Supporting Information

Microwave Promoted Radical Addition/Cyclization of Biaryl Vinyl Ketones with Diacyl Peroxides in Water Under Metal-Free Conditions

Xingyu Yang,[a,b] Gan Zhang,[b] Jingwen Zhou,[b] Chao Zhou,*[b] Lei Wang[c] and Pinhua Li*[a]

[a] College of Chemical and Environmental Engineering, Anhui Polytechnic University, Wuhu, Anhui 241000, P. R. of China. E-mail: pphuali@126.com

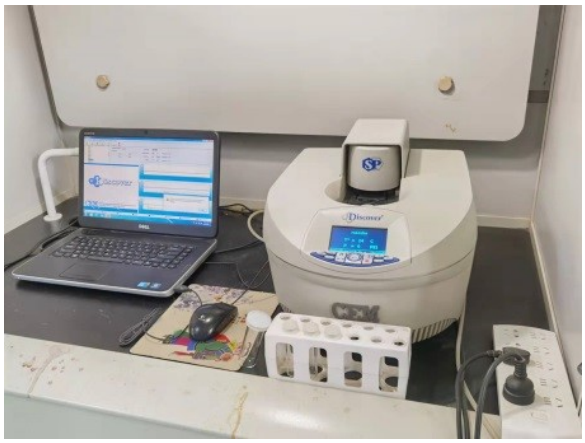
[b] Key Laboratory of Green and Precise Synthetic Chemistry, Ministry of Education, Huaibei Normal University, Huaibei, Anhui 235000, P. R. China; E-mail: zhouch110@163.com

[c] Advanced Research Institute and Department of Chemistry, Taizhou University, Taizhou, Zhejiang 318000, P. R. China.

Table of Contents

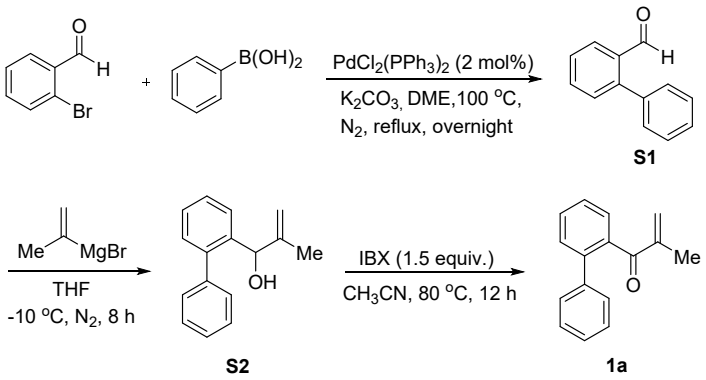
1. General information

All materials were obtained from commercial suppliers or prepared according to standard procedures in literature unless otherwise noted. Analytical thin layer chromatography (TLC) was performed on precoated silica gel 60 F_{254} plates, and compounds were visualized by exposure to UV light. Flash column chromatography was performed with silica gel (300-400 meshes). NMR spectra were recorded on a 600 MHz spectrometer at ambient temperature, and chemical shifts were given in dimensionless δ values and were frequency referenced relative to TMS in ^{1}H, ^{13}C and ^{19}F NMR spectroscopy. The peak patterns are indicated as follows: **s**, singlet; **d**, doublet; **t**, triplet; **q**, quartet; **m**, multiplet; **td**, triplet of doublet; **dd**, doublet of doublet. The coupling constants, *J*, are reported in Hertz (Hz). HRMS data were recorded on a Thermo scientific Q exactive and Agilent technologies 6540 UHD ESI–TOF mass spectrometer. All MW reactions were carried out under microwave irradiation conditions and air atmosphere in a Discover SP (CEM) microwave reactor.



2. Experimental section

2.1 General procedure to prepare 1a



The synthesis of compound S1: Under N_2 atmosphere, a flame-dried 250 mL round-bottom flask was charged with phenylboronic acid (1.2 equiv., 2.60 g, 19.2 mmol), $PdCl_2(PPh_3)_2$ (0.02 equiv., 0.224 g, 0.32 mmol) and K_2CO_3 (2.0 equiv., 4.42 g, 32 mmol) in dry DME (20 mL). And then 2-bromobenzaldehyde (2.96 g, 16 mmol) was added and the mixture was kept for stirring in a preheated oil bath at 100 °C for 12 h. The organic phase was separated and the aqueous phase was extracted with EtOAc (15 mL × 3). The combined organic layers were dried over Na_2SO_4, filtered and evaporated under reduced pressure. The residue was purified by silica gel column chromatography (petroleum ether/ethyl acetate = 50:1) to afford the product **S1** in 91% yield as a white solid.

The synthesis of compound S2: A solution of **S1** (2.7 g, 15.0 mmol) in anhydrous THF (15 mL) was cooled to -10 ℃ under nitrogen atmosphere. Isopropenyl magnesium bromide (15 mL, 15.0 mmol, 1.0 mol/L) was added and the resulting mixture was stirred over 8 h. The reaction mixture was quenched with saturated ammonium chloride (10 mL), followed by extraction with EtOAc (3×15 mL). The combined organic extracts were washed with brine, dried over Na_2SO_4 filtered and concentrated. The residue was purified by silica gel column chromatography (petroleum ether: ethyl acetate = 20:1) to give the product as a yellow oil (72% yield).

The synthesis of compound 1a: To an oven-dried round-bottom flask **S2** (2.24 g, 10.0 mmol), IBX (1.5 equiv., 4.2 g, 15.0 mmol) and CH_3CN (30 mL) were added. The reaction mixture was stirred at 80 ℃ for 12 h. Concentration of the reaction mixture in vacuo followed by silica gel chromatography eluting with petroleum ether: ethyl acetate = 9:1 (V/V) afforded the product **1a** as a white solid (92% yield).

2.2 General procedure to prepare diacyl peroxide

2.2.1 Preparation of aryl diacyl peroxides[1]

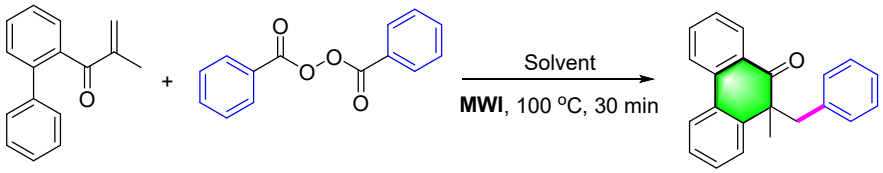
In a round-bottomed flask, the solution of aryl acid chloride (30 mmol) in diethyl ether (7 mL) was cooled to 0 ℃ in an ice-bath. Then, hydrogen peroxide (1.669 g, 35 wt.% in H_2O, 17.2 mmol) was added dropwise over 10 minutes to the cold solution. Then an aqueous solution of NaOH (1.517 g, 37.9 mmol, dissolved in 10 mL of water) was added dropwise over 20 minutes. The resulting white precipitate was collected by filtration. After washing with water (3×5 mL) and diethyl ether (3×5 mL), the solid was crystallized from a cold acetone/water mixture (v/v = 1/3) to give the pure aroyl peroxide.

2.2.2 Preparation of alkyl diacyl peroxides[2]

In a round-bottomed flask, the solution of pyridine (3.16 mL, 40 mmol) in diethyl ether (10 mL) was cooled to -10 ℃ in an ice-bath. Then, hydrogen peroxide (1.25 mL, 35 wt.% in H_2O, 11.0 mmol) was added dropwise over 10 minutes to the cold solution. The acid chloride (20.0 mmol) was added dropwise, maintaining the temperature between -5 and -10 ℃. The mixture was stirred for additional 8 hours at 0 ℃ and then carefully neutralized with a chilled 10% sulfuric acid solution. The reaction mixture was followed by extraction. The aqueous phase was extracted with EtOAc (10 mL × 2). The combined organic layers were dried over Na_2SO_4, filtered and concentrated. The residue was purified by flash chromatography (ethyl acetate/petroleum ether = 1/20~1/15) to afforded the desired product.

2.3 The optimization of reaction conditions

Table S1. Screening solvents[a]

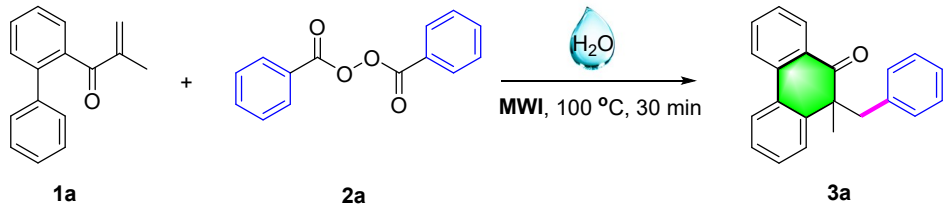


1a **2a** **3a**

Entry	Solvent	Yield **3a** (%)[b]
1	CH_3CN	59
2	Acetone	47
3	DMF	0
4	DCE	30
5	H_2O	83
6[c]	H_2O	trace
7	THF	0
8	1,4-Dioxane	0
9	Toluene	0
10	EtOH	trace

[a]All reactions were carried out with **1a** (0.2 mmol), **2a** (0.3 mmol) and solvent (2 mL) at 100 ℃ under microwave irradiation for 30 min. [b]Isolated yield. [c]In an oil bath for 12 h.

Table S2. Screening the loading of 2a[a]

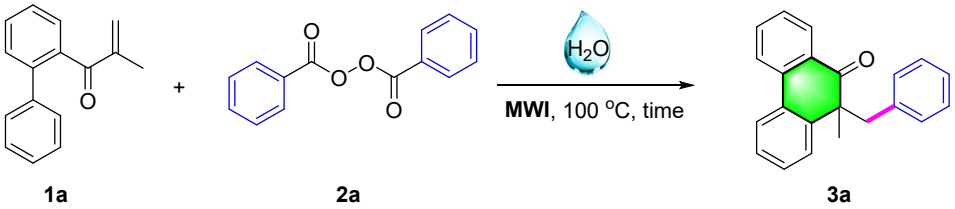


1a 2a 3a

Entry	**2a** (x equiv.)	Yield **3a** (%)[b]
1	1.0	63
2	1.5	83
3	2.0	81
4	2.5	76

[a]All reactions were carried out with **1a** (0.2 mmol), **2a** (x equiv.) and H_2O (2 mL) at 100 °C under microwave irradiation for 30 min. [b]Isolated yield.

Table S3. Screening reaction time[a]

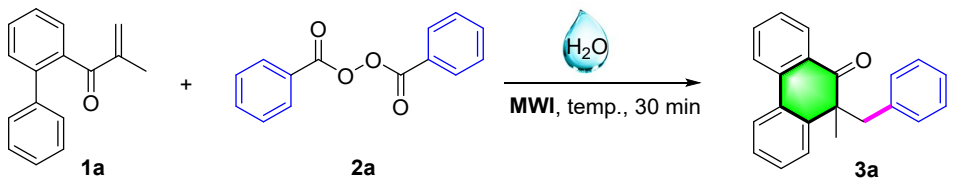


1a 2a 3a

Entry	Time (min)	Yield **3a** (%)[b]
1	25	76
2	30	83
3	35	82
4	60	80

[a]All reactions were carried out with **1a** (0.2 mmol), **2a** (0.3 mmol) and H_2O (2 mL) at 100 °C under microwave irradiation. [b]Isolated yield.

Table S4. Screening reaction temperature[a]



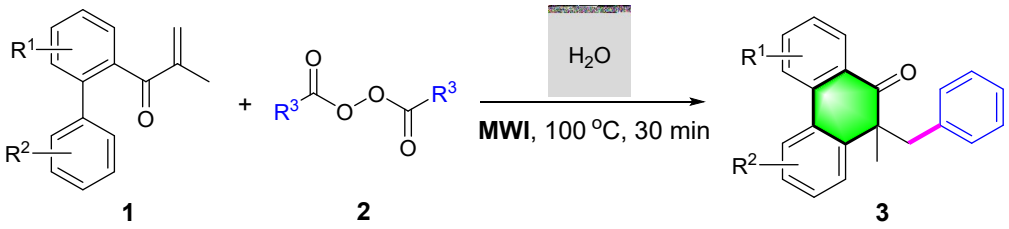
1a 2a 3a

Entry	Temp. (°C)	Yield **3a** (%)[b]

1	50	41
2	70	64
3	90	80
4	100	83
5	120	72

[a]All reactions were carried out with **1a** (0.2 mmol), BPO (0.3 mmol) and H_2O (2 mL) under microwave irradiation for 30 min. [b]Isolated yield.

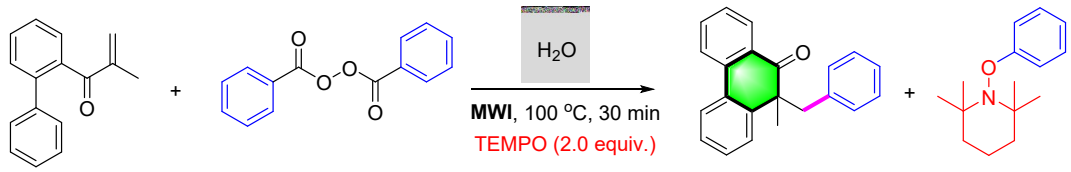
2.4 General procedure for the radical addition/cyclization reaction



A 10 mL oven-dried reaction vessel equipped with a magnetic stirrer bar was charged with biaryl vinyl ketone (**1**, 0.2 mmol), diacyl peroxides (**2**, 0.3 mmol) and H_2O (2 mL). The reaction vessel was placed in a Discover SP (CEM) microwave reactor, and the reaction mixture was irradiated at 150 W and 100 °C for 30 min. The reaction mixture was extracted with EtOAc (10 mL × 2). The combined organic extracts were washed with brine and dried over Na_2SO_4. The organic solvent was removed under reduced pressure and the residue was purified by flash chromatography to give the desire product **3**.

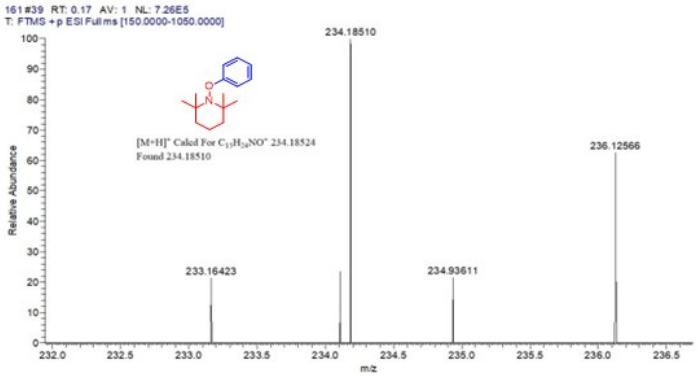
2.5 Mechanistic studies

Radical Trapping experiments (Trapped with TEMPO)

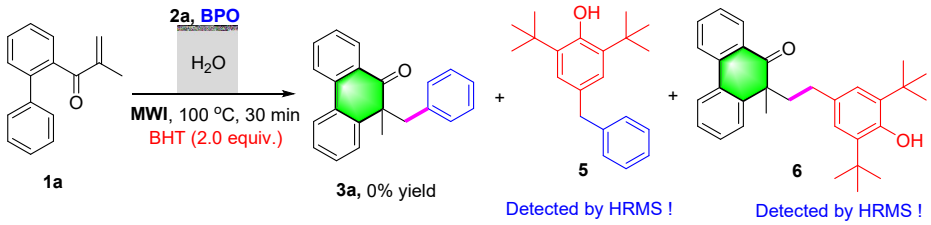


A 10 mL oven-dried reaction vessel equipped with a magnetic stirrer bar was charged with 2-methyl-1-(2-phenylphenyl)prop-2-en-1-one (**1a**, 0.2 mmol), BPO (**2a**, 0.3 mmol), TEMPO (62.5 mg, 0.4 mmol) and H_2O (2 mL). The reaction vessel was placed in a Discover SP (CEM) microwave reactor, and the reaction mixture was

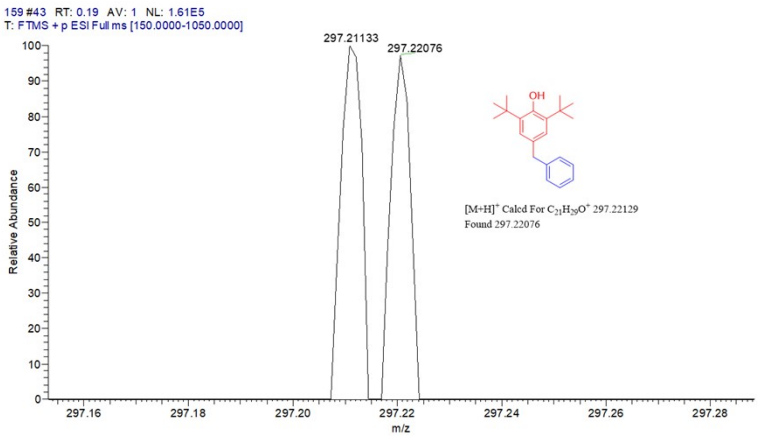
irradiated at 150 W and 100 ℃ for 30 min. In the reaction mixture, no desired product **3a** was detected, while an adduct of TEMPO with a phenyl radical was formed, which was detected by HRMS.

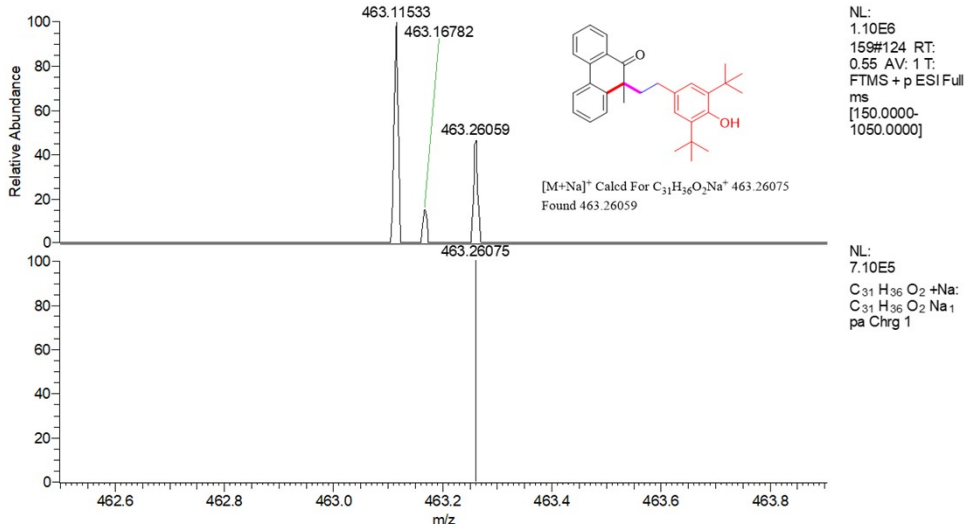


Radical Trapping experiments (Trapped with BHT)

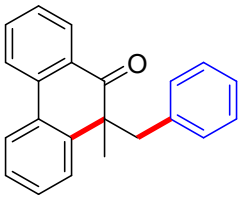


A 10 mL oven-dried reaction vessel equipped with a magnetic stirrer bar was charged with 2-methyl-1-(2-phenylphenyl)prop-2-en-1-one (**1a**, 0.2 mmol), BPO (**2a**, 0.3 mmol), BHT (88.2 mg, 0.4 mmol) and H_2O (2 mL). The reaction vessel was placed in a Discover SP (CEM) microwave reactor, and the reaction mixture was irradiated at 150 W and 100 ℃ for 30 min. After the reaction, no **3a** was detected in the reaction mixture, while **5** and **6** were detected by HPLC/HRMS.

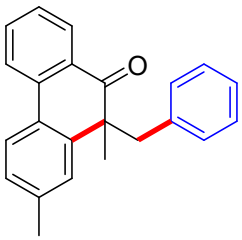




3. Characterization data for the products

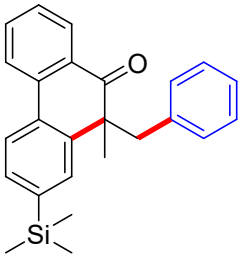


10-Benzyl-10-methylphenanthren-9(10*H*)-one (3a). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3a**. Yellow oil, 48.3 mg, 81% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.06 (d, *J* = 7.7 Hz, 1H), 7.93 (d, *J* = 7.4 Hz, 1H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.61–7.58 (m, 1H), 7.40–7.33 (m, 4H), 7.01–6.99 (m, 1H), 6.98–6.96 (m, 2H), 6.62 (d, *J* = 7.4 Hz, 2H), 3.23 (d, *J* = 13.3 Hz, 1H), 3.01 (d, *J* = 13.3 Hz, 1H), 1.66 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.2, 141.6, 137.0, 136.2, 134.1, 130.0, 129.9, 129.5, 128.6, 128.0, 127.6, 127.5, 127.4, 127.1, 126.3, 123.7, 122.7, 52.4, 49.5, 22.9. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{19}O^+$ 299.1430; Found 299.1429.

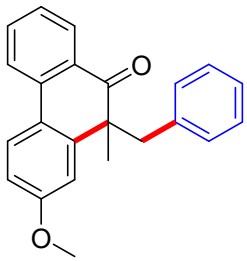


10-Benzyl-2,10-dimethylphenanthren-9(10*H*)-one (3b). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3b**. Yellow oil, 51.9 mg, 83% yield.

^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (d, *J* = 7.7 Hz, 1H), 7.87 (d, *J* = 8.0 Hz, 1H), 7.82 (d, *J* = 8.0 Hz, 1H), 7.57 (t, *J* = 7.6 Hz, 1H), 7.35 (t, *J* = 7.4 Hz, 1H), 7.17 (d, *J* = 8.0 Hz, 1H), 7.12 (s, 1H), 7.03–6.98 (m, 3H), 6.63 (d, *J* = 7.4 Hz, 2H), 3.19 (d, *J* = 13.3 Hz, 1H), 3.00 (d, *J* = 13.3 Hz, 1H), 2.38 (s, 3H), 1.64 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.3, 141.5, 138.5, 137.2, 136.3, 134.1, 130.0, 129.2, 129.0, 128.2, 127.9, 127.5, 127.32, 127.25, 126.3, 123.6, 122.5, 52.3, 49.5, 22.8, 21.4. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O^+$ 313.1587; Found 313.1584.

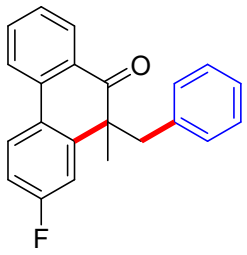


10-Benzyl-10-methyl-2-(trimethylsilyl)phenanthren-9(10*H*)-one (3c). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3c**. Yellow oil, 60.7 mg, 80% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.08 (dd, *J* = 7.74, 1.2 Hz, 1H), 7.94 (d, *J* = 7.92 Hz, 1H), 7.92 (d, *J* = 7.8 Hz, 1H), 7.64–7.61 (m, 1H), 7.48 (dd, *J* = 7.74, 1.02 Hz, 1H), 7.40 (t, *J* = 7.8 Hz, 1H), 7.28 (s, 1H), 7.07–7.04 (m, 1H), 7.01 (t, *J* = 7.56 Hz, 2H), 6.63 (d, *J* = 7.08 Hz, 2H), 3.19 (d, *J* = 13.2 Hz, 1H), 2.98 (d, *J* = 13.2 Hz, 1H), 1.67 (s, 3H), 0.25 (s, 9H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.5, 140.9, 140.0, 137.0, 136.3, 134.1, 132.7, 132.0, 130.20, 130.16, 129.4, 128.1, 127.7, 127.4, 126.3, 122.83, 122.77, 52.4, 48.9, 22.1, −1.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{25}H_{27}OSi^+$ 371.1826; Found 371.1824.

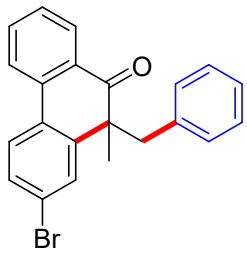


10-Benzyl-2-methoxy-10-methylphenanthren-9(10*H*)-one (3d). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3d**. Yellow oil, 50.5 mg, 77% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.02 (d, *J* = 7.7 Hz, 1H), 7.85 (d, *J* = 8.8 Hz, 1H), 7.79 (d, *J* = 8.0 Hz, 1H), 7.55 (t, *J* = 7.6 Hz, 1H), 7.31 (t, *J* = 7.4 Hz, 1H), 7.03–7.00 (m,

3H), 6.89 (d, J = 8.7 Hz, 1H), 6.78 (s, 1H), 6.65 (d, J = 7.4 Hz, 2H), 3.78 (s, 3H), 3.19 (d, J = 13.3 Hz, 1H), 2.97 (d, J = 13.3 Hz, 1H), 1.62 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.2, 159.8, 143.5, 137.2, 136.2, 134.2, 130.0, 128.6, 127.6, 127.4, 127.0, 126.4, 125.2, 122.9, 122.2, 113.1, 112.7, 55.3, 52.6, 49.4, 22.9. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O_2^+$ 329.1536; Found 329.1537.

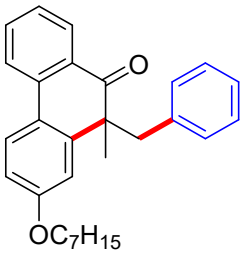


10-Benzyl-2-fluoro-10-methylphenanthren-9(10*H*)-one (3e). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3e**. Yellow oil, 43.6 mg, 69% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.04 (d, J = 7.7 Hz, 1H), 7.90–7.88 (m, 1H), 7.79 (d, J = 8.0 Hz, 1H), 7.58 (t, J = 7.6 Hz, 1H), 7.38–7.36 (m, 1H), 7.07–7.04 (m, 1H), 7.02–6.97 (m, 4H), 6.62 (d, J = 7.5 Hz, 2H), 3.22 (d, J = 13.3 Hz, 1H), 2.96 (d, J = 13.3 Hz, 1H), 1.63 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: −112.5. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.5, 162.9 (d, $J_{C\text{-}F}$ = 247.1 Hz), 144.3 (d, $J_{C\text{-}F}$ = 7.3 Hz), 136.3, 135.7, 134.3, 129.9, 129.0, 127.9, 127.7, 127.5, 126.5, 125.6 (d, $J_{C\text{-}F}$ = 8.6 Hz), 122.6, 114.5, 114.4 (d, $J_{C\text{-}F}$ = 4.2 Hz), 114.3, 52.5, 49.5, 22.9. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}FO^+$ 317.1336; Found 317.1341.

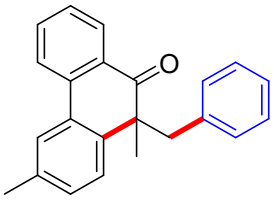


10-Benzyl-2-bromo-10-methylphenanthren-9(10*H*)-one (3f). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3f**. Yellow oil, 62.4 mg, 83% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.04 (d, J = 7.7 Hz, 1H), 7.81 (d, J = 8.0 Hz, 1H), 7.76 (d, J = 8.4 Hz, 1H), 7.58 (t, J = 7.6 Hz, 1H), 7.47 (d, J = 8.5 Hz, 1H), 7.43 (s, 1H), 7.40 (t, J = 7.4 Hz, 1H), 7.03–6.98 (m, 3H), 6.61 (d, J = 7.5 Hz, 2H), 3.19 (d, J = 13.3 Hz, 1H), 2.95 (d, J = 13.3 Hz, 1H), 1.63 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.1,

143.7, 136.1, 135.7, 134.3, 130.6, 130.3, 129.9, 129.3, 129.1, 128.4, 127.7, 127.5, 126.6, 125.2, 122.9, 122.7, 52.4, 49.4, 22.7. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}BrO^+$ 377.0536; Found 377.0531.

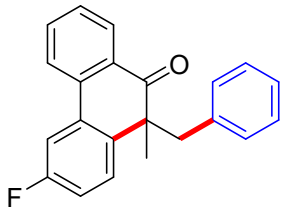


10-benzyl-2-(heptyloxy)-10-methylphenanthren-9(10*H*)-one (3g). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3g**. Colorless oil, 71.0 mg, 83% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.01 (d, *J* = 7.74 Hz, 1H), 7.82 (d, *J* = 8.82 Hz, 1H), 7.77 (d, *J* = 7.98 Hz, 1H), 7.54–7.51 (m, 1H), 7.30–7.27 (m, 1H), 7.02–6.97 (m, 3H), 6.87 (dd, *J* = 8.7, 2.64 Hz, 1H), 6.79 (d, *J* = 2.4 Hz, 1H), 6.65 (d, *J* = 7.02 Hz, 2H), 3.97–3.93 (m, 1H), 3.89–3.86 (m, 1H), 3.18 (d, *J* = 13.26 Hz, 1H), 2.97 (d, *J* = 13.26 Hz, 1H), 1.80–1.75 (m, 2H), 1.62 (s, 3H), 1.48–1.42 (m, 2H), 1.39–1.35 (m, 2H), 1.34–1.30 (m, 4H), 0.91 (t, *J* = 6.42 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.2, 159.5, 143.4, 137.3, 136.2, 134.1, 130.0, 128.6, 127.6, 127.4, 126.9, 126.3, 125.1, 122.7, 122.1, 113.6, 113.2, 68.0, 52.5, 49.5, 31.8, 29.2, 29.0, 26.0, 22.9, 22.6, 14.1. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{29}H_{33}O_2^+$ 413.2475; Found 413.2477.

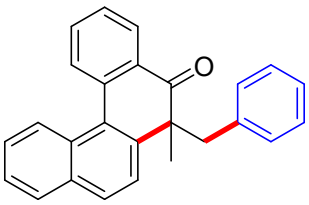


10-Benzyl-3,10-dimethylphenanthren-9(10*H*)-one (3h). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3h**. Yellow oil, 39.4 mg, 63% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (d, *J* = 7.7 Hz, 1H), 7.89 (d, *J* = 8.0 Hz, 1H), 7.73 (s, 1H), 7.57 (t, *J* = 7.5 Hz, 1H), 7.36 (t, *J* = 7.4 Hz, 1H), 7.21 (d, *J* = 8.0 Hz, 1H), 7.14 (d, *J* = 8.0 Hz, 1H), 7.02–6.96 (m, 3H), 6.63 (d, *J* = 7.4 Hz, 2H), 3.20 (d, *J* = 13.3 Hz, 1H), 2.98 (d, *J* = 13.3 Hz, 1H), 2.42 (s, 3H), 1.61 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.5, 138.6, 137.1, 136.6, 136.4, 134.0, 129.9, 129.7, 129.6, 129.5, 127.9, 127.6, 127.44, 127.37, 126.3, 124.3, 122.7, 52.0, 49.4, 23.1, 21.3. HRMS (ESI) m/z: $[M+H]^+$

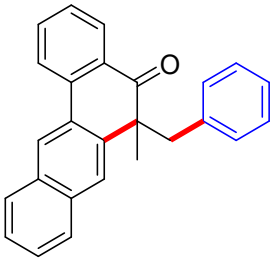
Calcd For $C_{23}H_{21}O^+$ 313.1587; Found 313.1584.



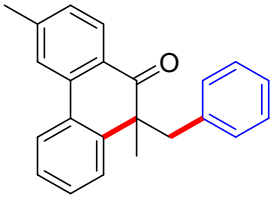
10-Benzyl-3-fluoro-10-methylphenanthren-9(10*H*)-one (3i). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3i**. Colorless oil, 44.3 mg, 70% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.07 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.79 (d, *J* = 7.8 Hz, 1H), 7.62–7.58 (m, 2H), 7.43–7.41 (m, 1H), 7.27–7.25 (m, 1H), 7.03–7.01 (m, 2H), 6.98 (t, *J* = 7.8 Hz, 2H), 6.60 (d, *J* = 7.2 Hz, 2H), 3.22 (d, *J* = 13.2 Hz, 1H), 2.96 (d, *J* = 13.2 Hz, 1H), 1.65 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: –115.4. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.7, 162.0 (d, $J_{C\text{-}F}$ = 243.5 Hz), 137.2 (d, $J_{C\text{-}F}$ = 3.0 Hz), 135.94, 135.90 (d, $J_{C\text{-}F}$ = 2.0 Hz), 134.2, 132.2 (d, $J_{C\text{-}F}$ = 7.3 Hz), 129.9, 129.6, 129.4 (d, $J_{C\text{-}F}$ = 7.8 Hz), 128.7, 127.7, 127.5, 126.4, 122.9, 115.4 (d, $J_{C\text{-}F}$ = 21.0 Hz), 110.2 (d, $J_{C\text{-}F}$ = 22.7 Hz), 52.0, 49.5, 23.1. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}FO^+$ 317.1336; Found 317.1336.



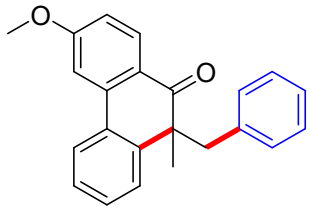
6-Benzyl-6-methylbenzo[c]phenanthren-5(6*H*)-one (3j). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3j**. Colorless oil, 54.3 mg, 78% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.51–8.50 (m, 1H), 7.98 (t, *J* = 8.1 Hz, 2H), 7.89–7.87 (m, 1H), 7.81 (d, *J* = 8.5 Hz, 1H), 7.62 (t, *J* = 7.6 Hz, 1H), 7.52–7.50 (m, 2H), 7.45 (t, *J* = 7.5 Hz, 1H), 7.39 (d, *J* = 8.6 Hz, 1H), 7.04–7.02 (m, 1H), 6.99–6.97 (m, 2H), 6.64 (d, *J* = 7.5 Hz, 2H), 3.11 (d, *J* = 13.4 Hz, 1H), 2.98 (d, *J* = 13.4 Hz, 1H), 1.65 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.9, 137.7, 136.6, 136.1, 133.6, 132.7, 132.1, 129.9, 129.6, 128.90, 128.85, 128.5, 127.7, 127.5, 127.3, 126.5, 126.4, 125.7, 124.3, 53.0, 48.3, 21.0. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{26}H_{21}O^+$ 349.1587; Found 349.1585.



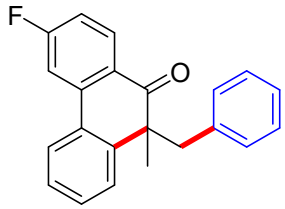
6-Benzyl-6-methyltetraphen-5(6*H*)-one (3k). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3k**. Colorless oil, 43.2 mg, 62% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.72 (d, *J* = 8.8 Hz, 1H), 8.10 (d, *J* = 7.7 Hz, 1H), 8.02 (d, *J* = 8.7 Hz, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.88 (d, *J* = 8.1 Hz, 1H), 7.85 (d, *J* = 8.8 Hz, 1H), 7.64 (d, *J* = 7.1 Hz, 1H), 7.62–7.53 (m, 2H), 7.36 (t, *J* = 7.5 Hz, 1H), 6.79 (t, *J* = 7.3 Hz, 1H), 6.72 (d, *J* = 7.3 Hz, 2H), 6.70 (d, *J* = 7.6 Hz, 2H), 4.09 (d, *J* = 13.3 Hz, 1H), 3.72 (d, *J* = 13.3 Hz, 1H), 2.09 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 203.2, 137.9, 137.7, 136.8, 134.7, 134.4, 131.9, 129.8, 129.2, 128.8, 128.7, 128.5, 127.9, 127.5, 127.2, 126.9, 126.0, 125.8, 125.7, 123.9, 121.4, 53.3, 47.3, 27.2. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{26}H_{21}O^+$ 349.1587; Found 349.1587.



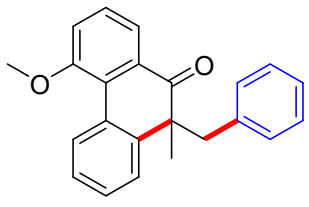
10-Benzyl-6,10-dimethylphenanthren-9(10*H*)-one (3l). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3l**. Yellow oil, 52.4 mg, 84% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 7.96 (d, *J* = 7.9 Hz, 1H), 7.93 (d, *J* = 7.5 Hz, 1H), 7.70 (s, 1H), 7.35–7.33 (m, 1H), 7.31–7.30 (m, 2H), 7.19 (d, *J* = 7.9 Hz, 1H), 7.01–6.99 (m, 1H), 6.89–6.95 (m, 2H), 6.61 (d, *J* = 7.6 Hz, 2H), 3.24 (d, *J* = 13.3 Hz, 1H), 2.99 (d, *J* = 13.3 Hz, 1H), 2.44 (s, 3H) 1.63 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.8, 144.8, 141.9, 137.0, 136.4, 130.0, 129.9, 129.1, 128.5, 127.8, 127.6, 127.4, 127.2, 127.0, 126.2, 123.6, 123.2, 52.2, 49.3, 23.3, 22.1. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O^+$ 313.1587; Found 313.1585.



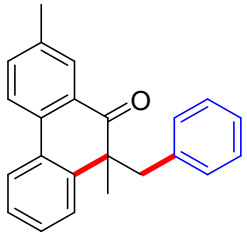
10-Benzyl-6-methoxy-10-methylphenanthren-9(10*H*)-one (3m). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3m**. Yellow oil, 59.0 mg, 90% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 7.84 (t, *J* = 8.6 Hz, 2H), 7.53 (d, *J* = 1.7 Hz, 1H), 7.34–7.28 (m, 3H), 7.16 (dd, *J* = 8.7, 1.68 Hz, 1H), 7.02–6.96 (m, 3H), 6.62 (d, *J* = 7.6 Hz, 2H), 3.90 (s, 3H), 3.25 (d, *J* = 13.3 Hz, 1H), 3.01 (d, *J* = 13.3 Hz, 1H), 1.64 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.2, 159.4, 140.7, 136.3, 130.6, 130.4, 130.0, 129.9, 127.7, 127.5, 127.4, 127.1, 126.3, 124.5, 123.1, 122.3, 109.4, 55.6, 52.4, 49.3, 23.4. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O_2^+$ 329.1536; Found 329.1533.



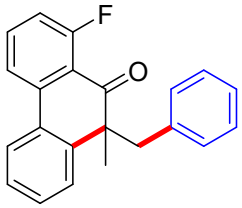
10-Benzyl-6-fluoro-10-methylphenanthren-9(10*H*)-one (3n). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3n**. Yellow oil, 45.6 mg, 72% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.07 (t, *J* = 7.4 Hz, 1H), 7.80 (d, *J* = 7.2 Hz, 1H), 7.49 (d, *J* = 10.6 Hz, 1H), 7.38 (s, 3H), 7.04–6.98 (m, 2H), 6.94 (t, *J* = 7.2 Hz, 2H), 6.56 (d, *J* = 7.6 Hz, 2H), 3.25 (d, *J* = 13.3 Hz, 1H), 2.99 (d, *J* = 13.3 Hz, 1H), 1.67 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: –103.7. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 200.6, 166.8 (d, $J_{C\text{-}F}$ = 252.4 Hz), 142.2, 140.0 (d, $J_{C\text{-}F}$ = 8.8 Hz), 136.0, 130.7 (d, $J_{C\text{-}F}$ = 9.8 Hz), 129.8, 129.3, 129.1 (d, $J_{C\text{-}F}$ = 1.9 Hz), 127.7, 127.4, 127.3, 126.4, 126.2, 123.8, 115.4 (d, $J_{C\text{-}F}$ = 22.4 Hz), 109.2 (d, $J_{C\text{-}F}$ = 23.0 Hz), 52.3, 49.9, 23.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}FO^+$ 317.1336; Found 317.1332.



10-Benzyl-5-methoxy-10-methylphenanthren-9(10*H*)-one (3o). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3o**. Yellow oil, 49.9 mg, 76% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.06 (d, *J* = 8.6 Hz, 1H), 7.88–7.87 (m, 1H), 7.35–7.32 (m, 4H), 6.98 (d, *J* = 7.0 Hz, 1H), 6.95 (t, *J* = 6.9 Hz, 2H), 6.90 (d, *J* = 8.6 Hz, 1H), 6.60 (d, *J* = 7.6 Hz, 2H), 3.92 (s, 3H), 3.28 (d, *J* = 13.3 Hz, 1H), 3.01 (d, *J* = 13.3 Hz, 1H), 1.64 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 200.6, 164.4, 142.3, 139.1, 136.5, 130.2, 129.9, 129.8, 128.7, 127.7, 127.3, 127.0, 126.2, 123.5, 123.3, 114.0, 107.2, 55.5, 51.9, 49.5, 24.0. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O_2^+$ 329.1536; Found 329.1533.

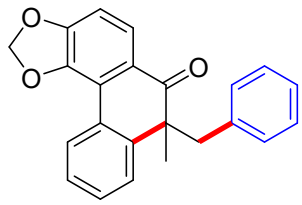


10-Benzyl-7,10-dimethylphenanthren-9(10*H*)-one (3p). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3p**. Yellow oil, 49.4 mg, 79% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 7.91 (d, *J* = 7.7 Hz, 1H), 7.87 (s, 1H), 7.81 (d, *J* = 8.1 Hz, 1H), 7.42 (d, *J* = 8.2 Hz, 1H), 7.35–7.34 (m, 1H), 7.30 (d, *J* = 4.0 Hz, 2H), 7.02–6.97 (m, 3H), 6.63 (d, *J* = 7.5 Hz, 2H), 3.24 (d, *J* = 13.3 Hz, 1H), 3.01 (d, *J* = 13.3 Hz, 1H), 2.42 (s, 3H) 1.63 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.5, 141.3, 138.0, 136.4, 135.1, 134.5, 130.1, 130.0, 129.3, 128.2, 127.7, 127.5, 127.4, 127.1, 126.3, 123.4, 122.8, 52.4, 49.1, 23.1, 21.1. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O^+$ 313.1587; Found 313.1587.

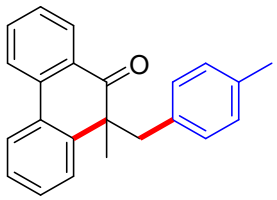


10-Benzyl-6-fluoro-10-methylphenanthren-9(10*H*)-one (3q). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3q**. Yellow oil, 55.0 mg, 87% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 7.88 (d, *J* = 7.7 Hz, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.54 (dd, *J* = 13.0, 7.9 Hz, 1H), 7.3–7.32 (m, 2H), 7.24 (s, 1H), 7.09–7.03 (m, 4H), 6.66 (d, *J*

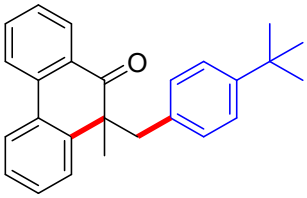
= 7.4 Hz, 2H), 3.06 (d, J = 13.3 Hz, 1H), 2.99 (d, J = 13.3 Hz, 1H), 1.59 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: −114.2. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 200.2, 161.3 (d, $J_{C\text{-}F}$ = 261.1 Hz), 141.3, 139.4, 135.9, 134.65, 134.58, 129.9, 129.2, 127.6, 127.4, 127.2, 126.6, 124.5, 118.84, 118.81, 116.0 (d, $J_{C\text{-}F}$ = 21.7 Hz), 53.5, 49.1, 20.0 HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}FO^+$ 317.1336; Found 317.1335.



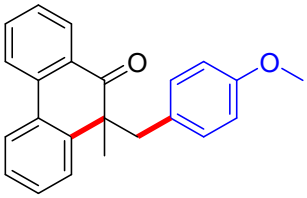
7-Benzyl-7-methylphenanthro[3,4-d][1,3]dioxol-6(7*H*)-one (3r). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3r**. Colorless oil, 49.2 mg, 72% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 7.75–7.74 (m, 1H), 7.50 (s, 1H), 7.36–7.32 (m, 3H), 7.29 (s, 1H), 7.01–6.94 (m, 3H), 6.59 (d, J = 7.5 Hz, 2H), 6.04 (d, J = 6.5 Hz, 2H), 3.28 (d, J = 13.3 Hz, 1H), 3.01 (d, J = 13.3 Hz, 1H), 1.64 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 200.4, 153.1, 147.9, 141.6, 136.4, 134.3, 129.9, 129.8, 128.1, 127.5, 127.4, 127.0, 126.3, 125.1, 123.2, 106.4, 102.3, 101.9, 52.0, 49.7, 24.2. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{19}O_3^+$ 343.1329; Found 343.1324.



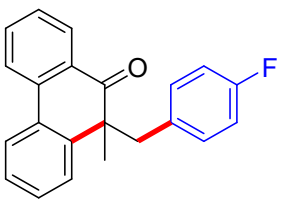
10-Methyl-10-(4-methylbenzyl)phenanthren-9(10*H*)-one (3s). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3s**. Yellow oil, 50.0 mg, 80% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.06 (d, J = 7.7 Hz, 1H), 7.94 (dd, J = 13.8, 7.7 Hz, 2H), 7.62 (t, J = 7.6 Hz, 1H), 7.41–7.31 (m, 4H), 6.81 (d, J = 7.6 Hz, 2H), 6.52 (d, J = 7.6 Hz, 2H), 3.17 (d, J = 13.4 Hz, 1H), 2.96 (d, J = 13.3 Hz, 1H), 2.18 (s, 3H), 1.63 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.3, 141.7, 137.0, 135.8, 134.0, 133.1, 130.0, 129.8, 129.5, 128.6, 128.1, 128.0, 127.6, 127.5, 127.1, 123.7, 122.8, 52.5, 48.9, 22.5, 20.9. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O^+$ 313.1587; Found 313.1584.



10-(4-(tert-butyl)benzyl)-10-methylphenanthren-9(10*H*)-one (3t). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3t**. Colorless oil, 58.8 mg, 83% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.02 (d, *J* = 7.7 Hz, 1H), 7.92 (d, *J* = 7.9 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.56 (t, *J* = 7.5 Hz, 1H), 7.37–7.34 (m, 4H), 6.97 (d, *J* = 7.7 Hz, 2H), 6.52 (d, *J* = 7.8 Hz, 2H), 3.15 (d, *J* = 13.3 Hz, 1H), 2.97 (d, *J* = 13.3 Hz, 1H), 1.66 (s, 3H), 1.17 (s, 9H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.3, 149.1, 141.8, 137.1, 133.9, 133.0, 130.3, 129.8, 129.5, 128.7, 127.9, 127.5, 127.4, 127.1, 124.2, 123.7, 122.7, 52.5, 49.4, 34.2, 31.2, 22.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{26}H_{27}O^+$ 355.2056; Found 355.2053.

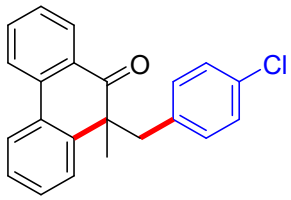


10-(4-methoxybenzyl)-10-methylphenanthren-9(10*H*)-one (3u). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3u**. Colorless oil, 54.6 mg, 78% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.04 (d, *J* = 7.7 Hz, 1H), 7.92 (dd, *J* = 13.8, 7.7 Hz, 2H), 7.60 (t, *J* = 7.6 Hz, 1H), 7.40–7.31 (m, 4H), 6.80 (d, *J* = 7.6 Hz, 2H), 6.52 (d, *J* = 7.6 Hz, 2H), 3.15 (d, *J* = 13.4 Hz, 1H), 2.95 (d, *J* = 13.3 Hz, 1H), 2.17 (s, 3H), 1.62 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.3, 141.7, 137.0, 135.8, 134.0, 133.1, 130.0, 129.8, 129.5, 128.6, 128.1, 128.0, 127.6, 127.5, 127.1, 123.7, 122.8, 52.5, 48.9, 22.5, 20.9. HRMS (ESI) m/z: $[M+Na]^+$ Calcd For $C_{23}H_{20}O_2Na^+$ 351.13555; Found 351.13501.

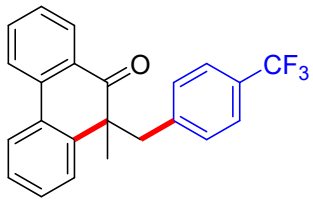


10-(4-fluorobenzyl)-10-methylphenanthren-9(10*H*)-one (3v). Purification by column

chromatography (EtOAc/PE, V/V = 1:50) afforded **3v**. Colorless oil, 51.2 mg, 81% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (d, J = 7.7 Hz, 1H), 7.93–7.92 (m, 1H), 7.88 (d, J = 8.0 Hz, 1H), 7.59 (t, J = 7.6 Hz, 1H), 7.39–7.36 (m, 4H), 6.63 (t, J = 8.3 Hz, 2H), 6.55–6.53 (m, 2H), 3.22 (d, J = 13.3 Hz, 1H), 2.97 (d, J = 13.4 Hz, 1H), 1.65 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: –116.7. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.1, 161.5 (d, $J_{C\text{-}F}$ = 243.0 Hz), 141.4, 140.0, 134.3, 131.9 (d, $J_{C\text{-}F}$ = 3.1 Hz), 131.2 (d, $J_{C\text{-}F}$ = 8.2 Hz), 130.1, 129.4, 128.7, 127.51, 127.49, 127.3, 123.7, 122.8, 114.2, 114.1, 52.3, 48.8, 23.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}FO^+$ 317.1336; Found 317.1330.

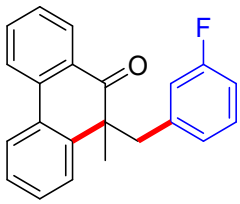


10-(4-chlorobenzyl)-10-methylphenanthren-9(10*H*)-one (3w). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3w**. Colorless oil, 59.2 mg, 89% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.04 (d, J = 7.7 Hz, 1H), 7.94 (d, J = 7.0 Hz, 1H), 7.90 (d, J = 8.0 Hz, 1H), 7.61 (t, J = 7.5 Hz, 1H), 7.40–7.36 (m, 4H), 6.92 (d, J = 7.6 Hz, 2H), 6.53 (d, J = 7.7 Hz, 2H), 3.23 (d, J = 13.4 Hz, 1H), 2.97 (d, J = 13.4 Hz, 1H), 1.65 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.9, 141.2, 137.0, 134.8, 134.3, 132.2, 131.1, 130.0, 129.3, 128.7, 128.1, 127.6, 127.5, 127.4, 127.3, 123.8, 122.8, 52.2, 48.6, 23.5. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}ClO^+$ 333.1041; Found 333.1040.

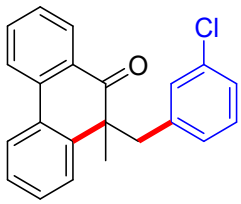


10-methyl-10-(4-(trifluoromethyl)benzyl)phenanthren-9(10*H*)-one (3x). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3x**. Colorless oil, 50.5 mg, 69% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (d, J = 7.7 Hz, 1H), 7.93–7.91 (m, 1H), 7.85 (d, J = 8.0 Hz, 1H), 7.58 (t, J = 7.6 Hz, 1H), 7.38–7.36 (m, 4H), 7.18 (d, J = 7.9 Hz, 2H), 6.69 (d, J = 7.9 Hz, 2H), 3.33 (d, J = 13.3 Hz, 1H), 3.06 (d, J = 13.3 Hz, 1H), 1.67 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: –62.5. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.7, 141.0, 140.4, 136.9, 134.4, 130.1, 130.0, 129.3, 128.8, 128.5 (d, $J_{C\text{-}F}$ = 32.4

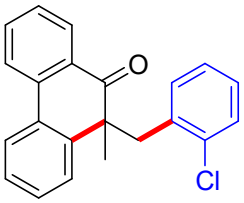
Hz), 128.1, 127.5, 127.4, 127.3, 124.2 (q, $J_{C\text{-}F}$ = 3.5 Hz), 124.1 (q, $J_{C\text{-}F}$ = 270.6 Hz), 123.8, 122.8, 52.1, 48.9, 23.9. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{18}F_3O^+$ 367.1304; Found 367.1307.



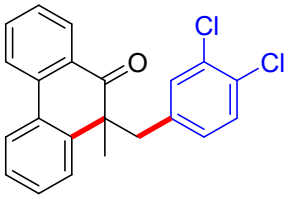
10-(3-fluorobenzyl)-10-methylphenanthren-9(10*H*)-one (3y). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3y**. Colorless oil, 51.8 mg, 82% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.05 (d, *J* = 7.8 Hz, 1H), 7.95–7.93 (m, 1H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.59 (t, *J* = 7.5 Hz, 1H), 7.39–7.36 (m, 4H), 6.91 (dd, J = 14.5, 7.1 Hz, 1H), 6.68 (t, *J* = 8.4 Hz, 1H), 6.40 (d, *J* = 7.6 Hz, 1H), 6.30 (d, *J* = 10.1 Hz, 1H), 3.26 (d, *J* = 13.3 Hz, 1H), 3.00 (d, *J* = 13.3 Hz, 1H), 1.65 (s, 3H). ^{19}F NMR (564 MHz, $CDCl_3$) δ: −114.4. ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.9, 162.0 (d, $J_{C\text{-}F}$ = 243.6 Hz), 141.2, 138.8 (d, $J_{C\text{-}F}$ = 7.5 Hz), 137.0, 134.3, 130.0, 129.4, 128.8, 128.7, 128.1, 127.6, 127.3 (d, $J_{C\text{-}F}$ = 8.6 Hz), 125.6, 125.5, 123.8, 122.8, 116.6 (d, $J_{C\text{-}F}$ = 21.4 Hz), 113.2 (d, *J* = 20.7 Hz), 52.2, 48.9, 23.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}FO^+$ 317.1336; Found 317.1335**.**



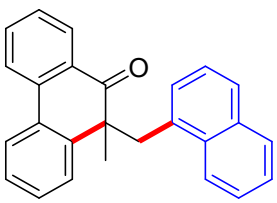
10-(3-chlorobenzyl)-10-methylphenanthren-9(10*H*)-one (3z). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3z**. Yellow oil, 57.1 mg, 86% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.04 (d, *J* = 7.7 Hz, 1H), 7.93 (d, *J* = 7.4 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.59 (t, *J* = 7.5 Hz, 1H), 7.39–7.34 (m, 4H), 6.96 (d, J = 7.9 Hz, 1H), 6.86 (t, *J* = 7.7 Hz, 1H), 6.56 (s, 1H), 6.46 (d, *J* = 7.6 Hz, 1H), 3.20 (d, *J* = 13.3 Hz, 1H), 2.95 (d, *J* = 13.3 Hz, 1H), 1.66 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.8, 141.1, 138.2, 136.9, 134.3, 133.1, 130.1, 129.9, 129.4, 128.8, 128.6, 128.4, 128.1, 128.0, 127.5, 127.4, 126.5, 123.8, 122.7, 52.2, 49.1, 23.2. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}ClO^+$ 333.1041; Found 333.1040.



10-(2-chlorobenzyl)-10-methylphenanthren-9(10*H*)-one (3aa). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3aa**. Yellow oil, 52.5 mg, 79% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.09 (d, *J* = 7.7 Hz, 1H), 7.93 (t, *J* = 8.3 Hz, 2H), 7.62 (t, *J* = 7.5 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 1H), 7.37–7.34 (m, 1H), 7.29–7.28 (m, 2H), 7.13 (d, *J* = 7.8 Hz, 1H), 6.96 (t, *J* = 7.5 Hz, 1H), 6.84 (t, *J* = 7.6 Hz, 1H), 6.43 (d, *J* = 7.7 Hz, 1H), 3.50 (d, *J* = 14.3 Hz, 1H), 3.17 (d, *J* = 14.3 Hz, 1H), 1.67 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.9, 141.2, 137.1, 135.0, 134.3, 134.2, 131.4, 130.1, 129.4, 129.1, 128.9, 128.1, 127.9, 127.6, 127.3, 127.2, 125.8, 123.9, 122.7, 52.0, 43.9, 23.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{18}ClO^+$ 333.1041; Found 333.1043.

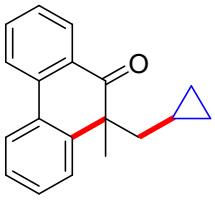


10-(3,4-dichlorobenzyl)-10-methylphenanthren-9(10*H*)-one (3ab). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ab**. Yellow oil, 59.3 mg, 81% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (d, *J* = 7.7 Hz, 1H), 7.95–7.93 (m, 1H), 7.88 (d, J = 8.0 Hz, 1H), 7.61 (t, *J* = 7.7 Hz, 1H), 7.40–7.38 (m, 4H), 6.98 (d, *J* = 8.2 Hz, 1H), 6.65 (s, 1H), 6.40 (d, *J* = 8.2 Hz, 1H), 3.21 (d, *J* = 13.3 Hz, 1H), 2.94 (d, *J* = 13.4 Hz, 1H), 1.65 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 201.6, 140.8, 136.9, 136.5, 134.4, 131.7, 131.3, 130.4, 130.1, 129.3, 129.2, 129.1, 128.9, 128.2, 127.53, 127.51, 127.3, 123.8, 122.8, 52.1, 48.4, 23.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{22}H_{17}Cl_2O^+$ 367.0651; Found 367.0656.

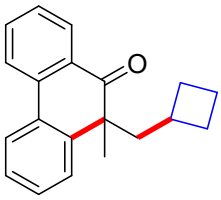


10-methyl-10-(naphthalen-1-ylmethyl)phenanthren-9(10*H*)-one (3ac). Purification

by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ac**. Yellow oil, 41.1 mg, 61% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.06 (d, *J* = 7.7 Hz, 1H), 7.91 (d, *J* = 7.9 Hz, 1H), 7.84 (d, *J* = 8.0 Hz, 1H), 7.65–7.64 (m, 1H), 7.54–7.52 (m, 2H), 7.43 (d, *J* = 8.4 Hz, 1H), 7.37–7.31 (m, 6H), 7.08 (s, 1H), 6.72 (d, *J* = 8.4 Hz, 1H), 3.38 (d, *J* = 13.3 Hz, 1H), 3.15 (d, *J* = 13.3 Hz, 1H), 1.69 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.3, 141.5, 137.0, 134.1, 133.9, 132.8, 132.0, 130.0, 129.5, 128.8, 128.6, 128.4, 128.0, 127.63, 127.58, 127.5, 127.3, 127.2, 126.8, 125.5, 125.3, 123.8, 122.7, 52.6, 49.4, 22.8. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{26}H_{21}O^+$ 349.1587; Found 349.1590.

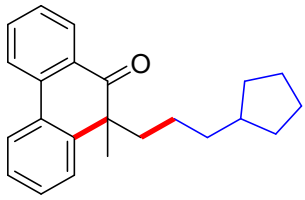


10-(cyclopropylmethyl)-10-methylphenanthren-9(10*H*)-one (3ad). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ad**. Colorless oil, 43.0 mg, 82% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.28 (dd, *J* = 7.8, 1.26 Hz, 1H), 8.21–8.18 (m, 2H), 7.84–7.81 (m, 1H), 7.67–7.66 (m, 1H), 7.60-7.58 (m, 1H), 7.57–7.55 (m, 1H), 7.54–7.52 (m, 1H), 2.02–1.97 (m, 2H), 1.81 (s, 3H), 0.53–0.47 (m, 1H), 0.35–0.30 (m, 1H), 0.25–0.19 (m, 1H), 0.02– -0.02 (m, 1H), -0.05– -0.09 (m, 1H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 203.0, 143.2, 137.2, 134.1, 129.8, 129.7, 128.8, 128.0, 127.6, 127.1, 126.9, 123.6, 122.8, 51.6, 49.3, 23.9, 7.2, 4.8, 4.4. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{19}H_{19}O^+$ 263.1430; Found 263.1431.

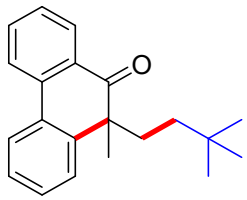


10-(cyclobutylmethyl)-10-methylphenanthren-9(10*H*)-one (3ae). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ae**. Colorless oil, 46.4 mg, 84% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.09 (dd, *J* = 12.54, 7.74 Hz, 1H), 8.03 (d, *J* = 8.04 Hz, 1H), 8.01–7.99 (m, 1H), 7.67–7.64 (m, 1H), 7.46–7.45 (m, 1H), 7.42–7.40 (m, 1H), 7.37–7.33 (m, 2H), 2.14 (q, *J* = 7.08 Hz, 1H), 2.02–1.97 (m, 1H), 1.90 (q, *J* =

6.78 Hz, 1H), 1.58–1.56 (m, 1H), 1.56 (s, 3H), 1.56–1.55 (m, 2H), 1.51–1.47 (m, 1H), 1.43–1.39 (m, 1H), 1.34–1.29 (m, 1H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.7, 143.1, 137.1, 134.2, 129.5, 129.4, 128.8, 128.0, 127.7, 127.2, 126.8, 123.6, 122.8, 51.4, 50.7, 33.2, 29.6, 29.4, 24.7, 18.7. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{20}H_{21}O^+$ 277.1587; Found 277.1588.

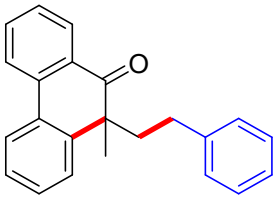


10-(3-cyclopentylpropyl)-10-methylphenanthren-9(10*H*)-one (3af). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3af**. Colorless oil, 45.9 mg, 72% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (dd, *J* = 7.8, 1.26 Hz, 1H), 7.97–7.94 (m, 2H), 7.61–7.58 (m, 1H), 7.39 (dd, *J* = 7.74, 1.5 Hz, 1H), 7.37–7.34 (m, 1H), 7.33–7.28 (m, 2H), 2.06–2.01 (m, 1H), 1.75–1.70 (m, 1H), 1.46 (s, 3H), 1.42–1.39 (m, 2H), 1.33–1.30 (m, 2H), 1.21–1.18 (m, 2H), 1.09–0.98 (m, 2H), 0.96–0.88 (m, 1H), 0.87–0.71 (m, 4H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.8, 143.1, 137.2, 134.2, 129.7, 129.3, 129.0, 128.1, 127.6, 126.84, 126.83, 123.7, 122.8, 51.2, 42.7, 39.6, 36.3, 32.6, 32.5, 25.9, 25.1, 25.0, 24.1. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{23}H_{27}O^+$ 319.2056; Found 319.2058.

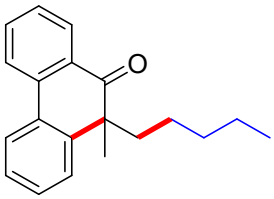


10-(3,3-dimethylbutyl)-10-methylphenanthren-9(10*H*)-one (3ag). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ag**. Colorless oil, 50.3 mg, 86% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.11 (dd, *J* = 7.8, 1.14 Hz, 1H), 8.04–8.01 (m, 2H), 7.67–7.65 (m, 1H), 7.45 (dd, *J* = 7.74, 1.2 Hz, 1H), 7.43–7.38 (m, 2H), 7.38–7.35 (m, 1H), 2.15 (td, *J* = 13.02, 4.56 Hz, 1H), 1.82 (td, *J* = 13.08, 3.9 Hz, 1H), 1.52 (s, 3H), 0.89 (td, *J* = 13.08, 4.56 Hz, 1H), 0.78–0.75 (m, 1H), 0.73 (s, 9H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.7, 143.1, 137.1, 134.2, 129.7, 129.2, 129.0, 128.0,

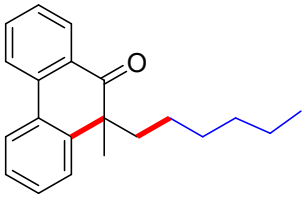
127.6, 126.80, 126.78, 123.7, 122.8, 51.0, 38.5, 37.1, 30.0, 29.0, 26.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{21}H_{25}O^+$ 293.1900; Found 293.1899.



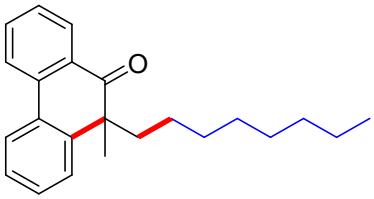
(S)-10-methyl-10-(3-phenylpropyl)phenanthren-9(10*H*)-one (3ah). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ah**. Colorless oil, 54.4 mg, 87% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.15 (dd, *J* = 7.8, 1.2 Hz, 1H), 8.05–8.02 (m, 2H), 7.69–7.66 (m, 1H), 7.45–7.37 (m, 4H), 7.22 (t, J = 1.44 Hz, 2H), 7.15 (t, J = 7.32 Hz, 1H), 7.01 (d, *J* = 7.02 Hz, 2H), 2.54–2.49 (m, 1H), 2.46–2.41 (m, 1H), 2.28–2.23 (m, 1H), 1.93–1.88 (m, 1H), 1.54 (s, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.5, 142.7, 141.8, 137.1, 134.3, 129.6, 129.1, 129.0, 128.2, 128.11, 128.05, 127.6, 126.9, 126.8, 125.6, 123.7, 122.9, 51.0, 41.6, 35.9, 26.6. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{23}H_{21}O^+$ 313.1587; Found 313.1589.



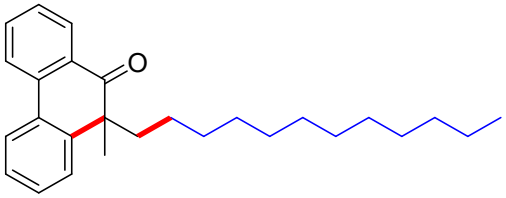
10-methyl-10-pentylphenanthren-9(10*H*)-one (3ai). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ai**. Colorless oil, 44.0 mg, 79% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.11 (d, *J* = 7.74 Hz, 1H), 8.03–8.00 (m, 2H), 7.65 (t, *J* = 7.5 Hz, 1H), 7.45 (dd, *J* = 7.74, 1.44 Hz, 1H), 7.41 (t, *J* = 7.68 Hz, 1H), 7.38 (td, *J* = 14.76, 2.4 Hz, 1H), 7.36–7.33 (m, 1H), 2.11 (td, *J* = 12.42, 4.68 Hz, 1H), 1.79 (td, *J* = 12.62, 4.5 Hz, 1H), 1.53 (s, 3H), 1.13–1.04 (m, 4H), 0.99–0.95 (m, 1H), 0.93–0.88 (m, 1H), 0.73 (t, *J* = 6.9 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.7, 143.0, 137.1, 134.2, 129.6, 129.3, 129.0, 128.0, 127.6, 126.82, 126.78, 123.7, 122.8, 51.1, 42.5, 32.0, 25.9, 24.6, 22.2, 13.9. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{20}H_{23}O^+$ 279.1743; Found 279.1743.



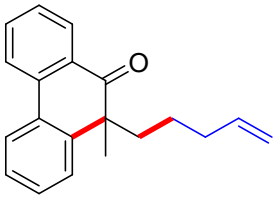
10-hexyl-10-methylphenanthren-9(10*H*)-one (3aj). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3aj**. Colorless oil, 48.5 mg, 83% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (dd, *J* = 7.74, 1.2 Hz, 1H), 7.97–7.94 (m, 2H), 7.61–7.58 (m, 1H), 7.39 (dd, *J* = 7.74, 1.44 Hz, 1H), 7.36–7.34 (m, 1H), 7.33–7.28 (m, 2H), 2.06–2.01 (m, 1H), 1.75–1.70 (m, 1H), 1.46 (s, 3H), 1.08–1.03 (m, 3H), 1.02–0.98 (m, 3H), 0.93–0.87 (m, 1H), 0.83–0.80 (m, 1H), 0.70 (t, *J* = 7.08 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.8, 143.1, 137.2, 134.2, 129.7, 129.3, 129.0, 128.1, 127.6, 126.9, 126.8, 123.7, 122.8, 51.2, 42.6, 31.4, 29.5, 26.0, 24.9, 22.5, 13.9. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{21}H_{25}O^+$ 293.1900; Found 293.1900.



10-methyl-10-octylphenanthren-9(10*H*)-one (3ak). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3ak**. Colorless oil, 52.6 mg, 82% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.03 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.95–7.92 (m, 2H), 7.56–7.22 (m, 1H), 7.37 (dd, *J* = 7.74, 1.38 Hz, 1H), 7.34–7.31 (m, 1H), 7.30 (td, *J* = 7.26, 1.38 Hz, 1H), 7.27 (td, *J* = 7.68, 1.62 Hz, 1H), 2.05–2.00 (m, 1H), 1.73–1.68 (m, 1H), 1.45 (s, 3H), 1.13–1.10 (m, 2H), 1.04–1.00 (m, 8H), 0.90–0.85 (m, 1H), 0.83–0.78 (m, 1H), 0.73 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.7, 143.0, 137.1, 134.2, 129.6, 129.3, 128.9, 128.0, 127.6, 126.84, 126.79, 123.7, 122.8, 51.1, 42.6, 31.7, 29.8, 29.11, 29.08, 25.9, 24.9, 22.5, 14.0. HRMS (ESI)m/z: $[M+H]^+$ Calcd For $C_{23}H_{29}O^+$ 321.2213; Found 321.2213.



10-dodecyl-10-methylphenanthren-9(10*H*)-one (3al). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3al**. Colorless oil, 63.2 mg, 84% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.11 (dd, *J* = 7.7, 1.2 Hz, 1H), 8.02–7.99 (m, 2H), 7.65–7.63 (m, 1H), 7.46–7.44 (m, 1H), 7.42–7.39 (m, 1H), 7.39–7.33 (m, 2H), 2.13–2.08 (m, 1H), 1.82–1.77 (m, 1H), 1.53 (s, 3H), 1.28–1.08 (m, 20H), 0.87–0.85 (m, 3H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.6, 143.0, 137.1, 134.2, 129.6, 129.3, 128.9, 128.0, 127.6, 126.83, 126.78, 123.6, 122.8, 51.1, 42.6, 31.9, 29.8, 29.54, 29.48, 29.4, 29.3, 29.2, 25.9, 24.9, 22.6, 14.1. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{27}H_{37}O^+$ 377.28389; Found 377.28378.



10-methyl-10-(pent-4-en-1-yl)phenanthren-9(10*H*)-one (3am). Purification by column chromatography (EtOAc/PE, V/V = 1:50) afforded **3am**. Colorless oil, 33.2 mg, 60% yield. ^{1}H NMR (600 MHz, $CDCl_3$) δ: 8.11 (dd, *J* = 7.8, 1.26 Hz, 1H), 8.04–8.01 (m, 2H), 7.68–7.65 (m, 1H), 7.46 (dd, *J* = 7.8, 1.5 Hz, 1H), 7.43–7.41 (m, 1H), 7.40–7.38 (m, 1H), 7.37–7.35 (m, 1H), 5.64–5.57 (m, 1H), 4.87–4.83 (m, 2H), 2.17–2.12 (m, 1H), 1.90–1.85 (m, 2H), 1.84–1.80 (m, 1H), 1.53 (s, 3H), 1.12–1.06 (m, 1H), 1.04–0.96 (m, 1H). ^{13}C NMR (150 MHz, $CDCl_3$) δ: 202.3, 149.1, 141.8, 137.1, 133.9, 133.0, 129.5, 128.7, 127.9, 127.5, 127.4, 127.1, 124.2, 123.7, 122.7, 52.5, 49.4, 34.2, 31.2, 22.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd For $C_{20}H_{21}O^+$ 277.1587; Found 277.1591.

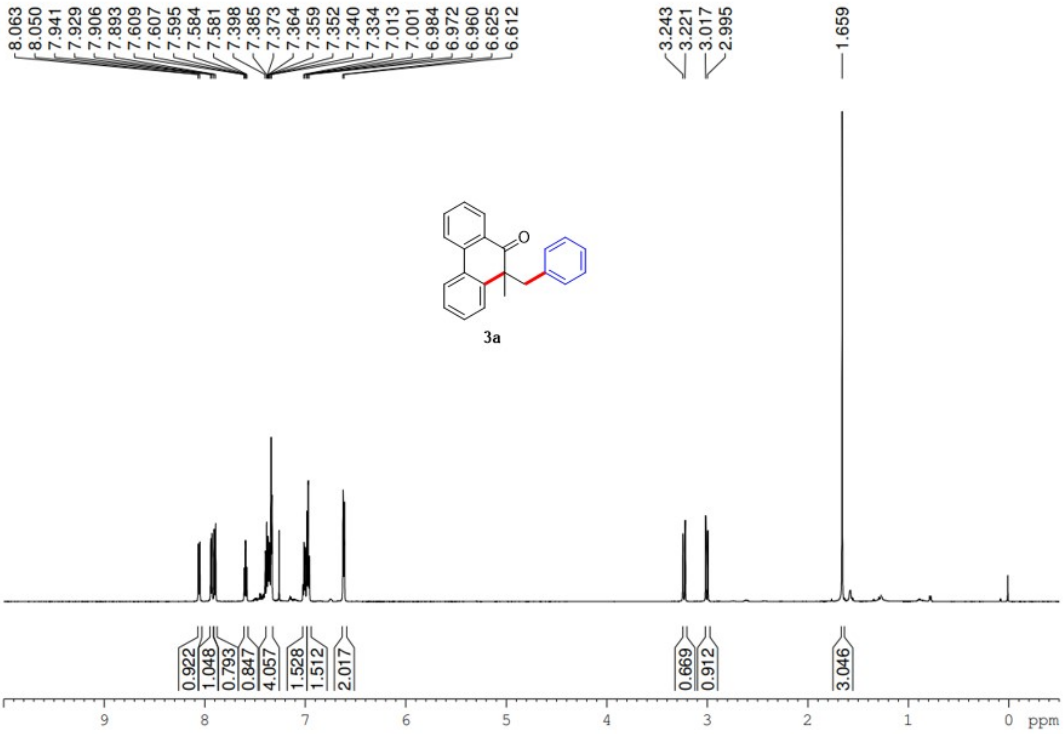
4. References

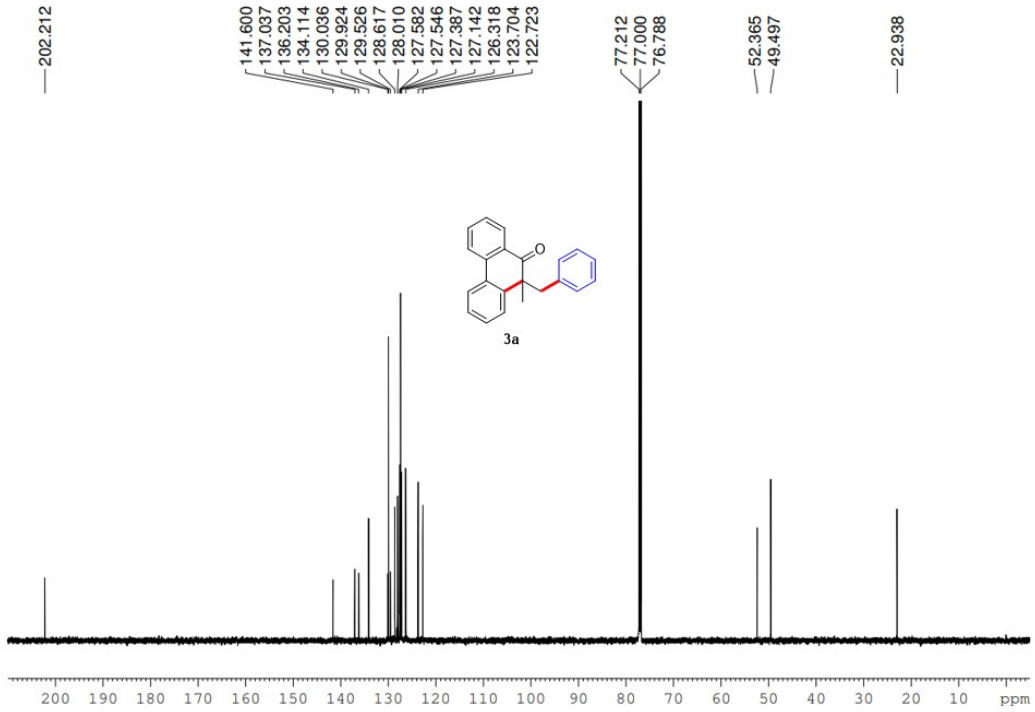
1. Yu, W. Y.; Sit, W. N.; Zhou, Z.; Chan, A. S. C. *Org. Lett.* **2009**, *11*, 3174–3177.

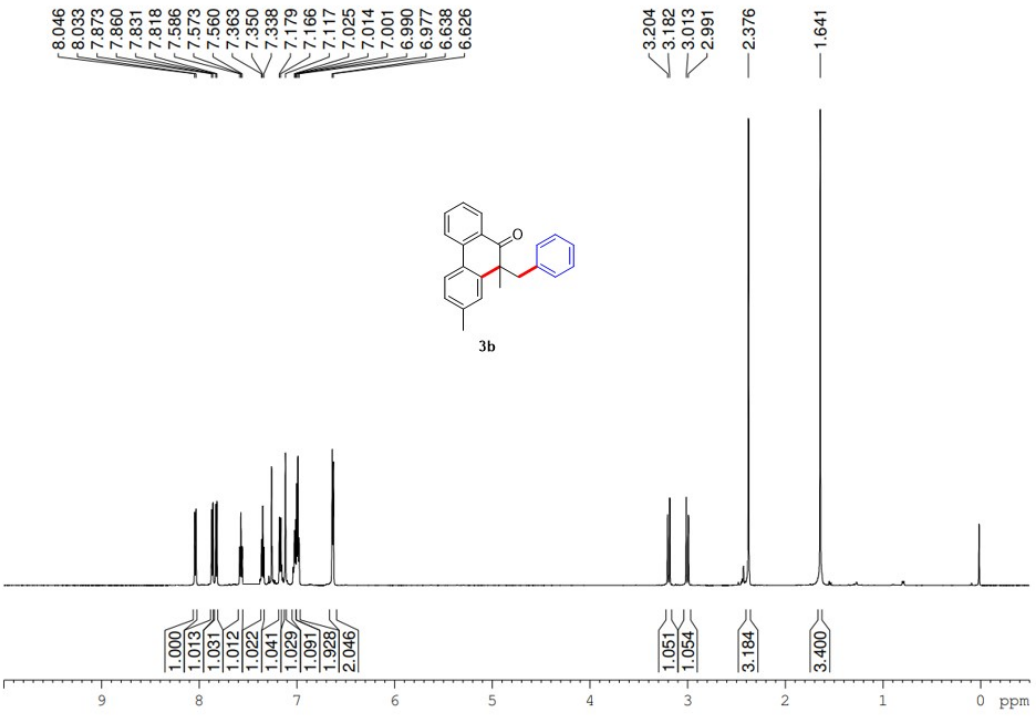
2. Y. Li, Y. Han, H. Xiong, N. Zhu, B. Qian, C. Ye, E. A. B. Kantchev and H. Bao, *Org.*

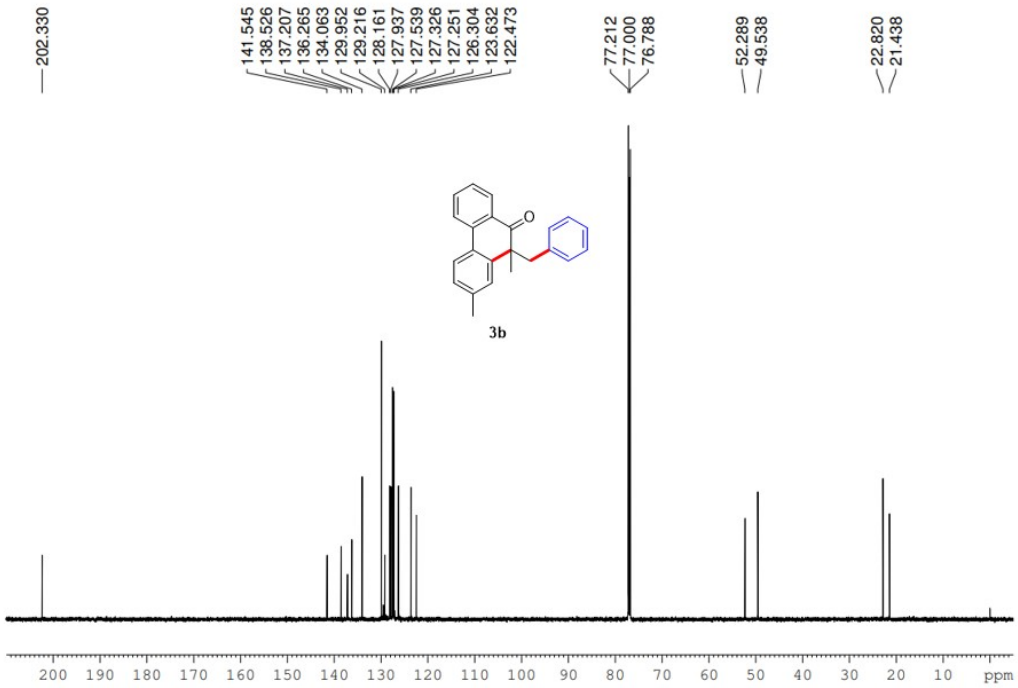
Lett., 2016, **18**, 392–395.

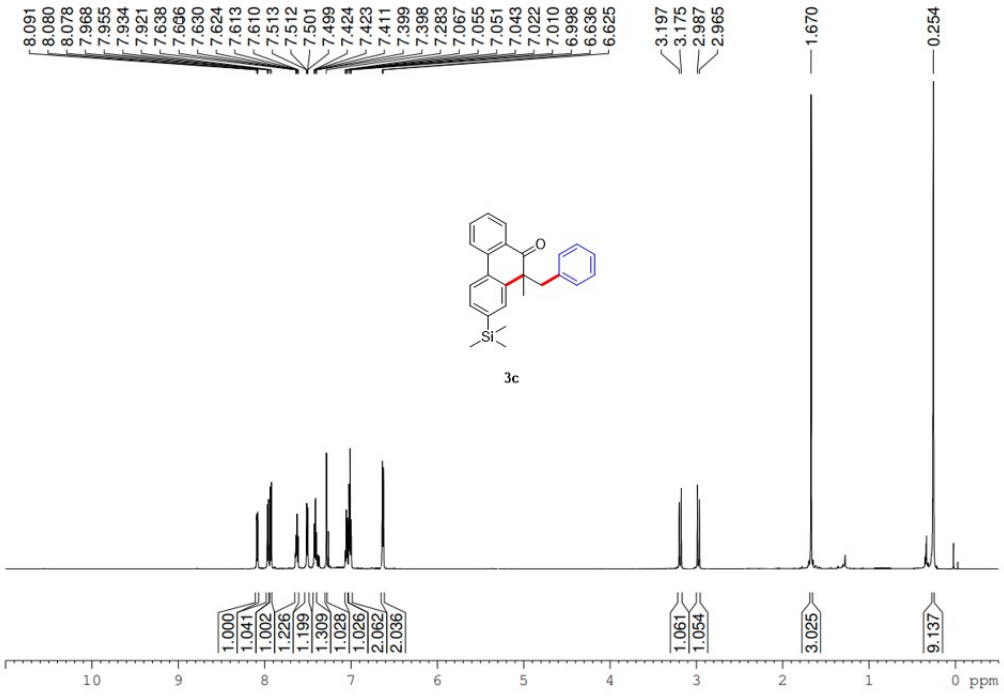
5. ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra of the products.

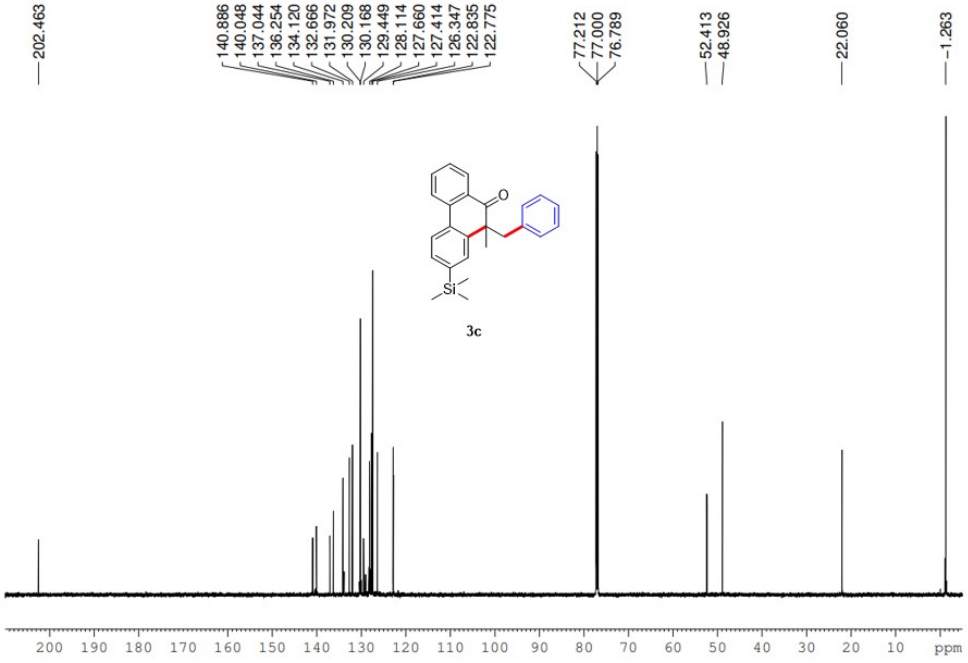


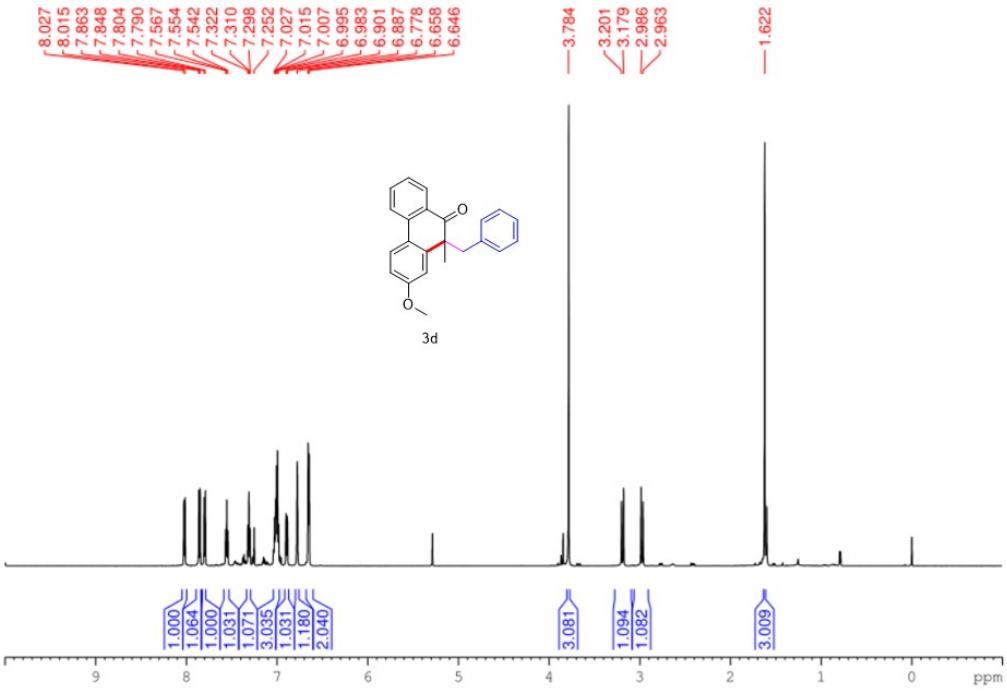

202.212
141.600
137.037
136.203
134.114
130.036
129.924
129.526
128.617
128.010
127.582
127.546
127.387
127.142
126.318
123.704
122.723
77.212
77.000
76.788
52.365
49.497
22.938
O
3a
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

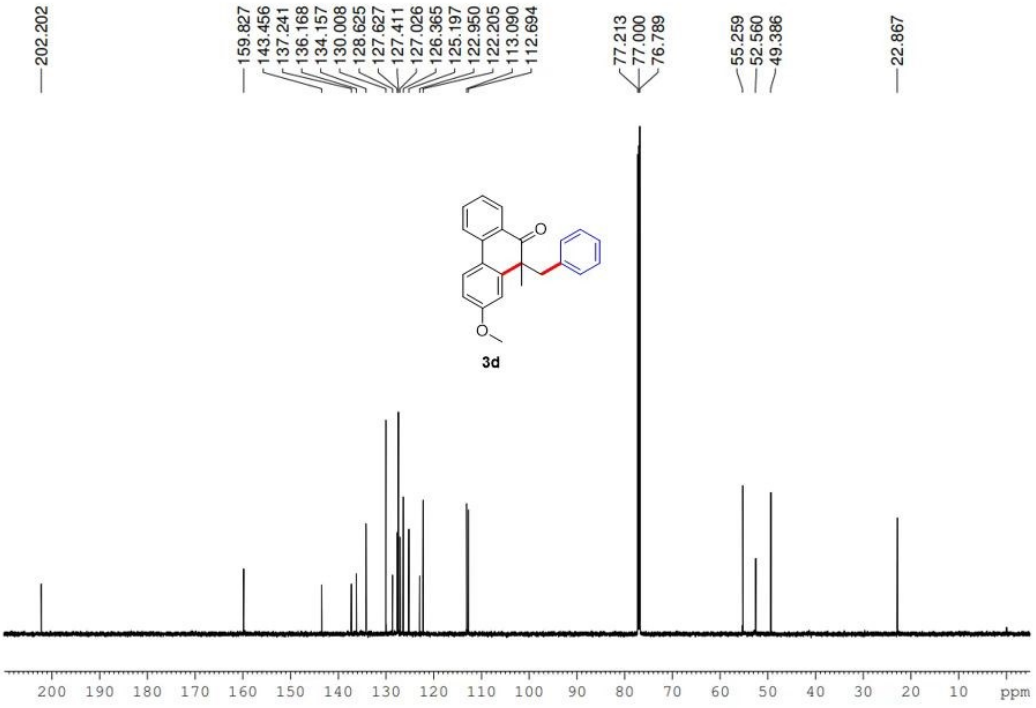

8.046
8.033
7.873
7.860
7.831
7.818
7.586
7.573
7.560
7.363
7.350
7.338
7.179
7.166
7.117
7.025
7.014
7.001
6.990
6.977
6.638
6.626
3.204
3.182
3.013
2.991
2.376
1.641
O
3b
1.000
1.013
1.031
1.012
1.022
1.041
1.029
1.091
1.928
2.046
1.051
1.054
3.184
3.400
9 8 7 6 5 4 3 2 1 0 ppm

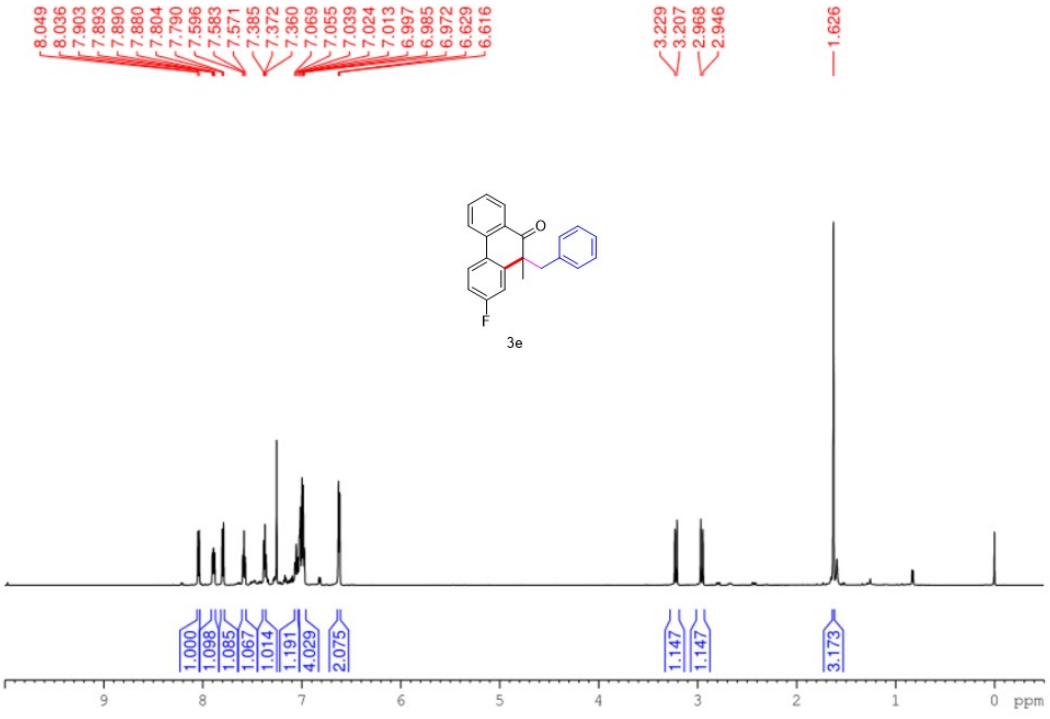

202.330
141.545
138.526
137.207
136.265
134.063
129.952
129.216
128.161
127.937
127.539
127.326
127.251
126.304
123.632
122.473
77.212
77.000
76.788
52.289
49.538
22.820
21.438
O
3b
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

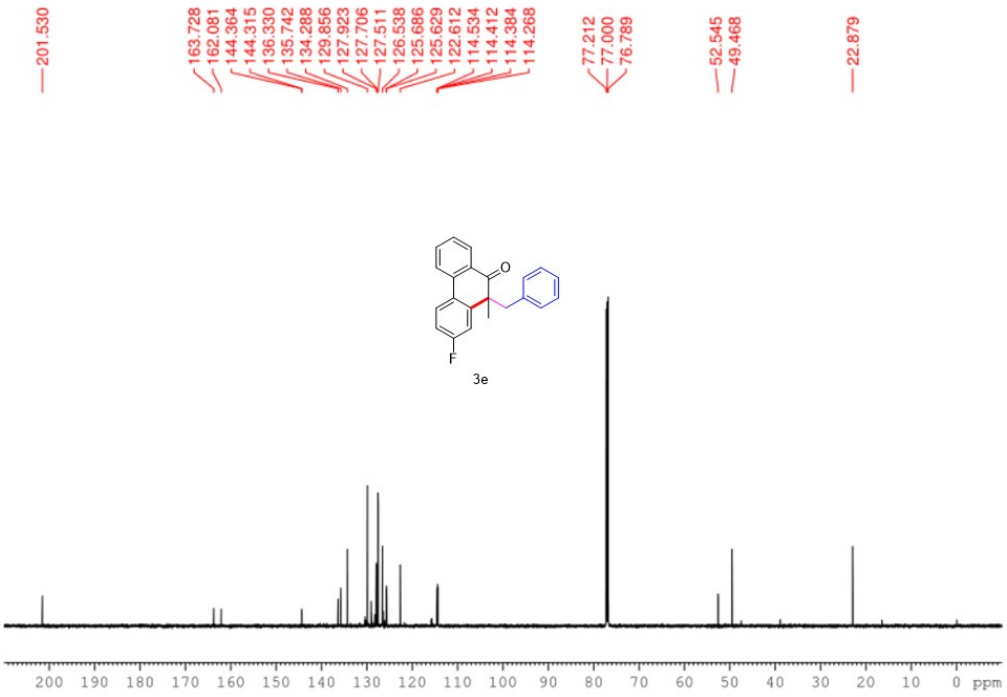

8.091
8.080
8.078
7.968
7.955
7.934
7.921
7.638
7.606
7.630
7.624
7.613
7.610
7.513
7.512
7.501
7.499
7.424
7.423
7.411
7.399
7.398
7.283
7.067
7.055
7.051
7.043
7.022
7.010
6.998
6.636
6.625
3.197
3.175
2.987
2.965
1.670
0.254
O
Si
3c
1.000
1.041
1.002
1.226
1.199
1.309
1.028
1.026
2.062
2.036
1.061
1.054
3.025
9.137
10 9 8 7 6 5 4 3 2 1 0 ppm

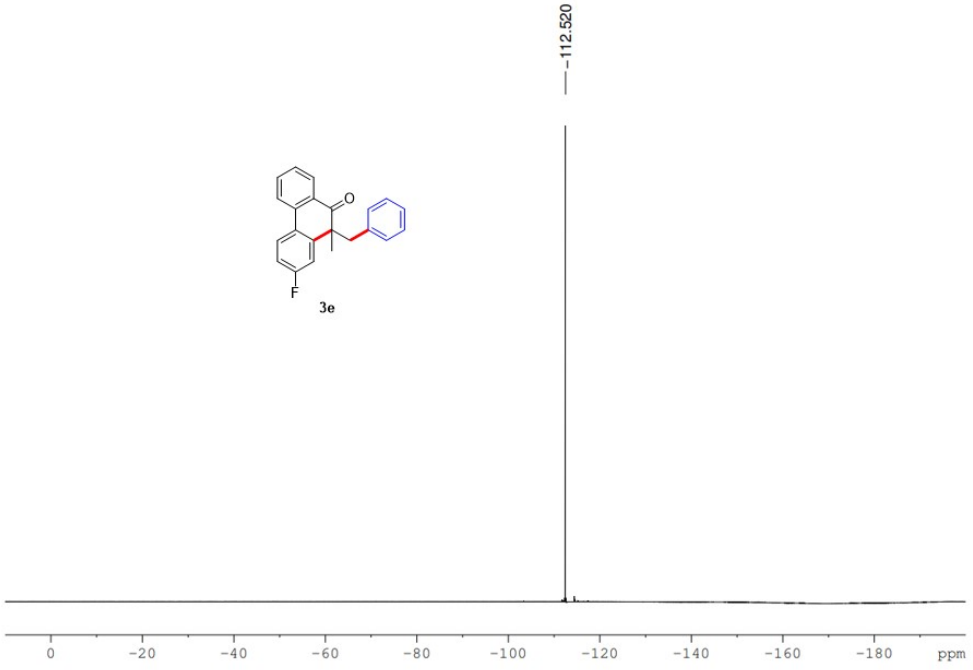

202.463
140.886
140.048
137.044
136.254
134.120
132.666
131.972
130.209
130.168
129.449
128.114
127.660
127.414
126.347
122.835
122.775
77.212
77.000
76.789
52.413
48.926
22.060
1.263
O
Si
3c
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

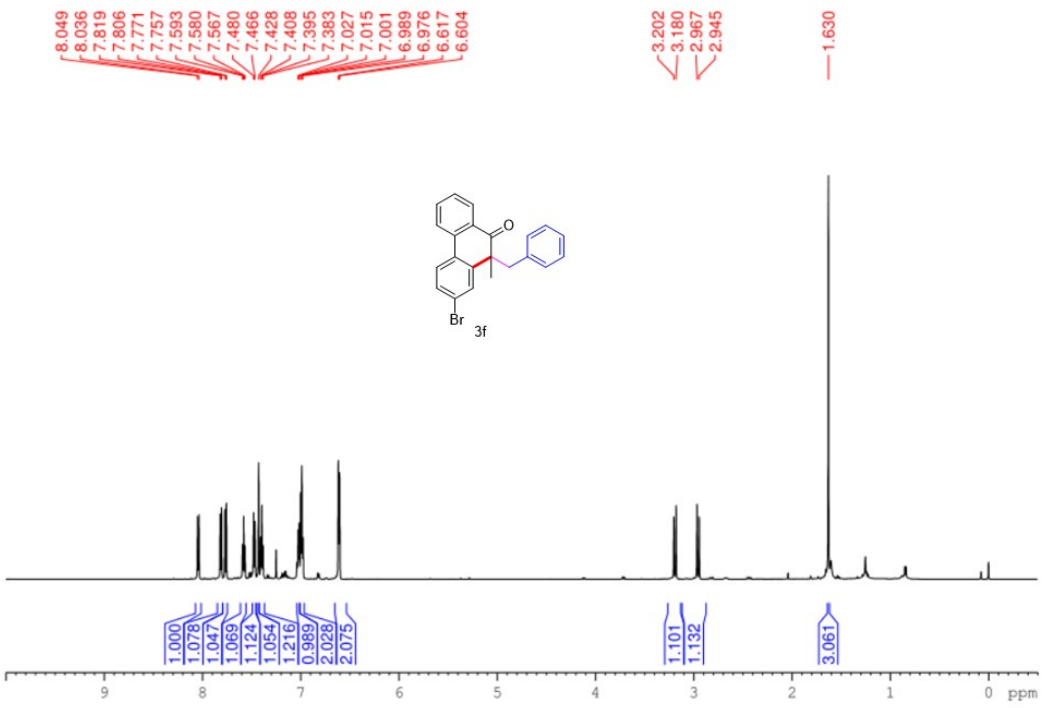

8.027
8.015
7.863
7.848
7.804
7.790
7.567
7.554
7.542
7.322
7.310
7.298
7.252
7.027
7.015
7.007
6.995
6.983
6.901
6.887
6.778
6.658
6.646
3.784
3.201
3.179
2.986
2.963
1.622
O
O
3d
1.000
1.064
1.000
1.031
1.071
3.035
1.031
1.180
2.040
3.081
1.094
1.082
3.009
9 8 7 6 5 4 3 2 1 0 ppm

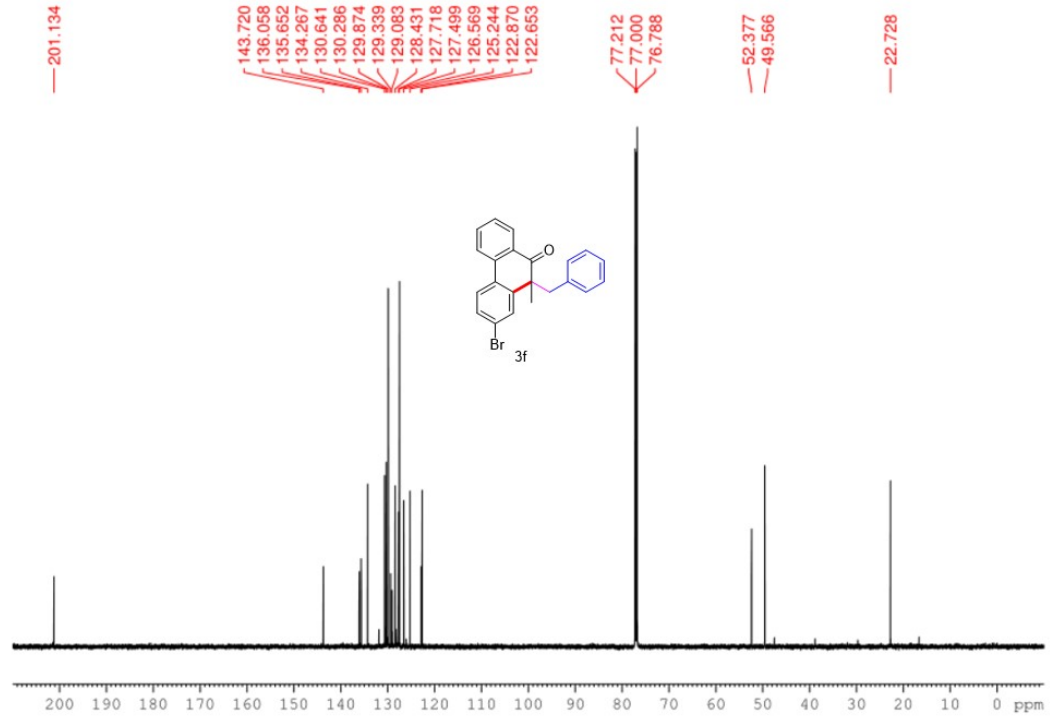

202.202
159.827
143.456
137.241
136.168
134.157
130.008
128.625
127.627
127.411
127.026
126.365
125.197
122.950
122.205
113.090
112.694
77.213
77.000
76.789
55.259
52.560
49.386
22.867
O
O
3d
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

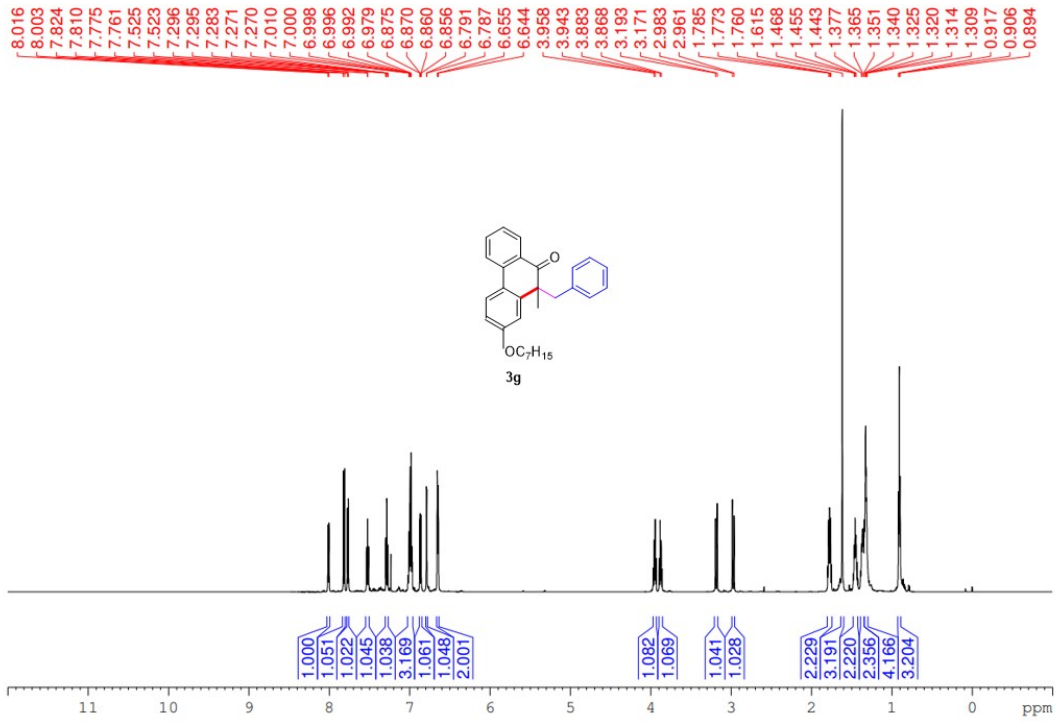

8.049
8.036
7.903
7.893
7.890
7.880
7.804
7.790
7.596
7.583
7.571
7.385
7.372
7.360
7.069
7.055
7.039
7.024
7.013
6.997
6.985
6.972
6.629
6.616
3.229
3.207
2.968
2.946
1.626
O
F
3e
1.000
1.098
1.085
1.067
1.014
1.191
4.029
2.075
1.147
1.147
3.173
9 8 7 6 5 4 3 2 1 0 ppm

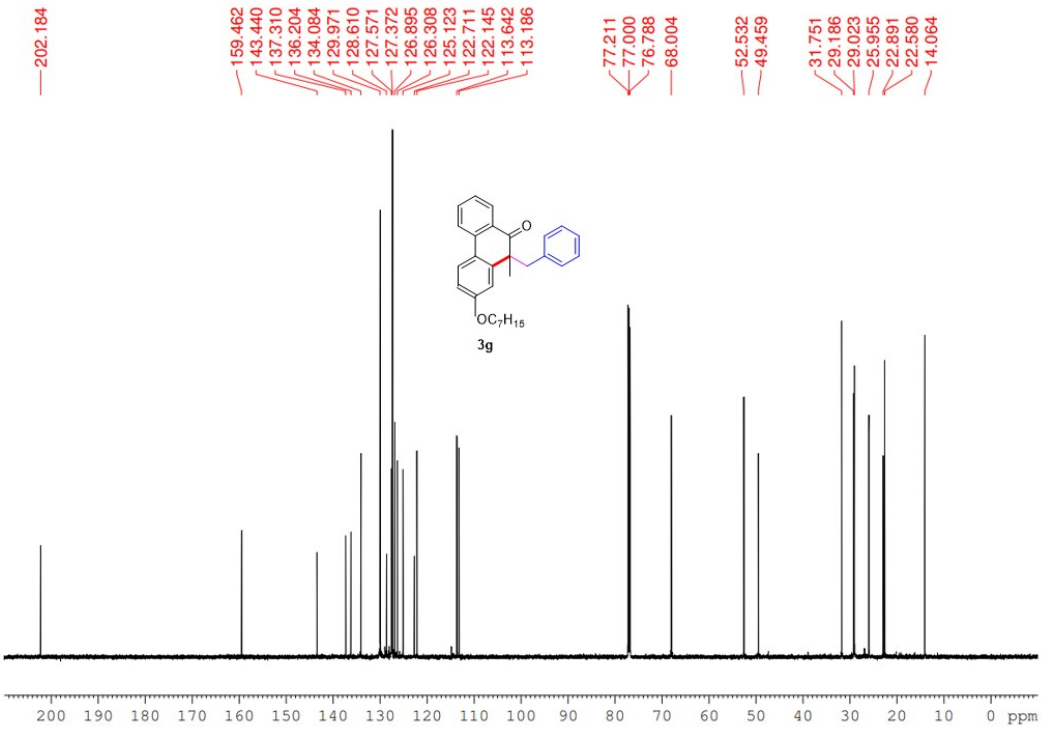

201.530
163.728
162.081
144.364
144.315
136.330
135.742
134.288
129.856
127.923
127.706
127.511
126.538
125.686
125.629
122.612
114.534
114.412
114.384
114.268
77.212
77.000
76.789
52.545
49.468
22.879
O
F
3e
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

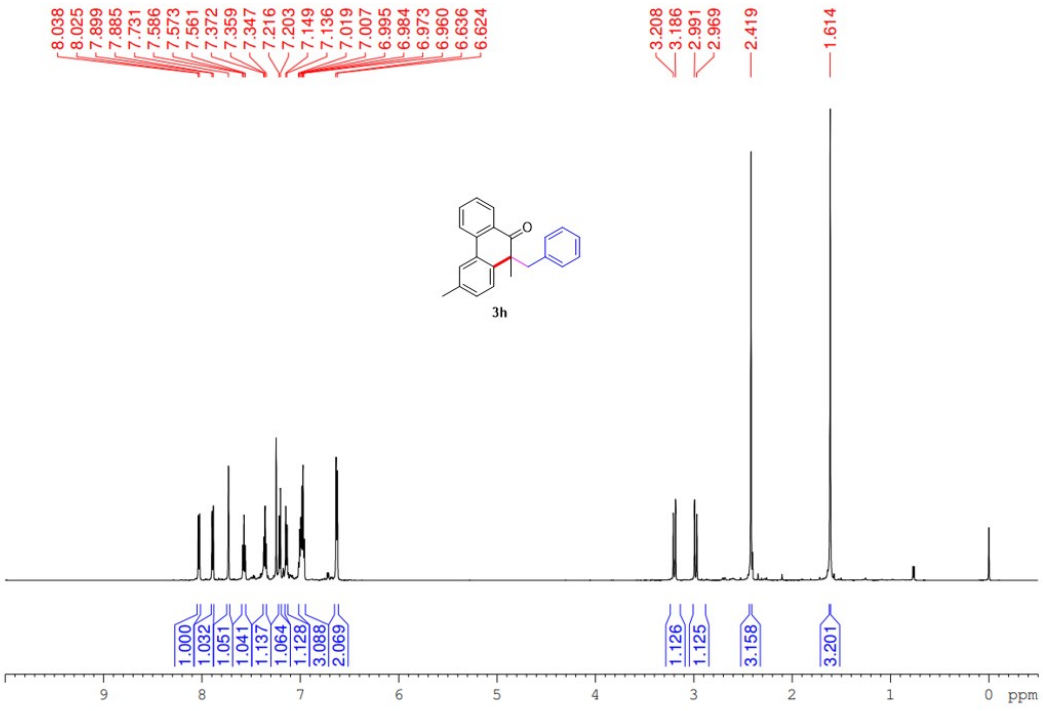

112.520
O
F
3e
0 -20 -40 -60 -80 -100 -120 -140 -160 -180 ppm

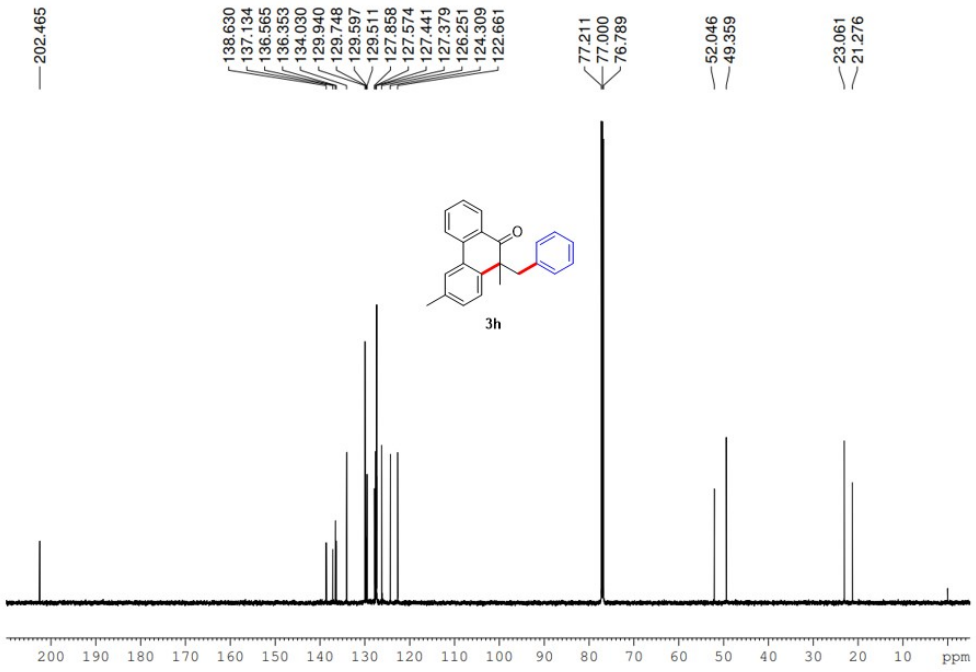

8.049
8.036
7.819
7.806
7.771
7.757
7.593
7.580
7.567
7.480
7.466
7.428
7.408
7.395
7.383
7.027
7.015
7.001
6.989
6.976
6.617
6.604
3.202
3.180
2.967
2.945
1.630
O
Br
3f
1.000
1.078
1.047
1.069
1.124
1.054
1.216
0.989
2.028
2.075
1.101
1.132
3.061
9
8
7
6
5
4
3
2
1
0 ppm

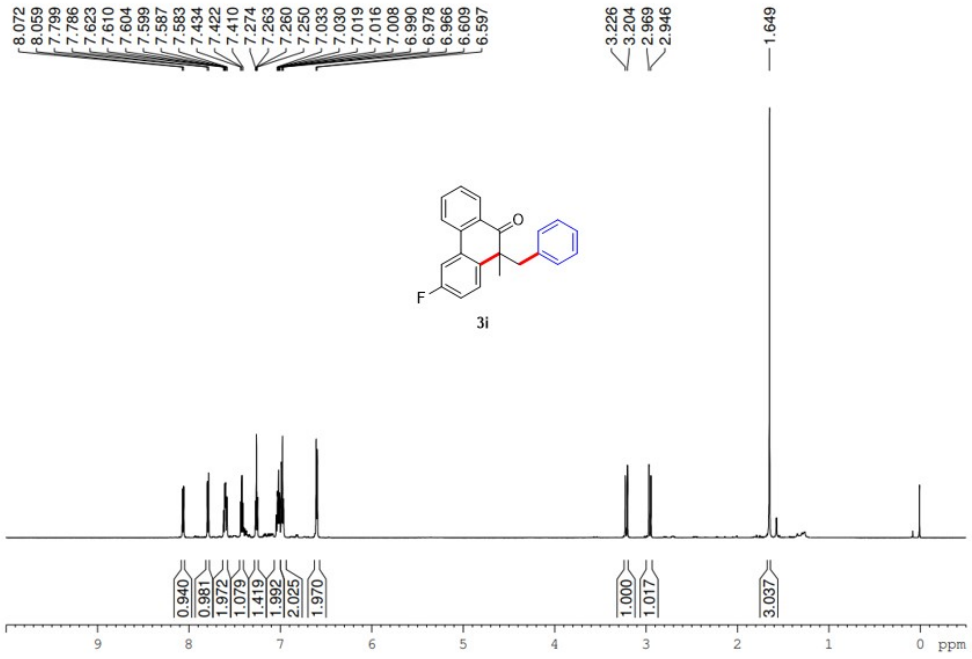

201.134
143.720
136.058
135.652
134.267
130.641
130.286
129.874
129.339
129.083
128.431
127.718
127.499
126.569
125.244
122.870
122.653
77.212
77.000
76.788
52.377
49.566
22.728
O
Br
3f
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

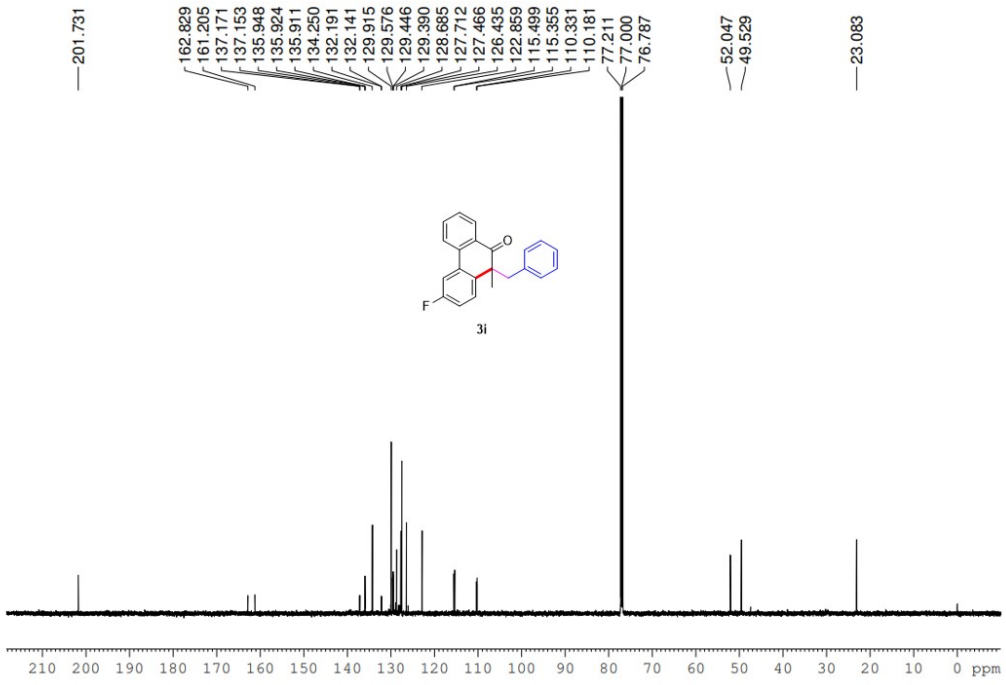

8.016
8.003
7.824
7.810
7.775
7.761
7.525
7.523
7.296
7.295
7.283
7.271
7.270
7.010
7.000
6.998
6.996
6.992
6.979
6.875
6.870
6.860
6.856
6.791
6.787
6.655
6.644
3.958
3.943
3.883
3.868
3.193
3.171
2.983
2.961
1.785
1.773
1.760
1.615
1.468
1.455
1.443
1.377
1.365
1.351
1.340
1.325
1.320
1.314
1.309
0.917
0.906
0.894
O
OC7H15
3g
1.000
1.051
1.022
1.045
1.038
3.169
1.061
1.048
2.001
1.082
1.069
1.041
1.028
2.229
3.191
2.220
2.356
4.166
3.204
11
10
9
8
7
6
5
4
3
2
1
0
ppm

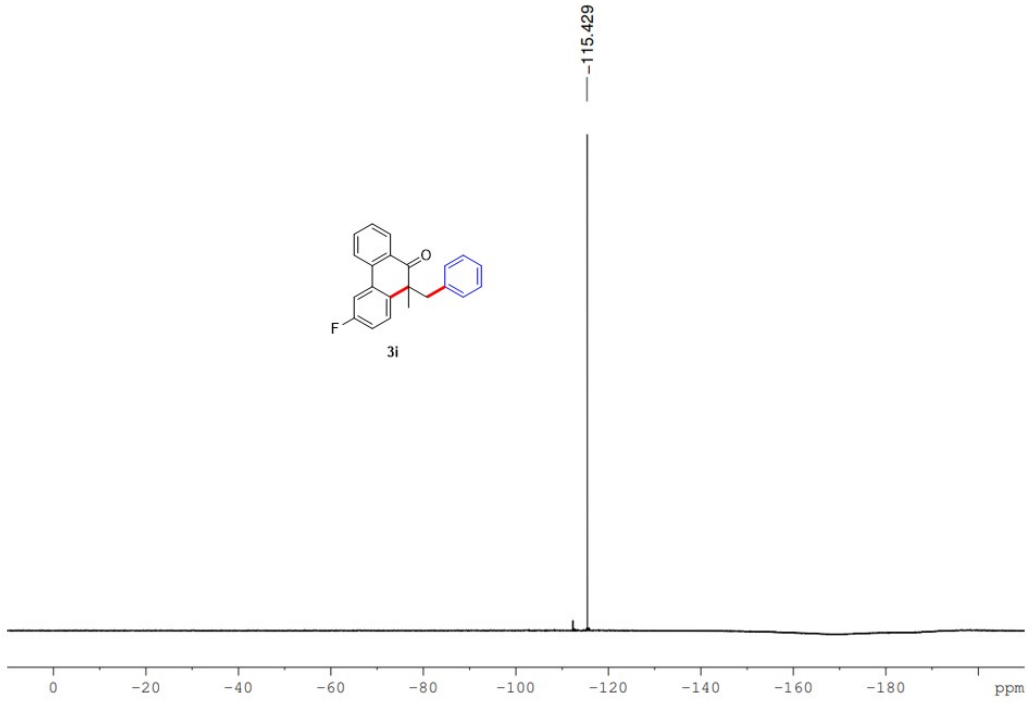

202.184
159.462
143.440
137.310
136.204
134.084
129.971
128.610
127.571
127.372
126.895
126.308
125.123
122.711
122.145
113.642
113.186
77.211
77.000
76.788
68.004
52.532
49.459
31.751
29.186
29.023
25.955
22.891
22.580
14.064
O
OC7H15
3g
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

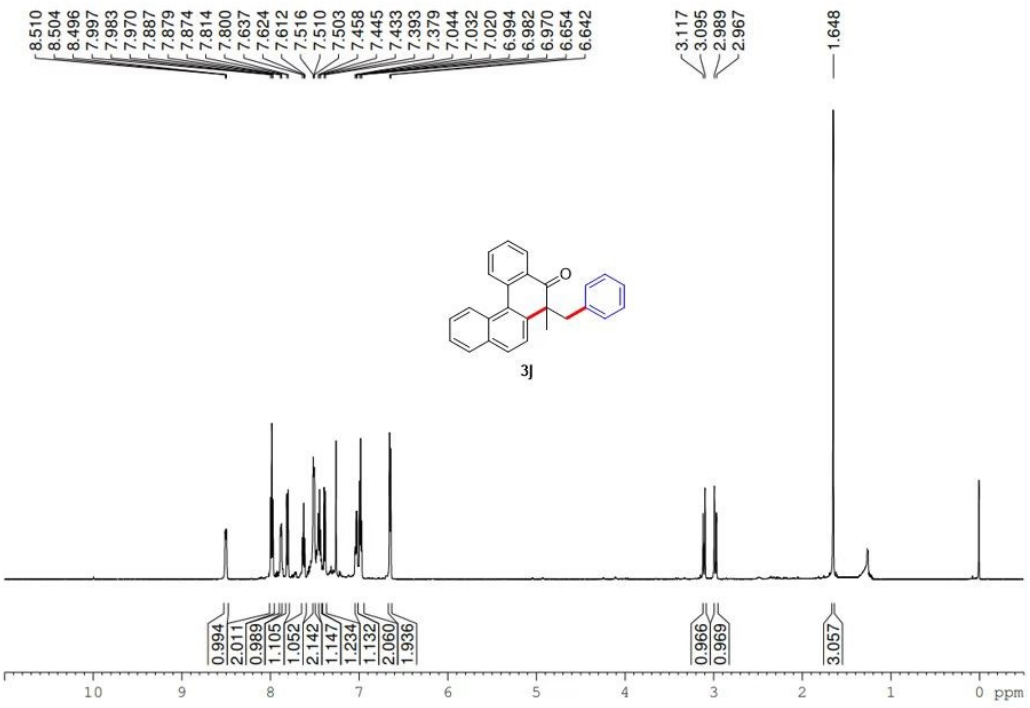

8.038
8.025
7.899
7.885
7.731
7.586
7.573
7.561
7.372
7.359
7.347
7.216
7.203
7.149
7.136
7.019
7.007
6.995
6.984
6.973
6.960
6.636
6.624
3.208
3.186
2.991
2.969
2.419
1.614
3h
1.000
1.032
1.051
1.041
1.137
1.064
1.128
3.088
2.069
1.126
1.125
3.158
3.201
9
8
7
6
5
4
3
2
1
0 ppm

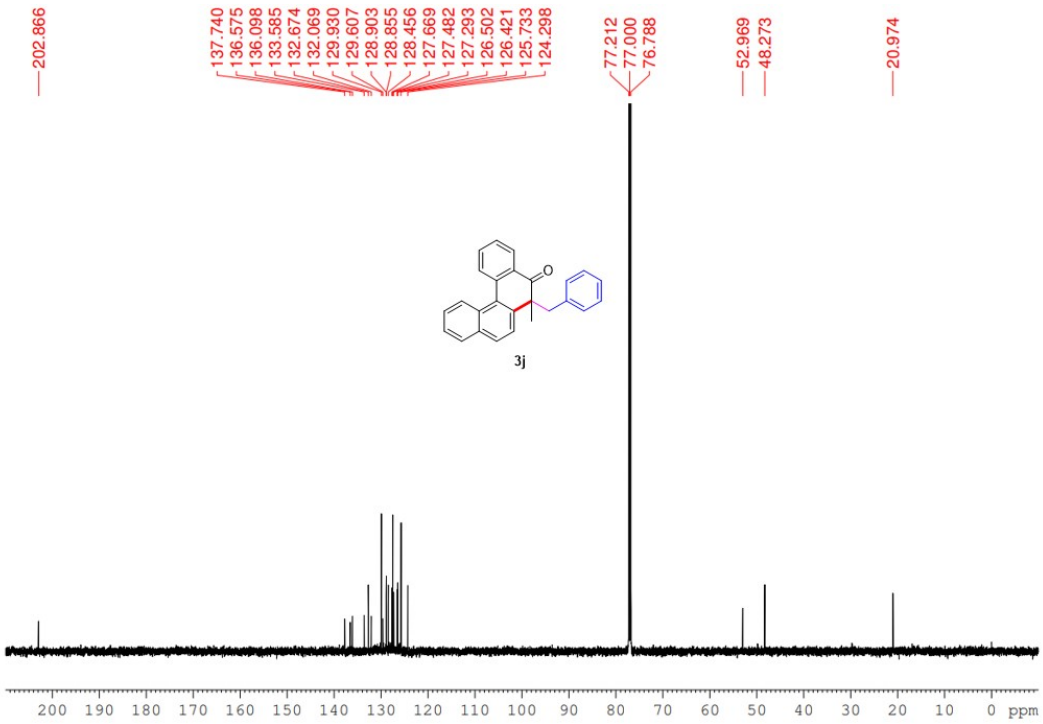

202.465
138.630
137.134
136.565
136.353
134.030
129.940
129.748
129.597
129.511
127.858
127.574
127.441
127.379
126.251
124.309
122.661
77.211
77.000
76.789
52.046
49.359
23.061
21.276
3h
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

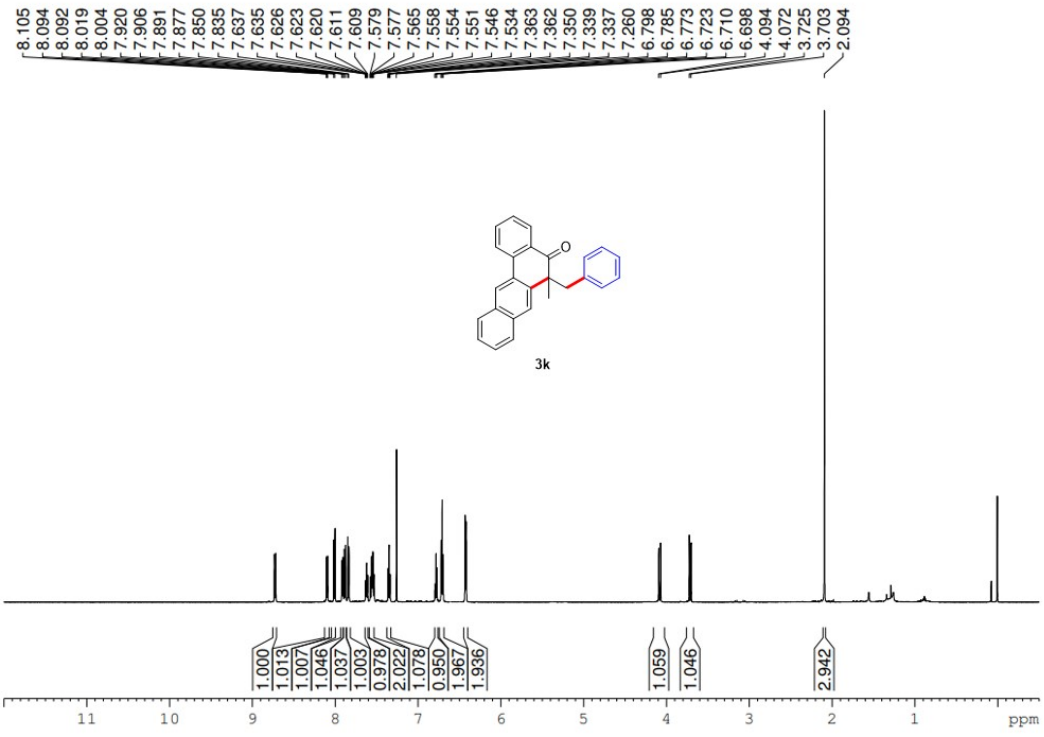

8.072
8.059
7.799
7.786
7.623
7.610
7.604
7.599
7.587
7.583
7.434
7.422
7.410
7.274
7.263
7.260
7.250
7.033
7.030
7.019
7.016
7.008
6.990
6.978
6.966
6.609
6.597
3.226
3.204
2.969
2.946
1.649
O
F
3i
0.940
0.981
1.972
1.079
1.419
1.992
2.025
1.970
1.000
1.017
3.037
9
8
7
6
5
4
3
2
1
0 ppm

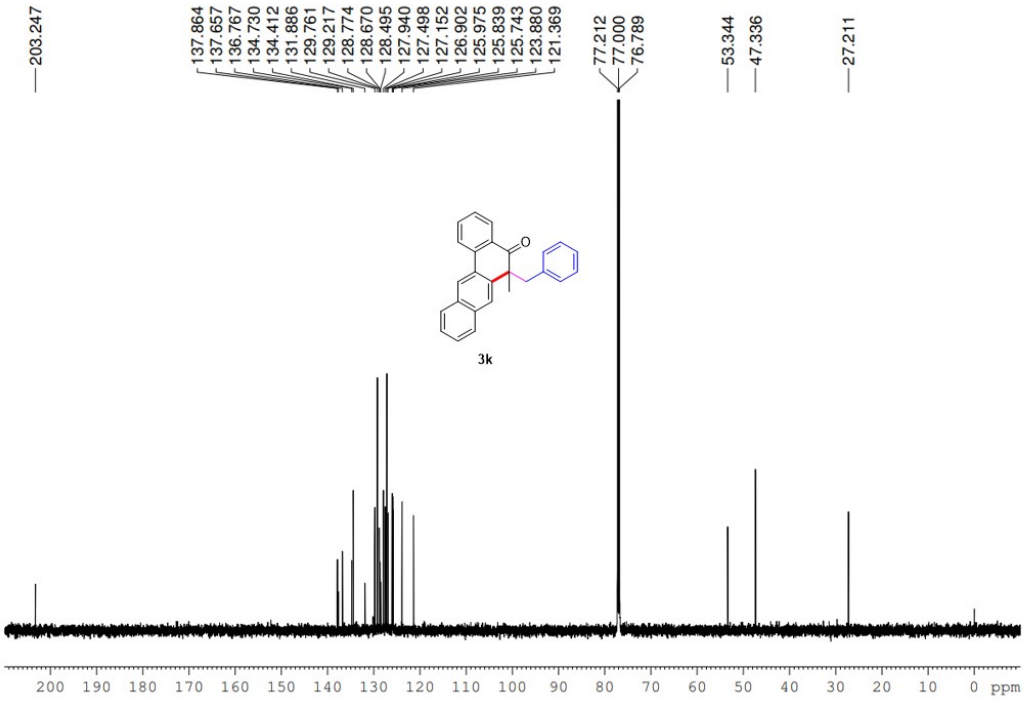

201.731
162.829
161.205
137.171
137.153
135.948
135.924
135.911
134.250
132.191
132.141
129.915
129.576
129.446
129.390
128.685
127.712
127.466
126.435
122.859
115.499
115.355
110.331
110.181
77.211
77.000
76.787
52.047
49.529
23.083
O
F
3i
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

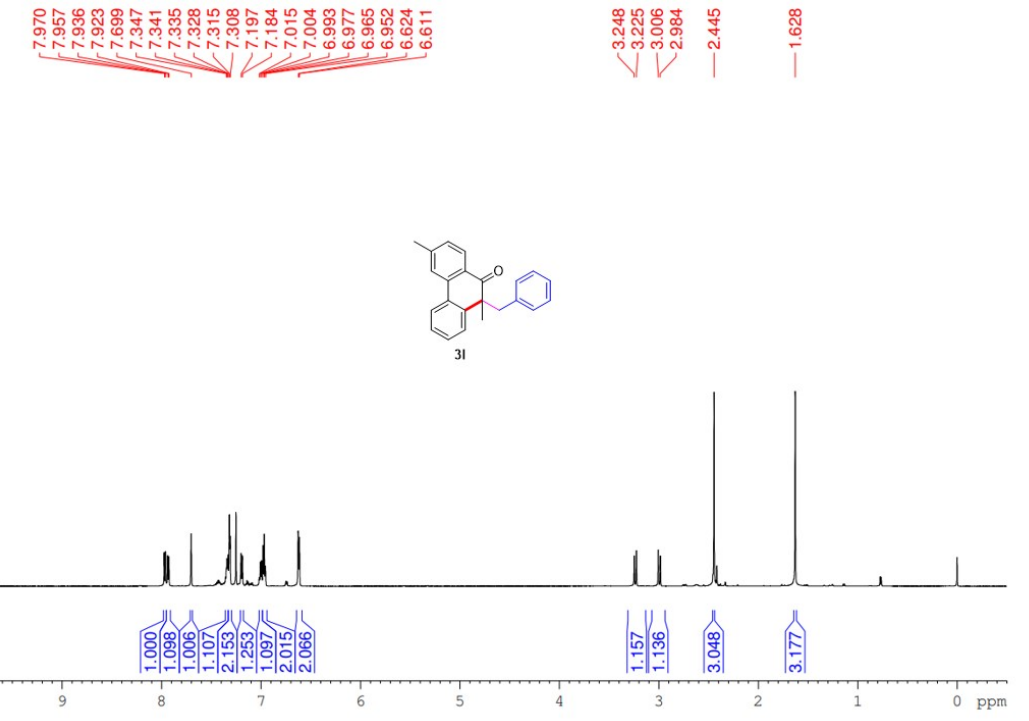

-115.429
O
F
3i
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
ppm

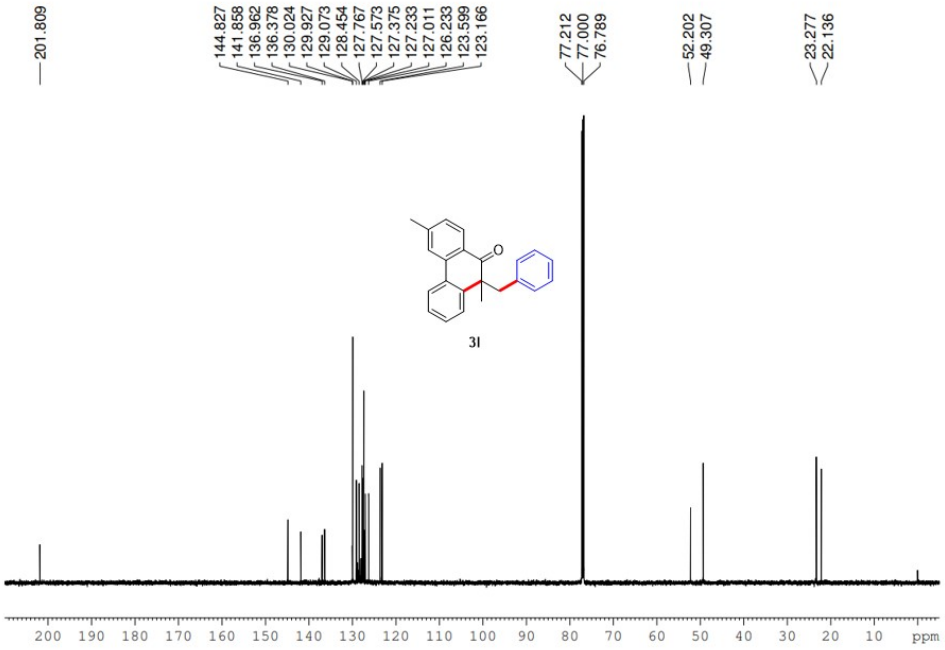

8.510
8.504
8.496
7.997
7.983
7.970
7.887
7.879
7.874
7.814
7.800
7.637
7.624
7.612
7.516
7.510
7.503
7.458
7.445
7.433
7.393
7.379
7.044
7.032
7.020
6.994
6.982
6.970
6.654
6.642
3.117
3.095
2.989
2.967
1.648
O
3J
0.994
2.011
0.989
1.105
1.052
2.142
1.147
1.234
1.132
2.060
1.936
0.966
0.969
3.057
10
9
8
7
6
5
4
3
2
1
0
ppm

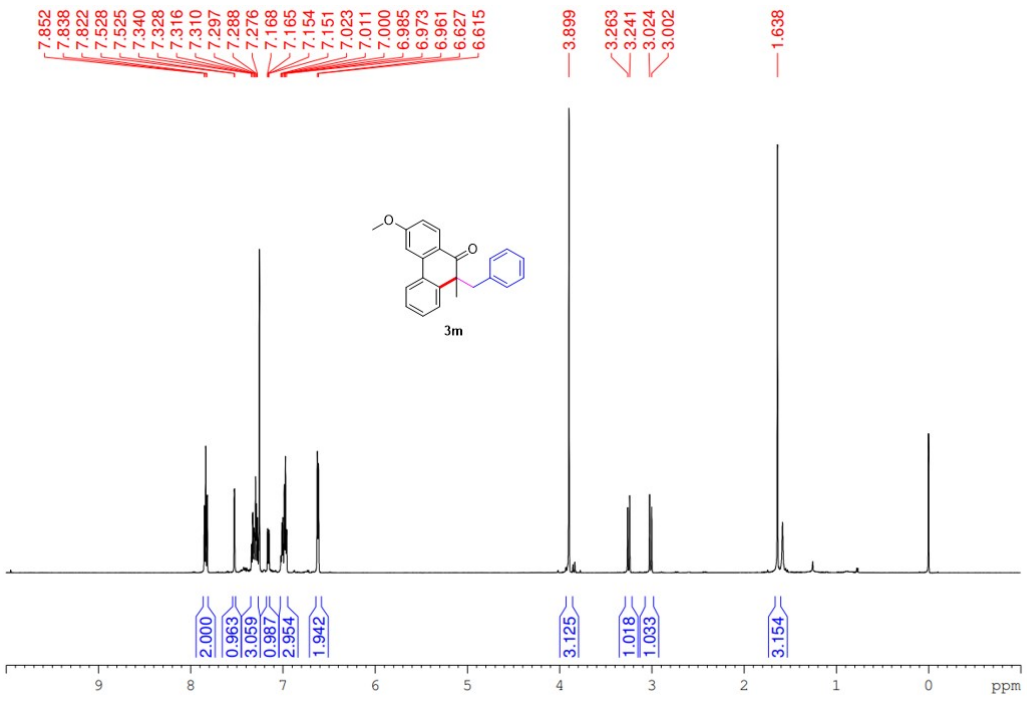

202.866
137.740
136.575
136.098
133.585
132.674
132.069
129.930
129.607
128.903
128.855
128.456
127.669
127.482
127.293
126.502
126.421
125.733
124.298
77.212
77.000
76.788
52.969
48.273
20.974
3j
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

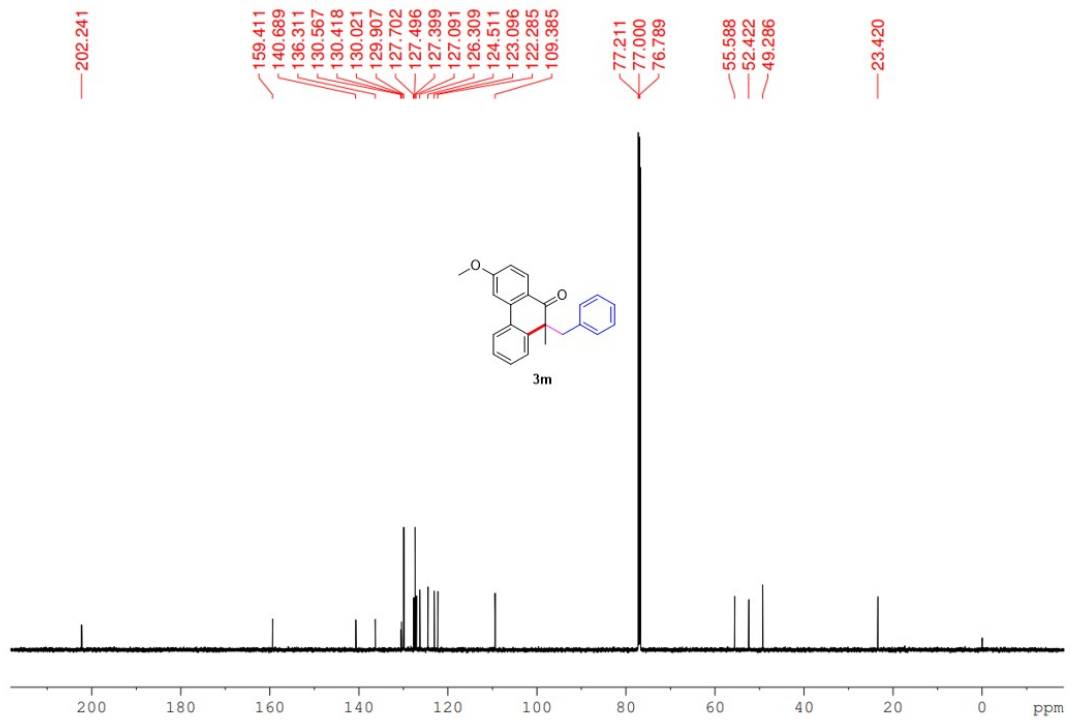

8.105
8.094
8.092
8.019
8.004
7.920
7.906
7.891
7.877
7.850
7.835
7.637
7.635
7.626
7.623
7.620
7.611
7.609
7.579
7.577
7.565
7.558
7.554
7.551
7.546
7.534
7.363
7.362
7.350
7.339
7.337
7.260
6.798
6.785
6.773
6.723
6.710
6.698
4.094
4.072
3.725
3.703
2.094
3k
1.000
1.013
1.007
1.046
1.037
1.003
0.978
2.022
1.078
0.950
1.967
1.936
1.059
1.046
2.942
11 10 9 8 7 6 5 4 3 2 1 ppm

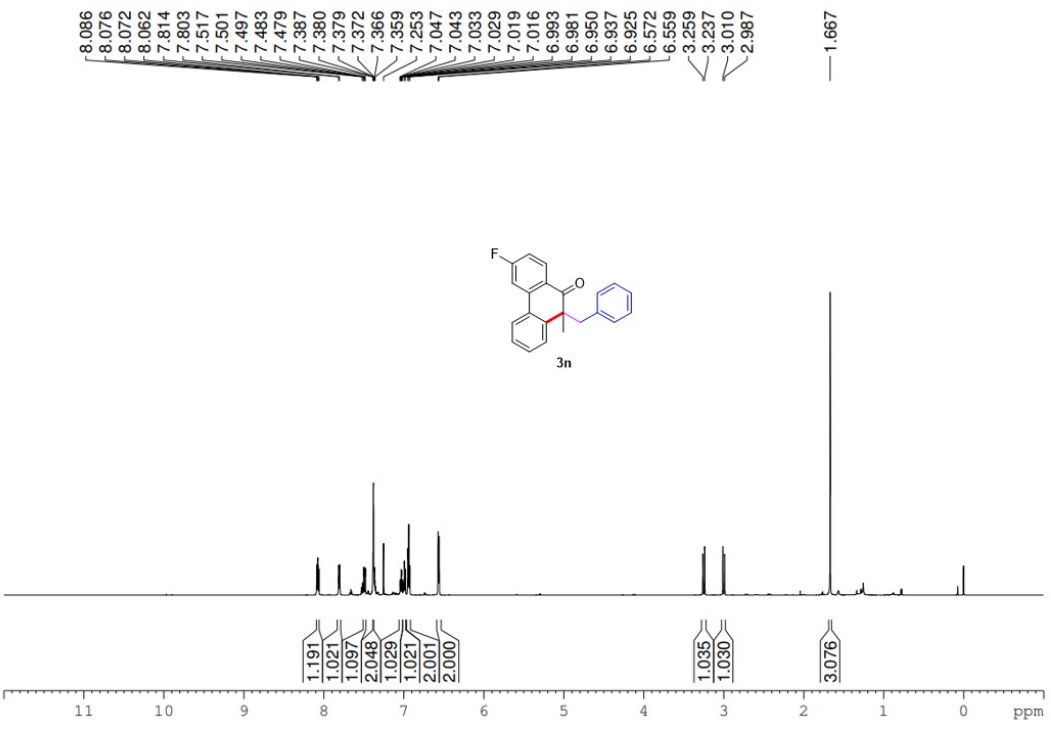

203.247
137.864
137.657
136.767
134.730
134.412
131.886
129.761
129.217
128.774
128.670
128.495
127.940
127.498
127.152
126.902
125.975
125.839
125.743
123.880
121.369
77.212
77.000
76.789
53.344
47.336
27.211
O
3k
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

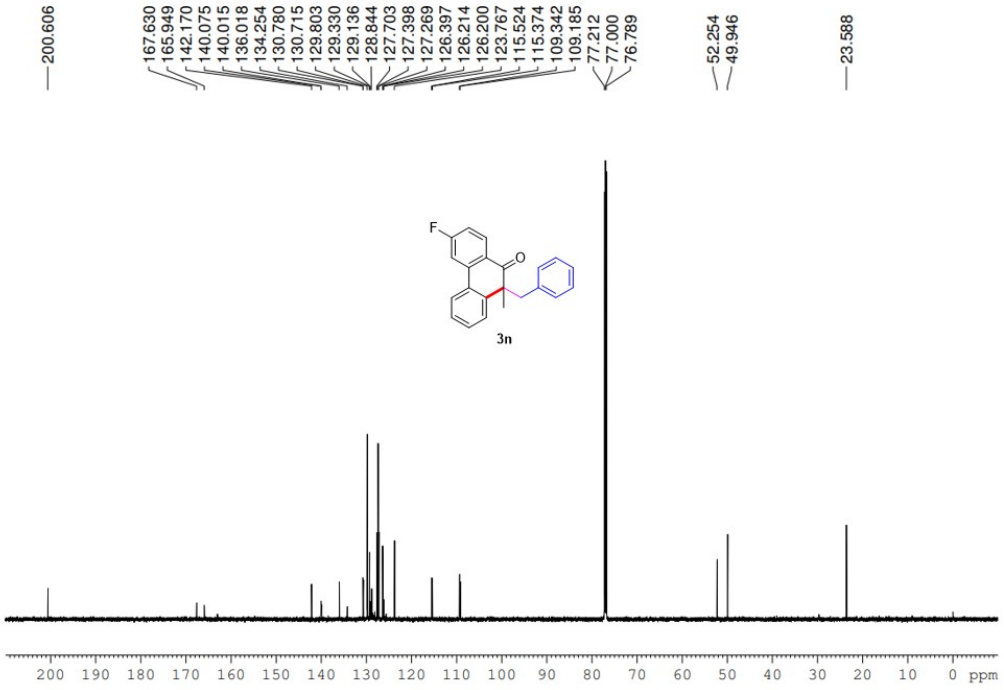

7.970
7.957
7.936
7.923
7.699
7.347
7.341
7.335
7.328
7.315
7.308
7.197
7.184
7.015
7.004
6.993
6.977
6.965
6.952
6.624
6.611
3.248
3.225
3.006
2.984
2.445
1.628
O
3l
1.000
1.098
1.006
1.107
2.153
1.253
1.097
2.015
2.066
1.157
1.136
3.048
3.177
9 8 7 6 5 4 3 2 1 0 ppm

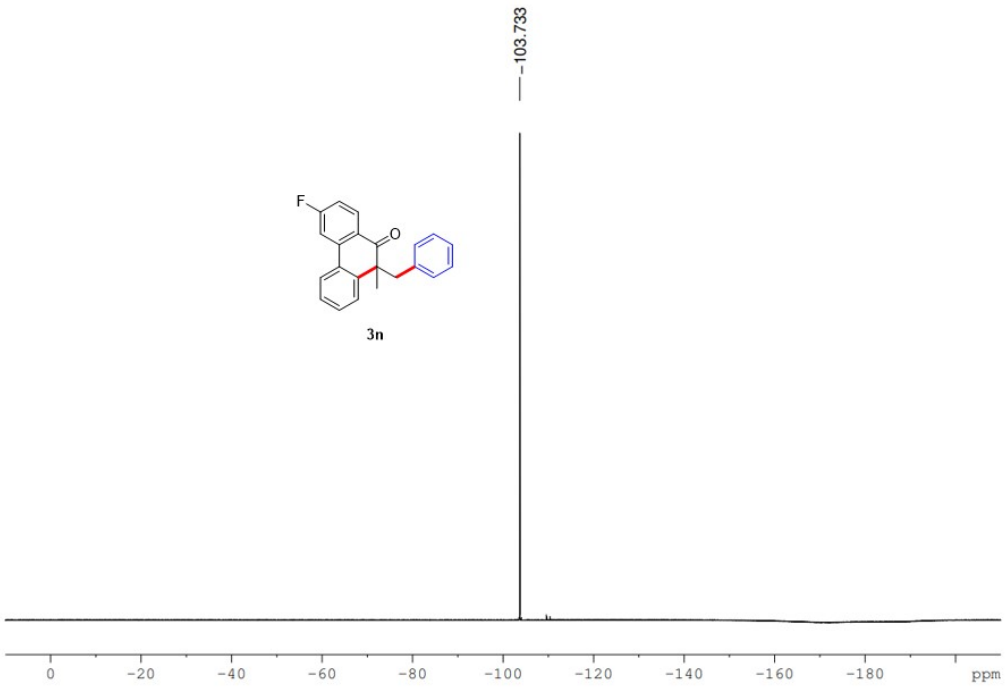

201.809
144.827
141.858
136.962
136.378
130.024
129.927
129.073
128.454
127.767
127.573
127.375
127.233
127.011
126.233
123.599
123.166
77.212
77.000
76.789
52.202
49.307
23.277
22.136
O
3l
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

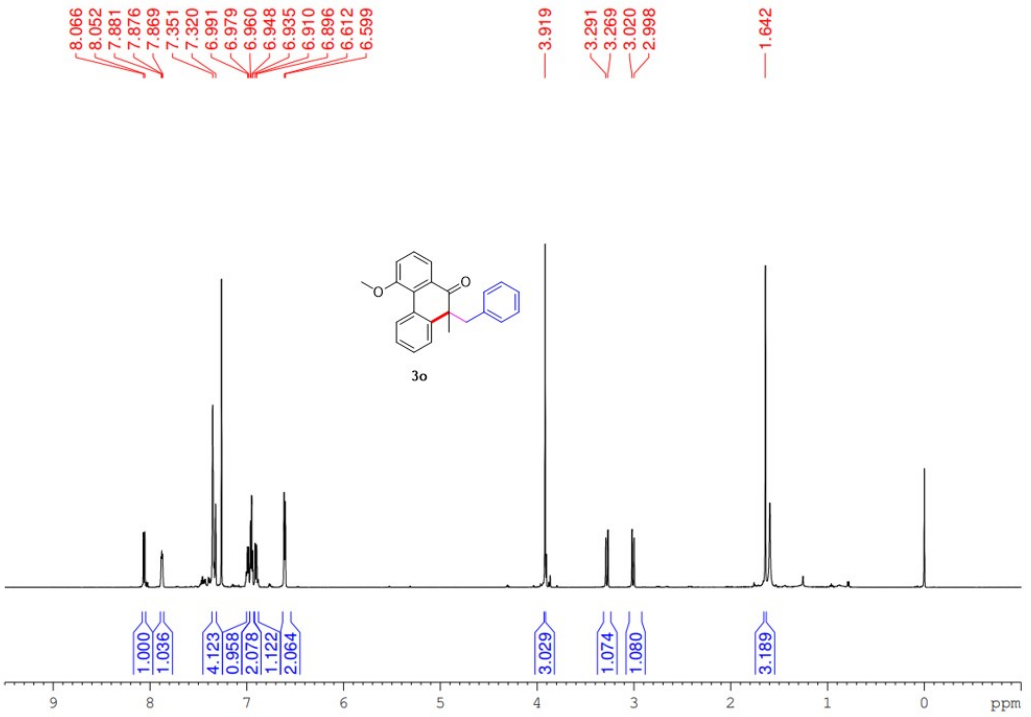

7.852
7.838
7.822
7.528
7.525
7.340
7.328
7.316
7.310
7.297
7.288
7.276
7.168
7.165
7.154
7.151
7.023
7.011
7.000
6.985
6.973
6.961
6.627
6.615
3.899
3.263
3.241
3.024
3.002
1.638
O
O
3m
2.000
0.963
3.059
0.987
2.954
1.942
3.125
1.018
1.033
3.154
9 8 7 6 5 4 3 2 1 0 ppm

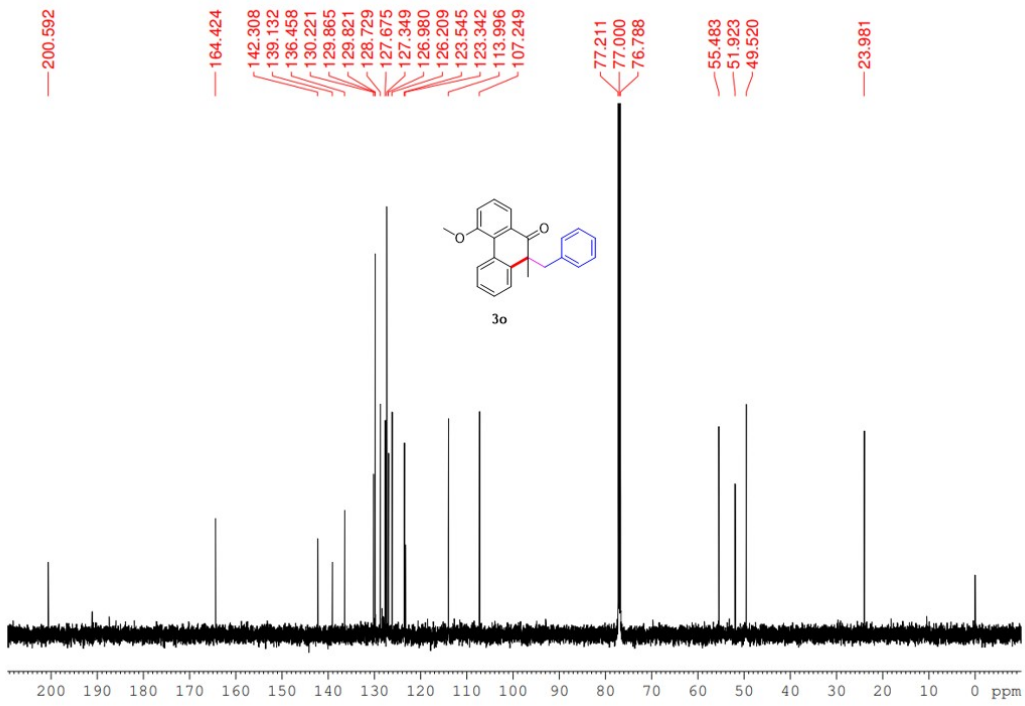

202.241
159.411
140.689
136.311
130.567
130.418
130.021
129.907
127.702
127.496
127.399
127.091
126.309
124.511
123.096
122.285
109.385
77.211
77.000
76.789
55.588
52.422
49.286
23.420
3m
200
180
160
140
120
100
80
60
40
20
0
ppm

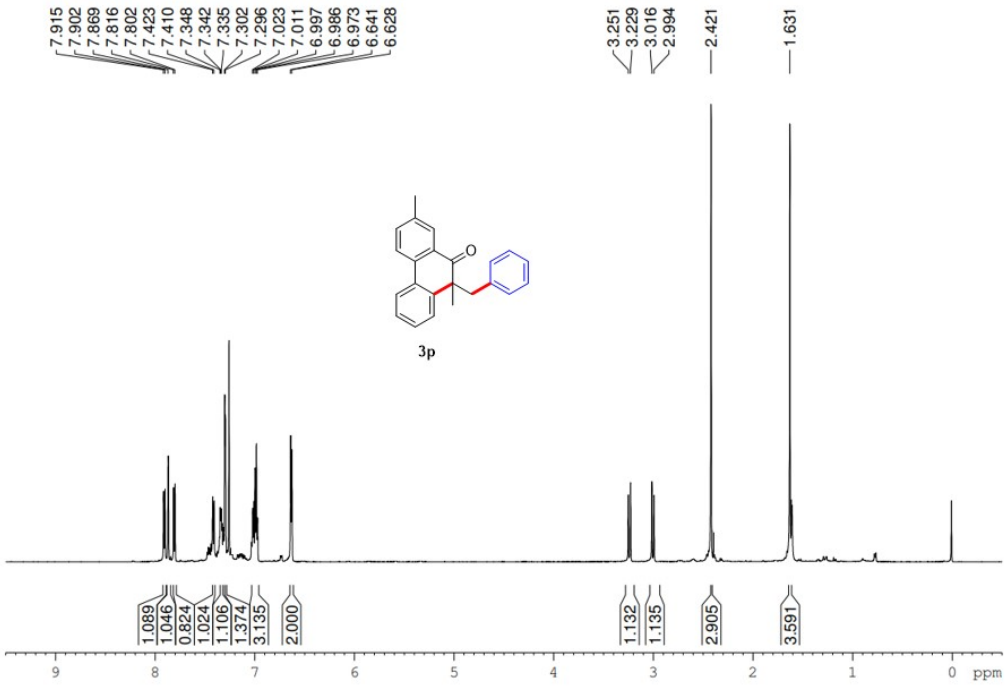

8.086
8.076
8.072
8.062
7.814
7.803
7.517
7.501
7.497
7.483
7.479
7.387
7.380
7.379
7.372
7.366
7.359
7.253
7.047
7.043
7.033
7.029
7.019
7.016
6.993
6.981
6.950
6.937
6.925
6.572
6.559
3.259
3.237
3.010
2.987
1.667
3n
1.191
1.021
1.097
2.048
1.029
1.021
2.001
2.000
1.035
1.030
3.076
11
10
9
8
7
6
5
4
3
2
1
0
ppm

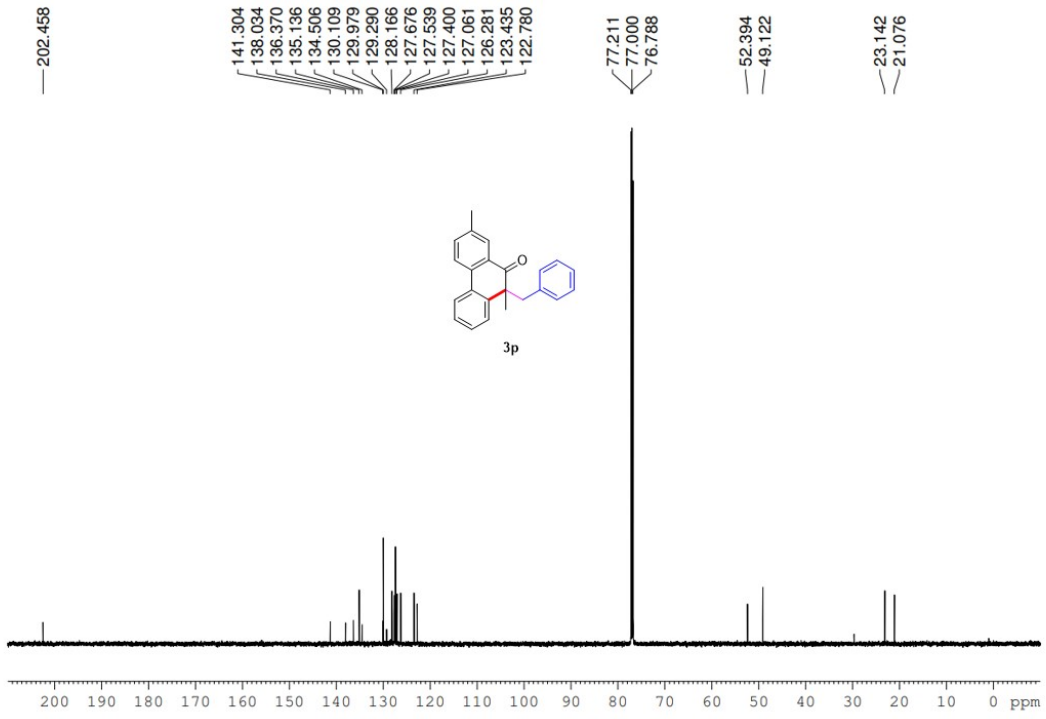

200.606
167.630
165.949
142.170
140.075
140.015
136.018
134.254
130.780
130.715
129.803
129.330
129.136
128.844
127.703
127.398
127.269
126.397
126.214
126.200
123.767
115.524
115.374
109.342
109.185
77.212
77.000
76.789
52.254
49.946
23.588
F
O
3n
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

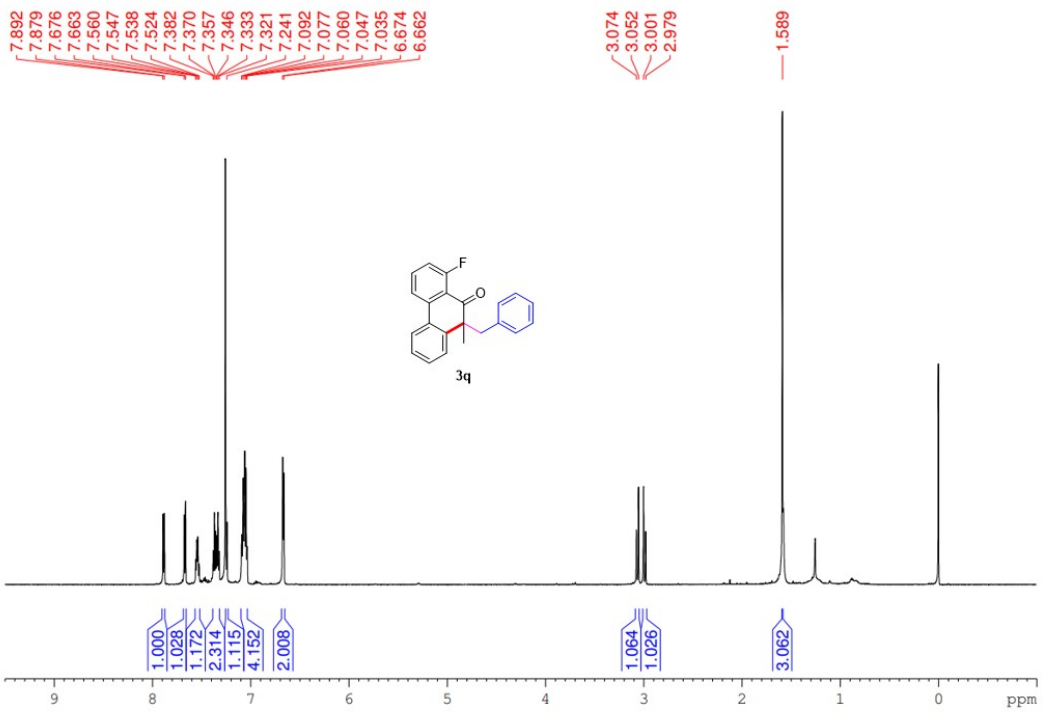

-103.733
F
O
3n
0 -20 -40 -60 -80 -100 -120 -140 -160 -180 ppm

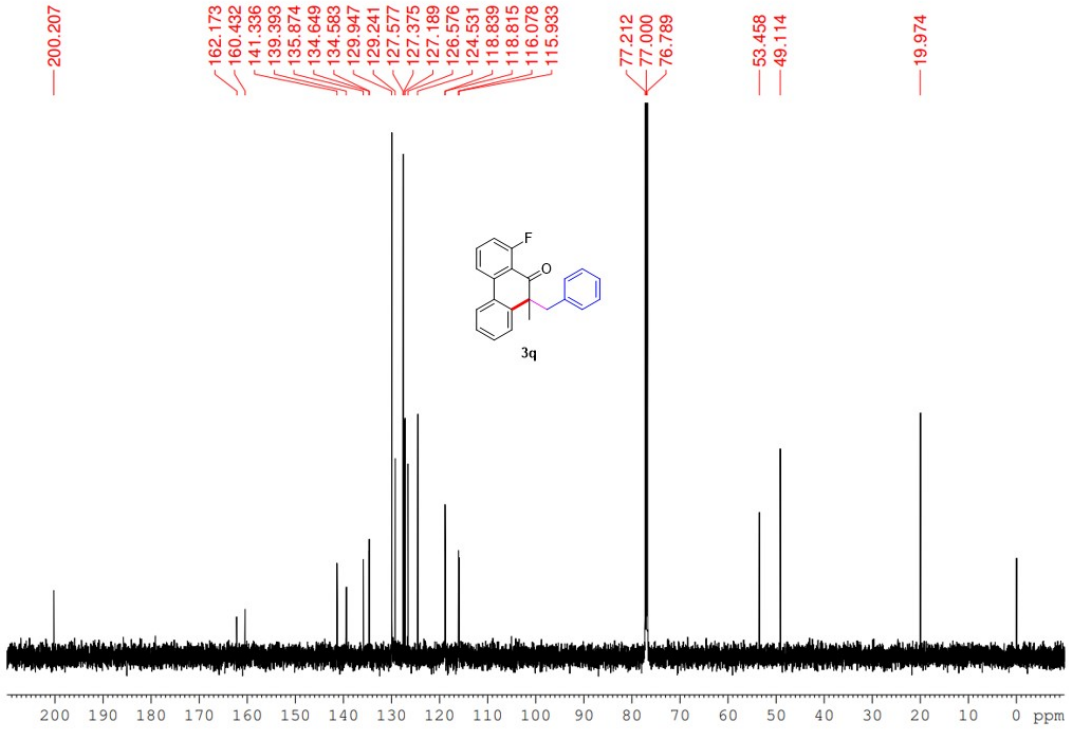

8.066
8.052
7.881
7.876
7.869
7.351
7.320
6.991
6.979
6.960
6.948
6.935
6.910
6.896
6.612
6.599
3.919
3.291
3.269
3.020
2.998
1.642
3o
1.000
1.036
4.123
0.958
2.078
1.122
2.064
3.029
1.074
1.080
3.189
9
8
7
6
5
4
3
2
1
0
ppm

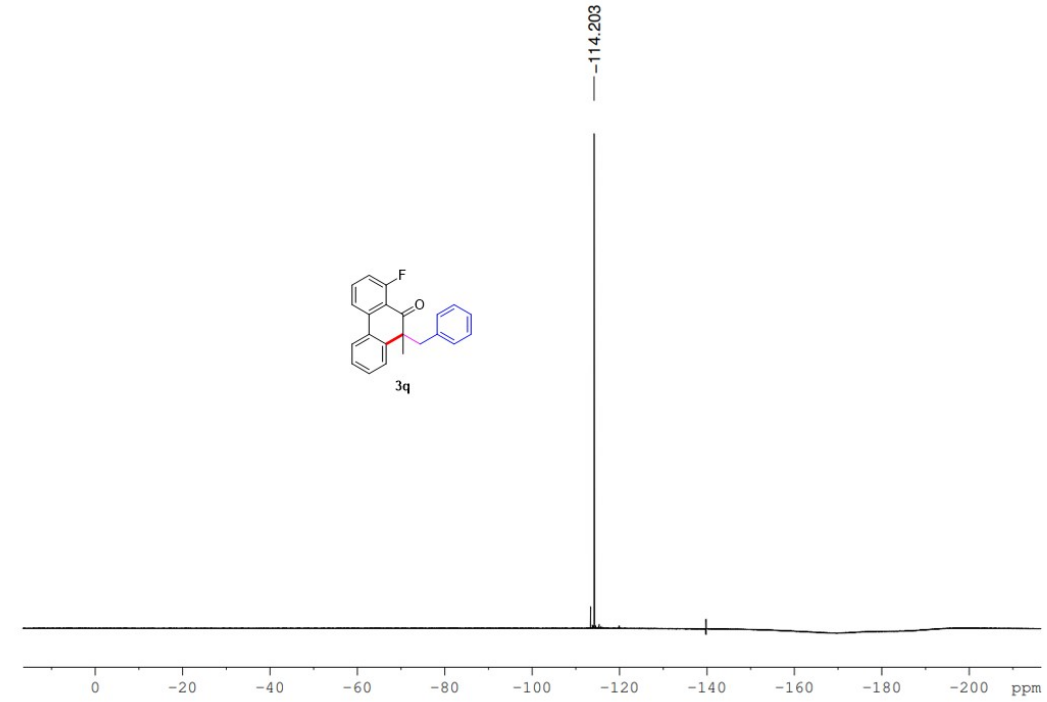

200.592
164.424
142.308
139.132
136.458
130.221
129.865
129.821
128.729
127.675
127.349
126.980
126.209
123.545
123.342
113.996
107.249
77.211
77.000
76.788
55.483
51.923
49.520
23.981
3o
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

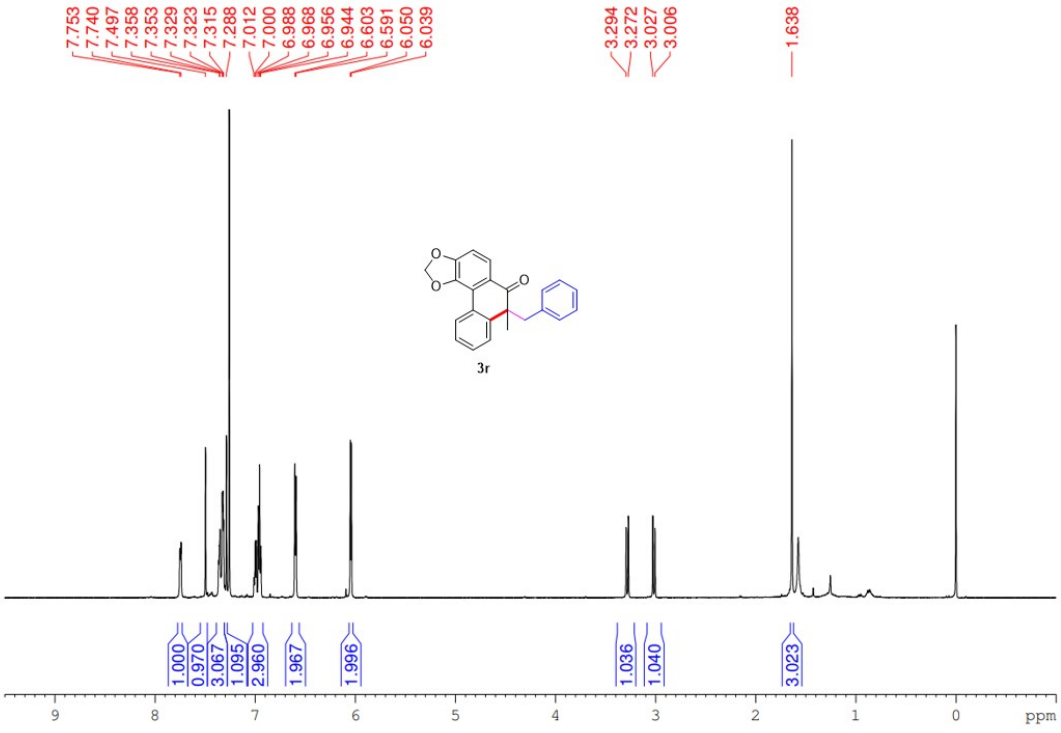

7.915
7.902
7.869
7.816
7.802
7.423
7.410
7.348
7.342
7.335
7.302
7.296
7.023
7.011
6.997
6.986
6.973
6.641
6.628
3.251
3.229
3.016
2.994
2.421
1.631
O
3p
1.089
1.046
0.824
1.024
1.106
1.374
3.135
2.000
1.132
1.135
2.905
3.591
9
8
7
6
5
4
3
2
1
0 ppm

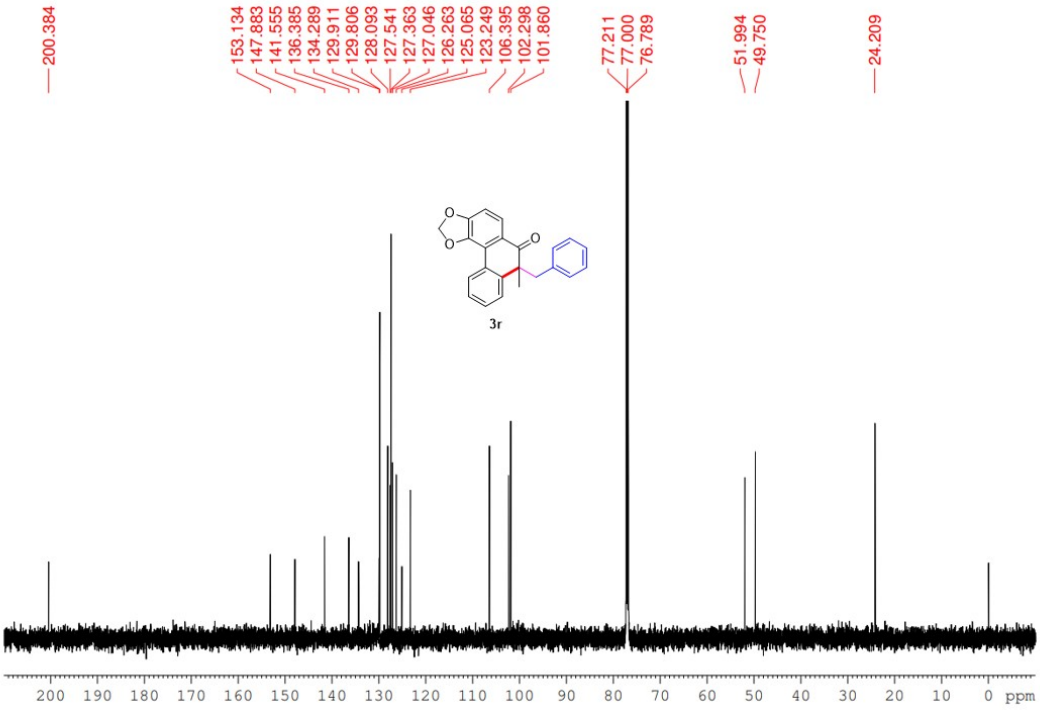

202.458
141.304
138.034
136.370
135.136
134.506
130.109
129.979
129.290
128.166
127.676
127.539
127.400
127.061
126.281
123.435
122.780
77.211
77.000
76.788
52.394
49.122
23.142
21.076
O
3p
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

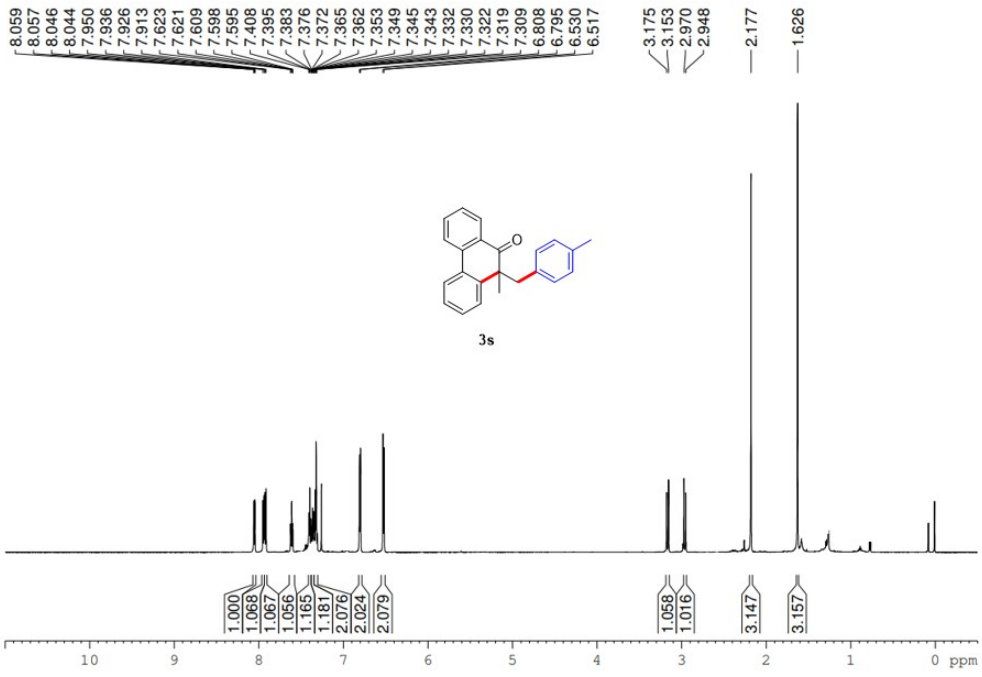

7.892
7.879
7.676
7.663
7.560
7.547
7.538
7.524
7.382
7.370
7.357
7.346
7.333
7.321
7.241
7.092
7.077
7.060
7.047
7.035
6.674
6.662
3.074
3.052
3.001
2.979
1.589
F
O
3q
1.000
1.028
1.172
2.314
1.115
4.152
2.008
1.064
1.026
3.062
9
8
7
6
5
4
3
2
1
0
ppm

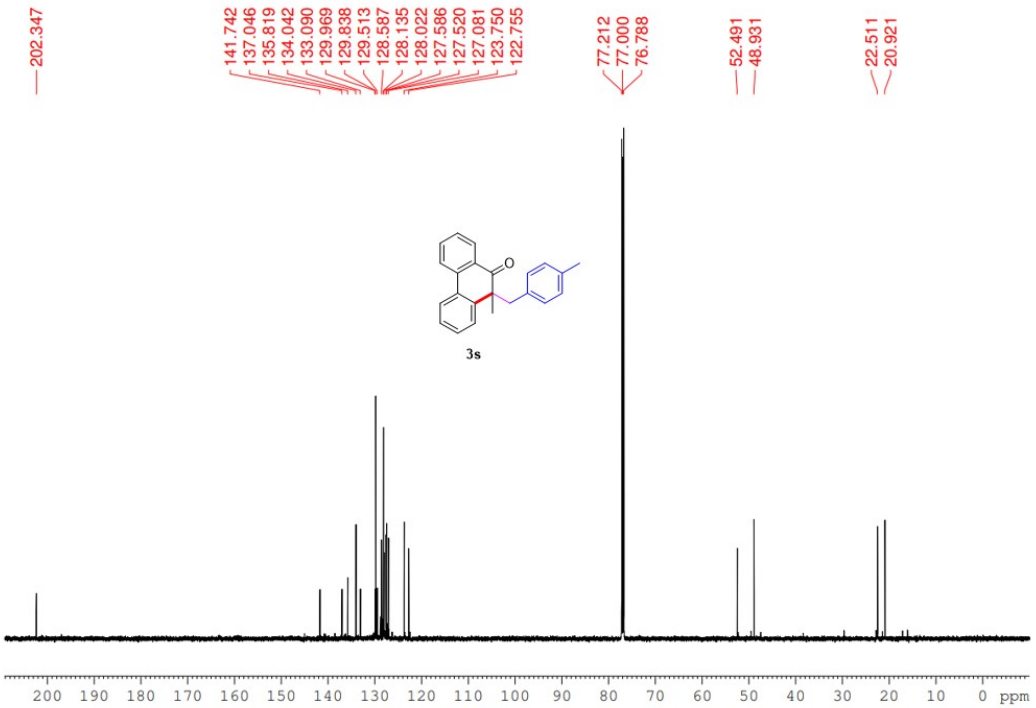

200.207
162.173
160.432
141.336
139.393
135.874
134.649
134.583
129.947
129.241
127.577
127.375
127.189
126.576
124.531
118.839
118.815
116.078
115.933
77.212
77.000
76.789
53.458
49.114
19.974
F
O
3q
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

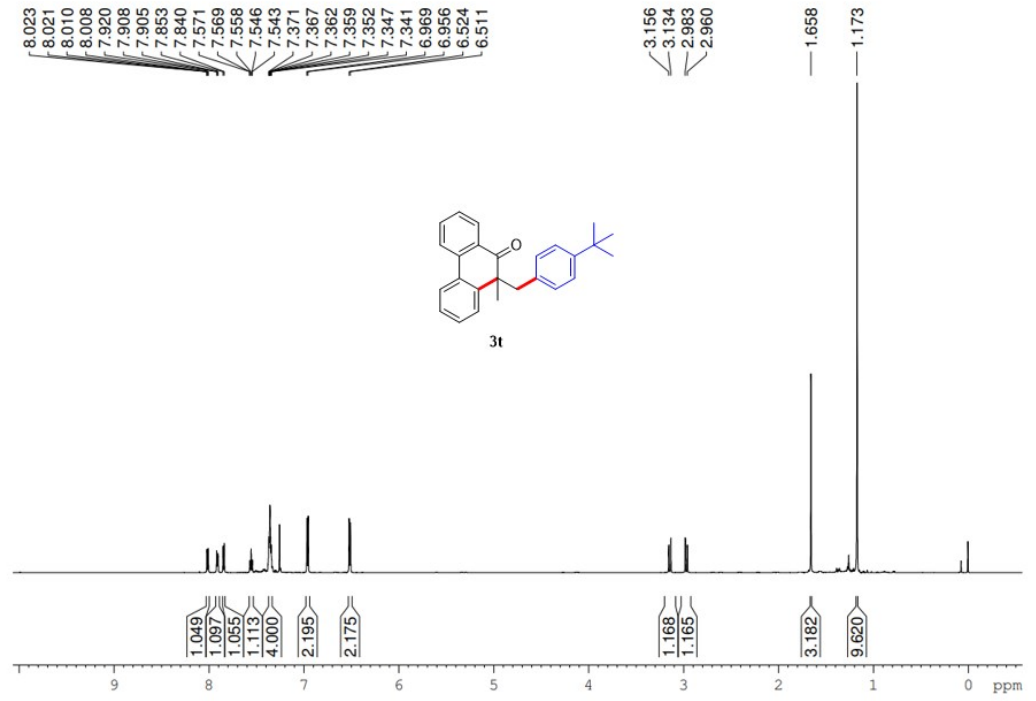

114.203
F
O
3q
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
ppm

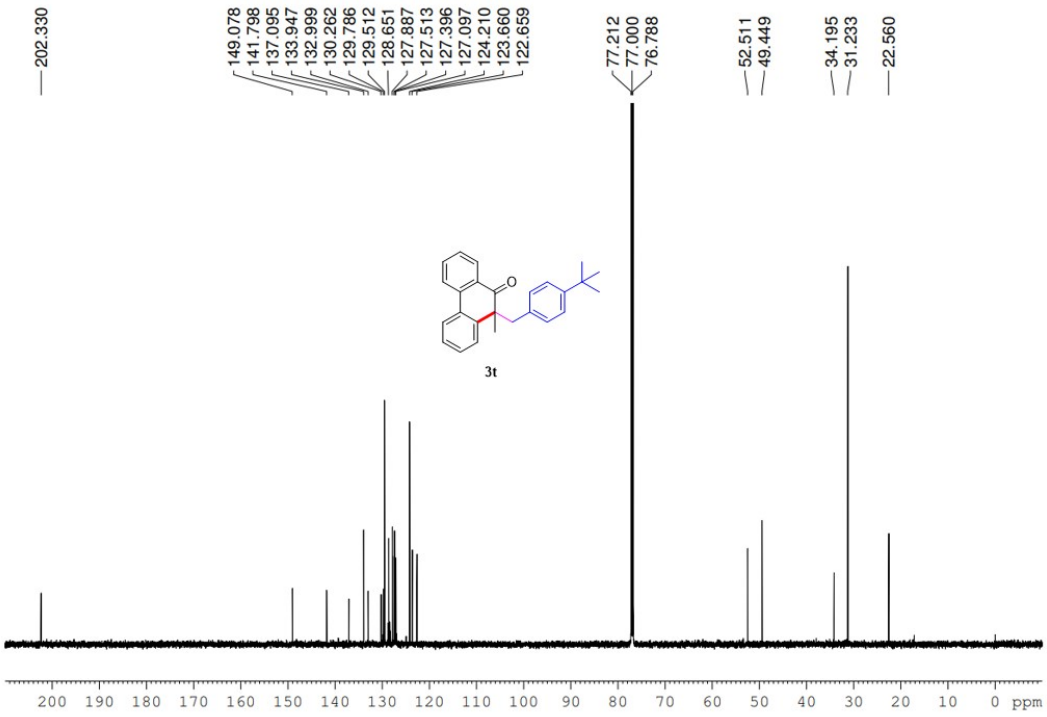

7.753
7.740
7.497
7.358
7.353
7.329
7.323
7.315
7.288
7.012
7.000
6.988
6.968
6.956
6.944
6.603
6.591
6.050
6.039
3.294
3.272
3.027
3.006
1.638
O
O
O
3r
1.000
0.970
3.067
1.095
2.960
1.967
1.996
1.036
1.040
3.023
9
8
7
6
5
4
3
2
1
0
ppm

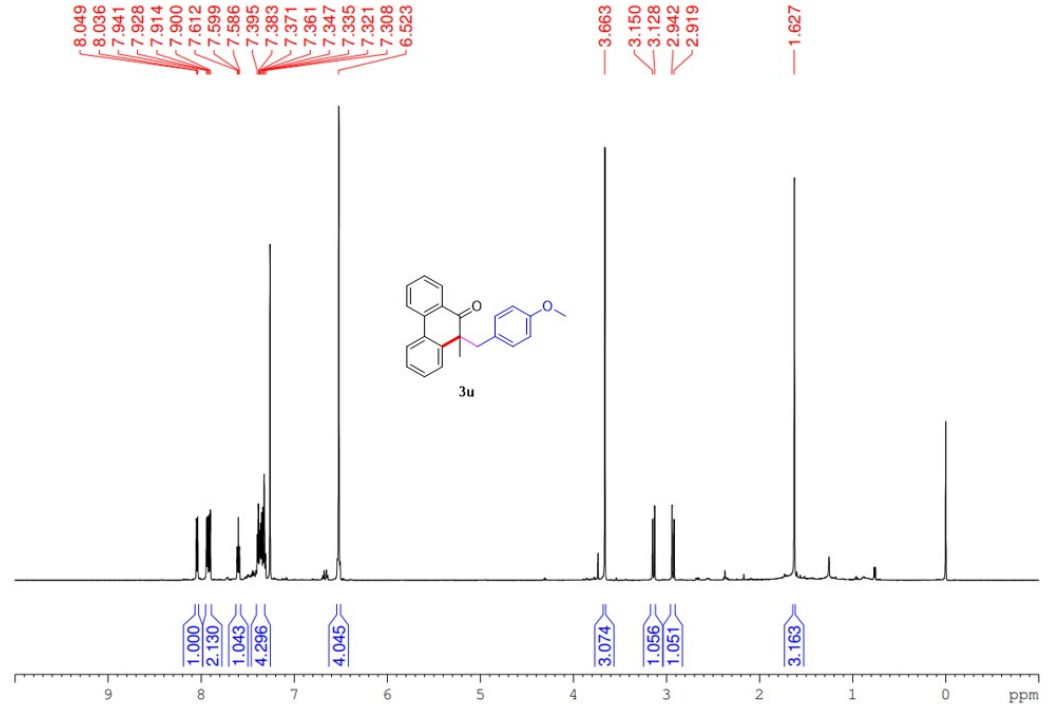

200.384
153.134
147.883
141.555
136.385
134.289
129.911
129.806
128.093
127.541
127.363
127.046
126.263
125.065
123.249
106.395
102.298
101.860
77.211
77.000
76.789
51.994
49.750
24.209
3r
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

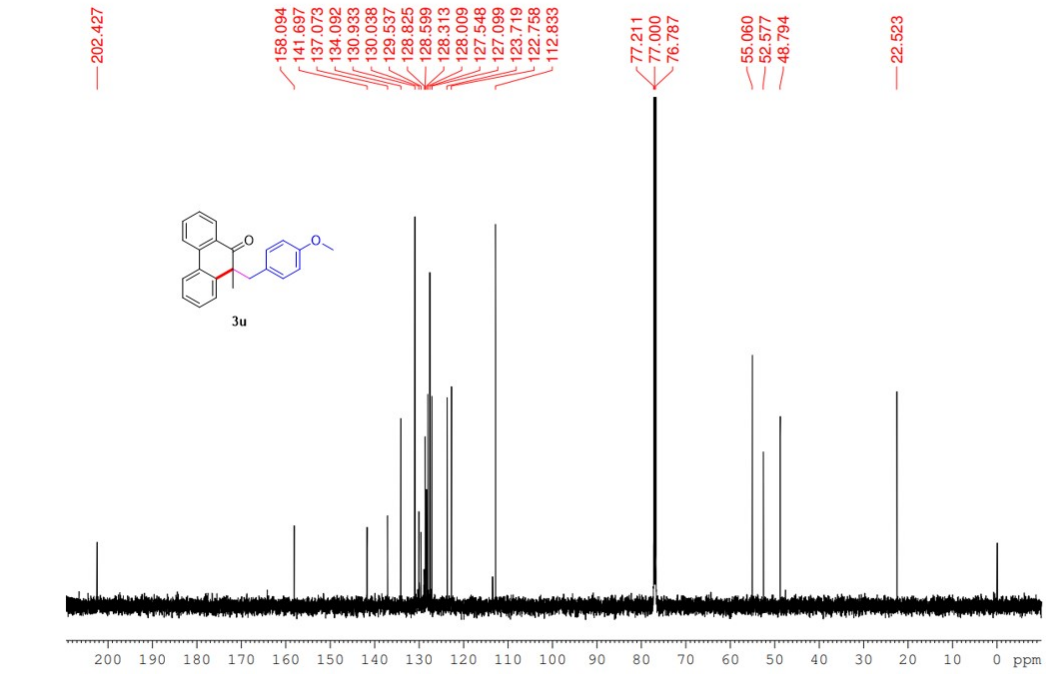

8.059
8.057
8.046
8.044
7.950
7.936
7.926
7.913
7.623
7.621
7.609
7.598
7.595
7.408
7.395
7.383
7.376
7.372
7.365
7.362
7.353
7.349
7.345
7.343
7.332
7.330
7.322
7.319
7.309
6.808
6.795
6.530
6.517
3.175
3.153
2.970
2.948
2.177
1.626
3s
1.000
1.068
1.067
1.056
1.165
1.181
2.076
2.024
2.079
1.058
1.016
3.147
3.157
10 9 8 7 6 5 4 3 2 1 0 ppm

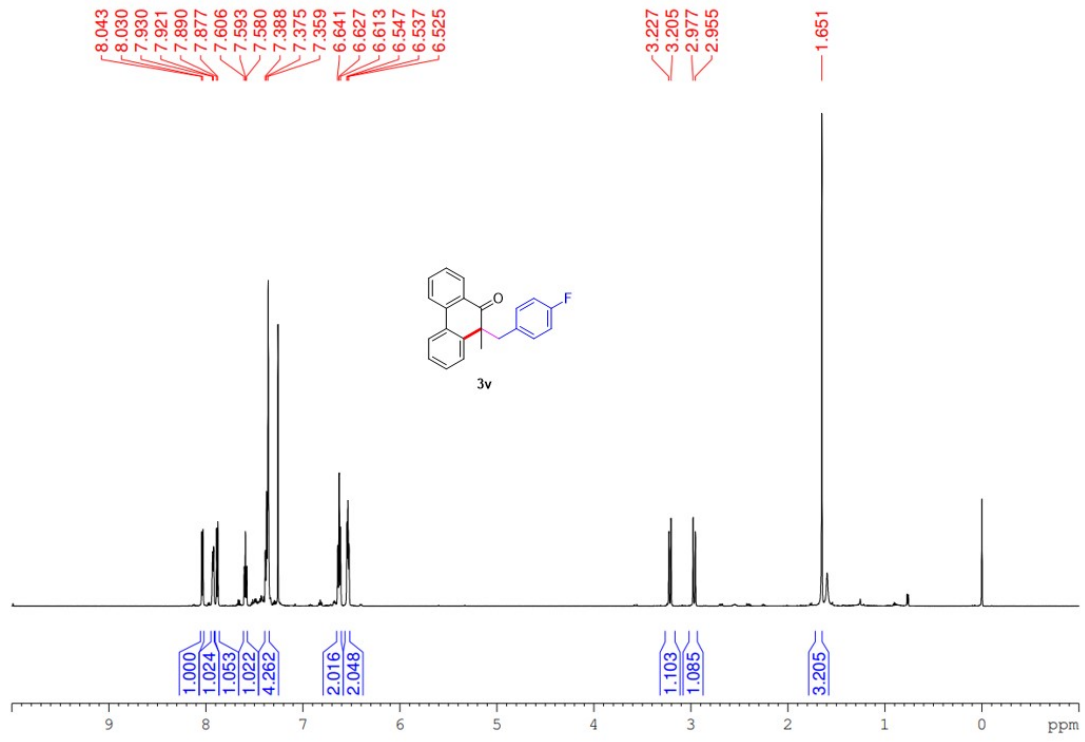

202.347
141.742
137.046
135.819
134.042
133.090
129.969
129.838
129.513
128.587
128.135
128.022
127.586
127.520
127.081
123.750
122.755
77.212
77.000
76.788
52.491
48.931
22.511
20.921
O
3s
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

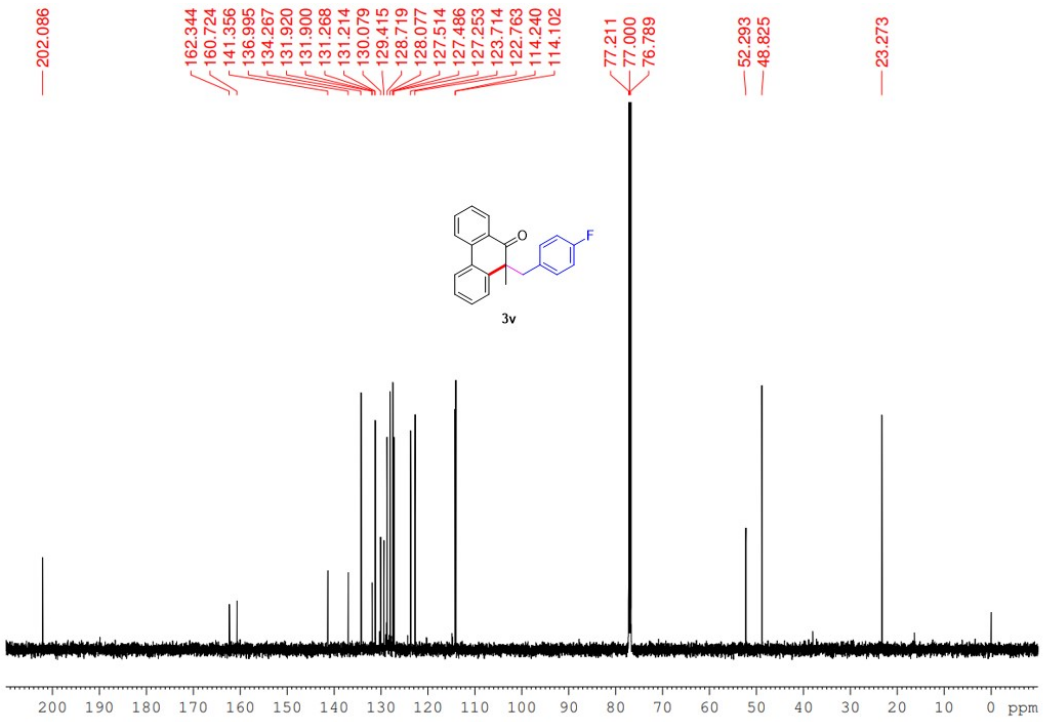

8.023
8.021
8.010
8.008
7.920
7.908
7.905
7.853
7.840
7.571
7.569
7.558
7.546
7.543
7.371
7.367
7.362
7.359
7.352
7.347
7.341
6.969
6.956
6.524
6.511
3.156
3.134
2.983
2.960
1.658
1.173
O
3t
1.049
1.097
1.055
1.113
4.000
2.195
2.175
1.168
1.165
3.182
9.620
9 8 7 6 5 4 3 2 1 0 ppm

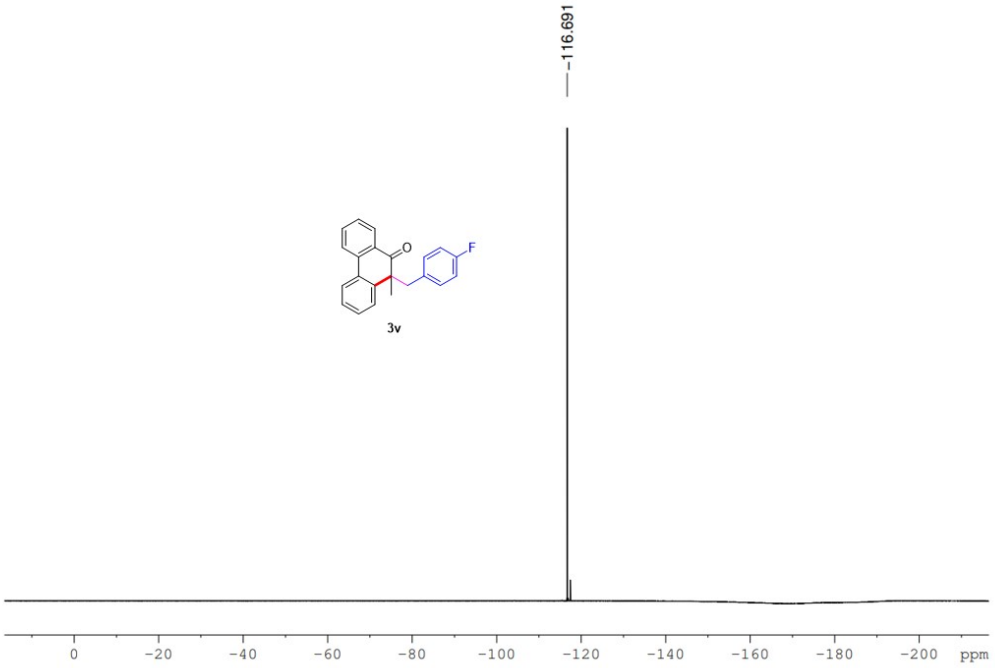

202.330
149.078
141.798
137.095
133.947
132.999
130.262
129.786
129.512
128.651
127.887
127.513
127.396
127.097
124.210
123.660
122.659
77.212
77.000
76.788
52.511
49.449
34.195
31.233
22.560
3t
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

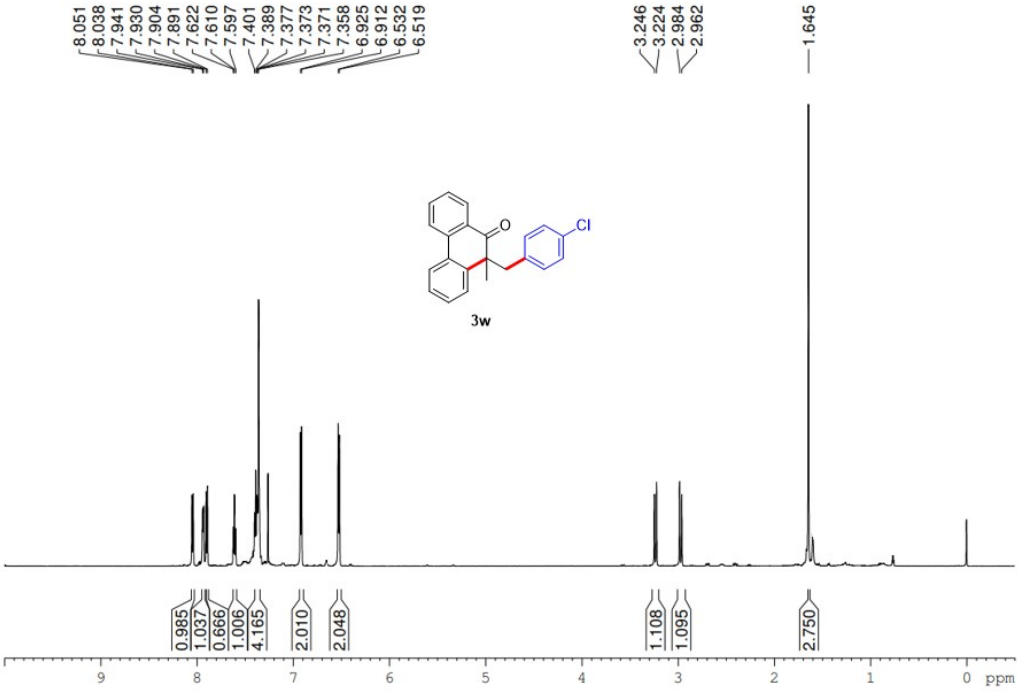

8.049
8.036
7.941
7.928
7.914
7.900
7.612
7.599
7.586
7.395
7.383
7.371
7.361
7.347
7.335
7.321
7.308
6.523
3.663
3.150
3.128
2.942
2.919
1.627
3u
1.000
2.130
1.043
4.296
4.045
3.074
1.056
1.051
3.163
9 8 7 6 5 4 3 2 1 0 ppm

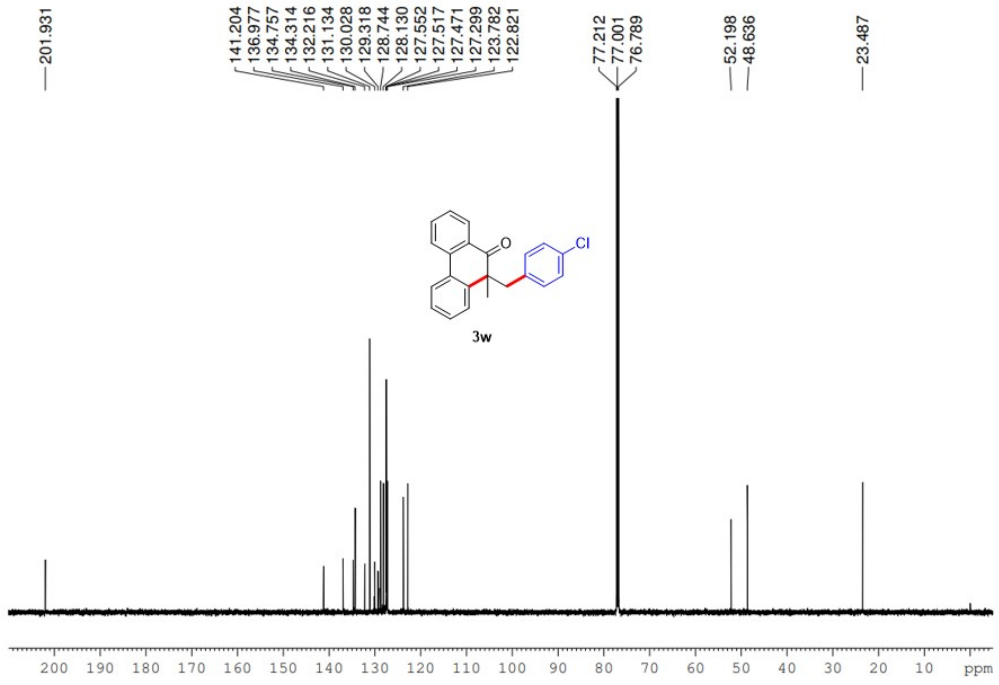

202.427
158.094
141.697
137.073
134.092
130.933
130.038
129.537
128.825
128.599
128.313
128.009
127.548
127.099
123.719
122.758
112.833
77.211
77.000
76.787
55.060
52.577
48.794
22.523
O
O
3u
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

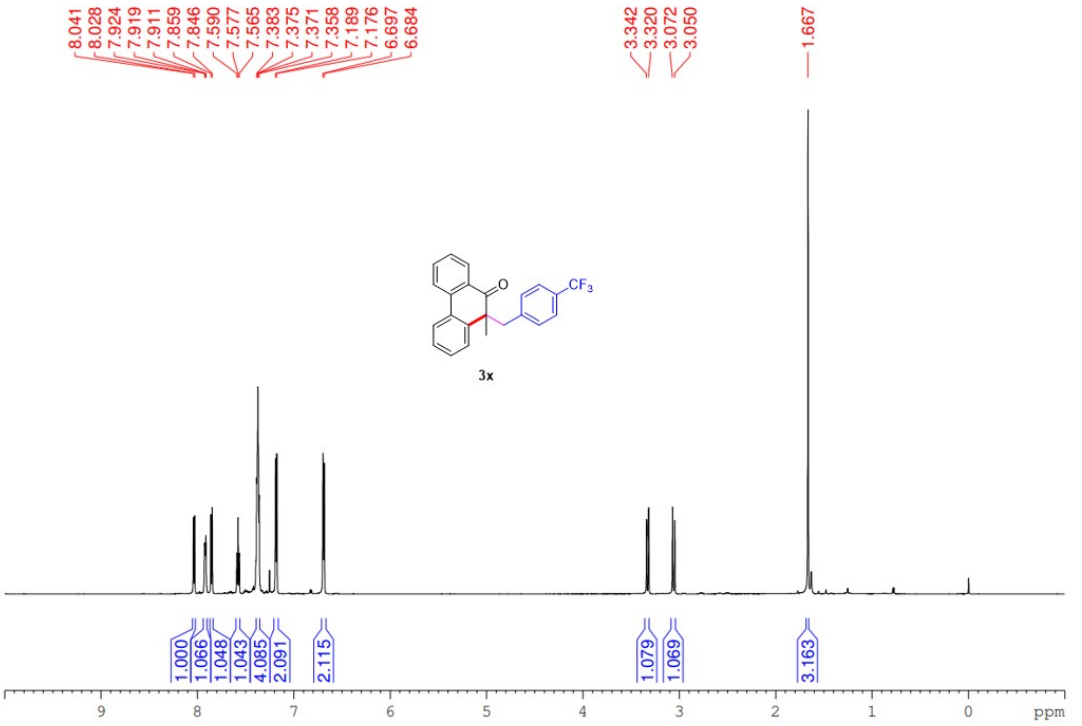

8.043
8.030
7.930
7.921
7.890
7.877
7.606
7.593
7.580
7.388
7.375
7.359
6.641
6.627
6.613
6.547
6.537
6.525
3.227
3.205
2.977
2.955
1.651
O
F
3v
1.000
1.024
1.053
1.022
4.262
2.016
2.048
1.103
1.085
3.205
9 8 7 6 5 4 3 2 1 0 ppm

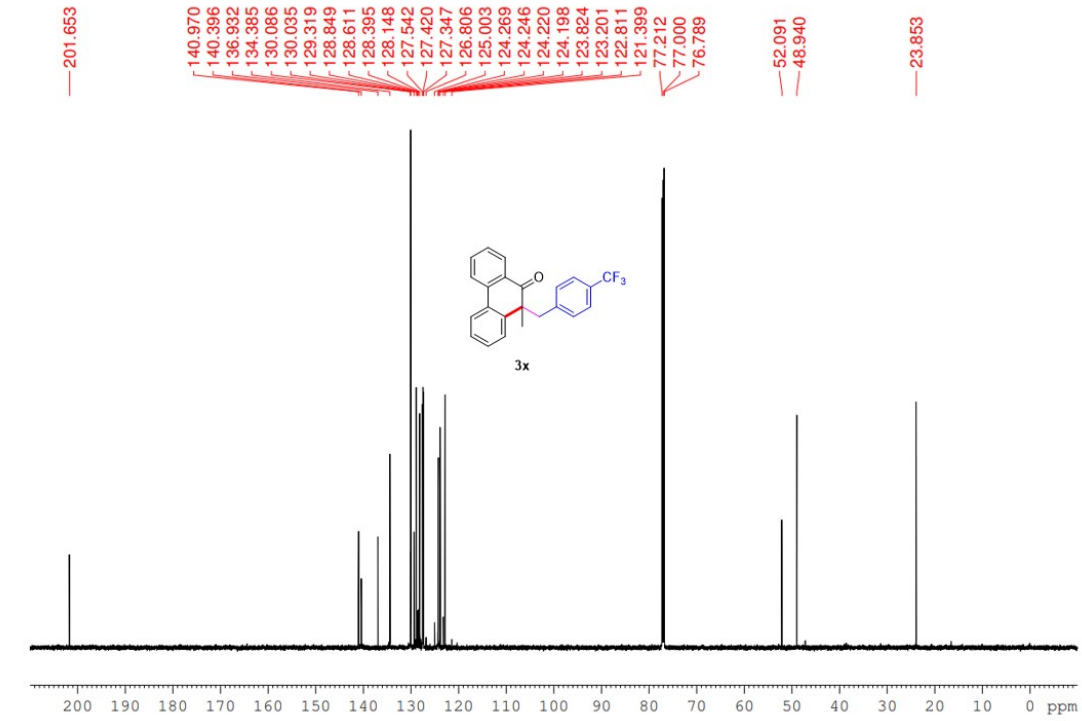

202.086
162.344
160.724
141.356
136.995
134.267
131.920
131.900
131.268
131.214
130.079
129.415
128.719
128.077
127.514
127.486
127.253
123.714
122.763
114.240
114.102
77.211
77.000
76.789
52.293
48.825
23.273
O
F
3v
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

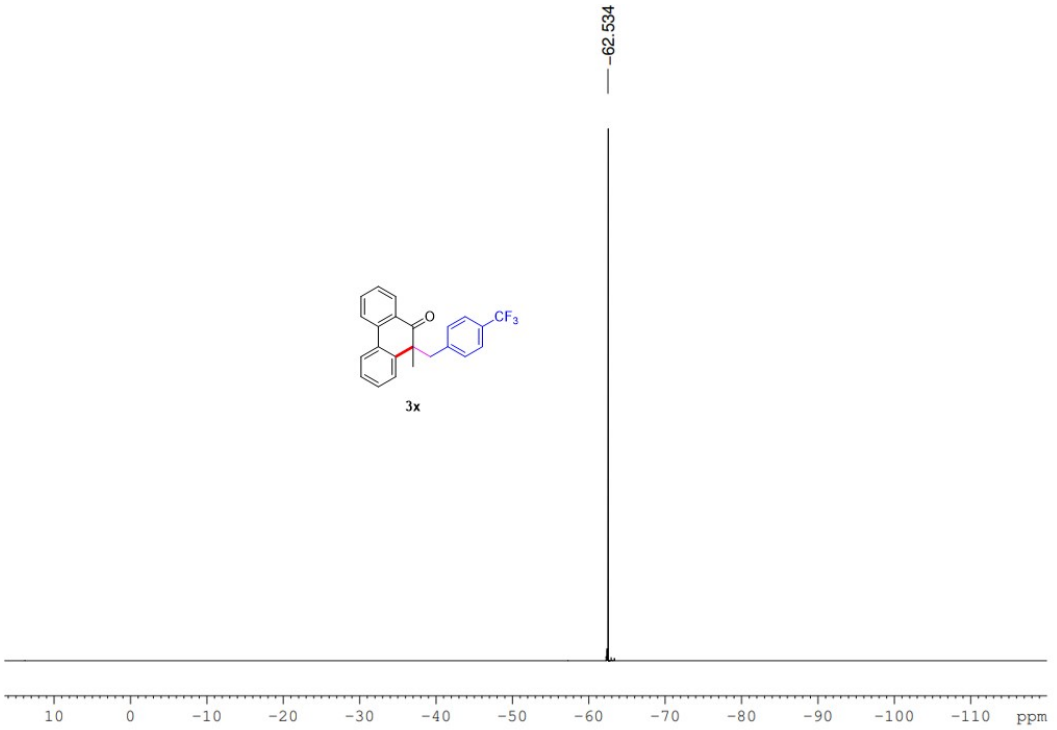

-116.691
O
F
3v
0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 ppm

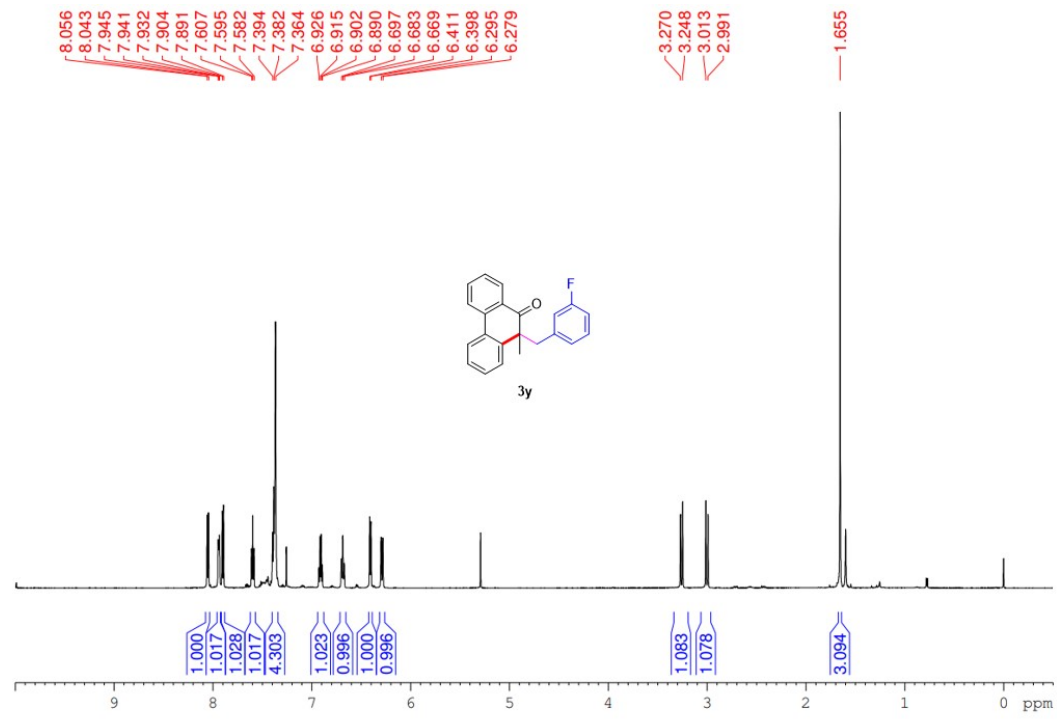

8.051
8.038
7.941
7.930
7.904
7.891
7.622
7.610
7.597
7.401
7.389
7.377
7.373
7.371
7.358
6.925
6.912
6.532
6.519
3.246
3.224
2.984
2.962
1.645
O
Cl
3w
0.985
1.037
0.666
1.006
4.165
2.010
2.048
1.108
1.095
2.750
9
8
7
6
5
4
3
2
1
0 ppm

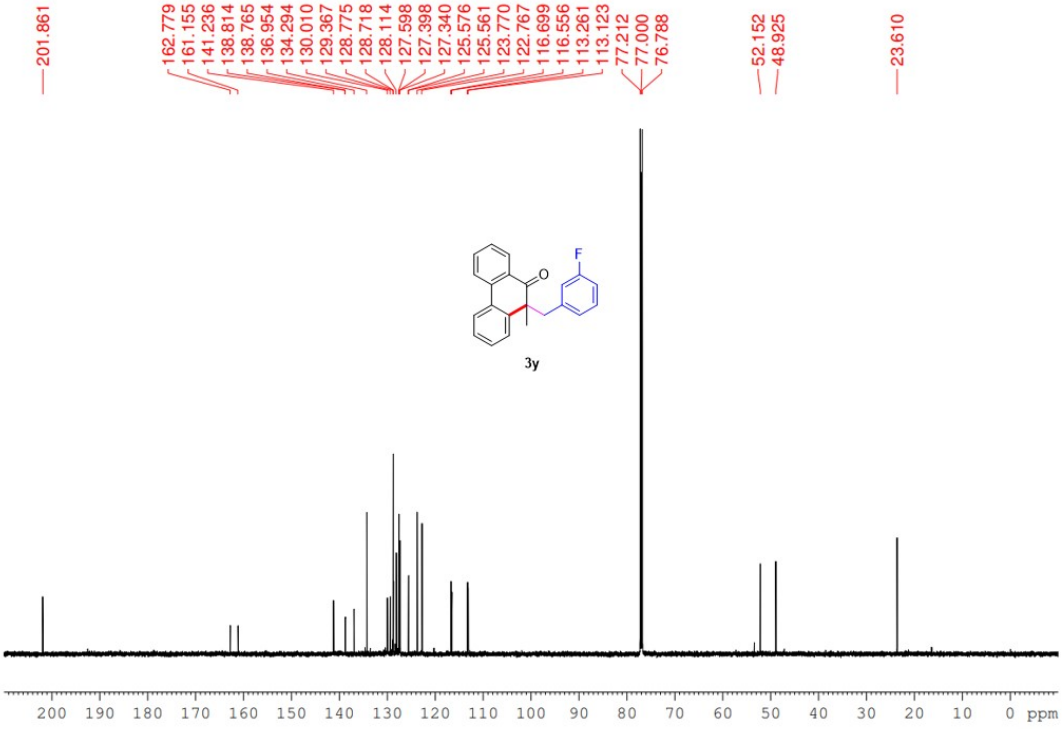

201.931
141.204
136.977
134.757
134.314
132.216
131.134
130.028
129.318
128.744
128.130
127.552
127.517
127.471
127.299
123.782
122.821
77.212
77.001
76.789
52.198
48.636
23.487
O
Cl
3w
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

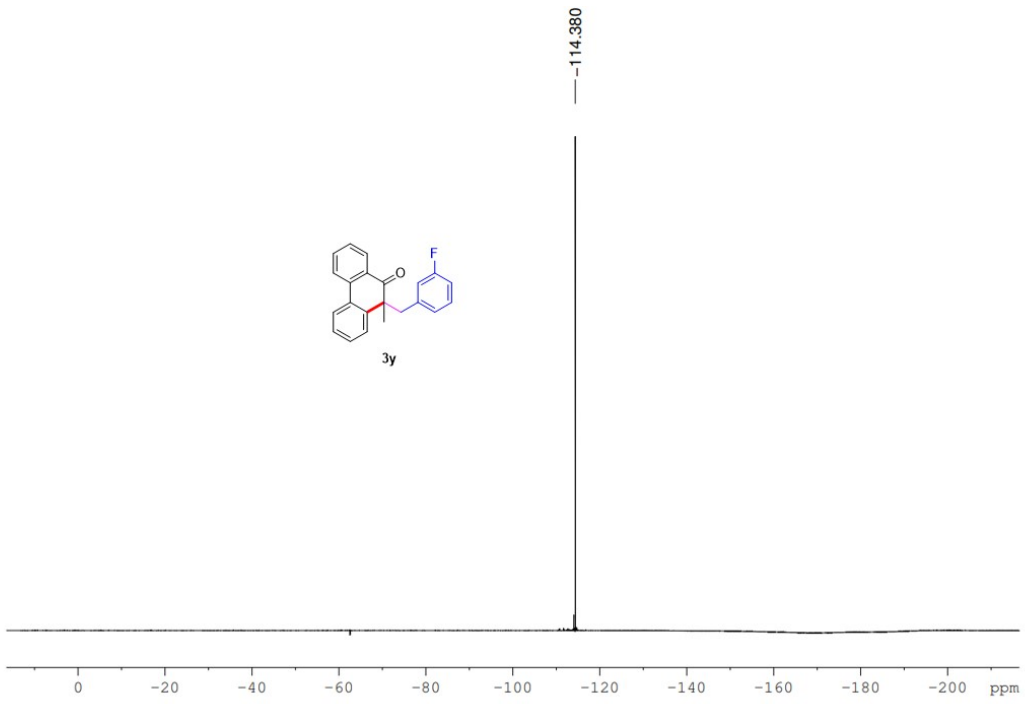

8.041
8.028
7.924
7.919
7.911
7.859
7.846
7.590
7.577
7.565
7.383
7.375
7.371
7.358
7.189
7.176
6.697
6.684
3.342
3.320
3.072
3.050
1.667
O
CF3
3x
1.000
1.066
1.048
1.043
4.085
2.091
2.115
1.079
1.069
3.163
9
8
7
6
5
4
3
2
1
0
ppm

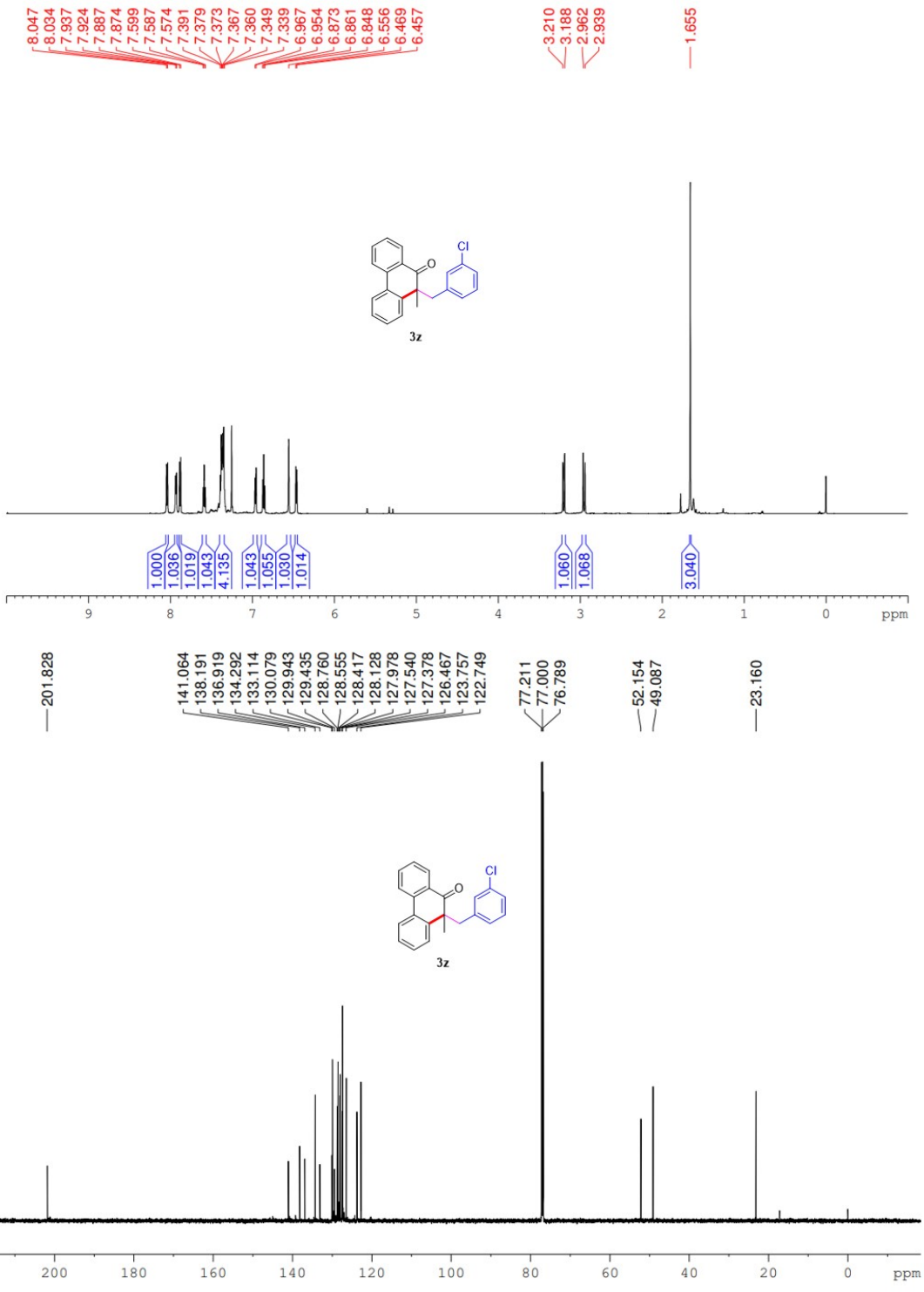

201.653
140.970
140.396
136.932
134.385
130.086
130.035
129.319
128.849
128.611
128.395
128.148
127.542
127.420
127.347
126.806
125.003
124.269
124.246
124.220
124.198
123.824
123.201
122.811
121.399
77.212
77.000
76.789
52.091
48.940
23.853
O
CF3
3x
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

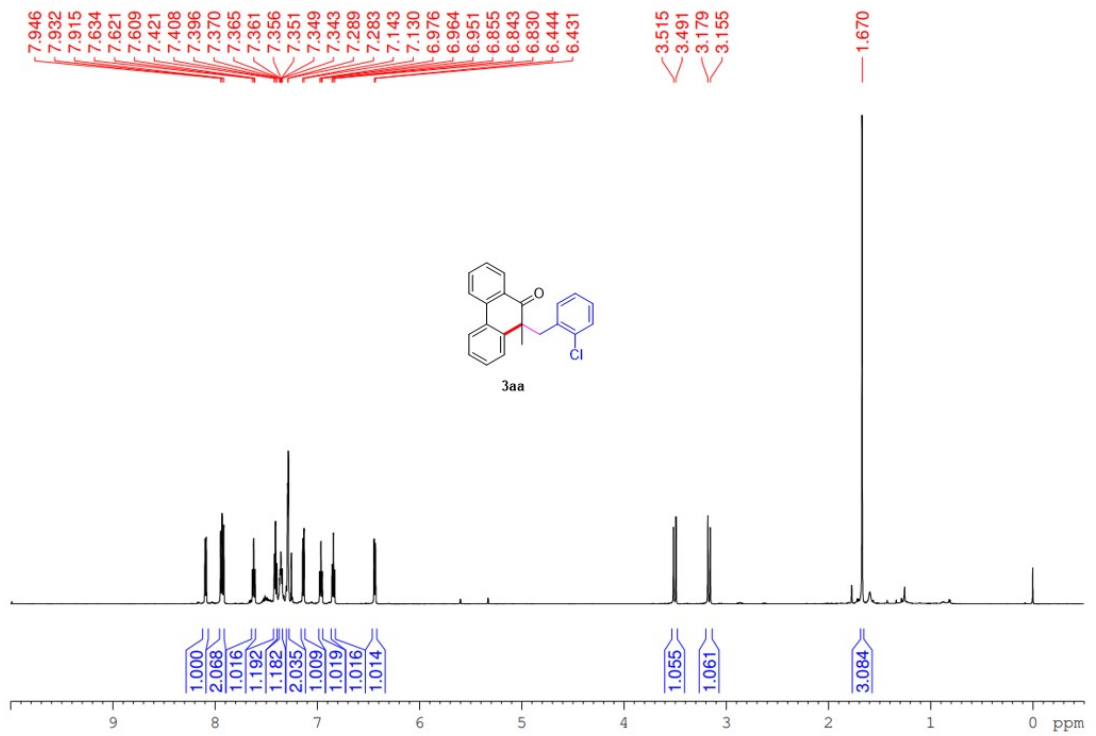

-62.534
O
CF3
3x
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
ppm

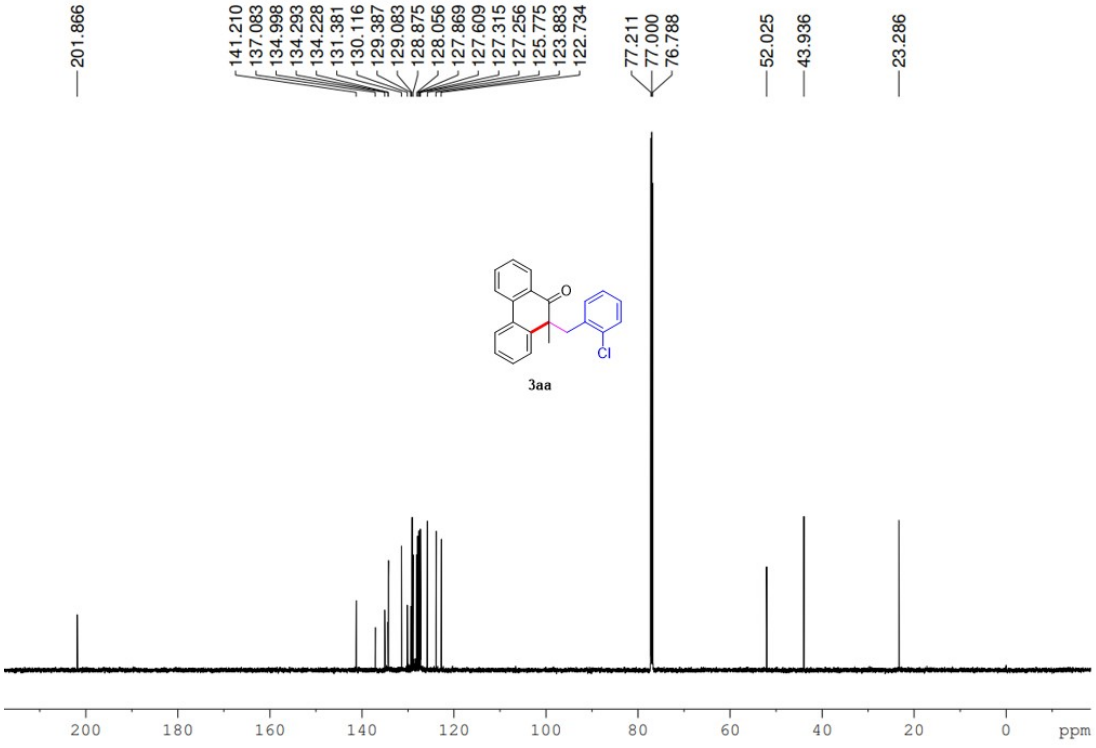

8.056
8.043
7.945
7.941
7.932
7.904
7.891
7.607
7.595
7.582
7.394
7.382
7.364
6.926
6.915
6.902
6.890
6.697
6.683
6.669
6.411
6.398
6.295
6.279
3.270
3.248
3.013
2.991
1.655
O
F
3y
1.000
1.017
1.028
1.017
4.303
1.023
0.996
1.000
0.996
1.083
1.078
3.094
9
8
7
6
5
4
3
2
1
0
ppm

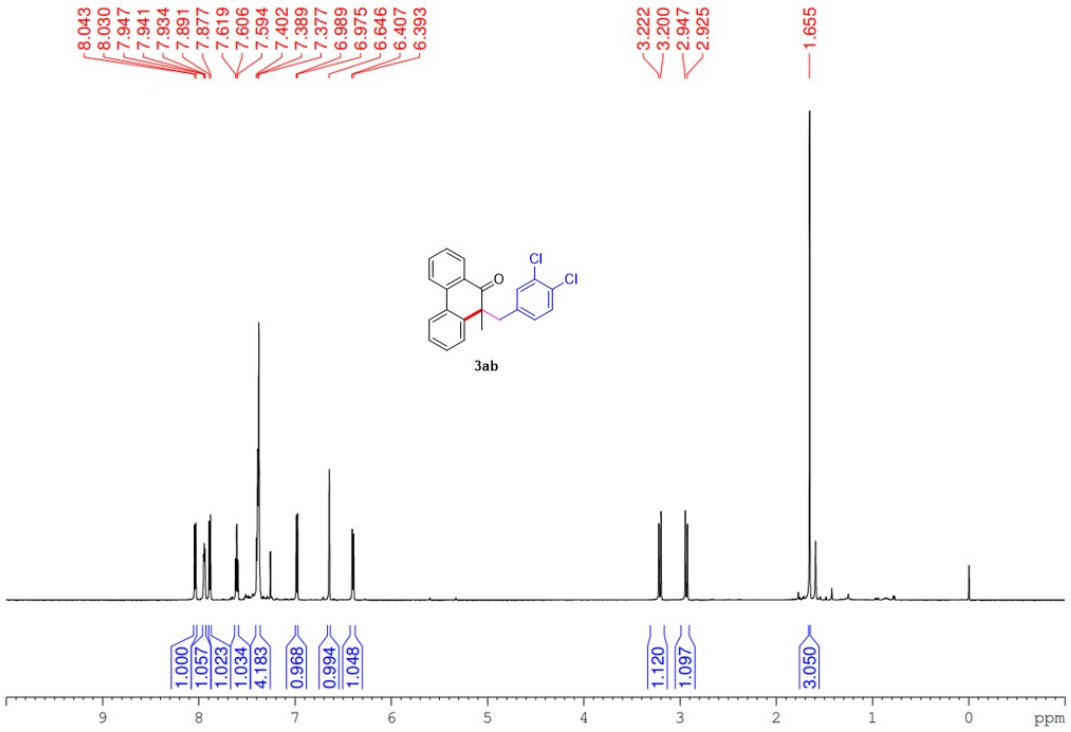

201.861
162.779
161.155
141.236
138.814
138.765
136.954
134.294
130.010
129.367
128.775
128.718
128.114
127.598
127.398
127.340
125.576
125.561
123.770
122.767
116.699
116.556
113.261
113.123
77.212
77.000
76.788
52.152
48.925
23.610
F
O
3y
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

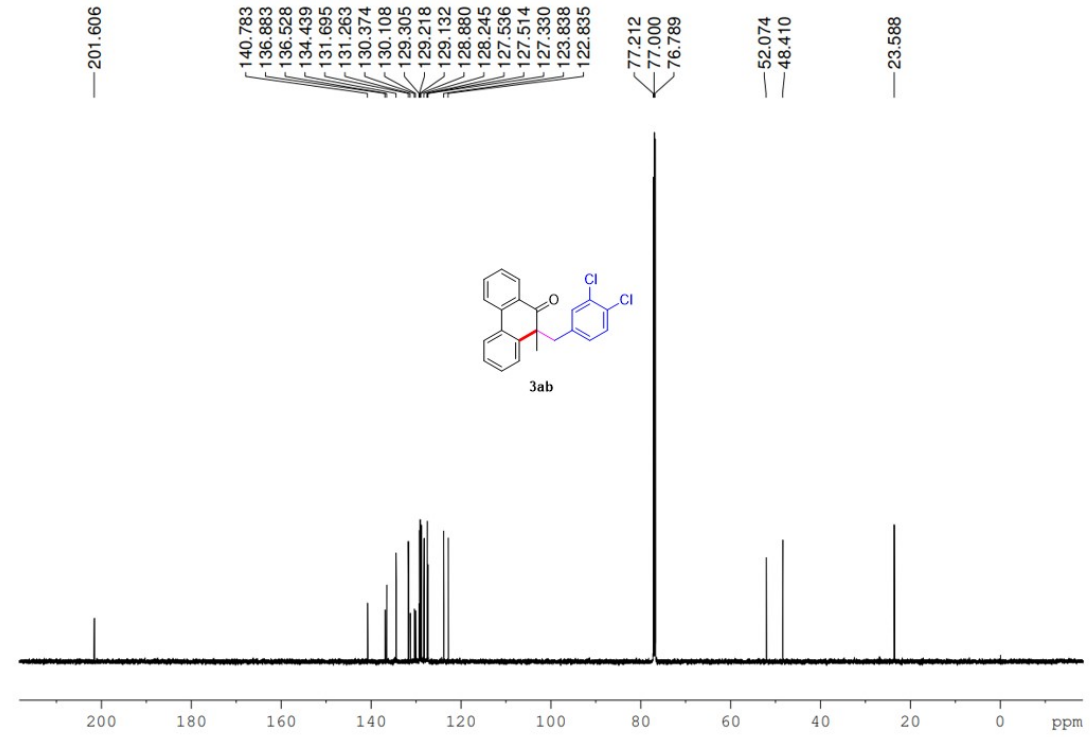

-114.380
F
O
3y
0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 ppm

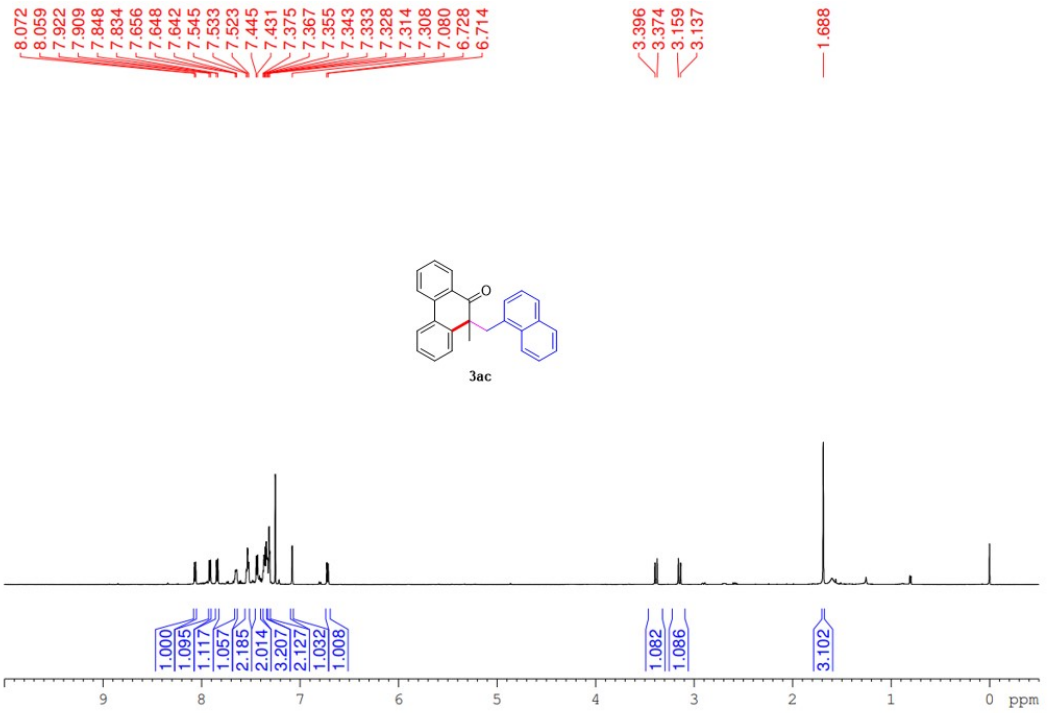

8.047
8.034
7.937
7.924
7.887
7.874
7.599
7.587
7.574
7.391
7.379
7.373
7.367
7.360
7.349
7.339
6.967
6.954
6.873
6.861
6.848
6.556
6.469
6.457
3.210
3.188
2.962
2.939
1.655
Cl
O
3z
1.000
1.036
1.019
1.043
4.135
1.043
1.055
1.030
1.014
1.060
1.068
3.040
9
8
7
6
5
4
3
2
1
0
ppm
201.828
141.064
138.191
136.919
134.292
133.114
130.079
129.943
129.435
128.760
128.555
128.417
128.128
127.978
127.540
127.378
126.467
123.757
122.749
77.211
77.000
76.789
52.154
49.087
23.160
Cl
O
3z
200
180
160
140
120
100
80
60
40
20
0
ppm

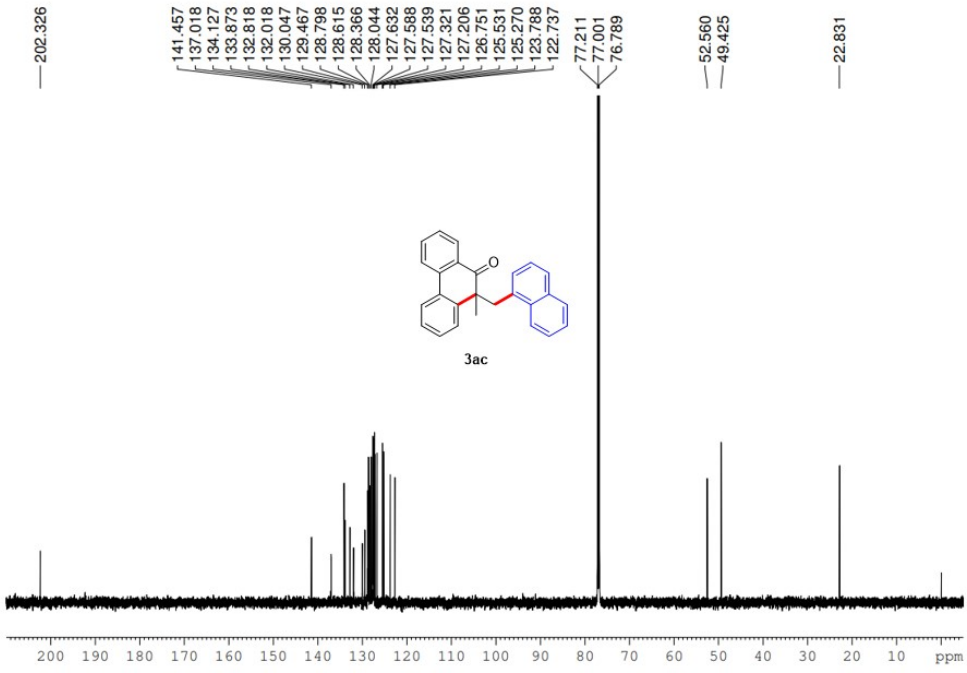

7.946
7.932
7.915
7.634
7.621
7.609
7.421
7.408
7.396
7.370
7.365
7.361
7.356
7.351
7.349
7.343
7.289
7.283
7.143
7.130
6.976
6.964
6.951
6.855
6.843
6.830
6.444
6.431
3.515
3.491
3.179
3.155
1.670
O
Cl
3aa
1.000
2.068
1.016
1.192
1.182
2.035
1.009
1.019
1.016
1.014
1.055
1.061
3.084
9
8
7
6
5
4
3
2
1
0
ppm

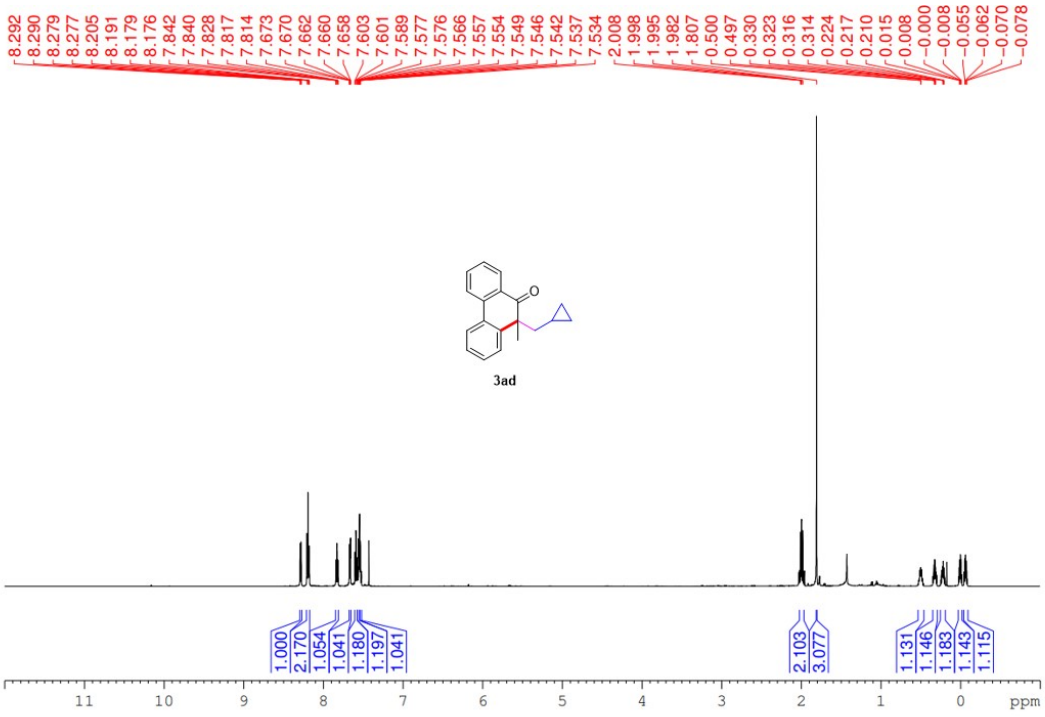

201.866
141.210
137.083
134.998
134.293
134.228
131.381
130.116
129.387
129.083
128.875
128.056
127.869
127.609
127.315
127.256
125.775
123.883
122.734
77.211
77.000
76.788
52.025
43.936
23.286
O
Cl
3aa
200
180
160
140
120
100
80
60
40
20
0
ppm

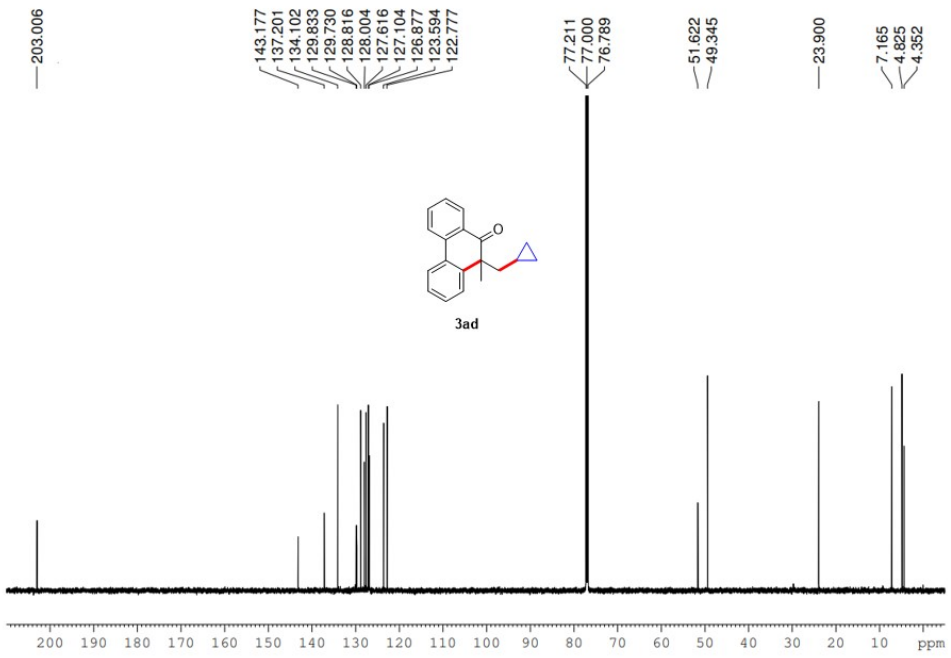

8.043
8.030
7.947
7.941
7.934
7.891
7.877
7.619
7.606
7.594
7.402
7.389
7.377
6.989
6.975
6.646
6.407
6.393
3.222
3.200
2.947
2.925
1.655
Cl
Cl
O
3ab
1.000
1.057
1.023
1.034
4.183
0.968
0.994
1.048
1.120
1.097
3.050
9
8
7
6
5
4
3
2
1
0
ppm

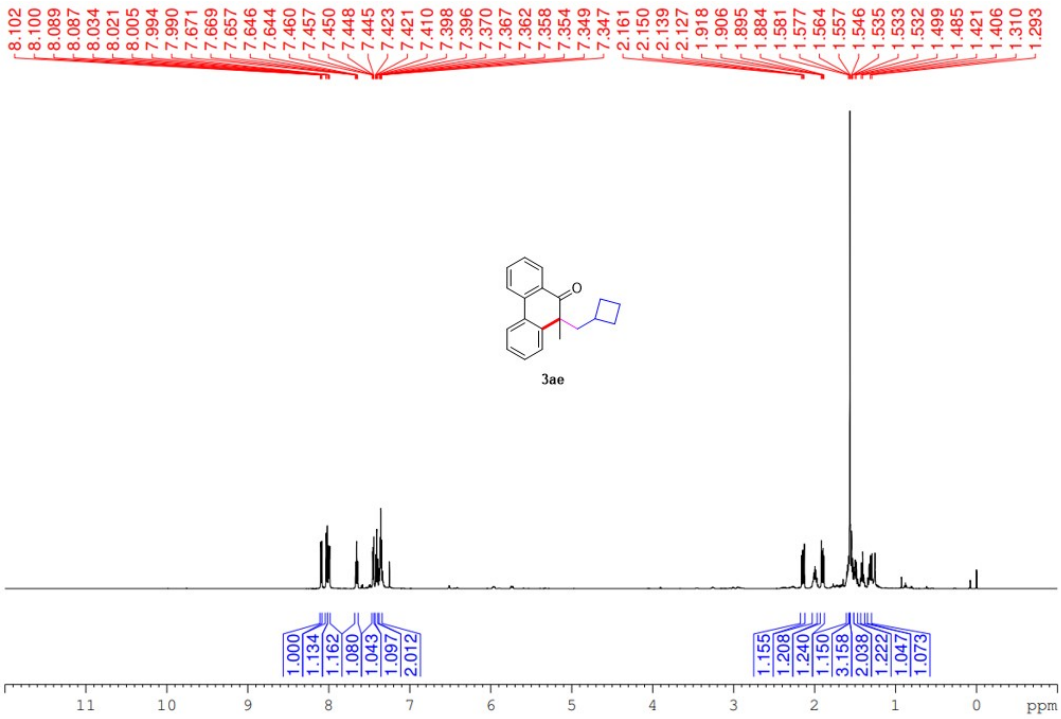

201.606
140.783
136.883
136.528
134.439
131.695
131.263
130.374
130.108
129.305
129.218
129.132
128.880
128.245
127.536
127.514
127.330
123.838
122.835
77.212
77.000
76.789
52.074
48.410
23.588
Cl
Cl
O
3ab
200
180
160
140
120
100
80
60
40
20
0
ppm

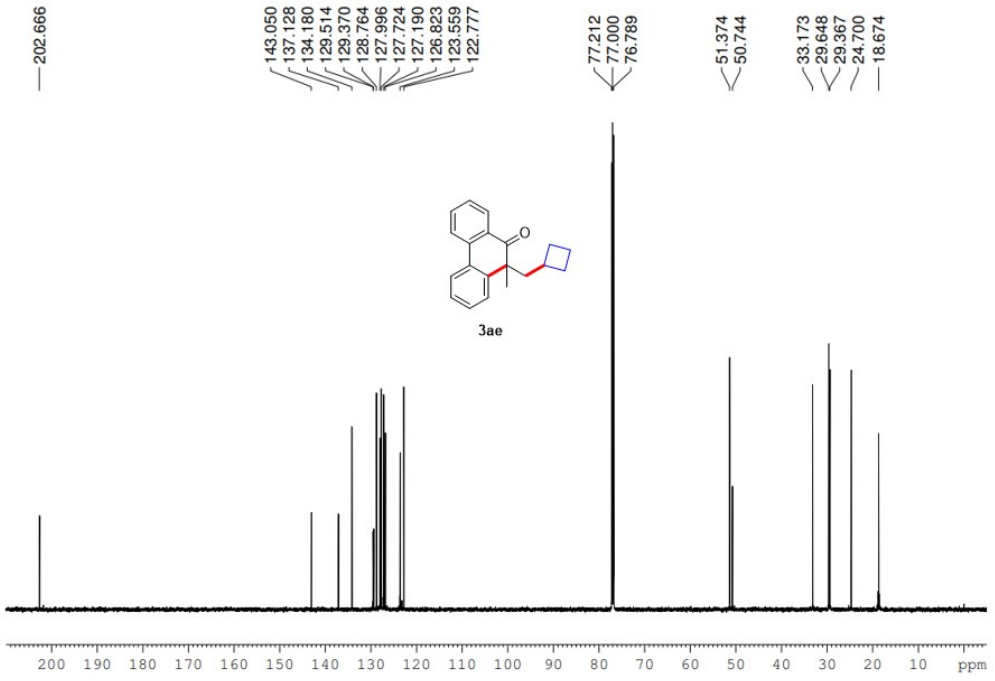

8.072
8.059
7.922
7.909
7.848
7.834
7.656
7.648
7.642
7.545
7.533
7.523
7.445
7.431
7.375
7.367
7.355
7.343
7.333
7.328
7.314
7.308
7.080
6.728
6.714
3.396
3.374
3.159
3.137
1.688
3ac
1.000
1.095
1.117
1.057
2.185
2.014
3.207
2.127
1.032
1.008
1.082
1.086
3.102
ppm

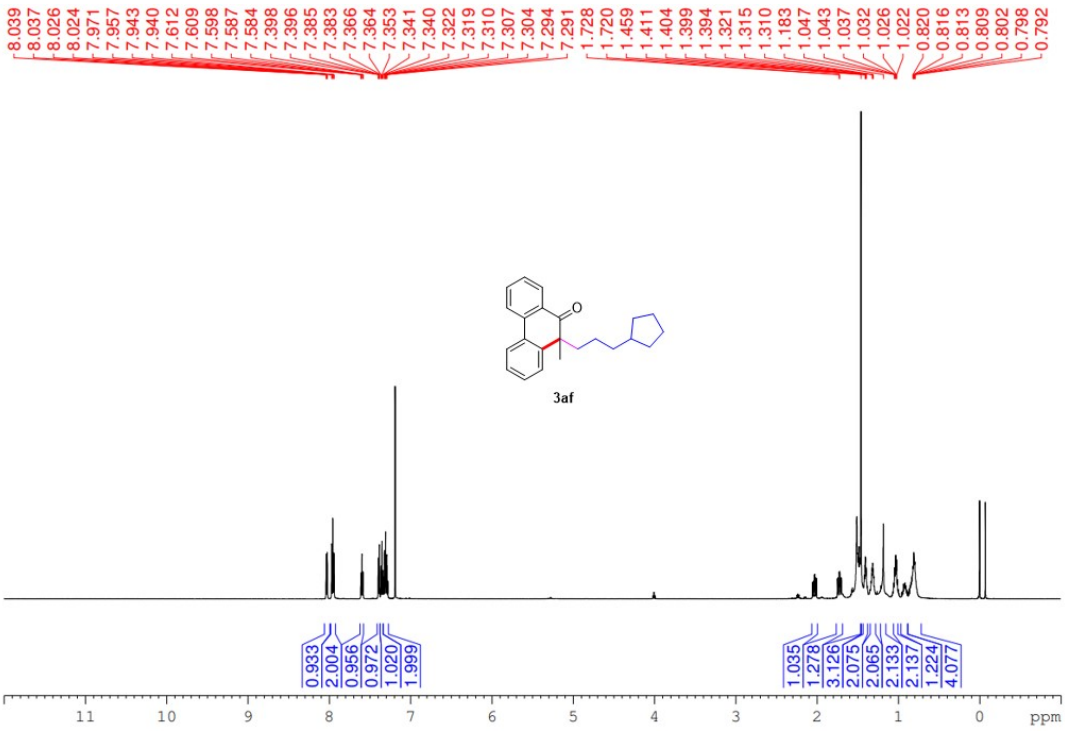

202.326
141.457
137.018
134.127
133.873
132.818
132.018
130.047
129.467
128.798
128.615
128.366
128.044
127.632
127.588
127.539
127.321
127.206
126.751
125.531
125.270
123.788
122.737
77.211
77.001
76.789
52.560
49.425
22.831
3ac
ppm

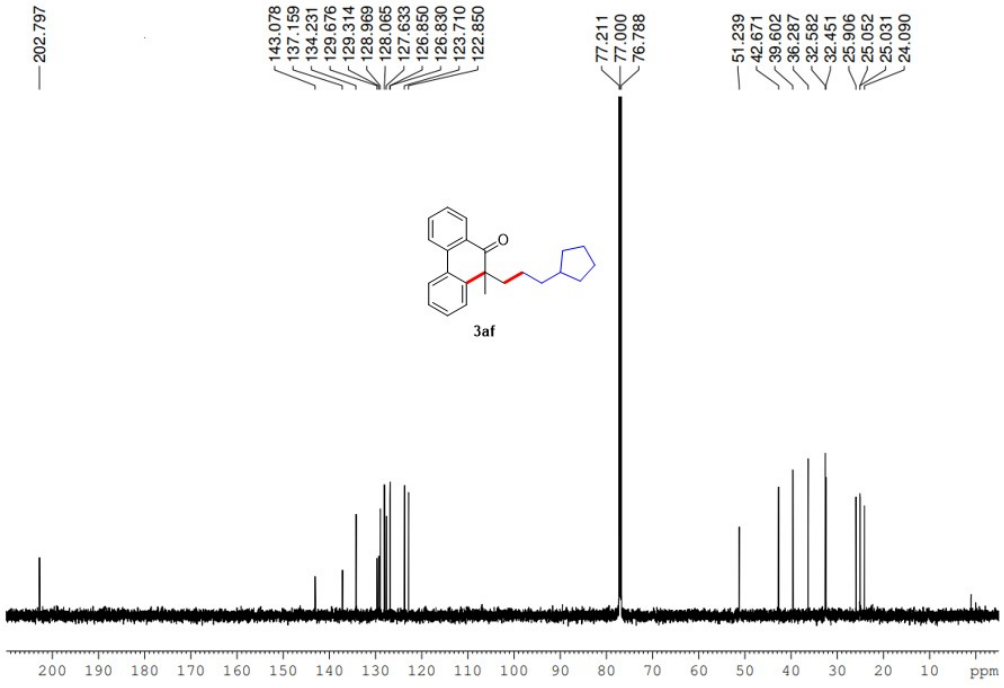

8.292
8.290
8.279
8.277
8.205
8.191
8.179
8.176
7.842
7.840
7.828
7.817
7.814
7.673
7.670
7.662
7.660
7.658
7.603
7.601
7.589
7.577
7.576
7.566
7.557
7.554
7.549
7.546
7.542
7.537
7.534
2.008
1.998
1.995
1.982
1.807
0.500
0.497
0.330
0.323
0.316
0.314
0.224
0.217
0.210
0.015
0.008
-0.000
-0.008
-0.055
-0.062
-0.070
-0.078
3ad
1.000
2.170
1.054
1.041
1.180
1.197
1.041
2.103
3.077
1.131
1.146
1.183
1.143
1.115
11
10
9
8
7
6
5
4
3
2
1
0
ppm

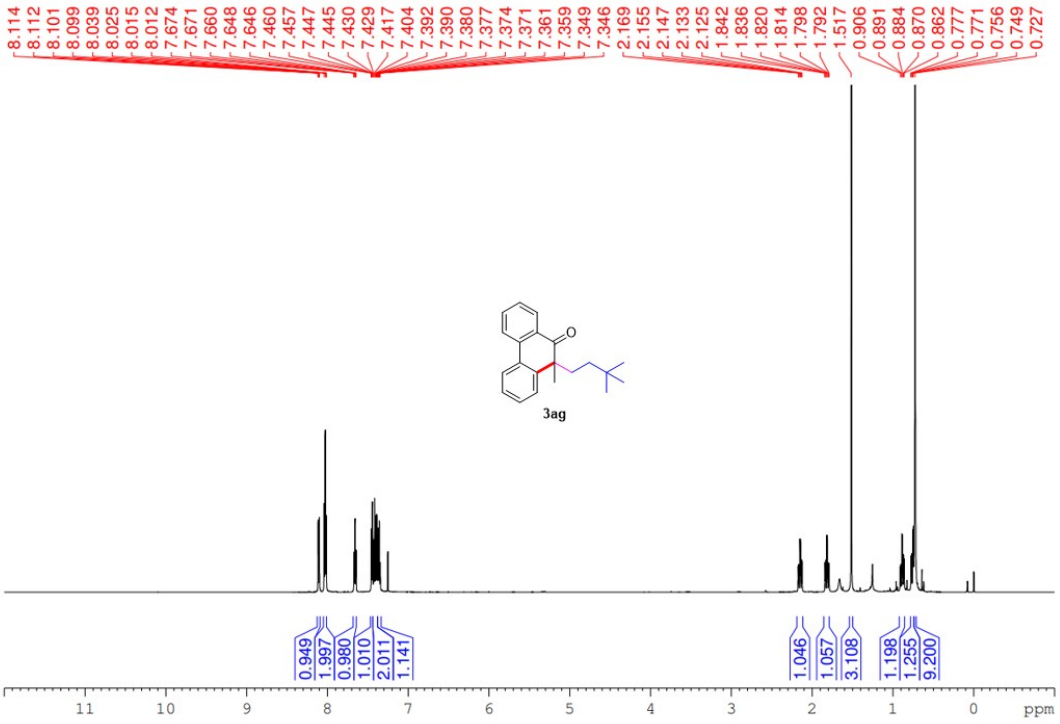

203.006
143.177
137.201
134.102
129.833
129.730
128.816
128.004
127.616
127.104
126.877
123.594
122.777
77.211
77.000
76.789
51.622
49.345
23.900
7.165
4.825
4.352
3ad
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

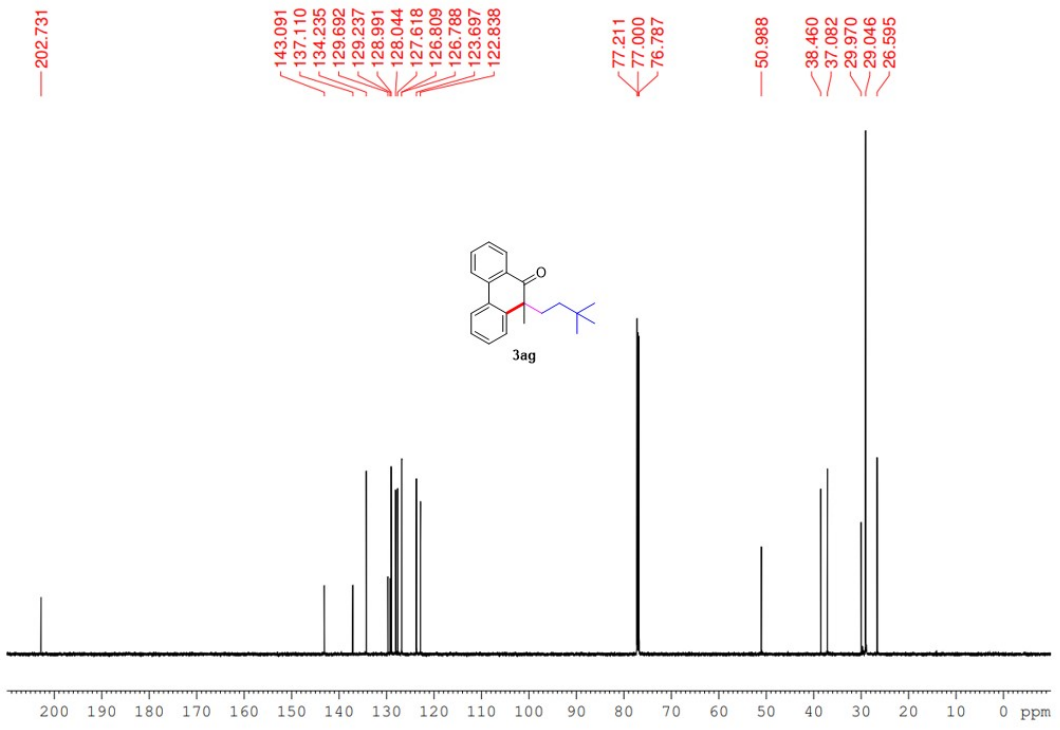

8.102
8.100
8.089
8.087
8.034
8.021
8.005
7.994
7.990
7.671
7.669
7.657
7.646
7.644
7.460
7.457
7.450
7.448
7.445
7.423
7.421
7.410
7.398
7.396
7.370
7.367
7.362
7.358
7.354
7.349
7.347
2.161
2.150
2.139
2.127
1.918
1.906
1.895
1.884
1.581
1.577
1.564
1.557
1.546
1.535
1.533
1.532
1.499
1.485
1.421
1.406
1.310
1.293
3ae
1.000
1.134
1.162
1.080
1.043
1.097
2.012
1.155
1.208
1.240
1.150
3.158
2.038
1.222
1.047
1.073
11
10
9
8
7
6
5
4
3
2
1
0
ppm

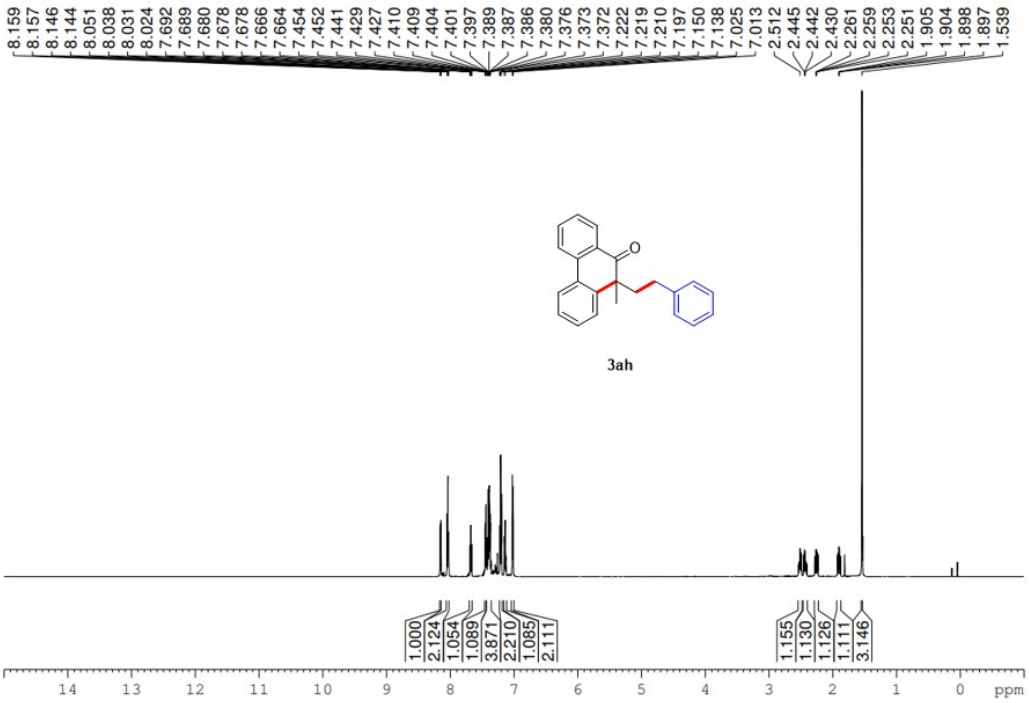

202.666
143.050
137.128
134.180
129.514
129.370
128.764
127.996
127.724
127.190
126.823
123.559
122.777
77.212
77.000
76.789
51.374
50.744
33.173
29.648
29.367
24.700
18.674
3ae
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

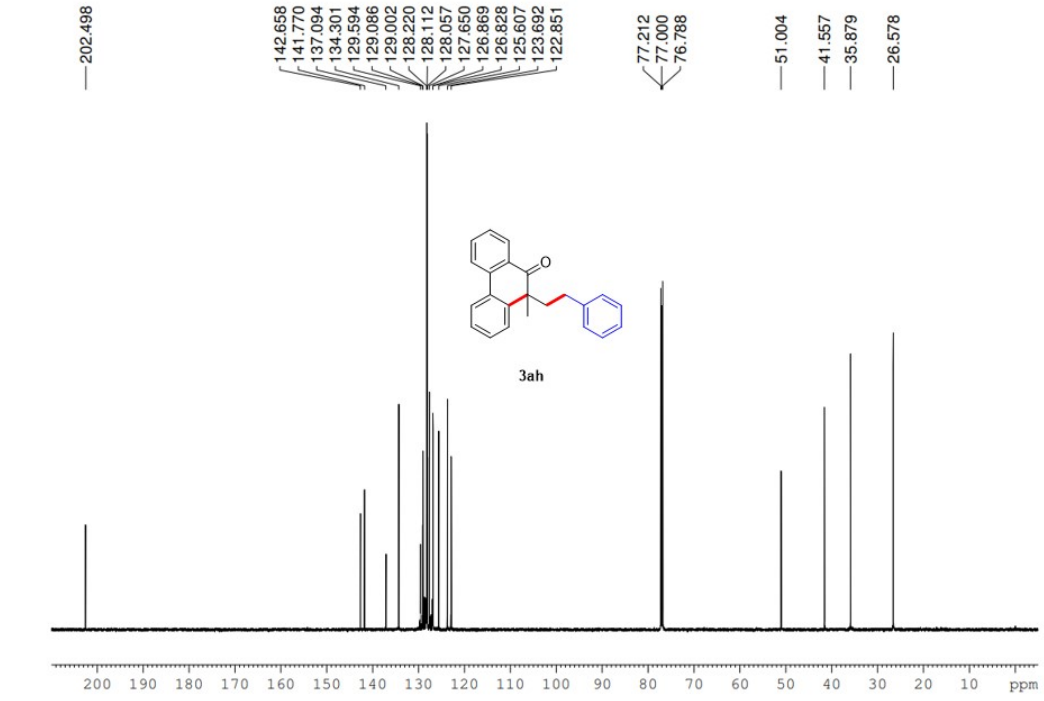

8.039
8.037
8.026
8.024
7.971
7.957
7.943
7.940
7.612
7.609
7.598
7.587
7.584
7.398
7.396
7.385
7.383
7.366
7.364
7.353
7.341
7.340
7.322
7.319
7.310
7.307
7.304
7.294
7.291
1.728
1.720
1.459
1.411
1.404
1.399
1.394
1.321
1.315
1.310
1.183
1.047
1.043
1.037
1.032
1.026
1.022
0.820
0.816
0.813
0.809
0.802
0.798
0.792
O
3af
0.933
2.004
0.956
0.972
1.020
1.999
1.035
1.278
3.126
2.075
2.065
2.133
2.137
1.224
4.077
11
10
9
8
7
6
5
4
3
2
1
0
ppm

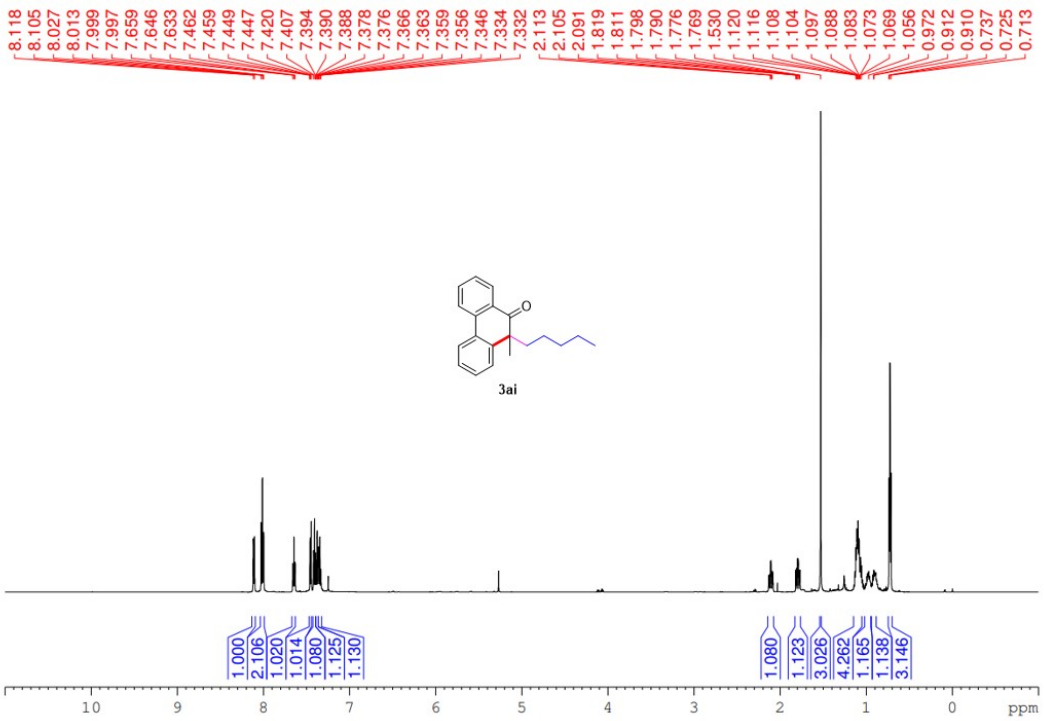

202.797
143.078
137.159
134.231
129.676
129.314
128.969
128.065
127.633
126.850
126.830
123.710
122.850
77.211
77.000
76.788
51.239
42.671
39.602
36.287
32.582
32.451
25.906
25.052
25.031
24.090
O
3af
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

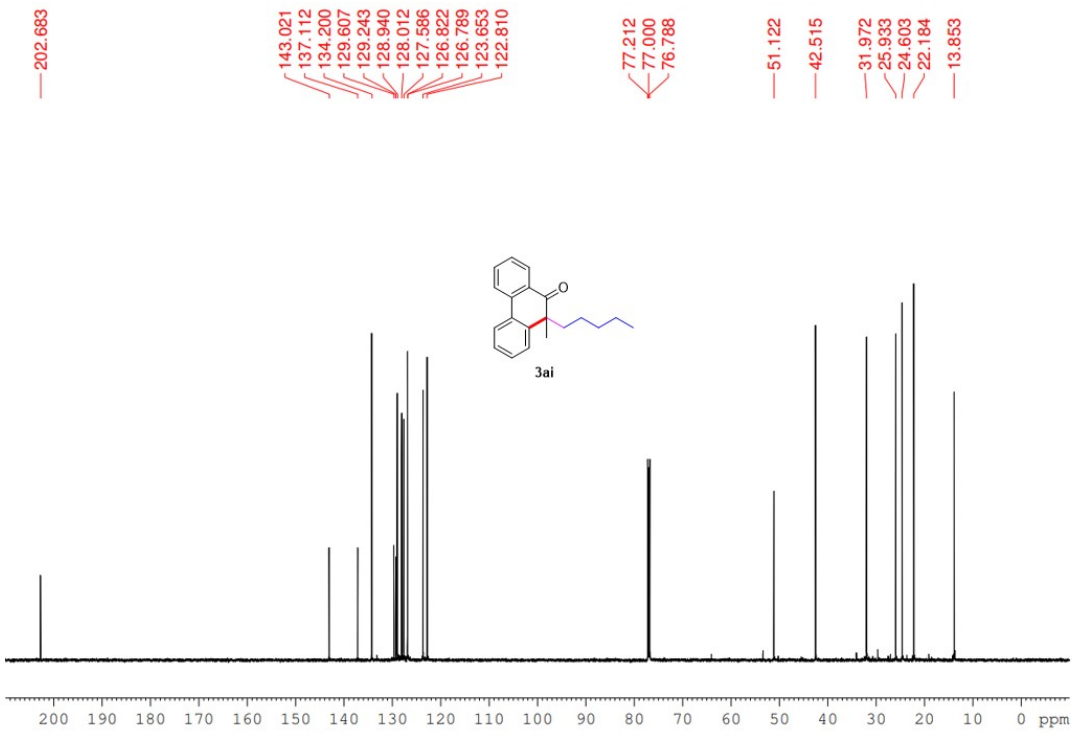

8.114
8.112
8.101
8.099
8.039
8.025
8.015
8.012
7.674
7.671
7.660
7.648
7.646
7.460
7.457
7.447
7.445
7.430
7.429
7.417
7.404
7.392
7.390
7.380
7.377
7.374
7.371
7.361
7.359
7.349
7.346
2.169
2.155
2.147
2.133
2.125
1.842
1.836
1.820
1.814
1.798
1.792
1.517
0.906
0.891
0.884
0.870
0.862
0.777
0.771
0.756
0.749
0.727
3ag
0.949
1.997
0.980
1.010
2.011
1.141
1.046
1.057
3.108
1.198
1.255
9.200
11 10 9 8 7 6 5 4 3 2 1 0 ppm

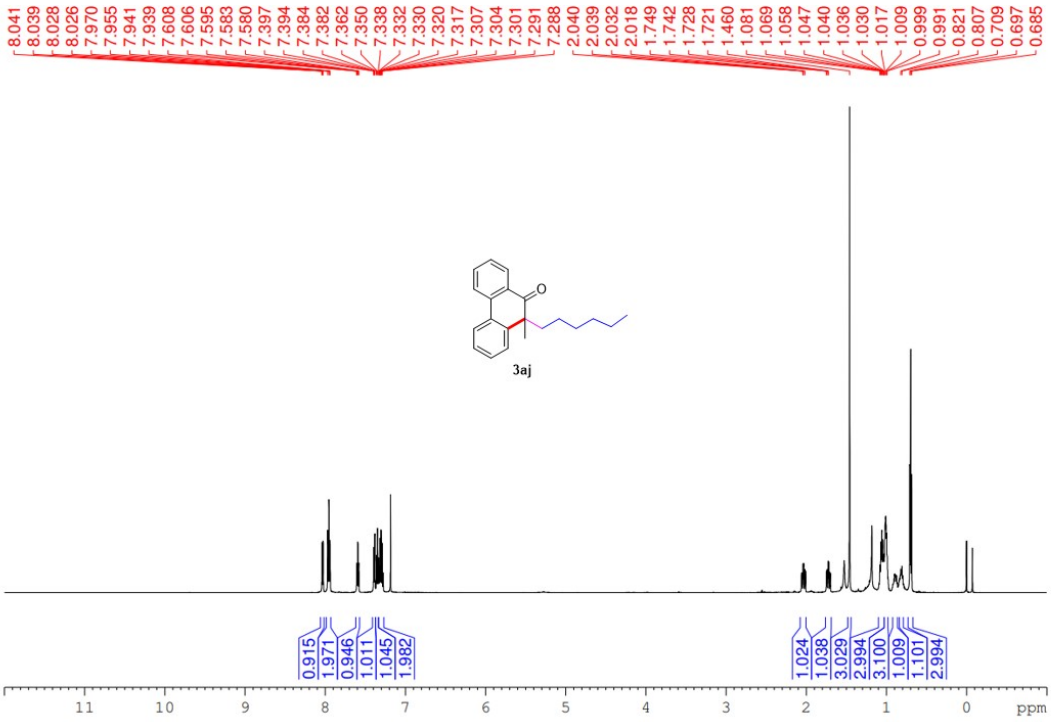

202.731
143.091
137.110
134.235
129.692
129.237
128.991
128.044
127.618
126.809
126.788
123.697
122.838
77.211
77.000
76.787
50.988
38.460
37.082
29.970
29.046
26.595
3ag
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 ppm

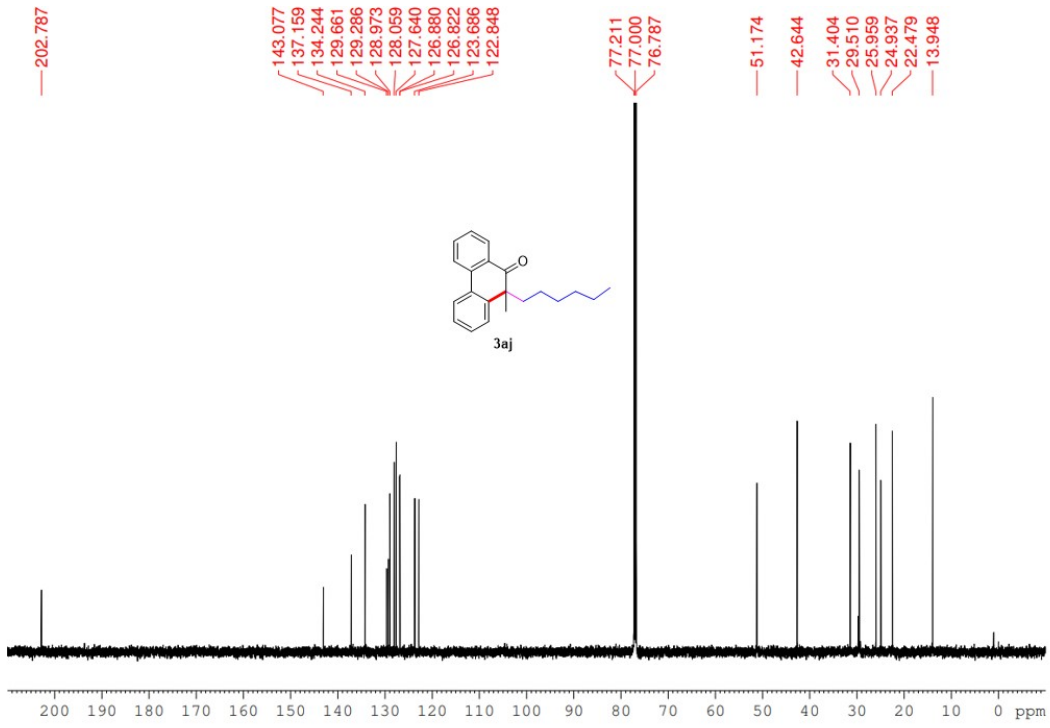

8.159
8.157
8.146
8.144
8.051
8.038
8.031
8.024
7.692
7.689
7.680
7.678
7.678
7.666
7.664
7.454
7.452
7.441
7.429
7.427
7.410
7.409
7.404
7.401
7.397
7.389
7.387
7.386
7.380
7.376
7.373
7.372
7.222
7.219
7.210
7.197
7.150
7.138
7.025
7.013
2.512
2.445
2.442
2.430
2.261
2.259
2.253
2.251
1.905
1.904
1.898
1.897
1.539
O
3ah
1.000
2.124
1.054
1.089
3.871
2.210
1.085
2.111
1.155
1.130
1.126
1.111
3.146
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 ppm

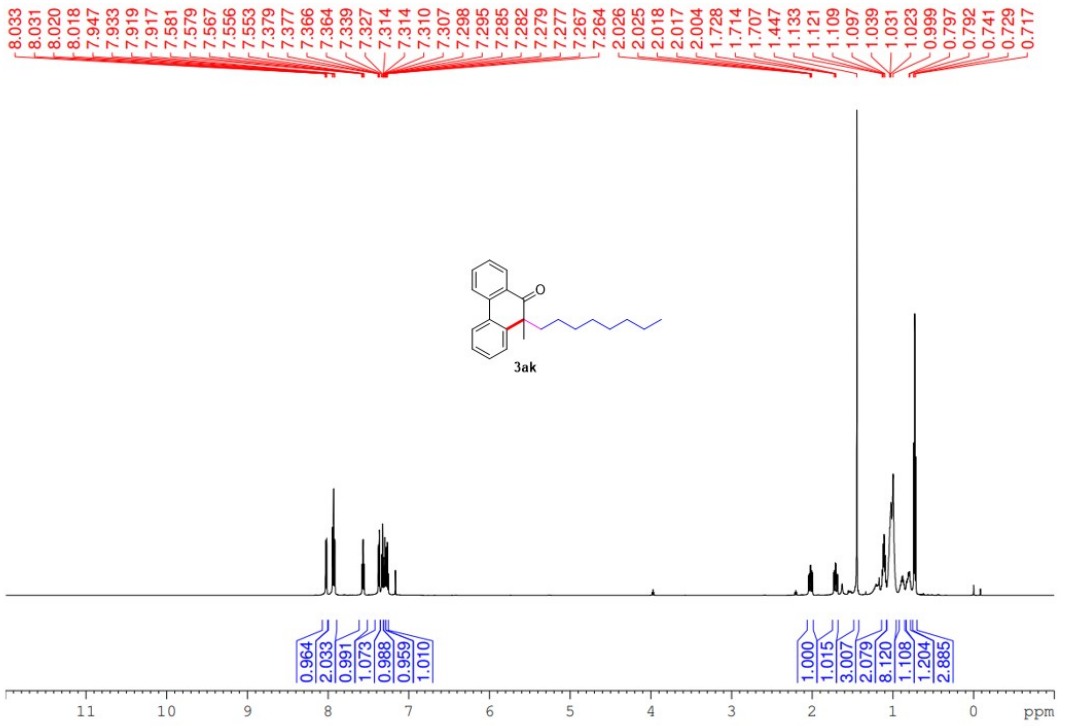

202.498
142.658
141.770
137.094
134.301
129.594
129.086
129.002
128.220
128.112
128.057
127.650
126.869
126.828
125.607
123.692
122.851
77.212
77.000
76.788
51.004
41.557
35.879
26.578
O
3ah
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm

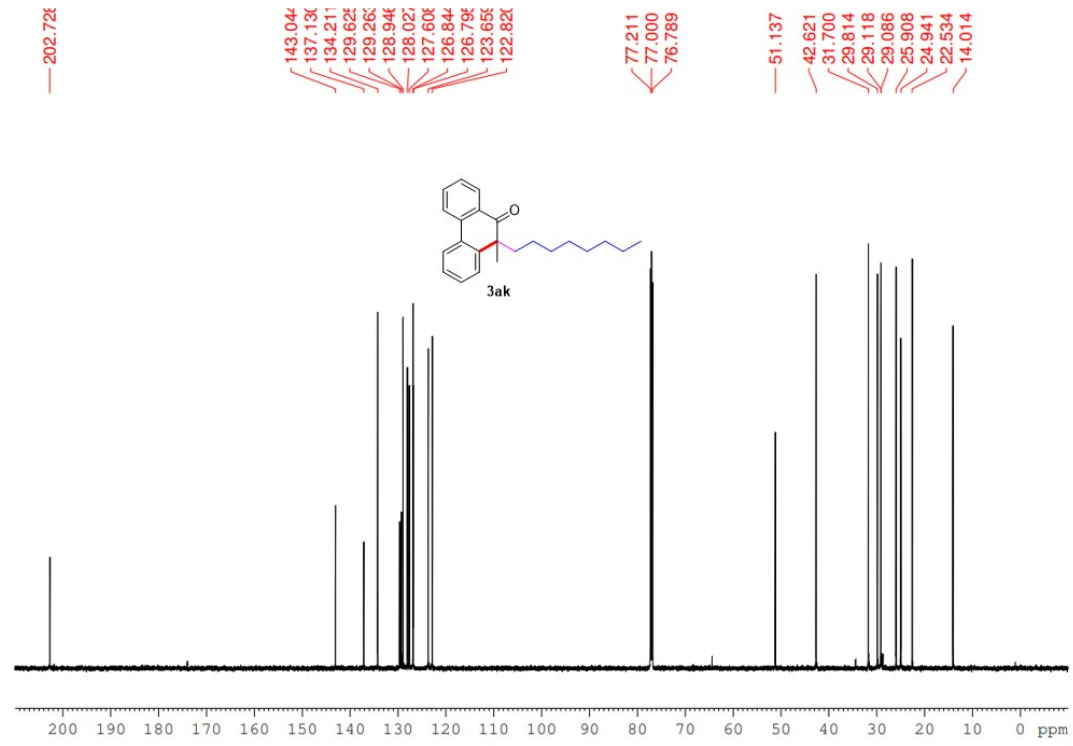

8.118
8.105
8.027
8.013
7.999
7.997
7.659
7.646
7.633
7.462
7.459
7.449
7.447
7.420
7.407
7.394
7.390
7.388
7.378
7.376
7.366
7.363
7.359
7.356
7.346
7.334
7.332
2.113
2.105
2.091
1.819
1.811
1.798
1.790
1.776
1.769
1.530
1.120
1.116
1.108
1.104
1.097
1.088
1.083
1.073
1.069
1.056
0.972
0.912
0.910
0.737
0.725
0.713
O
3ai
1.000
2.106
1.020
1.014
1.080
1.125
1.130
1.080
1.123
3.026
4.262
1.165
1.138
3.146
10
9
8
7
6
5
4
3
2
1
0
ppm

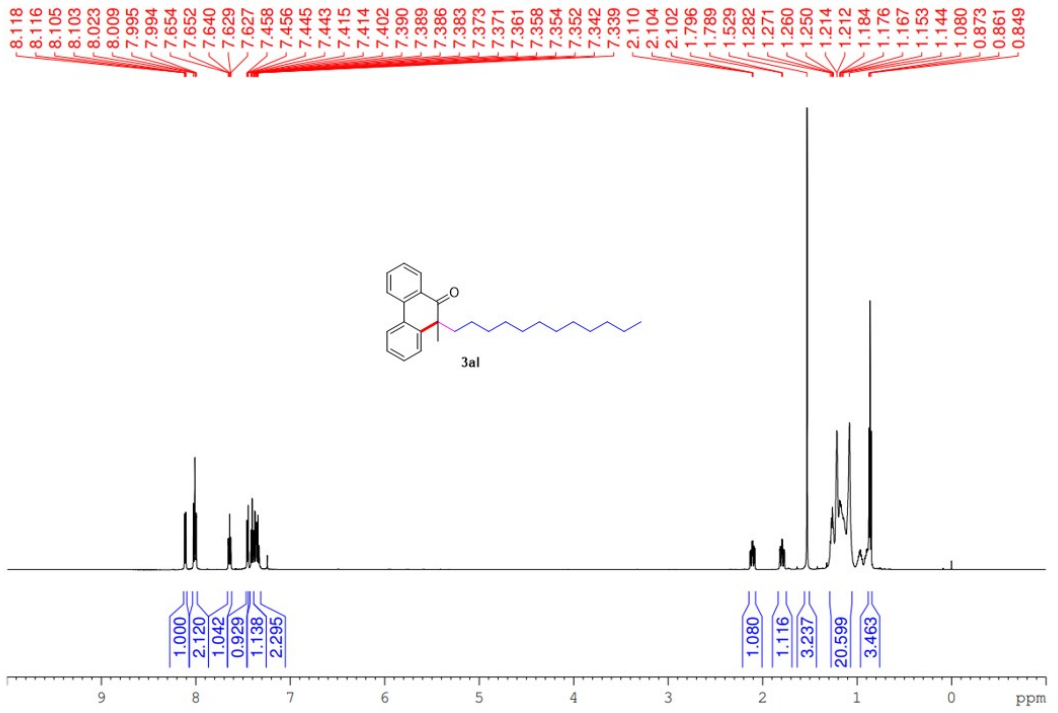

202.683
143.021
137.112
134.200
129.607
129.243
128.940
128.012
127.586
126.822
126.789
123.653
122.810
77.212
77.000
76.788
51.122
42.515
31.972
25.933
24.603
22.184
13.853
O
3ai
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

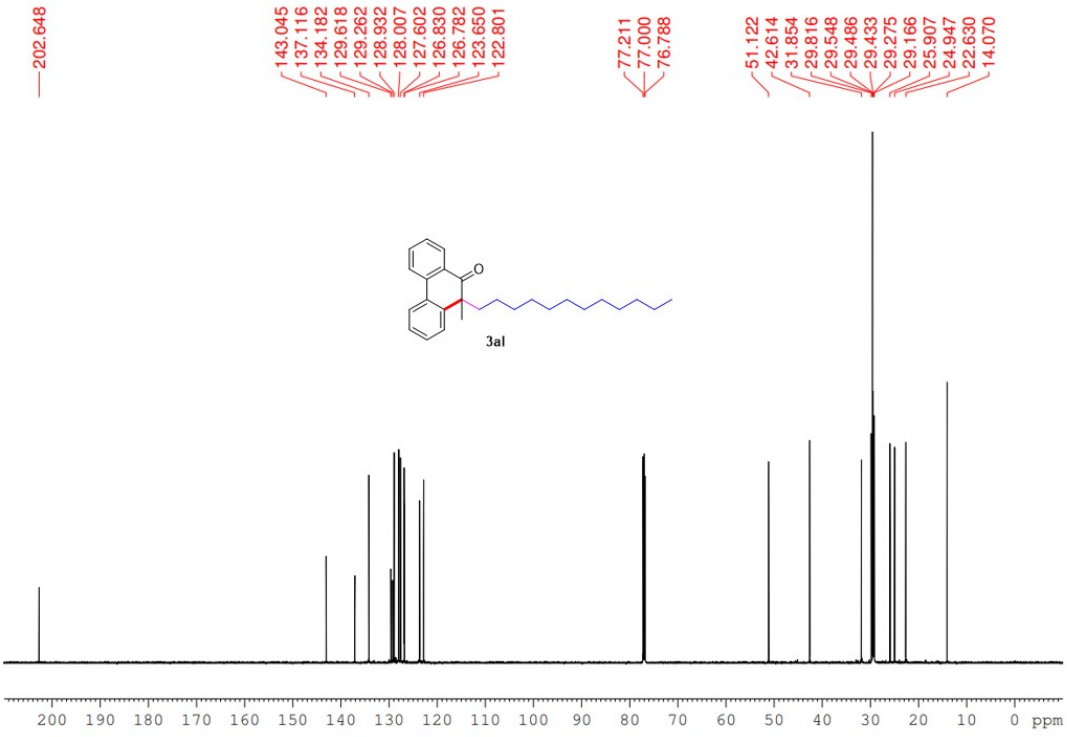

8.041
8.039
8.028
8.026
7.970
7.955
7.941
7.939
7.608
7.606
7.595
7.583
7.580
7.397
7.394
7.384
7.382
7.362
7.350
7.338
7.332
7.330
7.320
7.317
7.307
7.304
7.301
7.291
7.288
2.040
2.039
2.032
2.018
1.749
1.742
1.728
1.721
1.460
1.081
1.069
1.058
1.047
1.040
1.036
1.030
1.017
1.009
0.999
0.991
0.821
0.807
0.709
0.697
0.685
O
3aj
0.915
1.971
0.946
1.011
1.045
1.982
1.024
1.038
3.029
2.994
3.100
1.009
1.101
2.994
11
10
9
8
7
6
5
4
3
2
1
0
ppm

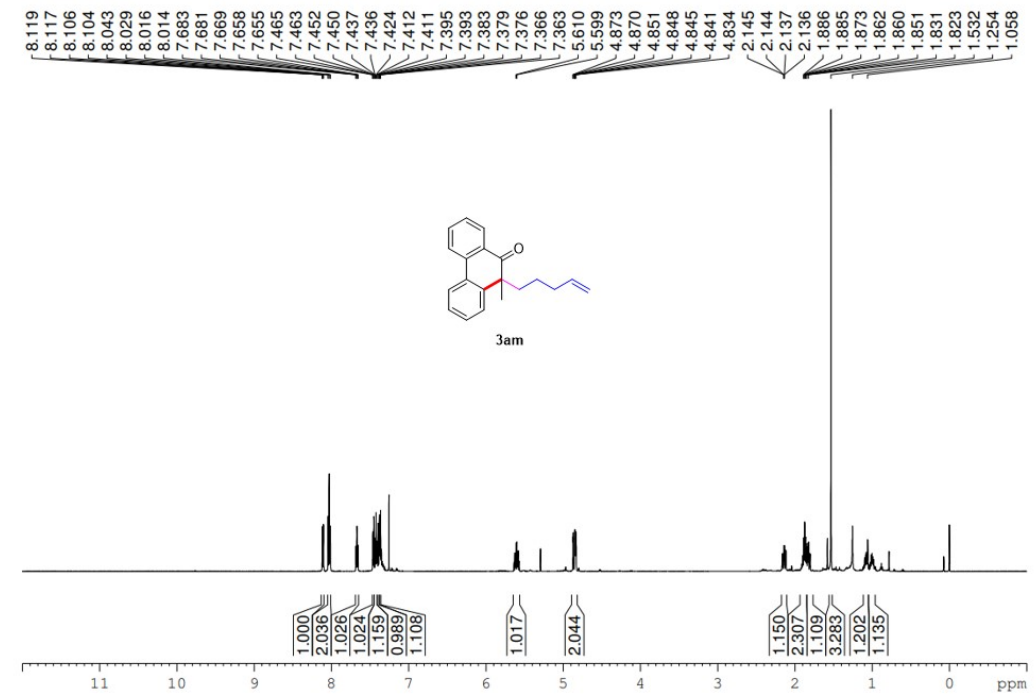

202.787
143.077
137.159
134.244
129.661
129.286
128.973
128.059
127.640
126.880
126.822
123.686
122.848
77.211
77.000
76.787
51.174
42.644
31.404
29.510
25.959
24.937
22.479
13.948
O
3aj
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm

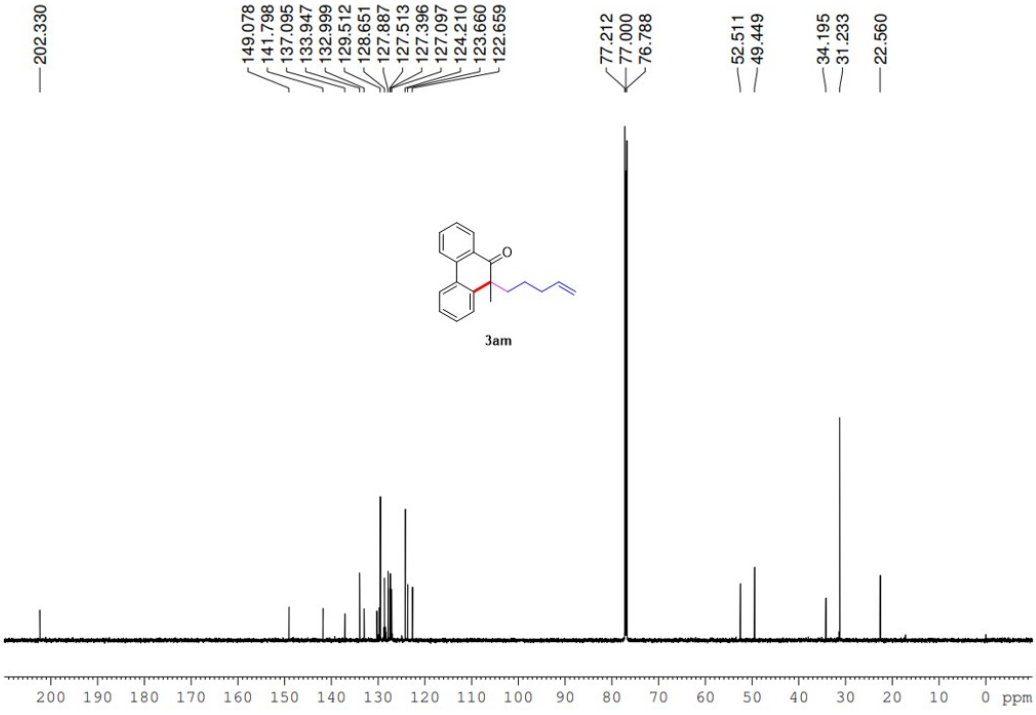

8.033
8.031
8.020
8.018
7.947
7.933
7.919
7.917
7.581
7.579
7.567
7.556
7.553
7.379
7.377
7.366
7.364
7.339
7.327
7.314
7.314
7.310
7.307
7.298
7.295
7.285
7.282
7.279
7.277
7.267
7.264
2.026
2.025
2.018
2.017
2.004
1.728
1.714
1.707
1.447
1.133
1.121
1.109
1.097
1.039
1.031
1.023
0.999
0.797
0.792
0.741
0.729
0.717
O
3ak
0.964
2.033
0.991
1.073
0.988
0.959
1.010
1.000
1.015
3.007
2.079
8.120
1.108
1.204
2.885
11
10
9
8
7
6
5
4
3
2
1
0
ppm


202.72
143.04
137.13
134.21
129.62
129.26
128.94
128.02
127.60
126.84
126.79
123.65
122.82
77.211
77.000
76.789
51.137
42.621
31.700
29.814
29.118
29.086
25.908
24.941
22.534
14.014
O
3ak
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.118
8.116
8.105
8.103
8.023
8.009
7.995
7.994
7.654
7.652
7.640
7.629
7.627
7.458
7.456
7.445
7.443
7.415
7.414
7.402
7.390
7.389
7.386
7.383
7.373
7.371
7.361
7.358
7.354
7.352
7.342
7.339
2.110
2.104
2.102
1.796
1.789
1.529
1.282
1.271
1.260
1.250
1.214
1.212
1.184
1.176
1.167
1.153
1.144
1.080
0.873
0.861
0.849
O
3al
1.000
2.120
1.042
0.929
1.138
2.295
1.080
1.116
3.237
20.599
3.463
9
8
7
6
5
4
3
2
1
0
ppm


202.648
143.045
137.116
134.182
129.618
129.262
128.932
128.007
127.602
126.830
126.782
123.650
122.801
77.211
77.000
76.788
51.122
42.614
31.854
29.816
29.548
29.486
29.433
29.275
29.166
25.907
24.947
22.630
14.070
O
3al
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm


8.119
8.117
8.106
8.104
8.043
8.029
8.016
8.014
7.683
7.681
7.669
7.658
7.655
7.465
7.463
7.452
7.450
7.437
7.436
7.424
7.412
7.411
7.395
7.393
7.383
7.379
7.376
7.366
7.363
5.610
5.599
4.873
4.870
4.851
4.848
4.845
4.841
4.834
2.145
2.144
2.137
2.136
1.886
1.885
1.873
1.862
1.860
1.851
1.831
1.823
1.532
1.254
1.058
O
3am
1.000
2.036
1.026
1.024
1.159
0.989
1.108
1.017
2.044
1.150
2.307
1.109
3.283
1.202
1.135
11
10
9
8
7
6
5
4
3
2
1
0
ppm


202.330
149.078
141.798
137.095
133.947
132.999
129.512
128.651
127.887
127.513
127.396
127.097
124.210
123.660
122.659
77.212
77.000
76.788
52.511
49.449
34.195
31.233
22.560
O
3am
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
ppm