Electronic Supplementary Material (ESI) for Green Chemistry.

– Supporting Information –

Iron-Catalyzed Carbonylation of Aryl halides with Arylborons Using Stoichiometric Chloroform as the Carbon Monoxide Source

Hongyuan Zhao, Hongyan Du, Xiaorong Yuan, Tianjiao Wang 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

Email: whhanwei@gmail.com

Table of Contents

1. General Information

Reagent Information. All the aryl halides and the arylborons were purchased from Alfa Aesar, Energy Chemical, Beijing InnoChem Science & Technology Co., Ltd., and Accela ChemBio Co., Ltd. and were used as received. PEG-400 (bought from Acros, Energy Chemical, and Aladdin) was pre-dried (toluene azeotrope) and deoxygenated. The following iron salts and reagents were used: $FeCl_2$ (98% from Sigma−Aldrich; 99.99% from Alfa Aesar), Na_2CO_3 (99.5% and 99.997%, Alfa Aesar), $CsOH{\cdot}H_2O$ (99%, Energy Chemical), AcOK (99%, Alfa Aesar), NaI (99%, Alfa Aesar; 99.999%, Acros), and PivOH (99%, Alfa Aesar).

Physical Methods. ^1H and ^{13}C NMR spectra of solutions in $CDCl_3$ or DMSO-d_6 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; DMSO-d_6: H 2.50 and C 39.5 ppm). The signals of water were observed at about 1.58 ppm in $CDCl_3$ and 3.42 ppm in DMSO-d_6, 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; tdd, doublet of doublet of triplets. Coupling constants, *J,* were reported in hertz unit (Hz). Infrared spectra of neat substances were recorded on a BRUKER TENSOR 27 FT-IR spectrometer. HRMS was performed on a Bruker's solarix 94 (ESI-FTICR-MS) mass spectrometer. ICP-AES analysis was measured on a Prodigy (LEEMAN LABS INC.) machine. GC-MS were determined with Agilent 7890-5975C. Column chromatography was performed using silica gel 300-400 mesh (Yantai Jiangyou Silica Gel Co., Ltd., China) as the solid support.

2. General Procedure for Iron-Catalyzed Carbonylative Suzuki-Miyaura Coupling using $CHCl_3$ as CO Source

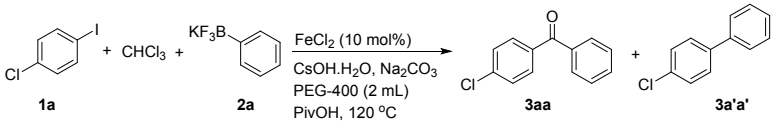
General Procedure A: With no precautions to exclude air or moisture, a 10-ml screw-cap vial equipped with a magnetic stir bar was charged with $FeCl_2$ (0.025 mmol, 3.2 mg), arylboronic acid (0.375 mmol), aryl halide (0.25 mmol), NaI (0.125 mmol, 18.9 mg), Na_2CO_3 (0.5 mmol, 53.3 mg), $CsOH{\cdot}H_2O$ (1.25

mmol, 212.0 mg), $CHCl_3$ (0.75 mmol, 61 μL), PivOH (0.375 mmol, 42 μL), and PEG-400 (2.0 mL). The vial was capped and heated to 120 °C in a heating block for the indicated time. After being allowed to cool to room temperature, the reaction mixture was diluted with 3 mL water and extracted with diethyl ether (3 × 5 mL). The organic phases were combined, and the volatile components were evaporated in a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum ether: diethyl ether = 100 : 1 to 10 : 1).

General Procedure B: With no precautions to exclude air or moisture, a 10-ml screw-cap vial equipped with a magnetic stir bar was charged with $FeCl_2$ (0.025 mmol, 3.2 mg), arylboronic acid (0.375 mmol), aryl halide (0.25 mmol), NaI (0.125 mmol, 18.9 mg), Na_2CO_3 (0.5 mmol, 53.3 mg), $CsOH{\cdot}H_2O$ (1.25 mmol, 212.0 mg), $CHCl_3$ (0.75 mmol, 61 μL), and PEG-400 (2.0 mL). The vial was capped and heated to 140 °C in a heating block for the indicated time. After being allowed to cool to room temperature, the reaction mixture was diluted with 3 mL water and extracted with diethyl ether (3 × 5 mL). The organic phases were combined, and the volatile components were evaporated in a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum ether: diethyl ether = 100 : 1 to 10 : 1).

3. Optimization of Reaction Parameters

Table S1. Varying PivOH Equivalencies.[a]

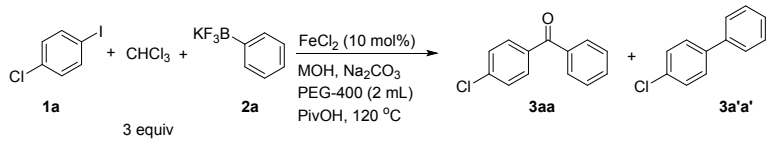


1a 2a 3aa 3a'a'

Entry	PivOH (equiv)	**3aa** (%)[b]	**3a'a'** (%)[b]
1	0	50	38
2	0.5	61	30
3	1.0	70	16
4	1.5	84	8
5	2.0	30	3

[a] *Reaction conditions* (unless otherwise stated): **1a** (0.25 mmol), **2a** (1.5 equiv), $FeCl_2$ (10 mol%), Na_2CO_3 (0.5 mmol, 2.0 equiv), $CsOH{\cdot}H_2O$ (1.25 mmol, 5 equiv), $CHCl_3$ (0.75 mmol, 3.0 equiv), PivOH, PEG-400 (2.0 mL), 120 °C, and 24 h. [b] determined by GC analysis using hexadecane as internal standard.

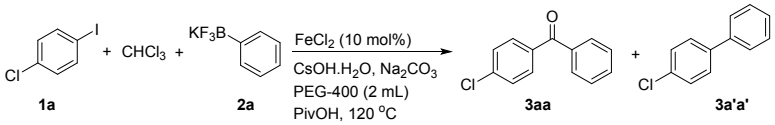
Table S2. The Effect of Hydroxide.[a]



Entry	MOH (equiv)	**3aa** (%)[b]	**3a'a'** (%)[b]
1	$CsOH{\cdot}H_2O$ (4.0)	64%	13%
2	$CsOH{\cdot}H_2O$ (5.0)	84%	8%
3	$CsOH{\cdot}H_2O$ (5.5)	62%	15%
4	KOH (5.0)	60%	25%
5	NaOH (5.0)	55%	10%
6	*t*-BuNOH (5.0)	-	-

[a] *Reaction conditions* (unless otherwise stated): **1a** (0.25 mmol), **2a** (1.5 equiv), $FeCl_2$ (10 mol%), Na_2CO_3 (0.5 mmol, 2.0 equiv), MOH, $CHCl_3$ (0.75 mmol, 3 equiv), PivOH (0.375 mmol, 1.5 equiv), PEG-400 (2.0 mL), 120 °C, and 24 h. [b] determined by GC analysis using hexadecane as internal standard.

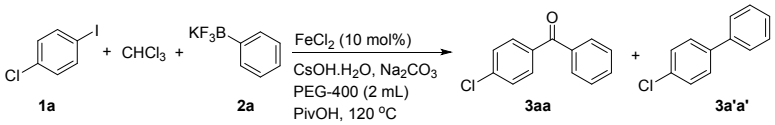
Table S3. Varying Chloroform Equivalencies.[a]



Entry	$CHCl_3$ (equiv)	3aa (%)[b]	3a'a' (%)[b]
1	2.0	49	31
2	3.0	84	8
3	5.0	72	8

[a] *Reaction conditions* (unless otherwise stated): **1a** (0.25 mmol), **2a** (1.5 equiv), $FeCl_2$ (10 mol%), Na_2CO_3 (0.5 mmol, 2.0 equiv), $CsOH{\cdot}H_2O$ (1.25 mmol, 5 equiv), $CHCl_3$, PivOH (0.375 mmol, 1.5 equiv), PEG-400 (2.0 mL), 120 °C, and 24 h. [b] determined by GC analysis using hexadecane as internal standard.

Table S4. The Effect of Iodide.[a]

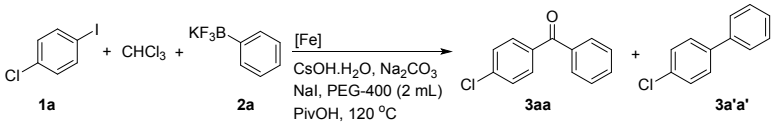


1a 2a 3aa 3a'a'

Entry	[I] (equiv)	**3aa** (%)[b]	**3a'a'** (%)[b]
1	NaI (0.2)	72	14
2	NaI (0.5)	87	5
3	NaI (1.0)	70	10
4	KI (0.5)	50	-
5	TBAI (0.5)	75	11

[a] *Reaction conditions* (unless otherwise stated): **1a** (0.25 mmol), **2a** (1.5 equiv), $FeCl_2$ (10 mol%), Na_2CO_3 (0.5 mmol, 2.0 equiv), $CsOH{\cdot}H_2O$ (1.25 mmol, 5 equiv), $CHCl_3$ (0.75 mmol, 3.0 equiv), PivOH (0.375 mmol, 1.5 equiv), iodide, PEG-400 (2.0 mL), 120 °C, and 24 h. [b] determined by GC analysis using hexadecane as internal standard.

Table S5. The Effect of Iron Catalyst.[a]

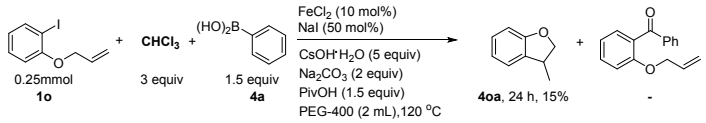


1a 2a 3aa 3a'a'

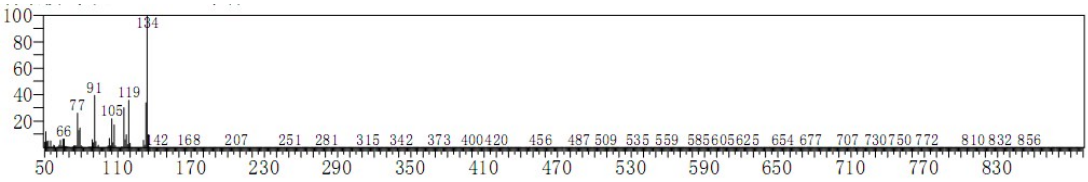
Entry	[Fe] (mol%)	**3aa** (%)[b]	**3a'a'** (%)[b]
1	$FeCl_2$ (10)	87	5
2	$FeCl_2$ (5)	80	7
3	$FeBr_2$ (10)	72	5
4	$Fe(acac)_2$ (10)	50	5
5	$Fe(acac)_3$ (10)	77	15
6	$FeCl_3$ (10)	72	20
7	FeF_3 (10)	72	5

[a] *Reaction conditions* (unless otherwise stated): **1a** (0.25 mmol), **2a** (1.5 equiv), [Fe], Na_2CO_3 (0.5 mmol, 2.0 equiv), $CsOH{\cdot}H_2O$ (1.25 mmol, 5 equiv), $CHCl_3$ (0.75 mmol, 3.0 equiv), PivOH (0.375 mmol, 1.5 equiv), NaI (0.125 mmol, 0.5 equiv), PEG-400 (2.0 mL), 120 °C, and 24 h. [b] determined by GC analysis using hexadecane as internal standard.

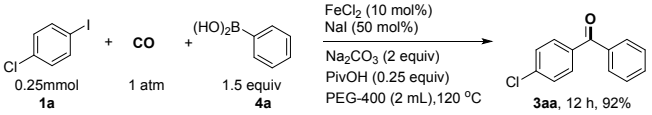
4. Effect of A Free-Radical Probe



Following *general procedure A*, a cyclization product, 3-methyl-2,3-dihydrobenzofuran (**4oa**) in 15% yield was obtained based on GC-MS analysis and no any carbonylated product was observed.

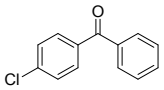


5. Reaction using CO gas

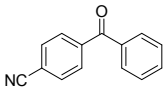


A 25 mL flask equipped with a magnetic stir bar was charged with $FeCl_2$ (0.025 mmol, 3.2 mg), phenylboronic acid (0.375 mmol), NaI (0.125 mmol, 18.9 mg), Na_2CO_3 (0.5 mmol, 53.3 mg), PivOH (0.375 mmol, 7.0 μL), and PEG-400 (2 ml) before standard cycles of evacuation and back-filling with dry and pure carbon monoxide. 1-chloro-4-iodobenzen (0.25 mmol) was added successively. The mixture was then stirred at 120 °C for 12 h. After being allowed to cool to room temperature, the reaction mixture was diluted with 3 mL water and extracted with diethyl ether (4 × 5 mL). The organic phases were combined, and the volatile components were evaporated in a rotary evaporator. The residue was purified by column chromatography on silica gel (petroleum ether: diethyl ether = 20 : 1) to afford the desired product as a white solid (50 mg, 92%).

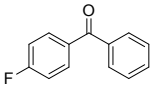
6. Analytical Data of Products



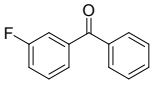
(4-Chlorophenyl)(phenyl)methanone (3aa): Following *general procedure A*, **3aa** was isolated as a white solid (46 mg, 85%), known compound. The NMR spectroscopic data agree with those described in ref.[S1] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.72 (m, 4 H), 7.58 (tt, *J* = 7.2, 1.2 Hz, 1 H), 7.50–7.43 ppm (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5, 138.9, 137.2, 135.9, 132.6, 131.4, 129.9, 128.6, 128.4 ppm; mp 73.5–74.0 °C.



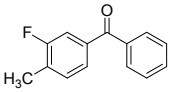
4-Benzoylbenzonitrile (3ba): Following *general procedure B*, **3ba** was isolated as a white solid (23 mg, 45%), known compound. The NMR spectroscopic data agree with those described in ref.[S2] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (dd, *J* = 8,4 Hz, 2 H), 7.77 (t, *J* = 1.2 Hz, 2 H), 7.75 (dd, *J* = 4, 2 Hz, 2 H) 7.62 (tt, *J* = 7.6, 1.2 Hz, 1 H), 7.49 ppm (t, *J* = 8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.0, 141.2, 136.3, 133.3, 132.1, 130.2, 130.0, 128.6, 118.0,115.6 ppm; mp 110.8–111.1 °C.



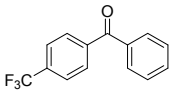
(4-Fluorophenyl)(phenyl)methanone (3ca): Following *general procedure A*, **3ca** was isolated as a light yellow oil (45 mg, 92%), known compound; The NMR spectroscopic data agree with those described in ref.[S1] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83 (td, *J* = 8, 4 Hz, 2 H),7.75 (dd, *J* = 8, 1.2 Hz, 2 H), 7.58 (tt, *J* = 8, 1.2 Hz, 1H),7.47 (t, *J* = 8 Hz, 2 H); 7.14 ppm (td, *J* = 8, 4 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3, 165.4 (d, J = 252 Hz), 137.5, 133.8 (d, *J* = 3 Hz), 132.7, 132.5 (d, *J* = 15 Hz), 129.9, 128.3, 115.4 ppm (d, *J* = 22 Hz).



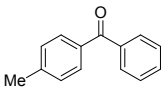
(3-Fluorophenyl)(phenyl)methanone (3da): Following general procedure A, **3da** was isolated as a light yellow oil (44 mg, 88%), known compound. The NMR spectroscopic data agree with those described in ref.[S3] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (dt, *J* = 8, 1.2 Hz, 2 H),7.59 (tt, *J* = 7.2, 1.6 Hz, 2 H), 7.55 (dt, *J* = 7.6,1.2, 1 H), 7.50 (t, *J* = 2 Hz,1 H)7.48-7.46 (m, 2 H),7.45-7.42 (m, 1H),7.27 ppm (tdd, *J* = 8.0, 2.4, 0.8 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3 (d, J = 2 Hz), 162.5 (d, *J* = 246 Hz), 139.6 (d, *J* = 6 Hz), 137.0, 132.8, 130.0, 129.9, 128.4, 125.8 (d, *J* = 4 Hz),
119.4 (d, *J* = 21 Hz), 116.7 ppm (d, *J* = 22 Hz).



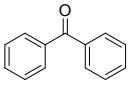
(3-Fluoro-4-methylphenyl)(phenyl)methanone (3ea): Following general procedure A, **3ea** was isolated as a light yellow solid (42.8 mg, 80%), known compound; The NMR spectroscopic data agree with those described in ref. [S4] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77–7.75 (m, 2 H), 7.57 (tt, *J* = 7.6, 1.2 Hz, 1H),7.48 (d, *J* = 1.2 Hz, 1 H), 7.46 (s, 1 H), 7.45 (d, *J* = 2 Hz, 1 H), 7.27 (t, *J* = 8 Hz, 1 H), 2.35 ppm (d, *J* = 2 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.2 (d, *J* = 2 Hz), 160.9 (d, *J* = 245 Hz), 137.4, 137.1 (d, *J* = 7 Hz), 132.5, 131.3 (d, *J* = 5 Hz), 130.2 (d, *J* = 17 Hz), 129.9, 128.3, 125.8 (d, *J* = 4 Hz), 116.5 (d, *J* = 24 Hz), 14.8 ppm (d, *J* = 3 Hz); mp 40.0–40.7 °C.



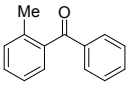
Phenyl(4-(trifluoromethyl)phenyl)methanone (3fa): Following general procedure A, **3fa** was isolated as a white solid (50 mg, 81%), known compound. The NMR spectroscopic data agree with those described in ref.[S1] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87 (d, *J* = 8.0 Hz, 2 H), 7.80–7.77 (m, 2 H), 7.74 (d, *J* = 8.0 Hz, 2 H), 7.61 (tt, *J* = 8, 1.6 Hz, 1H),7.49 ppm (t, *J* = 8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5, 140.7, 136.7, 133.7 (q, *J* = 33 Hz), 133.1, 130.11, 130.08, 128.5,125.3 (q, *J* = 4 Hz), 123.7 ppm (q, *J* = 271 Hz); mp 114.4–114.9 °C.



Phenyl(*p*-tolyl)methanone (3ga): Following general procedure A, **3ga** was isolated as a white solid with low melting point (42 mg, 86%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (dd, *J* = 8, 4 Hz, 2 H), 7.70 (d, *J* = 8 Hz, 2 H), 7.56 (tt, *J* = 8, 1.2 Hz, 1H), 7.45 (tt, *J* = 8, 1.2 Hz, 2 H), 7.26 (d, *J* = 8 Hz, 2 H), 2.42 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.5, 143.2, 138.0, 134.9, 132.2, 130.3, 129.9, 129.0, 128.2, 21.6 ppm.

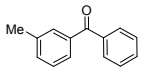


Benzophenone (3ha): Following *general procedure A*, **3ha** was isolated as a white solid with low melting point (38 mg, 85%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79 (d, *J* = 8, 1.6 Hz, 4 H), 7.57 (tt, *J* = 8, 1.2 Hz, 2H), 7.47 ppm (t, *J* = 8 Hz, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.8, 137.6, 132.4, 130.1, 128.3 ppm.

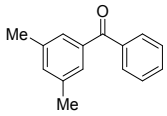


Phenyl(*o*-tolyl)methanone (3ia): Following *general procedure B*, **3ia** was isolated as a light yellow oil (29 mg, 60%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80–7.77 (m, 2 H), 7.56 (tt, J = 7.6, 1.2 Hz, 1 H), 7.44 (t, *J* = 8 Hz, 2 H), 7.38 (td, *J* = 8, 4Hz, 1 H), 7.28 (t, *J* = 8 Hz, 2 H), 7.23 (t, *J* = 8 Hz), 2.32 ppm (s, 3 H); ^{13}C NMR (100

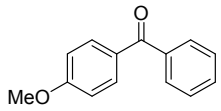
MHz, $CDCl_3$): δ 198.6, 138.6, 137.7, 136.7, 133.1, 131.0, 130.2, 130.1, 128.5, 128.4, 125.2, 19.9 ppm.



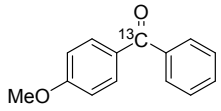
Phenyl(*m*-tolyl)methanone (3ja): Following *general procedure A*, **3ja** was isolated as a light yellow oil (39 mg, 80%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79–7.77 (m, 2 H), 7.61 (s, 1 H), 7.60–7.54 (m, 2 H), 7.46 (m, 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, 137.8, 137.6, 133.2, 132.3, 130.4, 130.0, 128.2, 128.1, 127.4, 21.3 ppm.



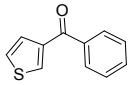
(3, 5-Dimethylphenyl)(phenyl)methanone (3ka): Following *general procedure A* except using KOAc (0.05 mmol) instead of PivOH, **3ka** was isolated as a light yellow solid (32 mg, 60%), known compound. The NMR spectroscopic data agree with those described in ref.[S6] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (dd, J = 8, 4 Hz, 2 H), 7.56 (tt, J = 8, 4 Hz, 1 H), 7.46 (tt, J = 8, 4 Hz, 2 H), 7.38 (s, 2 H), 7.20 (s, 1 H), 2.35 ppm (s, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.2, 137.9, 137.7, 134.1, 132.2, 123.0, 128.2, 127.8, 21.2 ppm; mp 58.6–59.9 °C.



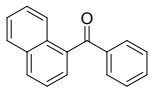
(4-Methoxyphenyl)(phenyl)methanone (3la): Following *general procedure A*, **3la** was isolated as light white solid (34 mg, 65%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81 (d, J = 9.6 Hz, 2 H), 7.75–7.72 (m, 2 H), 7.54 (tt, J = 7.2, 1.6 Hz, 1 H), 7.45 (t, J = 8 Hz, 2 H), 6.94 (d, J = 8.8, 2.4 Hz, 2 H), 3.86 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5, 163.2, 138.2, 132.5, 131.8, 130.1, 129.7, 128.1,113.5, 55.4 ppm; mp 85.9–86.5 °C.



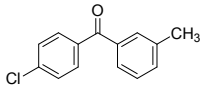
[^{13}C](4-methoxyphenyl)(phenyl)methanone (3la-^{13}C): Following *general procedure A* using ^{13}C-labeled $CHCl_3$ instead of $CHCl_3$, **3la-^{13}C** was isolated as a low-melting solid (45 mg, 85%), known compound. The NMR spectroscopic data agree with those described in ref.[S7] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82-7.80 (m, 2 H), 7.74–7.72 (m, 2 H), 7.54 (t, J = 8 Hz, 1 H), 7.45 (t, J = 8 Hz, 2 H), 6.94 (d, J = 8 Hz, 2 H), 3.86 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5 (^{13}C), 163.2, 138.2 (d, J = 55.0 Hz), 132.5 (d, J = 3.0 Hz), 131.8, 130.1 (d, J = 57.0 Hz), 129.7 (d, J = 2.0 Hz), 128.1 (d, J = 4.0 Hz), 113.5 (d, J = 5.0 Hz), 55.4 ppm.



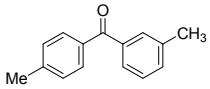
Phenyl(thiophen-3-yl)methanone (3ma): Following *general procedure A* except using reducing the amount of PivOH to 0.125 mmol, **3ma** was isolated as a light yellow oil (19 mg, 40%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (dd, *J* = 2.8, 1.2 Hz, 1 H), 7.83 (dt, J = 8.0, 4Hz, 2 H), 7.58 (dt, J = 4, 1.2 Hz, 1 H), 7.55 (dt, J = 8, 1.2 Hz, 1 H), 7.47 (tt, *J* = 8，1.2 Hz, 2 H); 7.36 ppm (dd, *J* = 4.8, 3.2 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.0, 141.3, 138.6, 133.9, 132.3, 129.3, 128.6, 128.4, 126.2 ppm.



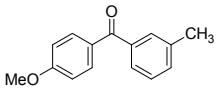
Naphthalen-1-yl(phenyl)methanone (3na): Following *general procedure B*, **3na** was isolated as a light white solid (26 mg, 45%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.09–8.07 (m, 1 H), 7.99 (d, *J* = 8.0 Hz, 1 H), 7.91(dd, *J* = 8, 2 Hz, 1 H), 7.87–7.84 (m, 2 H), 7.61–7.57 (m, 2 H), 7.56 (dd, *J* = 3.2, 1.2 Hz, 1 H),7.54-7.52 (m, 1 H), 7.51-7.48 (m, 2 H), 7.44 ppm (t, *J* = 8.0 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 198.0, 138.3, 136.3, 133.7, 133.2, 131.2, 130.9, 130.4, 128.4, 128.37, 127.7, 127.2, 126.4, 125.7, 124.3 ppm; mp 64-65 °C.



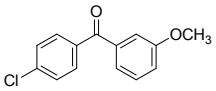
(4-Chlorophenyl)(*m*-tolyl)methanone (3ab): Following *general procedure A*, **3ab** was isolated as a light white solid (42 mg, 73%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.73 (d, *J* = 8 Hz 2 H), 7.57 (s, 1 H);7.52 (d, *J* = 8 Hz, 1 H), 7.44 (d, J = 8.4 Hz, 2 H), 7.39 (d, J = 8 Hz,1 H),7.35 (t, J = 6 Hz,1 H), 2.40 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.7, 138.8, 138.3, 137.3, 136.0, 133.4, 131.4, 130.3, 128.6, 128.2, 127.2, 21.3 ppm.; mp 102.6–102.8 °C.



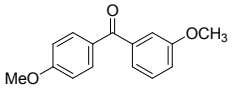
***m*-Tolyl(*p*-tolyl)methanone (3gb)：** Following *general procedure A*, **3gb** was isolated as a yellow liquid (47 mg, 90%), known compound (CAS: 13152-94-8). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8 Hz, 2 H), 7.58 (s, 1 H), 7.54 (d, *J* = 7.2 Hz, 1 H), 7.37 (d, 1 H), 7.33 (t, *J* = 8 Hz, 1 H), 7.26 (d, *J* = 8 Hz, 2 H), 2.42 (s, 3H), 2.40 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.7, 143.1, 138.1, 138.0, 135.0, 133.0, 130.4, 130.3, 129.0, 128.0, 127.2, 21.6, 21.3 ppm.



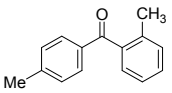
(4-Methoxyphenyl)(*m*-tolyl)methanone (3lb): Following *general procedure A*, **3lb** was isolated as a light white solid (40 mg, 70%), known compound (CAS: 53039-63-7); ^{1}H NMR (400 MHz, $CDCl_3$) : δ 7.81 (d, *J* = 8.2 Hz, 2 H), 7.56 (s, 1 H), 7.51 (d, *J* = 8 Hz, 1 H), 7.37 – 7.30 (m, 2 H), 6.94 (d, *J* = 8 Hz, 2 H), 3.87 (s, 3H), 2.40 ppm (s, 3H); ^{13}C NMR (100MHz, $CDCl_3$): δ 195.8, 163.1, 138.3, 138.0, 132.6, 132.5, 130.3, 130.2, 128.0, 127.0, 113.5, 55.5, 21.3; mp 55.3-56.4 ^{o}C.



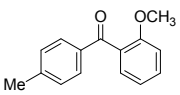
(4-Chlorophenyl)(3-methoxyphenyl)methanone (3ac): Following *general procedure A*, **3ac** was isolated as a light white solid (45 mg, 72%), known compound (CAS: 32363-45-4). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, *J* = 8 Hz, 2 H), 7.44 (d, *J* = 8 Hz, 2 H), 7.36 (t, *J* = 8 Hz, 1 H), 7.31 – 7.26 (m, 2 H), 7.12 (ddd, *J* = 8, 2.7, 1.1 Hz, 1 H), 3.84 ppm (s, 3 H);^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3, 159.6, 138.9, 138.5, 135.9, 131.4, 129.3, 128.6, 122.6, 119.0, 114.2, 55.5 ppm; mp 108-109 ^{o}C.



(3-Methoxyphenyl)(4-methoxyphenyl)methanone (3lc): Following *general procedure A*, **3lc** was isolated as a yellow liquid (41 mg, 67%), known compound **(**CAS: 75731-44-1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, *J* = 8.8 Hz, 2 H), 7.35 (t, *J* = 8 Hz, 1 H), 7.30 – 7.25 (m, 2 H), 7.09 (ddd, *J* = 8, 2.4, 1.2 Hz, 1 H), 6.94 (d, *J* = 8 Hz, 2 H), 3.87 (s, 3 H), 3.84 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3, 163.2, 159.5, 139.6, 132.5, 130.1, 129.1, 122.4, 118.2, 114.2, 113.5, 55.5, 55.4 ppm.

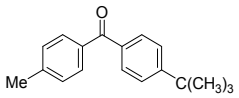


***o*-Tolyl(*p*-tolyl)methanone (3gd):** Following *general procedure A*, **3gd** was isolated as pale yellow liquid (32 mg, 60%), known compound. The NMR spectroscopic data agree with those described in ref.[S8] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8 Hz, 2 H), 7.36 (td, *J* = 8, 1.6 Hz, 1H), 7.26 (dd, *J* = 12, 4 Hz, 4 H), 7.21 (d, *J* = 8 Hz, 1 H), 2.41 (s, 3 H), 2.30 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 198.4, 144.1, 139.0, 136.4, 135.1, 130.9, 130.3, 123.0, 129.2, 128.2, 125.1, 21.7, 19.9 ppm.

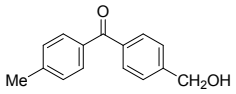


(2-Methoxyphenyl)(*p*-tolyl)methanone (3ge): Following general procedure A, **3ge** was isolated as pale yellow solid (44 mg, 77%), known compound (CAS: 28137-36-2) ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8 Hz, 2 H), 7.43 (ddd, *J* = 8.8, 7.5, 1.8 Hz, 1 H), 7.31 (dd, *J* = 8 , 1.7 Hz, 1 H), 7.21 (d, *J* = 8 Hz,

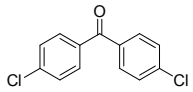
2 H), 7.01 (td, *J* = 8, 0.8 Hz, 1 H), 6.97 (d, *J* = 8 Hz, 1 H), 3.71 (s, 3 H), 2.39 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.1, 157.2, 143.8, 135.2, 131.6, 130.1, 129.4, 129.2, 129.0, 120.5, 111.4, 55.6, 21.7 ppm; mp 64-65 °C.



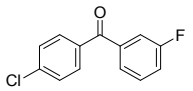
(4-(*t*-Butyl)phenyl)(*p*-tolyl)methanone (3gf): Following *general procedure A*, **3gf** was isolated as a yellow liquid (44 mg, 70%), known compound (CAS: 55709-38-1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (t, J = 8 Hz), 7.47 (d, *J* = 8Hz), 7.26(d, *J* = 8 Hz), 2.42 (s, 3 H), 1.35 ppm (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.2, 155.9, 142.9, 135.2, 135.1, 130.2, 130.0, 128.9, 125.2, 35.1, 31.1, 21.6 ppm.



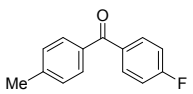
(4-(Hydroxymethyl)phenyl)(*p*-tolyl)methanone (3gg): Following *general procedure A*, **3gg** was isolated as pale yellow solid (48 mg, 85%), known compound (CAS: 460062-30-0). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (d, *J* = 8 Hz, 2 H), 7.69 (d, *J* = 8 Hz, 2 H), 7.45 (d, *J* = 8 Hz, 2 H), 7.26 (d, *J* = 8 Hz, 2 H), 4.78 (s, 2H), 2.42 ppm (s, 3H);^{13}C NMR (100 MHz, $CDCl_3$): δ 196.2, 145.2, 143.3, 137.2, 134.9, 130.3, 130.2, 129.0, 126.4, 64.8, 21.6 ppm; mp 84-85 °C



Bis(4-chlorophenyl)methanone (3ah): Following *general procedure A*, **3ah** was isolated as a light white solid (47 mg, 75%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71(d, *J* = 8 Hz, 4 H), 7.45 ppm (d, *J* = 8 Hz, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.2, 139.1, 135.5, 131.3, 128.7 ppm; mp 144.6–145.4 °C.

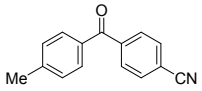


(4-Chlorophenyl)(3-fluorophenyl)methanone (3ai): Following *general procedure A*, **3ai** was isolated as a light white solid (45 mg, 77%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.73 (d, *J* = 8 Hz, 2 H), 7.52 (d, *J* = 8 Hz, 1 H), 7.45 (d, *J* = 8 Hz, 4 H), 7.28 ppm (tdd, *J* = 8, 2, 1.2, 1 H);^{13}C NMR (100 MHz, $CDCl_3$): δ 193.9, 162.4(d, *J* = 247 Hz), 139.2, 139.2, 135.2, 131.3, 129.98 (d, *J* = 8 Hz), 128.7, 125.54 (d, *J* = 3 Hz), 119.5(d, *J* = 21 Hz), 116.5 ppm (d, *J* = 22 Hz); mp 76.6–77.3 °C.

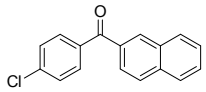


(4-Fluorophenyl)(*p*-tolyl)methanone (3gj): Following *general procedure A*, **3gj** was isolated as a

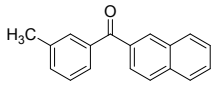
white solid (40 mg, 75%), known compound. The NMR spectroscopic data agree with those described in ref.[S6] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80 (td, *J* = 6, 2.8 Hz, 2 H), 7.67 (d, *J* = 8 Hz, 2 H), 7.27 (d, *J* = 8 Hz, 2 H), 7.13 (t, *J*=8 Hz, 2 H), 2.42 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): 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* = 12 Hz), 21.6 ppm; mp 91.8–92.3 °C.



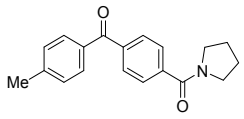
4-(4-Methylbenzoyl)benzonitrile (3gk): Following *general procedure A*, **3gk** was isolated as a white solid (50 mg, 90%), known compound (CAS: 35776-95-5). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83 (d, *J* = 8 Hz, 2 H), 7.76 (d, *J* = 8 Hz, 2 H), 7.67 (d, *J* = 8 Hz, 2 H), 7.29 (d, *J* = 8 Hz, 2 H), 2.44 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.7, 144.4, 141.6, 133.7, 132.1, 130.3, 130.1, 129.3, 118.1, 115.4, 21.7 ppm; 150-151 ^{o}C



(4-Chlorophenyl)(naphthalen-2-yl)methanone (3al): Following *general procedure A*, **3al** was isolated as a light white solid (45 mg, 68%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.21 (s, 1 H), 7.95–7.88 (m, 4 H), 7.79 (d, *J* = 8.8 Hz, 2 H), 7.61 (td, *J* = 8, 1.2 Hz, 1 H), 7.55 (td, *J* = 8, 1.2 Hz, 1 H), 7.48 ppm (d, *J* = 8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.5, 138.8, 136.2, 135.3, 134.5, 132.2, 131.7, 131.5, 129.4, 128.7, 128.5, 128.4, 127.8, 126.9, 125.6 ppm; mp 122.3–123.1 °C.

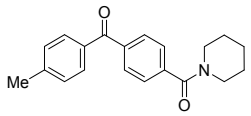


Naphthalen-2-yl(*m*-tolyl)methanone (3jl): Following *general procedure A*, **3jl** was isolated as a light white solid (44 mg, 72%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.25 (d, *J* = 0.8 Hz, 1 H), 7.93–7.89 (m, 4 H), 7.67 (s, 1 H), 7.63–7.58 (m, 2 H), 7.54 (td, *J* = 8, 1.2 Hz, 1 H), 7.43–7.36 (m, 2 H), 2.43 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.0, 138.2, 137.9, 135.2, 135.0, 133.1, 132.3, 131.8, 130.5, 129.4, 128.3, 128.2, 128.1, 127.8, 127.4, 126.7, 125.8, 21.4 ppm; mp 72.3–73.3 °C.

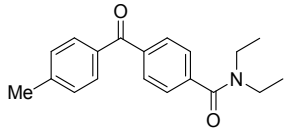


(4-(4-Methylbenzoyl)phenyl)(pyrrolidin-1-yl)methanone (3gm): Following *general procedure A*, **3gm** was isolated as a white solid (64 mg, 87%), unknown compound; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.74 (d, *J* = 8 Hz, 2 H), 7.66 (dd, *J* = 8, 5.6 Hz, 4 H), 7.38 (d, *J* = 8 Hz, 2 H), 3.49 (t, *J* = 8 Hz, 2 H),

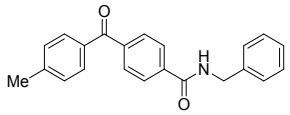
3.38 (s, 2 H), 2.41 (s, 3H), 1.90 - 1.80ppm(m, 4 H); ^{13}C NMR (100 MHz, DMSO- d_6): δ 195.4, 167.9, 143.9, 141.1, 138.6, 134.5, 130.4, 129.8, 129.7, 127.5, 49.3, 46.4, 26.4, 24.4, 21.7 ppm; HRMS (ESI) calcd for $C_{19}H_{19}NO_2Na^+$ [M + Na^+] *m/z* 316.13240, found *m/z* 316.13080; IR: ν_{max} (KBr) = 1717, 1653, 1636, 1607, 1540, 1442, 1312, 1272, 933, 832, 712 cm^{-1}; mp 110-111 °C



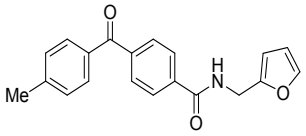
(4-(4-Methylbenzoyl)phenyl)(piperidin-1-yl)methanone (3gn): Following *general procedure A*, **3gn** was isolated as a white solid (65 mg, 85%), unknown compound. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (d, *J* = 8 Hz,2 H), 7.69 (d, J = 8 Hz, 1 H), 7.46 (d, *J* = 8 Hz, 2 H), 7.26 (d, *J* = 8 Hz, 2 H), 3.71 (s, 2 H),3.31 (s, 2 H), 2.41 (s, 3 H), 1.67 (s, 4 H), 1.50 ppm (s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.8, 169.3, 143.6, 140.0, 138.7, 134.4, 130.3, 130.0, 129.1, 126.6, 48.7, 43.1, 26.5, 25.5, 24.5, 21.6 ppm; HRMS (ESI) calcd for $C_{20}H_{21}NO_2Na^+$ [M + Na^+] *m/z* 330.14847, found *m/z* 330.14645; IR: ν_{max} (KBr) = 1717, 1653, 1636, 1607, 1540, 1442, 1312, 1272, 933, 712 cm^{-1}; mp 113-114 °C



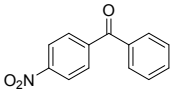
***N,N*-diethyl-4-(4-methylbenzoyl)benzamide (3go):** Following *general procedure A*, **3go** was isolated as a yellow liquid (55 mg, 75%), unknown compound. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (d, *J* = 8 Hz, 2 H), 7.67 (d, *J* = 8 Hz, 2 H), 7.43 (d, *J* = 8 Hz, 2 H), 7.25 (d, *J* = 8 Hz, 2 H), 3.53 (d, *J* = 8 Hz, 2 H), 3.21 (d, *J* = 8 Hz, 2 H), 2.40 (s, 3 H), 1.22 (s, 3 H), 1.08 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.9, 170.3, 143.6, 140.7, 138.5, 134.4, 130.3, 130.0, 129.1, 126.1, 43.3, 39.3, 21.7, 14.2, 12.9 ppm; HRMS (ESI) calcd for $C_{19}H_{21}NO_2$ [M+Na] *m/z* 318.14783, found *m/z* 318.14645; IR: ν_{max} (KBr) = 1723, 1656, 1630, 1603, 1503, 1457, 1314, 1277, 927, 777, 714 cm^{-1}.



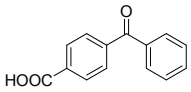
***N*-Benzyl-4-(4-methylbenzoyl)benzamide (3gp):** Following *general procedure A*, **3gp** was isolated as a yellow solid (66 mg, 80%), unknown compound. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.86 (d, *J* = 8 Hz, 2 H), 7.78 (d, *J* = 8 Hz, 2 H), 7.67 (d, *J* = 8 Hz, 2 H), 7.35 (d, *J* = 4 Hz, 4 H), 7.31 – 7.25 (m, 3 H), 6.59 (s, 1 H), 4.65 (d, *J* = 8 Hz, 2 H), 2.42 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.7, 166.5, 143.8, 140.5, 137.8, 137.4, 134.3, 130.3, 130.0, 129.1, 128.8, 128.0, 127.8, 126.9, 44.3, 21.7 ppm.; HRMS (ESI) calcd for $C_{22}H_{19}NO_2Na^+$ [M + Na^+] *m/z* 352.13132, found *m/z* 352.13080; IR: ν_{max} (KBr) = 3406, 2850, 1653, 1634, 1618, 1541, 1455, 930, 863, 833 cm^{-1}; mp 162.3-163.1 °C.



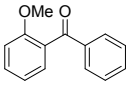
***N*-(furan-2-ylmethyl)-4-(4-methylbenzoyl)benzamide (3gq):** Following *general procedure A*, **3gq** was isolated as a white solid (60 mg, 75%), unknown compound; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86 (d, *J* = 8 Hz, 2 H), 7.79 (d, *J* = 8 Hz, 2 H), 7.67 (d, *J* = 8 Hz, 2 H), 7.37 (dd, *J* = 1.6, 0.4 Hz, 1H), 7.27 (d, *J* = 8 Hz, 2 H), 6.56 (s, 1 H), 6.34 – 6.29 (m, 2 H), 4.65 (d, *J* = 8 Hz, 2 H), 2.42 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.7, 166.4, 150.8, 143.8, 142.4, 140.6, 137.1, 134.3, 130.3, 130.0, 129.1, 126.9, 110.6, 108.0, 37.1, 21.7 ppm.; HRMS (ESI) calcd for $C_{20}H_{17}NO_3Na^+$ [M + Na^+] *m/z* 342.11061, found *m/z* 352.11006; IR: ν_{max} (KBr) = 3472, 3118, 1641, 1606, 1541, 1511, 1398, 930, 827, 858, 728 cm^{-1}; mp 106.4-107.8 °C.



(4-Nitrophenyl)(phenyl)methanone (5oa): Following *general procedure A*, **5oa** was isolated as a light pink solid (49 mg, 87%), 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 Hz, 2 H), 7.91 (d, *J* = 8 Hz, 2 H), 7.78 (dd, *J* = 8, 1.2 Hz, 2 H), 7.63 (tt, *J* = 7.2, 1.3 Hz, 1 H), 7.50 ppm (t, *J* = 7.6 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.8, 149.8, 142.9, 136.3, 133.4, 130.7, 130.1, 128.7, 123.5 ppm; mp 136.7–136.9 °C.

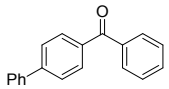


4-Benzoylbenzoic acid (5pa): Following *general procedure A* except that PivOH was not added and the amounts of both Na_2CO_3 and $CsOH·H_2O$ were adjusted to be 0.75 mmol and 1.5 mmol, respectively, **5pa** was isolated as a white solid (42 mg, 75%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, DMSO): δ 8.10 (d, *J* = 8 Hz, 2 H), 7.82 (d, *J* = 8 Hz, 2 H), 7.76 (dd, J = 8, 1.2 Hz, 2 H), 7.62 (tt, J = 8, 1.2 Hz, 1 H), 7.51–7.48 ppm (m, 2 H); ^{13}C NMR (100 MHz, DMSO): δ 195.5, 166.8, 140.6, 136.5, 134.2, 133.2, 129.8, 129.7, 12954,128.8 ppm; mp 193.2–193.5 °C.

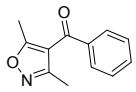


(2-Methoxyphenyl)(phenyl)methanone (5qa): Following *general procedure A*, **5qa** was isolated as a light yellow solid (40 mg, 75%), known compound. The NMR spectroscopic data agree with those described in ref.[S9] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (dd, *J* = 8.4, 1.2 Hz, 2 H), 7.58 (tt, J = 8, 1.2 Hz, 1H), 7.52 – 7.43 (m, 3 H), 7.39 (dd, *J* = 8, 4, 1 H), 7.07 (td, *J* = 8, 1.2 Hz, 1H), 7.02 (d, *J* = 8 Hz, 1 H),

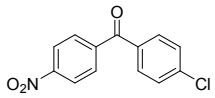
3.75 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.5, 157.3, 137.8, 132.9, 131.9, 129.8, 129.6, 128.8, 128.2, 120.5, 111.4, 55.6 ppm; mp 36-37 °C.



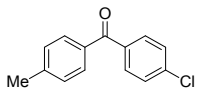
[1, 1'-Biphenyl]-4-yl(phenyl)methanone(5ra): Following *general procedure A* except reducing the amount of PivOH to 0.125 mmol, **5ra** was isolated as a light yellow solid (32 mg, 50%), known compound. The NMR spectroscopic data agree with those described in ref.[S10] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (d, *J* = 8 Hz, 2 H), 7.83 (dd, *J* = 8 , 1.2 Hz, 2 H), 7.70 (d, *J* = 8.8, 2 H), 7.64 (dd, *J* = 8, 1.2 Hz, 2 H), 7.59 (tt, *J* = 8, 1.2 Hz, 1 H), 7.51 – 7.44 (m, 4 H), 7.40 ppm (tt, J = 8, 2 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.3, 145.2, 140.0, 137.7, 136.2, 132.3, 130.7, 130.0, 128.9, 128.3, 128.2, 127.3, 127.0 ppm; mp 100.7-101.5 °C.



(3,5-Dimethylisoxazol-4-yl)(phenyl)methanone (5sa): Following *general procedure A* except reducing the amount of PivOH to 0.125 mmol, **5sa** was isolated as a colorless liquid (33 mg, 65%), known compound. The NMR spectroscopic data agree with those described in ref.[S5] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71–7.68 (m, 2 H), 7.59 (tt, *J* = 8, 1.2 Hz, 1H), 7.50–7.46 (m, 2 H), 2.31 (s, 3 H), 2.28 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.4, 172.3, 159.6, 138.4, 133.2, 128.9, 128.8, 116.5, 13.3, 11.3 ppm.

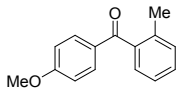


(4-Chlorophenyl)(4-nitrophenyl)methanone (5ob): Following *general procedure A*, **5ob** was isolated as a light pink solid (52 mg, 80%), known compound (CAS: 7497-60-1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.33 (d, *J* = 8 Hz, 2 H), 7.89 (d, *J* = 8 Hz, 2 H), 7.73 (d, *J* = 8.8 Hz, 2 H), 7.49 ppm (d, *J* = 8.8 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 193.6, 149.9, 142.5, 140.1, 134.5, 131.4, 130.6, 129.1, 123.7 ppm; mp 89-90 °C.

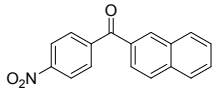


(4-Chlorophenyl)(*p*-tolyl)methanone (5gb): Following *general procedure A*, **5gb** was isolated as a light pink solid (47 mg, 82%), known compound (CAS: 5395-79-9). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d, *J* = 8.8 Hz, 2 H), 7.67 (d, *J* = 8 Hz, 2 H), 7.43 (d, *J* = 8 Hz, 2 H), 7.27 (d, *J* = 8 Hz, 2 H), 2.43 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.3, 143.5, 138.6, 136.2, 131.3, 130.2, 129.1, 128.5,

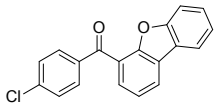
21.7 ppm; mp 123.4-123.9 °C



(4-Methoxyphenyl)(*o*-tolyl)methanone (5lc): Following *general procedure A*, **5lc** was isolated as a light pink solid (40 mg, 70%), known compound. The NMR spectroscopic data agree with those described in ref.[S11] ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (d, *J* = 8 Hz, 2 H), 7.35 (td, J = 8, 1.2 Hz, 1 H), 7.27 – 7.20 (m, 3 H), 6.91 (d, *J* = 9.2 Hz, 2 H), 3.85 (s, 3 H), 2.28 ppm (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 197.3, 163.7, 139.2, 136.1, 132.5, 130.8, 130.5, 129.7, 127.9, 125.1, 113.7, 55.5, 19.7 ppm;



Naphthalen-2-yl(4-nitrophenyl)methanone (5od): Following *general procedure A*, **5od** was isolated as a yellow solid (45 mg, 65%), known compound. The NMR spectroscopic data agree with those described in ref.[S1] ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.36 (d, *J* = 8 Hz, 2 H), 8.21 (s, 1 H), 7.99 – 7.95 (m, 3 H), 7.94 – 7.90 (m, 3 H), 7.64 (tt, *J* = 8, 1.2 Hz, 1 H), 7.57 ppm (tt, *J* = 8, 1.2 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.8, 149.8, 143.3, 135.7, 133.6, 132.4, 132.2, 130.7, 129.5, 129.0, 128.8, 127.9, 127.2, 125.2, 123.6 ppm; mp 129-130 °C



(4-Chlorophenyl)(dibenzo[b,d]furan-4-yl)methanone (5ae): Following *general procedure A* except using KOAc (0.05 mmol) instead of PivOH, **5ae** was isolated as a white solid (55 mg, 72%), unknown compound. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.15 (dd, *J* = 8 Hz, 1.2 Hz, 1 H), 7.98 (ddd, *J* = 8, 1.6, 0.8 Hz, 1 H), 7.83 (d, *J* = 8 Hz, 2 H), 7.69 (dd, *J* = 8, 1.2 Hz, 1 H), 7.53 – 7.50 (m, 1 H), 7.48 – 7.44 (m, 4 H), 7.37 ppm (td, *J* = 8,0.8 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.6, 156.3, 153.7, 139.6, 136.0, 131.5, 128.7, 128.5, 127.9, 125.6, 124.4, 123.3, 123.2, 122.8, 122.6, 120.7, 112.1 ppm; HRMS (ESI) calcd for $C_{19}H_{11}ClO_2H^+$ [M + H$^+$] m/z 307.05257, found m/z 307.05203; IR: ν_{max} (KBr) = 3094, 2915, 1653, 1586, 1489, 1457, 1417, 1290, 1184, 1091, 850, 750 cm^{-1}; mp 127-128 °C.

7. References

[S1] Q. Zhou, S. H. Wei and W. Han, *J. Org. Chem.*, 2014, **79**, 1454.

[S2] L. J. Cheng, Y. Z. Zhong, Z. C. Ni, H. Y. Du, F. l. Jin, Q. Rong and W. Han, *RSC Adv.*, 2014, **4**, 44312.

[S3] A. T. Biju and F. Glorius, *Angew. Chem., Int. Ed.*, 2010, **49**, 9761.

[S4] Y. Z. Zhong and W. Han, *Chem. Commun.*, 2014, **50**, 3874.

[S5] T. Ohishi, M. Nishiura and Z. Hou, *Angew. Chem., Int. Ed.*, 2008, **47**, 5792.

[S6] M. Javier, M. H. Chen, J. D. Clark and T. Nussbaumer, *J. Org. Chem.*, 2006, **71**, 7103.

[S7] A. Ahlburg, A. T. Lindhardt, R. H. Taaning, A. E. Modvig and T. Skrydstrup, *J. Org. Chem.*, 2013, **78**, 10310.

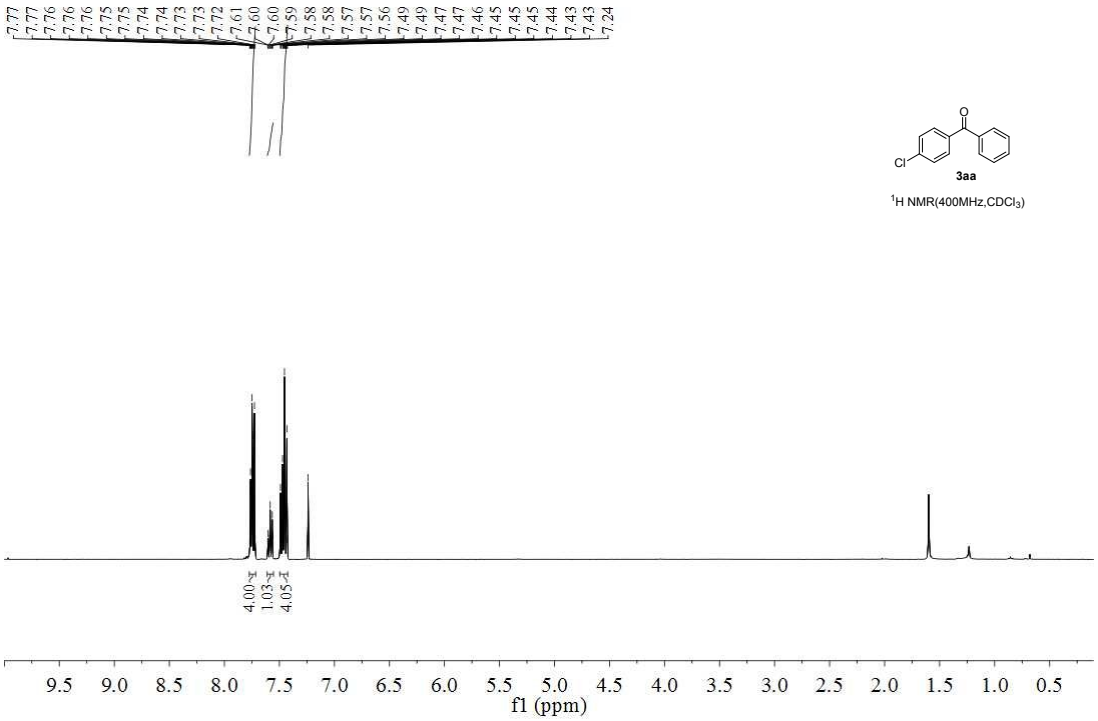
[S8] J. -Y. Chen, S. -C. Chen, Y. -J. Tang, C. Y. Mou and F. Y. Tsai, *J. Mol. Catal. A: Chem.*, 2009, **307**, 88.

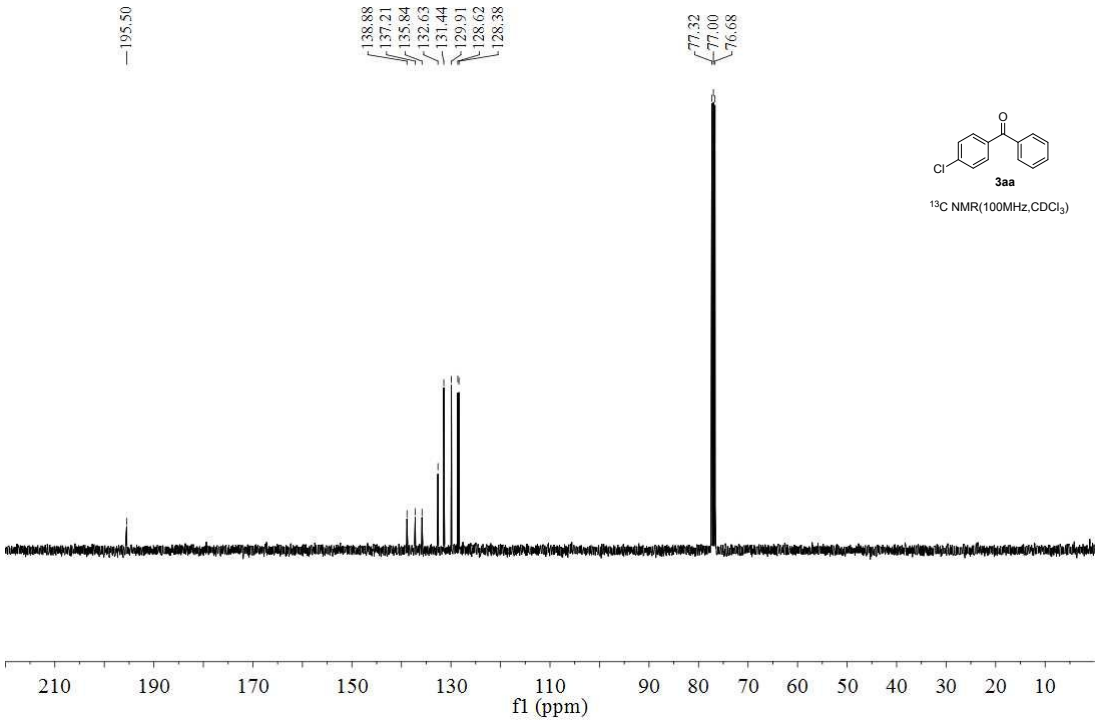
[S9] H. Neumann, A. Brennführer and M. Beller, *Chem. Eur. J.*, 2008, **14**, 3645.

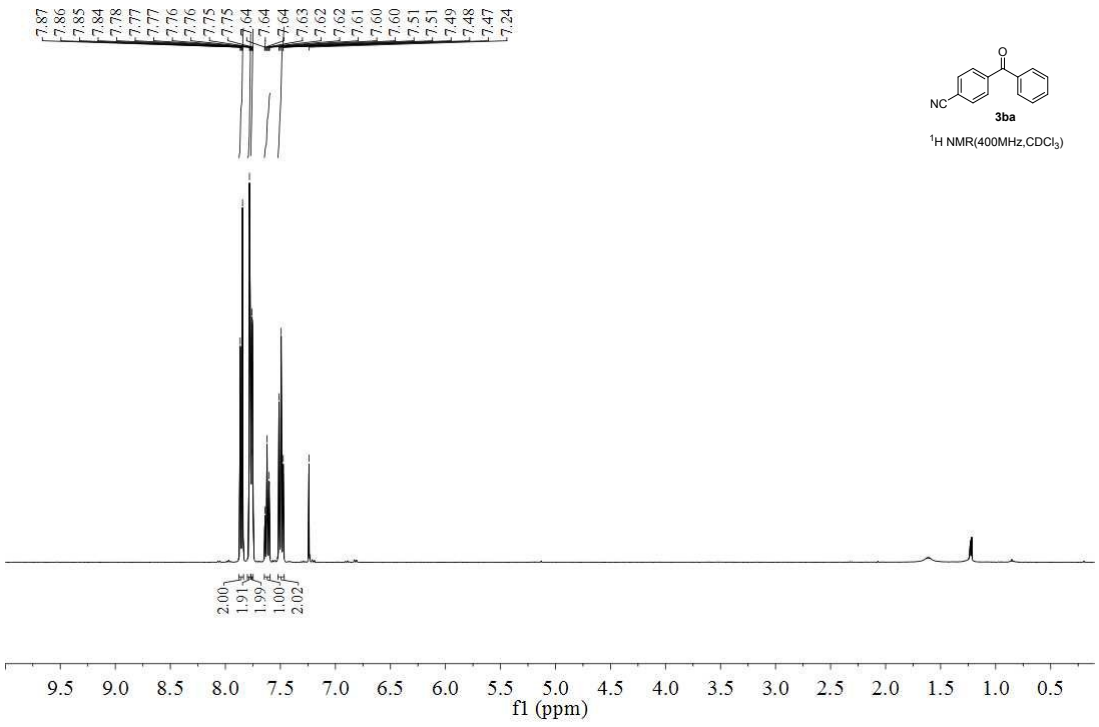
[S10] M. Chidambaram, C. Venkatesan, P. Moreau, A. Finiels, A. V. Ramaswamy and A. P. Singh, *Appl. Catal. A- Gen.*, 2002, **224**, 129.

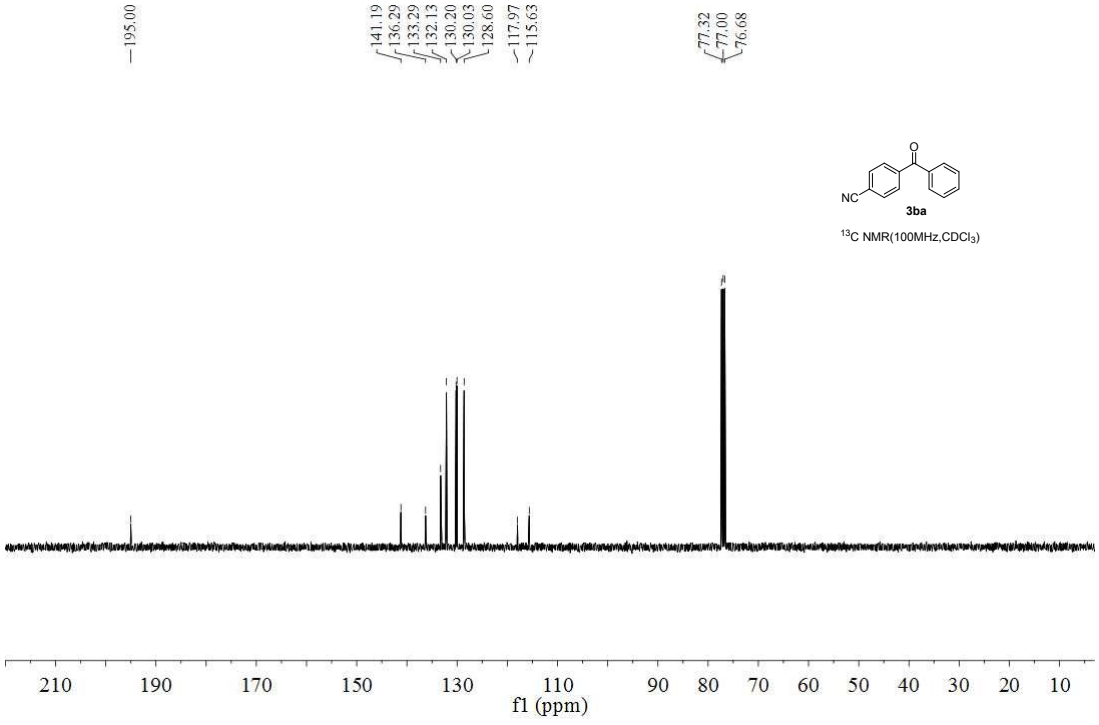
[S11] O. Chuzel, A. Roesch, J.-P. Genet and S. Darses, *J. Org. Chem.*, 2008, **73**, 7800.

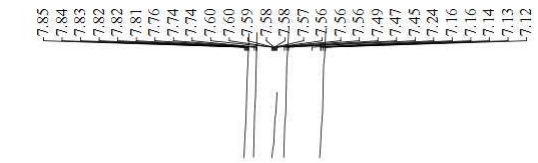
8. NMR Spectra for Products

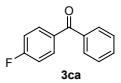





7.87
7.86
7.85
7.84
7.78
7.77
7.77
7.76
7.76
7.75
7.75
7.64
7.64
7.64
7.63
7.62
7.62
7.61
7.60
7.60
7.51
7.51
7.49
7.48
7.47
7.24
O
NC
3ba
1H NMR(400MHz,CDCl3)
2.00
1.91
1.99
1.00
2.02
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

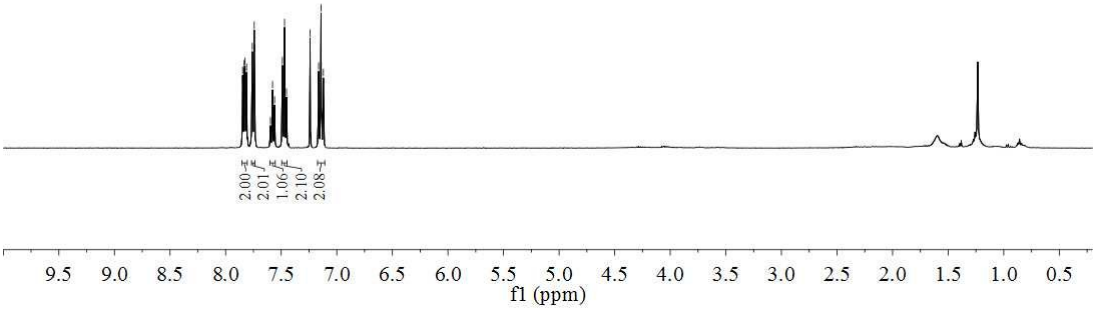

195.00
141.19
136.29
133.29
132.13
130.20
130.03
128.60
117.97
115.63
77.32
77.00
76.68
O
NC
3ba
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

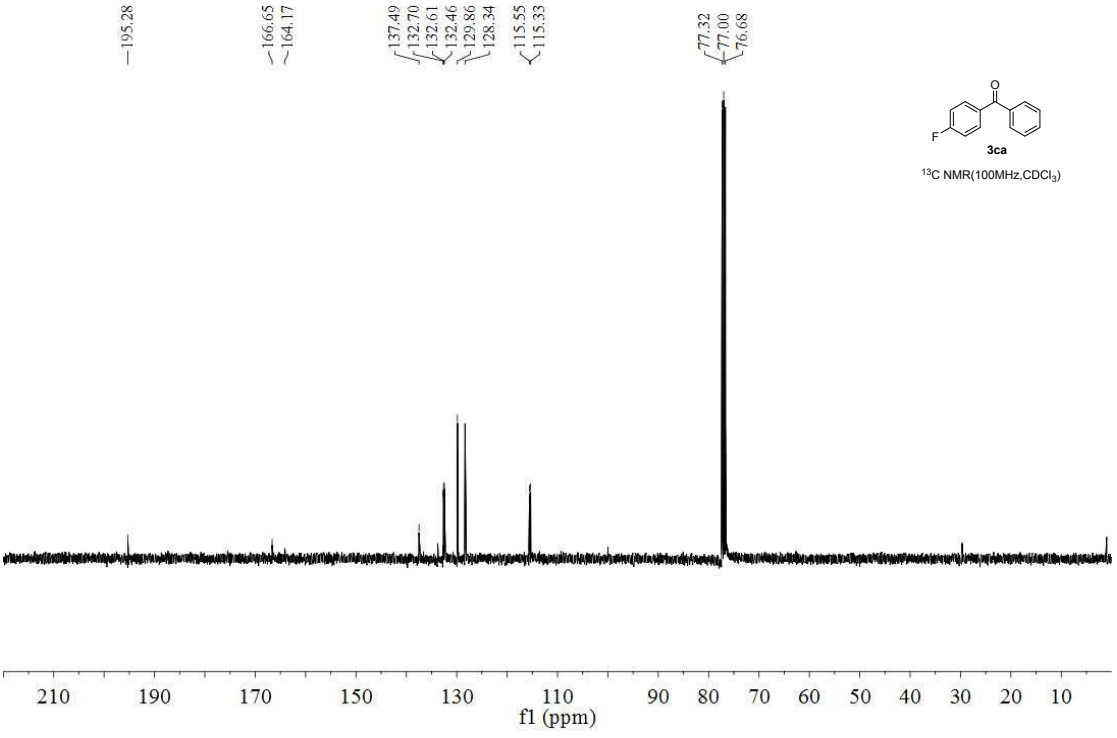




3ca

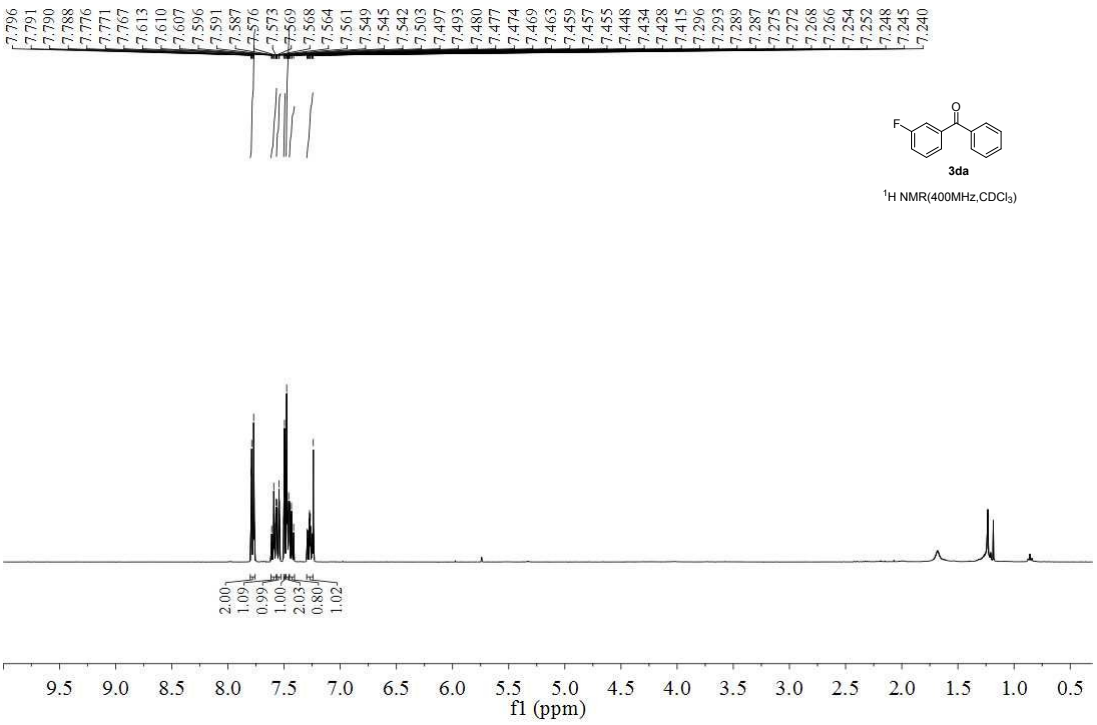
^{1}H NMR(400MHz,CDCl$_3$)

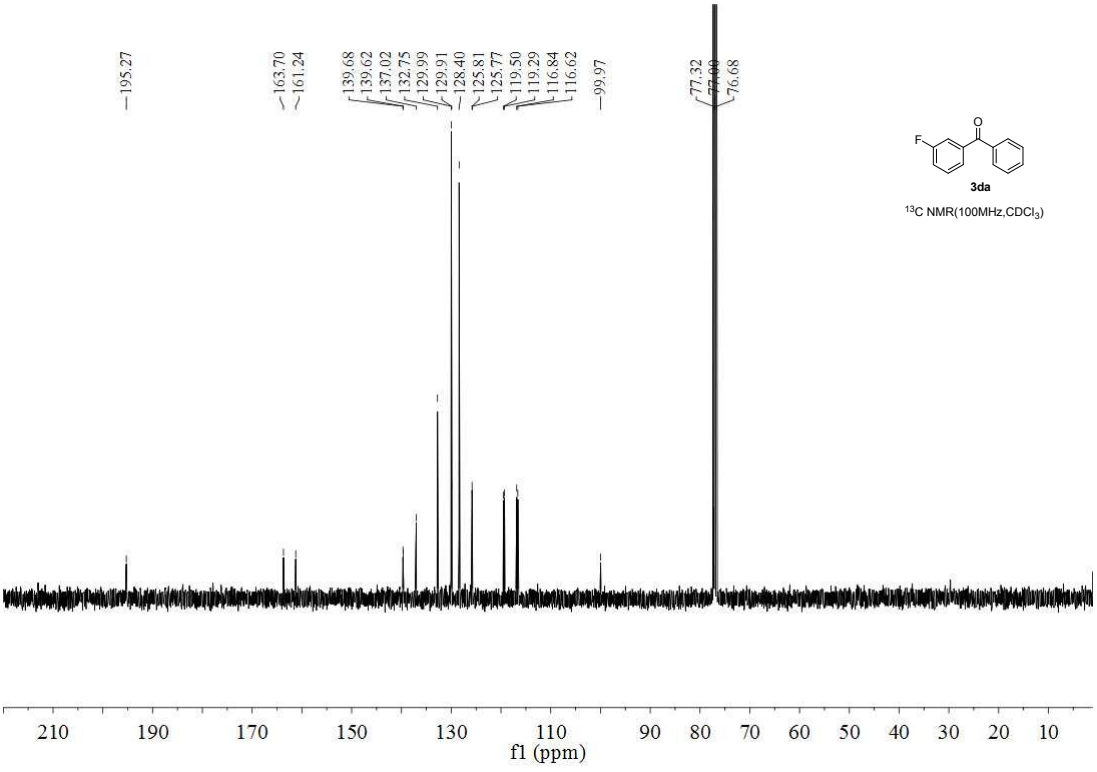


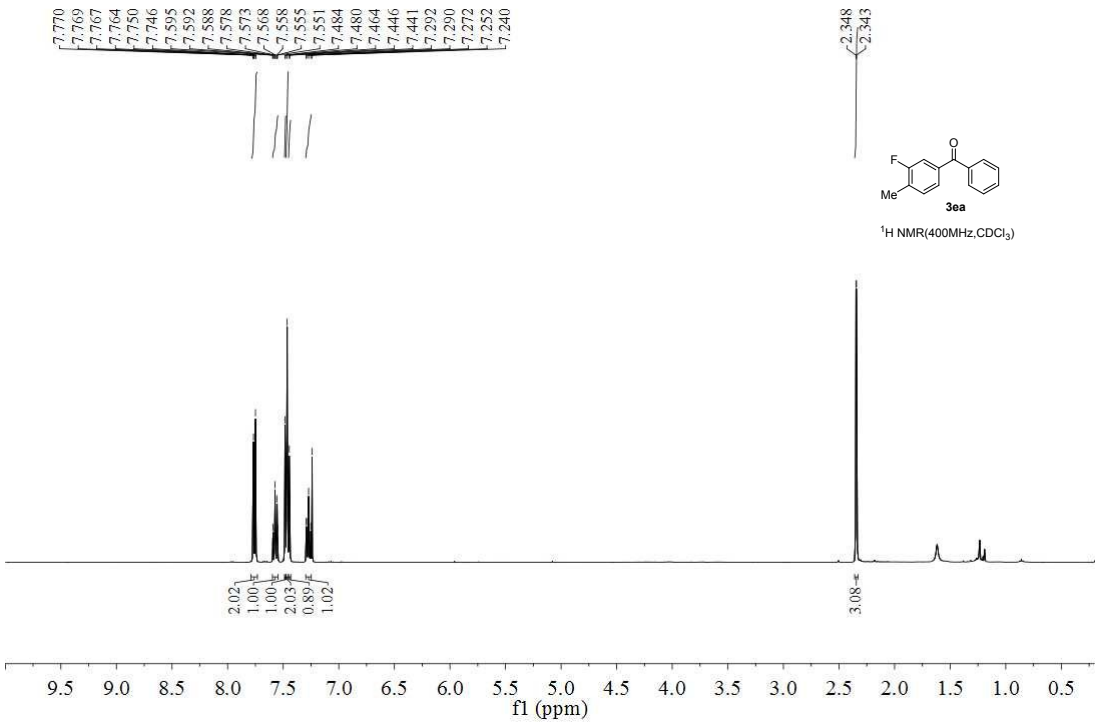


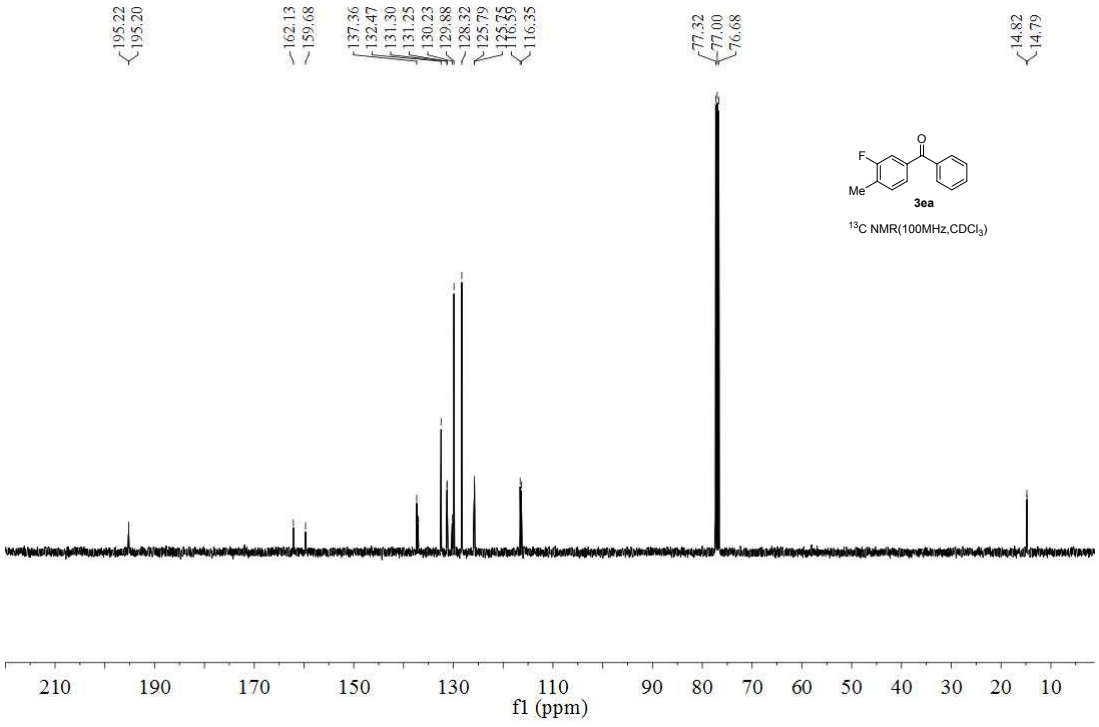
3ca

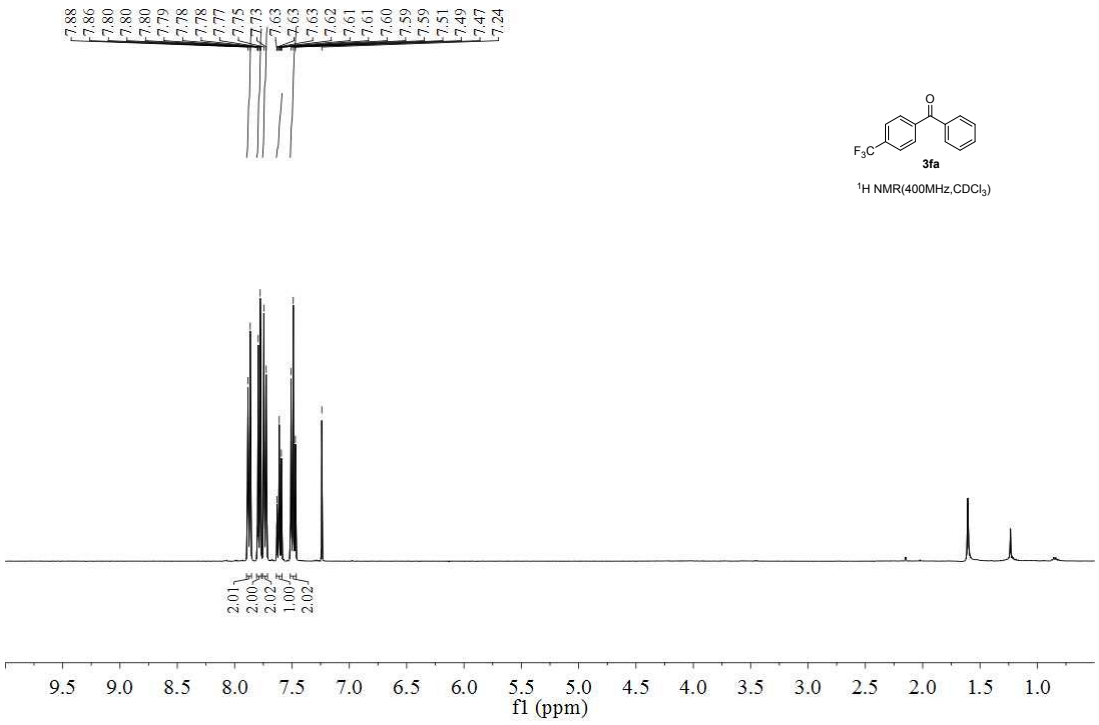
^{13}C NMR(100MHz,CDCl$_3$)

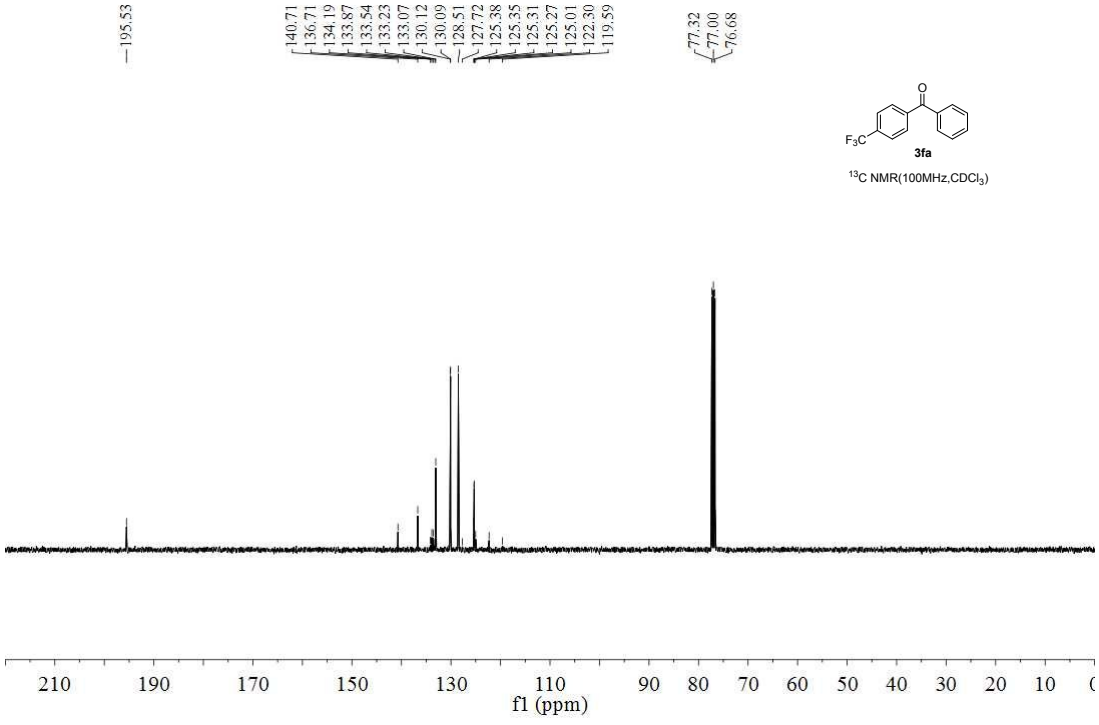

7.796
7.791
7.790
7.788
7.776
7.771
7.767
7.613
7.610
7.607
7.596
7.591
7.587
7.576
7.573
7.569
7.568
7.564
7.561
7.549
7.545
7.542
7.503
7.497
7.493
7.480
7.477
7.474
7.469
7.463
7.459
7.457
7.455
7.448
7.434
7.428
7.415
7.296
7.293
7.289
7.287
7.275
7.272
7.268
7.266
7.254
7.252
7.248
7.245
7.240
F
O
3da
1H NMR(400MHz,CDCl3)
2.00
1.09
0.99
1.00
2.03
0.80
1.02
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
f1 (ppm)

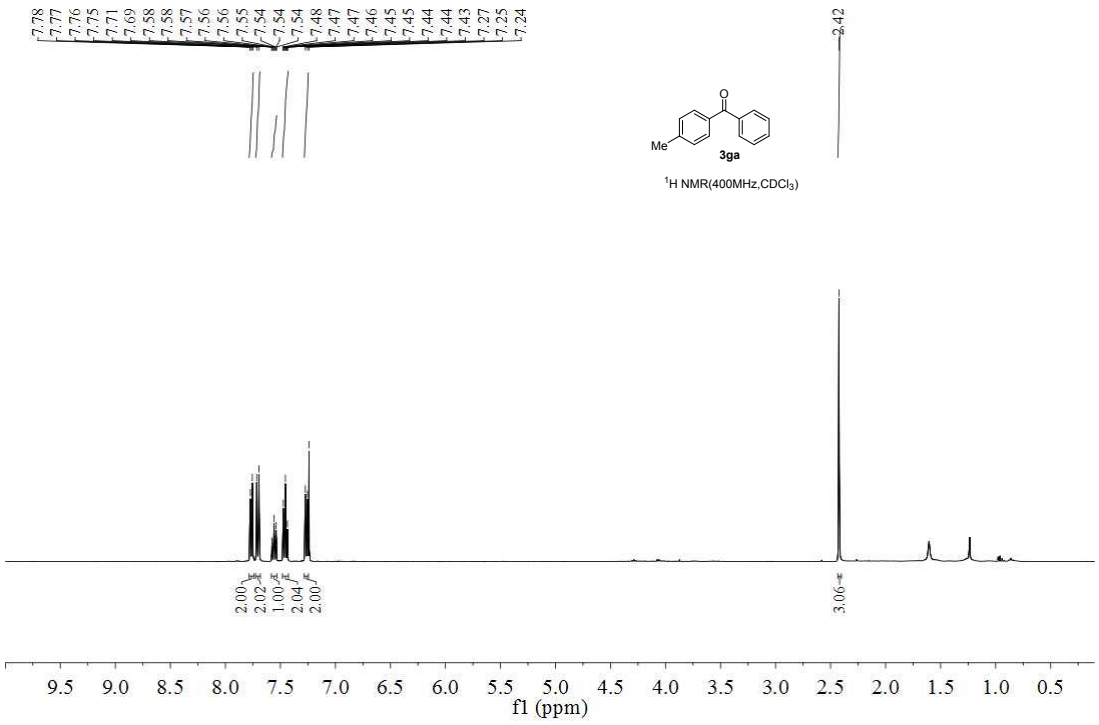

195.27
163.70
161.24
139.68
139.62
137.02
132.75
129.99
129.91
128.40
125.81
125.77
119.50
119.29
116.84
116.62
99.97
77.32
77.00
76.68
F
O
3da
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

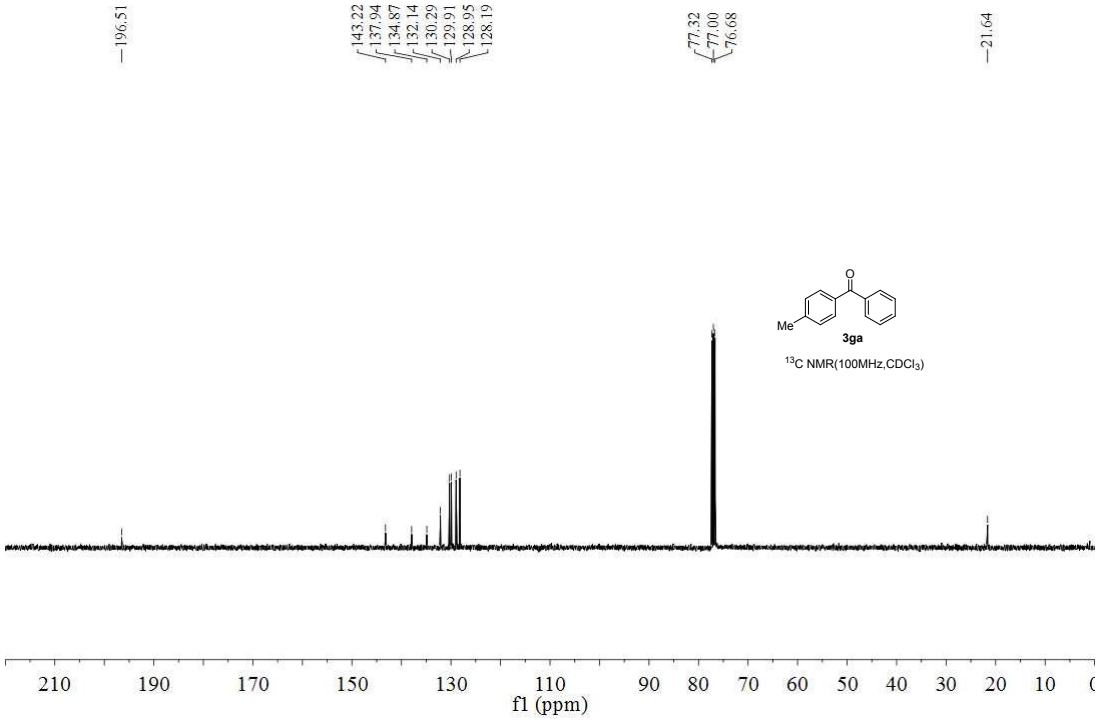

7.770
7.769
7.767
7.764
7.750
7.746
7.595
7.592
7.588
7.578
7.573
7.568
7.558
7.555
7.551
7.484
7.480
7.464
7.446
7.441
7.292
7.290
7.272
7.252
7.240
2.348
2.343
F
O
Me
3ea
^{1}H NMR(400MHz,CDCl$_3$)
2.02
1.00
1.00
2.03
0.89
1.02
3.08
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

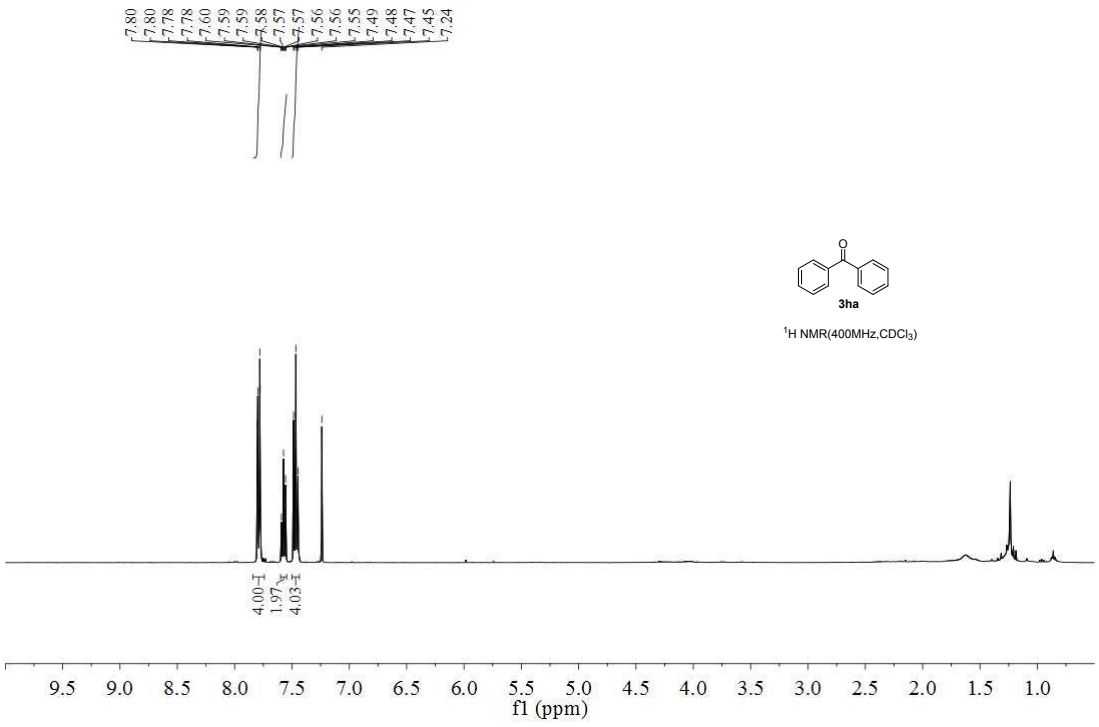

195.22
195.20
162.13
159.68
137.36
132.47
131.30
131.25
130.23
129.88
128.32
125.79
125.75
116.59
116.35
77.32
77.00
76.68
14.82
14.79
F
O
Me
3ea
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

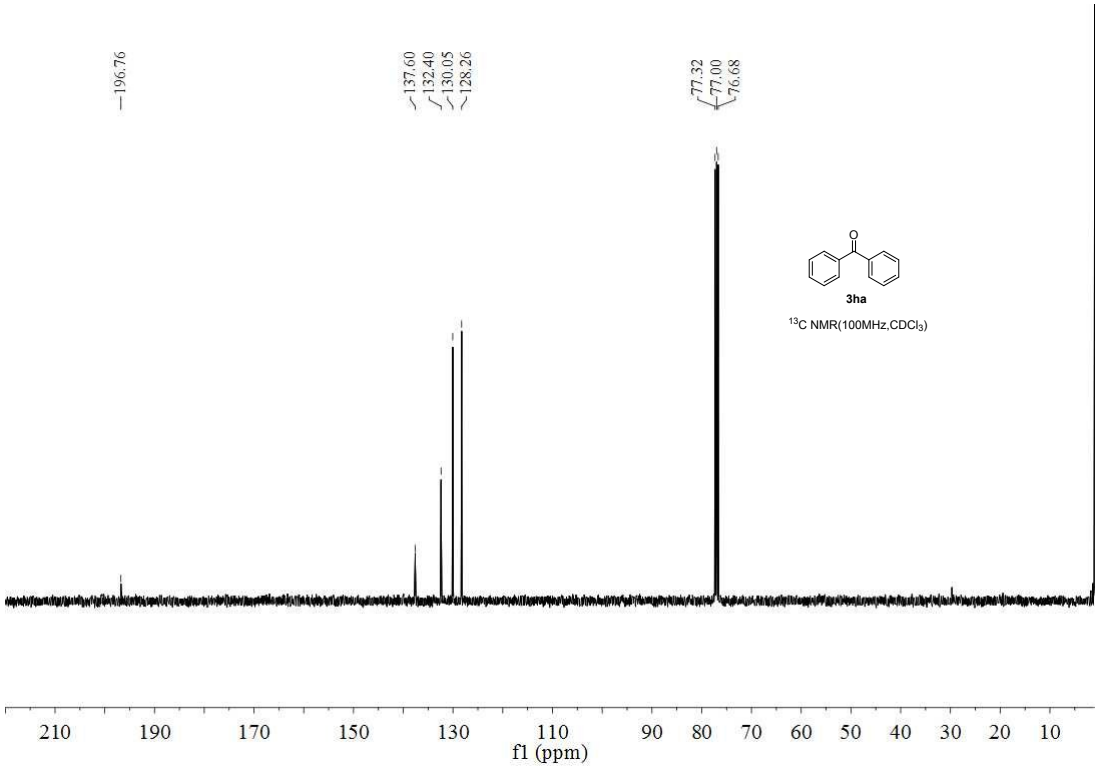

7.88
7.86
7.80
7.80
7.80
7.79
7.78
7.78
7.77
7.75
7.73
7.63
7.63
7.63
7.62
7.61
7.61
7.60
7.59
7.59
7.51
7.49
7.47
7.24
O
F3C
3fa
1H NMR(400MHz,CDCl3)
2.01
2.00
2.02
2.02
1.00
2.02
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
f1 (ppm)

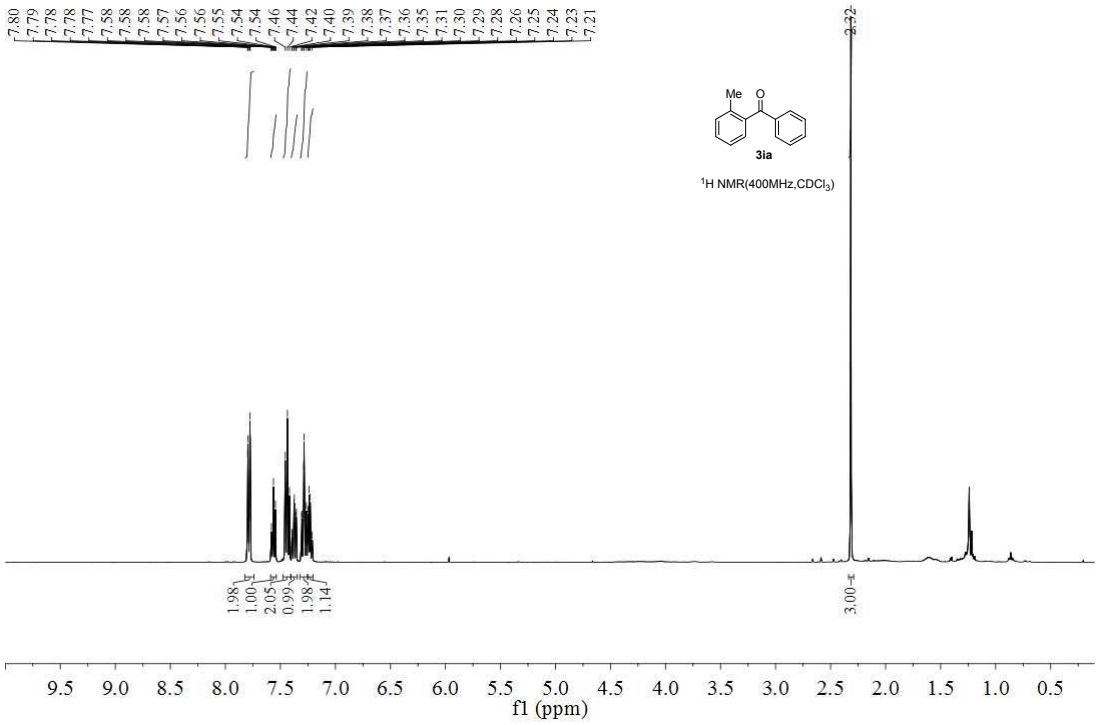

195.53
140.71
136.71
134.19
133.87
133.54
133.23
133.07
130.12
130.09
128.51
127.72
125.38
125.35
125.31
125.27
125.01
122.30
119.59
77.32
77.00
76.68
O
F3C
3fa
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

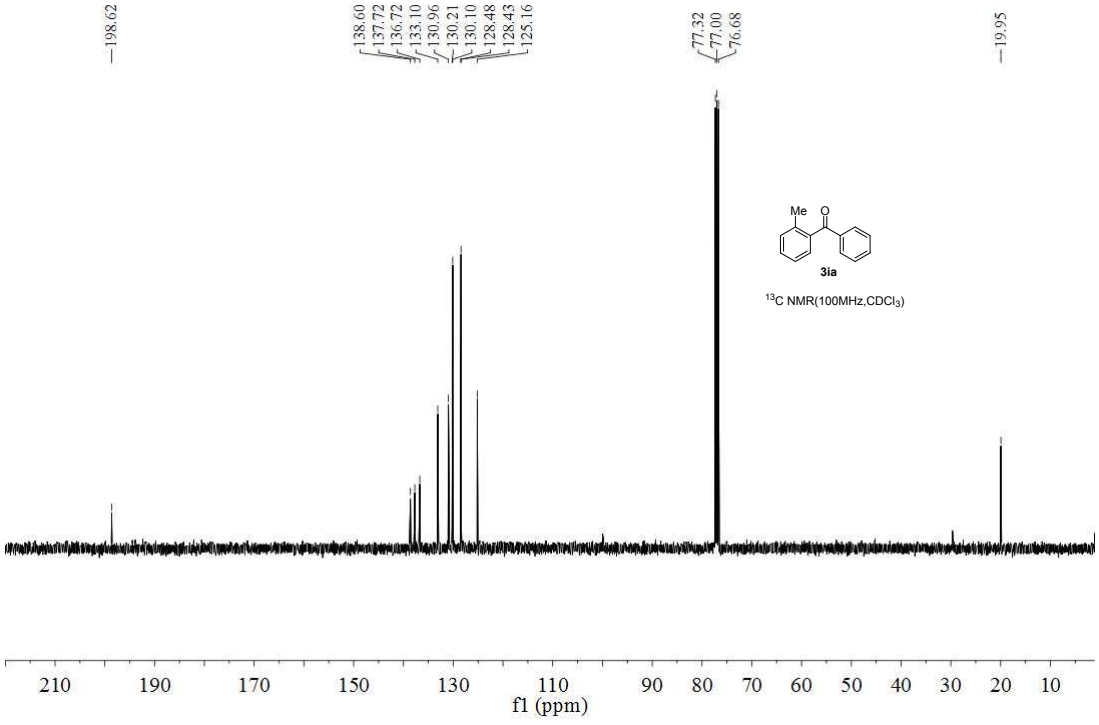

7.78
7.77
7.76
7.75
7.71
7.69
7.58
7.58
7.57
7.56
7.56
7.55
7.54
7.54
7.54
7.48
7.47
7.47
7.46
7.45
7.45
7.44
7.44
7.43
7.27
7.25
7.24
2.42
O
Me
3ga
1H NMR(400MHz,CDCl3)
2.00
2.02
1.00
2.04
2.00
3.06
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

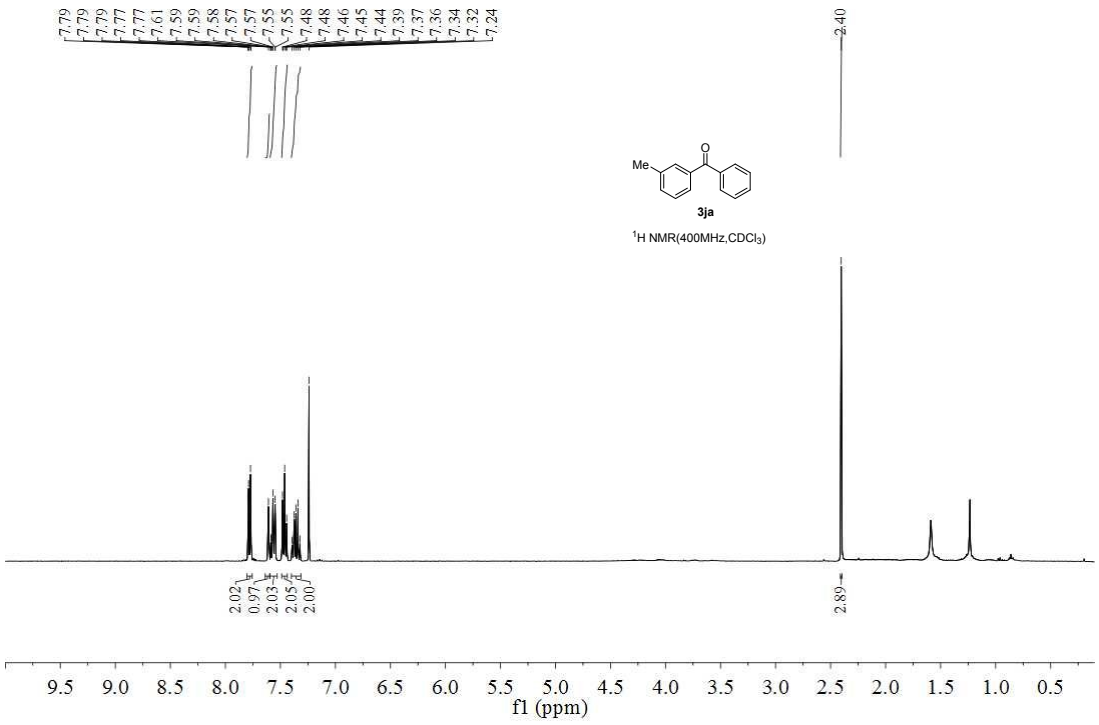

196.51
143.22
137.94
134.87
132.14
130.29
129.91
128.95
128.19
77.32
77.00
76.68
21.64
O
Me
3ga
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

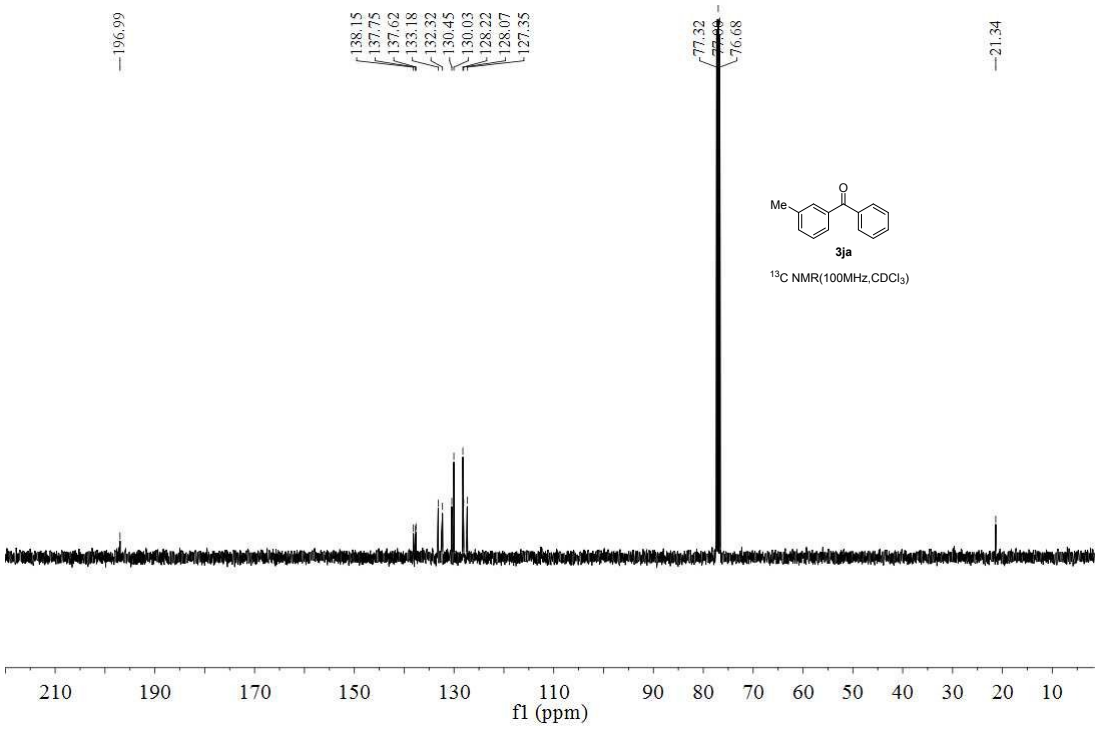

7.80
7.80
7.78
7.78
7.60
7.59
7.59
7.58
7.57
7.57
7.56
7.56
7.55
7.49
7.48
7.47
7.45
7.24
3ha
1H NMR(400MHz,CDCl3)
4.00
1.97
4.03
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
f1 (ppm)

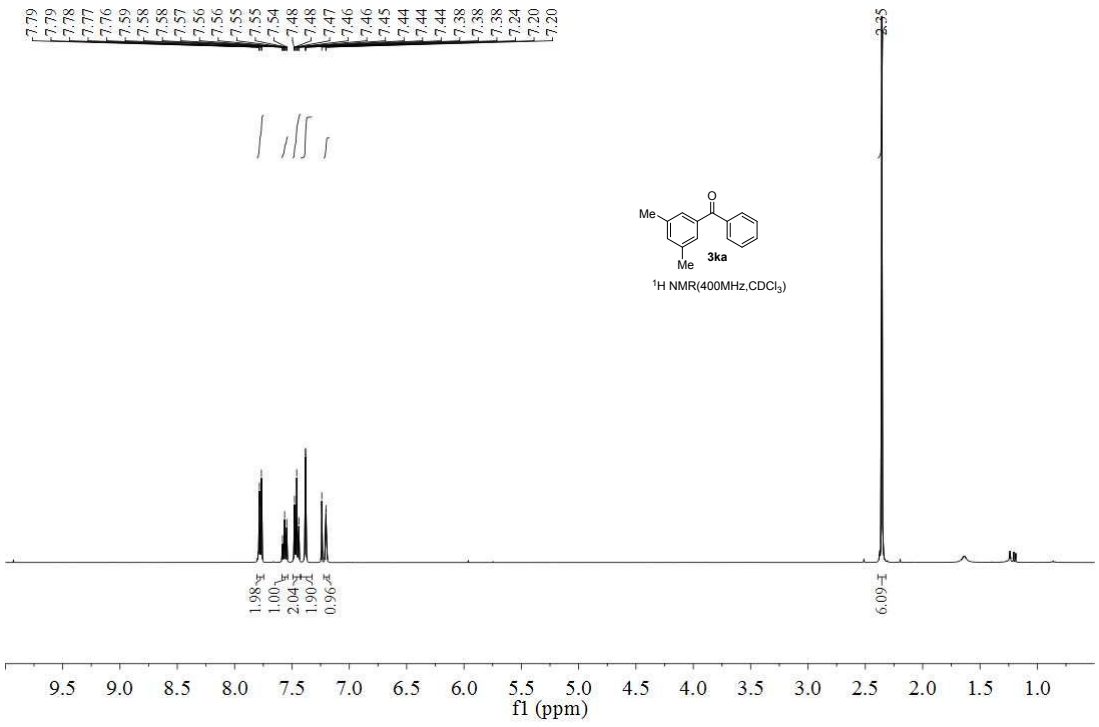

196.76
137.60
132.40
130.05
128.26
77.32
77.00
76.68
3ha
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

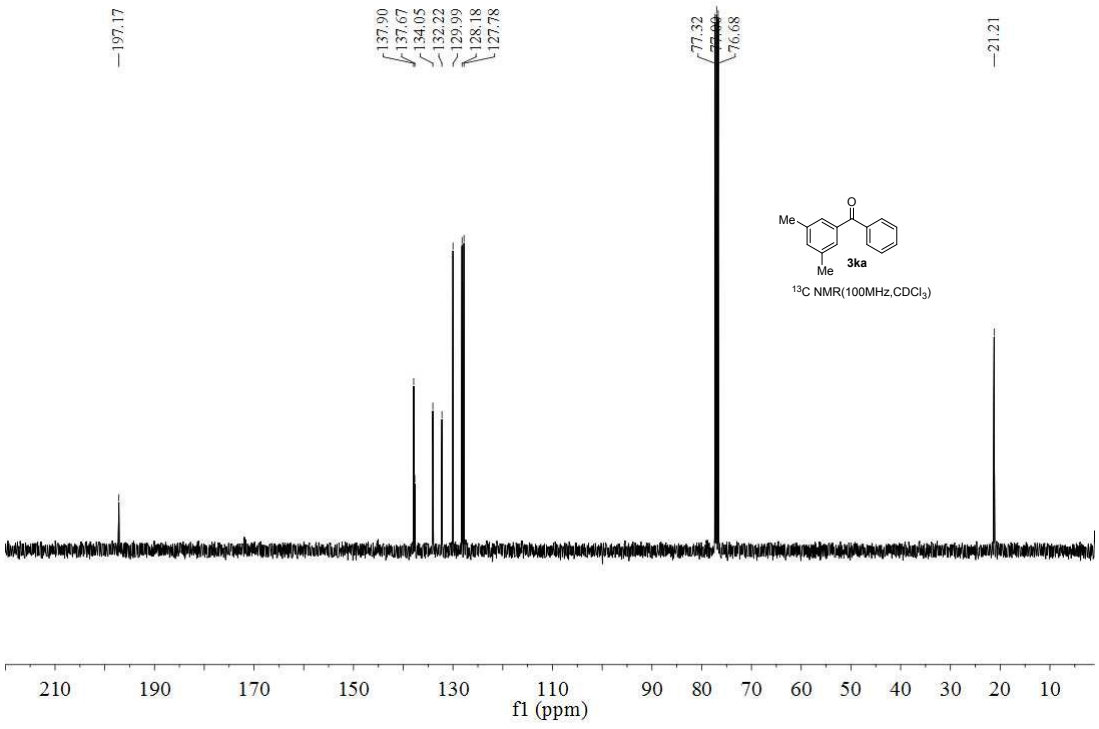

7.80
7.79
7.78
7.78
7.77
7.58
7.58
7.58
7.57
7.56
7.56
7.55
7.54
7.54
7.46
7.44
7.42
7.40
7.39
7.38
7.37
7.36
7.35
7.31
7.30
7.29
7.28
7.26
7.25
7.24
7.23
7.21
2.32
Me
O
3ia
1H NMR(400MHz,CDCl3)
1.98
1.00
2.05
0.99
1.98
1.14
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

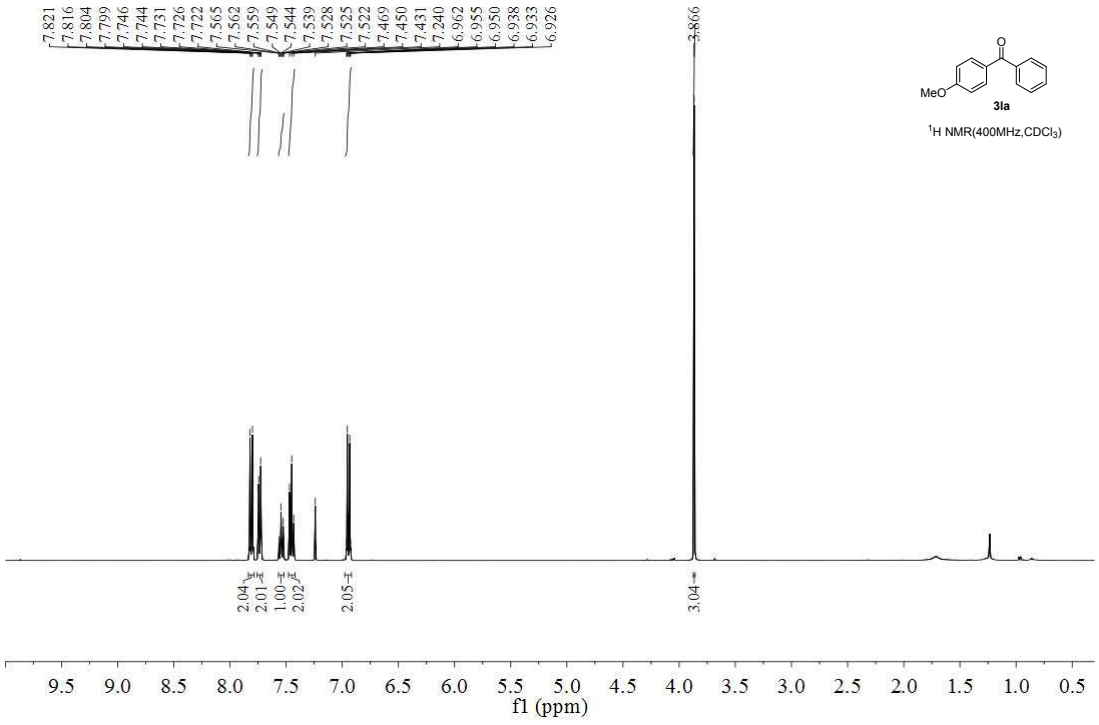

198.62
138.60
137.72
136.72
133.10
130.96
130.21
130.10
128.48
128.43
125.16
77.32
77.00
76.68
19.95
Me
O
3ia
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

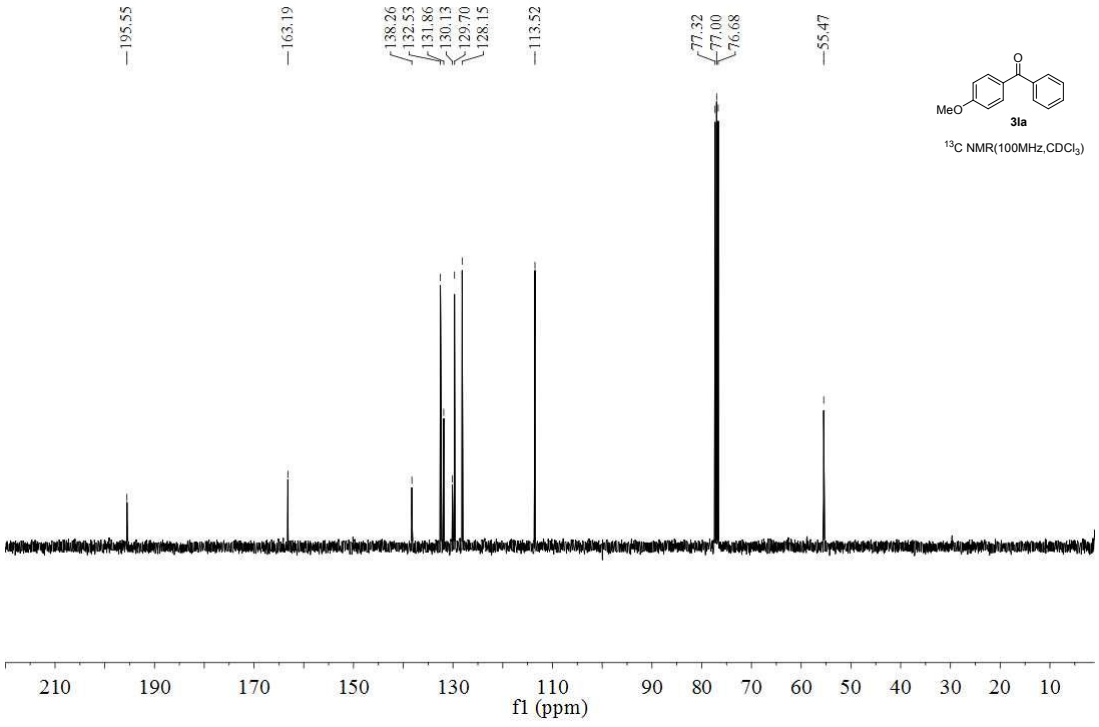

7.79
7.79
7.79
7.77
7.77
7.61
7.59
7.59
7.58
7.57
7.57
7.55
7.55
7.48
7.48
7.46
7.45
7.44
7.39
7.37
7.36
7.34
7.32
7.24
2.40
Me
O
3ja
1H NMR(400MHz,CDCl3)
2.02
0.97
2.03
2.05
2.00
2.89
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

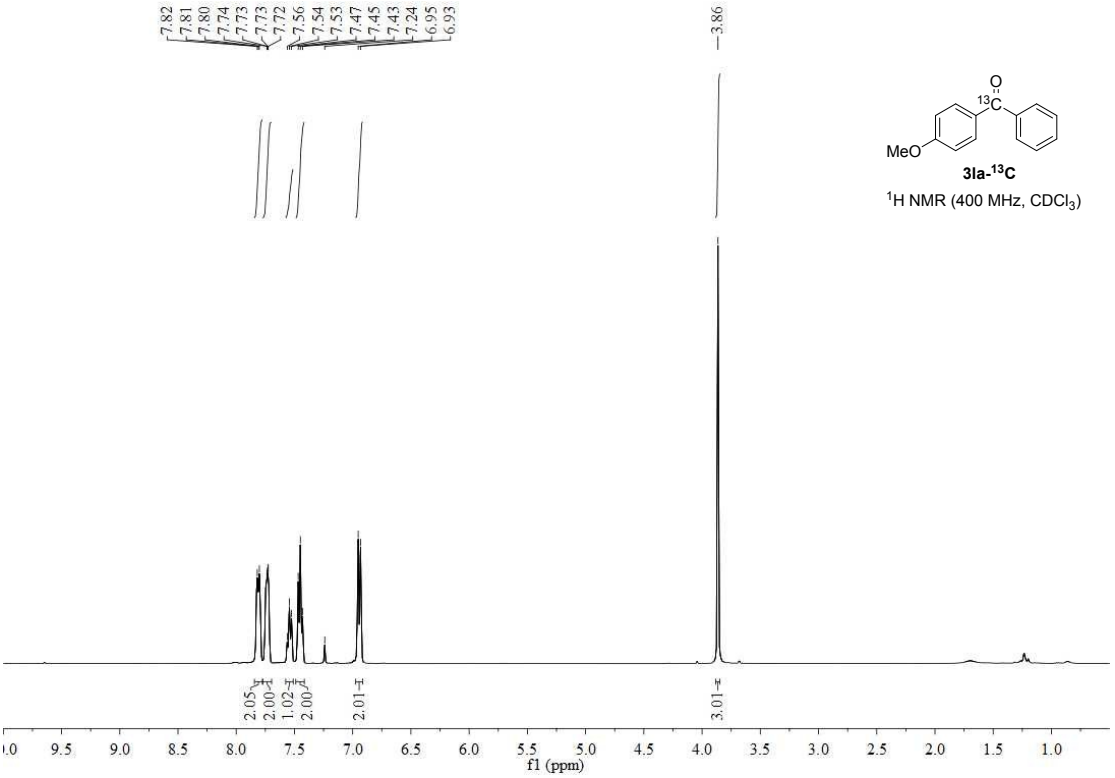

196.99
138.15
137.75
137.62
133.18
132.32
130.45
130.03
128.22
128.07
127.35
77.32
77.00
76.68
21.34
Me
O
3ja
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.79
7.79
7.78
7.77
7.76
7.59
7.58
7.58
7.57
7.56
7.56
7.55
7.55
7.54
7.48
7.48
7.47
7.46
7.46
7.45
7.44
7.44
7.44
7.38
7.38
7.38
7.24
7.20
7.20
2.35
Me
Me
O
3ka
1H NMR(400MHz,CDCl3)
1.98
1.00
2.04
1.90
0.96
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
f1 (ppm)


197.17
137.90
137.67
134.05
132.22
129.99
128.18
127.78
77.32
77.00
76.68
21.21
Me
Me
O
3ka
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

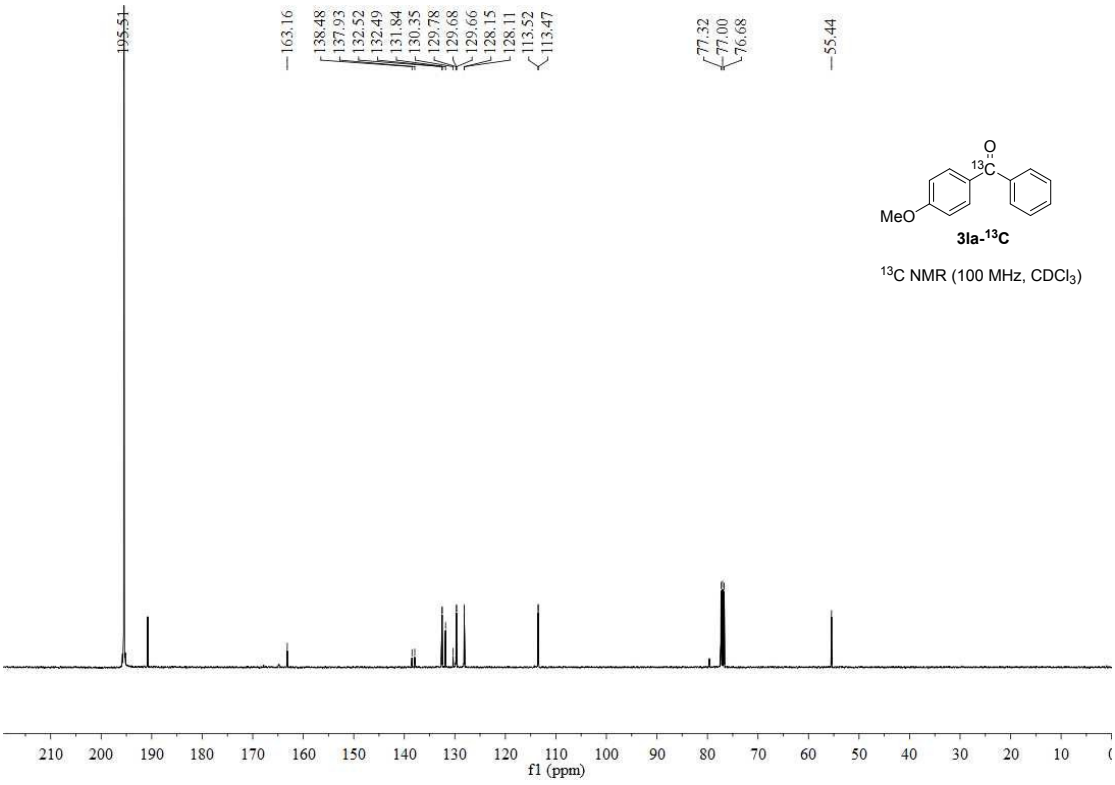

7.821
7.816
7.804
7.799
7.746
7.744
7.731
7.726
7.722
7.565
7.562
7.559
7.549
7.544
7.539
7.528
7.525
7.522
7.469
7.450
7.431
7.240
6.962
6.955
6.950
6.938
6.933
6.926
3.866
2.04
2.01
1.00
2.02
2.05
3.04
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)
MeO
3la
^{1}H NMR(400MHz,CDCl$_3$)


195.55
163.19
138.26
132.53
131.86
130.13
129.70
128.15
113.52
77.32
77.00
76.68
55.47
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)
MeO
3la
^{13}C NMR(100MHz,CDCl$_3$)



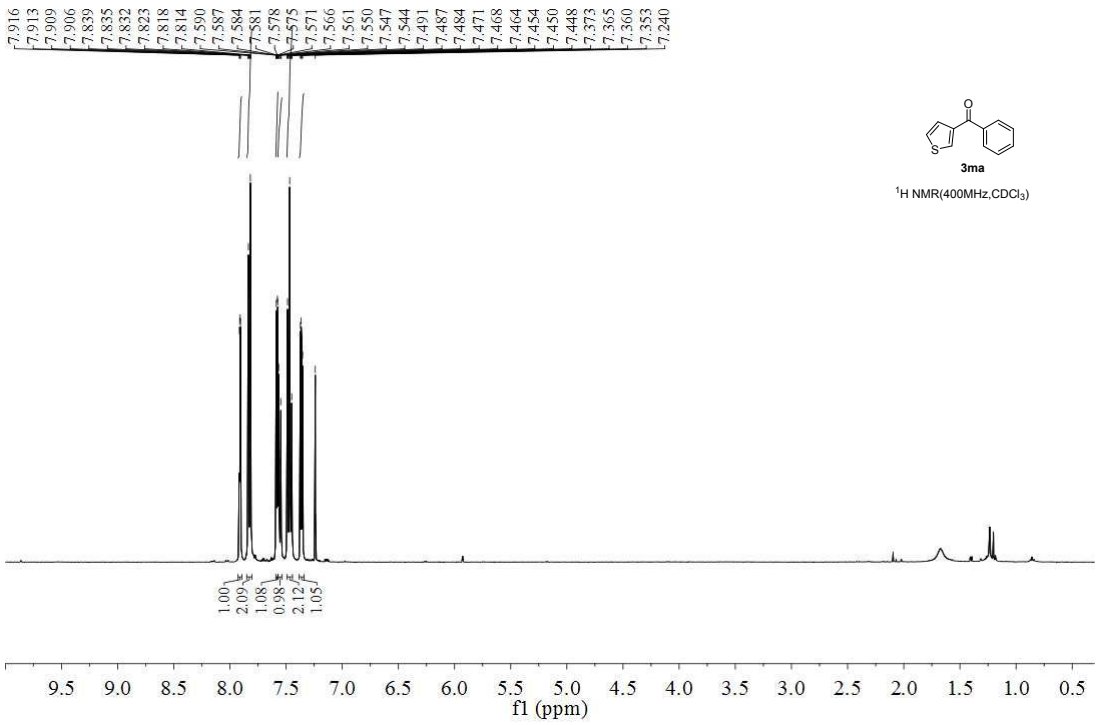
3la-^{13}C

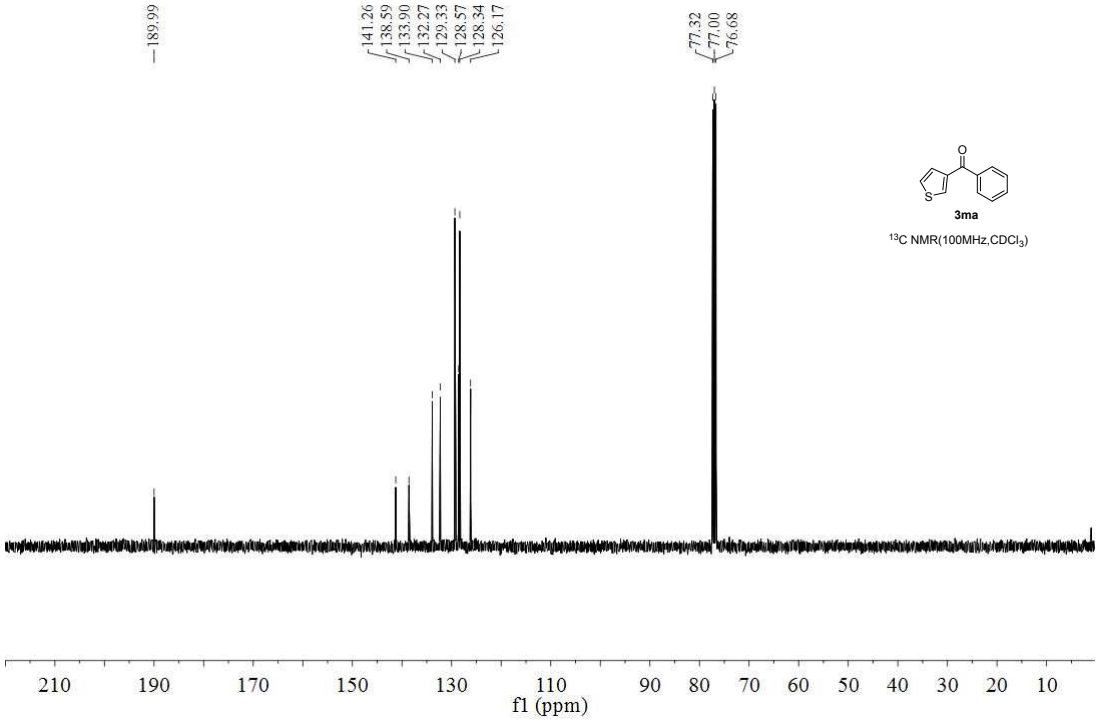
^{1}H NMR (400 MHz, $CDCl_3$)

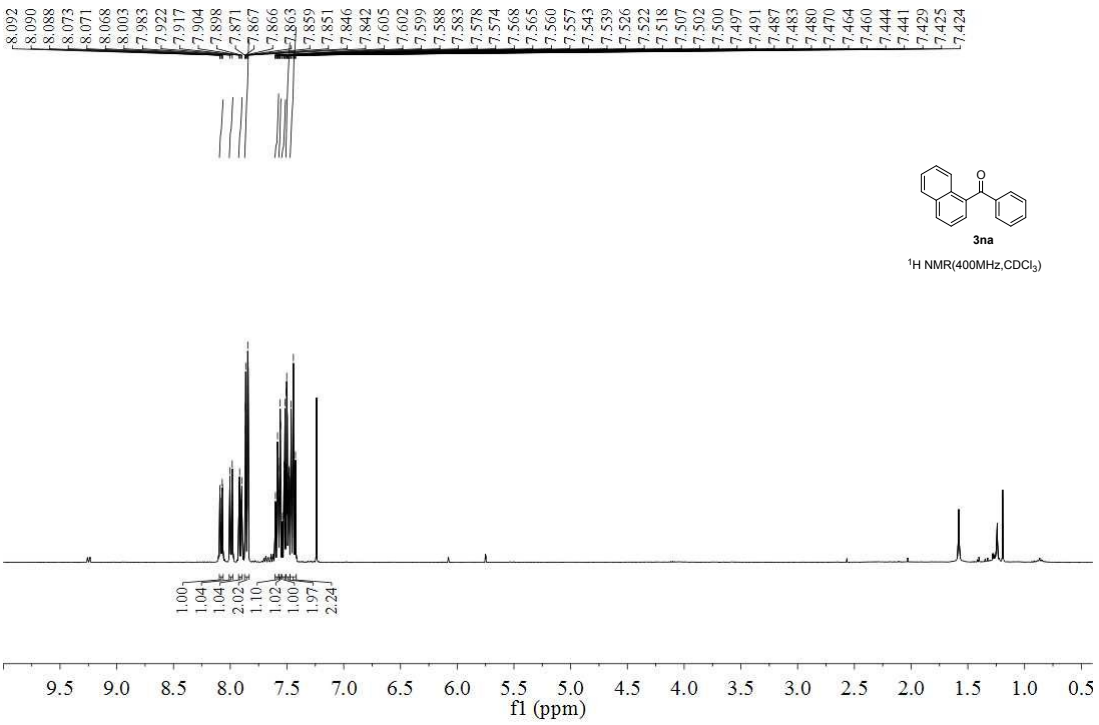


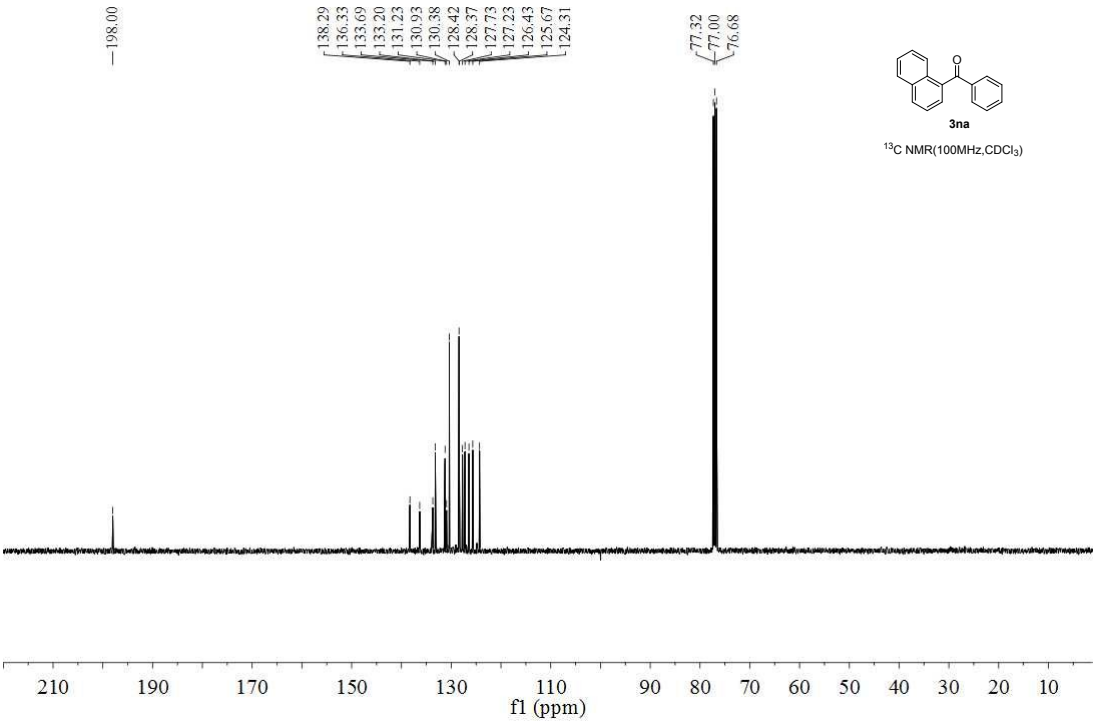
3la-^{13}C

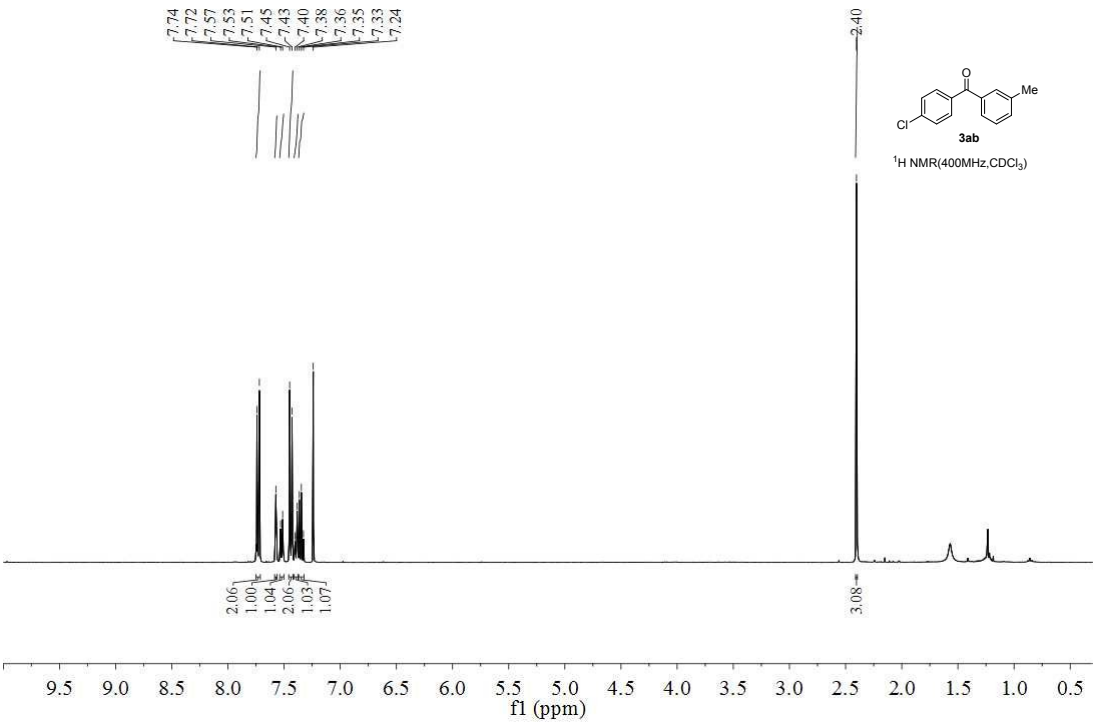
^{13}C NMR (100 MHz, $CDCl_3$)


7.916
7.913
7.909
7.906
7.839
7.835
7.832
7.823
7.818
7.814
7.590
7.587
7.584
7.581
7.578
7.575
7.571
7.566
7.561
7.550
7.547
7.544
7.491
7.487
7.484
7.471
7.468
7.464
7.454
7.450
7.448
7.373
7.365
7.360
7.353
7.240
1.00
2.09
1.08
0.98
2.12
1.05
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)
3ma
1H NMR(400MHz,CDCl3)


189.99
141.26
138.59
133.90
132.27
129.33
128.57
128.34
126.17
77.32
77.00
76.68
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)
3ma
13C NMR(100MHz,CDCl3)

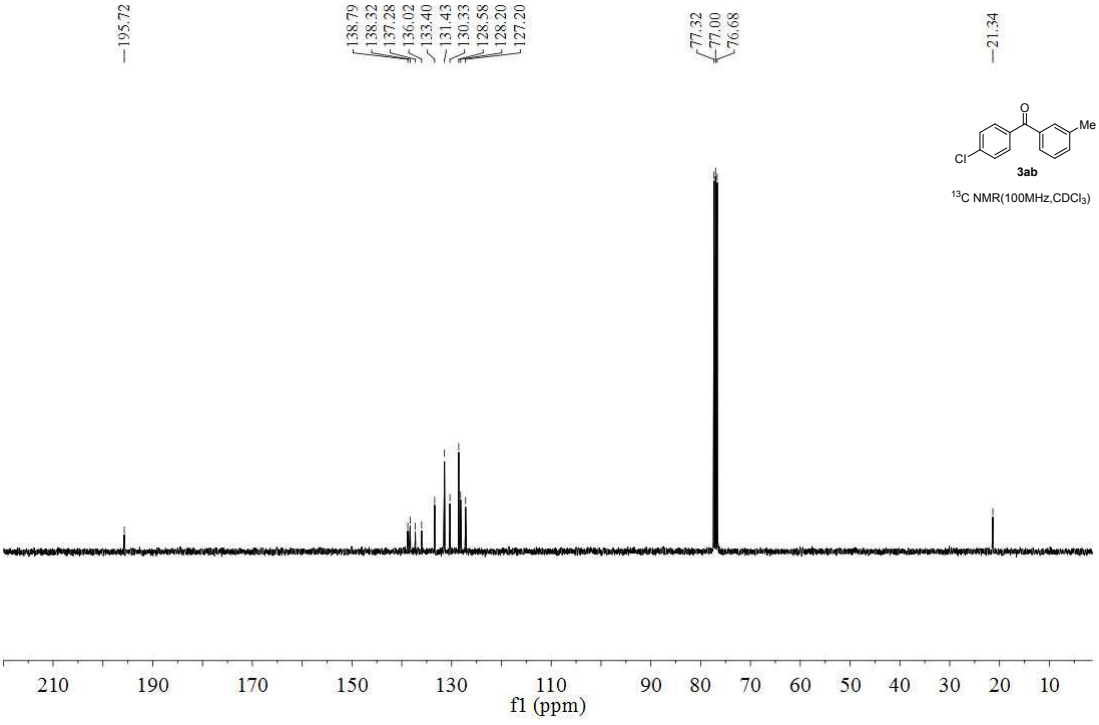

8.092
8.090
8.088
8.073
8.071
8.068
8.003
7.983
7.922
7.917
7.904
7.898
7.871
7.867
7.866
7.863
7.859
7.851
7.846
7.842
7.605
7.602
7.599
7.588
7.583
7.578
7.574
7.568
7.565
7.560
7.557
7.543
7.539
7.526
7.522
7.518
7.507
7.502
7.500
7.497
7.491
7.487
7.483
7.480
7.470
7.464
7.460
7.444
7.441
7.429
7.425
7.424
3na
1H NMR(400MHz,CDCl3)
1.00
1.04
1.04
2.02
1.10
1.02
1.00
1.97
2.24
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
f1 (ppm)


198.00
138.29
136.33
133.69
133.20
131.23
130.93
130.38
128.42
128.37
127.73
127.23
126.43
125.67
124.31
77.32
77.00
76.68
3na
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)



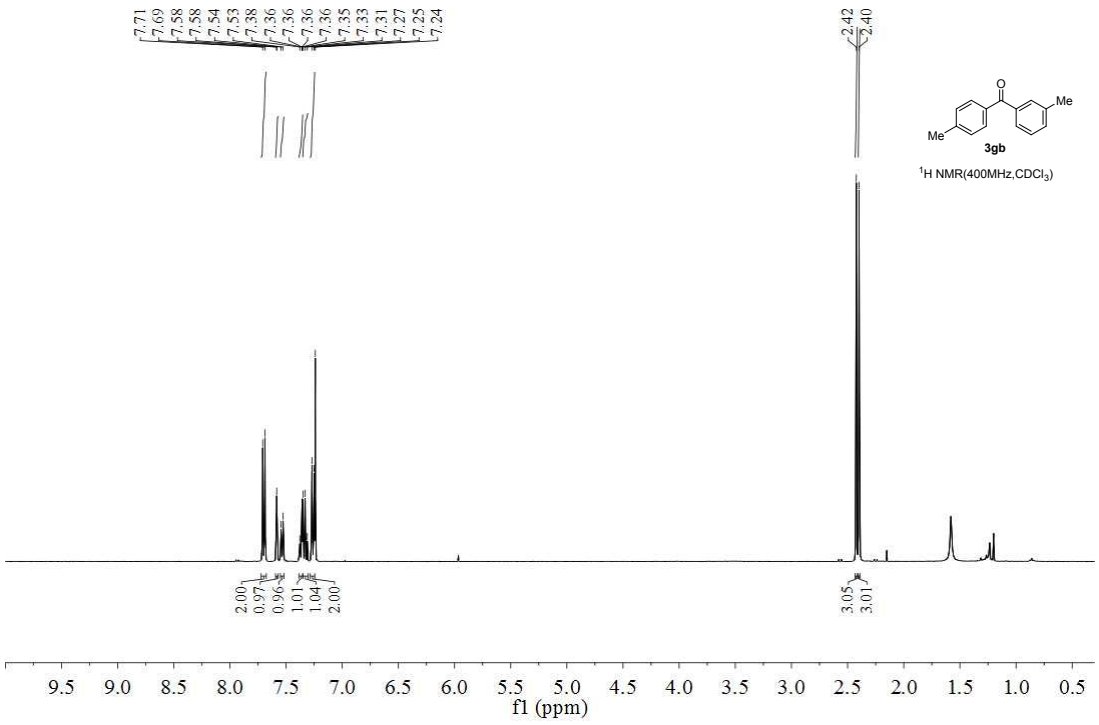
3ab

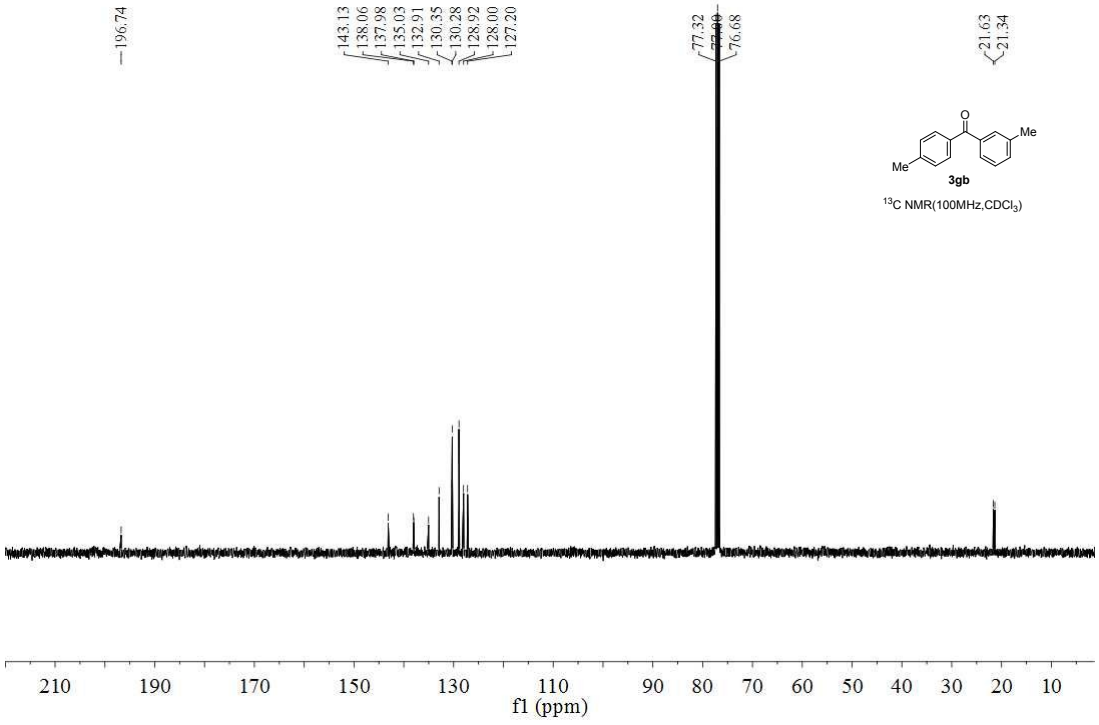
^{1}H NMR(400MHz,CDCl$_3$)

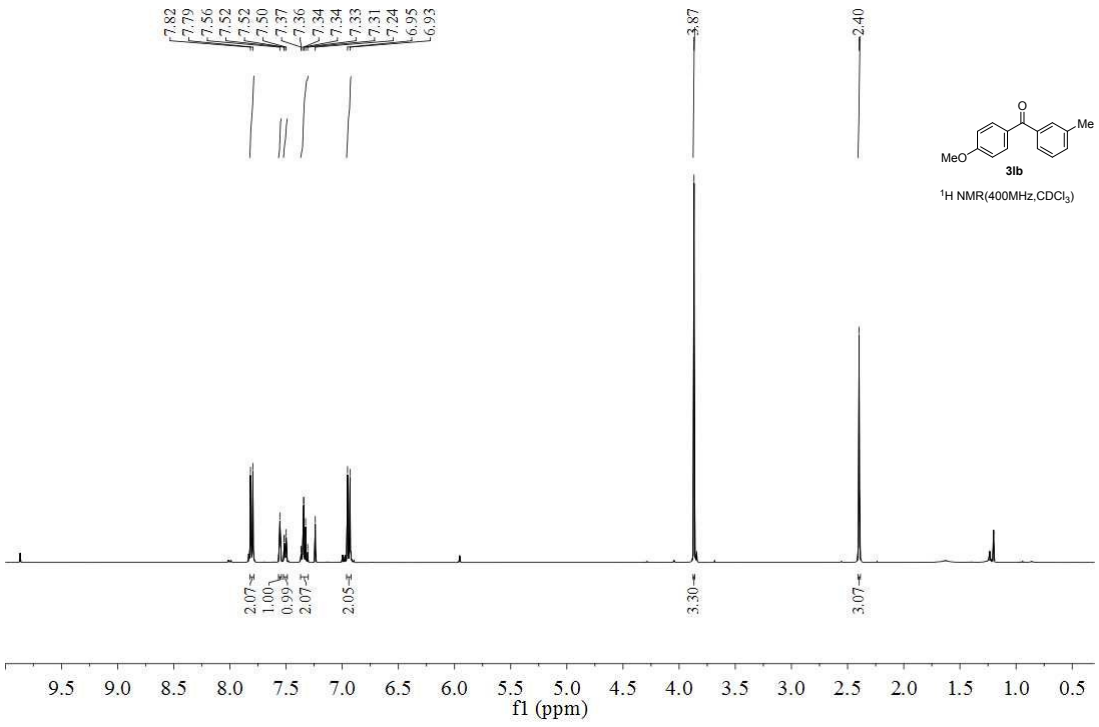


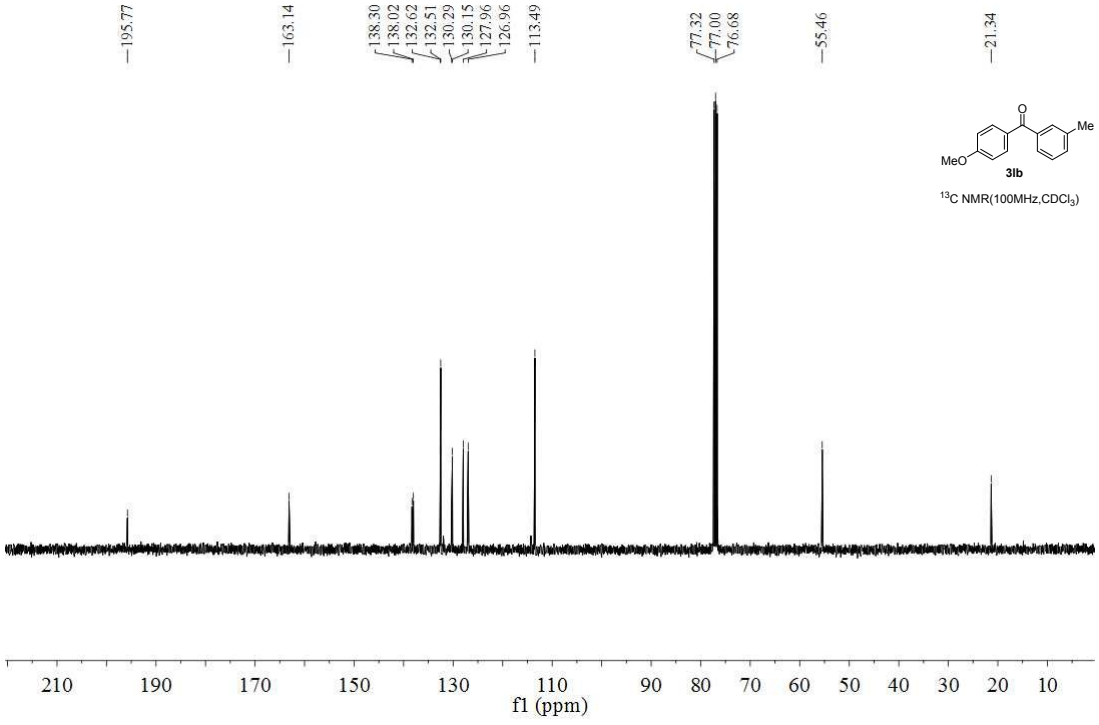
3ab

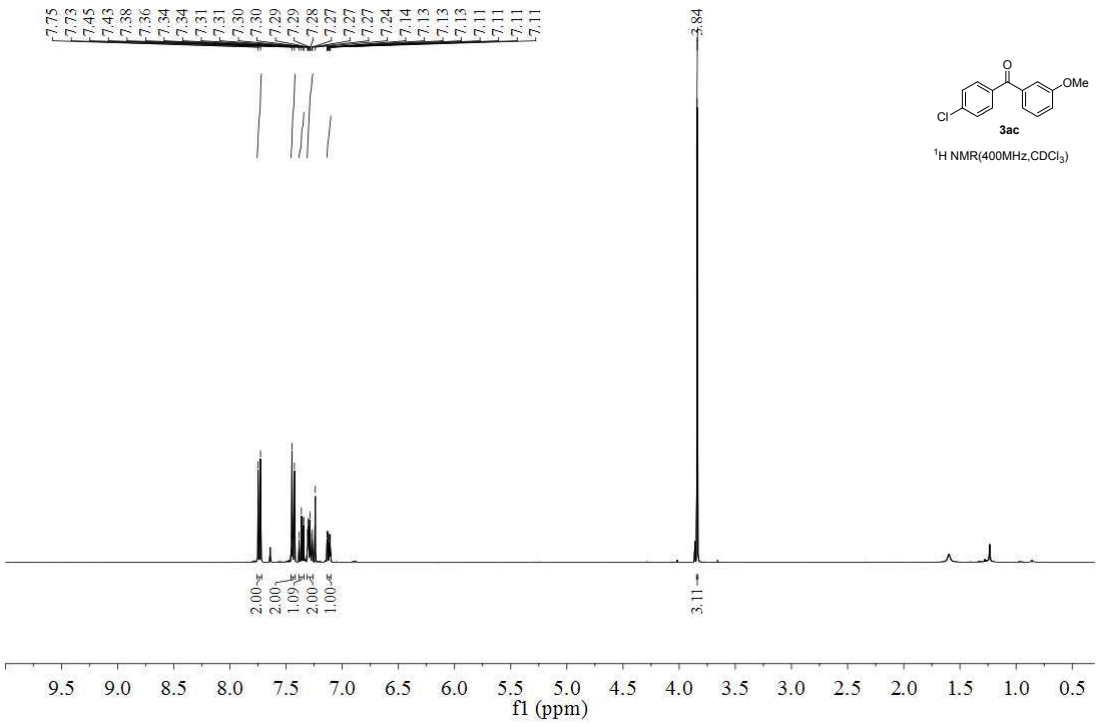
^{13}C NMR(100MHz,CDCl$_3$)

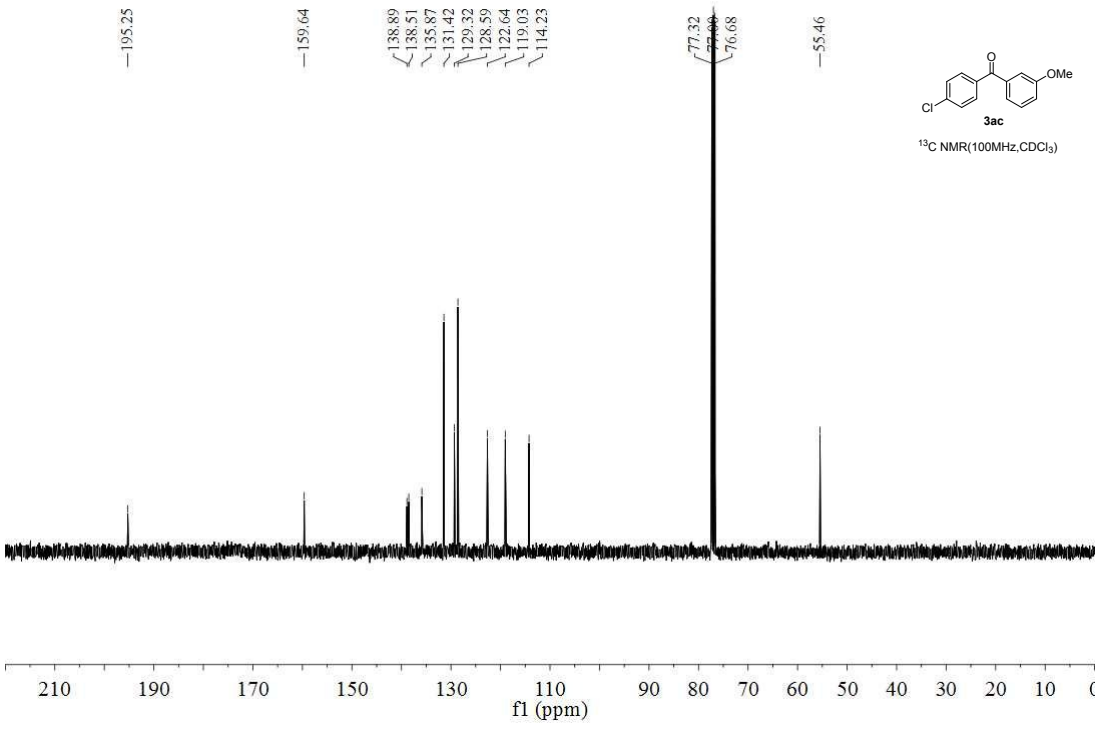

7.71
7.69
7.58
7.58
7.54
7.53
7.38
7.36
7.36
7.36
7.35
7.33
7.31
7.27
7.25
7.24
2.42
2.40
Me
Me
O
3gb
^{1}H NMR(400MHz,CDCl$_3$)
2.00
0.97
0.96
1.01
1.04
2.00
3.05
3.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

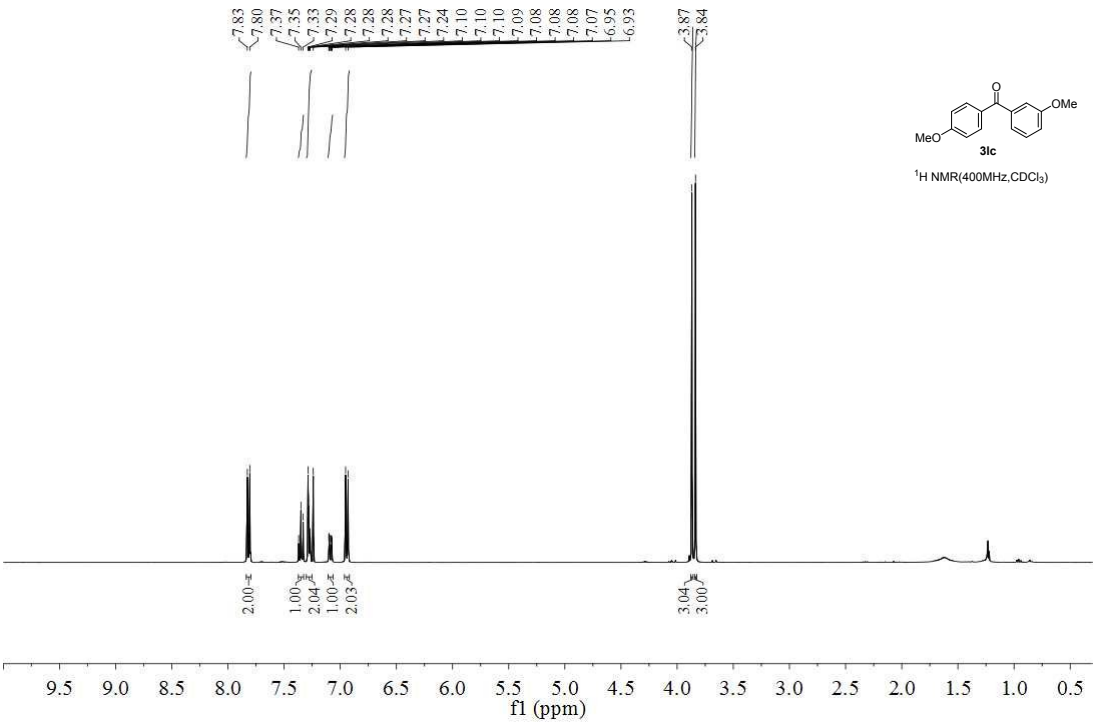

196.74
143.13
138.06
137.98
135.03
132.91
130.35
130.28
128.92
128.00
127.20
77.32
77.00
76.68
21.63
21.34
Me
Me
O
3gb
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

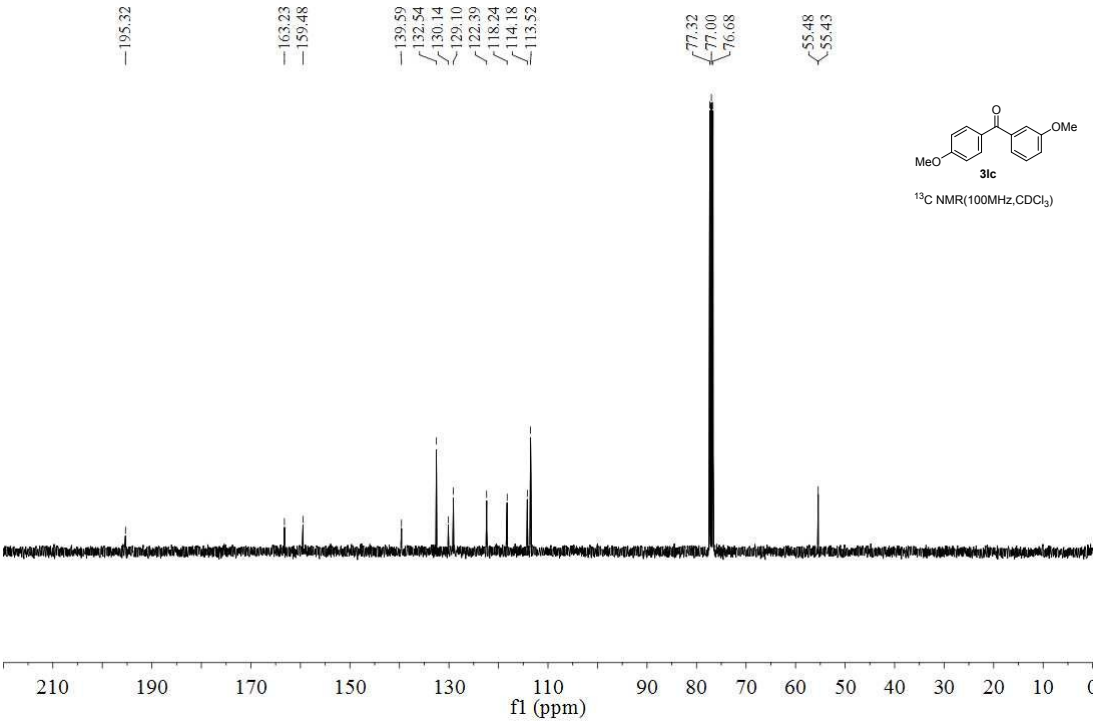

7.82
7.79
7.56
7.52
7.52
7.50
7.37
7.36
7.34
7.34
7.33
7.31
7.24
6.95
6.93
3.87
2.40
2.07
1.00
0.99
2.07
2.05
3.30
3.07
MeO
Me
O
3lb
1H NMR(400MHz,CDCl3)
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

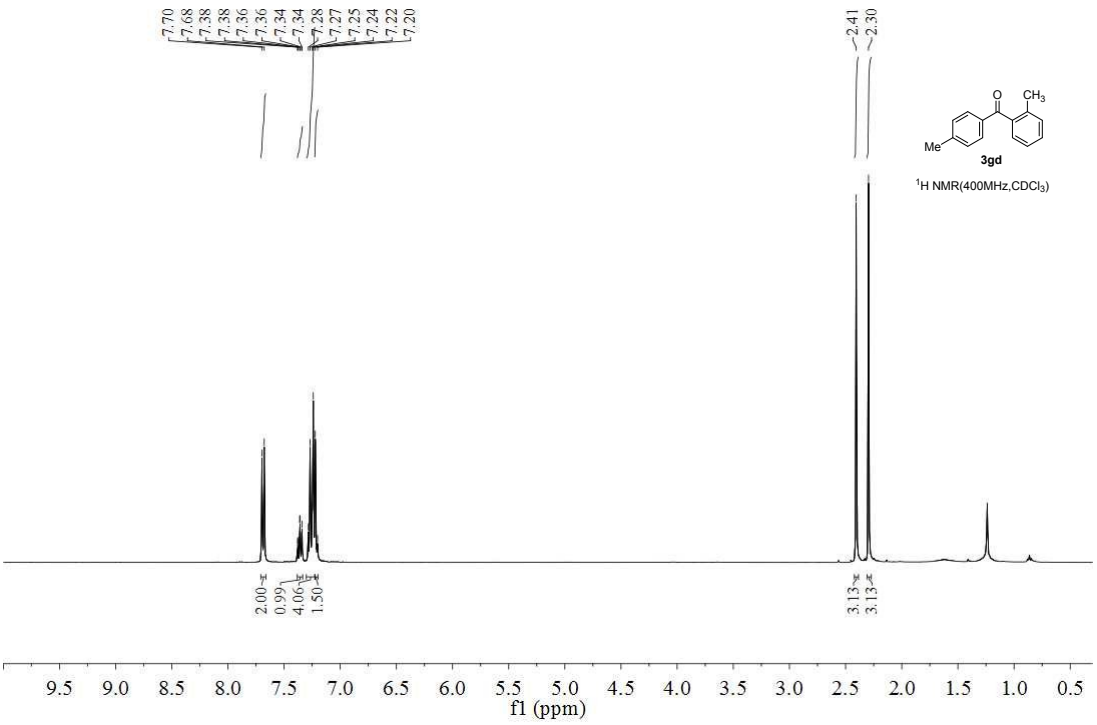

195.77
163.14
138.30
138.02
132.62
132.51
130.29
130.15
127.96
126.96
113.49
77.32
77.00
76.68
55.46
21.34
MeO
Me
O
3lb
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

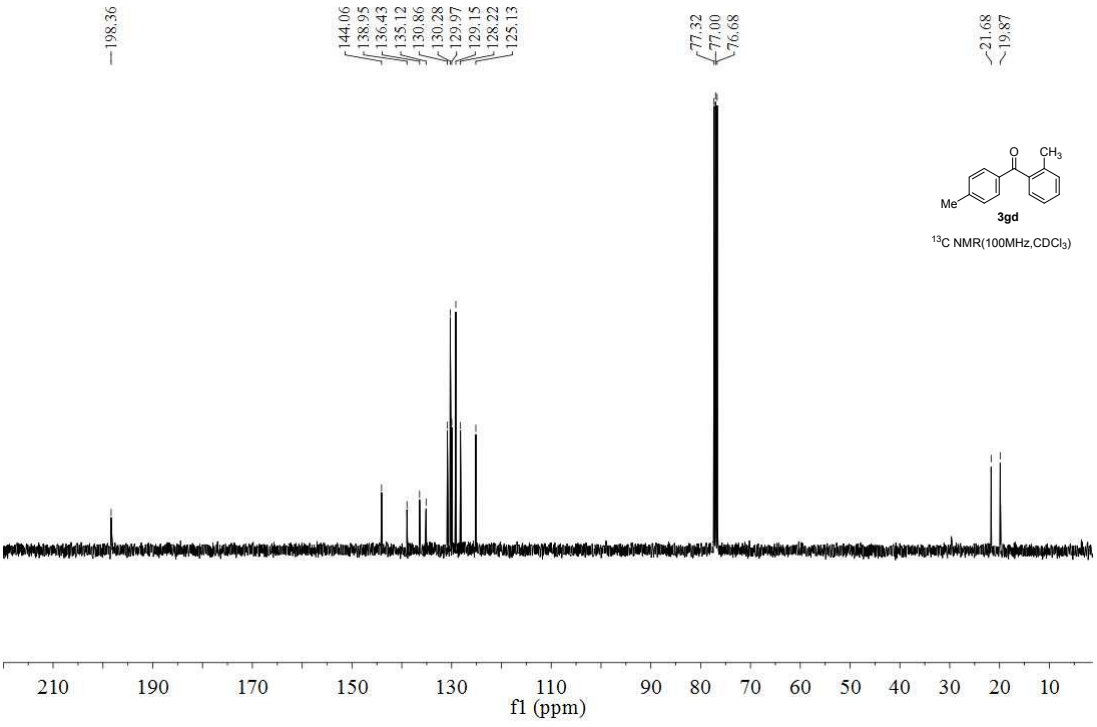

7.75
7.73
7.45
7.43
7.38
7.36
7.34
7.34
7.31
7.31
7.30
7.30
7.29
7.29
7.28
7.27
7.27
7.27
7.24
7.14
7.13
7.13
7.13
7.11
7.11
7.11
7.11
3.84
2.00
2.00
1.09
2.00
1.00
3.11
O
OMe
Cl
3ac
^{1}H NMR(400MHz,CDCl$_3$)
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

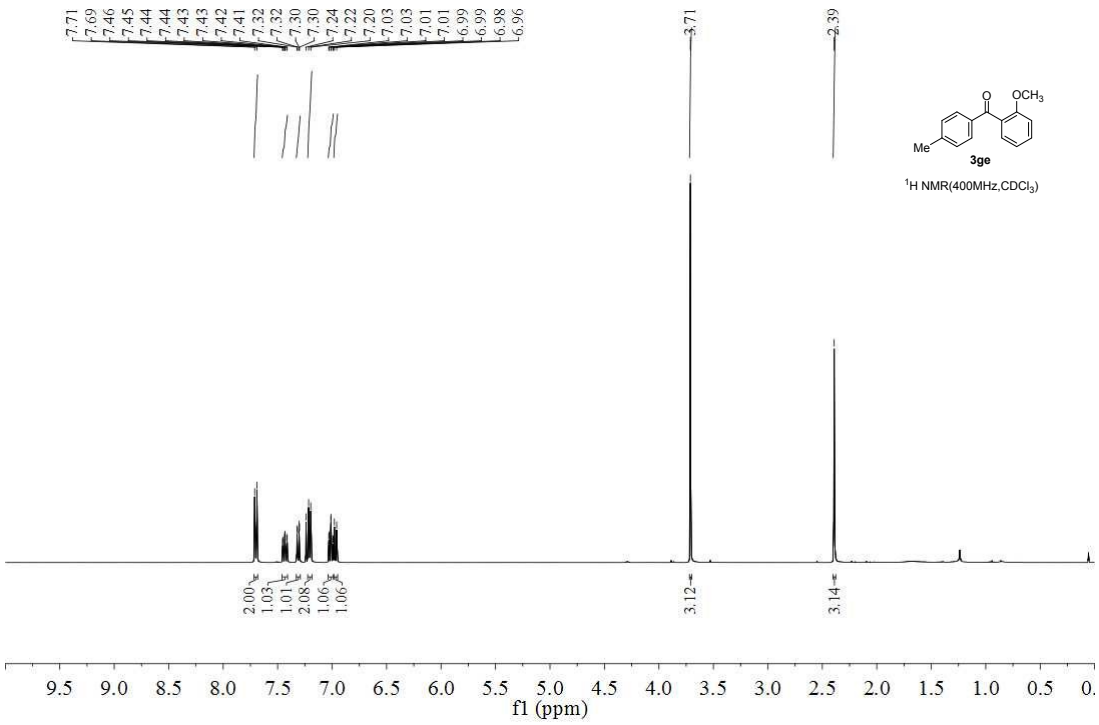

195.25
159.64
138.89
138.51
135.87
131.42
129.32
128.59
122.64
119.03
114.23
77.32
77.00
76.68
55.46
O
OMe
Cl
3ac
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

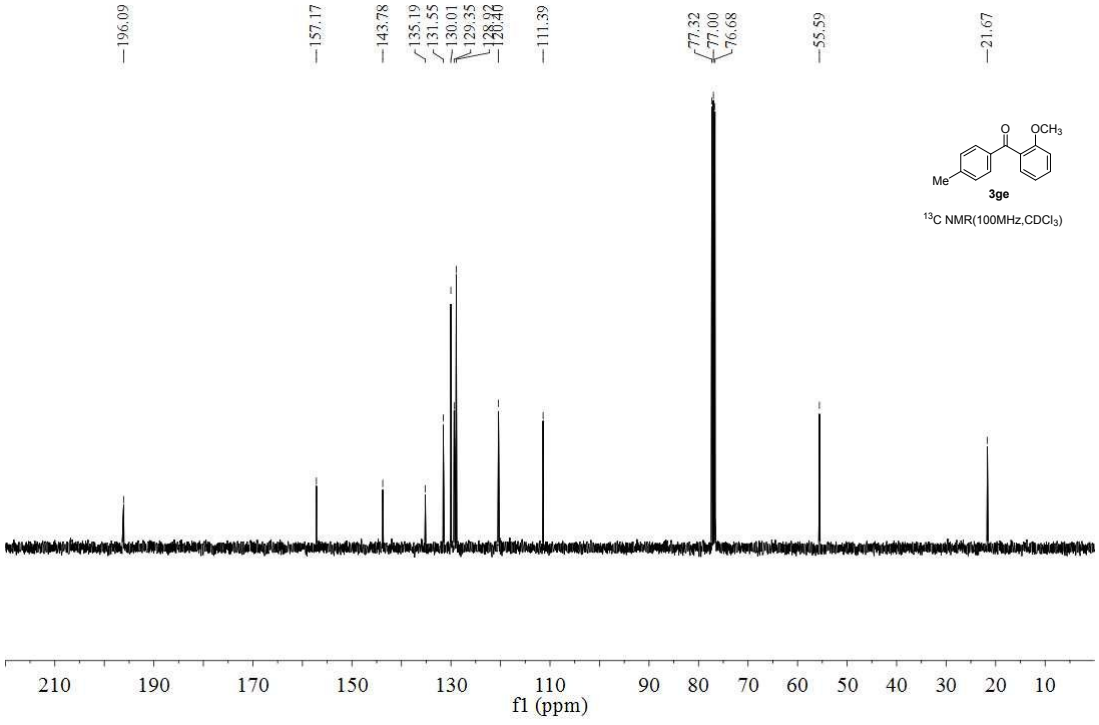

7.83
7.80
7.37
7.35
7.33
7.29
7.28
7.28
7.28
7.27
7.27
7.24
7.10
7.10
7.10
7.09
7.08
7.08
7.08
7.07
6.95
6.93
3.87
3.84
2.00
1.00
2.04
1.00
2.03
3.04
3.00
OMe
MeO
3lc
1H NMR(400MHz,CDCl3)
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

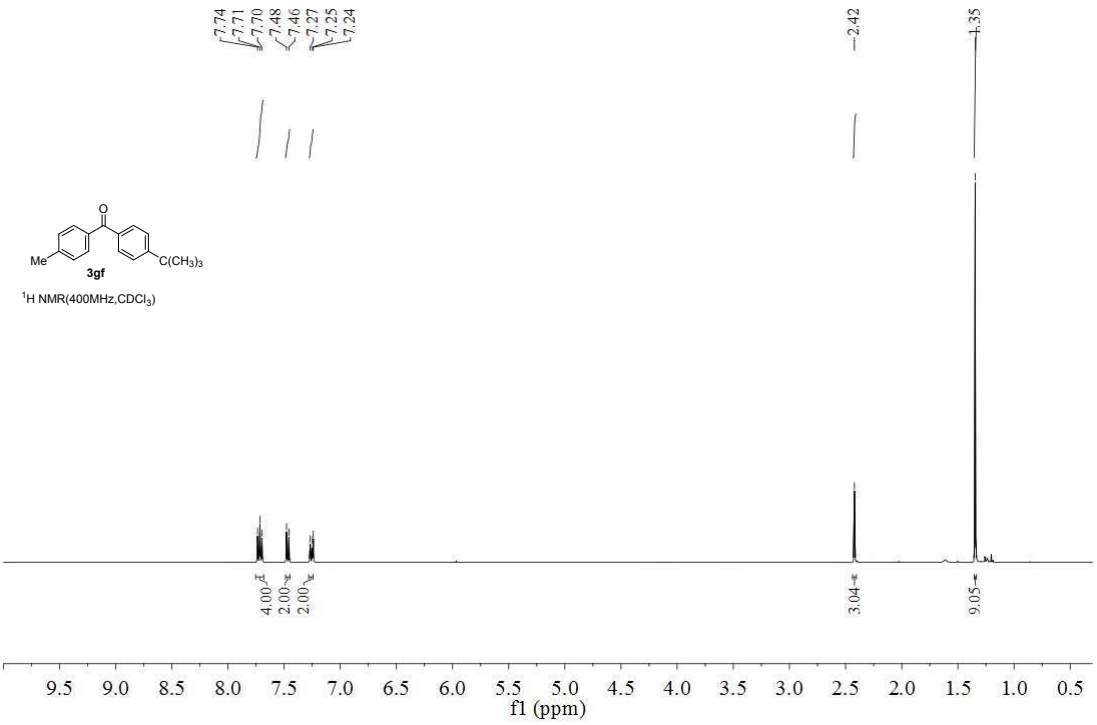

195.32
163.23
159.48
139.59
132.54
130.14
129.10
122.39
118.24
114.18
113.52
77.32
77.00
76.68
55.48
55.43
OMe
MeO
3lc
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

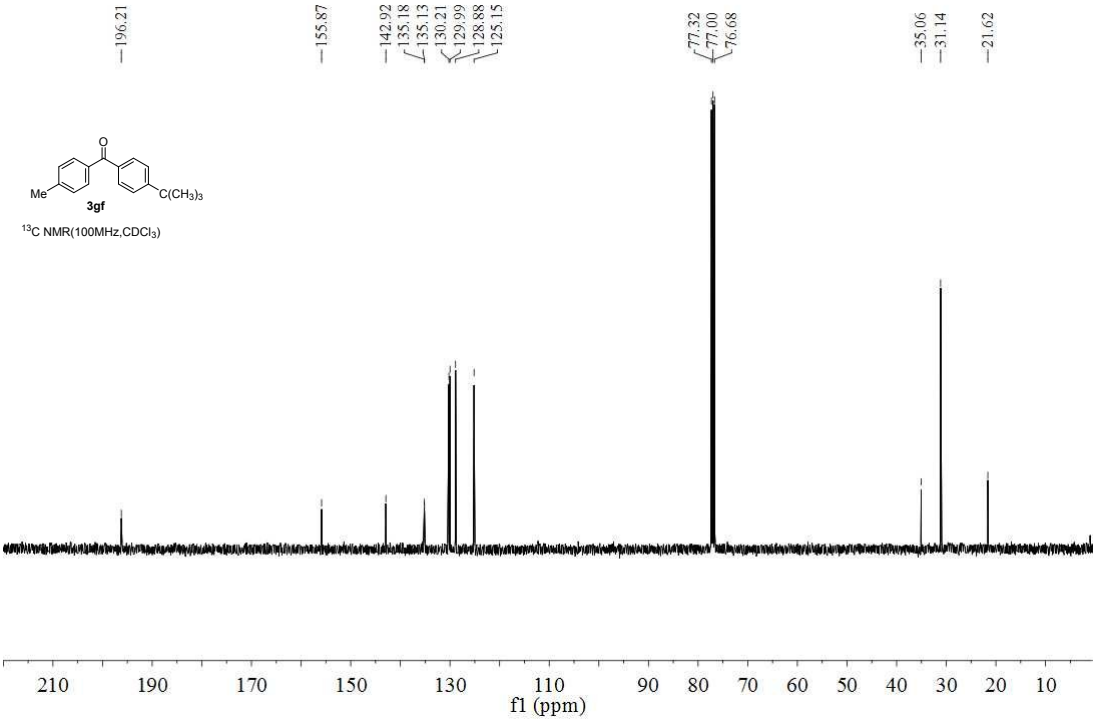

7.70
7.68
7.38
7.38
7.36
7.36
7.34
7.34
7.28
7.27
7.25
7.24
7.22
7.20
2.41
2.30
O
CH3
Me
3gd
1H NMR(400MHz,CDCl3)
2.00
0.99
4.06
1.50
3.13
3.13
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

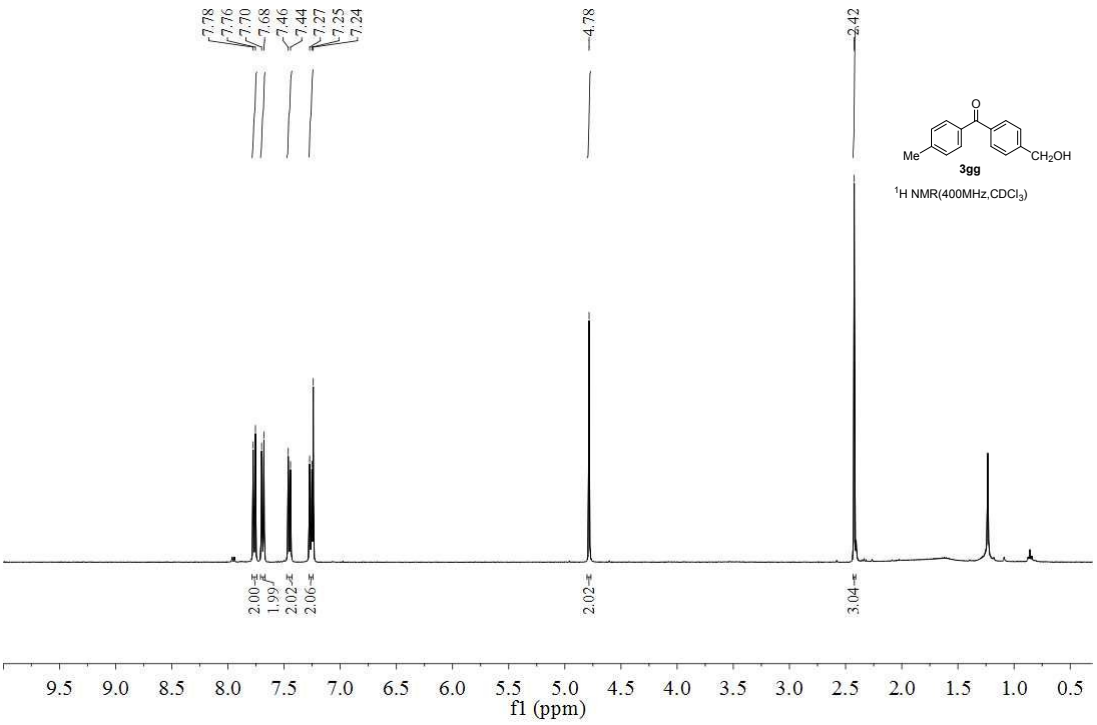

198.36
144.06
138.95
136.43
135.12
130.86
130.28
129.97
129.15
128.22
125.13
77.32
77.00
76.68
21.68
19.87
O
CH3
Me
3gd
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

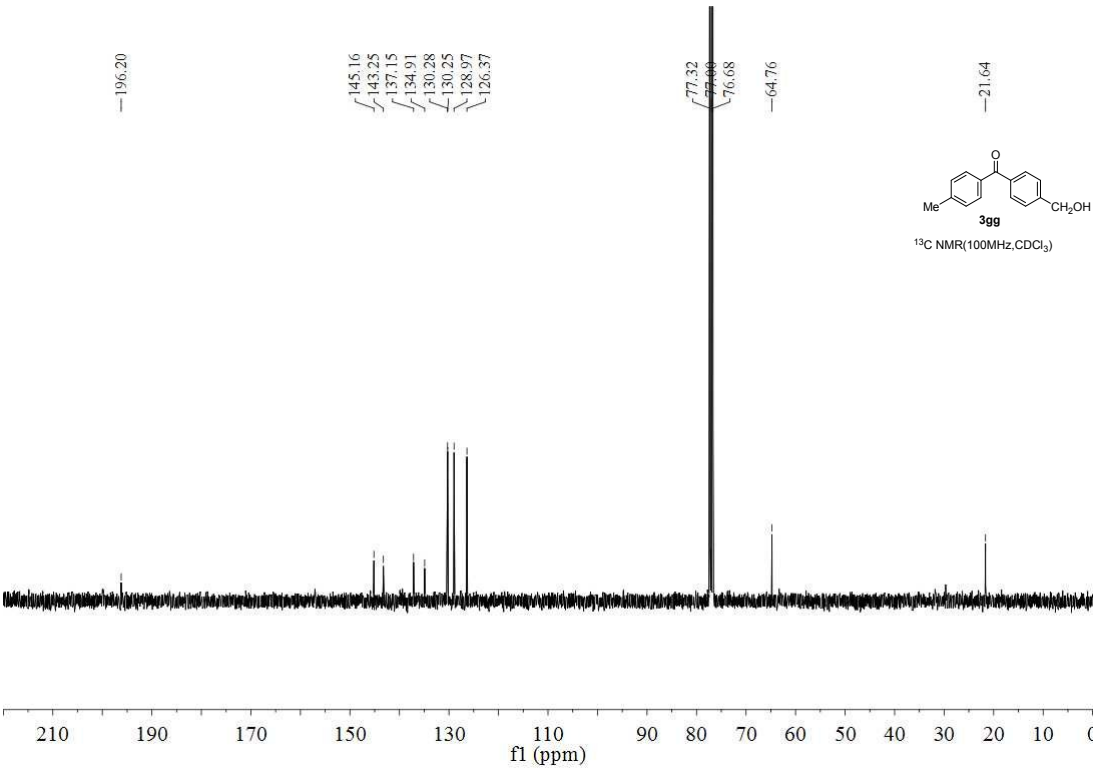

7.71
7.69
7.46
7.45
7.44
7.44
7.43
7.43
7.42
7.41
7.32
7.32
7.30
7.30
7.24
7.22
7.20
7.03
7.03
7.01
7.01
6.99
6.98
6.96
3.71
2.39
2.00
1.03
1.01
2.08
1.06
1.06
3.12
3.14
OCH3
Me
3ge
1H NMR(400MHz,CDCl3)
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)

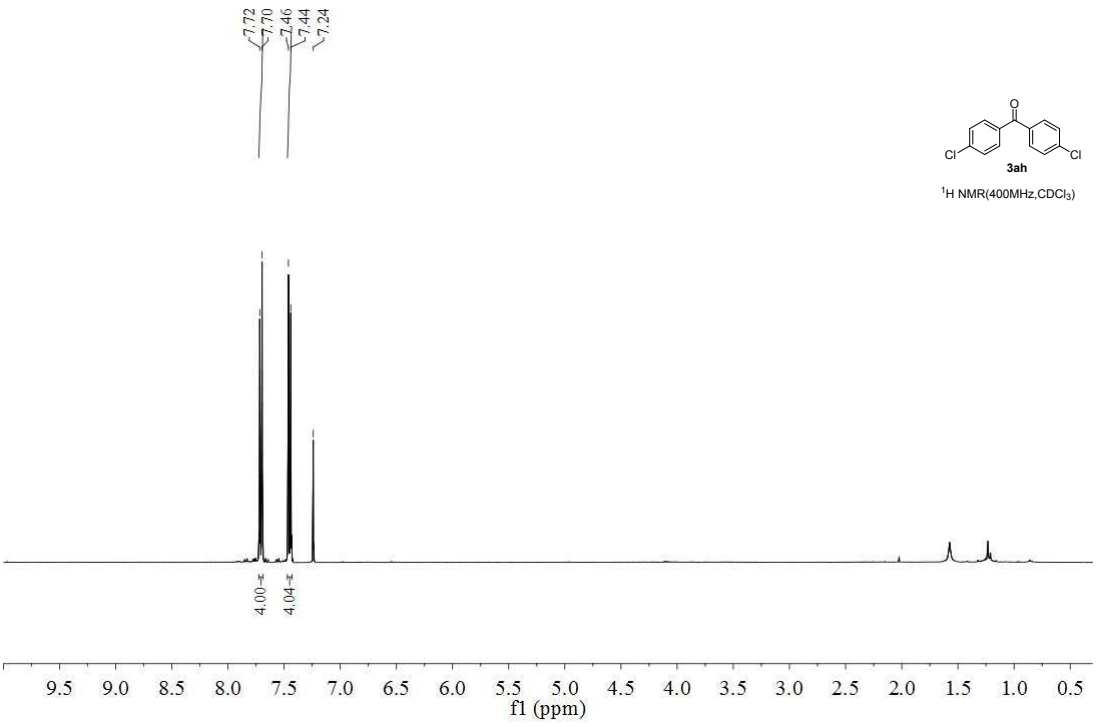

196.09
157.17
143.78
135.19
131.55
130.01
129.35
128.92
128.46
111.39
77.32
77.00
76.68
55.59
21.67
OCH3
Me
3ge
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

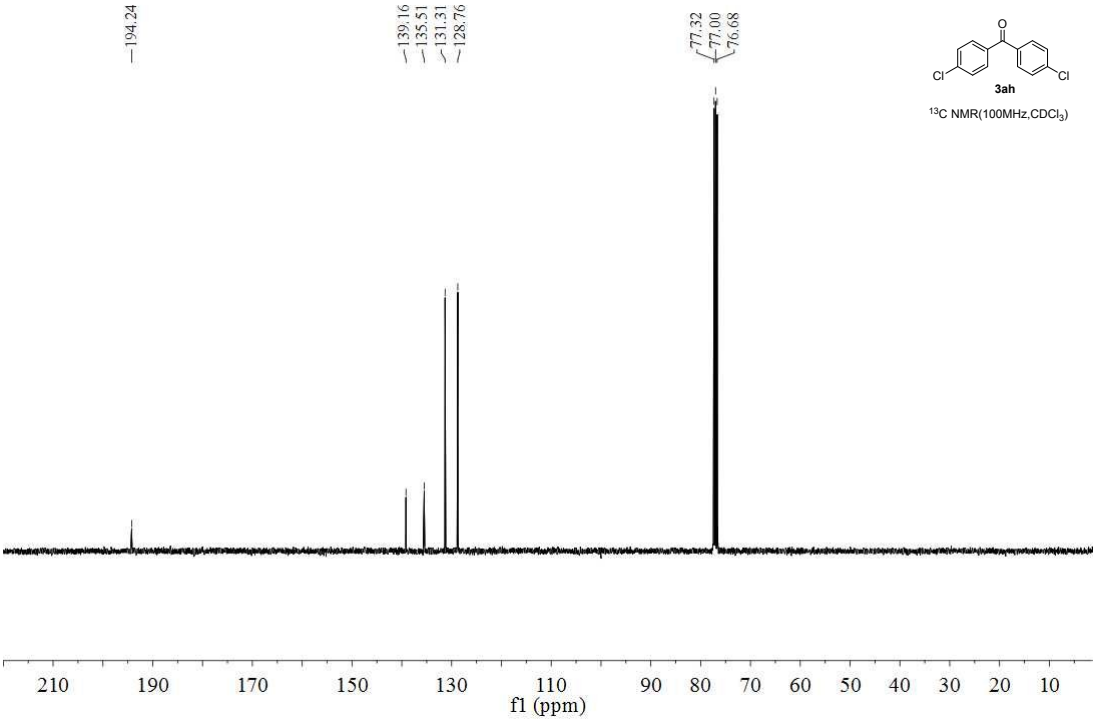

7.74
7.71
7.70
7.48
7.46
7.27
7.25
7.24
2.42
1.35
Me
C(CH3)3
3gf
1H NMR(400MHz,CDCl3)
4.00
2.00
2.00
3.04
9.05
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

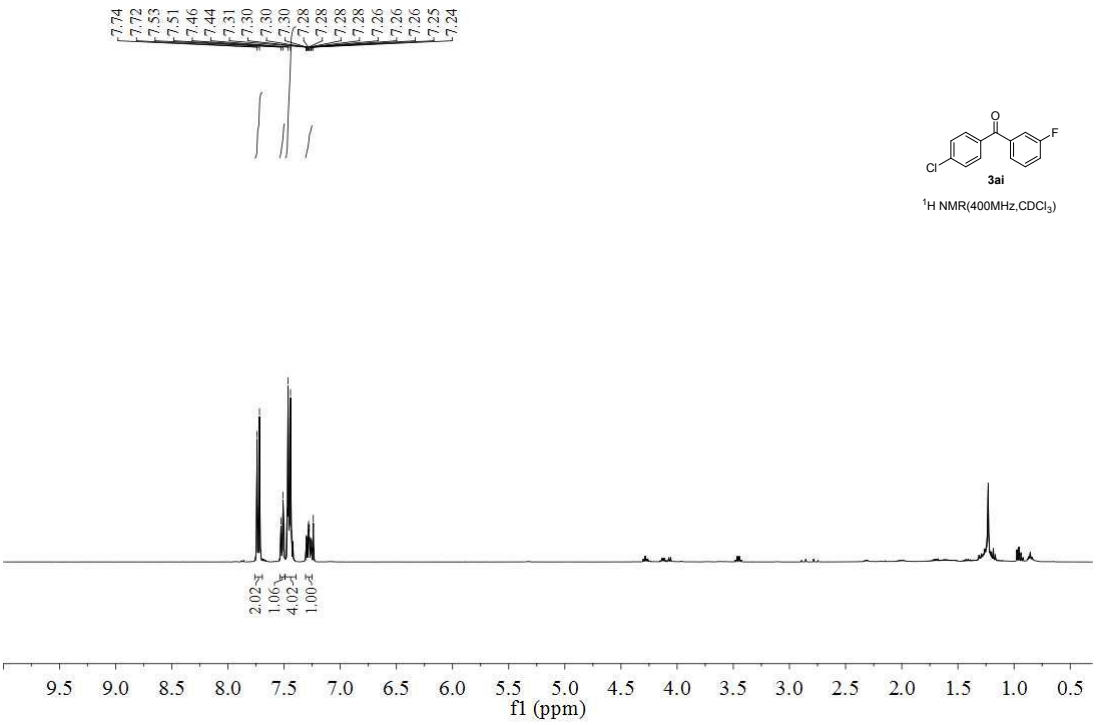

196.21
155.87
142.92
135.18
135.13
130.21
129.99
128.88
125.15
77.32
77.00
76.68
35.06
31.14
21.62
Me
C(CH3)3
3gf
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

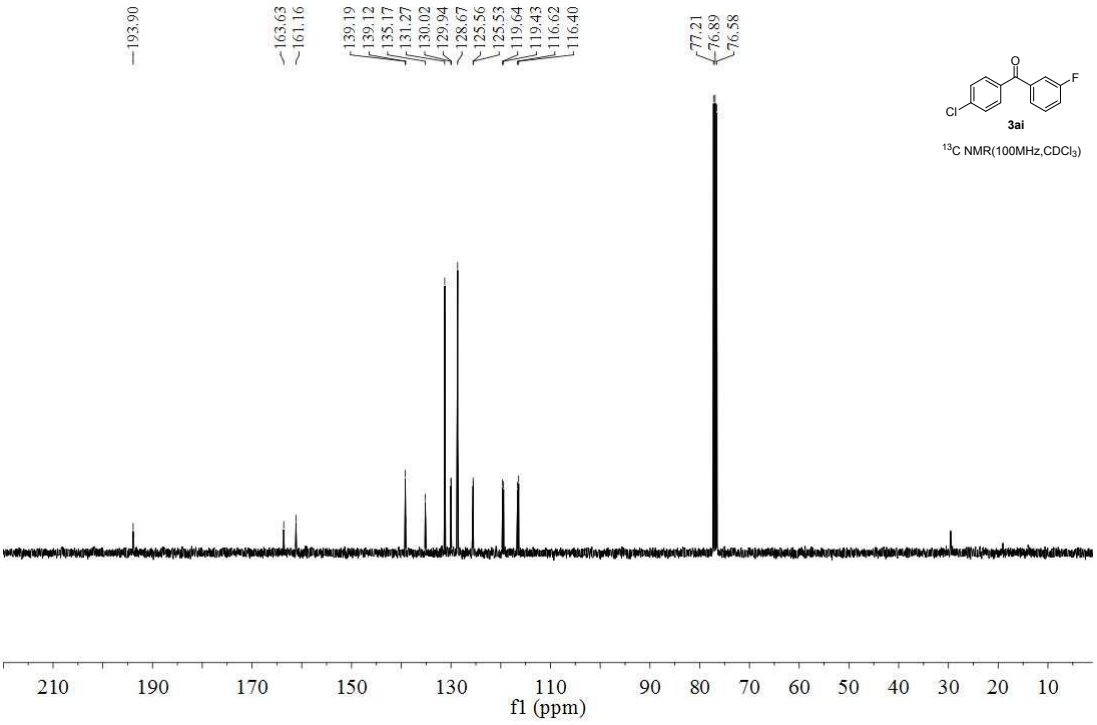

7.78
7.76
7.70
7.68
7.46
7.44
7.27
7.25
7.24
4.78
2.42
2.00
1.99
2.02
2.06
2.02
3.04
f1 (ppm)
Me
CH2OH
3gg
1H NMR(400MHz,CDCl3)

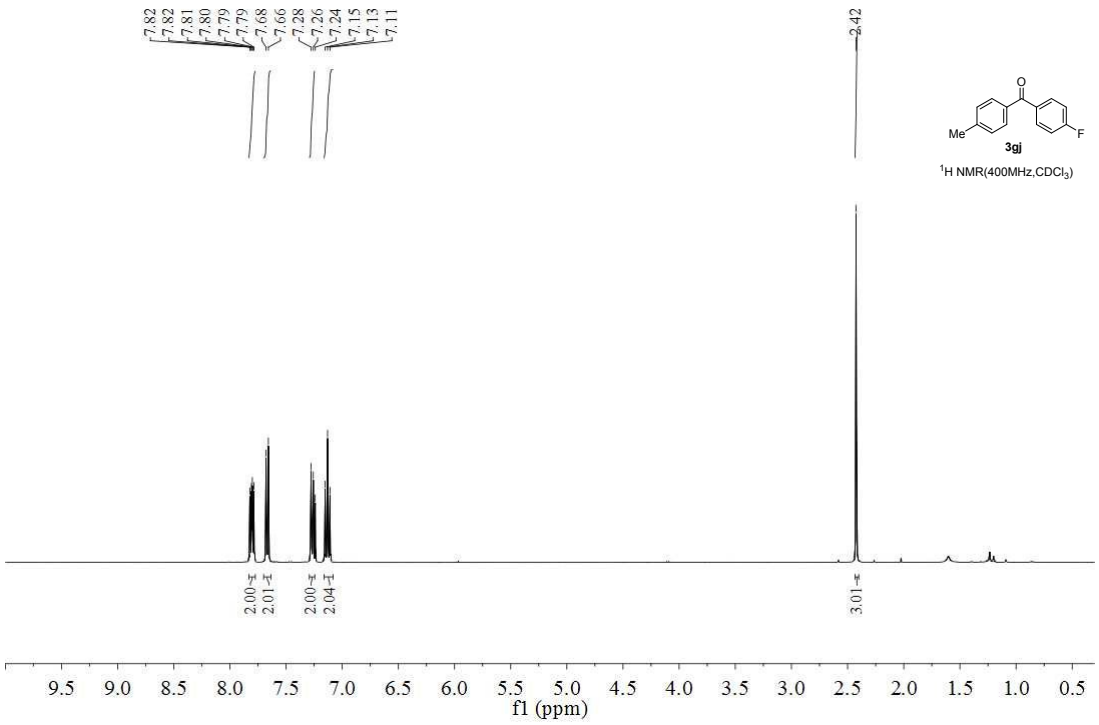

196.20
145.16
143.25
137.15
134.91
130.28
130.25
128.97
126.37
77.32
77.00
76.68
64.76
21.64
f1 (ppm)
Me
CH2OH
3gg
13C NMR(100MHz,CDCl3)

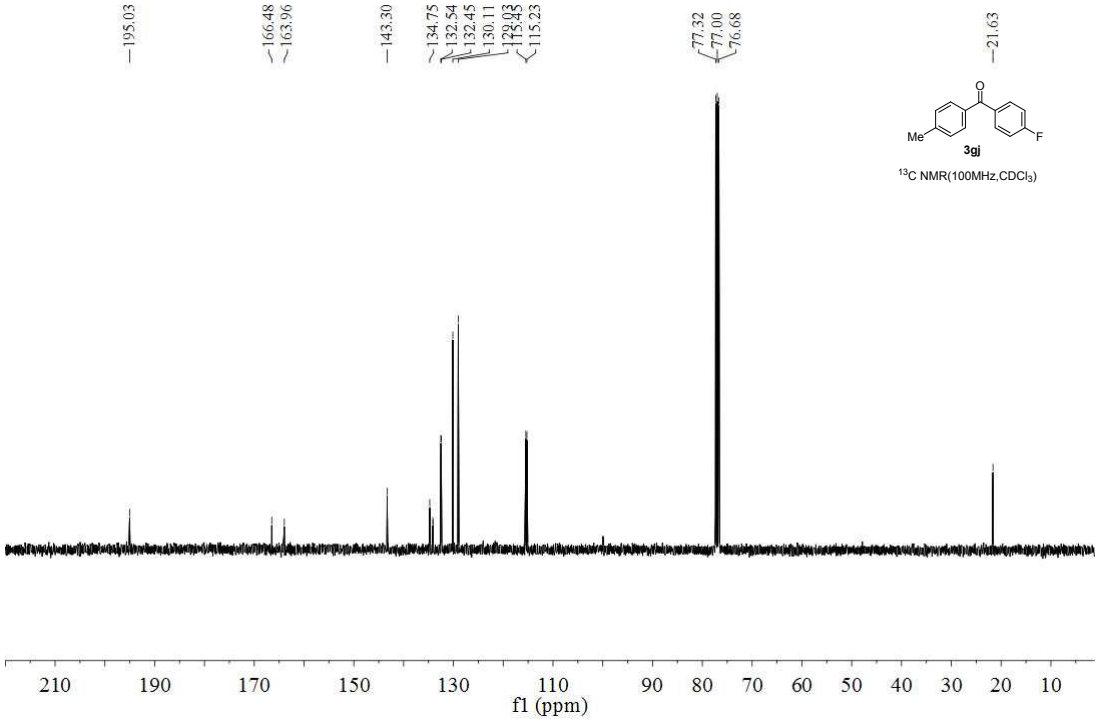

7.72
7.70
7.46
7.44
7.24
3ah
^{1}H NMR(400MHz,CDCl$_3$)
4.00
4.04
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

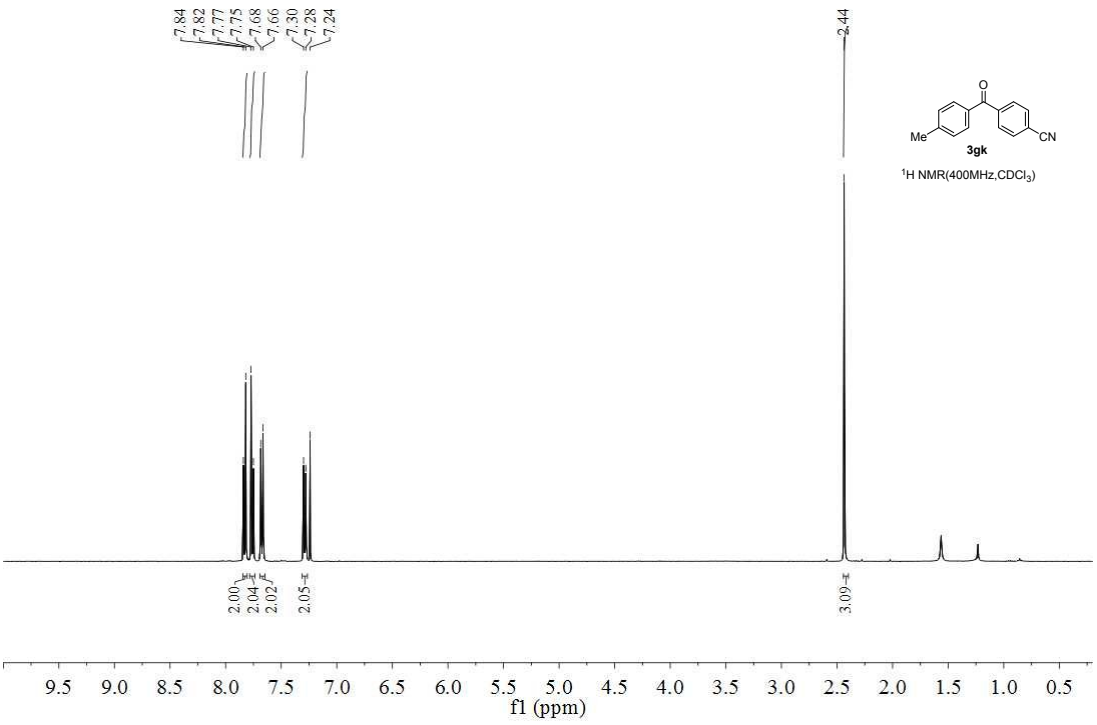

194.24
139.16
135.51
131.31
128.76
77.32
77.00
76.68
3ah
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

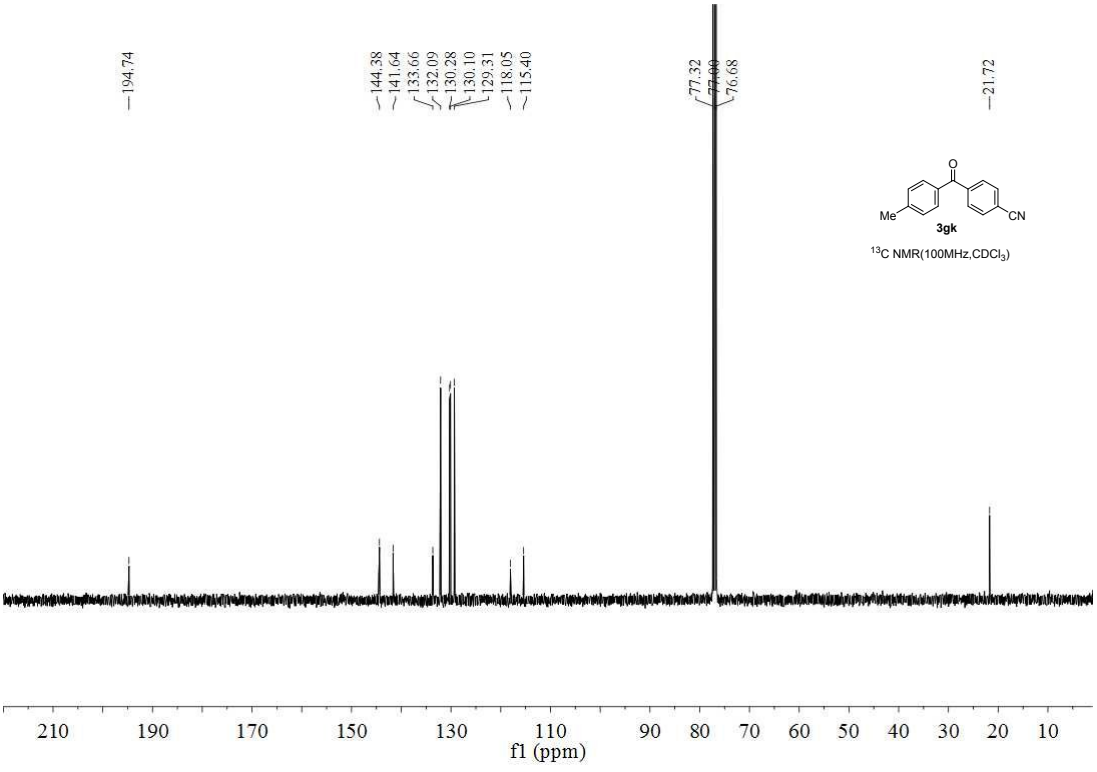

7.74
7.72
7.53
7.51
7.46
7.44
7.31
7.30
7.30
7.30
7.28
7.28
7.28
7.28
7.26
7.26
7.26
7.25
7.24
O
F
Cl
3ai
1H NMR(400MHz,CDCl3)
2.02
1.06
4.02
1.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

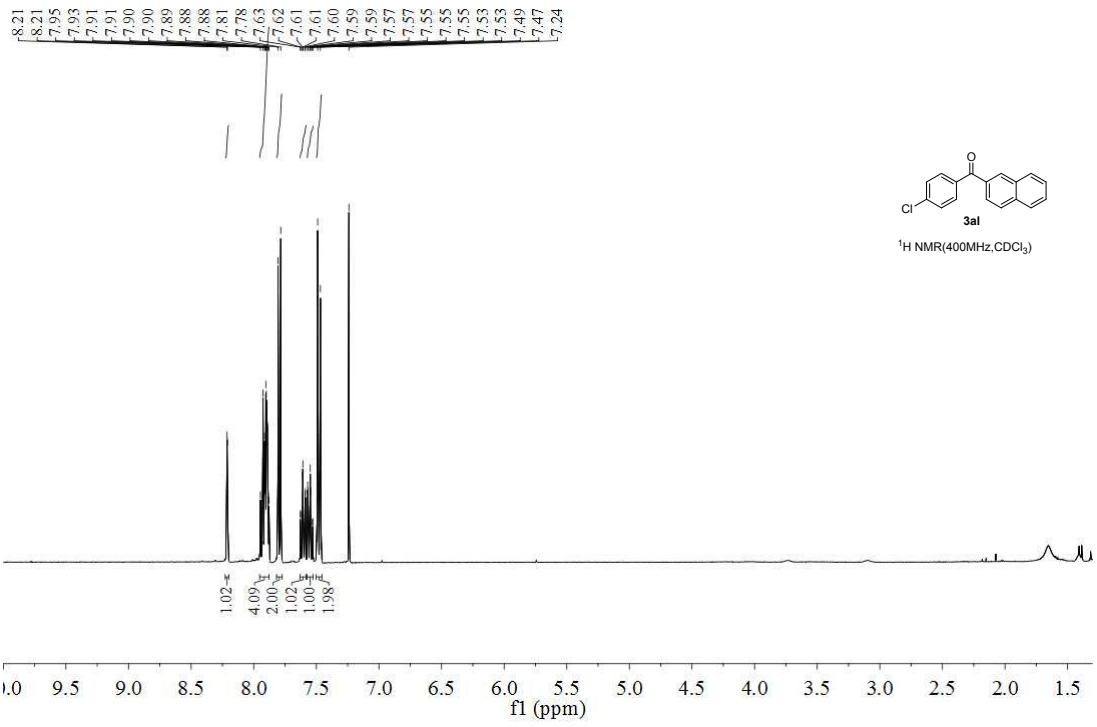

193.90
163.63
161.16
139.19
139.12
135.17
131.27
130.02
129.94
128.67
125.56
125.53
119.64
119.43
116.62
116.40
77.21
76.89
76.58
O
F
Cl
3ai
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

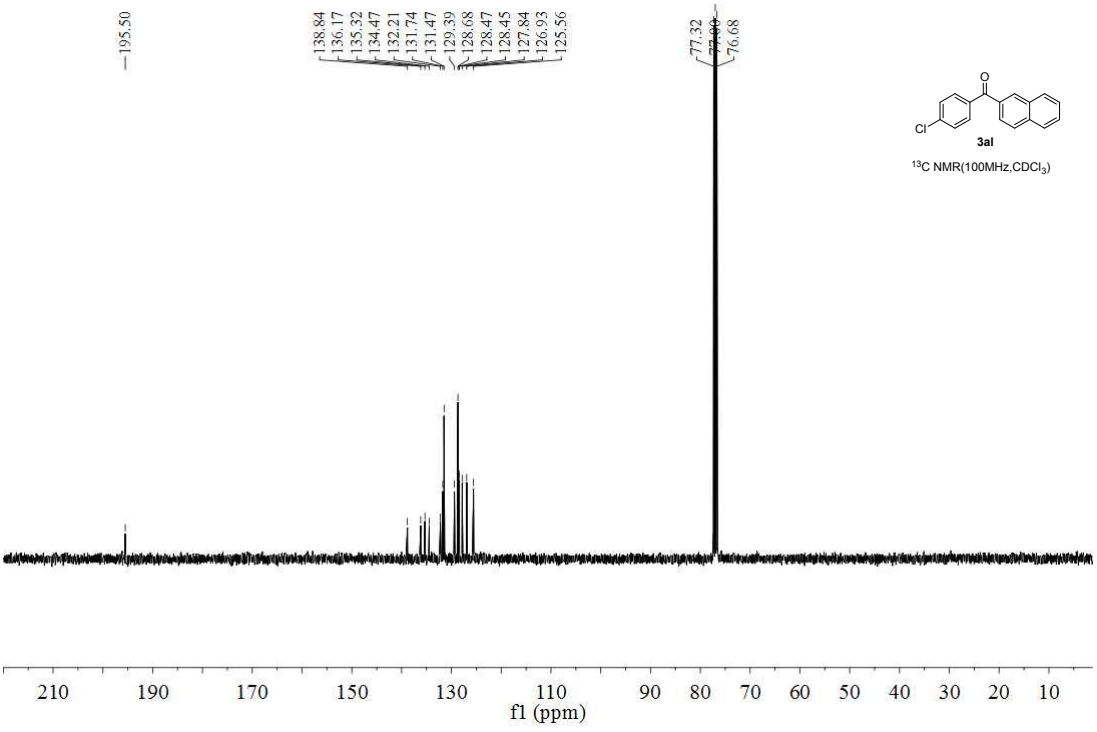

7.82
7.82
7.81
7.80
7.79
7.79
7.68
7.66
7.28
7.26
7.24
7.15
7.13
7.11
2.42
Me
F
3gj
^{1}H NMR(400MHz,CDCl$_3$)
2.00
2.01
2.00
2.04
3.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

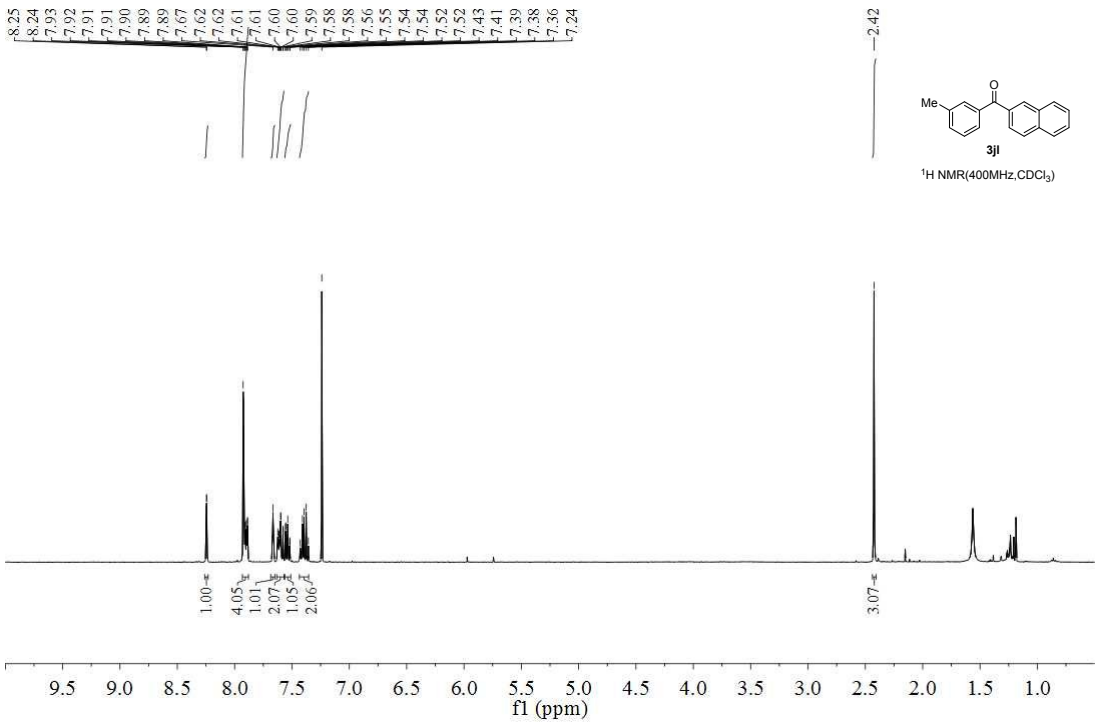

195.03
166.48
163.96
143.30
134.75
132.54
132.45
130.11
129.03
115.45
115.23
77.32
77.00
76.68
21.63
Me
F
3gj
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

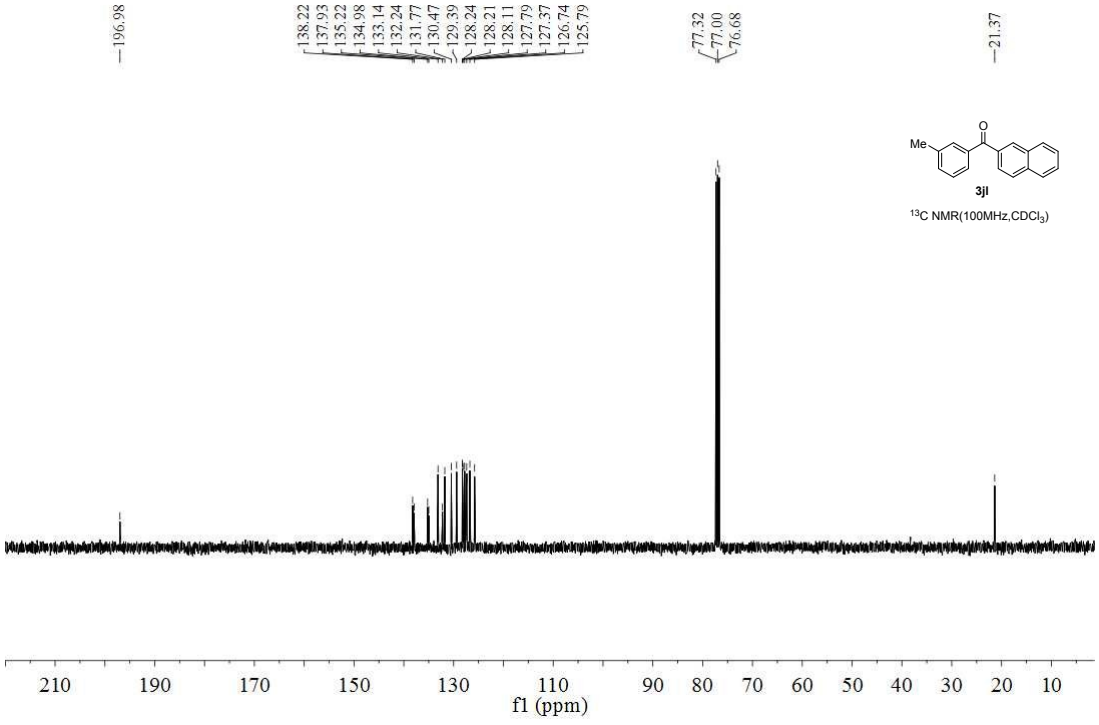

7.84
7.82
7.77
7.75
7.68
7.66
7.30
7.28
7.24
2.44
2.00
2.04
2.02
2.05
3.09
O
Me
CN
3gk
^{1}H NMR(400MHz,CDCl$_3$)
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

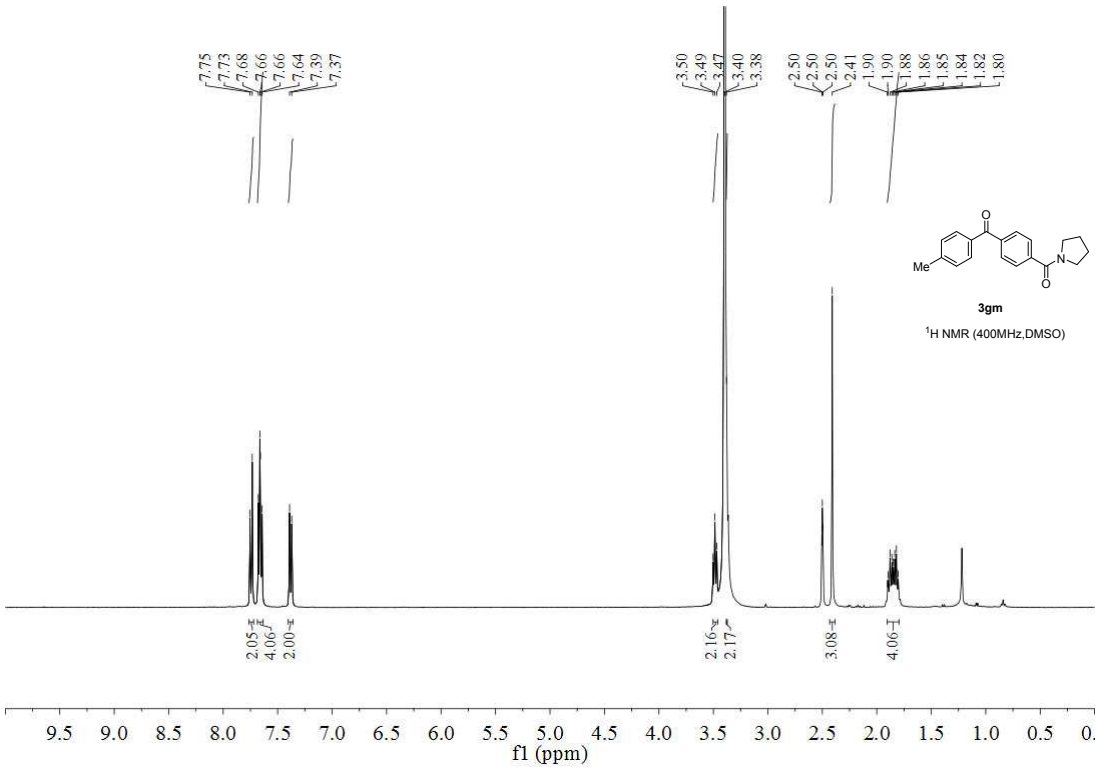

194.74
144.38
141.64
133.66
132.09
130.28
130.10
129.31
118.05
115.40
77.32
77.00
76.68
21.72
O
Me
CN
3gk
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

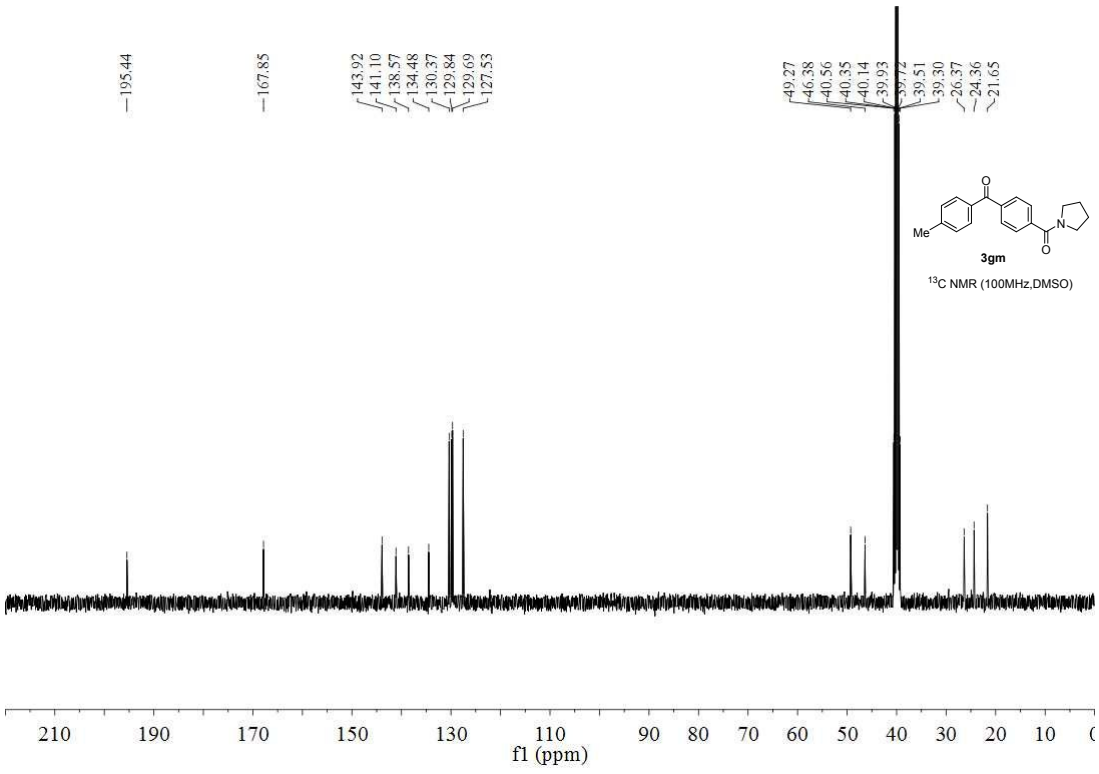

8.21
8.21
7.95
7.93
7.91
7.91
7.90
7.90
7.89
7.88
7.88
7.81
7.78
7.63
7.62
7.61
7.61
7.60
7.59
7.59
7.57
7.57
7.55
7.55
7.53
7.53
7.49
7.47
7.24
1.02
4.09
2.00
1.02
1.00
1.98
f1 (ppm)
3al
^{1}H NMR(400MHz,CDCl$_3$)

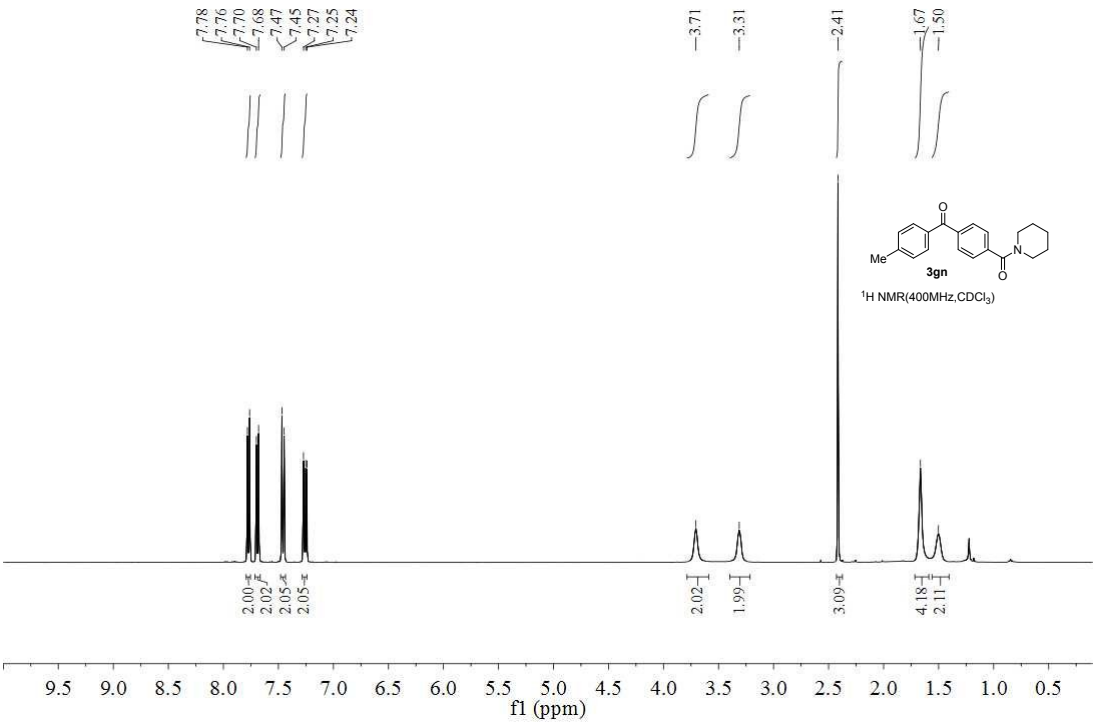

195.50
138.84
136.17
135.32
134.47
132.21
131.74
131.47
129.39
128.68
128.47
128.45
127.84
126.93
125.56
77.32
77.00
76.68
f1 (ppm)
3al
^{13}C NMR(100MHz,CDCl$_3$)

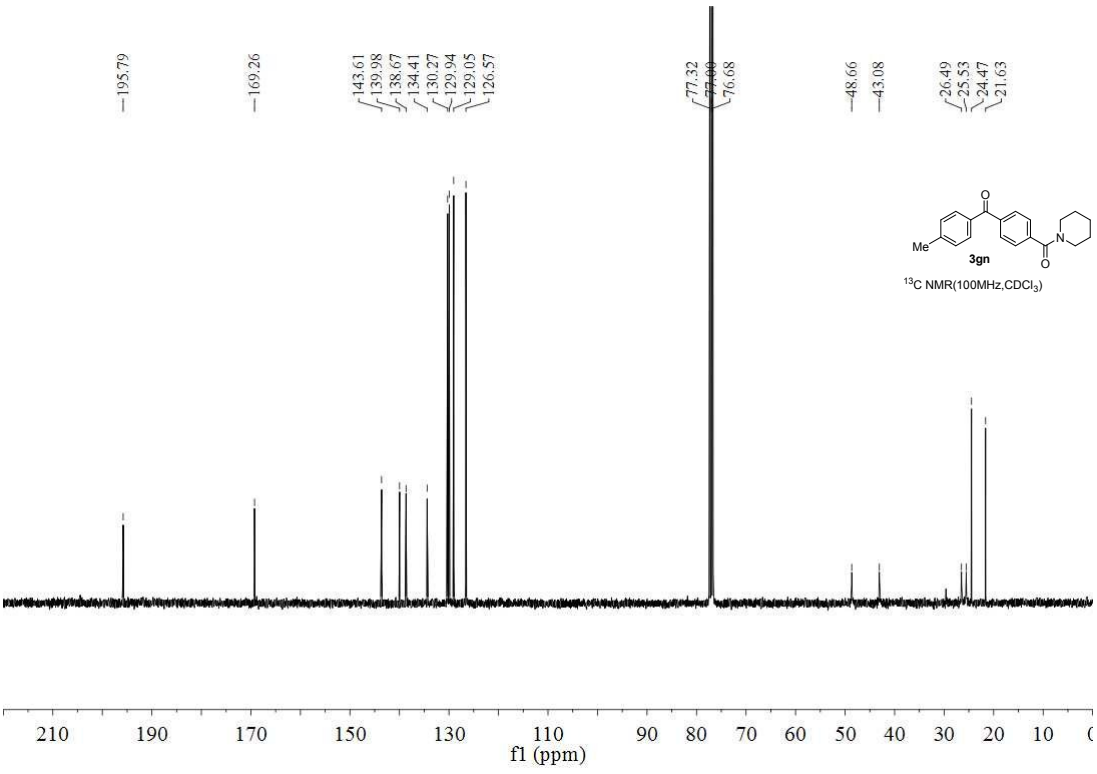

8.25
8.24
7.93
7.92
7.91
7.91
7.90
7.89
7.89
7.67
7.62
7.62
7.61
7.61
7.60
7.60
7.59
7.58
7.58
7.56
7.55
7.54
7.54
7.52
7.52
7.43
7.41
7.39
7.38
7.36
7.24
2.42
Me
O
3jl
1H NMR(400MHz,CDCl3)
1.00
4.05
1.01
2.07
1.05
2.06
3.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
f1 (ppm)

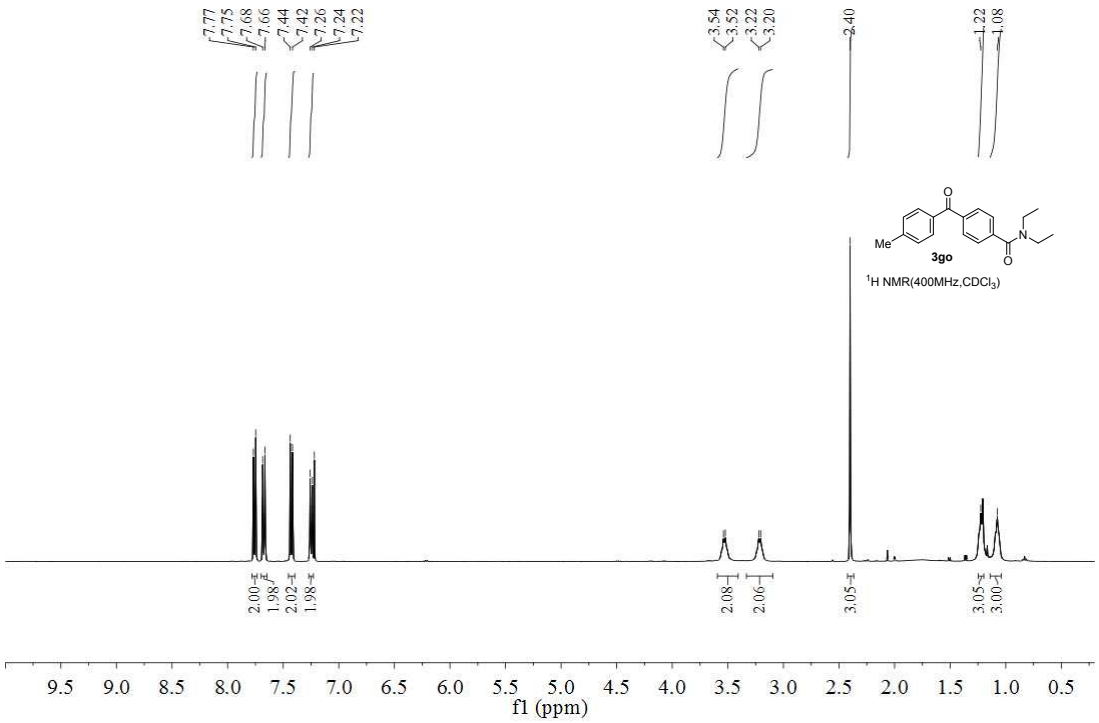

196.98
138.22
137.93
135.22
134.98
133.14
132.24
131.77
130.47
129.39
128.24
128.21
128.11
127.79
127.37
126.74
125.79
77.32
77.00
76.68
21.37
Me
O
3jl
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

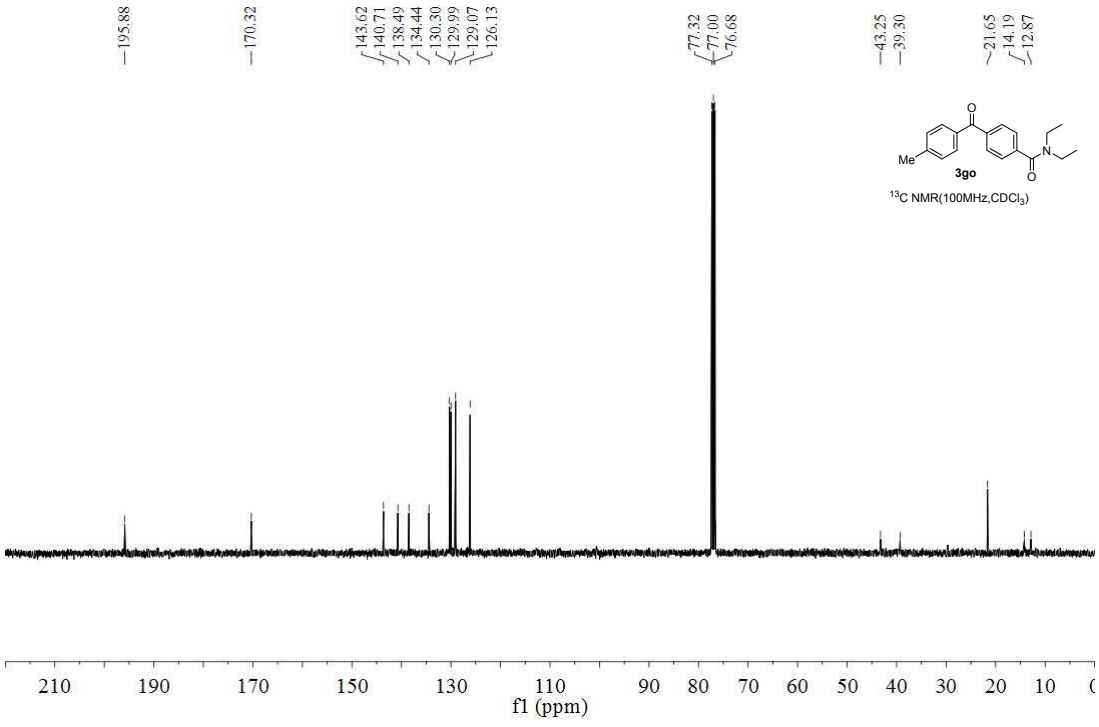

7.75
7.73
7.68
7.66
7.66
7.64
7.39
7.37
3.50
3.49
3.47
3.40
3.38
2.50
2.50
2.50
2.41
1.90
1.90
1.88
1.86
1.85
1.84
1.82
1.80
Me
O
N
O
3gm
1H NMR (400MHz,DMSO)
2.05
4.06
2.00
2.16
2.17
3.08
4.06
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)

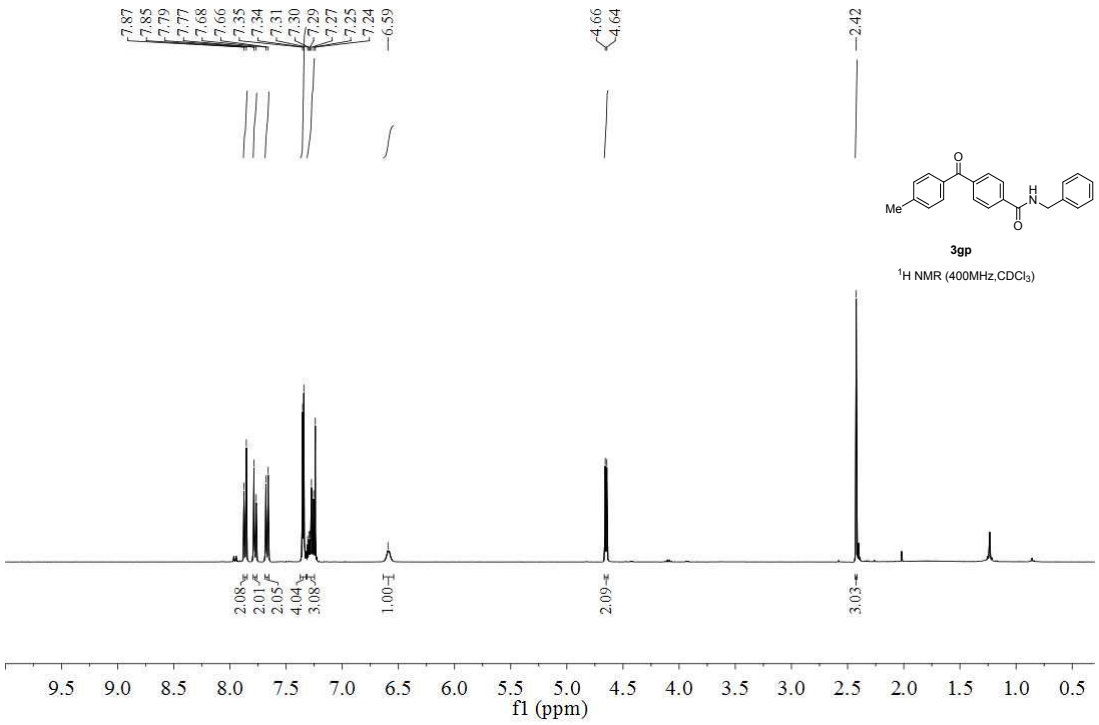

195.44
167.85
143.92
141.10
138.57
134.48
130.37
129.84
129.69
127.53
49.27
46.38
40.56
40.35
40.14
39.93
39.72
39.51
39.30
26.37
24.36
21.65
Me
O
N
O
3gm
13C NMR (100MHz,DMSO)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.78
7.76
7.70
7.68
7.47
7.45
7.27
7.25
7.24
3.71
3.31
2.41
1.67
1.50
Me
O
N
O
3gn
^{1}H NMR(400MHz,CDCl$_3$)
2.00
2.02
2.05
2.05
2.02
1.99
3.09
4.18
2.11
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
f1 (ppm)


195.79
169.26
143.61
139.98
138.67
134.41
130.27
129.94
129.05
126.57
77.32
77.00
76.68
48.66
43.08
26.49
25.53
24.47
21.63
Me
O
N
O
3gn
^{13}C NMR(100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

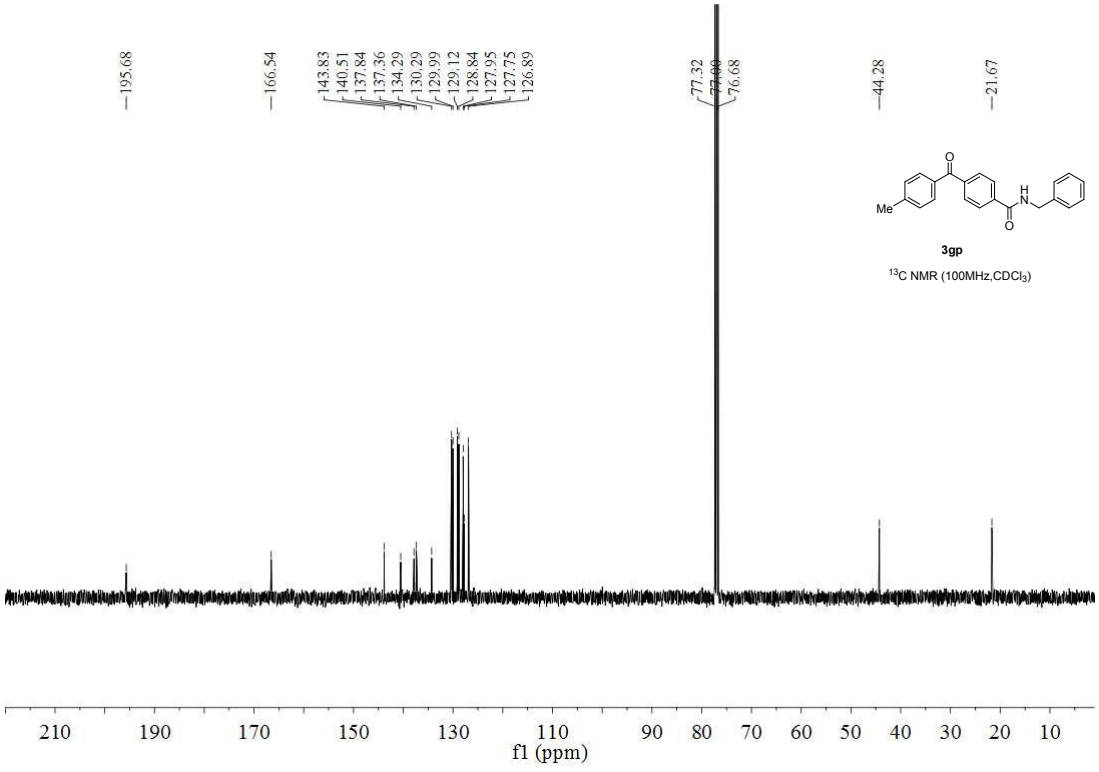

7.77
7.75
7.68
7.66
7.44
7.42
7.26
7.24
7.22
3.54
3.52
3.22
3.20
2.40
1.22
1.08
Me
3go
1H NMR(400MHz,CDCl3)
2.00
1.98
2.02
1.98
2.08
2.06
3.05
3.05
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


195.88
170.32
143.62
140.71
138.49
134.44
130.30
129.99
129.07
126.13
77.32
77.00
76.68
43.25
39.30
21.65
14.19
12.87
Me
3go
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)



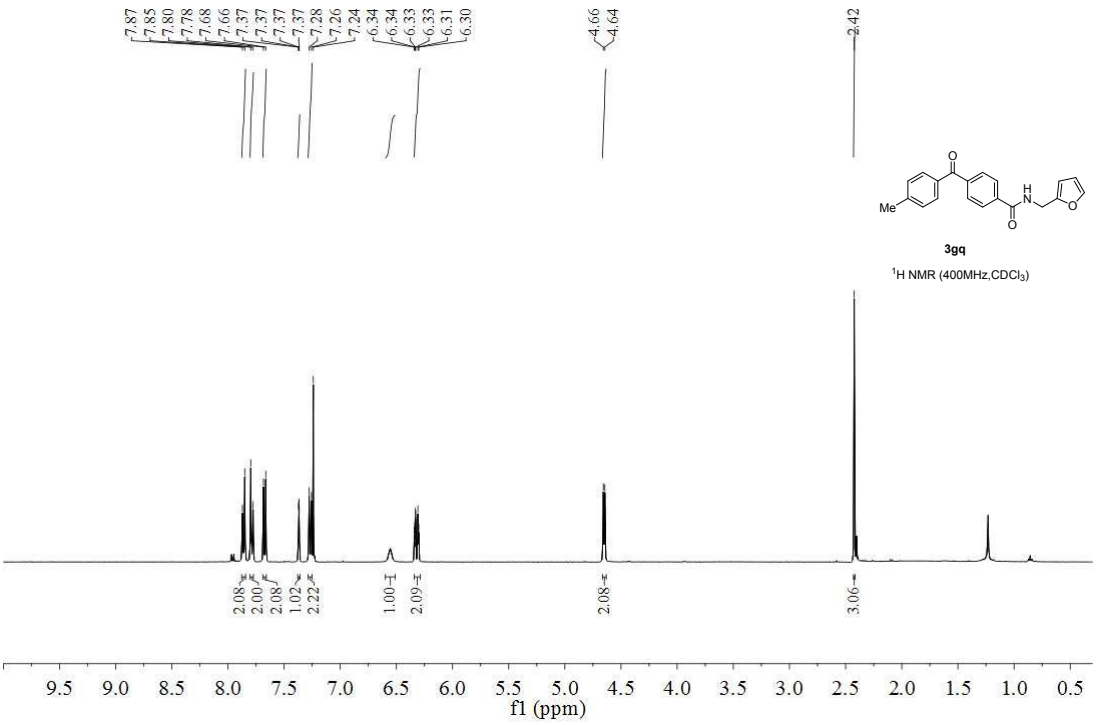
3gp

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



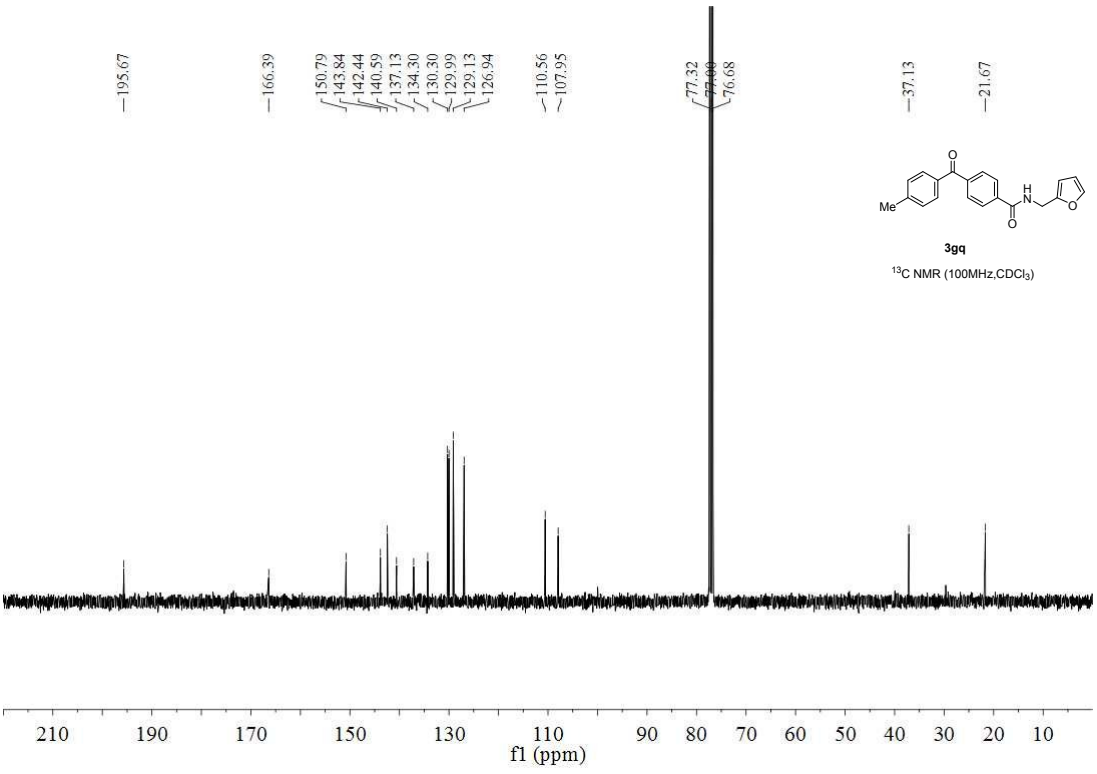
3gp

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



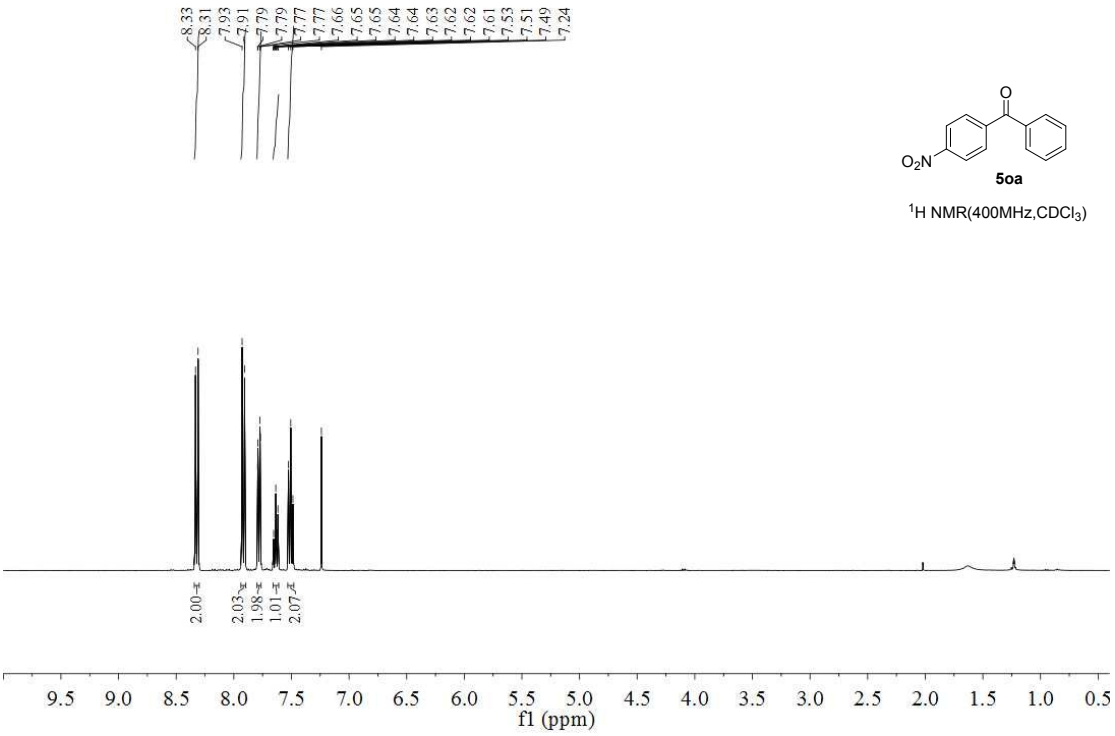
3gq

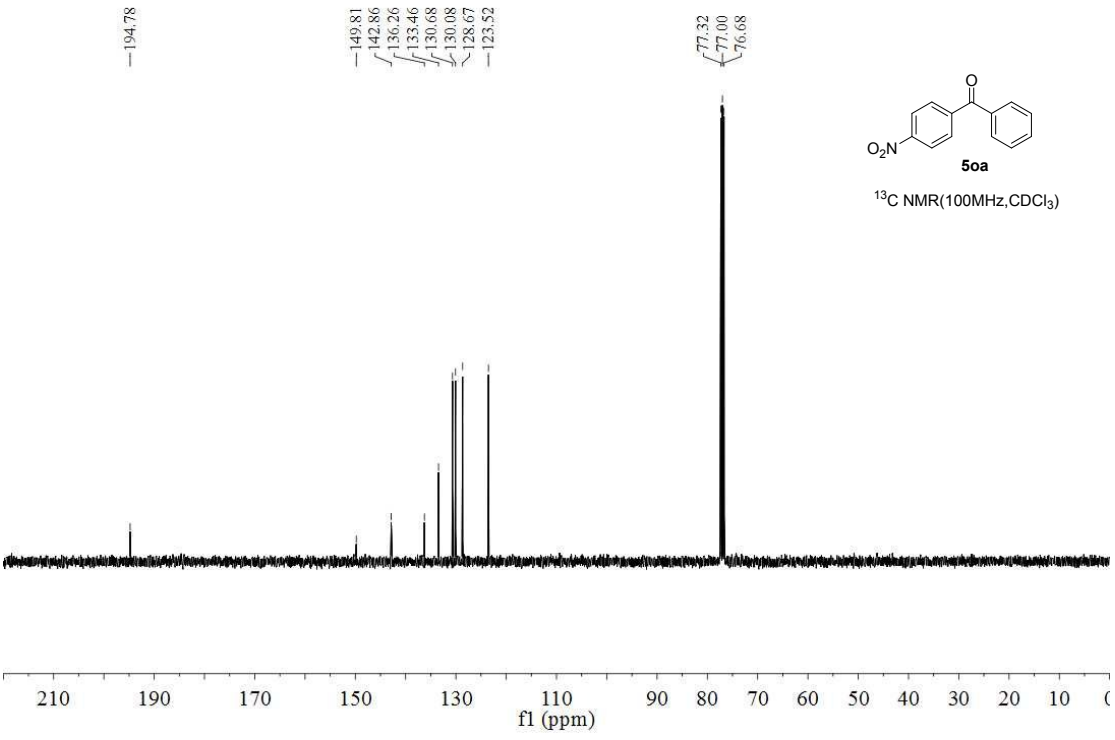
^{1}H NMR (400MHz,$CDCl_3$)

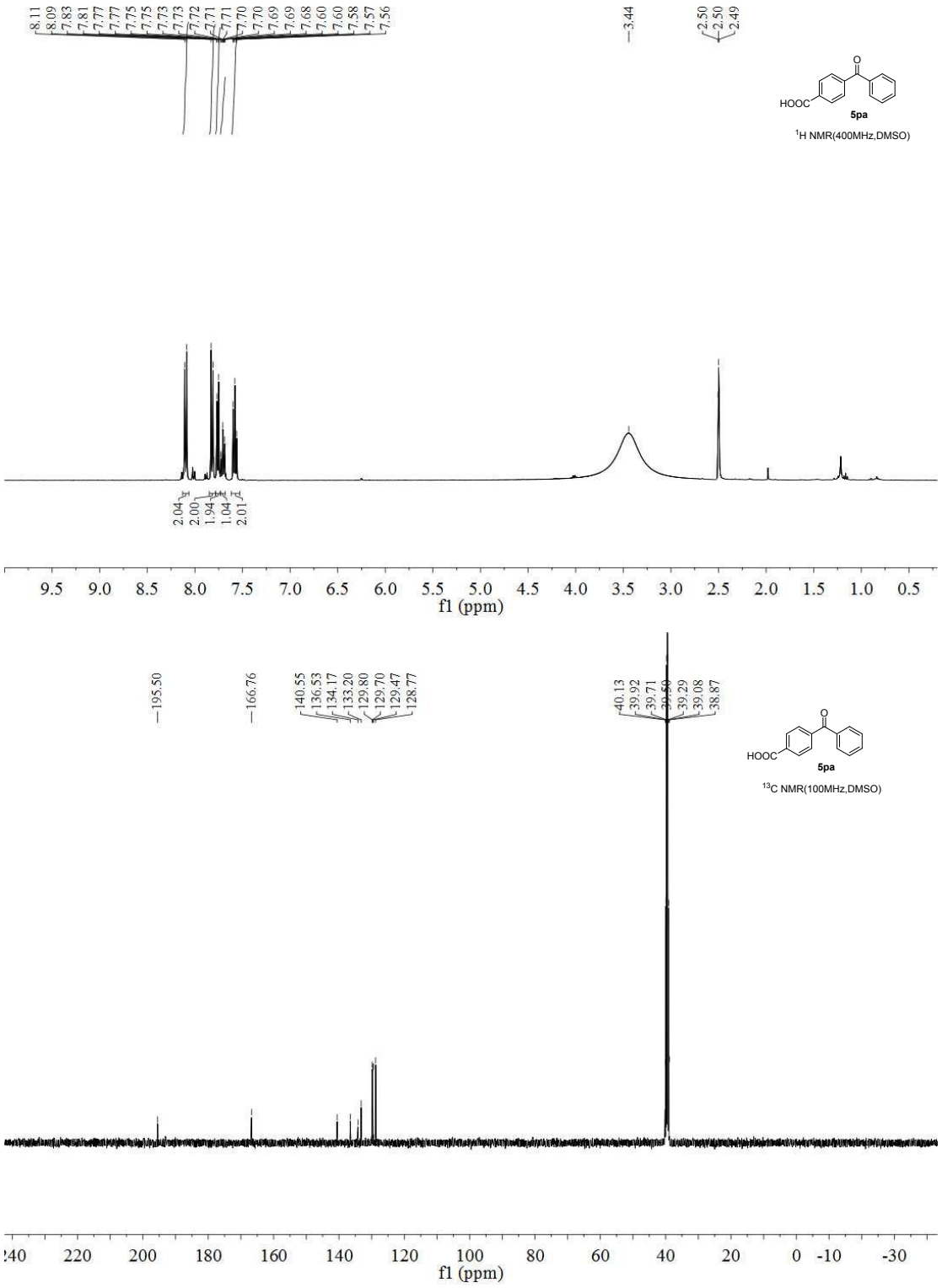


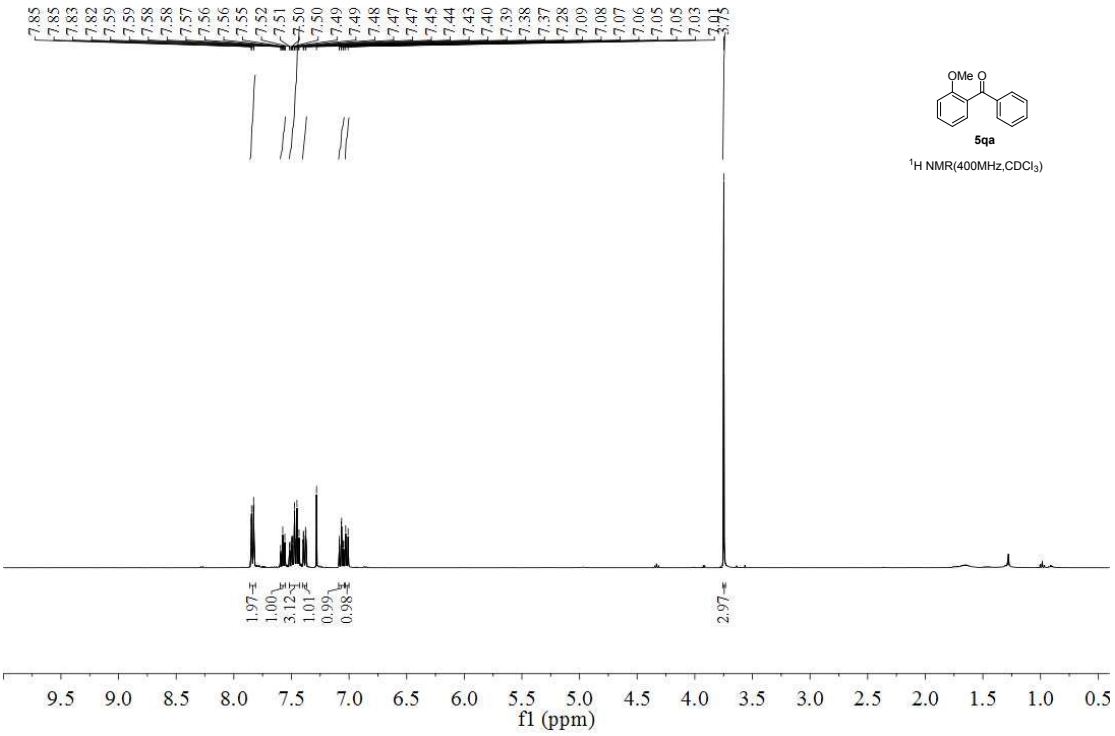
3gq

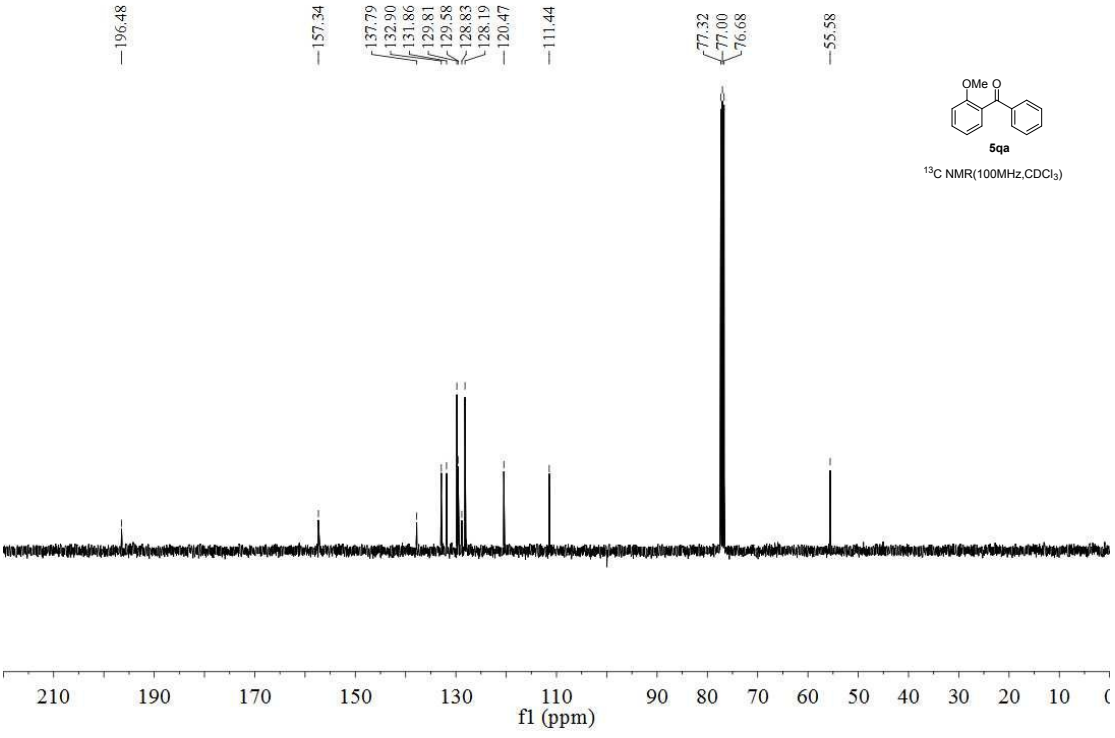
^{13}C NMR (100MHz,$CDCl_3$)

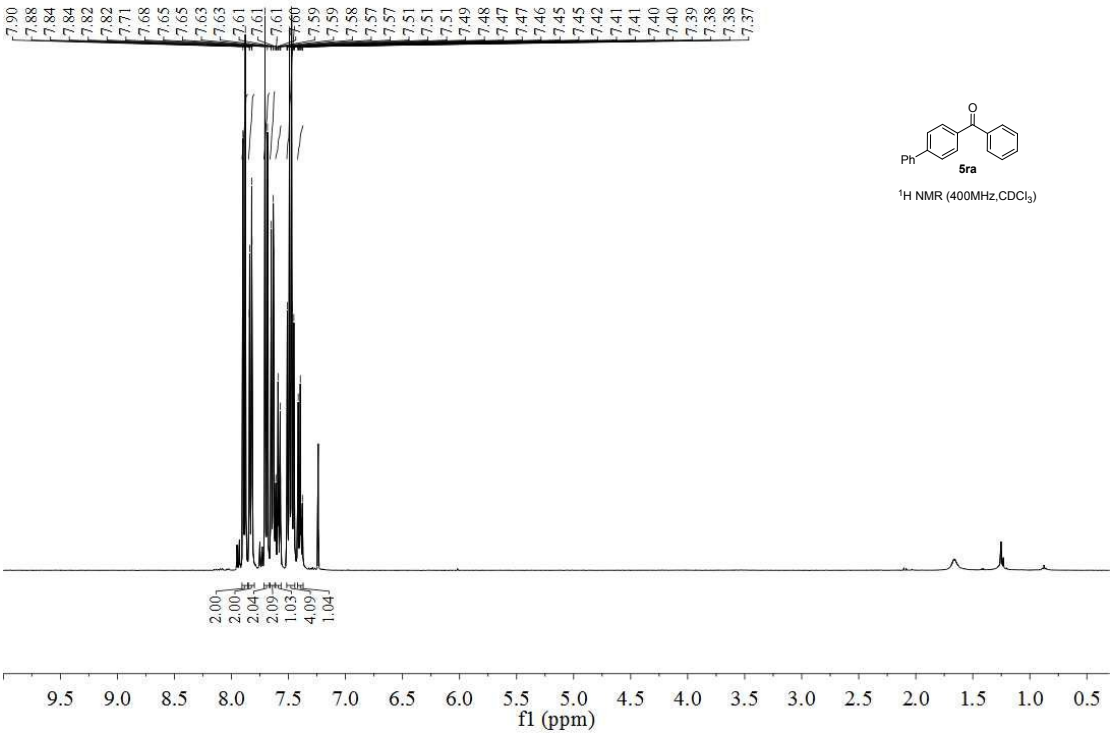

8.33
8.31
7.93
7.91
7.79
7.79
7.79
7.77
7.77
7.66
7.65
7.65
7.64
7.64
7.63
7.62
7.62
7.61
7.53
7.51
7.49
7.24
O
O2N
5oa
1H NMR(400MHz,CDCl3)
2.00
2.03
1.98
1.01
2.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


194.78
149.81
142.86
136.26
133.46
130.68
130.08
128.67
123.52
77.32
77.00
76.68
O
O2N
5oa
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)


8.11
8.09
7.83
7.81
7.77
7.77
7.75
7.75
7.73
7.73
7.72
7.71
7.71
7.70
7.70
7.69
7.69
7.68
7.60
7.60
7.58
7.57
7.56
3.44
2.50
2.50
2.49
HOOC
5pa
1H NMR(400MHz,DMSO)
2.04
2.00
1.94
1.04
2.01
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
f1 (ppm)
195.50
166.76
140.55
136.53
134.17
133.20
129.80
129.70
129.47
128.77
40.13
39.92
39.71
39.50
39.29
39.08
38.87
HOOC
5pa
13C NMR(100MHz,DMSO)
240 220 200 180 160 140 120 100 80 60 40 20 0 -10 -30
f1 (ppm)

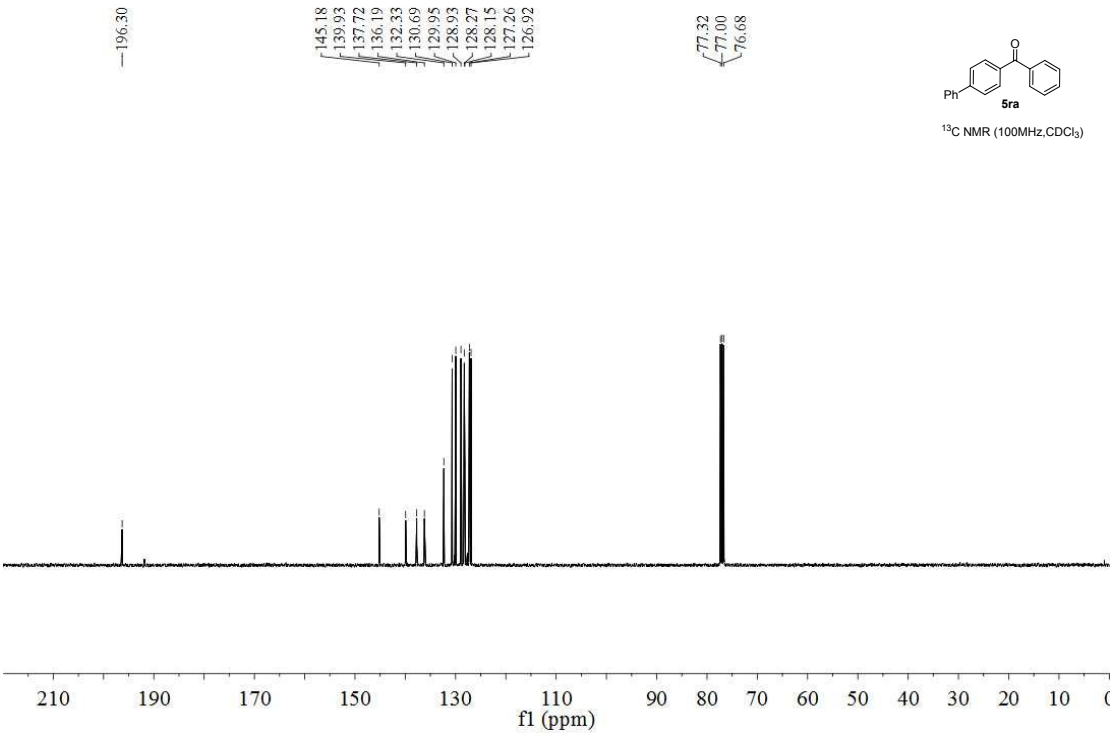

7.85
7.85
7.83
7.82
7.59
7.59
7.58
7.58
7.57
7.56
7.56
7.55
7.52
7.51
7.50
7.50
7.49
7.49
7.48
7.47
7.47
7.45
7.44
7.43
7.40
7.39
7.38
7.37
7.28
7.09
7.08
7.07
7.06
7.05
7.03
3.75
OMe O
5qa
1H NMR(400MHz,CDCl3)
1.97
1.00
3.12
1.01
0.99
0.98
2.97
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


196.48
157.34
137.79
132.90
131.86
129.81
129.58
128.83
128.19
120.47
111.44
77.32
77.00
76.68
55.58
OMe O
5qa
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)



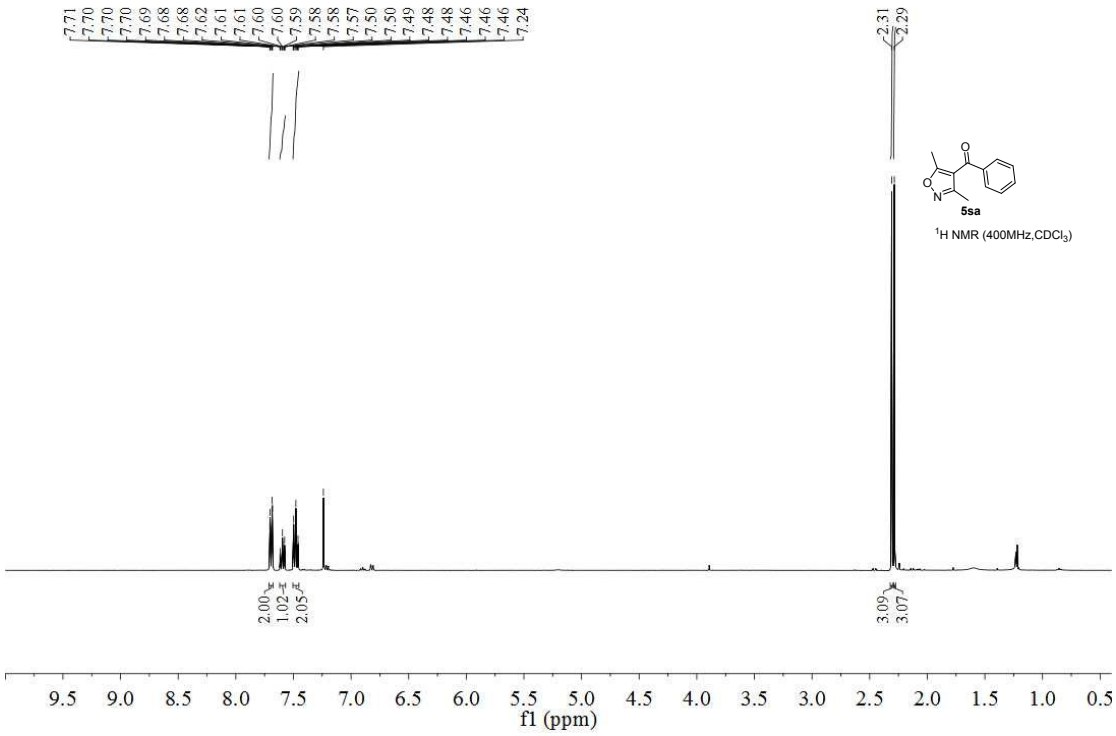
5ra

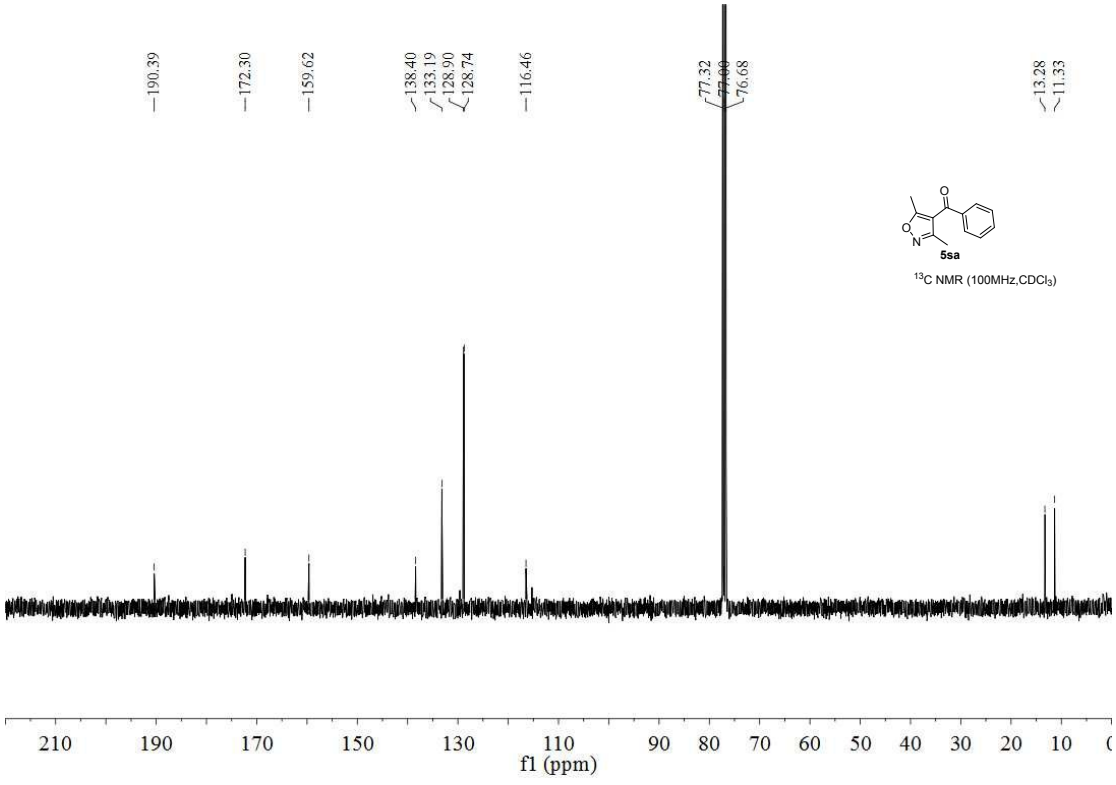
^{1}H NMR (400MHz,$CDCl_3$)

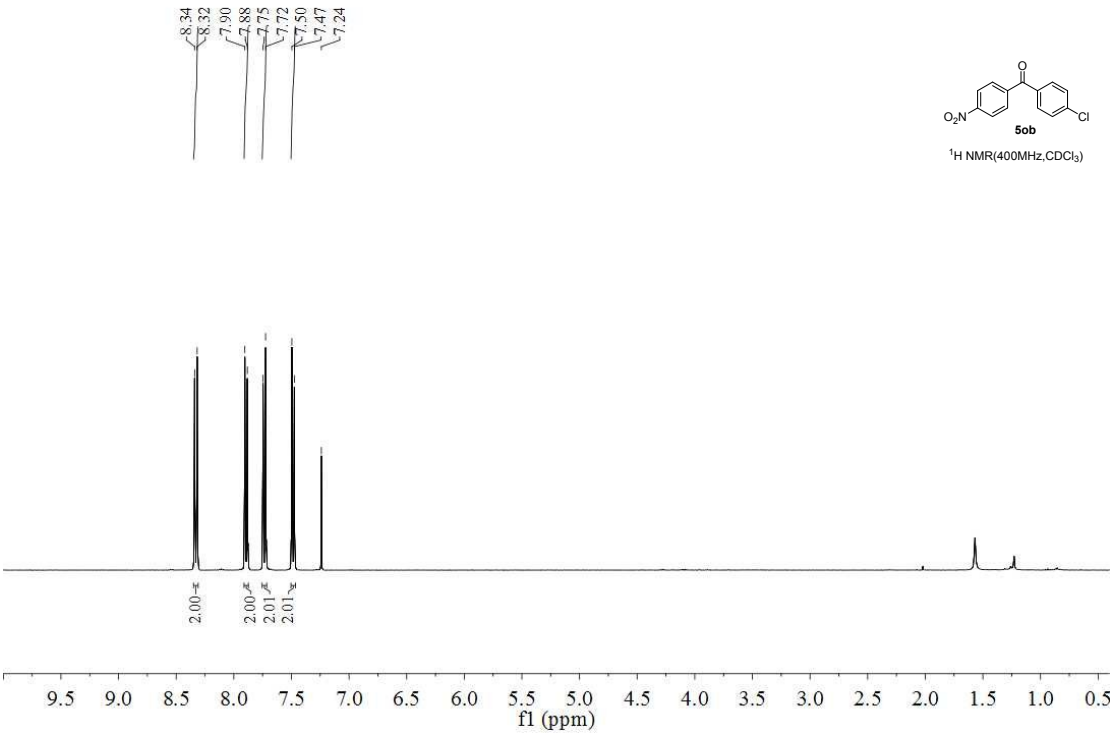


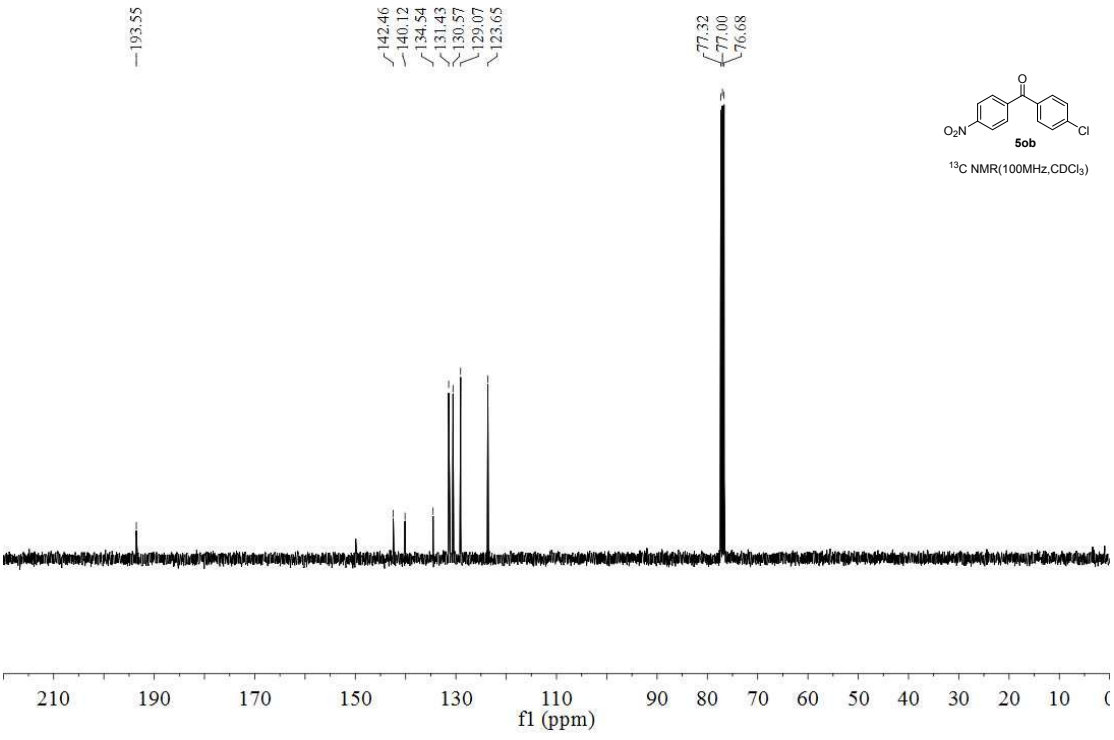
5ra

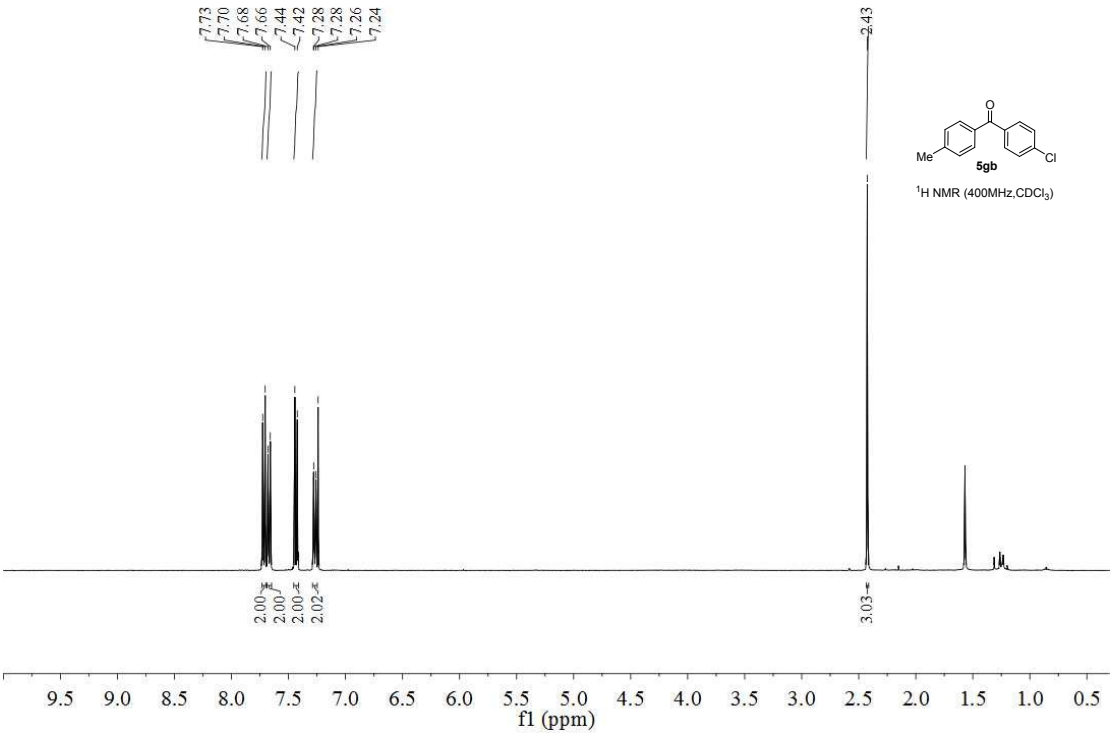
^{13}C NMR (100MHz,$CDCl_3$)

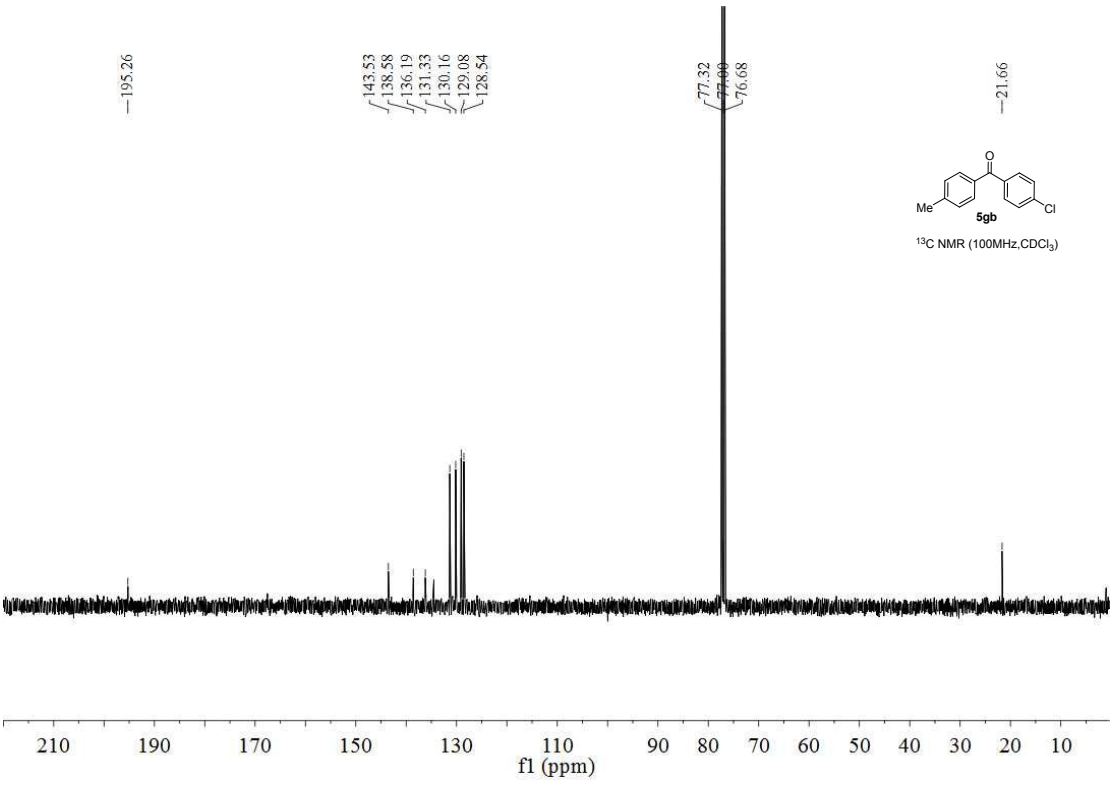

7.71
7.70
7.70
7.70
7.69
7.68
7.68
7.62
7.61
7.61
7.60
7.60
7.59
7.58
7.58
7.57
7.50
7.50
7.49
7.48
7.48
7.46
7.46
7.46
7.24
2.31
2.29
5sa
1H NMR (400MHz,CDCl3)
2.00
1.02
2.05
3.09
3.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

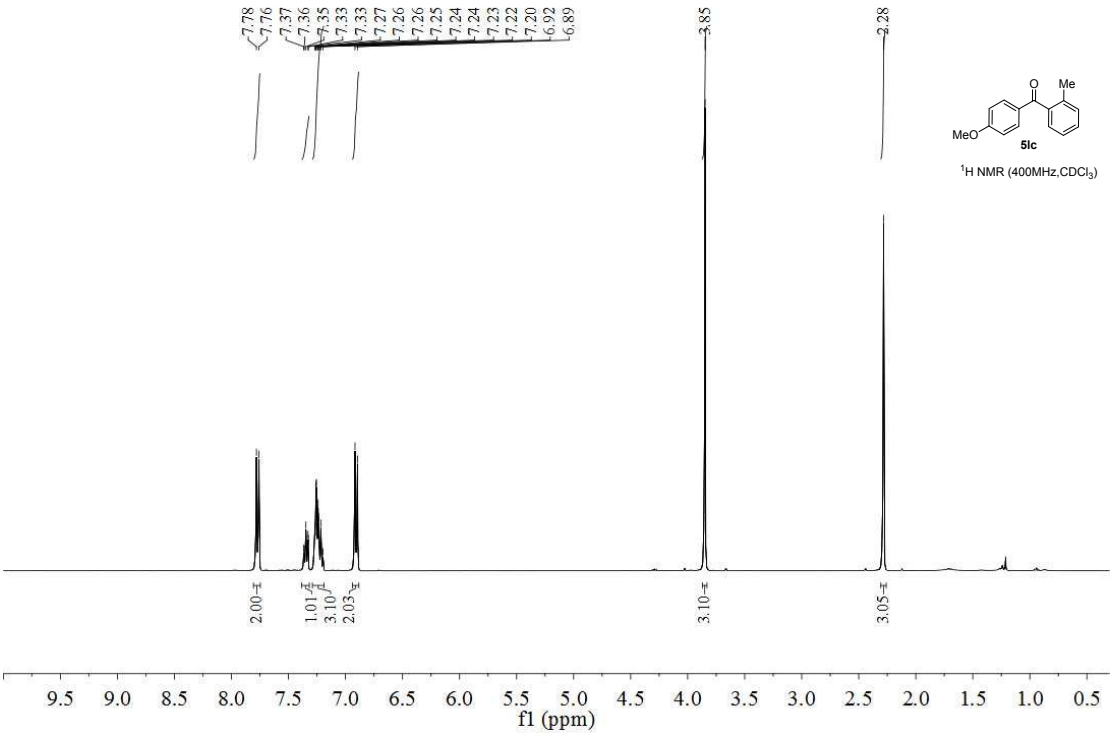

190.39
172.30
159.62
138.40
133.19
128.90
128.74
116.46
77.32
77.00
76.68
13.28
11.33
5sa
13C NMR (100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

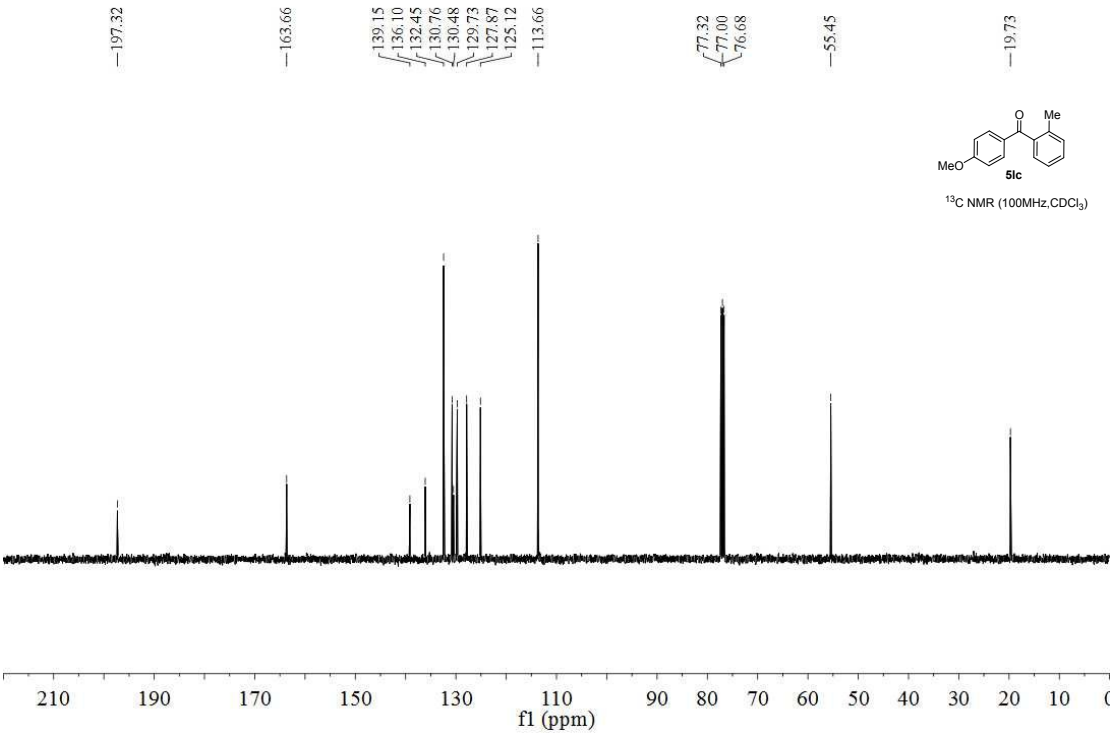

8.34
8.32
7.90
7.88
7.75
7.72
7.50
7.47
7.24
O
O2N
Cl
5ob
1H NMR(400MHz,CDCl3)
2.00
2.00
2.01
2.01
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

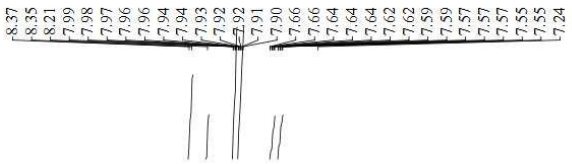

193.55
142.46
140.12
134.54
131.43
130.57
129.07
123.65
77.32
77.00
76.68
O
O2N
Cl
5ob
13C NMR(100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

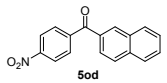

7.73
7.70
7.68
7.66
7.44
7.42
7.28
7.28
7.26
7.24
2.43
O
Me
Cl
5gb
^{1}H NMR (400MHz,CDCl$_3$)
2.00
2.00
2.00
2.02
3.03
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


195.26
143.53
138.58
136.19
131.33
130.16
129.08
128.54
77.32
77.00
76.68
21.66
O
Me
Cl
5gb
^{13}C NMR (100MHz,CDCl$_3$)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.78
7.76
7.37
7.36
7.35
7.33
7.33
7.27
7.26
7.26
7.25
7.24
7.24
7.23
7.22
7.20
6.92
6.89
3.85
2.28
2.00
1.01
3.10
2.03
3.10
3.05
O
Me
MeO
5lc
1H NMR (400MHz,CDCl3)
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
f1 (ppm)

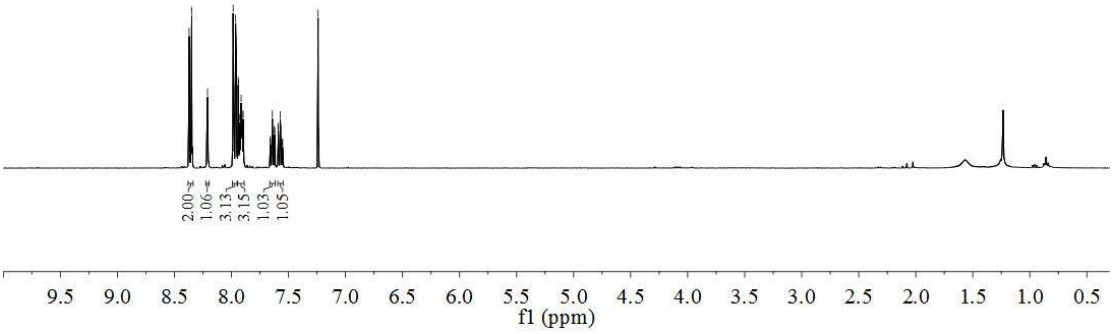

197.32
163.66
139.15
136.10
132.45
130.76
130.48
129.73
127.87
125.12
113.66
77.32
77.00
76.68
55.45
19.73
O
Me
MeO
5lc
13C NMR (100MHz,CDCl3)
210 190 170 150 130 110 90 80 70 60 50 40 30 20 10
f1 (ppm)

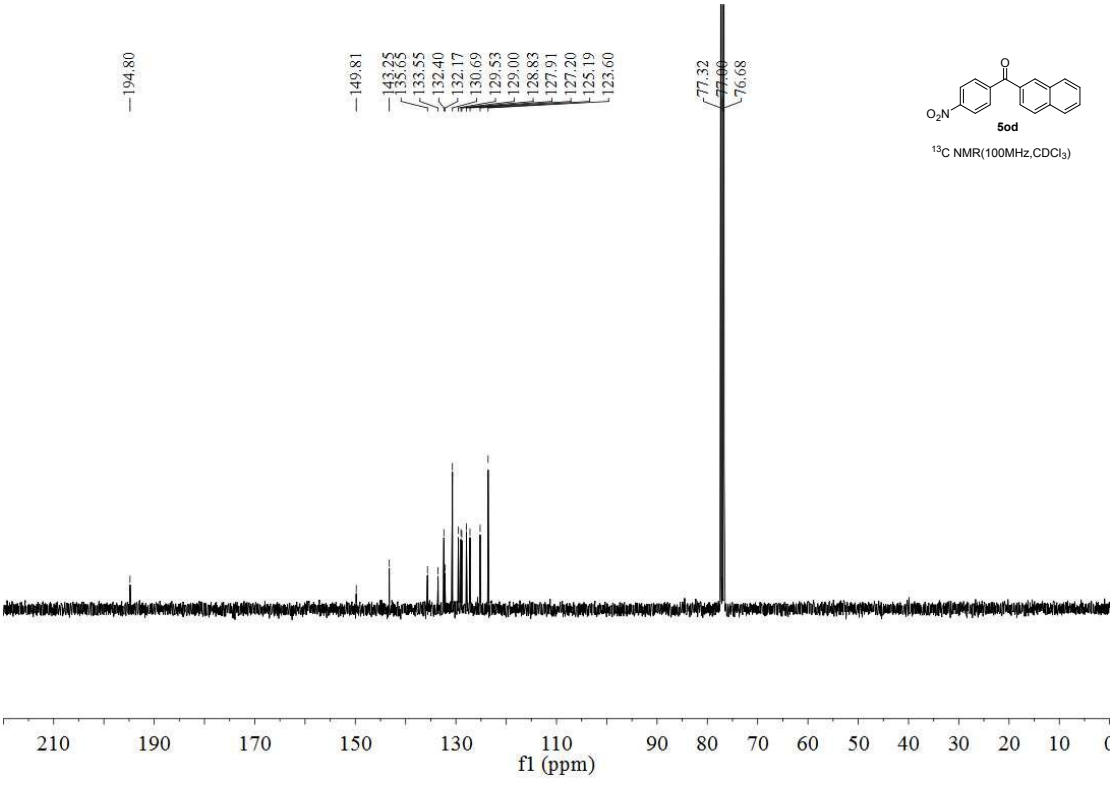




5od

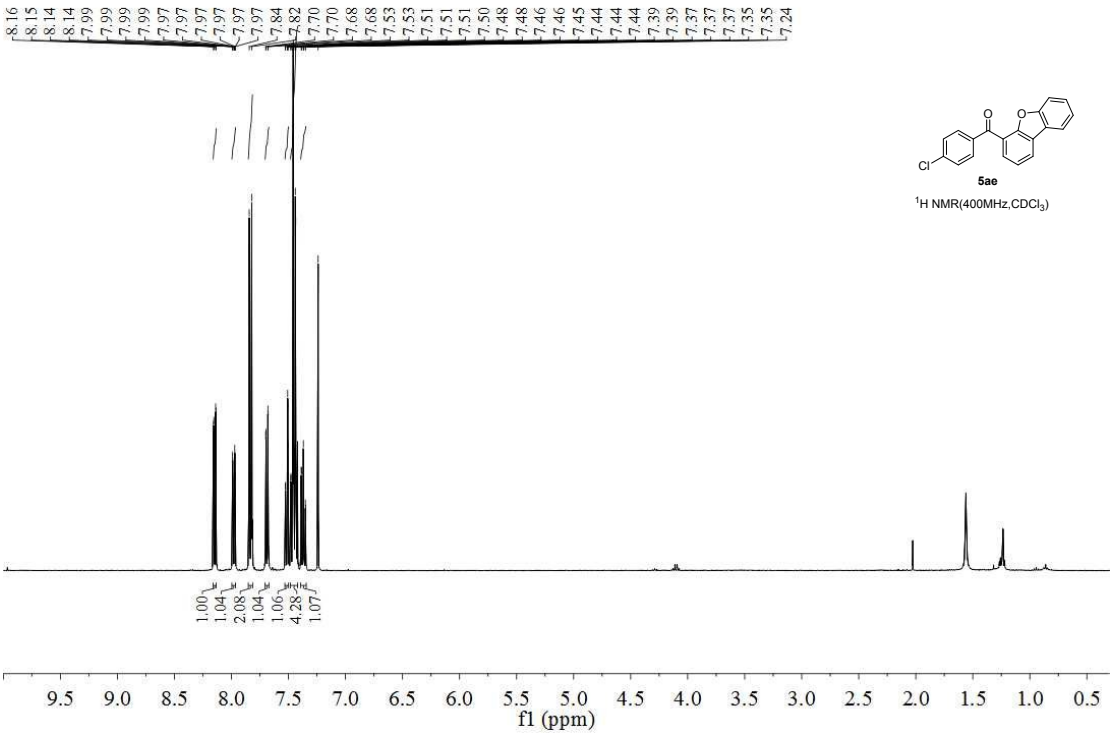
^{1}H NMR(400MHz,CDCl$_3$)

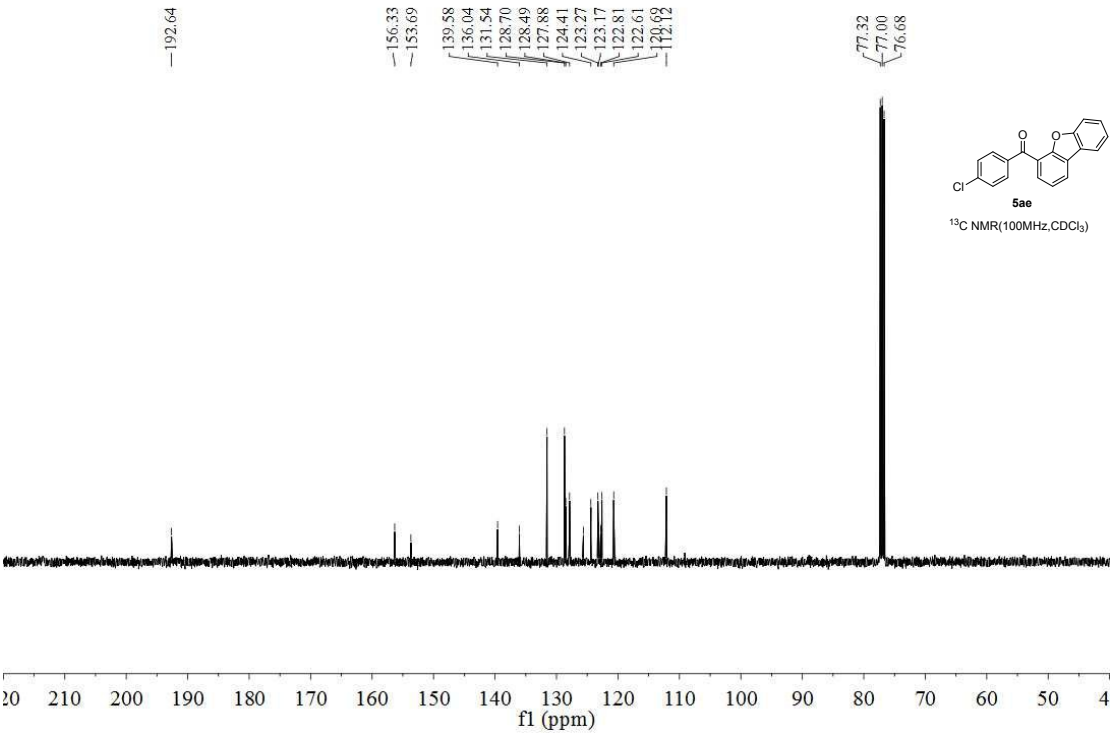




5od

^{13}C NMR(100MHz,CDCl$_3$)


8.16
8.15
8.14
8.14
7.99
7.99
7.99
7.99
7.97
7.97
7.97
7.97
7.97
7.97
7.84
7.82
7.70
7.70
7.68
7.68
7.53
7.53
7.51
7.51
7.51
7.50
7.48
7.48
7.46
7.46
7.45
7.44
7.44
7.44
7.39
7.39
7.37
7.37
7.37
7.35
7.35
7.24
1.00
1.04
2.08
1.04
1.06
4.28
1.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)
O
O
Cl
5ae
1H NMR(400MHz,CDCl3)


192.64
156.33
153.69
139.58
136.04
131.54
128.70
128.49
127.88
124.41
123.27
123.17
122.81
122.61
120.69
112.12
77.32
77.00
76.68
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 4
f1 (ppm)
O
O
Cl
5ae
13C NMR(100MHz,CDCl3)