

*Supporting Information for*

# **Diastereoselective Synthesis of Dioxaadamantane Skeletons from Coumarin-Fused Bridged Ketones via Triple Grignard Addition and Hydroalkoxylation Sequence**

Haoran Yang,<sup>a</sup> Jiawei Liu,<sup>a</sup> Changmeng Yang,<sup>a</sup> Dunru Zhu,<sup>a</sup> Ruwei Shen<sup>a,\*</sup>

<sup>a</sup> State Key Laboratory of Materials-Oriented Chemical Engineering, College of Chemistry and Chemical Engineering, Nanjing Tech University, Nanjing 211816, China.

E-mail: shenrw@njtech.edu.cn

## **Table of Contents**

<b>1. General information .....</b>	<b>2</b>
<b>2. Synthesis and characterization data of coumarin-fused bridged ring ketones 1 .....</b>	<b>2</b>
<b>3. Synthesis and characterization data of products 3 and 4.....</b>	<b>8</b>
<b>4. Synthesis and characterization data of products 5 .....</b>	<b>20</b>
<b>5. Plausible mechanism for the conversion of 3 into 5.....</b>	<b>30</b>
<b>6. Synthetic transformation of compound 5 .....</b>	<b>35</b>
<b>7. X-ray data of products 3b and 5a .....</b>	<b>37</b>
<b>8. References .....</b>	<b>39</b>
<b>9. Copies of <sup>1</sup>H and <sup>13</sup>C NMR spectra of all new compounds .....</b>	<b>39</b>

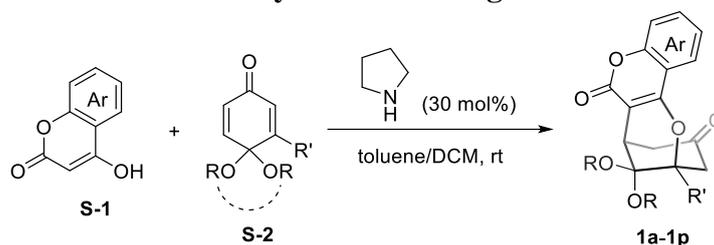
## 1. General information

All moisture and air sensitive reactions were performed under dry N<sub>2</sub> atmosphere in dry solvents with the standard Schlenk techniques. Thin layer chromatography was performed on precoated glass-backed plates and visualized with UV light at 254 nm. Flash chromatography was performed on silica gel using petroleum ether, hexane and EtOAc as eluent. Melting points were determined with a Shanghai Jingke WRS-2A digital melting point apparatus instrument. Proton nuclear magnetic resonance (<sup>1</sup>H NMR) spectra were recorded on a Bruker Ascend™ 400 spectrometer at 400 MHz. Carbon nuclear magnetic resonance (<sup>13</sup>C NMR) spectra were recorded on a Bruker Ascend™ 400 spectrometer at 101 MHz. Spectra were obtained in CDCl<sub>3</sub>, DMSO-d<sub>6</sub>, or acetone-d<sub>6</sub>. Chemical shifts are expressed in ppm and *J* values are given in Hz. Proton chemical shifts are reported relative to internal tetramethylsilane (TMS, δ 0.0 ppm), or with the solvent reference relative to TMS employed as an internal standard (CDCl<sub>3</sub>, δ 7.26 ppm; DMSO-d<sub>6</sub>, δ 2.50 ppm; acetone-d<sub>6</sub>, δ 2.05 ppm). Carbon chemical shifts were reported in ppm (δ) relative to TMS with the respective solvent resonance as the internal standard (CDCl<sub>3</sub>, δ 77.0 ppm; DMSO-d<sub>6</sub>, δ 39.5 ppm; acetone-d<sub>6</sub>, δ 29.8 ppm). HRMS analysis was performed on an Agilent 6540 UHD accurate-mass quadrupole time-of-flight (Q-TOF) mass spectrometer in the electrospray ionization mode. Allylic Grignard reagents were purchased from commercial source (Energy Chemical and Macklin), and titrated following the Knochel's procedure before use.<sup>[1]</sup>

## 2. Synthesis and characterization data of coumarin-fused bridged ring ketones **1**

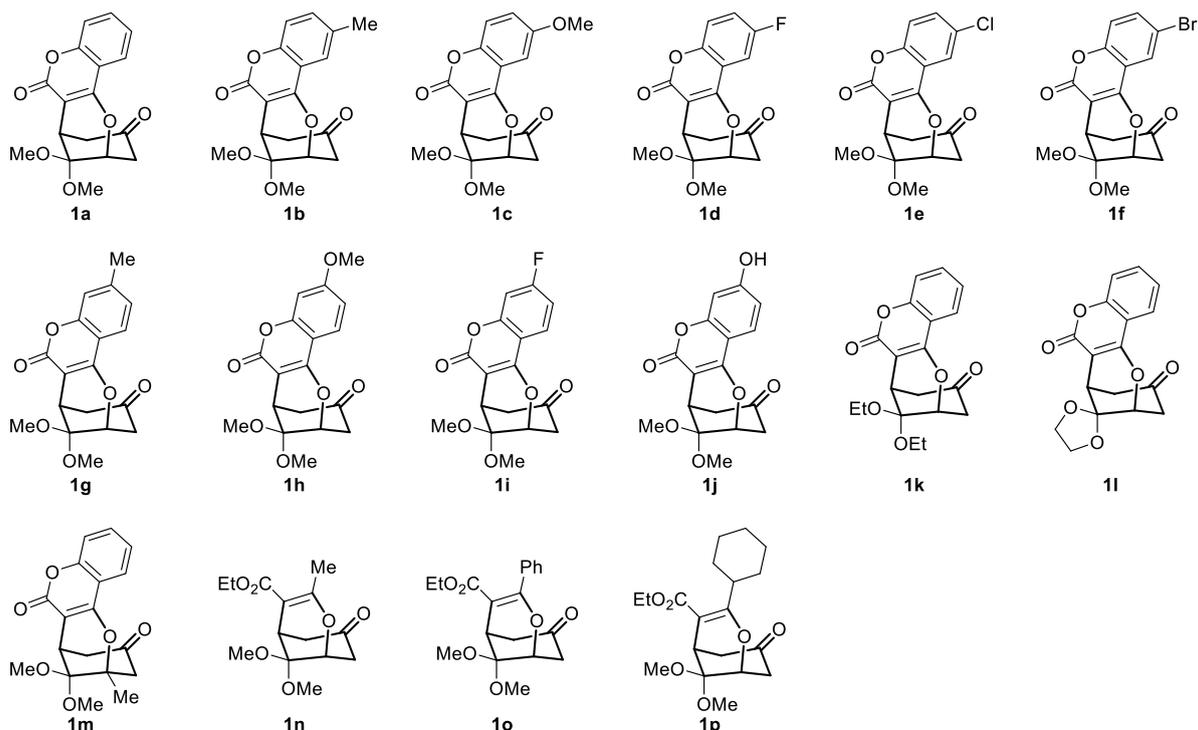
Coumarin-fused bridged ketones **1** were prepared by the pyrrolidine-catalyzed annulation of 3-hydroxyl coumarins with QMAs at room temperature, previously developed by our group.<sup>[2]</sup> This protocol was also applicable to the synthesis of the precursors **1m-1p**. The structure of compounds **1** and synthetic details were listed in Table S1.

**Table S1. The synthesis of bridged ketones 1**

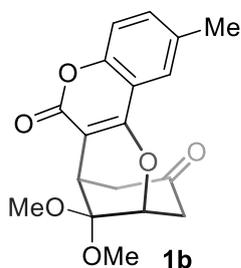


entry	Compound 1	Solvent, Temperature (°C), Time (h)	Yield (%)
1	<b>1a</b>	Toluene/DCM, rt, 48 h	76
2	<b>1b</b>	Toluene/DCM, rt, 72 h	71
3	<b>1c</b>	Toluene/DCM, rt, 72 h	59
4	<b>1d</b>	Toluene/DCM, rt, 72 h	83
5	<b>1e</b>	Toluene/DCM, rt, 72 h	67
6	<b>1f</b>	Toluene/DCM, rt, 48 h	75
7	<b>1g</b>	Toluene/DCM, rt, 72 h	73
8	<b>1h</b>	Toluene/DCM, rt, 72 h	61
9	<b>1i</b>	Toluene/DCM, rt, 72 h	69
10	<b>1j</b>	Toluene/EtOH, rt, 48 h	59
11	<b>1k</b>	Toluene/DCM, rt, 48 h	72
12	<b>1l</b>	Toluene/DCM, rt, 32 h	76
13	<b>1m</b>	Toluene/DCM, rt, 48 h	57
14	<b>1n</b>	Toluene, rt, 72 h	48
15	<b>1o</b>	Toluene, 60, 48 h	51
16	<b>1p</b>	Toluene, rt, 72 h	46

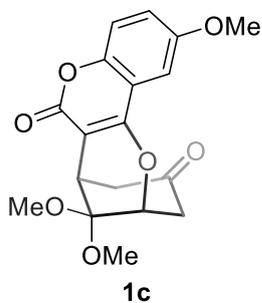
**Procedures:** To a mixture of 3-hydroxyl coumarin (1.2 equiv) and QMA (1 equiv) in mixed solvents (toluene, 3 mL; dichloromethane, 3 mL) was added pyrrolidine (0.3 equiv) at room temperature; the mixture was stirred at room temperature or 60 °C for the specific time till the starting materials were consumed. The reaction mixture was quenched by diluted HCl, and extracted by EtOAc. The products **1** were obtained after purification by flash column chromatography on silica gel using PE/EtOAc (5/1-3/1) as an eluent.



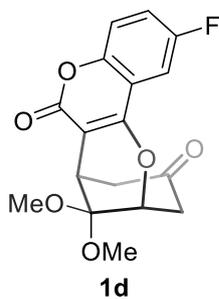
Compounds **1a**, and **11-1p** were known.<sup>[2,3]</sup> Characterization data of new compounds are given as below.



**1b.** White solid. M.p. 167.4-169.2 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.53 (s, 1H), 7.34 (d, *J* = 8.4 Hz, 1H), 7.20 (d, *J* = 8.4 Hz, 1H), 4.96 (s, 1H), 3.55 (dd, *J*<sub>1</sub> = 7.2 Hz, *J*<sub>2</sub> = 3.2 Hz, 1H), 3.47 (s, 3H), 3.35 (s, 3H), 2.93 (dd, *J*<sub>1</sub> = 17.6 Hz, *J*<sub>2</sub> = 4.8 Hz, 1H), 2.85-2.68 (m, 3H), 2.40 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, CDCl<sub>3</sub>): δ 206.3, 162.0, 157.9, 150.9, 133.8, 133.2, 122.5, 116.5, 114.4, 102.4, 95.8, 73.3, 49.0, 48.9, 44.6, 41.7, 33.0, 20.9. HRMS (ESI/Q-TOF) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>18</sub>H<sub>19</sub>O<sub>6</sub><sup>+</sup> 331.1176, found 331.1182.

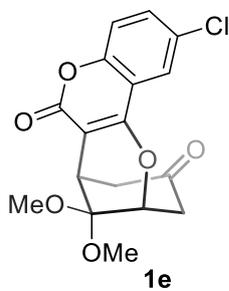


**1c.** White solid. M.p. 160.1-160.8 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.24 (d, *J* = 9.2 Hz, 1H), 7.15-7.10 (m, 2H), 4.99-4.97 (m, 1H), 3.85 (s, 3H), 3.56 (dd, *J*<sub>1</sub> = 7.2 Hz, *J*<sub>2</sub> = 3.6 Hz, 1H), 3.47 (s, 3H), 3.35 (s, 3H), 2.94 (dd, *J*<sub>1</sub> = 17.6 Hz, *J*<sub>2</sub> = 4.8 Hz, 1H), 2.84 (dd, *J*<sub>1</sub> = 16.0 Hz, *J*<sub>2</sub> = 4.4 Hz, 1H), 2.78-2.68 (m, 2H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, CDCl<sub>3</sub>): δ 206.3, 161.9, 157.7, 156.0, 147.2, 120.5, 117.9, 115.0, 104.4, 102.7, 95.8, 73.4, 55.9, 49.0, 48.9, 44.6, 41.7, 33.0. HRMS (ESI/Q-TOF) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>18</sub>H<sub>19</sub>O<sub>7</sub><sup>+</sup> 347.1125, found 347.1132.

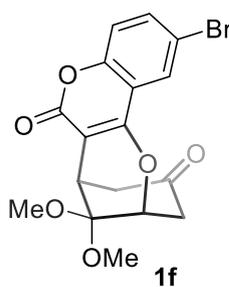


**1d.** White solid. M.p. 154.2-154.6 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.41 (dd, *J*<sub>1</sub> = 8.4 Hz, *J*<sub>2</sub> = 3.2 Hz, 1H), 7.31-7.23 (m, 2H), 5.00-4.97 (m, 1H), 3.57-3.55 (m, 1H), 3.48 (s, 3H), 3.35 (s, 3H), 2.95 (dd, *J*<sub>1</sub> = 17.2 Hz, *J*<sub>2</sub> = 4.8 Hz, 1H), 2.84 (dd, *J*<sub>1</sub> = 16.4 Hz, *J*<sub>2</sub> = 4.4 Hz, 1H), 2.77-2.66 (m, 2H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, CDCl<sub>3</sub>): δ 206.1, 161.5, 158.7 (d, *J*<sub>F-C</sub> = 242.8 Hz), 157.2 (d, *J*<sub>F-C</sub> = 2.7 Hz), 148.8 (d, *J*<sub>F-C</sub> = 2.0 Hz), 119.8 (d, *J*<sub>F-C</sub> = 24.5 Hz), 118.4 (d, *J*<sub>F-C</sub> = 8.3 Hz), 115.6 (d, *J*<sub>F-C</sub> = 9.1 Hz), 108.6 (d, *J*<sub>F-C</sub> = 25.3

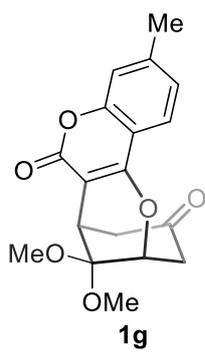
Hz), 103.3, 95.7, 73.6, 49.03, 48.95, 44.5, 41.6, 33.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{17}H_{16}O_6F^+$  335.0925, found 335.0933.



**1e**. White solid. M.p. 167.5-167.9 °C.  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  7.72 (d,  $J$  = 2.4 Hz, 1H), 7.48 (dd,  $J_1$  = 8.8 Hz,  $J_2$  = 2.8 Hz, 1H), 7.25 (d,  $J$  = 8.8 Hz, 1H), 4.99-4.97 (m, 1H), 3.57-3.54 (m, 1H), 3.47 (s, 3H), 3.35 (s, 3H), 2.95 (dd,  $J_1$  = 17.2 Hz,  $J_2$  = 4.8 Hz, 1H), 2.84 (dd,  $J_1$  = 16.4 Hz,  $J_2$  = 4.4 Hz, 1H), 2.77-2.66 (m, 2H).  $^{13}C\{^1H\}$  NMR (101 MHz,  $CDCl_3$ ):  $\delta$  206.0, 161.2, 156.9, 151.0, 132.2, 129.7, 122.4, 118.2, 115.8, 103.4, 95.7, 73.6, 49.1, 49.0, 44.5, 41.6, 33.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{17}H_{16}O_6Cl^+$  351.0630, found 351.0641.

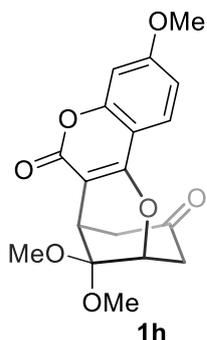


**1f**. White solid. M.p. 157.8-158.7 °C.  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  7.87 (d,  $J$  = 2.0 Hz, 1H), 7.62 (dd,  $J_1$  = 8.8 Hz,  $J_2$  = 2.4 Hz, 1H), 7.20 (d,  $J$  = 8.8 Hz, 1H), 4.99-4.97 (m, 1H), 3.56-3.54 (m, 1H), 3.47 (s, 3H), 3.35 (s, 3H), 2.95 (dd,  $J_1$  = 17.2 Hz,  $J_2$  = 4.8 Hz, 1H), 2.83 (dd,  $J_1$  = 16.4 Hz,  $J_2$  = 4.4 Hz, 1H), 2.77-2.66 (m, 2H).  $^{13}C\{^1H\}$  NMR (101 MHz,  $CDCl_3$ ):  $\delta$  206.0, 161.2, 156.8, 151.5, 135.1, 125.4, 119.0, 118.5, 116.9, 116.3, 103.4, 95.7, 73.6, 49.1, 49.0, 44.5, 41.6, 33.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{17}H_{16}O_6Br^+$  395.0125, found 395.0135.

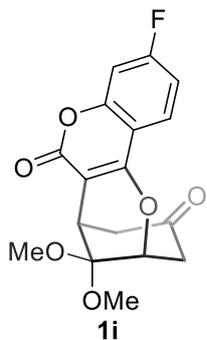


**1g**. White solid. M.p. 134.5-134.8 °C.  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  7.61 (d,  $J$  = 8.0 Hz, 1H), 7.11-7.08 (m, 2H), 4.96-4.94 (m, 1H), 3.55 (dd,  $J_1$  = 7.2 Hz,  $J_2$  = 3.6 Hz, 1H), 3.47 (s, 3H), 3.34 (s, 3H), 2.93 (dd,  $J_1$  = 17.6 Hz,  $J_2$  = 4.8 Hz, 1H), 2.82 (dd,  $J_1$  = 17.6 Hz,  $J_2$  = 4.4 Hz, 1H), 2.76-2.68 (m, 2H),

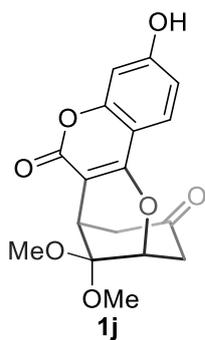
2.44 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  206.4, 162.1, 158.2, 152.8, 143.5, 125.3, 122.5, 116.8, 112.2, 101.5, 95.9, 73.3, 49.0, 48.9, 44.6, 41.7, 32.9, 21.8. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{18}\text{H}_{19}\text{O}_6^+$  331.1176, found 331.1182.



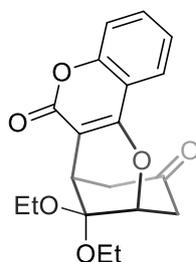
**1h.** White solid. M.p. 163.1-163.7 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.62 (d,  $J_1 = 8.8$  Hz,  $J_2 = 1.2$  Hz, 1H), 6.85-6.82 (m, 1H), 6.78 (t,  $J = 2.0$  Hz, 1H), 4.96-4.93 (m, 1H), 3.86 (s, 3H), 3.54-3.52 (m, 1H), 3.46 (s, 3H), 3.34 (s, 3H), 2.92 (dd,  $J_1 = 17.6$  Hz,  $J_2 = 4.8$  Hz, 1H), 2.82 (dd,  $J_1 = 16.0$  Hz,  $J_2 = 4.4$  Hz, 1H), 2.75-2.67 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  206.5, 163.2, 162.2, 158.4, 154.5, 123.8, 112.4, 107.9, 100.4, 99.7, 95.9, 73.3, 55.8, 49.0, 48.9, 44.6, 41.8, 41.3, 32.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{18}\text{H}_{19}\text{O}_7^+$  347.1125, found 347.1135.



**1i.** White solid. M.p. 139.1-140.2 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.75-7.71 (m, 1H), 7.04-6.99 (m, 2H), 4.99-4.96 (m, 1H), 3.56-3.53 (m, 1H), 3.47 (s, 3H), 3.35 (s, 3H), 2.94 (dd,  $J_1 = 17.6$  Hz,  $J_2 = 4.8$  Hz, 1H), 2.83 (dd,  $J_1 = 16.0$  Hz,  $J_2 = 4.4$  Hz, 1H), 2.77-2.67 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  206.2, 164.8 (d,  $J_{\text{F-C}} = 252.3$  Hz), 161.6, 157.7, 153.9 (d,  $J_{\text{F-C}} = 13.1$  Hz), 124.6 (d,  $J_{\text{F-C}} = 10.3$  Hz), 112.3 (d,  $J_{\text{F-C}} = 22.7$  Hz), 111.3 (d,  $J_{\text{F-C}} = 2.7$  Hz), 104.2 (d,  $J_{\text{F-C}} = 25.5$  Hz), 101.5 (d,  $J_{\text{F-C}} = 2.2$  Hz), 95.8, 73.6, 49.03, 48.93, 44.5, 41.6, 33.0. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{17}\text{H}_{16}\text{O}_6\text{F}^+$  335.0925, found 335.0932.

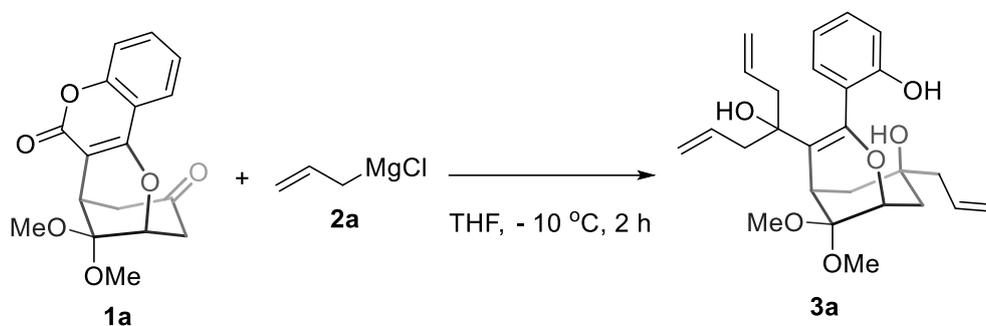


**1j**, white solid. M.p.120.8-121.4 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.84 (br, 1H), 7.56 (d,  $J = 8.8$  Hz, 1H), 6.78 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 2.4$  Hz, 1H), 6.71 (d,  $J = 2.4$  Hz, 1H), 4.98-4.95 (m, 1H), 3.55-3.53 (m, 1H), 3.48 (s, 3H), 3.37 (s, 3H), 2.96 (dd,  $J_1 = 17.6$  Hz,  $J_2 = 4.8$  Hz, 1H), 2.84 (dd,  $J_1 = 16.4$  Hz,  $J_2 = 4.4$  Hz, 1H), 2.78-2.70 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  207.9, 162.8, 160.6, 159.0, 154.2, 124.2, 113.4, 107.3, 102.6, 99.1, 96.0, 73.4, 49.1, 49.0, 44.6, 41.8, 33.0. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{17}\text{H}_{15}\text{O}_7$  331.0823, found 331.0834.



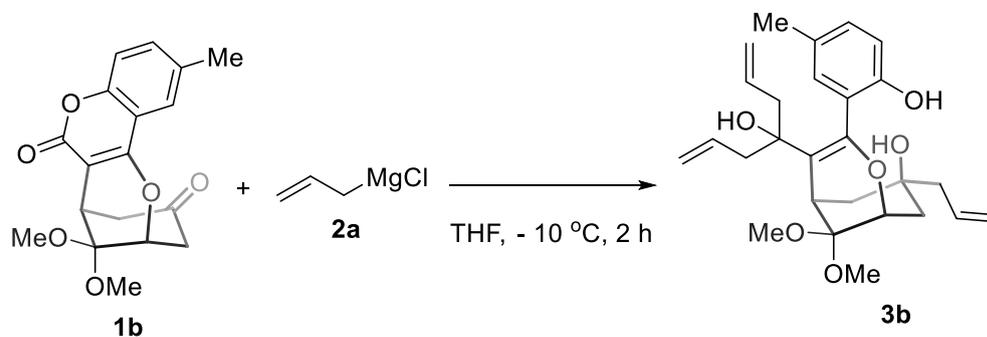
**1k**, White solid. M.p.135.8-136.5 °C.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.80 (dd,  $J_1 = 8.0$  Hz,  $J_2 = 2.4$  Hz, 1H), 7.65 (td,  $J_1 = 7.6$  Hz,  $J_2 = 2.4$  Hz, 1H), 7.39-7.34 (m, 2H), 5.20-5.18 (m, 1H), 3.90-3.79 (m, 2H), 3.77-3.64 (m, 2H), 3.48 (dd,  $J_1 = 7.6$  Hz,  $J_2 = 2.8$  Hz, 1H), 3.08 (dd,  $J_1 = 17.6$  Hz,  $J_2 = 4.8$  Hz, 1H), 2.95 (dd,  $J_1 = 15.6$  Hz,  $J_2 = 4.8$  Hz, 1H), 2.66 (dt,  $J_1 = 17.6$  Hz,  $J_2 = 2.4$  Hz, 1H), 2.46 (dd,  $J_1 = 15.6$  Hz,  $J_2 = 2.8$  Hz, 1H), 1.32 (t,  $J = 6.8$  Hz, 3H), 1.10 (t,  $J = 6.8$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  206.4, 161.7, 158.4, 153.6, 133.2, 125.0, 123.5, 117.3, 115.6, 103.7, 96.4, 75.5, 57.6, 57.5, 45.3, 42.3, 34.9, 15.44, 15.42. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{19}\text{H}_{21}\text{O}_6$  345.1333, found 345.1342.

### 3. Synthesis and characterization data of products 3 and 4

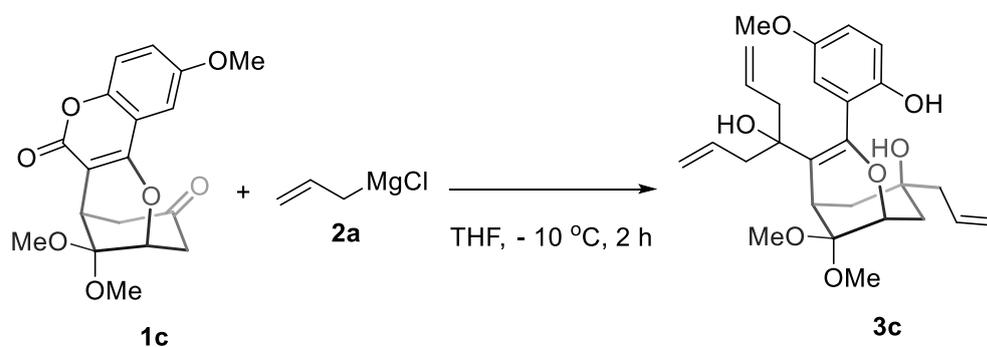


**General Procedure:** under dry N<sub>2</sub>, a solution of allylmagnesium chloride **2a** (4 equiv, 0.8 mL, 1.0 M) in THF was added dropwise to an oven-dried Schlenk tube containing bridged-ring ketone **1a** (0.2 mmol, 63.7 mg) and THF (2 mL) at -10 °C. The mixture was stirred at this temperature for 2 h, and then warmed to room temperature and quenched with aqueous NH<sub>4</sub>Cl solution (3 mL). The mixture was extracted with EtOAc (3 × 5 mL). The combined organic layers were then washed with brine, dried over MgSO<sub>4</sub> and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent to afford **3a** (57.5 mg, 65%). White solid. M.p. 116.3-116.6 °C. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 8.53 (s, 1H), 7.18 (td, *J*<sub>1</sub> = 8.0 Hz, *J*<sub>2</sub> = 2.0 Hz, 1H), 7.09 (dd, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 2.0 Hz, 1H), 6.77 (td, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 1.6 Hz, 1H), 6.72 (d, *J* = 8.0 Hz, 1H), 6.19-6.08 (m, 1H), 5.99-5.89 (m, 2H), 5.12-5.00 (m, 4H), 4.92 (d, *J* = 10.0 Hz, 1H), 4.74 (d, *J* = 17.2 Hz, 1H), 4.29 (dd, *J*<sub>1</sub> = 6.0 Hz, *J*<sub>2</sub> = 3.2 Hz, 1H), 4.07 (s, 1H), 3.31 (s, 3H), 3.27 (s, 3H), 3.00-2.97 (m, 1H), 2.46-2.41 (m, 1H), 2.35-2.20 (m, 5H), 2.06-1.97 (m, 4H). <sup>1</sup>H NMR (400 MHz, DMSO-d<sub>6</sub>): δ 8.97 (s, 1H), 7.15 (t, *J*<sub>1</sub> = 8.0 Hz, 1H), 6.97 (d, *J* = 7.6 Hz, 1H), 6.73 (t, *J*<sub>1</sub> = 7.6 Hz, 1H), 6.69 (d, *J* = 8.4 Hz, 1H), 6.03-5.94 (m, 1H), 5.92-5.81 (m, 2H), 5.09-4.87 (m, 4H), 4.95 (d, *J* = 17.2 Hz, 1H), 4.89 (d, *J* = 10.0 Hz, 1H), 4.60 (d, *J* = 17.2 Hz, 1H), 4.24 (s, 1H), 4.00 (s, 1H), 3.20 (s, 3H), 3.17 (s, 3H), 2.84 (s, 1H), 2.81-2.08 (m, 6H), 1.91-1.77 (m, 4H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 157.2, 143.5, 136.5, 136.4, 134.9, 130.9, 130.5, 125.6, 118.8, 118.4, 117.9, 117.8, 117.6, 116.2, 98.5, 75.4, 71.5, 70.1, 50.6, 48.1, 47.9, 46.2, 44.6, 41.7, 40.6, 33.8. <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, DMSO-d<sub>6</sub>): δ 155.7, 141.7, 135.8, 135.6, 134.5, 129.9, 129.7, 124.5, 118.0, 117.7, 117.0, 116.9, 116.7, 115.1, 97.3, 74.3, 69.7, 68.8, 49.4, 47.6, 47.4, 44.0, 43.3, 40.7, 39.4, 32.2. HRMS (ESI/Q-TOF) *m/z*: [M-H]<sup>-</sup> Calcd for C<sub>26</sub>H<sub>33</sub>O<sub>6</sub><sup>-</sup> 441.2283, found 441.2291. Gram scale reaction: a solution of allylmagnesium chloride **2a** (4 equiv, 6.8 mL, 1.87 M) in THF was added dropwise to an oven-dried Schlenk tube containing bridged-ring ketone **1a** (3.2 mmol, 1.012 g) and THF (20 mL) at -10 °C. The mixture was stirred at this temperature for 2 h, and then warmed to room temperature and quenched with aqueous NH<sub>4</sub>Cl solution (10 mL). The mixture was extracted with EtOAc (3 × 20 mL). The combined organic layers were then washed

with brine, dried over  $\text{MgSO}_4$  and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent to afford **3a** (0.875 g, 62%).

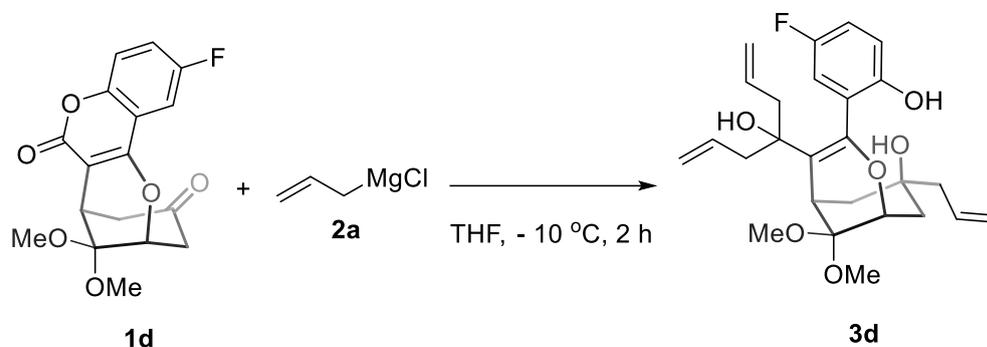


Following the general procedure, the reaction of **1b** (0.2 mmol, 66.2 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10\text{ }^\circ\text{C}$  for 2 h afforded compound **3b** (56.1 mg, 62% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. M.p.  $110.1\text{-}110.6\text{ }^\circ\text{C}$ .  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.30 (s, 1H), 6.97 (d,  $J=8.4$  Hz, 1H), 6.90 (s, 1H), 6.60 (d,  $J=8$ . Hz, 1H), 6.18-6.07 (m, 1H), 5.99-5.87 (m, 2H), 5.10-4.98 (m, 4H), 4.92 (d,  $J=10.0$  Hz, 1H), 4.74 (d,  $J=16.8$  Hz, 1H), 4.27 (s, 1H), 3.99 (s, 1H), 3.30 (s, 3H), 3.25 (s, 3H), 3.00-2.95 (m, 1H), 2.86 (br, 1H), 2.45-2.40 (m, 1H), 2.34-2.20 (m, 5H), 2.20 (s, 3H), 2.07-1.95 (m, 4H).  $^{13}\text{C}$   $\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  154.9, 143.7, 136.7, 136.5, 134.9, 131.2, 130.9, 127.5, 125.2, 118.3, 117.8, 117.5, 117.4, 115.9, 98.5, 75.4, 71.4, 70.1, 50.6, 48.1, 47.9, 46.1, 44.6, 41.7, 40.6, 33.7, 20.4. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M-H}]^-$  Calcd for  $\text{C}_{27}\text{H}_{35}\text{O}_6^-$  455.2439, found 455.2451.

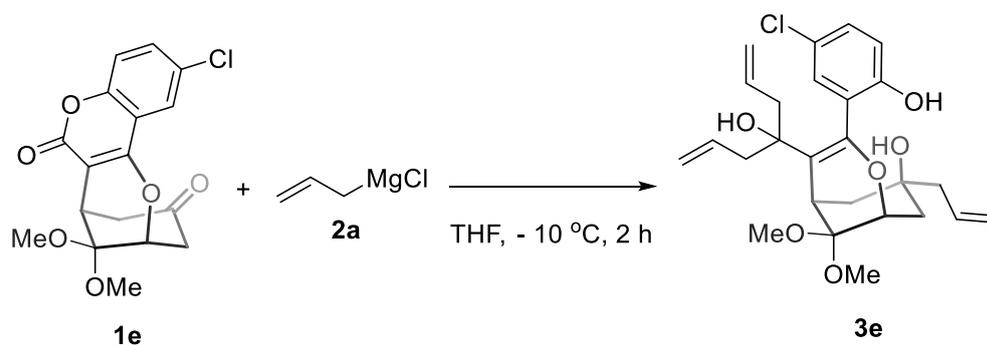


Following the general procedure, the reaction of **1c** (0.2 mmol, 69.3 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10\text{ }^\circ\text{C}$  for 2 h afforded **3c** (58.2 mg, 63% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. M.p.  $100.6\text{-}101.1\text{ }^\circ\text{C}$ .  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.15 (br, 1H), 6.77 (dd,  $J_1=8.8$  Hz,  $J_2=3.2$  Hz, 1H), 6.65-6.61 (m, 2H), 6.18-6.08 (m, 1H), 6.00-5.87 (m, 2H), 5.10-5.01 (m, 4H), 4.93 (d,  $J=9.2$  Hz, 1H), 4.74 (d,  $J=16.8$  Hz, 1H), 4.29 (dd,  $J_1=6.0$  Hz,  $J_2=3.0$

Hz, 1H), 4.02 (br, 1H), 3.70 (s, 3H), 3.30 (s, 3H), 3.26 (s, 3H), 2.97-2.95 (m, 1H), 2.47-2.42 (m, 1H), 2.36-2.18 (m, 5H), 2.10-2.06 (m, 3H), 1.98 (dd,  $J_1 = 14.4$  Hz,  $J_2 = 4.0$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  152.7, 151.1, 143.5, 136.6, 136.5, 135.0, 125.7, 118.4, 117.9, 117.6, 116.7, 116.3, 116.0, 98.5, 75.5, 71.5, 70.2, 56.0, 50.7, 48.2, 47.9, 46.0, 44.6, 41.7, 40.7, 33.8. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{27}\text{H}_{35}\text{O}_7^-$  471.2388, found 471.2395.

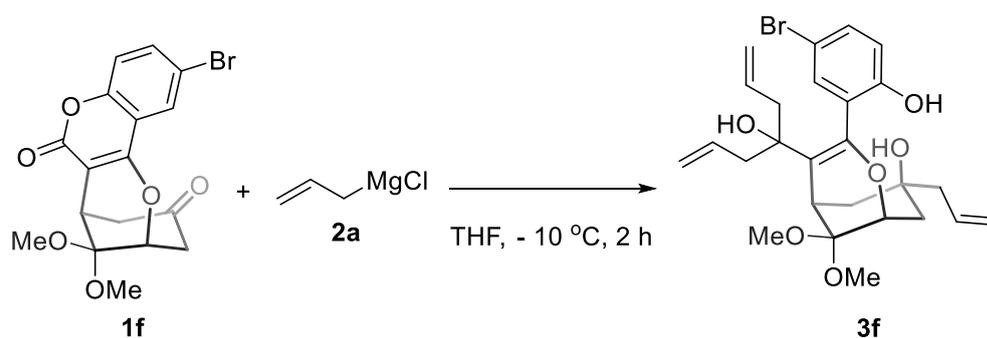


Following the general procedure, the reaction of **1d** (0.2 mmol, 66.9 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10\text{ }^\circ\text{C}$  for 2 h afforded compound **3d** (51.6 mg, 56% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. M.p.  $115.0\text{--}115.7\text{ }^\circ\text{C}$ .  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.45 (br, 1H), 6.97-6.92 (m, 1H), 6.82 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 3.2$  Hz, 1H), 6.15-6.05 (m, 1H), 5.99-5.87 (m, 2H), 5.11-5.06 (m, 5H), 4.95 (d,  $J = 10.0$  Hz, 1H), 4.77 (d,  $J = 17.2$  Hz, 1H), 4.31 (dd,  $J_1 = 6.0$  Hz,  $J_2 = 3.2$  Hz, 1H), 4.08 (br, 1H), 3.31 (s, 3H), 3.26 (s, 3H), 2.97-2.95 (m, 1H), 2.92 (br, 1H), 2.44-2.21 (m, 6H), 2.09-1.96 (m, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  156.0 ( $J_{\text{F-C}} = 223.8$  Hz), 153.5, 142.5, 136.4, 136.2, 134.8, 126.3 ( $J_{\text{F-C}} = 7.9$  Hz), 118.4 ( $J_{\text{F-C}} = 14.7$  Hz), 117.9 ( $J_{\text{F-C}} = 10.2$  Hz), 116.99 ( $J_{\text{F-C}} = 8.4$  Hz), 116.98, 116.8, 116.7, 116.6, 98.4, 75.4, 71.6, 70.2, 50.6, 48.2, 47.9, 45.7, 44.5, 41.6, 40.5, 33.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_6\text{F}^-$  459.2188, found 459.2195.

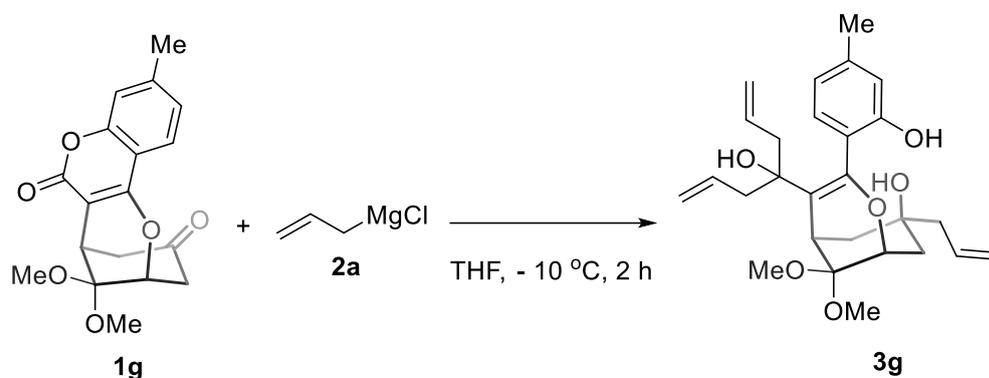


Following the general procedure, the reaction of **1e** (0.2 mmol, 70.2 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M

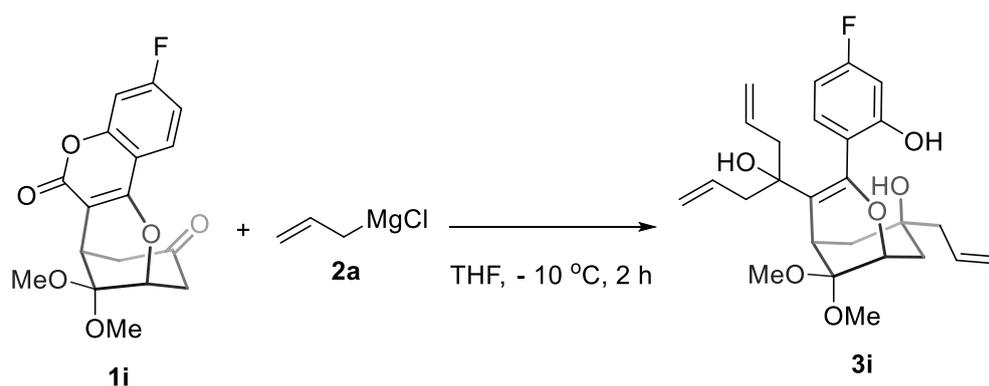
in THF) at -10 °C for 2 h afforded compound **3e** (61.0 mg, 64% yield) as a white slurry after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.66 (br, 1H), 7.17 (d,  $J = 8.8$  Hz, 1H), 7.08 (s, 1H), 6.71 (d,  $J = 8.8$  Hz, 1H), 6.13-5.88 (m, 3H), 5.10-4.94 (m, 5H), 4.77 (d,  $J = 16.8$  Hz, 1H), 4.31 (s, 1H), 4.16 (br, 1H), 3.31 (s, 3H), 3.26 (s, 3H), 2.96-2.89 (m, 1H), 2.41-2.22 (m, 6H), 2.06-1.97 (m, 4H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  152.7, 151.1, 143.5, 136.6, 136.5, 135.0, 125.7, 118.4, 117.9, 117.6, 116.7, 116.3, 116.0, 98.5, 75.5, 71.5, 70.2, 56.0, 50.7, 48.2, 47.9, 46.0, 44.6, 41.7, 40.7, 33.79. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_6\text{Cl}^-$  475.1893, found 475.1905.



Following the general procedure, the reaction of **1f** (0.2 mmol, 79.1 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at -10 °C for 2 h afforded compound **3f** (71.5 mg, 68% yield) as a white slurry after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.30 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 2.4$  Hz, 1H), 7.22 (d,  $J = 2.4$  Hz, 1H), 6.67 (d,  $J = 8.8$  Hz, 1H), 6.14-6.03 (m, 1H), 5.99-5.86 (m, 2H), 5.11-4.94 (m, 5H), 4.77 (d,  $J = 15.6$  Hz, 1H), 4.31 (dd,  $J_1 = 6.0$  Hz,  $J_2 = 3.2$  Hz, 1H), 4.16 (br, 1H), 3.31 (s, 3H), 3.26 (s, 3H), 2.97-2.95 (m, 1H), 2.42-2.20 (m, 6H), 2.09-2.06 (m, 2H), 2.03-1.97 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  156.6, 142.2, 136.3, 136.1, 134.8, 133.3, 133.1, 127.8, 118.5, 118.3, 118.1, 117.9, 109.9, 98.4, 75.4, 71.7, 70.3, 50.5, 48.2, 47.9, 45.7, 44.5, 41.6, 40.5, 33.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_6\text{Br}^-$  519.1388, found 519.1401.

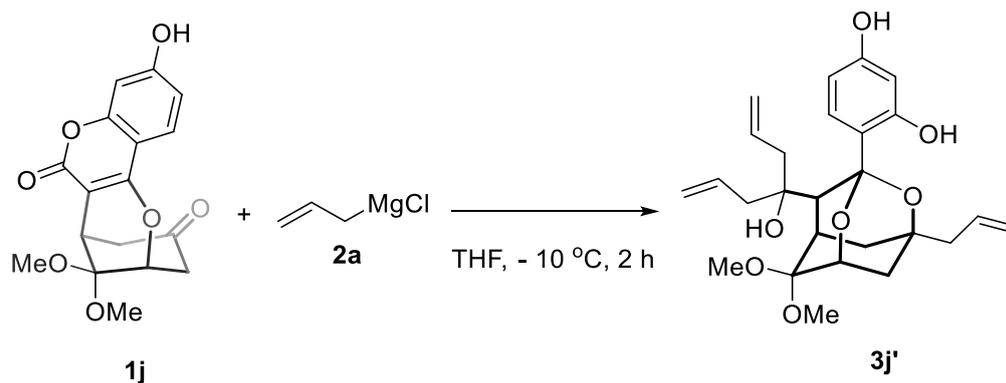


Following the general procedure, the reaction of **1g** (0.2 mmol, 66.1 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at -10 °C for 2 h afforded compound **3g** (57.6 mg, 63% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. M.p. 106.8-108.0 °C. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 8.39 (s, 1H), 6.95 (d, *J* = 7.6 Hz, 1H), 6.58 (d, *J* = 7.6 Hz, 1H), 6.55 (s, 1H), 6.17-6.07 (m, 1H), 5.99-5.87 (m, 2H), 5.10-4.98 (m, 4H), 4.92 (d, *J* = 10.4 Hz, 1H), 4.75 (d, *J* = 17.2 Hz, 1H), 4.26 (s, 1H), 4.01 (s, 1H), 3.29 (s, 3H), 3.25 (s, 3H), 2.96 (s, 1H), 2.45-2.41 (m, 1H), 2.34-2.18 (m, 5H), 2.24 (s, 3H), 2.09-1.94 (m, 4H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 156.2, 142.7, 139.6, 135.8, 135.7, 134.1, 129.8, 121.9, 118.9, 117.5, 117.0, 116.7, 115.9, 97.7, 74.5, 70.6, 69.2, 49.8, 47.3, 47.0, 45.4, 43.8, 40.9, 39.8, 32.9, 20.5. HRMS (ESI/Q-TOF) *m/z*: [M-H]<sup>-</sup> Calcd for C<sub>27</sub>H<sub>35</sub>O<sub>6</sub><sup>-</sup> 455.2439, found 455.2448.

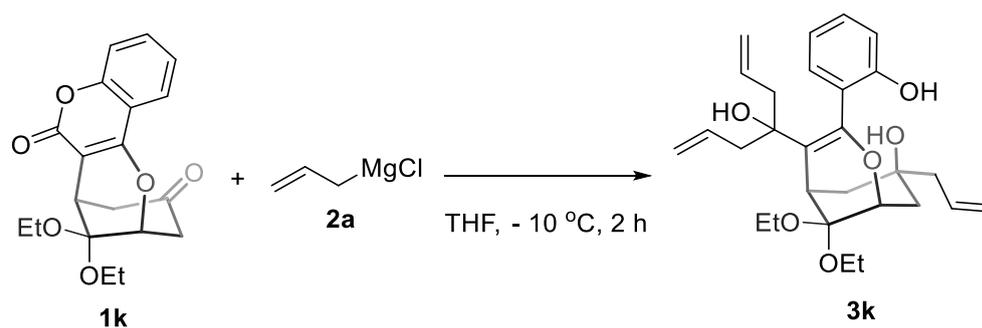


Following the general procedure, the reaction of **1i** (0.2 mmol, 66.9 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at -10 °C for 2 h afforded compound **3i** (49.6 mg, 54% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. M.p. 90.5-92.4 °C. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 7.10-7.06 (m, 1H), 6.56-6.44 (m, 2H), 6.15-6.05 (m, 1H), 5.98-5.86 (m, 2H), 5.11-5.00 (m, 4H), 4.93 (d, *J* = 10.4 Hz, 1H), 4.75 (d, *J* = 16.8 Hz, 1H), 4.29 (dd, *J*<sub>1</sub> = 6.4 Hz, *J*<sub>2</sub> = 3.2 Hz, 1H), 4.15 (br, 1H), 3.29 (s, 3H), 3.26 (s, 3H), 2.96 (br, 1H), 2.42-2.21 (m, 6H), 2.09-1.96 (m, 4H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 165.1 (*J*<sub>F-C</sub> = 241.8 Hz), 158.9 (*J*<sub>F-C</sub> = 12.8 Hz), 142.6, 136.4, 136.2, 134.8, 132.0 (*J*<sub>F-</sub>

$c = 10.3$  Hz), 122.1 ( $J_{F-C} = 3.1$  Hz), 118.6, 118.5, 117.9, 117.8, 105.6 ( $J_{F-C} = 21.6$  Hz), 103.2 ( $J_{F-C} = 24.1$  Hz), 98.4, 75.4, 71.7, 70.1, 50.5, 48.1, 47.9, 46.0, 44.6, 41.6, 40.6, 33.8. HRMS (ESI/Q-TOF)  $m/z$ :  $[M-H]^-$  Calcd for  $C_{26}H_{32}O_6F^-$  459.2188, found 459.2194.

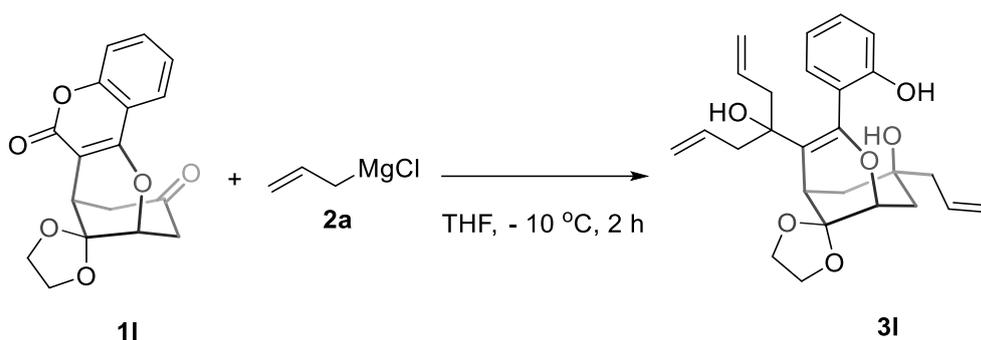


Following the general procedure, the reaction of **1j** (0.2 mmol, 66.5 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10\text{ }^\circ\text{C}$  for 2 h afforded compound **3j'** (50.6 mg, 55% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (2/1) as an eluent. The product **3j'** was obtained as a mixture of diastereoisomers. NMR data of the major isomer was listed.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.26 (s, 1H), 7.40 (d,  $J = 8.8$  Hz, 1H), 6.33-6.29 (m, 2H), 5.87-5.73 (m, 3H), 5.64-5.57 (m, 1H), 5.23-5.01 (m, 4H), 4.95-4.84 (m, 2H), 4.74 (s, 1H), 4.38-4.35 (m, 1H), 3.41 (s, 3H), 3.29 (s, 3H), 2.96 (br, 1H), 2.58-2.53 (m, 1H), 2.32-2.20 (m, 4H), 1.92-1.82 (m, 4H), 1.67 (dd,  $J_1 = 14.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 1.43 (dd,  $J_1 = 14.4$  Hz,  $J_2 = 8.0$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  157.7, 155.9, 134.3, 134.0, 131.2, 129.9, 120.2, 118.3, 117.6, 107.5, 103.7, 101.0, 97.7, 74.5, 73.2, 68.3, 50.7, 47.8, 47.26, 45.0, 42.8, 40.6, 37.6, 34.7, 32.3.  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  159.5, 157.1, 136.3, 136.0, 132.8, 131.3, 119.7, 119.0, 117.2, 106.8, 103.7, 101.7, 98.5, 74.4, 73.8, 69.1, 51.6, 48.0, 47.5, 45.6, 43.7, 41.6, 38.2, 35.3, 33.2. HRMS (ESI/Q-TOF)  $m/z$ :  $[M-H-H_2O]^-$  Calcd for  $C_{26}H_{31}O_6^-$  439.2126, found 439.2135.

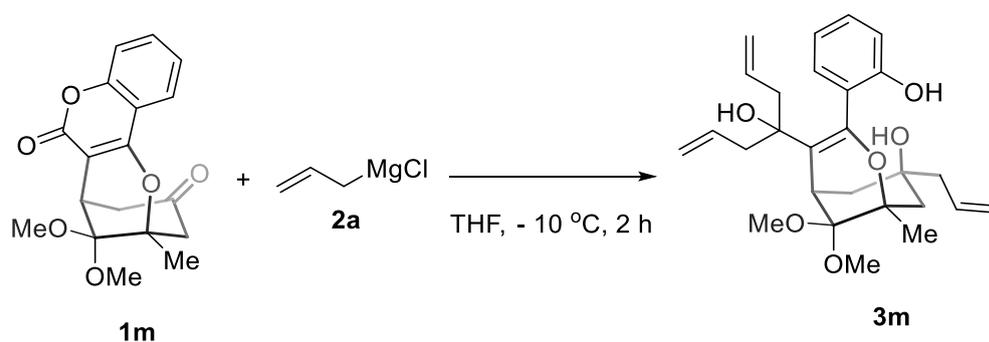


Following the general procedure, the reaction of **1k** (0.2 mmol, 68.8 mg) and **2a** (0.8 mmol, 0.43 mL, 1.87 M in THF) at  $-10\text{ }^\circ\text{C}$  for 2 h afforded compound **3k** (61.2 mg, 66% yield) as a white solid after flash

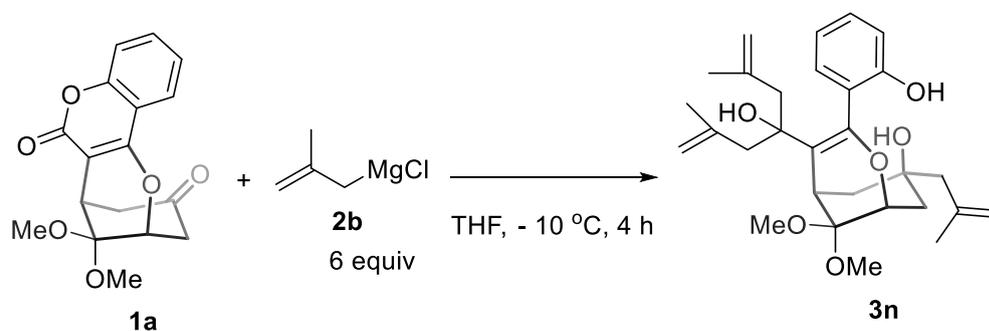
chromatography on silica gel using PE/EtOAc (6/1) as an eluent. M.p. 123.9-124.6 °C. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 8.51 (s, 1H), 7.17 (td, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 1.6 Hz, 1H), 7.08 (dd, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 2.0 Hz, 1H), 6.77-6.70 (m, 2H), 6.28-6.17 (m, 1H), 6.00-5.87 (m, 2H), 5.10-4.90 (m, 5H), 4.72 (d, *J* = 16.8 Hz, 1H), 4.27 (dd, *J*<sub>1</sub> = 6.0 Hz, *J*<sub>2</sub> = 3.2 Hz, 1H), 4.06 (br, 1H), 3.69-3.48 (m, 4H), 2.99-2.96 (m, 1H), 2.43 (dd, *J*<sub>1</sub> = 14.0 Hz, *J*<sub>2</sub> = 6.0 Hz, 1H), 2.36-2.10 (m, 7H), 2.05-1.97 (m, 2H), 1.23 (t, *J* = 6.8 Hz, 3H), 1.20 (t, *J* = 6.8 Hz, 3H). <sup>13</sup>C {<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 157.3, 143.4, 136.8, 136.5, 135.0, 130.8, 130.5, 125.7, 118.9, 118.4, 118.2, 117.8, 117.3, 116.2, 98.30, 75.4, 71.6, 70.7, 56.1, 56.0, 50.6, 46.2, 44.8, 41.6, 40.5, 34.5, 15.8, 15.6. HRMS (ESI/Q-TOF) *m/z*: [M-H]<sup>-</sup> Calcd for C<sub>28</sub>H<sub>37</sub>O<sub>6</sub><sup>-</sup> 469.2596, found 469.2611.



Following the general procedure, the reaction of **11** (0.4 mmol, 125.7 mg) and **4a** (1.6 mmol, 1.6 mL, 1.0 M in THF) at -10 °C for 2 h afforded compound **31** (108.0 mg, 63% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (6/1) as an eluent. M.p. 109.8-110.4 °C. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 8.53 (s, 1H), 7.19-7.15 (m, 1H), 7.09 (dd, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 1.6 Hz, 1H), 6.75 (td, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 1.2 Hz, 1H), 6.71 (d, *J* = 8.0 Hz, 2H), 6.21-6.10 (m, 1H), 6.00-5.88 (m, 2H), 5.11-5.01 (m, 4H), 4.92 (d, *J* = 10.0 Hz, 1H), 4.73 (d, *J* = 17.2 Hz, 1H), 4.08-3.97 (m, 6H), 2.89-2.87 (m, 2H), 2.70-2.67 (m, 1H), 2.47-2.41 (m, 1H), 2.70-2.67 (m, 1H), 2.32-2.16 (m, 6H), 2.04-1.98 (m, 1H). <sup>13</sup>C {<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 157.3, 143.6, 136.4, 134.9, 130.8, 130.6, 125.5, 118.9, 118.4, 118.4, 117.9, 117.7, 116.2, 106.7, 75.3, 73.4, 71.3, 65.6, 65.2, 50.6, 46.4, 44.7, 42.4, 41.8, 36.2. HRMS (ESI/Q-TOF) *m/z*: [M-H]<sup>-</sup> Calcd for C<sub>26</sub>H<sub>31</sub>O<sub>6</sub><sup>-</sup> 439.2126, found 439.2135.

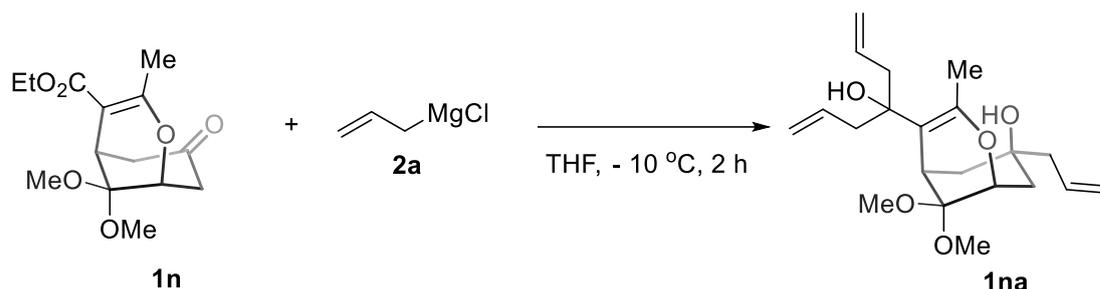


Following the general procedure, the reaction of **1m** (0.4 mmol, 132.2 mg) and **2a** (1.6 mmol, 1.6 mL, 1.0 M in THF) at  $-10\text{ }^\circ\text{C}$  for 2 h afforded compound **3m** (122.3 mg, 67% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.59 (s, 1H), 7.18-7.08 (m, 2H), 6.77-6.69 (m, 2H), 6.16-6.06 (m, 1H), 5.99-5.87 (m, 2H), 5.10-4.90 (m, 5H), 4.75 (d,  $J = 17.2$  Hz, 1H), 4.03 (br, 1H), 3.42 (s, 3H), 3.34 (s, 3H), 3.03-3.00 (m, 1H), 2.40-2.16 (m, 6H), 2.08-2.03 (m, 3H), 1.85 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 2.8$  Hz, 1H), 1.29 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  157.1, 143.9, 136.6, 136.5, 134.9, 131.0, 130.4, 125.6, 118.8, 118.4, 117.8, 117.6, 117.2, 116.2, 99.4, 78.7, 75.2, 72.2, 50.8, 50.7, 49.9, 49.6, 46.2, 45.0, 40.7, 35.1, 24.2. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{27}\text{H}_{35}\text{O}_6$  455.2439, found 455.2451.

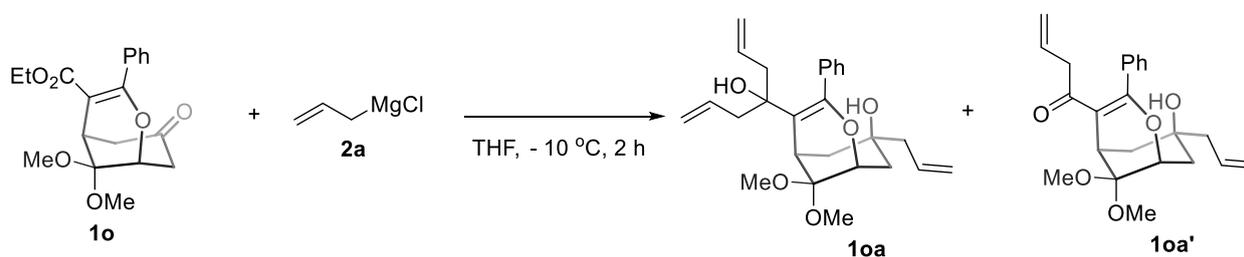


Following the general procedure, the reaction of **1a** (0.2 mmol, 63.1 mg) and **2a** (1.2 mmol, 1.2 mL, 1.0 M in THF) at  $-10\text{ }^\circ\text{C}$  for 4 h afforded compound **3n** (44.5 mg, 46% yield) as an oil after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.57 (br, 1H), 7.19-7.17 (m, 2H), 6.81-6.73 (m, 2H), 4.90-4.72 (m, 6H), 4.48 (t,  $J = 1.6$  Hz, 1H), 4.28 (dd,  $J_1 = 6.0$  Hz,  $J_2 = 2.8$  Hz, 1H), 3.99 (br, 1H), 3.26 (s, 3H), 3.25 (s, 3H), 3.01-2.99 (m, 1H), 2.71 (s, 1H), 2.45 (d,  $J = 14.4$  Hz, 1H), 2.34-2.25 (m, 6H), 2.10-2.09 (m, 2H), 2.00 (dd,  $J_1 = 14.4$  Hz,  $J_2 = 4.4$  Hz, 1H), 1.87 (s, 3H), 1.85 (s, 3H), 1.63 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  157.2, 144.5, 144.0, 143.5, 130.9, 130.6, 125.4, 119.0, 118.9, 116.4, 115.5, 115.1, 115.0, 98.4, 75.5, 72.0, 69.8, 53.9, 48.6, 48.2, 47.9, 47.8, 42.2, 41.1, 34.1, 25.40,

25.35, 24.8. HRMS (ESI/Q-TOF)  $m/z$ :  $[M-H]^-$  Calcd for  $C_{29}H_{39}O_6^-$  483.2752, found 483.2771. **Note:** Compound **3n** was unstable and underwent partial decomposition when purified by silica gel chromatography.

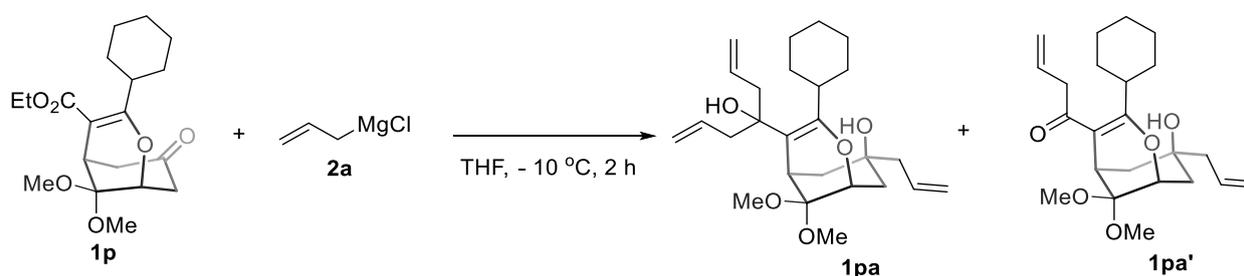


Following the general procedure, the reaction of **1n** (0.2 mmol, 56.9 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10\text{ }^{\circ}\text{C}$  for 2 h afforded compound **1na** (44.2 mg, 61% yield) as a white slurry after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  6.12-5.84 (m, 3H), 5.11-4.98 (m, 6H), 4.22 (dd,  $J_1 = 6.0\text{ Hz}$ ,  $J_2 = 3.2\text{ Hz}$ , 1H), 3.36 (s, 1H), 3.20 (s, 3H), 3.18 (s, 3H), 3.14 (s, 1H), 2.84 (br, 1H), 2.77-2.74 (m, 1H), 2.67-2.62 (m, 1H), 2.54-2.38 (m, 3H), 2.08-2.07 (m, 1H), 1.92 (d,  $J = 3.2\text{ Hz}$ , 2H), 1.90-1.89 (m, 1H), 1.87 (s, 3H), 1.83-1.78 (m, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  146.7, 136.3, 135.9, 135.8, 118.1, 117.5, 117.1, 112.7, 98.4, 75.7, 70.5, 70.2, 49.8, 48.0, 47.9, 46.4, 45.8, 42.5, 39.9, 33.6, 19.5. HRMS (ESI/Q-TOF)  $m/z$ :  $[M-H]^-$  Calcd for  $C_{21}H_{31}O_5^-$  363.2177, found 363.2187.

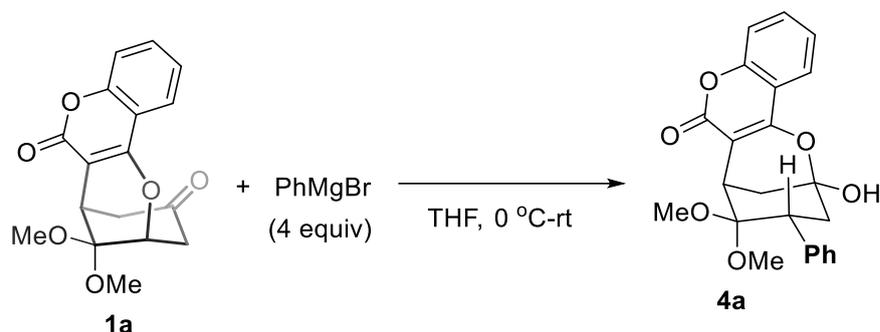


Following the general procedure, the reaction of **1o** (0.2 mmol, 69.2 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10\text{ }^{\circ}\text{C}$  for 2 h afforded compound **1oa** (46.2 mg, 54% yield) and **1oa'** (8.3 mg, 11% yield) after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. **1oa**:  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.34-7.30 (m, 5H), 6.14-5.90 (m, 3H), 4.94-5.07 (m, 5H), 4.74 (d,  $J = 17.2\text{ Hz}$ , 1H), 4.30 (dd,  $J_1 = 6.0\text{ Hz}$ ,  $J_2 = 2.8\text{ Hz}$ , 1H), 3.30 (s, 3H), 3.25 (s, 3H), 3.20 (s, 1H), 2.97 (dd,  $J_1 = 7.2\text{ Hz}$ ,  $J_2 = 2.8\text{ Hz}$ , 1H), 2.85 (br, 1H), 2.45 (dd,  $J_1 = 14.0\text{ Hz}$ ,  $J_2 = 6.0\text{ Hz}$ , 1H), 2.25 (dd,  $J_1 = 14.0\text{ Hz}$ ,  $J_2 = 8.4\text{ Hz}$ , 1H), 2.17-2.09

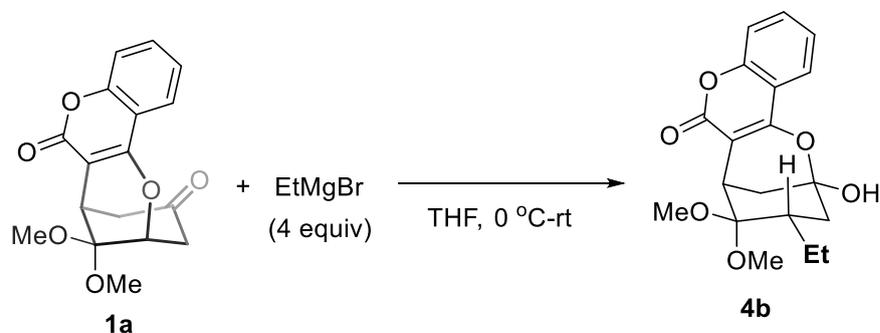
(m, 4H), 2.01-1.96 (m, 3H), 1.90 (dd,  $J_1 = 14.0$  Hz,  $J_2 = 4.0$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  148.0, 139.4, 136.4, 136.2, 135.7, 130.4, 128.7, 128.3, 117.9, 117.9, 117.5, 114.9, 98.6, 75.4, 70.9, 70.4, 50.4, 48.2, 48.0, 46.8, 45.2, 42.5, 40.0, 33.7. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{26}\text{H}_{33}\text{O}_5^-$  425.2333, found 425.2346. **10a'**:  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.46-7.38 (m, 5H), 5.97-5.86 (m, 1H), 5.81-5.70 (m, 1H), 5.08-5.04 (m, 2H), 4.84-4.81 (m, 1H), 4.61-4.55 (m, 1H), 4.51 (dd,  $J_1 = 6.4$  Hz,  $J_2 = 3.2$  Hz, 1H), 3.28-3.26 (m, 1H), 3.26 (s, 3H), 3.21 (s, 3H), 2.83 (br, 1H), 2.61 (dt,  $J_1 = 6.8$  Hz,  $J_2 = 1.6$  Hz, 2H), 2.18 (dt,  $J_1 = 7.2$  Hz,  $J_2 = 1.2$  Hz, 2H), 2.16-2.11 (m, 1H), 2.07-2.01 (m, 1H), 1.93 (dd,  $J_1 = 14.0$  Hz,  $J_2 = 4.0$  Hz, 1H), 1.76 (dt,  $J_1 = 14.4$  Hz,  $J_2 = 2.8$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  197.8, 164.0, 138.3, 135.3, 134.3, 130.1, 129.8, 129.0, 118.0, 116.6, 116.4, 97.6, 73.4, 70.0, 50.9, 48.3, 47.9, 46.9, 41.6, 39.1, 33.3. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{23}\text{H}_{27}\text{O}_5^-$  383.1864, found 383.1872.



Following the general procedure, the reaction of **1p** (0.2 mmol, 70.5 mg) and **2a** (0.8 mmol, 0.8 mL, 1.0 M in THF) at  $-10$  °C for 2 h afforded compound **1pa** (51.1 mg, 59% yield) and **1pa'** (8.1 mg, 10% yield) after flash chromatography on silica gel using PE/EtOAc (10/1) as an eluent. **1pa**:  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  6.15-6.04 (m, 2H), 5.94-5.84 (m, 1H), 5.09-4.98 (m, 6H), 4.26 (dd,  $J_1 = 6.4$  Hz,  $J_2 = 3.2$  Hz, 1H), 3.27 (s, 1H), 3.19 (s, 3H), 3.17 (s, 3H), 3.12 (s, 1H), 2.80-2.75 (m, 2H), 2.66 (dd,  $J_1 = 14.0$  Hz,  $J_2 = 7.2$  Hz, 1H), 2.59-2.54 (m, 1H), 2.49 (dd,  $J_1 = 14.4$  Hz,  $J_2 = 7.2$  Hz, 1H), 2.39 (dd,  $J_1 = 14.0$  Hz,  $J_2 = 8.8$  Hz, 1H), 2.06 (d,  $J = 2.4$  Hz, 1H), 1.93-1.86 (m, 3H), 1.79-1.72 (m, 3H), 1.65-1.51 (m, 5H), 1.26-1.15 (m, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.1, 136.3, 136.0, 135.8, 118.1, 117.8, 117.1, 112.7, 98.6, 75.2, 70.4, 70.2, 49.7, 48.0, 47.8, 47.3, 46.6, 42.5, 41.2, 39.8, 33.6, 30.7, 30.5, 27.1, 27.0, 26.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{26}\text{H}_{39}\text{O}_5^-$  431.2803, found 431.2814. **1pa'**:  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  6.07-5.83 (m, 2H), 5.10-5.01 (m, 4H), 4.40 (dd,  $J_1 = 6.4$  Hz,  $J_2 = 3.2$  Hz, 1H), 3.45-3.24 (m, 3H), 3.23 (s, 3H), 3.16 (s, 3H), 3.03 (dd,  $J_1 = 6.8$  Hz,  $J_2 = 3.2$  Hz, 1H), 2.77 (s, 1H), 2.12 (d,  $J = 7.6$  Hz, 2H), 2.00-1.92 (m, 3H), 1.82-1.56 (m, 7H), 1.47-1.39 (m, 2H), 1.25-1.15 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  196.8, 170.64 135.4, 134.4, 117.7, 116.9, 111.6, 97.3, 72.4, 69.8, 50.6, 48.2, 47.9, 46.0, 41.20, 41.16, 39.8, 33.6, 30.5, 27.0, 26.91, 26.88. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}-\text{H}]^-$  Calcd for  $\text{C}_{23}\text{H}_{33}\text{O}_5^-$  389.2333, found 389.2341.

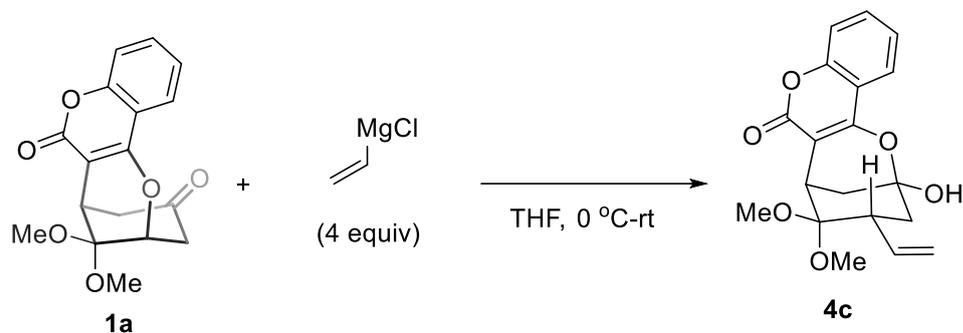


Under dry N<sub>2</sub>, a solution of phenylmagnesium bromide (4 equiv, 0.8 mL, 1.0 M) in THF was added dropwise to an oven-dried Schlenk tube containing bridged-ring ketone **1a** (0.2 mmol, 63.5 mg) and THF (2 mL) at 0 °C. The mixture was stirred and warmed naturally to room temperature. After the reaction was complete (monitored by TLC), the reaction was quenched with aqueous NH<sub>4</sub>Cl solution (3 mL). The mixture was extracted with EtOAc (3 × 5 mL). The combined organic layers were then washed with brine, dried over MgSO<sub>4</sub> and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel using PE/EtOAc (3/1) as an eluent to afford **4a** (61.8 mg, 78%). White solid. M.p. 150.2-151.4 °C. <sup>1</sup>H NMR (400 MHz, DMSO-d<sub>6</sub>): δ 7.79 (t, *J*<sub>1</sub> = 8.0 Hz, *J*<sub>2</sub> = 1.6 Hz, 1H), 7.74 (s, 1H), 7.67-7.63 (m, 1H), 7.39 (t, *J* = 7.6 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2 H), 7.23-7.17 (m, 3H), 3.54 (t, *J* = 3.2 Hz, 1H), 3.33 (s, 3H), 3.23 (s, 3H), 2.98 (dd, *J*<sub>1</sub> = 13.2 Hz, *J*<sub>2</sub> = 4.4 Hz, 1H), 2.37-2.30 (m, 2H), 2.12-2.06 (m, 1H), 1.89 (dt, *J*<sub>1</sub> = 13.2 Hz, *J*<sub>2</sub> = 3.4 Hz, 1H). <sup>13</sup>C {<sup>1</sup>H} NMR (101 MHz, DMSO-d<sub>6</sub>): δ 161.2, 160.6, 152.4, 140.6, 132.2, 129.9, 127.9, 126.7, 124.0, 122.5, 116.3, 114.8, 102.8, 102.6, 101.4, 50.8, 49.0, 45.4, 45.0, 34.9, 31.9. HRMS (ESI/Q-TOF) *m/z*: [M-H]<sup>-</sup> Calcd for C<sub>23</sub>H<sub>21</sub>O<sub>6</sub><sup>-</sup> 393.1344, found 393.1361.



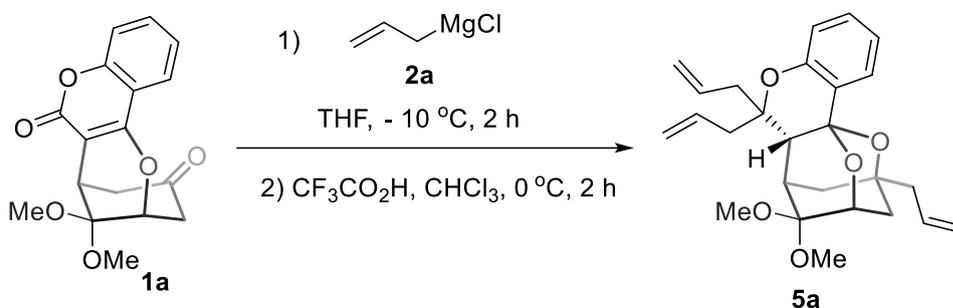
Following a similar procedure for the synthesis of **4a**, the reaction of **1a** (0.2 mmol, 63.4 mg) and EtMgBr (0.4 mL, 2 M in THF) afforded compound **4b** as a white solid (56.4 mg, 81%). M.p. 122.2-122.4 °C. <sup>1</sup>H NMR (400 MHz, DMSO-d<sub>6</sub>): δ 7.77 (t, *J* = 7.6 Hz, 1H), 7.66 (br, 1H), 7.64 (t, *J* = 7.6 Hz, 1H), 7.40-7.35 (m, 2H), 3.43 (t, *J* = 3.2 Hz, 1H), 3.343 (s, 3H), 3.339 (s, 3H), 2.31-2.22 (m, 2H), 1.89-1.81 (m, 2H), 1.64

(t,  $J = 13.2$  Hz, 1H), 1.52-1.44 (m, 1H), 1.20-1.08 (m, 1H), 0.73 (t,  $J = 7.2$  Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, DMSO- $d_6$ ):  $\delta$  161.5, 160.9, 152.3, 132.3, 124.1, 122.5, 116.3, 114.6, 103.0, 102.2, 101.4, 50.7, 49.9, 41.7, 41.2, 34.5, 32.5, 21.2, 12.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M-H}]^-$  Calcd for  $\text{C}_{19}\text{H}_{21}\text{O}_6^-$  345.1344, found 345.1352.



Following a similar procedure for the synthesis of **4a**, the reaction of **1a** (0.2 mmol, 63.4 mg) and  $\text{EtMgBr}$  (1.3 mL, 0.61 M in THF) afforded compound **4c** as a white solid (50.1 mg, 73%). M.p.  $146.9\text{-}147.1\text{ }^\circ\text{C}$ .  $^1\text{H}$  NMR (400 MHz, DMSO- $d_6$ ):  $\delta$  7.77 (t,  $J = 7.6.0$  Hz, 1H), 7.74 (br, 1H), 7.64 (t,  $J = 8.0$  Hz, 1H), 7.40-7.35 (m, 2H), 6.15-6.07 (m, 1H), 5.03-4.94 (m, 2H), 3.43 (t,  $J = 3.2$  Hz, 1H), 3.29 (s, 3H), 3.24 (s, 3H), 2.47-2.41 (m, 1H), 2.23 (dd,  $J_1 = 12.8$  Hz,  $J_2 = 2.8$  Hz, 1H), 2.08-2.03 (m, 1H), 1.93-1.81 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, DMSO- $d_6$ ):  $\delta$  161.1, 160.7, 152.4, 138.1, 132.3, 124.1, 122.5, 116.3, 115.0, 114.7, 102.5, 102.3, 101.1, 50.3, 49.6, 43.2, 42.4, 34.5, 31.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M-H}]^-$  Calcd for  $\text{C}_{19}\text{H}_{19}\text{O}_6^-$  343.1187, found 343.1193.

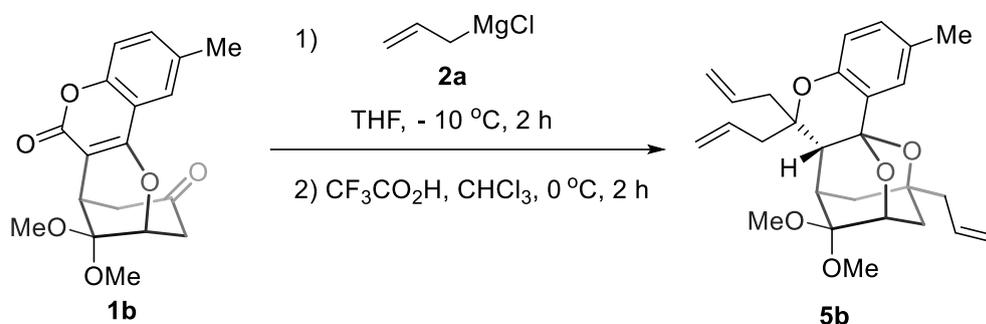
#### 4. Synthesis and characterization data of products 5



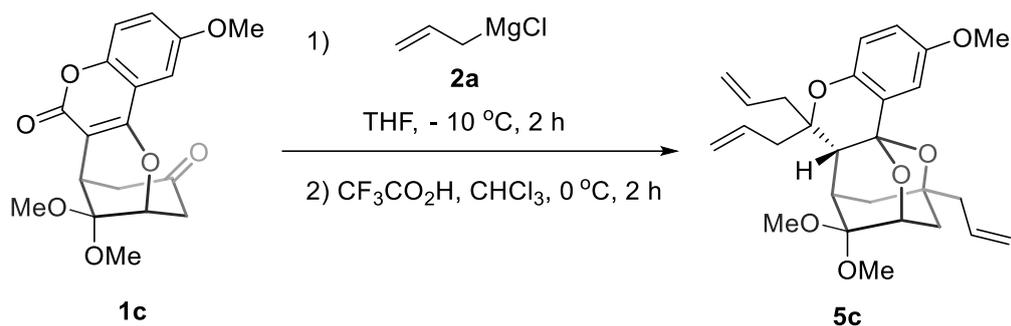
**General Procedure:** under dry  $\text{N}_2$ , a solution of allylmagnesium chloride **2a** (4 equiv, 0.4 mL, 2.0 M) in THF was added dropwise to an oven-dried Schlenk tube containing bridged-ring ketone **1a** (0.2 mmol, 63.7 mg) and THF (2 mL) at -10 °C. The mixture was stirred at this temperature for 2 h, and then warmed to room temperature and quenched with aqueous  $\text{NH}_4\text{Cl}$  solution (3 mL). The mixture was extracted with EtOAc ( $3 \times 5$  mL). The combined organic layers were then washed with brine, dried over  $\text{MgSO}_4$  and filtrated. The filtrate was evaporated in vacuo and the remaining residue was dissolved in  $\text{CHCl}_3$  (2 mL) at 0 °C, followed by adding  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ). The mixture was stirred at this temperature for 2 h, and then evaporated in vacuo and the remaining residue was purified by column chromatography on silica gel using PE/EtOAc (50/1) as an eluent to afford **5a** (51.8 mg, 61%).

**1 mmol Scale:** a solution of allylmagnesium chloride **2a** (4 equiv, 2.2 mL, 1.87 M) in THF was added dropwise to an oven-dried Schlenk tube containing bridged-ring ketone **1a** (1 mmol, 316 mg) and THF (5 mL) at -10 °C. The mixture was stirred at this temperature for 2 h, and then warmed to room temperature. The reaction was quenched with aqueous  $\text{NH}_4\text{Cl}$  solution (10 mL). The mixture was extracted with EtOAc ( $3 \times 15$  mL). The combined organic layers were then washed with brine, dried over  $\text{MgSO}_4$  and filtrated. The filtrate was evaporated in vacuo and the remaining residue was dissolved in  $\text{CHCl}_3$  (5 mL) at 0 °C, followed by adding  $\text{CF}_3\text{CO}_2\text{H}$  (0.1 mL). The mixture was stirred at this temperature for 2 h, and then evaporated in vacuo. The remaining residue was purified by column chromatography on silica gel using PE/EtOAc (50/1) as an eluent to afford **5a** (0.224 g, 53%) as a white solid. White solid. M.p. 113.9-114.3 °C.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.55 (dd,  $J_1 = 8.0$  Hz,  $J_2 = 2.0$  Hz, 1H), 7.25-7.21 (m, 1H), 6.92 (td,  $J_1 = 7.2$  Hz,  $J_2 = 1.2$  Hz, 1H), 6.78 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 1.2$  Hz, 1H), 6.04-5.94 (m, 1H), 5.91-5.78 (m, 2H), 5.23-4.96 (m, 6H), 4.27-4.25 (m, 1H), 3.41-3.35 (m, 1H), 3.22 (s, 3H), 3.20 (s, 3H), 2.99 (d,  $J = 2.0$  Hz, 1H), 2.76-2.71 (m, 2H), 2.49 (dd,  $J_1 = 14.8$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.26-2.18 (m, 3H), 2.05-1.98 (m, 2H), 1.82 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.69 (dd,  $J_1 = 13.6$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.9, 135.2, 134.0, 133.7, 131.0, 128.3, 125.1, 121.1, 118.7, 118.4, 117.9, 117.8, 99.4, 92.9, 82.3, 72.6, 70.7, 48.4, 47.2, 46.4, 42.4, 41.1, 40.1, 36.0,

32.6, 30.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{26}H_{33}O_5^+$  425.2323, found 425.2331.

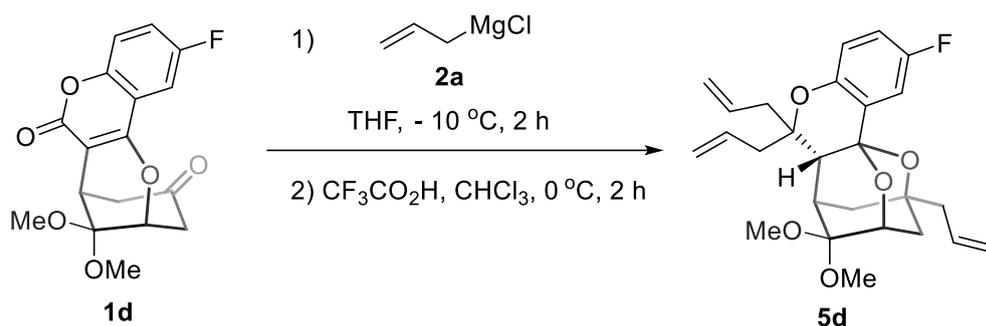


Following the general procedure, the reaction of **1b** (0.2 mmol, 66.2 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5b** (48.9 mg, 56% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (40/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.35 (d,  $J = 2.0$  Hz, 1H), 7.04 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 6.67 (d,  $J = 8.4$  Hz, 1H), 6.03-5.93 (m, 1H), 5.90-5.78 (m, 2H), 5.21-4.96 (m, 6H), 4.26-4.24 (m, 1H), 3.40-3.35 (m, 1H), 3.22 (s, 3H), 3.20 (s, 3H), 2.96 (d,  $J = 2.8$  Hz, 1H), 2.74-2.68 (m, 2H), 2.47 (dd,  $J_1 = 14.8$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.25 (s, 3H), 2.23-2.16 (m, 3H), 2.04-1.96 (m, 2H), 1.82 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.68 (dd,  $J_1 = 13.2$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  151.7, 135.3, 134.1, 133.8, 131.8, 130.0, 128.4, 124.7, 118.7, 118.5, 117.8, 117.7, 99.5, 93.0, 82.0, 72.6, 70.7, 48.5, 47.2, 46.5, 42.5, 41.2, 40.1, 36.1, 32.6, 30.1, 20.6. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{27}H_{35}O_5^+$  439.2479, found 439.2495.

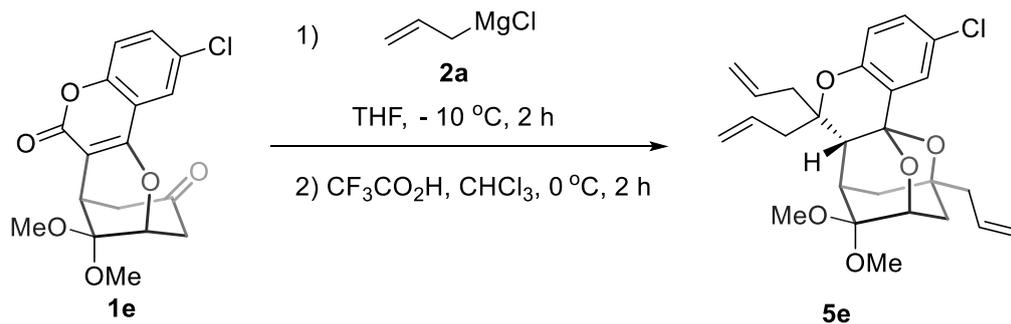


Following the general procedure, the reaction of **1c** (0.2 mmol, 66.1 mg), **2a** (0.2 mmol, 0.4 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5c** (52.3 mg, 58% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (40/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.09 (d,  $J = 3.2$  Hz, 1H), 6.84 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 3.2$  Hz, 1H), 6.72 (d,  $J = 8.8$  Hz, 1H), 6.04-5.90 (m, 1H), 5.90-5.78 (m, 2H), 5.22-4.95 (m, 6H), 4.27-4.25 (m, 1H), 3.74 (m, 3H), 3.40-3.34 (m, 1H), 3.22 (s, 3H), 3.21 (s, 3H), 2.96 (d,  $J = 2.4$  Hz, 1H), 2.73-2.67 (m, 2H), 2.46 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 8.0$  Hz, 1H), 2.22-2.14 (m, 3H), 2.04-1.96 (m, 2H), 1.82 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.68 (dd,  $J_1 = 13.2$  Hz,  $J_2 = 3.2$  Hz,

1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  154.5, 147.8, 135.3, 134.2, 133.8, 125.4, 118.7, 118.6, 118.5, 117.8, 117.7, 112.2, 99.5, 93.1, 81.9, 72.7, 70.8, 55.9, 48.5, 47.3, 46.4, 42.5, 41.2, 40.0, 36.0, 32.6, 30.2. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{27}\text{H}_{35}\text{O}_6^+$  455.2428, found 455.2436.

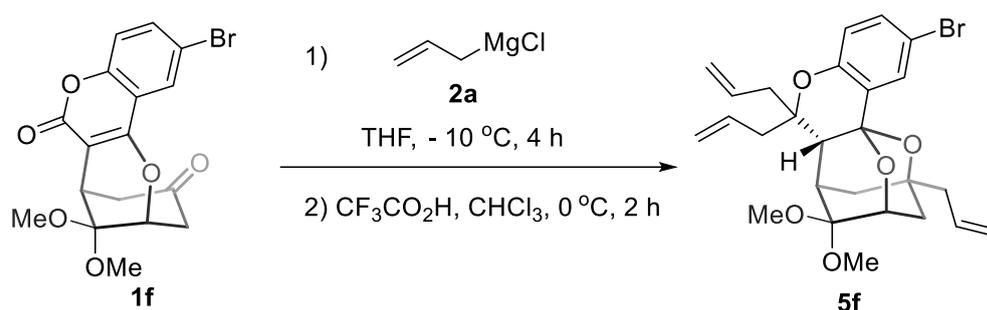


Following the general procedure, the reaction of **1d** (0.2 mmol, 66.9 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5d** (49.3 mg, 56% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (40/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.24 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 3.2$  Hz, 1H), 7.03 (td,  $J_1 = 8.8$  Hz,  $J_2 = 3.2$  Hz, 1H), 6.81 (dd,  $J_1 = 9.2$  Hz,  $J_2 = 4.8$  Hz, 1H), 6.03-5.93 (m, 1H), 5.89-5.78 (m, 2H), 5.24-4.96 (m, 6H), 4.29-4.27 (m, 1H), 3.37-3.31 (m, 1H), 3.23 (s, 3H), 3.21 (s, 3H), 2.96 (d,  $J = 2.0$  Hz, 1H), 2.76-2.70 (m, 2H), 2.49 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.26-2.19 (m, 3H), 2.02-1.98 (m, 2H), 1.83 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.70 (dd,  $J_1 = 12.8$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  157.7 (d,  $J_{\text{C-F}} = 235.0$  Hz), 150.1 (d,  $J_{\text{C-F}} = 2.0$  Hz), 135.6, 133.9, 133.6, 126.1 (d,  $J_{\text{C-F}} = 7.2$  Hz), 119.5 (d,  $J_{\text{C-F}} = 7.7$  Hz), 118.9, 118.6, 118.12 (d,  $J_{\text{C-F}} = 24.4$  Hz), 118.10, 113.8 (d,  $J_{\text{C-F}} = 23.4$  Hz), 99.4, 92.7, 82.6, 72.9, 70.9, 48.5, 47.3, 46.3, 42.2, 41.1, 40.0, 36.0, 32.5, 30.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_5\text{F}^+$  443.2228, found 443.2239.

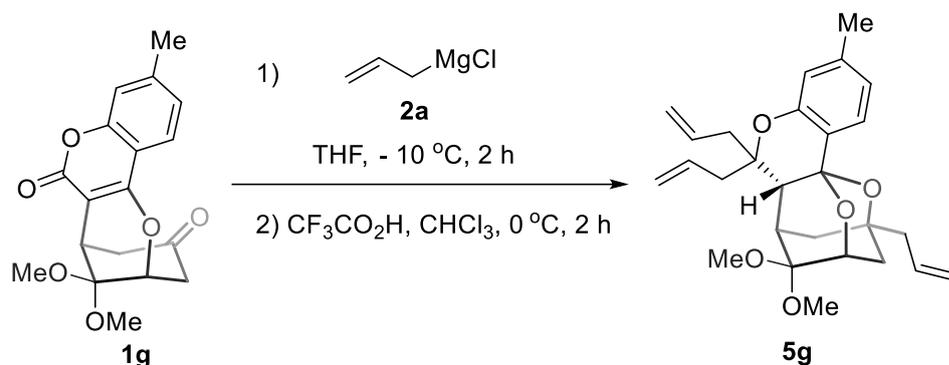


Following the general procedure, the reaction of **1e** (0.2 mmol, 70.2 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5e** (55.2 mg, 60% yield) as an oil after flash

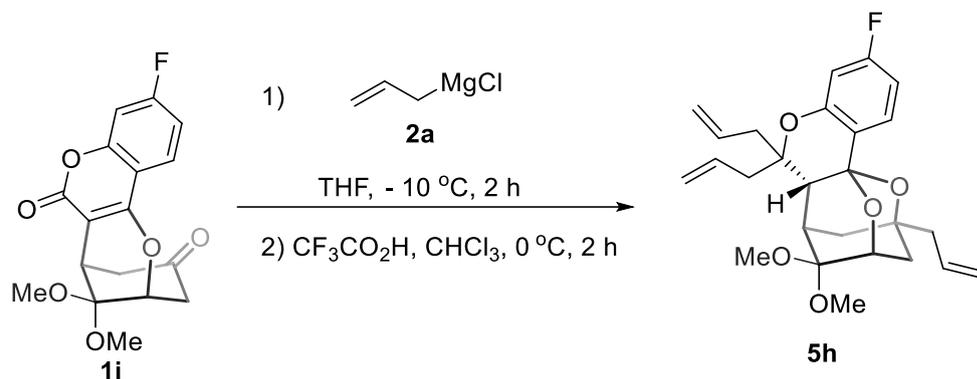
chromatography on silica gel using PE/EtOAc (40/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.52 (d,  $J = 2.8$  Hz, 1H), 7.25 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 2.8$  Hz, 1H), 6.82 (d,  $J = 8.8$  Hz, 1H), 6.02-5.92 (m, 1H), 5.89-5.78 (m, 2H), 5.24-4.96 (m, 6H), 4.29-4.27 (m, 1H), 3.37-3.31 (m, 1H), 3.23 (s, 3H), 3.21 (s, 3H), 2.96 (d,  $J = 2.0$  Hz, 1H), 2.77-2.71 (m, 2H), 2.50 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.27-2.19 (m, 3H), 2.05-1.98 (m, 2H), 1.84 (dd,  $J_1 = 12.8$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.70 (dd,  $J_1 = 13.6$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  152.8, 134.8, 133.8, 133.6, 131.1, 128.0, 126.6, 125.5, 120.0, 119.0, 118.6, 118.2, 99.4, 92.6, 83.0, 73.0, 70.9, 48.5, 47.3, 46.3, 42.1, 41.0, 40.1, 36.0, 32.6, 30.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_5\text{Cl}^+$  459.1933, found 459.1945.



Following the general procedure, the reaction of **1f** (0.2 mmol, 79.1 mg), **2a** (0.8 mmol, 0.43 mL, 1.87 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5f** (56.4 mg, 56% yield) as an oil after flash chromatography on silica gel using PE/EtOAc (60/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.66 (d,  $J = 2.8$  Hz, 1H), 7.38 (dd,  $J_1 = 8.8$  Hz,  $J_2 = 2.8$  Hz, 1H), 6.78 (d,  $J = 8.8$  Hz, 1H), 6.02-5.91 (m, 1H), 5.89-5.78 (m, 2H), 5.24-4.96 (m, 6H), 4.29-4.27 (m, 1H), 3.36-3.31 (m, 1H), 3.22 (s, 3H), 3.21 (s, 3H), 2.96 (d,  $J = 2.0$  Hz, 1H), 2.77-2.71 (m, 2H), 2.50 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.28-2.16 (m, 3H), 2.07-1.98 (m, 2H), 1.83 (dd,  $J_1 = 12.8$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.69 (dd,  $J_1 = 13.6$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.2, 134.8, 134.0, 133.7, 133.6, 131.0, 127.1, 120.4, 119.1, 118.7, 118.3, 112.7, 99.3, 92.5, 83.0, 73.0, 70.9, 48.5, 47.3, 46.3, 42.1, 41.0, 40.1, 36.0, 32.5, 30.2. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_5\text{Br}^+$  503.1428, found 503.1436.

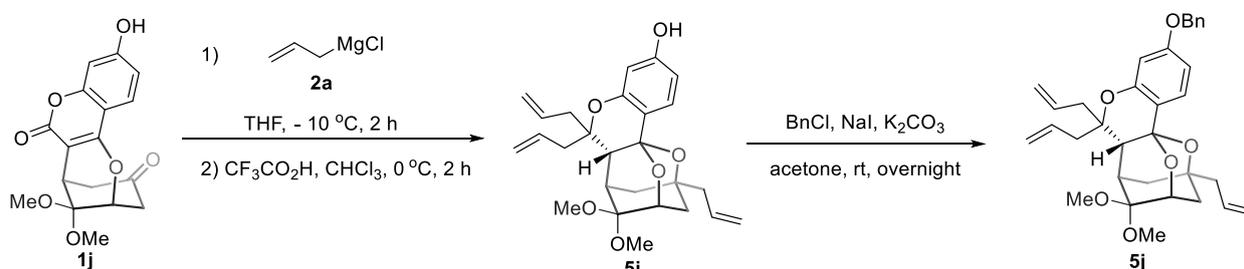


Following the general procedure, the reaction of **1g** (0.2 mmol, 66.1 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5g** (50.6 mg, 58% yield) as an oil after flash chromatography on silica gel using PE/EtOAc (40/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.42 (d,  $J = 8.0$  Hz, 1H), 6.75 (d,  $J = 8.0$  Hz, 1H), 6.61 (s, 1H), 6.03-5.93 (m, 1H), 5.91-5.77 (m, 2H), 5.22-4.97 (m, 6H), 4.25-4.23 (m, 1H), 3.41-3.35 (m, 1H), 3.22 (s, 3H), 3.20 (s, 3H), 2.96 (d,  $J = 1.2$  Hz, 1H), 2.74-2.68 (m, 2H), 2.47 (dd,  $J_1 = 14.2$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.26 (s, 3H), 2.24-2.16 (m, 3H), 2.04-1.96 (m, 2H), 1.81 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.67 (dd,  $J_1 = 13.6$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}$   $\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.8, 141.1, 135.3, 134.1, 133.8, 128.2, 122.4, 122.1, 118.7, 118.4, 118.0, 117.9, 99.5, 92.9, 82.2, 72.5, 70.7, 48.5, 47.2, 46.5, 42.4, 41.2, 40.2, 36.1, 32.6, 30.2, 21.3. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{27}\text{H}_{35}\text{O}_5^+$  439.2479, found 439.2494.



Following the general procedure, the reaction of **1i** (0.2 mmol, 67.2 mg), **2a** (0.8 mmol, 0.43 mL, 1.87 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5h** (45.8 mg, 52% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.57 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 2.8$  Hz, 1H), 6.71 (td,  $J_1 = 8.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 6.54 (dd,  $J_1 = 10.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 6.02-5.77 (m, 3H), 5.24-4.97 (m, 6H), 4.27-4.25 (m, 1H), 3.39-3.34 (m, 1H), 3.22 (s, 3H), 3.21 (s, 3H), 2.97 (d,  $J = 2.0$  Hz, 1H), 2.77-2.71 (m, 2H), 2.50 (dd,  $J_1 = 14.8$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.28-2.18 (m, 3H), 2.04-1.97 (m, 2H), 1.82 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.69 (dd,  $J_1 = 14.4$  Hz,  $J_2 = 2.8$  Hz, 1H).

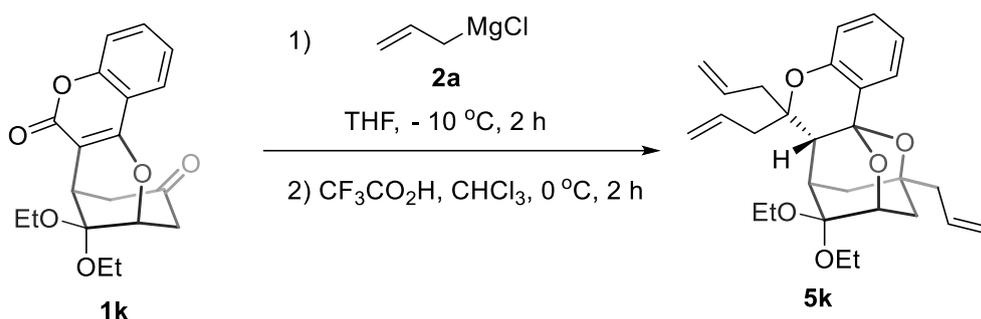
$^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  164.6 (d,  $J_{\text{C-F}} = 243.5$  Hz), 155.4 (d,  $J_{\text{C-F}} = 12.4$  Hz), 134.9, 133.7 (d,  $J_{\text{C-F}} = 6.0$  Hz), 130.2 (d,  $J_{\text{C-F}} = 10.3$  Hz), 121.7 (d,  $J_{\text{C-F}} = 3.0$  Hz), 119.0, 118.6, 118.2, 108.5 (d,  $J_{\text{C-F}} = 21.9$  Hz), 104.4 (d,  $J_{\text{C-F}} = 24.0$  Hz), 99.4, 92.5, 83.4, 72.7, 70.8, 48.5, 47.3, 46.4, 42.2, 41.0, 40.2, 36.0, 32.5, 30.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{32}\text{O}_5\text{F}^+$  443.2228, found 443.2240.



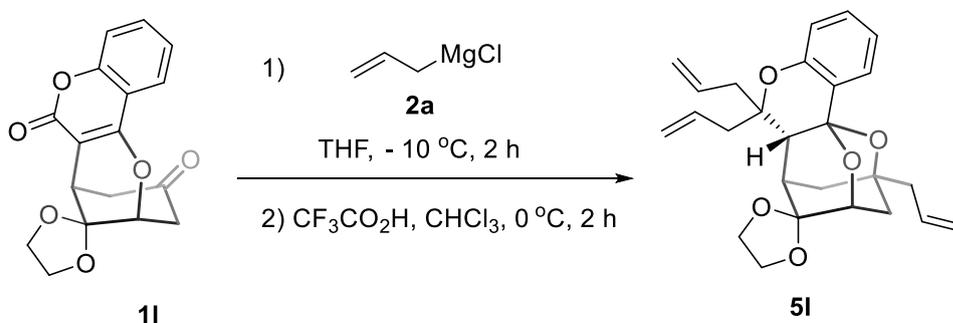
Following the general procedure, the reaction of **1j** (0.2 mmol, 66.2 mg), **2a** (0.8 mmol, 0.43 mL, 1.87 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5i** (44.7 mg, 51% yield) as a white solid after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent. M.p. 176.4-177.1  $^\circ\text{C}$ .  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  8.41 (br, 1H), 7.37 (d,  $J = 8.4$  Hz, 1H), 6.44 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 6.24 (d,  $J = 2.4$  Hz, 1H), 6.03-5.78 (m, 3H), 5.22-4.97 (m, 6H), 4.24-4.22 (m, 1H), 3.43-3.37 (m, 1H), 3.21 (s, 3H), 3.20 (s, 3H), 2.93 (d,  $J = 1.6$  Hz, 1H), 2.73-2.67 (m, 2H), 2.46 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.23-2.13 (m, 3H), 2.02-1.95 (m, 2H), 1.79 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.66 (dd,  $J_1 = 14.0$  Hz,  $J_2 = 2.8$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  160.0, 155.1, 135.3, 134.1, 133.9, 129.3, 118.7, 118.4, 117.9, 117.1, 109.3, 103.6, 99.5, 93.0, 82.4, 72.4, 70.6, 48.4, 47.2, 46.5, 42.4, 41.1, 40.3, 36.0, 32.6, 30.2. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{33}\text{O}_6^+$  441.2272, found 441.2281.

A mixture of **5i** (30.0 mg, 0.068 mmol),  $\text{K}_2\text{CO}_3$  (3.5 equiv, 32.5 mg), BnCl (3 equiv, 24.2 mg) and KI (5.6 mg, 0.5 equiv) in acetone (2 mL) was stirred for 34 h. The reaction mixture was diluted with water (2 mL), and extracted with EtOAc ( $3 \times 5$  mL). The combined organic layers were then washed with brine, dried over  $\text{MgSO}_4$  and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent to afford compound **5j** as a colorless slurry (24.2 mg, 67%).  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.48-7.44 (m, 3H), 7.41-7.37 (m, 2H), 7.34-7.30 (m, 1H), 6.61 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 2.8$  Hz, 1H), 6.43 (d,  $J = 2.8$  Hz, 1H), 6.03-5.77 (m, 3H), 5.22-4.96 (m, 8H), 4.24-4.23 (m, 1H), 3.42-3.36 (m, 1H), 3.21 (s, 3H), 3.19 (s, 3H), 2.95 (s, 1H), 2.74-2.68 (m, 2H), 2.47 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 7.6$  Hz, 1H), 2.23-2.17 (m, 3H), 2.03-1.95 (m, 2H), 1.79 (dd,  $J_1 = 12.4$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.66 (dd,  $J_1 = 14.0$  Hz,  $J_2 = 2.8$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  161.4, 155.1,

138.3, 135.2, 134.0, 133.8, 129.2, 128.6, 128.3, 118.8, 118.4, 118.1, 118.0, 109.2, 103.0, 99.5, 92.8, 82.6, 72.5, 70.6, 70.4, 48.4, 47.2, 46.4, 42.3, 41.1, 40.2, 36.0, 32.5, 30.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{33}H_{39}O_6^+$  531.2741, found 531.2760.

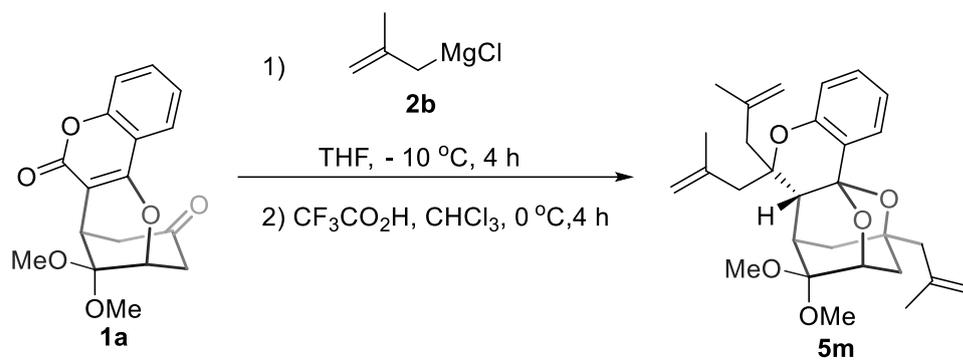


Following the general procedure, the reaction of **1k** (0.2 mmol, 68.9 mg), **2a** (0.8 mmol, 0.43 mL, 1.87 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5k** (54.1 mg, 60% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (60/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.56 (dd,  $J_1 = 8.0$  Hz,  $J_2 = 2.0$  Hz, 1H), 7.25-7.21 (m, 1H), 6.92 (t,  $J = 7.6$  Hz, 1H), 6.78 (d,  $J = 8.0$  Hz, 1H), 6.04-5.78 (m, 3H), 5.22-4.96 (m, 6H), 4.24-4.22 (m, 1H), 3.57-3.42 (m, 4H), 3.40-3.35 (m, 1H), 3.07 (d,  $J = 2.0$  Hz, 1H), 2.76-2.71 (m, 2H), 2.46 (dd,  $J_1 = 15.2$  Hz,  $J_2 = 8.0$  Hz, 1H), 2.24-2.18 (m, 3H), 2.05-1.97 (m, 2H), 1.89-1.85 (m, 1H), 1.72 (dd,  $J_1 = 13.6$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.9, 135.2, 133.9, 133.8, 131.0, 128.4, 125.2, 121.1, 118.8, 118.4, 117.94, 117.86, 99.3, 92.9, 82.3, 72.5, 71.5, 56.2, 55.2, 46.4, 42.2, 41.0, 40.2, 36.1, 33.3, 30.3, 15.6, 15.4. HRMS (ESI/Q-TOF)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{28}H_{37}O_5^+$  453.2636, found 453.2645.

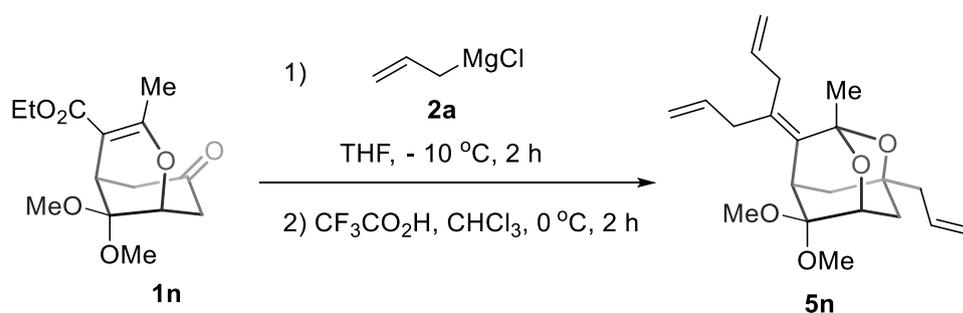


Following the general procedure, the reaction of **1l** (0.4 mmol, 125.7 mg), **2a** (1.6 mmol, 0.8 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (40  $\mu\text{L}$ ) afforded compound **5l** (93.1 mg, 55% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.56 (d,  $J = 7.6$  Hz, 1H), 7.26-7.21 (m, 1H), 6.94-6.91 (m, 1H), 6.79 (d,  $J = 8.4$  Hz, 1H), 6.02-5.78 (m, 3H), 5.22-4.96 (m, 6H), 4.04-3.97 (m, 4H), 3.90-3.88 (m, 1H), 3.40-3.35 (m, 1H), 3.02 (d,  $J = 1.6$  Hz, 1H), 2.78-

2.73 (m, 1H), 2.44-2.38 (m, 2H), 2.22-2.17 (m, 3H), 2.09-2.05 (m, 2H), 1.87-1.82 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.9, 135.1, 134.2, 133.7, 131.1, 128.4, 125.1, 121.2, 118.5, 118.1, 117.9, 107.5, 92.7, 82.1, 74.3, 72.4, 65.7, 65.6, 46.5, 43.4, 41.1, 40.2, 37.0, 35.5, 31.5. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{31}\text{O}_5^+$  423.2166, found 423.2183.

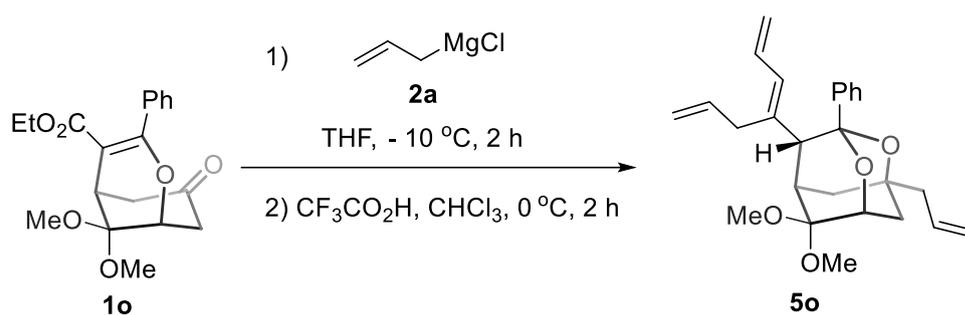


Following the general procedure, the reaction of **1a** (0.2 mmol, 63.2 mg), **2b** (1.2 mmol, 1.2 mL, 1.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5m** (39.2 mg, 42% yield) as a slurry solid after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.57 (dd,  $J_1 = 8.0$  Hz,  $J_2 = 2.0$  Hz, 1H), 7.24 (td,  $J_1 = 8.0$  Hz,  $J_2 = 1.6$  Hz, 1H), 6.91 (td,  $J_1 = 8.0$  Hz,  $J_2 = 1.6$  Hz, 1H), 6.75 (dd,  $J_1 = 8.0$  Hz,  $J_2 = 1.2$  Hz, 1H), 4.95 (d,  $J = 13.6$  Hz, 2H), 4.90-4.86 (m, 2H), 4.73 (d,  $J = 11.6$  Hz, 2H), 4.27-4.24 (m, 1H), 3.23 (s, 3H), 3.18 (s, 3H), 3.15 (d,  $J = 14.0$  Hz, 1H), 3.05 (d,  $J = 2.0$  Hz, 1H), 2.83-2.81 (m, 1H), 2.74 (d,  $J = 14.4$  Hz, 1H), 2.49 (d,  $J = 14.4$  Hz, 1H), 2.33 (d,  $J = 14.4$  Hz, 1H), 2.22-2.07 (m, 4H), 1.85 (s, 3H), 1.79 (dd,  $J_1 = 12.8$  Hz,  $J_2 = 2.0$  Hz, 1H), 1.75 (s, 3H), 1.72 (s, 3H), 1.66 (dd,  $J_1 = 13.6$  Hz,  $J_2 = 3.2$  Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  153.4, 143.8, 142.7, 142.2, 131.0, 128.3, 124.9, 120.8, 117.9, 116.7, 116.0, 115.1, 99.9, 92.9, 83.8, 73.0, 70.3, 49.6, 48.5, 47.0, 44.2, 43.4, 41.1, 36.0, 33.2, 30.8, 25.0, 24.9, 24.8. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{29}\text{H}_{39}\text{O}_5^+$  467.2792, found 467.2805.

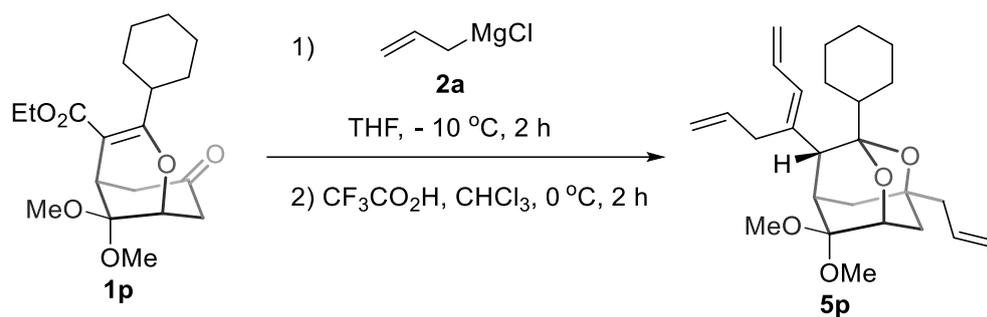


Following the general procedure, the reaction of **1n** (0.2 mmol, 56.6 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in

THF) and CF<sub>3</sub>CO<sub>2</sub>H (20 uL) afforded compound **5n** (41.8 mg, 60% yield) as an oil after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 5.89-5.76 (m, 3H), 5.18-5.12 (m, 1H), 5.08-5.03 (m, 4H), 5.00-4.96 (m, 1H), 4.11-4.09 (m, 1H), 3.22 (s, 3H), 3.18 (s, 3H), 3.13-3.07 (m, 1), 3.02 (dd, *J*<sub>1</sub> = 15.2 Hz, *J*<sub>2</sub> = 6.4 Hz, 1H), 2.81-2.77 (m, 1H), 2.62-2.57 (m, 1H), 2.11 (dt, *J*<sub>1</sub> = 7.6 Hz, *J*<sub>2</sub> = 1.2 Hz, 2H), 1.87-1.73 (m, 3H), 1.66 (dt, *J*<sub>1</sub> = 12.8 Hz, *J*<sub>2</sub> = 3.2 Hz, 1H), 1.53 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 137.3, 136.9, 135.1, 134.1, 125.4, 118.1, 116.3, 115.4, 99.8, 98.7, 71.8, 68.9, 48.1, 47.2, 46.3, 39.4, 38.7, 38.0, 37.1, 34.8, 27.5. HRMS (ESI/Q-TOF) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>21</sub>H<sub>31</sub>O<sub>4</sub><sup>+</sup> 347.2217, found 347.2224.



Following the general procedure, the reaction of **1o** (0.2 mmol, 66.5 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in THF) and CF<sub>3</sub>CO<sub>2</sub>H (20 uL) afforded compound **5o** (32.0 mg, 39% yield) as an oil after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent. <sup>1</sup>H NMR (400 MHz, acetone-d<sub>6</sub>): δ 7.47 (dd, *J*<sub>1</sub> = 8.0 Hz, *J*<sub>2</sub> = 1.2 Hz, 2H), 7.27-7.18 (m, 3H), 6.49-6.34 (m, 2H), 6.11-6.01 (m, 1H), 5.49-4.39 (m, 1H), 5.20-5.15 (m, 2H), 5.07 (dd, *J*<sub>1</sub> = 16.0 Hz, *J*<sub>2</sub> = 2.4 Hz, 1H), 4.91 (dd, *J*<sub>1</sub> = 9.6 Hz, *J*<sub>2</sub> = 2.4 Hz, 1H), 4.83 (ddd, *J*<sub>1</sub> = 9.6 Hz, *J*<sub>2</sub> = 3.2 Hz, *J*<sub>3</sub> = 1.6 Hz, 1H), 4.71 (ddd, *J*<sub>1</sub> = 16.4 Hz, *J*<sub>2</sub> = 3.6 Hz, *J*<sub>3</sub> = 2.0 Hz, 1H), 4.21-4.19 (m, 1H), 3.35 (s, 3H), 3.24 (s, 3H), 3.15 (d, *J* = 2.4 Hz, 1H), 2.98-2.93 (m, 1H), 2.57 (dd, *J*<sub>1</sub> = 15.2 Hz, *J*<sub>2</sub> = 7.2 Hz, 1H), 2.45-2.42 (m, 1H), 2.40-2.28 (m, 2H), 2.10-2.05 (m, 2H), 1.91 (dt, *J*<sub>1</sub> = 12.8 Hz, *J*<sub>2</sub> = 3.6 Hz, 1H), 1.60 (dd, *J*<sub>1</sub> = 12.4 Hz, *J*<sub>2</sub> = 2.0 Hz, 1H), 1.60 (dd, *J*<sub>1</sub> = 12.8 Hz, *J*<sub>2</sub> = 2.4 Hz, 1H). <sup>13</sup>C{<sup>1</sup>H} NMR (101 MHz, acetone-d<sub>6</sub>): δ 143.0, 137.3, 136.4, 134.10, 134.07, 132.6, 128.2, 127.9, 126.7, 118.6, 116.5, 116.2, 98.9, 98.3, 73.1, 70.6, 48.2, 47.6, 47.3, 46.6, 36.4, 36.2, 36.0, 28.7. HRMS (ESI/Q-TOF) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>26</sub>H<sub>33</sub>O<sub>4</sub><sup>+</sup> 409.2373, found 409.2384.



Following the general procedure, the reaction of **1p** (0.2 mmol, 70.5 mg), **2a** (0.8 mmol, 0.4 mL, 2.0 M in THF) and  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ ) afforded compound **5p** (42.4 mg, 51% yield) as an oil after flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  6.70-6.57 (m, 2H), 5.97-5.76 (m, 2H), 5.19 (dd,  $J_1 = 16.0$  Hz,  $J_2 = 2.8$  Hz, 1H), 5.11-5.00 (m, 5H), 4.08-4.06 (m, 1H), 3.24 (s, 3H), 3.17 (s, 3H), 3.15-3.09 (m, 1H), 2.77-2.73 (m, 2H), 2.27-2.24 (m, 1H), 2.18-2.14 (m, 2H), 2.00-1.95 (m, 2H), 1.92 (dt,  $J_1 = 13.2$  Hz,  $J_2 = 3.2$  Hz, 1H), 1.77-1.55 (m, 7H), 1.48 (dd,  $J_1 = 12.8$  Hz,  $J_2 = 3.2$  Hz, 1H), 1.30-1.18 (m, 2H), 1.14-1.06 (m, 2H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  138.4, 137.3, 134.3, 134.2, 131.7, 118.2, 116.8, 116.2, 99.8, 98.8, 71.9, 69.6, 48.0, 47.4, 46.7, 44.3, 43.4, 37.1, 36.0, 35.9, 29.2, 27.3, 27.1, 27.0, 26.7, 25.3. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{39}\text{O}_4^+$  415.2843, found 415.2853.

## 5. Plausible mechanism for the conversion of 3 into 5

5.1 The plausible mechanism for the acid-mediated conversion of 3a into 5a and 5a' is presented in Figure S1.

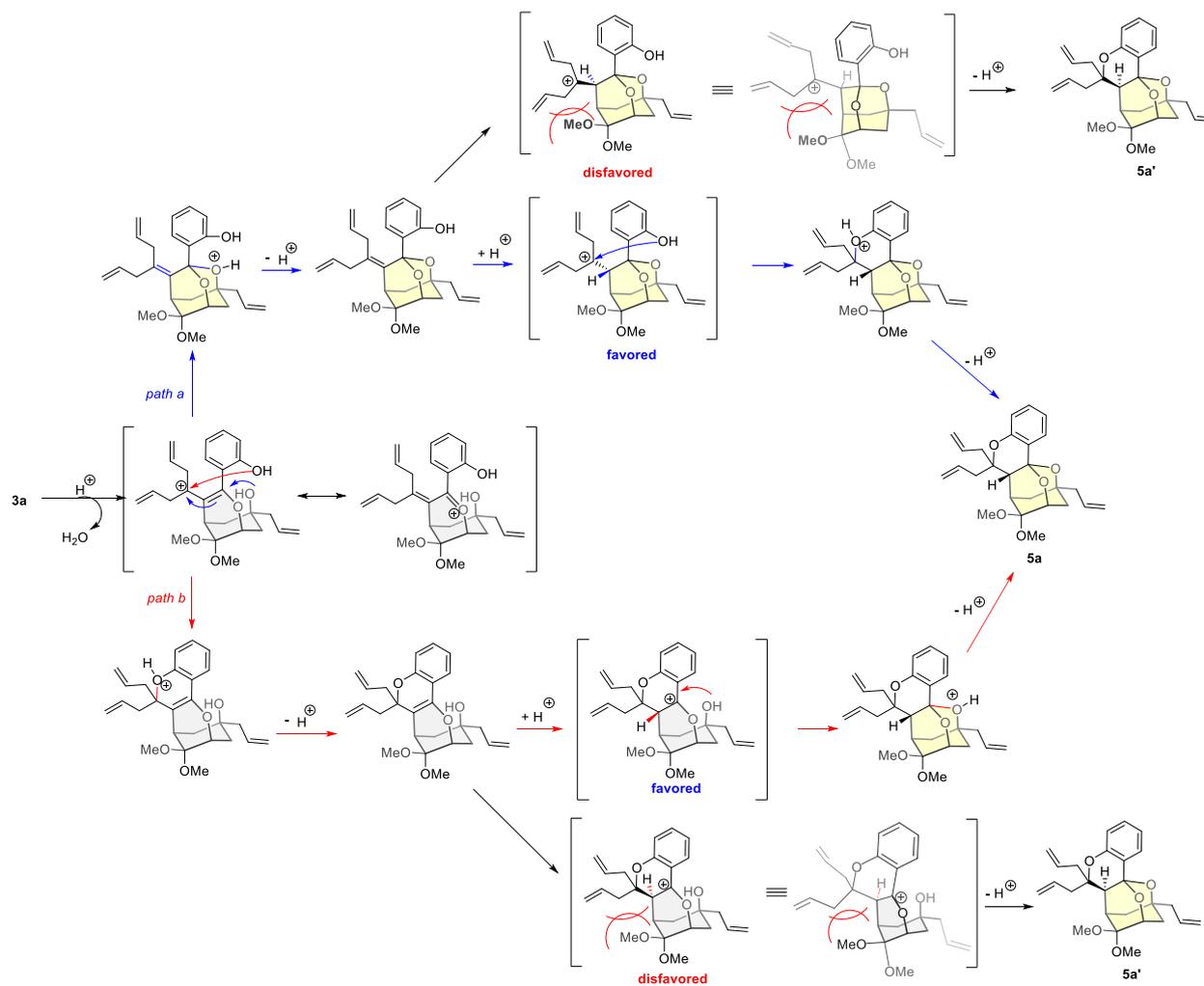
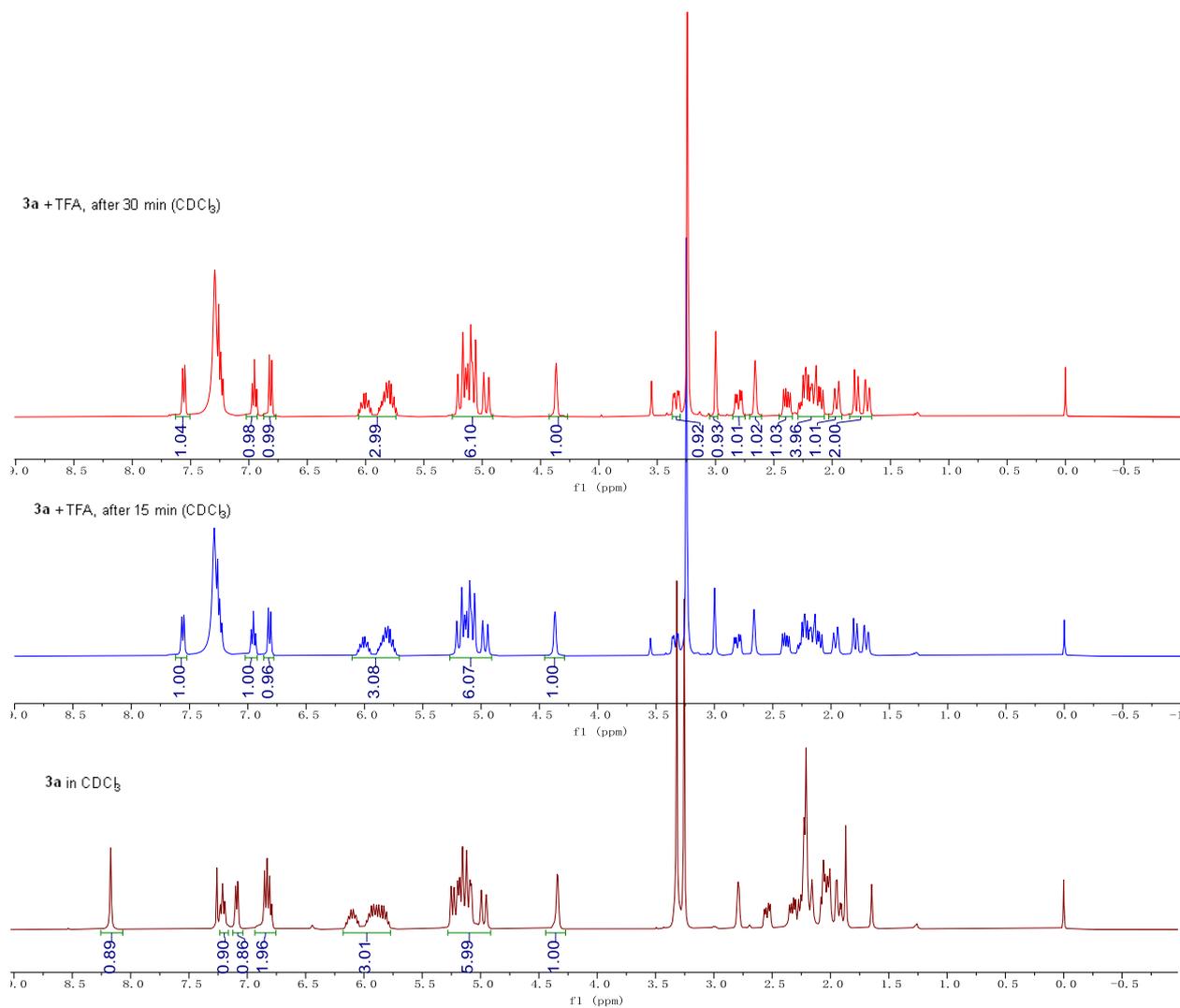


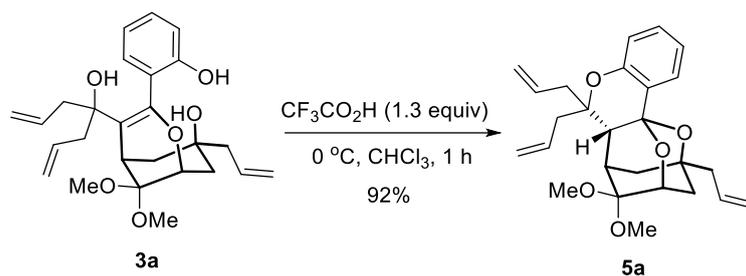
Figure S1. Proposed Mechanism

## 5.2 $^1\text{H}$ NMR monitor of the reaction of **3a** with TFA in $\text{CDCl}_3$

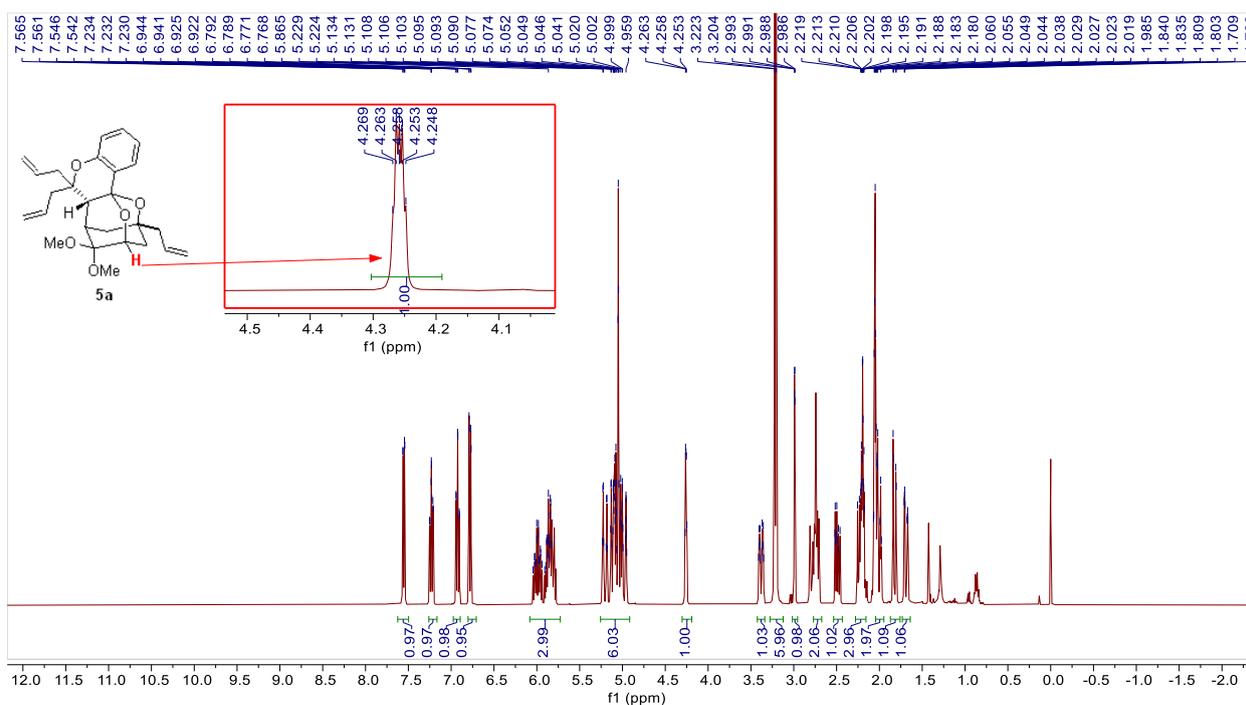
$^1\text{H}$  NMR of a solution of **3a** (0.05 mmol, 21.6 mg) in  $\text{CDCl}_3$  (0.6 mL) was recorded at first (Figure S2, maroon). After adding TFA (10  $\mu\text{L}$ ) to the above solution at room temperature,  $^1\text{H}$  NMR was recorded after 15 min (Figure S2, blue) and 30 min (Figure S2, red). The spectra are showed in Figure S2.  $^1\text{H}$  NMR analysis indicated a clean and full conversion of **3a** into **5a**.



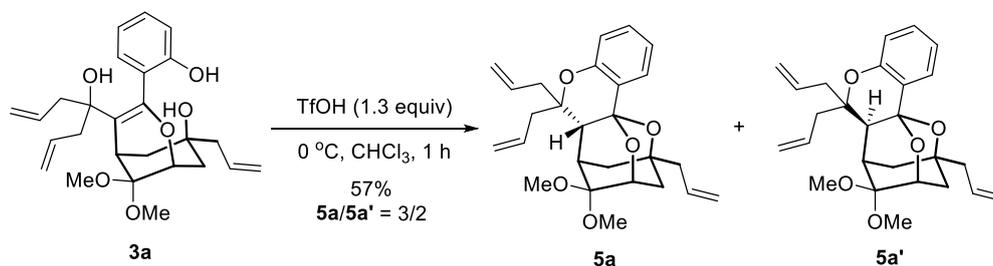
**Figure S2.**  $^1\text{H}$  NMR monitor of the reaction of **3a** with TFA in  $\text{CDCl}_3$



To a mixture of **3a** (0.2 mmol, 88.2 mg) in  $\text{CHCl}_3$  (2 mL) was injected  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ , 0.26 mmol) at  $0\text{ }^\circ\text{C}$ . The mixture was stirred at this temperature for 1 h. The mixed products **5a** (white solid, 77.9 mg, 92%) were obtained after purification by flash column chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR analysis showed that **5a** was formed exclusively (**Figure S3**).

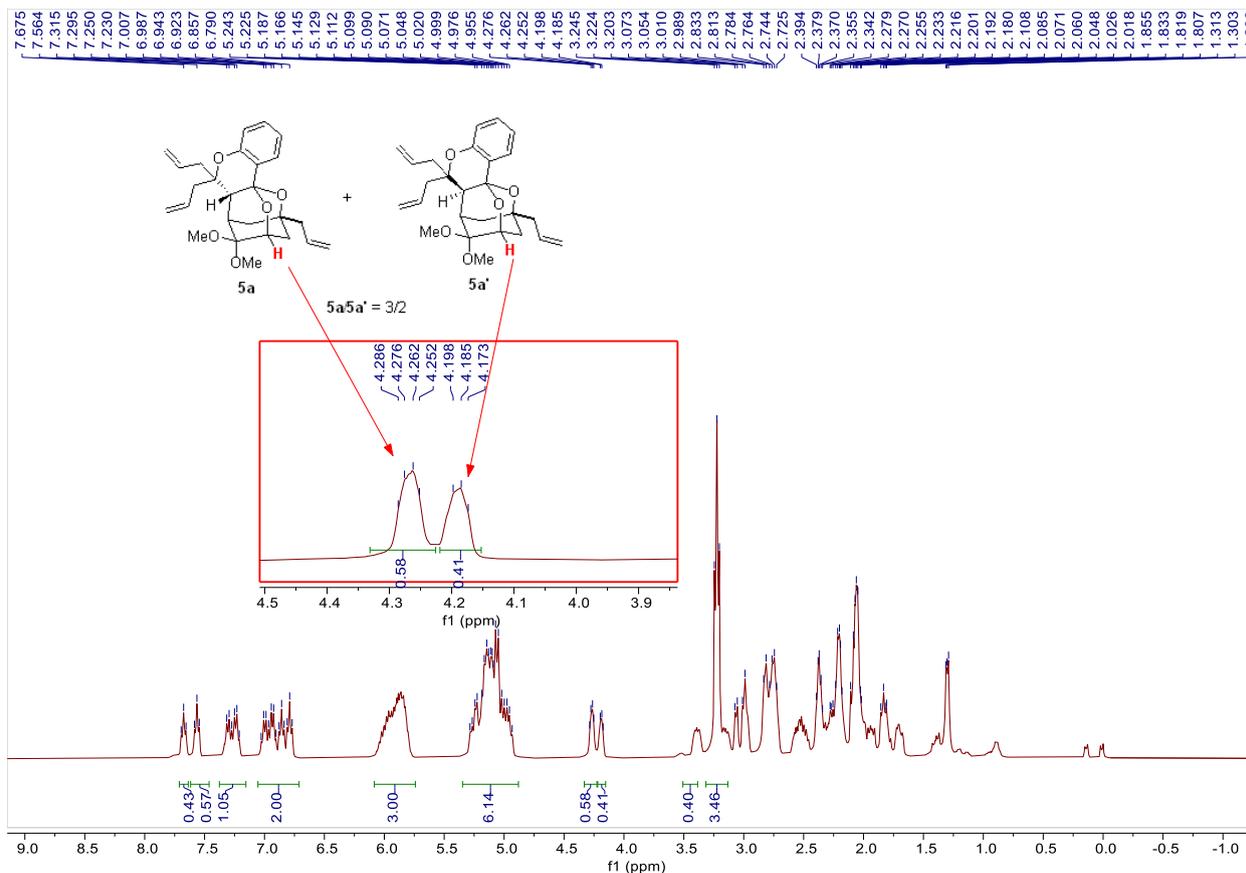


**Figure S3.**  $^1\text{H}$  NMR of **5a** in acetone- $d_6$

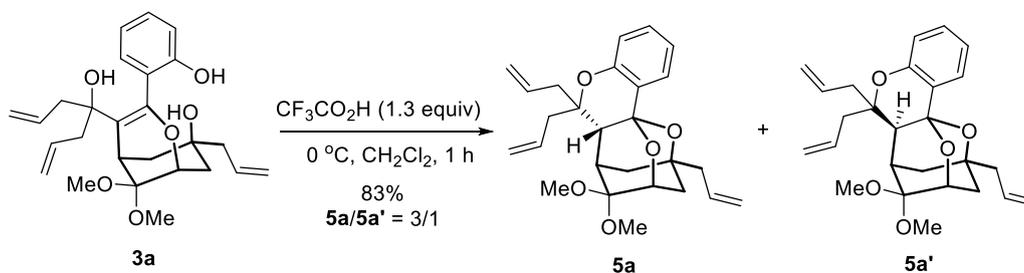


To a mixture of **3a** (0.2 mmol, 88.6 mg) in  $\text{CHCl}_3$  (2 mL) was injected TfOH (23  $\mu\text{L}$ , 0.26 mmol) at  $0\text{ }^\circ\text{C}$ . The mixture was stirred at this temperature for 1 h. The mixed products **5a** and **5a'** (white solid, 48.5 mg, 57%) were obtained after

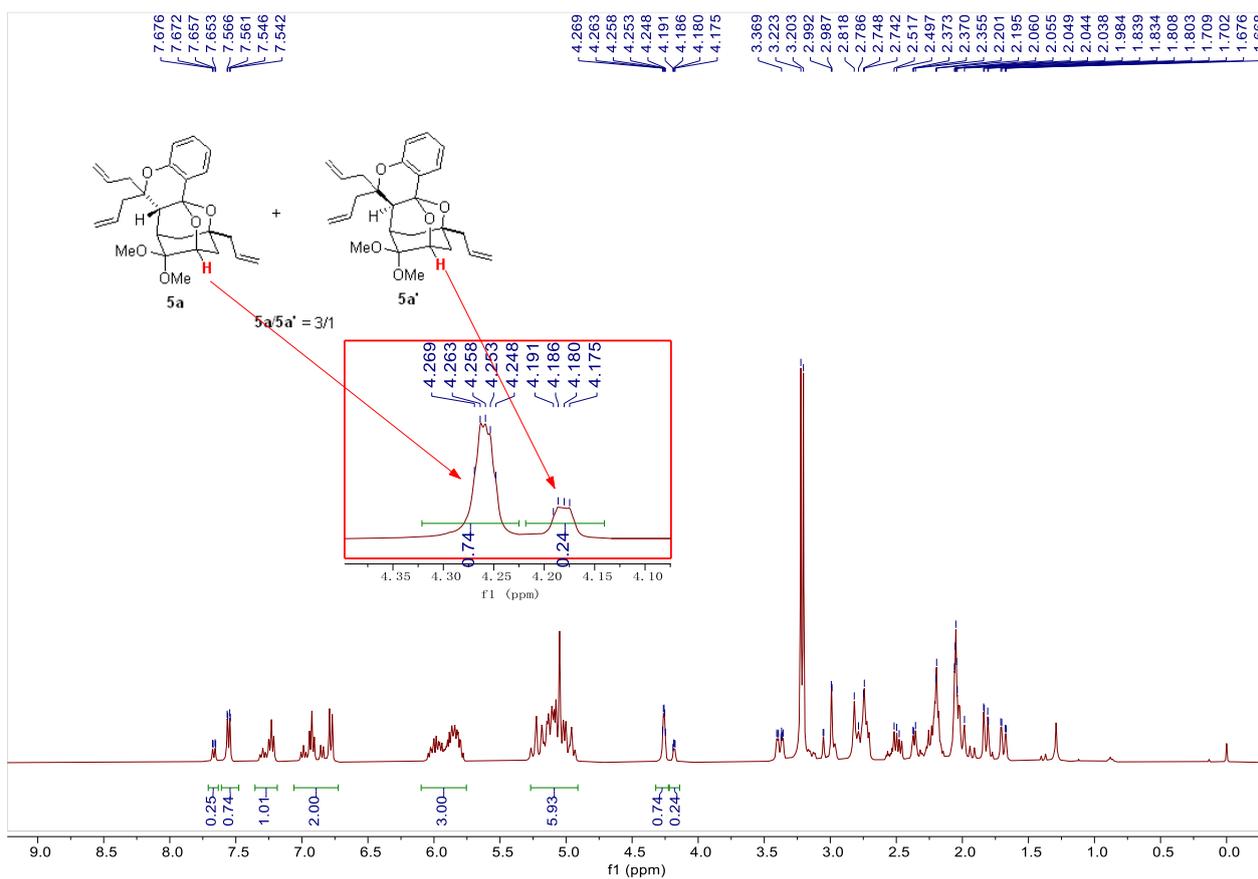
purification by flash column chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR analysis showed that a 3/2 mixture of diastereomers **5a** and **5a'** was formed (**Figure S4**).



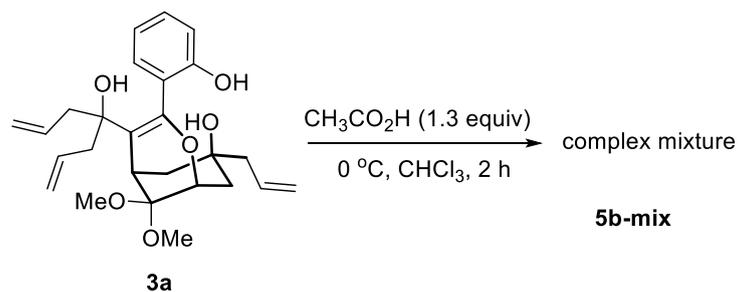
**Figure S4.**  $^1\text{H}$  NMR of **5a/5a'** (3/2) in acetone- $d_6$



To a mixture of **3a** (0.2 mmol, 88.6 mg) in  $\text{CH}_2\text{Cl}_2$  (2 mL) was injected  $\text{CF}_3\text{CO}_2\text{H}$  (20  $\mu\text{L}$ , 0.26 mmol) at 0  $^\circ\text{C}$ . The mixture was stirred at this temperature for 1 h. The mixed products **5a** and **5a'** (white solid, 70.8 mg, 83%) were obtained after purification by flash column chromatography on silica gel using PE/EtOAc (50/1) as an eluent.  $^1\text{H}$  NMR analysis showed that a 3/1 mixture of diastereomers **5a** and **5a'** was formed (**Figure S5**).



**Figure S5.**  $^1\text{H}$  NMR of **5a/5a'** (3/1) in acetone- $d_6$



To a mixture of **3a** (0.2 mmol, 88.4 mg) in  $\text{CHCl}_3$  (2 mL) was injected  $\text{CH}_3\text{CO}_2\text{H}$  (15  $\mu\text{L}$ , 0.26 mmol) at  $0\text{ }^\circ\text{C}$ . The mixture was stirred at this temperature for 2 h. A mixed products **5b-mix** (slurry solid, 57.6 mg) were obtained after purification by flash column chromatography on silica gel using using PE/EtOAc (50/1) as an eluent, and 28% of **3a** (24.4 mg) was recovered. While the exact structures of the products could not be fully elucidated, it is clear that that the phenol-hydroxyl group remains intact.  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra of **5b-mix** was showed in **Figure S6**.

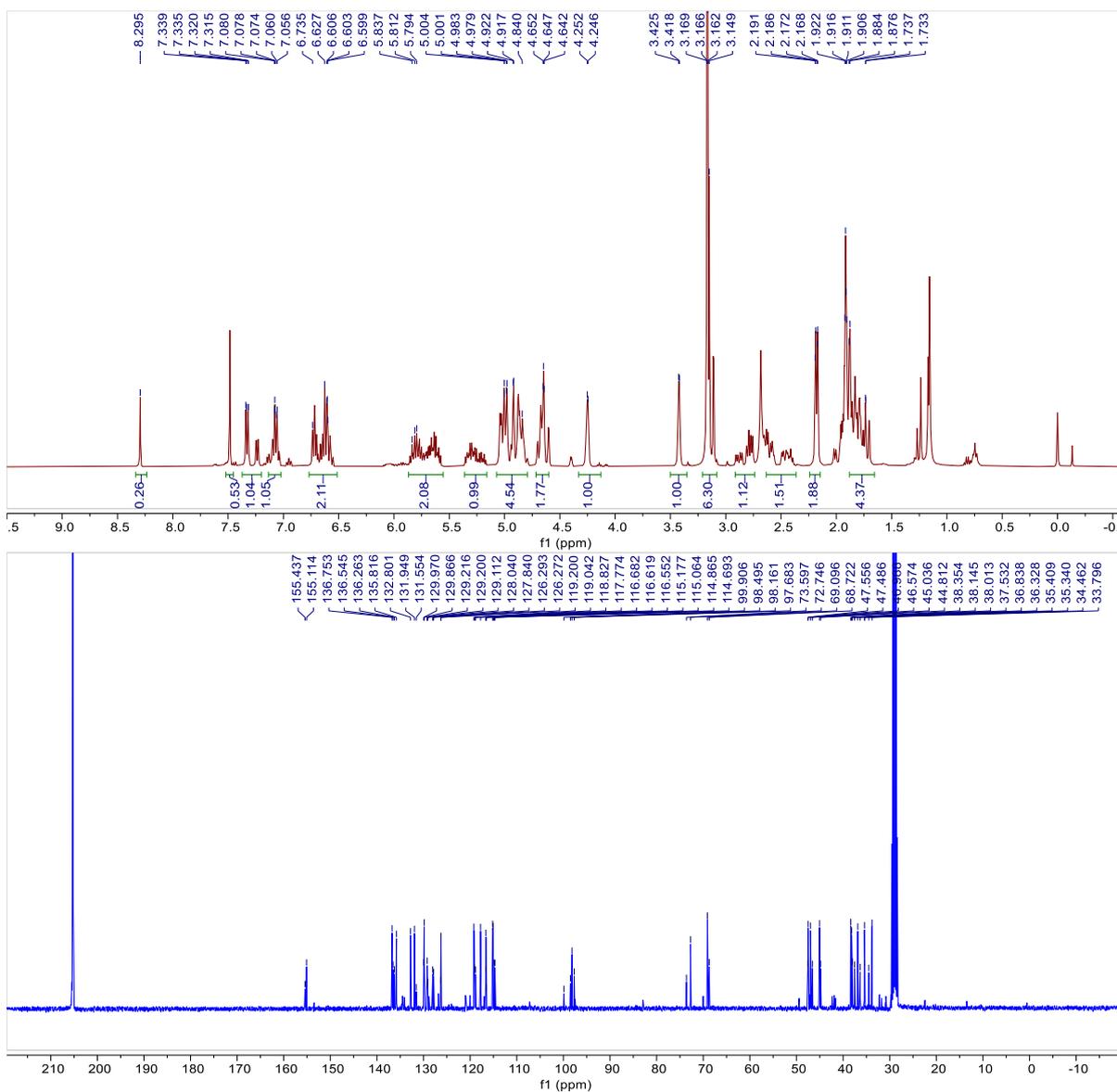
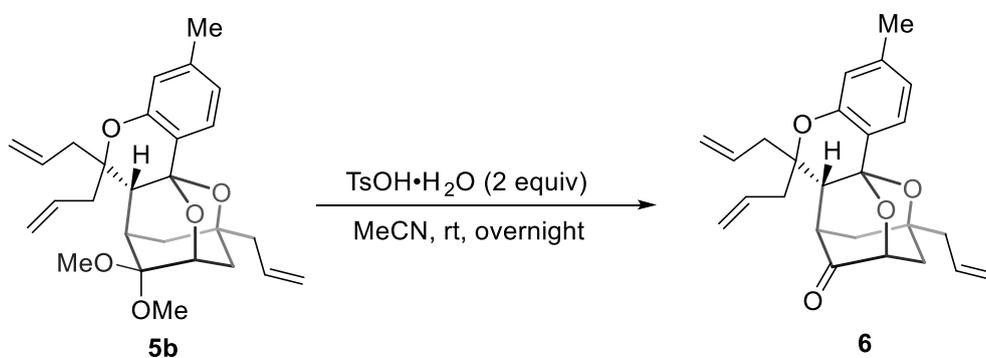
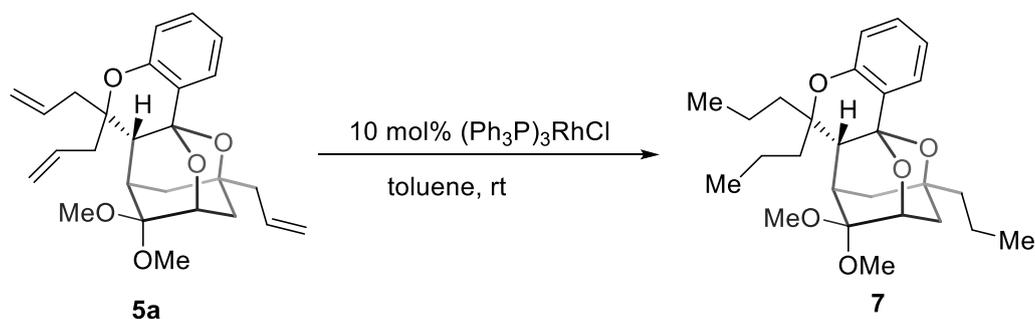


Figure S6. <sup>1</sup>H and <sup>13</sup>C NMR of **5b-mix** in acetone-d<sub>6</sub>

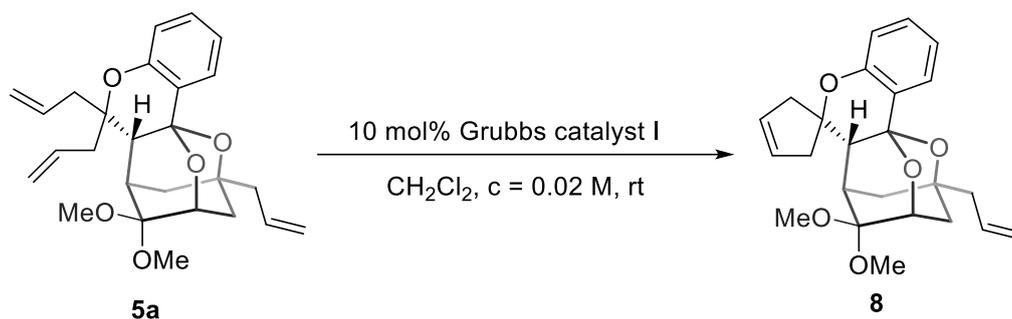
## 6. Synthetic transformation of compound **5**



To a solution of compound **5b** (42.2 mg, 0.1 mmol) in acetonitrile (0.5 mL) was added tosylic acid monohydrate (38.5 mg, 0.2 mmol) under air. The mixture was stirred at room temperature overnight. The reaction mixture was concentrated under reduced pressure, and the residue was purified by flash chromatography on silica gel using PE/EtOAc (50/1) as an eluent to afford **6** (22.6 mg, 58%) as a colorless slurry.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.53 (d,  $J$  = 7.6 Hz, 1H), 6.81 (dd,  $J_1$  = 8.0 Hz,  $J_2$  = 0.8 Hz, 1H), 6.67 (s, 1H), 5.98-5.79 (m, 3H), 5.27-4.93 (m, 6H), 4.18-4.16 (m, 1H), 3.17-3.11 (m, 1H), 3.01 (d,  $J$  = 2.0 Hz, 1H), 2.96-2.93 (m, 1H), 2.75-2.69 (m, 1H), 2.53 (dt,  $J_1$  = 13.6 Hz,  $J_2$  = 4.4 Hz, 1H), 2.36-2.30 (m, 3H), 2.30-2.25 (m, 1H), 2.29 (s, 3H), 2.17 (dd,  $J_1$  = 13.6 Hz,  $J_2$  = 3.6 Hz, 1H), 1.91 (dd,  $J_1$  = 13.6 Hz,  $J_2$  = 2.0 Hz, 1H), 1.78 (dd,  $J_1$  = 14.8 Hz,  $J_2$  = 9.2 Hz, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  211.0, 153.5, 141.8, 134.3, 134.0, 133.4, 127.8, 122.4, 120.5, 119.0, 118.6, 118.1, 92.7, 81.5, 77.7, 74.3, 53.4, 45.2, 44.2, 43.8, 41.0, 40.1, 37.7, 21.3. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{25}\text{H}_{29}\text{O}_4^+$  393.2060, found 393.2069.



To a solution of compound **5a** (84.2 mg, 0.2 mmol) in toluene (2 mL) was added the Wilkinson catalyst (18.5 mg, 0.02 mmol) under an atmosphere of  $\text{H}_2$  (balloon). The mixture was stirred at room temperature for 56 h. The reaction mixture was concentrated under reduced pressure, and the residue was purified by flash chromatography on silica gel using PE/EtOAc (60/1) as an eluent to afford **7** (73.2 mg, 86%) as a colorless oil.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.53 (dd,  $J_1$  = 8.0 Hz,  $J_2$  = 2.0 Hz, 1H), 7.22-7.17 (m, 1H), 6.88 (td,  $J_1$  = 8.0 Hz,  $J_2$  = 1.2 Hz, 1H), 6.73 (dd,  $J_1$  = 8.4 Hz,  $J_2$  = 1.2 Hz, 1H), 4.26-4.24 (m, 1H), 3.22 (s, 6H), 2.97 (t,  $J$  = 1.6 Hz, 1H), 2.61-2.55 (m, 2H), 2.03-1.91 (m, 3H), 1.84-1.81 (m, 1H), 1.70-1.32 (m, 11H), 0.96 (t,  $J$  = 7.2 Hz, 3H), 0.88-0.85 (m, 3H), 0.77 (t,  $J$  = 7.2 Hz, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  154.4, 130.8, 128.4, 125.4, 120.7, 117.8, 99.7, 93.0, 83.0, 72.5, 70.5, 48.5, 47.1, 44.5, 41.8, 39.0, 38.4, 36.5, 33.0, 30.1, 17.4, 16.7, 16.4, 15.0, 14.9, 14.9. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{39}\text{O}_5^+$  431.2792, found 431.2805.



To a solution of compound **5a** (84.9 mg, 0.2 mmol) in  $\text{CH}_2\text{Cl}_2$  (10 mL) was added the Grubbs'catalyst I (16.4 mg, 0.02 mmol) at room temperature under dry  $\text{N}_2$ . The mixture was stirred at room temperature for 6 h. The reaction mixture was concentrated under reduced pressure, and the residue was purified by flash chromatography on silica gel using PE/EtOAc (20/1) as an eluent to afford **8** (63.0 mg, 80%) as a white solid. M.p. 143.4-144.3 °C.  $^1\text{H}$  NMR (400 MHz, acetone- $d_6$ ):  $\delta$  7.55 (dd,  $J_1 = 8.0 \text{ Hz}, J_2 = 2.0 \text{ Hz}, 1\text{H}$ ), 7.23-7.19 (m, 1H), 6.92 (dd,  $J_1 = 8.0 \text{ Hz}, J_2 = 7.6 \text{ Hz}, 1\text{H}$ ), 6.73 (d,  $J = 8.0 \text{ Hz}, 1\text{H}$ ), 5.91-5.80 (m, 1H), 5.77-5.66 (m, 2H), 5.10-5.06 (m, 2H), 4.28-4.26 (m, 1H), 3.36 (d,  $J = 14.0 \text{ Hz}, 1\text{H}$ ), 3.223 (s, 3H), 3.219 (s, 3H), 2.82-2.63 (m, 3H), 2.56 (t,  $J = 2.8 \text{ Hz}, 1\text{H}$ ), 2.36-2.30 (m, 1H), 2.26-2.16 (m, 2H), 2.09-2.06 (m, 1H), 1.89 (dt,  $J_1 = 13.6 \text{ Hz}, J_2 = 3.2 \text{ Hz}, 1\text{H}$ ), 1.80 (dd,  $J_1 = 12.8 \text{ Hz}, J_2 = 2.0 \text{ Hz}, 1\text{H}$ ), 1.61 (dd,  $J_1 = 13.6 \text{ Hz}, J_2 = 2.8 \text{ Hz}, 1\text{H}$ ).  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz, acetone- $d_6$ ):  $\delta$  154.4, 133.7, 130.9, 129.8, 128.5, 128.4, 125.5, 121.1, 118.6, 118.1, 99.3, 93.1, 89.1, 73.0, 71.1, 48.1, 47.5, 46.4, 44.2, 43.3, 41.5, 36.1, 33.5, 29.1. HRMS (ESI/Q-TOF)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{29}\text{O}_5^+$  397.2010, found 397.2021.

## 7. X-ray data of products **3b** and **5a**

The single crystals of compound **3b** and **5a** were obtained from its solution in acetone by slow evaporation of the solvent. The X-Ray crystallographic analysis was performed on a Bruker SMART APEX II CCD diffractometer using a graphite-monochromated Mo- $K\alpha$  ( $\lambda=0.71073 \text{ \AA}$ ) radiation. The structure was solved by direct methods and refined on F2 by full-matrix least squares procedures using SHELXTL 2018 program. All non-hydrogen atoms were refined anisotropically. All H atoms were located from a difference map and refined isotropically. CIF files of **3b** (CCDC 2481068) and **5a** (CCDC 2493450) can be obtained from the Cambridge Crystallographic Data Centre using the corresponding deposition numbers. Copies of the data can be obtained, free of charge, on application to the CCDC, 12 Union Road, Cambridge CB2 1EZ, UK [e-mail: deposit@ccdc.cam.ac.uk]. The X-ray structure is shown in Figure S7. Crystallographic data are given in Table S2.

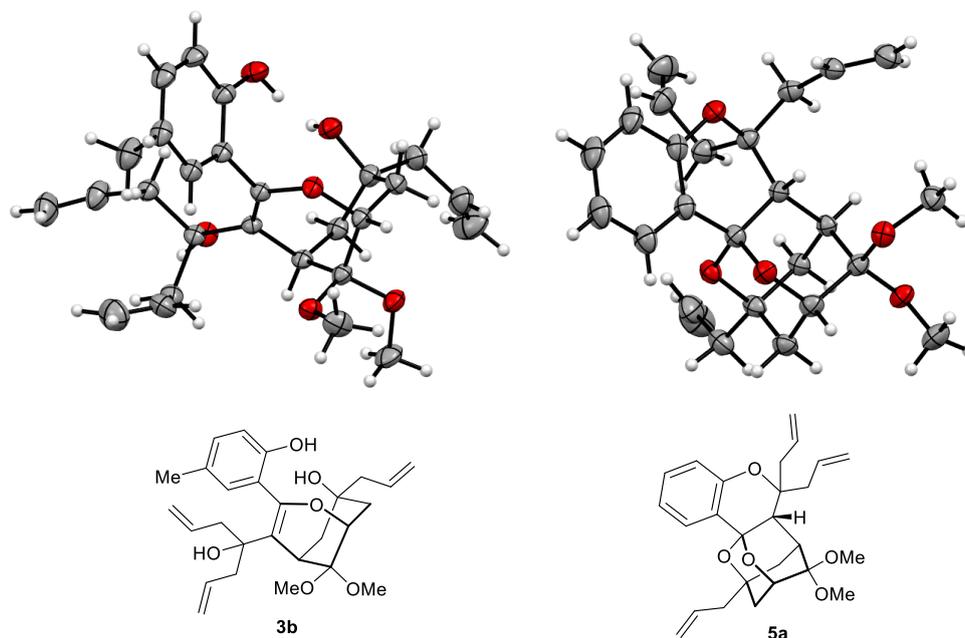


Figure S7. The X-ray structures of **3b** (CCDC 2481068) and **5a** (CCDC 2493450)

Table S2. Crystallographic data

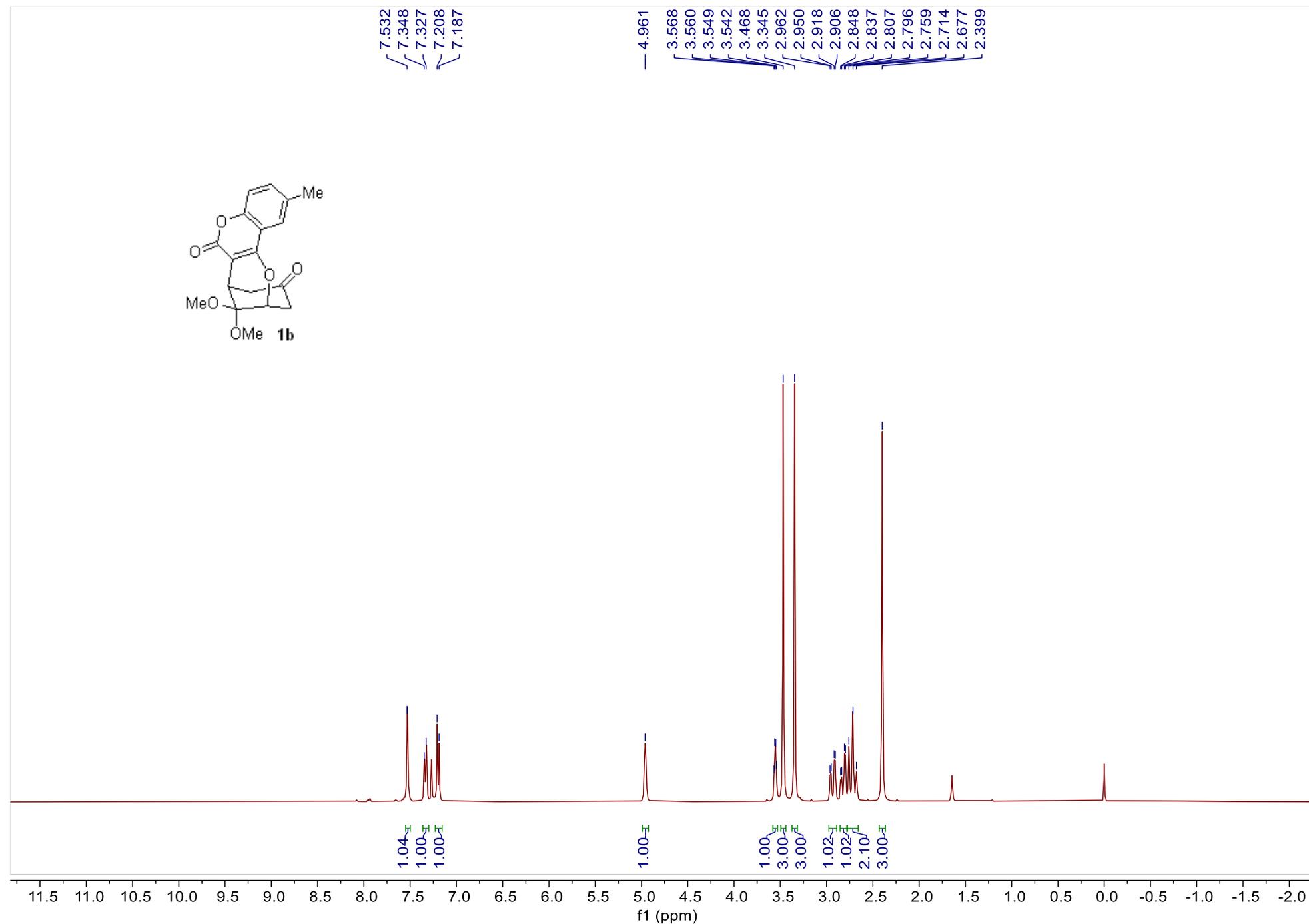
Compound	<b>3b</b>	<b>5a</b>
Empirical formula	C <sub>27</sub> H <sub>36</sub> O <sub>6</sub>	C <sub>26</sub> H <sub>32</sub> O <sub>5</sub>
Formula weight	456.56	424.51
Crystal system	triclinic	monoclinic
Space group	<i>P</i> -1	<i>P</i> 21/ <i>c</i>
<i>a</i> (Å)	9.8874(6)	12.2914(7)
<i>b</i> (Å)	11.1984(6)	9.9942(7)
<i>c</i> (Å)	12.5144(9)	18.3242(11)
$\alpha$ (°)	66.087(6)	90
$\beta$ (°)	87.688(5)	90.935(5)
$\gamma$ (°)	83.296(5)	90
<i>V</i> (Å <sup>3</sup> )	1257.99(15)	2250.7(2)
<i>Z</i>	2	4
<i>D</i> <sub>c</sub> (g·cm <sup>-3</sup> )	1.205	1.253
$\mu$ (mm <sup>-1</sup> )	0.084	0.086
<i>F</i> (000)	492	912
Crystal size (mm <sup>3</sup> )	0.18 × 0.17 × 0.16	0.13 × 0.12 × 0.11
$\theta$ Range (°)	2.001-24.998	2.223-24.998
Reflections collected	14201	16034
Independent reflections	4440 [ <i>R</i> <sub>int</sub> = 0.0350]	3954 [ <i>R</i> <sub>int</sub> = 0.0449]
Reflections observed [ <i>I</i> > 2 $\sigma$ ( <i>I</i> )	3549	2539
Data/restraints/parameters	4440/0/327	3954/32/301
Goodness-of-fit on <i>F</i> <sup>2</sup>	1.095	1.041
<i>R</i> <sub>1</sub> / <i>wR</i> <sub>2</sub> [ <i>I</i> > 2 $\sigma$ ( <i>I</i> )	0.0485/0.1436	0.0462/0.1134
<i>R</i> <sub>1</sub> / <i>wR</i> <sub>2</sub> (all data)	0.0586/0.1510	0.0775/0.1244
Max., Min. $\Delta\rho$ (e·Å <sup>-3</sup> )	0.194, -0.466	0.143, -0.189

## 8. References

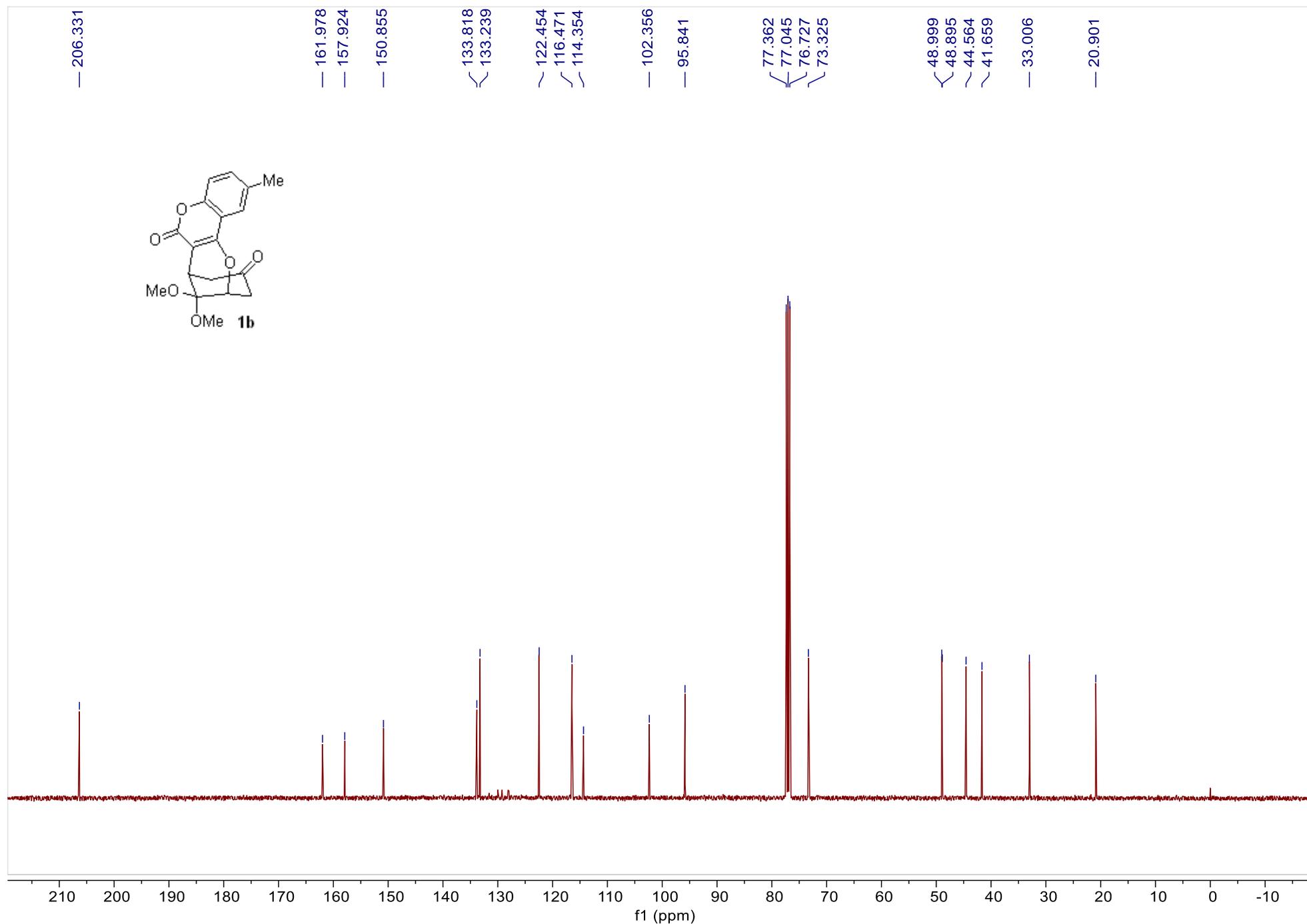
- (1) Krasovskiy, A.; Knochel, P. *Synthesis* **2006**, *5*, 890–891.
- (2) Li, X.; Xiao, T.; He, G.; Zhu, S.; Zhu, D.; Shen, R. *Adv. Synth. Catal.* **2022**, *364*, 622–636.
- (3) Parker, K. A.; Kang, S. K. *J. Org. Chem.* **1980**, *45*, 1218–1224.

## 9. Copies of $^1\text{H}$ and $^{13}\text{C}$ NMR spectra of all new compounds

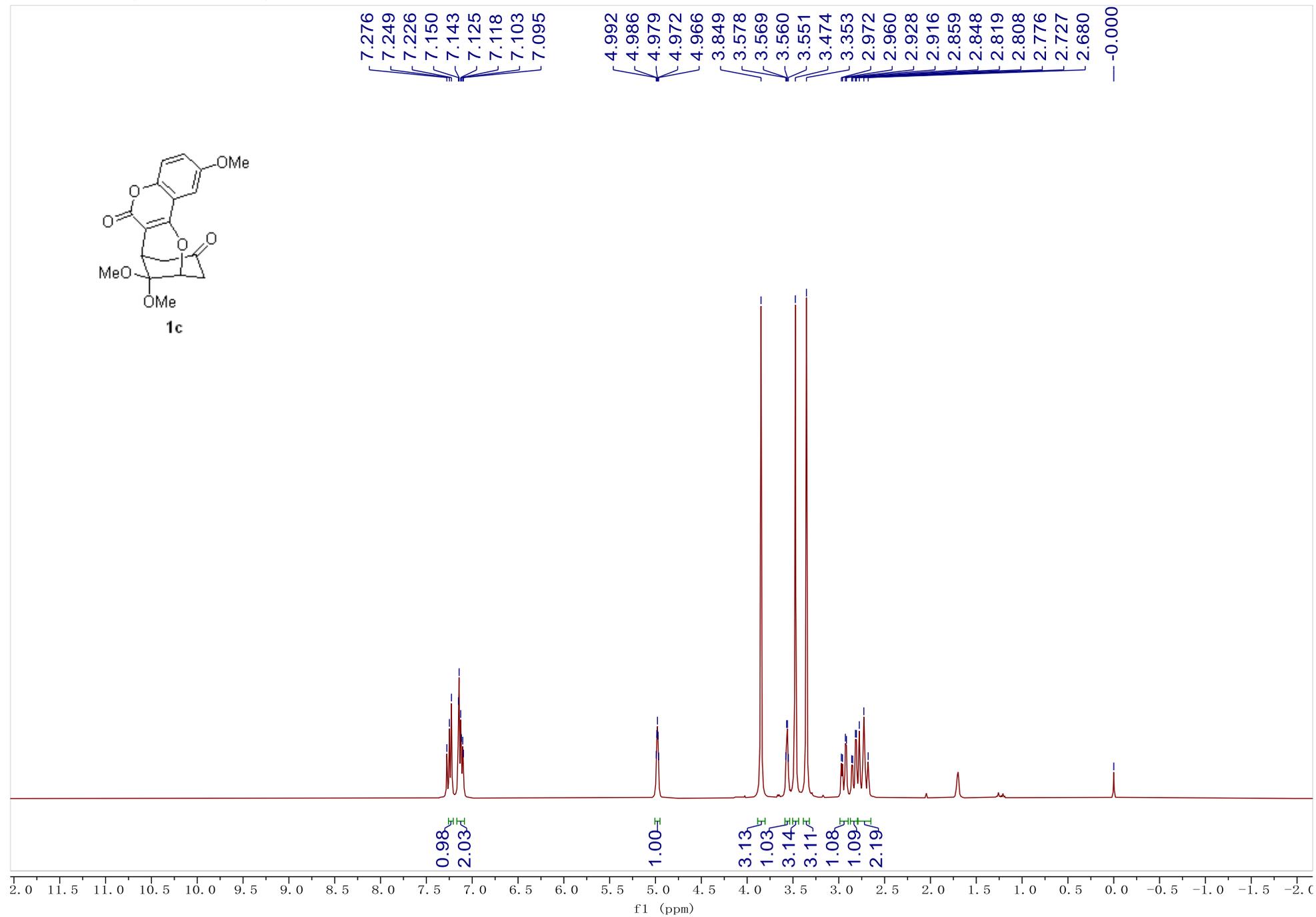
<sup>1</sup>H NMR of **1b** (400MHz, CDCl<sub>3</sub>)



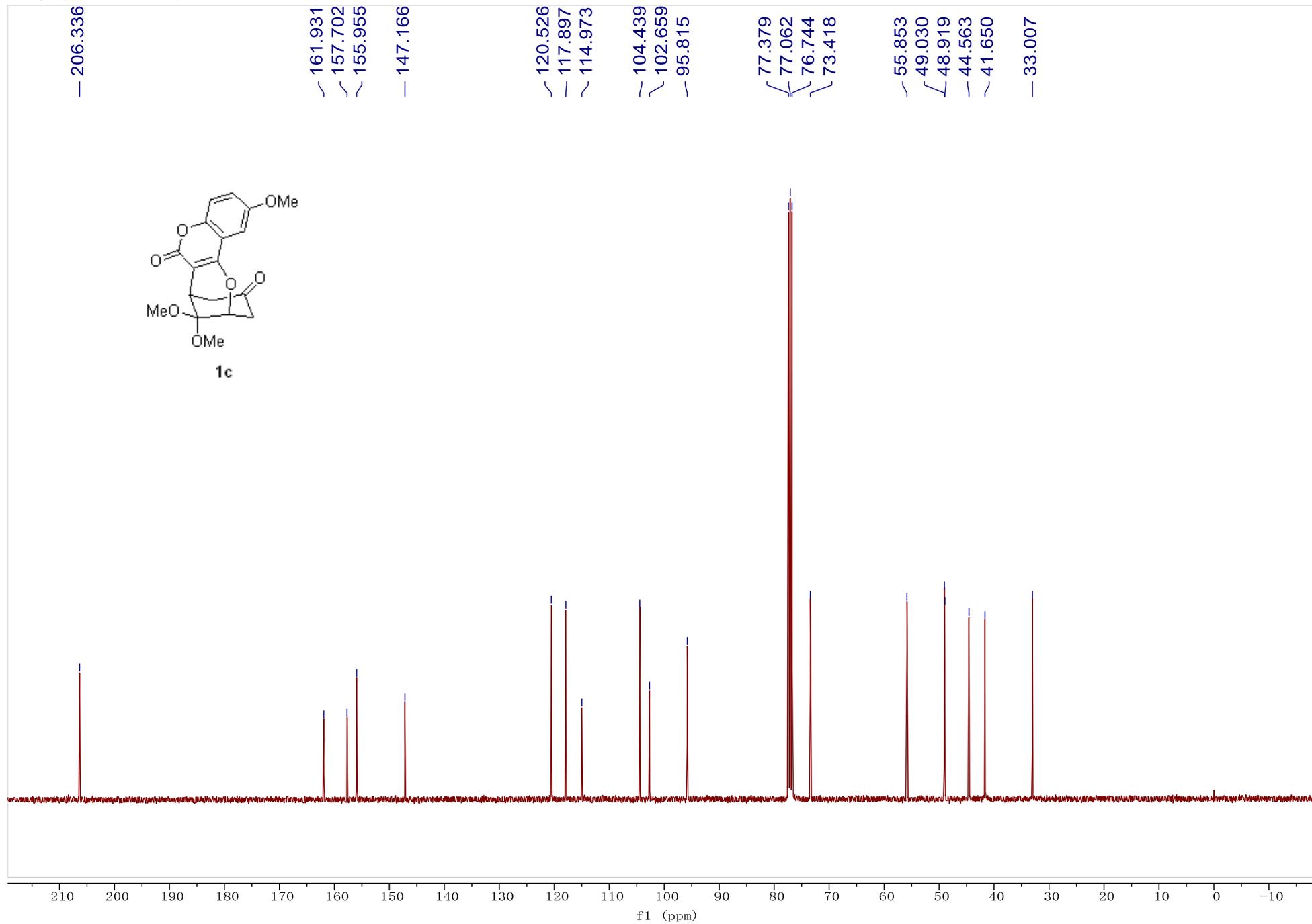
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1b** (101 MHz,  $\text{CDCl}_3$ )



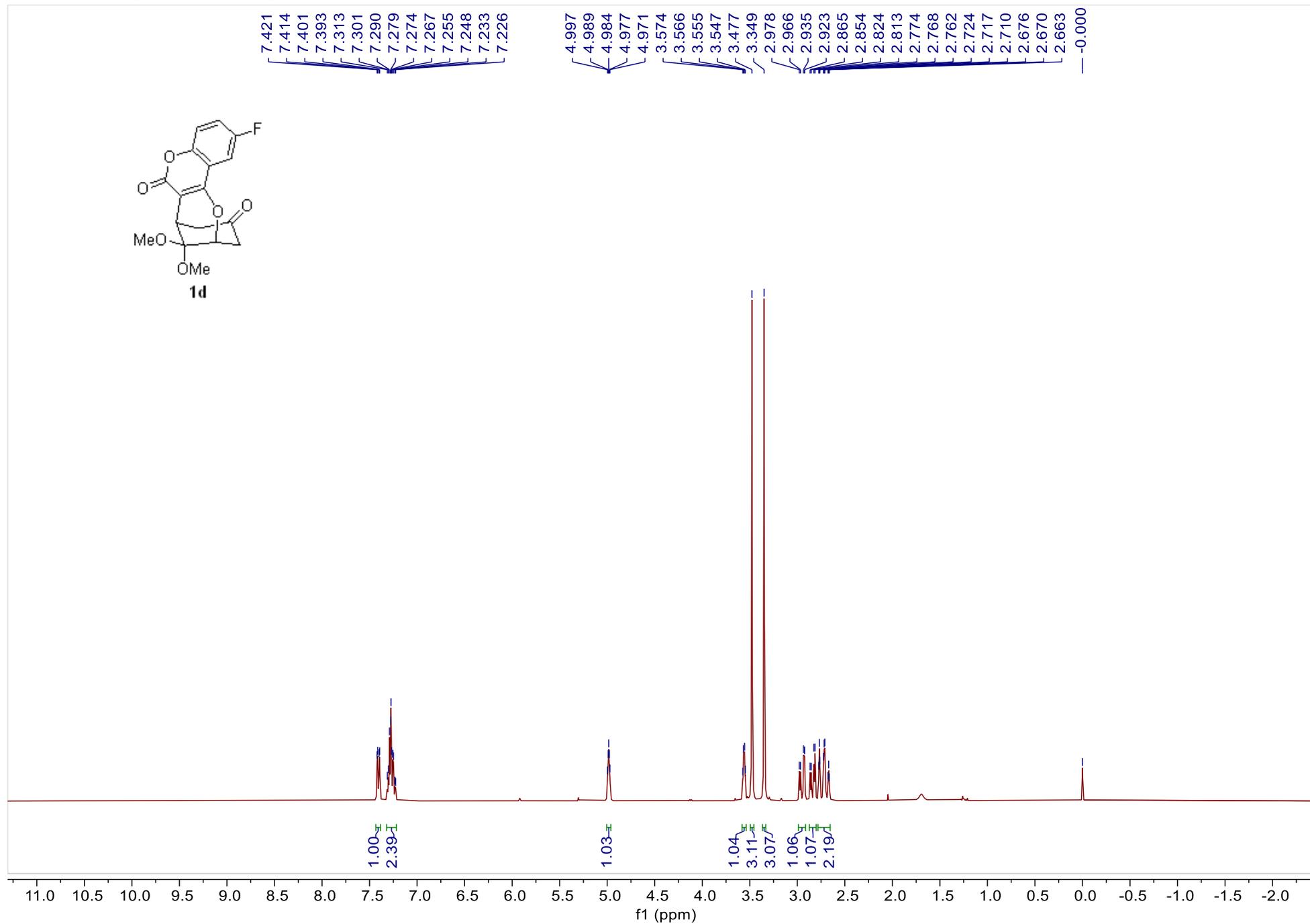
<sup>1</sup>H NMR of **1c** (400MHz, CDCl<sub>3</sub>)



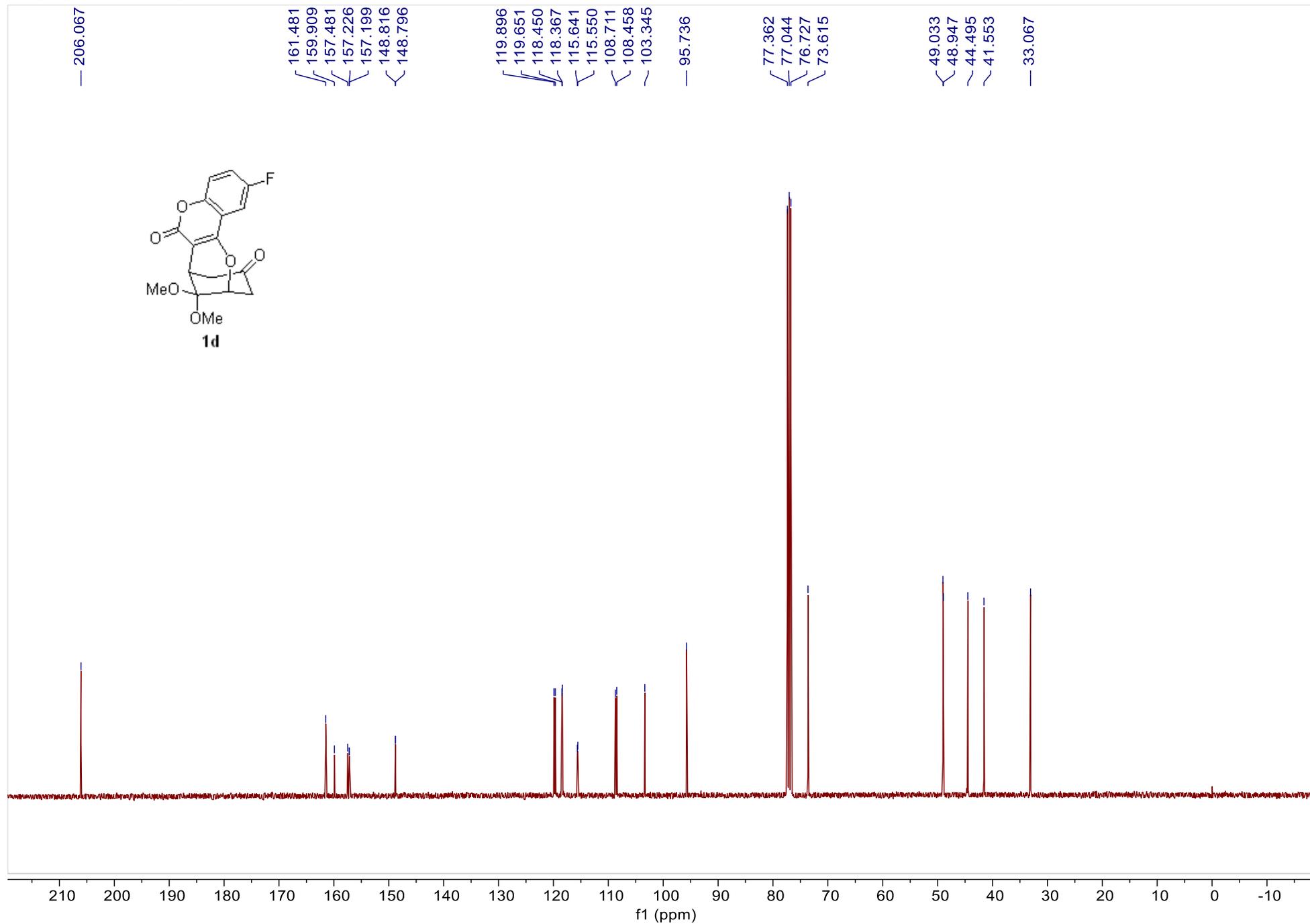
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1c** (101 MHz,  $\text{CDCl}_3$ )



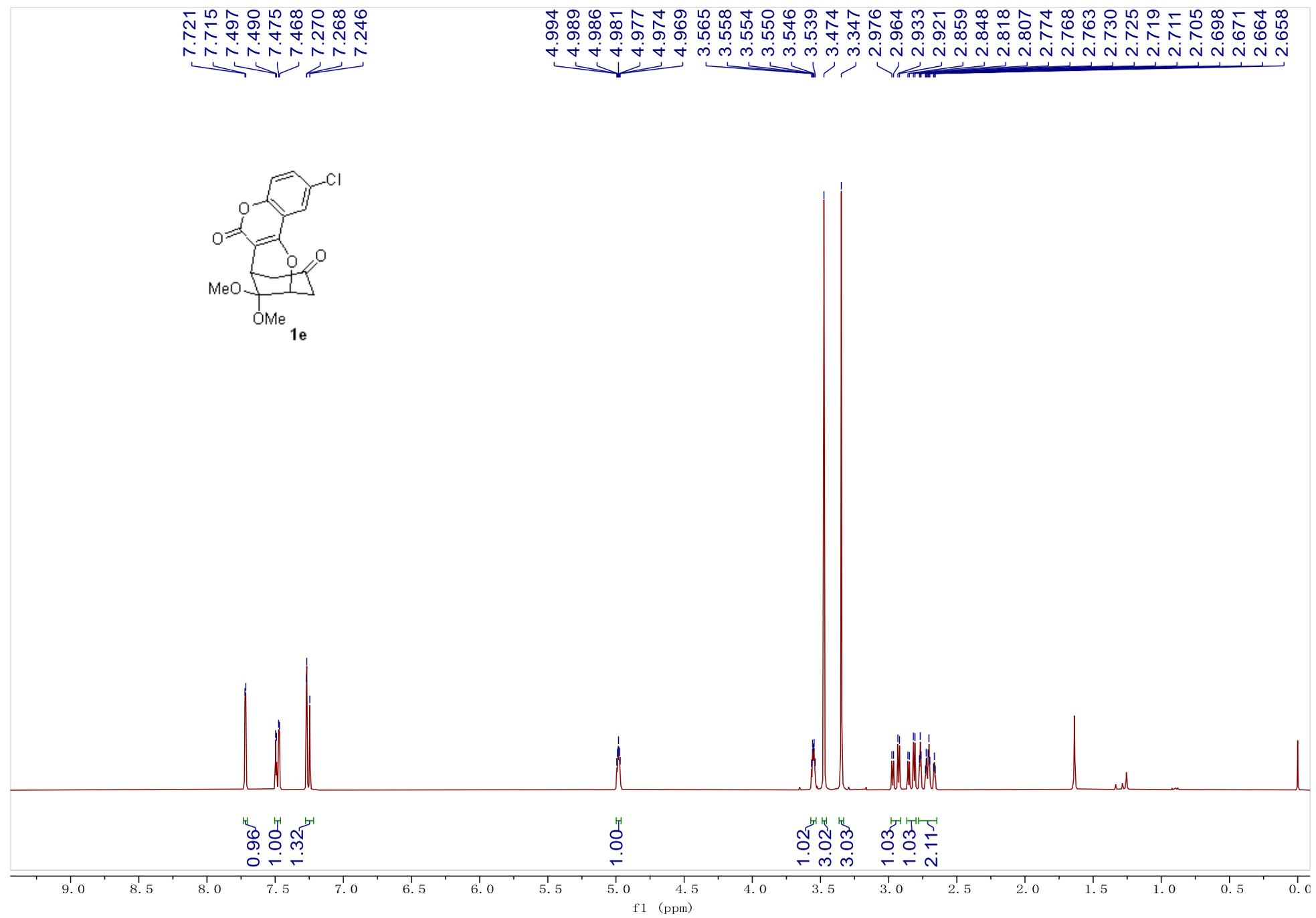
<sup>1</sup>H NMR of **1d** (400MHz, CDCl<sub>3</sub>)



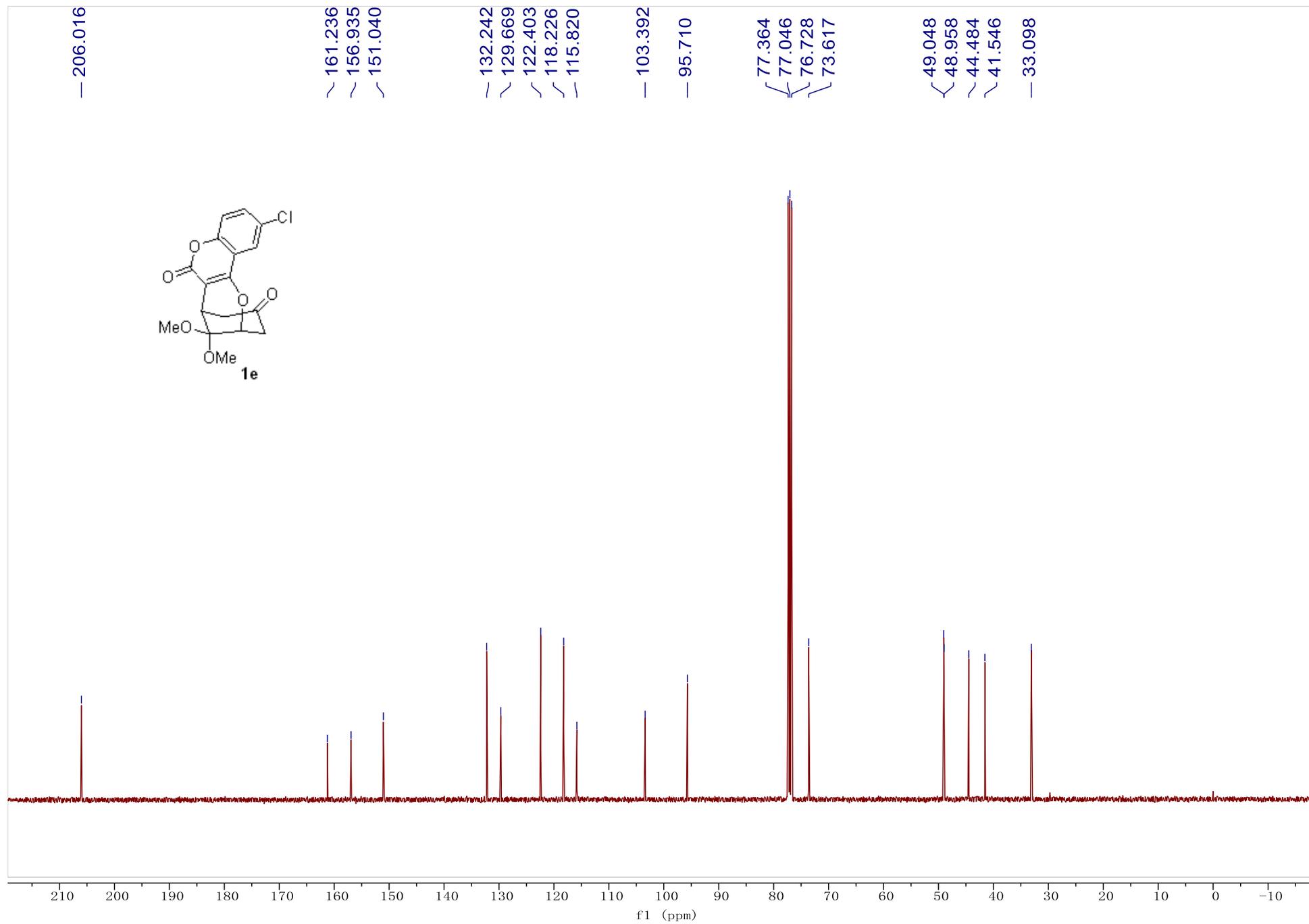
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1d** (101 MHz,  $\text{CDCl}_3$ )



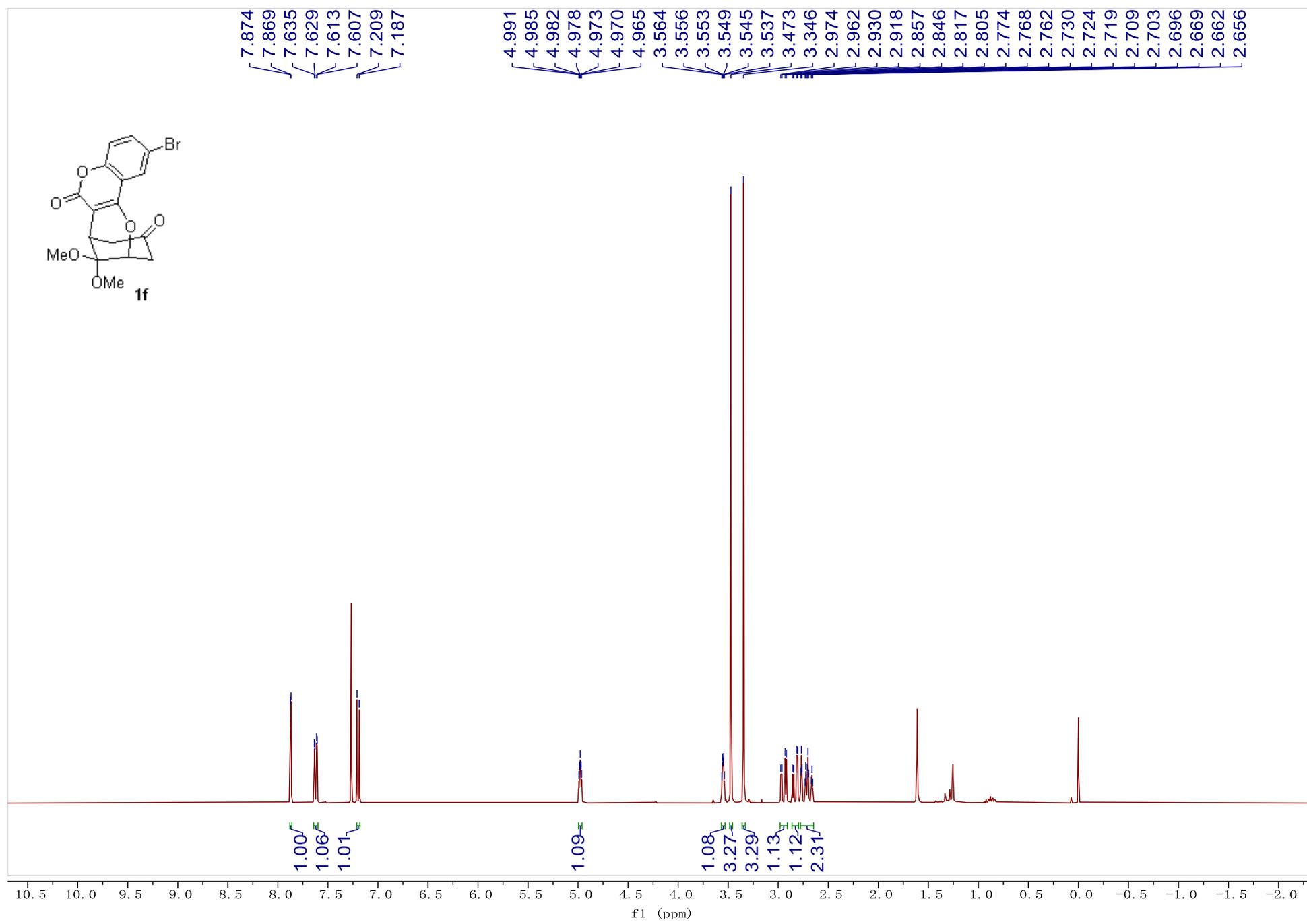
<sup>1</sup>H NMR of **1e** (400MHz, CDCl<sub>3</sub>)



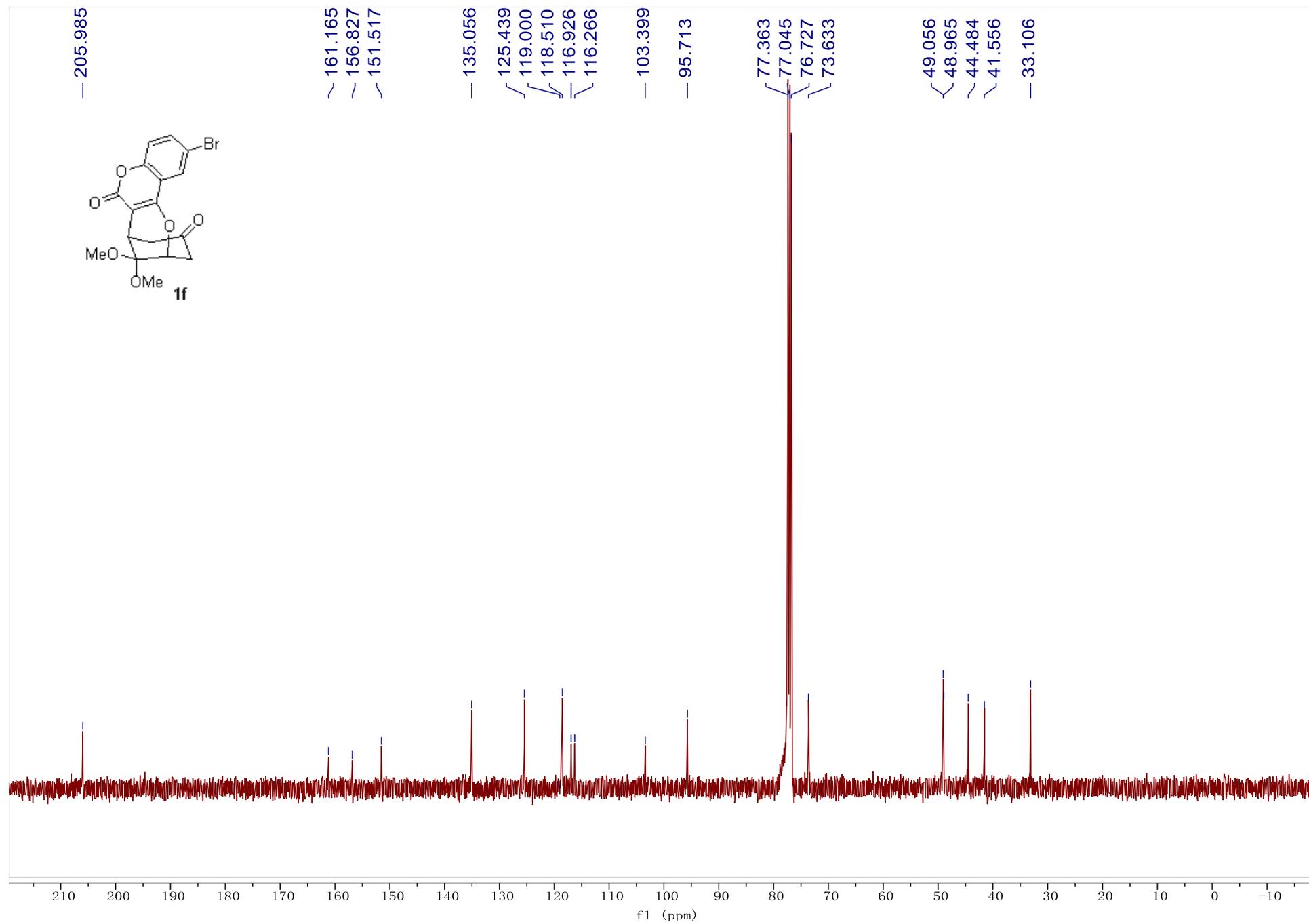
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1e** (101 MHz,  $\text{CDCl}_3$ )



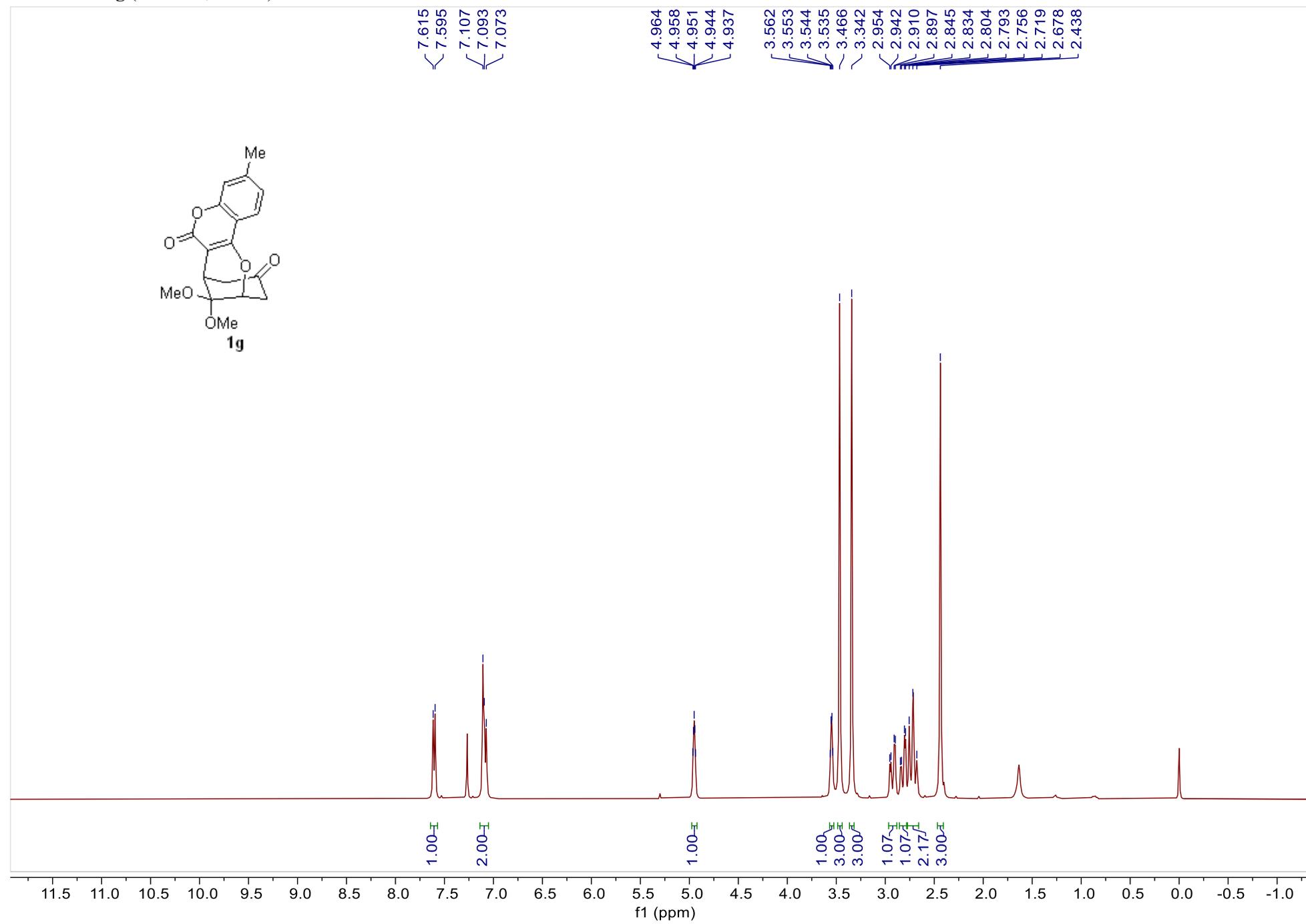
<sup>1</sup>H NMR of **1f** (400MHz, CDCl<sub>3</sub>)



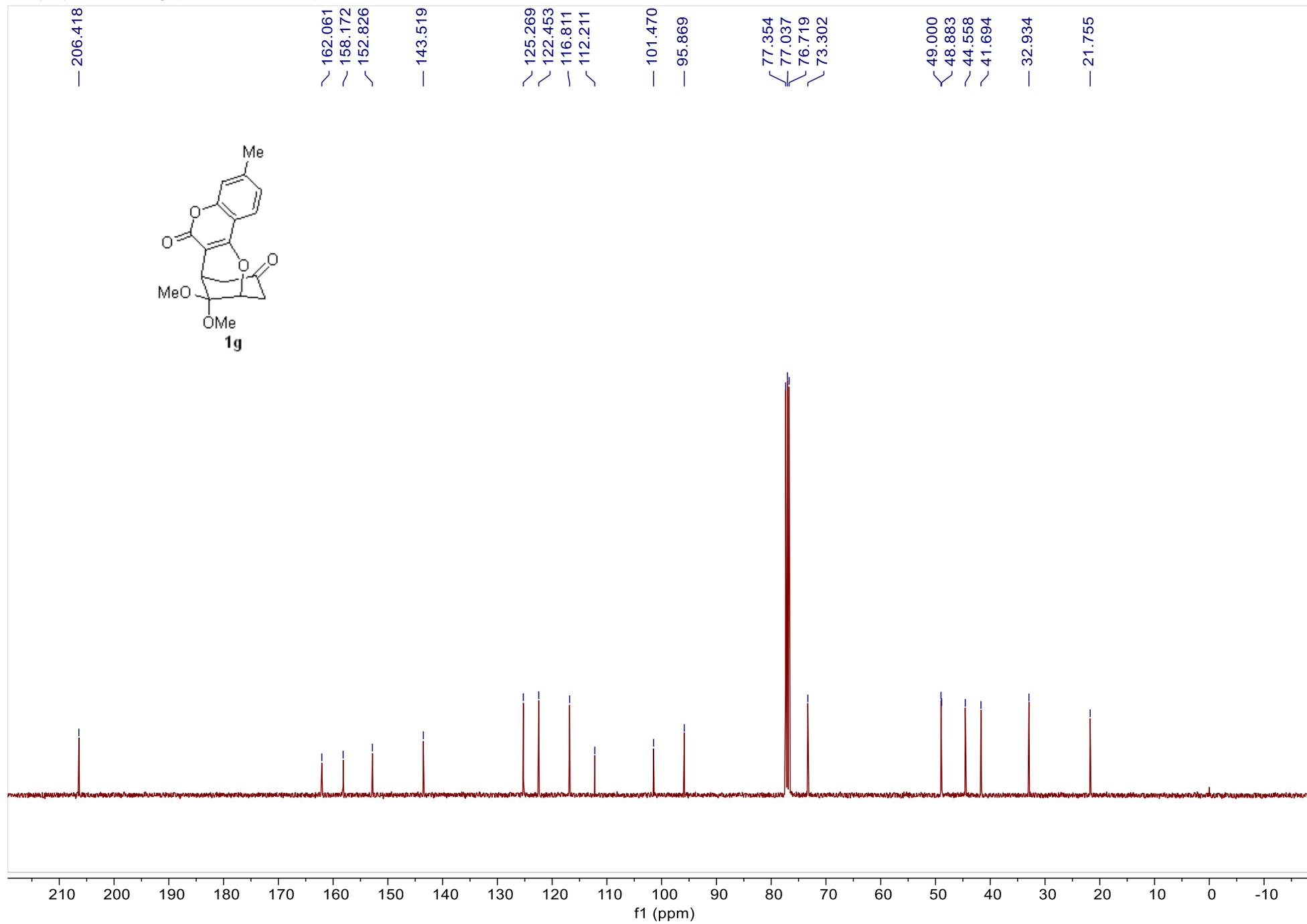
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1f** (101 MHz,  $\text{CDCl}_3$ )



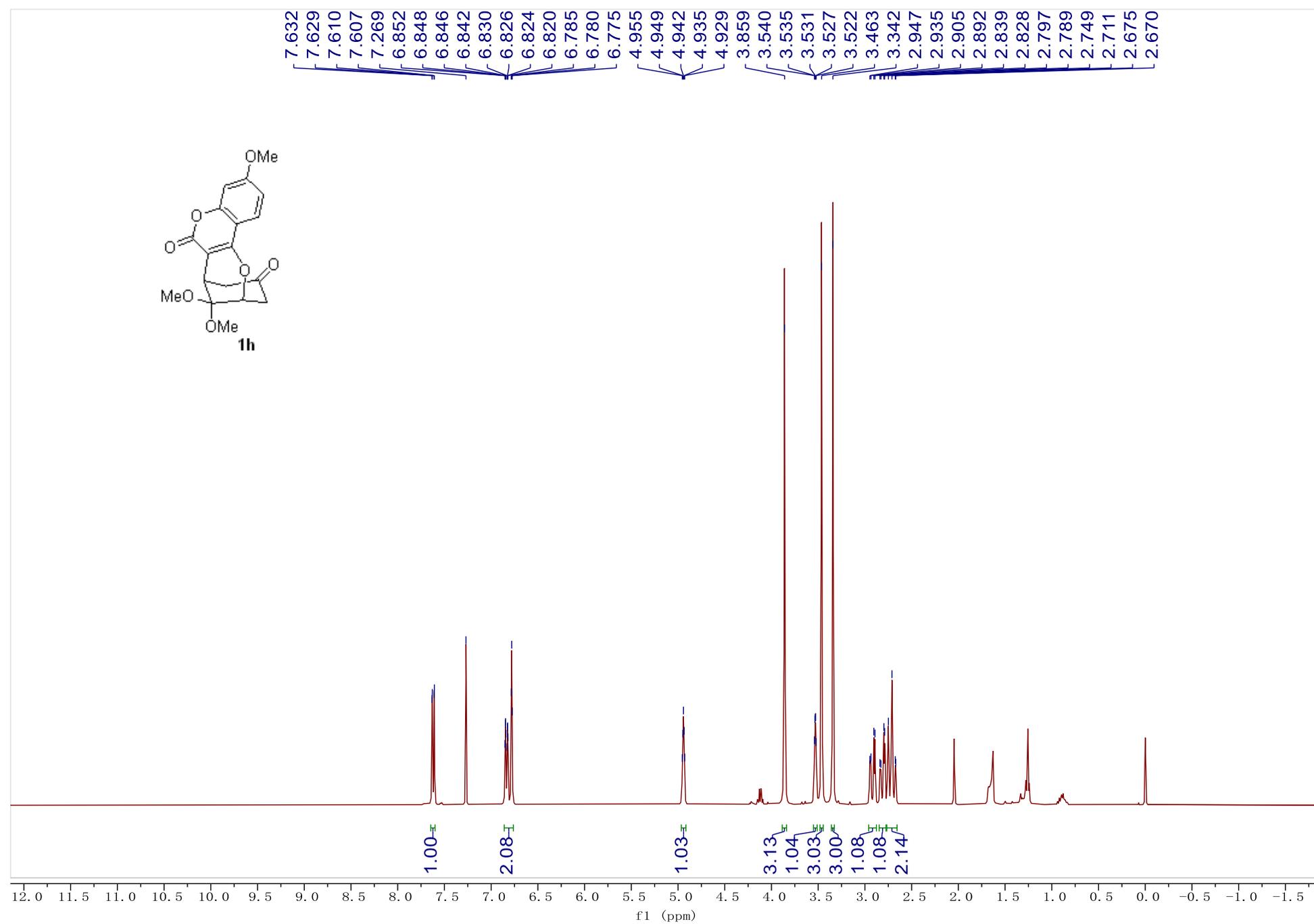
<sup>1</sup>H NMR of **1g** (400MHz, CDCl<sub>3</sub>)



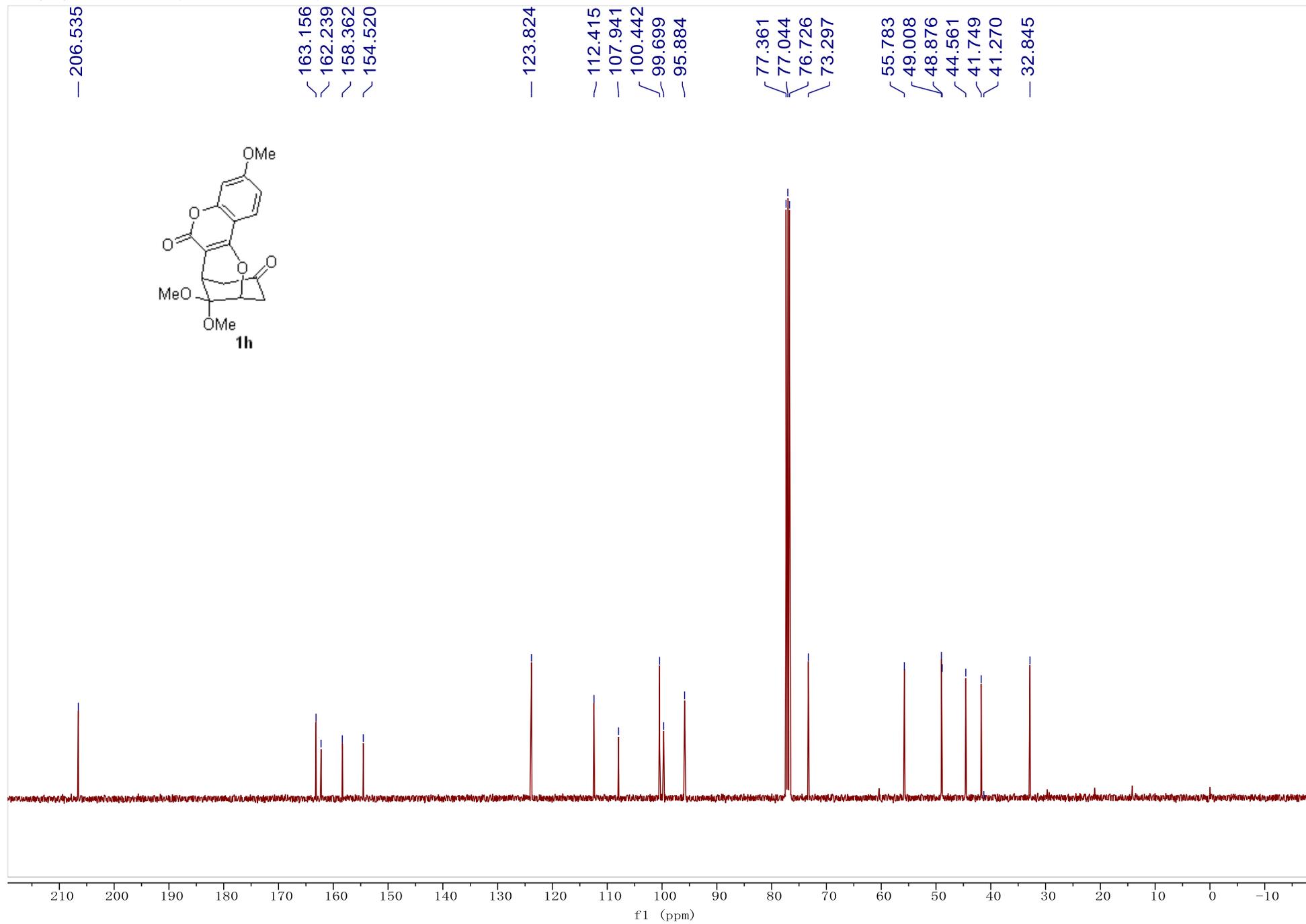
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1g** (101 MHz,  $\text{CDCl}_3$ )



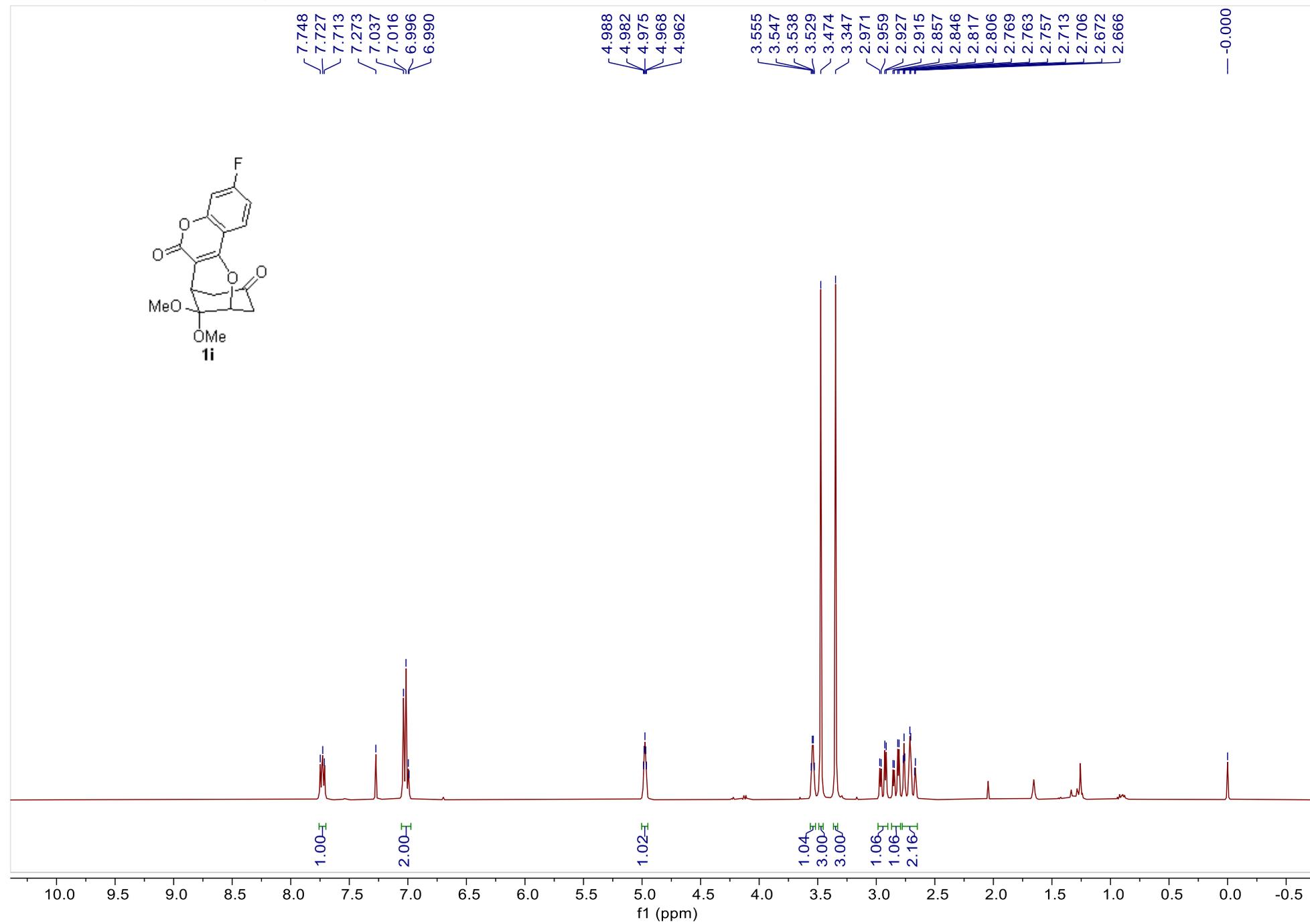
<sup>1</sup>H NMR of **1h** (400MHz, CDCl<sub>3</sub>)



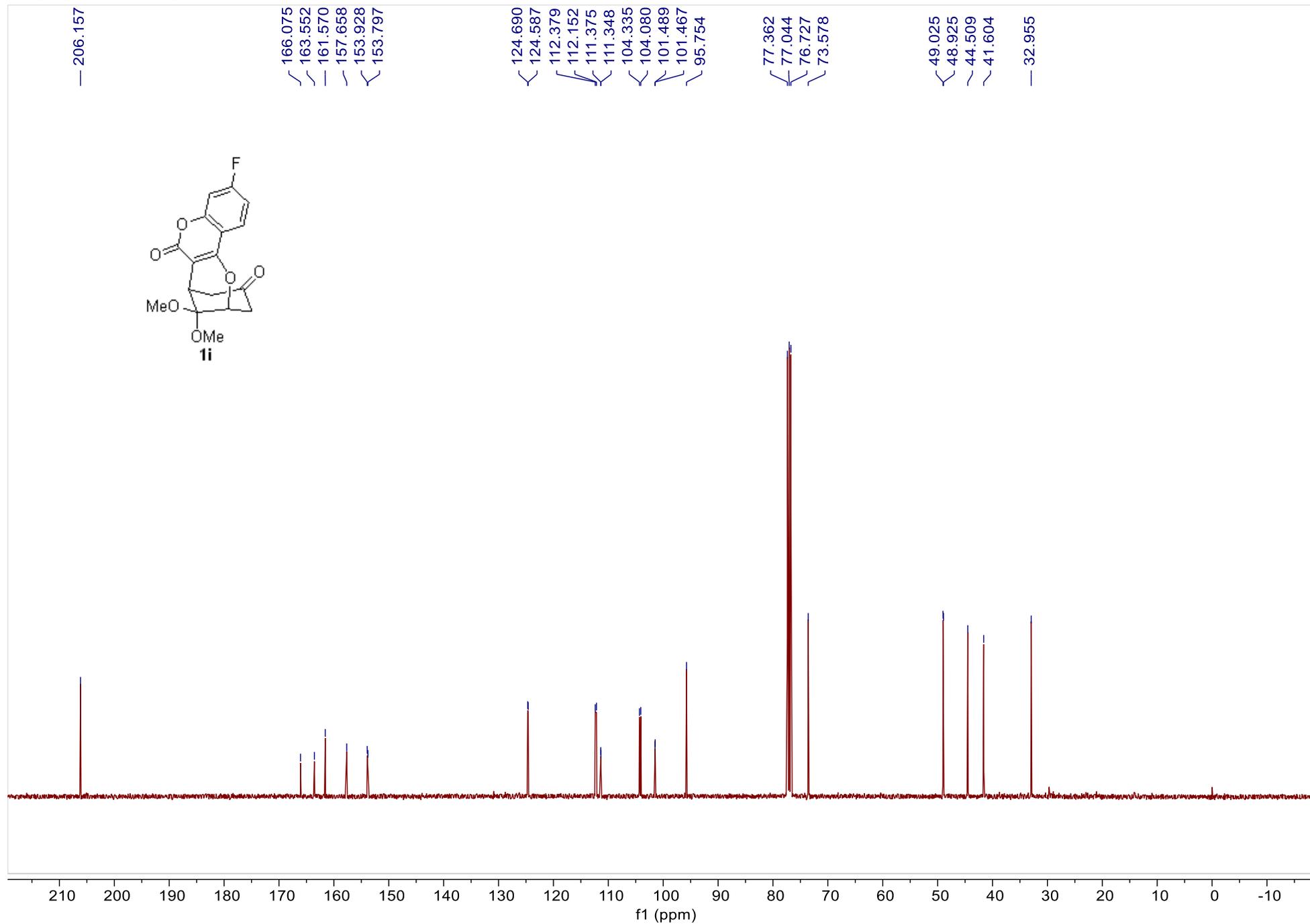
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1h** (101 MHz,  $\text{CDCl}_3$ )



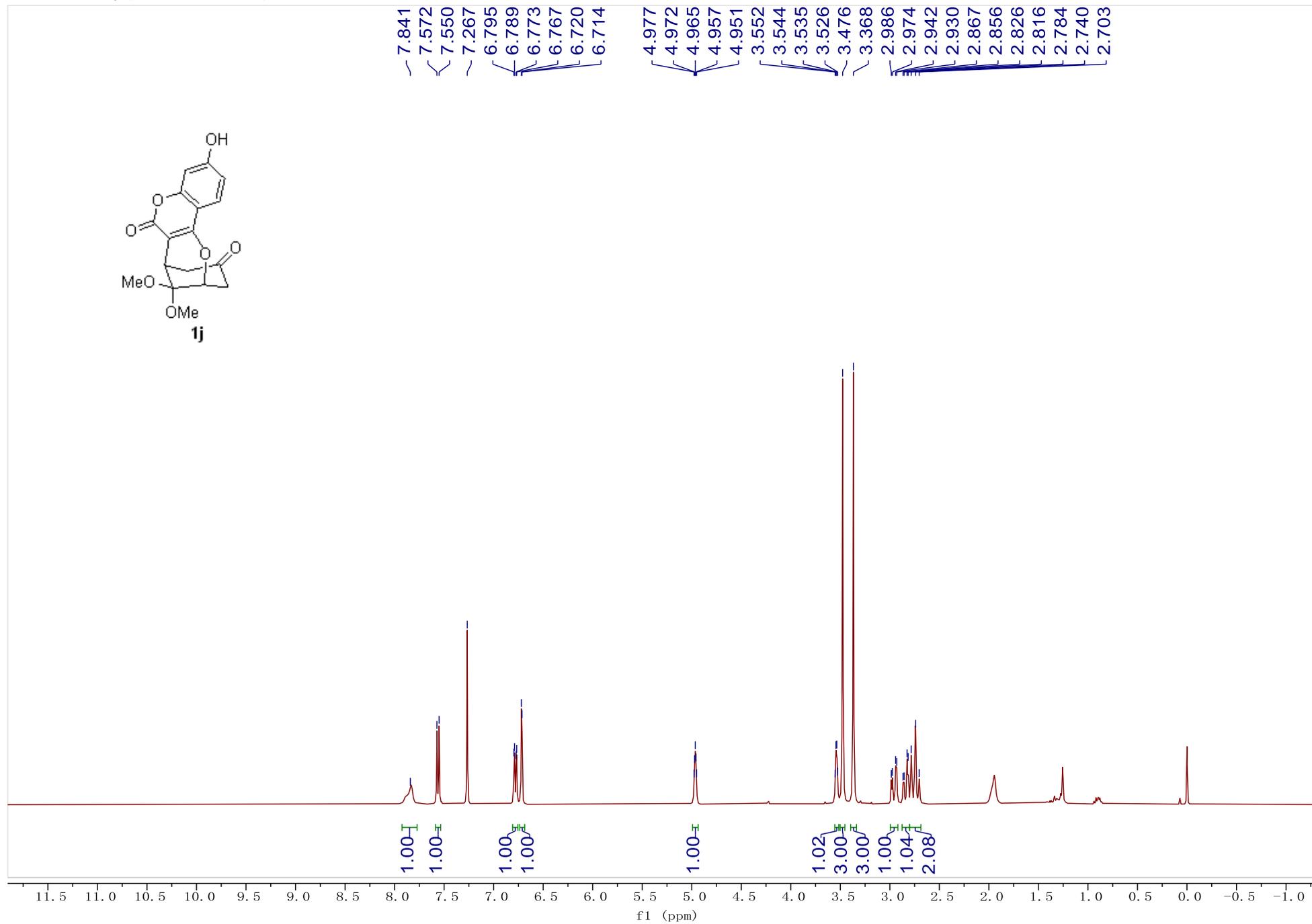
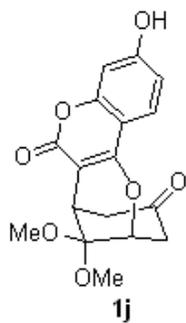
<sup>1</sup>H NMR of **1i** (400MHz, CDCl<sub>3</sub>)



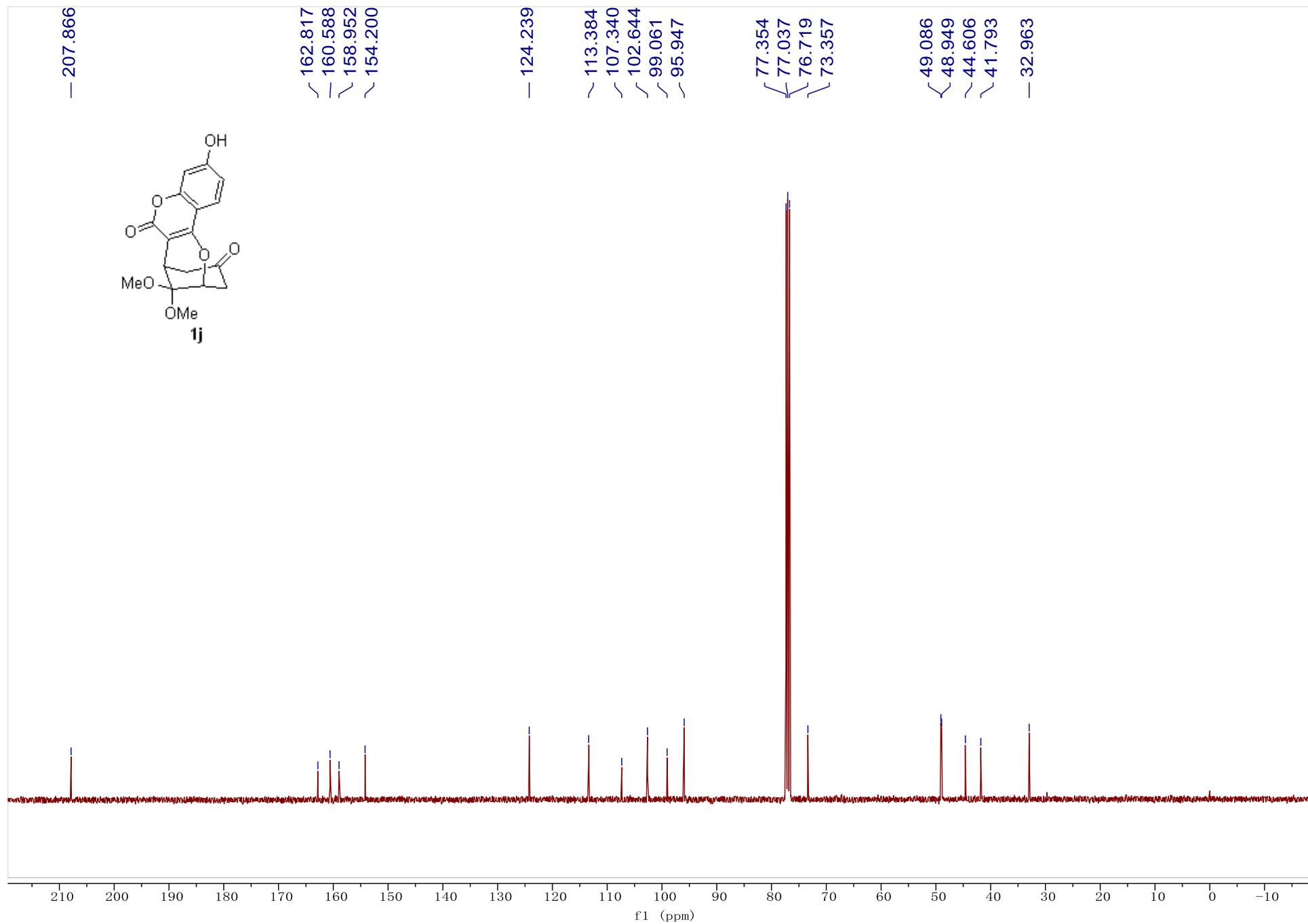
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1i** (101 MHz,  $\text{CDCl}_3$ )



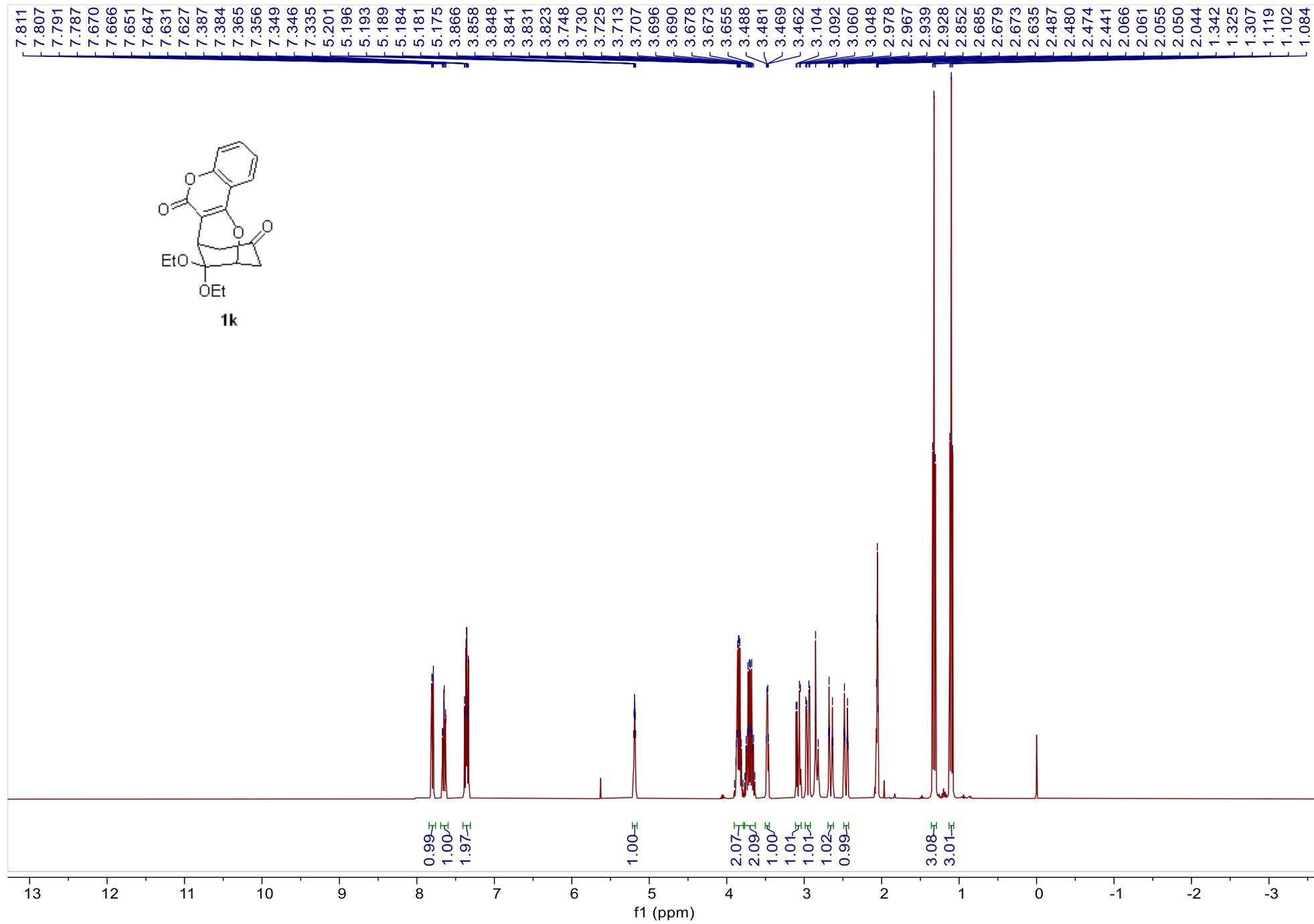
<sup>1</sup>H NMR of **1j** (400MHz, CDCl<sub>3</sub>)



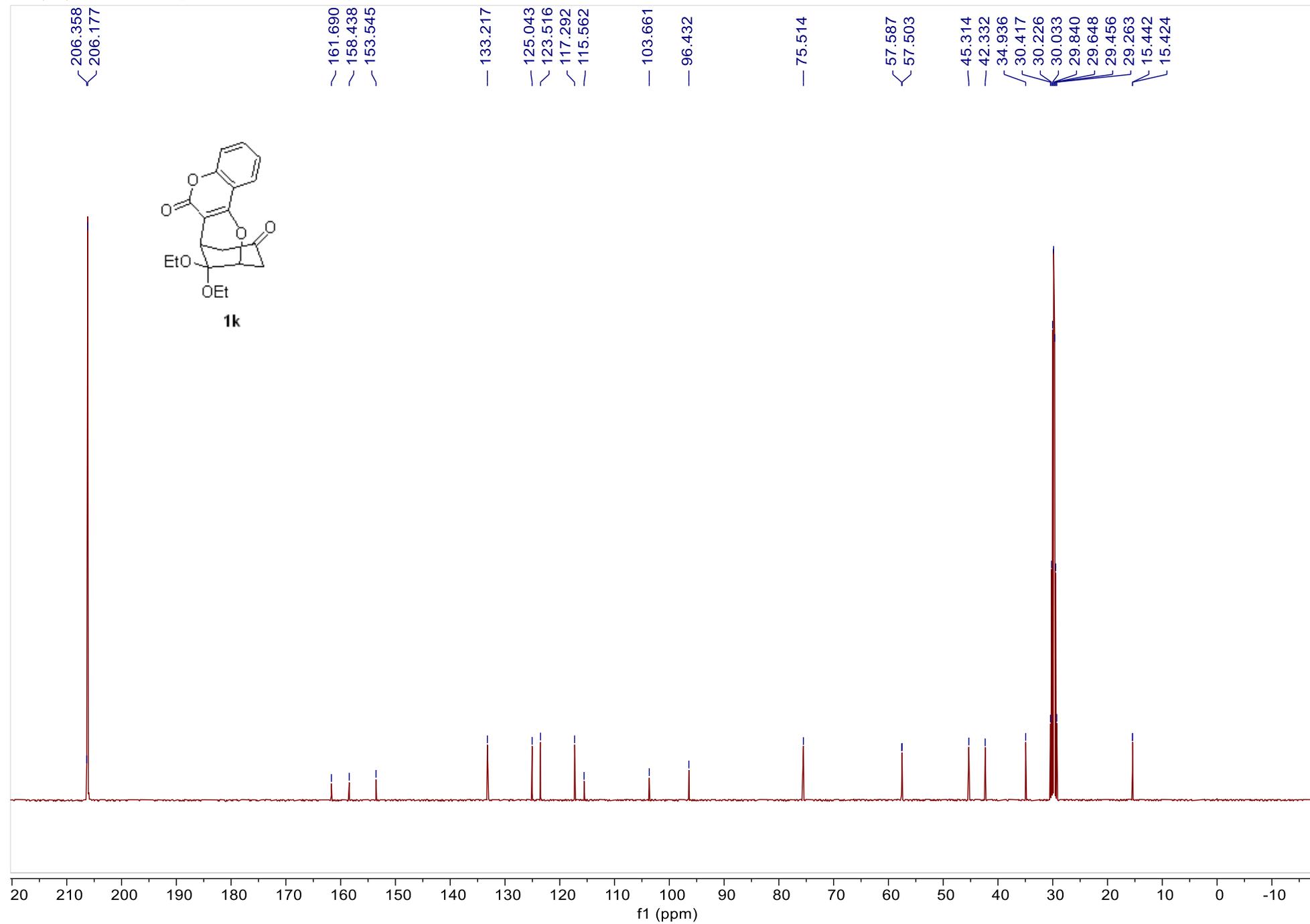
$^{13}\text{C}\{^1\text{H}\}$  NMR of **1j** (101 MHz,  $\text{CDCl}_3$ )



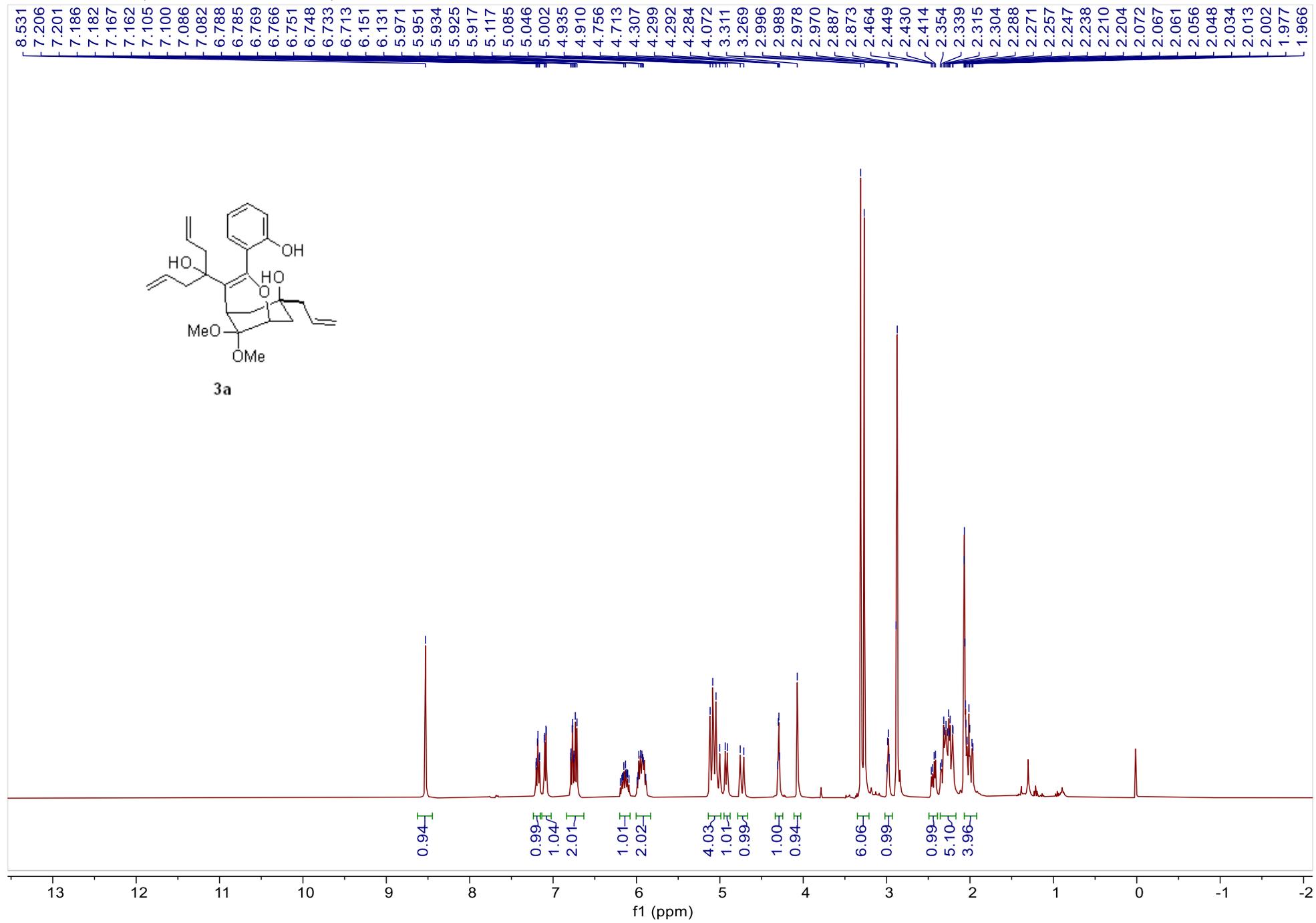
<sup>1</sup>H NMR of **1k** (400MHz, acetone-d<sub>6</sub>)



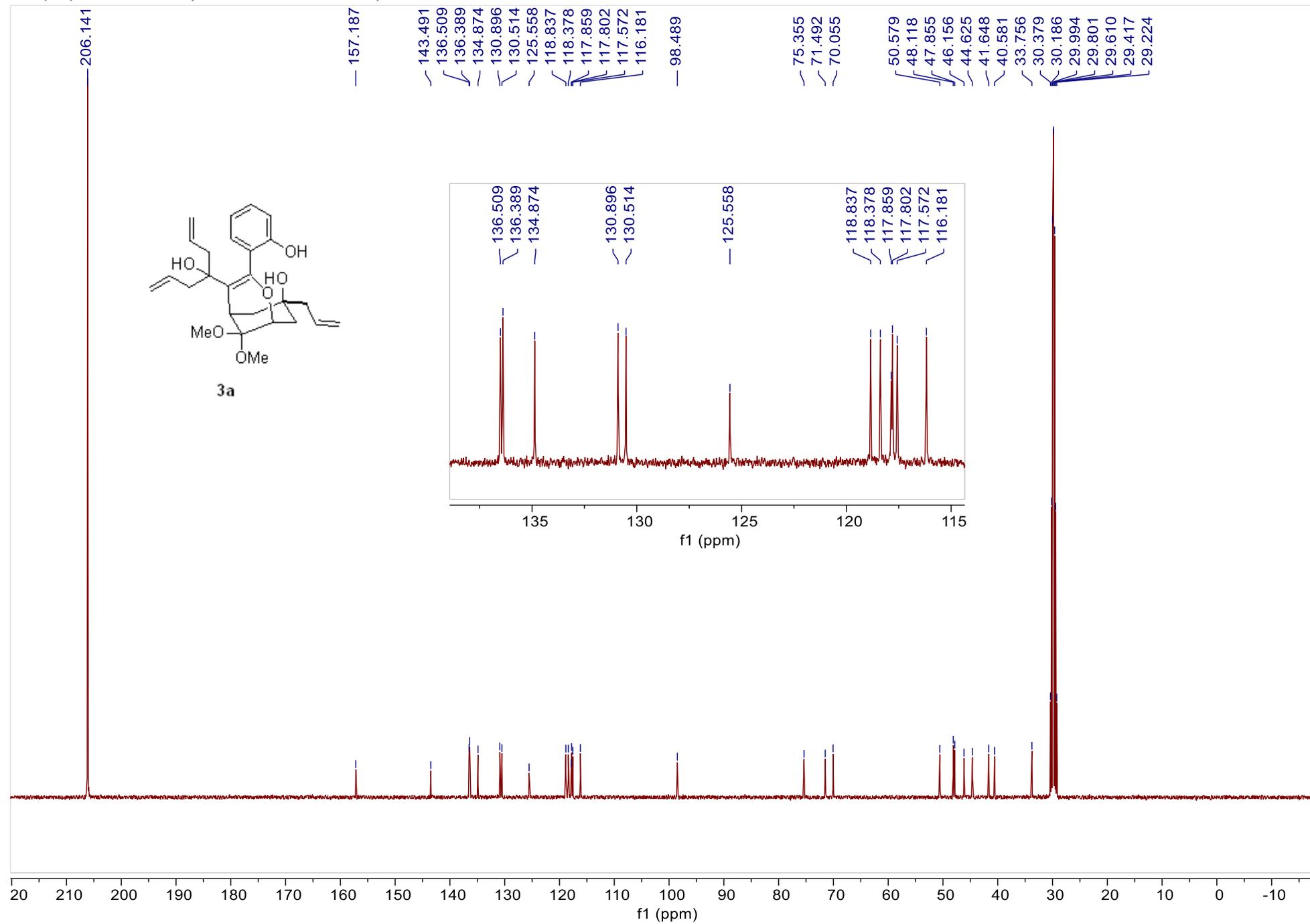
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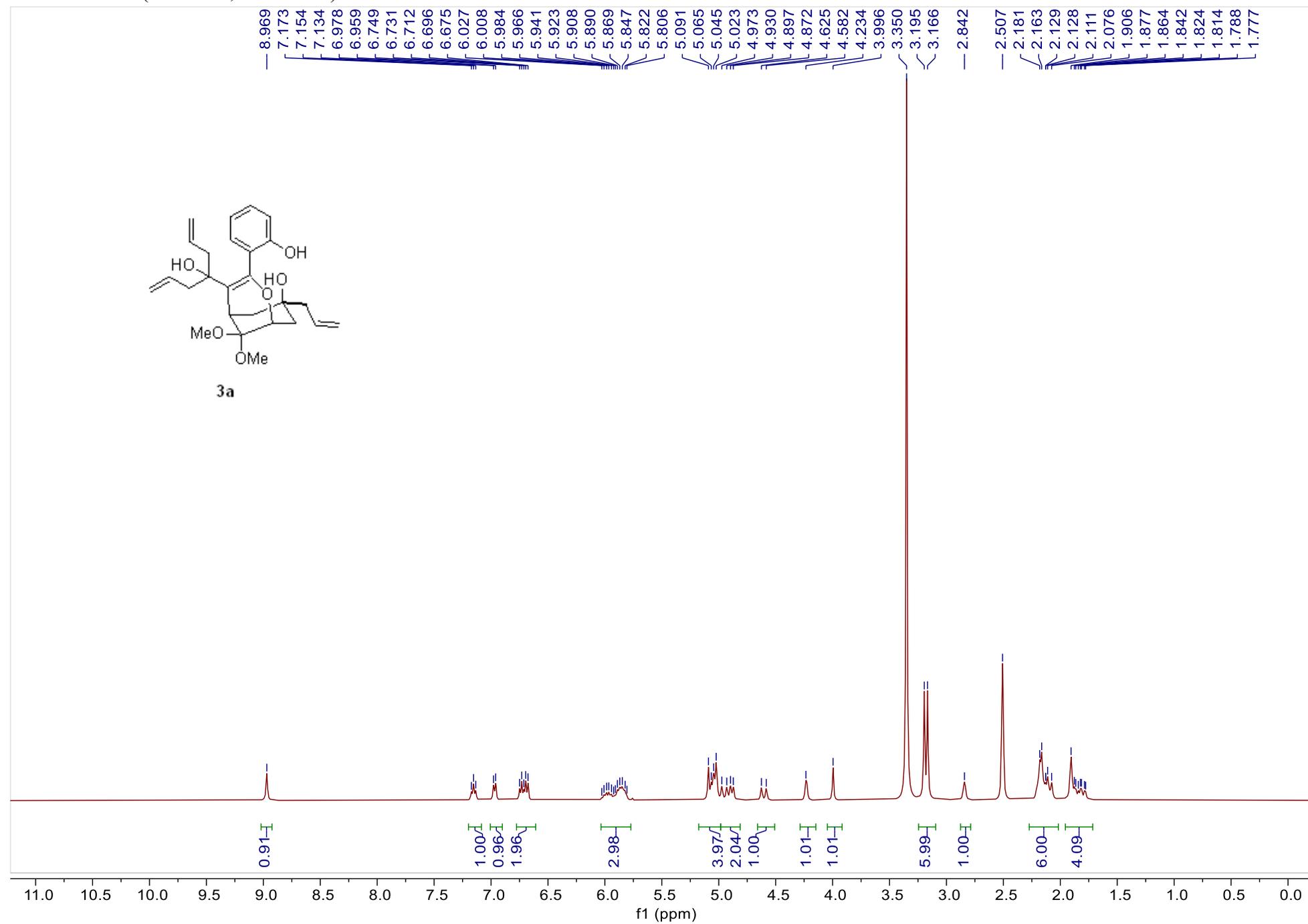
<sup>1</sup>H NMR of **3a** (400 MHz, acetone-d<sub>6</sub>)



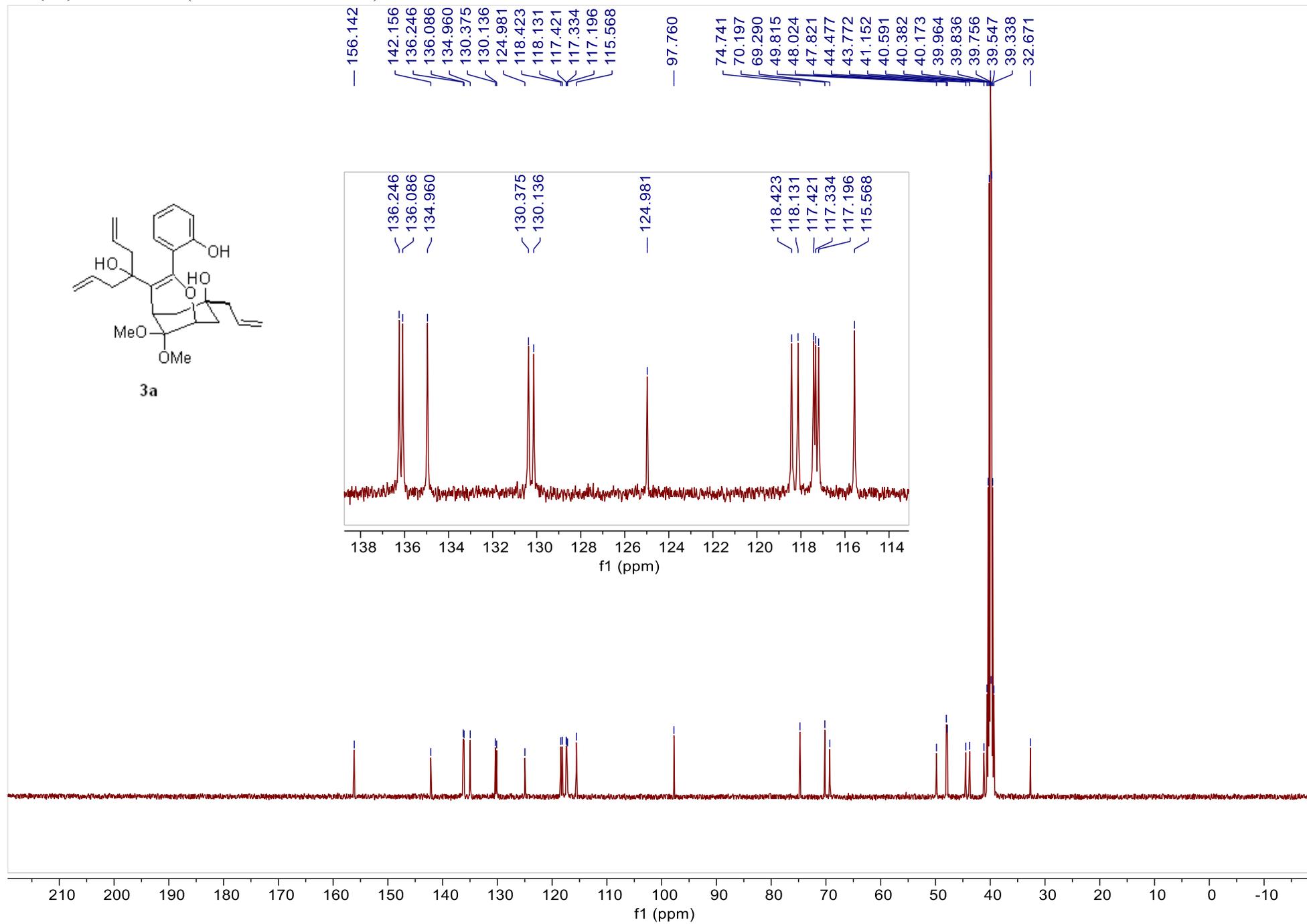
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3a** (101 MHz, acetone- $d_6$ )



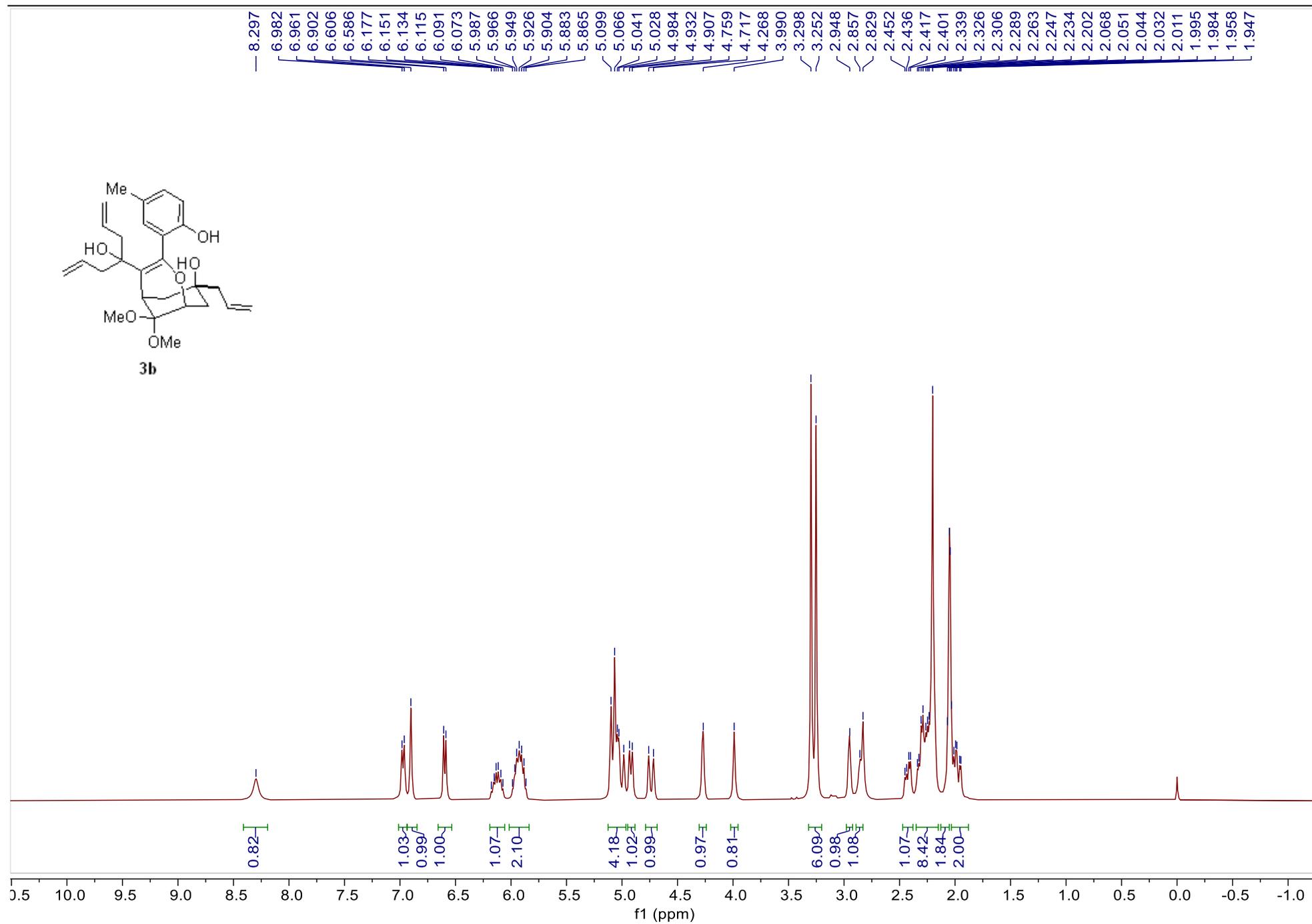
<sup>1</sup>H NMR of **3a** (400 MHz, DMSO-d<sub>6</sub>)



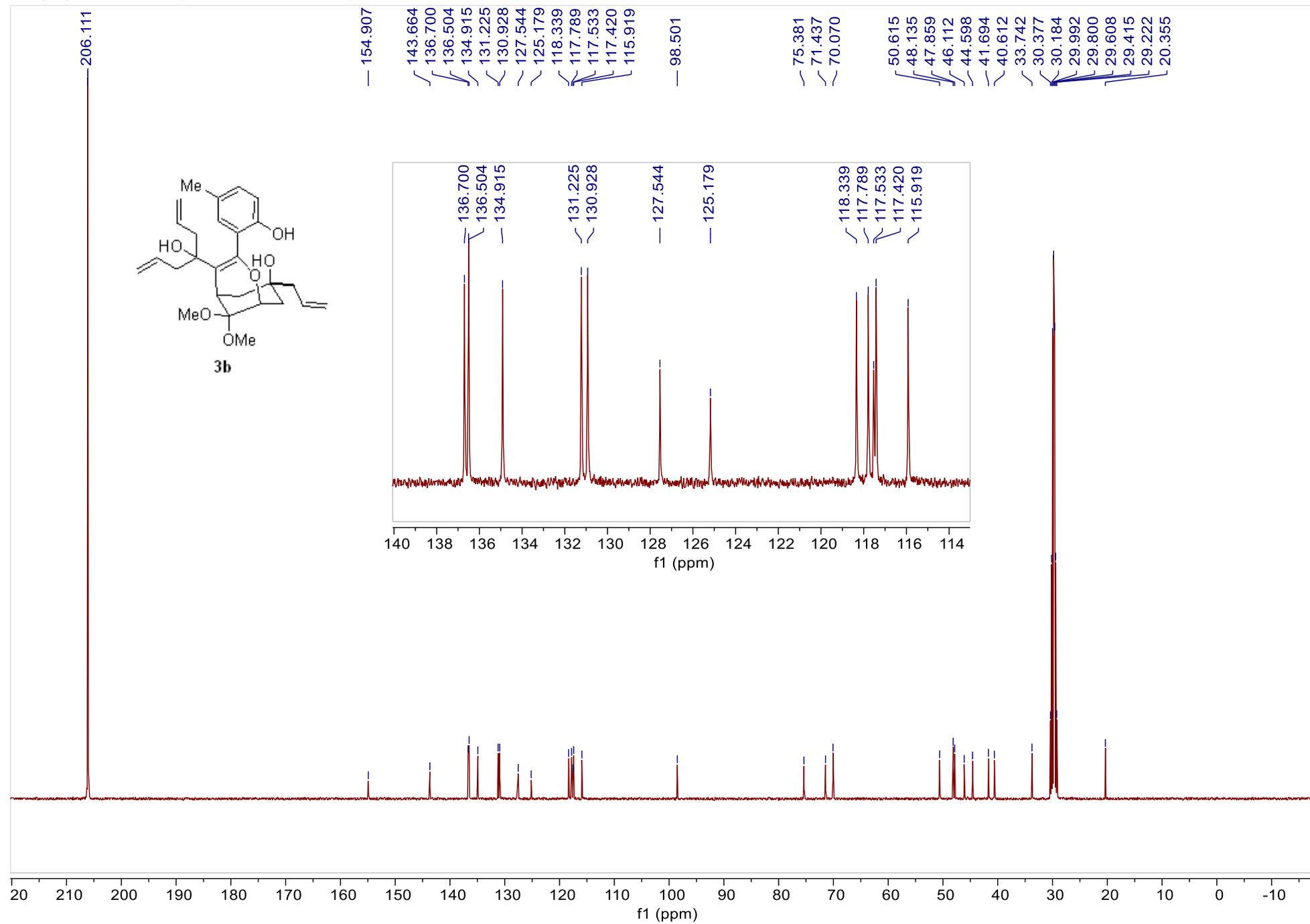
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3a** (400 MHz, DMSO-d<sub>6</sub>)



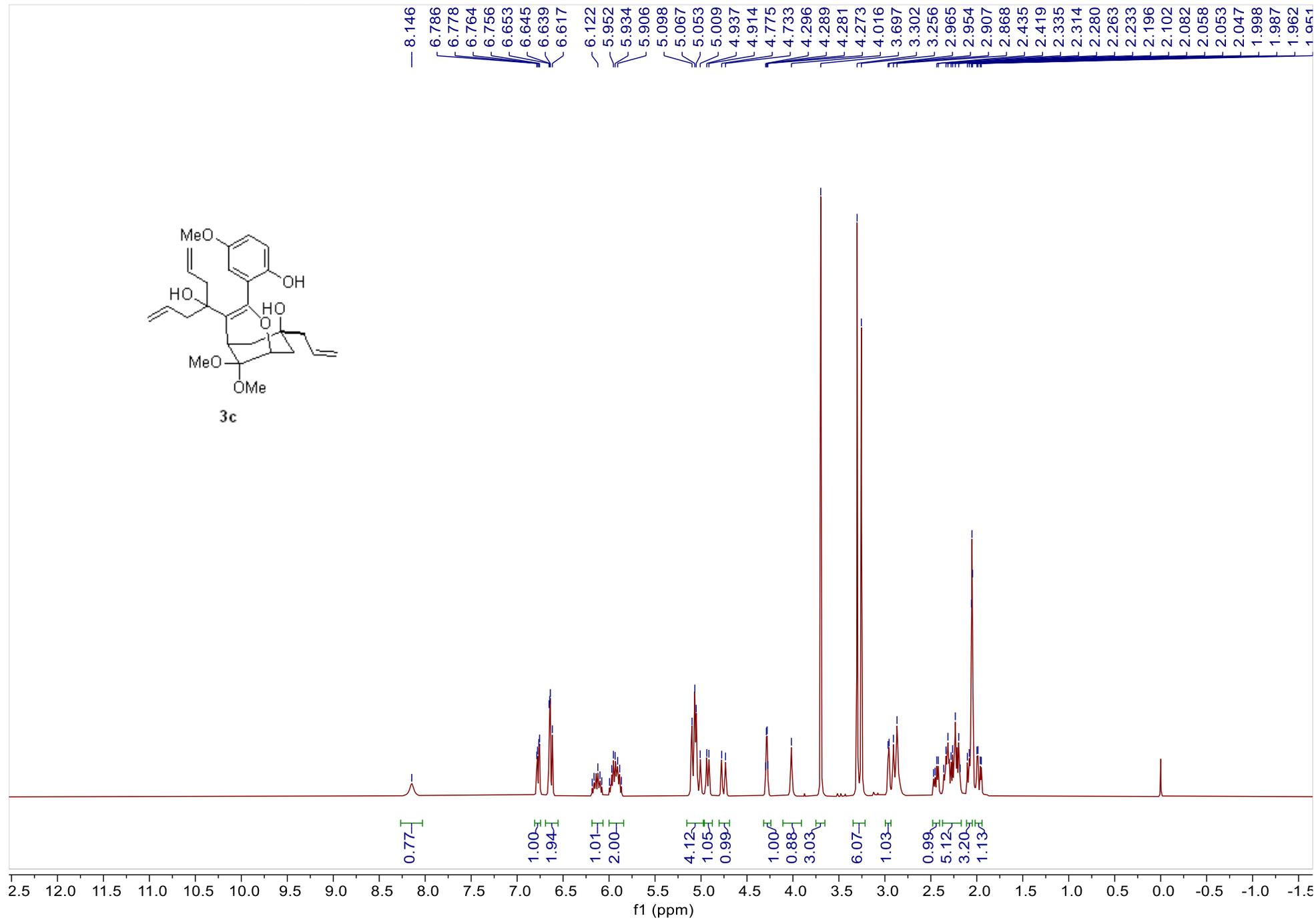
$^1\text{H}$  NMR of **3b** (400 MHz, acetone-d<sub>6</sub>)



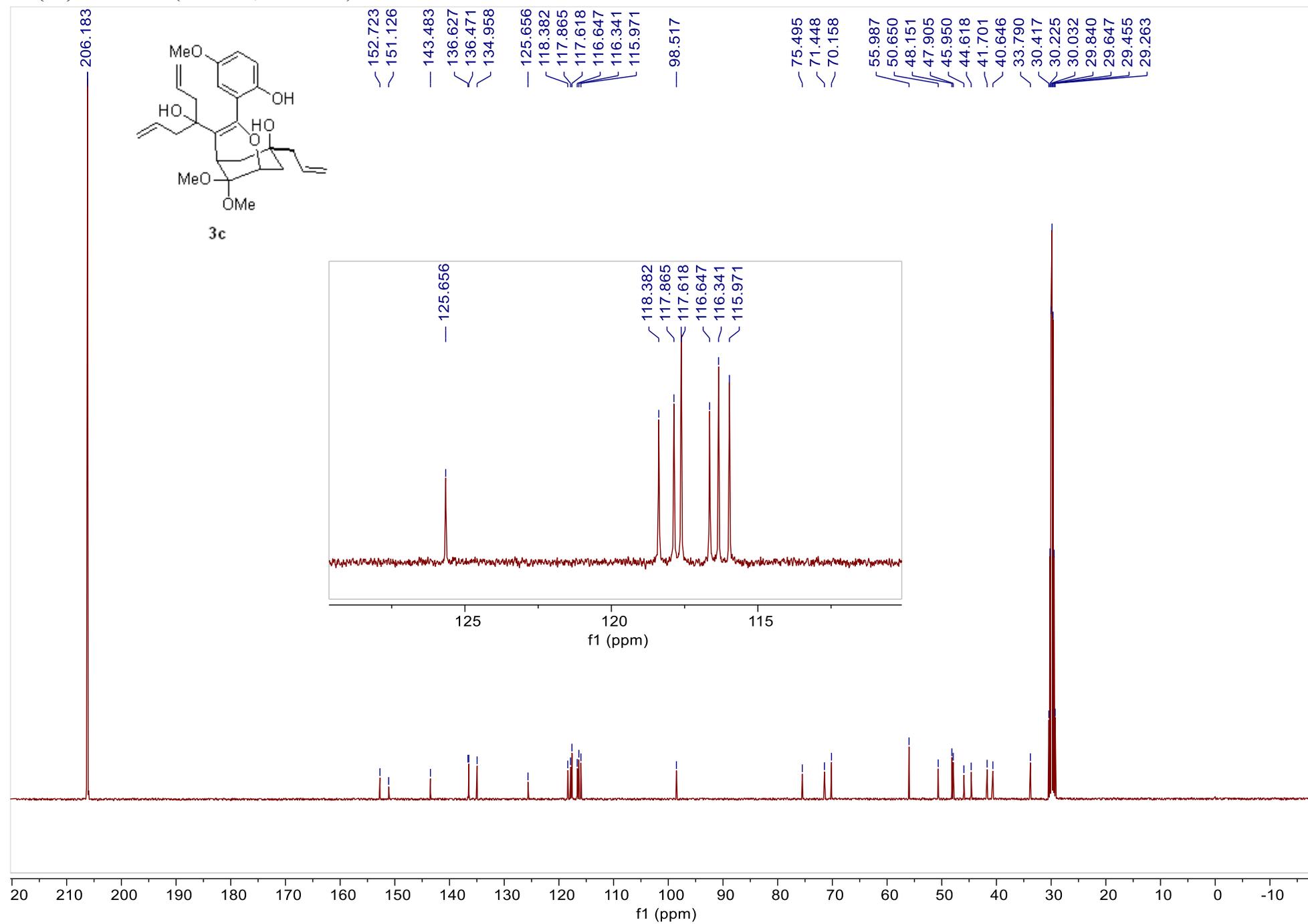
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3b** (101 MHz, acetone- $d_6$ )



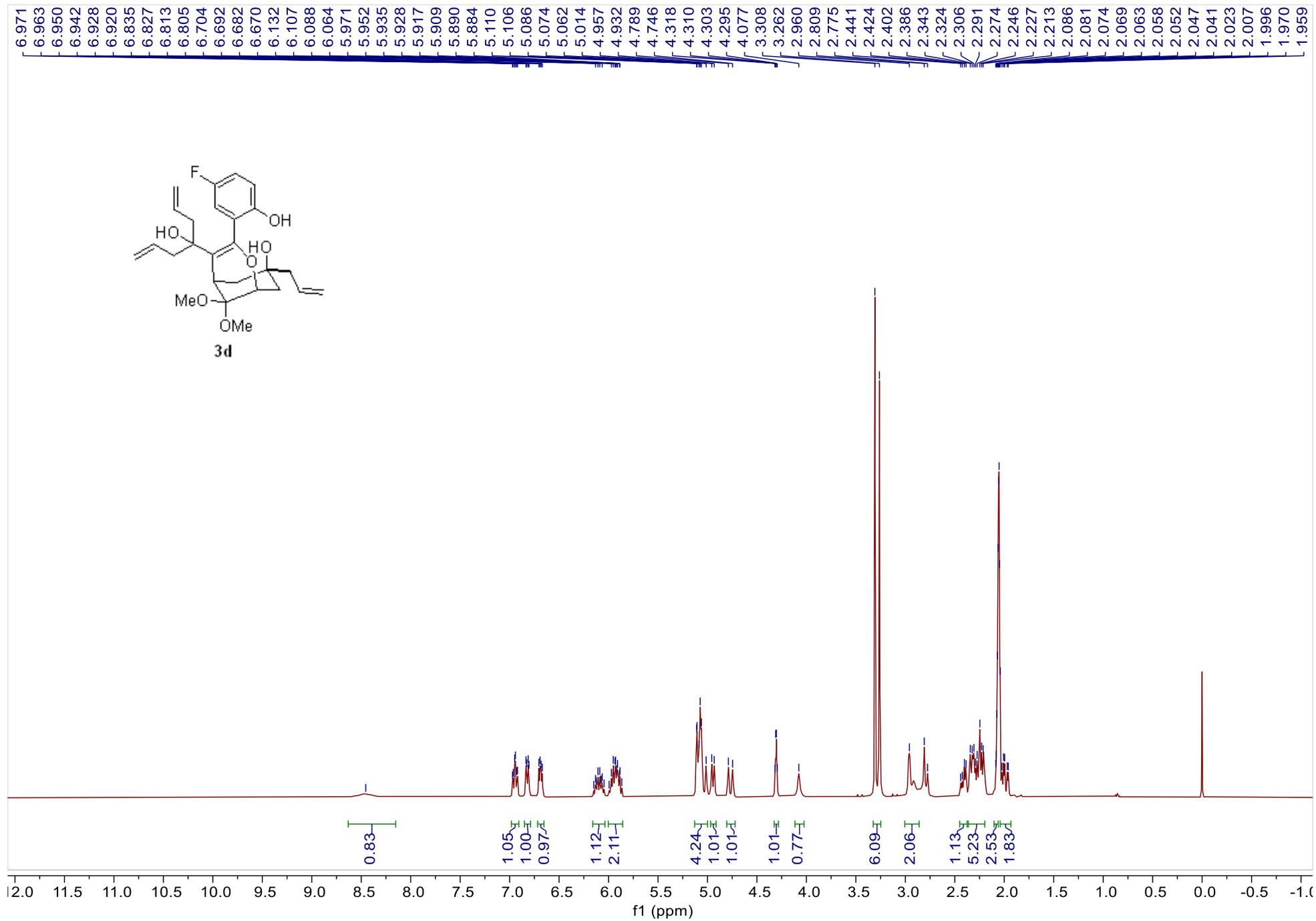
<sup>1</sup>H NMR of **3c** (400 MHz, acetone-d<sub>6</sub>)



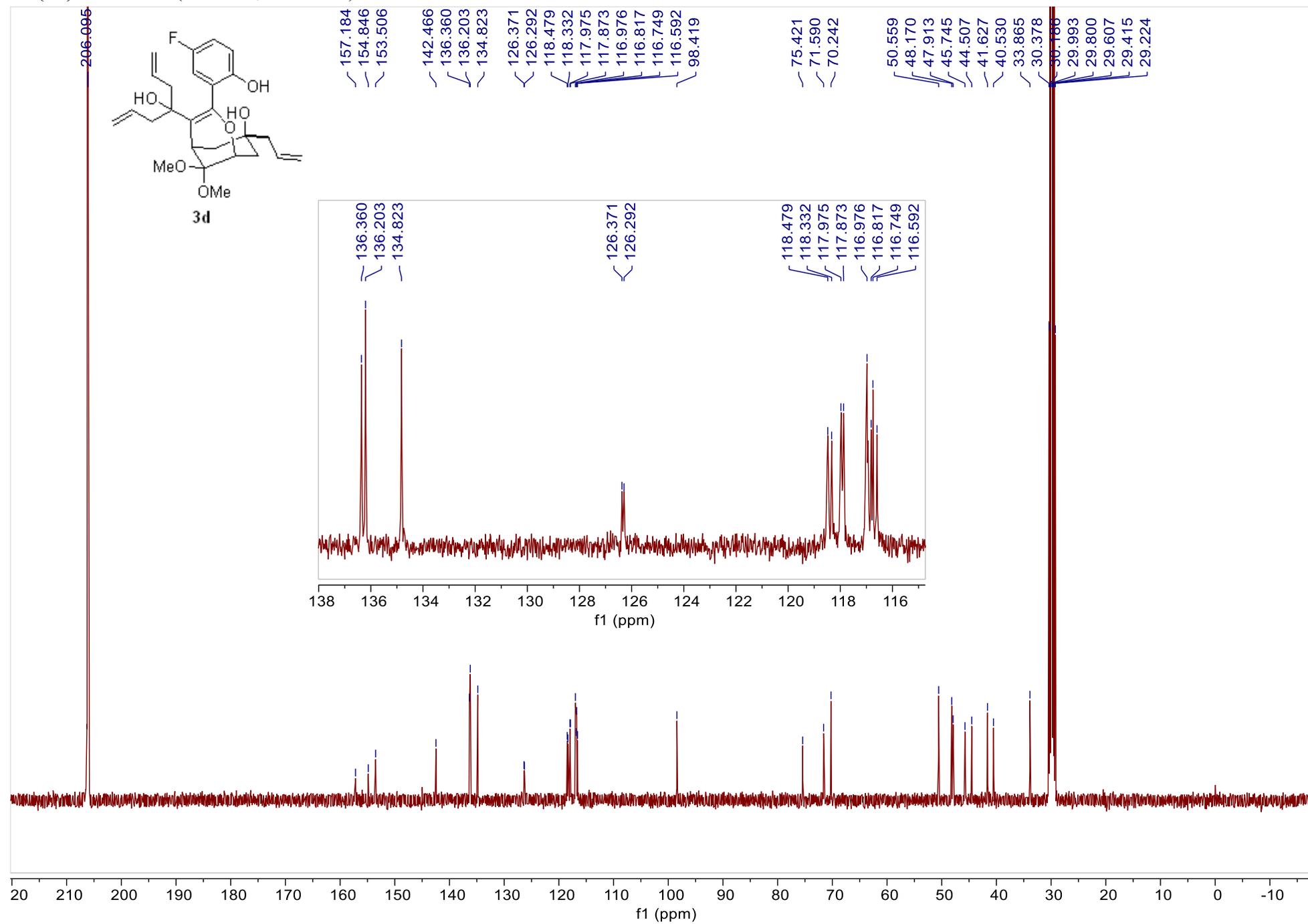
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3c** (101 MHz, acetone- $d_6$ )



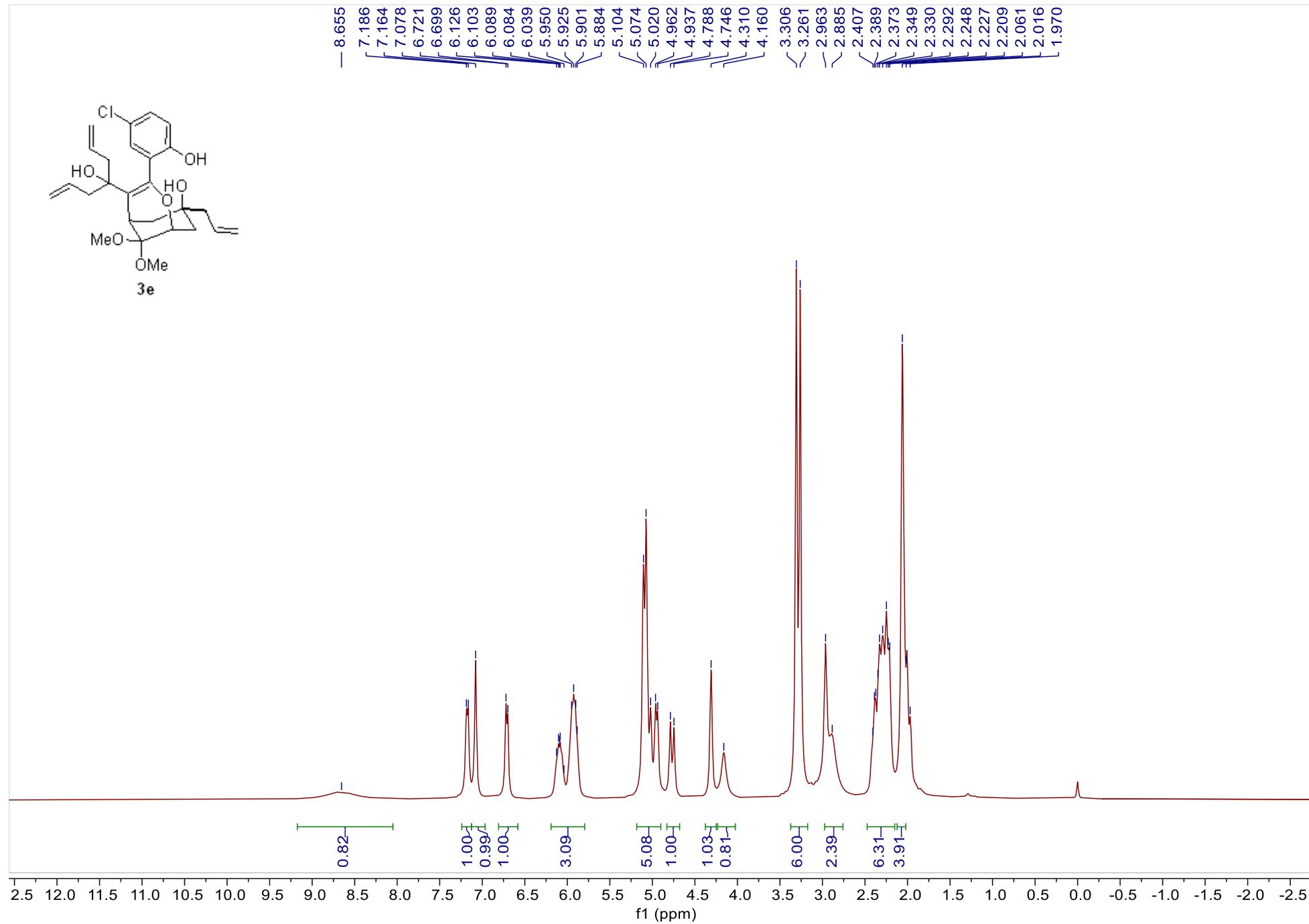
<sup>1</sup>H NMR of **3d** (400 MHz, acetone-d<sub>6</sub>)



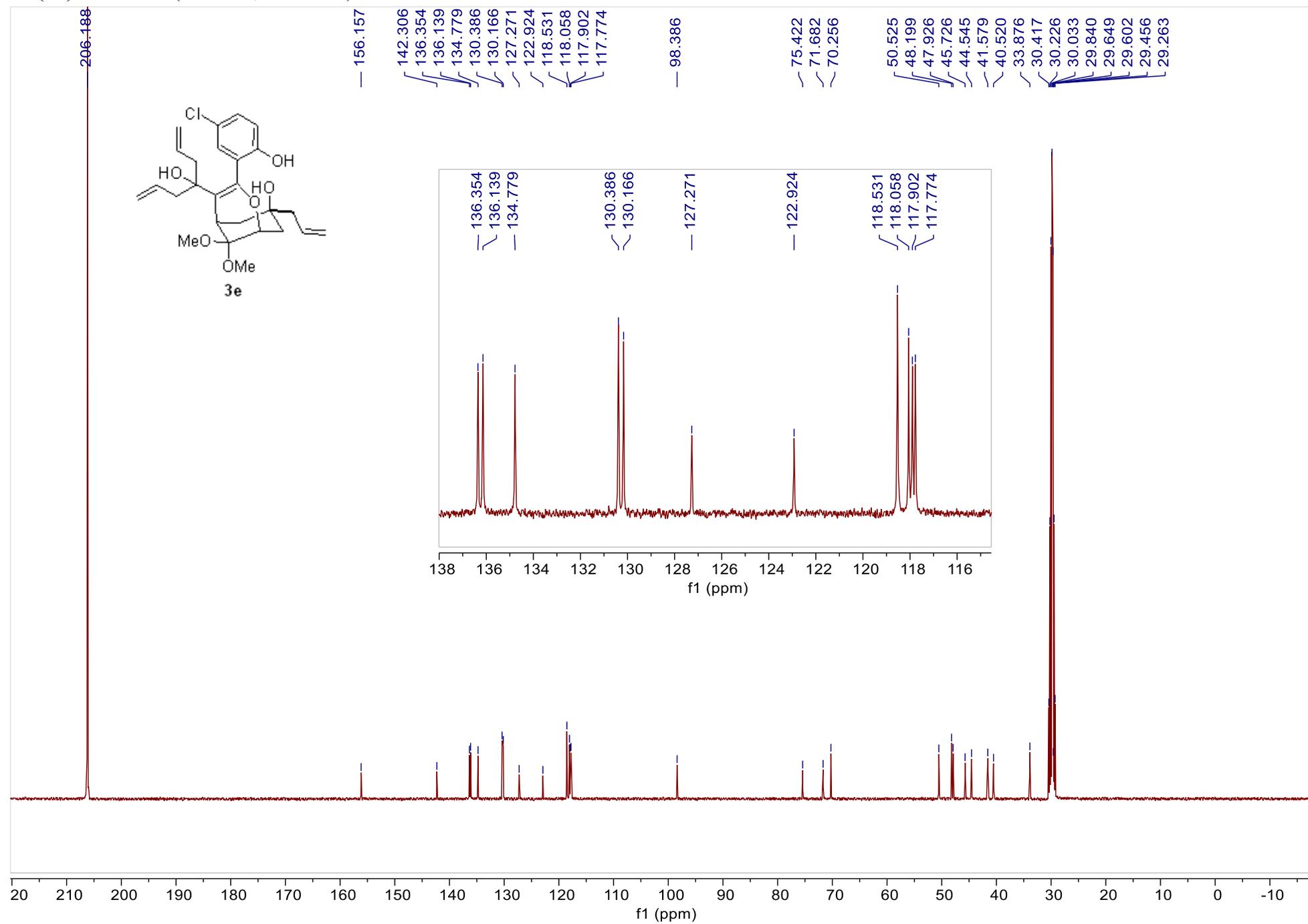
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3d** (101 MHz, acetone- $d_6$ )



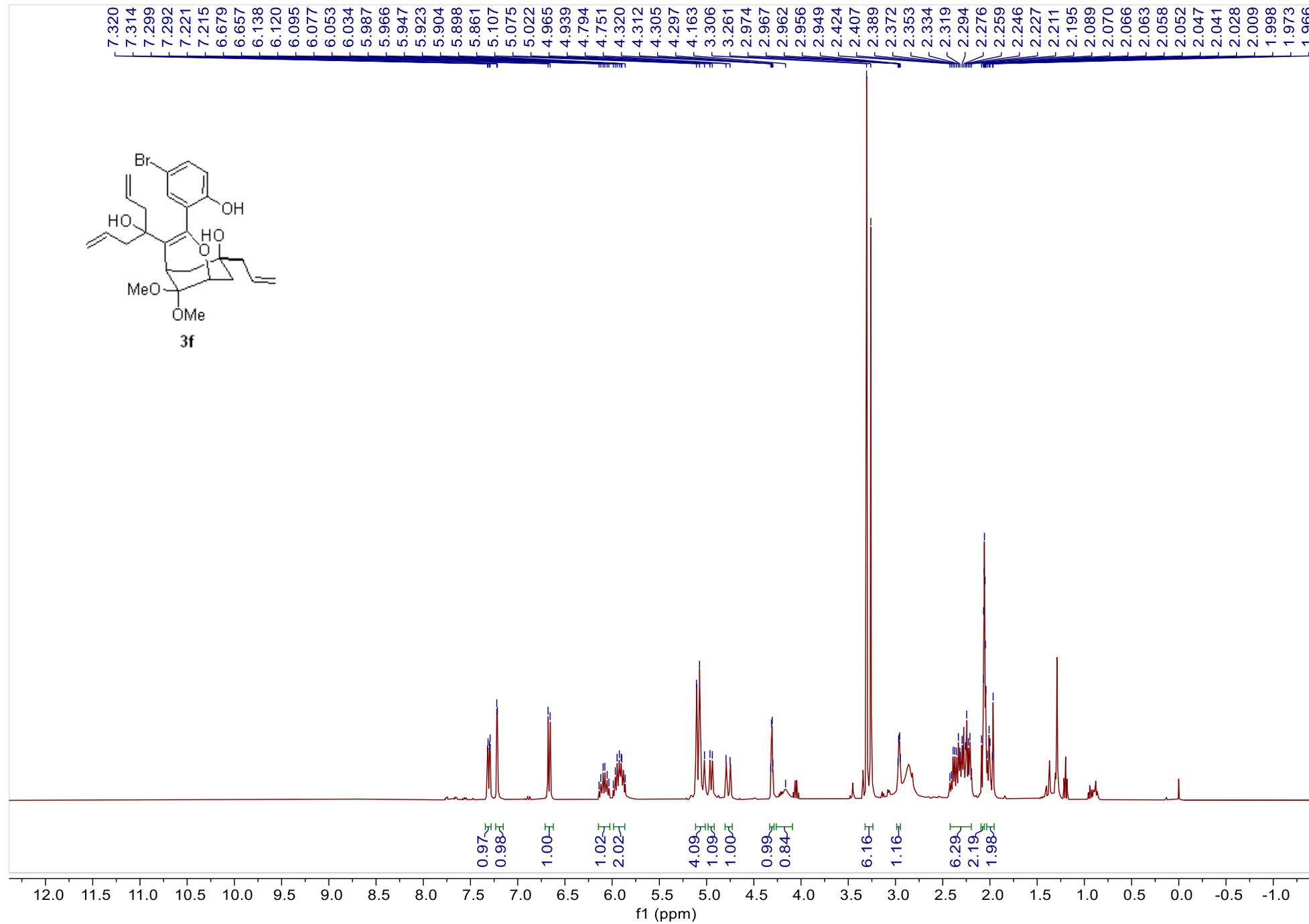
<sup>1</sup>H NMR of **3e** (400 MHz, acetone-d<sub>6</sub>)



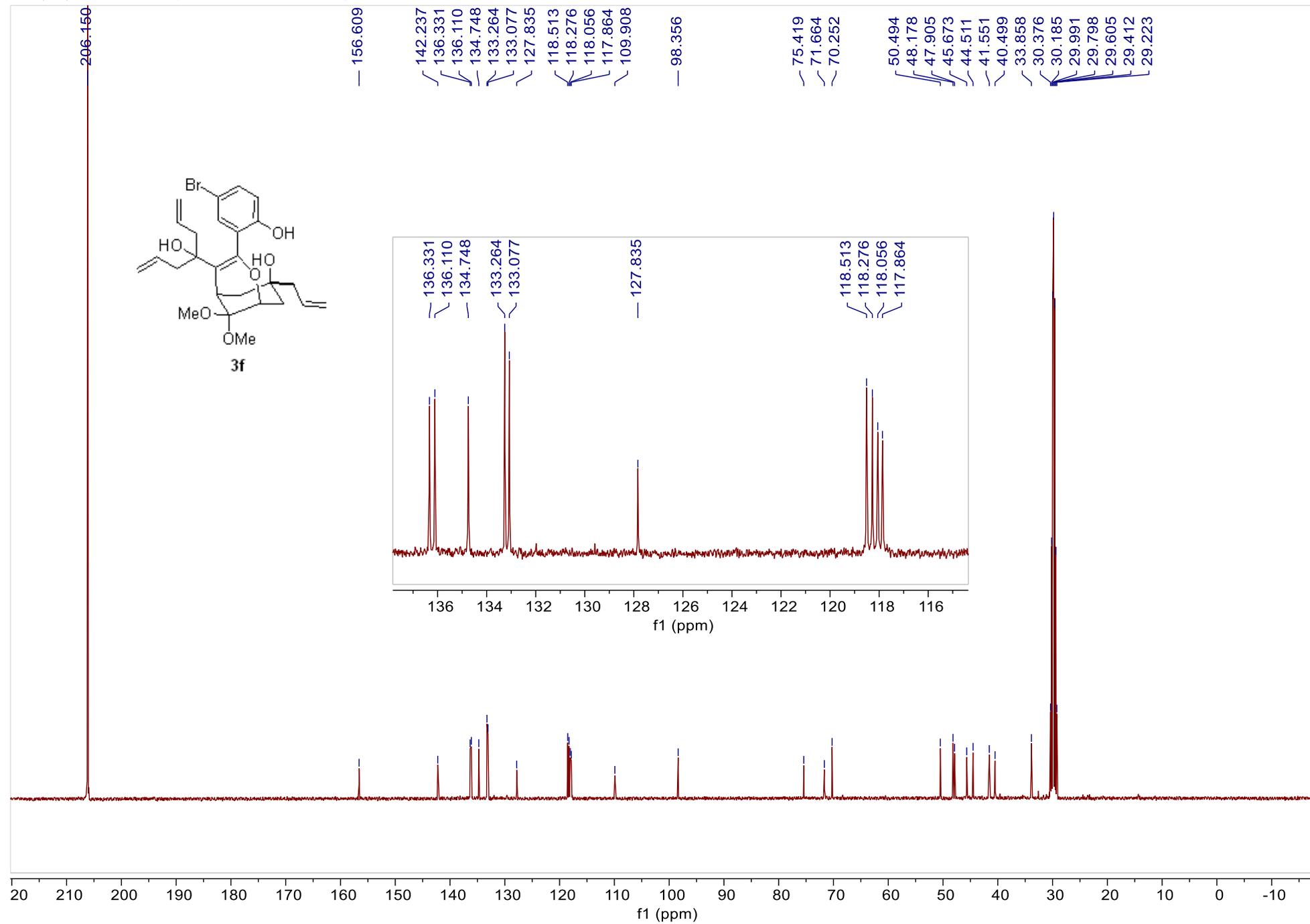
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3e** (101 MHz, acetone- $d_6$ )



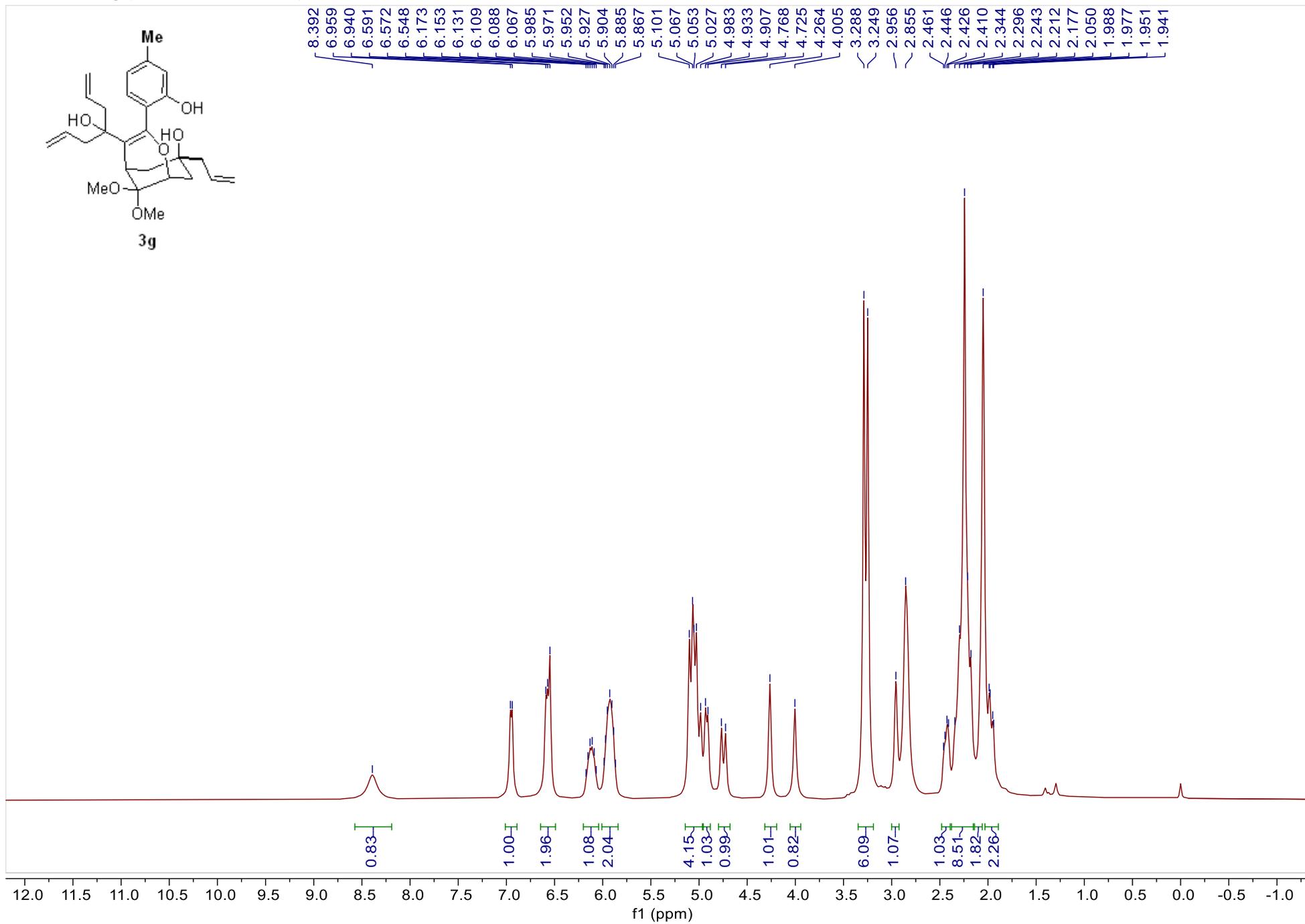
<sup>1</sup>H NMR of **3f** (400 MHz, acetone-d<sub>6</sub>)



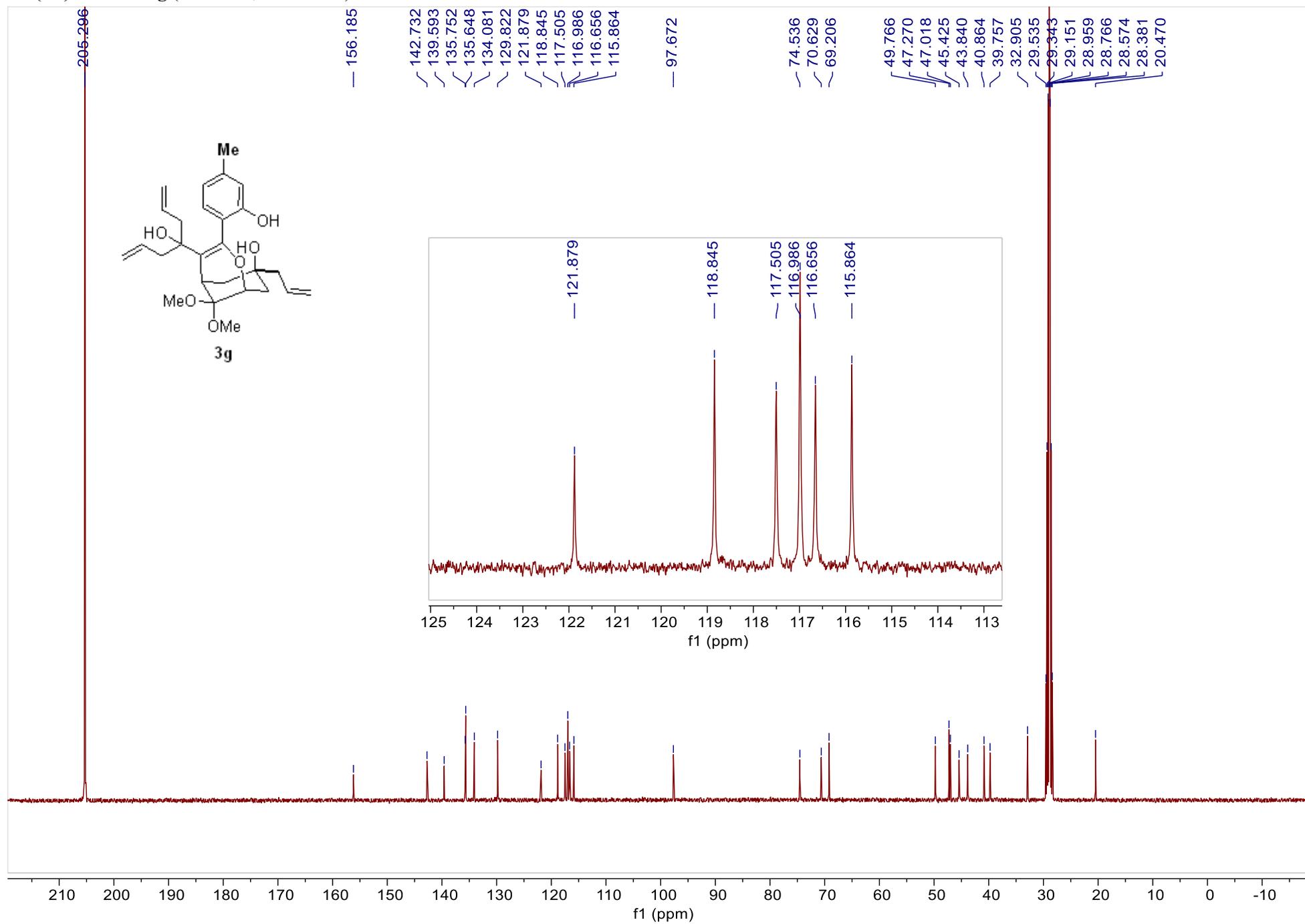
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3f** (101 MHz, acetone- $\text{d}_6$ )



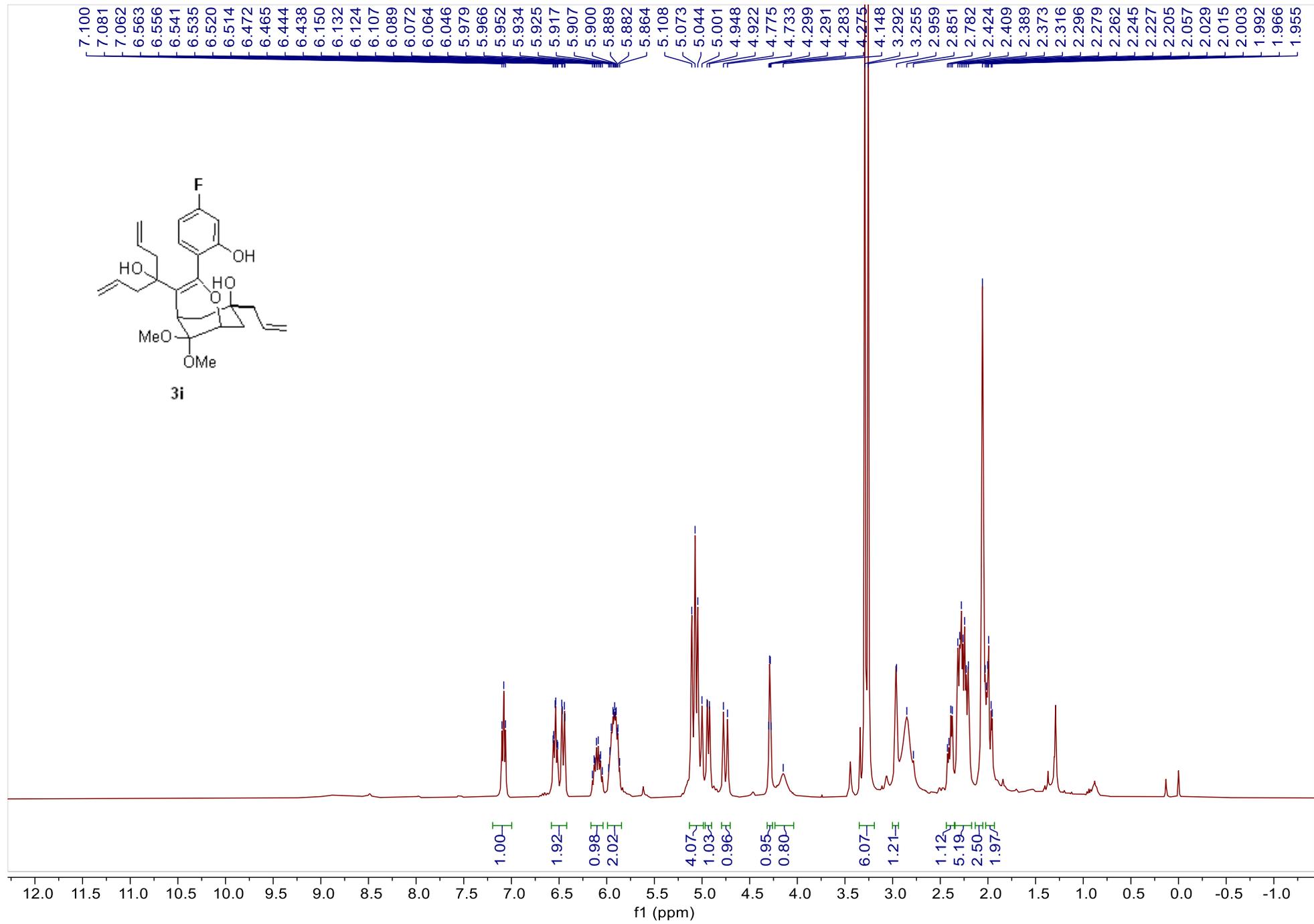
<sup>1</sup>H NMR of **3g** (400 MHz, acetone-d<sub>6</sub>)



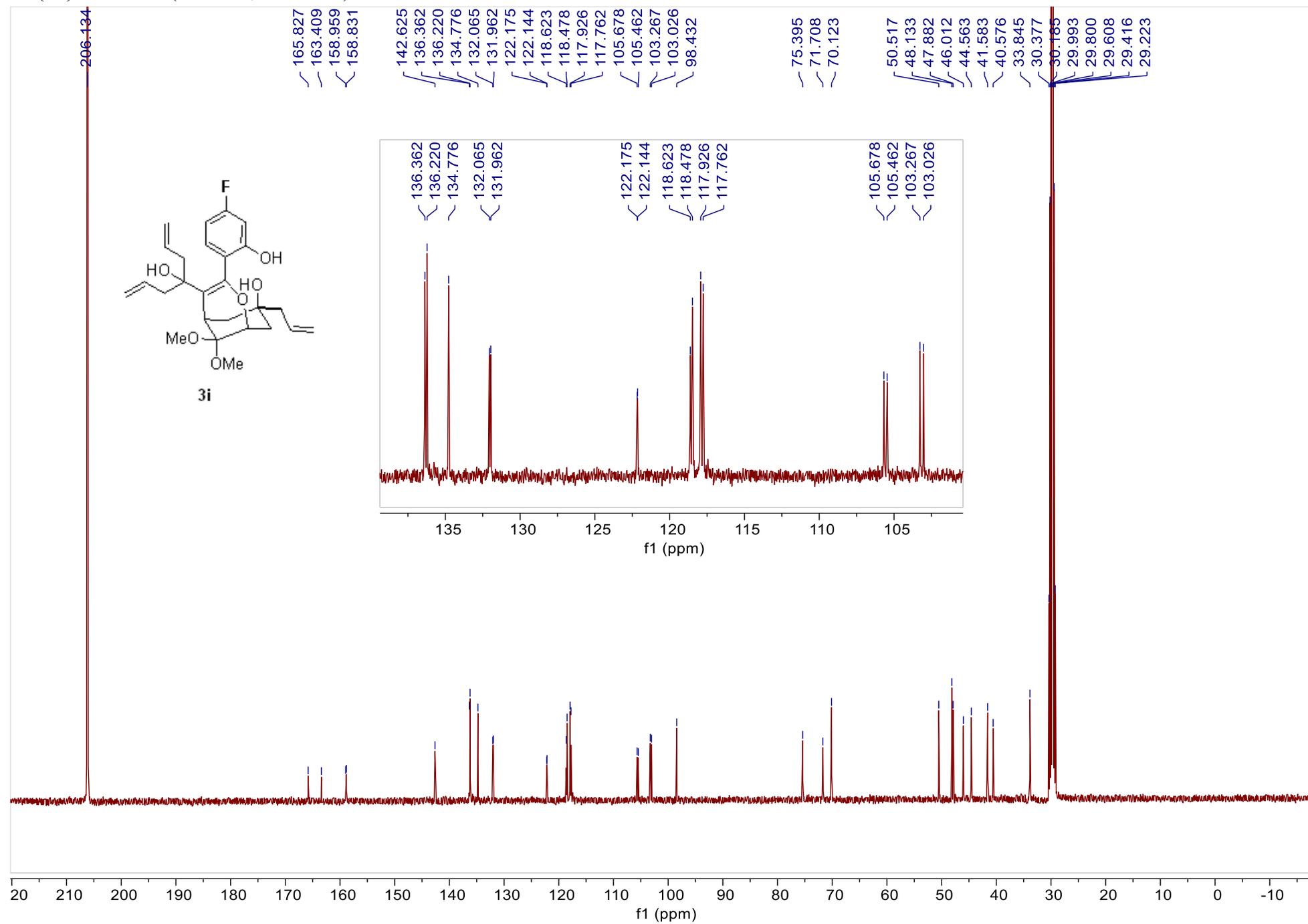
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3g** (101 MHz, acetone- $\text{d}_6$ )



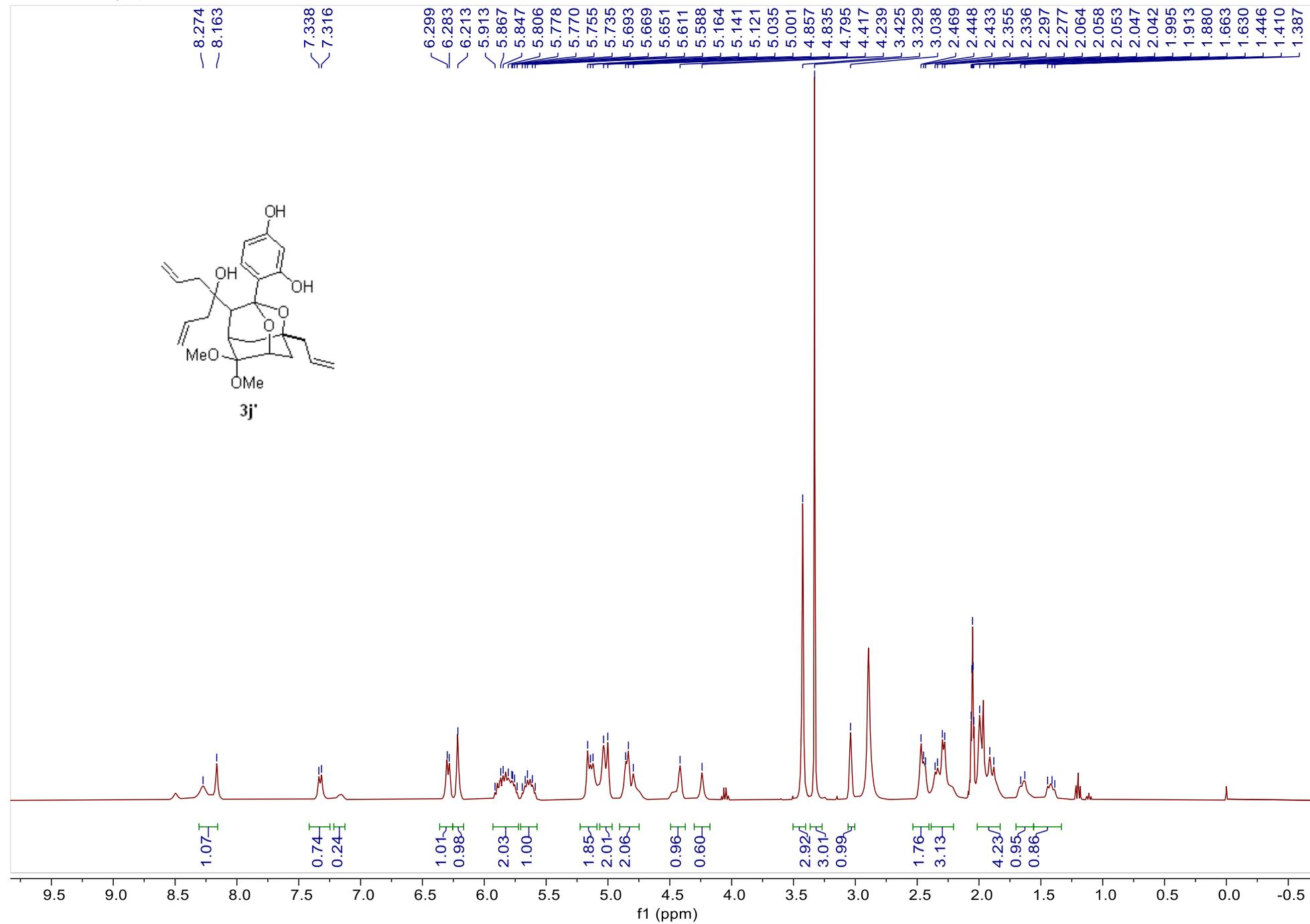
<sup>1</sup>H NMR of **3i** (400 MHz, acetone-d<sub>6</sub>)



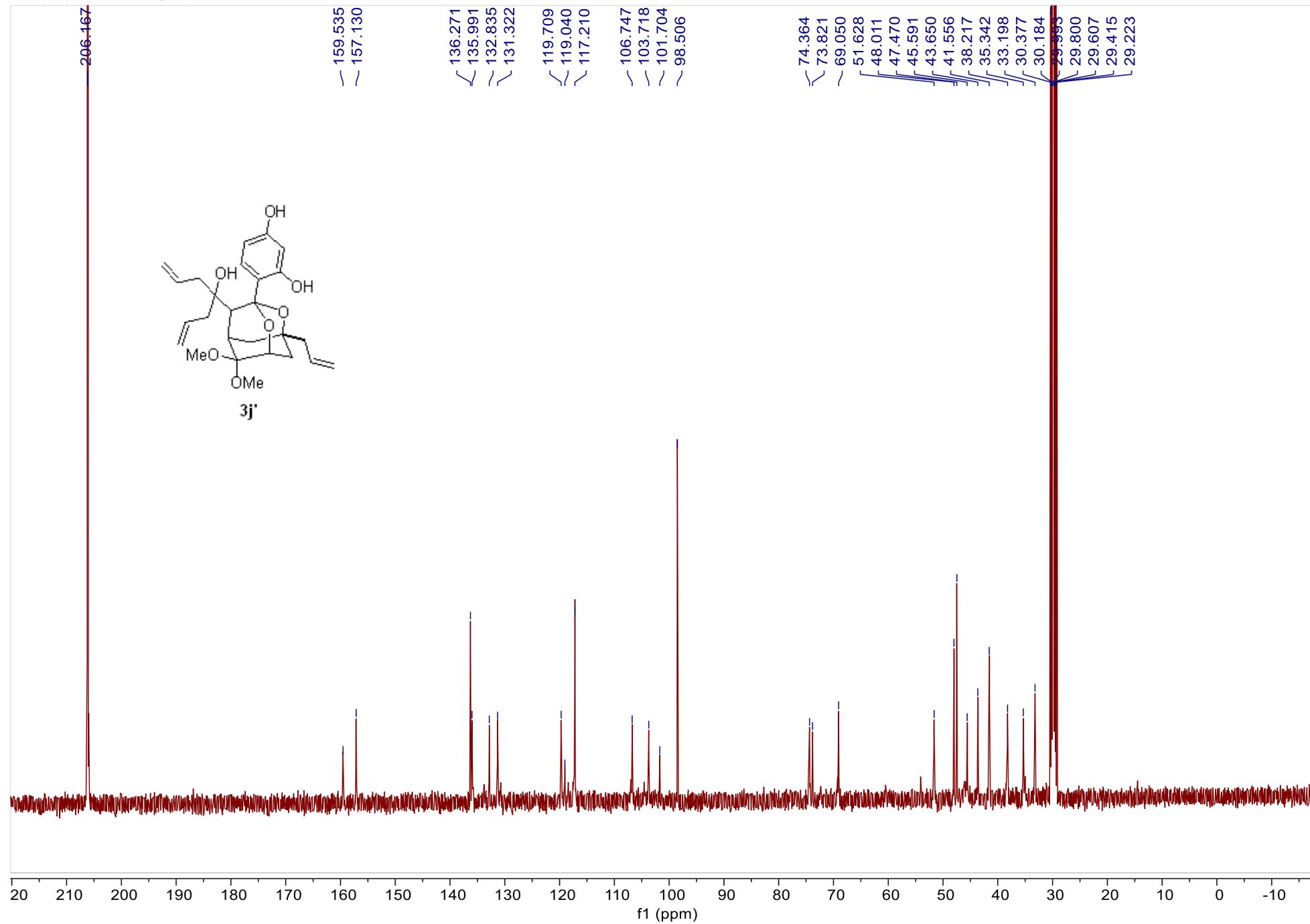
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3i** (101 MHz, acetone- $d_6$ )



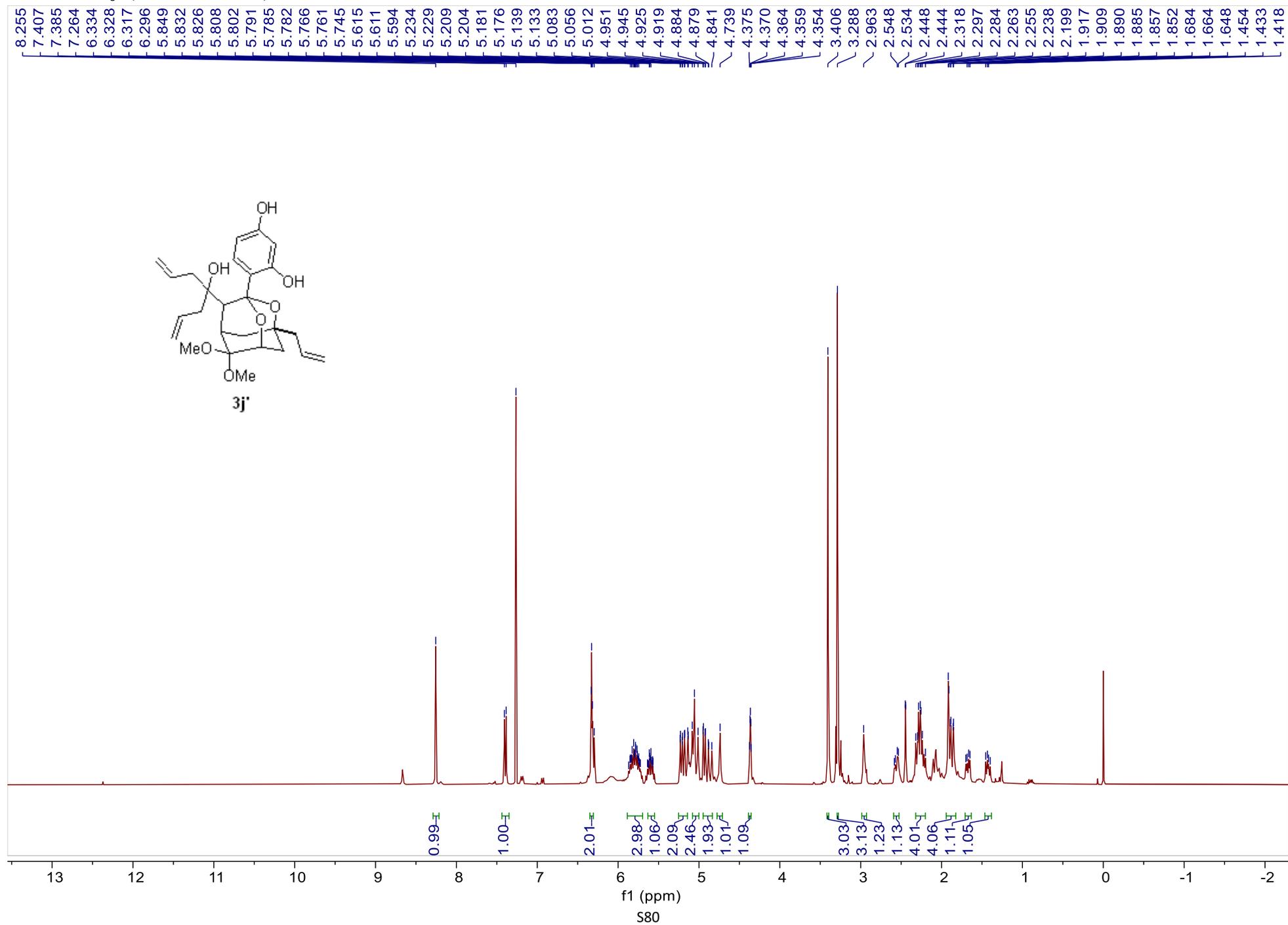
<sup>1</sup>H NMR of **3j'** (400 MHz, acetone-d<sub>6</sub>)



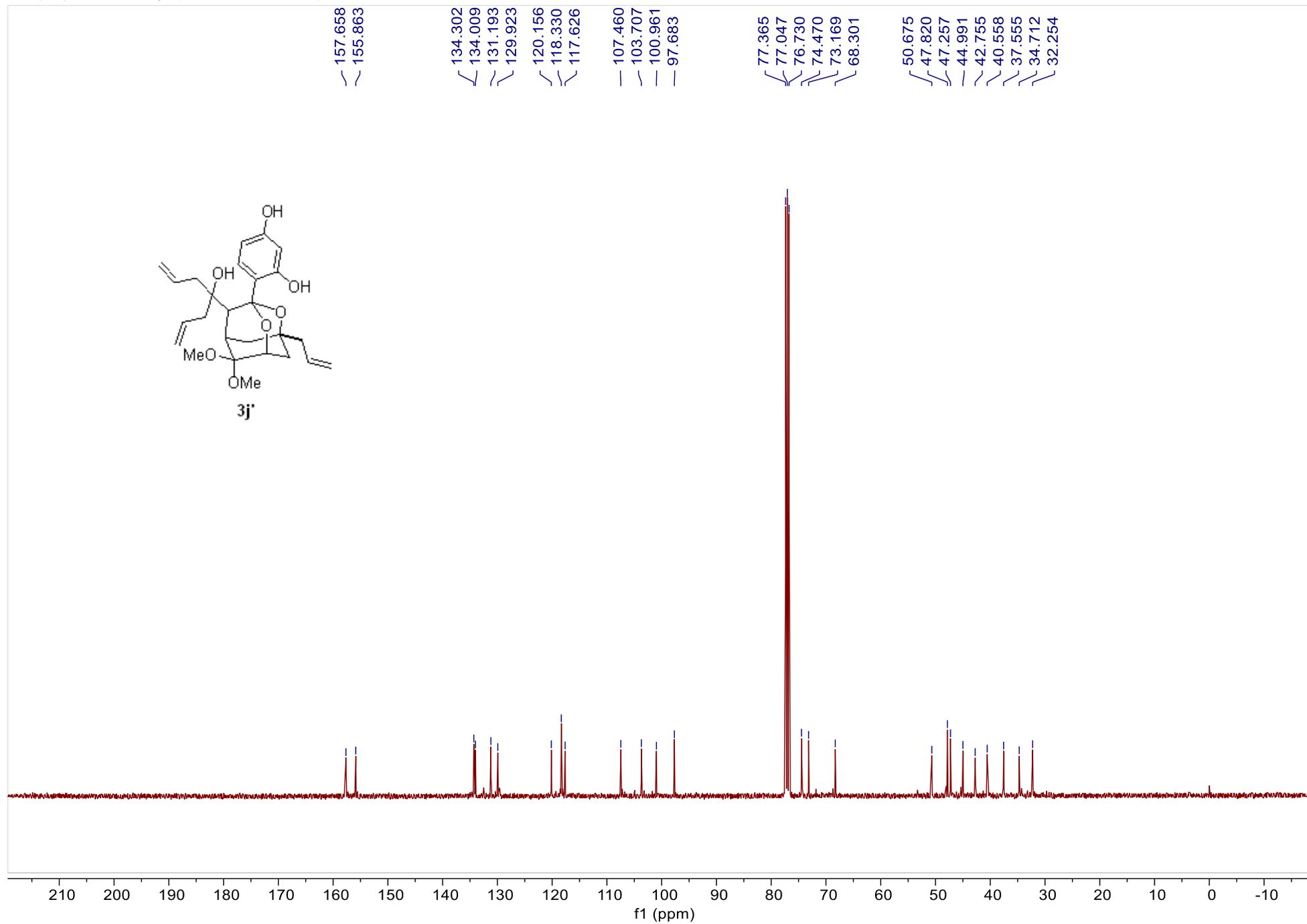
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3j'** (101 MHz, acetone- $d_6$ )



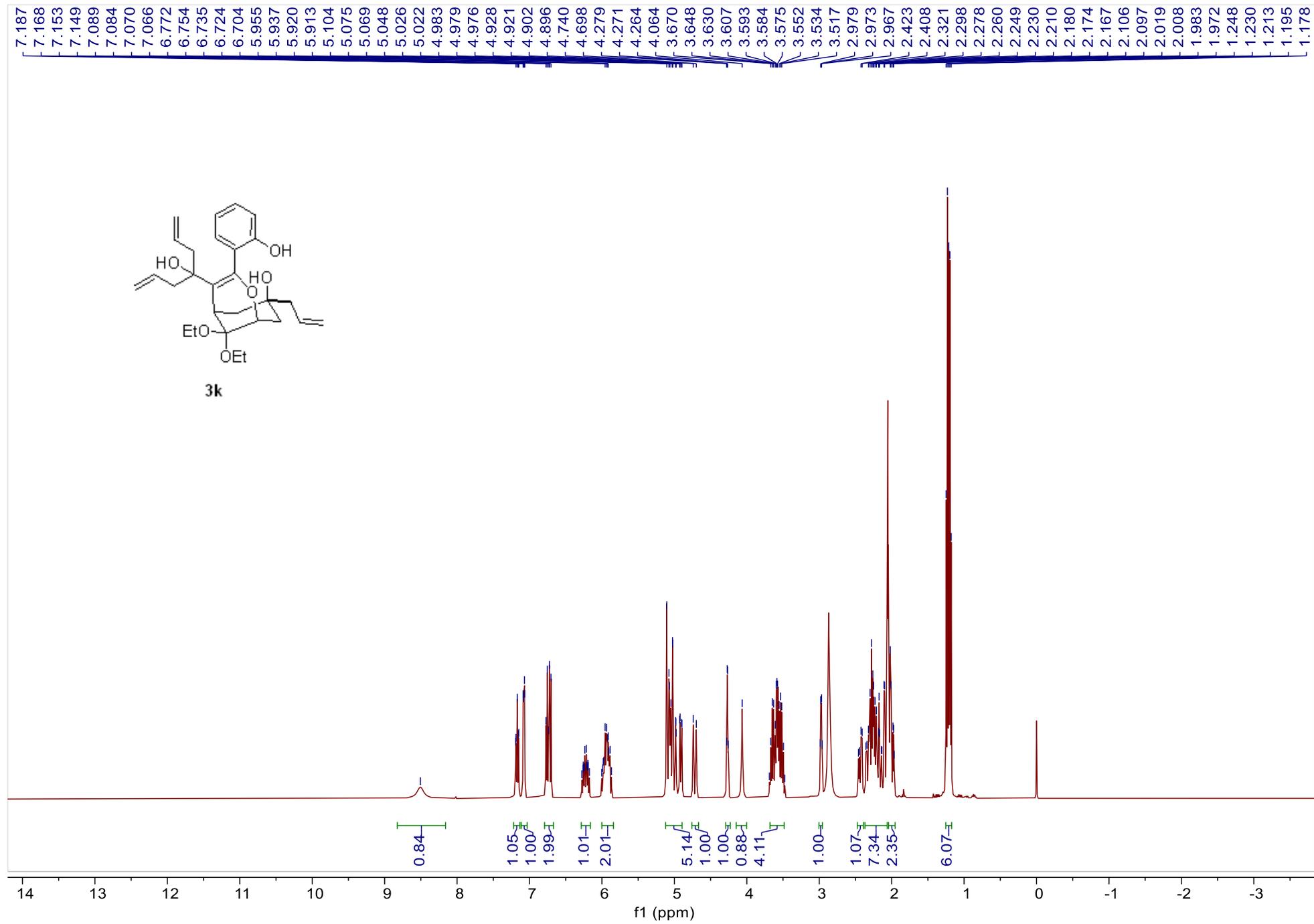
<sup>1</sup>H NMR of **3j'** (400MHz, CDCl<sub>3</sub>)



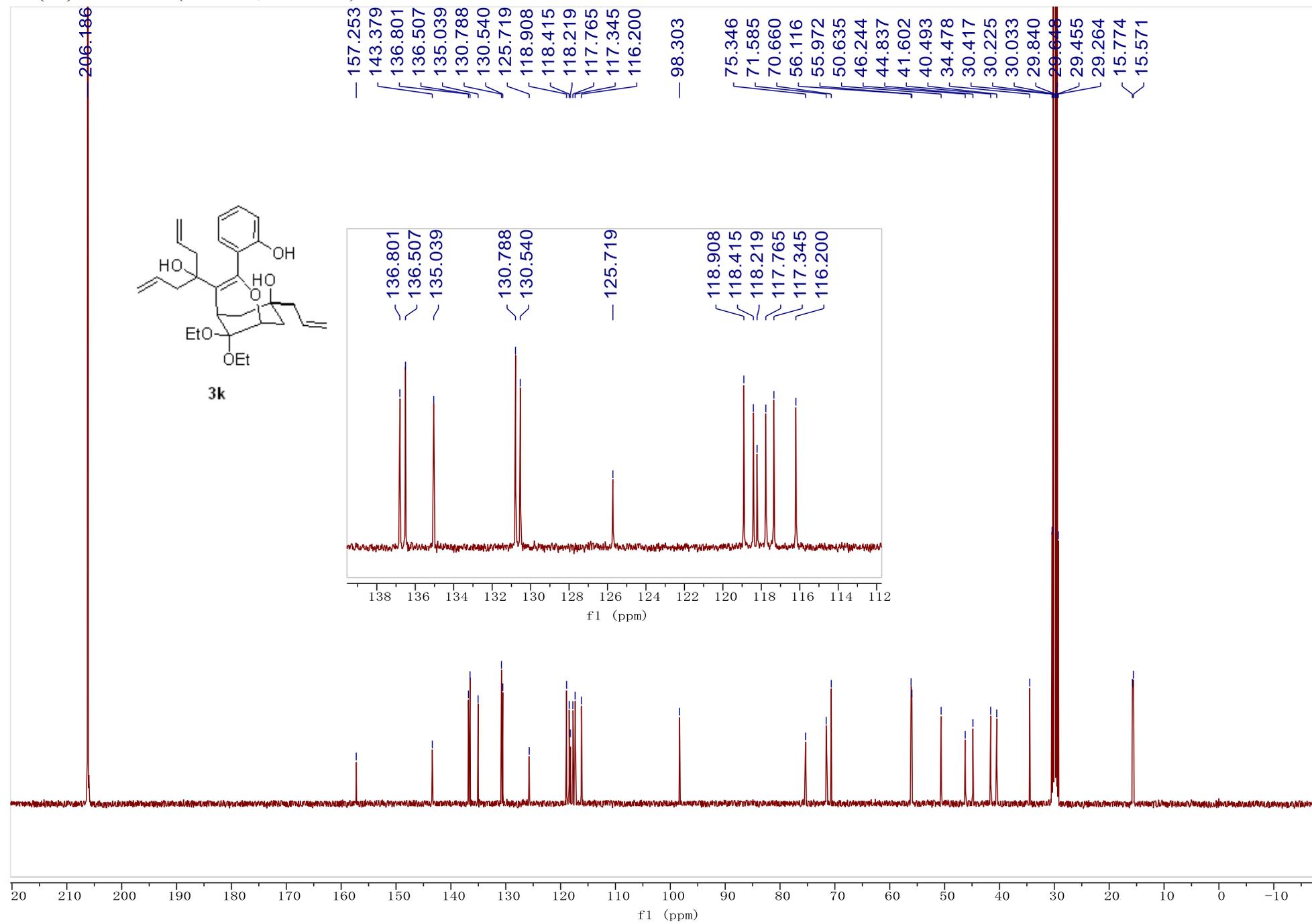
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3j'** (101 MHz,  $\text{CDCl}_3$ )



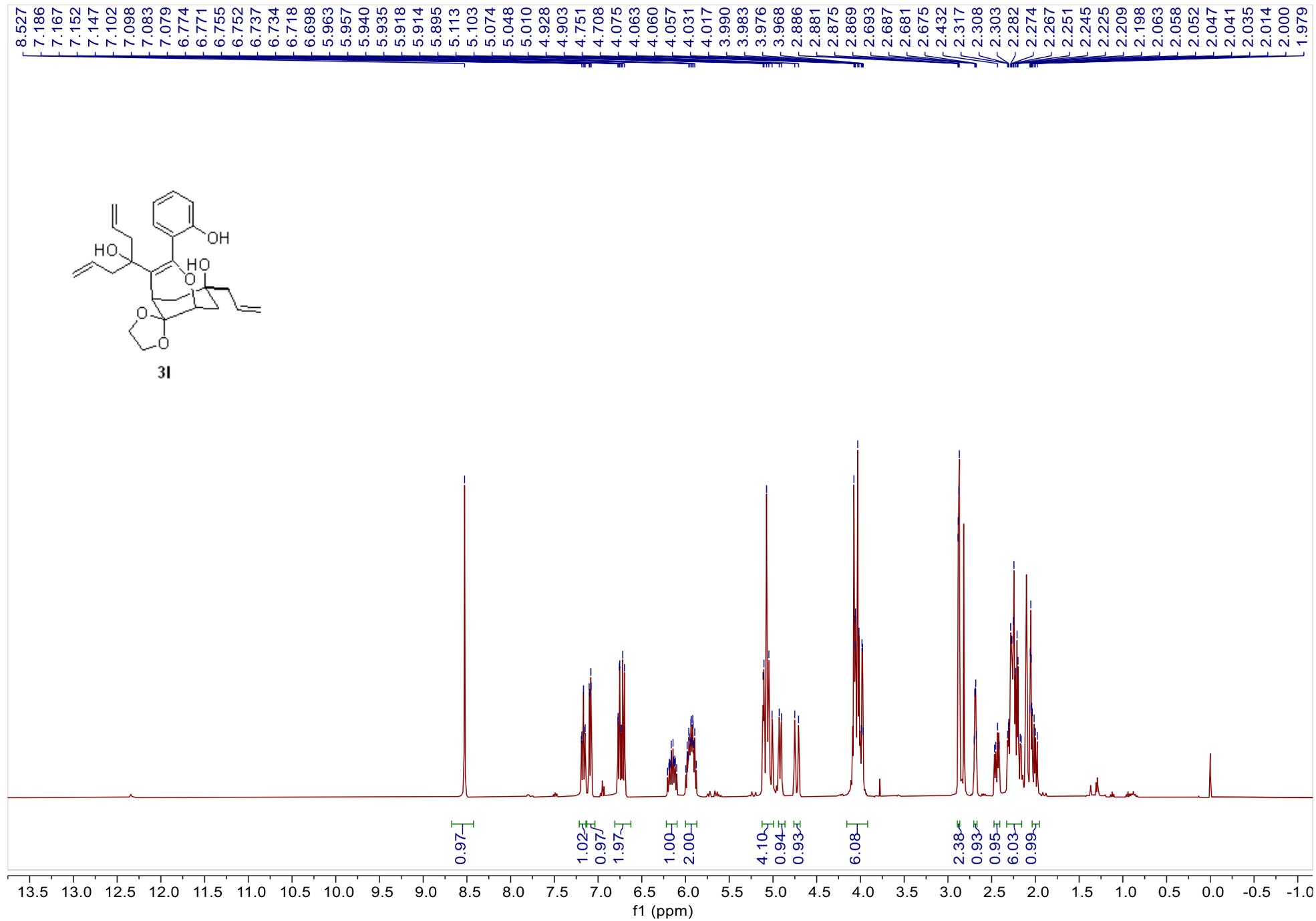
<sup>1</sup>H NMR of **3k** (400 MHz, acetone-d<sub>6</sub>)



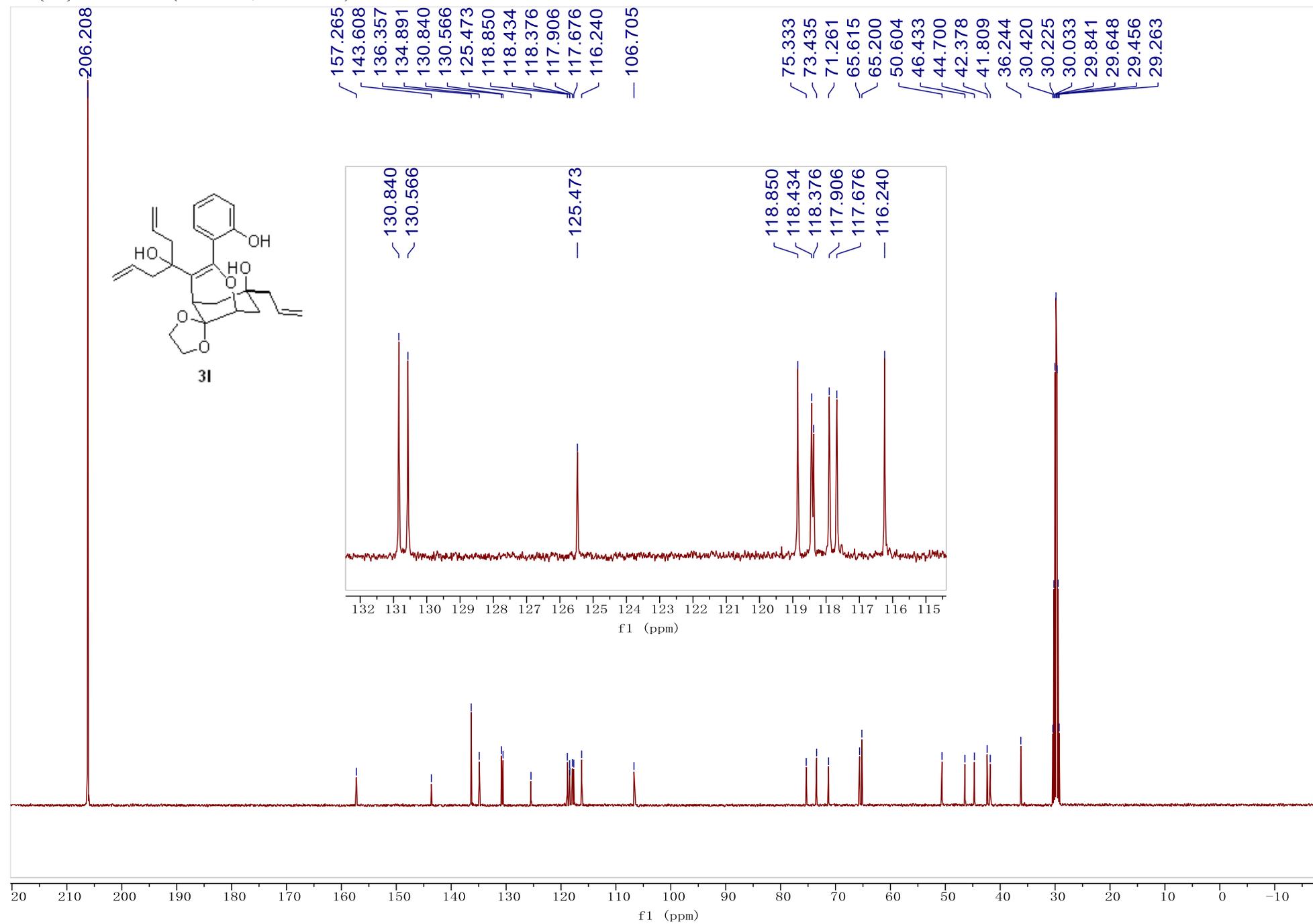
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3k** (101 MHz, acetone- $d_6$ )



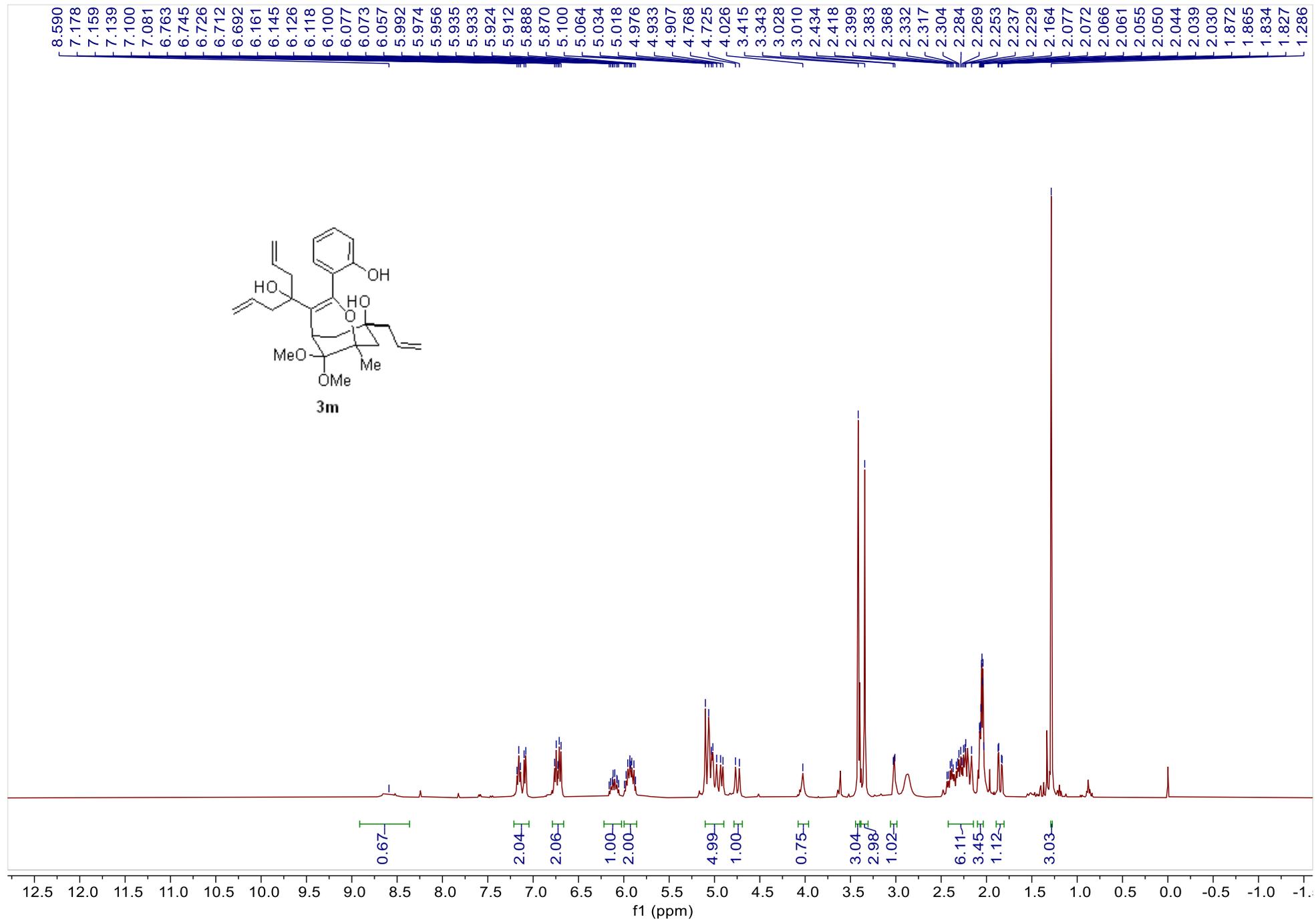
<sup>1</sup>H NMR of **31** (400 MHz, acetone-d<sub>6</sub>)



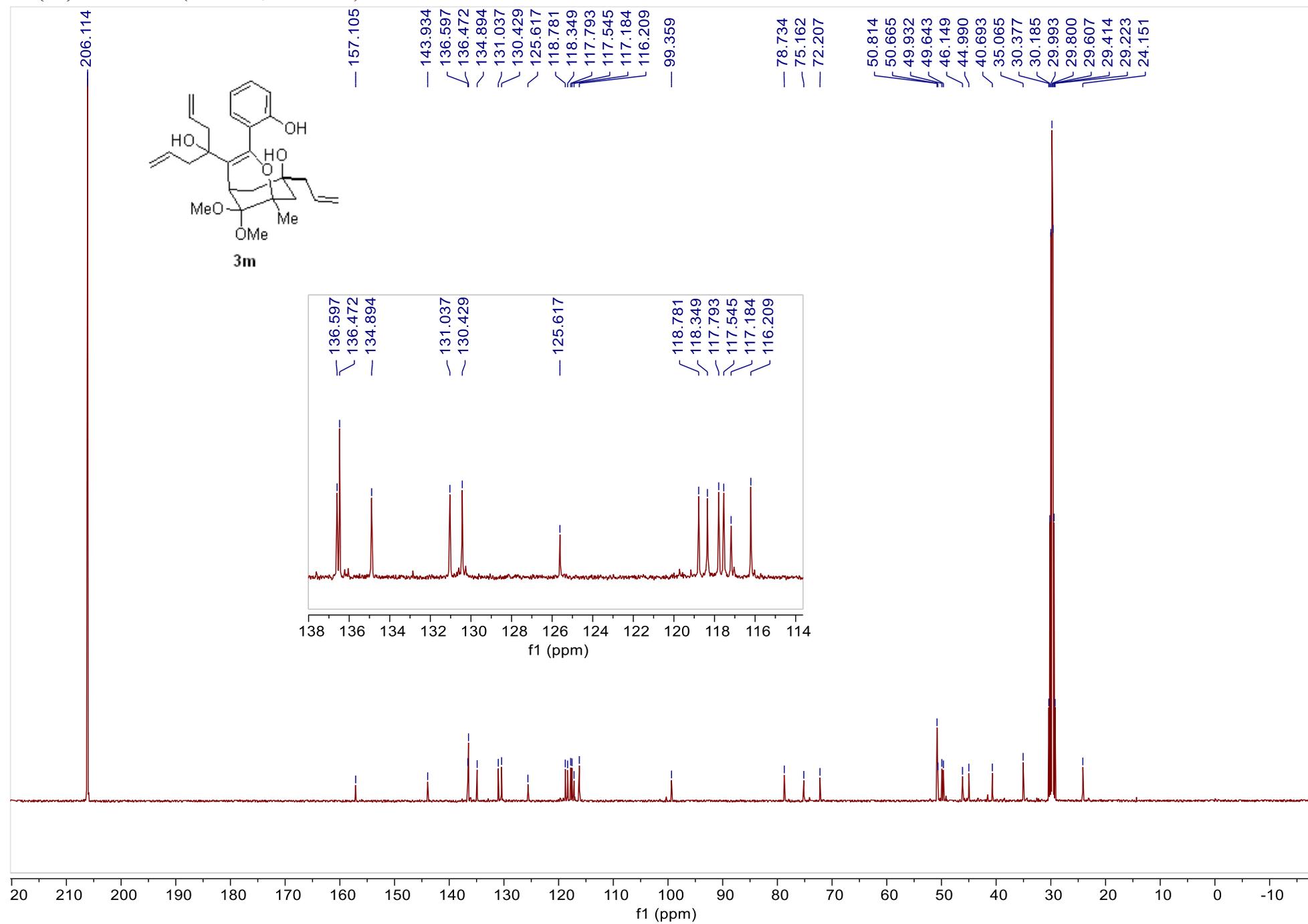
$^{13}\text{C}\{^1\text{H}\}$  NMR of **31** (101 MHz, acetone- $d_6$ )



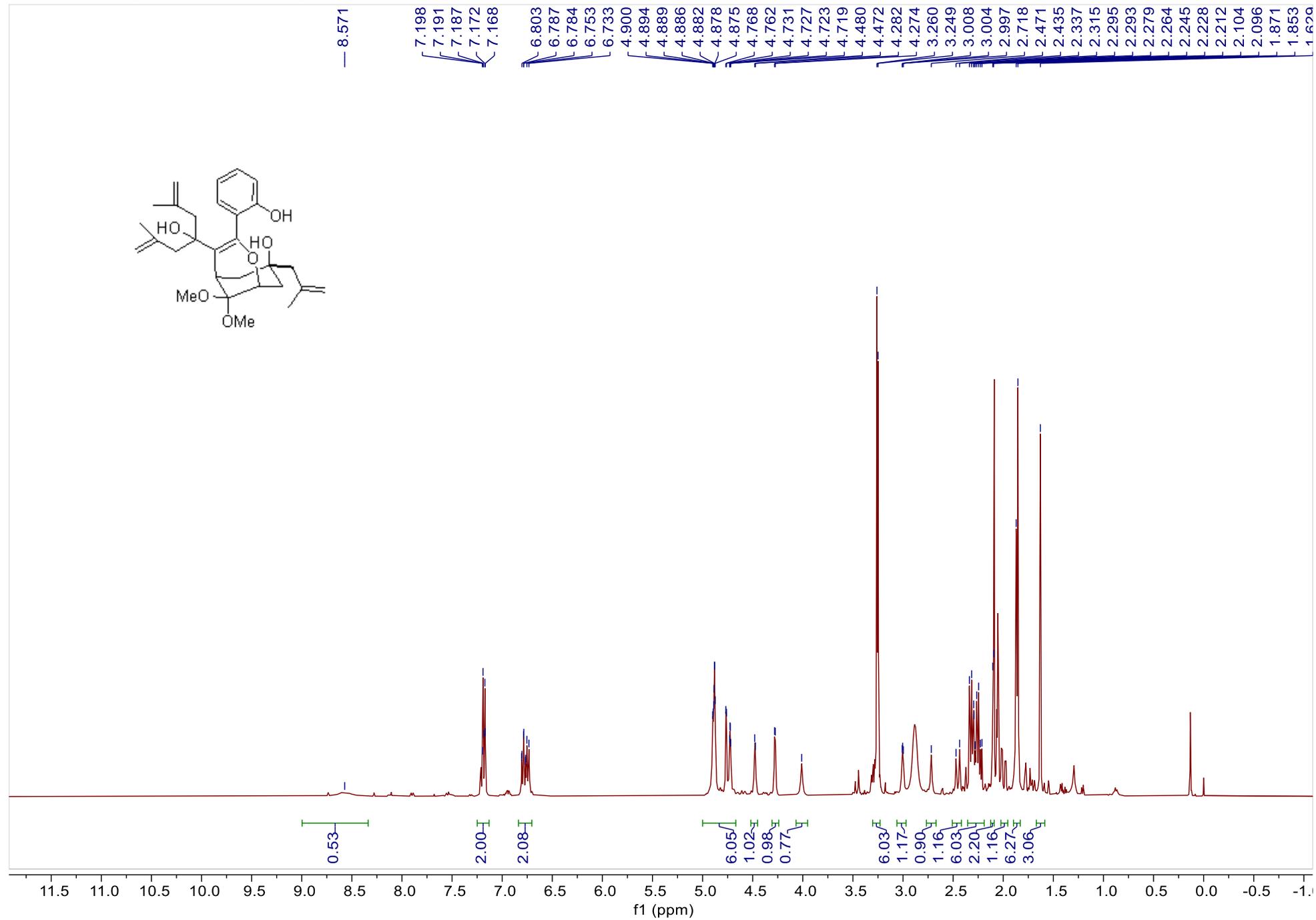
<sup>1</sup>H NMR of **3m** (400 MHz, acetone-d<sub>6</sub>)



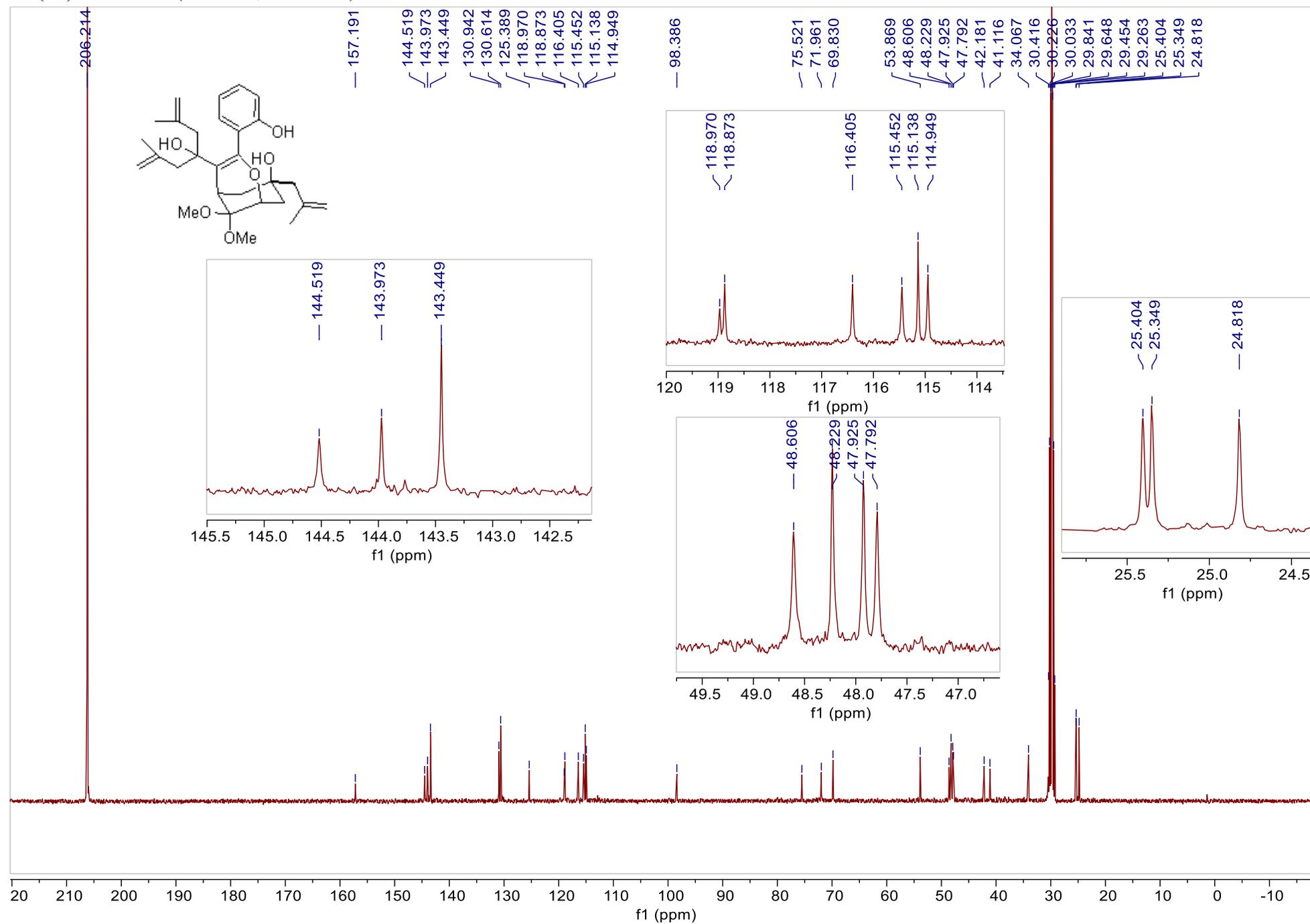
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3m** (101 MHz, acetone- $d_6$ )



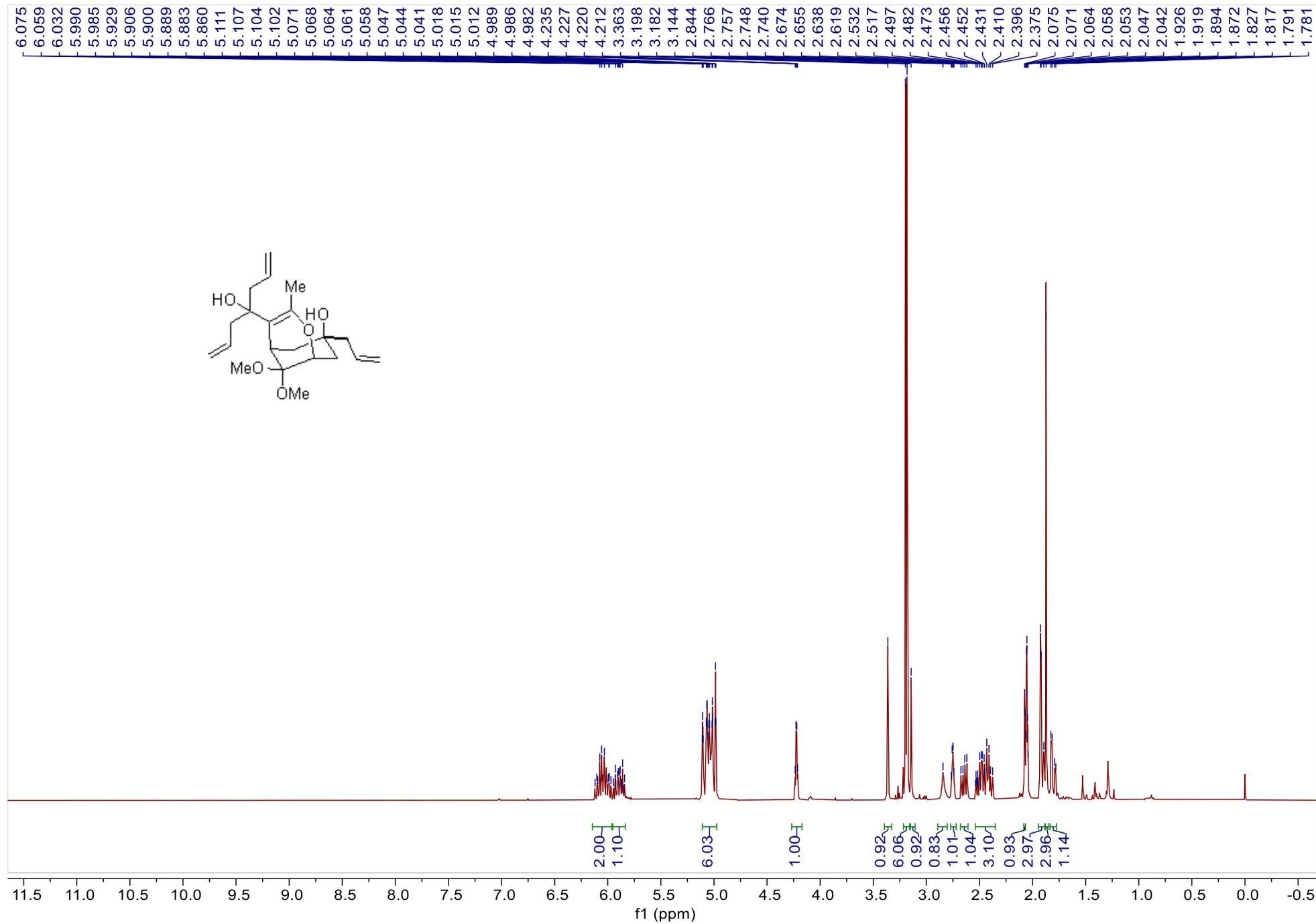
<sup>1</sup>H NMR of **3n** (400 MHz, acetone-d<sub>6</sub>)



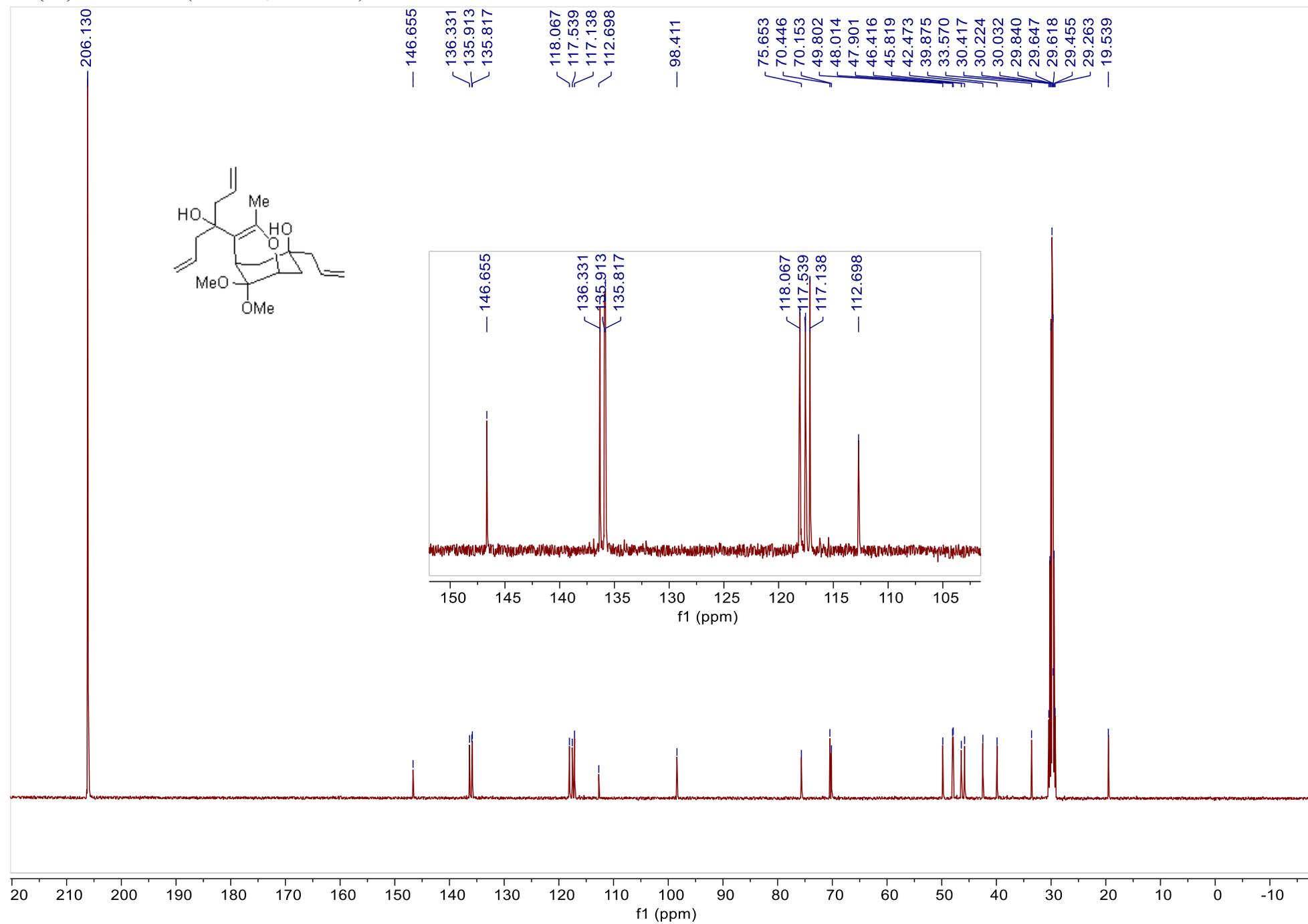
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3n** (101 MHz, acetone- $d_6$ )



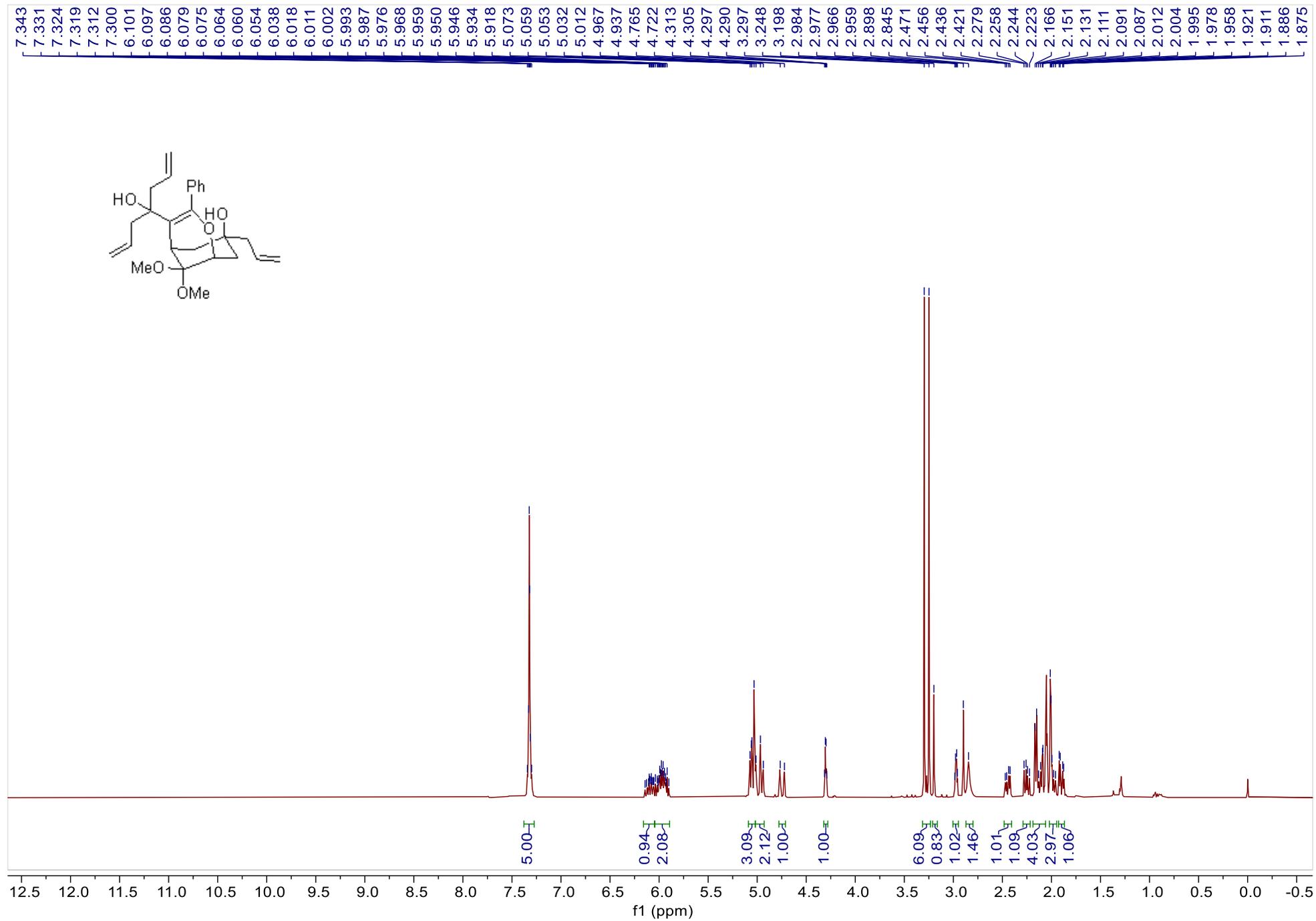
<sup>1</sup>H NMR of **3na** (400 MHz, acetone-d<sub>6</sub>)



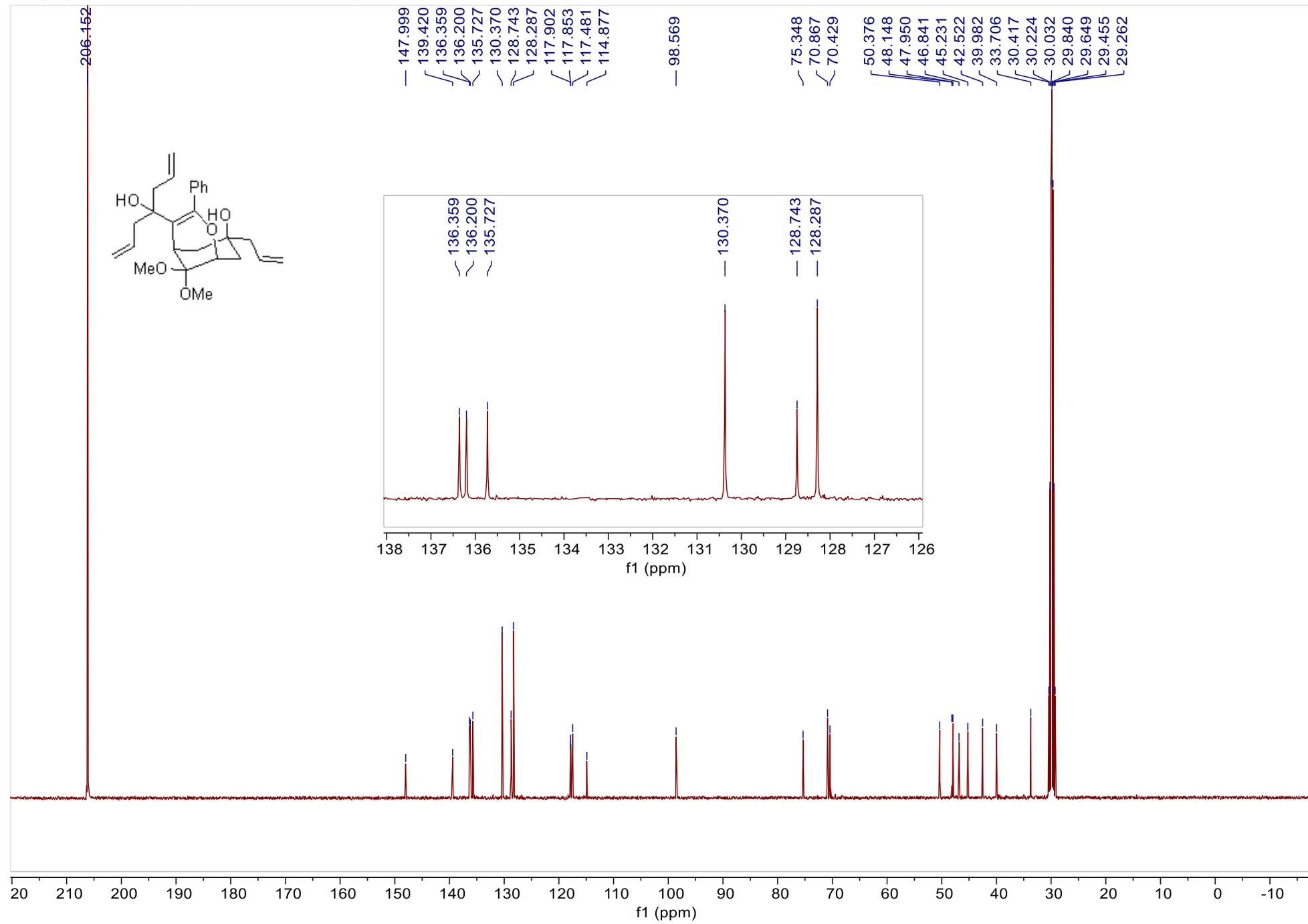
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3na** (101 MHz, acetone- $\text{d}_6$ )



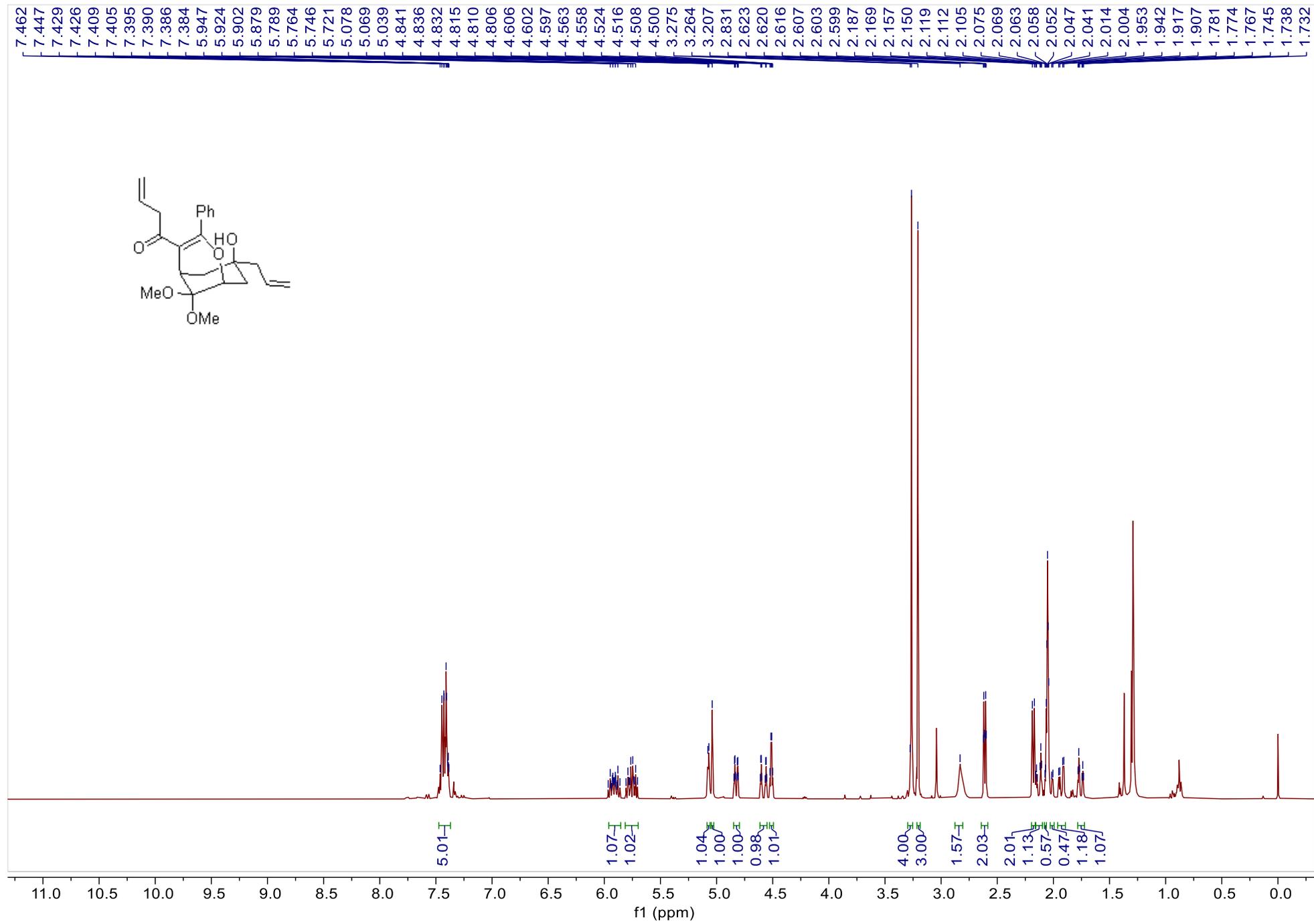
<sup>1</sup>H NMR of **30a** (400 MHz, acetone-d<sub>6</sub>)



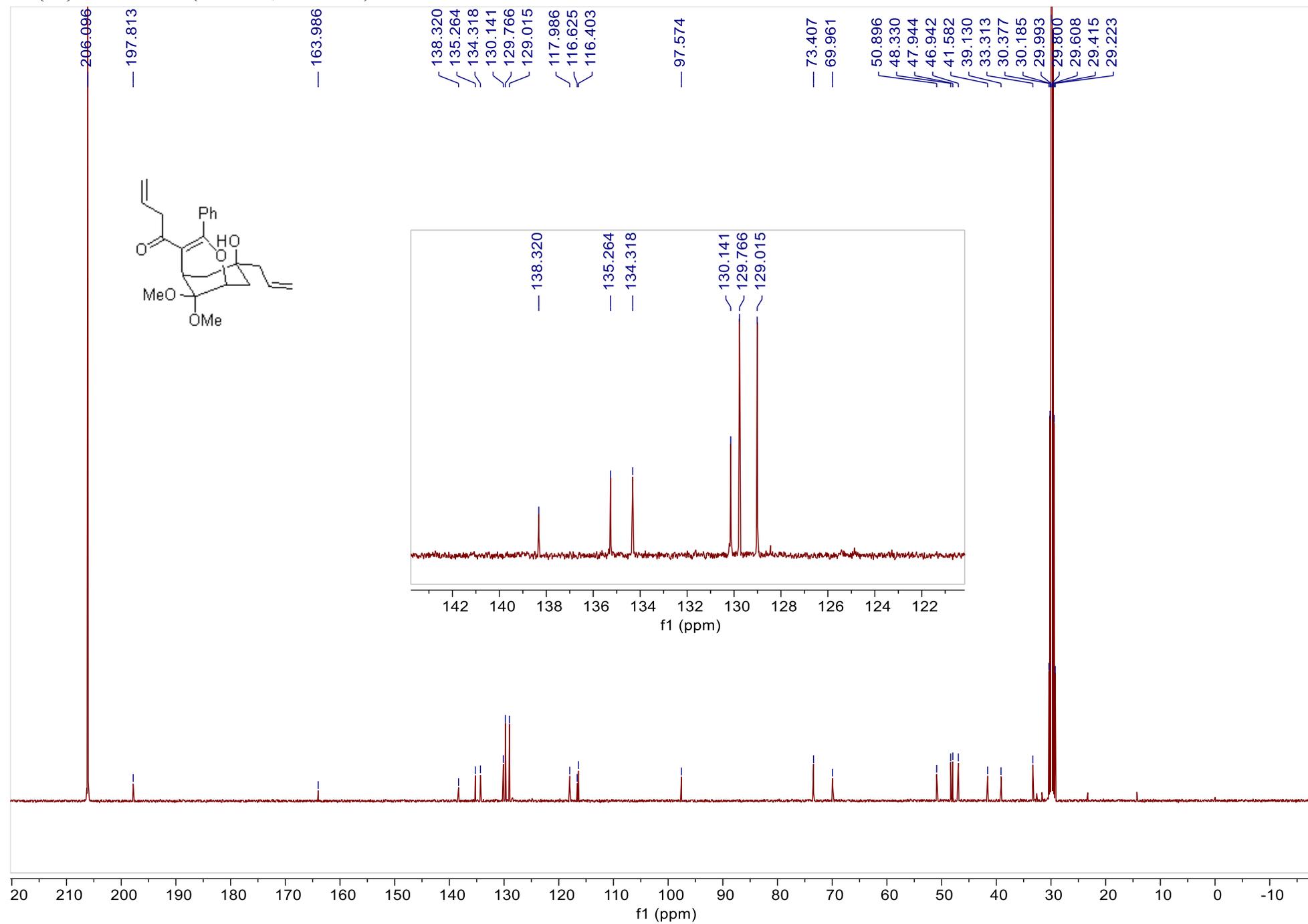
$^{13}\text{C}\{^1\text{H}\}$  NMR of **30a** (101 MHz, acetone- $d_6$ )



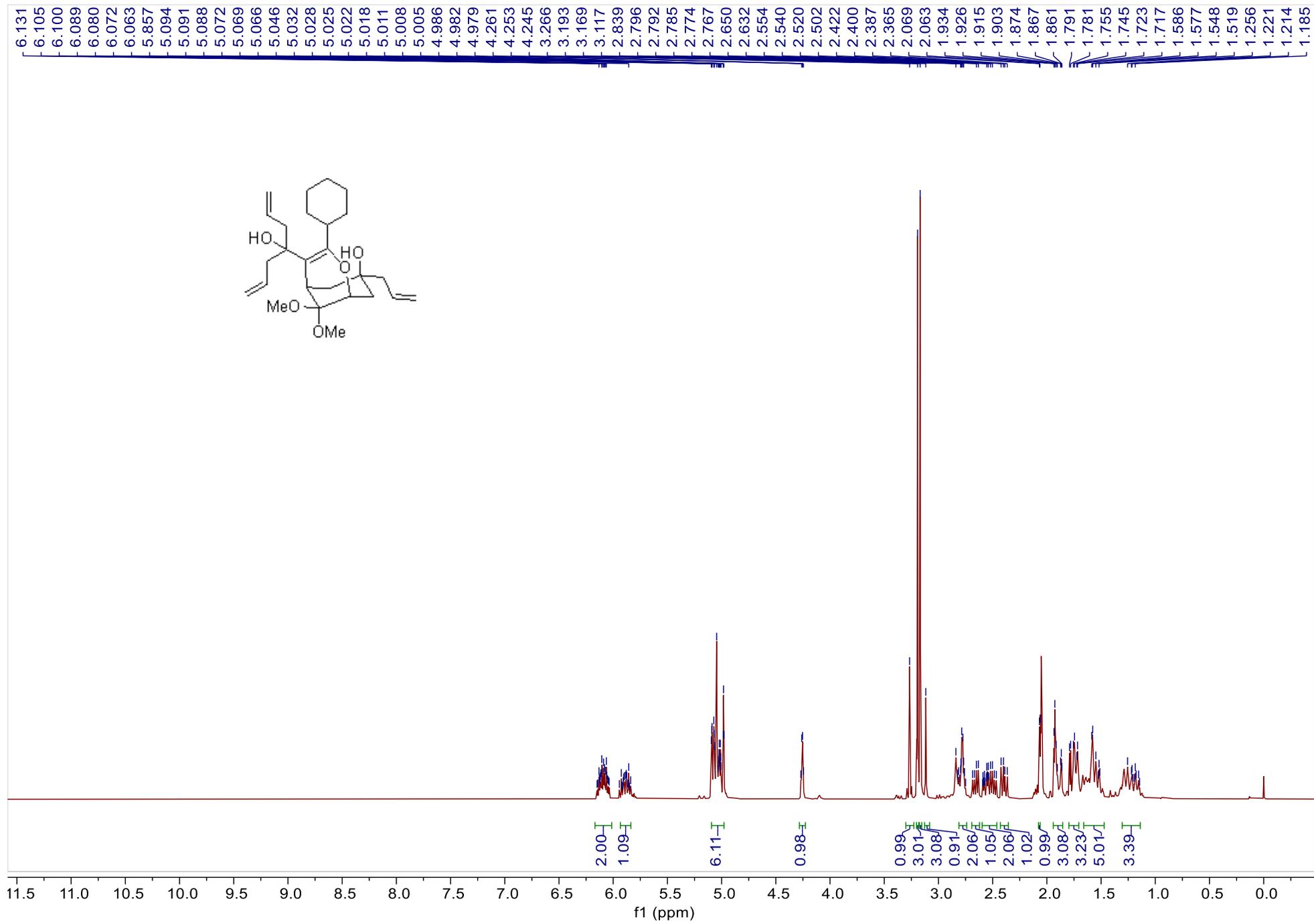
<sup>1</sup>H NMR of **30a'** (400 MHz, acetone-d<sub>6</sub>)



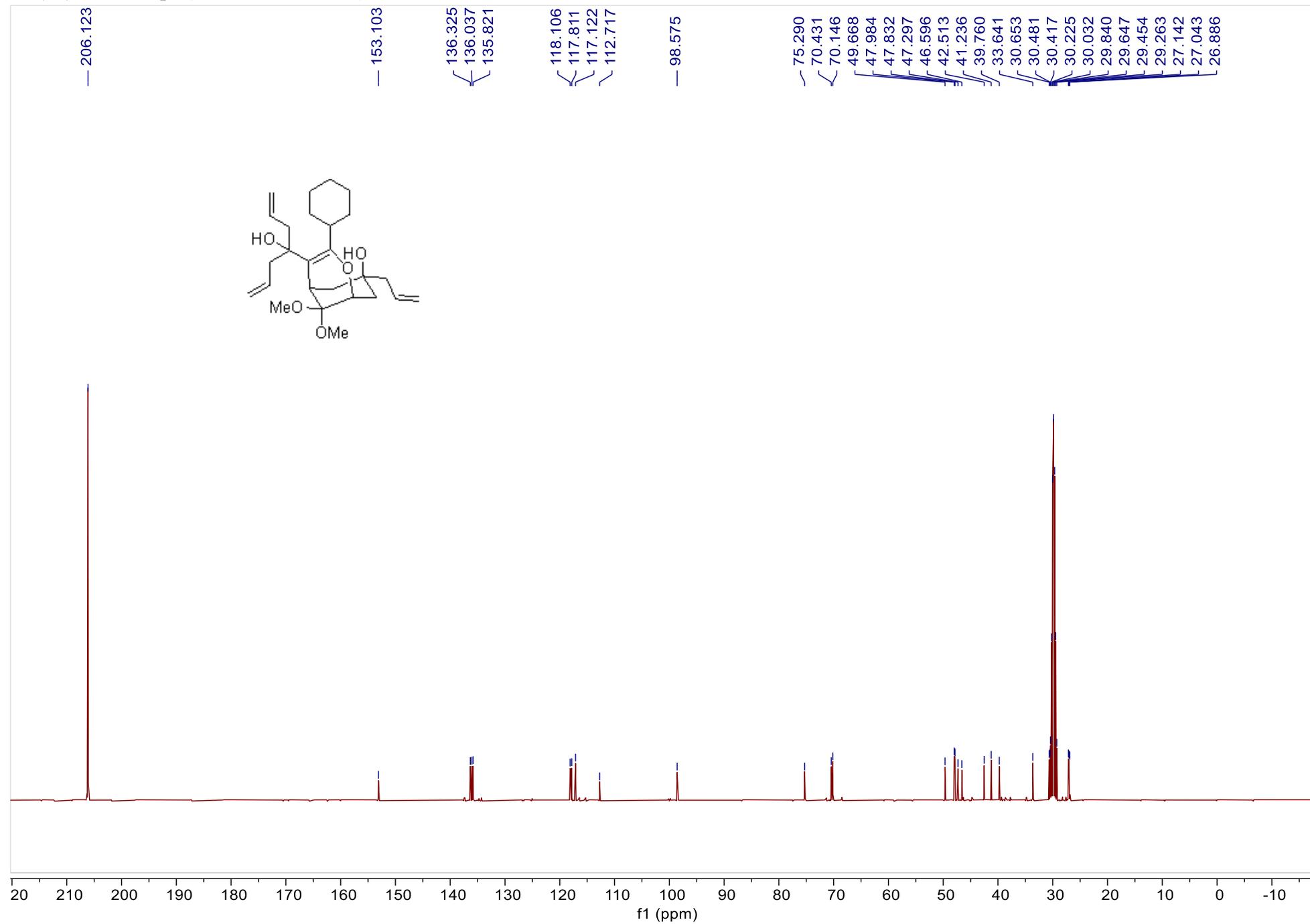
$^{13}\text{C}\{^1\text{H}\}$  NMR of **30a'** (101 MHz, acetone- $\text{d}_6$ )



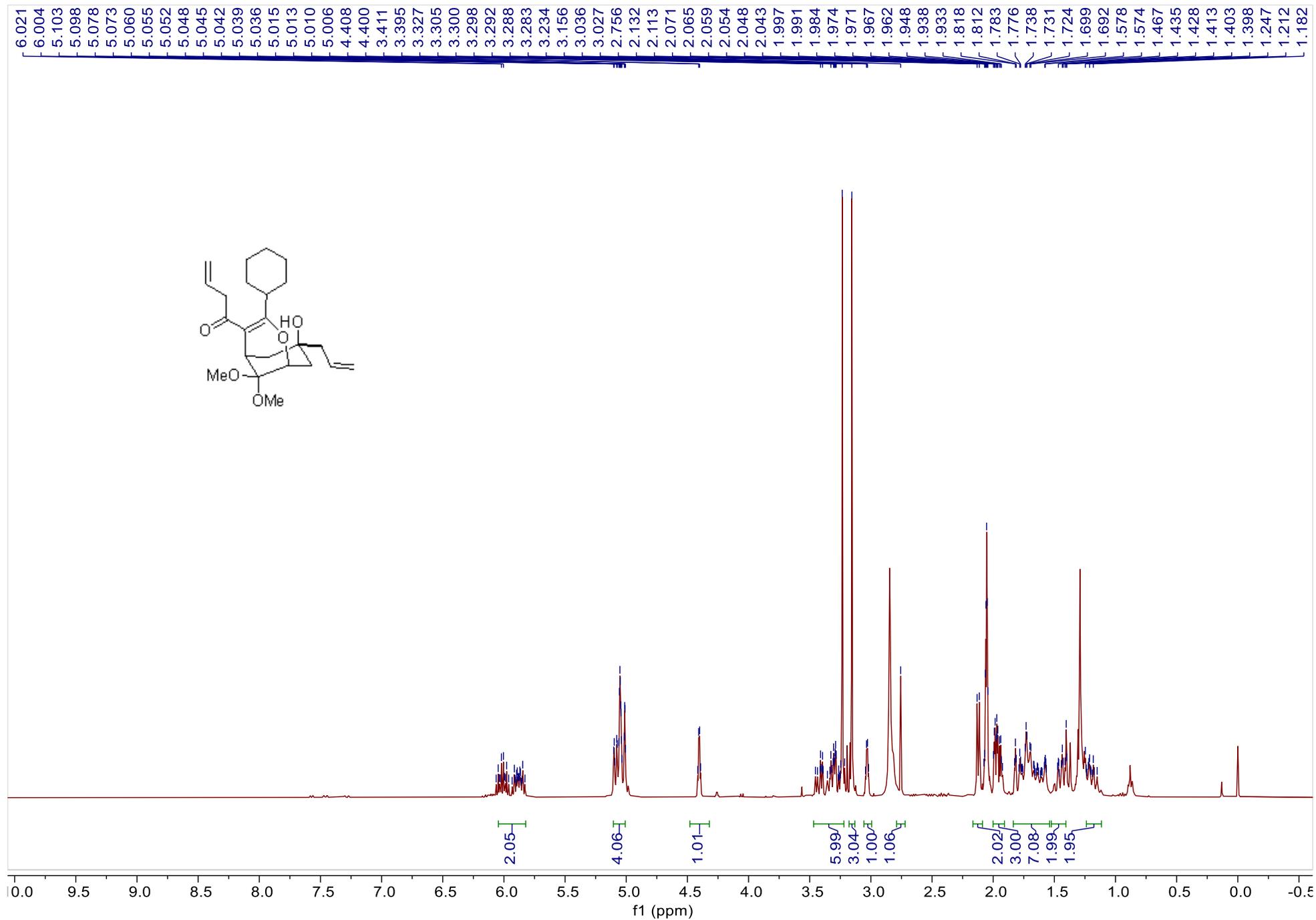
<sup>1</sup>H NMR of **3pa** (400 MHz, acetone-d<sub>6</sub>)



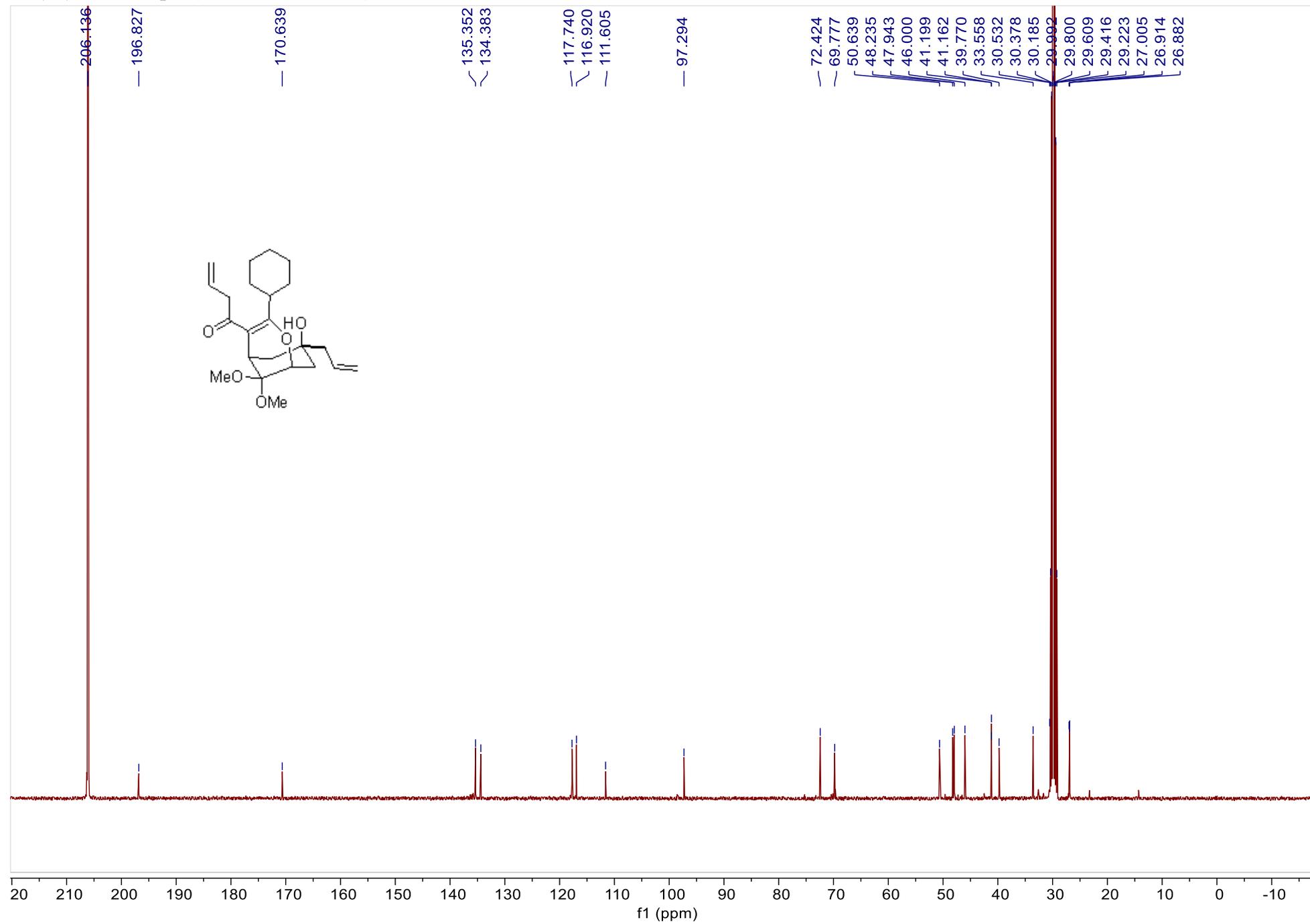
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3pa** (101 MHz, acetone- $\text{d}_6$ )



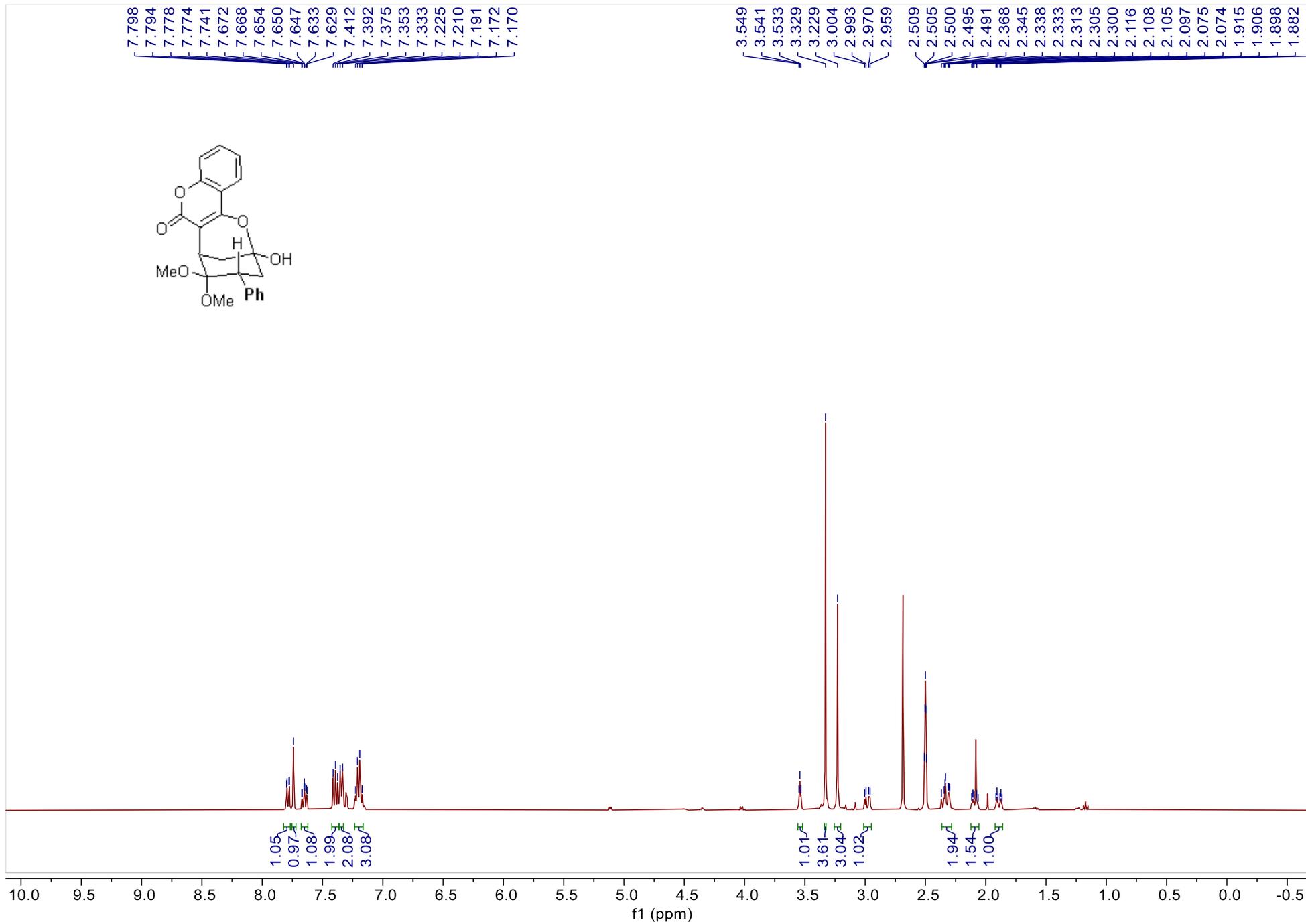
<sup>1</sup>H NMR of **3pa'** (400MHz, acetone-d<sub>6</sub>)



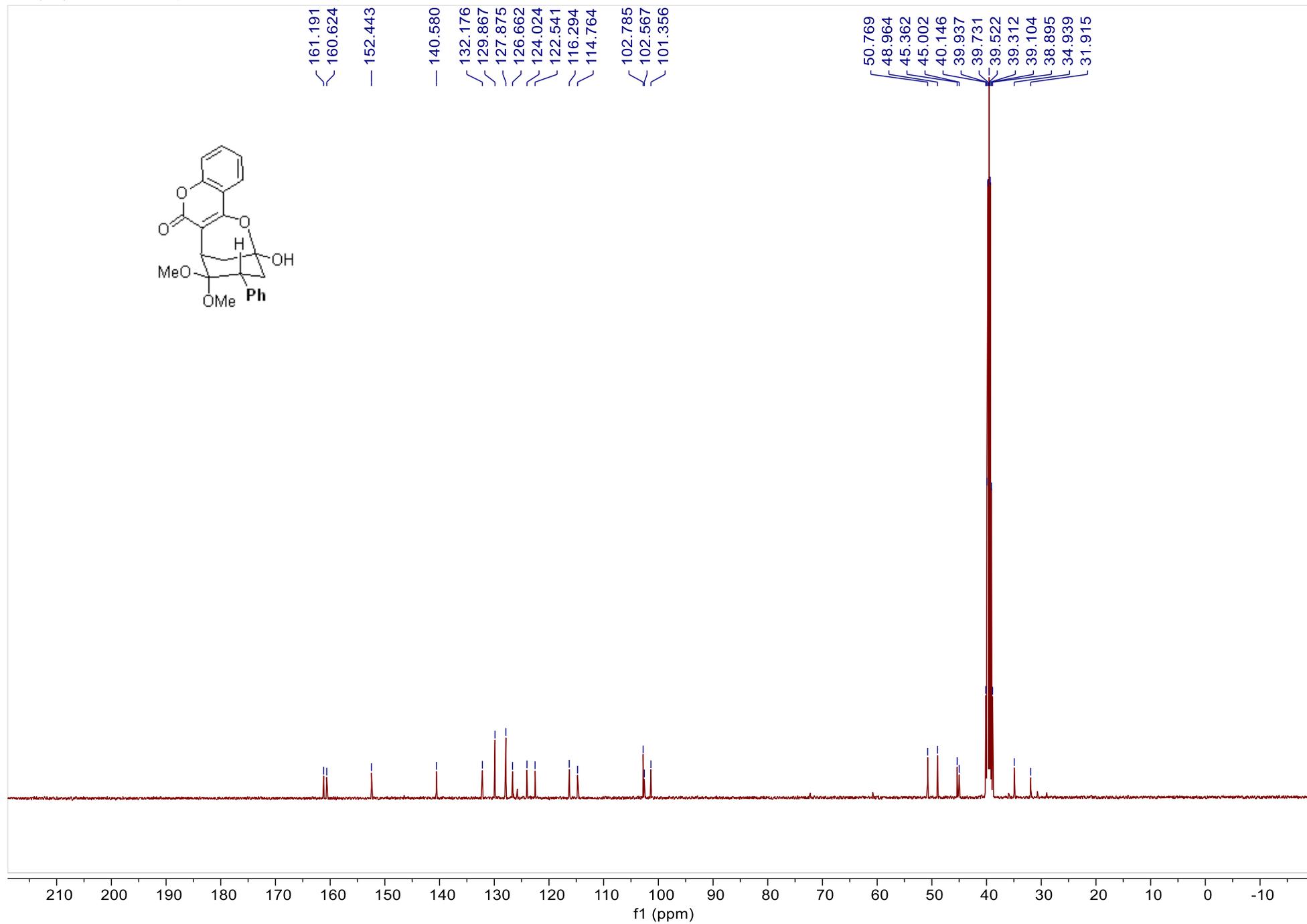
$^{13}\text{C}\{^1\text{H}\}$  NMR of **3pa'** (101 MHz, acetone- $\text{d}_6$ )



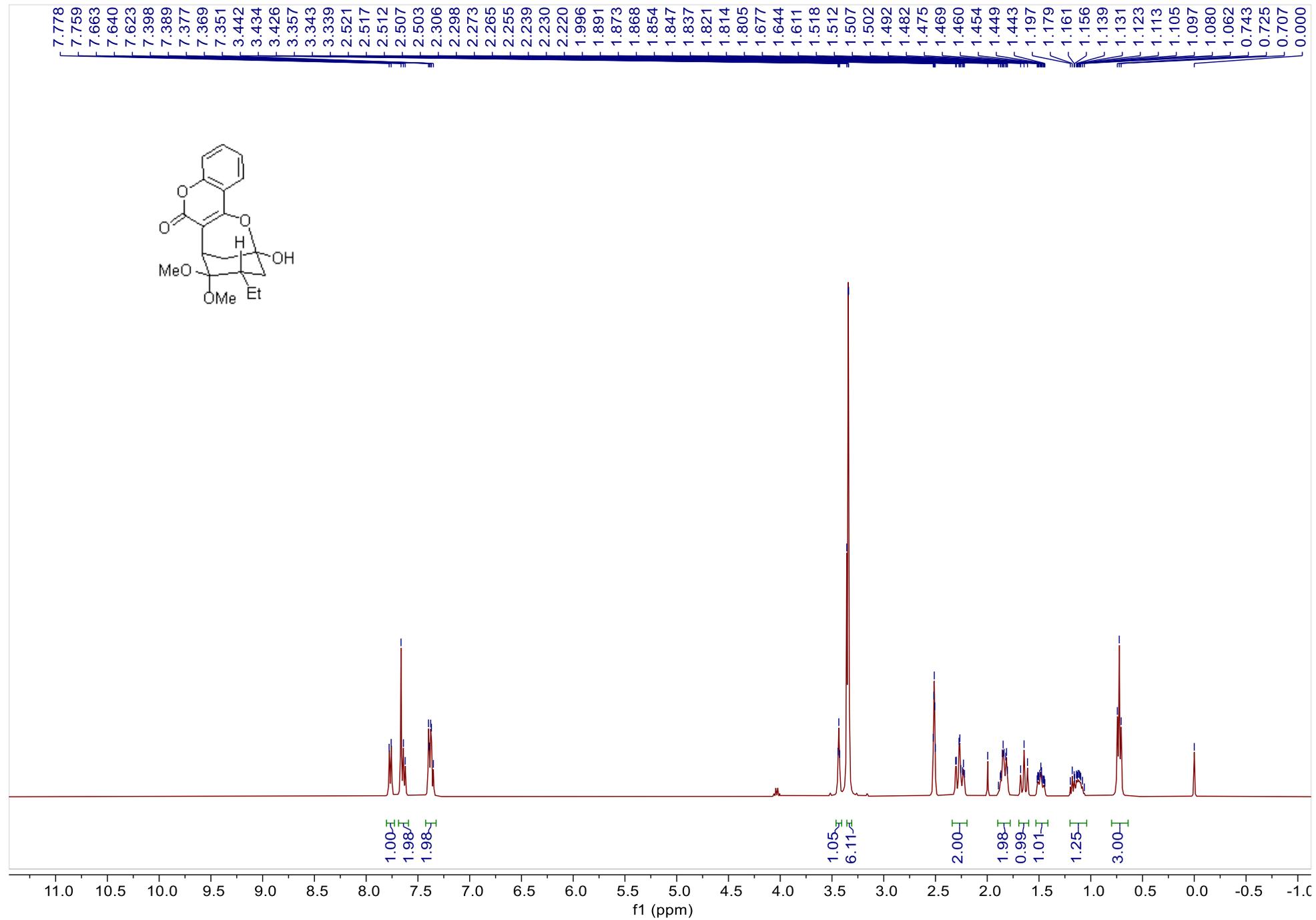
<sup>1</sup>H NMR of **4a** (400 MHz, DMSO-d<sub>6</sub>)



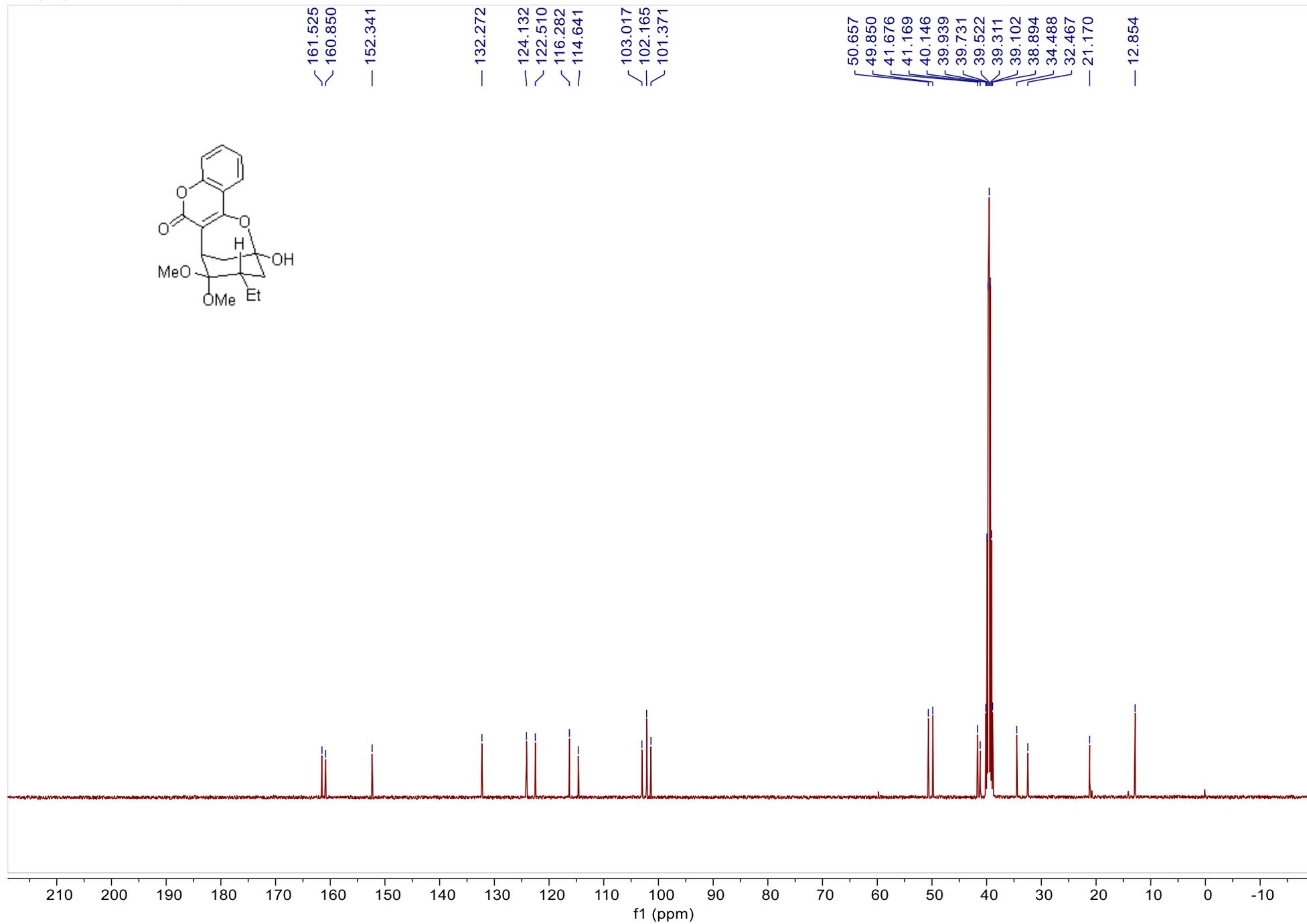
$^{13}\text{C}\{^1\text{H}\}$  NMR of **4a** (101MHz, DMSO- $d_6$ )



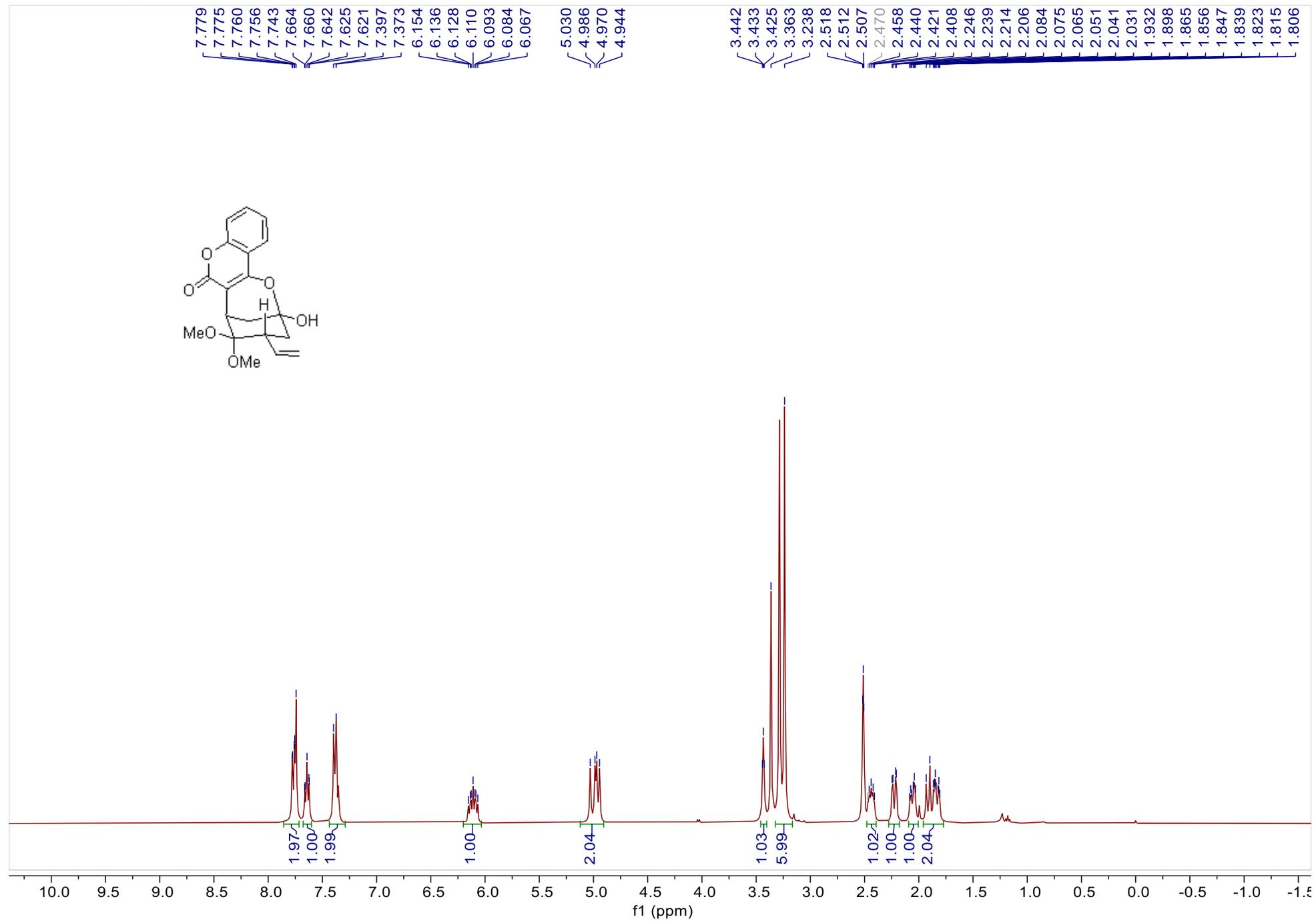
<sup>1</sup>H NMR of **4b** (400 MHz, DMSO-d<sub>6</sub>)



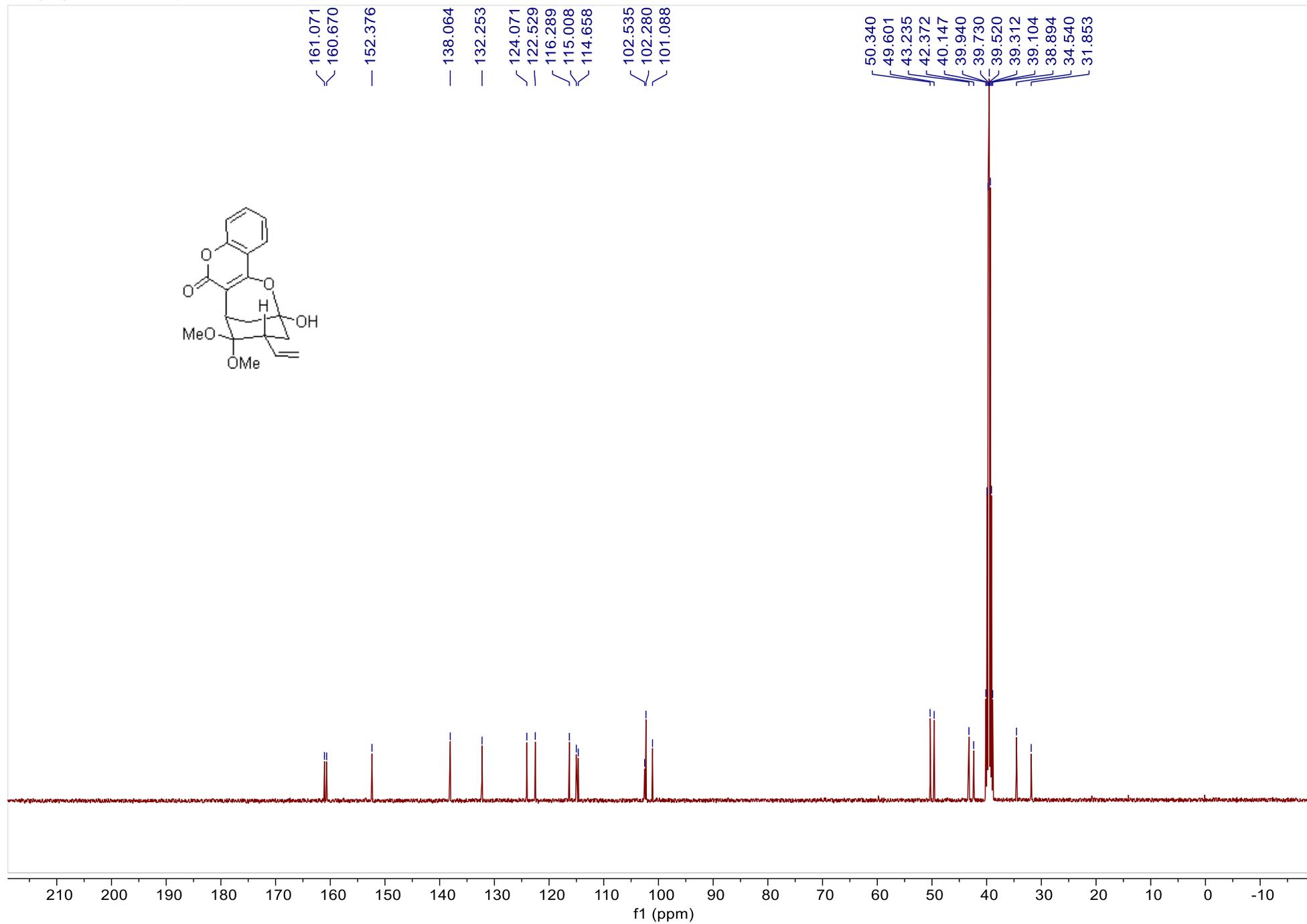
$^{13}\text{C}\{^1\text{H}\}$  NMR of **4b** (101MHz, DMSO- $d_6$ )



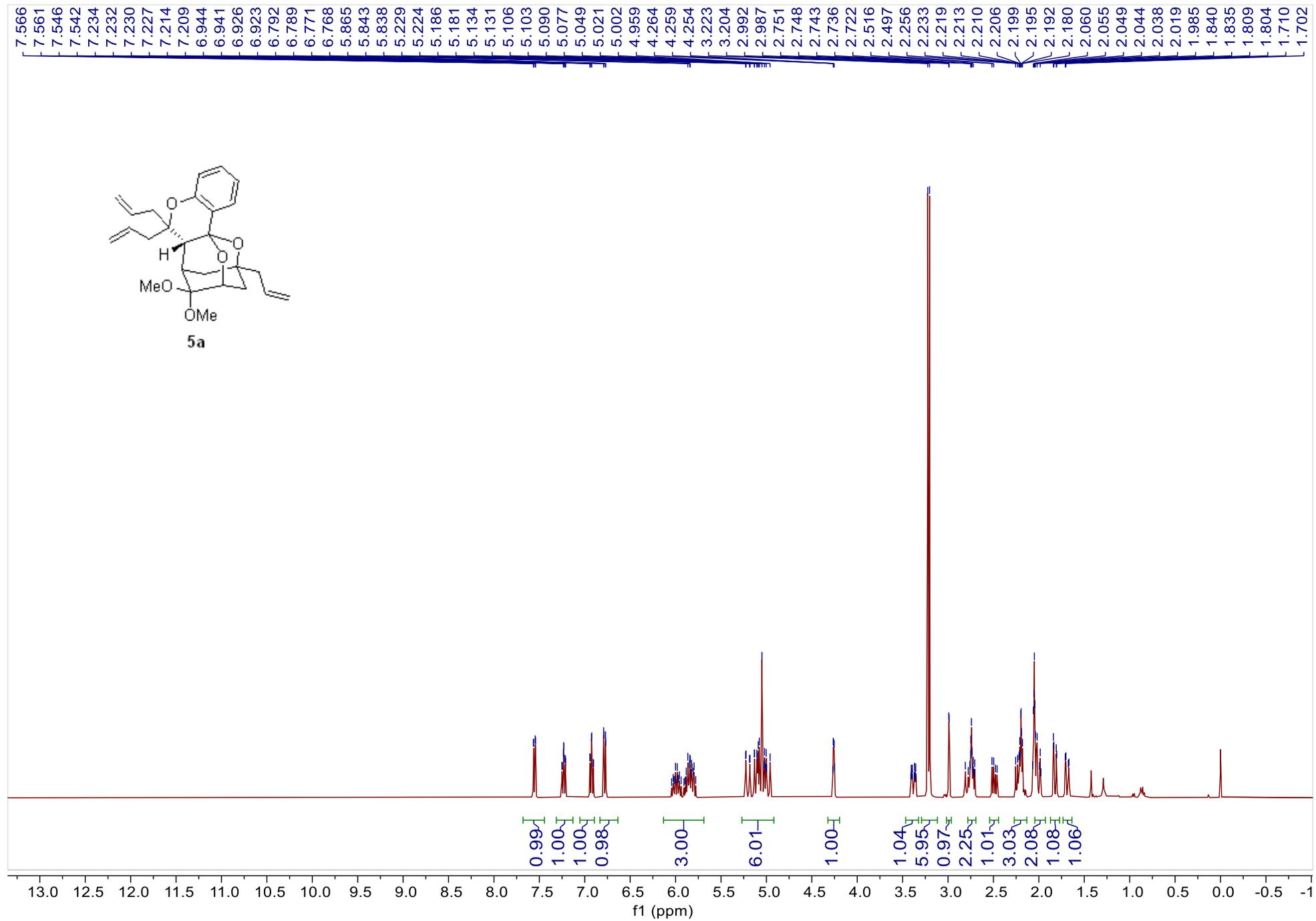
<sup>1</sup>H NMR of 4c (400 MHz, DMSO-d<sub>6</sub>)



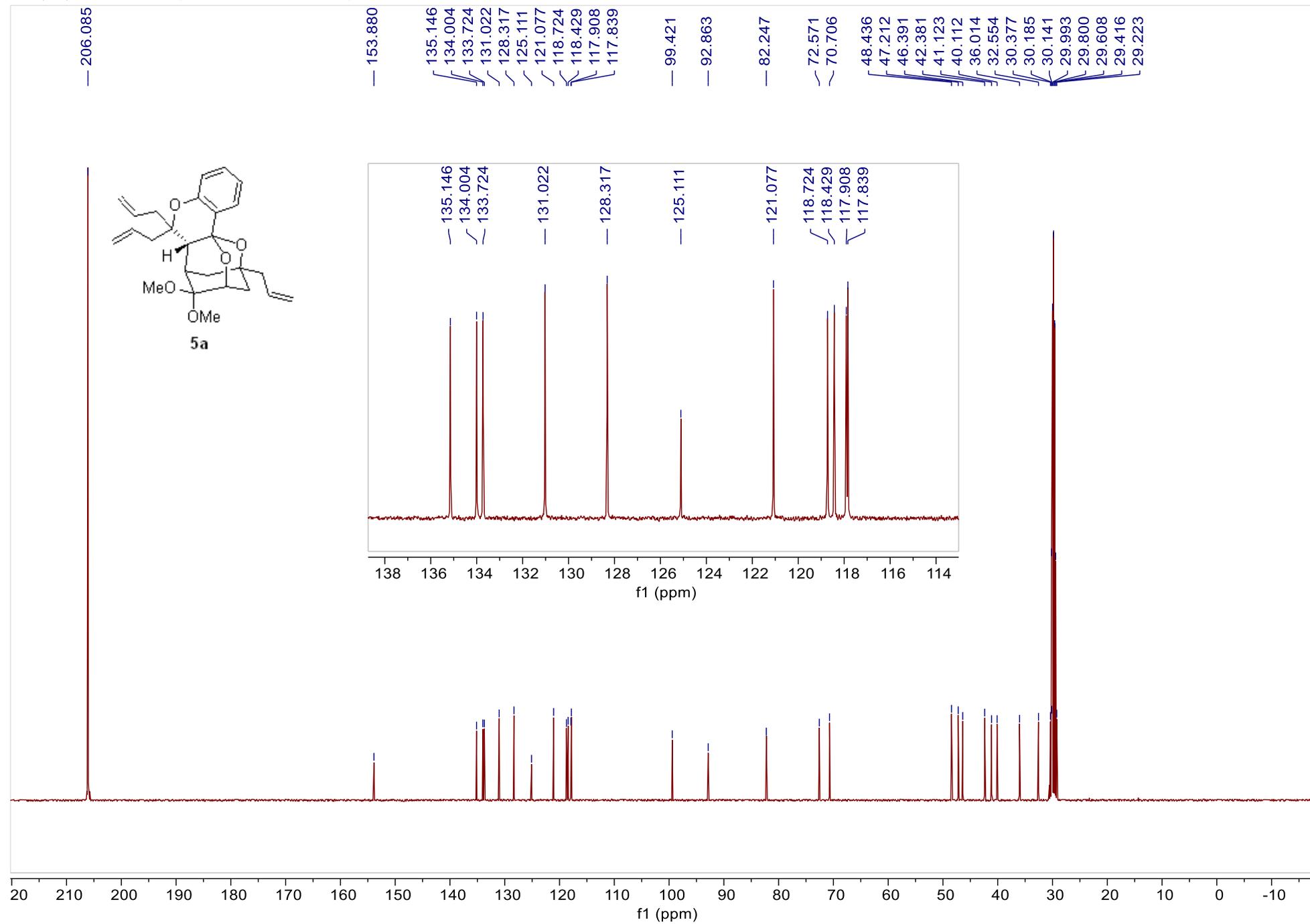
$^{13}\text{C}\{^1\text{H}\}$  NMR of **4c** (101MHz, DMSO- $d_6$ )



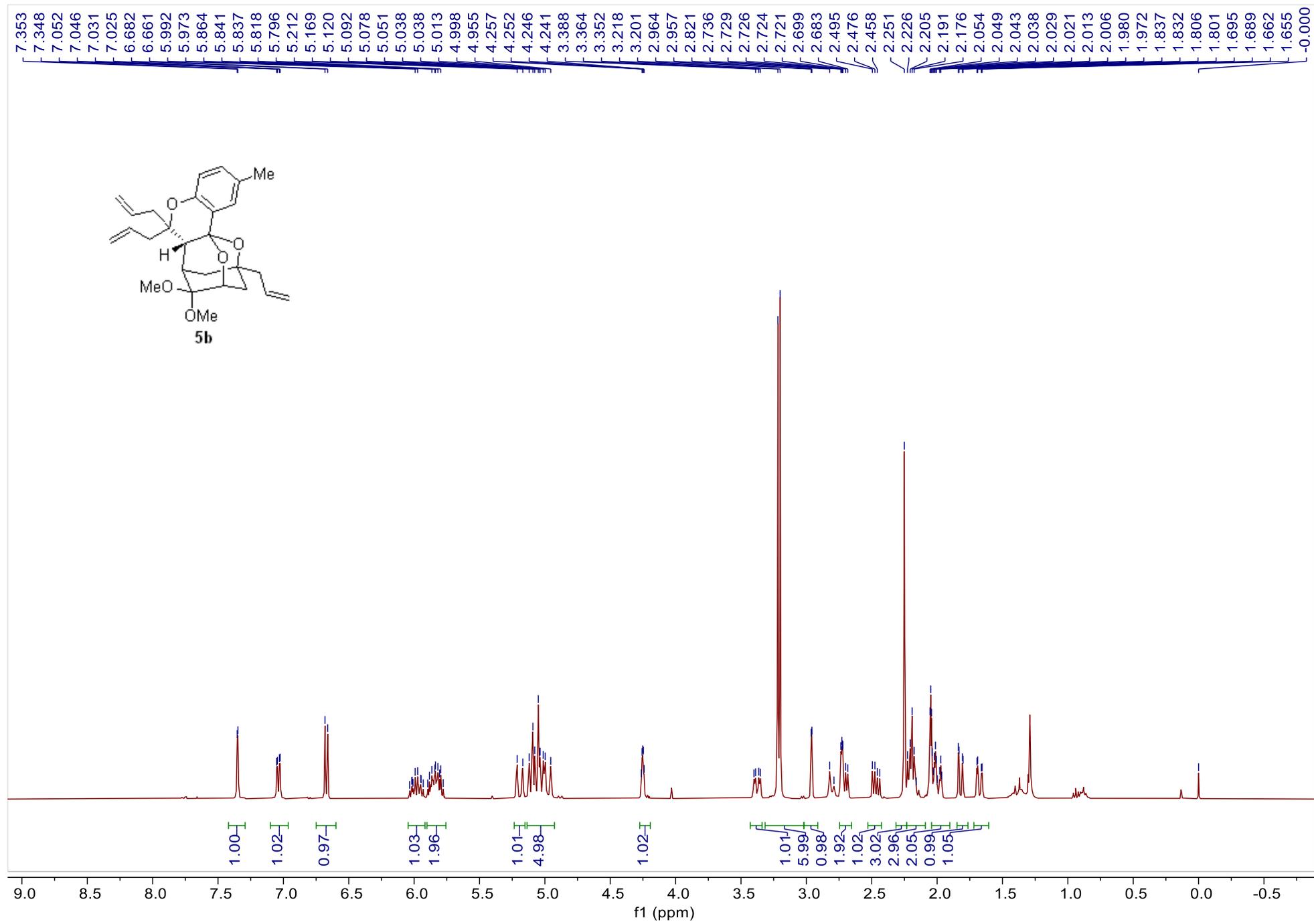
<sup>1</sup>H NMR of **5a** (400MHz, acetone-d<sub>6</sub>)



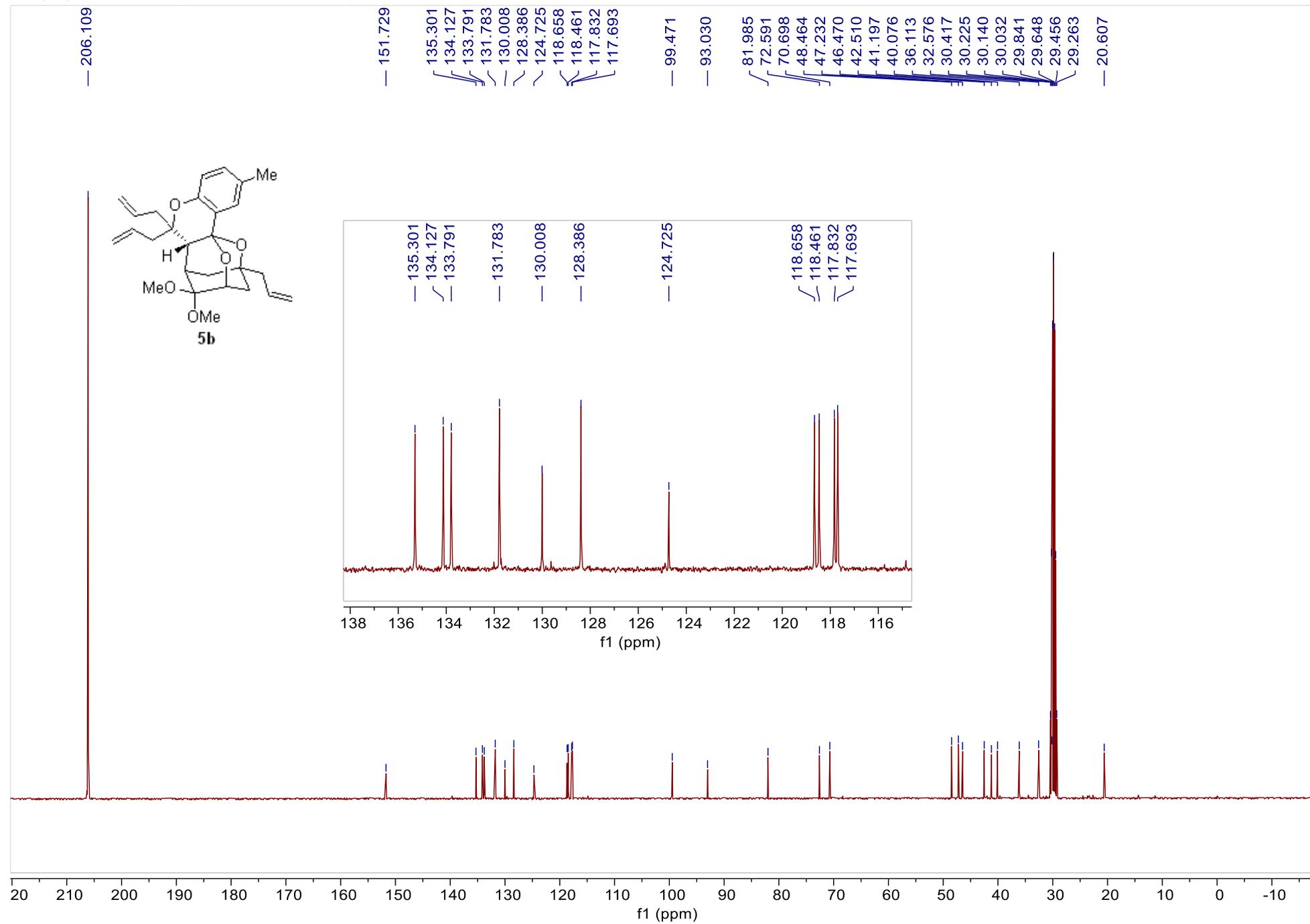
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5a** (101 MHz, acetone- $d_6$ )



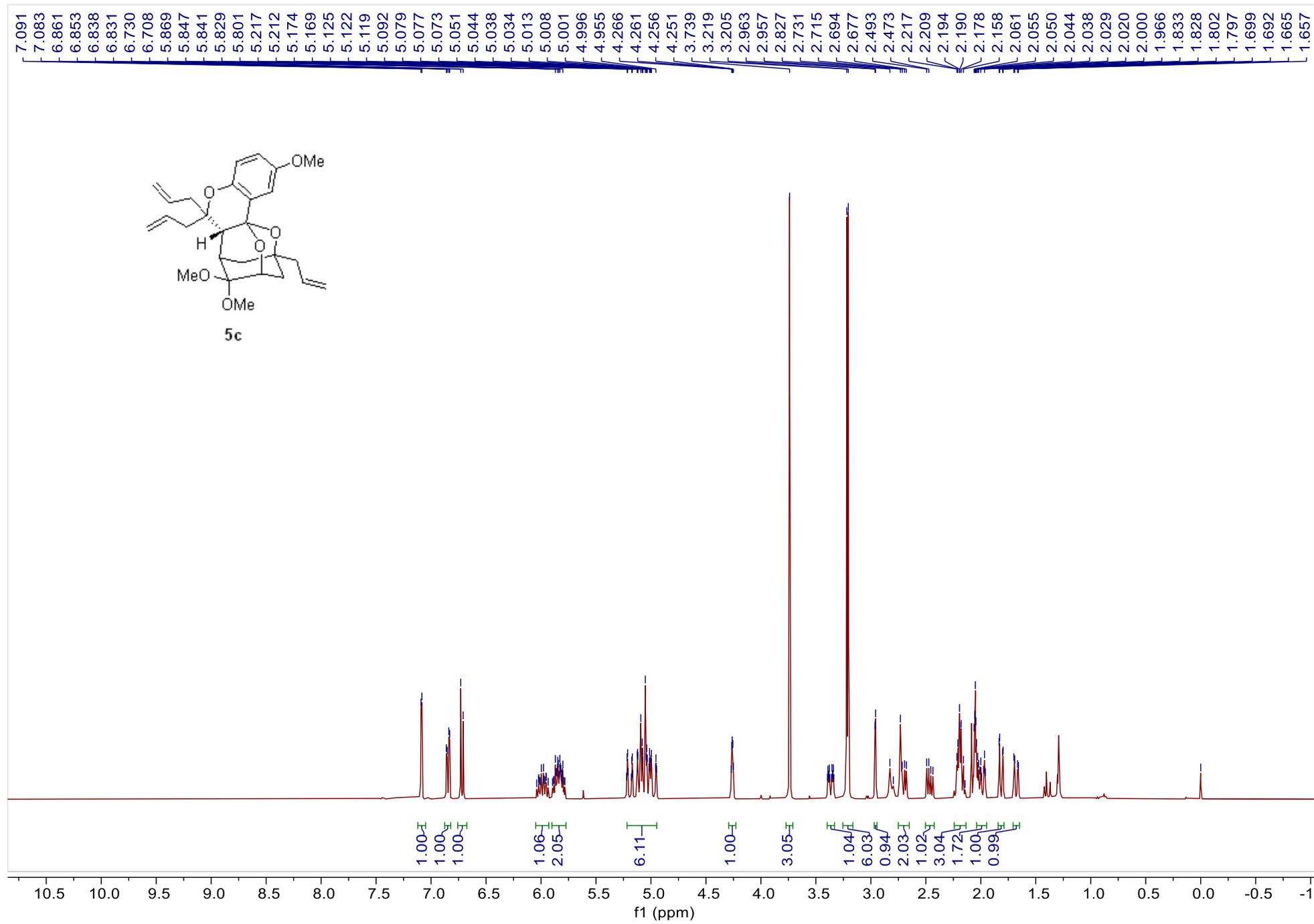
<sup>1</sup>H NMR of **5b** (400 MHz, acetone-d<sub>6</sub>)



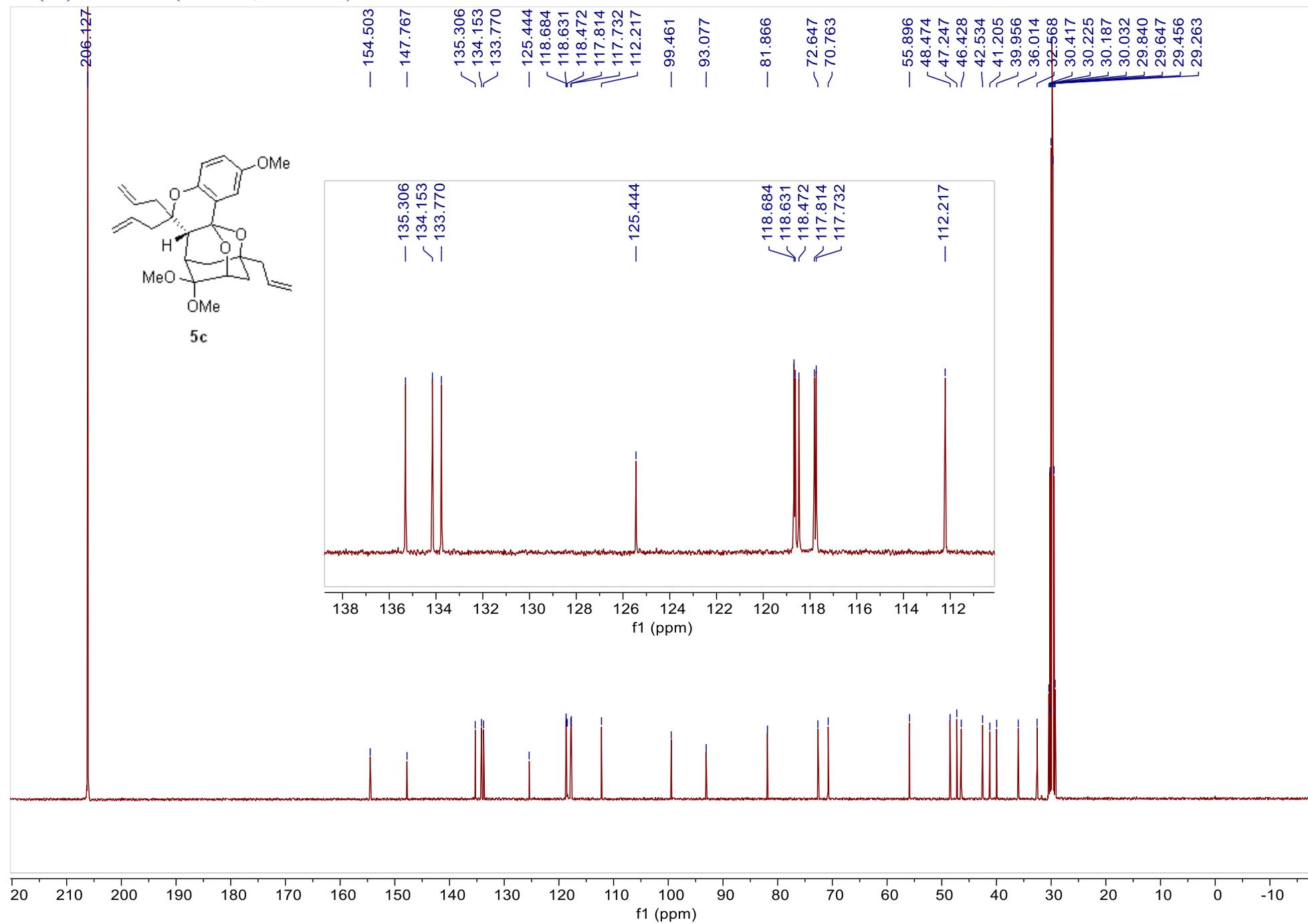
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5b** (101 MHz, acetone- $\text{d}_6$ )



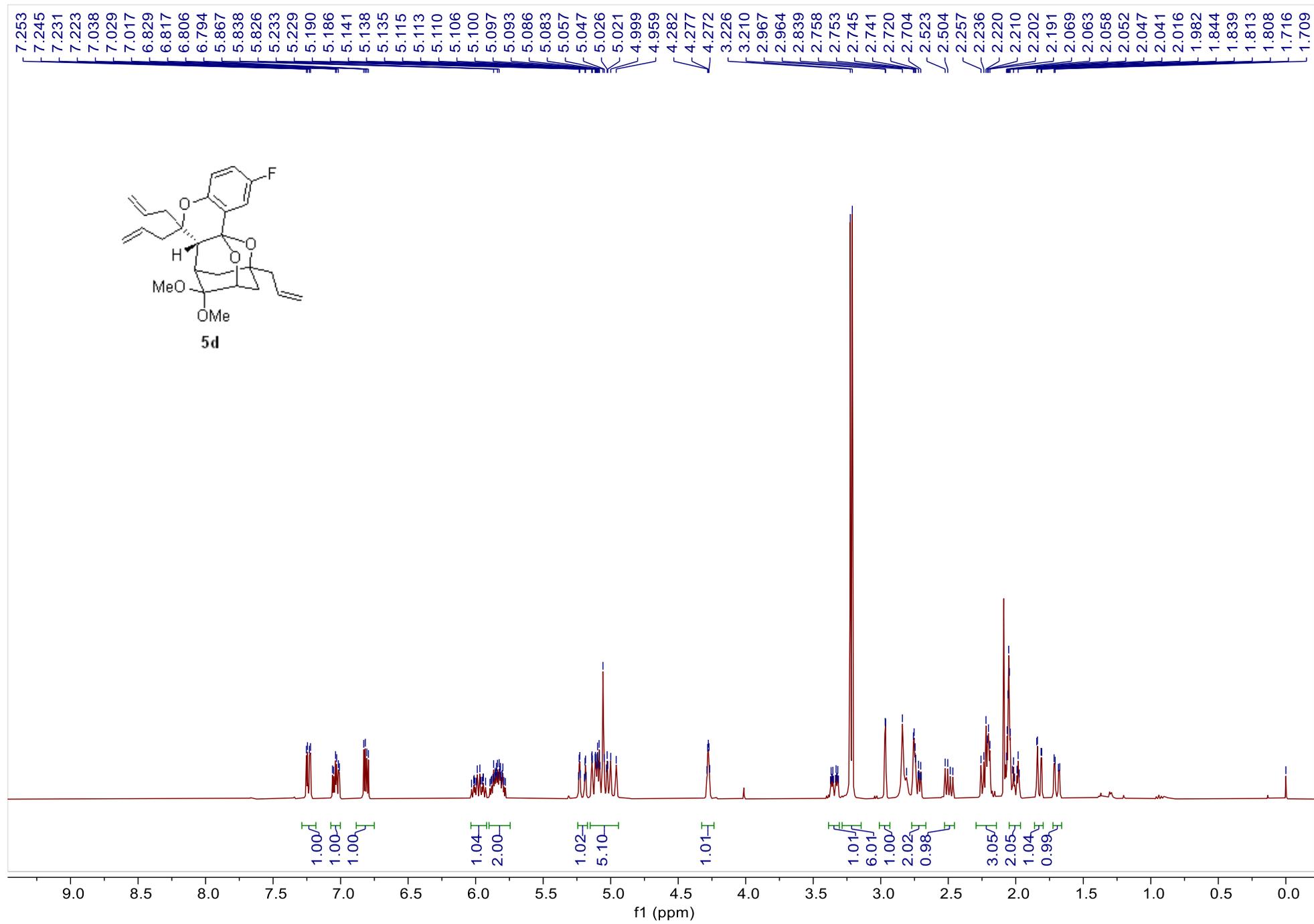
<sup>1</sup>H NMR of 5c (400 MHz, acetone-d<sub>6</sub>)



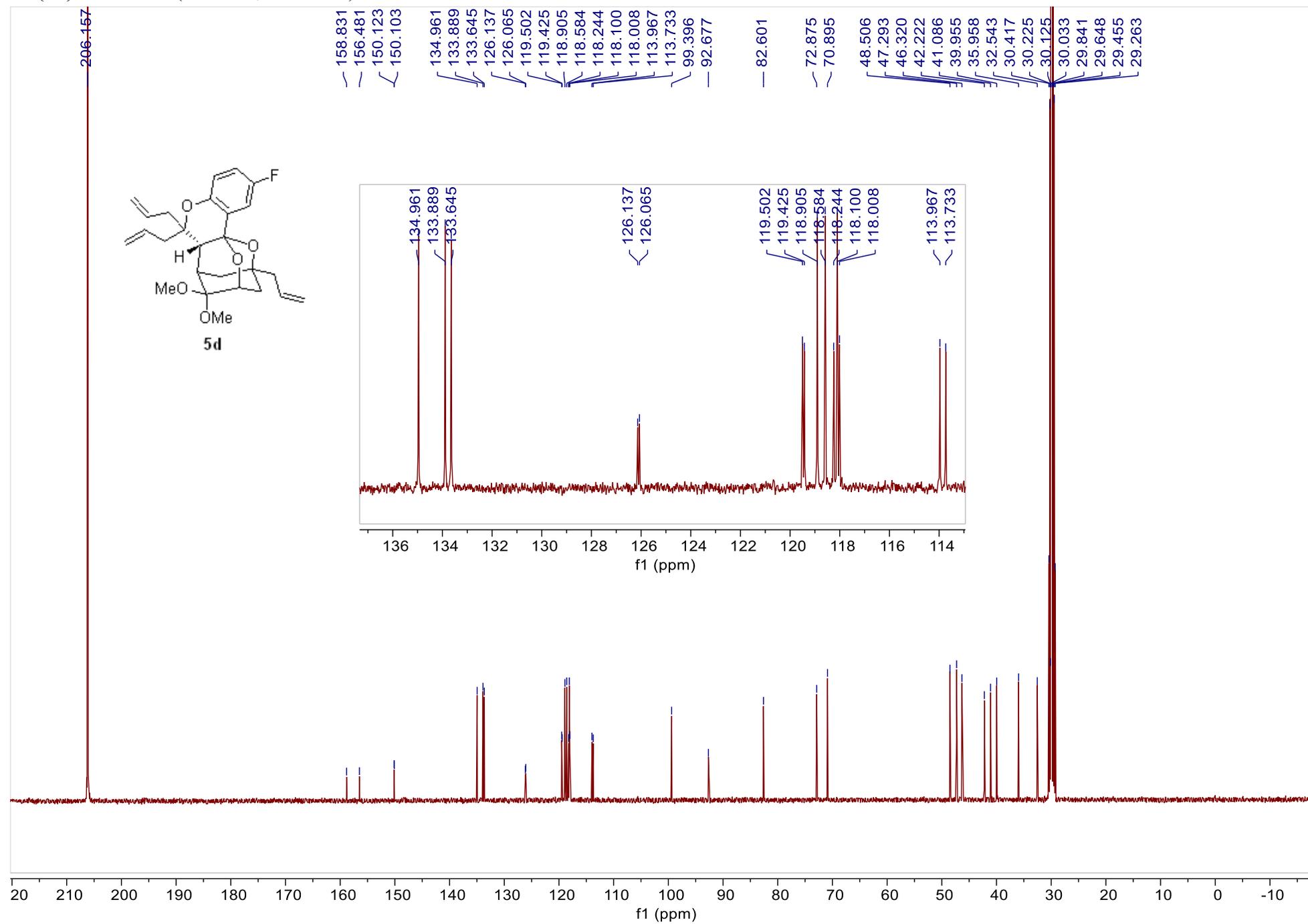
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5c** (101 MHz, acetone- $d_6$ )



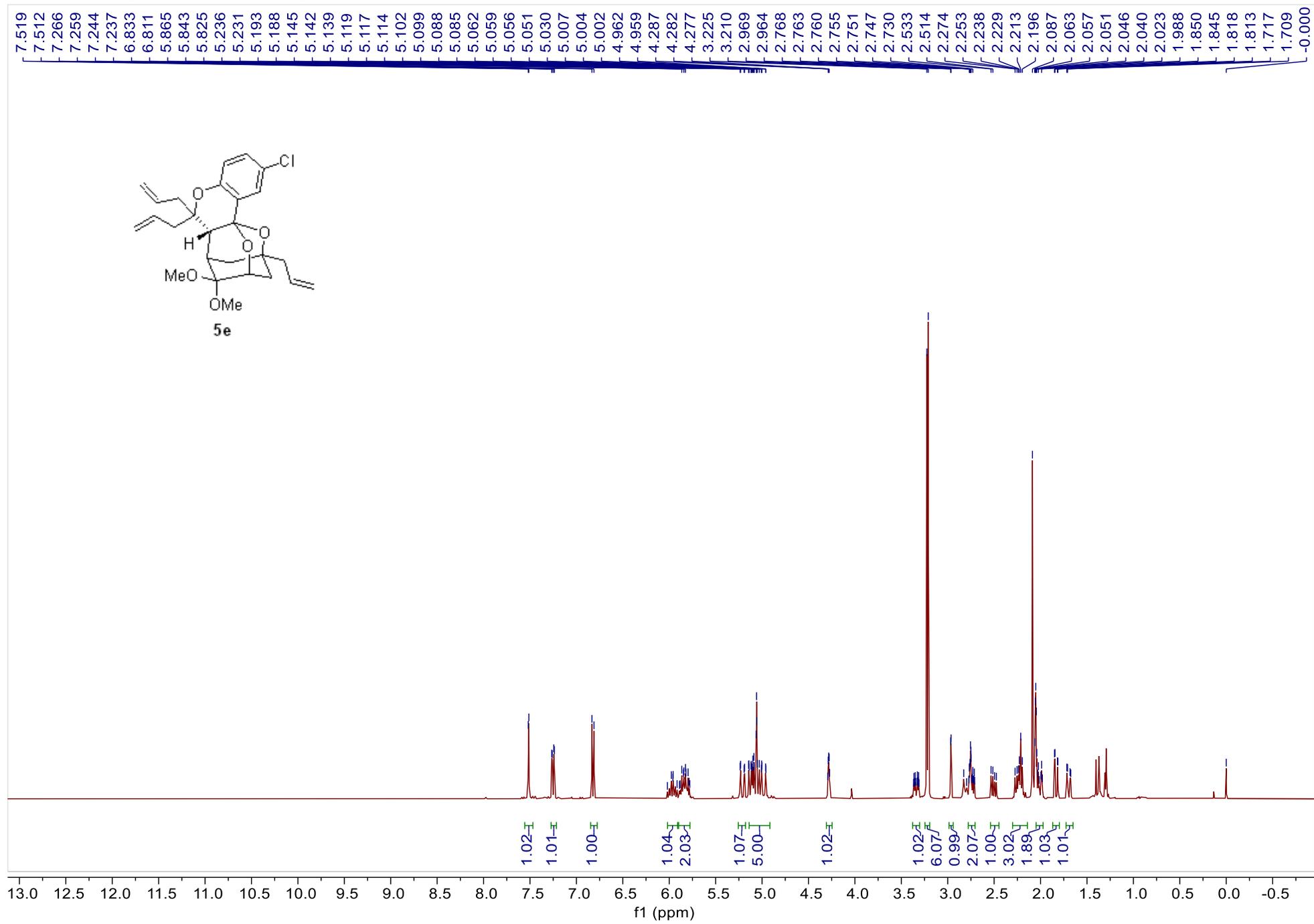
<sup>1</sup>H NMR of **5d** (400 MHz, acetone-d<sub>6</sub>)



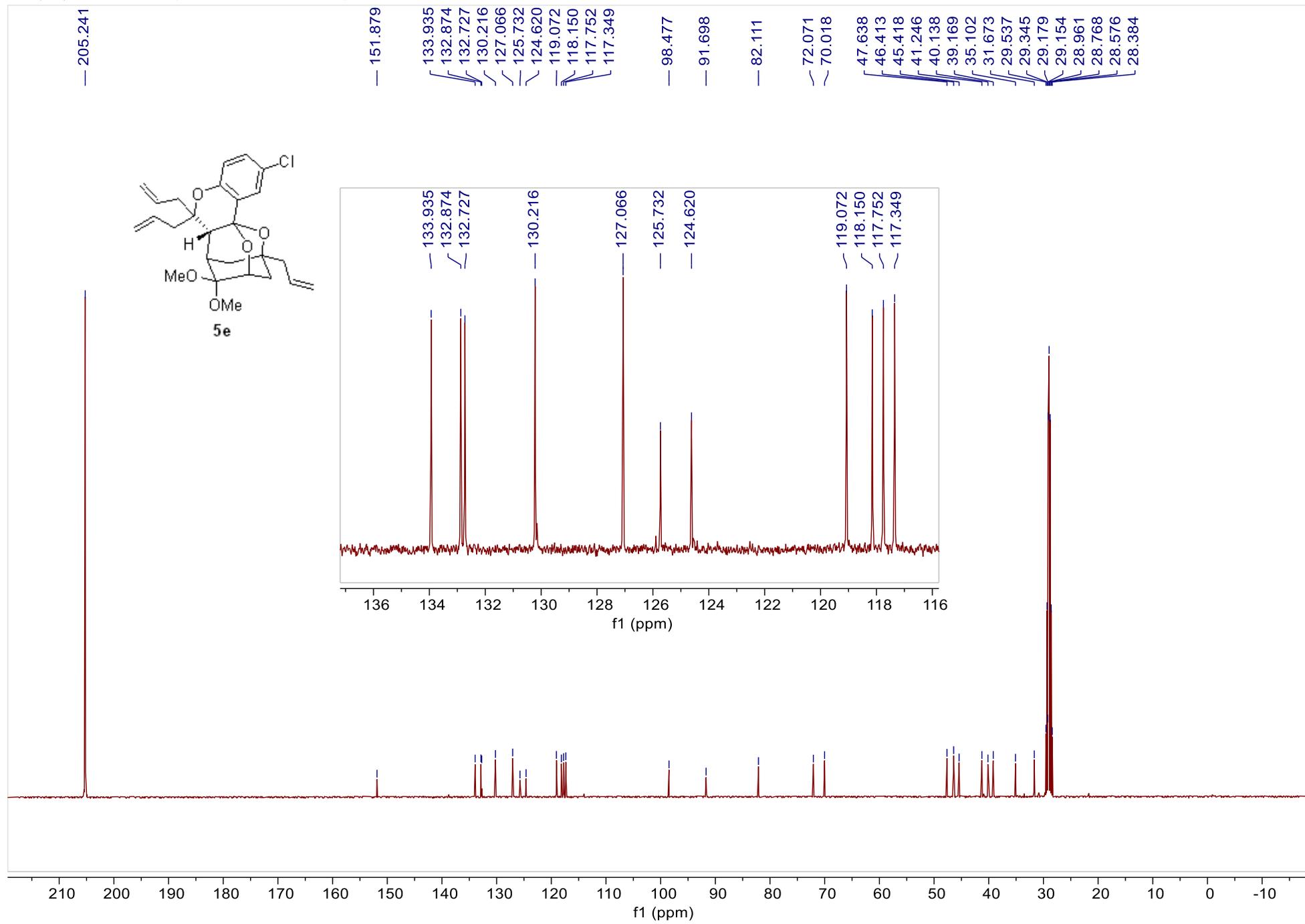
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5d** (101 MHz, acetone- $d_6$ )



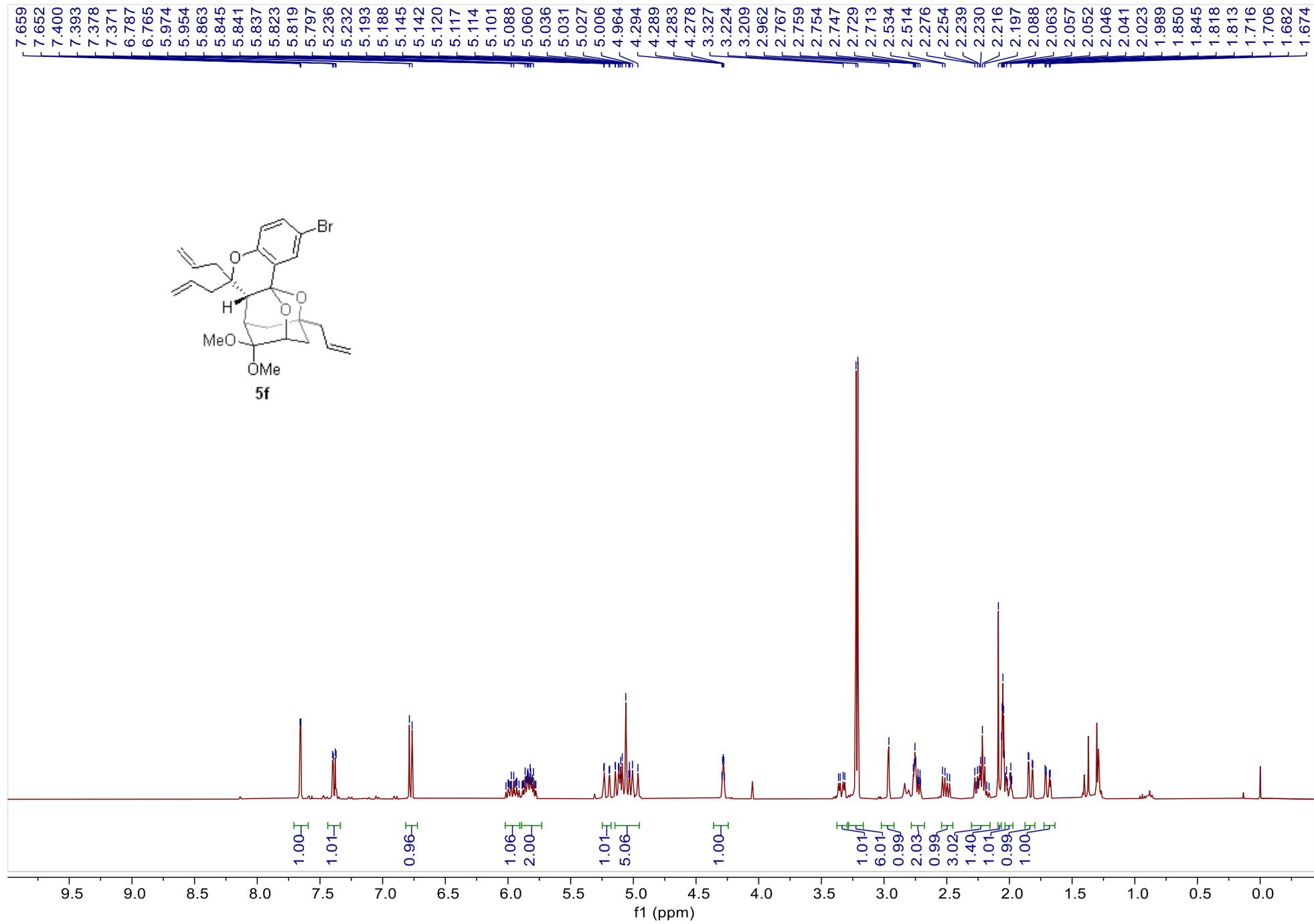
<sup>1</sup>H NMR of **5e** (400 MHz, acetone-d<sub>6</sub>)



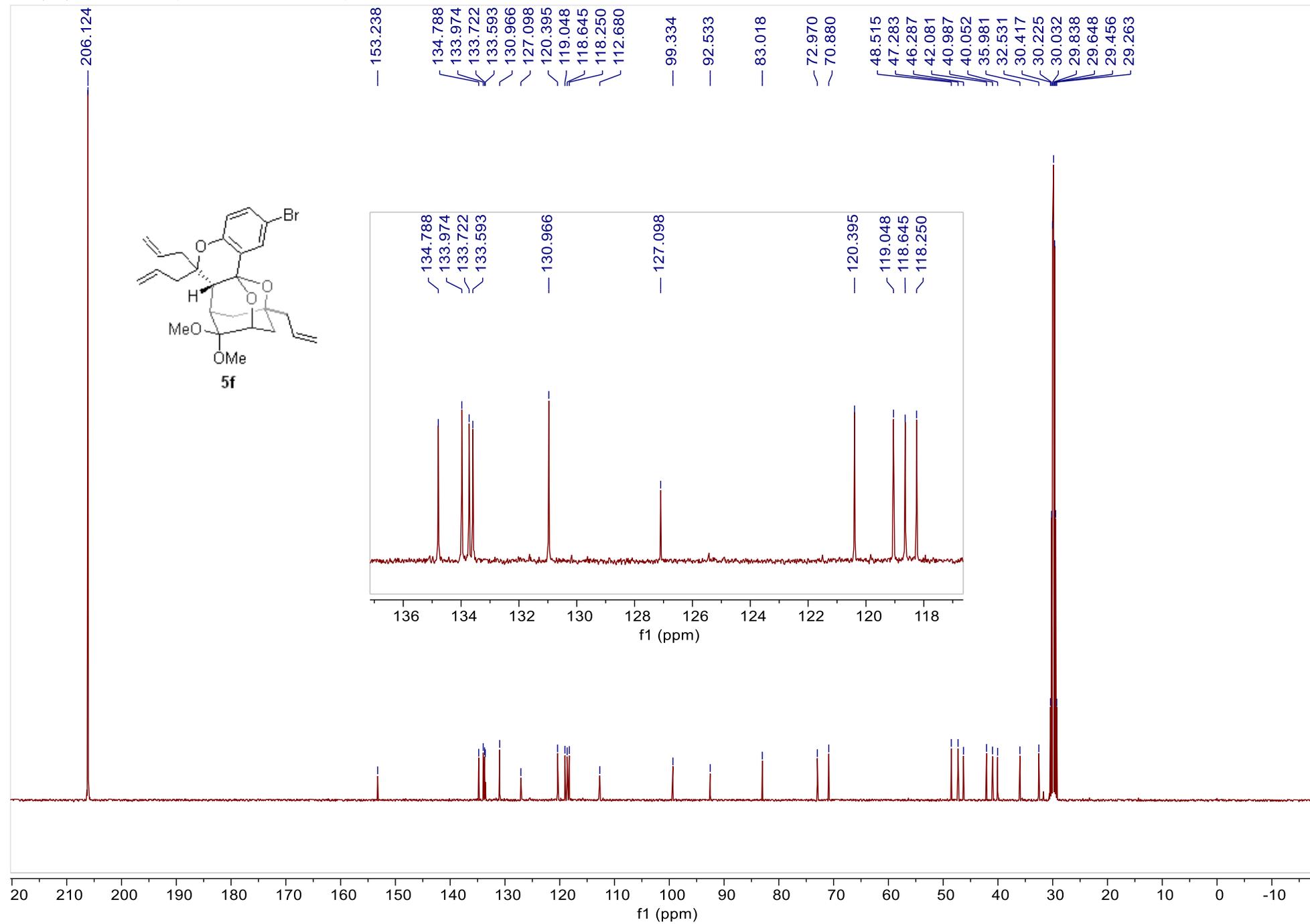
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5e** (101 MHz, acetone- $d_6$ )



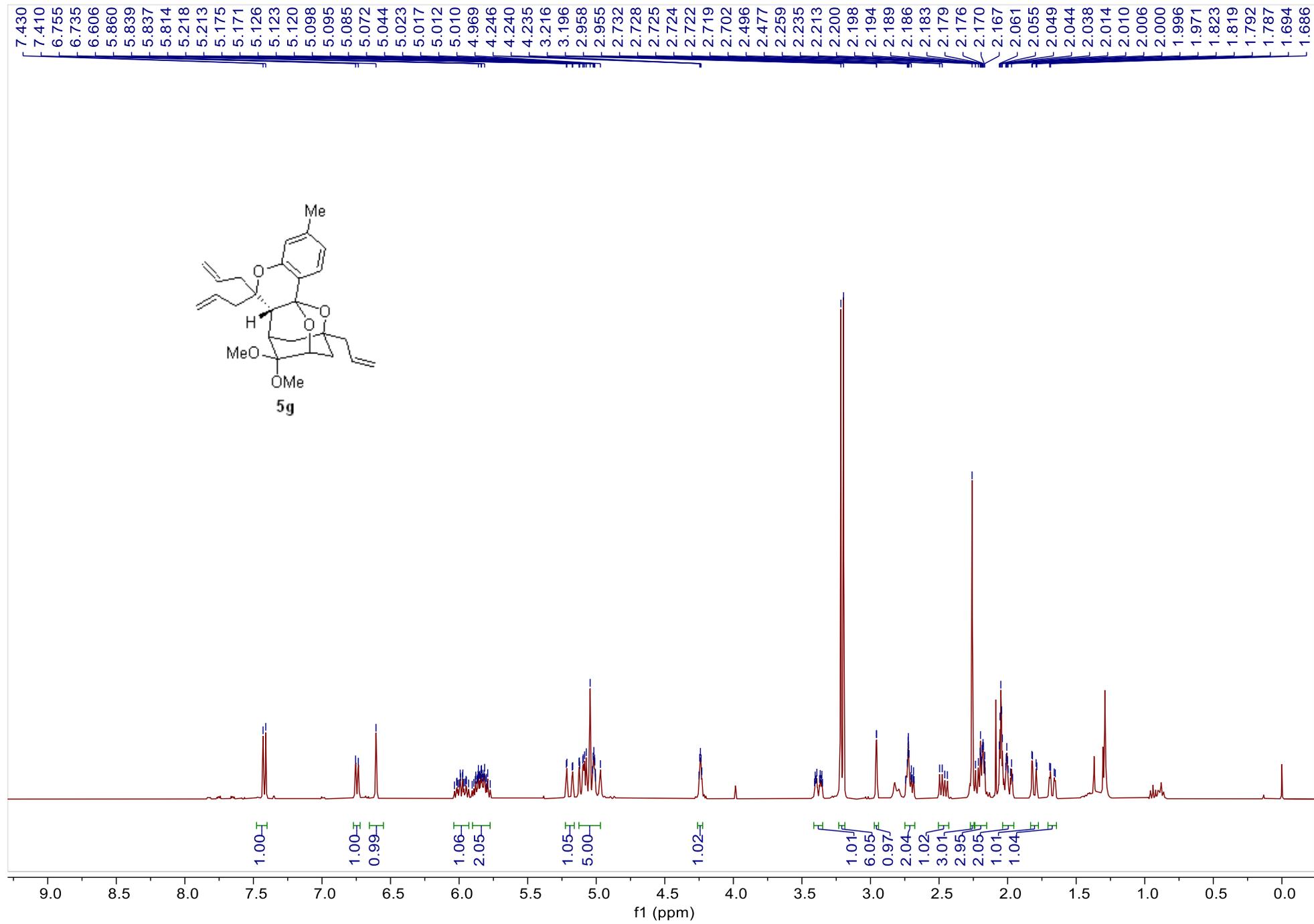
<sup>1</sup>H NMR of **5f** (400 MHz, acetone-d<sub>6</sub>)



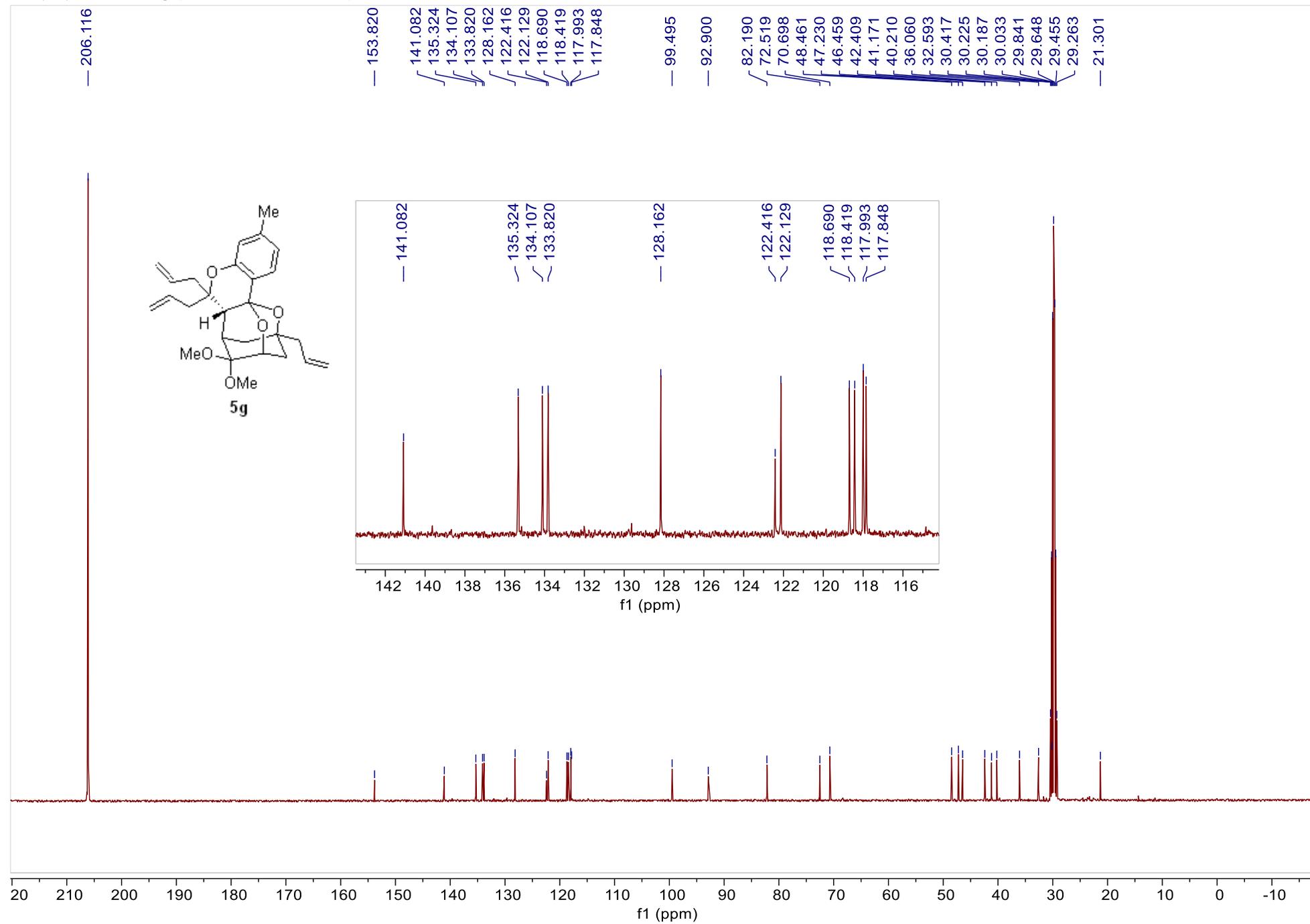
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5f** (101 MHz, acetone- $d_6$ )



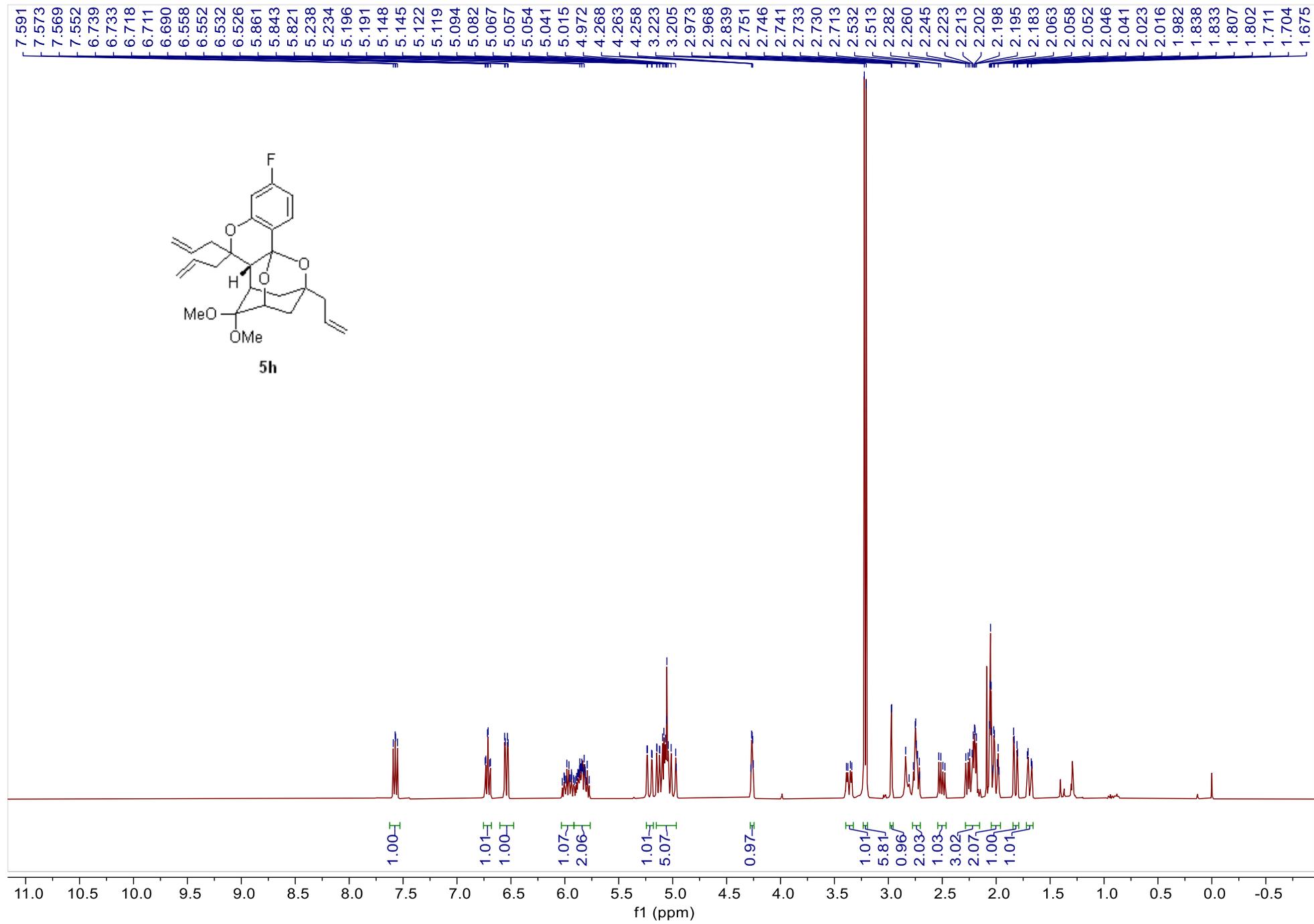
<sup>1</sup>H NMR of **5g** (400 MHz, acetone-d<sub>6</sub>)



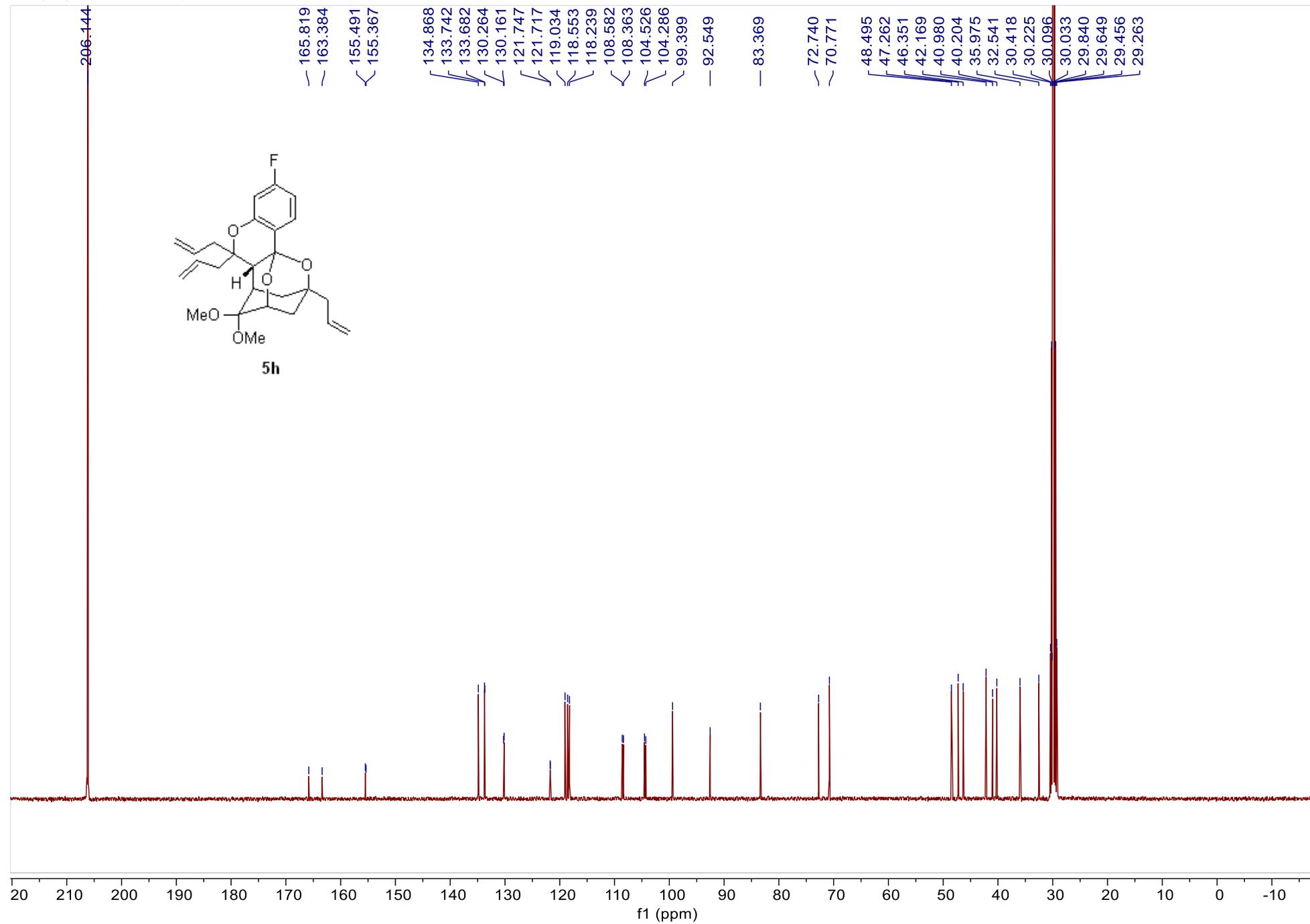
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5g** (101 MHz, acetone- $d_6$ )



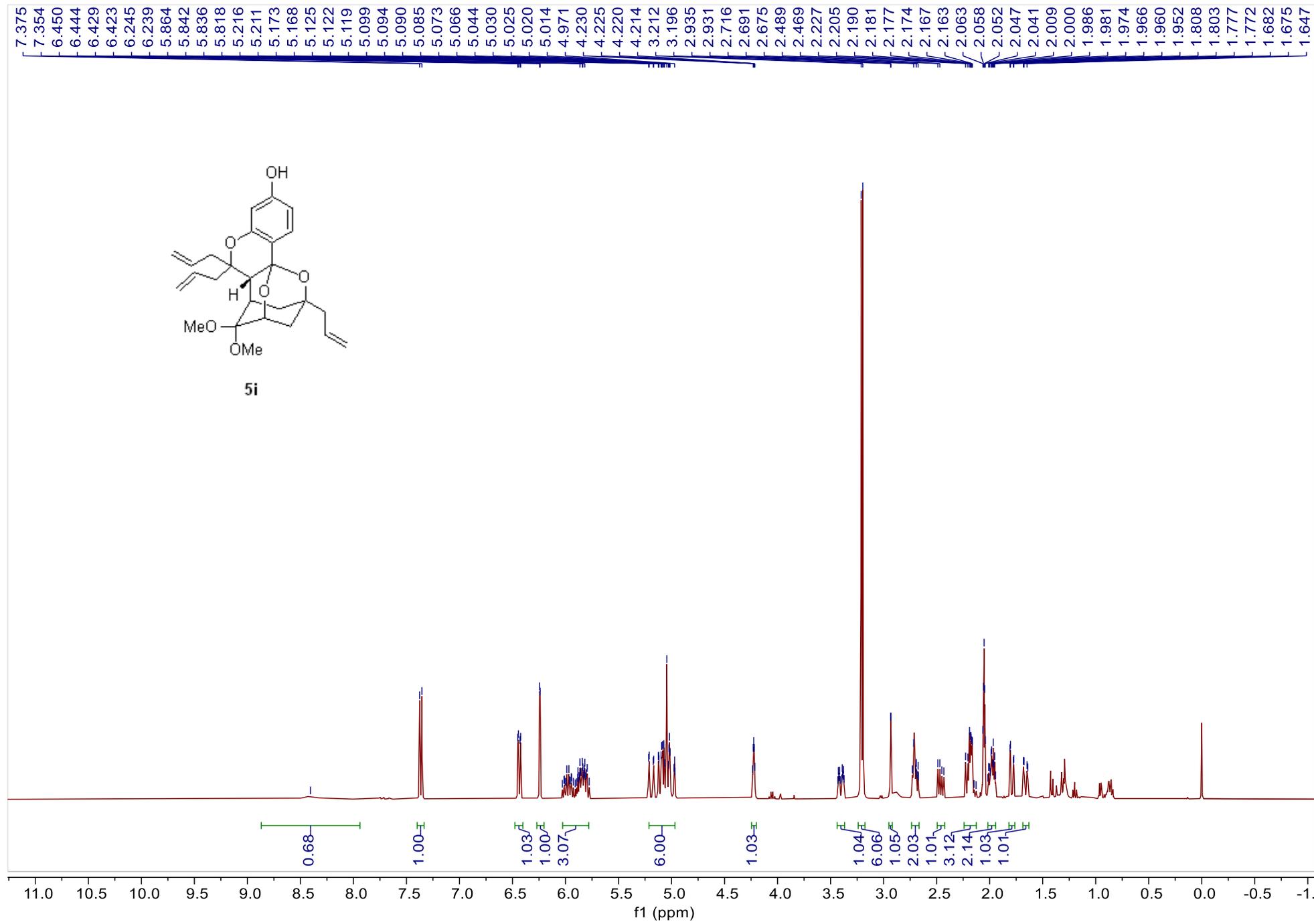
<sup>1</sup>H NMR of **5h** (400 MHz, acetone-d<sub>6</sub>)



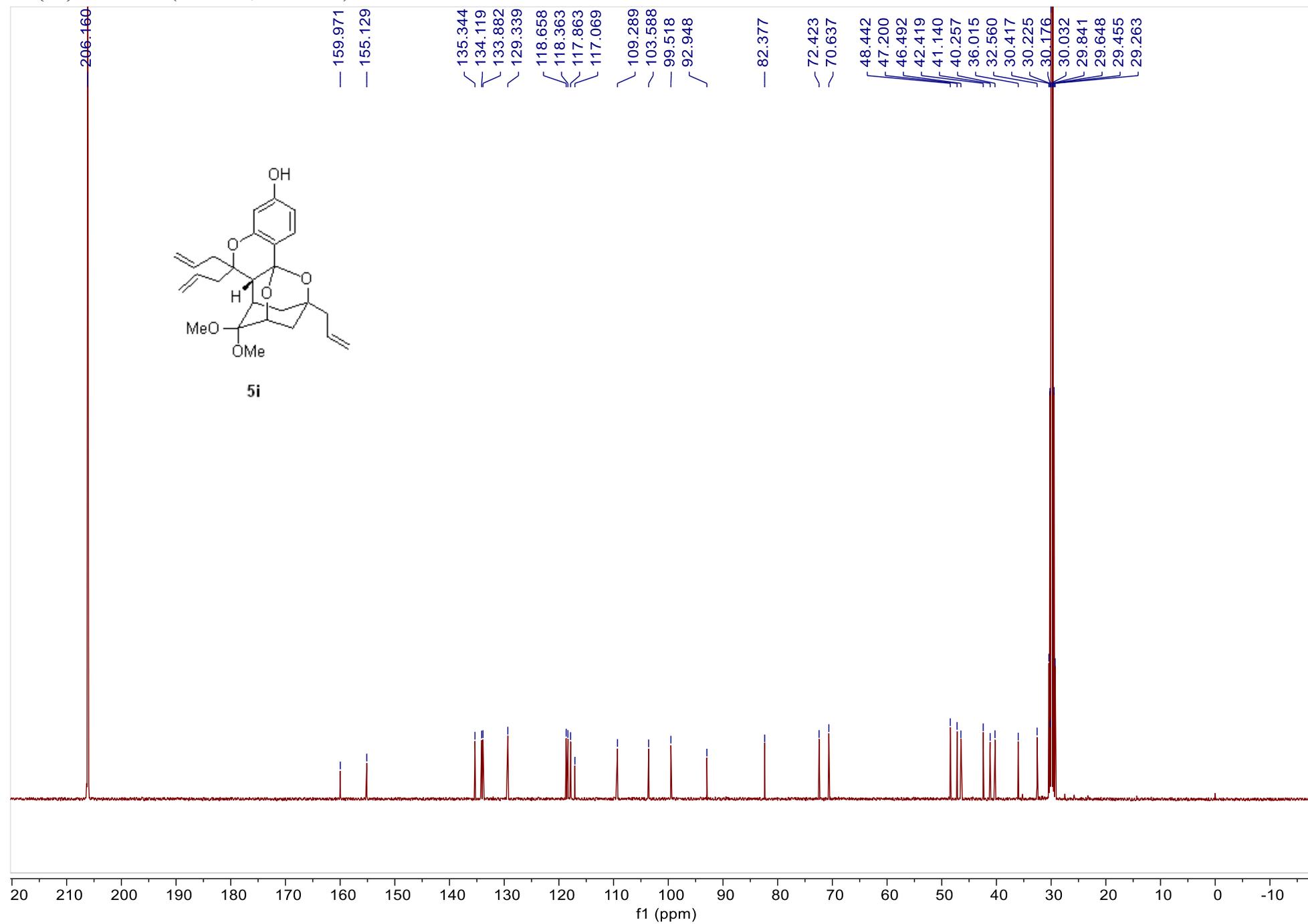
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5h** (101 MHz, acetone- $d_6$ )



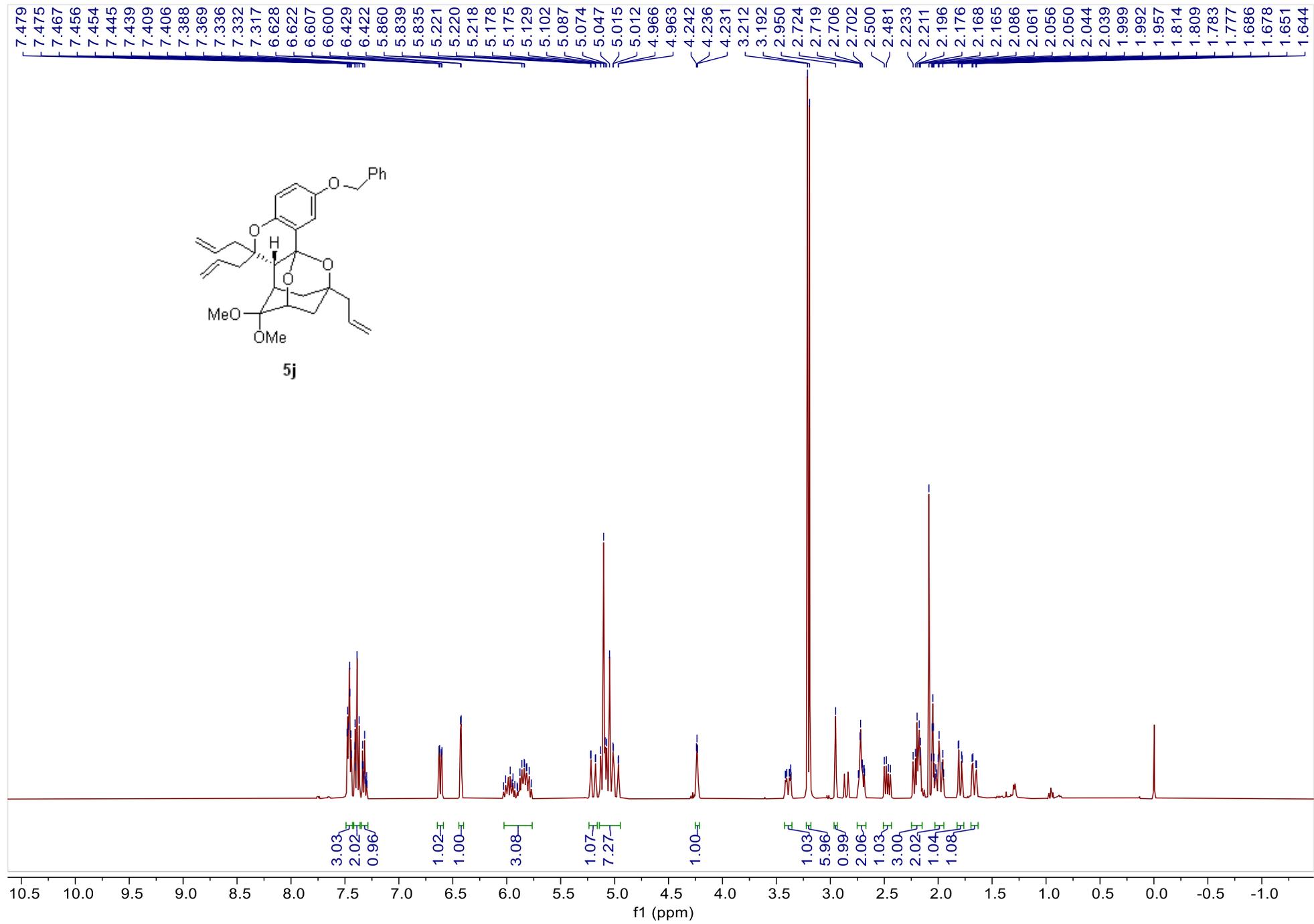
<sup>1</sup>H NMR of **5i** (400 MHz, acetone-d<sub>6</sub>)



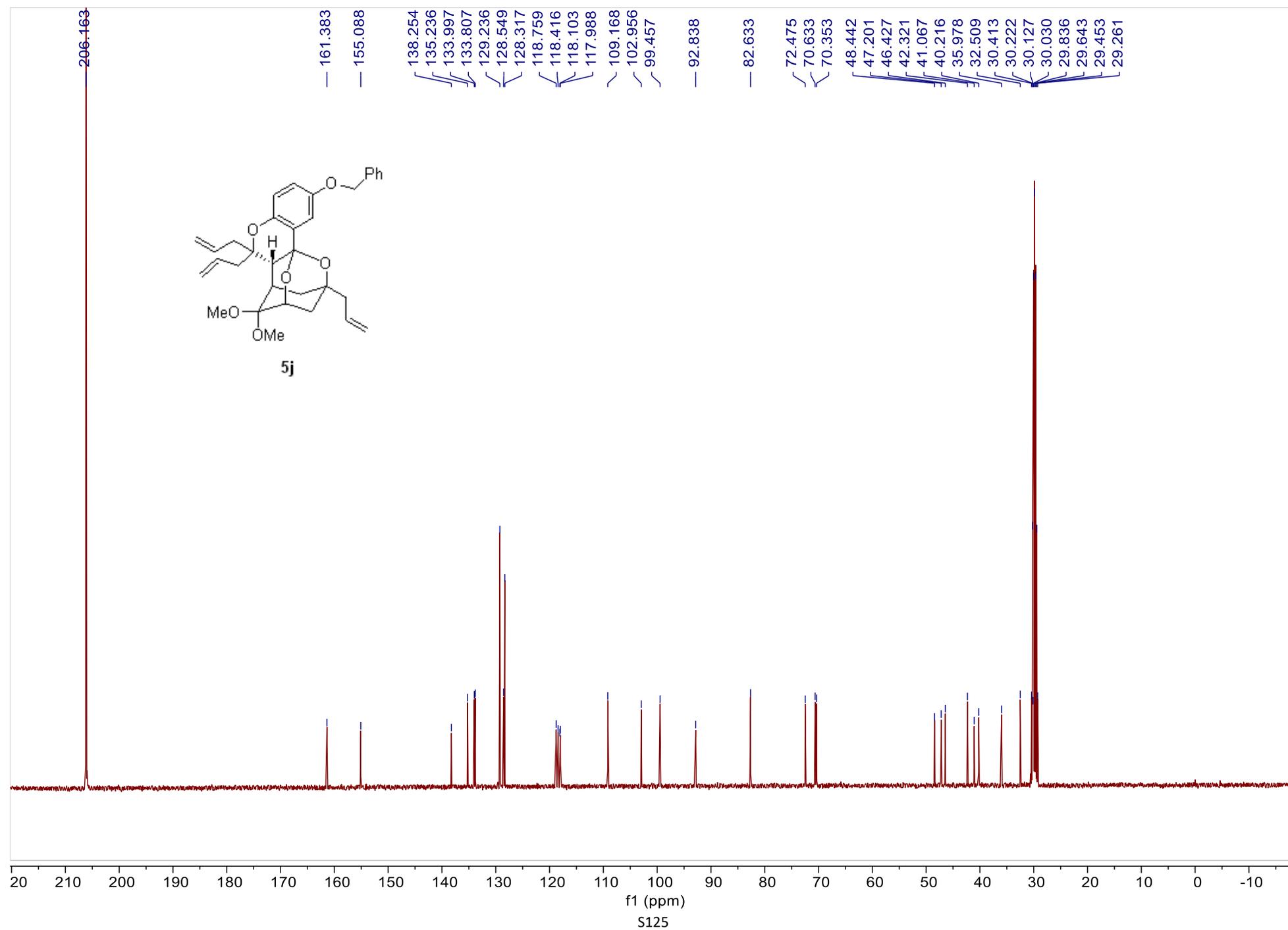
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5i** (101 MHz, acetone- $d_6$ )



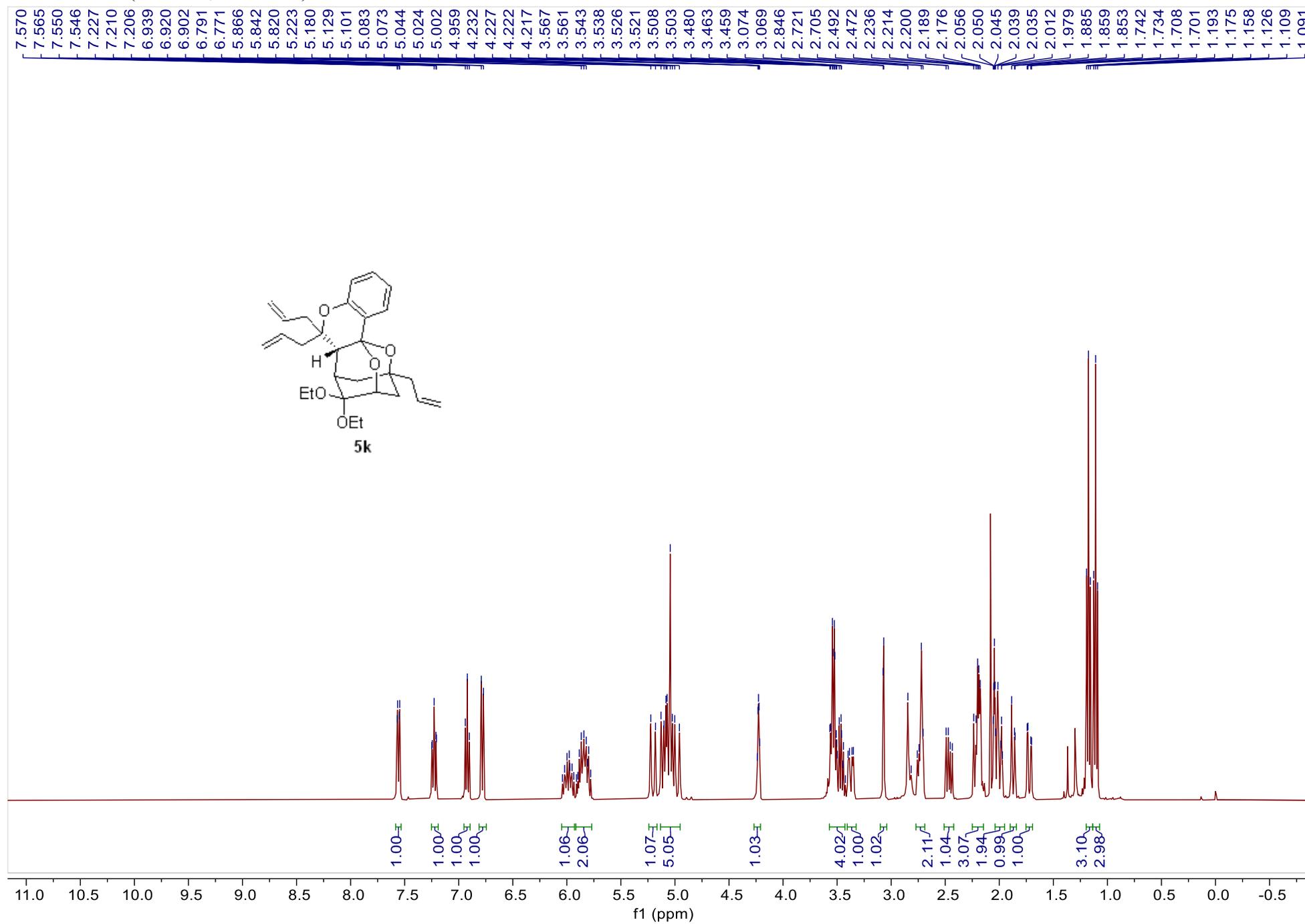
<sup>1</sup>H NMR of **5j** (400 MHz, acetone-d<sub>6</sub>)



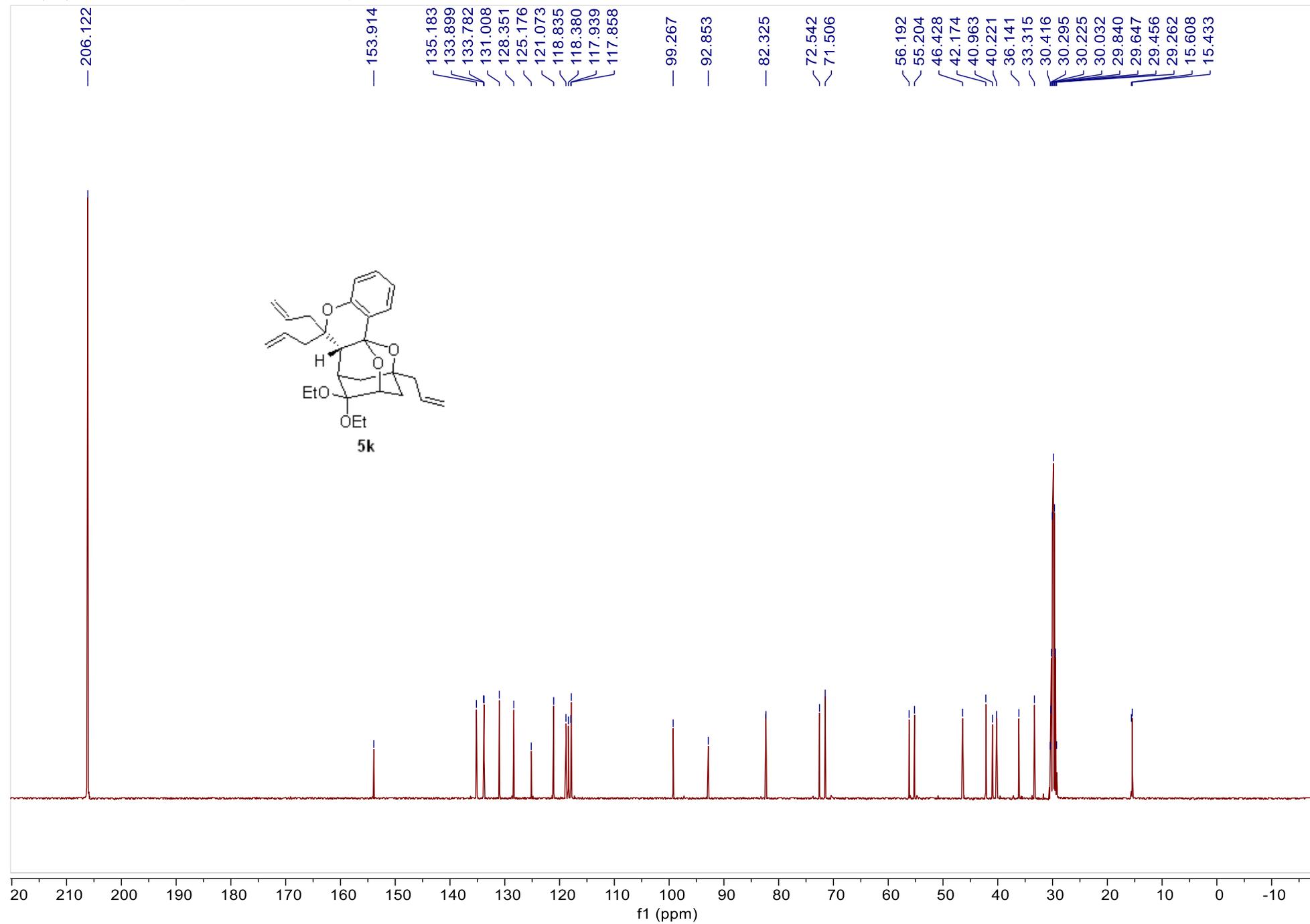
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5j** (101MHz, acetone- $d_6$ )



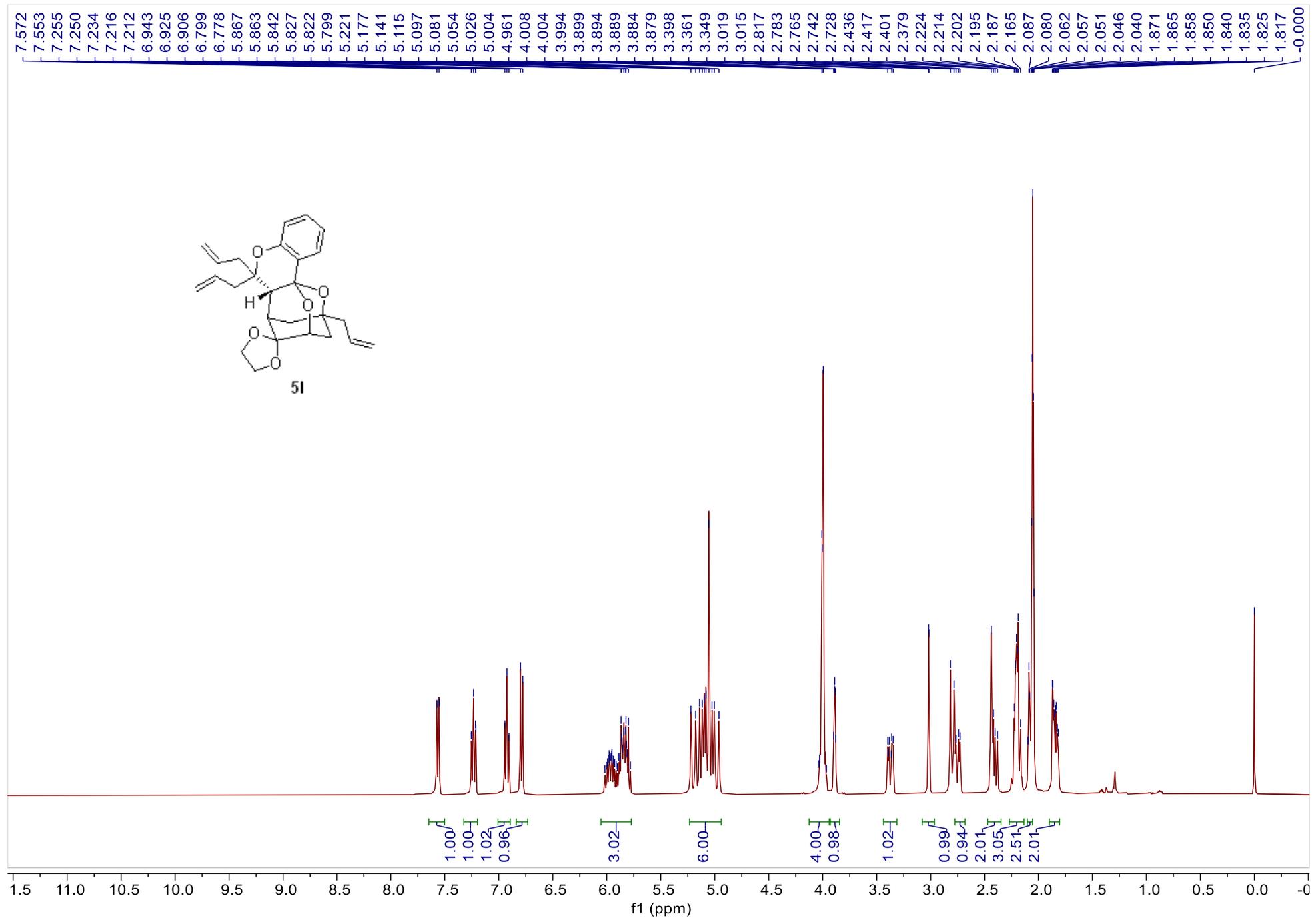
<sup>1</sup>H NMR of **5k** (400 MHz, acetone-d<sub>6</sub>)



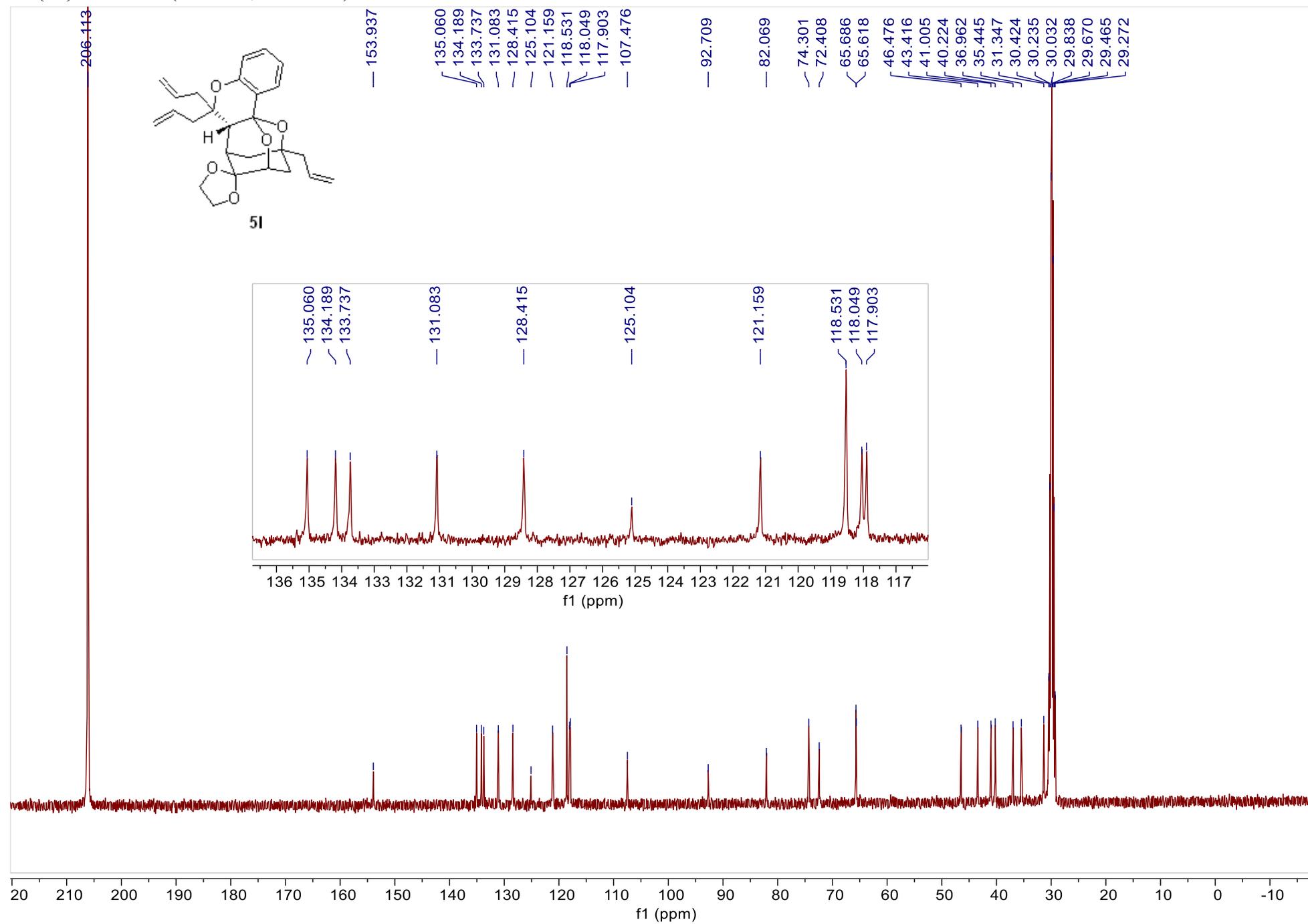
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5k** (101 MHz, acetone- $d_6$ )



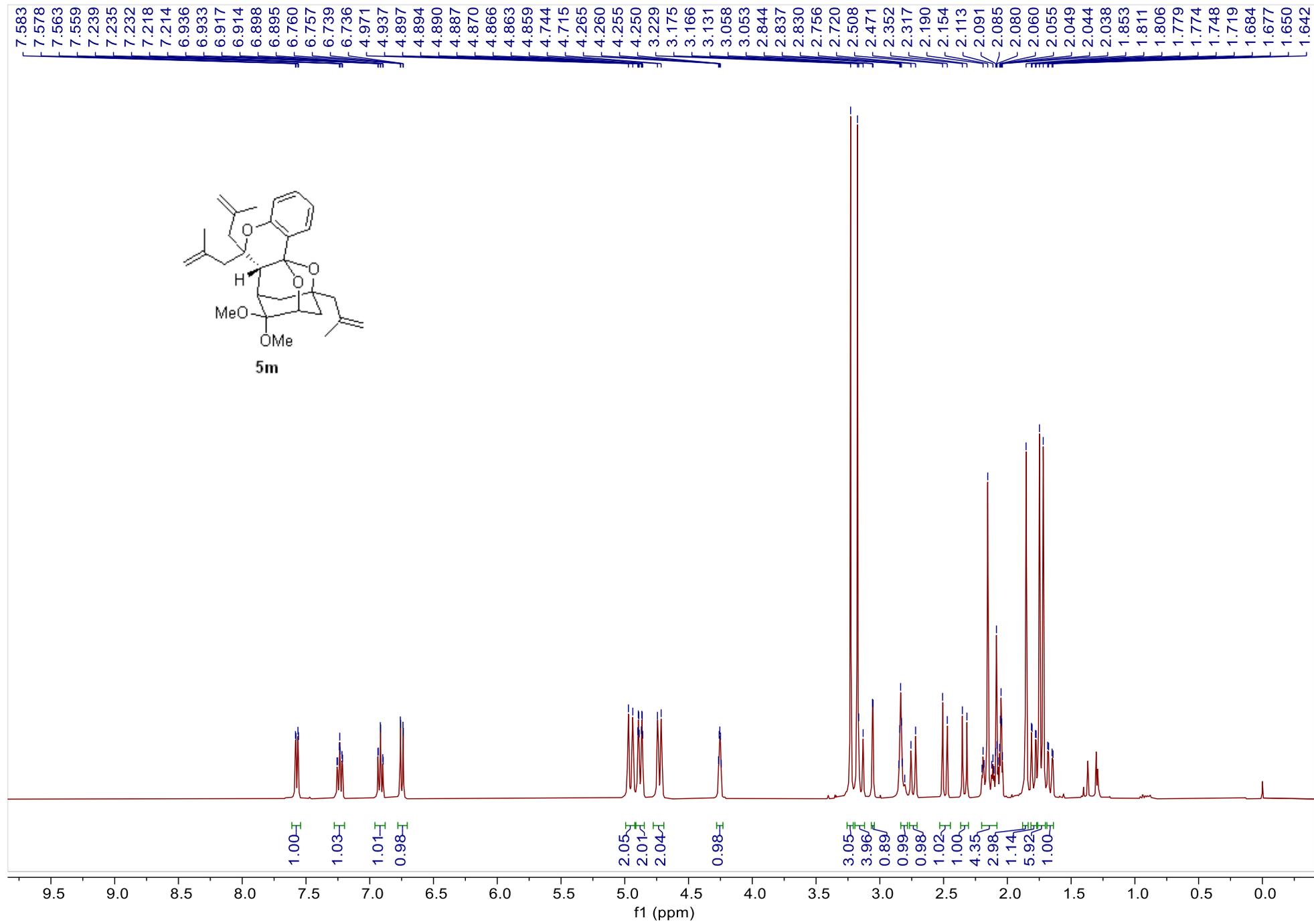
<sup>1</sup>H NMR of **51** (400 MHz, acetone-d<sub>6</sub>)



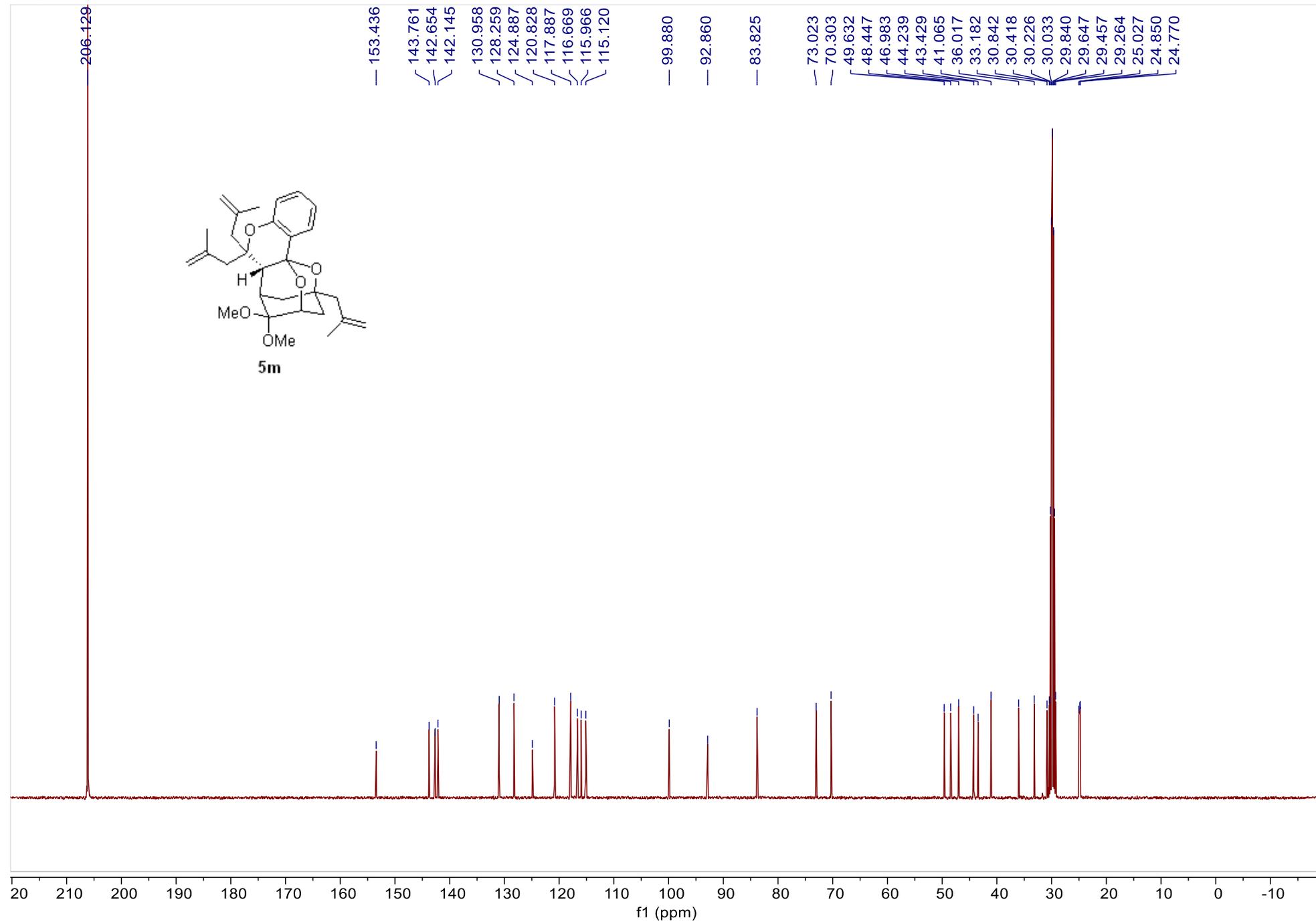
$^{13}\text{C}\{^1\text{H}\}$  NMR of **51** (101 MHz, acetone- $d_6$ )



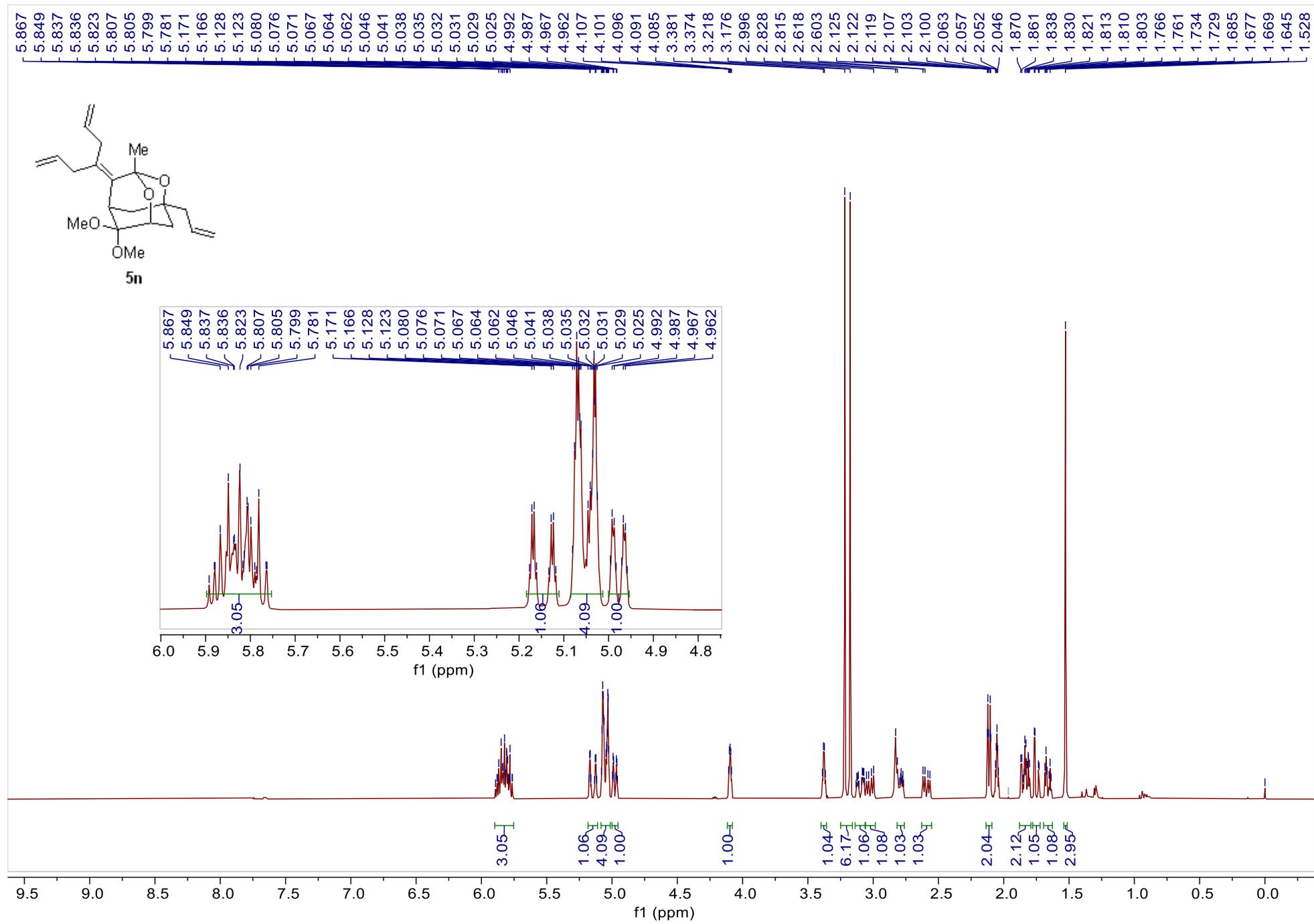
<sup>1</sup>H NMR of **5m** (400MHz, acetone-d<sub>6</sub>)



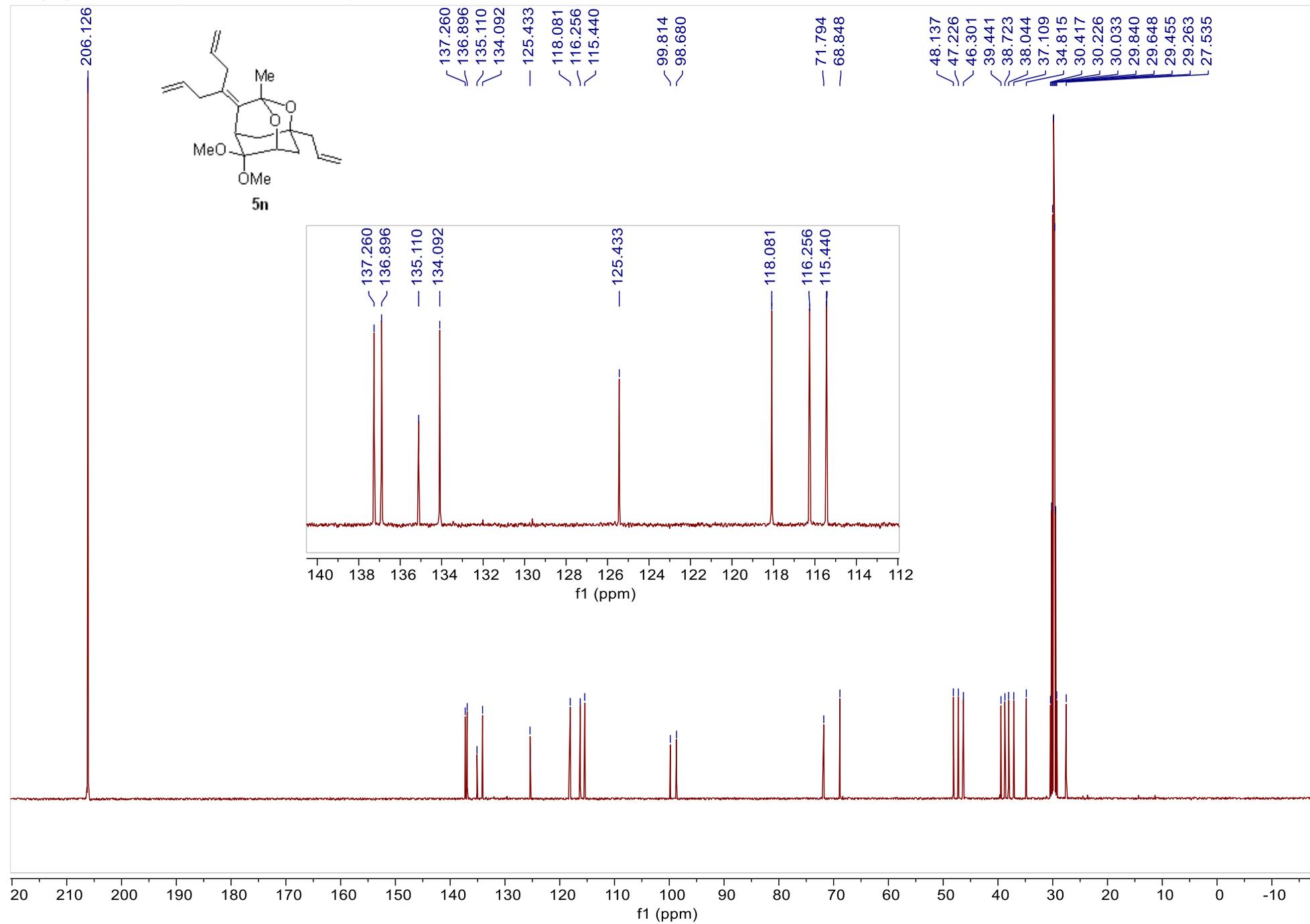
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5m** (101 MHz, acetone- $\text{d}_6$ )



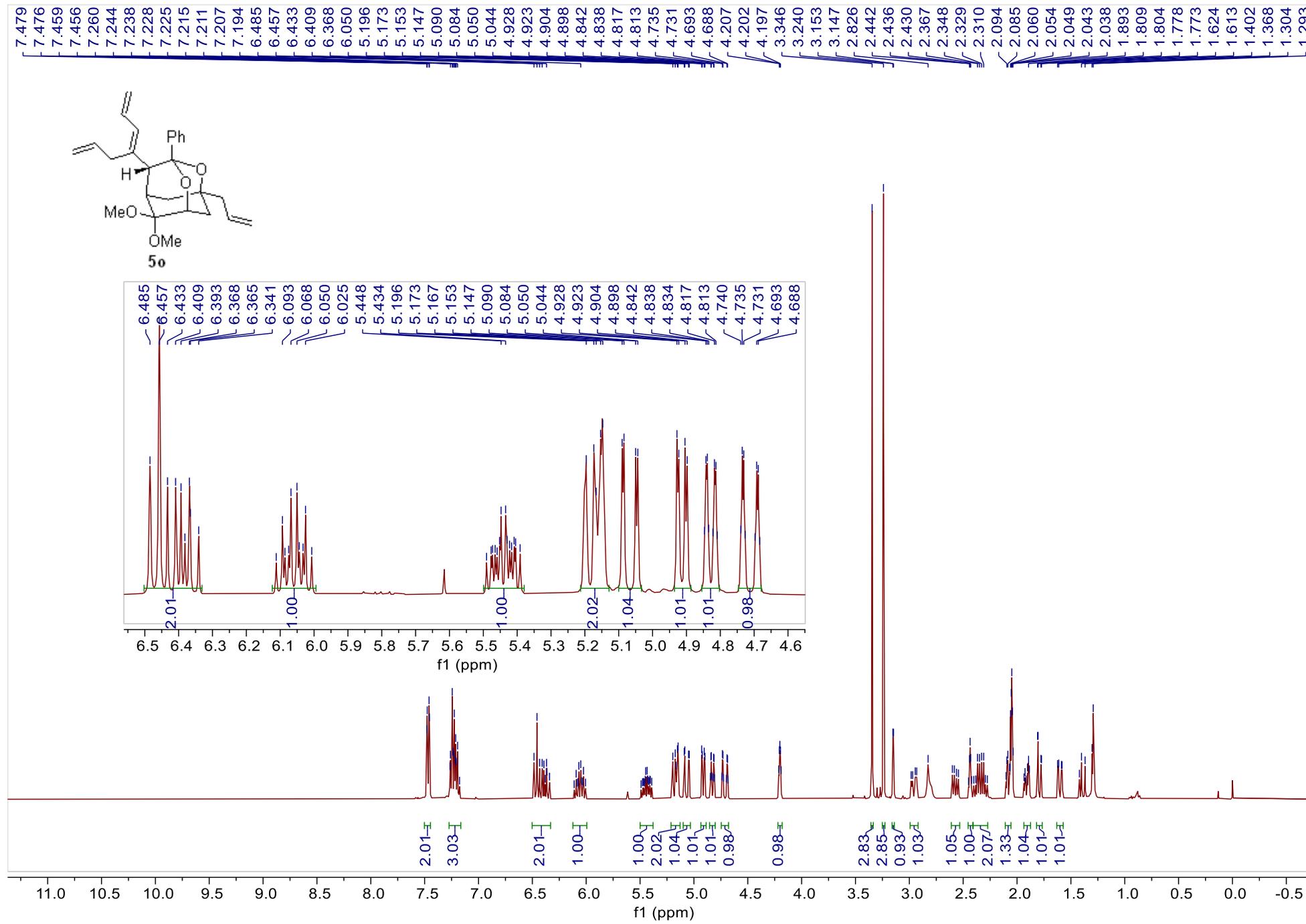
<sup>1</sup>H NMR of **5n** (400MHz, acetone-d<sub>6</sub>)



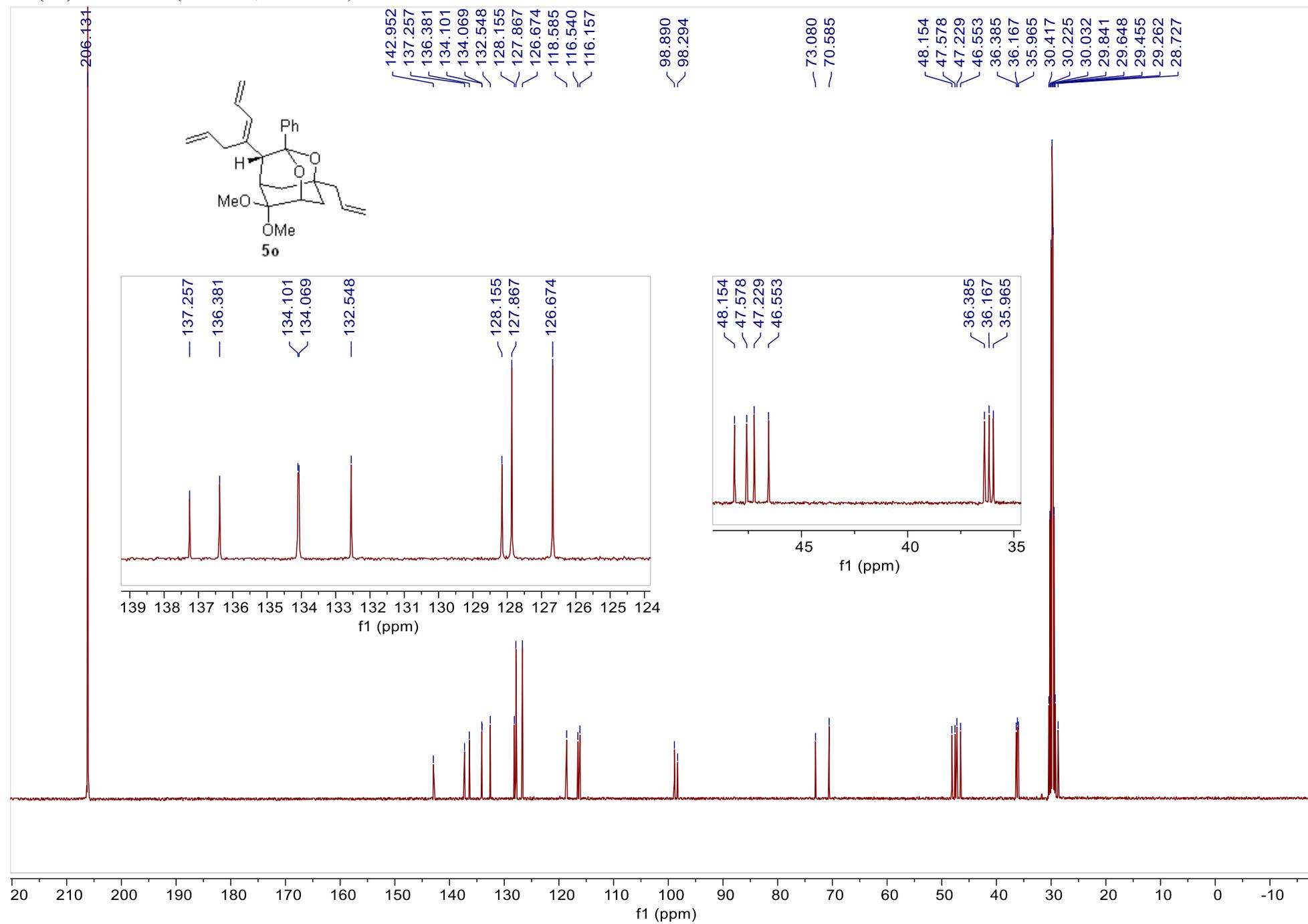
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5n** (101 MHz, acetone- $d_6$ )



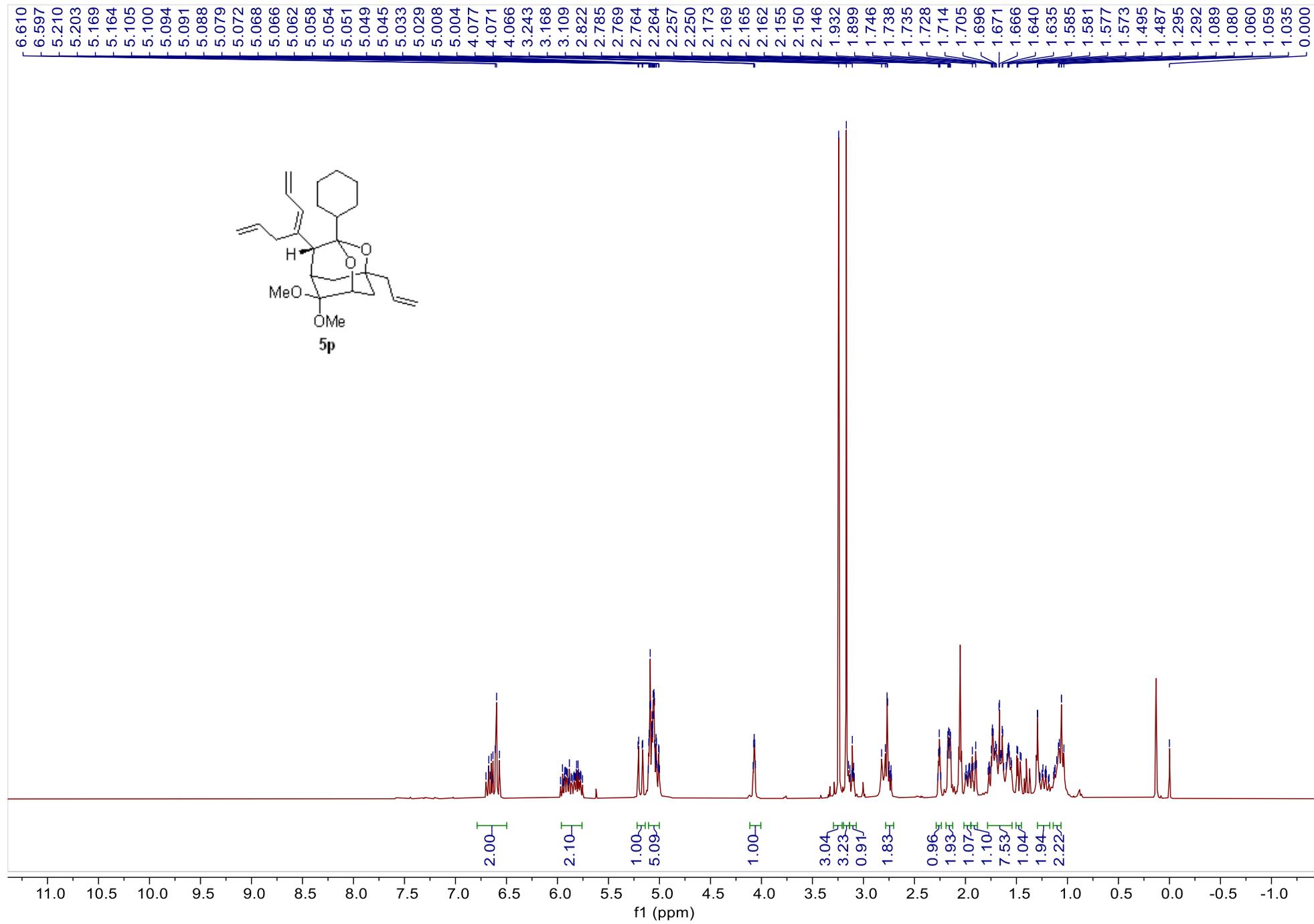
<sup>1</sup>H NMR of **5o** (400MHz, acetone-d<sub>6</sub>)



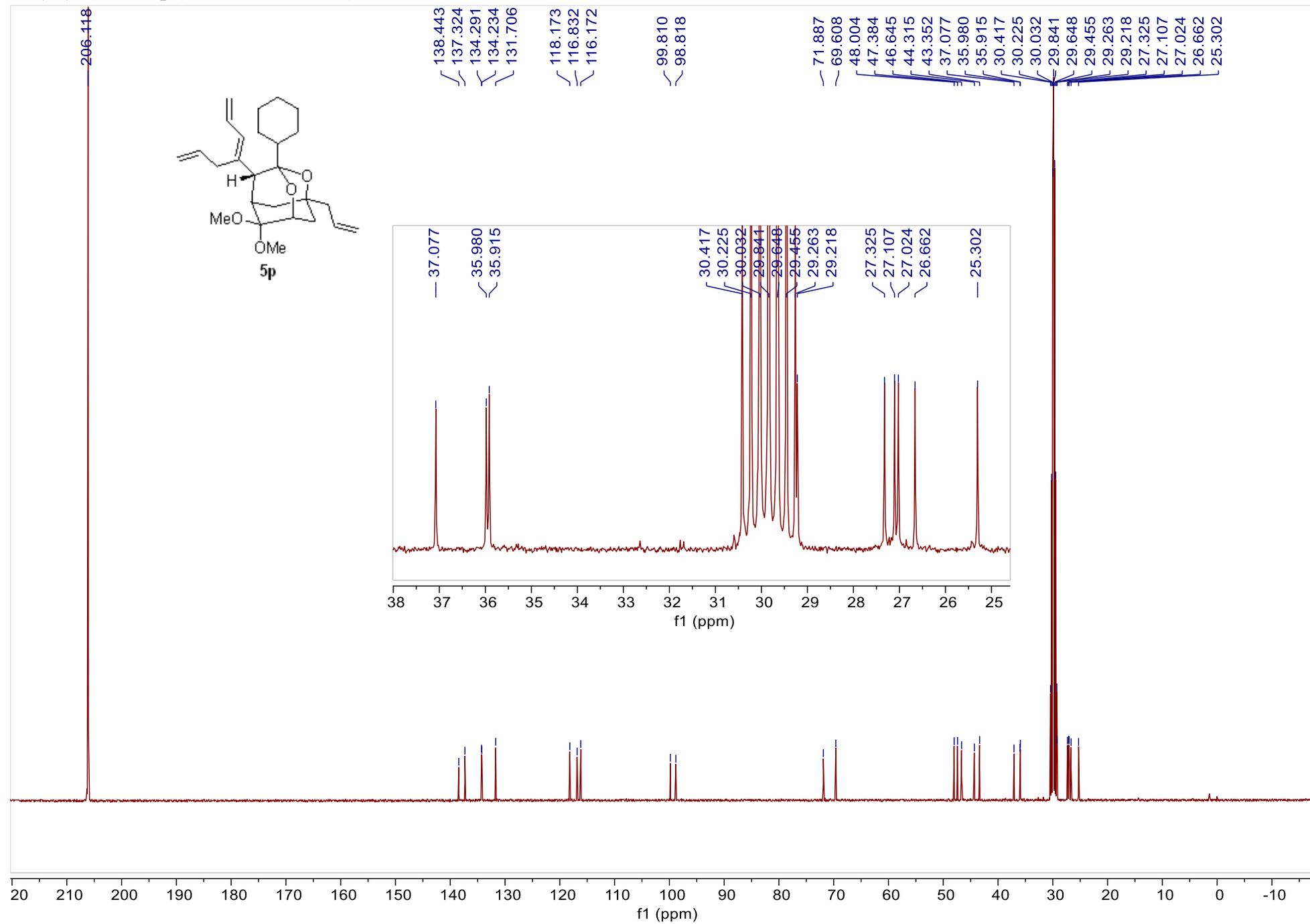
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5o** (101 MHz, acetone- $d_6$ )



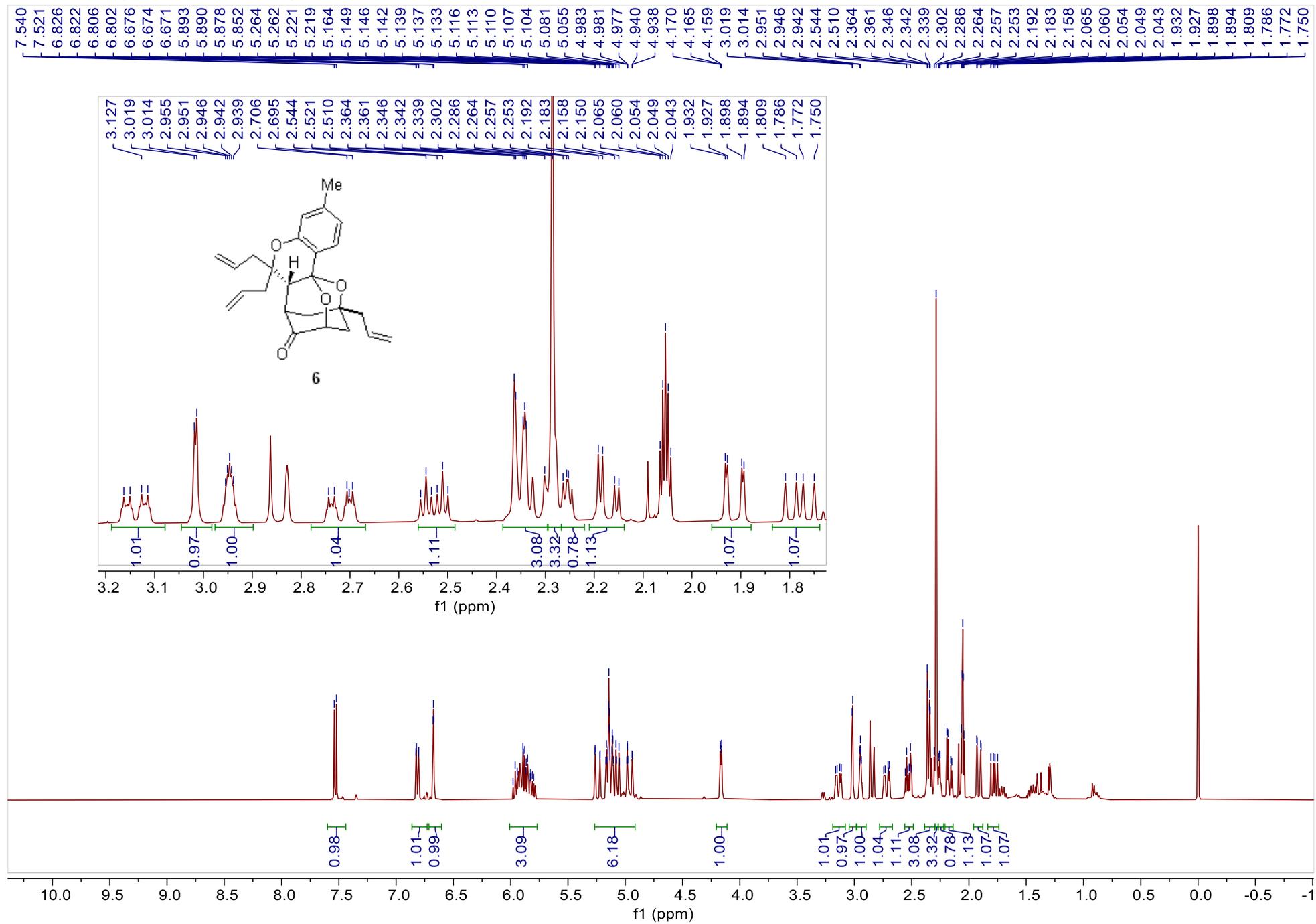
<sup>1</sup>H NMR of **5p** (400MHz, acetone-d<sub>6</sub>)



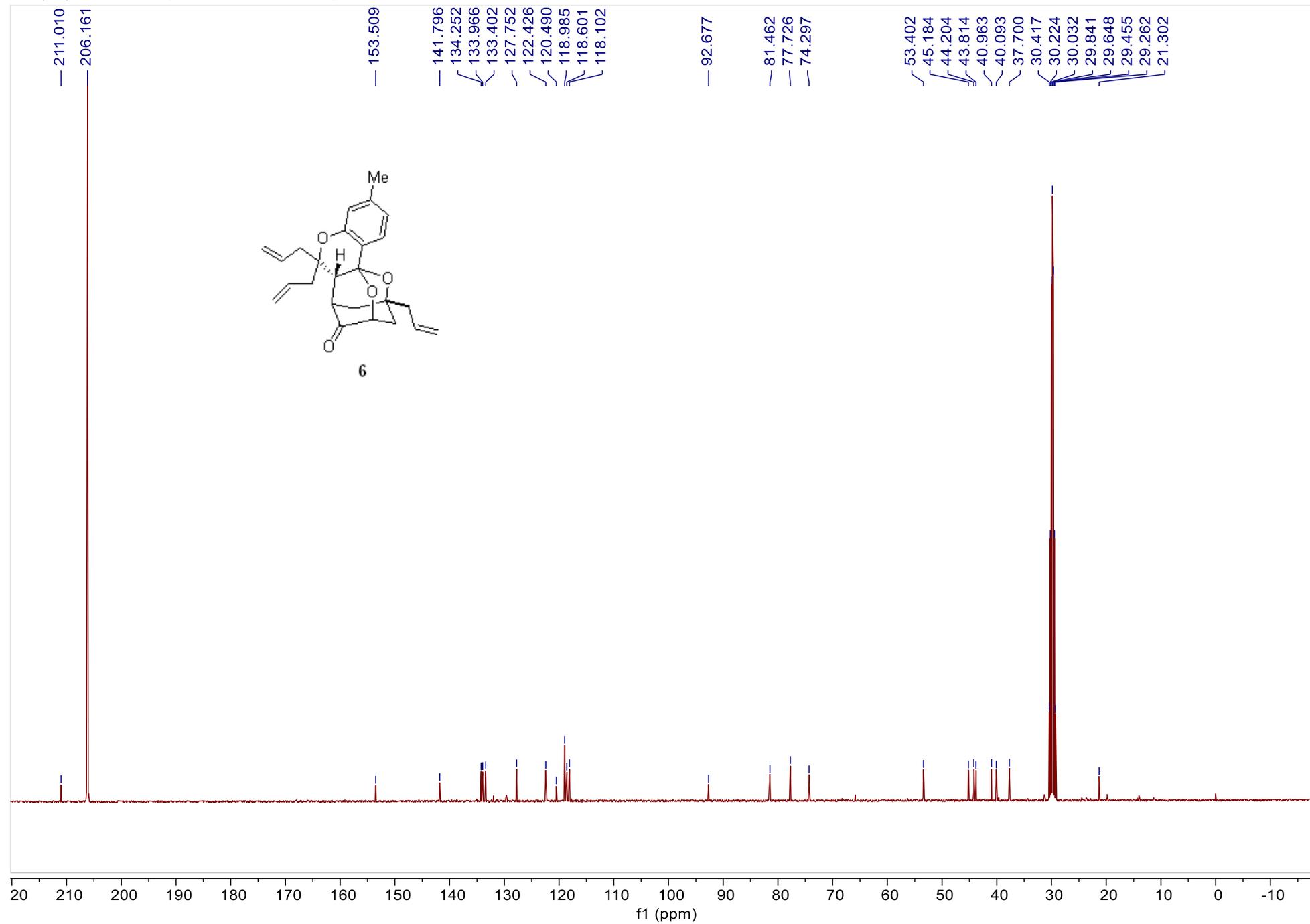
$^{13}\text{C}\{^1\text{H}\}$  NMR of **5p** (101 MHz, acetone- $d_6$ )



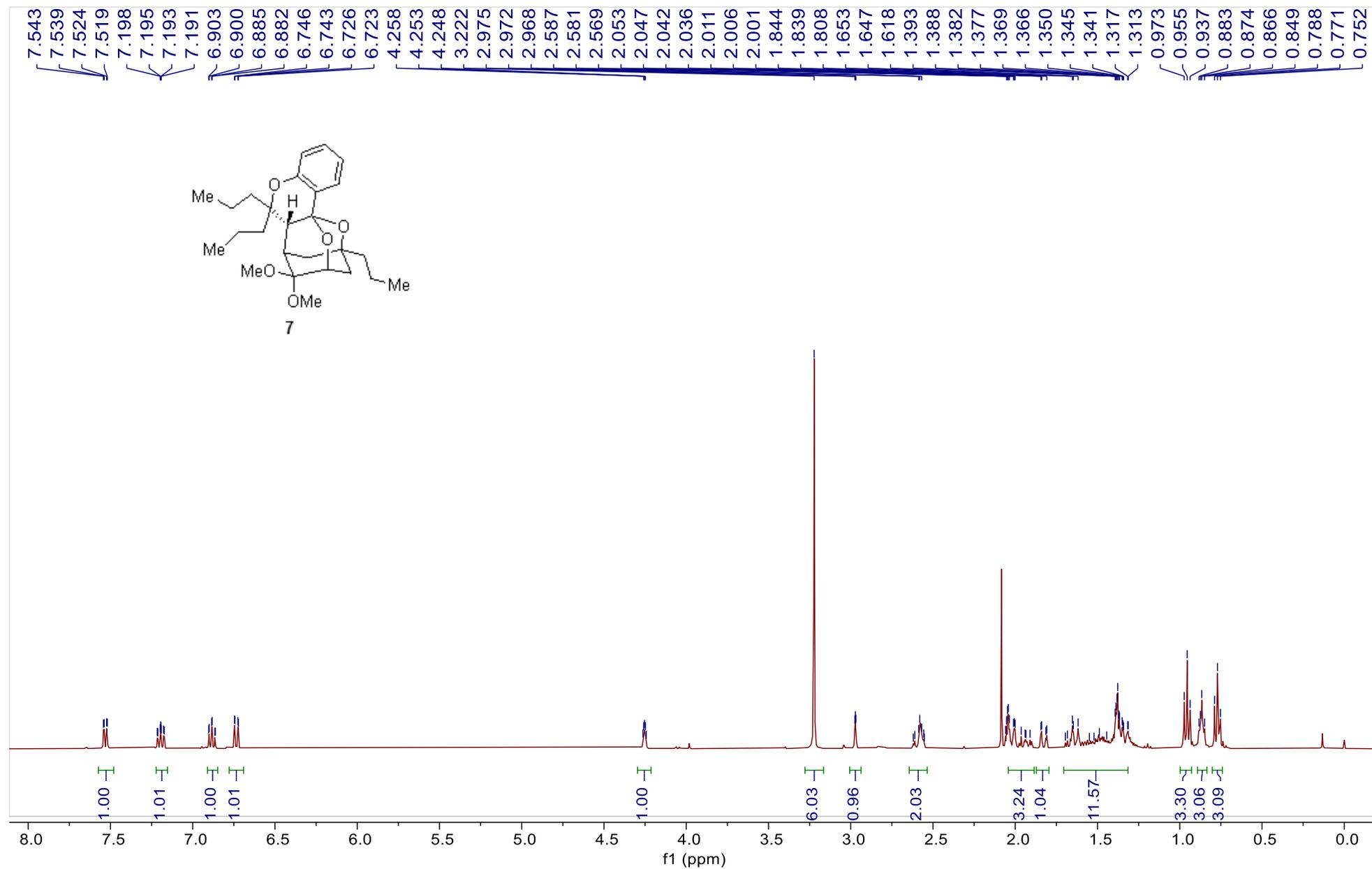
<sup>1</sup>H NMR of 6 (400 MHz, acetone-d<sub>6</sub>)



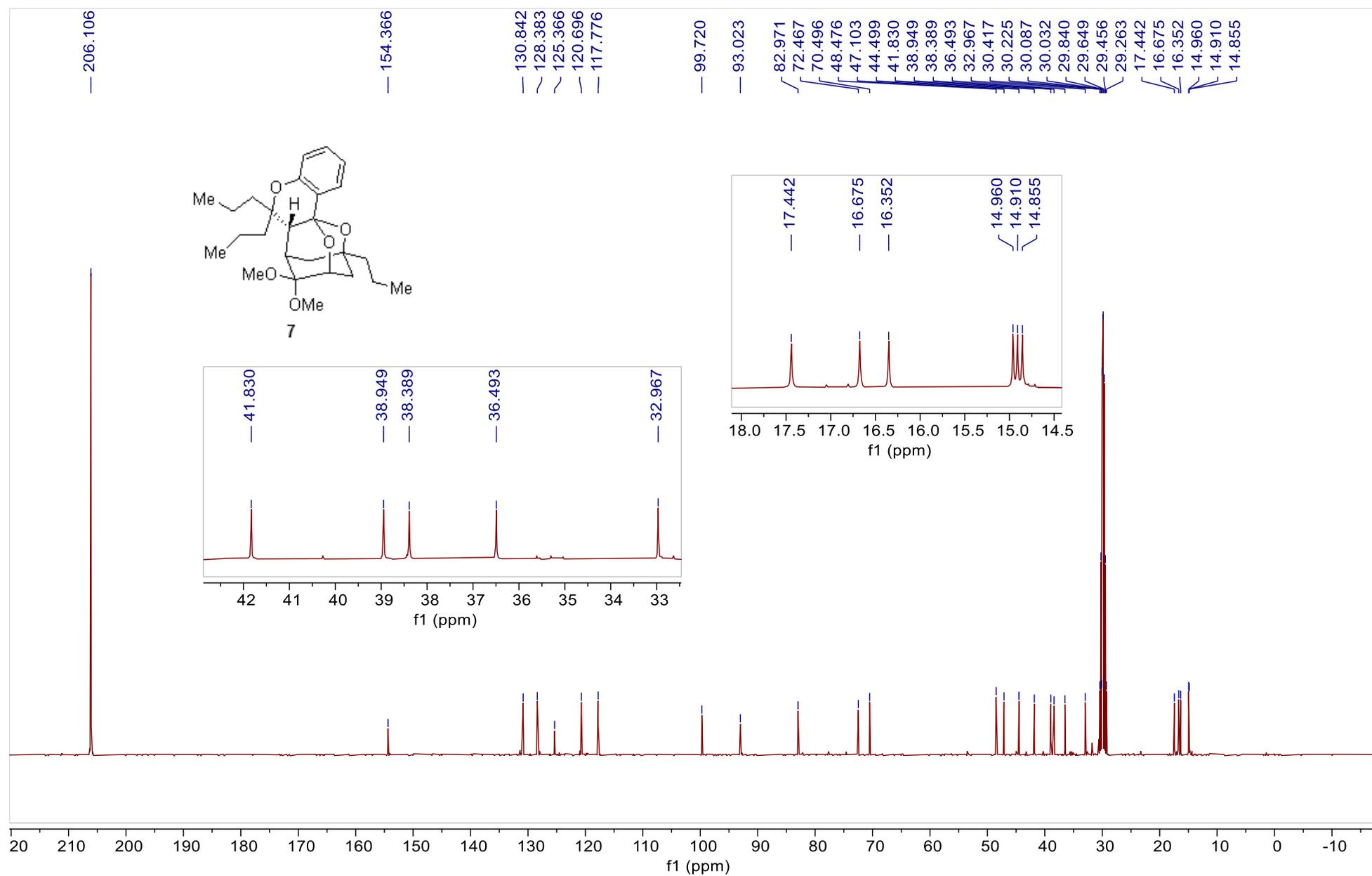
$^{13}\text{C}\{^1\text{H}\}$  NMR of **6** (101MHz, acetone- $d_6$ )



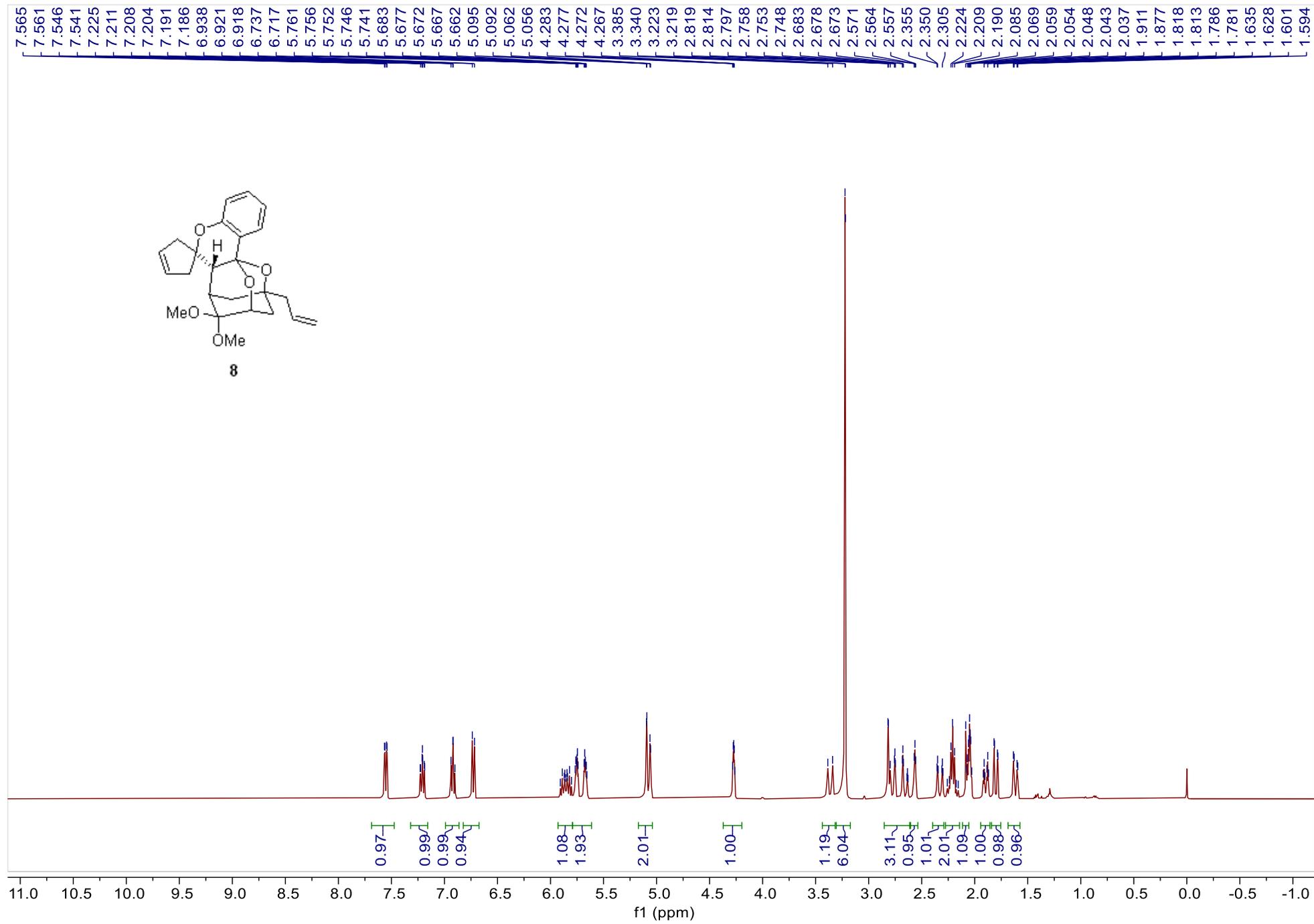
<sup>1</sup>H NMR of 7 (400 MHz, acetone-d<sub>6</sub>)



$^{13}\text{C}\{^1\text{H}\}$  NMR of **7** (101MHz, acetone- $\text{d}_6$ )



<sup>1</sup>H NMR of **8** (400MHz, acetone-d<sub>6</sub>)



$^{13}\text{C}\{^1\text{H}\}$  NMR of **8** (101 MHz, acetone- $d_6$ )

