Carbene-Catalyzed formal [5+5] Reaction for Coumarin Construction and Total Synthesis of Defucogilvocarcins

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Supplementary Information

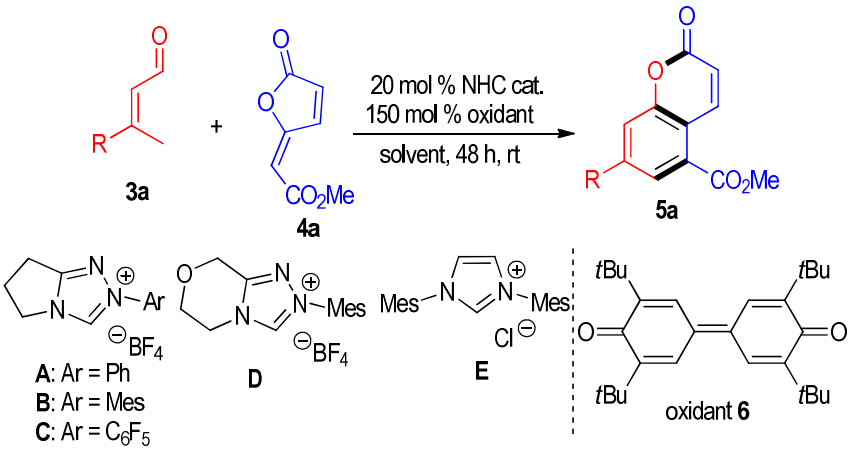
Contents

I: General Information

All reactions were carried out under an argon atmosphere with dry solvents under anhydrous conditions, unless otherwise noted. THF were distilled from sodium-benzophenone, CH_2Cl_2 and CH_3CN was distilled from calcium hydride. All the chemicals were purchased commercially and used without further purification, unless otherwise stated. Flash chromatography was performed using silica gel (200-300 mesh). Reactions were monitored by thin layer chromatography (TLC). Visualization was achieved under a UV lamp (254nm and 365 nm), I_2 and by developing the plates with *p*-anisaldehyde or phosphomolybdic acid. ^1H and ^{13}C NMR were recorded on Bruker BBFO 400 MHz NMR, Bruker AV-500 MHz NMR spectrometer with TMS as the internal standard and were calibrated using residual undeuterated solvent as an internal reference ($CDCl_3$: ^1H NMR = 7.26, ^{13}C NMR = 77.16). The following abbreviations were used to explain the multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, *br* = broad. Coupling constants (*J*) are reported in Hertz (Hz). IR spectra were recorded on a Shimadzu IR Prestige-21 FT-IR spectrometer as neat thinfilms between KBr plates. High resolution Mass spectra (HRMS) were recorded by using Finnigan MAT 95 XP mass spectrometer (Thermo Electron Corporation). Enals **3**[1] and furanone **4**[2] were prepared with reported procedures or commercial available. If not further mentioned, silica gel column chromatography for product purification was eluted with hexane/ethyl acetate.

II: Experimental Procedures

Table 1. Optimization of the reaction conditions[a]

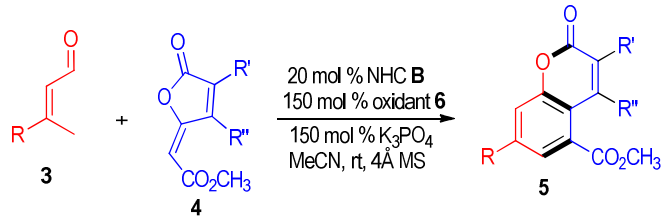


Entry	NHC	Base	Solvent	Temp.(°C)	Time(h)	Yield(%)[b]
1	**A**	Cs_2CO_3(1.0 eq)	THF	23	48	trace
2	**B**	Cs_2CO_3(1.0 eq)	THF	23	48	14
3	**C**	Cs_2CO_3(1.0 eq)	THF	23	48	trace
4	**D**	Cs_2CO_3(1.0 eq)	THF	23	48	5
5	**E**	Cs_2CO_3(1.0 eq)	THF	23	48	trace
6	**B**	DBU (1.0 eq)	THF	23	48	trace
7	**B**	Et_3N (1.0 eq)	THF	23	48	0
8	**B**	K_3PO_4(1.0 eq)	THF	23	48	50
9	**B**	K_3PO_4(1.0 eq)	DCM	23	48	53
10	**B**	K_3PO_4(1.0 eq)	MeCN	23	48	76
11	**B**	K_3PO_4 (1.0 eq)	MeCN	40	24	66
12	**B**	K_3PO_4 (1.0 eq)	MeCN	60	3	55
13	**B**	K_3PO_4 (1.0 eq)	MeCN	80	3	60
14	**B**	K_3PO_4 (1.2 eq)	MeCN	23	48	79
15	**B**	K_3PO_4 (1.5 eq)	MeCN	23	48	86
16	**B**	K_3PO_4 (2.0 eq)	MeCN	23	48	77
17	--	K_3PO_4 (1.5eq)	MeCN	23	48	0

[a]Reaction conditions unless otherwise specified: **3a** (0.12 mmol), **4a** (0.10 mmol), NHC (0.02mmol), **4** (0.15 mmol), base (0.10 mmol), solvent (1 mL), 4 Å molecular sieves, 48 h, rt. [b]Isolated yield based on **1a** after chromatography.

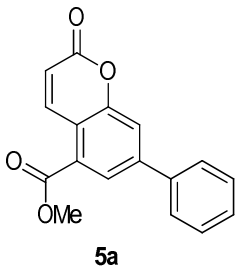
As shown in Supplementary Table 1, Triazolium-based NHC catalyst **B** and **D** with an *N*-mesityl substituent were found to mediate the formation of **5a**.(Supplementary Table 1, entries 2 & 4). Selection of base is critical for this reaction. Changing Cs2CO3 to DBU or Et3N led to little formation of **5a** (Supplementary Table 1, entries 6-7), and K3PO4 was found to be the best base for the reaction(Supplementary Table 1, entry 8). Solvent screening show CH3CN is better than CH2Cl2 or THF (Supplementary Table 1, entries 9-10). Increasing reaction temperature can shorten the reaction time, but with slightly lower yield (Supplemetary Table 1, entreis 11-13). Screening the amount of base K_3PO_4 showed 1.5equiv is the optimized (Supplementary Table1, entries 14-16). No reaction occurred without NHC precatalyst.

General procedure for the catalytic synthesis of products 5



Under Ar atmosphere, a solution of enal **3** (0.12 mmol), furanone **4** (0.1 mmol), oxidant **6** (0.15 mmol), K_3PO_4 (0.1 mmol or 0.15 mmol), activated 4Å MS (30 mg) and NHC pre-catalyst **B** (0.02 mmol) in 1.0 mL MeCN was stirred at rt for 48 hours. The mixture was concentrated under reduced pressure and purified by silica gel column chromatography to afford the corresponding product **5**.

Methyl 2-oxo-7-phenyl-2H-chromene-5-carboxylate (5a)



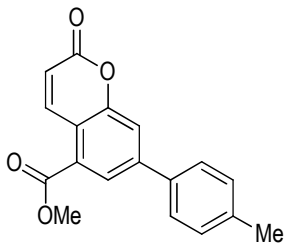
5a

White solid (48 mg, 86%); mp 184−185 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87 (d, *J* = 10.0 Hz, 1H), 8.17 (s, 1H), 7.69 (s, 1H), 7.63 (d, *J* = 7.6 Hz, 2H), 7.54 – 7.38 (m, 3H), 6.50 (d, *J* = 10.0 Hz, 1H), 3.99 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 159.9, 155.3, 144.1, 141.2, 138.2, 129.3, 129.1, 128.0, 127.3, 126.2,

119.1, 117.7, 117.5, 52.8; IR ν_{max} (neat, cm^{-1}):1755, 1717, 1607, 1252, 1209, 1026, 849, 696; HRMS: (ESI) for $C_{17}H_{13}O_4^+$ $[M+H]^+$: calcd 281.0808, found 281.0819.

Methyl 2-oxo-7-(p-tolyl)-2H-chromene-5-carboxylate (5b)

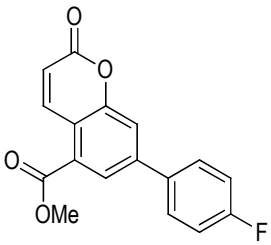


5b

White solid (52 mg, 88%); mp 202−203 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87 (d, *J* = 10.0 Hz, 1H), 8.17 (d, *J* = 1.6 Hz, 1H), 7.69 (s, 1H), 7.55 (d, *J* = 8.0 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 6.50 (d, *J* = 10.0 Hz, 1H), 4.00 (s, 3H), 2.42 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 160.0, 155.4, 144.1, 141.2, 139.3, 135.3, 130.1, 128.0, 127.1, 126.0, 118.8, 117.5, 117.3, 52.8, 21.3; IR ν_{max} (neat, cm^{-1}): 1744, 1721, 1609, 1433, 1338, 1321, 1254, 1215, 1109, 1028, 822;HRMS: (ESI) for $C_{18}H_{15}O_4^+$ $[M+H]^+$: calcd 295.0965, found 295.0976.

Methyl 7-(4-fluorophenyl)-2-oxo-2H-chromene-5-carboxylate (5c)

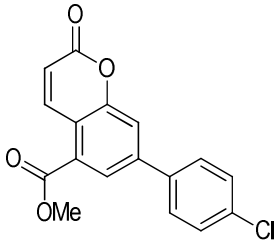


5c

Yellow solid (38 mg, 67%); mp 172−173 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.86 (d, *J* = 10.0 Hz, 1H), 8.12 (d, *J* = 2.0 Hz, 1H), 7.68 – 7.54 (m, 3H), 7.24 – 7.13 (m, 2H), 6.50 (d, *J* = 10.0 Hz, 1H), 3.99 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 163.5 (d, J_{CF} = 249.6 Hz), 159.8, 155.4, 143.0, 141.1, 134.4 (d, J_{CF} = 3.3 Hz), 129.1 (d, J_{CF} = 8.4 Hz), 128.2, 126.0, 118.9, 117.8, 117.5, 116.4 (d, J_{CF} = 21.8 Hz), 52.9; ^{19}F NMR (377 MHz, $CDCl_3$) δ -112.5; IR ν_{max} (neat, cm^{-1}): 1748, 1713, 1609, 1516, 1425, 1256, 1231, 1117, 1026, 829; HRMS: (ESI) for $C_{17}H_{12}O_4F^+$ $[M+H]^+$: calcd 299.0714, found 299.0726.

Methyl 7-(4-chlorophenyl)-2-oxo-2H-chromene-5-carboxylate (5d)



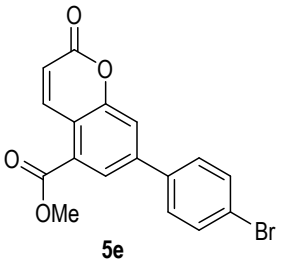
5d

White solid (45 mg, 72%); mp 174−175 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.87 (d, *J* = 10.0 Hz, 1H), 8.13 (d, *J* = 1.6 Hz, 1H), 7.66 (s, 1H), 7.57 (d, *J* = 8.4 Hz, 2H), 7.47 (d, *J* = 8.4 Hz, 2H), 6.52 (d, *J* = 10.0 Hz, 1H), 4.00 (s, 3H); ^{13}C NMR (100

MHz, $CDCl_3$) δ 166.1, 159.8, 155.4, 142.8, 141.1, 136.7, 135.4, 129.6, 128.5, 128.3, 126.0, 119.0,118.0, 117.8, 52.9; IR ν_{max} (neat, cm^{-1}): 1751, 1713, 1610, 1502, 1433, 1253, 1234, 1215, 1092, 1036, 957, 902, 787; HRMS: (ESI) for $C_{17}H_{12}O_4Cl^+$ $[M+H]^+$: calcd 315.0419, found 315.0420.

Methyl 7-(4-bromophenyl)-2-oxo-2H-chromene-5-carboxylate (5e)

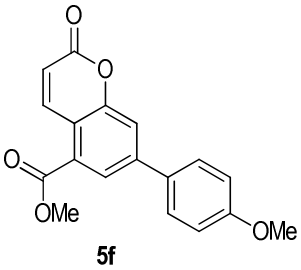


5e

Yellow solid (54.5 mg, 76%); mp 174−175 °C;

^1H NMR (400 MHz, $CDCl_3$) δ 8.88 (d, *J* = 10.0 Hz, 1H), 8.14 (d, *J* = 2.0 Hz, 1H), 7.67 (d, *J* = 1.6 Hz, 1H), 7.66 – 7.60 (m, 2H), 7.56 – 7.48 (m, 2H), 6.53 (d, *J* = 10.0 Hz, 1H), 4.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 159.8, 155.4, 142.9, 141.1, 137.2, 132.6, 128.8, 128.3, 125.9, 123.7, 119.0, 118.0, 117.9, 52.9;IR ν_{max} (neat, cm^{-1}): 1747, 1713, 1608, 1434, 1340, 1254, 1119, 1032, 837, 816;HRMS: (ESI) for $C_{17}H_{12}O_4Br^+$ $[M+H]^+$: calcd 358.9913, found 358.9911.

Methyl 7-(4-methoxyphenyl)-2-oxo-2H-chromene-5-carboxylate (5f)

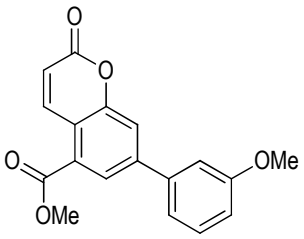


5f

White solid (37 mg 60%); mp 170−172 °C;

^1H NMR (400 MHz, $CDCl_3$) δ 8.85 (d, *J* = 10.0 Hz, 1H), 8.14 (d, *J* = 2.0 Hz, 1H), 7.65 (d, *J* = 1.2 Hz, 1H), 7.59 (d, *J* = 8.8 Hz, 2H), 7.01 (d, *J* = 8.8 Hz, 2H), 6.48 (d, *J* = 10.0 Hz, 1H), 3.99 (s, 3H), 3.87 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 160.6, 160.1, 155.5, 143.8, 141.3, 130.6, 128.5, 128.0, 125.7, 118.4, 117.3, 117.0, 114.8, 55.6, 52.8; IR ν_{max} (neat, cm^{-1}): 1740, 1721, 1605, 1518, 1259, 1111, 1032, 829;HRMS: (ESI) for $C_{18}H_{14}O_5Na^+$ $[M+Na]^+$: calcd 333.0733, found 333.0733.

Methyl 7-(3-methoxyphenyl)-2-oxo-2H-chromene-5-carboxylate (5g)

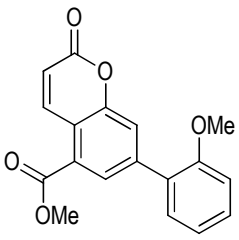


5g

Yellow solid (53 mg, 85%); mp 196−198 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.89 (d, *J* = 10.0 Hz, 1H), 8.18 (d, *J* = 1.6 Hz, 1H), 7.71 (d, *J* = 1.6 Hz, 1H), 7.42 (t, *J*= 8.0 Hz, 1H), 7.23 (d, *J* = 7.6 Hz, 1H), 7.16 (t, *J* = 1.6 Hz, 1H), 6.99 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.53 (d, *J* = 10.0 Hz, 1H), 4.00 (s, 3H), 3.89 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 160.4, 160.0, 155.4, 144.1, 141.2, 139.8, 130.5, 128.1, 126.3, 119.8, 119.3, 117.8, 117.7, 114.4, 113.2, 55.6, 52.9;IR ν_{max} (neat, cm^{-1}): 1742, 1719, 1607, 1580, 1439, 1319, 1257, 1207, 1111, 1028, 878, 845, 777;HRMS: (ESI) for $C_{18}H_{14}O_5Na$ $[M+Na]^+$: calcd 333.0733, found 333.0740.

Methyl 7-(2-methoxyphenyl)-2-oxo-2H-chromene-5-carboxylate (5h)

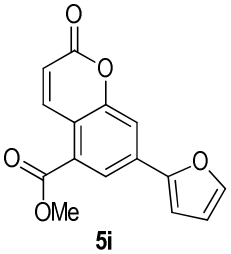


5h

White solid (28 mg, 45%); mp 163−167 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.90 (d, *J* = 10.0 Hz, 1H), 8.11 (d, *J* = 1.6 Hz, 1H), 7.75 (d, *J* = 1.2 Hz, 1H), 7.46 – 7.32 (m, 2H), 7.08 (td, *J* = 7.6, 0.8 Hz, 1H), 7.03 (d, *J* = 8.0 Hz, 1H), 6.51 (d, *J* = 10.0 Hz, 1H), 3.97 (s, 3H), 3.85 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 160.2, 156.6, 154.7, 141.9, 141.4, 130.7, 130.4, 128.9, 127.8, 127.2, 122.2, 121.3, 117.7, 117.3, 111.6, 55.7, 52.7;IR ν_{max} (neat, cm^{-1}): 1740, 1713, 1611, 1258, 1215, 1111, 1028, 833, 752; HRMS: (ESI) for $C_{18}H_{15}O_5$ $[M+H]^+$: calcd 311.0914, found 311.0912.

Methyl 7-(furan-2-yl)-2-oxo-2H-chromene-5-carboxylate (5i)



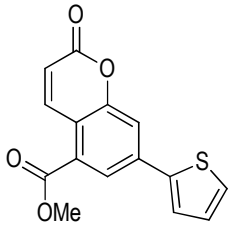
5i

White solid (27 mg, 50%); mp 168−169 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.82 (d, *J* = 10.0 Hz, 1H), 8.18 (d, *J* = 2.0 Hz, 1H), 7.71 (s, 1H), 7.56 (d, *J* = 1.2 Hz, 1H), 6.87 (d, *J* = 3.6 Hz, 1H), 6.55 (dd, *J* = 3.2, 1.6 Hz, 1H), 6.47 (d, *J* = 10.0 Hz, 1H), 3.99 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.0, 159.9, 155.5, 151.4, 144.1, 141.1, 133.3, 128.3, 122.8, 117.4, 117.3, 115.2, 112.5, 108.8, 52.9; IR

ν_{max} (neat, cm^{-1}): 1745, 1717, 1610, 1585, 1254, 1207, 1113, 1028, 845;HRMS: (ESI) for $C_{15}H_{11}O_5$ $[M+H]^+$: calcd 271.0601, found 271.0605.

Methyl 2-oxo-7-(thiophen-2-yl)-2H-chromene-5-carboxylate (5j)

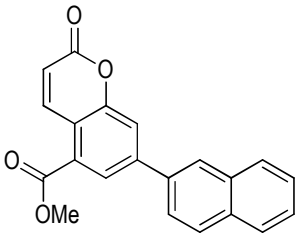


5j

White solid (40.5 mg, 71%); mp 182−183 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.82 (d, *J* = 10.0 Hz, 1H), 8.14 (d, *J* = 2.0 Hz, 1H), 7.67 (d, *J* = 1.6 Hz, 1H), 7.47 (dd, *J* = 3.6, 1.2 Hz, 1H), 7.42 (dd, *J* = 5.2, 1.0 Hz, 1H), 7.14 (dd, *J* = 5.2, 3.6 Hz, 1H), 6.47 (d, *J* = 10.0 Hz, 1H), 4.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.0, 159.8, 155.4, 141.3, 141.1, 137.3, 128.8, 128.3, 127.5, 125.6, 124.8, 117.5, 117.2, 52.9;IR ν_{max} (neat, cm^{-1}): 1728, 1607, 1308, 1256, 1215, 1115, 1036, 733;HRMS: (ESI) for $C_{15}H_{10}O_4SNa[M+Na]^+$: calcd 309.0192, found 309.0198.

Methyl 7-(naphthalen-2-yl)-2-oxo-2H-chromene-5-carboxylate (5k)

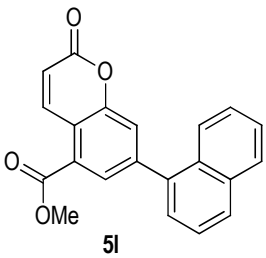


5k

White solid (63 mg, 95%); mp 211−212 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.91 (d, *J* = 10.0 Hz, 1H), 8.33 (d, *J* = 1.6 Hz, 1H), 8.13 (d, *J* = 1.2 Hz, 1H), 8.01 – 7.87 (m, 3H), 7.85 (d, *J* = 1.2 Hz, 1H), 7.77 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.61 – 7.49 (m, 2H), 6.54 (d, *J* = 10.0 Hz, 1H), 4.03 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 160.0, 155.5, 144.1, 141.2, 135.5, 133.6, 133.4, 129.3, 128.6, 128.2, 127.9, 127.1, 127.0, 126.7, 126.4, 124.7, 119.3, 117.8, 117.6, 52.9;IR ν_{max} (neat, cm^{-1}): 1748, 1721, 1609, 1439, 1260, 1219, 1107, 1030, 843, 824, 756; HRMS: (ESI) for $C_{21}H_{15}O_4^+$ $[M+H]^+$: calcd 331.0965, found 331.0972.

Methyl 7-(naphthalen-1-yl)-2-oxo-2H-chromene-5-carboxylate (5l)



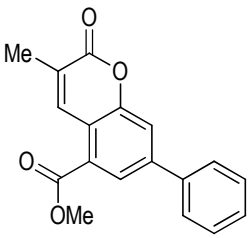
5l

Yellow solid (42 mg, 64%); mp 149−151 °C;

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.97 (d, *J* = 10.0 Hz, 1H), 8.11 (d, *J* = 2.0 Hz, 1H), 7.94 (dd, *J* = 8.0, 3.0 Hz, 2H), 7.81 (d, *J* = 8.5 Hz, 1H), 7.67 (d, *J* = 1.5 Hz, 1H), 7.60 – 7.52 (m, 2H), 7.52 – 7.42 (m, 2H), 6.58 (d, *J* = 10.0 Hz, 1H), 3.96 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.2, 159.9, 154.9, 144.2, 141.3, 137.3, 134.0, 131.1, 129.3, 129.2, 128.8, 127.7,

127.4, 127.0, 126.4, 125.5, 125.2, 122.5, 118.1, 117.7, 52.8;IR ν_{max} (neat, cm^{-1}): 1738, 1724, 1608, 1431, 1381, 1338, 1263, 1234, 1206, 1119, 1036, 945, 839, 806, 785; HRMS: (ESI) for $C_{21}H_{15}O_4^+$ $[M+H]^+$: calcd 331.0965, found 331.0976.

Methyl 3-methyl-2-oxo-7-phenyl-2H-chromene-5-carboxylate (5m)

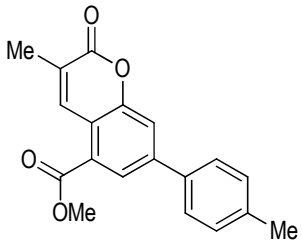


5m

Yellow solid (44.5 mg, 76%); mp 181−182 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (d, *J* = 0.8 Hz, 1H), 8.14 (d, *J* = 1.6 Hz, 1H), 7.67 (d, *J* = 1.2 Hz, 1H), 7.65 – 7.58 (m, 2H), 7.55 – 7.45 (m, 2H), 7.45 – 7.38 (m, 1H), 3.99 (s, 3H), 2.26 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 161.4, 154.5, 142.7, 138.4, 136.9, 129.3, 128.9, 127.3, 127.2, 126.0, 118.7, 118.4, 52.7, 17.8;IR ν_{max} (neat, cm^{-1}): 1728, 1709, 1605, 1580, 1439, 1246, 1165, 1028, 756;HRMS: (ESI) for $C_{18}H_{15}O_4^+$ $[M+H]^+$: calcd 295.0965, found 295.0970.

Methyl 3-methyl-2-oxo-7-(p-tolyl)-2H-chromene-5-carboxylate (5n)

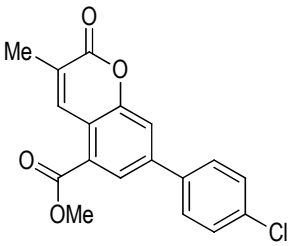


5n

White solid (48 mg, 78%); mp 186−190 °C;

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.68 (s, 1H), 8.13 (d, *J* = 1.5 Hz, 1H), 7.66 (d, *J* = 1.5 Hz, 1H), 7.53 (d, *J* = 8.5 Hz, 2H), 7.29 (d, *J* = 7.9 Hz, 2H), 3.99 (s, 3H), 2.41 (s, 3H), 2.26 (d, *J* = 1.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 166.5, 161.5, 154.5, 142.7, 139.0, 137.0, 135.5, 130.0, 127.2, 127.1, 127.0, 125.8, 118.4, 118.1, 52.7, 21.3, 17.8; IR ν_{max} (neat, cm^{-1}): 1728, 1607, 1435, 1244, 1180, 822;HRMS: (ESI) for $C_{19}H_{17}O_4^+$ $[M+H]^+$: calcd 309.1121, found 309.1130.

Methyl 7-(4-chlorophenyl)-3-methyl-2-oxo-2H-chromene-5-carboxylate (5o)



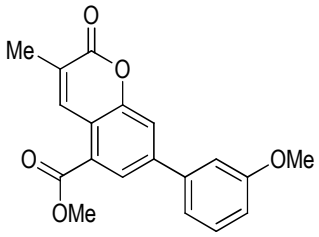
5o

White solid (62 mg, 94%); mp 167−169 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.69 (d, *J* = 0.8 Hz, 1H), 8.11 (d, *J* = 1.6 Hz, 1H), 7.65 (d, *J* = 1.6 Hz, 1H), 7.60 – 7.53 (m, 2H), 7.51 – 7.43 (m, 2H), 4.00 (s, 3H), 2.27 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR

(100 MHz, $CDCl_3$) δ 166.3, 161.3, 154.5, 141.5, 136.9, 136.8, 135.2, 129.6, 128.5, 127.7, 127.5, 125.8, 118.7, 118.6, 52.8, 17.8;IR ν_{max} (neat, cm^{-1}): 1736, 1724, 1609, 1501, 1429, 1346, 1244, 1088, 1003, 824, 758; HRMS: (ESI) for $C_{18}H_{14}O_4Cl^+$ $[M+H]^+$: calcd 329.0575, found 329.0583.

Methyl 7-(3-methoxyphenyl)-3-methyl-2-oxo-2H-chromene-5-carboxylate (5p)

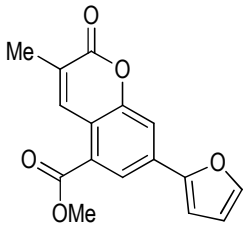


5p

White solid (57 mg, 88%); mp 175−177 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.67 (s, 1H), 8.11 (d, *J* = 1.6 Hz, 1H), 7.64 (s, 1H), 7.38 (t, *J* = 8.0 Hz, 1H), 7.19 (d, *J* = 7.6 Hz, 1H), 7.12 (s, 1H), 6.95 (dd, *J* = 8.0, 2.4 Hz, 1H), 3.98 (s, 3H), 3.87 (s, 3H), 2.25 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 161.3, 160.3, 154.4, 142.5, 139.8, 136.8, 130.3, 127.3, 127.1, 126.0, 119.6, 118.7, 118.5, 114.1, 113.0, 55.5, 52.7, 17.7;IR ν_{max} (neat, cm^{-1}): 1721, 1609, 1582, 1441, 1400, 1348, 1256, 1215, 1026, 878, 777;HRMS: (ESI) for $C_{19}H_{17}O_5^+$ $[M+H]^+$: calcd 325.1071, found 325.1072.

Methyl 7-(furan-2-yl)-3-methyl-2-oxo-2H-chromene-5-carboxylate (5q)

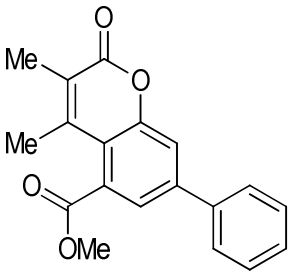


5q

White solid (40 mg, 71%); mp 166−167 °C;

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.63 (s, 1H), 8.16 (d, *J* = 1.6 Hz, 1H), 7.69 (s, 1H), 7.54 (d, *J* = 1.6 Hz, 1H), 6.83 (d, *J* = 3.6 Hz, 1H), 6.53 (dd, *J* = 3.6, 1.6 Hz, 1H), 3.99 (s, 3H), 2.25 (d, *J* = 1.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 161.4, 154.6, 151.6, 143.8, 136.9, 132.1, 127.4, 127.0, 122.7, 118.2, 114.9, 112.4, 108.2, 52.7, 17.8; IR ν_{max} (neat, cm^{-1}): 1728, 1610, 1250, 1028, 1011, 735;HRMS: (ESI) for $C_{16}H_{13}O_5^+$ $[M+H]^+$: calcd 285.0757, found 285.0772.

Methyl 3,4-dimethyl-2-oxo-7-phenyl-2H-chromene-5-carboxylate (5r)

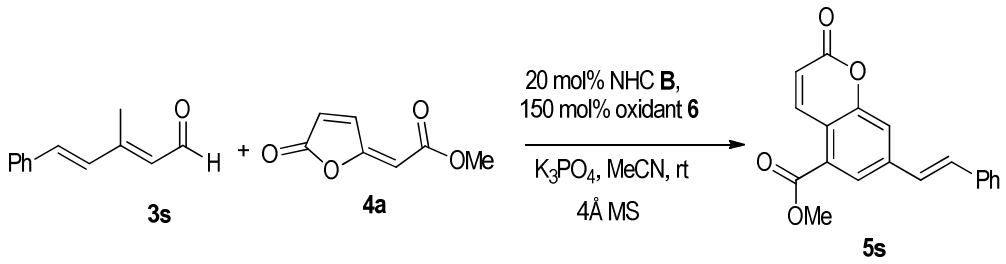


5r

Yellow solid (37 mg, 60%); mp 169−170 °C

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 – 7.63 (m, 1H), 7.63 – 7.60 (m, 2H), 7.59 (d, *J* = 1.6 Hz, 1H), 7.51 – 7.45 (m, 2H), 7.45 – 7.39 (m, 1H), 3.98 (s, 3H), 2.32 (d, *J* = 0.4 Hz, 3H), 2.25 (d, *J* = 0.4 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.1, 161.2, 152.9, 145.3, 142.7, 138.2, 131.7, 129.3, 128.9, 127.2, 124.7, 123.7, 117.5, 117.1, 53.2, 17.9, 14.0;IR ν_{max} (neat, cm^{-1}): 1724, 1601, 1437, 1348, 1331, 1219, 1101, 1018, 766;HRMS: (ESI) for $C_{19}H_{17}O_4^+$ $[M+H]^+$: calcd 309.1121, found 309.1119.

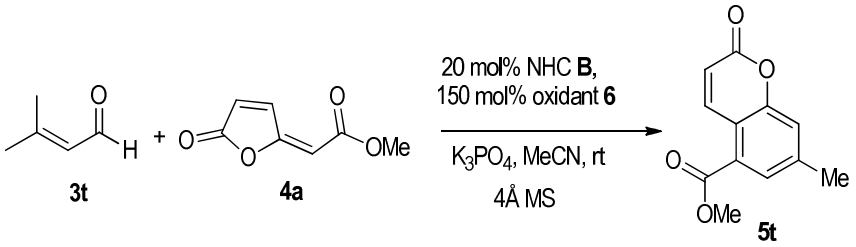
Methyl (*E*)-2-oxo-7-styryl-2H-chromene-5-carboxylate (5s)



3s **4a** **5s**

Under Ar atmosphere, a solution of enal **3s** (1.70 g, 9.9mmol) and **4a** (1.38 g, 9.0 mmol), oxidant **6** (4.1 g, 9.9mmol), K_3PO_4 (2.9 g,13.5 mmol), activated 4Å MS (1 g) and NHC pre-catalyst **B** (550 mg, 1.8mmol) in 80 mL MeCN was stirred at rt for 48 hours. The mixture was concentrated under reduced pressure and purified by silica gel column chromatography to afford the corresponding product **5s** (1.93 g, 70%) as a red solid; mp 165−167 °C;^{1}H NMR (400 MHz, $CDCl_3$) δ 8.83 (d, *J* = 10.0 Hz, 1H), 8.09 (d, *J* = 2.0 Hz, 1H), 7.57 (d, *J* = 1.2 Hz, 2H), 7.55 (s, 1H), 7.40 (t, *J* = 6.8 Hz, 2H), 7.36 – 7.31 (m, 1H), 7.28 (s, *J* = 16.0 Hz, 1H), 7.11 (d, *J* = 16.4 Hz, 1H), 6.48 (d, *J* = 10.0 Hz, 1H), 4.01 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 160.0, 155.4, 141.2, 140.6, 136.2, 133.1, 129.1, 129.0, 128.0, 127.2, 126.1, 125.6, 118.2, 117.7, 117.4, 52.8;IR ν_{max} (neat, cm^{-1}): 1732, 1713, 1601, 1433, 1302, 1219, 1194, 1134, 1115, 1034, 980, 833, 694;HRMS: (ESI) for $C_{19}H_{15}O_4^+$ $[M+H]^+$: calcd 307.0965 found 307.0973.

Methyl 7-methyl-2-oxo-2H-chromene-5-carboxylate (5t)

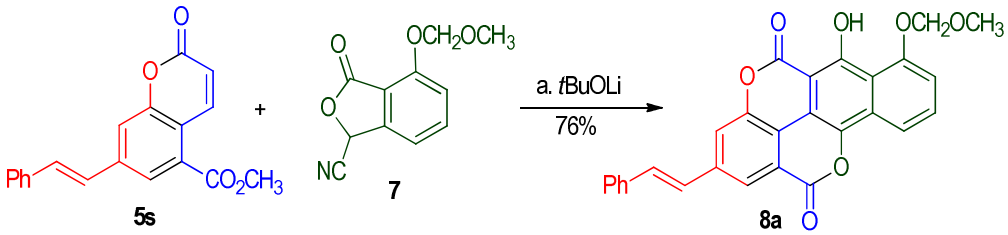


Under Ar atmosphere, a solution of enal **3t** (0.23 ml, 2.4mmol) and **4a** (308mg, 2.0 mmol), oxidant **6** (1.49 g, 3.6mmol), K_3PO_4 (510mg,2.4mmol), activated 4Å MS (300mg) and NHC pre-catalyst **B** (126 mg, 0.4mmol) in 20 mL MeCN was stirred at rt for 48 hours. The mixture was concentrated under reduced pressure and purified by silica gel column chromatography to afford the corresponding product **5t** (86.2mg, 40%) as a yellow solid, all analytical data of **5t** are in agreement with the reported data;[3] mp145−146 °C(lit. mp[3]144.5−144.9 °C);^{1}H NMR (400 MHz, $CDCl_3$) δ 8.81 (d, J = 10.0 Hz, 1H), 7.75 (d, J = 1.1 Hz, 1H), 7.30 (s, 1H), 6.45 (d, J = 10.0 Hz, 1H), 3.96 (s, 3H), 2.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 160.1, 155.0, 142.2, 141.4, 128.6, 127.4, 121.5, 117.1, 116.4, 52.7, 21.7;IR ν_{max} (neat, cm^{-1}): 1740, 1717, 1612, 1308, 1254, 1111, 1308, 837;HRMS: (ESI) for $C_{12}H_{11}O_4^+$ $[M+H]^+$: calcd 219.0652, found 219.0661.

Total Synthesis of Defucogilvocarcins

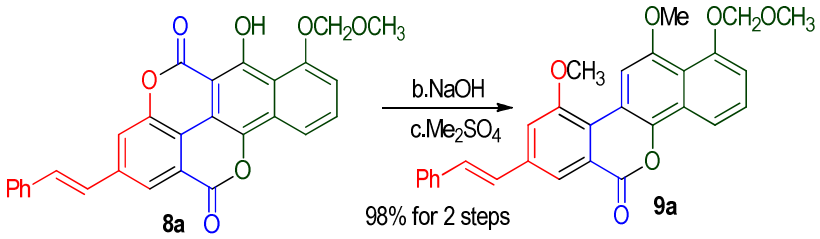
Phthalide **7** is a commercial available compound used as reagents in other reports[3], and can be prepared in 2 steps synthesis from substituted amide using literature methods[4].

(*E*)-6-hydroxy-7-(methoxymethoxy)-2-styrylbenzo[h]chromeno[5,4,3-cde]chromene-5,12-dione (8a)[3]



Compound (**8a**) was prepared as a yellow solid in 76% yield (177 mg) from coumarin **5s** (153 mg, 0.50mmol) and phthalide **7** (120 mg, 0.55 mmol), following the procedure of described in synthesis of **8b**. mp 280°C→black; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.17 (s, 1H), 8.36 (d, *J* = 1.2 Hz, 1H), 8.20 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.80 – 7.74 (m, 2H), 7.62 – 7.56 (m, 2H), 7.42 (t, *J* = 7.2 Hz, 2H), 7.39 – 7.32 (m, 3H), 7.22 (d, *J* = 16.4 Hz, 1H), 5.46 (s, 2H), 3.64 (s, 3H);IR ν_{max} (neat, cm^{-1}): 1730, 1676, 1647, 1616, 1377, 1199, 1107, 988, 752; HRMS: (ESI) for $C_{28}H_{19}O_7^+$ $[M+H]^+$: calcd467.1125, found 467.1120. (Due to the poor solubility of the product in various solvents, ^{13}C NMR cannot be detected)

(*E*)-10,12-dimethoxy-1-(methoxymethoxy)-8-styryl-6H-dibenzo[c,h]chromen-6-one (9a)[5]

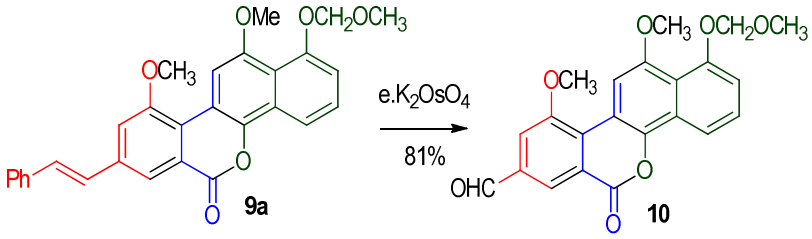


To a Schlenk tube equipped with a magnetic stir bar, was added 1 *N* NaOH (4 ml) and 1,4-dioxane (4 ml),the resulting mixture was degassed (three freeze-pump-thaw cycles) and the reaction tube was refilled with Ar. To this solution was added **8a** (100 mg, 0.21mmol) in glove box. The reaction mixture was stirred at 60°C for 5 h when the yellow suspension turns to a clear yellow solution, and then cooled to 0°C. It was quenched with saturated 1 *N* HCl and extracted with DCM (3 x 10 mL).The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure, the desired product was used without further purification as a yellow solid.

To a solution of this yellow solid in dry acetone, was added Me_2SO_4 (1 ml) and K_2CO_3 (2 g) at rt. The reaction mixture was stirred at 50 °C overnight, and then cooled to rt. The mixture was filtered, washed with acetone and the volatiles were removed under reduced pressure afforded as a yellow suspension. Then the resulting suspension was filtered, the filter cake was washed with water and acetone, then dried in vacuum to yield **9a** (96 mg, 98% yield for 2 steps) as a yellow solid. mp 285 °C→black;

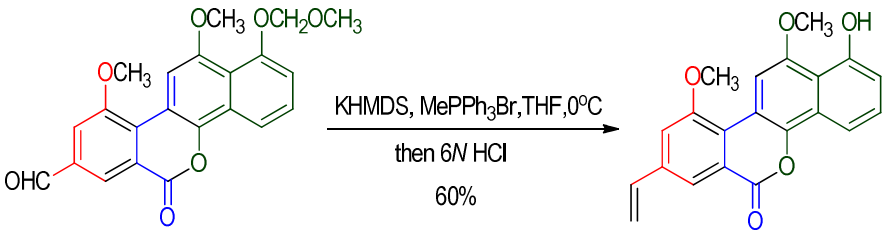
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (s, 1H), 8.27 (dd, *J* = 8.4, 0.8 Hz, 1H), 8.20 (d, *J* = 1.6 Hz, 1H), 7.57 – 7.51 (m, 2H), 7.47 (t, *J* = 8.0 Hz, 1H), 7.39 (t, *J* = 7.6 Hz, 2H), 7.36 – 7.29 (m, 2H), 7.23 (d, *J* = 16.4 Hz, 1H), 7.18 (dd, *J* = 7.6, 0.8 Hz, 1H), 7.10 (d, *J* = 16.4 Hz, 1H), 5.28 (s, 2H), 4.11 (s, 3H), 3.99 (s, 3H), 3.63 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 161.5, 157.7, 153.8, 152.6, 141.0, 138.6, 136.7, 131.2, 129.0, 128.5, 127.3, 126.96, 126.92, 126.86, 123.7, 123.6, 120.7, 118.9, 117.0, 115.5, 114.5, 113.6, 104.4, 97.1, 56.67, 56.64, 56.4;IR ν_{max} (neat, cm^{-1}): 1726, 1589, 1390, 1375, 1256, 1229, 1130, 1022, 781;HRMS: (ESI) for $C_{29}H_{25}O_6^+$ $[M+H]^+$: calcd469.1646, found 469.1646.

10,12-dimethoxy-1-(methoxymethoxy)-6-oxo-6H-dibenzo[c,h]chromene-8-carbaldehyde (10)



To a suspension of **9a** (50 mg, 0.107mmol) in THF (6 mL) and H_2O (6 mL) was $K_2OsO_4{\cdot}2H_2O$ (1 mg, 0.002mmol) and $NaIO_4$ (92 mg, 0.428mmol) at 0°C. The reaction was stirred at rt overnight then quenched with saturated aqueous $Na_2S_2O_3$ (10 mL). The layers were separated and the aqueous phase was extracted with DCM (3 x 10 mL), the combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure. The residue was triturated with Et_2O (2 × 1mL) to afford **10** (35 mg, 83%) as a yellow solid. All analytical data of **10** are in agreement with the reported data[7a]. mp195−198 °C (lit. mp[7a] 200−203 °C);^{1}H NMR (400 MHz, $CDCl_3$) δ 10.00 (s, 1H), 8.44 (d, *J* = 1.6 Hz, 1H), 8.28 (s, 1H), 8.23 (dd, *J* = 8.4, 0.8 Hz, 1H), 7.65 (d, *J* = 1.2 Hz, 1H), 7.50 (t, *J* = 8.0 Hz, 1H), 7.23 (dd, *J* = 7.6, 0.8 Hz, 1H), 5.30 (s, 2H), 4.10 (s, 3H), 4.00 (s, 3H), 3.64 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.3, 160.3, 157.8, 153.7, 152.7, 142.3, 136.1, 129.7, 127.5, 127.0, 126.5, 123.5, 119.5, 117.0, 116.1, 112.63, 112.61, 103.7, 96.9, 56.6, 56.5, 56.4;IR ν_{max} (neat, cm^{-1}): 1732, 1703, 1665, 1587, 1452, 1393, 1117, 1059, 1013; HRMS: (ESI) for $C_{22}H_{18}O_7Na^+$ $[M+Na]^+$: calcd 417.0945, found 417.0958.

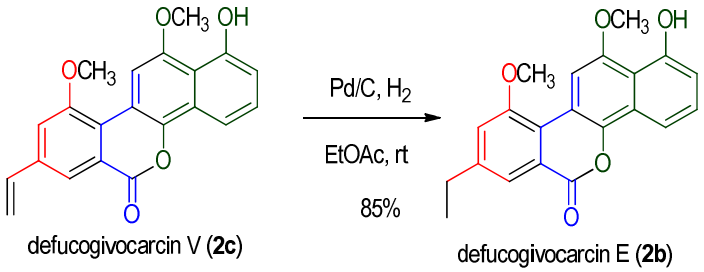
Defucogivocarcin V (2c)



10 defucogivocarcin V (**2c**)

To a suspension of $MePPh_3Br$ (132mg, 0.368mmol) in THF (6 mL) was added KHMDS (0.7M in PhMe, 0.53 mL, 0.368mmol) at 0 °C and stirring was continued for 15 min. A solution of **10** (29 mg, 0.074 mmol) in THF (2 mL) was added dropwise and the mixture was stirred for 2h at 0 °C and then quenched with 6*N*HCl (5 ml), the resulting mixture was stirred overnightat rt. The aqueous layerwas extracted with DCM (3 x 10 mL) and the combined organic layers were then driedover Na_2SO_4, filtered and concentrated under reduced pressure. The residue was purifiedby flash column chromatography on silica gel (20 : 1 DCM/MeOH) to provide **2c** (15.5 mg,60%) as a yellow solid. All analytical data of **2c** are in agreement with the reported data.[7]mp263−266 °C(lit. mp[7b] 267−272 °C);^{1}H NMR (400 MHz, $CDCl_3$) δ 9.31 (s, 1H), 8.22 (s, 1H), 8.09 (d, J = 1.6 Hz, 1H), 8.04 (dd, J = 8.4, 0.8 Hz, 1H), 7.48 (t, J = 8.0 Hz, 1H), 7.27 (d, J = 1.2 Hz, 1H), 6.99 (dd, J = 8.0, 1.2 Hz, 1H), 6.77 (dd, J = 17.6, 10.8 Hz, 1H), 5.93 (d, J = 17.6 Hz, 1H), 5.45 (d, J = 10.8 Hz, 1H), 4.08 (s, 3H), 4.07 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 161.3, 157.5, 154.4, 152.0, 141.8, 138.8, 135.5, 128.7, 126.3, 123.8, 123.6, 120.8, 116.6, 115.0, 114.2, 113.6, 112.9, 101.8, 56.4, 56.2;IR ν_{max} (neat, cm^{-1}): 3339, 1721, 1605, 1385, 1238, 1167, 1065; HRMS: (ESI) for $C_{21}H_{16}O_5Na^+$ $[M+Na]^+$: calcd 371.0890, found 371.0900.

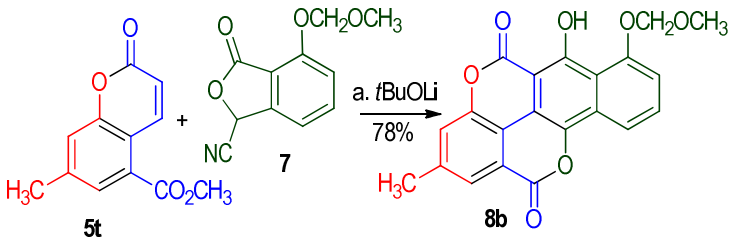
DefucogivocarcinE (2b)



defucogivocarcin V (**2c**) defucogivocarcin E (**2b**)

A solution of **2c** (8 mg, 0.023mmol) in EtOAc (3 mL) was treated with hydrogen in the presence of 10% Pd-C (2.4mg, 0.002mmol) at rt and stirred for 1.5h. The mixture was filtered through Celite, washed with EtOAc and the volatiles were removed under reduced pressure. The residue was triturated with Et_2O (2 × 1 mL) to afford **2b** (6.8 mg, 85%) as a pale yellow solid. All analytical data of **2b** are in agreement with the reported data[8].mp 254−256 °C(lit. mp[8] 255−256 °C);^{1}H NMR (400 MHz, $CDCl_3$) δ 9.36 (s, 1H), 8.33 (s, 1H), 8.08 (dd, *J* = 8.4, 1.2 Hz, 1H), 7.97 (d, *J* = 1.6 Hz, 1H), 7.49 (t, *J* = 8.0 Hz, 1H), 7.17 (d, *J* = 1.6 Hz, 1H), 7.00 (dd, *J* = 7.6, 0.8 Hz, 1H), 4.11 (s, 3H), 4.08 (s, 3H), 2.80 (q, *J* = 7.6 Hz, 2H), 1.35 (t, *J* = 7.6 Hz, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 161.5, 157.3, 154.3, 152.0, 146.3, 141.5, 128.6, 126.4, 123.4, 122.2, 121.8, 117.3, 114.8, 113.6, 113.1, 112.6, 102.0, 56.4, 56.2, 29.1, 15.3; IR ν_{max} (neat, cm^{-1}): 3356, 1719, 1589, 1437, 1387, 1250, 1171, 1123, 1057; HRMS: (ESI) for $C_{21}H_{19}O_5[M+H]^+$: calcd351.1227, found 351.1228.

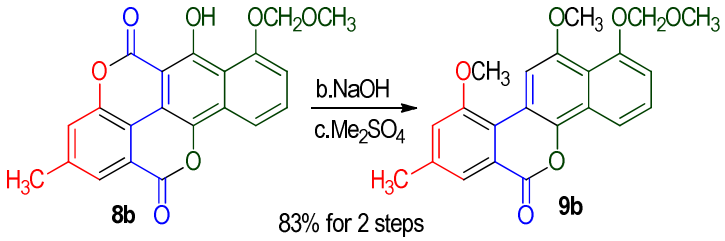
6-hydroxy-7-(methoxymethoxy)-2-methylbenzo[h]chromeno[5,4,3-cde]chromene-5,12-di one (8b)[3]



To a stirred solution of ^{t}BuOH (124 µl, 1.36 mmol) in THF (3 mL) at -60^{o}C was added ^{n}BuLi (2.0 M in cyclohexane, 0.68 mL, 1.36mmol) and stirring for 10 min. Then a solution of a phthalide **7**[4] (90 mg, 0.41mmol) in THF (1 mL) was added dropwise. The resulting yellowish solution was stirred at -60 ^{o}C for 40 min, after which a solution of coumarin **5t** (90 mg, 0.41

mmol)in THF (5 mL) was added to it. The cooling bath was removed after about 1 h at -60 °C and the reaction mixture was brought to rt over a period of 1 h and further stirred overnight. The reaction was then quenched with saturatedaqueousNH_4Cl (15 mL) and stirred for 30 min at rt. The THF was removed in vacuum and the resulting suspension was filtered. The filter cake was washed with water and acetone, then dried in vacuum to yield the pure product **8b** (121 mg, 78%) as a yellow solid. mp 265°C→black; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.18 (s, 1H), 8.20 (dd, *J* = 8.4, 1.0 Hz, 1H), 8.06 (s, 1H), 7.76 (t, *J* = 8.0 Hz, 1H), 7.51 (s, 1H), 7.34 (dd, *J* = 8.0, 1.0 Hz, 1H), 5.45 (s, 2H), 3.64 (s, 3H), 2.61 (s, 3H);IR ν_{max} (neat, cm^{-1}): 3160, 1701, 1624, 1400, 1223, 1107, 976, 752; HRMS: (ESI) for $C_{21}H_{14}O_7Na^+$ $[M+Na]^+$: calcd 401.0632, found 401.0618. (Due to the poor solubility of the product in various solvents, ^{13}C NMR cannot be detected)

10,12-dimethoxy-1-(methoxymethoxy)-8-methyl-6H-dibenzo[c,h]chromen-6-one (9b)[5]

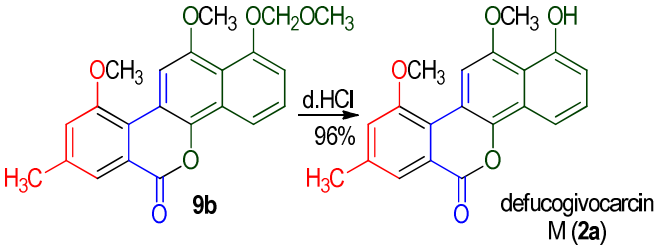


To a Schlenk tube equipped with a magnetic stir bar, was added 1*N* NaOH (4 ml) and 1,4-dioxane (4 ml),the resulting mixture was degassed (three freeze-pump-thaw cycles) and the reaction tube was refilled with Ar. To this solution was added **8b** (80 mg, 0.21mmol) in glovebox. The reaction mixture was stirred at 60°C for 5 h when the yellow suspension turns to a clear yellow solution, and then cooled to 0°C.It was quenched with saturated 1*N* HCl and extracted with DCM (3 x 10 mL).The combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure, the desired product was used without further purification as a yellow solid.

To a solution of this yellow solid in dry acetone, was added Me_2SO_4 (1 ml) and K_2CO_3 (2g) at rt. The reaction mixture was stirred at 50 °C overnight, and then cooled to rt. The mixture was filtered, washed with acetone and the volatiles were removed under reduced pressure afforded

as a yellow suspension. Then the resulting suspension was filtered, the filter cake was washed with water and acetone, then dried in vacuum to yield **9b** (66.3 mg, 83% for two steps) as a yellow solid.mp195−198 °C;^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (s, 1H), 8.28 (d, *J* = 8.4 Hz, 1H), 7.87 (s, 1H), 7.49 (t, *J* = 8.0 Hz, 1H), 7.20 (d, *J* = 7.6 Hz, 1H), 7.06 (s, 1H), 5.29 (s, 2H), 4.02 (s, 3H), 3.98 (s, 3H), 3.63 (s, 3H), 2.45 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 161.5, 157.2, 153.7, 152.5, 140.6, 139.9, 127.2, 126.9, 123.2, 122.8, 122.0, 118.7, 118.2, 117.0, 115.4, 113.7, 104.5, 97.1, 56.6, 56.3, 21.7;IR ν_{max} (neat, cm^{-1}):1720, 1589, 1334, 1153, 1061, 1018;HRMS: (ESI) for $C_{22}H_{21}O_6^+$ $[M+H]^+$: calcd381.1333, found 381.1320.

Defucogivocarcin M (2a)



To a suspension of **9b** (18 mg, 0.047 mmol) in MeOH (2 mL) was added 6 *N* HCl (0.2 mL) at rt. The reaction mixture was stirred at 50°C for 2 h. The reaction was diluted with DCM (20 mL) and washed with saturated aqueous NaCl (2 x 10 mL),the combined organic layers were dried over Na_2SO_4, filtered and concentrated under reduced pressure to yield **2a** (15.3 mg, 96%) as a yellow solid. All analytical data of **2a** are in agreement with the reported data[6]. mp 284−286 °C (lit. mp[6a]289−291 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.34 (s, 1H), 8.26 (s, 1H), 8.05 (dd, *J* = 8.4, 0.8 Hz, 1H), 7.90 (d, *J* = 0.8 Hz, 1H), 7.48 (t, *J* = 8.4 Hz, 1H), 7.09 (d, *J* = 1.2 Hz, 1H), 6.99 (dd, *J* = 7.6, 0.8 Hz, 1H), 4.09 (s, 3H), 4.05 (s, 3H), 2.48 (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$) δ 161.4, 157.1, 154.3, 151.9, 141.4, 140.0, 128.6, 126.3, 123.2, 122.9, 121.9, 118.2, 114.8, 113.5, 113.1, 112.5, 101.9, 56.3, 56.1, 21.8; IR ν_{max} (neat, cm^{-1}): 3372, 1720, 1512, 1260, 602;HRMS: (ESI) for $C_{20}H_{17}O_5^+$ $[M+H]^+$: calcd337.1071, found 337.1068.

III: References

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6. (a) Takemura, I.; Imura, K.; Matsumoto, T.; Suzuki, K. *Org. Lett.* **2004**, *6*, 2503–2505; (b) Sumida,Y.; Harada, R.; Kato-Sumida,T.; Johmoto,K.;Uekusa,H.; Hosoya T. *Org. Lett.* **2014**, 1*6*, 6240–6243.
7. (a) Nandaluru, P. R.; Bodwell, G. J.*J. Org. Chem.***2012**, *77*, 8028–8037; (b) Petten, A. D.; Nguyen, N. H.; Danishefsky, S. J. *J. Org. Chem.***1988**, *53*, 1003–1007.
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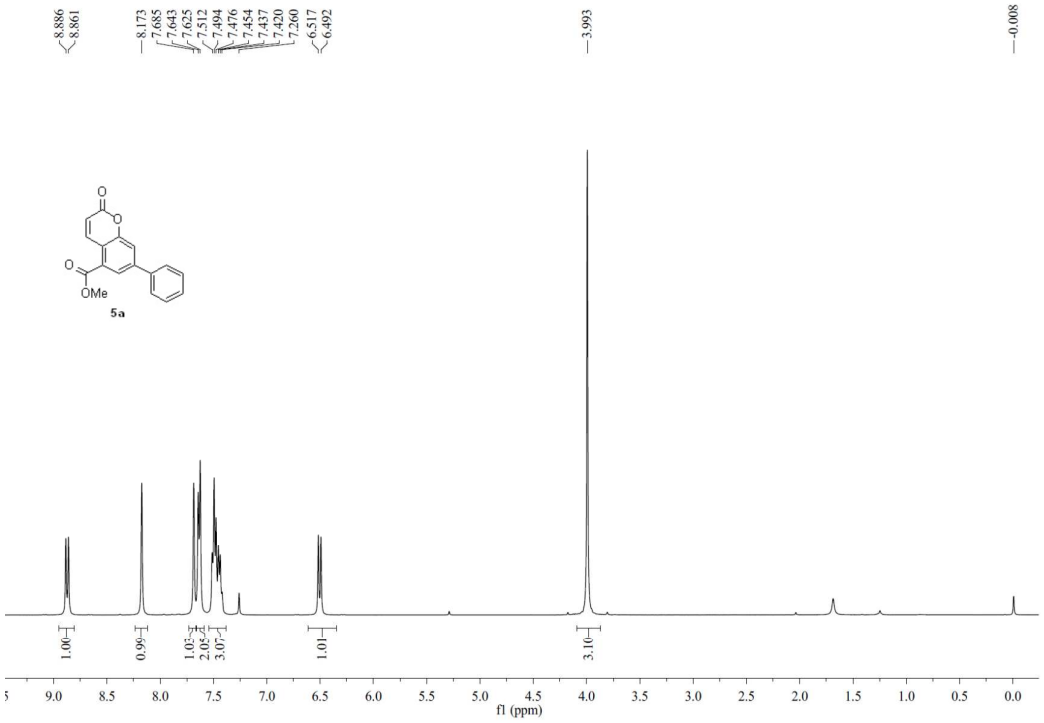
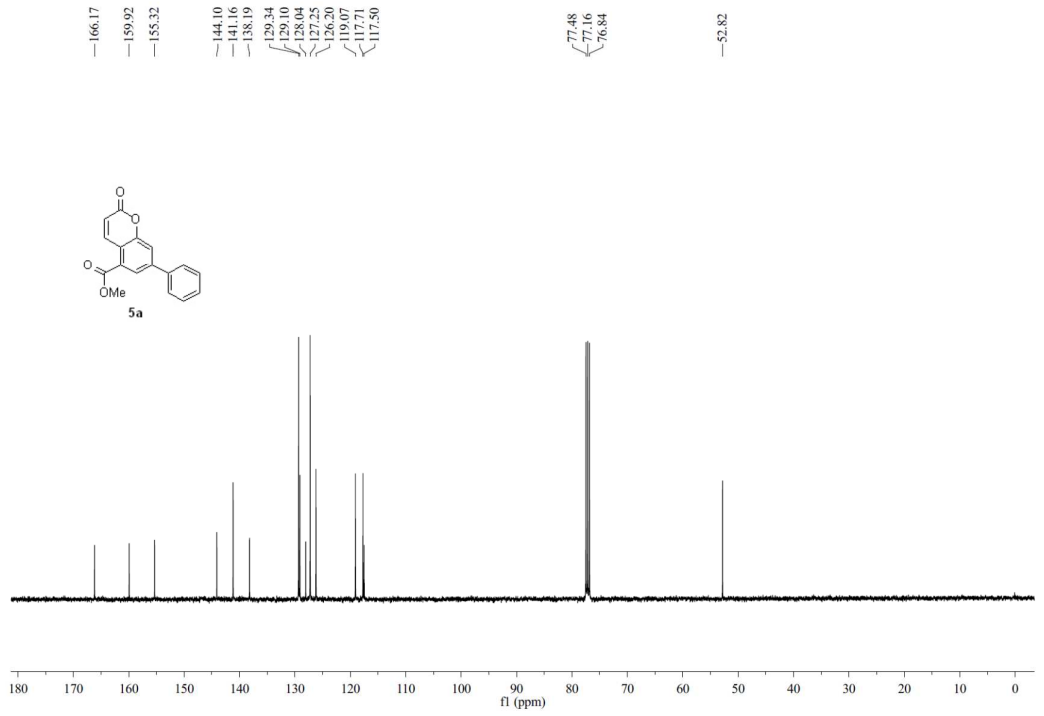
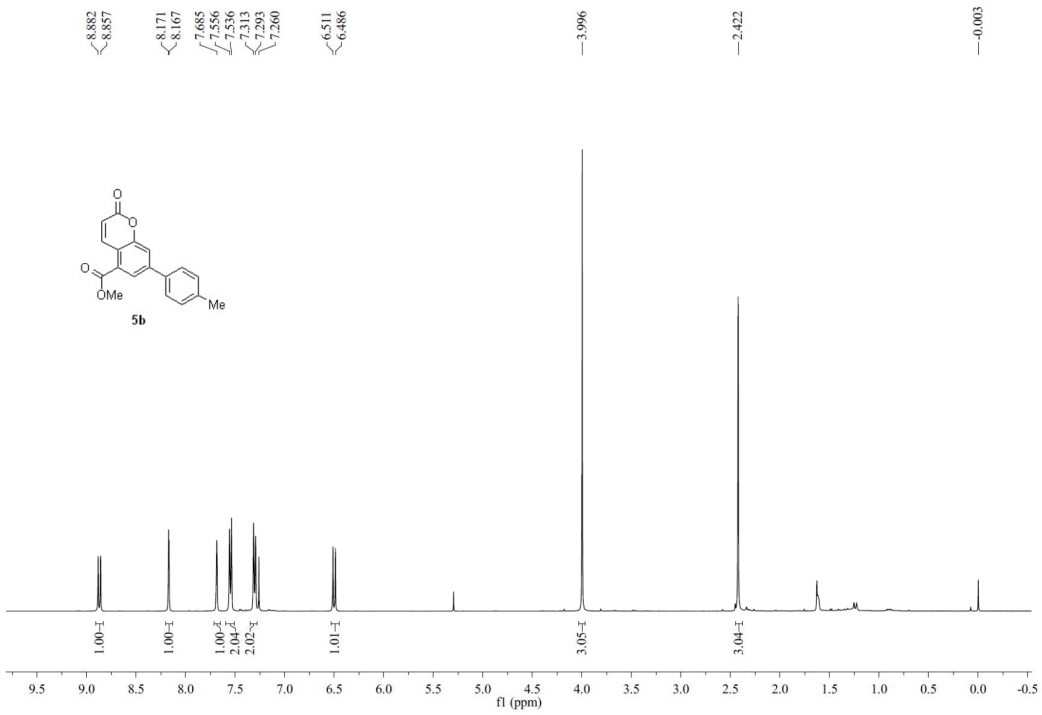
^{1}H NMR, ^{13}C NMR spectra of products



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3.996
2.422
-0.003
O
O
O
OMe
Me
5b
1.00
1.00
1.00
2.04
2.02
1.01
3.05
3.04
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
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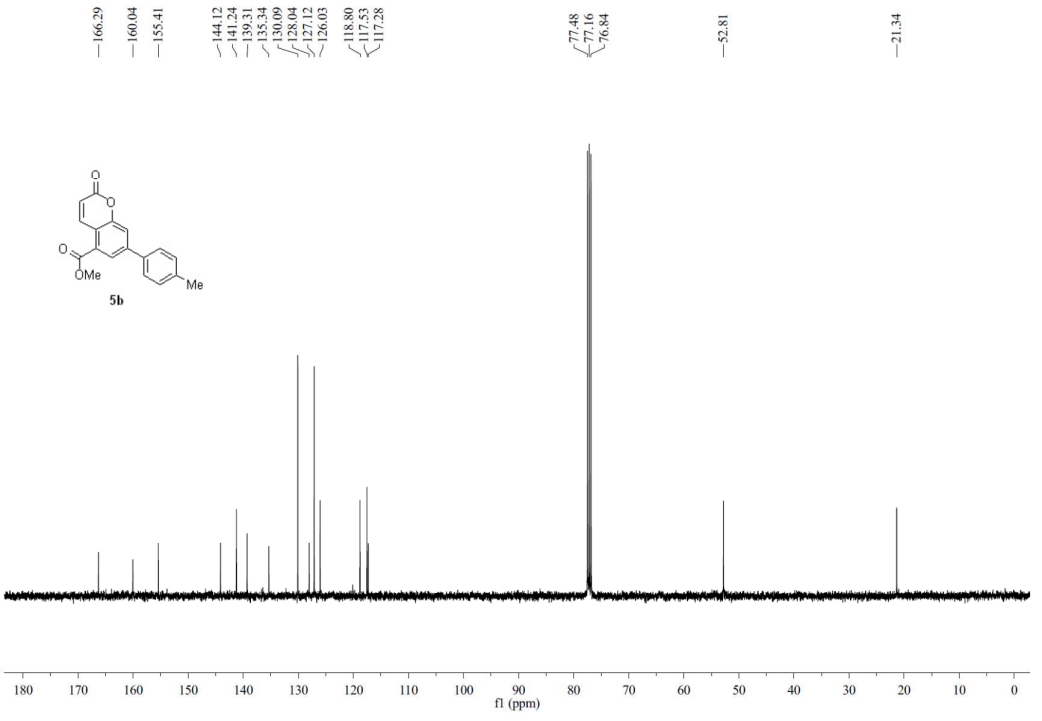
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117.53
117.28
77.48
77.16
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O
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OMe
Me
5b
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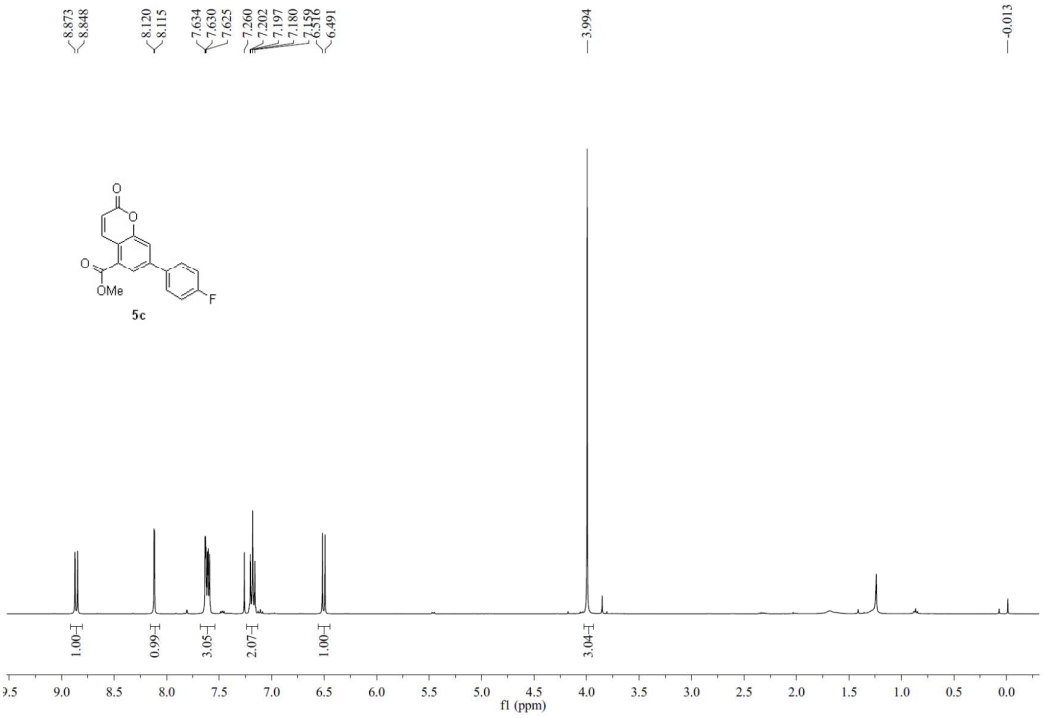
f1 (ppm)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6.491
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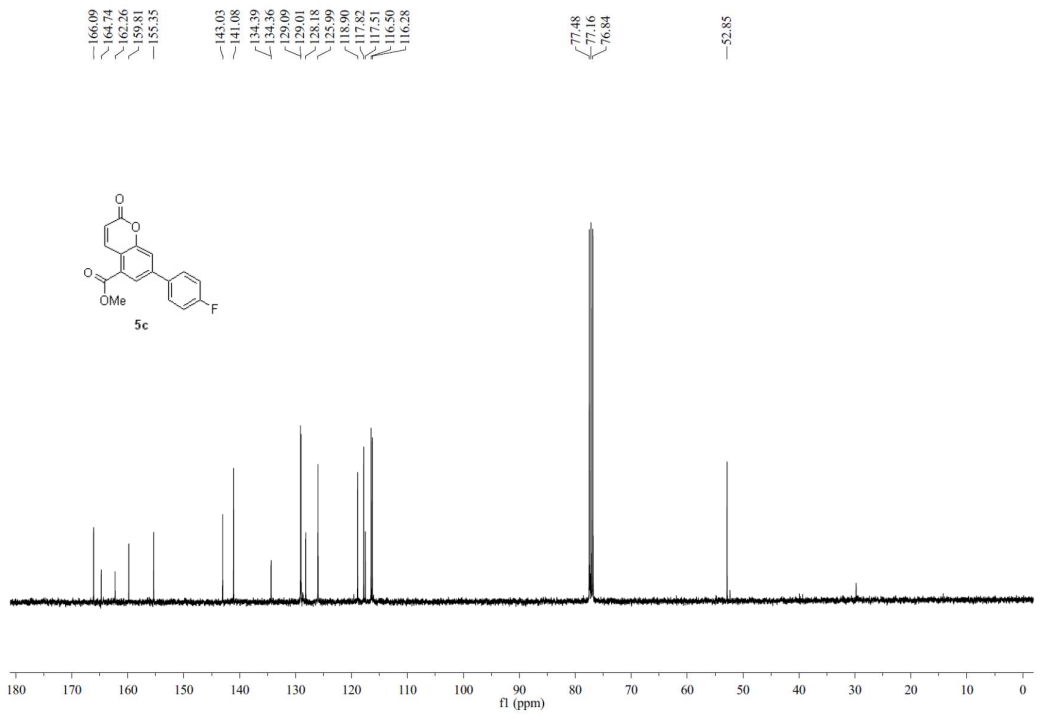
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129.09
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118.90
117.82
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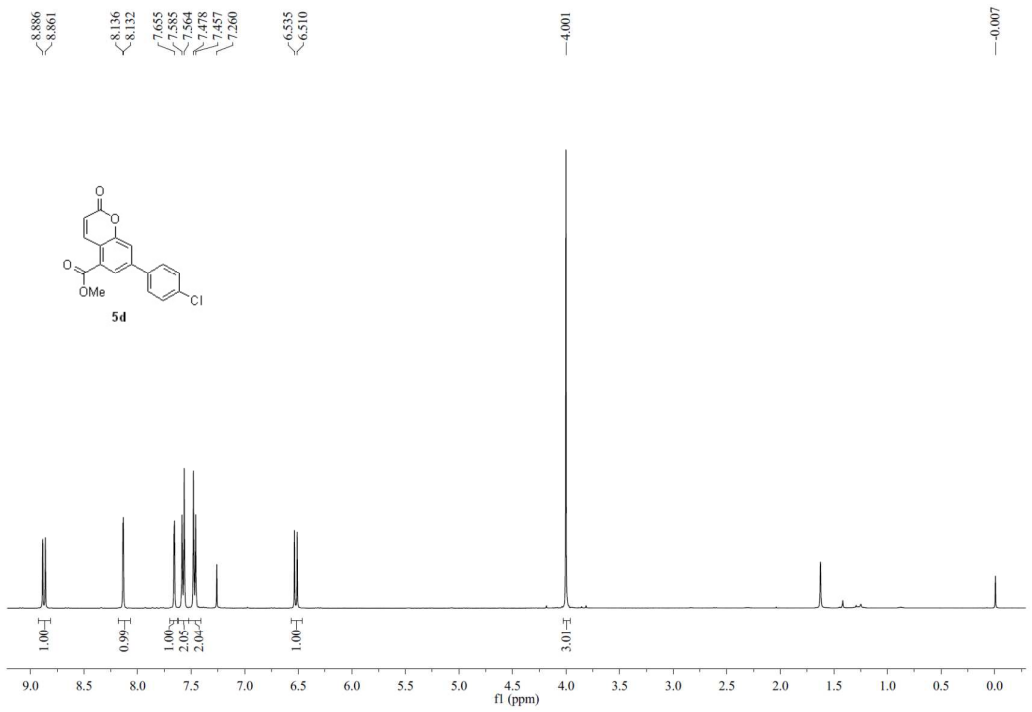
O
O
OMe
F
5c
f1 (ppm)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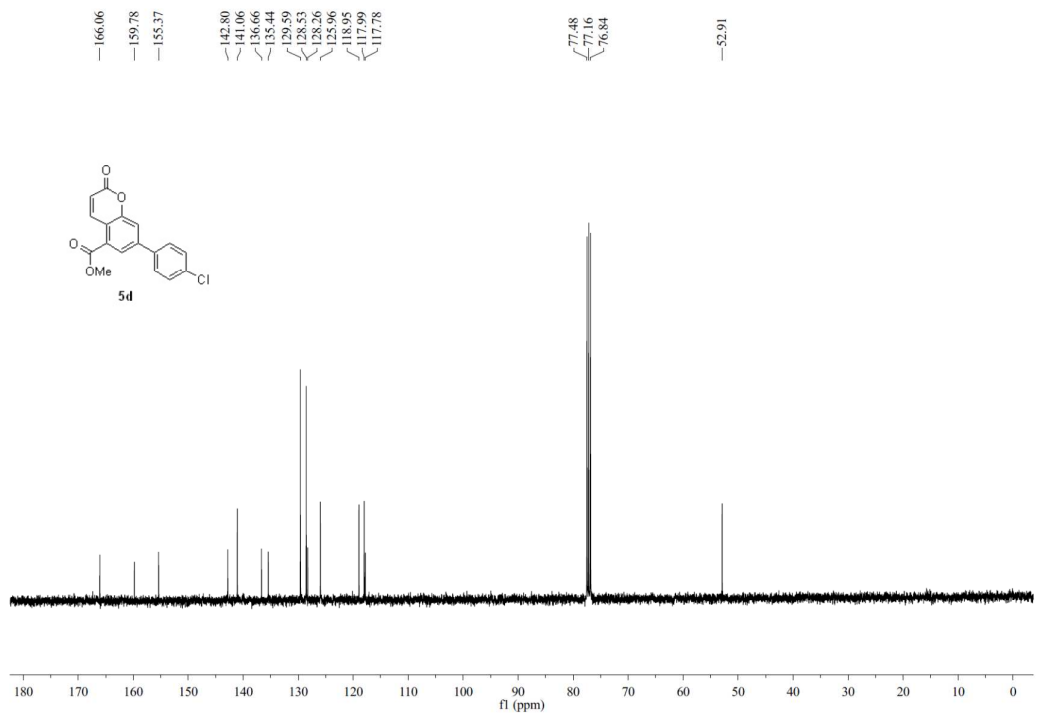
f1 (ppm)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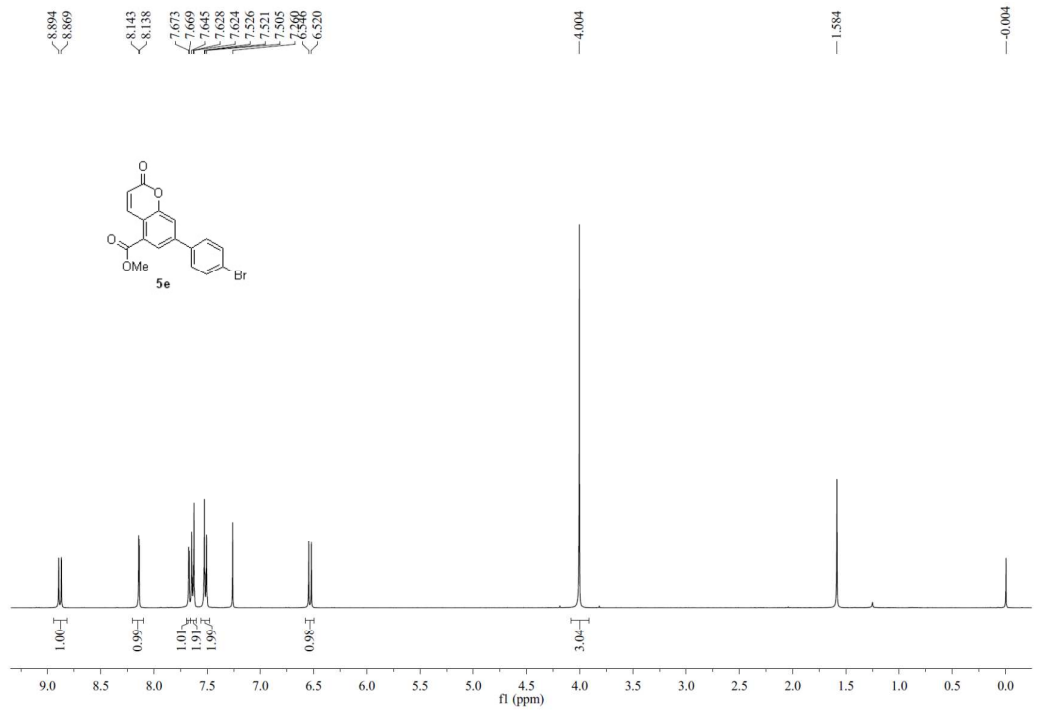
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Br
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1.01
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1.96
0.98
3.04
9.0
8.5
8.0
7.5
7.0
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6.0
5.5
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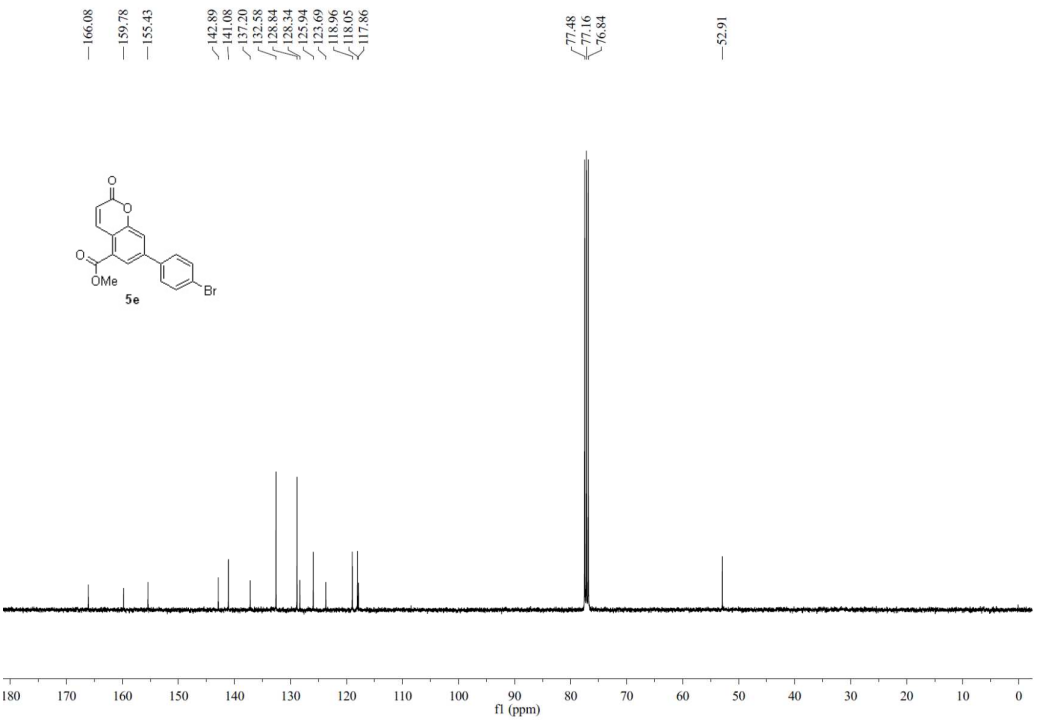
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Br
5e
180
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50
40
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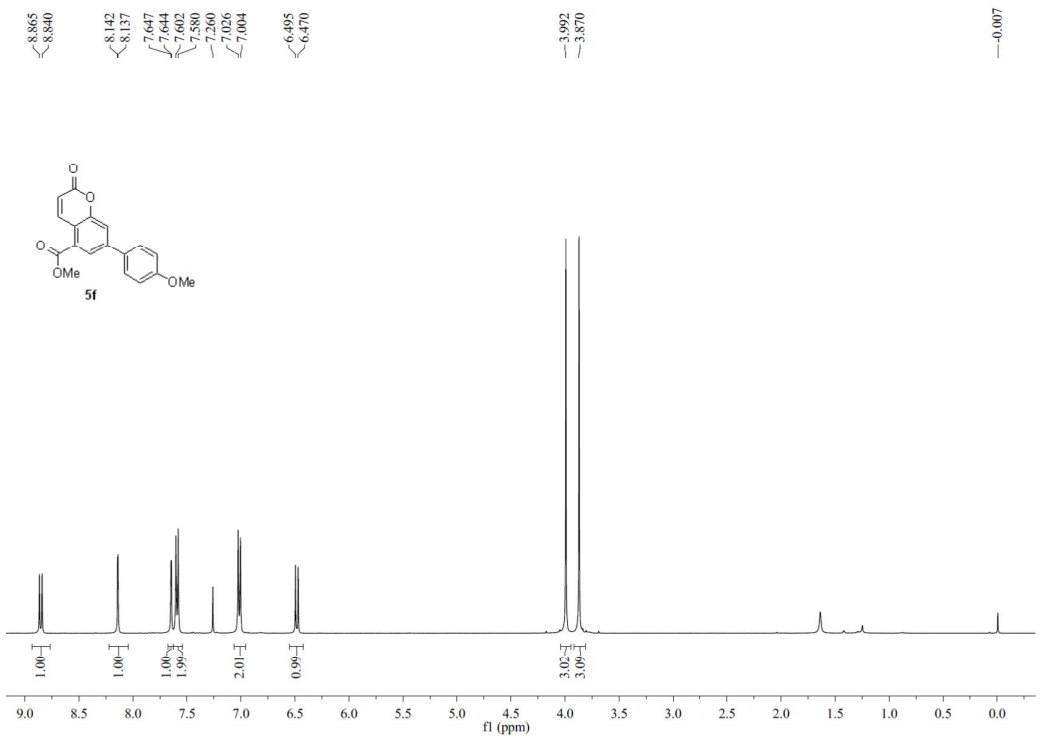
f1 (ppm)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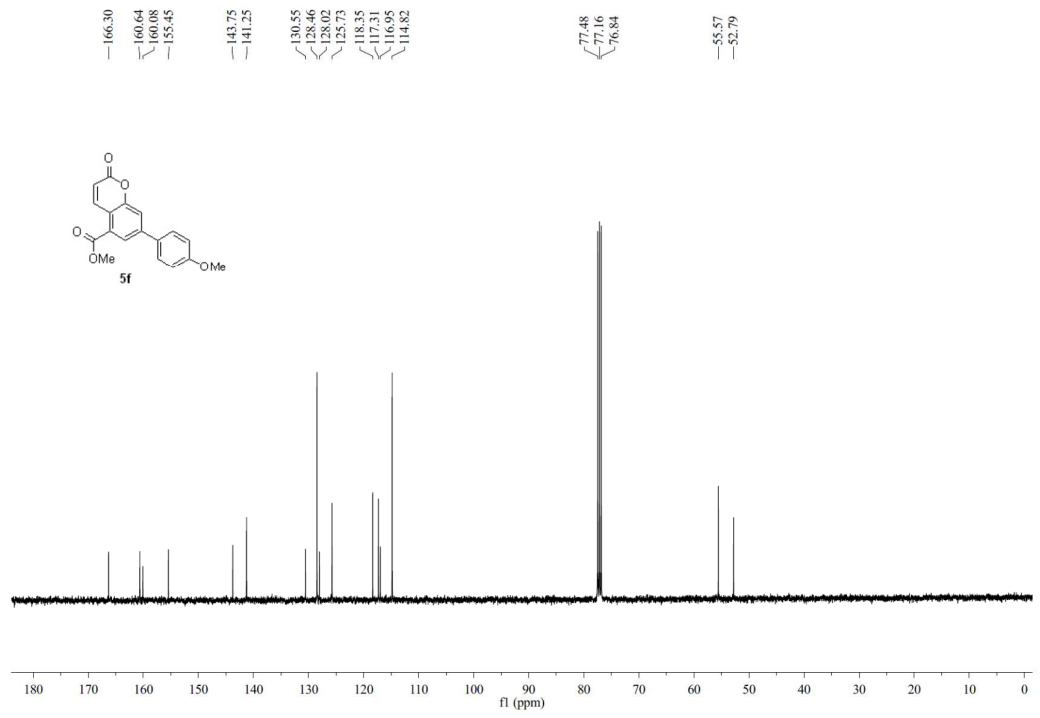
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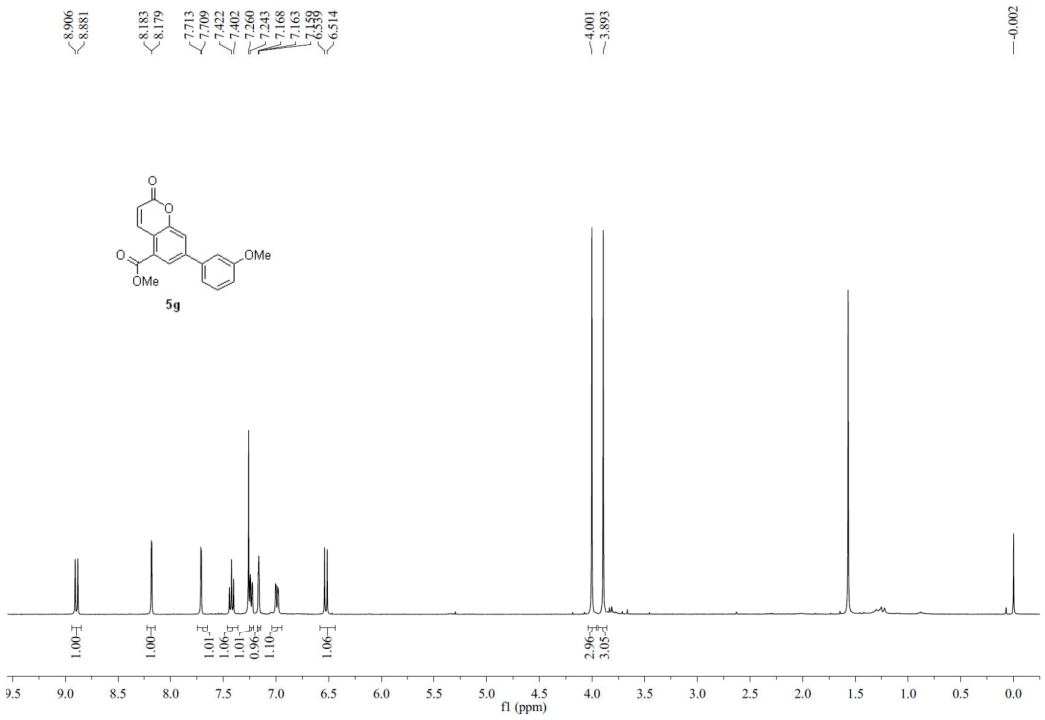
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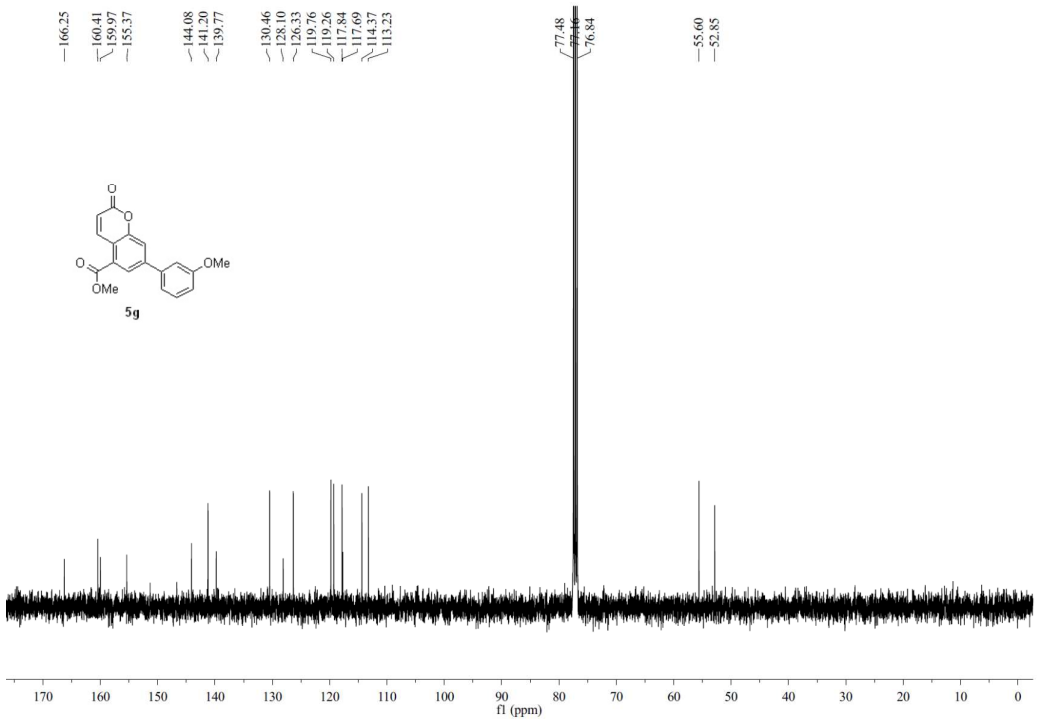
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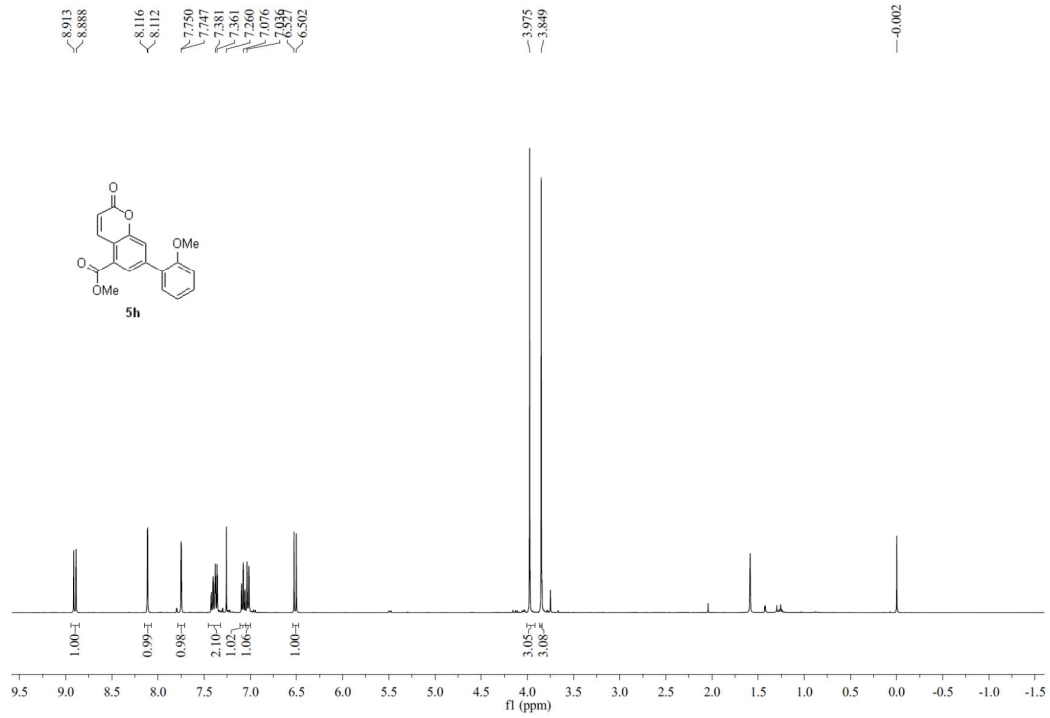
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3.849
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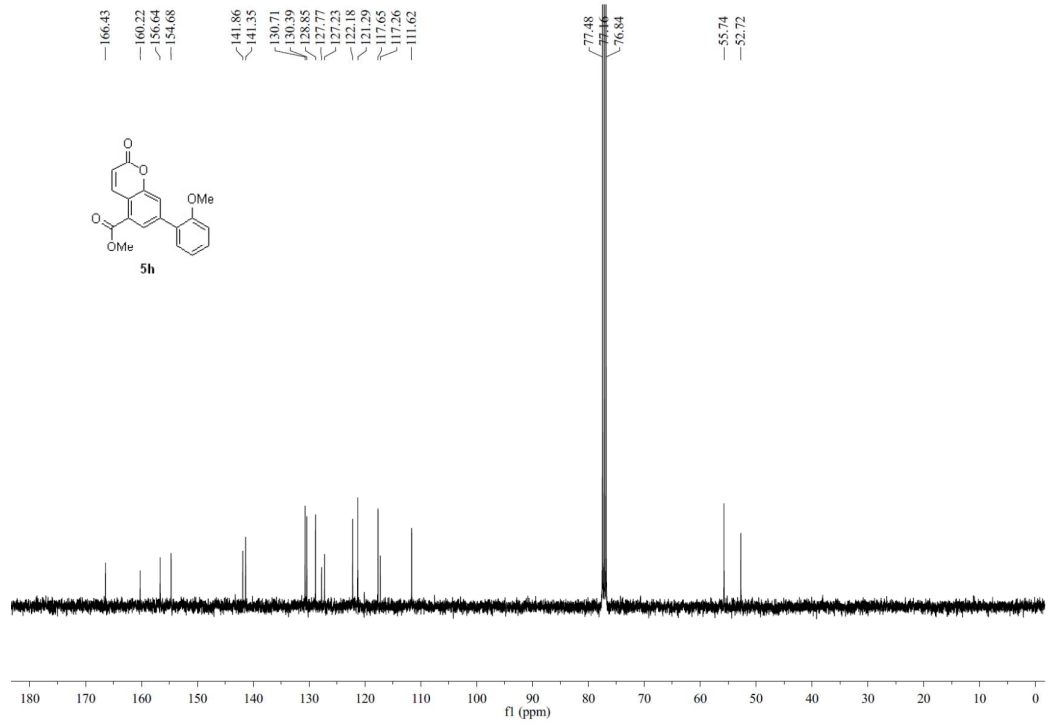
fl (ppm)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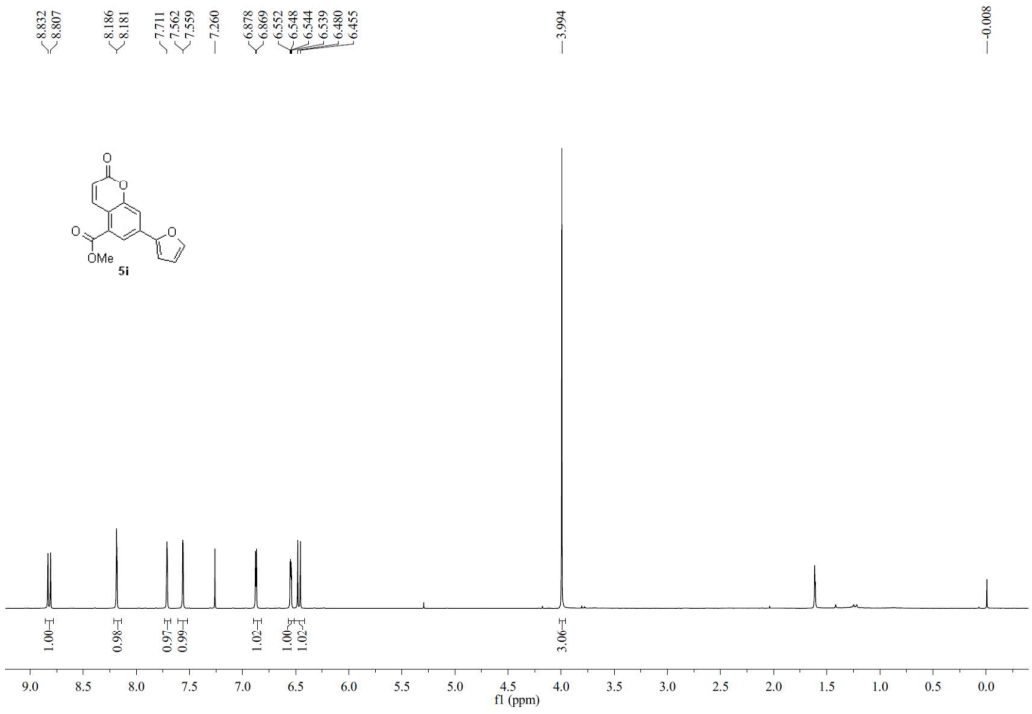
fl (ppm)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5i
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0.99
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1.00
1.02
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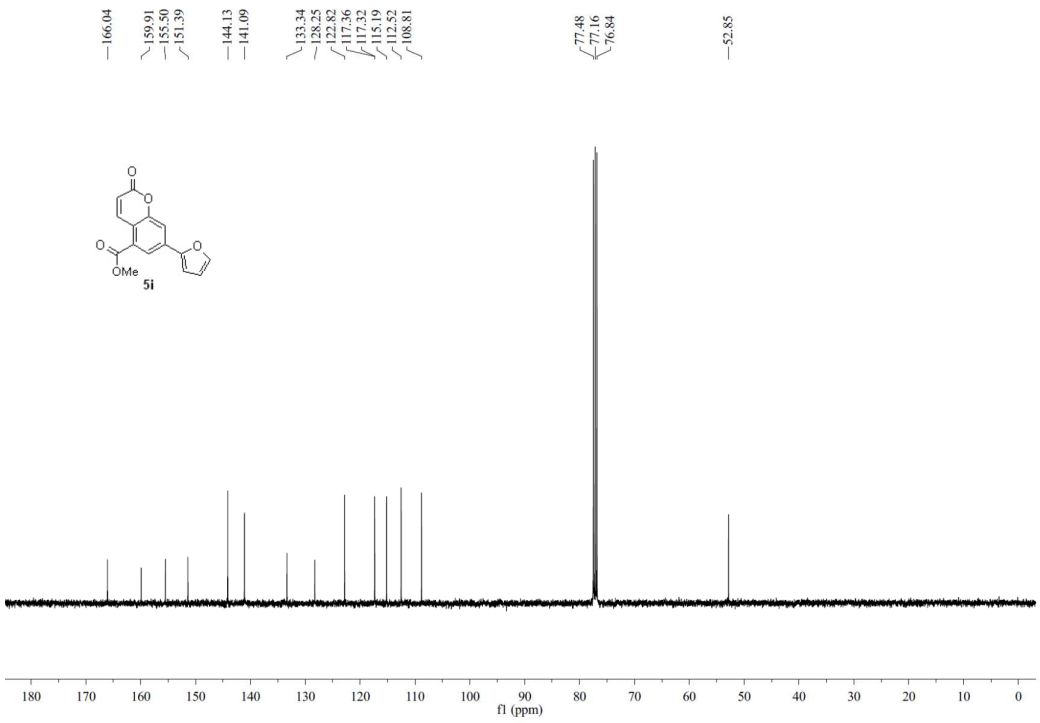
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O
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O
OMe
5i
180
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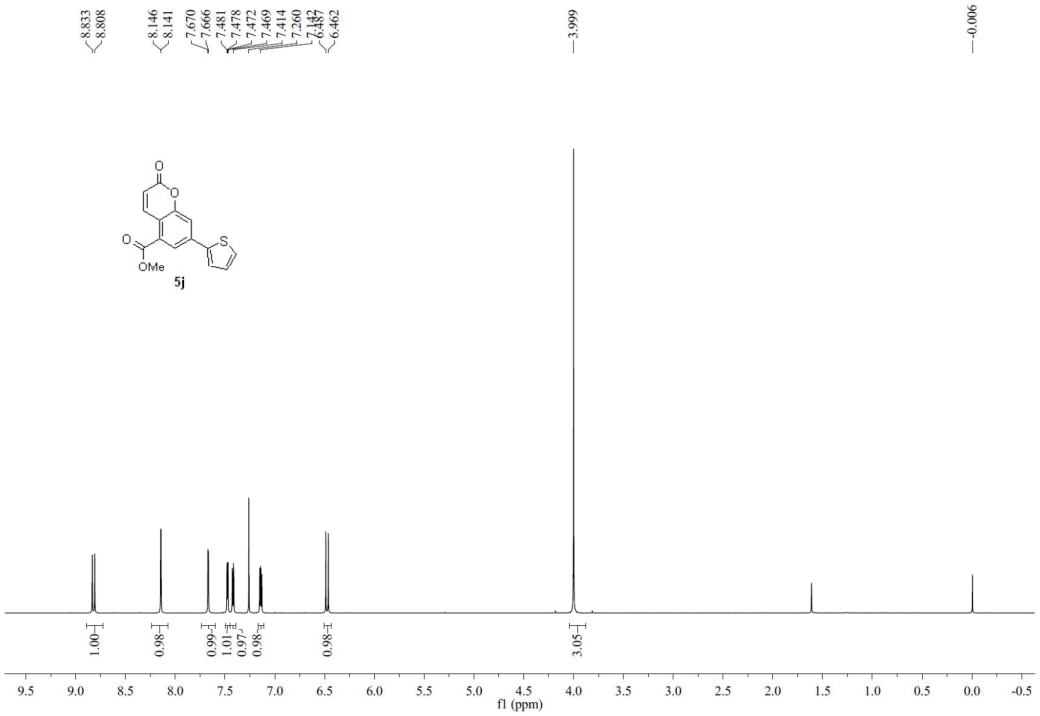
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0.97
0.98
0.98
3.05
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
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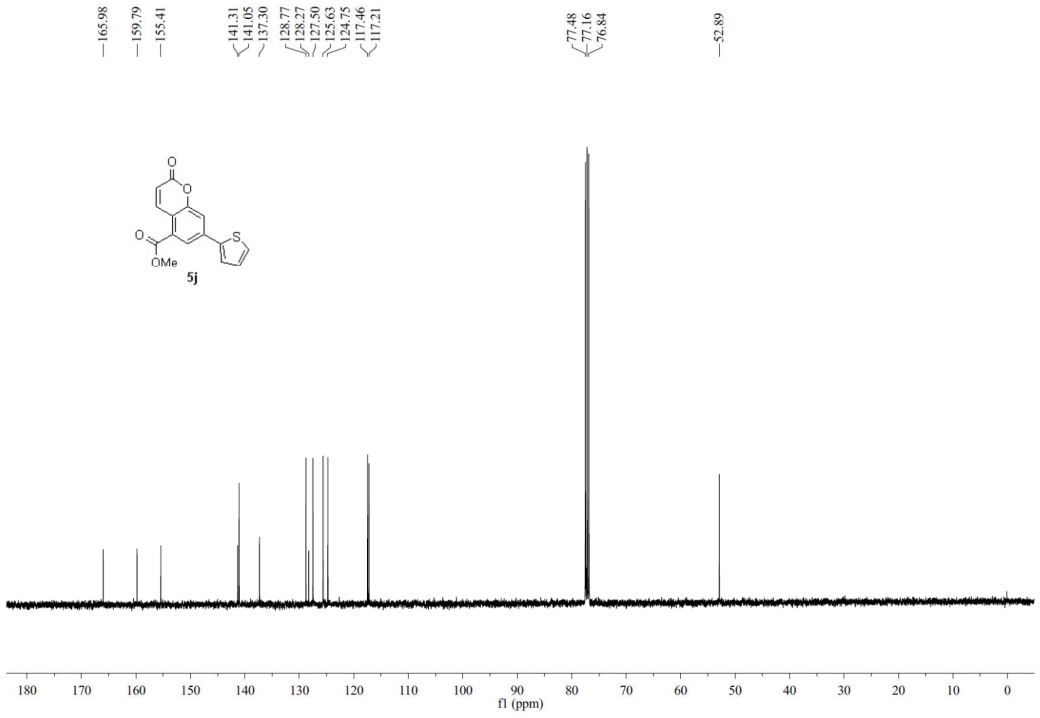
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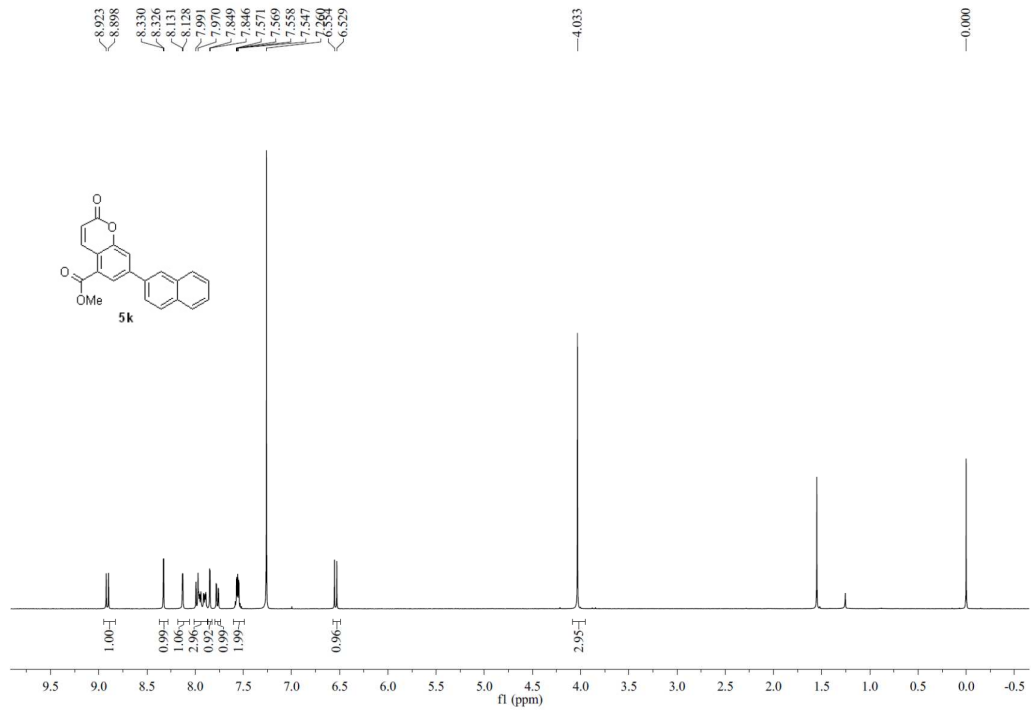
52.89
OMe
5j
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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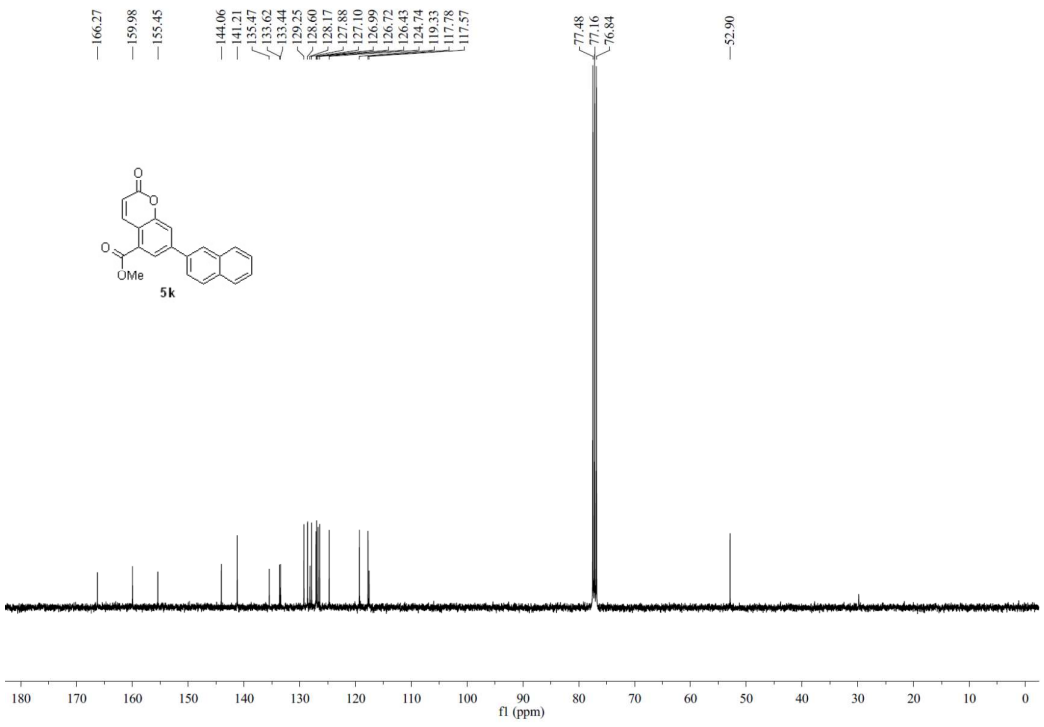
8.898
8.330
8.326
8.131
8.128
7.991
7.970
7.849
7.846
7.571
7.569
7.558
7.547
6.534
6.529
4.033
0.000
5k
1.00
0.99
1.06
2.96
0.92
0.99
1.99
0.96
2.95
fl (ppm)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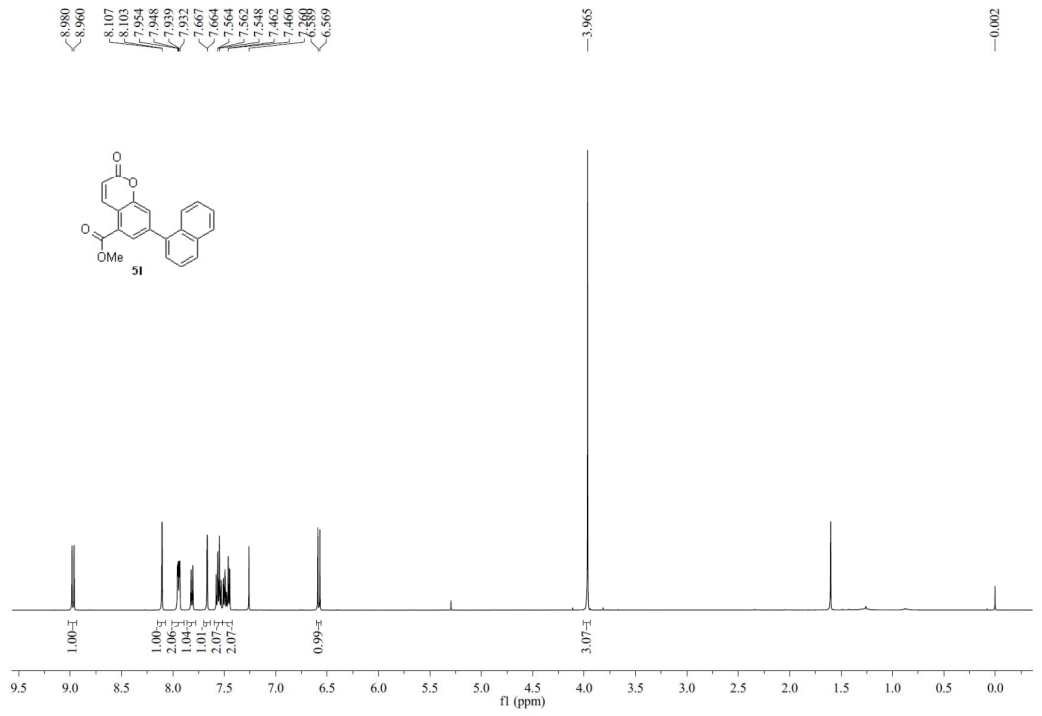
159.98
155.45
144.06
141.21
135.47
133.62
133.44
129.25
128.60
128.17
127.88
127.10
126.99
126.72
126.43
124.74
119.33
117.78
117.57
77.48
77.16
76.84
52.90
5k
fl (ppm)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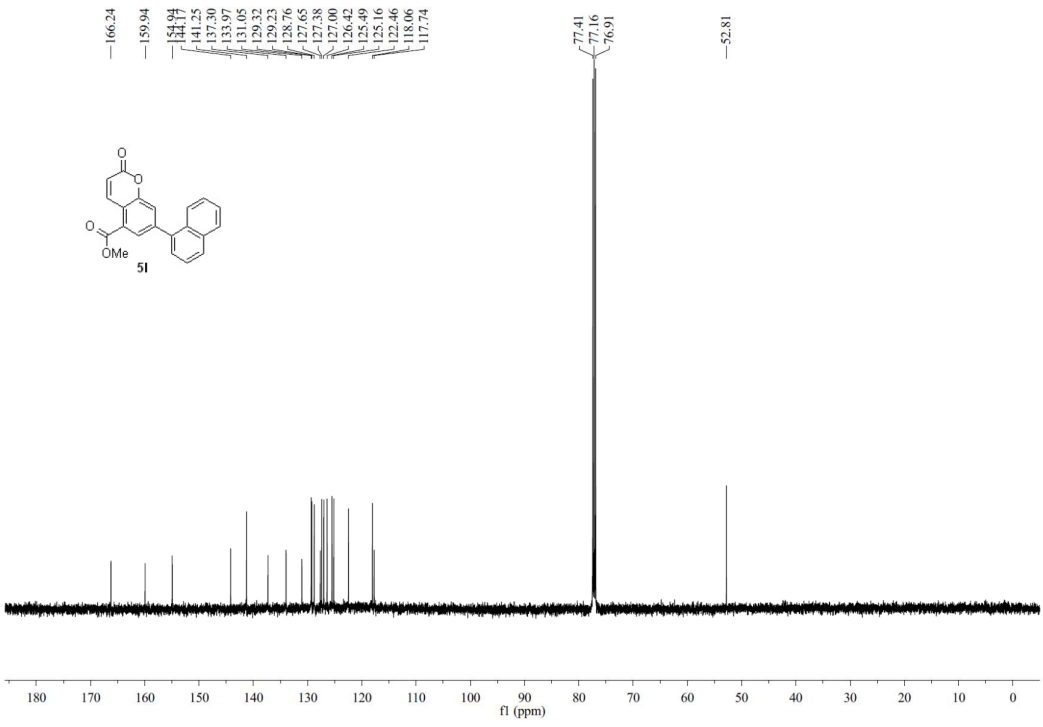
8.960
8.107
8.103
7.954
7.948
7.939
7.932
7.667
7.664
7.564
7.562
7.548
7.462
7.460
7.260
6.589
6.569
3.965
0.002
O
O
O
OMe
5l
1.00
1.00
2.06
1.04
1.01
2.07
2.07
0.99
3.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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154.04
144.17
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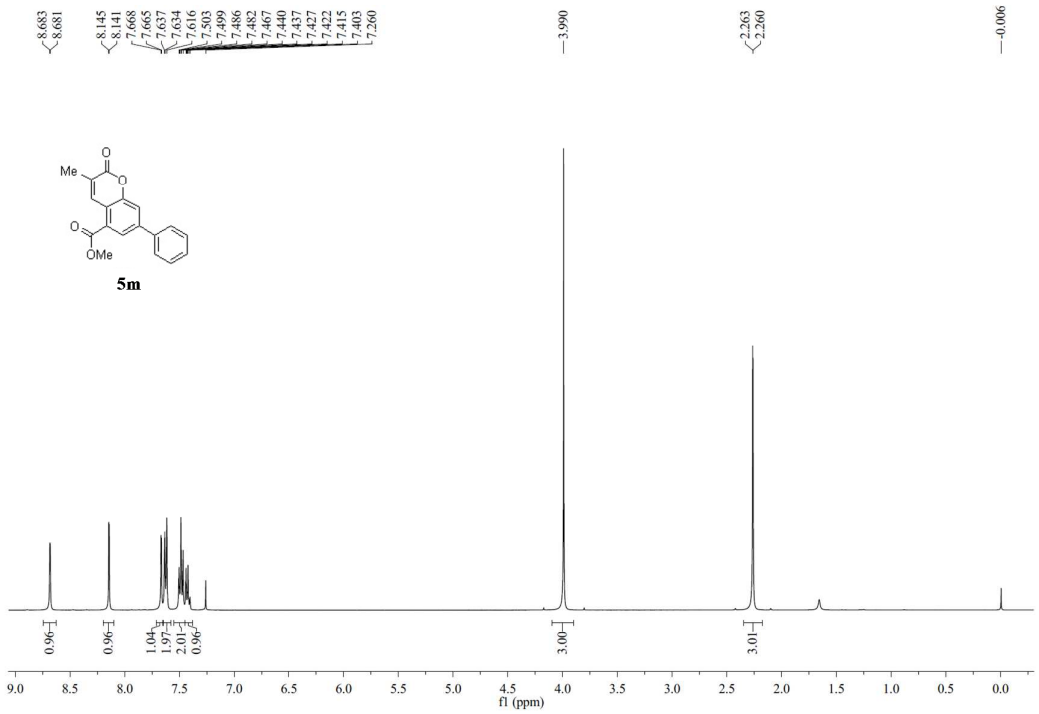
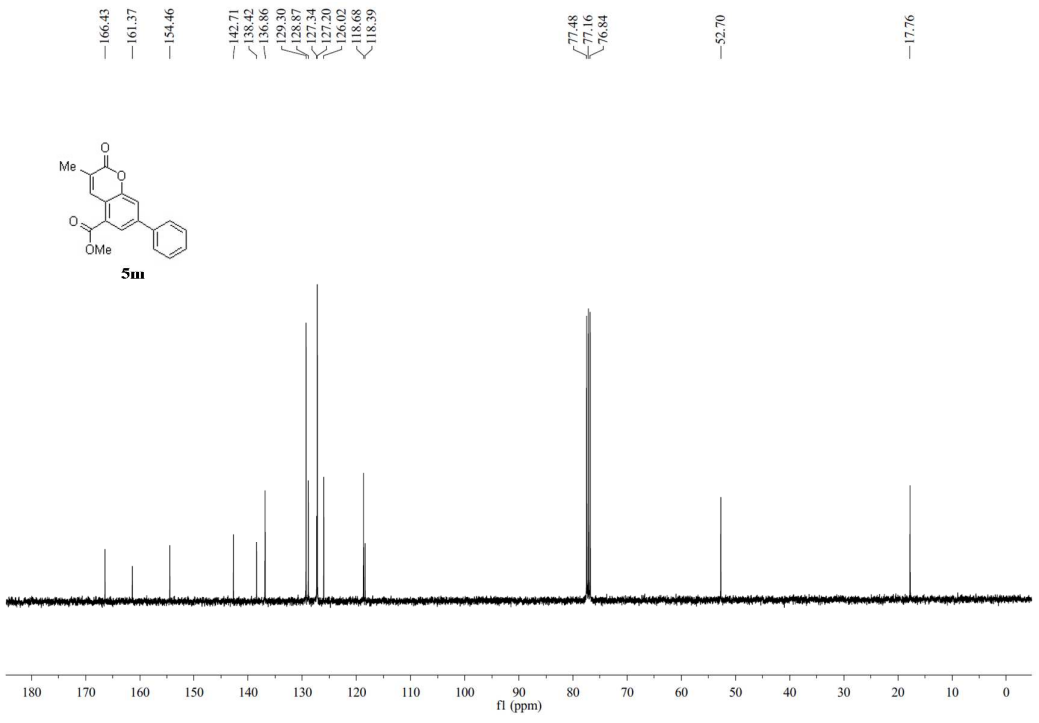
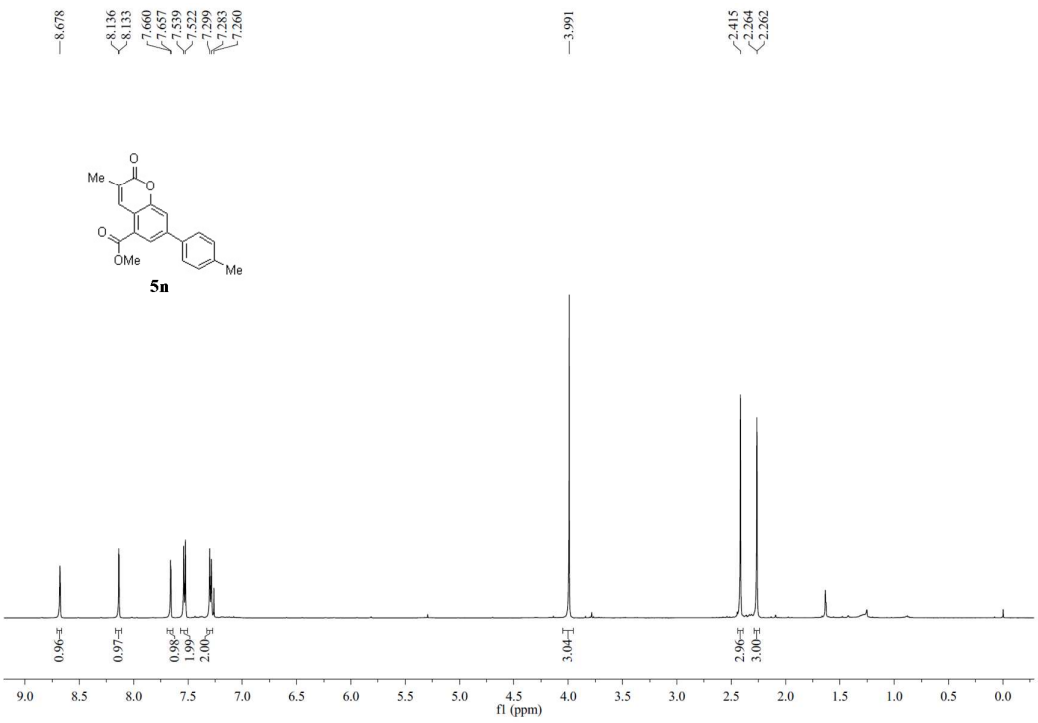
137.30
133.97
131.05
129.32
129.23
128.76
127.65
127.38
127.00
126.42
125.49
125.16
122.46
118.06
117.74
77.41
77.16
76.91
52.81
O
O
O
OMe
5l
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.683
8.681
8.145
8.141
7.668
7.665
7.637
7.634
7.616
7.503
7.499
7.486
7.482
7.467
7.440
7.437
7.427
7.422
7.415
7.403
7.260
3.990
2.263
2.260
-0.006
Me
O
O
OMe
5m
0.96
0.96
1.04
1.97
2.01
0.96
3.00
3.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


166.43
161.37
154.46
142.71
138.42
136.86
129.30
128.87
127.34
127.20
126.02
118.68
118.39
77.48
77.16
76.84
52.70
17.76
Me
O
O
OMe
5m
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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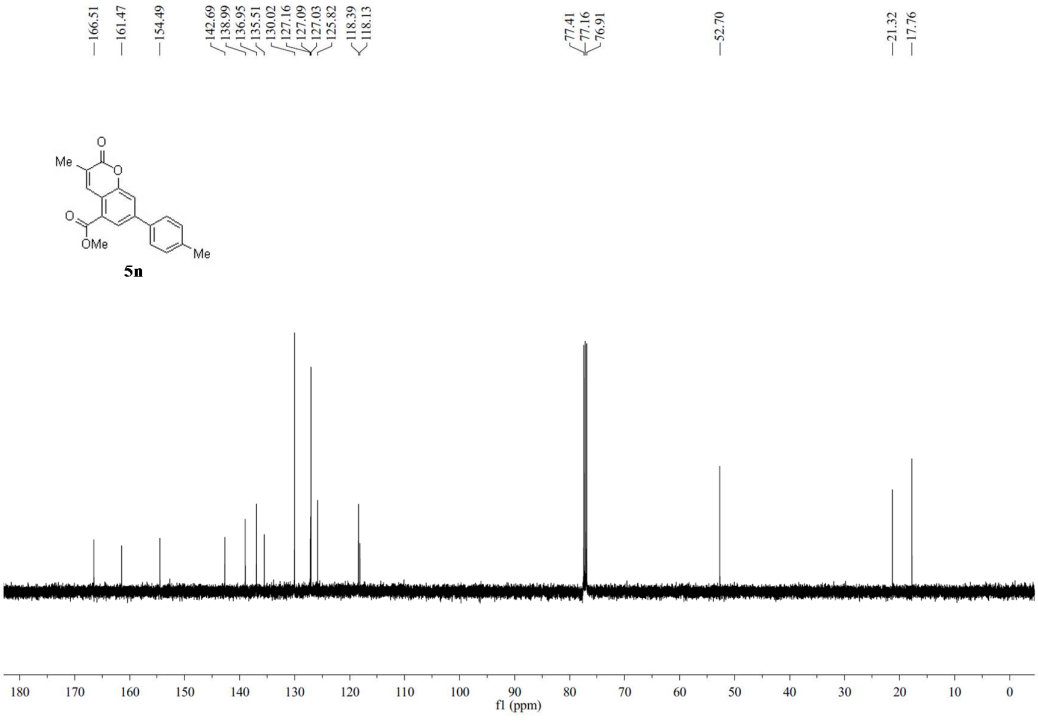
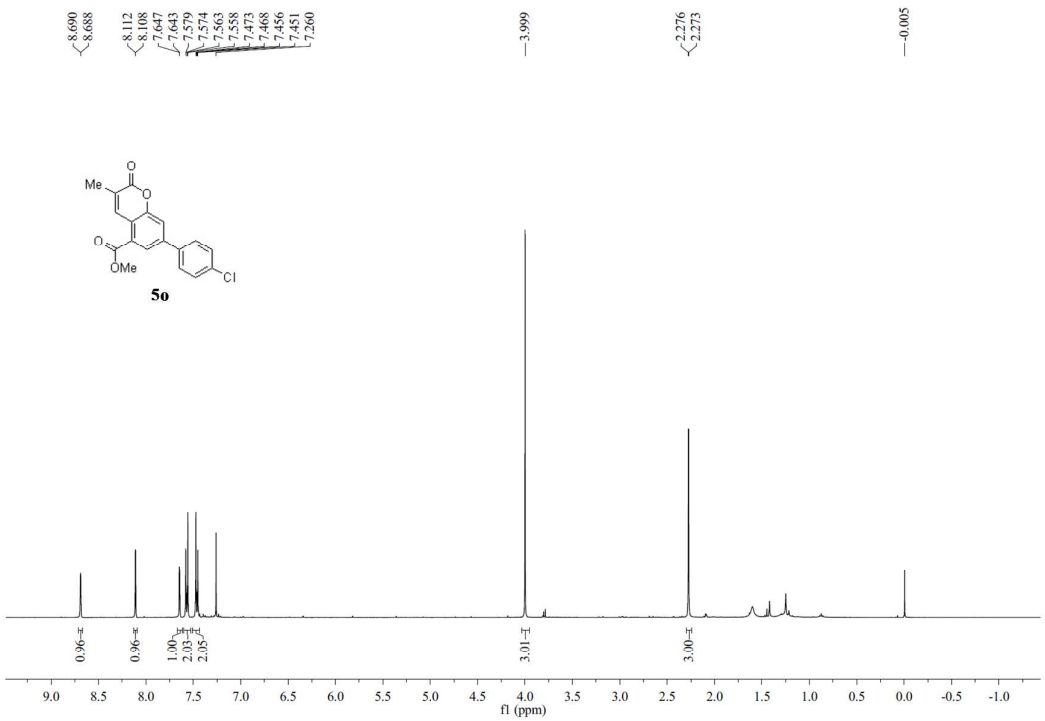
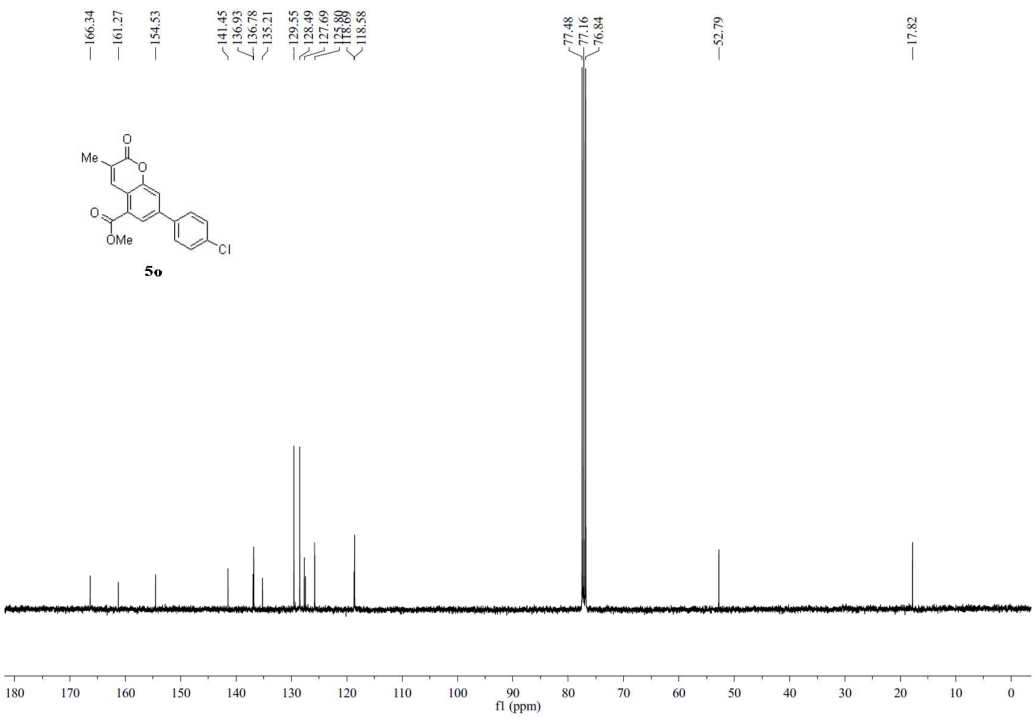
8.136
8.133
7.660
7.657
7.539
7.522
7.299
7.283
7.260
3.991
2.415
2.264
2.262
Me
O
O
OMe
Me
5n
0.96
0.97
0.98
1.99
2.00
3.04
2.96
3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


166.51
161.47
154.49
142.69
138.99
136.95
135.51
130.02
127.16
127.09
127.03
125.82
118.39
118.13
77.41
77.16
76.91
52.70
21.32
17.76
Me
O
O
OMe
Me
5n
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.690
8.688
8.112
8.108
7.647
7.643
7.579
7.574
7.563
7.558
7.473
7.468
7.456
7.451
7.260
3.999
2.276
2.273
0.005
Me
O
O
OMe
Cl
5o
0.96
0.96
1.00
2.03
2.05
3.01
3.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)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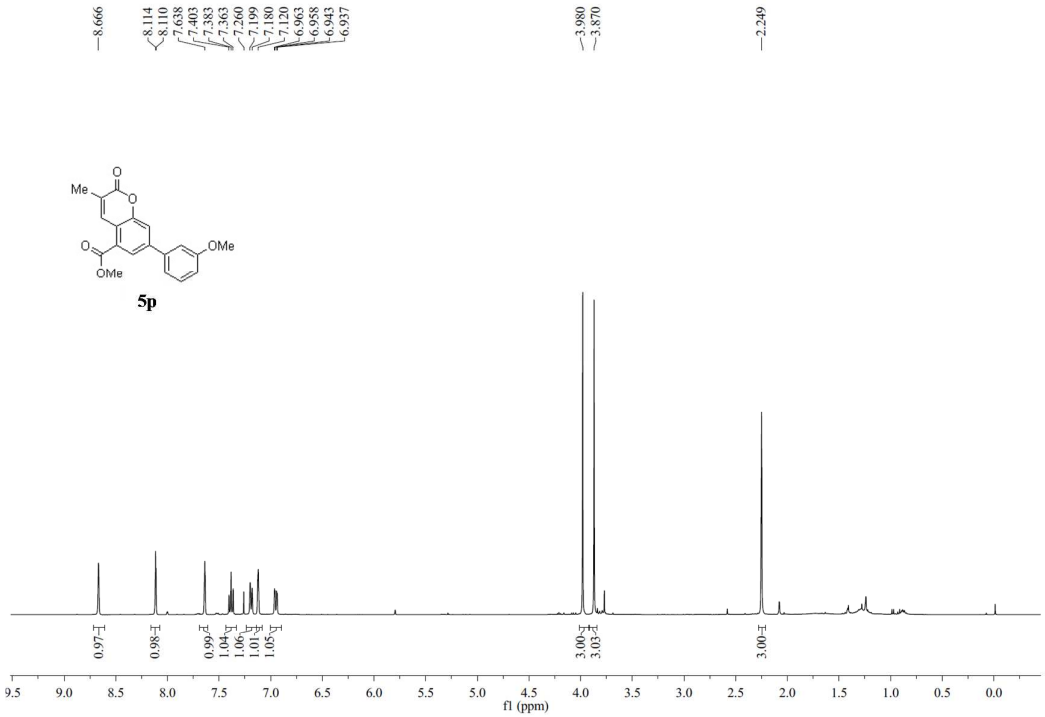
161.27
154.53
141.45
136.93
136.78
135.21
129.55
128.49
127.69
118.58
77.48
77.16
76.84
52.79
17.82
Me
O
O
OMe
Cl
5o
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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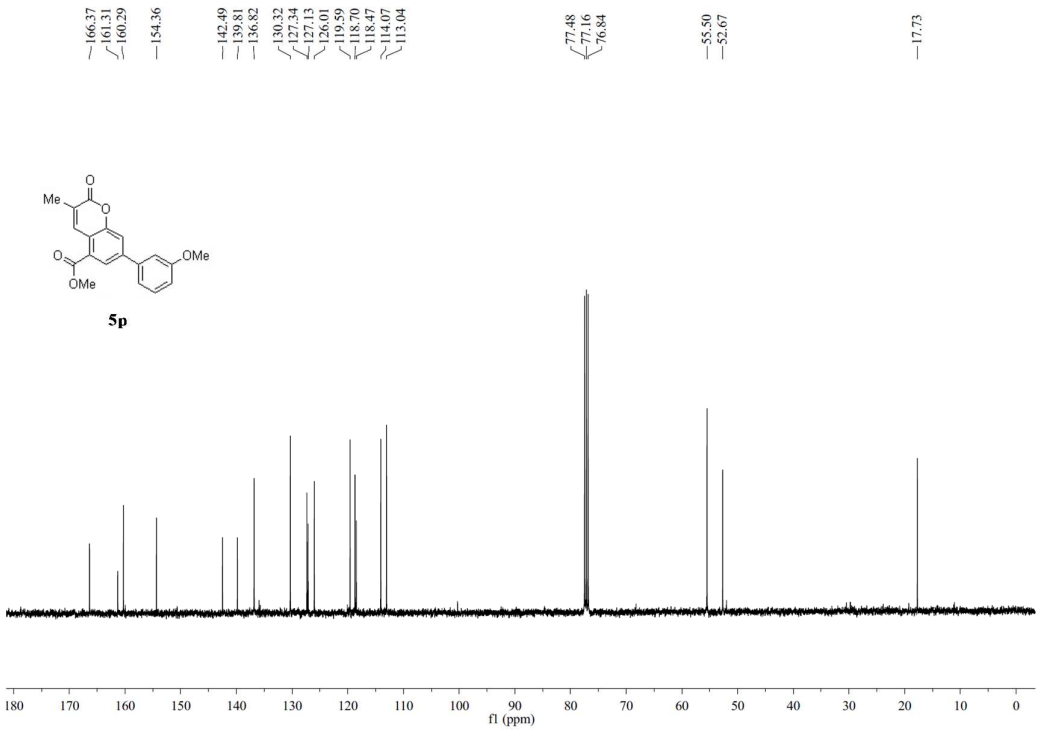
8.114
8.110
7.638
7.403
7.383
7.363
7.260
7.199
7.180
7.120
6.963
6.958
6.943
6.937
3.980
3.870
2.249
Me
O
O
O
OMe
OMe
0.97
0.98
0.99
1.04
1.06
1.01
1.05
3.00
3.03
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

5p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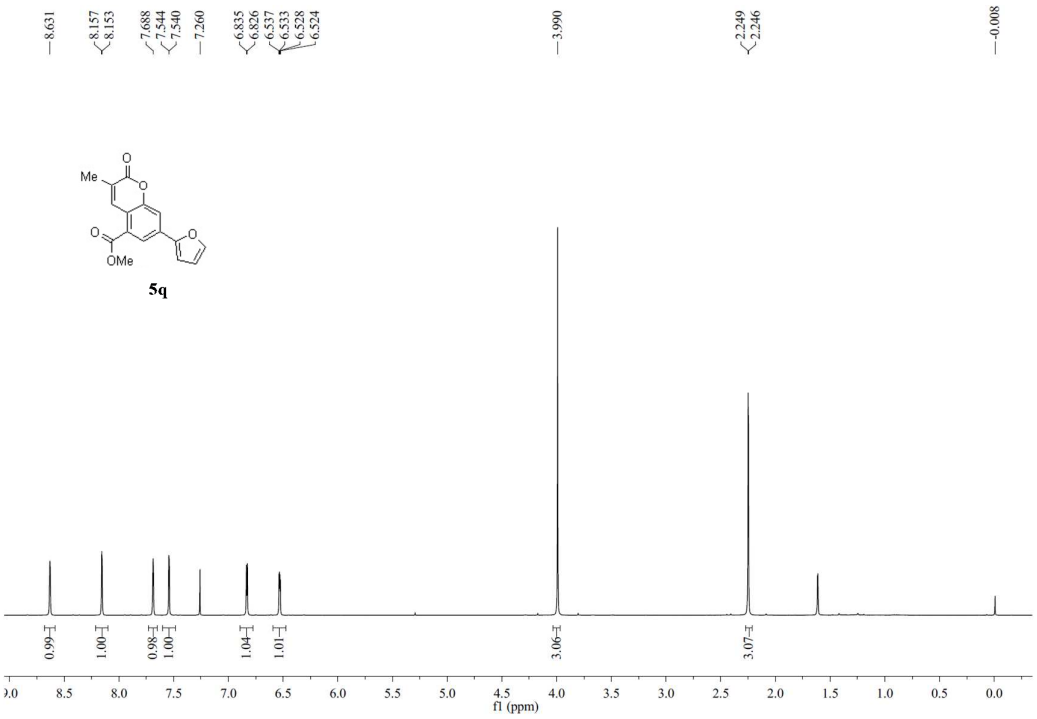
161.31
160.29
154.36
142.49
139.81
136.82
130.32
127.34
127.13
126.01
119.59
118.70
118.47
114.07
113.04
77.48
77.16
76.84
55.50
52.67
17.73
Me
O
O
O
OMe
OMe
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

5p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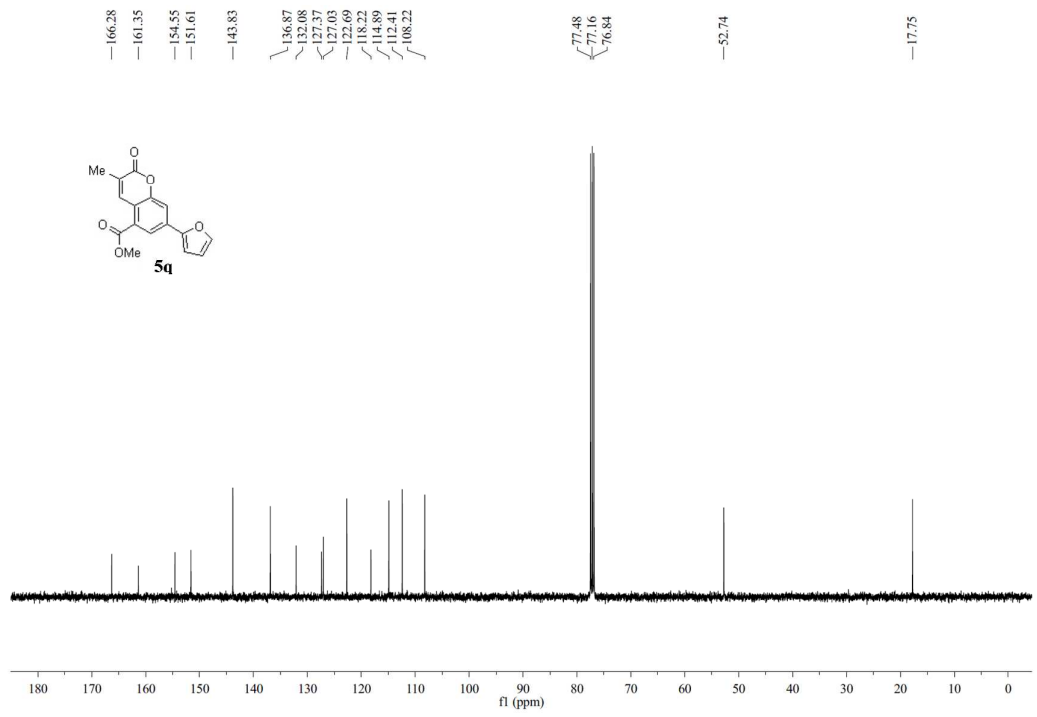
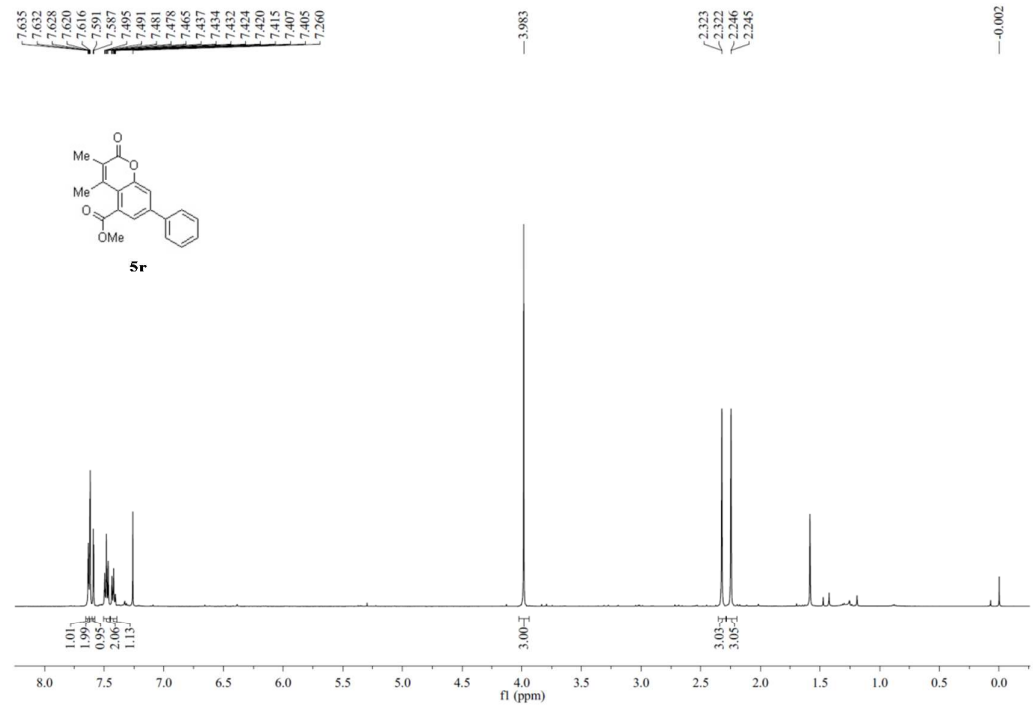
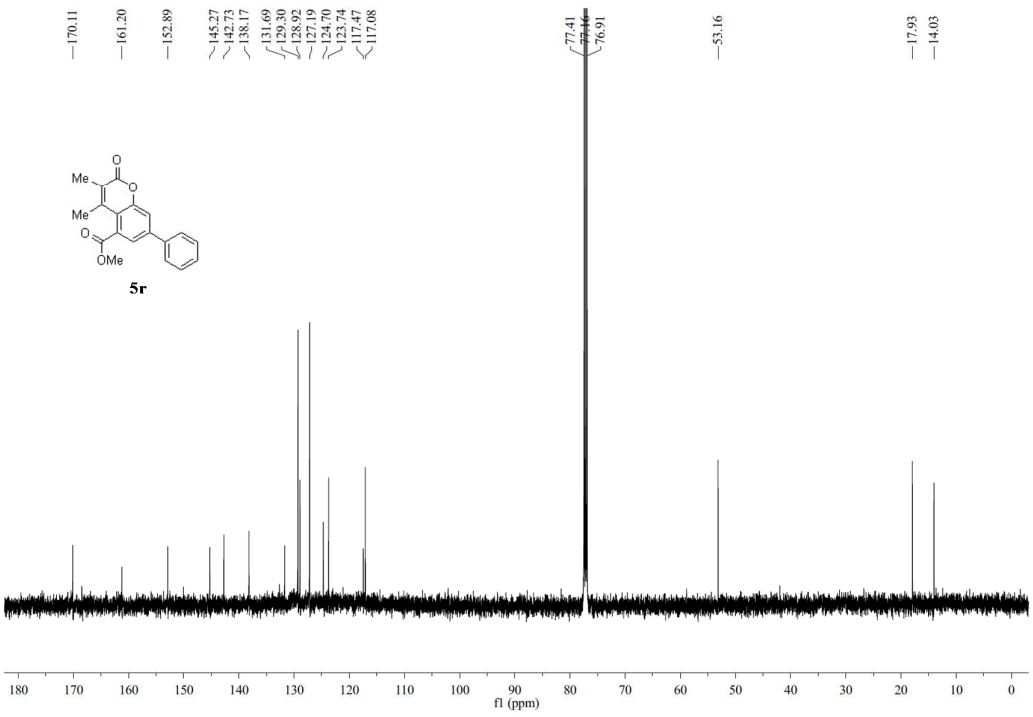
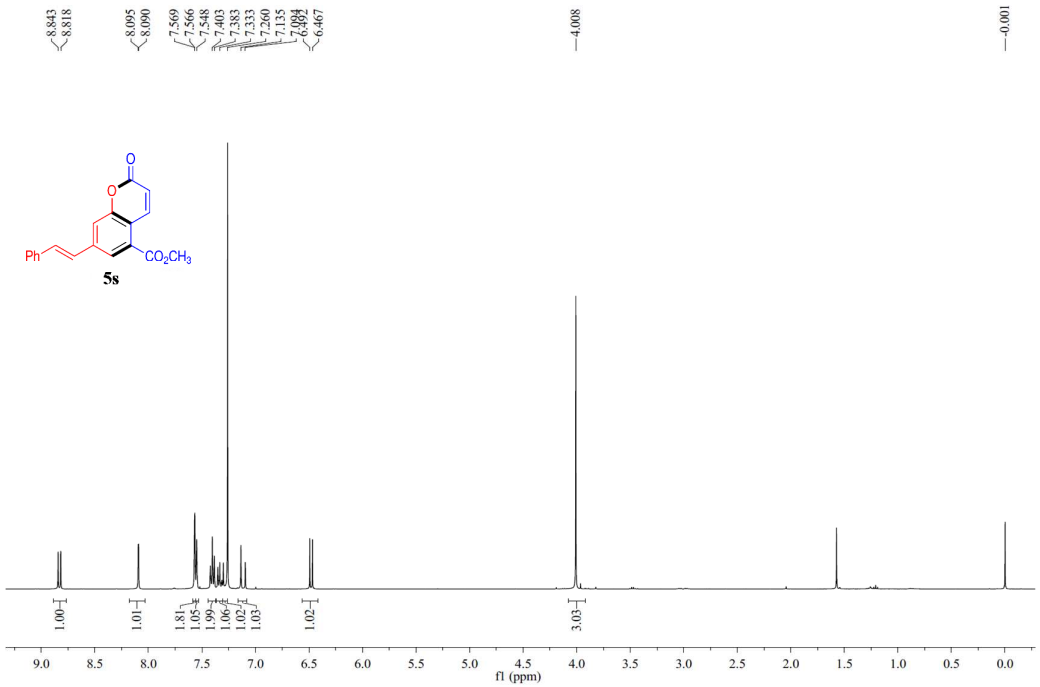
8.157
8.153
7.688
7.544
7.540
7.260
6.835
6.826
6.537
6.533
6.528
6.524
3.990
2.249
2.246
0.008
Me
O
O
O
OMe
O
5q
0.99
1.00
0.98
1.00
1.04
1.01
3.06
3.07
f1 (ppm)


166.28
161.35
154.55
151.61
143.83
136.87
132.08
127.37
127.03
122.69
118.22
114.89
112.41
108.22
77.48
77.16
76.84
52.74
17.75
Me
O
O
O
OMe
O
5q
f1 (ppm)


7.635
7.632
7.628
7.620
7.616
7.591
7.587
7.495
7.491
7.481
7.478
7.465
7.437
7.434
7.432
7.424
7.420
7.415
7.407
7.405
7.260
3.983
2.323
2.322
2.246
2.245
0.002
Me
Me
O
OMe
5r
1.01
1.99
0.95
2.06
1.13
3.00
3.03
3.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


170.11
161.20
152.89
145.27
142.73
138.17
131.69
129.30
128.92
127.19
124.70
123.74
117.47
117.08
77.41
77.16
76.91
53.16
17.93
14.03
Me
Me
O
OMe
5r
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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8.090
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7.566
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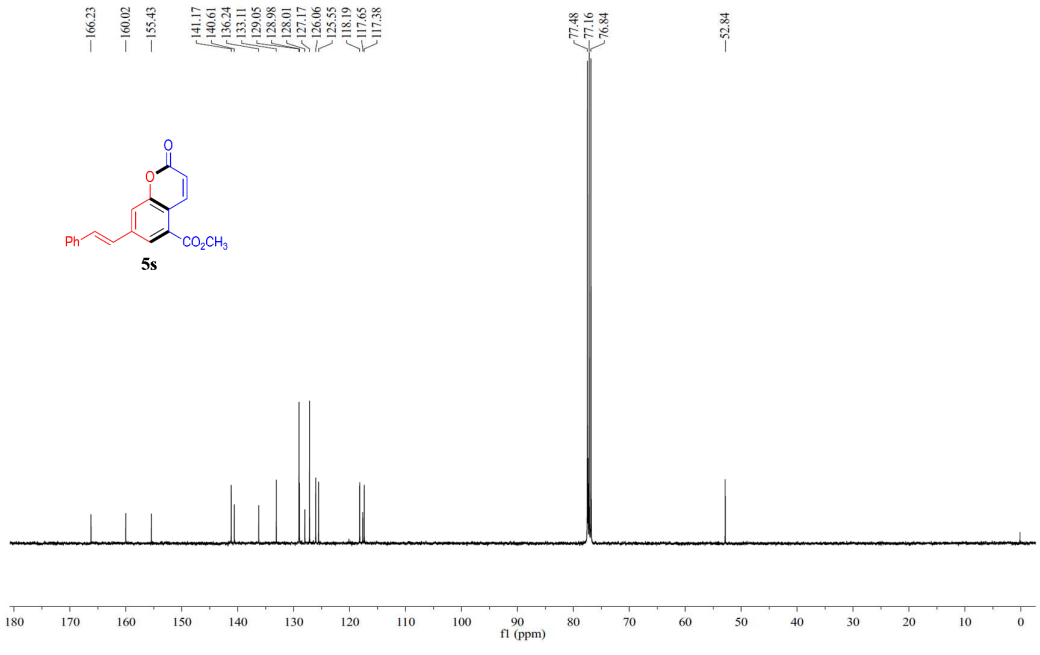
7.403
7.383
7.333
7.260
7.135
6.467
4.008
0.001
O
O
Ph
CO2CH3
5s
1.00
1.01
1.81
1.05
1.99
1.06
1.02
1.03
1.02
3.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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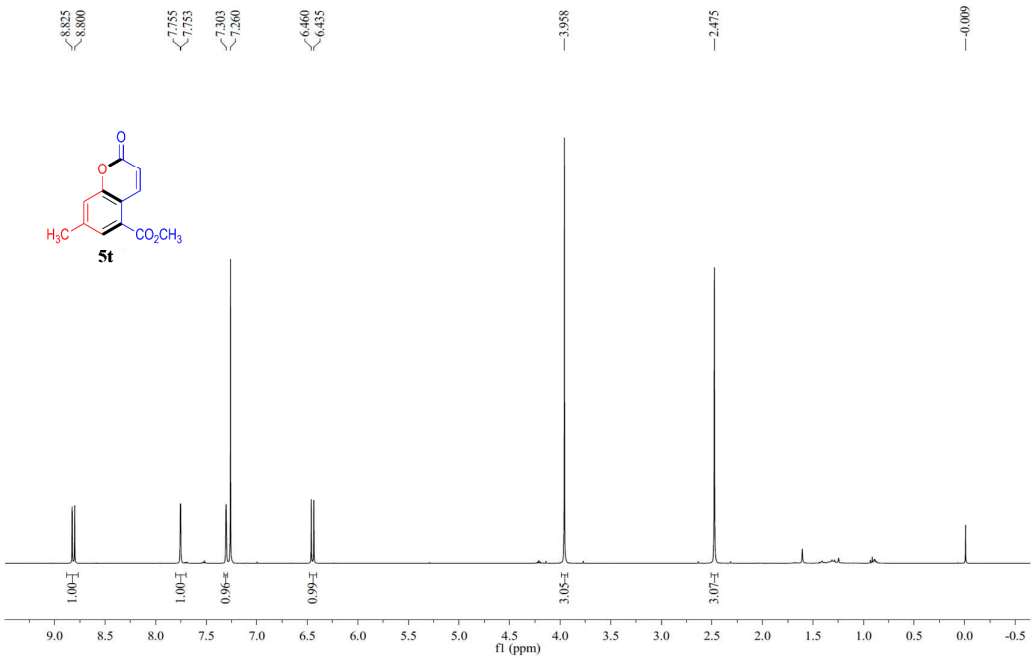
140.61
136.24
133.11
129.05
128.98
128.01
127.17
126.06
125.55
118.19
117.65
117.38
77.48
77.16
76.84
52.84
O
O
Ph
CO2CH3
5s
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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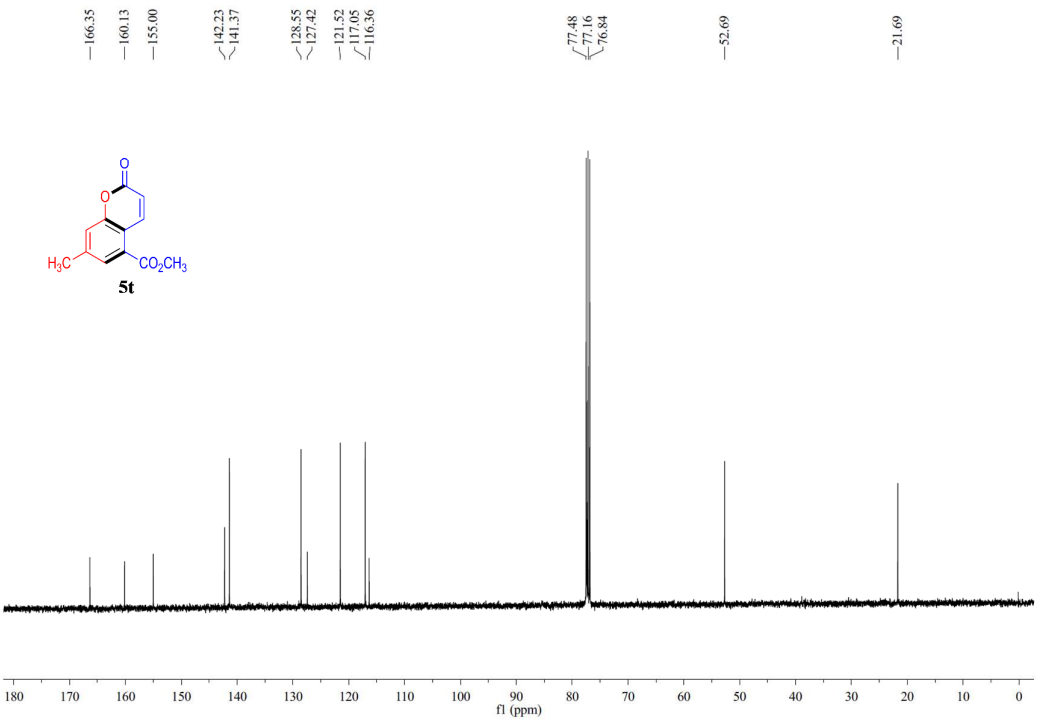
7.755
7.753
7.303
7.260
6.460
6.435
3.958
2.475
0.009
O
O
H3C
CO2CH3
5t
1.00
1.00
0.96
0.99
3.05
3.07
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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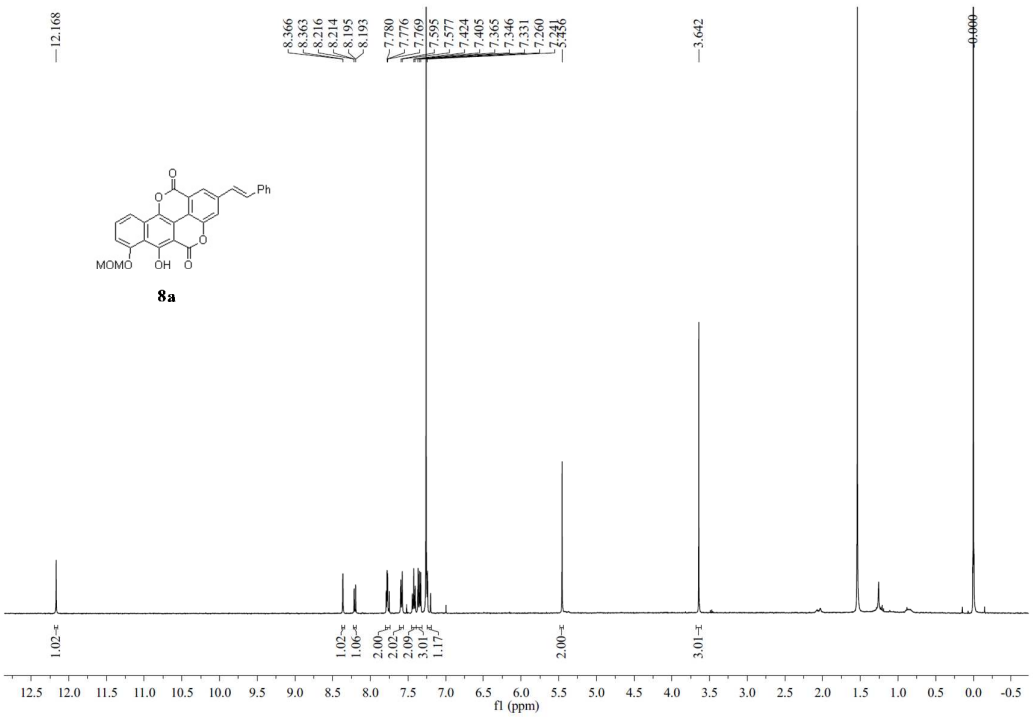
142.23
141.37
128.55
127.42
121.52
117.05
116.36
77.48
77.16
76.84
52.69
21.69
O
O
H3C
CO2CH3
5t
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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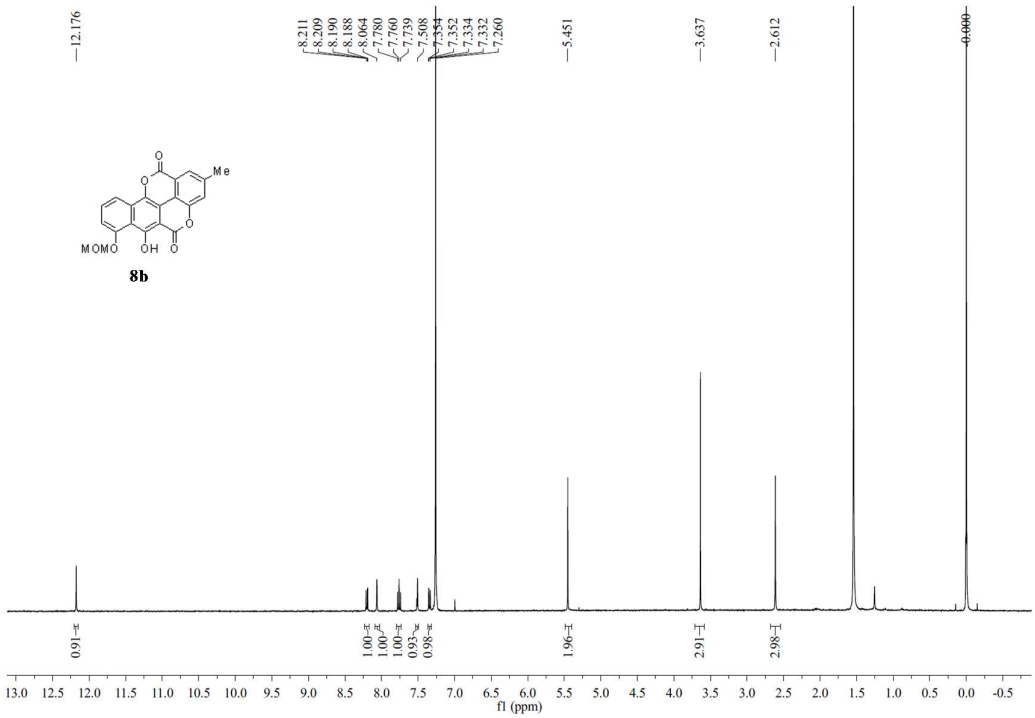
8.195
8.193
7.780
7.776
7.769
7.595
7.577
7.424
7.405
7.365
7.346
7.331
7.260
7.241
3.436
3.642
0.000
Ph
MOMO
OH
O
8a
1.02
1.02
1.06
2.00
2.02
2.09
3.01
1.17
2.00
3.01
fl (ppm)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8.209
8.190
8.188
8.064
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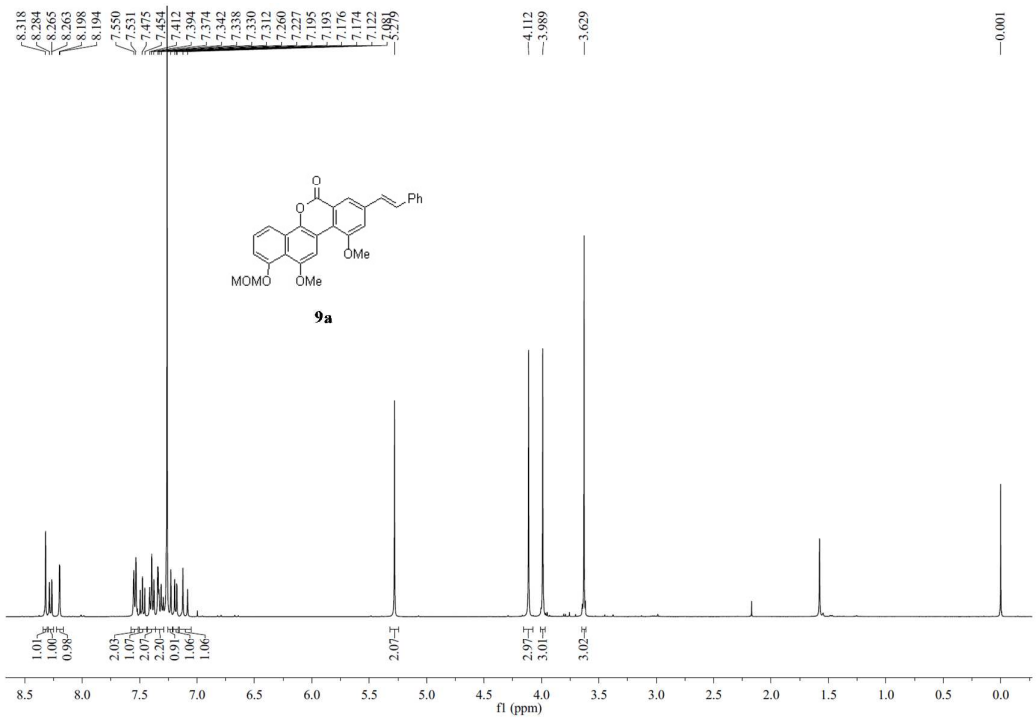
7.760
7.739
7.508
7.354
7.352
7.334
7.332
7.260
5.451
3.637
2.612
0.000
Me
MOMO
OH
O
8b
0.91
1.00
1.00
1.00
0.93
0.98
1.96
2.91
2.98
fl (ppm)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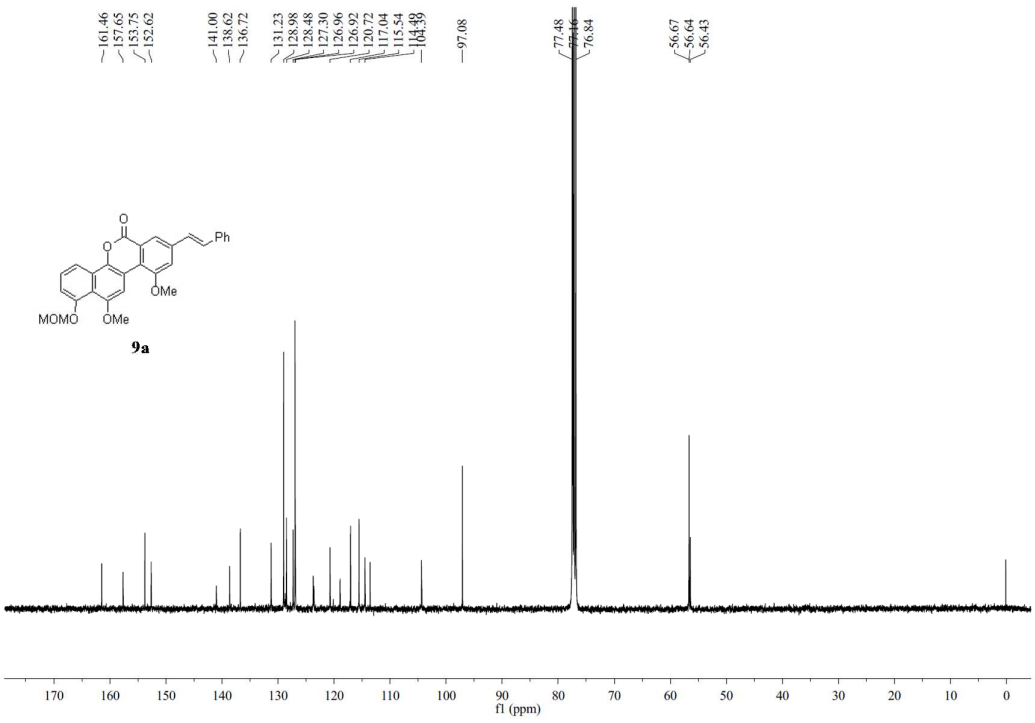
8.263
8.198
8.194
7.550
7.531
7.475
7.454
7.412
7.394
7.374
7.342
7.338
7.330
7.312
7.260
7.227
7.195
7.193
7.176
7.174
7.122
5.296
4.112
3.989
3.629
0.001
O
O
Ph
OMe
MOMO
OMe
9a
1.01
1.00
0.98
2.03
1.07
2.07
2.20
0.91
1.06
1.06
2.07
2.97
3.01
3.02
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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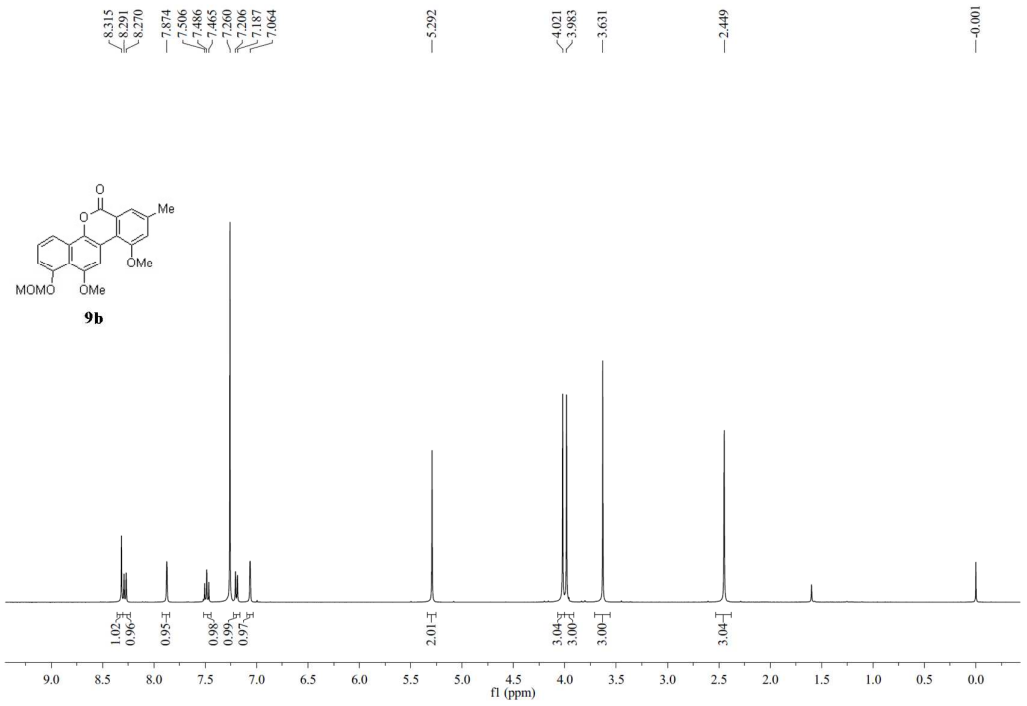
152.62
141.00
138.62
136.72
131.23
128.98
128.48
127.30
126.96
126.92
120.72
117.04
115.54
104.39
97.08
77.48
77.16
76.84
56.67
56.64
56.43
O
O
Ph
OMe
MOMO
OMe
9a
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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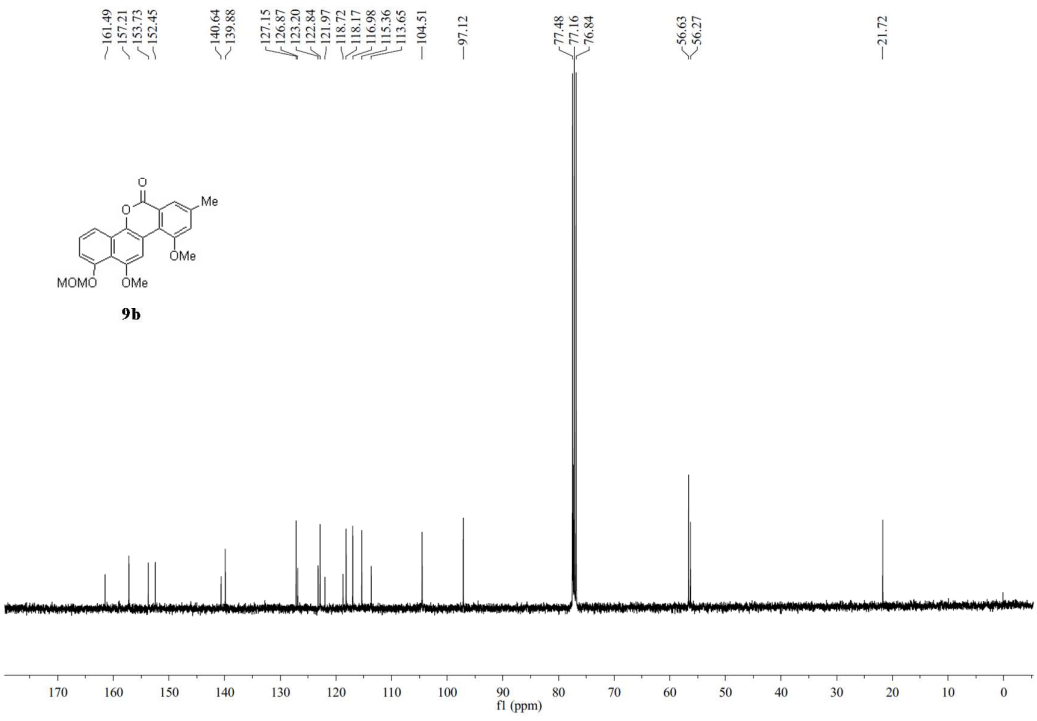
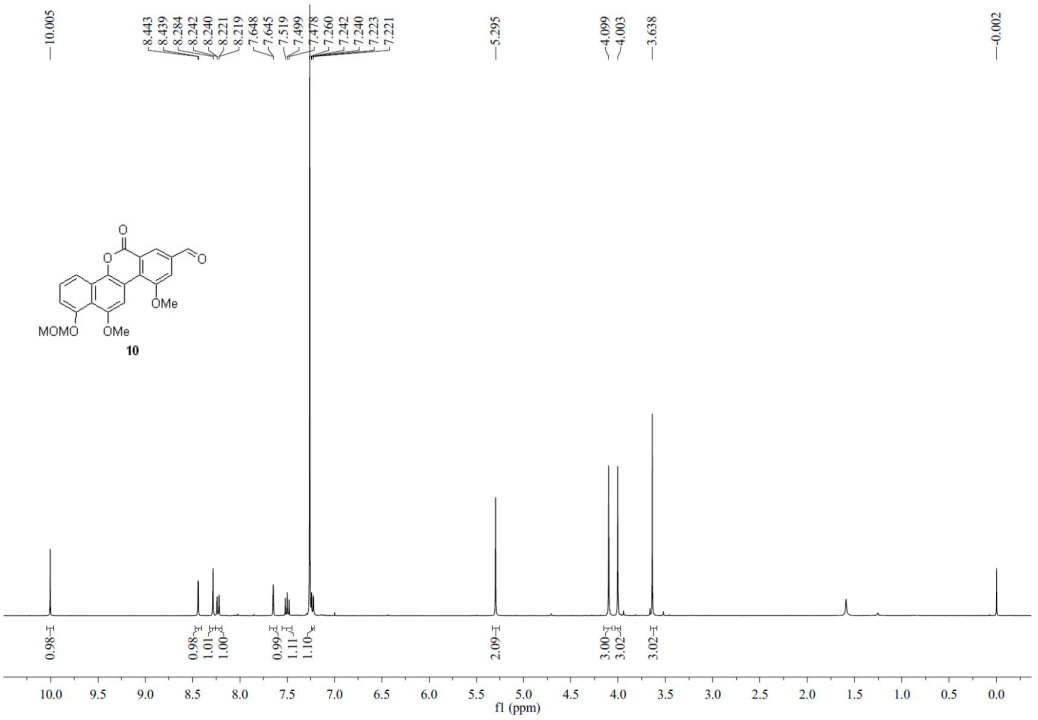
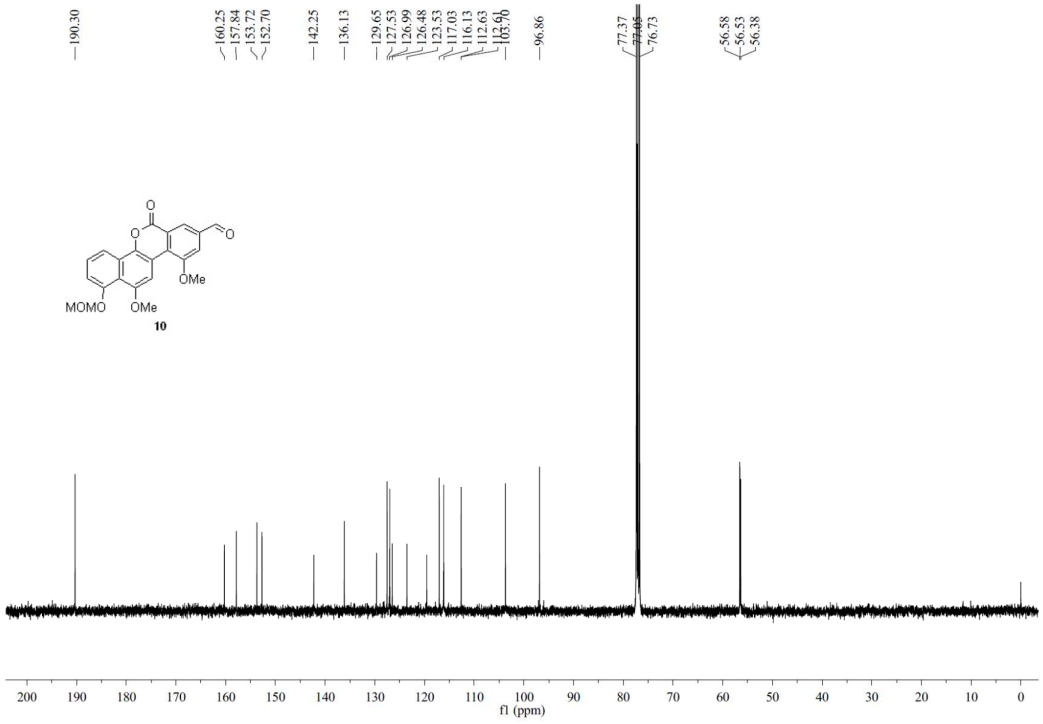
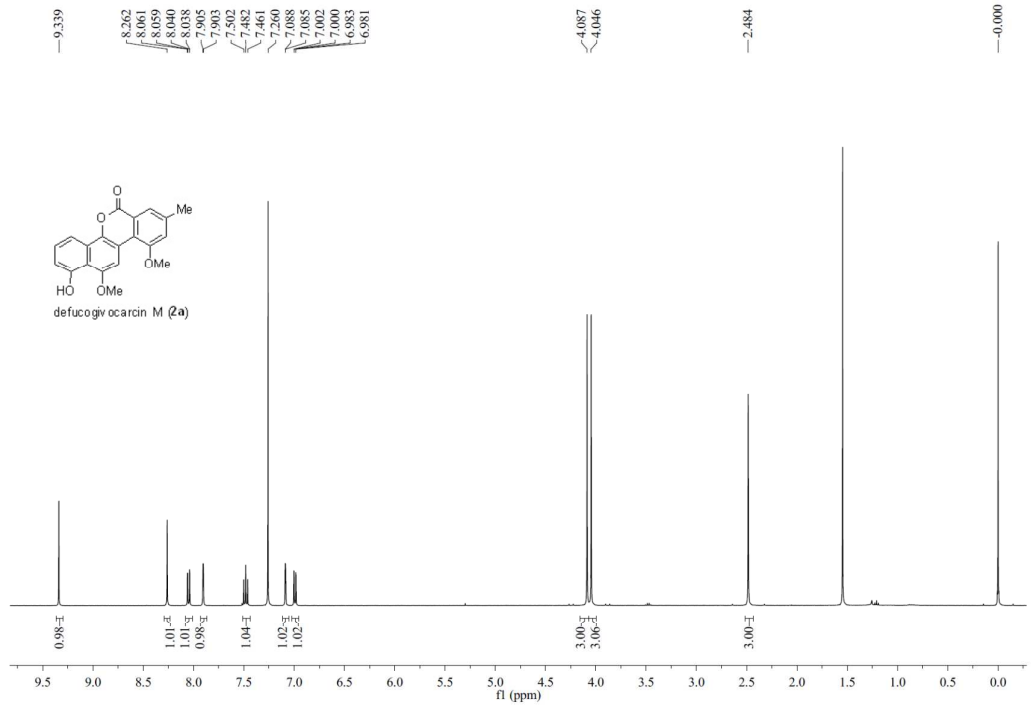
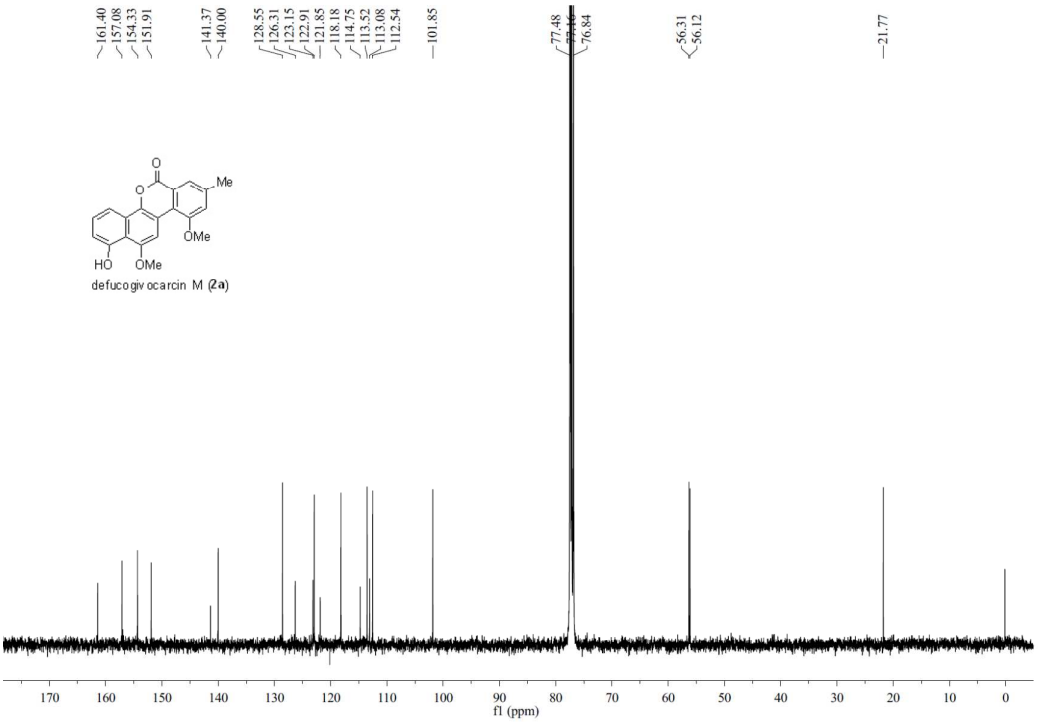
7.465
7.260
7.206
7.187
7.064
5.292
4.021
3.983
3.631
2.449
0.001
O
O
Me
OMe
MOMO
OMe
9b
1.02
0.96
0.95
0.98
0.99
0.97
2.01
3.04
3.00
3.00
3.04
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

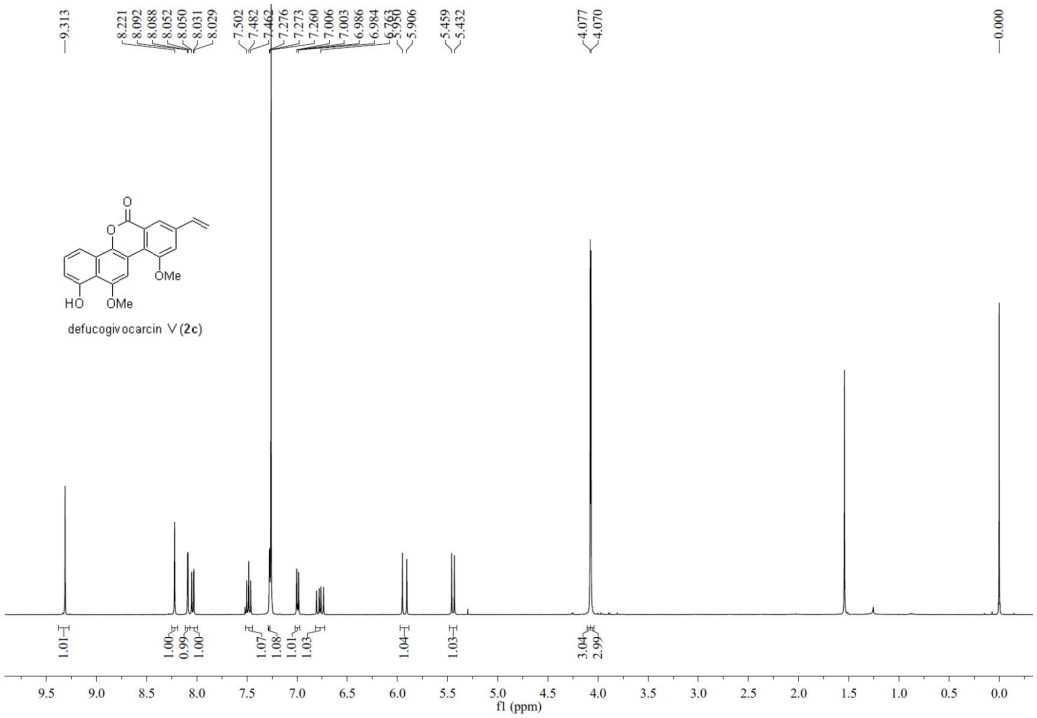

161.49
157.21
153.73
152.45
140.64
139.88
127.15
126.87
123.20
122.84
121.97
118.72
118.17
116.98
115.36
113.65
104.51
97.12
77.48
77.16
76.84
56.63
56.27
21.72
O
O
Me
OMe
MOMO
OMe
9b
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

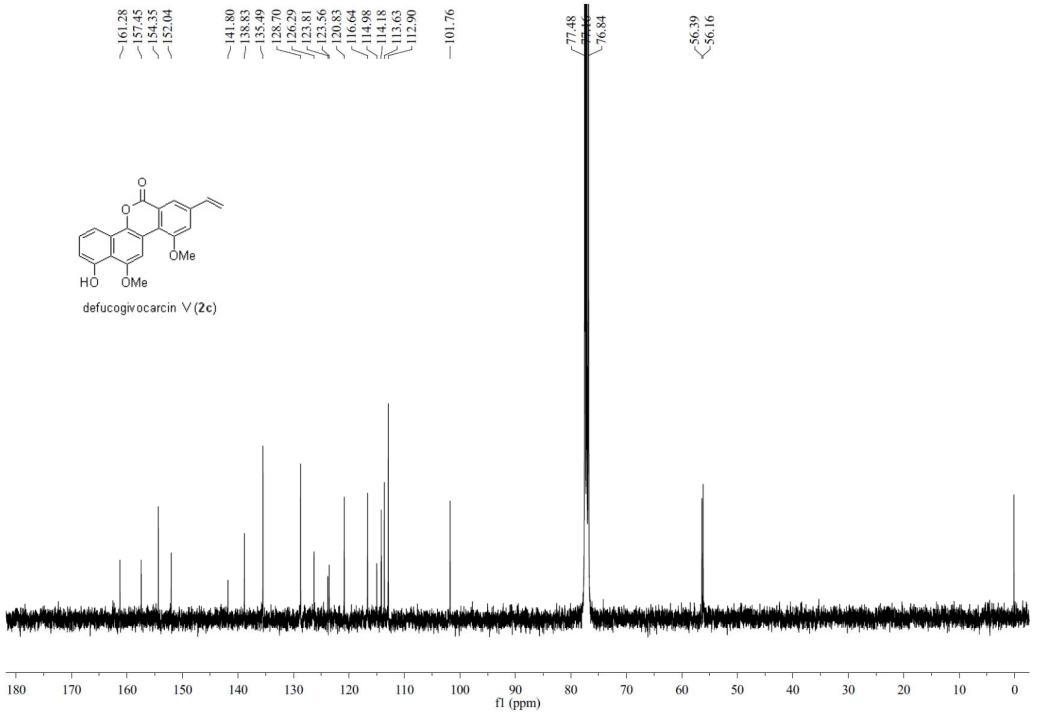

10.005
8.443
8.439
8.284
8.242
8.240
8.221
8.219
7.648
7.645
7.519
7.499
7.478
7.260
7.242
7.240
7.223
7.221
5.295
4.099
4.003
3.638
0.002
O
O
O
OMe
MOMO
OMe
10
0.98
0.98
1.01
1.00
0.99
1.11
1.10
2.09
3.00
3.02
3.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

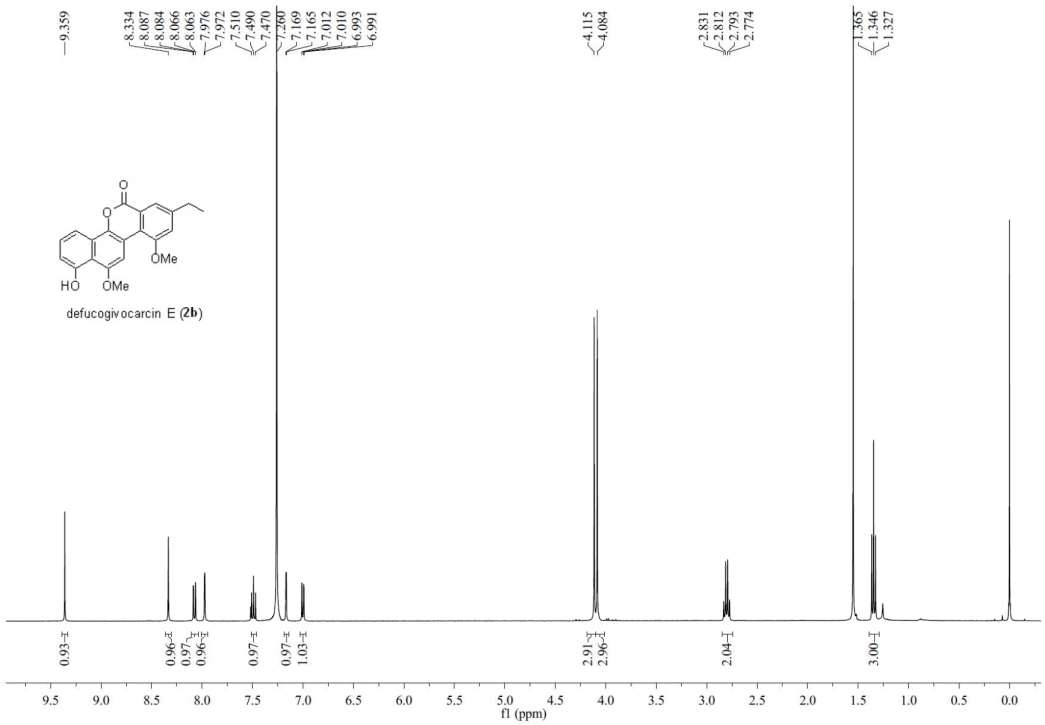

190.30
160.25
157.84
153.72
152.70
142.25
136.13
129.65
127.53
126.99
126.48
123.53
117.03
116.13
112.63
112.61
103.70
96.86
77.37
77.05
76.73
56.58
56.53
56.38
O
O
O
OMe
MOMO
OMe
10
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

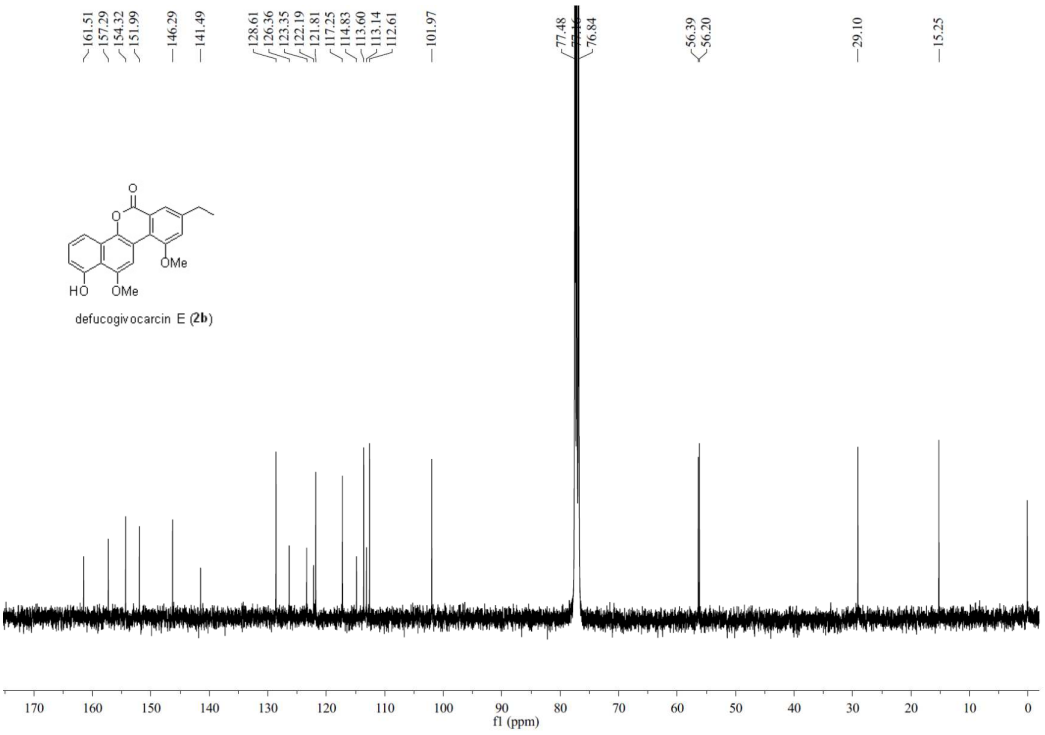

9.339
8.262
8.061
8.059
8.040
8.038
7.905
7.903
7.502
7.482
7.461
7.260
7.088
7.085
7.002
7.000
6.983
6.981
4.087
4.046
2.484
0.000
O
O
Me
OMe
HO
OMe
defucogivocarcin M (2a)
0.98
1.01
1.01
0.98
1.04
1.02
1.02
3.00
3.06
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


161.40
157.08
154.33
151.91
141.37
140.00
128.55
126.31
123.15
122.91
121.85
118.18
114.75
113.52
113.08
112.54
101.85
77.48
77.16
76.84
56.31
56.12
21.77
O
O
Me
OMe
HO
OMe
defucogivocarcin M (2a)
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


9.313
8.221
8.092
8.088
8.052
8.050
8.031
8.029
7.502
7.482
7.462
7.276
7.273
7.260
7.006
7.003
6.986
6.984
5.906
5.459
5.432
4.077
4.070
0.000
O
O
OMe
HO
OMe
defucogivocarcin V (2c)
1.01
1.00
0.99
1.00
1.07
1.08
1.01
1.03
1.04
1.03
3.04
2.99
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


161.28
157.45
154.35
152.04
141.80
138.83
135.49
128.70
126.29
123.81
123.56
120.83
116.64
114.98
114.18
113.63
112.90
101.76
77.48
77.16
76.84
56.39
56.16
O
O
OMe
HO
OMe
defucogivocarcin V (2c)
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


9.359
8.334
8.087
8.084
8.066
8.063
7.976
7.972
7.510
7.490
7.470
7.260
7.169
7.165
7.012
7.010
6.993
6.991
4.115
4.084
2.831
2.812
2.793
2.774
1.365
1.346
1.327
HO
OMe
OMe
defucogivocarcin E (2b)
0.93
0.96
0.97
0.96
0.97
0.97
1.03
2.91
2.96
2.04
3.00
fl (ppm)


161.51
157.29
154.32
151.99
146.29
141.49
128.61
126.36
123.35
122.19
121.81
117.25
114.83
113.60
113.14
112.61
101.97
77.48
76.84
56.39
56.20
29.10
15.25
HO
OMe
OMe
defucogivocarcin E (2b)
fl (ppm)