– Supporting Information –

Iron-Catalyzed Carbonylative Suzuki Reactions under Atmospheric Pressure of Carbon Monoxide

Yanzhen Zhong, and Wei Han*

Jiangsu Collaborative Innovation Center of Biomedical Functional Materials, Jiangsu Key Laboratory of Biofunctional Materials, Key Laboratory of Applied Photochemistry, School of Chemistry and Materials Science, Nanjing Normal University
Wenyuan Road No.1, 210023 Nanjing (China)

Fax: (+)86-(0)25-8589-1455
E-mail: whhanwei@gmail.com

Table of Contents

1. General Information

Reagent Information. All the aryl halides and the arylboronic acids were purchased from Alfa Aesar and Accela ChemBio Co., Ltd. and were used as received. PEG-400 was bought from Acros and was pre-dried by using toluene azeotrope. The following iron salts and bases were used: $FeCl_2$ (98% from Sigma−Aldrich; 99.99% from Alfa Aesar), $FeCl_3$ (98% and 99.99%, Sigma−Aldrich), $NaHCO_3$ (99% and 99.998%, Alfa Aesar), and AcOK (99%, Alfa Aesar).

Analytical methods. ^1H and ^{13}C NMR spectra of solutions in $CDCl_3$ were recorded on a Bruker Avance 400 instrument. Chemical shifts were expressed in parts per million (ppm) downfield from tetramethylsilane and refer to the solvent signals ($CDCl_3$: H 7.24 and C 77.0 ppm) . The signals of water were observed at about 1.58 ppm in $CDCl_3$, respectively. Abbreviations for signal couplings are: br, broad; s, singlet; d, doublet; t, triplet; m, multiplet; dd, doublet of doublets; dt, triplet of doublets; td, doublet of triplets; tt, triplet of triplets; ddd, doublet of doublet of doublets; tdd, doublet of doublet of triplets. Coupling constants, *J,* were reported in hertz unit (Hz). Infrared spectra of neat substances were recorded on a Thermo Nicolet Corporation GC-FTIR NEXUS670 spectrometer. HRMS was performed on a Bruker's *solarix 94* (ESI-*FTICR-MS*) mass spectrometer.

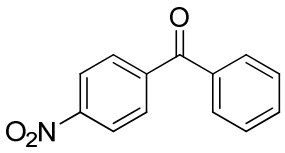
2. General Procedures for Iron-Catalyzed Carbonylative Suzuki Reactions

General Procedure A: A 25 mL Schlenk flask was charged with arylboronic acid (0.75mmol), $FeCl_2$ (0.02 mmol, 2.6 mg), ferric chloride (0.03 mmol, 4.9 mg), sodium bicarbonate (1.0 mmol, 84.8 mg), potassium acetate (0.1 mmol, 10.0 mg), PEG-400 (2.0 mL) before standard cycles of evacuation and back-filling with dry and pure carbon monoxide. Corresponding aryl iodide (0.5 mmol) was added successively. The mixture was stirred at 100 °C for the indicated time. At the end of the reaction, the reaction mixture was poured into a saturated aqueous NaCl solution (15 mL) and extracted with ethyl acetate (3 × 15 mL). The organic phases were combined, and the

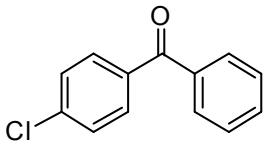
volatile components were evaporated in a rotary evaporator. The crude product was purified by column chromatography on silica gel (petroleum ether: diethyl ether = 25 : 1).

General Procedure B: A 25 mL Schlenk flask was charged with arylboronic acid (0.75 mmol), $FeCl_2$ (0.05 mmol, 6.4 mg), sodium bicarbonate (1.0 mmol, 84.8 mg), potassium acetate (0.1 mmol, 10.0 mg), PEG-400 (2.0 mL) before standard cycles of evacuation and back-filling with dry and pure carbon monoxide. Corresponding aryl iodide (0.5 mmol) was added successively. The mixture was stirred at 100 °C for the indicated time. At the end of the reaction, the reaction mixture was poured into a saturated aqueous NaCl solution (15 mL) and extracted with ethyl acetate (3 × 15 mL). The organic phases were combined, and the volatile components were evaporated in a rotary evaporator. The crude product was purified by column chromatography on silica gel (eluent mixture: petroleum ether/diethyl ether = 25 : 1).

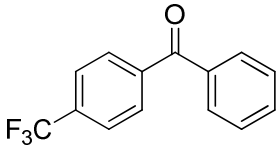
3. Analytical Data of Products



(4-Nitrophenyl)(phenyl)methanone(3aa): Following general procedure A, **3aa** was isolated as a light pink solid (104 mg, 92%), known compound. The NMR spectroscopic data agree with those described in ref.[S1]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.32 (d, *J* = 8.8 Hz, 2 H), 7.92 (d, *J* = 8.8 Hz, 2 H), 7.79–7.77 (m, 2 H), 7.64 (tt, *J* = 7.4, 1.3 Hz, 1 H), 7.51 ppm (t, *J* = 7.7 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.8, 149.8, 142.9, 136.3, 133.5, 130.7, 130.1, 128.7, 123.5 ppm; mp 136.8–137.2 °C.

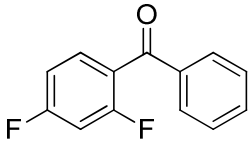


(4-Chlorophenyl)(phenyl)methanone (3ba): Following general procedure A, **3ba** was isolated as a white solid (98 mg, 90%), known compound. The NMR spectroscopic data agree with those described in ref.[S1]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.72 (m, 4 H), 7.58 (tt, *J* = 7.4, 1.3 Hz, 1 H), 7.49–7.43 ppm (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5, 138.9, 137.2, 135.8, 132.6, 131.4, 129.9, 128.6, 128.4 ppm.; mp 74.3–74.7 °C.

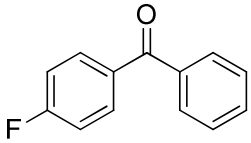


Phenyl(4-(trifluoromethyl)phenyl)methanone (3ca): Following general procedure A, **3ca**was isolated as a white solid (94 mg, 75%), known compound. The NMR spectroscopic data agree with those described in ref.[S2]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87 (d, *J* = 8.0 Hz, 2 H), 7.80–7.77 (m, 2 H), 7.73 (d, *J* = 8.0 Hz, 2 H), 7.61 (tt, *J* =

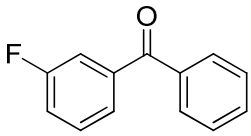
7.4, 1.3 Hz, 1 H), 7.49 ppm (t, *J* = 7.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5, 140.7, 136.7, 133.7 (q, *J* = 32 Hz), 133.1, 130.11, 130.08, 128.5, 125.3 (q, *J* = 4 Hz), 123.6 ppm (q, *J* = 271 Hz); mp 116.4–116.9 °C.



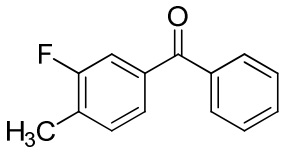
(2,4-Difluorophenyl)(phenyl)methanone (3da): Following general procedure A, **3da** was isolated as light yellow oil (76 mg, 71%), known compound. The NMR spectroscopic data agree with those described in ref.[S3]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (d, *J* = 8.4 Hz, 2 H), 7.61–7.55 (m, 2 H), 7.46 (t, *J* = 7.7 Hz, 2 H), 7.01–6.96 (m, 1 H), 6.89 (ddd, *J* = 10.5, 8.2, 2.4 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.3, 164.9 (dd, *J* = 253, 12 Hz), 160.9 (dd, *J* = 254, 12 Hz), 137.4, 133.4, 132.5 (dd, *J* = 10, 4 Hz), 129.7, 128.5, 123.3 (dd, *J* = 14, 4 Hz), 111.8 (dd, *J* = 21, 4 Hz), 104.7 ppm (t, *J* = 25 Hz).



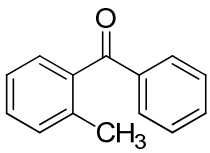
(4-Fluorophenyl)(phenyl)methanone (3ea): Following general procedure A, **3ea** was isolated as a light yellow oil (92 mg, 93%), known compound; The NMR spectroscopic data agree with those described in ref.[S4]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83–7.86 (m, 2 H), 7.74–7.76 (m, 2 H), 7.58 (tt, *J* = 7.4, 1.3 Hz, 1 H), 7.47 (t, *J* = 7.5 Hz, 2 H), 7.14 ppm (t, *J* = 8.7 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3, 165.4 (d, *J* = 253 Hz), 137.5, 133.8 (d, *J* = 3 Hz), 132.61, 132.58 (d, *J* = 15 Hz), 129.9, 128.4, 115.4 ppm (d, *J* = 22 Hz).



(3-Fluorophenyl)(phenyl)methanone (3fa): Following general procedure A, **3fa** was isolated as a light yellow oil (92 mg, 92%), known compound. The NMR spectroscopic data agree with those described in ref.[S5]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.77 (m, 2 H), 7.61–7.54 (m, 2 H), 7.50–7.42 (m, 4 H), 7.27 ppm (tdd, *J* = 8.3, 2.6, 1.0 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3 (d, *J* = 2 Hz), 162.5 (d, *J* = 247 Hz), 139.6 (d, *J* = 6 Hz), 137.0, 132.8, 130.0, 129.9, 128.4, 125.8 (d, *J* = 3 Hz), 119.4 (d, *J* = 21 Hz), 116.7 ppm (d, *J* = 22 Hz).

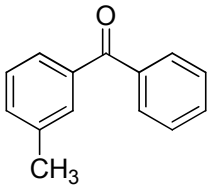


(3-Fluoro-4-methylphenyl)(phenyl)methanone (3ga): Following general procedure A, **3ga** was isolated as a light yellow solid (88 mg, 82%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78–7.75 (m, 2 H), 7.58 (tt, *J* = 7.4, 1.3 Hz, 1 H), 7.49–7.47 (m, 3 H), 7.45 (s, 1 H), 7.27 (t, *J* = 7.5 Hz, 1 H), 2.35 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.2 (d, *J* = 2 Hz), 160.9 (d, *J* = 245 Hz), 137.4, 137.0 (d, *J* = 6 Hz), 132.5, 131.3 (d, *J* = 5 Hz), 130.2 (d, *J* = 17 Hz), 129.9, 128.3, 125.8 (d, *J* = 3 Hz), 116.5 (d, *J* = 23 Hz), 14.8 ppm (d, *J* = 4 Hz); HRMS (ESI) calcd for $C_{14}H_{12}FO$ [M+H] *m/z* 215.08722, found *m/z* 215.08641; IR: ν_{max}(KBr) = 3414, 3068, 2929, 2855, 1651, 1598, 1500, 1449, 1421, 1384, 1288, 899, 832, 723, 697 cm^{-1}; mp 43.7–44.5 °C.

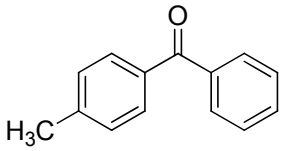


Phenyl(*o*-tolyl)methanone (3ha): Following general procedure A, **3ha** was isolated as a light yellow oil (86 mg, 87%), known compound. The NMR spectroscopic data agree with those described in ref.[S2]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.77 (m, 2 H), 7.56 (tt, *J* = 7.4, 1.3 Hz, 1 H), 7.44 (t, *J* = 7.6 Hz, 2 H), 7.38 (td, *J* = 7.4, 1.6 Hz, 1

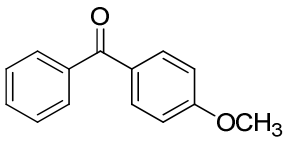
H), 7.31–7.21 (m, 3 H), 2.31 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 198.7, 138.6, 137.7, 136.7, 133.1, 131.0, 130.2, 130.1, 128.5, 128.4, 125.2, 20.0 ppm.



Phenyl(*m*-tolyl)methanone (3ia): Following general procedure A, **3ia** was isolated as light yellow oil (80 mg, 82%), known compound. The NMR spectroscopic data agree with those described in ref.[S2]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.77 (m, 2 H), 7.61 (s, 1 H), 7.60–7.54 (m, 2 H), 7.46 (m, 2 H), 7.39–7.32 (m, 2 H), 2.40 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.0, 138.1, 137.7, 137.6, 133.2, 132.3, 130.4, 130.0, 128.2, 128.1, 127.4, 21.4 ppm.

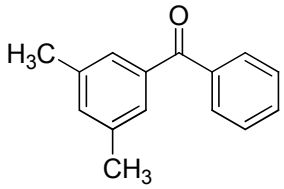


Phenyl(*p*-tolyl)methanone (3ja): Following general procedure A, **3ja** was isolated as a white solid with low melting point (90 mg, 92%), known compound. The NMR spectroscopic data agree with those described in ref.[S2]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78–7.75 (m, 2 H), 7.71 (d, J = 8.0 Hz, 2 H), 7.56 (tt, J = 7.4, 1.3 Hz, 1 H), 7.46 (t, J = 7.5 Hz, 2 H), 7.26 (d, J = 8.0 Hz, 2 H), 2.42 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.5, 143.2, 137.9, 134.8, 132.1, 130.3, 129.9, 129.0, 128.2, 21.6 ppm.

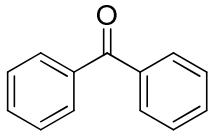


(4-Methoxyphenyl)(phenyl)methanone (3ka): Following general procedure A, **3ka** was isolated as light white solid (84 mg, 80%), known compound. The NMR spectroscopic data agree with those described in ref.[S2].^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81 (d, J = 8.0 Hz, 2 H), 7.75–7.72 (m, 2 H), 7.54 (tt, J = 8.0, 2.0 Hz, 1 H),

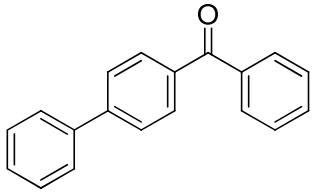
7.47–7.43 (m, 2 H), 6.94 (d, J = 8.0 Hz, 2 H), 3.87 (s, 3 H).^{13}C NMR (100 MHz, $CDCl_3$): δ 195.6, 163.2, 138.3, 132.6, 131.9, 130.2, 129.7, 128.2, 113.6, 55.5 ppm; mp 60.2–61.1 °C.



3,5-Dimethylphenyl)(phenyl)methanone (3la): Following general procedure A, **3la** was isolated as a light yellow solid (96 mg, 91%), known compound. The NMR spectroscopic data agree with those described in ref.[S6]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.77 (m, 2 H), 7.56 (tt, J = 7.4, 1.3 Hz, 1 H), 7.46 (t, J = 7.8 Hz, 2 H), 7.38 (s, 2 H), 7.20 (s, 1 H), 2.36 ppm (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.1, 137.88, 137.86, 137.7, 134.0, 132.2, 130.0, 128.2, 127.8, 21.20 ppm; mp 58.4–59.3 °C.

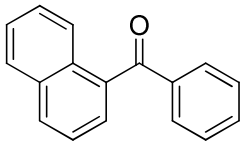


Benzophenone (3ma): Following general procedure A, **3ma** was isolated as a white solid with low melting point (86 mg, 95%), known compound. The NMR spectroscopic data agree with those described in ref.[S2]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.78 (m, 4 H), 7.57 (tt, J = 7.4, 1.3 Hz, 2 H), 7.46 ppm (t, J = 7.6 Hz, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.7, 137.6, 132.4, 130.0, 128.2 ppm.

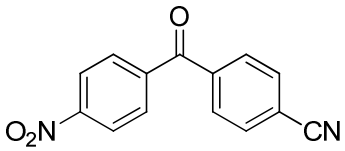


[1,1'-Biphenyl]-4-yl(phenyl)methanone (3na): Following general procedure A, **3na** was isolated as a light white solid (102 mg, 80%), known compound. The NMR spectroscopic data agree with those described in ref.[S7]. ^{1}H NMR (400 MHz, $CDCl_3$):

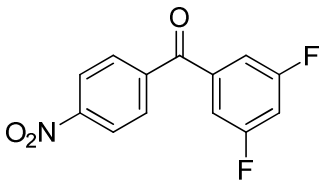
δ = 7.89 (d, *J* =8.0 Hz, 2 H), 7.83 (dd, *J* =8.0, 1.2 Hz, 2 H), 7.69 (d, *J* =8.0 Hz, 2 H), 7.64 (dd, *J* =8.0, 1.6 Hz, 2 H), 7.59 (tt, *J* =8.0, 2.0 Hz, 1 H), 7.51–7.45 (m, 4 H), 7.39 (tt, *J* =8.0, 1.2 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.3, 145.2, 139.9, 137.7, 136.2, 132.3, 130.7, 130.0, 128.9, 128.3, 128.2, 127.3, 126.9 ppm; mp 101.4–102.3 °C.



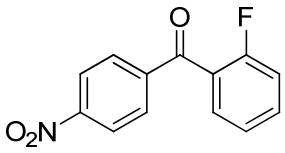
Naphthalen-1-yl(phenyl)methanone (3oa): Following general procedure A, **3oa** was isolated as light white solid (104 mg, 91%), known compound. The NMR spectroscopic data agree with those described in ref.[S2]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.09 (d, *J* = 9.0 Hz, 1 H), 7.99 (d, *J* = 8.1 Hz, 1 H), 7.91 (d, *J* = 7.5 Hz, 1 H), 7.86 (d, *J* = 8.4 Hz, 2 H), 7.60–7.56 (m, 2 H), 7.55–7.48 (m, 3 H), 7.45 ppm (t, *J* = 7.7 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 198.0, 138.2, 136.3, 133.7, 133.2, 131.2, 130.9, 130.4, 128.4, 128.3, 127.7, 127.2, 126.4, 125.6, 124.3 ppm; mp 73.1–73.8 °C.



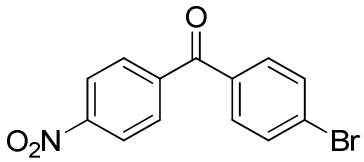
4-(4-Nitrobenzoyl)benzonitrile (3ac): Following general procedure B, **3ac** was isolated as a light yellow solid (114 mg, 91%), known compound. The NMR spectroscopic data agree with those described in ref.[S8]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.35 (d, *J* = 8.9 Hz, 2 H), 7.92 (d, *J* = 8.9 Hz, 2 H), 7.87 (d, *J* = 8.6 Hz, 2 H), 7.82 ppm (d, *J* = 8.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 193.2, 150.3, 141.3, 139.7, 132.5, 130.8, 130.3, 123.8, 117.6, 116.7 ppm; mp 151.7–152.4 °C.



(3,5-Difluorophenyl)(4-nitrophenyl)methanone (3ad): Following general procedure A, **3ad** was isolated as a white solid (118 mg, 90%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.35 (d, *J* = 8.9 Hz, 2 H), 7.92 (d, *J* = 8.9 Hz, 2 H), 7.31–7.28 (m, 2 H), 7.09 ppm (tt, *J* = 8.4, 2.3 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.1 (t, *J* = 3 Hz), 162.9 (dd, *J* = 251, 12 Hz), 150.2, 141.5, 139.1(t, *J* = 8 Hz), 130.7, 123.8, 113.0 (dd, *J* = 19, 8 Hz), 108.8 ppm (t, *J* = 25 Hz); HRMS (ESI) calcd. for $C_{13}H_8F_2NO_3$ [M+H] *m/z* 264.04722, found *m/z* 264.04683; IR: ν_{max}(KBr) = 3416, 3080, 1669, 1594, 1523, 1442, 1330, 1239, 869, 815, 729 cm^{-1}; mp 122.6–123.0 °C.

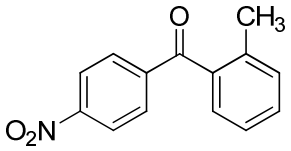


(2-Fluorophenyl)(4-nitrophenyl)methanone (3ae): Following general procedure A, **3ae** was isolated as a white solid (110 mg, 90%), known compound. The NMR spectroscopic data agree with those described in ref.[S10]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.29 (d, *J* = 8.9 Hz, 2 H), 7.94 (d, *J* = 8.9 Hz, 2 H), 7.64–7.56 (m, 2 H), 7.30 (td, *J* = 7.6, 1.0 Hz, 1 H), 7.19–7.14 ppm (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 191.7, 160.3 (d, *J* = 252 Hz), 150.2, 142.4, 134.4 (d, *J* = 9 Hz), 131.0 (d, *J* = 2Hz), 130.4 (d, *J* = 1 Hz), 125.6 (d, *J* = 14 Hz), 124.7 (d, *J* = 4 Hz), 123.6, 116.5 ppm (d, *J* = 21 Hz); mp 116.3–116.8 °C.

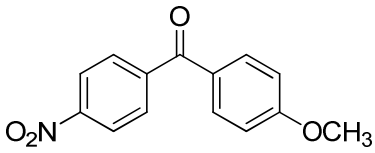


(4-bromophenyl)(4-nitrophenyl)methanone (3ag): Following general procedure B, **3ag** was isolated as a yellow solid (130 mg, 86%), known compound. The NMR spectroscopic data agree with those described in ref.[S11].^{1}H NMR (400 MHz, $CDCl_3$):

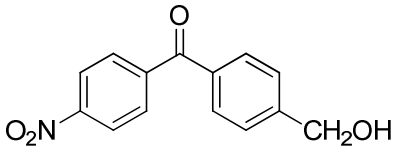
δ 8.36–8.29 (m, 2 H), 7.93–7.85 (m, 2 H), 7.65 (s, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 193.70, 149.87, 142.32, 134.92, 132.01, 131.47, 130.57, 128.76, 123.62; mp 123.6–124.3 °C.



(4-Nitrophenyl)(*o*-tolyl)methanone (3ah): Following general procedure A, **3ah** was isolated as a light pink solid (94 mg, 79%), known compound. The NMR spectroscopic data agree with those described in ref.[S1]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.28 (d, *J* = 8.9 Hz, 2 H), 7.92 (d, *J* = 8.9 Hz, 2 H), 7.45–7.41 (m, 1 H), 7.33–7.26 (m, 3 H), 2.36 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.6, 150.2, 142.7, 137.6, 136.9, 131.5, 131.3, 130.9, 129.1, 125.5, 123.6, 20.2 ppm; mp 86.8–87.3 °C.

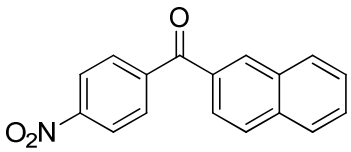


(4-Methoxyphenyl)(4-nitrophenyl)methanone (3ai): Following general procedure A, **3ai** was isolated as a white solid (110 mg, 87%), known compound. The NMR spectroscopic data agree with those described in ref.[S12]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30 (d, *J* = 8.8 Hz, 2 H), 7.85 (d, *J* = 8.8 Hz, 2 H), 7.78 (d, *J* = 8.9 Hz, 2 H), 6.96 (d, *J* = 8.9 Hz, 2 H); 3.88 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 193.4, 164.0, 149.4, 143.7, 132.6, 130.3, 128.8, 123.4, 113.9, 55.6 ppm; mp 122.1–122.7 °C.

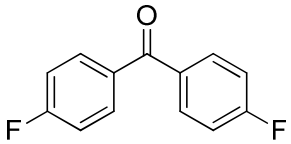


(4-(Hydroxymethyl)phenyl)(4-nitrophenyl)methanone (3aj): Following general procedure B, **3aj** was isolated as a light yellow solid (104 mg, 81%), known

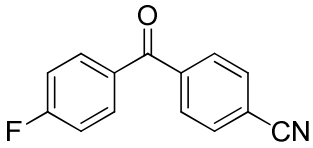
compound. The NMR spectroscopic data agree with those described in ref.[S13]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.32 (d, *J* = 8.9 Hz, 2 H), 7.90 (d, *J* = 8.9 Hz, 2 H), 7.78 (d, *J* = 8.3 Hz, 2 H), 7.50 (d, *J* = 8.3 Hz, 2 H), 4.81 (s, 2 H), 1.76 ppm (br s, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.5, 149.8, 146.7, 142.9, 135.4, 130.6, 130.4, 126.7, 123.5, 64.5 ppm; mp 141.2–141.6 °C.



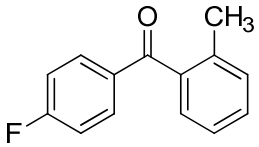
Naphthalen-2-yl(4-nitrophenyl)methanone (3ak): Following general procedure A, **3ak** was isolated as a white solid (126 mg, 92%), known compound. The NMR spectroscopic data agree with those described in ref.[S11]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.36 (d, *J* = 8.5 Hz, 2 H), 8.21 (s, 1 H), 7.97 (d, *J* = 8.5 Hz, 2 H), 7.95–7.87 (m, 4 H), 7.64 (t, *J* = 7.6 Hz, 1 H), 7.57 ppm (t, *J* = 7.5 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.8, 149.8, 143.2, 135.6, 133.5, 132.4, 132.2, 130.7, 129.5, 129.0, 128.8, 127.9, 127.2, 125.2, 123.6 ppm; mp 145.8–146.3 °C.



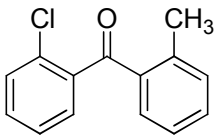
4,4'-Difluorobenzophenone (3ef): Following general procedure A, **3ef** was isolated as a white solid (92 mg, 85%), known compound. The NMR spectroscopic data agree with those described in ref.[S14]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81–7.76 (m, 4 H), 7.17–7.11 ppm (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 193.8, 165.3 (d, *J* = 253 Hz), 133.6 (d, *J* = 3 Hz), 132.5 (d, *J* = 9 Hz), 115.5 ppm (d, *J* = 22 Hz); mp 106.7–107.2 °C.



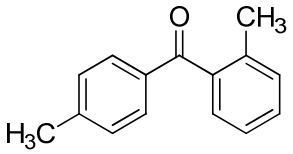
4-(4-Fluorobenzoyl)benzonitrile (3ec): Following general procedure A, **3ec** was isolated as a white solid (86 mg, 78%), known compound. The NMR spectroscopic data agree with those described in ref.[S15]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92–7.78 (m, 6 H), 7.22 (t, *J* = 8.0 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 193.6, 165.9 (d, *J* = 254 Hz),141.13, 132.8 (d, *J* = 9 Hz), 132.6 (d, *J* = 3 Hz), 132.3, 130.1, 116.9 (d, *J* = 217 Hz), 116.1, 115.8 ppm; mp 88.0–88.3 °C.



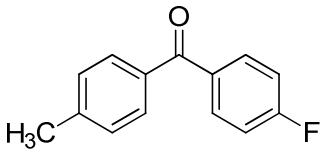
(4-Fluorophenyl)(2-tolyl)methanone (3hf): Following general procedure B, **3hf** was isolated as pale yellow liquid (92 mg, 86%), known compound. The NMR spectroscopic data agree with those described in ref.[S16].^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83–7.79 (m, 2 H), 7.40–7.36 (m, 1 H), 7.28–7.24 (m, 3 H), 7.13–7.08 (m, 2 H), 2.30 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.0, 165.8 (d, *J* = 254 Hz), 138.4, 136.6, 134.1 (d, *J* = 3 Hz), 132.7 (d, *J* = 9 Hz), 131.0, 130.3, 128.2, 125.3, 115.6 (d, *J* = 22 Hz), 19.9 ppm.



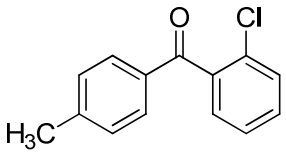
(2-Chlorophenyl)(2-tolyl)methanone (3hl): Following general procedure B, **3hl** was isolated as a pale yellow liquid (92 mg, 81%), known compound. The NMR spectroscopic data agree with those described in ref.[S16]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44–7.35 (m, 4 H), 7.35–7.27 (m, 3 H), 7.20–7.15 (m, 1 H), 2.56 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.3, 139.6, 139.5, 136.9, 132.0, 131.8, 131.4, 131.3, 130.3, 129.9, 126.7, 125.5, 21.1 ppm.



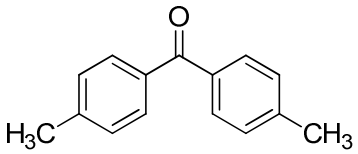
***o*-Tolyl(*p*-tolyl)methanone (3hm):** Following general procedure B, **3hm** was isolated as pale yellow liquid (88 mg, 84%), known compound. The NMR spectroscopic data agree with those described in ref.[S16]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.2, 2H), 7.35 (dd, *J* = 7.1, 1.8, 1H), 7.29–7.19 (m, 5H), 2.40 (s, 3H), 2.30 ppm(s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 198.3, 144.0, 138.9, 136.4, 135.1, 130.8, 130.3, 130.0, 129.1, 128.2, 125.1, 21.6, 19.8 ppm.



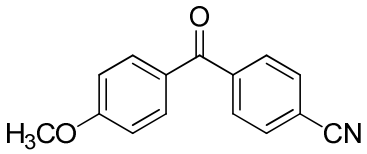
(4-Fluorophenyl)(4-tolyl)methanone (3jf): Following general procedure A, **3jf** was isolated as a white solid (96 mg, 91%), known compound. The NMR spectroscopic data agree with those described in ref.[S16]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (dd, *J* = 8.9, 5.5 Hz, 2 H), 7.67 (d, *J* = 8.4 Hz, 2 H), 7.27 (d, *J* = 8.4 Hz, 2 H), 7.13 (t, *J* = 8.7 Hz, 2 H), 2.42 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.0, 165.2 (d, *J* = 252 Hz), 143.3, 134.8, 134.1 (d, *J* = 3 Hz), 132.5 (d, *J* = 9 Hz), 130.1, 129.0, 115.3 (d, *J* = 22 Hz), 21.6 ppm; mp 91.8–92.3 °C.



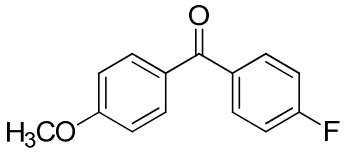
(2-Chlorophenyl)(4-tolyl)methanone (3jl): Following general procedure A, **3jl** was isolated as a pale yellow liquid (102 mg, 90%), known compound. The NMR spectroscopic data agree with those described in ref.[S16]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.4 Hz, 2 H), 7.45–7.38 (m, 2 H), 7.35–7.33 (m, 2 H), 7.24 (d, *J* = 8.4 Hz, 2 H), 2.4 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.9, 144.7, 138.9, 134.0, 131.2, 130.9, 130.2, 130.0, 129.3, 129.0, 126.6, 21.7 ppm; mp 92.8–93.6 °C.



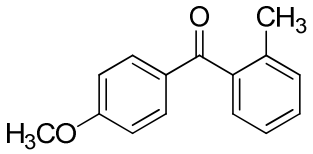
Di-*p*-tolylmethanone (3jm): Following general procedure A, **3jm** was isolated as a white solid (86 mg, 83%), known compound. The NMR spectroscopic data agree with those described in ref.[S16]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 (d, *J* = 8.0 Hz, 4 H), 7.25 (d, *J* = 8.0 Hz, 4 H). 2.42 ppm(s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.3, 142.9, 135.2, 130.2, 128.9, 21.6 ppm; mp 76.0–76.6 °C.



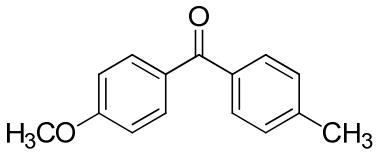
4-(4-Methoxybenzoyl)benzonitrile (3kc): Following general procedure A, **3kc** was isolated as a white solid (108 mg, 91%), known compound. The NMR spectroscopic data agree with those described in ref.[17]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79–7.72 (m, 6 H), 6.94 (d, *J* = 8.0, 2 H), 3.86 (s, 3 H).^{13}C NMR (100 MHz, $CDCl_3$): δ 193.6, 163.8, 143.0, 132.5, 132.0, 129.8, 128.8, 118.0, 115.0, 113.8, 55.5 ppm; mp 129.3–130.1 °C.



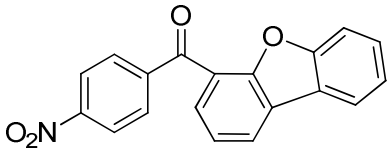
(4-Fluorophenyl)(4-methoxyphenyl)methanone (3kf): Following general procedure A, **3kf** was isolated as a white solid (96 mg, 83%), known compound. The NMR spectroscopic data agree with those described in ref.[S18]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (dt, *J*=8.0, 2.4, 4 H), 7.12 (t, *J*=8.0, 2 H), 6.94 (d, *J*=8.0, 2 H), 3.85 (s, 3 H).^{13}C NMR (100 MHz, $CDCl_3$): δ 194.0, 165.0 (d, *J* = 251 Hz), 163.2, 134.4 (d, *J* = 3 Hz), 132.3 , 132.2 (d, *J* = 9 Hz), 129.9, 115.3 (d, *J* = 22 Hz), 113.6, 55.4 ppm; mp 88.0-88.3 °C.



(4-Methoxyphenyl)(2-tolyl)methanone (3kh): Following general procedure B, **3kh** was isolated as a pale yellow liquid (104 mg, 92%), known compound. The NMR spectroscopic data agree with those described in ref.[S19]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81 (d, *J* = 8.0, 2 H), 7.41–7.37 (m, 1 H), 7.32–7.24 (m, 3 H), 6.95 (d, *J* = 8.0, 2 H) 3.89 (s, 3 H), 2.32 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.3, 163.7, 139.1, 136.1, 132.5, 130.8, 130.5, 129.7, 127.9, 125.1, 113.7, 55.5, 19.8 ppm.



(4-Methoxyphenyl)(4-tolyl)methanone (3km): Following general procedure B, **3km** was isolated as a white solid (92 mg, 83%), known compound. The NMR spectroscopic data agree with those described in ref.[S20]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83 (d, *J*=8.0, 2 H), 7.70 (d, *J*=8.0, 2 H), 7.26 (d, *J*=8.0, 2 H), 6.93 (d, *J*=8.0, 2 H), 3.90 (s, 3 H), 2.45 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.4, 163.0, 142.6, 135.5, 132.4, 130.5, 130.0, 128.9, 113.5, 55.5, 21.6 ppm; mp76.3-77.0 °C.



Dibenzofuran-4-yl(4-nitrophenyl)methanone (3an): Following general procedure B, **3an** was isolated as a white solid (110 mg, 70%). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.31 (d, *J*=8.4, 2 H), 8.19 (d, *J* = 7.6, 1 H), 8.02–7.97 (m, 3 H), 7.76 (d, *J*=7.6, 1 H), 7.52–7.33 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.1, 156.2, 153.8, 150.1, 142.9, 130.8, 128.8, 128.1, 125.9, 125.4, 123.5, 123.4, 122.9, 122.8, 121.8, 120.8, 112.0 ppm; HRMS (ESI) calcd for $C_{19}H_{11}NO_4$ [M+H] *m/z* 318.0761, found *m/z* 318.0757; IR: ν_{max}(KBr) = 3414, 3066, 2930, 2853, 2368, 1936, 1653, 1607, 1510, 1477, 1458,

1419, 1421, 1355, 1291, 1187, 1110, 941, 871, 845, 741, 703, 670 cm^{-1}; mp 158.4–158.7 °C.

4. References

[S1] C. M. Qin, J. X. Chen, H. Y. Wu, J. Cheng, Q. Zhang, B. Zuo, W. K. Su, J. C. Ding, *Tetrahedron Lett.* **2008**, *49*, 1884–1888.

[S2] M. Z. Li, C. Wang, H. B. Ge, *Org. Lett.* **2011**, *13*, 2062–2064.

[S3] A. T. Biju, F. Glorius, *Angew. Chem.* **2010**, *122*, 9955–9958; *Angew. Chem .Int. Ed.* **2010**, *49*, 9761–9764.

[S4] A. J. Yu, L. Shen, X. L. Cui, D. P. Peng, Y. J. Wu, *Tetrahedron* **2012**, *68*, 2283–2288.

[S5] K. O. Jeon, J. H. Jun, J. S. Yu, C. K. Lee, *J. Heterocycl. Chem.* **2003**, *40*, 763–771.

[S6] J. N. Moorthy, S. Samanta, *J. Org. Chem.* **2007**, *72*, 9786–9789.

[S7] M. Chidambaram, C. Venkatesan, P. Moreau, A. Finiels, A.V. Ramaswamy, A.P. Singh, *Applied Catalysis A: General* **2002**, *224,* 129–140.

[S8] J. H. Gorvin, *J. Chem. Res., Miniprint* **1990**, *7*, 1662–1681.

[S9] Z. Vejdělek, M. Rajšner, A. Dlabač, M. Ryska, J. Holubek, E. Svátek, M. Protiva, *Collect. Czech. Chem. Commun.* **1980**, *45*, 3593–3615.

[S10] L. Kaganovsky, D. Gelman, K. R. Braun, *J. Organomet. Chem.* **2010**, *695*, 260–266.

[S11] H. M. Zheng, J. C. Ding, J. X. Chen, M. C. Liu, W. X. Gao, H. Y. Wu, *Synlett* **2011**, *11*, 1626–1630.

[S12] Y. Suzuki, S. Ota, Y. Fukuta, Y. Ueda, M. Sato, *J. Org. Chem.* **2008**, *73*, 2420–2423.

[S13] J. P. Griffiths, M. D. Eason, R. C. Wincewicz, S. J. Hunter, *Int. Patent WO 100410*, **2010**.

[S14] Y. J. Su, L. R. Zhang, N. Jiao, *Org. Lett.* **2011**, *13*, 2168–2171.

[S15] J. Karthikeyan, K. Parthasarathy, C.-H. Chen, *Chem. Commun.* **2011**, *47*, 10461–10463.

[S16] J.-Y. Chen, S.-C. Chen, Y.-J. Tang, C.-Y.. Mou , F.-Y. Tsai, *J. Mol. Catal. A*: *Chem.* **2009**,*307*,88–92

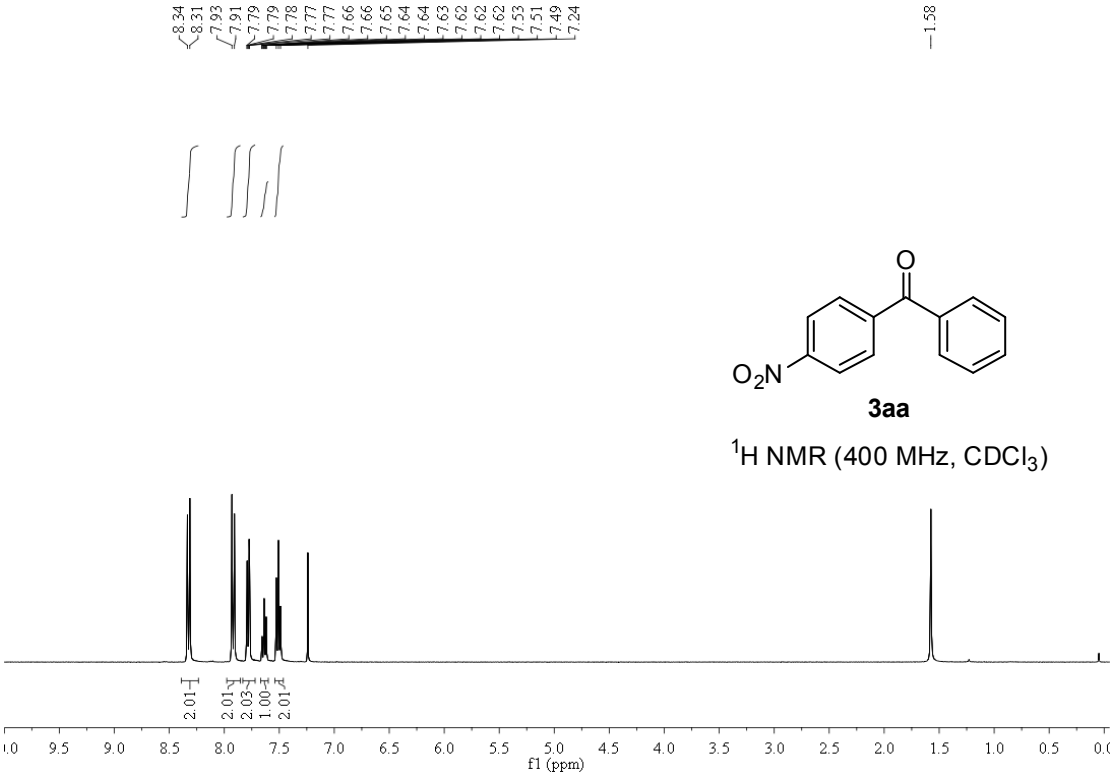
[S17] D. Christophe, B. Filip1, S. Ioannis, J. K .Tobias, C. Gérard, K. Paul, *Angew. Chem. Int. Ed.* **2004**, *43*, 2968–2970.

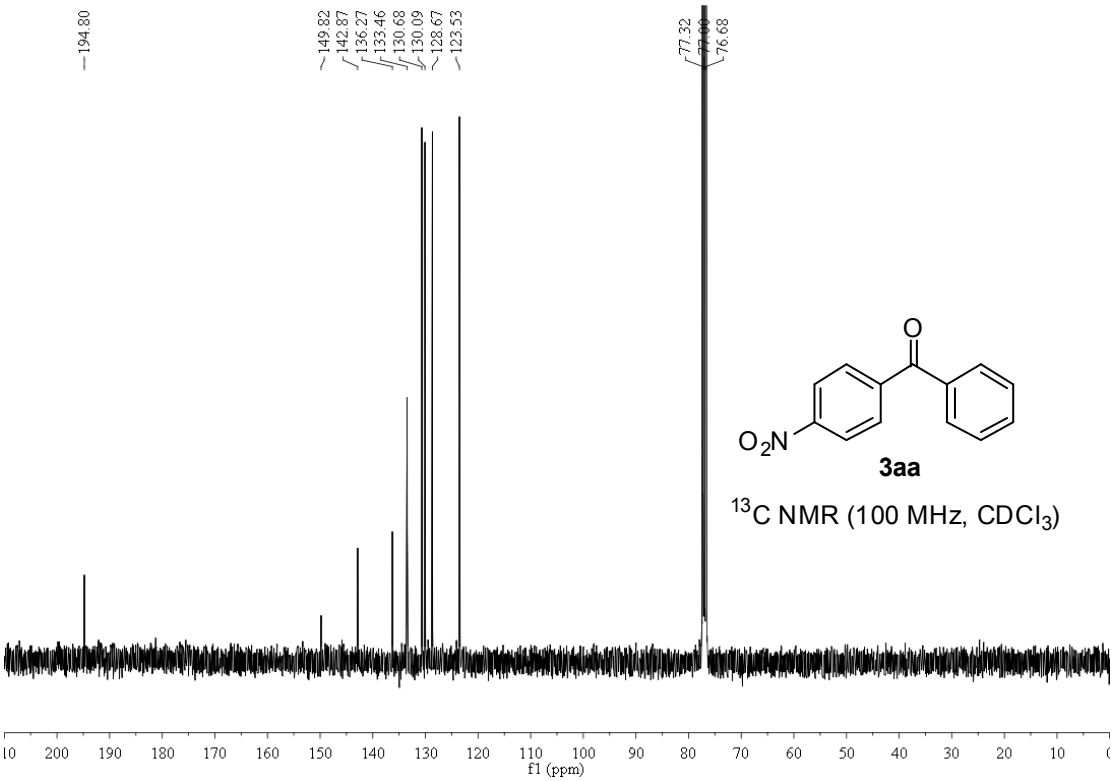
[S18] M. L. N. Rao, V. Venkatesh, D. Banerjee, *Tetrahedron* **2007**, *63*, 12917–12926.

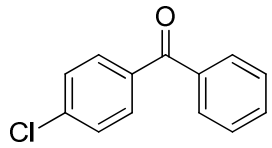
[S19] C. Olivier, R. Alexander, G. Jean-Pierre, D. Sylvain, *J. Org. Chem.* **2008**, *73*, 7800–7802.

[S20] E. C. Lathioor, W. J. Leigh, *Photochem. Photobiol.* **2006**, *82*, 291–300.

5. Copies of NMR Spectra

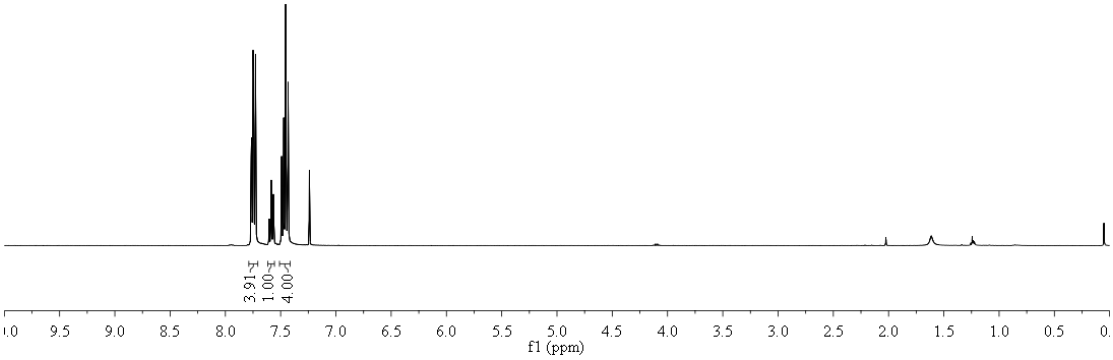


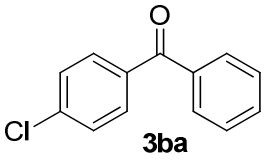




3ba

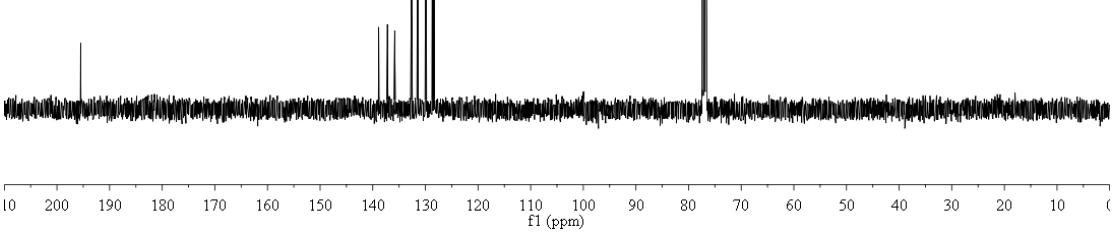
1H NMR (400 MHz, $CDCl_3$)

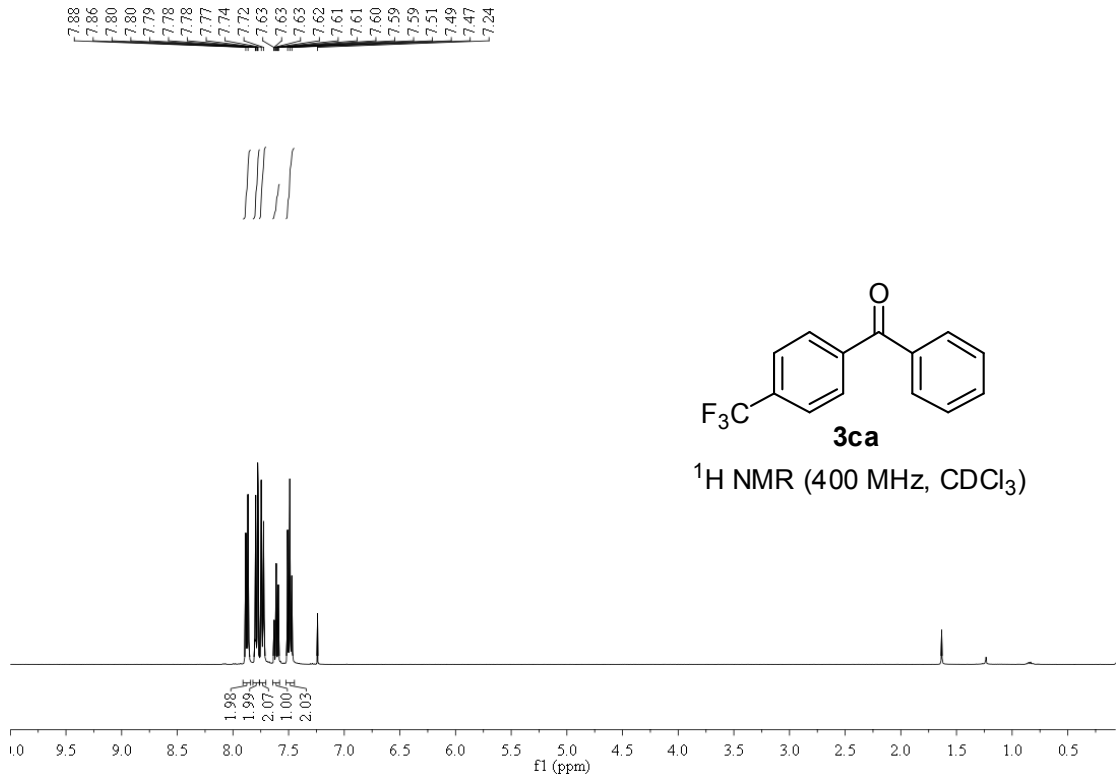


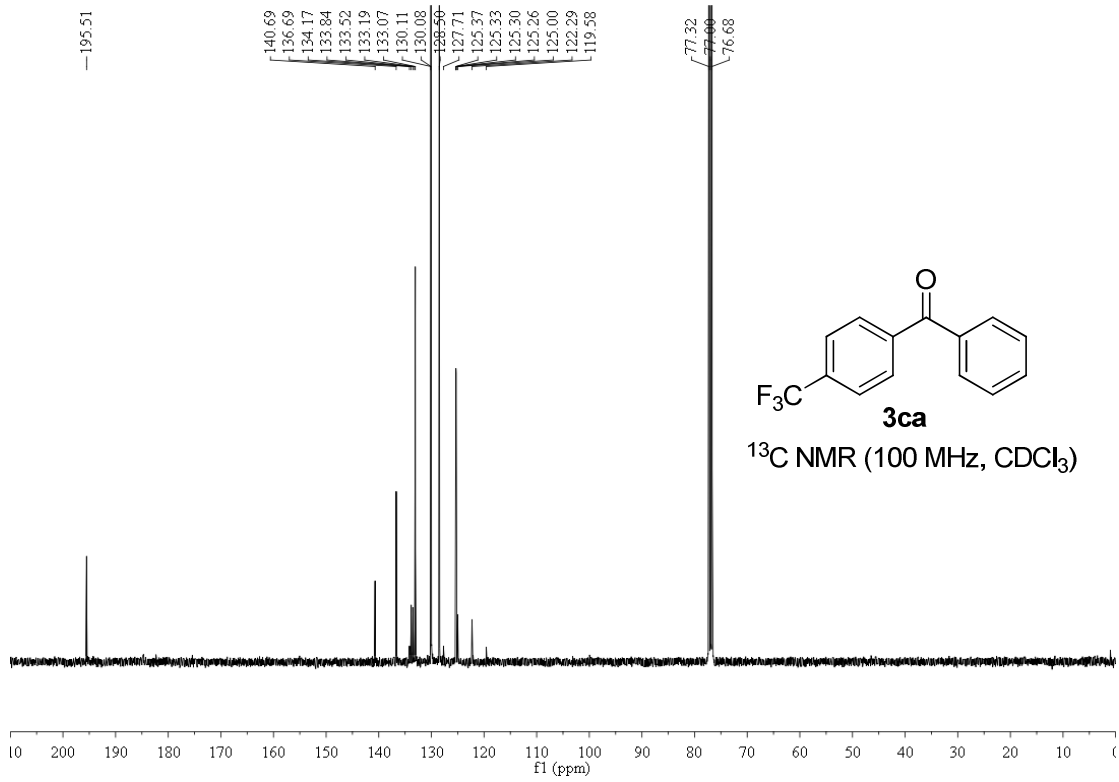


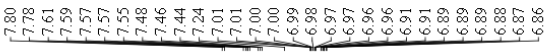
3ba

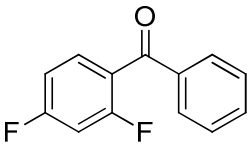
^{13}C NMR (100 MHz, $CDCl_3$)




7.88
7.86
7.80
7.80
7.79
7.78
7.78
7.77
7.74
7.72
7.63
7.63
7.63
7.62
7.61
7.61
7.60
7.59
7.59
7.51
7.49
7.47
7.24
O
F3C
3ca
1H NMR (400 MHz, CDCl3)
1.98
1.99
2.07
1.00
2.03
f1 (ppm)

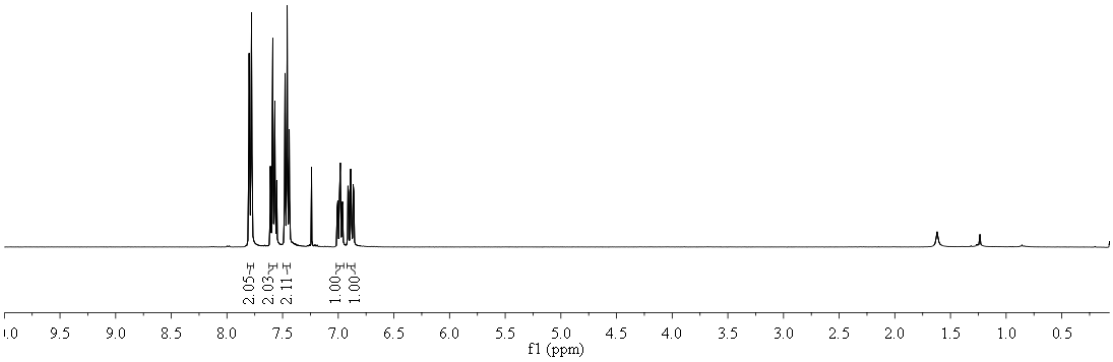

195.51
140.69
136.69
134.17
133.84
133.52
133.19
133.07
130.11
130.08
128.56
127.71
125.37
125.33
125.30
125.26
125.00
122.29
119.58
77.32
77.00
76.68
O
F3C
3ca
13C NMR (100 MHz, CDCl3)
f1 (ppm)

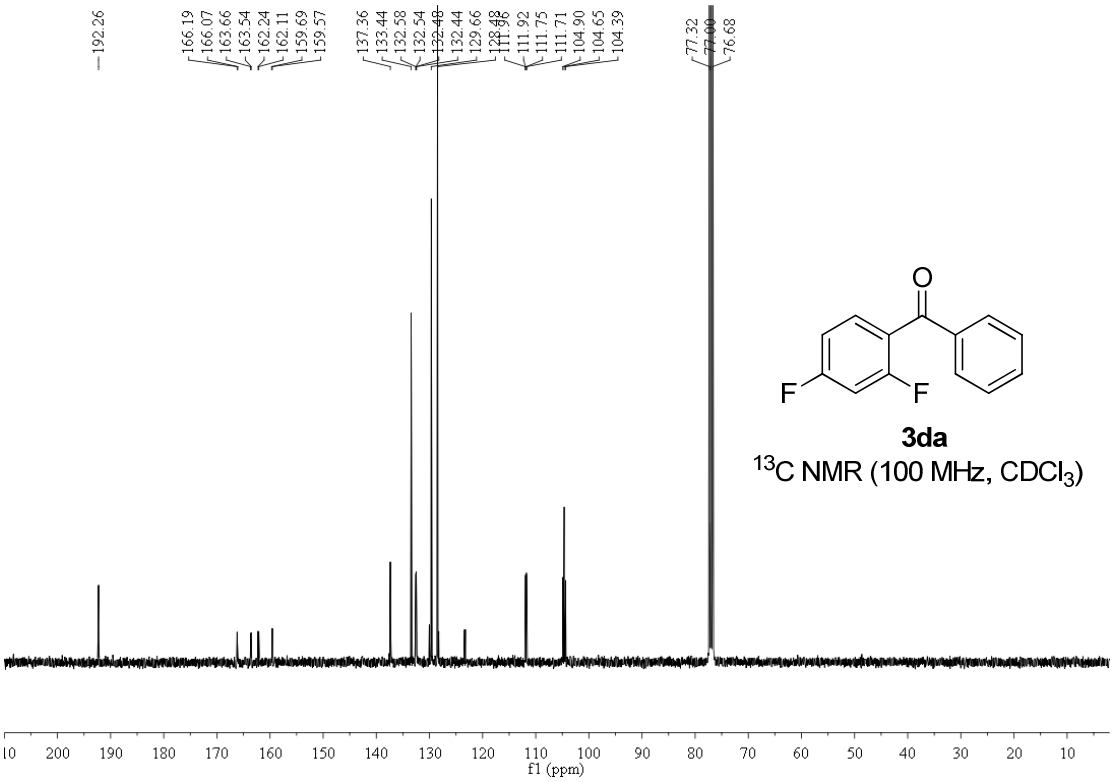




3da

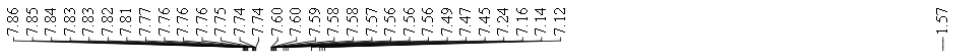
^{1}H NMR (400 MHz, $CDCl_3$)

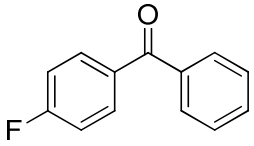




3da

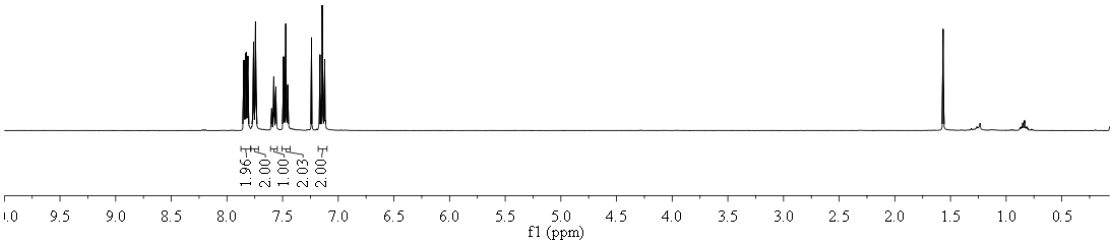
^{13}C NMR (100 MHz, $CDCl_3$)

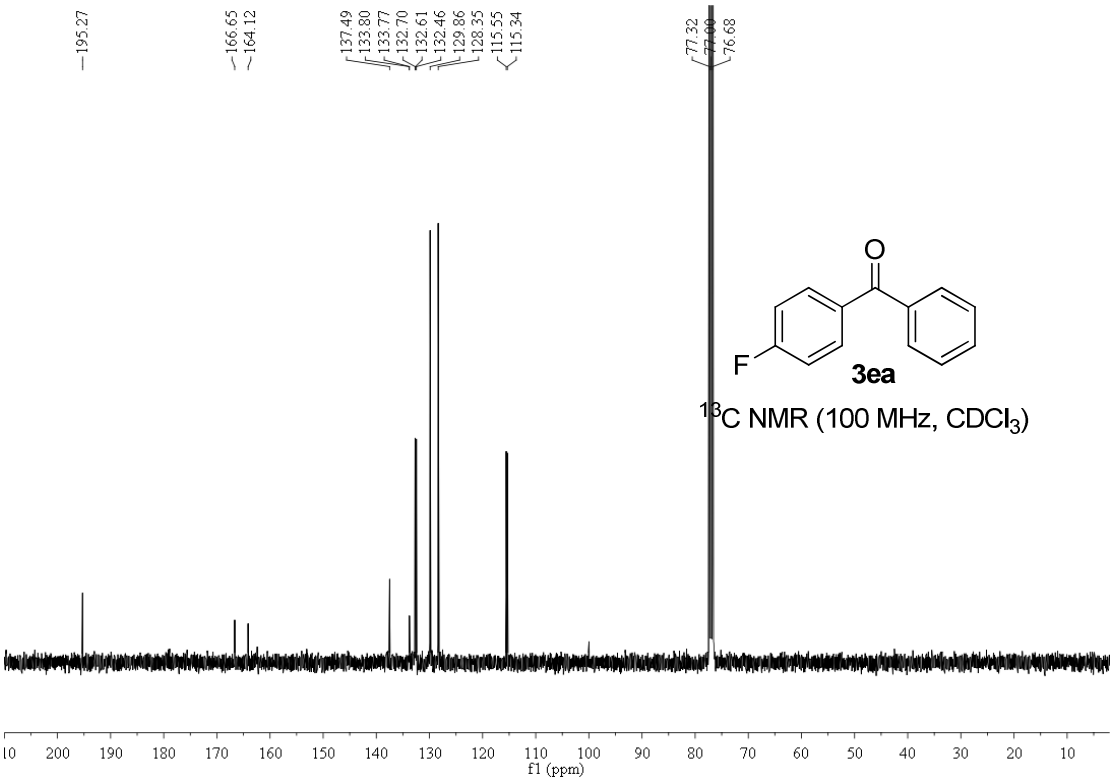




3ea

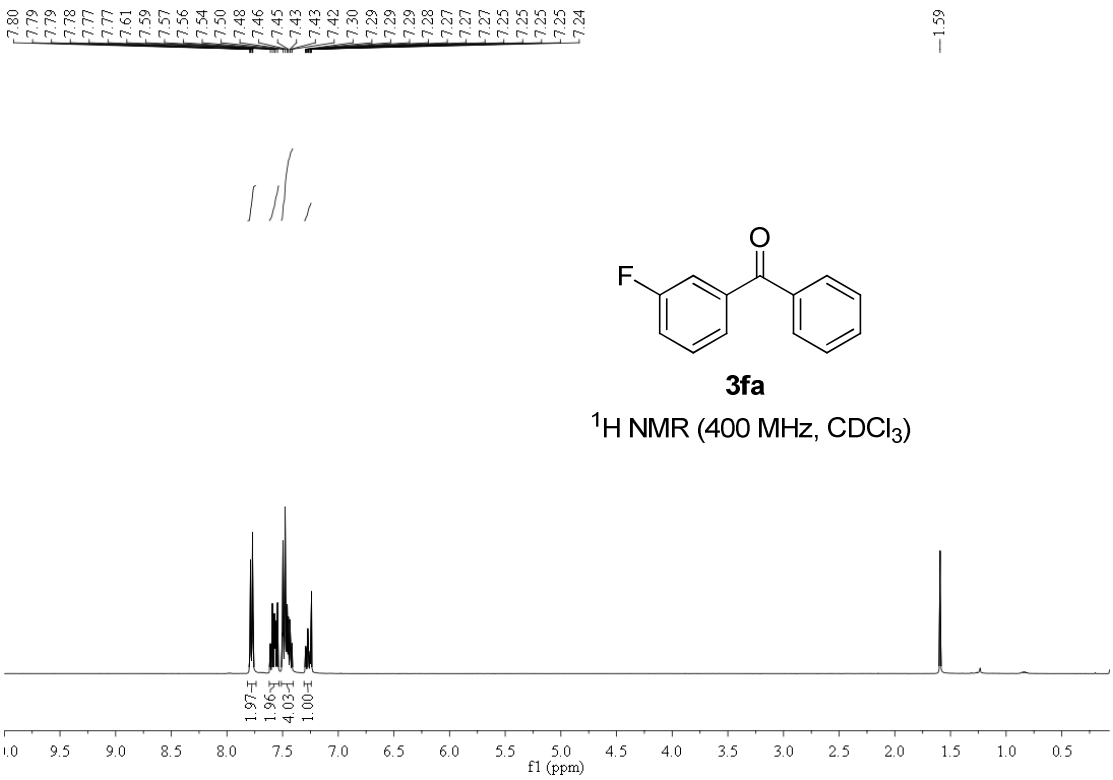
^{1}H NMR (400 MHz, $CDCl_3$)

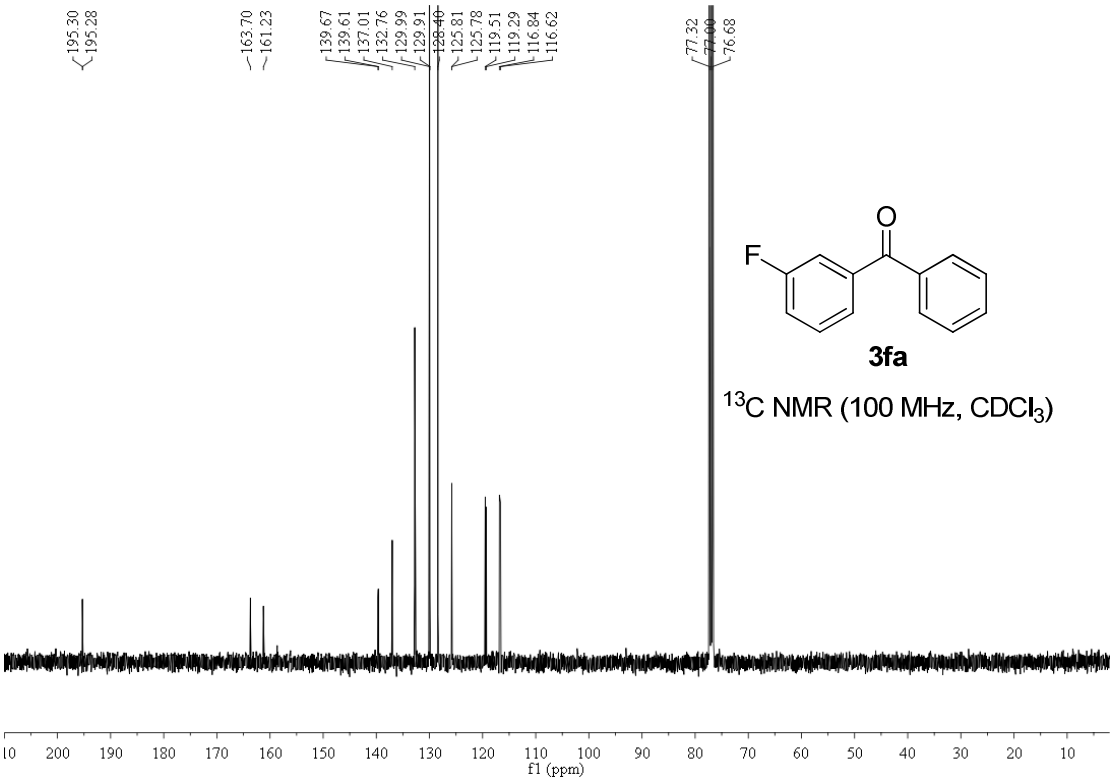


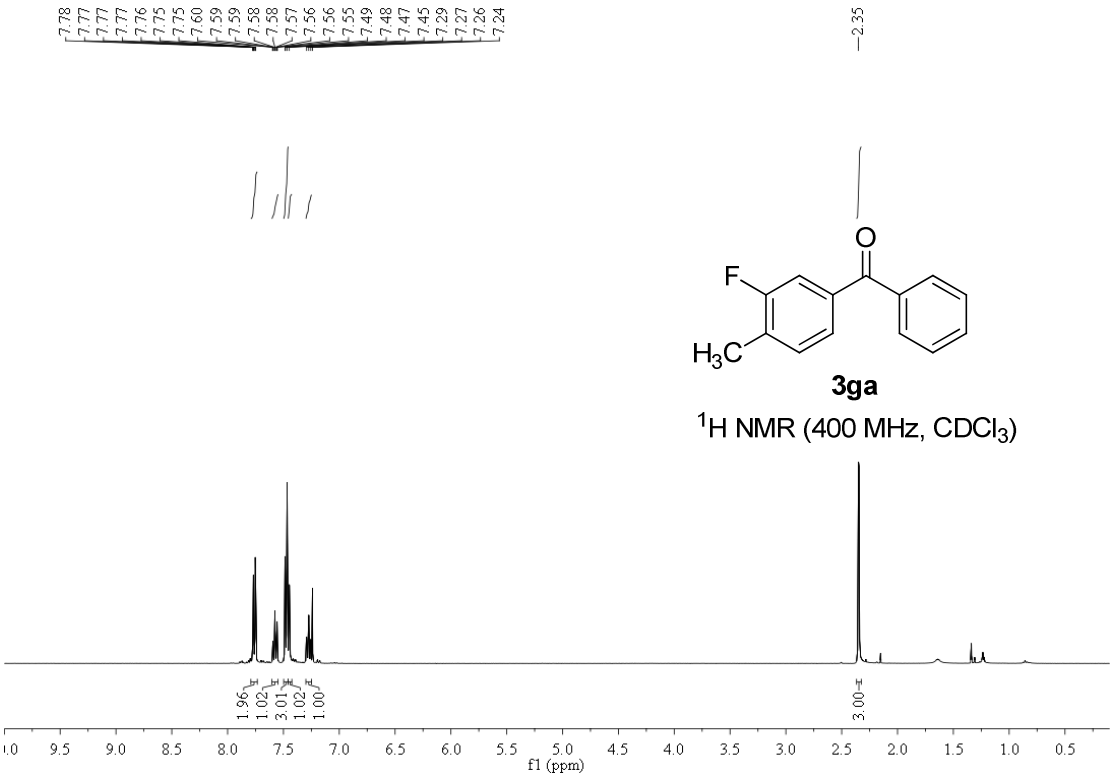


3ea

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

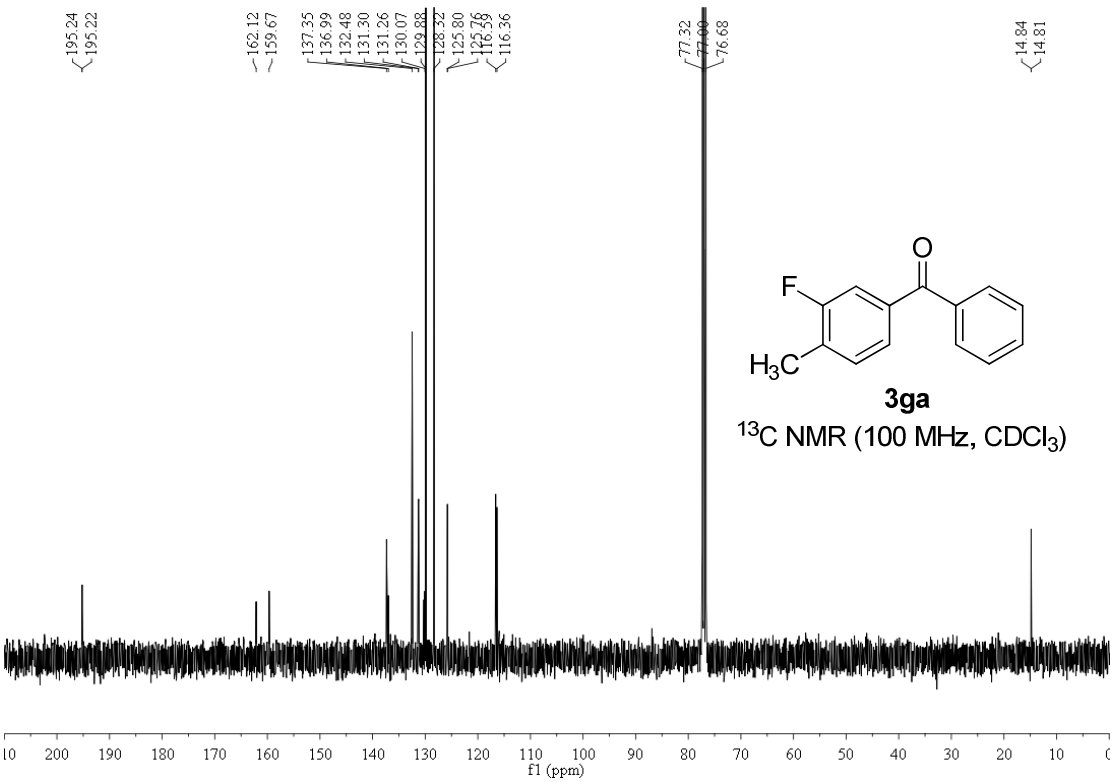

7.80
7.79
7.79
7.78
7.77
7.77
7.61
7.59
7.57
7.56
7.54
7.50
7.48
7.46
7.45
7.43
7.43
7.42
7.30
7.29
7.29
7.29
7.28
7.27
7.27
7.27
7.25
7.25
7.25
7.24
1.59
O
F
3fa
1H NMR (400 MHz, CDCl3)
1.97
1.96
4.03
1.00
f1 (ppm)


195.30
195.28
163.70
161.23
139.67
139.61
137.01
132.76
129.99
129.91
128.40
125.81
125.78
119.51
119.29
116.84
116.62
77.32
77.00
76.68
O
F
3fa
13C NMR (100 MHz, CDCl3)
f1 (ppm)



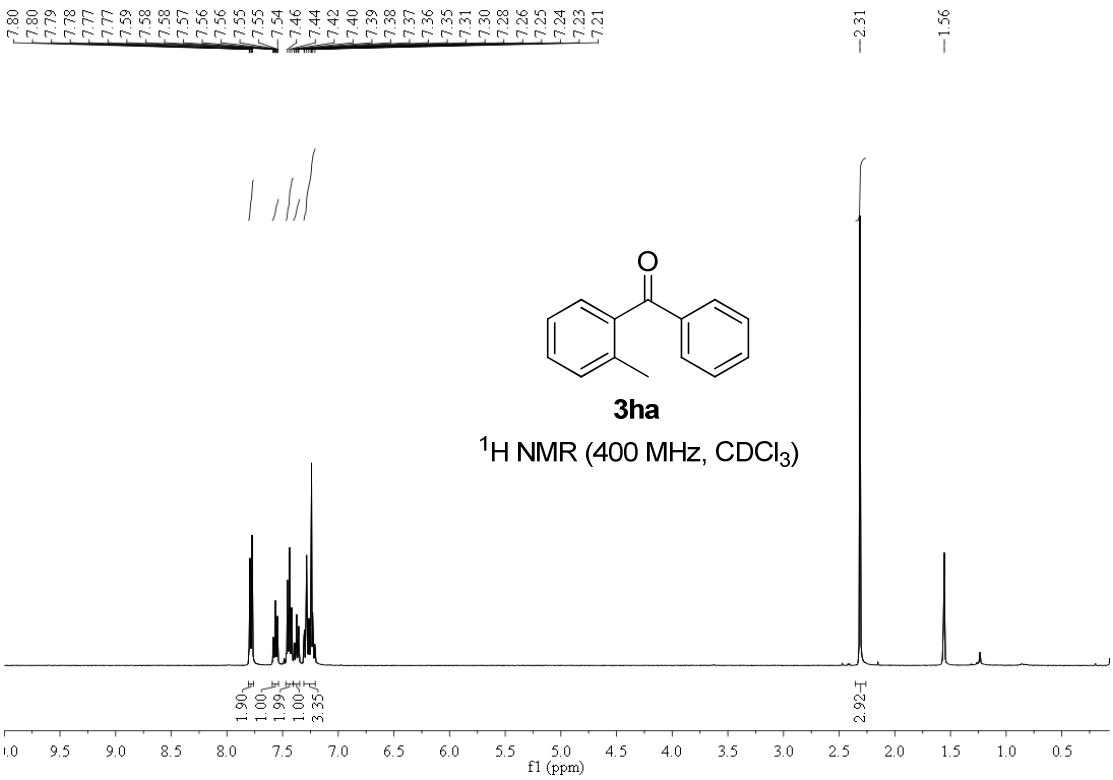
3ga

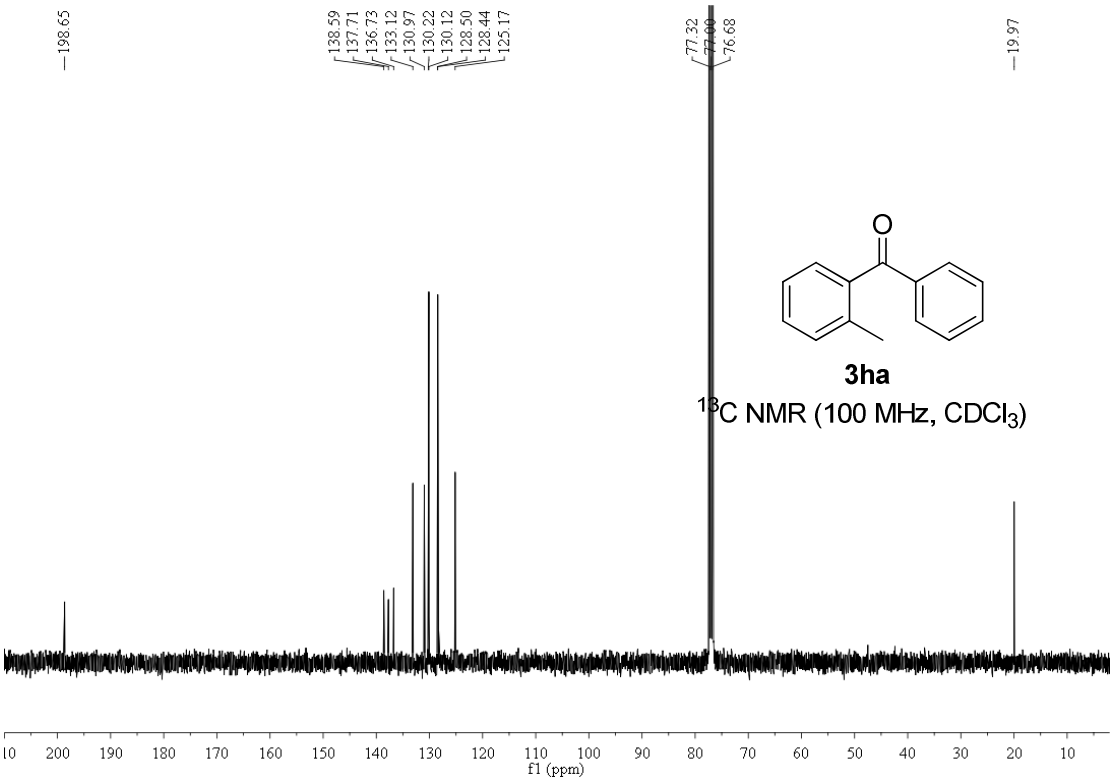
^{1}H NMR (400 MHz, $CDCl_3$)

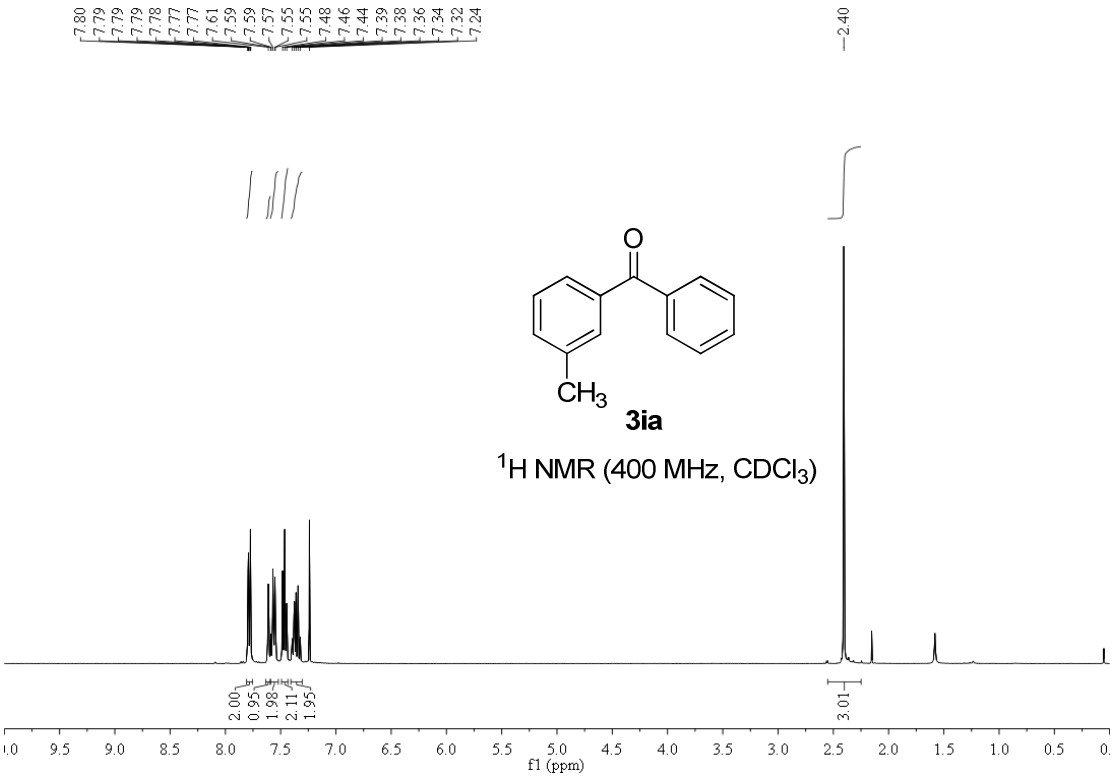


3ga

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

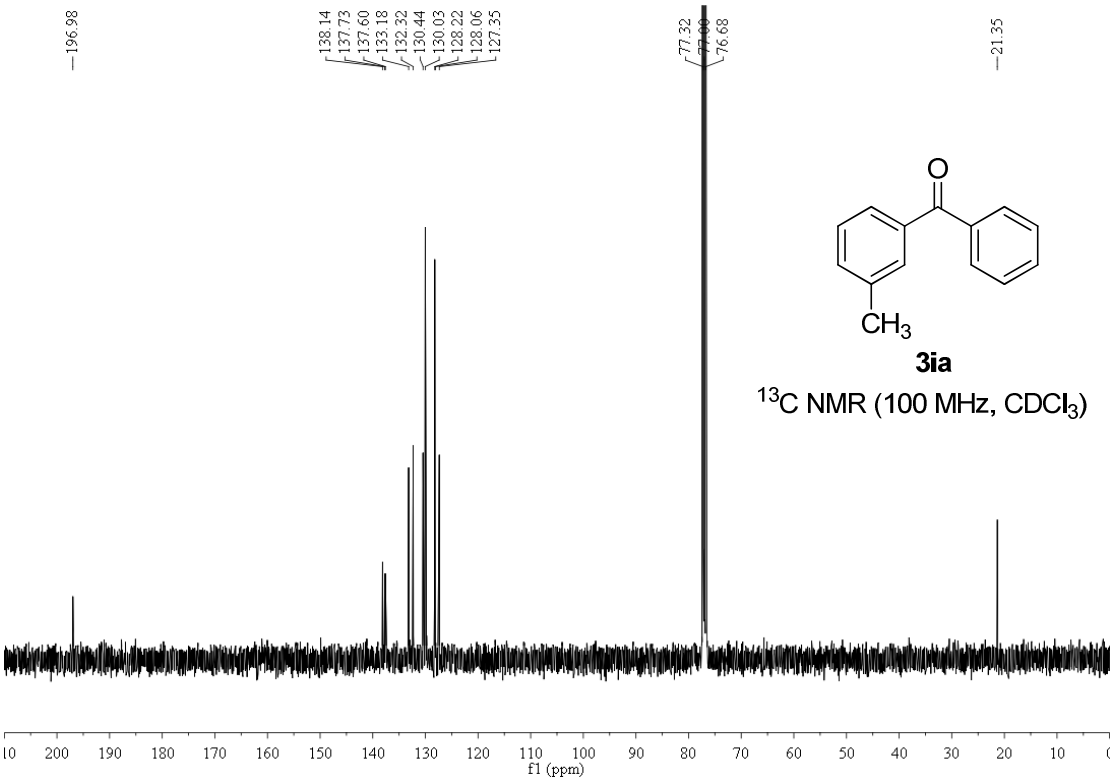

7.80
7.80
7.79
7.78
7.77
7.77
7.59
7.58
7.58
7.57
7.56
7.56
7.55
7.55
7.54
7.46
7.44
7.42
7.40
7.39
7.38
7.37
7.36
7.35
7.31
7.30
7.28
7.26
7.25
7.24
7.23
7.21
2.31
1.56
O
3ha
1H NMR (400 MHz, CDCl3)
1.90
1.00
1.99
1.00
3.35
2.92
f1 (ppm)


198.65
138.59
137.71
136.73
133.12
130.97
130.22
130.12
128.50
128.44
125.17
77.32
77.00
76.68
19.97
O
3ha
13C NMR (100 MHz, CDCl3)
f1 (ppm)



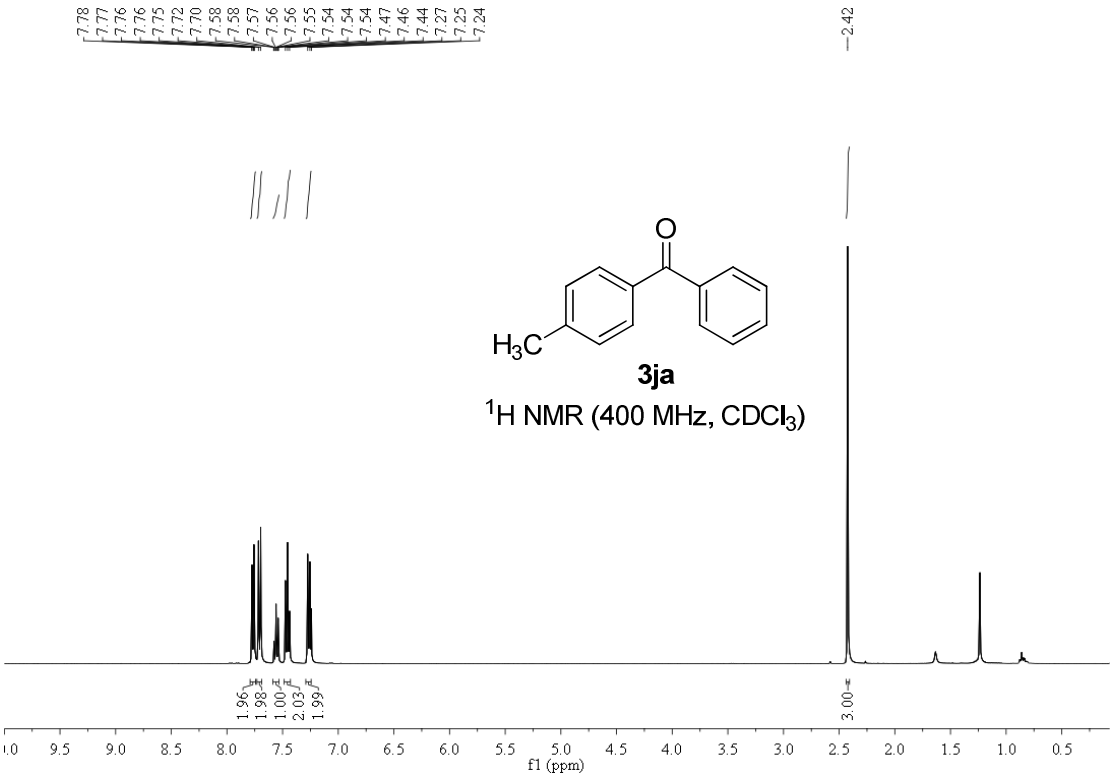
3ia

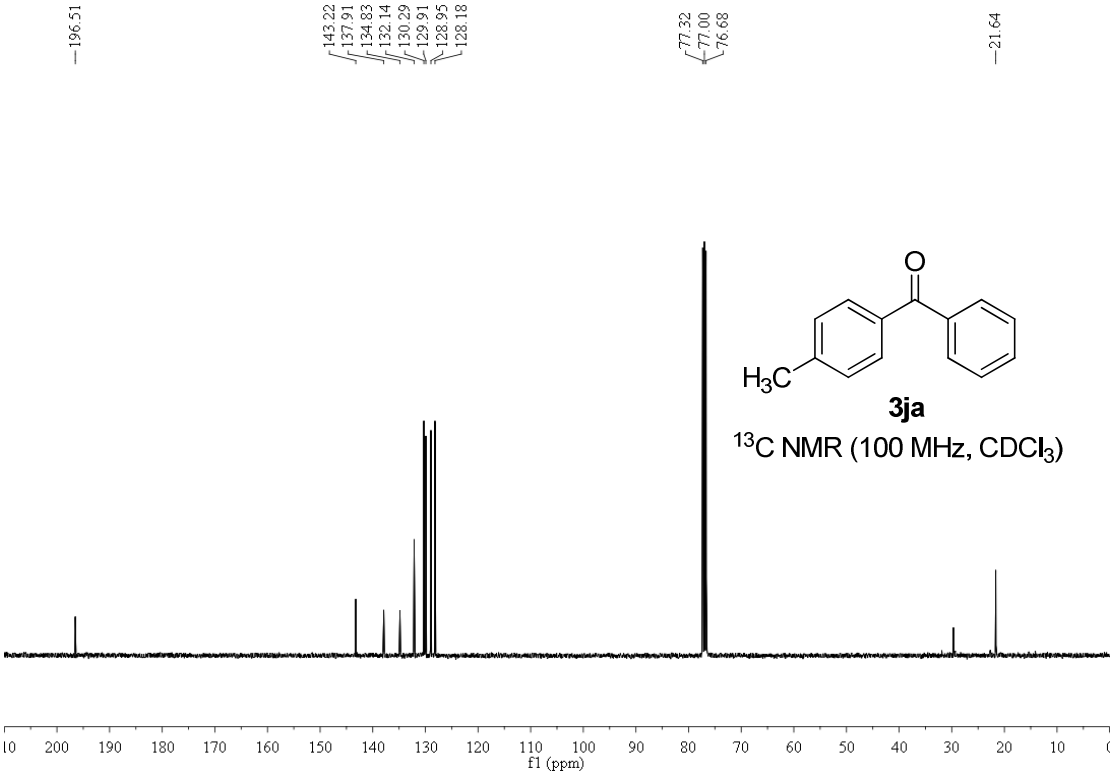
^{1}H NMR (400 MHz, $CDCl_3$)

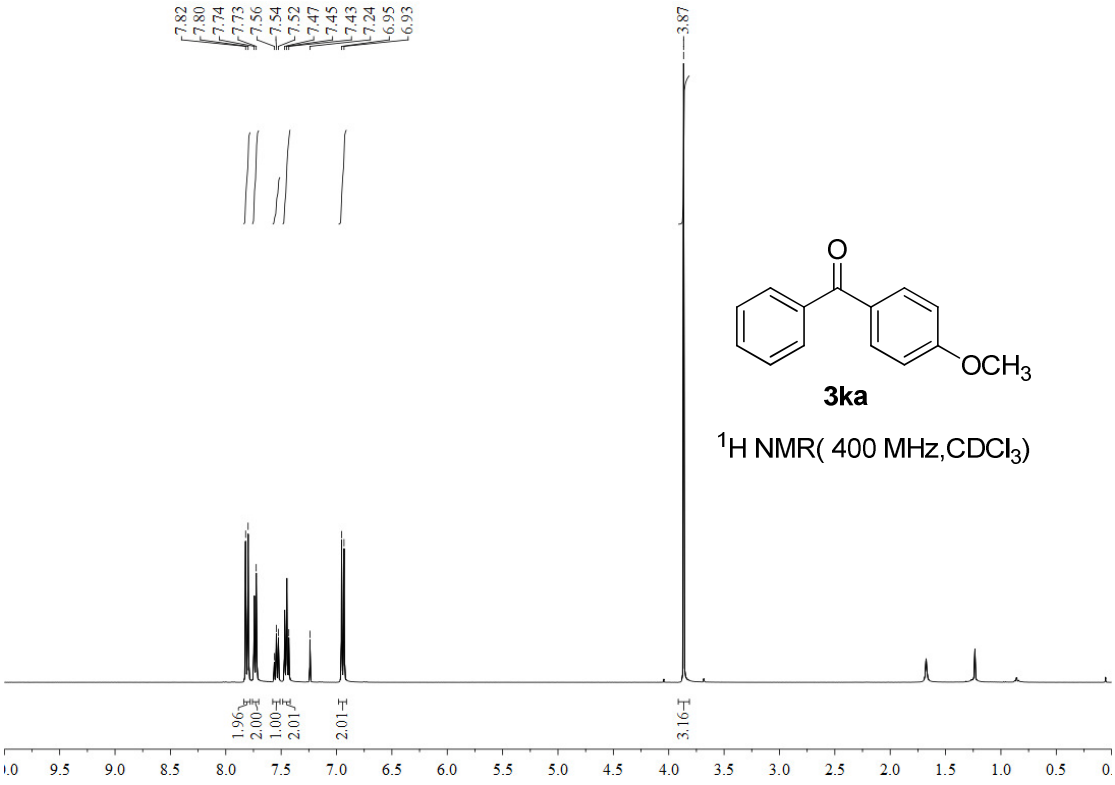


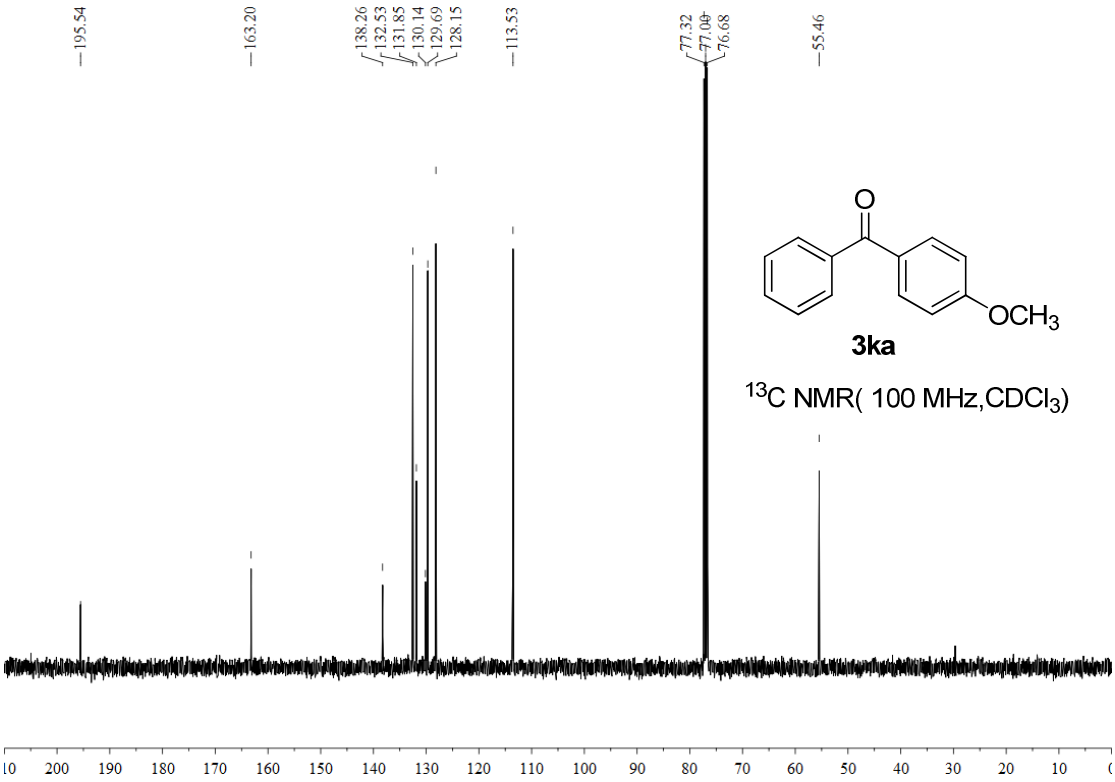
3ia

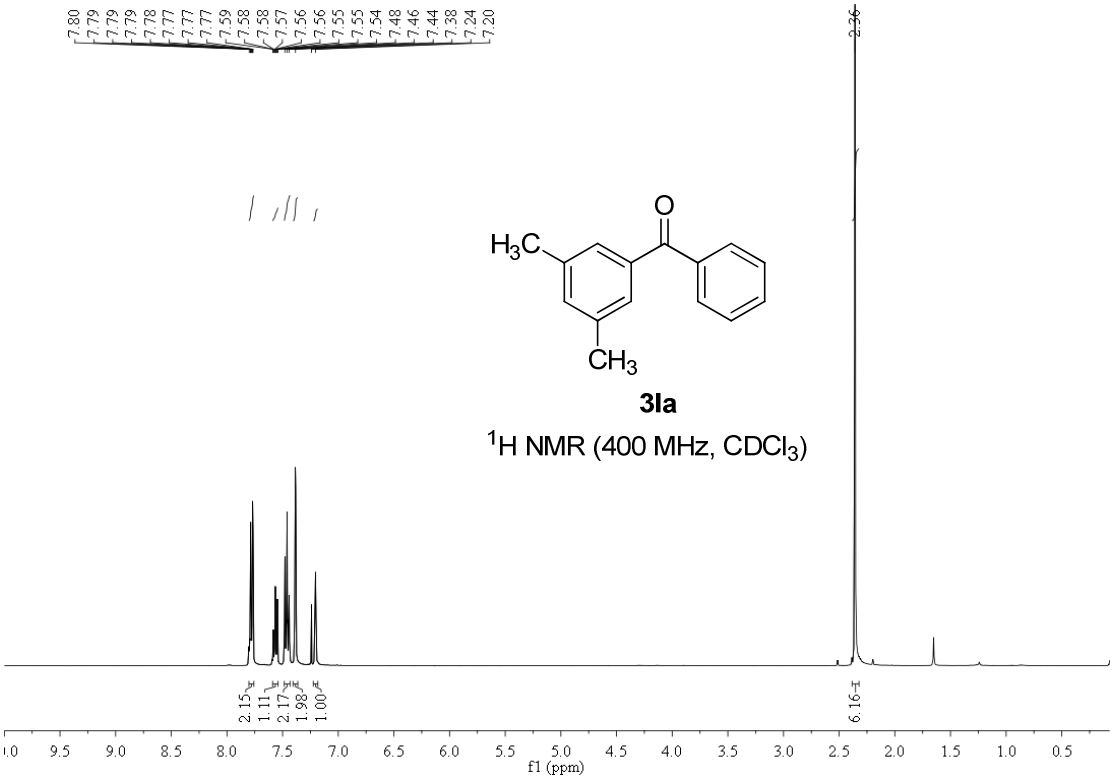
^{13}C NMR (100 MHz, $CDCl_3$)

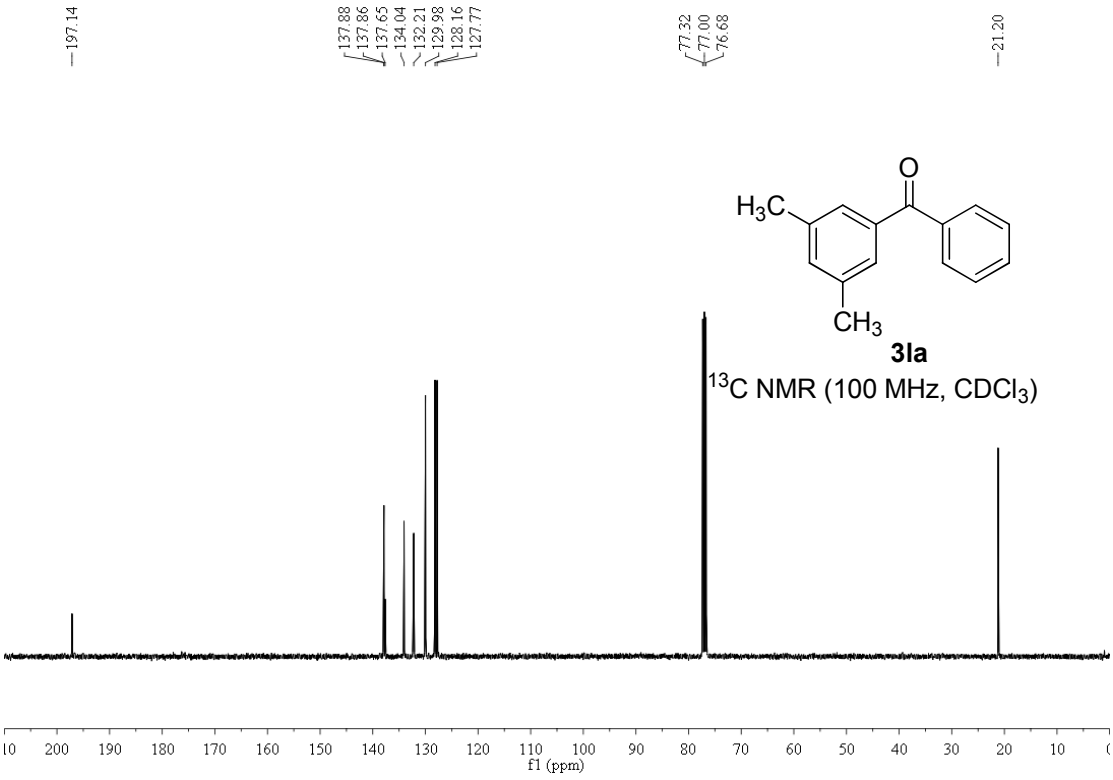

7.78
7.77
7.76
7.76
7.75
7.72
7.70
7.58
7.58
7.57
7.56
7.56
7.55
7.54
7.54
7.54
7.47
7.46
7.44
7.27
7.25
7.24
2.42
O
H3C
3ja
1H NMR (400 MHz, CDCl3)
1.96
1.98
1.00
2.03
1.99
3.00
f1 (ppm)

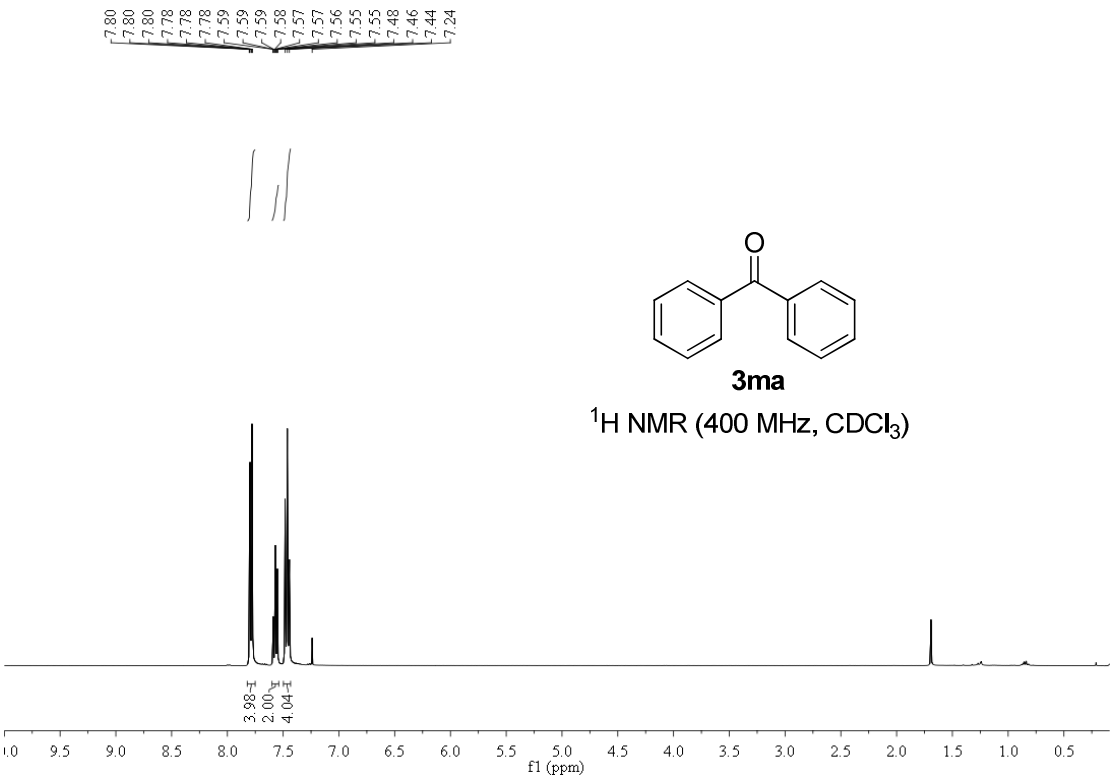

196.51
143.22
137.91
134.83
132.14
130.29
129.91
128.95
128.18
77.32
77.00
76.68
21.64
O
H3C
3ja
13C NMR (100 MHz, CDCl3)
f1 (ppm)


7.82
7.80
7.74
7.73
7.56
7.54
7.52
7.47
7.45
7.43
7.24
6.95
6.93
3.87
1.96
2.00
1.00
2.01
2.01
3.16
O
OCH3
3ka
1H NMR(400 MHz,CDCl3)


195.54
163.20
138.26
132.53
131.85
130.14
129.69
128.15
113.53
77.32
77.00
76.68
55.46
O
OCH3
3ka
13C NMR(100 MHz,CDCl3)

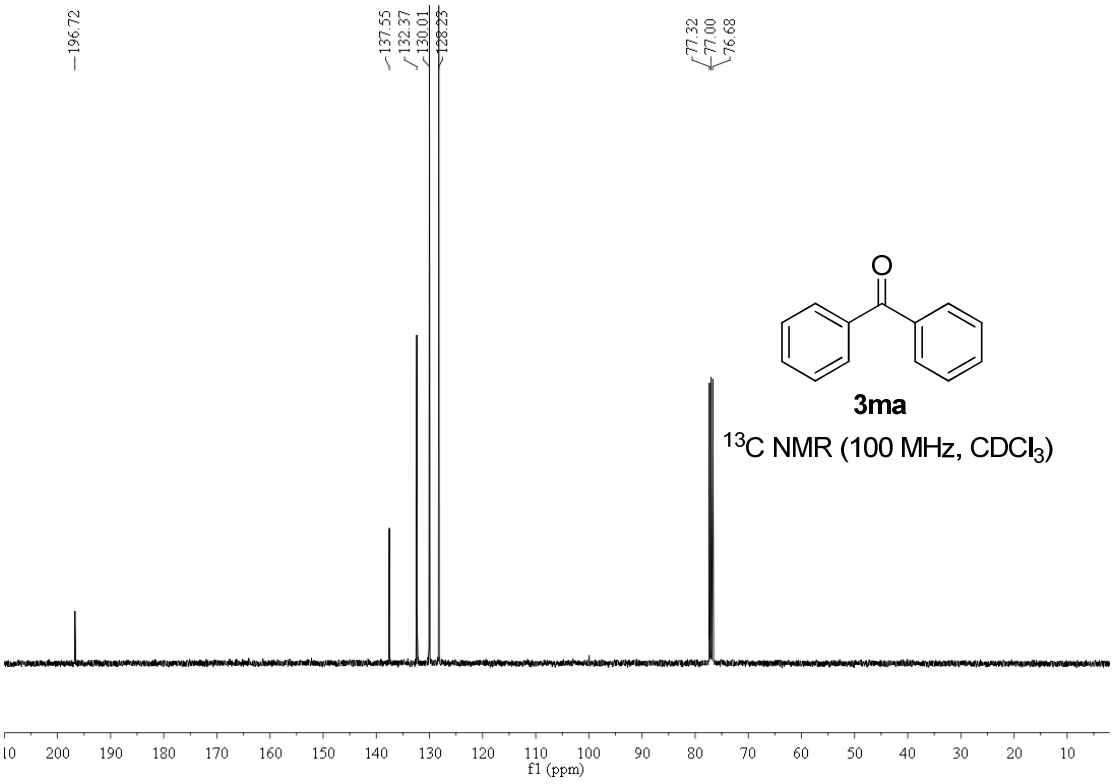

7.80
7.79
7.79
7.79
7.78
7.77
7.77
7.77
7.59
7.58
7.58
7.57
7.56
7.56
7.55
7.55
7.54
7.48
7.46
7.44
7.38
7.24
7.20
2.36
O
H3C
CH3
3la
1H NMR (400 MHz, CDCl3)
2.15
1.11
2.17
1.98
1.00
6.16
f1 (ppm)


197.14
137.88
137.86
137.65
134.04
132.21
129.98
128.16
127.77
77.32
77.00
76.68
21.20
O
H3C
CH3
3la
13C NMR (100 MHz, CDCl3)
f1 (ppm)



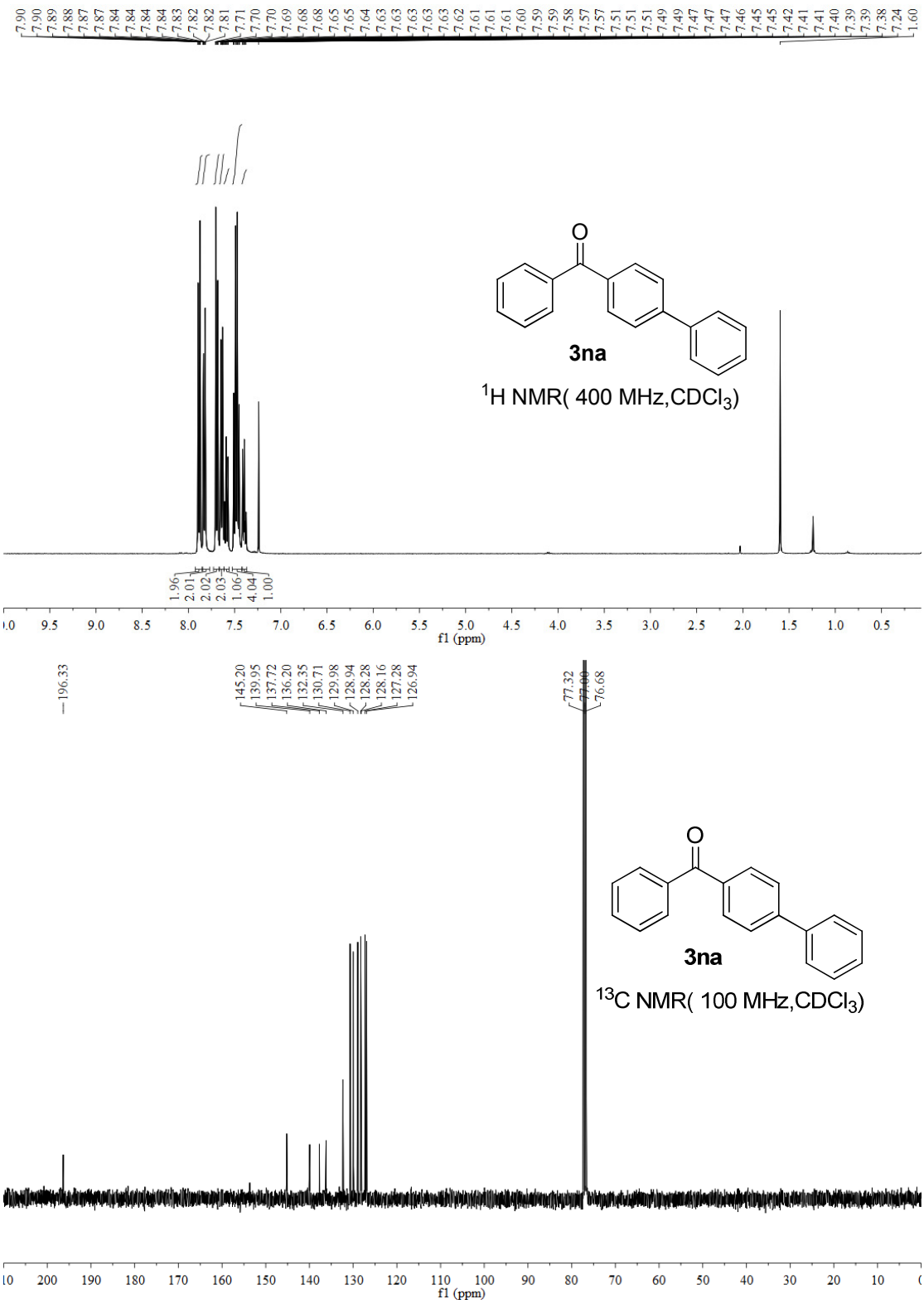
3ma

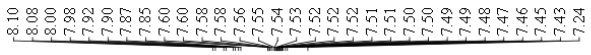
^{1}H NMR (400 MHz, $CDCl_3$)

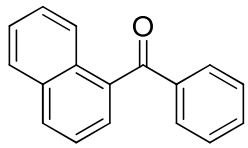


3ma

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

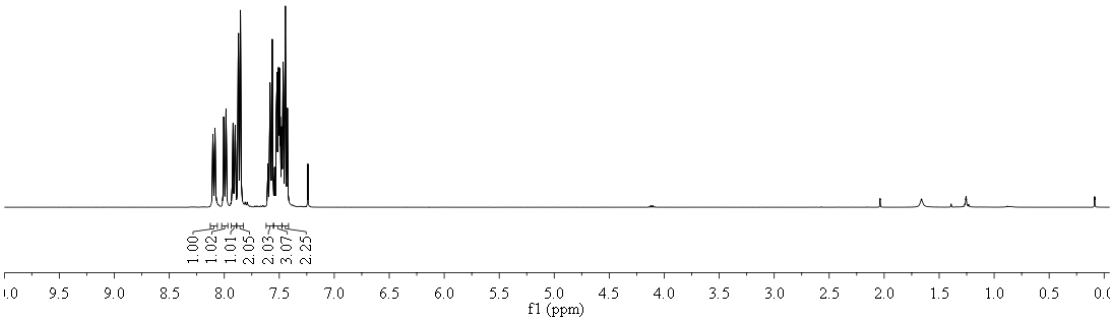

7.90 7.90 7.89 7.88 7.87 7.87 7.84 7.84 7.84 7.84 7.83 7.82 7.82 7.81 7.71 7.70 7.70 7.69 7.68 7.68 7.65 7.65 7.64 7.63 7.63 7.63 7.63 7.63 7.62 7.61 7.61 7.61 7.60 7.59 7.59 7.58 7.57 7.57 7.51 7.51 7.51 7.49 7.49 7.47 7.47 7.47 7.46 7.45 7.45 7.42 7.41 7.41 7.40 7.39 7.39 7.38 7.24 1.60
O
3na
1H NMR(400 MHz,CDCl3)
1.96 2.01 2.02 2.03 1.06 4.04 1.00
f1 (ppm)
196.33
145.20 139.95 137.72 136.20 132.35 130.71 129.98 128.94 128.28 128.16 127.28 126.94
77.32 77.00 76.68
O
3na
13C NMR(100 MHz,CDCl3)
f1 (ppm)

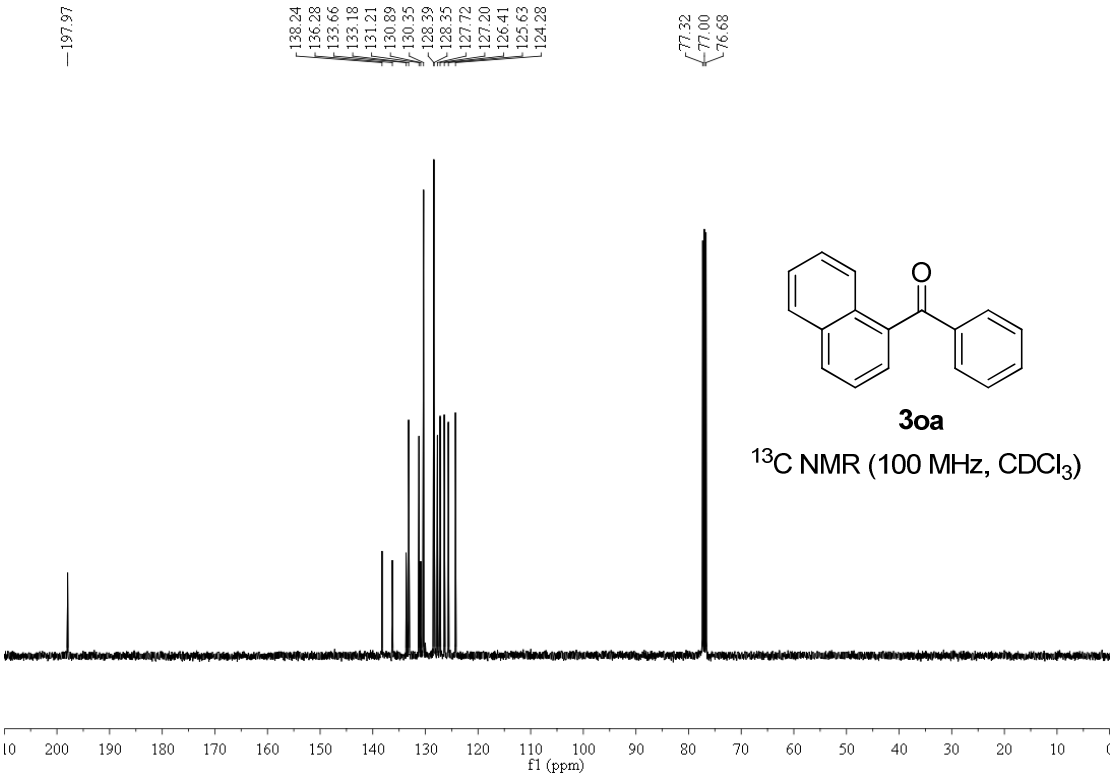




3oa

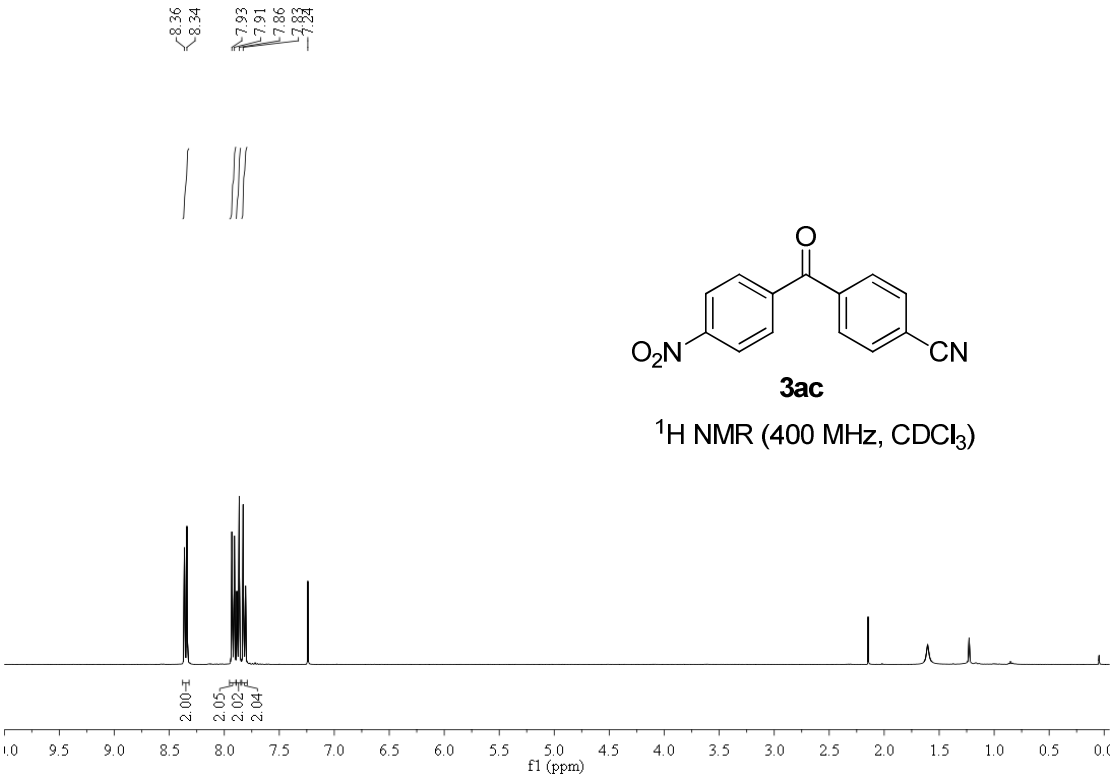
^{1}H NMR (400 MHz, $CDCl_3$)

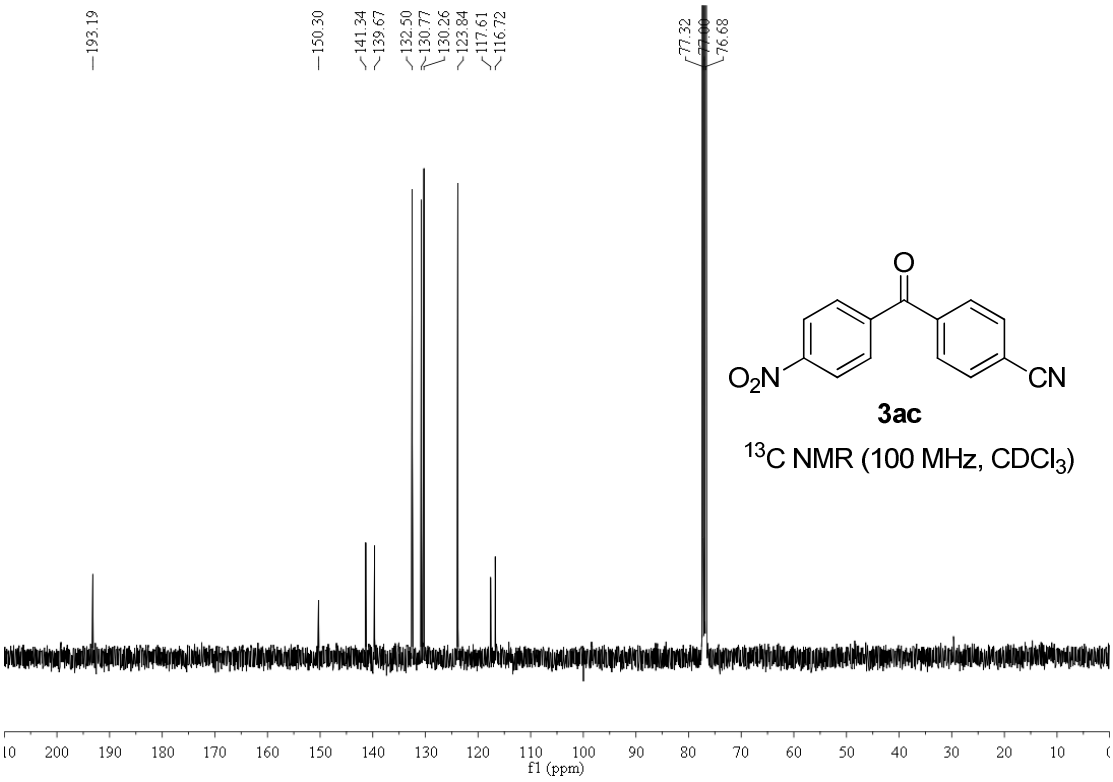


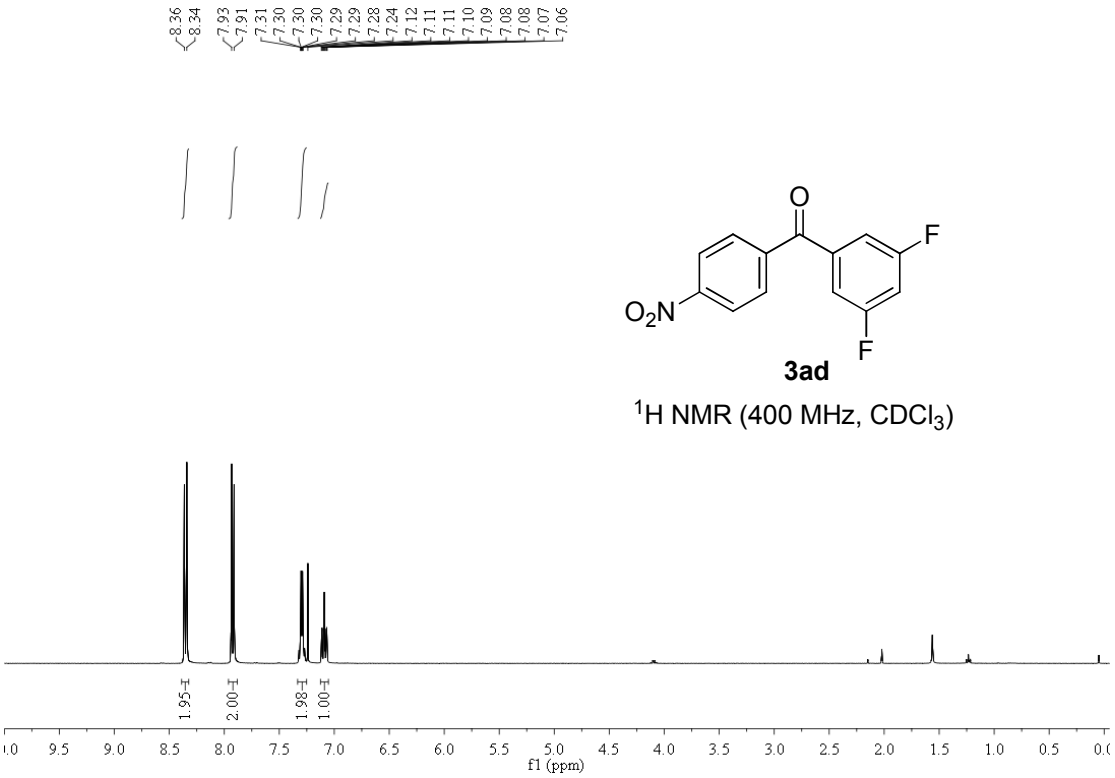


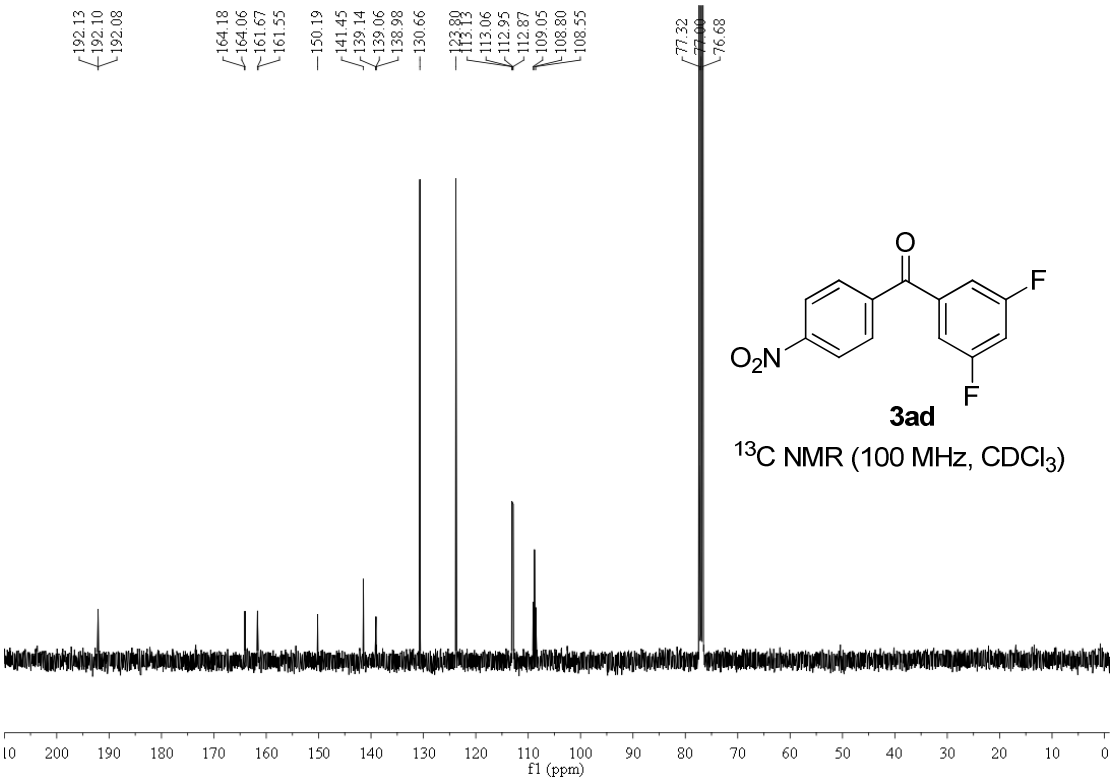
3oa

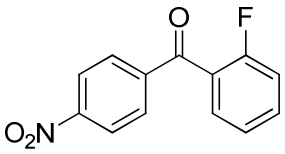
^{13}C NMR (100 MHz, $CDCl_3$)


8.36
8.34
7.93
7.91
7.86
7.83
7.24
O
O2N
CN
3ac
1H NMR (400 MHz, CDCl3)
2.00
2.05
2.02
2.04
f1 (ppm)


193.19
150.30
141.34
139.67
132.50
130.77
130.26
123.84
117.61
116.72
77.32
77.00
76.68
O
O2N
CN
3ac
13C NMR (100 MHz, CDCl3)
f1 (ppm)

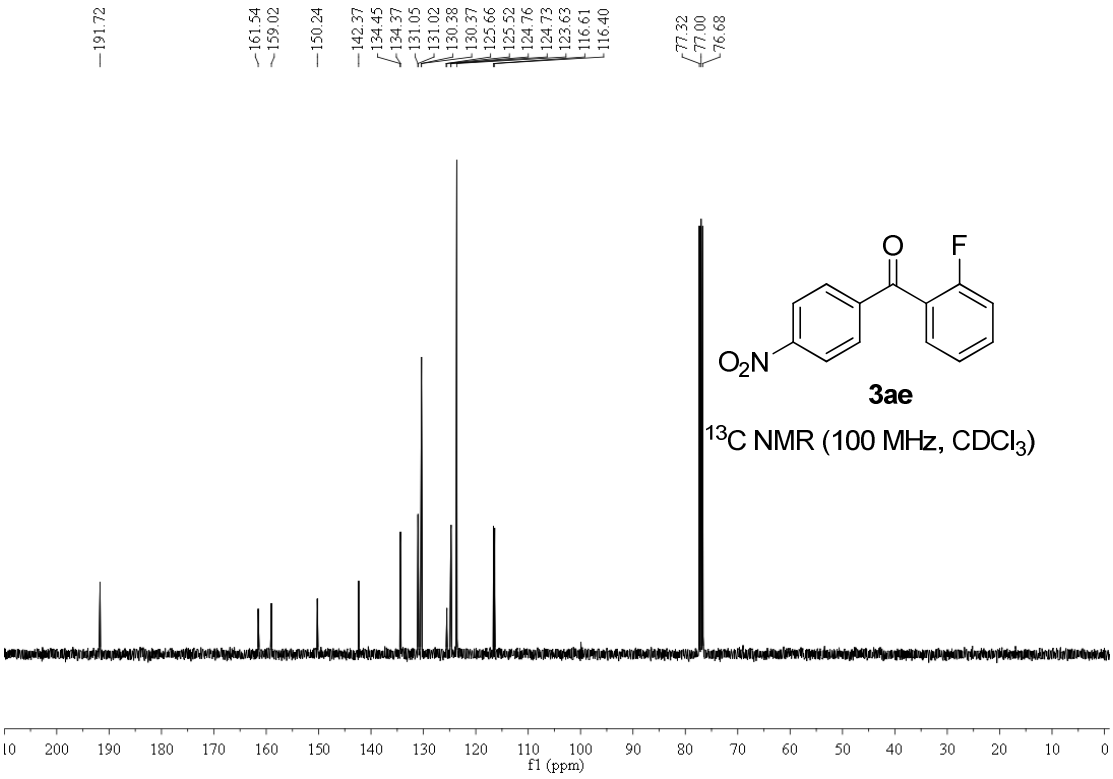

8.36
8.34
7.93
7.91
7.31
7.30
7.30
7.30
7.29
7.29
7.28
7.24
7.12
7.11
7.11
7.10
7.09
7.08
7.08
7.07
7.06
O
F
O2N
F
3ad
1H NMR (400 MHz, CDCl3)
1.95
2.00
1.98
1.00
f1 (ppm)


192.13
192.10
192.08
164.18
164.06
161.67
161.55
150.19
141.45
139.14
139.06
138.98
130.66
123.80
123.13
113.06
112.95
112.87
109.05
108.80
108.55
77.32
77.00
76.68
O
F
O2N
F
3ad
13C NMR (100 MHz, CDCl3)
f1 (ppm)



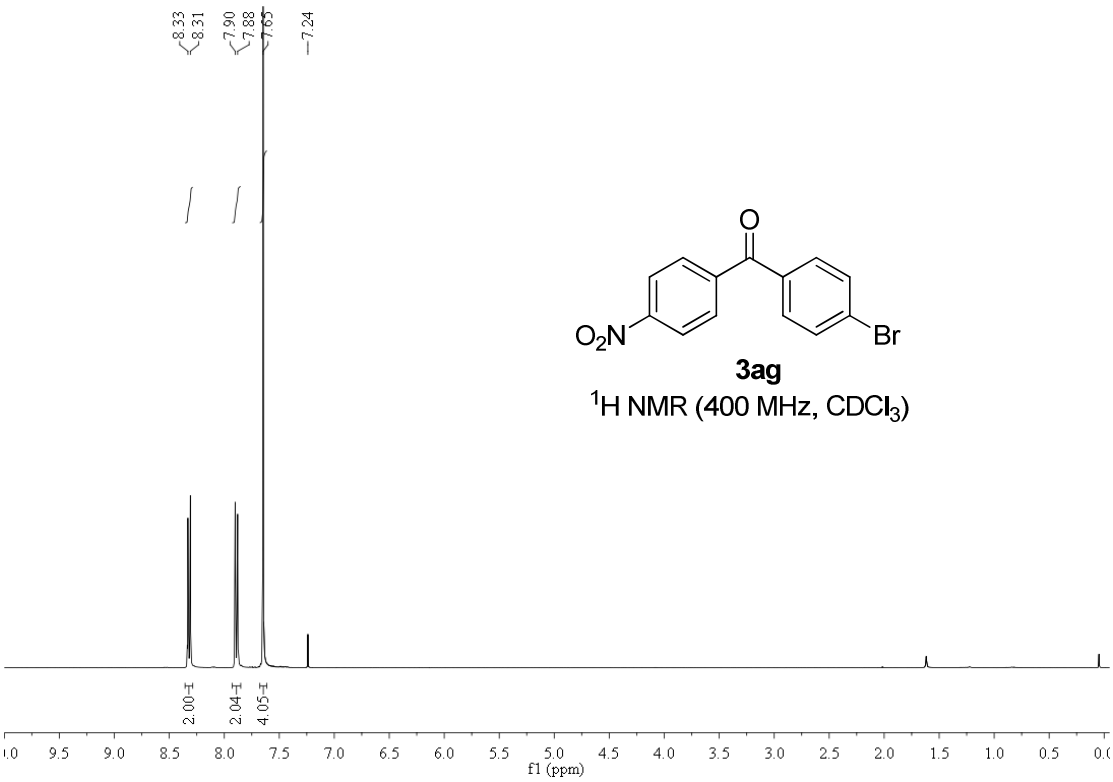
3ae

^{1}H NMR (400 MHz, $CDCl_3$)



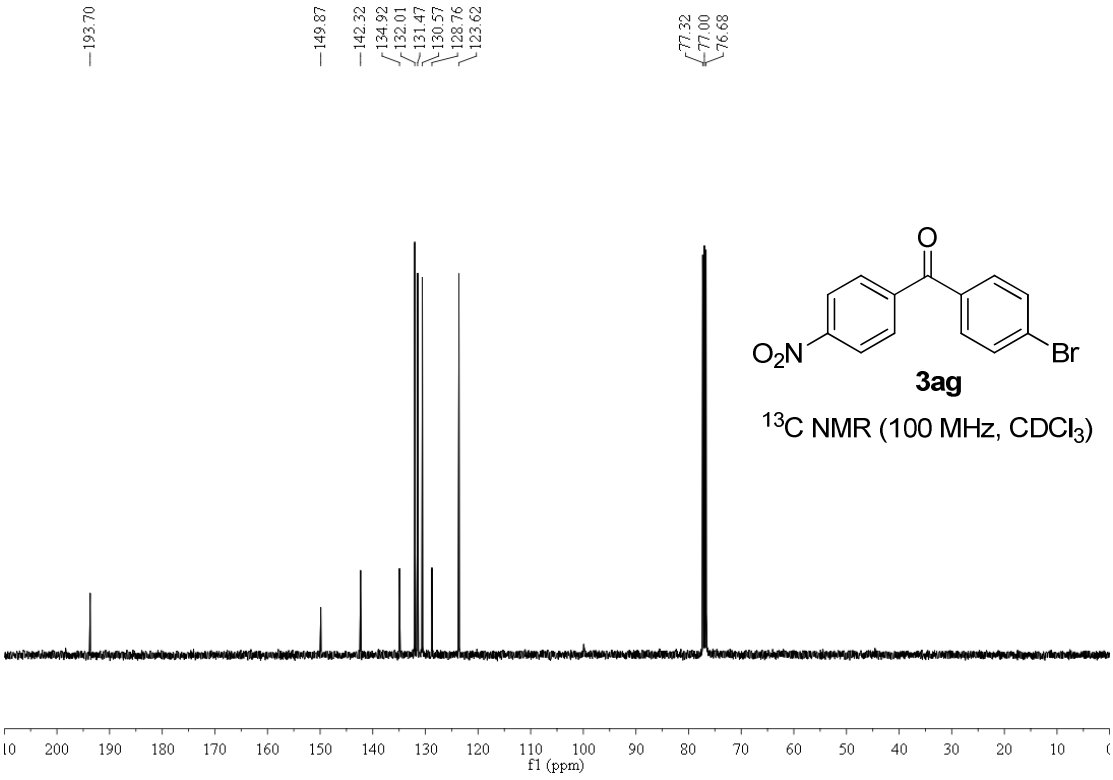
3ae

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



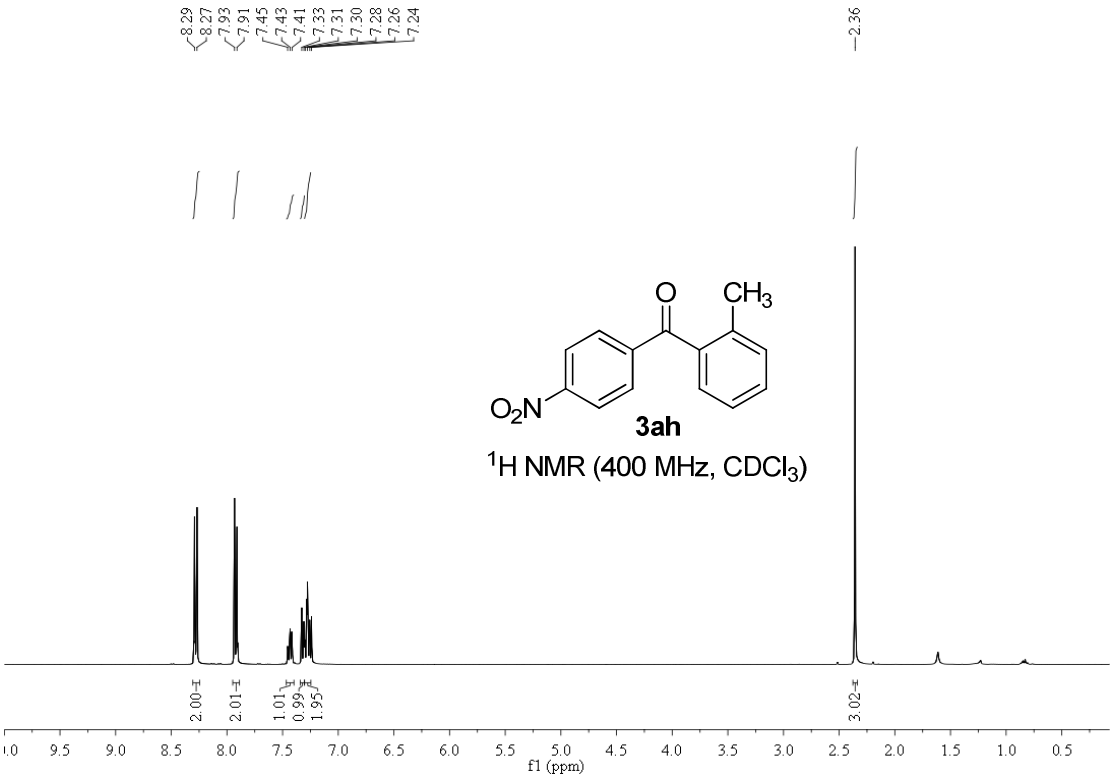
3ag

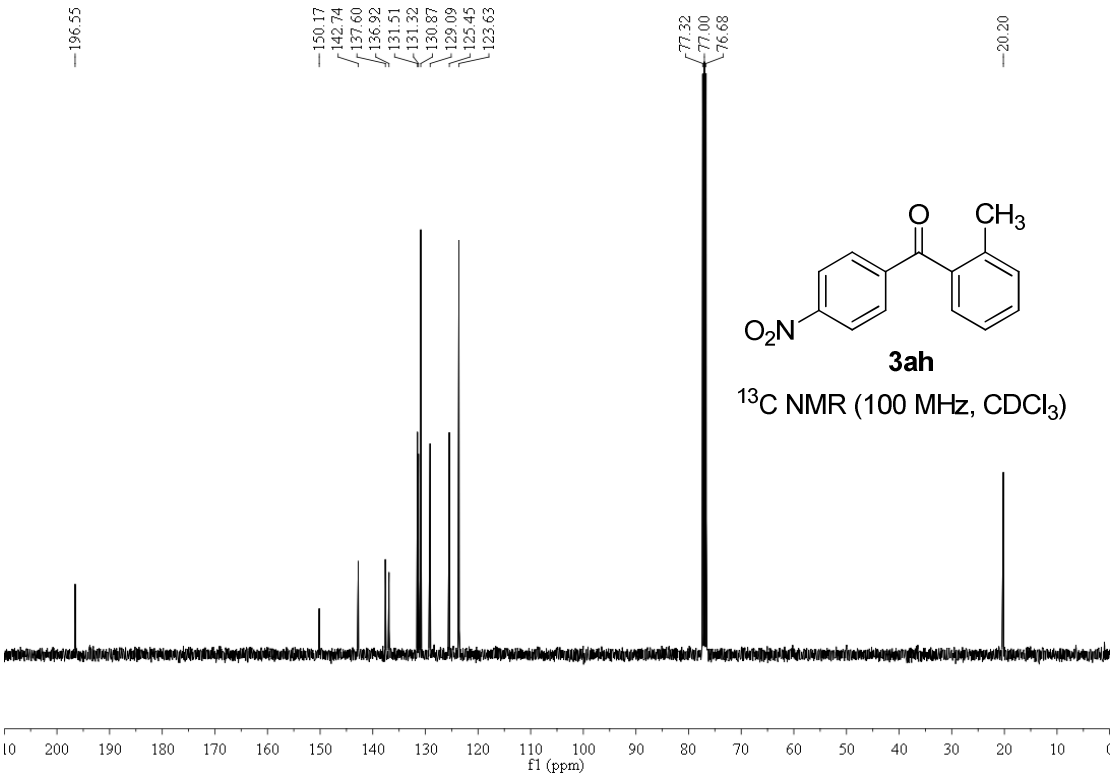
^{1}H NMR (400 MHz, $CDCl_3$)

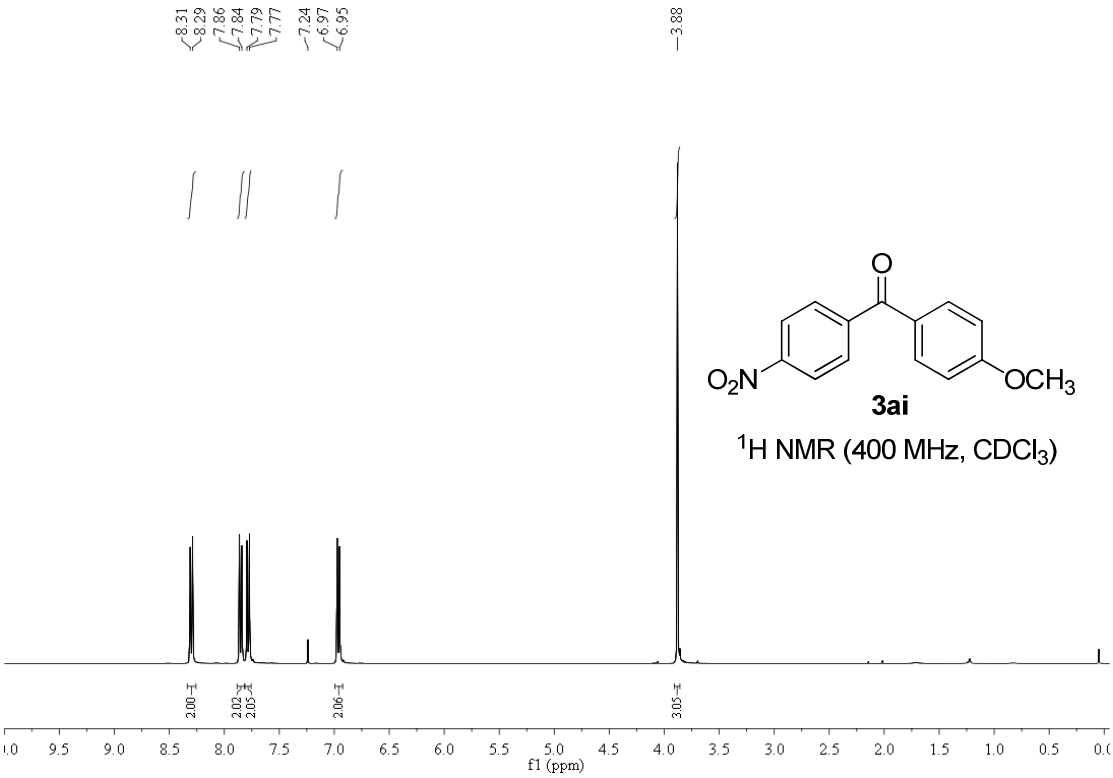


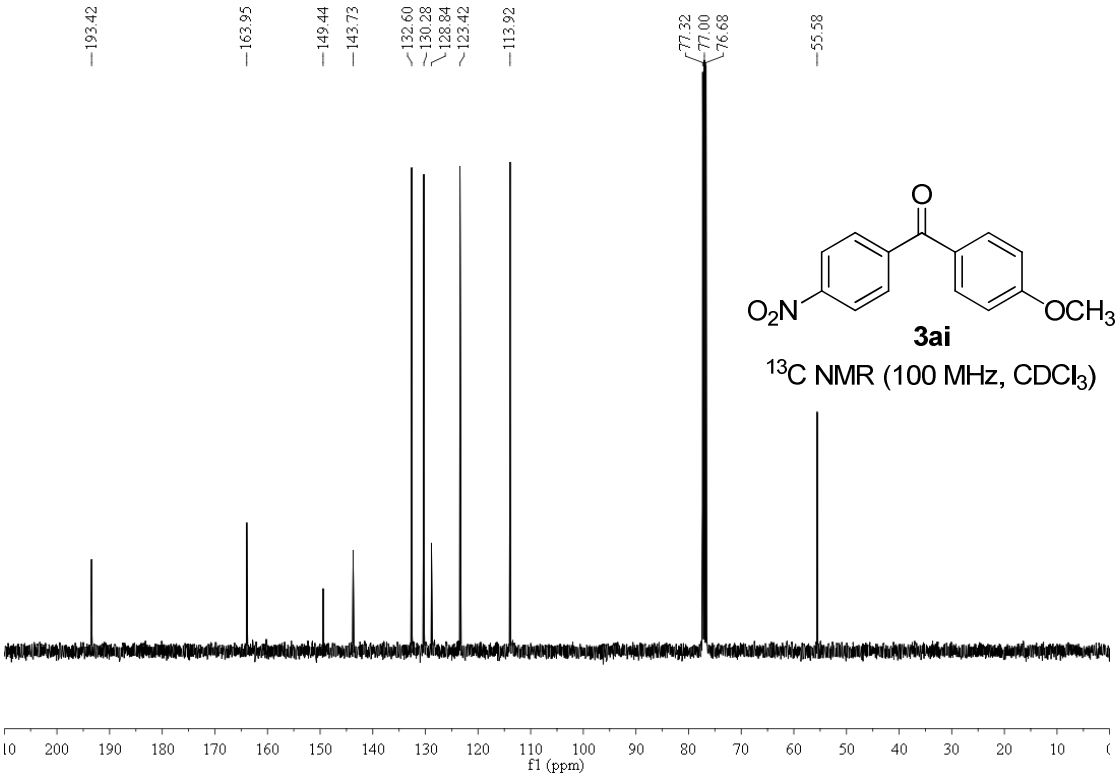
3ag

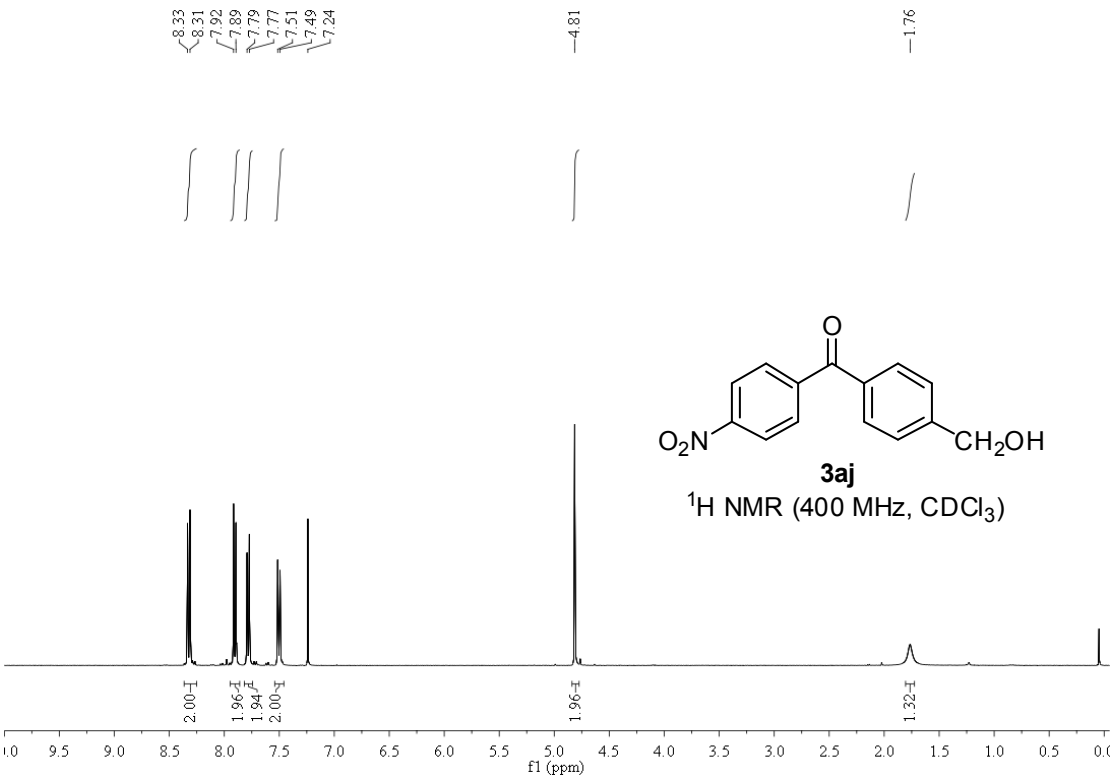
^{13}C NMR (100 MHz, $CDCl_3$)

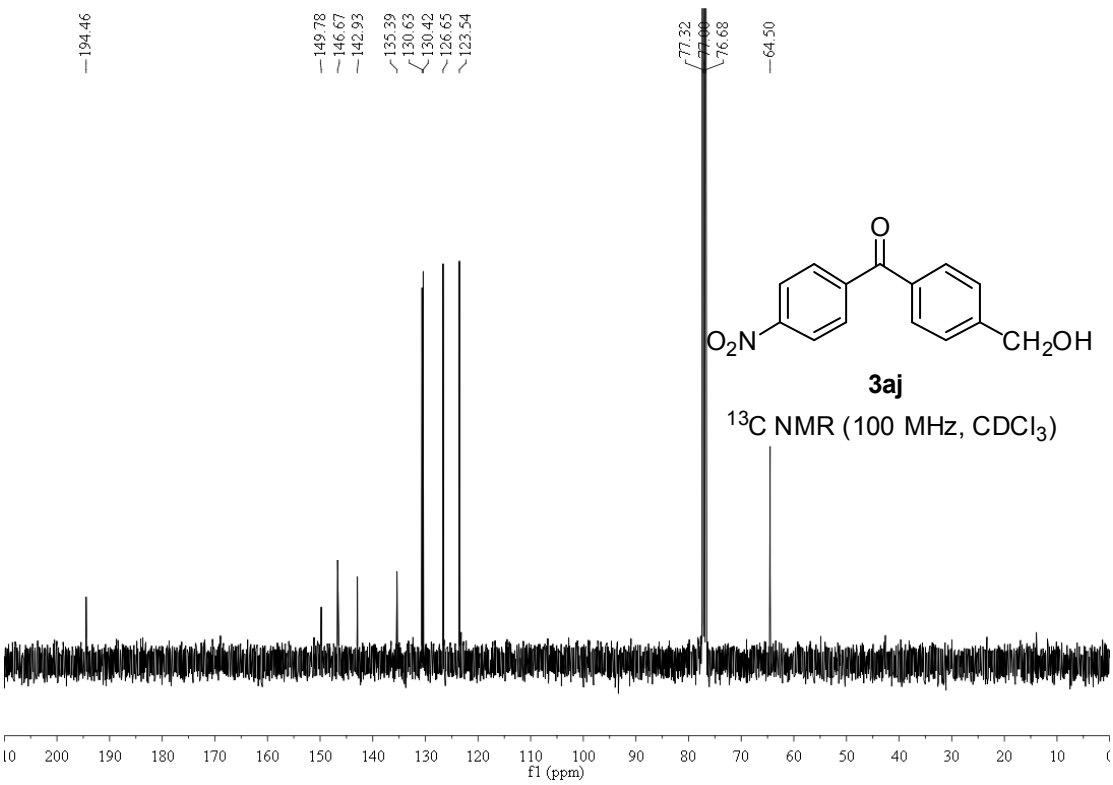

8.29
8.27
7.93
7.91
7.45
7.43
7.41
7.33
7.31
7.30
7.28
7.26
7.24
2.36
O
CH3
O2N
3ah
1H NMR (400 MHz, CDCl3)
2.00
2.01
1.01
0.99
1.95
3.02
f1 (ppm)

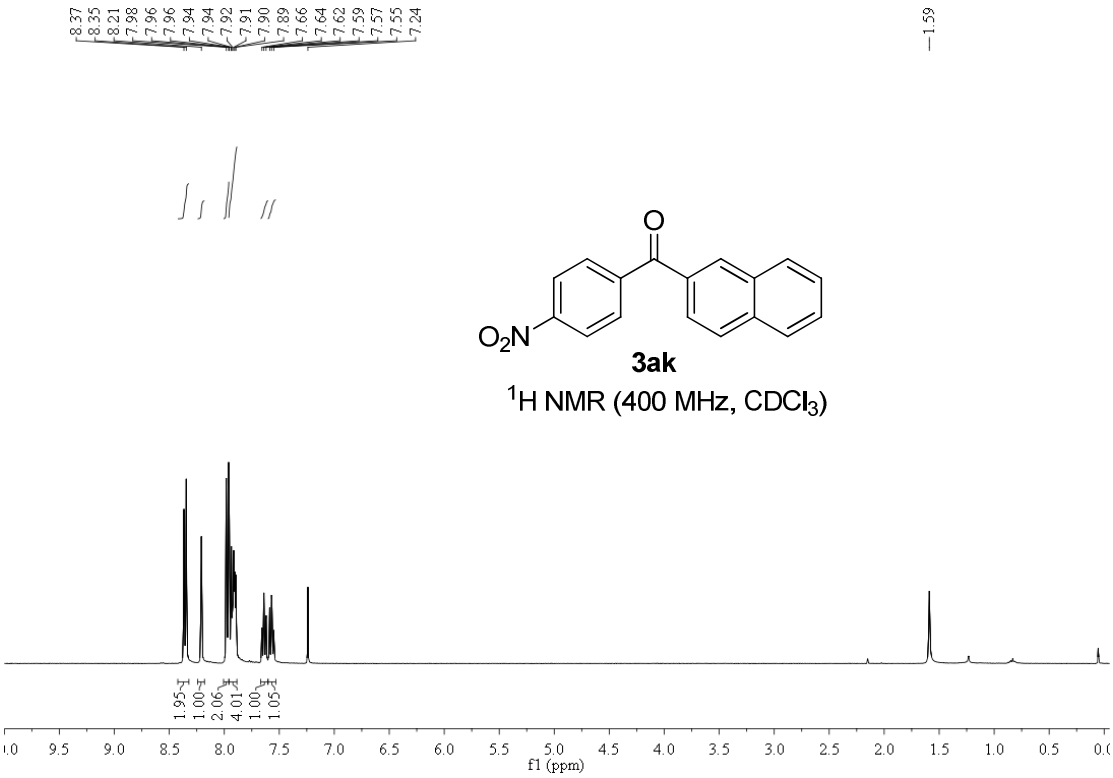

196.55
150.17
142.74
137.60
136.92
131.51
131.32
130.87
129.09
125.45
123.63
77.32
77.00
76.68
20.20
O
CH3
O2N
3ah
13C NMR (100 MHz, CDCl3)
f1 (ppm)

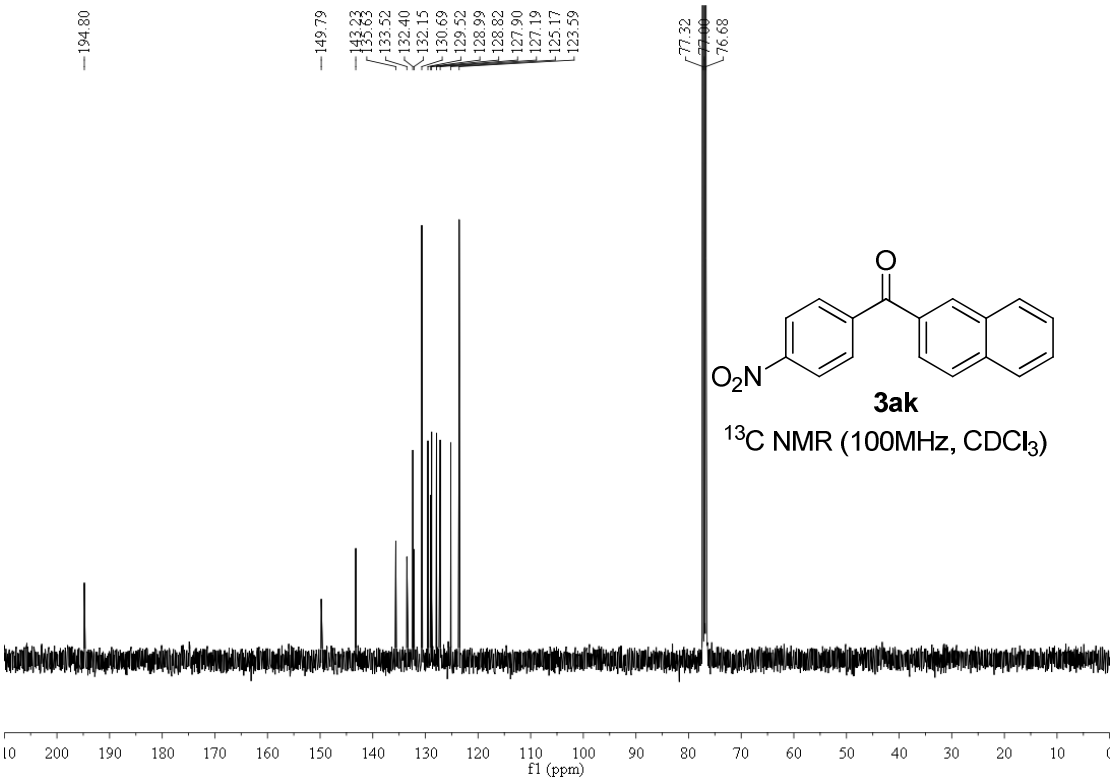

8.31
8.29
7.86
7.84
7.79
7.77
7.24
6.97
6.95
3.88
O
O2N
OCH3
3ai
1H NMR (400 MHz, CDCl3)
2.00
2.02
2.05
2.06
3.05
f1 (ppm)

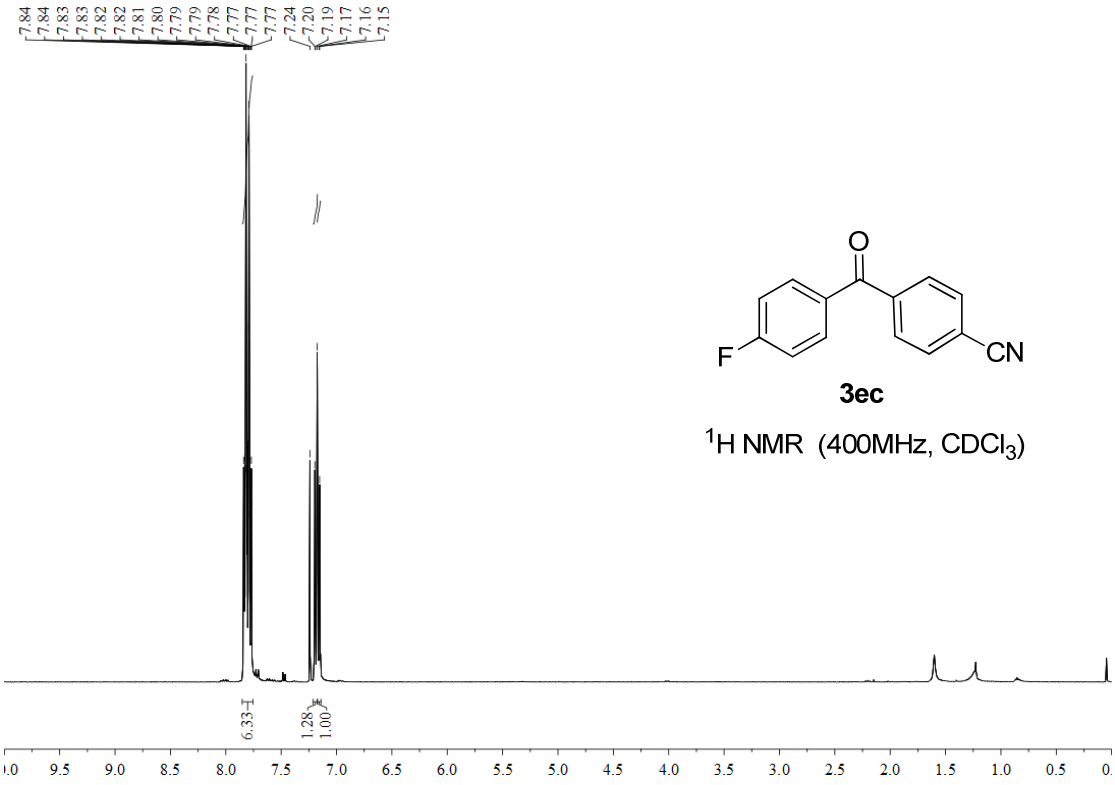

193.42
163.95
149.44
143.73
132.60
130.28
128.84
123.42
113.92
77.32
77.00
76.68
55.58
O
O2N
OCH3
3ai
13C NMR (100 MHz, CDCl3)
f1 (ppm)


8.33
8.31
7.92
7.89
7.79
7.77
7.51
7.49
7.24
4.81
1.76
O
O2N
CH2OH
3aj
1H NMR (400 MHz, CDCl3)
2.00
1.96
1.94
2.00
1.96
1.32
f1 (ppm)


194.46
149.78
146.67
142.93
135.39
130.63
130.42
126.65
123.54
77.32
77.00
76.68
64.50
O
O2N
CH2OH
3aj
13C NMR (100 MHz, CDCl3)
f1 (ppm)

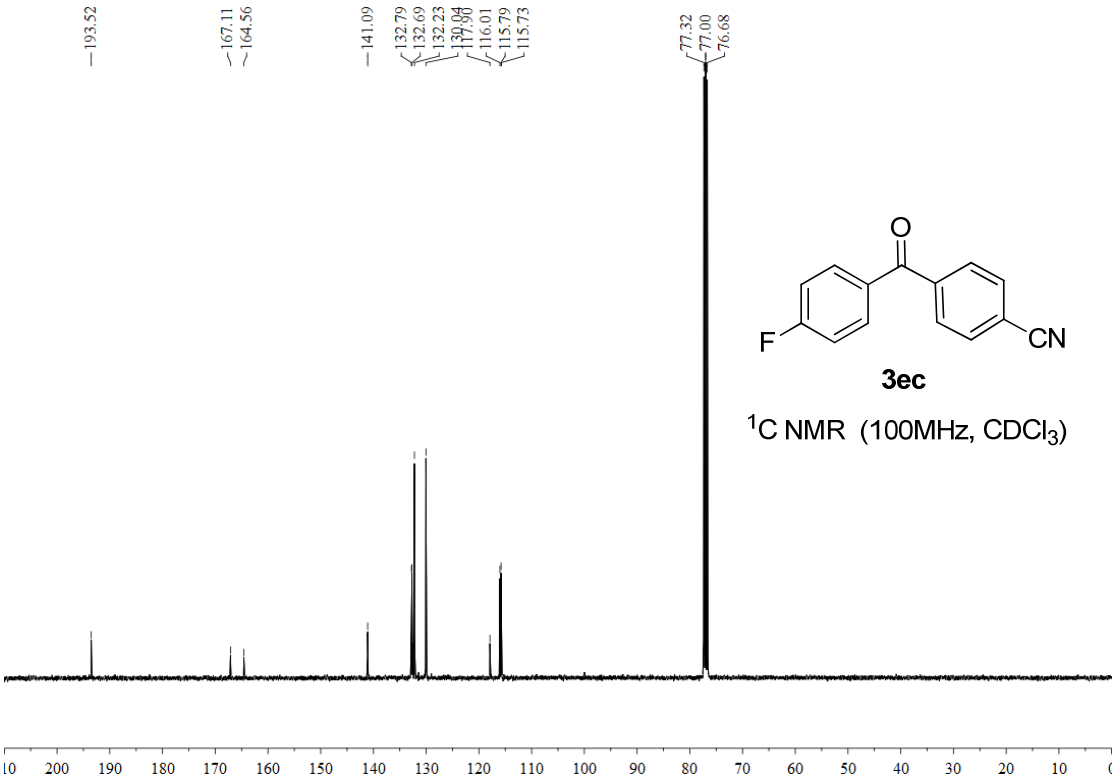

8.37
8.35
8.21
7.98
7.96
7.96
7.94
7.94
7.92
7.91
7.90
7.89
7.66
7.64
7.62
7.59
7.57
7.55
7.24
1.59
O
O2N
3ak
1H NMR (400 MHz, CDCl3)
1.95
1.00
2.06
4.01
1.00
1.05
f1 (ppm)


194.80
149.79
143.23
135.63
133.52
132.40
132.15
130.69
129.52
128.99
128.82
127.90
127.19
125.17
123.59
77.32
77.00
76.68
O
O2N
3ak
13C NMR (100MHz, CDCl3)
f1 (ppm)



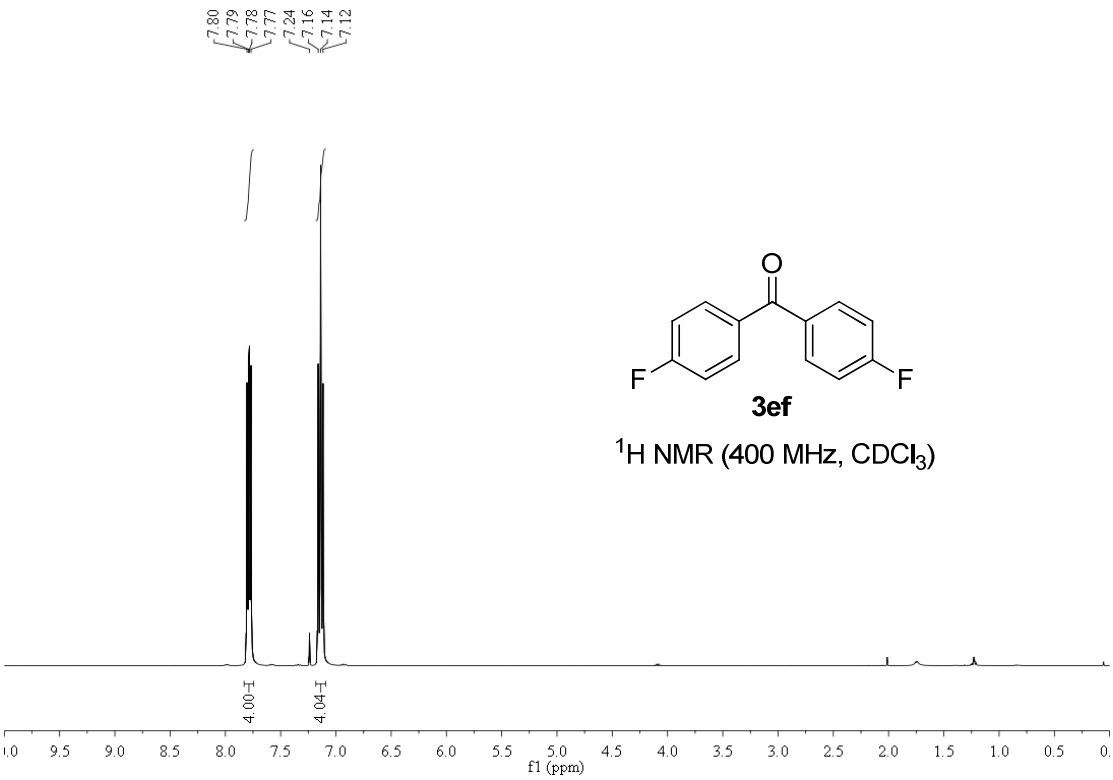
3ec

^{1}H NMR (400MHz, $CDCl_3$)



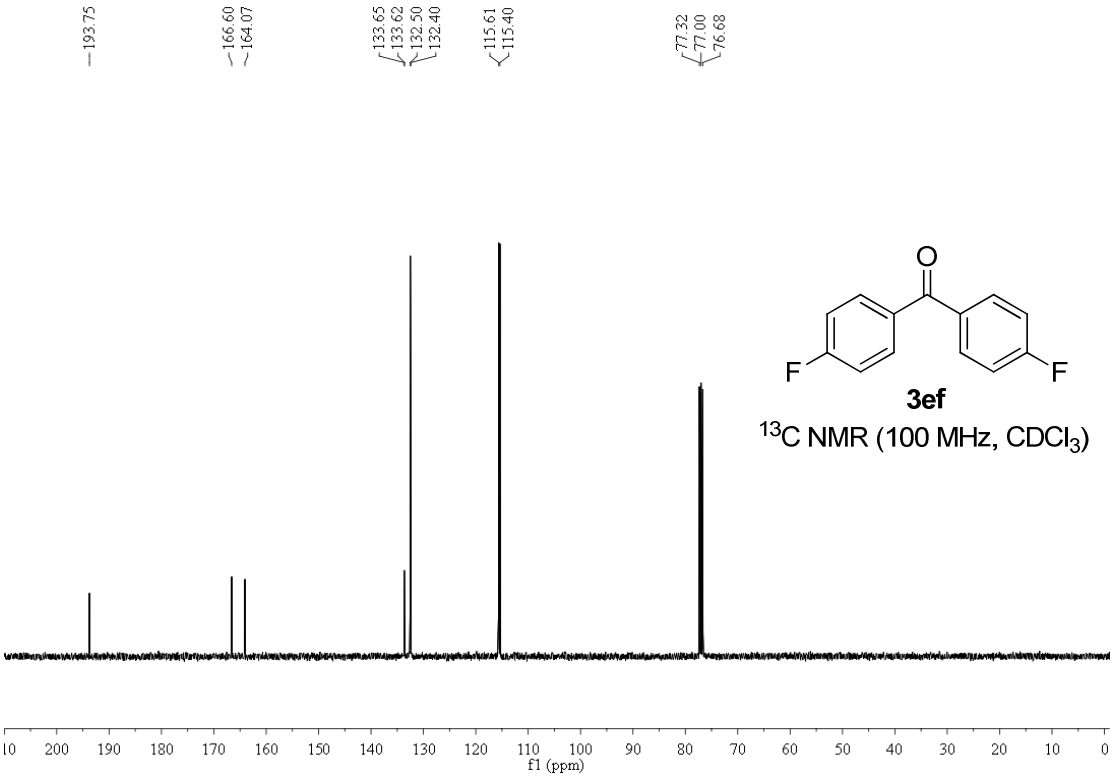
3ec

^{1}C NMR (100MHz, $CDCl_3$)



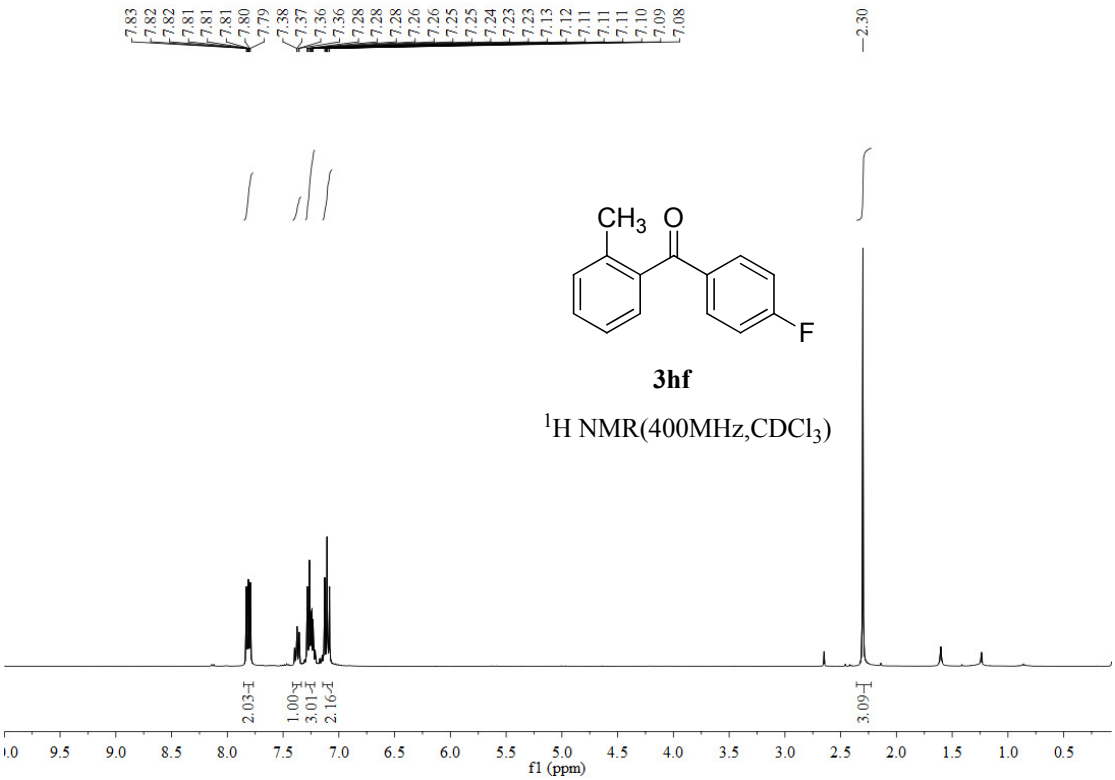
3ef

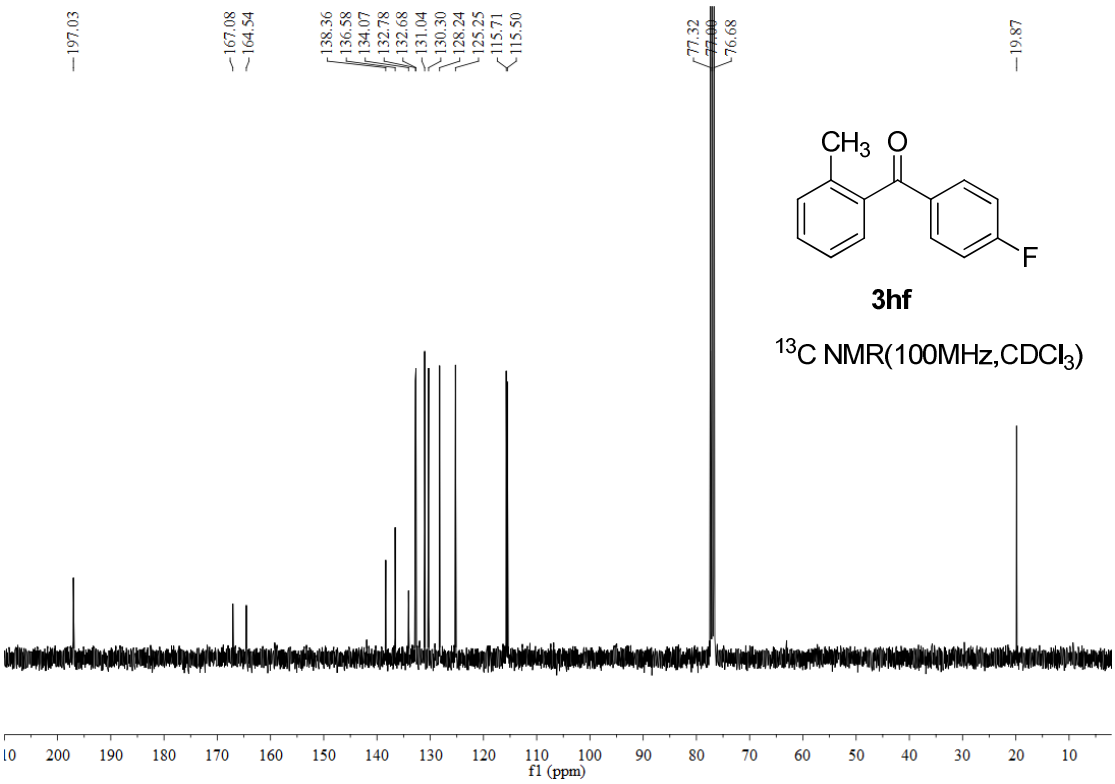
^{1}H NMR (400 MHz, $CDCl_3$)

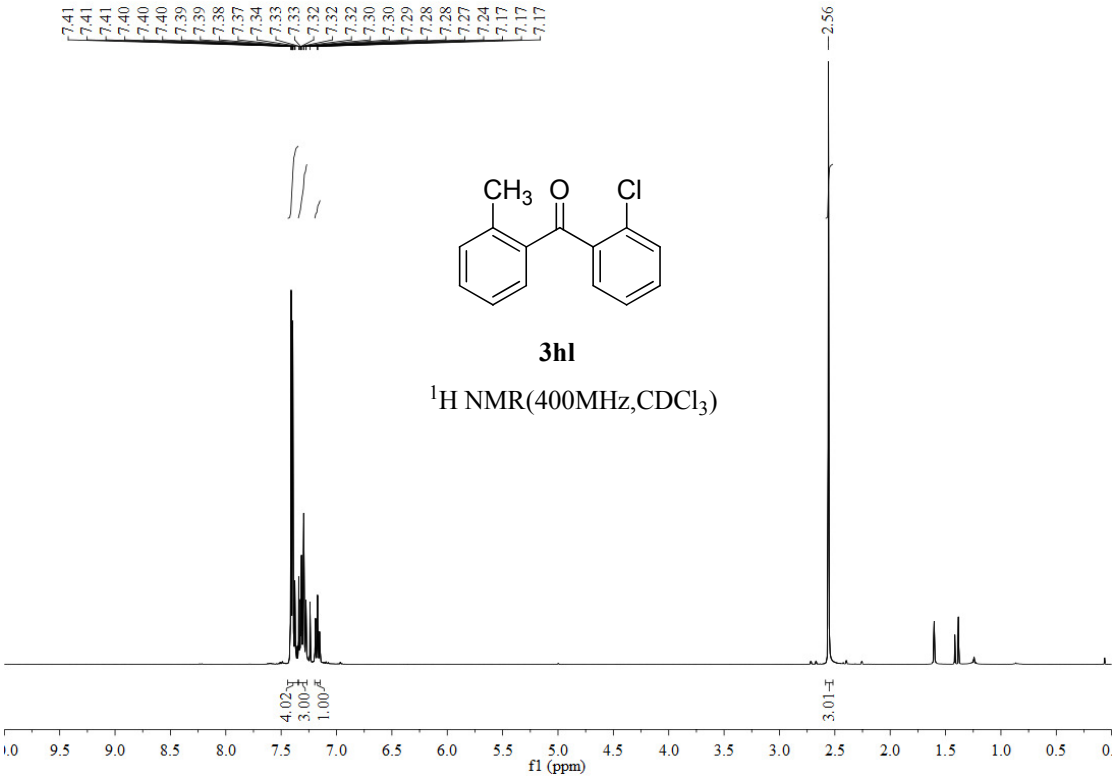


3ef

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

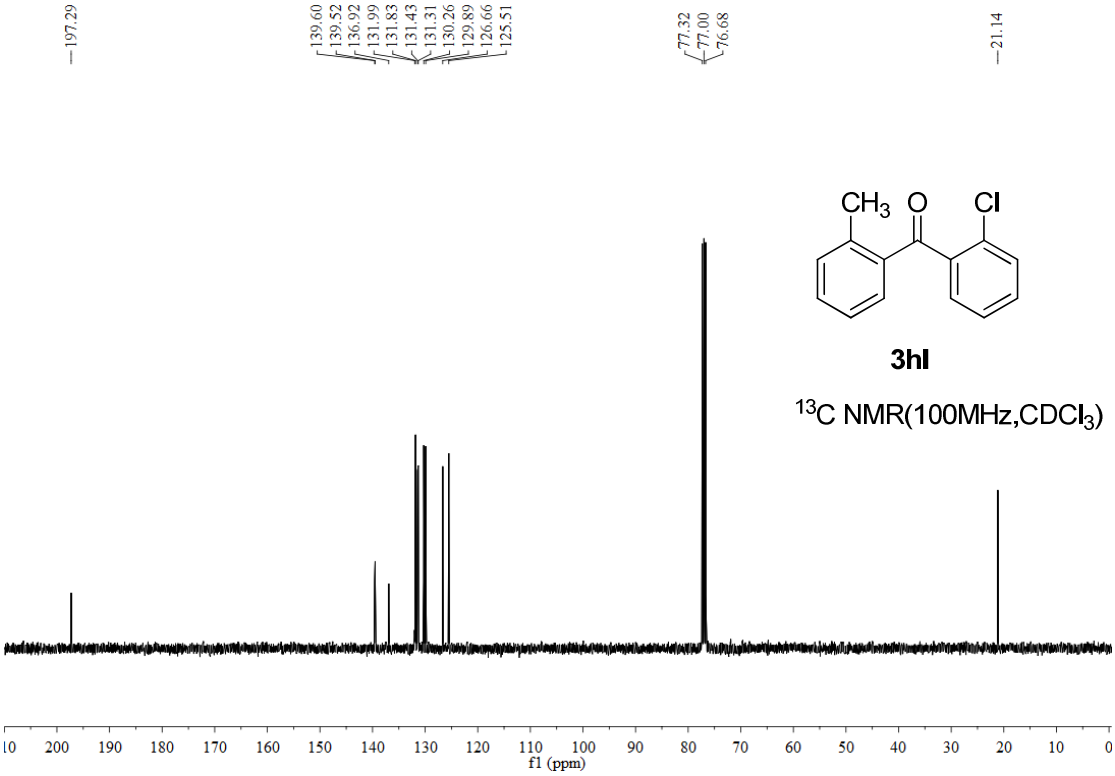

7.83
7.82
7.82
7.81
7.81
7.81
7.80
7.79
7.38
7.37
7.36
7.36
7.28
7.28
7.28
7.26
7.26
7.25
7.25
7.24
7.23
7.23
7.13
7.12
7.11
7.11
7.11
7.10
7.09
7.08
2.30
CH3 O
F
3hf
1H NMR(400MHz,CDCl3)
2.03
1.00
3.01
2.16
3.09
f1 (ppm)


197.03
167.08
164.54
138.36
136.58
134.07
132.78
132.68
131.04
130.30
128.24
125.25
115.71
115.50
77.32
77.00
76.68
19.87
CH3 O
F
3hf
13C NMR(100MHz,CDCl3)
f1 (ppm)



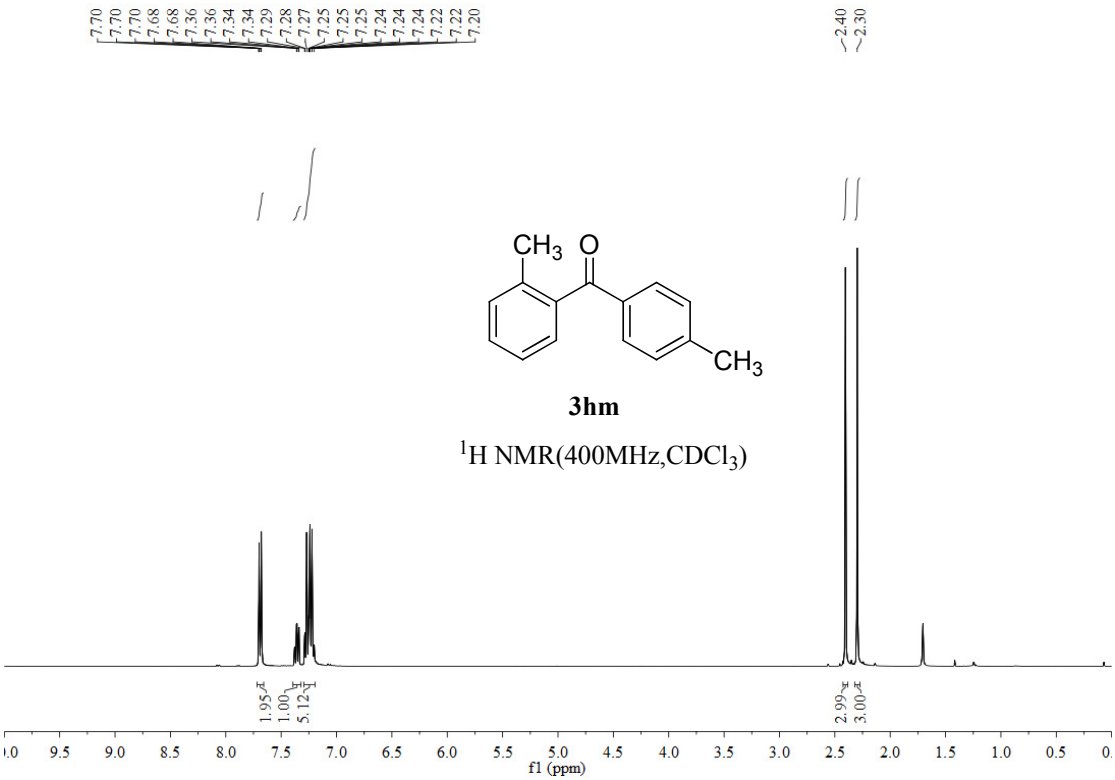
3hl

^{1}H NMR(400MHz,$CDCl_3$)



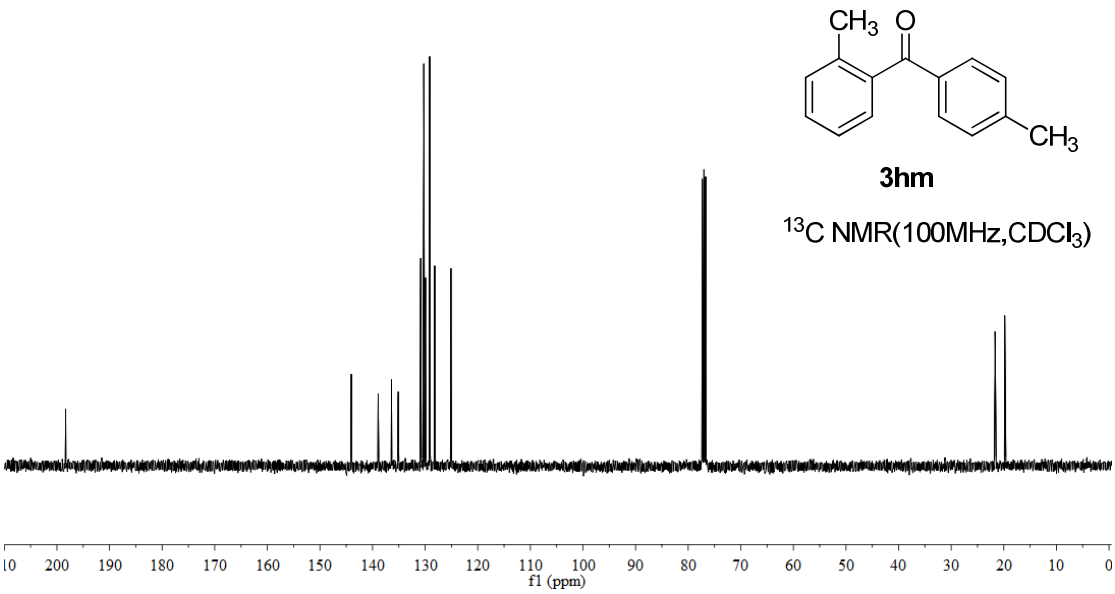
3hl

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



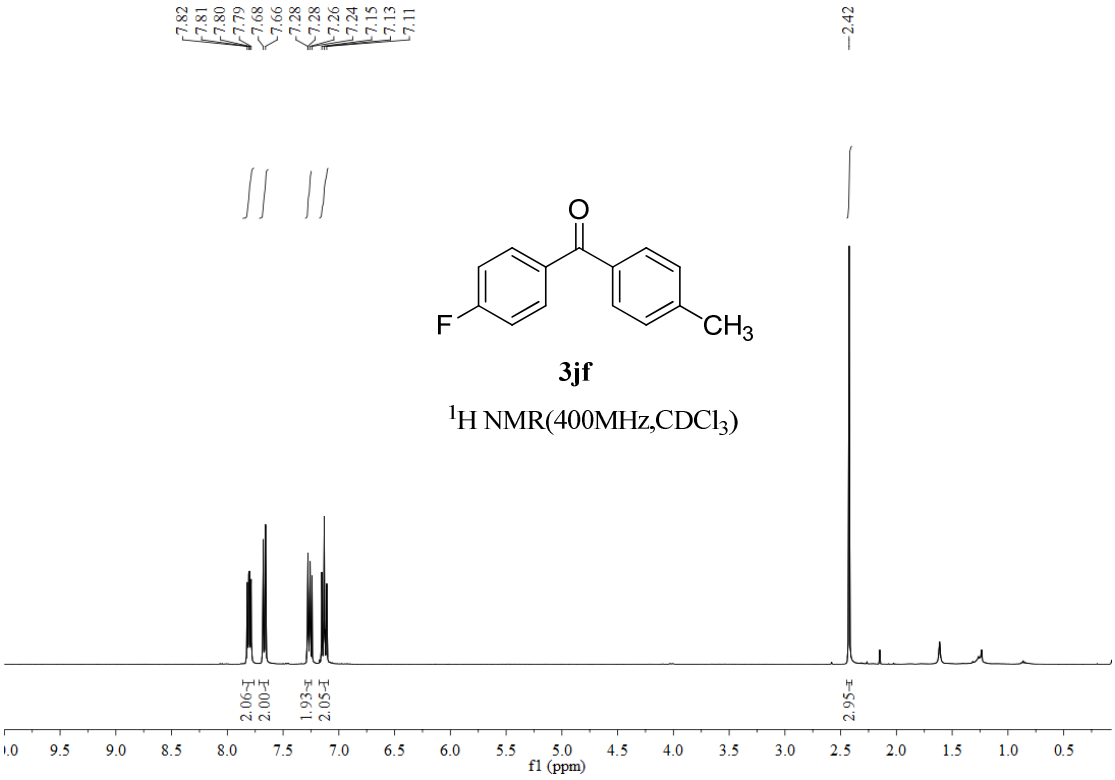
3hm

^{1}H NMR(400MHz,$CDCl_3$)



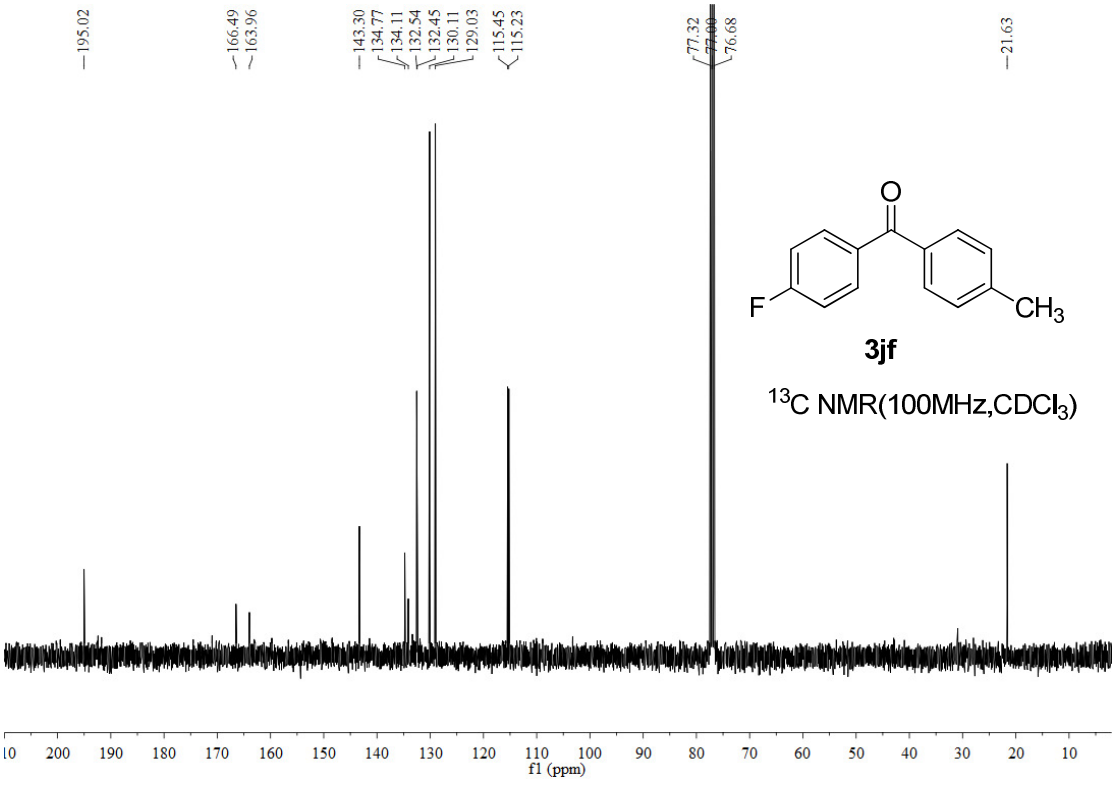
3hm

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



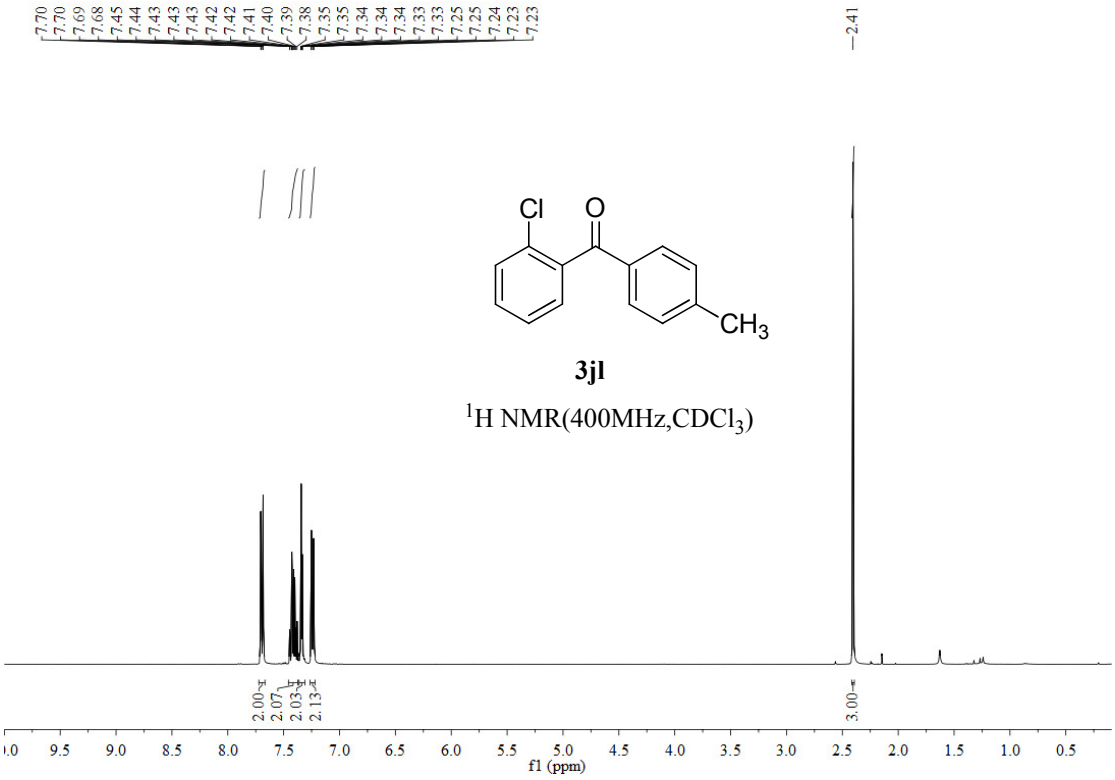
3jf

^{1}H NMR(400MHz,$CDCl_3$)



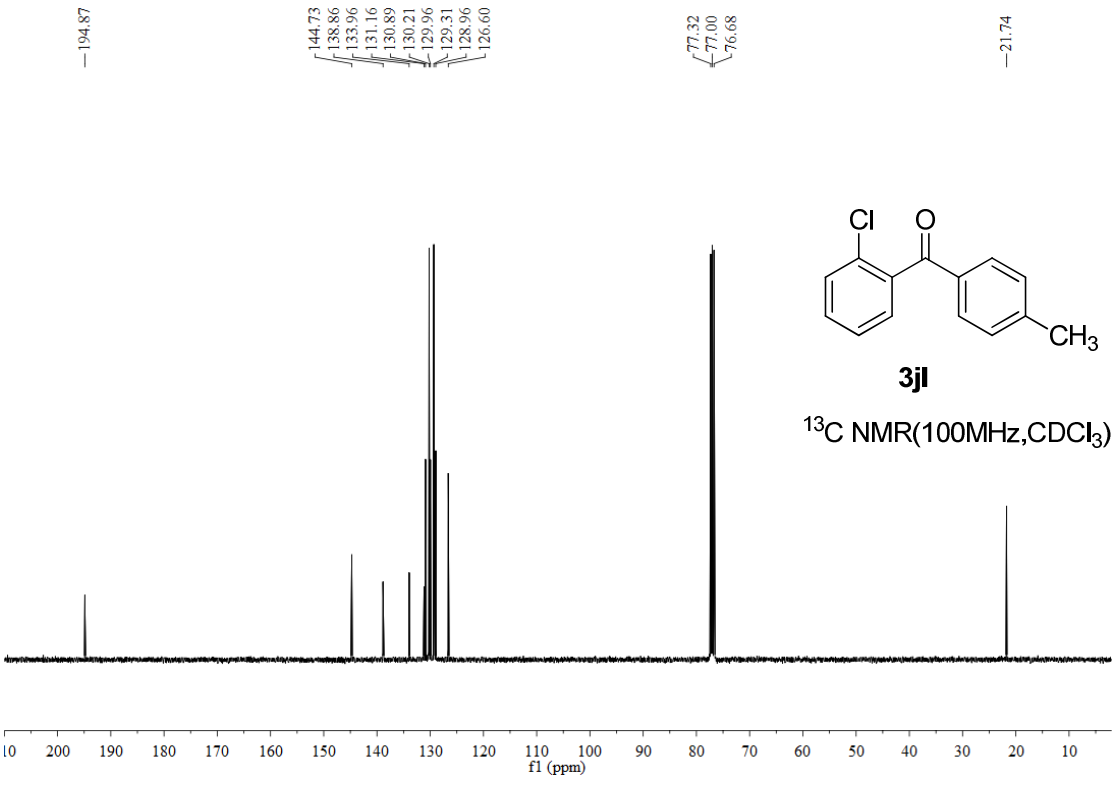
3jf

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



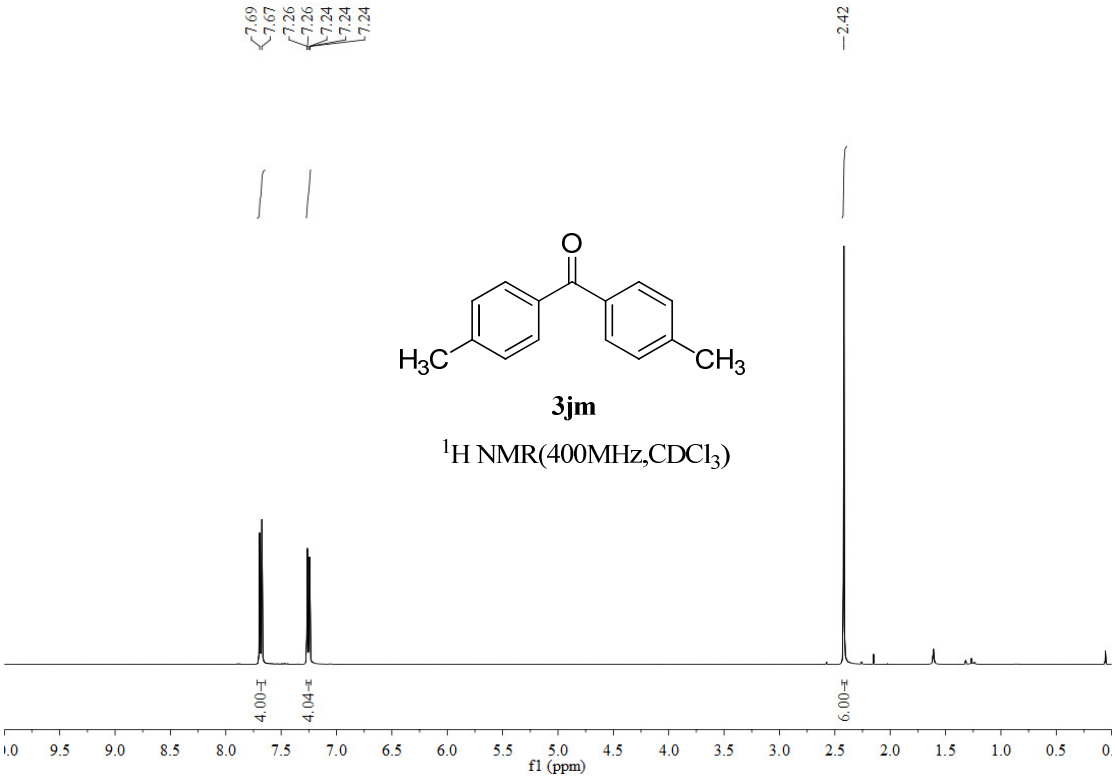
3jl

^{1}H NMR(400MHz,$CDCl_3$)



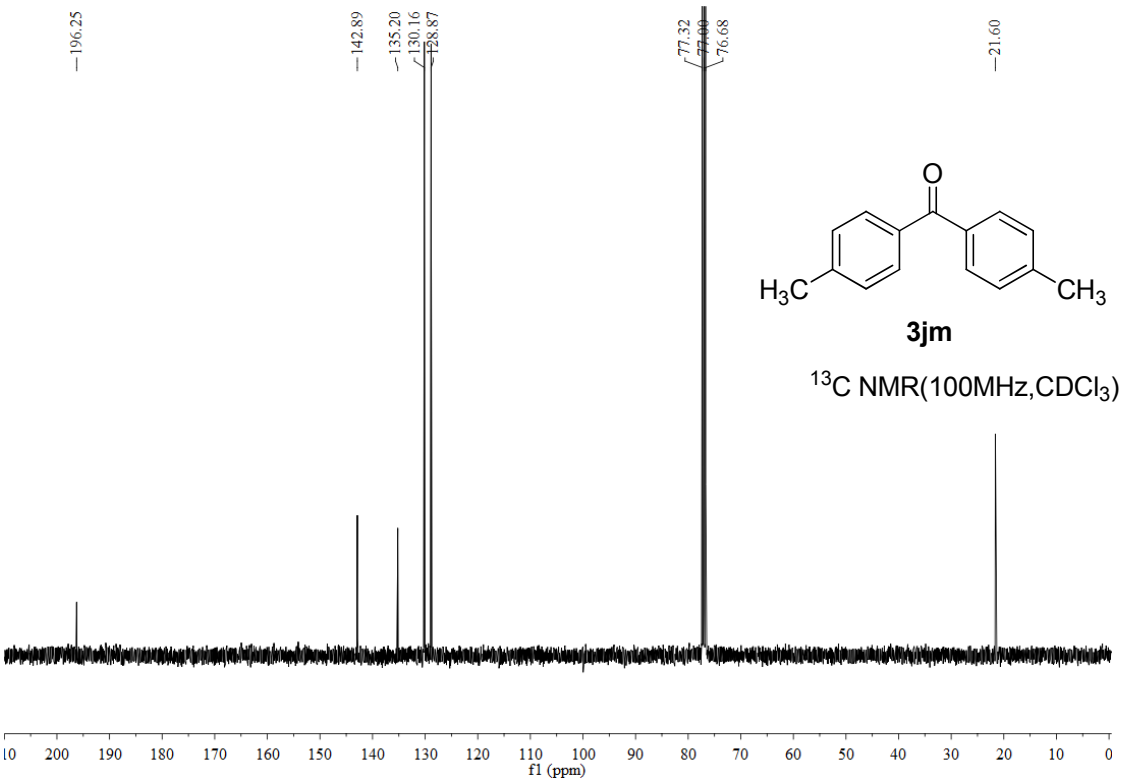
3jl

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



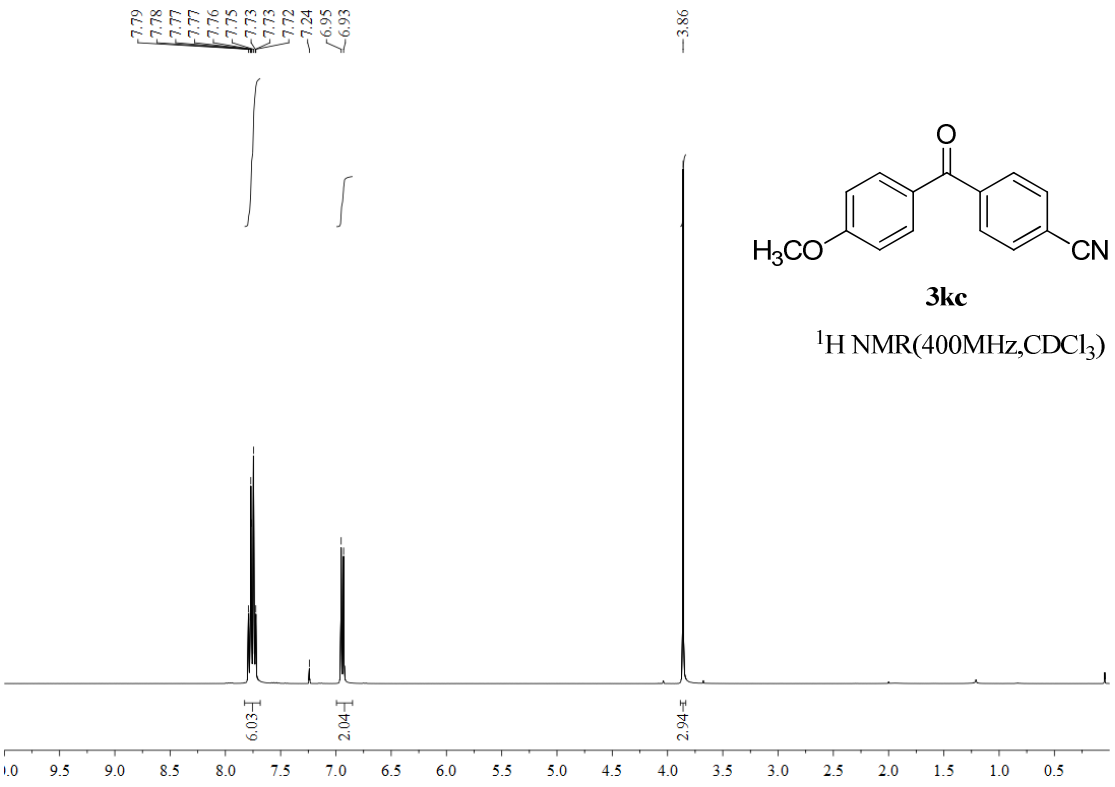
3jm

^{1}H NMR(400MHz,$CDCl_3$)



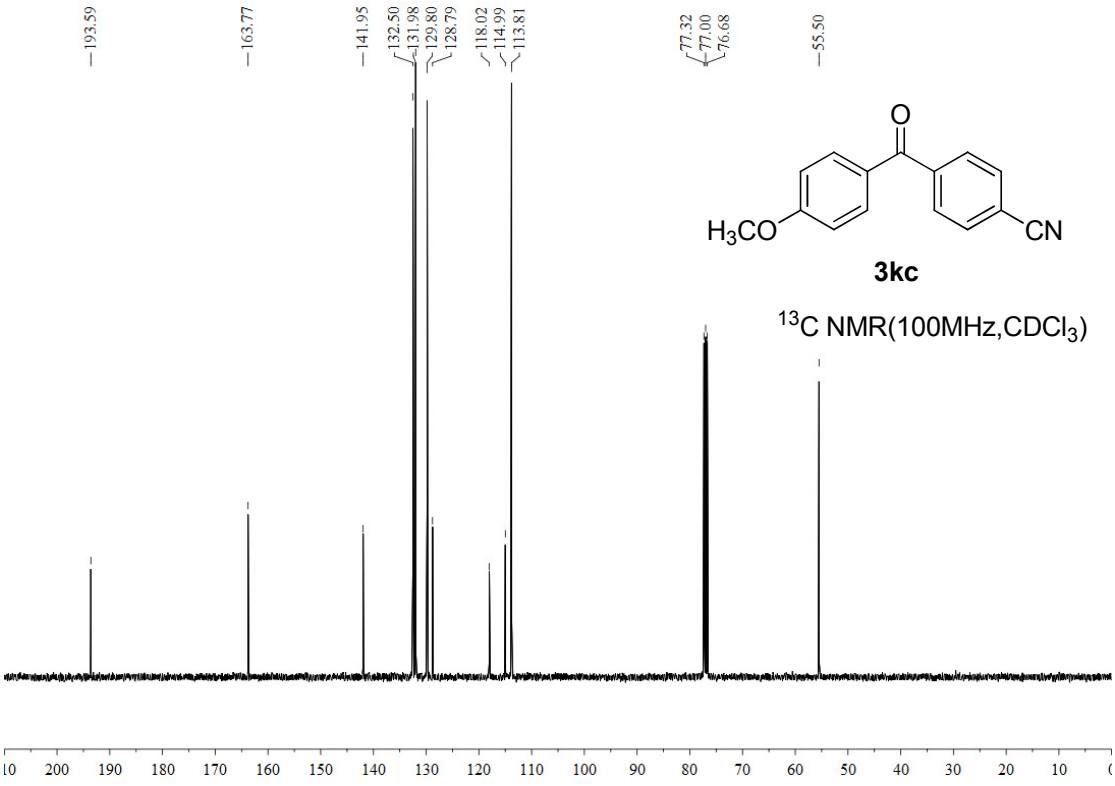
3jm

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



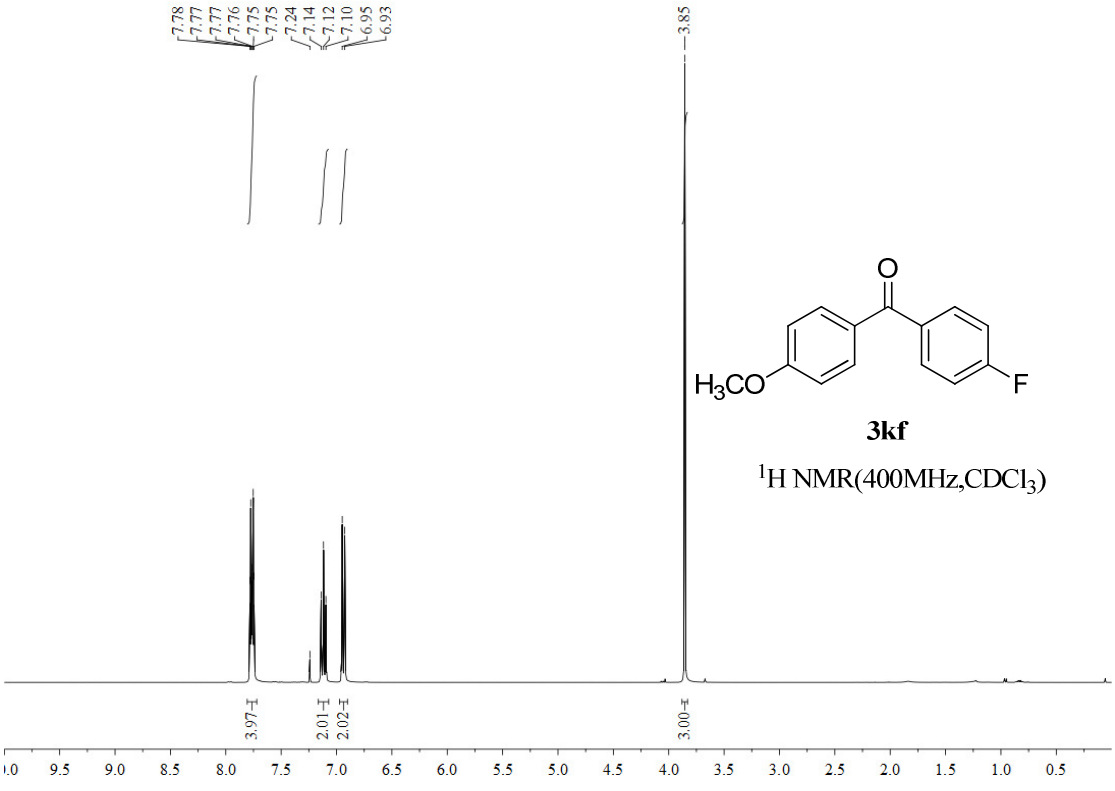
3kc

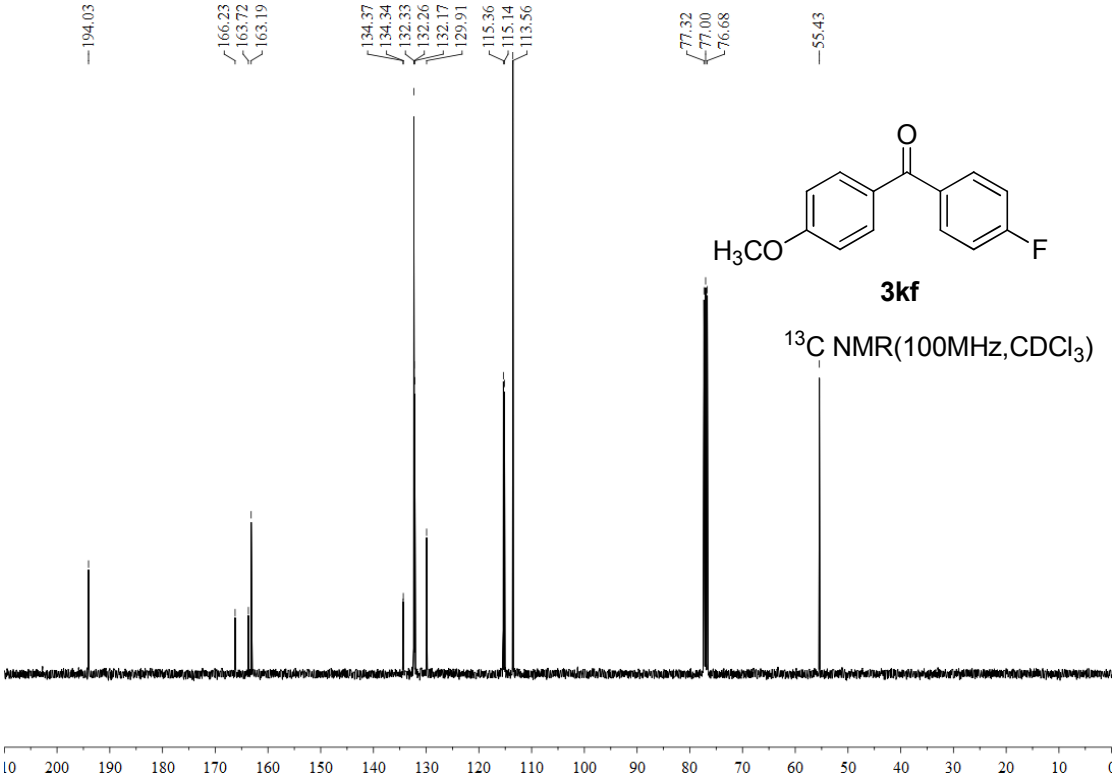
^{1}H NMR(400MHz,$CDCl_3$)

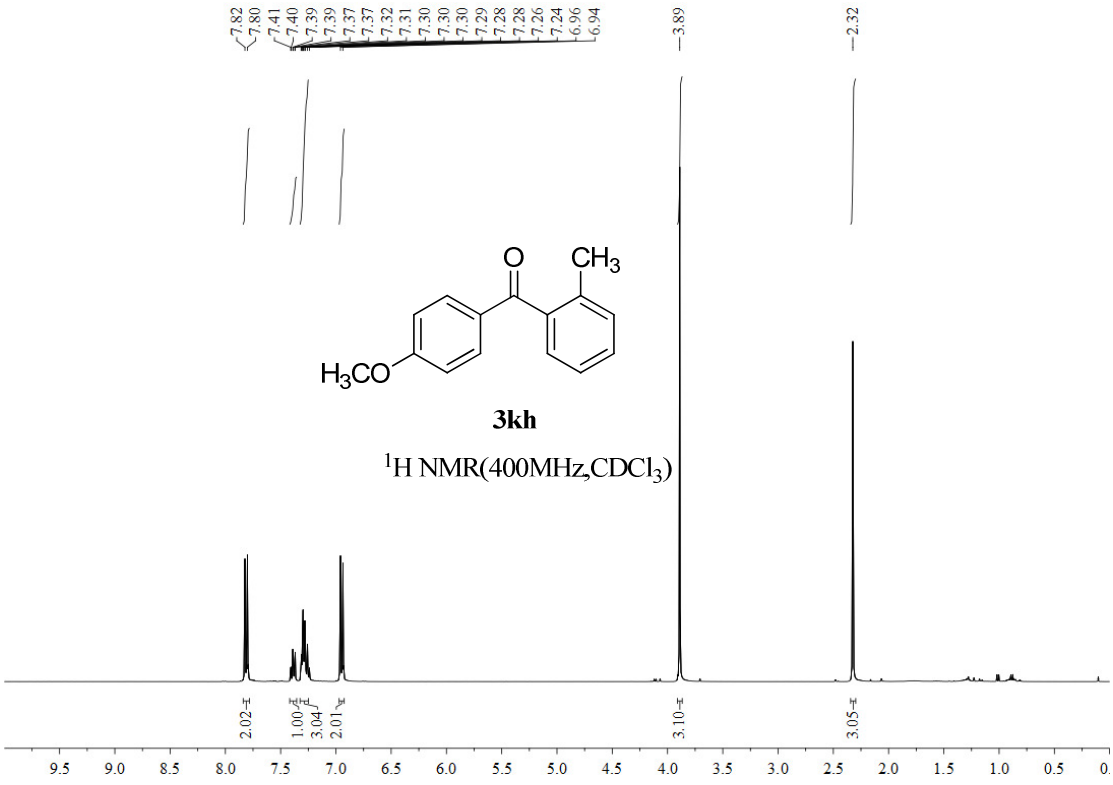


3kc

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

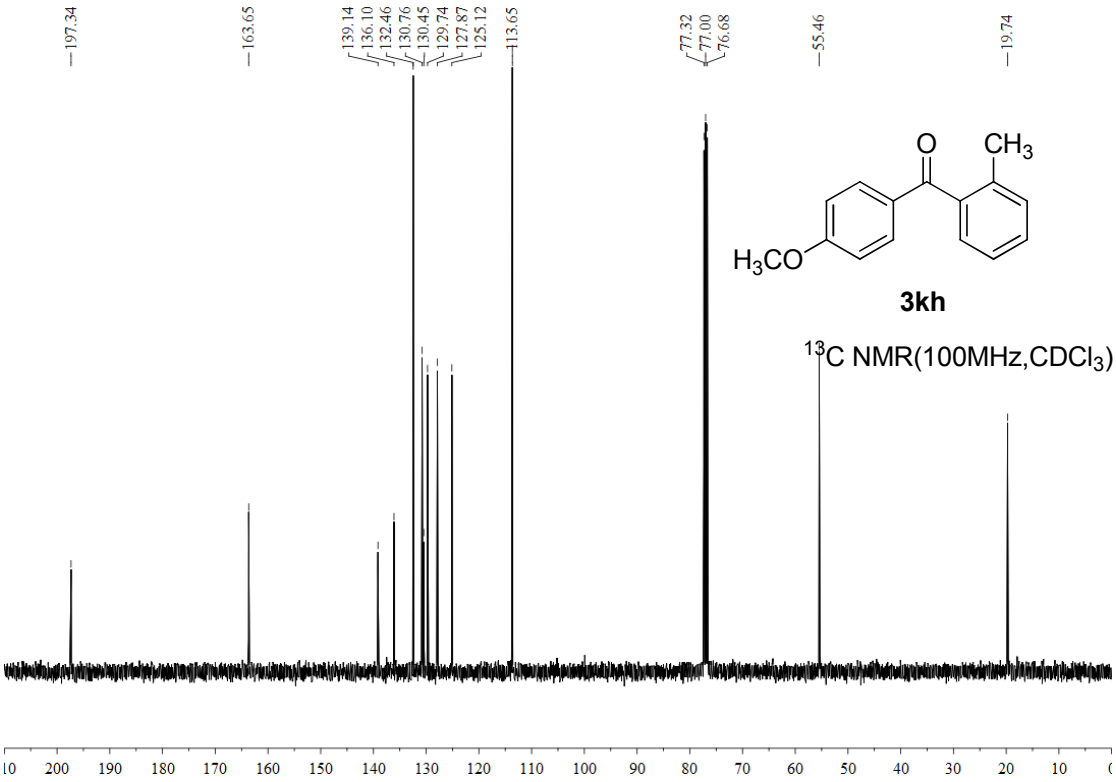

7.78
7.77
7.77
7.76
7.75
7.75
7.24
7.14
7.12
7.10
6.95
6.93
3.85
3.97
2.01
2.02
3.00
O
H3CO
F
3kf
1H NMR(400MHz,CDCl3)


194.03
166.23
163.72
163.19
134.37
134.34
132.33
132.26
132.17
129.91
115.36
115.14
113.56
77.32
77.00
76.68
55.43
O
H3CO
F
3kf
13C NMR(100MHz,CDCl3)



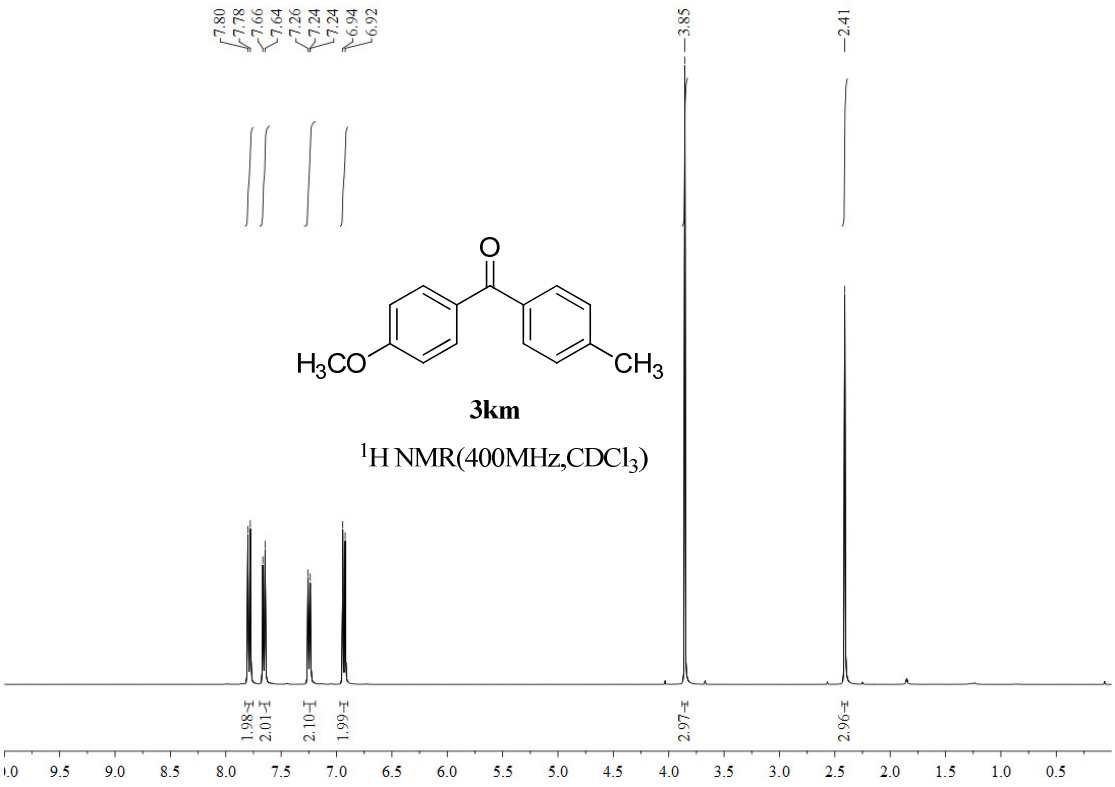
3kh

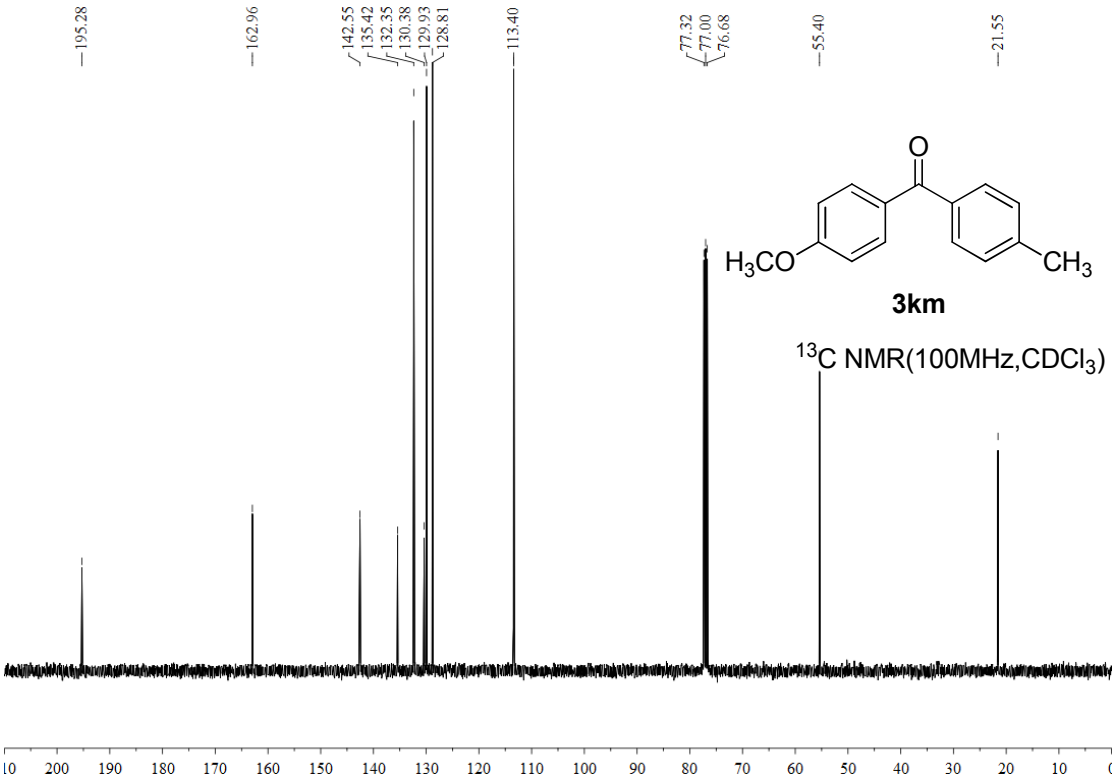
^{1}H NMR(400MHz,$CDCl_3$)

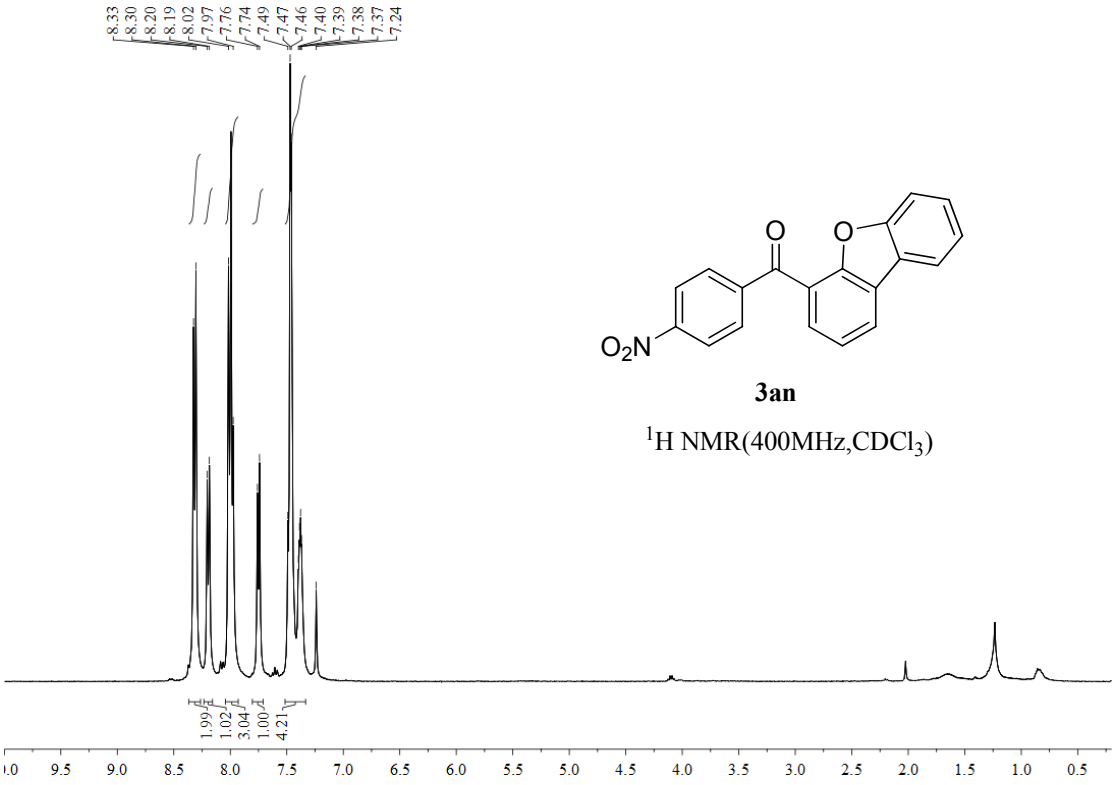


3kh

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

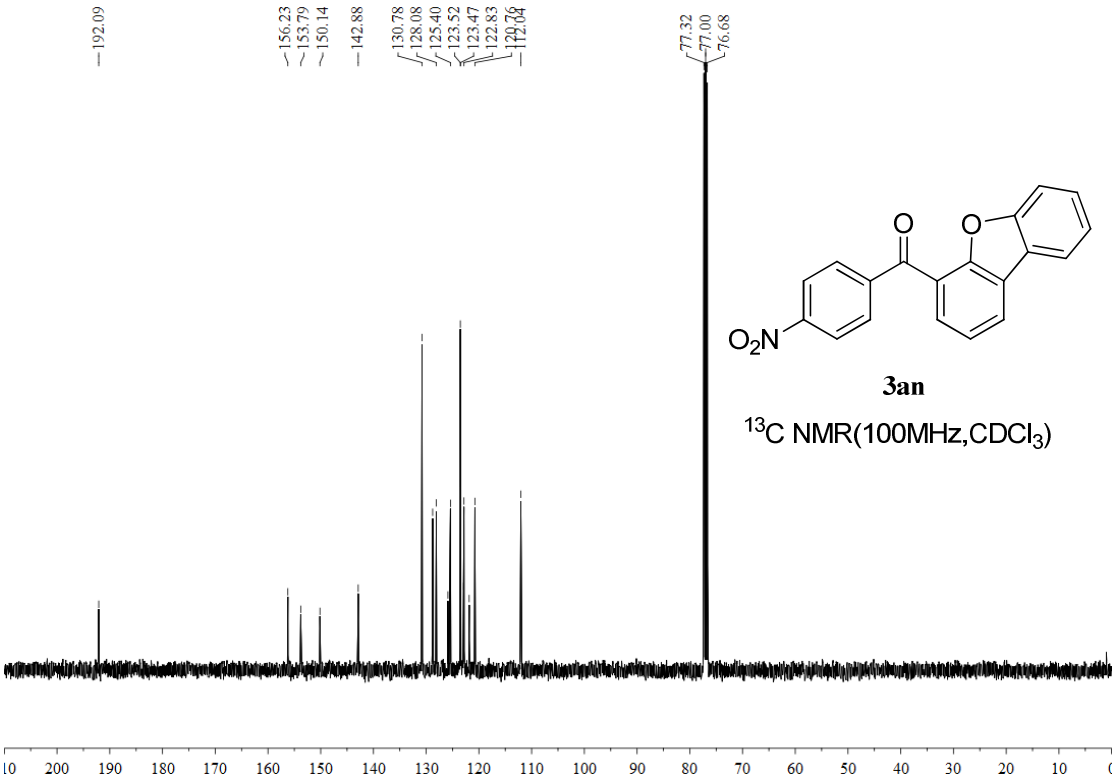

7.80
7.78
7.66
7.64
7.26
7.24
7.24
6.94
6.92
3.85
2.41
O
H3CO
CH3
3km
1H NMR(400MHz,CDCl3)
1.98
2.01
2.10
1.99
2.97
2.96


195.28
162.96
142.55
135.42
132.35
130.38
129.93
128.81
113.40
77.32
77.00
76.68
55.40
21.55
O
H3CO
CH3
3km
13C NMR(100MHz,CDCl3)



3an

^{1}H NMR(400MHz,$CDCl_3$)



3an

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