Visible light-mediated radical addition cascade cyclization of aryl isocyanide with tricarbonyls: Rapid access to substituted phenanthridines and isoquinolines

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General Experimental

All reactions were carried out using distilled solvents. Reactions were monitored by using precoated silica TLC plates (GF-254). Mass spectra were recorded in EI and ESI (TOF) modes. NMR spectra were recorded in at 400 MHz spectrometers in $CDCl_3$, DMSO-d_6, and tetramethylsilane (TMS; δ = 0.00 ppm) served as an internal standard for ^{1}H NMR. The corresponding residual non-deuterated solvent signal ($CDCl_3$; δ = 77.00 ppm and DMSO-d_6; δ = 39.52 ppm) was used as an internal standard for ^{13}C NMR. Column chromatography was carried out on silica gel 230-400 mesh or 100-200 mesh (Merck), and thin-layer chromatography was carried out using Silica Gel GF-254. Chemicals obtained from commercial suppliers were used without further purification. Aryl isocyanides were prepared according to the literature procedures.[1] and $(Ir[df(CF_3)ppy]_2(dtbpy))PF_6$[2] were prepared according to the literature reports.

Emission Spectra of Blue LED Strip:

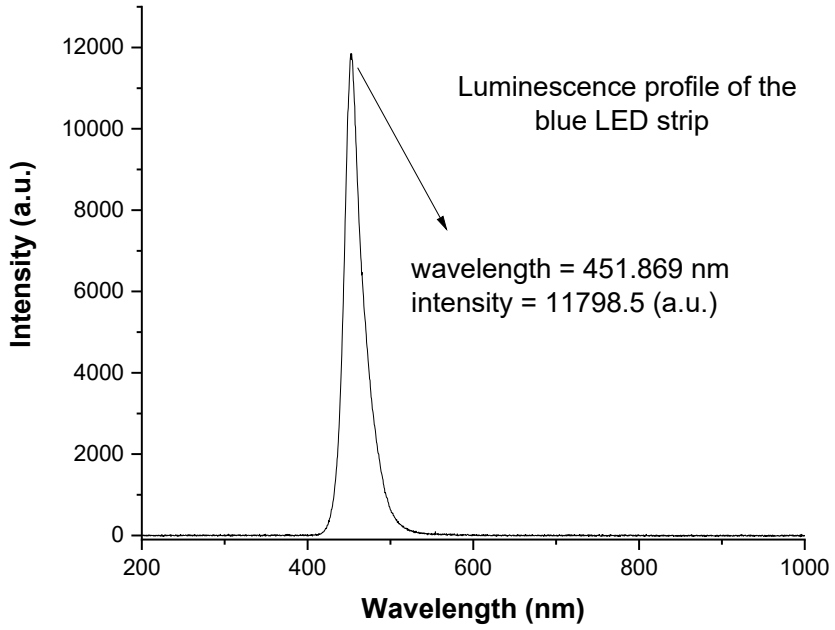


Fig 1: Plot of Intensity versus wavelength for the emission from the blue LED strip

An Ocean Optics spectrometer was used to record the emission spectrum of the blue LED strip, which was oriented toward the aperture of the spectrometer unit at a distance of approximately 8 cm.

Optimization and Control Studies

(a) Optimization of reaction conditions for the synthesis of phenanthridines:

In an 8 mL screw cap reaction vial equipped with a magnetic stirrer bar was added 2-isocyano-5-methyl-1,1'-biphenyl (0.2 mmol, 1 equiv.), triethyl methanetricarboxylate, appropriate oxidant, and appropriate photocatalyst. The appropriate solvent was added to the vial, and it was purged three times with argon and sealed with a cap containing a TFE-lined silicone septa. The reaction vial was degassed with argon for 15 minutes via an inlet needle. After this, the cap was changed with a solid-top cap under argon flow, and the vial was irradiated with 2 × 27 W CFL for 6-24 h. The reaction temperature was maintained at approximately 25 °C *via* a fan. After the reaction was stopped, the reaction mixture was transferred to a separatory funnel and diluted with EtOAc (10 mL) and water (10 mL). Sat. $NaHCO_3$ was then added and extracted with EtOAc (10 mL x 3) and washed with brine (saturated aq NaCl, 10 mL). The combined organic layer was dried over Na_2SO_4, and the solvent was removed in a rotatory evaporator followed by *a vacuo*. The reaction mixture was analyzed by ^1H NMR using 1,3,5-trimethoxybenzene as an internal standard.

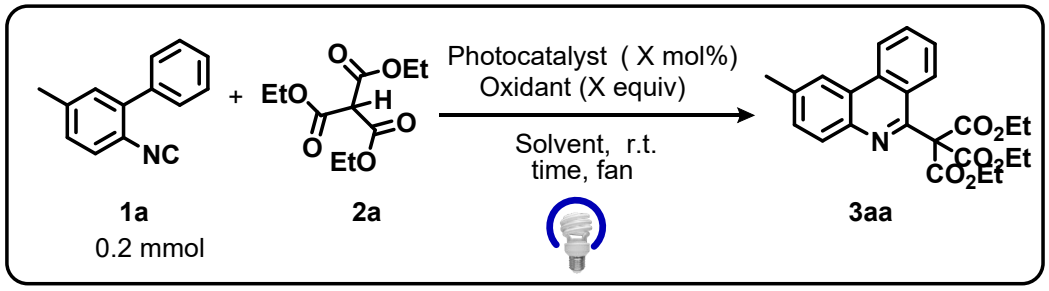


Table 1 Optimization studies [a]

Entry	2a (equiv)	Oxidant (equiv)	Atmosphere	Time (h)	Photocatalyst (mol%)	Solvent	NMR Yield of 3aa (%)[b]
1	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CN:H_2O$ (1:1) 2 mL	62
2	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN	n.d.
3	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CH_2CN:H_2O$ (1:1) 2 mL	6
4	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$C_3H_7CN:H_2O$ (1:1) 2 mL	n.d.

5	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	DCM:H_2O (1:1) 2 mL	trace
6	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	DMSO:H_2O (1:1) 2 mL	trace
7	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	TFE:H_2O (1:1) 2 mL	n.d.
8	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	HFIP:H_2O (1:1) 2 mL	n.d.
9	2	$K_2S_2O_8$ (2)	air	12	Eosin Y (5)	CH_3CN:H_2O (1:1) 2 mL	n.d.
10	2	$K_2S_2O_8$ (2)	air	12	$Ir[\{dF(CF_3)ppy\}_2(dtbpy)]PF_6$ (2)	CH_3CN:H_2O (1:1) 2 mL	n.d.
11	2	$K_2S_2O_8$ (2)	air	12	Mes-Acr-$PhBF_4$ (5)	CH_3CN:H_2O (1:1) 2 mL	n.d.
12	2	$Na_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN:H_2O (1:1) 2 mL	59
13	2	$(NH_4)_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN:H_2O (1:1) 2 mL	53
14	2	70% aq. TBHP(2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN:H_2O (1:1) 2 mL	n.d.
15	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN:H_2O (1:1) 1 mL	46
16	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN:H_2O (1:1) 4 mL	38
17	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	CH_3CN:H_2O (3:1)	59

						2 mL	
18	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CN:H_2O$ (1:3) 2 mL	52
19	2	$K_2S_2O_8$ (2)	air	24	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CN:H_2O$ (1:1) 2 mL	60
20	2	$K_2S_2O_8$ (2)	air	6	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CN:H_2O$ (1:1) 2 mL	56
21	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	65
22	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3(PF_6)_2$ (1)	$CH_3CN:H_2O$ (1:1) 2 mL	61
23	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3(PF_6)_2$ (3)	$CH_3CN:H_2O$ (1:1) 2 mL	57
24 [c]	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	71
25 [c, d]	2	$K_2S_2O_8$ (2)	purged and degassed with Ar	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	78
26 [c, d]	2	$K_2S_2O_8$ (1.5)	purged and degassed with Ar	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	76
27 [c, d]	2	$K_2S_2O_8$ (1.2)	purged and degassed with Ar	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	71
28 [c, d]	2	$K_2S_2O_8$ (2.5)	purged and degassed with Ar	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	75
29 [c, d]	1.5	$K_2S_2O_8$ (1.5)	purged and degassed	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1)	79

			with Ar			2 mL	
30 [c, d]	1.2	$K_2S_2O_8$ (1.5)	purged and degassed with Ar	12	$Ru(bpy)_3(PF_6)_2$ (2)	$CH_3CN:H_2O$ (1:1) 2 mL	57
31	2	$K_2S_2O_8$ (2)	air	12	none	$CH_3CN:H_2O$ (1:1) 2 mL	n.d.
32	2	none	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CN:H_2O$ (1:1) 2 mL	n.d.
33 [e]	2	$K_2S_2O_8$ (2)	air	12	$Ru(bpy)_3Cl_2$. 6 H_2O (2)	$CH_3CN:H_2O$ (1:1) 2 mL	n.d.

[a] Reaction conditions: **1a** (0.2 mmol), **2a** (X mmol), oxidant (X mmol), Photocatalyst (x mol%), Solvent (x mL) under 2 × 27W CFL for 6-12 h. [b] NMR yield (using 1,3,5-trimethoxybenzene as an internal standard). [c] Reaction was performed under blue LED strip (452 nm, 1.5 mW/cm^2). [d] Reaction mixture was degassed with Ar for 15 min. [e] Reaction was performed in the dark.

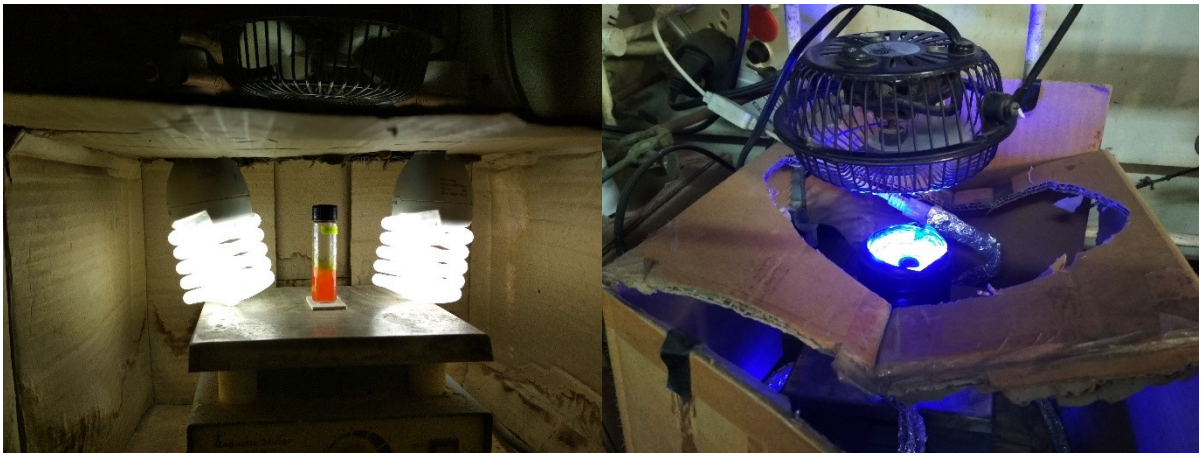


Fig 2: Reaction set-up under CFL (left) and Blue LED strips (right)

General Experimental Procedure

(a) General experimental procedure for synthesis of phenanthridines from *ortho*-aryl isocyanides and tricarbonyls:

In a 8 mL screw cap reaction vial equipped with a magnetic stirr bar was added *ortho*-aryl isocyanide (0.2 mmol, 1 equiv.), tricarbonyl (0.3 mmol, 1.5 equiv.), $K_2S_2O_8$ (0.3 mmol, 1.5 equiv.), $Ru(bpy)_3(PF_6)_2$ (0.004 mmol, 2 mol%). 2 mL of degassed CH_3CN:H_2O (1:1) was added to the vial and it was purged three times with argon and was sealed with a cap containing TFE-lined silicone septa. The reaction vial was then degassed with argon for 15 min *via* an inlet needle. After this, the cap was changed with a solid-top cap under argon flow and the vial was irradiated with a blue LED strip (0.11 W/cm^2, measured through a Newport optical power meter 1916-R at a distance of 2 cm) for 12-24 h. The temperature of the reaction vial was maintained at approximately 25 °C *via* a fan. After the reaction was stopped, the reaction mixture was transferred to a separatory funnel and diluted with EtOAc (10 mL) and water (10 mL). Sat. $NaHCO_3$ was then added to the reaction mixture and it was extracted with EtOAc (10 mL x 3) and washed with brine (saturated aq NaCl, 10 mL). The combined organic layer was dried over Na_2SO_4, and the solvent was removed in a rotatory evaporator followed by a *vacuo*. The crude products were then purified on a silica gel column (230-400 mesh) using EtOAc/petroleum ether mixture to get the pure product.

(b) Experimental procedure for synthesis of isoquinolines from vinyl isocyanides and tricarbonyls:

In an 8 mL screw cap reaction vial equipped with a magnetic stir bar was added vinyl-isocyanide (0.2 mmol, 1 equiv.), tricarbonyl (0.3 mmol, 1.5 equiv.), $K_2S_2O_8$ (0.3 mmol, 1.5 equiv.), $Ru(bpy)_3(PF_6)_2$ (0.004 mmol, 2 mol%). 2 mL of degassed CH_3CN: H_2O (1:1) was added to the vial, and it was purged three times with argon and was sealed with a cap containing TFE-lined silicone septa. The reaction vial was degassed with argon for 15 minutes *via* an inlet needle. After this, the cap was changed with a solid-top cap under argon flow and the vial was irradiated with a blue LED strip (0.11 W/cm^2, measured through a Newport optical power meter 1916-R at a distance of 2 cm) for 12-24 h. The temperature of the reaction vial was maintained at approximately 25 °C *via* a fan. After the reaction was stopped, the reaction mixture was transferred to a separatory funnel and diluted with EtOAc (10 mL) and water (10 mL). Sat. $NaHCO_3$ was then added to the reaction mixture and it was extracted with EtOAc (10 mL x 3) and washed with brine (saturated aq NaCl, 10 mL). The combined organic layer was dried over Na_2SO_4, and the solvent was removed in a rotatory evaporator followed by *a vacuum*. The crude products were then purified on a silica gel column (230-400 mesh) using EtOAc/petroleum ether mixture to get the pure product.

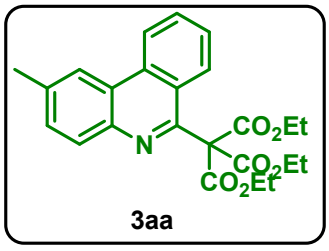
(c) Experimental Procedure for the scale-up reaction for phenanthridine from *ortho*-aryl isocyanide and triethylmethane tricarboxylate:

In a 50 mL RB (round bottom flask), equipped with a magnetic stir bar was added the 2-isocyano-5-methyl-1,1'-biphenyl (5.175 mmol, 1 equiv.), tricarbonyl (7.7625 mmol, 1.5 equiv.), $K_2S_2O_8$ (7.7625 mmol, 1.5 equiv.), $Ru(bpy)_3(PF_6)_2$ (0.1035 mmol, 2 mol%). 52 mL of

degassed $CH_3CN:H_2O$ (1:1) was added to the RB, and it was purged three times with argon and was sealed with a rubber septum. The rb was then degassed with argon for 15 min via an inlet needle. After this, the rb was irradiated with a blue LED strip (0.11 W/cm^2, measured through an optical power meter 1916-R at a distance of 1 cm) for 12 h. The temperature of the RB was maintained at approximately 25 °C *via* a fan. After the reaction was stopped, the reaction mixture was transferred to a separatory funnel and diluted with EtOAc (20 mL) and water (20 mL). Sat. $NaHCO_3$ was then added to the reaction mixture, and it was extracted with EtOAc (20 mL x 3) and washed with brine (saturated aq NaCl, 20 mL). The combined organic layer was dried over Na_2SO_4 and the solvent was removed in a rotatory evaporator followed by a *vacuo*. The crude products were then purified on a silica gel column (230-400 mesh) using EtOAc/petroleum ether mixture to get the pure product **3aa** in 61% yield (1.34 gm).

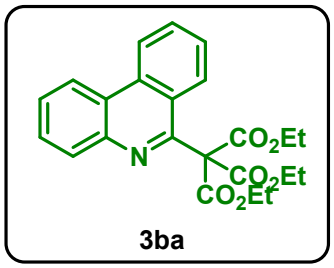
Characterization data for products:

1. **triethyl (2-methylphenanthridin-6-yl)methanetricarboxylate (3aa)**. White solid; Yield – (56.7 mg, 67%); ***mp***: 145-147 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2982, 2925, 1739,1219, 1060; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.65 (d, *J* = 8.3 Hz, 1 H), 8.35 (s, 1 H), 7.98 (d, *J* = 8.3 Hz, 1 H), 7.81-7.73 (m, 2 H), 7.60-7.53 (m, 2 H), 4.37 (q, *J* = 7.1 , 6 H), 2.64 (s, 3 H), 1.25 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.6, 153.5, 140.8, 137.5, 132.9, 130.2, 130.1, 129.8, 126.6, 126.2, 125.2, 124.0, 122.4, 121.4, 74.7, 62.6, 22.0, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{24}H_{25}NO_6H$ (M + H): 424.1760, found (M + H): 424.1759.



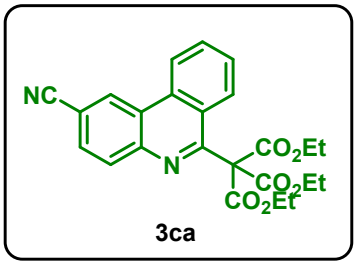
3aa

2. **triethyl phenanthridin-6-ylmethanetricarboxylate (3ba)**. White solid; Yield – (52.1 mg, 64%); ***mp***: 109-111 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, 1731, 1221, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.67 (d, *J* = 8.3 Hz, 1 H), 8.59-8.57 (m, 1 H), 8.11-8.09 (m, 1 H), 7.84-7.77 (m, 2 H), 7.75-7.68 (m, 2 H), 7.63-7.59 (m, 1 H), 4.38 (q, *J* = 7.1 Hz, 6 H), 1.26 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.6, 154.5, 142.5, 133.2, 130.5, 130.1, 128.4, 127.6, 126.7, 126.2, 125.2, 124.1, 122.4, 121.8, 74.7, 62.7, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{23}H_{23}NO_6H$ (M + H): 410.1604, found (M + H): 410.1610.



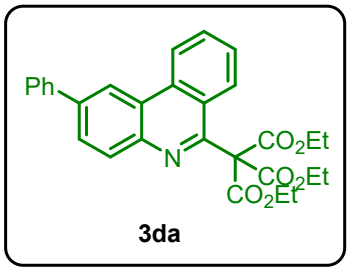
3ba

3. **triethyl (2-cyanophenanthridin-6-yl)methanetricarboxylate (3ca)**. White solid; Yield – (71.6 mg, 82%); ***mp***: 164-166 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2983, 2228, 1736, 1218, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.91 (d, *J* = 1.28 Hz, 1 H), 8.61 (d, *J* = 8.3 Hz, 1 H), 8.15 (d, *J* = 8.4 Hz, 1 H), 7.91-7.88 (m, 2 H), 7.81 (d, *J* = 8.2 Hz, 1 H), 7.71-7.67 (m, 1 H), 4.38 (q, *J* = 7.1 Hz, 6 H), 1.26 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.1, 157.7, 144.0, 132.1, 131.5, 131.2, 130.1, 128.0, 127.7, 126.6, 125.5, 124.3, 122.4, 118.9, 111.0, 74.7, 62.9, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{24}H_{22}N_2O_6H$ (M + H): 435.1556, found (M + H): 435.1552.



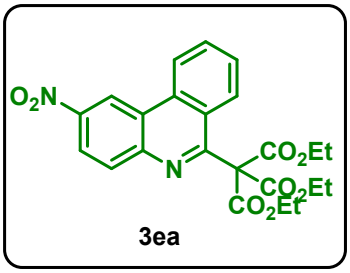
3ca

4. **triethyl (2-phenylphenanthridin-6-yl)methanetricarboxylate (3da)**. White solid; Yield – (65.7 mg, 67%); ***mp***: 168-170 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, 2934, 1738, 1224, 1060; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.77-8.74 (m, 2 H), 8.16 (d, *J* = 8.4 Hz, 1 H), 7.97 (dd, J_1 = 8.4 Hz, J_2 = 1.8 Hz, 1 H), 7.84-7.79 (m, 4 H), 7.63 (t, *J* = 7.4 Hz, 1 H), 7.55 (t, *J* = 7.4 Hz, 2 H), 7.45 (t, *J* = 7.4 Hz, 1 H), 4.41 (q, *J* = 7.2 Hz, 6 H), 1.29 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.6, 154.4, 141.8, 141.0, 140.5, 133.2, 130.9, 130.1, 128.9, 127.9, 127.7, 127.6 , 126.9, 126.3, 125.4, 124.3, 122.4, 120.2, 74.7, 62.7, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{29}H_{27}NO_6H$ (M + H): 486.1917, found (M + H): 486.1920.



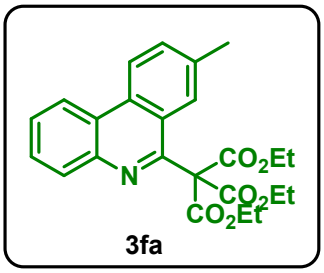
3da

5. **triethyl (2-nitrophenanthridin-6-yl)methanetricarboxylate (3ea)**. White solid; Yield – (41.8 mg, 46%); ***mp***: 166-168 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2983, 1732, 1217, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.49(d, *J* = 2.4 Hz, 1 H), 8.74 (d, *J* = 8.3 Hz, 1 H), 8.51 (dd, J_1 = 8.9 Hz, J_2 = 2.4 Hz, 1 H), 8.20 (d, *J* = 8.9 Hz, 1 H), 7.97-7.92 (m, 1 H), 7.85-7.83 (m, 1 H), 7.75-7.71 (m, 1 H), 4.39 (q, J = 7.1 Hz, 6 H), 1.27 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.1, 158.4, 146.3, 145.3, 133.0, 131.8, 131.4, 128.3, 126.8, 125.6, 124.2, 122.7, 122.4, 118.7, 74.82, 63.0, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{23}H_{22}N_2O_8H$ (M + H): 455.1454, found (M + H): 455.1452.



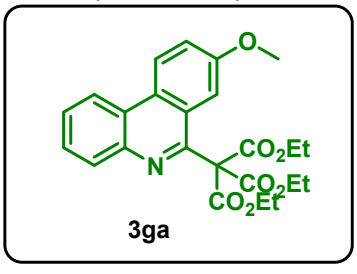
3ea

6. **triethyl (8-methylphenanthridin-6-yl)methanetricarboxylate (3fa)**. White solid; Yield – (57.1 mg, 68%); ***mp***: 162-164 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, , 1737, 1206, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.56-8.54 (m, 2 H), 8.08-8.05 (m, 1 H), 7.69-7.63(m, 3 H), 7.51 (s, 1 H), 4.38 (q, *J* = 7.1 Hz, 6 H), 2.53 (s, 3 H), 1.26 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.6, 154.2, 142.2, 136.7, 131.9, 131.2, 130.5, 128.0, 127.5, 125.6, 125.4, 124.3, 122.4, 121.6, 74.8, 62.7, 21.8, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{24}H_{25}NO_6H$ (M + H): 424.1760, found (M + H): 424.1760.



3fa

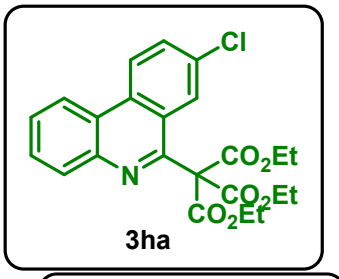
7. **triethyl (8-methoxyphenanthridin-6-yl)methanetricarboxylate (3ga)**. White solid; Yield – (62.6 mg, 71%); ***mp***: 121-123 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, 1736, 1220, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.57 (d, *J* = 9.1 Hz, 1 H), 8.50-8.48 (m, 1 H), 8.08-8.05 (m, 1 H), 7.68-7.66 (m, 2 H), 7.45 (dd, J_1 = 9.0 Hz, J_2 = 2.4 Hz 1 H), 7.10 (s, 1 H), 4.38 (q, *J* = 7.1 Hz, 6 H), 3.87 (s, 3 H), 1.27 (t, *J* = 7.0 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.6, 158.1, 153.6, 141.7, 130.4, 127.6, 127.4, 126.4, 124.2, 124.0, 121.3, 121.0, 106.3, 74.9, 62.6, 55.3, 13.9; **HRESI-MS** (*m/z*): Calculated for $C_{24}H_{25}NO_7H$ (M + H): 440.1709, found (M + H): 440.1711.



3ga

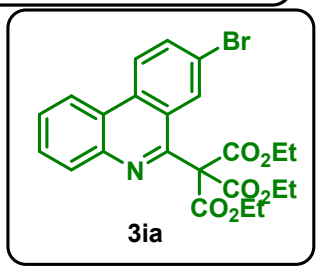
8. **triethyl (8-chlorophenanthridin-6-yl)methanetricarboxylate (3ha)**. White solid; Yield – (61.7 mg, 70%); ***mp***: 143-145 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, 1736, 1207, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.57 (d, *J* = 9.0 Hz, 1 H), 8.49

(d, *J* = 7.4 Hz, 1 H), 8.08 (d, *J* = 7.9 Hz, 1 H), 7.75-7.67 (m, 4 H), 4.41 (q, *J* = 7.1 Hz, 6 H), 1.30 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.2, 153.3, 142.3, 132.7, 131.6, 130.6, 130.5, 128.7, 128.0, 126.1, 125.7, 124.1, 123.5, 121.6, 74.7, 62.8, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{23}H_{22}ClNO_6H$ (M + H): 444.1214, found (M + H): 444.1211.



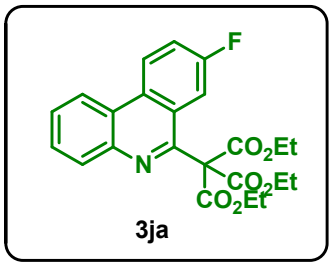
3ha

9. **triethyl (8-bromophenanthridin-6-yl)methanetricarboxylate (3ia)**. White solid; Yield – (76.8 mg, 79%); ***mp***: 149-151 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2982, 1736, 1208, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.49 (d, *J* = 8.4 Hz, 2 H), 8.07 (d, *J* = 7.92 Hz, 1 H), 7.89-7.86 (m, 2 H), 7.75-7.67 (m, 2 H), 4.41 (q, *J* = 7.1 Hz, 6 H), 1.31 (t, *J* = 7.0 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.2, 153.2, 142.3, 133.3, 131.9, 130.5, 128.9, 128.8, 128.0, 126.4, 124.2, 123.5, 121.6, 120.8, 74.7, 62.8, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{23}H_{22}BrNO_6H$ (M + H): 488.0709, found (M + H): 488.0702.



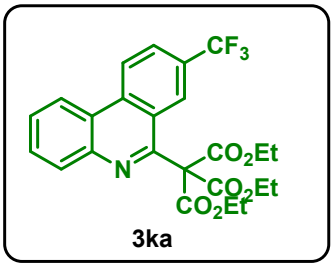
3ia

10. **triethyl (8-fluorophenanthridin-6-yl)methanetricarboxylate (3ja)**. White solid; Yield – (49.2 mg, 57%); ***mp***: 105-107 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2982, 2937, 1734, 1194, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.67-8.63 (m, 1 H), 8.52-8.50 (m, 1 H), 8.10-8.08 (m, 1 H), 7.74-7.68 (m, 2 H), 7.59-7.55 (m, 1 H), 7.43-7.40 (m, 1 H), 4.40 (q, J = 7.1 Hz, 6 H), 1.29 (t, J = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.3, 160.7 (d, $J_{C\text{-}F}$ = 246.9 Hz), 153.6 (d, $J_{C\text{-}F}$ = 3.8 Hz), 142.1, 130.5, 129.9, 128.3, 128.0, 126.4 (d, $J_{C\text{-}F}$ = 7.9 Hz), 125.0 (d, $J_{C\text{-}F}$ = 8.4 Hz), 123.7, 121.5, 119.5 (d, $J_{C\text{-}F}$ = 23.6 Hz), 111.0 (d, $J_{C\text{-}F}$ = 22.1 Hz), 74.7, 62.8, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{23}H_{22}FNO_6H$ (M + H): 428.1059, found (M + H): 428.1509.



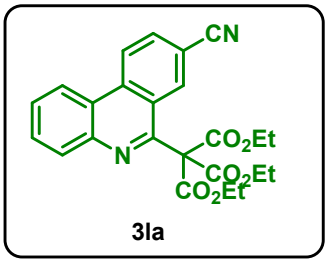
3ja

11. **triethyl (8-(trifluoromethyl)phenanthridin-6-yl)methanetricarboxylate (3ka)**. White solid; Yield – (74.3 mg, 78%); ***mp***: 144-146 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2983, 1733, 1208, 1124, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.76 (d, *J* = 8.7 Hz, 1 H), 8.57 (d, *J* = 8.0 Hz, 1 H), 8.11 (d, *J* = 8.0 Hz, 1 H), 8.05 (s, 1 H), 8.0 (d, *J* = 8.7 Hz, 1 H), 7.81-7.72 (m, 2 H), 4.41 (q, *J* = 7.1 Hz, 6 H), 1.30 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.3, 154.4, 143.1, 135.5, 130.7, 129.8, 128.5 (q, *J* = 35.2 Hz), 128.3, 125.9 (q, *J* = 3.7 Hz), 124.7, 124.2 (q, *J* = 4.3 Hz), 123.8 (q, *J* = 270.8 Hz), 123.6, 123.3, ,122.3, 74.9, 63.0, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{24}H_{22}F_3NO_6H$ (M + H): 478.1477, found (M + H): 478.1478.



3ka

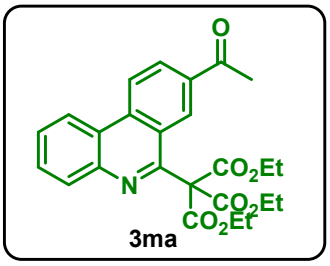
12. **triethyl (8-cyanophenanthridin-6-yl)methanetricarboxylate (3la)**. White solid; Yield – (50.1 mg, 58%); ***mp***: 155-157 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2982, 2230, 1733, 1206, 1057; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.74 (d, *J* = 8.6 Hz, 1 H), 8.57 (d, *J* = 8.0 Hz, 1 H), 8.13-8.08 (m, 2 H), 7.98 (d, *J* = 8.3 Hz, 1 H), 7.85-7.76 (m, 2 H), 4.43 (q, *J* = 7.1 Hz, 6 H), 1.33 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, CDCl3) δ 165.1, 153.7, 143.3, 135.9,



3la

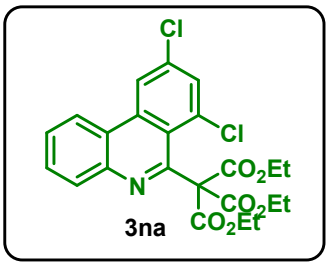
131.9, 131.2, 130.7, 130.3, 128.6, 124.8, 123.8, 122.9, 122.4, 118.3, 110.3, 74.7, 63.1, 13.8 ; **HRESI-MS** (*m/z*): Calculated for $C_{24}H_{22}N_2O_6H$ (M + H): 435.1556, found (M + H): 435.1575.

13. **triethyl (8-acetylphenanthridin-6-yl)methanetricarboxylate (3ma)**. White solid; Yield – (59.8 mg, 66%); ***mp***: 136-138 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, 2937, 1731, 1686, 1249, 1057; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.71 (d, *J* = 8.6 Hz, 1 H), 8.59 (d, *J* = 8.0 Hz, 1 H), 8.39 (s, 1 H), 8.36 (d, *J* = 8.6 Hz, 1 H), 8.11 (d, *J* = 7.9 Hz, 1 H), 7.81-7.72 (m, 2 H), 4.41 (q, *J* = 7.0 Hz, 6 H), 2.69 (s, 3 H), 1.30 (t, *J* = 7.4 Hz, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.9, 166.0, 165.5, 154.8, 143.3, 136.4, 134.7, 130.6, 129.7, 128.4, 128.1, 128.0, 124.7, 123.5, 123.0, 122.5, 74.9, 63.3, 63.0, 26.4, 13.9; **HRESI-MS** (*m/z*): Calculated for $C_{25}H_{25}NO_7Na$ (M + Na): 474.1529, found (M + H): 474.1531.



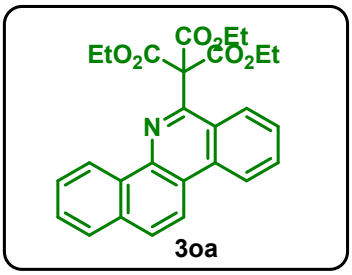
3ma

14. **triethyl (7,9-dichlorophenanthridin-6-yl)methanetricarboxylate (3na)**. White solid; Yield – (83.8 mg, 88%); ***mp***: 177-179 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2982, 1746, 1592, 1197, 1062; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.62 (s, 1 H), 8.44 (d, *J* = 8.1Hz, 1 H), 8.01 (d, *J* = 7.9 Hz, 1 H), 7.77-7.67 (m, 3 H), 4.53-4.48 (m, 2 H), 4.31-4.30 (m, 4 H), 1.44 (t, *J* = 7.08, 3 H), 1.21 (s, 6 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.9, 165.5, 152.6, 141.7, 137.1, 135.6, 132.7, 130.5, 130.1, 129.8, 128.4, 122.5, 122.3, 122.1, 121.8, 77.8, 62.9, 62.6, 14.0, 13.6; **HRESI-MS** (*m/z*): Calculated for $C_{23}H_{21}Cl_2NO_6Na$ (M + Na): 500.0644, found (M + Na): 500.0643.



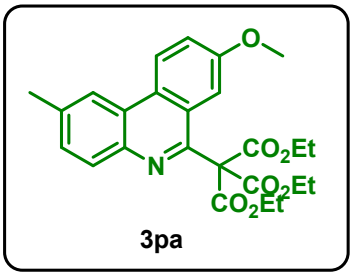
3na

15. **triethyl benzo[c]phenanthridin-6-ylmethanetricarboxylate (3oa)**. White solid; Yield – (50.4 mg, 64%); ***mp***: 150-152 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2982, 2925, 1736, 1225, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.23 (d, *J* = 7.9 Hz, 1 H), 8.74 (d, *J* = 8.4 Hz, 1 H), 8.56 (d, *J* = 9.0 Hz, 1 H), 8.06 (d, *J* = 8.9 Hz, 1 H), 7.99-7.97 (m, 1 H), 7.90-7.84 (m, 2 H) , 7.75-7.63 (m, 3 H) ,4.45 (q, *J* = 7.1 Hz, 6 H), 1.27 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.7, 153.0, 139.2, 133.6, 133.1, 131.9, 130.0, 128.4, 127.5, 127.3, 126.8, 126.6, 126.3, 125.6, 124.7, 75.2, 62.7, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{27}H_{25}NO_6H$ (M + H): 460.1760, found (M + H): 460.1759.



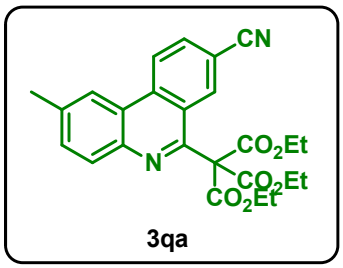
3oa

16. **triethyl (8-methoxy-2-methylphenanthridin-6-yl)methanetricarboxylate (3pa)**. White solid; Yield – (64.4 mg, 71%); ***mp***: 133-135 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2981, 2926, 1737, 1222, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.55 (d, *J* = 9.12 Hz, 1 H), 8.27 (s, 1 H), 7.95 (d, *J* = 8.3 Hz, 1 H), 7.48 (d, *J* = 8.2 Hz, 1 H), 7.43 (dd, J_1 = 9.1 Hz, J_2 = 2.4 Hz, 1 H), 7.08 (d, *J* = 2.4 Hz, 1 H), 4.38 (q, *J* = 7.1 Hz, 6 H), 3.87 (s, 3 H), 2.64 (s, 3 H), 1.27 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.7, 158.0, 152.6, 140.1, 137.6, 130.2, 129.2, 127.5, 126.5, 124.1, 124.0, 120.9 , 120.8, 106.2, 74.9, 62.7, 55.3, 22.1, 13.9; **HRESI-MS** (*m/z*): Calculated for $C_{25}H_{27}NO_7H$ (M + H): 454.1866, found (M + H): 454.1865.



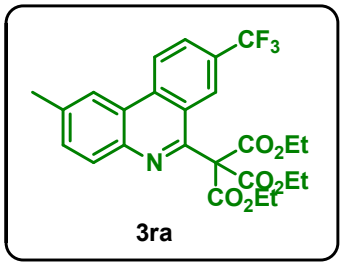
3pa

17. **triethyl (8-cyano-2-methylphenanthridin-6-yl)methanetricarboxylate (3qa)**. White solid; Yield – (42.3 mg, 47%); ***mp***: 130-132 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2226, 1734, 1216, 1054; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.71 (d, *J* = 8.5 Hz, 1 H), 8.32 (s, 1 H), 8.07 (s, 1 H), 7.99 (d, *J* = 8.3 Hz, 1 H), 7.94 (dd, J_1 = 8.5 Hz, J_2 = 1.2 Hz, 1 H), 7.63 (d, *J* = 8.3 Hz, 1 H), 4.42 (q, *J* = 7.1 Hz, 6 H), 2.66 (s, 3 H), 1.32 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.2, 152.6, 141.7, 138.8, 135.6, 132.0, 131.9, 131.0, 130.4, 124.8, 123.8, 122.7 , 121.9, 118.4, 110.1, 74.7, 63.0, 22.0, 13.9; **HRESI-MS** (*m/z*): Calculated for $C_{25}H_{24}N_2O_6Na$ (M + Na): 471.1532, found (M + H): 471.1533.



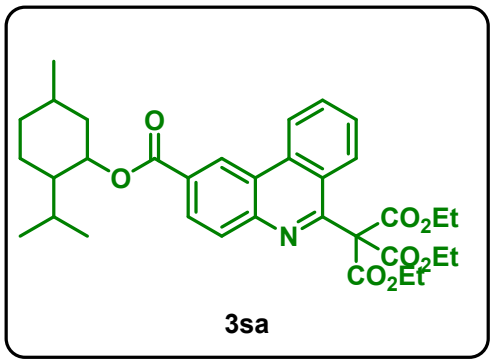
3qa

18. **triethyl (2-methyl-8-(trifluoromethyl)phenanthridin-6-yl)methanetricarboxylate (3ra)**. White solid; Yield – (79.8 mg, 81%); ***mp***: 102-104 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2983, 1731, 1210, 1124, 1056; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.75 (d, *J* = 8.7 Hz, 1 H), 8.35 (s, 1 H), 8.02-7.96 (m, 3 H), 7.61 (d, *J* = 8.2 Hz, 1 H), 4.40 (q, *J* = 7.1 Hz, 6 H), 2.66 (s, 3 H), 1.29 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.3, 153.4, 141.4, 138.4, 135.2, 131.2, 130.4, 128.3 (q, *J* = 32.5 Hz), 125.6 (q, *J* = 2.9 Hz), 124.1 (q, *J* = 4.2 Hz), 123.8 (q, *J* = 270.8 Hz), 123.5, 121.8, 74.8, 62.9, 22.0, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{25}H_{24}F_3NO_6H$ (M + H): 492.1634, found (M + H): 492.1632.



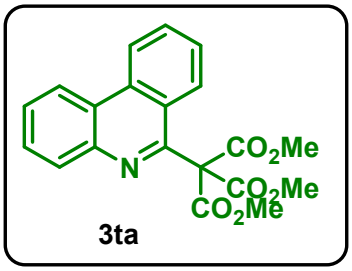
3ra

19. **Triethyl (2-(((2-isopropyl-5-methylcyclohexyl)oxy)carbonyl)phenanthridin-6-yl)methanetricarboxylate (3sa).** White solid; Yield – (96.9 mg, 80%); ***mp***: 62-64 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2955, 2928, 2869, 1738, 1712, 1285, 1254, 1060; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.32 (s, 1 H), 8.77 (d, *J* = 8.3 Hz, 1 H), 8.33 (d, J_1 = 8.5 Hz, J_2 = 1.5 Hz, 1 H), 8.12 (d, *J* = 8.5 Hz, 1 H), 7.88 (t, *J* = 7.5 Hz, 1 H), 7.79 (d, *J* = 8.3 Hz, 1 H), 7.65 (t, *J* = 7.5 Hz, 1 H), 5.07 (td, J_1 = 10.9 Hz, J_2 = 4.2 Hz, 1 H), 4.37 (q, *J* = 7.1 Hz, 6 H), 2.24-2.21 (m, 1 H), 2.07-2.01 (m, 1 H), 1.80-1.77 (m, 2 H), 1.71-1.63 (m, 2 H), 1.27-1.22 (m, 11 H), 0.99-0.97 (m, 7H), 0.86 (d, *J* = 6.8 Hz, 3 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.9, 165.3, 156.7, 144.8, 133.3, 130.7, 130.5, 129.5, 128.5, 127.3, 126.4, 125.3, 124.5, 123.7, 122.7, 75.3, 74.7, 62.8, 47.3, 41.0, 34.3, 31.4, 26.6, 23.7, 22.0, 20.7, 16.6, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{34}H_{41}NO_8H$ (M + H): 592.2910, found (M + H): 592.2913.



3sa

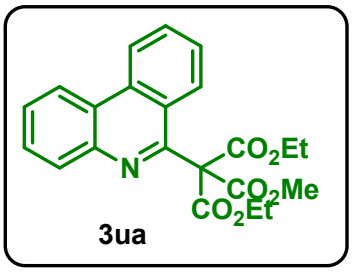
20. **trimethyl phenanthridin-6-ylmethanetricarboxylate (3ta)**. White solid; Yield – (49.2 mg, 67%); ***mp***: 190-192 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2952, 1742, 1232, 1066; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.69 (d, *J* = 8.3 Hz, 1 H), 8.60-8.58 (m, 1 H), 8.11-8.08 (m, 1 H), 7.84 (t, *J* = 8 Hz, 1 H), 7.76-7.70 (m, 3 H), 7.64-7.60 (m, 1 H), 3.89 (s, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.9, 154.2, 142.3, 133.3, 130.7, 130.2,



3ta

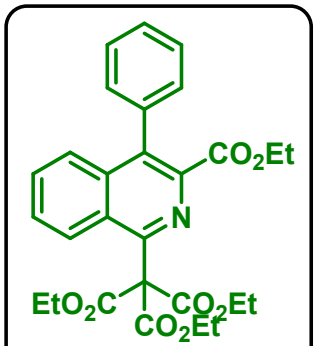
128.6, 127.8, 127.1, 125.0, 124.2, 121.8, 74.6, 53.7; **HRESI-MS** (*m/z*): Calculated for $C_{20}H_{17}NO_6H$ (M + H): 368.1134, found (M + H): 368.1138.

21. **trimethyl phenanthridin-6-ylmethanetricarboxylate (3ua)**. White solid; Yield – (51.4 mg, 65%); ***mp***: 179-181 °C; Prepared as shown in the general experimental procedure (a). **IR** (Neat, cm^{-1}): 2923, 2855, 1740, 1510, 1458, 1352, 1251, 1172, 1065; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.68 (d, *J* = 8.3 Hz, 1 H), 8.60-8.58 (m, 1 H), 8.11-8.09 (m, 1 H), 7.85-7.81 (m, 1 H), 7.76-7.71 (m, 3 H), 7.63-7.60 (m, 1 H), 4.39 (t, *J* = 7.1 Hz, 4 H), 3.87 (s, 3 H), 1.27 (t, *J* = 7.1 Hz, 6 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.2, 165.4, 154.4, 142.4, 133.2, 130.5, 130.1, 128.5, 127.7, 126.8, 126.1, 125.1, 124.1, 122.5, 121.8, 74.7, 62.7, 53.5, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{22}H_{21}NO_6H$ (M + H): 396.1447, found (M + H): 396.1448.



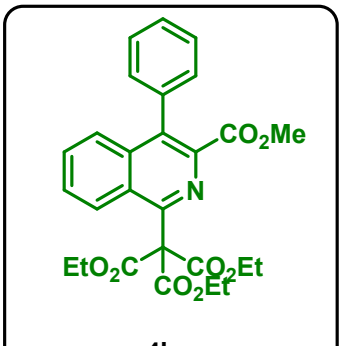
3ua

22. **triethyl (3-(ethoxycarbonyl)-4-phenylisoquinolin-1-yl)methanetricarboxylate (4aa) .** white sticky solid; Yield – (85.2 mg, 70%); Prepared as shown in the general experimental procedure (b). **IR** (Neat, cm^{-1}): 2982, 1735, 1221, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.80-7.70 (m, 1 H), 7.67-7.64 (m, 1 H), 7.61-7.59 (m 2 H), 7.51-7.50 (m, 3H), 7.38-7.36 (m, 2 H), 4.39 (q, *J* = 7.1 Hz, 6 H), 4.11 (q, *J* = 7.1 Hz, 2 H), 1.29 (t, *J* = 7.1 Hz, 9 H), 1.05 (t, *J* = 7.1 Hz, 3 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.2, 165.4, 153.4, 139.7, 136.4, 136.1, 134.7, 130.0, 129.7, 128.1, 128.0, 127.9, 127.8, 127.2, 125.5, 74.5, 62.8, 60.9, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{28}H_{29}NO_8H$ (M + H): 508.1971, found (M + H): 508.1973.



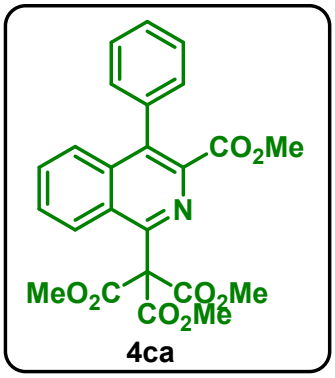
4aa

23. **triethyl (3-(methoxycarbonyl)-4-phenylisoquinolin-1-yl)methanetricarboxylate (4ba).** White solid; Yield – (78.3 mg, 79%); ***mp***: 90-92 °C; Prepared as shown in the general experimental procedure (b). **IR** (Neat, cm^{-1}): 2982, 2925, 1733, 1221, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.79-7.78 (m, 1 H), 7.63-7.61 (m, 3 H), 7.52-7.50 (m, 3 H), 7.35 (d, *J* = 7.2 Hz, 2 H), 4.39 (q, *J* = 7.2 Hz, 6 H), 3.69 (s, 3 H), 1.29 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.5, 165.4, 153.4, 138.9, 136.5, 135.9, 135.3, 130.0, 129.5, 128.2, 128.1, 127.9, 127.4, 125.5, 74.5, 62.8, 51.9, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{27}H_{27}NO_8Na$ (M + Na): 516.1634, found (M + H): 516.1631.



4ba

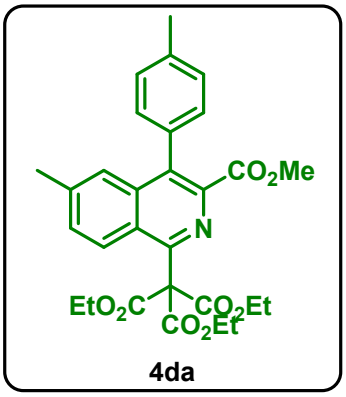
24. **trimethyl (3-(methoxycarbonyl)-4-phenylisoquinolin-1-yl)methanetricarboxylate (4ca)**. White solid; Yield – (61.9 mg, 69%); ***mp***: 168-170 °C; Prepared as shown in the general experimental procedure (b). **IR** (Neat, cm^{-1}): 2953, 1736, 1433, 1226, 1065; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.74-7.72 (m, 1 H), 7.64-7.62 (m, 3 H), 7.52-7.51 (m, 3 H), 7.34-7.33 (m, 2 H), 3.90 (s, 9 H), 3.69 (s, 3 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.3, 165.8, 153.1, 138.5, 136.7, 135.9, 130.2, 129.5, 128.6, 128.1, 128.0, 127.9, 127.7, 125.0, 74.4, 53.8, 52.1; **HRESI-MS**



4ca

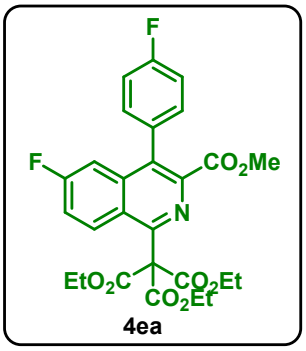
(*m/z*): Calculated for $C_{24}H_{21}NO_8Na$ (M + Na): 474.1165, found (M + H): 474.1165.

25. **triethyl(3-(methoxycarbonyl)-6-methyl-4-(p-tolyl)isoquinolin-1-yl)methanetricarboxylate (4da)**. White solid; Yield – (64.7 mg, 62%); ***mp***: 105-107 °C; Prepared as shown in the general experimental procedure (b). **IR** (Neat, cm^{-1}): 2981, 2923, 1736, 1221, 1059; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 8.7 Hz, 1 H), 7.51 (s, 1 H), 7.42 (dd, J_1 = 8.6 Hz, J_2 = 1.2 Hz, 1 H), 7.32 (d, *J* = 7.9 Hz, 2 H), 7.22 (d, *J* = 7.9 Hz, 2 H), 4.40 (q, *J* = 7.1 Hz, 6 H), 3.70 (s, 3 H), 2.50 (s, 3 H), 2.48 (s, 3 H), 1.29 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.6, 165.5, 152.4, 138.5, 138.0, 137.5, 135.6, 135.0, 133.0, 132.2, 129.3, 128.8, 128.2, 127.3, 124.3, 74.4, 62.8, 51.9, 22.2, 21.3, 13.7; **HRESI-MS** (*m/z*): Calculated for $C_{29}H_{31}NO_8H$ (M + H): 522.2128, found (M + H): 522.2128.



4da

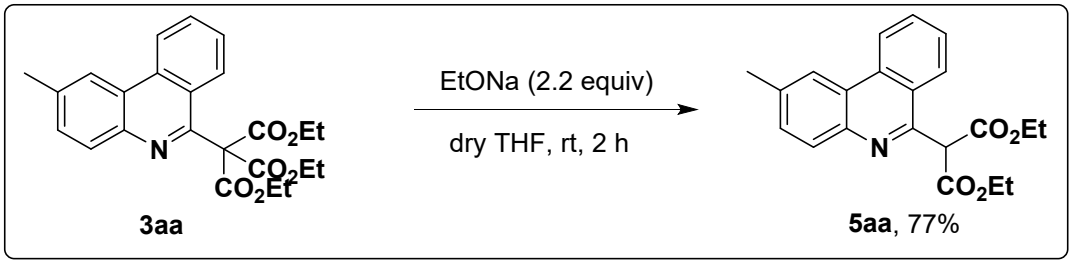
26. **Triethyl (6-fluoro-4-(4-fluorophenyl)-3-(methoxycarbonyl)isoquinolin-1-yl)methanetricarboxylate (4ea).** White solid; Yield – (83.8 mg, 79%); ***mp***: 124-126 °C; Prepared as shown in the general experimental procedure (b). **IR** (Neat, cm^{-1}): 2984, 1735, 1220, 1196, 1058; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.65-7.61 (m, 1 H), 7.43-7.39 (m, 2 H), 7.33-7.29 (m, 2 H), 7.24-7.20 (m, 2 H), 4.41 (q, *J* = 7.1 Hz, 6 H), 3.70 (s, 3 H), 1.32 (t, *J* = 7.1 Hz, 9 H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.1, 165.1, 162.6 (d, $J_{c\text{-}f}$ = 245.8 Hz), 161.3 (d, $J_{c\text{-}f}$ = 251.1 Hz), 153.1 (d, $J_{c\text{-}f}$ = 5.5 Hz), 138.7, 134.3, 131.5(d, $J_{c\text{-}f}$ = 3.6 Hz), 131.3(d, $J_{c\text{-}f}$ = 8.0 Hz), 130.2(d, $J_{c\text{-}f}$ = 8.8 Hz), 129.3 (d, $J_{c\text{-}f}$ = 8.9 Hz), 120.8 (d, $J_{c\text{-}f}$ = 24.7 Hz), 115.5(d, $J_{c\text{-}f}$ = 21.5 Hz), 109.8(d, $J_{c\text{-}f}$ = 22.3 Hz), 74.5, 63.0, 52.0, 13.8; **HRESI-MS** (*m/z*): Calculated for $C_{27}H_{25}F_2NO_8H$ (M + H): 530.1626, found (M + H): 530.1624.



4ea

Product modification

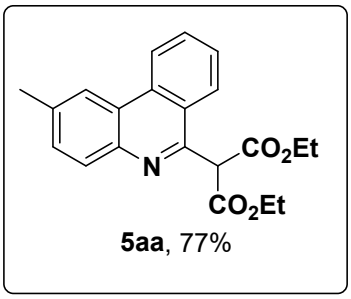
Synthesis of dicarbonyl 5aa:



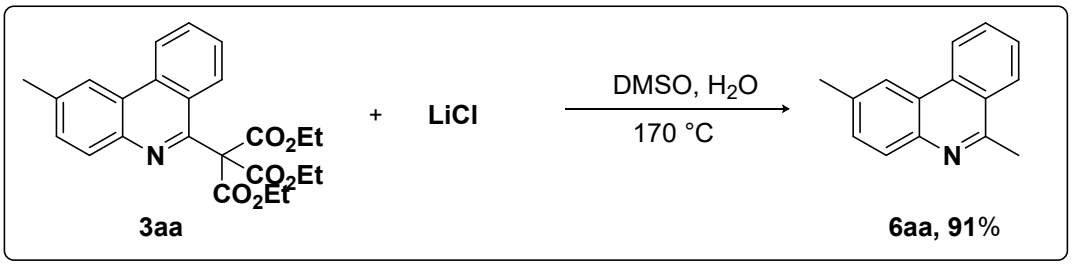
The compound **3aa** (0.2 mmol, 1 equiv) in dry THF (2 mL) was added dropwise to a well stirred solution of sodium ethoxide (0.44 mmol, 2.2 equiv) in THF (2 mL) under argon at rt. After stirring at rt for 2 h the solution was acidified with 1N HCl and diluted with ethyl acetate (10 mL). The organic layer was collected and washed with water, sat. $NaHCO_3$ solution, brine. The organic layer collected was then dried over Na_2SO_4. The solvent was concentrated in rotatory evaporator followed by in *vacuo* and purified by silica gel (230-400 mesh) column chromatography with EtOAc/petroleum ether mixture to provide the pure dicarbonyl product **5aa** (54.1 mg, 77% yield)

diethyl 2-(2-methylphenanthridin-6-yl)malonate (5aa)

White solid; Yield – (54.1 mg, 77%); ***mp***: 129-131 °C; **IR** (Neat, cm^{-1}): 2981, 1737, 1451, 1365, 1304, 1252, 1179, 1148, 1097, 1035; **^{1}H NMR δ ($CDCl_3$, 400 MHz):** 8.65 (d, *J* = 8.2 Hz, 1 H), 8.34 (s, 1 H), 8.07-7.99 (m, 2 H), 7.85-7.81 (m, 1 H), 7.69-7.65 (m, 1 H), 7.56 (d, *J* = 8.3 Hz, 1 H), 5.65 (s, 1 H), 4.41-4.29 (m, 4 H), 2.63 (s, 3 H), 1.30 (t, J = 7.1 Hz, 6 H); **^{13}C NMR δ ($CDCl_3$, 100 MHz):** 167.5, 152.5, 141.5, 137.2, 132.9, 130.3, 130.2, 130.1, 127.3, 125.0, 124.9, 123.7, 122.5, 121.4, 61.9, 59.3, 21.9, 14.0; **HRMS (ESI) (*m/z*):** Calculated for $C_{21}H_{21}NO_4H$ [M+H]: 352.1549, found [M+H]: 352.1551.



Synthesis of 2,6-dimethylphenanthridine 6aa:

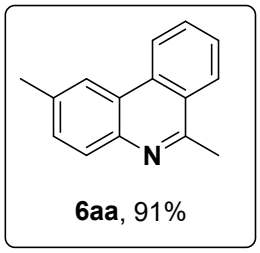


DMSO (2 mL) solution of the compound triethyl (2-methylphenanthridin-6-yl)methanetricarboxylate, **3aa** (84.69 mg, 0.2 mmol, 1.0 equiv.), LiCl (27.13 mg, 0.64 mmol, 3.2 equiv), and water (7 mg, 0.4 mmol, 2.0 equiv.) was heated at 170°C for 2 h. After cooling down to room temperature, the reaction mixture was washed with water (10 mL), and the aqueous layer was extracted with diethyl ether (3x20 mL). The combined organic layers were washed with brine (10 mL), dried over anhydrous Na_2SO_4, and then concentrated under

reduced pressure to give a crude product. The crude product was purified by flash chromatography on silica gel using EtOAc/petroleum ether as the eluant in 91% (37.7 mg) yield.

2,6-dimethylphenanthridine (6aa)

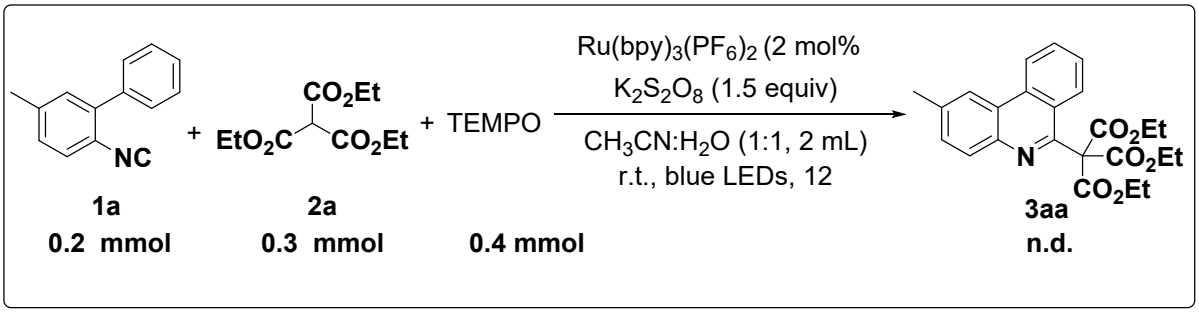
White solid; Yield – (37.7 mg, 91%); **IR** (Neat, cm^{-1}): 2922, 2854, 1582, 1495, 1457, 1375, 1315, 1244, 1187, 1082, 825, 760; **^{1}H NMR δ ($CDCl_3$, 400 MHz):** 8.63 (d, *J* = 8.3 Hz, 1 H), 8.34 (s, 1 H), 8.22 (d, *J* = 8.1 Hz, 1 H), 8.02 (d, J = 8.3 Hz, 1 H), 7.86-7.82 (m, 1 H), 7.71-7.67 (m, 1 H), 7.56-7.54 (m, 1 H), 3.05 (s, 3 H), 2.63 (s, 3 H); **^{13}C NMR δ ($CDCl_3$, 100 MHz):** 157.8, 141.8, 136.0, 132.3, 130.3, 130.2, 128.9, 127.1, 126.4, 125.9, 123.5, 122.2, 121.5, 23.2, 21.8; **HRMS (ESI) (*m/z*):** Calculated for $C_{15}H_{13}NH$ [M+H]: 208.1126, found [M+H]: 208.1128.



6aa, 91%

Mechanistic Studies:

Tempo Quenching Studies

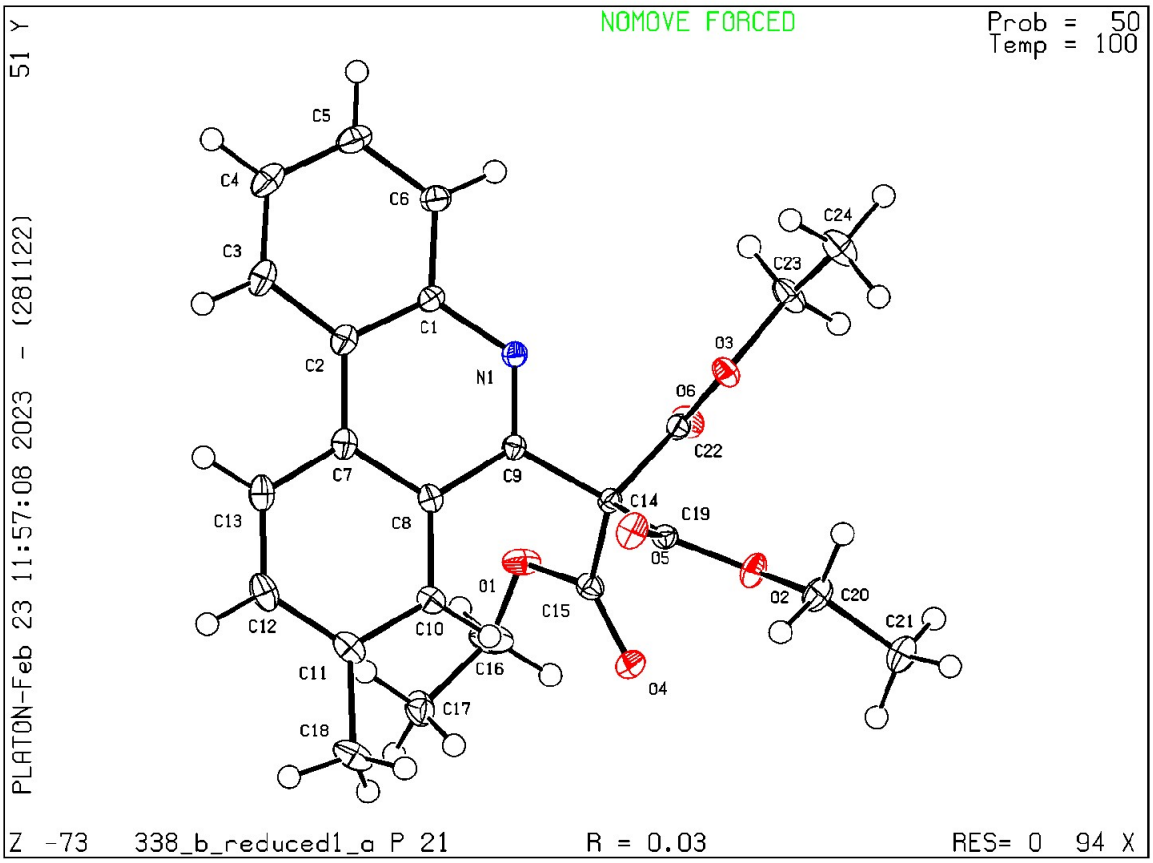


In a 8 mL screw cap reaction vial equipped with a magnetic stirrer bar was added 2-isocyano-5-methyl-1,1'-biphenyl **1a** as ortho-aryl isocyanide (0.2 mmol, 1 equiv.), tricarbonyl **2a** (0.3 mmol, 1.5 equiv.), $K_2S_2O_8$ (0.3 mmol, 1.5 equiv.), 2,2,6,6--1-piperidinyloxy (0.4 mmol, 2 equiv.), $Ru(bpy)_3(PF_6)_2$ (0.004 mmol, 2 mol%). 2 mL of degassed $CH_3CN:H_2O$ (1:1) was added to the vial then and it was purged three times with argon and was sealed with a cap containing PTFE-lined silicone septa. The reaction vial was then degassed with argon for 15 min via an inlet needle. After this, the cap was changed with a PTFE-lined solid-top cap under argon flow and the vial was irradiated with a blue LED strip (1.5 mW/cm2, at a distance of 2 cm) for 12 h. The temperature of the reaction vial was maintained at approximately 25 °C via a fan. After the reaction was stopped, the reaction mixture was transferred to a separatory funnel and diluted with EtOAc (10 mL) and water (10 mL). The residue was extracted with EtOAc (10 mL x 3) and washed with brine (saturated aq NaCl, 10 mL). The combined organic layer was dried over Na_2SO4 and the solvent was removed in rotatory evaporator followed by in vacuo. The crude product was then purified by column chromatography on silica gel (230-400 mesh) using EtOAc/petroleum ether mixture.

Crystal Data:

Crystal data for 3fa:

The ORTEP diagram and crystal parameters of **3fa** in thermal ellipsoids are drawn at 50% probability level. The crystal of suitable quality was obtained from slow evaporation of solution of pure isolated **3fa** in DCM/hexane and was analyzed by single crystal diffractometer. Atomic coordinates, bond lengths, bond angles, and thermal parameters for this compound have been deposited at the Cambridge Crystallographic Data Centre. CCDC 2344514 contains supplementary crystallographic data.



Bond precision: C-C = 0.0022 A Wavelength = 0.71076

Cell: a=7.8789 (9) b=14.2204 (13) c=10.1298 (19)

alpha=90 beta=110.174 (7) gamma=90

Temperature: 100 K

	Calculated	Reported
Volume	1065.3 (3)	1065.3 (3)
Space group	P 21	P 21
Hall group	P 2yb	P 2yb
Moiety formula	$C_{24}H_{25}NO_6$	?
Sum formula	$C_{24}H_{25}NO_6$	$C_{24}H_{25}NO_6$
Mr	423.45	423.45
Dx, g cm^{-3}	1.320	1.320
Z	2	2

Mu (mm^{-1})	0.095	0.095
F000	448.0	448.0
F000’	448.24	
h, k, lmax	11, 20, 14	11, 20, 14
Nref	6535[3388]	6437
Tmin, Tmax		
Tmin′	0.973	

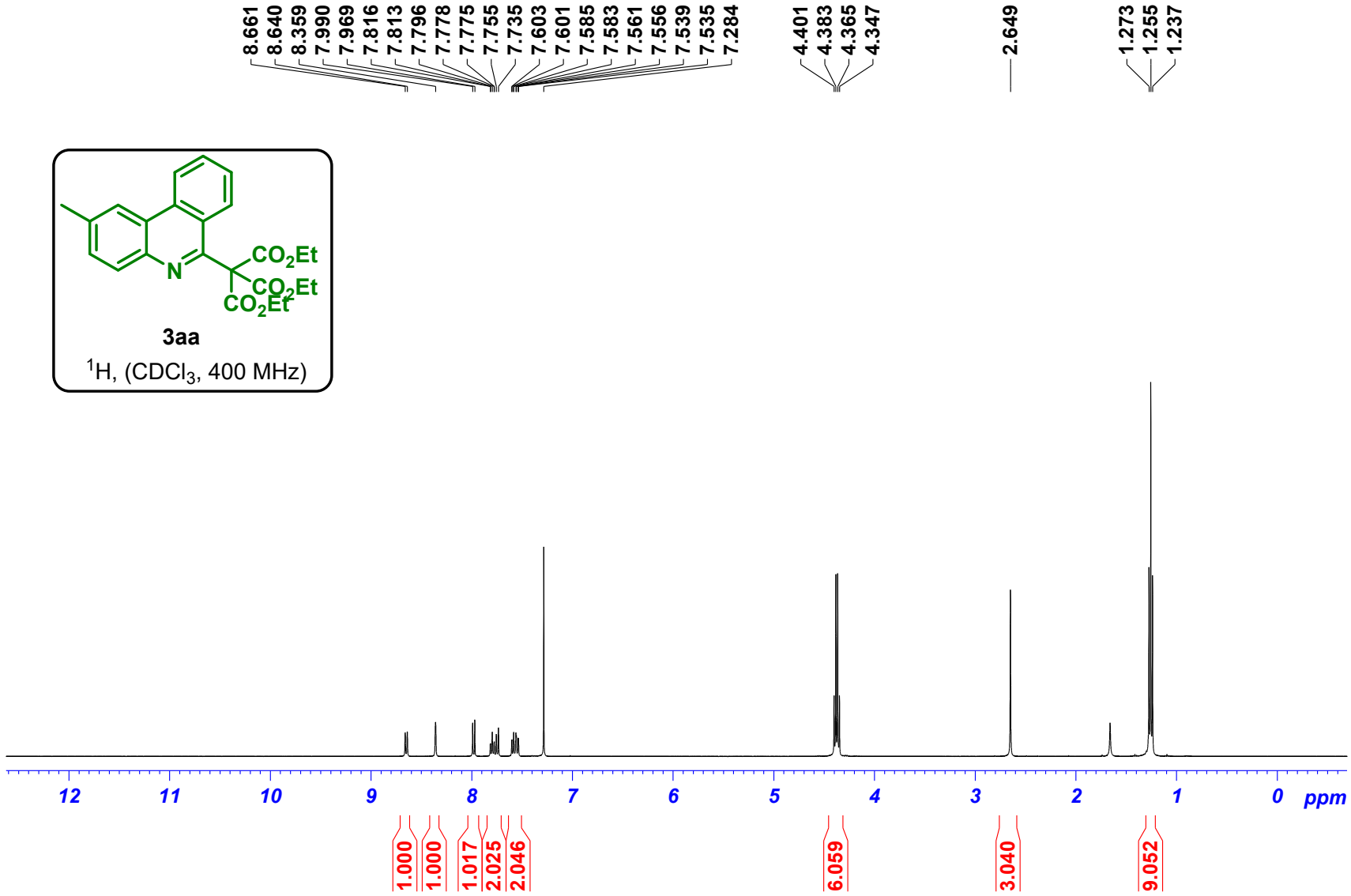
Correction method= Not given

Data completeness= 1.90/0.99; Theta(max)= 30.564; R (reflections) = 0.0336 (6269); S =1.086; Npar= 284; wR2 (reflections) = 0.0925 (6437).

References:

1. (a) M. Tobisu, K. Koh, T. Furukawa and N. Chatani, *Angew. Chem. Int. Ed.*, 2012, **51**, 11363 –11366. (b) J. Rong, L. Deng, P. Tan, C. Ni, Y. Gu and J. Hu, *Angew. Chem. Int. Ed.*, 2016, **55**, 2743 –2747.
2. C. B. Kelly, N. R. Patel, D. N. Primer, M. Jouffroy, J. C. Tellis, G. A. Molander, *Nat. Protoc.*, 2017, **12**, 472-492.

Spectras: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CO2Et
CO2Et
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9
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6
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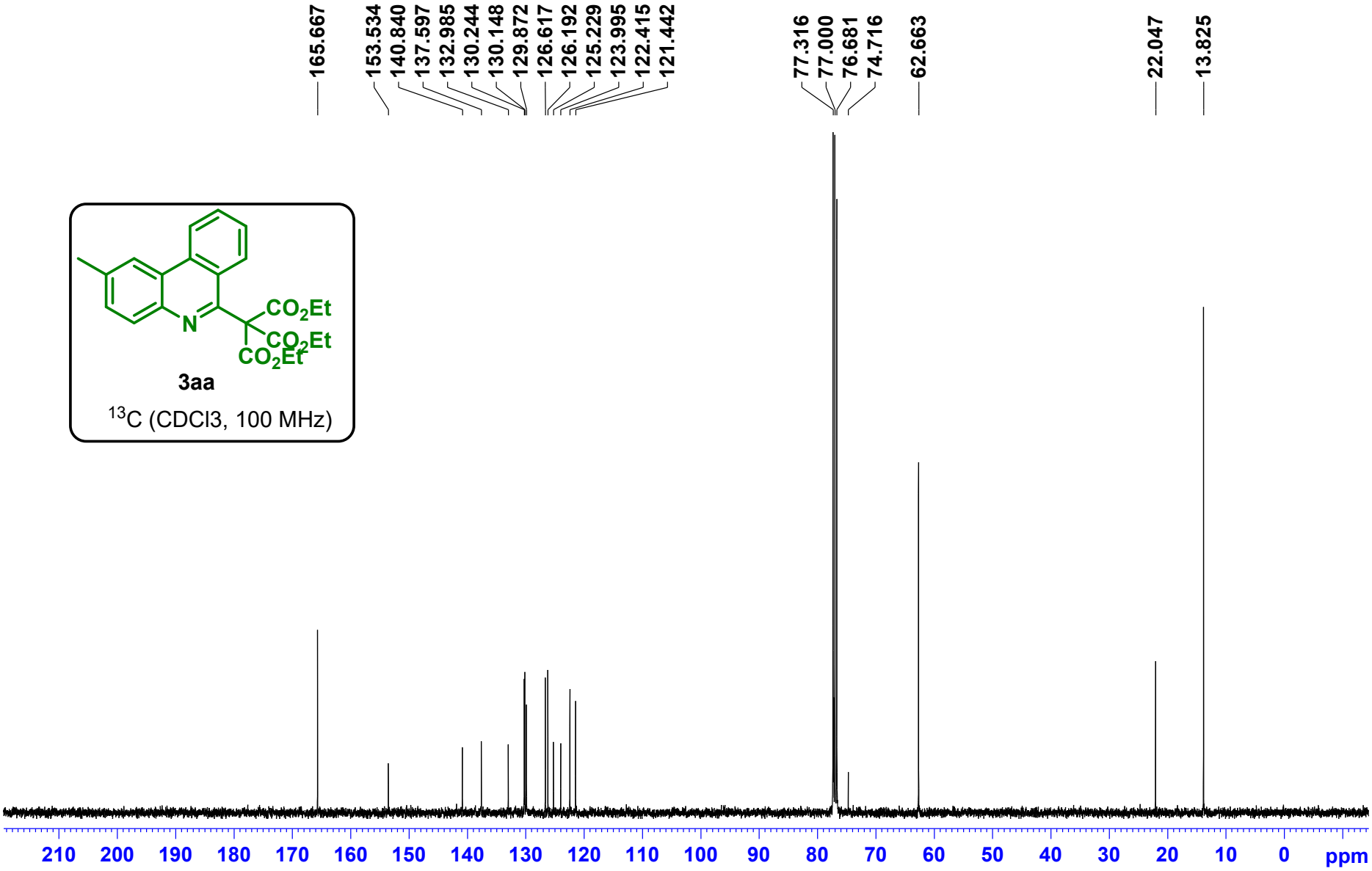
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13.825
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CO2Et
CO2Et
CO2Et
3aa
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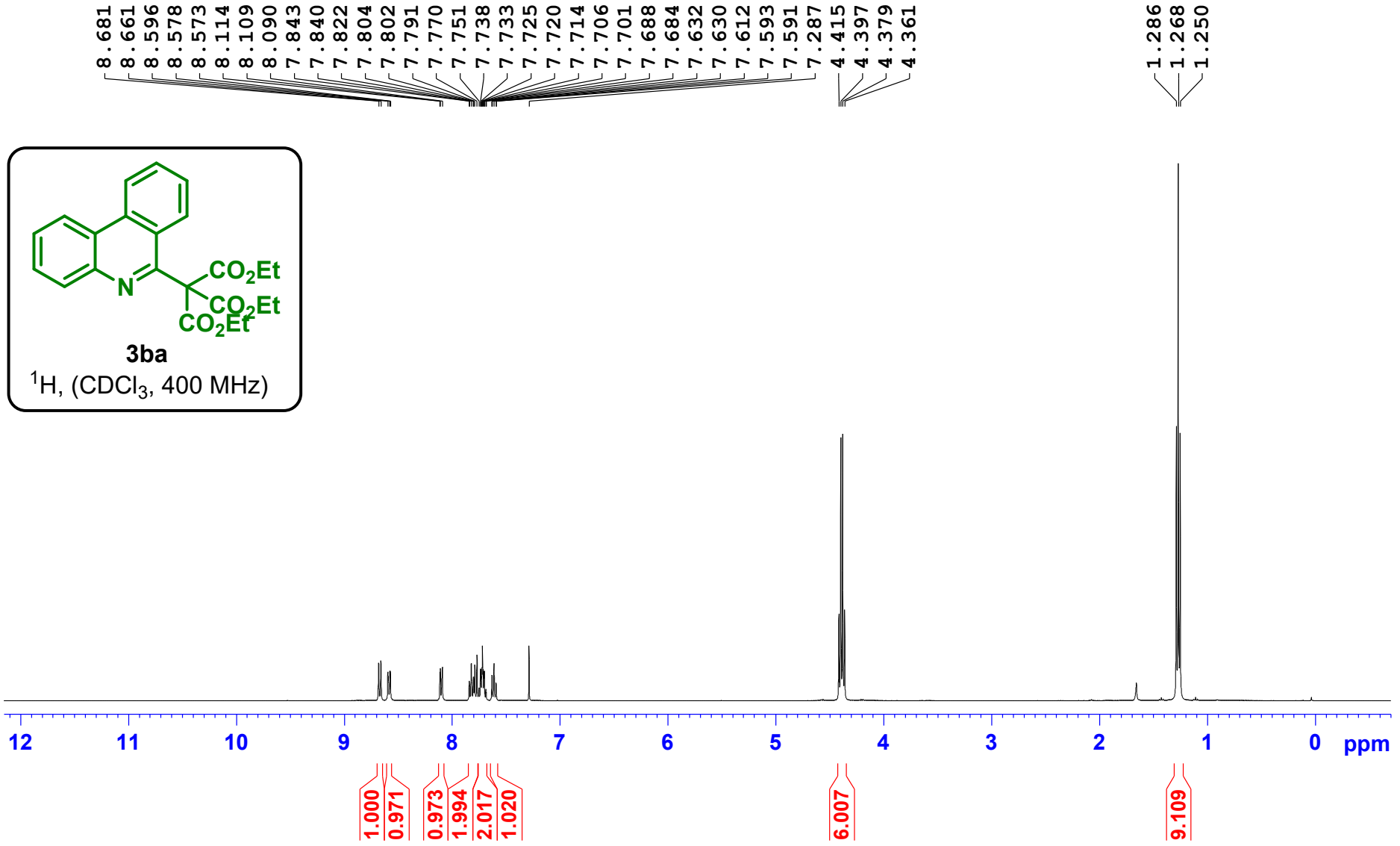
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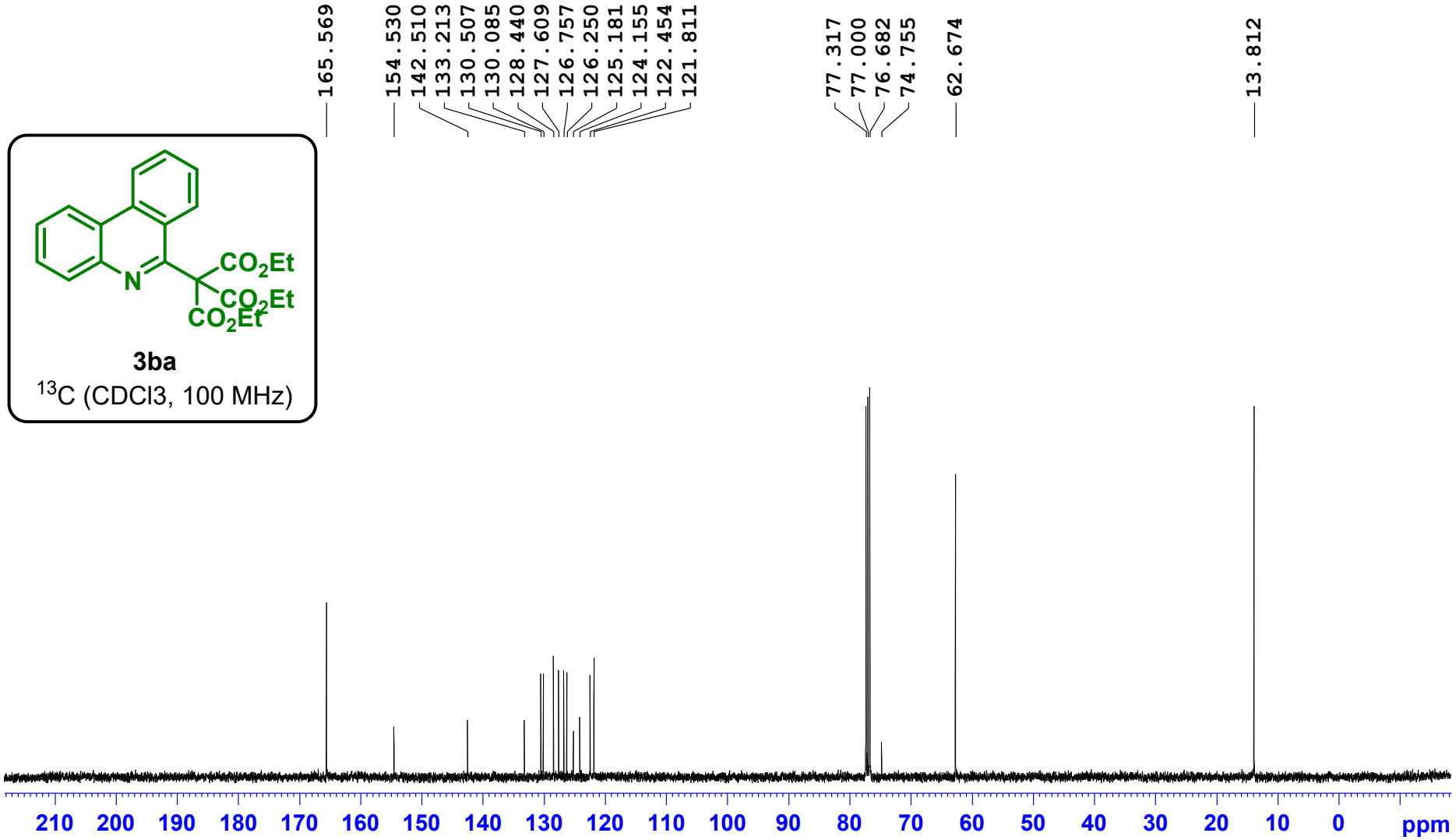
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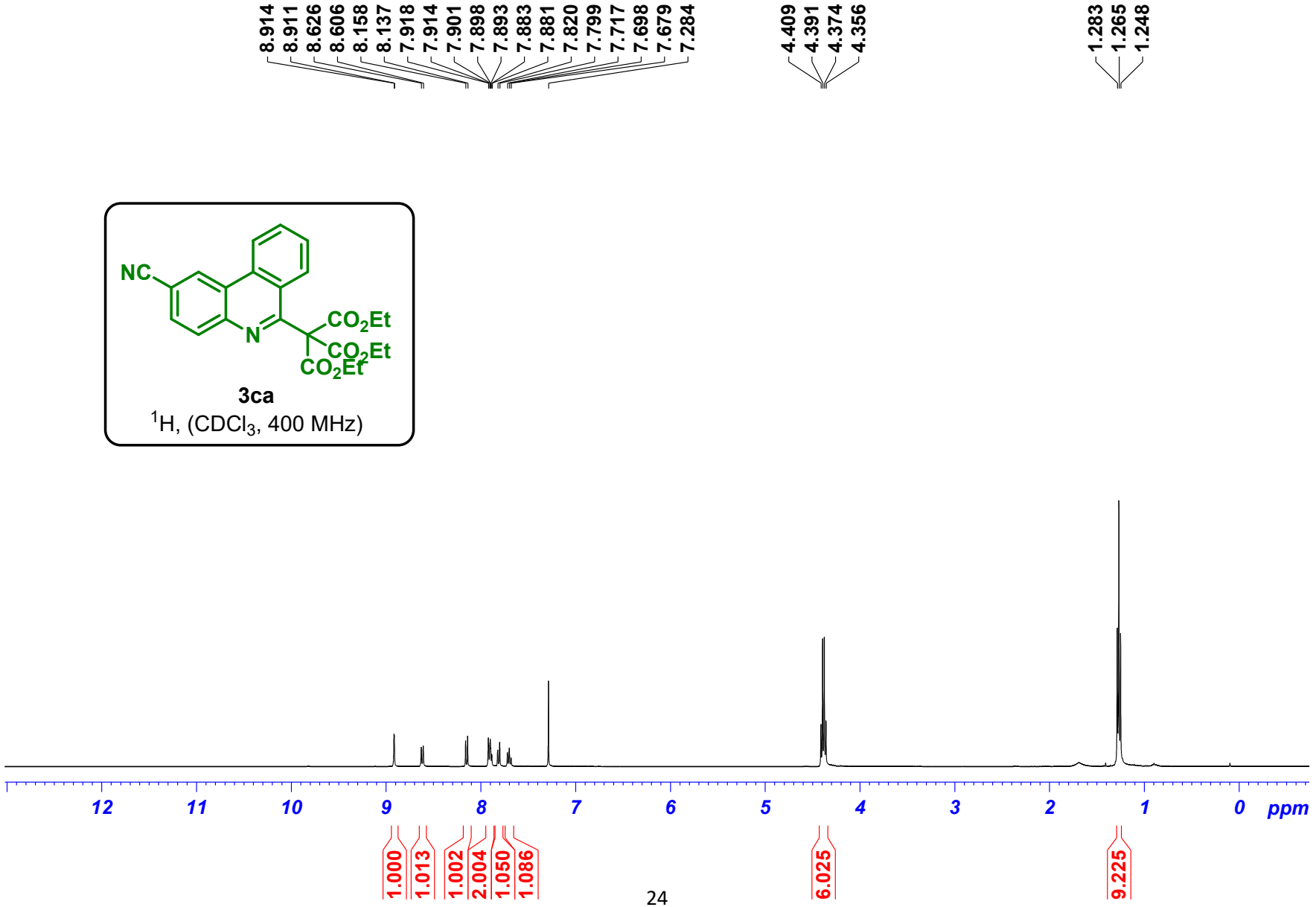
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CO2Et
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ppm
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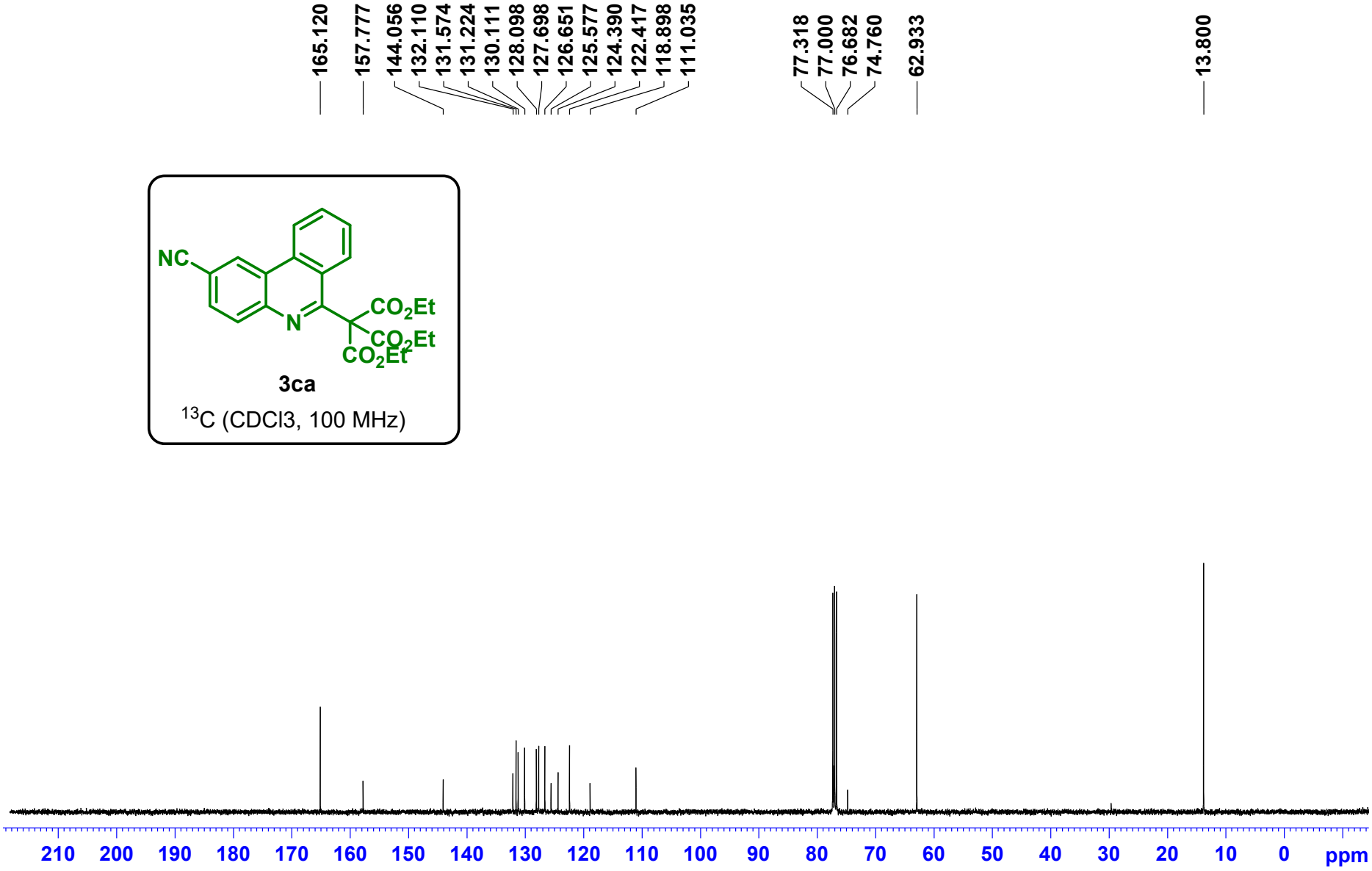
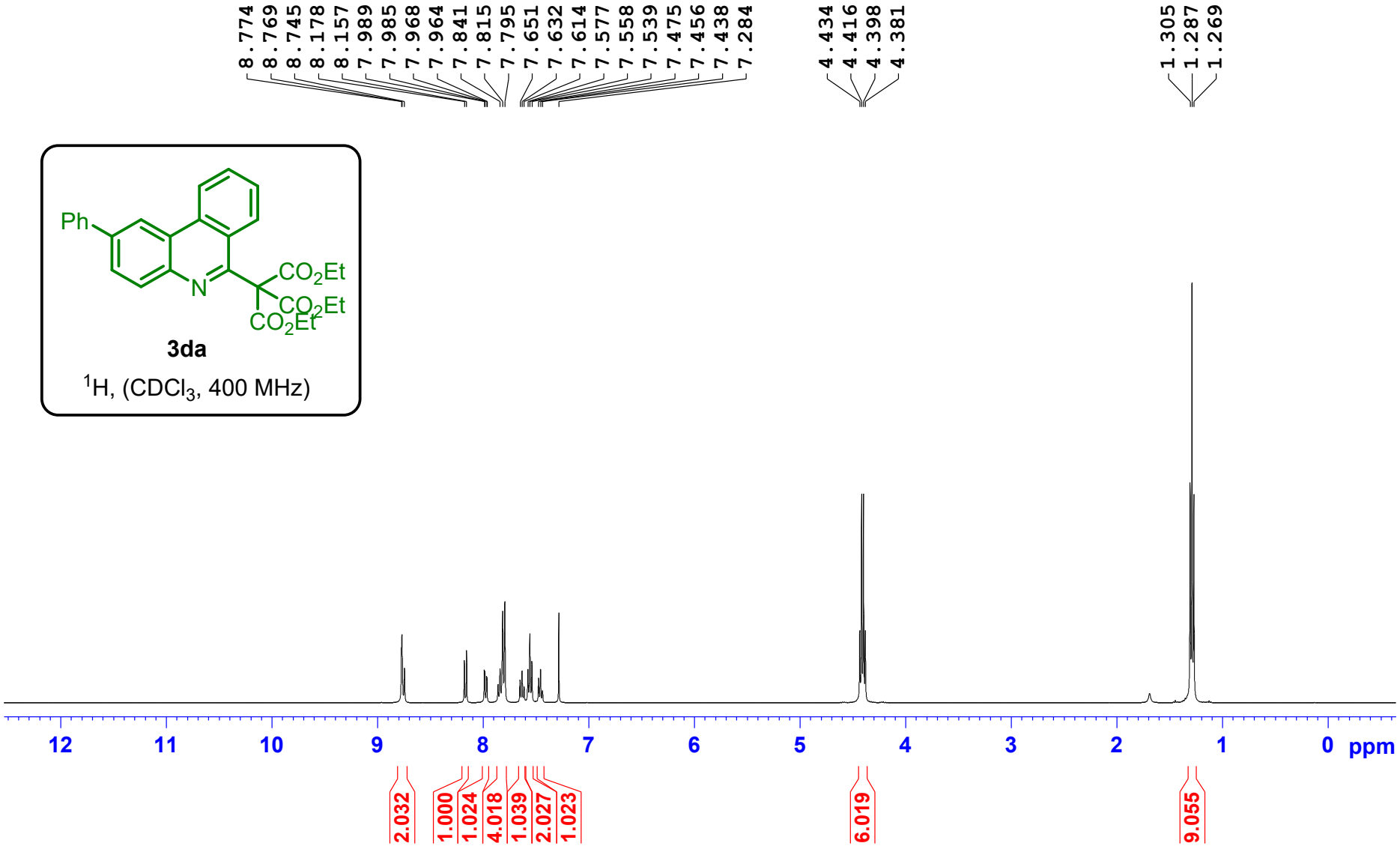
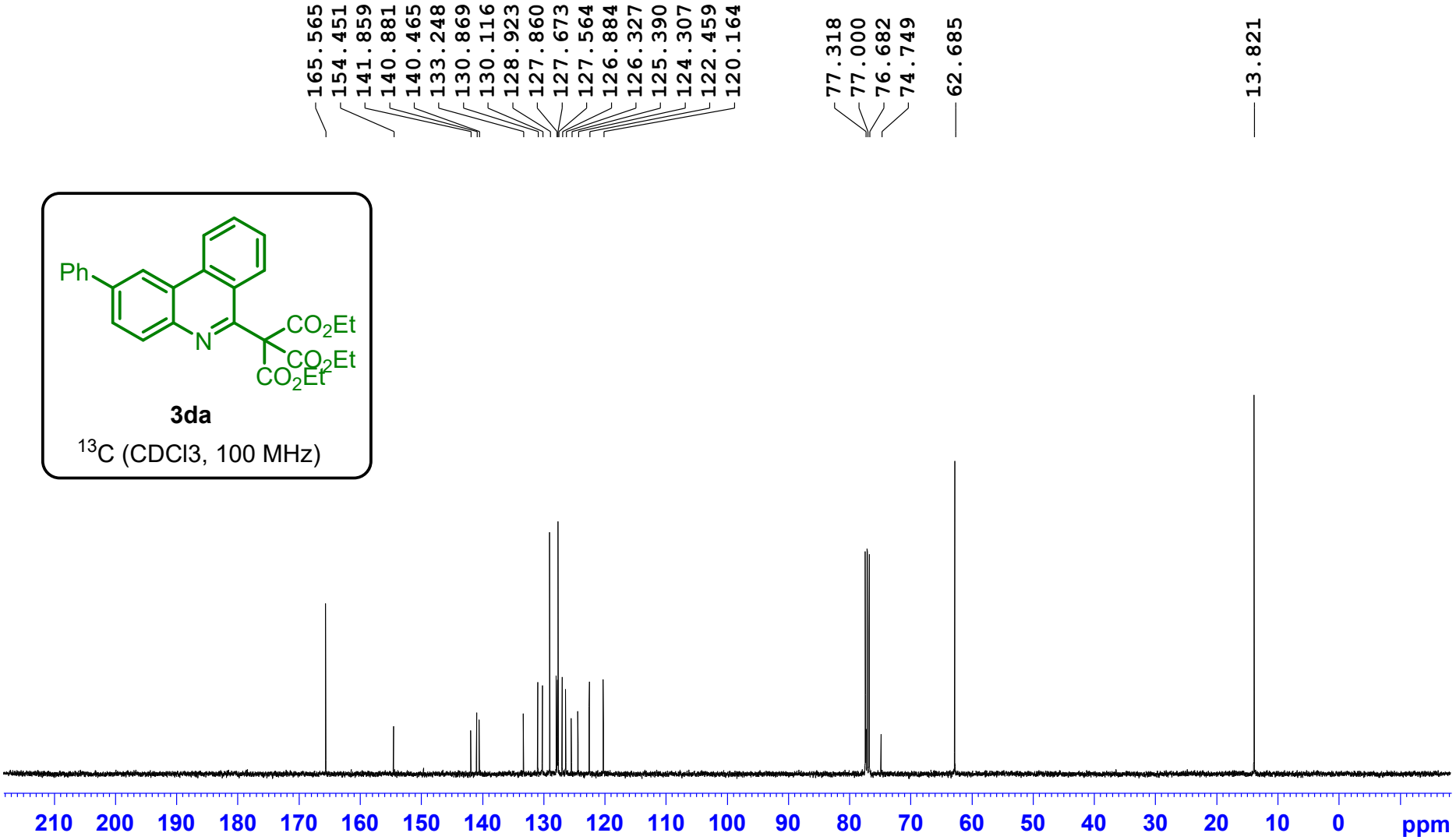
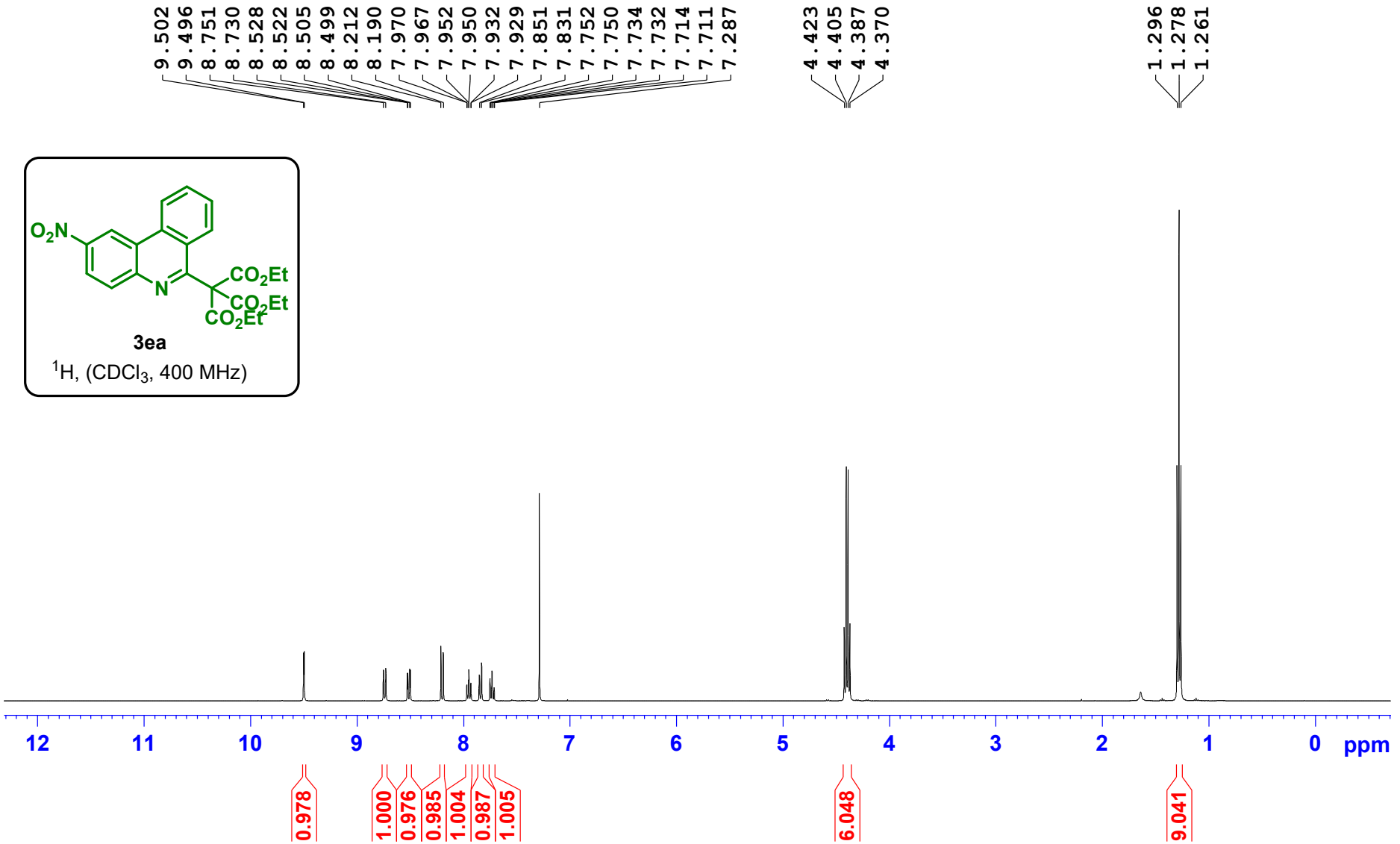
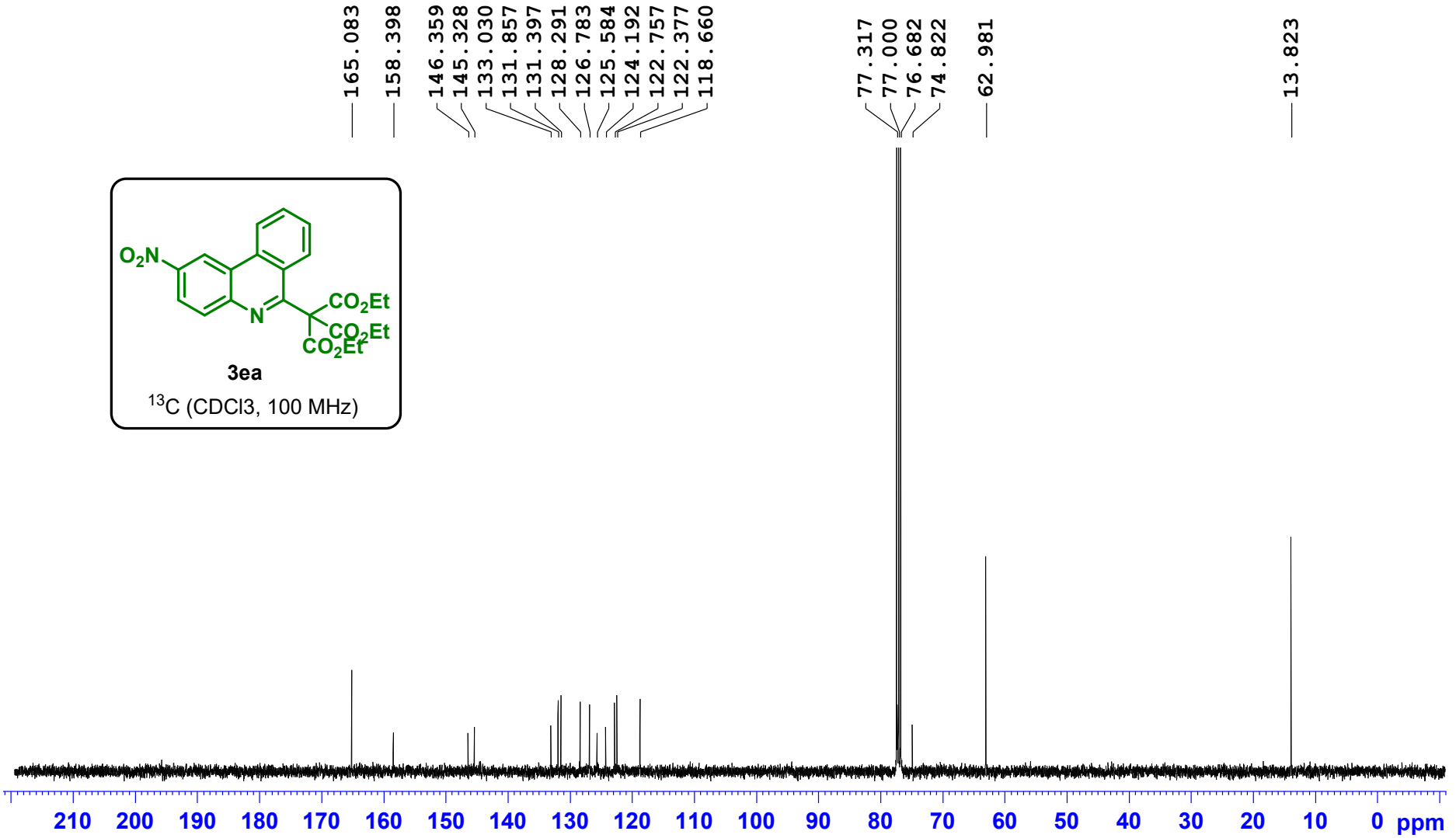
1.013
1.002
2.004
1.050
1.086
6.025
9.225

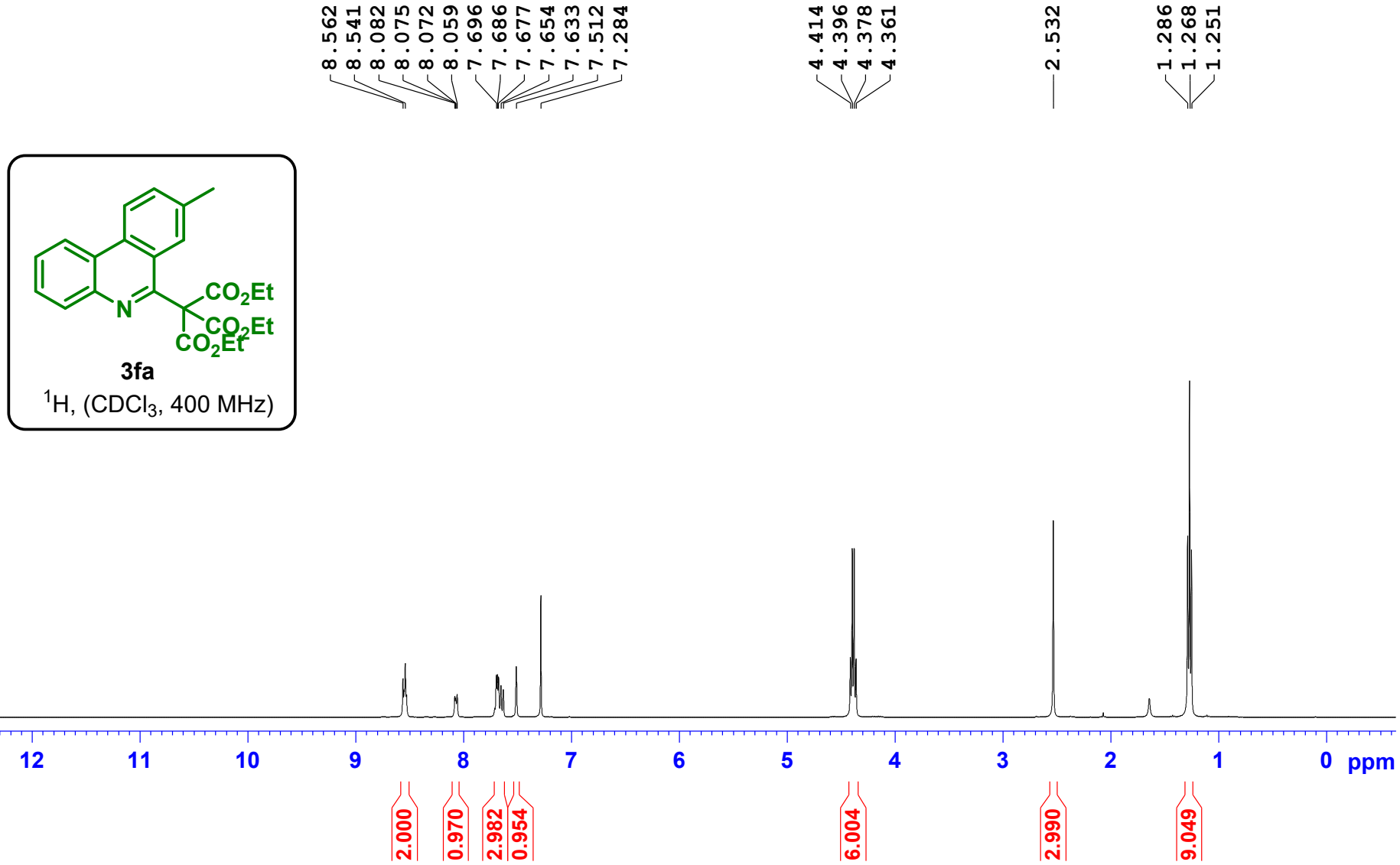

165.120
157.777
144.056
132.110
131.574
131.224
130.111
128.098
127.698
126.651
125.577
124.390
122.417
118.898
111.035
77.318
77.000
76.682
74.760
62.933
13.800
NC
N
CO2Et
CO2Et
CO2Et
3ca
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

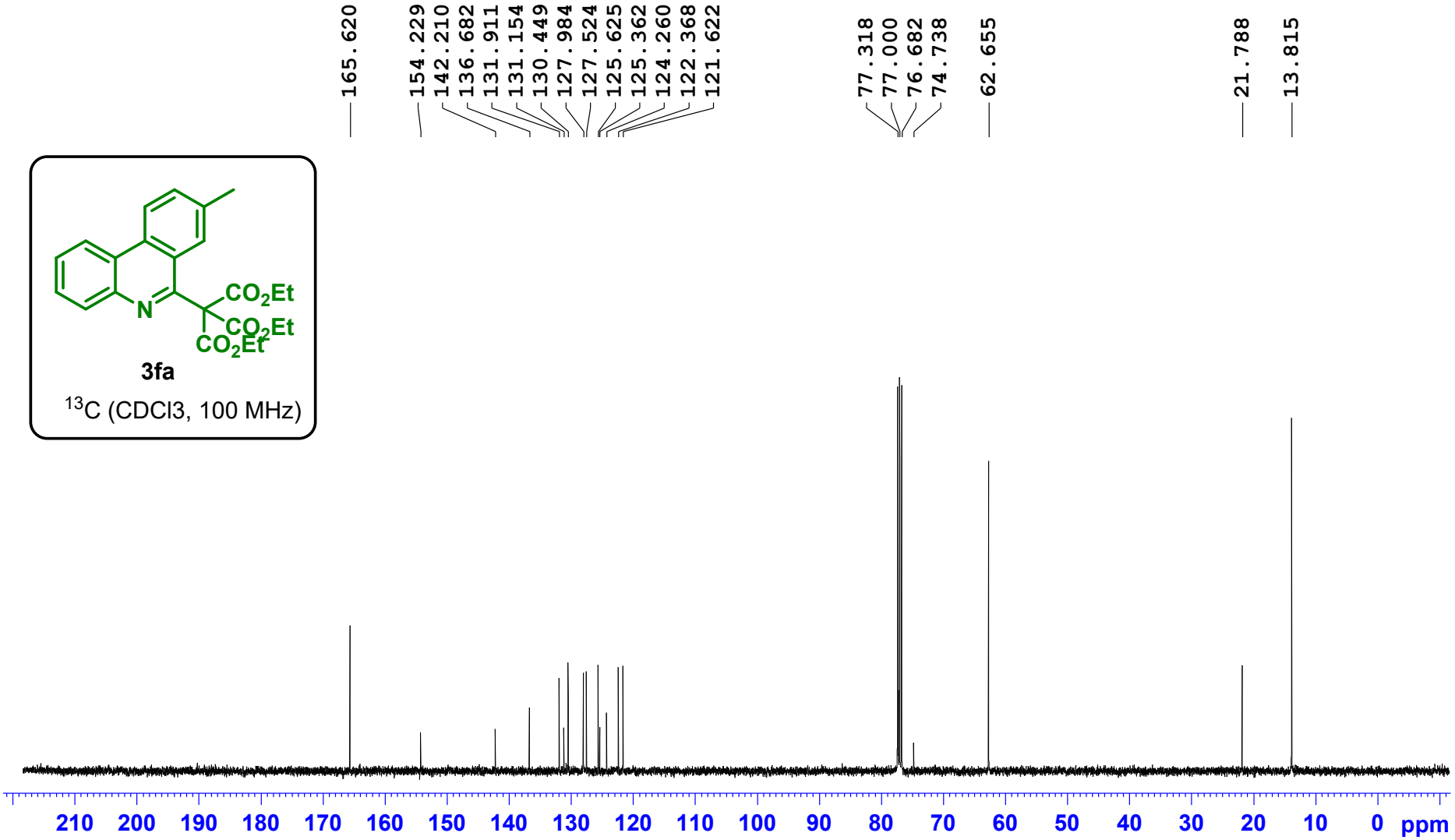

8.774
8.769
8.745
8.178
8.157
7.989
7.985
7.968
7.964
7.841
7.815
7.795
7.651
7.632
7.614
7.577
7.558
7.539
7.475
7.456
7.438
7.284
4.434
4.416
4.398
4.381
1.305
1.287
1.269
Ph
N
CO2Et
CO2Et
CO2Et
3da
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.032
1.000
1.024
4.018
1.039
2.027
1.023
6.019
9.055

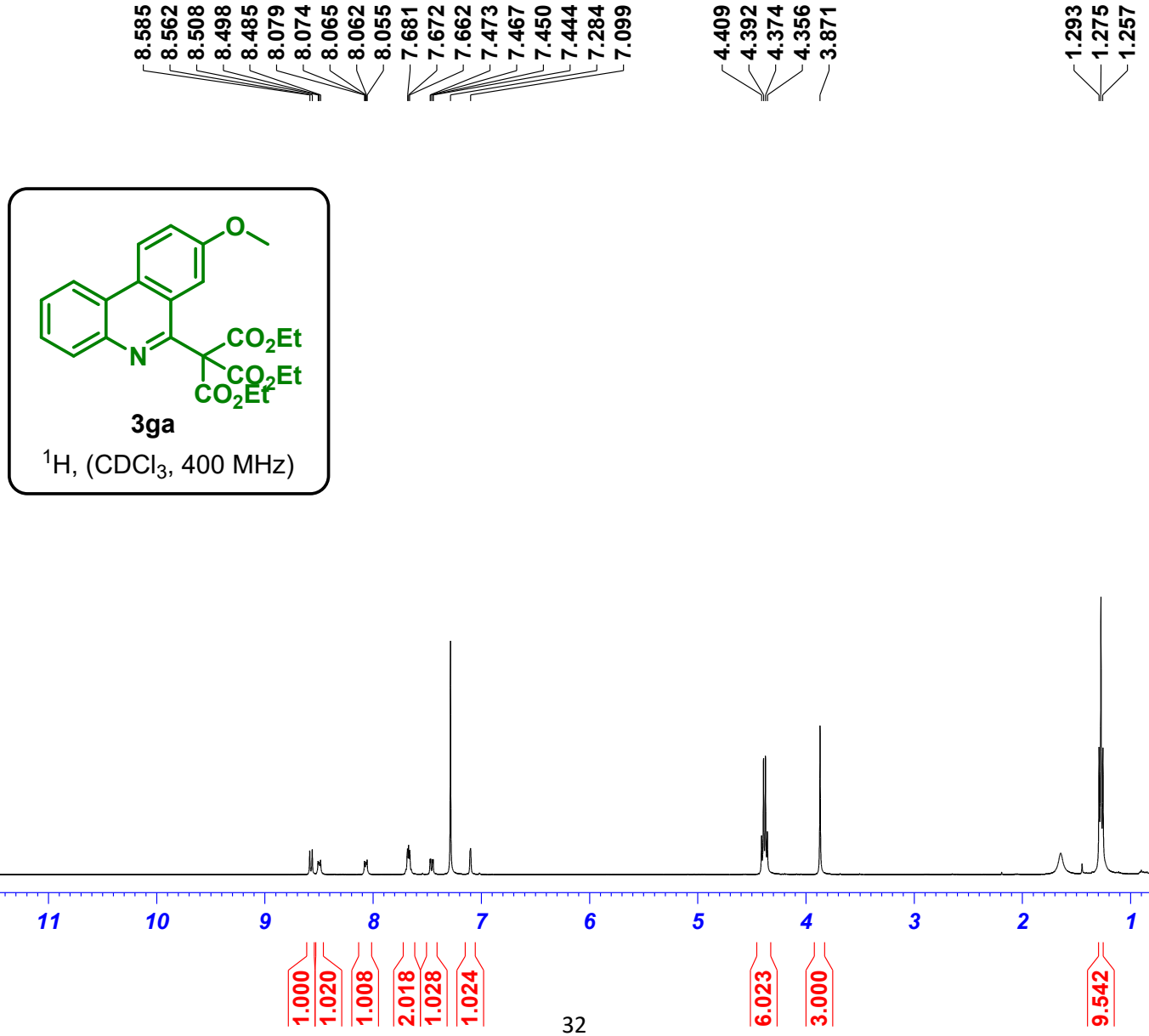

165.565
154.451
141.859
140.881
140.465
133.248
130.869
130.116
128.923
127.860
127.673
127.564
126.884
126.327
125.390
124.307
122.459
120.164
77.318
77.000
76.682
74.749
62.685
13.821
Ph
N
CO2Et
CO2Et
CO2Et
3da
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

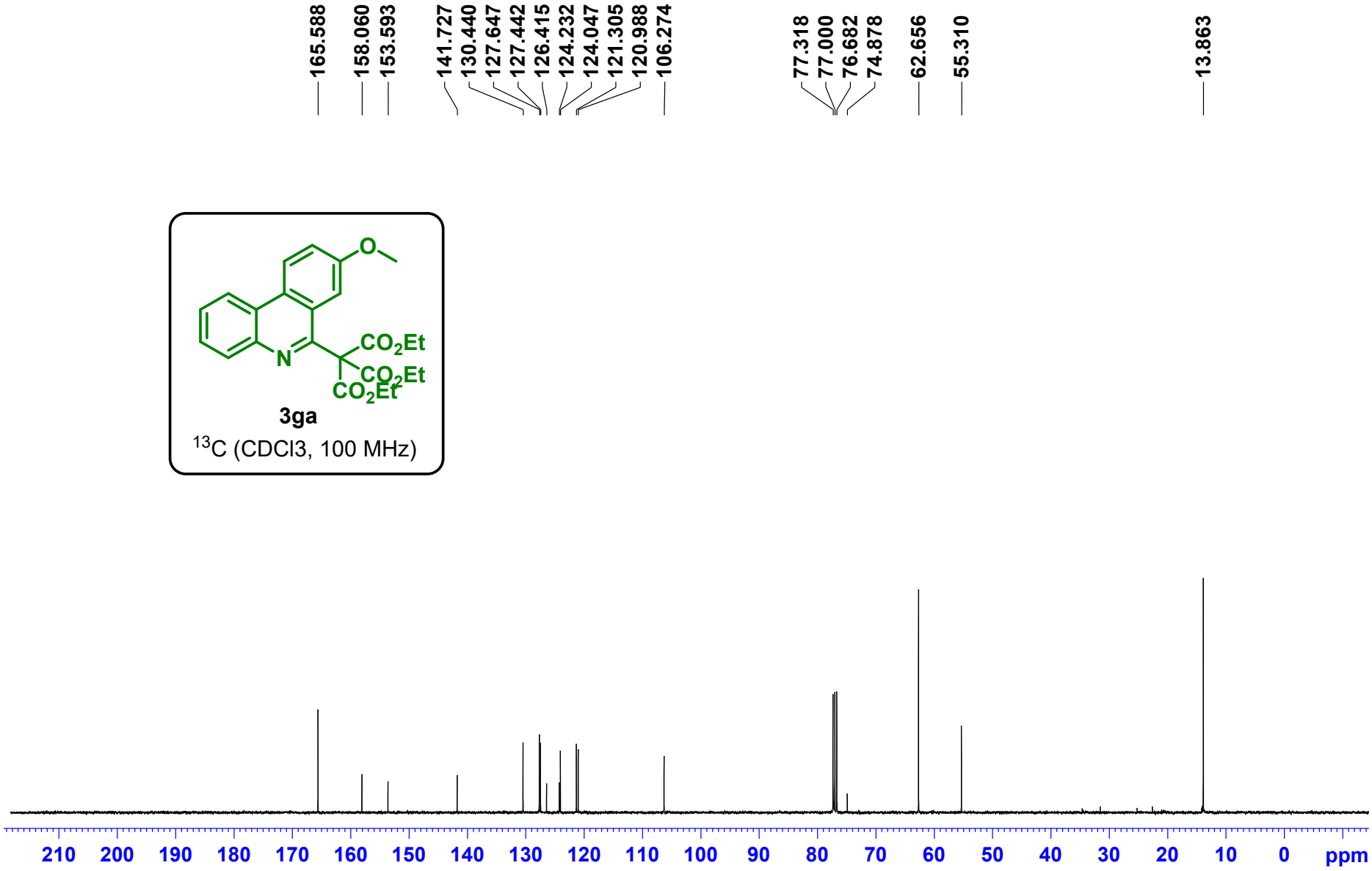

9.502
9.496
8.751
8.730
8.528
8.522
8.505
8.499
8.212
8.190
7.970
7.967
7.952
7.950
7.932
7.929
7.851
7.831
7.752
7.750
7.734
7.732
7.714
7.711
7.287
4.423
4.405
4.387
4.370
1.296
1.278
1.261
O2N
CO2Et
CO2Et
CO2Et
N
3ea
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.978
1.000
0.976
0.985
1.004
0.987
1.005
6.048
9.041

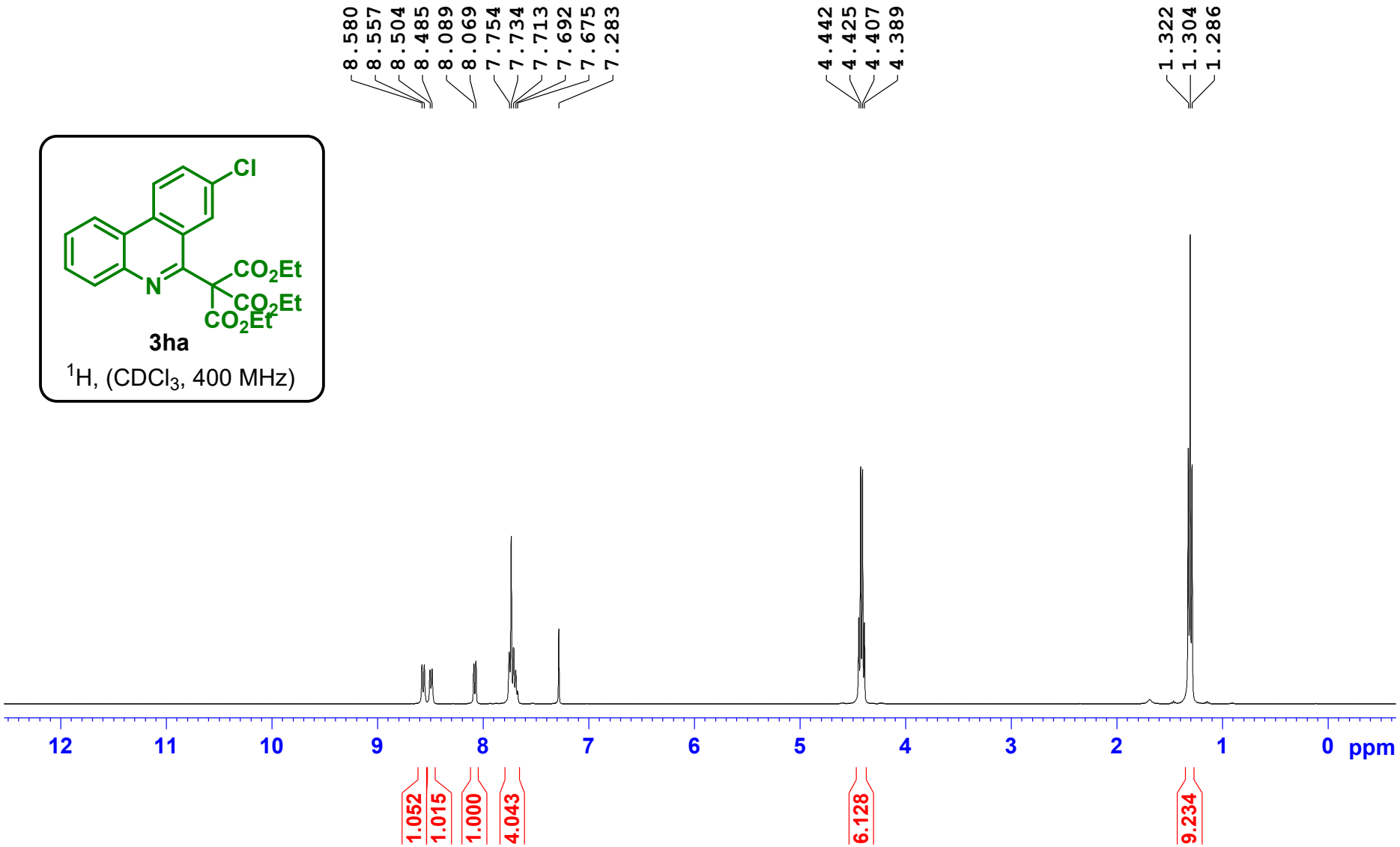

165.083
158.398
146.359
145.328
133.030
131.857
131.397
128.291
126.783
125.584
124.192
122.757
122.377
118.660
77.317
77.000
76.682
74.822
62.981
13.823
O2N
CO2Et
CO2Et
CO2Et
N
3ea
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

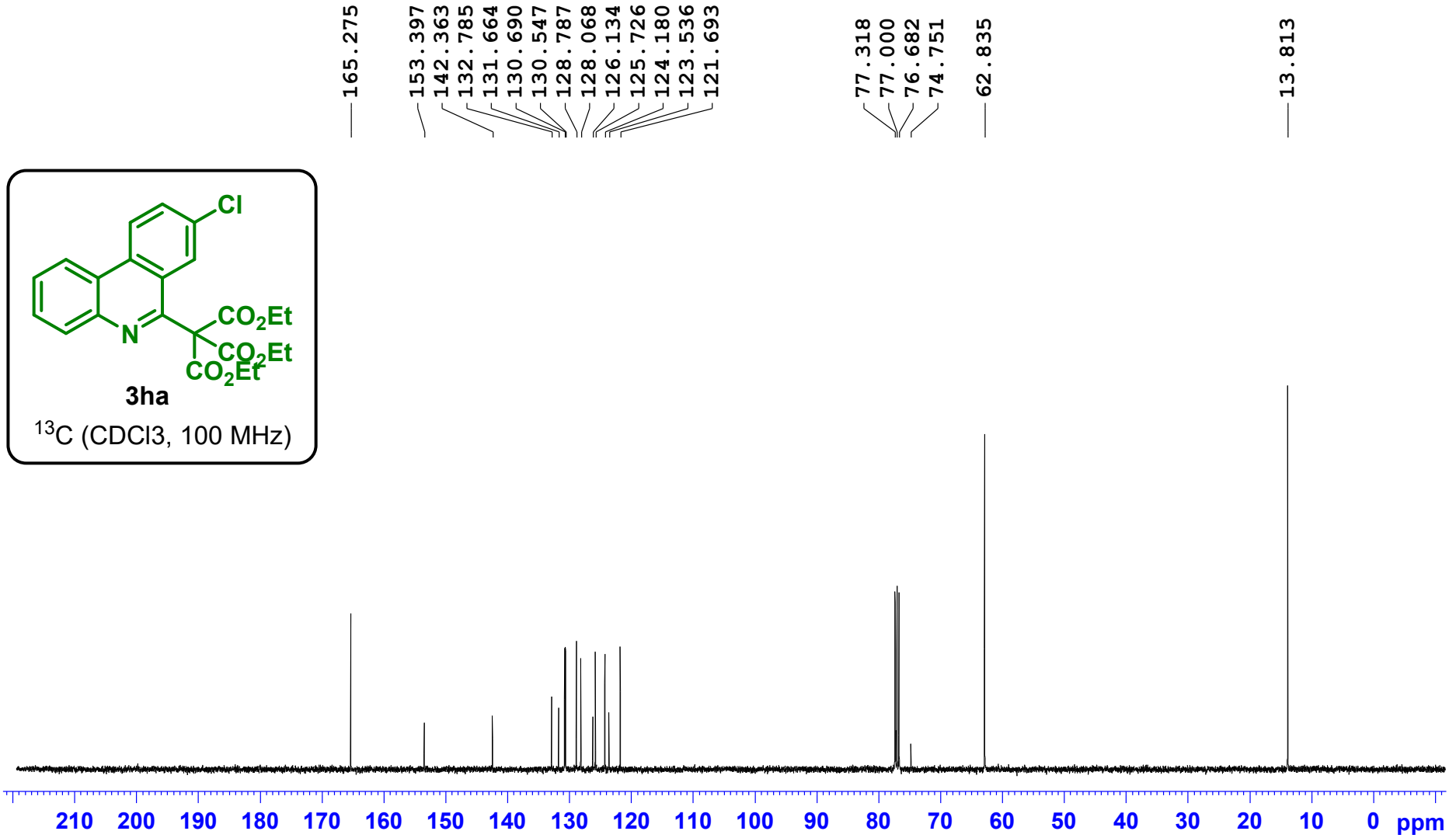

8.562
8.541
8.082
8.075
8.072
8.059
7.696
7.686
7.677
7.654
7.633
7.512
7.284
4.414
4.396
4.378
4.361
2.532
1.286
1.268
1.251
CO2Et
CO2Et
CO2Et
N
3fa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.000
0.970
2.982
0.954
6.004
2.990
9.049

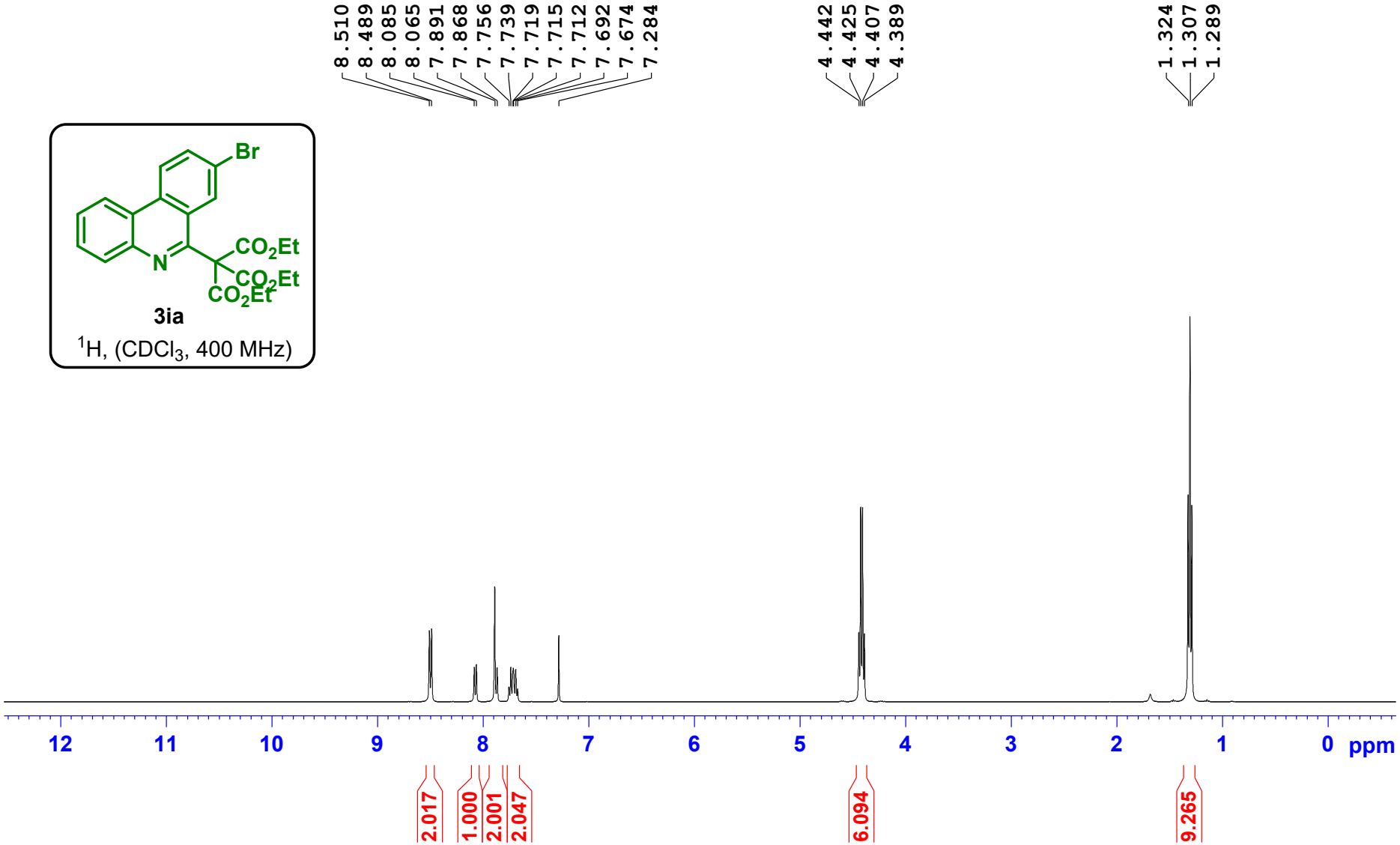

165.620
154.229
142.210
136.682
131.911
131.154
130.449
127.984
127.524
125.625
125.362
124.260
122.368
121.622
77.318
77.000
76.682
74.738
62.655
21.788
13.815
CO2Et
CO2Et
CO2Et
N
3fa
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

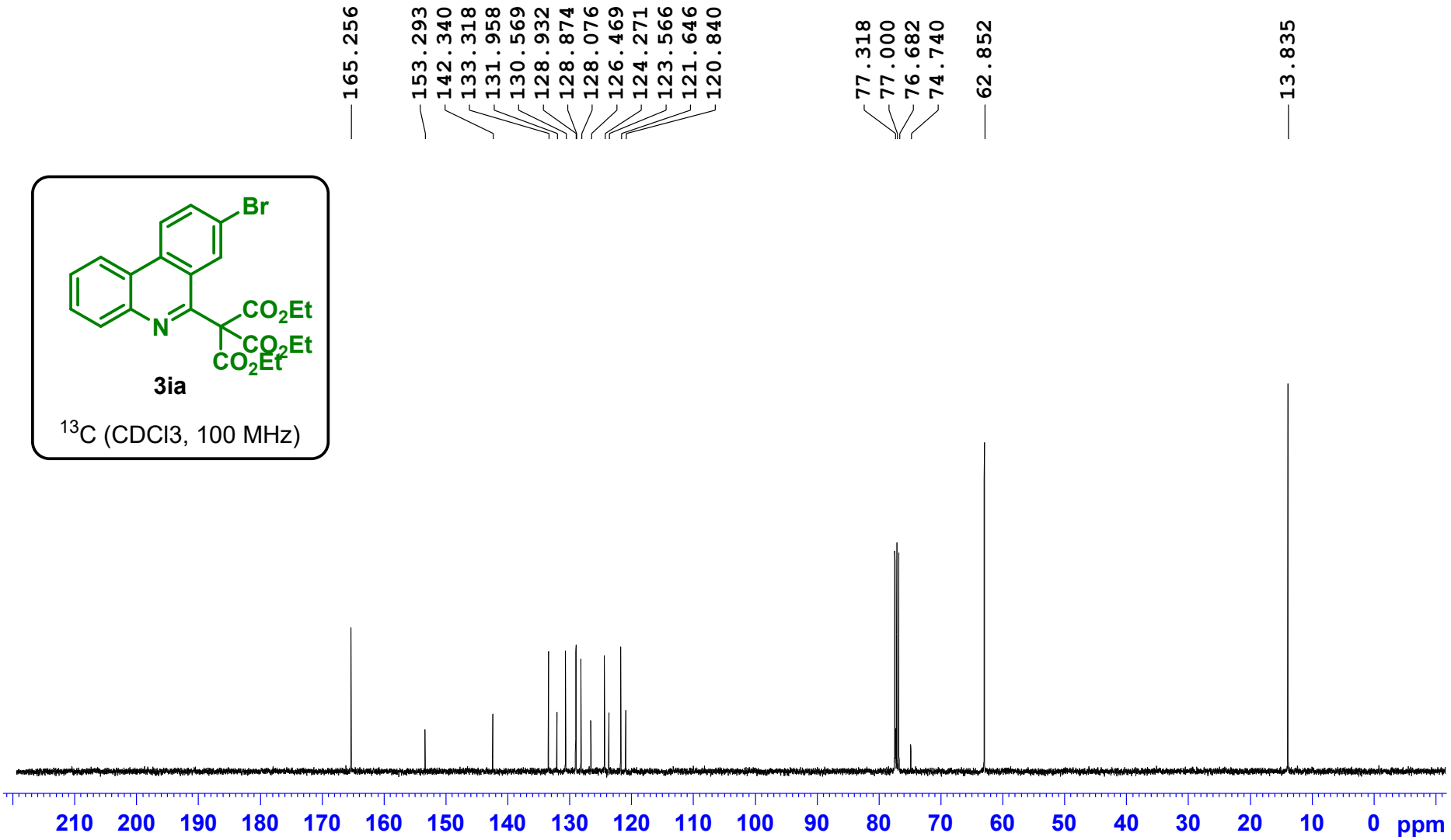

8.585
8.562
8.508
8.498
8.485
8.079
8.074
8.065
8.062
8.055
7.681
7.672
7.662
7.473
7.467
7.450
7.444
7.284
7.099
4.409
4.392
4.374
4.356
3.871
1.293
1.275
1.257
O
CO2Et
N
CO2Et
CO2Et
3ga
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.020
1.008
2.018
1.028
1.024
6.023
3.000
9.542

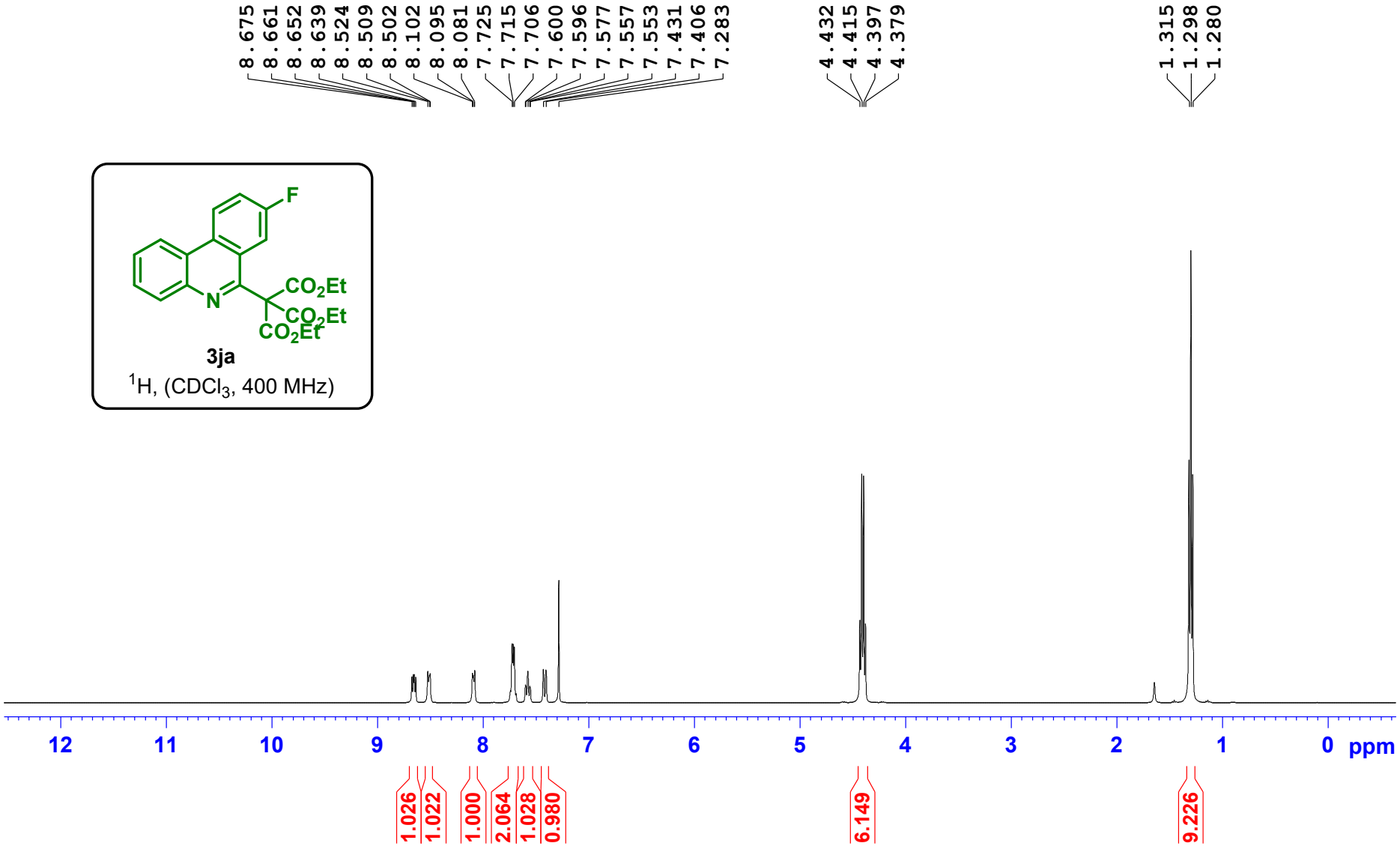

165.588
158.060
153.593
141.727
130.440
127.647
127.442
126.415
124.232
124.047
121.305
120.988
106.274
77.318
77.000
76.682
74.878
62.656
55.310
13.863
O
N
CO2Et
CO2Et
CO2Et
3ga
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

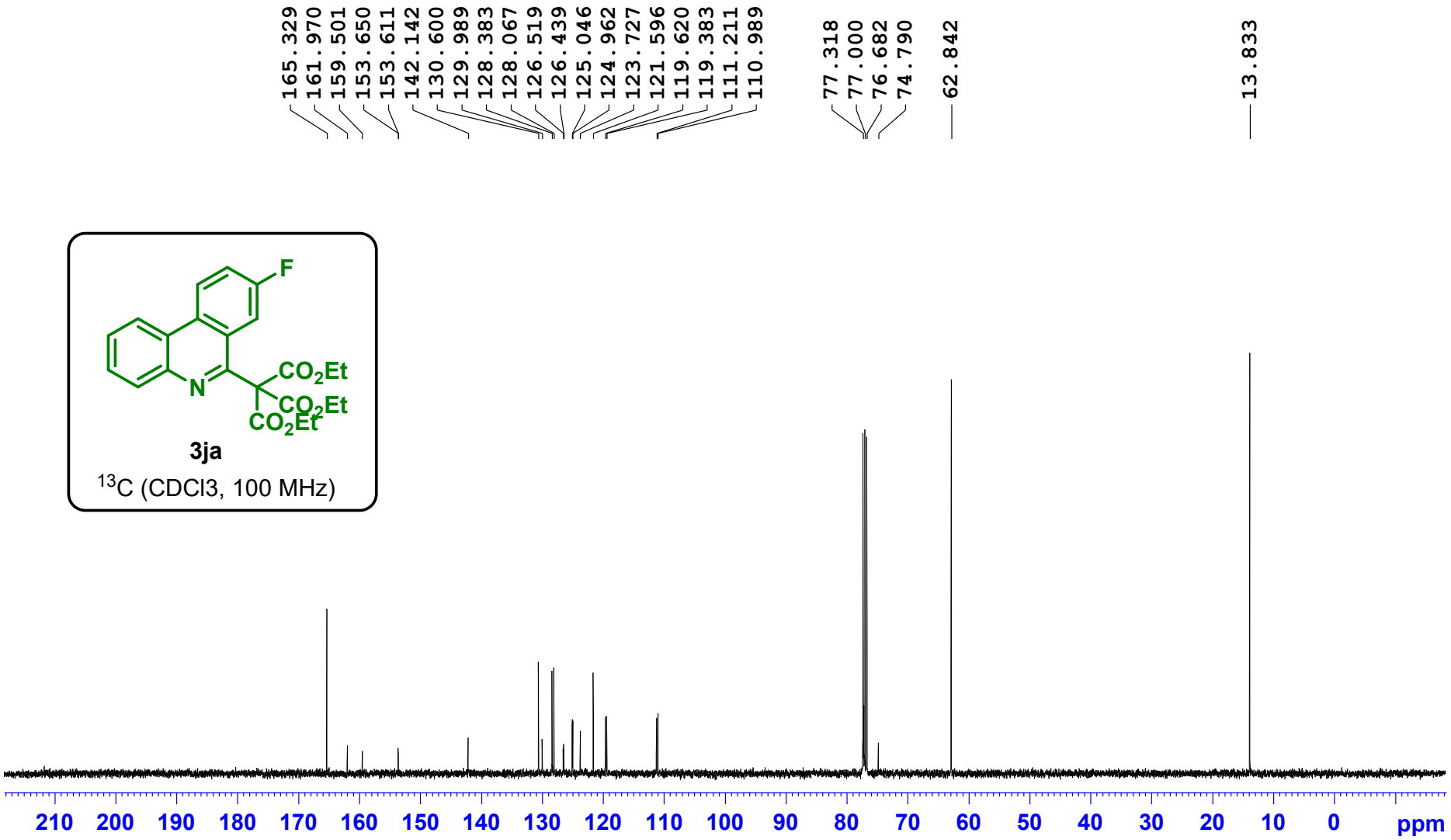

8.580
8.557
8.504
8.485
8.089
8.069
7.754
7.734
7.713
7.692
7.675
7.283
4.442
4.425
4.407
4.389
1.322
1.304
1.286
Cl
CO2Et
CO2Et
CO2Et
N
3ha
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.052
1.015
1.000
4.043
6.128
9.234

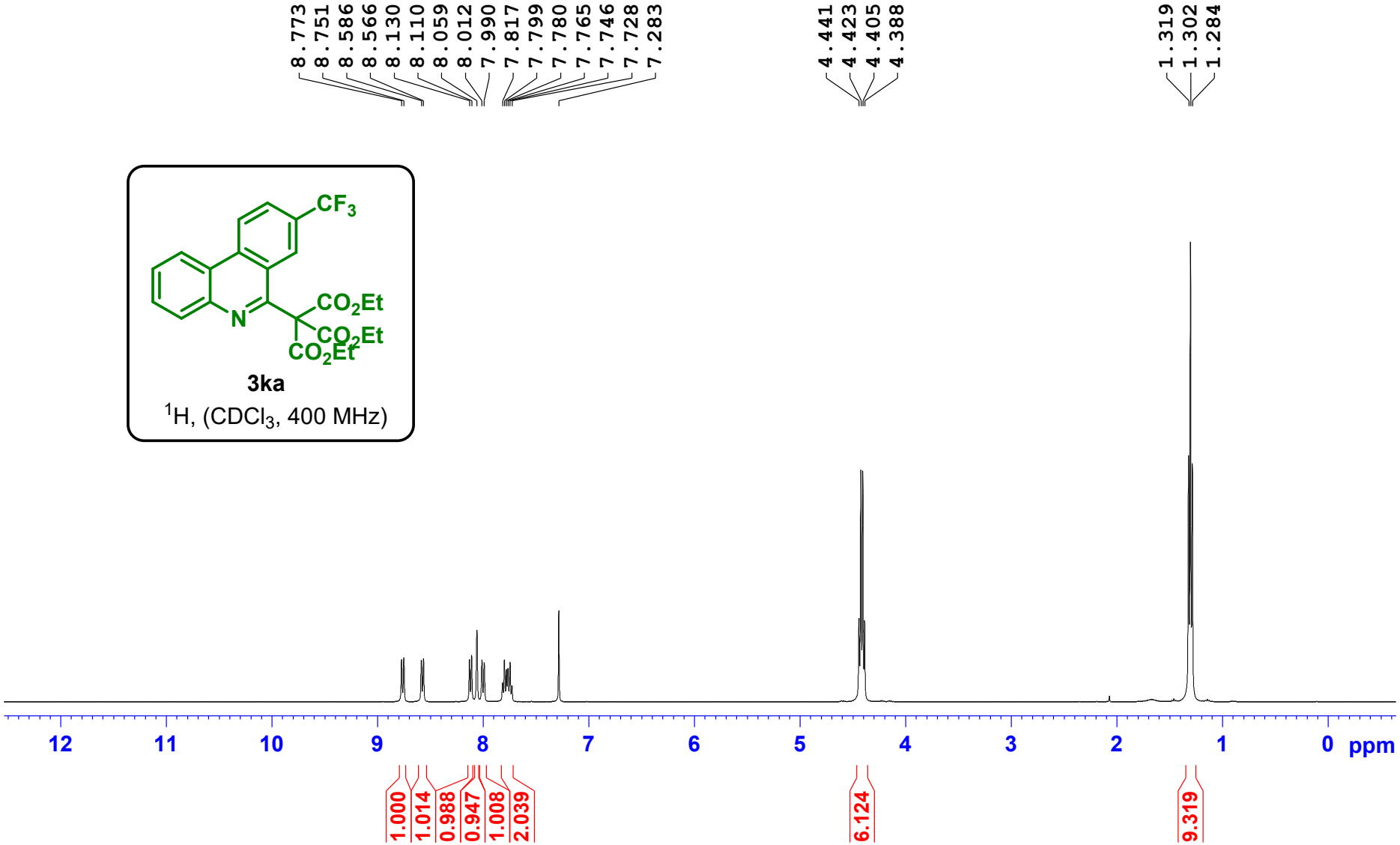

165.275
153.397
142.363
132.785
131.664
130.690
130.547
128.787
128.068
126.134
125.726
124.180
123.536
121.693
77.318
77.000
76.682
74.751
62.835
13.813
Cl
N
CO2Et
CO2Et
CO2Et
3ha
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

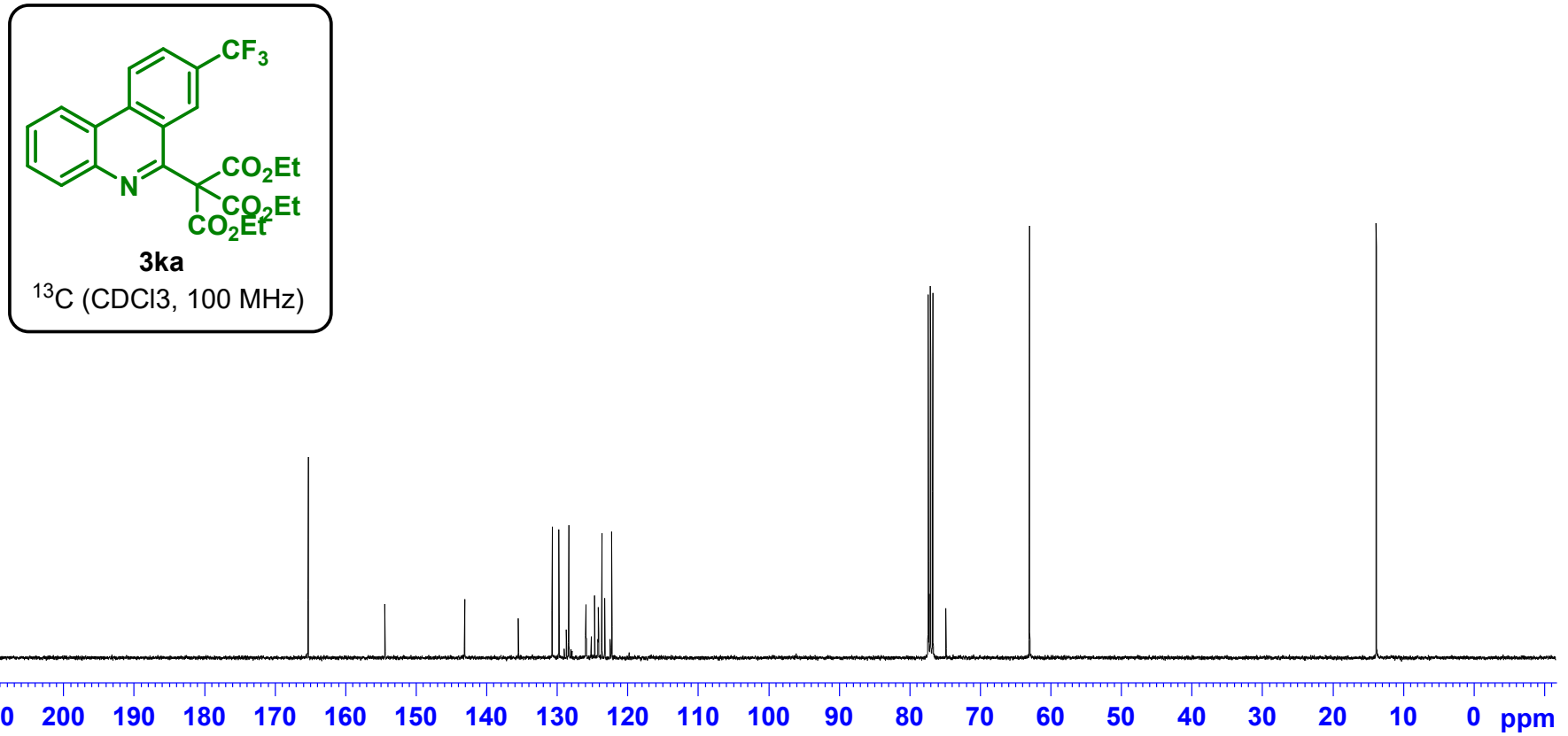

8.510
8.489
8.085
8.065
7.891
7.868
7.756
7.739
7.719
7.715
7.712
7.692
7.674
7.284
4.442
4.425
4.407
4.389
1.324
1.307
1.289
Br
N
CO2Et
CO2Et
CO2Et
3ia
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
2.017
1.000
2.001
2.047
6.094
9.265

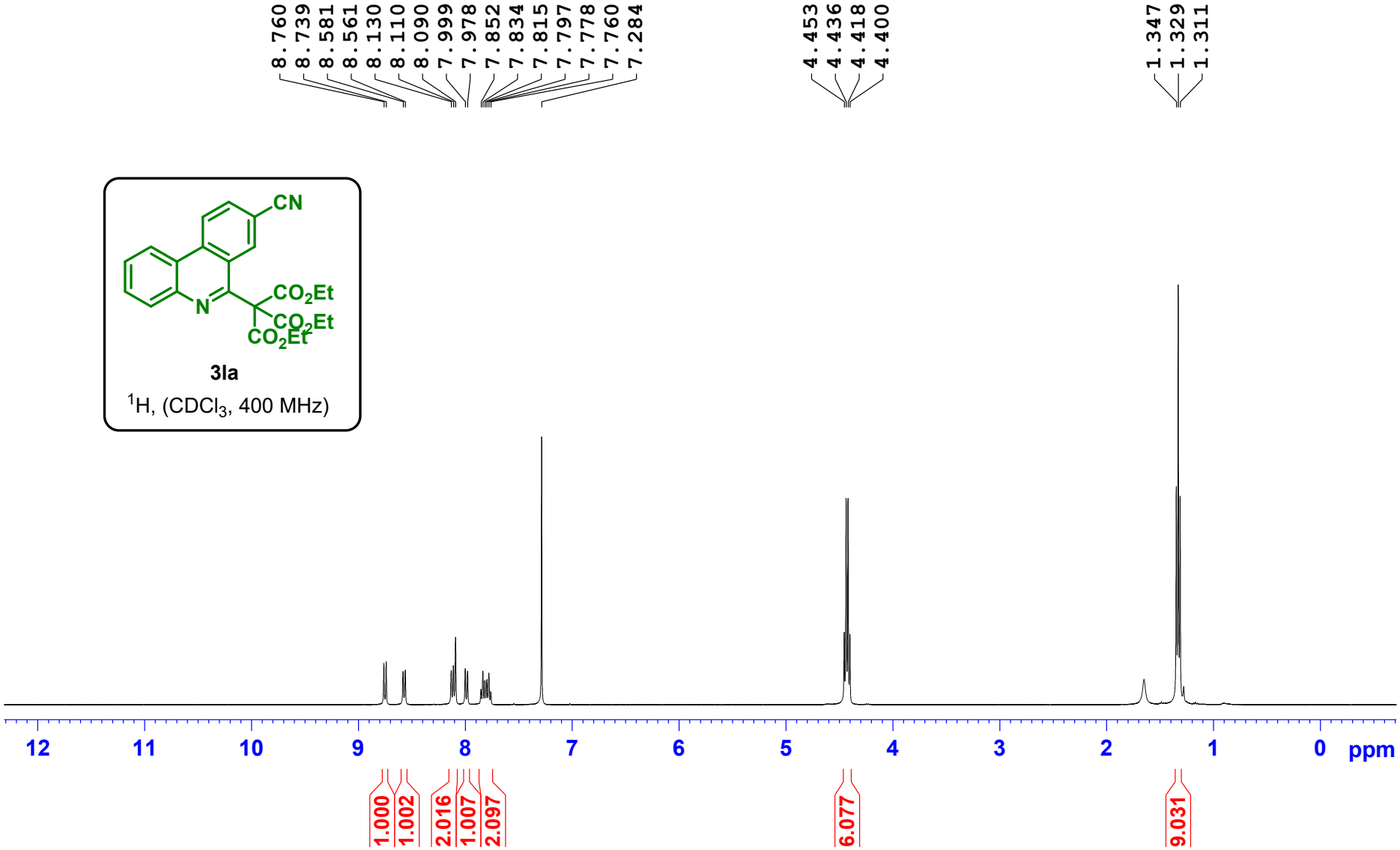

165.256
153.293
142.340
133.318
131.958
130.569
128.932
128.874
128.076
126.469
124.271
123.566
121.646
120.840
77.318
77.000
76.682
74.740
62.852
13.835
Br
CO2Et
CO2Et
CO2Et
N
3ia
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

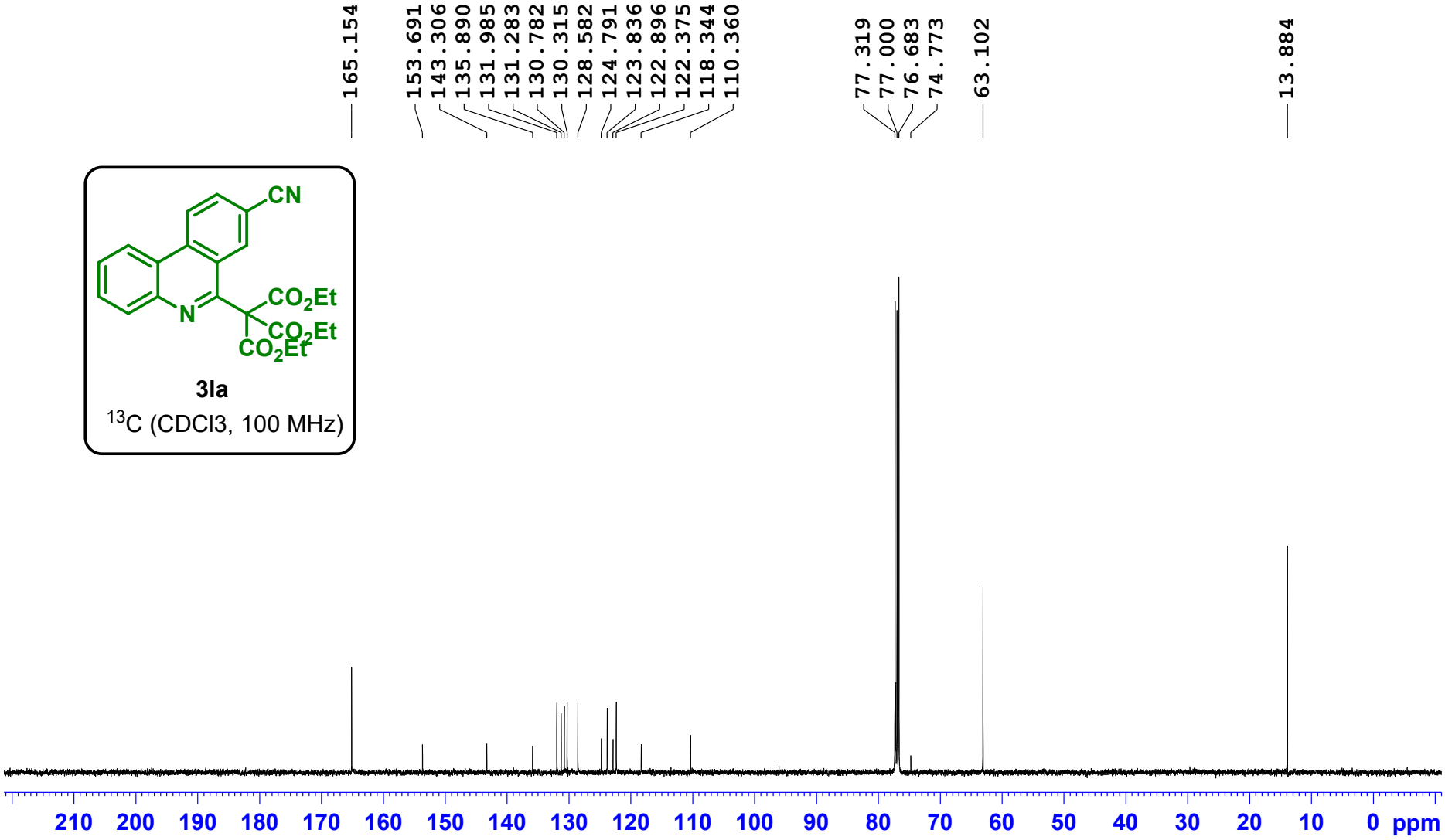

8.675
8.661
8.652
8.639
8.524
8.509
8.502
8.102
8.095
8.081
7.725
7.715
7.706
7.600
7.596
7.577
7.557
7.553
7.431
7.406
7.283
4.432
4.415
4.397
4.379
1.315
1.298
1.280
F
CO2Et
CO2Et
CO2Et
N
3ja
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.026
1.022
1.000
2.064
1.028
0.980
6.149
9.226

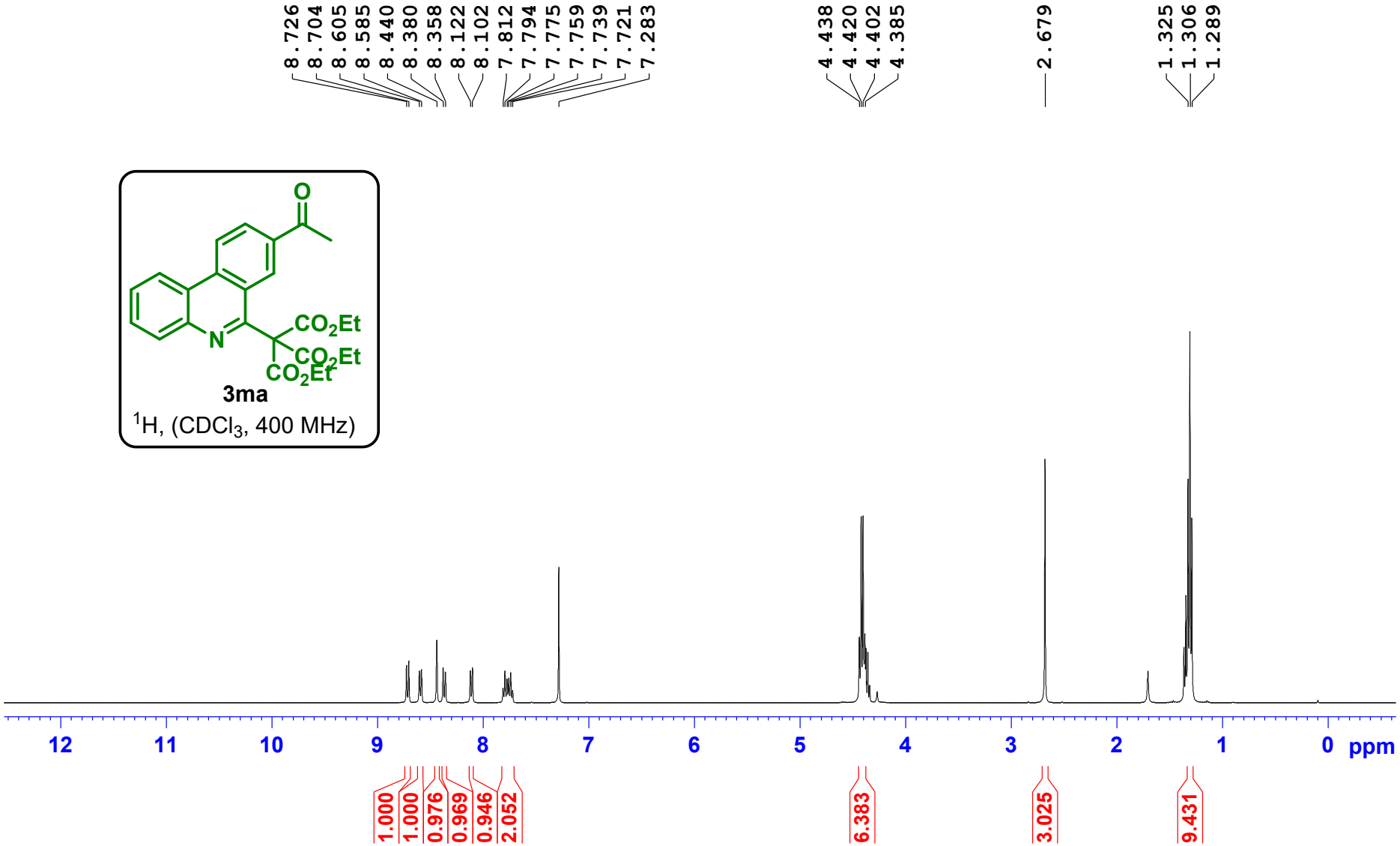

165.329
161.970
159.501
153.650
153.611
142.142
130.600
129.989
128.383
128.067
126.519
126.439
125.046
124.962
123.727
121.596
119.620
119.383
111.211
110.989
77.318
77.000
76.682
74.790
62.842
13.833
F
N
CO2Et
CO2Et
CO2Et
3ja
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

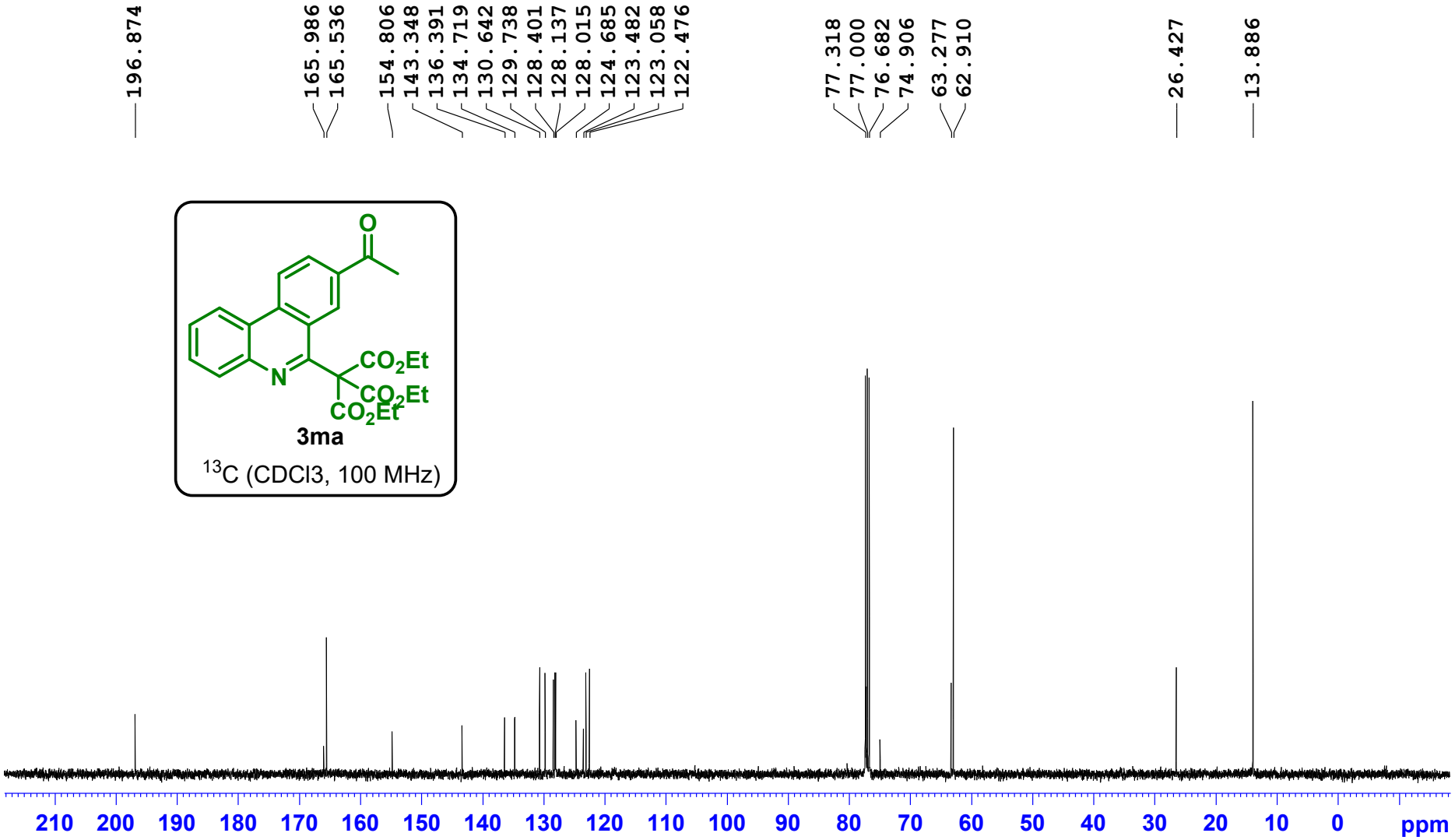

8.773
8.751
8.586
8.566
8.130
8.110
8.059
8.012
7.990
7.817
7.799
7.780
7.765
7.746
7.728
7.283
4.441
4.423
4.405
4.388
1.319
1.302
1.284
CF3
CO2Et
CO2Et
CO2Et
N
3ka
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.014
0.988
0.947
1.008
2.039
6.124
9.319

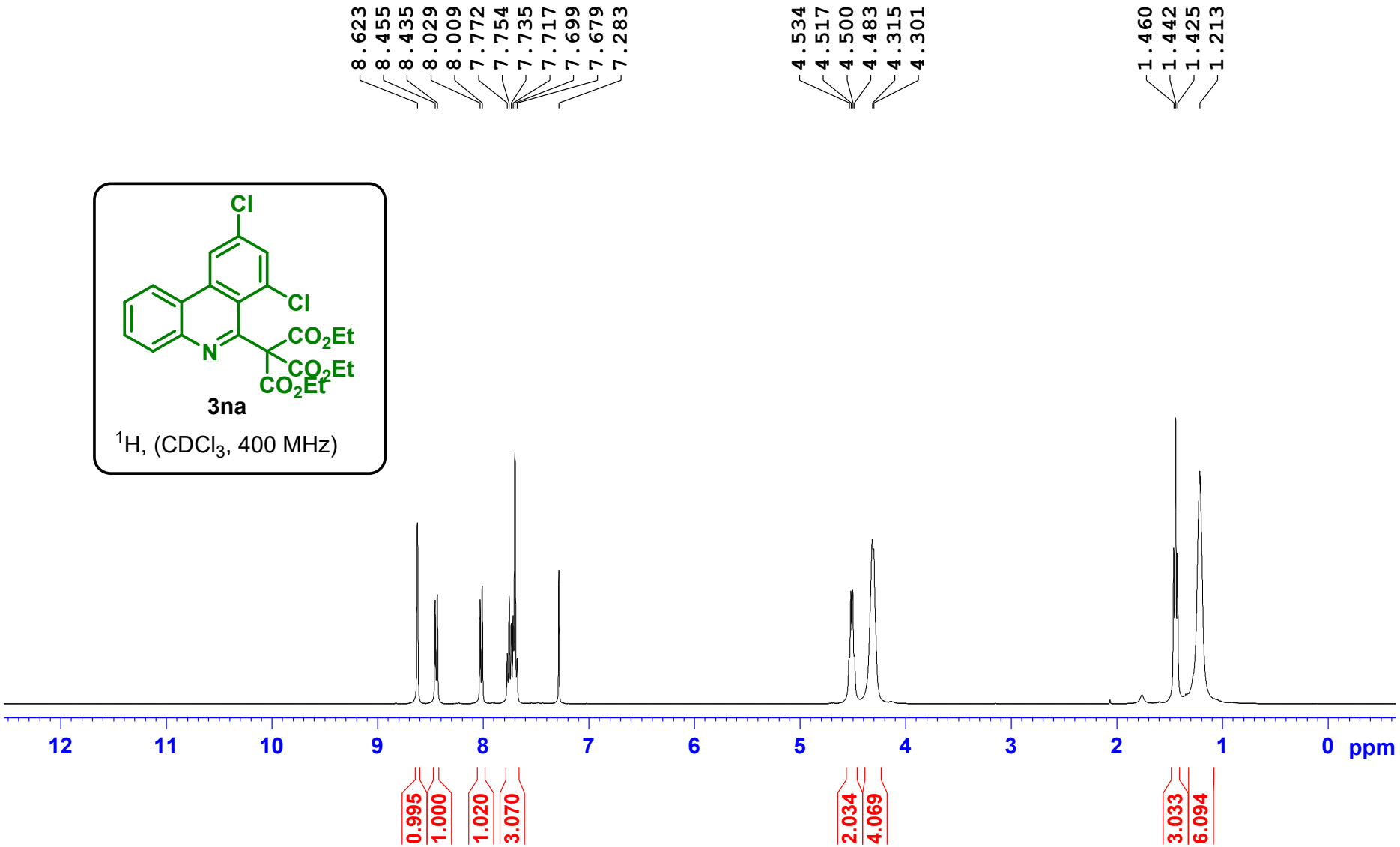

165.260
154.381
143.069
135.471
130.659
129.700
128.962
128.636
128.284
127.982
127.841
125.882
125.851
125.134
124.641
124.135
124.092
123.598
123.207
122.426
122.204
119.722
77.318
77.000
76.683
74.813
62.955
13.785
CF3
CO2Et
CO2Et
CO2Et
N
3ka
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

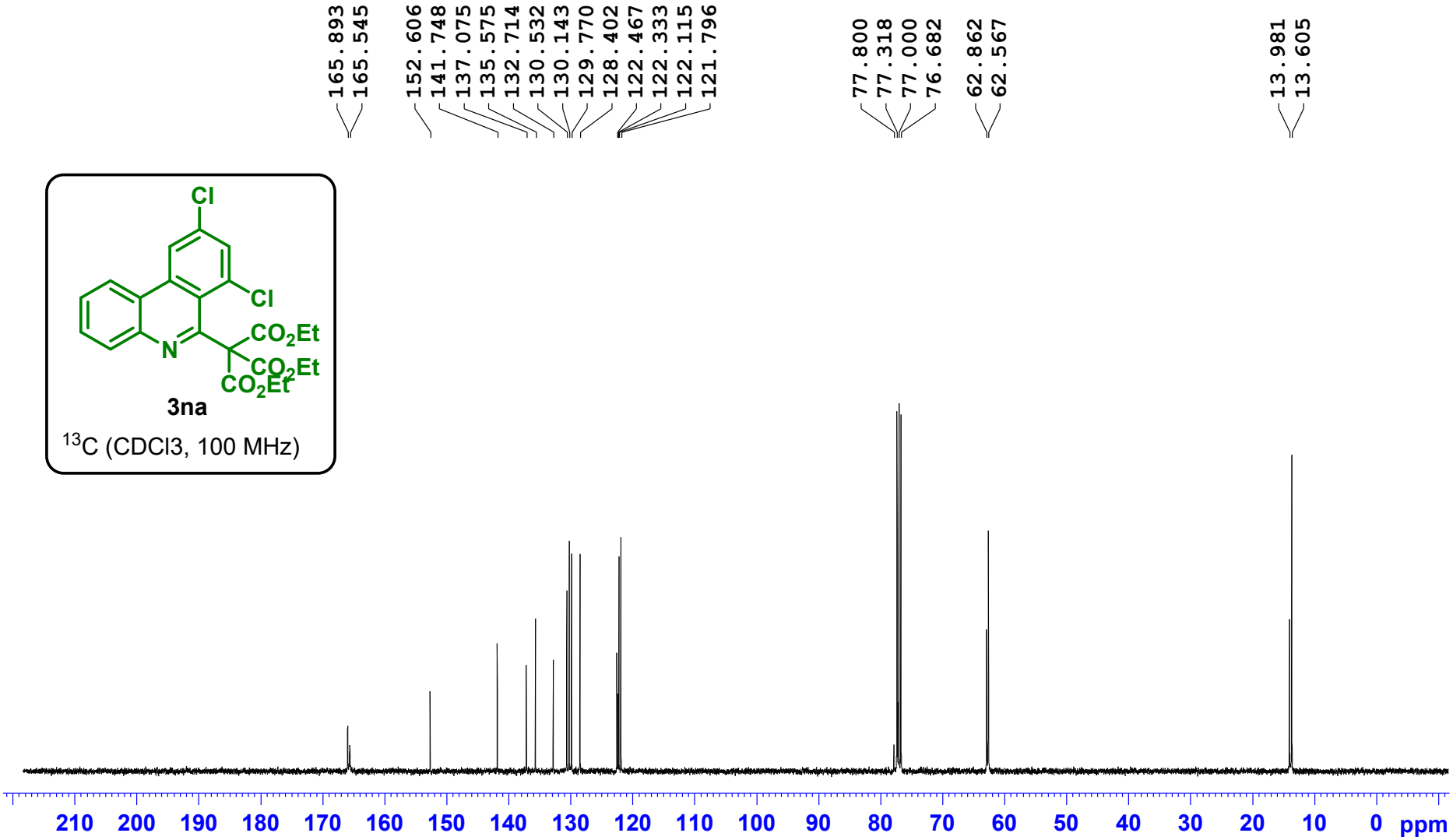

8.760
8.739
8.581
8.561
8.130
8.110
8.090
7.999
7.978
7.852
7.834
7.815
7.797
7.778
7.760
7.284
4.453
4.436
4.418
4.400
1.347
1.329
1.311
CN
CO2Et
CO2Et
CO2Et
N
3la
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.002
2.016
1.007
2.097
6.077
9.031

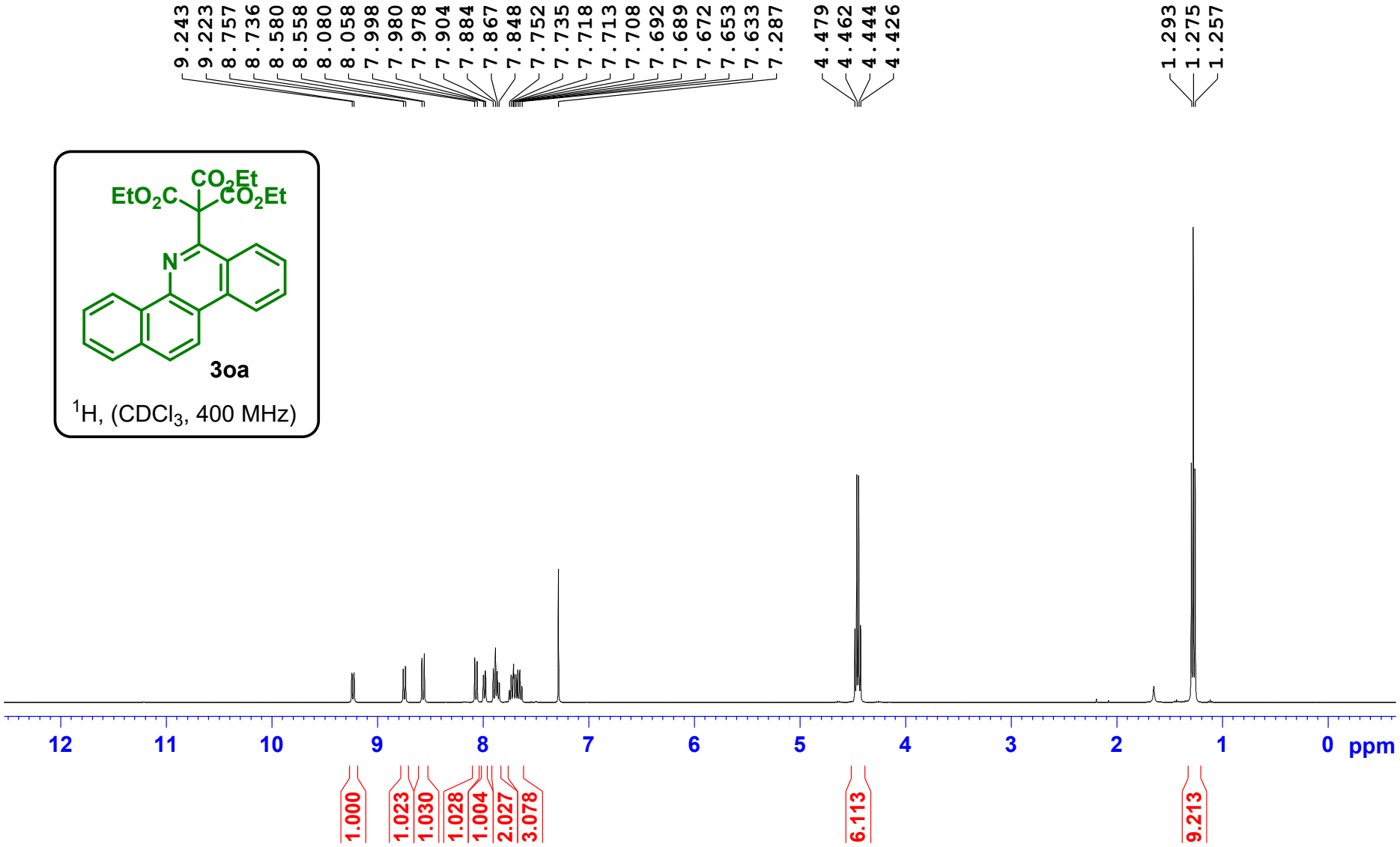

165.154
153.691
143.306
135.890
131.985
131.283
130.782
130.315
128.582
124.791
123.836
122.896
122.375
118.344
110.360
77.319
77.000
76.683
74.773
63.102
13.884
CN
CO2Et
CO2Et
CO2Et
N
3la
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

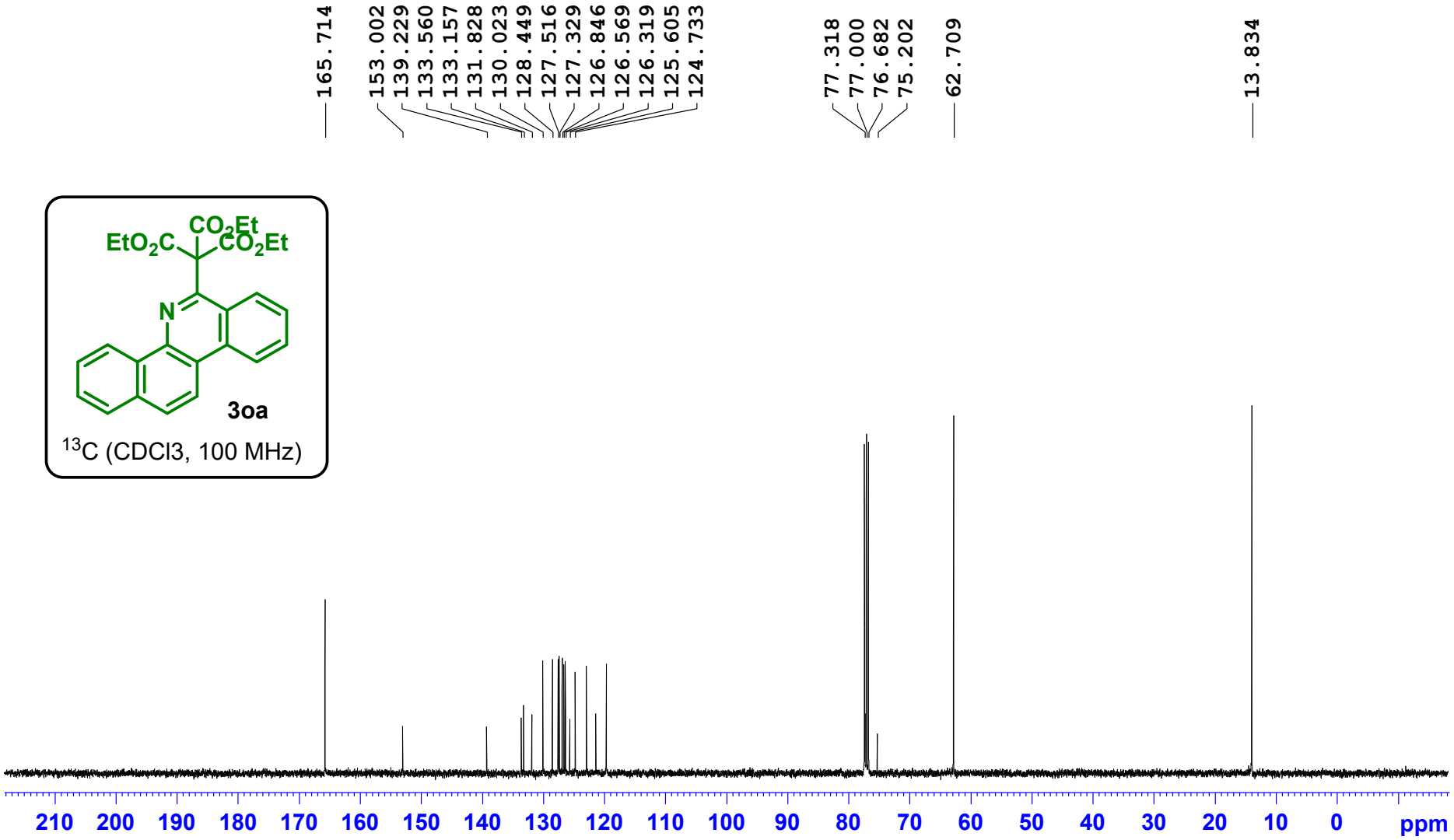

8.726
8.704
8.605
8.585
8.440
8.380
8.358
8.122
8.102
7.812
7.794
7.775
7.759
7.739
7.721
7.283
4.438
4.420
4.402
4.385
2.679
1.325
1.306
1.289
O
N
CO2Et
CO2Et
CO2Et
3ma
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.000
0.976
0.969
0.946
2.052
6.383
3.025
9.431

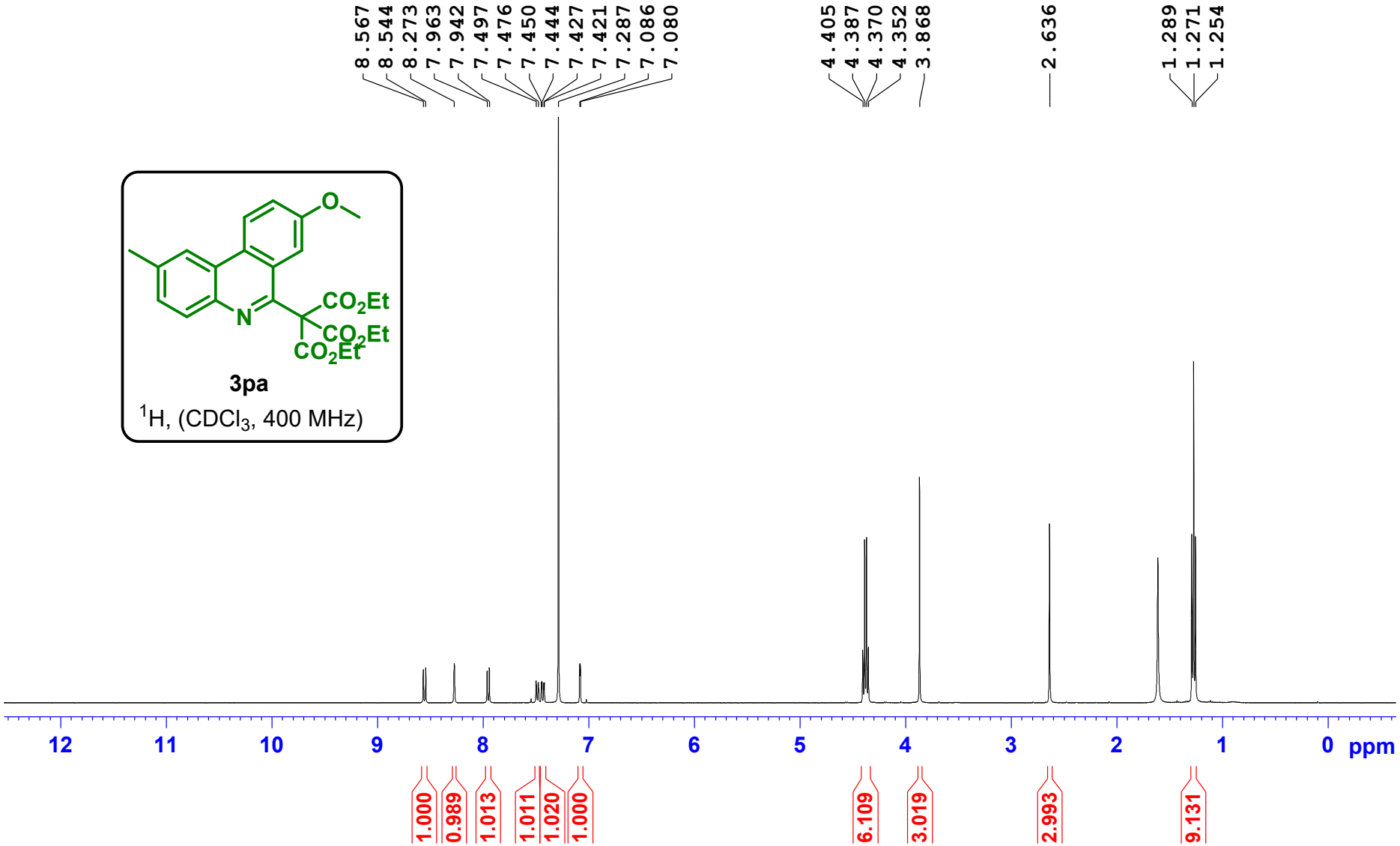

196.874
165.986
165.536
154.806
143.348
136.391
134.719
130.642
129.738
128.401
128.137
128.015
124.685
123.482
123.058
122.476
77.318
77.000
76.682
74.906
63.277
62.910
26.427
13.886
O
N
CO2Et
CO2Et
CO2Et
3ma
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

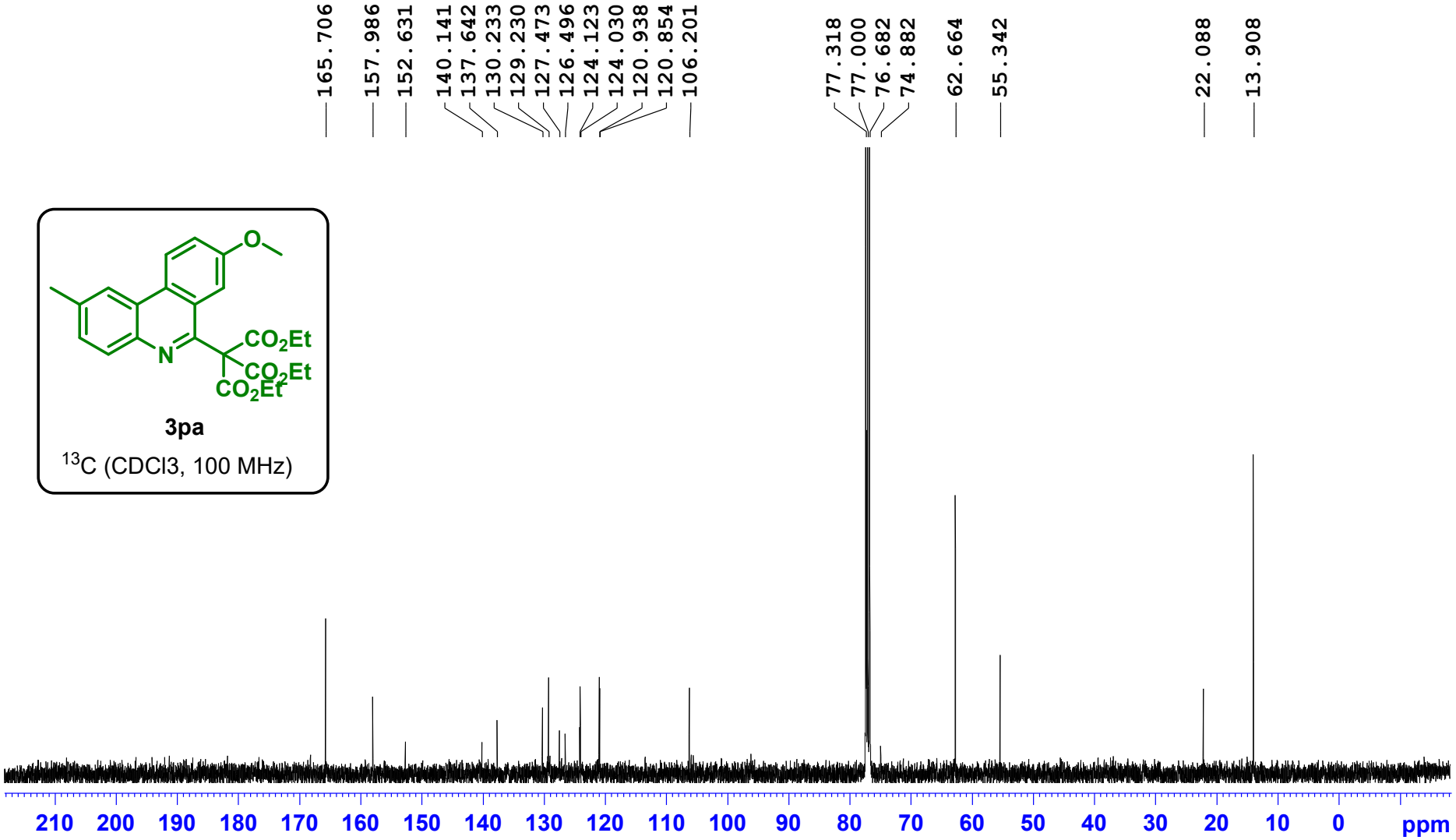

8.623
8.455
8.435
8.029
8.009
7.772
7.754
7.735
7.717
7.699
7.679
7.283
4.534
4.517
4.500
4.483
4.315
4.301
1.460
1.442
1.425
1.213
Cl
Cl
CO2Et
CO2Et
CO2Et
N
3na
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.995
1.000
1.020
3.070
2.034
4.069
3.033
6.094

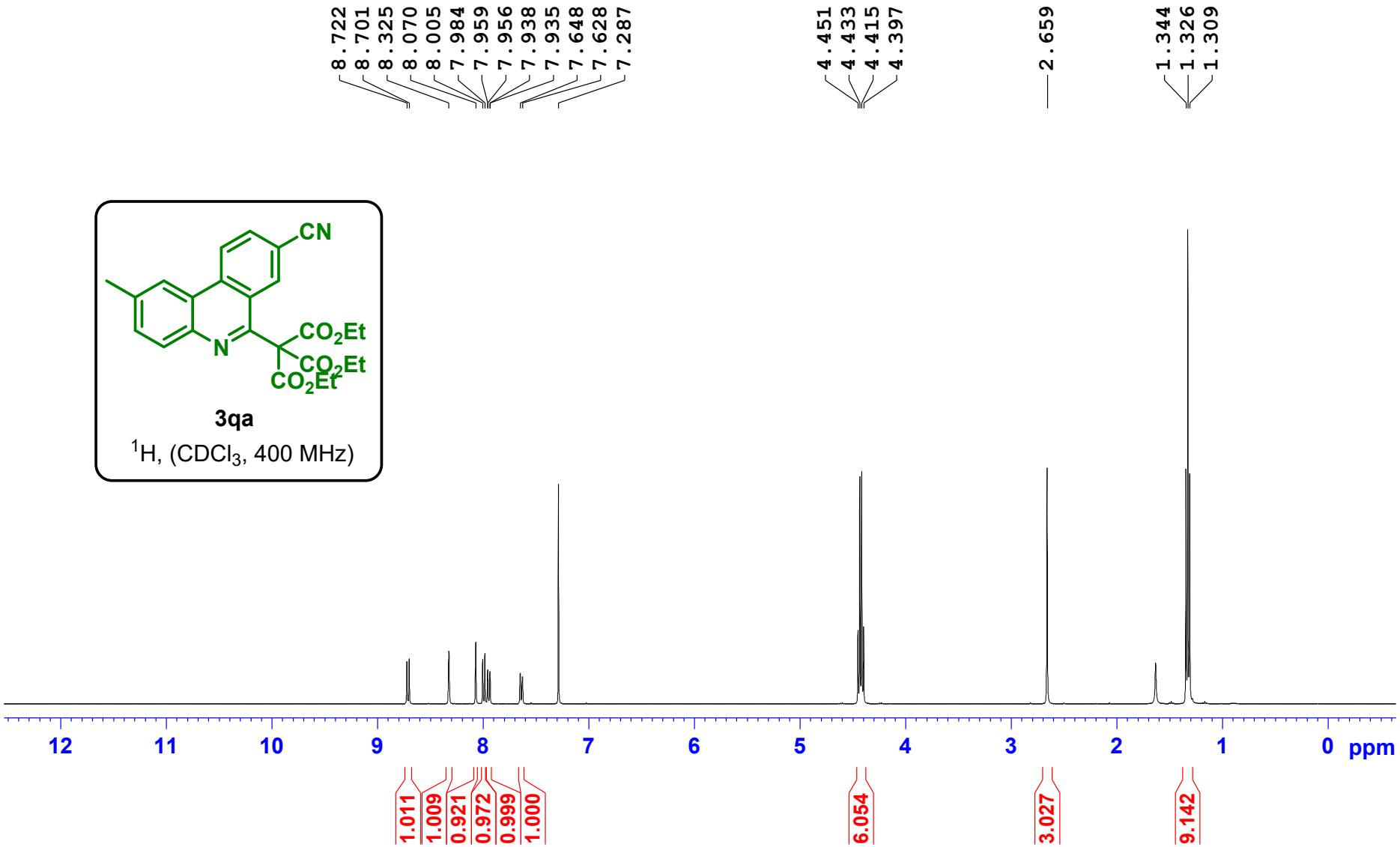

165.893
165.545
152.606
141.748
137.075
135.575
132.714
130.532
130.143
129.770
128.402
122.467
122.333
122.115
121.796
77.800
77.318
77.000
76.682
62.862
62.567
13.981
13.605
Cl
Cl
CO2Et
CO2Et
CO2Et
N
3na
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

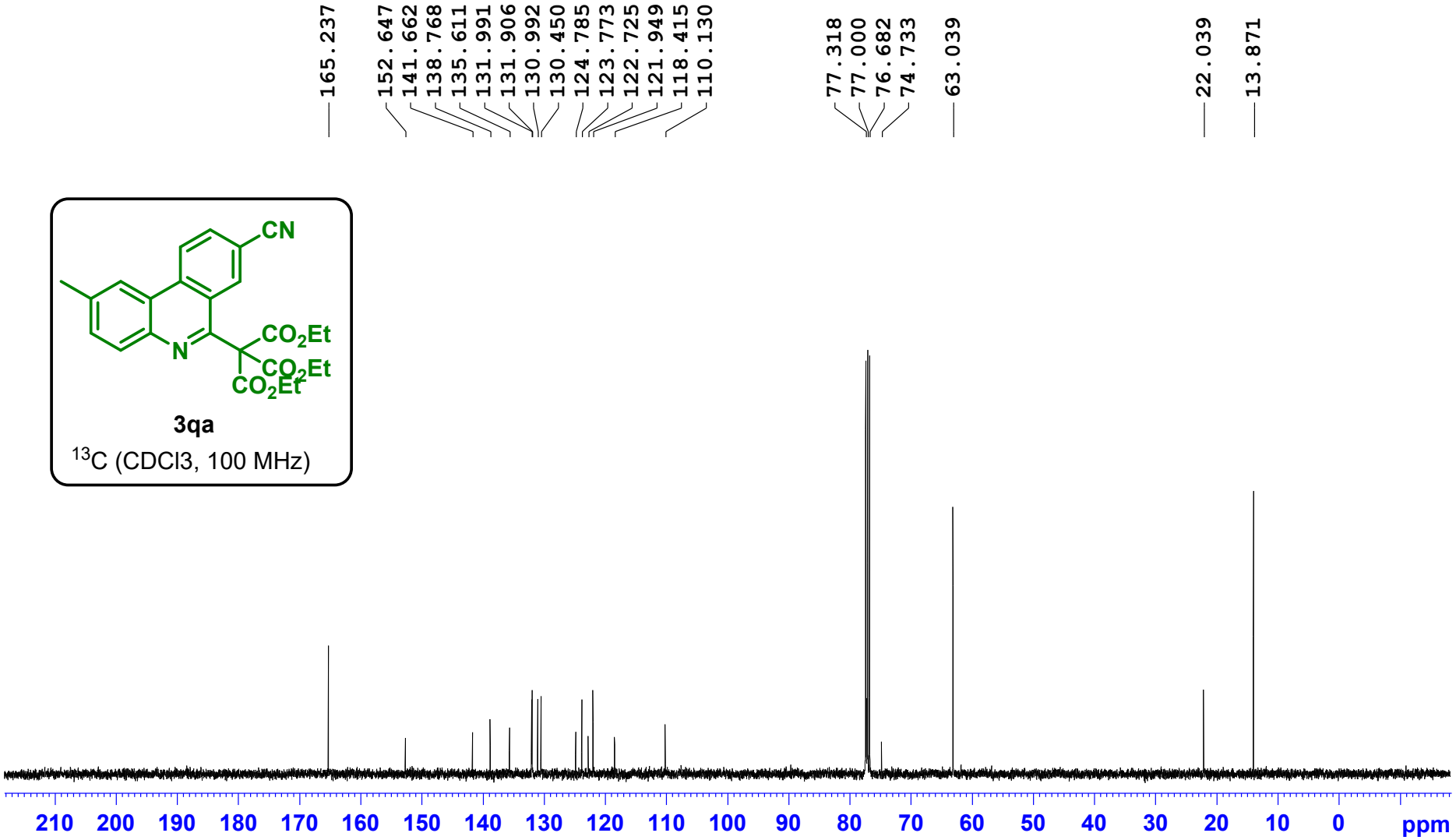

9.243
9.223
8.757
8.736
8.580
8.558
8.080
8.058
7.998
7.980
7.978
7.904
7.884
7.867
7.848
7.752
7.735
7.718
7.713
7.708
7.692
7.689
7.672
7.653
7.633
7.287
4.479
4.462
4.444
4.426
1.293
1.275
1.257
EtO2C
CO2Et
CO2Et
N
3oa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.023
1.030
1.028
1.004
2.027
3.078
6.113
9.213

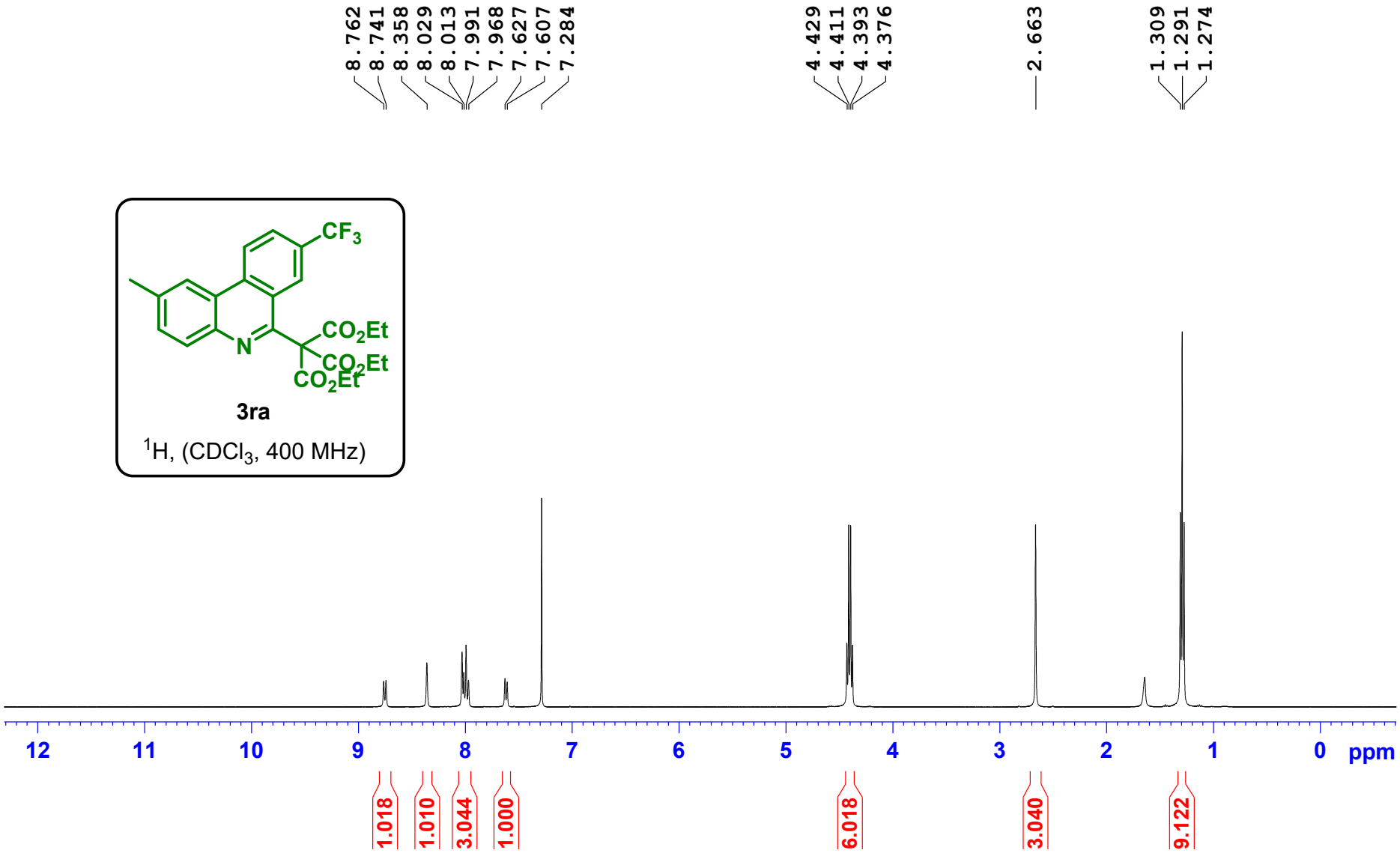

165.714
153.002
139.229
133.560
133.157
131.828
130.023
128.449
127.516
127.329
126.846
126.569
126.319
125.605
124.733
77.318
77.000
76.682
75.202
62.709
13.834
EtO2C
CO2Et
CO2Et
N
3oa
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

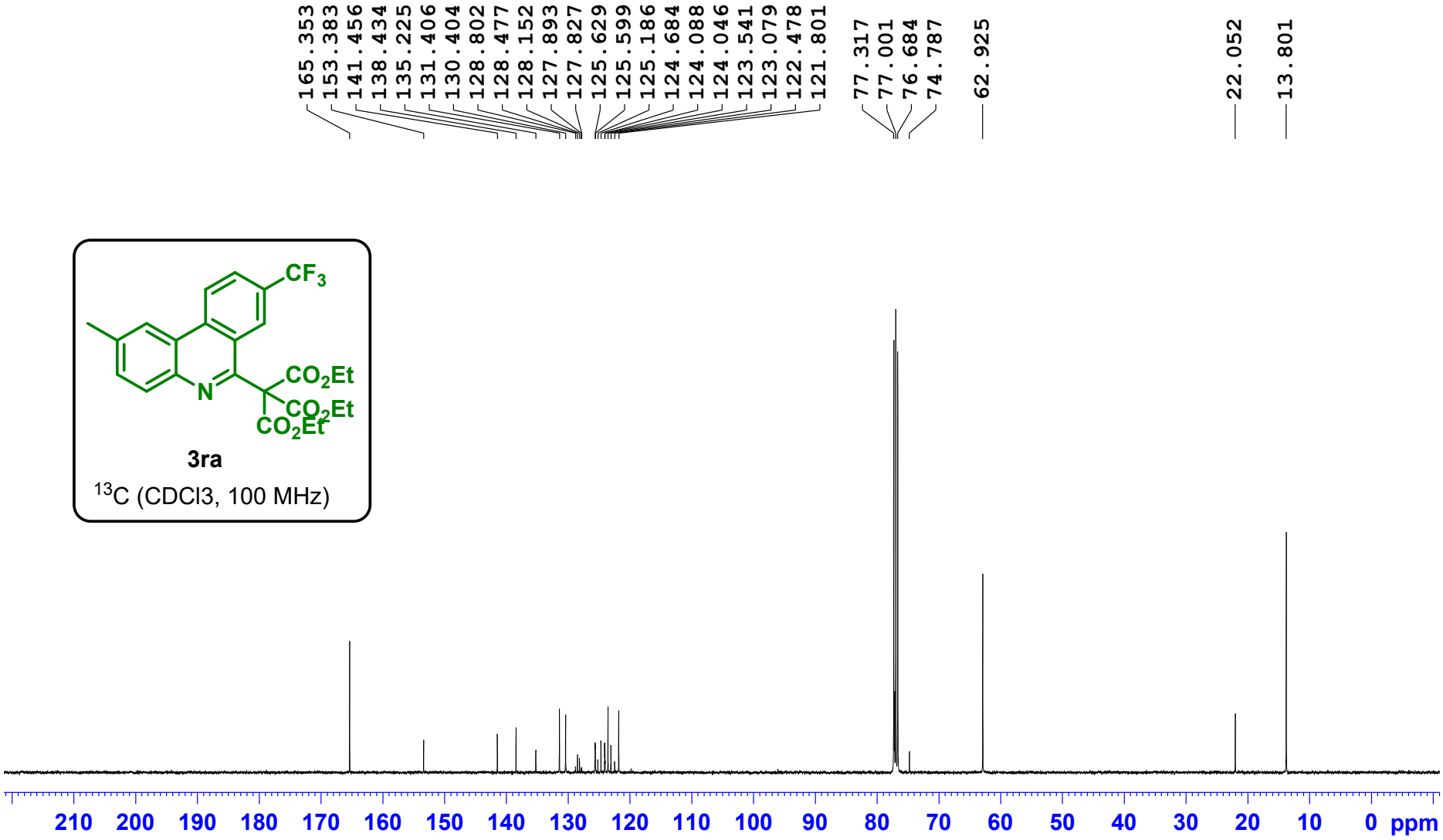

8.567
8.544
8.273
7.963
7.942
7.497
7.476
7.450
7.444
7.427
7.421
7.287
7.086
7.080
4.405
4.387
4.370
4.352
3.868
2.636
1.289
1.271
1.254
O
N
CO2Et
CO2Et
CO2Et
3pa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
0.989
1.013
1.011
1.020
1.000
6.109
3.019
2.993
9.131

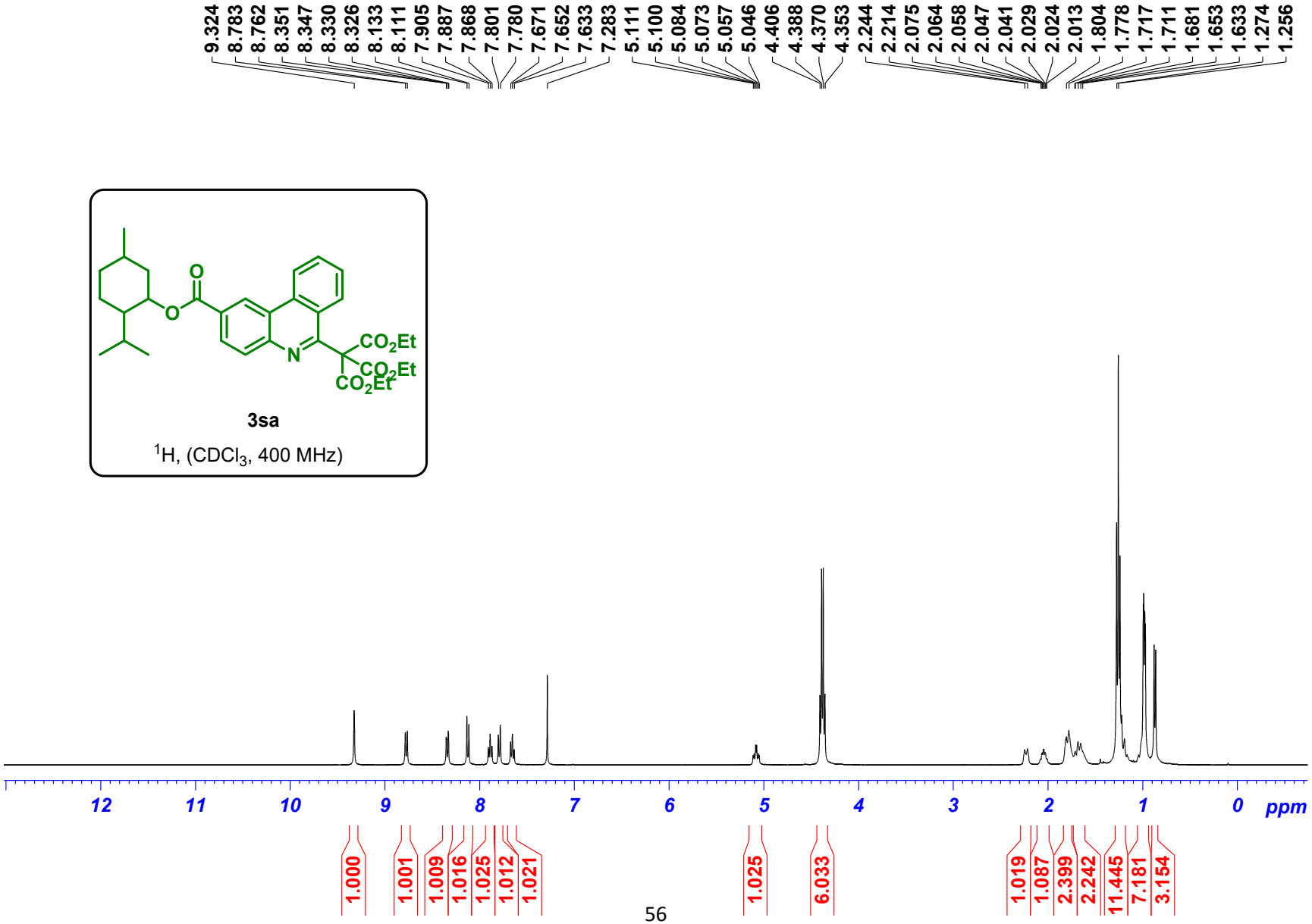

165.706
157.986
152.631
140.141
137.642
130.233
129.230
127.473
126.496
124.123
124.030
120.938
120.854
106.201
77.318
77.000
76.682
74.882
62.664
55.342
22.088
13.908
O
N
CO2Et
CO2Et
CO2Et
3pa
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

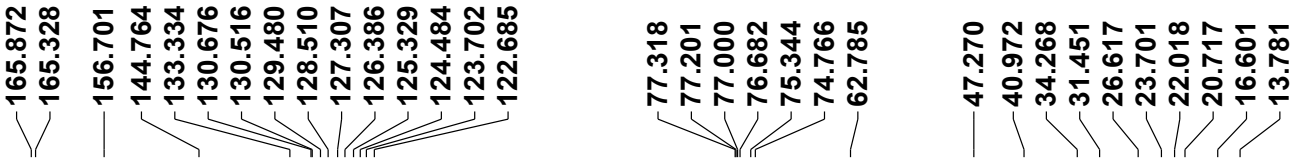

8.722
8.701
8.325
8.070
8.005
7.984
7.959
7.956
7.938
7.935
7.648
7.628
7.287
4.451
4.433
4.415
4.397
2.659
1.344
1.326
1.309
CN
CO2Et
CO2Et
CO2Et
N
3qa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.011
1.009
0.921
0.972
0.999
1.000
6.054
3.027
9.142

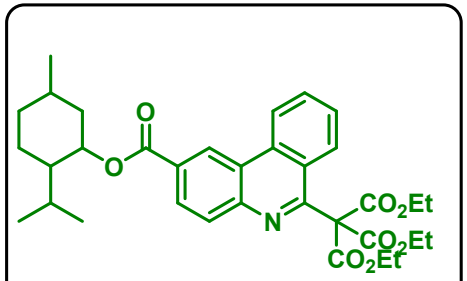

165.237
152.647
141.662
138.768
135.611
131.991
131.906
130.992
130.450
124.785
123.773
122.725
121.949
118.415
110.130
77.318
77.000
76.682
74.733
63.039
22.039
13.871
CN
CO2Et
CO2Et
CO2Et
N
3qa
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm


8.762
8.741
8.358
8.029
8.013
7.991
7.968
7.627
7.607
7.284
4.429
4.411
4.393
4.376
2.663
1.309
1.291
1.274
CF3
CO2Et
CO2Et
CO2Et
N
3ra
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.018
1.010
3.044
1.000
6.018
3.040
9.122


165.353
153.383
141.456
138.434
135.225
131.406
130.404
128.802
128.477
128.152
127.893
127.827
125.629
125.599
125.186
124.684
124.088
124.046
123.541
123.079
122.478
121.801
77.317
77.001
76.684
74.787
62.925
22.052
13.801
CF3
CO2Et
CO2Et
CO2Et
N
3ra
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

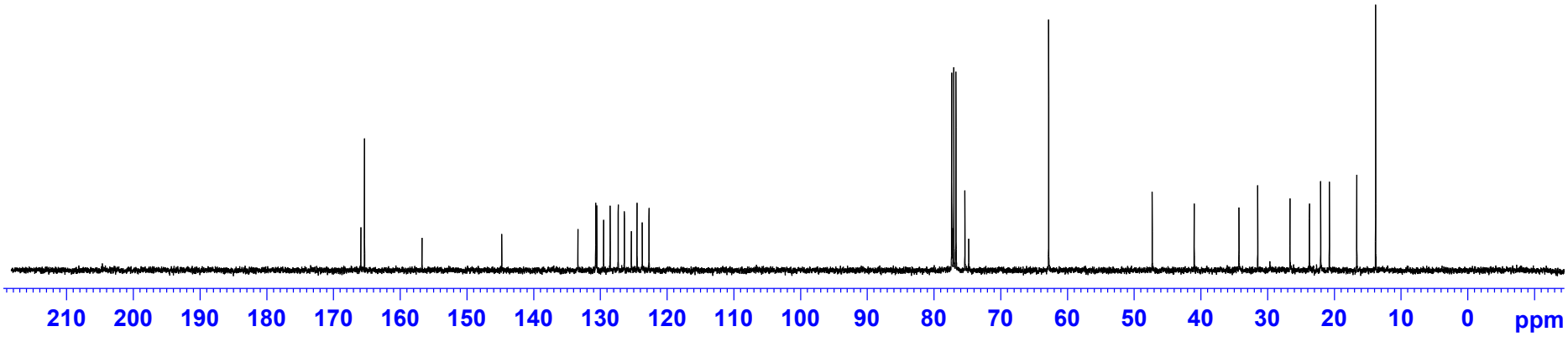

9.324
8.783
8.762
8.351
8.347
8.330
8.326
8.133
8.111
7.905
7.887
7.868
7.801
7.780
7.671
7.652
7.633
7.283
5.111
5.100
5.084
5.073
5.057
5.046
4.406
4.388
4.370
4.353
2.244
2.214
2.075
2.064
2.058
2.047
2.041
2.029
2.024
2.013
1.804
1.778
1.717
1.711
1.681
1.653
1.633
1.274
1.256
O
O
N
CO2Et
CO2Et
CO2Et
3sa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.001
1.009
1.016
1.025
1.012
1.021
1.025
6.033
1.019
1.087
2.399
2.242
11.445
7.181
3.154

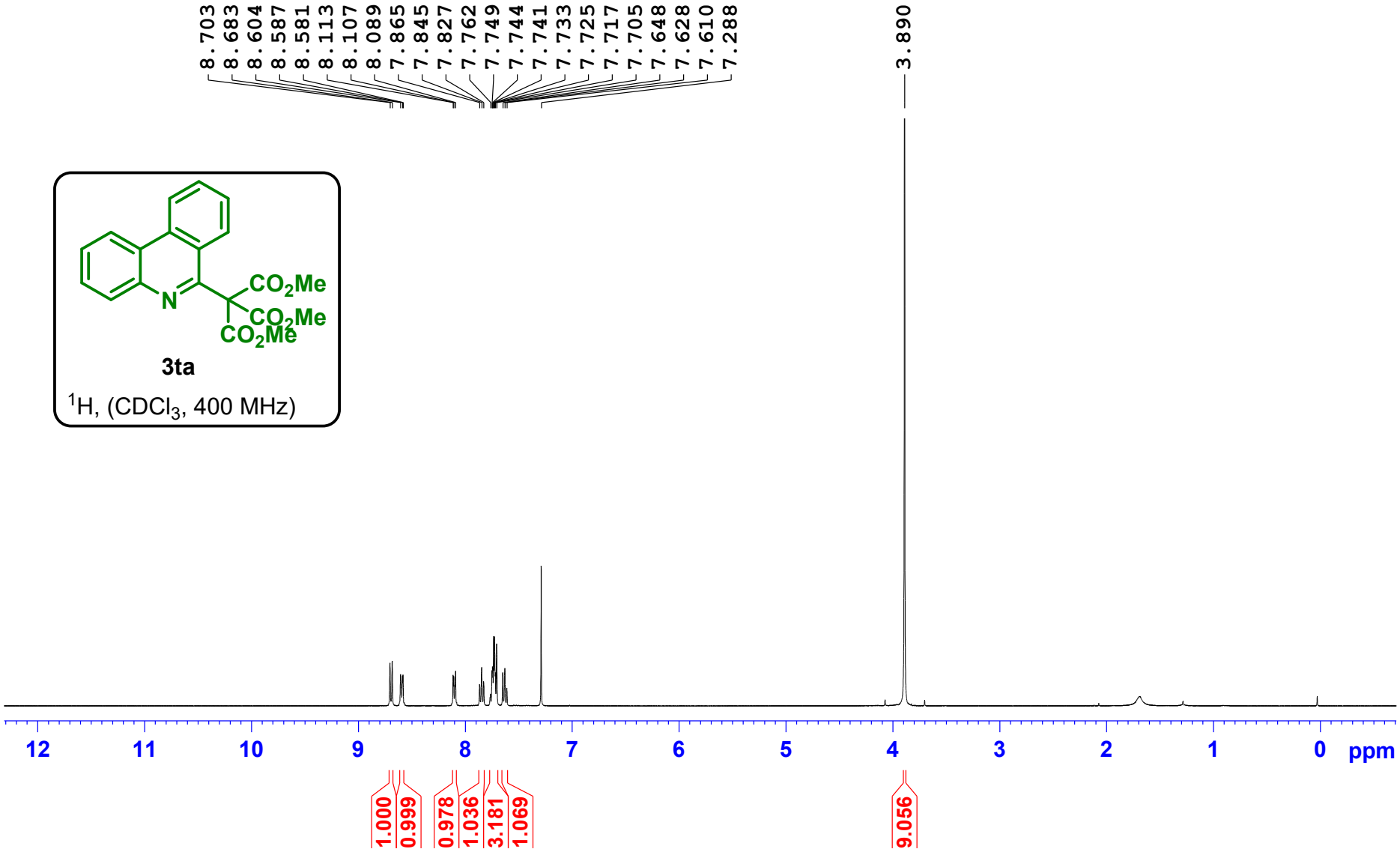


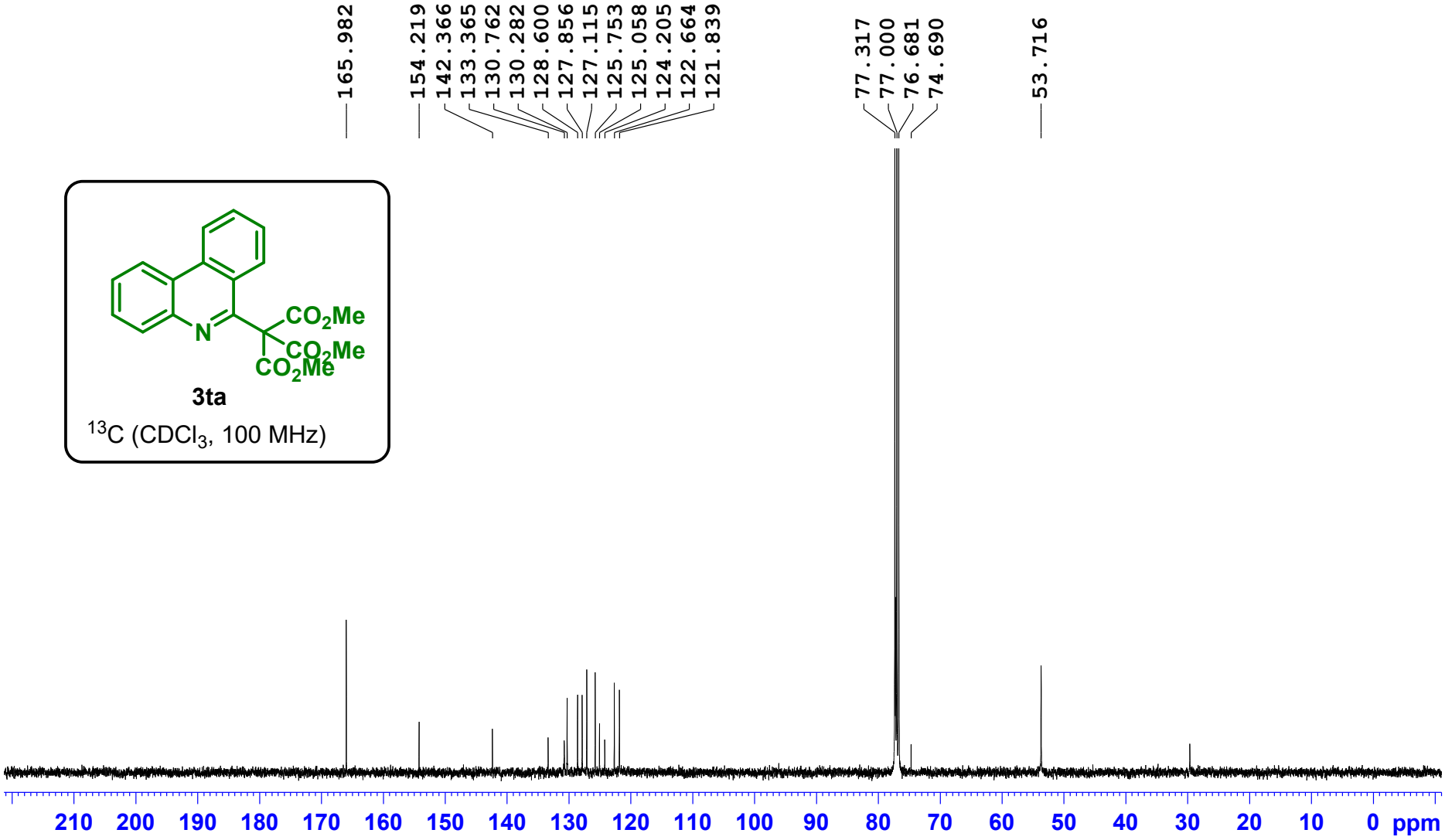


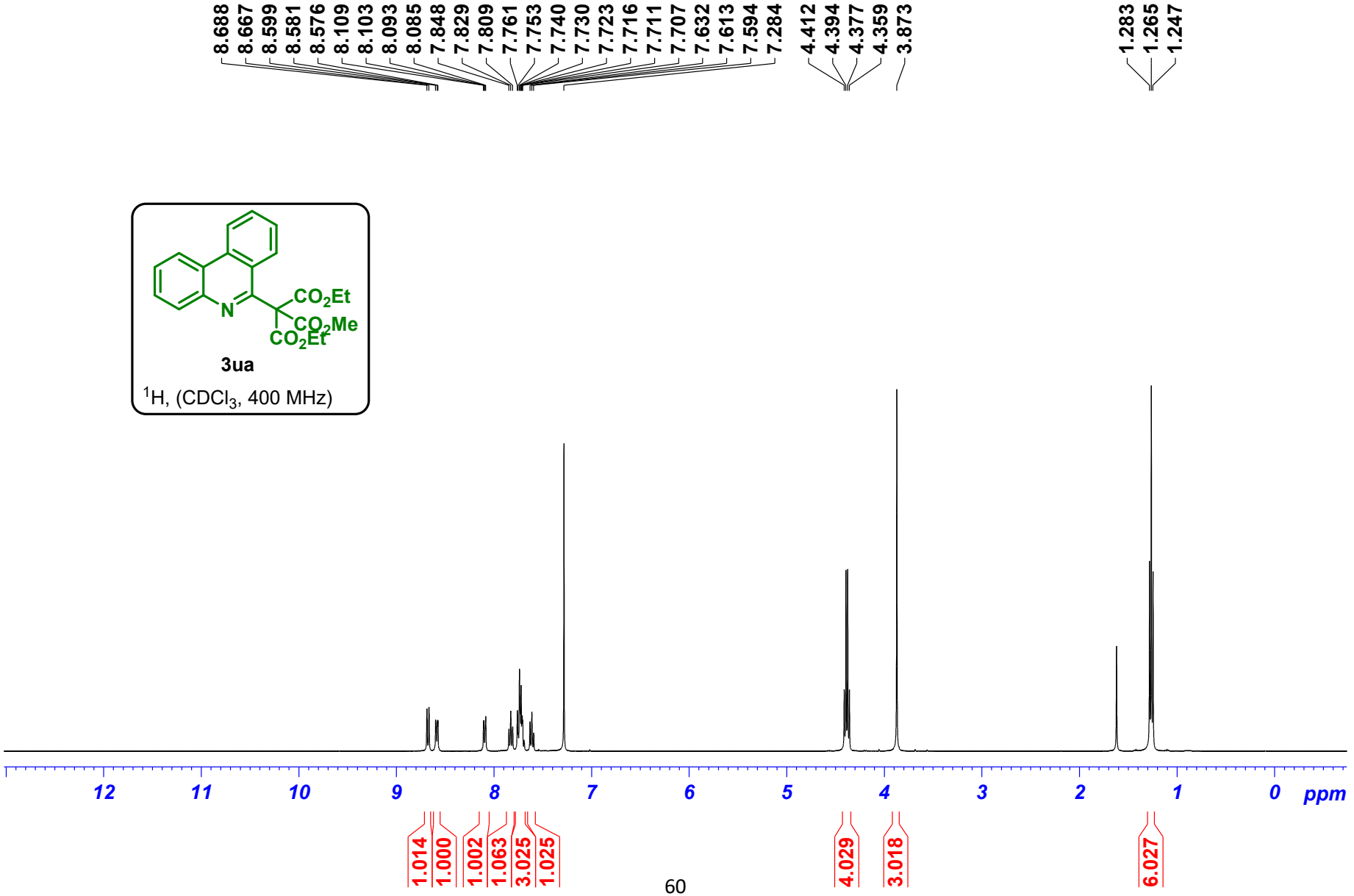
3sa

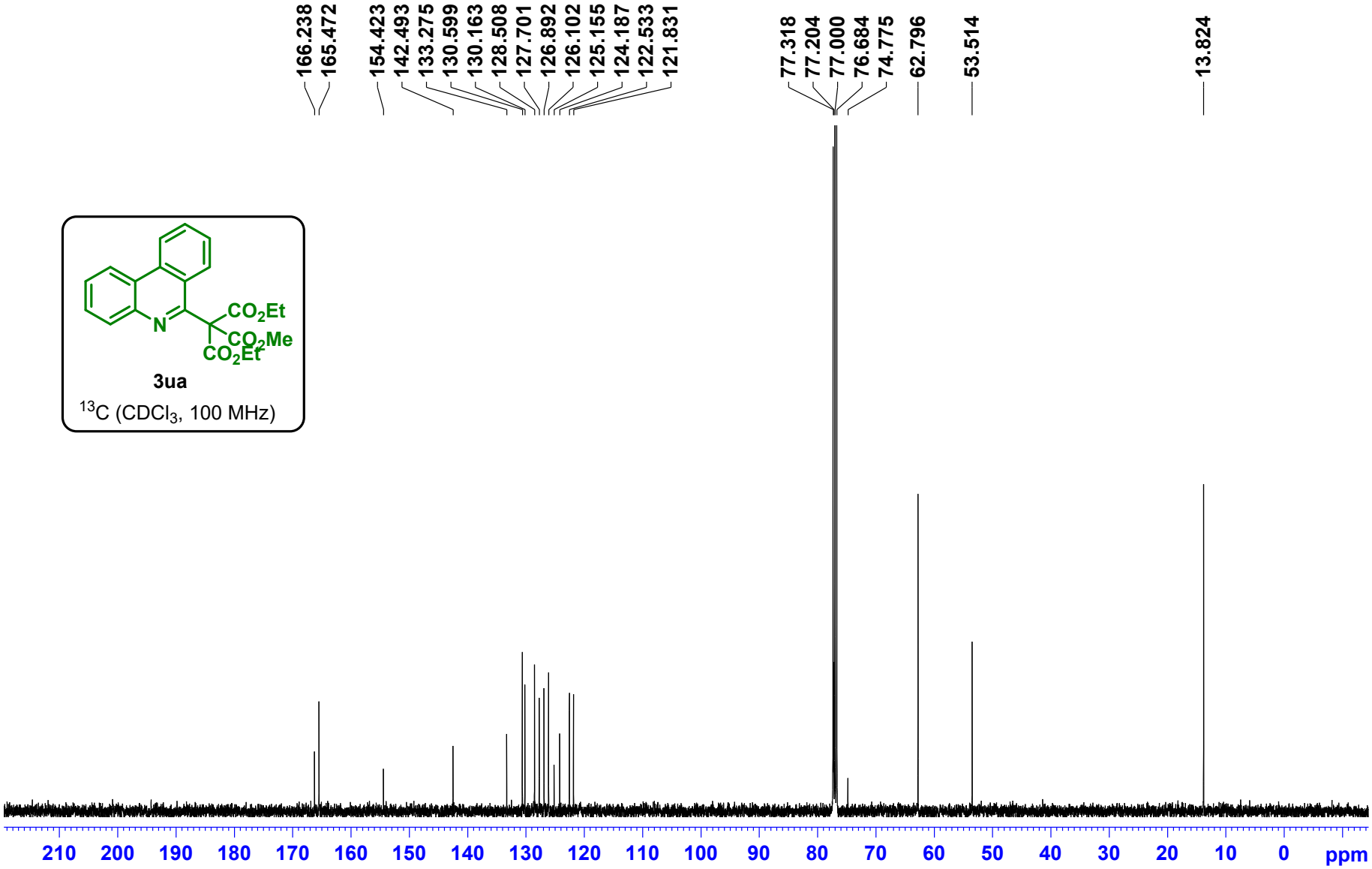
^{13}C ($CDCl_3$, 100 MHz)

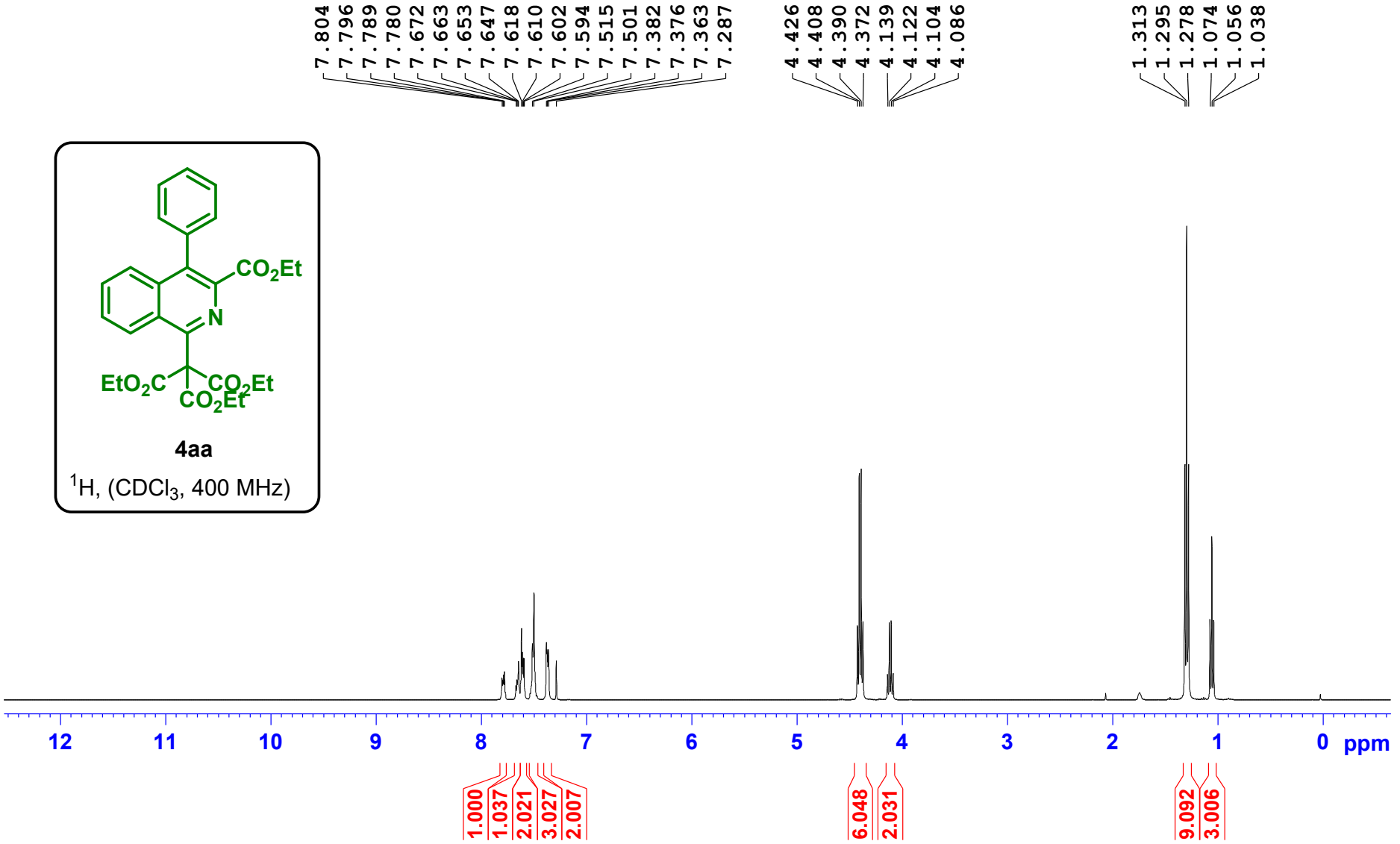


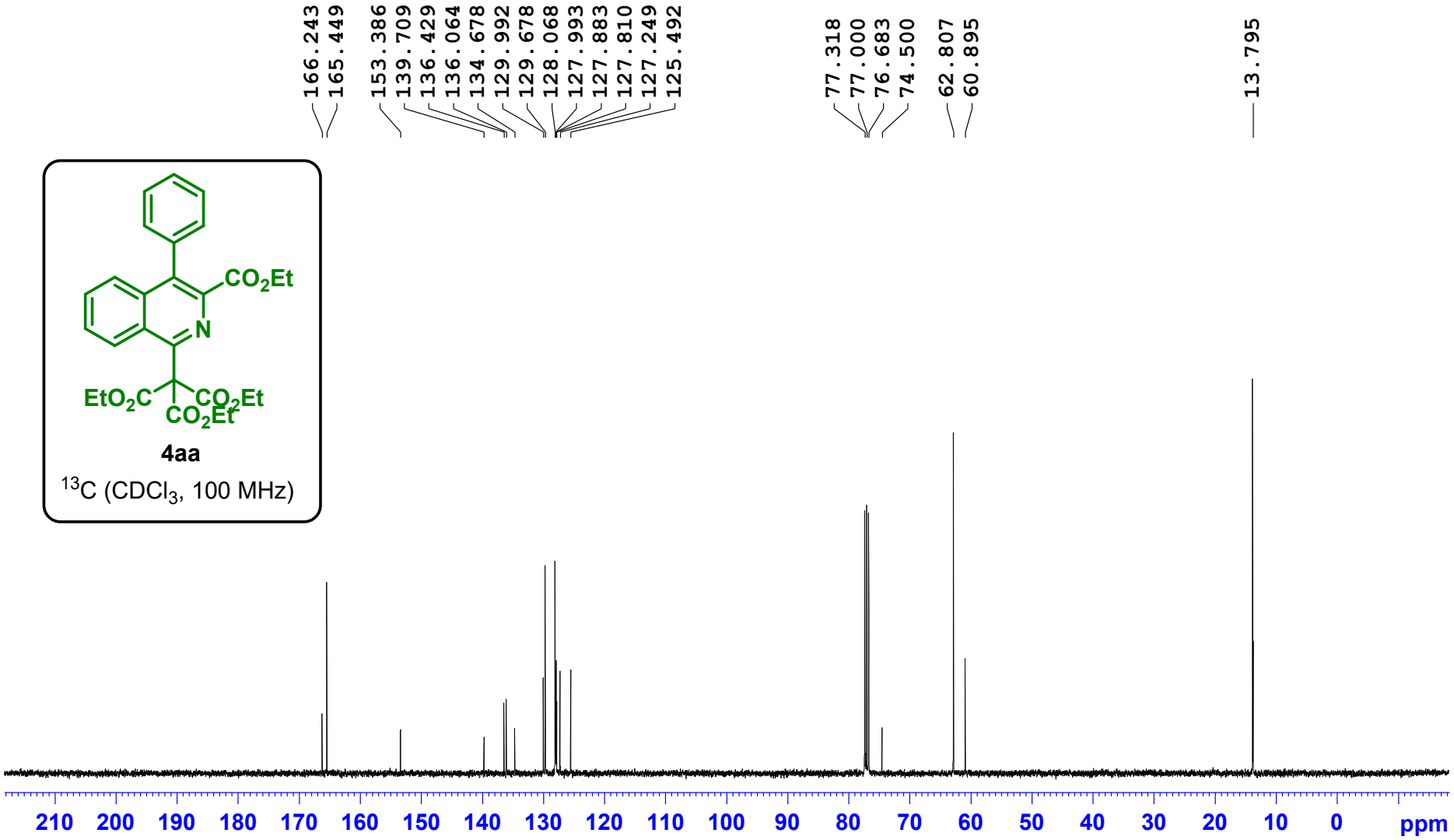

8.703
8.683
8.604
8.587
8.581
8.113
8.107
8.089
7.865
7.845
7.827
7.762
7.749
7.744
7.741
7.733
7.725
7.717
7.705
7.648
7.628
7.610
7.288
3.890
CO2Me
CO2Me
CO2Me
N
3ta
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
0.999
0.978
1.036
3.181
1.069
9.056

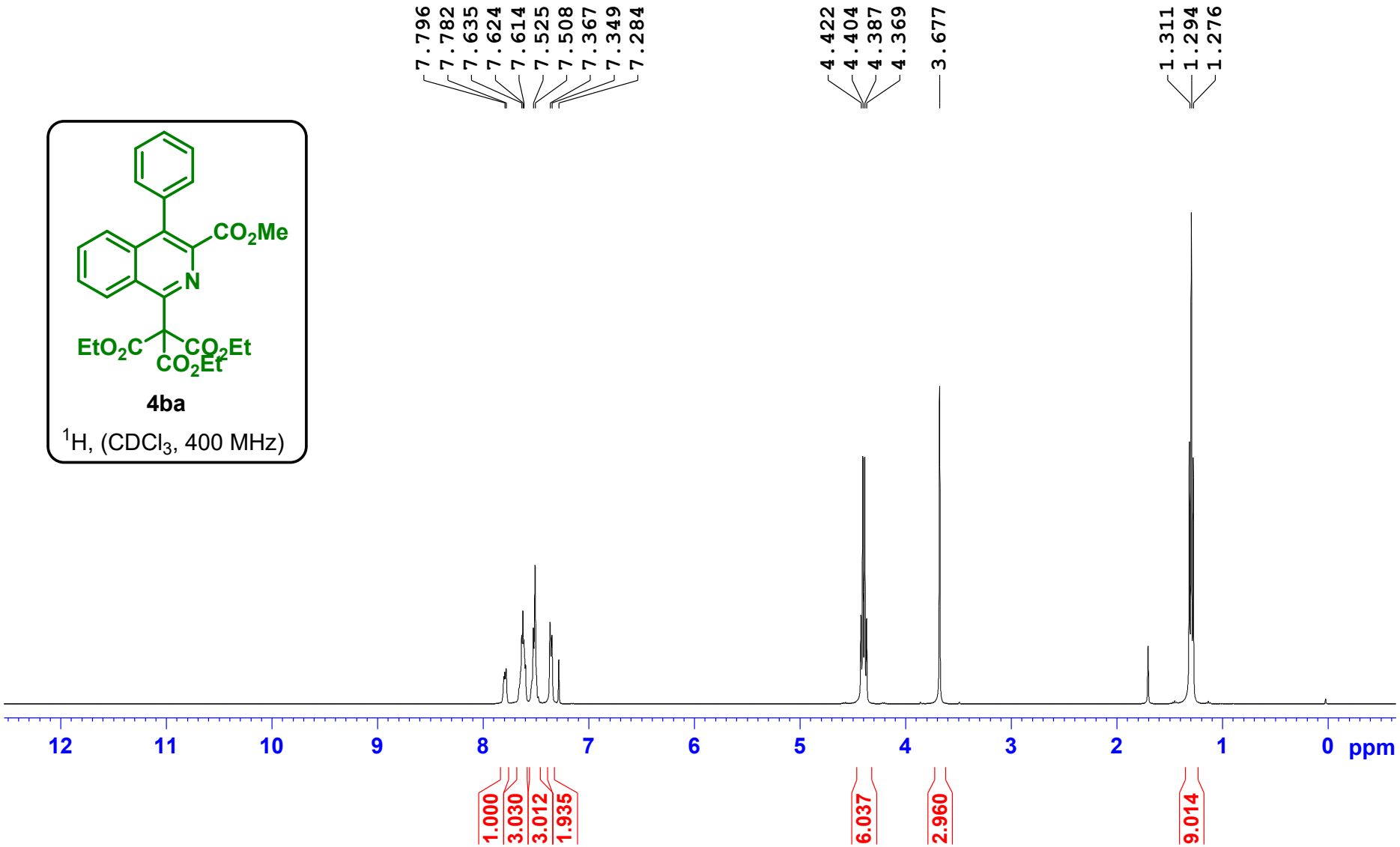

165.982
154.219
142.366
133.365
130.762
130.282
128.600
127.856
127.115
125.753
125.058
124.205
122.664
121.839
77.317
77.000
76.681
74.690
53.716
N
CO2Me
CO2Me
CO2Me
3ta
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

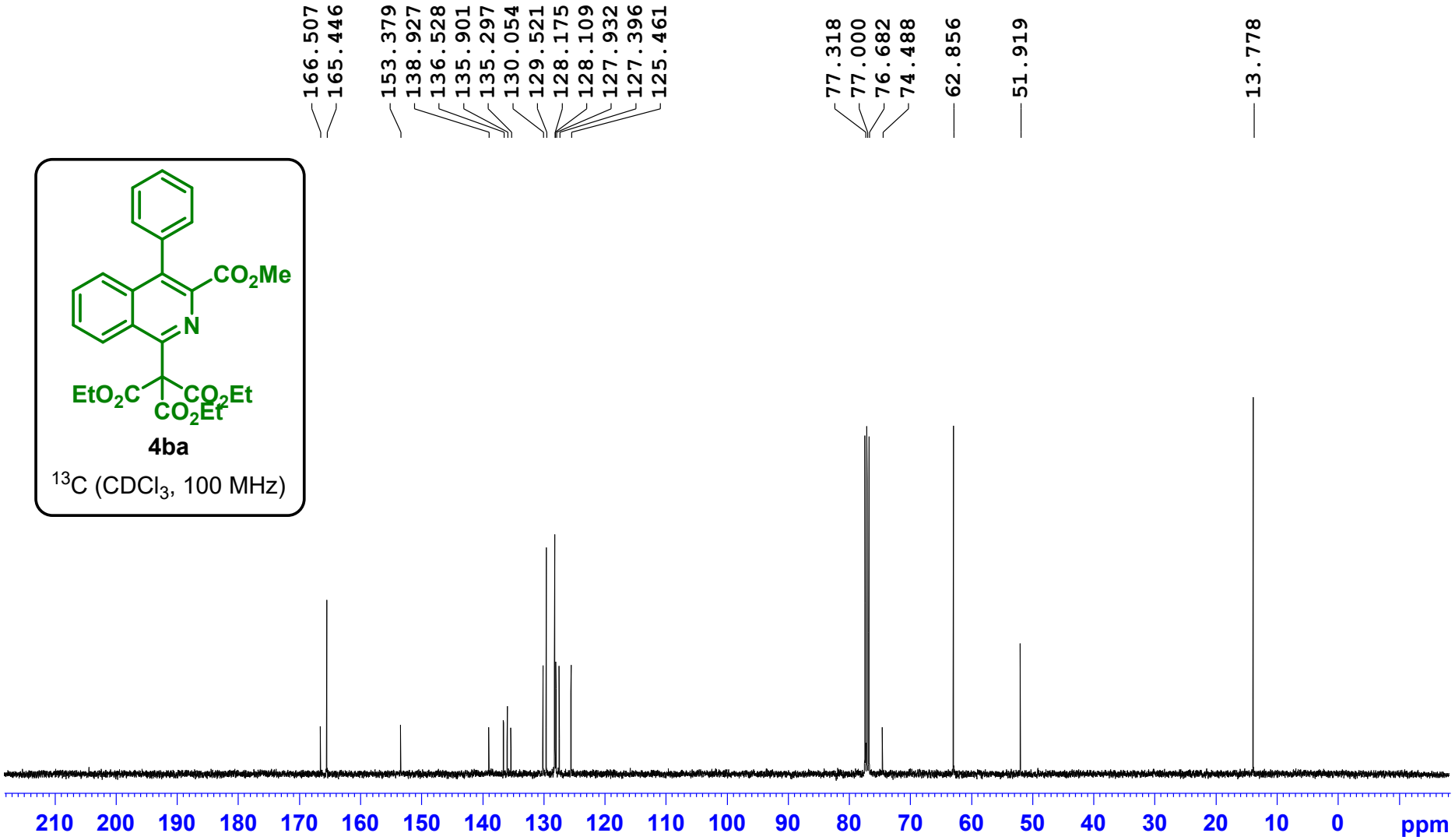

8.688
8.667
8.599
8.581
8.576
8.109
8.103
8.093
8.085
7.848
7.829
7.809
7.761
7.753
7.740
7.730
7.723
7.716
7.711
7.707
7.632
7.613
7.594
7.284
4.412
4.394
4.377
4.359
3.873
1.283
1.265
1.247
CO2Et
CO2Me
CO2Et
N
3ua
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.014
1.000
1.002
1.063
3.025
1.025
4.029
3.018
6.027

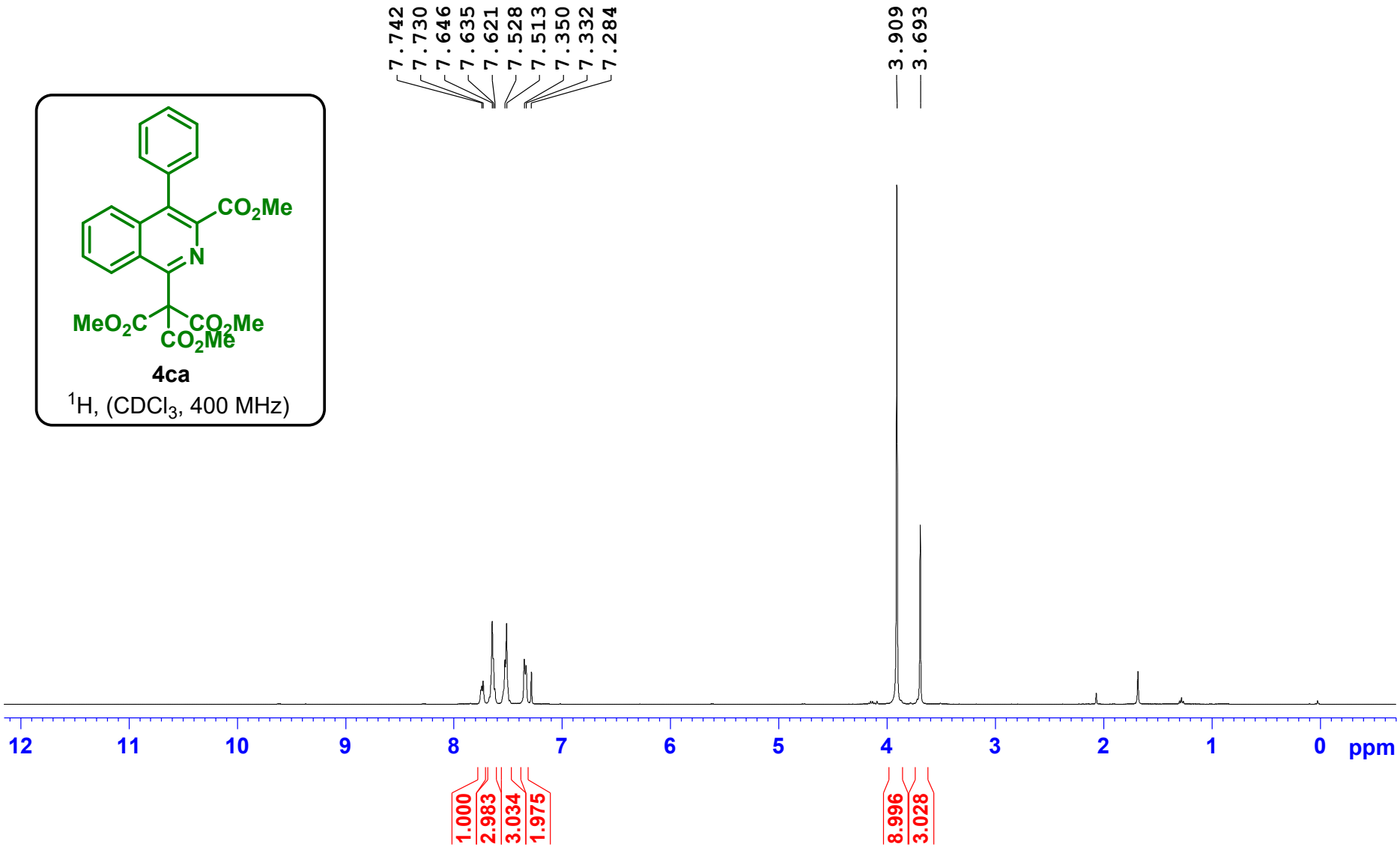

166.238
165.472
154.423
142.493
133.275
130.599
130.163
128.508
127.701
126.892
126.102
125.155
124.187
122.533
121.831
77.318
77.204
77.000
76.684
74.775
62.796
53.514
13.824
CO2Et
CO2Me
CO2Et
N
3ua
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

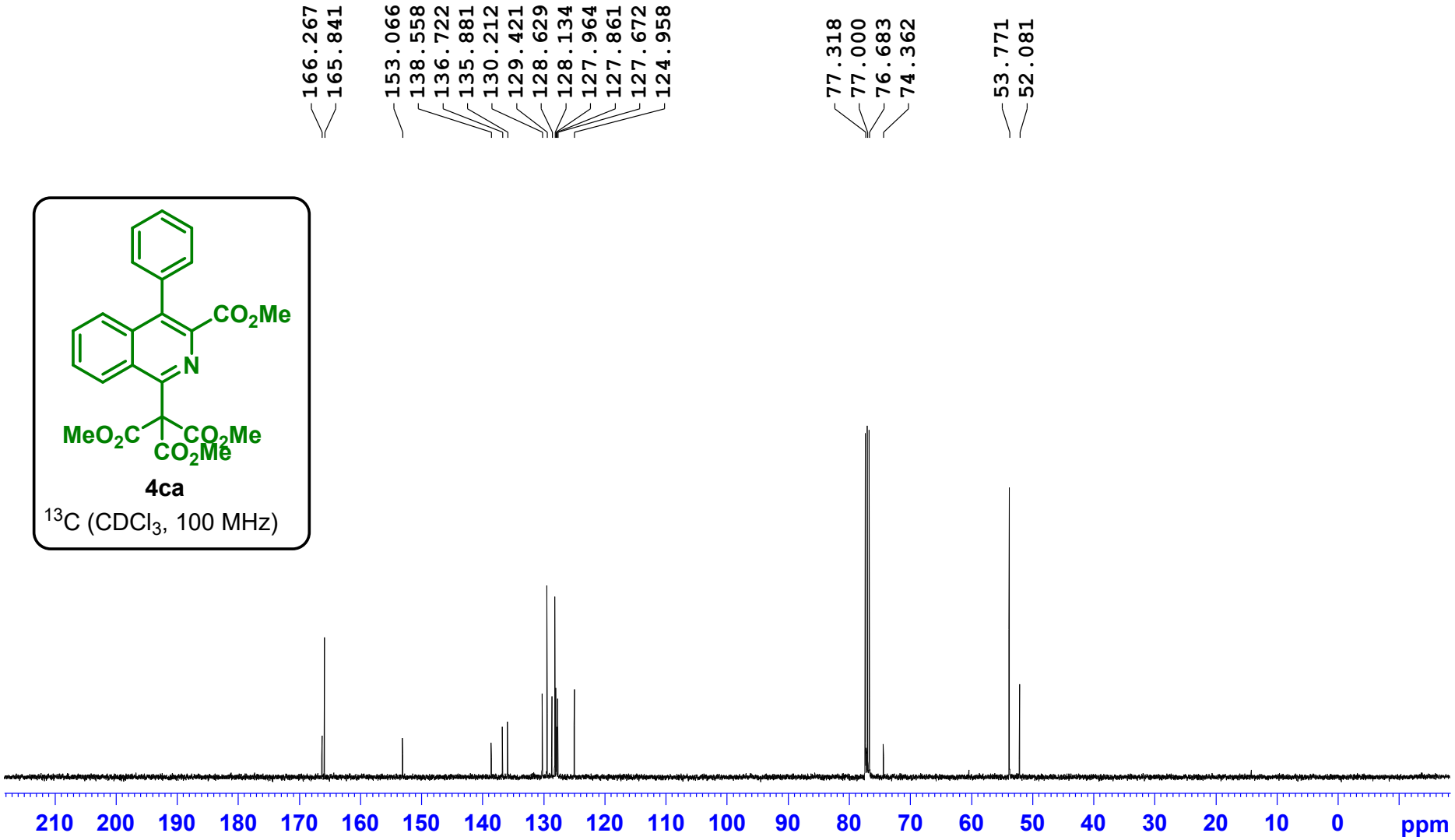

7.804
7.796
7.789
7.780
7.672
7.663
7.653
7.647
7.618
7.610
7.602
7.594
7.515
7.501
7.382
7.376
7.363
7.287
4.426
4.408
4.390
4.372
4.139
4.122
4.104
4.086
1.313
1.295
1.278
1.074
1.056
1.038
CO2Et
N
EtO2C
CO2Et
CO2Et
4aa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.037
2.021
3.027
2.007
6.048
2.031
9.092
3.006

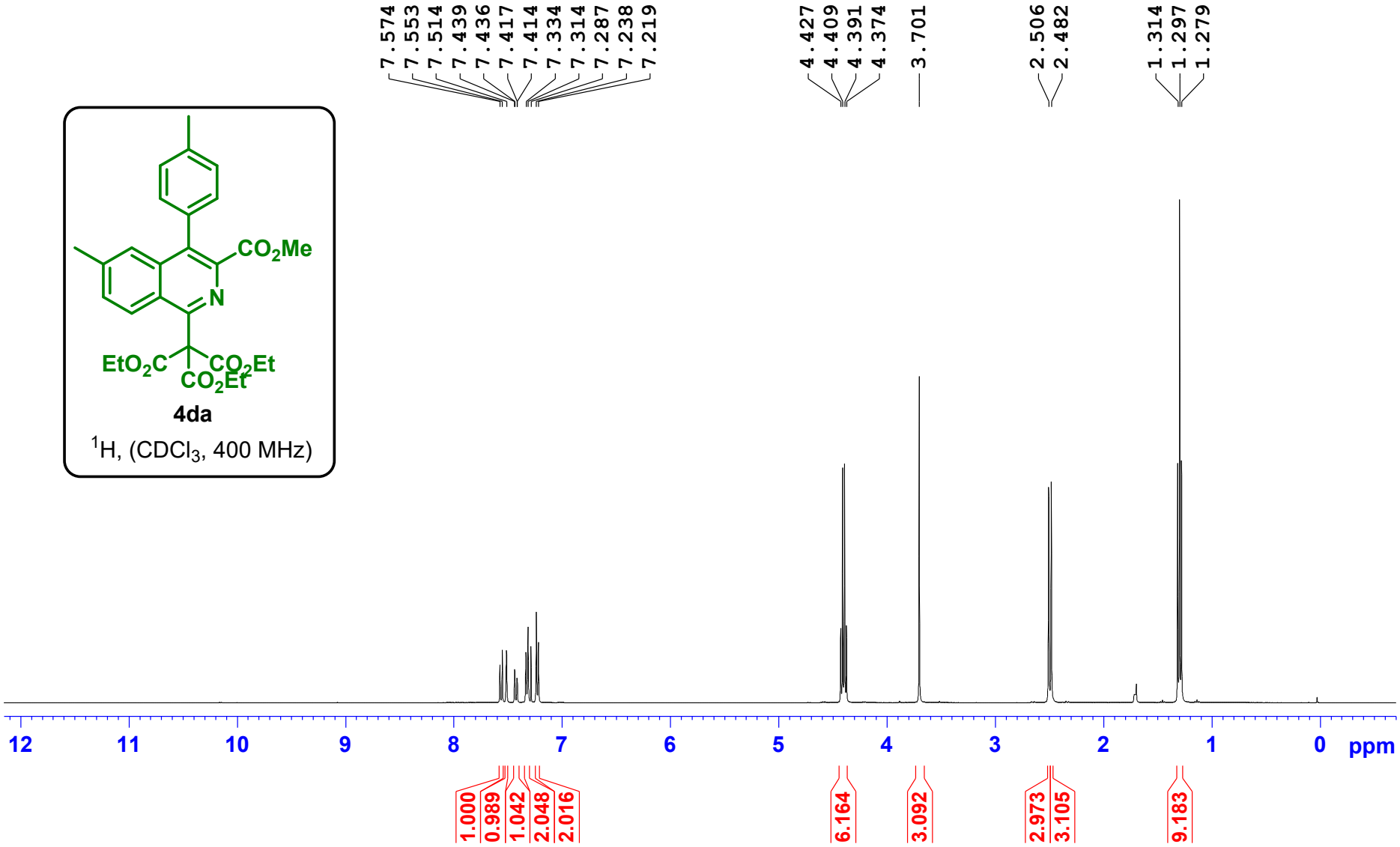

166.243
165.449
153.386
139.709
136.429
136.064
134.678
129.992
129.678
128.068
127.993
127.883
127.810
127.249
125.492
77.318
77.000
76.683
74.500
62.807
60.895
13.795
CO2Et
N
EtO2C
CO2Et
CO2Et
4aa
13C (CDCl3, 100 MHz)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

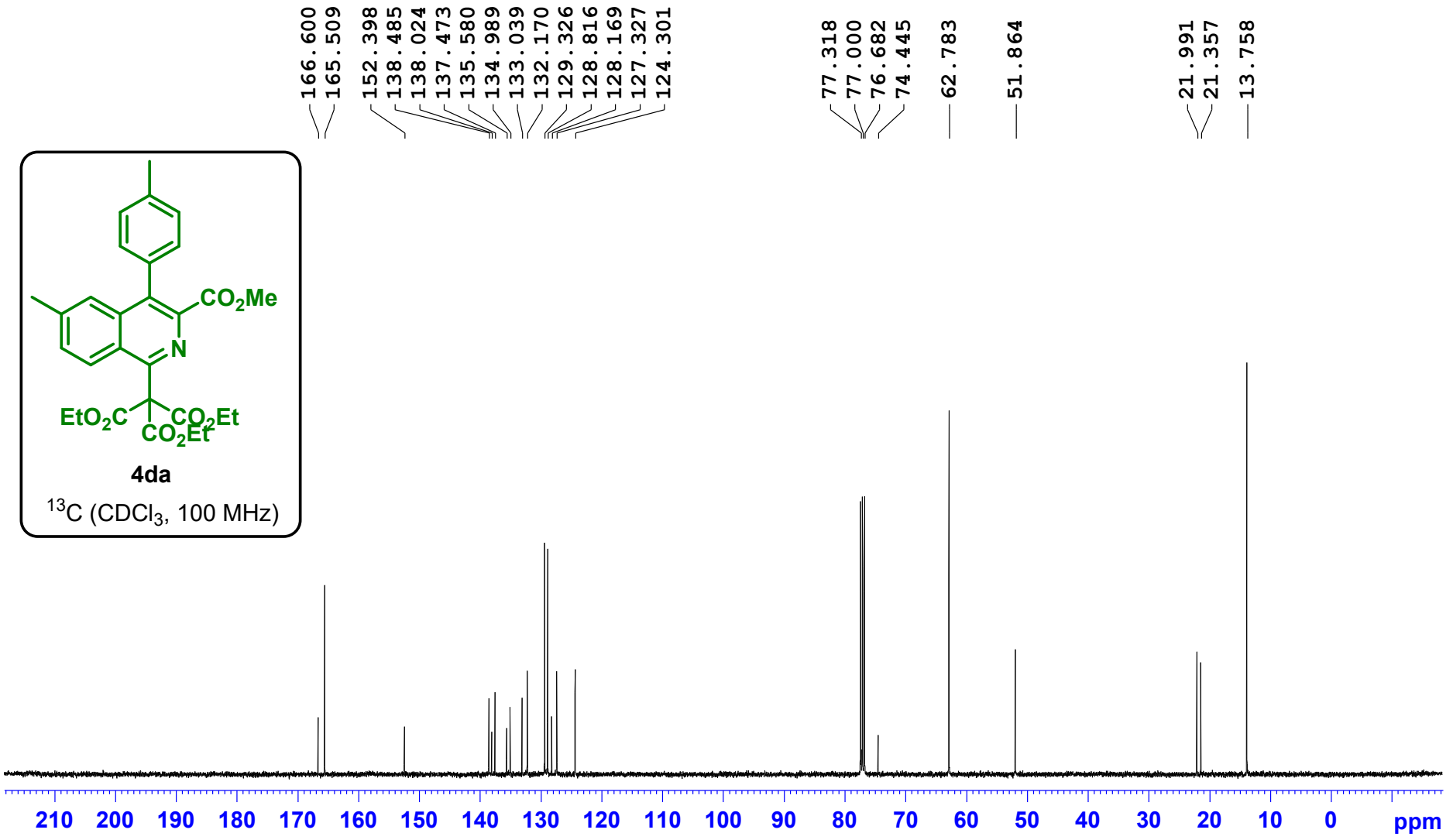

7.796
7.782
7.635
7.624
7.614
7.525
7.508
7.367
7.349
7.284
4.422
4.404
4.387
4.369
3.677
1.311
1.294
1.276
CO2Me
N
EtO2C
CO2Et
CO2Et
4ba
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
3.030
3.012
1.935
6.037
2.960
9.014

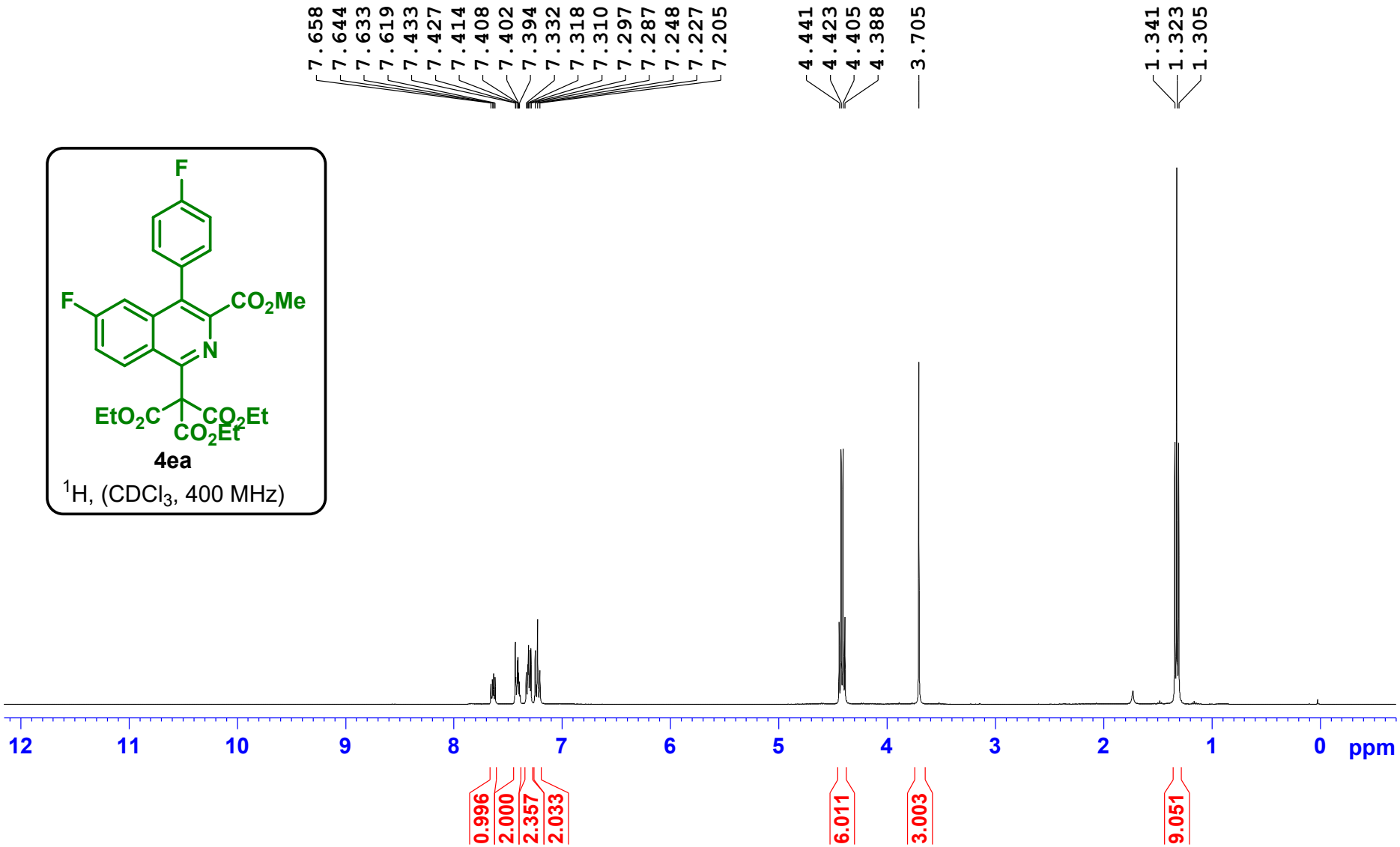

166.507
165.446
153.379
138.927
136.528
135.901
135.297
130.054
129.521
128.175
128.109
127.932
127.396
125.461
77.318
77.000
76.682
74.488
62.856
51.919
13.778
CO2Me
N
EtO2C
CO2Et
CO2Et
4ba
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

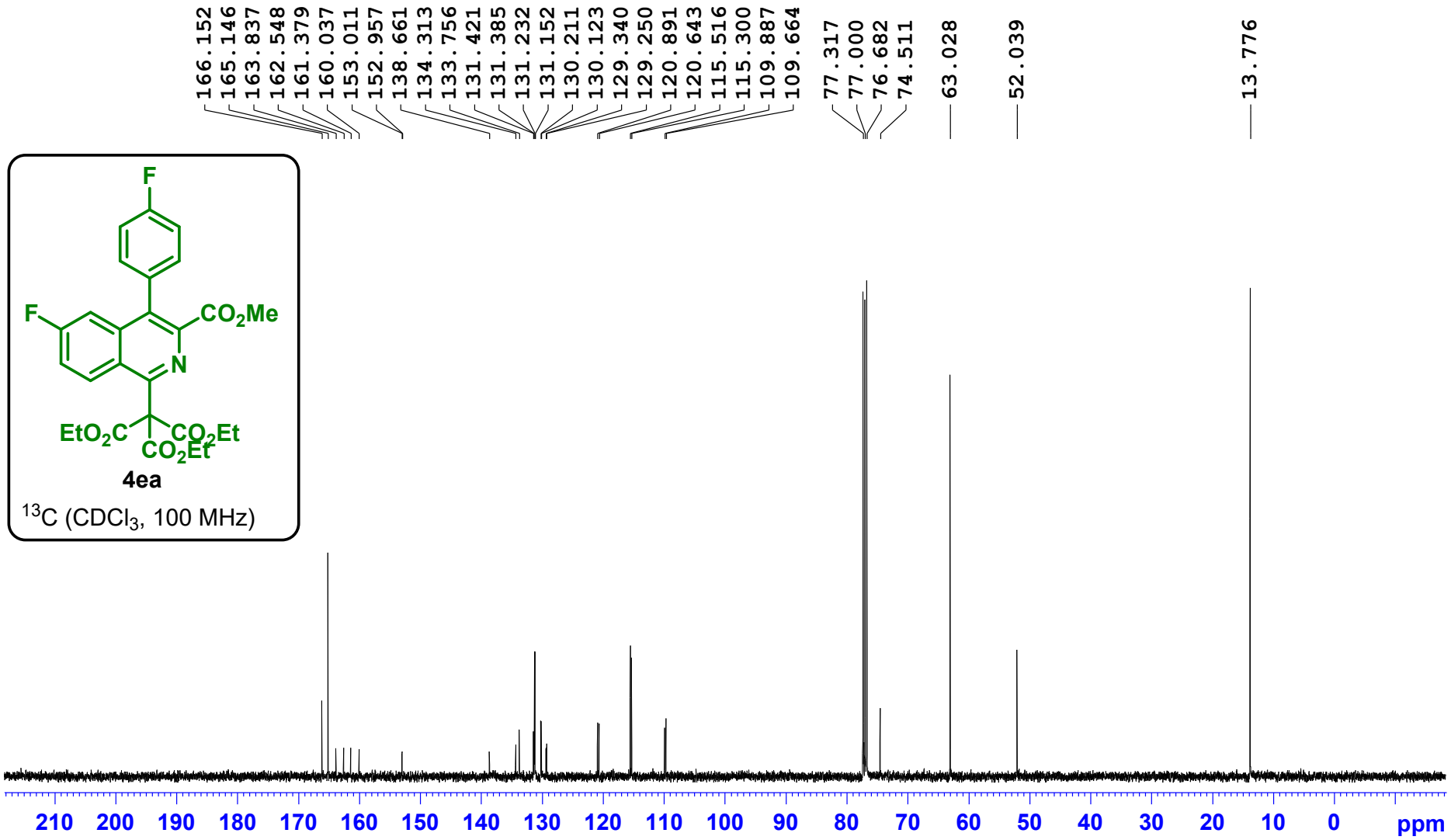

7.742
7.730
7.646
7.635
7.621
7.528
7.513
7.350
7.332
7.284
3.909
3.693
CO2Me
N
MeO2C
CO2Me
CO2Me
4ca
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
2.983
3.034
1.975
8.996
3.028

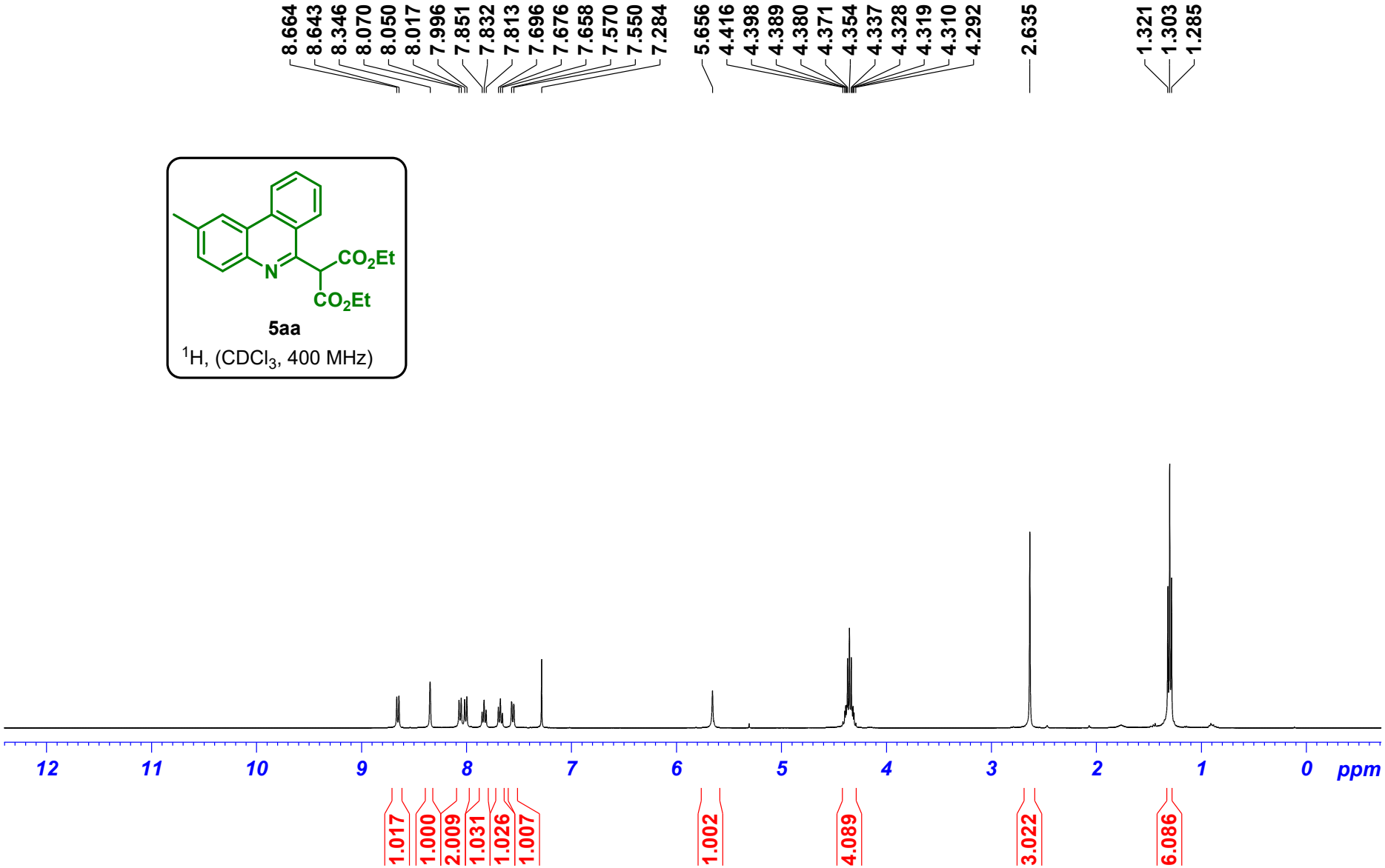

166.267
165.841
153.066
138.558
136.722
135.881
130.212
129.421
128.629
128.134
127.964
127.861
127.672
124.958
77.318
77.000
76.683
74.362
53.771
52.081
CO2Me
N
MeO2C
CO2Me
CO2Me
4ca
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

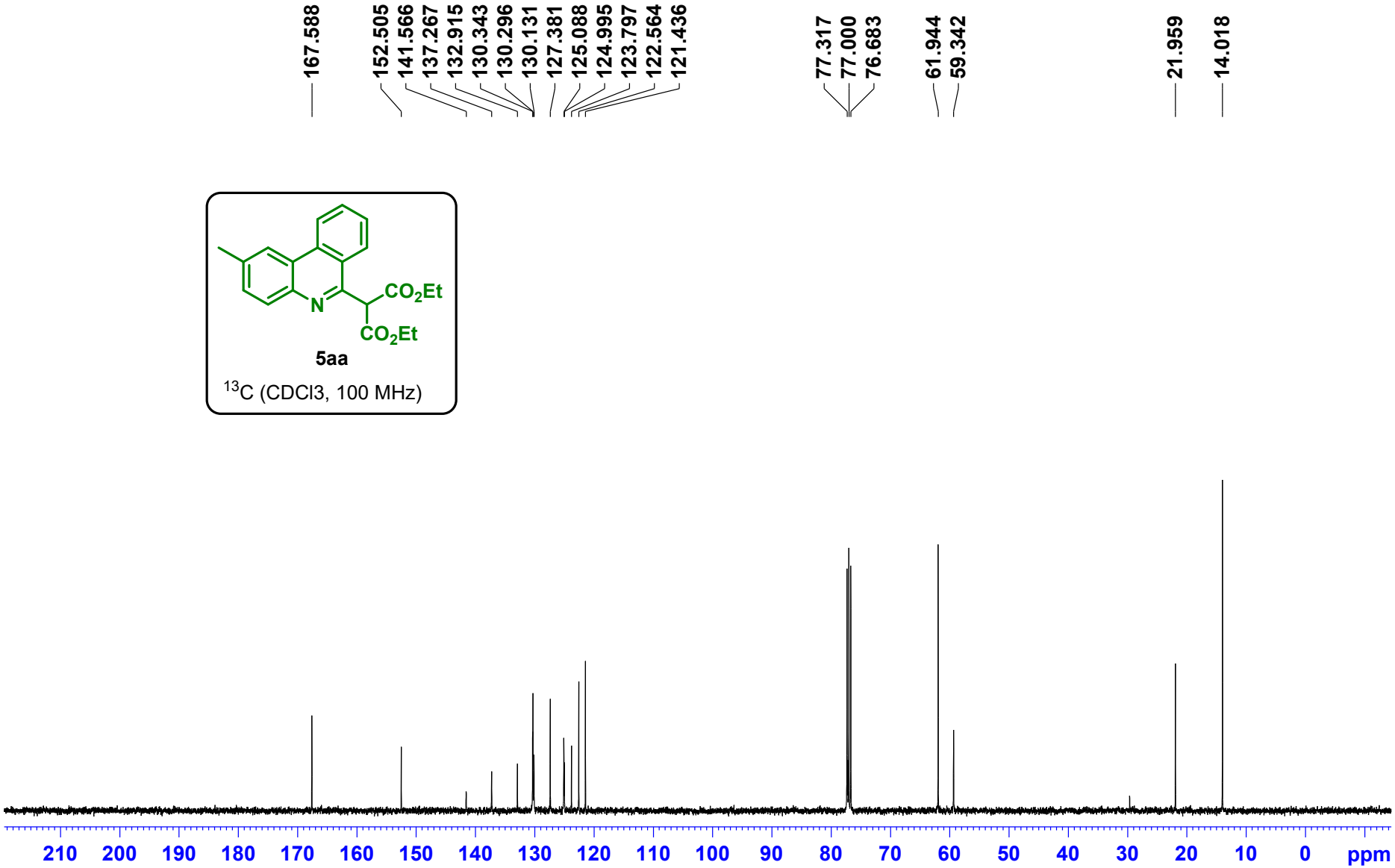

7.574
7.553
7.514
7.439
7.436
7.417
7.414
7.334
7.314
7.287
7.238
7.219
4.427
4.409
4.391
4.374
3.701
2.506
2.482
1.314
1.297
1.279
CO2Me
N
EtO2C
CO2Et
CO2Et
4da
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
0.989
1.042
2.048
2.016
6.164
3.092
2.973
3.105
9.183

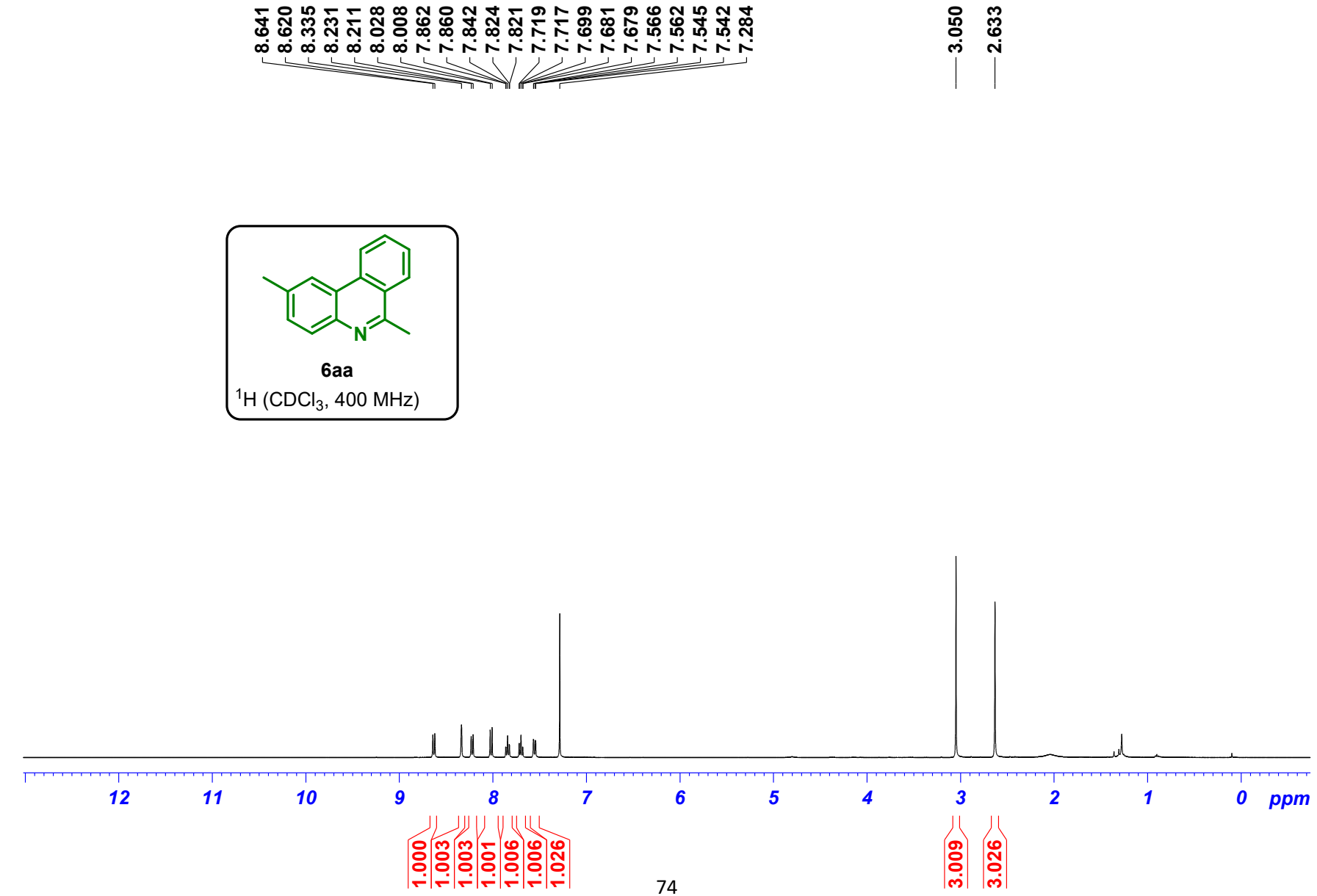

166.600
165.509
152.398
138.485
138.024
137.473
135.580
134.989
133.039
132.170
129.326
128.816
128.169
127.327
124.301
77.318
77.000
76.682
74.445
62.783
51.864
21.991
21.357
13.758
CO2Me
N
EtO2C
CO2Et
CO2Et
4da
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

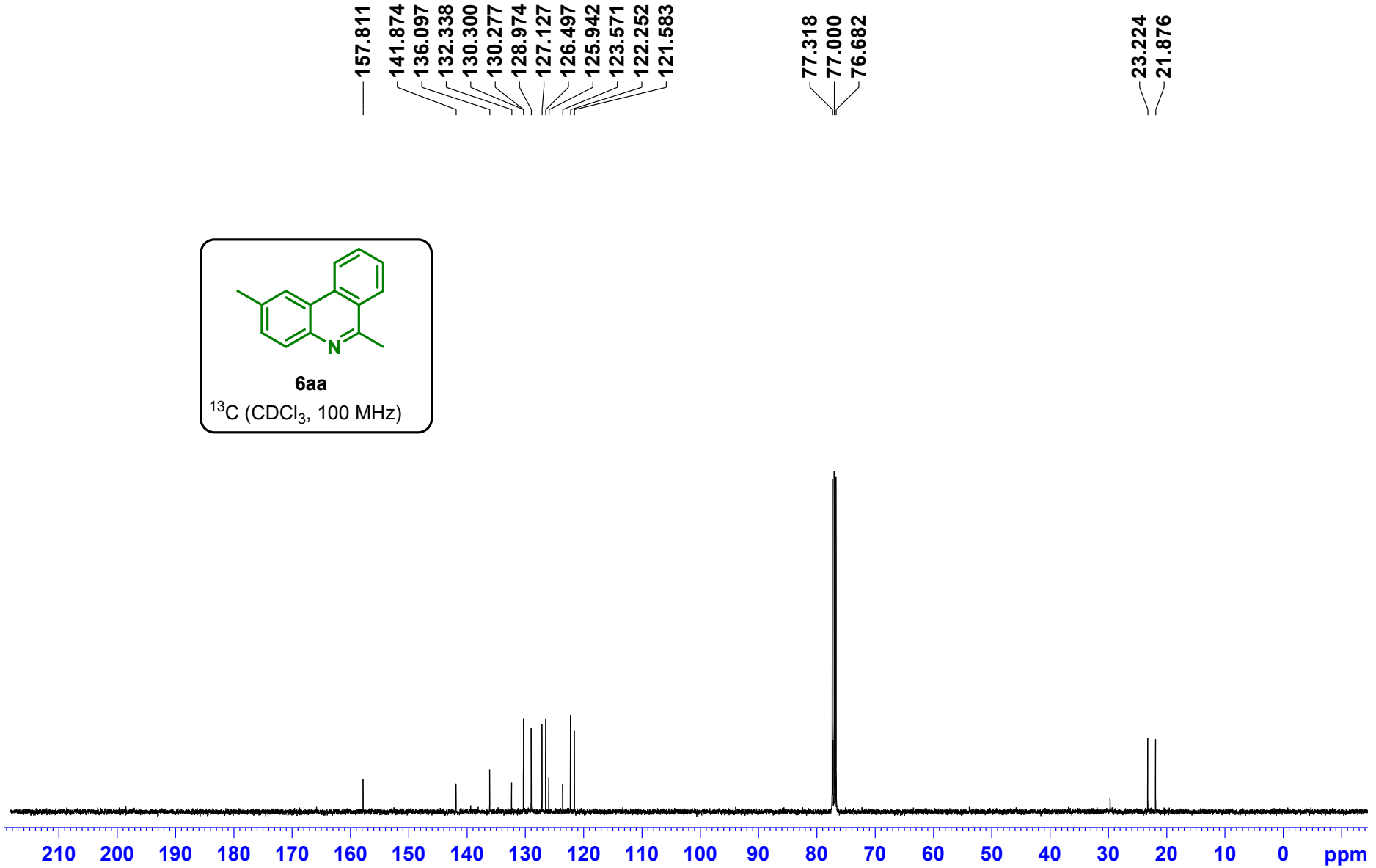

7.658
7.644
7.633
7.619
7.433
7.427
7.414
7.408
7.402
7.394
7.332
7.318
7.310
7.297
7.287
7.248
7.227
7.205
4.441
4.423
4.405
4.388
3.705
1.341
1.323
1.305
F
F
CO2Me
N
EtO2C
CO2Et
CO2Et
4ea
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
0.996
2.000
2.357
2.033
6.011
3.003
9.051


166.152
165.146
163.837
162.548
161.379
160.037
153.011
152.957
138.661
134.313
133.756
131.421
131.385
131.232
131.152
130.211
130.123
129.340
129.250
120.891
120.643
115.516
115.300
109.887
109.664
77.317
77.000
76.682
74.511
63.028
52.039
13.776
F
F
CO2Me
N
EtO2C
CO2Et
CO2Et
4ea
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.664
8.643
8.346
8.070
8.050
8.017
7.996
7.851
7.832
7.813
7.696
7.676
7.658
7.570
7.550
7.284
5.656
4.416
4.398
4.389
4.380
4.371
4.354
4.337
4.328
4.319
4.310
4.292
2.635
1.321
1.303
1.285
CO2Et
CO2Et
N
5aa
1H, (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.017
1.000
2.009
1.031
1.026
1.007
1.002
4.089
3.022
6.086


167.588
152.505
141.566
137.267
132.915
130.343
130.296
130.131
127.381
125.088
124.995
123.797
122.564
121.436
77.317
77.000
76.683
61.944
59.342
21.959
14.018
CO2Et
CO2Et
N
5aa
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.641
8.620
8.335
8.231
8.211
8.028
8.008
7.862
7.860
7.842
7.824
7.821
7.719
7.717
7.699
7.681
7.679
7.566
7.562
7.545
7.542
7.284
3.050
2.633
N
6aa
1H (CDCl3, 400 MHz)
12
11
10
9
8
7
6
5
4
3
2
1
0
ppm
1.000
1.003
1.003
1.001
1.006
1.006
1.026
3.009
3.026


157.811
141.874
136.097
132.338
130.300
130.277
128.974
127.127
126.497
125.942
123.571
122.252
121.583
77.318
77.000
76.682
23.224
21.876
N
6aa
13C (CDCl3, 100 MHz)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm