Supporting Information

Palladium-catalyzed direct reductive cross-coupling of aryltrimethylammonium salts with aryl bromides

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General Information

Analytical thin layer chromatography (TLC) was performed using silica gel plate (0.2 mm thickness). Subsequent to elution, plates were visualized using UV radiation (254 nm). Flash chromatography was performed using Merck silica gel (200-300 mesh) for column chromatography with freshly distilled solvents. Columns were typically packed as slurry and equilibrated with the appropriate solvent system prior to use. IR spectra were recorded on a FT-IR spectrophotometer using KBr optics. ^{1}H, ^{19}F, and ^{13}C NMR spectra were recorded in $CDCl_3$ on Bruker Avance or Jeol 400 MHz spectrometers. Tetramethylsilane (TMS) served as internal standard for ^{1}H, ^{19}F, and ^{13}C NMR analysis. High resolution mass spectra (HRMS) were obtained using a commercial apparatus (ESI or EI Source).

Optimization of Reaction Conditions

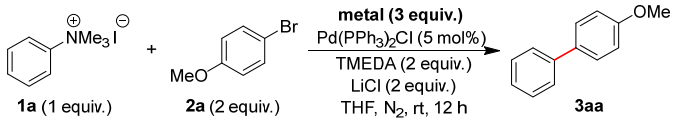
Table S1. Optimization of Reaction Conditions by Using Different Solvents

1a (1 equiv.) **2a** (2 equiv.) **3aa**

entry	solvent	yield (%)[a]	entry	solvent	yield (%)[a]
1	DMF	0	6	^{t}BuOMe	0
2	DMA	0	7	THF	94 (29)[b]
3	MeCN	0	8	DME	0
4	DMSO	0	9	Et_2O	0
5	1,4-dioxane	0	10	CpOMe	0

[a] Yields were determined by using 1,4-dimethoxybenzene as an internal standard. [b] Reaction was performed under 60 °C.

Table S2. Optimization of Reaction Conditions by Using Different Metals

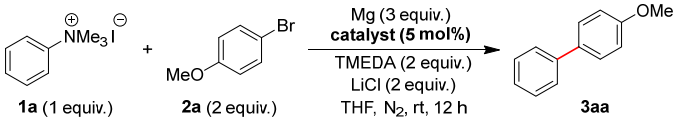


1a (1 equiv.) **2a** (2 equiv.) **3aa**

entry	metal	yield (%)[a]	entry	metal	yield (%)[a]
1	Mg	94	6	Ga	0
2	Al	0	7	Bi	0
3	Zn	0	8	Fe	0
4	Mn	0	9	Sn	0
5	In	0	10	Pb	0

[a] Yields were determined by using 1,4-dimethoxybenzene as an internal standard.

Table S3. Optimization of Reaction Conditions by Using Different Catalysts

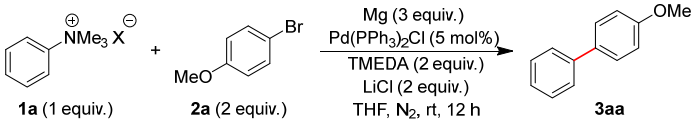


1a (1 equiv.) **2a** (2 equiv.) **3aa**

entry	catalyst	yield (%)[a]
1	$Pd(PPh_3)_2Cl_2$	94
2	$Co(PPh_3)_2Cl_2$	<5
3	$Ni(PPh_3)_2Cl_2$	0
4	$CuCl_2$	<5
5	$FeCl_3$	<5
6	$CrCl_2$	0

[a] Yields were determined by using 1,4-dimethoxybenzene as an internal standard.

Table S4. Optimization of Reaction Conditions by Using Different Aryltrimethylammonium Salts



1a (1 equiv.) **2a** (2 equiv.) **3aa**

entry	X	yield (%)[a]
1	I	94
2	Cl	77
3	Br	80
4	OTf	78

[a] Yields were determined by using 1,4-dimethoxybenzene as an internal standard.

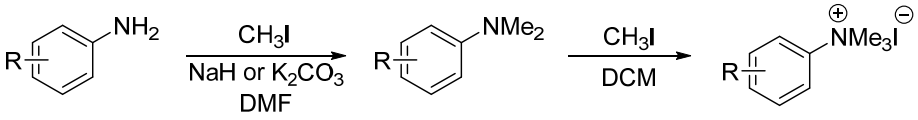
Experimental Procedure

Typical procedures for the cross-coupling reaction between aryltrimethylammonium salts with aryl bromides (taking product 3aa as an example)

To an oven-dried sealed tube equipped with a magnetic stir bar was added magnesium turnings (72.9 mg, 3 mmol) and LiCl (84.8 mg, 2 mmol). Then the mixture was dried under reduced pressure with a heat gun (320 °C) for 3 min. After cooling to room temperature, dry THF (3 mL) was added and the sealed tube was backfilled with nitrogen (x3). Then aryltrimethylammonium iodide (**1a**, 263.1 mg, 1 mmol) and $Pd(PPh_3)_2Cl_2$ (35.1 mg, 0.05 mmol) were weighed into the tube, after which 4-bromoanisole (**2a**, 374.1 mg, 2 mmol) and TMEDA (232.4 mg, 2 mmol) were added by syringe. Then the mixture was stirred at room temperature for 12 h. The resulting mixture was then quenched with saturated NH_4Cl solution and extracted with EtOAc (20 mL x3). The organic layers were

combined and washed with brine, dried over Na_2SO_4. The extracts were concentrated under reduced pressure to afford the crude product, which was further purified through silica gel column chromatography (using EtOAc/petroleum ether as eluents) to yield the product **3aa** as a white solid.

Typical procedures for the synthesis of different aryltrimethylammonium salts



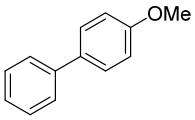
The aryltrimethylammonium salts were synthesized according to reported methods by a two-step procedure.

Step 1: [1-2] Aniline (10 mmol, 1 equiv.), K_2CO_3 (30 mmol, 4.14 g) and DMF (50 mL) were added to a 100 mL round-bottomed flask equipped with a magnetic stir bar under N_2. The mixture was stirred at room temperature and iodomethane (1.25 mL, 20 mmol, 2 equiv.) was added dropwise. After completion of the reaction (monitored by TLC), the resulting mixture was diluted with water and the solution was extracted with DCM, washed with brine, dried over Na_2SO_4. Solvents were removed under reduced pressure and the crude product was purified by silica gel column chromatography.

Step 2: [3-5] To a solution of the above amine in DCM (10 mL) was dropwise added iodomethane (1.5 equiv.). The resulting mixture was stirred at room temperature and monitored by TLC. After completion of the reaction, solvent was removed under reduced pressure and the residue was filtered, washed with petroleum ether to yield the salt.

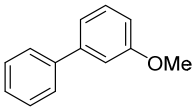
Characterization data of products

4-Methoxy-1,1'-biphenyl (3aa)



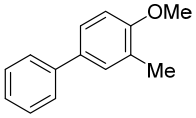
Yield = 90%, 165.4 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). White solid.
M.p.: 83.5-85.1 °C.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65–7.56 (m, 4H), 7.51–7.44 (m, 2H), 7.39–7.34 (m, 1H), 7.06–7.01 (m, 2H), 3.89 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.0, 140.7, 133.7, 128.7, 128.1, 126.7, 126.6, 114.1, 55.3 ppm.
IR (KBr): ν = 2961, 2836, 1606, 1522, 1488, 1288, 1252, 1035, 834, 760, 688 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{13}O$ $[M+H]^+$ 185.0961, found: 185.0965.

3-Methoxy-1,1'-biphenyl (3ab)



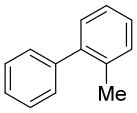
Yield = 70%, 128.2 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2b**). Yellow oil.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51–7.46 (m, 2H), 7.35–7.29 (m, 2H), 7.26–7.20 (m, 2H), 7.07 (ddd, *J* = 7.6, 1.6, 1.0 Hz, 1H), 7.04–7.01 (m, 1H), 6.78 (ddd, *J* = 8.2, 2.6, 0.9 Hz, 1H), 3.73 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.8, 142.7, 141.0, 129.7, 128.7, 127.4, 127.1, 119.6, 112.8, 112.6, 55.2 ppm.
IR (KBr): ν = 3031, 2937, 2834, 1599, 1478, 1421, 1296, 1213, 1054, 757, 713, 698 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{13}O$ $[M+H]^+$ 185.0961, found: 185.0970.

4-Methoxy-3-methyl-1,1'-biphenyl (3ac)



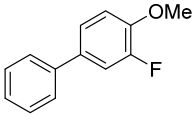
Yield = 93%, 185.2 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2c**). White solid.
M.p.: 74.8-75.8 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66–7.62 (m, 2H), 7.52–7.45 (m, 4H), 7.40–7.34 (m, 1H), 6.98–6.93 (m, 1H), 3.93 (s, 3H), 2.38 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 157.3, 141.0, 133.2, 129.4, 128.6, 126.8, 126.7, 126.5, 125.3, 110.1, 55.3, 16.4 ppm.
IR (KBr): ν = 1608, 1512, 1490, 1467, 1439, 1243, 1135, 1023, 887, 763, 752 cm^{-1}.
HRMS (m/z): calcd for $C_{14}H_{15}O$ $[M+H]^+$ 199.1117, found: 199.1123.

2-Methyl-1,1'-biphenyl (3ad)



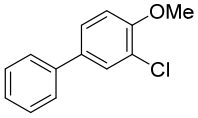
Yield = 78%, 131.2 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2d**). Colorless Oil.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56–7.51 (m, 2H), 7.48-7.44 (m, 3H), 7.41-7.36 (m, 4H), 2.41 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 141.9, 141.9, 135.3, 130.3, 129.8, 129.1, 128.0, 127.2, 126.7, 125.7, 20.4 ppm.
IR (KBr): ν = 3059, 3019, 1479, 1438, 1010, 748, 701, 618, 562, 455 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{12}$ $[M+H]^+$ 169.1012, found: 169.1013.

3-Fluoro-4-methoxy-1,1'-biphenyl (3ae)



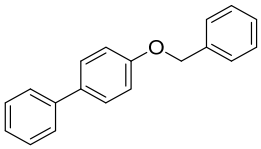
Yield = 86%, 173.9 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2e**). White solid.
M.p.: 88.2-89.3 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58–7.53 (m, 2H), 7.48–7.42 (m, 2H), 7.39–7.37 (m, 1H), 7.36–7.32 (m, 2H), 7.04 (t, *J* = 8.6 Hz, 1H), 3.94 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 152.5 (d, *J* = 245.3 Hz), 146.9 (d, *J* = 10.8 Hz), 139.6 (d, *J* = 2.1 Hz), 134.3 (d, *J* = 6.6 Hz), 128.8, 127.2, 126.6, 122.6 (d, *J* = 3.5 Hz), 114.7 (d, *J* = 18.9 Hz), 113.5 (d, *J* = 2.6 Hz), 56.2 ppm.
^{19}F NMR (376 MHz, $CDCl_3$): δ -134.88–-135.16 (m) ppm.
IR (KBr): ν = 2976, 2844, 1617, 1584, 1530, 1494, 1414, 1313, 1296, 1136, 1015, 872, 754 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{12}FO$ $[M+H]^+$ 203.0867, found: 203.0869.

3-Chloro-4-methoxy-1,1'-biphenyl (3af)



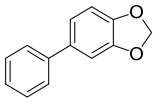
Yield = 54%, 116.9 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2f**). Colorless oil.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59 (d, *J* = 7.4 Hz, 2H), 7.51–7.37 (m, 4H), 7.13 (d, *J* = 7.7 Hz, 2H), 3.98 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 155.0, 141.2, 140.3, 130.3, 128.8, 127.6, 127.0, 121.5, 120.0, 110.9, 56.0 ppm.
IR (KBr): ν = 3030, 2938, 2853, 1593, 1567, 1479, 1396, 1306, 1226, 1072, 855, 760, 717 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{12}ClO$ $[M+H]^+$ 219.0571, found: 219.0575.

4-(Benzyloxy)-1,1'-biphenyl (3ag)



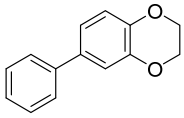
Yield = 81%, 210.4 mg (1 mmol scale with the use of 3 equiv. of aryl bromide **2g**). White solid.
M.p.: 128.8-130.1 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61–7.54 (m, 4H), 7.51–7.48 (m, 2H), 7.47–7.41 (m, 4H), 7.40–7.31 (m, 2H), 7.11–7.06 (m, 2H), 5.14 (s, 2H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 158.3, 140.7, 136.9, 133.9, 128.7, 128.6, 128.1, 128.0, 127.5, 126.7, 126.7, 115.1, 70.0 ppm.
IR (KBr): ν = 2923, 2907, 2865, 1608, 1523, 1488, 1468, 1453, 1377, 1249, 1198, 1021, 825, 760, 717, 695, 688 cm^{-1}.
HRMS (m/z): calcd for $C_{19}H_{17}O$ $[M+H]^+$ 261.1274, found: 261.1275.

5-Phenylbenzo[*d*][1,3]dioxole (3ah)



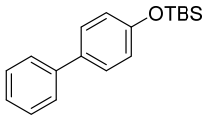
Yield = 91%, 179.7 mg (1 mmol scale with the use of 3 equiv. of aryl bromide **2h**). Yellow oil.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58–7.51 (m, 2H), 7.47–7.40 (m, 2H), 7.37–7.31 (m, 1H), 7.13–7.06 (m, 2H), 6.91 (dd, *J* = 7.8, 0.5 Hz, 1H), 6.01 (s, 2H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 148.0, 147.0, 140.9, 135.5, 128.7, 126.9, 126.8, 120.9, 108.5, 107.6, 101.1 ppm.
IR (KBr): ν = 1510, 1478, 1429, 1249, 1224, 1106, 1040, 937, 889, 812, 759, 712, 697 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{11}O_2$ $[M+H]^+$ 199.0754, found: 199.0756.

6-Phenyl-2,3-dihydrobenzo[*b*][1,4]dioxine (3ai)



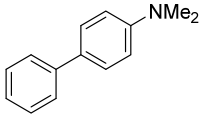
Yield = 86%, 183.0 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2i**). Colorless oil.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59–7.55 (m, 2H), 7.47–7.41 (m, 2H), 7.36–7.31 (m, 1H), 7.16 (d, *J* = 2.2 Hz, 1H), 7.12 (dd, *J* = 8.3, 2.2 Hz, 1H), 6.97 (d, *J* = 8.3 Hz, 1H), 4.31 (s, 4H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 143.6, 143.1, 140.5, 134.7, 128.7, 126.8, 126.7, 120.1, 117.5, 115.8, 64.4, 64.4 ppm.
IR (KBr): ν = 1590, 1574, 1518, 1485, 1309, 1283, 1246, 1226, 1070, 896, 764, 717, 698 cm^{-1}.
HRMS (m/z): calcd for $C_{14}H_{13}O_2$ $[M+H]^+$ 213.0910, found: 213.0914.

([1,1'-Biphenyl]-4-yloxy)(*tert*-butyl)dimethylsilane (3aj)



Yield = 75%, 212.6 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2j**). White solid.
M.p.: 57.1-58.4 °C.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.60 (dd, *J* = 8.3, 1.2 Hz, 2H), 7.54–7.50 (m, 2H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.38–7.32 (m, 1H), 6.99–6.94 (m, 2H), 1.07 (s, 9H), 0.29 (s, 6H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 155.2, 140.8, 134.2, 128.7, 128.1, 126.7, 126.6, 120.3, 25.7, 18.2, -4.4 ppm.
IR (KBr): ν = 2957, 2927, 2857, 1602, 1487, 1404, 1251, 1172, 1110, 916, 847, 777, 692 cm^{-1}.
HRMS (m/z): calcd for $C_{18}H_{25}OSi$ $[M+H]^+$ 285.1669, found: 285.1668.

***N*,*N*-Dimethyl-[1,1'-biphenyl]-4-amine (3ak)**



Yield = 76%, 150.2 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2k**). White solid.

M.p.: 122.7-123.2 ºC.

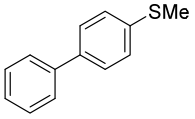
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73–7.69 (m, 2H), 7.67–7.63 (m, 2H), 7.53 (t, *J* = 7.7 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 1H), 6.97–6.89 (m, 2H), 3.09 (s, 6H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 149.8, 141.1, 129.2, 128.6, 127.6, 126.2, 125.9, 112.7, 40.5 ppm.

IR (KBr): ν = 1610, 1528, 1491, 1447, 1354, 1229, 956, 818, 760, 692 cm^{-1}.

HRMS (m/z): calcd for $C_{14}H_{16}N$ $[M+H]^+$ 198.1277, found: 198.1277.

[1,1'-Biphenyl]-4-yl(methyl)sulfane (3al)



Yield = 66%, 132.1 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2l**). White solid.

M.p.: 110.6-111.2 ºC.

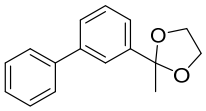
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63–7.54 (m, 4H), 7.47 (td, *J* = 6.9, 1.7 Hz, 2H), 7.40–7.34 (m, 3H), 2.55 (s, 3H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 140.4, 137.9, 137.5, 128.8, 127.4, 127.1, 126.8, 126.8, 15.8 ppm.

IR (KBr): ν = 2916, 1592, 1479, 1400, 1257, 1168, 1098, 1003, 954, 824, 754, 686 cm^{-1}.

HRMS (m/z): calcd for $C_{13}H_{13}S$ $[M+H]^+$ 201.0732, found: 201.0734.

2-([1,1'-Biphenyl]-3-yl)-2-methyl-1,3-dioxolane (3am)



Yield = 91%, 220.0 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2m**). Colorless oil.

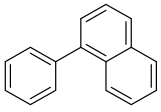
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (t, *J* = 1.7 Hz, 1H), 7.67–7.61 (m, 2H), 7.59–7.53 (m, 1H), 7.52–7.42 (m, 4H), 7.37 (tt, *J* = 6.7, 1.2 Hz, 1H), 4.08 (td, *J* = 6.1, 4.2 Hz, 2H), 3.89–3.78 (m, 2H), 1.74 (s, 3H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 143.8, 141.1, 141.0, 128.7, 128.7, 127.3, 127.2, 126.6, 124.2, 124.0, 108.8, 64.4, 27.7 ppm.

IR (KBr): ν = 2987, 2887, 1599, 1478, 1452, 1413, 1373, 1220, 1200, 1038, 871, 759, 708 cm^{-1}.

HRMS (m/z): calcd for $C_{16}H_{17}O_2$ $[M+H]^+$ 241.1223, found: 241.1233.

1-Phenylnaphthalene (3an)



Yield = 74%, 151.1 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2n**). Colorless oil.

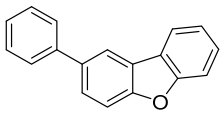
^{1}H NMR (400 MHz, $CDCl_3$): δ 8.12 – 7.99 (m, 3H), 7.70 – 7.54 (m, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 140.7, 140.2, 133.7, 131.5, 130.0, 128.2, 128.2, 127.6, 127.2, 126.9, 126.0, 126.0, 125.7, 125.3 ppm.

IR (KBr): ν = 3055, 1591, 1507, 1395, 1182, 1117, 1030, 1019, 802, 778, 760, 703, 615 cm^{-1}.

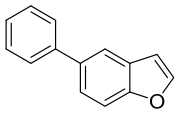
HRMS (m/z): calcd for $C_{16}H_{13}$ $[M+H]^+$ 205.1012, found: 205.1016.

2-Phenyldibenzo[*b*,*d*]furan (3ao)



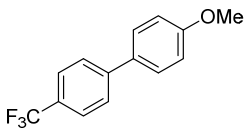
Yield = 66%, 153.4 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2o**). White solid.
M.p.: 181.8-182.9 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 8.16 (dd, *J* = 1.9, 0.6 Hz, 1H), 8.01 (ddd, *J* = 7.6, 1.3, 0.6 Hz, 1H), 7.70 (dt, *J* = 8.2, 1.4 Hz, 3H), 7.66–7.60 (m, 2H), 7.54–7.47 (m, 3H), 7.44 – 7.36 (m, 2H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 156.6, 155.7, 141.3, 136.4, 128.8, 127.4, 127.3, 127.0, 126.6, 124.7, 124.2, 122.8, 120.7, 119.2, 111.7 ppm.
IR (KBr): ν = 3054, 1603, 1471, 1446, 1202, 1187, 1121, 1022, 891, 843, 759, 747, 696, 573, 604, 429 cm^{-1}.
HRMS (m/z): calcd for $C_{18}H_{13}O$ $[M+H]^+$ 245.0961, found: 245.0960.

5-Phenylbenzofuran (3ap)



Yield = 38%, 74.7 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2p**). White solid.
M.p.: 65.9-67.2 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83–7.80 (m, 1H), 7.69–7.62 (m, 3H), 7.61–7.53 (m, 2H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.39–7.34 (m, 1H), 6.84 (dd, *J* = 2.2, 0.8 Hz, 1H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 154.5, 145.5, 141.6, 136.4, 128.7, 127.9, 127.4, 126.8, 123.9, 119.7, 111.5, 106.8 ppm.
IR (KBr): ν = 3144, 2923, 1536, 1462, 1428, 1233, 1163, 1107, 1026, 886, 823, 780, 696 cm^{-1}.
HRMS (m/z): calcd for $C_{14}H_{11}O$ $[M+H]^+$ 195.0804, found: 195.0810.

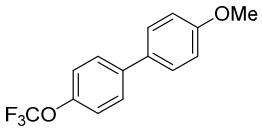
4-Methoxy-4'-(trifluoromethyl)-1,1'-biphenyl (3ba)



Yield = 95%, 120.3 mg (0.5 mmol scale with the use of 3 equiv. of aryl bromide **2a**). White solid.
M.p.: 121.4-122.3 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75–7.63 (m, 4H), 7.56 (d, *J* = 8.7 Hz, 2H), 7.02 (d, *J* = 8.7 Hz, 2H), 3.87 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.8, 144.2, 132.1, 128.6 (q, *J* = 32.5 Hz), 128.3, 126.8, 124.4 (q, *J* = 271.8 Hz), 125.6 (q, *J* = 3.8 Hz), 114.4, 55.3 ppm.
^{19}F NMR (376 MHz, $CDCl_3$): δ -62.15 (s, 3F) ppm.

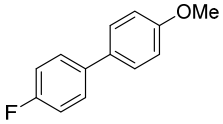
IR (KBr): ν = 2965, 2937, 2844, 1604, 1502, 1337, 1298, 1277, 1261, 1122, 1076, 1036, 1012, 830, 816, 719, 703 cm^{-1}.
HRMS (m/z): calcd for $C_{14}H_{12}F_3O$ $[M+H]^+$ 253.0835, found: 253.0843.

4-Methoxy-4'-(trifluoromethoxy)-1,1'-biphenyl (3ca)



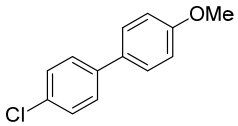
Yield = 92%, 247.9 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). White solid.
M.p.: 97.9-99.8 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42-7.34 (m, 4H), 7.13 (d, *J* = 8.2 Hz, 2H), 6.85 (d, *J* = 8.5 Hz, 2H), 3.71 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.4, 148.1, 139.6, 132.5, 128.1, 127.9, 121.2, 120.5 (q, *J* = 256.8 Hz), 114.3, 55.2 ppm.
^{19}F NMR (376 MHz, $CDCl_3$): δ -57.70 (s, 3F) ppm.
IR (KBr): ν = 2845, 1610, 1499, 1465, 1445, 1293, 1210, 1158, 1036, 1014, 828, 814 cm^{-1}.
HRMS (m/z): calcd for $C_{14}H_{12}F_3O_2$ $[M+H]^+$ 269.0784, found: 269.0784.

4-Fluoro-4'-methoxy-1,1'-biphenyl (3da)



Yield = 95%, 192.4 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). White solid.
M.p.: 91.1-91.6 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56–7.49 (m, 4H), 7.18–7.11 (m, 2H), 7.04–6.99 (m, 2H), 3.88 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 162.0 (d, *J* = 245.4 Hz), 159.0, 136.9 (d, *J* = 3.3 Hz), 132.7, 128.1 (d, *J* = 8.0 Hz), 127.9, 115.5 (d, *J* = 21.4 Hz), 114.2, 55.2 ppm.
^{19}F NMR (376 MHz, $CDCl_3$): δ -116.46 ppm.
IR (KBr): ν = 3414, 1607, 1600, 1496, 1291, 1236, 1160, 1038, 1012, 826, 810, 791, 540 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{12}FO$ $[M+H]^+$ 203.0867, found: 203.0871.

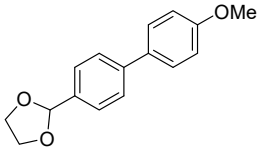
4-Chloro-4'-methoxy-1,1'-biphenyl (3ea)



Yield = 98%, 214.3 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). White solid.
M.p.: 112.1-113.5 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55–7.48 (m, 4H), 7.44–7.39 (m, 2H), 7.05–6.99 (m, 2H), 3.88 (s, 3H) ppm.

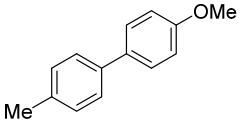
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.2, 139.1, 132.5, 132.3, 128.7, 127.9, 127.8, 114.2, 55.2 ppm.
IR (KBr): ν = 2962, 2936, 2839, 1606, 1485, 1309, 1263, 1199, 1132, 1037, 845, 821 cm^{-1}.
HRMS (m/z): calcd for $C_{13}H_{12}ClO$ $[M+H]^+$ 219.0571, found: 219.0575.

2-(4'-Methoxy-[1,1'-biphenyl]-4-yl)-1,3-dioxolane (3fa)



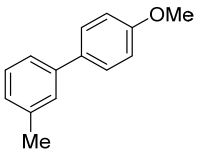
Yield = 99%, 127.7 mg (0.5 mmol scale with the use of 3 equiv. of aryl bromide **2a**). Brown solid.
M.p.: 105.4-106.8 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63-7.56 (m, 6H), 7.01 (d, *J* = 8.7 Hz, 2H), 5.89 (s, 1H), 4.20–4.13 (m, 2H), 4.12–4.03 (m, 2H), 3.86 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1, 141.5, 136.0, 133.0, 128.0, 126.7, 126.5, 114.0, 103.4, 65.1, 55.1 ppm.
IR (KBr): ν = 2891, 2836, 1607, 1499, 1465, 1310, 1254, 1195, 1089, 1036, 960, 813, 698 cm^{-1}.
HRMS (m/z): calcd for $C_{16}H_{17}O_3$ $[M+H]^+$ 257.1172, found: 257.1176.

4-Methoxy-4'-methyl-1,1'-biphenyl (3ga)



Yield = 94%, 186.8 mg (1 mmol scale with the use of 3 equiv. of aryl bromide **2a**). White solid.
M.p.: 109.3-109.8 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52–7.48 (m, 2H), 7.44 (d, *J* = 8.1 Hz, 2H), 7.21 (d, *J* = 8.6 Hz, 2H), 6.98–6.93 (m, 2H), 3.82 (s, 3H), 2.37 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 158.8, 137.9, 136.3, 133.6, 129.4, 127.9, 126.5, 114.1, 55.3, 21.0 ppm.
IR (KBr): ν = 2957, 2913, 2839, 1608, 1441, 1289, 1252, 1182, 1038, 1013, 842, 808, 498 cm^{-1}.
HRMS (m/z): calcd for $C_{14}H_{15}O$ $[M+H]^+$ 199.1117, found: 199.1122.

4'-Methoxy-3-methyl-1,1'-biphenyl (3ha)



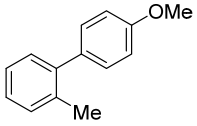
Yield = 94%, 186.9 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). White solid.
M.p.: 52.4-53.7 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68–7.62 (m, 2H), 7.53–7.47 (m, 2H), 7.43 (t, *J* = 7.5 Hz, 1H), 7.27–7.23 (m, 1H), 7.11–7.06 (m, 2H), 3.92 (s, 3H), 2.53 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 159.0, 140.7, 138.2, 133.7, 128.6, 128.0, 127.4, 127.3, 123.7,

114.0, 55.1, 21.5 ppm.

IR (KBr): ν = 2955, 2837, 1605, 1516, 1486, 1441, 1295, 1252, 1195, 1028, 838, 787, 696, 578, 438 cm^{-1}.

HRMS (m/z): calcd for $C_{14}H_{15}O$ $[M+H]^+$ 199.1117, found: 199.1124.

4'-Methoxy-2-methyl-1,1'-biphenyl (3ia)



Yield = 79%, 157.5 mg (1 mmol scale with the use of 3 equiv. of aryl bromide **2a**). Colorless oil.

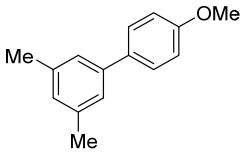
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.39–7.32 (m, 6H), 7.08–7.04 (m, 2H), 3.93 (s, 3H), 2.39 (s, 3H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 158.4, 141.4, 135.4, 134.2, 130.2, 130.2, 129.8, 126.9, 125.7, 113.4, 55.1, 20.5 ppm.

IR (KBr): ν = 2953, 2834, 1613, 1516, 1483, 1464, 1441, 1267, 1244, 1176, 1039, 1018, 834, 787, 761, 586 cm^{-1}.

HRMS (m/z): calcd for $C_{14}H_{15}O$ $[M+H]^+$ 199.1117, found: 199.1125.

4'-Methoxy-3,5-dimethyl-1,1'-biphenyl (3ja)



Yield = 82%, 173.3 mg (1 mmol scale with the use of 3 equiv. of aryl bromide **2a**). White solid.

M.p.: 45.3-47.1 °C.

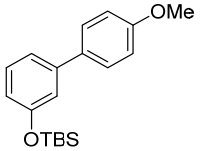
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61–7.56 (m, 2H), 7.26–7.23 (m, 2H), 7.03 (dt, *J* = 6.6, 2.6 Hz, 3H), 3.89 (s, 3H), 2.44 (s, 6H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 158.9, 140.7, 138.1, 133.9, 128.3, 128.1, 124.6, 114.0, 55.2, 21.4 ppm.

IR (KBr): ν = 2953, 2834, 1613, 1516, 1483, 1294, 1267, 1244, 1176, 1039, 834, 761, 731 cm^{-1}.

HRMS (m/z): calcd for $C_{15}H_{17}O$ $[M+H]^+$ 213.1274, found: 213.1279.

***tert*-Butyl((4'-methoxy-[1,1'-biphenyl]-3-yl)oxy)dimethylsilane (3ka)**

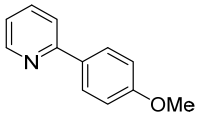


Yield = 84%, 264.5 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). Colorless oil.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56–7.51 (m, 2H), 7.29 (t, *J* = 7.9 Hz, 1H), 7.17 (ddd, *J* = 7.7, 1.7, 1.0 Hz, 1H), 7.08–7.05 (m, 1H), 7.02–6.97 (m, 2H), 6.82 (ddd, *J* = 8.0, 2.4, 1.0 Hz, 1H), 3.87 (s, 3H), 1.04 (s, 9H), 0.26 (s, 6H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1, 155.9, 142.2, 133.5, 129.6, 128.1, 119.8, 118.5, 118.3, 114.1, 55.3, 25.7, 18.2, -4.4 ppm.
IR (KBr): ν = 2956, 2930, 2857, 1601, 1586, 1518, 1479, 1441, 1289, 1249, 1211, 1180, 940, 834, 784, 697, 573 cm^{-1}.
HRMS (m/z): calcd for $C_{19}H_{27}O_2Si$ $[M+H]^+$ 315.1775, found: 315.1774.

2-(4-Methoxyphenyl)pyridine (3la)



Yield = 44%, 82.0 mg (1 mmol scale with the use of 2 equiv. of aryl bromide **2a**). Yellow solid.
M.p.: 53.3-54.7 ºC.
^{1}H NMR (400 MHz, $CDCl_3$): δ 8.65 (ddd, *J* = 4.8, 1.7, 1.0 Hz, 1H), 8.00–7.90 (m, 2H), 7.77–7.62 (m, 2H), 7.17 (ddd, *J* = 7.1, 4.8, 1.4 Hz, 1H), 7.06–6.93 (m, 2H), 3.86 (s, 3H) ppm.
^{13}C NMR (100 MHz, $CDCl_3$): δ 160.4, 157.1, 149.5, 136.6, 132.0, 128.1, 121.4, 119.8, 114.1, 55.3 ppm.
IR (KBr): ν = 2999, 2837, 1628, 1605, 1515, 1463, 1434, 1247, 1179, 1037, 840, 779, 739 cm^{-1}.
HRMS (m/z): calcd for $C_{12}H_{12}NO$ $[M+H]^+$ 186.0913, found: 186.0918.

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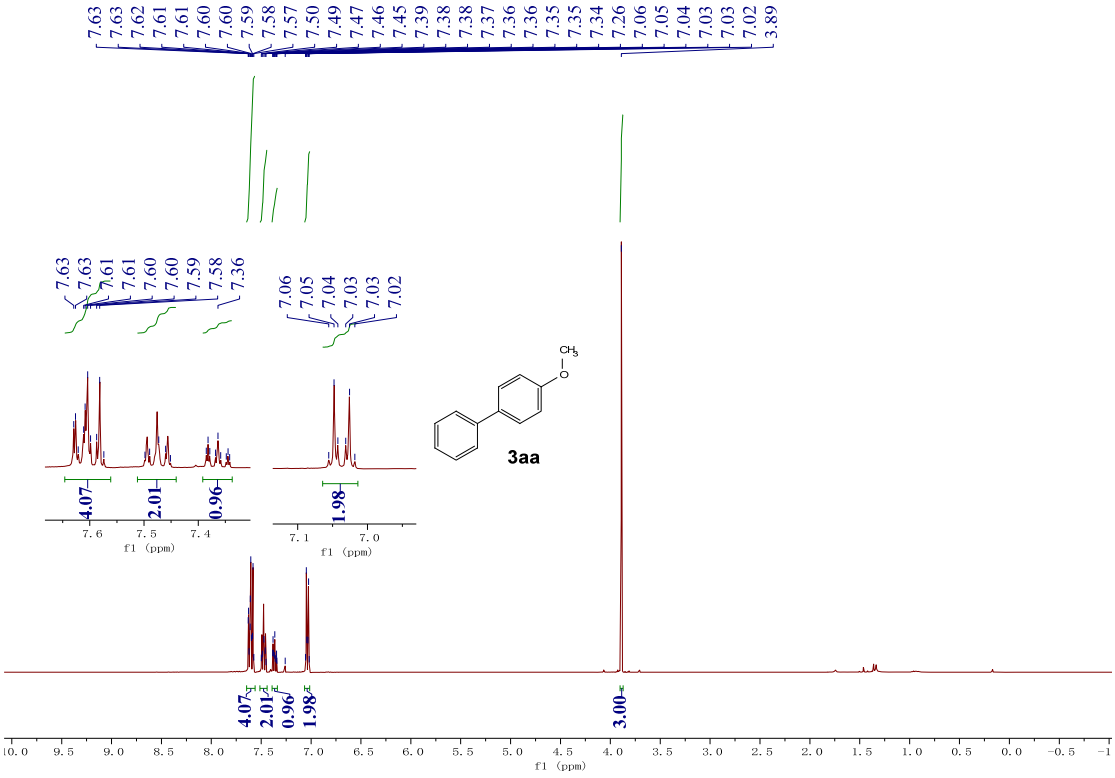
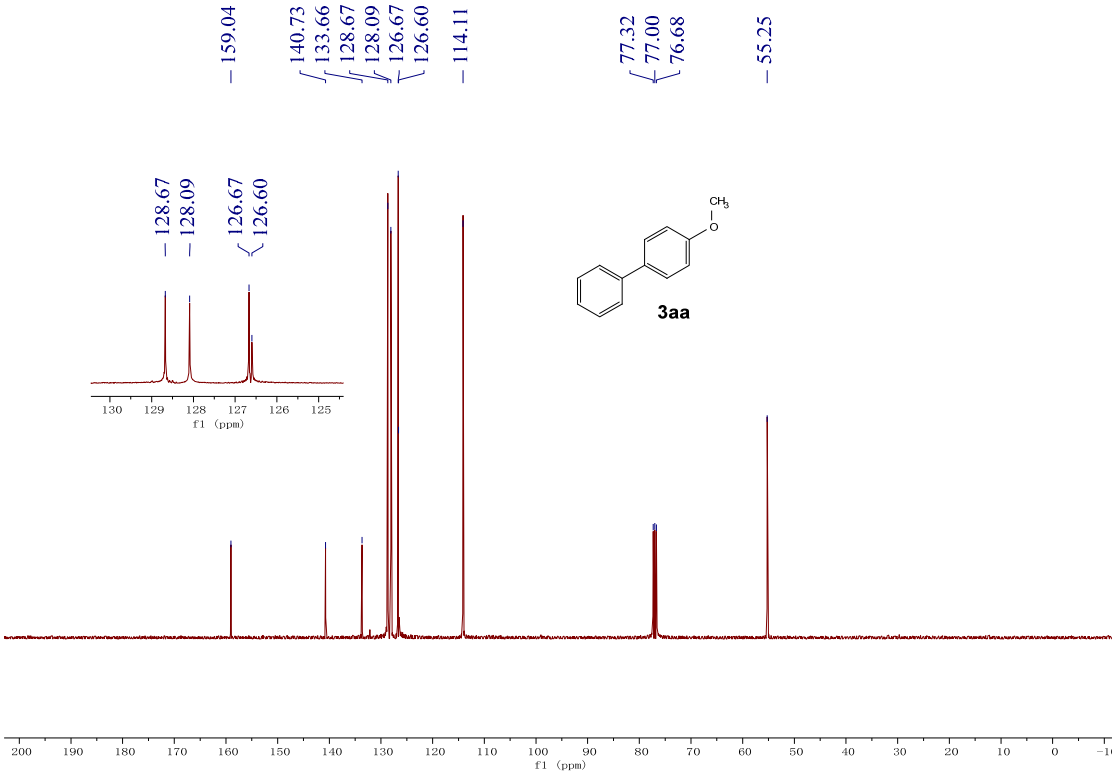
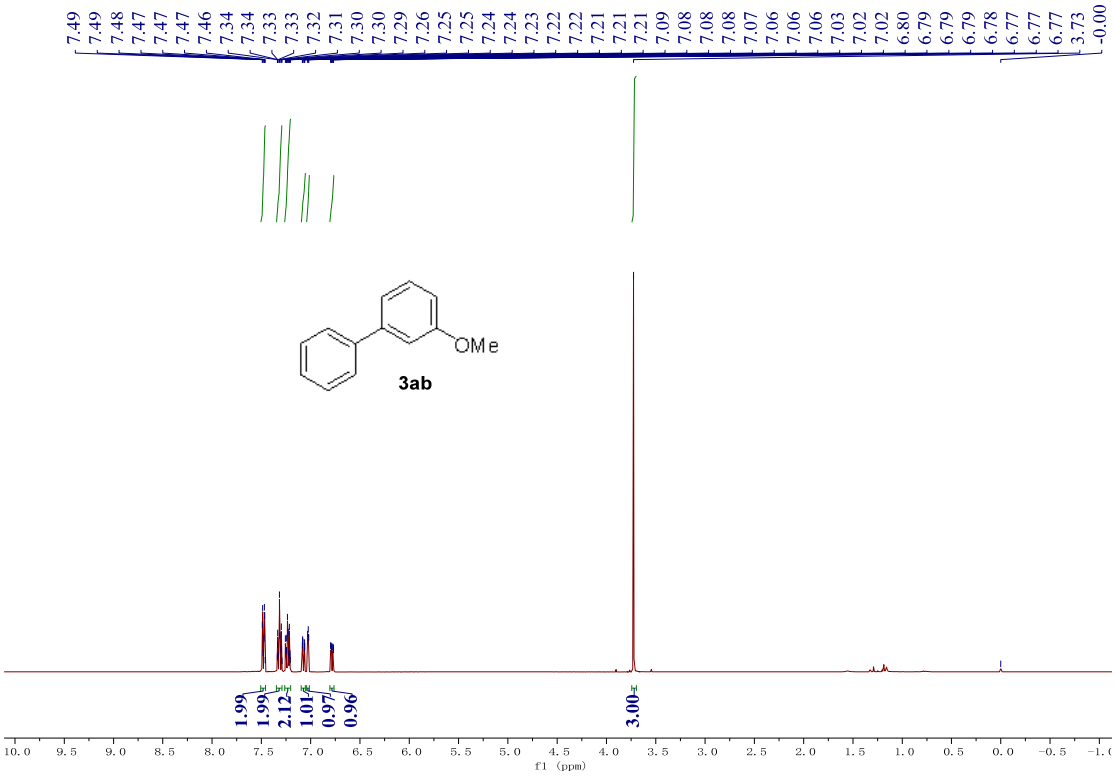
^{1}H, ^{13}C, and ^{19}F NMR spectra of products






7.49
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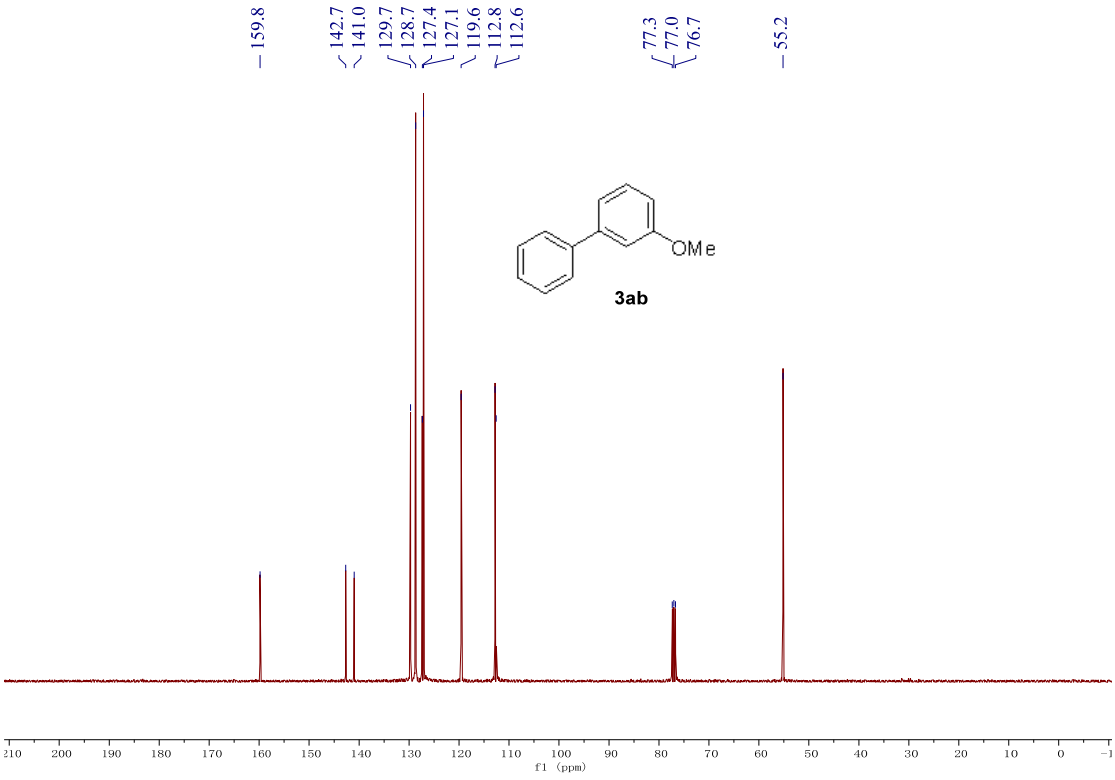
f1 (ppm)


159.8
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77.3
77.0
76.7
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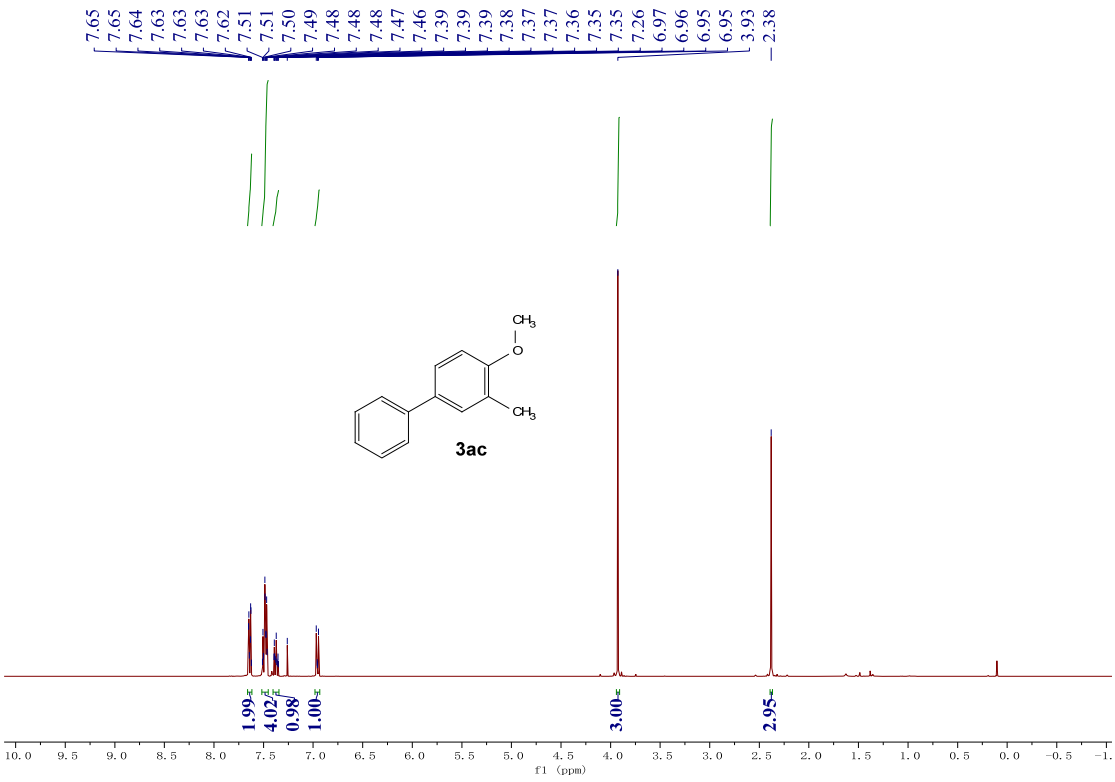
OMe
3ab
f1 (ppm)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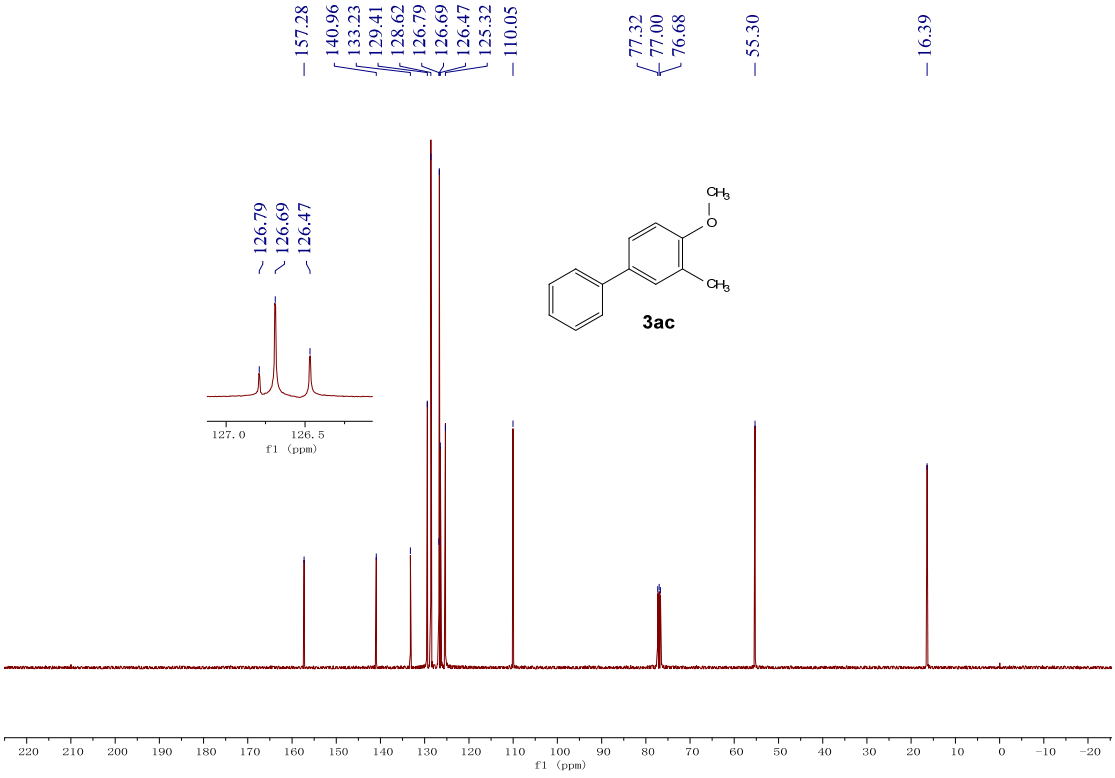
7.64
7.63
7.63
7.63
7.62
7.51
7.51
7.50
7.49
7.48
7.48
7.48
7.47
7.46
7.39
7.39
7.39
7.38
7.37
7.37
7.36
7.35
7.35
7.26
6.97
6.96
6.95
6.95
3.93
2.38
3ac
1.99
4.02
0.98
1.00
3.00
2.95
f1 (ppm)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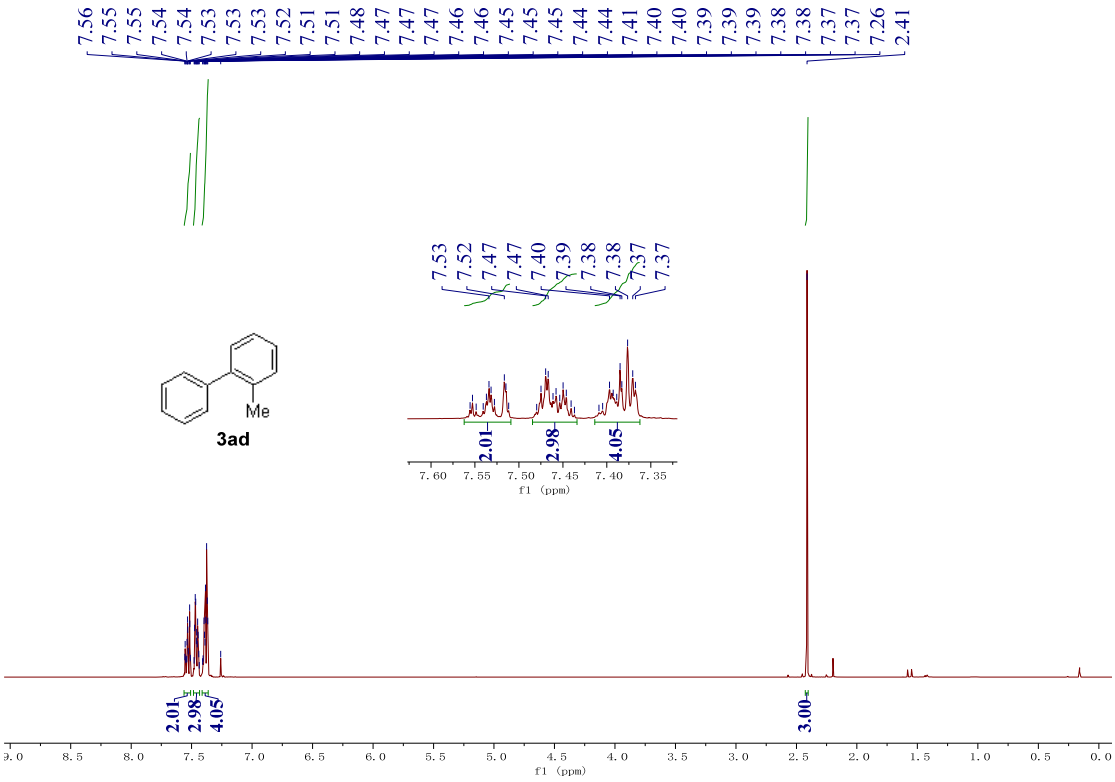
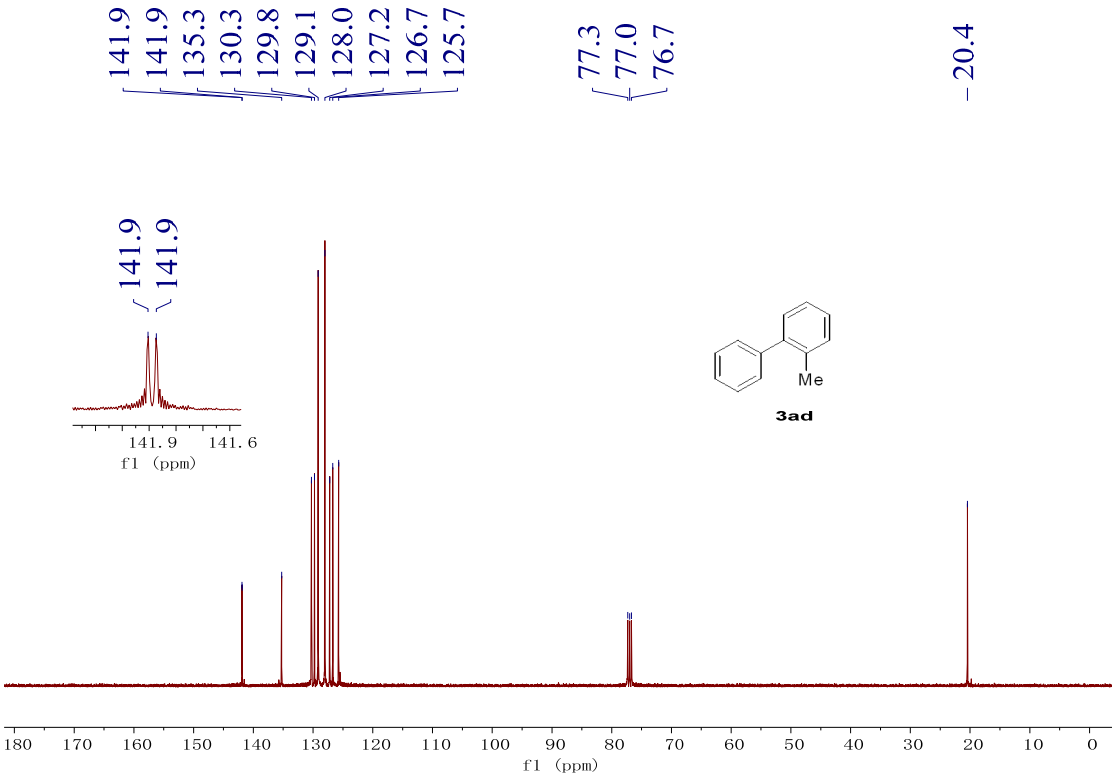
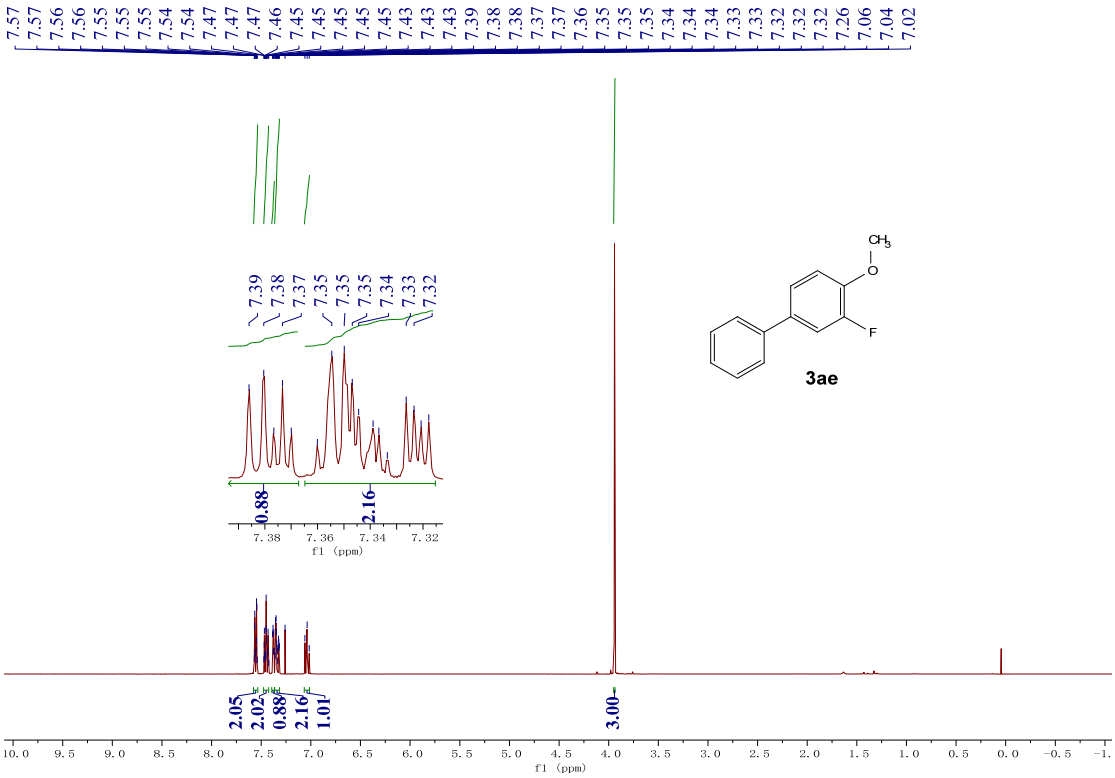
133.23
129.41
128.62
126.79
126.69
126.47
125.32
110.05
77.32
77.00
76.68
55.30
16.39
126.79
126.69
126.47
127.0
126.5
f1 (ppm)
3ac
f1 (ppm)


7.56 7.55 7.55 7.54 7.54 7.53 7.53 7.53 7.52 7.51 7.51 7.48 7.47 7.47 7.47 7.46 7.46 7.45 7.45 7.45 7.44 7.44 7.41 7.40 7.40 7.39 7.39 7.39 7.38 7.38 7.37 7.37 7.26 2.41
7.53 7.52 7.47 7.47 7.40 7.39 7.38 7.38 7.37 7.37
Me
3ad
2.01 2.98 4.05
7.60 7.55 7.50 7.45 7.40 7.35
f1 (ppm)
2.01 2.98 4.05 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)


141.9 141.9 135.3 130.3 129.8 129.1 128.0 127.2 126.7 125.7
77.3 77.0 76.7
20.4
141.9 141.9
141.9 141.6
f1 (ppm)
Me
3ad
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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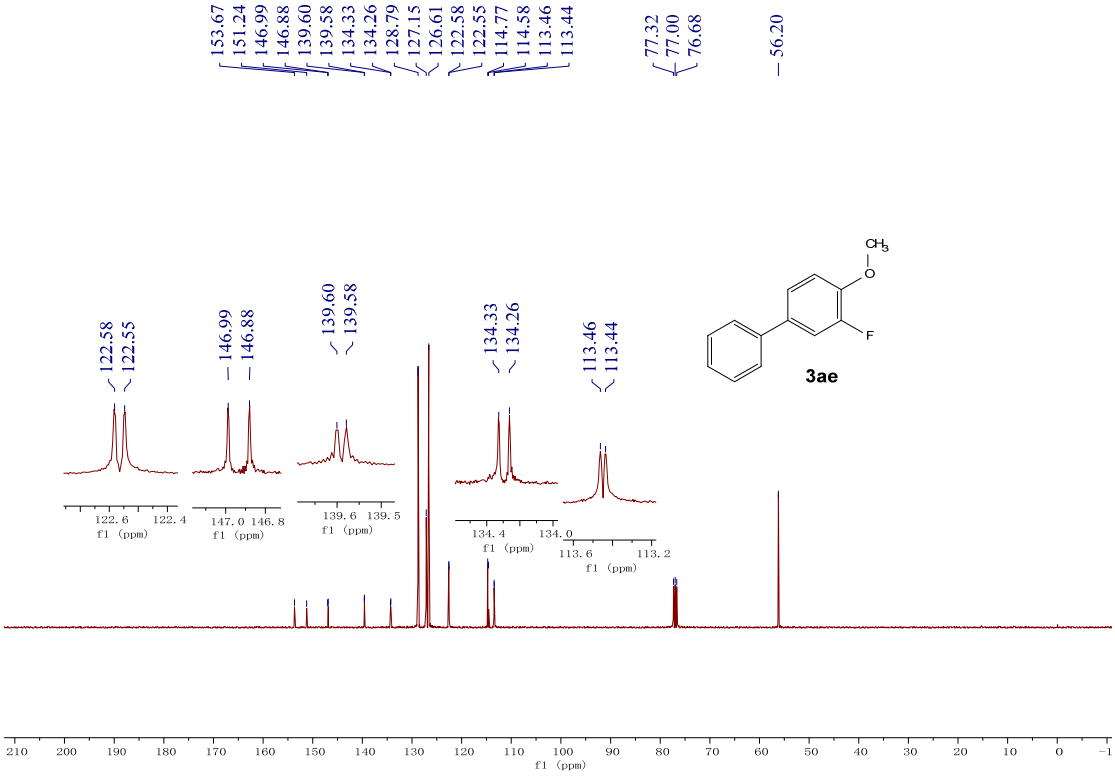
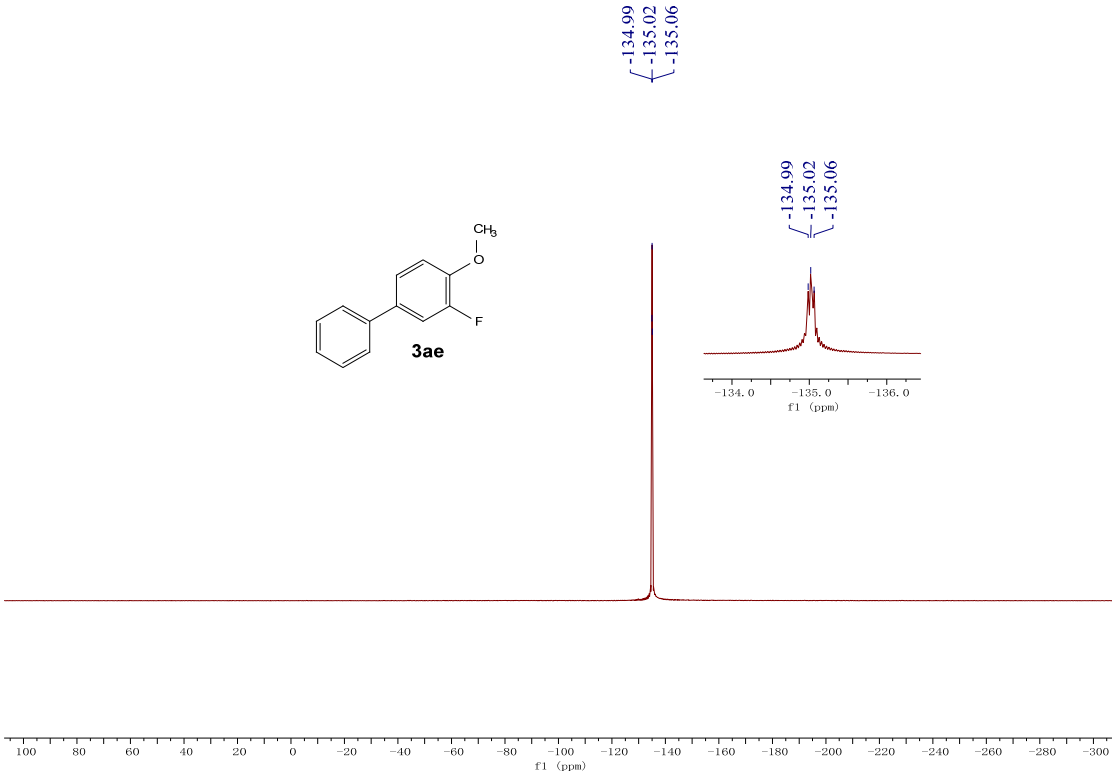
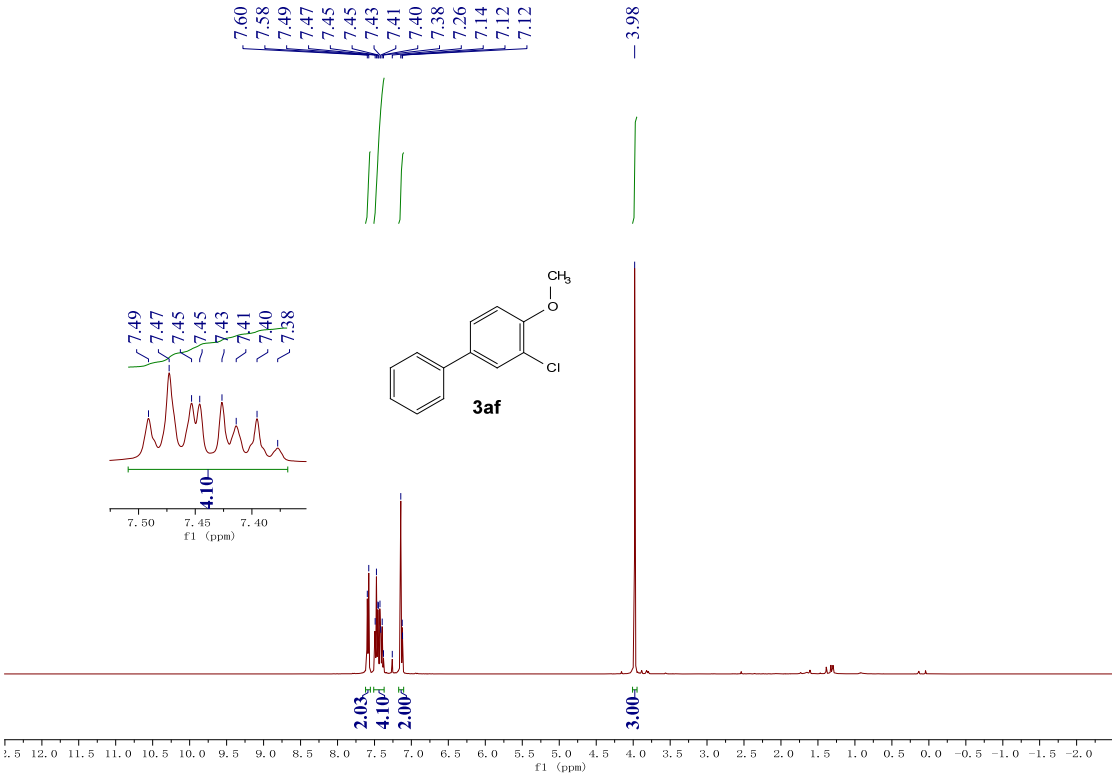
7.39 7.38 7.37 7.35 7.35 7.35 7.34 7.33 7.32
0.88 2.16
7.38 7.36 7.34 7.32
f1 (ppm)
CH3 O F
3ae
2.05 2.02 0.88 2.16 1.01 3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)


153.67 151.24 146.99 146.88 139.60 139.58 134.33 134.26 128.79 127.15 126.61 122.58 122.55 114.77 114.58 113.46 113.44
77.32 77.00 76.68
56.20
122.58 122.55
146.99 146.88
139.60 139.58
134.33 134.26
113.46 113.44
122.6 122.4 f1 (ppm)
147.0 146.8 f1 (ppm)
139.6 139.5 f1 (ppm)
134.4 134.0 f1 (ppm)
113.6 113.2 f1 (ppm)
CH3 O F
3ae
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)


-134.99
-135.02
-135.06
CH3
O
F
3ae
-134.99
-135.02
-135.06
-134.0
-135.0
-136.0
f1 (ppm)
100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280 -300
f1 (ppm)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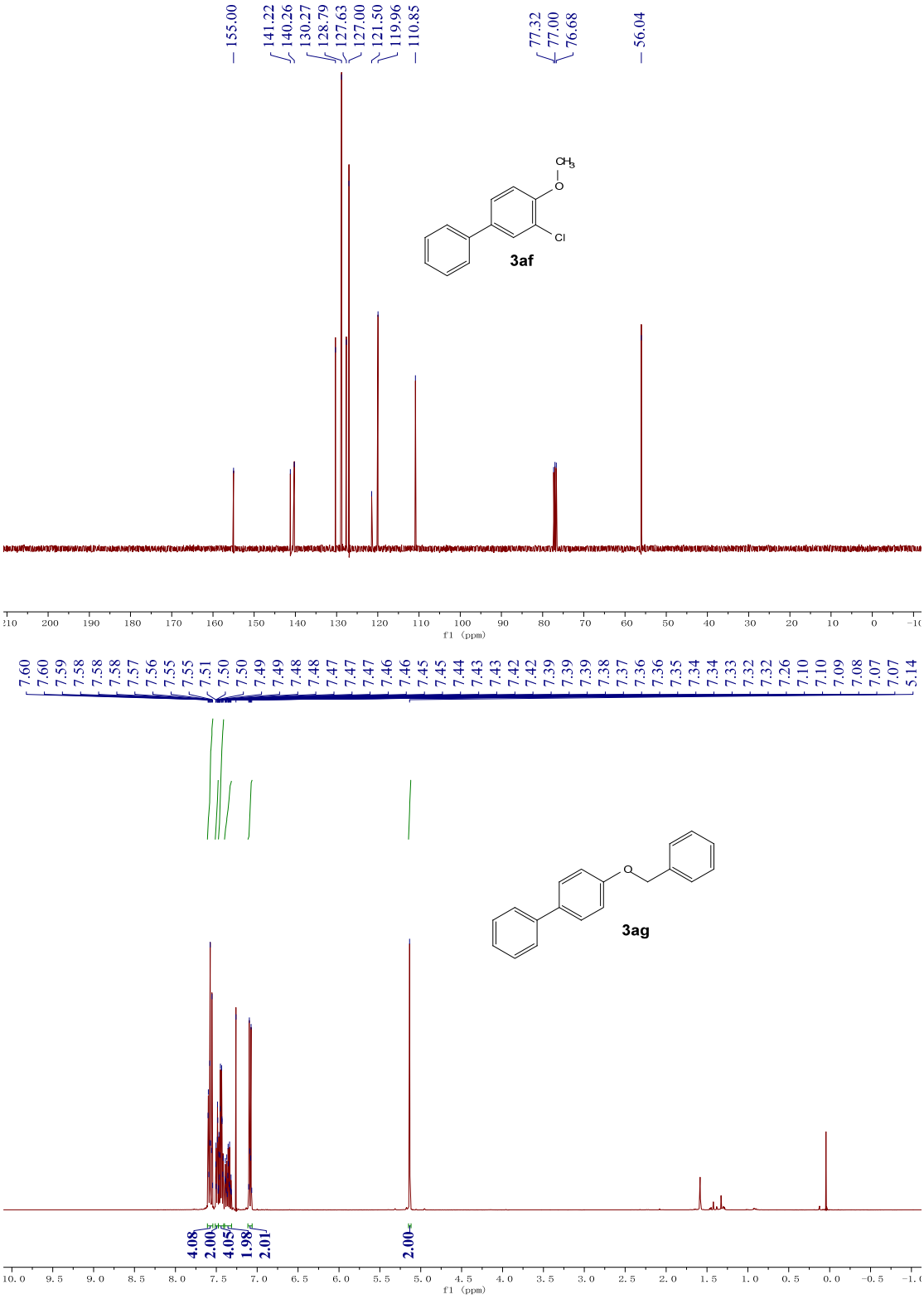
7.58
7.49
7.47
7.45
7.45
7.43
7.41
7.40
7.38
7.26
7.14
7.12
7.12
3.98
7.49
7.47
7.45
7.45
7.43
7.41
7.40
7.38
4.10
7.50
7.45
7.40
f1 (ppm)
CH3
O
Cl
3af
2.03
4.10
2.00
3.00
f1 (ppm)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141.22
140.26
130.27
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127.63
127.00
121.50
119.96
110.85
77.32
77.00
76.68
56.04
CH3
O
Cl
3af
f1 (ppm)
7.60
7.60
7.59
7.58
7.58
7.58
7.57
7.56
7.55
7.55
7.51
7.50
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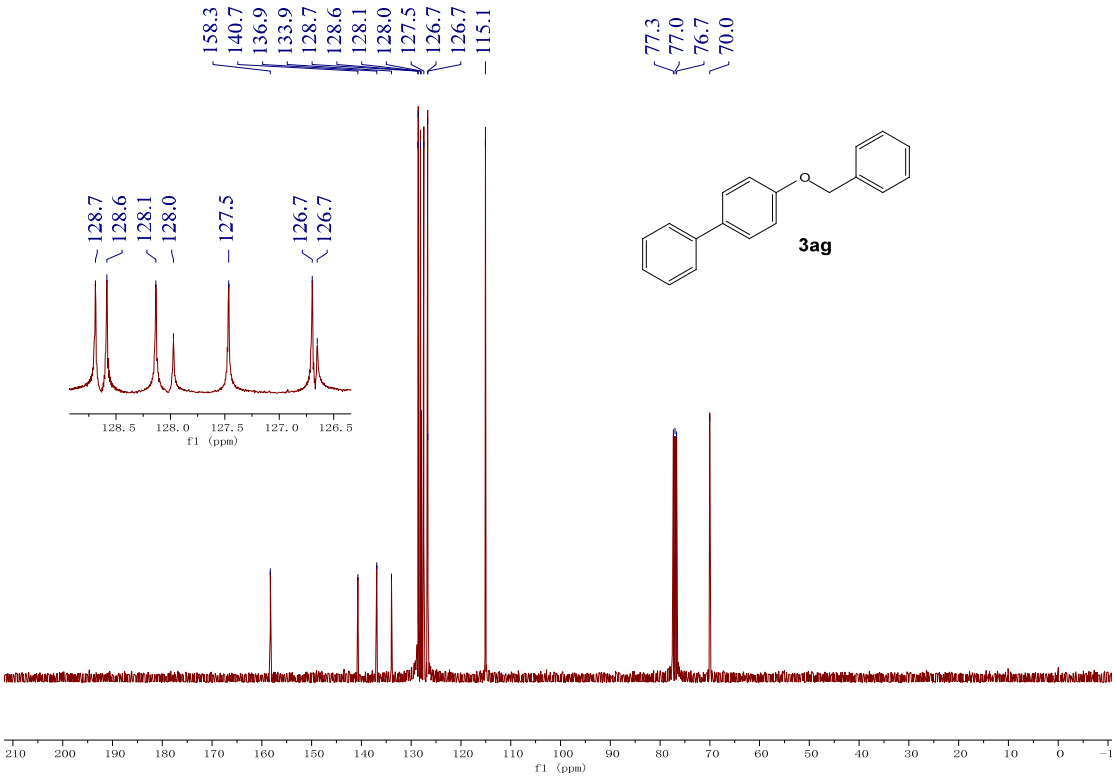
7.32
7.32
7.26
7.10
7.10
7.09
7.08
7.07
7.07
5.14
O
3ag
4.08
2.00
4.05
1.98
2.01
2.00
f1 (ppm)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140.7
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133.9
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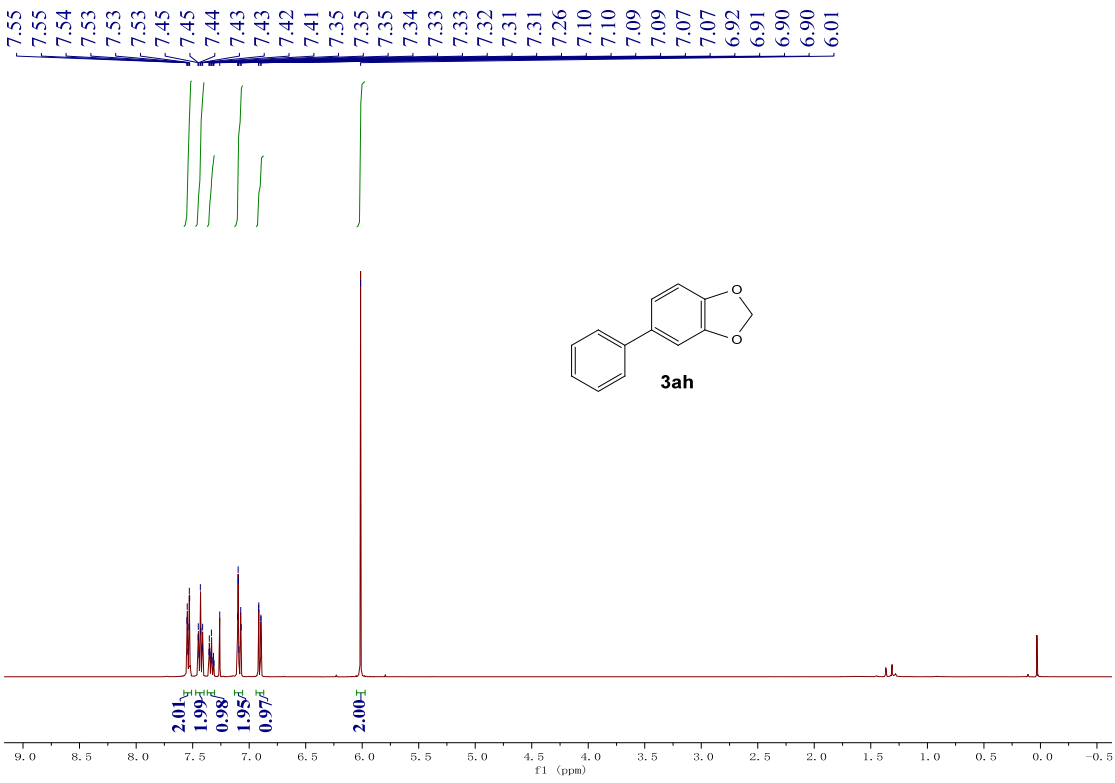
128.6
128.1
128.0
127.5
126.7
126.7
115.1
77.3
77.0
76.7
70.0
128.7
128.6
128.1
128.0
127.5
126.7
126.7
128.5
128.0
127.5
127.0
126.5
f1 (ppm)
3ag
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)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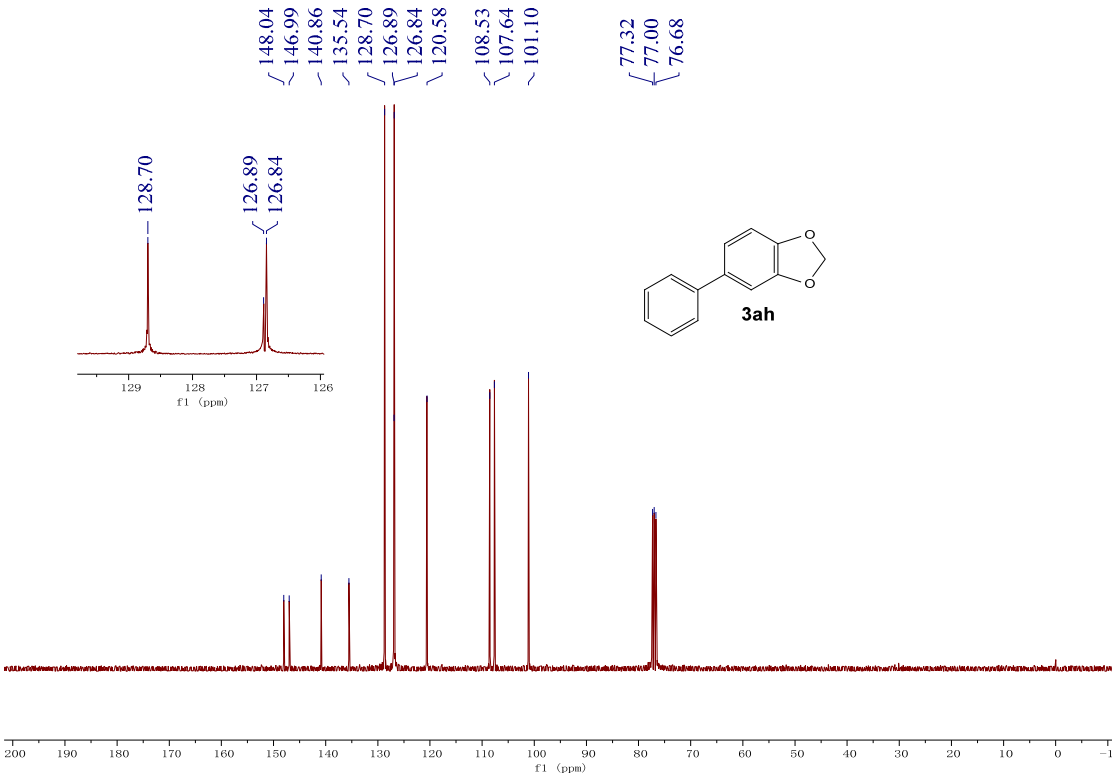
7.42
7.41
7.35
7.35
7.35
7.34
7.33
7.33
7.32
7.31
7.31
7.26
7.10
7.10
7.09
7.09
7.07
7.07
6.92
6.91
6.90
6.90
6.01
3ah
2.01
1.99
0.98
1.95
0.97
2.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
f1 (ppm)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146.99
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135.54
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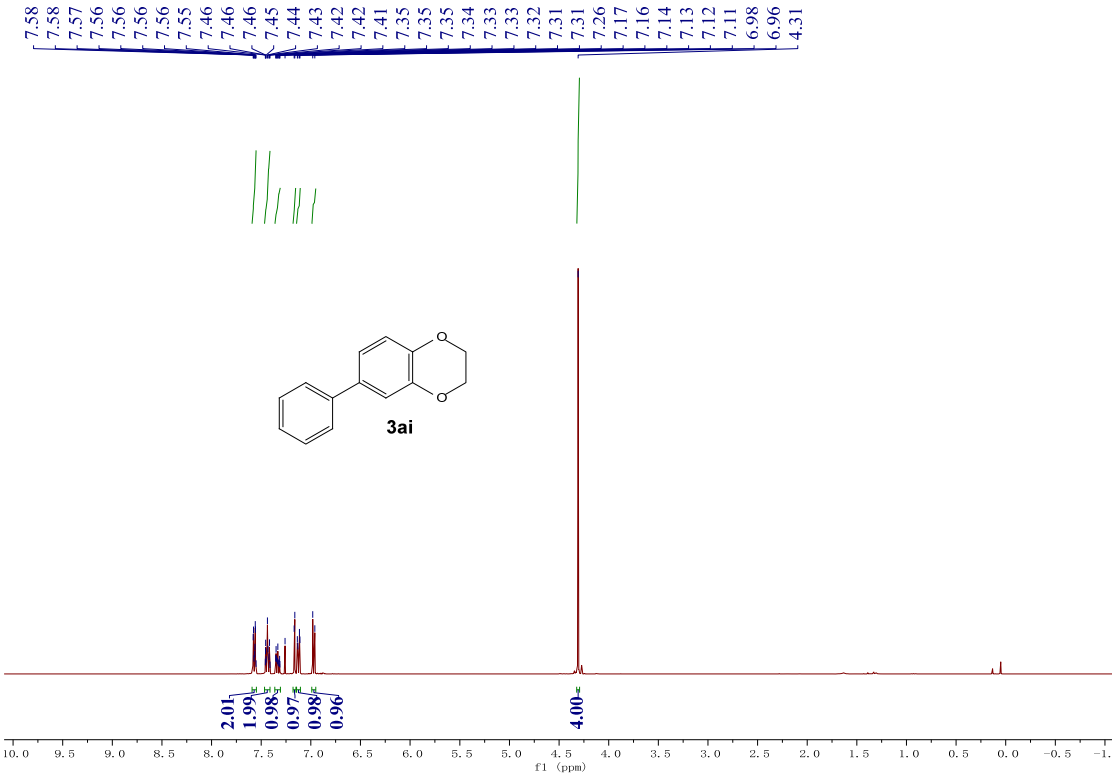
126.89
126.84
120.58
108.53
107.64
101.10
77.32
77.00
76.68
128.70
126.89
126.84
129
128
127
126
f1 (ppm)
3ah
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
−1
f1 (ppm)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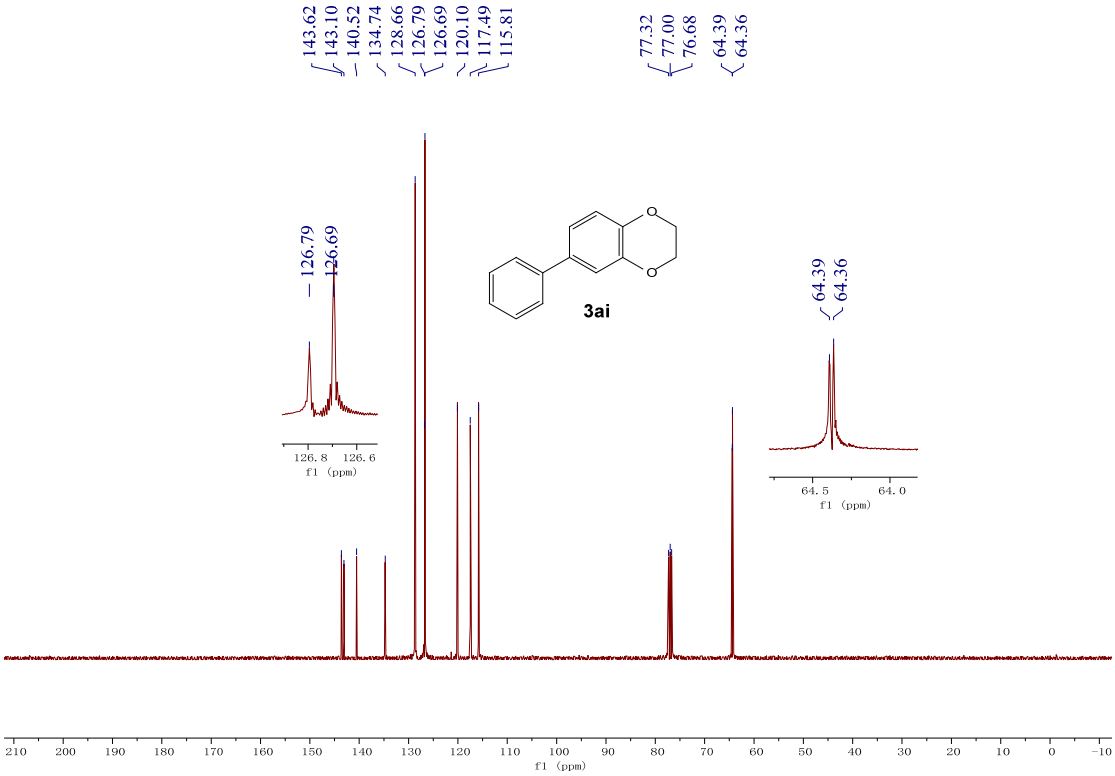
7.45
7.44
7.43
7.42
7.42
7.41
7.35
7.35
7.35
7.34
7.33
7.33
7.32
7.31
7.31
7.26
7.17
7.16
7.14
7.13
7.12
7.11
6.98
6.96
4.31
3ai
2.01
1.99
0.98
0.97
0.98
0.96
4.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.
f1 (ppm)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143.10
140.52
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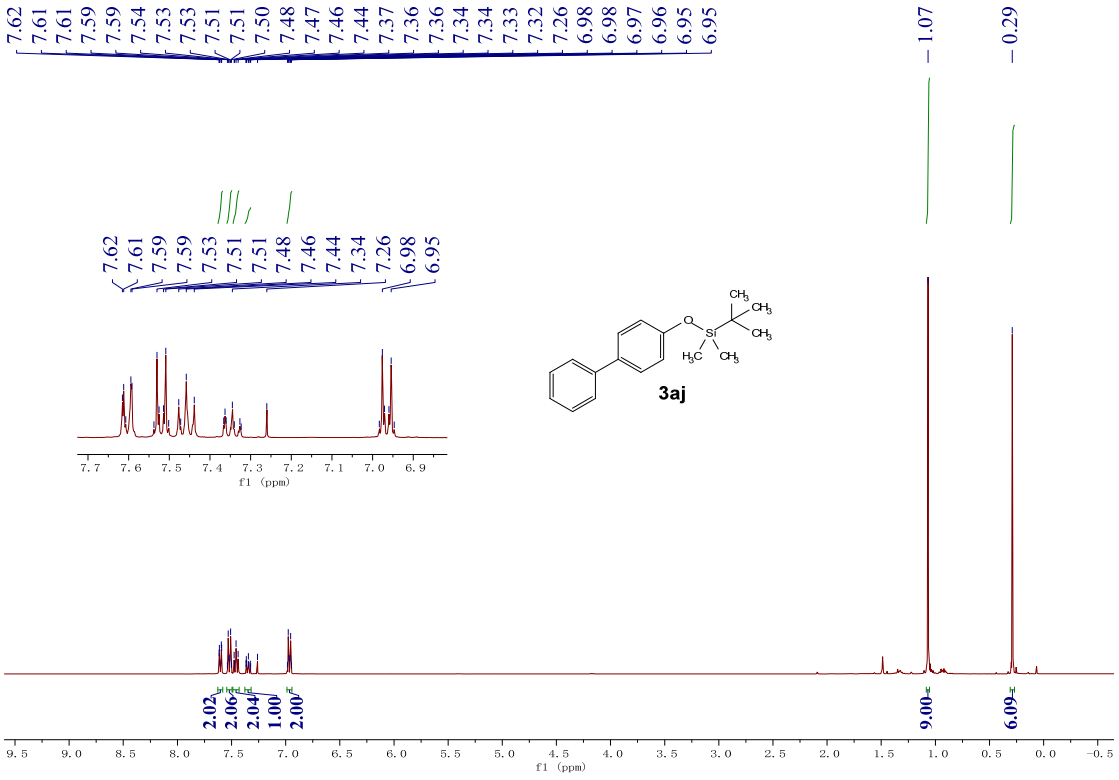
128.66
126.79
126.69
120.10
117.49
115.81
77.32
77.00
76.68
64.39
64.36
126.79
126.69
64.39
64.36
3ai
126.8
126.6
f1 (ppm)
64.5
64.0
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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7.61
7.61
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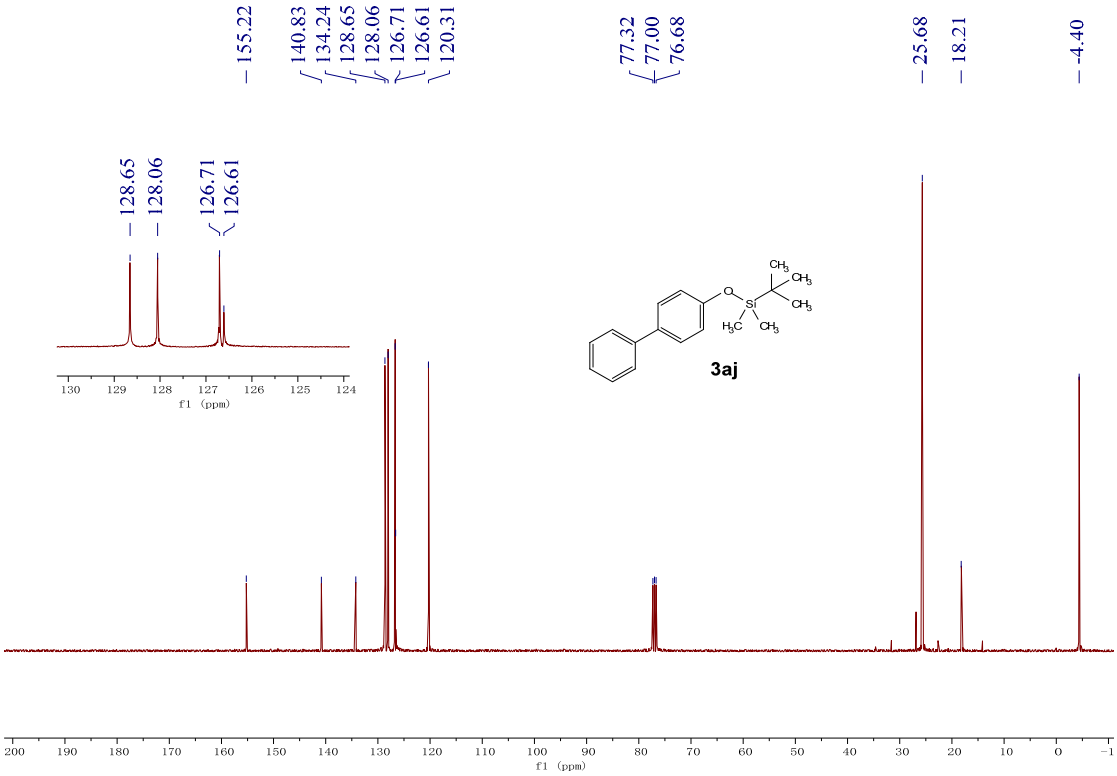
7.59
7.54
7.53
7.53
7.51
7.51
7.50
7.48
7.47
7.46
7.44
7.37
7.36
7.36
7.34
7.34
7.33
7.32
7.26
6.98
6.98
6.97
6.96
6.95
6.95
1.07
0.29
3aj
2.02
2.06
2.04
1.00
2.00
9.00
6.09
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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76.68
25.68
18.21
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128.65
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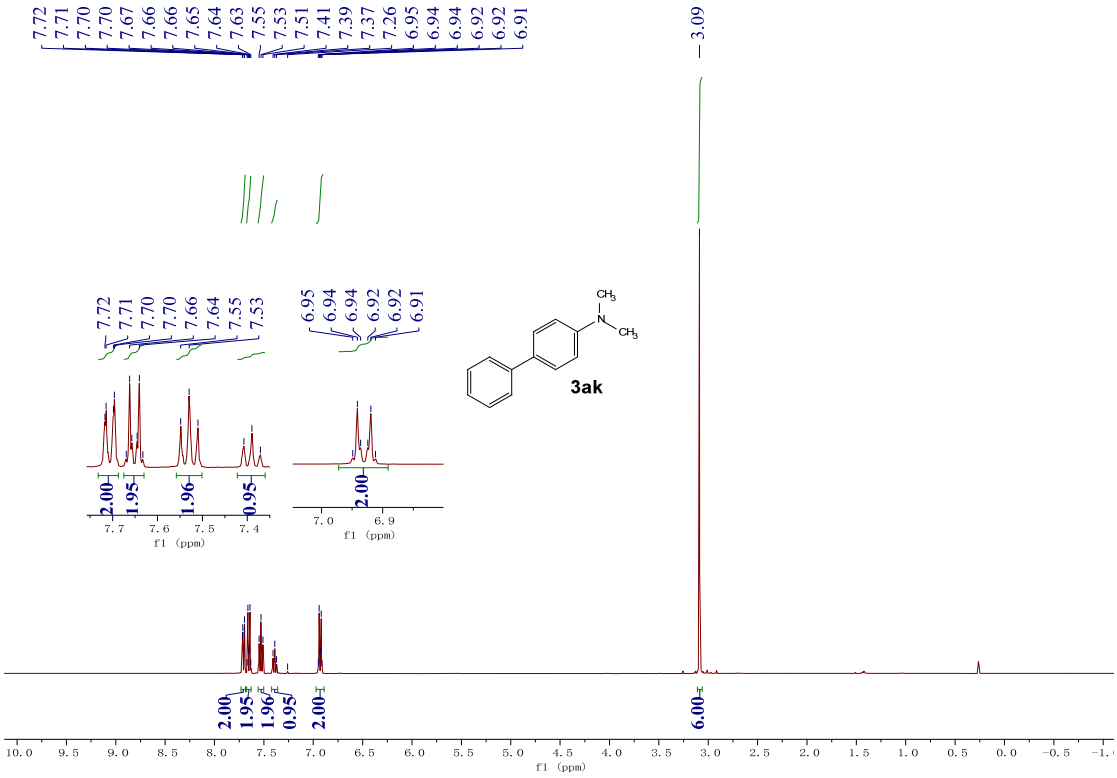
126.71
126.61
3aj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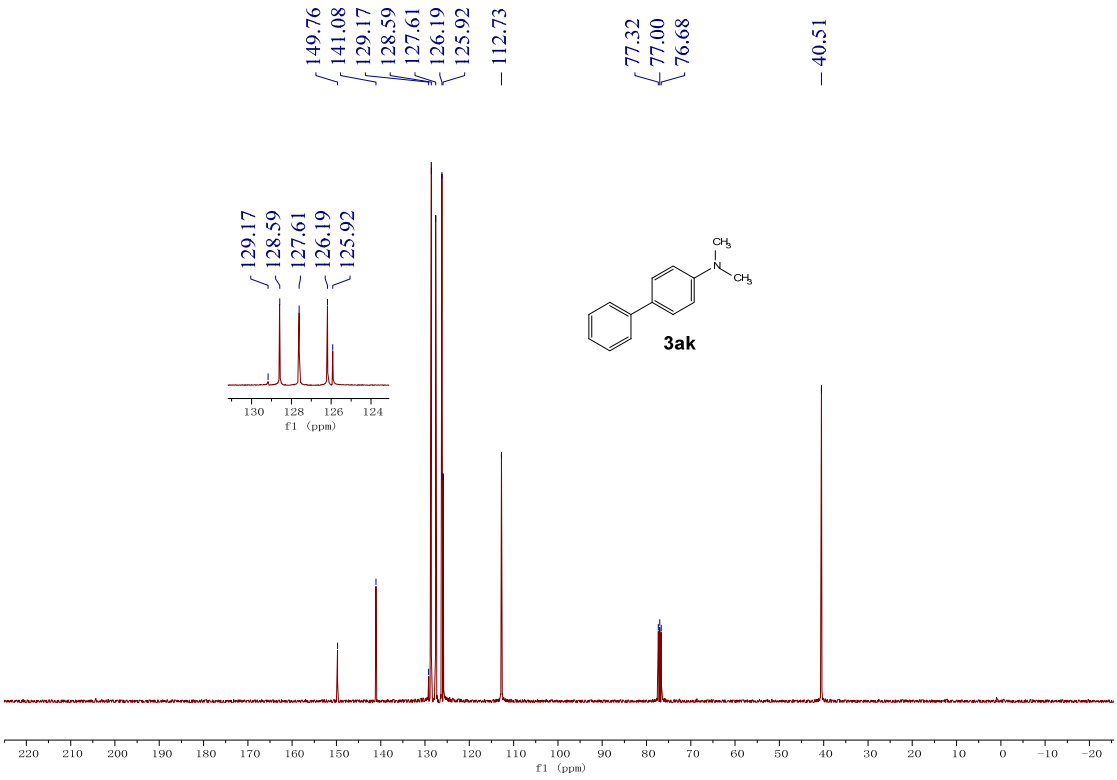
7.63
7.55
7.53
7.51
7.41
7.39
7.37
7.26
6.95
6.94
6.94
6.92
6.92
6.91
3.09
3ak
2.00
1.95
1.96
0.95
2.00
6.00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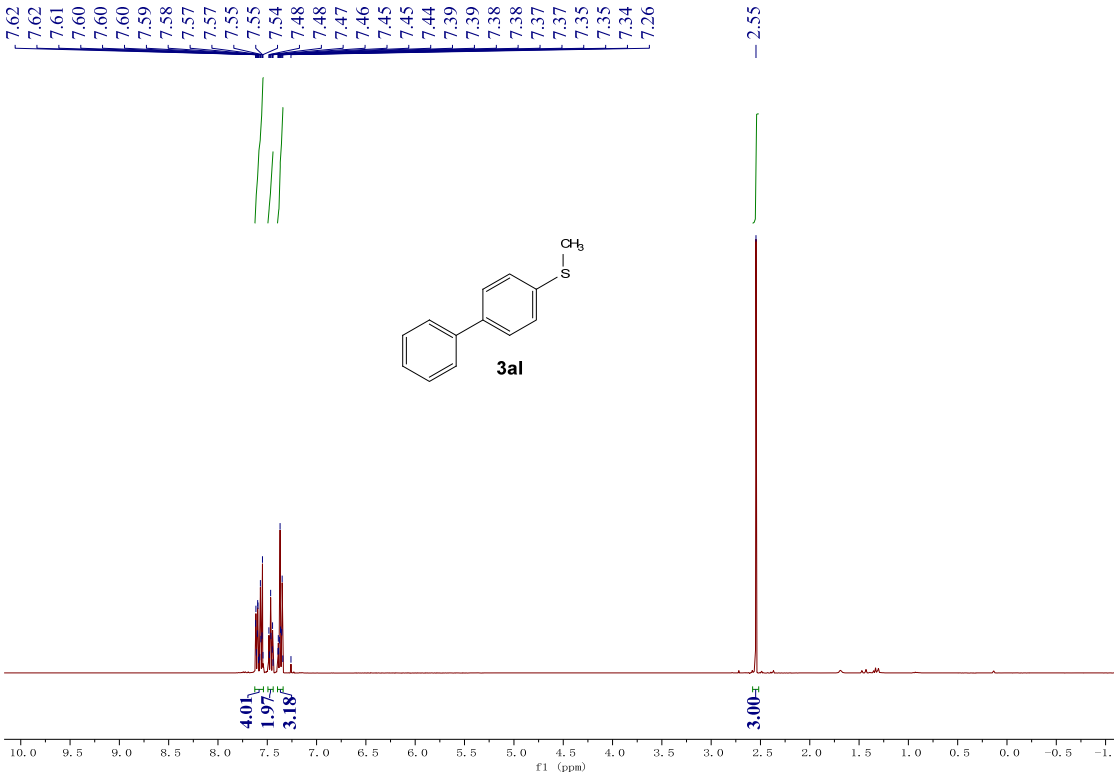
125.92
112.73
77.32
77.00
76.68
40.51
129.17
128.59
127.61
126.19
125.92
130
128
126
124
f1 (ppm)
CH3
N
CH3
3ak
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)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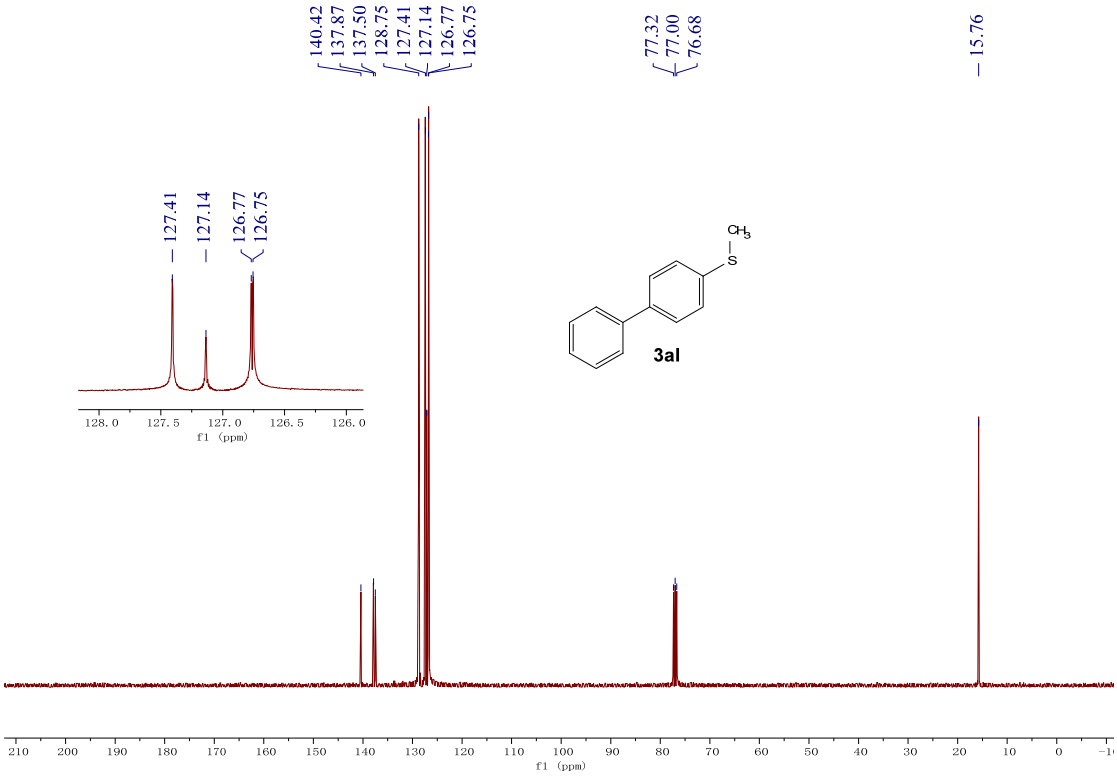
7.48
7.48
7.47
7.46
7.45
7.45
7.44
7.39
7.39
7.38
7.38
7.37
7.37
7.35
7.35
7.34
7.26
2.55
CH3
S
3al
4.01
1.97
3.18
3.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.
f1 (ppm)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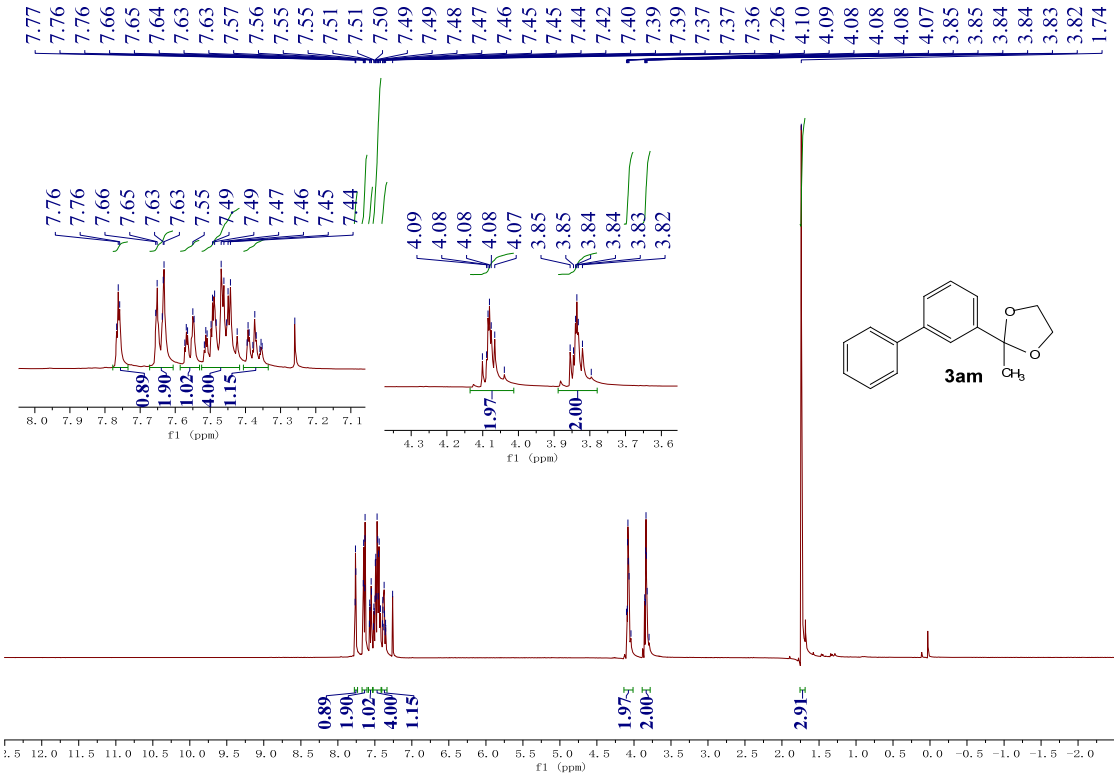
127.14
126.77
126.75
3al
f1 (ppm)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7.63
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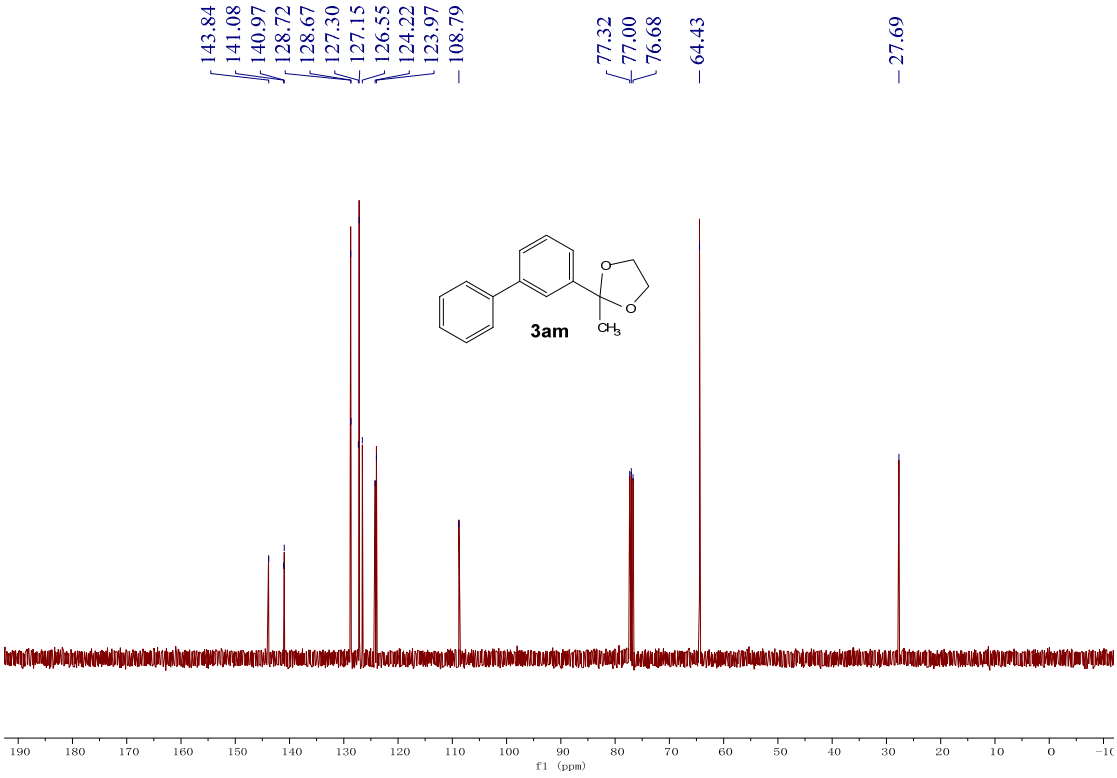
7.49
7.48
7.47
7.46
7.45
7.45
7.44
7.42
7.40
7.39
7.39
7.37
7.37
7.36
7.26
4.10
4.09
4.08
4.08
4.08
4.07
3.85
3.85
3.84
3.84
3.83
3.82
1.74
0.89
1.90
1.02
4.00
1.15
1.97
2.00
2.91
3am
f1 (ppm)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126.55
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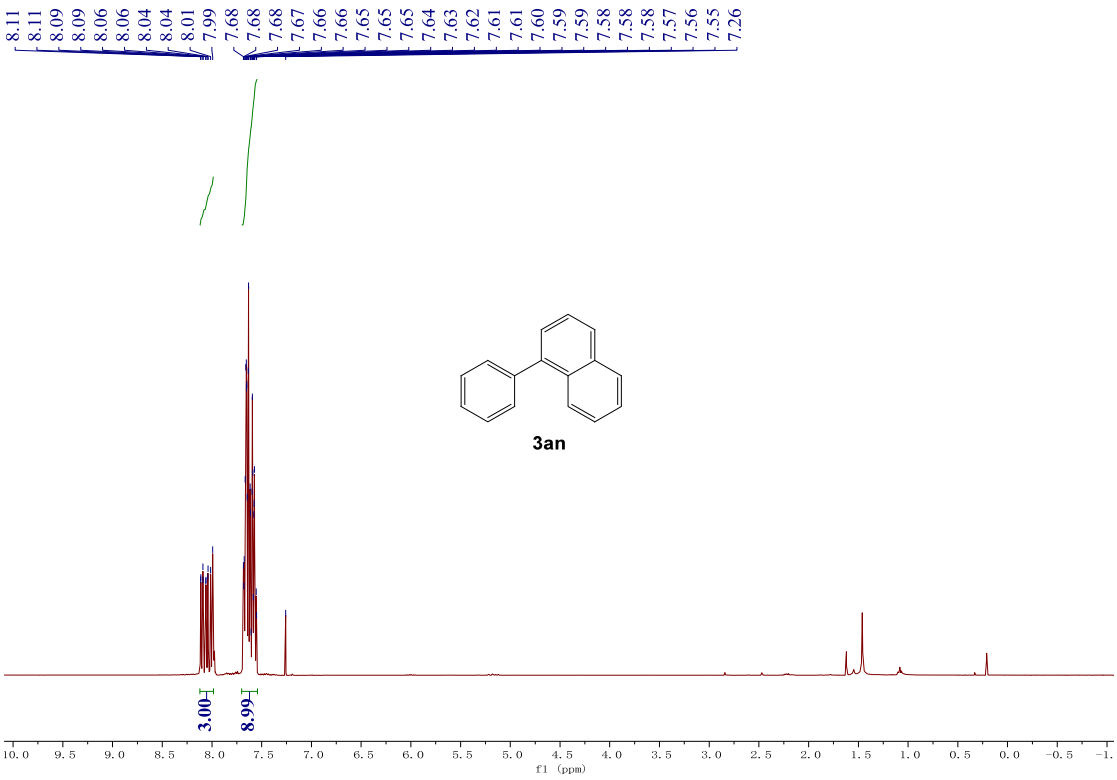
123.97
108.79
77.32
77.00
76.68
64.43
27.69
3am
f1 (ppm)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8.11
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8.09
8.06
8.06
8.04
8.04
8.01
7.99
7.68
7.68
7.68
7.67
7.66
7.66
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7.64
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7.61
7.61
7.60
7.59
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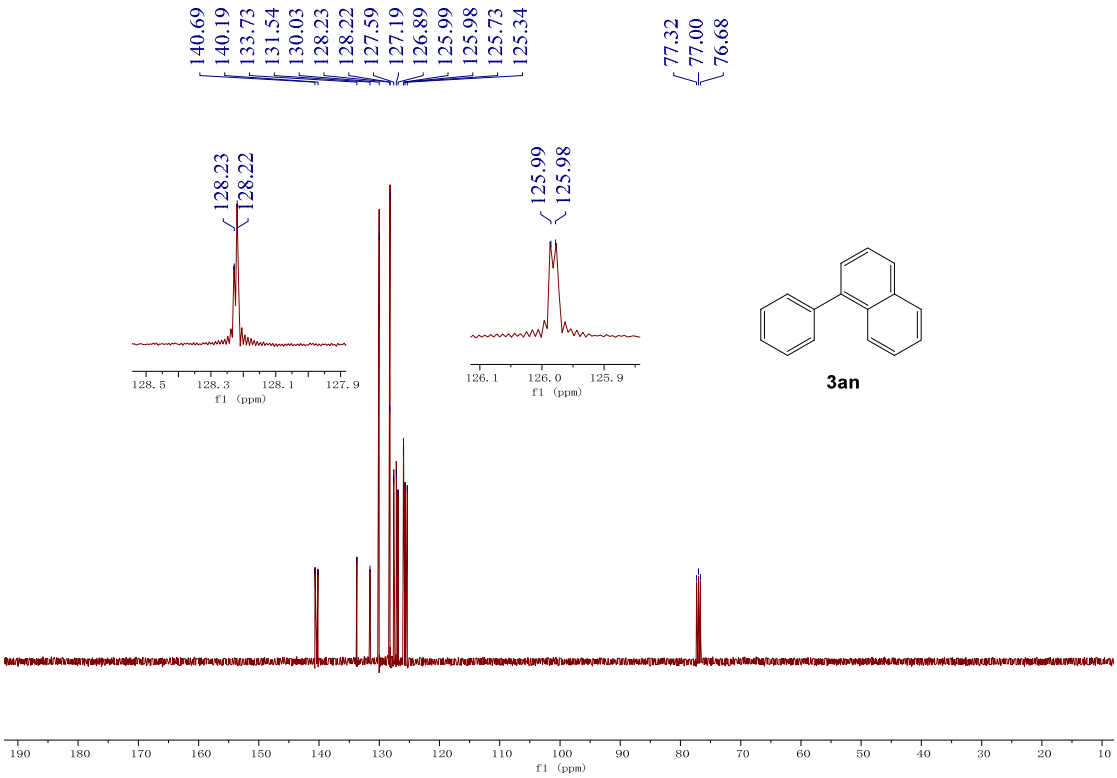
7.26
3an
3.00
8.99
f1 (ppm)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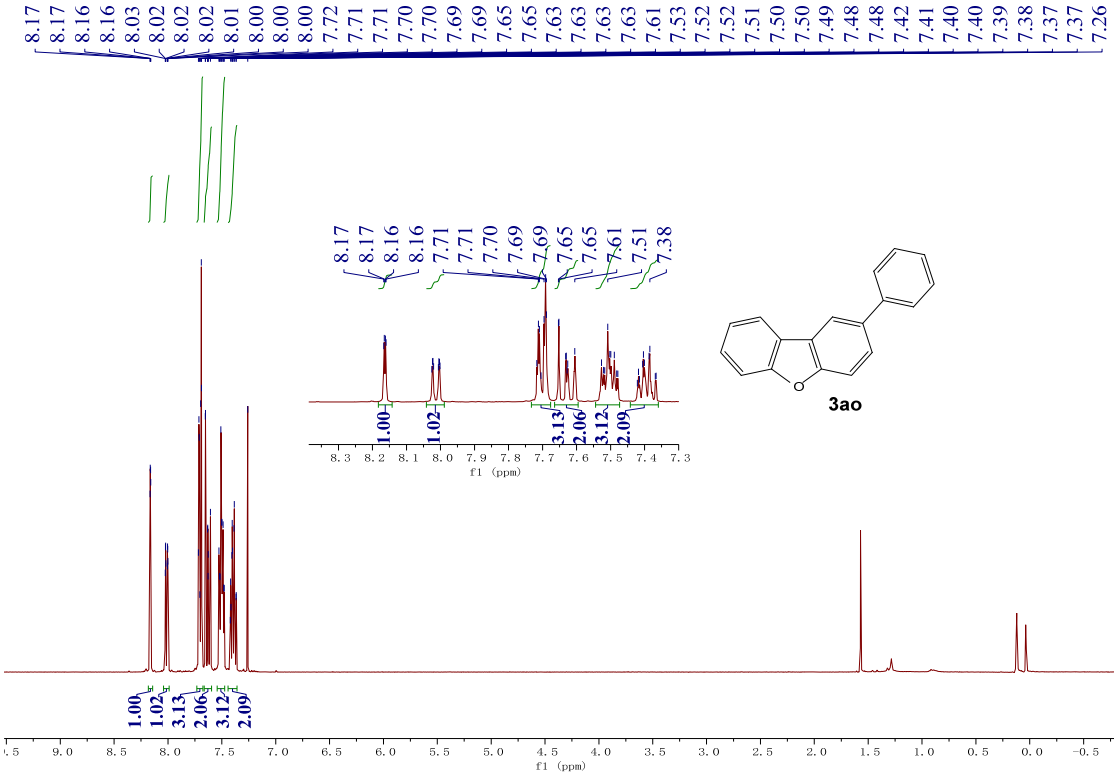
127.19
126.89
125.99
125.98
125.73
125.34
77.32
77.00
76.68
128.23
128.22
125.99
125.98
f1 (ppm)
3an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8.17
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8.16
8.03
8.02
8.02
8.02
8.01
8.00
8.00
8.00
7.72
7.71
7.71
7.70
7.70
7.69
7.69
7.65
7.65
7.63
7.63
7.63
7.63
7.61
7.53
7.52
7.52
7.51
7.50
7.50
7.49
7.48
7.48
7.42
7.41
7.40
7.40
7.39
7.38
7.37
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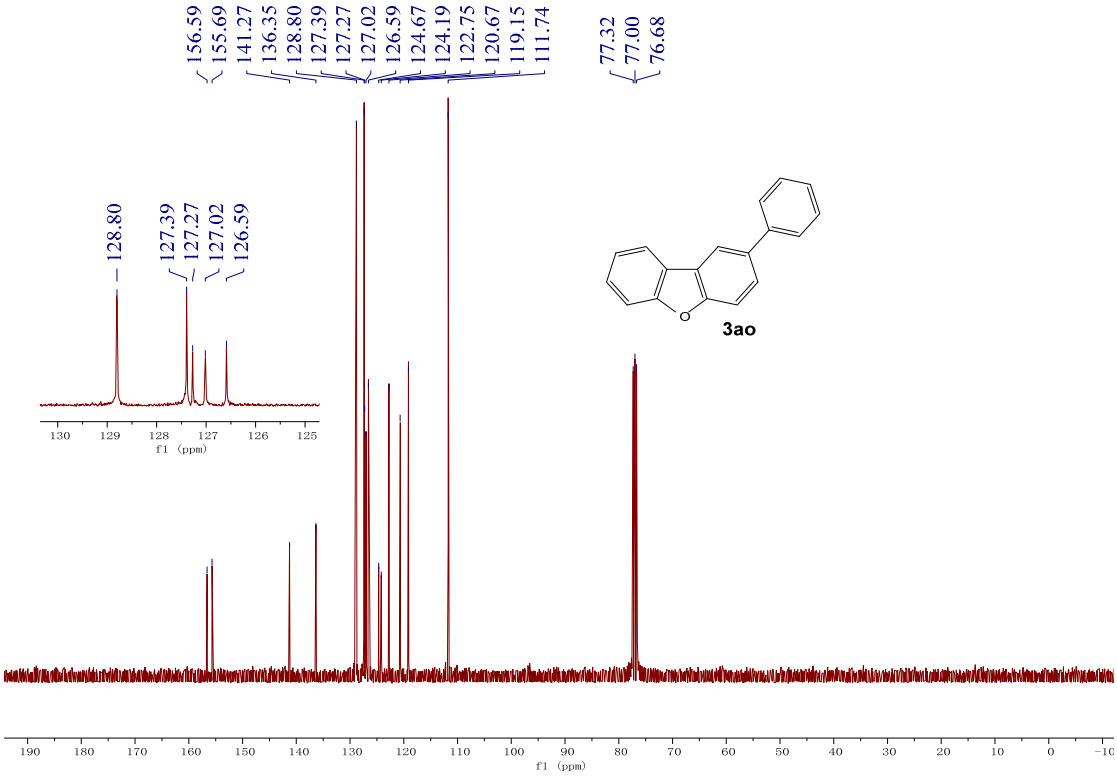
7.26
1.00
1.02
3.13
2.06
3.12
2.09
f1 (ppm)
3ao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141.27
136.35
128.80
127.39
127.27
127.02
126.59
124.67
124.19
122.75
120.67
119.15
111.74
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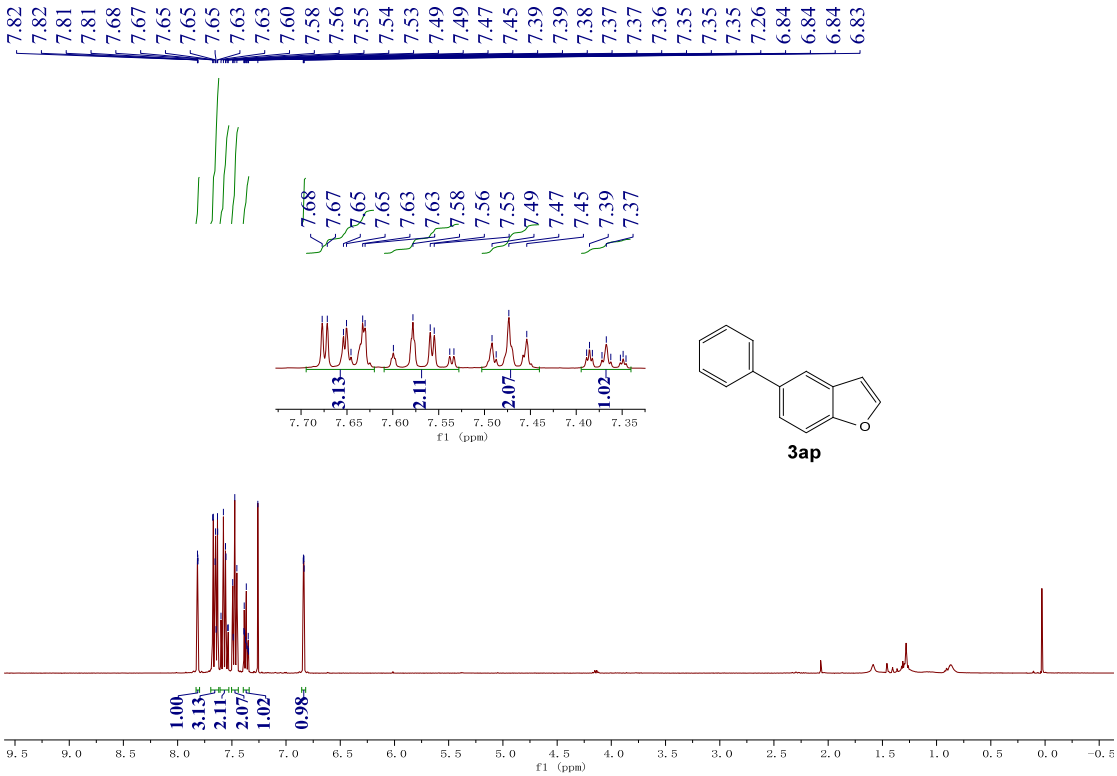
77.00
76.68
128.80
127.39
127.27
127.02
126.59
f1 (ppm)
3ao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7.82
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7.81
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7.67
7.65
7.65
7.65
7.63
7.63
7.60
7.58
7.56
7.55
7.54
7.53
7.49
7.49
7.47
7.45
7.39
7.39
7.38
7.37
7.37
7.36
7.35
7.35
7.35
7.26
6.84
6.84
6.83
7.68
7.67
7.65
7.65
7.63
7.63
7.58
7.56
7.55
7.49
7.47
7.45
7.39
7.37
3.13
2.11
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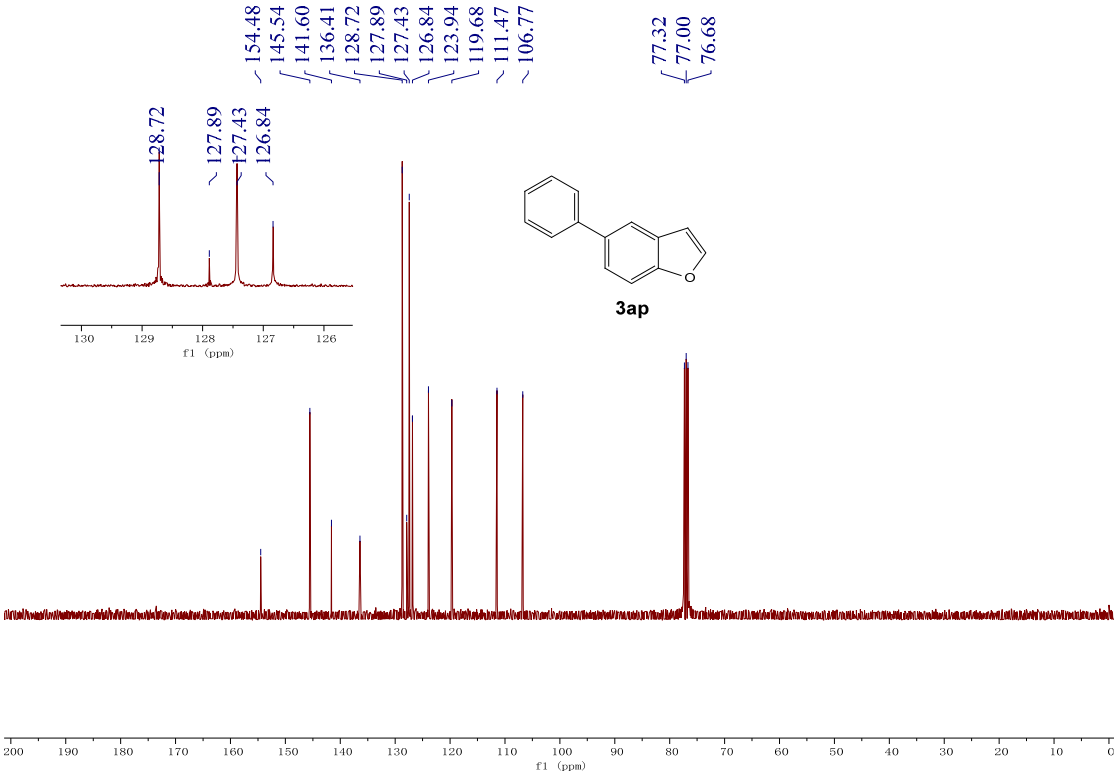
1.02
f1 (ppm)
3ap
1.00
3.13
2.11
2.07
1.02
0.98
f1 (ppm)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145.54
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127.89
127.43
126.84
123.94
119.68
111.47
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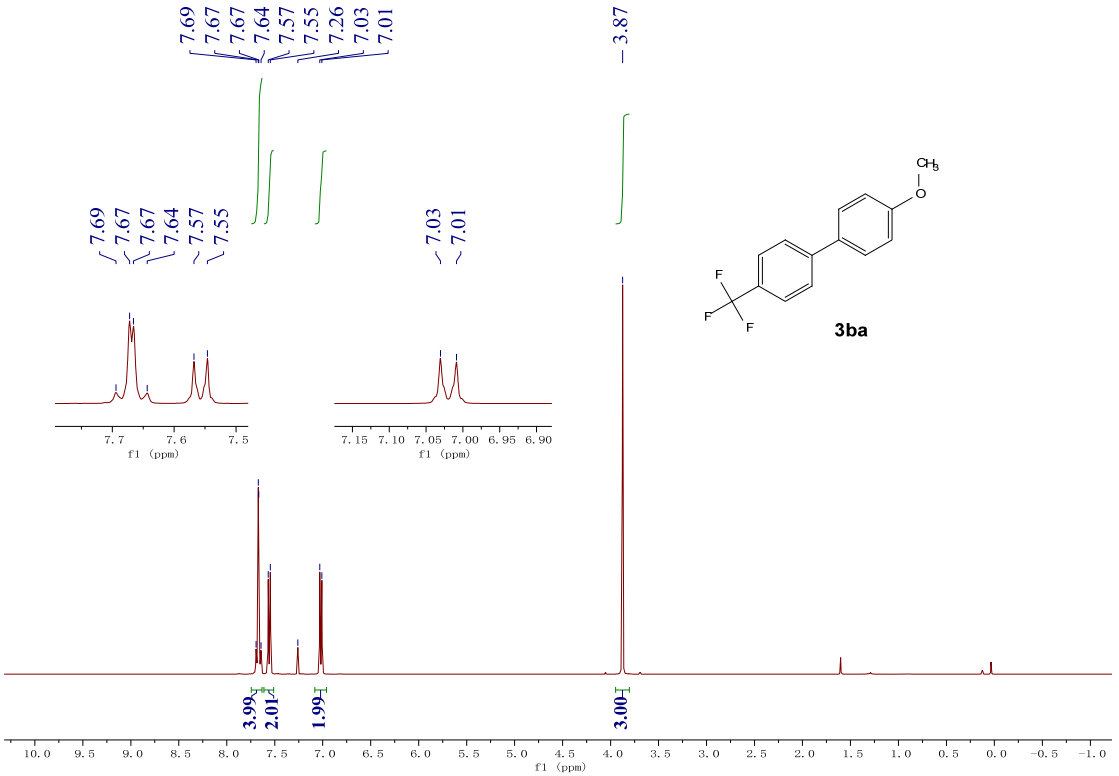
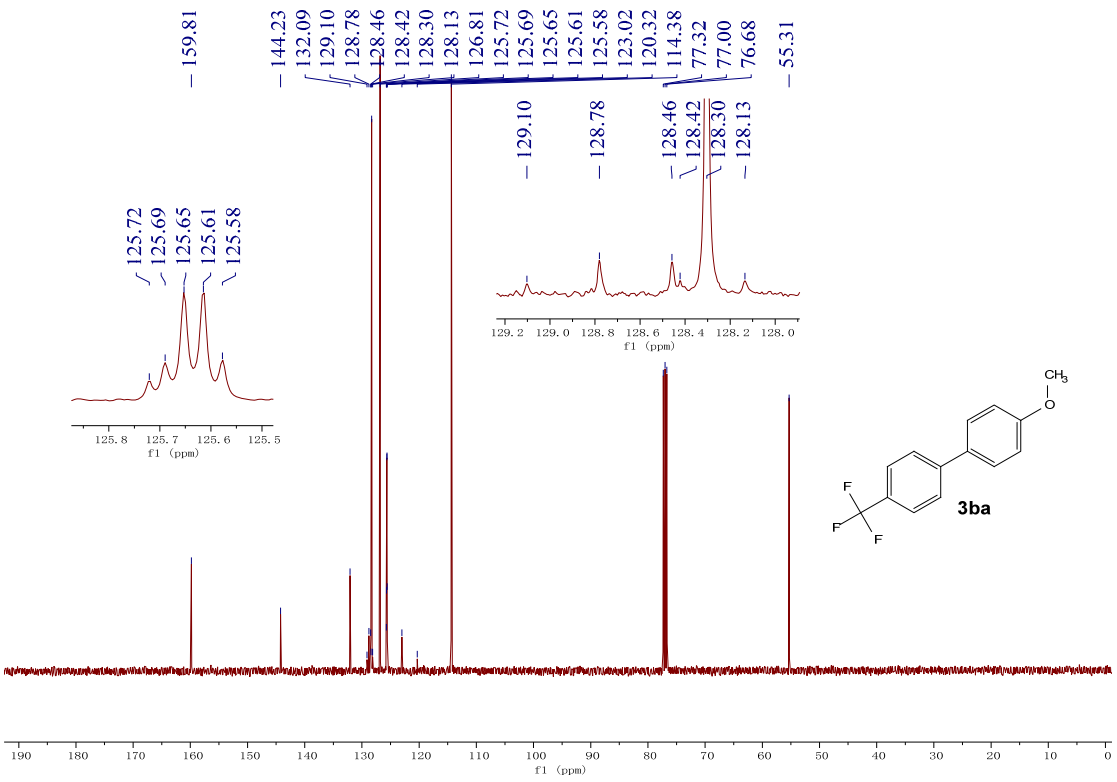
77.32
77.00
76.68
128.72
127.89
127.43
126.84
f1 (ppm)
3ap


7.69
7.67
7.67
7.64
7.57
7.55
7.26
7.03
7.01
3.87
f1 (ppm)
3.99
2.01
1.99
3.00
3ba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144.23
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128.46
128.42
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126.81
125.72
125.69
125.65
125.61
125.58
123.02
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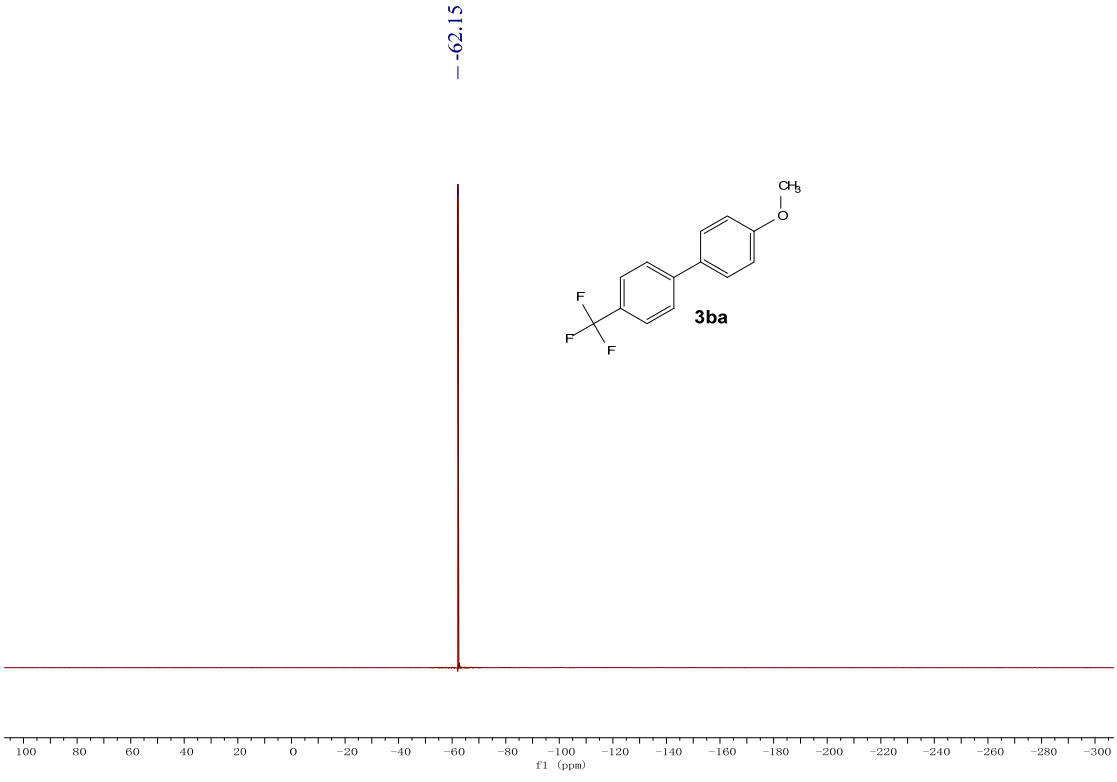
76.68
55.31
CH3
O
F
F
F
3ba
f1 (ppm)


-62.15
CH3
O
F
F
F
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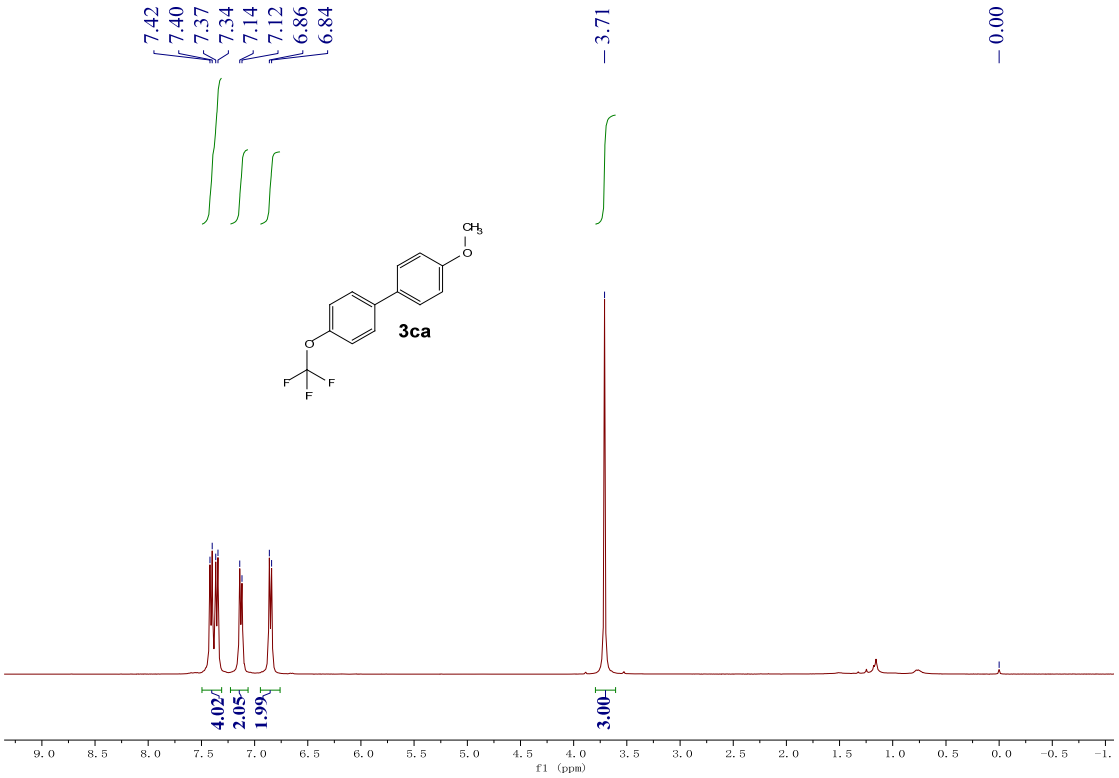
f1 (ppm)


7.42
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7.12
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6.84
3.71
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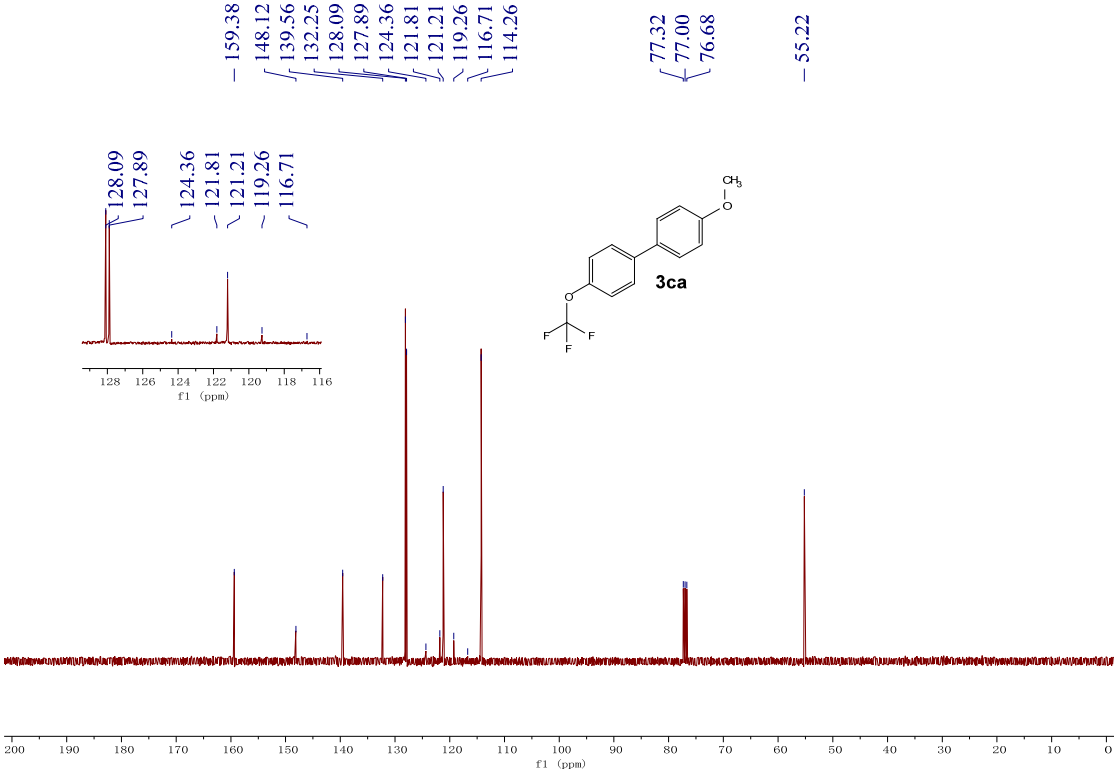
3ca
4.02
2.05
1.99
3.00
f1 (ppm)


159.38
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121.81
121.21
119.26
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114.26
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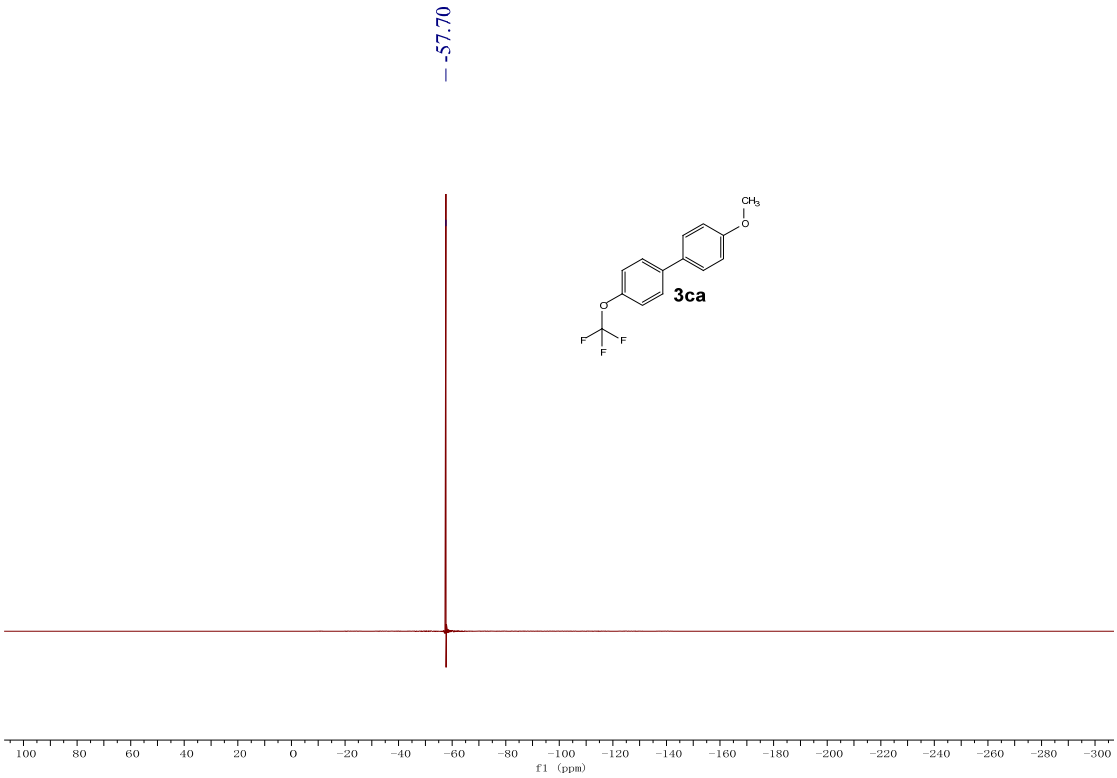
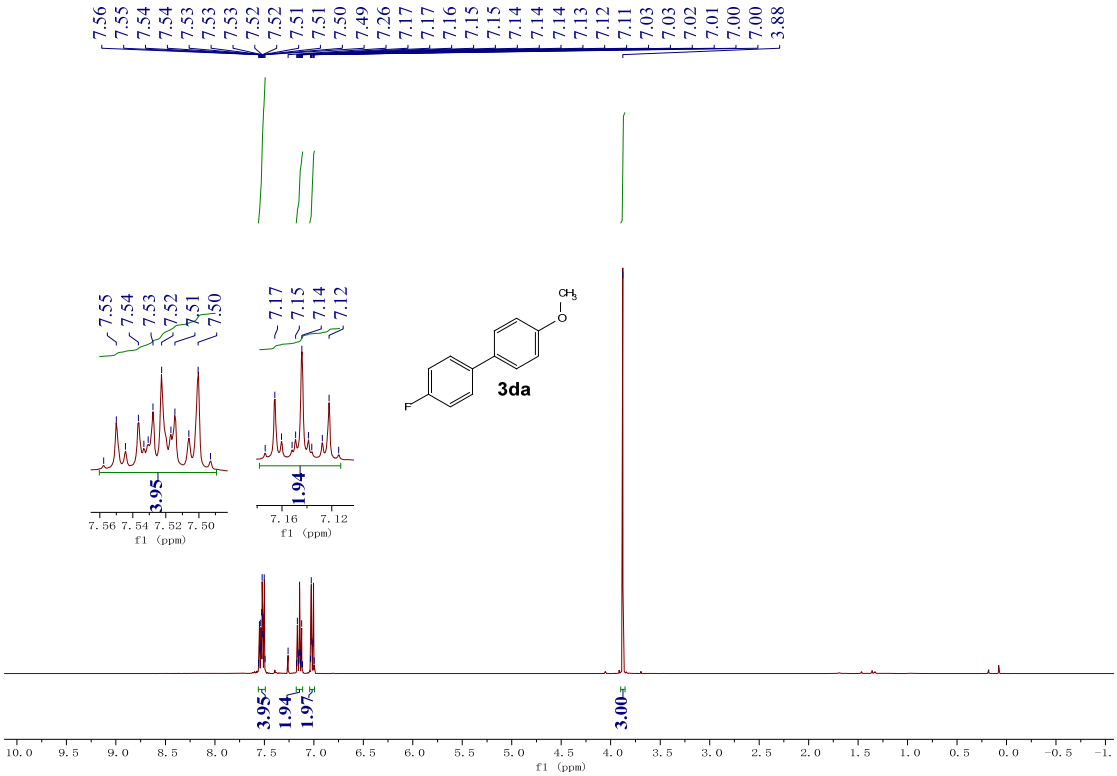
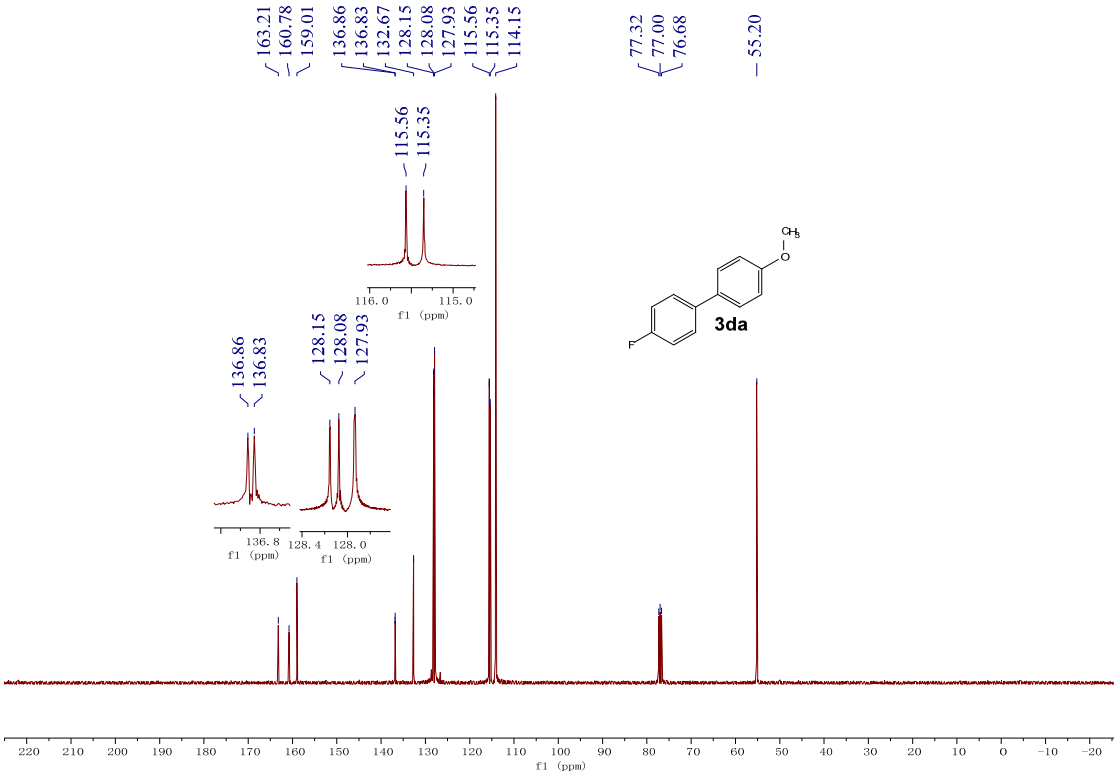
77.00
76.68
55.22
3ca
f1 (ppm)


-57.70
3ca
100 80 60 40 20 0 -20 -40 -60 -80 -100 -120 -140 -160 -180 -200 -220 -240 -260 -280 -300
f1 (ppm)


7.56 7.55 7.54 7.54 7.53 7.53 7.53 7.52 7.52 7.51 7.51 7.50 7.49 7.26 7.17 7.17 7.16 7.15 7.15 7.14 7.14 7.14 7.13 7.12 7.11 7.03 7.03 7.02 7.01 7.00 7.00 3.88
7.55 7.54 7.53 7.52 7.51 7.50
3.95
7.56 7.54 7.52 7.50
f1 (ppm)
7.17 7.15 7.14 7.12
1.94
7.16 7.12
f1 (ppm)
3da
3.95 1.94 1.97 3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)


163.21
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159.01
136.86
136.83
132.67
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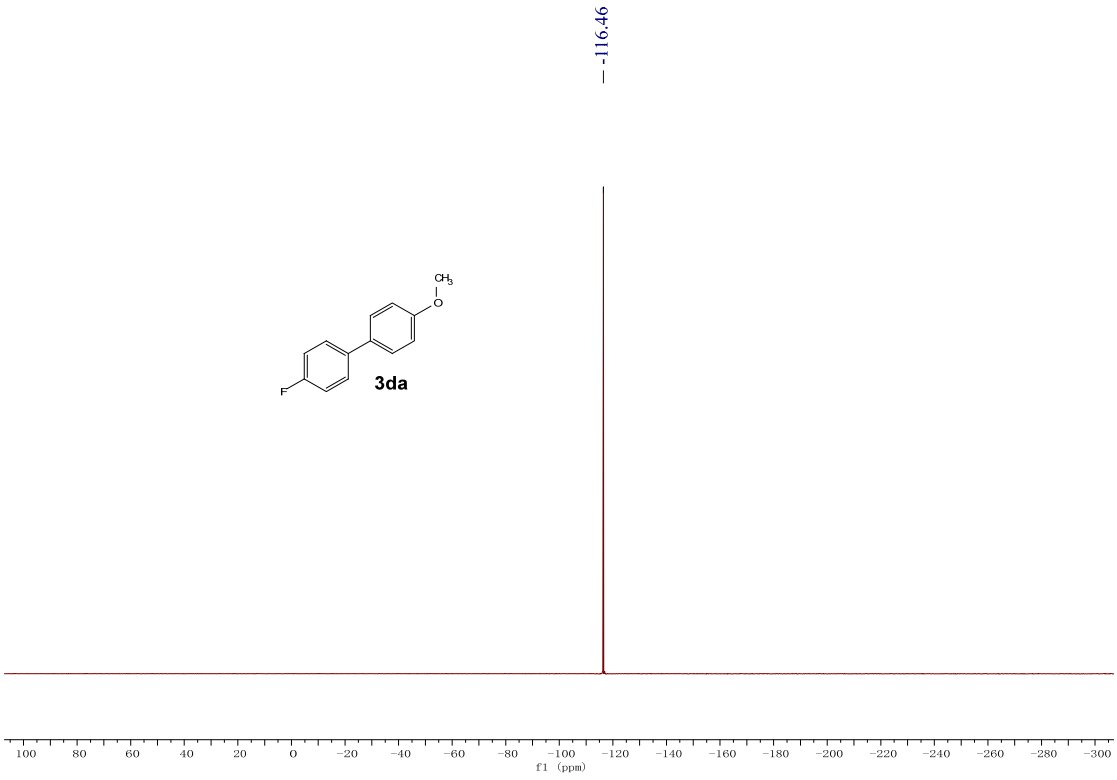
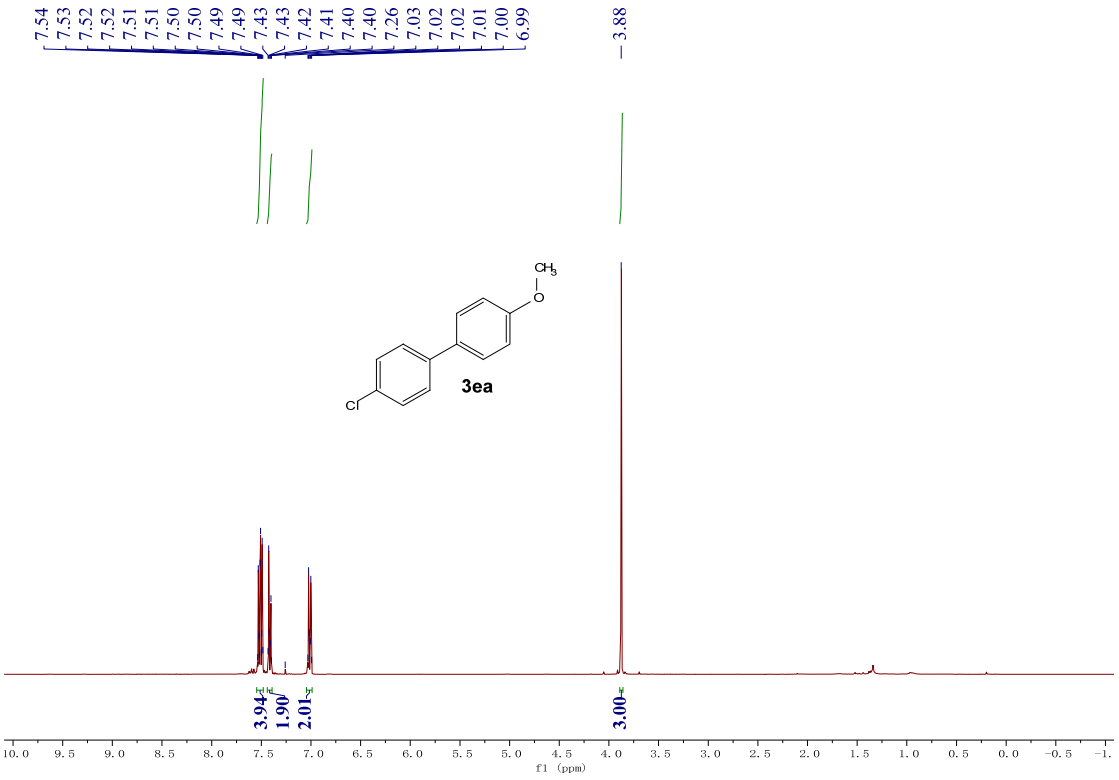
127.93
115.56
115.35
114.15
77.32
77.00
76.68
55.20
3da
f1 (ppm)


-116.46
3da
f1 (ppm)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7.53
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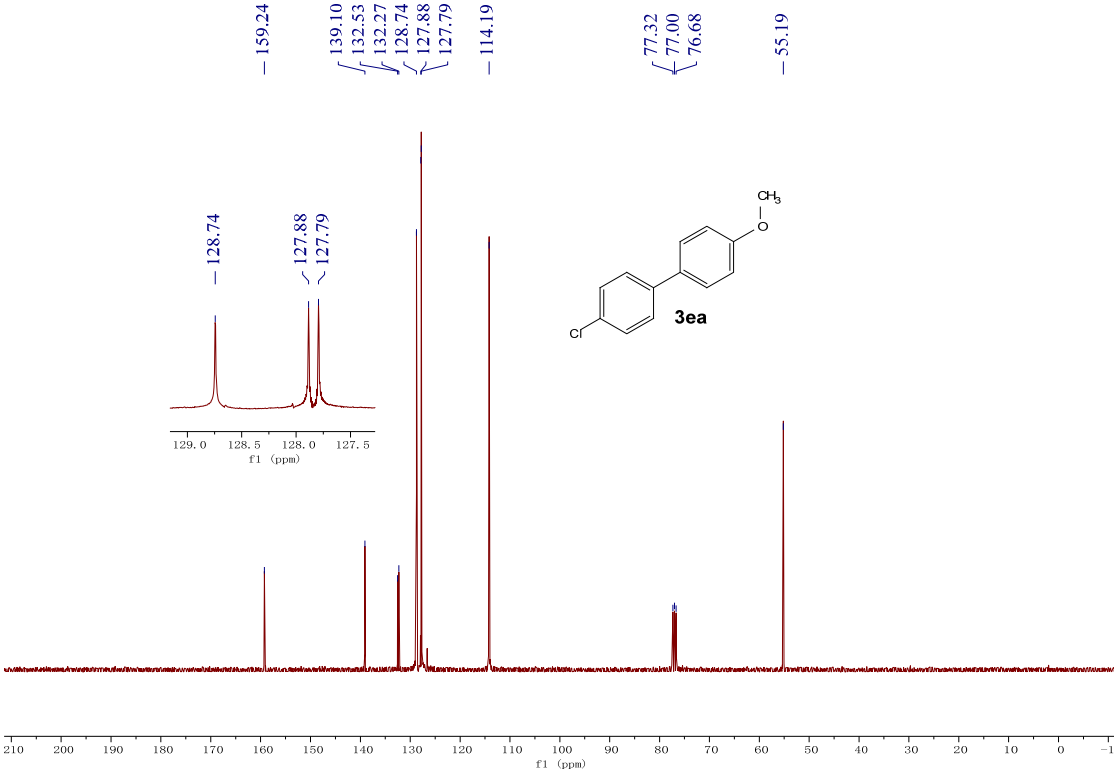
7.50
7.49
7.49
7.43
7.43
7.42
7.41
7.40
7.40
7.26
7.03
7.02
7.02
7.01
7.00
6.99
3.88
3ea
3.94
1.90
2.01
3.00
f1 (ppm)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132.27
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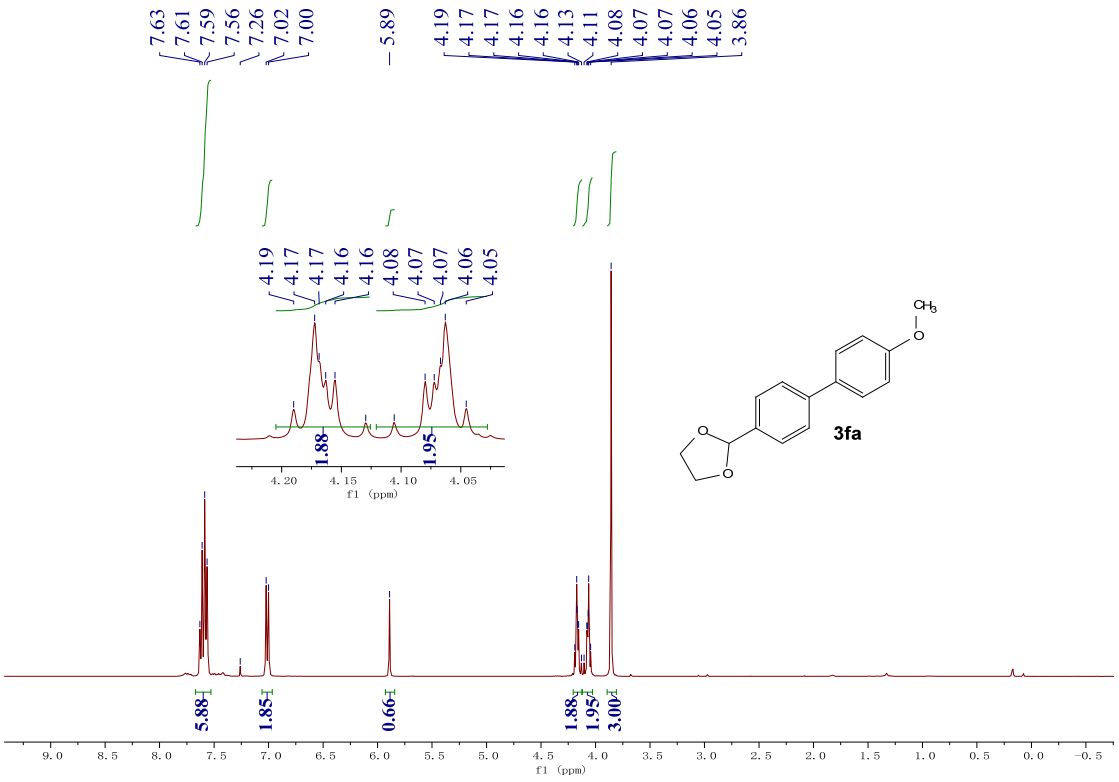
127.79
114.19
77.32
77.00
76.68
55.19
128.74
127.88
127.79
3ea
f1 (ppm)


7.63
7.61
7.59
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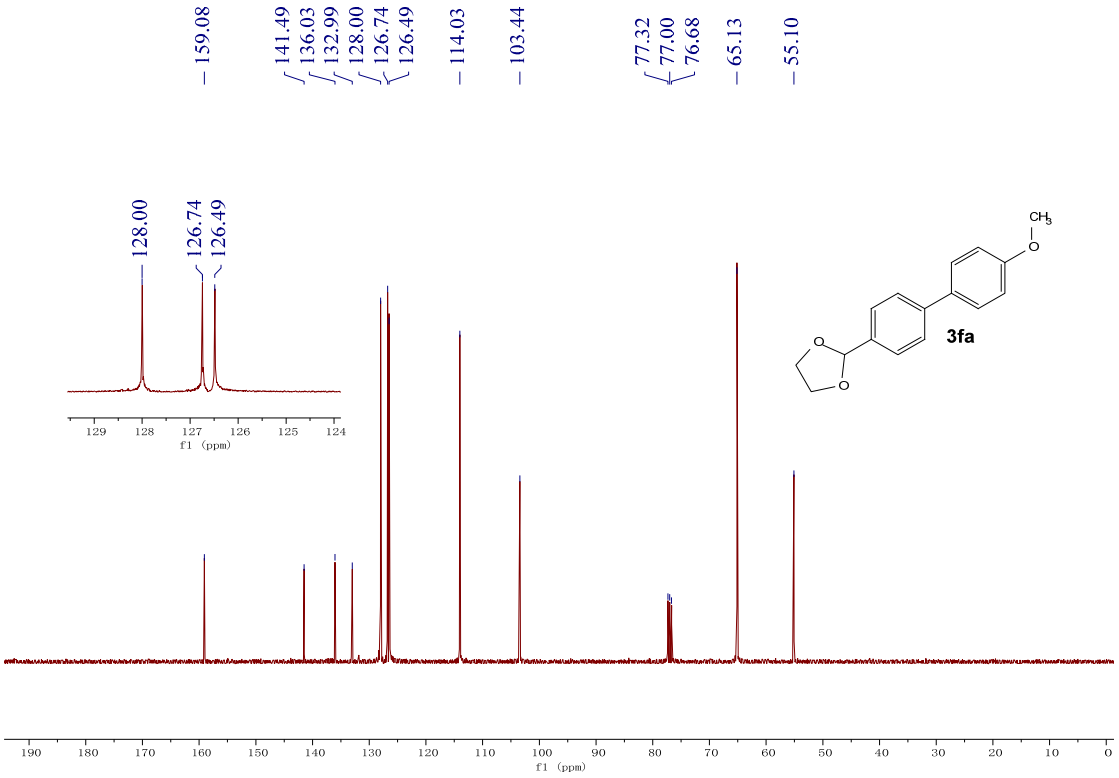
7.26
7.02
7.00
5.89
4.19
4.17
4.17
4.16
4.16
4.13
4.11
4.08
4.07
4.07
4.06
4.05
3.86
1.88
1.95
4.20
4.15
4.10
4.05
f1 (ppm)
3fa
5.88
1.85
0.66
1.88
1.95
3.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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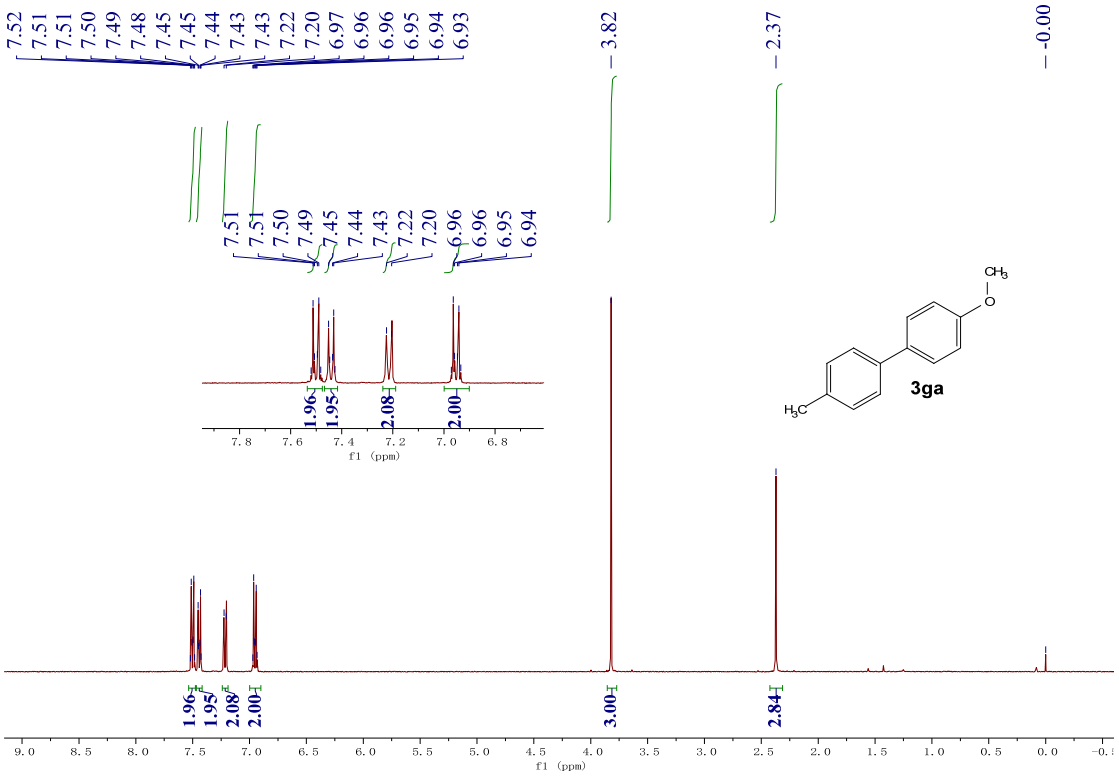
132.99
128.00
126.74
126.49
114.03
103.44
77.32
77.00
76.68
65.13
55.10
128.00
126.74
126.49
129
128
127
126
125
124
f1 (ppm)
3fa
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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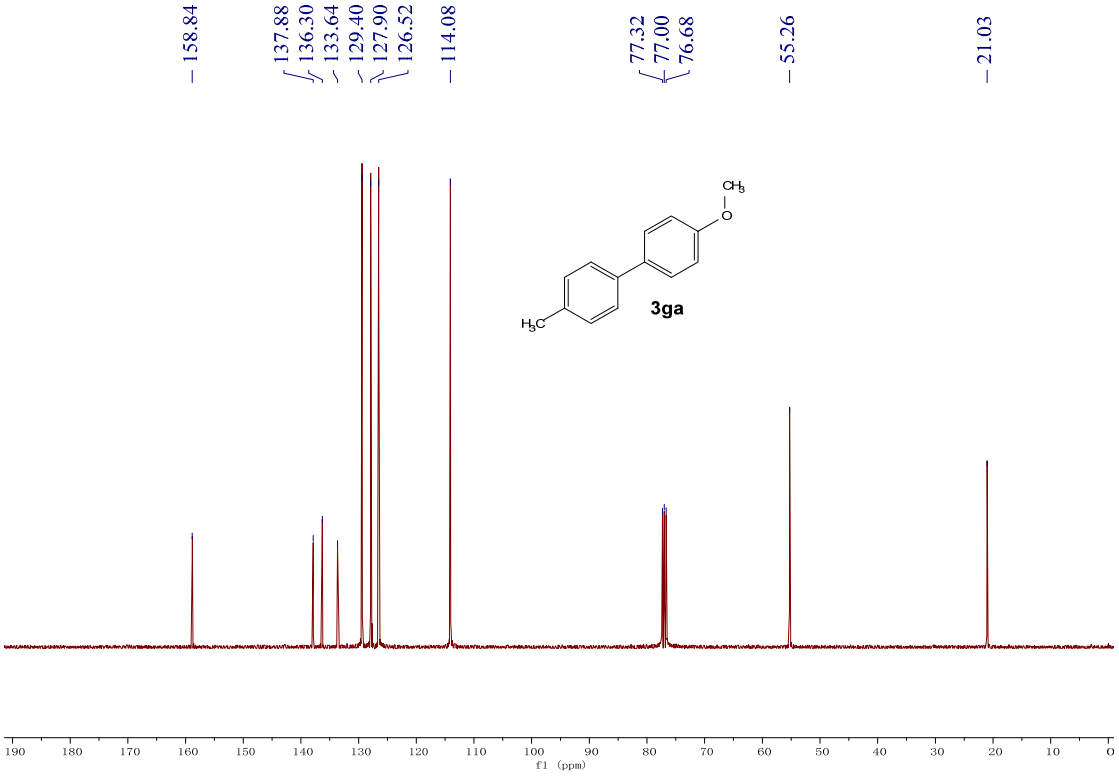
7.51
7.51
7.50
7.49
7.48
7.45
7.45
7.44
7.43
7.43
7.22
7.20
6.97
6.96
6.96
6.95
6.94
6.93
3.82
2.37
-0.00
1.96
1.95
2.08
2.00
3.00
2.84
f1 (ppm)
3ga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137.88
136.30
133.64
129.40
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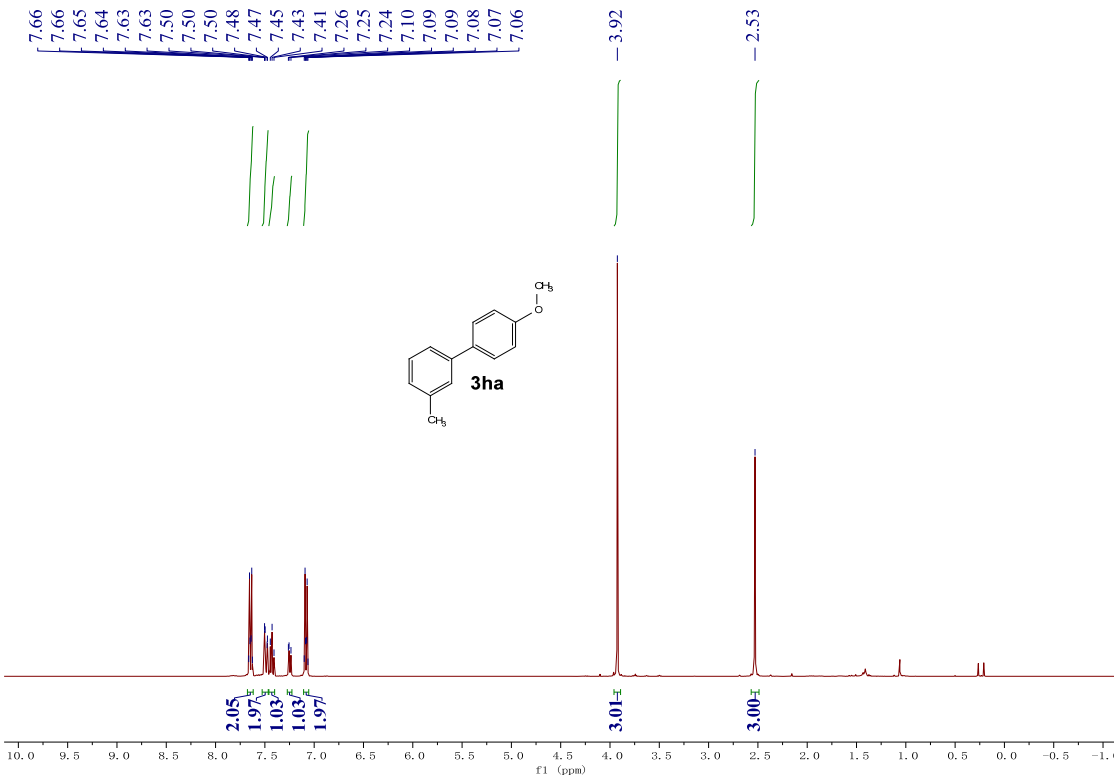
126.52
114.08
77.32
77.00
76.68
55.26
21.03
f1 (ppm)
3ga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7.66
7.65
7.64
7.63
7.63
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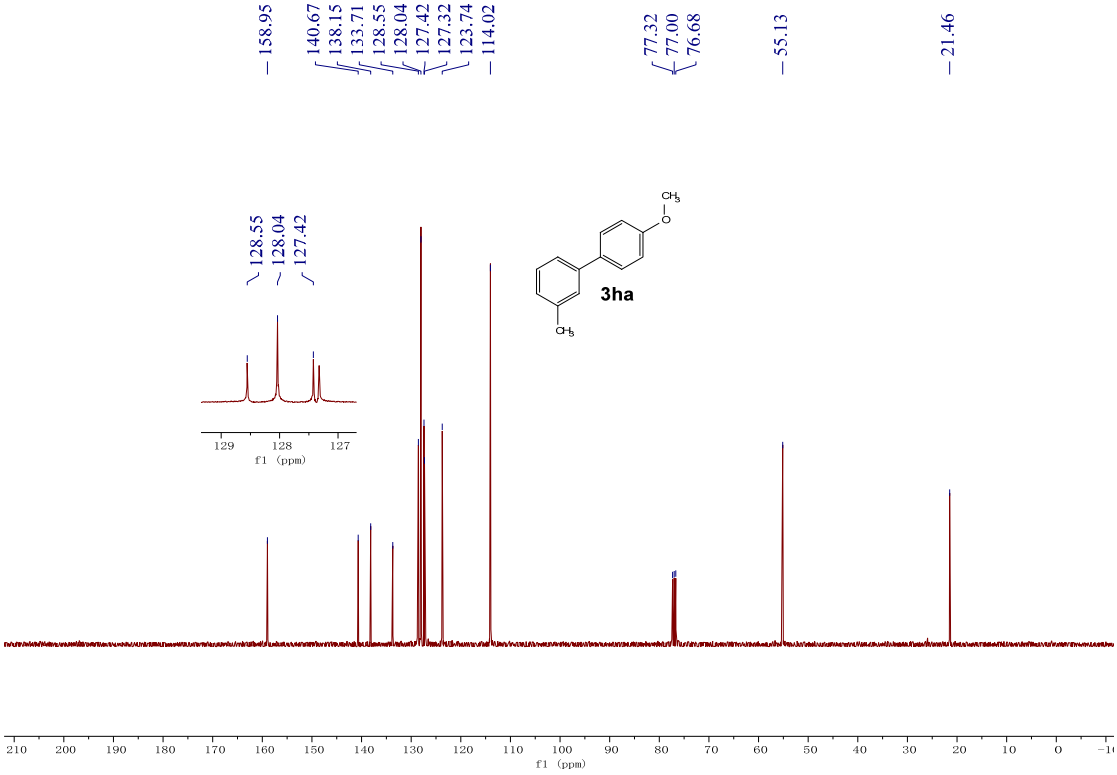
7.50
7.48
7.47
7.45
7.43
7.41
7.26
7.25
7.24
7.10
7.09
7.09
7.08
7.07
7.06
3.92
2.53
3ha
2.05
1.97
1.03
1.03
1.97
3.01
3.00
f1 (ppm)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128.04
127.42
127.32
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77.00
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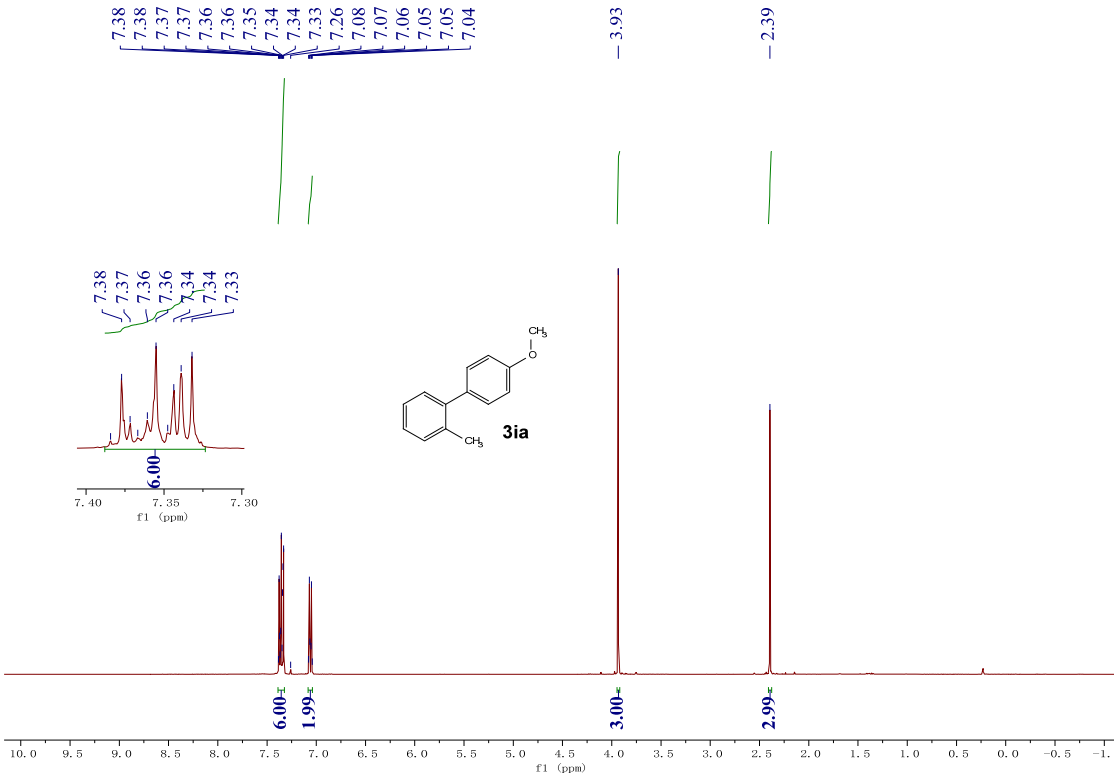
55.13
21.46
128.55
128.04
127.42
3ha
f1 (ppm)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7.33
7.26
7.08
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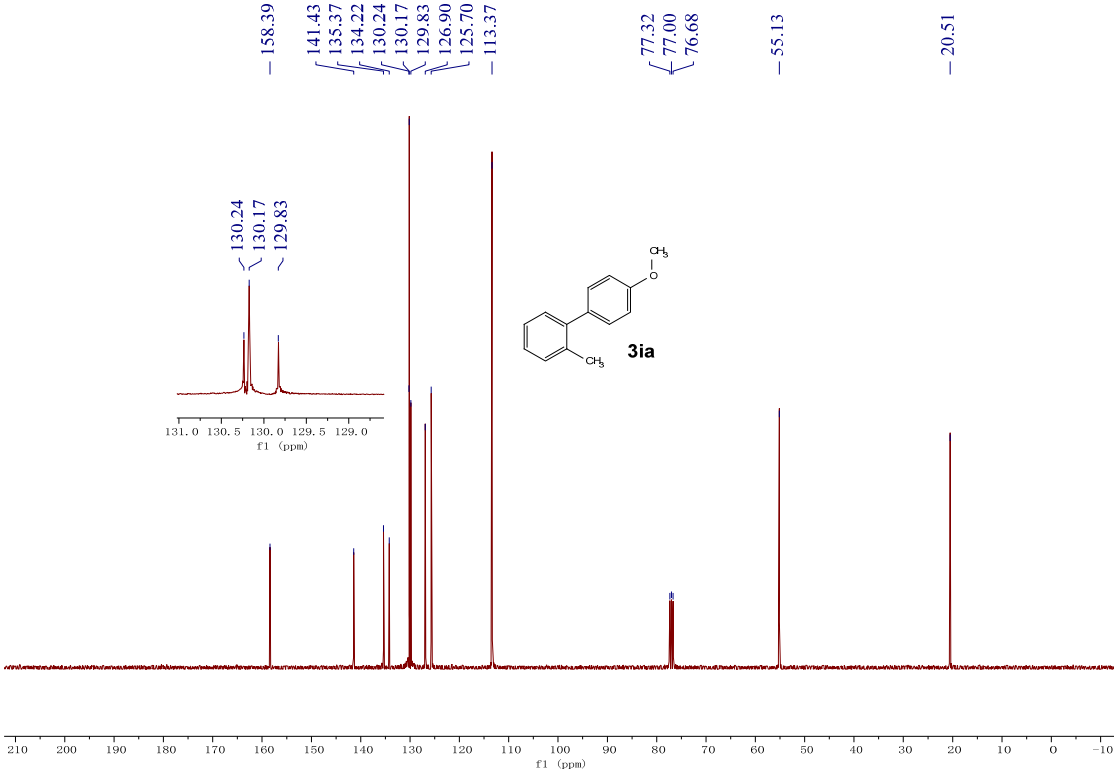
7.05
7.05
7.04
3.93
2.39
6.00
1.99
3.00
2.99
3ia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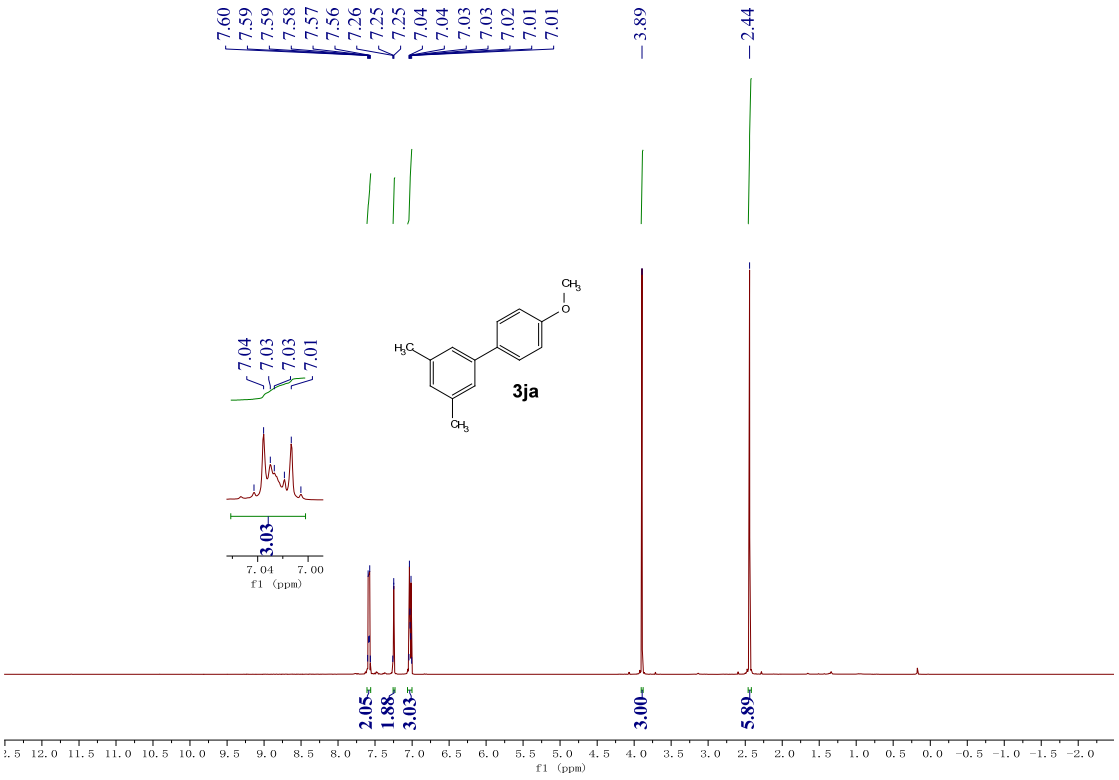
126.90
125.70
113.37
77.32
77.00
76.68
55.13
20.51
3ia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7.59
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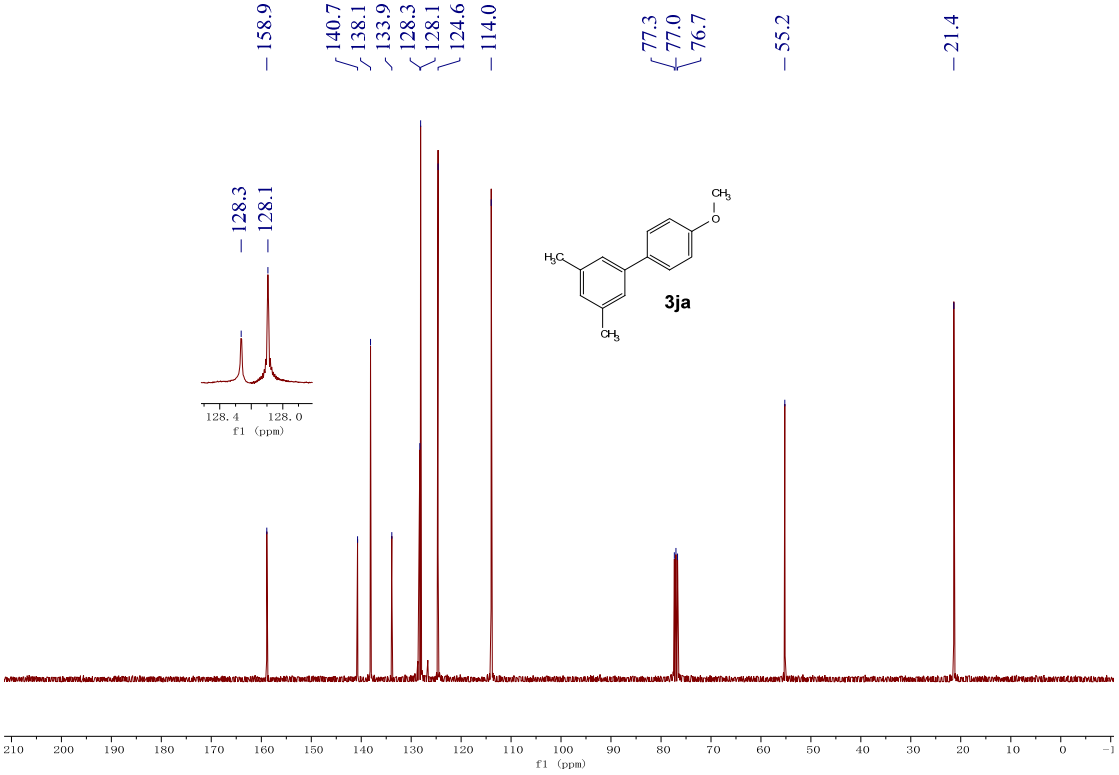
7.56
7.26
7.25
7.25
7.04
7.04
7.03
7.03
7.02
7.01
7.01
3.89
2.44
7.04
7.03
7.03
7.01
3.03
7.04
7.00
f1 (ppm)
3ja
2.05
1.88
3.03
3.00
5.89
f1 (ppm)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133.9
128.3
128.1
124.6
114.0
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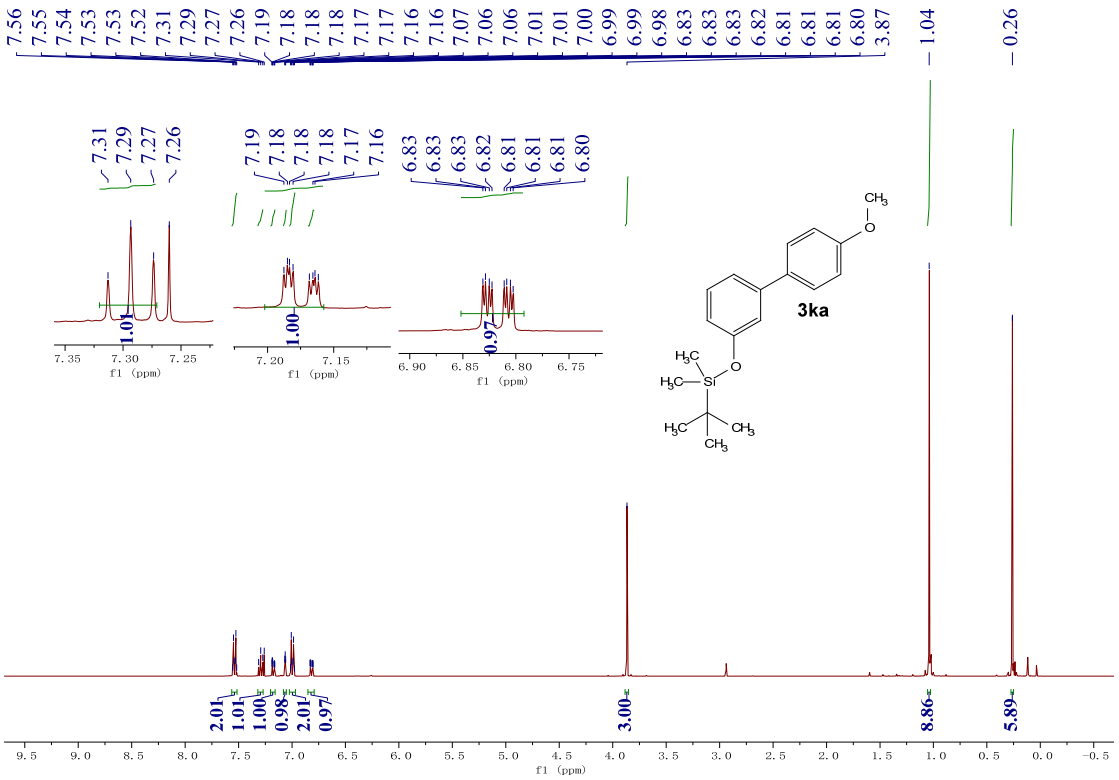
55.2
21.4
128.3
128.1
128.4
128.0
f1 (ppm)
3ja
f1 (ppm)


7.56 7.55 7.54 7.53 7.53 7.52 7.31 7.29 7.27 7.26 7.19 7.18 7.18 7.18 7.17 7.17 7.16 7.16 7.07 7.06 7.06 7.01 7.01 7.00 6.99 6.99 6.98 6.83 6.83 6.83 6.82 6.81 6.81 6.80 3.87 1.04 0.26
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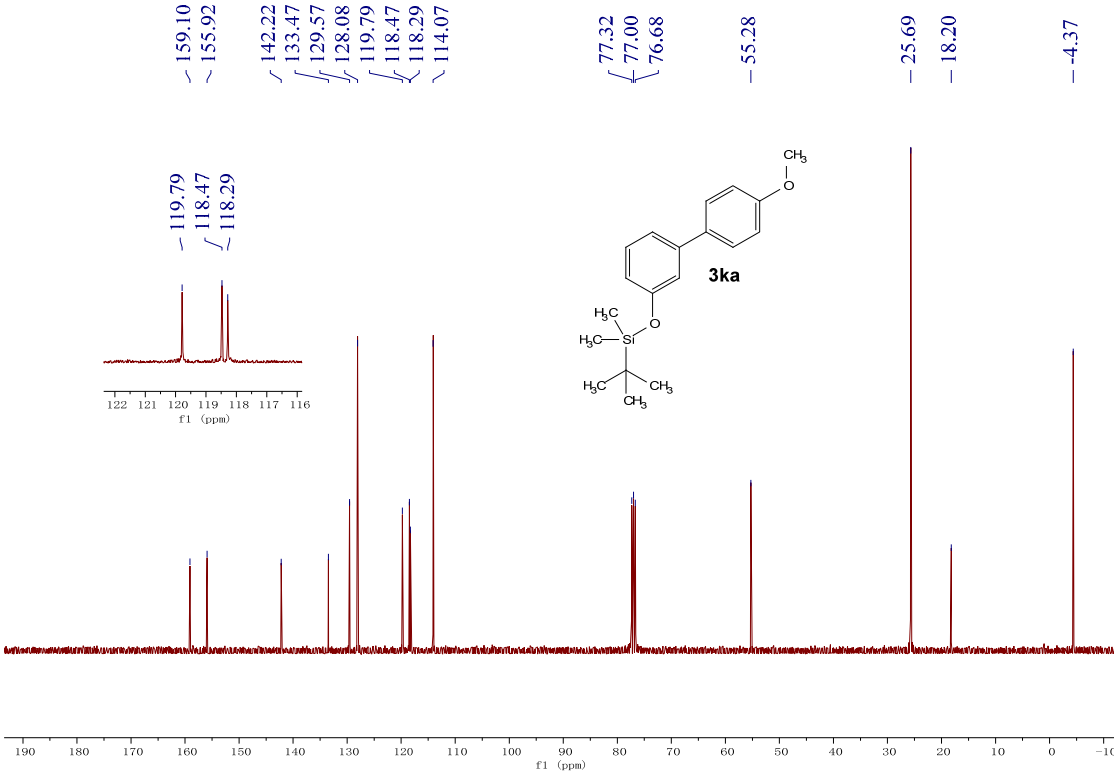
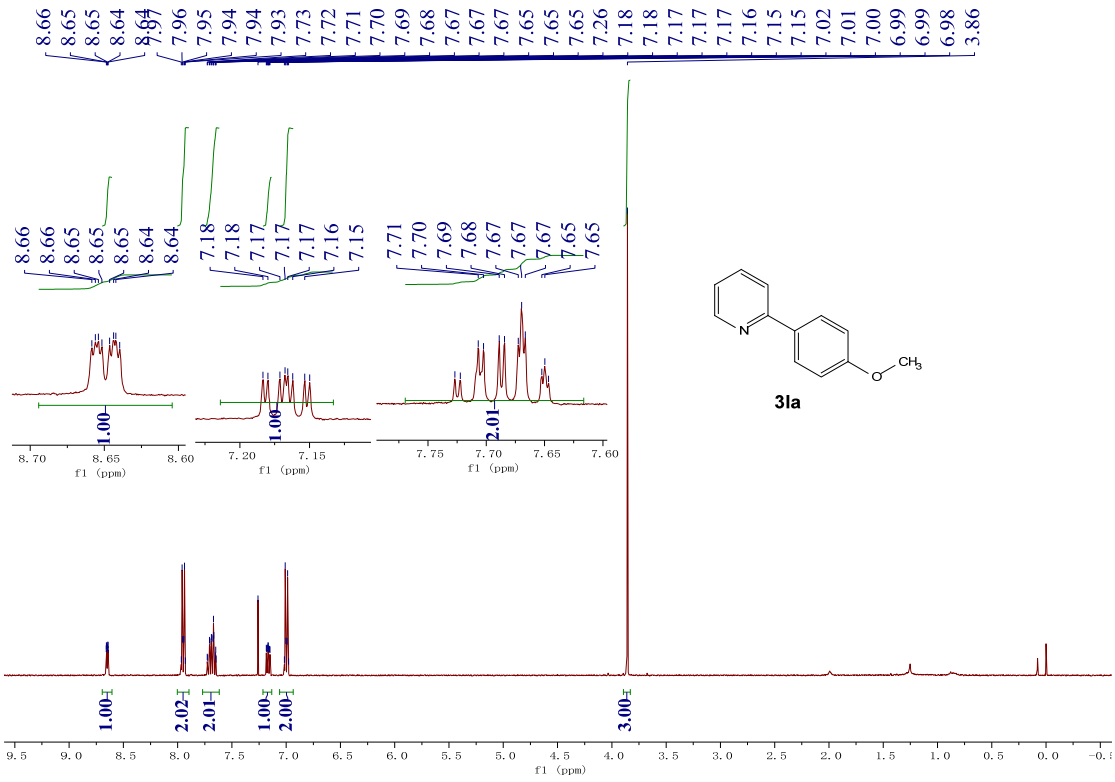
f1 (ppm)
3ka


159.10 155.92 142.22 133.47 129.57 128.08 119.79 118.47 118.29 114.07 77.32 77.00 76.68 55.28 25.69 18.20 -4.37
119.79 118.47 118.29
f1 (ppm)
3ka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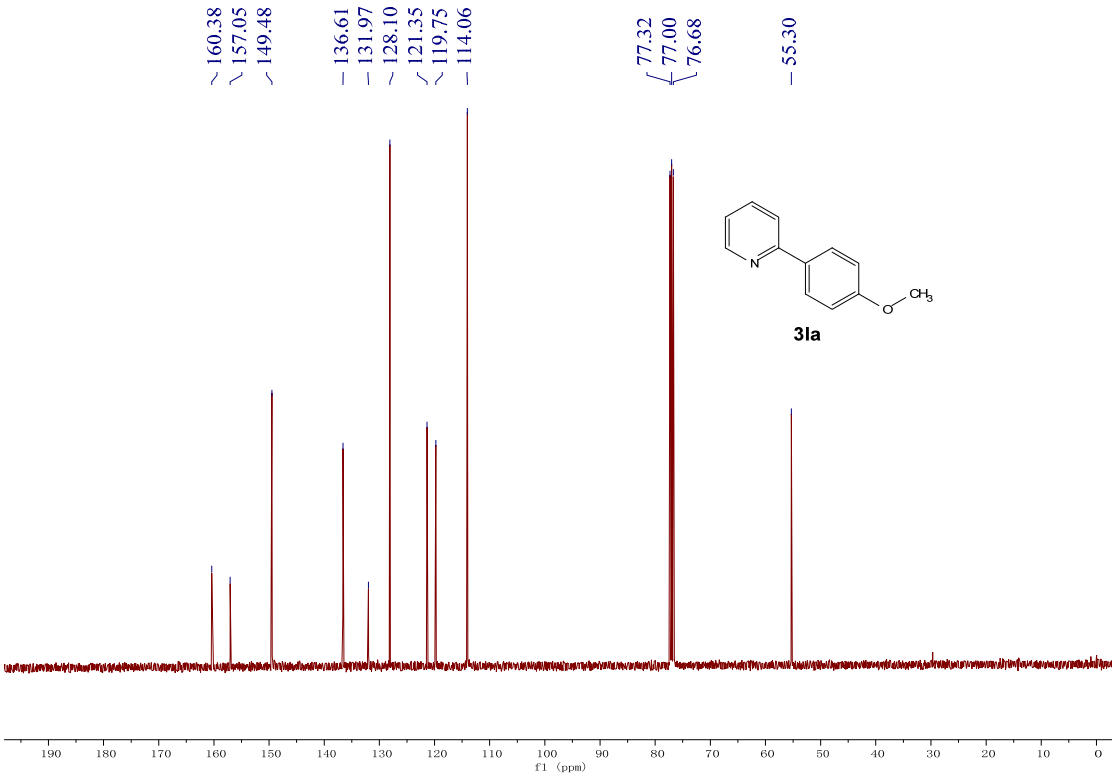
1.00 2.02 2.01 1.00 2.00 3.00
f1 (ppm)
3la


160.38 157.05 149.48 136.61 131.97 128.10 121.35 119.75 114.06 77.32 77.00 76.68 55.30
f1 (ppm)
3la