Palladium-catalyzed cyclization of benzamides with arynes: application to the synthesis of Phenaglydon and *N*-Methylcrinasiadine

*Sandeep Pimparkar and Masilamani Jeganmohan**

Department of Chemistry, Indian Institute of Science Education and Research, Pune 411021, India.

Email: mjeganmohan@iiserpune.ac.in

Electronic Supplementary Information (ESI)

Table of Contents

Experimental Section

General Information

Yields refer to isolated yields of compounds estimated to be > 95 % pure as determined by ^{1}H-NMR (25 °C). NMR spectra were recorded on solutions in deuterated chloroform ($CDCl_3$) with residual chloroform (δ 7.27 ppm for ^{1}H NMR and δ 77.1 ppm for ^{13}C NMR). Column chromatographical purifications were performed using SiO_2 (130–150 mesh ASTM) from Merck if not indicated otherwise. $Pd(OAc)_2$, $K_2S_2O_8$, 1-ademantane-carboxylic acid, CsF and other reagents or chemicals were used as purchased without further purification. Starting materials *N*-substituted benzamides **1** or **6**[1] and benzyne precursors **2**[2] were synthesized according to the literature procedures.

General Procedure for the cyclization of *N*-Substituted Benzamides with Benzynes Catalyzed by $Pd(OAc)_2$.

In a 15 mL pressure tube, *N*-substituted benzamides (150 mg), $Pd(OAc)_2$ (5.0 mol %), $K_2S_2O_8$ (1.0 equiv), 1-ademantanecarboxylic acid (30 mol %) were added. The tube was covered with septum and then evacuated and purged with nitrogen gas three times and CsF (2.0 equiv) was added (CsF was added inside the glove box). Then, acetonitrile (1.0 mL) and benzyne precursor **2** (1.5 equiv) in acetonitrile (2.0 mL) were added via syringes and the tube was evacuated and purged with nitrogen gas three times. After that, the septum was taken out immediately and a screw cap was used to cover the tube. Then, the reaction mixture was allowed to stir at 100 °C for 12 h. After cooling to ambient temperature, the reaction mixture was diluted with CH_2Cl_2, filtered through Celite and silica gel, and the filtrate was concentrated. The crude residue was purified through a silica gel column using hexanes and ethyl acetate as eluent to give pure **4** or **7**.

Representative procedure for photochemical reaction.

To the 25 ml round bottom flask **4c** or **4d** (50 mg) was dissolved in 10 mL dry MeOH and solution was freeze frost in liquid nitrogen (instantly cooling at liquid nitrogen temperature and subsequently applying high vacuum to remove traces of dissolved gases). Above reaction mixture was stirred at rt for 4 h under UV lamp (200-400 nm). After 4 h, reaction mixture was concentrated under vacuum and purified by flash column chromatography to give **8a** and **8b** in 69% and 67% yields, respectively.

The yield of the reaction can be increased by doing irradiation with Mercury lamp.

Please see the reported protocol below:

Ref: (*a*) T.-T. Yuan, D.-D. Li and G.-W. Wang *Angew. Chem. Int. Ed.* 2011, **50**, 1380; (*b*) J. Karthikeyan and C.-H. Cheng, *Angew. Chem. Int. Ed.* 2011, **50**, 9880.

Gereral Procedure for the Synthesis of Compound 9.

In a 25 mL round bottome flask fitted with a condenser, phenanthridin-6(5*H*)-one (**8b**) (0.050 g, 0.256 mmol) was taken and dissolved in acetic acid (2.0 mL). Later, 90% of nitric acid (1.0 mL) was added into the mixture slowly in 10 min at the ambient temperature. The mixture was refluxed at 100 ^{o}C for 2 h, then cooled to ambient temperature. The solid was filtered and washed with acetic acid and water, and dried under vacuum to afford 0.045 g (75%) of 2-nitrophenanthridin-6(5*H*)-one (**9**). Spectral data was consistant with the reported method.[3]

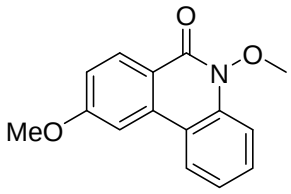
1. (*a*) N. Guimond, C. Gouliaras and K. Fagnou, *J. Am. Chem. Soc.* **2010**, *132*, 6908; (*b*) T. K. Hyster and T. Rovis, *J. Am. Chem. Soc.* **2010**, *132*, 10565.

2. D. Pena, A. Cobas, D. Perez and E. Guitian, *Synthesis*, **2002**, *10*, 1454.

3. Z. Tu, W. Chu, J. Zjang, C. S. Dence, M. J. Welch and R. H. Mach, *Nuclear Medicine and Biology*, **2005**, *32*, 437.

Spectral Data of Compounds.

5,9-Dimethoxyphenanthridin-6(5*H*)-one (4a).



White solid; mp = 129 °C, eluent (30% ethyl acetate in hexanes), 150 mg scale reaction, 140 mg was isolated, 66% yield.

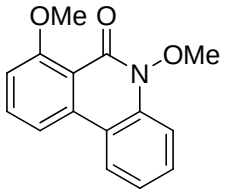
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2925, 1661, 1610 and 1450.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.49 (d, *J* = 8.8 Hz, 1 H), 8.20 (d, *J* = 8.4 Hz, 1 H), 7.68 - 7.64 (m, 2 H), 7.59 (td, *J* = 7.6, 1.2 Hz, 1 H), 7.34 (td, *J* = 7.6, 1.2 Hz, 1 H), 7.16 (dd, *J* = 8.8, 2.4 Hz, 1 H), 4.13 (s, 3 H), 4.00 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.1, 157.2, 136.2, 134.9, 130.7, 130.1, 123.2, 123.0, 119.8, 118.3, 115.9, 112.7, 104.9, 62.8, 55.7.

HR**MS (ESI):** calc. for [($C_{15}H_{13}NO_3$)H] (M+H) 256.0974, measured 256.0978.

5,7-Dimethoxyphenanthridin-6(5*H*)-one (4b).



Pale yellow semisolid; eluent (10% ethyl acetate in hexanes), 150 mg reaction scale, 115 mg was isolated 55% yield.

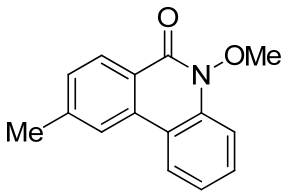
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2927, 1664 and 1613.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.24 (d, *J* = 7.6, 1 H), 7.90 (d, *J* = 8.0 Hz, 1 H), 7.69 (t, *J* = 8.2, 1 H), 7.63 - 7.56 (m, 2 H), 7.31 (td, *J* = 7.6, 1.6 Hz, 1 H), 7.08 (d, *J* = 8.2 Hz, 1 H), 4.13 (s, 3 H), 4.05 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.6, 156.2, 136.3, 136.0, 133.3, 130.3, 123.8, 122.8, 117.9, 115.5, 114.1, 112.3, 110.4, 62.6, 56.5.

HRMS (ESI): calc. for [($C_{15}H_{13}NO_3$)H] (M+H) 256.0974, measured 256.0970.

5-Methoxy-9-methylphenanthridin-6(5*H*)-one (4c).



Pale yellow solid; mp = 147 °C, eluent (25% ethyl acetate in hexanes), 150 mg reaction scale, 134 mg was isolated, yield 62%.

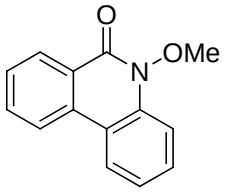
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2932, 1657, 1615 and 1325.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.43 (d, *J* =8.2 Hz, 1 H), 8.25 (d, *J* = 8.0 Hz, 1 H), 8.05 (s, 1 H), 7.66 (d, *J* = 7.8 Hz, 1 H), 7.57 (td, *J* = 7.8, 1.0 Hz, 1 H), 7.41 (d, *J* = 8.4 Hz, 1 H), 7.33 (t, *J* = 7.6 Hz, 1 H), 4.13 (s, 3 H), 2.56 (s, 3 H)

^{13}C NMR ($CDCl_3$, 100 MHz): δ 157.4, 143.3, 135.9, 133.0, 129.9, 129.5, 128.5, 124.0, 123.2, 123.1, 122.0, 118.6, 112.6, 62.7, 22.2.

HRMS (ESI): calc. for [($C_{15}H_{13}NO_2$)H] (M+H) 240.1025, measured 240.1029.

5-Methoxyphenanthridin-6(5*H*)-one (4d).



White solid; mp = 102 °C, eluent (23% ethyl acetate in hexanes), 150 mg reaction scale, 135 mg was isolated, 61% yield.

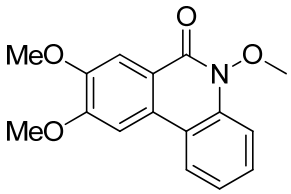
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2932, 1662, 1615 and 1330.

^{1}H NMR ($CDCl_3$, 200 MHz): δ 8.56 (dd, *J* = 8.2, 1.2 Hz, 1 H), 8.28 (d, *J* = 8.2 Hz, 2 H), 7.78 (d, *J* = 8.2, 1.6 Hz, 1 H), 7.63 (m, 3 H), 7.35 (td, *J* = 8.4, 1.6 Hz 1 H), 4.14 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 157.3, 135.8, 133.0, 132.7, 130.0, 130.0, 128.6, 128.1, 126.3, 123.3, 122.0, 118.6, 112.7, 62.8.

HRMS (ESI): calc. for [($C_{14}H_{11}NO_2$)H] (M+H) 226.0868, measured 226.0865.

5,8,9-Trimethoxyphenanthridin-6(5*H*)-one (4e).



White solid; mp = 191 °C, eluent (40% ethyl acetate in hexanes), 150 mg reaction scale, 120 mg was isolated, yield 61%.

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2940, 1651, 1610 and 1438.

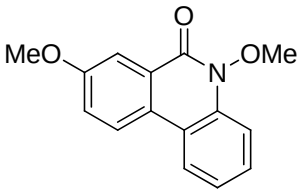
^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (d, *J* = 8.0 Hz, 1 H), 7.88 (s, 1 H), 7.63 (d, *J* = 8.2 Hz, 1 H), 7.55 (s, 1 H), 7.53 (t, *J* = 7.8 Hz, 1 H), 7.32 (t, *J* = 7.2 Hz, 1 H), 4.12 (s, 3 H), 4.08 (s, 3 H), 4.02 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 157.0, 153.4, 149.9, 135.2, 129.1, 127.7, 123.0, 122.6, 120.1, 118.4,

112.7, 108.6, 102.8, 62.8, 56.3, 56.2.

HRMS (ESI): calc. for [($C_{16}H_{15}NO_4$)H] (M+H) 286.1079, measured 285.1086.

5,8-Dimethoxyphenanthridin-6(5*H*)-one (4f).



White solid; mp = 138 °C, eluent (10% ethyl acetate in hexanes), 150 mg reaction scale, 121 mg was isolated, 58% yield.

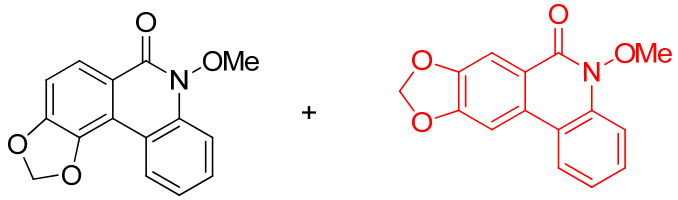
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2927, 1662, 1612, 1445 and 1317.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.19 (d, *J* = 8.0 Hz, 1 H), 8.18 (d, *J* = 8.0 Hz, 1 H), 7.97 (d, *J* = 2.8 Hz, 1H), 7.67 (dd, *J* = 8.4, 1.0 Hz, 1 H), 7.54 (td, *J* = 7.8, 1.2 Hz, 1 H), 7.38 - 7.34 (m, 2 H), 4.15 (s, 3 H), 3.97 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.6, 157.1, 134.7, 128.9, 127.6, 126.5, 123.7, 123.3, 122.7, 122.6, 118.7, 112.6, 108.9, 62.7, 55.8.

HRMS (ESI): calc. for [($C_{15}H_{13}NO_3$)H] (M+H) 256.0974, measured 256.0970.

A mixture of compounds 4g and 4g'. (The other regioisomer was highlighted in the red colour)



7-methoxy-[1,3]dioxolo[4,5-*k*] phenanthridin-6(7*H*)-one

5-methoxy-[1,3]dioxolo[4,5-*j* phenanthridin-6(5*H*)-one

4g Major : Minor 1.5 : 1 **4g'**

Pale yellow semisolid; eluent (30% ethyl acetate in hexanes), reaction scale 150 mg, 135 mg was isolated, 60% yield.

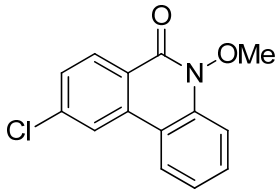
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2927, 1667, 1614 and 1322.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.62 (dd, *J* = 8.2, 1.2 Hz, 1 H), 8.20 (d, *J* = 8.0 Hz, 1 H), 8.07 (d, *J* = 8.4 Hz, 1 H), 7.90 (s, 1 H), 7.67 - 7.53 (m, 3 H), 7.35 - 7.30 (m, 4 H), 7.11 (d, *J* = 8.6 Hz, 1 H), 6.28 (s, 2 H), 6.14 (s, 2 H), 4.14 (s, 3 H), 4.12 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.9, 156.7, 152.4, 151.1, 148.5, 143.2, 135.6, 135.1, 129.7, 129.3, 127.5, 124.1, 123.1, 122.9, 121.9, 120.9, 118.4, 117.8, 116.6, 112.6, 112.1, 109.1, 106.6, 102.3, 102.2, 100.7, 62.8, 62.6.

HRMS (ESI): calc. for [($C_{15}H_{11}NO_4$)H] (M+H) 270.0766, measured 270.0773.

9-Chloro-5-methoxyphenanthridin-6(5*H*)-one (4h).



White solid; mp = 170 °C, eluent (24% ethyl acetate in hexanes), 150 mg reaction scale, 93 mg was isolated, 45% yield.

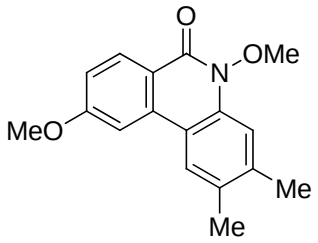
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2950, 1665, 1609, 1325 and 1023.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.50 (d, *J* = 8.6 Hz, 1 H), 8.25 (d, *J* = 1.0 Hz, 1 H), 8.21 (d, *J* = 7.8 Hz, 1 H), 7.69 (d, *J* = 7.8 Hz, 1 H), 7.64 (t, *J* = 7.8 Hz, 1 H), 7.56 (dd, *J* = 8.6, 2.0 Hz, 1 H), 7.38 (td, *J* = 7.6, 1.2 Hz, 1 H), 4.15 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.7, 139.5, 136.3, 134.5, 130.8, 130.3, 128.5, 124.7, 123.5, 123.4, 122.0, 117.5, 112.8, 62.8.

HRMS (ESI): calc. for [($C_{14}H_{10}ClNO_2$)H] (M+H) 260.0478, measured 260.0470.

5,9-Dimethoxy-2,3-dimethylphenanthridin-6(5*H*)-one (4i).



Pale yellow solid; mp = 103-105 °C, eluent (24% ethyl acetate in hexanes), 150 mg reaction scale, 142 mg was isolated, 61% yield.

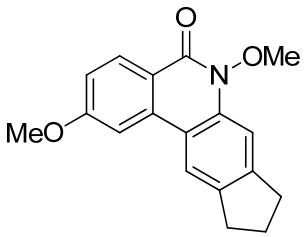
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2930, 1667, 1615 and 1025.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.45 (d, *J* = 8.8 Hz, 1 H), 7.90 (s, 1 H), 7.58 (d, *J* = 2.0 Hz, 1 H), 7.42 (s, 1 H), 7.12 (dd, *J* = 8.8, 2.4 Hz, 1 H), 4.12 (s, 3 H), 3.39 (s, 3 H), 2.43 (s, 3 H), 2.40 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.0, 157.2, 139.7, 135.0, 134.3, 131.6, 130.6, 123.8, 119.6, 116.1, 115.5, 113.3, 104.5, 62.7, 55.6, 20.4, 19.6.

HRMS (ESI): calc. for [($C_{17}H_{17}NO_3$)H] (M+H) 284.1287, measured 284.1293.

2,6-Dimethoxy-6,8,9,10-tetrahydro-5*H*-cyclopenta[*b*]phenanthridin-5-one (4j).



Colorless solid; mp = 123 °C, eluent (20% ethyl acetate in hexanes), 150 mg reaction scale, 134 mg was isolated, 55% yield.

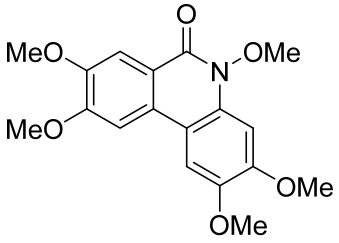
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2931, 1664, 1612 and 1092.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.45 (d, *J* = 8.8 Hz, 1 H), 8.02 (s, 1 H), 7.60 (d, *J* = 2.4 Hz, 1 H), 7.51 (s, 1 H), 7.12 (dd, *J* = 8.8, 2.4 Hz, 1 H), 4.12 (s, 3 H), 3.99 (s, 3 H), 3.09 - 3.03 (m, 4 H), 2.18 (q, *J* = 7.4 Hz, 2 H)

^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.0, 157.2, 147.5, 139.4, 135.3, 135.1, 130.6, 119.4, 118.4, 116.8, 115.5, 108.4, 104.5, 62.6, 55.6, 33.4, 32.4, 25.8.

HRMS (ESI): calc. for [($C_{18}H_{17}NO_3$)H] (M+H) 296.1287, measured 296.1284.

2,3,5,8,9-Pentamethoxyphenanthridin-6(5*H*)-one (4k).



Pale yellow solid; mp = 146 °C, eluent (60% ethyl acetate in hexanes), 150 mg reaction scale, 171 mg was isolated, 70% yield.

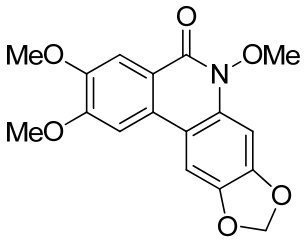
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2922, 1660, 1608 and 1325.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.83 (s, 1 H), 7.43 (s, 1 H), 7.34 (s, 1 H), 7.10 (s, 1 H), 4.13 (s, 3 H), 4.10 (s, 3 H), 4.04 (s, 3 H), 4.03 (s, 6 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 156.7, 153.3, 150.8, 149.0, 145.6, 130.0, 127.6, 119.0, 110.7, 108.3, 104.8, 102.0, 95.6, 62.7, 56.6, 56.2, 56.2, 56.1.

HRMS (ESI): calc. for [($C_{18}H_{19}NO_6$)H] (M+H) 346.1291, measured 346.1295.

2,3,6-Trimethoxy-[1,3]dioxolo[4,5-*b*]phenanthridin-5(6*H*)-one (4l).



Pale yellow semisolid, eluent (60% ethyl acetate in hexanes), 150 mg reaction scale, 147 mg was isolated, 63% yield.

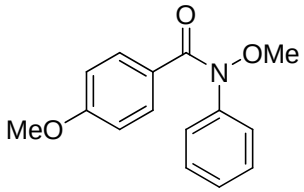
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2929, 1657, 1607 and 1452.

^1H NMR ($CDCl_3$, 400 MHz): δ 7.89 (s, 1 H), 7.51 (s, 1 H), 7.36 (s, 1 H), 7.18 (s, 1 H), 6.09 (s, 2 H), 4.12 (s, 3 H), 4.08 (s, 3 H), 4.04 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 163.8, 156.8, 153.4, 149.3, 144.6, 131.5, 128.0, 119.1, 112.2, 108.5, 102.4, 101.9, 101.5, 94.0, 62.8, 56.3, 56.2.

HRMS (ESI): calc. for [($C_{17}H_{15}NO_6$)H] (M+H) 330.0978, measured 330.0981.

***N*,4-Dimethoxy-*N*-phenylbenzamide (3a).**

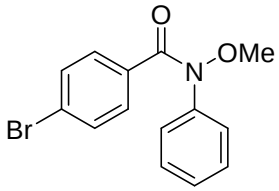


White semisolid; eluent (10 % ethyl acetate in hexanes), reaction scale 150 mg, 63 mg was isolated, 30% yield.

^1H NMR ($CDCl_3$, 400 MHz): δ 7.62 (d, *J* = 8.8 Hz, 2 H), 7.42 (d, *J* = 8.4 Hz, 2 H), 7.36 (t, *J* = 7.9 Hz, 2 H), 7.24 (t, *J* = 8.2 Hz, 1 H), 6.83 (d, *J* = 8.4 Hz, 2 H), 3.81 (s, 3 H), 3.72 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 167.6, 161.6, 139.8, 130.9, 129.0, 127.0, 126.5, 124.6, 113.3, 61.6, 55.3.

4-Bromo-*N*-methoxy-*N*-phenylbenzamide (3h).

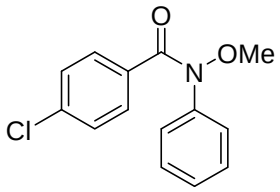


Colorless solid; mp= 103-105 °C, eluent (5 % ethyl acetate in hexanes), reaction scale 150 mg, 94 mg was isolated, 47% yield.

^1H NMR ($CDCl_3$, 400 MHz): δ 7.54 - 7.51 (m, 4 H), 7.45 (d, *J* = 7.8 Hz, 2 H), 7.39 (t, *J* = 7.8 Hz, 2 H), 7.29 (t, *J* = 7.4 Hz, 1 H), 3.69 (s, 3 H).

HRMS (ESI): calc. for [($C_{14}H_{12}BrNO_2$)Na] (M+Na) 327.9949 measured 327.9946.

4-Chloro-*N*-methoxy-*N*-phenylbenzamide (3i).



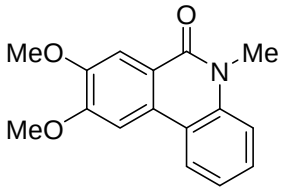
Colorless solid; mp = 115-117 °C, eluent (5% ethyl acetate in hexanes), 150 reaction scale, 105 mg was isolated, 51% yield.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.57 (d, *J* = 8.4 Hz, 2 H), 7.42 (d, *J* = 7.8 Hz, 2 H), 7.36 (t, *J* = 7.8 Hz, 2 H), 7.31 (d, *J* = 8.4 Hz, 2 H), 7.24 (t, *J* = 7.2 Hz, 1 H), 3.67 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 167.0, 138.9, 136.9, 132.9, 130.1, 129.1, 128.4, 127.4, 124.4, 61.8.

HRMS (ESI): calc. for [($C_{14}H_{12}ClNO_2$)H] (M+H) 262.0635 measured 262.0636.

8,9-Dimethoxy-5-methylphenanthridin-6(5*H*)-one (7a).



Yellow solid; mp = 220 °C, eluent (30% ethyl acetate in hexanes), reaction scale 150 mg, 110 mg was isolated, 49% yield.

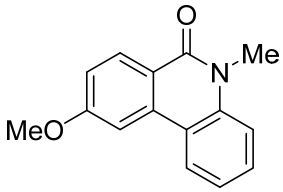
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2953, 1667 and 1615.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.15 (dd, *J* = 8.0, 1.2 Hz, 1 H), 7.93 (s, 1 H), 7.60 (s, 1 H), 7.52 (td, *J* = 7.8, 1.4 Hz, 1 H), 7.42 (d, *J* = 7.6 Hz, 1 H), 7.32 (td, *J* = 7.6, 1.2 Hz, 1 H), 4.10 (s, 3 H), 4.04 (s, 3 H), 3.82 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.2, 153.3, 149.8, 137.6, 128.7, 128.3, 122.7, 122.3, 119.7, 119.2, 115.1, 109.1, 102.5, 56.3, 56.1, 30.0.

HRMS (ESI): calc. for [($C_{16}H_{15}NO_3$)H] (M+H) 270.1130, measured 270.1127.

9-Methoxy-5-methylphenanthridin-6(5*H*)-one (7b).



Yellow solid; mp = 136 °C, eluent (25% ethyl acetate in hexanes), 150 mg reaction scale, 97 mg was isolated, 45% yield.

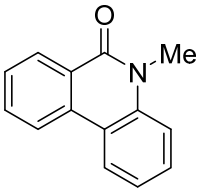
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2929, 1664, 1609 and 1467.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.48 (d, *J* = 8.8 Hz, 1 H), 8.20 (d, *J* = 6.8 Hz, 1 H), 7.63 (s, 1 H), 7.55 (t, *J* = 6.8 Hz, 1 H), 7.40 (d, *J* = 7.6 Hz, 1 H), 7.31 (t, *J* = 6.8 Hz, 1 H), 7.15 (d, *J*= 8.8 Hz, 1 H), 3.99 (s, 3 H), 3.79 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.9, 161.5, 138.5, 135.5, 131.1, 129.7, 123.3, 122.3, 119.4, 119.1, 115.9, 115.1, 104.4, 55.6, 29.8.

HRMS (ESI): calc. for [($C_{15}H_{13}NO_2$)H] (M+H) 240.1025, measured 240.1027.

5-Methylphenanthridin-6(5*H*)-one (7c).



Colorless solid; mp = 109 °C, eluent (25% ethyl acetate in hexanes), 150 mg reaction scale, 100 mg was isolated, 43% yield.

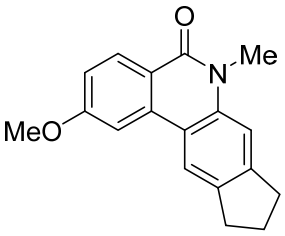
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2945, 1667, 1617 and 1335.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.57 (d, *J* = 8.0 Hz, 1 H), 8.30 (dd, *J* = 7.8, 1.2 Hz, 1 H), 8.29 (d, *J* = 8.2, 1 H), 7.77 (td, *J* = 7.6, 1.4 Hz, 1 H), 7.62 - 7.55 (m, 2 H), 7.44 (d, *J* = 8.0 Hz, 1 H), 7.34 (t, *J* = 7.6 Hz, 1 H), 3.84 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 138.1, 133.6, 132.5, 129.6, 128.9, 128.0, 125.6, 123.3, 122.5, 121.7, 119.3, 115.1, 30.0.

HRMS (ESI): calc. for [($C_{14}H_{11}NO$)H] (M+H) 210.0919, measured 210.0920.

2-Methoxy-6-methyl-6,8,9,10-tetrahydro-5*H*-cyclopenta[*b*]phenanthridin-5-one (7d).



Colorless solid; mp = 172 °C, eluent (25% ethyl acetate in hexanes), 150 mg reaction scale, 96 mg was isolated, 38% yield.

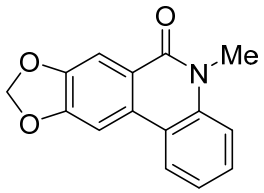
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2939, 1669, 1615 and 1337.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.47 (d, *J* = 8.8 Hz, 1 H), 8.05 (s, 1 H), 7.62 (d, *J* = 2.4 Hz, 1 H), 7.28 (s, 1 H), 7.12 (dd, *J* = 8.8, 2.4 Hz, 1 H), 4.00 (s, 3 H), 3.79 (s, 3 H), 3.06 - 3.03 (m, 4 H), 2.19 (q, *J* = 7.4 Hz, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.9, 161.5, 147.0, 138.5, 137.5, 135.9, 131.1, 119.0, 118.5, 117.6, 115.4, 110.9, 104.1, 55.5, 33.5, 32.4, 30.0, 25.8.

HRMS (ESI): calc. for [($C_{18}H_{17}NO_2$)H] (M+H) 280.1338, measured 280.1340.

5-Methyl-[1,3]dioxolo[4,5-*j*]phenanthridin-6(5*H*)-one (7e).



Light-yellow solid; mp = 239 °C, eluent (35% ethyl acetate in hexanes), reaction scale 150 mg, total isomeric yield 55 % [116 mg = 66 mg **7e** and 50 mg **7e'**] was isolated. **7e** in 30% yield.

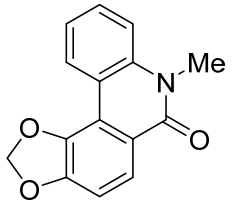
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2931, 1669, 1615 and 1015.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (dd, *J* = 8.2, 1.2 Hz, 1 H), 7.92 (s, 1 H), 7.63 (s, 1 H), 7.53 (td, *J* = 7.8, 1.4 Hz, 1 H), 7.41(d, *J* = 8.2 Hz, 1 H), 7.31 (td, *J* = 7.6, 1.2 Hz, 1 H), 6.14 (s, 2 H), 3.82 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.0, 152.2, 148.4, 137.5, 130.5, 128.9, 122.9, 122.4, 121.3, 119.3, 115.1, 107.0, 102.0, 100.5, 30.1.

HRMS (ESI): calc. for [($C_{15}H_{11}NO_3$)H] (M+H) 254.0817, measured 254.0816.

7-Methyl-[1,3]dioxolo[4,5-k]phenanthridin-6(7*H*)-one (7e').



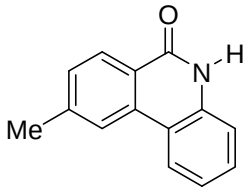
Pale yellow solid; mp = 200-202 °C, eluent (45% ethyl acetate in hexanes), reaction scale 150 mg, total isomeric yield 55 % [116 mg = 66 mg **7e** and 50 mg **7e'**] was isolated. **7e'** in 25% yield.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.67 (dd, *J* = 8.2, 1.6 Hz, 1 H), 8.22 (d, *J* = 8.4 Hz, 1 H), 7.55 (td, *J* = 7.8, 1.4 Hz, 1 H), 7.39 (d, *J* = 8.6 Hz, 1 H), 7.31 (td, *J* = 7.6, 1.4 Hz, 1 H), 7.11 (d, *J* = 8.6 Hz, 1 H), 6.28 (s, 2 H), 3.79 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100MHz): δ 161.2, 150.8, 142.9, 138.0, 129.4, 127.6, 124.5, 122.4, 120.6, 118.6, 117.5, 114.6, 109.1, 102.1, 30.1.

HRMS (ESI): calc. for [($C_{15}H_{11}NO_3$)H] (M+H) 254.0817, measured 254.0816.

9-Methylphenanthridin-6(5*H*)-one (8a).



White solid; mp = 272 °C, eluent (50% ethyl acetate in hexanes), reaction scale 100 mg, 63 mg was isolated, 72% yield.

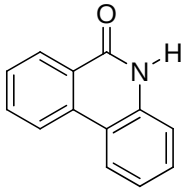
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1663, 1585 and 1457.

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.6 (s, 1 H), 8.37 (d, *J* = 8.0 Hz, 1 H), 8.32 (s, 1 H), 8.20 (d, *J* = 8.2 Hz, 1 H), 7.47 (t, *J* = 7.8 Hz, 2 H), 7.34 (d, *J* = 8.0 Hz, 1 H), 7.24 (t, *J* = 7.6 Hz, 1 H), 2.53 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.3, 143.5, 137.2, 134.7, 129.9, 129.6, 127.9, 123.9, 123.7, 123.0, 122.6, 118.0, 116.5, 22.0.

HRMS (ESI): calc. for [($C_{14}H_{11}NO$)H] (M+H) 210.0919, measured 210.0917.

6(5*H*)-Phenanthridinone (8b).[4]



Colorless solid; mp = 307-310 °C, eluent (50% ethyl acetate in hexanes), reaction scale 100 mg, 60 mg was isolated, 70% yield.

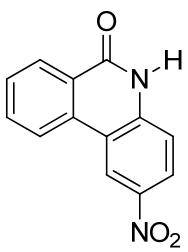
IR (ATR) $\tilde{\nu}$ (cm^{-1}): 1667, 1589 and 1337.

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.70 (s, 1 H), 8.50 (d, *J* = 8.2 Hz, 1 H), 8.38 (d, *J* = 8.0 Hz, 1 H), 8.32 (d, *J* = 8.0 Hz, 1 H), 7.85 (t, *J* = 7.6 Hz, 1 H), 7.64 (t, *J* = 7.6 Hz, 1 H), 7.49 (t, *J* = 7.6 Hz, 1 H), 7.37 (d, *J* = 7.6 Hz, 1 H), 7.26 (t, *J* = 7.6 Hz, 1 H).

^{13}C NMR (100 MHz, DMSO-d_6): δ 161.3, 137.0, 134.7, 133.3, 130.1, 128.4, 127.9, 126.1, 123.7, 123.1, 122.7, 118.0, 116.6.

Ref. 4. (a) B. S. Bhakuni, A. Kumar, S. H. Balkrishna, J. A. Sheikh, S. Konar, S. Kumar; *Org. Lett.,* **2012**, *14*, 2838. (b) Liang, D.; Hu, Z.; Peng, J.; Huang, J.; Zhu. Q. *Chem Commum.,* **2013**, *49*, 173.

2-Nitrophenanthridin-6(5*H*)-one (9).[3]



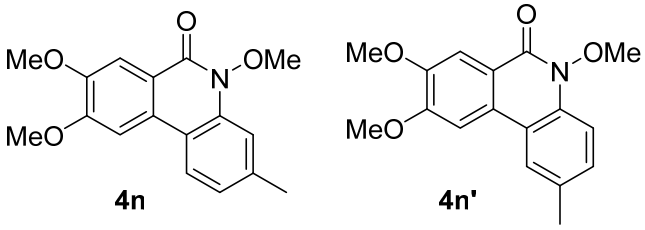
Light yellow solid; mp = decomposes at 275 °C, reaction scale 75 mg, 70 mg was isolated, 75% yield.

^{1}H NMR (DMSO-d_6, 400 MHz): δ 12.21 (s, 1 H), 9.14 (s, 1 H), 8.62 (d, *J* = 8.1 Hz, 1 H), 8.32 - 8.29 (m, 2 H), 7.89 (t, *J* = 7.2 Hz, 1 H), 7.72 (t, *J* = 7.6 Hz, 1 H), 7.46 (d, *J* = 8.8 Hz, 1 H),

HRMS (ESI): calc. for [($C_{13}H_8N_2O_3$)H] (M+H) 241.0613 measured 241.0619.

Ref. 3. Z. Tu, W. Chu, J. Zjang, C. S. Dence, M. J. Welch, R. H. Mach, *Nuclear Medicine and Biology*, **2005**, *32*, 437.

Mixtures of 5,8,9-trimethoxy-3-methylphenanthridin-6(5H)-one (4n) and 5,8,9-trimethoxy-2-methylphenanthridin-6(5H)-one (4n').



Light brown semisolid; eluent (45% ethyl acetate in hexanes).

IR (ATR) $\tilde{\nu}$ (cm^{-1}): 2935, 1659 and 1615.

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.01 (d *J* = 8.2 Hz, 1 H), 7.92 (s, 1 H), 7.90 (s, 1 H), 7.58 (s, 1 H), 7.55 (s, 2 H other isomer), 7.47 (s, 1 H), 7.36 (d, *J* = 8.2 Hz, 1 H other isomer), 7.15 (d, *J* = 8.2 Hz, 2 H other isomer), 4.14 (s, 3 H), 4.12 (s, 3 H other isomer), 4.11 (s, 3 H other isomer), 4.09 (s, 3 H), 4.05 (s, 3 H other isomer), 4.04 (s, 3 H), 2.53 (s, 3 H), 2.52 (s, 3 H other isomer).

^{13}C NMR ($CDCl_3$, 100MHz): δ 157.1, 156.8, 153.4, 153.3, 149.8, 149.6, 139.6, 135.2, 133.2, 132.5, 130.2, 128.0, 127.7, 124.2, 122.7, 122.6, 120.4, 119.7, 118.3, 116.0, 112.7, 112.7, 108.7, 108.6, 102.8, 102.6, 62.8, 62.7, 56.3, 56.2, 56.2, 29.7, 21.9, 21.2.

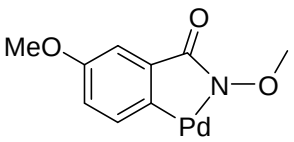
HRMS (ESI): calc. for [($C_{17}H_{17}NO_4$)H] (M+H) 300.1226 measured 300.1227.

Spectral Data and Crystolographic Studies of Complex 5.

General Procedure for the preparation of intermediate 5.

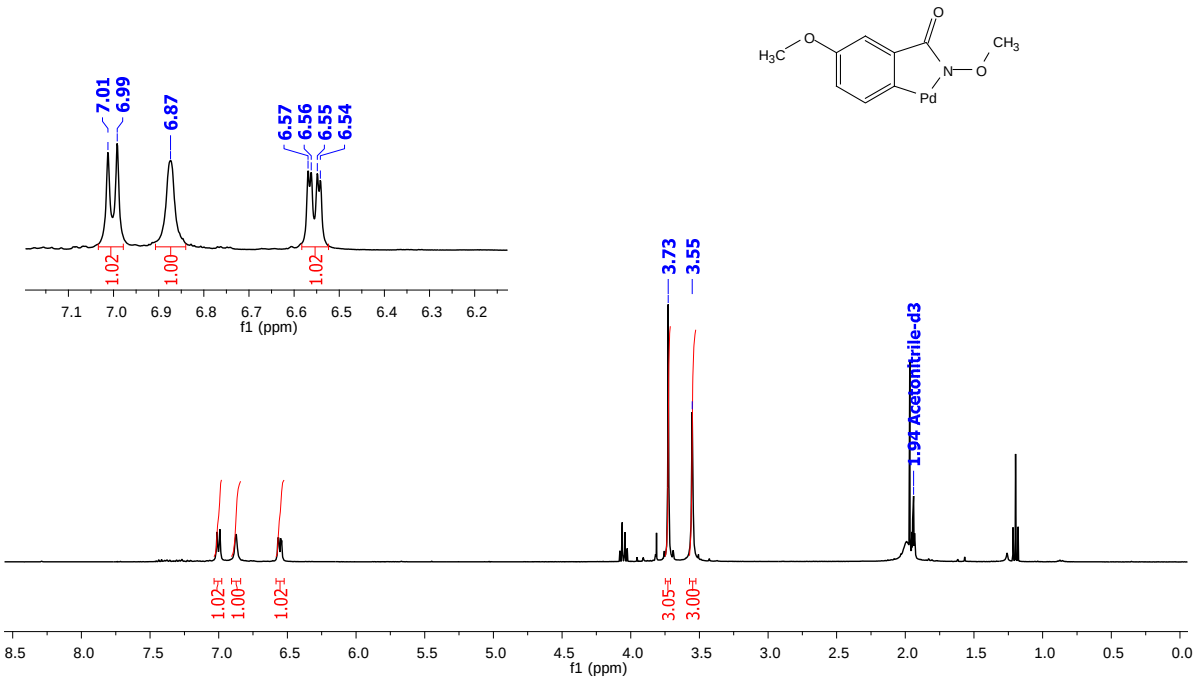
In a 15 mL pressure tube, *N*-substituted benzamides **5** (50 mg) and $Pd(OAc)_2$ (1.0 equiv) were added. Then, AcOH (3.0 mL) was added via syringe and the tube was evacuated and purged with nitrogen gas three times. After that, the septum was taken out immediately and a screw cap was used to cover the tube. Then, the reaction mixture was allowed to stir at 120 °C for 15 min. After cooling to ambient temperature, the reaction mixture was diluted with ethyl acetate and MeOH, filtered through Celite and silica gel, and the filtrate was concentrated. The crude residue was purified by recrystallization using CH_3CN solvent to give pure intermediate **5a-b**.

Intermediate (palladacycle) (5b).

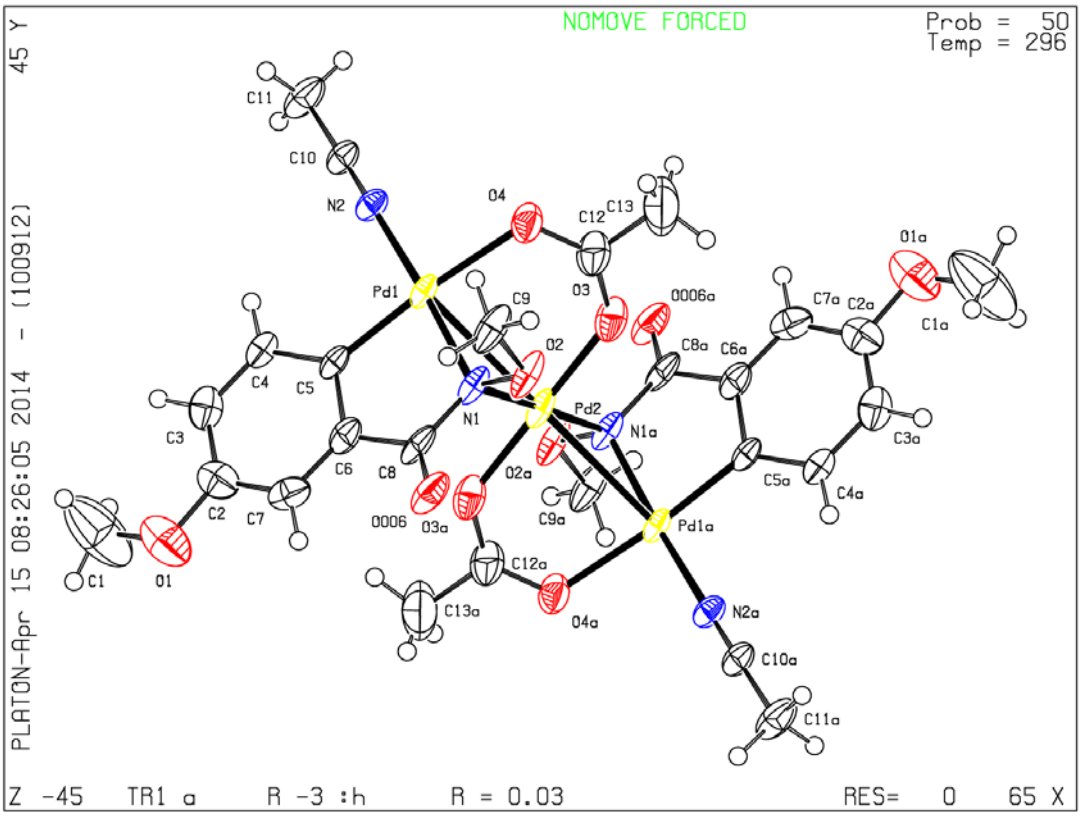


^{1}H NMR (CD_3CN, 400 MHz): δ 7.00 (d, *J* = 8.2 Hz, 1 H), 6.87 (s, 1 H), 6.56 (dd, *J* = 8.2, 2.6 Hz, 1 H), 3.73 (s, 3 H), 3.55 (s, 3 H).

^{1}H NMR spectrum of compound **5b**.



Crystolographic Studies (The structure is in dimer form with acetate linkage. Only monomer structure is given for the better clarity).



Isolated palladacycle was grown in acetonitrile for crystal developement. Above figure shows *N*-methoxy *meta*-OMe benzamide with incorporated Pd along with one acetonitrile and one acetate ligand. Presented image displays the dimer form where two aromatic moities shares three palladiums via acatate linkage.

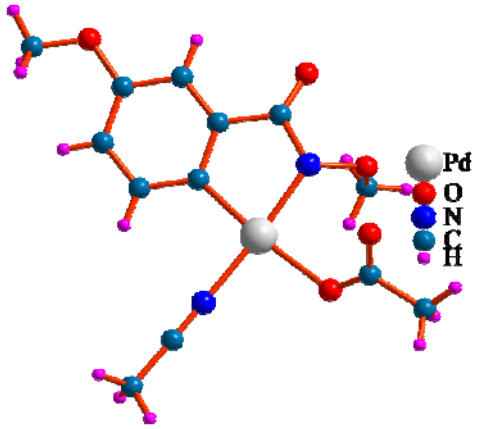


Table 1. Crystal data and structure refinement for sandeep.

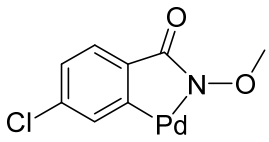
Identification code	5b
Empirical formula	C26 H30 N4 O10 Pd3
Formula weight	877.74
Temperature	296(2) K
Wavelength	0.71073 Å

Crystal system	Trigonal	
Space group	R -3 :H	
Unit cell dimensions	a = 27.371(3) Å	a= 90°.
	b = 27.371(3) Å	b= 90°.
	c = 10.3756(12) Å	g = 120°.
Volume	6731.8(17) $Å^3$	
Z	9	
Density (calculated)	1.949 Mg/m^3	
Absorption coefficient	1.845 mm^{-1}	
F(000)	3888	
Theta range for data collection	1.488 to 26.349°.	
Index ranges	-25<=h<=34, -34<=k<=33, -12<=l<=12	
Reflections collected	34368	
Independent reflections	3063 [R(int) = 0.0476]	
Completeness to theta = 25.242°	100.0 %	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3063 / 65 / 200	
Goodness-of-fit on F^2	1.053	
Final R indices [I>2sigma(I)]	R1 = 0.0347, wR2 = 0.1176	
R indices (all data)	R1 = 0.0438, wR2 = 0.1287	
Extinction coefficient	n/a	
Largest diff. peak and hole	1.570 and -0.798 $e.Å^{-3}$	

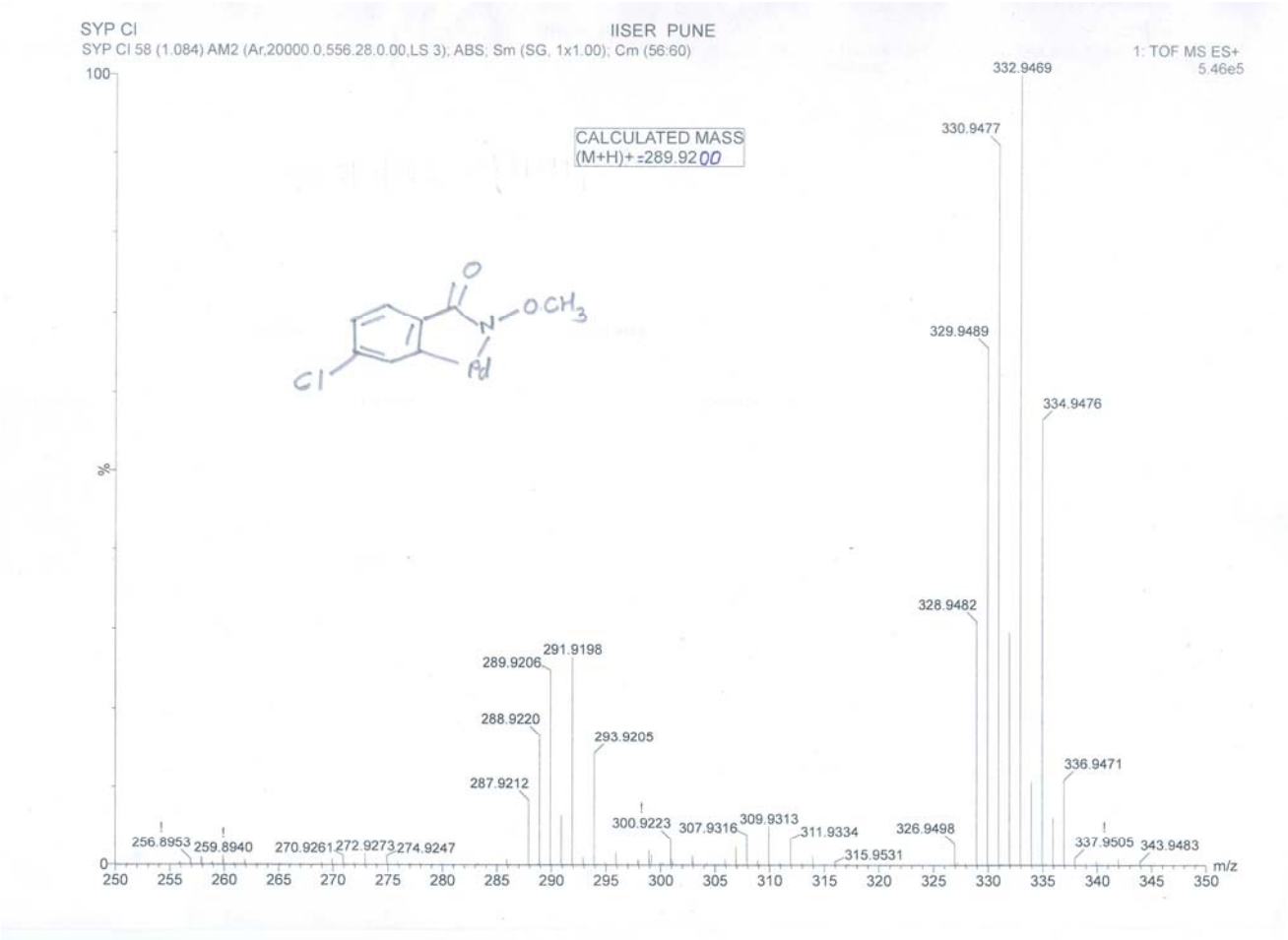
Intermediate (palladacycle) (5a).

Intermediate **5a** was confirmed by HRMS. X-ray crystallographic study was not done.

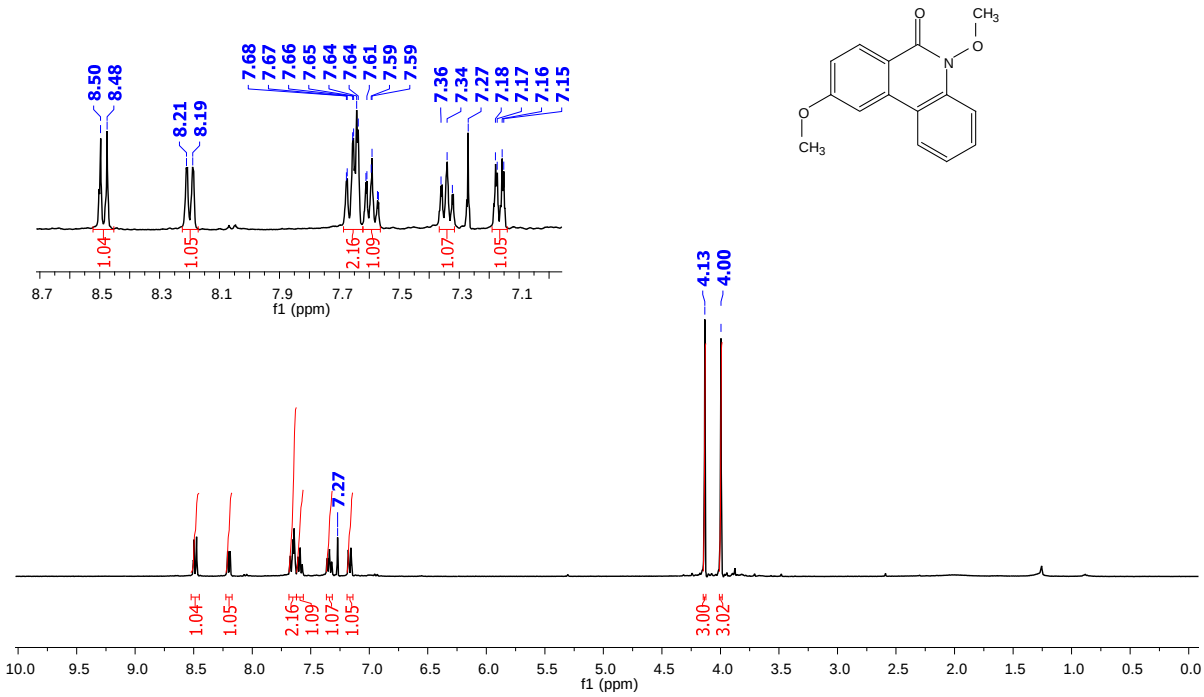
The HRMS observed value of intermediate **5a** was perfectly matching with the expected value.



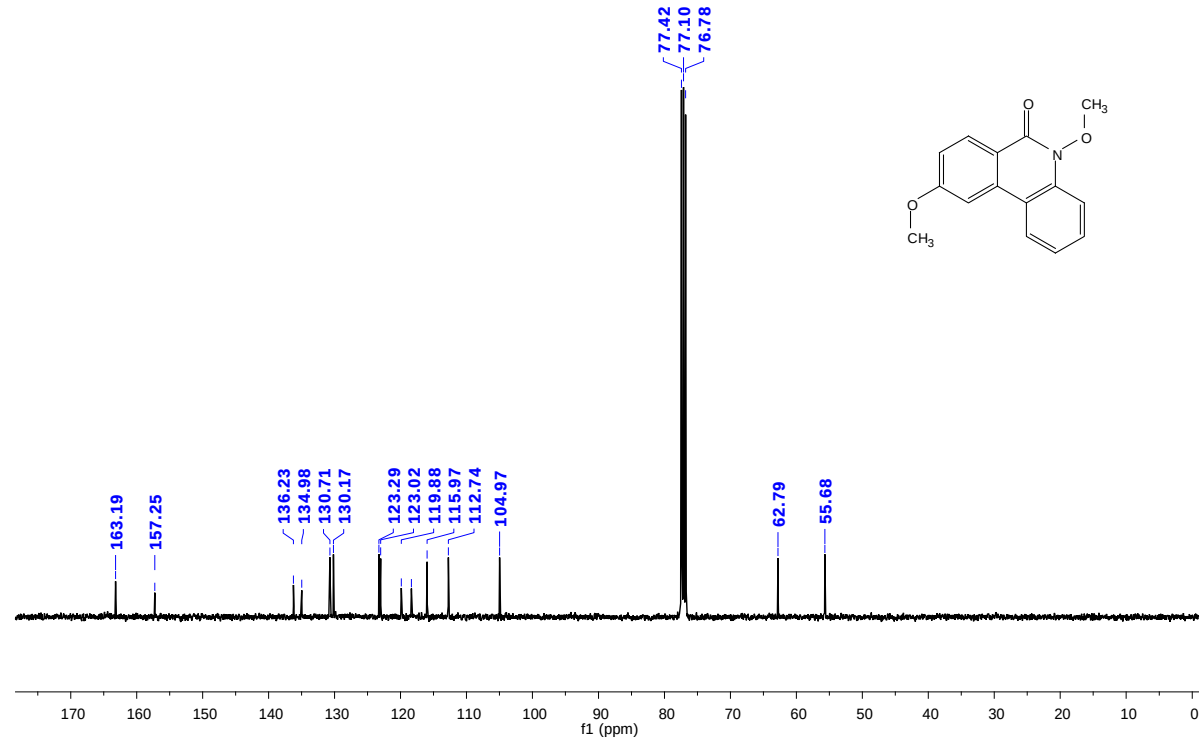
HRMS (ESI): calc. for [($C_8H_6ClNO_2Pd$)H] (M+H) 289.9200 measured 289.9206.



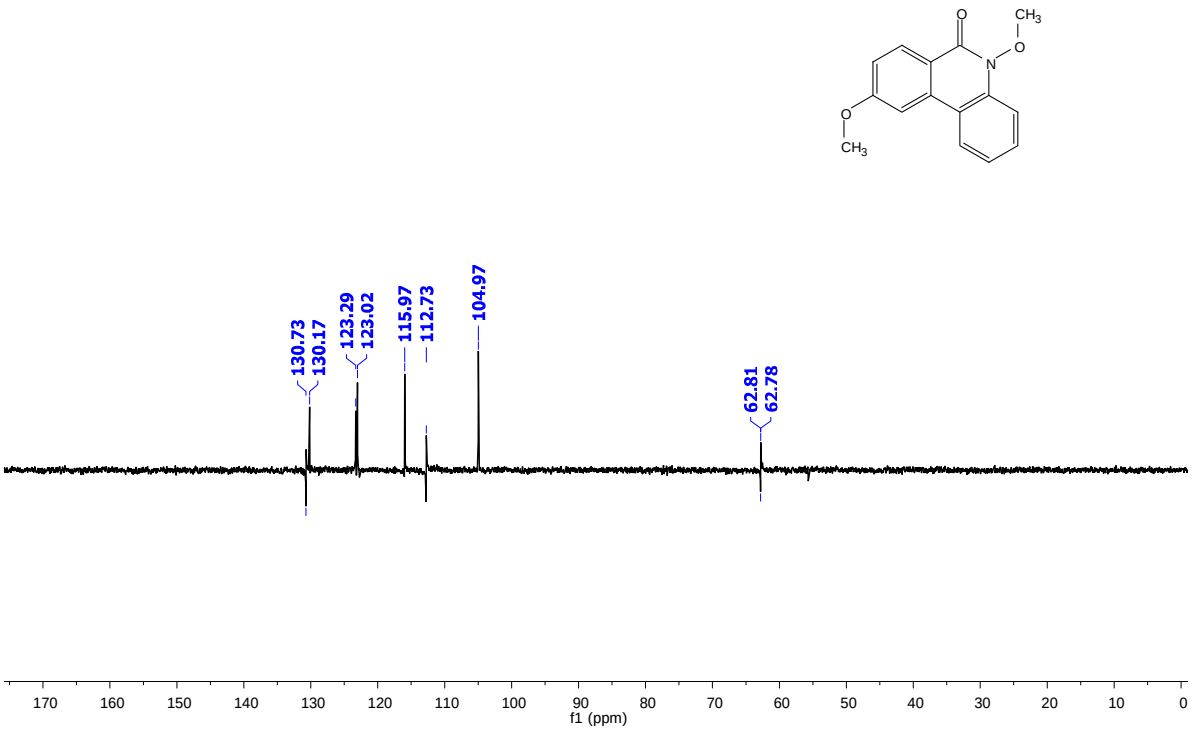
^{1}H NMR spectrum of compound **4a.**



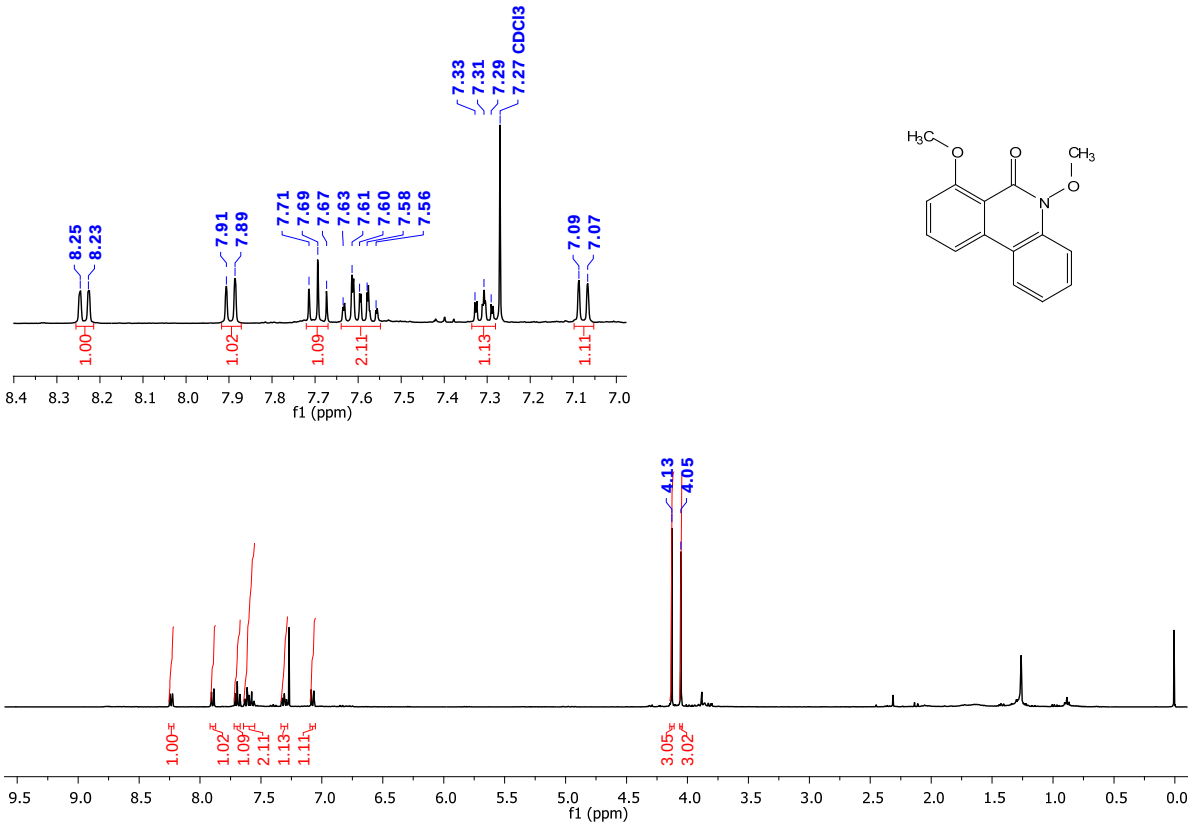
^{13}C NMR spectrum of compound **4a.**



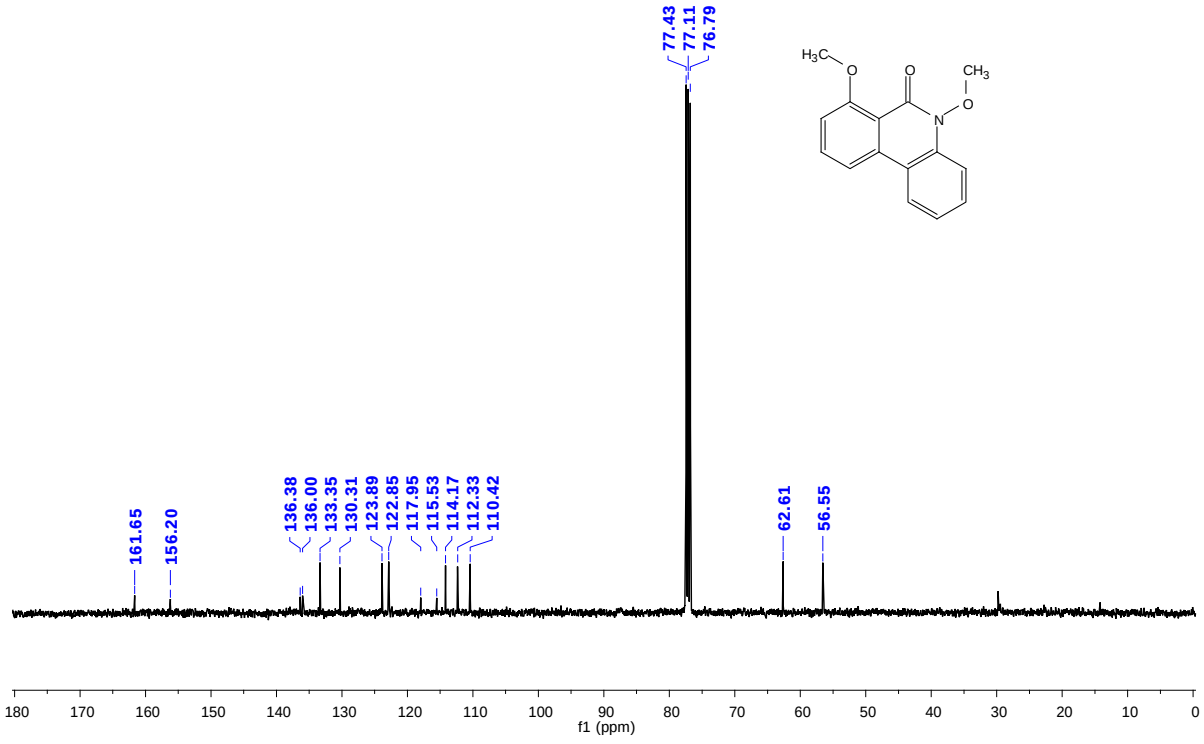
DEPT135 NMR spectrum of compound **4a.**



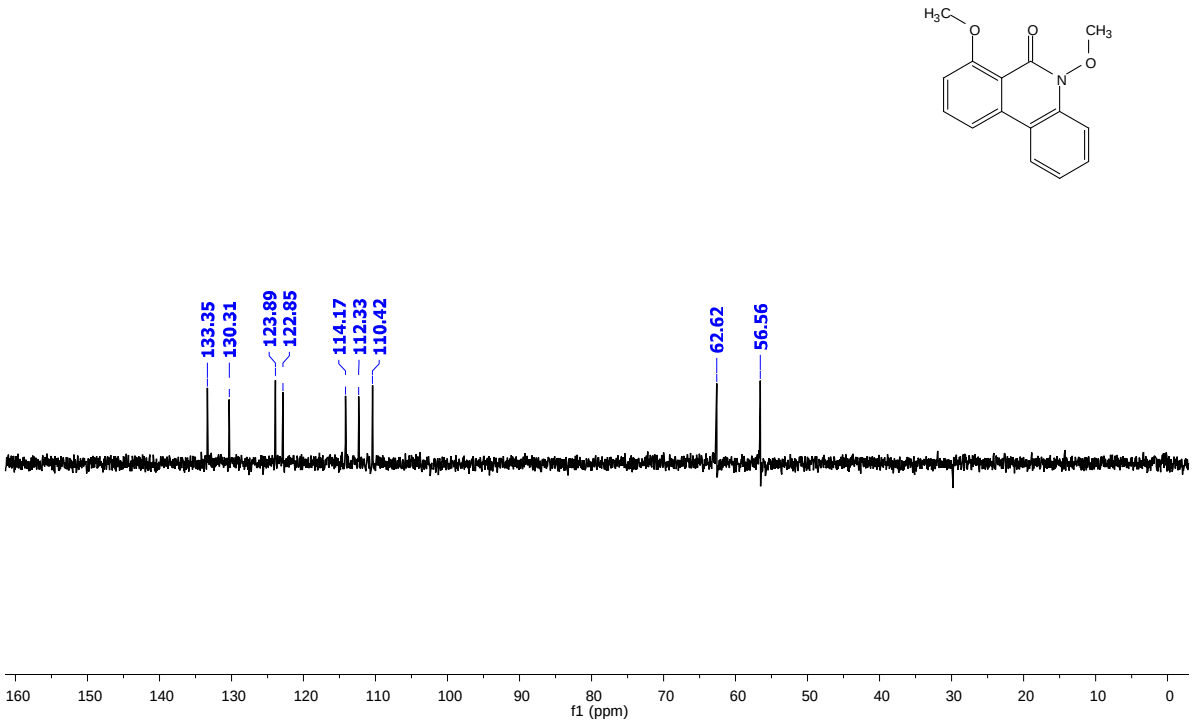
^{1}H NMR spectrum of compound **4b.**



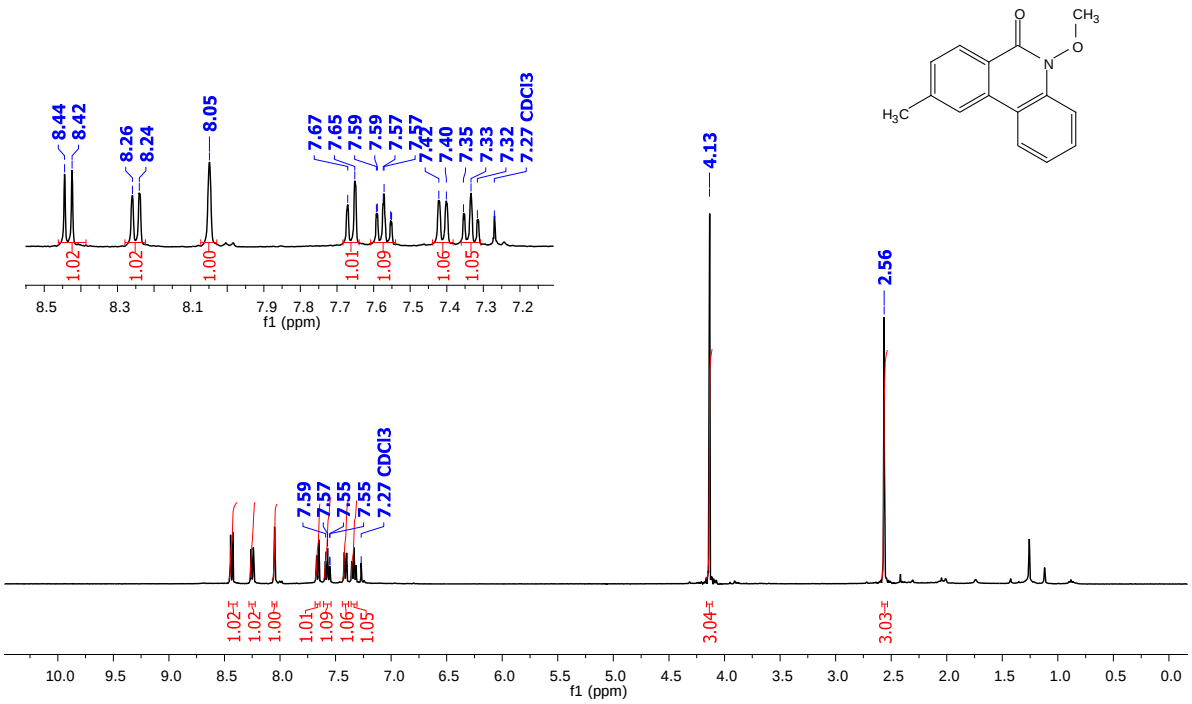
^{13}C NMR spectrum of compound **4b.**



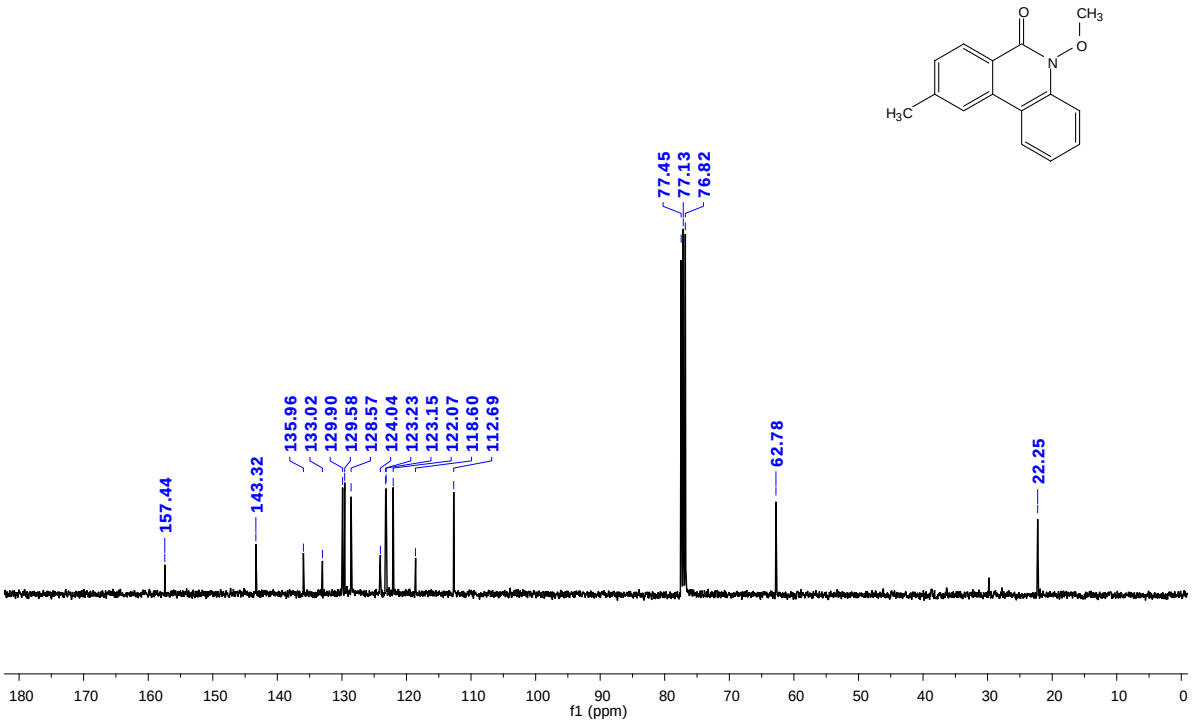
DEPT135 NMR spectrum of compound **4b.**



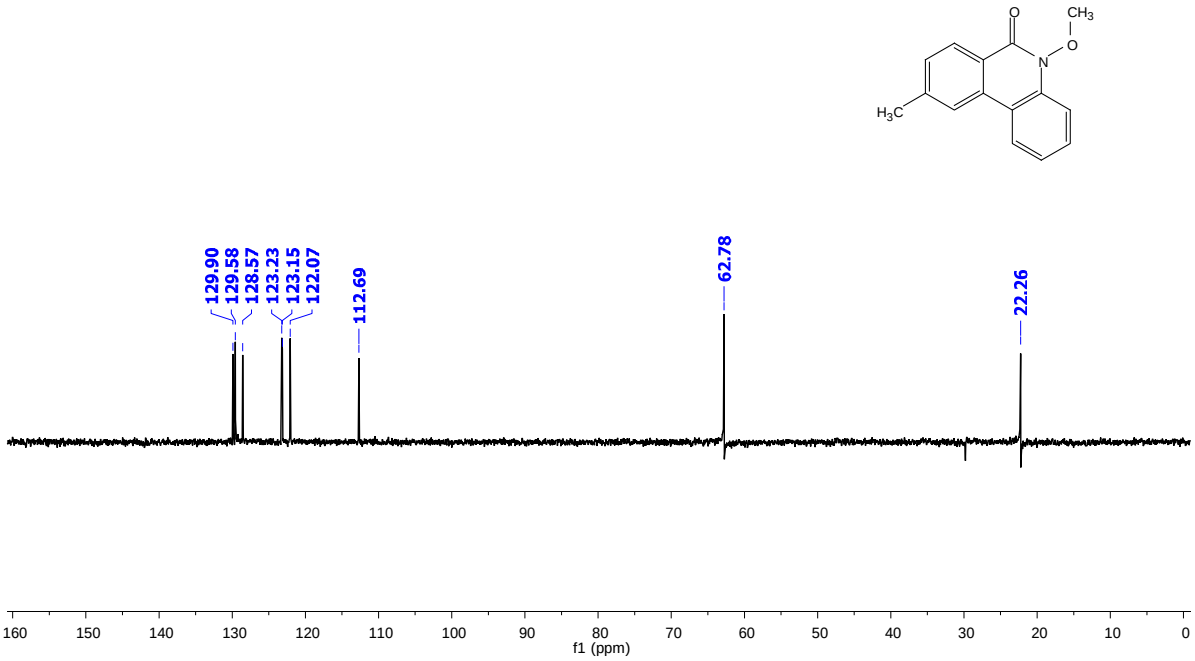
^{1}H NMR spectrum of compound **4c.**



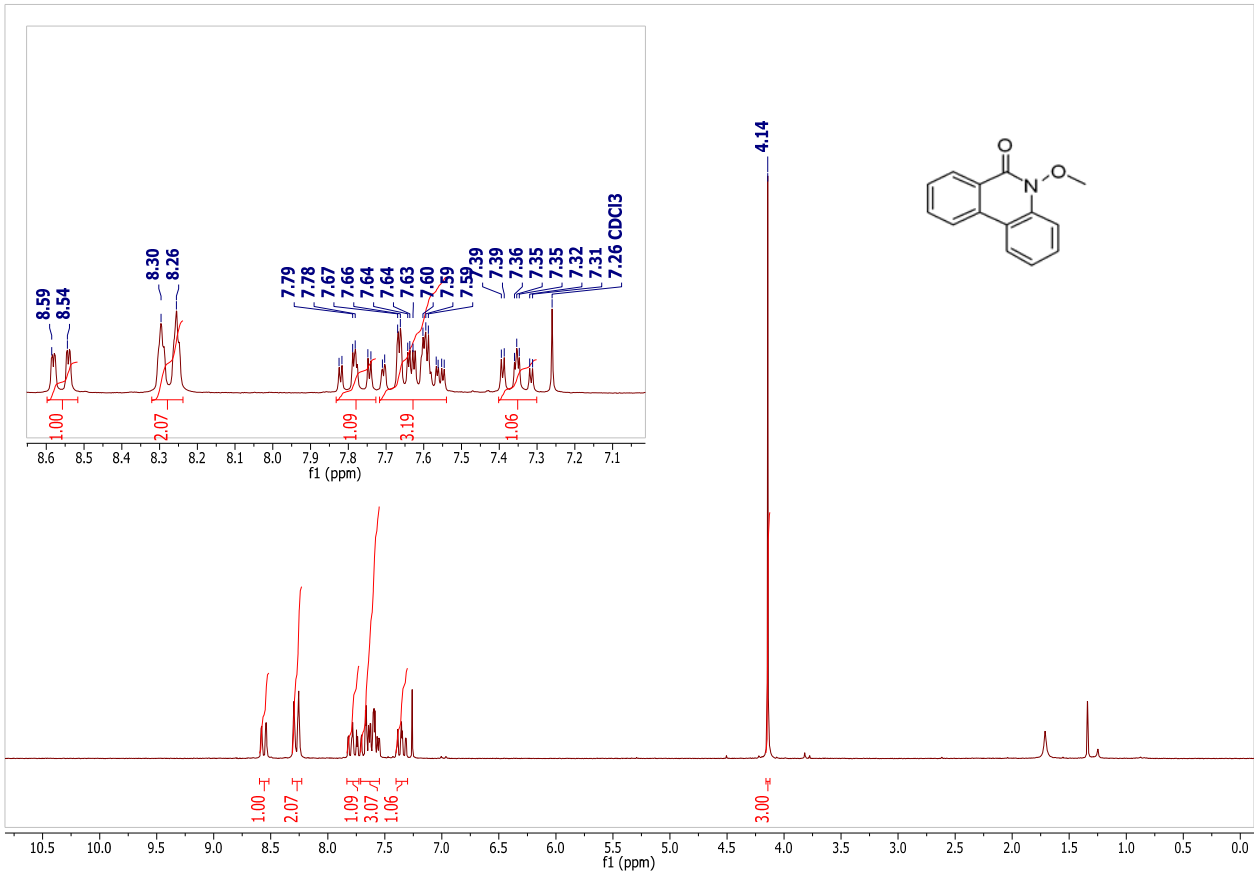
^{13}C NMR spectrum of compound **4c.**



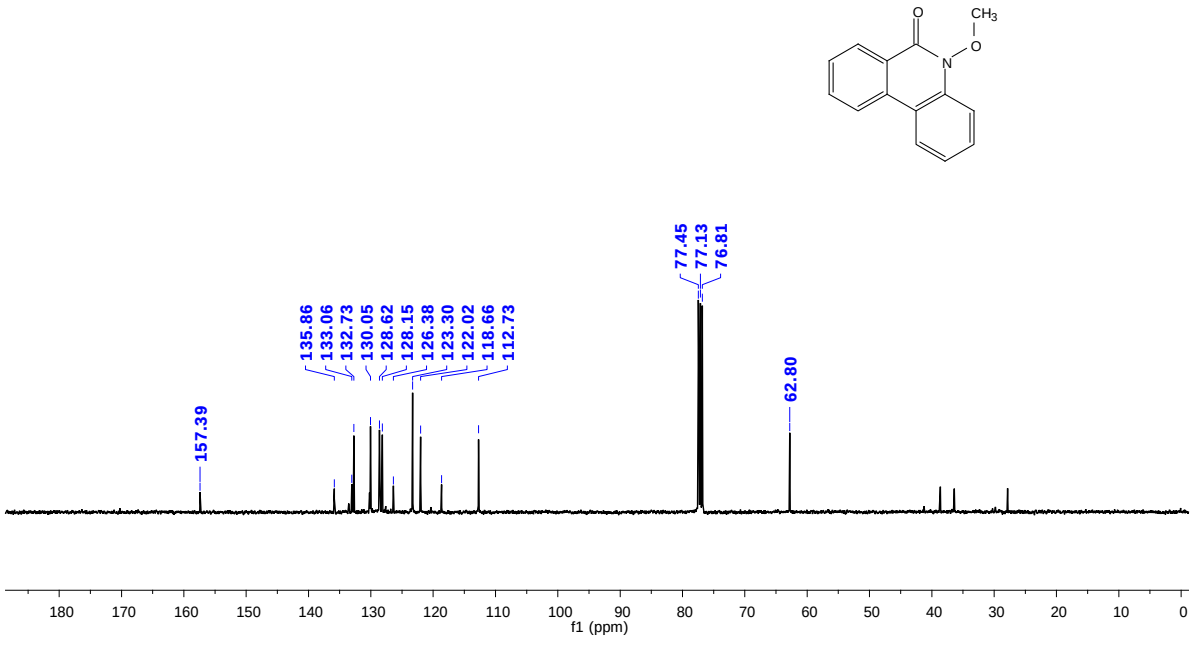
DEPT135 NMR spectrum of compound **4c.**



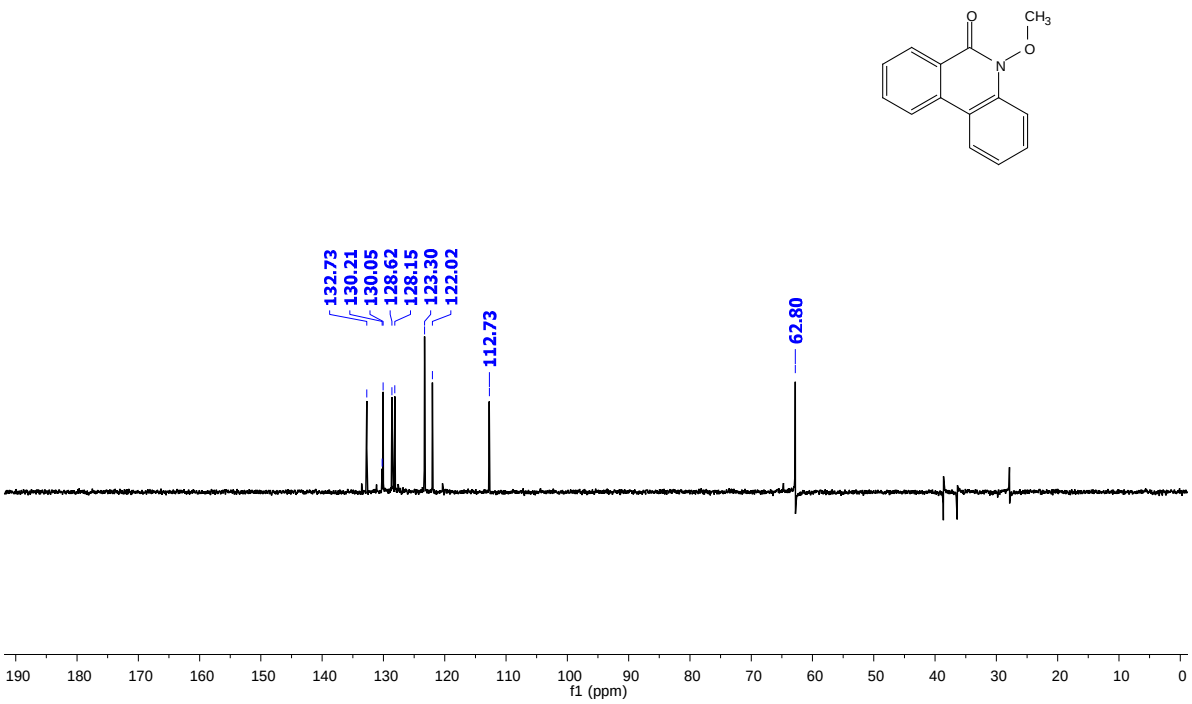
^{1}H NMR spectrum of compound **4d.**



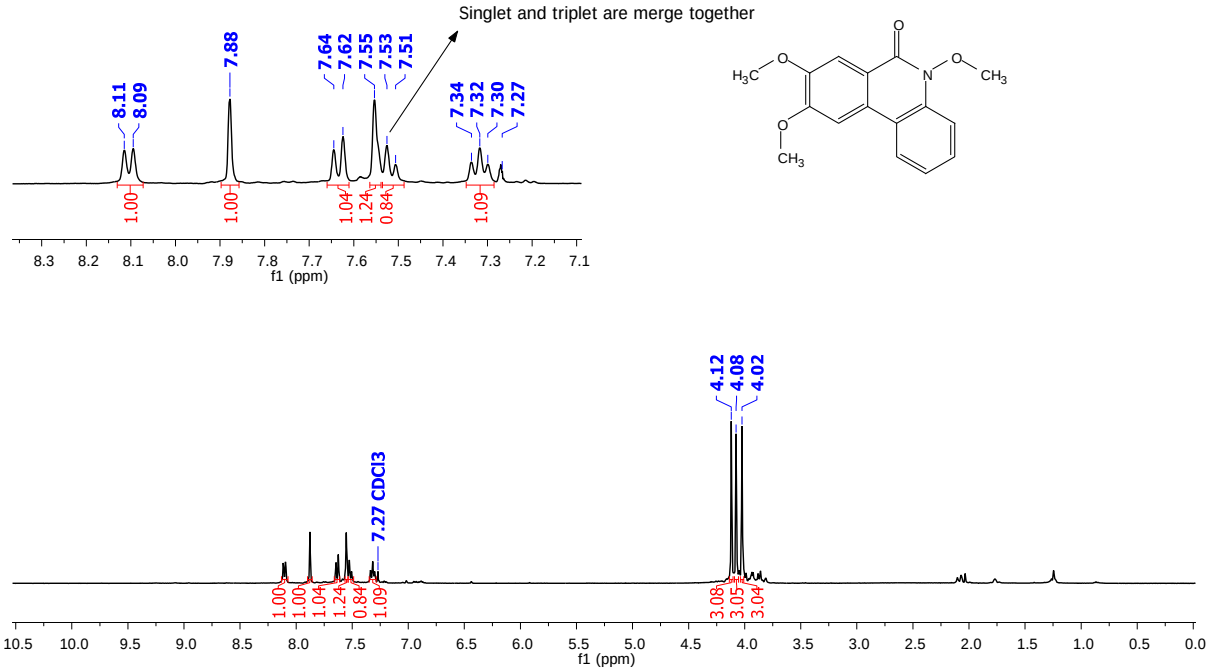
^{13}C NMR spectrum of compound **4d.**



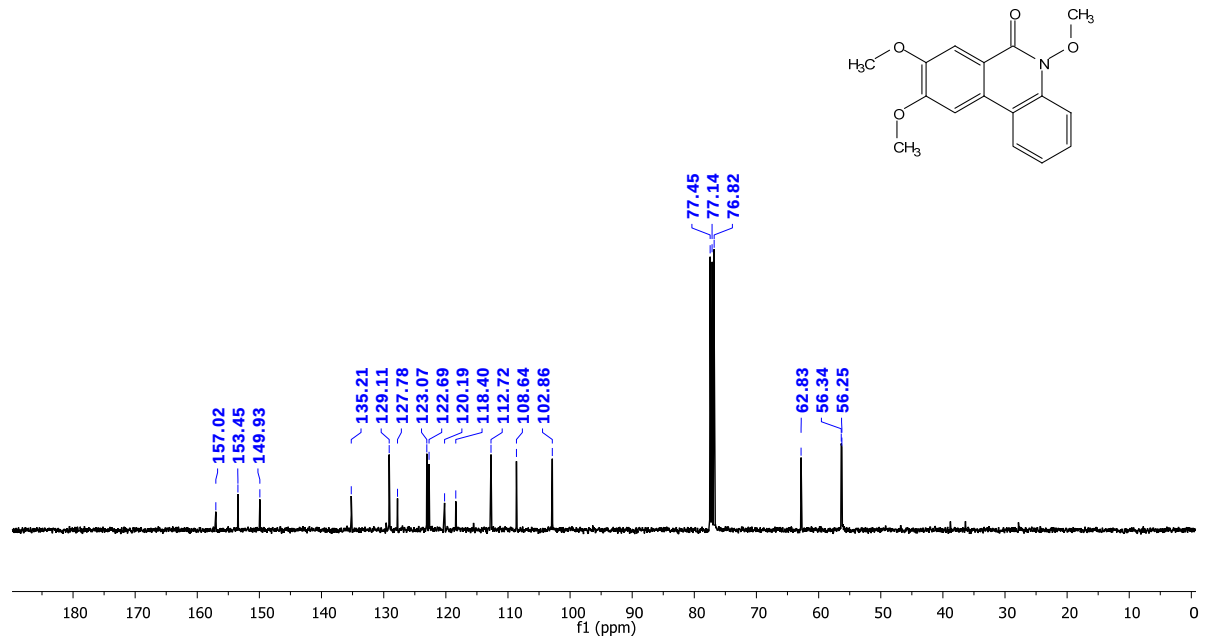
DEPT135 NMR spectrum of compound **4d.**



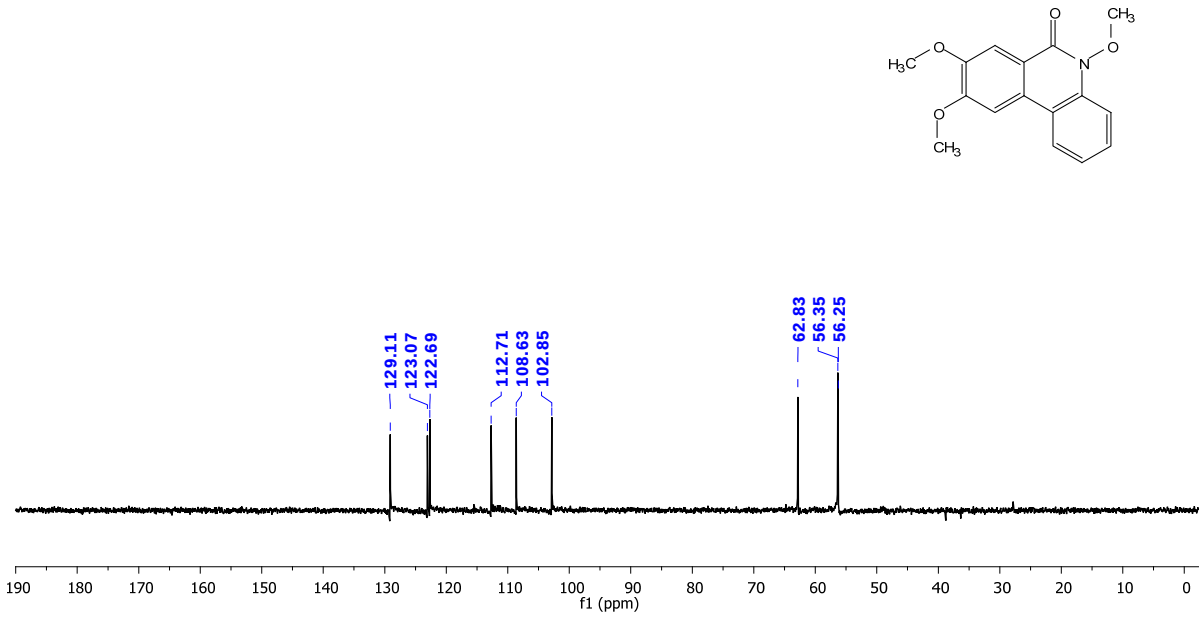
[1]H NMR spectrum of compound **4e.**



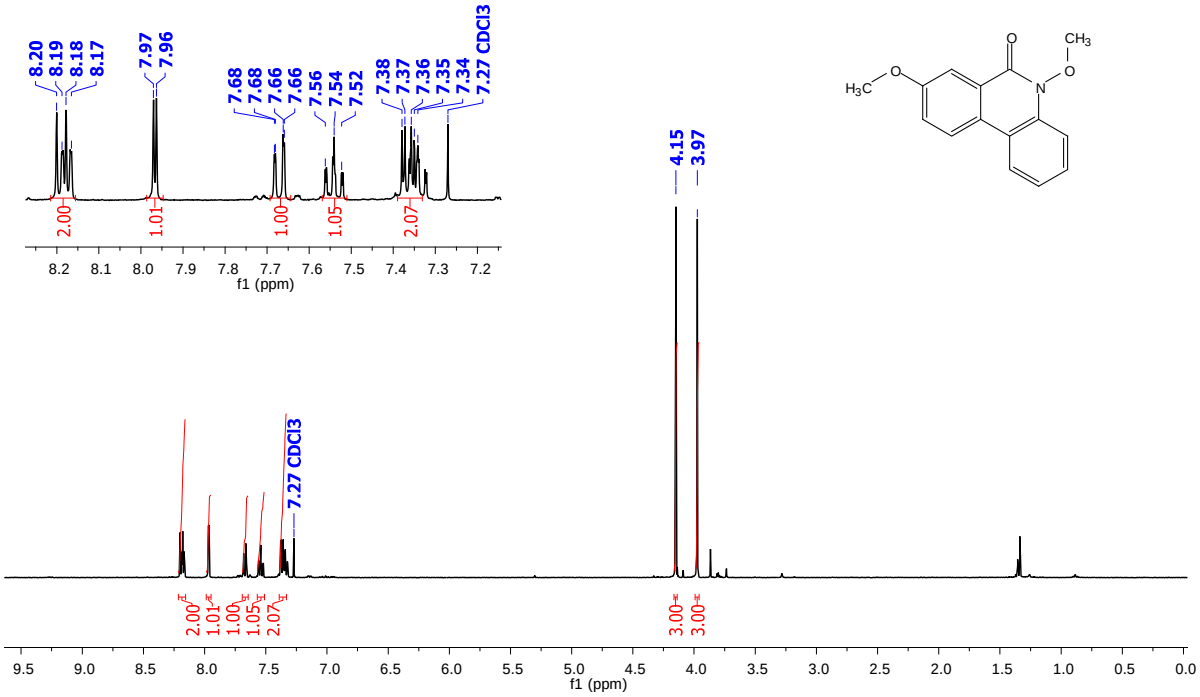
[13]C NMR spectrum of compound **4e.**



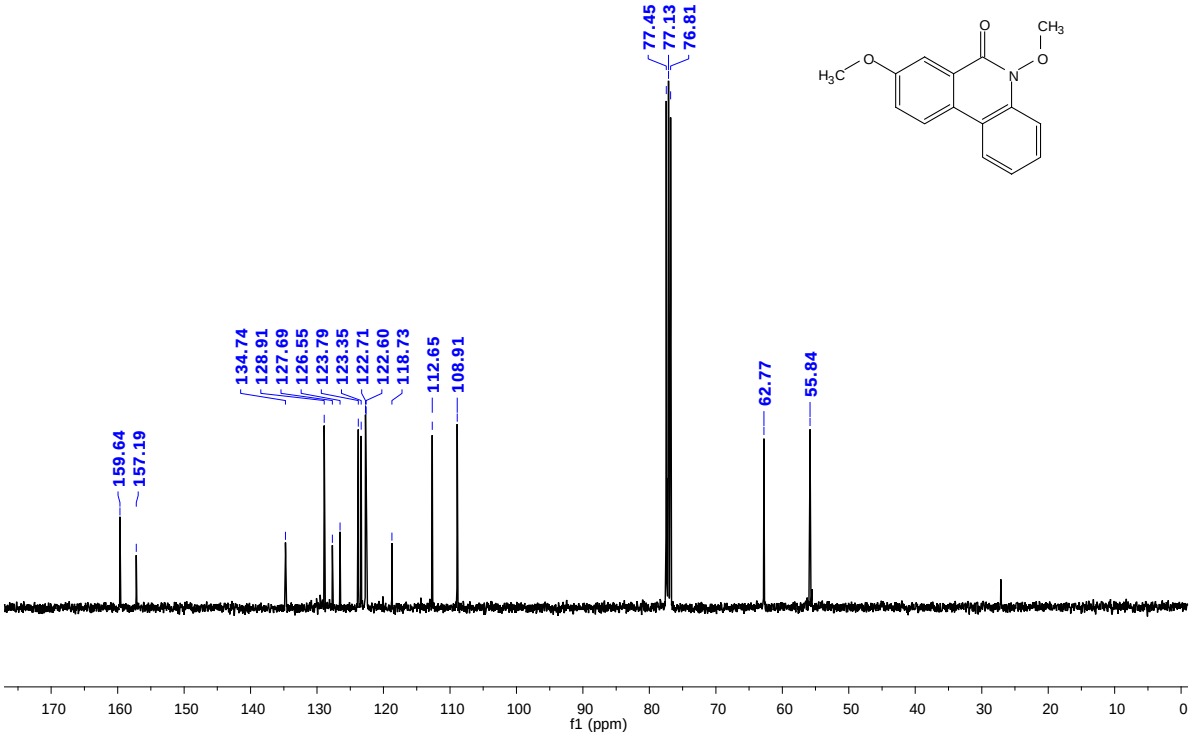
DEPT135 NMR spectrum of compound **4e.**



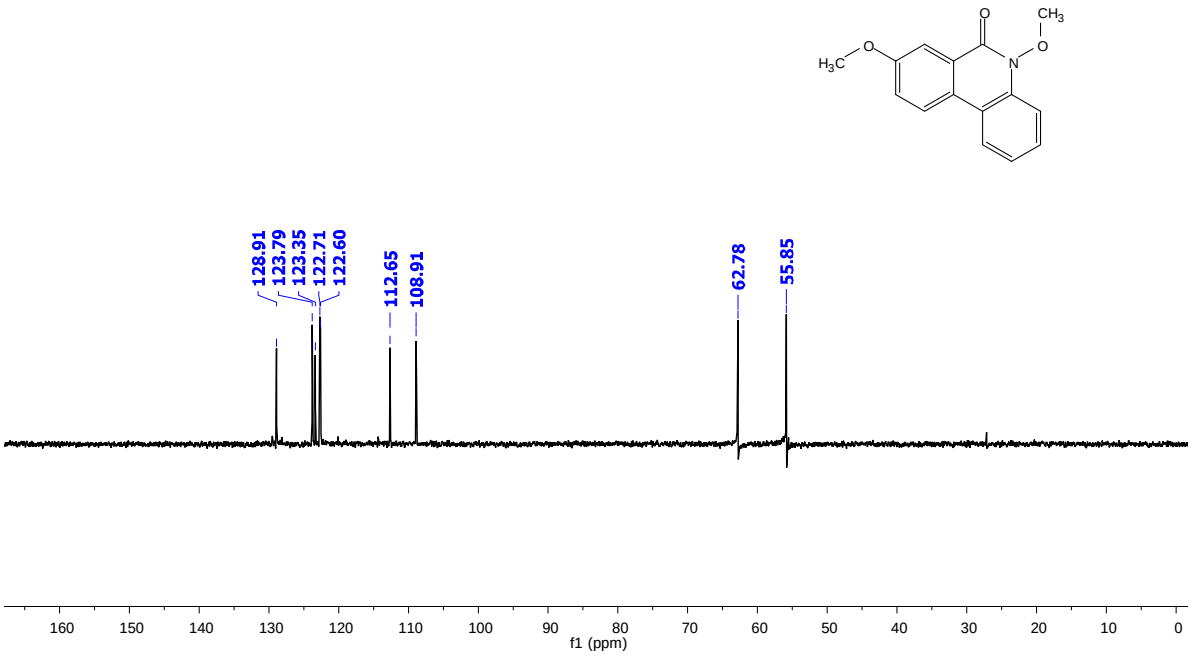
^{1}H NMR spectrum of compound **4f.**



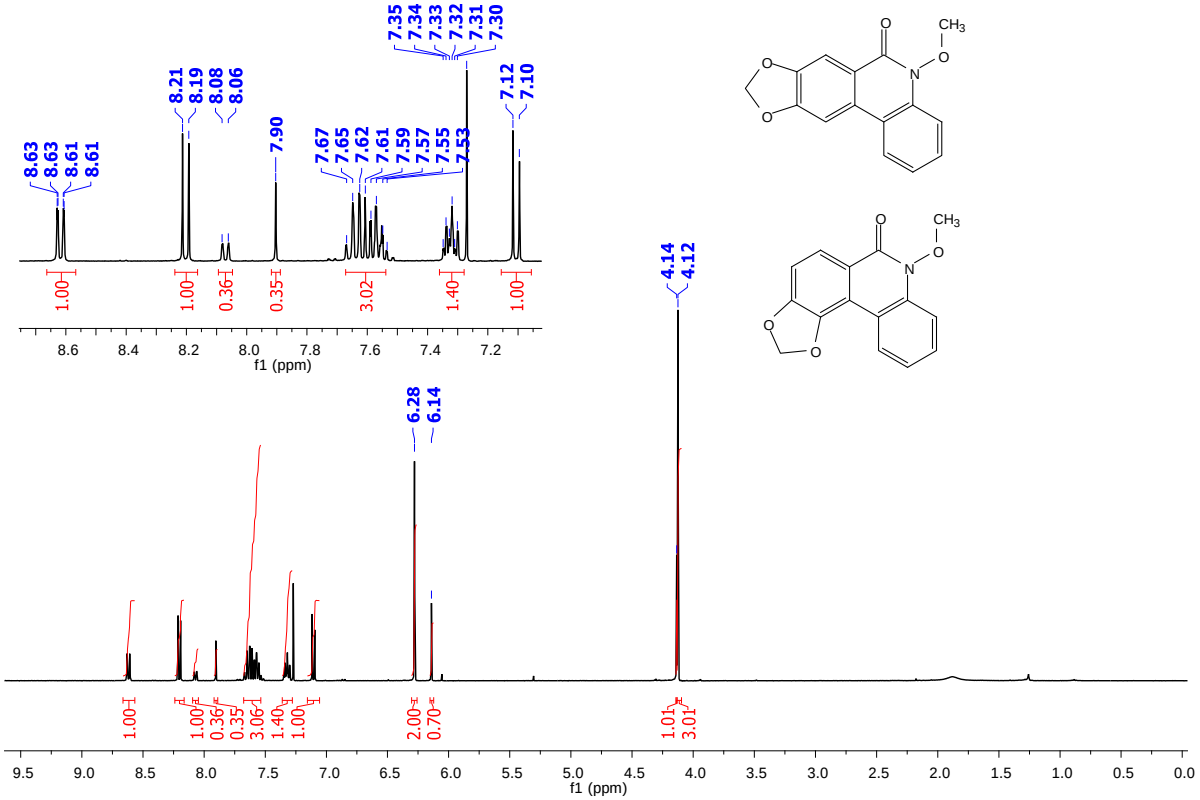
^{13}C NMR spectrum of compound **4f.**



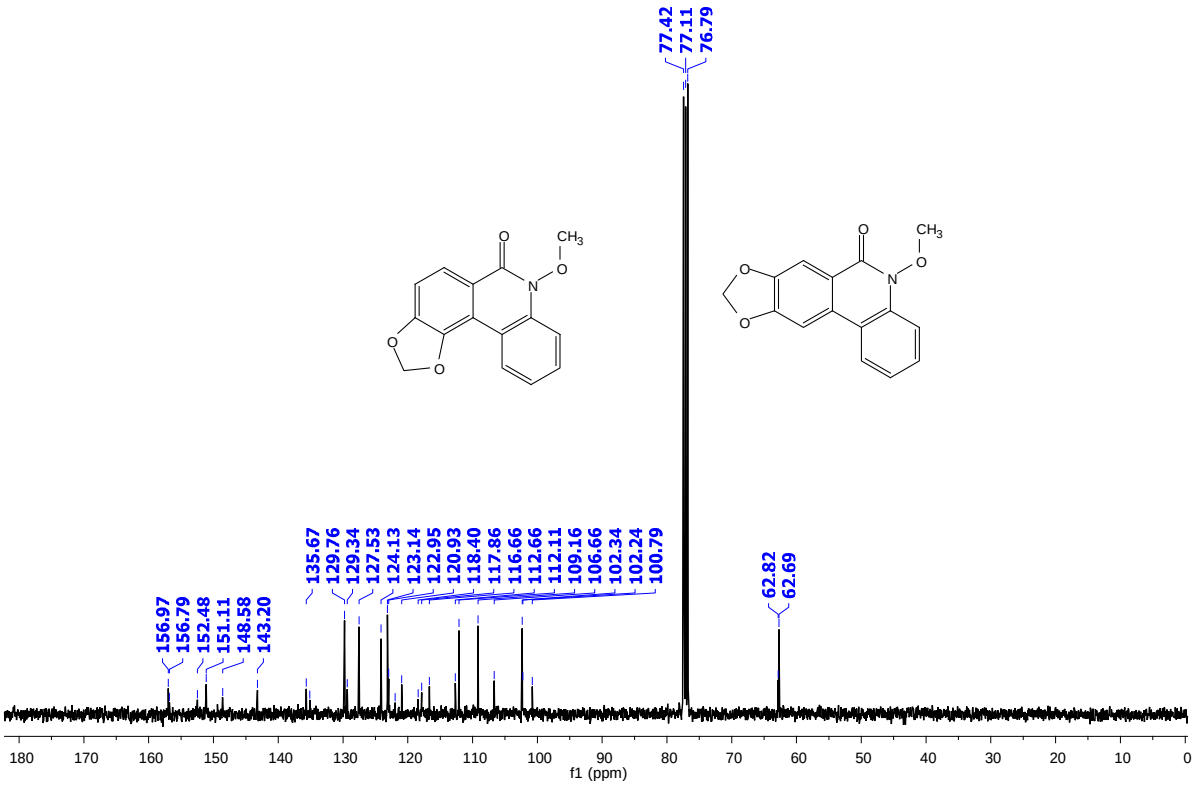
DEPT135 NMR spectrum of compound **4f.**



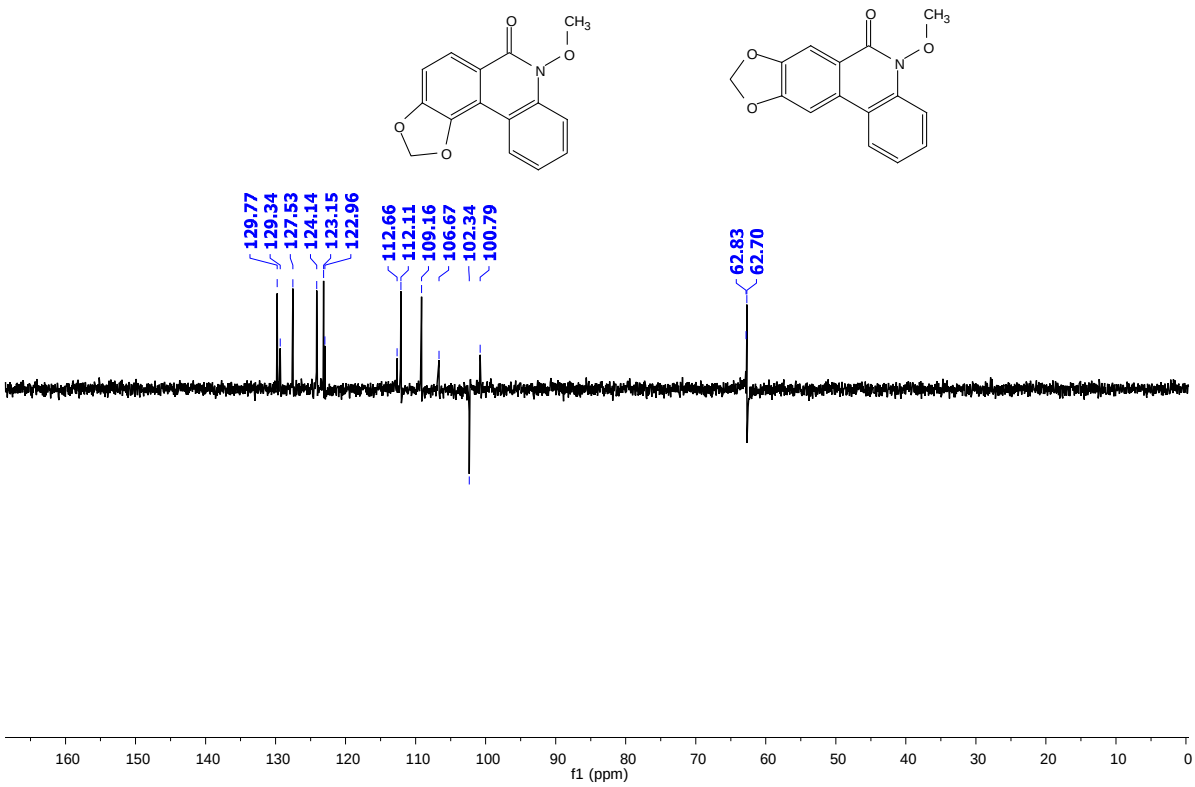
^{1}H NMR spectrum of compounds **4g** and **4g'**.



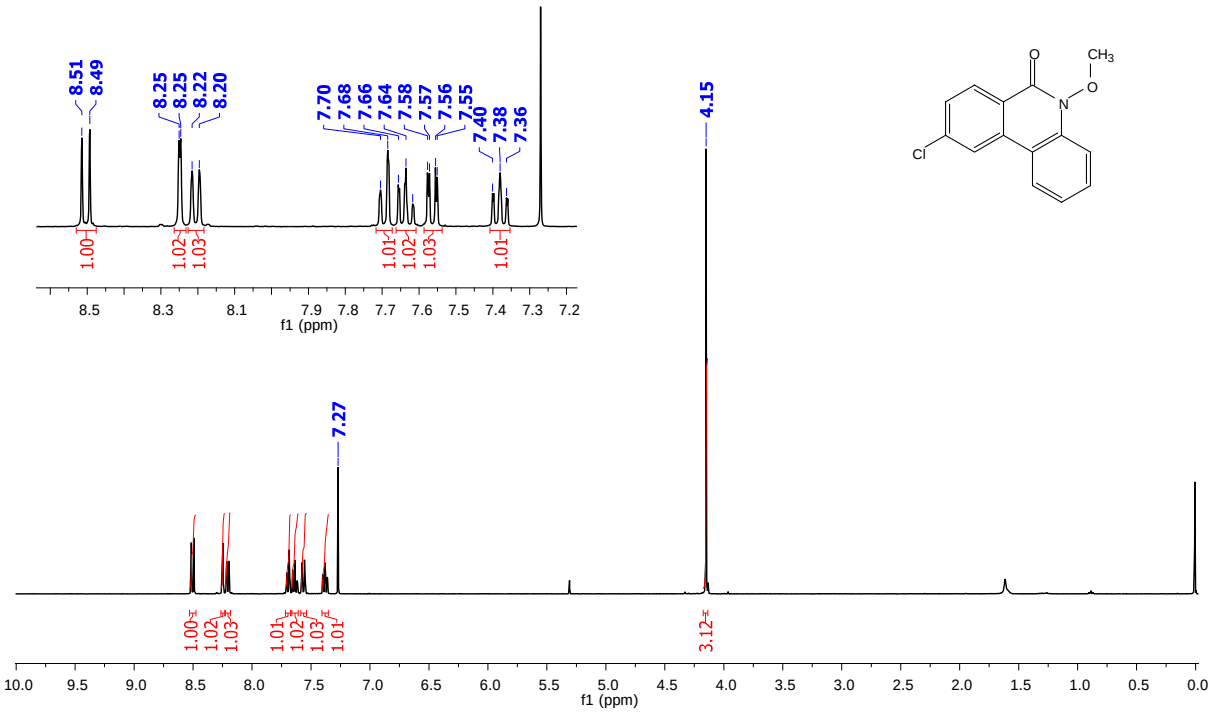
^{13}C NMR spectrum of compounds **4g** and **4g'**.



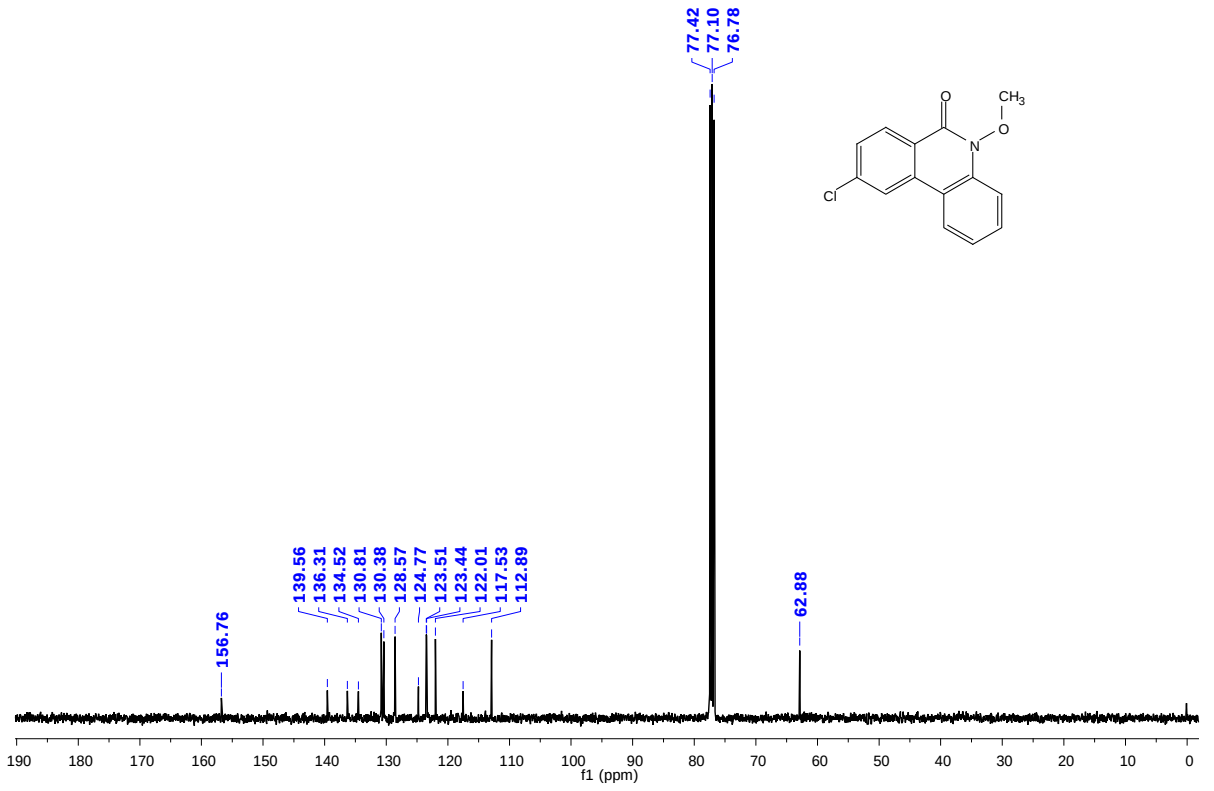
DEPT135 NMR spectrum of compounds **4g and 4g‘**.



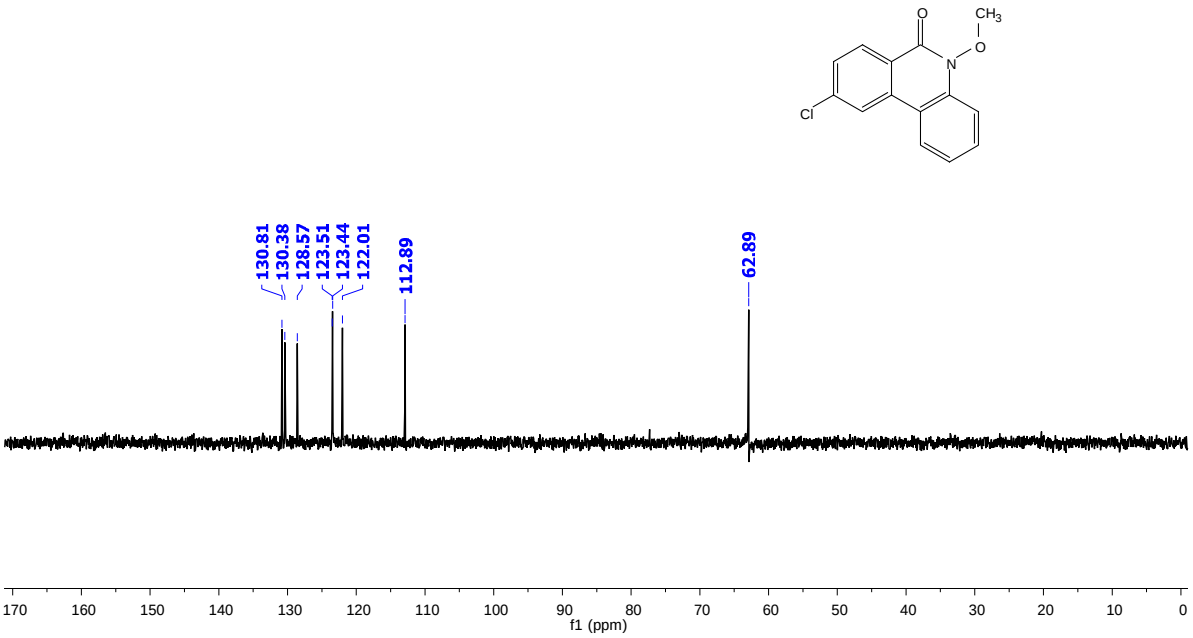
^{1}H NMR spectrum of compound of **4h**.



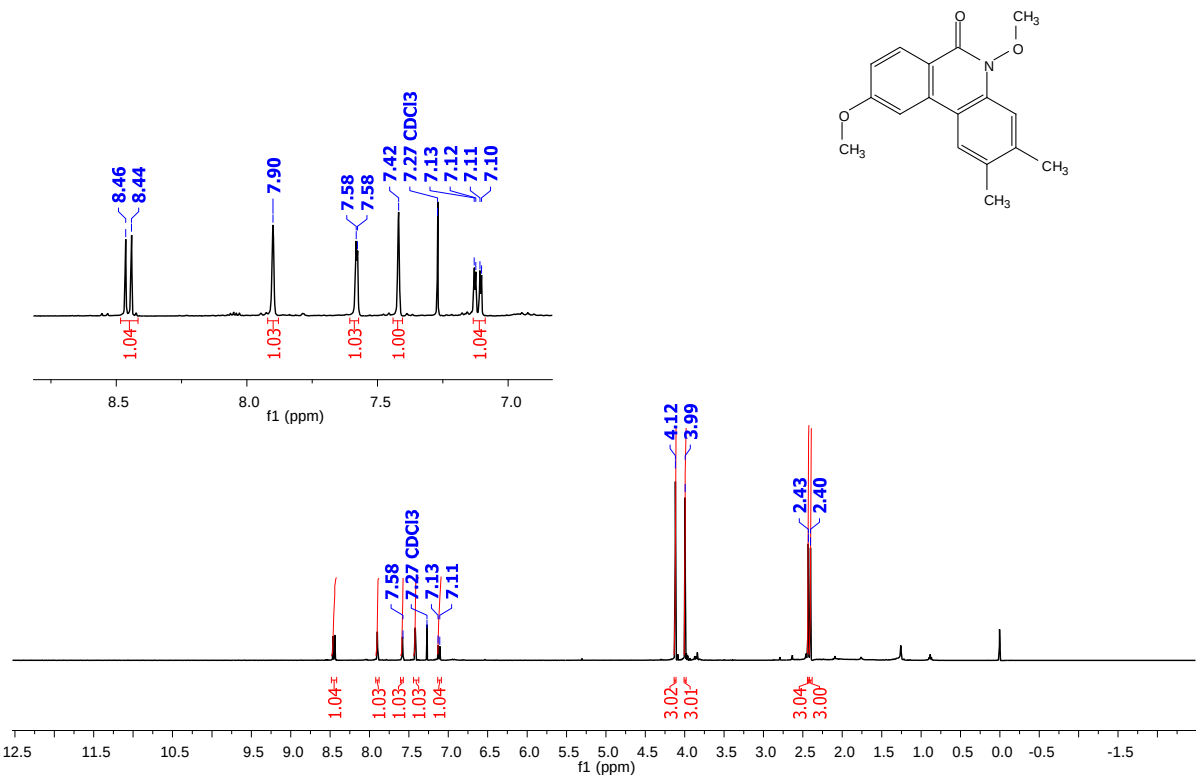
^{13}C NMR spectrum of compound of **4h**.



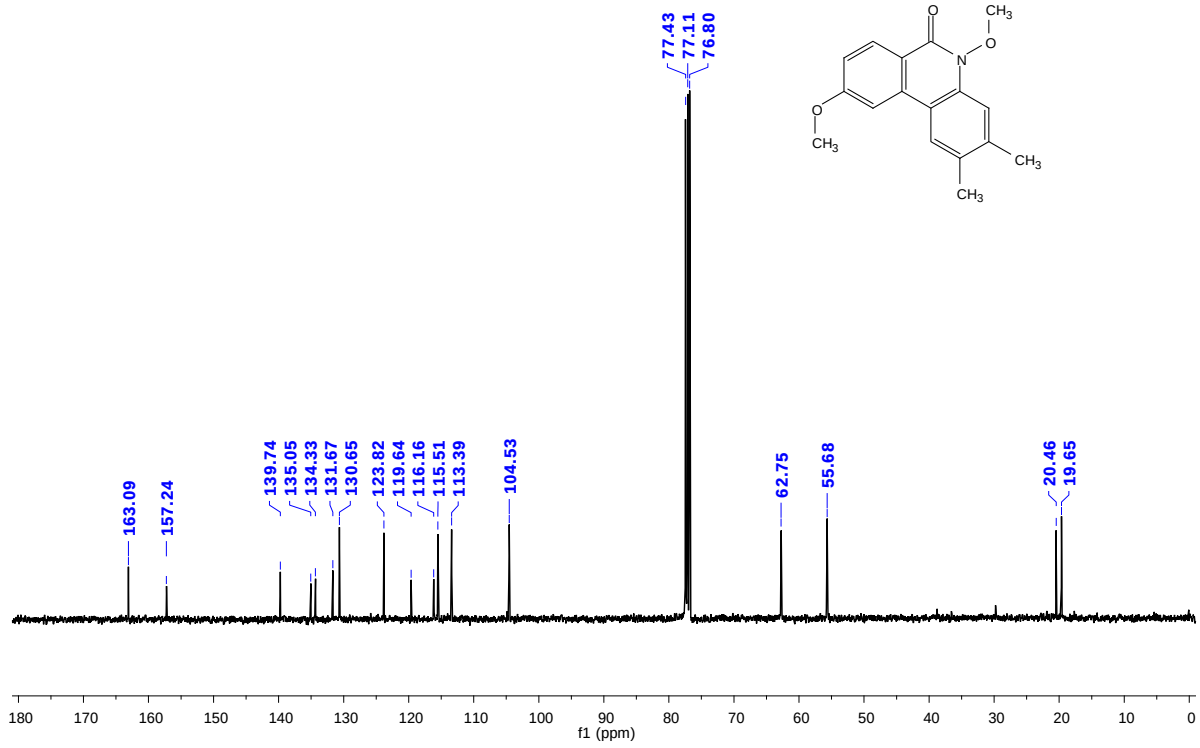
DEPT135 NMR spectrum of compound of **4h.**



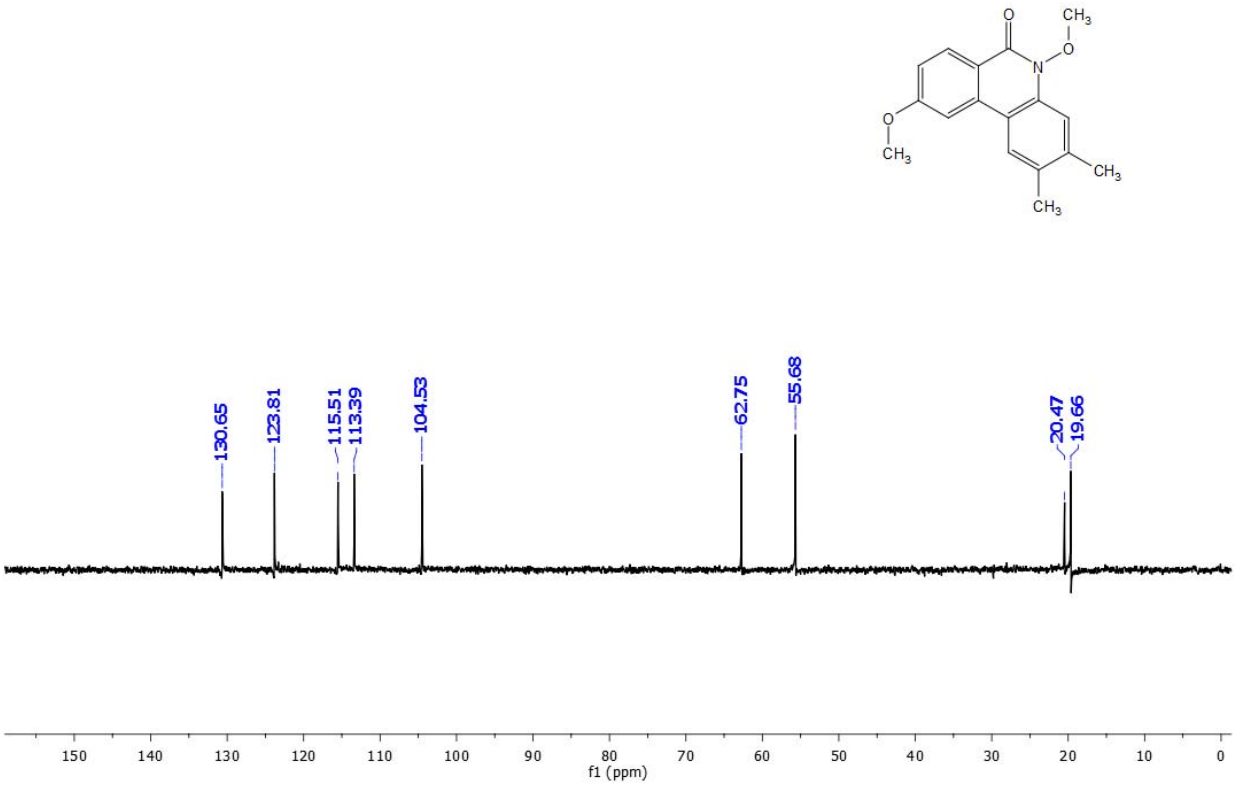
^{1}H NMR spectrum of compound of **4i**.



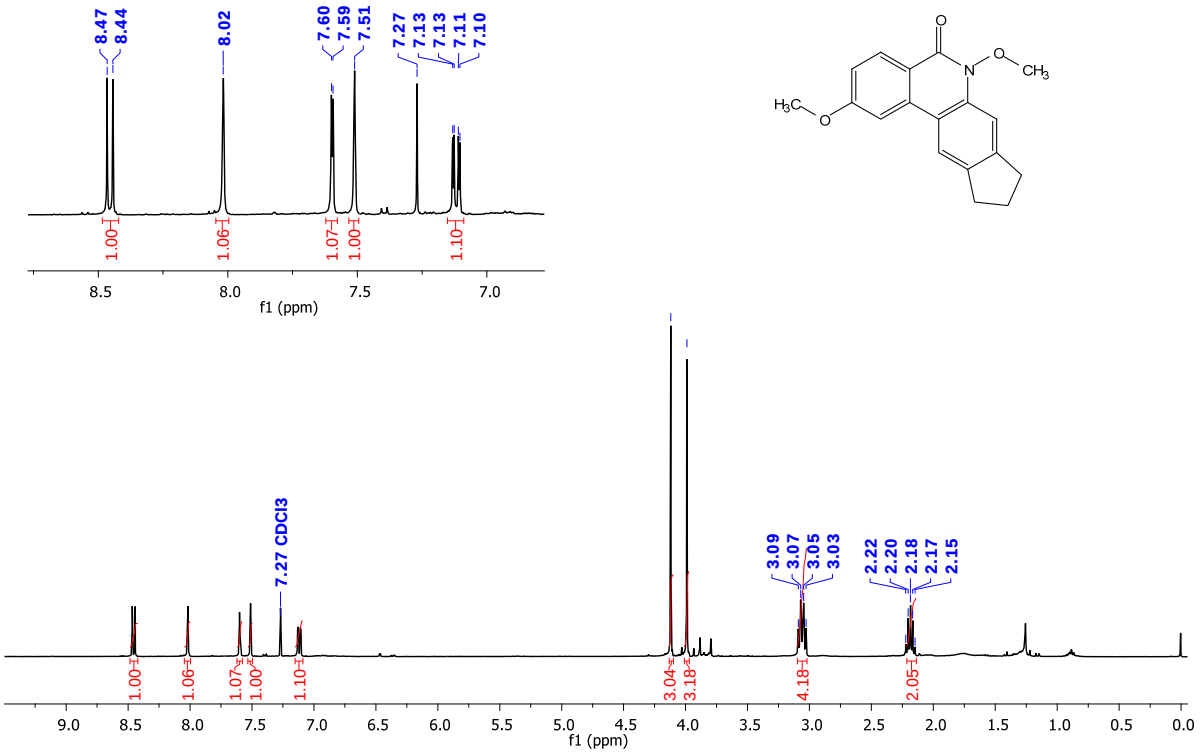
^{13}C NMR spectrum of compound of **4i**.



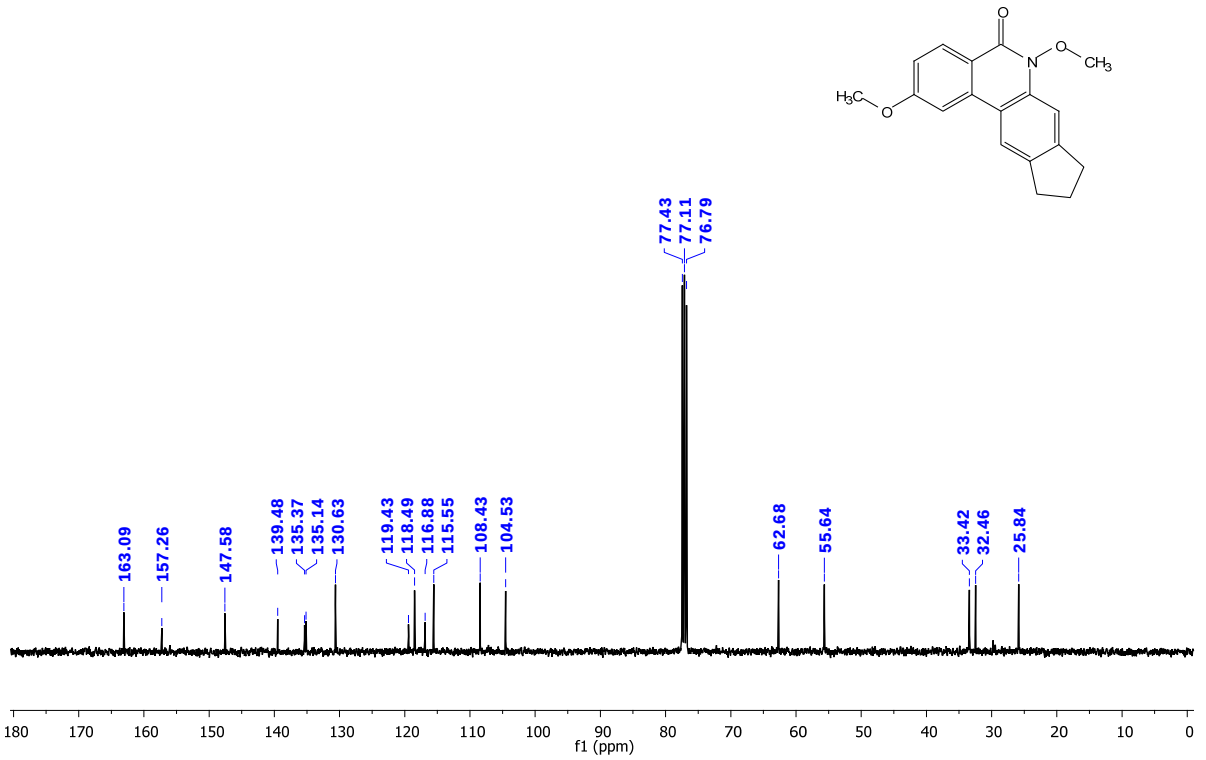
DEPT135 NMR spectrum of compound of **4i**.



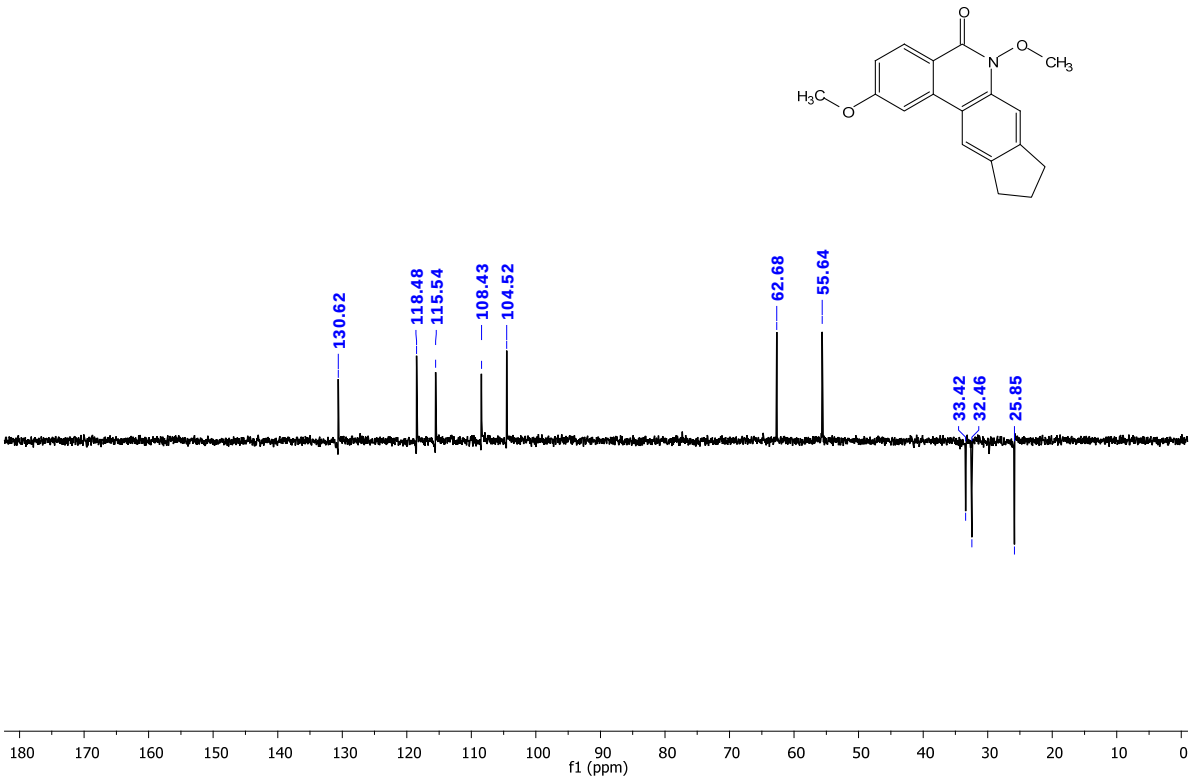
^{1}H NMR spectrum of compound of **4j**.



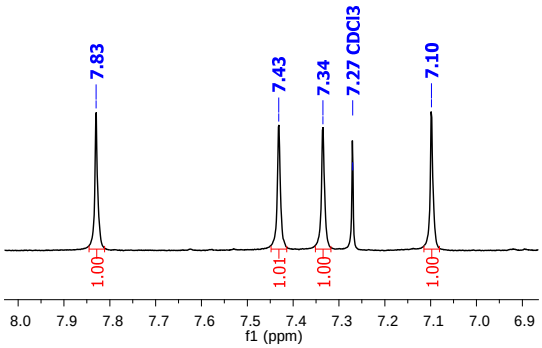
^{13}C NMR spectrum of compound of **4j**.

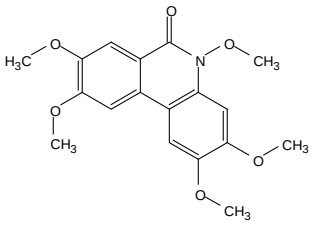


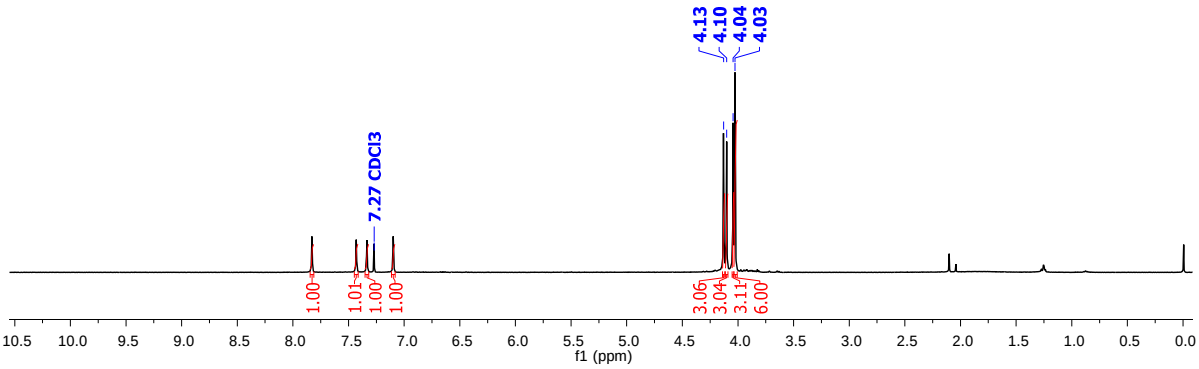
DEPT135 spectra of compound of **4j**.



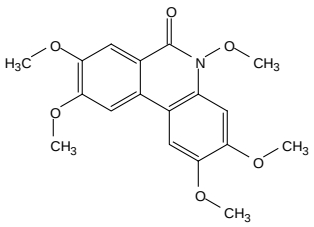
^{1}H NMR spectrum of compound of **4k**.

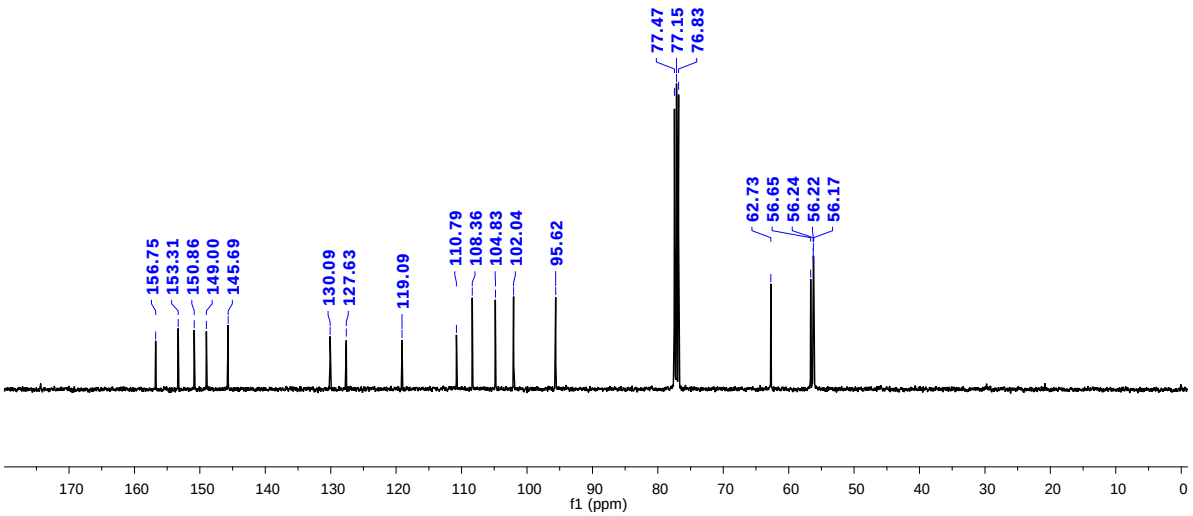




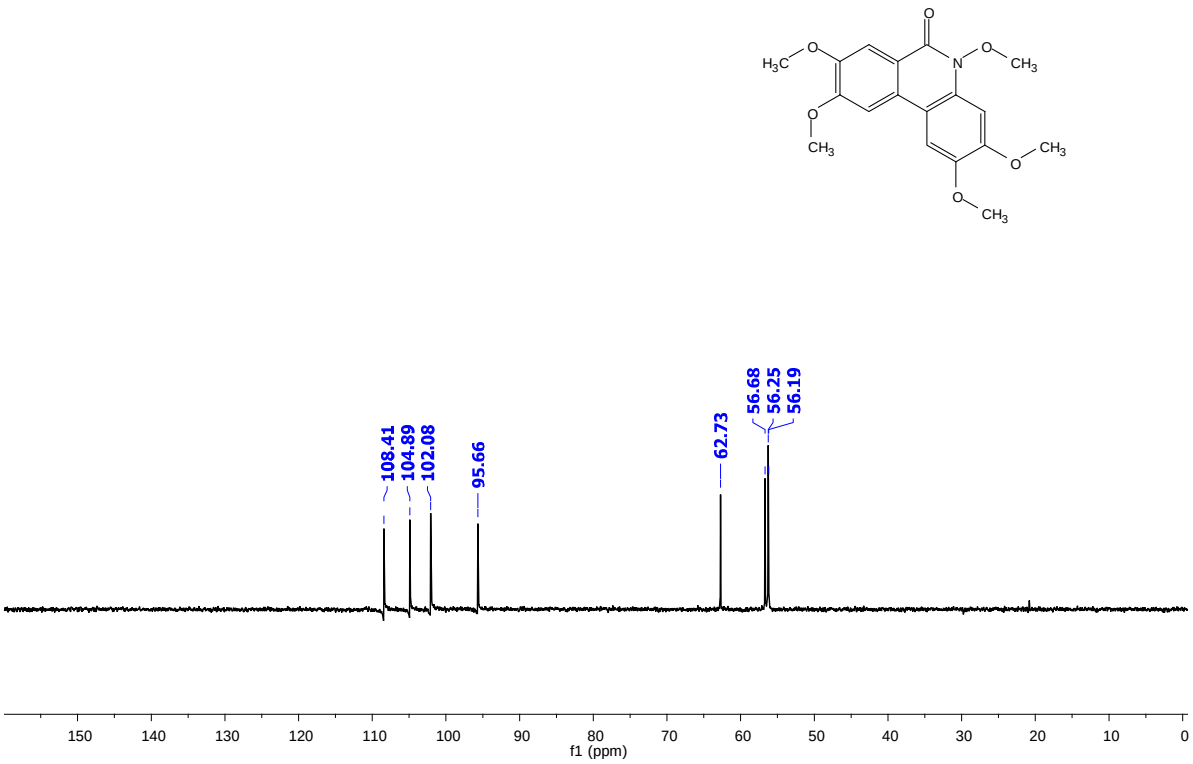


^{13}C NMR spectrum of compound of **4k**.

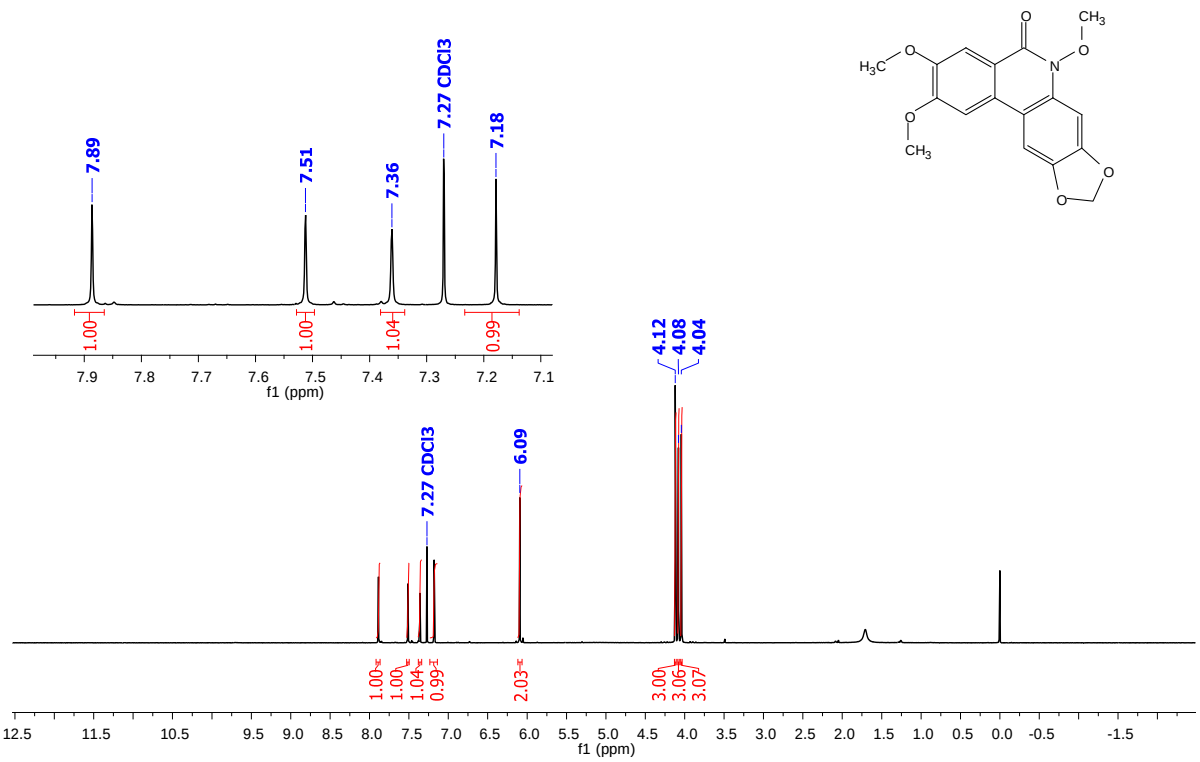




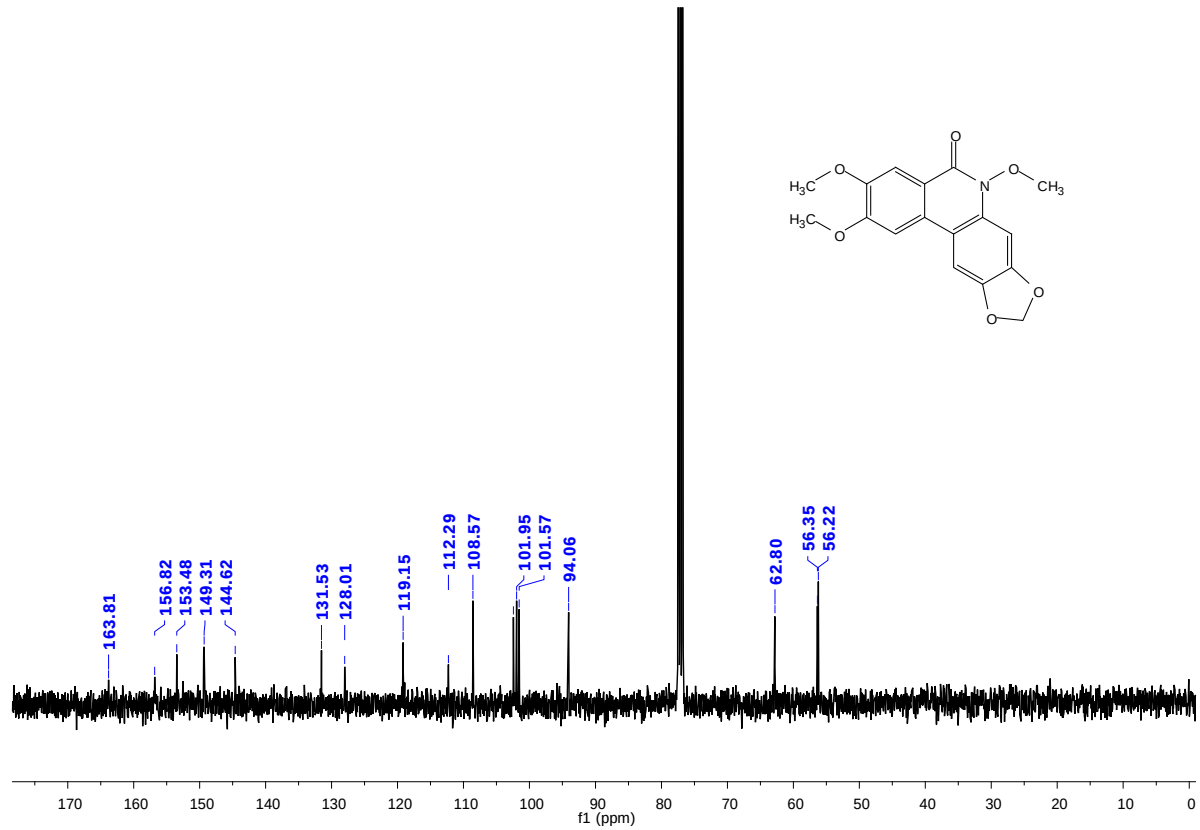
DEPT135 NMR spectrum of compound of **4k**.



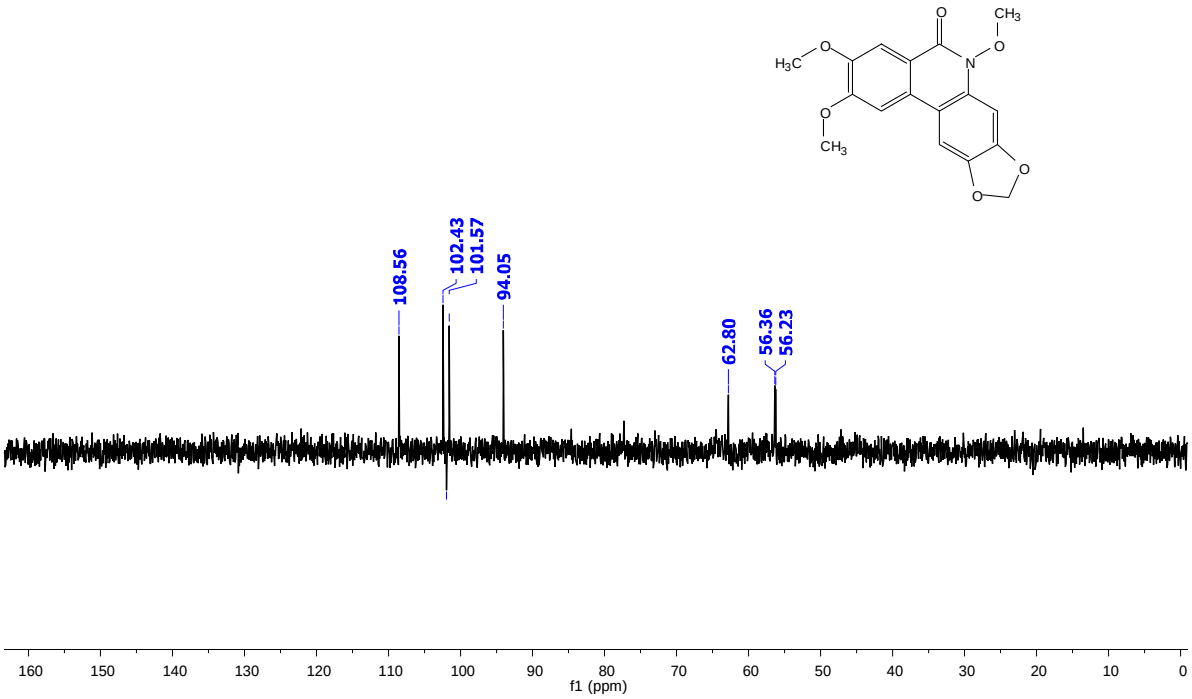
^{1}H NMR spectrum of compound of **4l**.



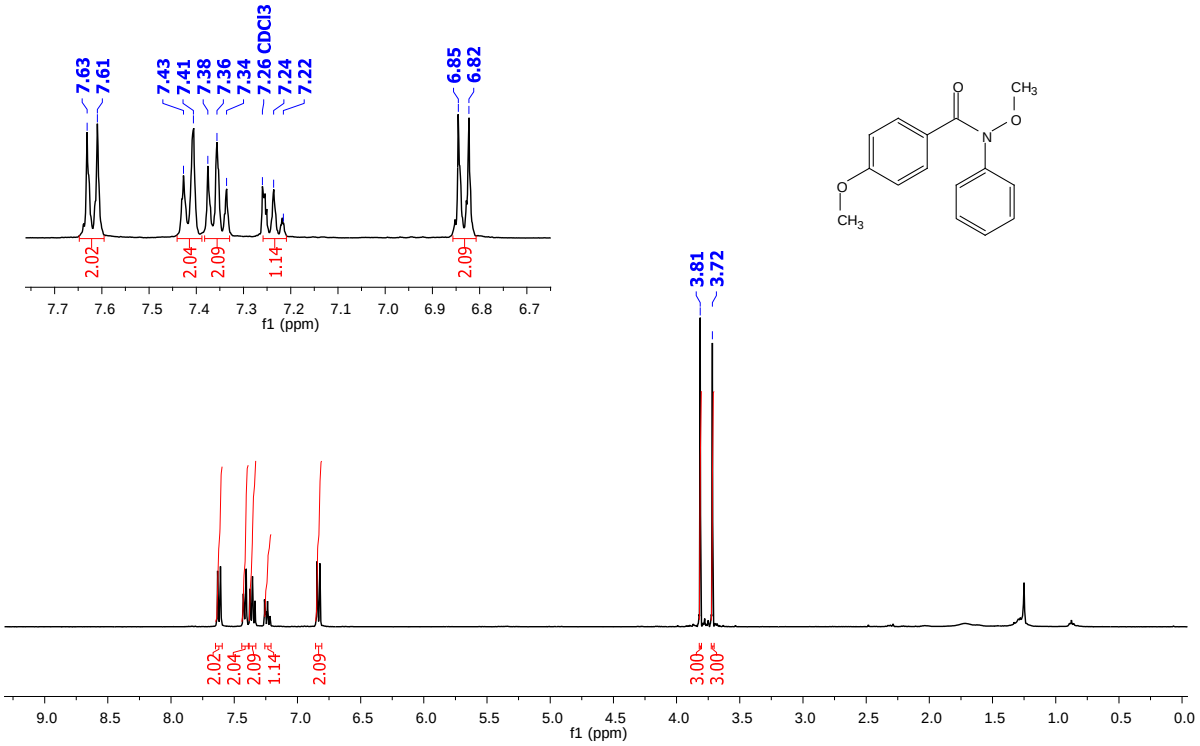
^{13}C NMR spectrum of compound of **4l**.



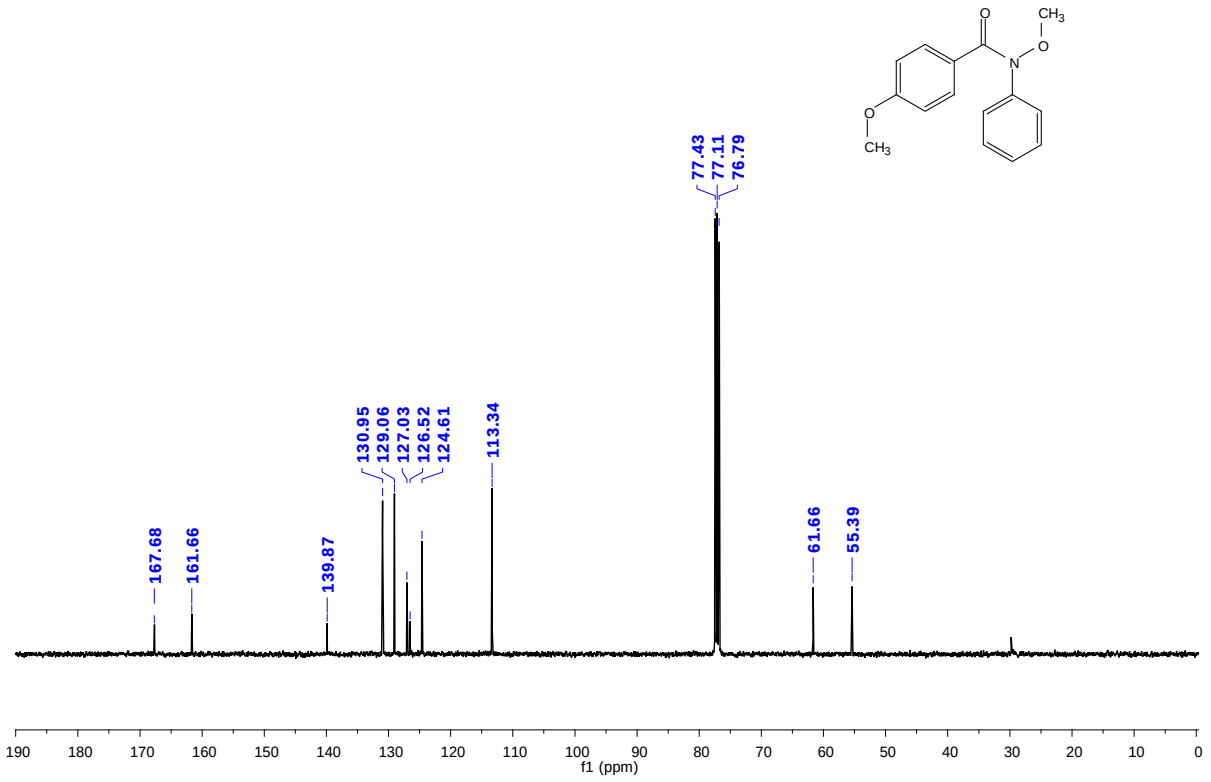
DEPT135 NMR spectrum of compound of **4l**.



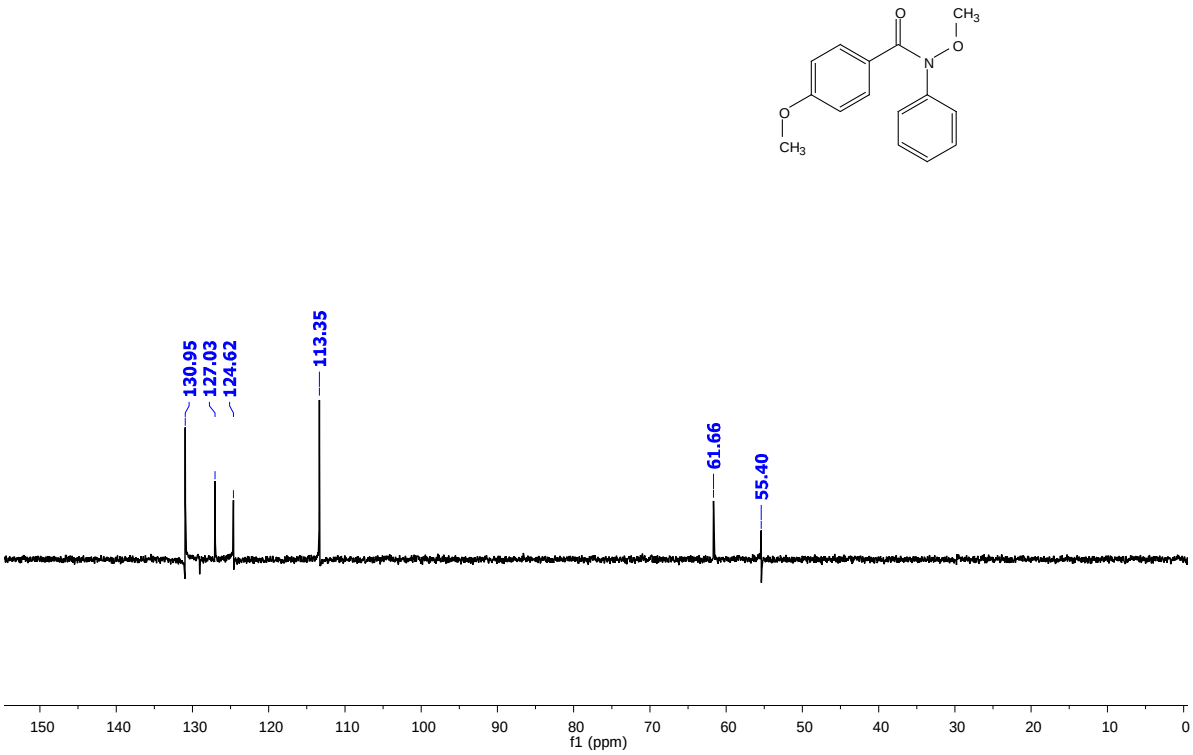
^{1}H NMR spectrum of compound of **3a**.



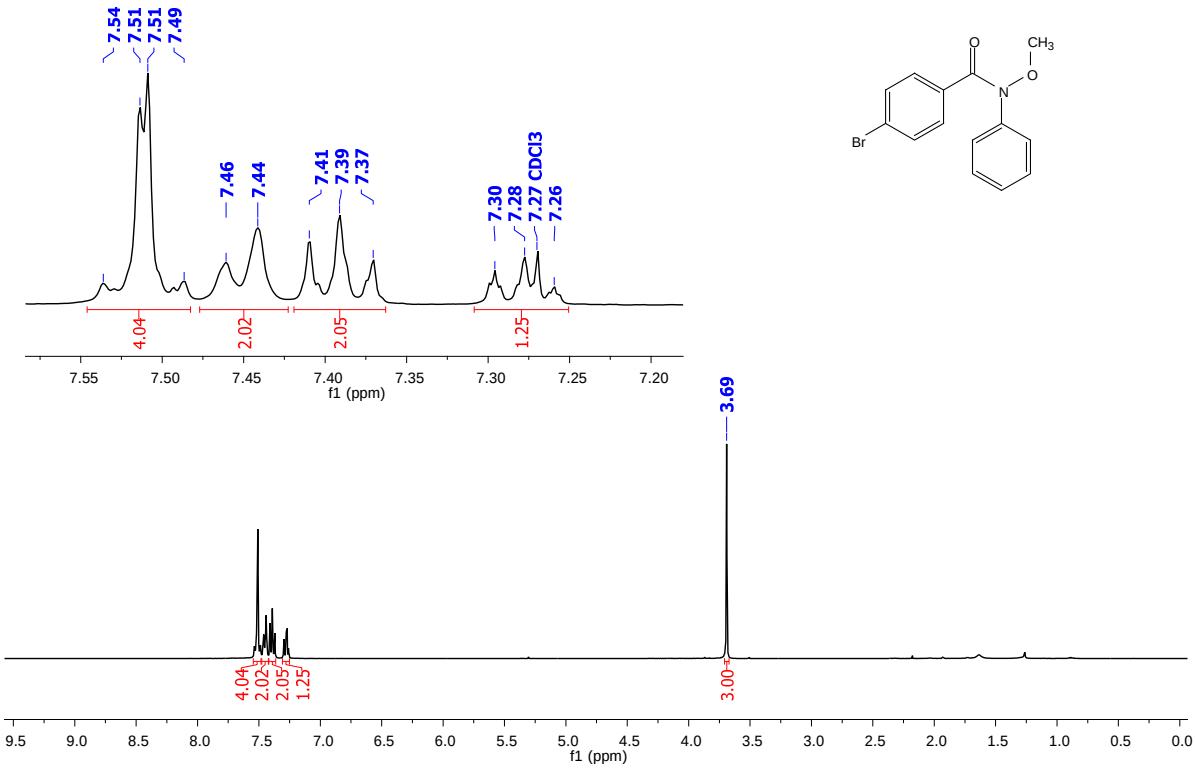
^{13}C NMR spectrum of compound of **3a**.



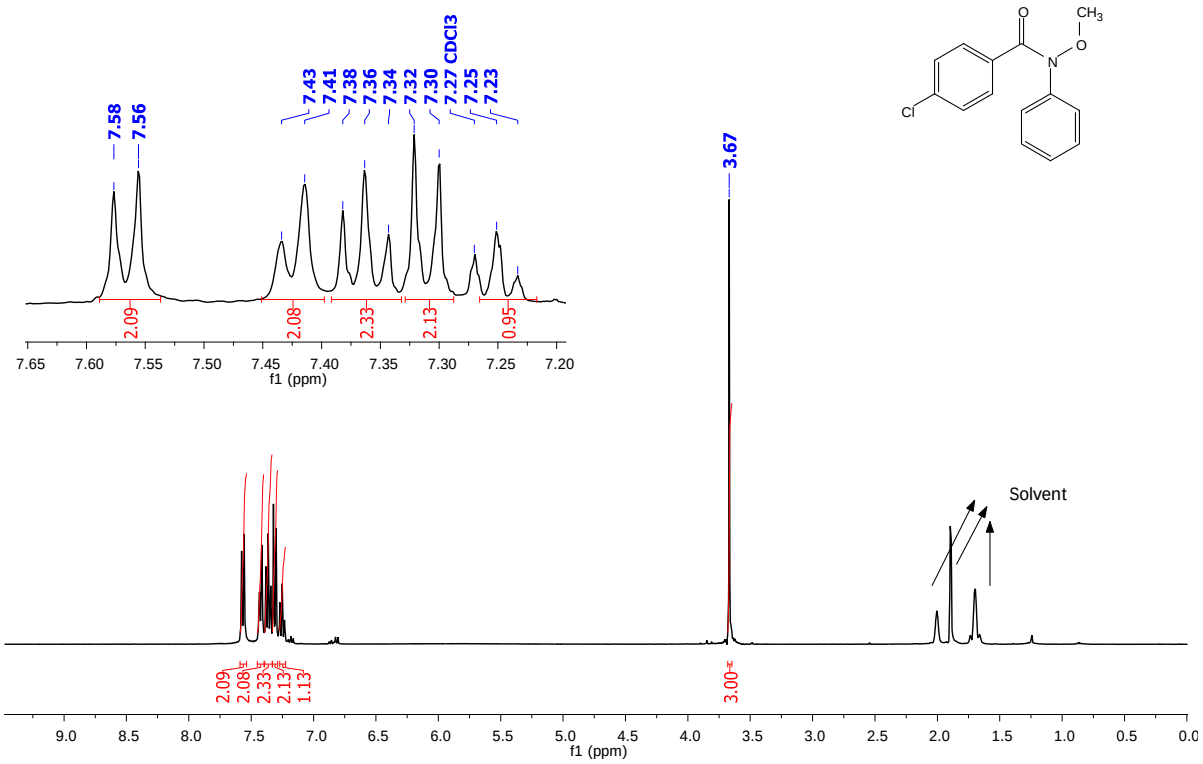
DEPT$_{135}$ NMR spectrum of compound of **3a**.



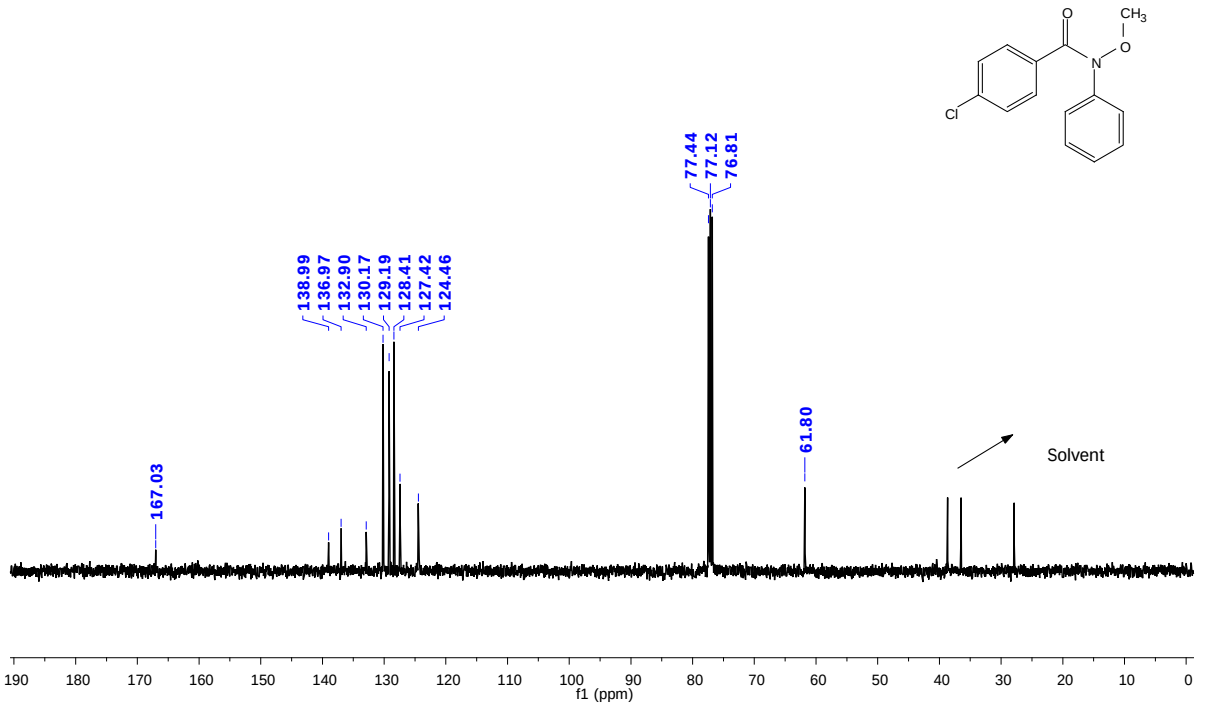
^{1}H NMR spectrum of compound of **3h**.



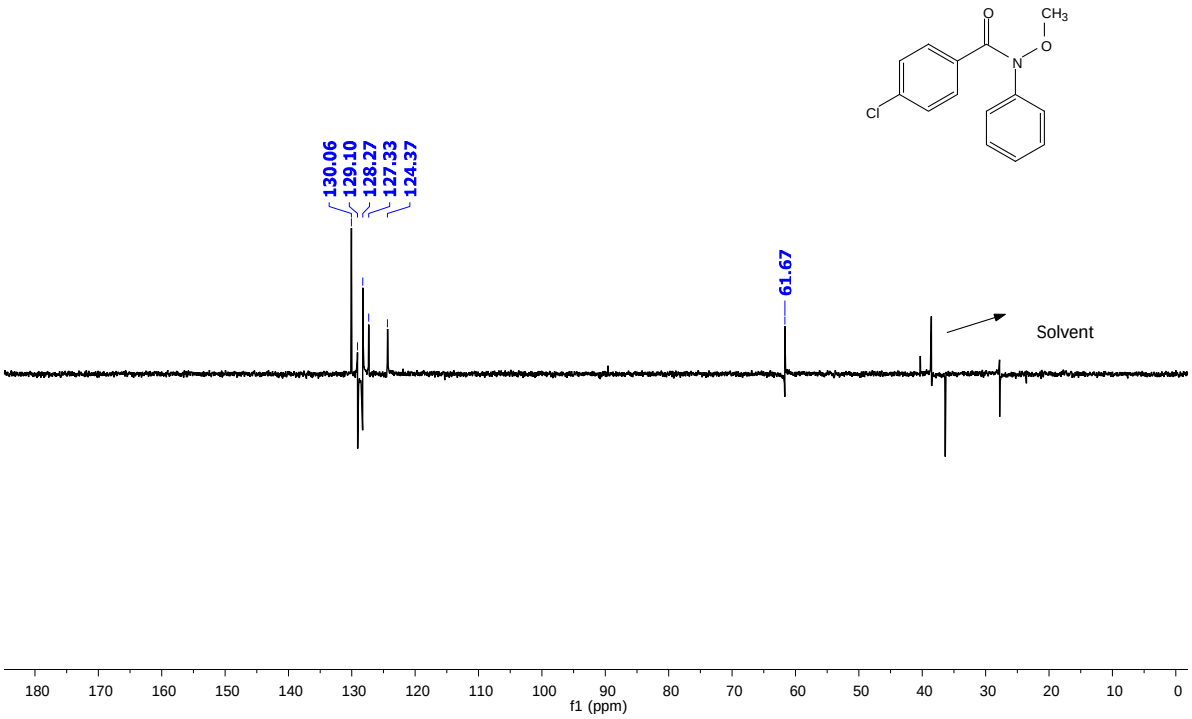
^{1}H NMR spectrum of compound of **3i**.



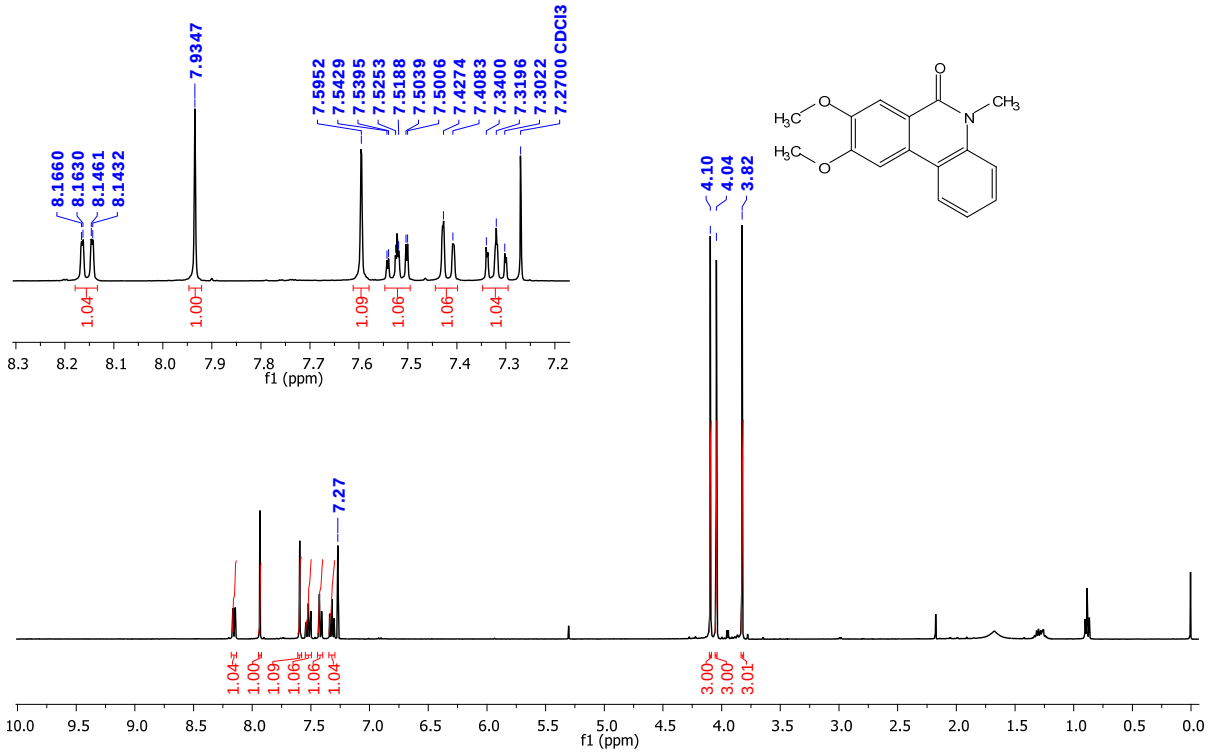
^{13}C NMR spectrum of compound of **3i**.



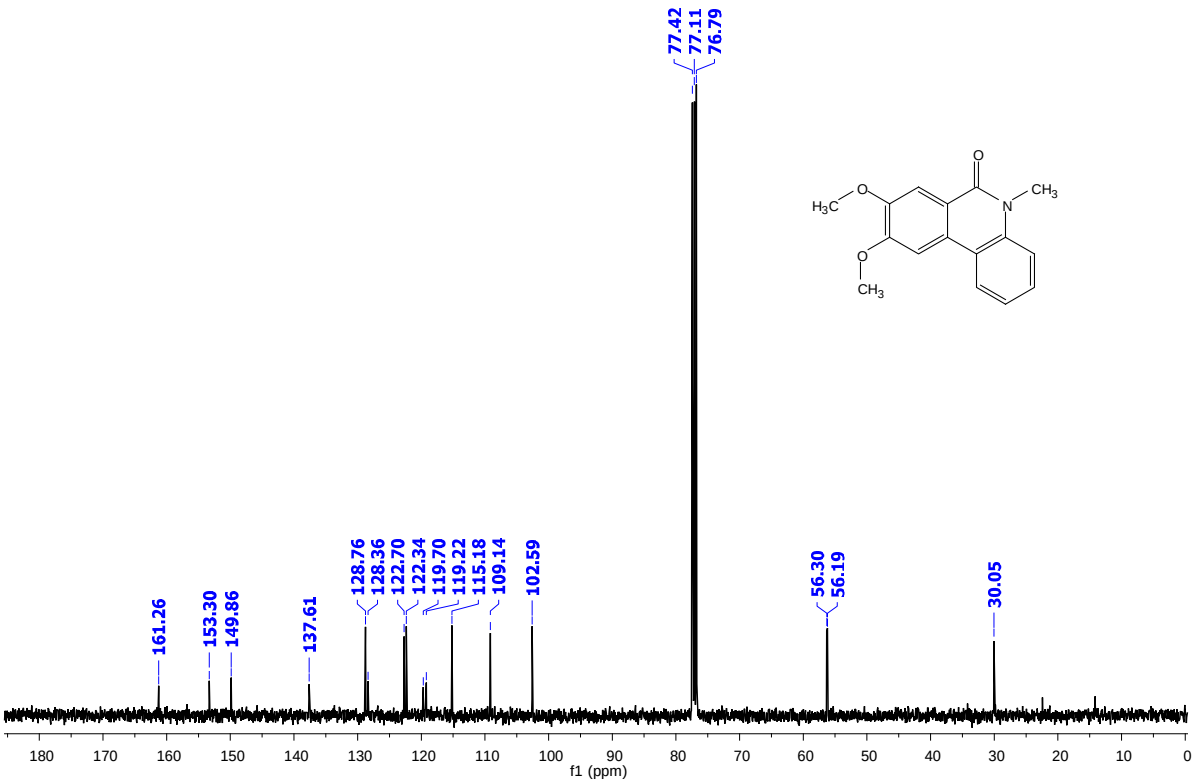
DEPT$_{135}$ spectra of compound **3i.**



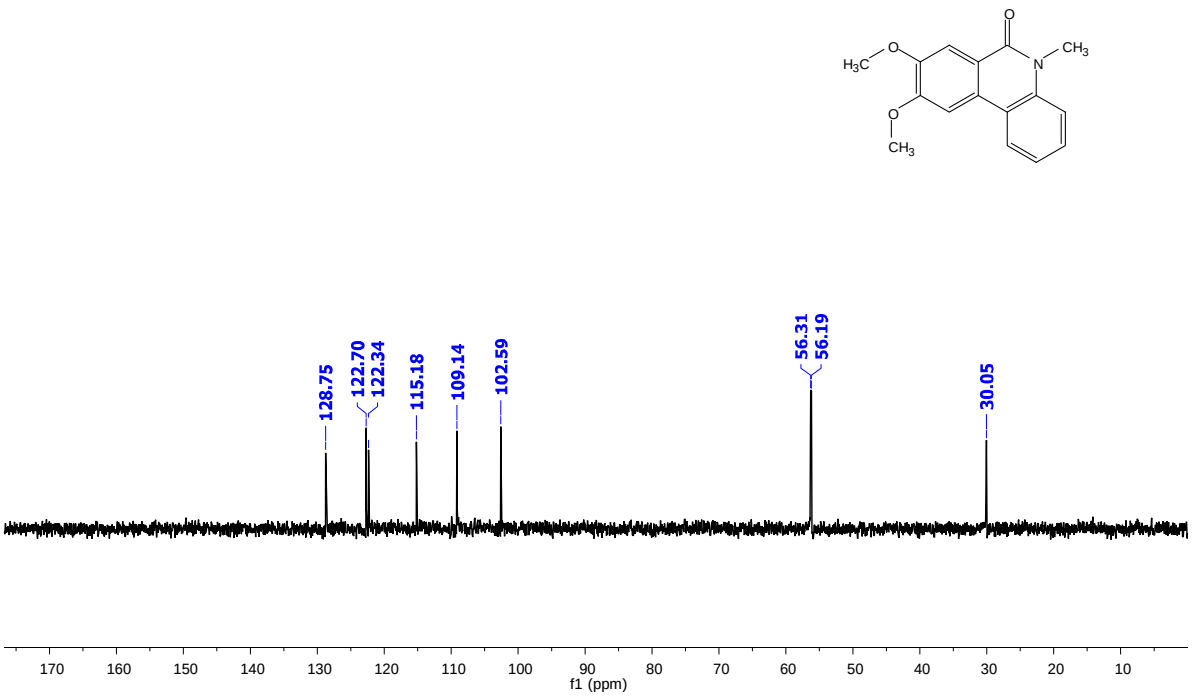
^{1}H NMR spectrum of compound of **7a**.



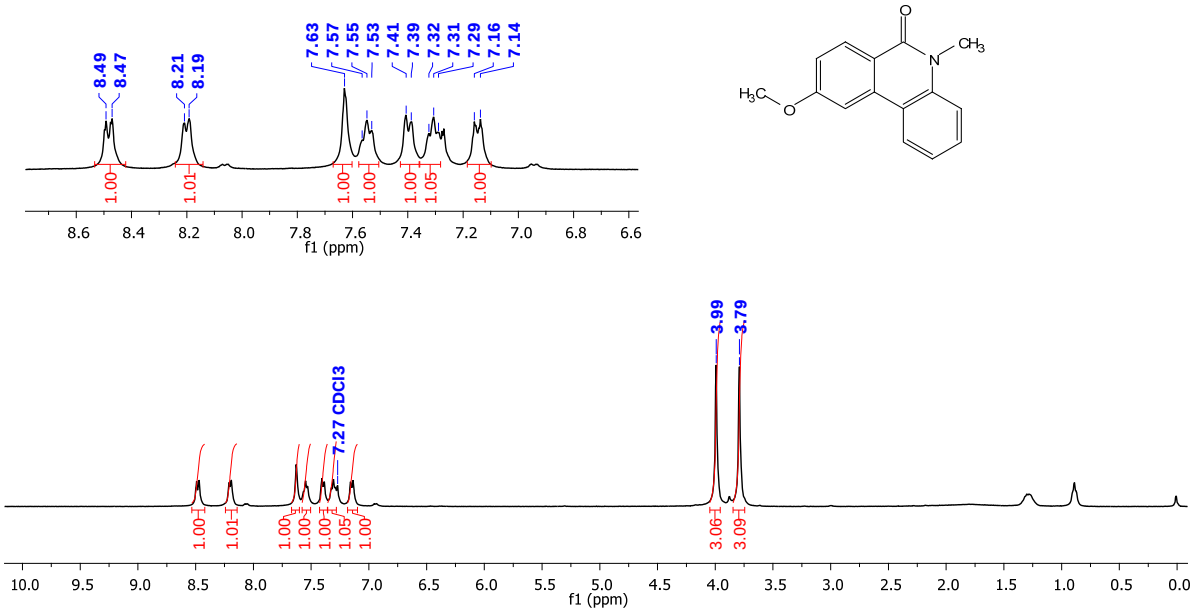
^{13}C NMR spectrum of compound of **7a**.



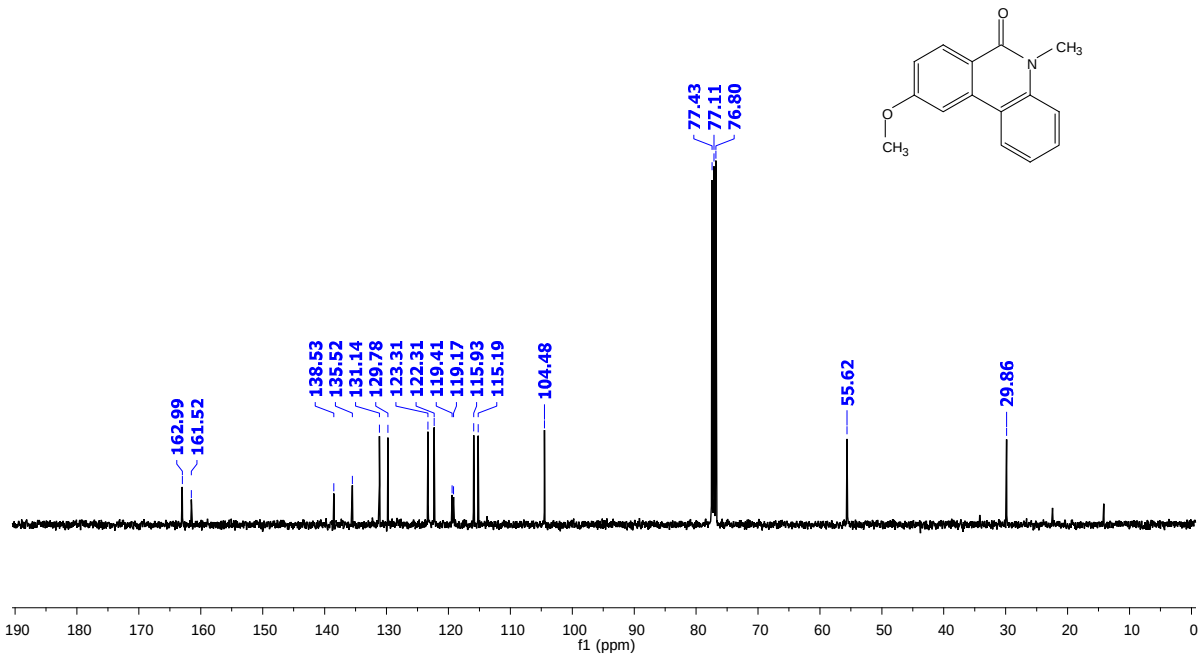
DEPT135 NMR spectrum of compound **7a**.



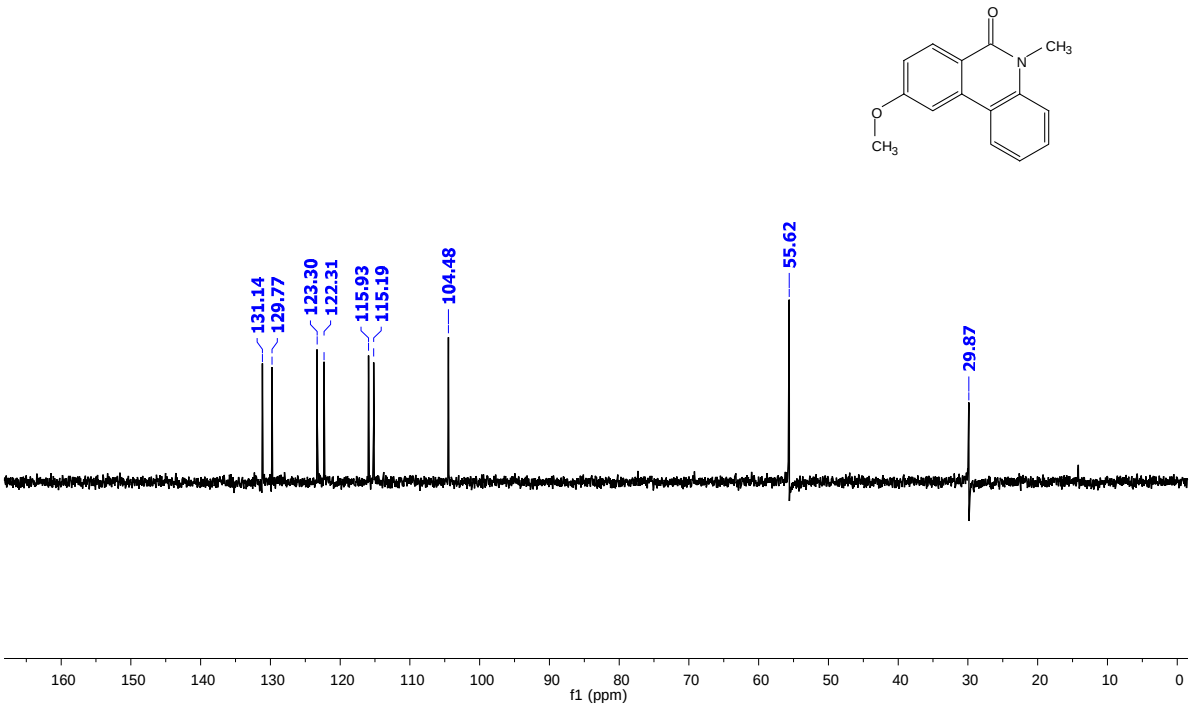
^{1}H NMR spectrum of compound of **7b**.



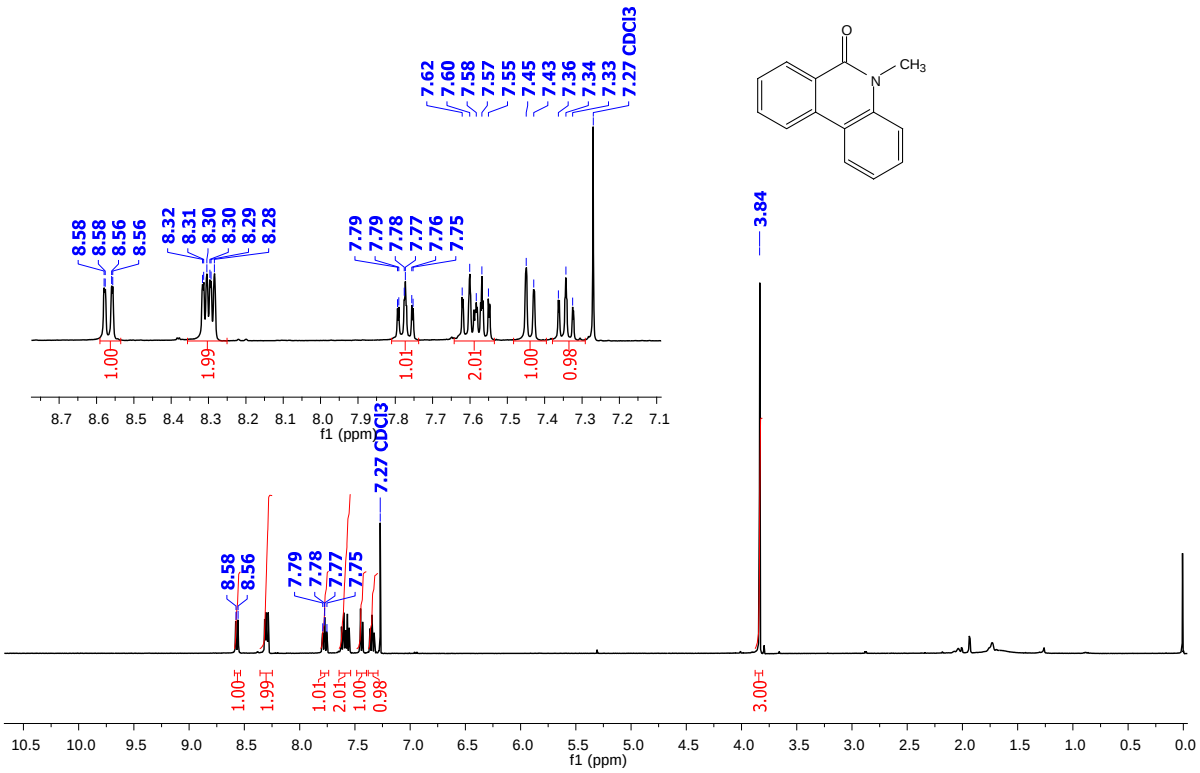
^{13}C NMR spectrum of compound of **7b**.



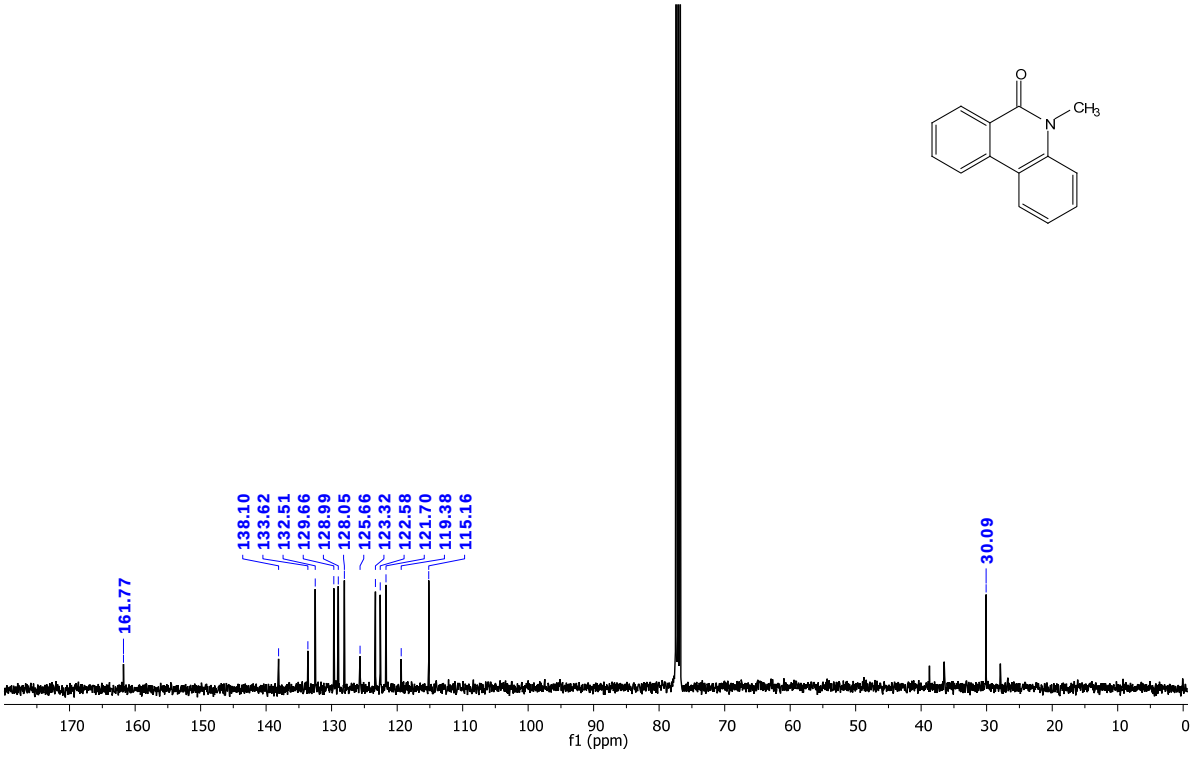
DEPT135 NMR spectrum of compound of **7b**.



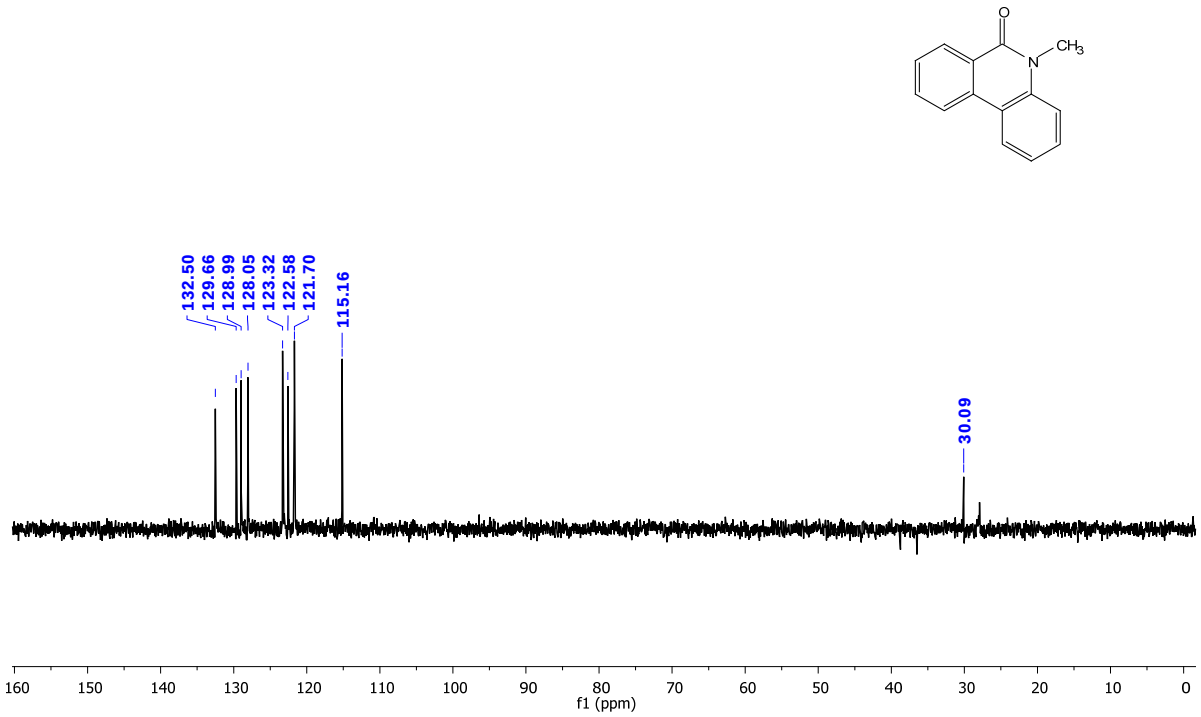
^{1}H NMR spectrum of compound of **7c**.



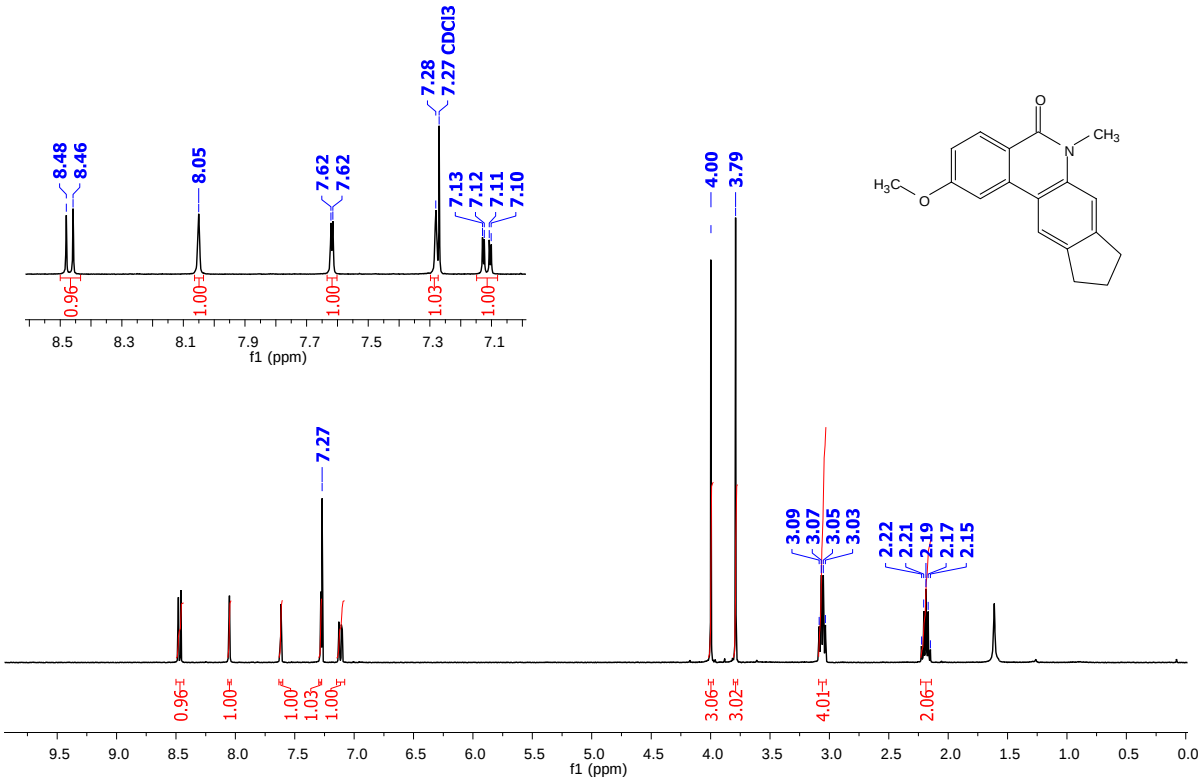
^{13}C NMR spectrum of compound of **7c**.



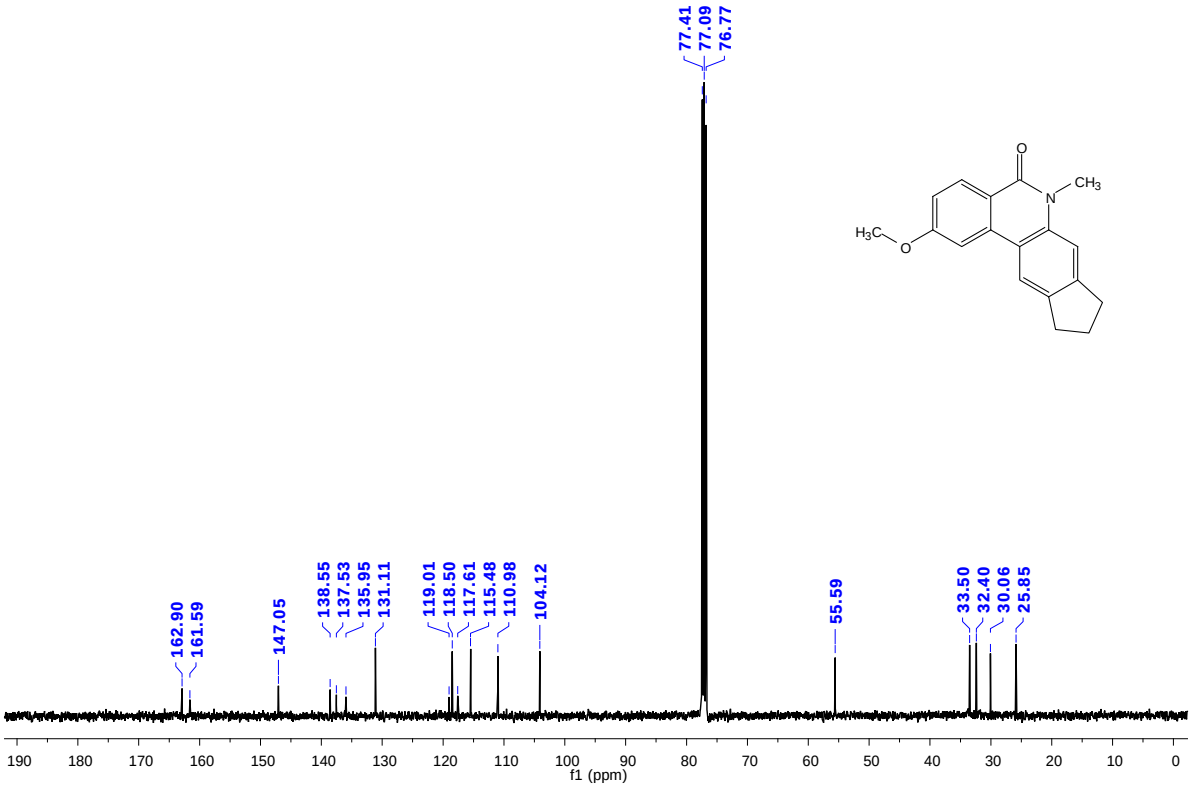
DEPT135 NMR spectrum of compound of **7c**.



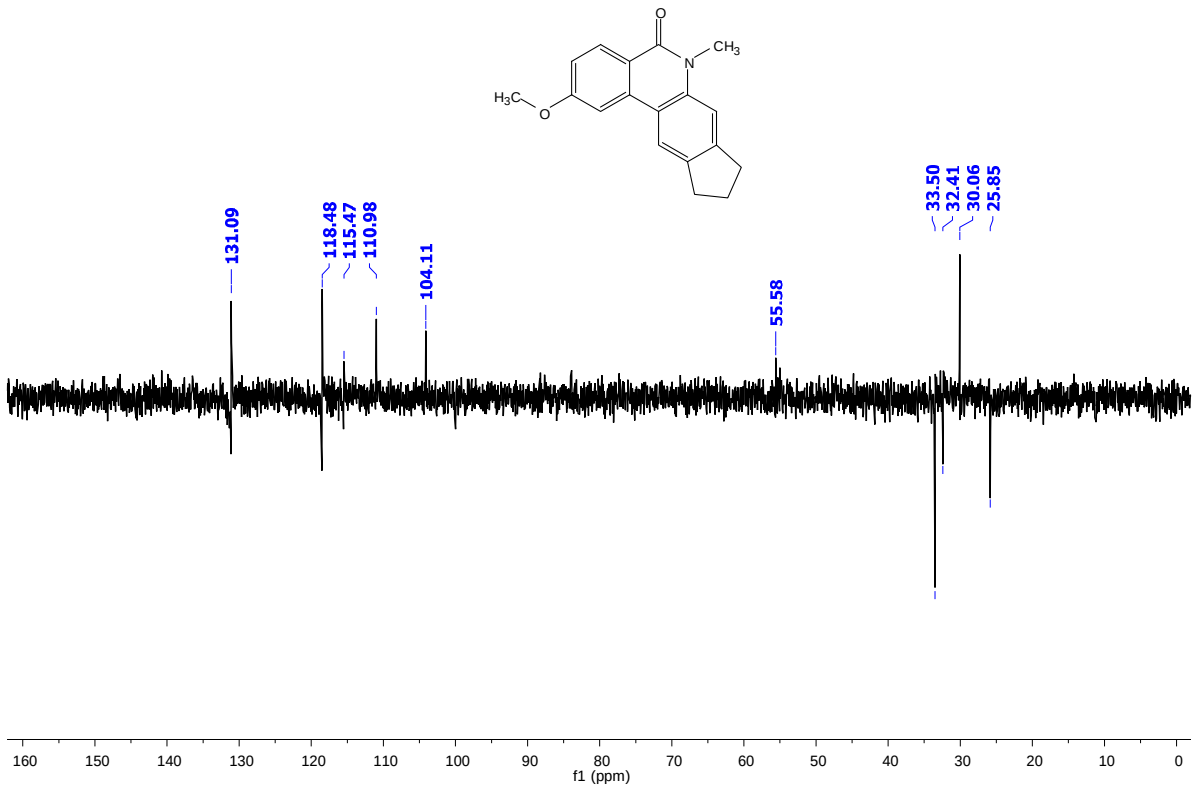
^{1}H NMR spectrum of compound **7d.**



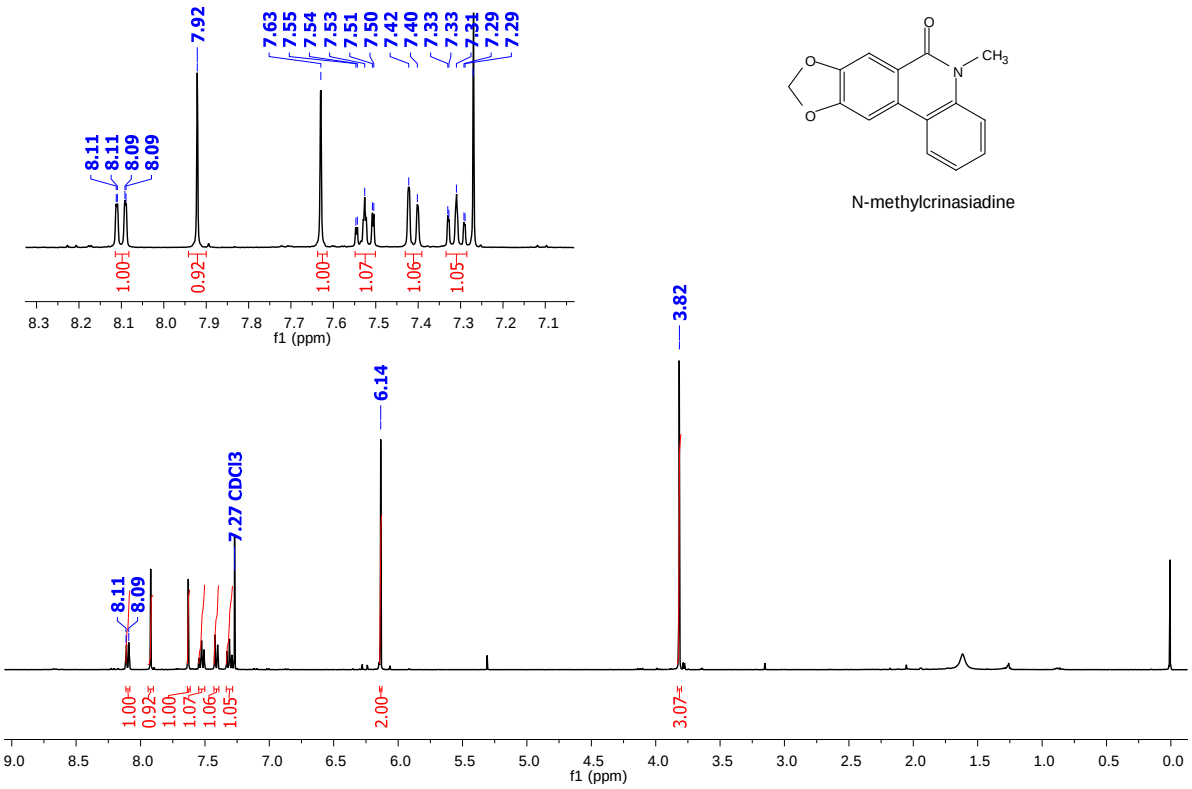
^{13}C NMR spectrum of compound **7d.**



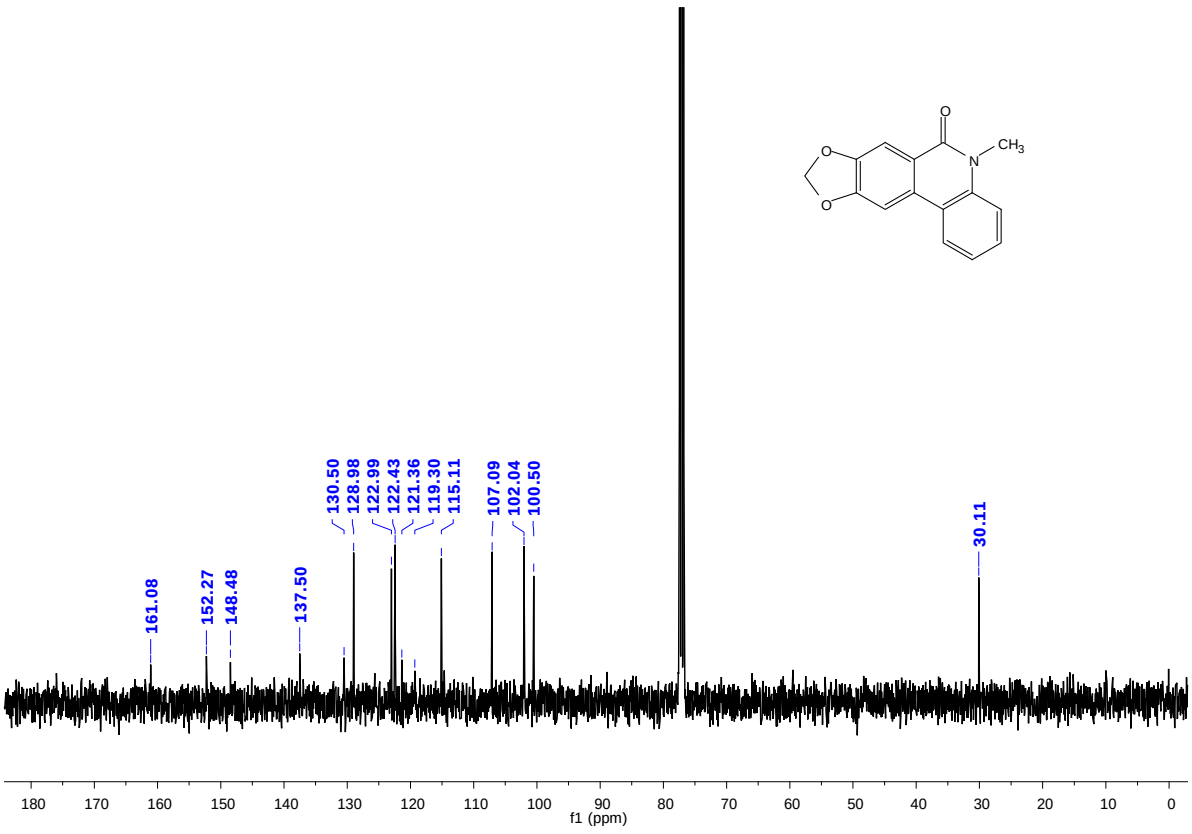
DEPT135 NMR spectrum of compound **7d.**



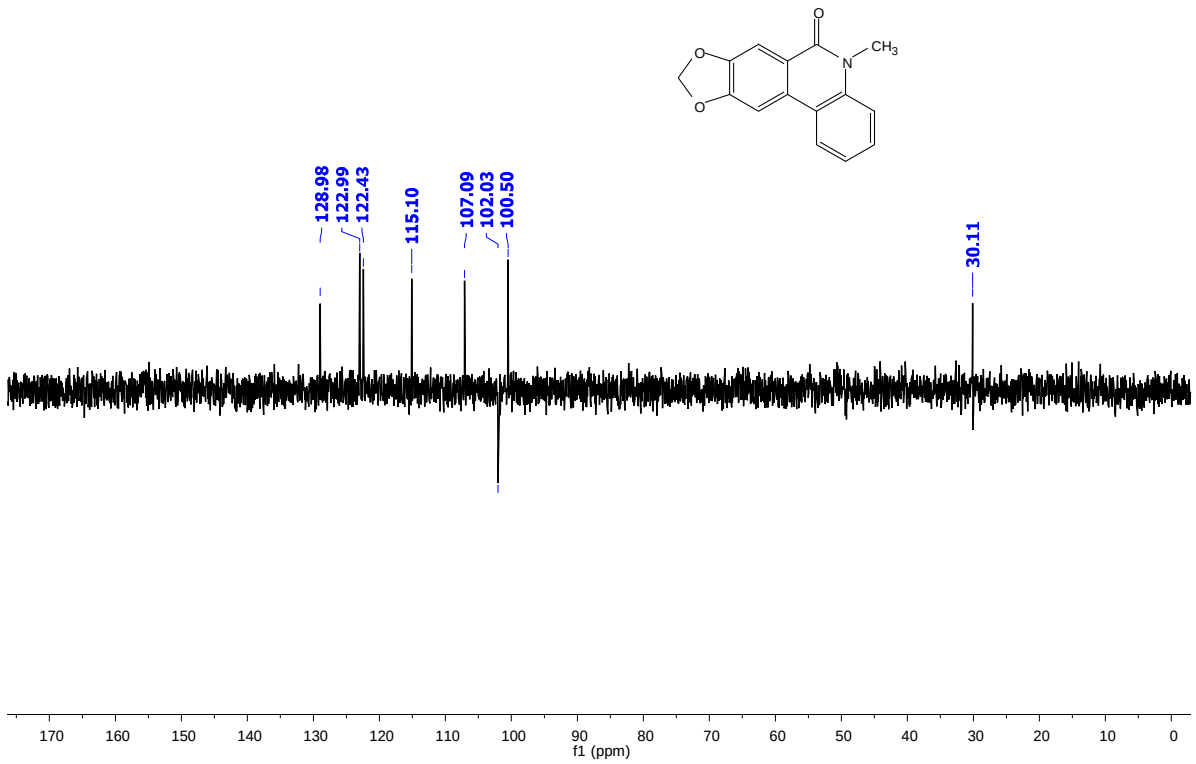
^{1}H NMR spectrum of compound of **7e**.



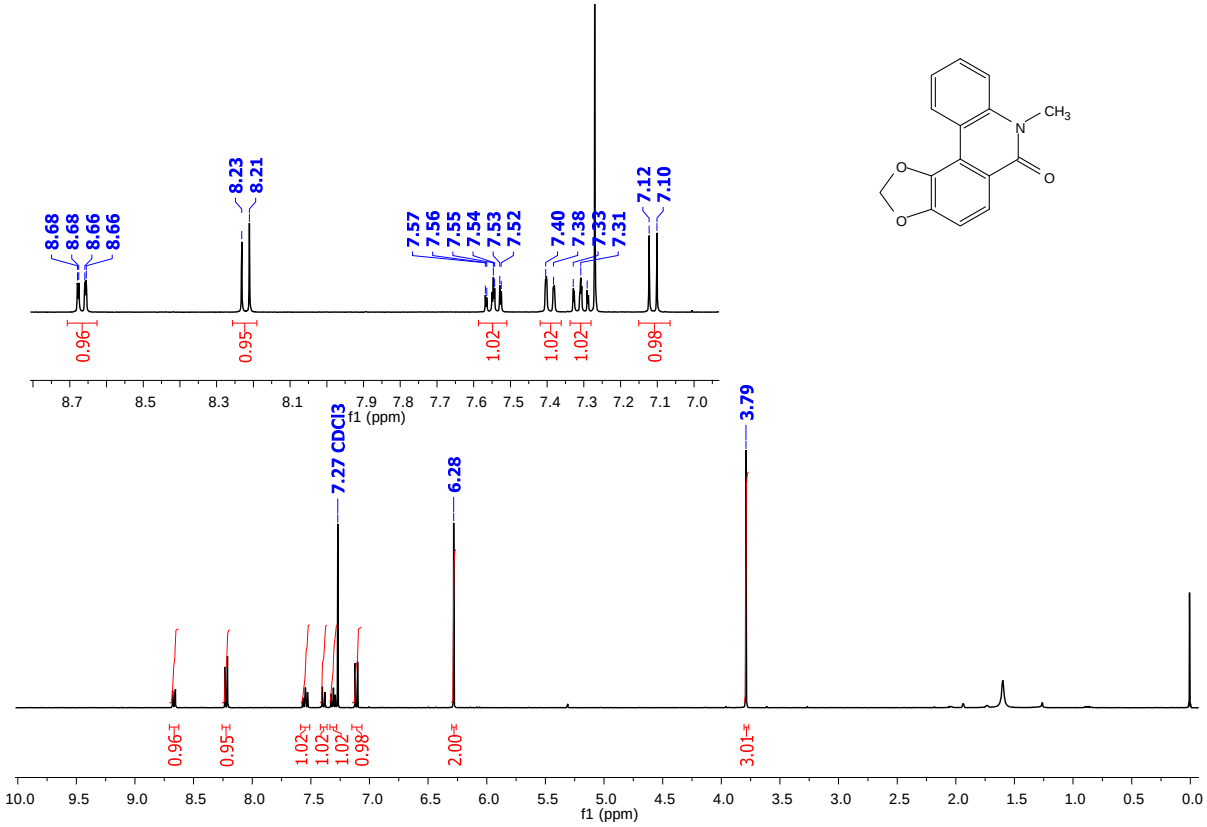
^{13}C NMR spectrum of compound of **7e**.



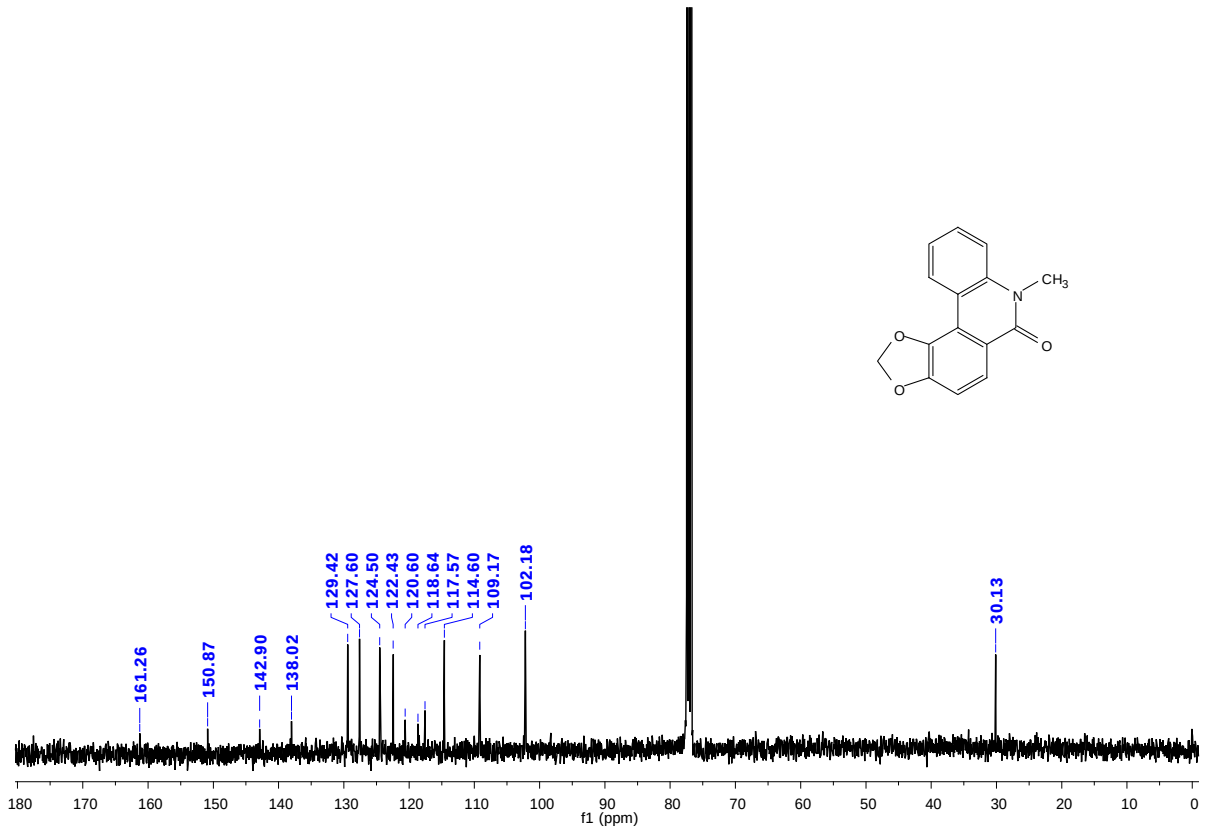
DEPT135 NMR spectrum of compound of **7e**.



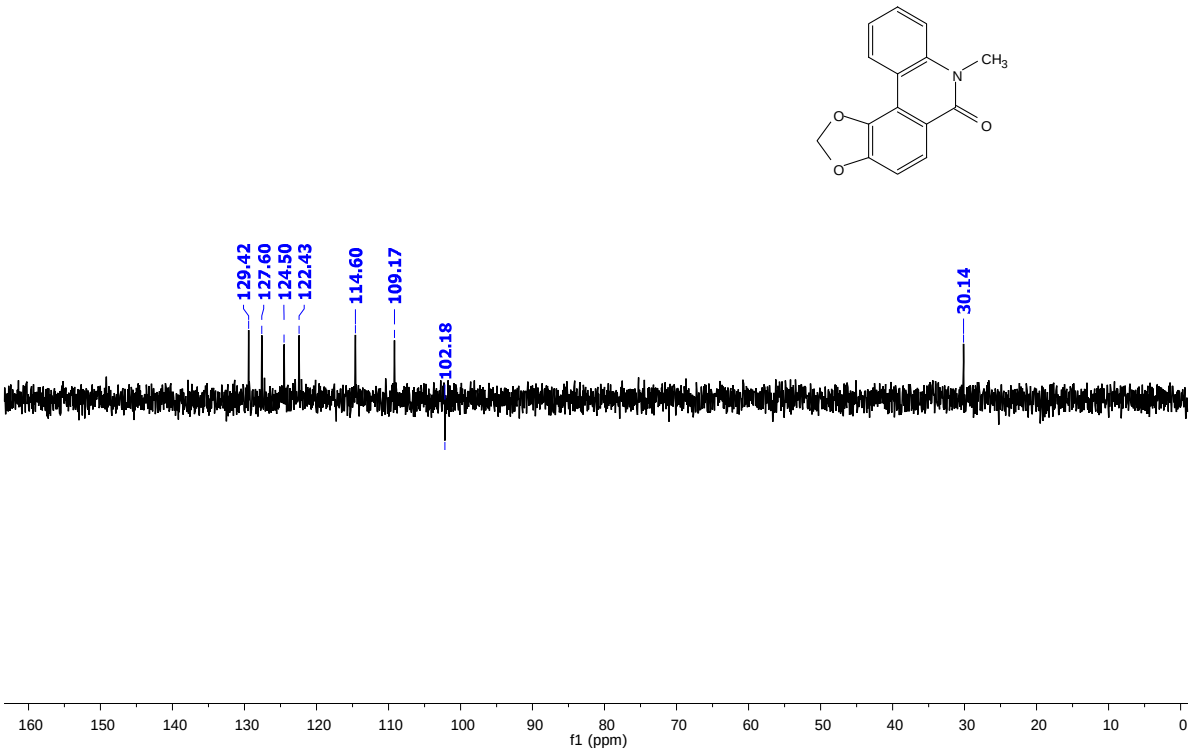
^{1}H NMR spectrum of compound **7e'**.



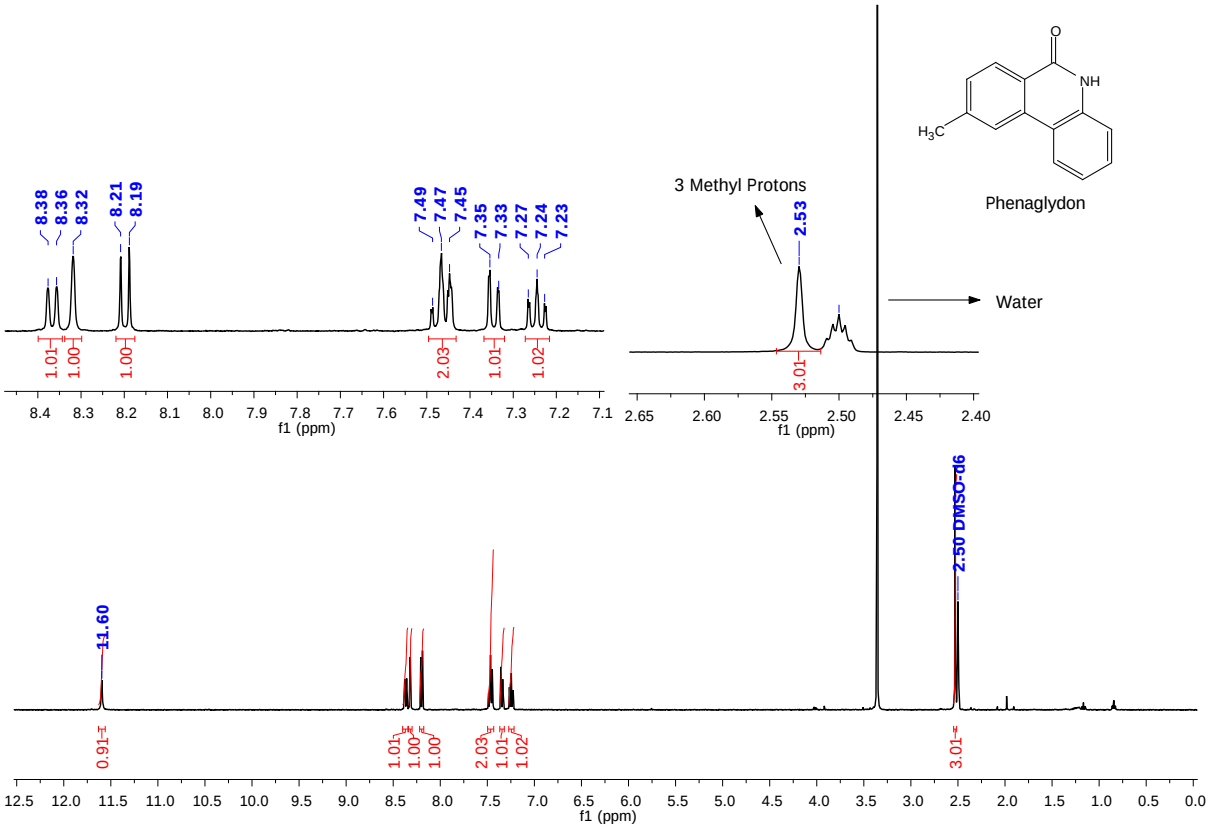
^{13}C NMR spectrum of compound of **7e'**.



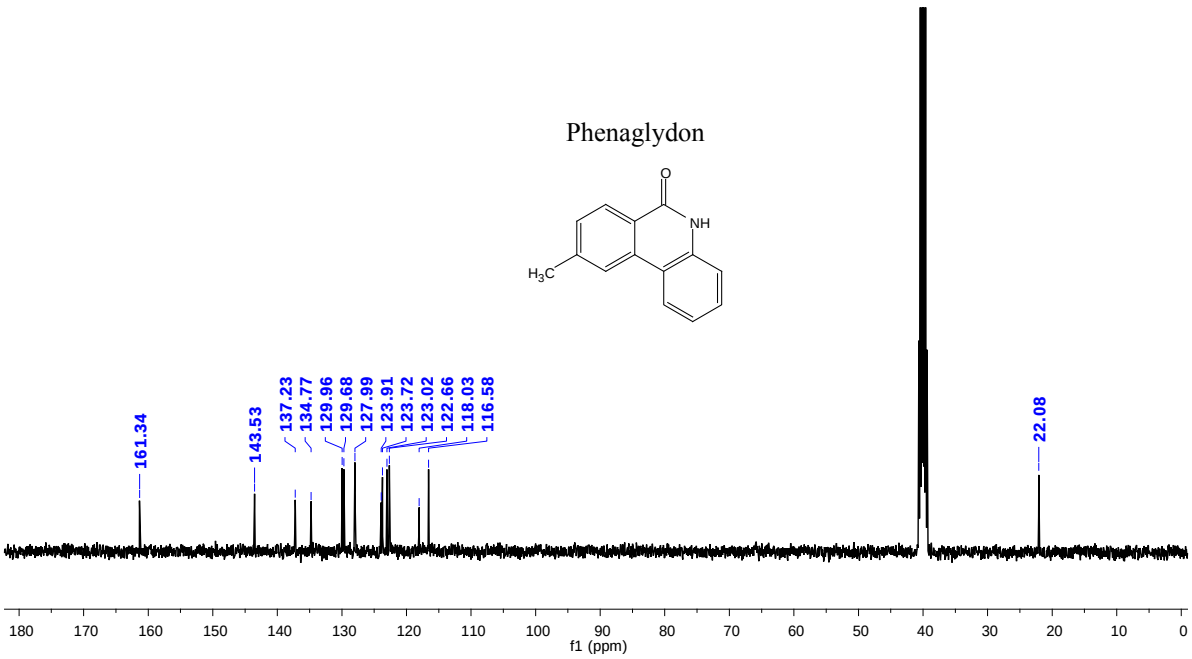
DEPT135 NMR spectrum of compound of **7e'**.



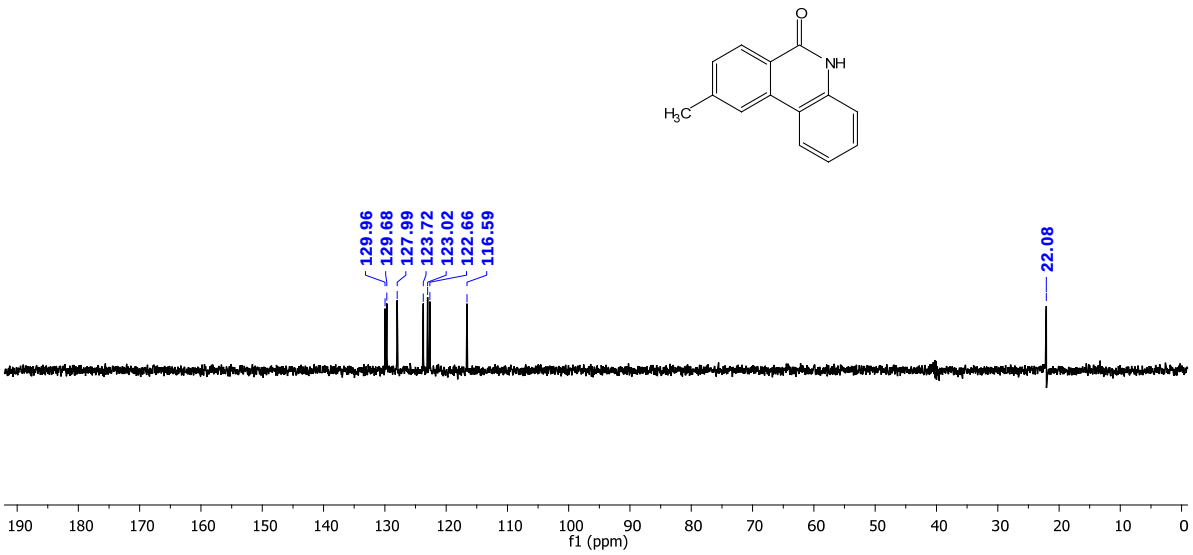
^{1}H spectra of compound of **8a**.



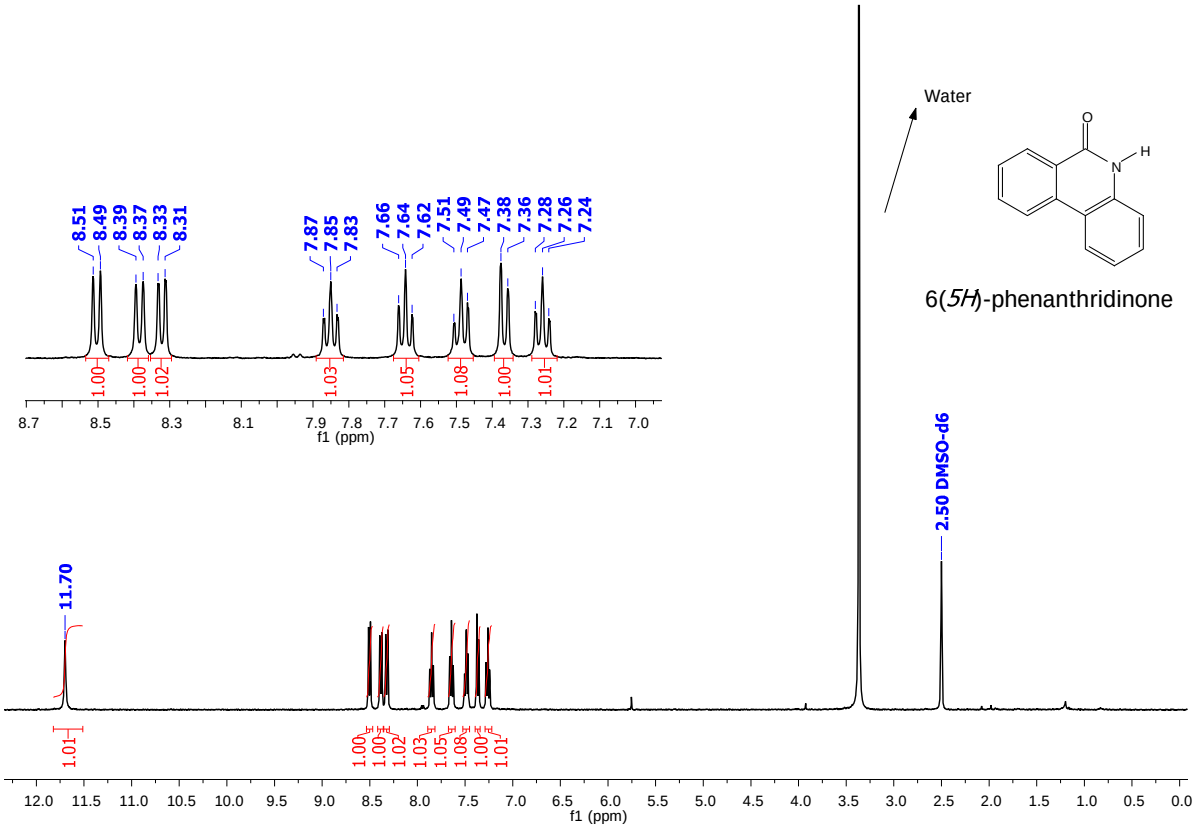
^{13}C NMR spectrum of compound of **8a**.



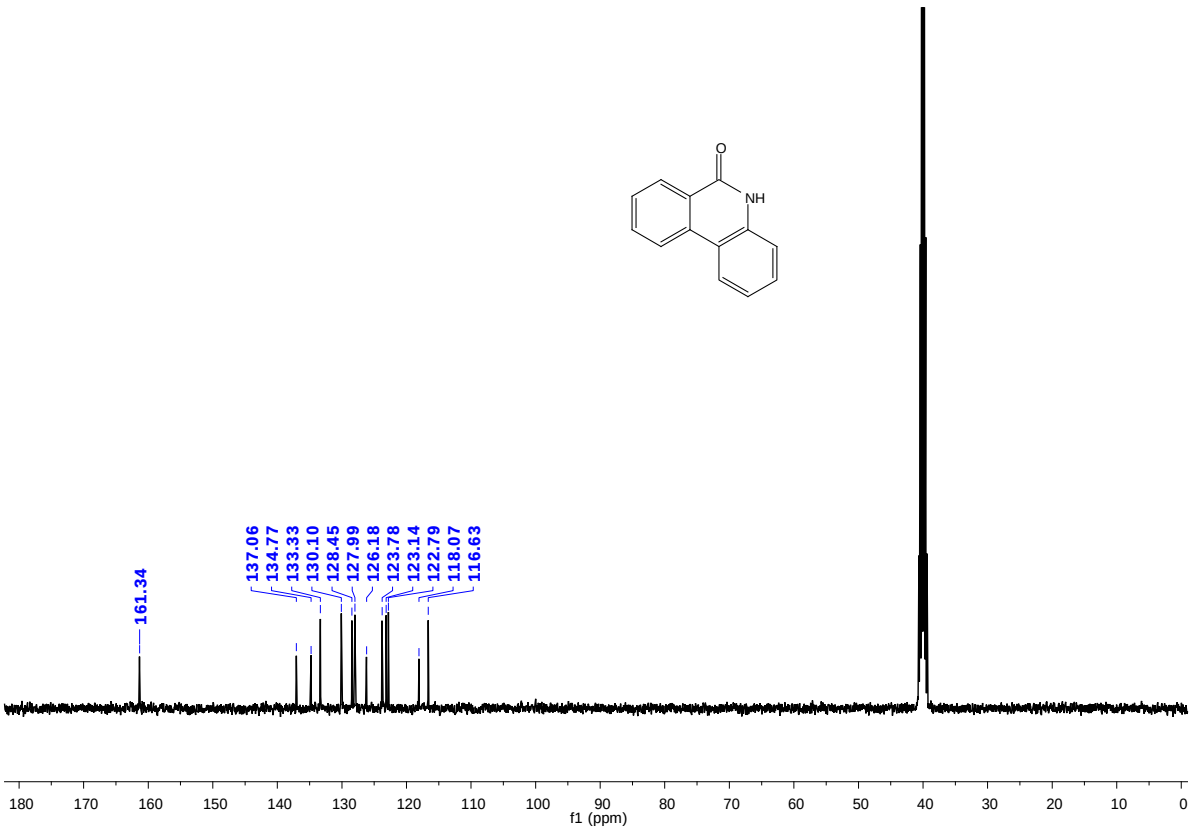
DEPT135 NMR spectrum of compound **8a**.



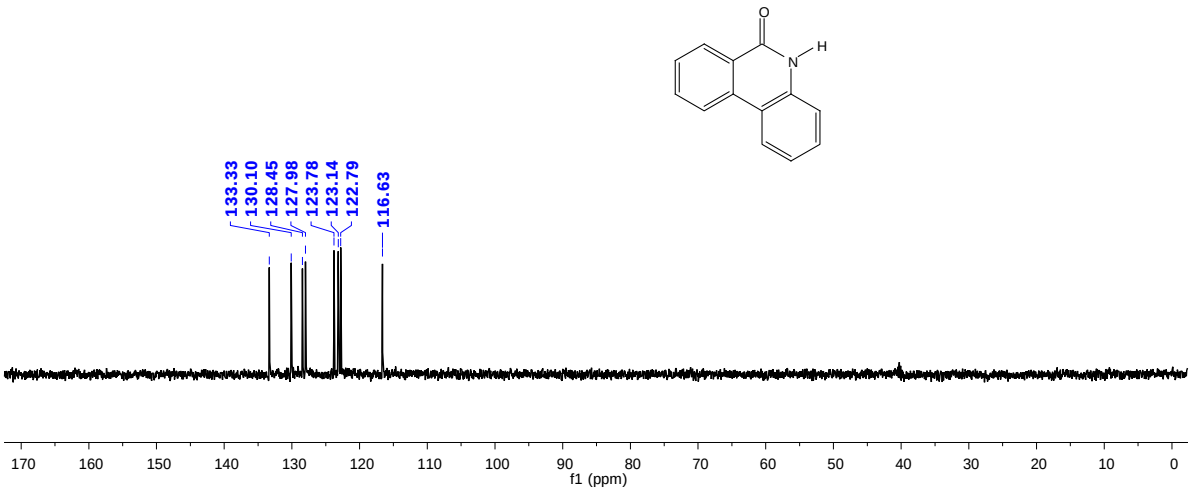
^{1}H NMR spectrum of compound **8b**.



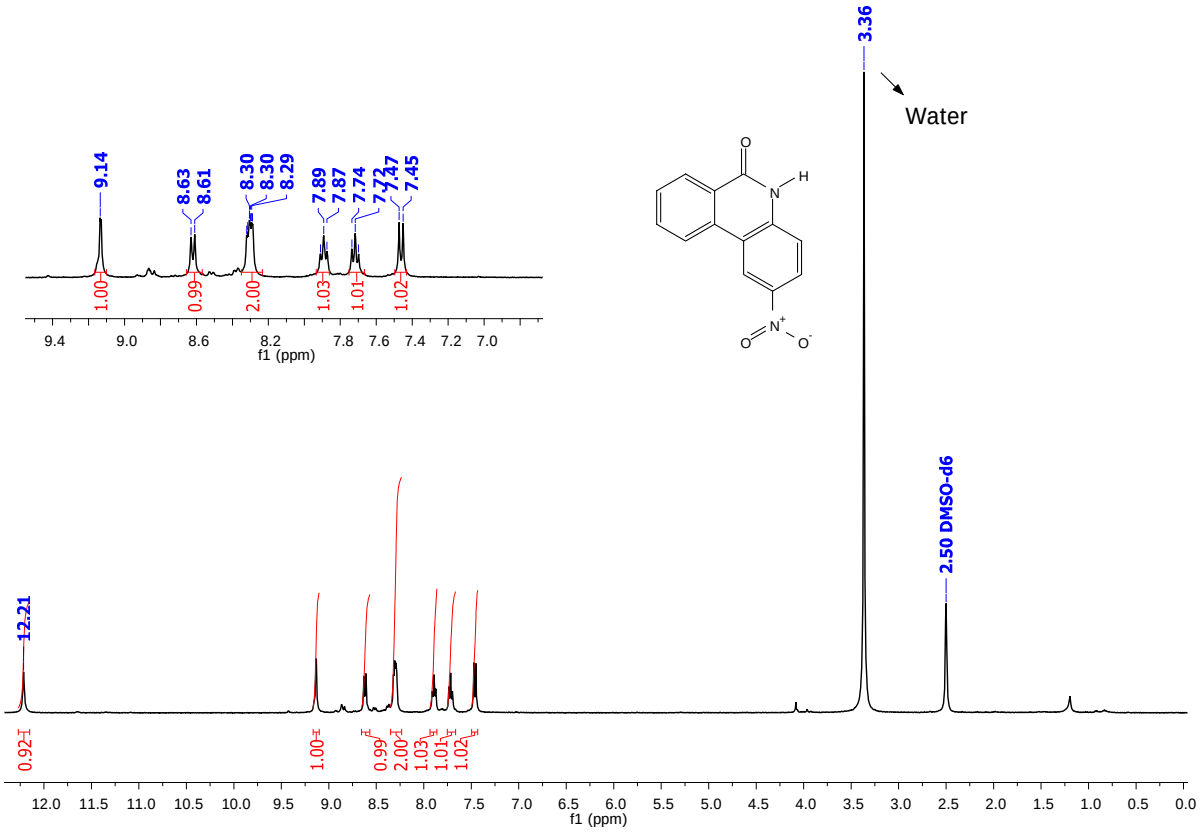
^{13}C spectra of compound of **8b**.



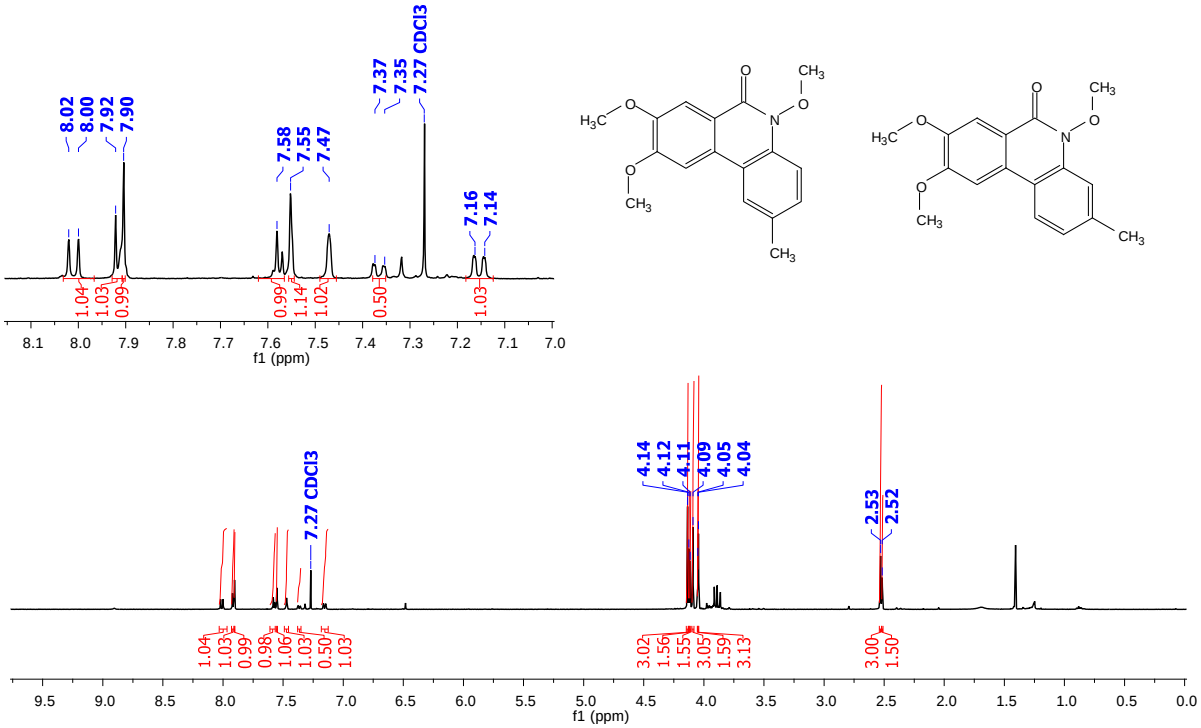
DEPT135 NMR spectrum of compound **8b**.



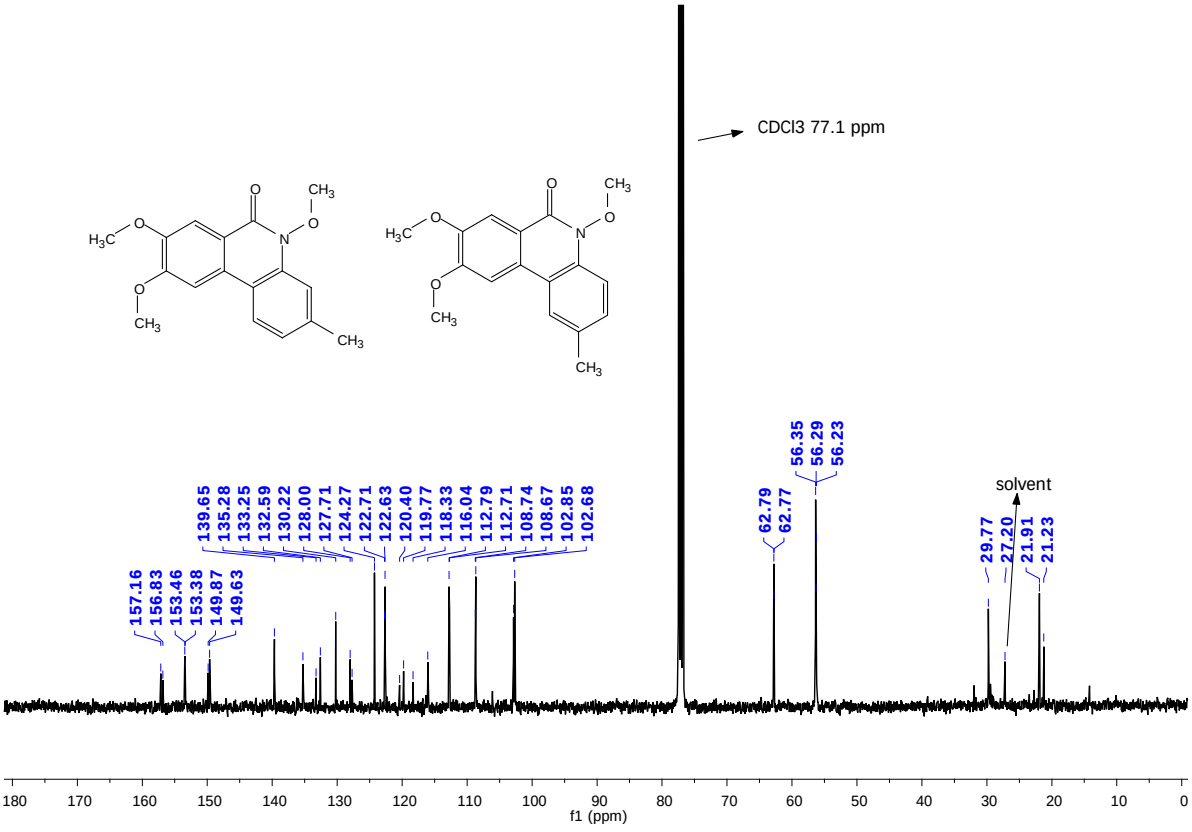
^{1}H NMR spectrum of compound of **9**.



^{1}H spectra of **4n & 4n'**.



^{13}C spectra of **4n & 4n'**.



DEPT135 NMR spectrum of compound **4n &4n‘**.