Supporting Information

Visible-light-promoted iminyl radical formation from vinyl azides: Synthesis of 6-(fluoro)alkylated phenanthridines

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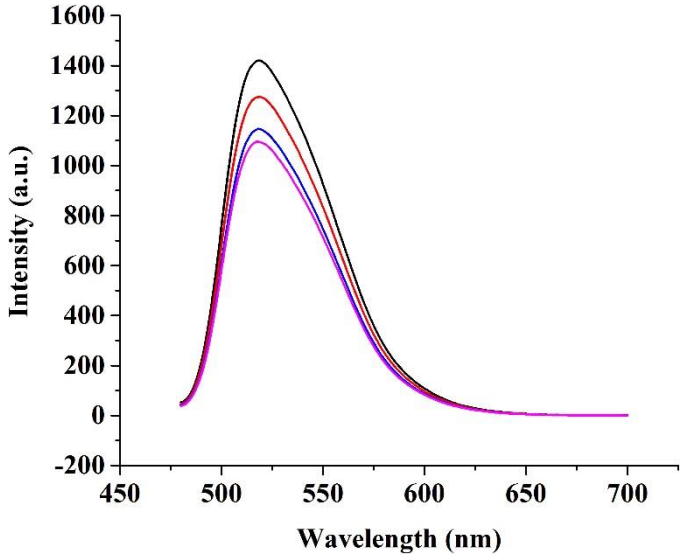
Table of Contents

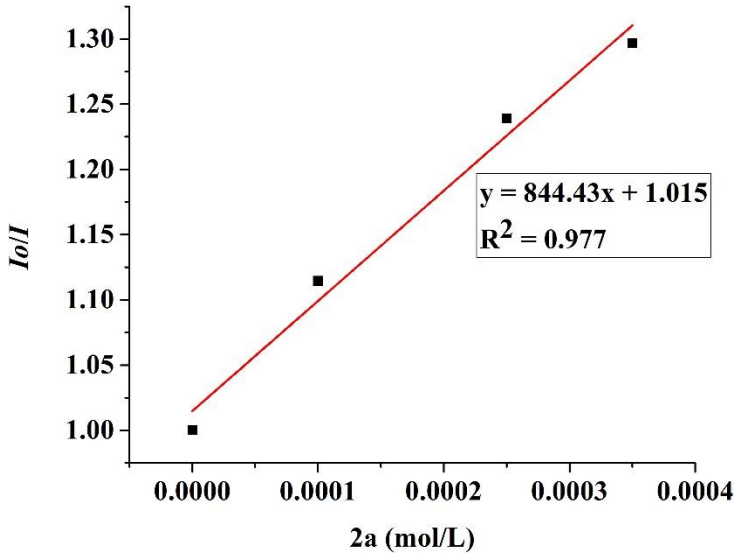
1. General Methods.

DMF was dried according to *Purification of Common Laboratory Chemicals*. Other reagents were used without further purification. Thin layer chromatography (TLC) was performed on EMD precoated plates (silica gel 60 F254, Art 5715) and visualized by fluorescence quenching under UV light and by staining with phosphomolybdic acid or potassium permanganate, respectively. Column chromatography was performed on EMD Silica Gel 60 (300–400 Mesh) using a forced flow of 0.5–1.0 bar. ^{1}H NMR (400 MHz), ^{13}C NMR (100 MHz) and ^{19}F (376 MHz) were measured on a Bruker AVANCE III–400 spectrometer. Chemical shifts are expressed in parts per million (ppm) with respect to the residual solvent peak. Coupling constants are reported as Hertz (Hz), signal shapes and splitting patterns are indicated as follows: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. Infrared (IR) spectra were recorded on a Nicolet 6700 spectrophotometer and are reported as wavenumber (cm^{-1}). Vinyl azides were prepared according to published literature procedures.[1]

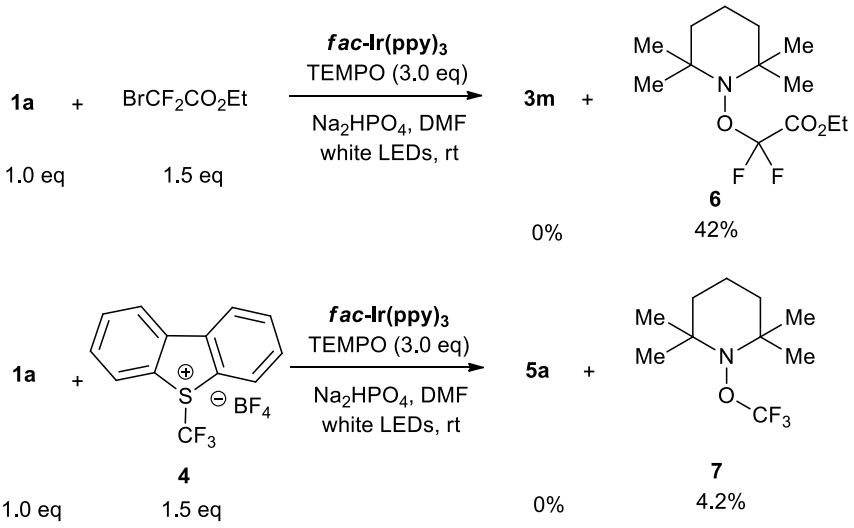
2. Stern-Volmer Studies.

A Hitachi F-7000 fluoresence spectrometer was used to record the emission intensities. All the solutions were excited at 463 nm and the emission intensity at 518 nm was observed. DMF was degassed with a stream of Ar for 15 min. In a typical experiment, the emission spectrum of a 5×10^{-4} M solution of *fac*-Ir(ppy)$_3$ in DMF was collected. Then, appropriate amount of quencher **2a** was added to the measured solution in a quartz cuvette and the emission spectrum of the sample was collected. I_0 and I represent the intensities of the emission in the absence and presence of the quencher at 518 nm.





3. TEMPO Trapping Experiments.

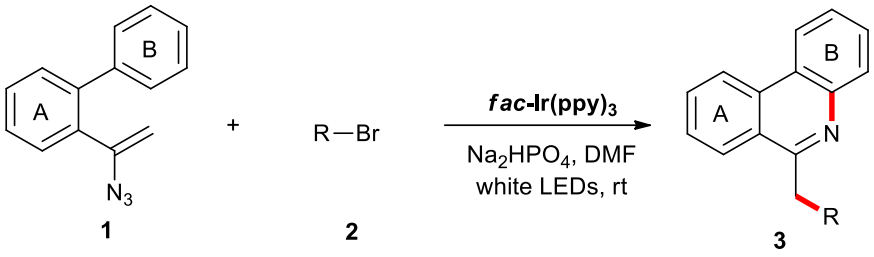


Reaction conditions: A solution of **1a** (0.2 mmol), $BrCF_2CO_2Et$ or **4** (0.3 mmol),

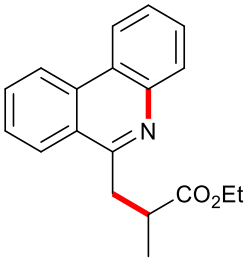
Na_2HPO_4 (0.3 mmol), TEMPO (0.6 mmol) and *fac*-Ir(ppy)$_3$ (0.002 mmol, 1.0 mol%) in DMF (2.0 mL) was irradiated by white LED strips at rt for 24h or 12 h. Yields of TEMPO trapping products **6** and **7** were determined based on ^{19}F NMR using benzotrifluoride as the internal standard.

4. General Procedures.

4.1 General procedure for alkyl radical onto vinyl azides.



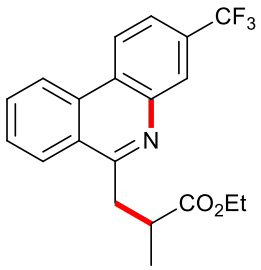
A 10 mL round bottom flask equipped with a rubber septum and magnetic stir bar was charged with vinyl azides **1** (0.2 mmol, 1.0 equiv), *fac*-Ir(ppy)$_3$ (0.002 mmol, 0.01 equiv), Na_2HPO_4 (0.3 mmol, 1.5 equiv). The flask was evacuated and backfilled with N_2 for 3 times. Bromides **2** (0.3 mmol, 1.5 equiv) and DMF (2.0 mL, 0.1 M) were added with syringe under N_2. The mixture was then irradiated by white LED strips at room temperature for 24 h. Then the mixture was poured into a separatory funnel containing 20 mL H_2O and 20 mL Et_2O. The layers were separated and the aqueous layer was extracted with Et_2O (2 × 20 mL). The combined organic layers were dried with Na_2SO_4 and concentrated under reduced pressure after filtration. The crude product was purified by flash chromatography on silica gel to afford the desired product phenanthridine derivatives **3**.



3a

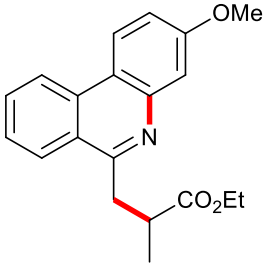
Ethyl 2-methyl-3-(phenanthridin-6-yl)propanoate (3a): yellow solid, yield: 70%. ^1H NMR (400 MHz, $CDCl_3$): δ 8.60 (d, *J* = 8.2 Hz, 1H), 8.51 (d, *J* = 8.1 Hz, 1H), 8.25

(d, *J* = 8.1 Hz, 1H), 8.07 (dd, *J* = 8.1, 0.9 Hz, 1H), 7.84 – 7.76 (m, 1H), 7.68 (tdd, *J* = 8.1, 3.4, 1.2 Hz, 2H), 7.64 – 7.55 (m, 1H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.82 (dq, *J* = 6.9, 3.9 Hz, 1H), 3.49 – 3.30 (m, 2H), 1.36 (d, *J* = 6.9 Hz, 3H), 1.19 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.72, 158.83, 143.55, 132.71, 130.28, 129.76, 128.48, 127.28, 126.40, 125.75, 125.50, 123.60, 122.43, 121.89, 60.30, 38.45, 38.12, 17.54, 14.25. FTIR (film) ν_{max} 2978.63, 2898.13, 1721.04, 1605.61, 1585.86, 1527.10, 1486.49, 1415.35, 1379.30, 1299.03, 954.46 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{20}NO_2$ $[M+H]^+$ 294.1494, found 294.1495.



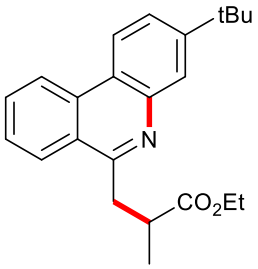
3b

Ethyl 2-methyl-3-(3-(trifluoromethyl)phenanthridin-6-yl)propanoate (3b): yellow solid, yield: 65%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.58 (t, *J* = 8.4 Hz, 2H), 8.33 (s, 1H), 8.28 (d, *J* = 7.7 Hz, 1H), 7.90 – 7.81 (m, 1H), 7.81 – 7.72 (m, 2H), 4.25 – 4.07 (m, 2H), 3.83 (dd, *J* = 15.5, 7.6 Hz, 1H), 3.51 – 3.33 (m, 2H), 1.39 (d, *J* = 6.9 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.66, 160.46, 142.79, 131.78, 130.82, 130.25 (q, *J* = 32.6 Hz), 128.46, 127.24 (q, *J* = 4.1 Hz), 126.69, 126.05, 125.87, 124.20 (q, *J* = 270.7 Hz), 122.92, 122.76, 122.21 (q, *J* = 3.3 Hz), 60.38, 38.37, 37.73, 17.64, 14.23; ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.22. FTIR (film) ν_{max} 1720.68, 1591.59, 1529.91, 1414.95, 1375.70, 1331.50, 1286.80, 1273.52, 1225.55, 1168.36, 1111.86, 1067.31, 934.70, 903.38, 758.65 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{19}F_3NO_2$ $[M+H]^+$ 362.1368, found 362.1373.



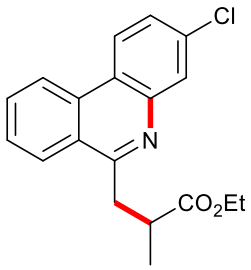
3c

Ethyl 3-(3-methoxyphenanthridin-6-yl)-2-methylpropanoate (3c): yellow solid, yield: 59%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.50 (d, *J* = 8.3 Hz, 1H), 8.40 (d, *J* = 9.0 Hz, 1H), 8.23 (d, *J* = 8.2 Hz, 1H), 7.77 (t, *J* = 7.6 Hz, 1H), 7.60 (t, *J* = 7.6 Hz, 1H), 7.48 (d, *J* = 2.6 Hz, 1H), 7.24 (dd, *J* = 9.0, 2.6 Hz, 1H), 4.19 – 4.04 (m, 2H), 3.97 (s, 3H), 3.88 – 3.76 (m, 1H), 3.44 – 3.21 (m, 2H), 1.35 (d, *J* = 6.7 Hz, 3H), 1.18 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.64, 160.01, 159.50, 145.14, 132.95, 130.38, 126.21, 125.85, 124.57, 123.14, 121.96, 117.63, 117.41, 109.60, 60.31, 55.56, 38.54, 38.39, 17.50, 14.26. FTIR (film) ν_{max} 2973.83, 2920.56, 2842.06, 1726.17, 1611.21, 1583.18, 1485.05, 1442.99, 1154.21, 1030.84, 851.40, 826.17 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{22}NO_3$ $[M+H]^+$ 324.1600, found 323.1594.



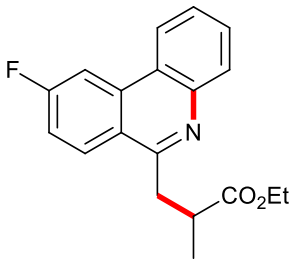
3d

Ethyl 3-(3-(*tert*-butyl)phenanthridin-6-yl)-2-methylpropanoate (3d): white solid, yield: 80%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.58 (d, *J* = 8.2 Hz, 1H), 8.45 (d, *J* = 8.6 Hz, 1H), 8.25 (d, *J* = 8.2 Hz, 1H), 8.06 (d, *J* = 1.8 Hz, 1H), 7.79 (t, *J* = 7.6 Hz, 1H), 7.73 – 7.60 (m, 2H), 4.14 (qq, *J* = 10.8, 7.1 Hz, 2H), 3.83 (q, *J* = 2.5 Hz, 1H), 3.47 – 3.32 (m, 2H), 1.46 (s, 9H), 1.35 (d, *J* = 6.7 Hz, 3H), 1.20 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.76, 158.88, 151.84, 143.53, 132.72, 130.25, 126.87, 125.82, 125.63, 125.29, 124.69, 122.32, 121.60, 121.22, 60.33, 38.57, 38.43, 34.96, 31.39, 17.52, 14.27. FTIR (film) ν_{max} 2960.83, 1721.91, 1612.35, 1586.55, 1486.24, 1457.75, 1443.62, 1378.39, 1298.44, 1232.83, 1033.93, 854.29, 825.98 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{23}H_{28}NO_2$ $[M+H]^+$ 350.2120, found 350.2124.



3e

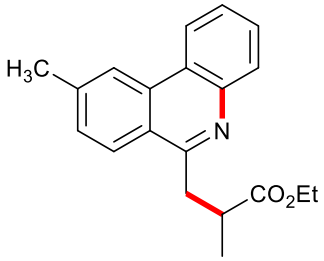
Ethyl 3-(3-chlorophenanthridin-6-yl)-2-methylpropanoate (3e): yellow solid, yield: 75%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.52 (d, *J* = 8.3 Hz, 1H), 8.39 (d, *J* = 8.8 Hz, 1H), 8.24 (d, *J* = 8.2 Hz, 1H), 8.03 (d, *J* = 2.1 Hz, 1H), 7.81 (t, *J* = 7.3 Hz, 1H), 7.69 (t, *J* = 7.6 Hz, 1H), 7.53 (dd, *J* = 8.7, 2.2 Hz, 1H), 4.14 (q, *J* = 7.1 Hz, 2H), 3.80 (dd, *J* = 15.2, 7.3 Hz, 1H), 3.46 – 3.32 (m, 2H), 1.37 (d, *J* = 6.9 Hz, 3H), 1.21 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.69, 160.20, 144.19, 134.04, 132.20, 130.68, 128.95, 127.59, 126.89, 125.84, 125.40, 123.29, 122.35, 122.07, 60.37, 38.36, 37.80, 17.63, 14.29. FTIR (film) ν_{max} 2978.57, 1719.48, 1601.98, 1587.46, 1570.32, 1477.85, 1443.88, 1369.41, 1352.08, 1275.40, 1259.49, 1230.81, 1170.16, 1079.56, 1028.60, 879.12 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{19}ClNO_2$ $[M+H]^+$ 328.1104, found 328.1099.



3f

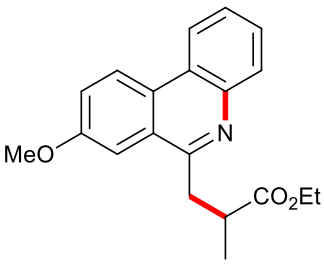
Ethyl 3-(9-fluorophenanthridin-6-yl)-2-methylpropanoate (3f): yellow solid, yield: 67%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.36 (d, *J* = 8.1 Hz, 1H), 8.26 (dd, *J* = 9.0, 5.7 Hz, 1H), 8.17 (dd, *J* = 10.4, 2.5 Hz, 1H), 8.05 (d, *J* = 8.1 Hz, 1H), 7.70 (t, *J* = 7.6 Hz, 1H), 7.59 (t, *J* = 7.6 Hz, 1H), 7.39 (td, *J* = 8.6, 2.5 Hz, 1H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.79 (dd, *J* = 15.3, 7.6 Hz, 1H), 3.46 – 3.30 (m, 2H), 1.37 (d, *J* = 6.9 Hz, 3H), 1.20 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.68, 163.63 (d, *J* = 249.7 Hz), 158.24, 143.83, 135.14 (d, *J* = 9.2 Hz), 129.82, 129.17, 128.64 (d, *J* = 9.3 Hz), 126.47, 123.16 (d, *J* = 4.0 Hz), 122.49 (d, *J* = 1.7 Hz), 122.09, 116.25 (d, *J* = 23.5 Hz), 107.56

(d, *J* = 21.9 Hz), 60.36, 38.49, 38.03, 17.61, 14.28; ^{19}F NMR (376 MHz, $CDCl_3$) δ -107.45. FTIR (film) ν_{max} 2981.26, 1712.38, 1620.37, 1588.23, 1532.86, 1497.64, 1457.79, 1443.56, 1378.86, 1260.17, 1228.82, 1029.53, 868.29 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{19}FNO2$ $[M+H]^+$ 312.1400, found 312.1404.



3g

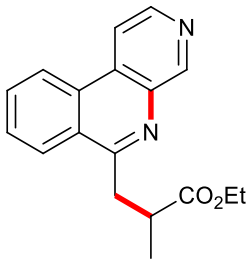
Ethyl 2-methyl-3-(9-methylphenanthridin-6-yl)propanoate (3g): yellow solid, yield: 74%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.49 (d, *J* = 7.8 Hz, 1H), 8.37 (s, 1H), 8.13 (d, *J* = 8.4 Hz, 1H), 8.04 (dd, *J* = 8.1, 0.8 Hz, 1H), 7.69 – 7.61 (m, 1H), 7.61 – 7.53 (m, 1H), 7.48 (dd, *J* = 8.4, 1.1 Hz, 1H), 4.12 (q, *J* = 7.1 Hz, 2H), 3.78 (dd, *J* = 14.7, 6.9 Hz, 1H), 3.48 – 3.22 (m, 2H), 2.61 (s, 3H), 1.34 (d, *J* = 6.9 Hz, 3H), 1.18 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.74, 158.70, 143.74, 140.57, 132.85, 129.69, 128.95, 128.33, 126.15, 125.68, 123.64, 123.50, 122.09, 121.87, 60.28, 38.44, 38.21, 22.20, 17.51, 14.26. FTIR (film) ν_{max} 3130.46, 3056.43, 2973.93, 2931.34, 2801.76, 1721.07, 1617.76, 1587. 37, 1520.40, 1455.68, 1409.53, 1233.29, 1032.62, 818.76 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{22}NO_2$ $[M+H]^+$ 308.1651, found 308.1656.



3h

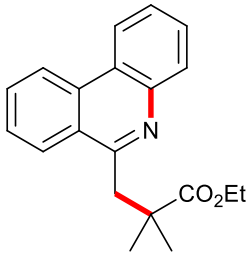
Ethyl 3-(8-methoxyphenanthridin-6-yl)-2-methylpropanoate (3h): yellow solid, yield: 75%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.53 (d, *J* = 9.1 Hz, 1H), 8.44 (dd, *J* = 8.1, 1.2 Hz, 1H), 8.04 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.68 – 7.54 (m, 3H), 7.45 (dd, *J* = 9.0, 2.6 Hz, 1H), 4.14 (q, *J* = 7.1 Hz, 2H), 4.00 (s, 3H), 3.78 (dd, *J* = 15.5, 7.6 Hz, 1H), 3.38

(ddd, *J* = 21.8, 14.6, 6.6 Hz, 2H), 1.38 (d, *J* = 7.0 Hz, 3H), 1.20 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.85, 158.67, 157.91, 142.71, 129.70, 127.48, 127.03, 126.77, 126.46, 124.14, 123.70, 121.40, 120.71, 105.99, 60.33, 55.59, 38.66, 37.98, 17.56, 14.27. FTIR (film) ν_{max} 2978.43, 1718.91, 1617.70, 1574.47, 1533.33, 1484.09, 1464.78, 1388.59, 1218.74, 1129.03, 1038.61, 830.73 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{22}NO_3$ $[M+H]^+$ 324.1600, found 323.1604.



3i

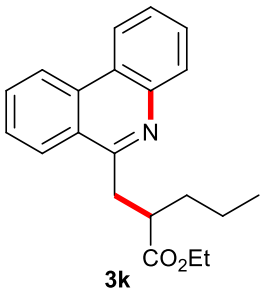
Ethyl 3-(benzo[*c*][1,7]naphthyridin-6-yl)-2-methylpropanoate (3i): yellow solid, yield: 78%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.38 (s, 1H), 8.72 (d, *J* = 5.5 Hz, 1H), 8.60 (d, *J* = 7.9 Hz, 1H), 8.32 (d, *J* = 7.6 Hz, 1H), 8.26 (d, *J* = 5.6 Hz, 1H), 7.94 – 7.87 (m, 1H), 7.86 – 7.75 (m, 1H), 4.25 – 4.06 (m, 2H), 3.85 (dd, *J* = 15.7, 8.0 Hz, 1H), 3.55 – 3.33 (m, 2H), 1.41 (d, *J* = 6.9 Hz, 3H), 1.24 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.69, 160.84, 152.99, 149.46, 145.07, 130.93, 130.63, 129.60, 128.59, 127.01, 125.90, 123.04, 115.15, 60.44, 38.40, 37.61, 17.71, 14.31. FTIR (film) ν_{max} 2974.84, 1725.89, 1589.31, 1574.77, 1518.69, 1454.21, 1406.54, 1377.60, 1260.58, 1232.43, 1162.68, 824.26 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{19}N_2O_2$ $[M+H]^+$ 295.1447, found 295.1450.



3j

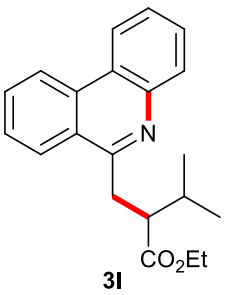
Ethyl 2,2-dimethyl-3-(phenanthridin-6-yl)propanoate (3j): yellow solid, yield: 73%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (d, *J* = 8.2 Hz, 1H), 8.51 (d, *J* = 7.2 Hz, 1H), 8.22 (d, *J* = 8.2 Hz, 1H), 8.03 (d, *J* = 8.0 Hz, 1H), 7.86 – 7.74 (m, 1H), 7.72 –

7.55 (m, 3H), 4.11 (q, *J* = 7.1 Hz, 2H), 3.64 (s, 2H), 1.44 (s, 6H), 1.10 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 178.14, 157.76, 143.30, 132.63, 130.12, 129.74, 128.42, 127.11, 126.36, 125.89, 125.72, 123.36, 122.43, 121.82, 60.20, 44.33, 41.70, 26.19, 14.16. FTIR (film) ν_{max} 2966.23, 1717.53, 1588.25, 1470.42, 1361.27, 1309.22, 1276.61, 1256.63, 1197.32, 1144.28, 1033.19, 751.19 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{20}H_{22}NO_2$ $[M+H]^+$ 308.1651, found 308.1654.



3k

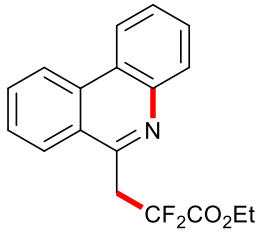
Ethyl 2-(phenanthridin-6-ylmethyl)pentanoate (3k): yellow solid, yield: 62%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.60 (d, *J* = 8.3 Hz, 1H), 8.50 (d, *J* = 8.1 Hz, 1H), 8.25 (d, *J* = 8.2 Hz, 1H), 8.06 (d, *J* = 8.1 Hz, 1H), 7.80 (t, *J* = 7.6 Hz, 1H), 7.67 (td, *J* = 7.4, 3.3 Hz, 2H), 7.59 (t, *J* = 7.5 Hz, 1H), 4.11 (q, *J* = 7.1 Hz, 2H), 3.76 (dd, *J* = 15.8, 9.2 Hz, 1H), 3.45 (dd, *J* = 15.8, 5.2 Hz, 1H), 3.35 (ddd, *J* = 10.7, 8.8, 5.5 Hz, 1H), 1.84 (ddd, *J* = 14.2, 12.0, 7.4 Hz, 1H), 1.69 (ddd, *J* = 19.5, 11.4, 6.3 Hz, 1H), 1.53 – 1.39 (m, 2H), 1.16 (t, *J* = 7.1 Hz, 3H), 0.95 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.40, 158.98, 143.52, 132.68, 130.29, 129.75, 128.47, 127.29, 126.39, 125.75, 125.48, 123.60, 122.43, 121.90, 60.14, 43.55, 37.20, 34.89, 20.67, 14.32, 14.14. FTIR (film) ν_{max} 2957.88, 2932.13, 1712.01, 1587.14, 1486.04, 1447.30, 1413.61, 1372.93, 1276.30, 1236.56, 1204.43, 1176.78, 1152.32, 1035.25, 921.25 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{21}H_{24}NO_2$ $[M+H]^+$ 322.1807, found 322.1802.



3l

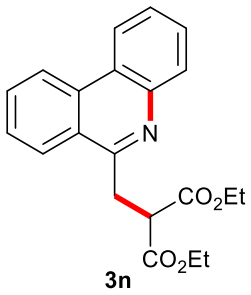
Ethyl 3-methyl-2-(phenanthridin-6-ylmethyl)butanoate (3l): yellow solid, yield:

49%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.3 Hz, 1H), 8.51 (d, *J* = 8.1 Hz, 1H), 8.27 (d, *J* = 8.2 Hz, 1H), 8.05 (d, *J* = 8.1 Hz, 1H), 7.81 (t, *J* = 7.6 Hz, 1H), 7.73 – 7.63 (m, 2H), 7.59 (t, *J* = 7.5 Hz, 1H), 4.08 (q, *J* = 7.1 Hz, 2H), 3.78 (dd, *J* = 16.2, 10.8 Hz, 1H), 3.50 (dd, *J* = 16.2, 3.8 Hz, 1H), 3.36 – 3.19 (m, 1H), 2.25 – 2.02 (m, 1H), 1.15 (dt, *J* = 7.1, 3.7 Hz, 6H), 1.10 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.50, 159.27, 143.51, 132.63, 130.25, 129.73, 128.42, 127.24, 126.32, 125.70, 125.53, 123.58, 122.42, 121.88, 49.72, 34.26, 30.84, 20.62, 20.43, 14.37. FTIR (film) ν_{max} 2961.93, 1711.53, 1611.21, 1587.02, 1472.21, 1407.55, 1373.84, 1348.60, 1275.65, 1257.69, 1115.61, 1037.67 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{21}H_{24}NO_2$ $[M+H]^+$ 322.1807, found 322.1802.



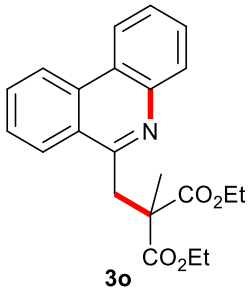
3m

Ethyl 2,2-difluoro-3-(phenanthridin-6-yl)propanoate (3m): yellow oil, yield: 55%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (d, *J* = 8.3 Hz, 1H), 8.52 (d, *J* = 7.9 Hz, 1H), 8.12 (d, *J* = 8.2 Hz, 1H), 8.02 (d, *J* = 7.8 Hz, 1H), 7.84 (t, *J* = 7.6 Hz, 1H), 7.74 – 7.66 (m, 2H), 7.63 (t, *J* = 7.0 Hz, 1H), 4.36 (q, *J* = 7.1 Hz, 2H), 4.23 (t, *J* = 14.0 Hz, 2H), 1.27 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.96 (t, *J* = 31.5 Hz), 152.92 (t, *J* = 6.0 Hz), 142.84, 132.86, 130.86, 129.59, 128.78, 127.64, 127.17, 125.45, 125.09, 123.70, 122.58, 121.97, 115.88 (t, *J* = 248.0 Hz), 62.62, 40.13 (t, *J* = 24.9 Hz), 13.97; ^{19}F NMR (376 MHz, $CDCl_3$) δ -103.33. FTIR (film) ν_{max} 2993.46, 1765.42, 1726.17, 1681.31, 1614.02, 1591.59, 1524.30, 1490.65, 1462.62, 1370.09, 1339.25, 1305.61, 1255.14, 1221.50, 1193.46, 751.76 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{16}F_2I_2NO_2$ $[M+H]^+$ 316.1149, found 316.1144.



3n

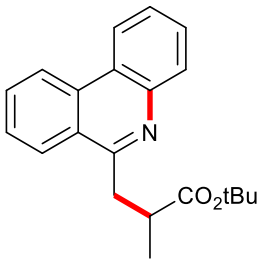
Diethyl 2-(phenanthridin-6-ylmethyl)malonate (3n): yellow solid, yield: 65%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.59 (d, *J* = 8.3 Hz, 1H), 8.50 (d, *J* = 8.0 Hz, 1H), 8.26 (d, *J* = 8.1 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 1H), 7.81 (t, *J* = 7.6 Hz, 1H), 7.68 (dd, *J* = 14.0, 7.1 Hz, 2H), 7.60 (t, *J* = 7.5 Hz, 1H), 4.57 (t, *J* = 7.4 Hz, 1H), 4.26 (q, *J* = 7.1 Hz, 4H), 4.00 (d, *J* = 7.4 Hz, 2H), 1.29 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.00, 156.96, 143.27, 132.57, 130.45, 129.70, 128.47, 127.41, 126.53, 125.43, 125.26, 123.70, 122.42, 121.94, 61.47, 49.47, 33.64, 14.20. FTIR (film) ν_{max} 2990.31, 2939.19, 1744.53, 1720.74, 1612.90, 1587.17, 1487.47, 1465.75, 1448.70, 1422.88, 1387.44, 1365.38, 1339.87, 1256.95, 1155.62, 1100.24, 1007.04, 949.98, 860.87 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{21}H_{22}NO_4$ $[M+H]^+$ 352.1549, found 352.1553.



3o

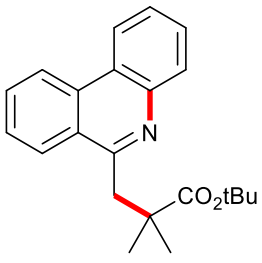
Diethyl 2-methyl-2-(phenanthridin-6-ylmethyl)malonate (3o): yellow solid, yield: 90%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.60 (d, *J* = 8.2 Hz, 1H), 8.50 (d, *J* = 8.0 Hz, 1H), 8.28 (d, *J* = 8.2 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 1H), 7.81 (t, *J* = 7.6 Hz, 1H), 7.67 (dd, *J* = 12.4, 7.4 Hz, 2H), 7.59 (t, *J* = 7.1 Hz, 1H), 4.25 (q, *J* = 7.1 Hz, 4H), 4.05 (s, 2H), 1.72 (s, 3H), 1.23 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.56, 156.40, 143.07, 132.63, 130.32, 129.59, 128.48, 127.32, 126.54, 125.72, 125.54, 123.40, 122.47, 121.86, 61.29, 53.04, 39.39, 20.70, 14.10. FTIR (film) ν_{max} 2979.44, 2931.78, 1757.16, 1723.48, 1622.43, 1591.59, 1580.37, 1440.19, 1378.50, 1361.68, 1275.22, 1249.03, 1184.26, 1099.15, 1022.43, 859.81 cm^{-1}. HRMS (ESI): *m/z* calcd

for $C_{22}H_{24}NO_4$ $[M+H]^+$ 366.1705, found 366.1700.



3p

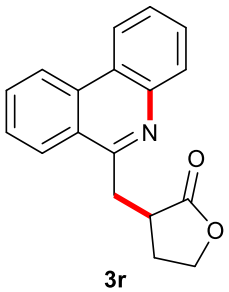
***Tert*-butyl 2-methyl-3-(phenanthridin-6-yl)propanoate (3p):** yellow oil, yield: 59%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.2 Hz, 1H), 8.52 (d, *J* = 7.9 Hz, 1H), 8.27 (d, *J* = 8.2 Hz, 1H), 8.09 (d, *J* = 7.9 Hz, 1H), 7.81 (t, *J* = 7.2 Hz, 1H), 7.68 (q, *J* = 6.0 Hz, 2H), 7.59 (dd, *J* = 11.1, 4.0 Hz, 1H), 3.78 (td, *J* = 9.7, 4.1 Hz, 1H), 3.33 (tt, *J* = 18.8, 6.6 Hz, 2H), 1.39 (s, 9H), 1.33 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.95, 159.16, 143.56, 132.70, 130.26, 129.75, 128.47, 127.28, 126.35, 125.88, 125.54, 123.61, 122.42, 121.91, 79.85, 38.98, 38.55, 28.08, 17.61. FTIR (film) ν_{max} 2979.44, 2934.58, 1728.97, 1608.41, 1585.98, 1485.05, 1459.81, 1361.68, 1277.57, 1255.14, 1232.71, 1145.79, 753.27 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{21}H_{24}NO_2$ $[M+H]^+$ 322.1807, found 322.1802.



3q

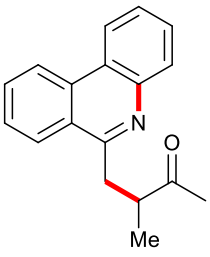
***Tert*-butyl 2,2-dimethyl-3-(phenanthridin-6-yl)propanoate (3q):** yellow solid, yield: 75%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.63 (d, *J* = 8.3 Hz, 1H), 8.52 (d, *J* = 8.0 Hz, 1H), 8.25 (d, *J* = 8.2 Hz, 1H), 8.08 (d, *J* = 8.0 Hz, 1H), 7.81 (t, *J* = 7.6 Hz, 1H), 7.67 (t, *J* = 7.5 Hz, 2H), 7.59 (t, *J* = 7.5 Hz, 1H), 3.60 (s, 2H), 1.41 (s, 6H), 1.35 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.20, 157.96, 143.33, 132.60, 130.04, 129.87, 128.36, 127.10, 126.25, 125.92, 125.81, 123.34, 122.40, 121.80, 79.24, 44.05, 42.03, 28.00, 26.34. FTIR (film) ν_{max} 2973.04, 2920.56, 2864.49, 1717.57, 1619.63, 1586.82, 1474,32, 1447.39, 1362.96, 1313.91, 1172.13, 899.28, 853.87 cm^{-1}. HRMS (ESI): *m/z*

calcd for $C_{22}H_{26}NO_2$ $[M+H]^+$ 336.1964, found 336.1967.



3r

3-(Phenanthridin-6-ylmethyl)dihydrofuran-2(3*H*)-one (3r): yellow solid, yield: 75%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.64 (d, *J* = 8.3 Hz, 1H), 8.55 (d, *J* = 7.8 Hz, 1H), 8.24 (d, *J* = 8.2 Hz, 1H), 8.09 (d, *J* = 7.7 Hz, 1H), 7.85 (t, *J* = 7.6 Hz, 1H), 7.71 (t, *J* = 7.5 Hz, 2H), 7.64 (t, *J* = 7.6 Hz, 1H), 4.52 (td, *J* = 8.9, 2.7 Hz, 1H), 4.36 (td, *J* = 9.3, 7.1 Hz, 1H), 4.07 (d, *J* = 13.9 Hz, 1H), 3.59 – 3.37 (m, 2H), 2.79 – 2.62 (m, 1H), 2.19 (tt, *J* = 12.7, 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 180.14, 157.30, 143.36, 132.73, 130.58, 129.73, 128.63, 127.59, 126.72, 125.42, 125.33, 123.72, 122.57, 122.01, 67.03, 37.53, 35.57, 29.11. FTIR (film) ν_{max} 2907.72, 1755.88, 1585.98, 1485.18, 1412.54, 1382.45, 1276.12, 1260.56, 1169.18, 1153.29, 1030.39, 960.90 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{16}NO_2$ $[M+H]^+$ 278.1181, found 278.1176.

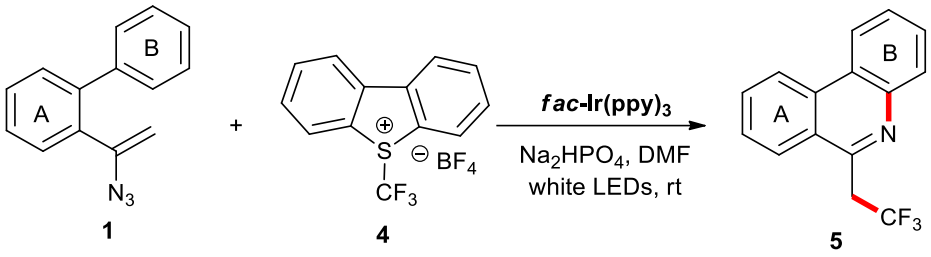


3s

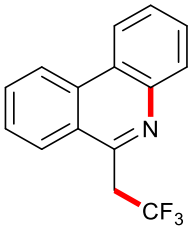
3-Methyl-4-(phenanthridin-6-yl)butan-2-one (3s): yellow solid, yield: 62%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.2 Hz, 1H), 8.52 (d, *J* = 8.2 Hz, 1H), 8.26 (d, *J* = 8.2 Hz, 1H), 8.06 (d, *J* = 8.1 Hz, 1H), 7.82 (t, *J* = 7.7 Hz, 1H), 7.75 – 7.65 (m, 2H), 7.62 (t, *J* = 7.5 Hz, 1H), 3.88 (dd, *J* = 16.5, 9.0 Hz, 1H), 3.66 (tt, *J* = 14.4, 7.2 Hz, 1H), 3.37 (dd, *J* = 16.5, 4.8 Hz, 1H), 2.48 (s, 3H), 1.33 (d, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 212.77, 158.78, 143.44, 132.57, 130.28, 129.44, 128.40, 127.27, 126.34, 125.69, 125.48, 123.60, 122.36, 121.93, 43.93, 38.20, 29.31, 17.13. FTIR

(film) ν_{max} 2970.96, 1701.94, 1614.02, 1585.95, 1524.30, 1486.34, 1409.63, 1377.81, 1364.05, 1344.99, 1297.20, 1224.30, 1168.35, 1036.45, 952.34, 919.38 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{18}H_{18}NO$ $[M+H]^+$ 264.1388, found 264.1384.

4.2 General procedure for trifluoromethyl radical onto vinyl azides.



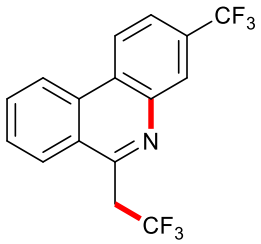
A 10 mL round bottom flask equipped with a rubber septum and magnetic stir bar was charged with vinyl azides **1** (0.2 mmol, 1.0 equiv), Umemoto's reagent **4** (0.3 mmol, 1.5 equiv), *fac*-Ir(ppy)$_3$ (0.002 mmol, 0.01 equiv), Na_2HPO_4 (0.3 mmol, 1.5 equiv). The flask was evacuated and backfilled with N_2 for 3 times. DMF (2.0 mL, 0.1 M) were added with syringe under N_2. The mixture was then irradiated by white LED strips at room temperature for 12 h. Then the mixture was poured into a separatory funnel containing 20 mL H_2O and 20 mL Et_2O. The layers were separated and the aqueous layer was extracted with Et_2O (2 × 20 mL). The combined organic layers were dried with Na_2SO_4 and concentrated under reduced pressure after filtration. The crude product was purified by flash chromatography on silica gel to afford the desired product phenanthridine derivatives **5**.



5a

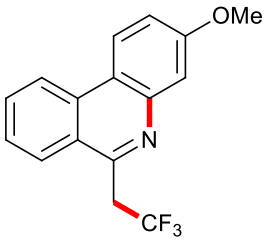
6-(2,2,2-Trifluoroethyl)phenanthridine (5a): yellow solid, yield: 79%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.63 (d, *J* = 8.3 Hz, 1H), 8.53 (d, *J* = 7.5 Hz, 1H), 8.17 (d, *J* = 8.1 Hz, 2H), 7.89 – 7.79 (m, 1H), 7.79 – 7.62 (m, 3H), 4.19 (q, *J* = 10.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 151.14 (q, *J* = 3.2 Hz), 143.45, 133.20, 130.79, 130.18, 128.91, 127.62, 127.53, 126.21, 125.65 (q, *J* = 276.5 Hz), 125.51, 124.05, 122.53,

121.98, 40.52 (q, J = 29.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.46. FTIR (film) ν_{max} 3068.92, 2953.79, 1969.29, 1930.84, 1613.51, 1575.20, 1526.88, 1488.67, 1460.78, 1445.82, 1434.06, 1368.08, 1347.92, 1307.06, 959.59 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{15}H_{11}F_3N$ $[M+H]^+$ 262.0844, found 262.0838.



5b

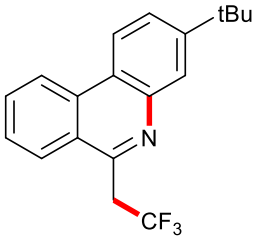
6-(2,2,2-Trifluoroethyl)-3-(trifluoromethyl)phenanthridine (5b): white solid, yield: 83%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.70 – 8.57 (m, 2H), 8.46 (s, 1H), 8.23 (d, J = 8.3 Hz, 1H), 7.97 – 7.88 (m, 1H), 7.88 – 7.75 (m, 2H), 4.21 (q, J = 10.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.80 (q, J = 3.3 Hz), 142.67, 132.37, 131.40, 130.74 (q, J = 32.6 Hz), 128.84, 127.76 (q, J = 4.1 Hz), 126.39, 126.27, 126.05, 125.44 (q, J = 276.4 Hz), 124.01 (q, J = 270.6 Hz), 123.34 (q, J = 3.3 Hz), 123.06, 122.90, 40.47 (q, J = 29.2 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.33, -62.43. FTIR (film) ν_{max} 2921.75, 2851.37, 1625.23, 1614.02, 1583.18, 1532.71, 1487.85, 1465.42, 1440.26, 1362.08, 1331.44, 1250.21, 1167.45, 951.08 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{10}F_6N$ $[M+H]^+$ 330.0717, found 330.0714.



5c

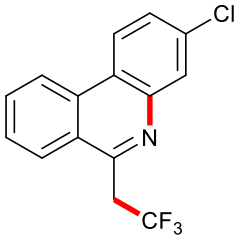
3-Methoxy-6-(2,2,2-trifluoroethyl)phenanthridine (5c): white solid, yield: 66%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.52 (d, J = 8.3 Hz, 1H), 8.41 (d, J = 9.1 Hz, 1H), 8.14 (d, J = 8.3 Hz, 1H), 7.80 (ddd, J = 8.3, 7.1, 1.1 Hz, 1H), 7.63 (ddd, J = 8.2, 7.1, 1.0 Hz, 1H), 7.56 (d, J = 2.7 Hz, 1H), 7.30 (dd, J = 9.0, 2.7 Hz, 1H), 4.18 (q, J = 10.4 Hz, 2H), 3.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.29, 151.56 (q, J = 3.4 Hz), 145.07, 133.43, 130.85, 126.53, 126.23, 125.82 (q, J = 276.5 Hz), 124.61, 123.20, 122.04,

118.85, 118.13, 109.66, 55.63, 40.49 (q, J = 29.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.52. FTIR (film) ν_{max} 2836.45, 1615.38, 1580.37, 1532.71, 1486.27, 1466.48, 1377.18, 1363.33, 1331.22, 1034.08, 966.83, 952.31 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{13}F_3N$ $[M+H]^+$ 292.0949, found 292.0944.



5d

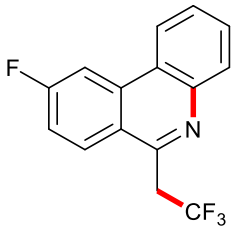
3-(*Tert*-butyl)-6-(2,2,2-trifluoroethyl)phenanthridine (5d): yellow solid, yield: 90%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.62 (d, J = 8.3 Hz, 1H), 8.49 (d, J = 8.7 Hz, 1H), 8.22 – 8.13 (m, 2H), 7.84 (ddd, J = 8.3, 7.1, 1.2 Hz, 1H), 7.77 (dd, J = 8.7, 2.1 Hz, 1H), 7.69 (ddd, J = 8.2, 7.1, 1.1 Hz, 1H), 4.20 (q, J = 10.4 Hz, 2H), 1.47 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.43, 151.03 (q, J = 3.4 Hz), 143.49, 133.19, 130.75, 127.21, 126.23, 126.00, 125.93, 125.67 (q, J = 276.5 Hz), 125.34, 122.41, 121.71, 121.52, 40.57 (q, J = 29.0 Hz), 35.07, 31.34; ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.50. FTIR (film) ν_{max} 2959.94, 1614.82, 1436.44, 1366.89, 1343.51, 1247.82, 1126.55, 1100.73, 1045.74, 958.18 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{19}F_3N$ $[M+H]^+$ 318.1470, found 318.1475.



5e

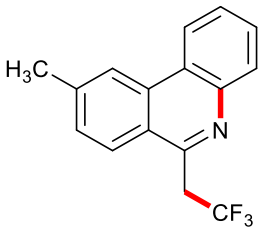
3-Chloro-6-(2,2,2-trifluoroethyl)phenanthridine (5e): yellow solid, yield: 86%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.52 (d, J = 8.3 Hz, 1H), 8.38 (d, J = 8.8 Hz, 1H), 8.16 (d, J = 8.3 Hz, 1H), 8.13 (d, J = 2.1 Hz, 1H), 7.84 (t, J = 7.7 Hz, 1H), 7.72 (t, J = 7.7 Hz, 1H), 7.57 (dd, J = 8.8, 2.1 Hz, 1H), 4.16 (q, J = 10.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.47 (q, J = 3.3 Hz), 143.98, 134.55, 132.71, 131.21, 129.35, 128.03, 127.93, 126.32, 125.51 (q, J = 276.5 Hz), 125.36, 123.31, 122.46, 122.43, 40.42 (q, J

= 29.1 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.43. FTIR (film) ν_{max} 2920.56, 1605.61, 1563.55, 1478.25, 1442.99, 1368.99, 1341.82, 1266.39, 1238.68, 1135.97, 1079.75, 1044.16, 946.90, 874.61 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{15}H_{10}ClF_3N$ $[M+H]^+$ 296.0454, found 296.0455.



5f

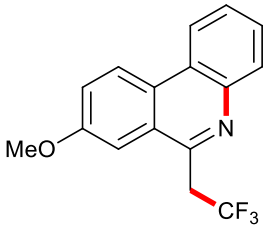
9-Fluoro-6-(2,2,2-trifluoroethyl)phenanthridine (5f): yellow solid, yield: 82%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.39 (d, *J* = 8.2 Hz, 1H), 8.24 – 8.11 (m, 3H), 7.77 (t, *J* = 7.6 Hz, 1H), 7.67 (t, *J* = 7.6 Hz, 1H), 7.44 (td, *J* = 8.7, 2.5 Hz, 1H), 4.16 (q, *J* = 10.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.81 (d, *J* = 251.3 Hz), 150.38 (q, *J* = 3.9 Hz), 143.70, 135.69 (d, *J* = 9.5 Hz), 130.25, 129.62, 129.19 (d, *J* = 47.1 Hz), 127.61, 125.52 (q, *J* = 276.6 Hz), 123.61 (d, *J* = 4.2 Hz), 122.52, 122.15, 116.79 (d, *J* = 23.8 Hz), 107.69 (d, *J* = 22.1 Hz), 40.71 (q, *J* = 29.1 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.53 (3F), -106.09 (1F). FTIR (film) ν_{max} 2988.10, 1623.69, 1586.51, 1529.74, 1499.73, 1464.77, 1426.02, 1372.05, 1349.09, 1242.14, 1134.70, 1094.24, 1044.67, 935.09 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{15}H_{10}F_4N$ $[M+H]^+$ 280.0749, found 280.0744.



5g

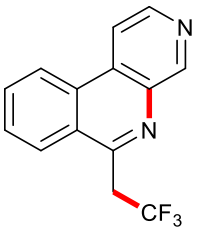
9-Methyl-6-(2,2,2-trifluoroethyl)phenanthridine (5g): yellow solid, yield: 85%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51 (d, *J* = 8.1 Hz, 1H), 8.39 (s, 1H), 8.15 (dd, *J* = 8.1, 0.9 Hz, 1H), 8.05 (d, *J* = 8.4 Hz, 1H), 7.77 – 7.68 (m, 1H), 7.68 – 7.59 (m, 1H), 7.51 (dd, *J* = 8.4, 1.1 Hz, 1H), 4.15 (q, *J* = 10.4 Hz, 2H), 2.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 150.95 (q, *J* = 3.3 Hz), 143.61, 141.32, 133.35, 130.08, 129.34, 128.77,

127.27, 126.11, 125.68 (q, *J* = 276.5 Hz), 123.93, 123.68, 122.14, 121.97, 40.51 (q, *J* = 28.9 Hz), 22.21; ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.51. FTIR (film) ν_{max} 2952.38, 2257.23, 2219.10, 2177.70, 2141.68, 2069.50, 2030.65, 1914.09, 1621.97, 1577.60, 1499.35, 1462.42, 1432.81, 1349.65, 1261.60, 1095.52, 935.41 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{13}F_3N$ $[M+H]^+$ 276.1000, found 276.0995.



5h

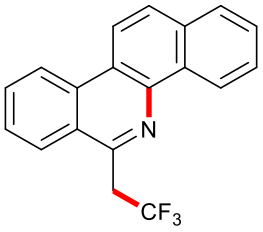
8-Methoxy-6-(2,2,2-trifluoroethyl)phenanthridine (5h): yellow solid, yield: 85%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51 (d, *J* = 8.9 Hz, 1H), 8.43 (d, *J* = 8.8 Hz, 1H), 8.14 (d, *J* = 7.7 Hz, 1H), 7.72 – 7.57 (m, 2H), 7.51 – 7.39 (m, 2H), 4.15 (q, *J* = 10.4 Hz, 2H), 3.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.80, 150.22 (q, *J* = 3.3 Hz), 142.62, 130.09, 127.91, 127.58, 127.55, 126.81, 125.65 (q, *J* = 276.6 Hz), 124.17, 124.14, 121.49, 121.28, 106.44, 55.55, 40.78 (q, *J* = 29.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.61. FTIR (film) ν_{max} 1618.51, 1573.02, 1533.53, 1485.94, 1467.46, 1419.83, 1382.84, 1350.34, 1257.08, 1222.58, 1129.35, 1090.45, 1041.83, 937.70, 848.46 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{16}H_{13}F_3N$ $[M+H]^+$ 292.0949, found 292.0944.



5i

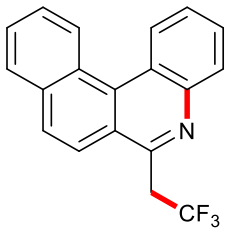
6-(2,2,2-Trifluoroethyl)benzo[*c*][1,7]naphthyridine (5i): yellow solid, yield: 98%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.51 (s, 1H), 8.79 (d, *J* = 5.5 Hz, 1H), 8.65 (d, *J* = 8.1 Hz, 1H), 8.28 (dd, *J* = 13.7, 6.9 Hz, 2H), 7.96 (t, *J* = 7.2 Hz, 1H), 7.89 (t, *J* = 7.2 Hz, 1H), 4.24 (q, *J* = 10.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.47, 153.08 (q, *J* = 3.3 Hz), 145.96, 131.52, 131.23, 129.97, 128.95, 127.00, 126.45,125.37 (q, *J* = 276.6

Hz), 123.17, 115.11, 40.47 (q, *J* = 29.3 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.40. FTIR (film) ν_{max} 1589.42, 1569.34, 1528.16, 1482.66, 1449.83, 1429.78, 1409.48, 1394.27, 1259.90, 1103.16, 1044.29, 1029.21, 928.15 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{14}H_{10}F_3N_2$ $[M+H]^+$ 263.0796, found 263.0791.



5j

6-(2,2,2-Trifluoroethyl)benzo[*c*]phenanthridine (5j): yellow solid, yield: 98%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.42 (d, *J* = 8.2 Hz, 1H), 8.65 (d, *J* = 8.4 Hz, 1H), 8.44 (d, *J* = 9.0 Hz, 1H), 8.19 (d, *J* = 8.3 Hz, 1H), 7.96 (d, *J* = 9.0 Hz, 1H), 7.93 (d, *J* = 7.9 Hz, 1H), 7.87 – 7.80 (m, 1H), 7.77 – 7.63 (m, 3H), 4.28 (q, *J* = 10.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 149.53 (q, *J* = 3.2 Hz), 140.30, 133.39, 133.26, 131.91, 130.48, 128.23, 127.55, 127.54, 127.28, 127.11, 125.84, 125.49 (q, *J* = 276.2 Hz), 124.99, 122.93, 120.91, 119.56, 40.33 (q, *J* = 28.8 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.45. FTIR (film) ν_{max} 1615.30, 1507.18, 1372.55, 1338.06, 1274.56, 1267.62, 1234.15, 1139.01, 1099.02, 1038.74, 927.15 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{13}F_3N$ $[M+H]^+$ 312.1000, found 312.0995.



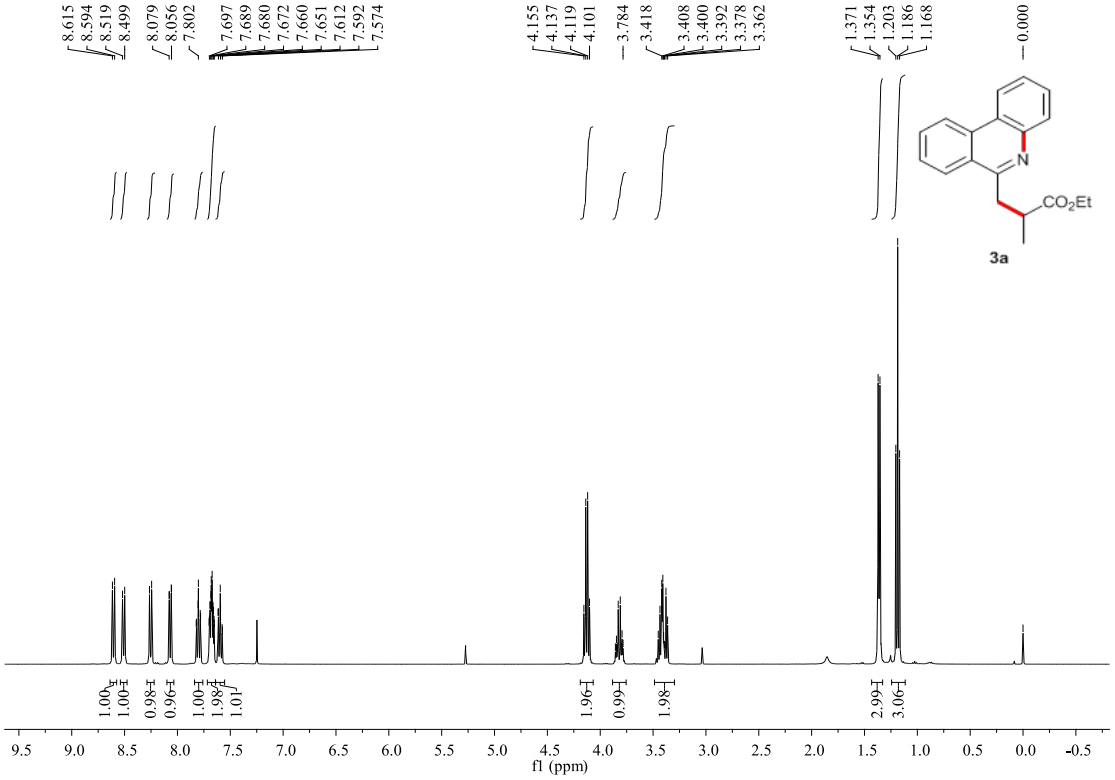
5k

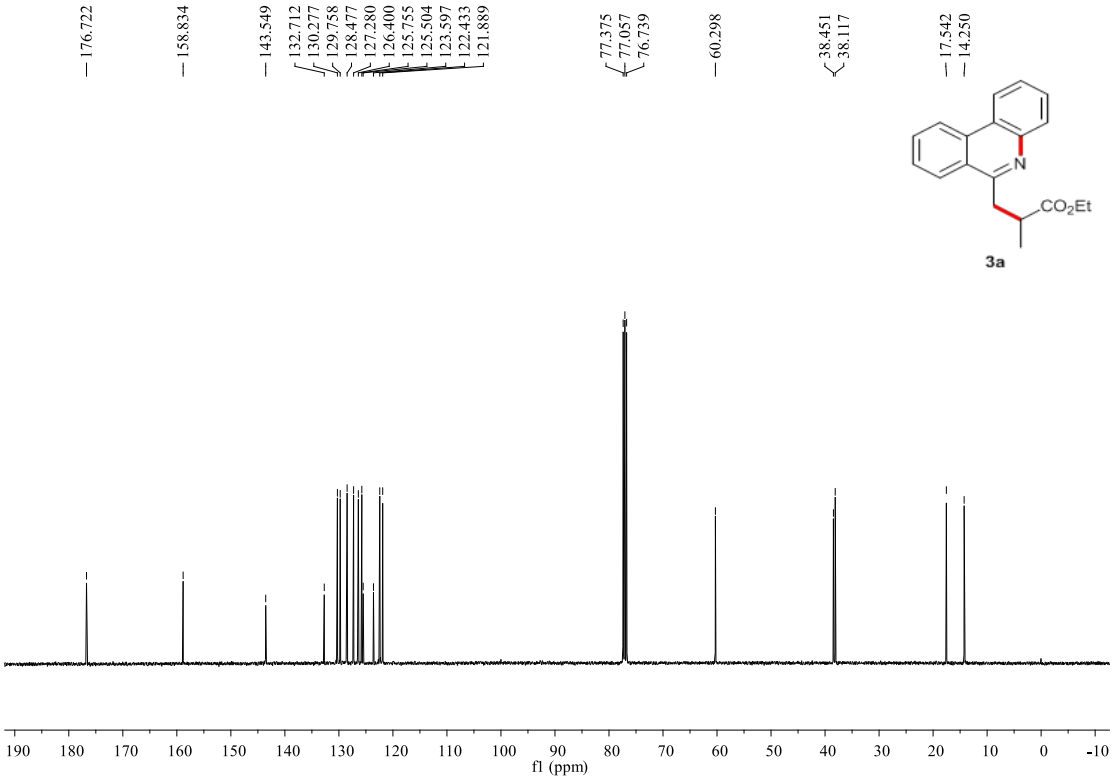
6-(2,2,2-Trifluoroethyl)benzo[*k*]phenanthridine (5k): yellow solid, yield: 56%. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.10 – 9.02 (m, 1H), 8.96 (d, *J* = 8.4 Hz, 1H), 8.29 (dd, *J* = 8.2, 1.0 Hz, 1H), 8.08 – 7.93 (m, 3H), 7.83 – 7.61 (m, 4H), 4.26 (q, *J* = 10.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 150.12 (q, *J* = 3.1 Hz), 145.41, 134.59, 132.57, 130.00, 128.97, 128.67, 128.63, 128.57, 128.15, 127.13, 127.08, 127.05, 125.51 (q, *J* = 274.4 Hz), 124.25, 122.24, 122.23, 40.74 (q, *J* = 29.1 Hz); ^{19}F NMR (376 MHz,

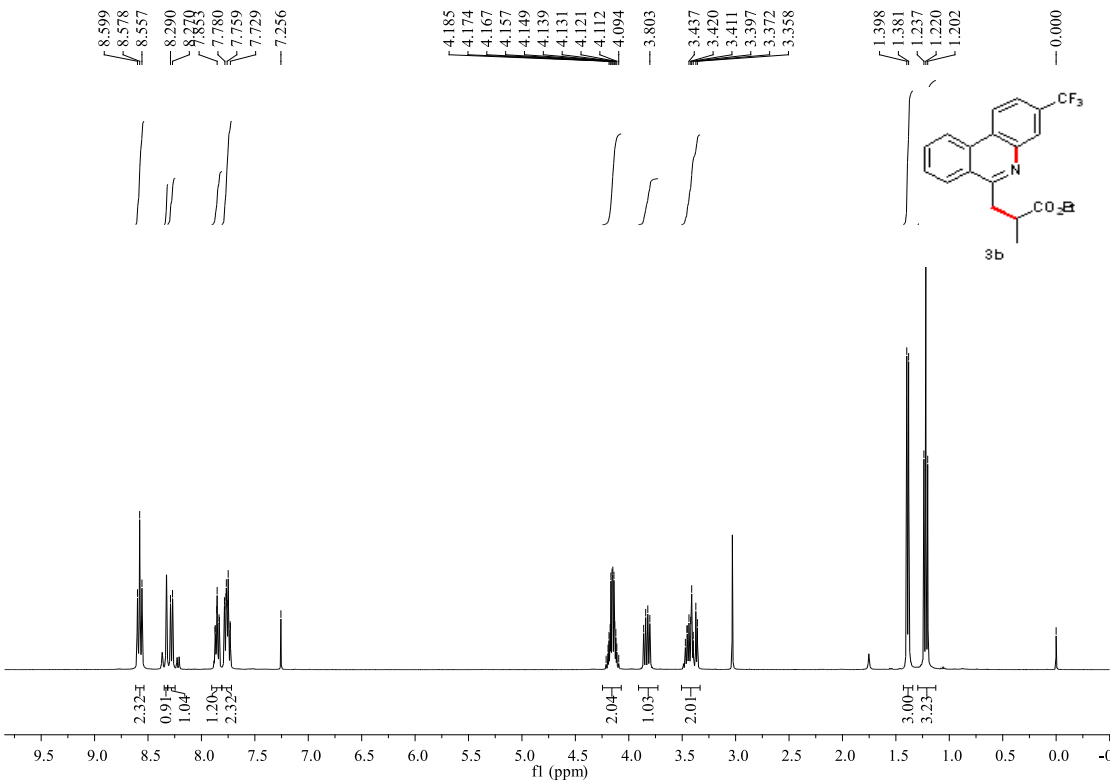
$CDCl_3$) δ -62.55. FTIR (film) ν_{max} 1600.00, 1563.55, 1476.64, 1389.72, 1356.41, 1274.77, 1254.86, 1140.88, 1106.82, 1070.00, 934.78, 842.31 cm^{-1}. HRMS (ESI): *m/z* calcd for $C_{19}H_{13}F_3N$ $[M+H]^+$ 312.1000, found 312.0995.

1. Wang, Y.-F.; Lonca, G. H.; Le Runigo, M.; Chiba, S. *Org. Lett.* **2014**, *16*, 4272.

5. NMR Spectra for All Compounds.



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4.167
4.157
4.149
4.139
4.131
4.121
4.112
4.094
3.803
3.437
3.420
3.411
3.397
3.372
3.358
1.398
1.381
1.237
1.220
1.202
0.000
CF3
N
CO2Et
3b
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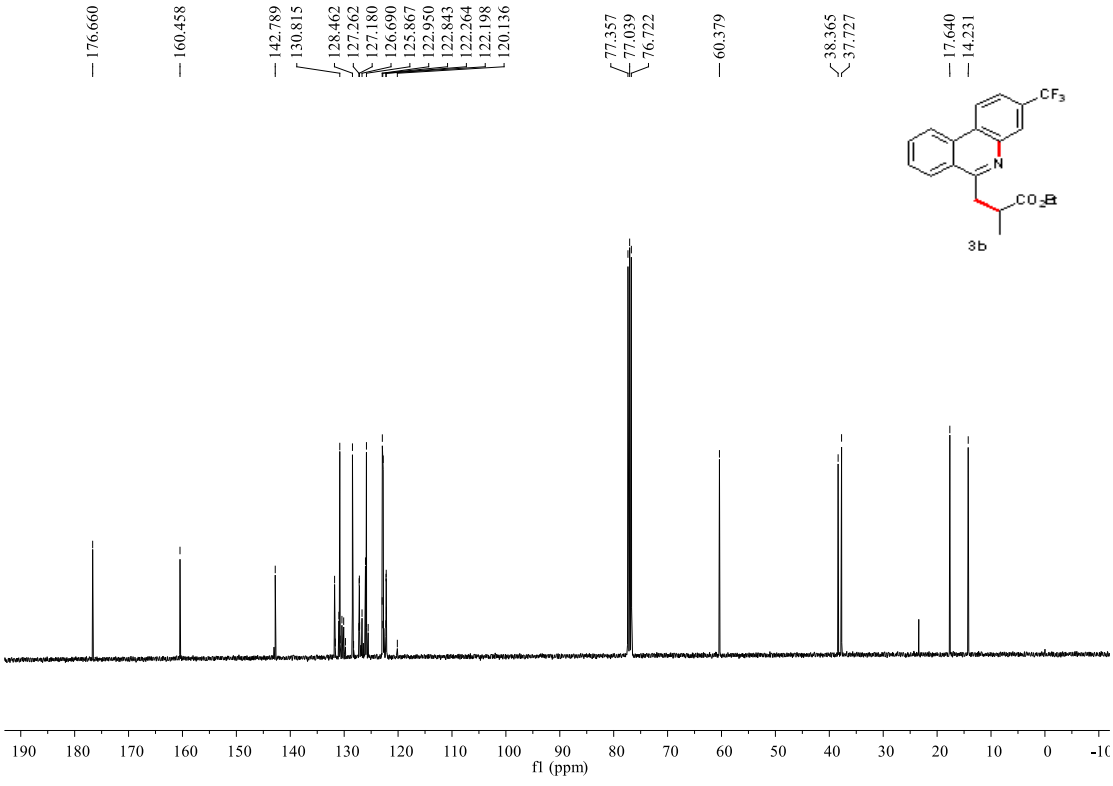
2.32
2.04
1.03
2.01
3.00
3.23
fl (ppm)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122.843
122.264
122.198
120.136
77.357
77.039
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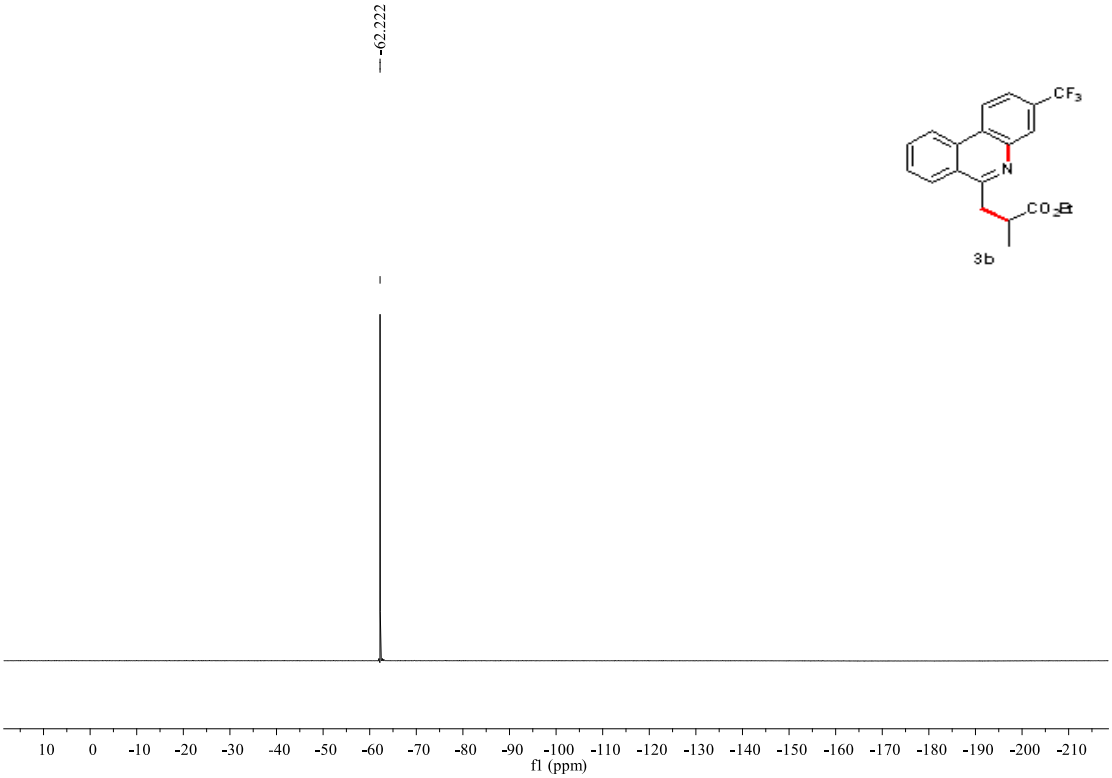
60.379
38.365
37.727
17.640
14.231
CF3
N
CO2Et
3b
fl (ppm)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3b
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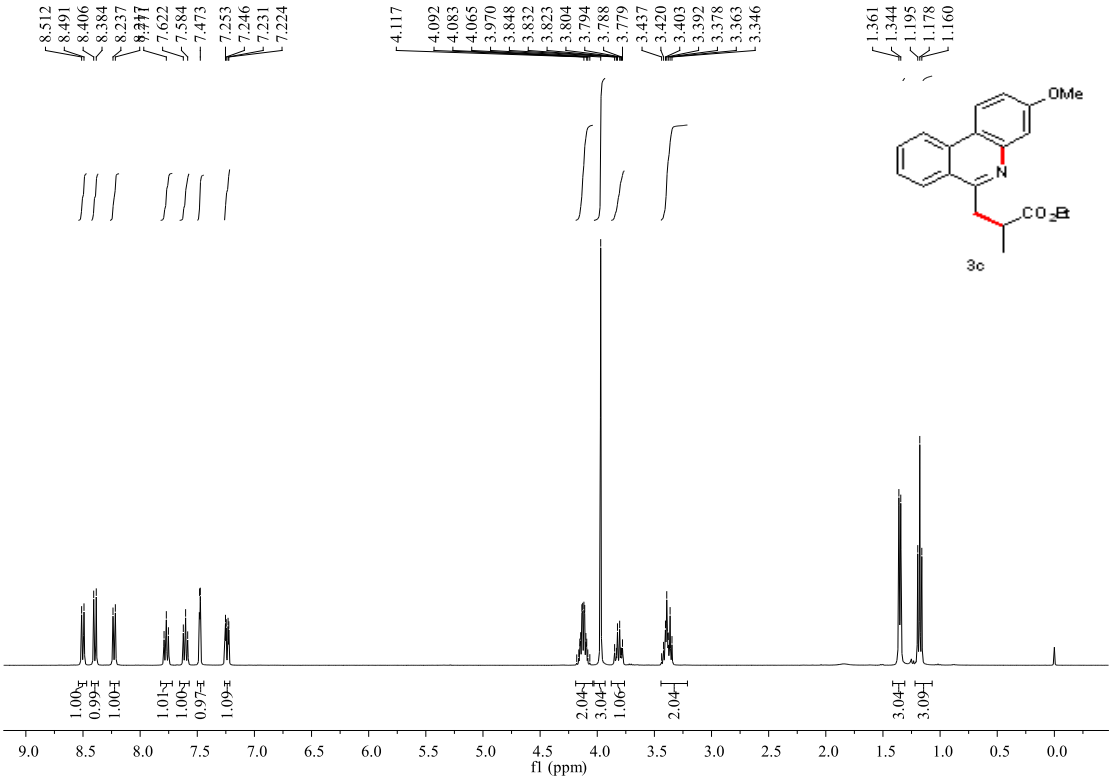
f1 (ppm)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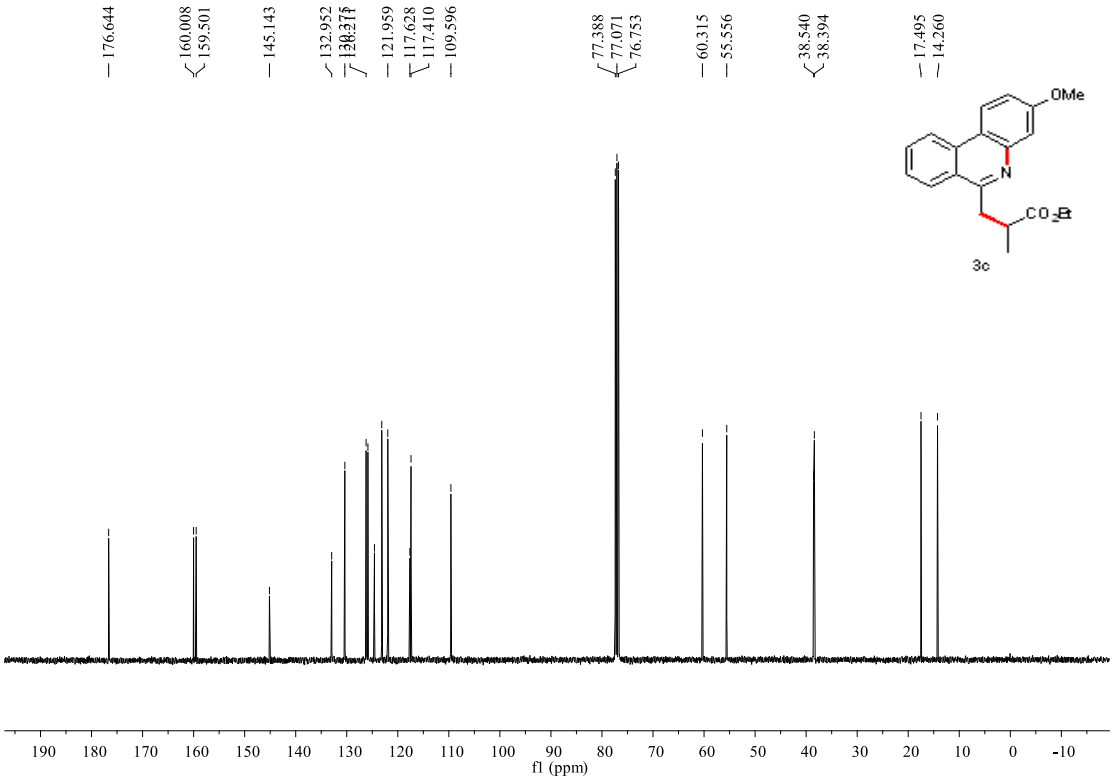
3.970
3.848
3.832
3.823
3.804
3.794
3.788
3.779
3.437
3.420
3.403
3.392
3.378
3.363
3.346
1.361
1.344
1.195
1.178
1.160
OMe
N
CO2Et
3c
1.00
0.99
1.00
1.01
1.00
0.97
1.09
2.04
3.04
1.06
2.04
3.04
3.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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76.753
60.315
55.556
38.540
38.394
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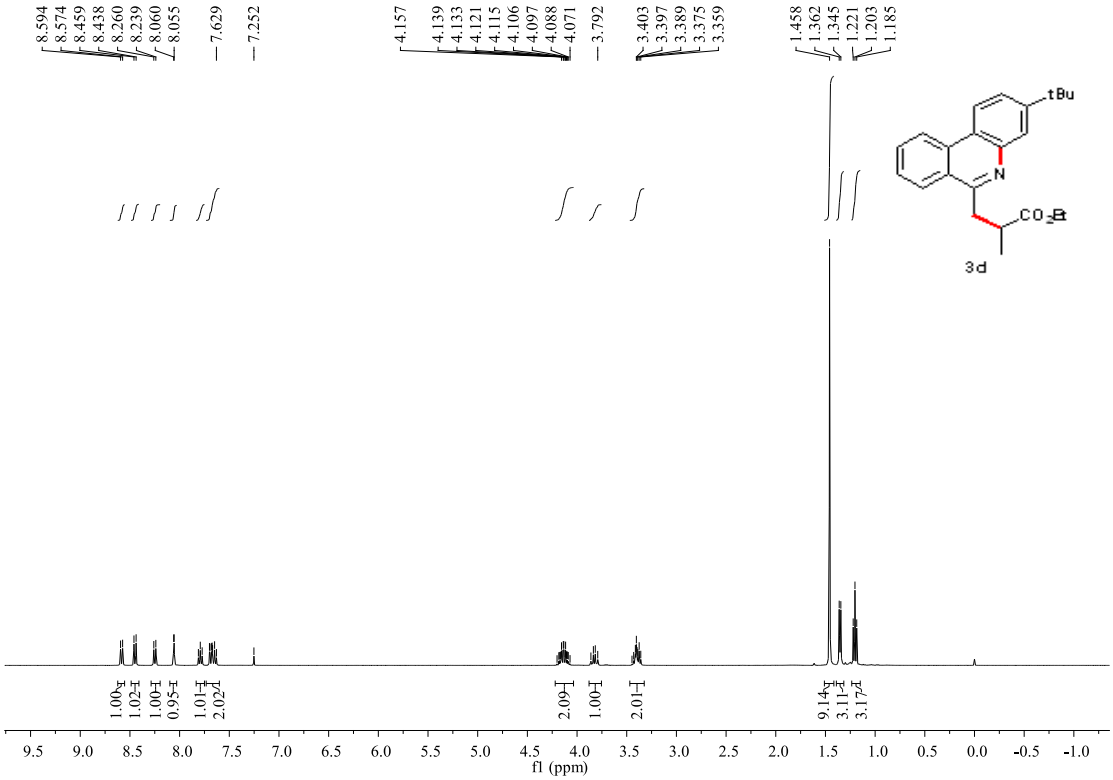
N
CO2Et
3c
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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4.071
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3.397
3.389
3.375
3.359
1.458
1.362
1.345
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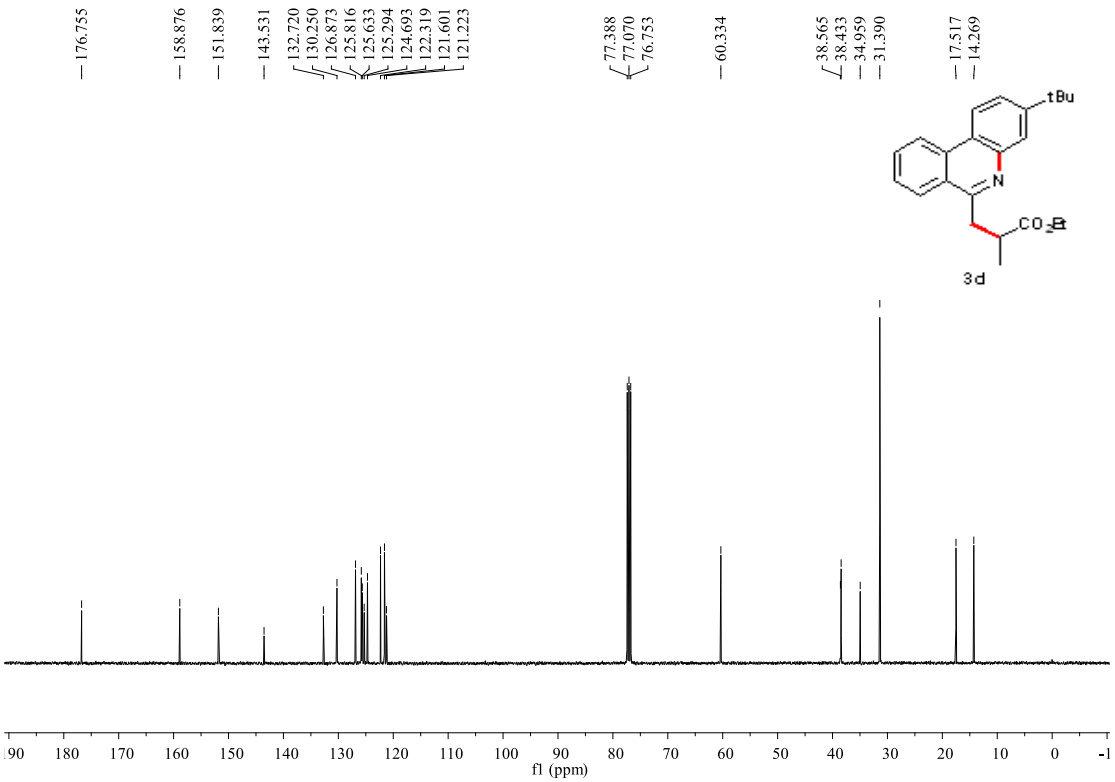
1.203
1.185
tBu
N
CO2Et
3d
1.00
1.02
1.00
0.95
1.01
2.02
2.09
1.00
2.01
9.14
3.11
3.17
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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121.601
121.223
77.388
77.070
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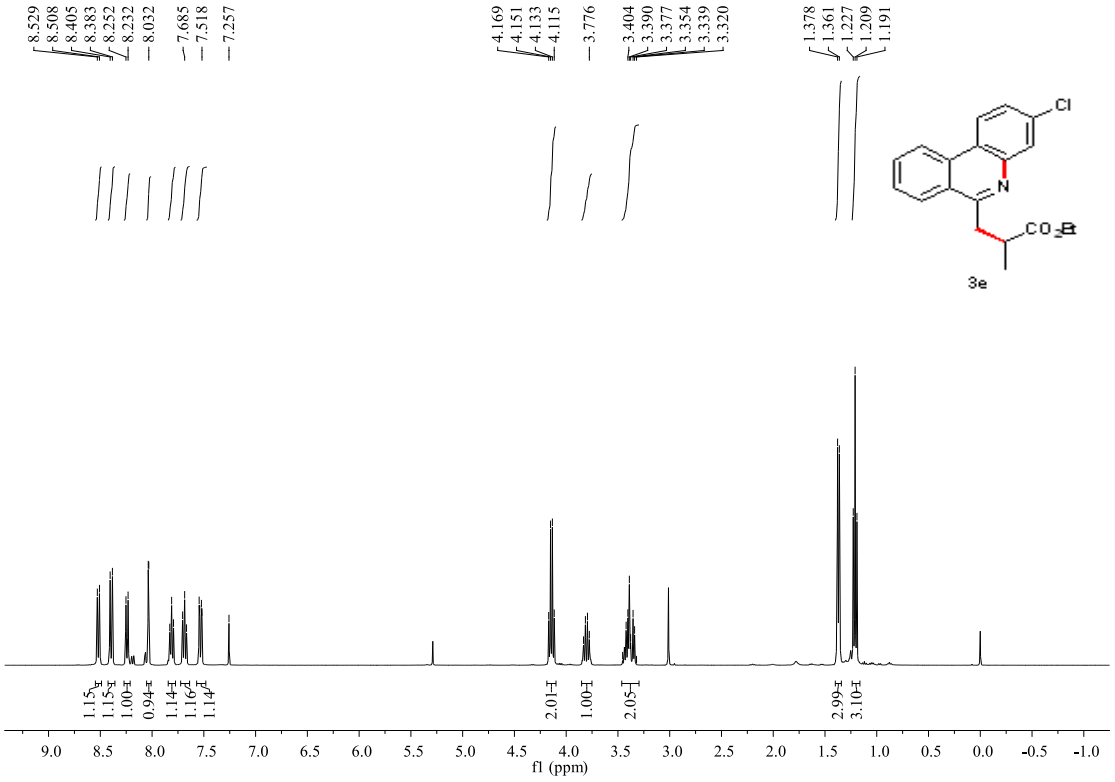
tBu
N
CO2Et
3d
f1 (ppm)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1.361
1.227
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Cl
N
CO2Et
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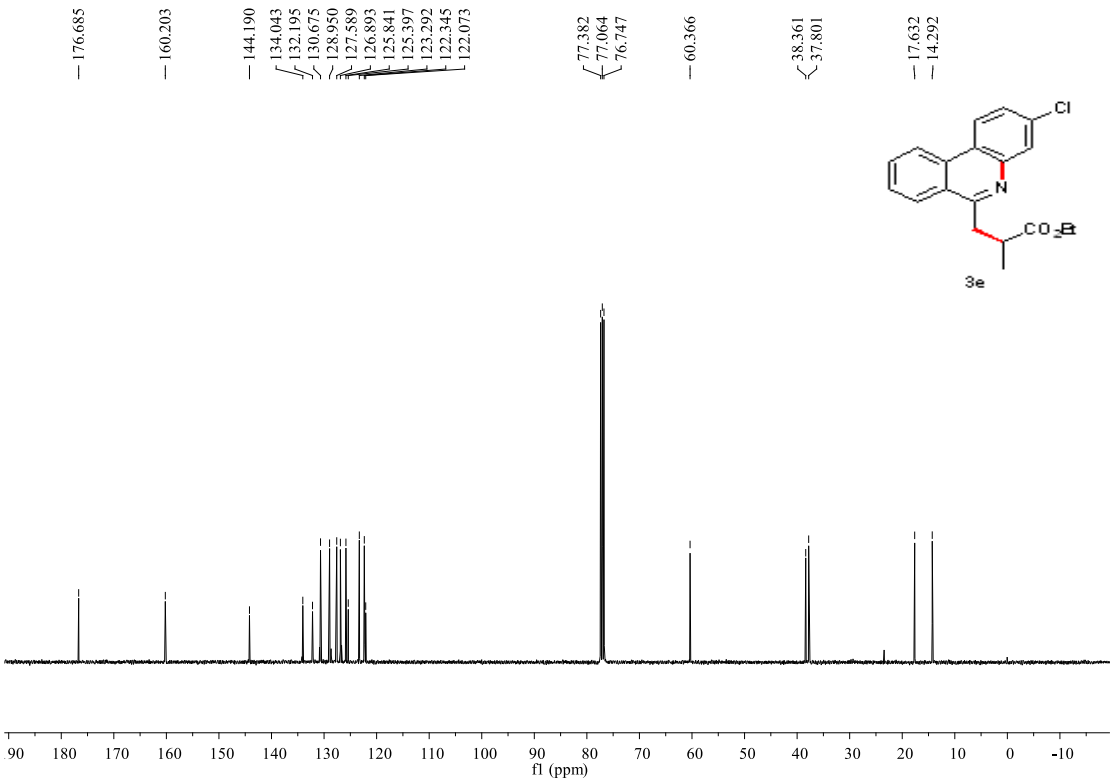
f1 (ppm)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125.841
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122.345
122.073
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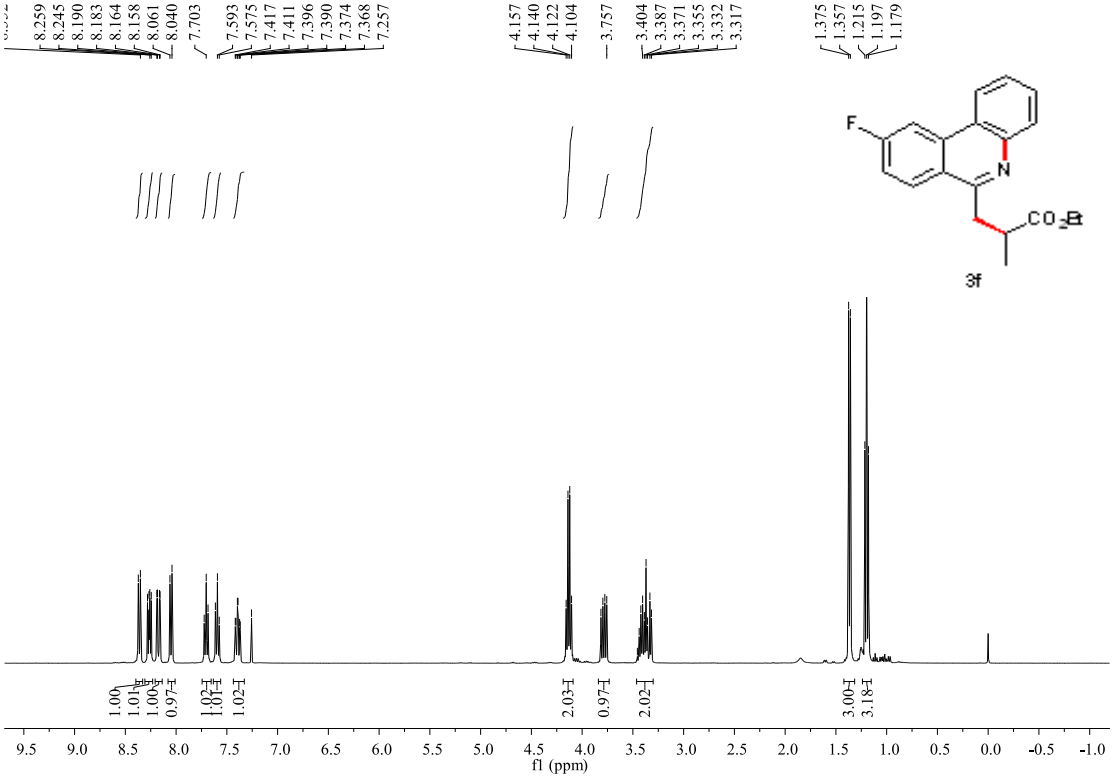
Cl
N
CO2Et
3e
fl (ppm)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3.317
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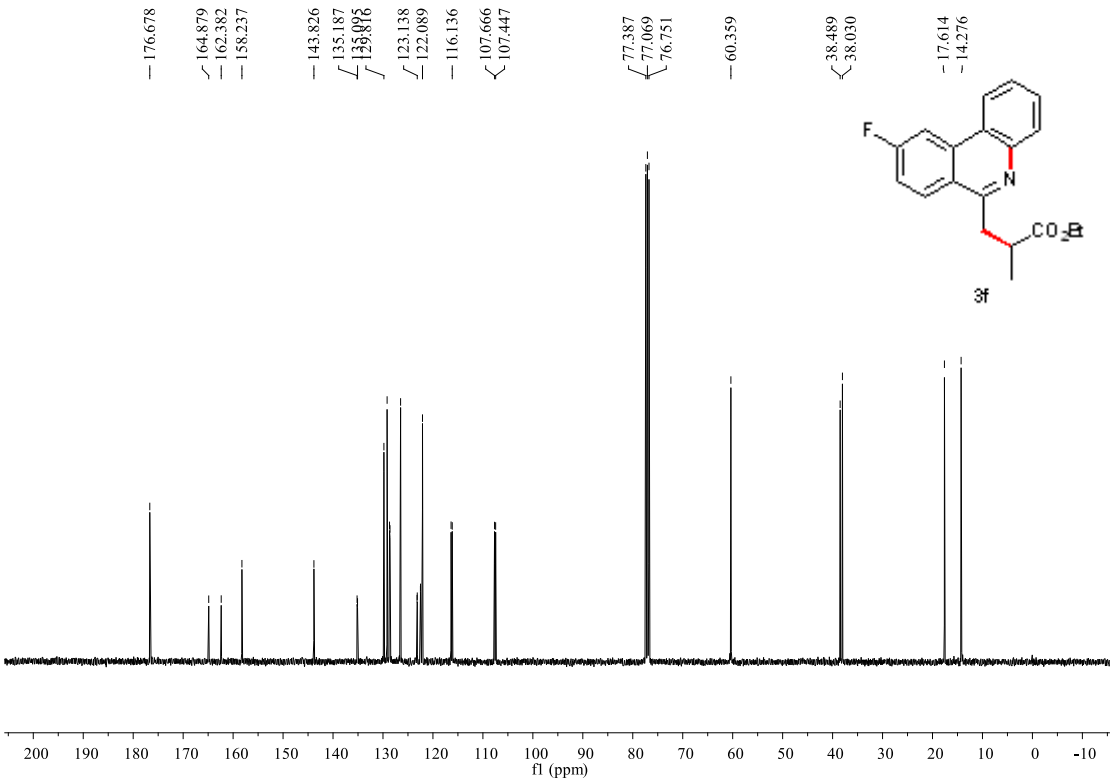
1.357
1.215
1.197
1.179
F
N
CO2Et
3f
1.00
1.01
1.00
0.97
1.02
1.01
1.02
2.03
0.97
2.02
3.00
3.18
fl (ppm)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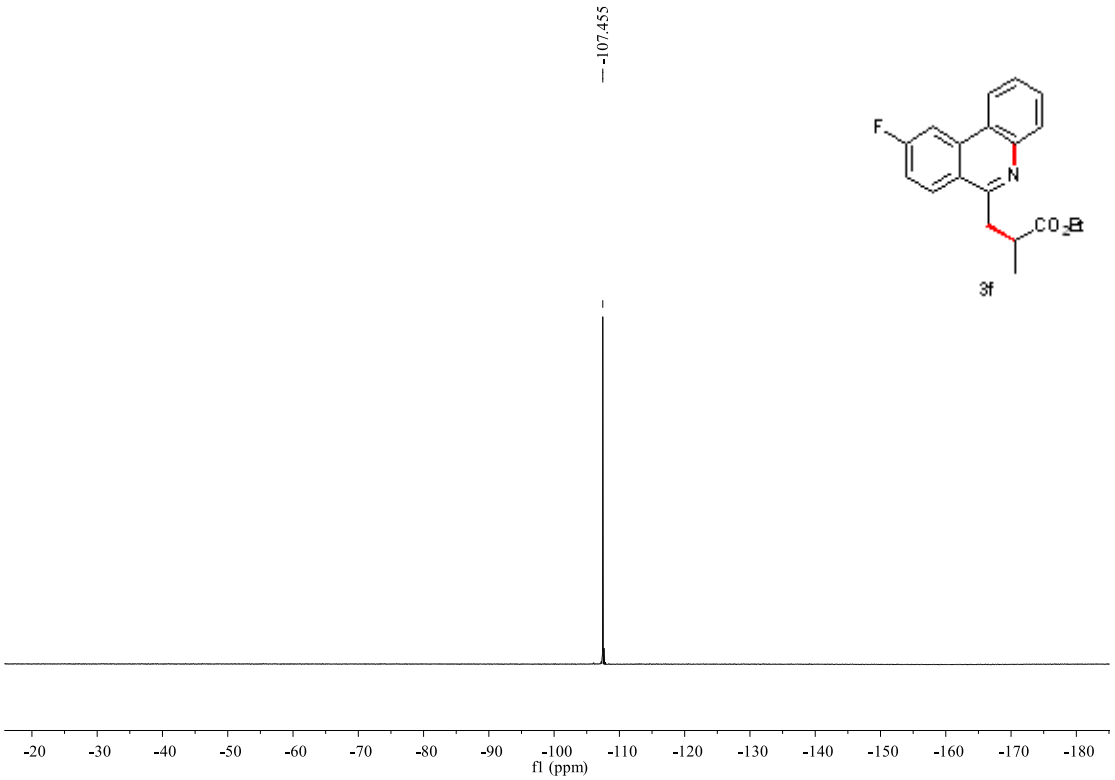
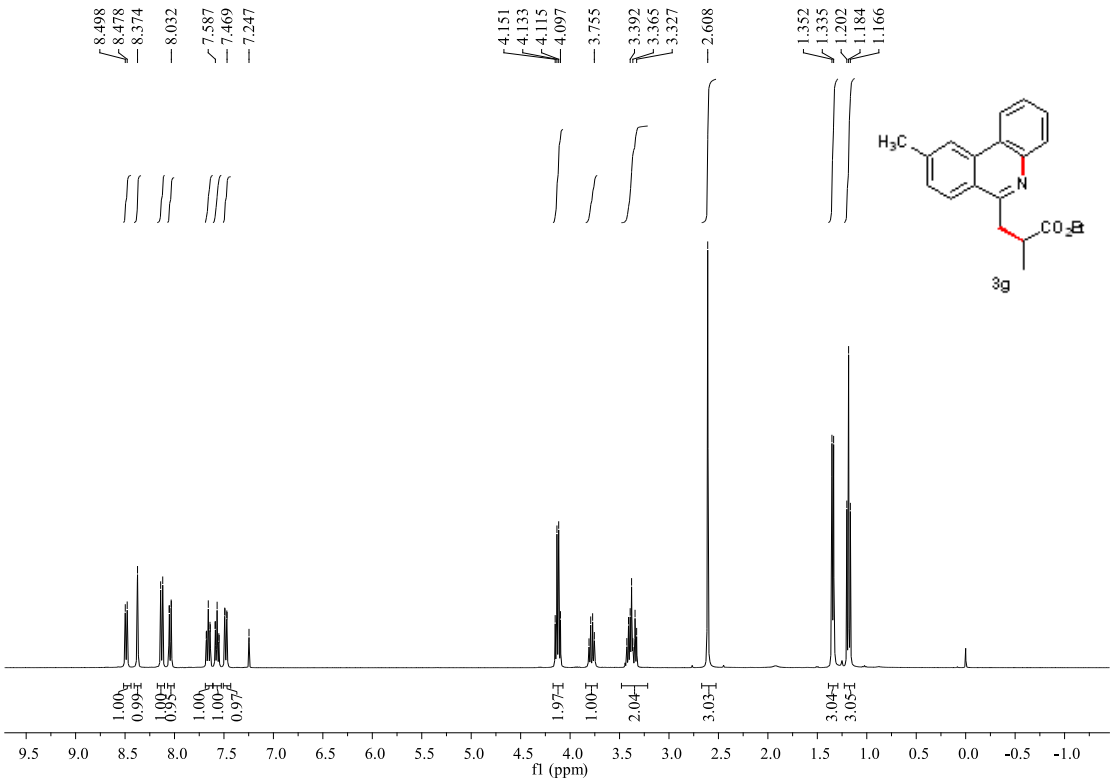
164.879
162.382
158.237
143.826
135.187
135.095
129.816
123.138
122.089
116.136
107.666
107.447
77.387
77.069
76.751
60.359
38.489
38.030
17.614
14.276
F
N
CO2Et
3f
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-107.455
F
N
CO2Et
3f
-20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180
f1 (ppm)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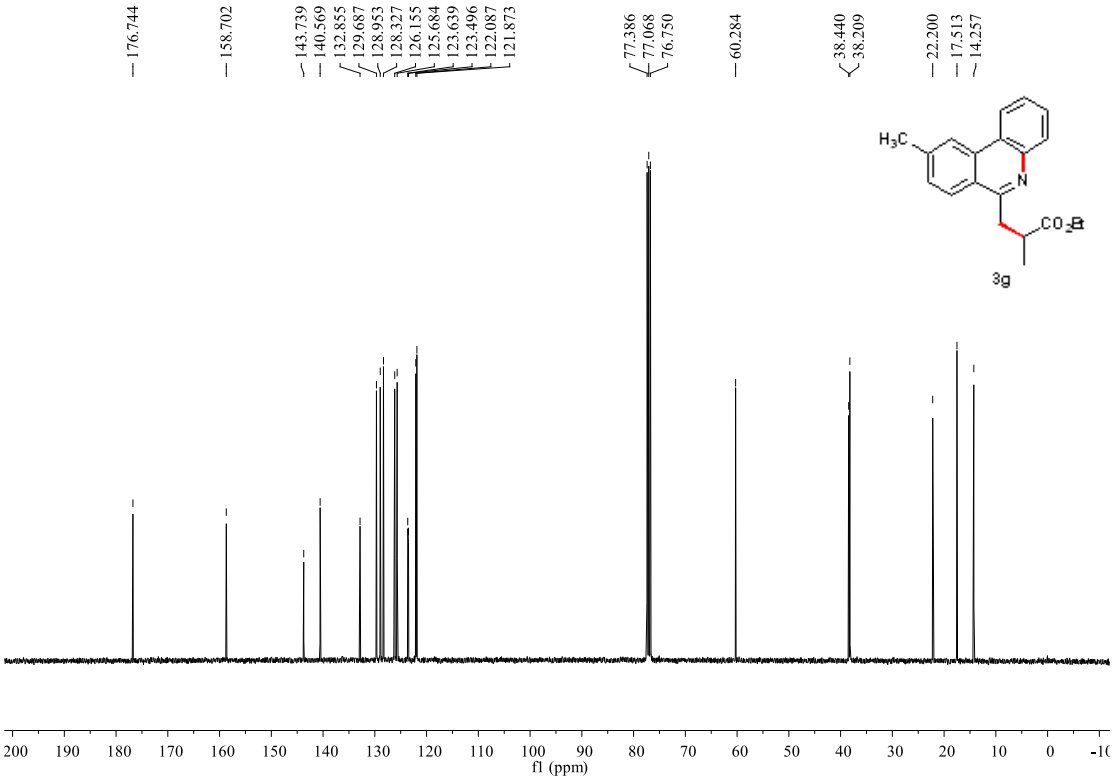
8.374
8.032
7.587
7.469
7.247
4.151
4.133
4.115
4.097
3.755
3.392
3.365
3.327
2.608
1.352
1.335
1.202
1.184
1.166
1.00
0.99
1.00
0.95
1.00
1.00
0.97
1.97
1.00
2.04
3.03
3.04
3.05
H3C
N
CO2Et
3g
fl (ppm)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143.739
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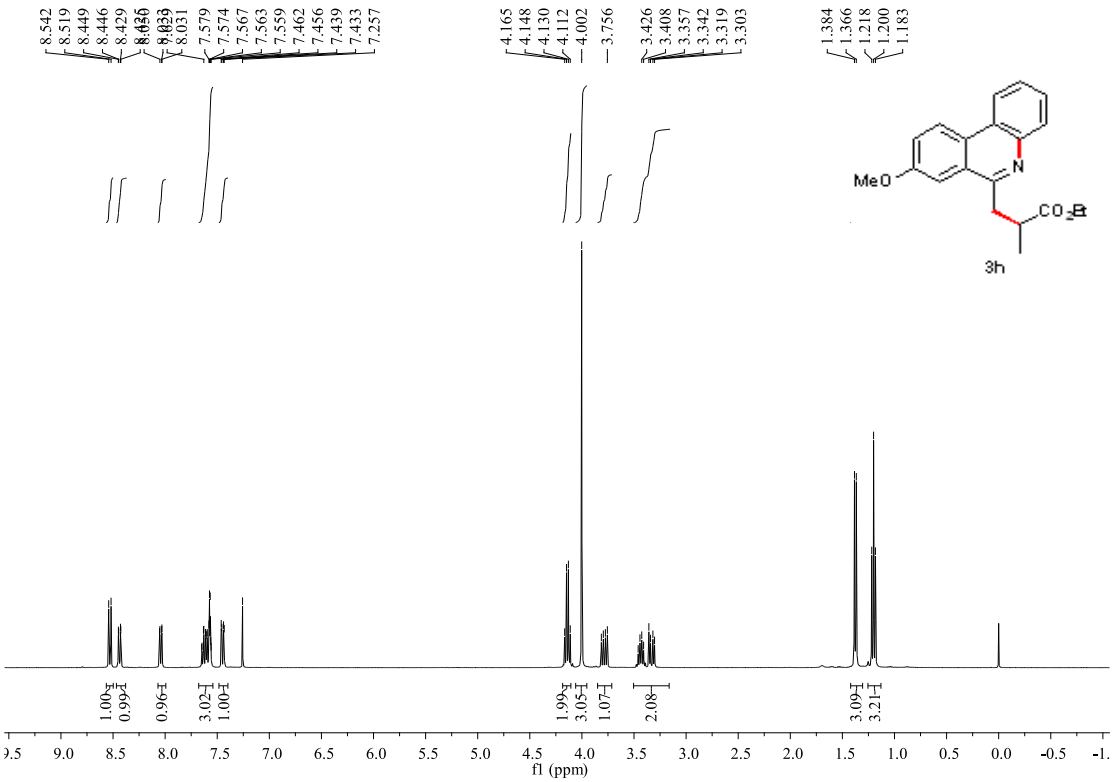
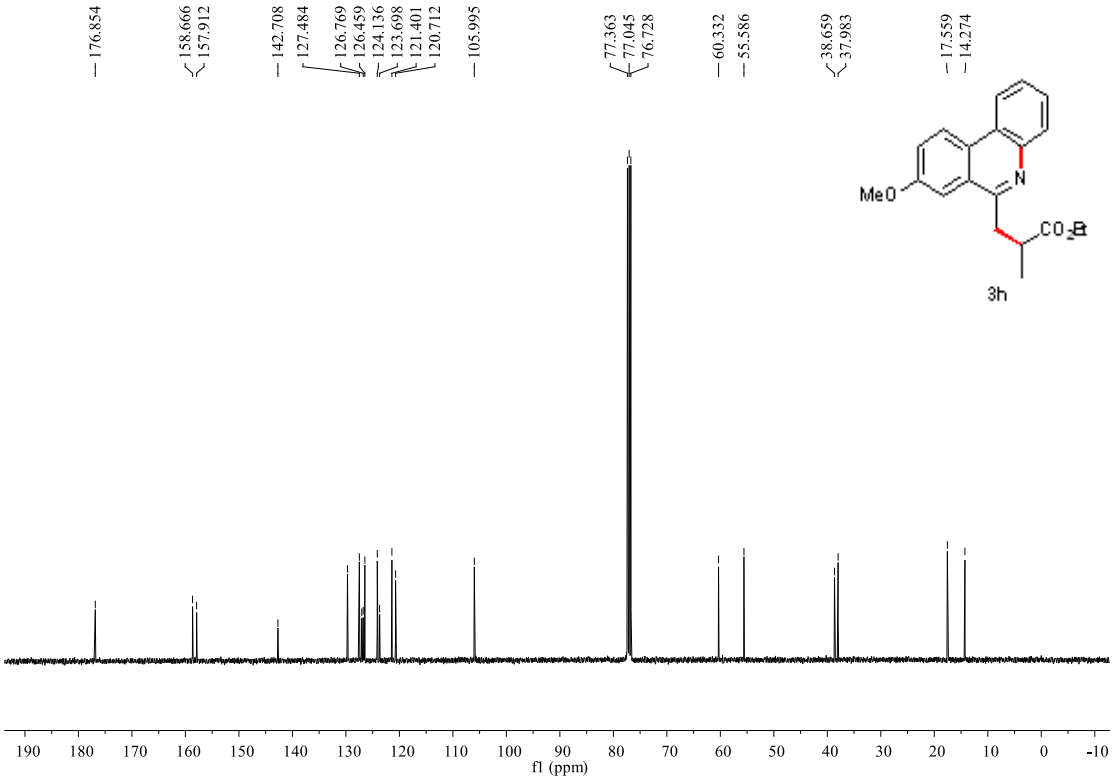
128.953
128.327
126.155
125.684
123.639
123.496
122.087
121.873
77.386
77.068
76.750
60.284
38.440
38.209
22.200
17.513
14.257
H3C
N
CO2Et
3g
fl (ppm)


8.542
8.519
8.449
8.446
8.429
8.033
8.031
7.579
7.574
7.567
7.563
7.559
7.462
7.456
7.439
7.433
7.257
4.165
4.148
4.130
4.112
4.002
3.756
3.426
3.408
3.357
3.342
3.319
3.303
1.384
1.366
1.218
1.200
1.183
MeO
CO2Et
N
3h
1.00
0.99
0.96
3.02
1.00
1.99
3.05
1.07
2.08
3.09
3.21
f1 (ppm)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157.912
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126.769
126.459
124.136
123.698
121.401
120.712
105.995
77.363
77.045
76.728
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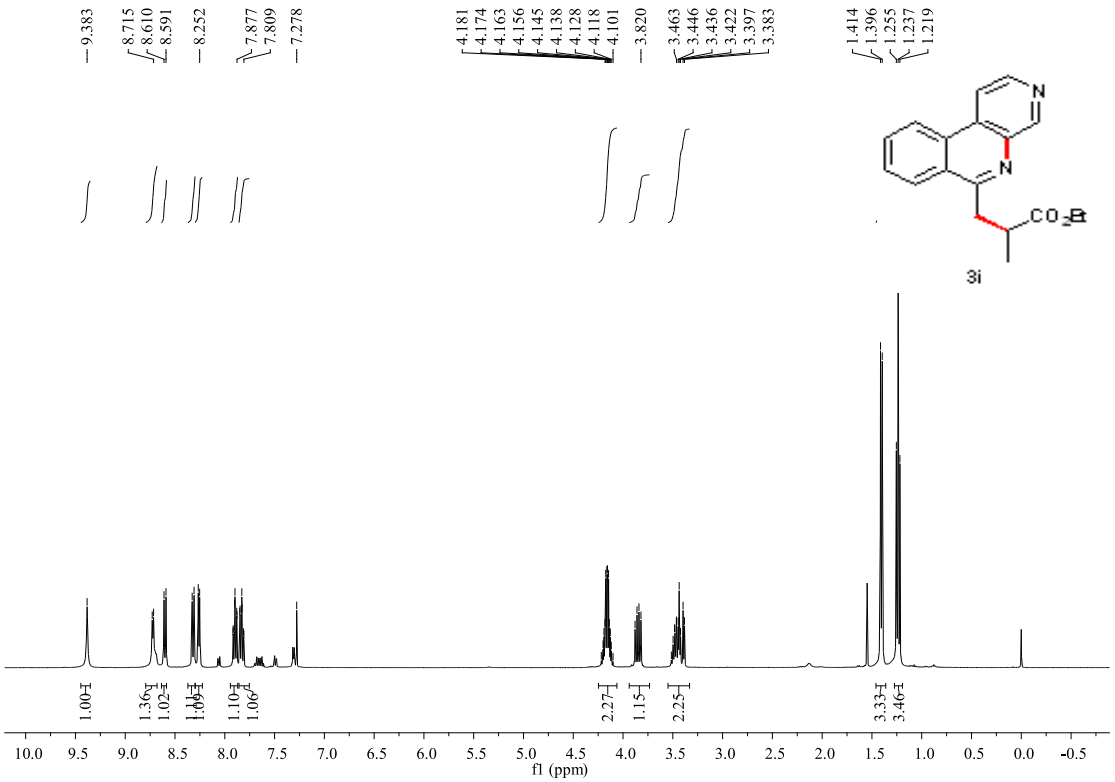
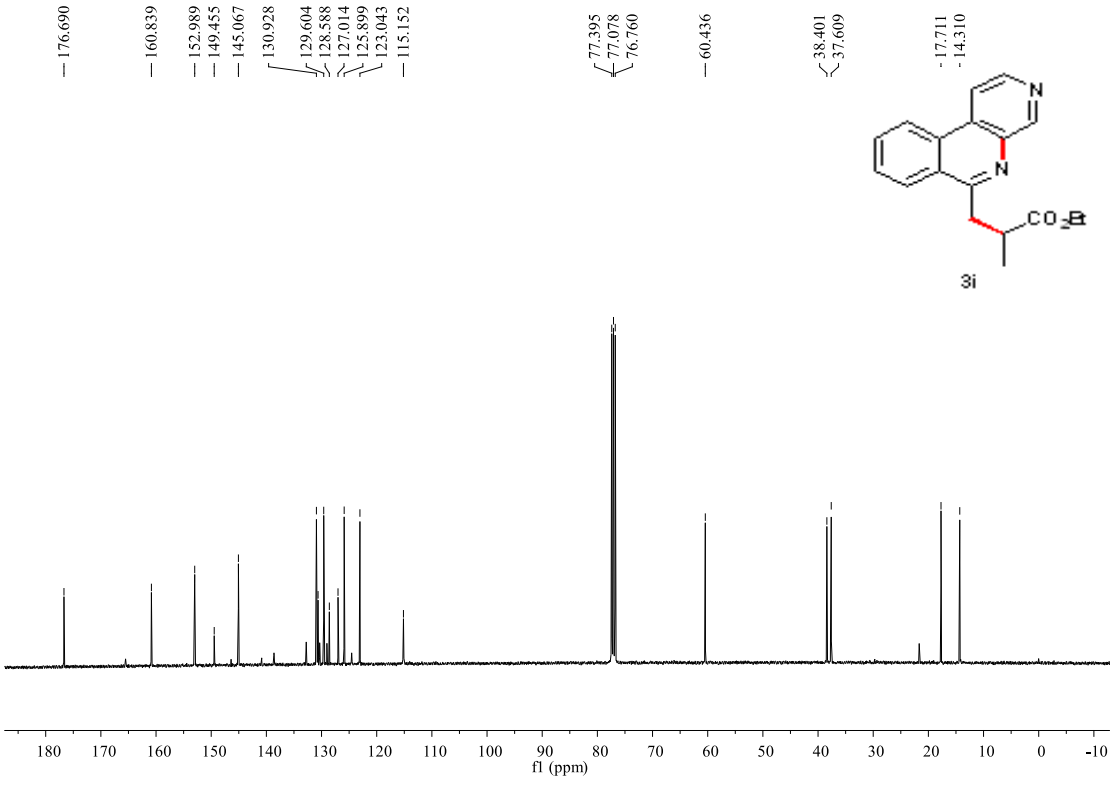
55.586
38.659
37.983
17.559
14.274
MeO
CO2Et
N
3h
f1 (ppm)


9.383
8.715
8.610
8.591
8.252
7.877
7.809
7.278
4.181
4.174
4.163
4.156
4.145
4.138
4.128
4.118
4.101
3.820
3.463
3.446
3.436
3.422
3.397
3.383
1.414
1.396
1.255
1.237
1.219
N
N
CO2Et
3i
1.00
1.36
1.02
2.27
1.15
2.25
3.33
3.46
fl (ppm)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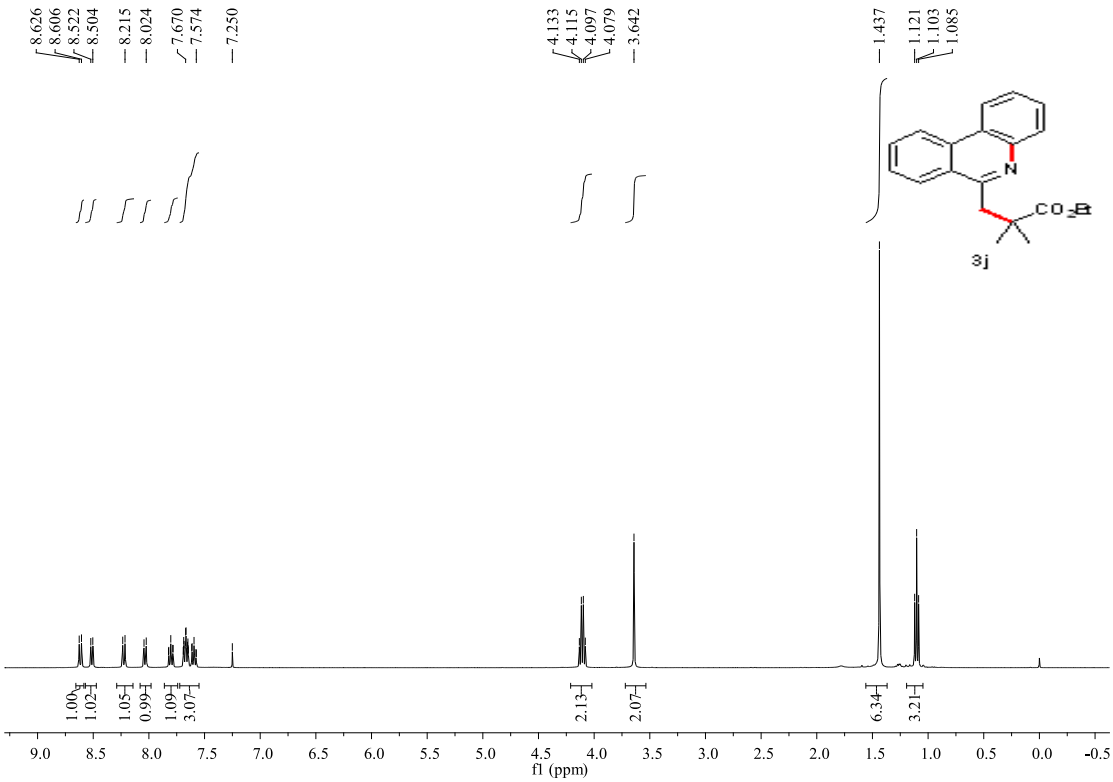
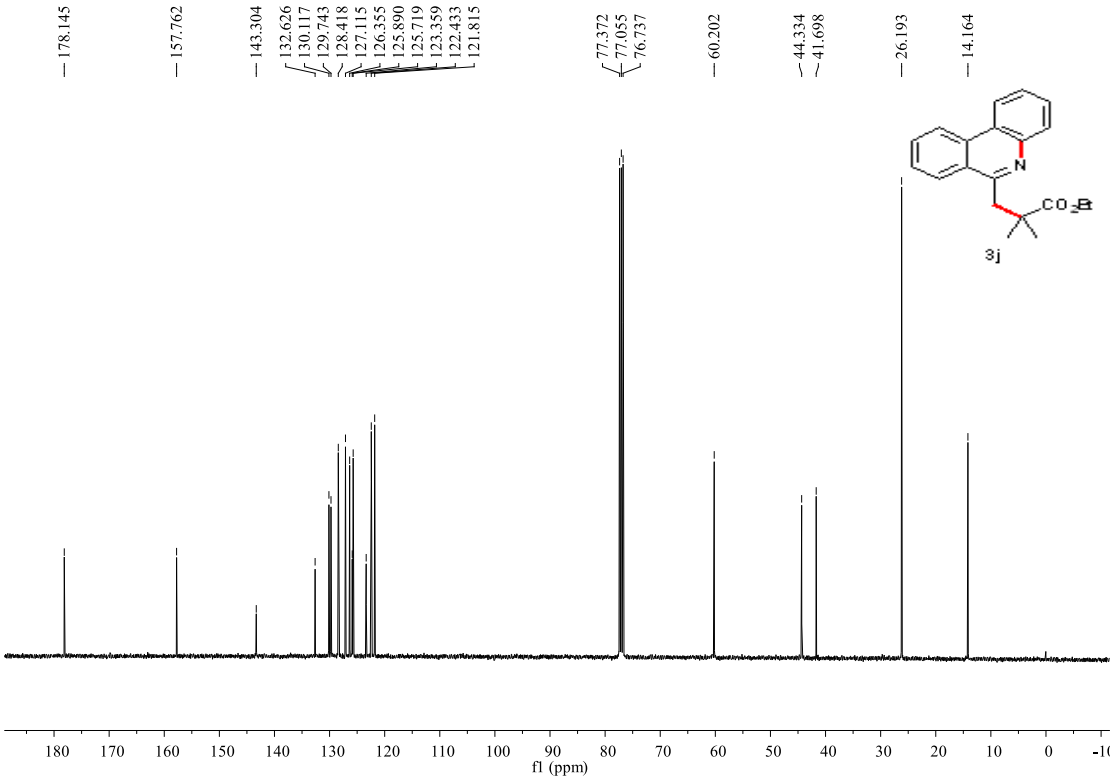
152.989
149.455
145.067
130.928
129.604
128.588
127.014
125.899
123.043
115.152
77.395
77.078
76.760
60.436
38.401
37.609
17.711
14.310
N
N
CO2Et
3i
fl (ppm)


8.626
8.606
8.522
8.504
8.215
8.024
7.670
7.574
7.250
4.133
4.115
4.097
4.079
3.642
1.437
1.121
1.103
1.085
1.00
1.02
1.05
0.99
1.09
3.07
2.13
2.07
6.34
3.21
fl (ppm)
3j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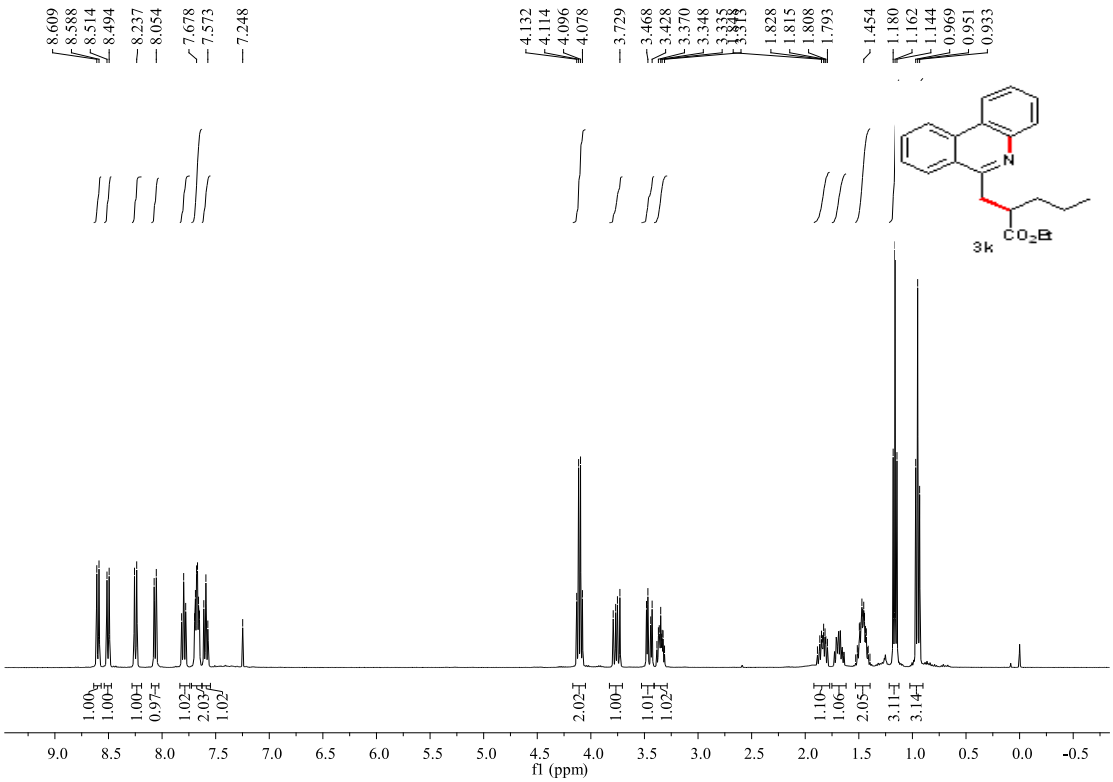
157.762
143.304
132.626
130.117
129.743
128.418
127.115
126.355
125.890
125.719
123.359
122.433
121.815
77.372
77.055
76.737
60.202
44.334
41.698
26.193
14.164
fl (ppm)
3j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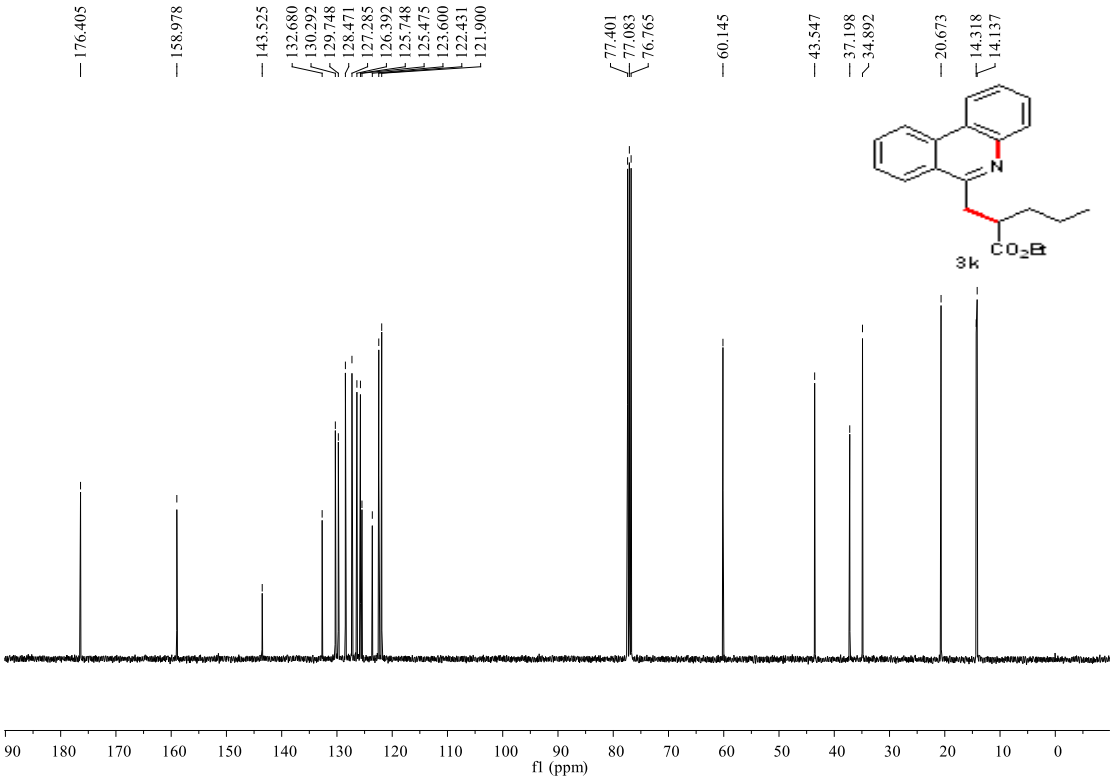
8.588
8.514
8.494
8.237
8.054
7.678
7.573
7.248
4.132
4.114
4.096
4.078
3.729
3.468
3.428
3.370
3.348
3.335
1.828
1.815
1.808
1.793
1.454
1.180
1.162
1.144
0.969
0.951
0.933
1.00
1.00
1.00
0.97
1.02
2.03
1.02
2.02
1.00
1.01
1.02
1.10
1.06
2.05
3.11
3.14
3k
CO2Et
N
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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128.471
127.285
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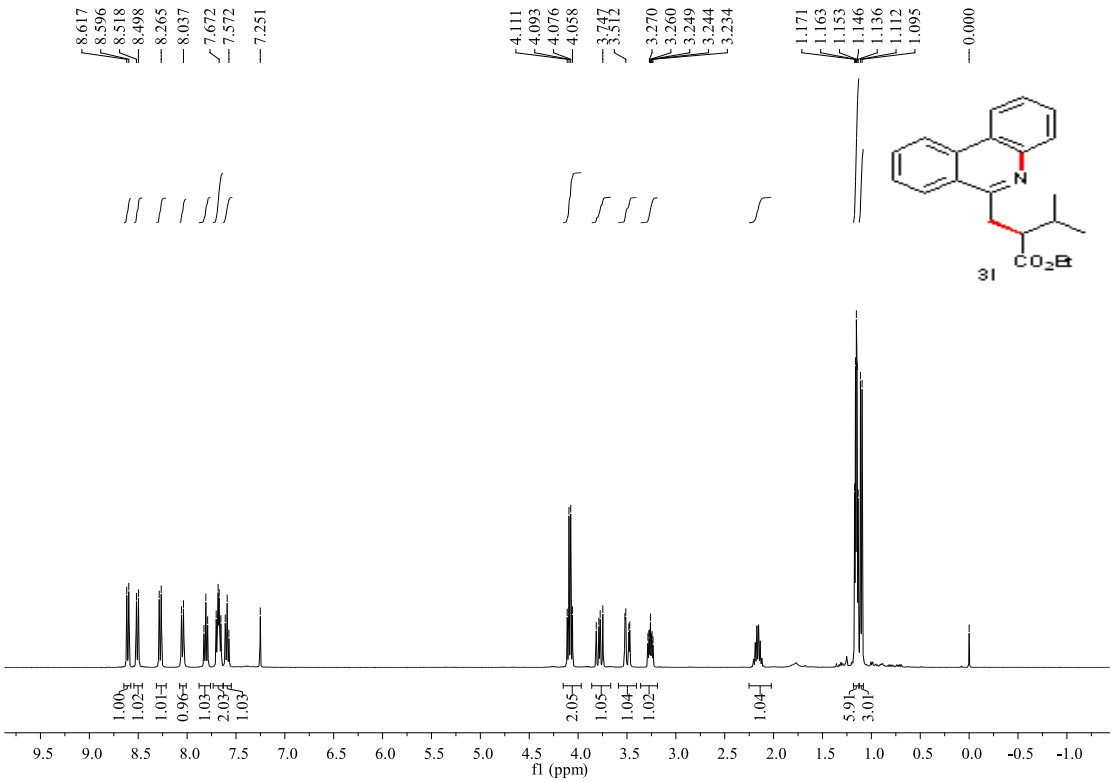
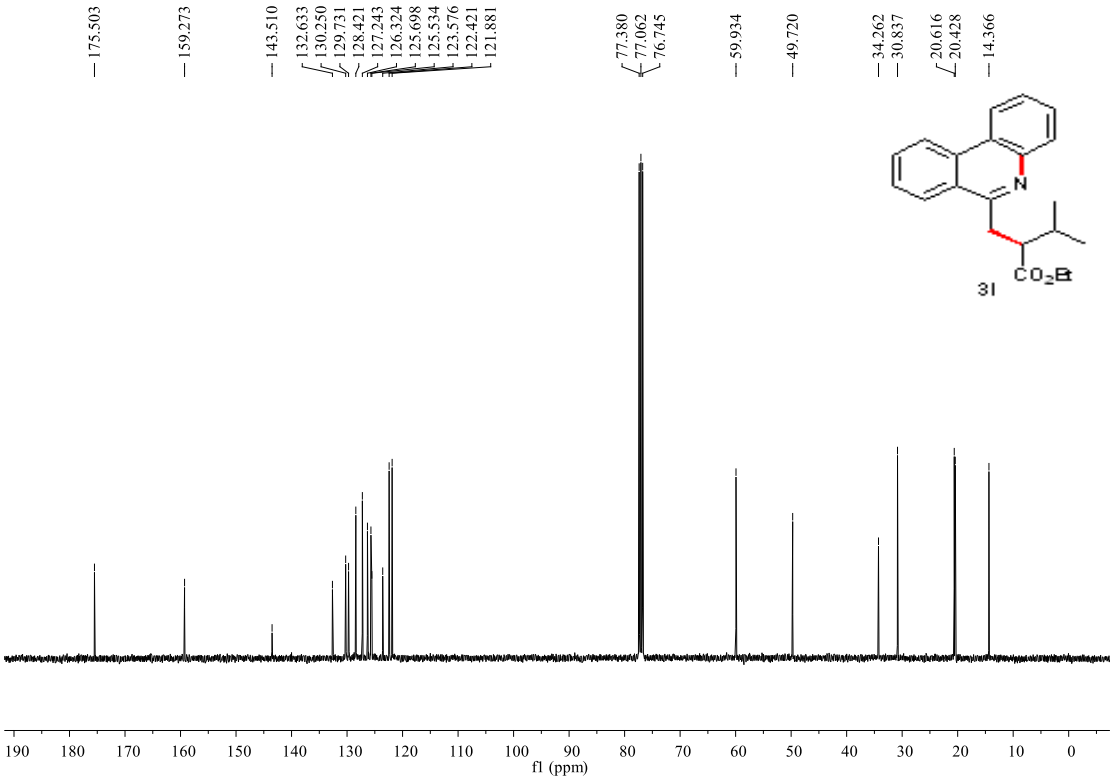
125.475
123.600
122.431
121.900
77.401
77.083
76.765
60.145
43.547
37.198
34.892
20.673
14.318
14.137
3k
CO2Et
N
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.617
8.596
8.518
8.498
8.265
8.037
7.672
7.572
7.251
4.111
4.093
4.076
4.058
3.747
3.512
3.270
3.260
3.249
3.244
3.234
1.171
1.163
1.153
1.146
1.136
1.112
1.095
0.000
1.00
1.02
1.01
0.96
1.03
2.03
1.03
2.05
1.05
1.04
1.02
1.04
5.91
3.01
N
CO2Et
3l
f1 (ppm)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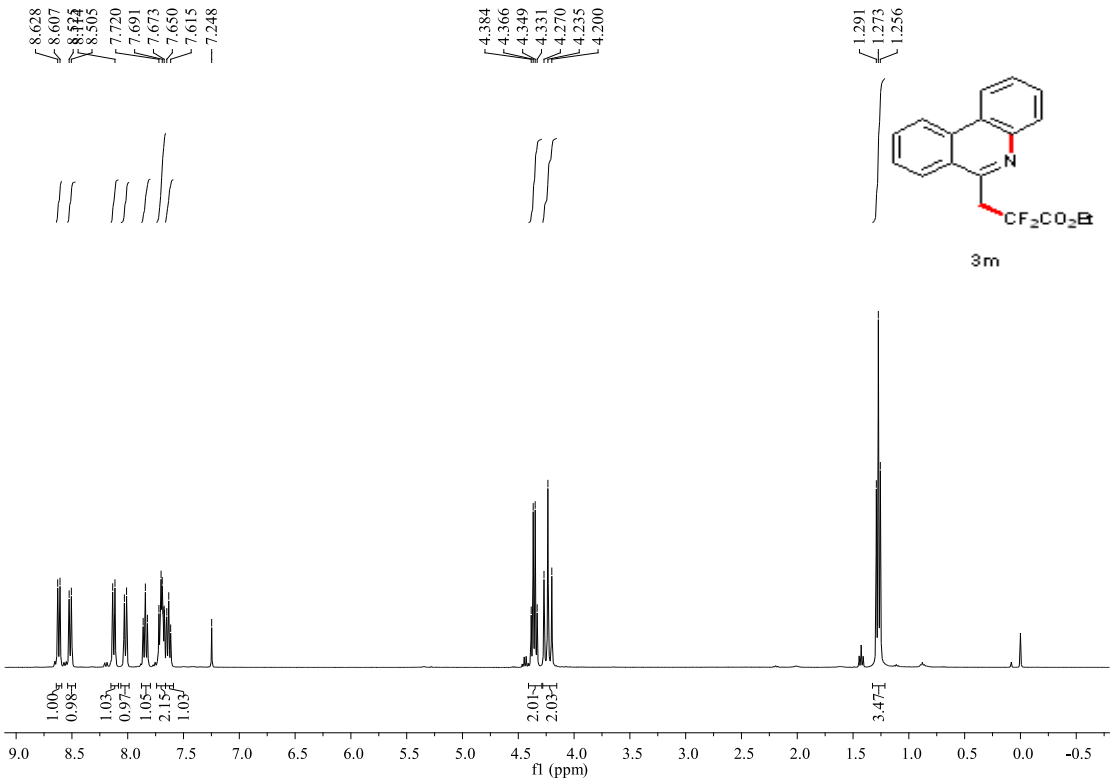
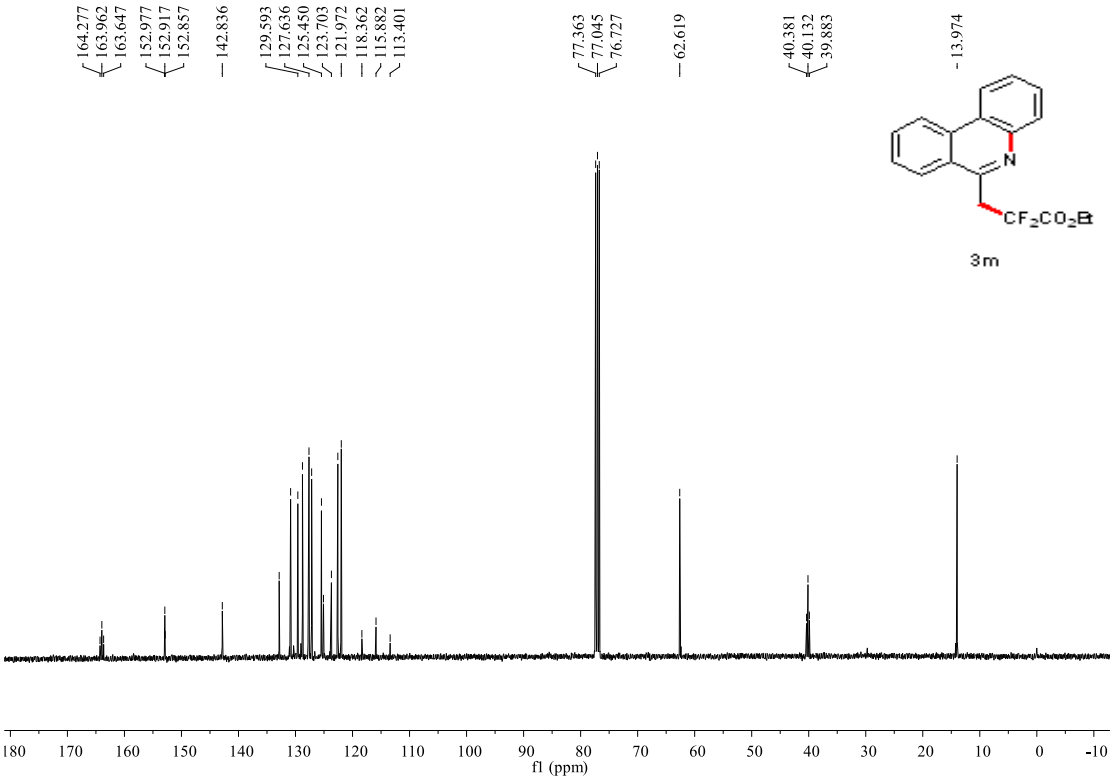
159.273
143.510
132.633
130.250
129.731
128.421
127.243
126.324
125.698
125.534
123.576
122.421
121.881
77.380
77.062
76.745
59.934
49.720
34.262
30.837
20.616
20.428
14.366
N
CO2Et
3l
f1 (ppm)


8.628
8.607
8.505
7.720
7.691
7.673
7.650
7.615
7.248
4.384
4.366
4.349
4.331
4.270
4.235
4.200
1.291
1.273
1.256
CF2CO2Et
3m
1.00
0.98
1.03
0.97
1.05
2.15
1.03
2.01
2.03
3.47
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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127.636
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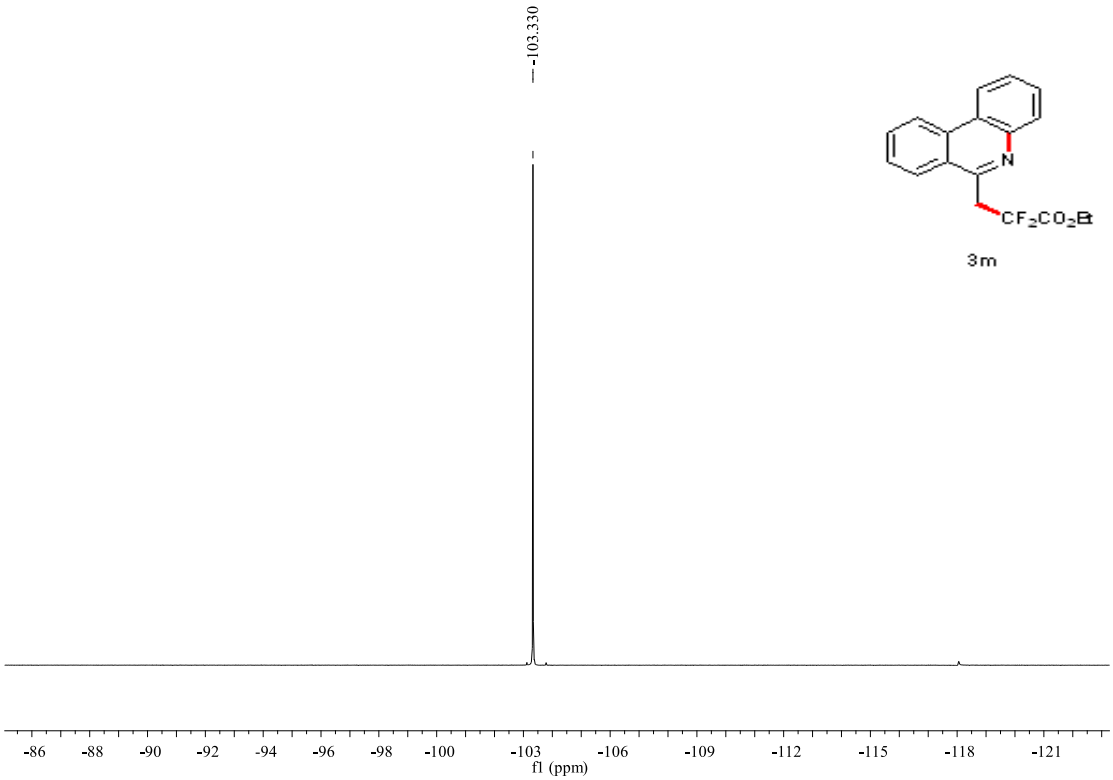
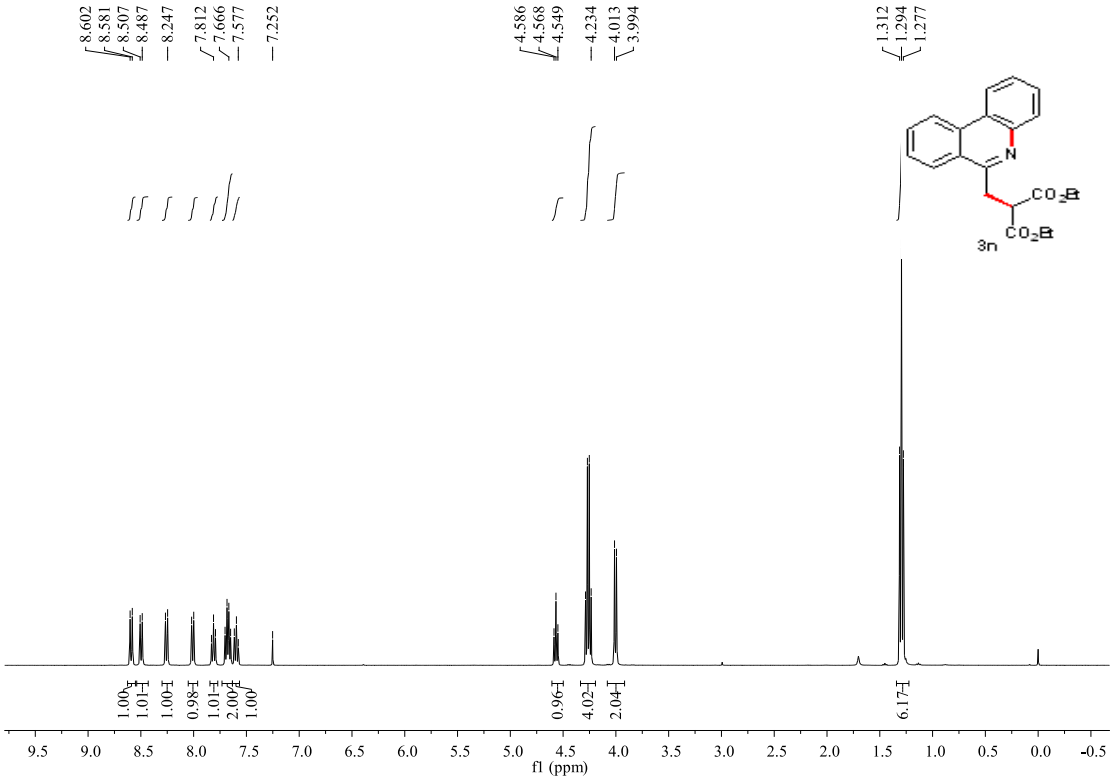
123.703
121.972
118.362
115.882
113.401
77.363
77.045
76.727
62.619
40.381
40.132
39.883
13.974
CF2CO2Et
3m
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-103.330
N
CF2CO2Et
3m
-86
-88
-90
-92
-94
-96
-98
-100
-103
-106
-109
-112
-115
-118
-121
f1 (ppm)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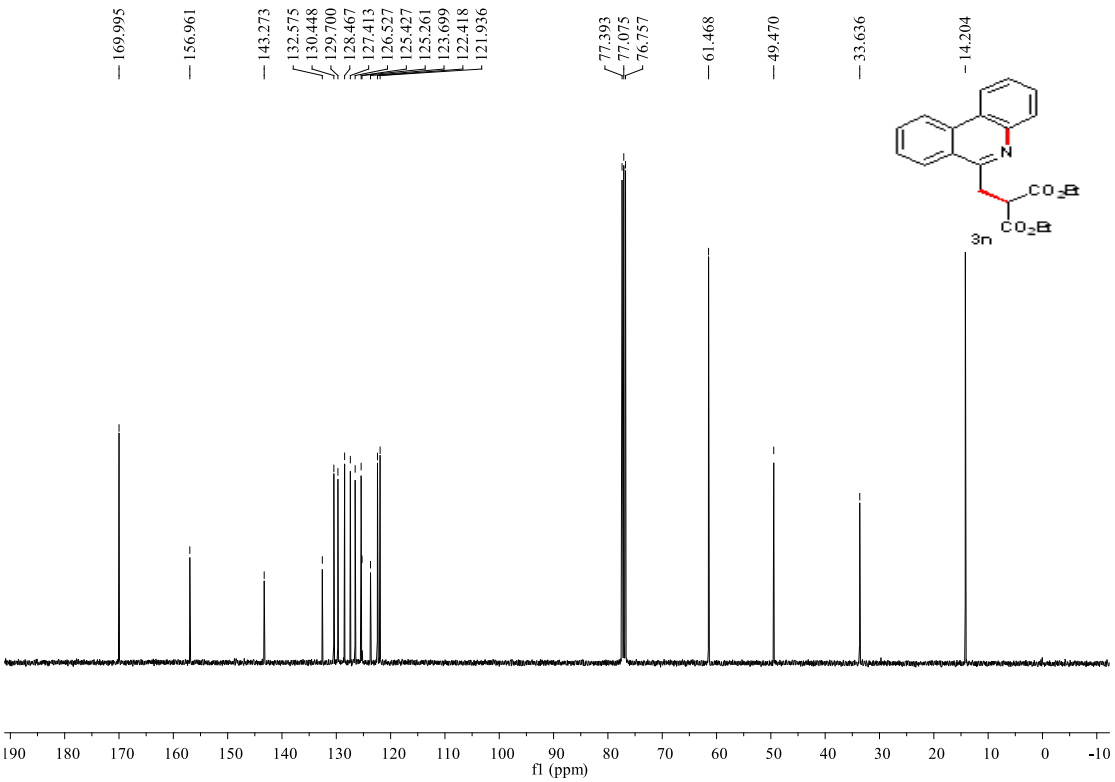
7.577
7.252
4.586
4.568
4.549
4.234
4.013
3.994
1.312
1.294
1.277
N
CO2Et
CO2Et
3n
1.00
1.01
1.00
0.98
1.01
2.00
1.00
0.96
4.02
2.04
6.17
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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127.413
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125.261
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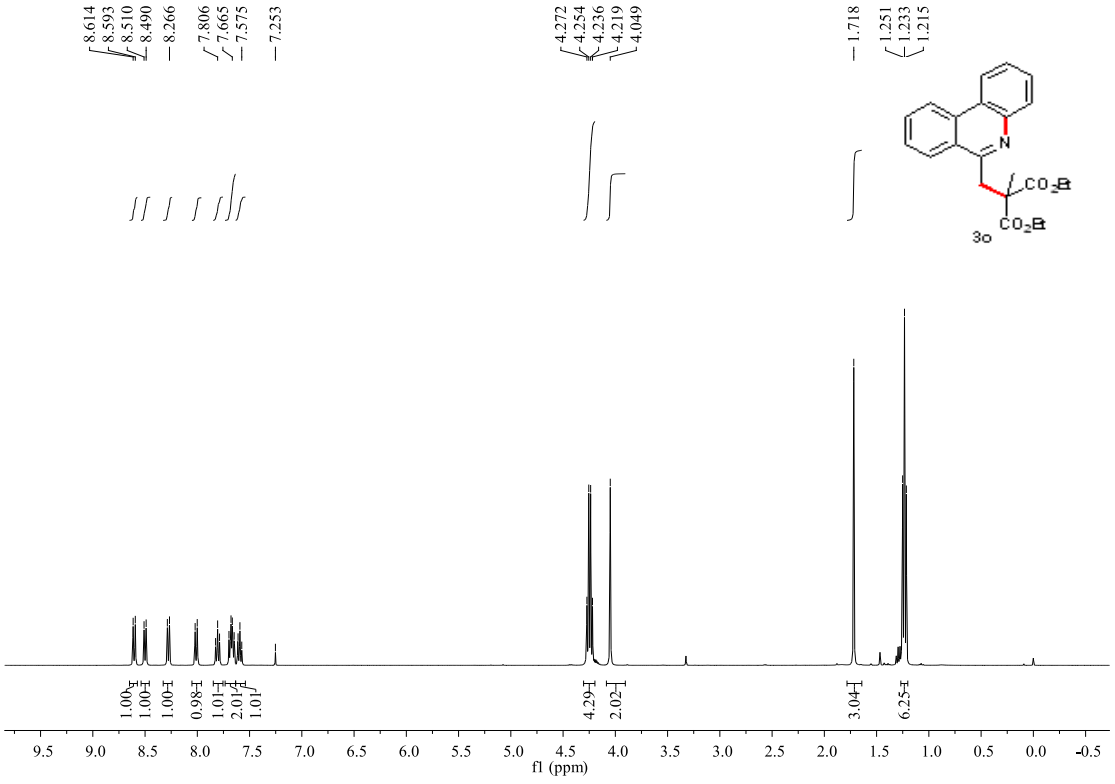
77.393
77.075
76.757
61.468
49.470
33.636
14.204
3n
fl (ppm)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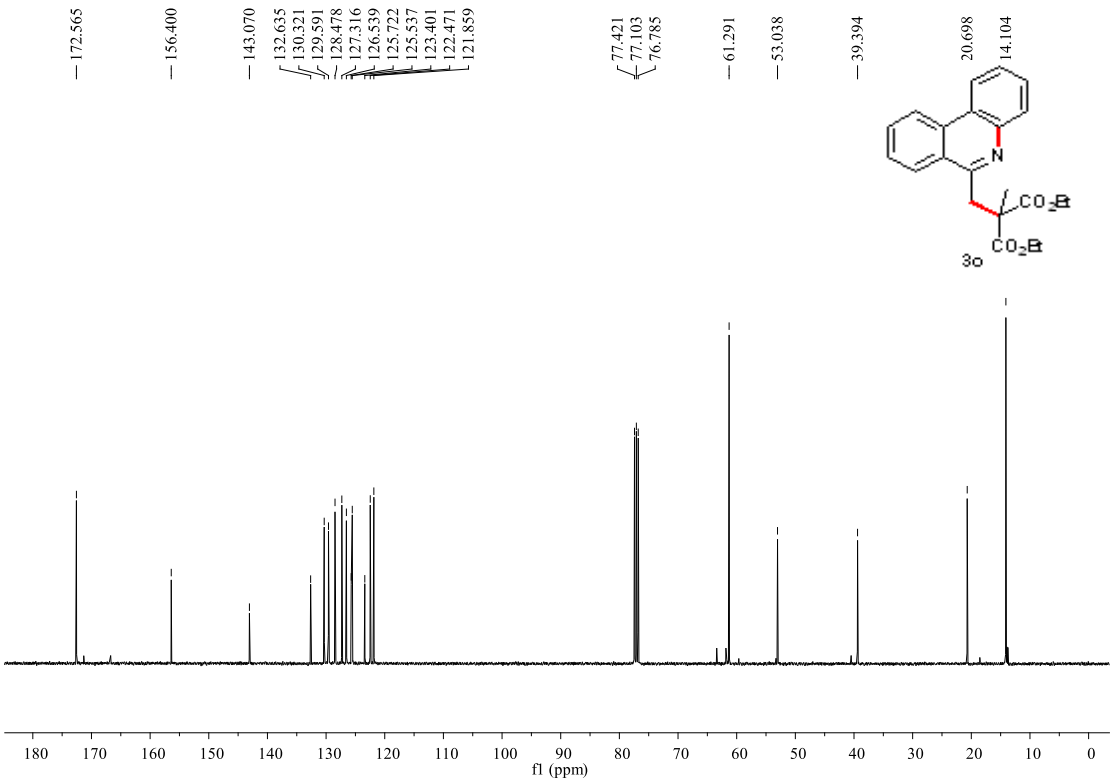
7.806
7.665
7.575
7.253
4.272
4.254
4.236
4.219
4.049
1.718
1.251
1.233
1.215
3o
1.00
1.00
1.00
0.98
1.01
2.01
1.01
4.29
2.02
3.04
6.25
fl (ppm)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125.722
125.537
123.401
122.471
121.859
77.421
77.103
76.785
61.291
53.038
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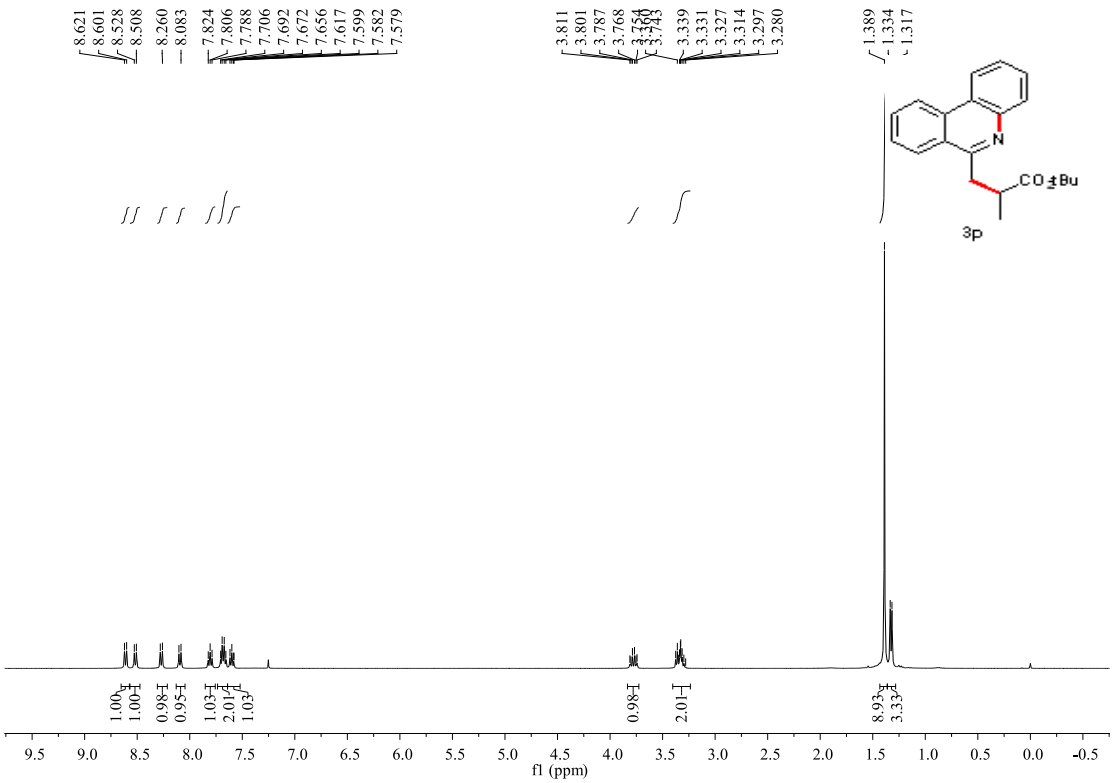
14.104
CO2Et
CO2Et
N
3o
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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8.083
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7.806
7.788
7.706
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7.672
7.656
7.617
7.599
7.582
7.579
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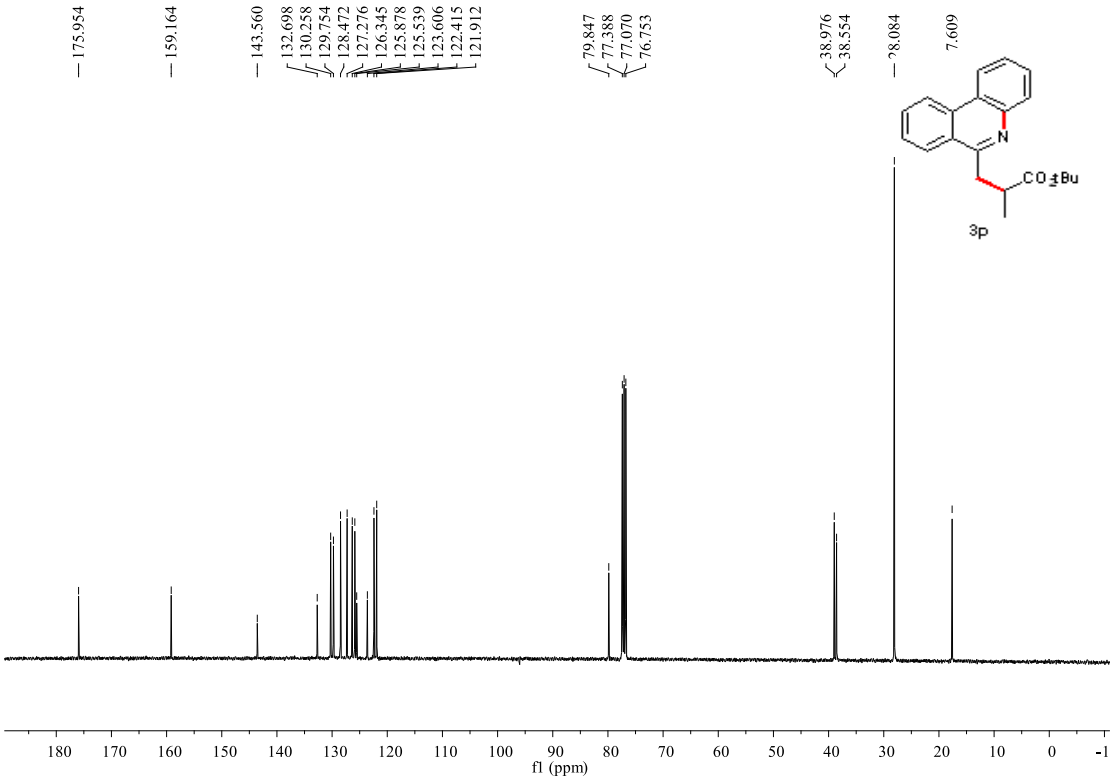
3.801
3.787
3.768
3.754
3.743
3.339
3.331
3.327
3.314
3.297
3.280
1.389
1.334
1.317
CO2tBu
N
3p
1.00
1.00
0.98
0.95
1.03
2.01
1.03
0.98
2.01
8.93
3.33
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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125.539
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122.415
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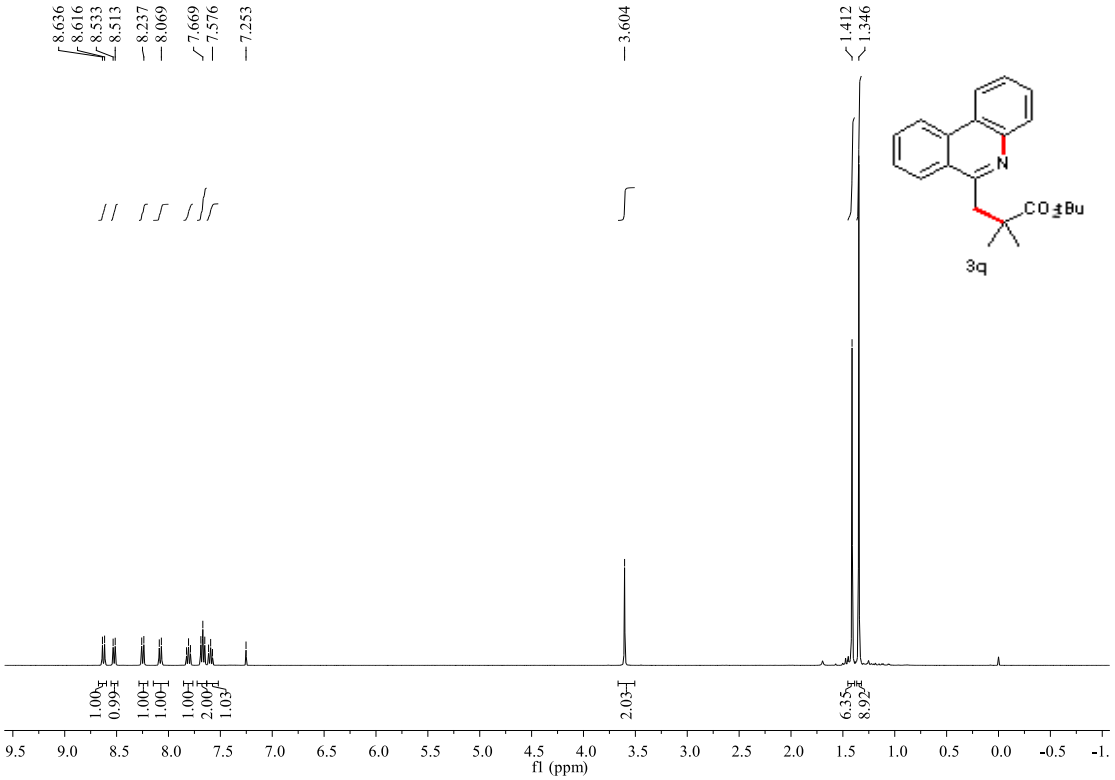
77.070
76.753
38.976
38.554
28.084
7.609
CO2tBu
3p
f1 (ppm)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8.513
8.237
8.069
7.669
7.576
7.253
3.604
1.412
1.346
CO2tBu
3q
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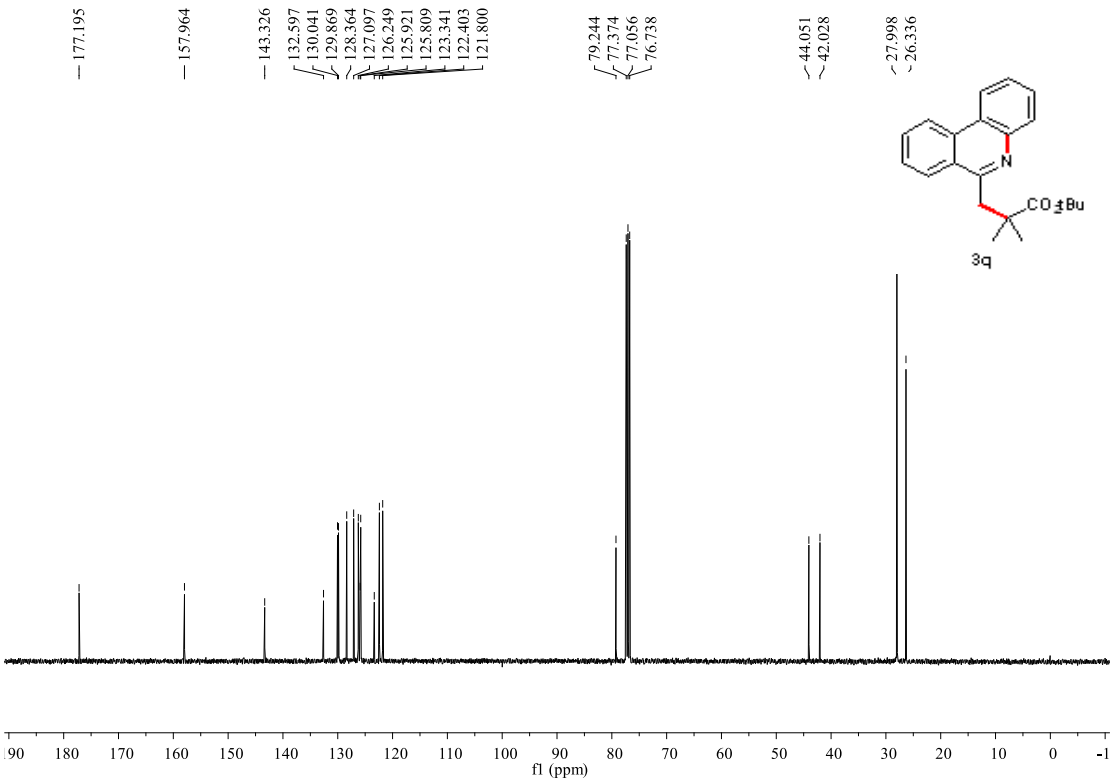
1.00
1.00
1.00
2.00
1.03
2.03
6.35
8.92
f1 (ppm)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128.364
127.097
126.249
125.921
125.809
123.341
122.403
121.800
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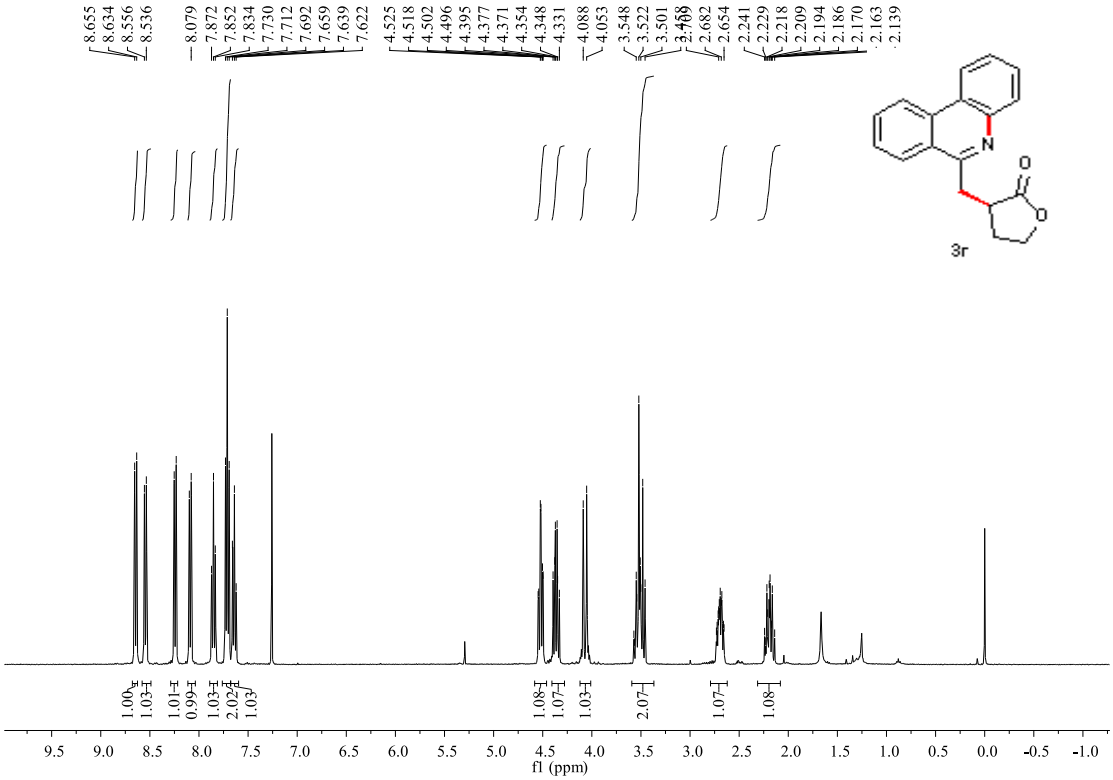
77.056
76.738
44.051
42.028
27.998
26.336
CO2tBu
3q
f1 (ppm)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7.692
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7.639
7.622
4.525
4.518
4.502
4.496
4.395
4.377
4.371
4.354
4.348
4.331
4.088
4.053
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3.522
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2.229
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2.209
2.194
2.186
2.170
2.163
2.139
O
O
3r
1.00
1.03
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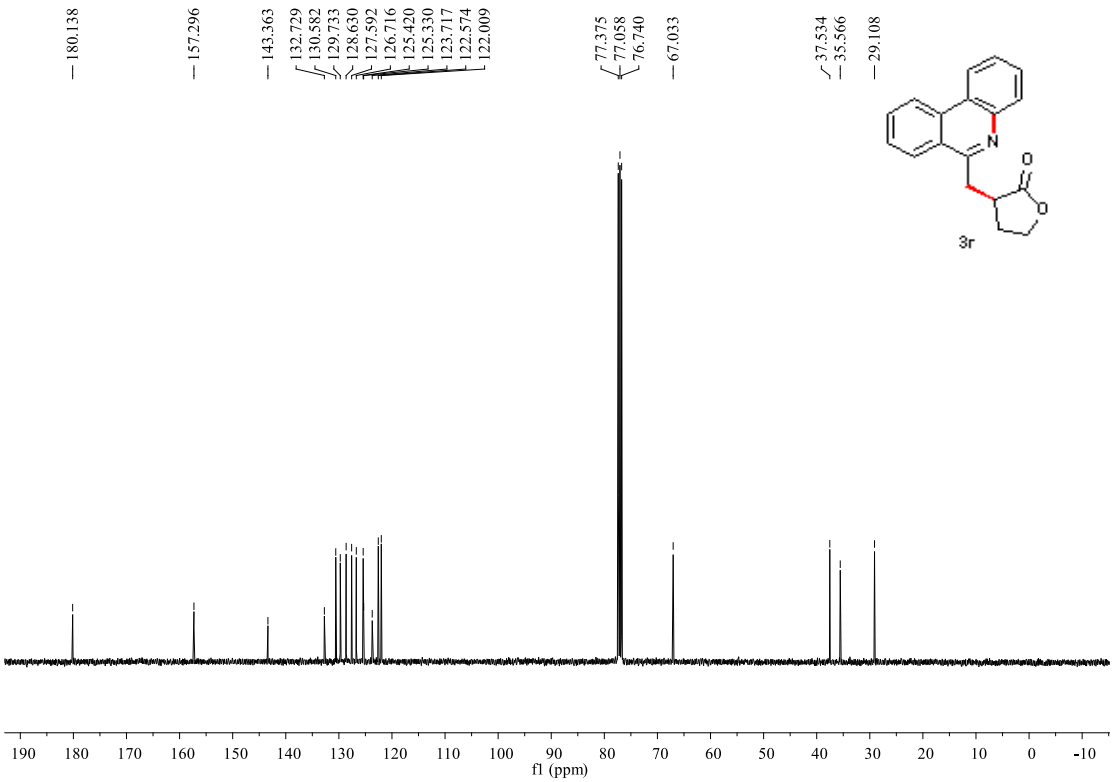
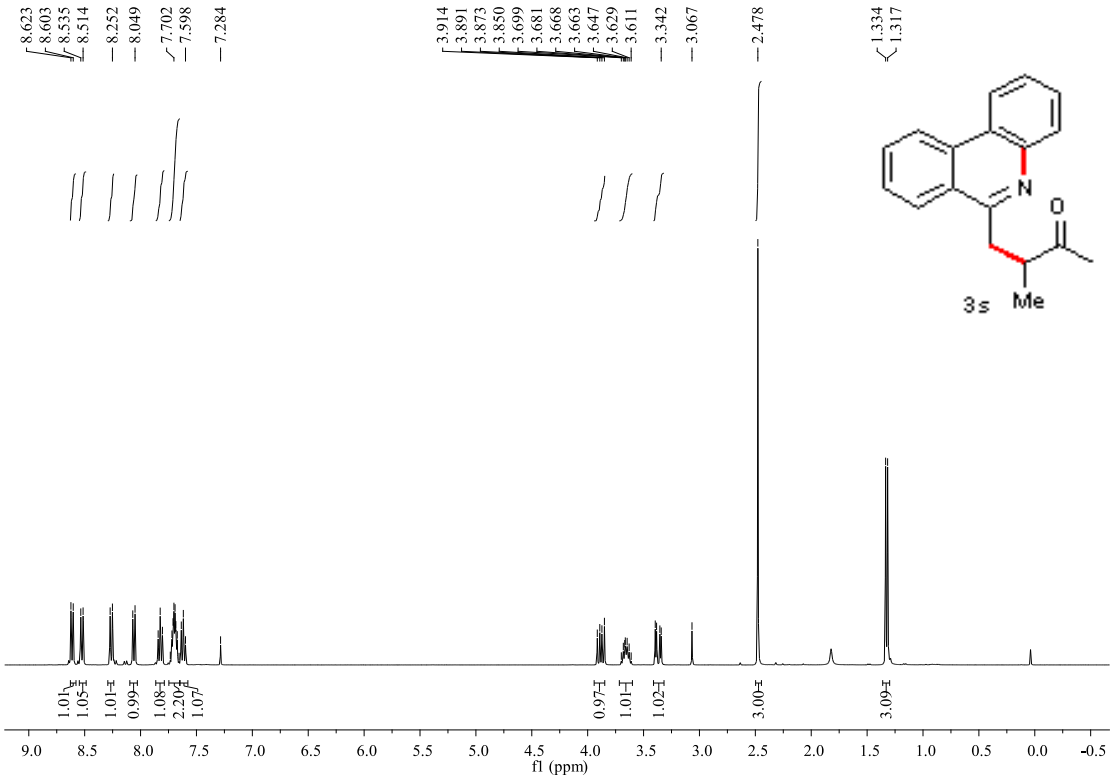
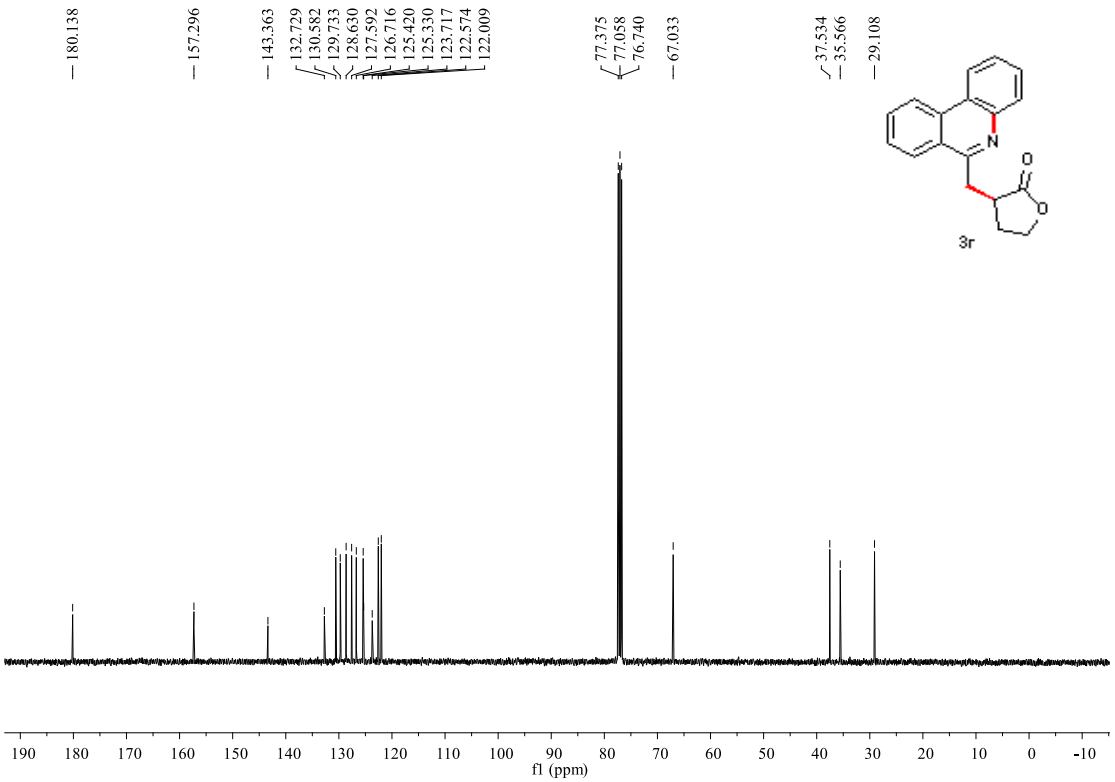
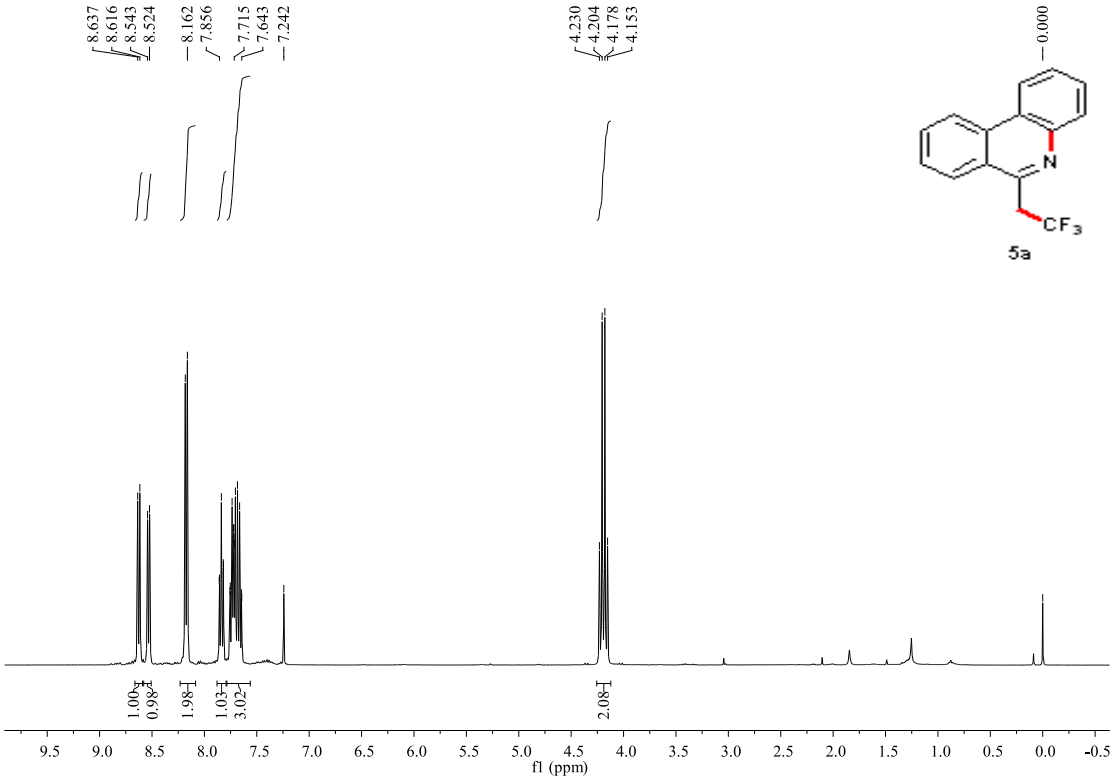
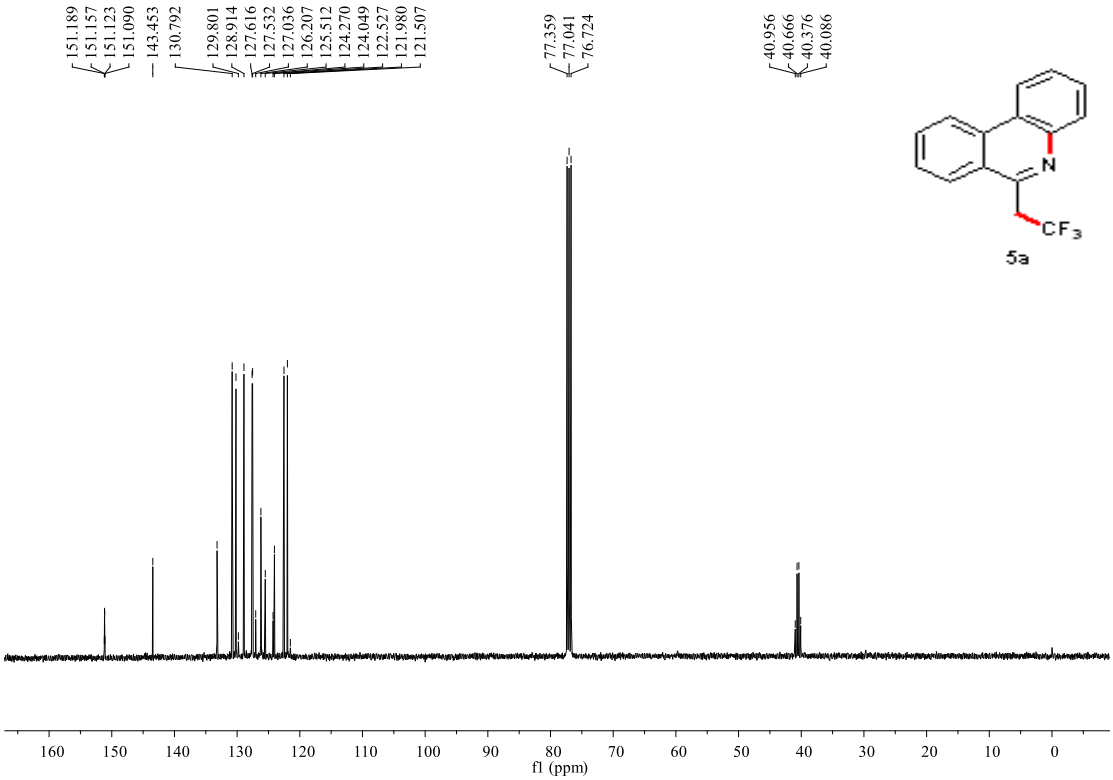
1.08
1.07
1.03
2.07
1.07
1.08
f1 (ppm)


180.138
157.296
143.363
132.729
130.582
129.733
128.630
127.592
126.716
125.420
125.330
123.717
122.574
122.009
77.375
77.058
76.740
67.033
37.534
35.566
29.108
N
O
O
3r
fl (ppm)

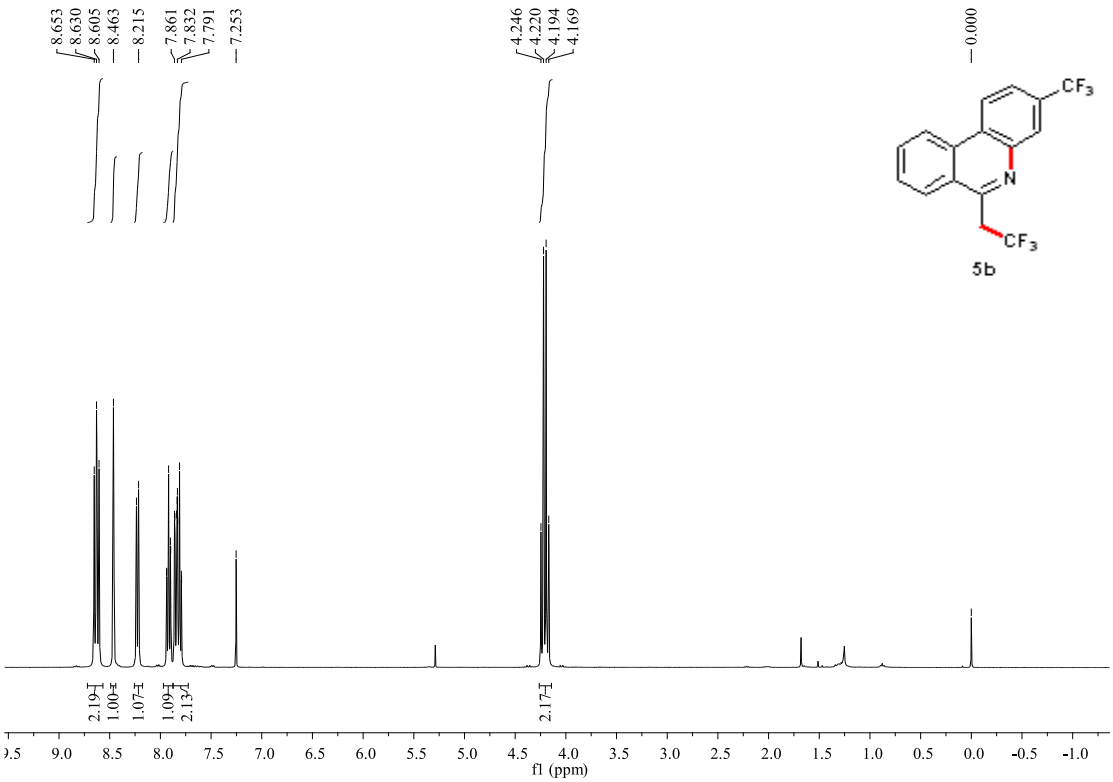

8.623
8.603
8.535
8.514
8.252
8.049
7.702
7.598
7.284
3.914
3.891
3.873
3.850
3.699
3.681
3.668
3.663
3.647
3.629
3.611
3.342
3.067
2.478
1.334
1.317
N
O
3s
Me
1.01
1.05
1.01
0.99
1.08
2.20
1.07
0.97
1.01
1.02
3.00
3.09
fl (ppm)

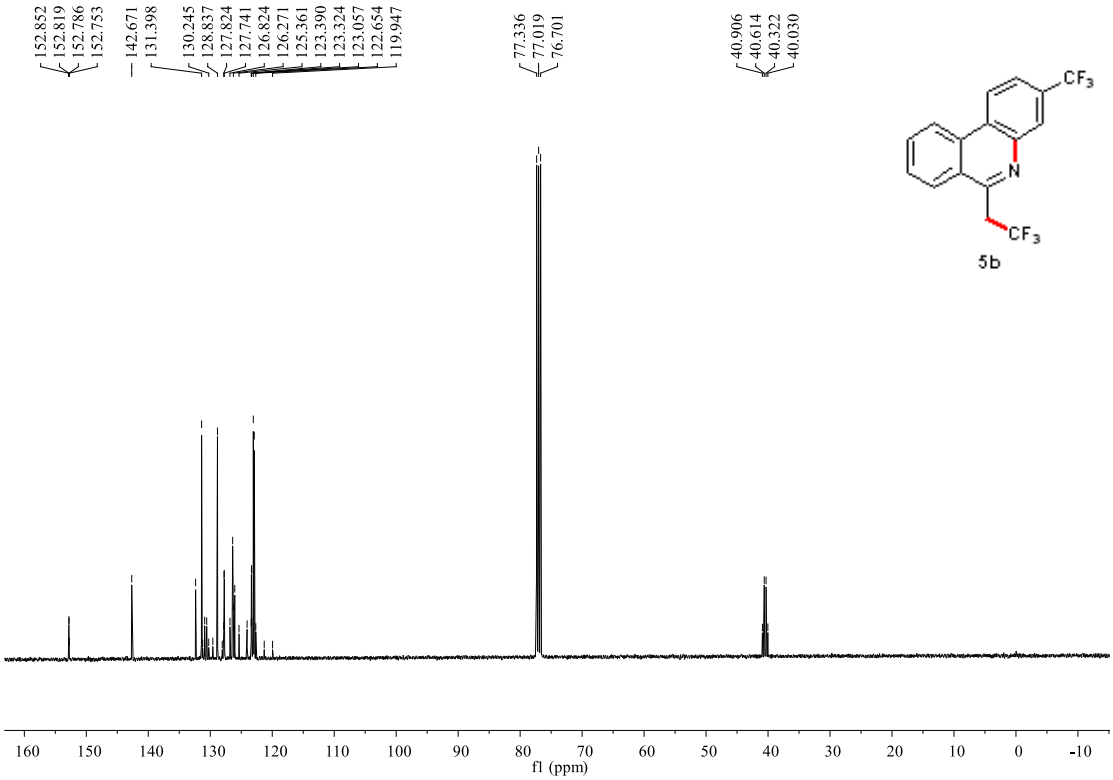

180.138
157.296
143.363
132.729
130.582
129.733
128.630
127.592
126.716
125.420
125.330
123.717
122.574
122.009
77.375
77.058
76.740
67.033
37.534
35.566
29.108
3r
fl (ppm)

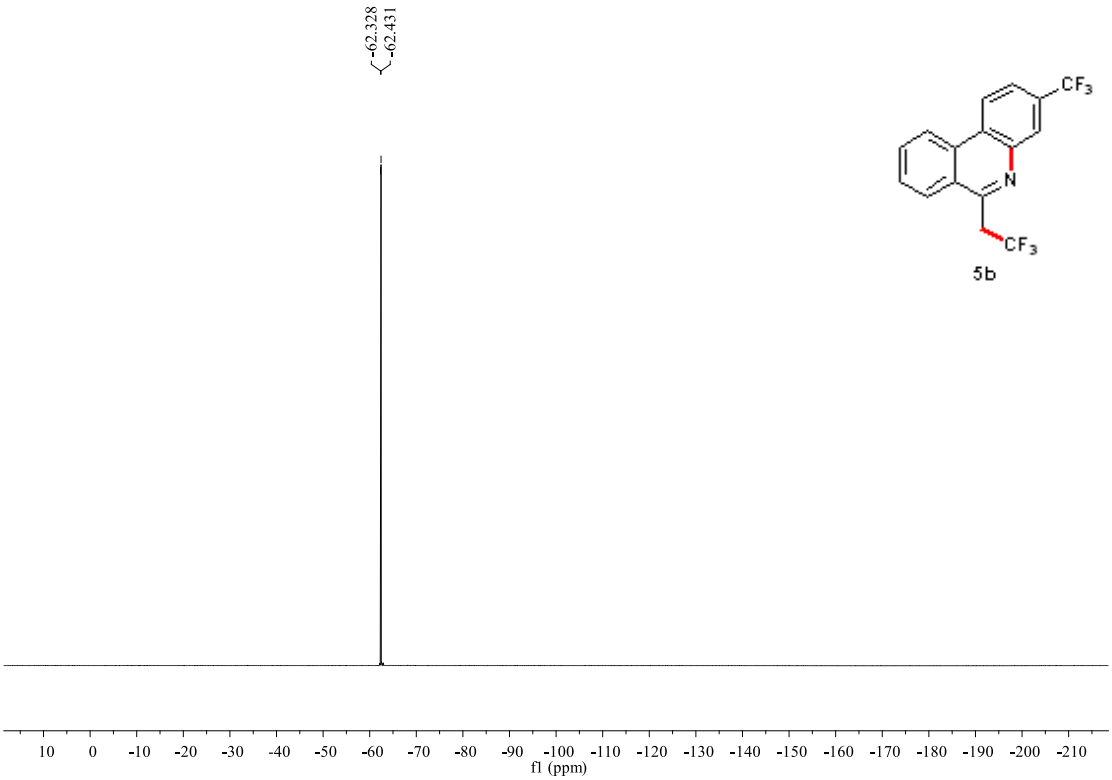

8.637
8.616
8.543
8.524
8.162
7.856
7.715
7.643
7.242
4.230
4.204
4.178
4.153
0.000
5a
1.00
0.98
1.98
1.03
3.02
2.08
fl (ppm)

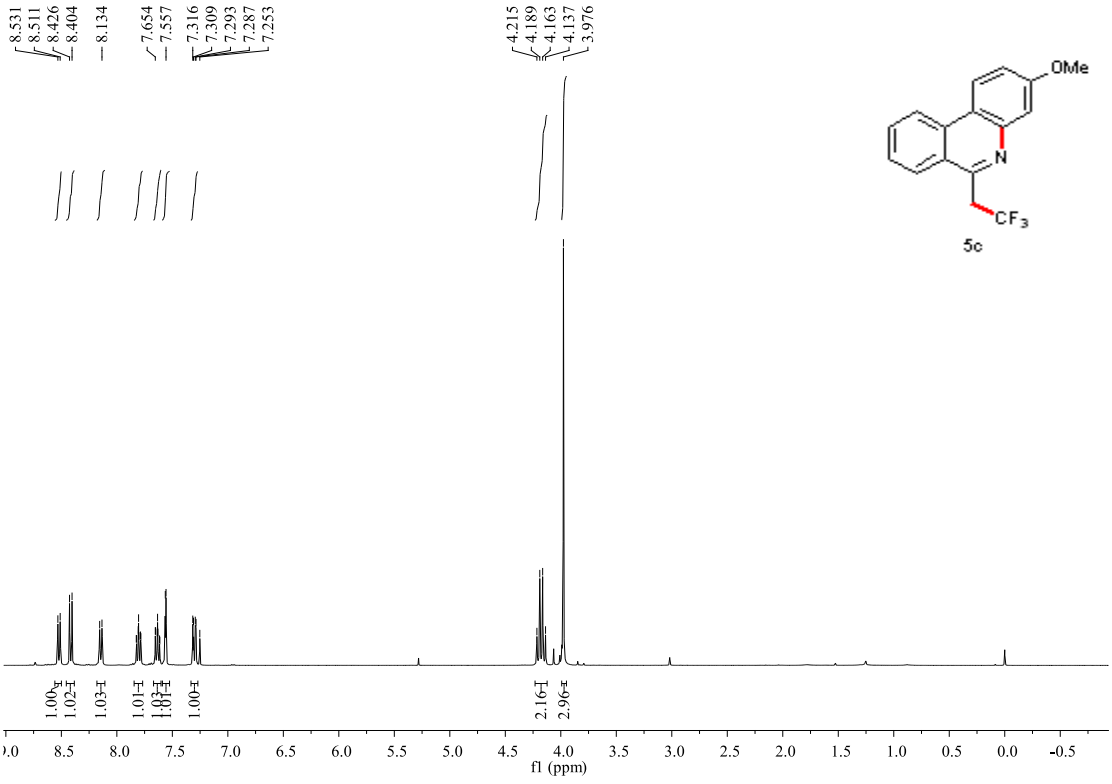

151.189
151.157
151.123
151.090
143.453
130.792
129.801
128.914
127.616
127.532
127.036
126.207
125.512
124.270
124.049
122.527
121.980
121.507
77.359
77.041
76.724
40.956
40.666
40.376
40.086
N
CF3
5a
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

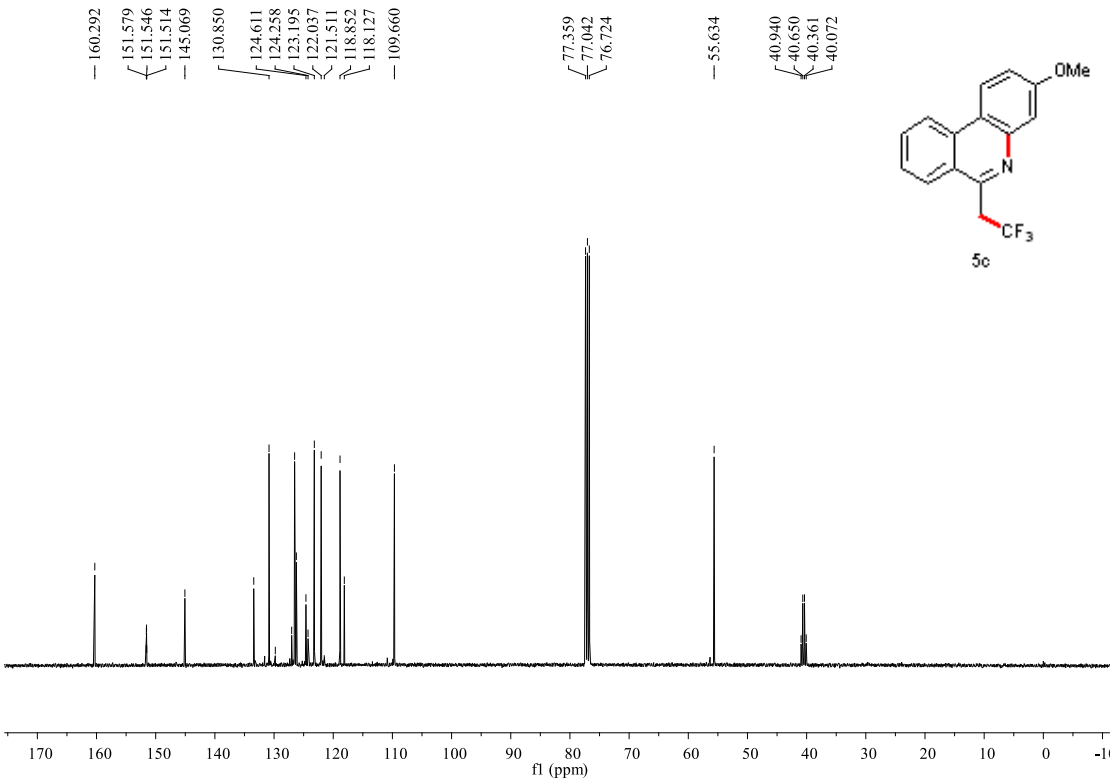

-62.457
N
CF3
5a
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

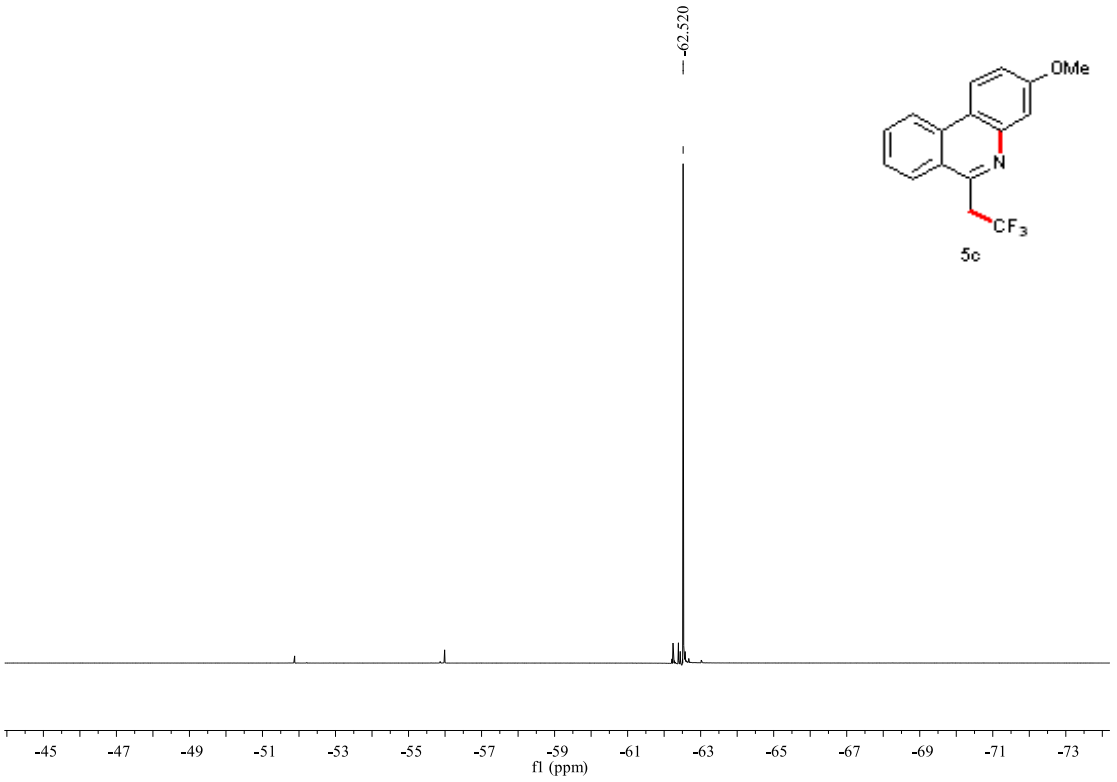

8.653
8.630
8.605
8.463
8.215
7.861
7.832
7.791
7.253
4.246
4.220
4.194
4.169
0.000
2.19
1.00
1.07
1.09
2.13
2.17
f1 (ppm)
5b

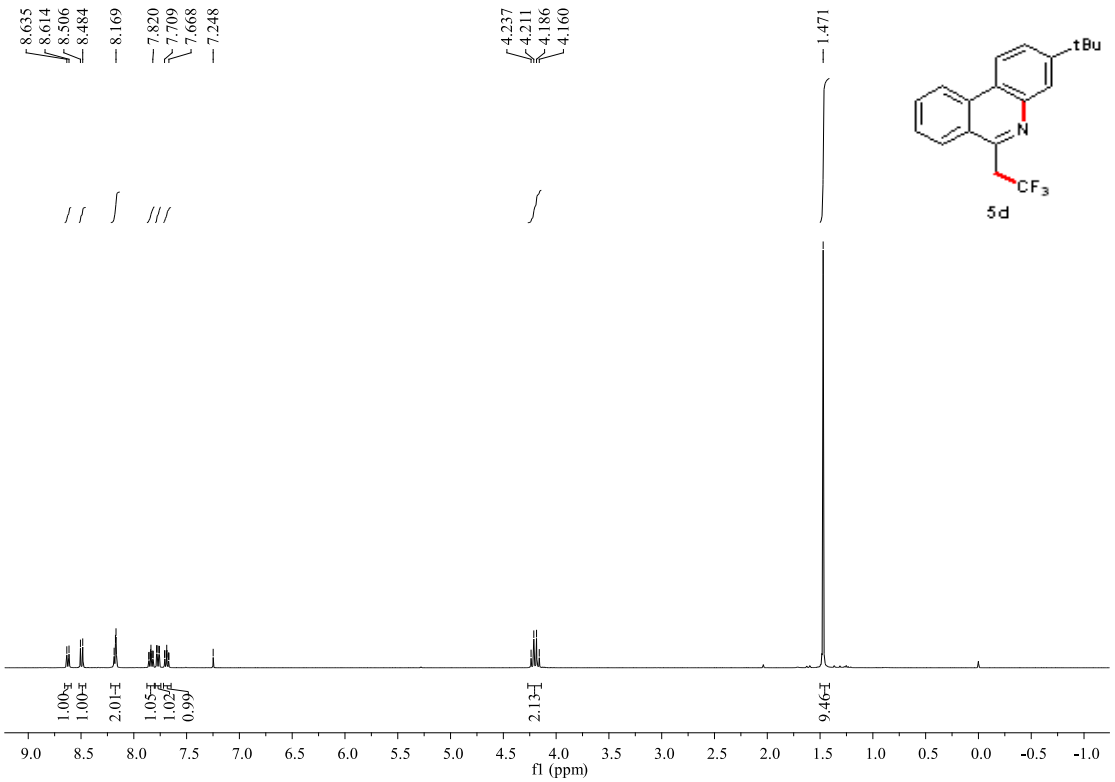

152.852
152.819
152.786
152.753
142.671
131.398
130.245
128.837
127.824
127.741
126.824
126.271
125.361
123.390
123.324
123.057
122.654
119.947
77.336
77.019
76.701
40.906
40.614
40.322
40.030
f1 (ppm)
5b

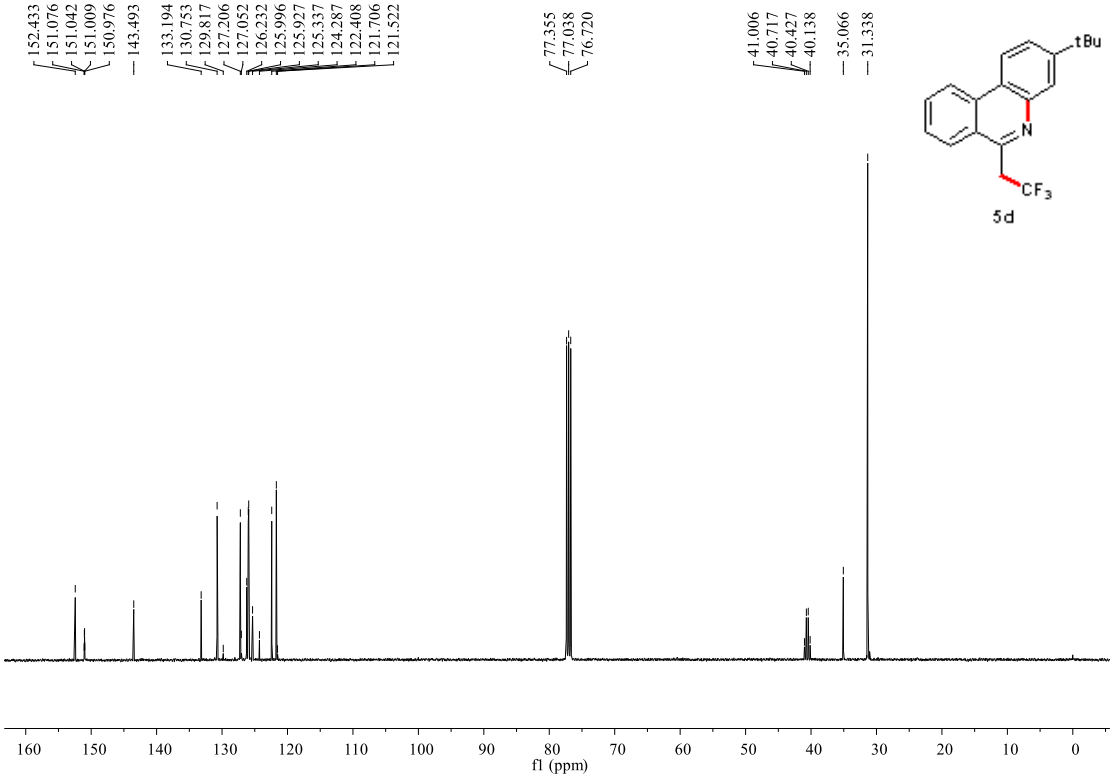

-62.328
-62.431
CF3
N
CF3
5b
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

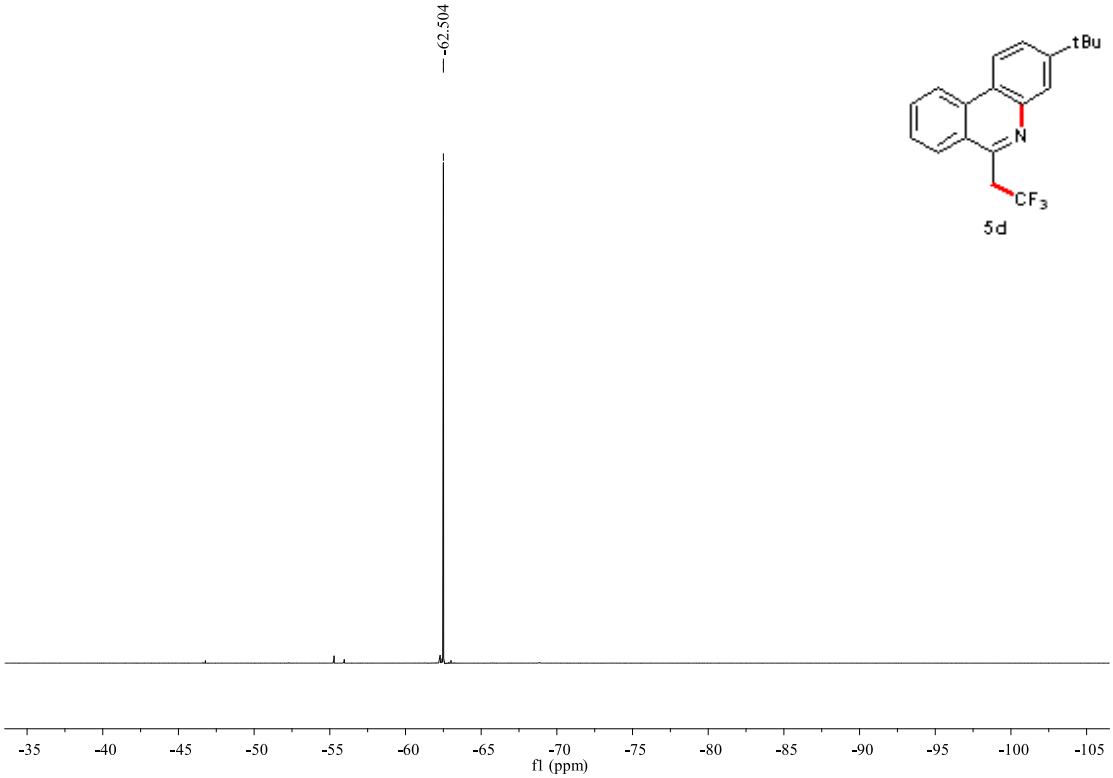

8.531
8.511
8.426
8.404
8.134
7.654
7.557
7.316
7.309
7.293
7.287
7.253
4.215
4.189
4.163
4.137
3.976
OMe
N
CF3
5c
1.00
1.02
1.03
1.01
1.03
1.01
1.00
2.16
2.96
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

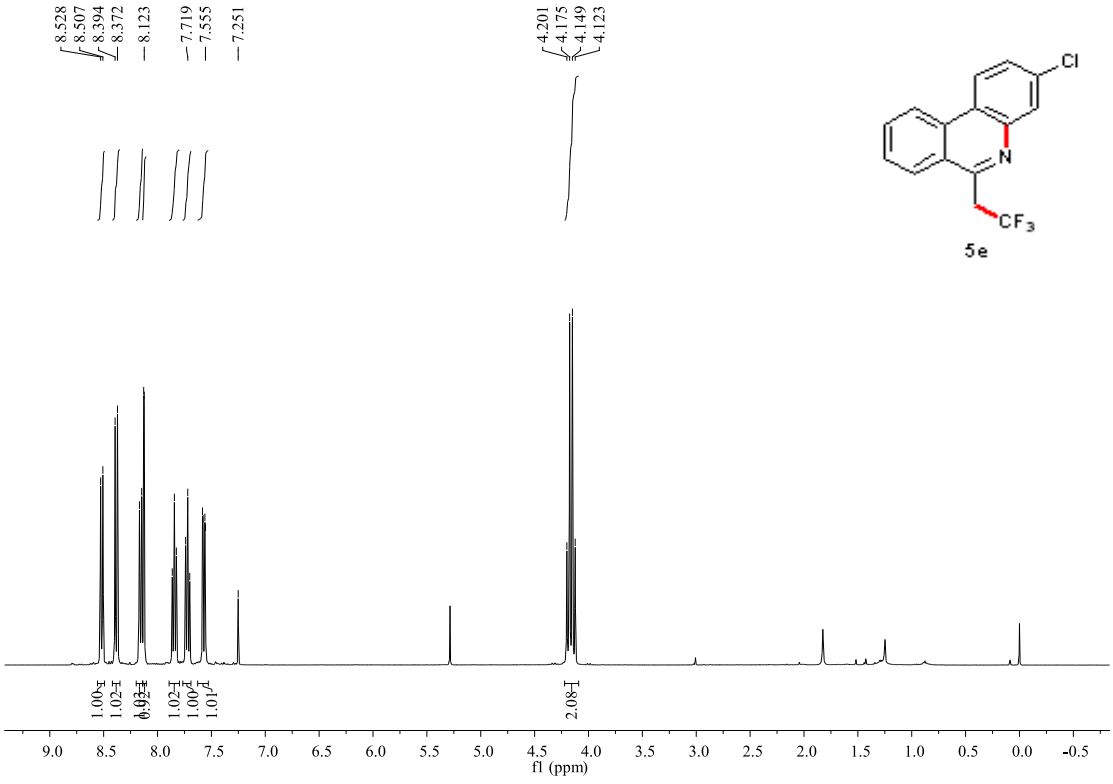

160.292
151.579
151.546
151.514
145.069
130.850
124.611
124.258
123.195
122.037
121.511
118.852
118.127
109.660
77.359
77.042
76.724
55.634
40.940
40.650
40.361
40.072
OMe
N
CF3
5c
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

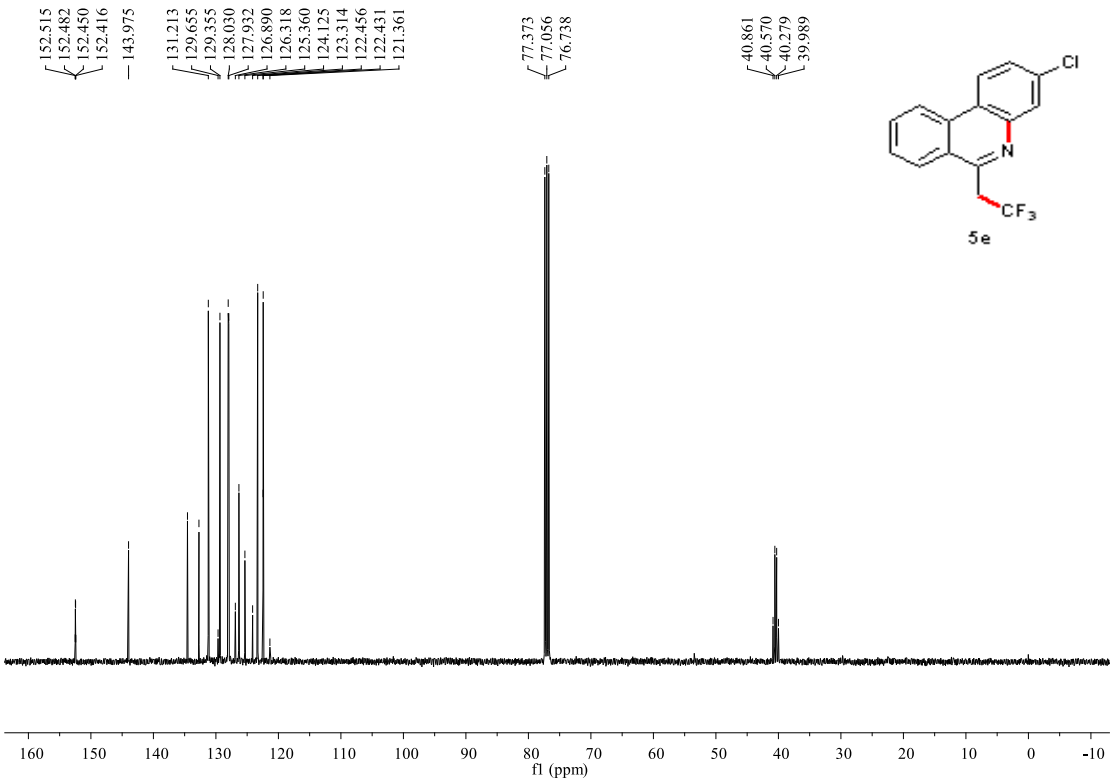

-62.520
OMe
N
CF3
5c
-45 -47 -49 -51 -53 -55 -57 -59 -61 -63 -65 -67 -69 -71 -73
f1 (ppm)


8.635
8.614
8.506
8.484
8.169
7.820
7.709
7.668
7.248
4.237
4.211
4.186
4.160
1.471
tBu
N
CF3
5d
1.00
1.00
2.01
1.05
1.02
0.99
2.13
9.46
fl (ppm)


152.433
151.076
151.042
151.009
150.976
143.493
133.194
130.753
129.817
127.206
127.052
126.232
125.996
125.927
125.337
124.287
122.408
121.706
121.522
77.355
77.038
76.720
41.006
40.717
40.427
40.138
35.066
31.338
tBu
N
CF3
5d
fl (ppm)


-62.504
tBu
N
CF3
5d
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
-105
f1 (ppm)


8.528
8.507
8.394
8.372
8.123
7.719
7.555
7.251
4.201
4.175
4.149
4.123
Cl
N
CF3
5e
1.00
1.02
1.02
1.00
1.01
2.08
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


152.515
152.482
152.450
152.416
143.975
131.213
129.655
129.355
128.030
127.932
126.890
126.318
125.360
124.125
123.314
122.456
122.431
121.361
77.373
77.056
76.738
40.861
40.570
40.279
39.989
Cl
N
CF3
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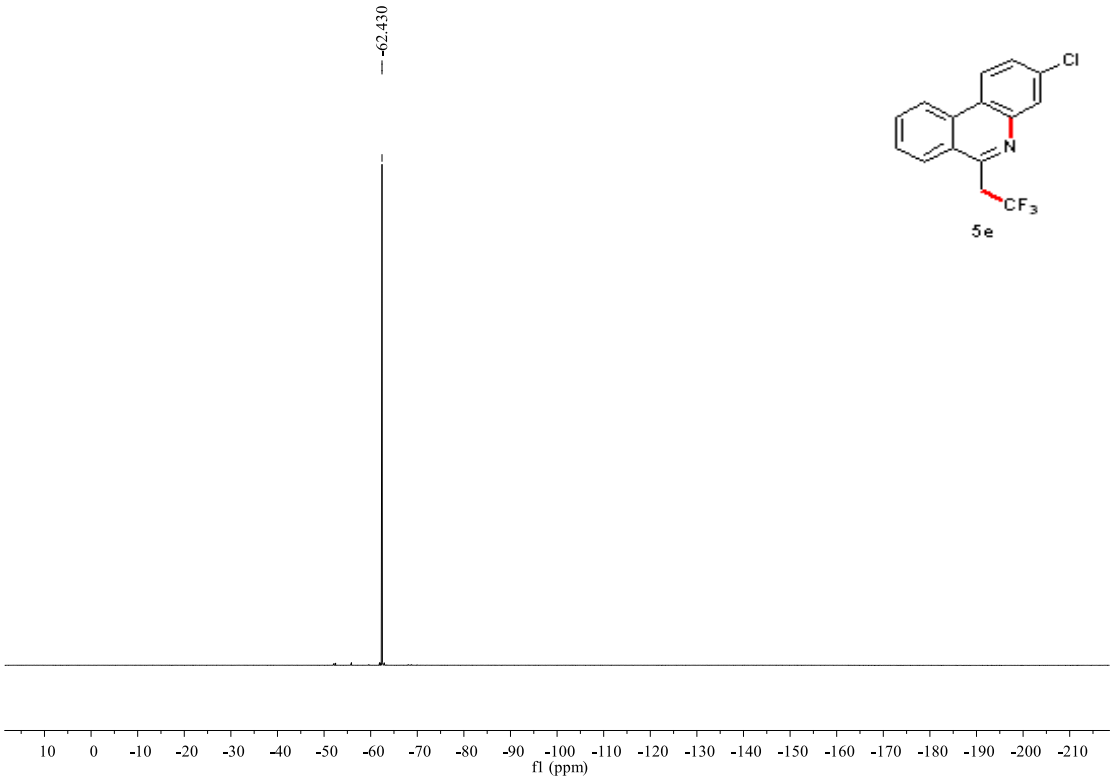
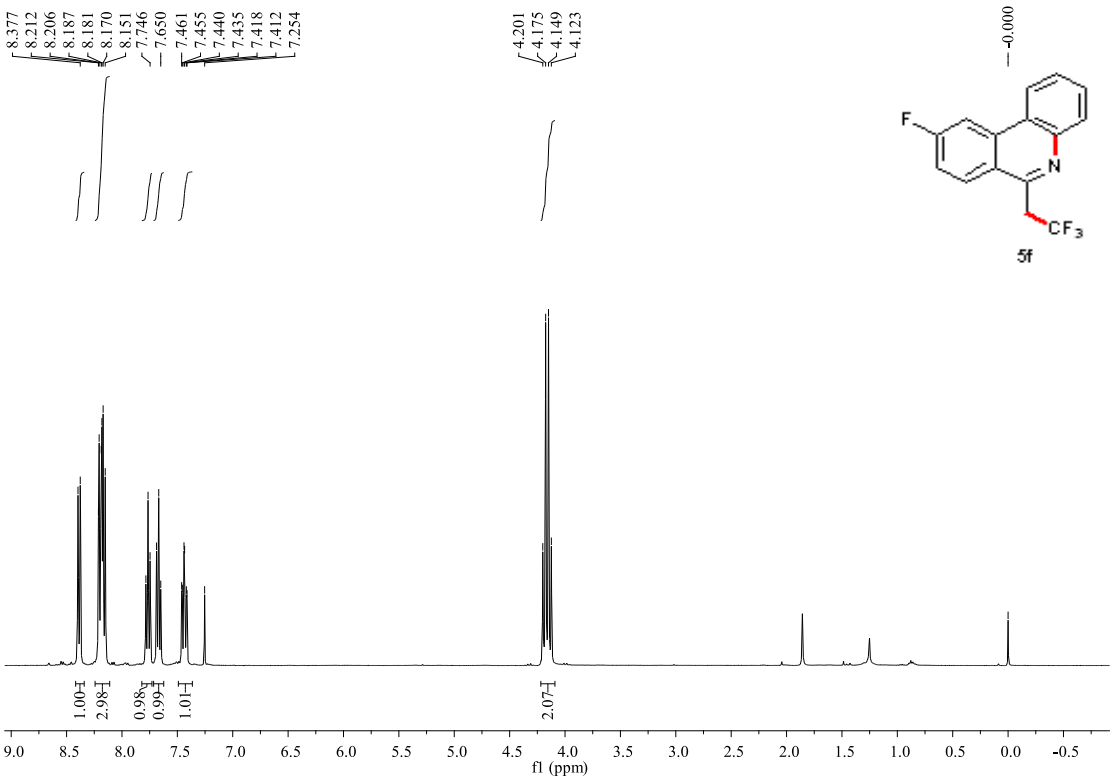
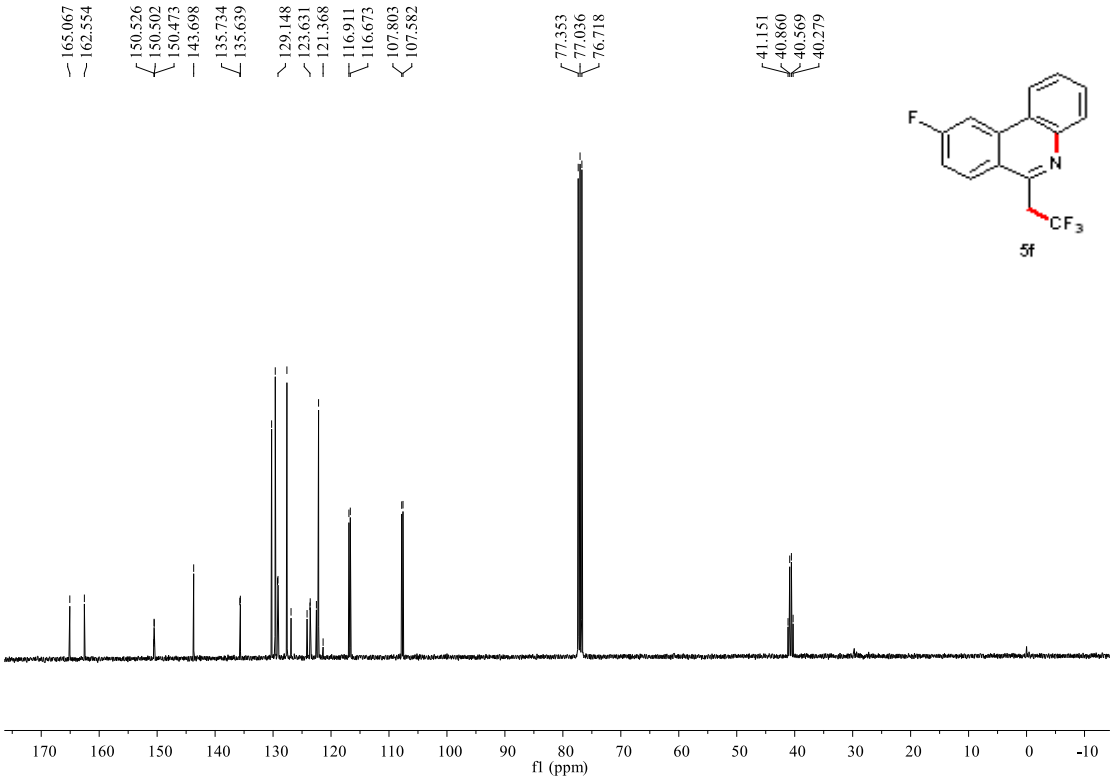
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-62.430
Cl
N
CF3
5e
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)


8.377
8.212
8.206
8.187
8.181
8.170
8.151
7.746
7.650
7.461
7.455
7.440
7.435
7.418
7.412
7.254
4.201
4.175
4.149
4.123
-0.000
F
N
CF3
5f
1.00
2.98
0.98
0.99
1.01
2.07
f1 (ppm)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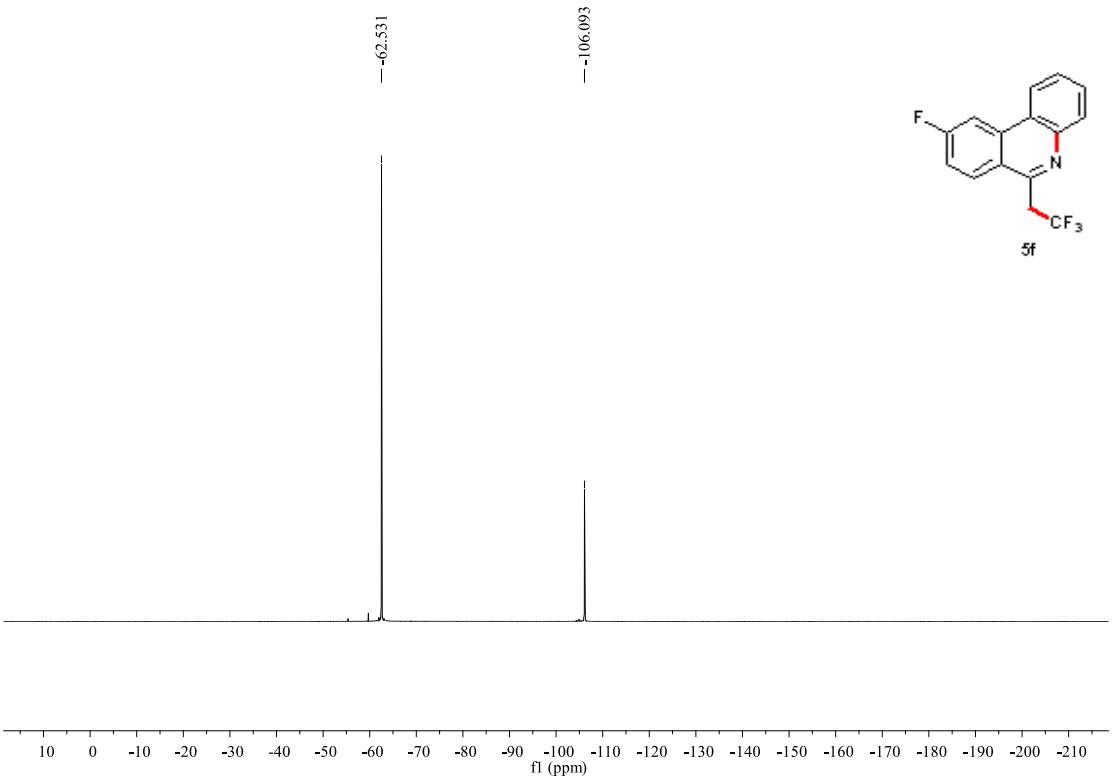
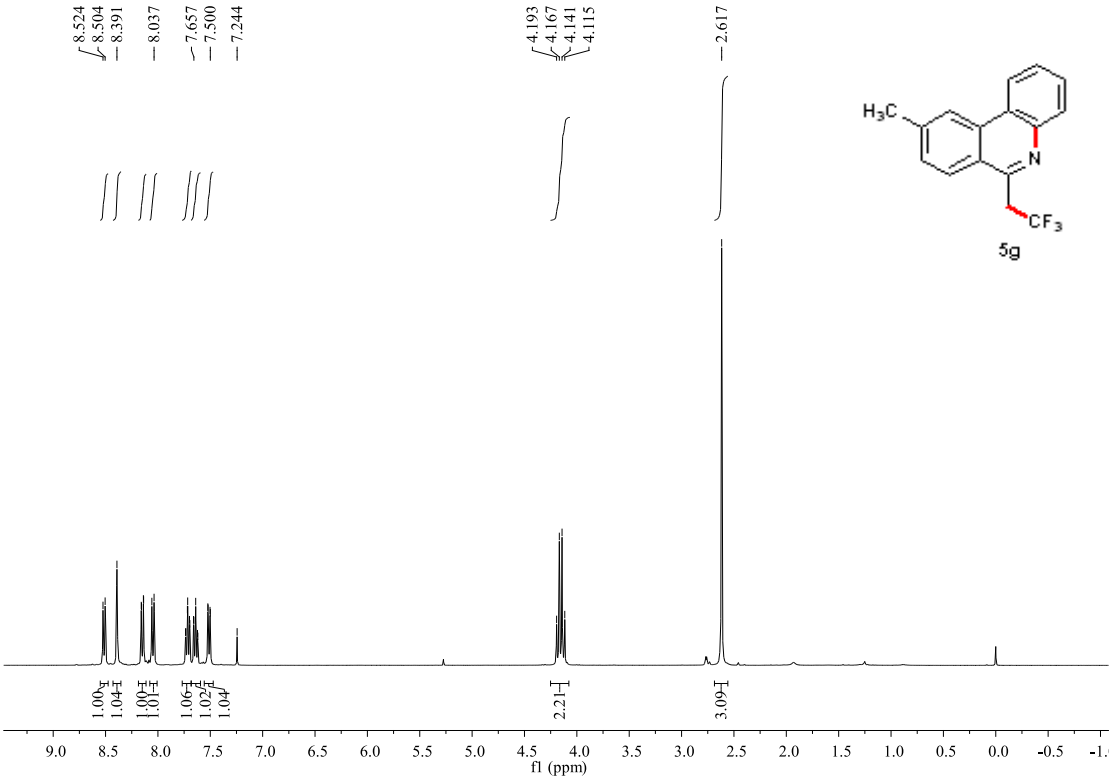
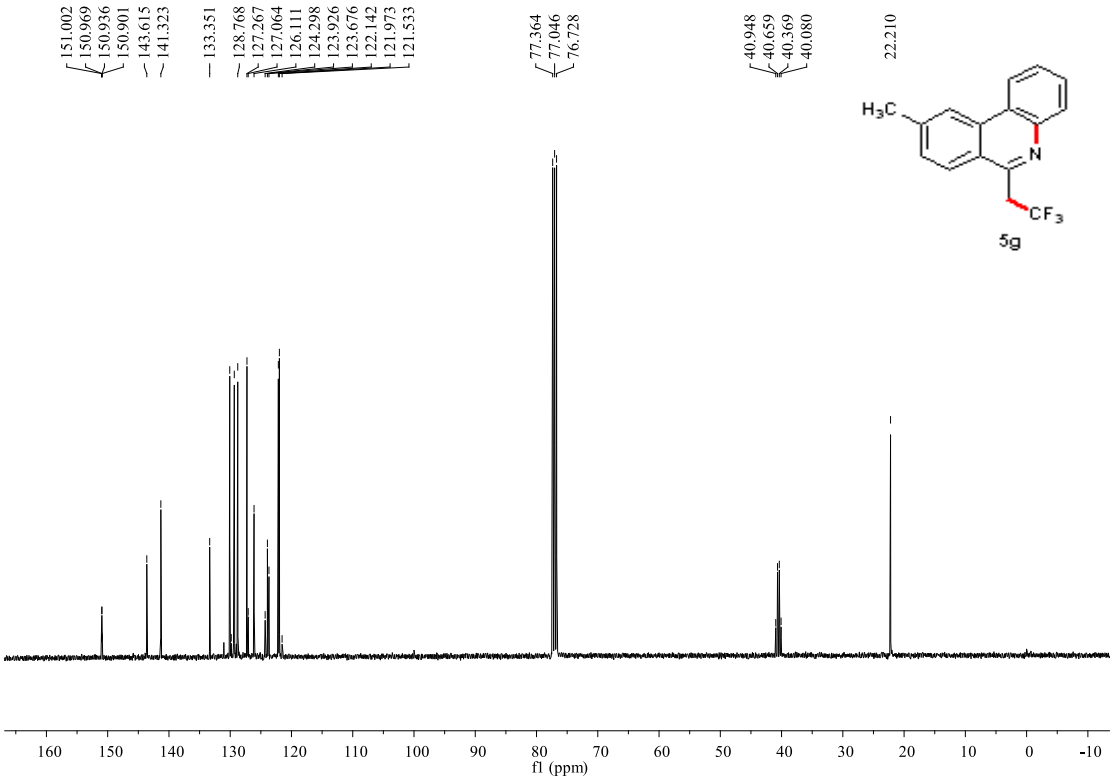
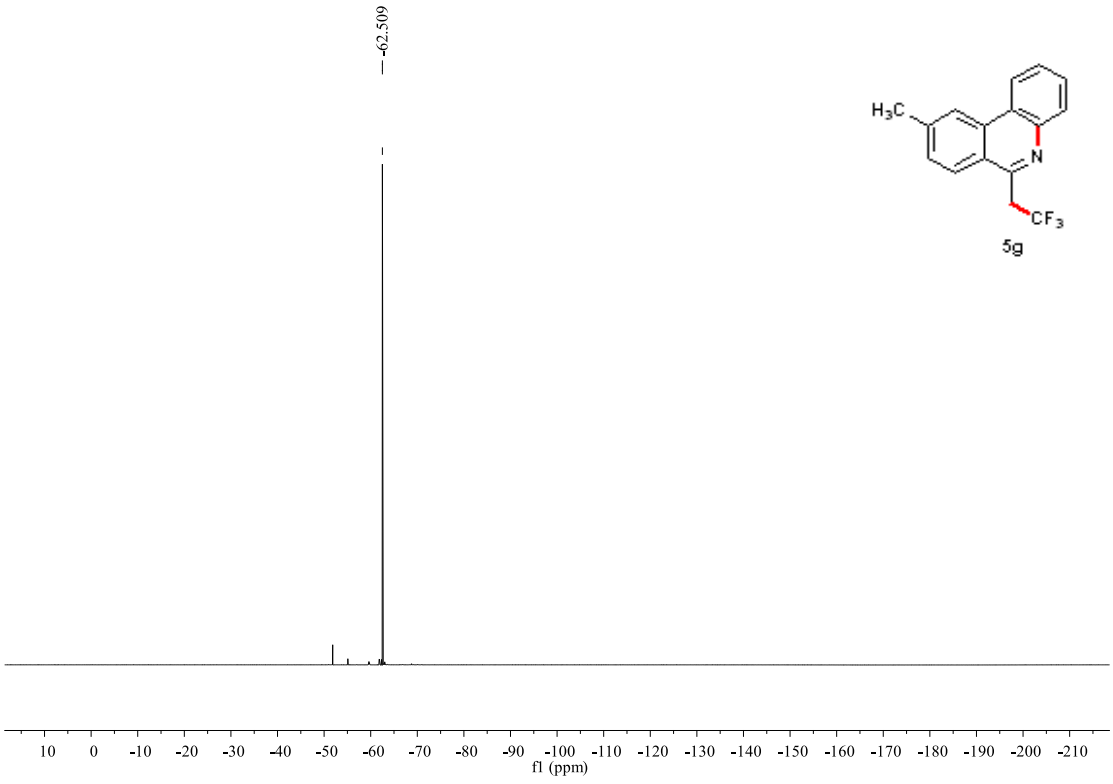
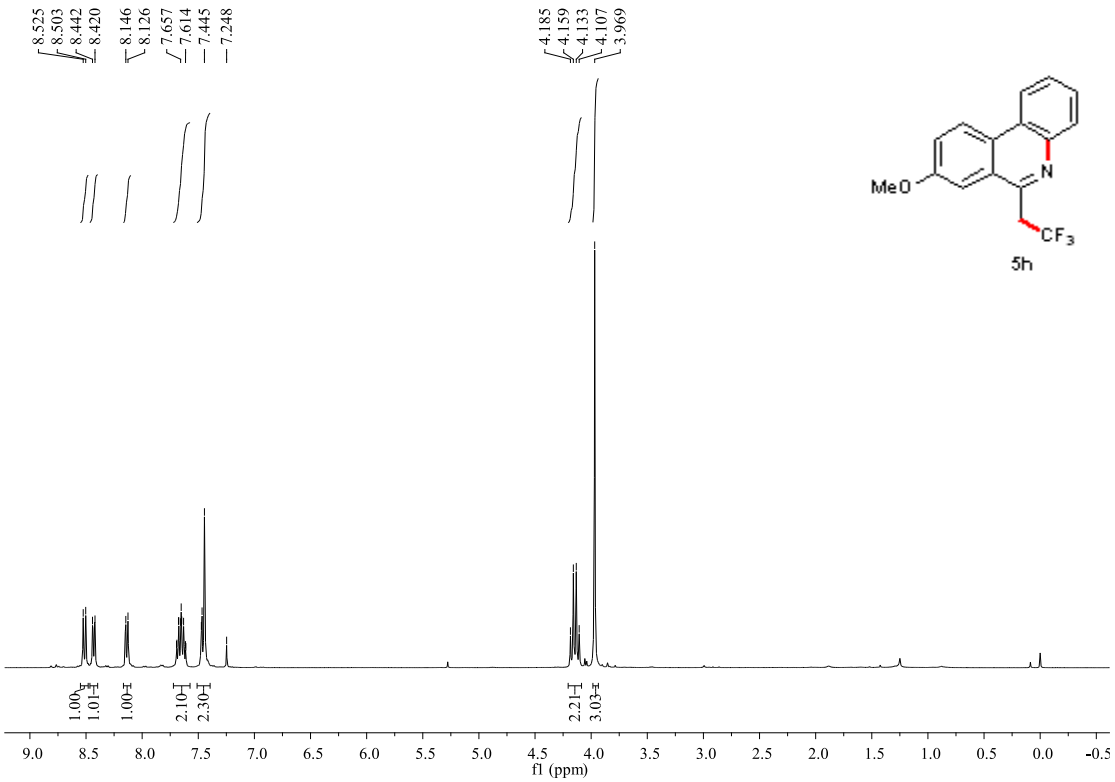
162.554
150.526
150.502
150.473
143.698
135.734
135.639
129.148
123.631
121.368
116.911
116.673
107.803
107.582
77.353
77.036
76.718
41.151
40.860
40.569
40.279
F
N
CF3
5f
f1 (ppm)

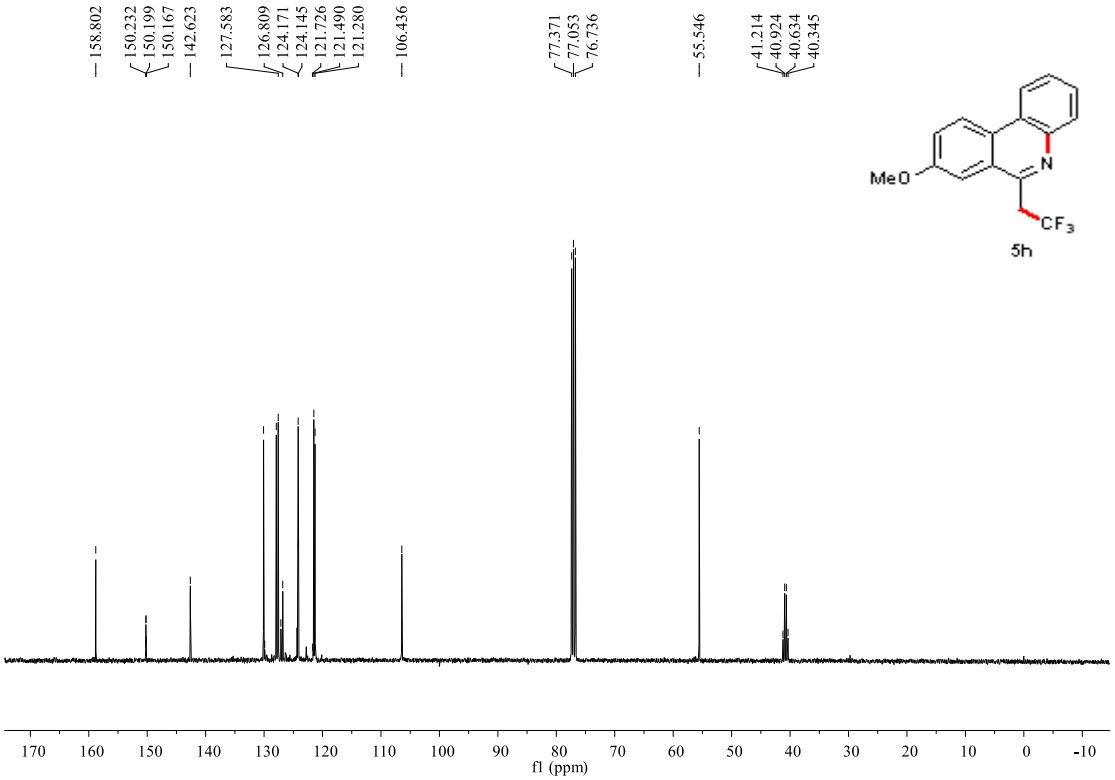

-62.531
-106.093
F
N
CF3
5f
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

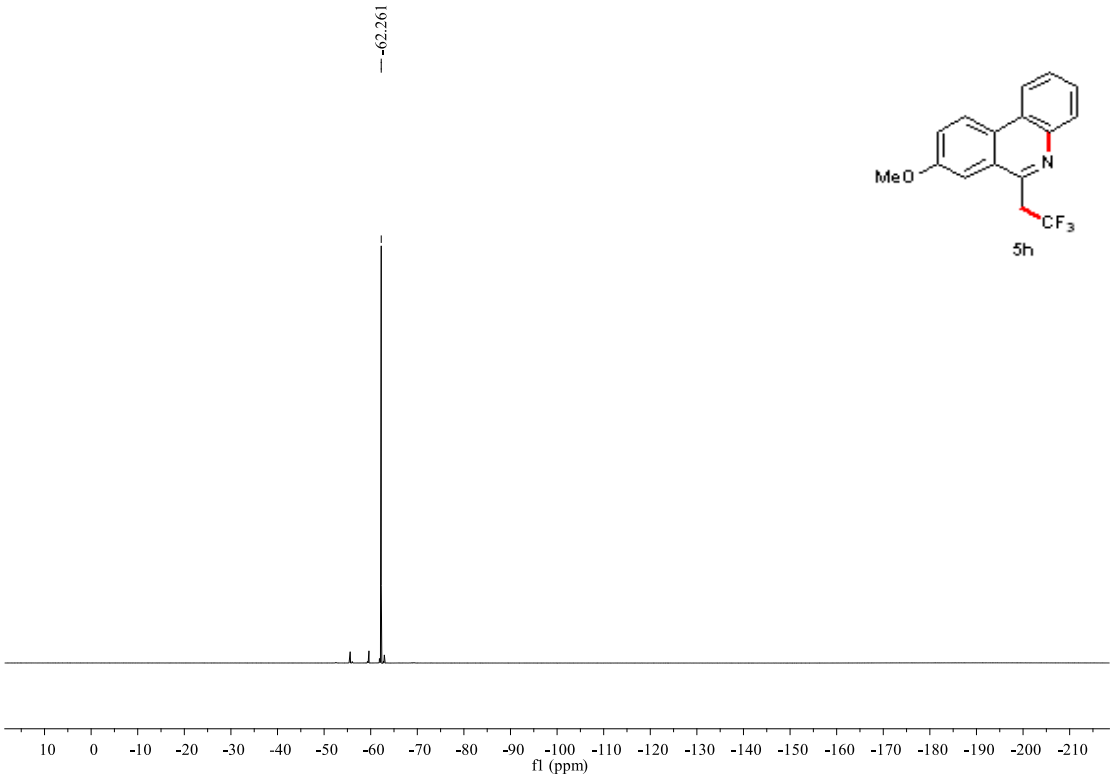

8.524
8.504
8.391
8.037
7.657
7.500
7.244
4.193
4.167
4.141
4.115
2.617
H3C
N
CF3
5g
1.00
1.04
1.00
1.01
1.06
1.02
1.04
2.21
3.09
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


151.002
150.969
150.936
150.901
143.615
141.323
133.351
128.768
127.267
127.064
126.111
124.298
123.926
123.676
122.142
121.973
121.533
77.364
77.046
76.728
40.948
40.659
40.369
40.080
22.210
H3C
N
CF3
5g
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-62.509
H3C
N
CF3
5g
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)


8.525
8.503
8.442
8.420
8.146
8.126
7.657
7.614
7.445
7.248
4.185
4.159
4.133
4.107
3.969
MeO
N
CF3
5h
1.00
1.01
1.00
2.10
2.30
2.21
3.03
fl (ppm)


158.802
150.232
150.199
150.167
142.623
127.583
126.809
124.171
124.145
121.726
121.490
121.280
106.436
77.371
77.053
76.736
55.546
41.214
40.924
40.634
40.345
MeO
N
CF3
5h
fl (ppm)


-62.261
MeO
N
CF3
5h
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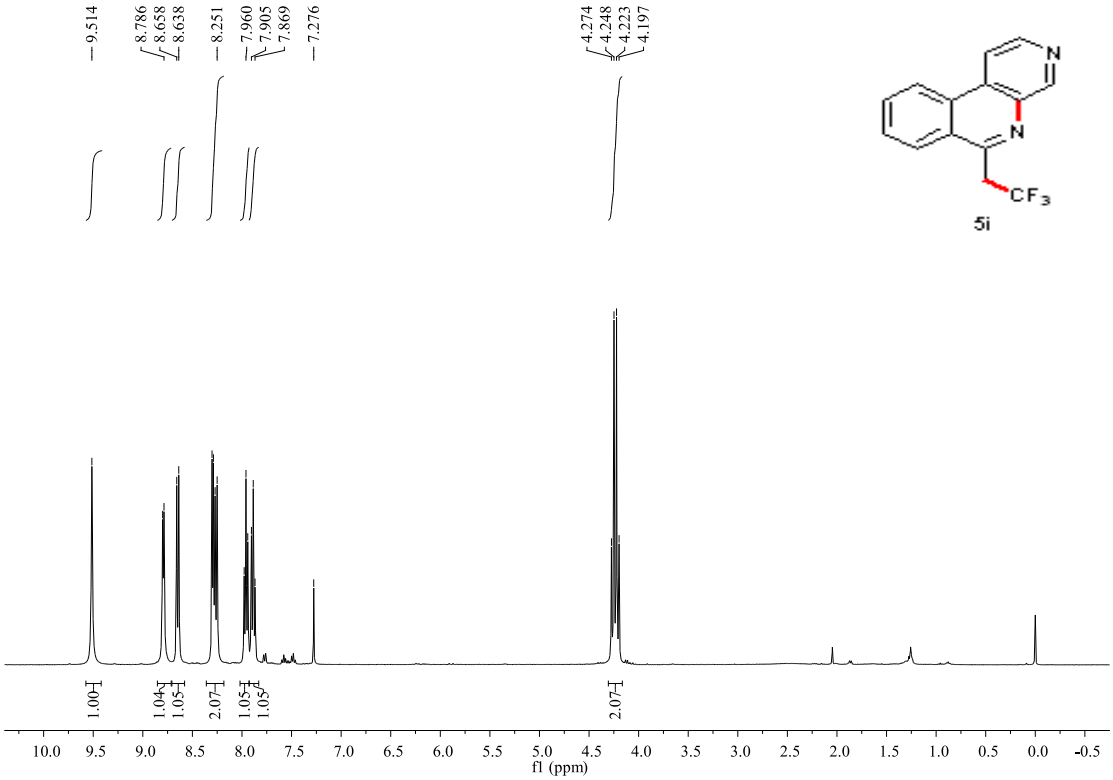
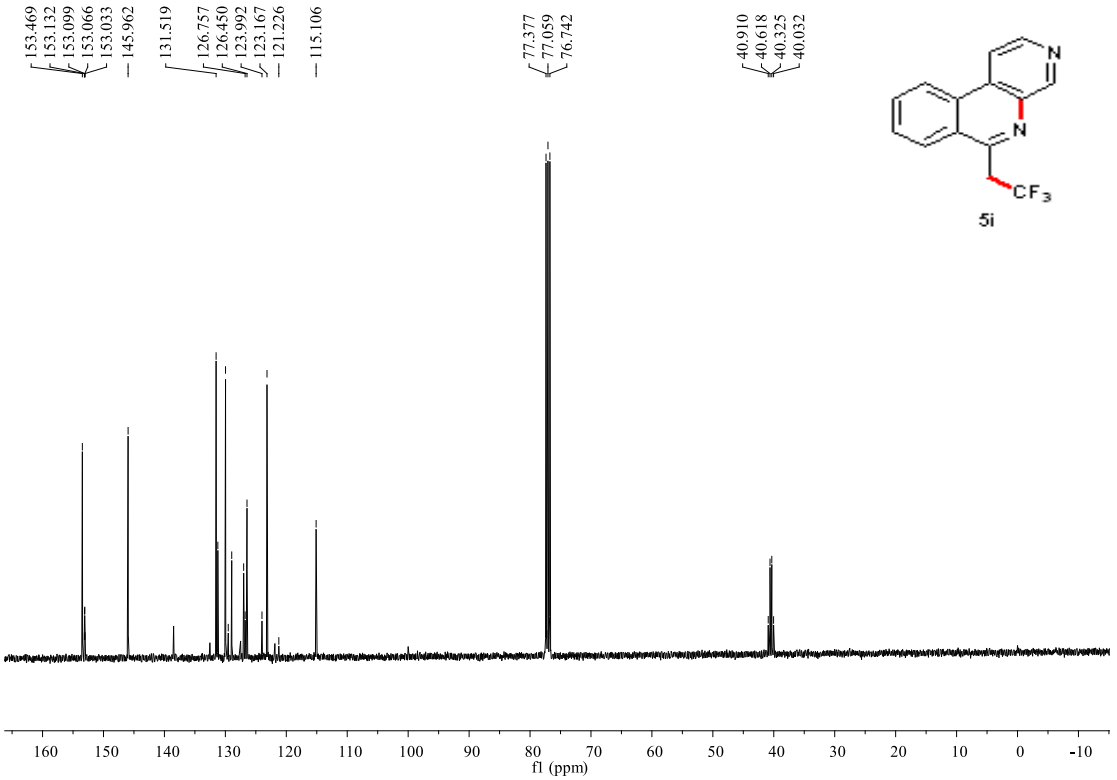
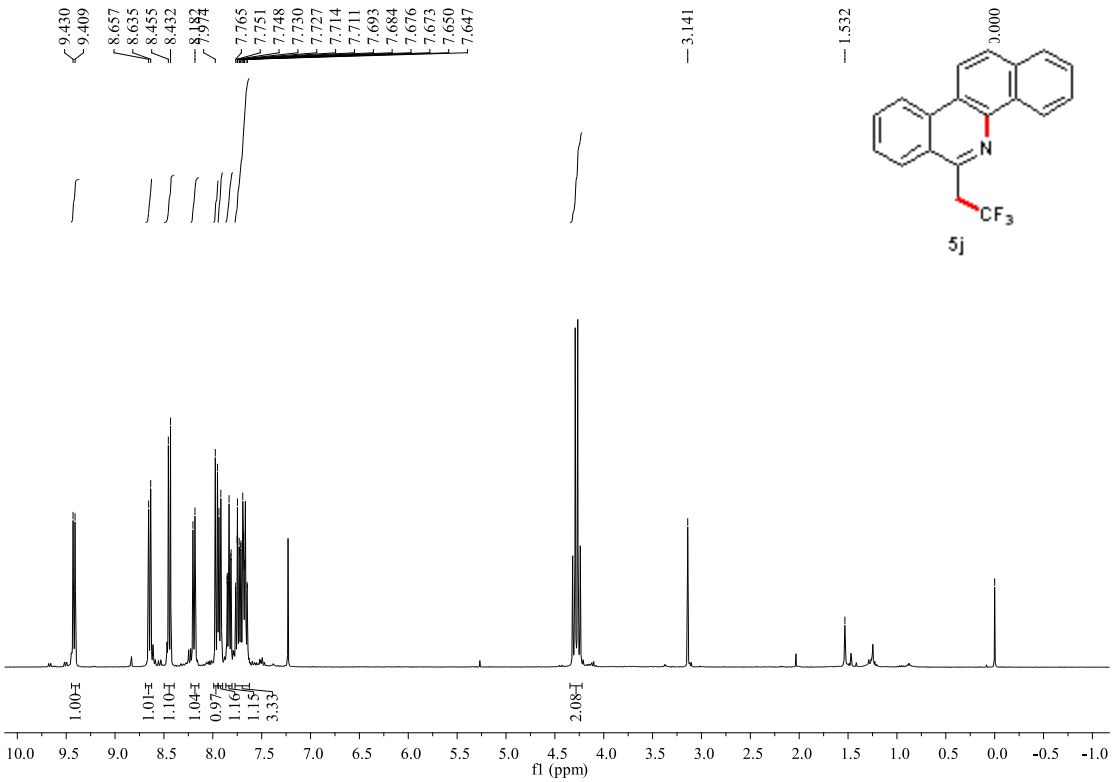
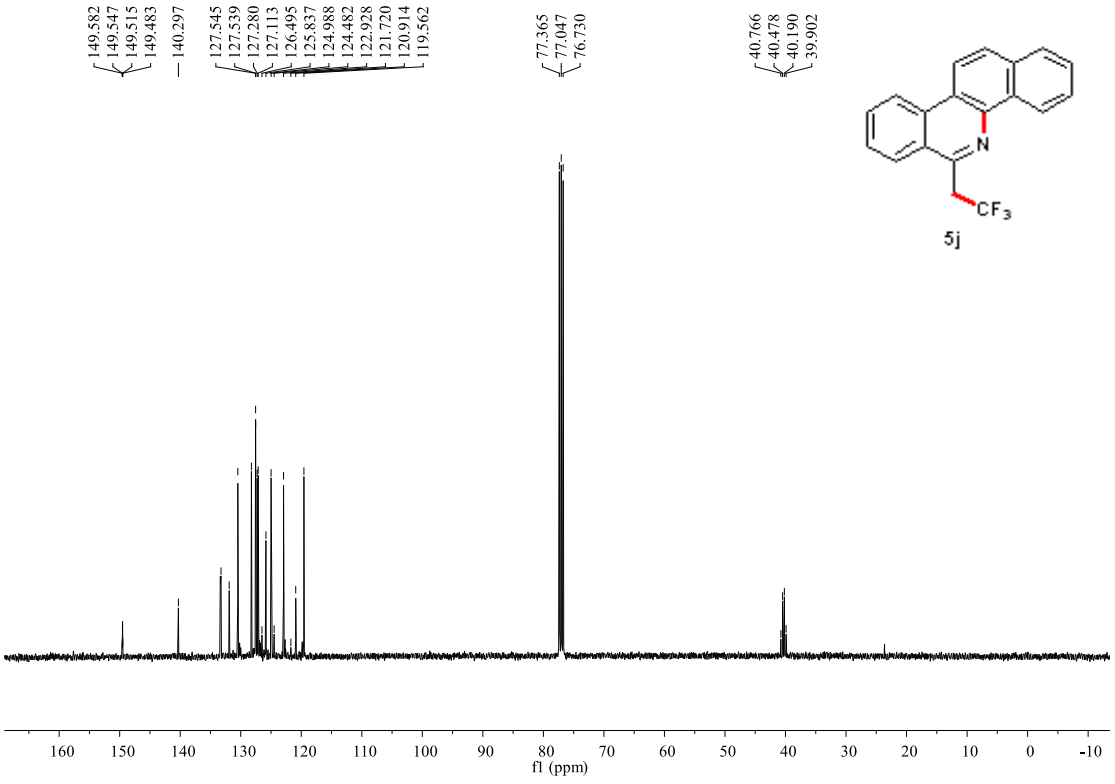
f1 (ppm)

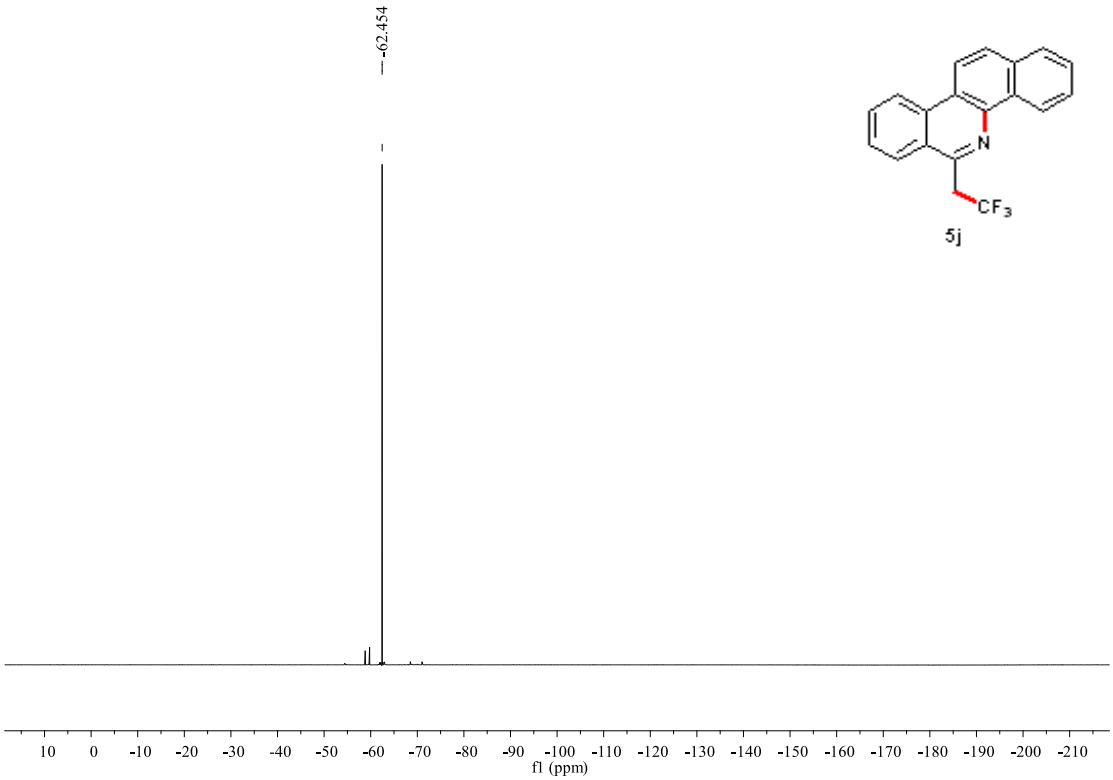

9.514
8.786
8.658
8.638
8.251
7.960
7.905
7.869
7.276
4.274
4.248
4.223
4.197
N
N
CF3
5i
1.00
1.04
1.05
2.07
1.05
1.05
2.07
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

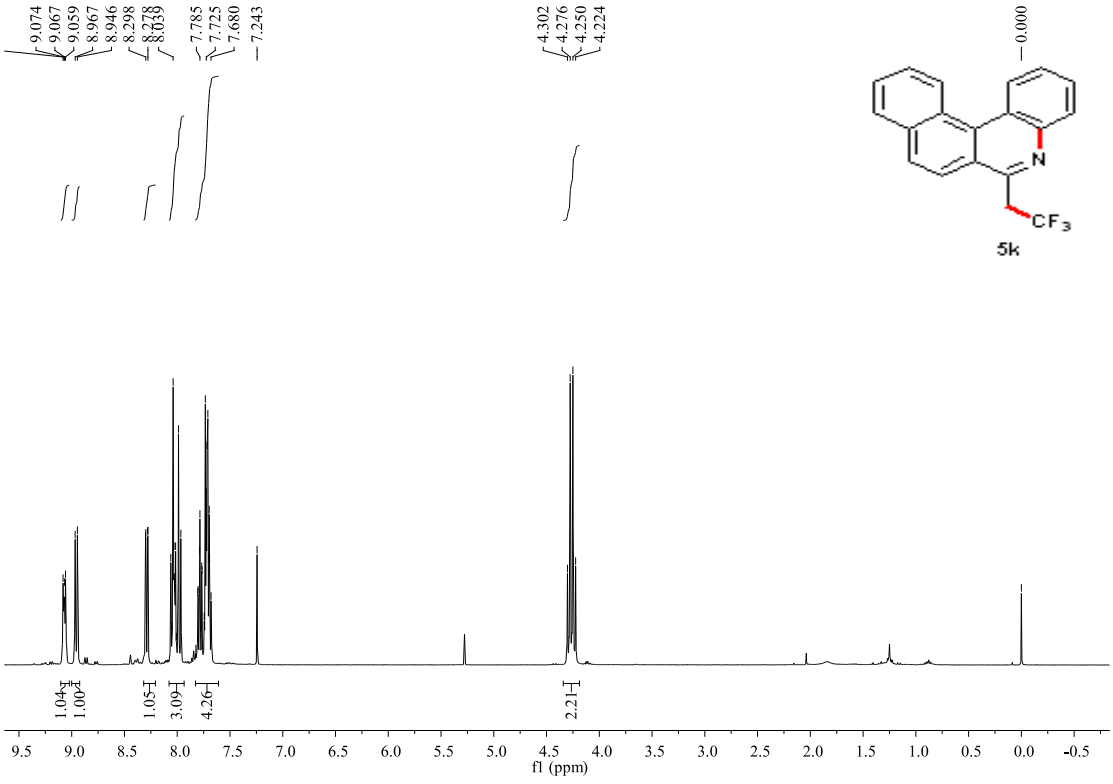

153.469
153.132
153.099
153.066
153.033
145.962
131.519
126.757
126.450
123.992
123.167
121.226
115.106
77.377
77.059
76.742
40.910
40.618
40.325
40.032
N
N
CF3
5i
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

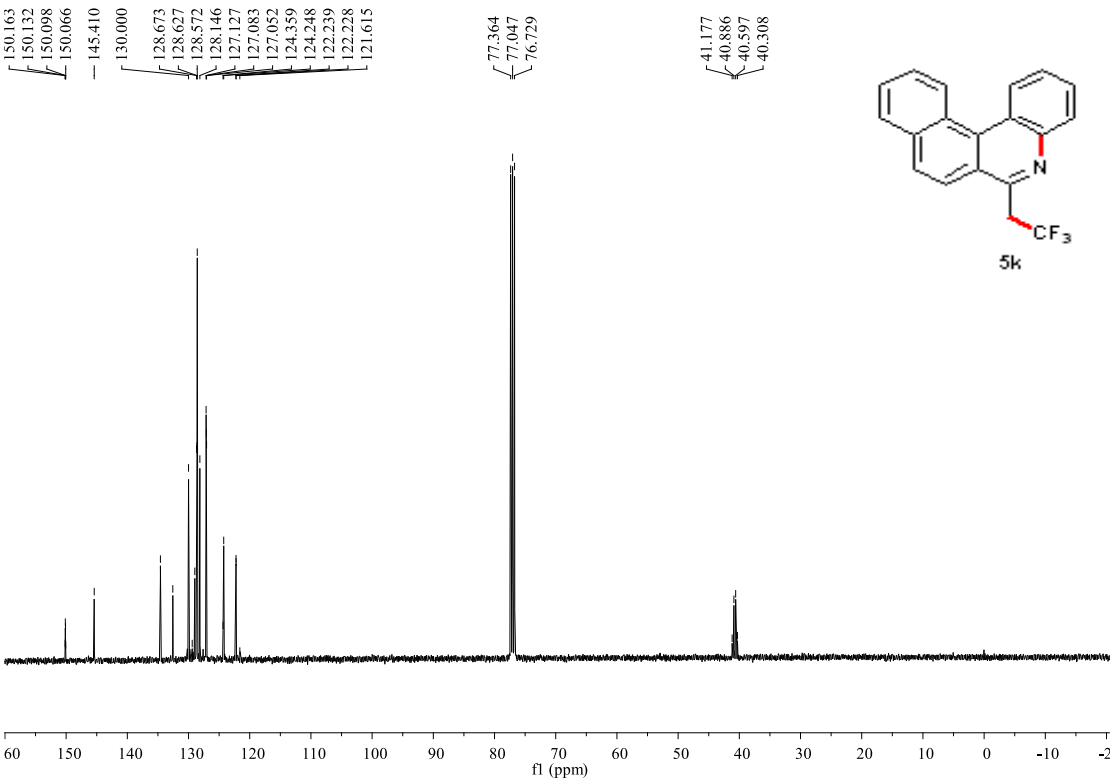

-62.420
N
N
CF3
5i
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)


9.430
9.409
8.657
8.635
8.455
8.432
7.765
7.751
7.748
7.730
7.727
7.714
7.711
7.693
7.684
7.676
7.673
7.650
7.647
3.141
1.532
3.000
N
CF3
5j
1.00
1.01
1.10
1.04
0.97
1.16
1.15
3.33
2.08
f1 (ppm)


149.582
149.547
149.515
149.483
140.297
127.545
127.539
127.280
127.113
126.495
125.837
124.988
124.482
122.928
121.720
120.914
119.562
77.365
77.047
76.730
40.766
40.478
40.190
39.902
N
CF3
5j
f1 (ppm)


-62.454
N
CF3
5j
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)


9.074
9.067
9.059
8.967
8.946
8.298
8.278
8.039
7.785
7.725
7.680
7.243
4.302
4.276
4.250
4.224
0.000
N
CF3
5k
1.04
1.00
1.05
3.09
4.26
2.21
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


150.163
150.132
150.098
150.066
145.410
130.000
128.673
128.627
128.572
128.146
127.127
127.083
127.052
124.359
124.248
122.239
122.228
121.615
77.364
77.047
76.729
41.177
40.886
40.597
40.308
N
CF3
5k
60 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -2
f1 (ppm)


-62.548
N
CF3
5k
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)