

**Palladium-Catalyzed Intramolecular Arylative
Carboxylation of Allenes with CO₂ for the Construction of
3-Substituted Indole-2-Carboxylic Acids**

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(A) General

Infrared (IR) spectra were recorded on a JASCO FT/IR 460 Plus Fourier transform infrared spectrophotometer. NMR spectra were recorded on a JEOL ECA-500 spectrometer, operating at 500 MHz (^1H) or 125 MHz (^{13}C). Chemical shifts in CDCl_3 were reported in the scale relative to CHCl_3 (7.26 ppm) for ^1H NMR and to CDCl_3 (77.0 ppm) for ^{13}C NMR as internal references. EI mass spectra were measured on a JEOL JMS-T100GCv. Column chromatography was performed with silica gel Kanto 60 (230-400 mesh ASTM). DMA was distilled under vacuum (ca. 10 mmHg) from CaH_2 . PdCl_2 was purchased from Wako Pure Chemical Industries, Ltd., and used as received. $\text{P}(\text{C}_6\text{H}_4\text{-}p\text{-CF}_3)_3$ was purchased from Sigma-Aldrich Co. LLC., and used as received. ZnEt_2 (1 M in hexane) was purchased from Kanto Chemical Co., Inc., and used as received. A cylinder of CO_2 was purchased from Hokkaido Air Water, Inc. In general, reactions were carried out under an argon atmosphere unless otherwise noted. **Caution!** TMSCHN_2 is potentially explosive, especially when CH_2N_2 is generated after a long time in storage.

(B) Investigation of Catalyst Loading

In palladium-catalyzed cyclization/carboxylation sequence, the loading of PdCl_2 was investigated (Table S1) to reveal that the use of 1 mol % of PdCl_2 and 2 mol % of $\text{P}(\text{C}_6\text{H}_4\text{-}p\text{-CF}_3)_3$ also afforded the desired product **2a** in high yield (entry 3). In addition, the larger-scale reaction (**1a**: 6.00 mmol, 2.14 g) was successful without decrease of the yield (entry 4: the result in Scheme 1).

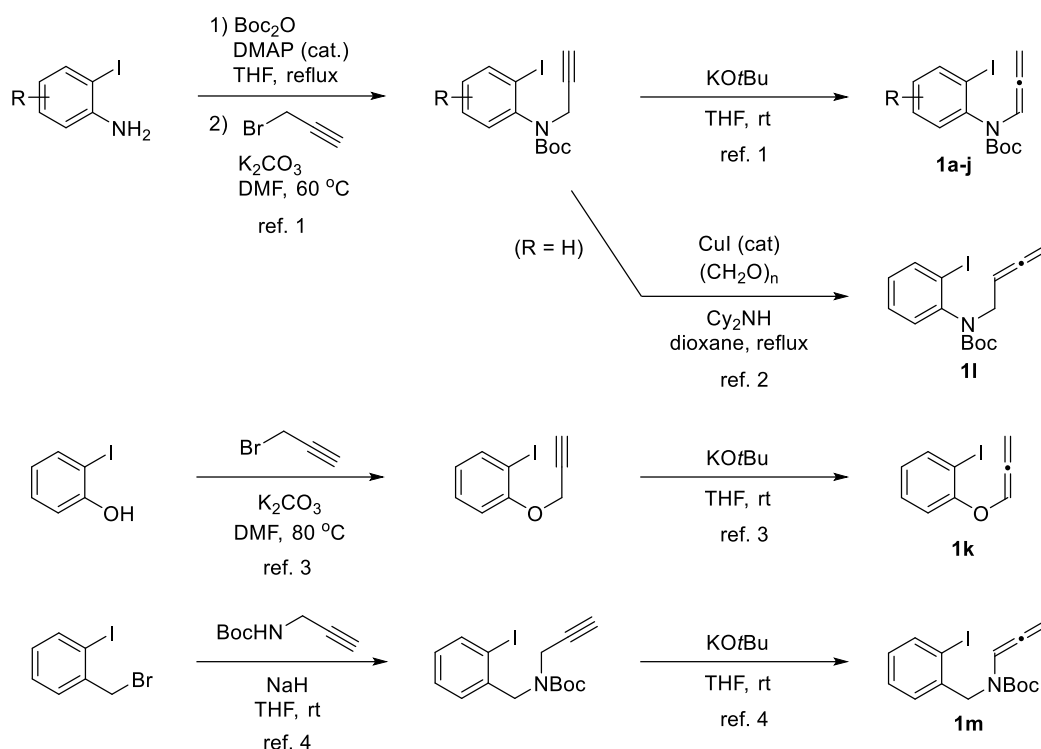
Table S1. Investigation of Pd Catalyst Loading

Entry	1a (mmol)	PdCl_2 (x mol%)	$\text{P}(\text{C}_6\text{H}_4\text{-}p\text{-CF}_3)_3$ (y mol%)	Yield of 2a or 2a''' (%) ^a
1	0.20	10 (3.5 mg)	20	2a : 89 (86)
2	0.20	5 (1.8 mg)	10	2a : 86 (84)
3	1.00	1 (1.8 mg)	2	2a : 82 (81)
4	6.00	1 (10.6 mg)	2	2a''' : (84)

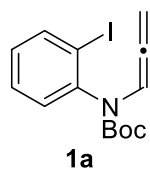
^a Yields were determined by ^1H NMR analysis using 1,1,2,2-tetrachloroethane as an internal standard. Isolated yields are given in parentheses.

(C) Synthesis of Substrates

N-Allenyl-2-iodoanilines **1a-j**¹ and other allenes (**1l**,² **1k**,³ and **1m**⁴) were synthesized according to the reported methods.



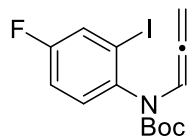
tert-Butyl (2-Iodophenyl)(propa-1,2-dien-1-yl)carbamate (**1a**)



1a

White solids; m.p. 63-65 °C; IR (CHCl₃): 3018, 2980, 2932, 1705, 1472, 1369, 1323, 1216, 1163, 757 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.84 (d, *J* = 7.7 Hz, 1H), 7.34 (t, *J* = 7.7 Hz, 1H), 7.31-7.23 (m, 1H), 7.22-7.10 (m, 1H), 7.00 (t, *J* = 7.7 Hz, 1H), 5.05-4.94 (m, 2H), 1.57 & 1.37 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.6, 151.4, 141.9, 139.2, 129.5, 129.1, 128.7, 101.0, 99.6, 86.8, 81.5, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₄H₁₆INO₂ [M]⁺: 357.0226. Found: 357.0225.

tert-Butyl (4-Fluoro-2-iodophenyl)(propa-1,2-dien-1-yl)carbamate (**1b**)



1b

White solids; m.p. 79-81 °C; IR (CHCl₃): 3019, 2980, 2932, 1706, 1485, 1369, 1322, 1216, 1164, 764 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.59-7.52 (m, 1H), 7.31-7.18 (m, 1H), 7.17-7.10 (m, 1H), 7.09-7.02 (m, 1H), 5.08-4.95 (m, 2H), 1.56 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.5, 160.8 (d, *J*_{CF} = 250.4 Hz), 151.3, 138.3, 130.1 (d, *J*_{CF} = 8.3 Hz), 126.1 (d, *J*_{CF} = 23.9 Hz), 115.8 (d, *J*_{CF} = 21.5 Hz), 101.1, 99.4 (d, *J*_{CF} = 8.3 Hz), 87.1, 81.7, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₀H₇FINO₂

¹ a) H. Fuwa, M. Sasaki, *Org. Biomol. Chem.* **2007**, *5*, 2214; b) M.-G. Braun, M. H. Katcher, A. G. Doyle, *Chem. Sci.* **2013**, *4*, 1216.

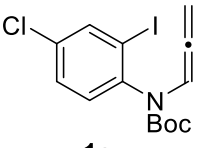
² K. Suzuki, H. Iwasaki, F. Ichiyoshi, M. Tominaga, N. Kojima, M. Ozeki, M. Yamashita, *Heterocycles* **2015**, *91*, 1244.

³ R. Grigg, J. M. Sansano, V. Santhakumar, V. Sridharan, R. Thangavelanthum, M. Thornton-Pett, D. Wilson, *Tetrahedron* **1997**, *53*, 11803.

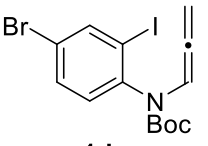
⁴ L. Shen, R. P. Hsung, *Org. Lett.* **2005**, *7*, 775.

[M-C₄H₈]⁺: 318.9506. Found: 318.9500.

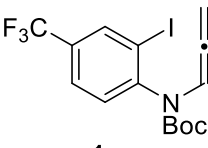
tert-Butyl (4-Chloro-2-iodophenyl)(propa-1,2-dien-1-yl)carbamate (**1c**)


1c White solids; m.p. 91-93 °C; IR (CHCl₃): 3019, 2980, 1707, 1472, 1368, 1321, 1216, 1163, 1016, 759 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.83 (s, 1H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.28-7.23 & 7.19-7.16 (m, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 5.08-4.97 (m, 2H), 1.56 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.4, 151.1, 140.7, 138.6, 133.7, 130.0, 129.1, 100.9, 99.9, 87.2, 81.8, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₀H₇ClINO₂ [M-C₄H₈]⁺: 334.9210. Found: 334.9202.

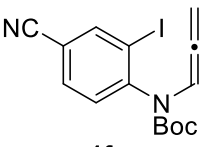
tert-Butyl (4-Bromo-2-iodophenyl)(propa-1,2-dien-1-yl)carbamate (**1d**)


1d White solids; m.p. 81-83 °C; IR (CHCl₃): 3017, 2980, 2932, 1710, 1469, 1368, 1321, 1163, 1014, 759 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.98 (s, 1H), 7.46 (d, *J* = 8.0 Hz, 1H), 7.29-7.21 (m, 1H), 7.14-7.02 (m, 1H), 5.09-4.98 (m, 2H), 1.56 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.4, 151.0, 141.3, 141.2, 132.0, 130.5, 121.7, 100.8, 100.4, 87.3, 81.9, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₀H₇BrINO₂ [M-C₄H₈]⁺: 378.8705. Found: 378.8703.

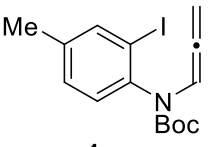
tert-Butyl (2-Iodo-4-(trifluoromethyl)phenyl)(propa-1,2-dien-1-yl)carbamate (**1e**)


1e White solids; m.p. 74-76 °C; IR (CHCl₃): 3009, 2981, 2933, 1710, 1370, 1319, 1176, 1135, 1018, 761 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 8.09 (s, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.39-7.25 & 7.16-7.06 (m, 2H), 5.08-4.98 (m, 2H), 1.57 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.2, 150.8, 145.3, 136.3, 129.9, 126.1, 125.9, 122.2 (q, *J*_{CF} = 272.3 Hz), 100.7, 99.7, 87.5, 82.2, 28.0 ppm; HRMS (EI) *m/z* calcd for C₁₅H₁₅F₃INO₂ [M]⁺: 425.0100. Found: 425.0091.

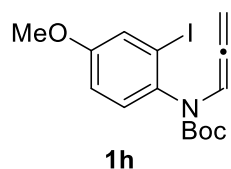
tert-Butyl (4-Cyano-2-iodophenyl)(propa-1,2-dien-1-yl)carbamate (**1f**)


1f White solids; m.p. 121-123 °C; IR (CHCl₃): 3020, 2981, 2234, 1712, 1369, 1321, 1216, 1160, 1018, 758 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 8.13 (s, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.37-7.03 (m, 2H), 5.08-4.98 (m, 2H), 1.56 & 1.37 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.2, 150.5, 146.4, 142.7, 132.6, 130.3, 116.7, 113.1, 100.6, 100.1, 87.7, 82.5, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₅H₁₅IN₂O₂ [M]⁺: 382.0178. Found: 382.0177.

tert-Butyl (2-Iodo-4-methylphenyl)(propa-1,2-dien-1-yl)carbamate (**1g**)

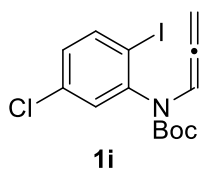

1g White solids; m.p. 79-81 °C; IR (CHCl₃): 3010, 2977, 2929, 1698, 1447, 1369, 1323, 1164, 1017, 761 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.66 (s, 1H), 7.30-7.24 (m, 1H), 7.17-7.08 (m, 1H), 7.04 (d, *J* = 8.0 Hz, 1H), 5.05-4.95 (m, 2H), 2.31 (s, 3H), 1.56 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.7, 151.5, 139.6, 139.2, 139.1, 129.5, 128.9, 101.1, 99.3, 86.7, 81.3, 28.1, 20.6 ppm; HRMS (EI) *m/z* calcd for C₁₁H₁₀INO₂ [M-C₄H₈]⁺: 314.9756. Found: 314.9755.

tert-Butyl (2-Iodo-4-methoxyphenyl)(propa-1,2-dien-1-yl)carbamate (**1h**)



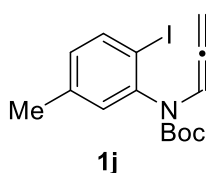
White solids; m.p. 74-76 °C; IR (CHCl₃): 3017, 2980, 1703, 1492, 1369, 1324, 1217, 1164, 1036, 759 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.34 (s, 1H), 7.30-7.24 (m, 1H), 7.15-7.03 (m, 1H), 6.85 (d, *J* = 8.0 Hz, 1H), 5.06-4.95 (m, 2H), 3.79 (s, 3H), 1.56 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.7, 158.7, 151.7, 134.9, 129.4, 123.9, 114.4, 101.4, 99.7, 86.7, 81.3, 55.5, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₁H₁₀INO₃ [M-C₄H₈]⁺: 330.9705. Found: 330.9704.

tert-Butyl (5-Chloro-2-iodophenyl)(propa-1,2-dien-1-yl)carbamate (**1i**)



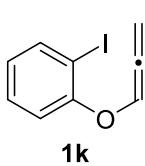
White solids; m.p. 77-79 °C; IR (CHCl₃): 3016, 2979, 2932, 1710, 1465, 1357, 1316, 1161, 1015, 762 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.75 (d, *J* = 7.8 Hz, 1H), 7.29-7.22 (m, 1H), 7.21-7.15 & 7.12-7.05 (m, 1H), 7.01 (d, *J* = 7.8 Hz, 1H), 5.08-5.01 (m, 2H), 1.56 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.3, 150.9, 143.0, 139.9, 134.3, 129.7, 129.4, 100.8, 97.1, 87.3, 82.0, 28.0 ppm; HRMS (EI) *m/z* calcd for C₁₄H₁₅ClINO₂ [M]⁺: 390.9836. Found: 390.9830.

tert-Butyl (2-Iodo-5-methylphenyl)(propa-1,2-dien-1-yl)carbamate (**1j**)



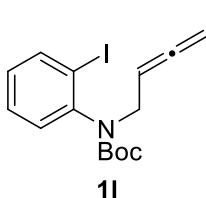
White solids; m.p. 78-81 °C; IR (CHCl₃): 3019, 2980, 1704, 1367, 1322, 1256, 1216, 1157, 1017, 759 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.68 (d, *J* = 7.8 Hz, 1H), 7.30-7.23 & 7.16-7.09 (m, 1H), 7.08-7.03 & 7.02-6.96 (m, 1H), 6.81 (d, *J* = 7.8 Hz, 1H), 5.05-4.94 (m, 2H), 2.30 (s, 3H), 1.57 & 1.38 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.7, 151.4, 141.6, 139.1, 138.9, 138.7, 130.1, 101.0, 95.3, 86.7, 81.4, 28.1, 20.8 ppm; HRMS (EI) *m/z* calcd for C₁₁H₁₀INO₂ [M-C₄H₈]⁺: 314.9756. Found: 314.9750.

1-Iodo-2-(propa-1,2-dien-1-yloxy)benzene (**1k**)³



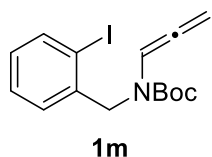
Colorless oil; ¹H NMR (500 MHz, CDCl₃): δ = 7.79 (d, *J* = 8.1 Hz, 1H), 7.31 (t, *J* = 8.1 Hz, 1H), 7.08 (d, *J* = 8.1 Hz, 1H), 6.85-6.79 (m, 2H), 5.45 (s, 1H), 5.44 (s, 1H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 202.4, 156.2, 139.6, 129.3, 124.7, 118.4, 116.8, 90.4, 87.2 ppm; The spectral data of **1k** was consistent with the reported one.³

tert-Butyl Buta-2,3-dien-1-yl(2-iodophenyl)carbamate (**1l**)²



Pale yellow solids; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.85 (d, *J* = 7.6 Hz, 1H), 7.32 (t, *J* = 7.6 Hz, 1H), 7.28 & 7.19 (d, *J* = 7.6 Hz, 1H), 6.97 (t, *J* = 7.8 Hz, 1H), 5.31-5.22 (m, 1H), 4.77-4.62 (m, 2H), 4.54-4.41 (m, 1H), 3.78-3.65 (m, 1H), 1.53 & 1.35 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 209.3, 153.7, 144.2, 139.2, 129.9, 128.7, 128.6, 100.6, 86.7, 80.3, 76.0, 48.1, 28.2 ppm; The spectral data of **1l** was consistent with the reported one.²

tert-Butyl (2-Iodobenzyl)(propa-1,2-dien-1-yl)carbamate (**1m**)⁴

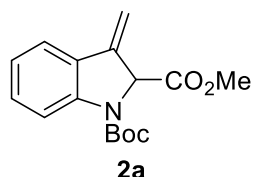


Pale yellow oil; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.80 (d, *J* = 7.5 Hz, 1H), 7.33-6.89 (m, 4H), 5.25-5.10 (m, 2H), 4.57-4.45 (m, 2H), 1.54 & 1.37 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 201.3, 152.8, 139.1, 128.4, 128.2, 126.1, 100.6, 97.1, 87.8, 81.4, 54.1, 28.1 ppm; The spectral

data of **1m** was consistent with the reported one.⁴

(D) Pd-Catalyzed Intramolecular Arylative Carboxylation of Allene Derivatives **1a-m**

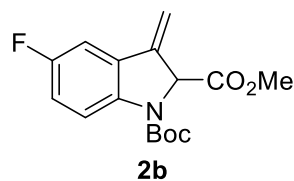
PdCl₂ (3.5 mg, 0.02 mmol, 10 mol %) and P(C₆H₄-*p*-CF₃)₃ (18.7 mg, 0.04 mmol, 20 mol %) were placed on the bottom of a sealed tube containing a stirring bar. The tube was evacuated and refilled with CO₂ (balloon) three times. After the addition of DMA (0.5 mL), the mixture was stirred at room temperature for 10 min under CO₂ atmosphere (1 atm, balloon). *N*-Allenyl-2-iodoaniline **1a** (71.4 mg, 0.20 mmol) in DMA (0.5 mL) and ZnEt₂ (1 M solution in hexane, 0.6 mL, 0.60 mmol, 3.0 equiv) were added at 0 °C, and then the tube was closed. The resulting reaction mixture was stirred at room temperature for 16 h. HCl aq. (3 M) and water were added at 0 °C, and the mixture (pH < 2) was extracted with Et₂O three times. The combined organic layer was washed with brine, dried over Na₂SO₄, and removed under reduced pressure. The residue was dissolved in Et₂O/MeOH = 4:1 (ca. 2 mL) followed by treatment with TMSCHN₂ (2 M in Et₂O, 110 μL, 0.22 mmol, 1.1 equiv). After 10 min, the mixture was directly concentrated under high vacuum to afford the crude product, which was then purified by silica gel column chromatography (hexane/AcOEt, 95:5), affording 1-(*tert*-butyl) 2-methyl 3-methyleneindoline-1,2-dicarboxylate (**2a**) (49.7 mg, 0.172 mmol) as white solids in 86% yield.



m.p. 64-67 °C; IR (neat): 2975, 2932, 1757, 1719, 1478, 1385, 1257, 1153, 1027, 752 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.97 & 7.55 (d, *J* = 7.7 Hz, 1H), 7.40 (d, *J* = 7.7 Hz, 1H), 7.28 (t, *J* = 7.7 Hz, 1H), 6.99 (t, *J* = 7.7 Hz, 1H), 5.55 (s, 1H), 5.37-5.27 (m, 2H), 3.77 (s, 3H), 1.61 & 1.50 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.8, 150.6, 144.7, 139.9, 130.5, 127.1, 122.7, 120.5, 115.1, 103.8, 81.7, 65.6, 52.6, 28.2 ppm; HRMS (EI) *m/z* calcd for C₁₆H₁₉NO₄ [M]⁺: 289.1314. Found: 289.1318.

1-(*tert*-Butyl) 2-Methyl 5-Fluoro-3-methyleneindoline-1,2-dicarboxylate (**2b**)

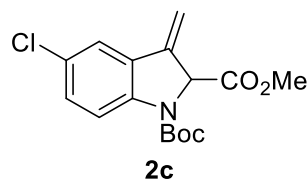
(**1b**: 75.0 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 95:5) to afford **2b** (53.3 mg, 0.173 mmol) as pale yellow oil in 87% yield.)



IR (CHCl₃): 3020, 2980, 2954, 1754, 1710, 1483, 1385, 1216, 1157, 764 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.94-7.89 & 7.50-7.44 (m, 1H), 7.08-7.03 (m, 1H), 7.00-6.91 (m, 1H), 5.52 (s, 1H), 5.41-5.27 (m, 2H), 3.77 (s, 3H), 1.60 & 1.48 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.5, 159.0 (d, *J*_{CF} = 239.6 Hz), 150.5, 140.8, 139.2 (d, *J*_{CF} = 3.5 Hz), 128.6 (d, *J*_{CF} = 9.5 Hz), 117.0 (d, *J*_{CF} = 23.9 Hz), 116.0 (d, *J*_{CF} = 8.4 Hz), 107.3 (d, *J*_{CF} = 25.1 Hz), 105.3, 81.8, 65.8, 52.6, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₆H₁₈FNO₄ [M]⁺: 307.1220. Found: 307.1214.

1-(*tert*-Butyl) 2-Methyl 5-Chloro-3-methyleneindoline-1,2-dicarboxylate (**2c**)

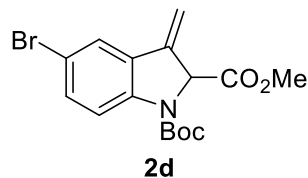
(**1c**: 78.3 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 95:5) to afford **2c** (57.0 mg, 0.176 mmol) as pale yellow oil in 88% yield.)



IR (CHCl₃): 3021, 2979, 2954, 2932, 1753, 1713, 1473, 1377, 1157, 758 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.90 & 7.45 (d, *J* = 8.5 Hz, 1H), 7.34 (d, *J* = 2.2 Hz, 1H), 7.22 (dd, *J* = 8.5, 2.2 Hz, 1H), 5.55 (s, 1H), 5.41-5.27 (m, 2H), 3.77 (s, 3H), 1.60 & 1.49 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.4, 150.4, 143.2, 138.8, 130.2, 128.7, 128.1, 120.6, 116.1, 105.4, 82.0, 65.8, 52.7, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₆H₁₈ClNO₄ [M]⁺: 323.0924. Found: 323.0913.

1-(*tert*-Butyl) 2-Methyl 5-Bromo-3-methyleneindoline-1,2-dicarboxylate (**2d**)

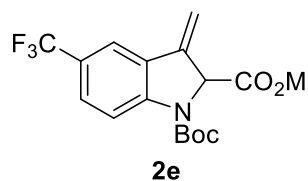
(**1d**: 87.0 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 95:5) to afford **2d** (60.2 mg, 0.163 mmol) as yellow oil in 82% yield.)



IR (CHCl₃): 3020, 2979, 2953, 2932, 1753, 1719, 1471, 1375, 1156, 757 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.84 & 7.40 (d, *J* = 8.5 Hz, 1H), 7.48 (d, *J* = 1.7 Hz, 1H), 7.36 (dd, *J* = 8.5, 1.7 Hz, 1H), 5.53 (s, 1H), 5.41-5.25 (m, 2H), 3.77 (s, 3H), 1.59 & 1.48 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.4, 150.4, 143.7, 138.6, 133.0, 129.1, 123.5, 116.6, 115.4, 105.4, 82.0, 65.7, 52.7, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₆H₁₈BrNO₄ [M]⁺: 367.0419. Found: 367.0419.

1-(*tert*-Butyl) 2-Methyl 3-Methylene-5-(trifluoromethyl)indoline-1,2-dicarboxylate (**2e**)

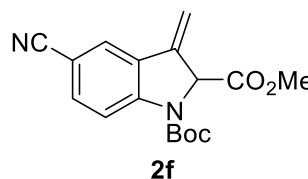
(**1e**: 85.0 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 95:5) to afford **2e** (56.1 mg, 0.157 mmol) as pale yellow oil in 78% yield.)



IR (neat): 2979, 2956, 2934, 1758, 1724, 1381, 1325, 1270, 1162, 736 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 8.06 (d, *J* = 8.5 Hz, 1H), 7.61 (s, 1H), 7.53 (d, *J* = 8.5 Hz, 1H), 5.65 (s, 1H), 5.49-5.31 (m, 2H), 3.79 (s, 3H), 1.62 & 1.50 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.3, 150.4, 147.2, 138.7, 127.6 (q, *J*_{CF} = 3.6 Hz), 127.5, 125.0 (q, *J*_{CF} = 33.0 Hz), 124.2 (q, *J*_{CF} = 270.3 Hz), 117.7, 115.1, 105.9, 82.4, 65.9, 52.8, 28.1 ppm; HRMS (EI) *m/z* calcd for C₁₇H₁₈F₃NO₄ [M]⁺: 357.1188. Found: 357.1183.

1-(*tert*-Butyl) 2-Methyl 5-Cyano-3-methyleneindoline-1,2-dicarboxylate (**2f**)

(**1f**: 76.4 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 5:1) to afford **2f** (50.1 mg, 0.159 mmol) as white solids in 80% yield.)

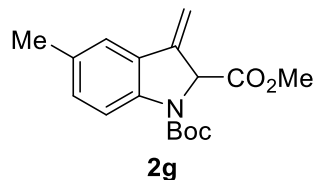


m.p. 135-138 °C; IR (CHCl₃): 3020, 2980, 2227, 1754, 1720, 1480, 1373, 1216, 1153, 763 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 8.05 & 7.58 (d, *J* = 8.3 Hz, 1H), 7.63 (s, 1H), 7.55 (d, *J* = 8.3 Hz, 1H), 5.65 (s, 1H), 5.48 & 5.45 (s, 1H), 5.39 & 5.33 (s, 1H), 3.79 (s, 3H), 1.61 & 1.49 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.0, 150.1, 147.9, 137.9, 134.6, 128.0,

124.3, 118.9, 115.6, 106.8, 105.9, 82.9, 65.8, 52.8, 28.0 ppm; HRMS (EI) m/z calcd for $C_{17}H_{18}N_2O_4$ $[M]^+$: 314.1267. Found: 314.1261.

1-(*tert*-Butyl) 2-Methyl 5-Methyl-3-methyleneindoline-1,2-dicarboxylate (**2g**)

(**1g**: 74.2 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 95:5) to afford **2g** (55.6 mg, 0.183 mmol) as pale yellow oil in 92% yield.)

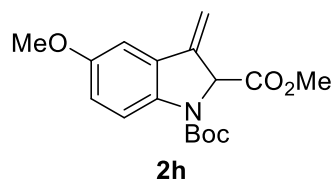


IR (CHCl₃): 3022, 2979, 2953, 2929, 1754, 1715, 1489, 1384, 1157, 758 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.84 & 7.43 (d, J = 8.5 Hz, 1H), 7.20 (s, 1H), 7.09 & 7.06 (d, J = 8.5 Hz, 1H), 5.51 (s, 1H), 5.35-5.25 (m, 2H), 3.76 (s, 3H), 2.30 (s, 3H), 1.60 &

1.49 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.9, 150.5, 142.5, 140.0, 132.3, 131.2, 127.0, 120.8, 114.8, 103.5, 81.4, 65.7, 52.5, 28.2, 20.8 ppm; HRMS (EI) m/z calcd for $C_{17}H_{21}NO_4$ $[M]^+$: 303.1471. Found: 303.1464.

1-(*tert*-Butyl) 2-Methyl 5-Methoxy-3-methyleneindoline-1,2-dicarboxylate (**2h**)

(**1h**: 77.4 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 5:1) to afford **2h** (53.1 mg, 0.166 mmol) as gray solids in 83% yield.)

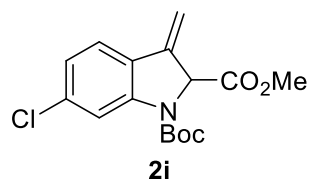


m.p. 112-114 °C; IR (CHCl₃): 3019, 2979, 2954, 1753, 1706, 1488, 1389, 1217, 1158, 761 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.88 & 7.45 (d, J = 8.5 Hz, 1H), 6.91 (d, J = 2.5 Hz, 1H), 6.85 (dd, J = 8.5, 2.5 Hz, 1H), 5.51 (s, 1H), 5.37-5.26 (m, 2H),

3.78 (s, 3H), 3.76 (s, 3H), 1.60 & 1.48 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 169.8, 155.8, 150.5, 139.9, 138.7, 128.0, 116.6, 115.8, 105.4, 104.0, 81.4, 65.8, 55.7, 52.5, 28.2 ppm; HRMS (EI) m/z calcd for $C_{17}H_{21}NO_5$ $[M]^+$: 319.1420. Found: 319.1410.

1-(*tert*-Butyl) 2-Methyl 6-Chloro-3-methyleneindoline-1,2-dicarboxylate (**2i**)

(**1i**: 78.3 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 10:1) to afford **2i** (56.8 mg, 0.175 mmol) as colorless oil in 88% yield.)

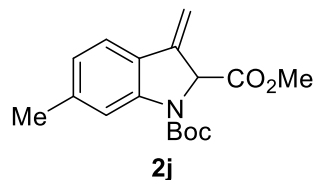


IR (CHCl₃): 3020, 2979, 1753, 1713, 1479, 1381, 1216, 1157, 1028, 758 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 8.02 & 7.54 (s, 1H), 7.28 (d, J = 8.0 Hz, 1H), 6.95 (d, J = 8.0 Hz, 1H), 5.52 (s, 1H), 5.38-5.26 (m, 2H), 3.77 (s, 3H), 1.61 & 1.49 (s, 9H) ppm; ¹³C

NMR (125 MHz, CDCl₃): δ = 169.4, 150.4, 145.5, 138.9, 136.2, 125.7, 123.0, 121.2, 115.5, 104.5, 82.2, 65.9, 52.7, 28.1 ppm; HRMS (EI) m/z calcd for $C_{16}H_{18}ClNO_4$ $[M]^+$: 323.0924. Found: 323.0919.

1-(*tert*-Butyl) 2-Methyl 6-Methyl-3-methyleneindoline-1,2-dicarboxylate (**2j**)

(**1j**: 74.2 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 95:5) to afford **2j** (51.1 mg, 0.168 mmol) as pale yellow oil in 84% yield.)



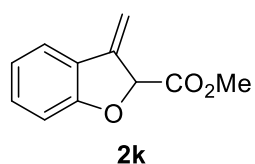
IR (neat): 2978, 2952, 2930, 1758, 1717, 1385, 1173, 1153, 1028, 733 cm⁻¹; “&” indicates two rotamers are present in ¹H NMR. ¹H NMR (500 MHz, CDCl₃): δ = 7.88 & 7.45 (d, J = 8.5 Hz, 1H), 6.91 (d, J = 2.5 Hz, 1H), 6.85 (dd,

$J = 8.5, 2.5$ Hz, 1H), 5.51 (s, 1H), 5.37-5.26 (m, 2H), 3.78 (s, 3H), 3.76 (s, 3H), 1.60 & 1.48 (s, 9H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 169.8, 155.8, 150.5, 139.9, 138.7, 128.0, 116.6, 115.8, 105.4, 104.0, 81.4, 65.8, 55.7, 52.5, 28.2$ ppm; HRMS (EI) m/z calcd for $\text{C}_{17}\text{H}_{21}\text{NO}_5$ $[\text{M}]^+$: 319.1420. Found: 319.1410.

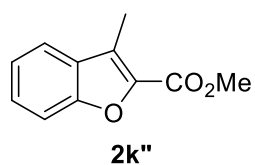
Methyl 3-Methylene-2,3-dihydrobenzofuran-2-carboxylate (**2k**)

Methyl 3-Methylbenzofuran-2-carboxylate (**2k''**)⁵

(**1k**: 51.6 mg, 0.20 mmol; These products were purified by silica gel column chromatography (hexane/AcOEt, 97:3), affording **2k** (25.5 mg, 0.134 mmol) as yellow oil in 67% yield and **2k''** (6.6 mg, 0.034 mmol) as yellow oil in 17% yield.)



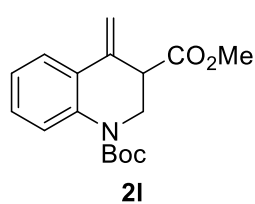
IR (neat): 2954, 2850, 1761, 1741, 1465, 1316, 1194, 1051, 1029, 749 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3): $\delta = 7.39$ (d, $J = 7.2$ Hz, 1H), 7.25 (t, $J = 7.2$ Hz, 1H), 6.99-6.93 (m, 2H), 5.62 (t, $J = 2.5$ Hz, 1H), 5.55 (d, $J = 2.5$ Hz, 1H), 5.35 (d, $J = 2.5$ Hz, 1H), 3.82 (s, 3H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 169.3, 162.5, 142.0, 130.9, 124.2, 121.6, 121.0, 110.8, 103.2, 82.0, 52.8$ ppm; HRMS (EI) m/z calcd for $\text{C}_{11}\text{H}_{10}\text{O}_3$ $[\text{M}]^+$: 190.0630. Found: 190.0626.



^1H NMR (500 MHz, CDCl_3): $\delta = 7.64$ (d, $J = 8.1$ Hz, 1H), 7.54 (t, $J = 8.1$ Hz, 1H), 7.46 (d, $J = 8.1$ Hz, 1H), 7.31 (d, $J = 8.1$ Hz, 1H), 3.99 (s, 3H), 2.60 (s, 3H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 160.9, 154.4, 140.7, 129.0, 127.9, 126.0, 123.2, 121.1, 112.2, 52.0, 9.3$ ppm; The spectral data of **2k''** was consistent with the reported one.⁵

1-(*tert*-Butyl) 3-Methyl 4-Methylene-3,4-dihydroquinoline-1,3(2*H*)-dicarboxylate (**2l**)

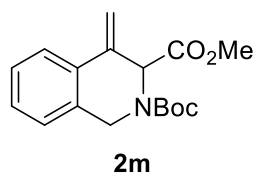
(**1l**: 74.2 mg, 0.20 mmol; ZnEt_2 was added over 8 hours, and the reaction mixture was then stirred for additional 8 hours.; The product was purified by silica gel column chromatography (hexane/AcOEt, 5:1) to afford **2l** (36.4 mg, 0.120 mmol) as yellow oil in 60% yield.)



IR (neat): 2977, 2952, 2930, 1739, 1704, 1368, 1245, 1163, 1061, 767 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3): $\delta = 7.67$ (d, $J = 7.8$ Hz, 1H), 7.57 (d, $J = 7.8$ Hz, 1H), 7.22 (t, $J = 7.8$ Hz, 1H), 7.06 (t, $J = 7.8$ Hz, 1H), 5.80 (s, 1H), 5.14 (s, 1H), 4.36 (dd, $J = 7.5, 4.5$ Hz, 1H), 3.74-3.66 (m, 5H), 1.51 (s, 9H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 172.1, 153.3, 137.7, 136.5, 128.0, 126.0, 124.6, 124.1, 124.0, 112.2, 81.2, 52.2, 47.4, 45.3, 28.2$ ppm; HRMS (EI) m/z calcd for $\text{C}_{17}\text{H}_{21}\text{NO}_4$ $[\text{M}]^+$: 303.1471. Found: 303.1467.

2-(*tert*-Butyl) 3-Methyl 4-Methylene-3,4-dihydroisoquinoline-2,3(1*H*)-dicarboxylate (**2m**)

(**1m**: 74.2 mg, 0.20 mmol; The product was purified by silica gel column chromatography (hexane/AcOEt, 10:1) to afford **2m** (31.2 mg, 0.103 mmol) as pale yellow oil in 51% yield.)



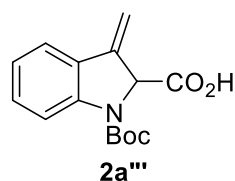
IR (CHCl_3): 3019, 2980, 2931, 1741, 1693, 1394, 1249, 1216, 1167, 758 cm^{-1} ; “&” indicates two rotamers are present in ^1H NMR. ^1H NMR (500 MHz, CDCl_3): $\delta = 7.61$ -7.54 (m, 1H), 7.29-7.10 (m, 3H), 5.75 & 5.72 (s, 1H), 5.61 & 5.41 (s, 1H), 5.39 & 5.37 (s, 1H), 4.71 & 4.70 (d, $J = 16.5$ Hz, 1H), 4.65 & 4.58 (d, $J = 16.5$ Hz, 1H), 3.66 & 3.64 (s, 3H), 1.52 & 1.49 (s, 9H) ppm; ^{13}C NMR (125 MHz, CDCl_3): $\delta = 170.8, 155.1, 136.3,$

⁵ G. Liu, Y. Shen, Z. Zhou, X. Lu, *Angew. Chem. Int. Ed.* **2013**, 52, 6033.

132.3, 130.6, 128.4, 126.8, 126.2, 124.6, 113.8, 80.9, 58.5, 52.4, 44.7, 28.4 ppm; HRMS (EI) m/z calcd for $C_{15}H_{18}NO_2 [M-CO_2Me]^+$: 244.1338. Found: 244.1336.

(E) Preparative Scale Procedure for Pd-Catalyzed Intramolecular Arylative Carboxylation of Allene **1a**

$PdCl_2$ (10.6 mg, 0.06 mmol, 1 mol %) and $P(C_6H_4-p-CF_3)_3$ (56.0 mg, 0.12 mmol, 2 mol %) were placed on the bottom of a round-bottom flask containing a stirring bar. The flask was evacuated and refilled with CO_2 (balloon) three times. After the addition of DMA (20 mL), the mixture was stirred at room temperature for 10 min under CO_2 atmosphere (1 atm, balloon). *N*-Allenyl-2-iodoaniline **1a** (2.14 g, 6.0 mmol) in DMA (10 mL) and $ZnEt_2$ (1 M solution in hexane, 18 mL, 18.0 mmol, 3.0 equiv) were added at 0 °C. The resulting reaction mixture was stirred at room temperature for 16 h. HCl aq. (3 M) and water were added at 0 °C, and the mixture (pH < 2) was extracted with Et_2O three times. The combined organic layer was washed with brine, dried over Na_2SO_4 , and removed under reduced pressure to afford the crude product. The product was then purified by silica gel column chromatography ($CH_2Cl_2/MeOH$, 15:1), affording 1-(*tert*-butoxycarbonyl)-3-methyleneindoline-2-carboxylic acid (**2a'''**) (1.39 g, 5.05 mmol) as white solids in 84% yield.

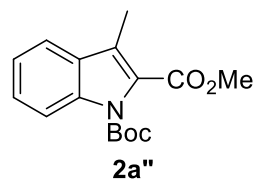


m.p. 85-88 °C; IR ($CHCl_3$): 3017, 2974, 2934, 1733, 1698, 1480, 1400, 1251, 1217, 755 cm^{-1} ; “&” indicates two rotamers are present in 1H NMR. 1H NMR (500 MHz, $CDCl_3$): δ = 7.96 & 7.54 (d, J = 7.7 Hz, 1H), 7.40 (d, J = 7.7 Hz, 1H), 7.28 (t, J = 7.7 Hz, 1H), 7.00 (t, J = 7.7 Hz, 1H), 6.13 (brs, 1H), 5.59 (s, 1H), 5.45-5.26 (m, 2H), 1.60 & 1.49 (s, 9H) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ = 175.0, 150.5, 144.5, 139.5, 130.6, 126.9, 122.9, 120.5, 115.1, 104.4, 82.1, 65.2, 28.2 ppm; HRMS (EI) m/z calcd for $C_{15}H_{17}NO_4 [M]^+$: 275.1158. Found: 275.1152.

(F) Derivatization of 3-Methyleneindoline-2-Carboxylate **2a**

(F-1) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-Methyl-1*H*-indole-1,2-dicarboxylate (**2a''**)

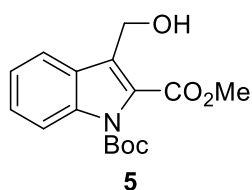
DBU (22.4 μ l, 0.15 mmol, 1.5 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in THF (1.0 mL), and the mixture was stirred at room temperature for 1 h. The solvent was then removed under reduced pressure to afford the crude product, which was then purified by silica gel column chromatography (hexane/ $AcOEt$, 10:1), affording the title compound (**2a''**) (28.8mg, 0.100 mmol) as colorless oil in a quantitative yield.



IR ($CHCl_3$): 3020, 2983, 2952, 1730, 1330, 1216, 1161, 1105, 1011, 755 cm^{-1} ; 1H NMR (500 MHz, $CDCl_3$): δ = 8.08 (d, J = 7.8 Hz, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.41 (t, J = 7.8 Hz, 1H), 7.28 (t, J = 7.8 Hz, 1H), 3.94 (s, 3H), 2.40 (s, 3H), 1.61 (s, 9H) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ = 163.1, 149.5, 136.8, 129.3, 126.8, 126.6, 123.5, 122.9, 120.1, 114.9, 84.1, 52.1, 27.9, 9.3 ppm; HRMS (EI) m/z calcd for $C_{16}H_{19}NO_4 [M]^+$: 289.1314. Found: 289.1312.

(F-2) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(Hydroxymethyl)-1*H*-indole-1,2-dicarboxylate (**5**)

DMDO⁶ (ca. 0.05 M solution in acetone, not dried, 3.0 mL, 0.15 mmol, 1.5 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in acetone (0.5 mL), and the mixture was stirred at room temperature for 1 h. The solvent was removed under reduced pressure to afford the crude product, which was then purified by silica gel column chromatography (hexane/AcOEt, 2:1), affording the title compound (**5**) (29.6 mg, 0.097 mmol) as colorless oil in 97% yield.



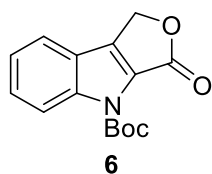
IR (CHCl₃): 3450, 2981, 2952, 2932, 1737, 1335, 1217, 1106, 1024, 755 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.08 (d, *J* = 7.6 Hz, 1H), 7.74 (d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 1H), 4.86 (s, 2H), 3.96 (s, 3H), 2.57 (brs, 1H), 1.62 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 163.2, 149.3, 136.8, 127.5, 127.3, 127.2, 126.9, 123.4, 120.5, 115.0, 84.8, 55.3, 52.6, 27.9 ppm; HRMS (EI) *m/z*

calcd for C₁₆H₁₉NO₅ [M]⁺: 305.1263. Found: 305.1263.

(F-3) Synthesis of 1,4-Dihydro-4-*tert*-butyloxycarbonyl-3*H*-furo[3,4-*b*]indol-3-one (**6**)⁷

DMDO⁶ (ca. 0.05 M solution in acetone, not dried, 3.0 mL, 0.15 mmol, 1.5 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in acetone (0.5 mL), and the mixture was stirred at room temperature for 1 h. After filtration through a short column of silica gel (hexane/AcOEt, 1:1), the filtrate was concentrated under reduced pressure affording the crude product (**5**), which was directly used in the next step.

A round bottomed flask was charged with the product (**5**), Zn₄(OCOCF₃)₆O⁸ (4.8 mg, 0.005 mmol, 5 mol %), and DMAP (12.2 mg, 0.10 mmol, 1.0 equiv). After toluene (10 mL) was added, the mixture was heated under reflux for 16 h. The resulting mixture was concentrated under reduced pressure to give the crude product, which was purified by silica gel column chromatography (hexane/AcOEt, 5:1), affording the title compound (**6**) (20.8 mg, 0.076 mmol) as white solids in 76% yield.

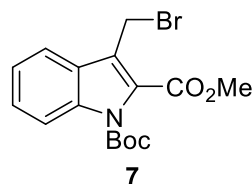


¹H NMR (500 MHz, CDCl₃): δ = 8.37 (d, *J* = 7.9 Hz, 1H), 7.60 (d, *J* = 7.9 Hz, 1H), 7.54 (t, *J* = 7.9 Hz, 1H), 7.36 (t, *J* = 7.9 Hz, 1H), 5.32 (s, 2H), 1.71 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 160.7, 148.8, 142.9, 142.7, 128.7, 128.2, 123.9, 121.5, 120.7, 117.1, 85.4, 65.1, 28.1 ppm; The spectral data of **6** was consistent with the

reported one.⁷

(F-4) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(Bromomethyl)-1*H*-indole-1,2-dicarboxylate (**7**)

NBS (29.4 mg, 0.165 mmol, 1.1 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (43.4 mg, 0.15 mmol) in CH₂Cl₂ (1.0 mL) at 0 °C, and the mixture was stirred at room temperature for 1 h. The residue was purified by silica gel column chromatography (hexane/AcOEt, 10:1), affording the title compound (**7**) (49.5 mg, 0.134 mmol) as white solids in 90% yield.



m.p. 71-74 °C; IR (CHCl₃): 3019, 2983, 1736, 1438, 1338, 1215, 1155, 1109, 1043, 765 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.09 (d, *J* = 7.8 Hz, 1H), 7.73 (d, *J* = 7.8 Hz, 1H), 7.45 (t, *J* = 7.8 Hz, 1H), 7.35 (t, *J* = 7.8 Hz, 1H), 4.78 (s, 2H), 3.99 (s, 3H),

⁶ D. F. Taber, P. W. DeMatteo, R. A. Hassan, *Org. Synth.* **2013**, *90*, 350.

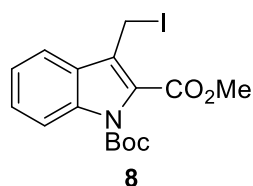
⁷ A. K. Jana, P. Pahari, D. Mal, *Synlett* **2012**, *23*, 1769.

⁸ Y. Maegawa, T. Ohshima, Y. Hayashi, K. Agura, T. Iwasaki, K. Mashima, *ACS Catal.* **2011**, *1*, 1178.

1.62 (s, 9H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 162.1, 148.9, 136.7, 127.7, 127.3, 126.8, 123.5, 122.2, 120.2, 115.1, 85.1, 52.6, 27.8, 21.5 ppm; HRMS (EI) m/z calcd for $\text{C}_{16}\text{H}_{18}\text{BrNO}_4$ $[\text{M}]^+$: 367.0419. Found: 367.0421.

(F-5) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(Iodomethyl)-1*H*-indole-1,2-dicarboxylate (**8**)

NIS (24.7 mg, 0.11 mmol, 1.1 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in CH_2Cl_2 (1.0 mL) at 0 °C, and the mixture was stirred at room temperature for 1 h. The residue was purified by silica gel column chromatography (hexane/AcOEt, 10:1), affording the title compound (**8**) (36.4 mg, 0.088 mmol) as pale yellow solids in 88% yield.

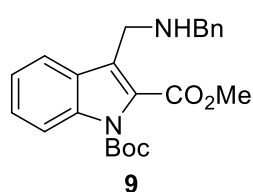


m.p. 83-85 °C; IR (CHCl_3): 3020, 2983, 2952, 1733, 1336, 1242, 1219, 1152, 1017, 757 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3): δ = 8.09 (d, J = 8.0 Hz, 1H), 7.68 (d, J = 8.0 Hz, 1H), 7.45 (t, J = 8.0 Hz, 1H), 7.36 (t, J = 8.0 Hz, 1H), 4.70 (s, 2H), 3.99 (s, 3H), 1.62 (s, 9H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 162.3, 148.9, 136.8, 127.4, 126.6, 126.2, 124.0, 123.3, 120.2, 115.0, 84.9, 52.5, 27.8, -7.8 ppm; HRMS (EI) m/z

calcd for $\text{C}_{12}\text{H}_9\text{INO}_3$ $[\text{M}-\text{O}t\text{Bu}]^+$: 341.9627. Found: 341.9626.

(F-6) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-((Benzylamino)methyl)-1*H*-indole-1,2-dicarboxylate (**9**)

NBS (19.6 mg, 0.11 mmol, 1.1 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in CH_2Cl_2 (1.0 mL) at 0 °C, and the mixture was stirred at room temperature for 1 h. H_2NBn (32.8 μl , 0.30 mmol, 3.0 equiv), K_2CO_3 (41.5 mg, 0.30 mmol, 3.0 equiv), and DMF (3.0 mL) were then added, and the resulting mixture was stirred at 50 °C for 2 h. After cooling to room temperature, water and Et_2O were added, and the mixture was extracted with Et_2O three times. The combined organic layer was washed with brine, dried over Na_2SO_4 , and removed under reduced pressure to afford the crude product. The product was then purified by silica gel column chromatography (hexane/AcOEt, 3:1), affording the title compound (**9**) (36.0 mg, 0.091 mmol) as colorless oil in 91% yield.



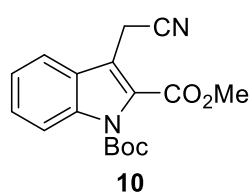
IR (CHCl_3): 3332, 3021, 2982, 2952, 2931, 1735, 1332, 1216, 1161, 755 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3): δ = 8.09 (d, J = 7.8 Hz, 1H), 7.68 (d, J = 7.8 Hz, 1H), 7.41 (t, J = 7.8 Hz, 1H), 7.35-7.22 (m, 6H), 3.98 (s, 2H), 3.87 (s, 3H), 3.82 (s, 2H), 1.85 (brs, 1H), 1.62 (s, 9H) ppm; ^{13}C NMR (125 MHz, CDCl_3): δ = 163.0, 149.3, 140.2, 136.6, 129.3, 128.3, 128.1, 127.8, 126.9, 126.7, 125.0, 123.1, 120.6, 115.0,

84.5, 53.2, 52.3, 42.3, 27.9 ppm; HRMS (EI) m/z calcd for $\text{C}_{23}\text{H}_{26}\text{N}_2\text{O}_4$ $[\text{M}]^+$: 394.1893. Found: 394.1889.

(F-7) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(Cyanomethyl)-1*H*-indole-1,2-dicarboxylate (**10**)

NBS (19.6 mg, 0.11 mmol, 1.1 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in CH_2Cl_2 (1.0 mL) at 0 °C, and the mixture was stirred at room temperature for 1 h. KCN (13.0 mg, 0.20 mmol, 2.0 equiv) and DMF (3.0 mL) were then added, and the resulting mixture was stirred at 50 °C for 6 h. After cooling to room temperature, water and Et_2O were added, and the mixture was extracted with Et_2O three times. The combined organic layer was washed with brine, dried over Na_2SO_4 , and removed under reduced pressure to afford the crude product. The product was then purified by silica gel column chromatography (hexane/AcOEt, 3:1), affording the title compound (**10**) (22.6 mg,

0.072 mmol) as white solids in 72% yield.

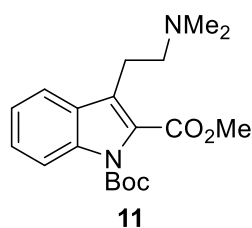


m.p. 106-110 °C; IR (CHCl₃): 3021, 2984, 2954, 2254, 1739, 1339, 1246, 1216, 1157, 765 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.10 (d, *J* = 8.3 Hz, 1H), 7.73 (d, *J* = 8.3 Hz, 1H), 7.49 (t, *J* = 8.3 Hz, 1H), 7.36 (t, *J* = 8.3 Hz, 1H), 3.99 (s, 2H), 3.98 (s, 3H), 1.62 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 161.8, 148.9, 136.7, 127.8, 127.7, 126.6, 123.8, 119.7, 116.4, 115.13, 115.12, 85.2, 52.6, 27.8, 13.4 ppm;

HRMS (EI) *m/z* calcd for C₁₇H₁₈N₂O₄ [M]⁺: 314.1267. Found: 314.1259.

(F-8) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(2-(Dimethylamino)ethyl)-1*H*-indole-1,2-dicarboxylate (**11**)

According to Buchwald's procedure,⁹ *N,N*-dimethylmethylethaniminium chloride (10.3 mg, 0.11 mmol, 1.1 equiv) was added to a solution of 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) in CH₃CN (2.0 mL) at 80 °C, and the mixture was stirred at the same temperature for 3 h. After cooling to room temperature, Et₂O was added, and the mixture was washed with 2M NaOH aq., water, and brine. The resulting organic layer was dried over Na₂SO₄, and removed under reduced pressure to afford the crude product, which was then purified by silica gel column chromatography (hexane/AcOEt = 60:40, then hexane/AcOEt/NEt₃ = 60:35:5), affording the title compound (**11**) (33.0 mg, 0.095 mmol) as white solids in 95% yield.



m.p. 48-51 °C; IR (CHCl₃): 3020, 2980, 2951, 2861, 2823, 1731, 1334, 1216, 1157, 762 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.08 (d, *J* = 7.4 Hz, 1H), 7.60 (d, *J* = 7.4 Hz, 1H), 7.40 (t, *J* = 7.4 Hz, 1H), 7.27 (t, *J* = 8.3 Hz, 1H), 3.93 (s, 3H), 3.00 (t, *J* = 8.0 Hz, 2H), 2.57 (t, *J* = 8.0 Hz, 2H), 2.33 (s, 3H), 1.61 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 163.0, 149.3, 136.8, 128.5, 126.9, 126.7, 125.2, 123.0, 120.0,

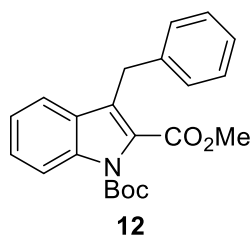
115.1, 84.3, 59.6, 52.1, 45.3, 27.9, 22.8 ppm; HRMS (EI) *m/z* calcd for C₁₉H₂₆N₂O₄ [M]⁺: 346.1893. Found: 346.1887.

(F-9) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-Benzyl-1*H*-indole-1,2-dicarboxylate (**12**)

According to Sigman's procedure,¹⁰ in a glove box, a round bottomed flask equipped with a stir bar was charged with 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol). To the flask containing **2a** was added phenyldiazonium tetrafluoroborate (28.8 mg, 0.15 mmol, 1.5 equiv) in DMA (1.0 mL), followed quickly by Pd(dba)₂ (5.8 mg, 0.01 mmol, 10 mol %) in DMA (1.0 mL). The flask was closed with a septum, and stirred for 3 h. After the flask was removed from the glove box, Et₂O and water were added, and the mixture was extracted with Et₂O three times. The combined organic layer was washed with brine, dried over Na₂SO₄, and removed under reduced pressure to afford the crude product. The product was then purified by silica gel column chromatography (hexane/AcOEt, 10:1), affording the title compound (**12**) (32.1 mg, 0.088 mmol) as pale yellow oil in 88% yield.

⁹ J. H. Tidwell, S. L. Buchwald, *J. Am. Chem. Soc.* **1994**, *116*, 11797.

¹⁰ E. W. Werner, M. S. Sigman, *J. Am. Chem. Soc.* **2011**, *133*, 9692.

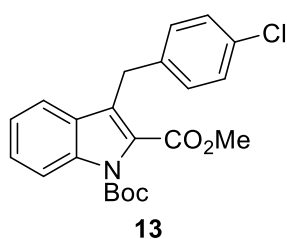


IR (CHCl₃): 3019, 2984, 1731, 1362, 1333, 1242, 1216, 1159, 1106, 751 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.09 (d, *J* = 7.9 Hz, 1H), 7.45 (d, *J* = 7.9 Hz, 1H), 7.37 (t, *J* = 7.9 Hz, 1H), 7.28-7.22 (m, 4H), 7.20-7.15 (m, 2H), 4.19 (s, 2H), 3.90 (s, 3H), 1.63 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 163.1, 149.3, 139.2, 136.8, 128.51, 128.46, 128.43, 127.4, 126.6, 126.2, 125.1, 123.0, 120.7, 115.0, 84.4, 52.2, 30.4, 27.9 ppm; HRMS (EI) *m/z* calcd for C₂₂H₂₃NO₄ [M]⁺: 365.1627. Found:

365.1621.

(F-10) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(4-Chlorobenzyl)-1H-indole-1,2-dicarboxylate (**13**)

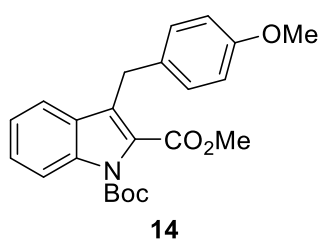
According to Sigman's procedure,¹⁰ in a glove box, a round bottomed flask equipped with a stir bar was charged with 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol). To the flask containing **2a** was added *p*-chlorophenyldiazonium tetrafluoroborate (34.0 mg, 0.15 mmol, 1.5 equiv) in DMA (1.0 mL), followed quickly by Pd(dba)₂ (5.8 mg, 0.01 mmol, 10 mol %) in DMA (1.0 mL). The flask was closed with a septum, and stirred for 3 h. After the flask was removed from the glove box, Et₂O and water were added, and the mixture was extracted with Et₂O three times. The combined organic layer was washed with brine, dried over Na₂SO₄, and removed under reduced pressure to afford the crude product. The product was then purified by silica gel column chromatography (hexane/AcOEt, 5:1), affording the title compound (**13**) (36.0 mg, 0.090 mmol) as pale yellow oil in 90% yield.



IR (CHCl₃): 3019, 2983, 2952, 1731, 1335, 1241, 1216, 1158, 1105, 759 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.09 (d, *J* = 8.0 Hz, 1H), 7.43-7.37 (m, 2H), 7.24-7.18 (m, 5H), 4.15 (s, 2H), 3.91 (s, 3H), 1.64 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 163.0, 149.3, 137.7, 136.8, 132.0, 129.8, 128.5, 128.3, 127.4, 126.8, 124.5, 123.1, 120.5, 115.1, 84.6, 52.3, 29.7, 27.9 ppm; HRMS (EI) *m/z* calcd for C₂₂H₂₂ClNO₄ [M]⁺: 399.1237. Found: 399.1224.

(F-11) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-(4-Methoxybenzyl)-1H-indole-1,2-dicarboxylate (**14**)

According to Sigman's procedure,¹⁰ in a glove box, a round bottomed flask equipped with a stir bar was charged with 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol). To the flask containing **2a** was added *p*-methoxyphenyldiazonium tetrafluoroborate (33.3 mg, 0.15 mmol, 1.5 equiv) in DMA (1.0 mL), followed quickly by Pd(dba)₂ (5.8 mg, 0.01 mmol, 10 mol %) in DMA (1.0 mL). The flask was closed with a septum, and stirred for 3 h. After the flask was removed from the glove box, Et₂O and water were added, and the mixture was extracted with Et₂O three times. The combined organic layer was washed with brine, dried over Na₂SO₄, and removed under reduced pressure to afford the crude product. The product was then purified by silica gel column chromatography (hexane/AcOEt, 5:1), affording the title compound (**14**) (36.8 mg, 0.093 mmol) as pale yellow oil in 93% yield.

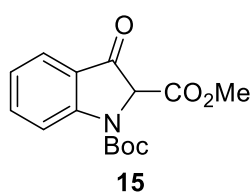


IR (CHCl₃): 3019, 2983, 2953, 1731, 1511, 1333, 1246, 1216, 1159, 755 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ = 8.09 (d, *J* = 8.0 Hz, 1H), 7.46 (d, *J* = 8.0 Hz, 1H), 7.38 (t, *J* = 8.0 Hz, 1H), 7.22-7.17 (m, 3H), 6.80 (d, *J* = 8.5 Hz, 2H), 4.14 (s, 2H), 3.92 (s, 3H), 3.76 (s, 3H), 1.64 (s, 9H) ppm; ¹³C NMR (125 MHz, CDCl₃): δ = 163.1, 158.0, 149.3, 136.8, 131.3, 129.4, 128.5, 127.2, 126.6, 125.5, 123.0, 120.7, 115.0, 113.8, 84.4, 55.2, 52.2, 29.5, 27.9 ppm; HRMS (EI)

m/z calcd for $C_{23}H_{25}NO_5$ $[M]^+$: 395.1733. Found: 395.1719.

(F-12) Synthesis of 1-(*tert*-Butyl) 2-Methyl 3-Oxindoline-1,2-dicarboxylate (**15**)

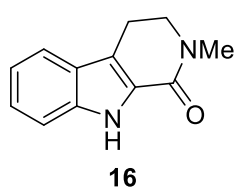
A round bottomed flask was charged with 3-methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol), CH_2Cl_2 (3.0 mL), and MeOH (1.0 mL). The flask was cooled to -78 °C and ozone was bubbled through the solution with stirring for 2 h. When the ozone generator was ceased, PPh_3 (52.5 mg, 0.20 mmol) was then added to the flask and the resulting mixture was stirred overnight (-78 °C to room temperature) Then, it was concentrated under high vacuum to give the crude product, which was purified by silica gel column chromatography (hexane/AcOEt, 4:1), affording the title compound (**15**) (25.3 mg, 0.087 mmol) as white solids in 87% yield.



m.p. 134-136 °C; IR ($CHCl_3$): 3021, 2980, 1759, 1718, 1468, 1371, 1216, 1153, 1060, 762 cm^{-1} ; “&” indicates two rotamers are present in 1H NMR. 1H NMR (500 MHz, $CDCl_3$): δ = 8.28 & 7.81 (d, J = 7.7 Hz, 1H), 7.70 (d, J = 7.7 Hz, 1H), 7.65 (t, J = 7.7 Hz, 1H), 7.14 (t, J = 7.7 Hz, 1H), 4.88 (s, 1H), 3.83 (s, 3H), 1.63 & 1.51 (s, 9H) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ = 189.8, 165.0, 153.9, 149.7, 137.8, 124.6, 123.4, 122.6, 116.4, 83.0, 67.8, 53.2, 28.0 ppm; HRMS (EI) m/z calcd for $C_{15}H_{17}NO_5$ $[M]^+$: 292.1107. Found: 292.1104.

(G) One-Pot Synthesis of Strychnocarpine (**16**)¹¹

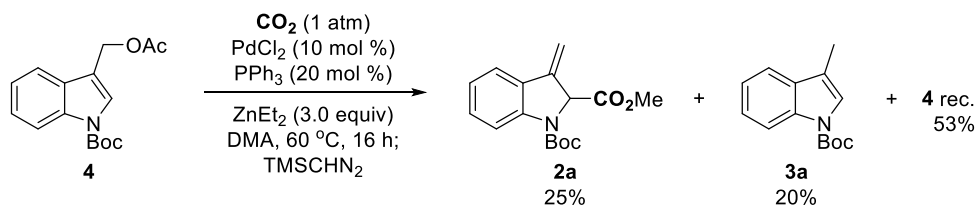
3-Methyleneindoline-2-carboxylate **2a** (28.9 mg, 0.10 mmol) and *N,N*-dimethylmethyleneiminium chloride (10.3 mg, 0.11 mmol, 1.1 equiv) were placed on the bottom of a sealed tube containing a stirring bar. After the addition of DMA (0.5 mL), the mixture was stirred at 80 °C for 2h, and the temperature was increased to 200 °C and maintained for 16 h. After cooling to room temperature, the solvent was removed under reduced pressure to give the crude product, which was then purified by silica gel column chromatography (hexane/AcOEt, 2:1), affording the title compound (**16**) (17.4 mg, 0.087 mmol) as white solids in 87% yield.



1H NMR (500 MHz, $CDCl_3$): δ = 10.19 (brs, 1H), 7.57 (d, J = 7.8 Hz, 1H), 7.50 (d, J = 7.8 Hz, 1H), 7.29 (t, J = 7.8 Hz, 1H), 7.14 (t, J = 7.8 Hz, 1H), 3.72 (t, J = 7.0 Hz, 2H), 3.20 (s, 3H), 3.09 (t, J = 7.0 Hz, 2H) ppm; ^{13}C NMR (125 MHz, $CDCl_3$): δ = 162.0, 137.5, 127.1, 125.2, 124.5, 120.0, 117.8, 112.6, 50.2, 34.1, 20.6 ppm; The spectral data of **16** was consistent with the reported one.¹¹

¹¹ a) C. Herdeis, A. Dimmerling, *Heterocycles* **1984**, 22, 2277; b) G. P. Tokmakov, *Chem. Heterocycl. Compd.* **2014**, 50, 211.

(H) Carboxylation of 3-Indolylmethyl Acetate **4**



PdCl_2 (3.5 mg, 0.02 mmol, 10 mol %) and PPh_3 (10.5 mg, 0.04 mmol, 20 mol %) were placed on the bottom of a sealed tube containing a stirring bar. The tube was evacuated and refilled with CO_2 (balloon) three times. After the addition of DMA (0.5 mL), the mixture was stirred at room temperature for 10 min under CO_2 atmosphere (1 atm, balloon). 3-Indolylmethyl acetate **4**¹² (57.9 mg, 0.20 mmol) in DMA (0.5 mL) and ZnEt_2 (1 M solution in hexane, 0.6 mL, 0.60 mmol, 3.0 equiv) were added at 0 °C, and then the tube was closed. The resulting reaction mixture was stirred at 60 °C for 16 h. HCl aq. (3 M) and water were added at 0 °C, and the mixture (pH < 2) was extracted with Et_2O three times. The combined organic layer was washed with brine, dried over Na_2SO_4 , and removed under reduced pressure. The residue was dissolved in $\text{Et}_2\text{O}/\text{MeOH} = 4:1$ (ca. 2 mL) followed by treatment with TMSCHN_2 (2 M in Et_2O , 110 μl , 0.22 mmol, 1.1 equiv). After 10 min, the mixture was directly concentrated under high vacuum to afford the crude product. Yields of **2a**, **3a**, and **4** were determined at this stage using 1,1,2,2-tetrachloroethane ($\delta = 5.9$ ppm in CDCl_3 , 2H) as an internal standard (**2a**: 25%; **3a**: 20%; **4** rec.: 53%).

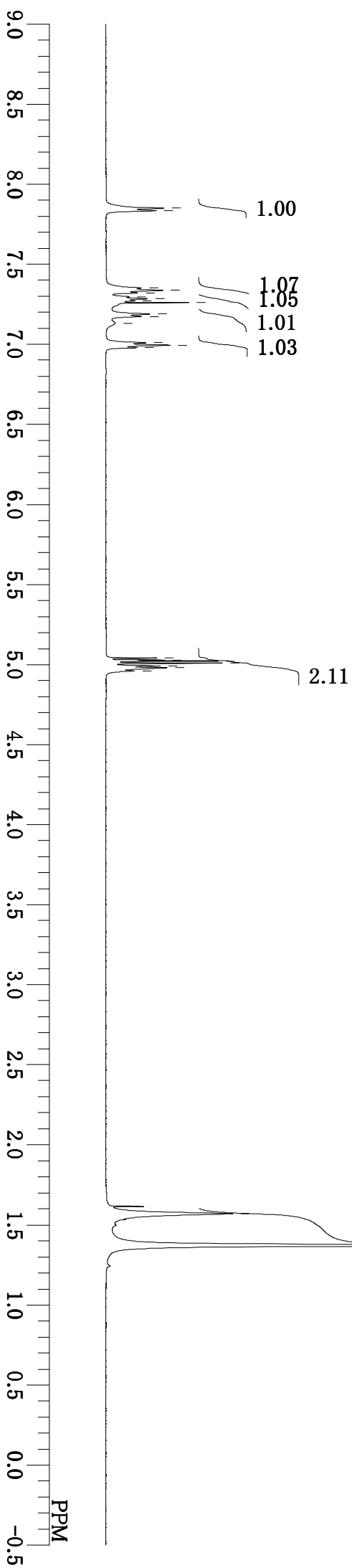
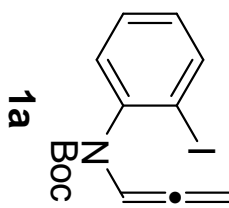
¹² H.-C. Hsu, D.-R. Hou, *Tetrahedron Lett.* **2009**, 50, 7169.

500MHz CDCl₃

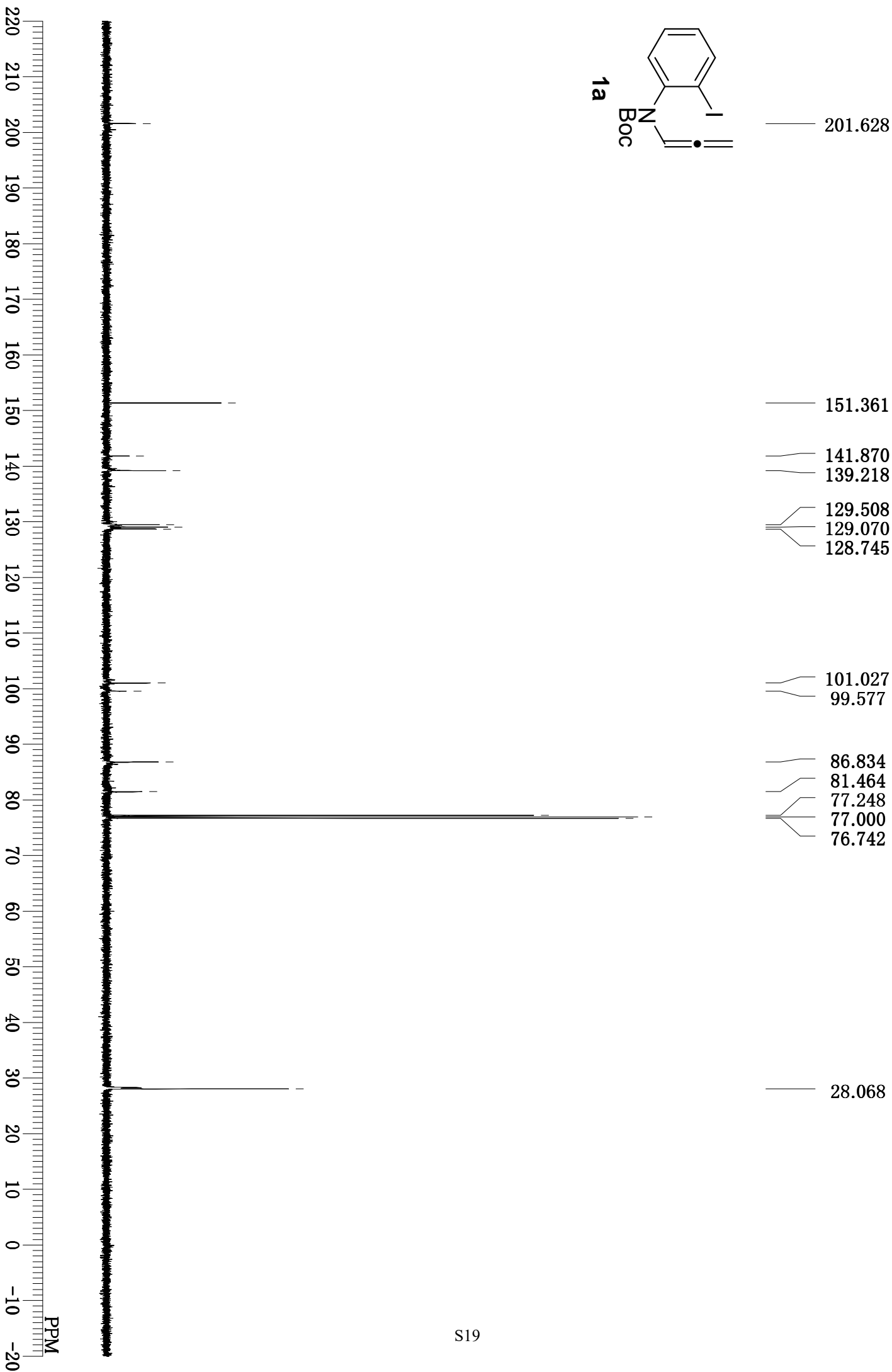
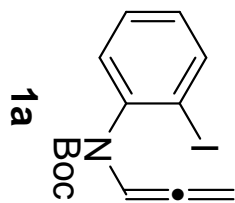
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7.835
7.352
7.338
7.323
7.298
7.285
7.273
7.260
7.190
7.174
7.131
7.010
6.995
6.981

5.041
5.028
5.021
5.009
4.993
4.980
4.960

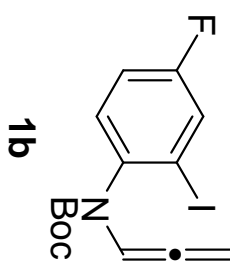
1.570
1.373



125MHz CDCl3



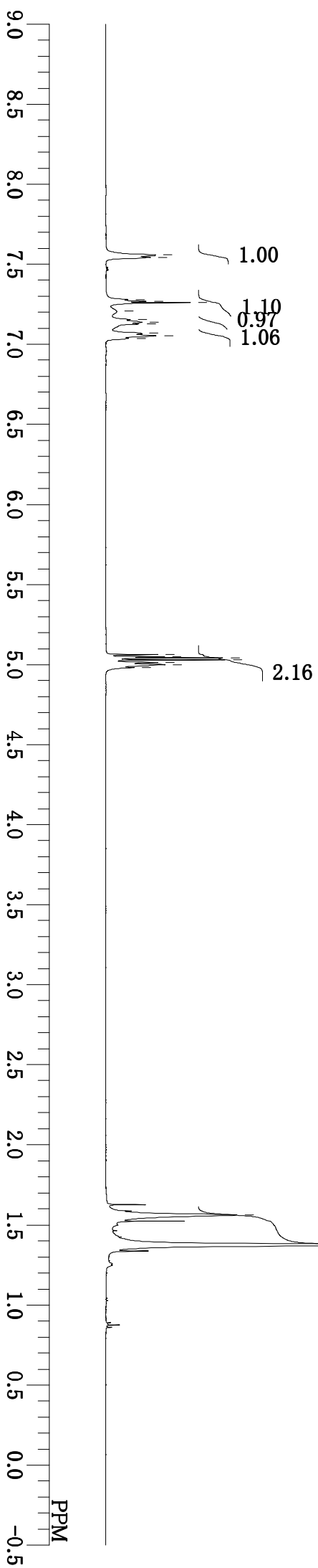
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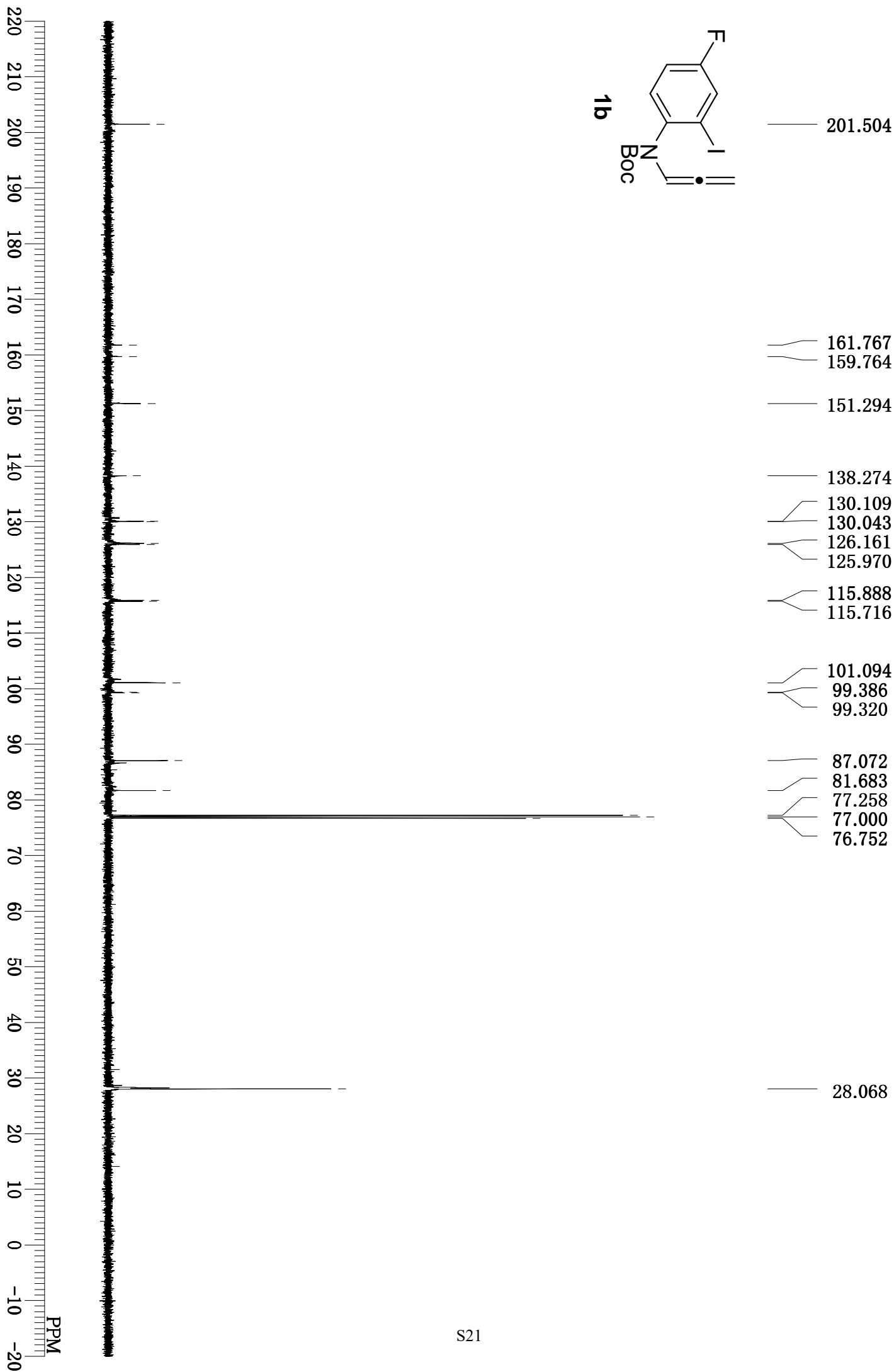
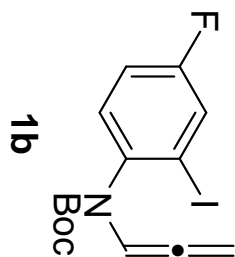
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7.544
7.281
7.269
7.260
7.207
7.155
7.139
7.127
7.071
7.055
7.038

5.061
5.049
5.042
5.029
5.013
5.001
4.981

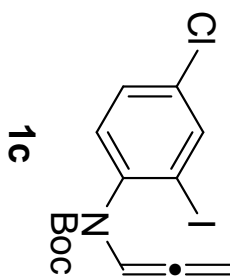
1.562
1.375



125MHz CDCl3



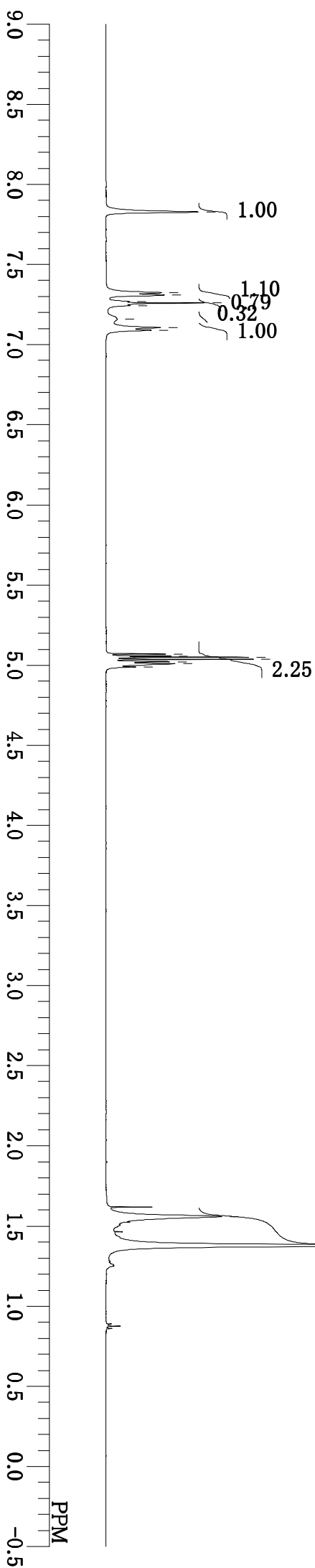
500MHz CDCl₃



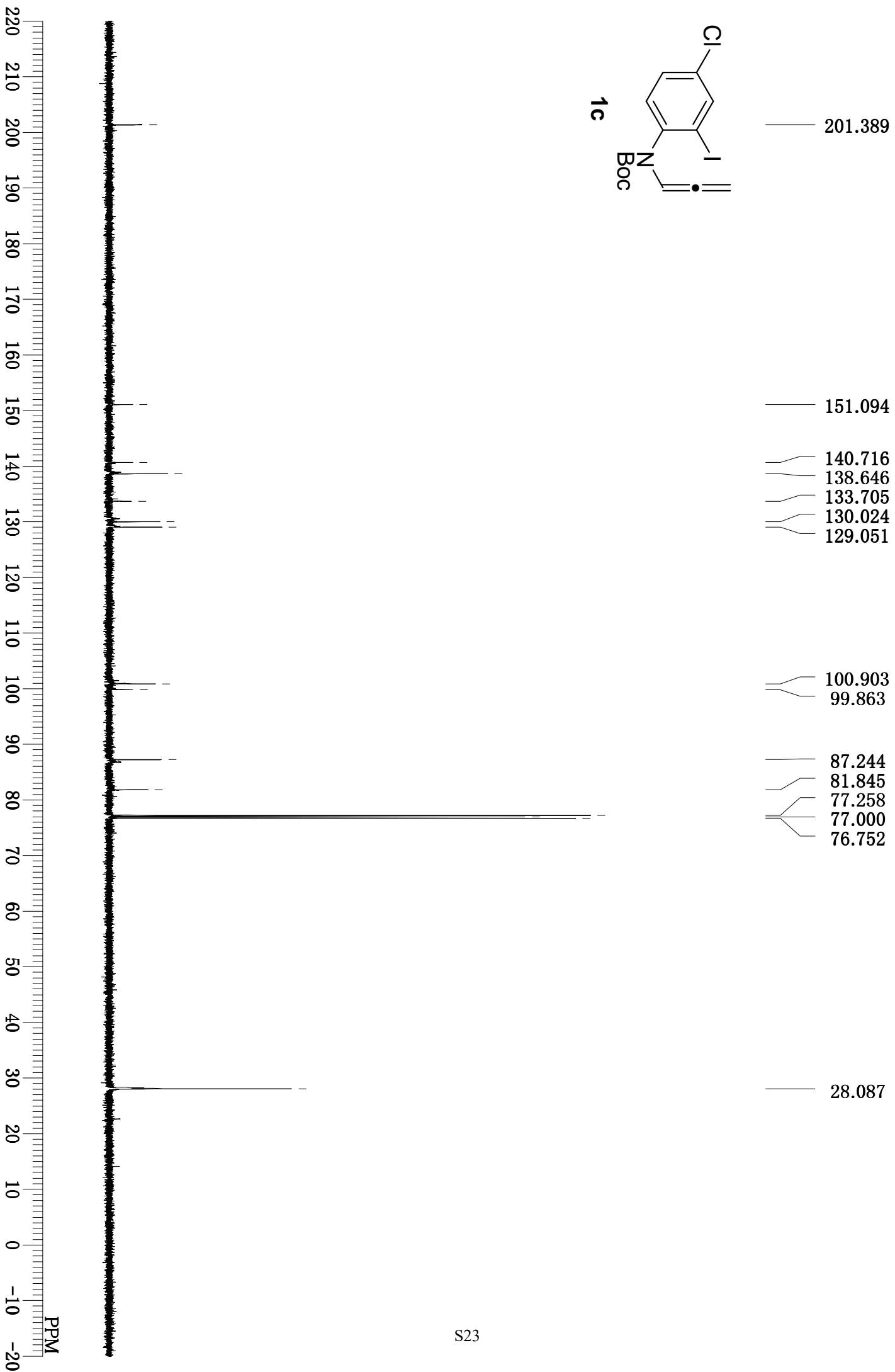
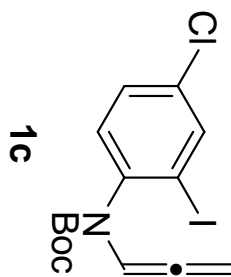
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7.325
7.309
7.270
7.260
7.245
7.158
7.107
7.091

5.070
5.057
5.050
5.037
5.021
5.009
4.989

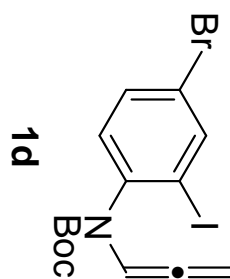
1.559
1.378



125MHz CDCl3



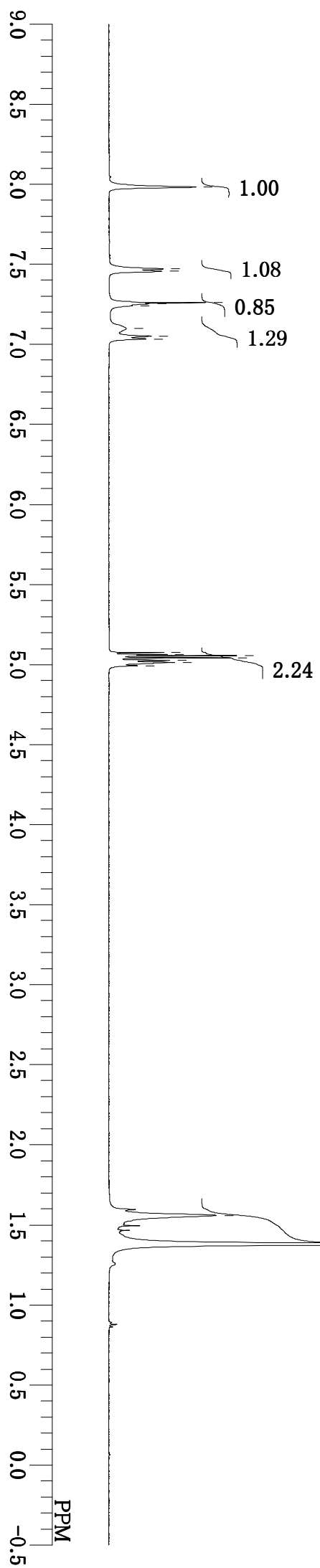
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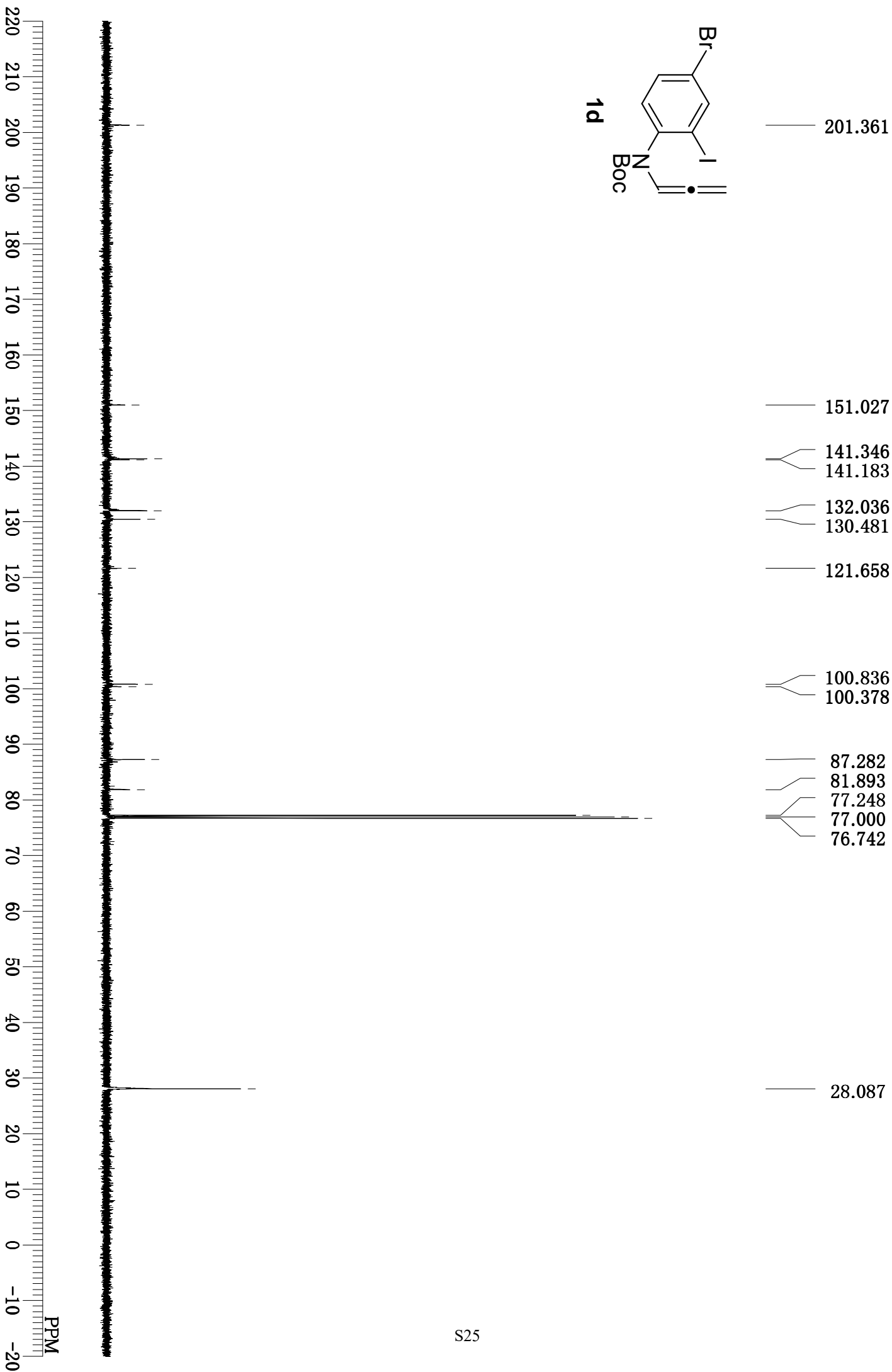
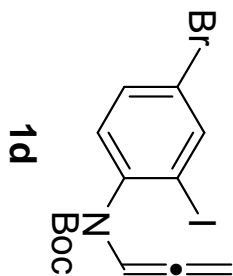
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7.472
7.457
7.260
7.253
7.242
7.099
7.050
7.034

5.075
5.062
5.056
5.043
5.026
5.013
4.994

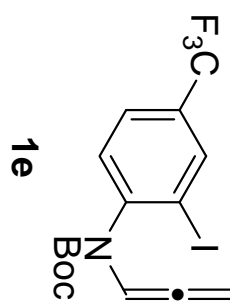
1.559
1.381



125MHz CDCl3



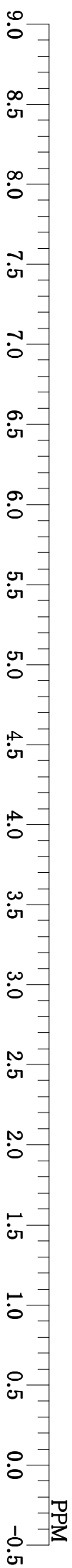
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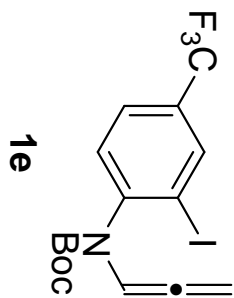
8.093
7.617
7.601
7.353
7.300
7.285
7.260
7.115

5.068
5.056
5.049
5.036
5.021
5.009
5.002
4.989

1.571
1.377



125MHz CDCl3



201.227

150.769

145.275

136.328

129.861

126.141

125.922

125.903

123.738

121.563

119.398

100.674

99.682

87.454

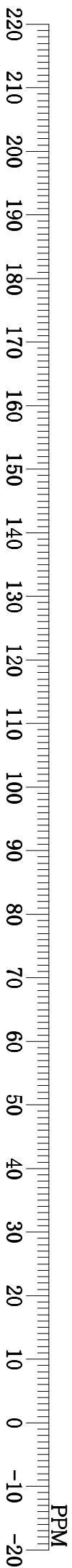
82.170

77.258

77.000

76.742

28.049

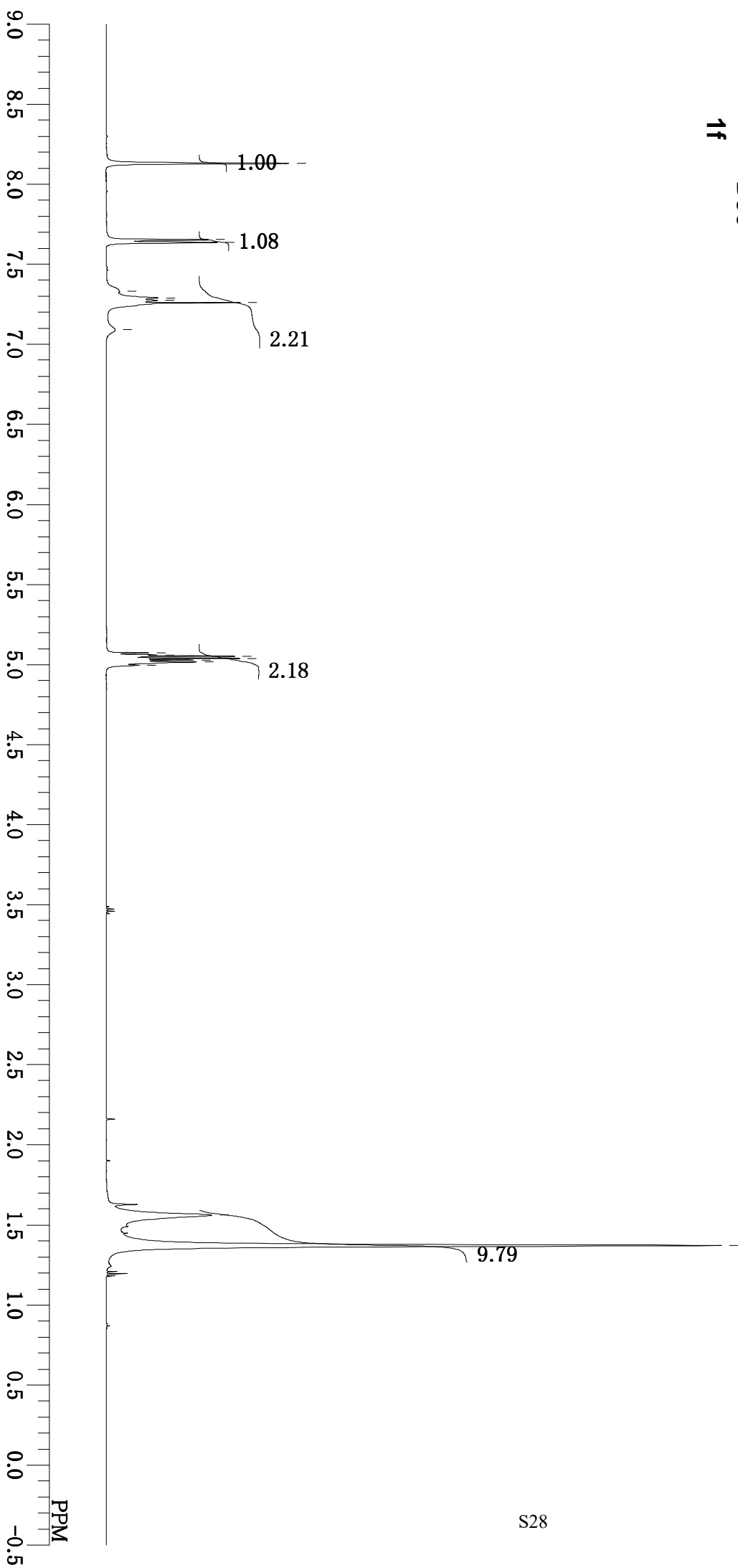
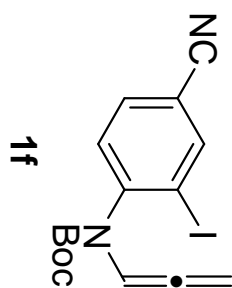


500MHz CDCl₃

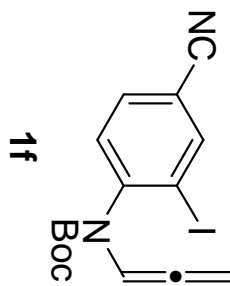
8.129
7.654
7.638
7.333
7.291
7.275
7.260
7.092

5.073
5.060
5.052
5.039
5.028
5.015
4.996

1.560
1.370



125MHz CDCl3



201.151

150.474

146.382

142.738

132.618

130.252

116.679

113.083

100.607

100.111

87.721

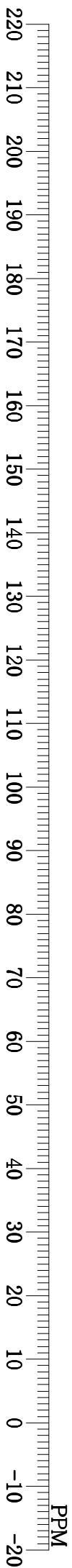
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77.353

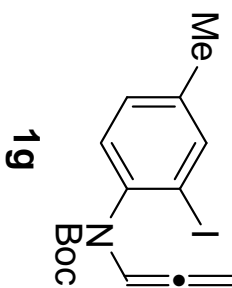
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76.838

28.087



500MHz CDCl₃

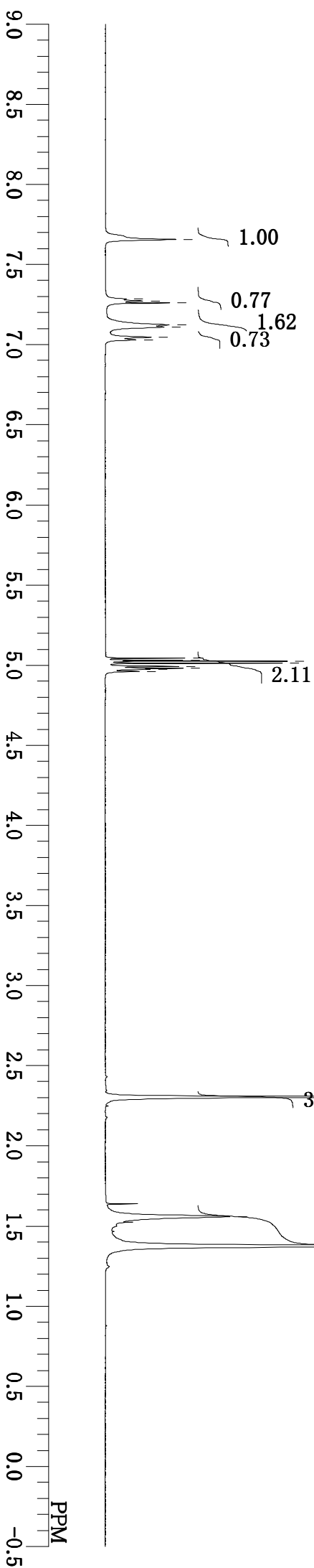


7.656
7.285
7.274
7.260
7.124
7.110
7.047
7.031

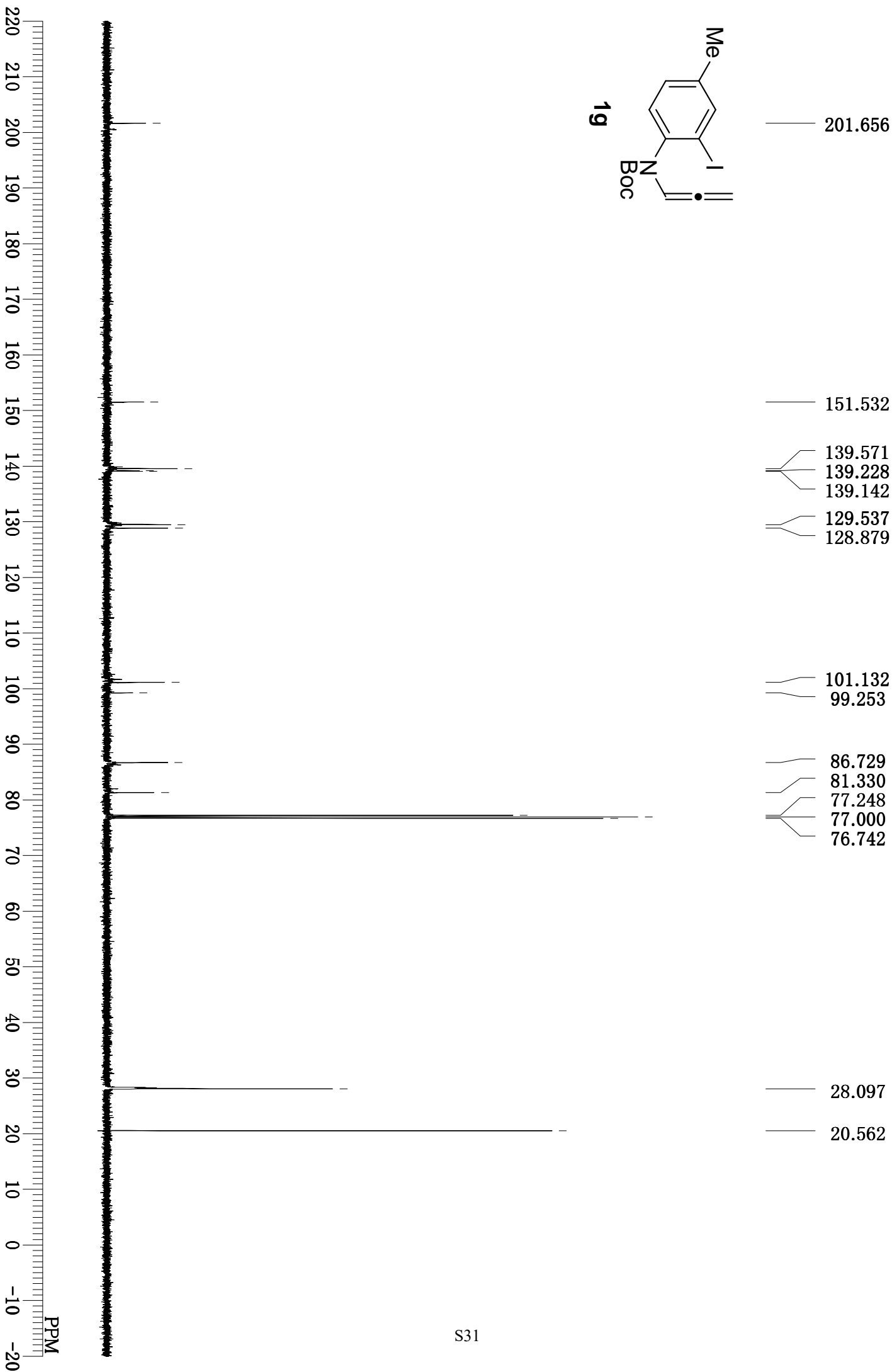
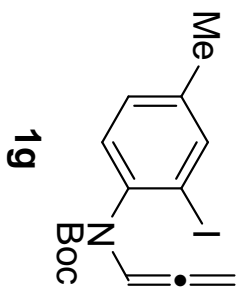
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5.031
5.025
5.012
4.993
4.980
4.974
4.962

2.307

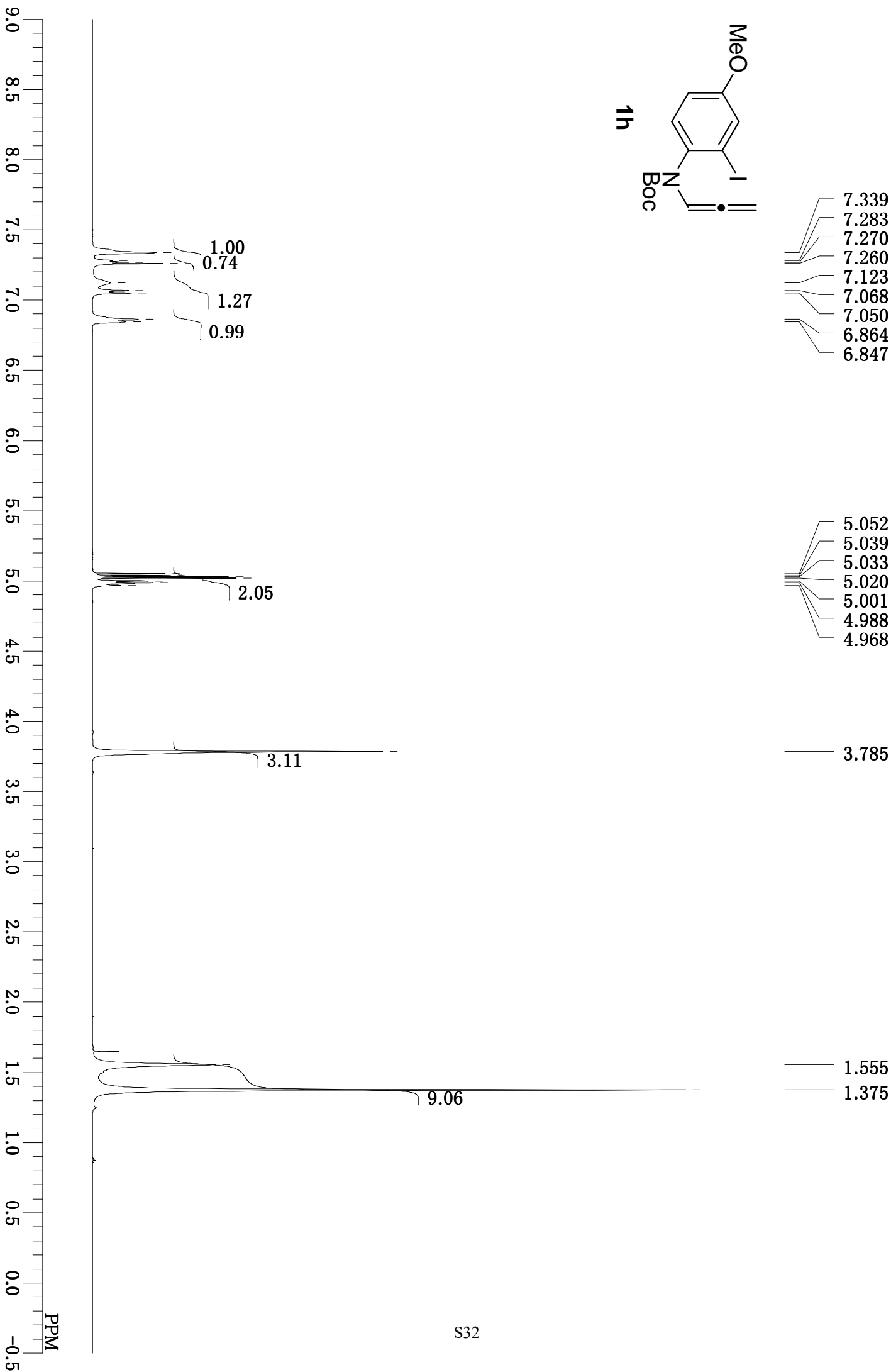
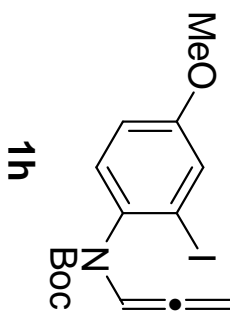
1.559
1.375



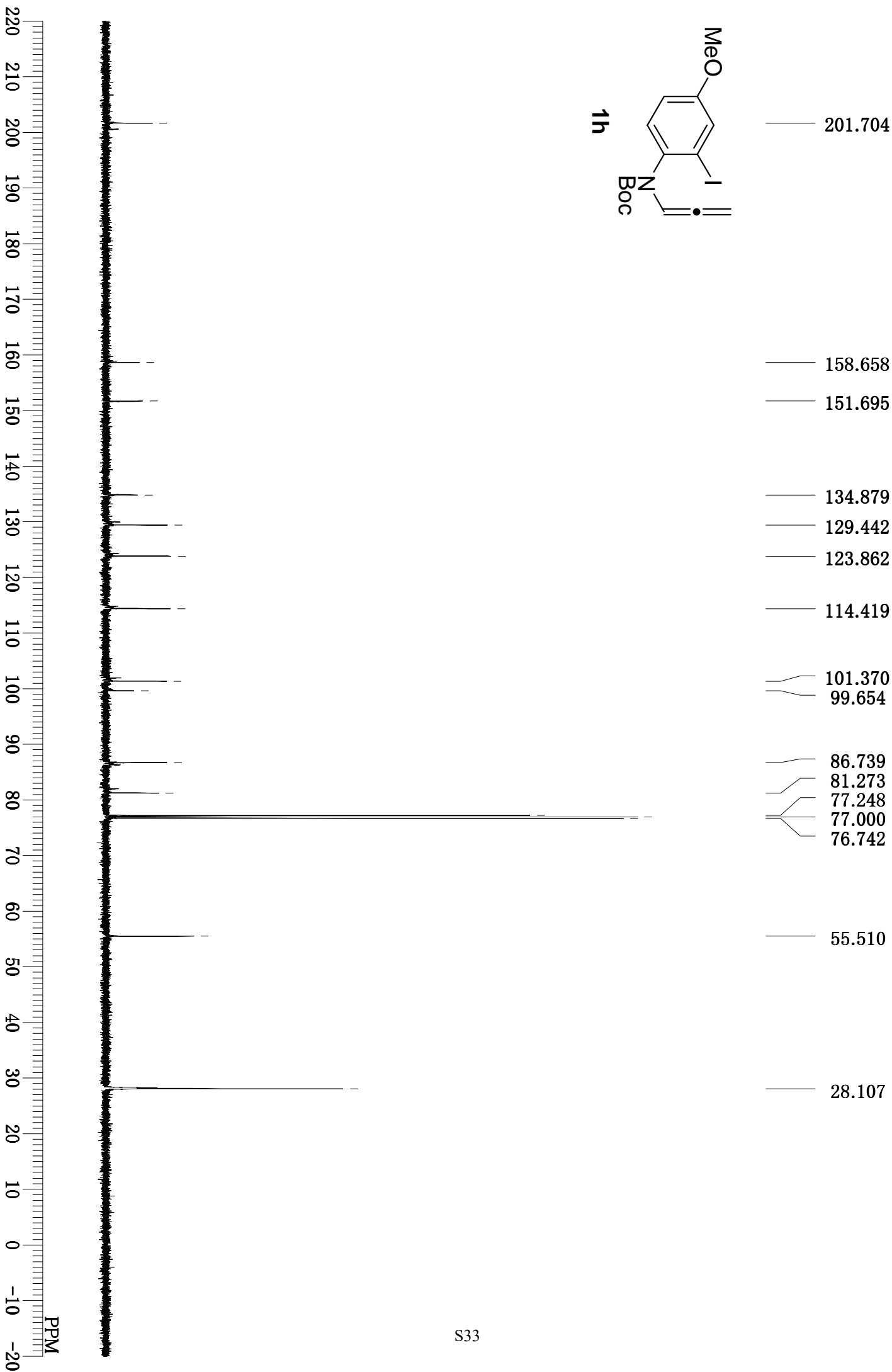
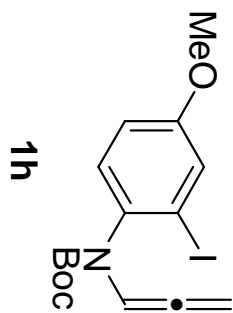
125MHz CDCl3



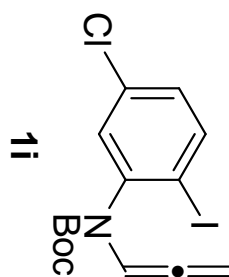
500MHz CDCl3



125MHz CDCl3



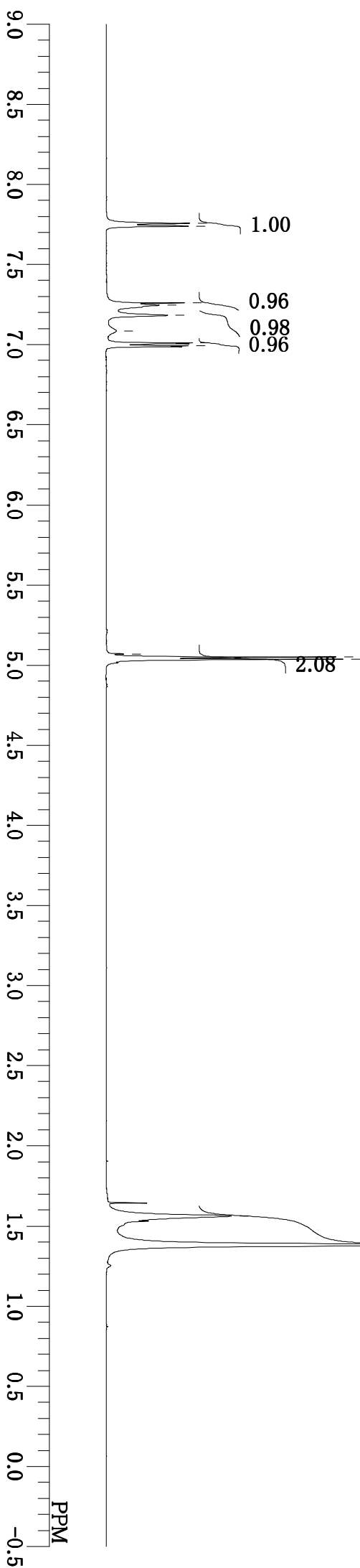
500MHz CDCl₃



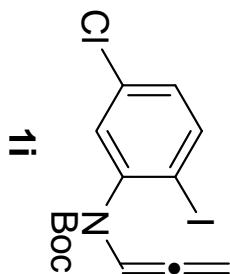
7.757
7.740
7.260
7.246
7.184
7.086
7.010
6.993

5.070
5.051
5.038

1.562
1.382



125MHz CDCl3



201.342

150.884

142.996

139.896

134.287

129.690

129.356

100.760

97.116

87.311

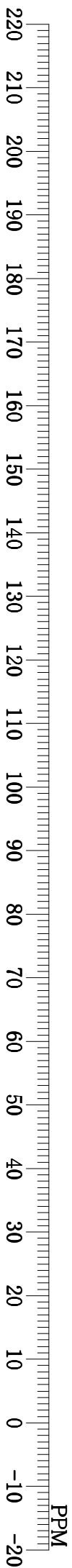
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77.258

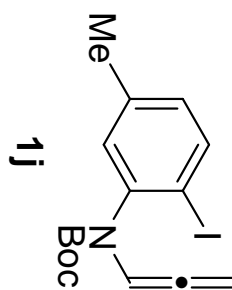
77.000

76.752

28.049



500MHz CDCl₃



7.687
7.671
7.279
7.268
7.260
7.115
7.071
6.991
6.818
6.803

5.041
5.028
5.022
5.009
4.993
4.979
4.960

2.300

1.565

1.377

1.00

1.03

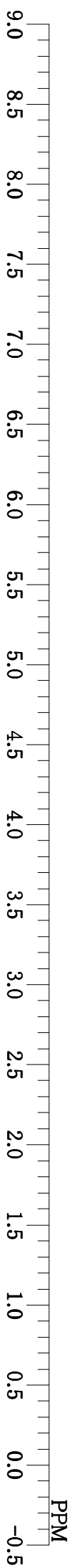
0.99

1.01

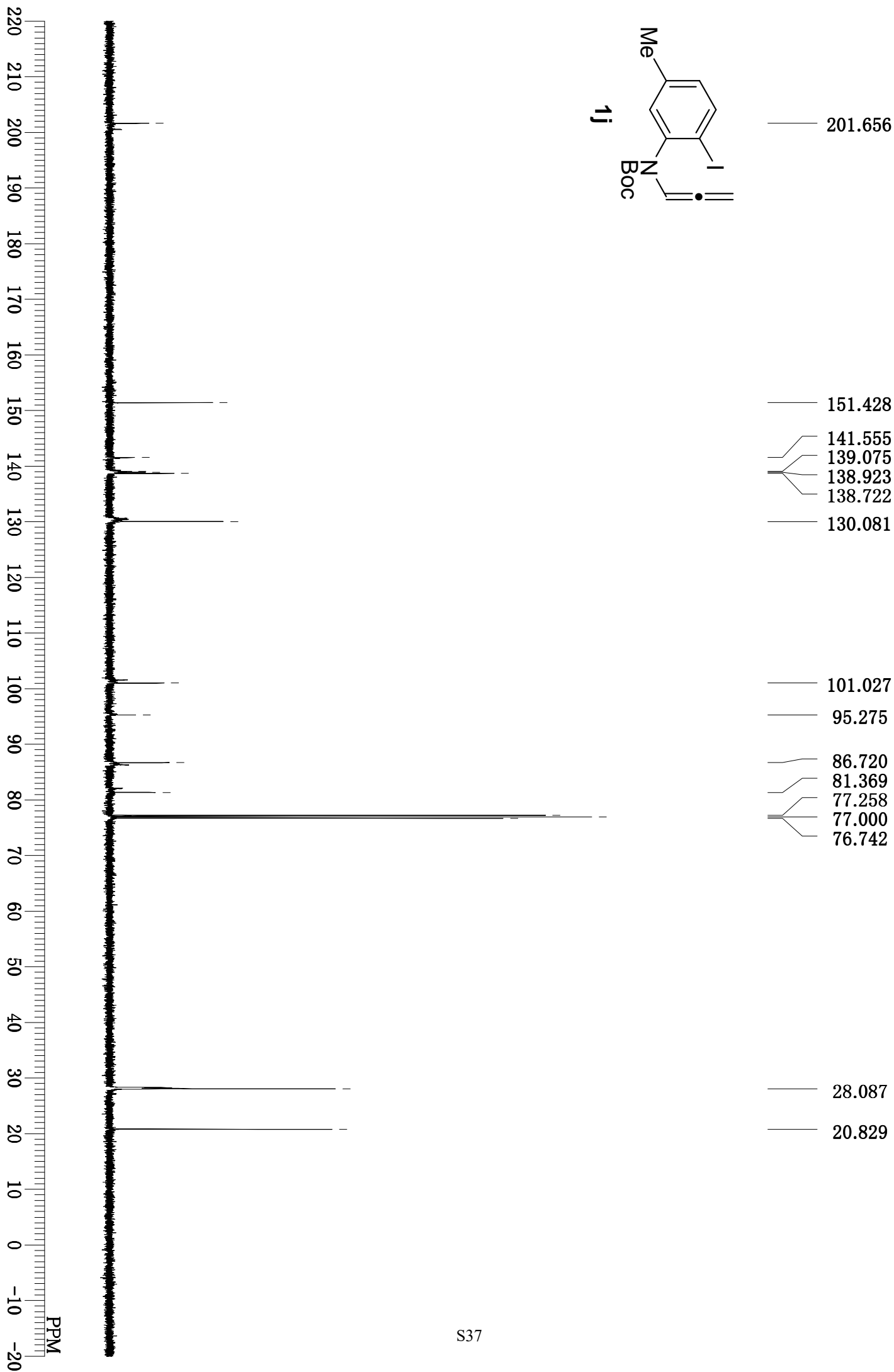
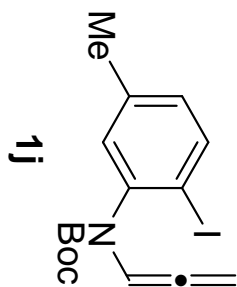
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3.13

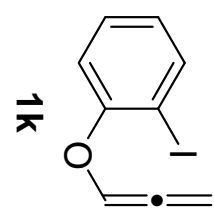
9.22



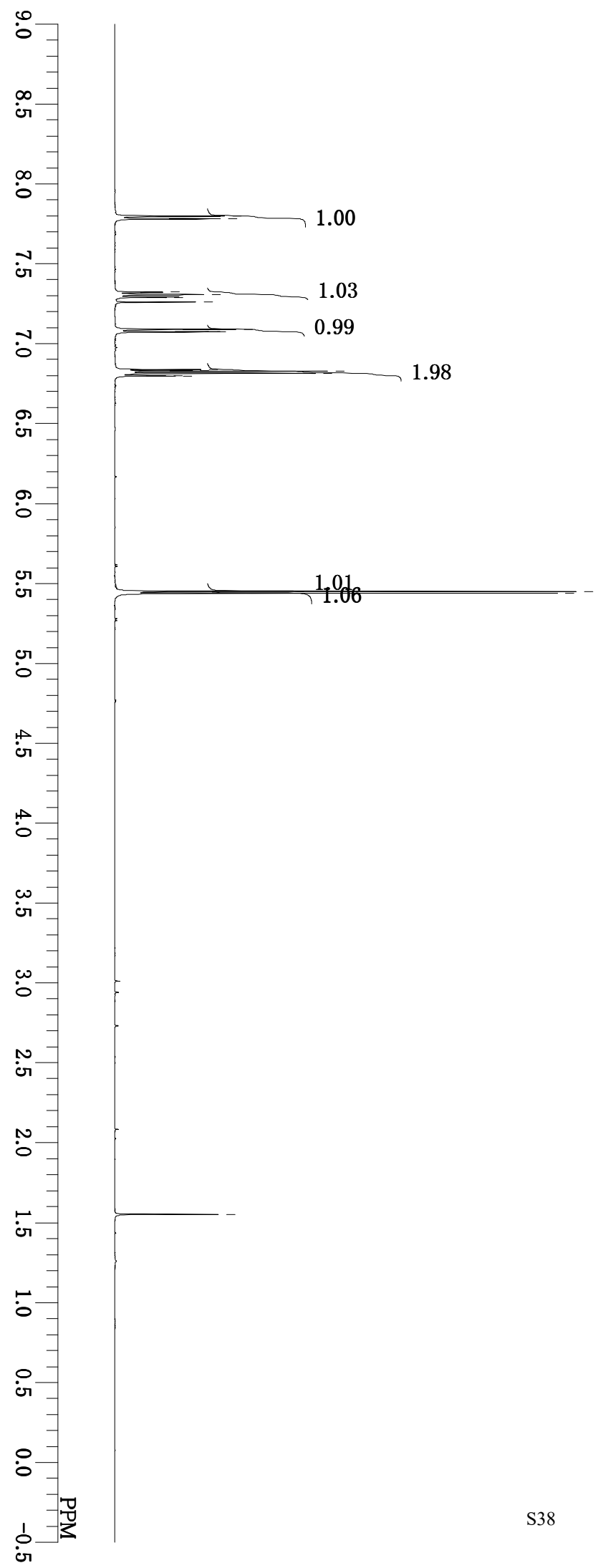
125MHz CDCl3



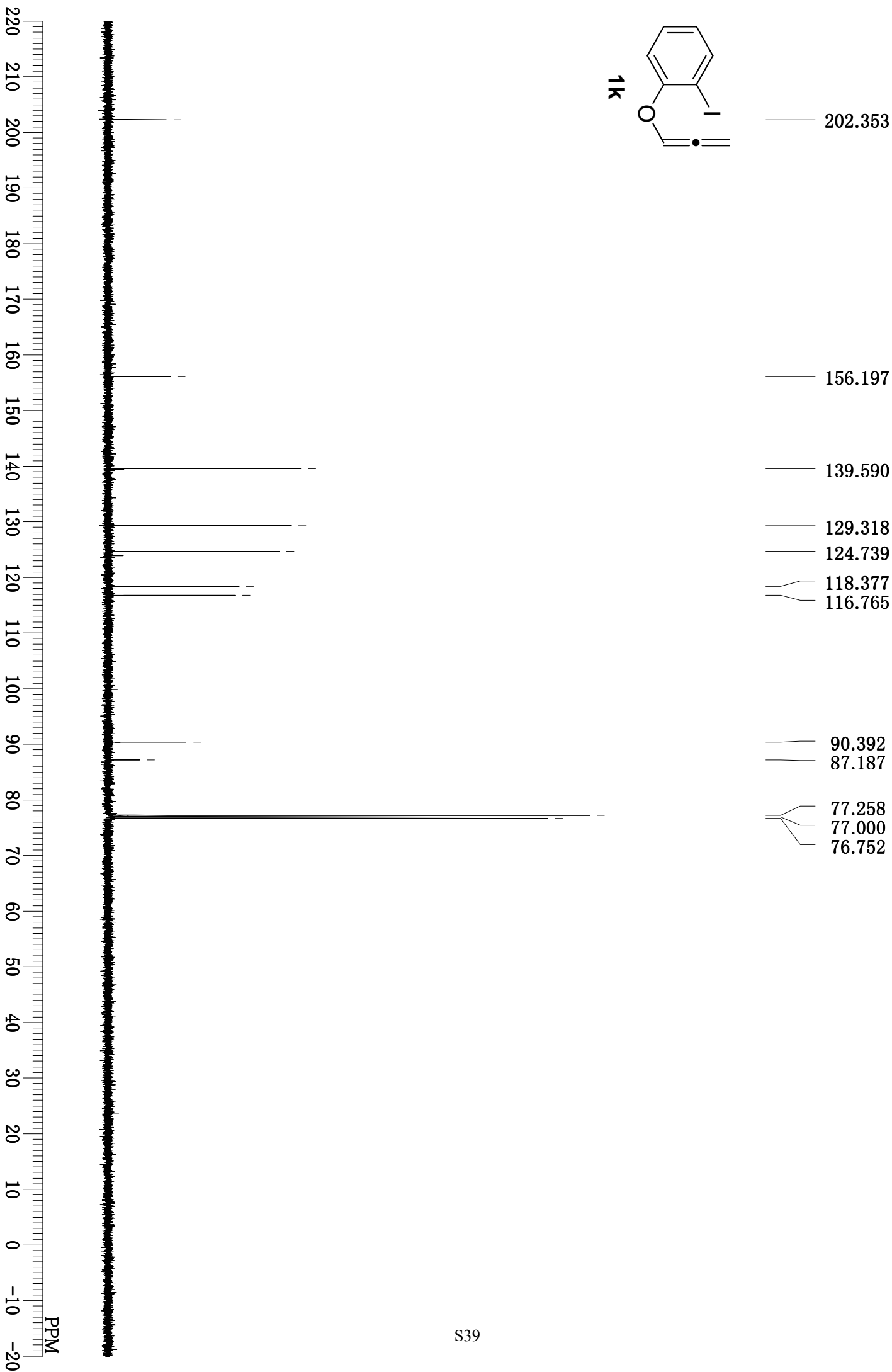
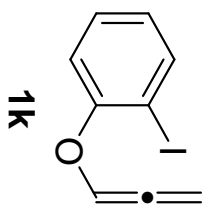
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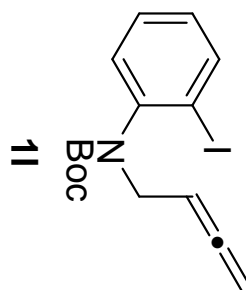
- 7.799
- 7.783
- 7.324
- 7.308
- 7.291
- 7.260
- 7.089
- 7.073
- 6.840
- 6.832
- 6.827
- 6.816
- 6.801
- 6.798
- 5.451
- 5.439
- 1.552



125MHz CDCl3



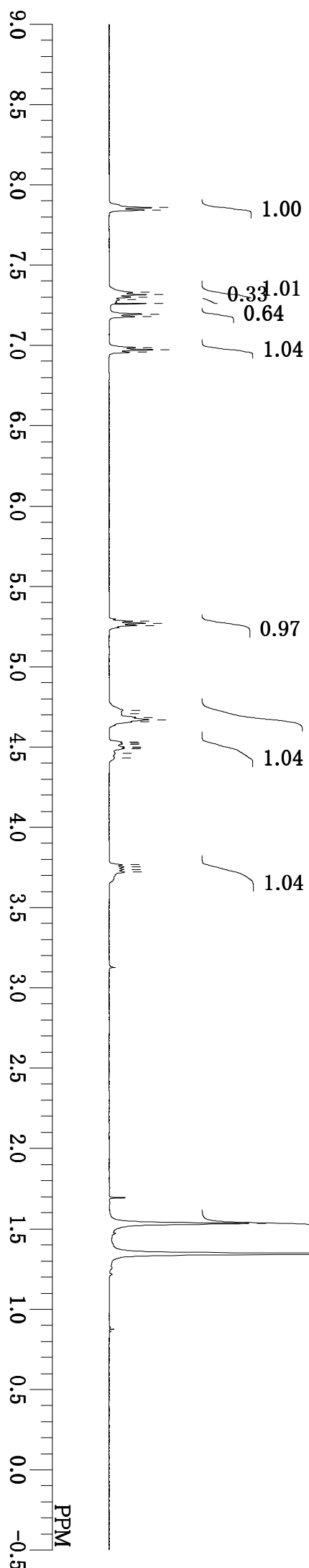
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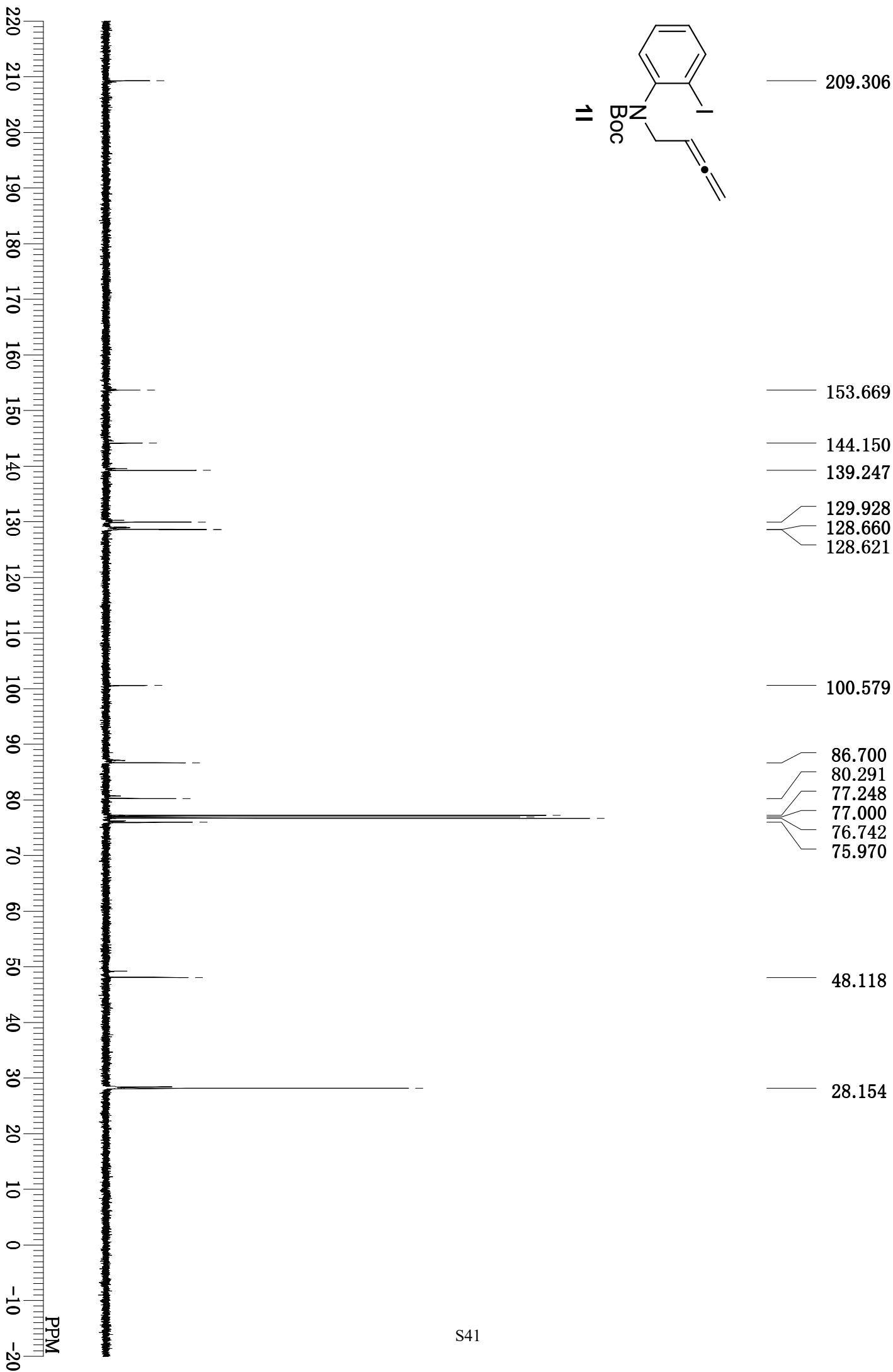
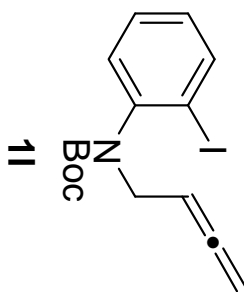
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7.843
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7.316
7.301
7.285
7.260
7.196
7.181
6.987
6.973
6.958

5.283
5.270
5.257
4.729
4.706
4.683
4.670
4.657
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4.490
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3.737
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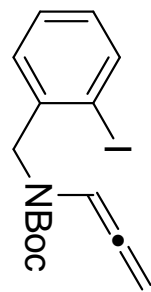
1.534
1.345



125MHz CDCl3



500MHz CDCl₃

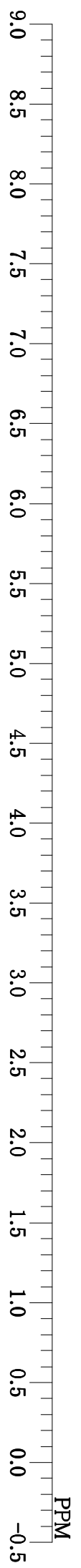


- 7.803
- 7.788
- 7.307
- 7.292
- 7.277
- 7.260
- 7.095
- 7.050
- 7.037
- 7.006
- 6.930
- 6.918

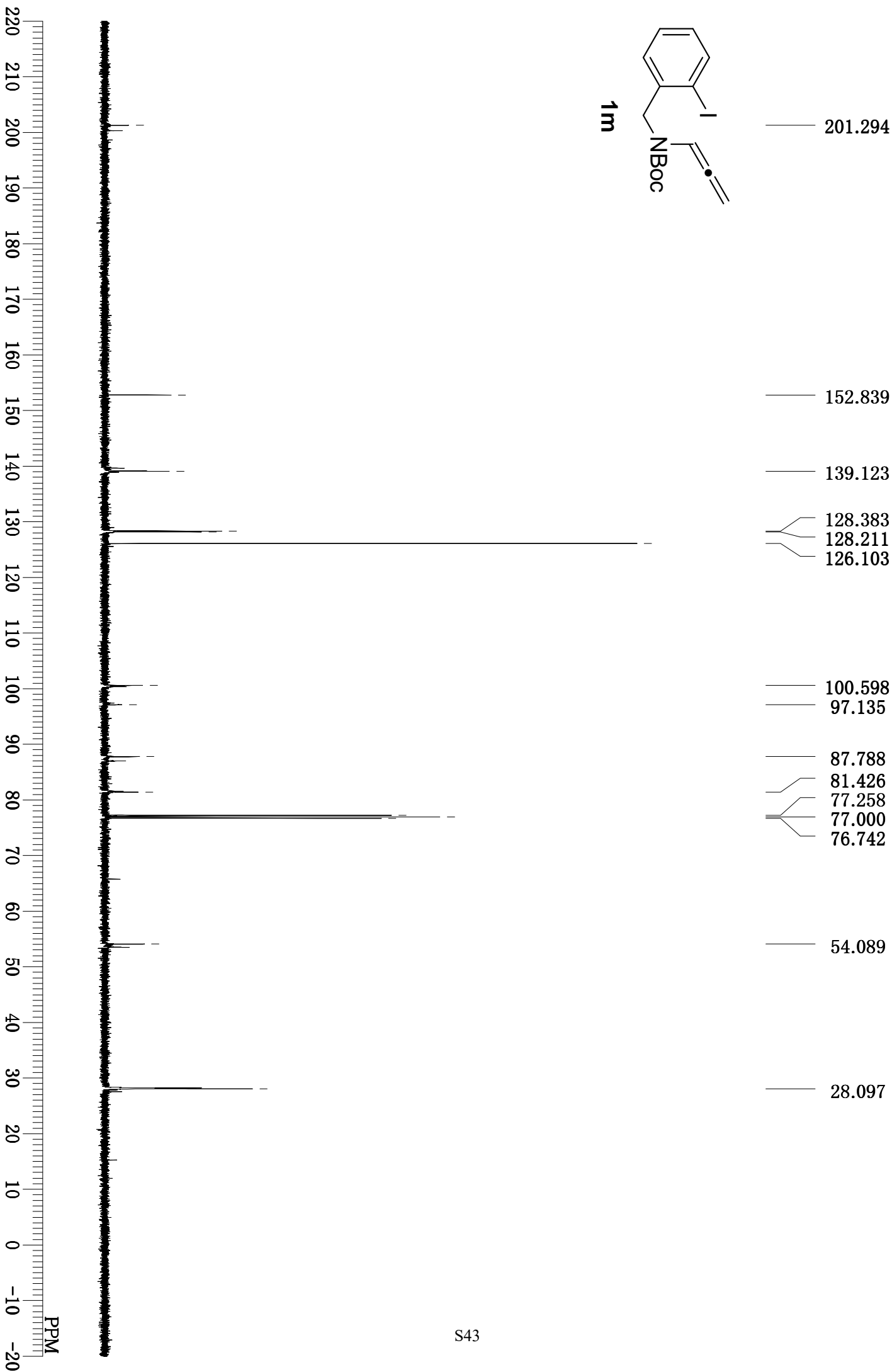
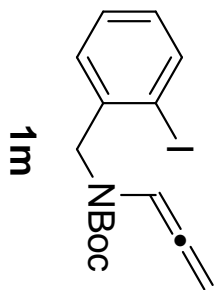
- 5.231
- 5.219
- 5.144

- 4.554
- 4.484

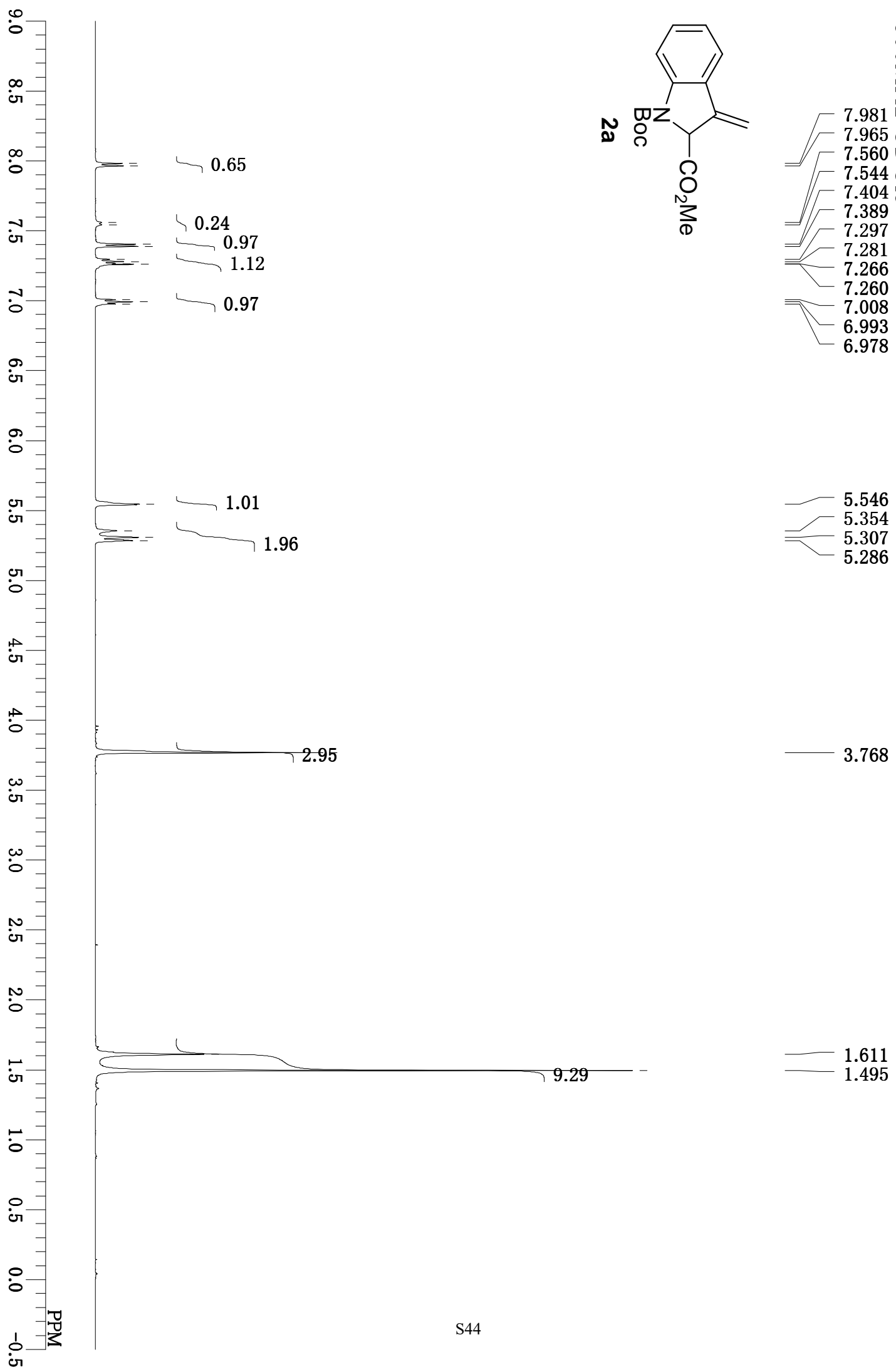
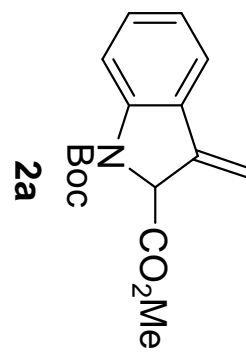
- 1.542
- 1.373



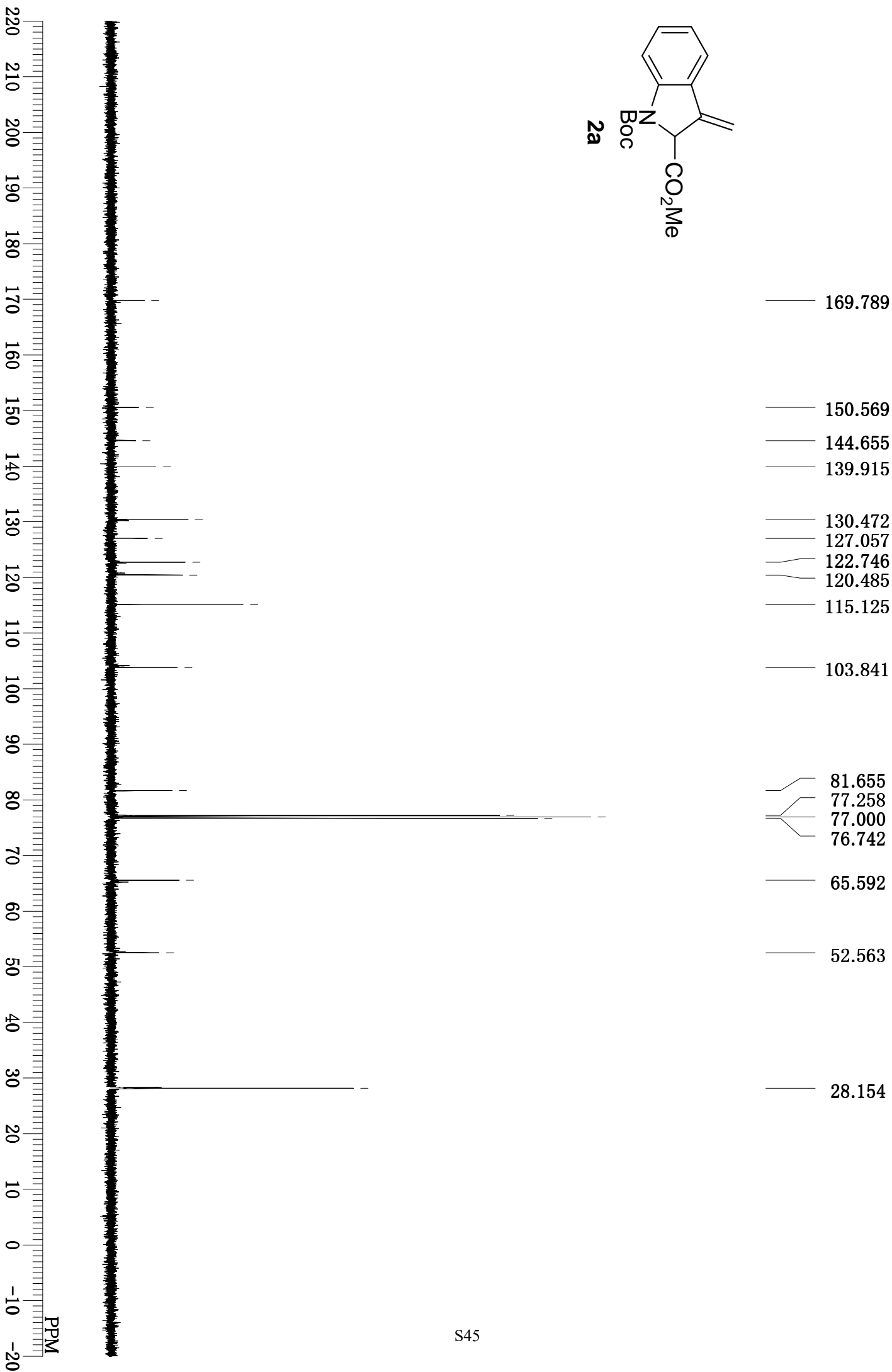
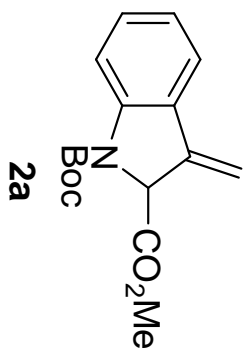
125MHz CDCl3



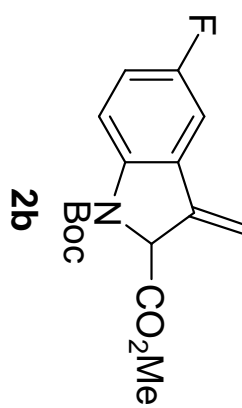
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125MHz CDCl₃



500MHz CDCl₃

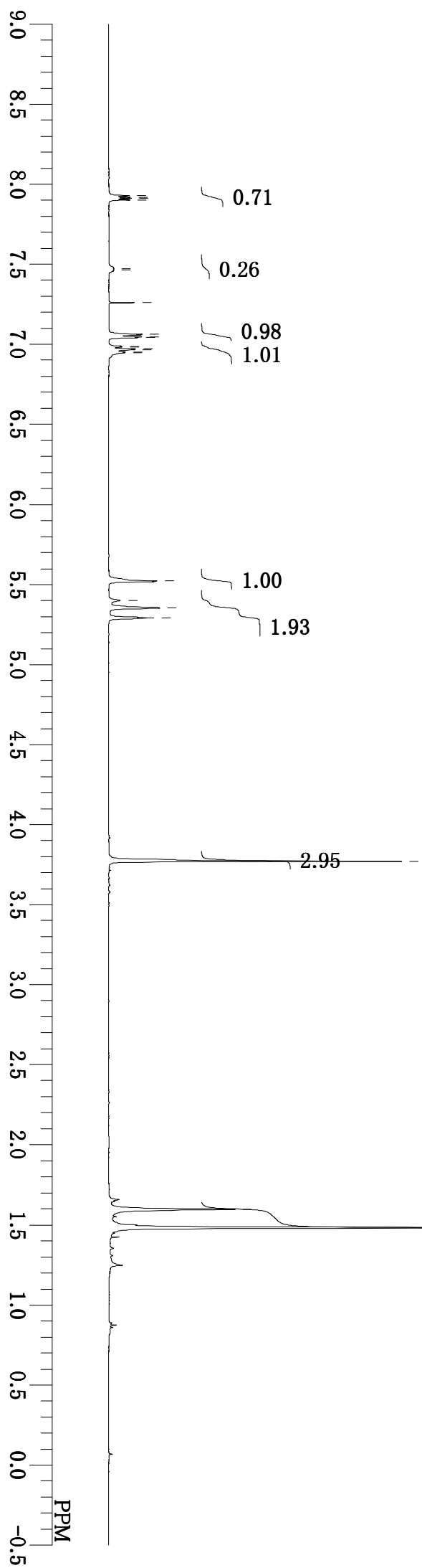


7.930
7.921
7.912
7.902
7.474
7.466
7.260
7.063
7.047
7.042
6.989
6.984
6.971
6.966
6.953
6.949

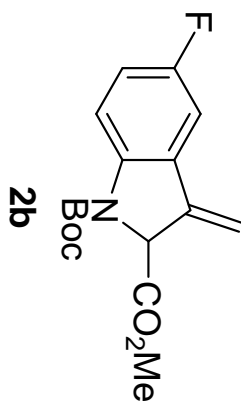
5.523
5.400
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3.772

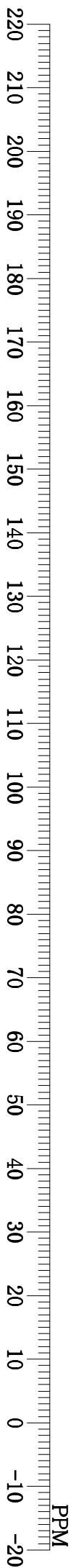
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1.483



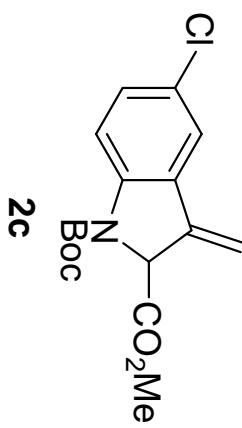
125MHz CDCl3



169.541
159.993
158.076
150.502
140.792
139.180
139.152
128.602
128.526
117.099
116.908
116.050
115.983
107.399
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105.281
81.798
77.258
77.000
76.752
65.840
52.649
28.126



500MHz CDCl₃

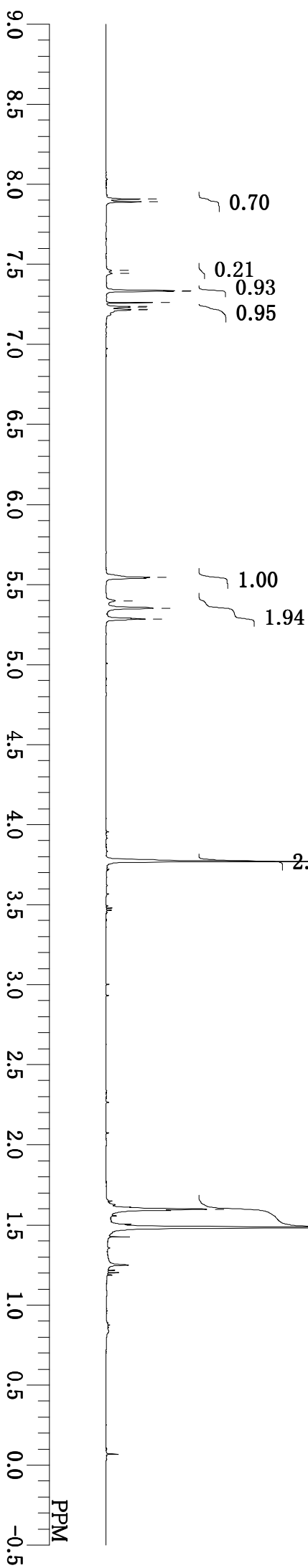


7.908
7.891
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7.214

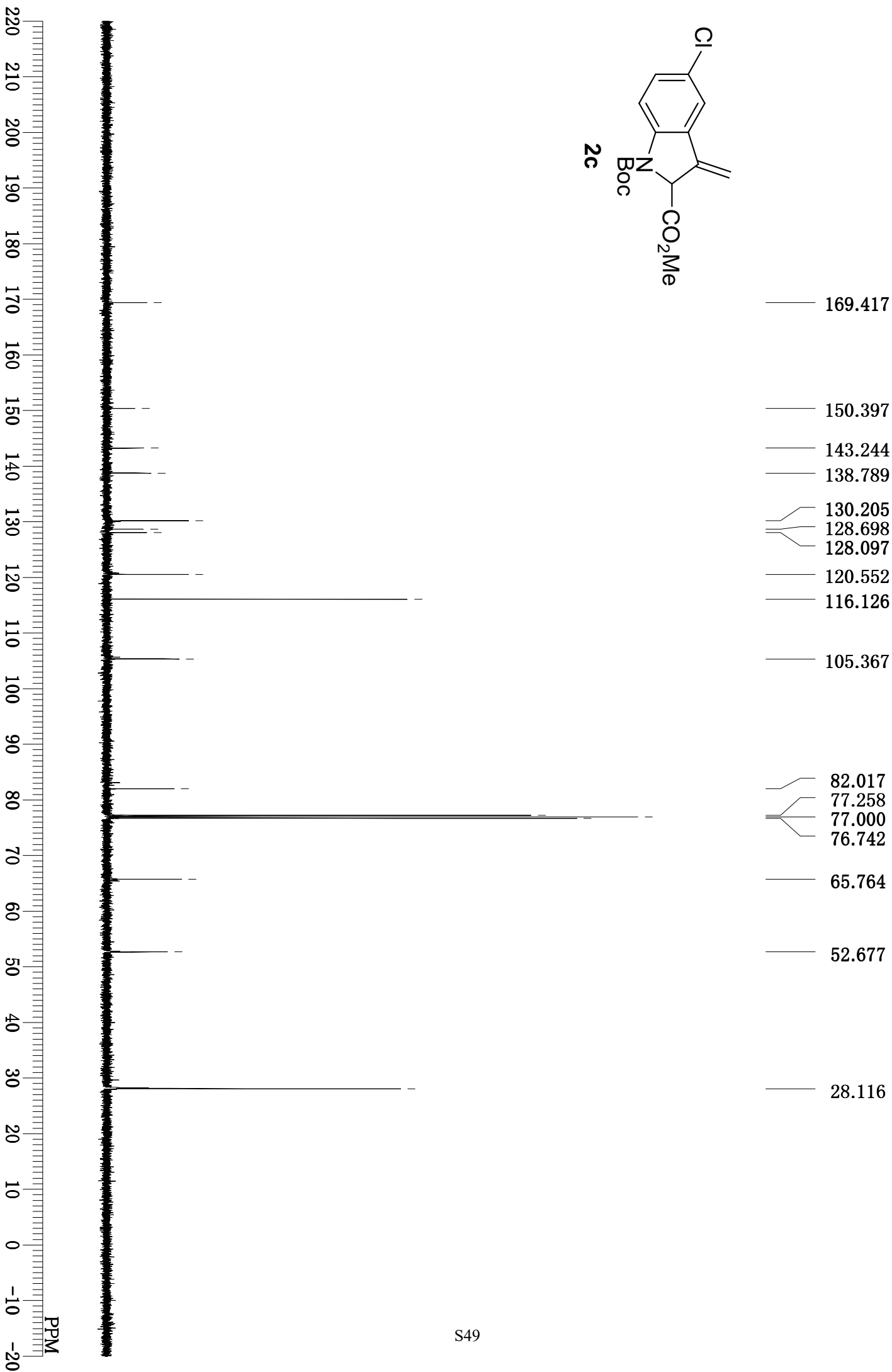
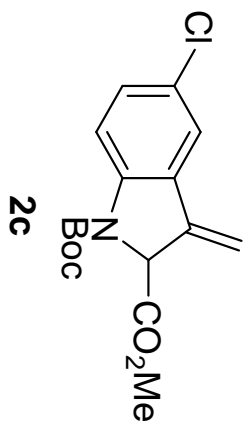
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3.771

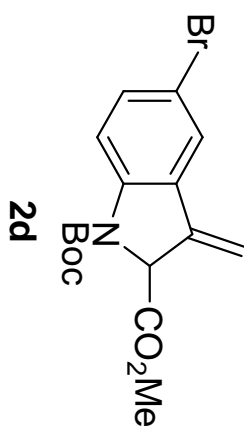
1.598
1.485



125MHz CDCl3



500MHz CDCl₃

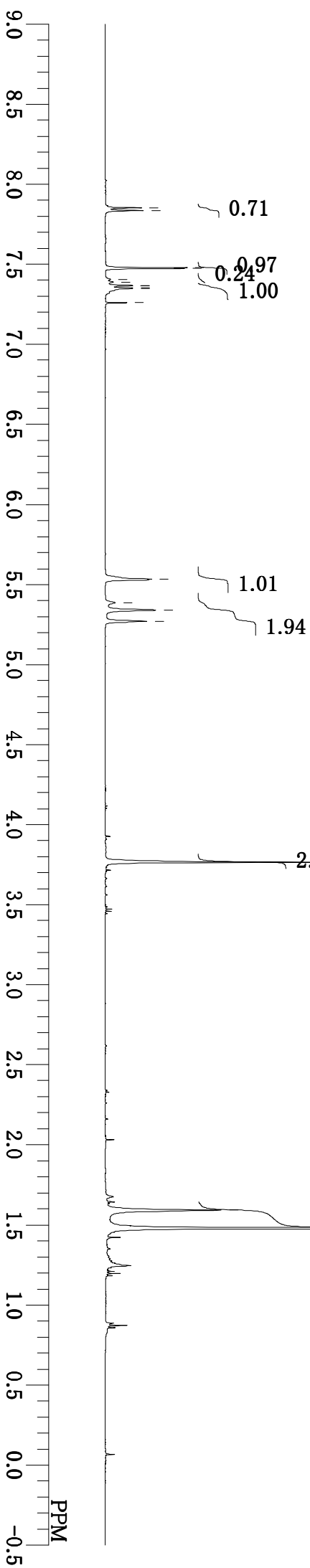


7.853
7.836
7.479
7.475
7.407
7.389
7.369
7.367
7.352
7.348
7.260

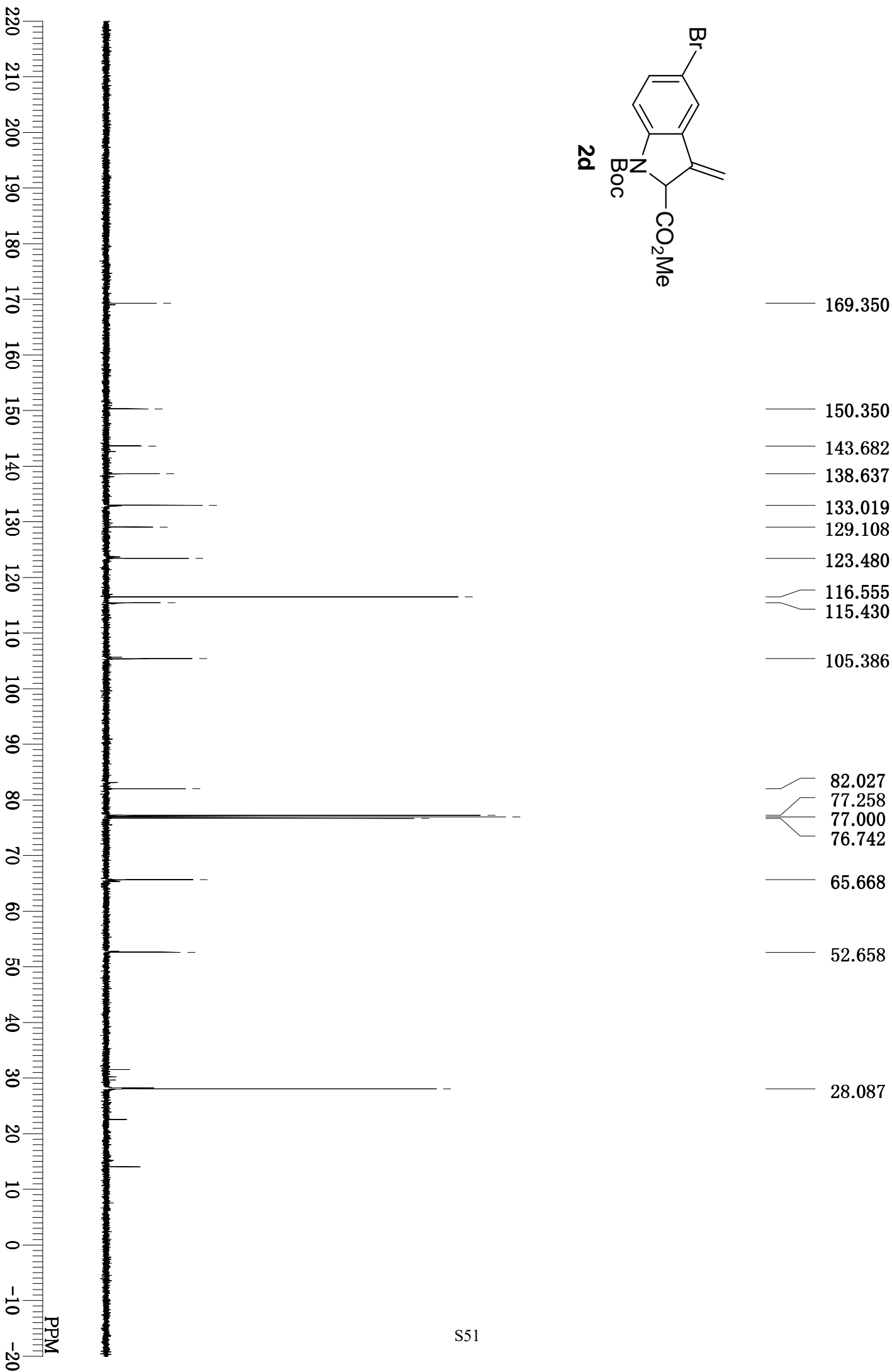
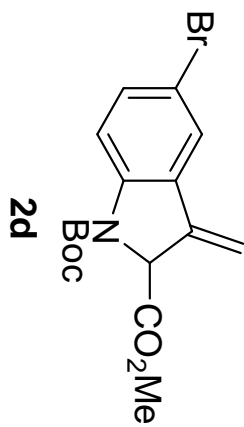
5.534
5.386
5.340
5.270

3.765

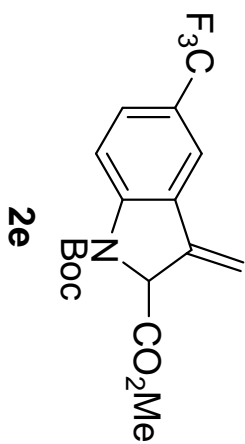
1.592
1.479



125MHz CDCl3



500MHz CDCl₃

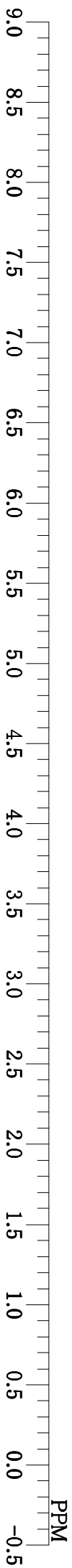


8.069
8.051
7.610
7.535
7.519
7.260

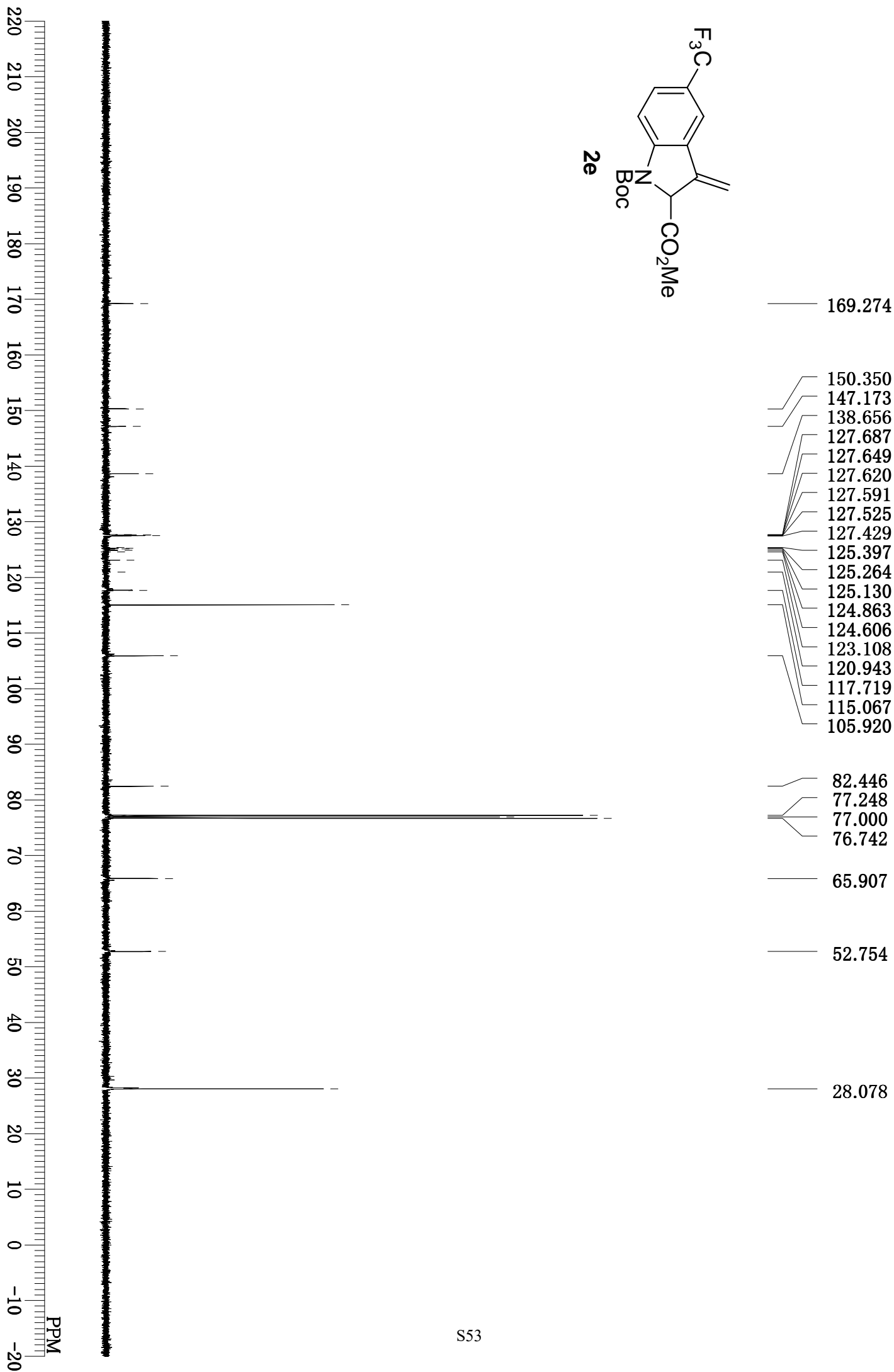
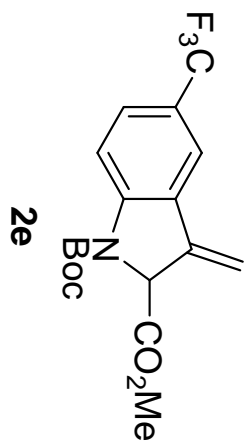
5.649
5.462
5.417
5.340

3.785

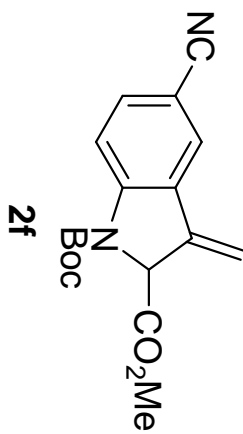
1.615
1.500



125MHz CDCl3



500MHz CDCl₃

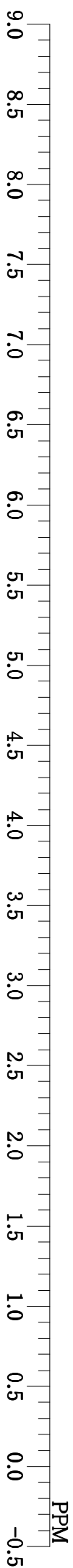


8.060
8.043
7.629
7.584
7.558
7.542
7.260

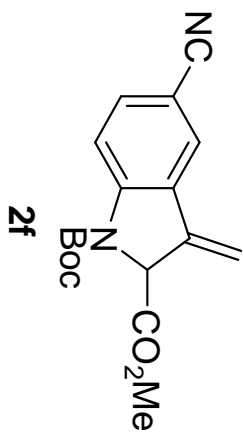
5.646
5.484
5.445
5.390
5.329

3.785

1.608
1.489



125MHz CDCl3



168.959

150.121
147.917

137.864
134.602

127.992
124.310

118.930
115.563

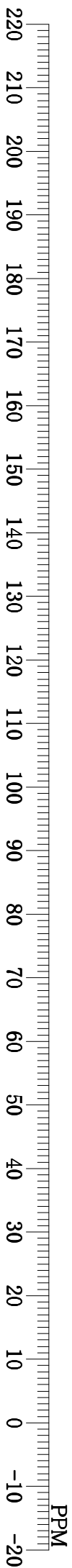
106.826
105.901

82.876
77.258
77.000
76.742

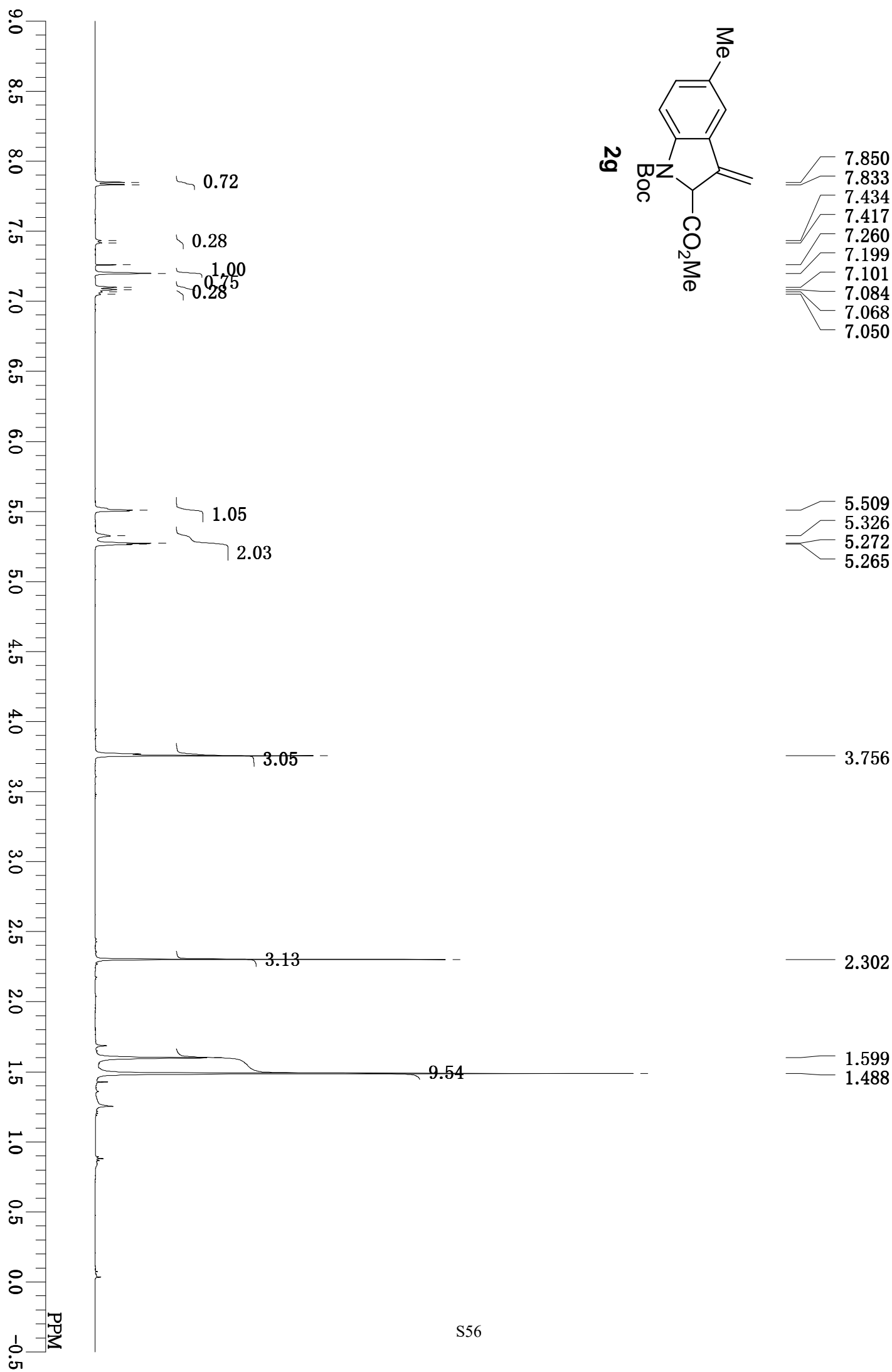
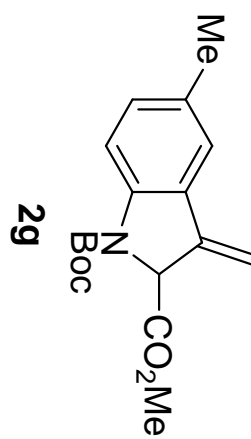
65.792

52.849

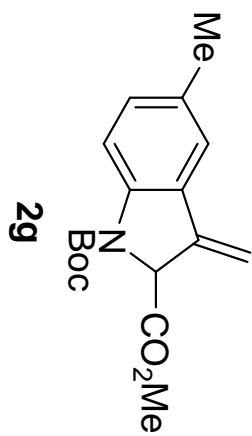
28.011



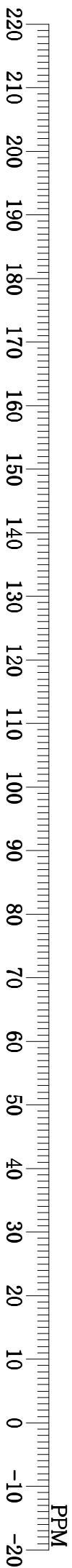
500MHz CDCl₃



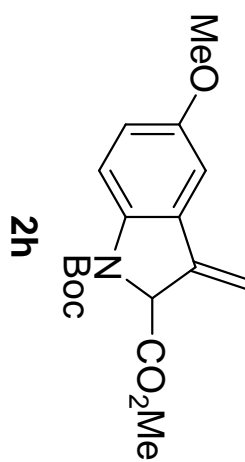
125MHz CDCl₃



169.865
150.540
142.500
139.991
132.275
131.216
127.038
120.838
114.800
103.459
81.445
77.248
77.000
76.742
65.745
52.506
28.164
20.848



500MHz CDCl₃

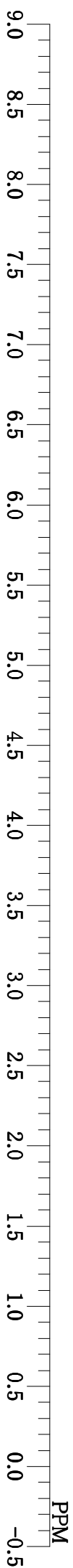


7.884
7.867
7.462
7.443
7.260
6.910
6.905
6.861
6.856
6.843
6.839
6.820

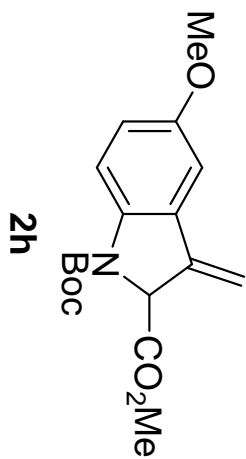
5.508
5.352
5.338
5.304
5.270

3.783
3.761

1.595
1.483



125MHz CDCl3



169.837

155.825

150.540

139.915

138.694

128.011

116.575

115.831

105.386

104.013

81.397

77.248

77.000

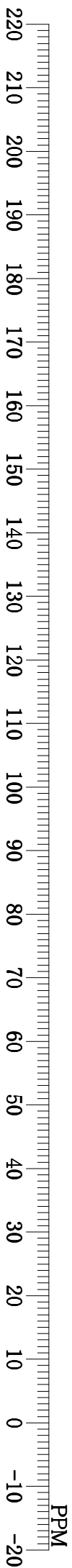
76.742

65.802

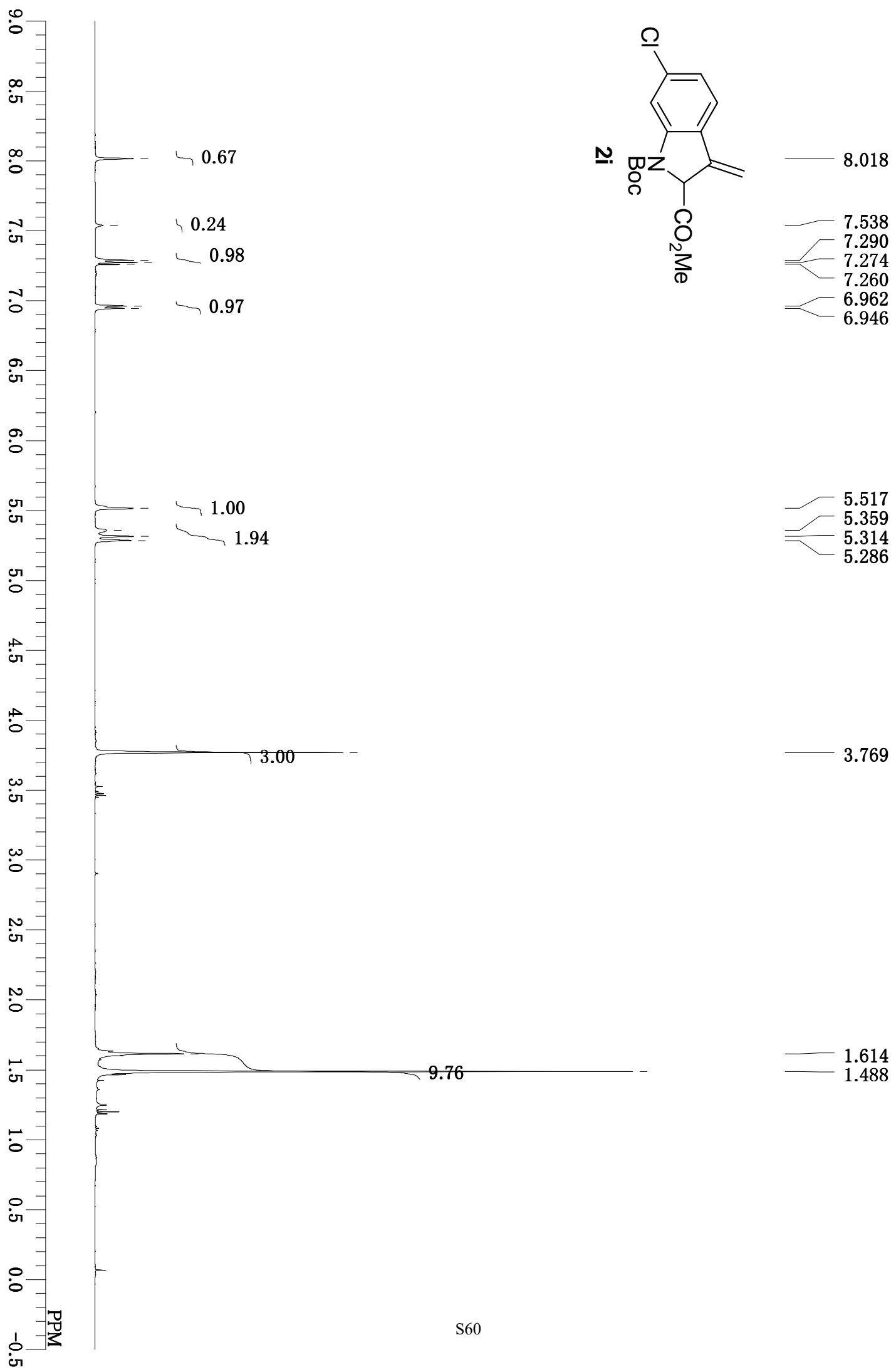
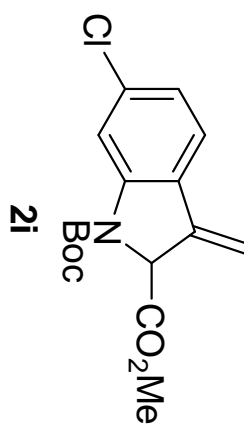
55.701

52.544

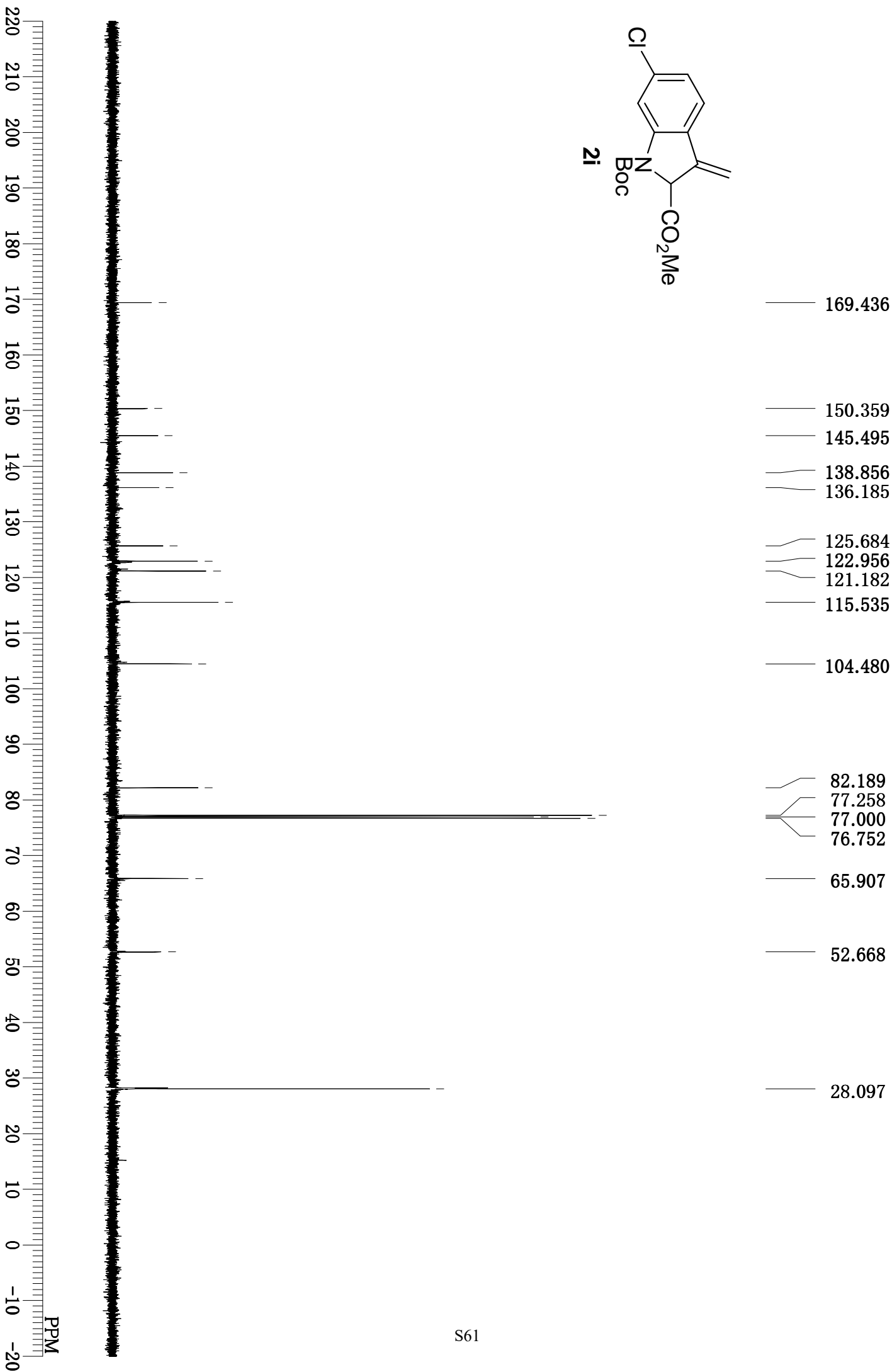
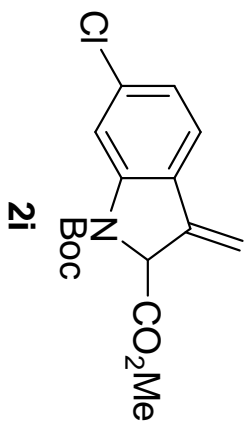
28.173



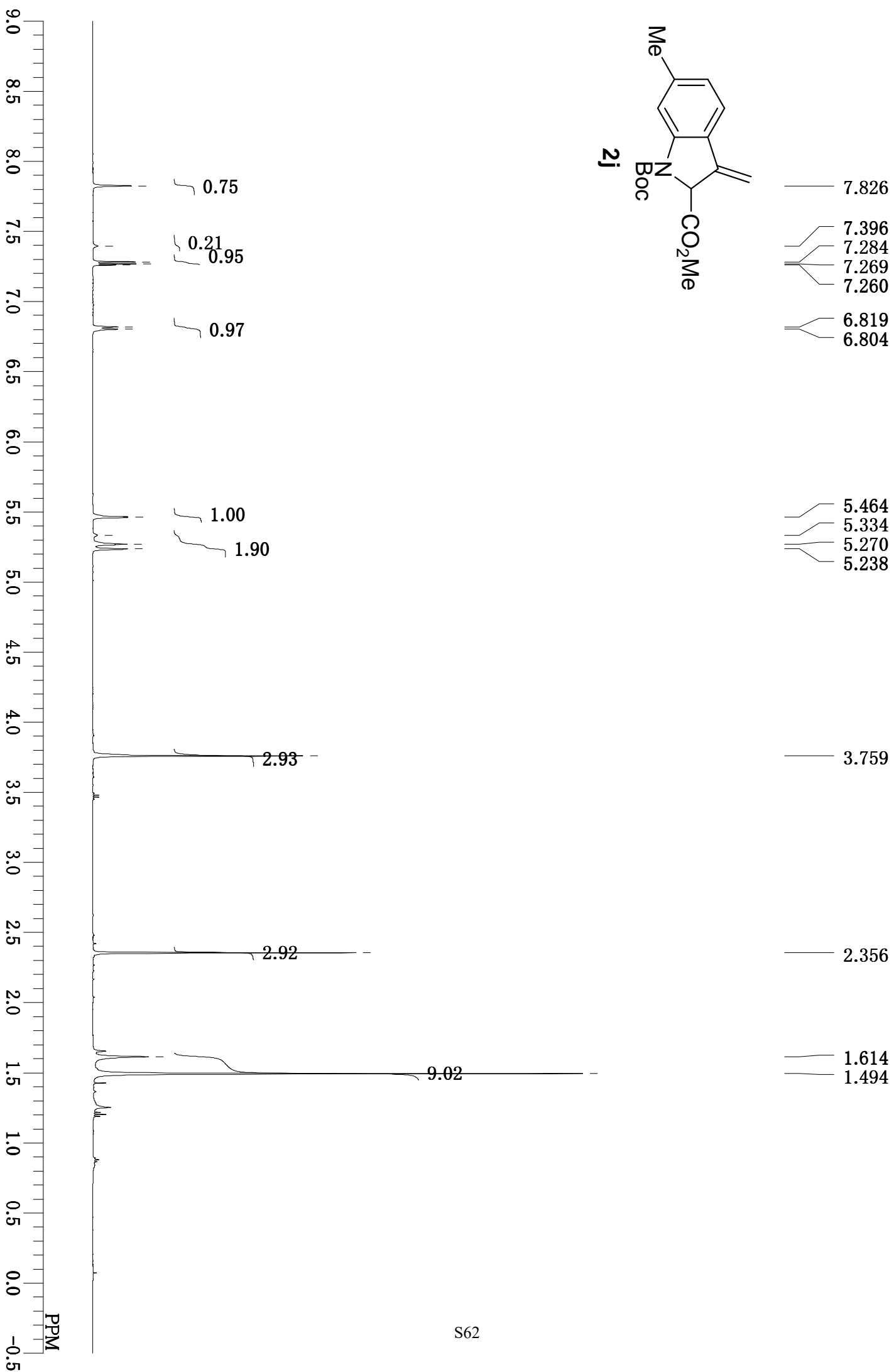
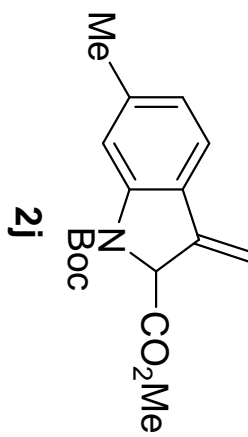
500MHz CDCl3



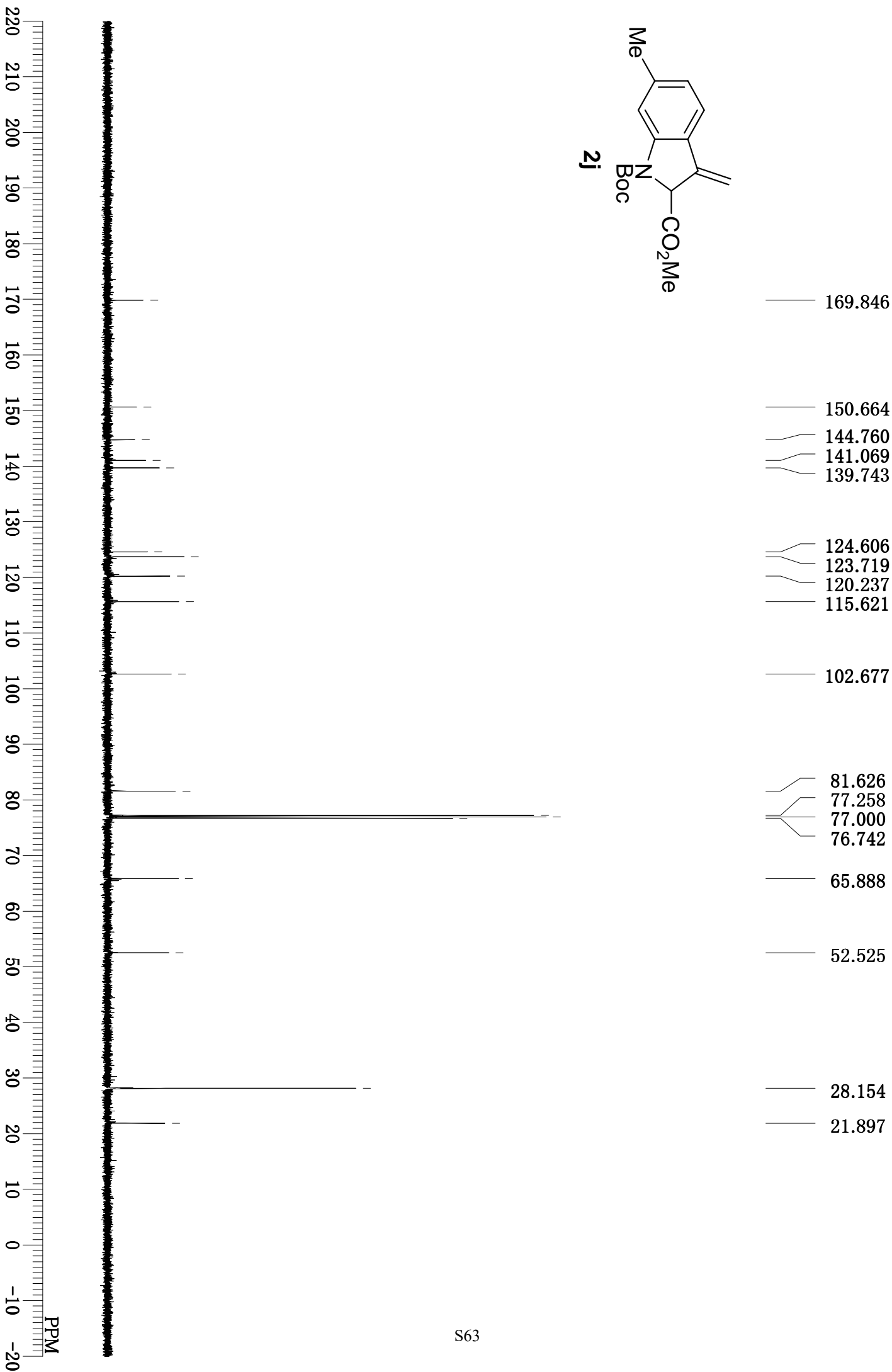
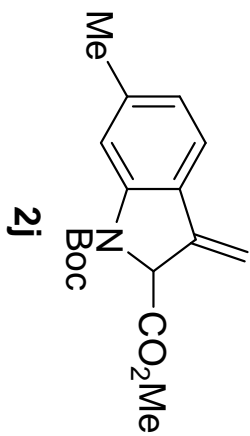
125MHz CDCl3



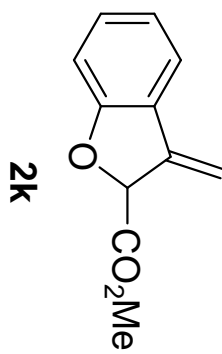
500MHz CDCl₃



125MHz CDCl3



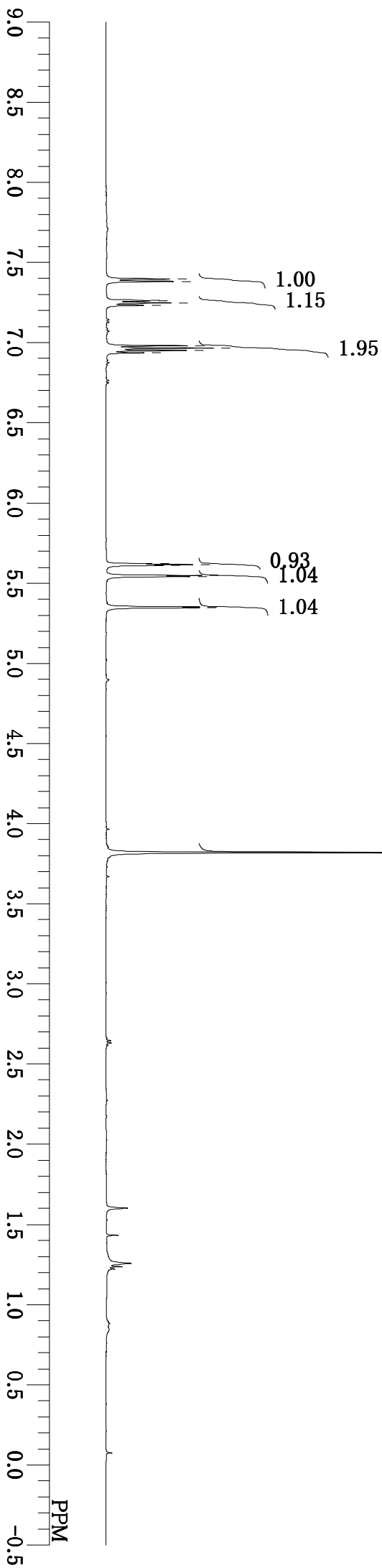
500MHz CDCl₃



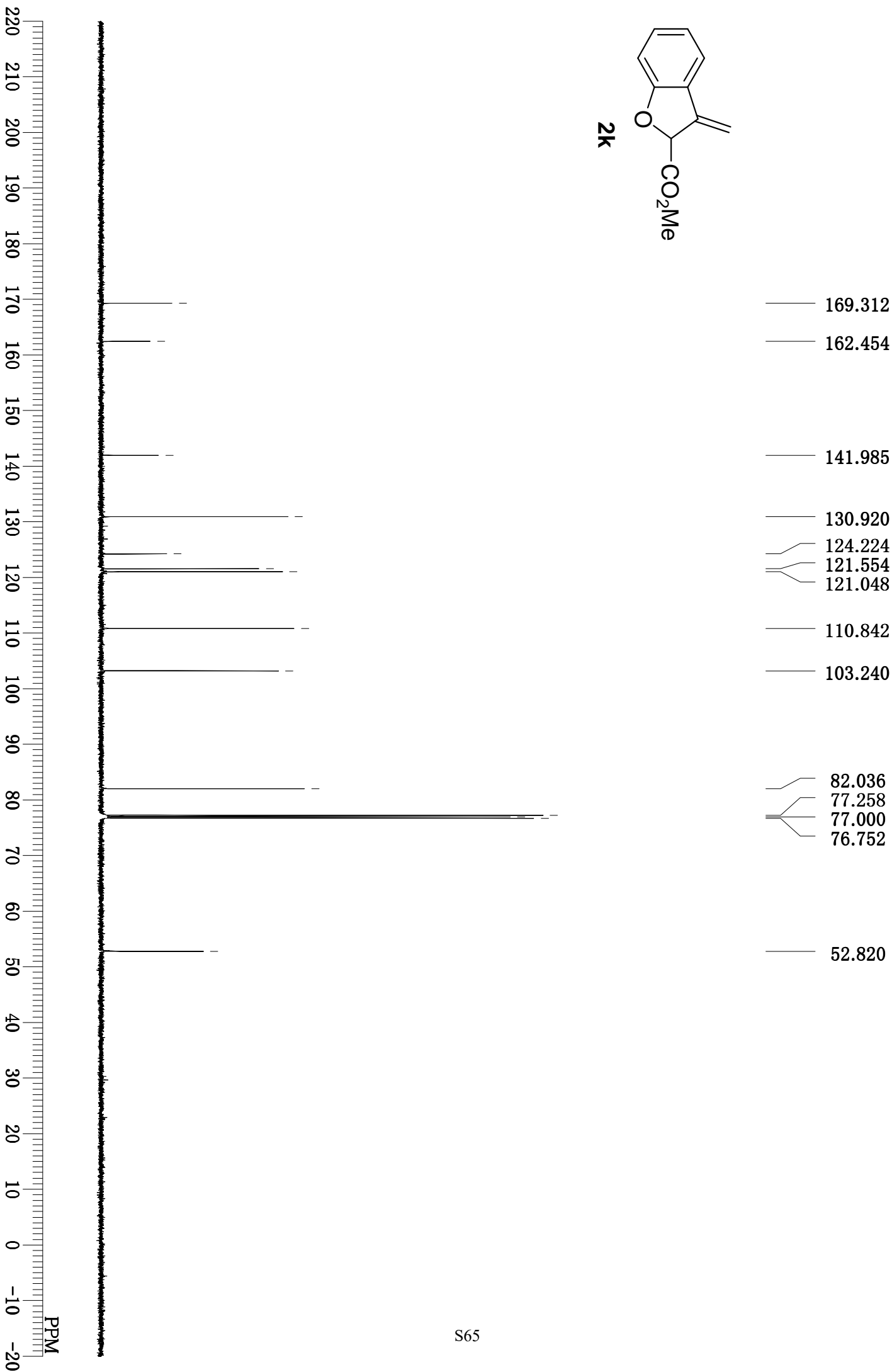
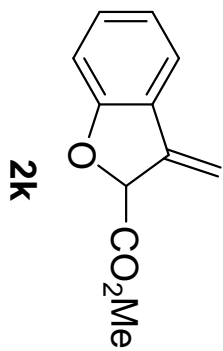
7.397
7.383
7.263
7.260
7.249
7.234
6.982
6.966
6.952
6.937

5.621
5.616
5.611
5.548
5.542
5.352
5.348

3.820

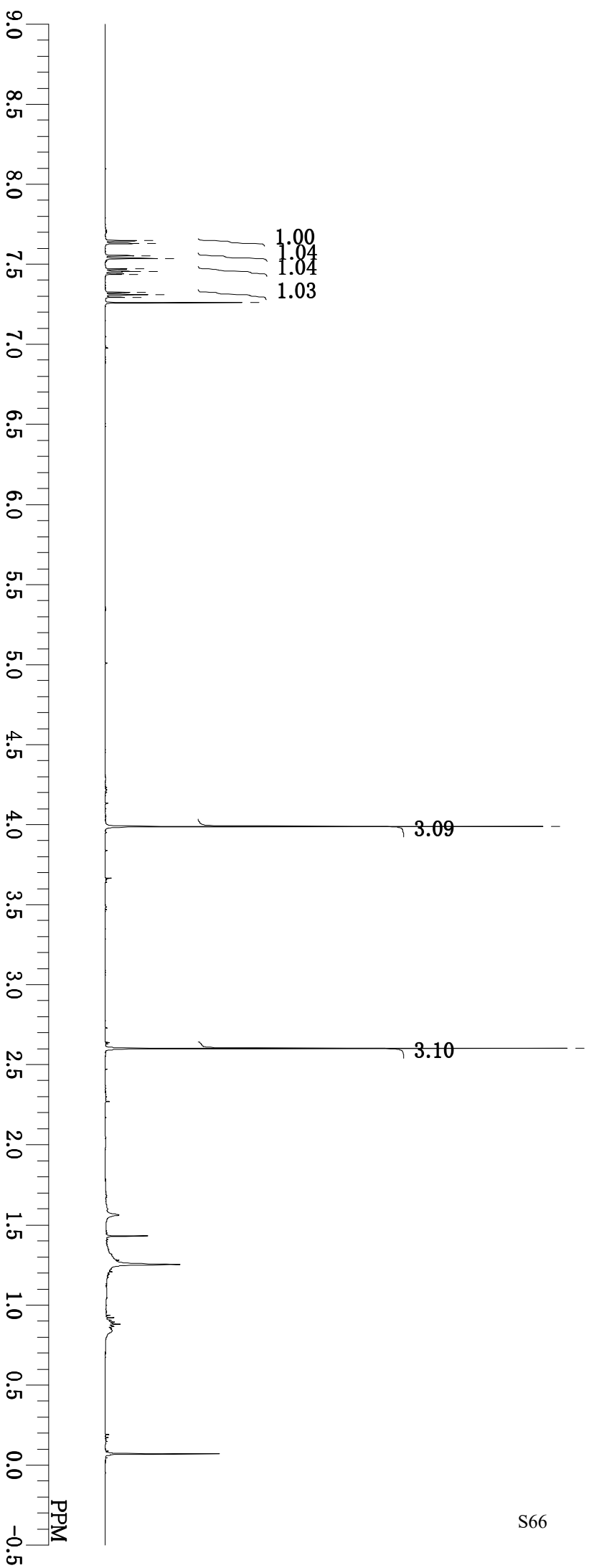
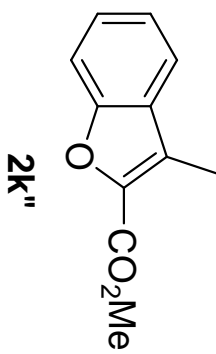


125MHz CDCl3



500MHz CDCl₃

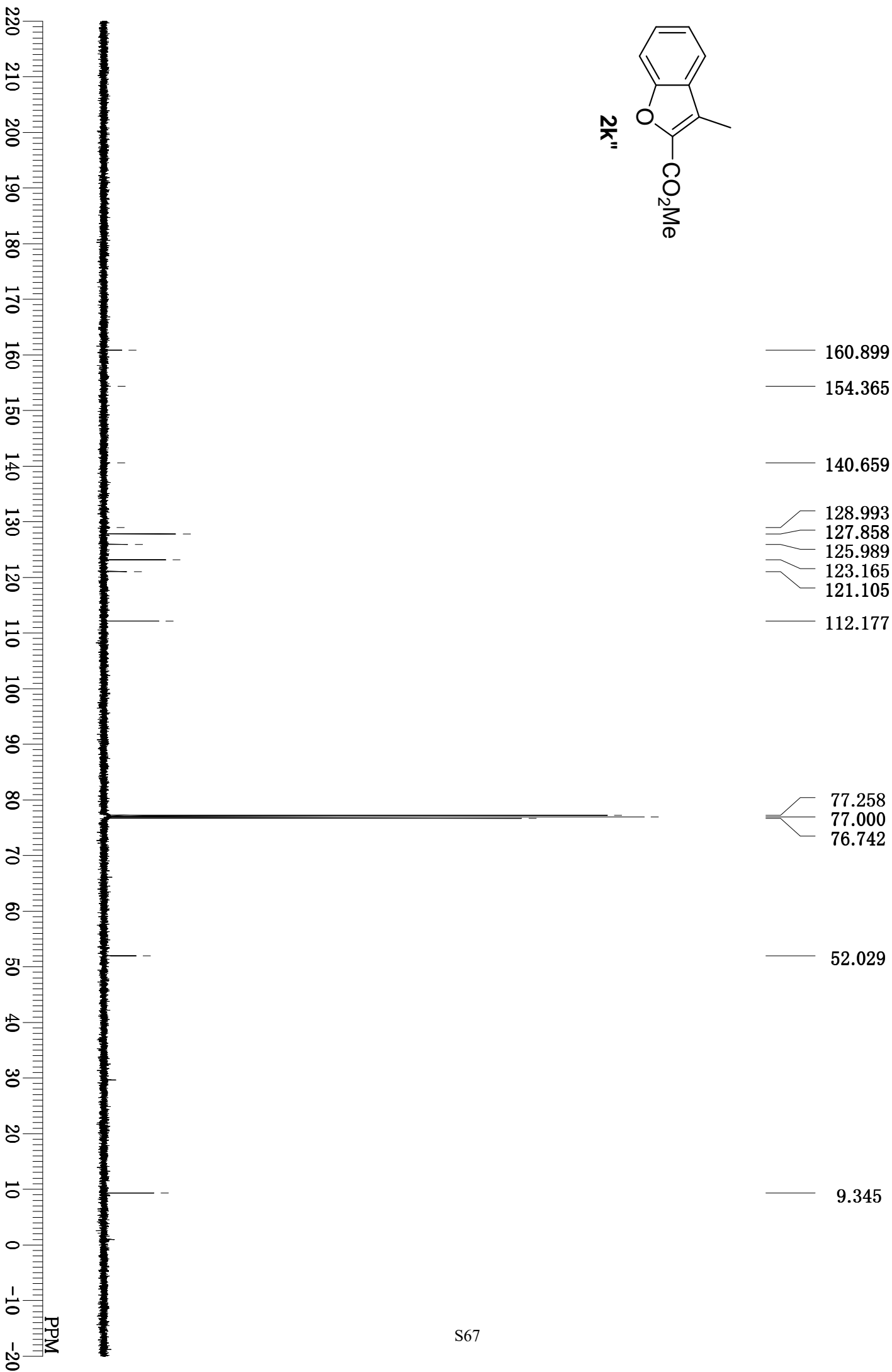
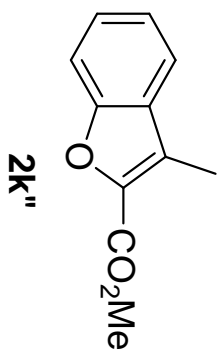
- 7.647
- 7.631
- 7.553
- 7.537
- 7.472
- 7.455
- 7.439
- 7.326
- 7.310
- 7.294
- 7.260



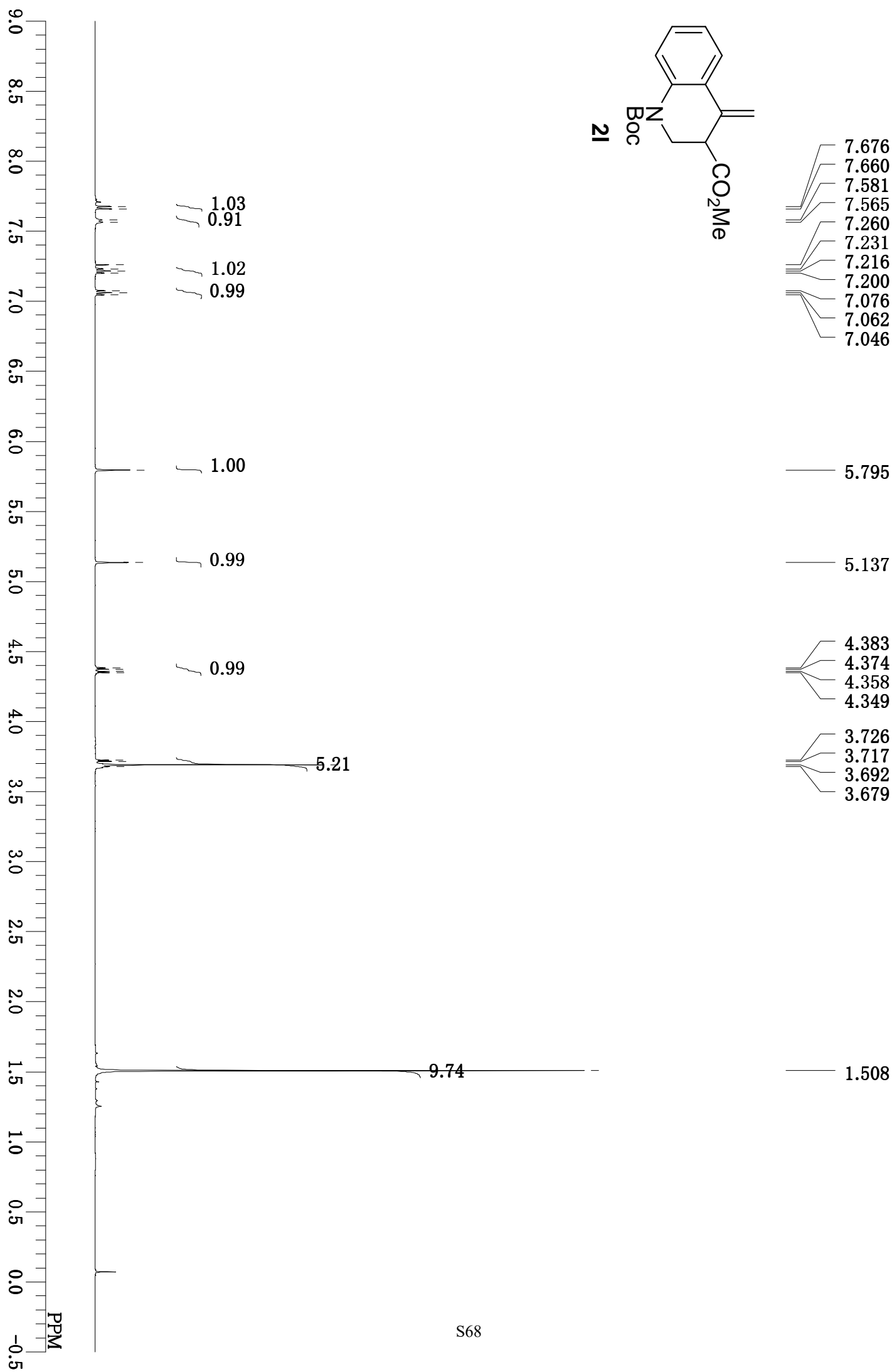
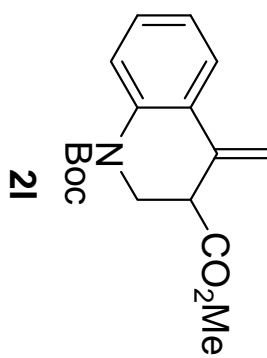
3.988

2.603

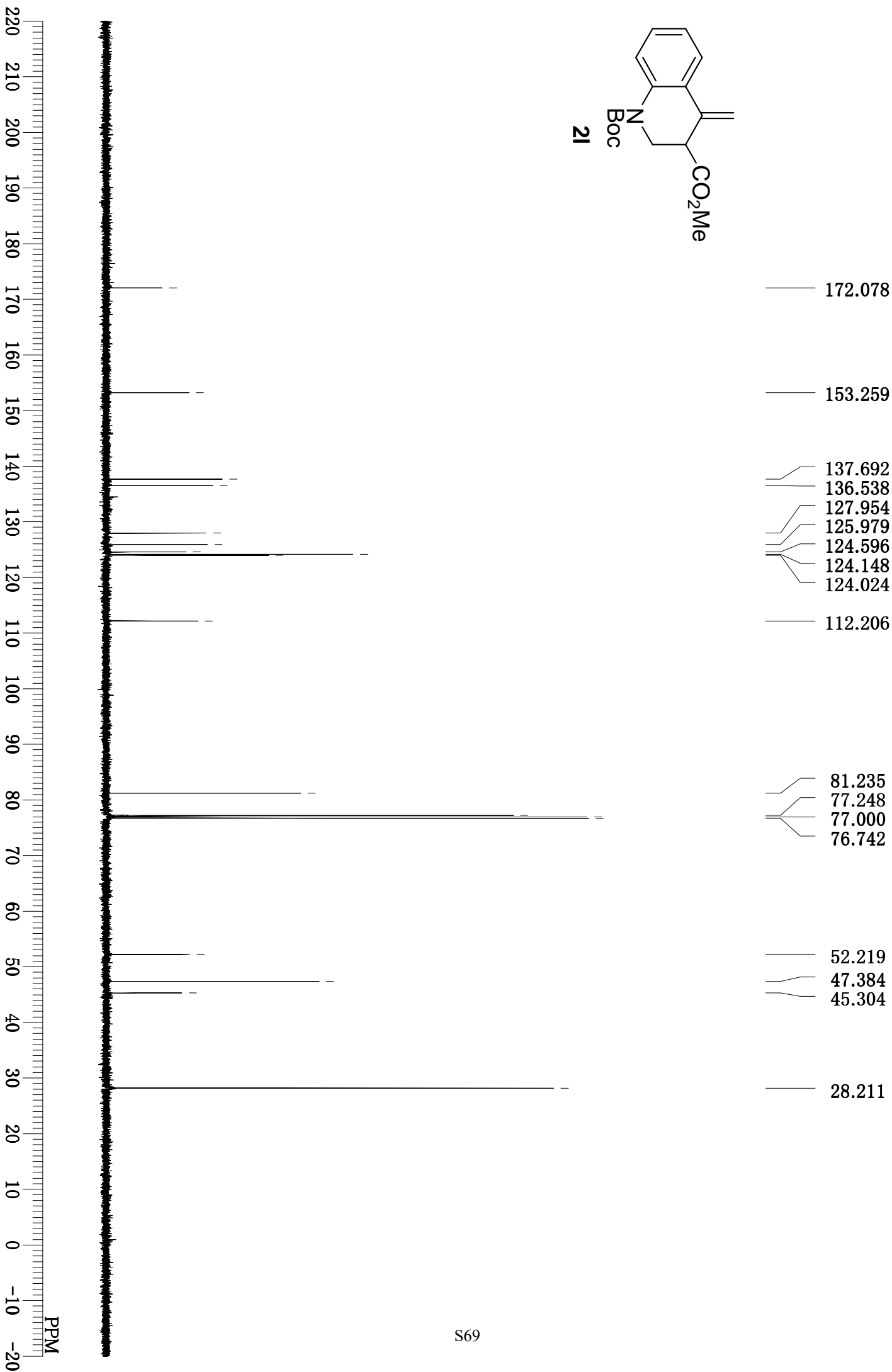
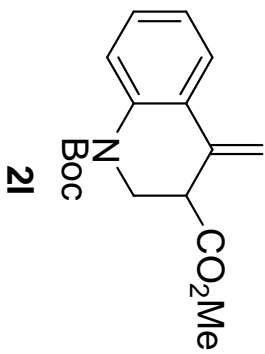
125MHz CDCl3



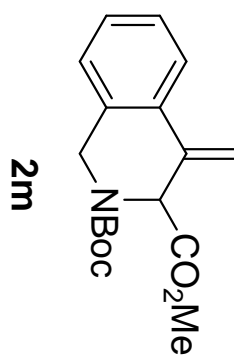
500MHz CDCl₃



125MHz CDCl3



500MHz CDCl₃

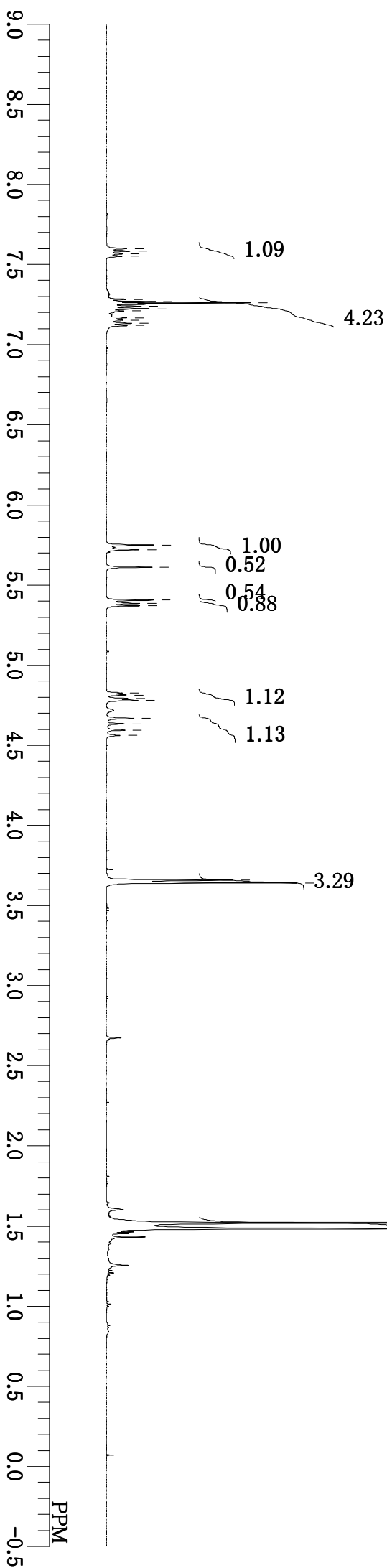


7.599
7.584
7.567
7.552
7.283
7.269
7.260
7.255
7.239
7.224
7.211
7.167
7.153
7.134
7.119

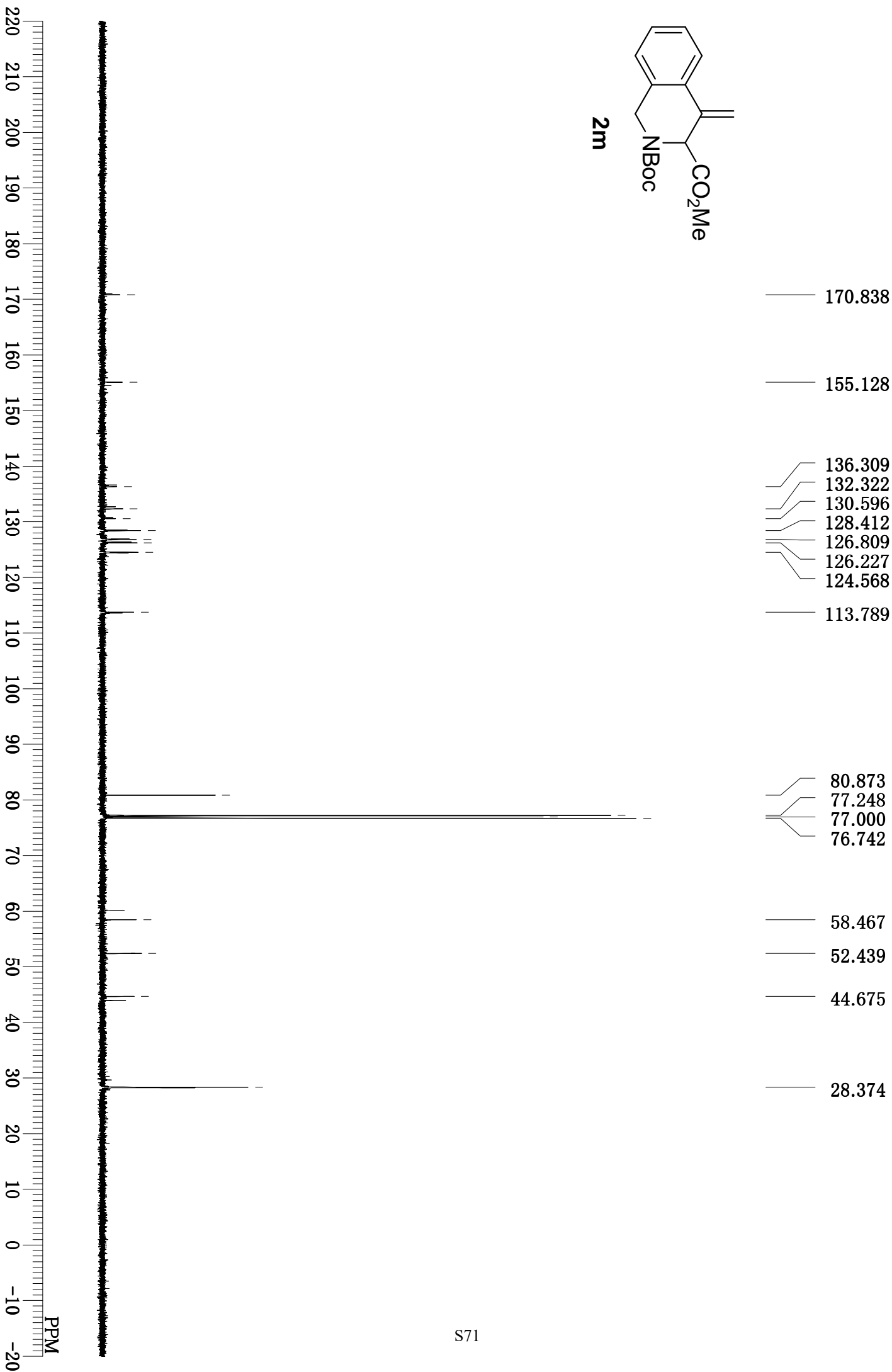
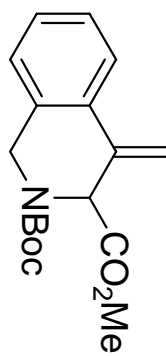
5.749
5.721
5.611
5.406
5.385
5.372
4.826
4.814
4.792
4.781
4.668
4.634
4.595
4.562

3.658
3.642

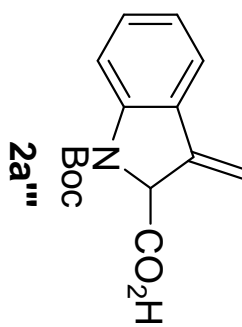
1.520
1.485



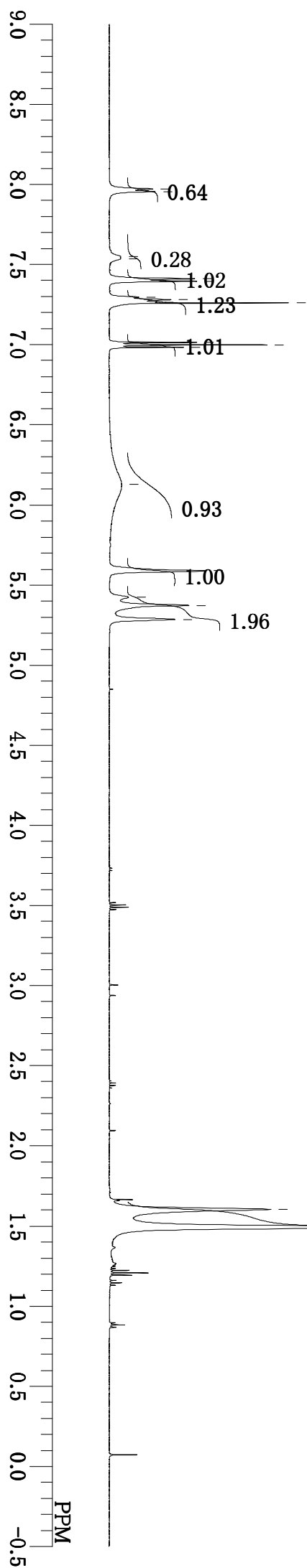
125MHz CDCl3



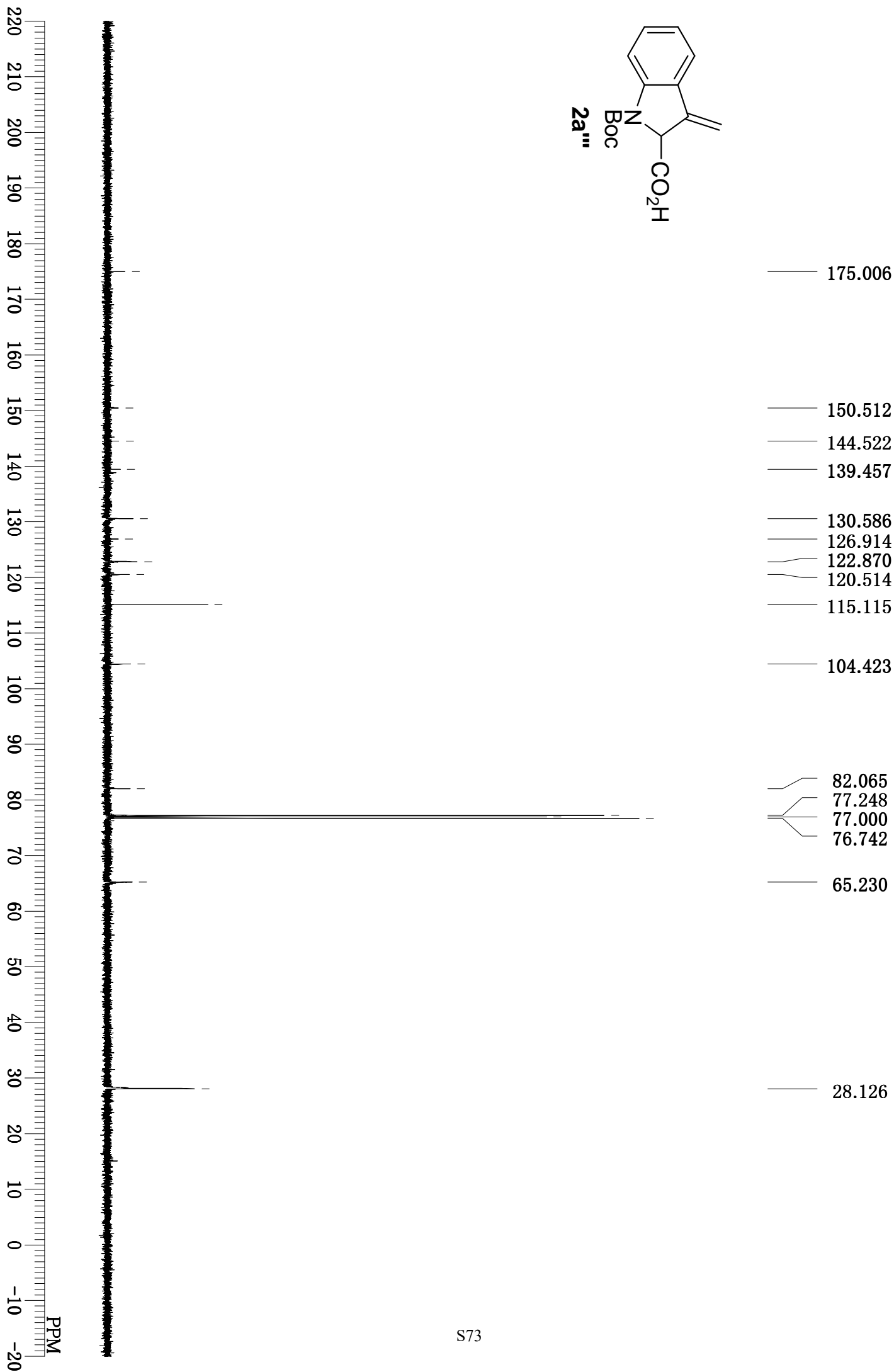
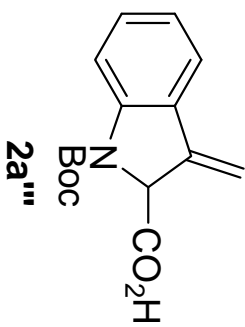
500MHz CDCl₃



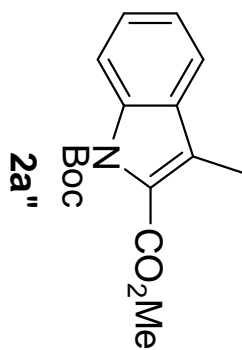
- 7.972
- 7.956
- 7.551
- 7.536
- 7.411
- 7.396
- 7.297
- 7.282
- 7.266
- 7.260
- 7.014
- 6.999
- 6.984
- 6.127
- 5.589
- 5.424
- 5.374
- 5.286
- 1.604
- 1.494



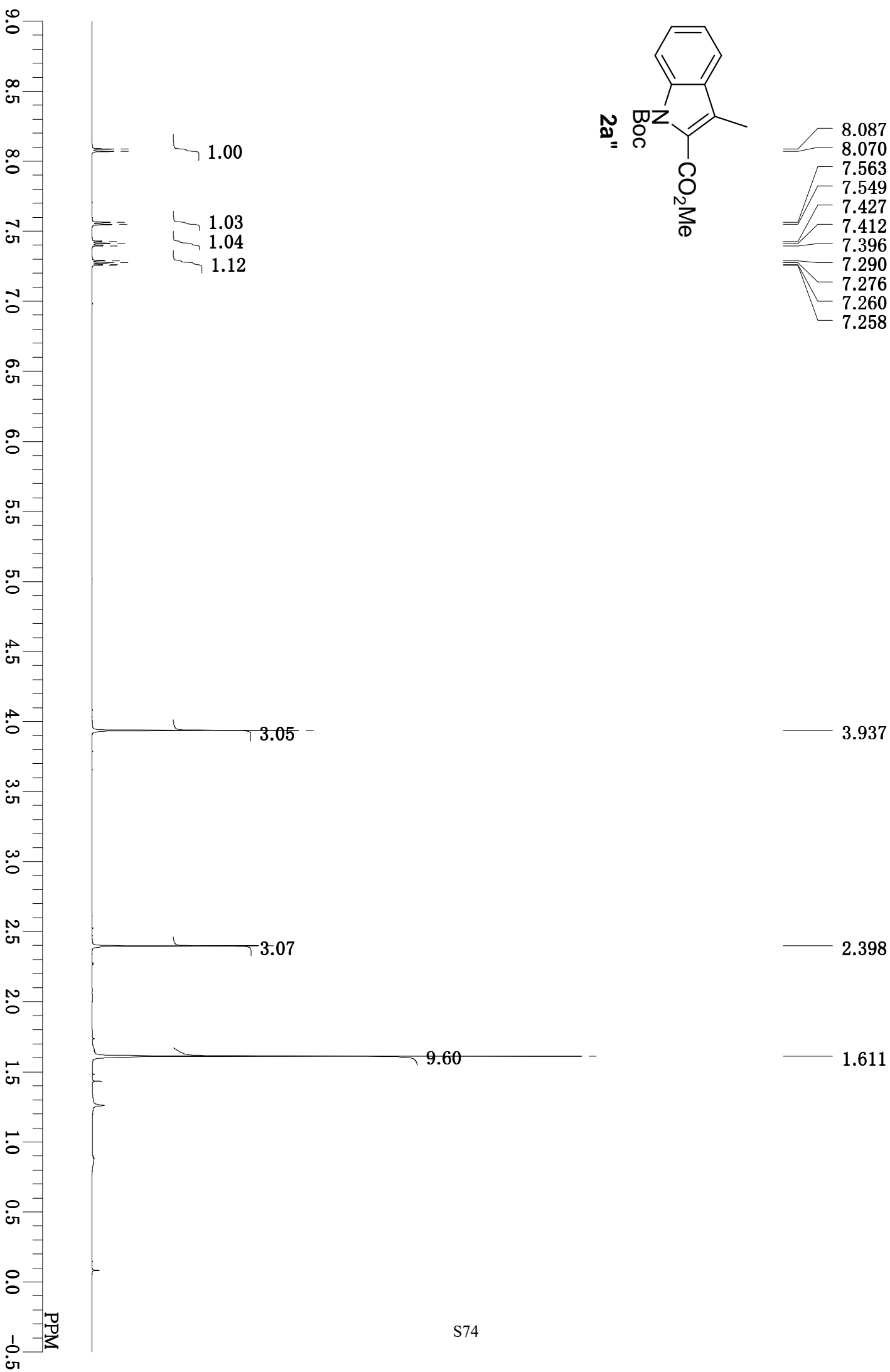
125MHz CDCl₃



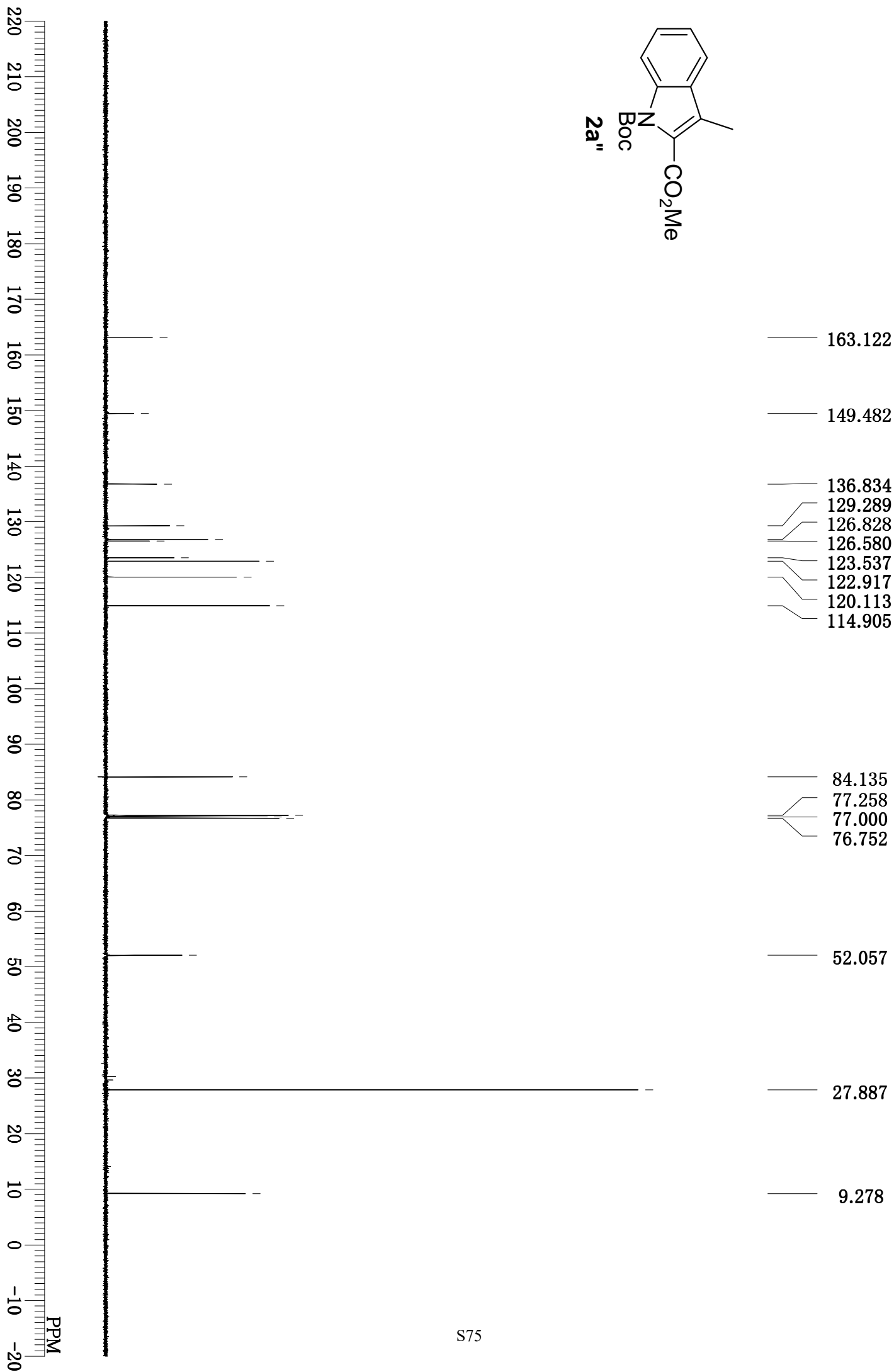
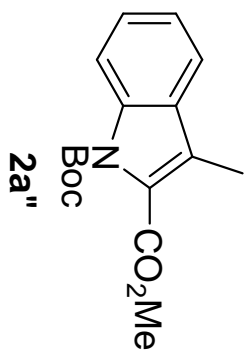
500MHz CDCl₃



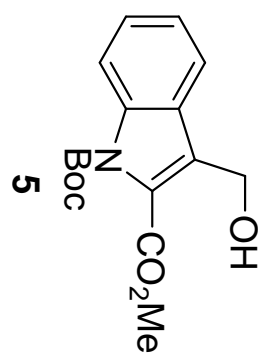
8.087
8.070
7.563
7.549
7.427
7.412
7.396
7.290
7.276
7.260
7.258



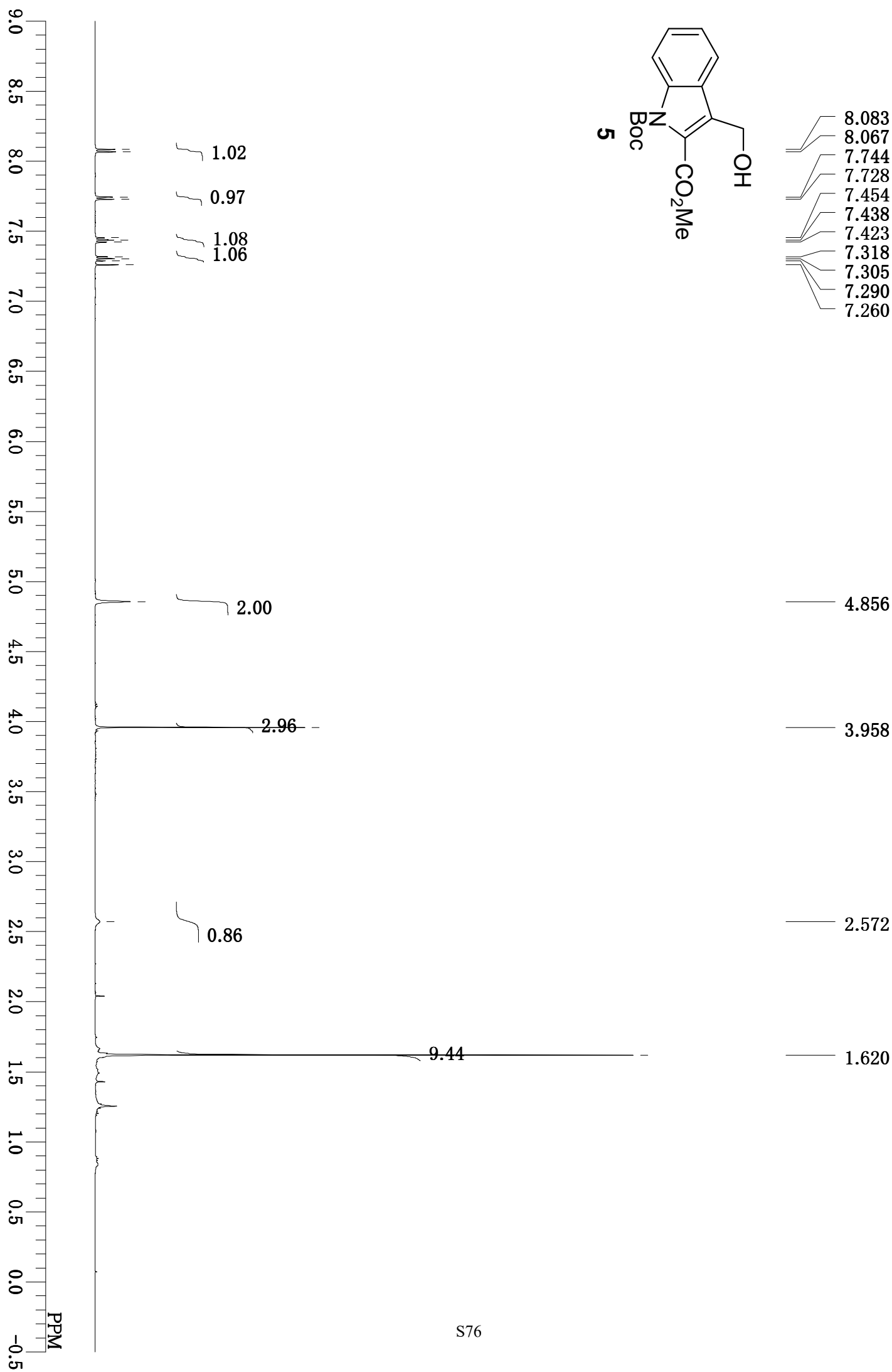
125MHz CDCl3



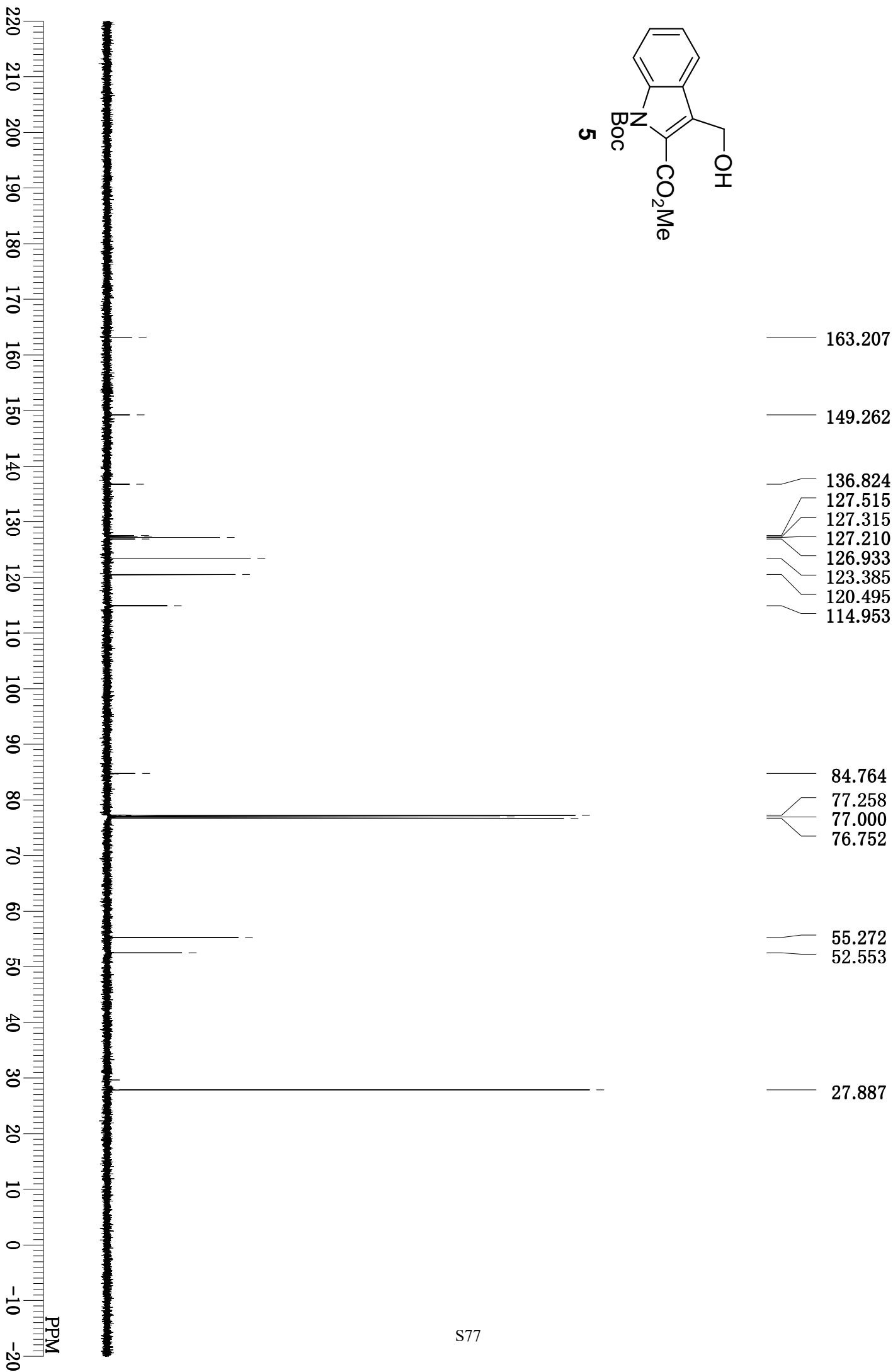
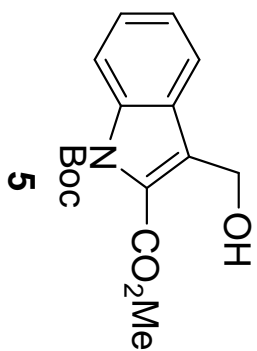
500MHz CDCl₃



8.083
8.067
7.744
7.728
7.454
7.438
7.423
7.318
7.305
7.290
7.260

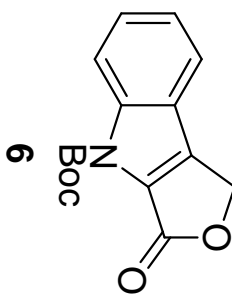


125MHz CDCl3



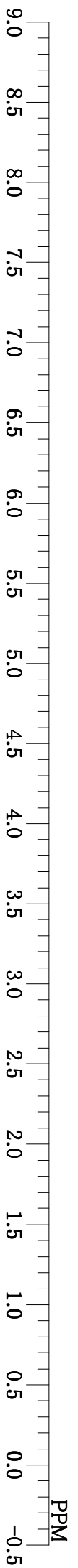
500MHz CDCl₃

- 8.377
- 8.359
- 7.606
- 7.590
- 7.557
- 7.542
- 7.527
- 7.375
- 7.360
- 7.344
- 7.260



5.320

1.709



0.96

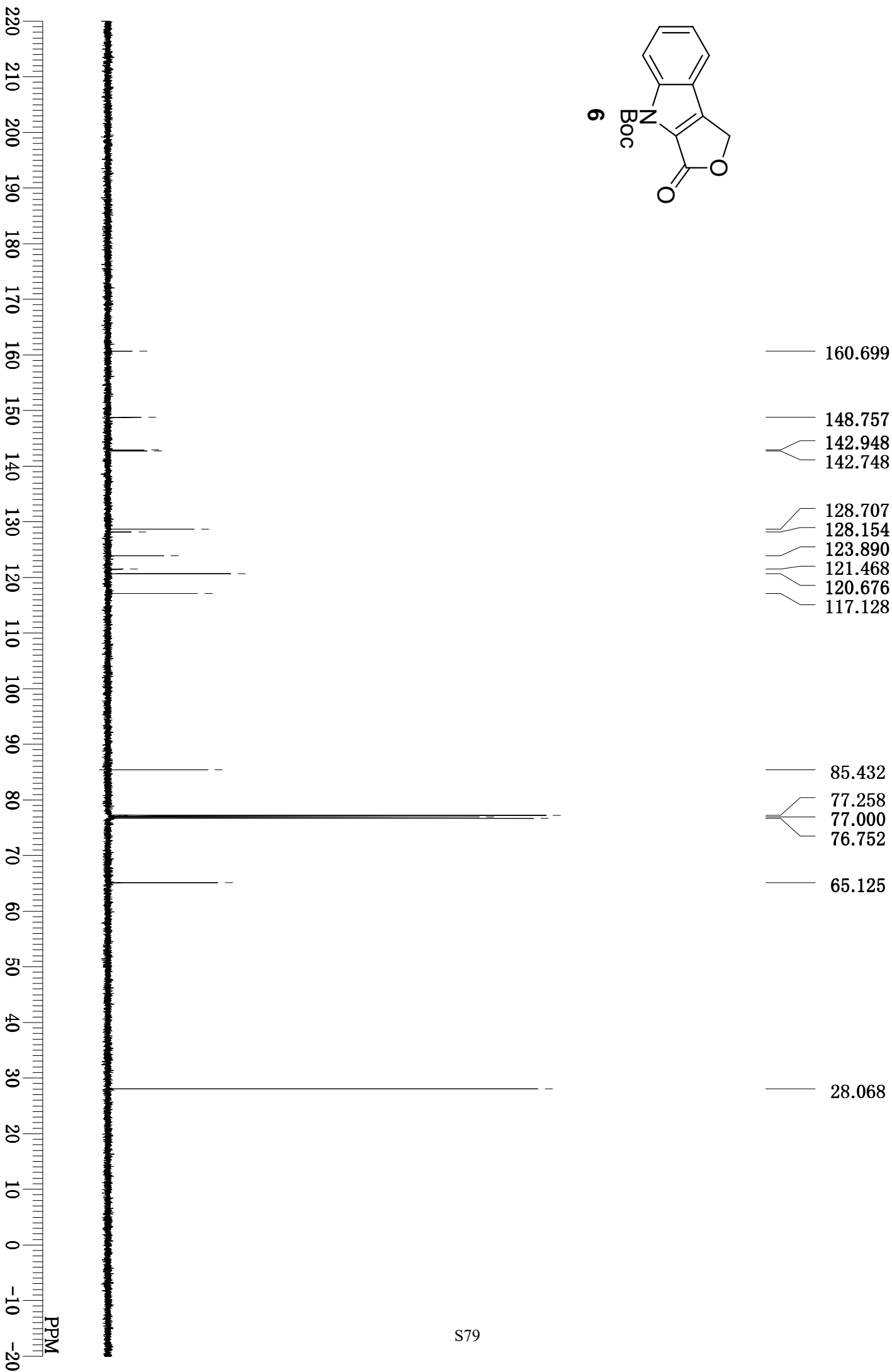
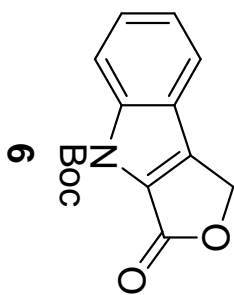
8.98

1.01

2.00

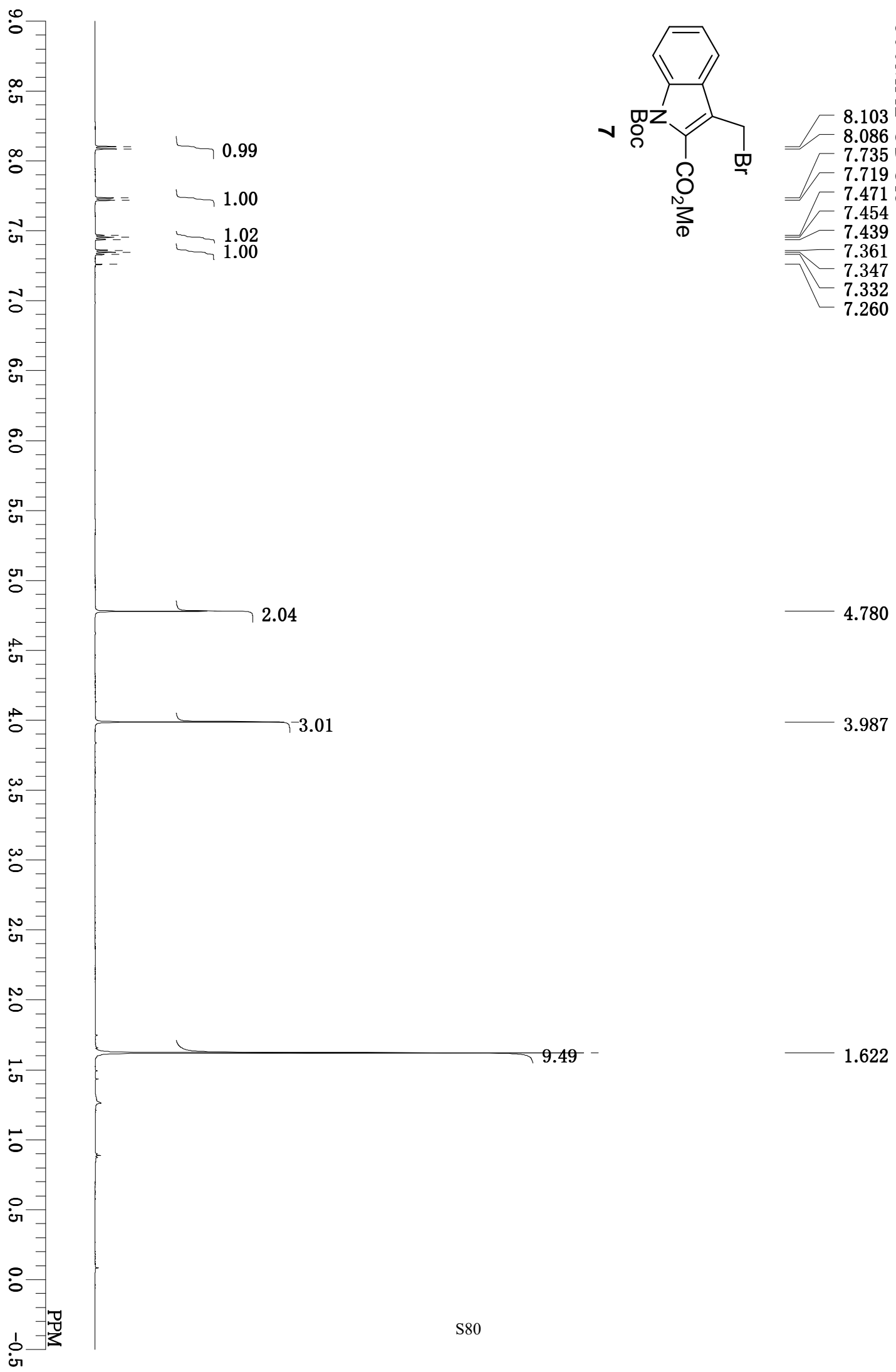
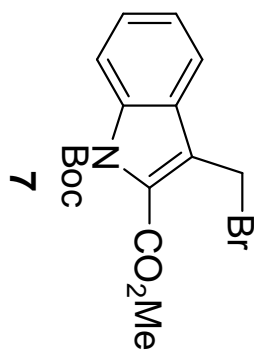
8.98

125MHz CDCl3

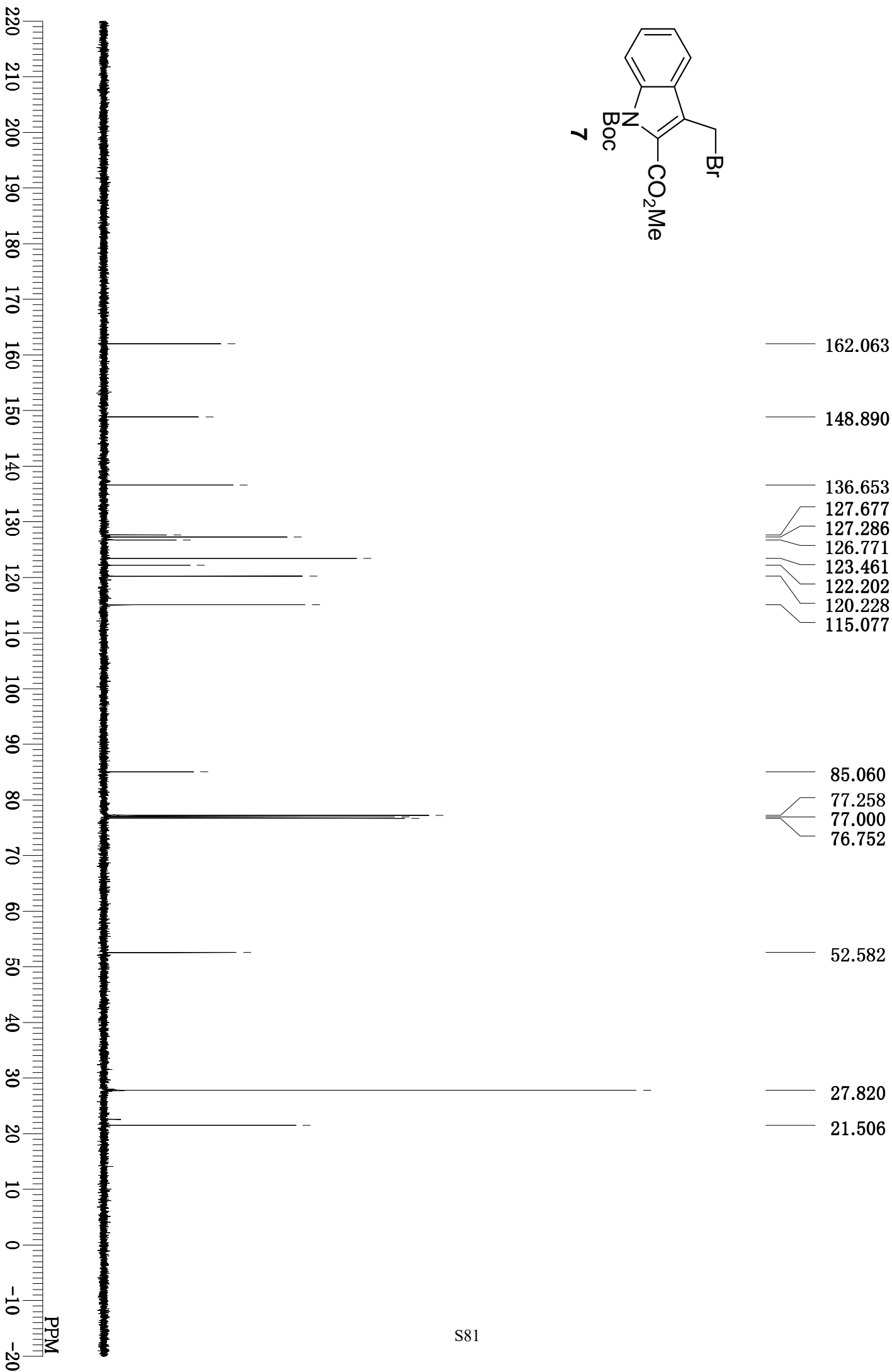
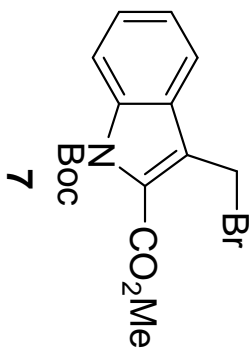


500MHz CDCl₃

- 8.103
- 8.086
- 7.735
- 7.719
- 7.471
- 7.454
- 7.439
- 7.361
- 7.347
- 7.332
- 7.260

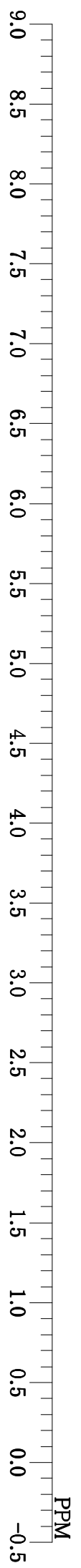
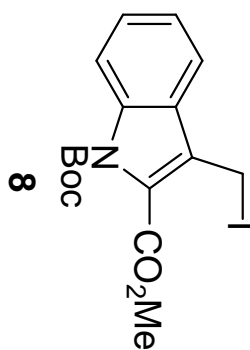


125MHz CDCl3



500MHz CDCl₃

- 8.097
- 8.080
- 7.689
- 7.673
- 7.464
- 7.448
- 7.433
- 7.376
- 7.360
- 7.344
- 7.260



1.00
1.02
1.04
1.01

2.06

3.04

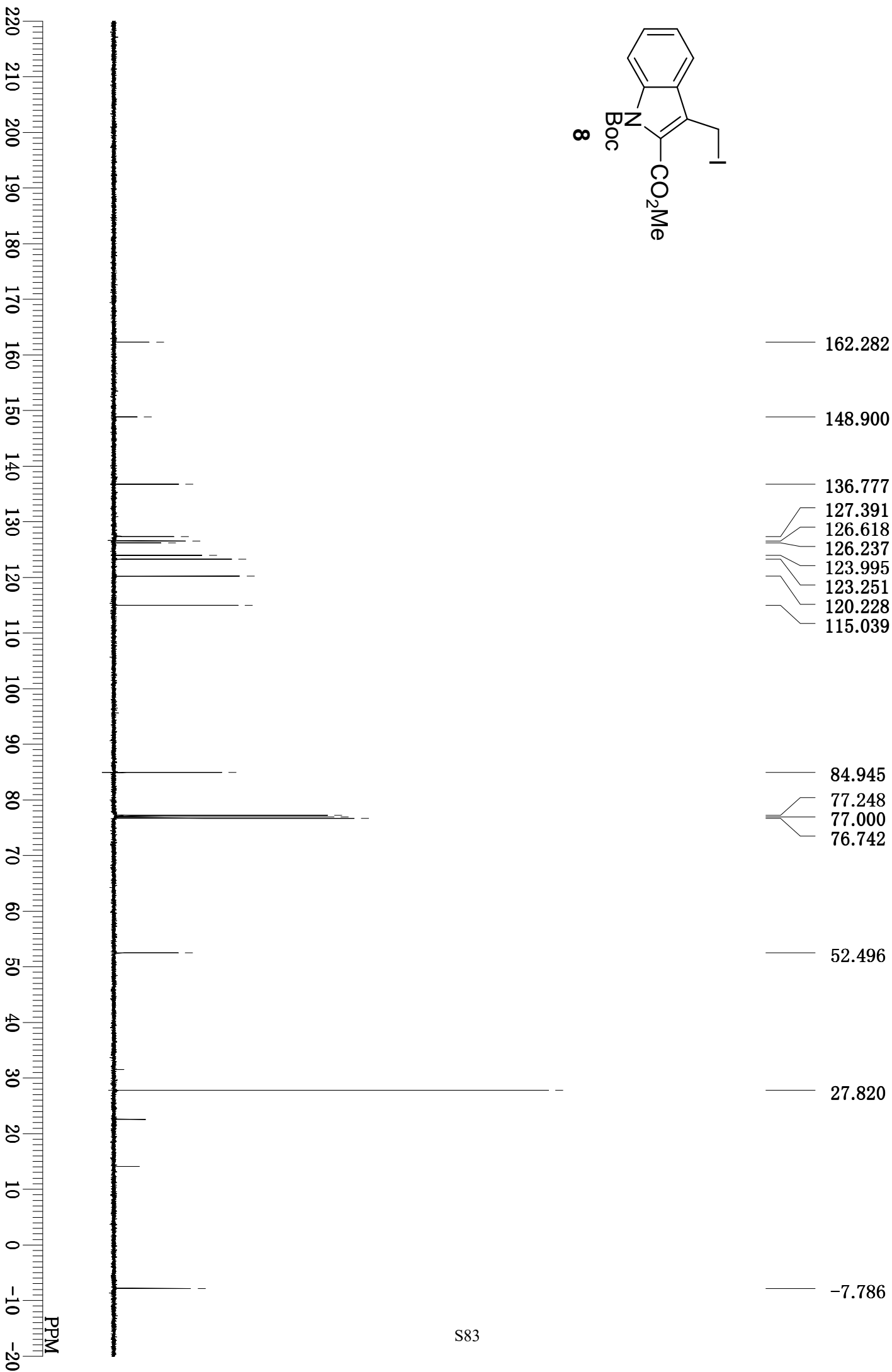
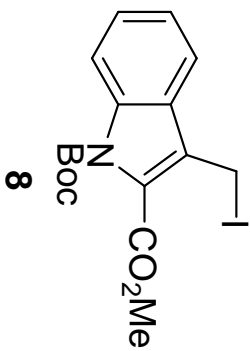
9.72

4.703

3.992

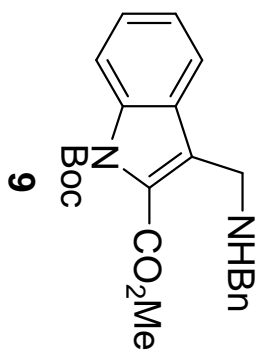
1.618

125MHz CDCl₃



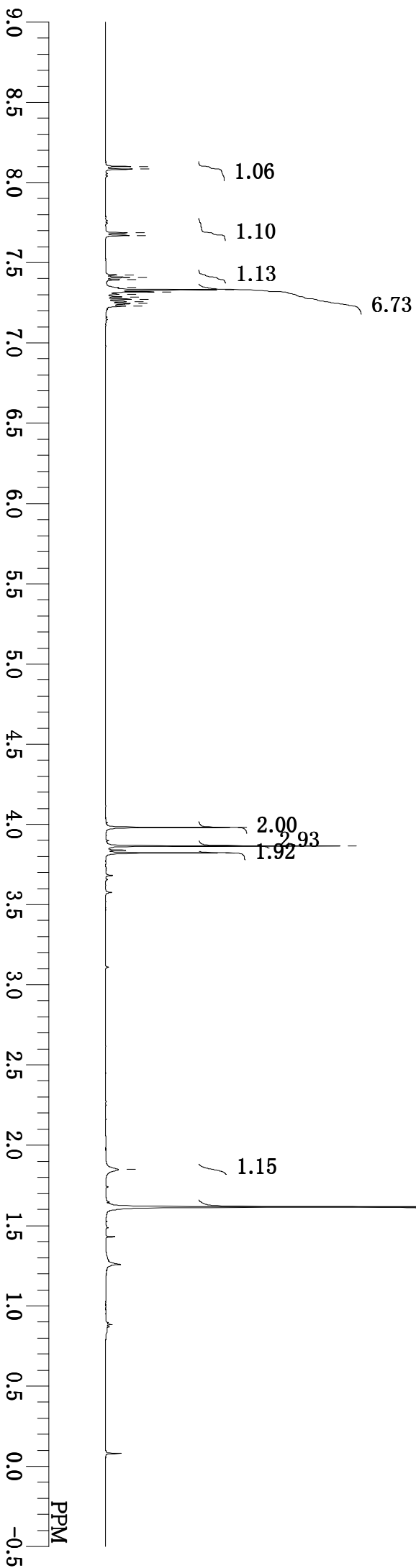
500MHz CDCl₃

8.101
8.083
7.686
7.671
7.424
7.409
7.394
7.345
7.332
7.320
7.304
7.287
7.274
7.257
7.246
7.230

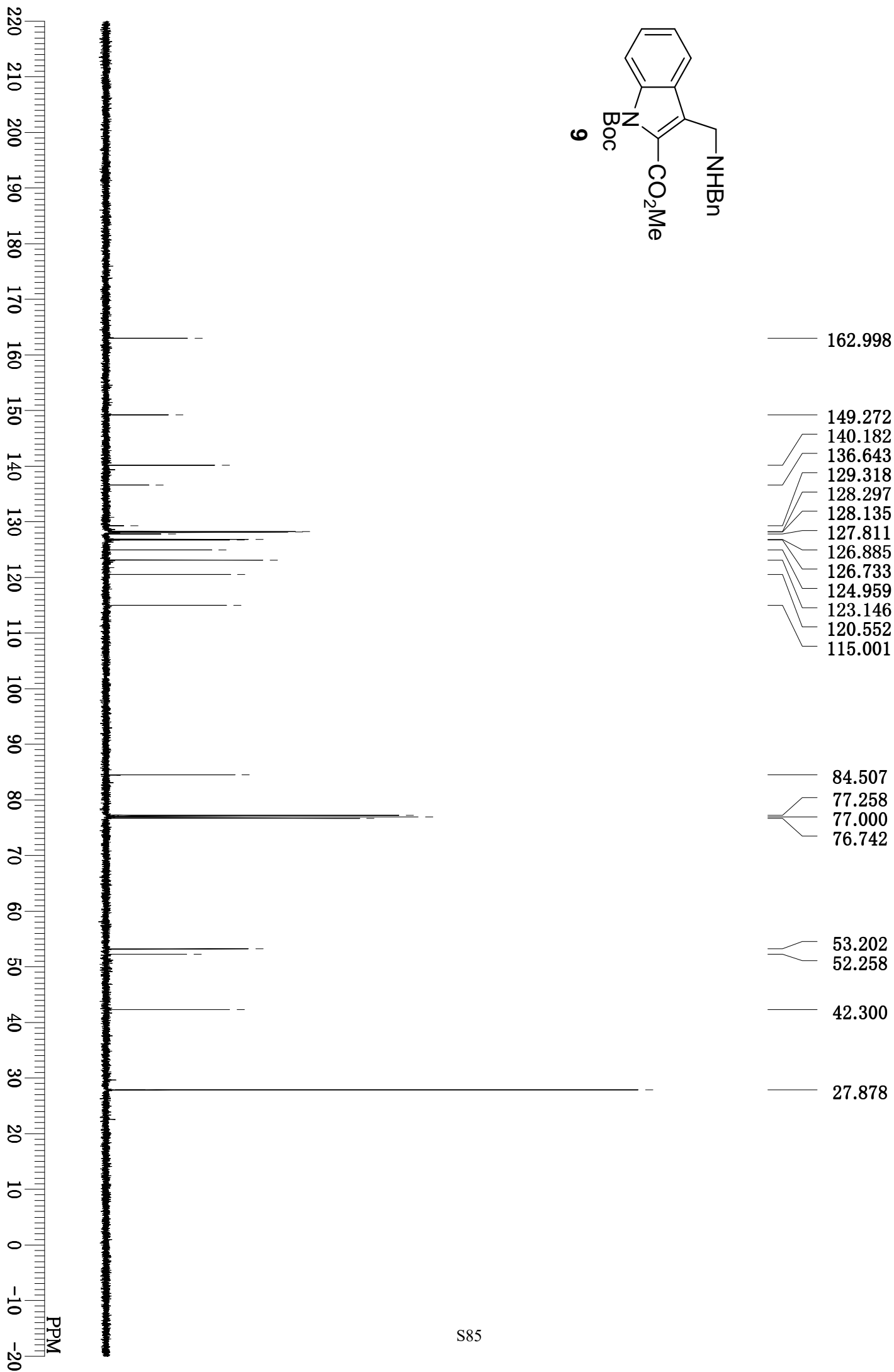
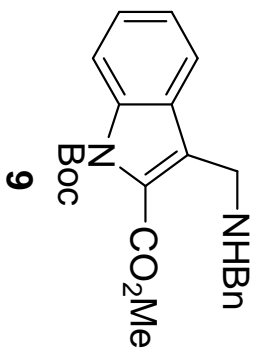


3.981
3.866
3.822

1.849
1.615

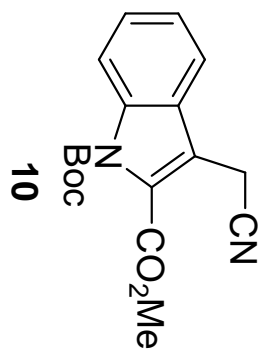


125MHz CDCl3



500MHz CDCl₃

8.107
8.090
7.738
7.722
7.503
7.486
7.468
7.376
7.360
7.344
7.260



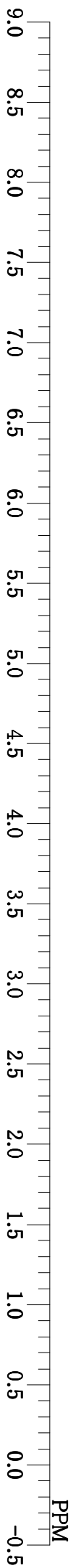
1.00
0.94
1.03
1.03

3.988
3.978

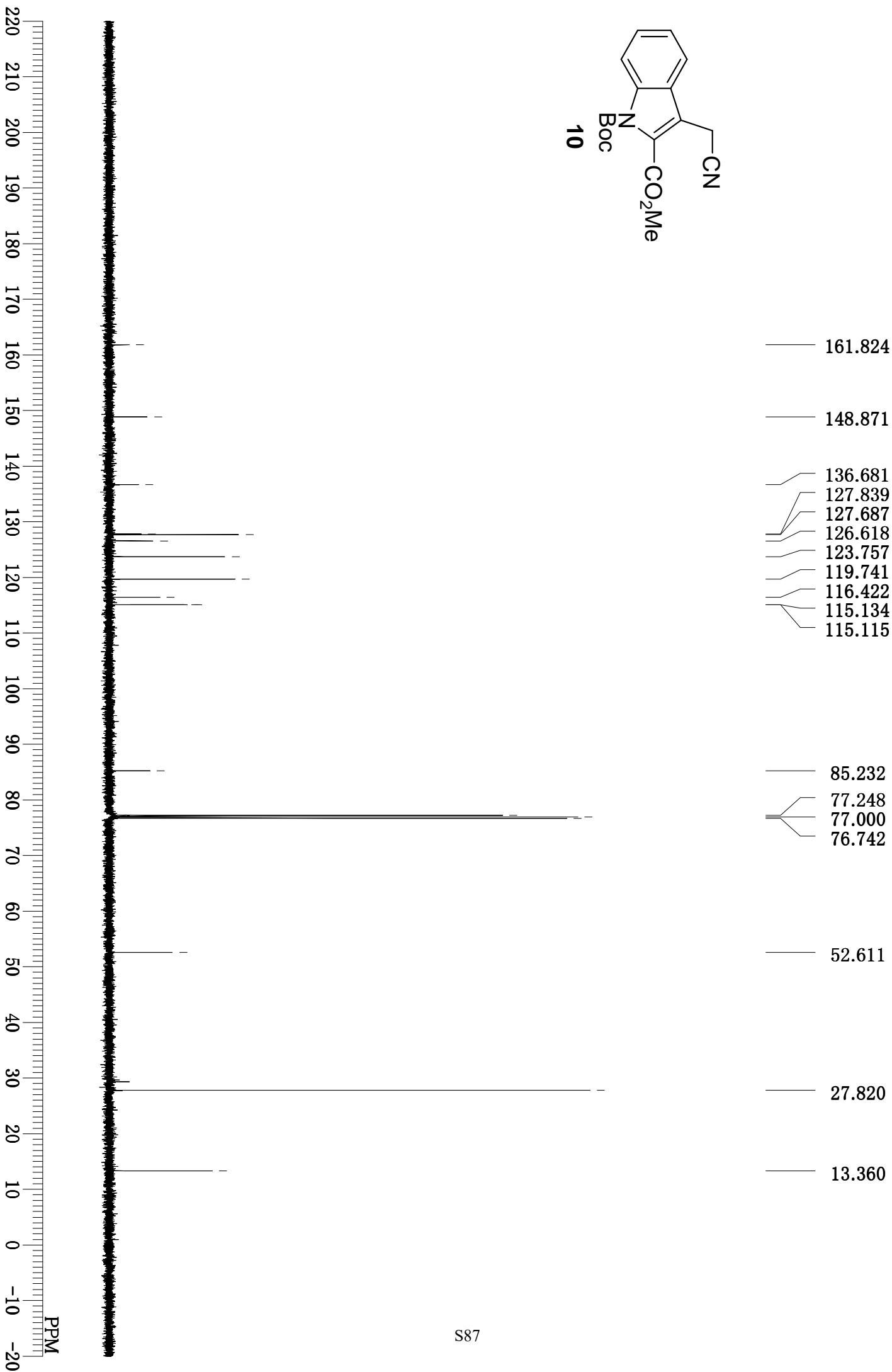
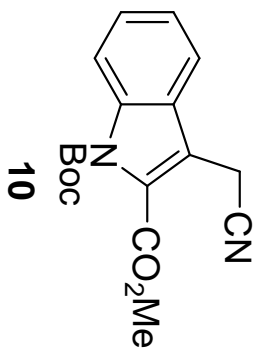
1.89
3.00

1.623

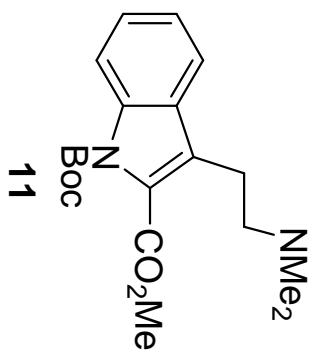
8.97



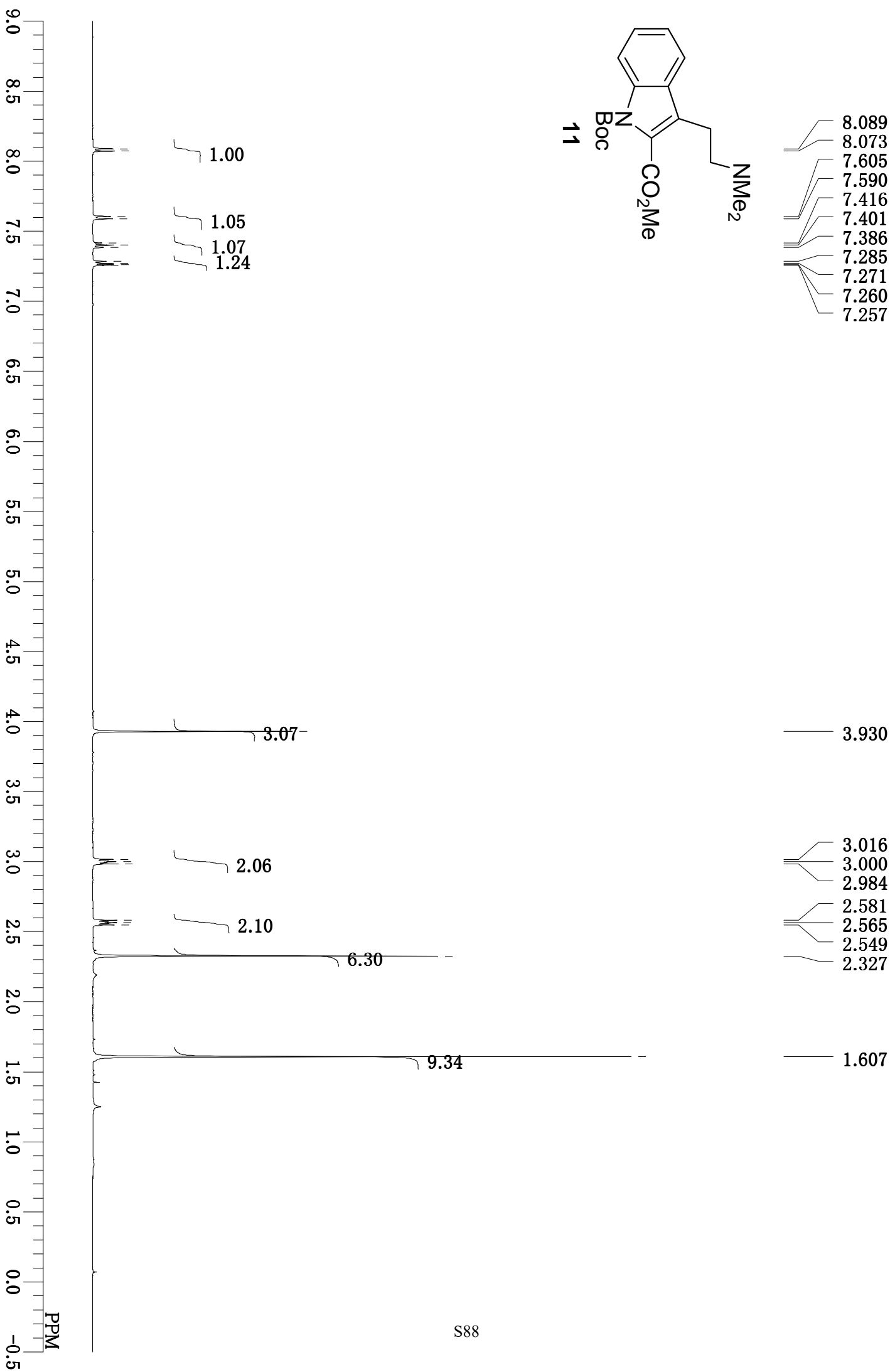
125MHz CDCl3



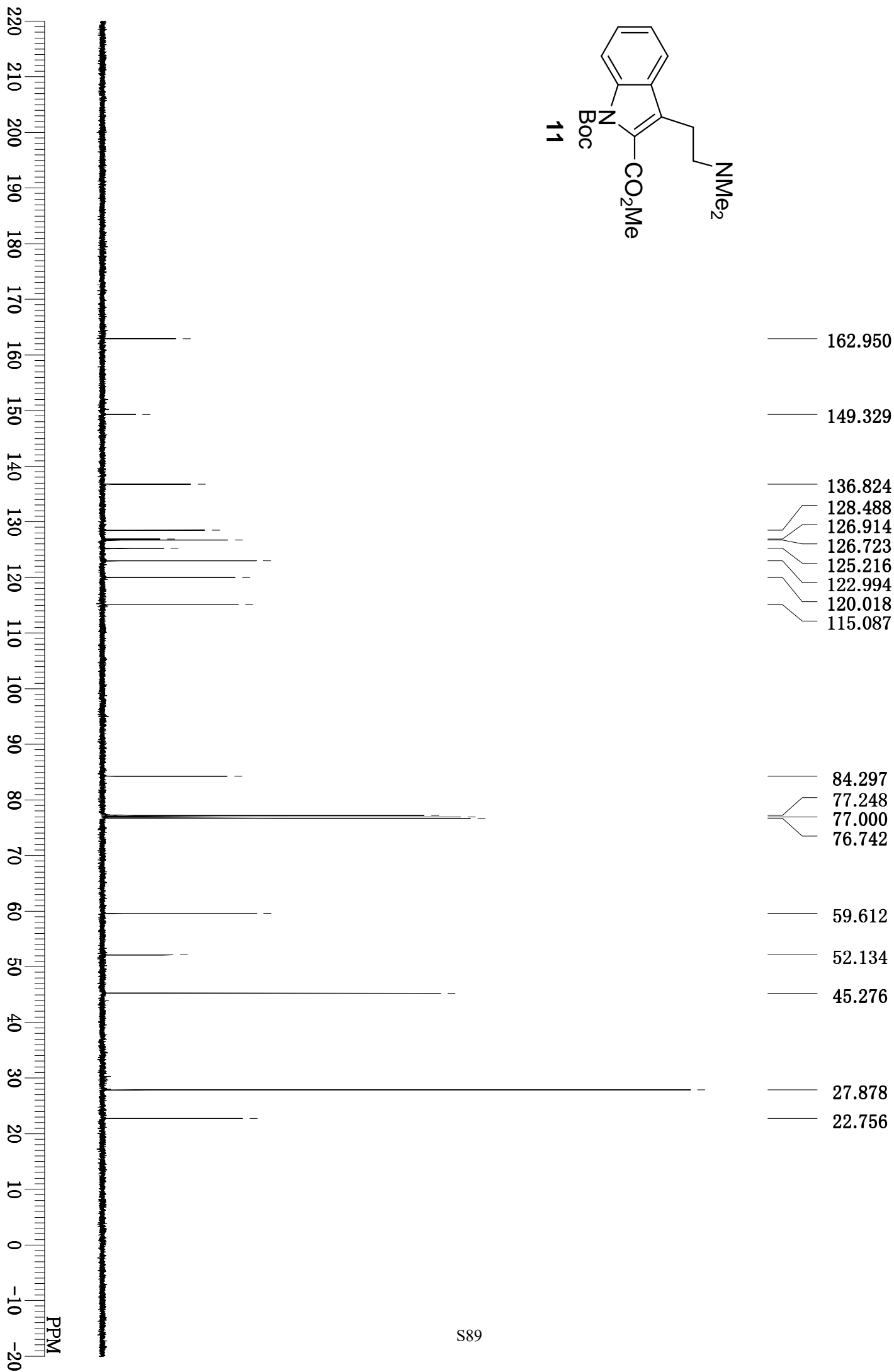
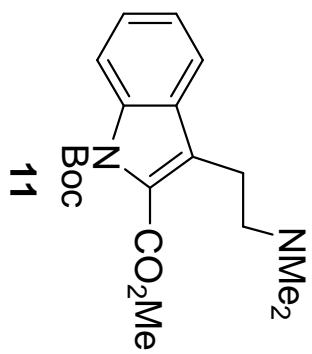
500MHz CDCl₃



8.089
8.073
7.605
7.590
7.416
7.401
7.386
7.285
7.271
7.260
7.257

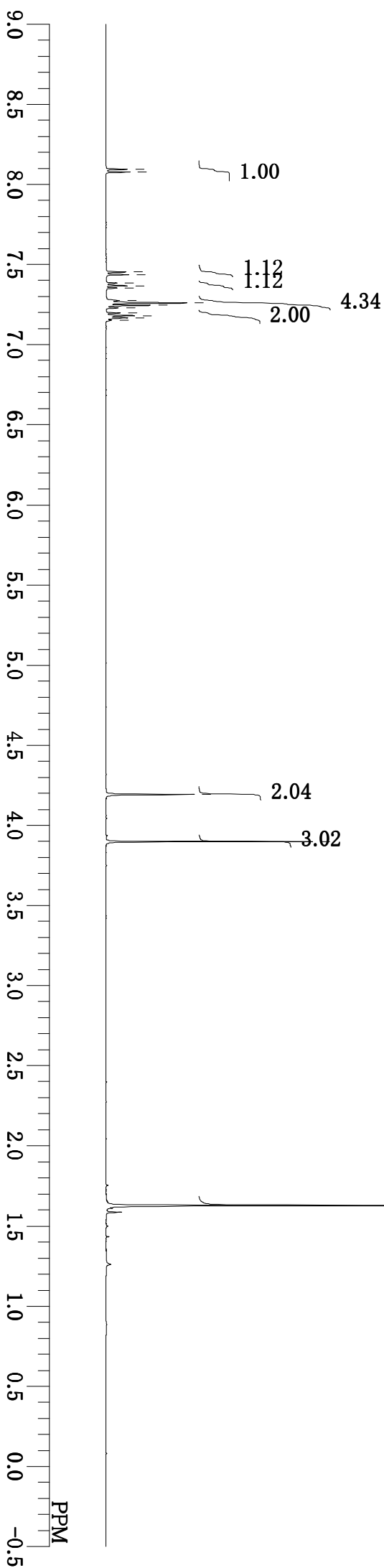
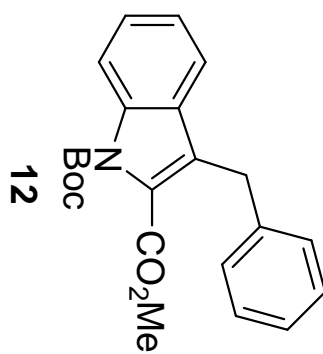


125MHz CDCl3



500MHz CDCl₃

- 8.094
- 8.078
- 7.454
- 7.438
- 7.384
- 7.369
- 7.353
- 7.276
- 7.260
- 7.246
- 7.229
- 7.197
- 7.182
- 7.166
- 7.152

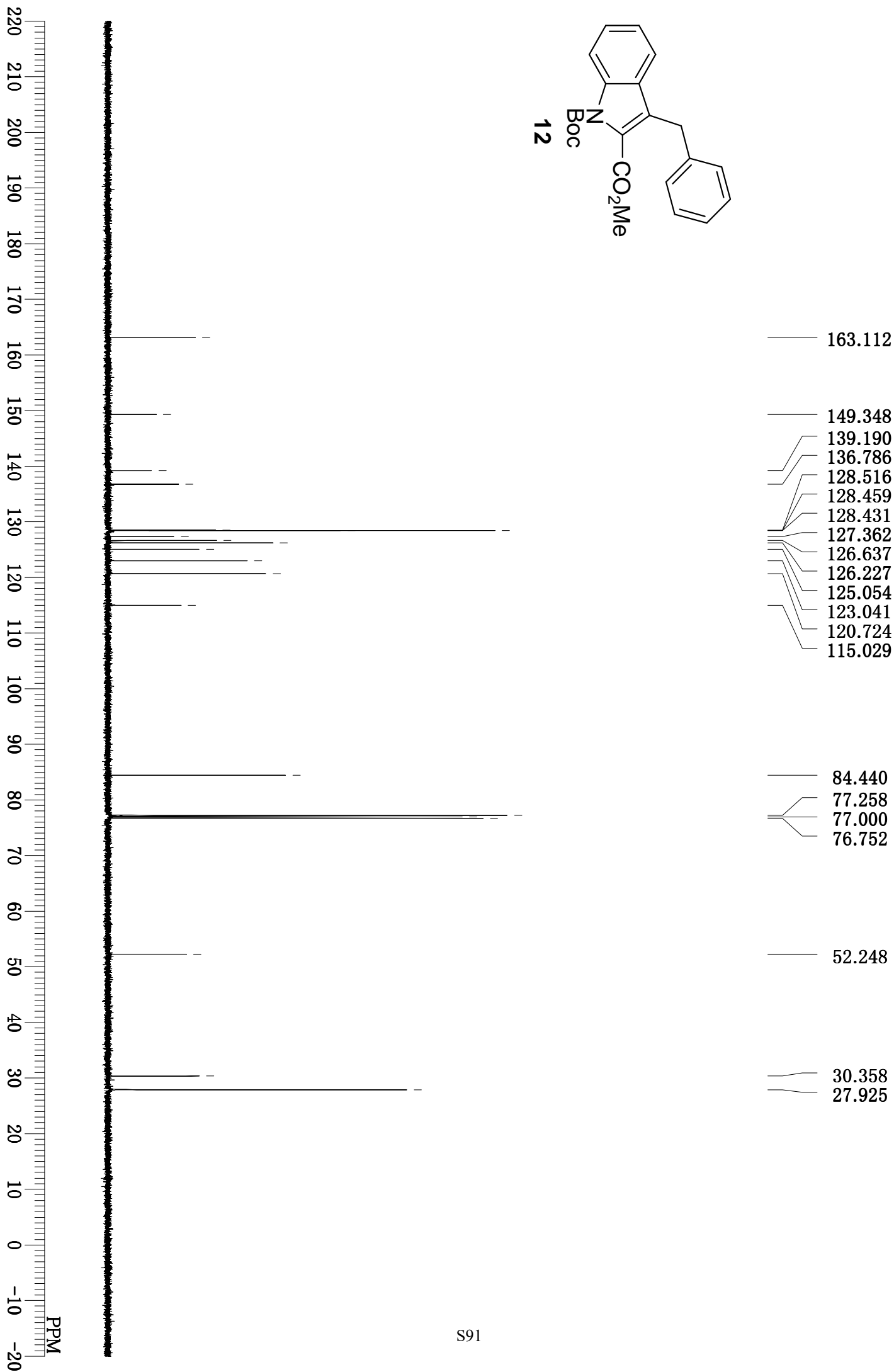
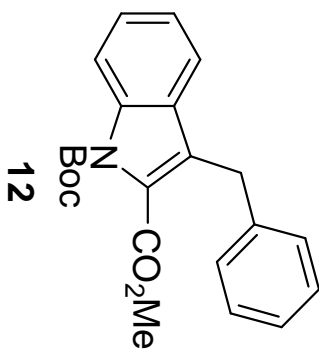


4.193

3.899

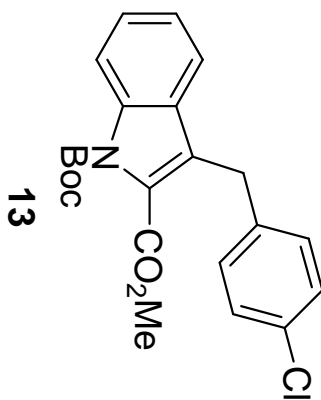
1.628

125MHz CDCl3



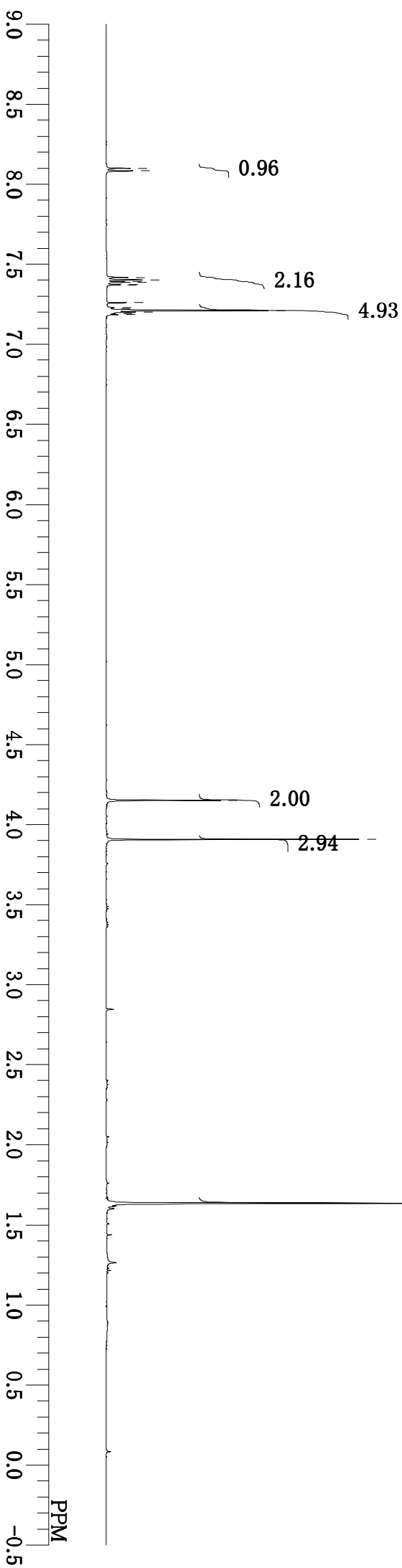
500MHz CDCl₃

8.099
8.083
7.418
7.403
7.391
7.388
7.373
7.371
7.260
7.230
7.224
7.212
7.200
7.192
7.187

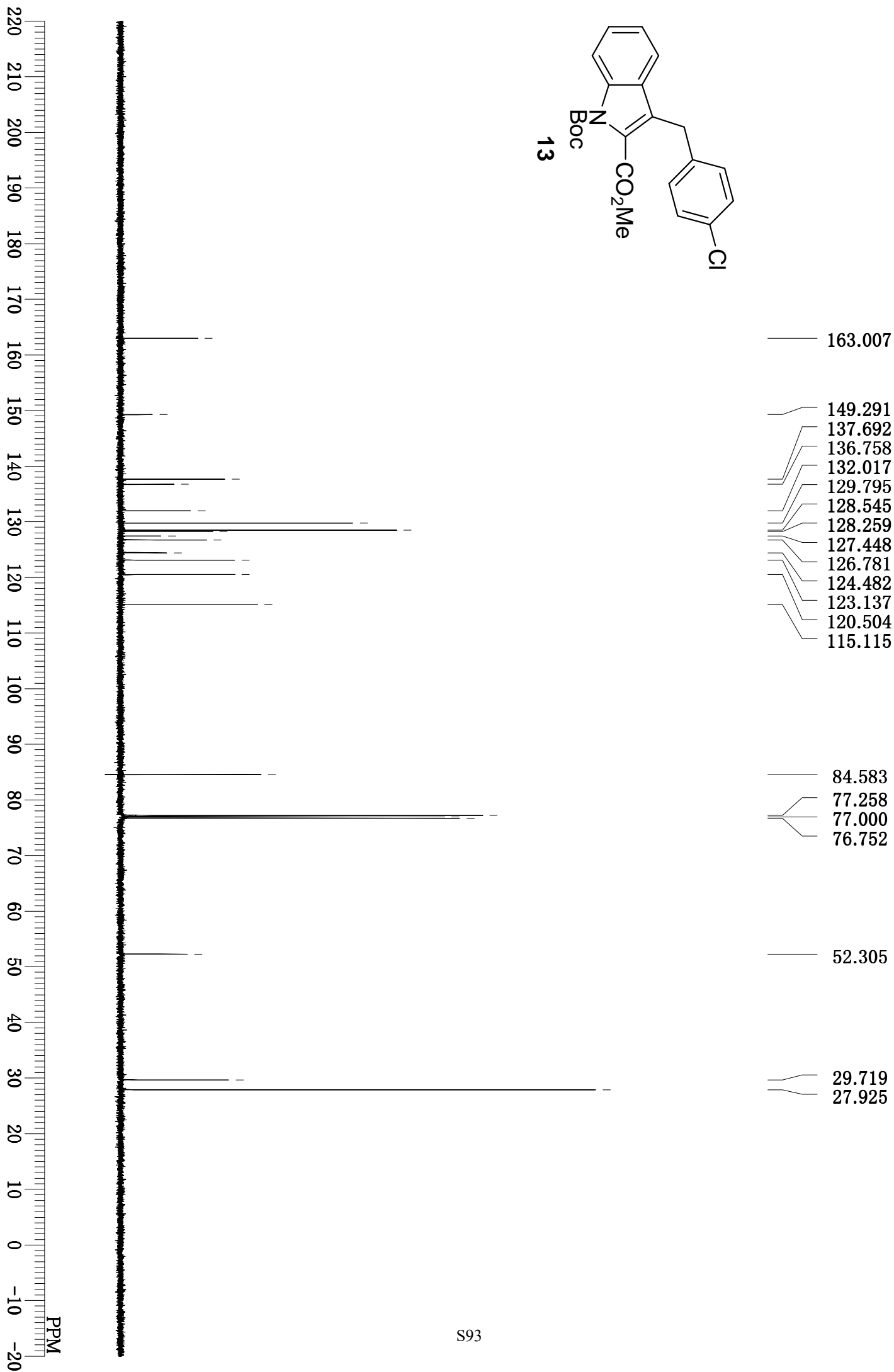
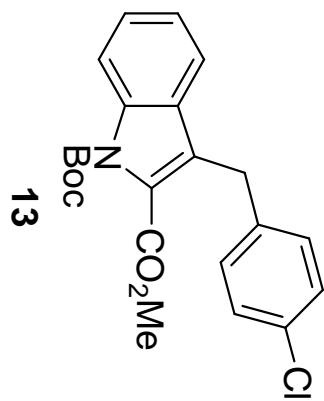


4.152
3.908

1.635

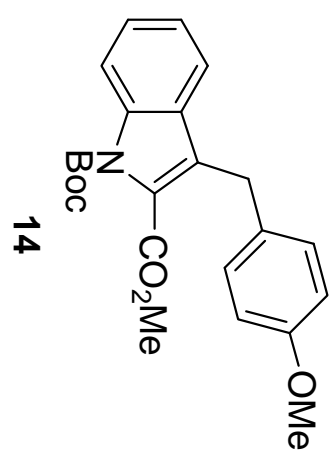


125MHz CDCl3



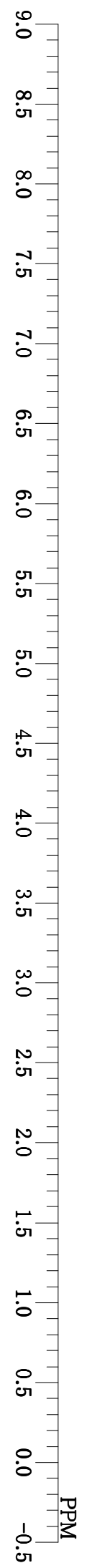
500MHz CDCl₃

- 8.103
- 8.086
- 7.467
- 7.452
- 7.394
- 7.377
- 7.361
- 7.260
- 7.208
- 7.195
- 7.191
- 7.181
- 7.179
- 6.810
- 6.793

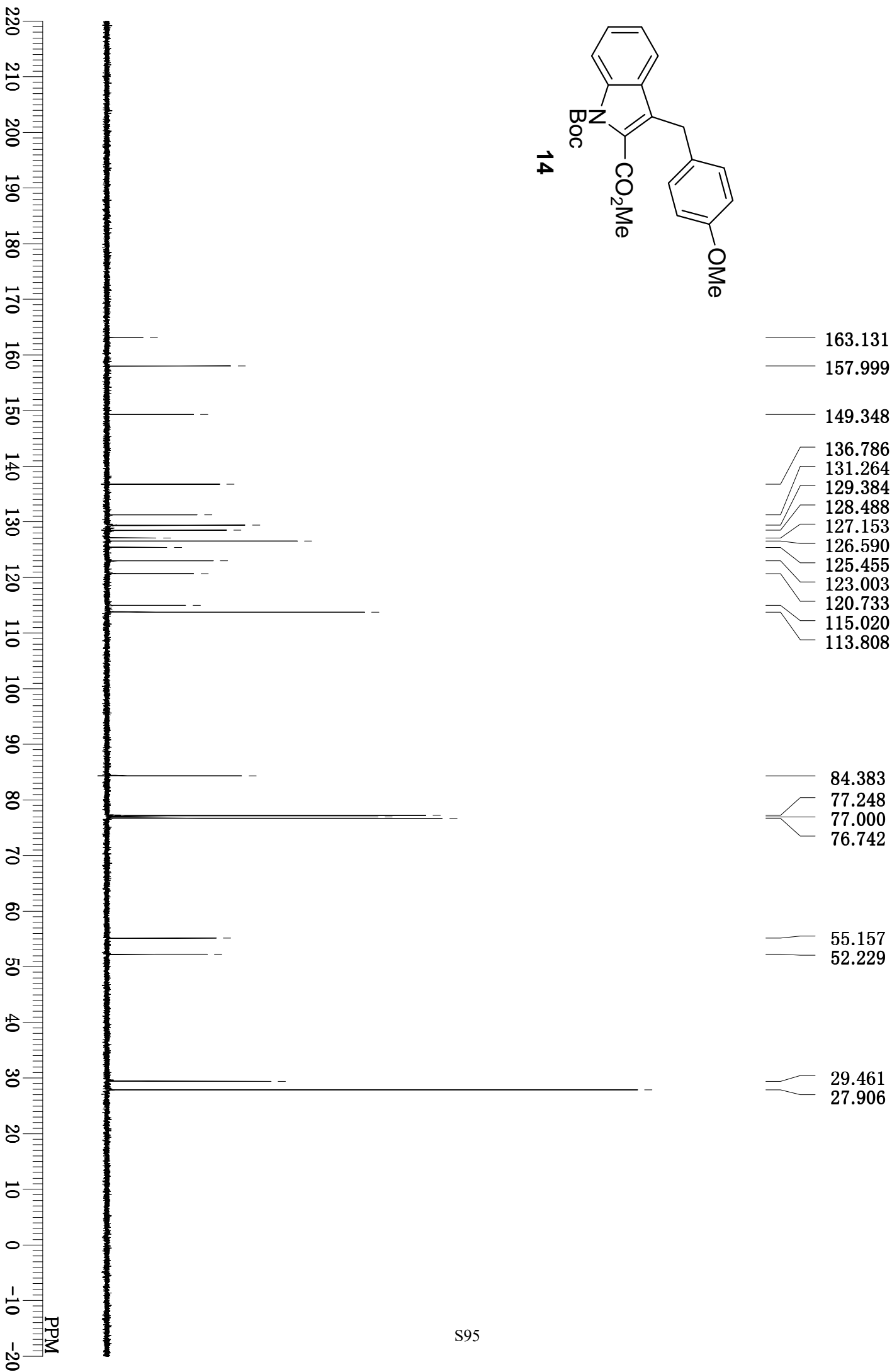
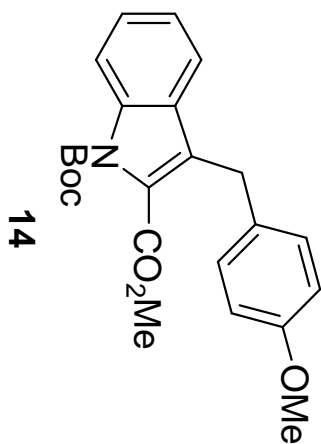


- 4.136
- 3.919
- 3.755

- 1.638

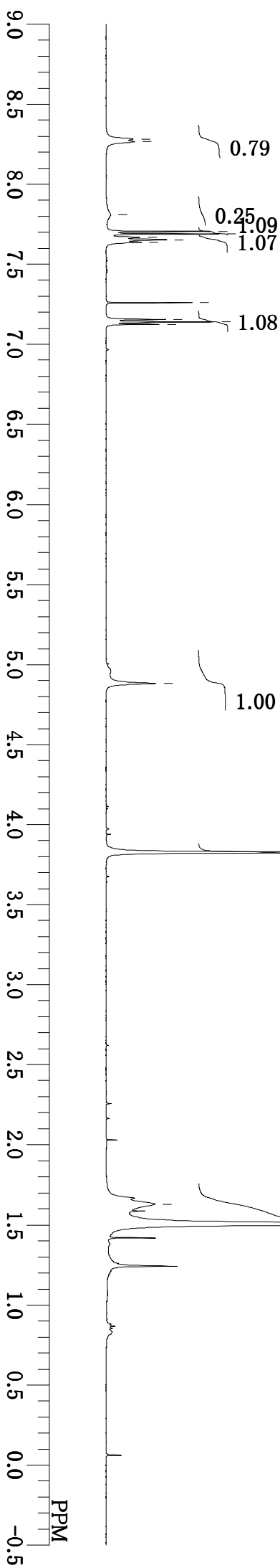
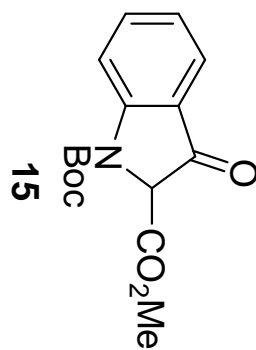


125MHz CDCl3



50MHz CDCl₃

- 8.282
- 8.267
- 7.812
- 7.705
- 7.689
- 7.669
- 7.653
- 7.638
- 7.260
- 7.156
- 7.141
- 7.126



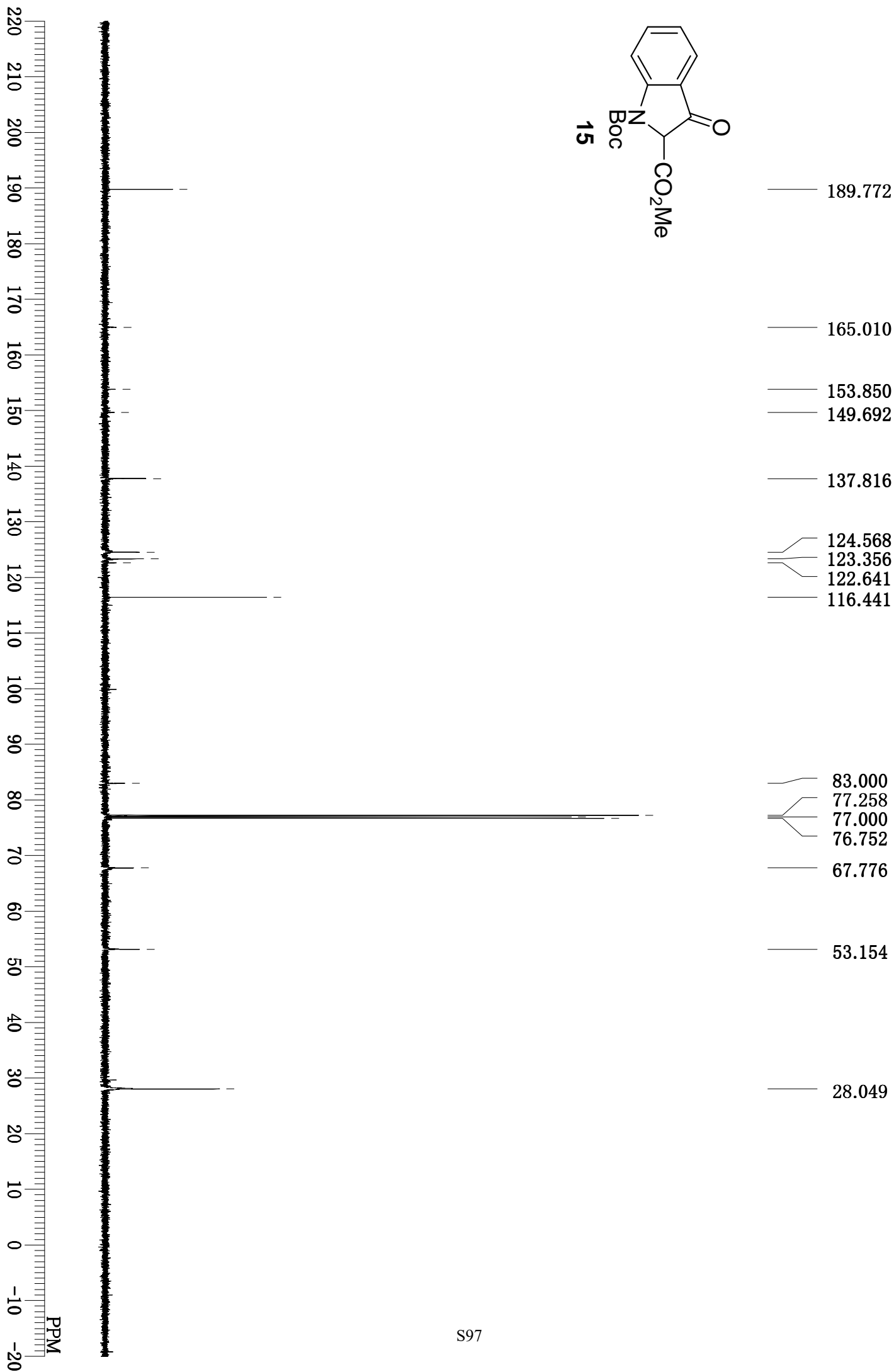
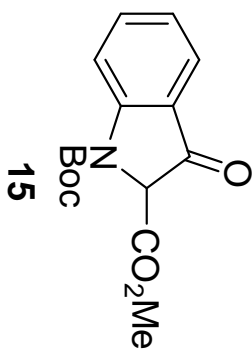
4.883

3.828

1.630

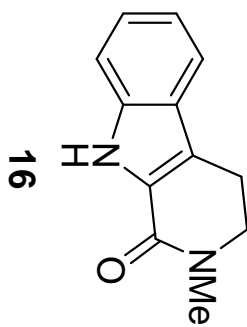
1.507

125MHz CDCl₃



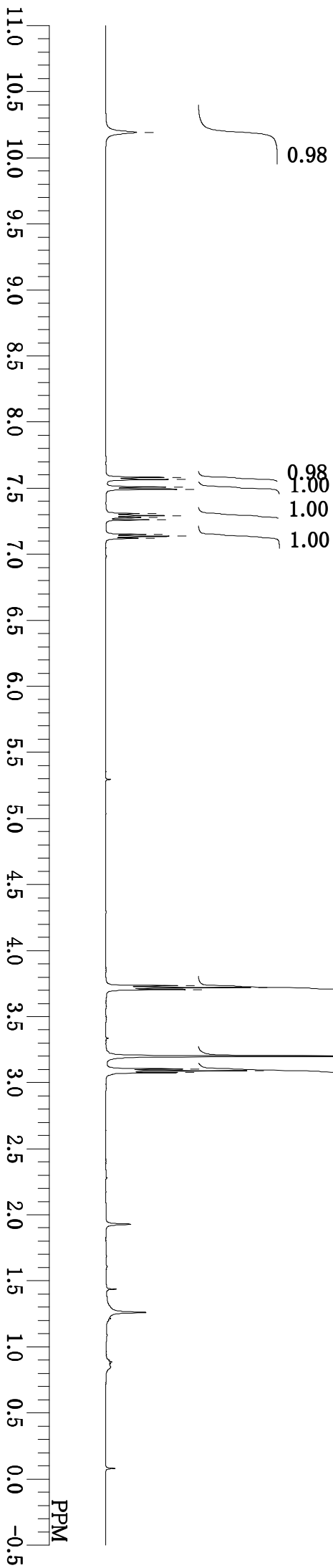
500MHz CDCl3

10.193



7.582
7.566
7.509
7.492
7.307
7.292
7.277
7.260
7.150
7.135
7.120

3.734
3.720
3.705
3.200
3.104
3.090
3.077



125MHz CDCl3

