, 1.00 mmol); sulfonylmethyl carbamate **2g** (488 mg, 1.50 mmol); Cs_2CO_3 (977 mg, 3.0 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 25% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **3g** (365 mg, 0.999 mmol, >99% yield) as a clear colorless oil. R_f = 0.25 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73 – 7.69 (m, 2H), 7.30 (dd, *J* = 8.4, 1.0 Hz, 2H), 5.88 (ddt, *J* = 17.2, 10.4, 5.9 Hz, 1H), 5.32 (dq, *J* = 17.2, 1.5 Hz, 1H), 5.27 (dq, *J* = 10.4, 1.2 Hz, 1H), 5.20 (dd, *J* = 8.3, 5.8 Hz, 1H), 4.61 (dt, *J* = 5.9, 1.3 Hz, 2H), 3.21 (dd, *J* = 12.5, 8.4 Hz, 1H), 3.06 (dd, *J* = 12.5, 5.8 Hz, 1H), 2.65 – 2.56 (m, 1H), 2.46 – 2.36 (m, 4H), 2.06 – 1.97 (m, 1H), 1.82 – 1.76 (m, 1H), 1.72 – 1.58 (m, 4H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.0, 170.4, 143.6, 137.0, 131.4, 129.9, 127.1, 119.6, 66.6, 61.6, 47.2, 40.9, 34.1, 27.0, 22.1, 21.7; IR (Neat Film, NaCl) 3289, 2942, 2867, 1728, 1709, 1451, 1335, 1206, 1163, 1092 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{18}H_{24}NO_5S$ $[M+H]^+$: 366.1375, found 366.1367.

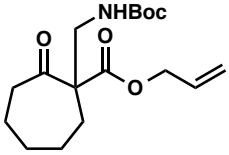
2-Phenylallyl 1-(((*tert*-butoxycarbonyl)amino)methyl)-2-oxocyclohexane-1-carboxylate (6a).



The reaction was conducted according to general procedure A. Keto ester **5a**[7] (311 mg, 1.2 mmol); sulfonylmethyl carbamate **2a** (392 mg, 1.44 mmol); Cs_2CO_3 (977 mg, 3.0 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6a** (368 mg, 0.95 mmol, 79% yield) as a pale yellow oil. R_f = 0.5 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 – 7.38 (m, 2H), 7.36 – 7.32 (m, 2H), 7.31 – 7.27 (m, 1H), 5.53 (d, *J* = 0.9

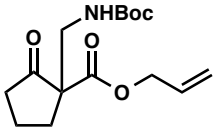
Hz, 1H), 5.37 (q, *J* = 1.1 Hz, 1H), 5.1 (d, *J* = 13.0 Hz, 1H), 5.07 (t, *J* = 7.0 Hz, 1H), 5.01 (d, *J* = 13.0, 1H), 3.48 (dd, *J* = 13.9, 7.6 Hz, 1H), 3.35 (dd, *J* = 13.9, 5.8 Hz, 1H), 2.38 – 2.27 (m, 2H), 2.26 – 2.18 (m, 1H), 1.81 (m, 1H), 1.69 – 1.63 (m, 1H), 1.60 – 1.50 (m, 1H), 1.49 – 1.41 (m, 2H), 1.39 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 208.7, 170.8, 155.0, 142.4, 137.9, 128.7, 128.3, 126.3, 116.3, 79.4, 66.9, 62.3, 44.3, 40.6, 33.7, 28.4, 27.2, 21.9; IR (Neat Film, NaCl) 3458, 3411, 2975, 2938, 2866, 1715, 1499, 1365, 1167, 1141 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{22}H_{29}NO_5Na$ $[M+Na]^+$: 410.1938, found 410.1923.

Allyl 1-(*t*-butoxycarbonylaminomethyl)-2-oxocycloheptane-1-carboxylate (6b).



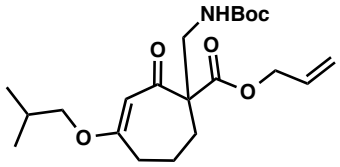
The reaction was conducted according to general procedure A. Keto ester **5b** (196 mg, 1.00 mmol); sulfonylmethyl carbamate **2a** (326 mg, 1.20 mmol); Cs_2CO_3 (815 mg, 2.50 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6b** (234 mg, 0.719 mmol, 72% yield) as a colorless oil. R_f = 0.47 (20% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.90 (m, 1H), 5.32 (m, 1H), 5.25 (m, 1H), 5.18 (m, 1H), 4.68 – 4.56 (m, 2H), 3.56 (dd, *J* = 14.0, 7.7 Hz, 1H), 3.50 (dd, *J* = 14.0, 5.8 Hz, 1H), 2.68 (m, 1H), 2.56 (ddd, *J* = 13.0, 8.3, 3.3 Hz, 1H), 2.08 (m, 1H), 1.86 – 1.76 (m, 2H), 1.73 – 1.48 (m, 5H), 1.40 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 210.2, 171.7, 156.1, 131.7, 119.0, 79.4, 66.2, 63.9, 45.3, 42.7, 31.7, 30.1, 28.4, 25.7, 25.3; IR (Neat Film, NaCl) 3461, 2976, 2933, 1718, 1501, 1456, 1366, 1248m 1225, 1169 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{17}H_{27}NO_5Na$ $[M+Na]^+$: 348.1781, found 348.1772.

Allyl 1-(*t*-butoxycarbonylaminomethyl)-2-oxocyclopentane-1-carboxylate (6c).



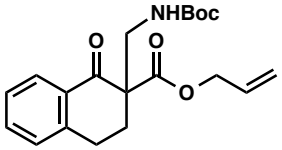
The reaction was conducted according to general procedure A. Keto ester **5c** (168 mg, 1.00 mmol); sulfonylmethyl carbamate **2a** (326 mg, 1.20 mmol); Cs_2CO_3 (815 mg, 2.50 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6c** (255 mg, 0.858 mmol, 86% yield) as a colorless oil. R_f = 0.50 (33% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.87 (ddt, *J* = 17.2, 10.4, 5.6 Hz, 1H), 5.29 (m, 1H), 5.24 (m, 1H), 5.13 (m, 1H), 4.67 – 4.55 (m, 2H), 3.50 (dd, *J* = 14.0, 7.0 Hz 1H), 3.46 (dd, *J* = 14.0, 6.0 Hz, 1H), 2.49 – 2.34 (m, 3H), 2.16 – 1.98 (m, 3H), 1.42 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 213.7, 171.3, 156.3, 131.5, 118.8, 79.7, 66.1, 61.5, 42.1, 38.2, 31.7, 28.4, 19.8; IR (Neat Film, NaCl) 3394, 2976, 1749, 1715, 1504, 1454, 1366, 1249, 1229, 1168, 966 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{15}H_{23}NO_5Na$ $[M+Na]^+$: 320.1468, found 320.1467.

Allyl 1-(((*tert*-butoxycarbonyl)amino)methyl)-4-isobutoxy-2-oxocyclohept-3-ene-1-carboxylate (6d).



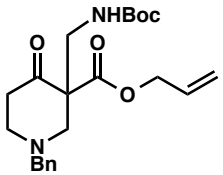
The reaction was conducted according to general procedure A. Keto ester **5d**[8] (100 mg, 0.375 mmol); sulfonylmethyl carbamate **2a** (122 mg, 0.45 mmol); Cs_2CO_3 (305 mg, 0.936 mmol). The reaction mixture was stirred for 10 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6d** (123 mg, 0.311 mmol, 83% yield) as a clear oil. R_f = 0.5 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.87 (ddt, *J* = 17.3, 10.5, 5.7 Hz, 1H), 5.38 (s, 1H), 5.29 (dq, *J* = 17.2, 1.6 Hz, 1H), 5.27 (m, 1H), 5.21 (dq, *J* = 10.5, 1.3 Hz, 1H), 4.63 (ddt, *J* = 13.2, 5.9, 1.4 Hz, 1H), 4.56 (ddt, *J* = 13.3, 5.8, 1.4 Hz, 1H), 3.64 (dd, *J* = 13.7, 7.8 Hz, 1H), 3.51 – 3.44 (m, 3H), 2.55 (ddd, *J* = 17.9, 10.0, 4.2 Hz, 1H), 2.44 (ddd, *J* = 17.8, 7.1, 3.8 Hz, 1H), 2.36 (m, 1H), 2.03 – 1.94 (m, 2H), 1.89 – 1.76 (m, 2H), 1.40 (s, 9H), 0.94 (dd, *J* = 6.7, 1.5 Hz, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 198.1, 174.9, 172.1, 156.1, 131.7, 118.8, 105.3, 79.3, 74.9, 66.2, 63.9, 46.4, 34.2, 29.3, 28.5, 27.9, 21.3, 19.2; IR (Neat Film, NaCl) 3459, 3394, 3083, 2961, 2934, 2874, 1734, 1718, 1636, 1610, 1499, 1388, 1366, 1232, 1171 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{21}H_{33}NO_6Na$ $[M+Na]^+$: 418.2200, found 418.2192.

Allyl 2-(((*tert*-butoxycarbonyl)amino)methyl)-1-oxo-1,2,3,4-tetrahydronaphthalene-2-carboxylate (6e).



The reaction was conducted according to general procedure A. Keto ester **5e**[7] (230.3 mg, 1.0 mmol); sulfonylmethyl carbamate **2a** (326 mg, 1.2 mmol); Cs_2CO_3 (815 mg, 2.5 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6e** (395 mg, 0.999 mmol, >99% yield) as a pale yellow oil. R_f = 0.5 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.49 (td, *J* = 7.5, 1.5 Hz, 1H), 7.34 – 7.29 (m, 1H), 7.23 (dq, *J* = 7.8, 0.7 Hz, 1H), 5.86 – 5.76 (m, 1H), 5.33 – 5.27 (m, 1H), 5.22 – 5.14 (m, 2H), 4.61 (dt, *J* = 2.4, 1.4 Hz, 1H), 4.59 (dt, *J* = 2.4, 1.4 Hz, 1H), 3.79 (dd, *J* = 13.9, 7.9 Hz, 1H), 3.56 (dd, *J* = 13.9, 5.4 Hz, 1H), 3.10 (dt, *J* = 17.5, 5.4 Hz, 1H), 3.02 (ddd, *J* = 17.4, 9.4, 4.8 Hz, 1H), 2.57 (dt, *J* = 13.8, 5.3 Hz, 1H), 2.20 (ddd, *J* = 14.1, 9.5, 5.0 Hz, 1H), 1.41 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 195.6, 171.0, 156.1, 143.4, 134.1, 131.9, 131.5, 129.0, 128.0, 127.0, 118.7, 79.5, 66.1, 59.4, 43.6, 29.3, 28.5, 25.8; IR (Neat Film, NaCl) 3454, 3395, 2977, 2934, 1731, 1717, 1683, 1601, 1505, 1456, 1366, 1235, 1170 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{20}H_{26}NO_5$ $[M+H]^+$: 360.1811, found 360.1801.

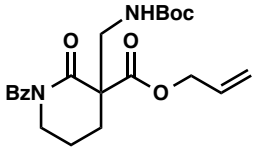
Allyl 1-benzyl-3-(((*tert*-butoxycarbonyl)amino)methyl)-4-oxopiperidine-3-carboxylate (6f).



The reaction was conducted according to general procedure A. Keto ester **5f**[7] (296 mg, 1.08 mmol); sulfonylmethyl carbamate **2a** (353 mg, 1.296 mmol); Cs_2CO_3 (882 mg, 2.7 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6f** (349 mg, 0.867 mmol,

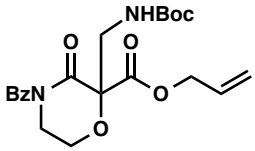
80% yield) as a clear colorless oil. R_f = 0.45 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, C_6D_6) δ 7.20 – 7.12 (m, 4H), 7.11 – 7.05 (m, 1H), 5.71 (ddt, *J* = 16.5, 10.9, 5.7 Hz, 1H), 5.37 (t, *J* = 6.8 Hz, 1H), 5.09 (dd, *J* = 17.2, 1.6 Hz, 1H), 4.94 (dq, *J* = 10.4, 1.3 Hz, 1H), 4.47 (d, *J* = 5.8, 1.4 Hz, 2H), 3.63 (dd, *J* = 13.9, 6.0 Hz, 1H), 3.57 (dd, *J* = 13.9, 7.4 Hz, 1H), 3.23 – 3.20 (m, 1H), 3.19 (d, *J* = 13.5 Hz, 1H), 3.10 (d, *J* = 13.4 Hz, 1H), 2.65 (ddd, *J* = 14.3, 10.0, 6.7 Hz, 1H), 2.37 – 2.29 (m, 2H), 1.99 (d, *J* = 11.6, 1H), 1.93 – 1.87 (m, 1H), 1.37 (s, 9H); ^{13}C NMR (126 MHz, C_6D_6) δ 205.9, 170.5, 155.9, 138.3, 132.2, 129.0, 128.7, 127.6, 118.4, 79.0, 66.1, 62.9, 61.9, 58.9, 53.1, 43.0, 40.3, 28.4; IR (Neat Film, NaCl) 3457, 2976, 2925, 2811, 1718, 1499, 1366, 1250, 1225, 1169 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{22}H_{31}N_2O_5$ $[M+H]^+$: 403.2233, found 403.2238.

Allyl 1-benzoyl-3-(*tert*-butoxycarbonylaminomethyl)-2-oxopiperidine-3-carboxylate (6g).



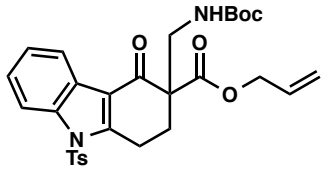
The reaction was conducted according to general procedure A. Amido ester **5g** (231 mg, 0.800 mmol); sulfonylmethyl carbamate **2a** (261 mg, 0.960 mmol); Cs_2CO_3 (652 mg, 2.00 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15→20% EtOAc in hexanes) afforded α-aminomethyl amido ester **6g** (245 mg, 0.588 mmol, 74% yield) as a colorless oil. R_f = 0.36 (33% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 – 7.74 (m, 2H), 7.50 (m, 1H), 7.44 – 7.36 (m, 2H), 5.97 (ddt, *J* = 16.6, 10.4, 6.0 Hz, 1H), 5.40 (m, 1H), 5.33 (m, 1H), 5.15 (m, 1H), 4.82 – 4.63 (m, 2H), 3.91 – 3.74 (m, 2H), 3.71 (dd, *J* = 13.9, 7.5 Hz, 1H), 3.50 (dd, *J* = 13.9, 5.9 Hz, 1H), 2.43 (m, 1H), 2.12 – 1.91 (m, 3H), 1.41 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 174.9, 172.2, 170.7, 156.1, 135.6, 132.1, 131.3, 128.3, 128.3, 119.9, 79.7, 66.8, 58.4, 46.8, 44.7, 29.1, 28.4, 20.0; IR (Neat Film, NaCl) 3446, 2976, 1714, 1684, 1500, 1449, 1391, 1366, 1271, 1249, 1164, 1141, 939 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{22}H_{28}N_2O_6Na$ $[M+Na]^+$: 439.1840, found 439.1854.

Allyl 4-benzoyl-2-(*tert*-butoxycarbonylaminomethyl)-3-oxomorpholine-2-carboxylate (6h).



The reaction was conducted according to general procedure A. Morpholinone **5h** (100 mg, 0.346 mmol); sulfonylmethyl carbamate **2a** (188 mg, 0.691 mmol); Cs_2CO_3 (338 mg, 1.04 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 20→25% EtOAc in hexanes) afforded α-aminomethyl morpholinone **6h** (132 mg, 0.315 mmol, 91% yield) as a colorless oil. R_f = 0.34 (10% EtOAc in toluene); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 – 7.65 (m, 2H), 7.52 (m, 1H), 7.43 – 7.38 (m, 2H), 5.97 (m, 1H), 5.41 (m, 1H), 5.33 (m, 1H), 5.00 (brs, 1H), 4.76 – 4.73 (m, 2H), 4.30 – 4.17 (m, 2H), 4.05 – 3.90 (m, 2H), 3.87 – 3.72 (m, 2H), 1.42 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 172.7, 167.7, 167.5, 155.8, 134.7, 132.5, 131.0, 128.5, 128.3, 119.9, 83.1, 79.9, 67.2, 62.1, 45.0, 44.8, 28.4; IR (Neat Film, NaCl) 3388, 2977, 2934, 1746, 1714, 1693, 1507, 1449, 1367, 1317, 1279, 1233, 1165, 1066, 944, 757, 727, 693 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{21}H_{26}N_2O_7Na$ $[M+Na]^+$: 441.1632, found 441.1636.

Allyl 3-(((*tert*-butoxycarbonyl)amino)methyl)-4-oxo-9-tosyl-2,3,4,9-tetrahydro-1*H*-carbazole-3-carboxylate (6i).

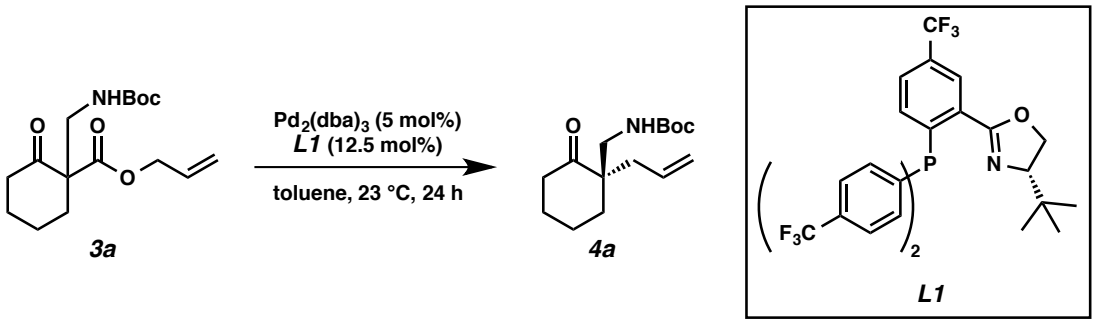


The reaction was conducted according to general procedure A. Keto ester **5i**[9] (400 mg, 0.994 mmol); sulfonylmethyl carbamate **2a** (307 mg, 1.13 mmol); Cs_2CO_3 (770 mg, 2.36 mmol). The reaction mixture was stirred for 24 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded α-aminomethyl β-keto ester **6i** (418 mg, 0.756 mmol, 80% yield) as a clear colorless oil. R_f = 0.33 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 – 8.17 (m, 1H), 8.15 – 8.12 (m, 1H), 7.78 (d, J = 8.4 Hz, 2H), 7.38 – 7.31 (m, 2H), 7.27 (d, J = 8.4 Hz, 2H), 5.80 (m, 1H), 5.25 – 5.17 (m, 2H), 5.15 (m, 1H),

4.58 (dt, *J* = 5.8, 1.4 Hz, 2H), 3.74 (dd, *J* = 14.0, 7.7 Hz, 1H), 3.59 (m, 2H), 3.41 (ddd, *J* = 19.2, 8.3, 5.2 Hz, 1H), 2.67 (dt, *J* = 13.9, 5.4 Hz, 1H), 2.37 (s, 3H), 2.28 (m, 1H), 1.42 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 191.4, 170.6, 156.1, 150.7, 146.1, 136.2, 135.3, 131.5, 130.4, 126.9, 125.8, 125.7, 125.2, 121.9, 118.9, 117.1, 114.0, 79.6, 66.2, 59.3, 43.3, 29.2, 28.5, 22.1, 21.8; IR (Neat Film, NaCl) 3445, 3054, 2977, 2933, 2254, 1733, 1713, 1596, 1558, 1505, 1481, 1451, 1410, 1380, 1244, 1174, 1090 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{29}H_{33}N_2O_7S$ $[M+H]^+$: 553.2003, found 553.1994.

General Procedure B: Palladium-Catalyzed Allylic Alkylation

Please note that the absolute configuration of all products **4** and **7** has been inferred from previous studies,[7] with the exception of **4b**, which was assigned by conversion to (–)-isonitramine. For isolated yields, see manuscript Tables 1 and 2. For GC, HPLC, or SFC conditions, as well as optical rotation data, please refer to Table S1.

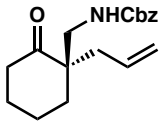


(*S*)-*Tert*-butyl ((1-allyl-2-oxocyclohexyl)methyl)carbamate (4a). In a nitrogen-filled glove box, [$Pd_2(dba)_3$] (9.2 mg, 0.010 mmol, 0.05 equiv) and (*S*)-$(CF_3)_3$-*t*-BuPHOX **L1** (14.8 mg, 0.025 mmol, 0.125 equiv) were added to a 20 mL scintillation vial equipped with a magnetic stirring bar. The vial was then charged with toluene (4.1 mL) and stirred at 25 °C for 30 min, generating a yellow solution. To the preformed catalyst solution was added a solution of **3a** (62.3 mg, 0.20 mmol, 1 equiv) in toluene (2.0 mL). The vial was sealed and stirred at 25 °C until the full consumption of β-keto ester **3a** was observed by TLC analysis. The reaction mixture was concentrated *in vacuo*. Flash column chromatography (SiO_2, 2% EtOAc in CH_2Cl_2 eluent) afforded α-quaternary ketone **4a** (50.2 mg, 94% yield) as a colorless oil. 86% ee, $[\alpha]_D^{25}$ –25.5 (*c* 0.865, C_6H_6); R_f = 0.55 (5% EtOAc in DCM); ^{1}H NMR (500 MHz, C_6D_6) δ 5.64 (m, 1H), 5.05 (br t, *J* = 6.4 Hz, 1H), 4.94 (ddt, *J* = 10.1, 2.0, 1.0 Hz, 1H), 4.87 (dq, *J* = 17.0, 1.5 Hz, 1H), 3.30 (dd, *J* = 13.9, 7.2 Hz, 1H), 3.24 (dd, *J* = 13.9, 6.1 Hz, 1H), 2.15 – 2.08 (m, 2H), 2.01 – 1.91 (m, 2H), 1.44 (s, 9H), 1.41 – 1.30 (m, 2H), 1.25 – 1.12 (m, 2H); ^{13}C NMR (126 MHz, C_6D_6) δ 213.5, 156.2, 133.3, 118.5, 78.7, 53.1, 45.2, 39.1, 37.9, 33.7, 28.5, 27.1, 20.6; IR (Neat Film, NaCl) 3462, 3395, 2977, 2939, 2867, 1718, 1499, 1167 cm^{-1}; HRMS (ESI+) *m/z*

calc'd for $C_{15}H_{25}NO_3Na$ $[M+Na]^+$: 290.1727, found 290.1718; SFC conditions: 10% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 7.65, minor = 8.46.

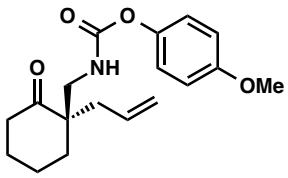
Spectroscopic Data for 4b–g and 7a–i

(*S*)-Benzyl (1-allyl-2-oxocyclohexyl)methylcarbamate (4b).



The reaction was conducted according to general procedure B. Keto ester **3b** (69.1 mg, 0.200 mmol). The reaction mixture was stirred at 23 ºC for 14 h. Flash column chromatography (SiO_2, 10→15% EtOAc in hexanes) afforded ketone **4b** (57.7 mg, 0.191 mmol, 96% yield) as a colorless oil. 86% ee, $[\alpha]_D^{25}$ –38.6 (*c* 1.20, $CHCl_3$); R_f = 0.44 (25% EtOAc in hexanes); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42 – 7.25 (m, 5H), 5.67 (m, 1H), 5.21 (m, 1H), 5.16 – 5.00 (m, 4H), 3.34 (dd, *J* = 13.9, 5.9 Hz, 1H), 3.24 (dd, *J* = 13.9, 7.4 Hz, 1H), 2.54 – 2.20 (m, 4H), 1.99 (m, 1H), 1.81 – 1.60 (m, 5H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 215.5, 156.9, 136.7, 132.2, 128.6, 128.2, 128.1, 119.2, 66.8, 53.2, 45.4, 39.3, 38.0, 33.7, 27.2, 20.6.; IR (Neat Film, NaCl) 3351, 2937, 1722, 1702, 1510, 1454, 1234, 1134 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{18}H_{24}NO_3$ $[M+H]^+$: 302.1751, found 302.1756; SFC conditions: 5% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 8.12, minor = 9.06.

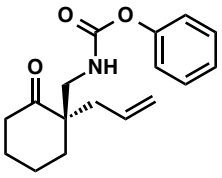
(*S*)-4-methoxyphenyl (1-allyl-2-oxocyclohexyl)methylcarbamate (4c).



The reaction was conducted according to general procedure B. Keto ester **3c** (72.3 mg, 0.200 mmol). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 15→20% EtOAc in hexanes) afforded ketone **4c** (57.6 mg, 0.181 mmol, 91% yield) as a colorless oil. 83% ee, $[\alpha]_D^{25}$ –29.3 (*c* 0.76, $CHCl_3$); R_f = 0.25 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.05 – 6.97 (m, 2H), 6.90 – 6.81

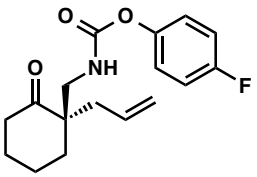
(m, 2H), 5.70 (m, 1H), 5.49 (m, 1H), 5.18 – 5.09 (m, 2H), 3.78 (s, 3H), 3.40 (dd, J = 13.9, 6.0 Hz, 1H), 3.28 (dd, J = 13.9, 7.2 Hz, 1H), 2.55 – 2.44 (m, 2H), 2.41 – 2.28 (m, 2H), 2.03 (m, 1H), 1.90 – 1.64 (m, 5H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 215.6, 157.0, 155.6, 144.8, 132.2, 122.5, 119.3, 114.4, 55.7, 53.2, 45.6, 39.4, 38.0, 33.8, 27.3, 20.6; IR (Neat Film, NaCl) 3345, 2937, 1740, 1700, 1501, 1201 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{18}H_{24}NO_4$ $[M+H]^+$: 318.1700, found 318.1705; SFC conditions: 10% IPA, 2.5 mL/min, Chiralcel OB-H column, λ = 210 nm, t_R (min): major = 9.47, minor = 11.13.

(*S*)-phenyl (1-allyl-2-oxocyclohexyl)methylcarbamate (4d).



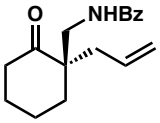
The reaction was conducted according to general procedure B. Keto ester **3d** (66.3 mg, 0.200 mmol). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 10→15% EtOAc in hexanes) afforded ketone **4d** (51.5 mg, 0.179 mmol, 90% yield) as a colorless oil. 77% ee, $[\alpha]_D^{25}$ –28.9 (*c* 0.40, $CHCl_3$); R_f = 0.29 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34 (t, J = 7.7 Hz, 2H), 7.17 (m, 1H), 7.11 (d, J = 8.0 Hz, 2H), 5.70 (m, 1H), 5.53 (m, 1H), 5.20 – 5.11 (m, 2H), 3.41 (dd, J = 14.0, 6.0 Hz, 1H), 3.29 (dd, J = 14.0, 7.2 Hz, 1H), 2.55 – 2.45 (m, 2H), 2.42 – 2.29 (m, 2H), 2.03 (m, 1H), 1.90 – 1.65 (m, 5H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 215.7, 155.1, 151.2, 132.1, 129.3, 125.3, 121.6, 119.4, 53.2, 45.6, 39.4, 38.0, 33.8, 27.3, 20.6; IR (Neat Film, NaCl) 3346, 2937, 1743, 1701, 1490, 1203 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{17}H_{22}NO_3$ $[M+H]^+$: 288.1594, found 288.1589; SFC conditions: 10% IPA, 2.5 mL/min, Chiralcel OB-H column, λ = 210 nm, t_R (min): major = 6.53, minor = 8.13.

(*S*)-4-fluorophenyl (1-allyl-2-oxocyclohexyl)methylcarbamate (4e).



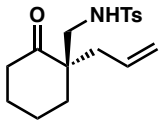
The reaction was conducted according to general procedure B. Keto ester **3e** (69.9 mg, 0.200 mmol). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 10→15% EtOAc in hexanes) afforded ketone **4e** (51.4 mg, 0.168 mmol, 84% yield) as a colorless oil. 77% ee, $[\alpha]_D^{25}$ –27.4 (*c* 0.78, $CHCl_3$); R_f = 0.37 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.10 – 6.97 (m, 4H), 5.69 (m, 1H), 5.54 (m, 1H), 5.17 – 5.10 (m, 2H), 3.40 (dd, *J* = 13.9, 6.0 Hz, 1H), 3.27 (dd, *J* = 13.9, 7.2 Hz, 1H), 2.55 – 2.45 (m, 2H), 2.41 – 2.29 (m, 2H), 2.04 (m, 1H), 1.91 – 1.63 (m, 5H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 215.7, 160.0 (*J* = 243 Hz), 155.1, 147.1 (*J* = 4 Hz), 132.1, 123.1 (*J* = 7 Hz), 119.4, 115.9 (*J* = 24 Hz), 53.2, 45.6, 39.4, 37.9, 33.8, 27.3, 20.6; IR (Neat Film, NaCl) 3347, 2938, 1742, 1699, 1498, 1192 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{17}H_{21}FNO_3$ $[M+H]^+$: 306.1500, found 306.1493; SFC conditions: 10% IPA, 2.5 mL/min, Chiralpak AS-H column, λ = 210 nm, t_R (min): major = 6.94, minor = 8.24.

(*S*)-*N*-((1-allyl-2-oxocyclohexyl)methyl)benzamide (4f).



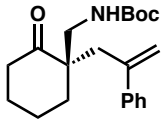
The reaction was conducted according to general procedure B. Keto ester **3f** (19.1 mg, 0.60 mmol). The reaction mixture was stirred at 23 ºC for 20 h. Flash column chromatography (SiO_2, 10→15% EtOAc in hexanes) afforded ketone **4f** as a colorless oil. 56% ee, R_f = 0.23 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 – 7.72 (m, 2H), 7.49 (m, 1H), 7.45 – 7.40 (m, 2H), 6.78 (m, 1H), 5.66 (m, 1H), 5.15 (d, *J* = 1.2 Hz, 1H), 5.12 (m, 1H), 3.58 (dd, *J* = 13.8, 6.1 Hz, 1H), 3.55 (dd, *J* = 13.8, 6.1 Hz, 1H), 2.56 – 2.47 (m, 2H), 2.40 – 2.32 (m, 2H), 2.03 (m, 1H), 1.92 – 1.79 (m, 2H), 1.77 – 1.61 (m, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 216.6, 167.5, 134.7, 132.3, 131.6, 128.7, 127.0, 119.4, 53.5, 43.9, 39.5, 38.3, 34.1, 27.4, 20.6; IR (Neat Film, NaCl) 3439, 3338, 3070, 2936, 2864, 1693, 1668, 1649, 1535, 1515, 1486, 1454, 1286, 1127 cm^{-1}; HRMS (ESI/APCI) *m/z* calc'd for $C_{17}H_{22}NO_2$ $[M+H]^+$: 272.1645, found 272.1638; SFC conditions: 20% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 4.04, minor = 4.91.

(*S*)-*N*-((1-allyl-2-oxocyclohexyl)methyl)-4-methylbenzenesulfonamide (4g).



The reaction was conducted according to general procedure B. Keto ester **3g** (74.0 mg, 0.202 mmol). The reaction mixture was stirred at 23 ºC for 20 h. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded ketone **4g** (35.3 mg, 0.109 mmol, 54% yield) as a yellow oil. 24% ee, R_f = 0.3 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71 (m, 2H), 7.30 (dd, *J* = 8.3, 0.9 Hz, 2H), 5.61 (dddd, *J* = 16.3, 10.8, 7.9, 6.9 Hz, 1H), 5.11 – 5.06 (m, 3H), 2.97 (dd, *J* = 12.6, 6.7 Hz, 1H), 2.70 (dd, *J* = 12.6, 7.5 Hz, 1H), 2.50 – 2.43 (m, 2H), 2.41 (s, 3H), 2.31 – 2.21 (m, 2H), 2.01 (m, 1H), 1.84 – 1.55 (m, 5H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 215.7, 143.4, 137.0, 131.5, 129.9, 127.0, 119.7, 52.5, 47.7, 39.2, 37.4, 33.4, 27.1, 21.6, 20.5; IR (Neat Film, NaCl) 3285, 3071, 2938, 2865, 1919, 1762, 1703, 1638, 1598, 1495, 1454, 1333, 1164, 1091 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{17}H_{24}NO_3S$ $[M+H]^+$: 322.1471, found 322.1456; SFC conditions: 15% IPA, 2.5 mL/min, Chiralcel OJ-H column, λ = 210 nm, t_R (min): major = 3.14, minor = 3.85.

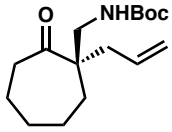
(*S*)-*tert*-butyl ((2-oxo-1-(2-phenylallyl)cyclohexyl)methyl)carbamate (7a).



The reaction was conducted according to general procedure B. Keto ester **6a** (110 mg, 0.284 mmol); $[Pd_2(pmdba)_3]$ (15.6 mg, 0.014 mmol, 0.05 equiv). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 20% acetone in hexanes) afforded ketone **7a** (88.7 mg, 0.258 mmol, 91% yield) as a yellow oil. 90% ee, $[\alpha]_D^{25}$ –30.9 (*c* 4.45, $CHCl_3$); R_f = 0.55 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.32 – 7.26 (m, 5H), 5.23 (d, *J* = 1.4 Hz, 1H), 5.08 (d, *J* = 2.0 Hz, 1H), 4.67 (dd, *J* = 8.3, 4.4 Hz, 1H), 3.16 (dd, *J* = 14.0, 8.5 Hz, 1H), 3.09 (dd, *J* = 13.9, 4.7 Hz, 1H), 2.99 (d, *J* = 14.1 Hz, 1H), 2.71 (d, *J* = 14.1 Hz, 1H), 2.38 (ddd, *J* = 14.4, 10.8, 5.7 Hz, 1H), 2.30 (dt, *J* = 13.9, 4.8 Hz, 1H), 1.87 (dt, *J* = 15.3, 5.5 Hz, 1H), 1.77 – 1.60 (m, 5H), 1.38 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 214.9, 156.3, 144.9, 142.7, 128.6, 127.7,

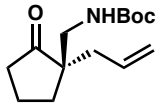
126.7, 118.3, 79.1, 54.0, 44.9, 39.8, 39.7, 34.4, 28.5, 27.2, 20.9; IR (Neat Film, NaCl) 3463, 3374, 2975, 2935, 2865, 1713, 1703, 1699, 1505, 1455, 1365, 1247, 1169 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{21}H_{30}NO_3$ $[M+H]^+$: 344.2226, found 344.2236; SFC conditions: 15% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 2.46, minor = 2.78.

(*S*)-*tert*-Butyl (1-allyl-2-oxocycloheptyl)methylcarbamate (7b).



The reaction was conducted according to general procedure B. Keto ester **6b** (97.6 mg, 0.300 mmol). The reaction mixture was stirred at 23 ºC for 20 h. Flash column chromatography (SiO_2, 10→15% EtOAc in hexanes) afforded ketone **7b** (78.7 mg, 0.280 mmol, 93% yield) as a pale yellow oil. 87% ee, $[\alpha]_D^{25}$ –22.7 (*c* 0.85, $CHCl_3$); R_f = 0.53 (20% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.72 (ddt, *J* = 17.3, 10.4, 7.5 Hz, 1H), 5.12 – 5.03 (m, 2H), 4.93 (brs, 1H), 3.31 – 3.19 (m, 2H), 2.65 – 2.56 (m, 1H), 2.46 (ddd, *J* = 11.3, 8.8, 2.5 Hz, 1H), 2.35 (m, 1H), 2.20 (m, 1H), 1.79 – 1.41 (m, 8H), 1.41 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 217.1, 156.2, 133.2, 118.8, 79.3, 54.8, 45.2, 41.1, 39.4, 33.3, 30.8, 28.5, 26.7, 24.7; IR (Neat Film, NaCl) 3372, 2930, 1716, 1698, 1503, 1365, 1247, 1117 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{17}H_{28}NO_3$ $[M+H]^+$: 282.2064, found 282.2051; SFC conditions: 5% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 4.25, minor = 4.63.

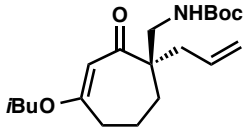
(*S*)-*tert*-Butyl (1-allyl-2-oxocyclopentyl)methylcarbamate (7c).



The reaction was conducted according to general procedure B. Keto ester **6c** (59.5 mg, 0.200 mmol). The reaction mixture was stirred at 23 ºC for 20 h. Flash column chromatography (SiO_2, 10→15% EtOAc in hexanes) afforded ketone **7c** (50.0 mg, 0.196 mmol, 98% yield) as a colorless oil. 82% ee, $[\alpha]_D^{25}$ –12.8 (*c* 0.96, $CHCl_3$); R_f = 0.38 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.69 (ddt, *J* = 17.4, 10.2, 7.4

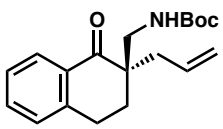
Hz, 1H), 5.14 – 5.05 (m, 2H), 4.86 (brs, 1H), 3.25 (dd, *J* = 13.9, 6.9 Hz, 1H), 3.14 (dd, *J* = 13.9, 5.7 Hz, 1H), 2.30 – 2.23 (m, 2H), 2.20 – 2.13 (m, 2H), 1.99 – 1.79 (m, 4H), 1.43 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 222.6, 156.3, 133.0, 119.1, 79.5, 52.5, 44.0, 38.4, 37.5, 31.1, 28.5, 18.8; IR (Neat Film, NaCl) 3360, 2975, 1713, 1510, 1365, 1248, 1166 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{14}H_{23}NO_3Na$ $[M+Na]^+$: 276.1570, found 276.1565; SFC conditions: 5% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 2.97, minor = 4.26.

(*S*)-*tert*-butyl ((1-allyl-4-isobutoxy-2-oxocyclohept-3-en-1-yl)methyl)carbamate (7d).



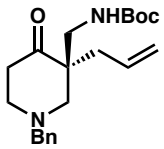
The reaction was conducted according to general procedure B. Keto ester **6d** (100 mg, 0.253 mmol); $[Pd_2(pmdba)_3]$ (13.9 mg, 0.012 mmol, 0.05 equiv). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 10% EtOAc in hexanes) afforded ketone **7d** (62.2 mg, 0.177 mmol, 70% yield) as a pale yellow oil. 92% ee, $[\alpha]_D^{25}$ –28.7 (*c* 0.65, $CHCl_3$); R_f = 0.6 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.70 (ddt, *J* = 17.5, 10.3, 7.4 Hz, 1H), 5.28 (s, 1H), 5.10 – 5.03 (m, 3H), 3.53 – 3.44 (m, 2H), 3.33 (dd, *J* = 13.6, 6.4 Hz, 1H), 3.18 (dd, *J* = 13.6, 6.4 Hz, 1H), 2.55 – 2.42 (m, 2H), 2.37 – 2.28 (m, 2H), 1.98 (dt, *J* = 13.3, 6.7 Hz, 1H), 1.94 – 1.87 (m, 1H), 1.81 – 1.72 (m, 3H), 1.41 (s, 9H), 0.95 (d, *J* = 6.7 Hz, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 205.8, 172.7, 156.4, 133.4, 118.8, 104.9, 79.1, 74.7, 55.5, 47.1, 41.3, 36.1, 31.6, 28.6, 28.0, 20.5, 19.3; IR (Neat Film, NaCl) 3373, 3075, 2972, 2931, 2868, 1716, 1694, 1504, 1393, 1366, 1249, 1166 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{20}H_{34}NO_4$ $[M+H]^+$: 352.2488, found 352.2474; SFC conditions: 3% IPA, 2.5 mL/min, Chiralpak AS-H column, λ = 254 nm, t_R (min): major = 4.41, minor = 6.12.

(*S*)-*tert*-butyl ((2-allyl-1-oxo-1,2,3,4-tetrahydronaphthalen-2-yl)methyl)carbamate (7e).



The reaction was conducted according to general procedure B. Keto ester **6e** (81 mg, 0.225 mmol); [$Pd_2(pmdba)_3$] (12.3 mg, 0.011 mmol, 0.05 equiv). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 10% EtOAc in hexanes) afforded ketone **7e** (52.2 mg, 0.167 mmol, 74% yield) as a pale yellow oil. 93% ee, $[\alpha]_D^{25}$ –1.3 (*c* 1.32, $CHCl_3$); R_f = 0.6 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.00 (dd, *J* = 8.0, 1.4 Hz, 1H), 7.48 (td, *J* = 7.5, 1.5 Hz, 1H), 7.30 (td, *J* = 7.6, 1.2 Hz, 1H), 7.23 (d, *J* = 7.6 Hz, 1H), 5.79 (m, 1H), 5.15 – 5.05 (m, 3H), 3.50 (dd, *J* = 13.9, 6.2 Hz, 1H), 3.29 (dd, *J* = 13.9, 6.9 Hz, 1H), 3.11 (ddd, *J* = 16.9, 11.1, 5.3 Hz, 1H), 2.94 (dt, *J* = 17.5, 4.6 Hz, 1H), 2.37 (dd, *J* = 14.2, 8.0 Hz, 1H), 2.28 (dd, *J* = 14.2, 6.8 Hz, 1H), 2.11 (ddd, *J* = 14.0, 11.1, 5.2 Hz, 1H), 2.03 (dt, *J* = 14.0, 4.7 Hz, 1H), 1.41 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.2, 156.4, 143.5, 133.7, 132.7, 131.6, 129.0, 127.9, 126.9, 119.2, 79.2, 49.3, 44.8, 36.6, 28.9, 28.5, 25.0; IR (Neat Film, NaCl) 3449, 3378, 3073, 2976, 2930, 1716, 1699, 1678, 1600, 1505, 1455, 1365, 1232, 1170 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{19}H_{26}NO_3$ $[M+H]^+$: 316.1913, found 316.1920; SFC conditions: 15% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 2.48, minor = 2.80.

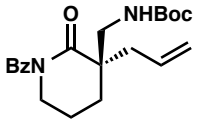
(*S*)-*tert*-butyl ((3-allyl-1-benzyl-4-oxopiperidin-3-yl)methyl)carbamate (7f).



The reaction was conducted according to general procedure B. Keto ester **6f** (115 mg, 0.286 mmol); [$Pd_2(pmdba)_3$] (15.7 mg, 0.014 mmol, 0.05 equiv). The reaction mixture was stirred at 23 ºC for 24 h. Flash column chromatography (SiO_2, 10% EtOAc in hexanes) afforded ketone **7f** (79.3 mg, 0.223 mmol, 78% yield) as a pale yellow oil. 90% ee, $[\alpha]_D^{25}$ –34.0 (*c* 1.58, $CHCl_3$); R_f = 0.55 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.37 – 7.27 (m, 5H), 5.61 (m, 1H), 5.07 (m, 1H), 5.04 (d, *J* = 1.1 Hz, 1H), 5.00 (m, 1H), 3.58 (d, *J* = 13.0 Hz, 1H), 3.53 (d, *J* = 13.0 Hz, 1H), 3.37 (dd, *J* = 14.0, 7.3 Hz, 1H), 3.19 (dd, *J* = 14.0, 5.7 Hz, 1H), 2.84 (m, 1H), 2.69 (d, *J* = 11.6 Hz, 1H), 2.63 – 2.50 (m, 3H), 2.48 – 2.36 (m, 3H), 1.41 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 212.8, 156.2, 138.3, 132.6, 129.0, 128.5, 127.4, 119.2, 79.3, 62.3, 59.7, 53.6, 53.1, 44.1,

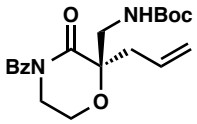
39.5, 38.1, 28.5; IR (Neat Film, NaCl) 3452, 3373, 3063, 2976, 2929, 2807, 1713, 1638, 1504, 1453, 1391, 1365, 1248, 1170 cm^{-1}; HRMS (FAB+) *m/z* calc'd for $C_{21}H_{31}N_2O_3$ $[M+H]^+$: 359.2335, found 359.2345; SFC conditions: 8% IPA, 2.5 mL/min, Chiralpak AD-H column, λ = 210 nm, t_R (min): major = 4.94, minor = 6.46.

(*S*)-*tert*-Butyl ((3-allyl-1-benzoyl-2-oxopiperidin-3-yl)methyl)carbamate (7g).



The reaction was conducted according to general procedure B. Amido ester **6g** (83.3 mg, 0.200 mmol). The reaction mixture was stirred at 40 ºC for 20 h. Flash column chromatography (SiO_2, 15→20% EtOAc in hexanes) afforded lactam **7g** (69.7 mg, 0.187 mmol, 94%) as a colorless oil. 90% ee, $[\alpha]_D^{25}$ +33.6 (*c* 1.05, $CHCl_3$); R_f = 0.29 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 – 7.46 (m, 3H), 7.44 – 7.37 (m, 2H), 5.78 (m, 1H), 5.24 – 5.15 (m, 2H), 4.96 (m, 1H), 3.84 (m, 1H), 3.73 (ddd, *J* = 12.7, 10.3, 4.3 Hz, 1H), 3.37 (dd, *J* = 13.8, 6.5 Hz, 1H), 3.22 (dd, *J* = 13.8, 6.5 Hz, 1H), 2.60 (dd, *J* = 13.8, 8.0 Hz, 1H), 2.48 (dd, *J* = 13.8, 6.7 Hz, 1H), 2.12 – 1.93 (m, 3H), 1.82 (m, 1H), 1.42 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 178.6, 175.4, 156.4, 136.3, 131.9, 131.8, 128.4, 127.6, 120.1, 79.5, 48.8, 47.2, 46.0, 39.7, 28.8, 28.5, 19.3; IR (Neat Film, NaCl) 3373, 2975, 1693, 1678, 1502, 1390, 1365, 1272, 1248, 1167 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{21}H_{28}N_2O_4Na$ $[M+Na]^+$: 395.1941, found 395.1954; SFC conditions: 10% MeOH, 3.0 mL/min, Chiralpak AD-H column, λ = 254 nm, t_R (min): major = 2.64, minor = 3.12.

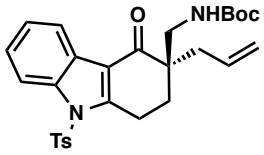
(*R*)-*tert*-Butyl ((2-allyl-4-benzoyl-3-oxomorpholin-2-yl)methyl)carbamate (7h).



The reaction was conducted according to general procedure B. Morpholinone **6h** (33.0 mg, 0.079 mmol). The reaction mixture was stirred at 40 ºC for 12 h. Flash column chromatography (SiO_2, 15→20% EtOAc in hexanes) afforded morpholinone **7h** (27.3 mg, 0.073 mmol, 92%) as a colorless oil. 99% ee, $[\alpha]_D^{25}$ +10.8 (*c* 0.93, $CHCl_3$); R_f = 0.43

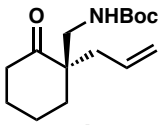
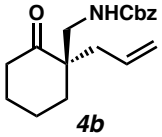
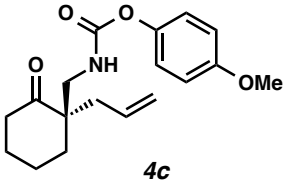
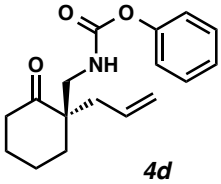
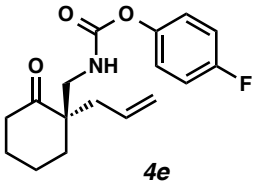
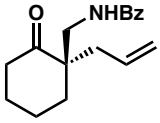
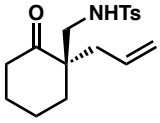
(33% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 – 7.48 (m, 3H), 7.43 – 7.38 (m, 2H), 5.89 (m, 1H), 5.23 – 5.17 (m, 2H), 4.88 (br s, 1H), 4.14 – 3.88 (m, 4H), 3.63 (m, 1H), 3.40 (dd, *J* = 14.1, 5.6 Hz, 1H), 2.69 (dd, *J* = 14.3, 7.4 Hz, 1H), 2.52 (dd, *J* = 14.3, 7.0 Hz, 1H), 1.44 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 173.0, 172.6, 155.9, 135.6, 132.1, 131.7, 128.3, 128.1, 119.9, 82.2, 79.9, 60.6, 46.0, 45.5, 40.0, 28.5; IR (Neat Film, NaCl) 3382, 2978, 1707, 1689, 1509, 1367, 1281, 1250, 1225, 1166, 1091 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{20}H_{26}N_2O_5Na$ $[M+Na]^+$: 397.1734, found 397.1728; SFC conditions: 3% MeOH, 2.5 mL/min, Chiralpak AS-H column, λ = 254 nm, t_R (min): major = 4.06, minor = 4.62.

(*S*)-*tert*-butyl ((3-allyl-4-oxo-9-tosyl-2,3,4,9-tetrahydro-1*H*-carbazol-3-yl)methyl)carbamate (7i).

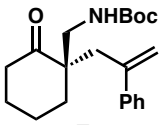
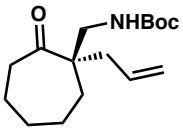
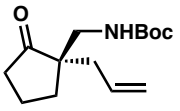
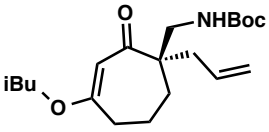
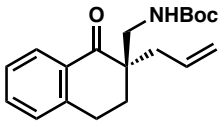
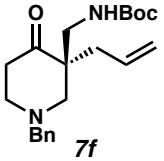
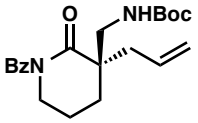
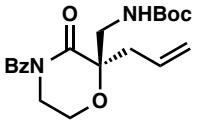
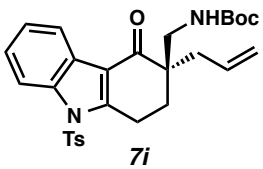


The reaction was conducted according to general procedure B. Keto ester **6i** (100 mg, 0.181 mmol); $[Pd_2(pmdba)_3]$ (10.0 mg, 0.009 mmol, 0.05 equiv). The reaction mixture was stirred at 40 ºC for 48 h. Flash column chromatography (SiO_2, 10% EtOAc in hexanes) afforded ketone **7i** (46.9 mg, 0.091 mmol, 51% yield) as a white foam.[10] 92% ee, $[\alpha]_D^{25}$ –13.3 (*c* 0.28, C_6H_6); R_f = 0.45 (25% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.20 (m, 1H), 8.16 (dd, *J* = 7.3, 1.8 Hz, 1H), 7.77 (d, *J* = 8.4 Hz, 2H), 7.41 – 7.31 (m, 2H), 7.28 (m, 2H), 5.77 (m, 1H), 5.11 (m, 1H), 5.08 (dd, *J* = 17.1, 1.8 Hz, 1H), 5.05 (br t, *J* = 6.7 Hz, 1H), 3.49 (dd, *J* = 13.9, 6.2 Hz, 1H), 3.44 (dt, *J* = 19.2, 4.8 Hz, 1H), 3.33 – 3.28 (m, 1H), 3.27 (dd, *J* = 13.9, 7.0 Hz, 1H), 2.38 (s, 3H), 2.32 – 2.28 (m, 2H), 2.16 – 2.11 (m, 2H), 1.40 (s, 9H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 199.1, 156.4, 150.1, 146.1, 136.4, 135.6, 132.9, 130.5, 126.8, 126.0, 125.6, 125.1, 121.9, 119.3, 116.6, 114.1, 79.4, 49.4, 44.6, 37.5, 29.5, 28.5, 21.8, 21.6; IR (Neat Film, NaCl) 3432, 3372, 3058, 2976, 2928, 1712, 1657, 1505, 1451, 1407, 1366, 1247, 1173 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{28}H_{33}N_2O_5S$ $[M+H]^+$: 509.2105, found 509.2094; SFC conditions: 15% IPA, 2.5 mL/min, Chiralcel OB-H column, λ = 210 nm, t_R (min): major = 7.21, minor = 5.19.

Determination of Enantiomeric Excess and Optical Rotation (Table S1)

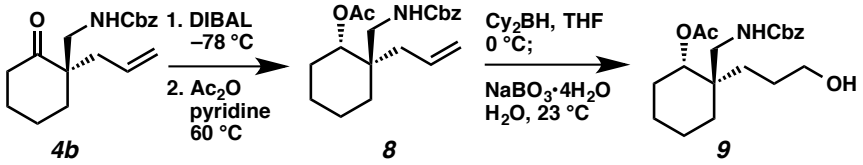
entry	compound	analytic conditions	ee (%)	polarimetry
1	 ***4a***	**SFC: 5% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 3.73, minor 4.30**	**86**	**$[\alpha]_D^{25}$ –25.5 (*c* 0.865, C_6H_6)**
2	 ***4b***	**SFC: 5% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 8.12, minor 9.06**	**86**	**$[\alpha]_D^{25}$ –38.6 (*c* 1.20, $CHCl_3$)**
3	 ***4c***	**SFC: 10% IPA, 2.5 mL/min Chiralcel OB-H, λ = 210 nm t_R (min): major 9.47, minor 11.13**	**83**	**$[\alpha]_D^{25}$ –29.3 (*c* 0.76, $CHCl_3$)**
4	 ***4d***	**SFC: 10% IPA, 2.5 mL/min Chiralcel OB-H, λ = 210 nm t_R (min): major 6.53, minor 8.13**	**77**	**$[\alpha]_D^{25}$ –28.9 (*c* 0.40, $CHCl_3$)**
5	 ***4e***	**SFC: 10% IPA, 2.5 mL/min Chiralpak AS-H, λ = 210 nm t_R (min): major 6.94, minor 8.24**	**77**	**$[\alpha]_D^{25}$ –27.4 (*c* 0.78, $CHCl_3$)**
6	 ***4f***	**SFC: 20% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 4.04, minor 4.91**	**56**	**Specific Rotation Not Determined**
7	 ***4g***	**SFC: 15% IPA, 2.5 mL/min Chiralcel OJ-H, λ = 210 nm t_R (min): major 3.14, minor 3.85**	**24**	**Specific Rotation Not Determined**

Determination of Enantiomeric Excess and Optical Rotation (Table S2)

entry	compound	analytic conditions	ee (%)	polarimetry
1	 ***7a***	**SFC: 15% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 2.46, minor 2.78**	**90**	**$[\alpha]_D^{25}$ –30.87 (*c* 4.45, $CHCl_3$)**
2	 ***7b***	**SFC: 5% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 4.25, minor 4.63**	**87**	**$[\alpha]_D^{25}$ –22.7 (*c* 0.85, $CHCl_3$)**
3	 ***7c***	**SFC: 5% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 2.97, minor 4.26**	**82**	**$[\alpha]_D^{25}$ –12.8 (*c* 0.96, $CHCl_3$)**
4	 ***7d***	**SFC: 3% IPA, 2.5 mL/min Chiralpak AS-H, λ = 254 nm t_R (min): major 4.41, minor 6.12**	**92**	**$[\alpha]_D^{25}$ –28.7 (*c* 0.65, $CHCl_3$)**
5	 ***7e***	**SFC: 15% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 2.48, minor 2.80**	**93**	**$[\alpha]_D^{25}$ –1.3 (*c* 1.32, $CHCl_3$)**
6	 ***7f***	**SFC: 8% IPA, 2.5 mL/min Chiralpak AD-H, λ = 210 nm t_R (min): major 4.94, minor 6.46**	**90**	**$[\alpha]_D^{25}$ –34.0 (*c* 1.58, $CHCl_3$)**
7	 ***7g***	**SFC: 10% MeOH, 3.0 mL/min Chiralpak AD-H, λ = 254 nm t_R (min): major 2.64, minor 3.12**	**90**	**$[\alpha]_D^{25}$ +33.6 (*c* 1.05, $CHCl_3$)**
8	 ***7h***	**SFC: 3% MeOH, 2.5 mL/min Chiralpak AS-H, λ = 254 nm t_R (min): major 4.06, minor 4.62**	**99**	**$[\alpha]_D^{25}$ +10.8 (*c* 0.93, $CHCl_3$)**
9	 ***7i***	**SFC: 15% IPA, 2.5 mL/min Chiralcel OB-H, λ = 210 nm t_R (min): major 7.21, minor 5.19**	**92**	**$[\alpha]_D^{25}$ –13.3 (*c* 0.28, C_6H_6)**

Total Synthesis of (–)-Isonitramine and (+)-Sibirinine

Synthesis of alcohol 9:



4b *8* *9*

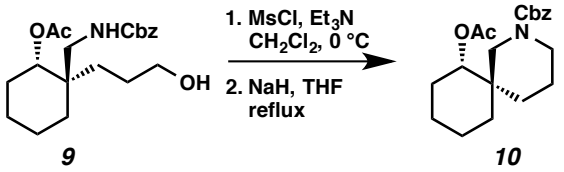
To a solution of enantioenriched ketone **4b** (851 mg, 2.82 mmol) in CH_2Cl_2 (14.2 mL) was added DIBAL (6.21 mL, 1.0 M solution in CH_2Cl_2, 6.21 mmol, 2.20 equiv) dropwise at –78 ºC. After stirring at –78 ºC for 15 min, the reaction mixture was quenched with saturated aqueous Rochelle's salt (20 mL) and stirred at 23 °C for 2 h. The phases were separated and the aqueous phase was extracted with CH_2Cl_2 (2 x 25 mL). The combined organic phases were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was used for the next reaction without further purification.

To a solution of the crude alcohol in Ac_2O (7.1 mL) was added pyridine (7.1 mL) at room temperature. After full consumption of the starting material was observed by TLC analysis, the reaction mixture was concentrated and azeotropically dried with toluene twice. The resulting residue was used in the next reaction without further purification.

To a flame-dried flask was added cyclohexene (1.43 mL, 14.1 mmol, 5.00 equiv), diethyl ether (10 mL), and BH_3•Me_2S (7.05 mL, 2.0 M solution in THF, 3.5 mmol, 1.24 equiv) at 0 ºC. The reaction mixture was stirred at 0 ºC for 3 h, then the solid was allowed to settle without stirring, and the supernatant was removed using a syringe. To the resulting solid was added THF (8.0 mL) and a solution of acetate **8** in THF (6.2 mL) at 0 ºC. After full consumption of acetate **8** by TLC analysis, the reaction mixture was quenched with $NaBO_3$ (3.25 g, 21.2 mmol, 7.52 equiv) and H_2O (14 mL) and stirred at room temperature for 1 h. The reaction mixture was diluted with EtOAc, the phases were separated, and the aqueous phase was extracted with EtOAc (2 x 25 mL). The combined organic phases were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Flash column chromatography (SiO_2, 30→50% EtOAc in hexanes) afforded alcohol **9** (886 mg, 86% yield, over 3 steps) as a colorless oil. $[\alpha]_D^{25}$ +7.5 (*c* 0.95, $CHCl_3$); R_f = 0.33 (50% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.39–7.28 (m, 5H), 5.35 (m, 1H),

5.14–5.02 (m, 2H), 4.77 (dd, *J* = 9.7, 4.5 Hz, 1H), 3.68–3.58 (m, 2H), 3.30 (dd, *J* = 14.3, 8.0 Hz, 1H), 2.88 (dd, *J* = 14.2, 5.5 Hz, 1H), 2.05 (s, 3H), 1.71–1.16 (m, 12H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 171.4, 157.1, 136.7, 128.6, 128.3, 128.2, 75.3, 66.9, 63.5, 45.5, 40.9, 30.0, 26.9, 26.0, 25.3, 23.9, 21.4, 20.4; IR (Neat Film, NaCl) 3385, 2937, 2866, 1718, 1528, 1455, 1374, 1247, 1026 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{20}H_{30}NO_5$ $[M+H]^+$: 364.2118, found 364.2109.

Synthesis of spiroamine 10:

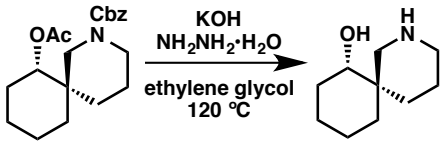


To a solution of primary alcohol **9** (865 mg, 2.38 mmol) in CH_2Cl_2 (12 mL) was added Et_3N (0.497 mL, 3.57 mmol, 1.50 equiv) and MsCl (0.203 mL, 2.63 mmol, 1.10 equiv) at 0 ºC. After full consumption of alcohol **9** was observed by TLC analysis, the reaction mixture was quenched with saturated aqueous $NaHCO_3$ (25 mL) and the phases were separated. The aqueous phase was extracted with CH_2Cl_2 (2 x 25 mL). The combined organic phases were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was used in the next reaction without further purification.

To a suspension of sodium hydride (114 mg, 60 wt% dispersion in mineral oil, 2.86 mmol) in THF (6 mL) was added a solution of the above methanesulfonate in THF (6 mL) at 0 ºC. The reaction mixture was stirred at reflux for 2 h. Upon cooling to 23 °C, the reaction mixture was quenched with saturated aqueous NH_4Cl (20 mL) and diluted with CH_2Cl_2 (20 mL). The phases were separated, and the aqueous phase was extracted with CH_2Cl_2 (3 x 25 mL). The combined organic phases were dried over Na_2SO_4, filtered, and concentrated under reduced pressure. Flash column chromatography (SiO_2, 15% EtOAc in hexanes) afforded spirocyclic carbamate **10** (732 mg, 89% yield, over 2 steps) as a colorless oil. $[\alpha]_D^{25}$ +46.8 (*c* 0.97, $CHCl_3$); R_f = 0.57 (33% EtOAc in hexanes); ^{1}H NMR (500 MHz, $CDCl_3$, mixture of rotamers) δ 7.39–7.26 (m, 5H), 5.20–5.01 (m, 2H), 4.86–4.61 (m, 1H), 3.96–2.91 (m, 4H), 2.05 (s, 3H), 1.87–1.00 (m, 12H); ^{13}C NMR (126 MHz, $CDCl_3$, mixture of rotamers) δ 170.6, 155.7, 137.0, 128.6, 128.1, 128.0, 75.2

(74.3), 67.2, 51.4 (50.7), 44.8, 37.0 (36.9), 30.6 (29.1), 30.2, 26.5, 22.4 (21.8), 21.3, 20.8 (20.7), 20.6 (20.5); IR (Neat Film, NaCl) 2938, 2861, 1732, 1699, 1434, 1242 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{20}H_{29}NO_4$ $[M+H]^+$: 346.2013, found 346.2016.

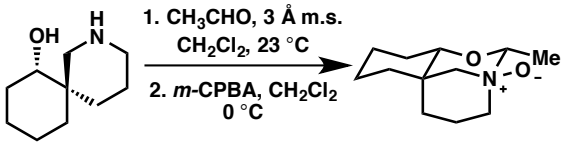
Synthesis of (–)-isonitramine (11):



(–)-isonitramine (11)

To a solution of spirocyclice carbamate **10** (712 mg, 2.06 mmol) in ethylene glycol (13 mL) was added KOH (3.00 g, 53.4 mmol, 25.92 equiv) and hydrazine hydrate (0.51 mL) at 23 °C. After stirring at 120 ºC for 1.5 h, the reaction mixture cooled to 23 °C and diluted with H_2O (100 mL). The aqueous phase was extracted with CH_2Cl_2 (200 mL) using a continuous liquid/liquid extractor and the organic phase was concentrated under reduced pressure. Flash column chromatography (SiO_2, $CHCl_3$:MeOH:NH_3(aq) = 46:50:4 eluent) afforded (–)-isonitramine (**11**) (270 mg, 77% yield) as a white solid. $[\alpha]_D^{25}$ –4.1 (*c* 0.96, $CHCl_3$); Lit: $[\alpha]_D^{20}$ –5.0 (*c* 2.1, $CHCl_3$)[12e]; R_f = 0.30 ($CHCl_3$:MeOH:NH_3 (aq) = 46:50:4); m.p. 86.9–88.8 ºC; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.66 (dd, *J* = 11.3, 3.7 Hz, 1H), 3.04 (m, 1H), 2.94 (m, 1H), 2.60 (ddd, *J* = 11.3, 11.3, 3.4 Hz, 1H), 2.52 (d, *J* = 11.3 Hz, 1H), 2.24 (m, 1H), 2.06 (m, 1H), 1.78–1.14 (m, 8H), 1.06 (ddd, *J* = 13.3, 13.3, 5.5 Hz, 1H), 0.96 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 80.7, 61.0, 47.4, 36.9, 36.3, 29.9, 29.0, 24.4, 23.3, 20.4; IR (Neat Film, NaCl) 3292, 2929, 2858, 1539, 1457, 1419, 1282, 1064 cm^{-1}; HRMS (ESI+) *m/z* calc'd for $C_{10}H_{20}NO$ $[M+H]^+$: 170.1539, found 170.1541.

Synthesis of (+)-sibirinine (12):



(–)-isonitramine (11) ***(+)-sibirinine (12)***

An oven-dried 1-dram vial was charged with a magnetic stirring bar, **11** (20 mg, 0.118 mmol), powdered 3 Å molecular sieves (40 mg), and CH_2Cl_2 (1.5 mL). To this stirring

suspension was added acetaldehyde (0.133 mL, 2.36 mmol, 20.0 equiv). The vial was sealed with a teflon cap, and the reaction was stirred at 23 °C for 30 h. The reaction mixture was then filtered through celite, washing with CH_2Cl_2. The filtrate was concentrated under reduced pressure to yield a pale yellow oil, which was used in the subsequent reaction without further purification.

The above crude hemiaminal was dissolved in CH_2Cl_2 (1.2 mL) and cooled to 0 °C (water/ice bath). To this stirring solution was added *m*-CPBA (29 mg, 0.13 mmol) in one portion. After 15 min, full consumption of starting material was observed by TLC analysis. The reaction mixture was filtered through celite, washing with CH_2Cl_2, and concentrated under reduced pressure. Flash column chromatography (SiO_2, CH_2Cl_2: NH_3 (7N solution in MeOH) = 92:8 eluent) afforded (+)-sibirinine (**12**) (22.9 mg, 92% yield, over 2 steps) as a colorless oil. $[\alpha]_D^{25}$ +10.3 (*c* 0.56, $CHCl_3$); R_f = 0.40 (CH_2Cl_2: NH_3 (7N solution in MeOH) = 9:1); ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.50 (qd, *J* = 5.8, 1.5 Hz, 1H), 3.73 (dd, *J* = 13.4, 7.1 Hz, 1H), 3.53 (ddd, *J* = 12.0, 4.1, 1.5 Hz, 1H), 3.21 (d, *J* = 12.2 Hz, 1H), 3.11 (dt, *J* = 12.2, 2.5 Hz, 1H), 3.03 (dddd, *J* = 14.7, 13.4, 5.5, 1.6 Hz, 1H), 2.45 (tdt, *J* = 14.4, 13.5, 5.9 Hz, 1H), 2.32 (dd, *J* = 14.1, 5.8 Hz, 1H), 1.87 (dtd, *J* = 13.1, 3.8, 1.7 Hz, 1H), 1.79 (dq, *J* = 12.3, 3.6 Hz, 1H), 1.65 (d, *J* = 5.8 Hz, 3H), 1.64 – 1.60 (m, 1H), 1.57 – 1.46 (m, 2H), 1.46 (dt, *J* = 13.0, 4.0 Hz, 1H), 1.41 – 1.31 (m, 2H), 1.23 (m, 1H), 1.17 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ 102.2, 84.4, 77.8, 62.5, 38.2, 34.7, 27.0, 26.3, 24.7, 21.2, 19.6, 14.6; IR (Neat Film, NaCl) 2934, 2854, 1466, 1446, 1367, 1138, 1120, 1103, 961, 940 cm^{-1}; HRMS (ESI/APCI) *m/z* calc'd for $C_{12}H_{22}NO_2$ $[M+H]^+$: 212.1645, found 212.1640.

Comparison of Synthetic Material to Published Data

As detailed above, we found that hemiaminal formation and subsequent *N*-oxidation of (–)-isonitramine furnished (+)-sibirinine. This finding is in contrast to a previous report, where (–)-sibirinine was obtained in a similar sequence from (–)-isonitramine.[11] Given that the optical rotation of our synthesized (–)-isonitramine matches those found in previously reported syntheses,[12] and that the optical rotation reported in the isolation

paper of (–)-isonitramine[13] has been refuted,[12e] the optical rotation values reported in the isolation of sibirinine[11] should be regarded as incorrect.

Limited spectral data were available for sibirinine (**12**) in the isolation paper.[11] Full ^{13}C NMR, partial ^{1}H NMR, optical rotation, and HRMS data were reported. Comparisons between data obtained from the synthetic material and data available in the literature are detailed in the following table.

Comparison of Synthetic and Natural Sibirinine (Table S3)

Synthetic (+)-sibirinine	**Natural**[11]
^{1}H NMR (500 MHz, $CDCl_3$)	*^{1}H NMR ($CDCl_3$)*
4.50 (qd, *J* = 5.8, 1.5 Hz, 1H)	4.58 (qd, *J* = 5.7, 1.2 Hz, 1H)
3.21 (d, *J* = 12.2 Hz, 1H)	3.31 (d, *J* = 12 Hz, 1H)
3.11 (dt, *J* = 12.2, 2.5 Hz, 1H)	3.17 (dd, *J* = 12, 2.3 Hz, 1H)
1.65 (d, *J* = 5.8 Hz, 3H)	1.65 (d, *J* = 5.7 Hz, 3H)
^{13}C NMR (126 MHz, $CDCl_3$)	*^{13}C NMR ($CDCl_3$)*
102.2	101.9
84.4	84.3
77.8	77.1
62.5	62.0
38.2	38.1
34.7	34.5
27.0	26.8
26.3	26.1
24.7	24.6
21.2	21.0
19.6	19.0
14.6	14.4

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[10] The carbazolone allylic alkylation product decomposes in chloroform after approximately 30 minutes. The resulting impurity was not isolated or identified.

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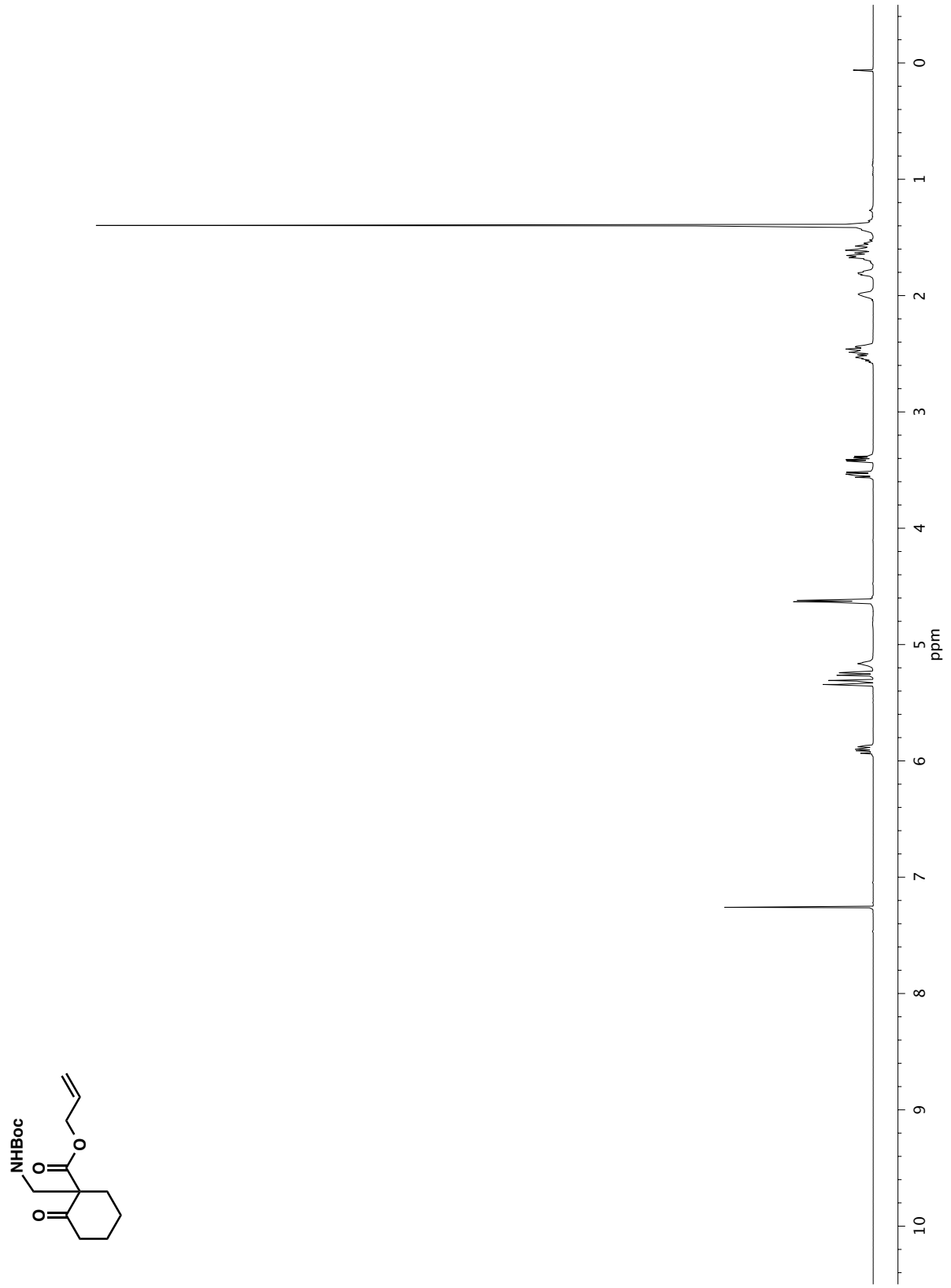
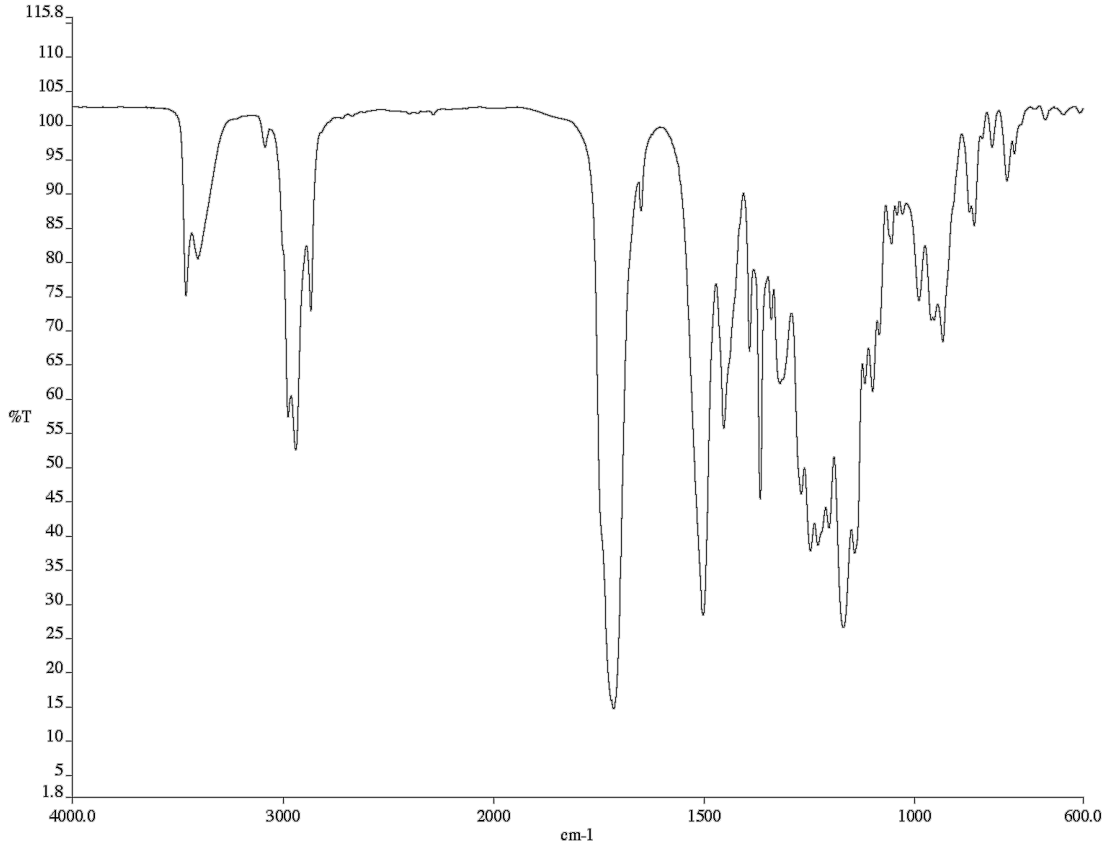
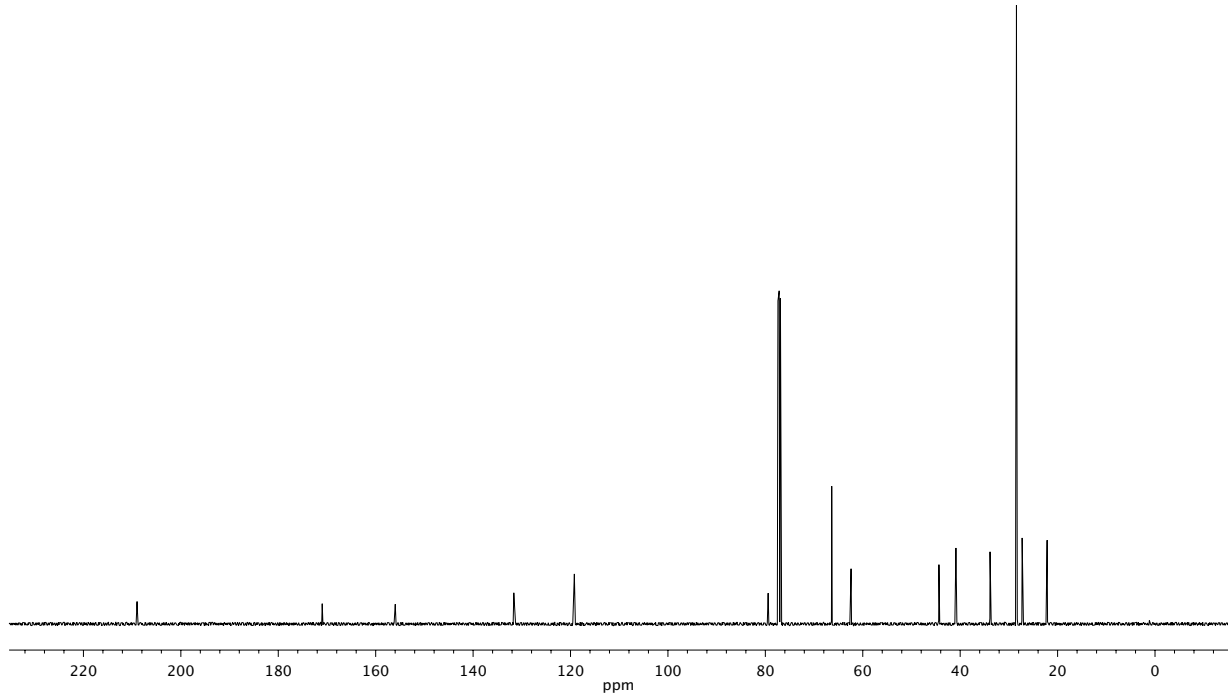


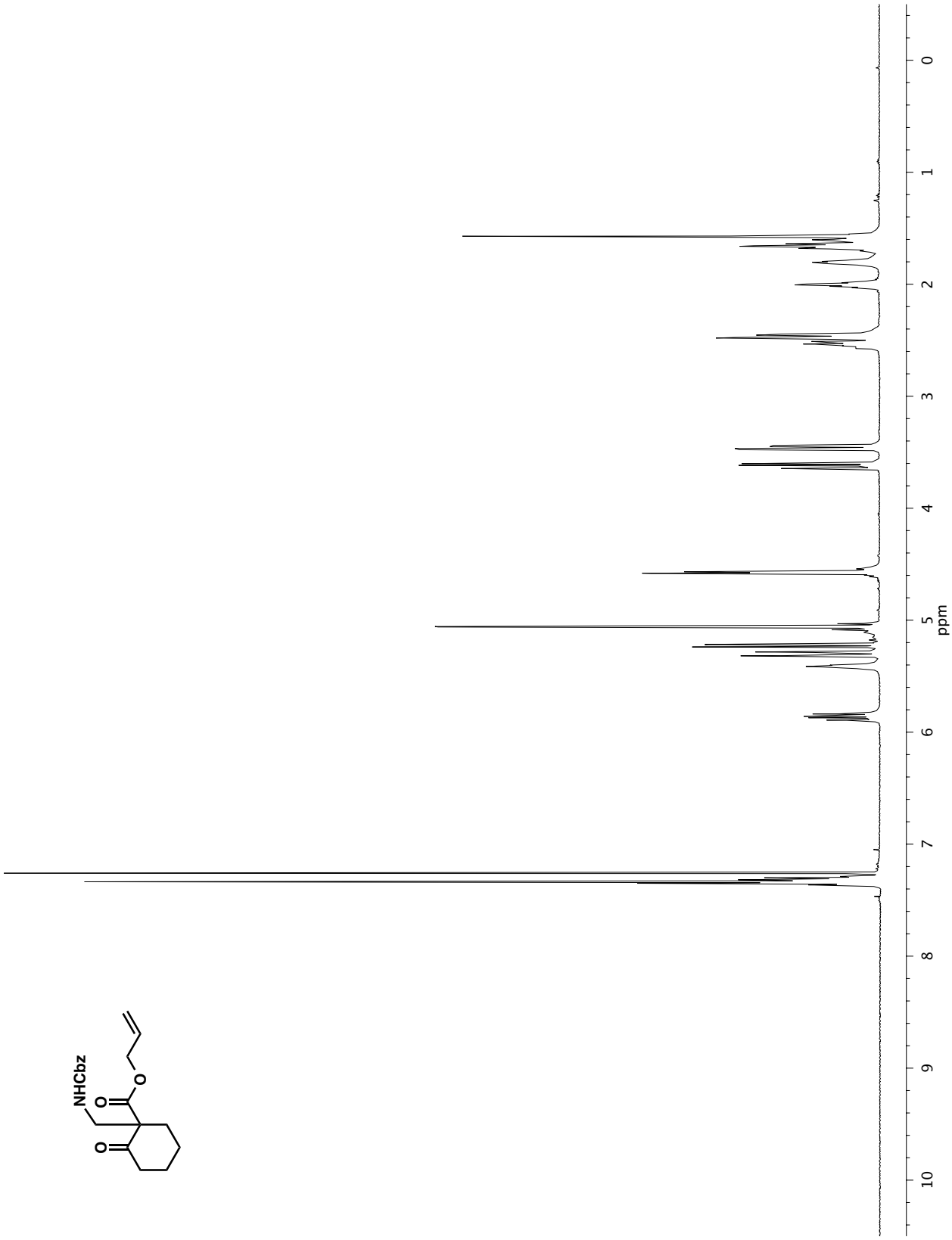
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3a**.



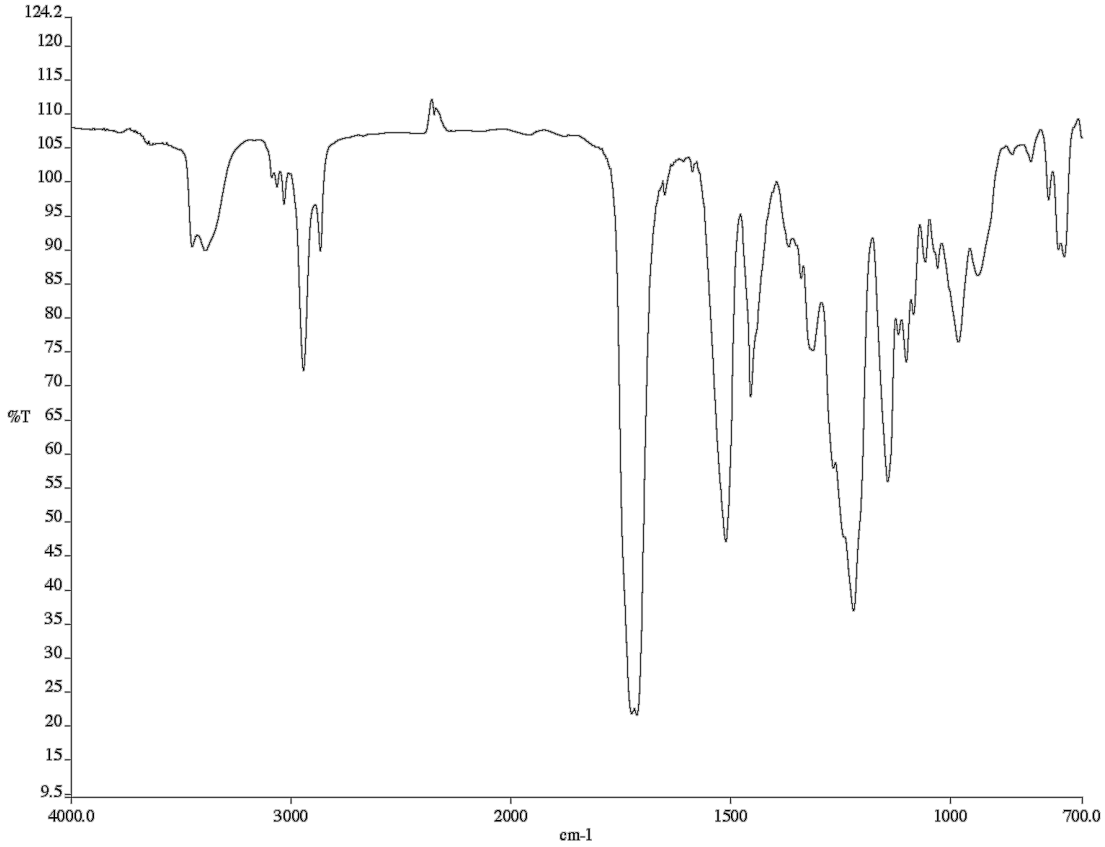
Infrared spectrum (Thin Film, NaCl) of compound **3a**.



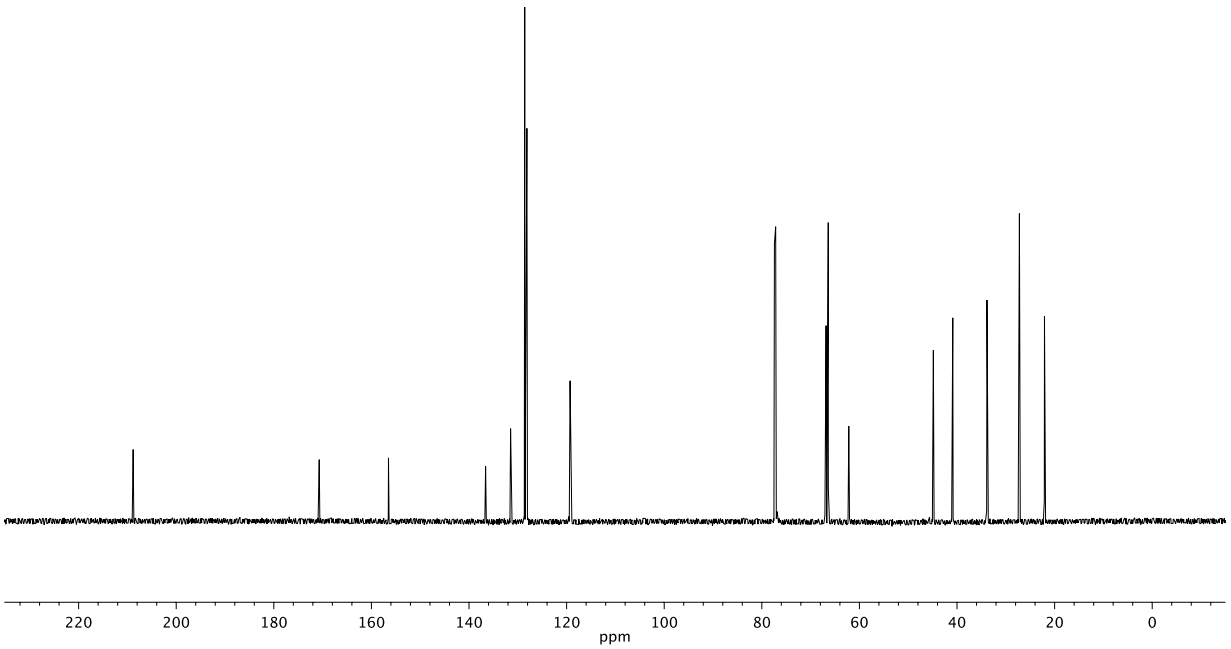
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3a**.



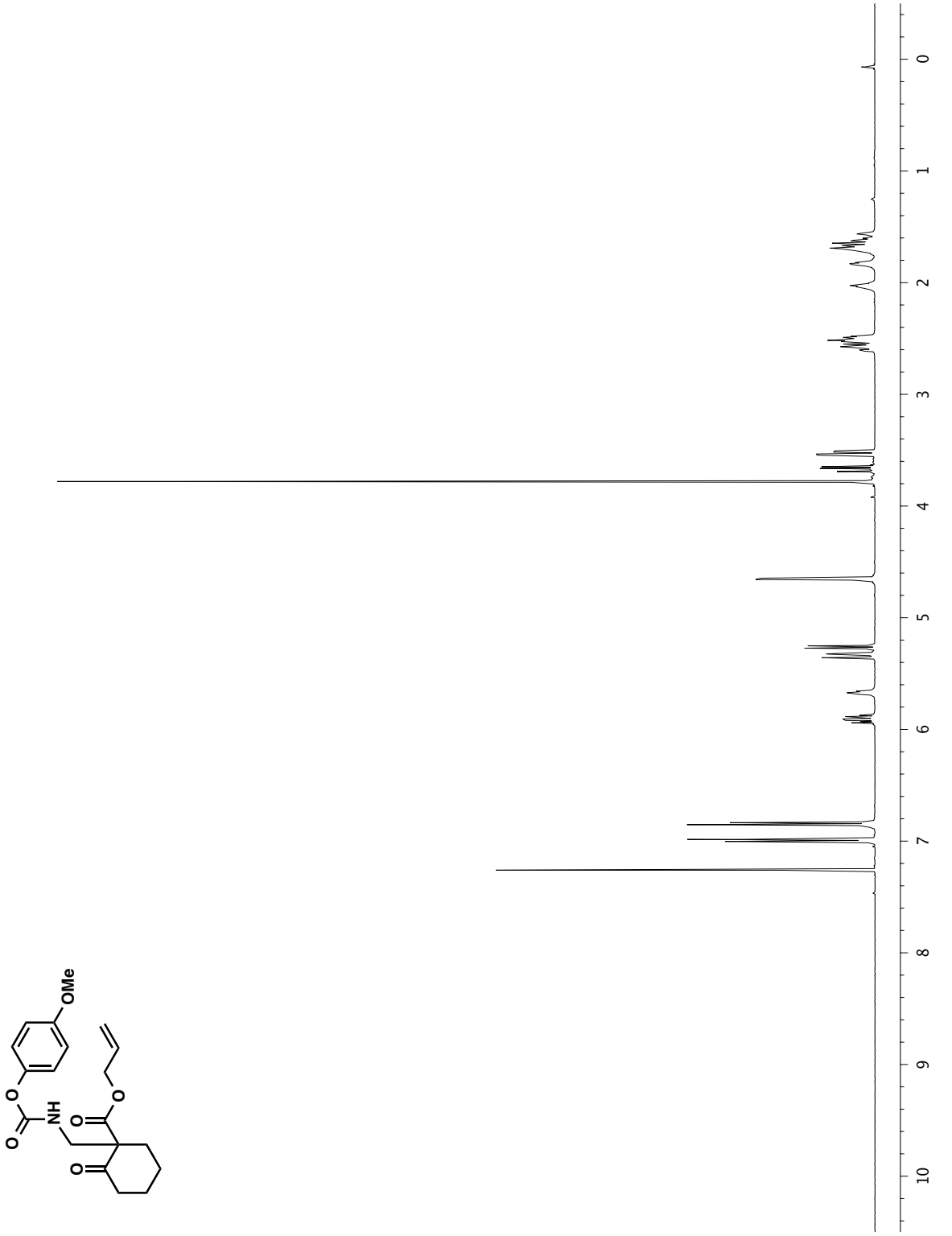
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3b**.



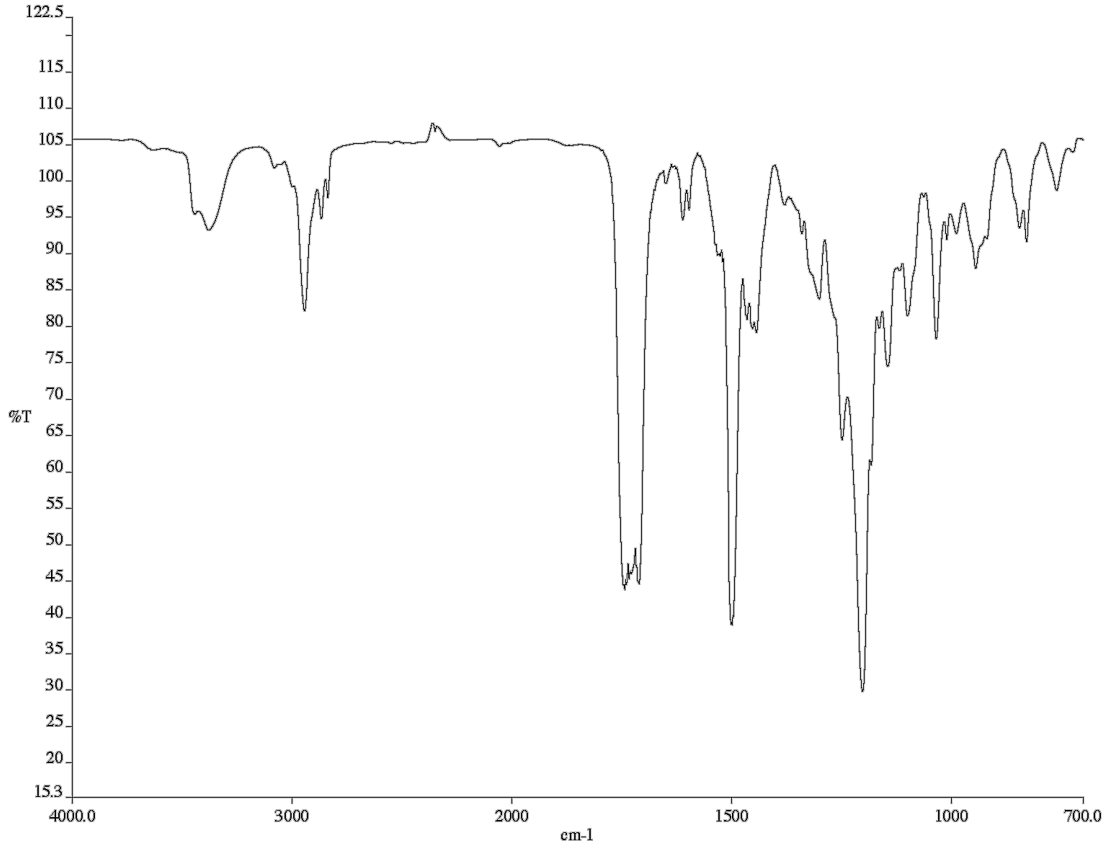
Infrared spectrum (Thin Film, NaCl) of compound **3b**.



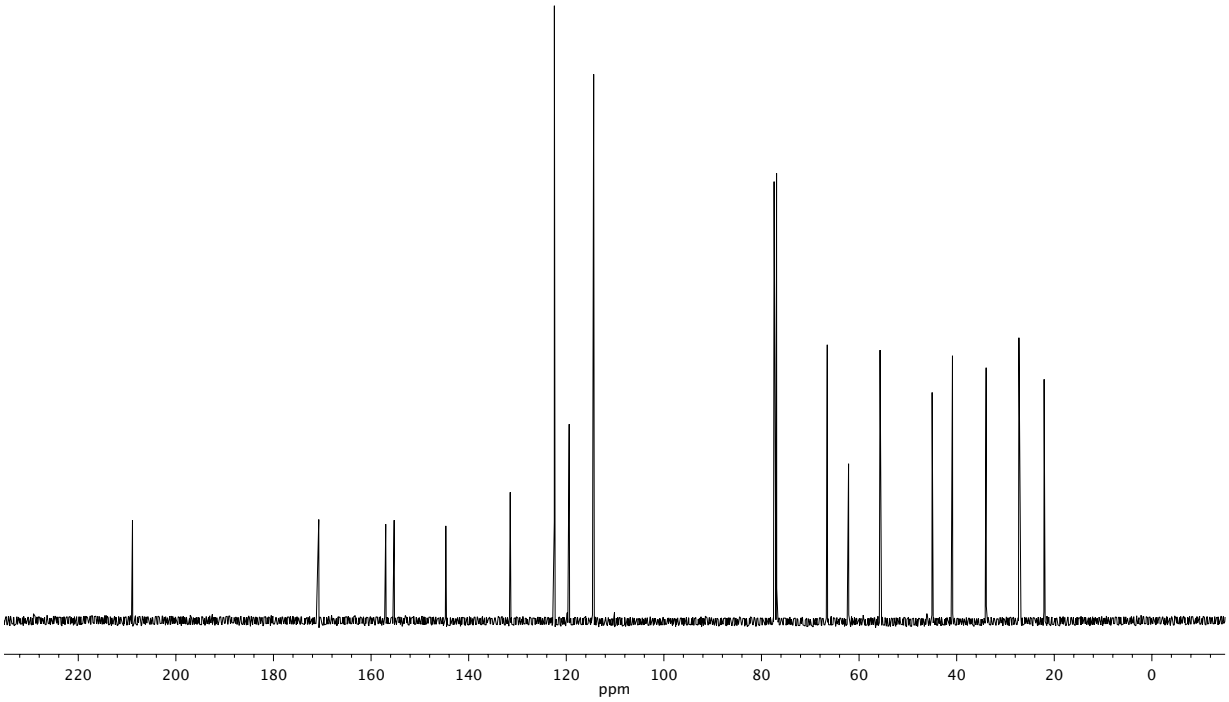
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3b**.



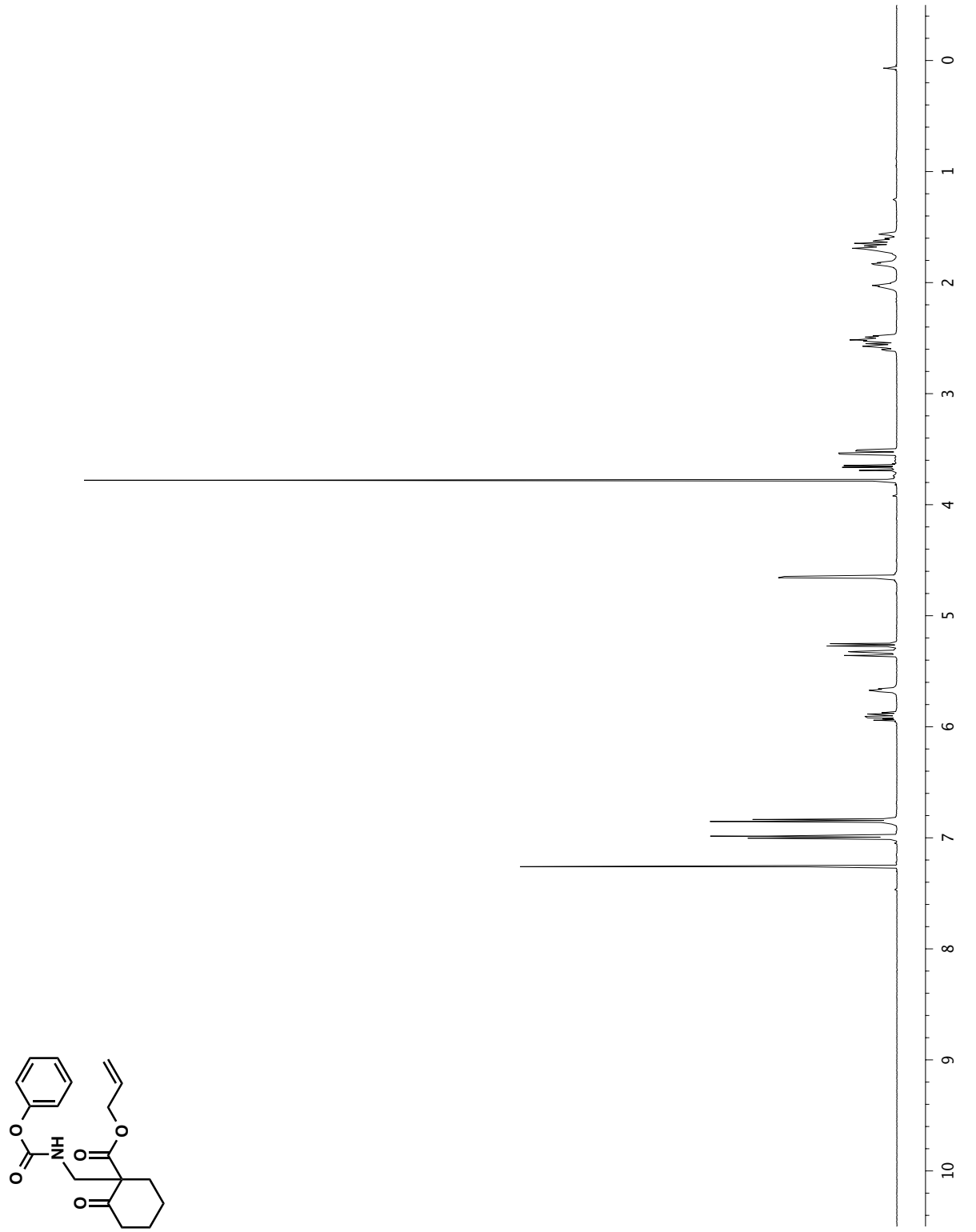
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3c.**



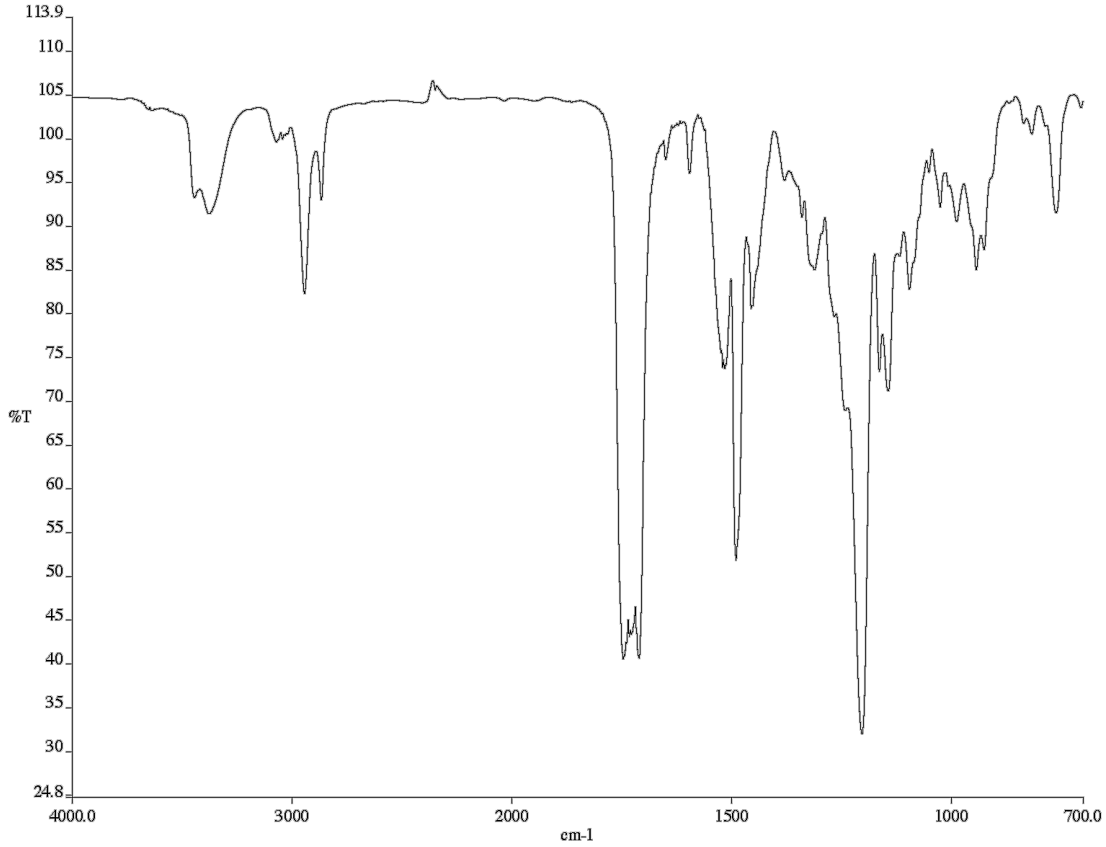
Infrared spectrum (Thin Film, NaCl) of compound **3c**.



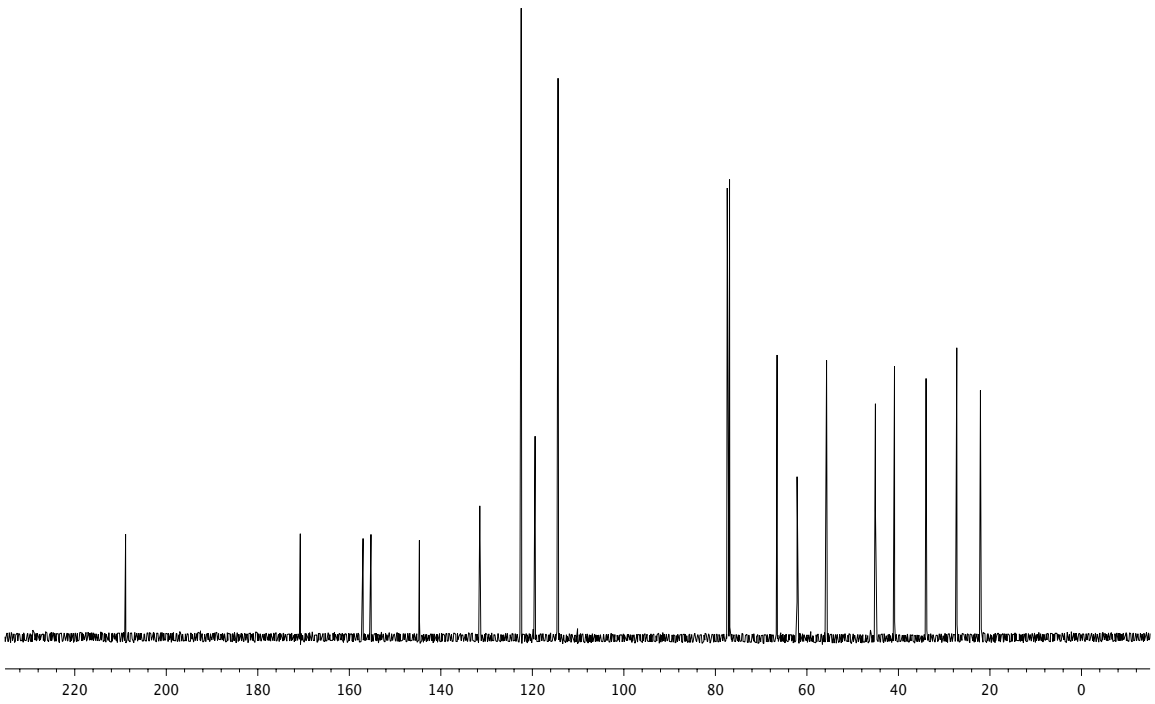
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3c**.



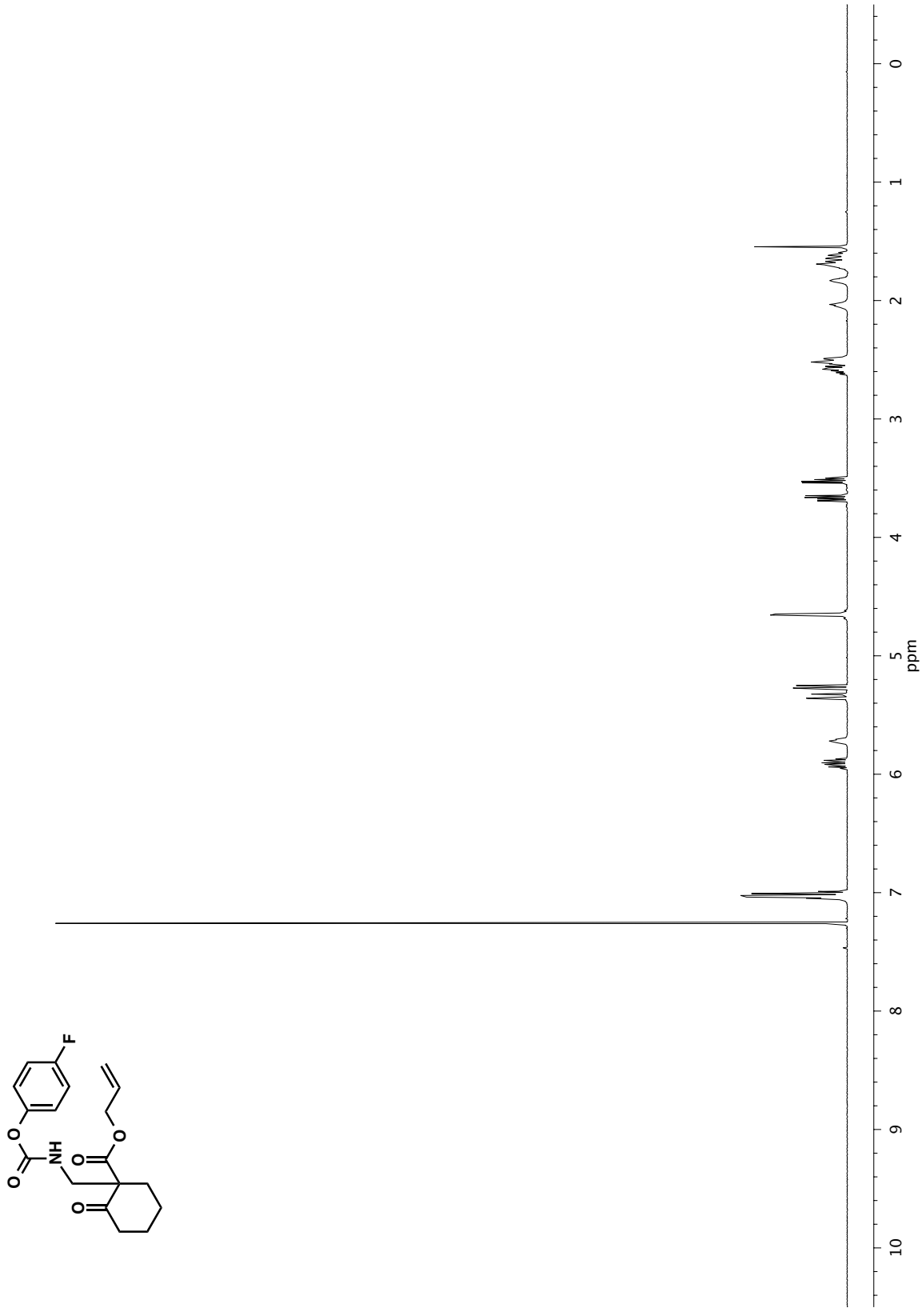
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3d**.



Infrared spectrum (Thin Film, NaCl) of compound **3d**.



^{13}C NMR (126 MHz, $CDCl_3$) of compound **3d**.



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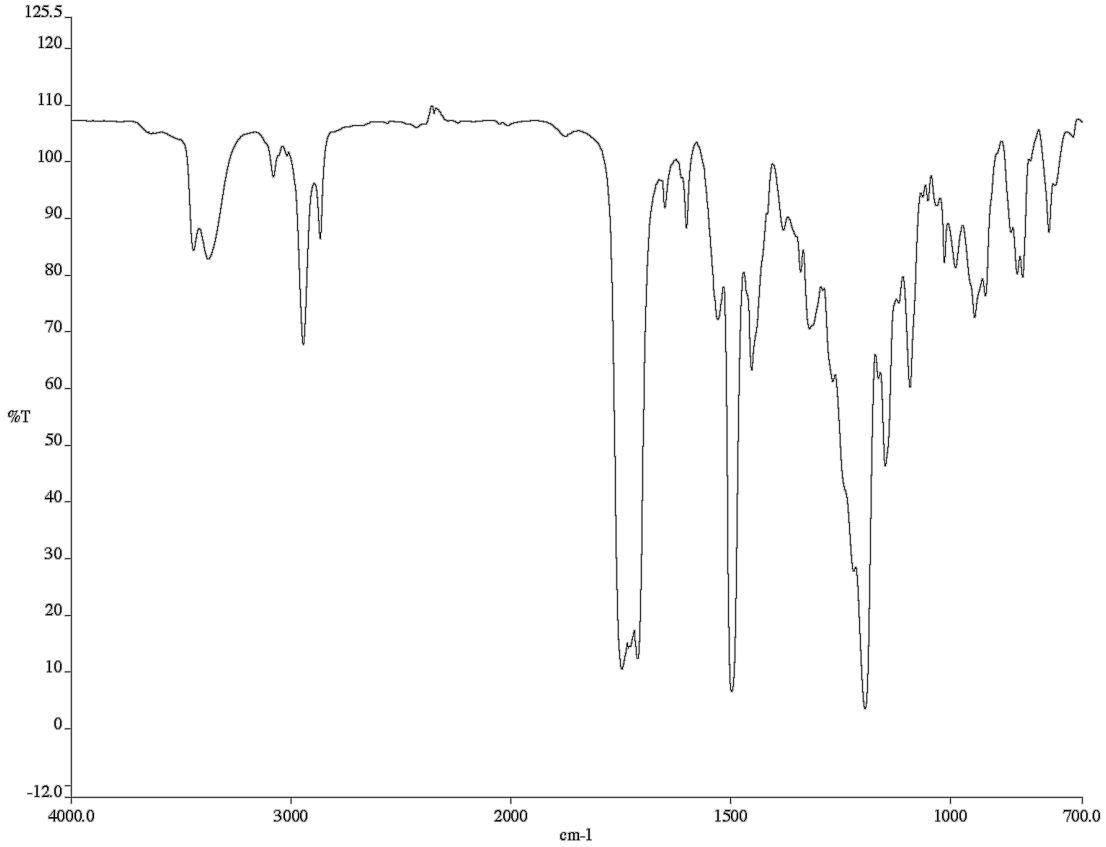
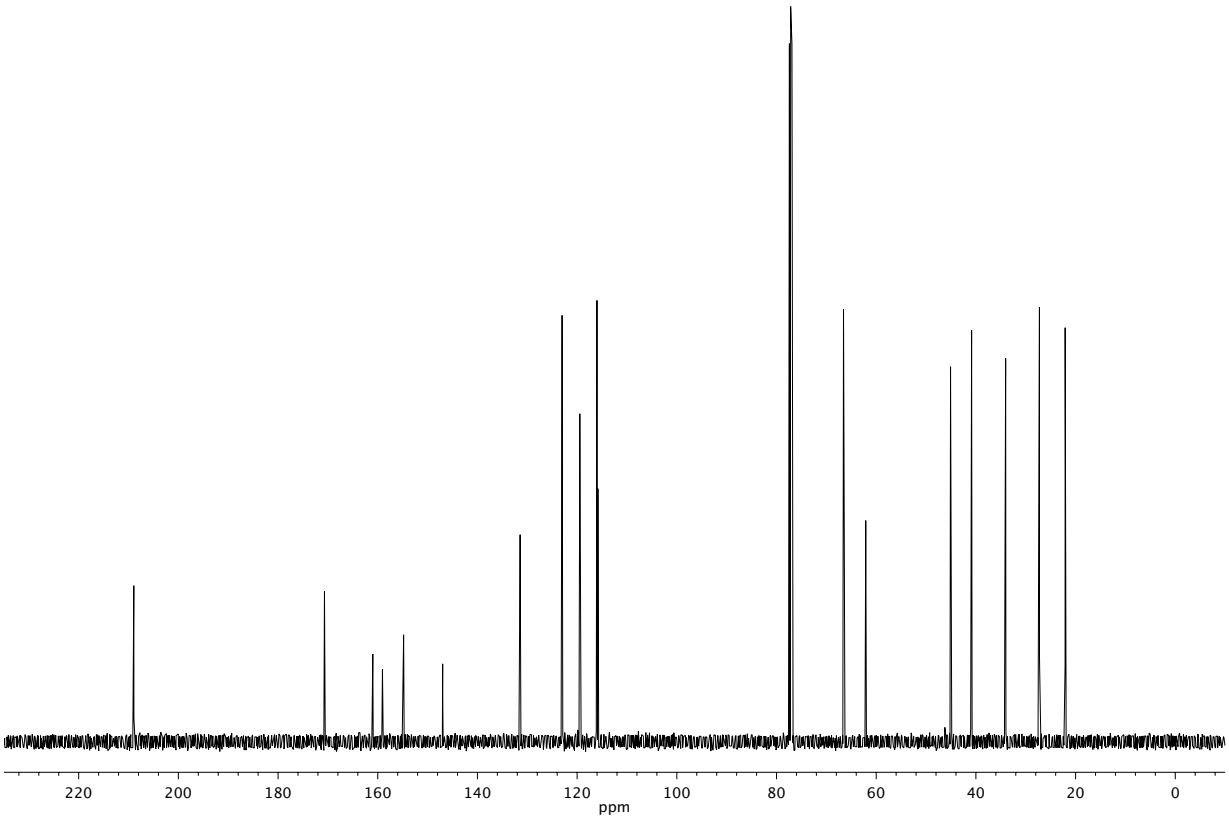


Infrared spectrum (Thin Film, NaCl) of compound **3e**.



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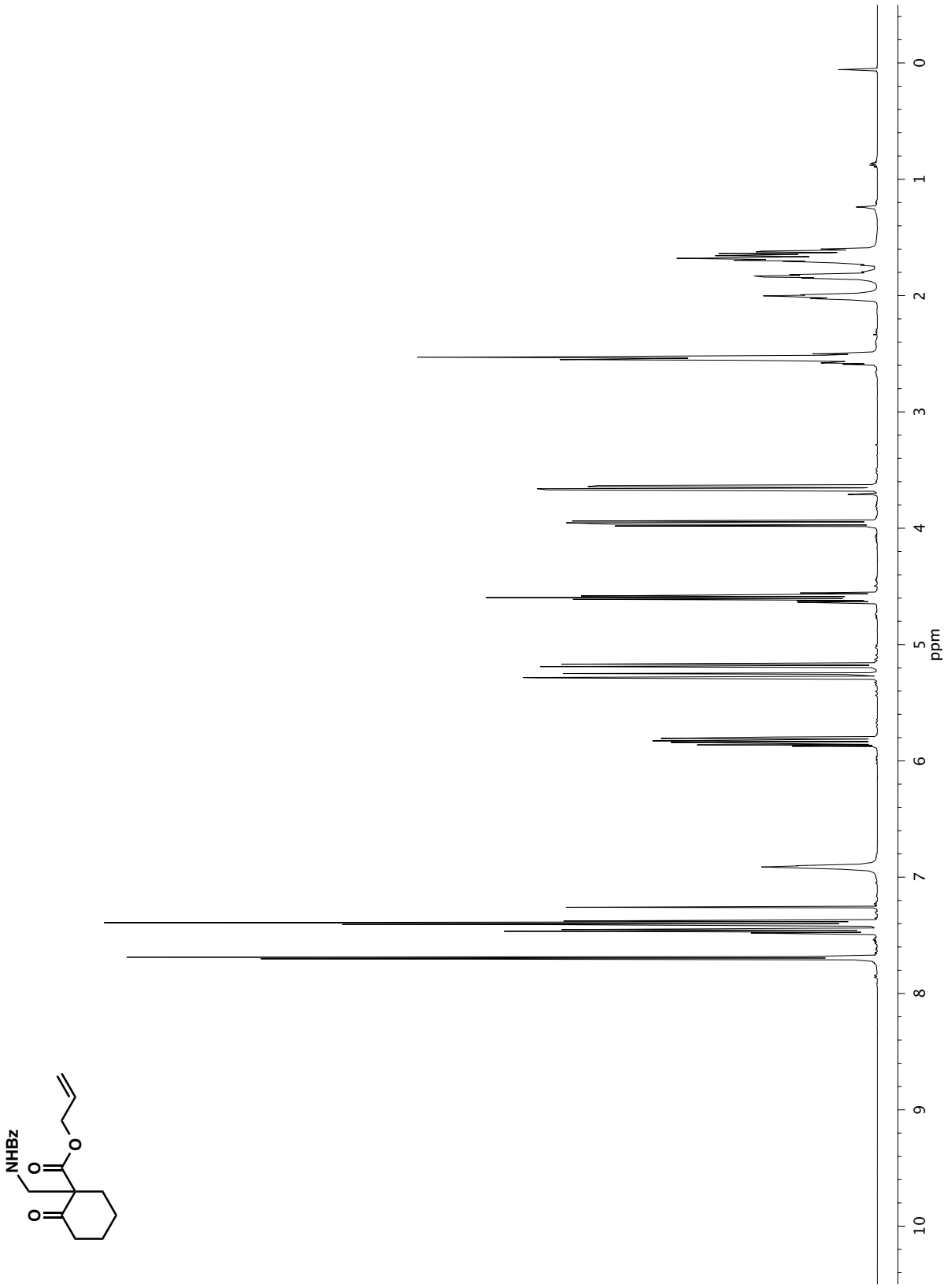
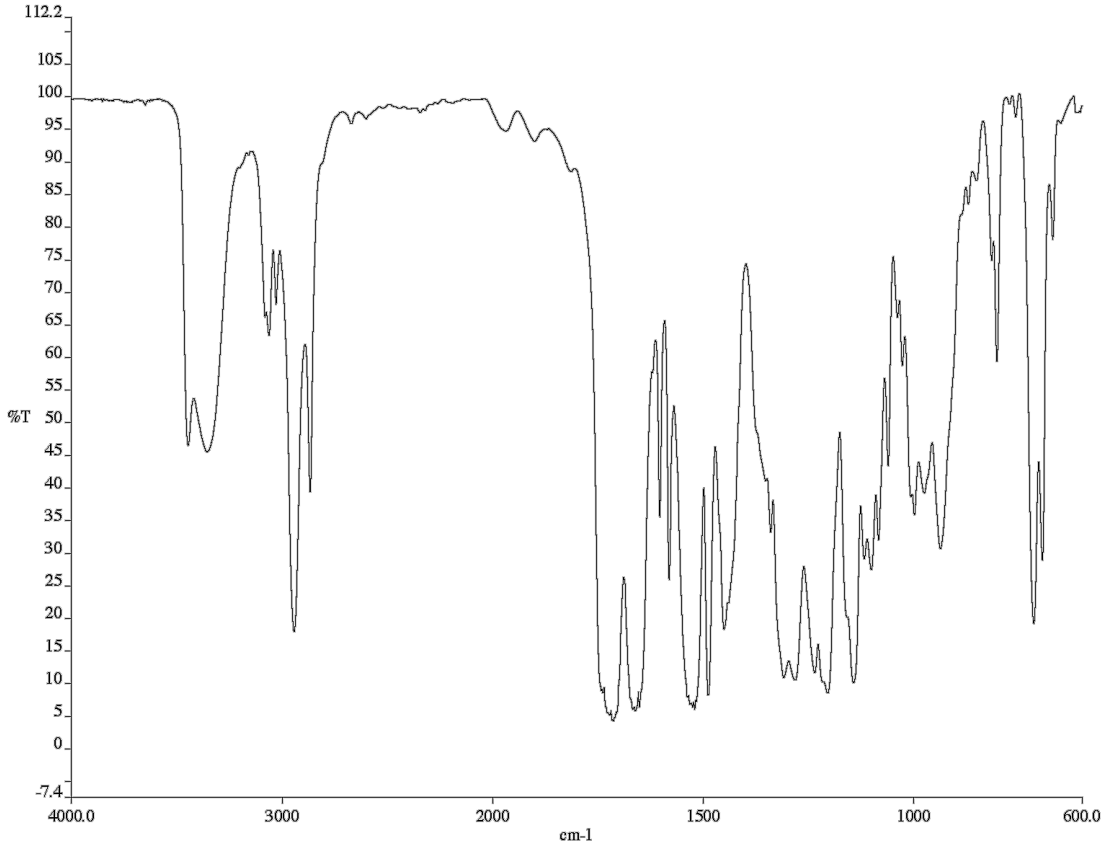
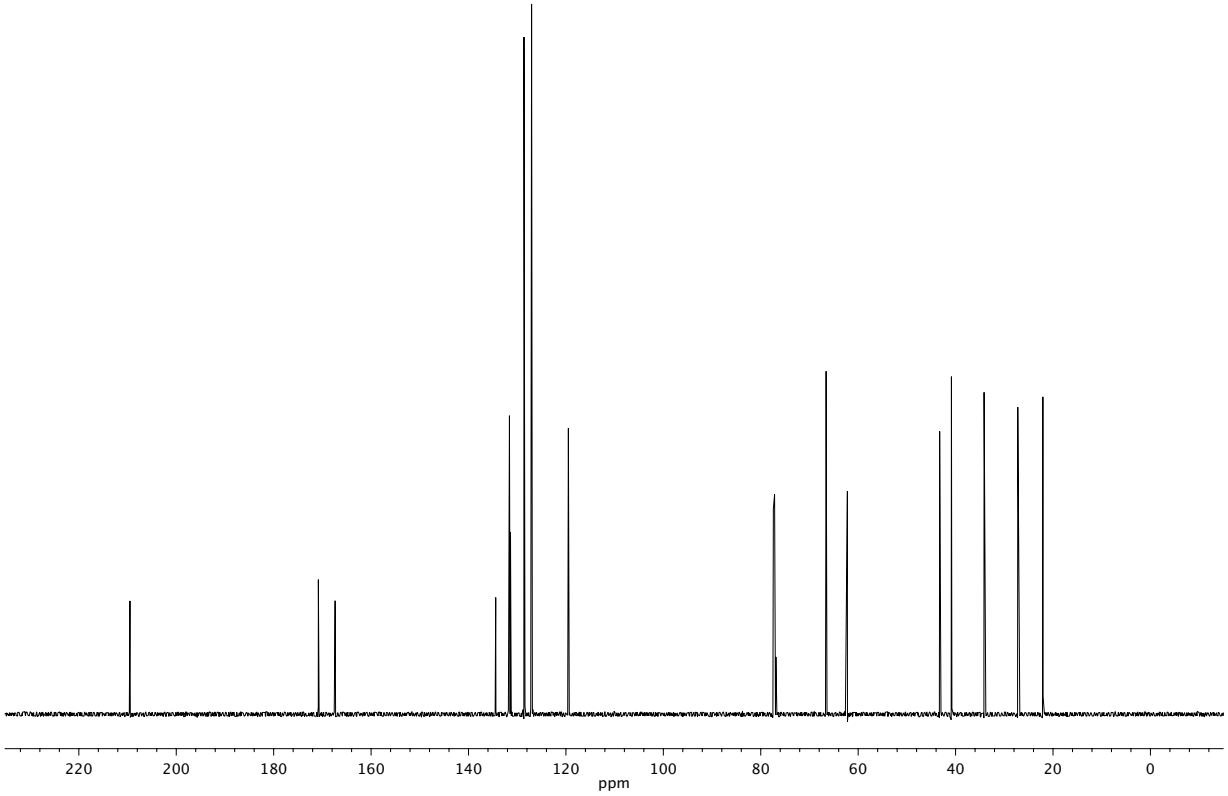


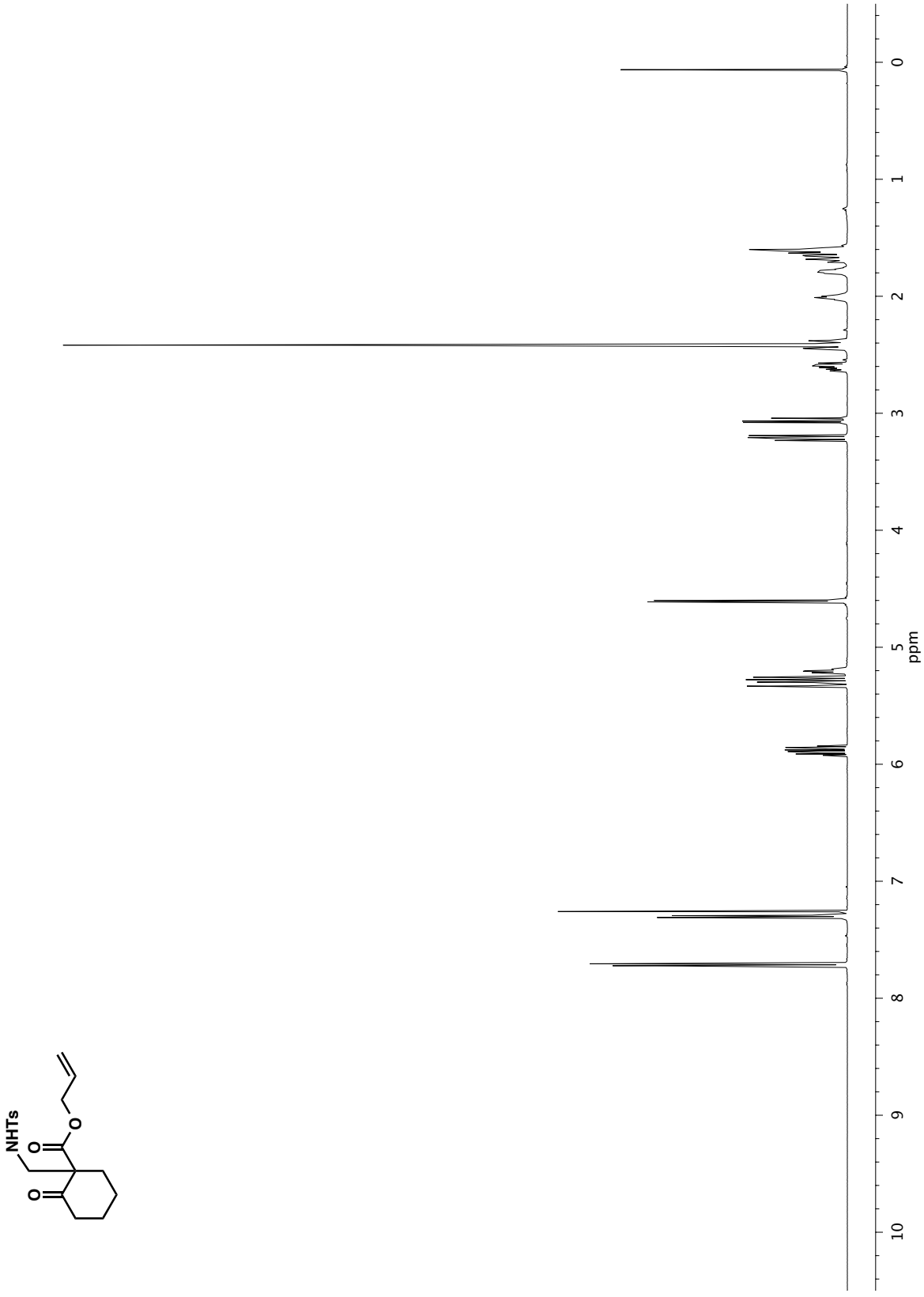
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3f**.



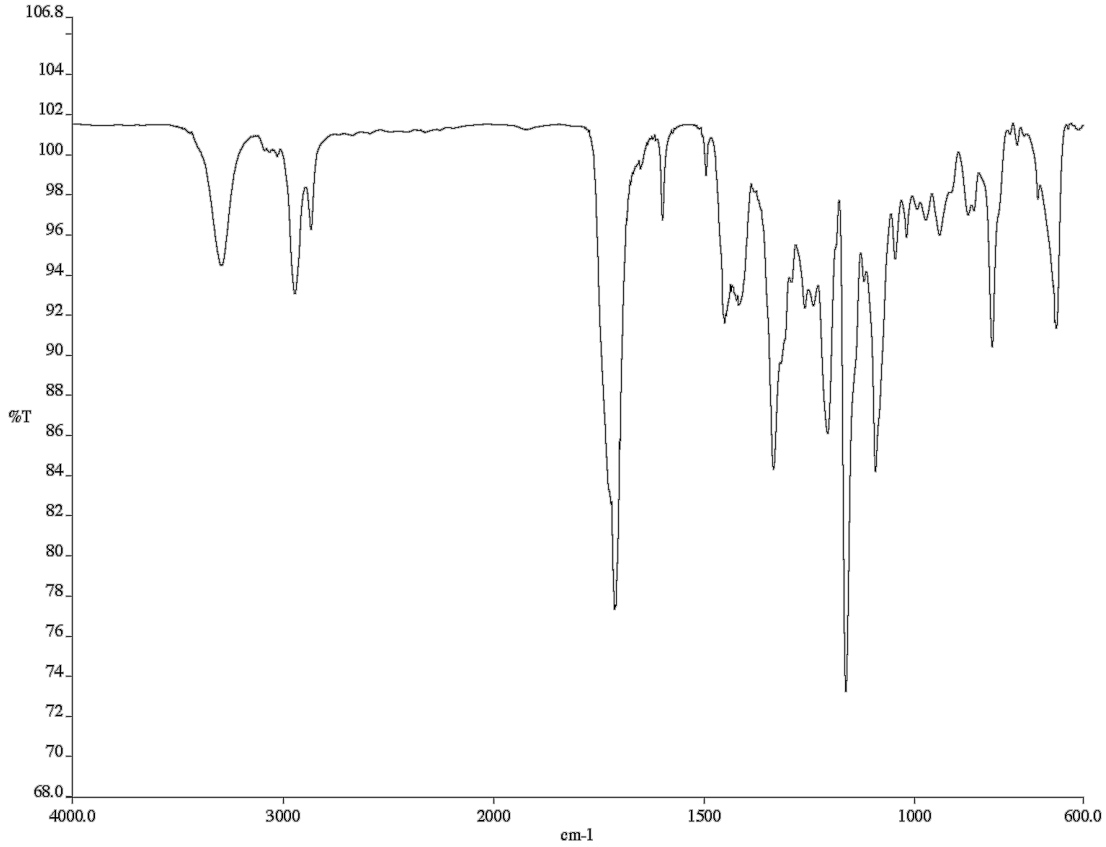
Infrared spectrum (Thin Film, NaCl) of compound **3f**.



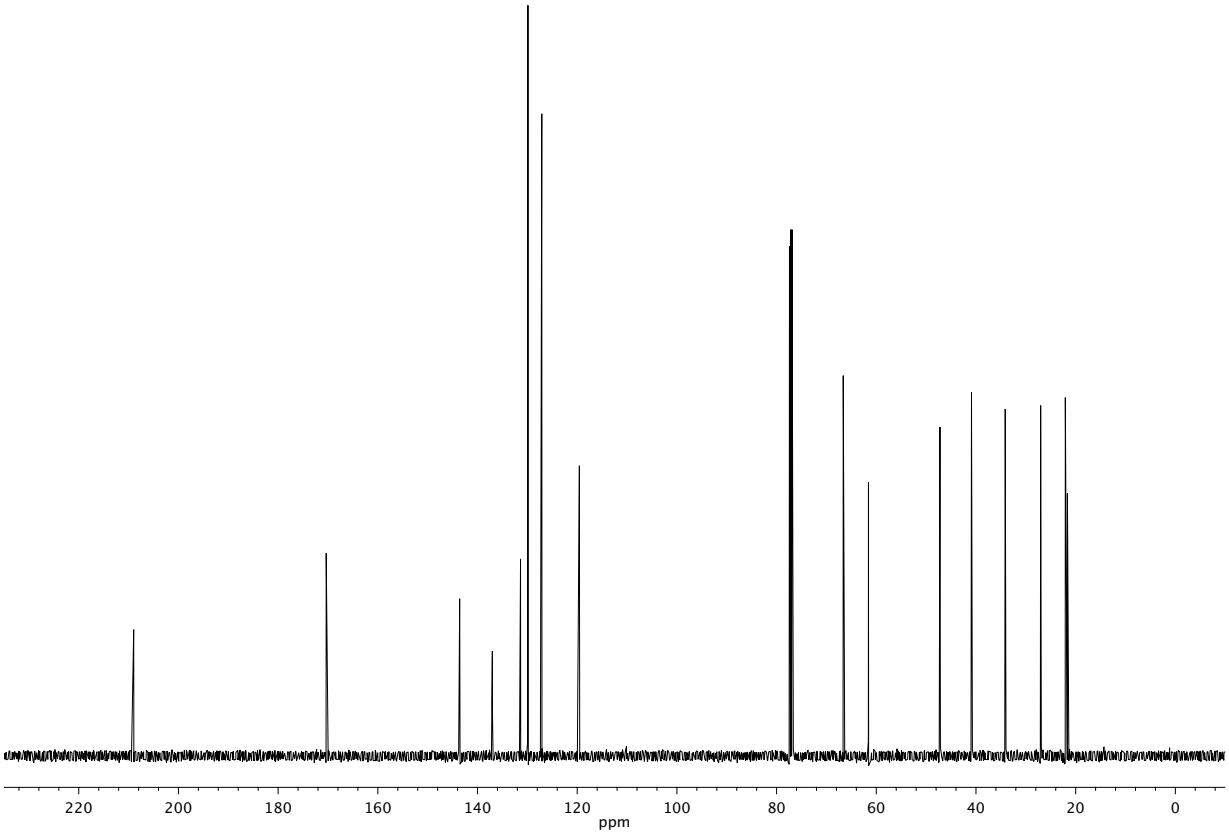
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3f**.



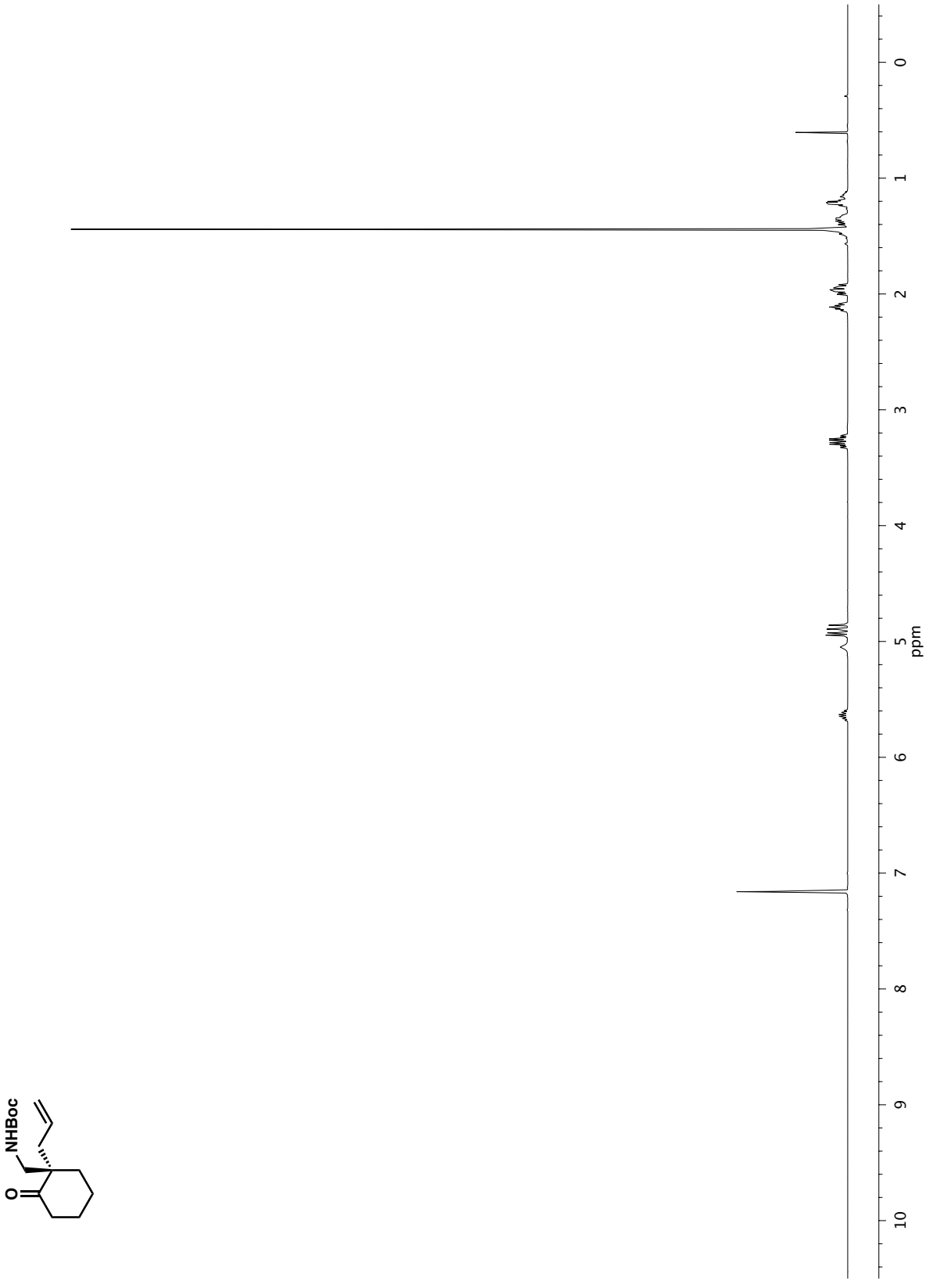
^{1}H NMR (500 MHz, $CDCl_3$) of compound **3g**.



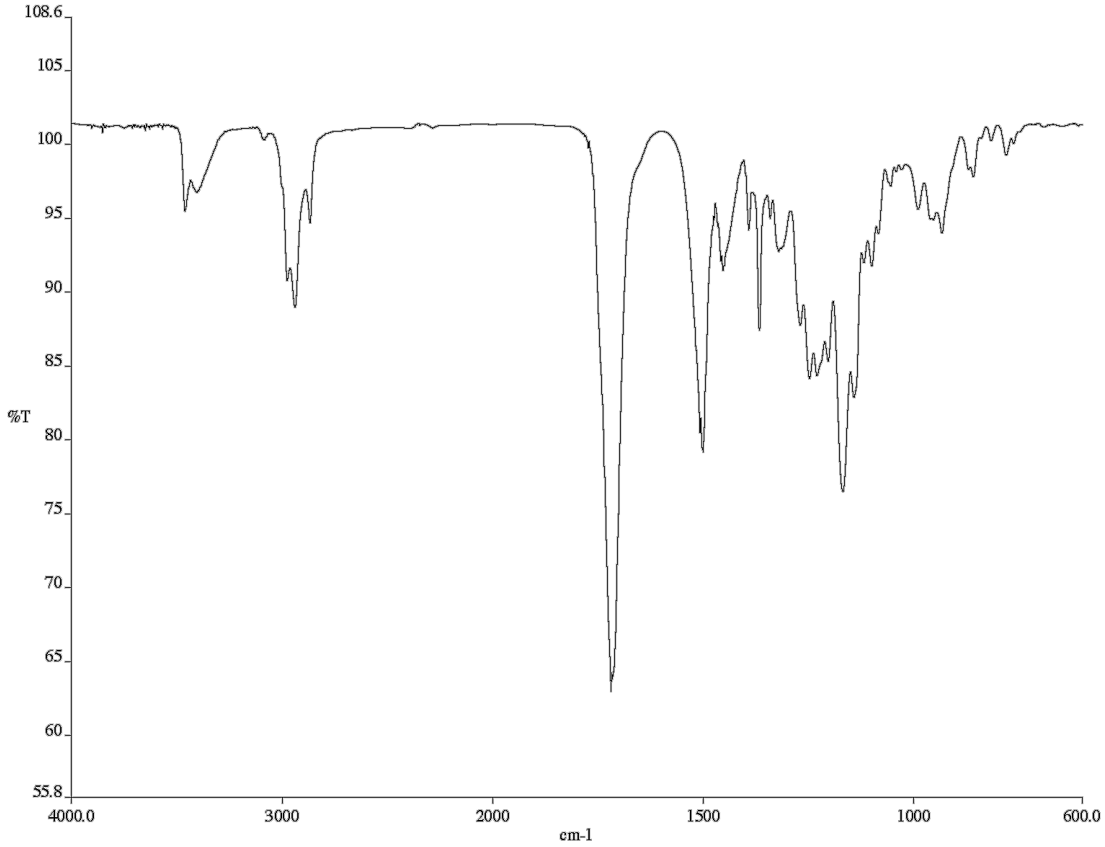
Infrared spectrum (Thin Film, NaCl) of compound **3g**.



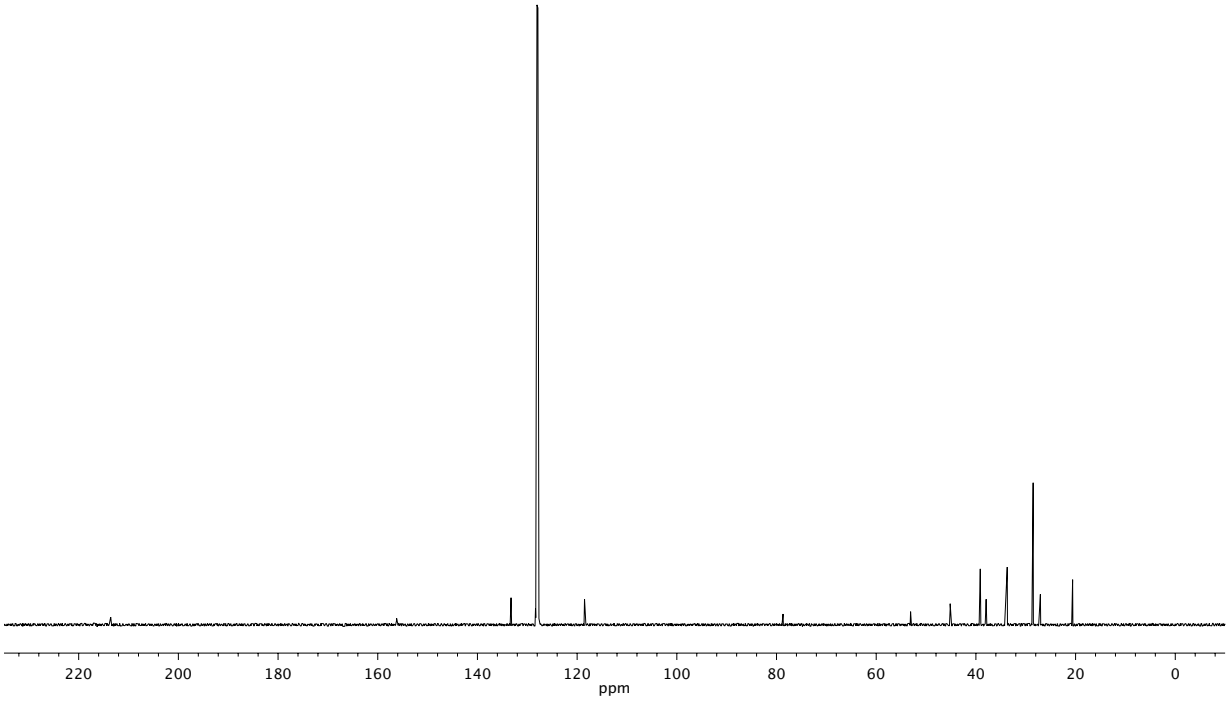
^{13}C NMR (126 MHz, $CDCl_3$) of compound **3g**.



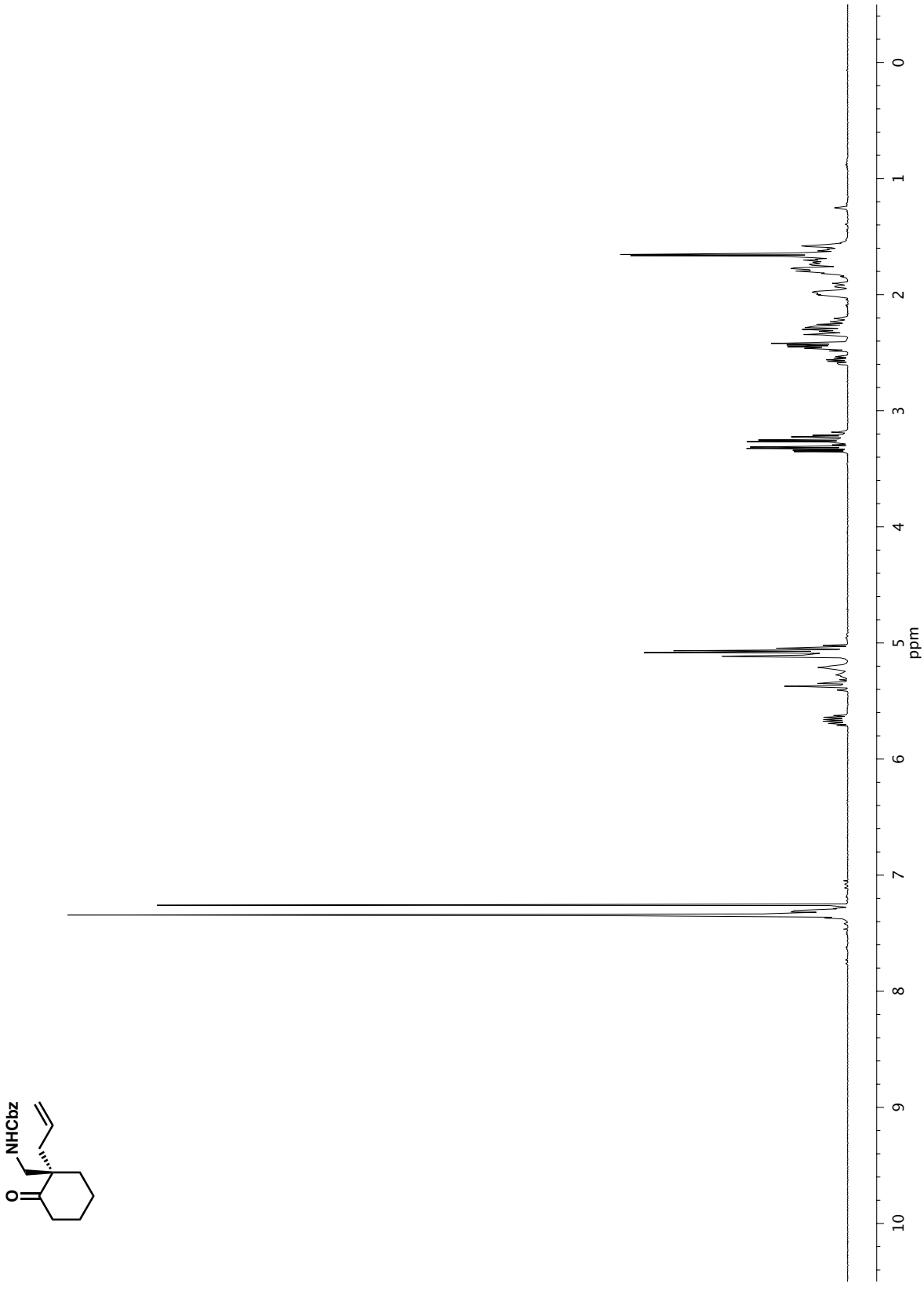
^{1}H NMR (500 MHz, C_6D_6) of compound **4a**.



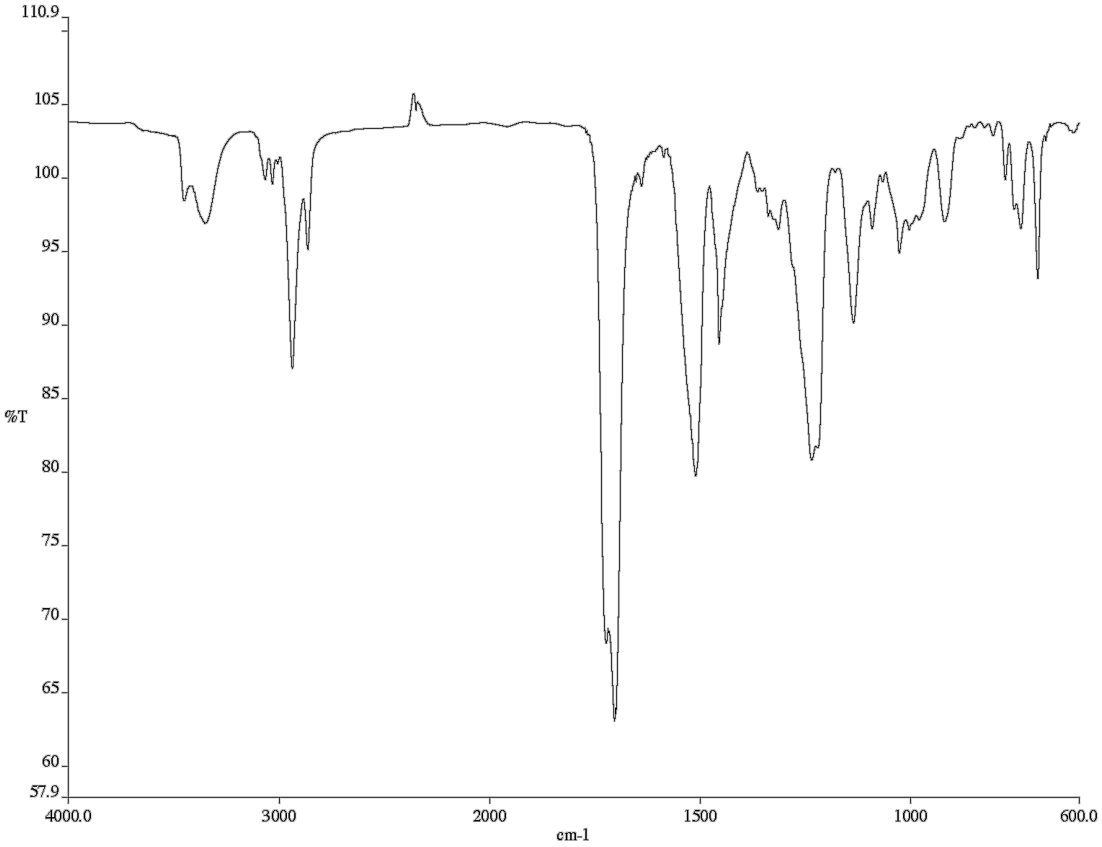
Infrared spectrum (Thin Film, NaCl) of compound **4a.**



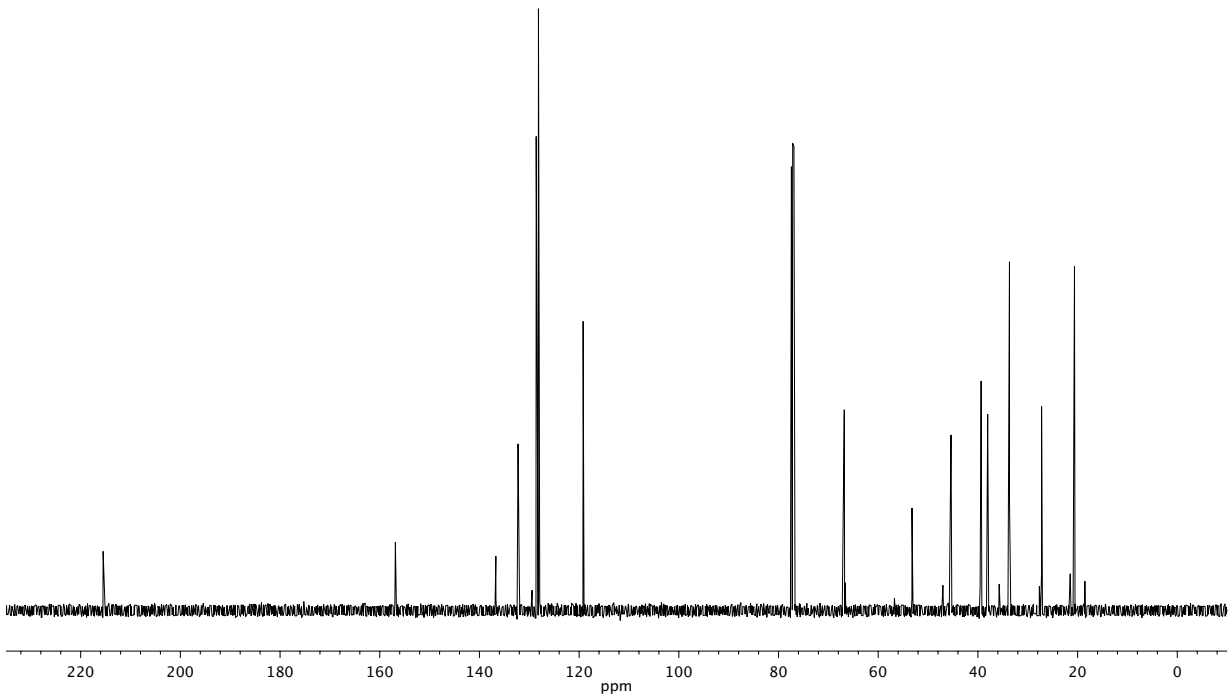
^{13}C NMR (126 MHz, C_6D_6) of compound **4a**.



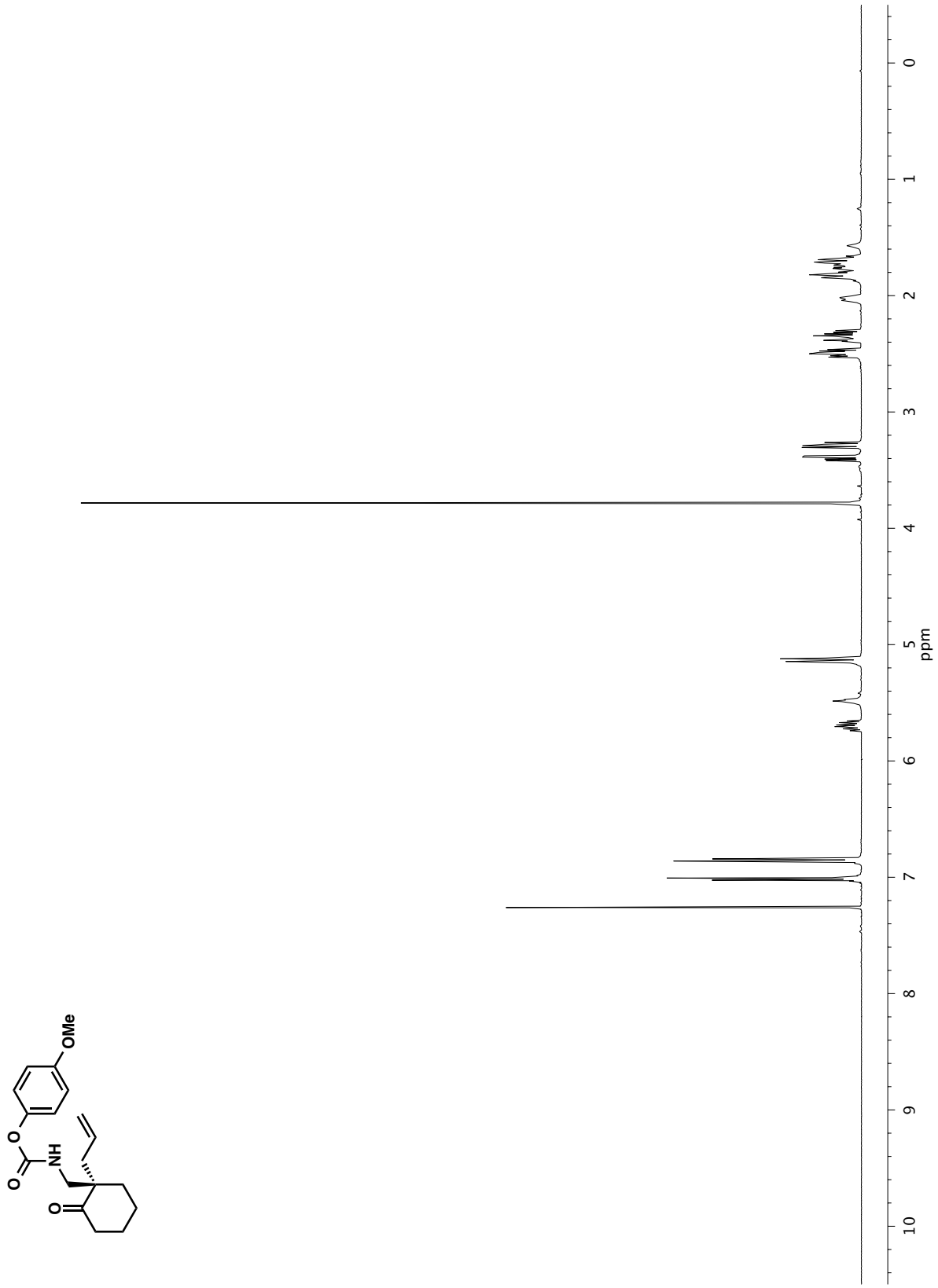
^{1}H NMR (500 MHz, $CDCl_3$) of compound **4b**.



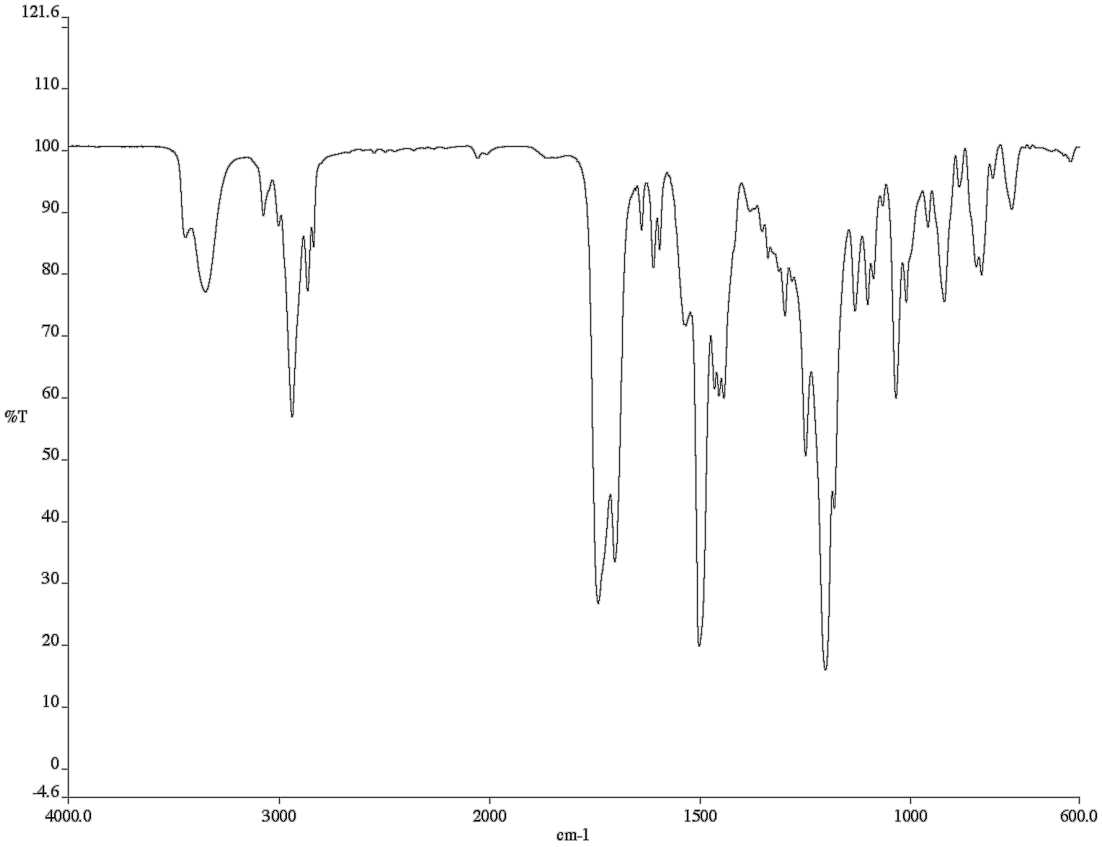
Infrared spectrum (Thin Film, NaCl) of compound **4b.**



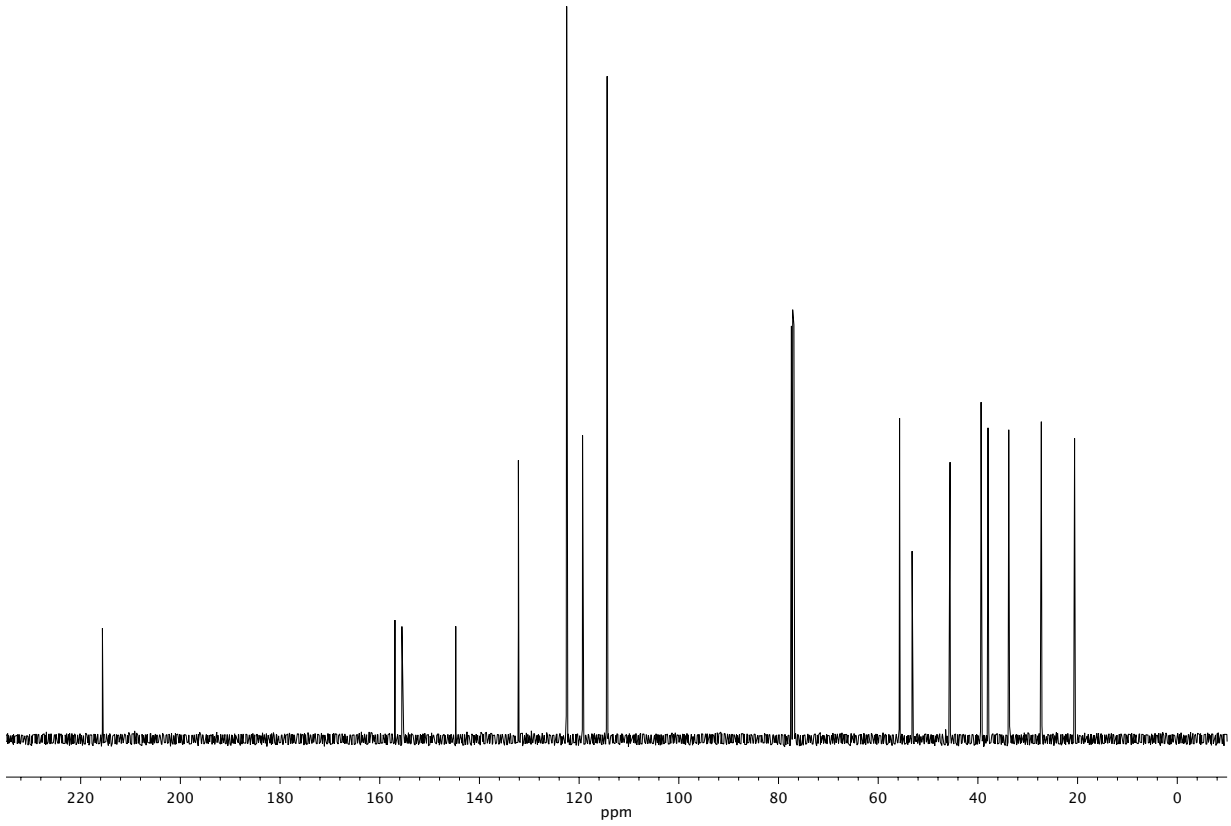
^{13}C NMR (126 MHz, $CDCl_3$) of compound **4b**.



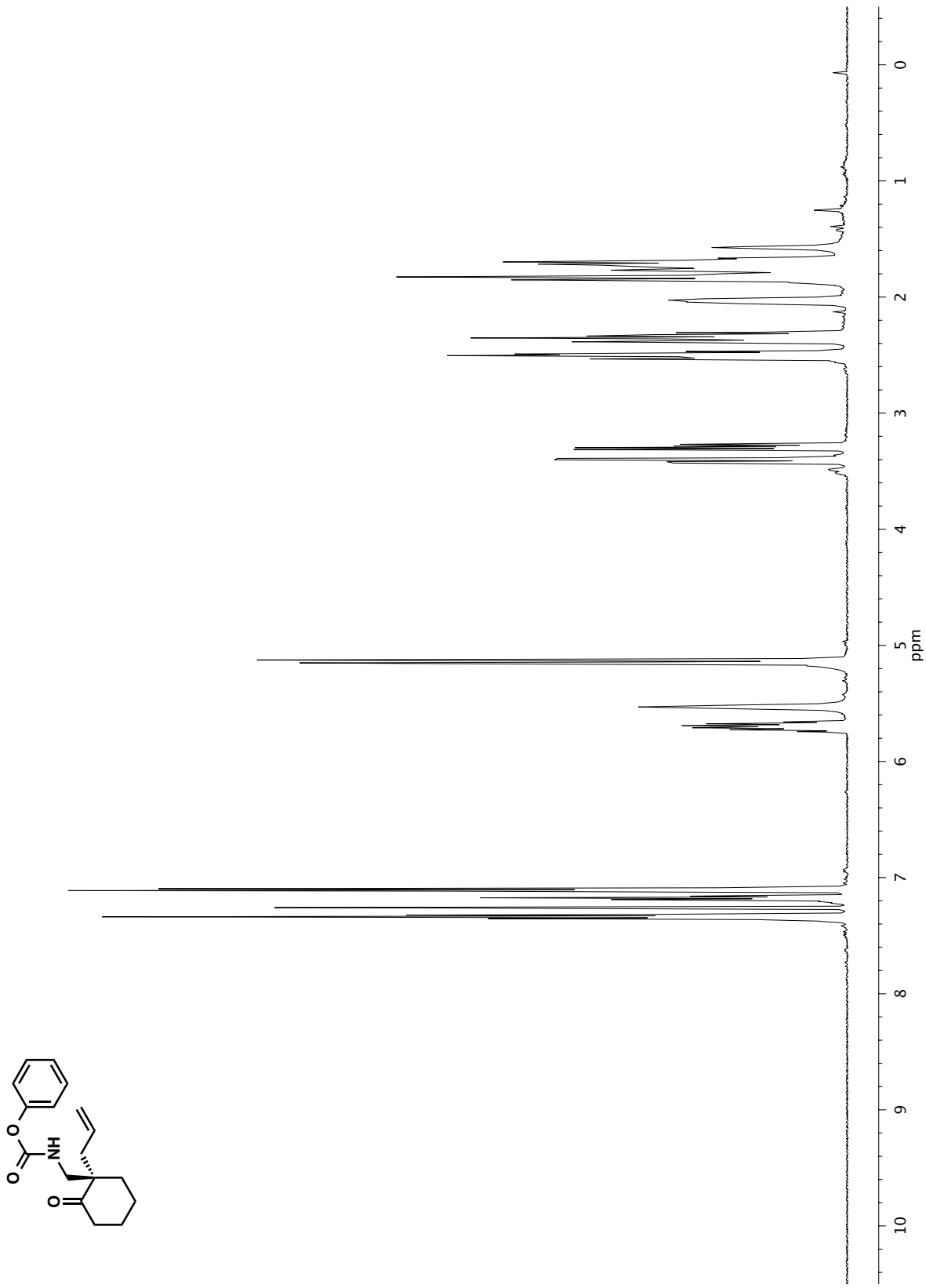
^{1}H NMR (500 MHz, $CDCl_3$) of compound **4c**.



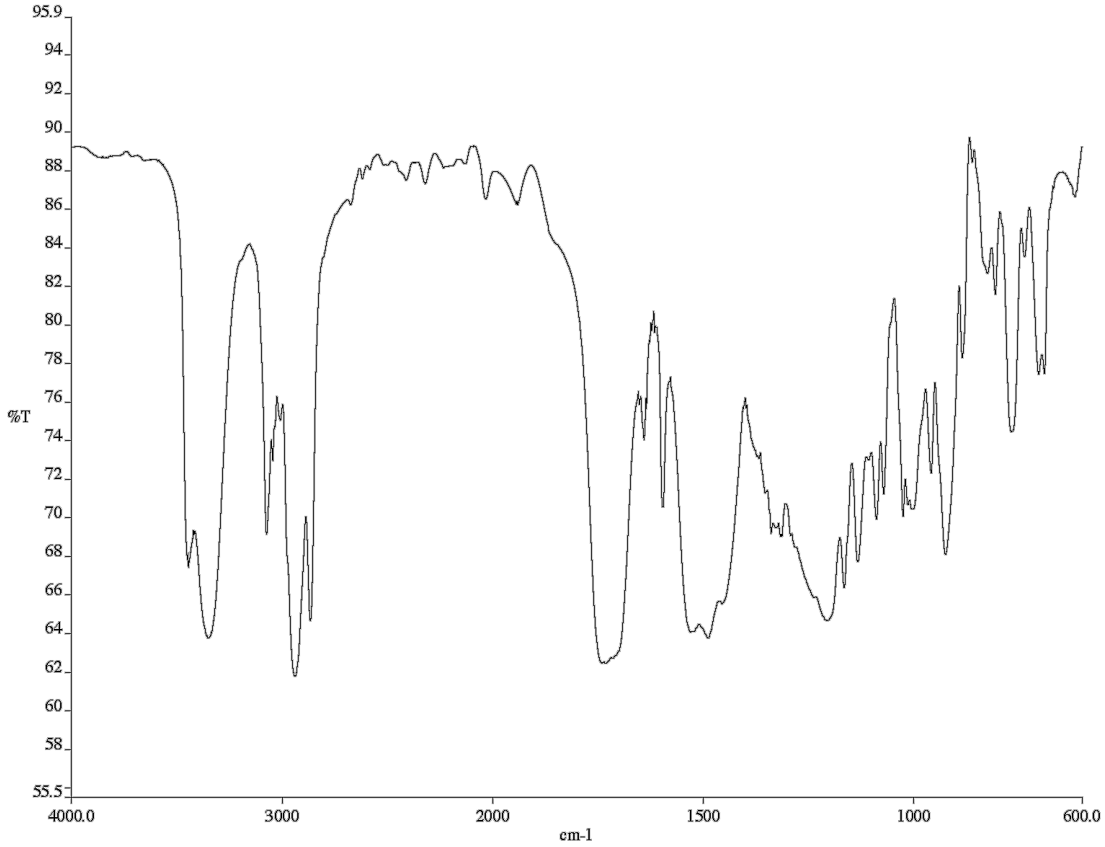
Infrared spectrum (Thin Film, NaCl) of compound **4c.**



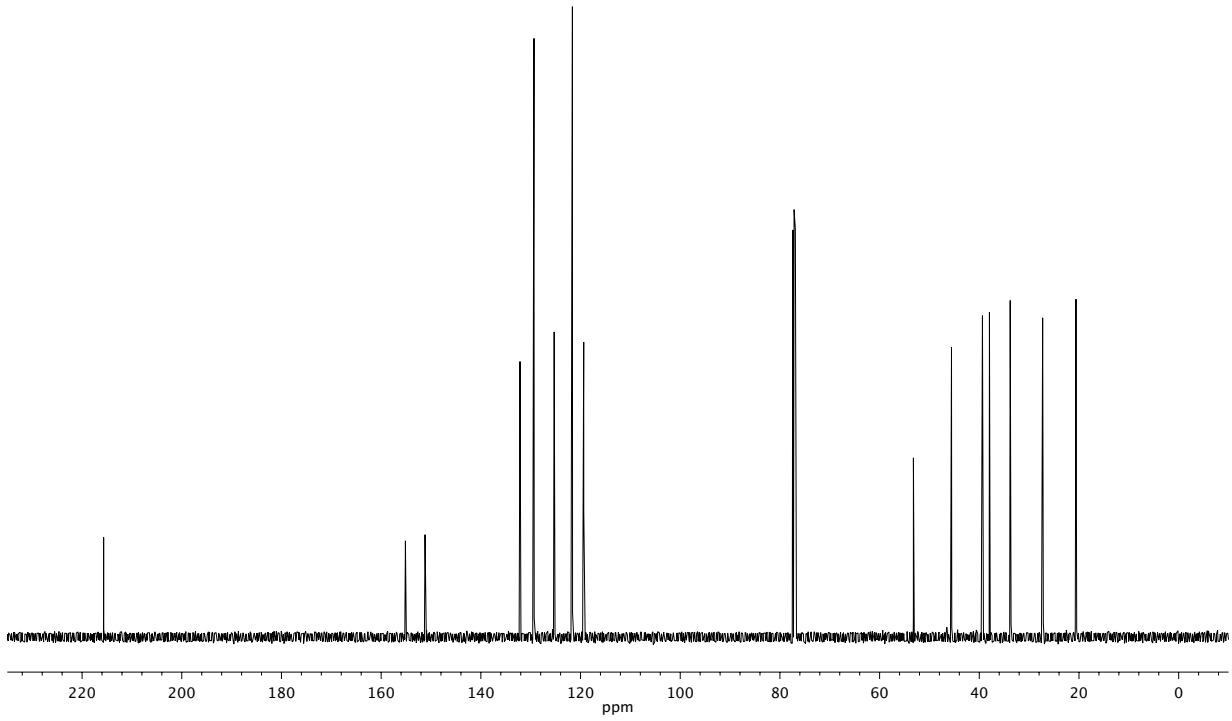
^{13}C NMR (126 MHz, $CDCl_3$) of compound **4c**.



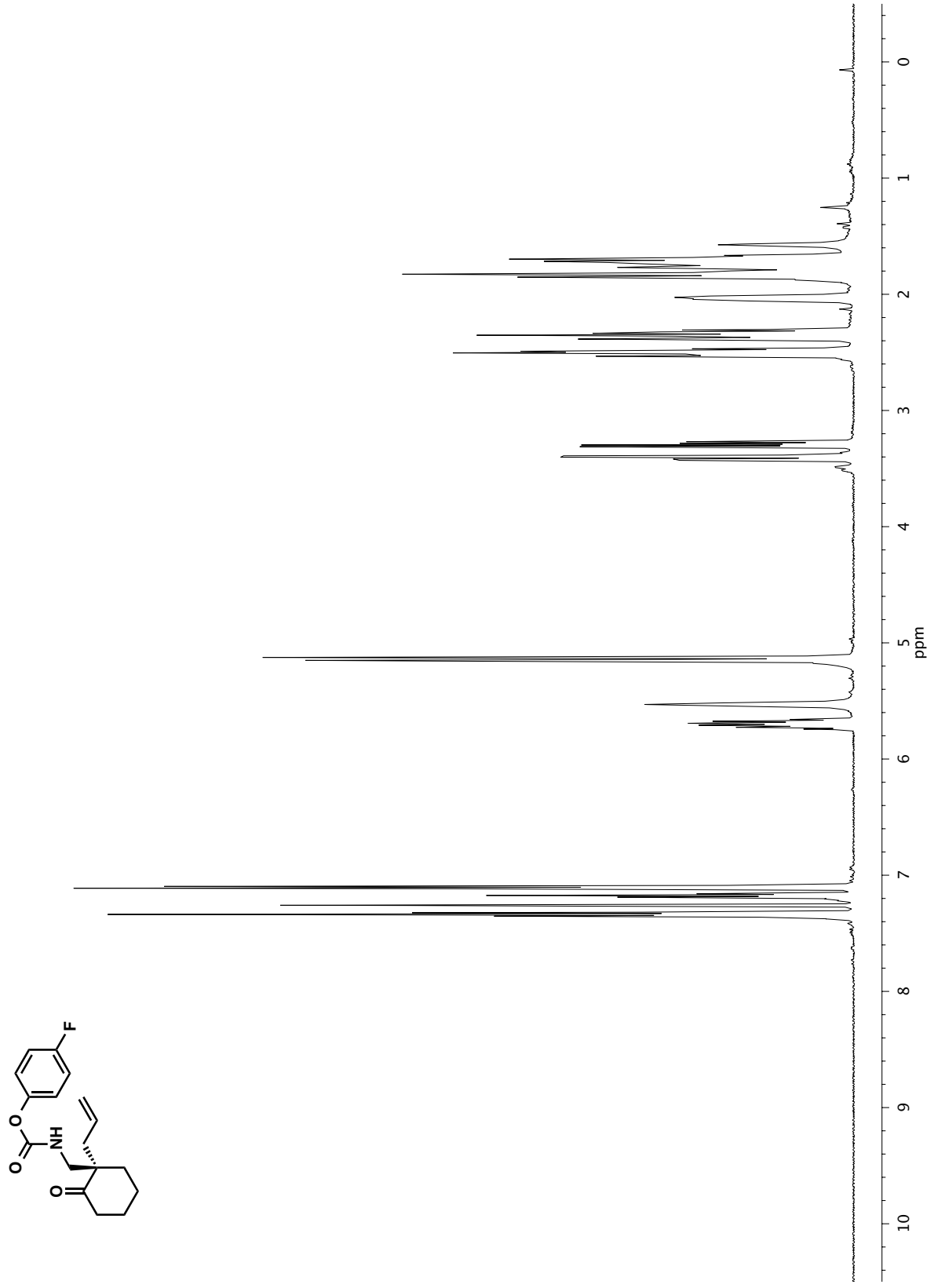
^{1}H NMR (500 MHz, $CDCl_3$) of compound **4d**.



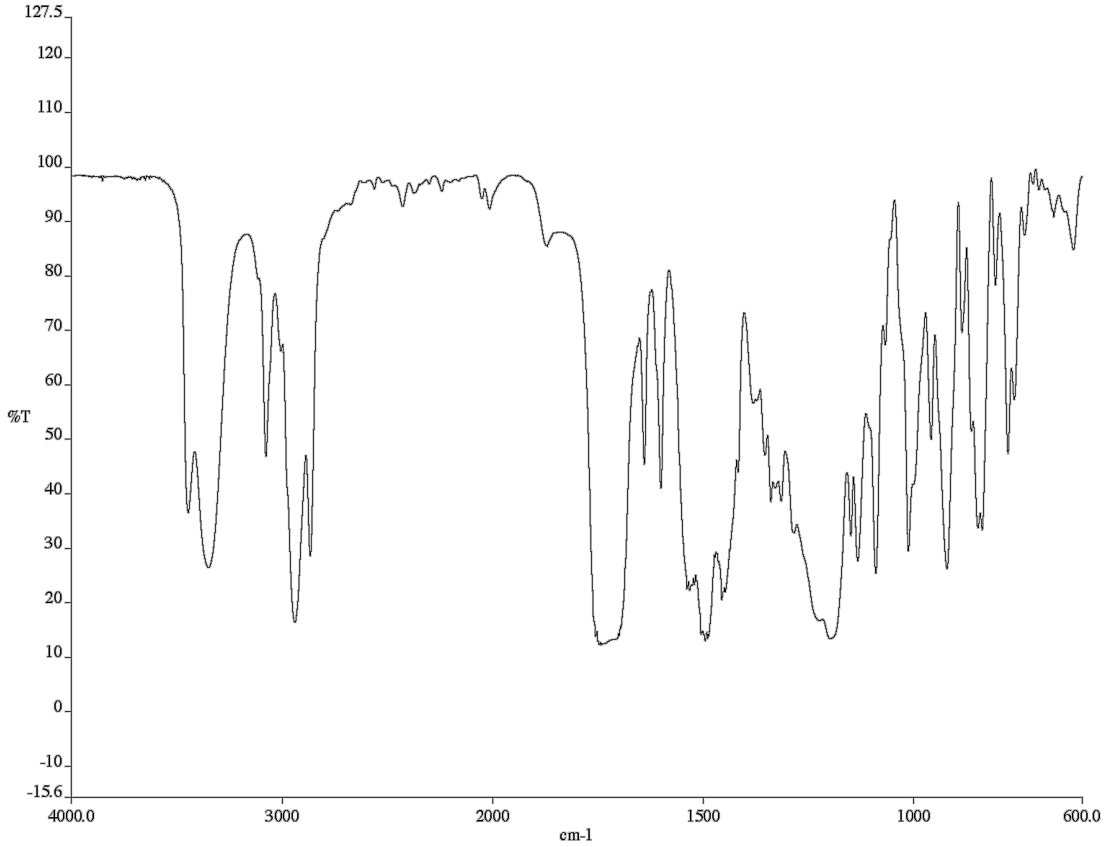
Infrared spectrum (Thin Film, NaCl) of compound **4d.**



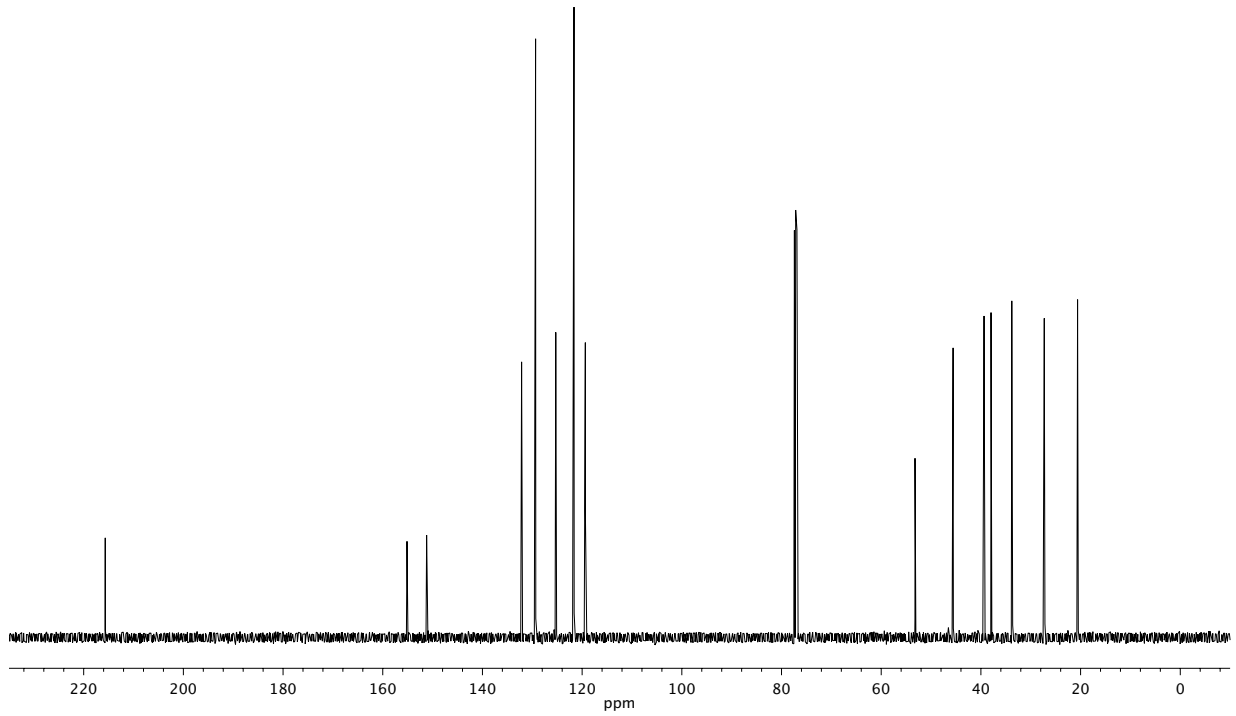
^{13}C NMR (126 MHz, $CDCl_3$) of compound **4d**.



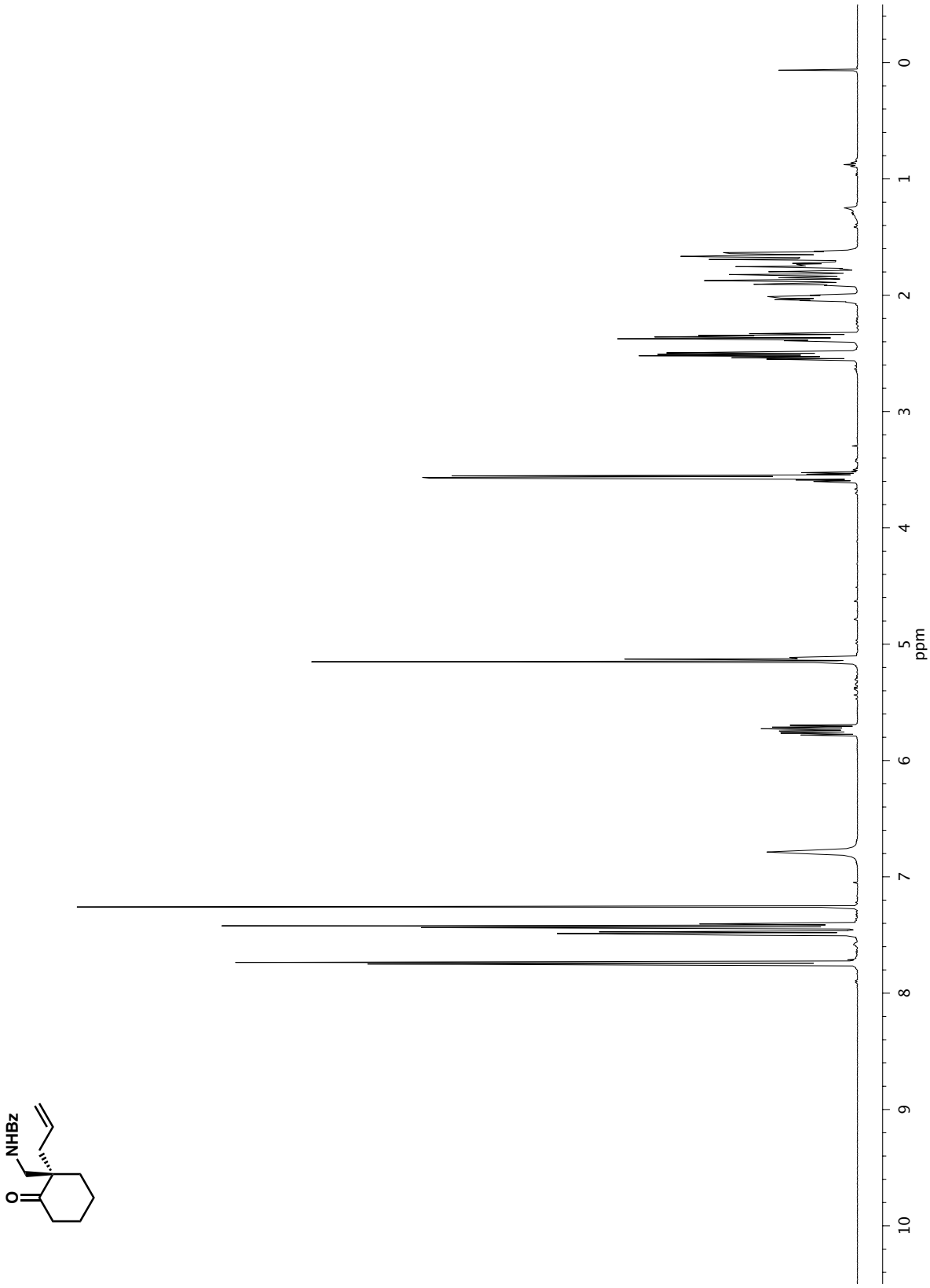
^{1}H NMR (500 MHz, $CDCl_3$) of compound **4e**.



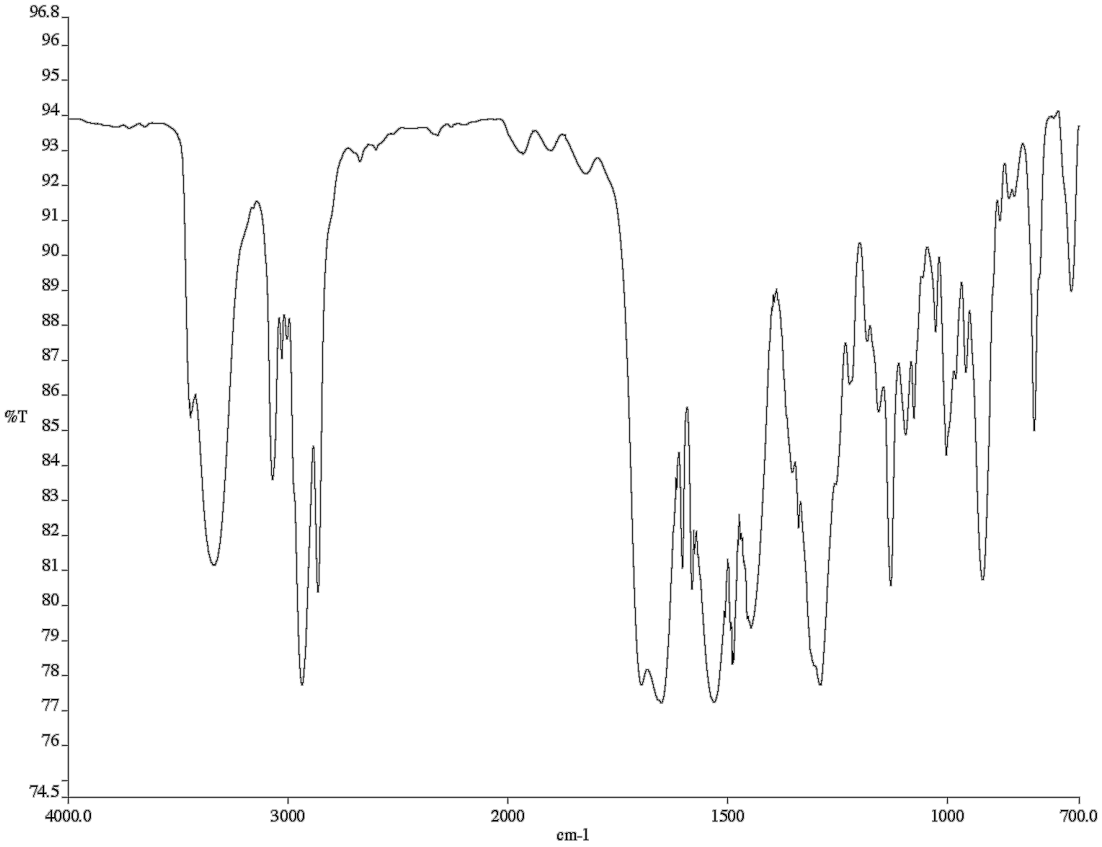
Infrared spectrum (Thin Film, NaCl) of compound **4e.**



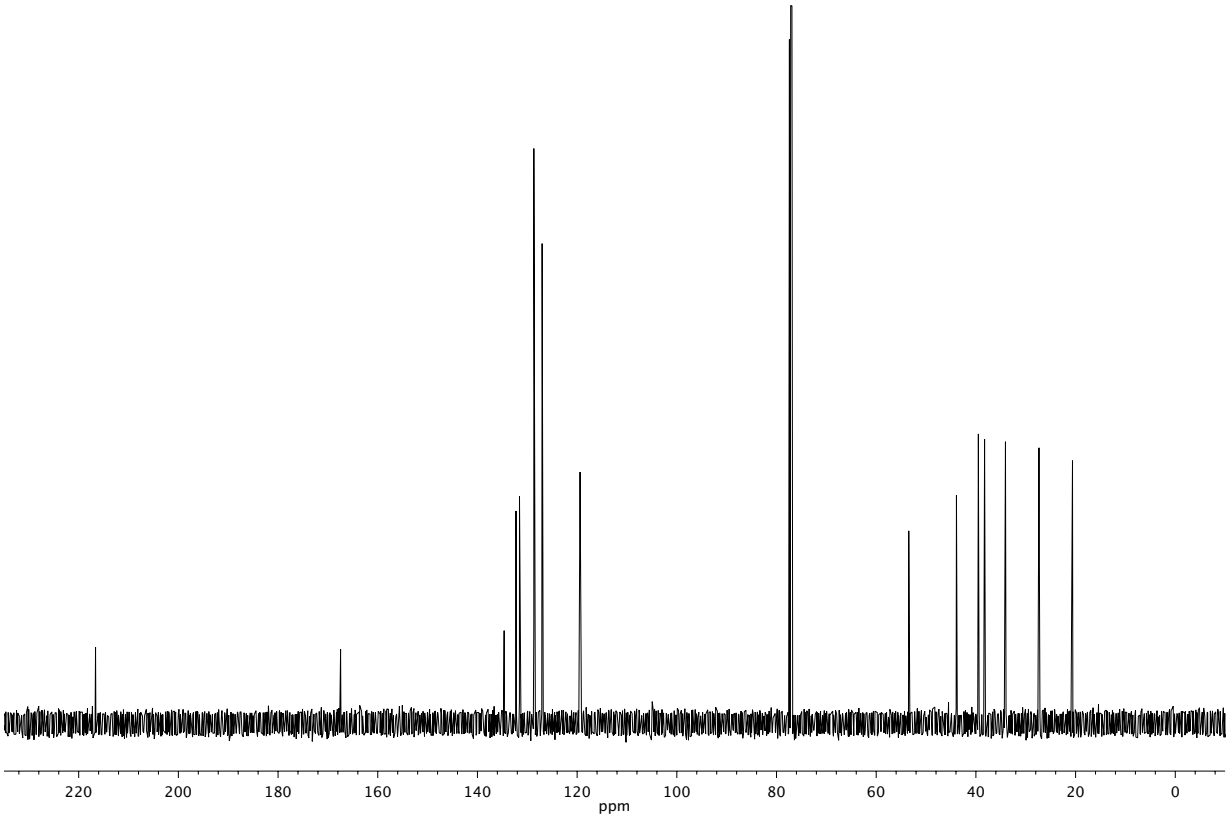
^{13}C NMR (126 MHz, $CDCl_3$) of compound **4e**.



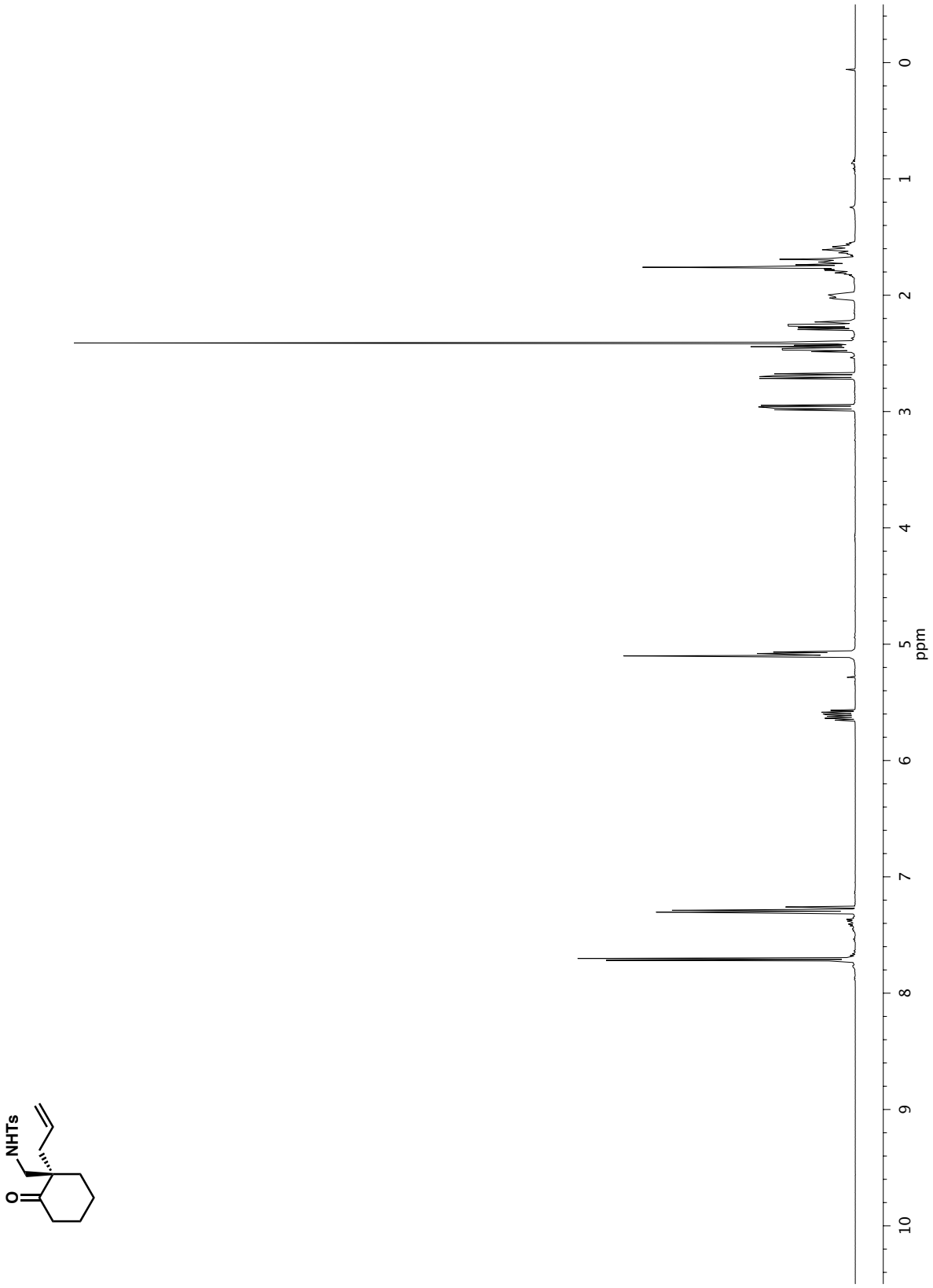
^{1}H NMR (500 MHz, $CDCl_3$) of compound **4f**.



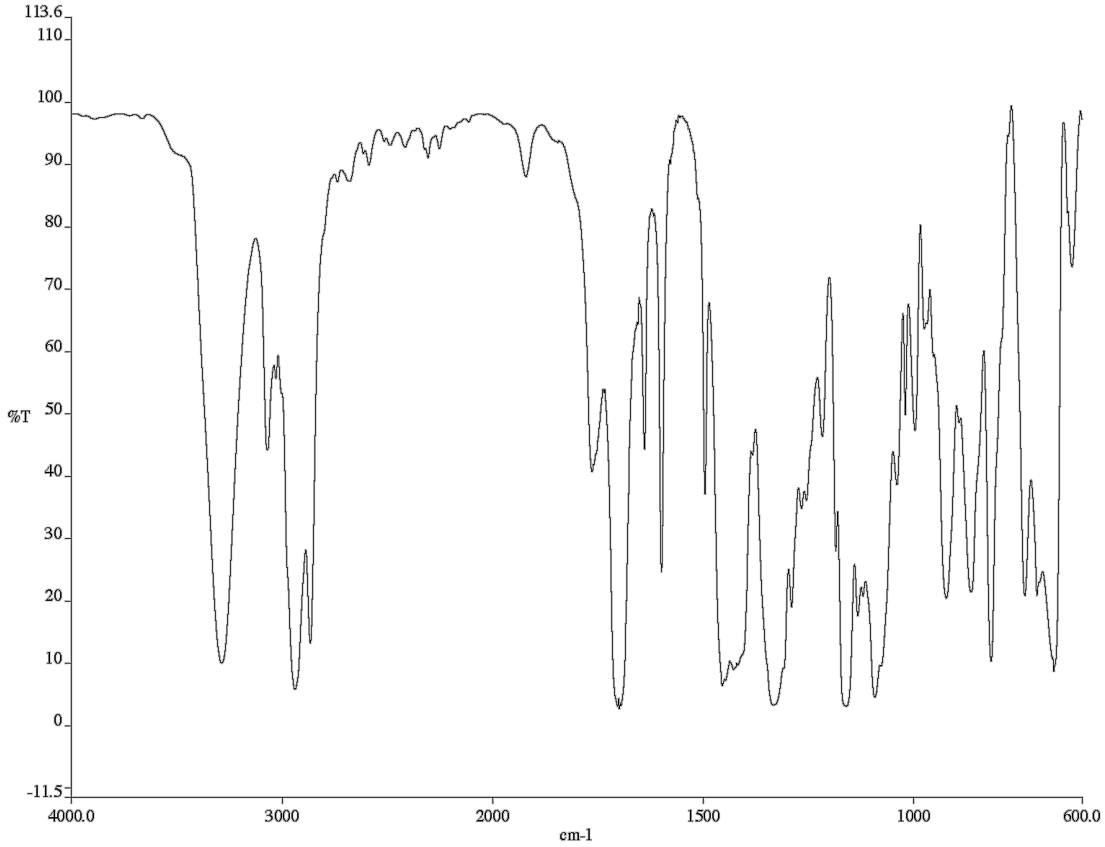
Infrared spectrum (Thin Film, NaCl) of compound **4f.**



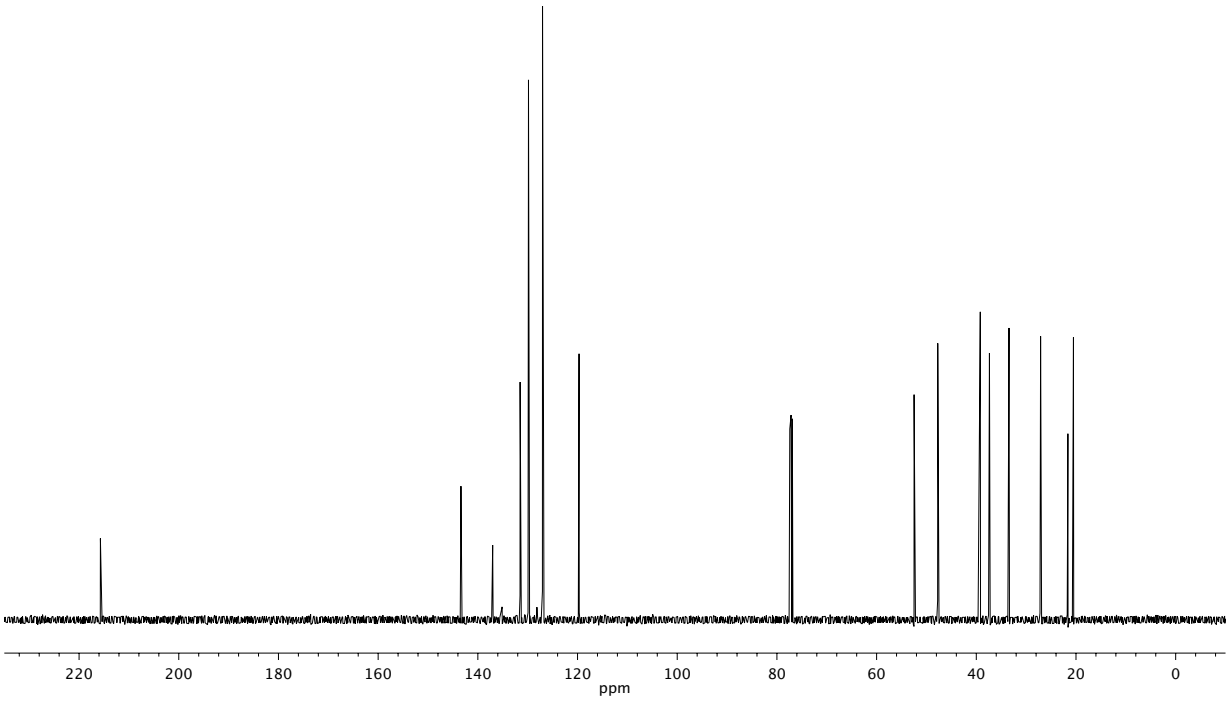
^{13}C NMR (126 MHz, $CDCl_3$) of compound **4f**.



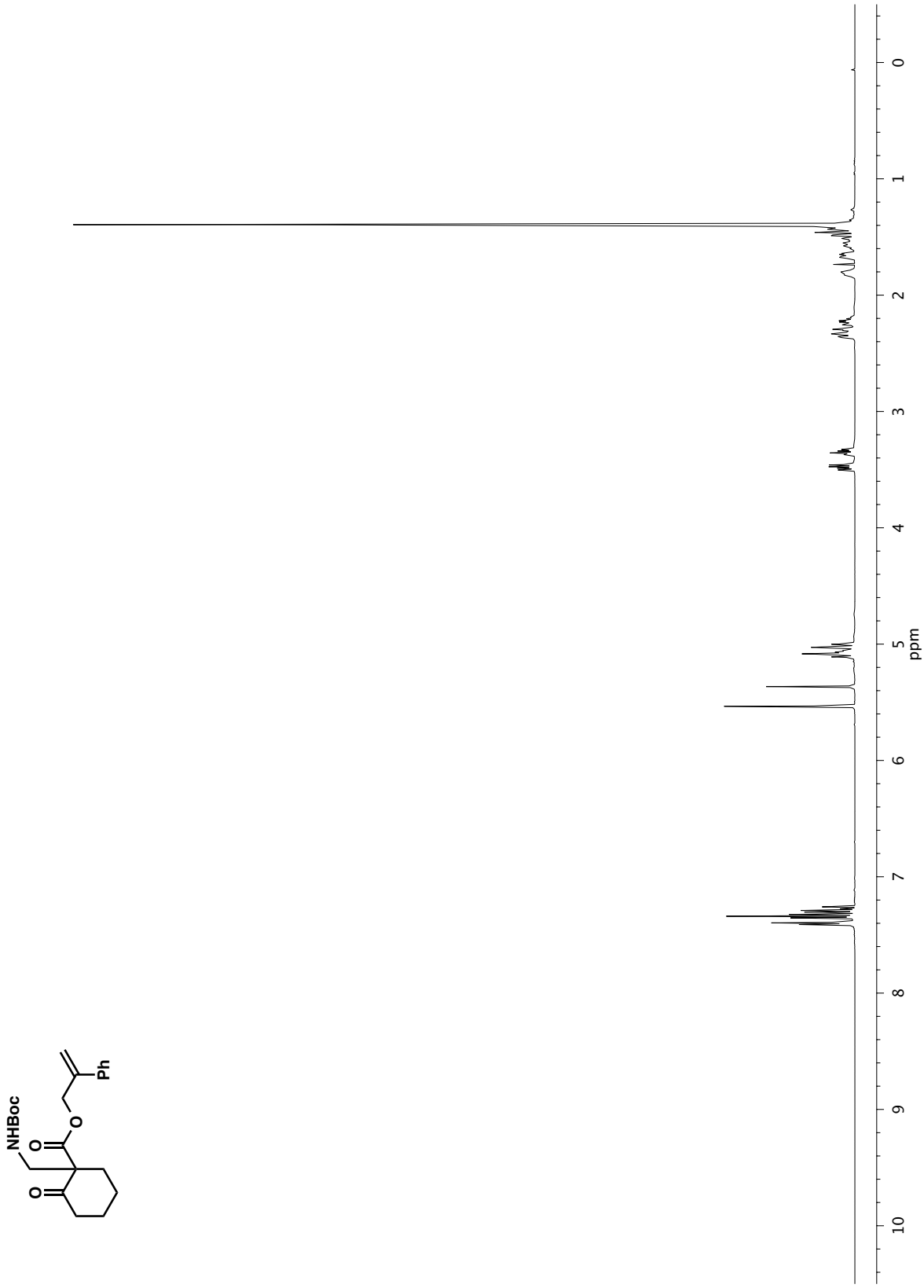
^{1}H NMR (500 MHz, $CDCl_3$) of compound **4g**.



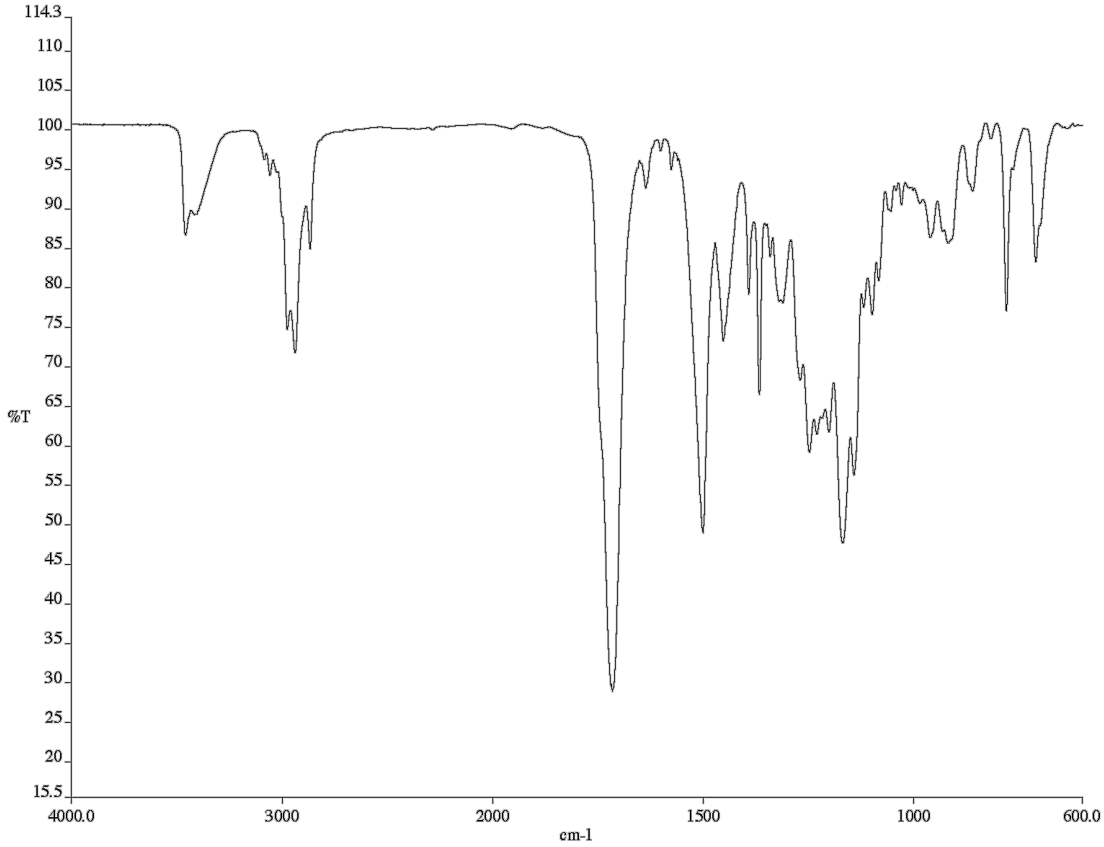
Infrared spectrum (Thin Film, NaCl) of compound **4g.**



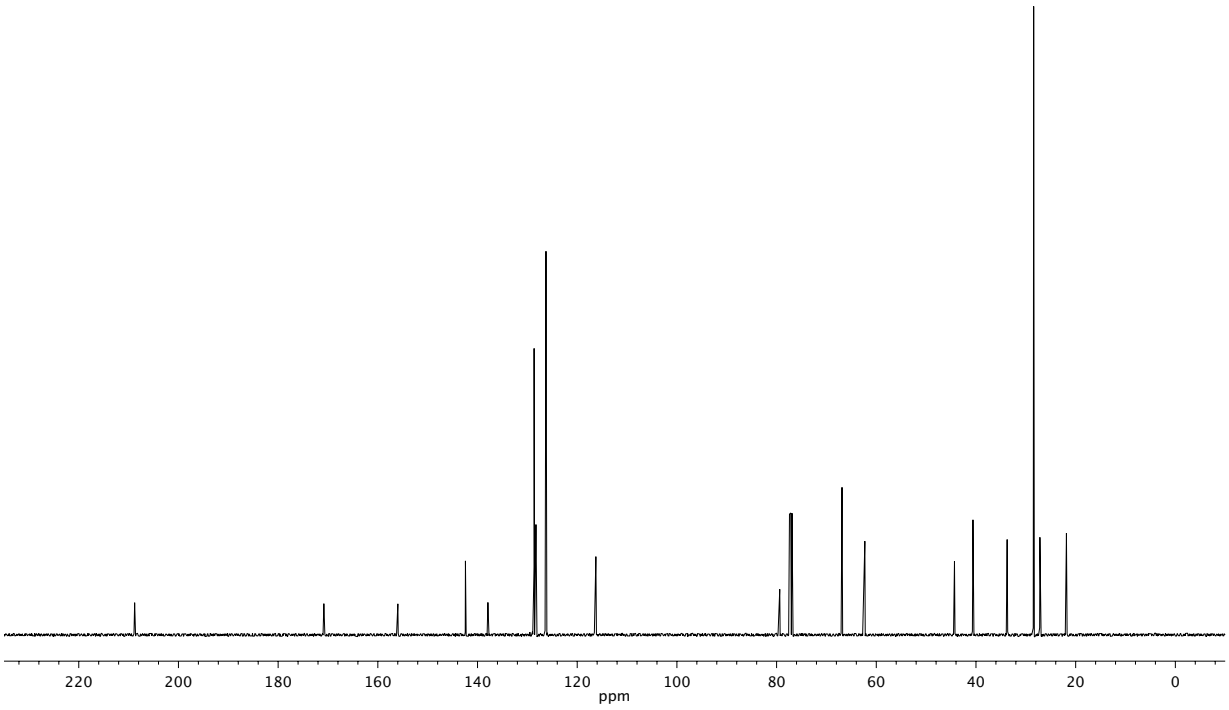
^{13}C NMR (126 MHz, $CDCl_3$) of compound **4g**.



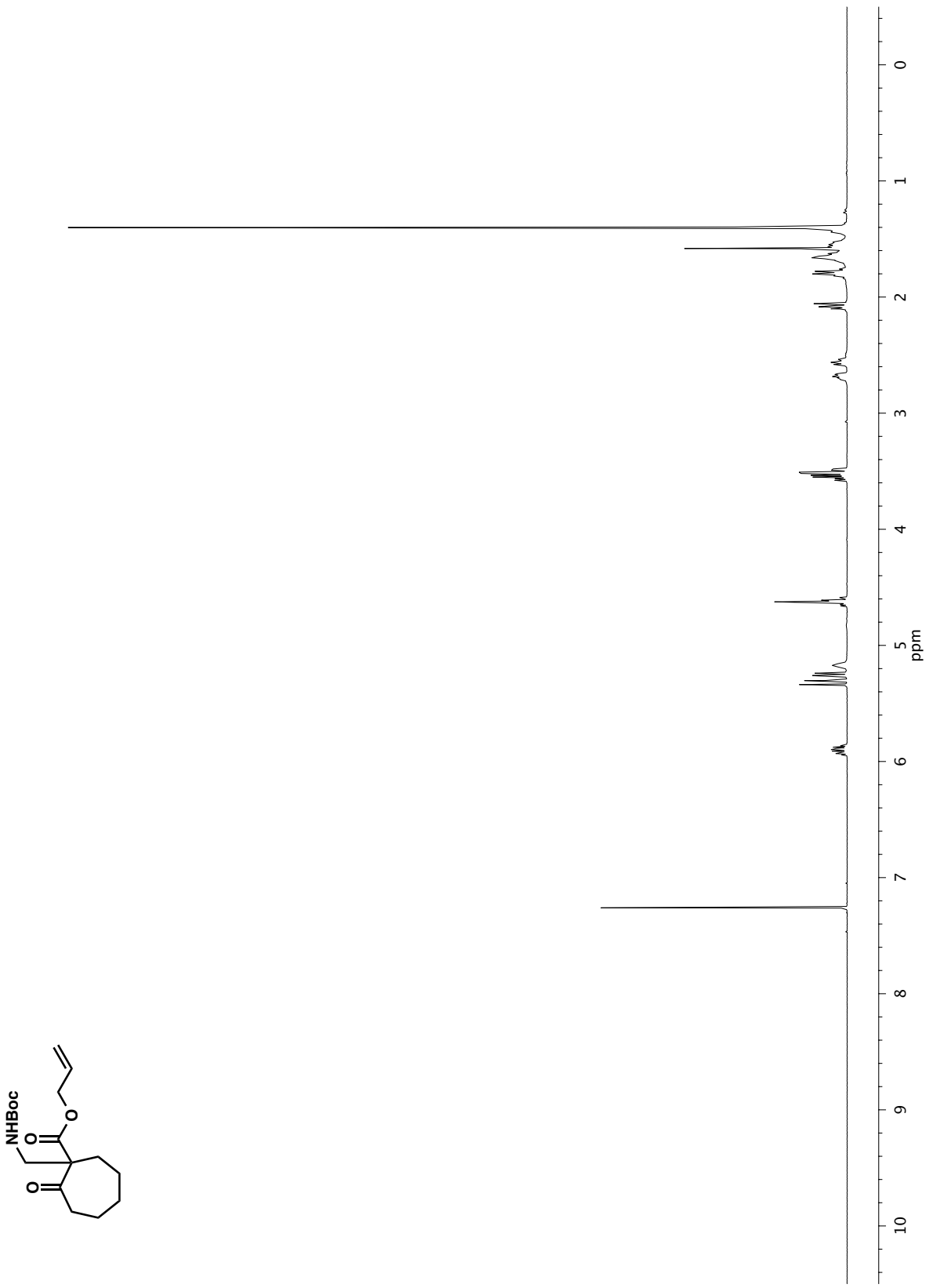
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6a**.



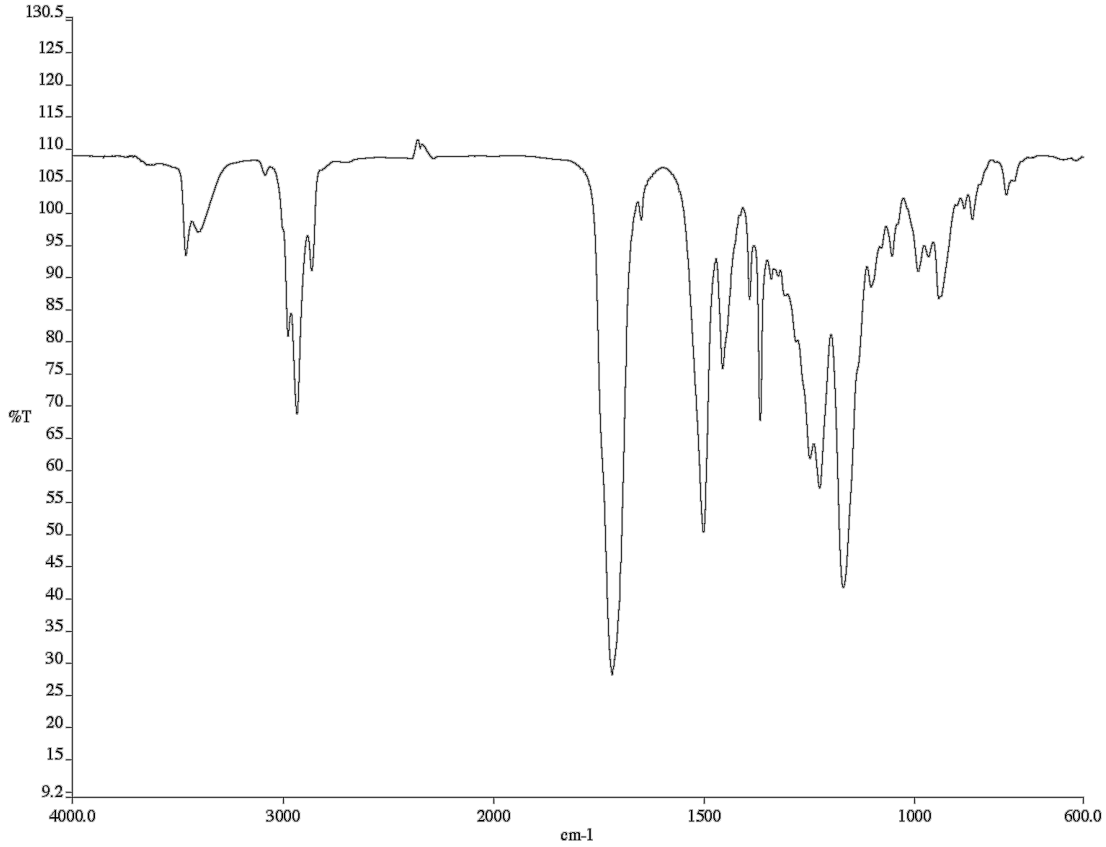
Infrared spectrum (Thin Film, NaCl) of compound **6a**.



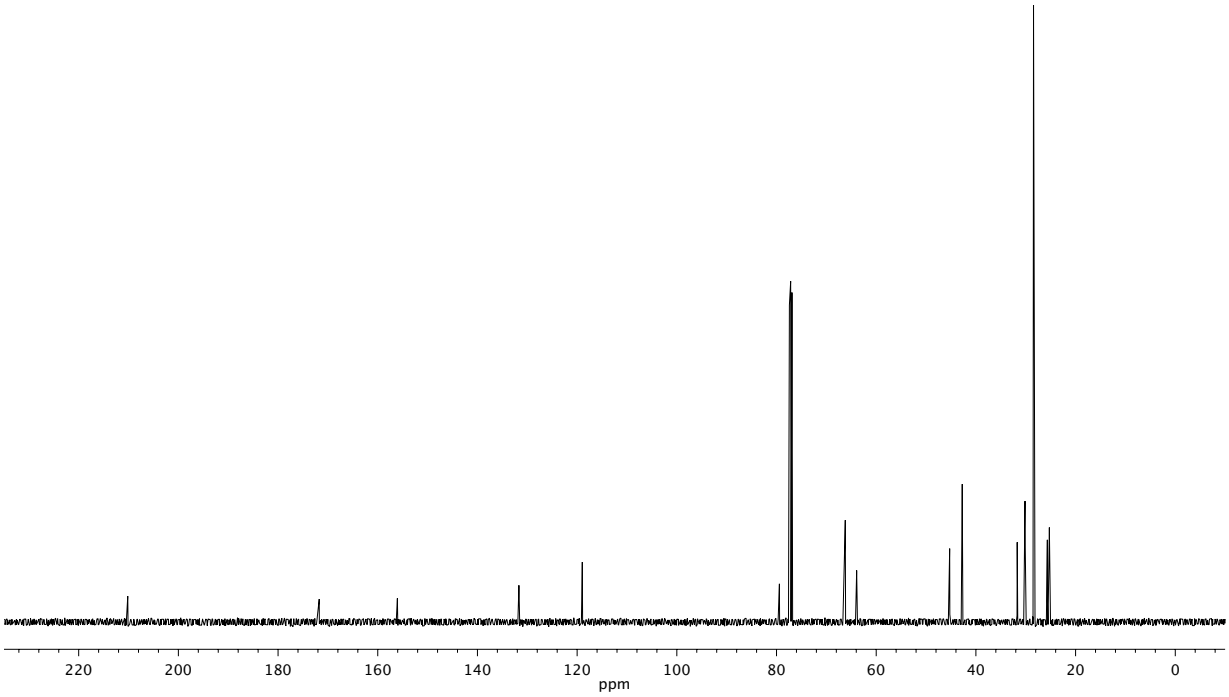
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6a**.



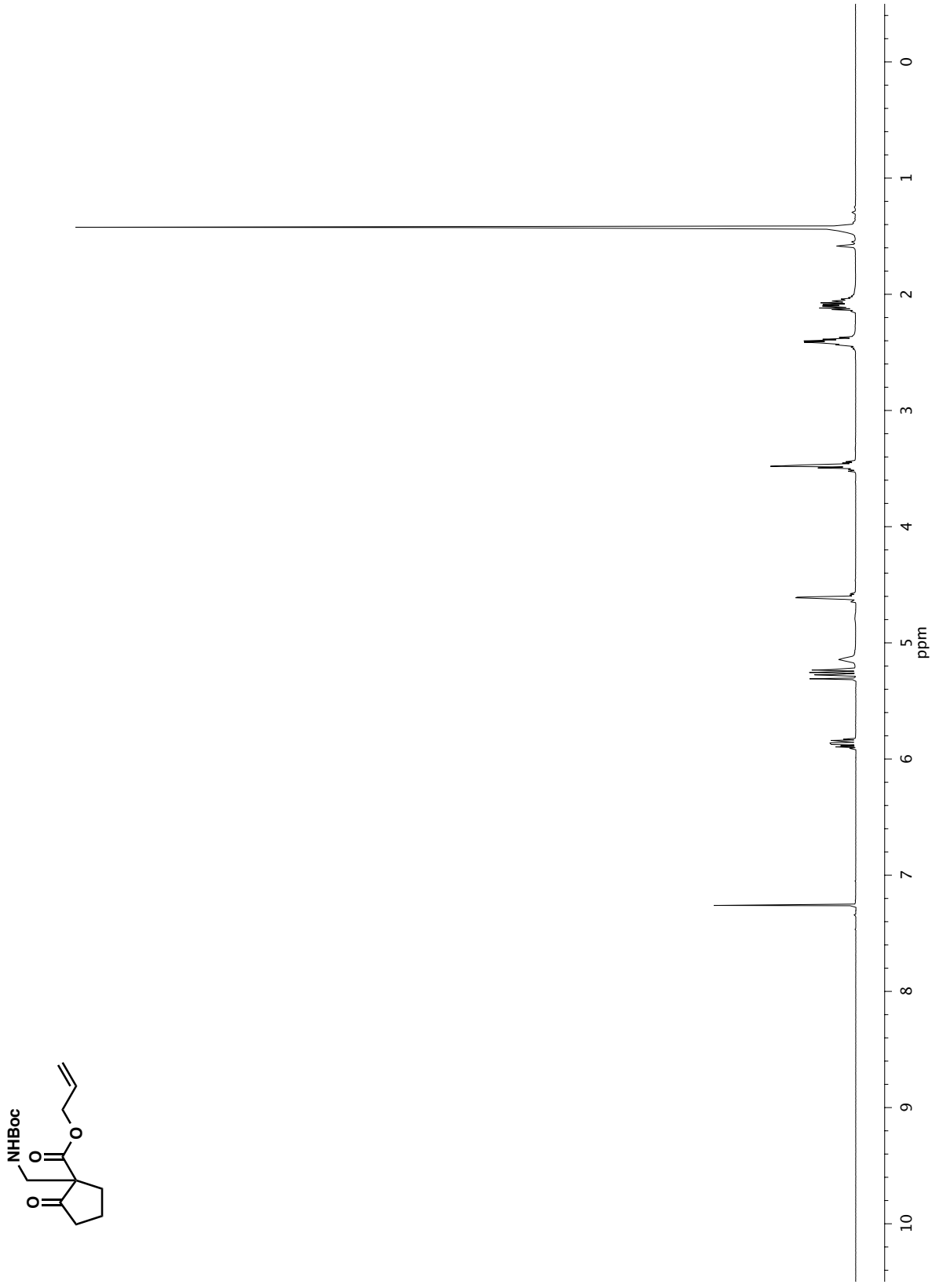
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6b**.



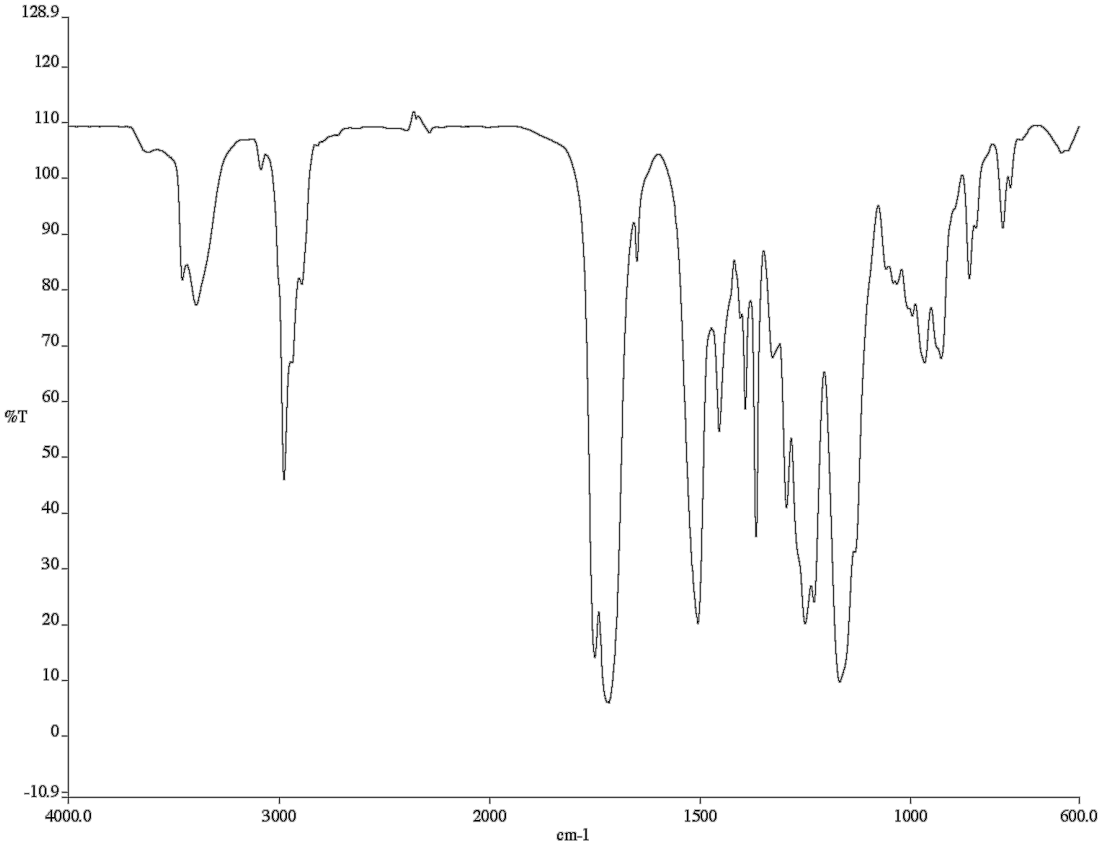
Infrared spectrum (Thin Film, NaCl) of compound **6b**.



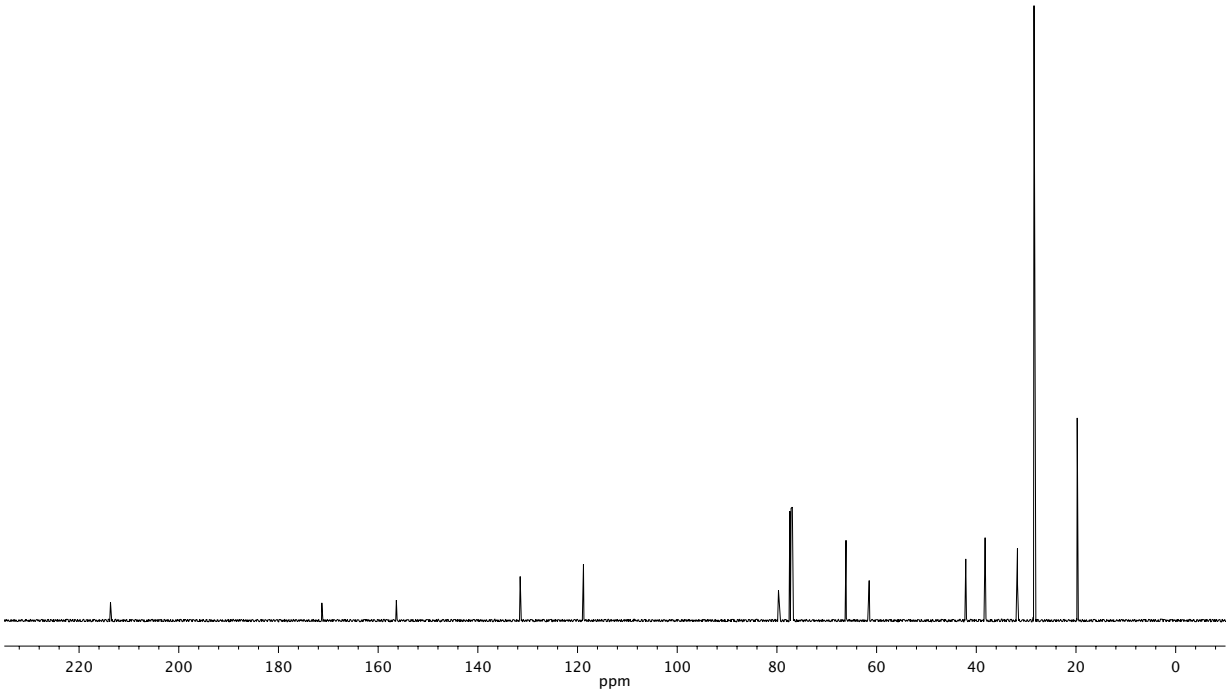
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6b**.



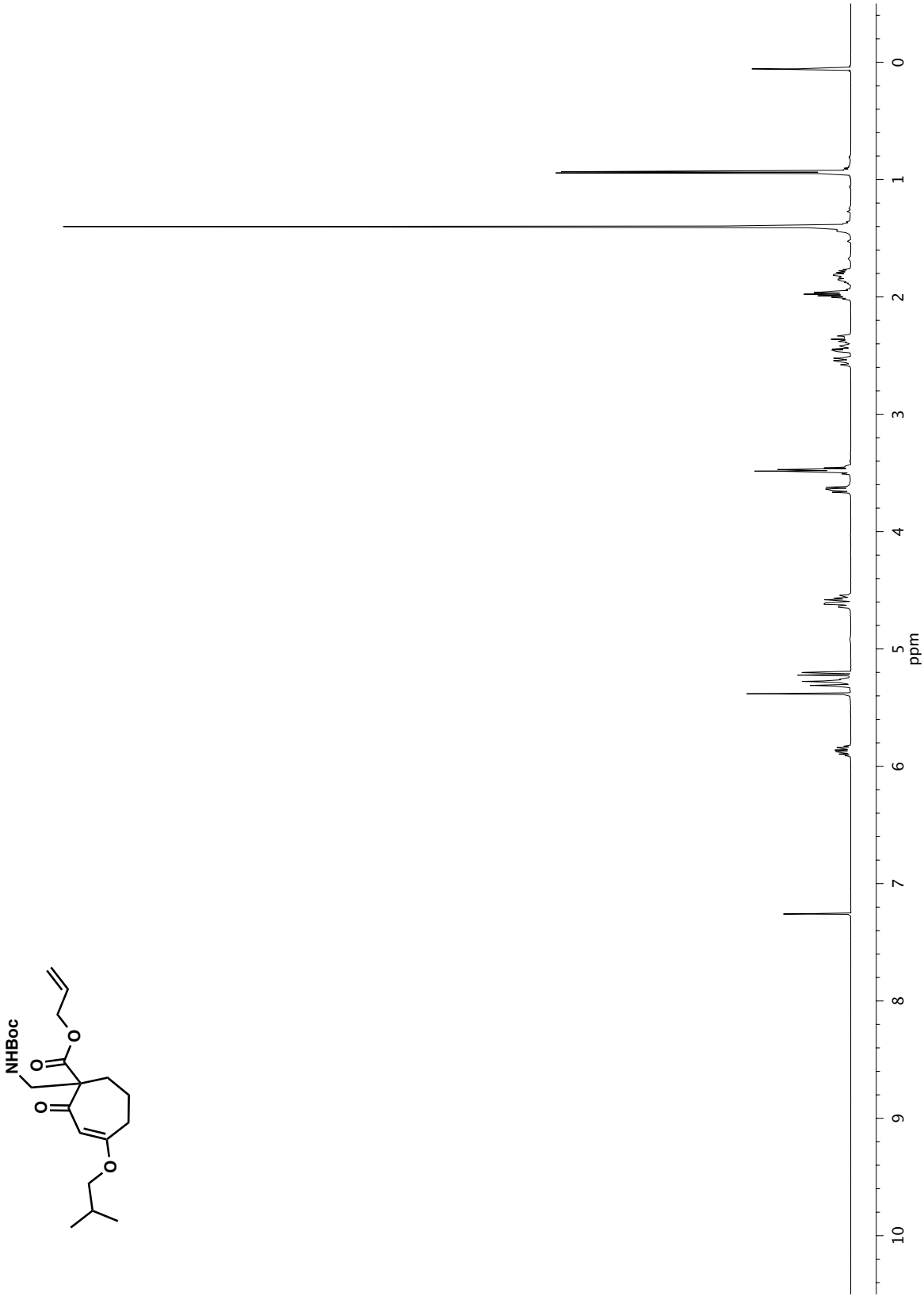
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6c**.



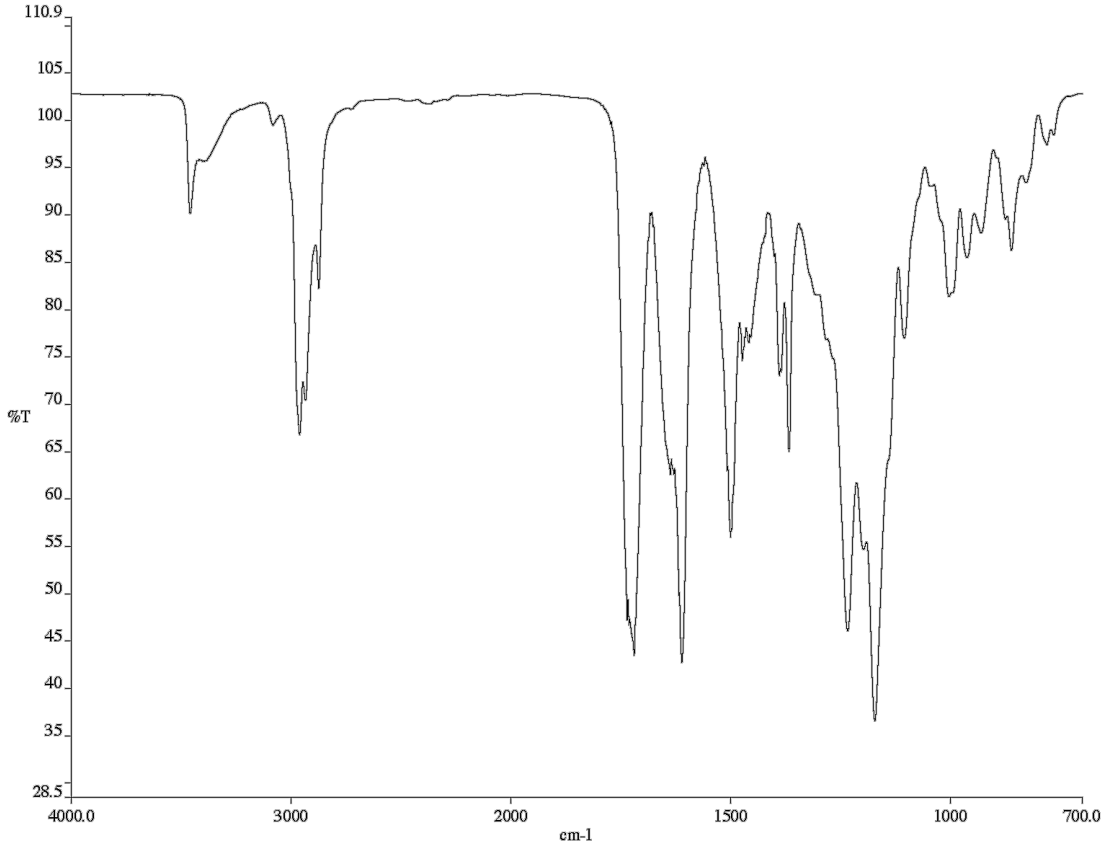
Infrared spectrum (Thin Film, NaCl) of compound **6c**.



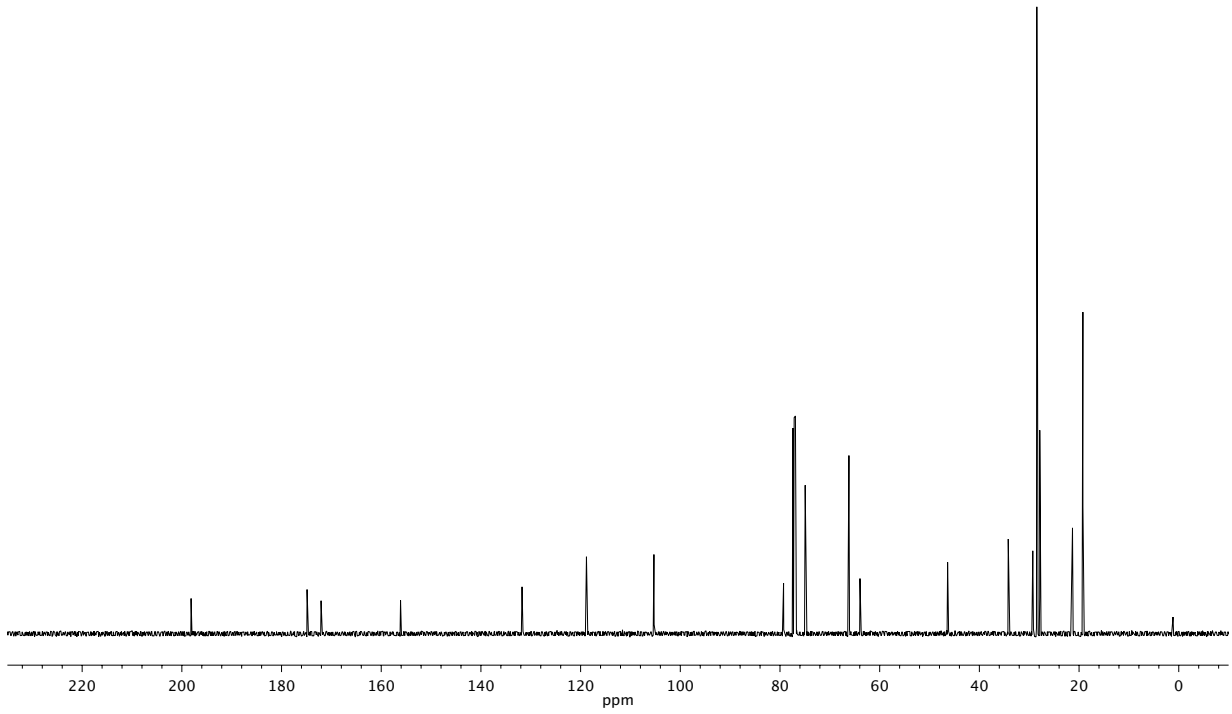
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6c**.



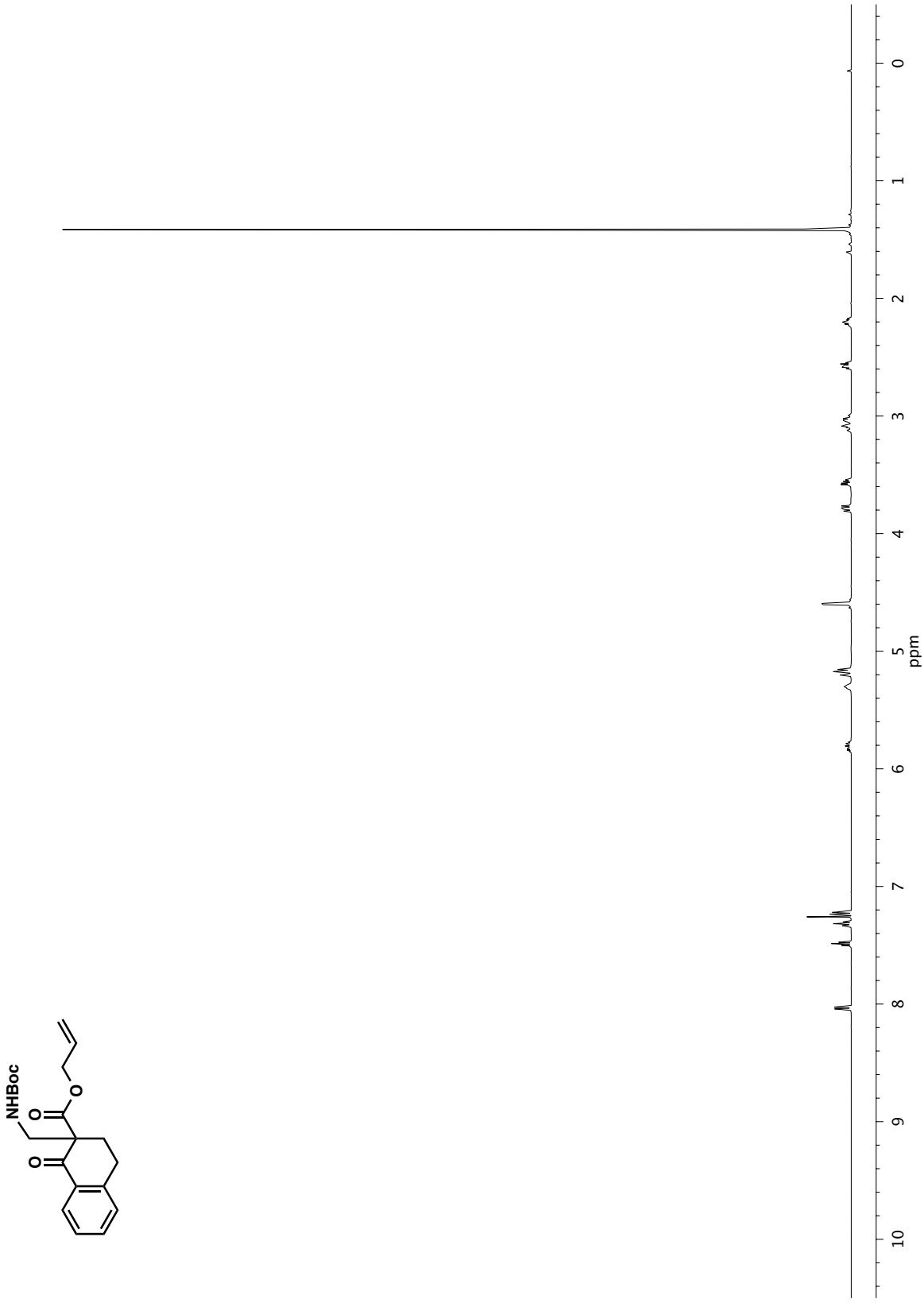
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6d**.



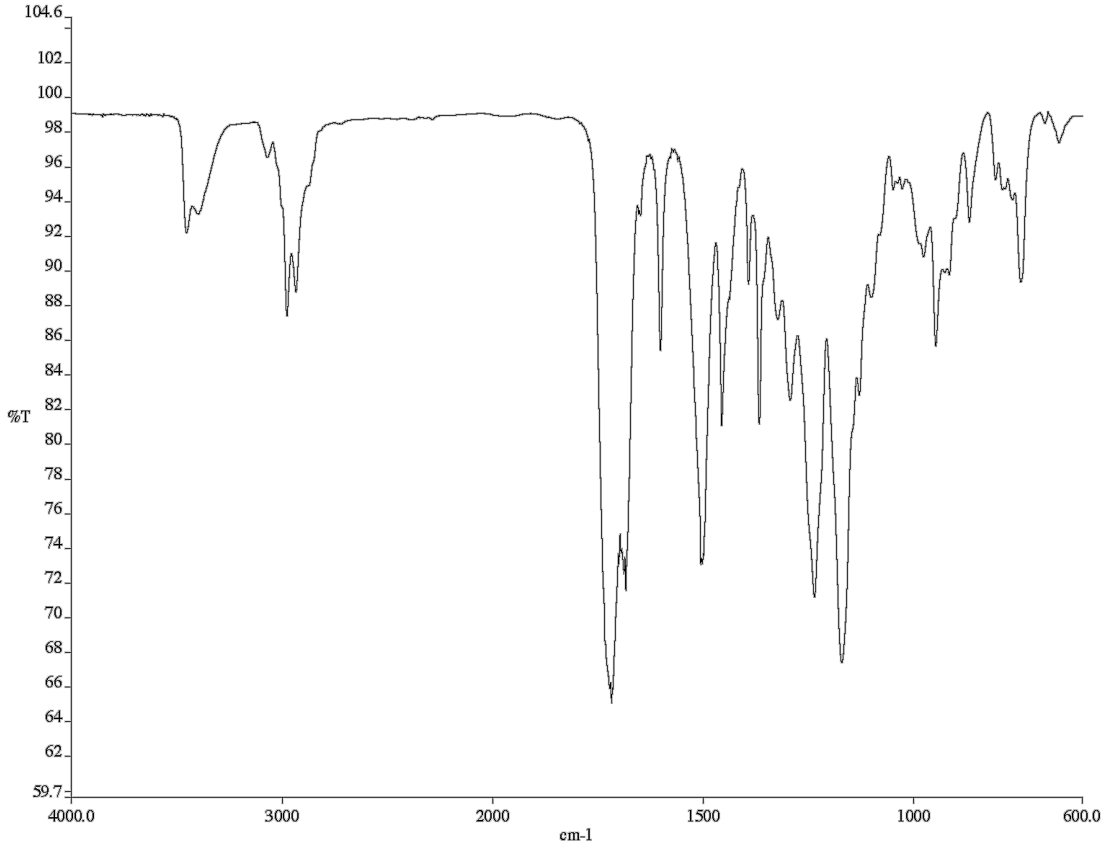
Infrared spectrum (Thin Film, NaCl) of compound **6d**.



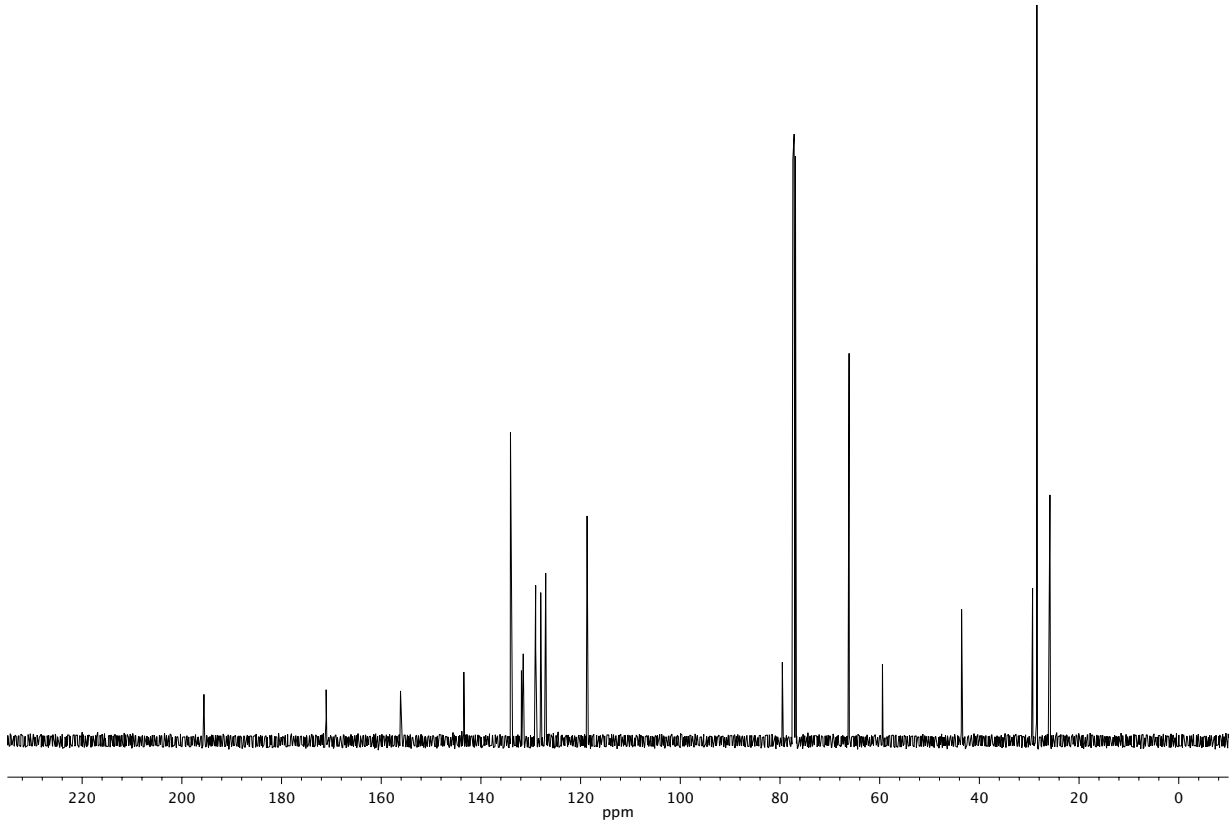
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6d**.



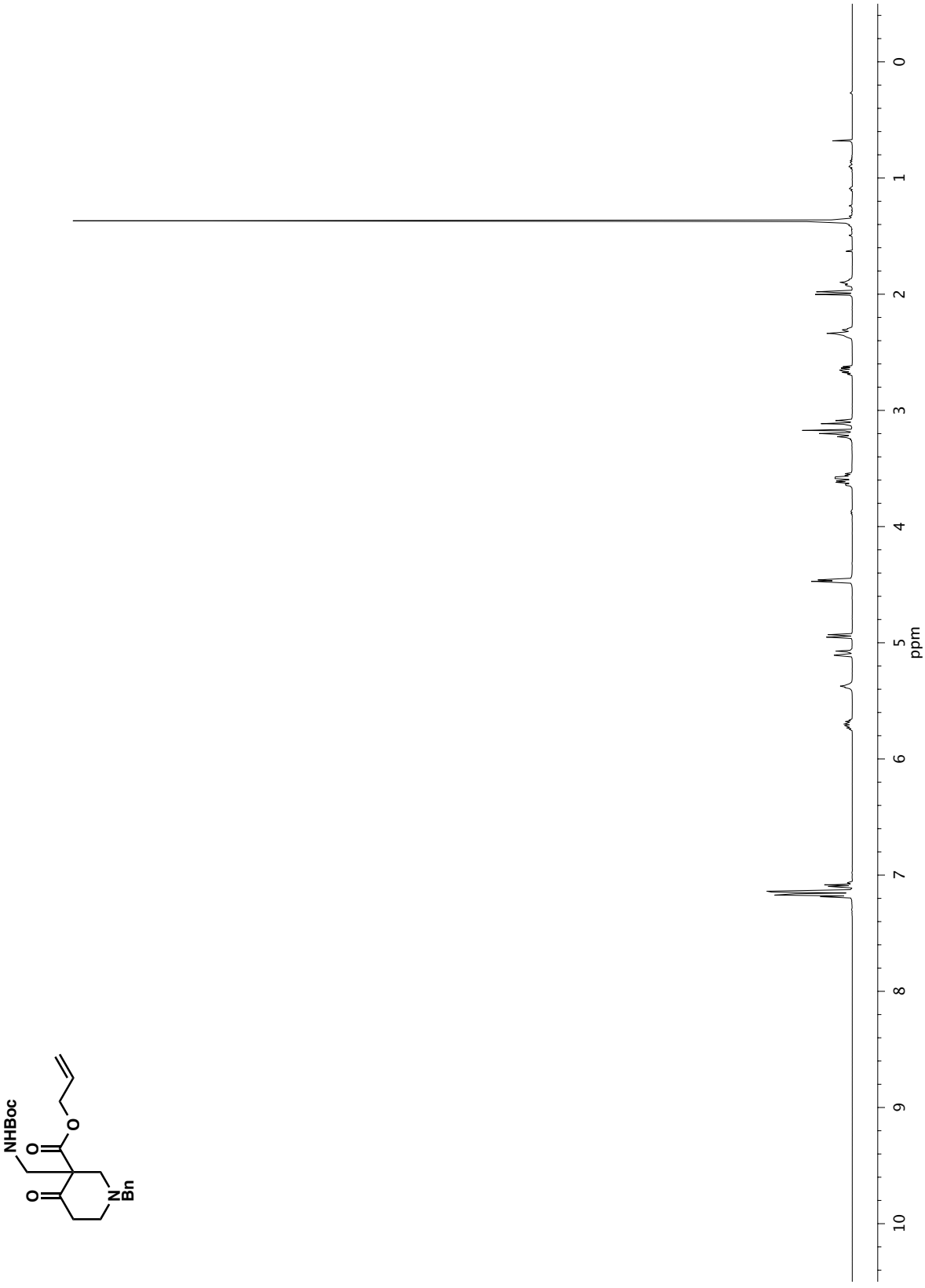
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6e**.



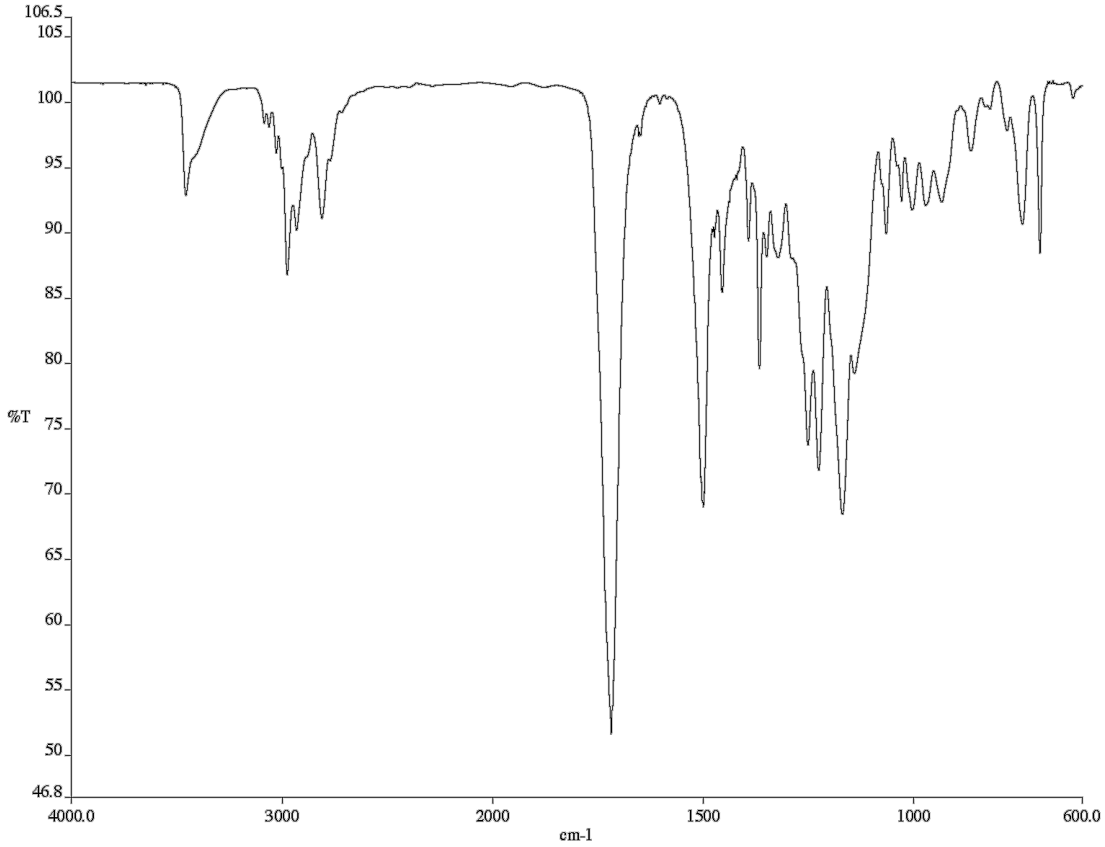
Infrared spectrum (Thin Film, NaCl) of compound **6e**.



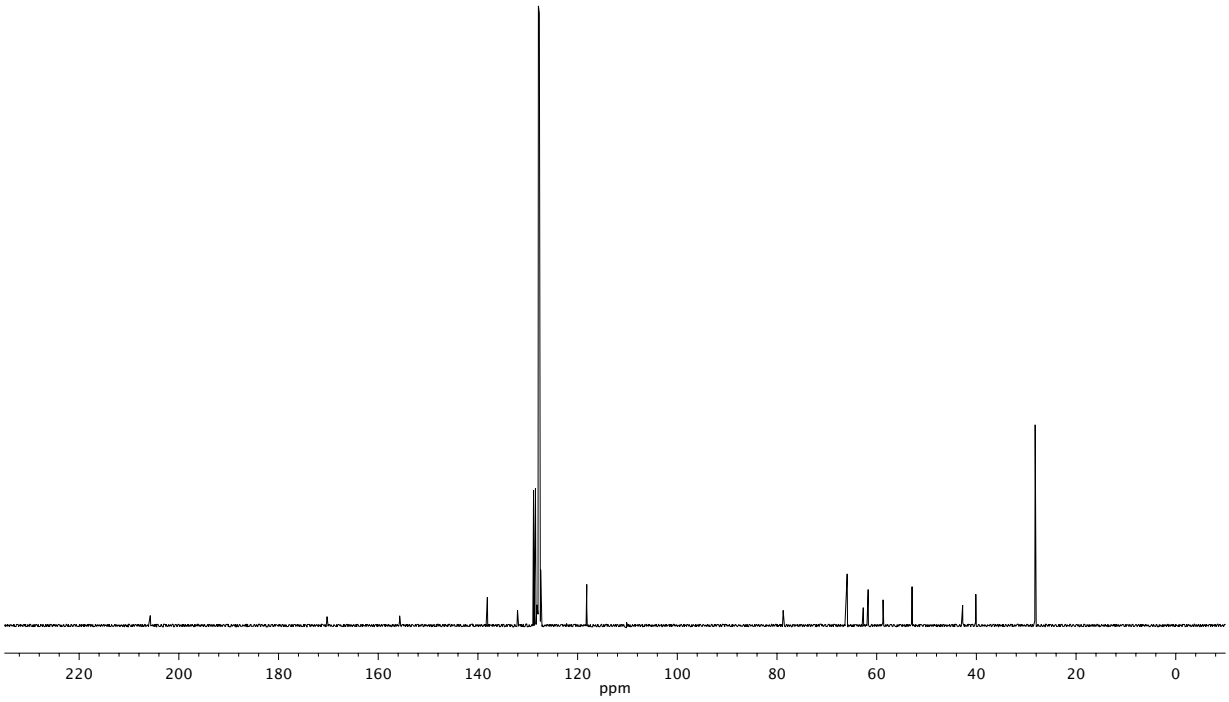
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6e**.



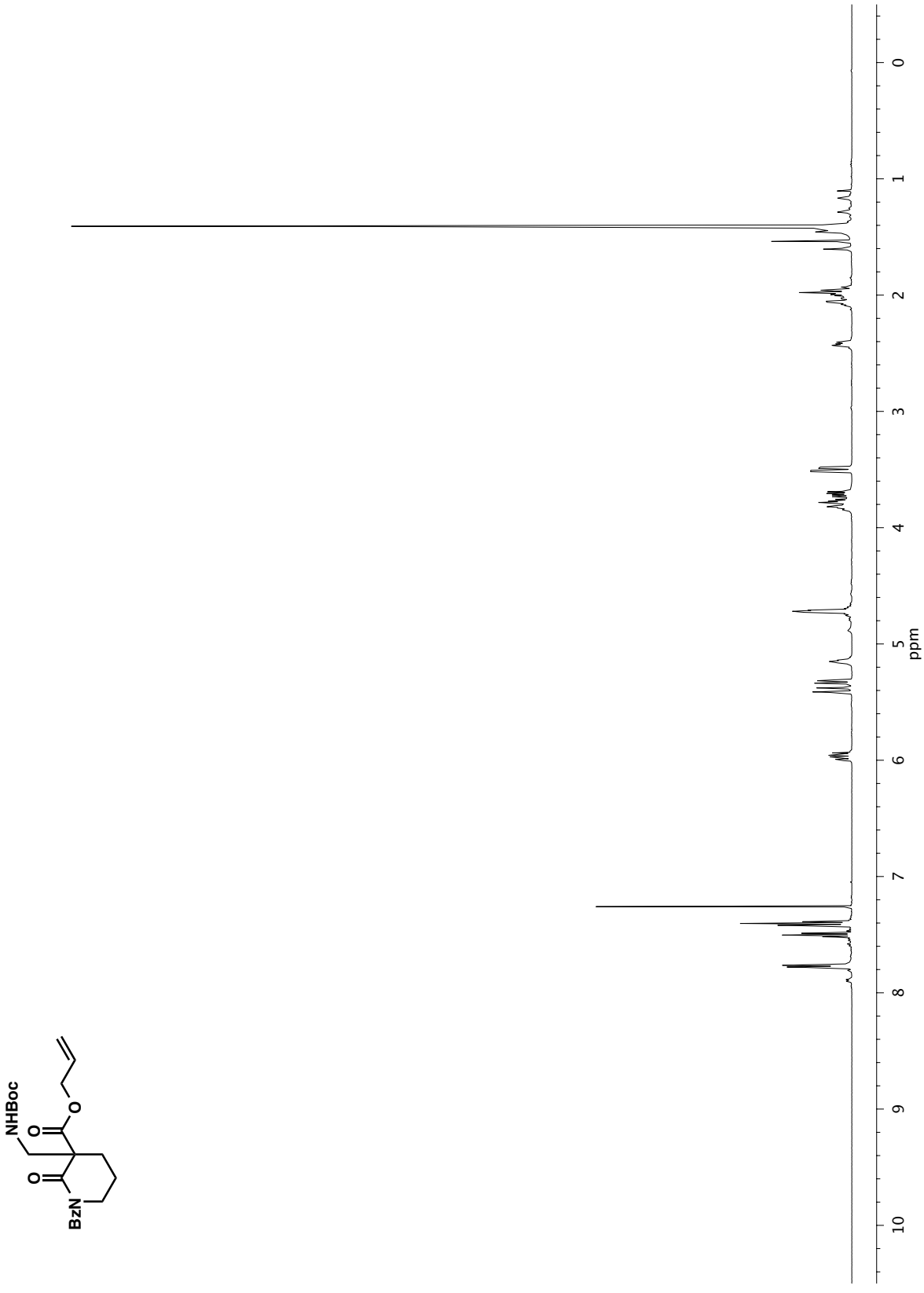
^{1}H NMR (500 MHz, C_6D_6) of compound **6f**.



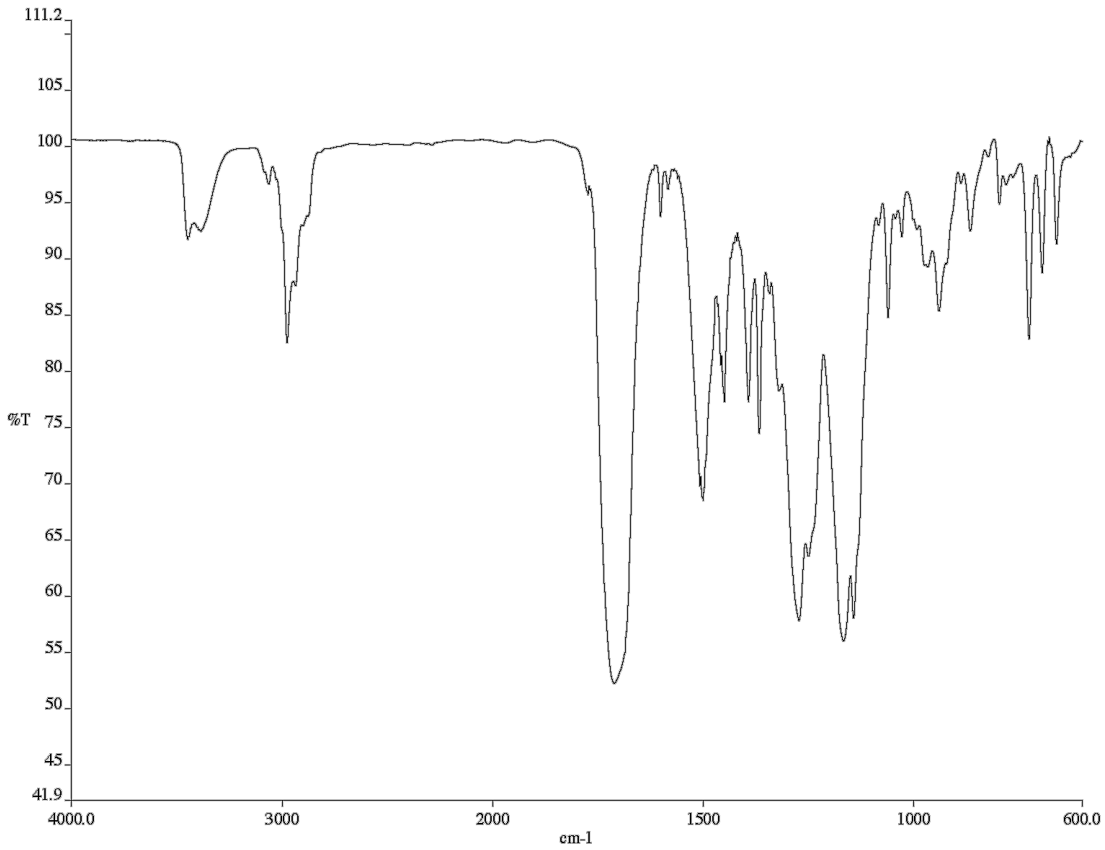
Infrared spectrum (Thin Film, NaCl) of compound **6f**.



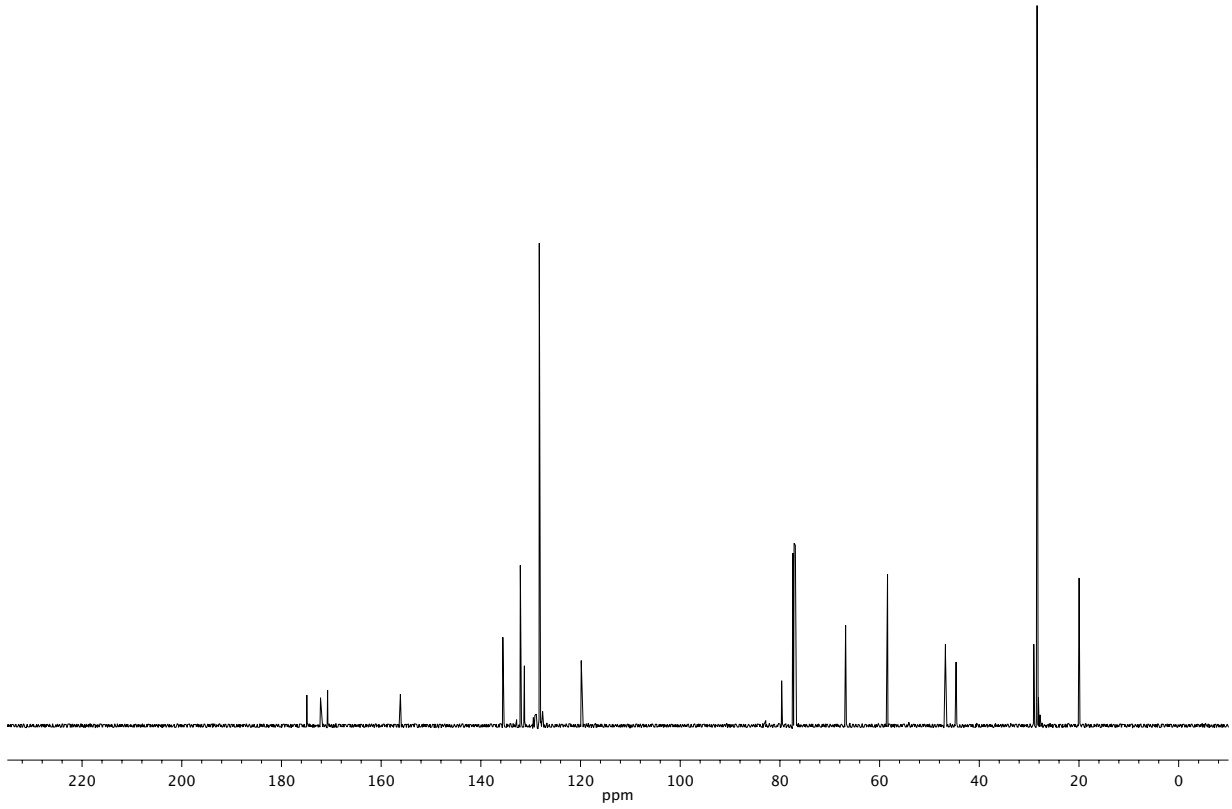
^{13}C NMR (126 MHz, C_6D_6) of compound **6f**.



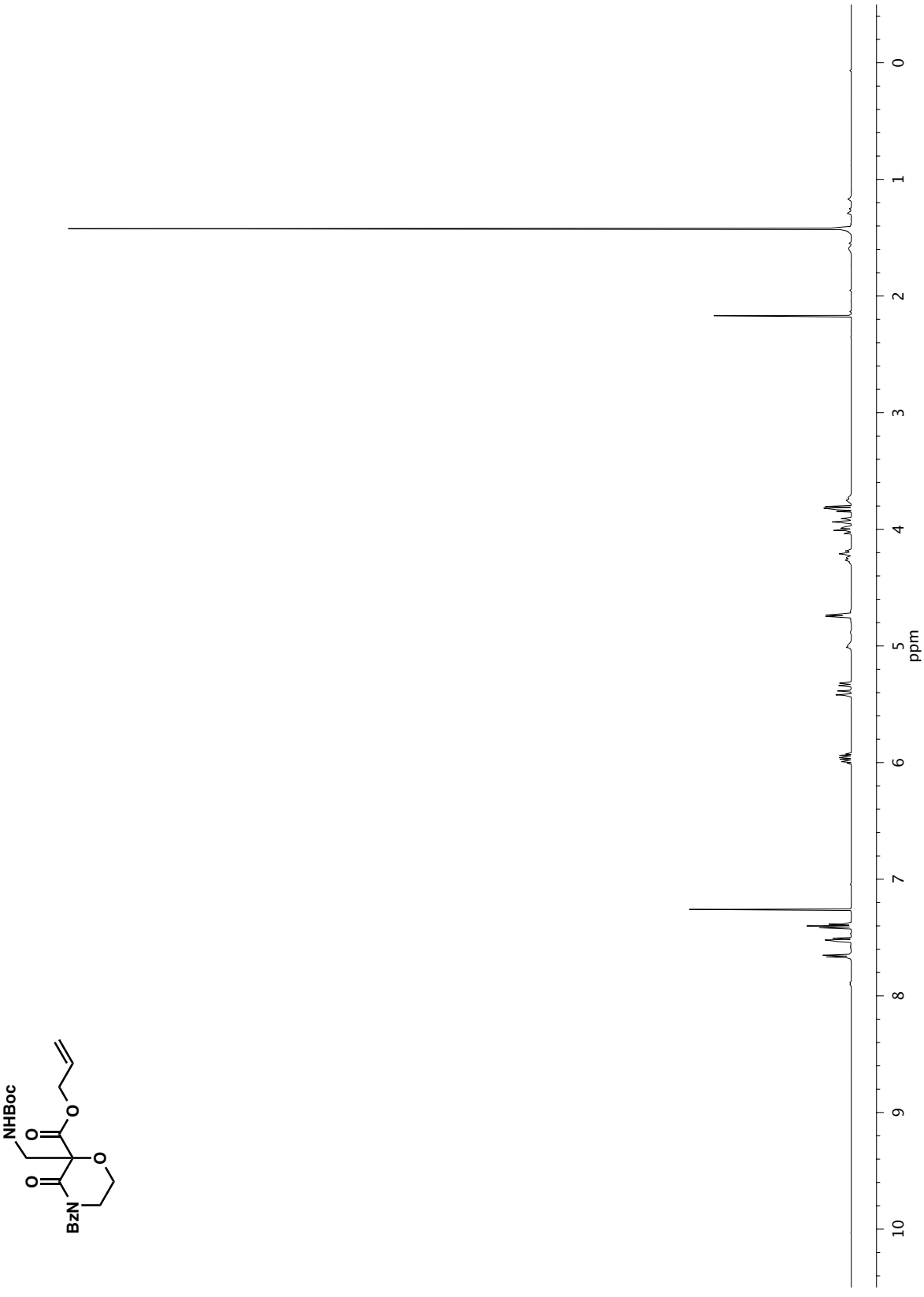
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6g**.



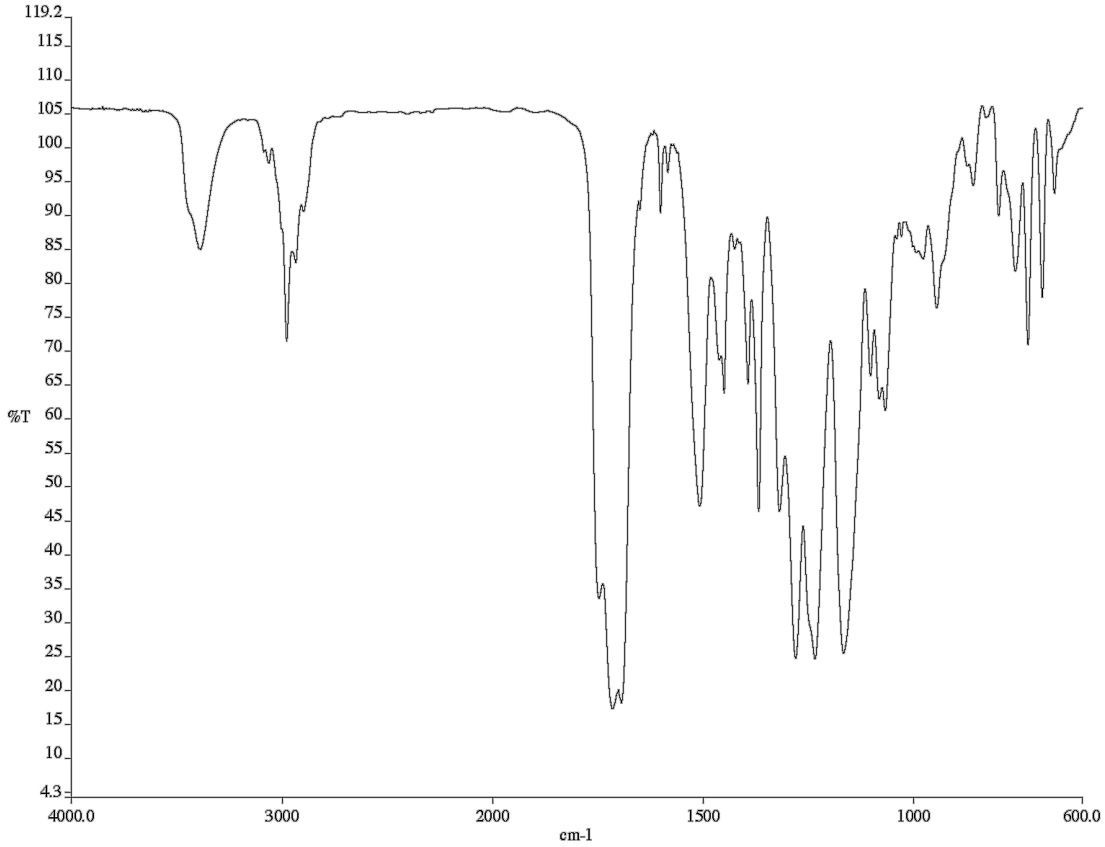
Infrared spectrum (Thin Film, NaCl) of compound **6g.**



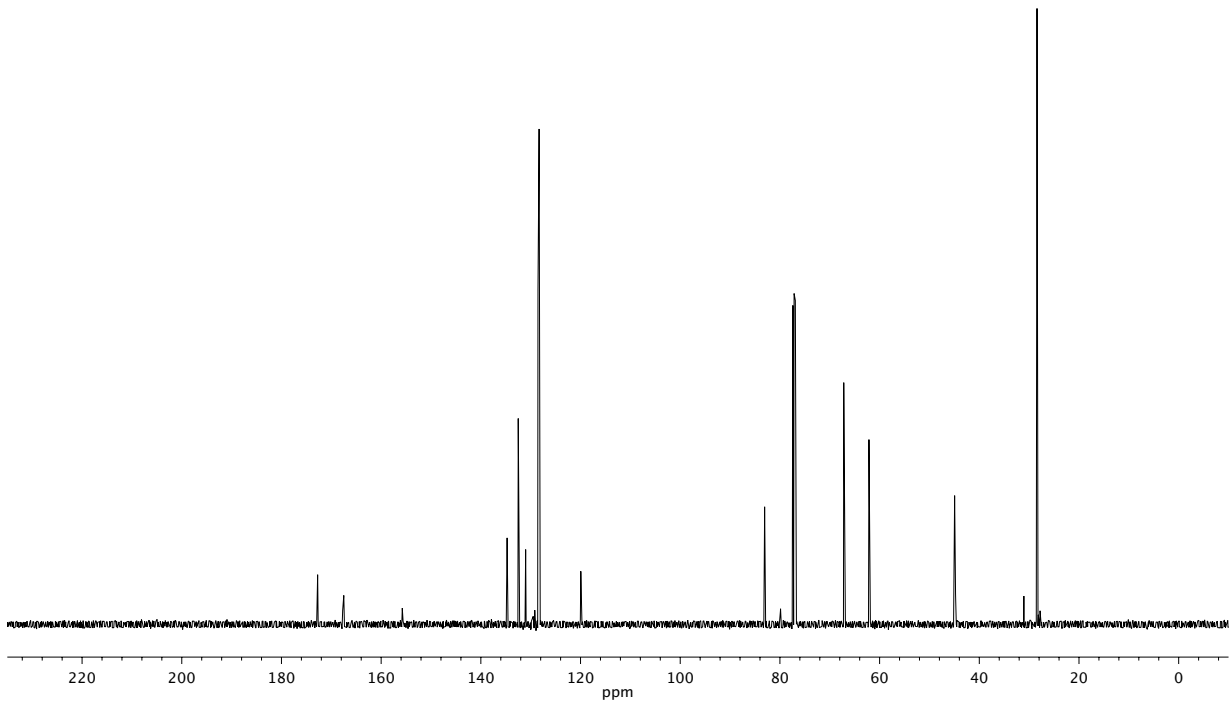
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6g**.



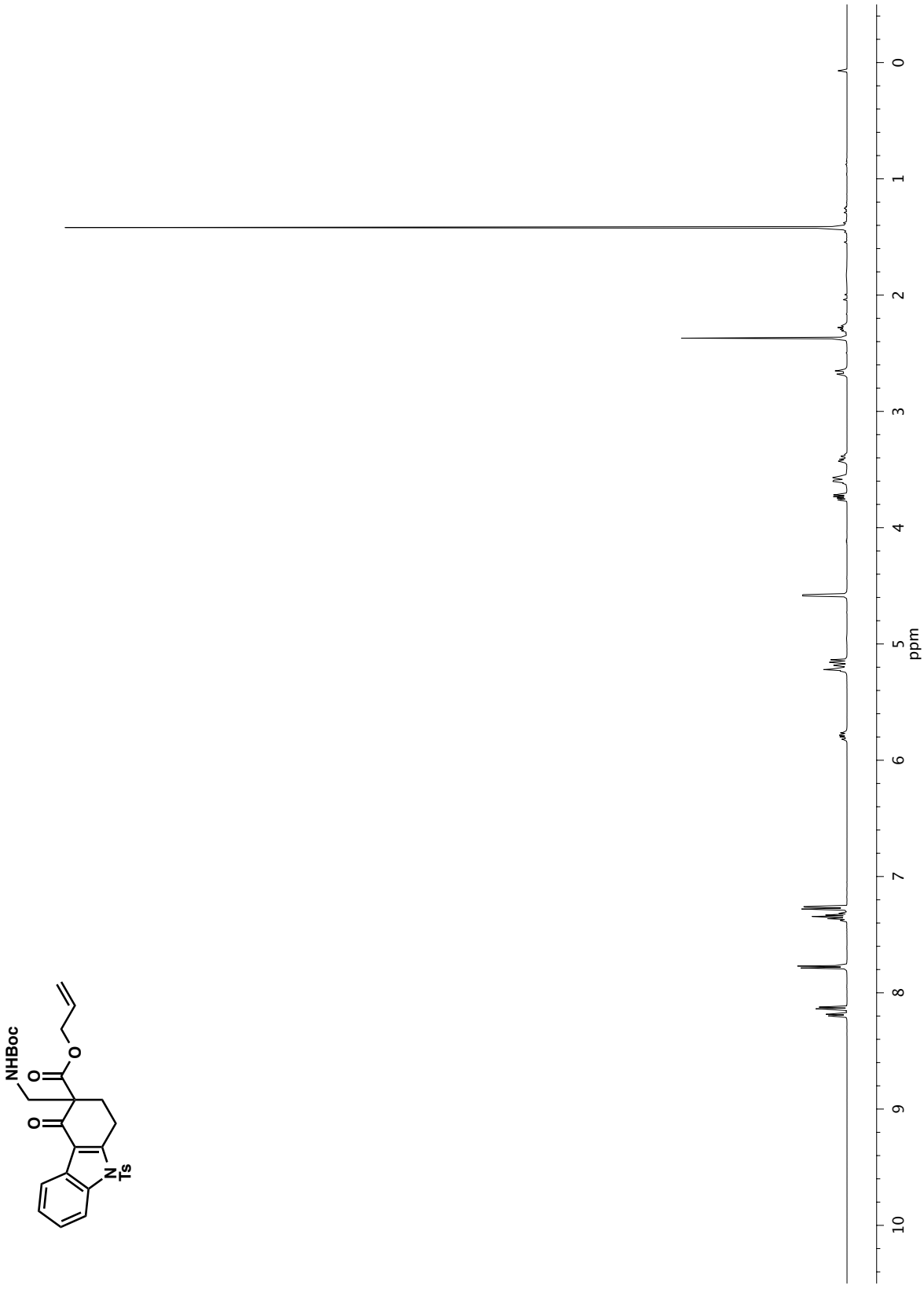
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6h**.



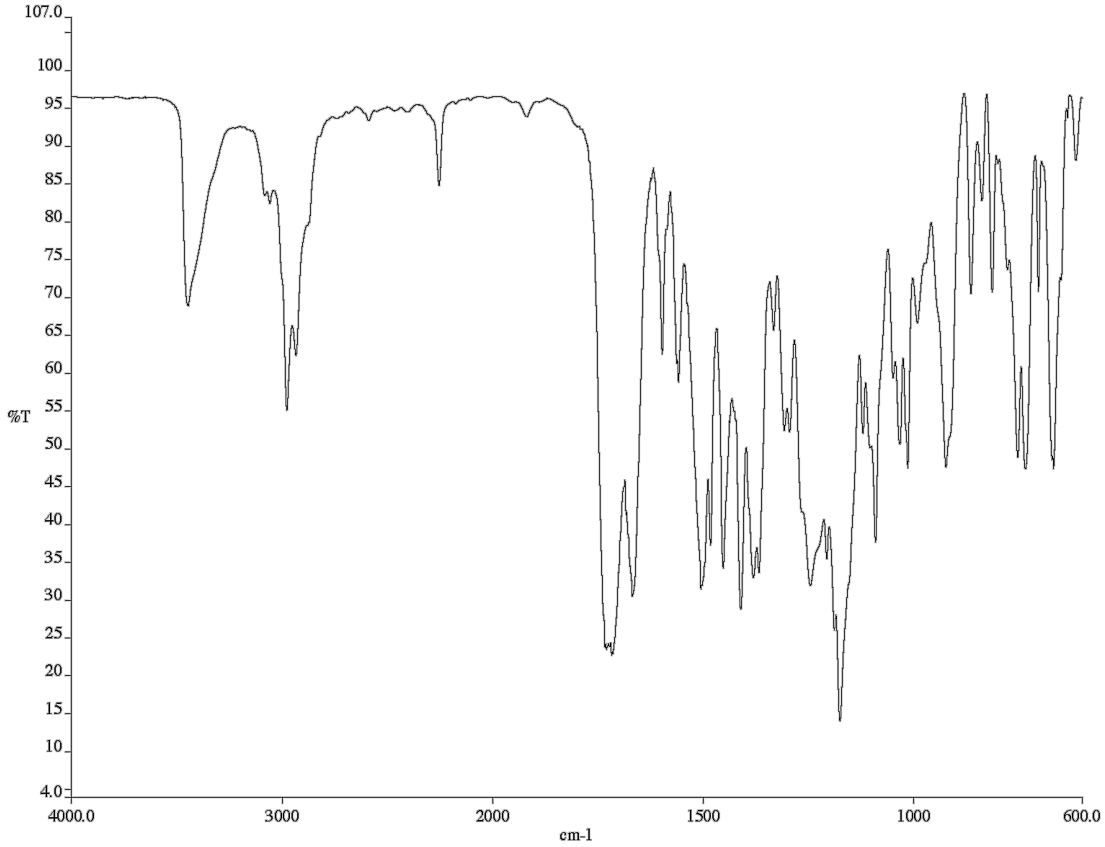
Infrared spectrum (Thin Film, NaCl) of compound **6h.**



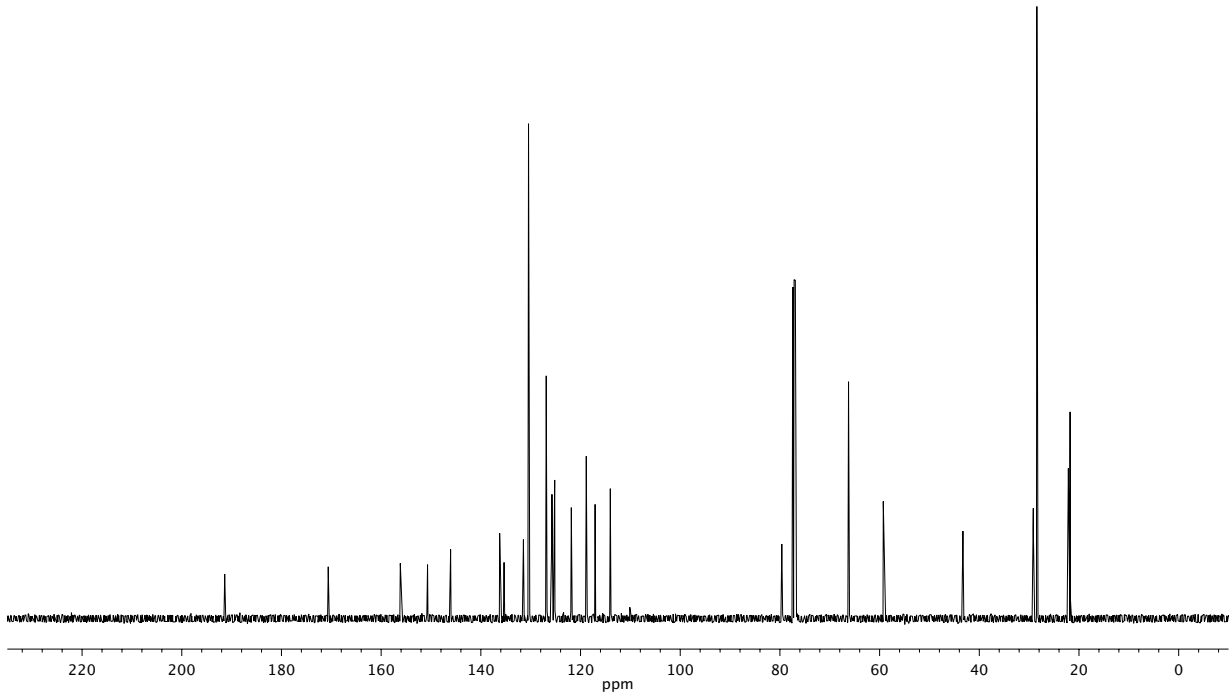
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6h**.



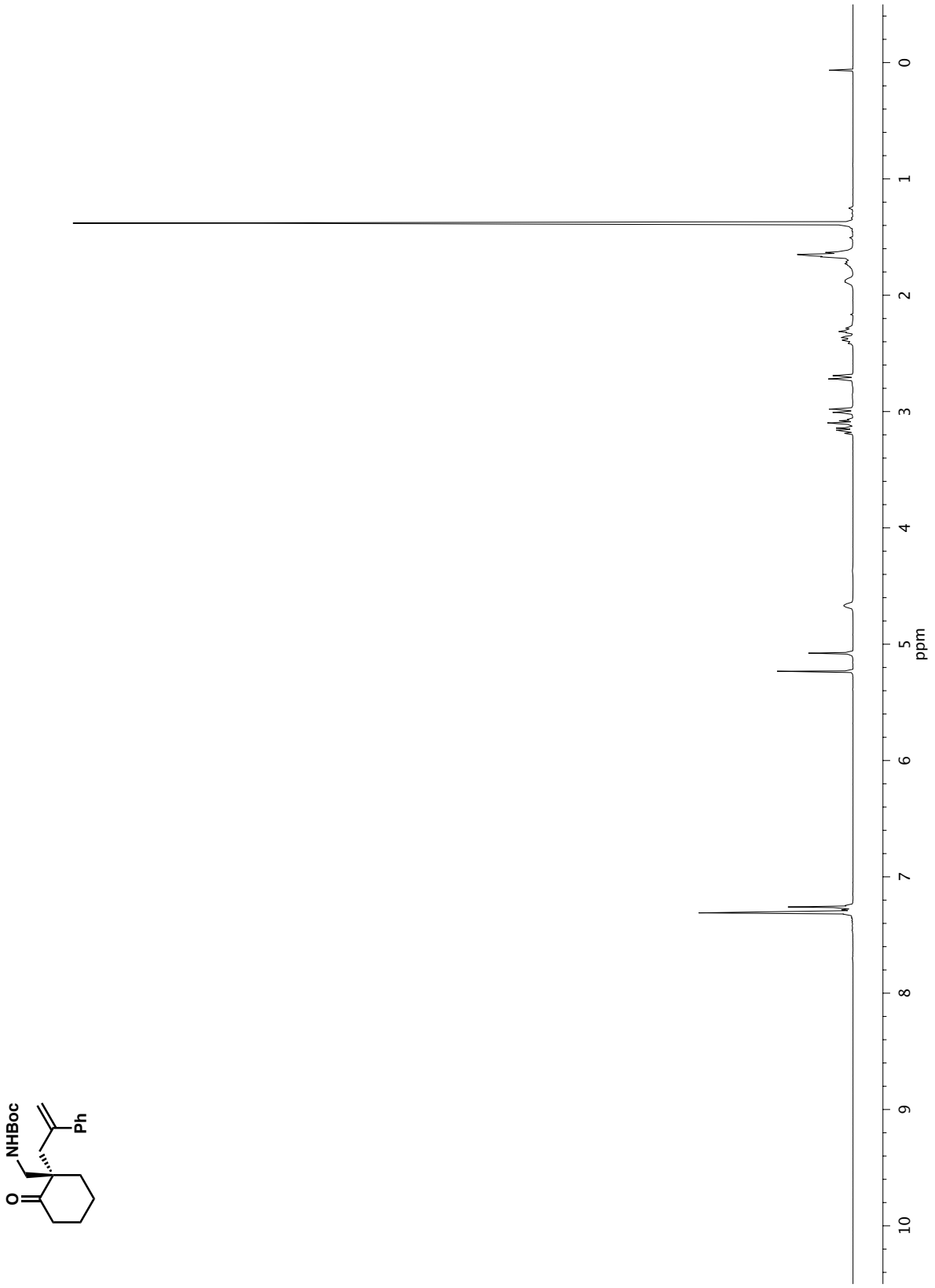
^{1}H NMR (500 MHz, $CDCl_3$) of compound **6i**.



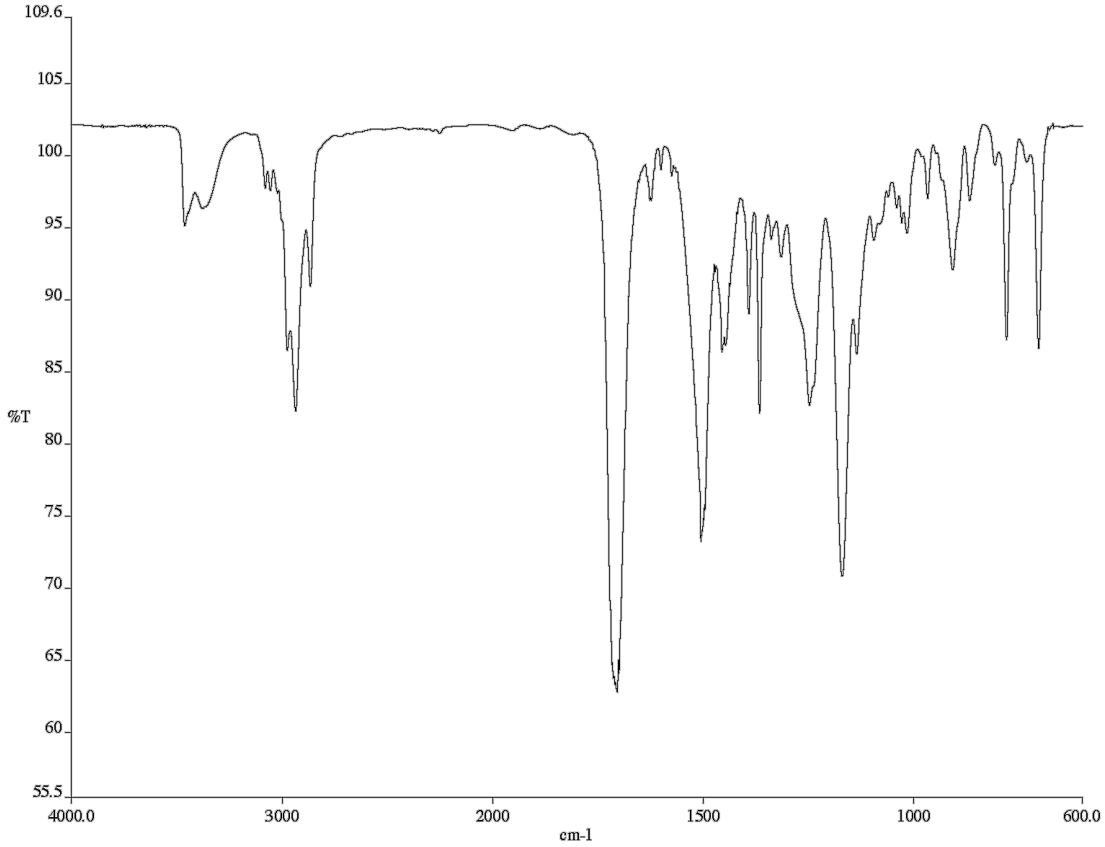
Infrared spectrum (Thin Film, NaCl) of compound **6i.**



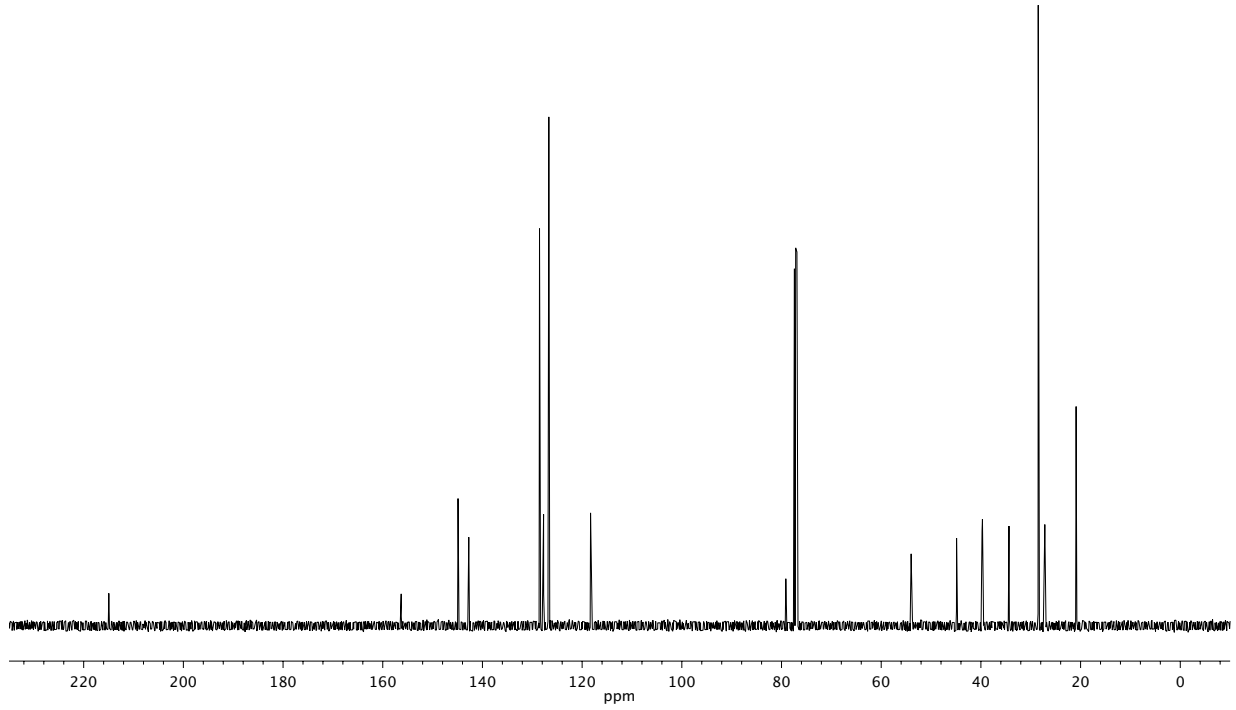
^{13}C NMR (126 MHz, $CDCl_3$) of compound **6i**.



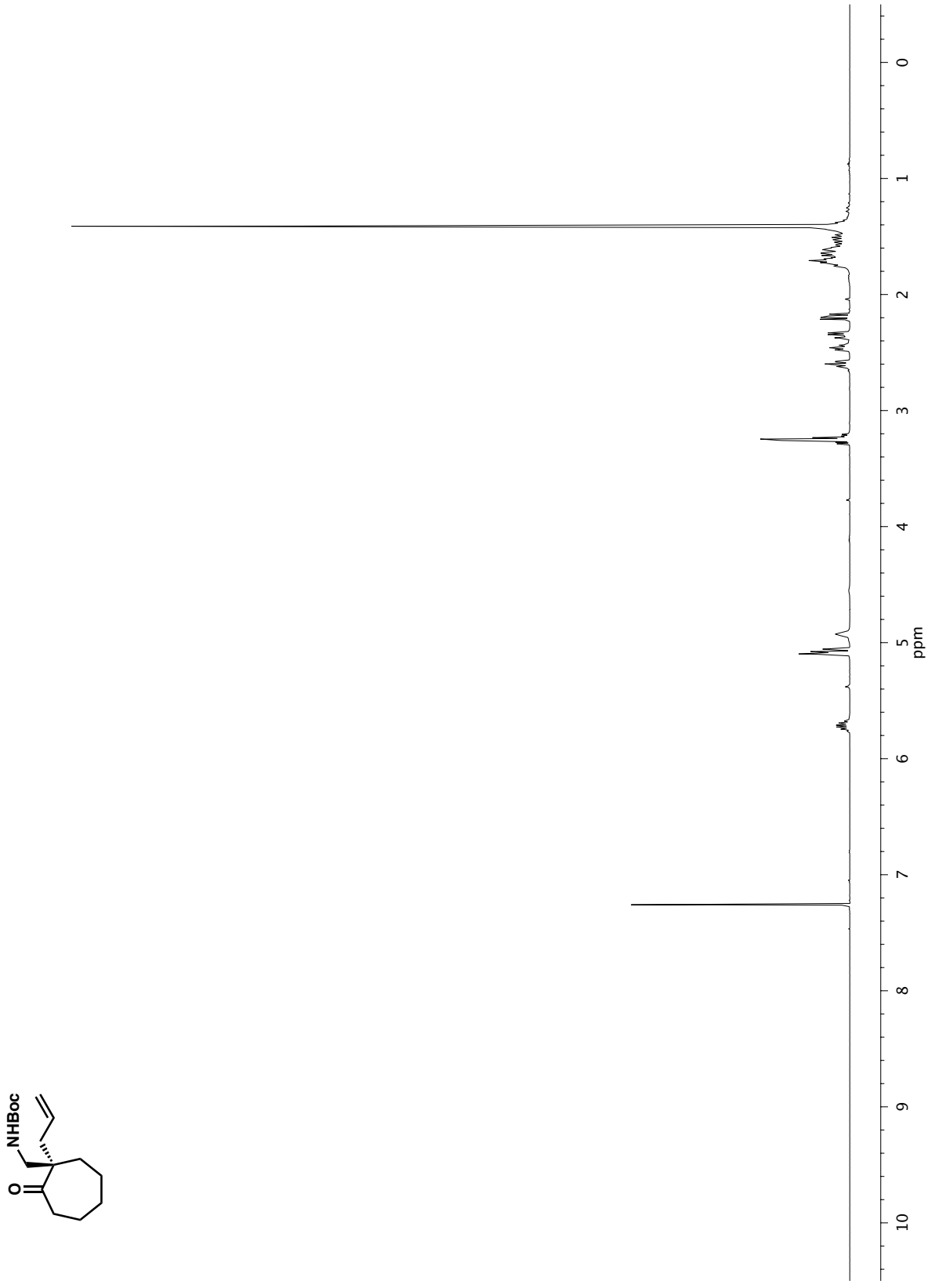
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7a**.



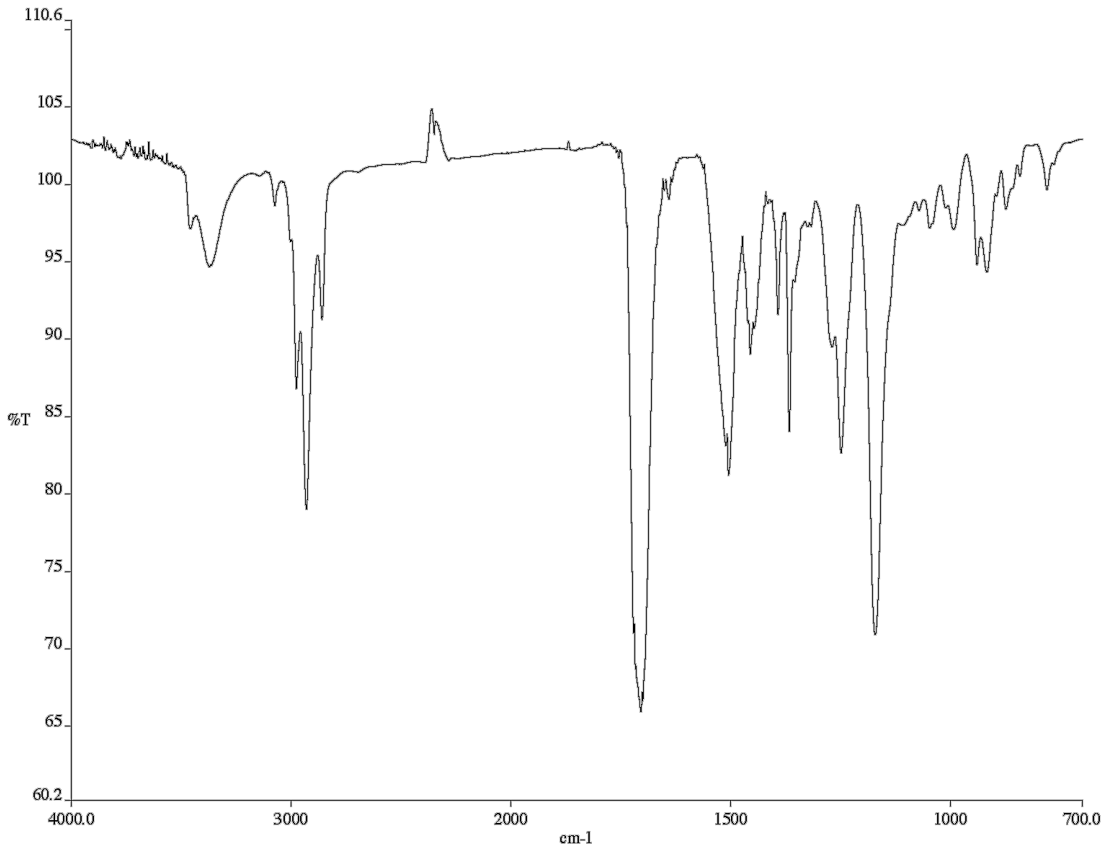
Infrared spectrum (Thin Film, NaCl) of compound **7a.**



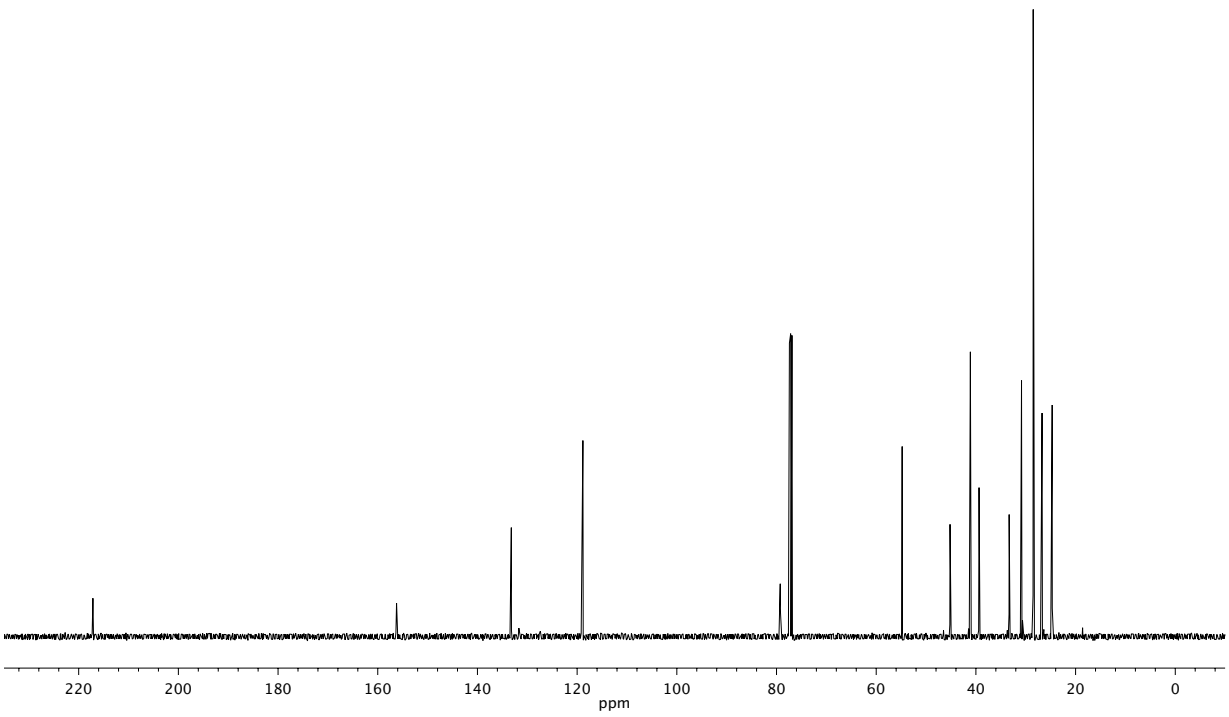
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7a**.



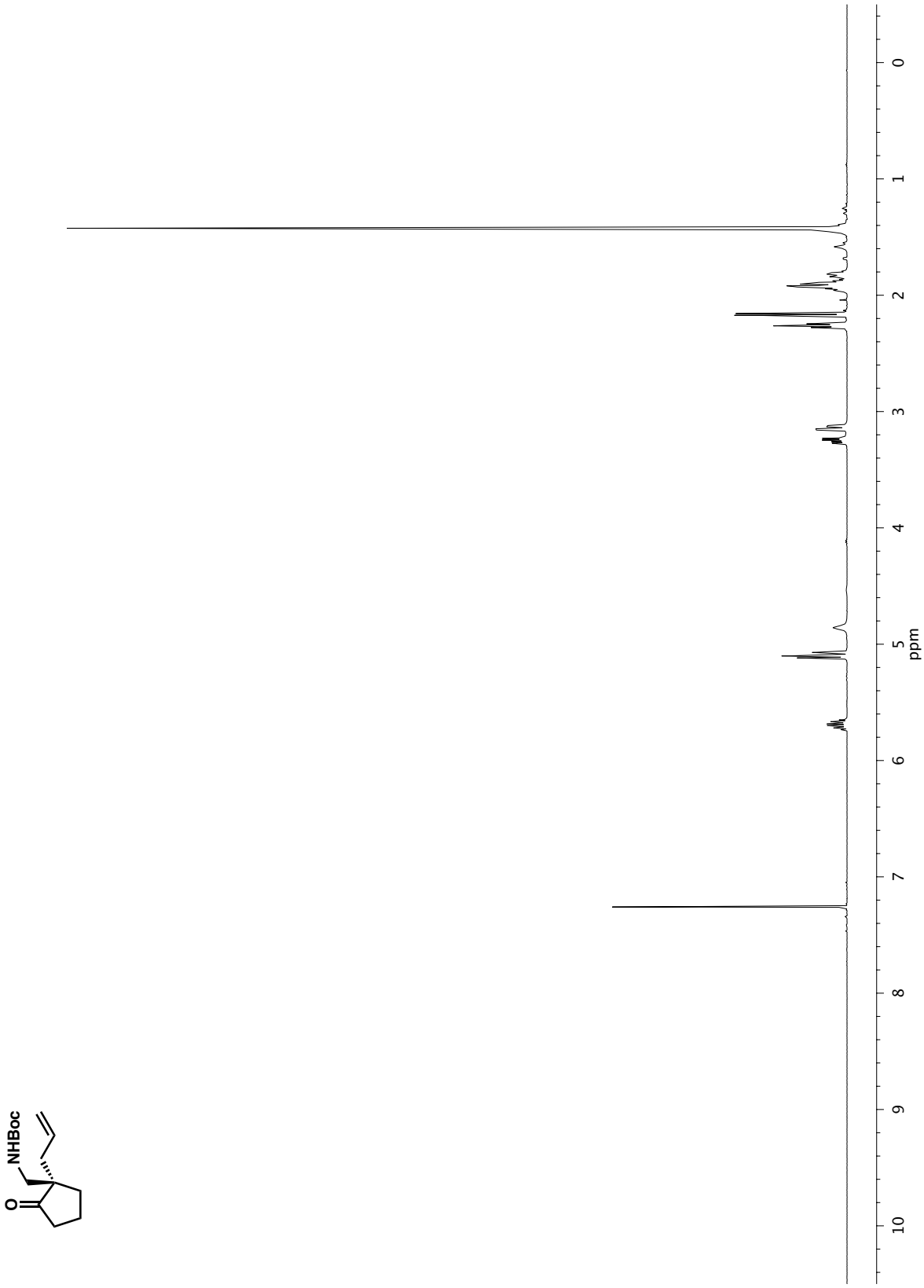
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7b**.



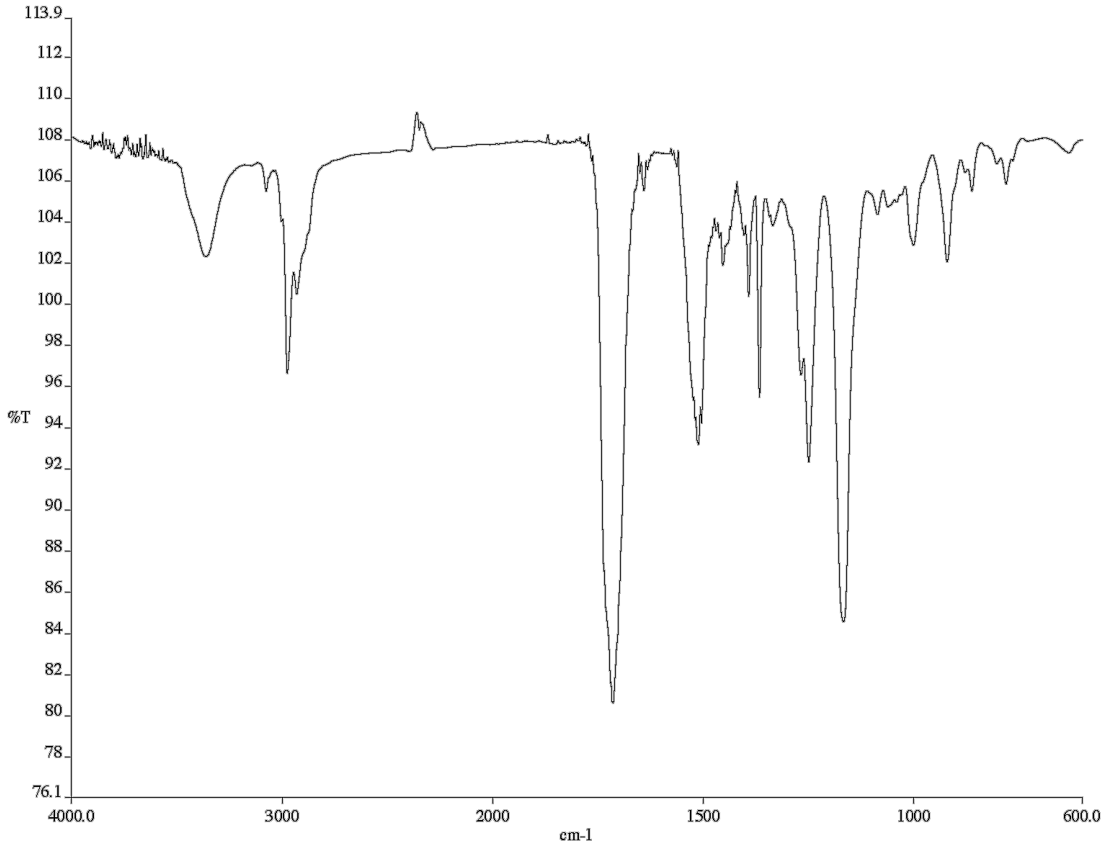
Infrared spectrum (Thin Film, NaCl) of compound **7b.**



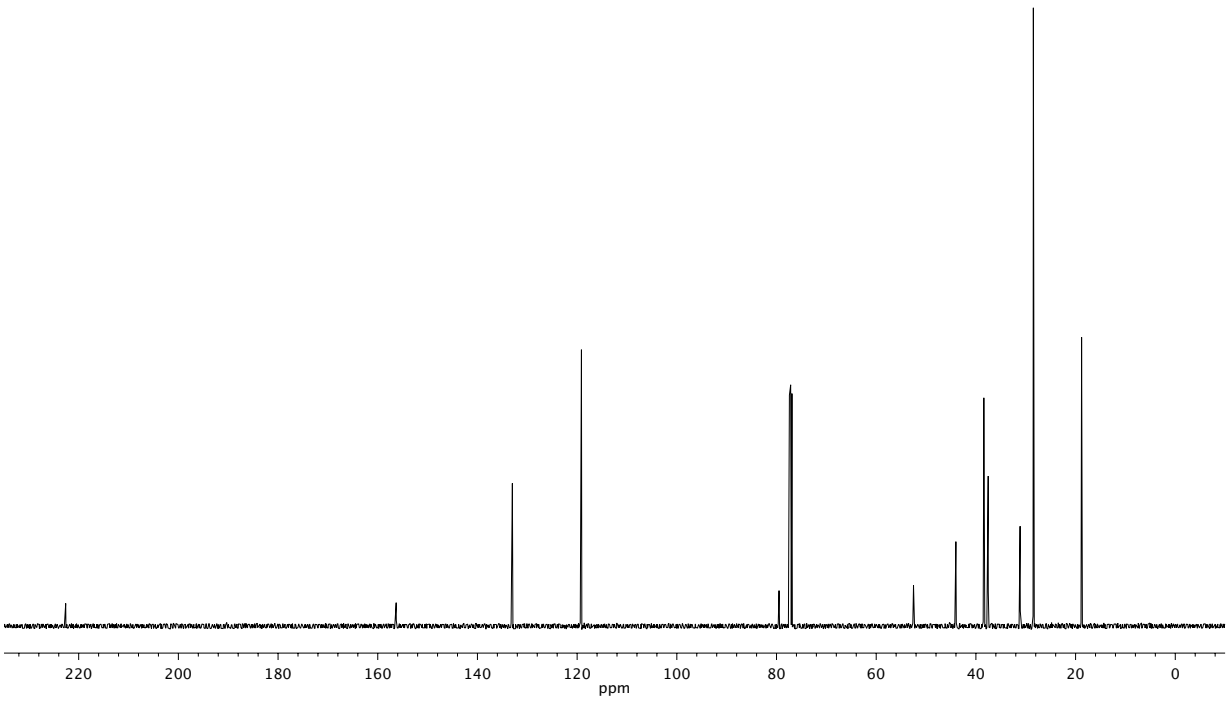
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7b**.



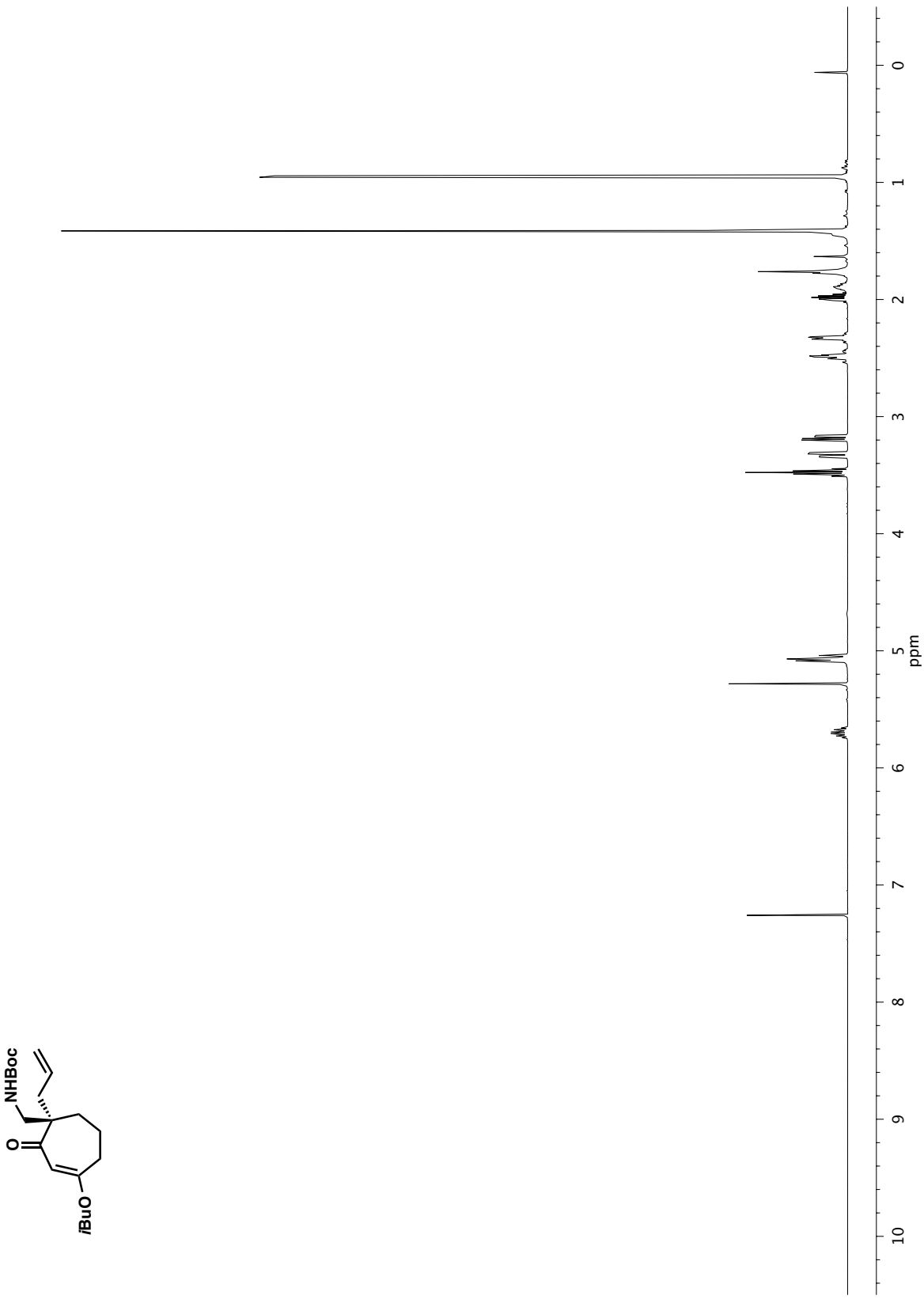
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7c**.



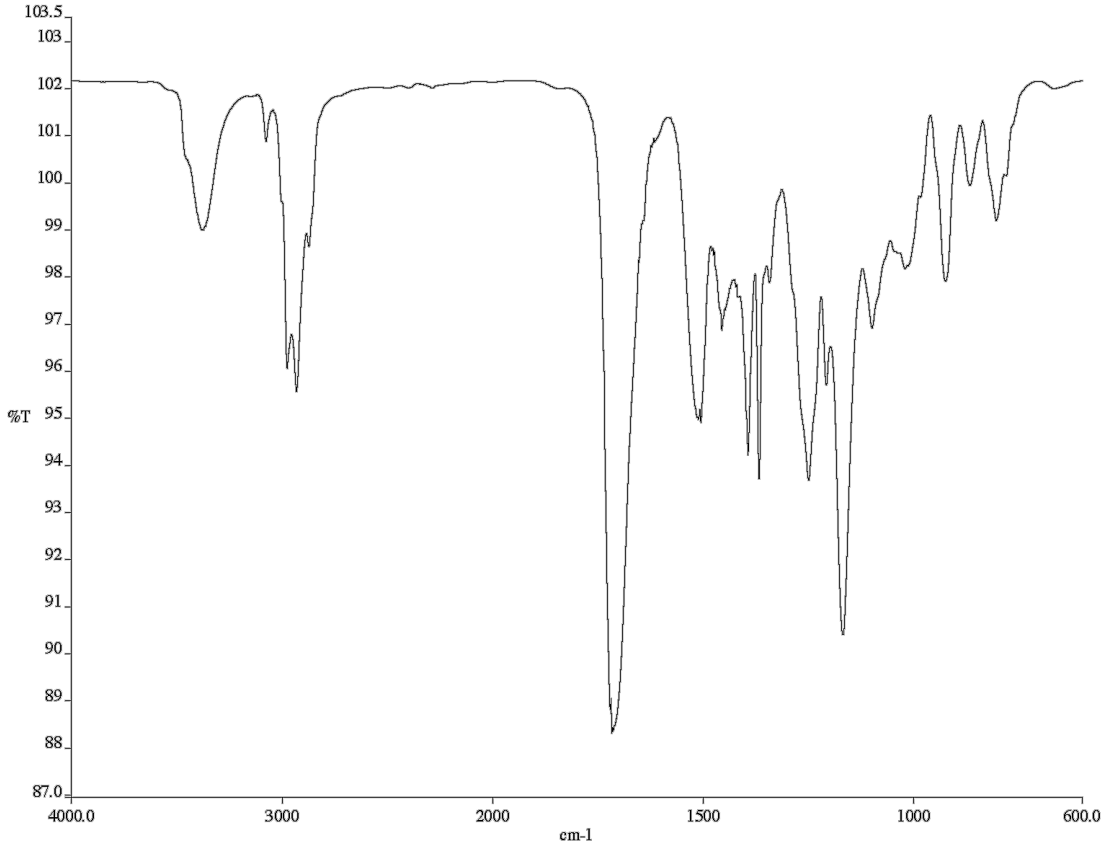
Infrared spectrum (Thin Film, NaCl) of compound **7c.**



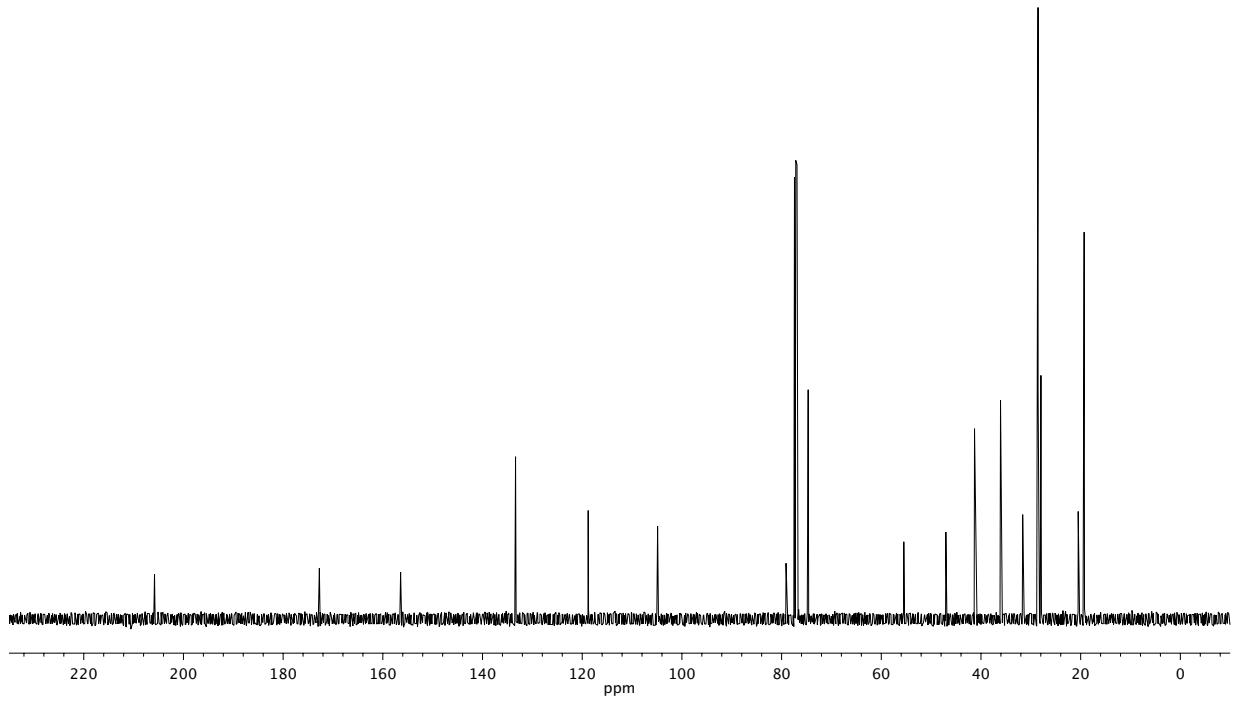
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7c**.



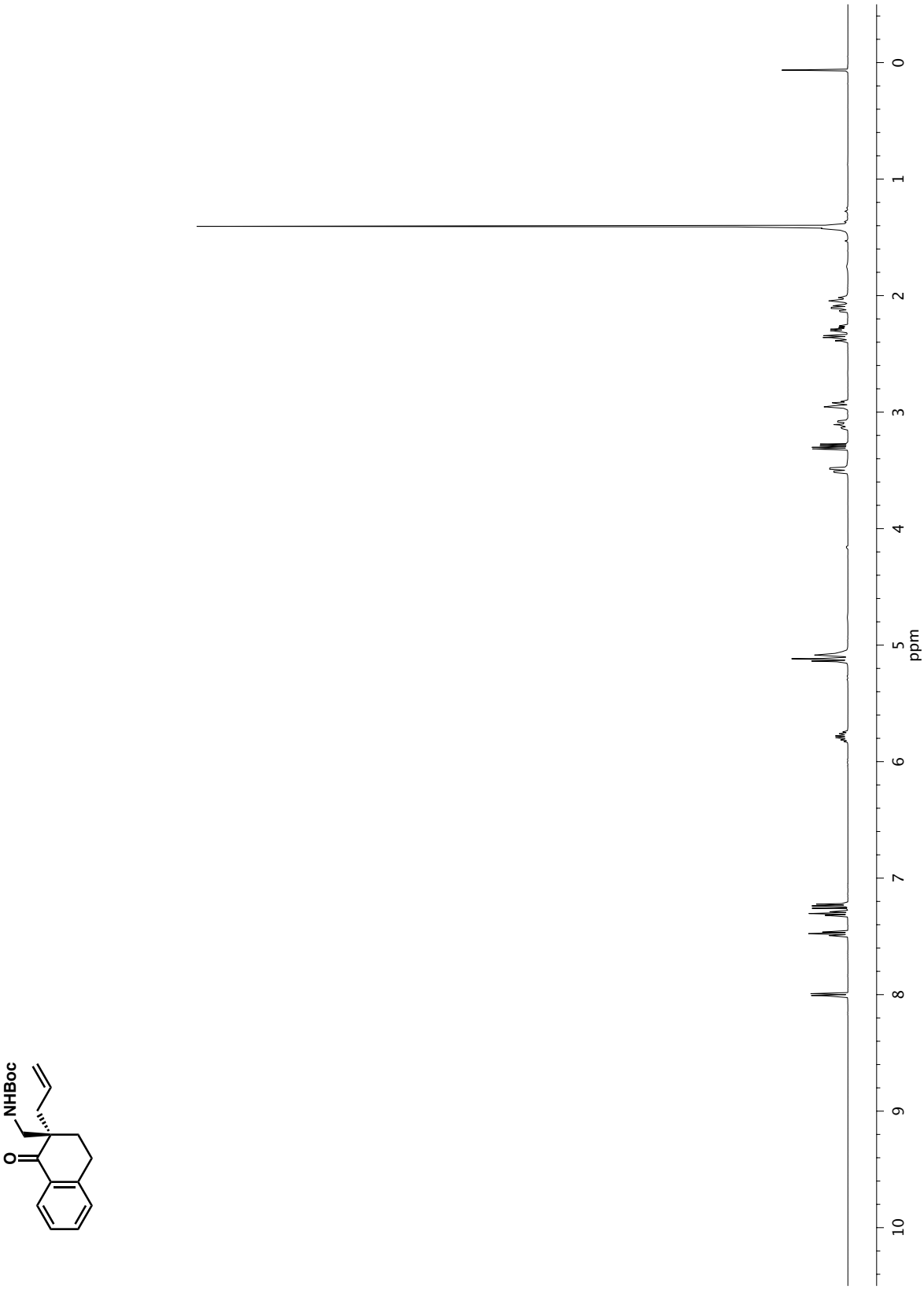
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7d**.



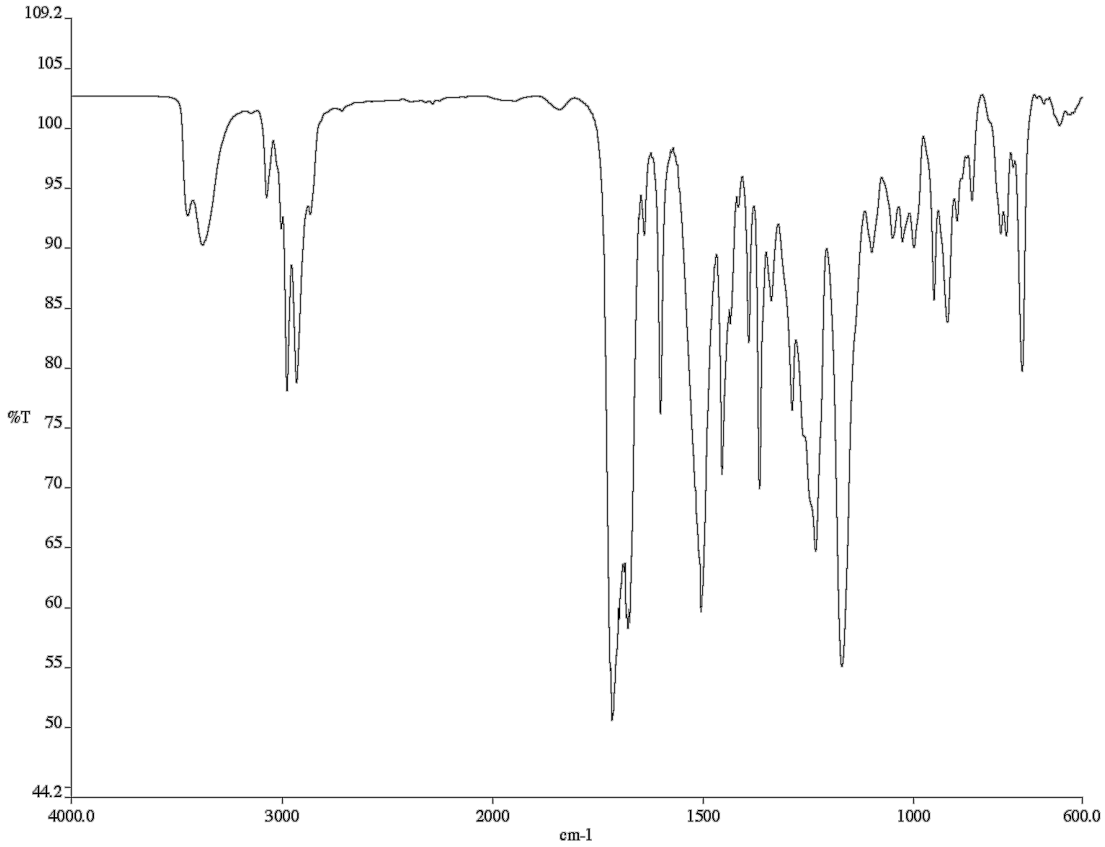
Infrared spectrum (Thin Film, NaCl) of compound **7d.**



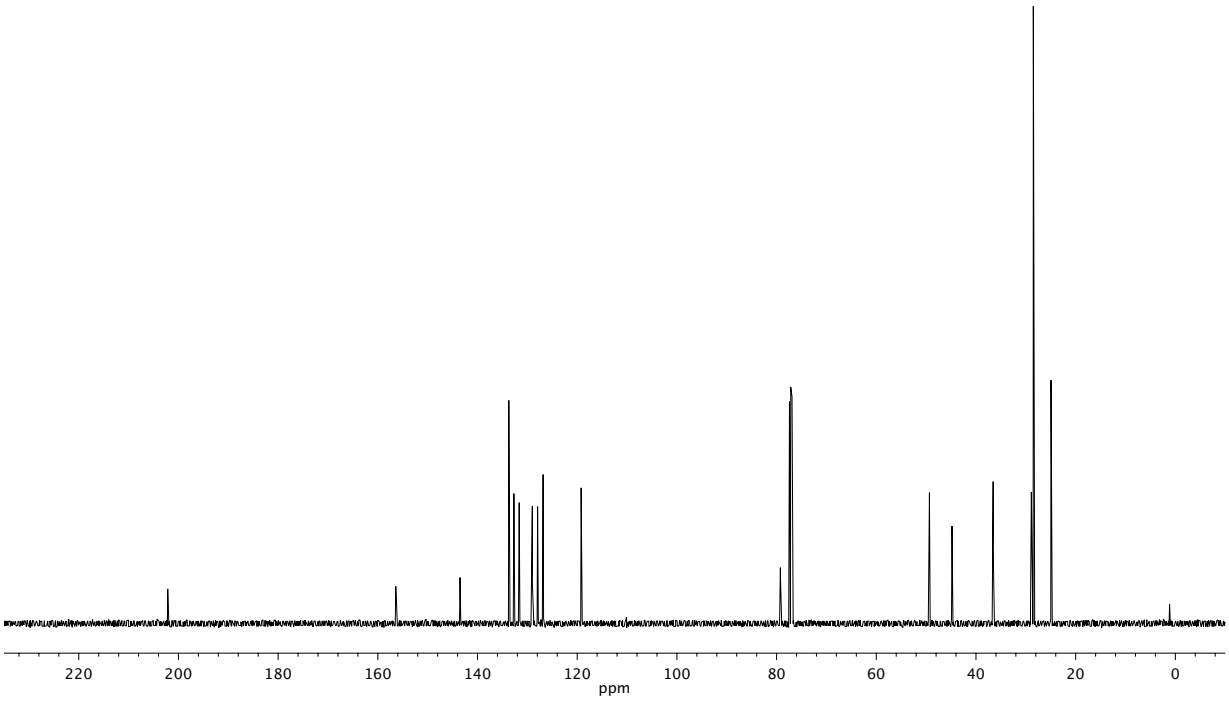
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7d**.



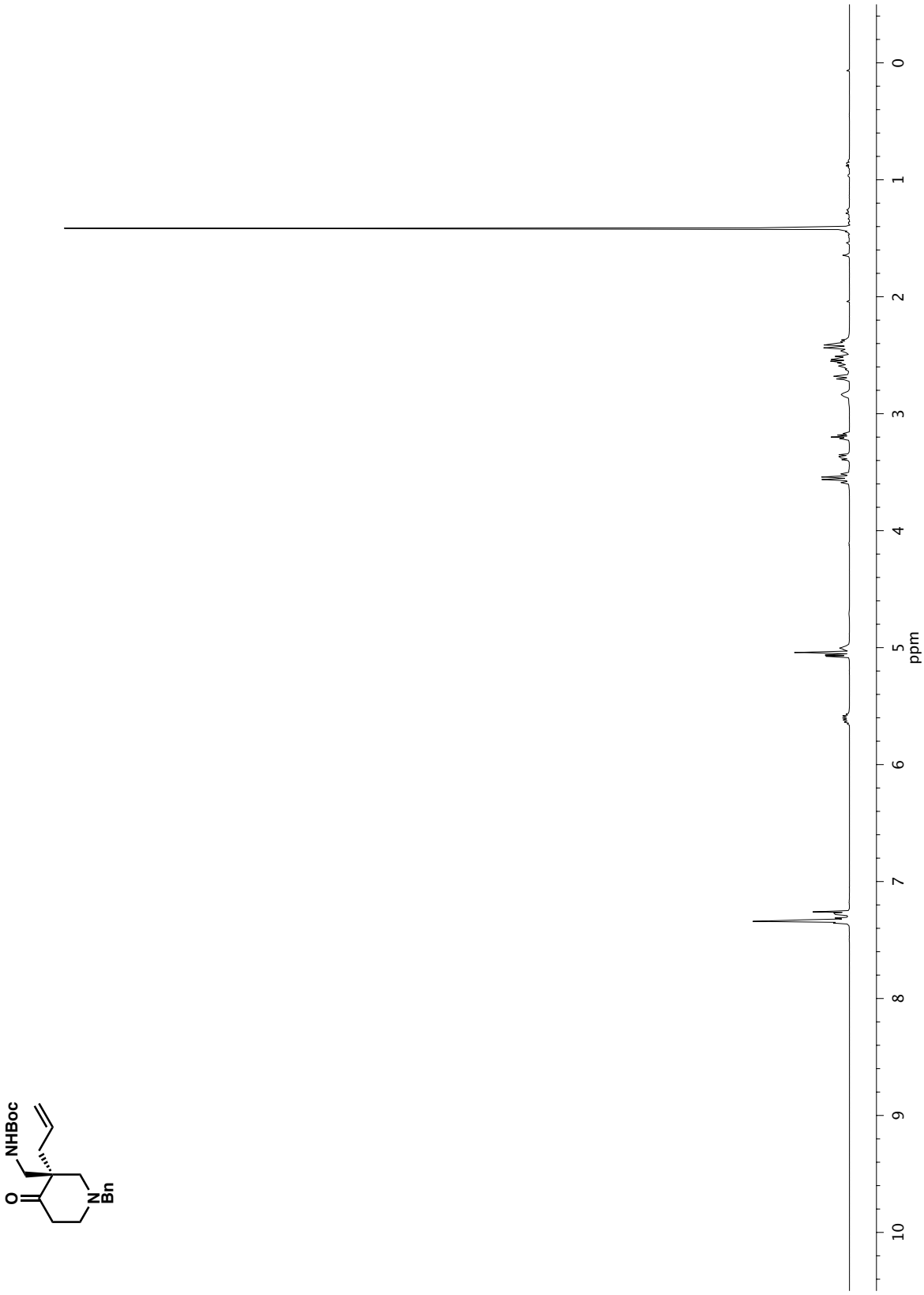
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7e**.



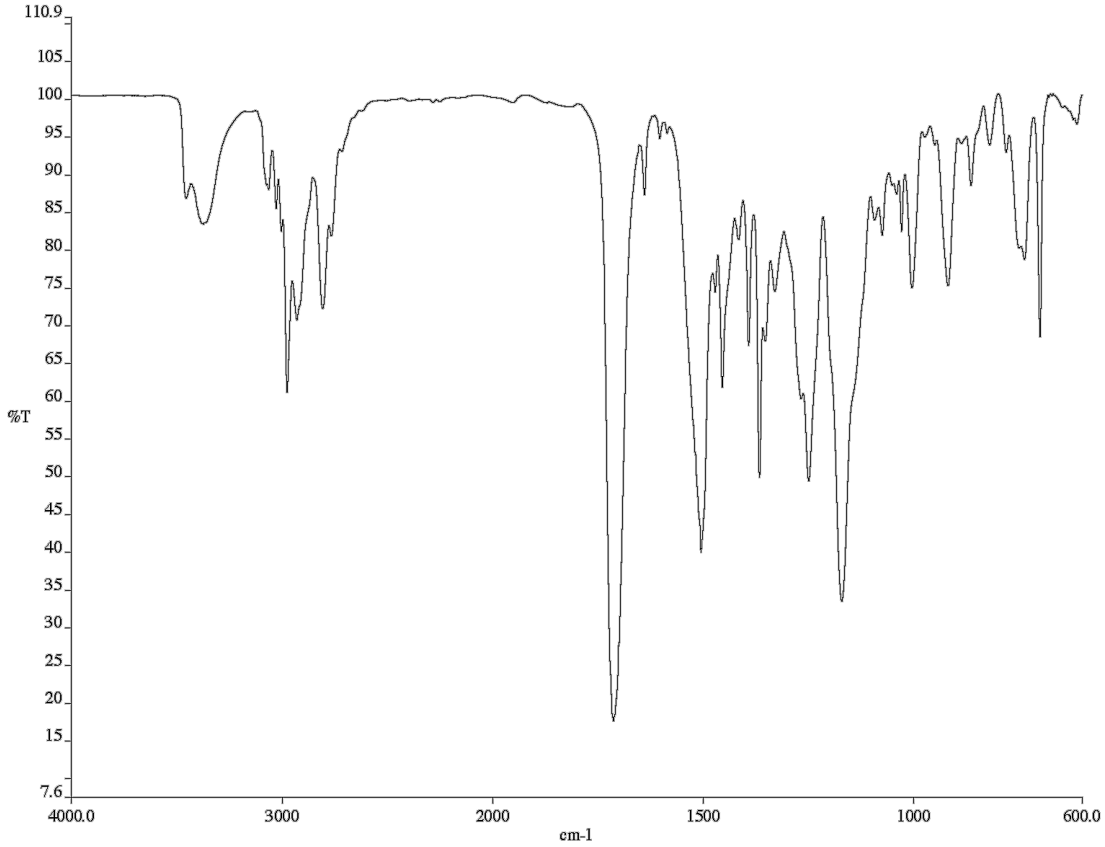
Infrared spectrum (Thin Film, NaCl) of compound **7e.**



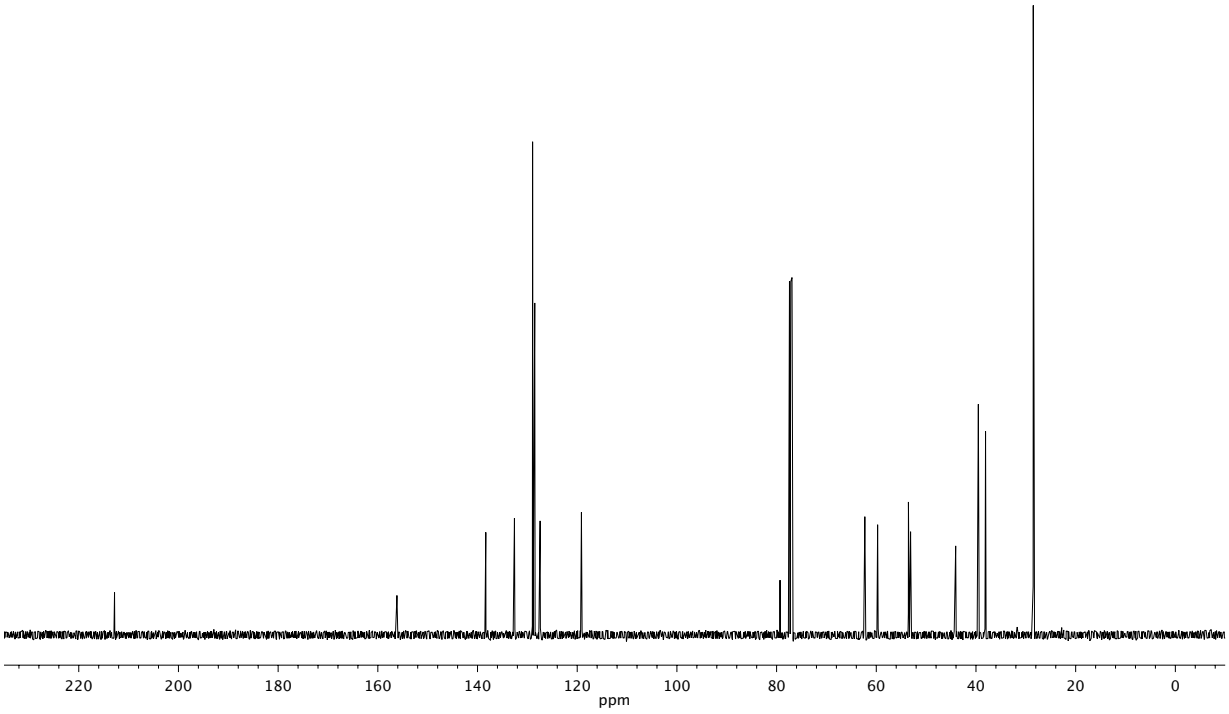
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7e**.



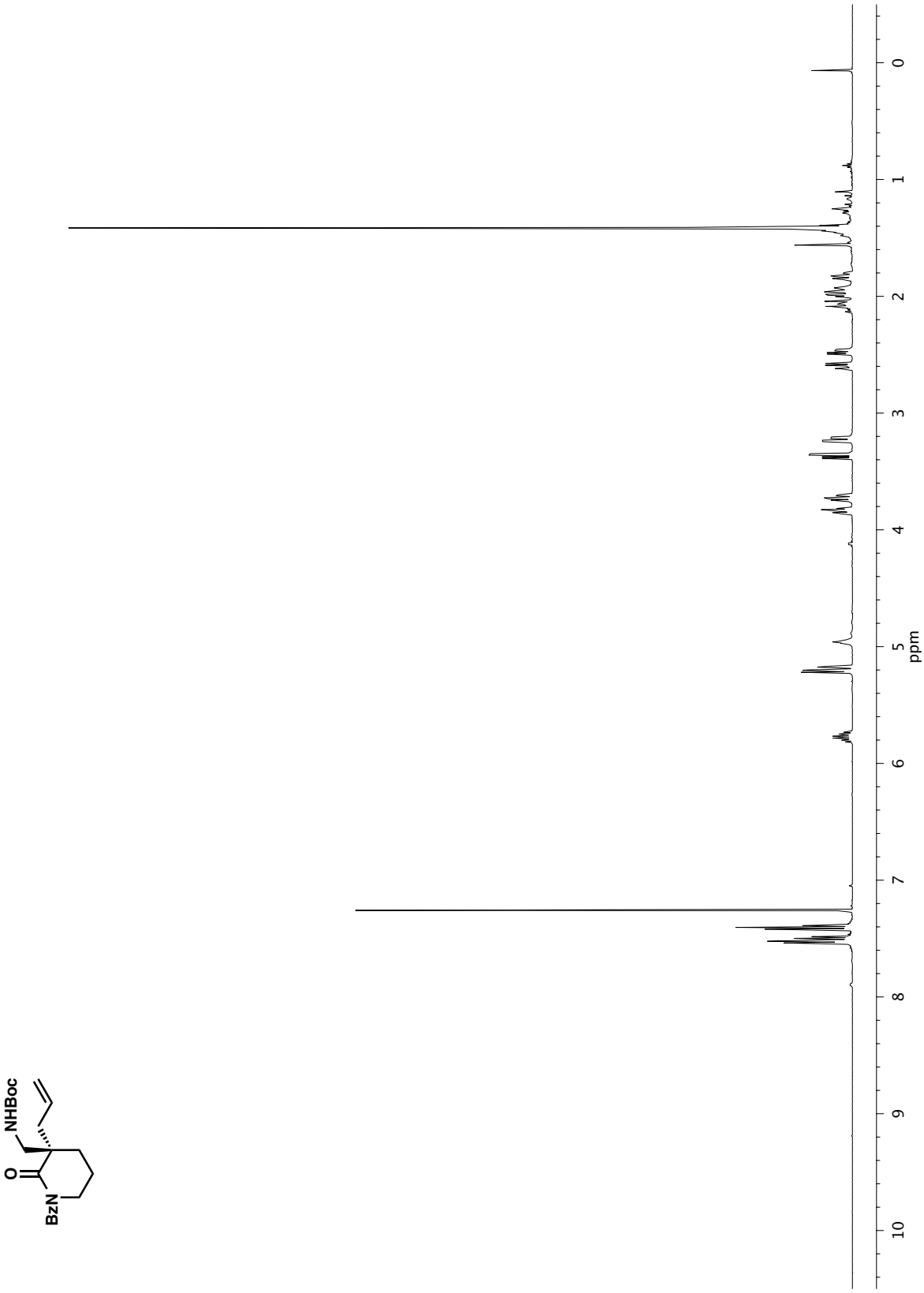
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7f**.



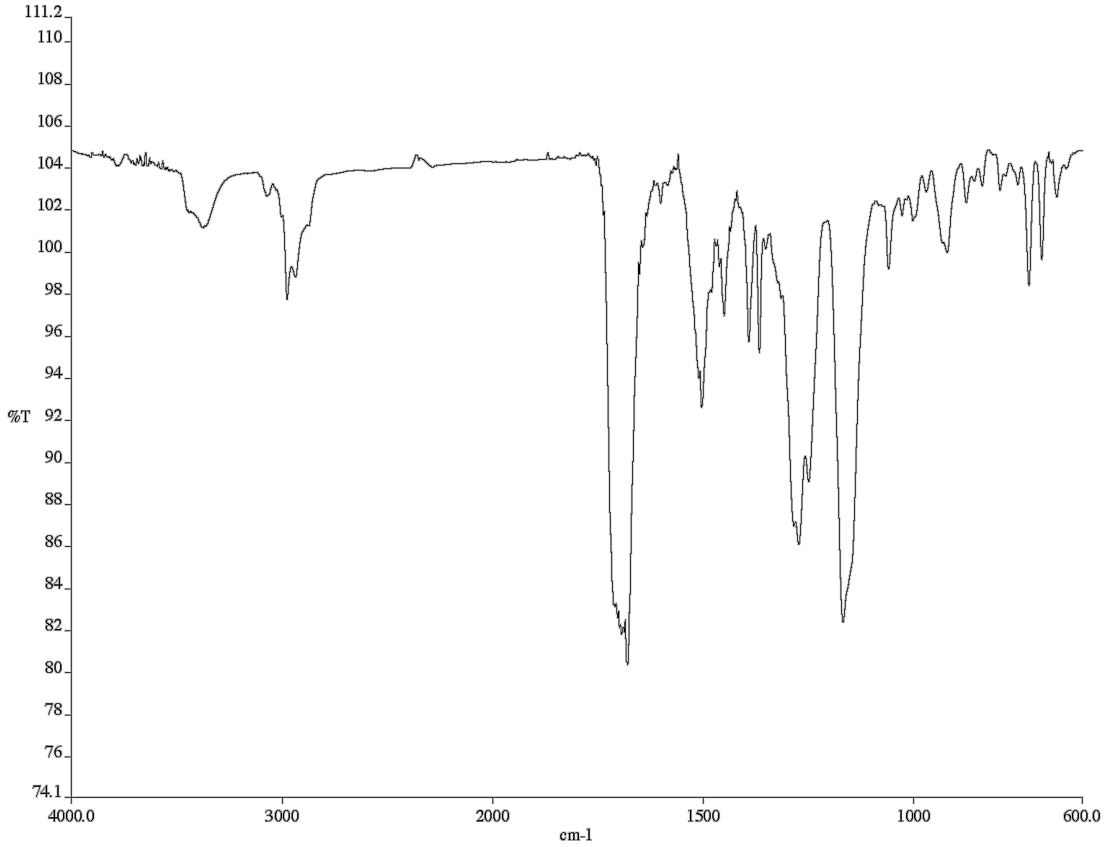
Infrared spectrum (Thin Film, NaCl) of compound **7f.**



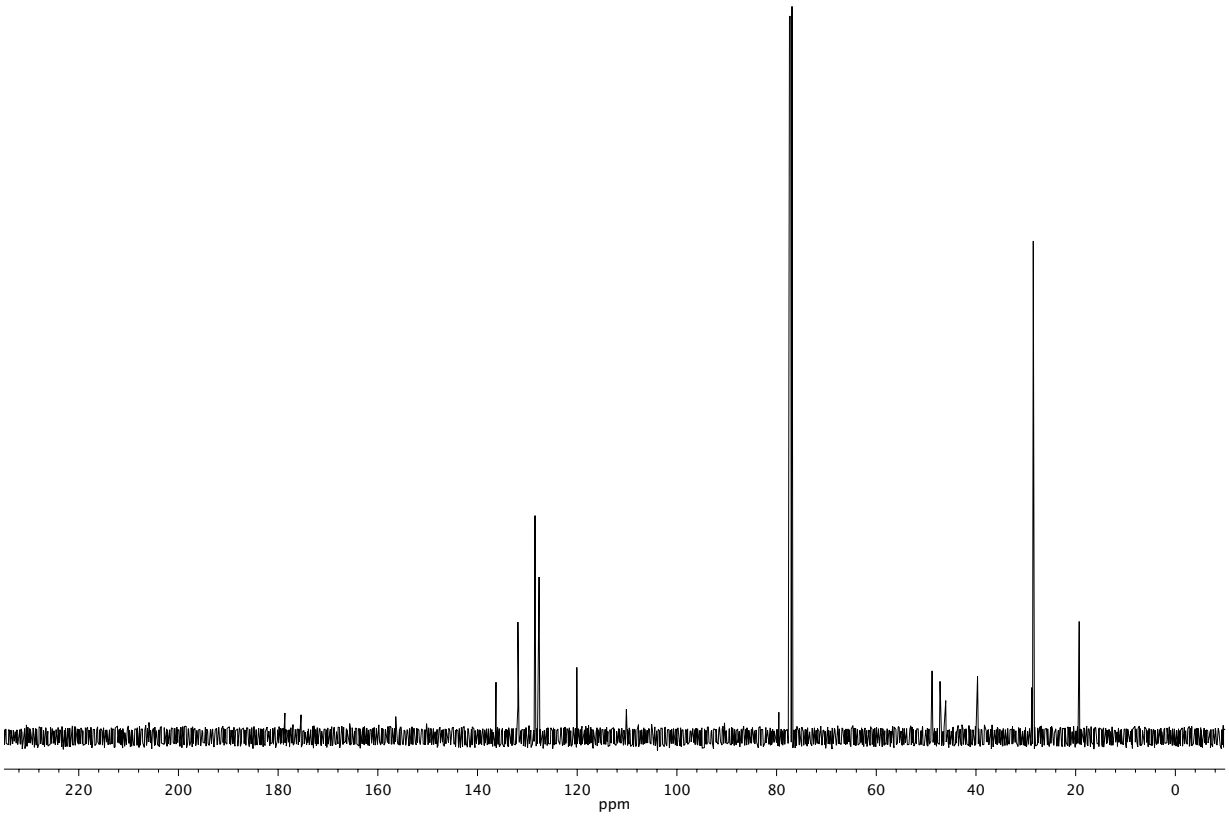
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7f**.



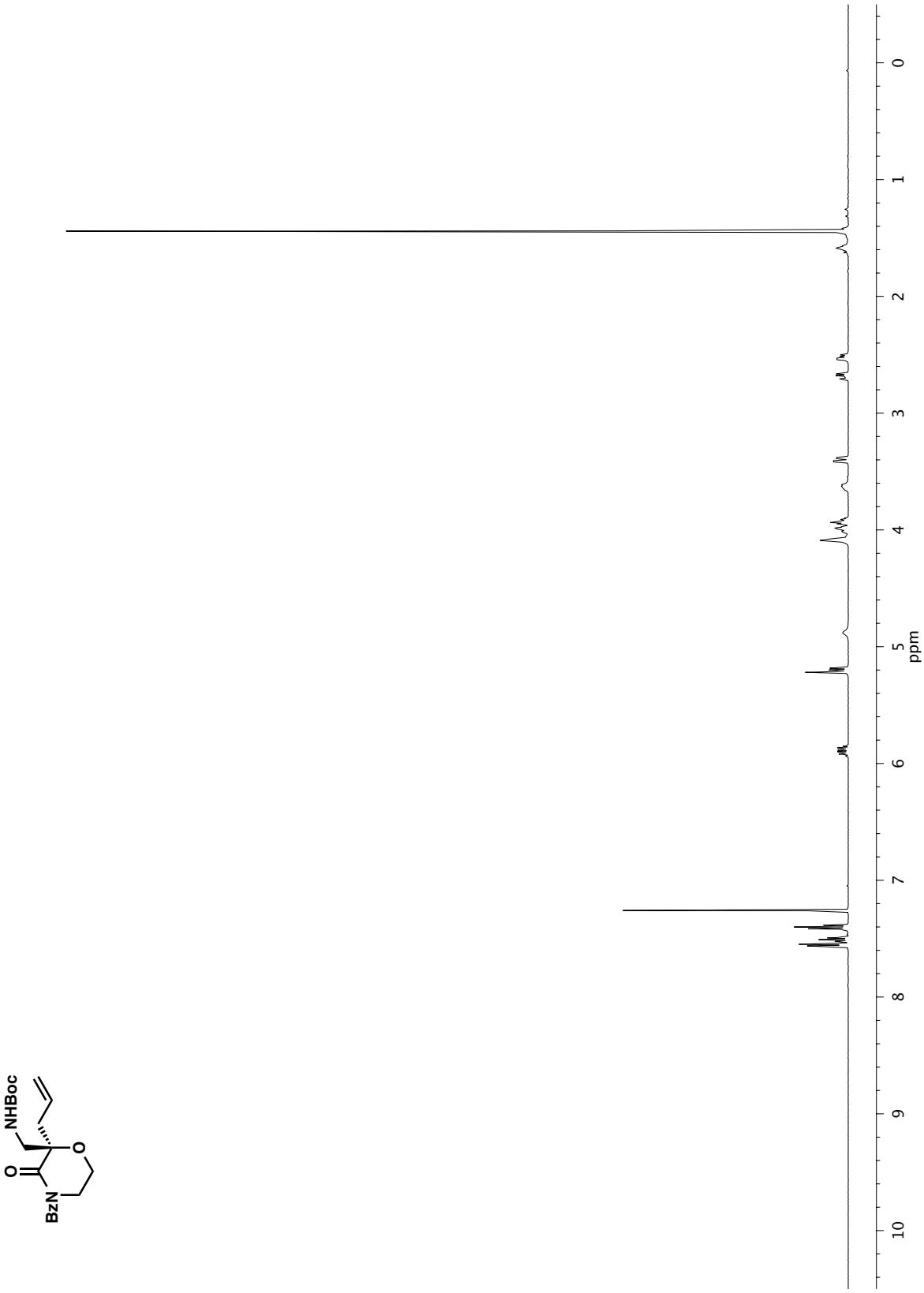
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7g**.



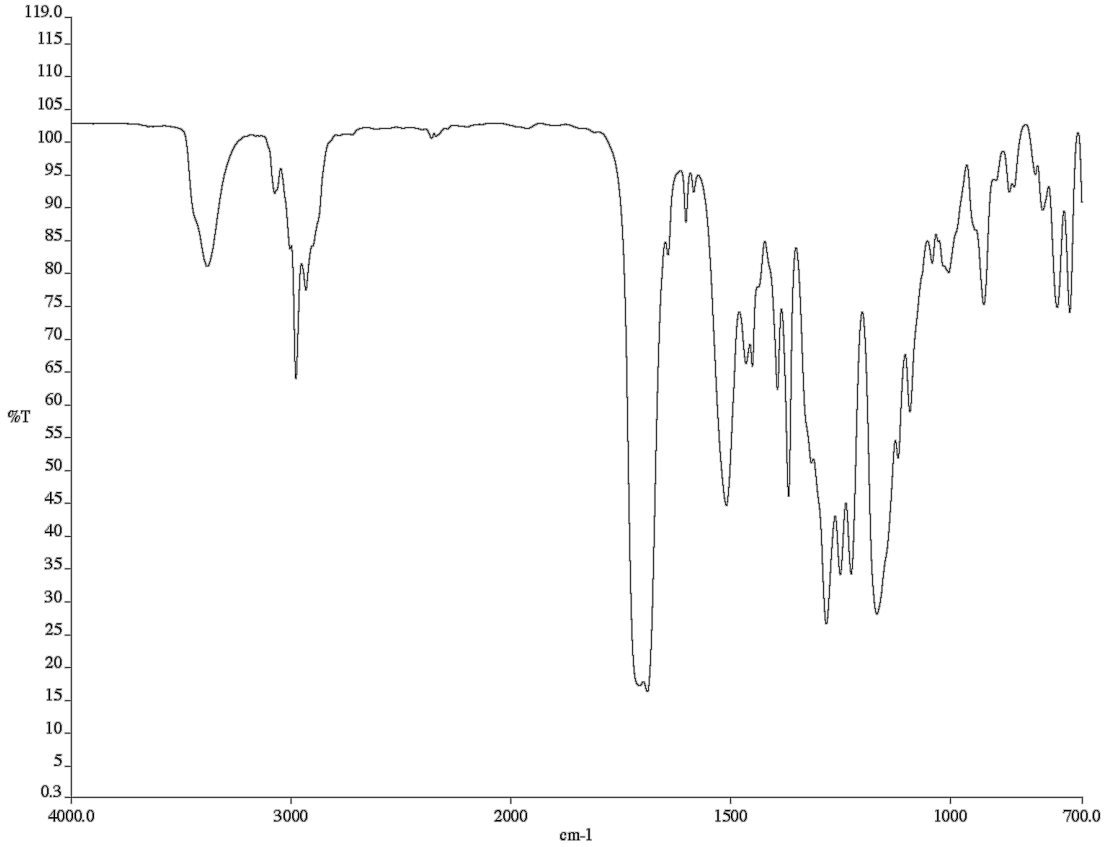
Infrared spectrum (Thin Film, NaCl) of compound **7g**.



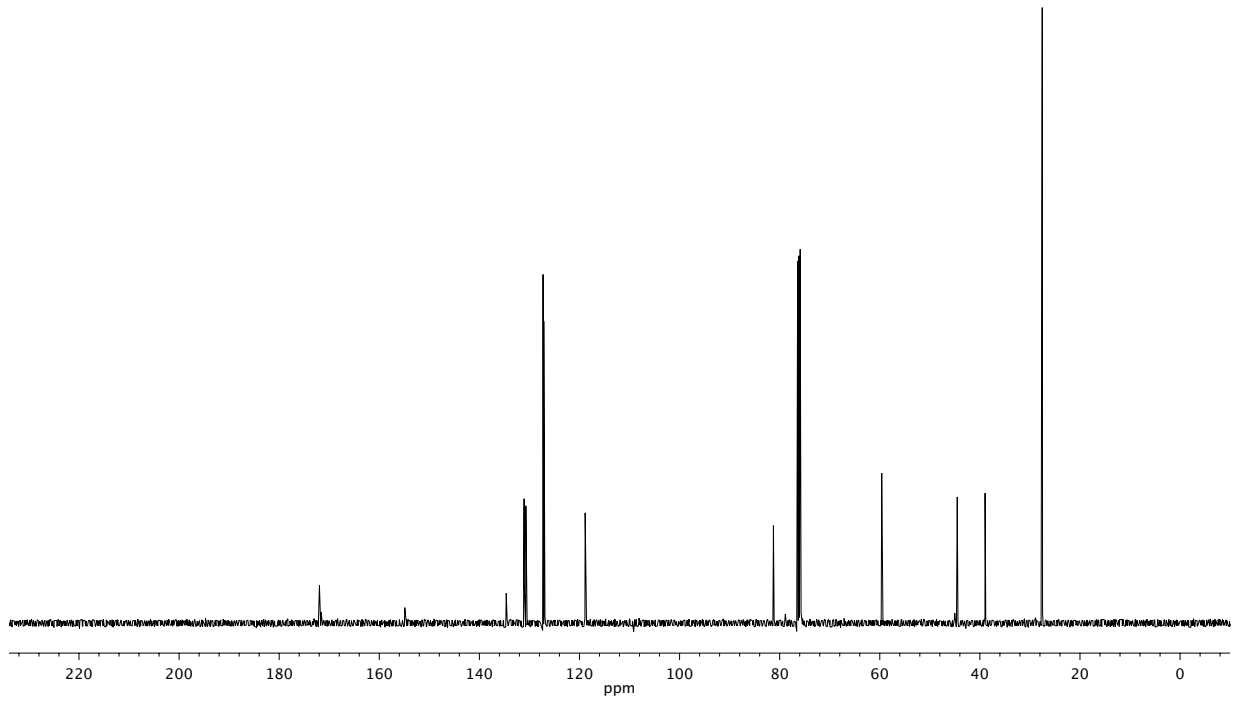
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7g**.



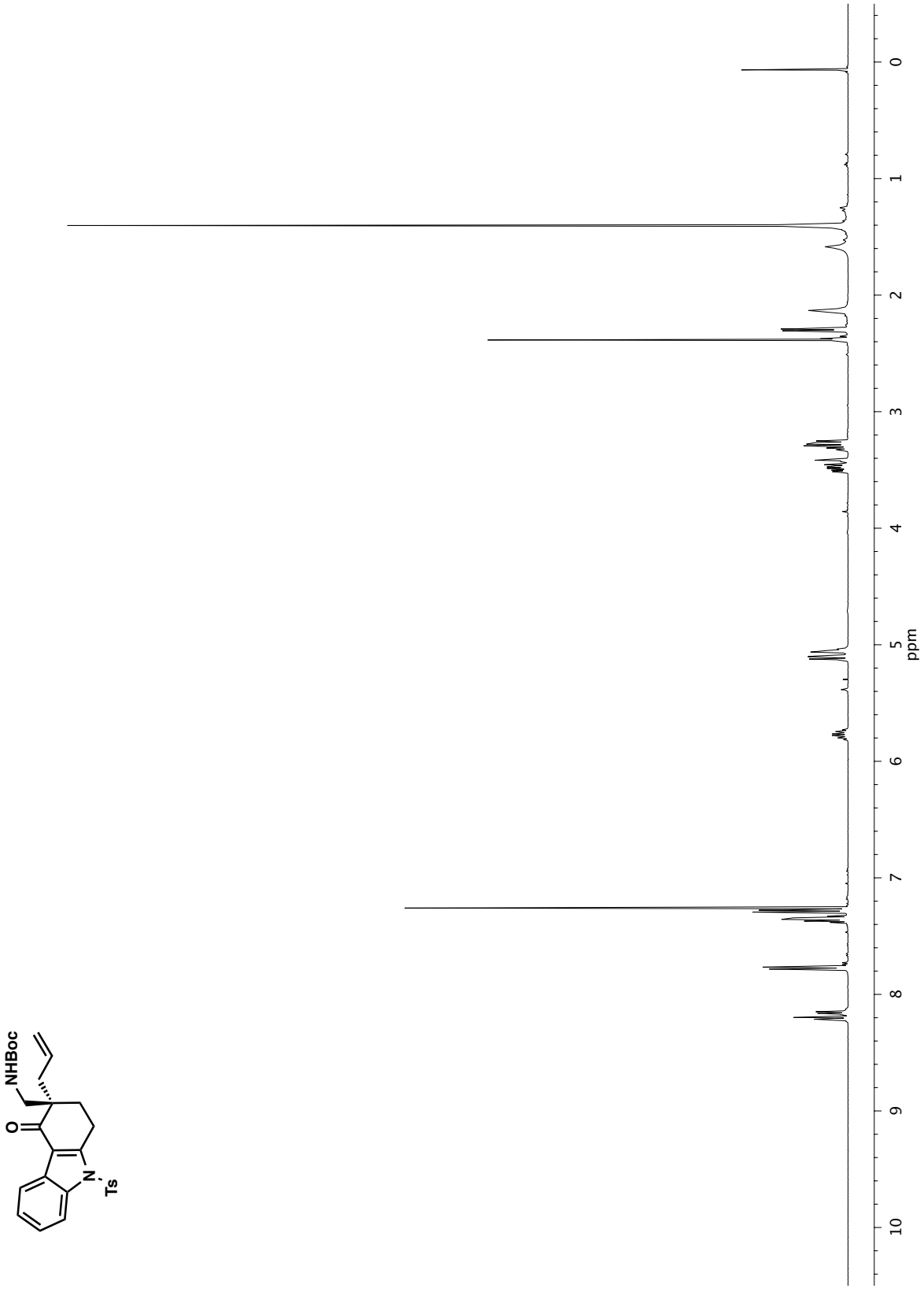
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7h**.



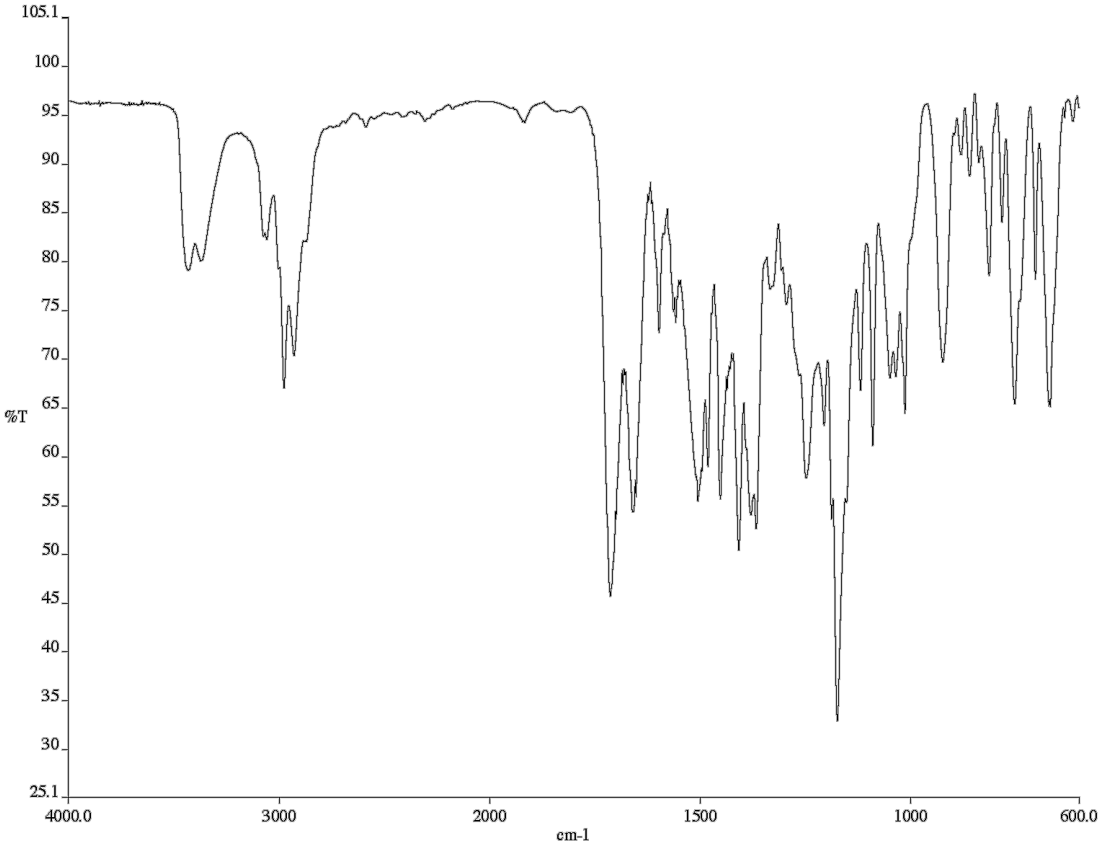
Infrared spectrum (Thin Film, NaCl) of compound **7h.**



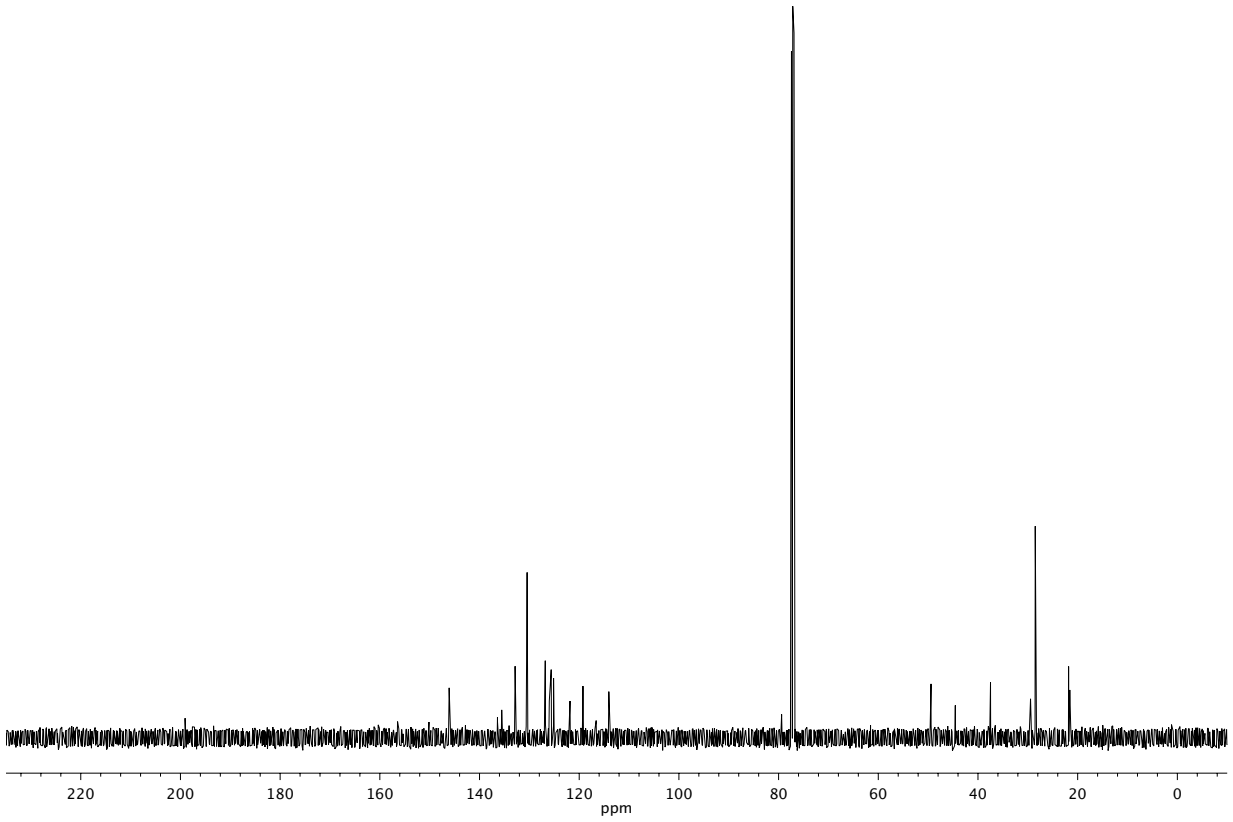
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7h**.



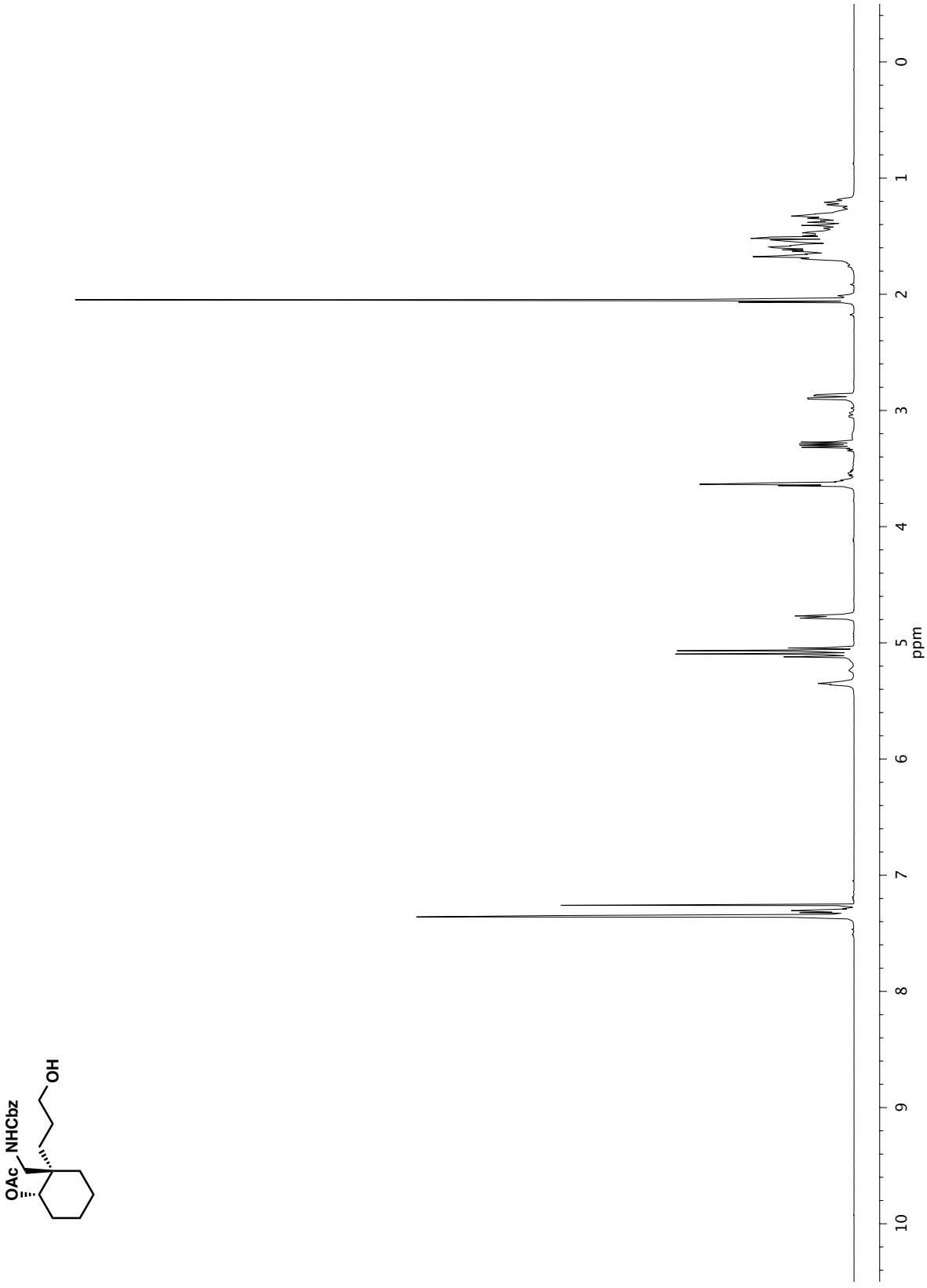
^{1}H NMR (500 MHz, $CDCl_3$) of compound **7i**.



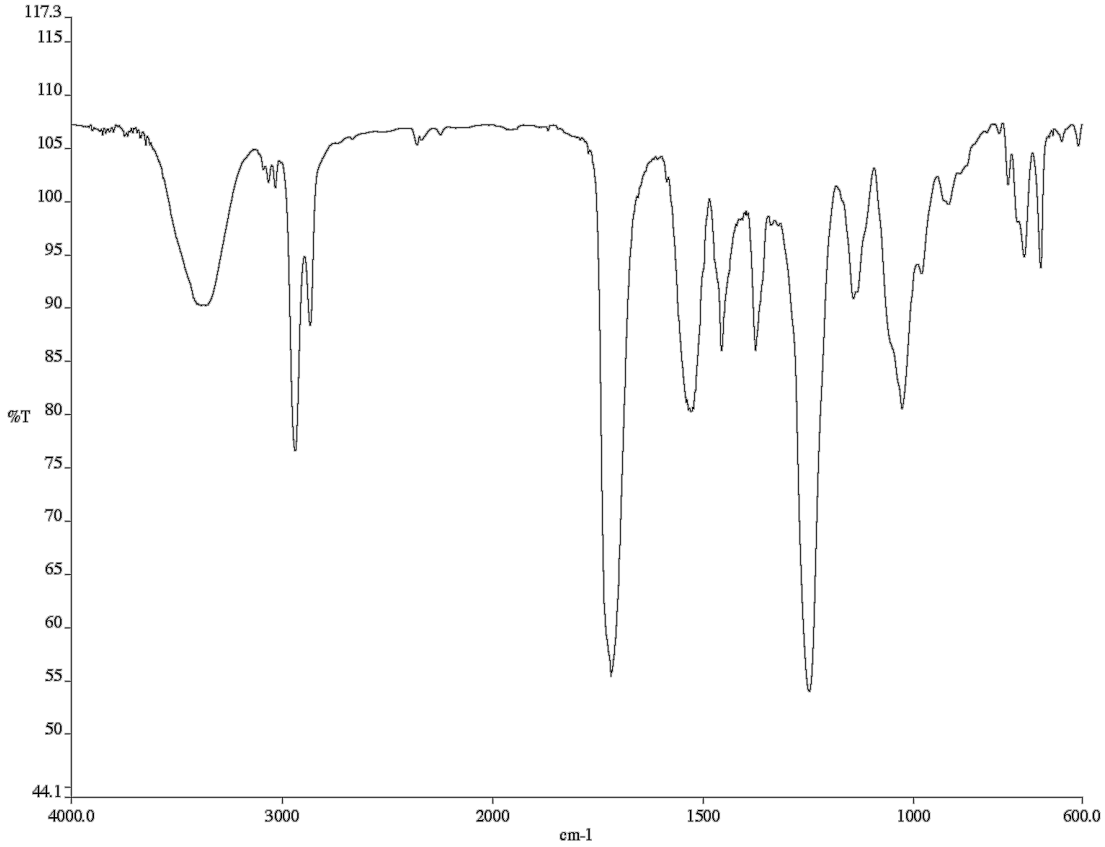
Infrared spectrum (Thin Film, NaCl) of compound **7i.**



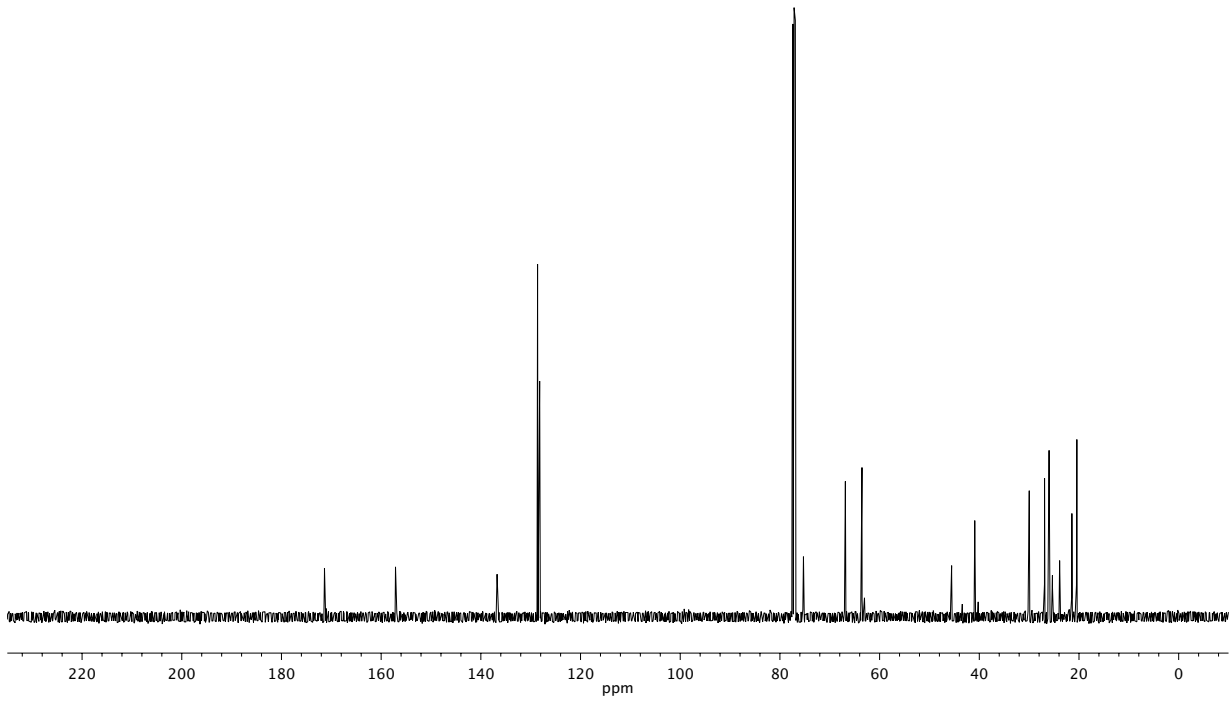
^{13}C NMR (126 MHz, $CDCl_3$) of compound **7i**.



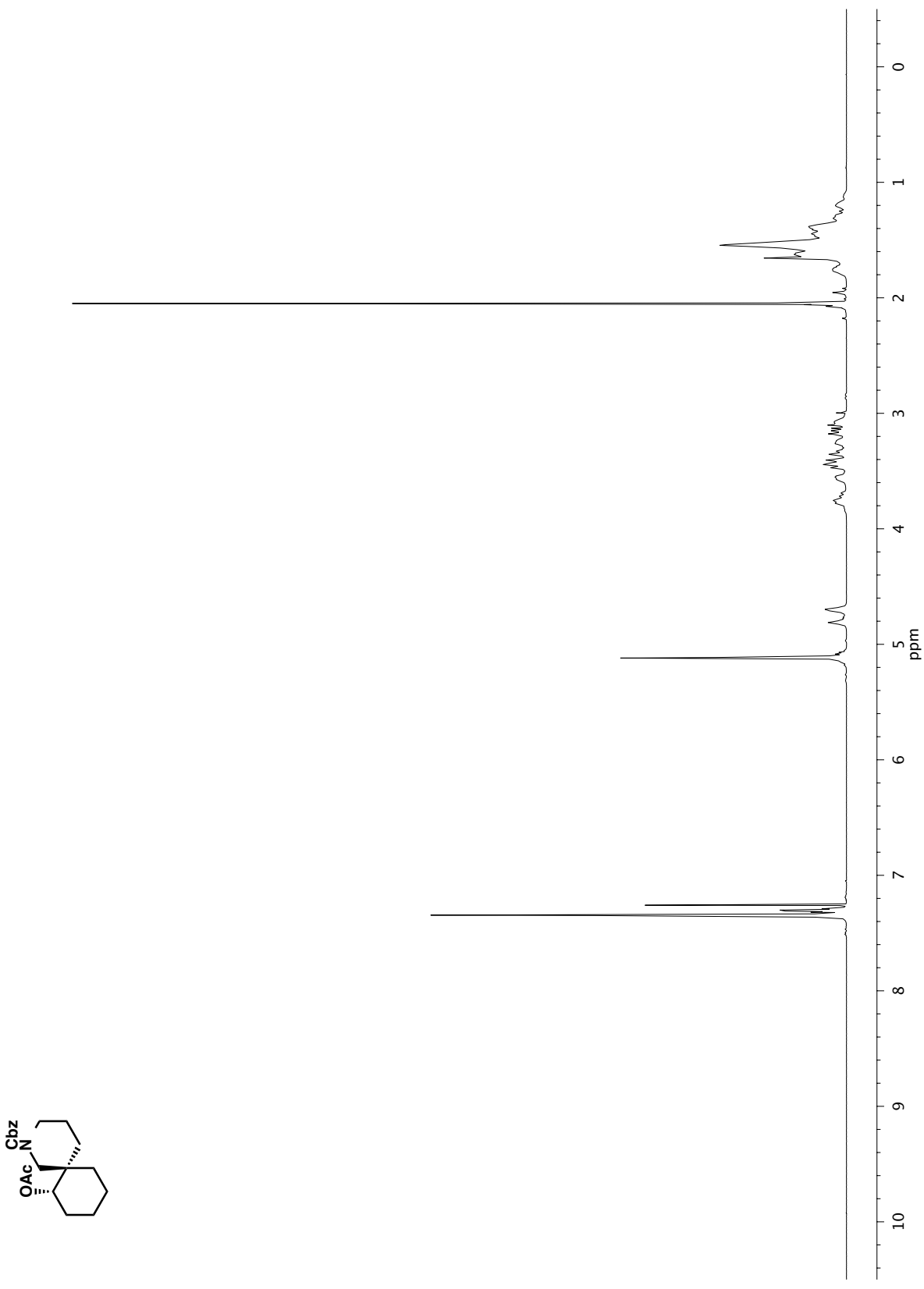
^{1}H NMR (500 MHz, $CDCl_3$) of compound **9**.



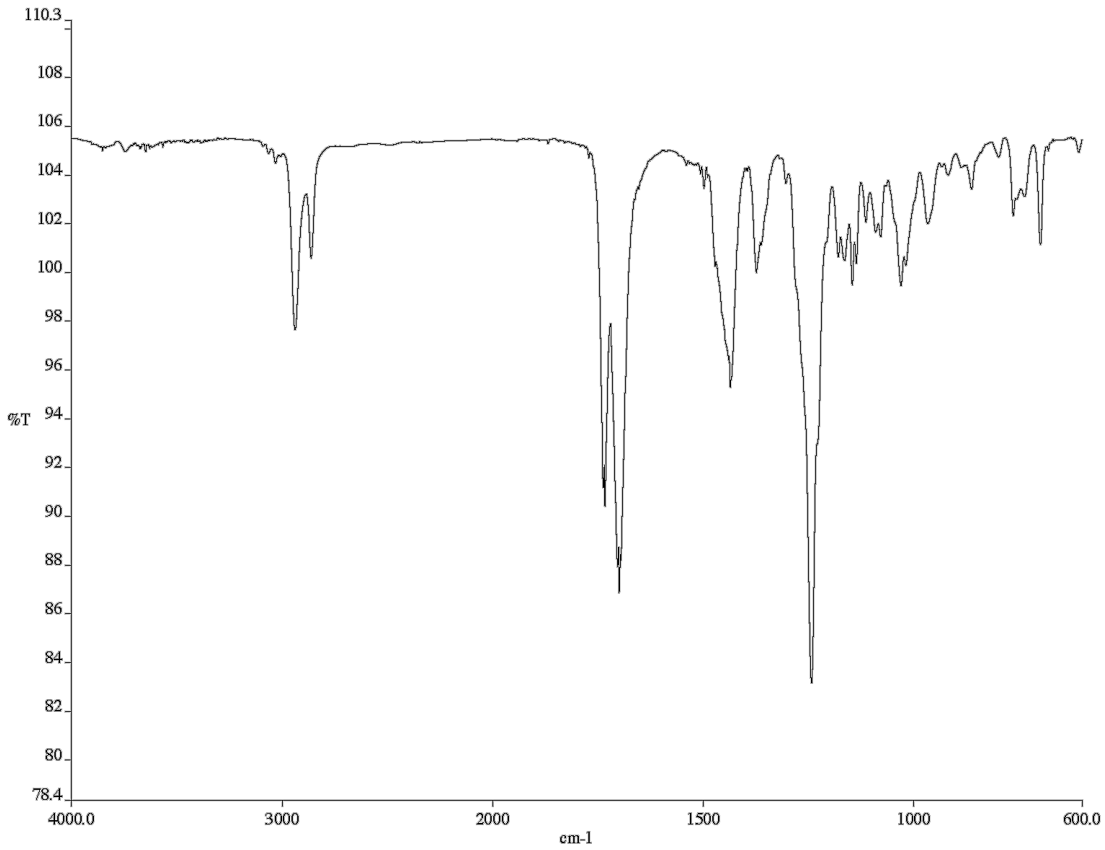
Infrared spectrum (Thin Film, NaCl) of compound **9.**



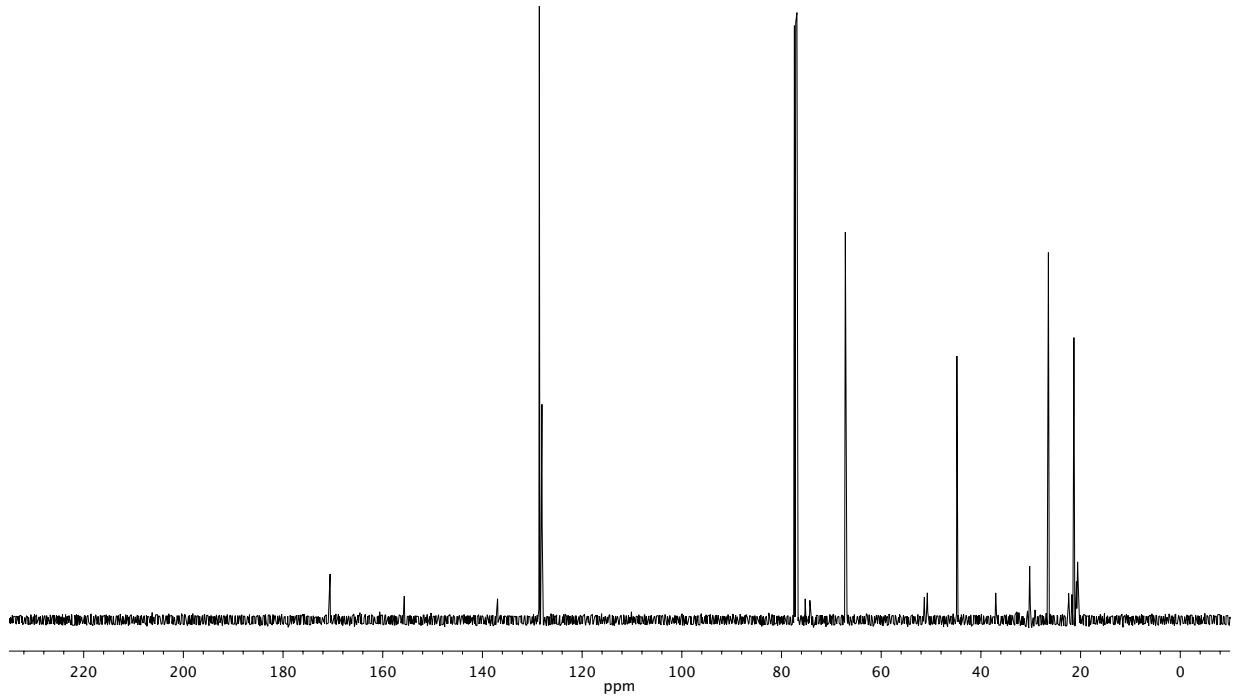
^{13}C NMR (126 MHz, $CDCl_3$) of compound **9**.



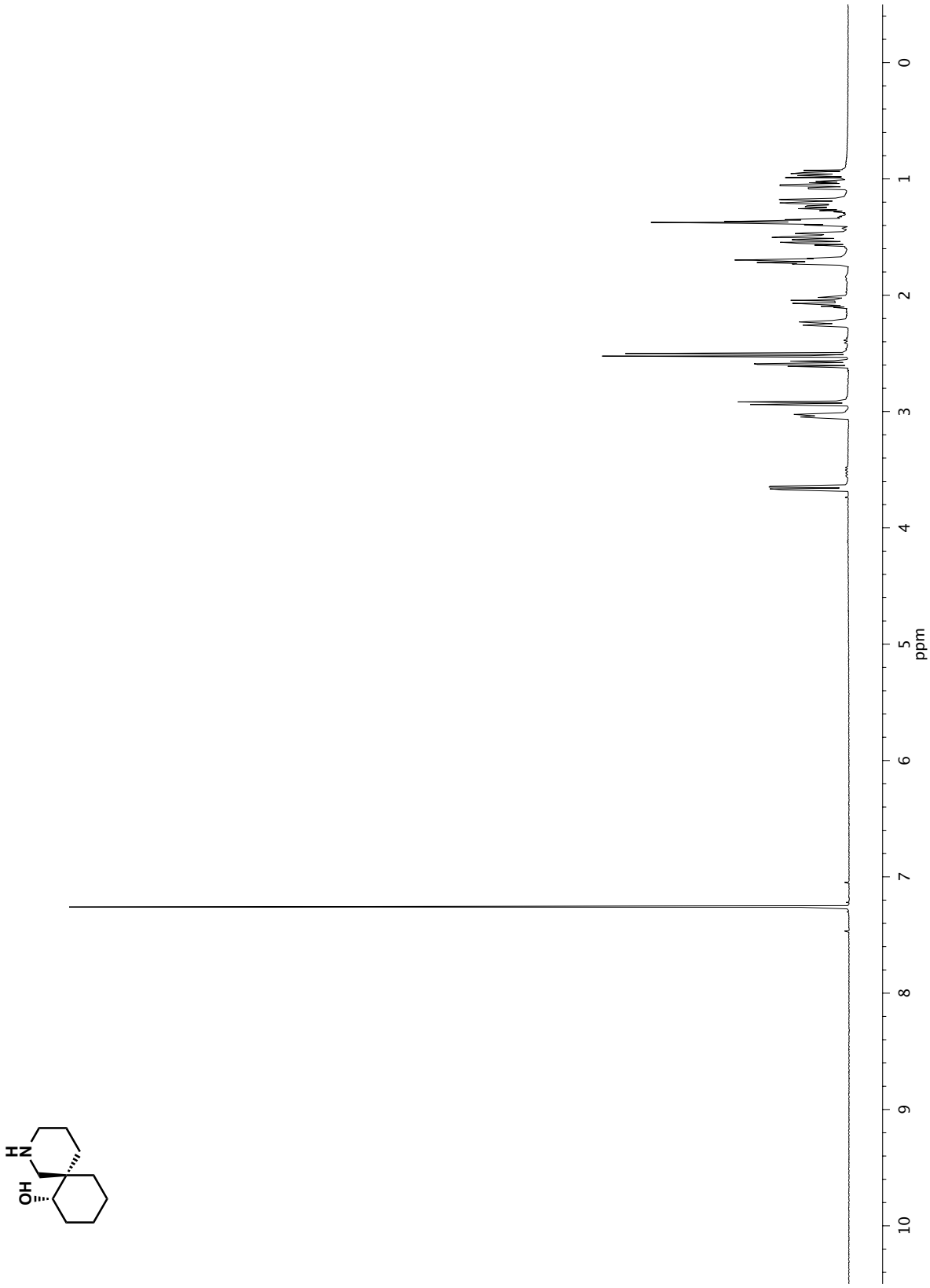
^{1}H NMR (500 MHz, $CDCl_3$) of compound **10**.



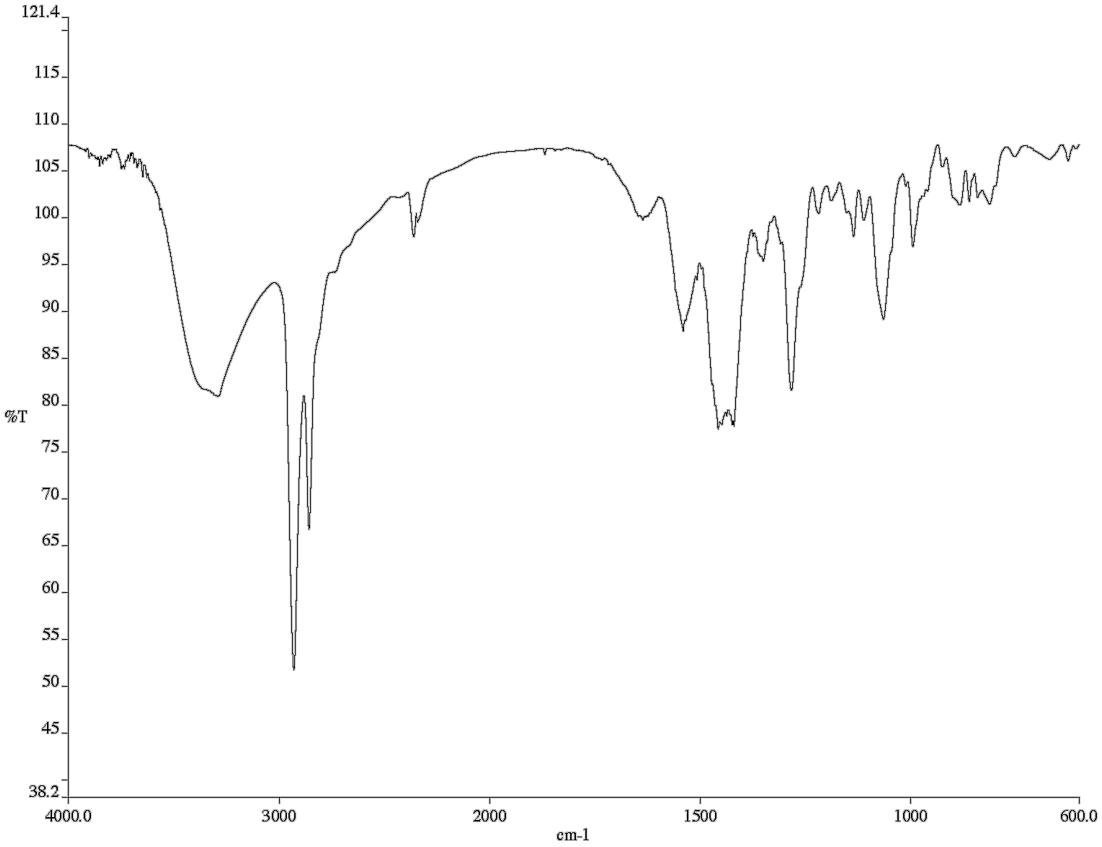
Infrared spectrum (Thin Film, NaCl) of compound **10.**



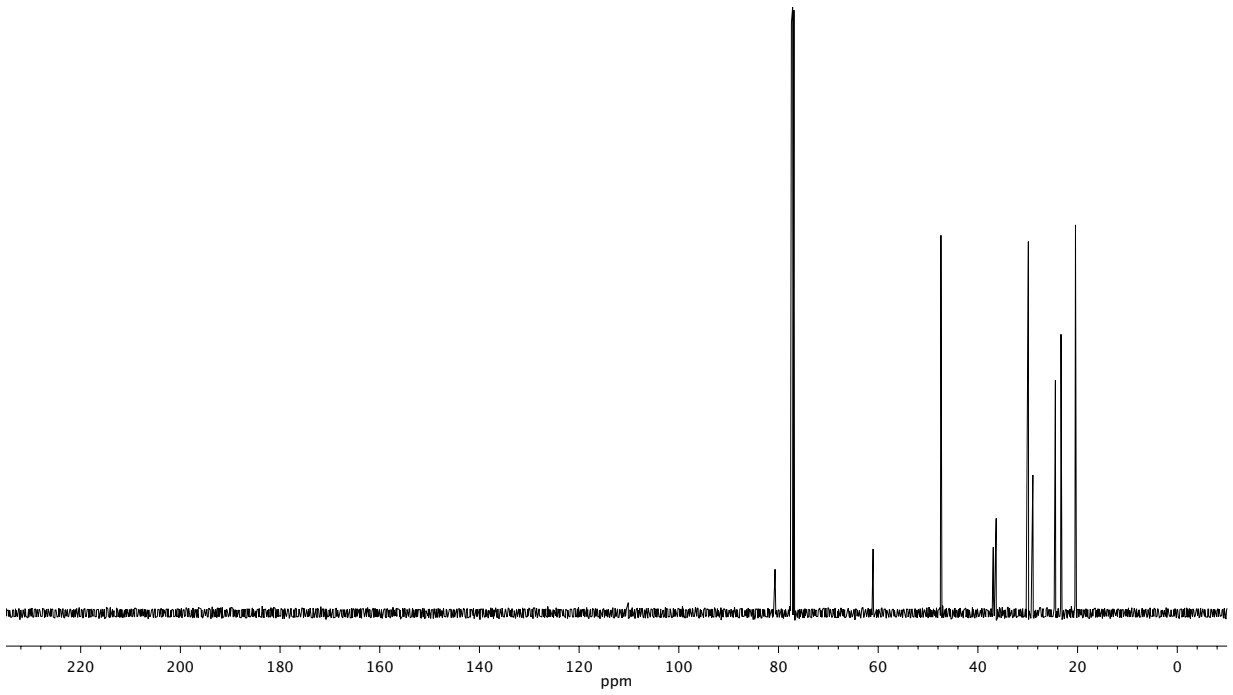
^{13}C NMR (126 MHz, $CDCl_3$) of compound **10**.



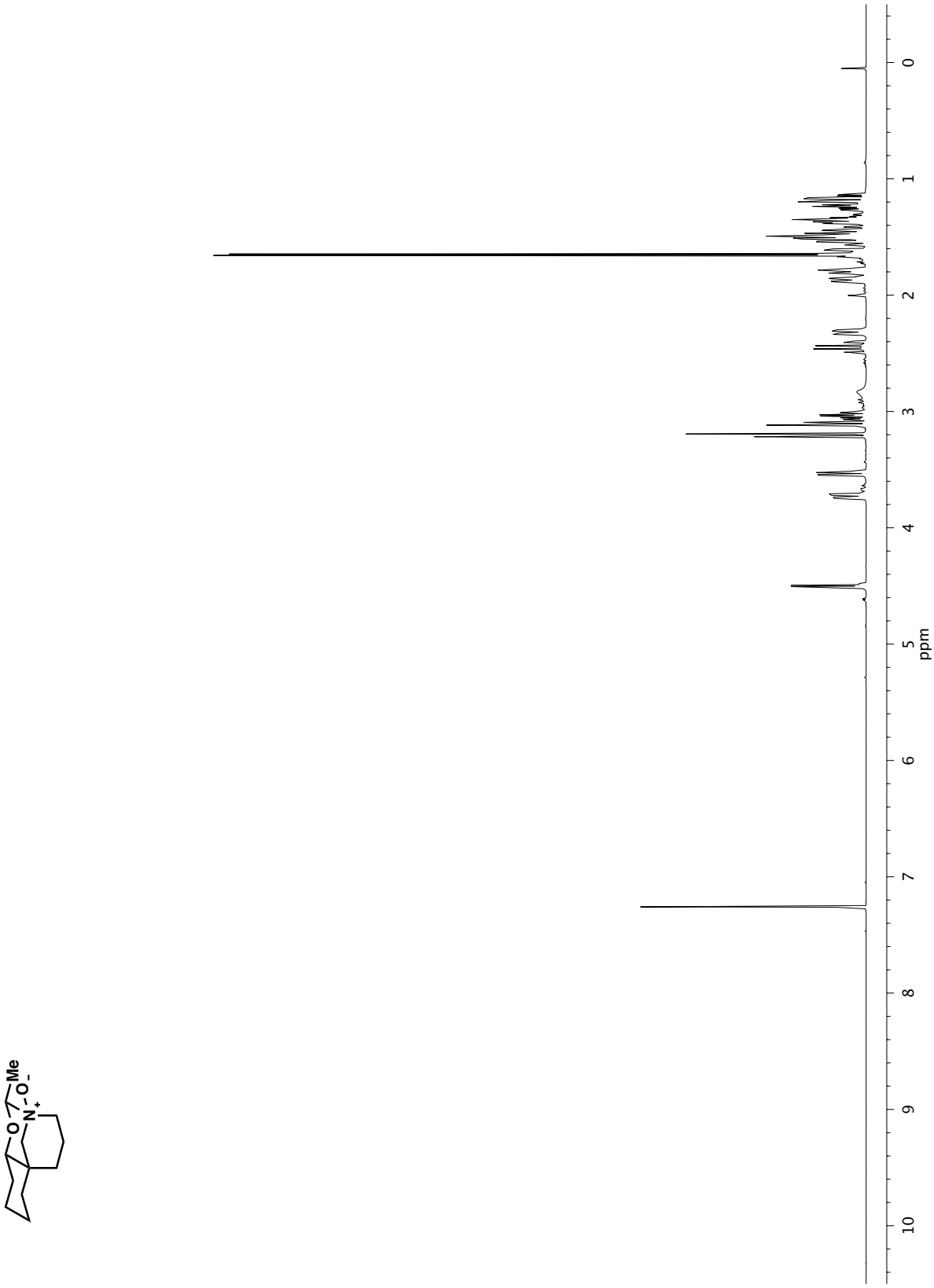
^{1}H NMR (500 MHz, $CDCl_3$) of compound **11**.



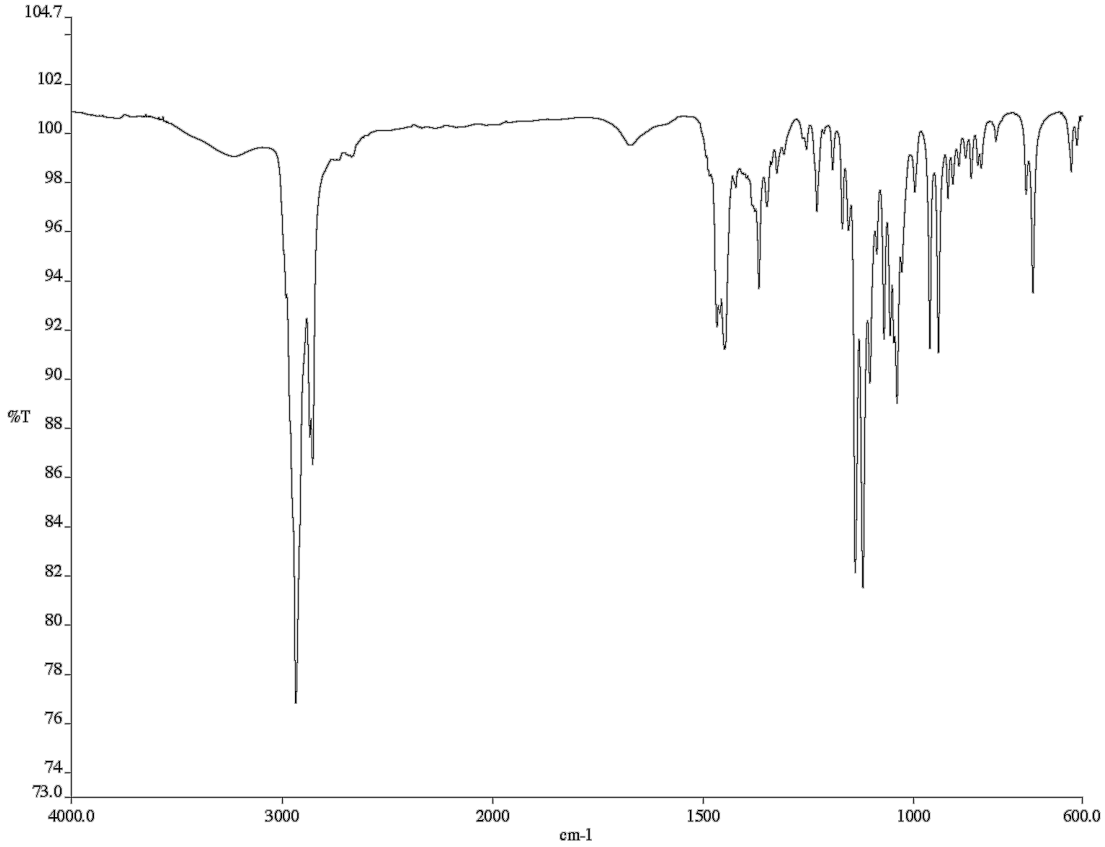
Infrared spectrum (Thin Film, NaCl) of compound **11.**



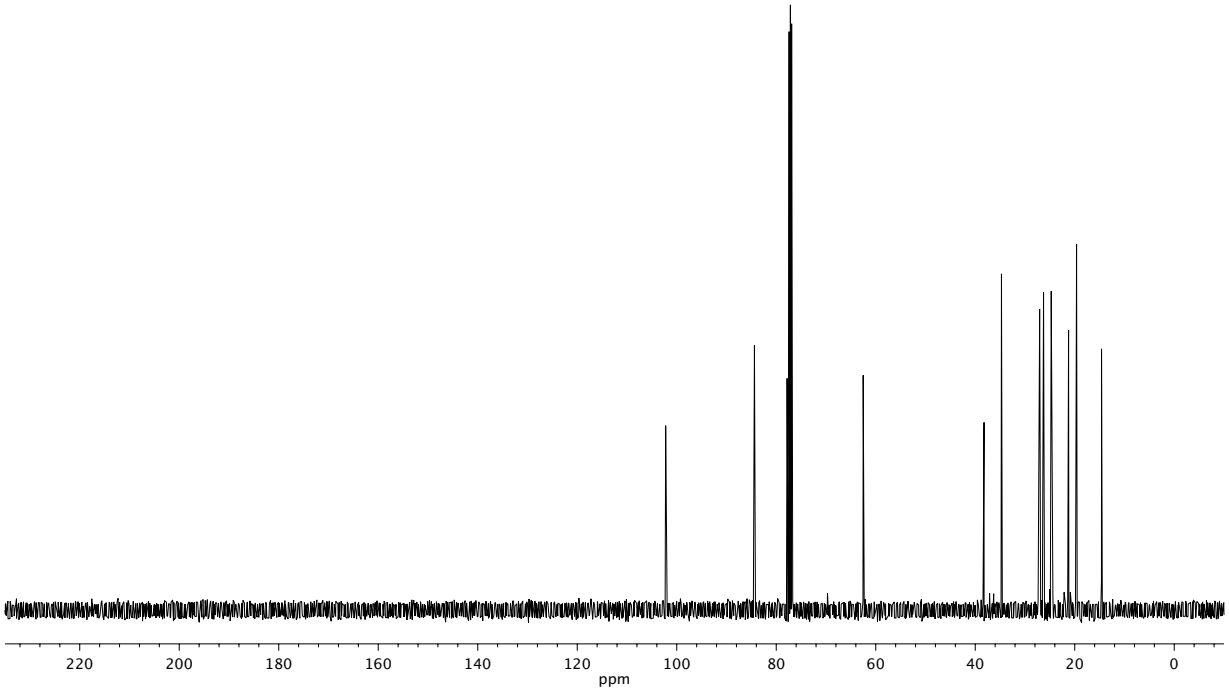
^{13}C NMR (126 MHz, $CDCl_3$) of compound **11**.



^{1}H NMR (500 MHz, $CDCl_3$) of compound **12**.



Infrared spectrum (Thin Film, NaCl) of compound **12**.



^{13}C NMR (126 MHz, $CDCl_3$) of compound **12**.