

# Electrochemical Aerobic Wacker-type Oxygenation of Triaryl Substituted Alkenes to 1,2,2-Triarylethanones

Zhou Zhang<sup>+</sup>,<sup>a</sup> Prof. Dr. Jin Li<sup>+</sup>,<sup>\*b</sup> Zhiwei Cai,<sup>c</sup> Songyao Kang,<sup>c</sup> Jian Wang,<sup>b</sup> Yue Cui,<sup>b</sup> Siyuan Han,<sup>b</sup> Lei Sheng,<sup>c</sup> Qing Yin,<sup>c</sup> Ang Dai,<sup>c</sup> Prof. Dr. Weining Zhao,<sup>\*c</sup> Prof. Dr. Fangyuan Zhao<sup>\*a</sup>

<sup>a</sup>School of Chemical Engineering & Technology, China University of Mining and Technology, Xuzhou 221116, Jiangsu (P. R. China).

<sup>b</sup> Faculty of Chemical Engineering, Huaiyin Institute of Technology, Huai'an 223003, Jiangsu (P. R. China).

<sup>c</sup> College of Pharmacy, Shenzhen Technology University, Shenzhen 518118, Guangdong (P. R. China).

## Supporting Information

### Table of Contents

1. General Information .....	S1
2. The condition optimization of solvent and electrochemical oxidation of other olefins .....	S2
3. X-ray data of 2-(4-fluorophenyl)-1,2-diphenylethan-1-one (2b): .....	S2
4. General procedure .....	S3
5. Scale-up transformation of 2d/2e.....	S5
6. Isotope labeling experiment .....	S5
7. Cyclic voltammetry experiment.....	S6
8. Spectroscopic data for the substrates .....	S7
9. Spectroscopic data of the products .....	S9
10. Copies of <sup>1</sup> H NMR, <sup>13</sup> C NMR and <sup>19</sup> F NMR Spectra .....	S15
11. References .....	S45

## 1. General Information

All reactions that required anhydrous conditions were carried out using standard procedures under an argon atmosphere. Unless otherwise noted, materials were purchased from commercial suppliers and used without any additional purification. The solvents were dried by distillation using the appropriate drying reagents. Other chemicals were obtained from commercial sources and were used without any additional purification.

Column chromatography was typically conducted using silica gel (300-400 mesh), and the reactions were monitored using thin-layer chromatography (TLC) with 210 nm/254 nm UV light to observe the reaction progress.

$^1\text{H}$  NMR (400 MHz),  $^{13}\text{C}$  NMR (100 MHz), and  $^{19}\text{F}$  NMR (376 MHz) spectra were acquired using a 400 MHz spectrometer in  $\text{CDCl}_3$ . The chemical shifts ( $\delta$ ) are reported in parts per million (ppm) relative to tetramethylsilane (TMS) as the internal standard. The NMR signals are described as singlet (s), doublet (d), or multiplet (m), and the coupling constants are given in hertz (Hz). High-resolution mass spectra (HRMS) were acquired using an electrospray ionization (ESI) and electron ionization (EI) source, coupled with a time-of-flight (TOF) detector mass spectrometer. The melting points were measured using a digital melting point detector.

Cyclic voltammetric (CV) curves were recorded using a three-electrode setup. The working electrode was a platinum plate, and a platinum wire served as counter electrode. Saturated calomel electrode (SCE) was used as the reference electrode. The working electrode was polished before recording each cyclic voltammetry (CV) measurements.

## 2. The condition optimization of solvent and electrochemical oxidation of other olefins

Table S1: the condition optimization of solvent<sup>a</sup>

entry	electricity	solvent	atmosphere	Yield (%)
1	LiClO <sub>4</sub>	CH <sub>3</sub> CN	O <sub>2</sub>	67
2	LiClO <sub>4</sub>	THF	O <sub>2</sub>	N.R.
3	LiClO <sub>4</sub>	CH <sub>2</sub> Cl <sub>2</sub>	O <sub>2</sub>	N.R.
4	LiClO <sub>4</sub>	EA	O <sub>2</sub>	N.R.
5	LiClO <sub>4</sub>	DMSO	O <sub>2</sub>	< 5
6	LiClO <sub>4</sub>	DMF	O <sub>2</sub>	N.R.
7	LiClO <sub>4</sub>	CHCl <sub>3</sub>	O <sub>2</sub>	N.R.
8	LiClO <sub>4</sub>	EtOH	O <sub>2</sub>	N.R.

[a] Undivided cell, graphite felt cathode (2 cm x 1 cm x 0.5 cm), **1a** (0.2 mmol), anhydrous solvent (5 mL), constant voltage at 5 V, room temperature, 1.5 h.

Table S2: electrochemical oxidation of other olefins<sup>a</sup>

entry	olefins	Yield <sup>b</sup> (%)
1	styrene	trace
2	(Z)-1,2-diphenylethene	N.R.
3	trans-stilbene	N.R.
4	ethene-1,1-diyldibenzene	trace
5	1,1,2,2-tetraphenylethene	trace
6	1-(4-bromophenyl)-1,2,2-triphenylethylene	N.R.

[a] Undivided cell, graphite felt cathode (2 cm x 1 cm x 0.5 cm), **1a** (0.2 mmol), anhydrous solvent (5 mL), constant voltage at 5 V, room temperature, 1.5 h. [b] Unseparated yield, The result was determined by LC-MS.

## 3. X-ray data of 2-(4-fluorophenyl)-1,2-diphenylethan-1-one (2b):

Single crystals of C<sub>20</sub>H<sub>15</sub>FO (2b) were figure S1. A suitable crystal was selected and on a CCD area detector diffractometer. The crystal was kept at 100.15 K during data collection. Using Olex<sub>2</sub> [1], the structure was solved with the XT [2] structure solution program using Intrinsic Phasing and refined with the XL [3]refinement package using Least Squares minimisation. Further information on the crystal structure determinations have been deposited with the Cambridge Crystallographic Data Center [2b(1\_a): CCDC 2323256]. Figure S1 shows the X-ray data of 2b.

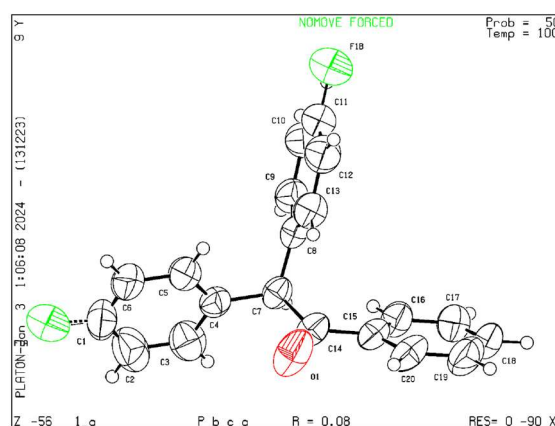


Fig S1: X-ray data of 2-(4-fluorophenyl)-1,2-diphenylethan-1-one (2b)

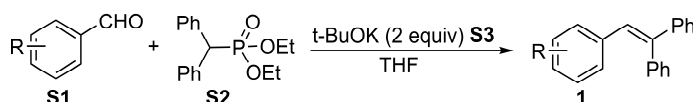
Table S3: Crystallographic data and structural refinement for compound 2b

Item	Date
Identification code	2b(1_a)
Empirical formula	C <sub>20</sub> H <sub>15</sub> FO
Formula weight	290.32
Temperature (K)	100.15
Crystal system	<i>orthorhombic</i>
Space group	Pbca
A (Å)	16.4099(16)
b (Å)	10.0684(10)
c (Å)	18.6788(16)
$\alpha$ (°)	90
$\beta$ (°)	90
$\gamma$ (°)	90
Volume (Å <sup>3</sup> )	3086.1(5)
Z	8
$\rho_{\text{calc}}$ (g/cm <sup>3</sup> )	1.250
$\mu$ (mm <sup>-1</sup> )	0.677
F (000)	1216.0
Crystal size (mm <sup>3</sup> )	0.22 × 0.2 × 0.18
Radiation	CuK $\alpha$ ( $\lambda$ = 1.54178)
2 $\theta$ range for data collection (°)	9.47 to 133.512
Index ranges	-19 ≤ h ≤ 16, -11 ≤ k ≤ 8, -22 ≤ l ≤ 21
Reflections collected	15338
Independent reflections	2713 [ $R_{\text{int}}$ = 0.0779, $R_{\text{sigma}}$ = 0.0650]
Data/restraints/parameters	2713/2/203
Goodness-of-fit on F <sup>2</sup>	1.081
Final R indexes [ $I \geq 2\sigma(I)$ ]	$R_1$ = 0.0822, $wR_2$ = 0.2170
Final R indexes [all data]	$R_1$ = 0.0998, $wR_2$ = 0.2324
Largest diff. peak/hole (e Å <sup>-3</sup> )	0.30/-0.31

#### 4. General procedure

##### 4.1 General procedure for the substrates

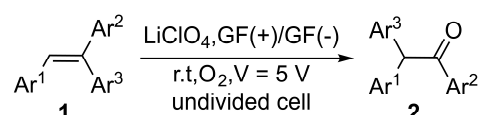
Substrates **1** were synthesized according to the reported literature<sup>[4]</sup>.



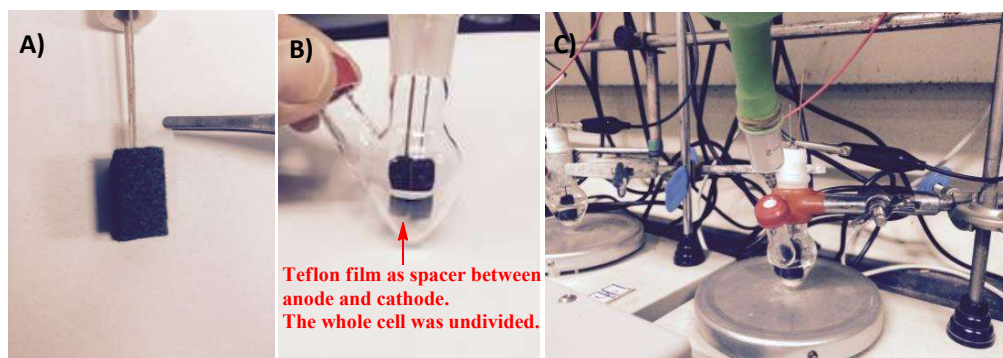
The potassium t-butoxide (**t-BuOK**) (1.12 g, 10 mmol, 2 equiv) was added dropwise to a solution of diethyl benzhydrylphosphonate (**S2**) (3.04 g, 10 mmol, 2 equiv) in tetrahydrofuran (THF, 50 mL) under argon atmosphere at -78 °C. Subsequently, the mixture was stirred for 30 minutes at -78 °C.

Then, ArCHO **S1** (5 mmol, 1 equiv) was added, and stirring was continued until the reaction mixture slowly warmed to room temperature overnight. After the reaction was completed, the mixture was concentrated under reduced pressure. The residue was then extracted with ethyl acetate (EtOAc, 3 × 20 mL), and the combined organic layer was washed with water and brine. It was then dried over anhydrous magnesium sulfate (MgSO<sub>4</sub>), filtered, and concentrated. The residue was purified by flash chromatography using silica gel, resulting in the desired product.

#### 4.2 General procedure of electrochemical oxidation



A 10 mL two-necked heart-shaped flask was equipped with a stir bar. Substrate **1** (0.2 mmol) and LiClO<sub>4</sub> (0.1 mmol) were added to the flask, followed by 5 mL of CH<sub>3</sub>CN solvent. The reaction flask was equipped with graphite felt (2 cm × 1 cm × 0.5 cm) as the anode and cathode. Two electrodes were separated by a Teflon film, which served as a spacer between the anode and cathode. The entire cell was undivided. The graphite felt anode was attached to a platinum wire, and cathode was attached to a silver wire. A Teflon wire was tied around two electrodes. The solution was stirred and electrolyzed at a constant voltage of 5 V for 1.5 hours at room temperature without a reference electrode, in the presence of oxygen. When the reaction was completed, as monitored with TLC and GC-MS analysis, the mixture was extracted with ethyl acetate (3 × 15 mL). The combined organic layer was combined, washed with brine (10 mL), and then dried over MgSO<sub>4</sub>. It was filtered, and concentrated under reduced pressure. Purified product **2** was obtained after column chromatography using silica gel.



**Figure S2.** Graphical guide for the 0.2 mmol reaction setup. A) A Teflon film was put between the anode and cathode (made of graphite felts) to act as an isolated film and a spacer; B) The isolated anode and cathode were put inside the two-necked heart-shaped flask for the electrochemical reaction; C) An overall view of the electrochemical reaction setup

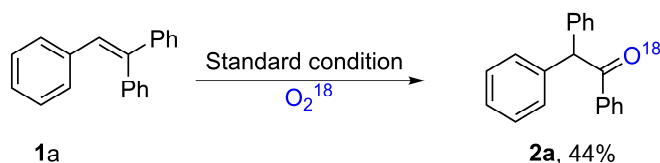
## 5. Scale-up transformation of 2d/2e



In an undivided flask (100 mL) equipped with a stir bar, **1d/1e** (6 mmol), LiClO<sub>4</sub> (3 mmol), and CH<sub>3</sub>CN (V = 90 mL) were added. The reaction flask was equipped with graphite felt as both the anode and cathode, with dimensions of 3.6 cm × 1.8 cm × 0.5 cm for each electrode. The solution was stirred and electrolyzed at a constant voltage of 5 V without a reference electrode for 45 hours at room temperature in the presence of oxygen. After completing the reaction, the mixture was quenched with water (200 mL) and extracted with ethyl acetate (3 × 50 mL). The combined organic layer was combined, washed with brine (50 mL), and then dried over MgSO<sub>4</sub>. It was filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel using a mixture of petroleum ether (PE) and ethyl acetate (EA) as the eluent. This process yielded the desired product **2d/2e** in solid form.

## 6. Isotope labeling experiment

### 6.1 O<sub>2</sub><sup>18</sup> labeling experiment



The isotope labeling experiment was designed to rationalize the reaction pathway. A 10 mL two-necked heart-shaped flask was equipped with a stir bar. **1a** (0.2 mmol), LiClO<sub>4</sub> (0.1 mmol), and 5 mL of CH<sub>3</sub>CN solvent were added. The reaction flask was equipped with graphite felt (2 cm × 1 cm × 0.5 cm) as the anode and cathode. Two electrodes were separated by a Teflon film, which acted as an isolated film and a spacer between the anode and cathode. The entire cell was undivided. The graphite felt anode is attached to a platinum wire, and the cathode was attached to a silver wire. A Teflon wire was tied around two electrodes. The reaction was degassed and backfilled with argon three times. After that, the flask was vacuumed, and then 10 mL of O<sub>2</sub><sup>18</sup> was added to the flask using a syringe. The solution was stirred and electrolyzed at a constant voltage of 5 V without a reference electrode for 1.5 hours at room temperature. When the reaction was completed, as monitored with TLC and GC-MS analysis, the mixture was extracted with ethyl acetate (3 × 15 mL). The organic layer was combined, washed with brine (10 mL), and then dried over MgSO<sub>4</sub>. It was filtered and concentrated under reduced pressure. Purified O<sup>18</sup> labeled **2a** was obtained after column chromatography using silica gel. The purified product was detected using a high-resolution mass spectrometer, and the resulting picture is shown in the following figure. HRMS (ESI)([M + H]<sup>+</sup>) Calcd For C<sub>20</sub>H<sub>17</sub>O<sup>18</sup>: 275.1317, found: 275.1322.

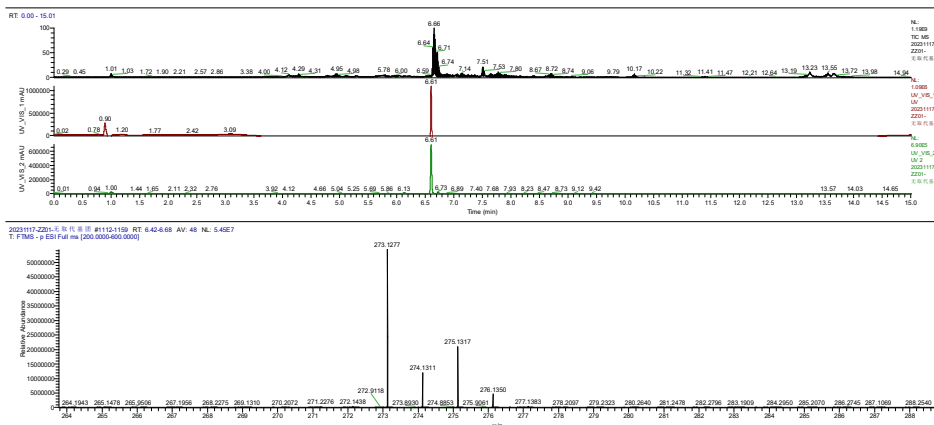


Figure S3 High resolution mass spectrum of  $O^{18}$  labeled product **2a** when using  $O_2^{18}$ .

## 6.2 $H_2O^{18}$ labeling experiment



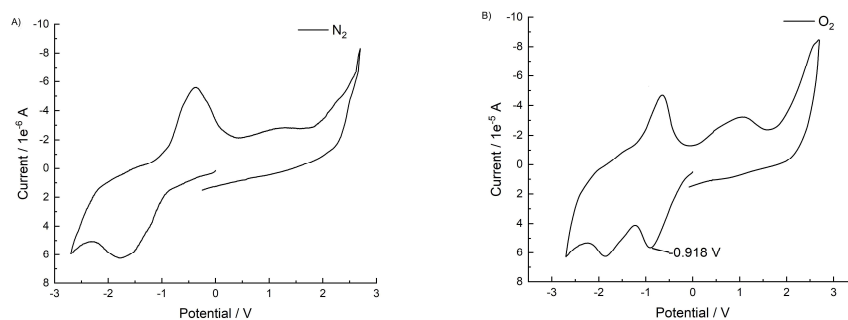
Table S4 Results of  $H_2O^{18}$  labeling experiment.

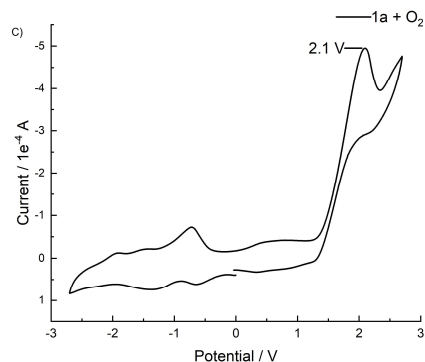
solvent	additive	equivalent	yield
$CH_3CN$	$H_2O$	0.5	N.R.
$CH_3CN$	$H_2O$	1.0	N.R.
$CH_3CN$	$H_2O$	2.0	N.R.
$CH_3CN$	$H_2O^{18}$	0.5	N.R.
$CH_3CN$	$H_2O^{18}$	1.0	N.R.
$CH_3CN$	$H_2O^{18}$	2.0	N.R.
$CH_3CN$	$H_2O$	$CH_3CN/H_2O = 4:1^a$	N.R.

[a] The reaction solvent used here consisted of a mixture of  $CH_3CN$  and  $H_2O$  in a ratio of 4:1.

An argon atmosphere was employed instead of an oxygen atmosphere under standard conditions. Different equivalents of water ( $H_2O^{18}$ ) were added to the electrochemical reaction tank to observe the reaction phenomenon. The data in the above table were obtained after monitoring through TLC and LC-MS.

## 7. Cyclic voltammetry experiment

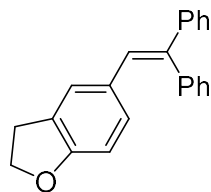




**Figure S3.** A) Cyclic voltammetry experiment of  $N_2$ : a solution of  $LiClO_4$  (0.1 mmol) in 5 mL anhydrous  $CH_3CN$  was subject to cyclic voltammetry experiment under  $N_2$  atmosphere. B) Cyclic voltammetry experiment of  $O_2$ : a solution of  $LiClO_4$  (0.1 mmol) in 5 mL anhydrous  $CH_3CN$  was subject to cyclic voltammetry experiment under  $O_2$  atmosphere. C) A solution of substrate **1a** (0.2 mmol),  $LiClO_4$  (0.1 mmol) in 5 mL anhydrous  $CH_3CN$  was subject to cyclic voltammetry experiment under  $O_2$  atmosphere. For all experiments, cyclic voltammetry (CV) curves were recorded using a three-electrode setup. The working electrode was a platinum plate, and a platinum wire served as counter electrode. A saturated calomel electrode (SCE) was used as the reference electrode. The working electrode was polished before recording each cyclic voltammetry (CV) curve.

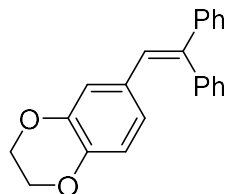
## 8. Spectroscopic data for the substrates

### 5-(2,2-diphenylvinyl)-2,3-dihydrobenzofuran **1k**:



2.32 g, yield: 78%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.4).  $^1H$  NMR (400 MHz, Chloroform- $d$ )  $\delta$  = 8.06 – 8.00 (m, 2H), 7.56 – 7.51 (m, 1H), 7.46 – 7.41 (m, 2H), 7.37 – 7.32 (m, 2H), 7.30 – 7.27 (m, 3H), 7.14 (s, 1H), 7.03 (dd,  $J$  = 8.2, 1.6 Hz, 1H), 6.75 (d,  $J$  = 8.2 Hz, 1H), 5.99 (s, 1H), 4.56 (t,  $J$  = 8.7 Hz, 2H), 3.19 (t,  $J$  = 8.7 Hz, 2H).  $^{13}C$  NMR (100 MHz, Chloroform- $d$ )  $\delta$  = 198.54, 159.26, 139.62, 136.87, 132.87, 130.91, 128.96, 128.86, 128.81, 128.59, 128.51, 127.56, 126.93, 125.57, 109.25, 71.25, 58.73, 29.65. HRMS (ESI) ( $[M + Na]^+$ ) Calcd For  $C_{22}H_{18}ONa$ : 321.1250, found: 321.1244.

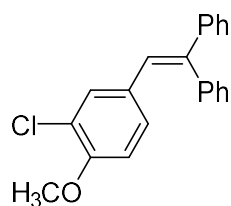
### 6-(2,2-diphenylvinyl)-2,3-dihydrobenzo[b][1,4]dioxine **1l**:



2.36 g, yield: 75%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.38).  $^1H$  NMR (400 MHz, Chloroform- $d$ )  $\delta$  = 7.41 – 7.24 (m, 10H), 6.88 (s, 1H), 6.66 – 6.64 (m, 1H), 6.56 – 6.54 (m, 2H), 4.23 – 4.20 (m, 4H).  $^{13}C$  NMR (100 MHz, Chloroform- $d$ )  $\delta$  = 143.46, 142.89, 142.57, 141.06, 140.45, 131.00, 130.29, 128.71, 128.14, 127.47, 127.38, 127.36, 127.23, 123.15, 118.18, 116.66, 64.41, 64.22. HRMS (ESI) ( $[M + H]^+$ ) Calcd For  $C_{22}H_{19}O_2$ : 315.1380, found: 315.1388.



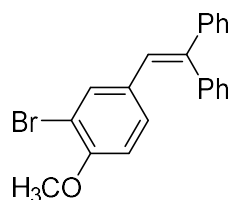
**(2-(3-chloro-4-methoxyphenyl)ethene-1,1-diyl)dibenzene 1m:**



2.37 g, yield: 74%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,

$R_f = 0.4$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 7.41 - 7.31$  (m, 8H), 7.25 – 7.21 (m, 2H), 7.05 (d,  $J = 2.0$  Hz, 1H), 6.90 – 6.86 (m, 2H), 6.70 (d,  $J = 8.7$  Hz, 1H), 3.86 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 153.66, 143.10, 142.08, 140.10, 131.28, 131.05, 130.25, 128.84, 128.79, 128.21, 127.55, 127.49, 127.42, 126.22, 121.87, 111.44, 56.05$ . HRMS (EI) ( $[\text{M}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{17}\text{ClO}$ : 320.0962, found: 320.0957.

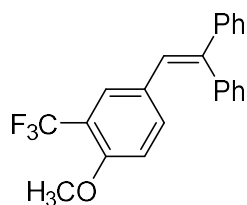
**(2-(3-bromo-4-methoxyphenyl)ethene-1,1-diyl)dibenzene 1n:**



2.67 g, yield: 73%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,

$R_f = 0.35$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 7.36$  (m, 3H), 7.33 – 7.27 (m, 5H), 7.21 – 7.19 (m, 3H), 6.89 (dd,  $J = 8.6, 2.1$  Hz, 1H), 6.85 (s, 1H), 6.65 (d,  $J = 8.6$  Hz, 1H), 3.83 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 154.53, 143.07, 142.09, 140.09, 134.44, 131.54, 130.26, 129.51, 128.78, 128.21, 127.54, 127.49, 127.42, 126.08, 111.25, 111.08, 56.14$ . HRMS (EI) ( $[\text{M}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{17}\text{BrO}$ : 364.0457, found: 364.0456.

**(2-(4-methoxy-3-(trifluoromethyl)phenyl)ethene-1,1-diyl)dibenzene 1o:**

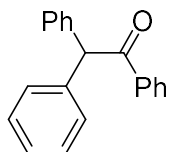


2.5 g, yield: 71%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,

$R_f = 0.4$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 7.51 - 7.39$  (m, 9H), 7.37 – 7.32 (m, 2H), 7.24 (dd,  $J = 8.7, 2.0$  Hz, 1H), 7.05 (s, 1H), 6.84 (d,  $J = 8.7$  Hz, 1H), 3.91 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 156.13$  (q,  $J_{\text{C-F}} = 1.8$  Hz), 143.04, 142.50, 140.14, 134.13, 130.29, 129.76, 129.04, 128.49 (q,  $J = 5.4$  Hz), 128.40, 127.76 (q,  $J = 5.1$  Hz), 127.53, 126.24, 123.64 (q,  $J = 272.6$  Hz), 118.33 (q,  $J = 30.7$  Hz), 111.66, 55.89.  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*)  $\delta = -62.38$ . HRMS (EI) ( $[\text{M}]^+$ ) Calcd For  $\text{C}_{22}\text{H}_{17}\text{OF}_3$ : 354.1226, found: 354.1222.

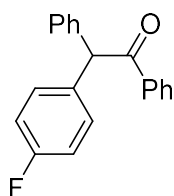
## 9. Spectroscopic data of the products

### 1,2,2-triphenylethan-1-one 2a:



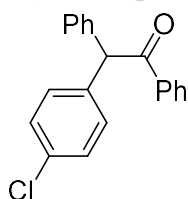
32 mg, yield: 58.7%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.4).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 8.09 – 8.02 (m, 2H), 7.57 – 7.53 (m, 1H), 7.467 – 7.43 (m, 2H), 7.39 – 7.27 (m, 10H), 6.09 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 198.14, 139.06, 136.82, 132.98, 129.11, 128.92, 128.68, 128.57, 127.10, 59.40. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{17}\text{O}^+$ : 273.1274, found: 273.1276. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{17}\text{O}$ : 273.1274, found: 273.1276.

### 2-(4-fluorophenyl)-1,2-diphenylethan-1-one 2b:



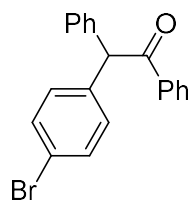
49 mg, yield: 84%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.45).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 8.08 – 8.00 (m, 2H), 7.58 – 7.52 (m, 1H), 7.49 – 7.42 (m, 2H), 7.39 – 7.34 (m, 2H), 7.33 – 7.25 (m, 5H), 7.09 – 7.00 (m, 2H), 6.06 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 198.03, 161.93 (d,  $J$  = 245.9 Hz), 138.9, 136.66, 134.90 (d,  $J$  = 3.3 Hz), 133.12, 130.70 (d,  $J$  = 8.0 Hz), 128.96, 128.90, 128.85, 128.63, 127.27, 115.49 (d,  $J$  = 21.4 Hz), 58.51.  $^{19}\text{F}$  NMR (376 MHz, Chloroform-*d*)  $\delta$  = -115.59. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{16}\text{FO}$ : 291.1180, found: 291.1183.

### 2-(4-chlorophenyl)-1,2-diphenylethan-1-one 2c:



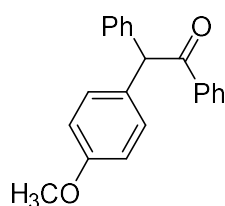
50 mg, yield: 82%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.45).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 8.00 – 7.98 (m, 2H), 7.55 – 7.51 (m, 1H), 7.45 – 7.39 (m, 2H), 7.36 – 7.25 (m, 7H), 7.23 – 7.18 (m, 2H), 6.01 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 197.79, 138.61, 137.68, 136.60, 133.19, 133.11, 130.50, 128.98, 128.92, 128.90, 128.79, 128.67, 127.36, 58.68. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{16}\text{ClO}$ : 307.0884, found: 307.0889.

**2-(4-bromophenyl)-1,2-diphenylethan-1-one 2d:**



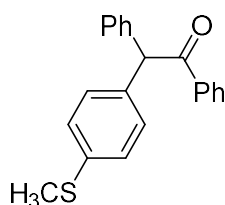
53 mg, yield: 80%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.3).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 8.05 – 8.00 (m, 2H), 7.58 – 7.53 (m, 1H), 7.50 – 7.42 (m, 4H), 7.39 – 7.33 (m, 2H), 7.31 – 7.28 (m, 3H), 7.20 – 7.16 (m, 2H), 6.03 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 197.66, 138.49, 138.19, 136.53, 133.18, 131.70, 130.85, 128.94, 128.88, 128.64, 127.34, 121.22, 58.70. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{16}\text{BrO}$ : 351.0379, found: 351.0385.

**2-(4-methoxyphenyl)-1,2-diphenylethan-1-one 2e:**



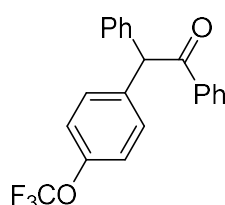
51 mg, yield: 84%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.32).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 8.03 (d,  $J$  = 7.5 Hz, 2H), 7.55 – 7.52 (m, 1H), 7.45 – 7.41 (m, 2H), 7.36 – 7.21 (m, 7H), 6.89 (d,  $J$  = 8.6 Hz, 2H), 6.02 (s, 1H), 3.80 (s, 3H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 198.42, 158.68, 139.48, 136.89, 132.91, 131.13, 130.14, 129.02, 128.90, 128.64, 128.55, 127.00, 114.16, 58.58, 55.19. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{19}\text{O}_2$ : 303.1380, found: 303.1382.

**2-(4-(methylthio)phenyl)-1,2-diphenylethan-1-one 2f:**



39 mg, yield: 61%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.36).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 8.05 – 8.00 (m, 2H), 7.56 – 7.52 (m, 1H), 7.46 – 7.42 (m, 2H), 7.38 – 7.33 (m, 2H), 7.32 – 7.28 (m, 3H), 7.24 (s, 4H), 6.03 (s, 1H), 2.48 (s, 3H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 198.06, 139.00, 137.34, 136.76, 135.93, 133.03, 129.57, 129.02, 128.90, 128.72, 128.60, 127.15, 126.88, 58.84, 15.77. HRMS (ESI) ( $[\text{M} + \text{Na}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{18}\text{OSNa}$ : 341.0971, found: 341.0969.

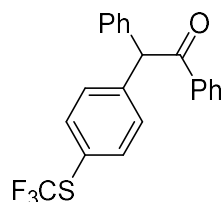
**1,2-diphenyl-2-(4-(trifluoromethoxy)phenyl)ethan-1-one 2g:**



63 mg, yield: 89%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,

$R_f = 0.32$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.08 - 8.00$  (m, 2H), 7.57 – 7.52 (m, 1H), 7.46 – 7.42 (m, 2H), 7.39 – 7.27 (m, 7H), 7.19 (d,  $J = 8.0$  Hz, 2H), 6.09 (s, 1H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.75, 148.26$  (q,  $J = 1.8$  Hz), 138.52, 137.89, 136.56, 133.22, 130.54, 128.97, 128.94, 128.90, 128.67, 127.42, 120.93, 120.45 (q,  $J = 257.1$  Hz), 58.56.  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*)  $\delta = -57.76$ . HRMS (EI) ( $[\text{M}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{15}\text{F}_3\text{O}_2$ : 356.1019, found: 356.1025.

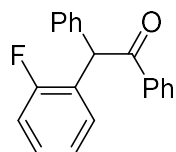
#### 1,2-diphenyl-2-(4-((trifluoromethyl)thio)phenyl)ethan-1-one 2h:



60 mg, yield: 81%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,

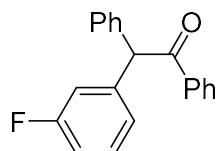
$R_f = 0.3$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.05 - 7.98$  (m, 2H), 7.61 (d,  $J = 8.2$  Hz, 2H), 7.56 – 7.52 (m, 1H), 7.45 – 7.41 (m, 2H), 7.39 – 7.27 (m, 7H), 6.08 (s, 1H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.48, 142.42, 138.15, 136.54, 136.39, 133.34, 130.35, 129.57$  (d,  $J = 308.2$  Hz), 129.09, 129.03, 128.96, 128.74, 127.58, 123.07 (d,  $J = 2.0$  Hz), 58.98.  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*)  $\delta = -42.57$ . HRMS (EI) ( $[\text{M}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{15}\text{F}_3\text{OS}$ : 372.0790, found: 372.0795.

#### 2-(2-fluorophenyl)-1,2-diphenylethan-1-one 2i:

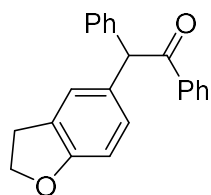


39 mg, yield: 41%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f = 0.39$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.07 - 8.02$  (m, 2H), 7.56 – 7.52 (m, 1H), 7.46 – 7.28 (m, 8H), 7.14 – 7.07 (m, 3H), 6.35 (s, 1H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.27, 160.16$  (d,  $J = 245.8$  Hz), 136.78 (d,  $J = 73.5$  Hz), 133.07, 130.62 (d,  $J = 3.5$  Hz), 129.39, 128.93, 128.88, 128.80, 128.60, 127.45, 126.80 (d,  $J = 14.9$  Hz), 124.14 (d,  $J = 3.5$  Hz), 115.21 (d,  $J = 22.2$  Hz), 51.96 (d,  $J = 2.5$  Hz).  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*)  $\delta = -116.82$ . HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{16}\text{FO}$ : 291.1180, found: 291.1181.

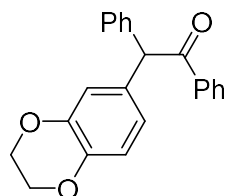
#### 2-(3-fluorophenyl)-1,2-diphenylethan-1-one 2j:



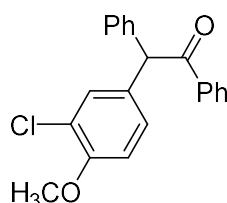
24 mg, yield: 41%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f = 0.28$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.00$  (d,  $J = 7.4$  Hz, 2H), 7.54 (t,  $J = 7.4$  Hz, 1H), 7.43 (t,  $J = 7.8$  Hz, 2H), 7.36 – 7.27 (m, 6H), 7.06 (d,  $J = 7.7$  Hz, 1H), 7.02 – 6.93 (m, 2H), 6.03 (s, 1H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.59, 162.93$  (d,  $J = 246.2$  Hz), 141.60 (d,  $J = 7.3$  Hz), 138.37, 136.63, 133.20, 129.99 (d,  $J = 8.3$  Hz), 129.03, 128.92, 128.67, 127.42, 124.79 (d,  $J = 2.9$  Hz), 116.29 (d,  $J = 22.1$  Hz), 114.10 (d,  $J = 21.2$  Hz), 58.95.  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*)  $\delta = -112.67$ . HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{16}\text{FO}$ : 291.1180, found: 291.1182.

**2-(3-fluorophenyl)-1,2-diphenylethan-1-one 2k:**

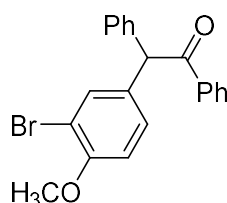
48 mg, yield: 76%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f = 0.29$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.06 - 8.00$  (m, 2H), 7.56 – 7.51 (m, 1H), 7.46 – 7.41 (m, 2H), 7.37 – 7.32 (m, 2H), 7.30 – 7.26 (m, 3H), 7.14 (s, 1H), 7.03 (dd,  $J = 8.2, 1.7$  Hz, 1H), 6.75 (d,  $J = 8.2$  Hz, 1H), 6.00 (s, 1H), 4.56 (t,  $J = 8.7$  Hz, 2H), 3.19 (t,  $J = 8.7$  Hz, 2H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 198.54, 159.26, 139.62, 136.87, 132.87, 130.91, 128.96, 128.86, 128.81, 128.59, 128.51, 127.56, 126.93, 125.57, 109.25, 71.25, 58.73, 29.65$ . HRMS (ESI) ( $[\text{M} + \text{Na}]^+$ ) Calcd For  $\text{C}_{22}\text{H}_{18}\text{O}_2\text{Na}$ : 337.1199, found: 337.1197.

**2-(2,3-dihydrobenzo[b][1,4]dioxin-6-yl)-1,2-diphenylethan-1-one 2l:**

28 mg, yield: 42%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f = 0.33$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.05 - 8.00$  (m, 2H), 7.55 – 7.51 (m, 1H), 7.43 (t,  $J = 7.6$  Hz, 2H), 7.36 – 7.26 (m, 5H), 6.86 – 6.76 (m, 3H), 5.95 (s, 1H), 4.24 (s, 4H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 198.14, 143.58, 142.74, 139.18, 136.89, 132.92, 132.26, 129.03, 128.91, 128.66, 128.56, 127.06, 122.04, 118.01, 117.40, 64.29, 58.66$ . HRMS (ESI) ( $[\text{M} + \text{Na}]^+$ ) Calcd For  $\text{C}_{22}\text{H}_{18}\text{O}_3\text{Na}$ : 353.1148, found: 353.1138.

**2-(3-chloro-4-methoxyphenyl)-1,2-diphenylethan-1-one 2m:**

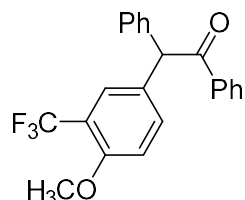
55 mg, yield: 82%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f = 0.36$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.03$  (d,  $J = 7.4$  Hz, 2H), 7.55 (t,  $J = 7.4$  Hz, 1H), 7.44 (t,  $J = 7.7$  Hz, 2H), 7.38 – 7.28 (m, 6H), 7.16 (dd,  $J = 8.5, 2.2$  Hz, 1H), 6.90 (d,  $J = 8.5$  Hz, 1H), 6.00 (s, 1H), 3.88 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.84, 154.08, 138.73, 136.58, 133.11, 132.24, 130.85, 128.89, 128.87, 128.84, 128.62, 128.33, 127.27, 122.57, 112.11, 58.12, 56.08$ . HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{18}\text{ClO}_2$ : 337.0990, found: 337.0994.

**2-(3-bromo-4-methoxyphenyl)-1,2-diphenylethan-1-one 2n:**

64 mg, yield: 84%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,

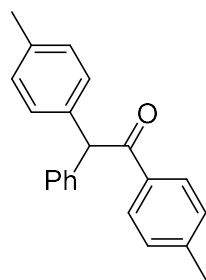
$R_f = 0.37$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.04 - 8.01$  (m, 2H), 7.58 – 7.50 (m, 2H), 7.47 – 7.41 (m, 2H), 7.39 – 7.33 (m, 2H), 7.31 – 7.28 (m, 3H), 7.21 (dd,  $J = 8.5, 2.2$  Hz, 1H), 6.87 (d,  $J = 8.5$  Hz, 1H), 5.99 (s, 1H), 3.88 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.83, 154.96, 138.75, 136.57, 133.84, 133.12, 132.68, 129.10, 128.89, 128.87, 128.84, 128.62, 127.27, 111.93, 111.82, 58.04, 56.18$ . HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{18}\text{BrO}_2$ : 381.0485, found: 381.0487.

#### 2-(4-methoxy-3-(trifluoromethyl)phenyl)-1,2-diphenylethan-1-one 2o:



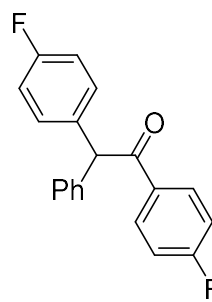
v/v,  $R_f = 0.34$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.05$  (d,  $J = 7.8$  Hz, 2H), 7.58 – 7.54 (m, 2H), 7.46 (t,  $J = 7.7$  Hz, 3H), 7.41 – 7.35 (m, 2H), 7.33 – 7.29 (m, 3H), 6.99 (d,  $J = 8.6$  Hz, 1H), 6.07 (s, 1H), 3.89 (s, 3H).  $^{13}\text{C NMR}$  (100 MHz, Chloroform-*d*)  $\delta = 197.83, 156.55, 138.65, 136.47, 133.91, 133.21, 130.96, 128.98, 128.89, 128.82, 128.66, 127.76$  (q,  $J = 5.2$  Hz), 127.38, 123.52 (q,  $J = 272.5$  Hz), 118.70 (q,  $J = 30.8$  Hz), 112.21, 58.22, 55.91.  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*)  $\delta = -62.25$ . HRMS (ESI) ( $[\text{M} + \text{Na}]^+$ ) Calcd For  $\text{C}_{22}\text{H}_{17}\text{F}_3\text{O}_2\text{Na}$ : 393.1073, found: 393.1072.

#### 2-phenyl-1,2-di-p-tolylethan-1-one 2p:



$R_f = 0.37$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 7.95$  (d,  $J = 8.3$  Hz, 2H), 7.36 – 7.15 (m, 11H), 6.02 (s, 1H), 2.40 (s, 3H), 2.34 (s, 3H).  $^{13}\text{C NMR}$  (101 MHz, Chloroform-*d*)  $\delta = 197.91, 143.74, 139.51, 136.67, 136.23, 134.39, 129.39, 129.25, 129.09, 129.06, 128.97, 128.59, 126.94, 58.92, 21.57, 21.01$ . HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{22}\text{H}_{21}\text{O}_2$ : 301.1587, found: 301.1584.

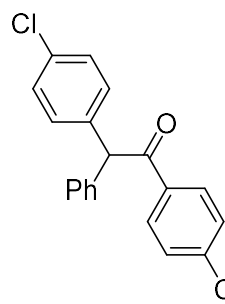
#### 1,2-bis(4-fluorophenyl)-2-phenylethan-1-one 2q:



$R_f = 0.34$ ).  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta = 8.08 - 8.03$  (m, 2H), 7.40 – 7.34 (m, 2H), 7.32 – 7.23 (m, 5H), 7.15 – 7.08 (m, 2H), 7.07 – 7.02 (m, 2H), 6.00 (s, 1H).  $^{13}\text{C NMR}$  (100 MHz,

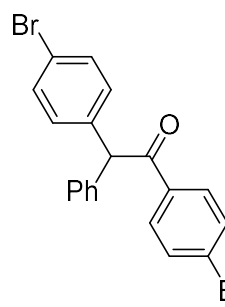
Chloroform-*d*)  $\delta$  = 196.44, 165.63 (d,  $J$  = 255.6 Hz), 161.96 (d,  $J$  = 246.2 Hz), 138.70, 134.69 (d,  $J$  = 3.3 Hz), 132.97 (d,  $J$  = 3.0 Hz), 131.58 (d,  $J$  = 9.3 Hz), 130.66 (d,  $J$  = 8.1 Hz), 128.92, 128.90, 127.38, 115.65 (d,  $J$  = 43.8 Hz), 115.65, 58.56.  $^{19}\text{F}$  NMR (376 MHz, Chloroform-*d*)  $\delta$  = -104.70, -115.39. HRMS (EI) ( $[\text{M}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{14}\text{F}_2\text{O}$ : 308.1007, found: 308.1010.

#### 1,2-bis(4-chlorophenyl)-2-phenylethan-1-one 2r:



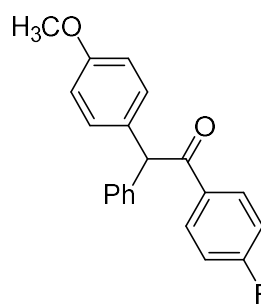
38 mg, yield: 56%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.46).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 7.95 (d,  $J$  = 8.6 Hz, 2H), 7.43 – 7.26 (m, 9H), 7.21 (d,  $J$  = 8.5 Hz, 2H), 5.97 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 196.57, 139.69, 138.25, 137.32, 134.80, 133.24, 130.45, 130.32, 128.99, 128.90, 128.84, 127.50, 58.77. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{15}\text{Cl}_2\text{O}$ : 341.0494, found: 341.0498.

#### 1,2-bis(4-bromophenyl)-2-phenylethan-1-one 2s:



34 mg, yield: 40%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.27).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  = 7.90 – 7.83 (m, 2H), 7.61 – 7.55 (m, 2H), 7.51 – 7.44 (m, 2H), 7.39 – 7.33 (m, 2H), 7.32 – 7.25 (m, 3H), 7.17 – 7.12 (m, 2H), 5.94 (s, 1H).  $^{13}\text{C}$  NMR (100 MHz, Chloroform-*d*)  $\delta$  = 196.66, 138.12, 137.80, 135.18, 131.99, 131.79, 130.80, 130.41, 129.00, 128.89, 128.46, 127.52, 121.40, 58.82. HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{20}\text{H}_{15}\text{Br}_2\text{O}$ : 428.9484, found: 428.9494.

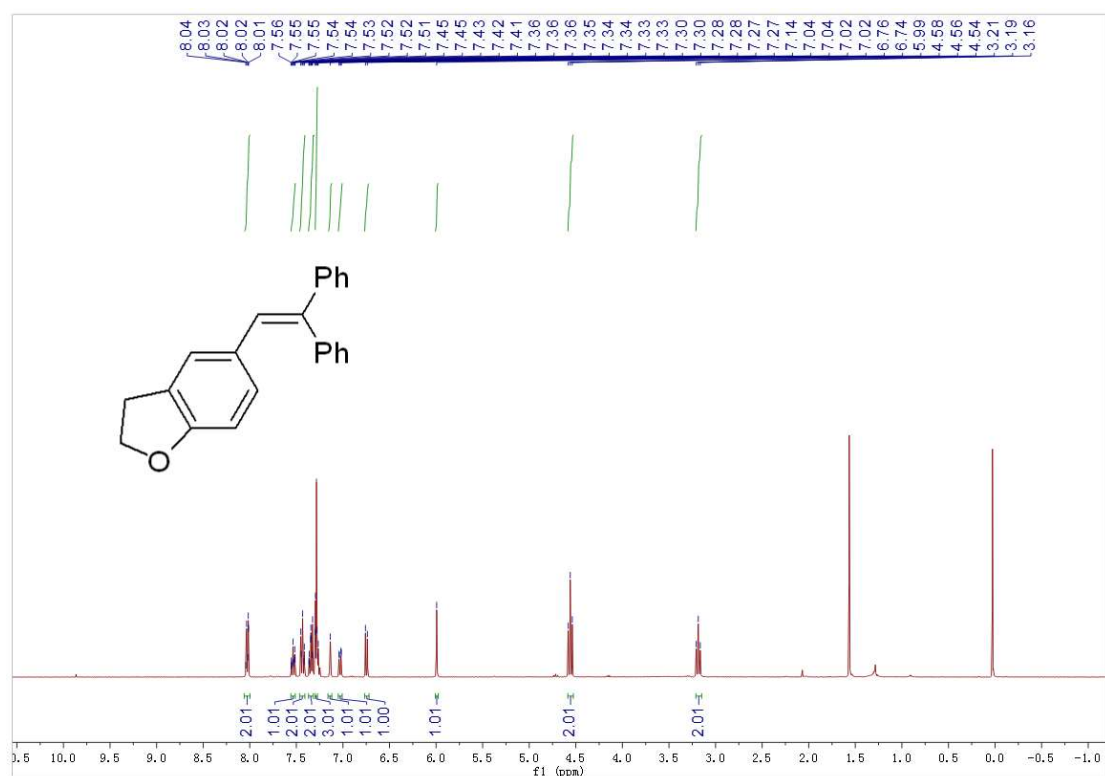
#### 1-(4-fluorophenyl)-2-(4-methoxyphenyl)-2-phenylethan-1-one 2t:



41 mg, yield: 64%, chromatography on silica gel (n-Hexane:EtOAc = 98:2, v/v,  $R_f$  = 0.46).  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*)  $\delta$  8.01 (m,  $J$  = 8.4, 5.3, 2.5 Hz, 2H), 7.31 (d,  $J$

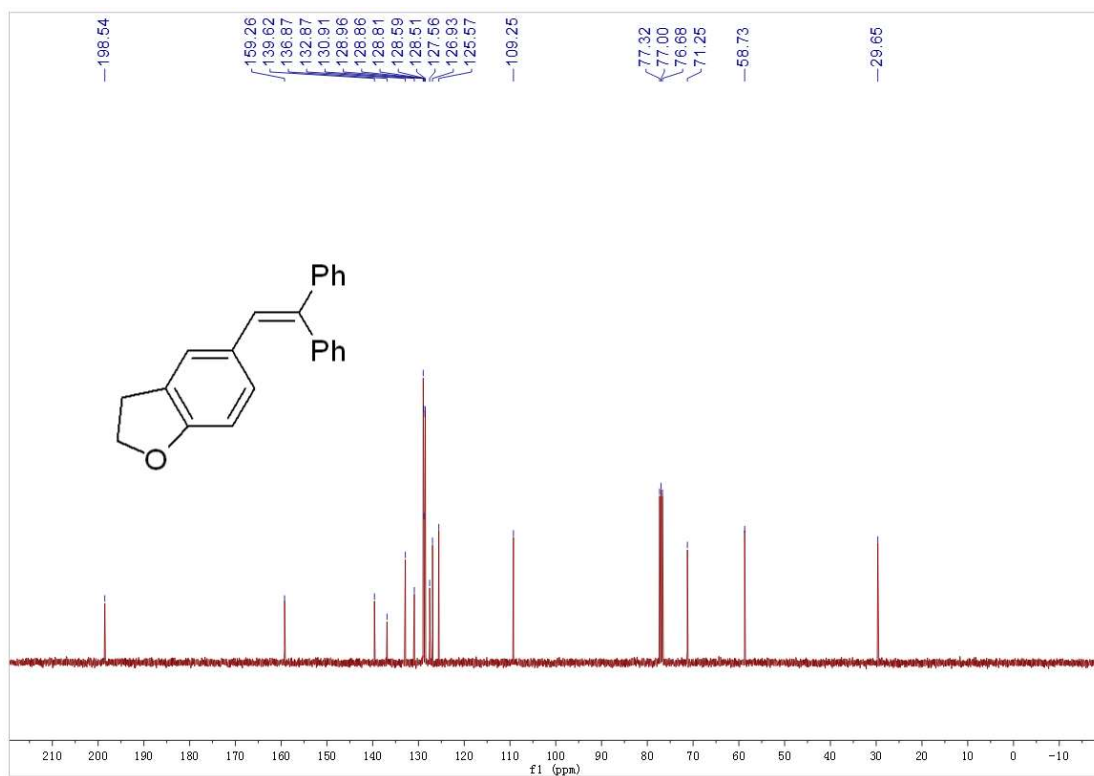
= 7.1 Hz, 2H), 7.26 – 7.22 (m, 3H), 7.17 (d,  $J = 8.7$  Hz, 2H), 7.07 (t,  $J = 8.6$  Hz, 2H), 6.86 (d,  $J = 8.8$  Hz, 2H), 5.92 (s, 1H), 3.78 (s, 3H).  $^{13}\text{C}$  NMR (101 MHz, Chloroform- $d$ )  $\delta = 196.91, 165.14$  (d,  $J = 253.0$  Hz), 158.76, 139.27, 131.63 (d,  $J = 1.0$  Hz), 130.92, 130.14, 128.88 (d,  $J = 250$  Hz), 127.16, 115.72 (d,  $J = 21.0$  Hz), 114.23, 58.67, 55.25.  $^{19}\text{F}$  NMR (376 MHz, Chloroform- $d$ )  $\delta = -105.16$ . HRMS (ESI) ( $[\text{M} + \text{H}]^+$ ) Calcd For  $\text{C}_{21}\text{H}_{18}\text{FO}_2$ : 321.1285, found: 321.1287.

## 10. Copies of $^1\text{H}$ NMR, $^{13}\text{C}$ NMR and $^{19}\text{F}$ NMR Spectra

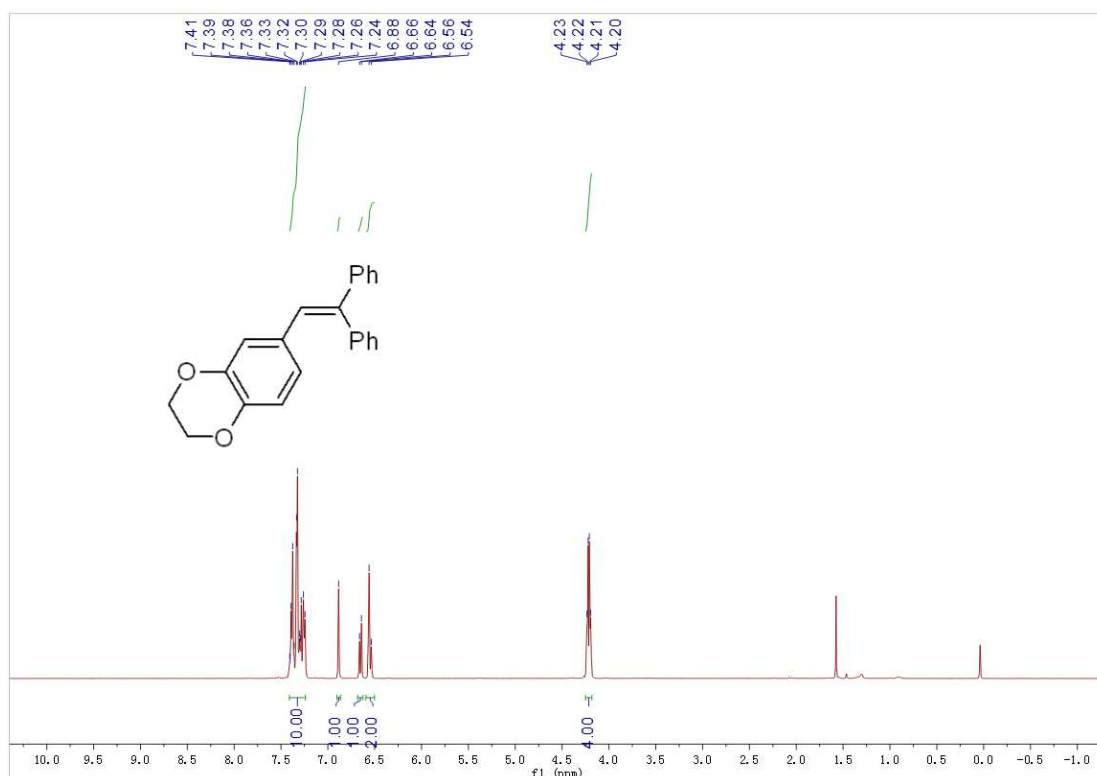


$^1\text{H}$  NMR Spectrum of Compound 1k

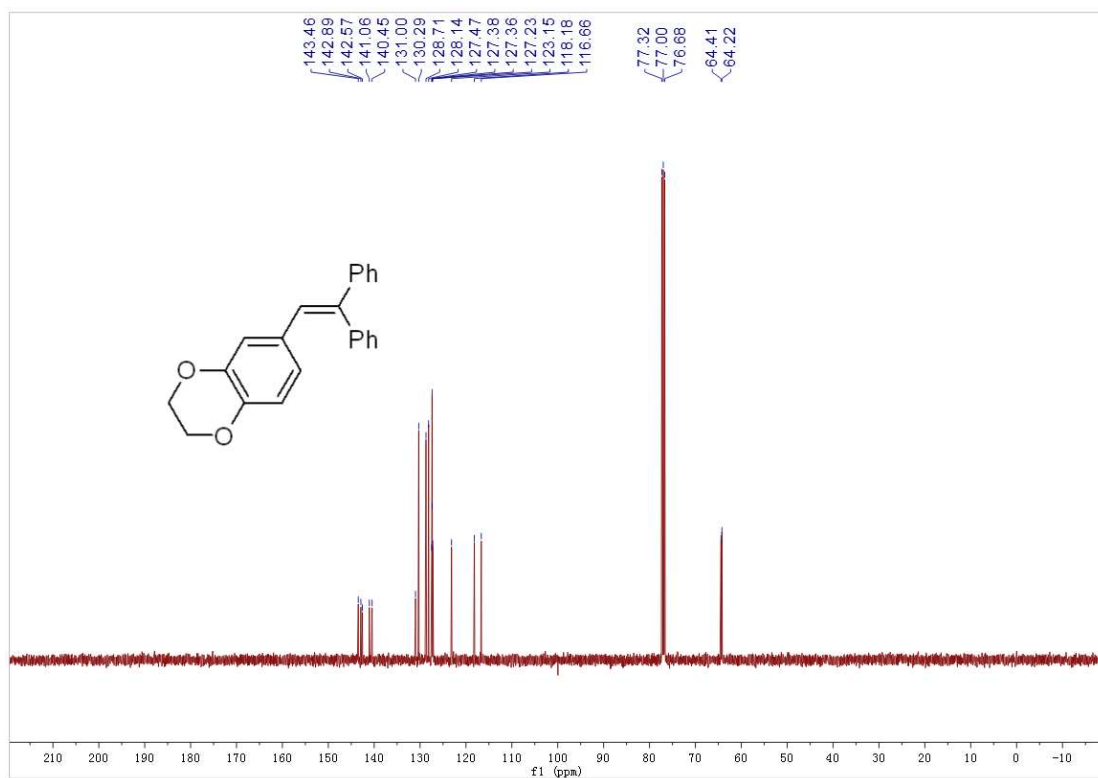




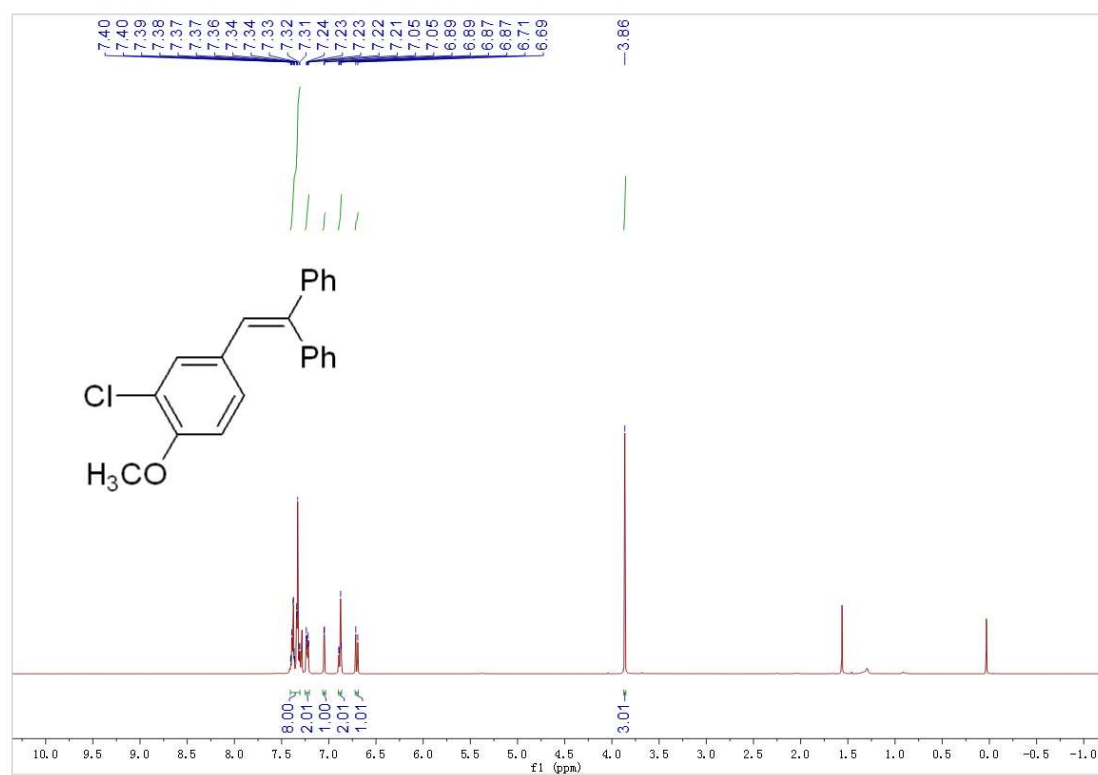
**<sup>13</sup>C NMR Spectrum of Compound 1k**



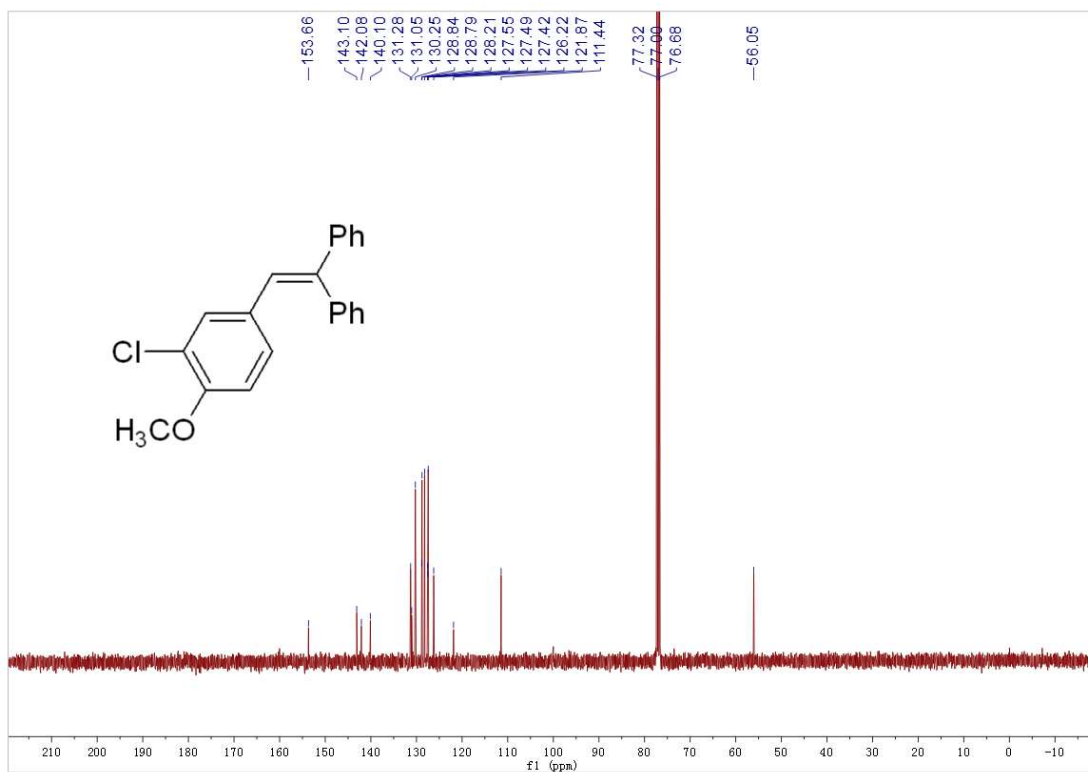
**<sup>1</sup>H NMR Spectrum of Compound 1l**



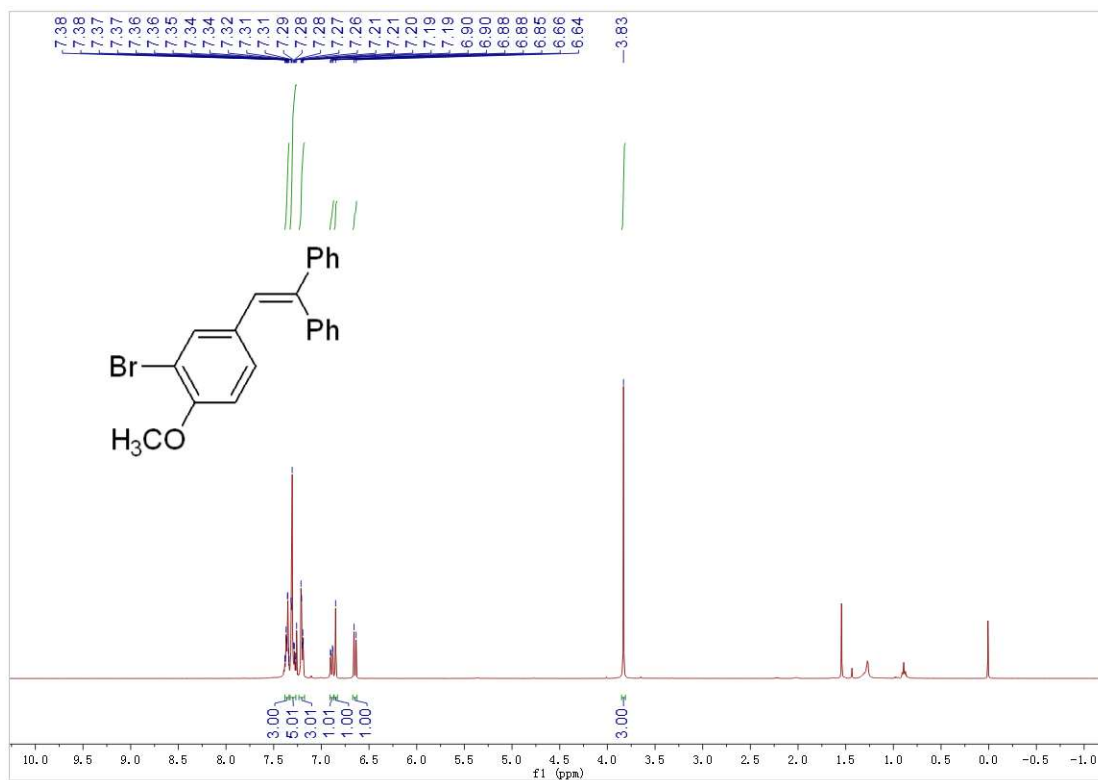
**<sup>13</sup>C NMR Spectrum of Compound 1l**



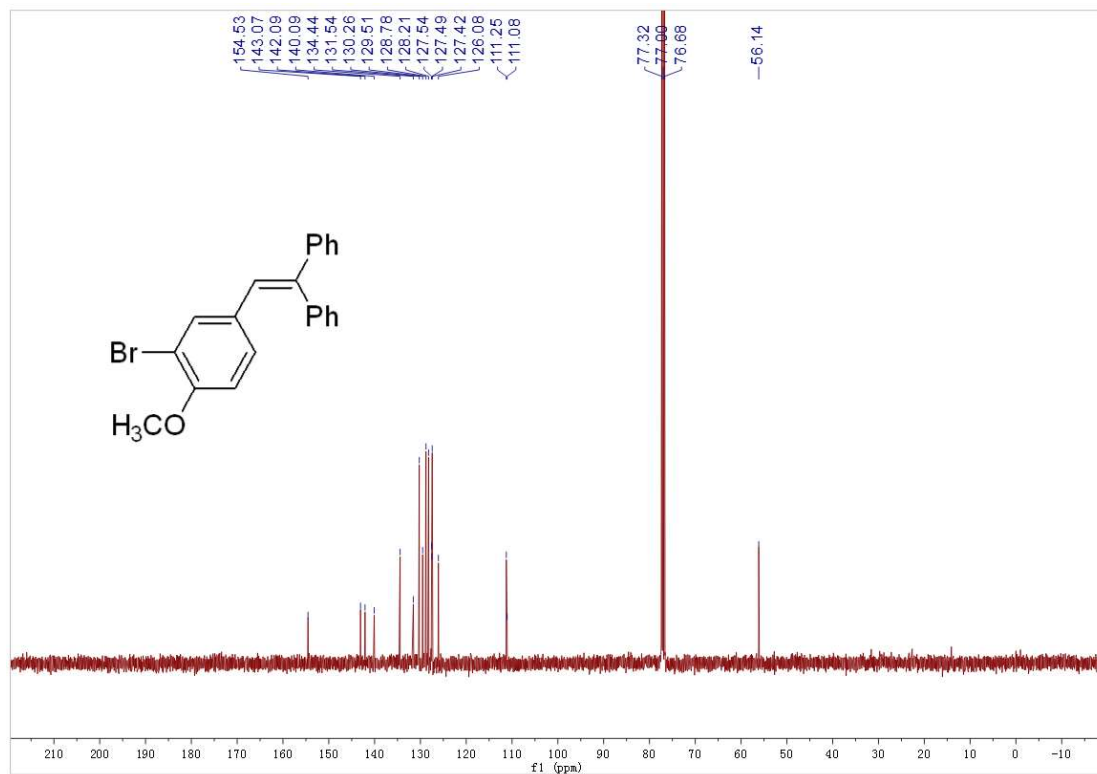
**<sup>1</sup>H NMR Spectrum of Compound 1m**



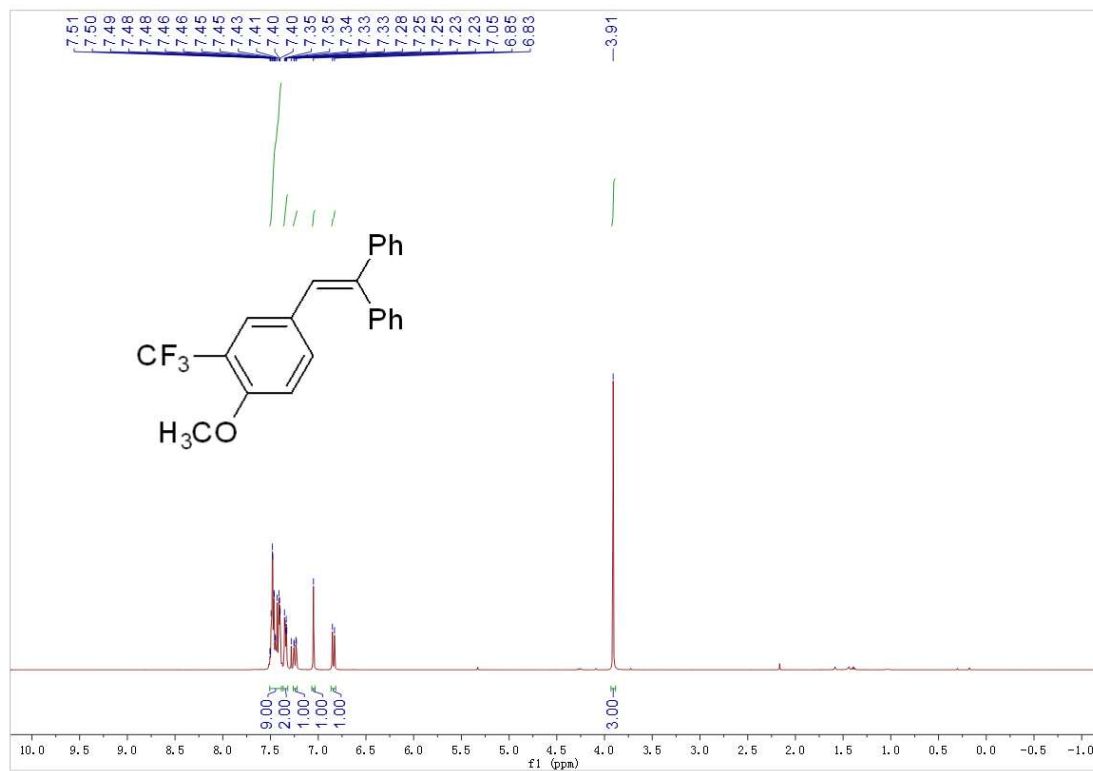
**<sup>13</sup>C NMR Spectrum of Compound 1m**



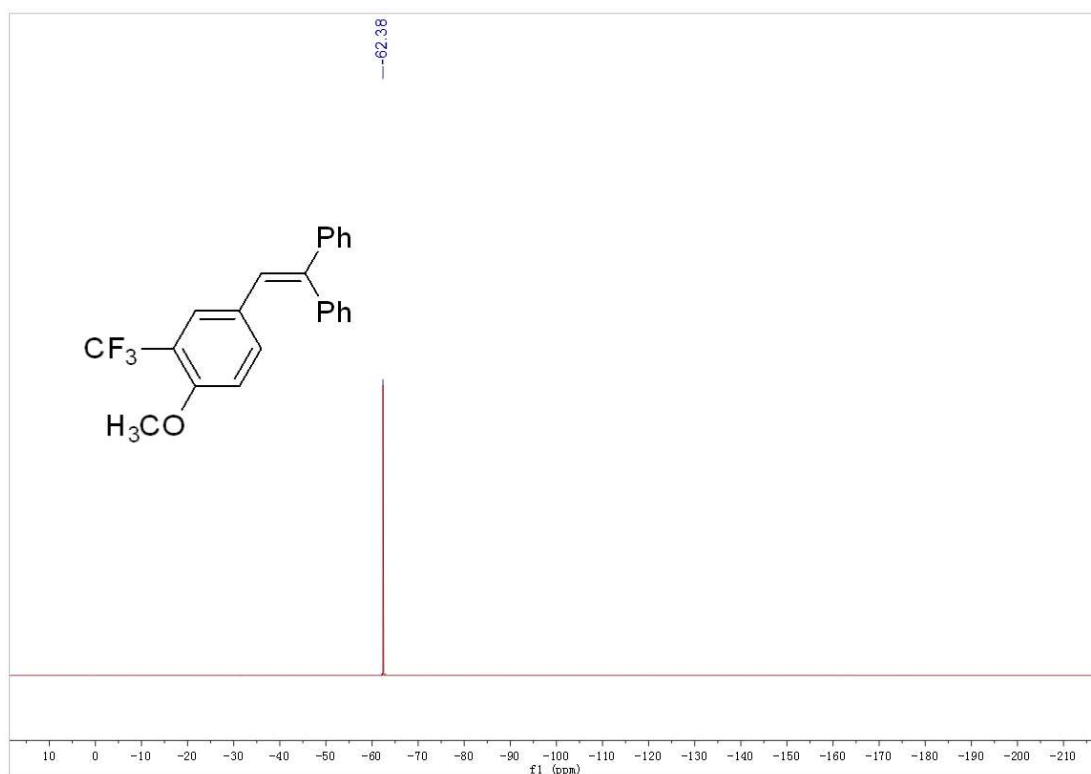
### <sup>13</sup>C NMR Spectrum of Compound 1n



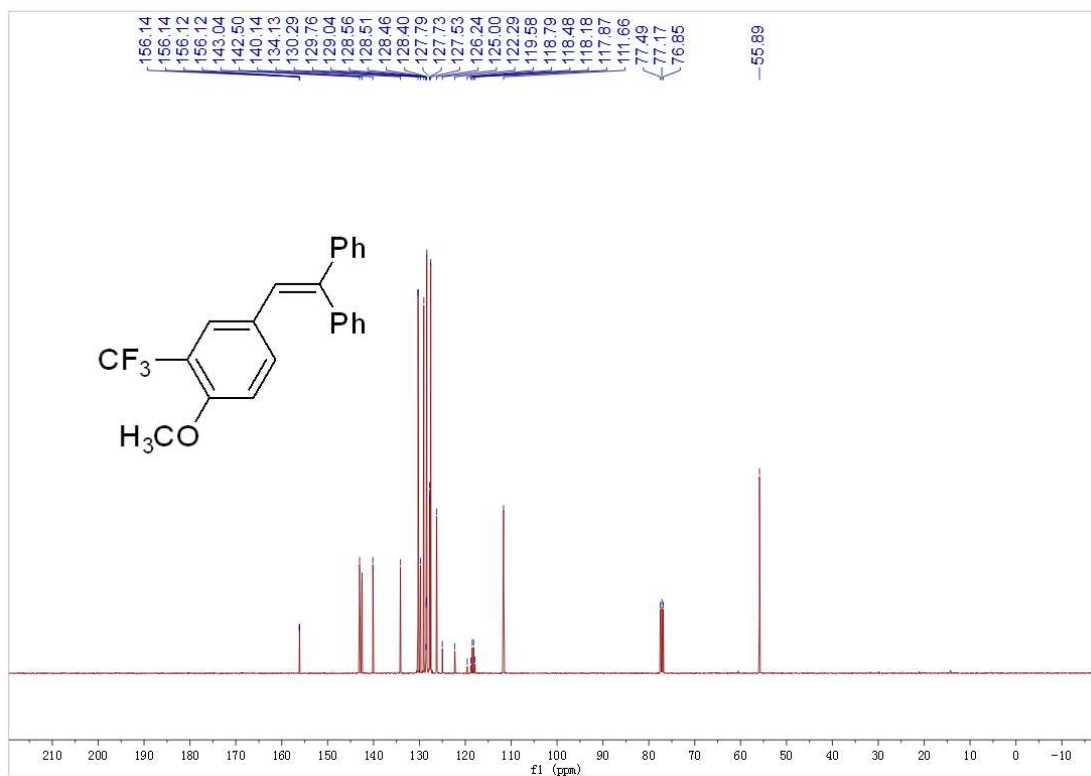
### <sup>13</sup>C NMR Spectrum of Compound 1n



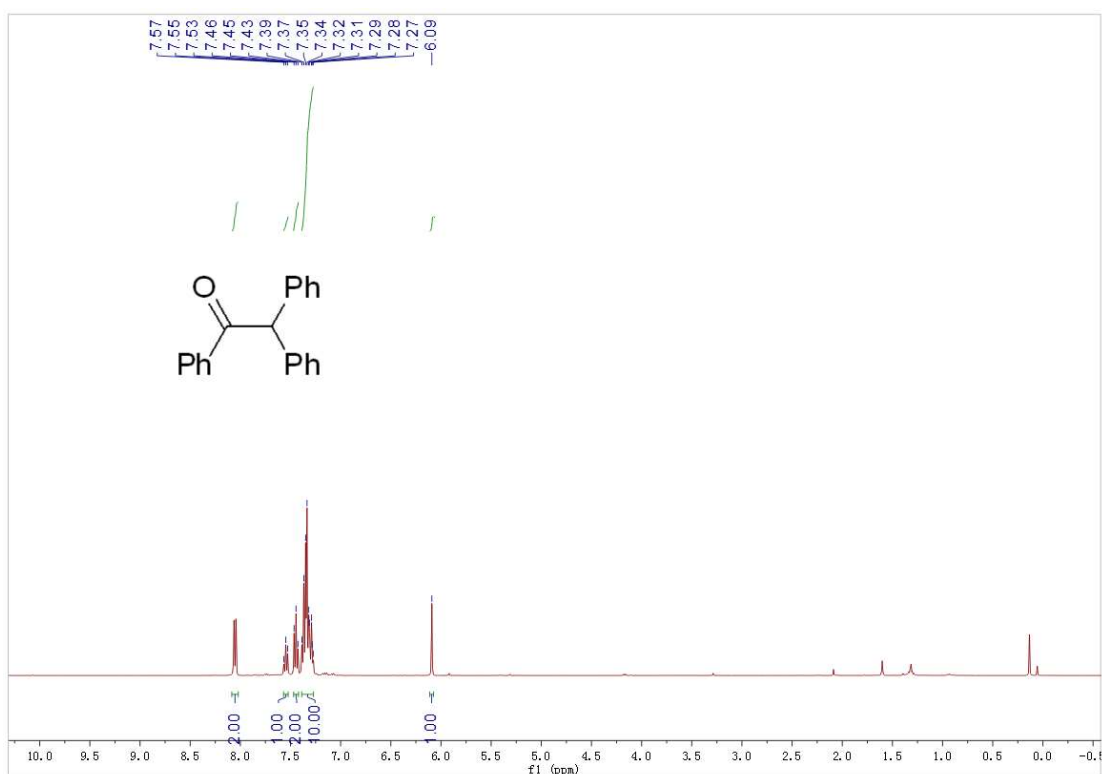
### <sup>1</sup>H NMR Spectrum of Compound 1o



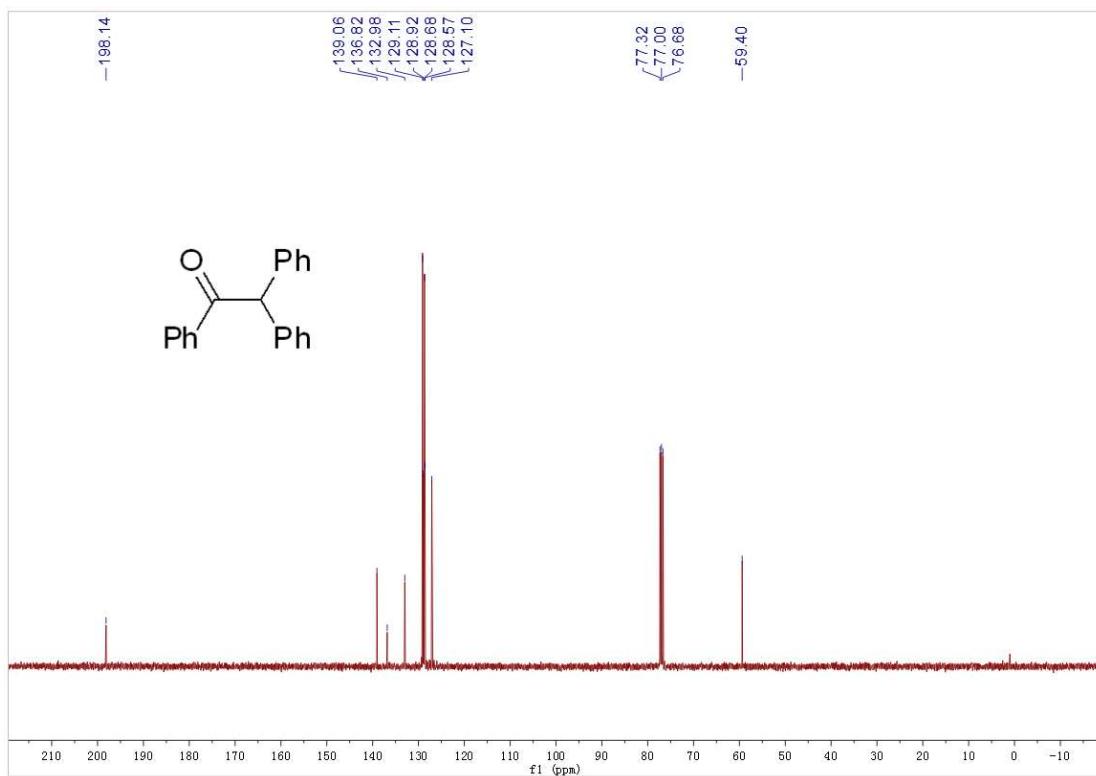
<sup>19</sup>F NMR Spectrum of Compound 1o



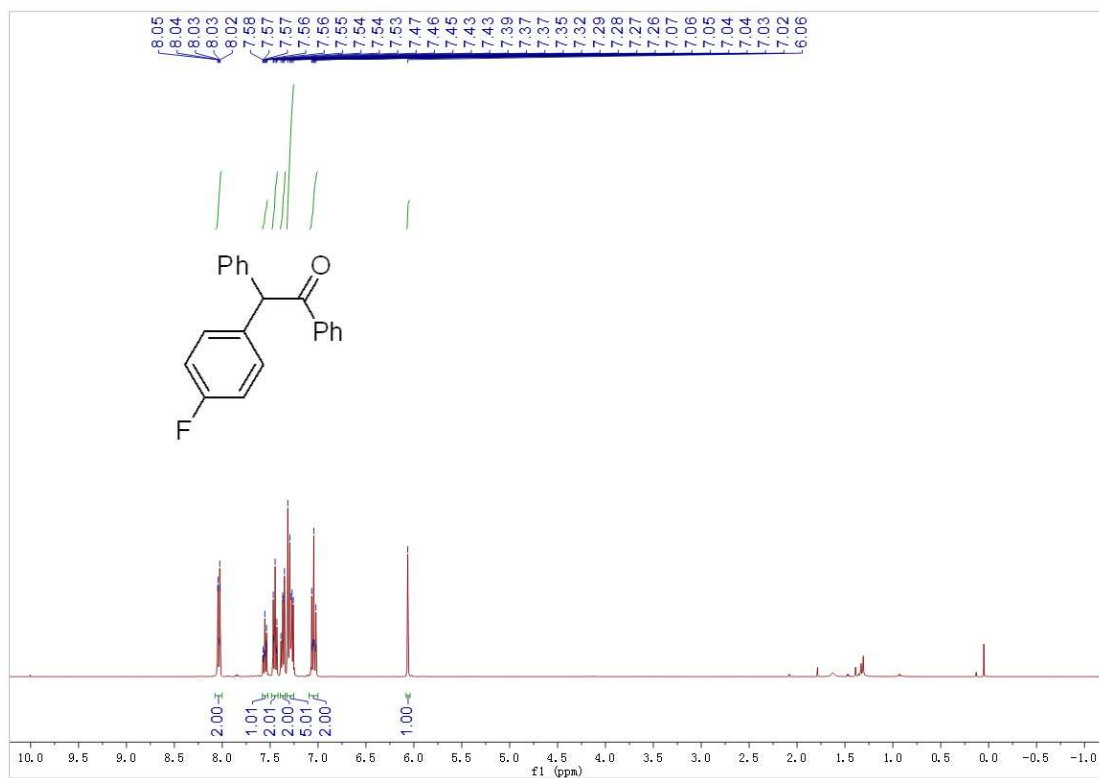
<sup>13</sup>C NMR Spectrum of Compound 1o



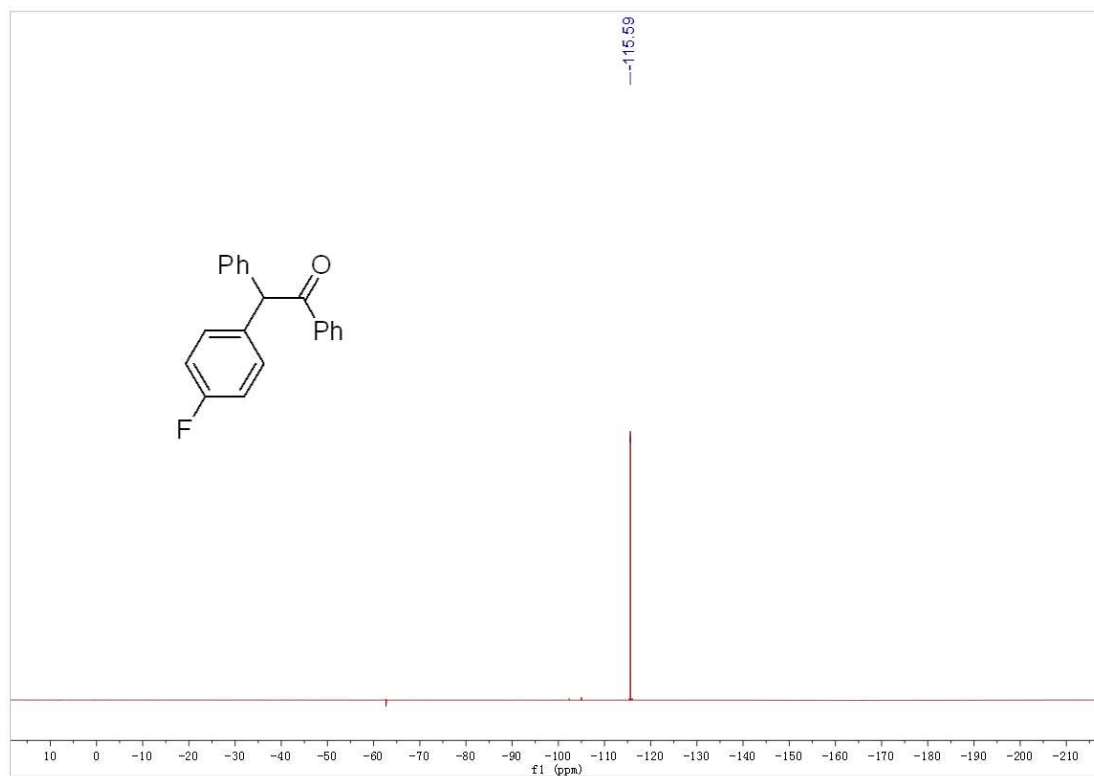
**<sup>1</sup>H NMR Spectrum of Compound 2a**



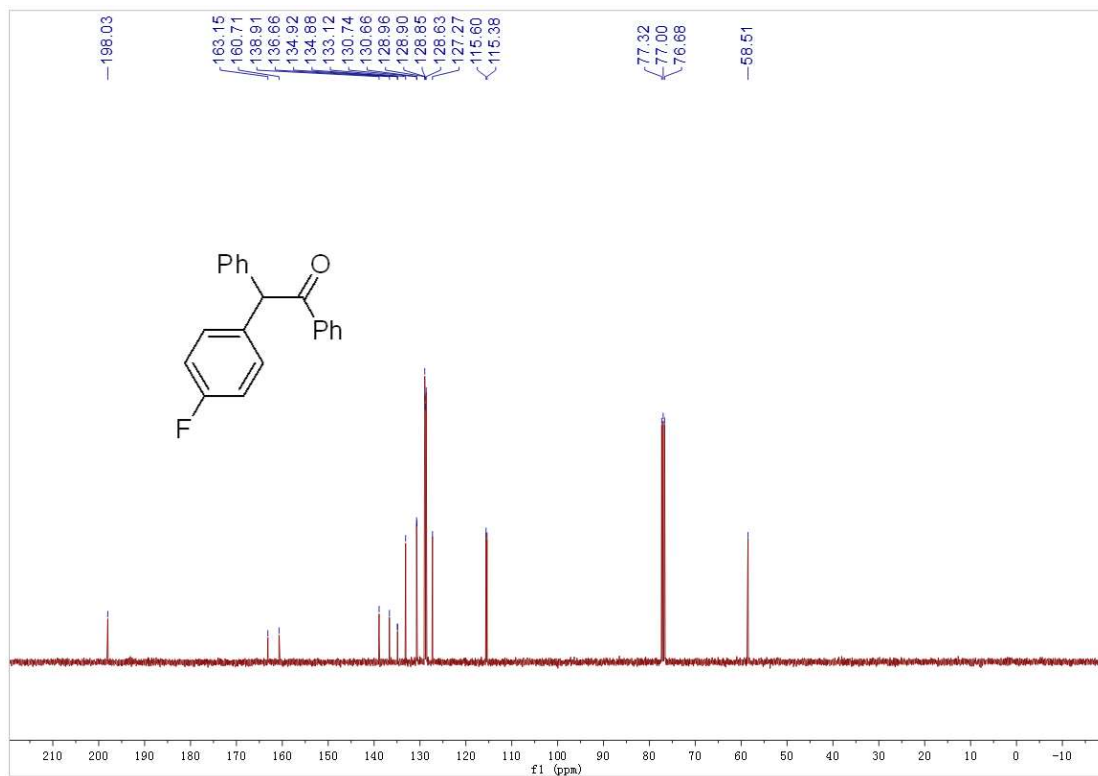
**<sup>13</sup>C NMR Spectrum of Compound 2a**



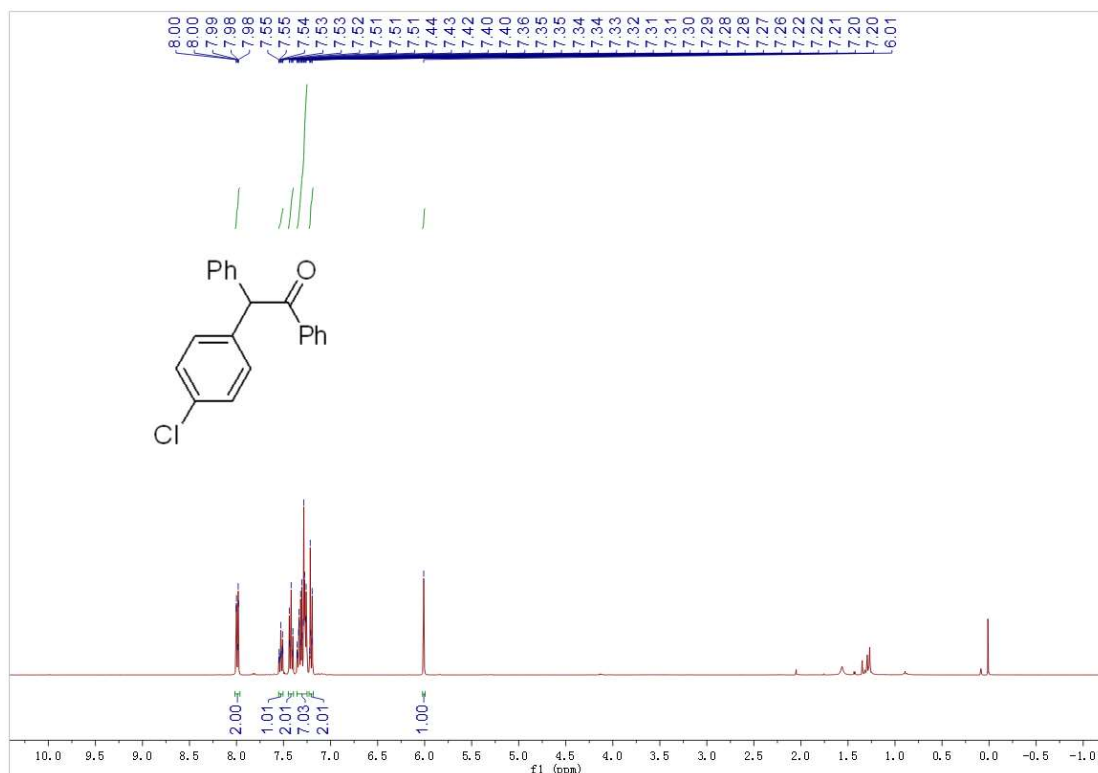
**<sup>1</sup>H NMR Spectrum of Compound 2b**



**<sup>19</sup>F NMR Spectrum of Compound 2b**

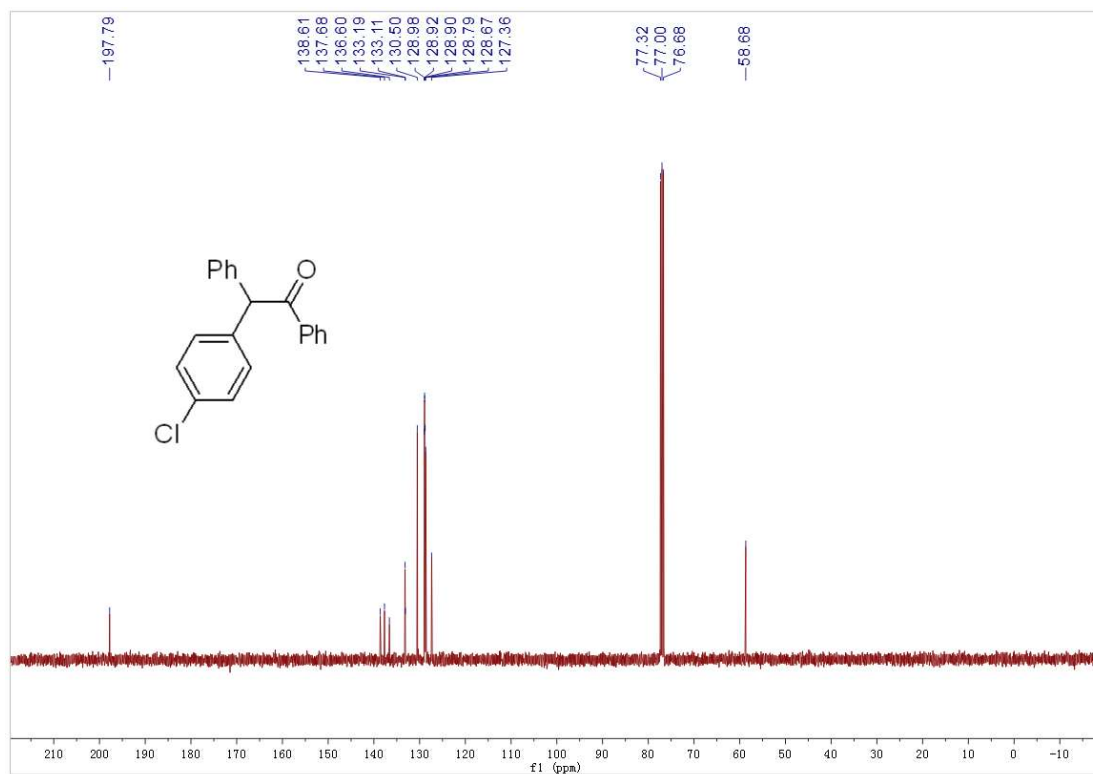


**<sup>13</sup>C NMR Spectrum of Compound 2b**

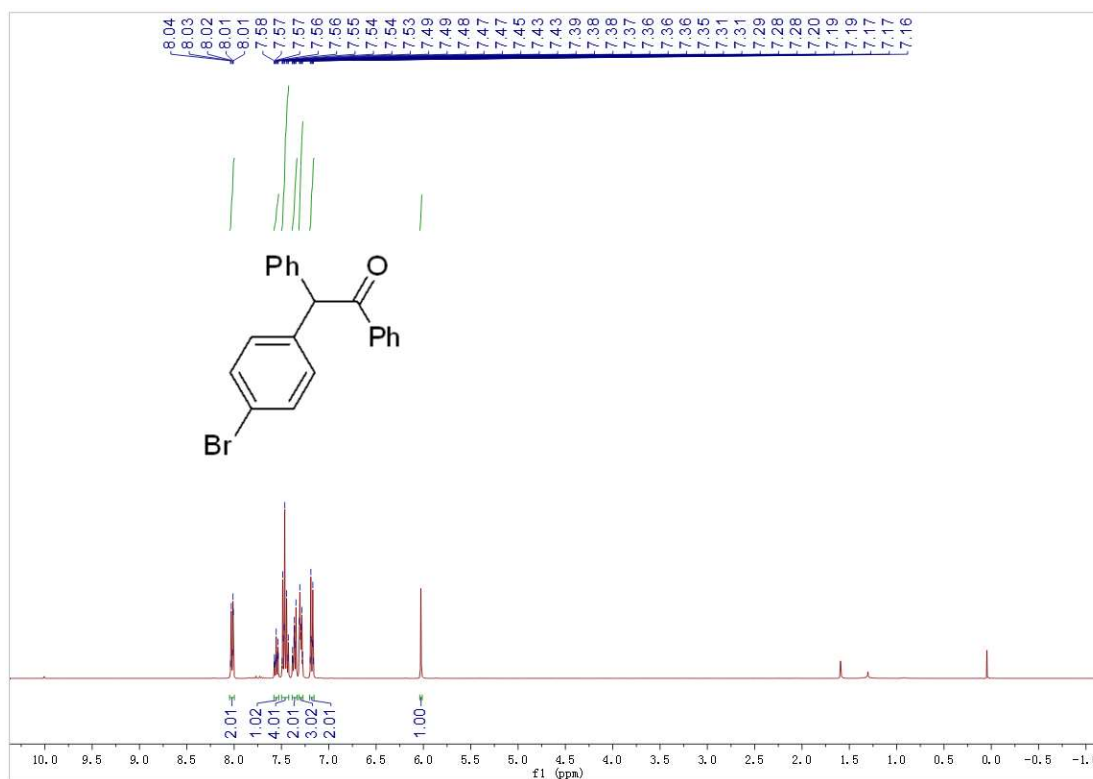


**<sup>1</sup>H NMR Spectrum of Compound 2c**

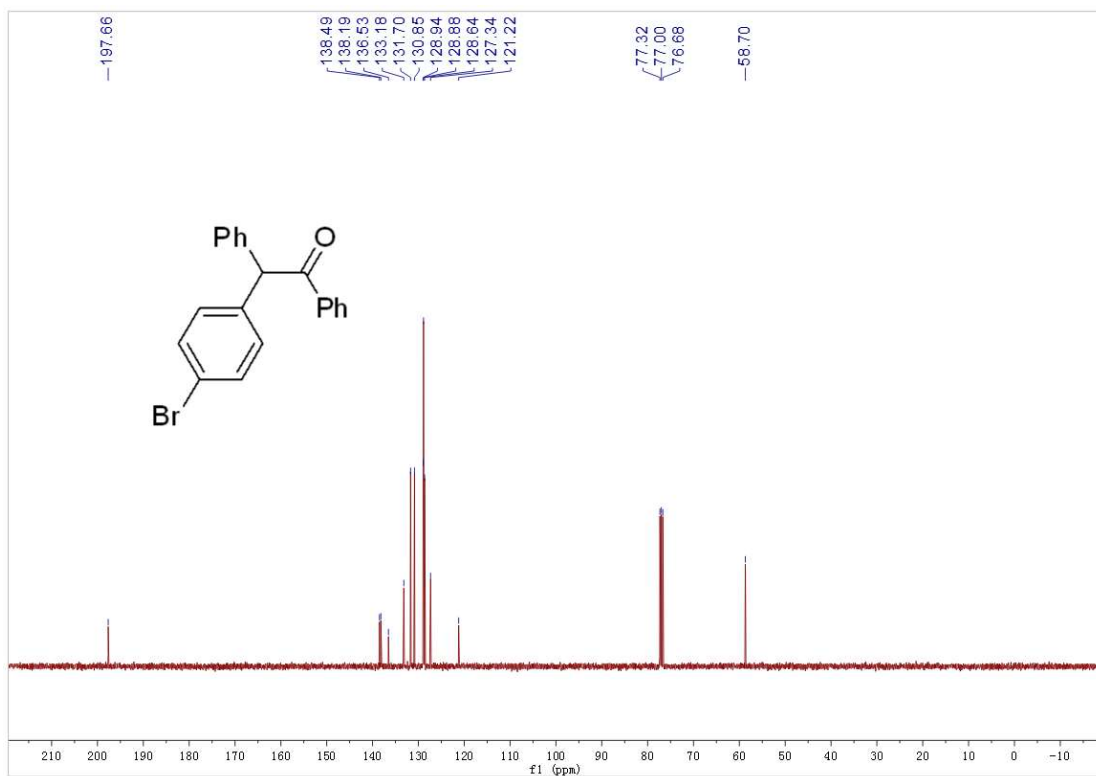




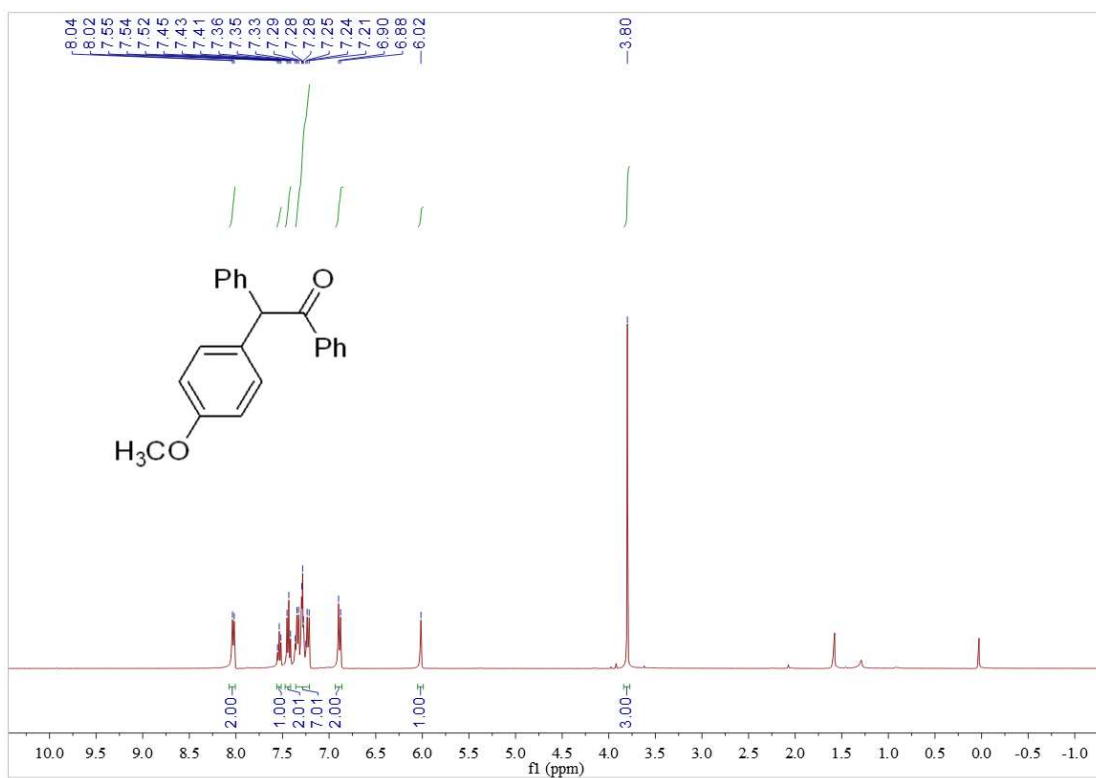
**<sup>13</sup>C NMR Spectrum of Compound 2c**



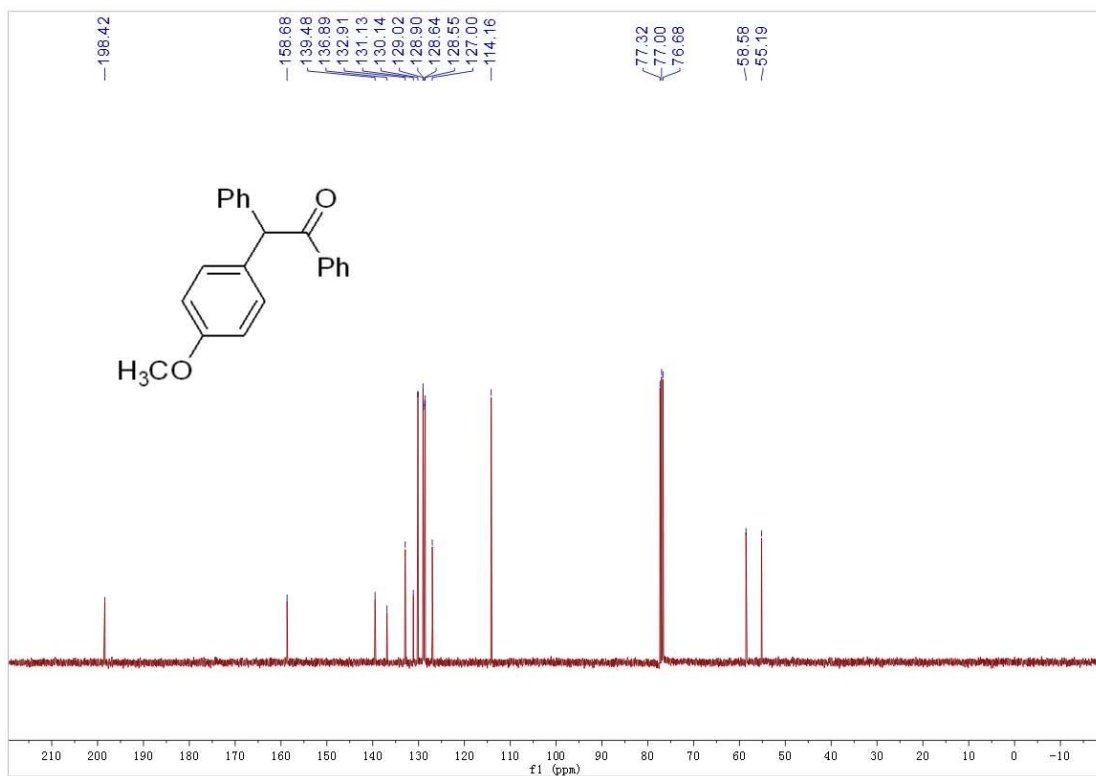
**<sup>1</sup>H NMR Spectrum of Compound 2d**



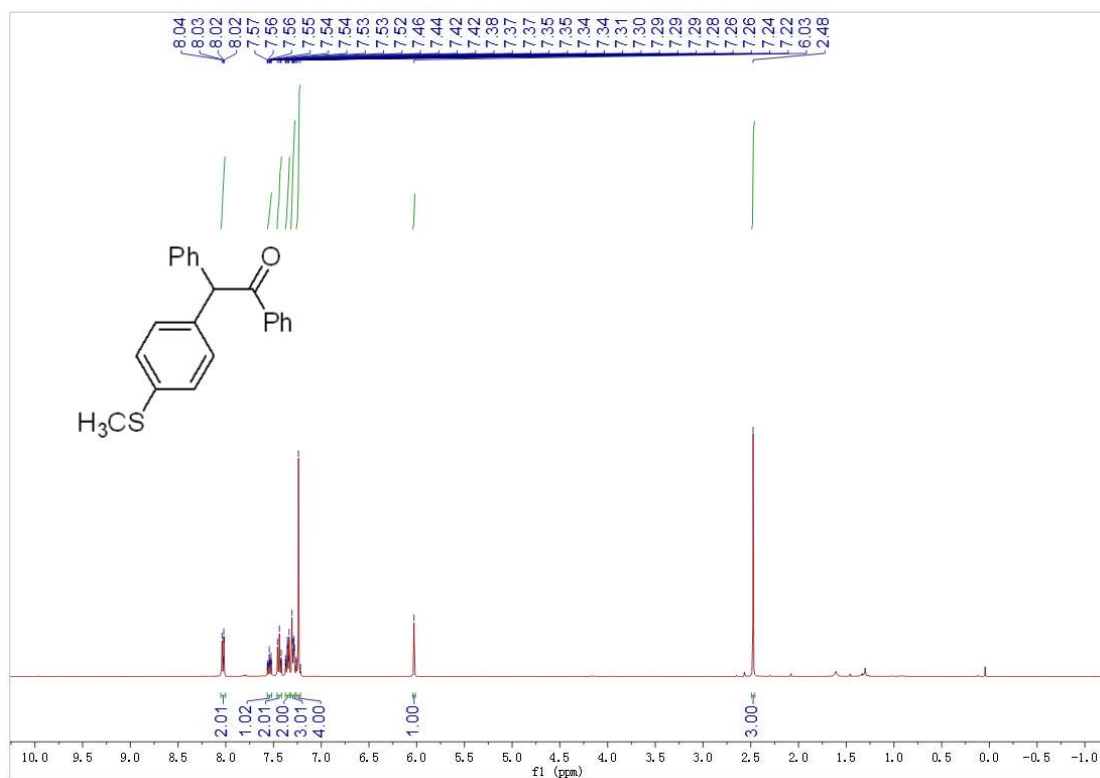
<sup>13</sup>C NMR Spectrum of Compound 2d



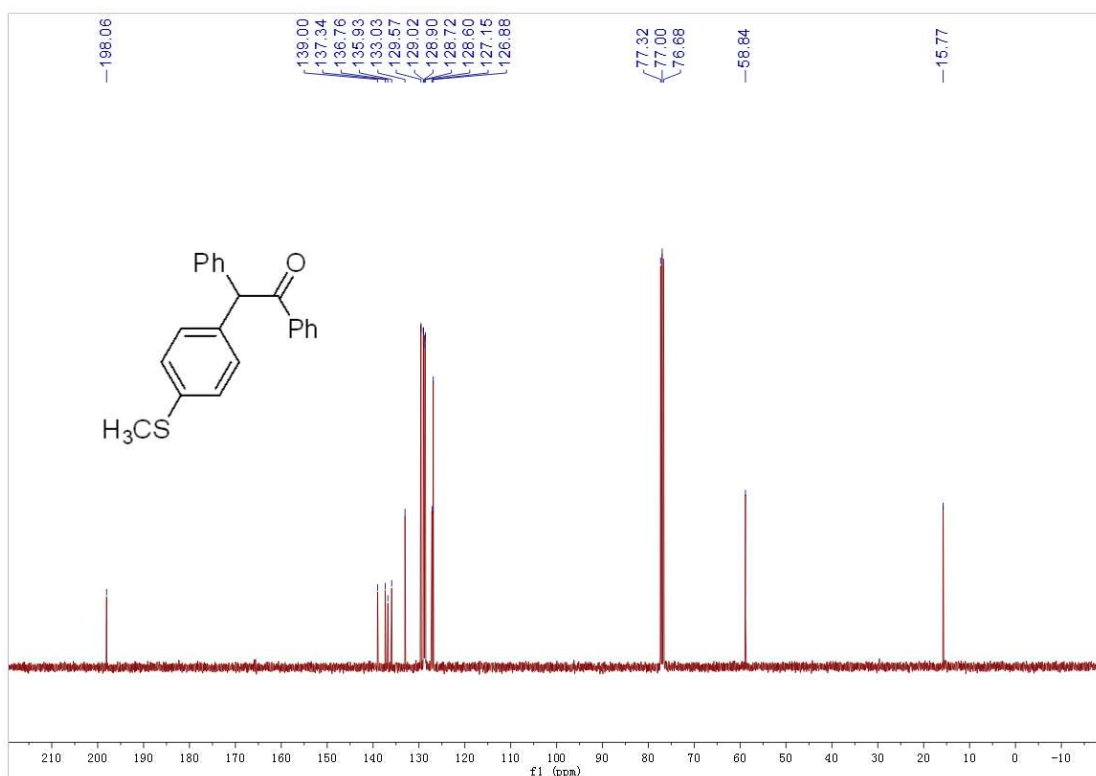
<sup>1</sup>H NMR Spectrum of Compound 2e



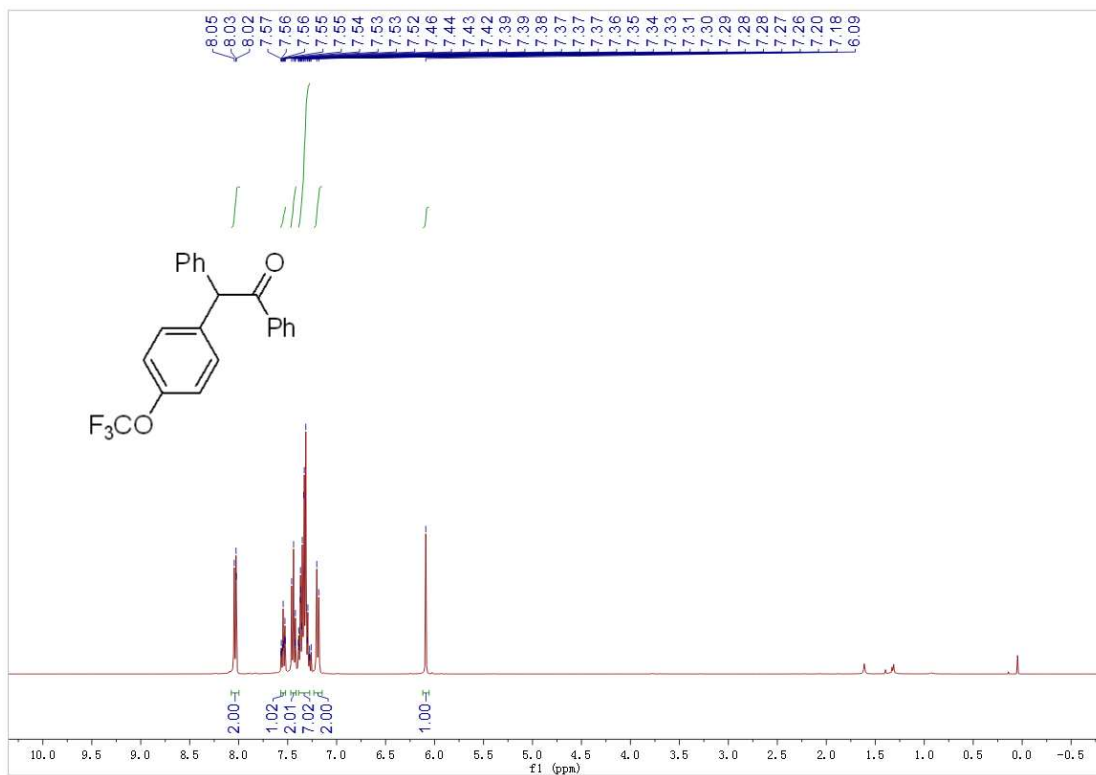
<sup>13</sup>C NMR Spectrum of Compound 2e



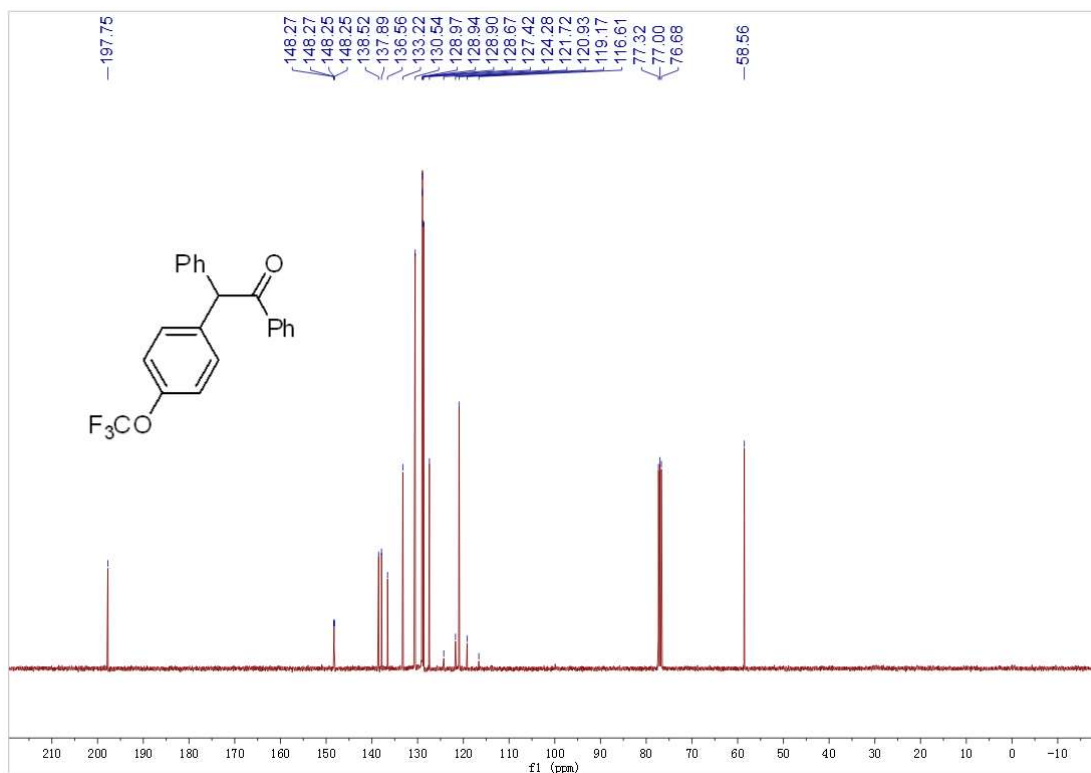
<sup>1</sup>H NMR Spectrum of Compound 2f



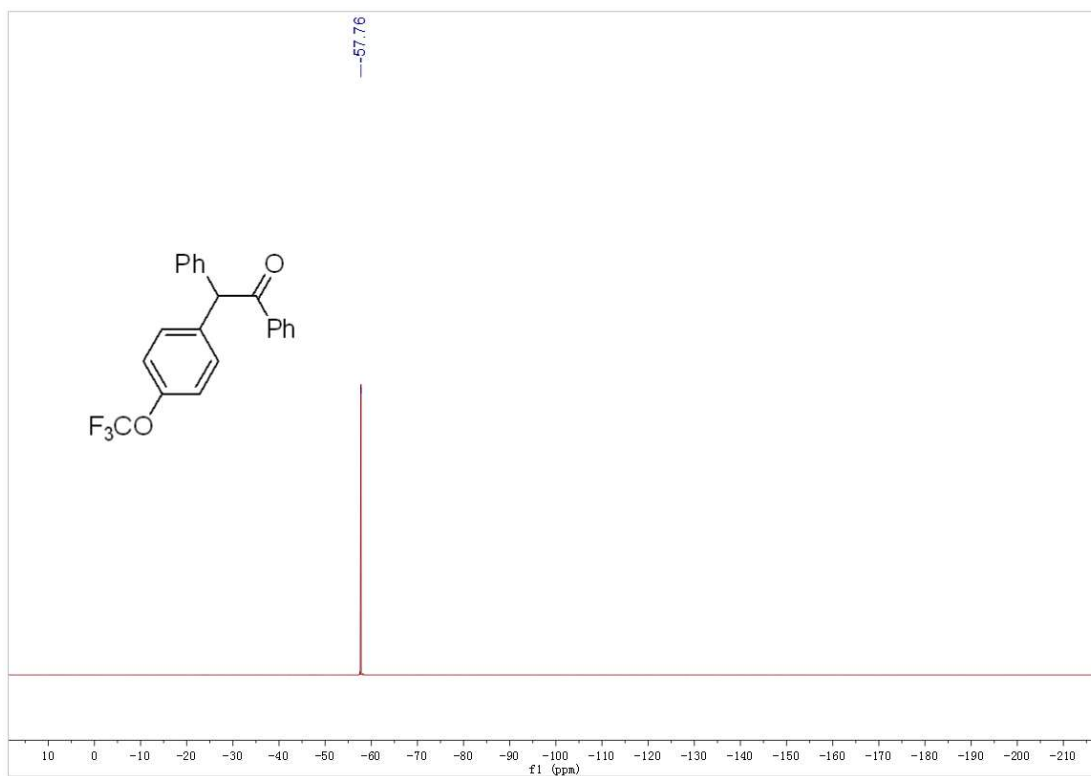
<sup>13</sup>C NMR Spectrum of Compound 2f



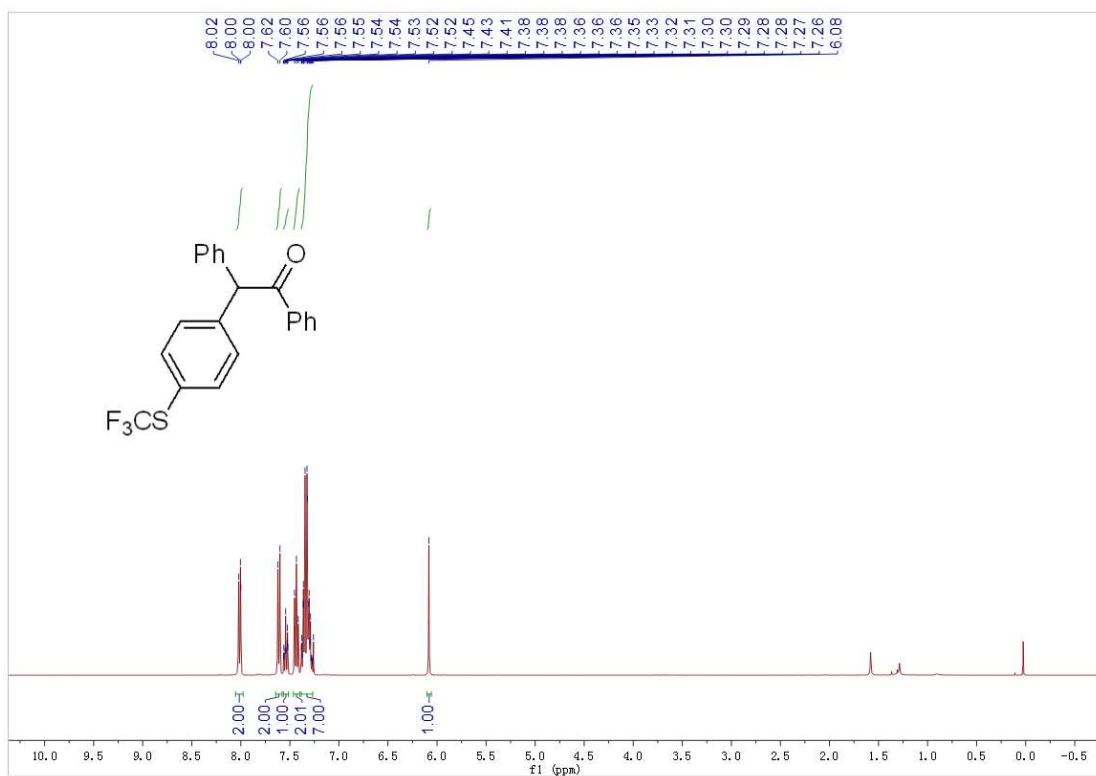
<sup>1</sup>H NMR Spectrum of Compound 2g



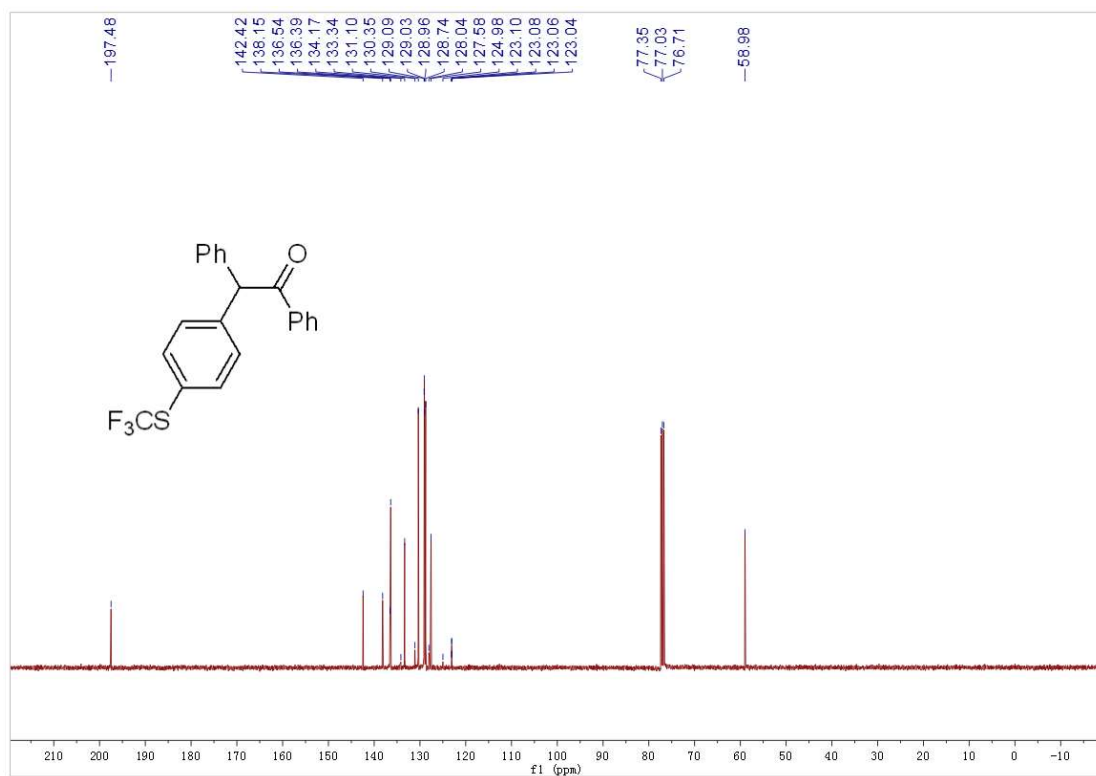
<sup>13</sup>C NMR Spectrum of Compound 2g



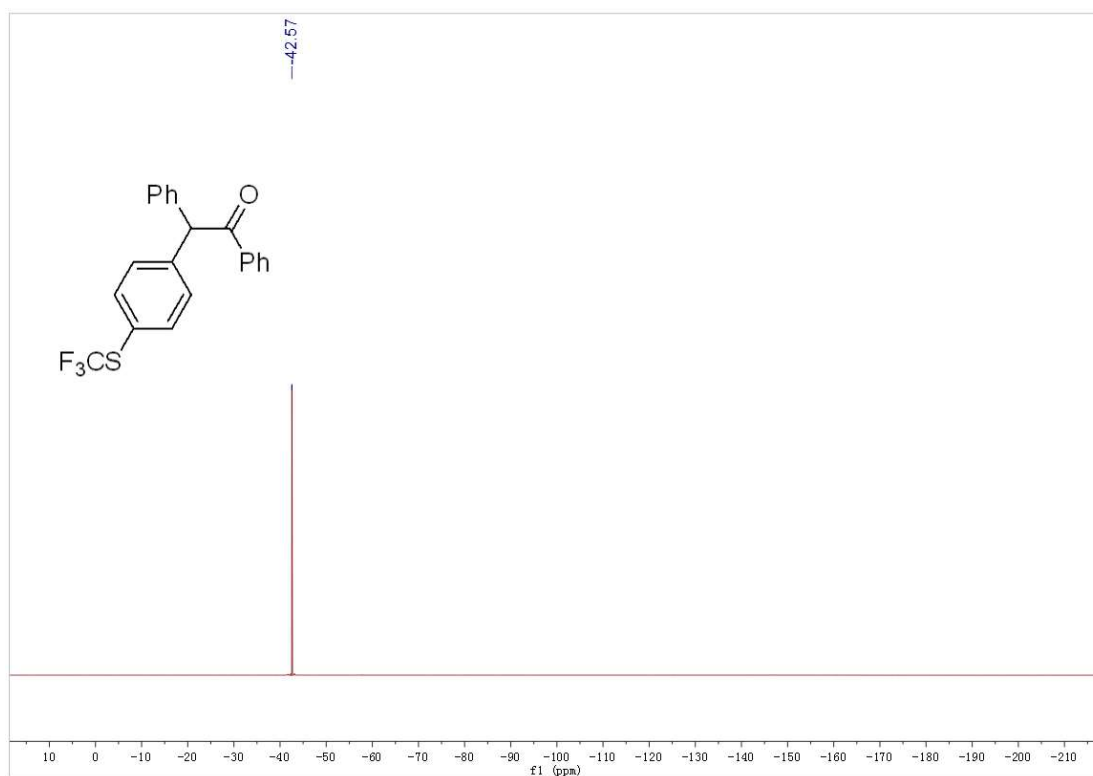
<sup>19</sup>F NMR Spectrum of Compound 2g



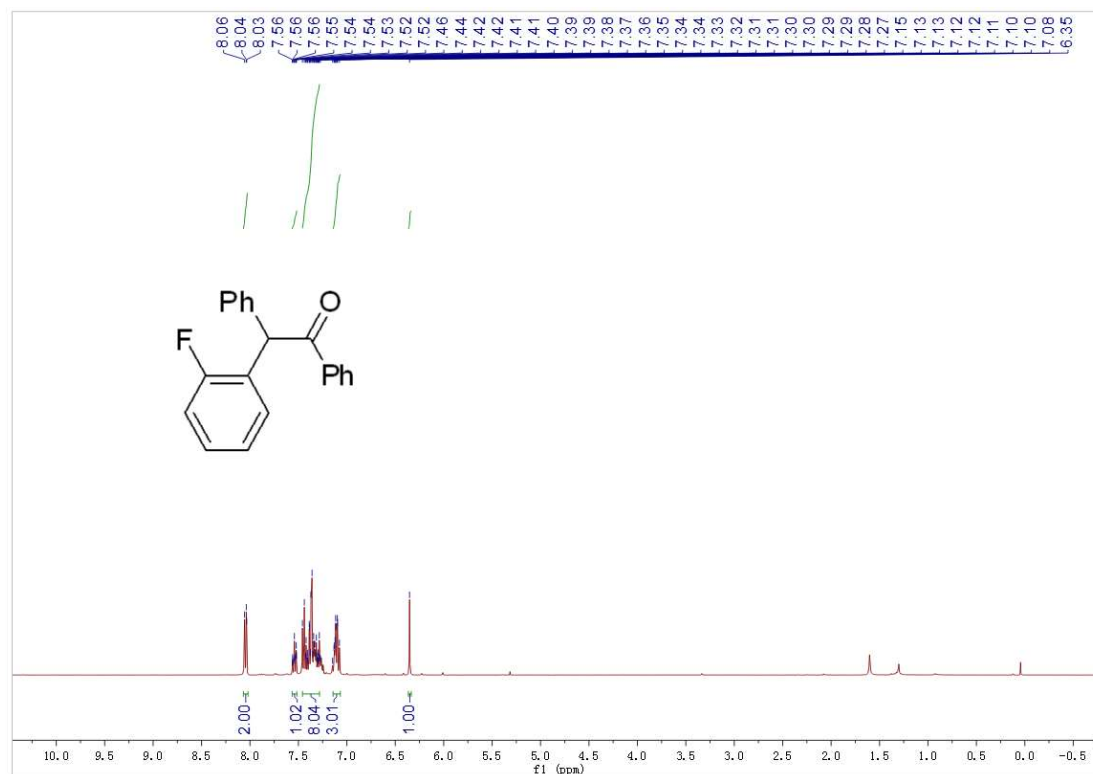
**<sup>1</sup>H NMR Spectrum of Compound 2h**



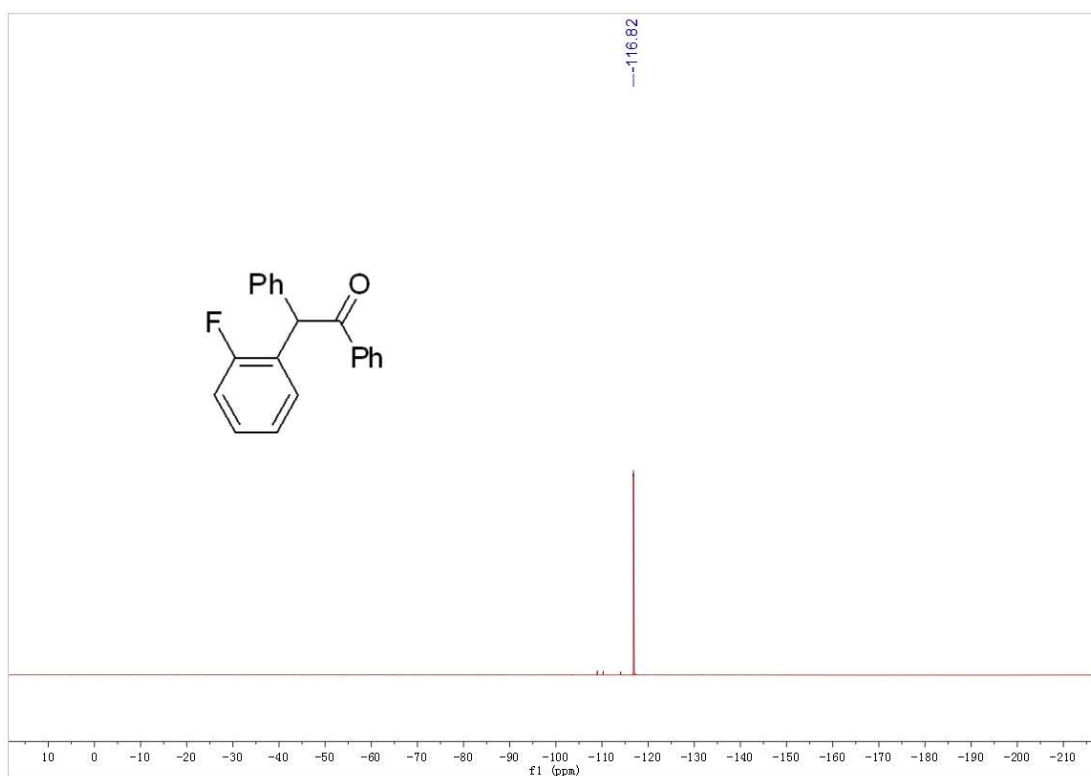
**<sup>13</sup>C NMR Spectrum of Compound 2h**



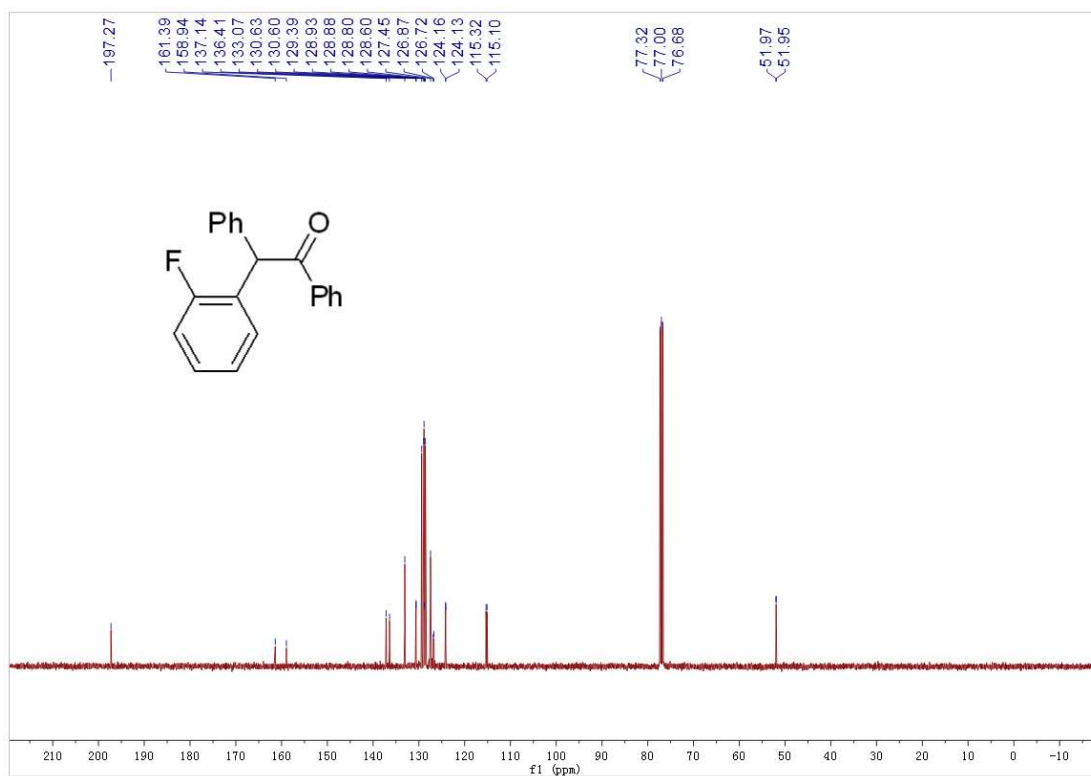
<sup>19</sup>F NMR Spectrum of Compound 2h



<sup>1</sup>H NMR Spectrum of Compound 2i

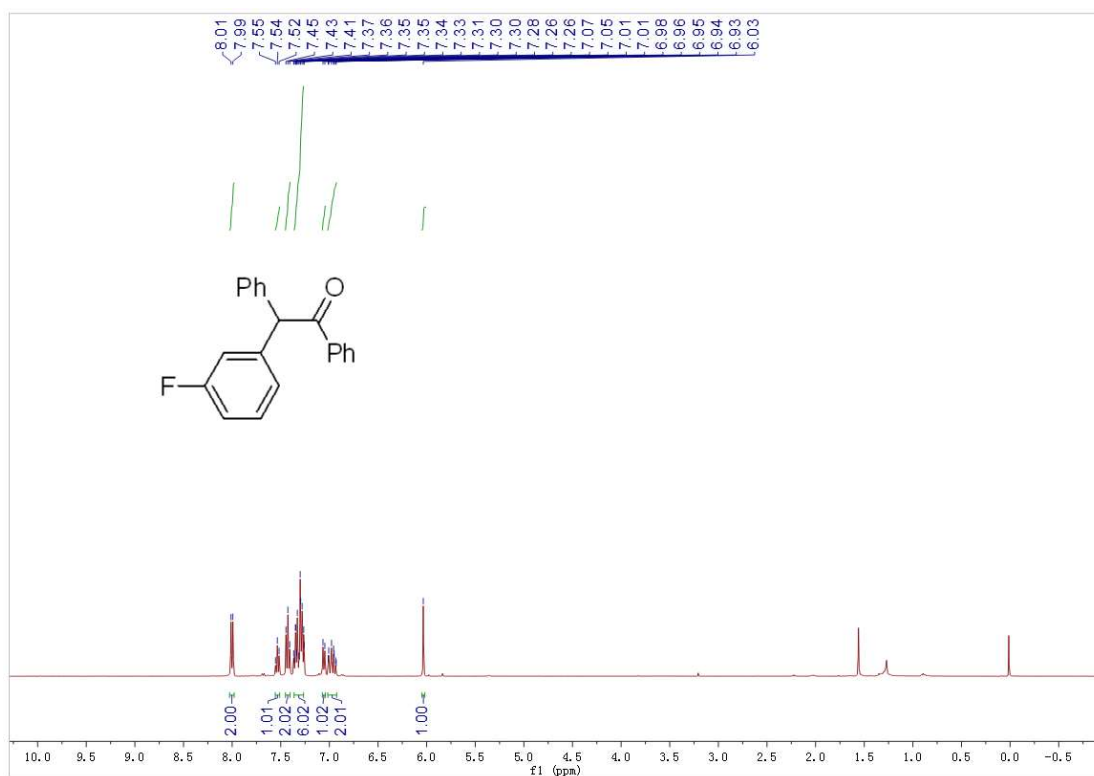


$^{19}\text{F}$  NMR Spectrum of Compound 2i

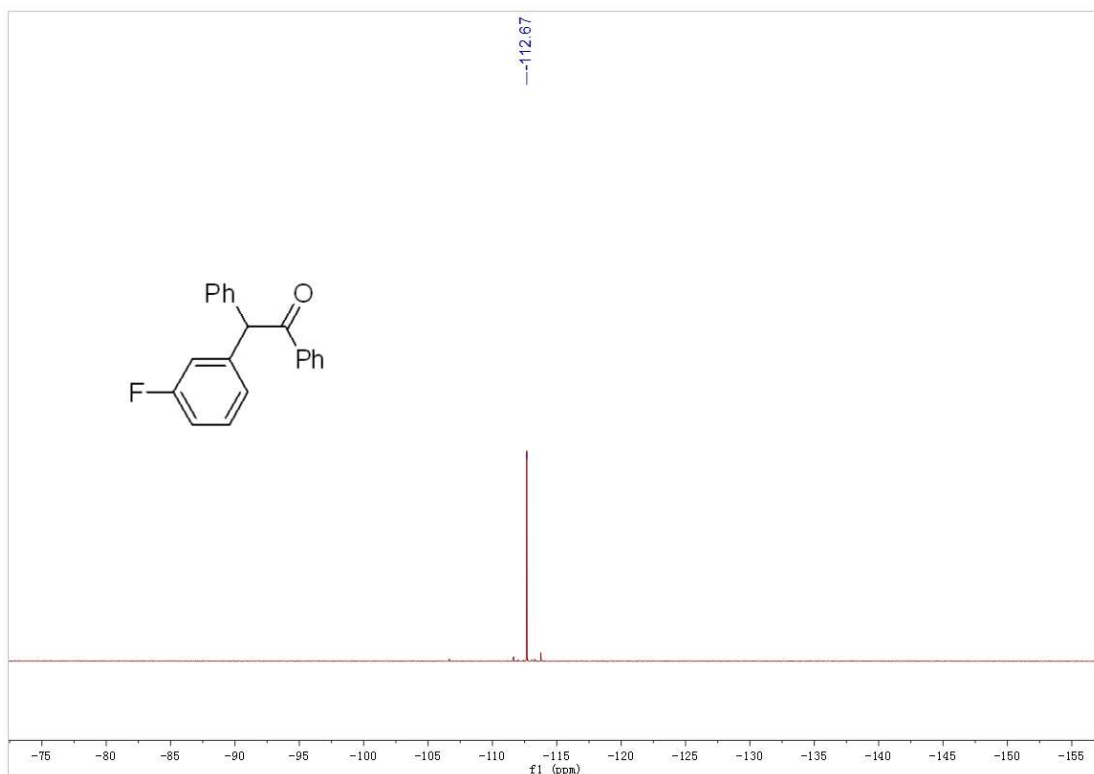


$^{13}\text{C}$  NMR Spectrum of Compound 2i

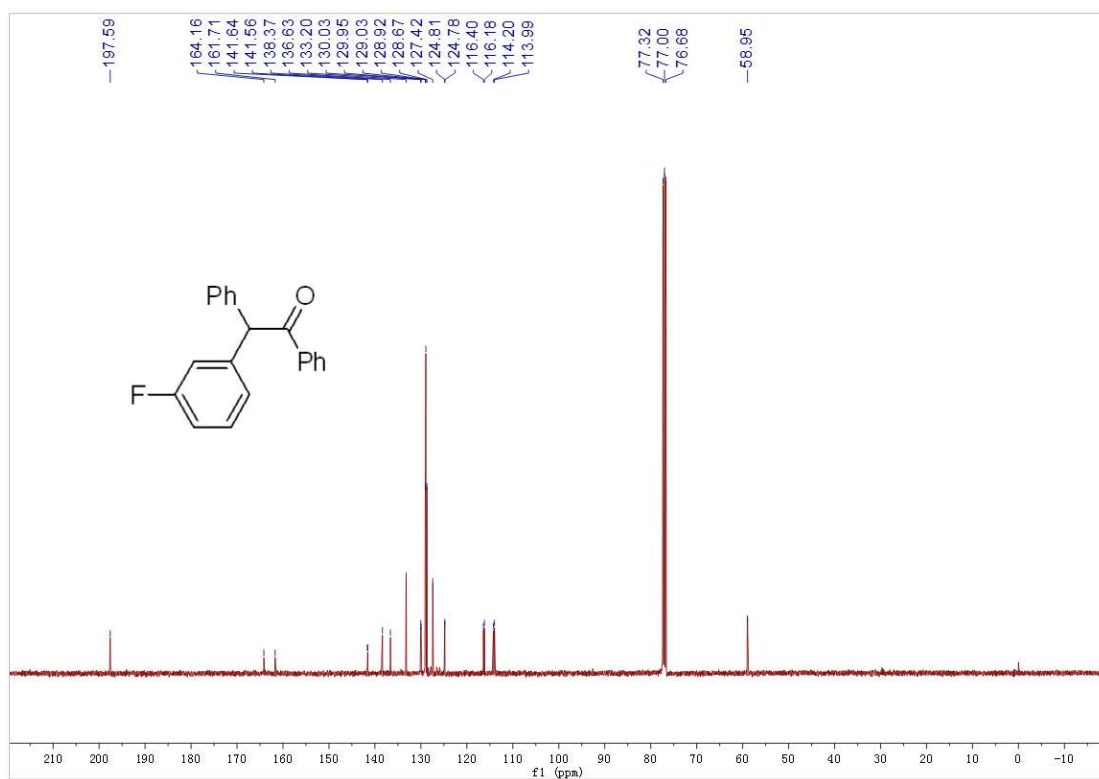




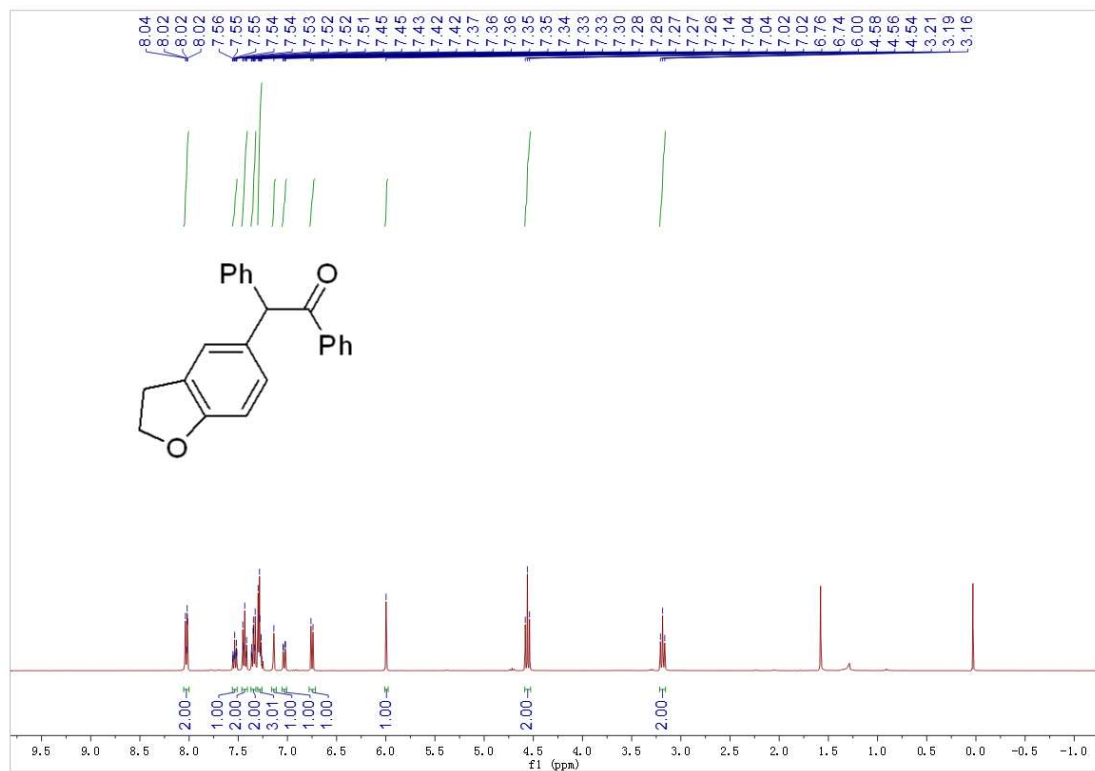
<sup>1</sup>H NMR Spectrum of Compound 2j



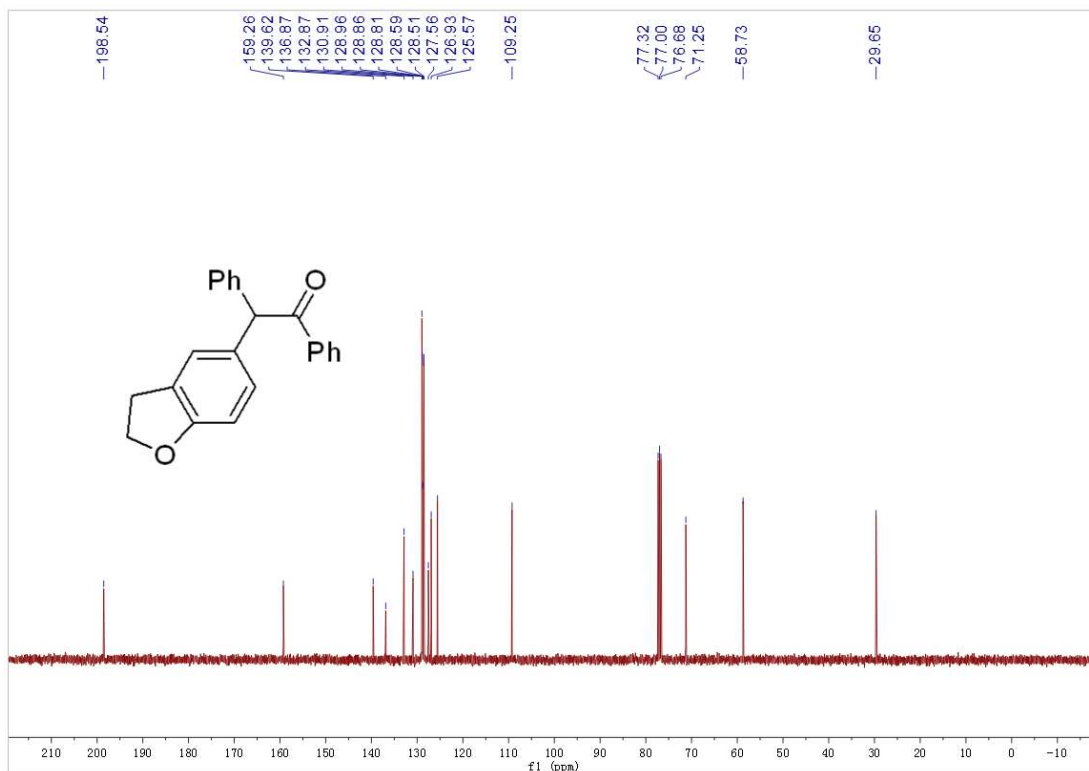
<sup>19</sup>F NMR Spectrum of Compound 2j



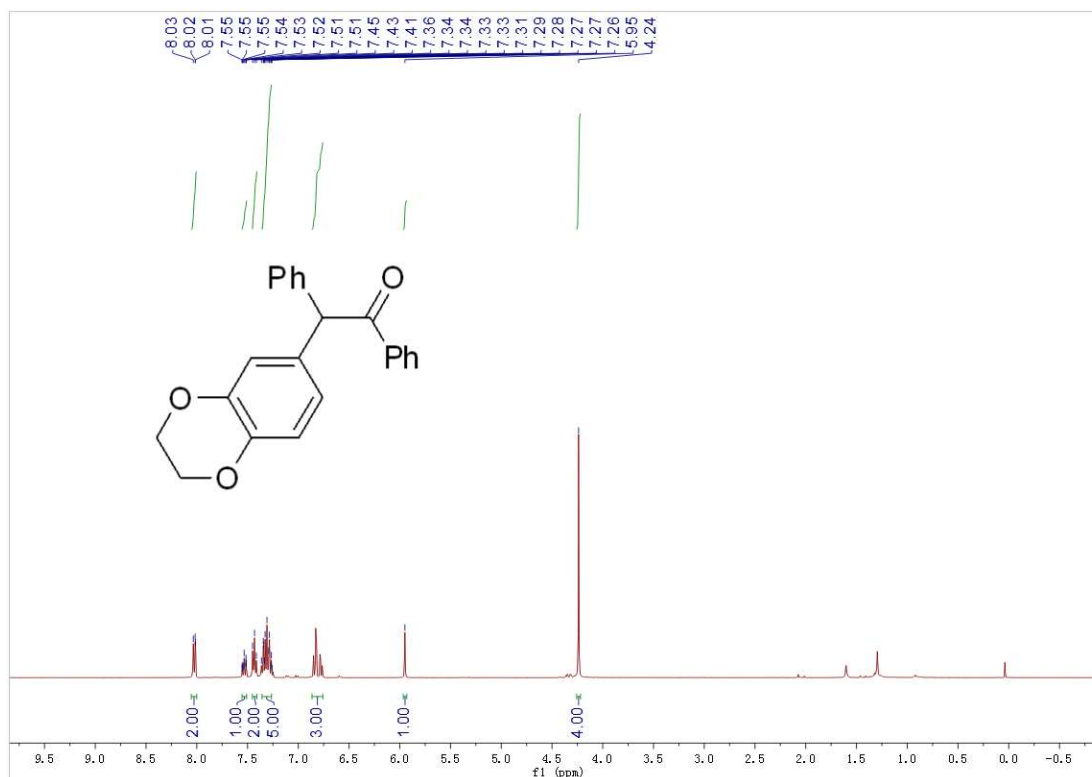
<sup>13</sup>C NMR Spectrum of Compound 2j



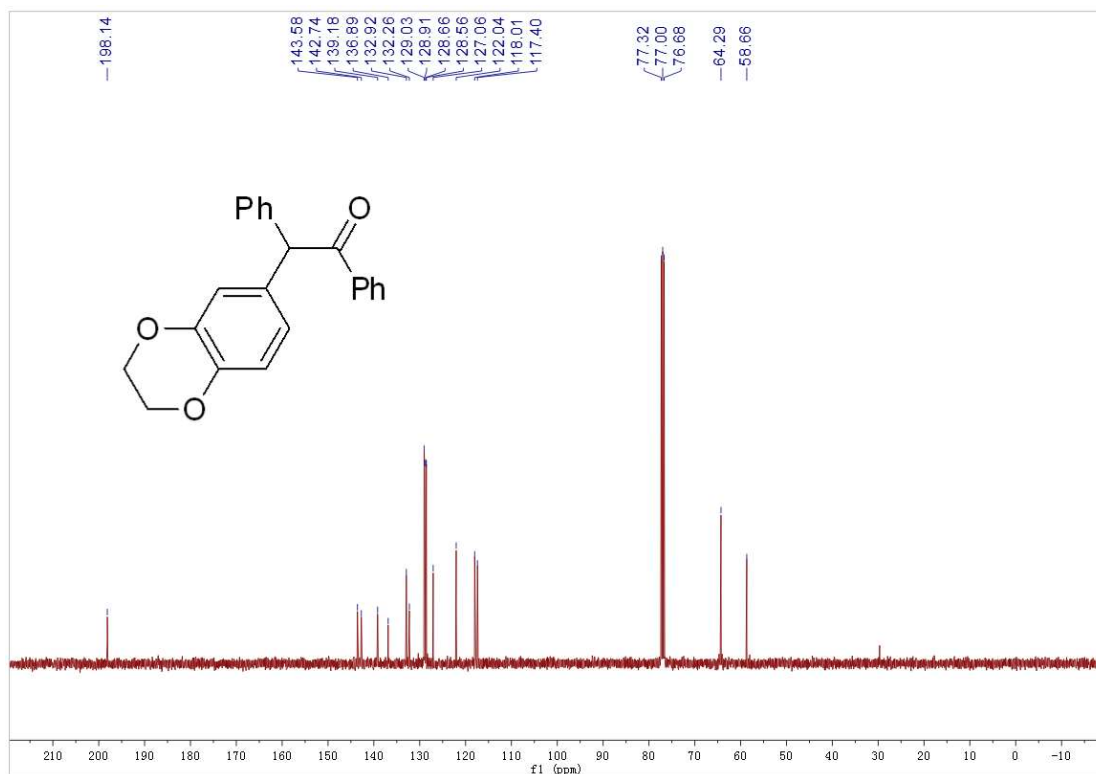
<sup>1</sup>H NMR Spectrum of Compound 2k



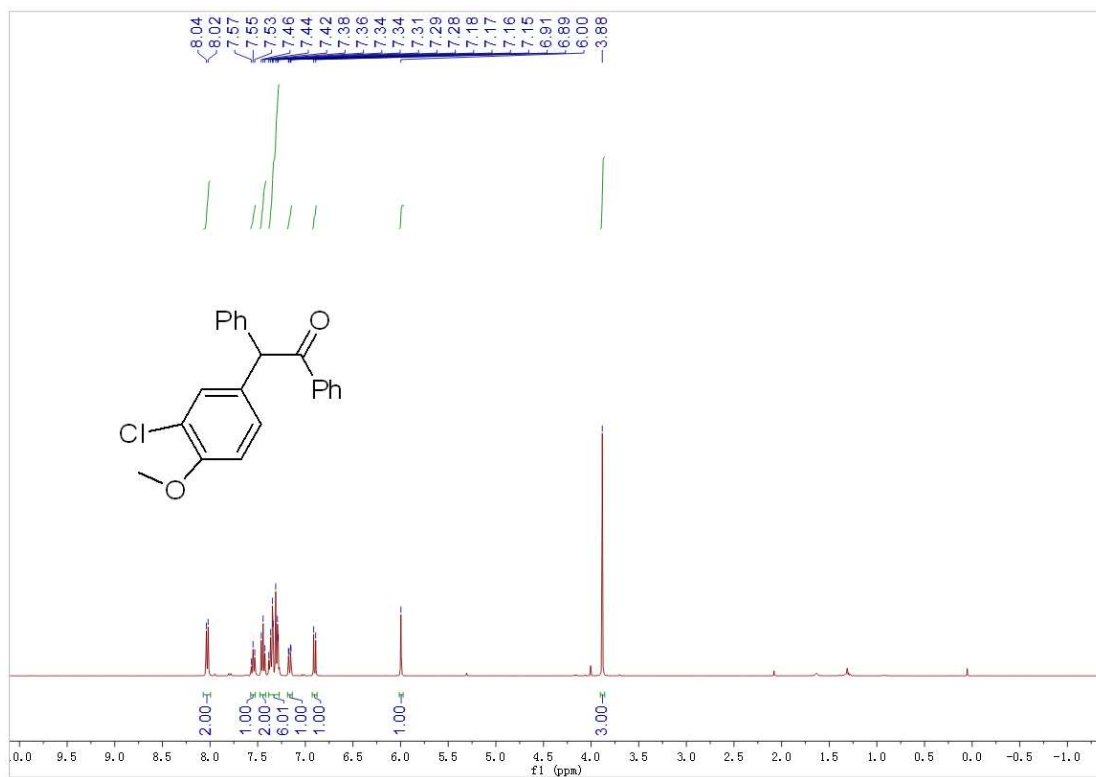
**<sup>13</sup>C NMR Spectrum of Compound 2k**



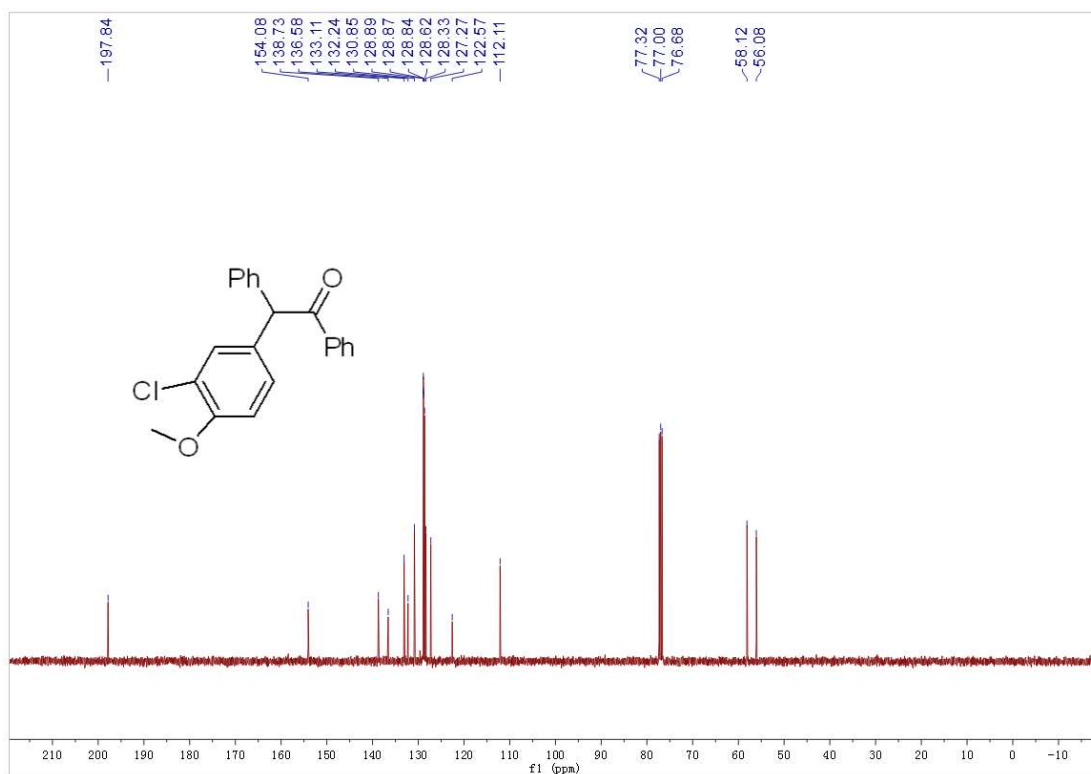
**<sup>1</sup>H NMR Spectrum of Compound 2l**



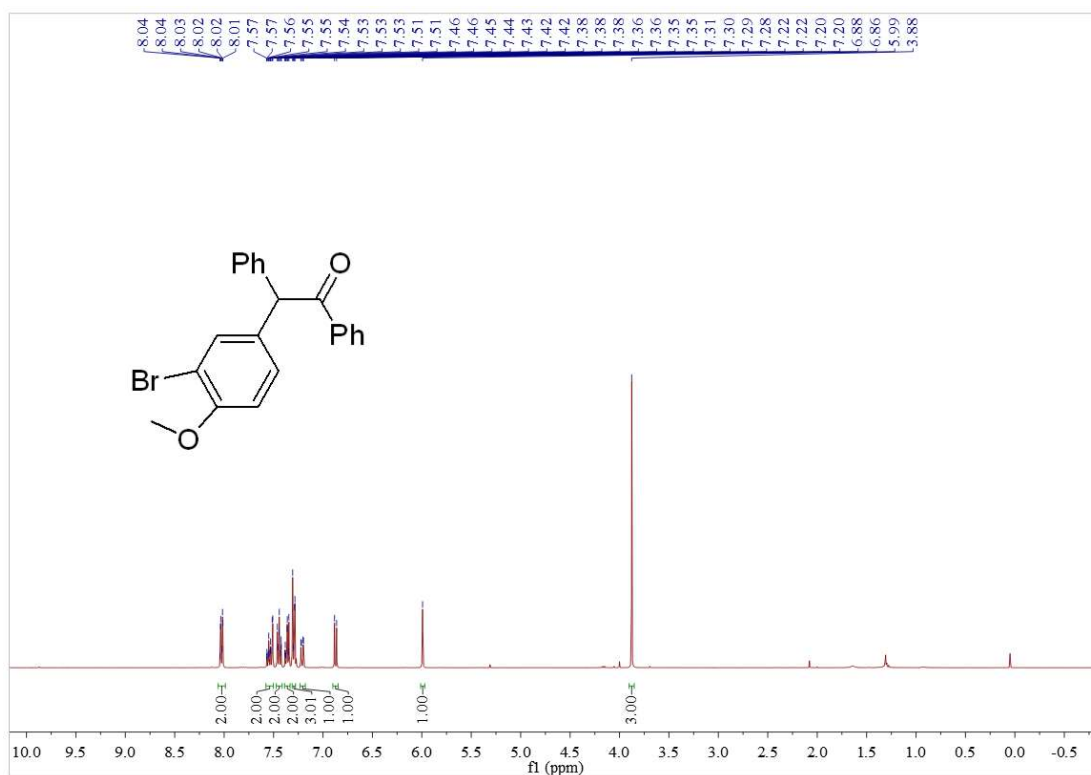
**<sup>13</sup>C NMR Spectrum of Compound 2l**



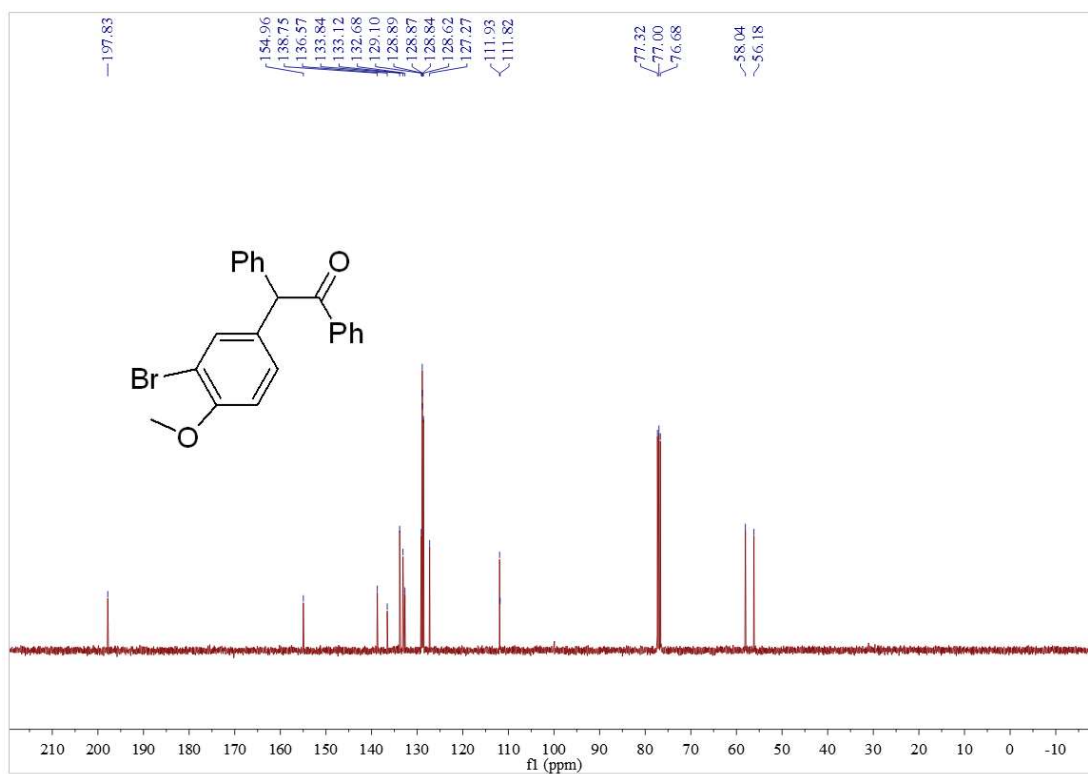
**<sup>1</sup>H NMR Spectrum of Compound 2m**



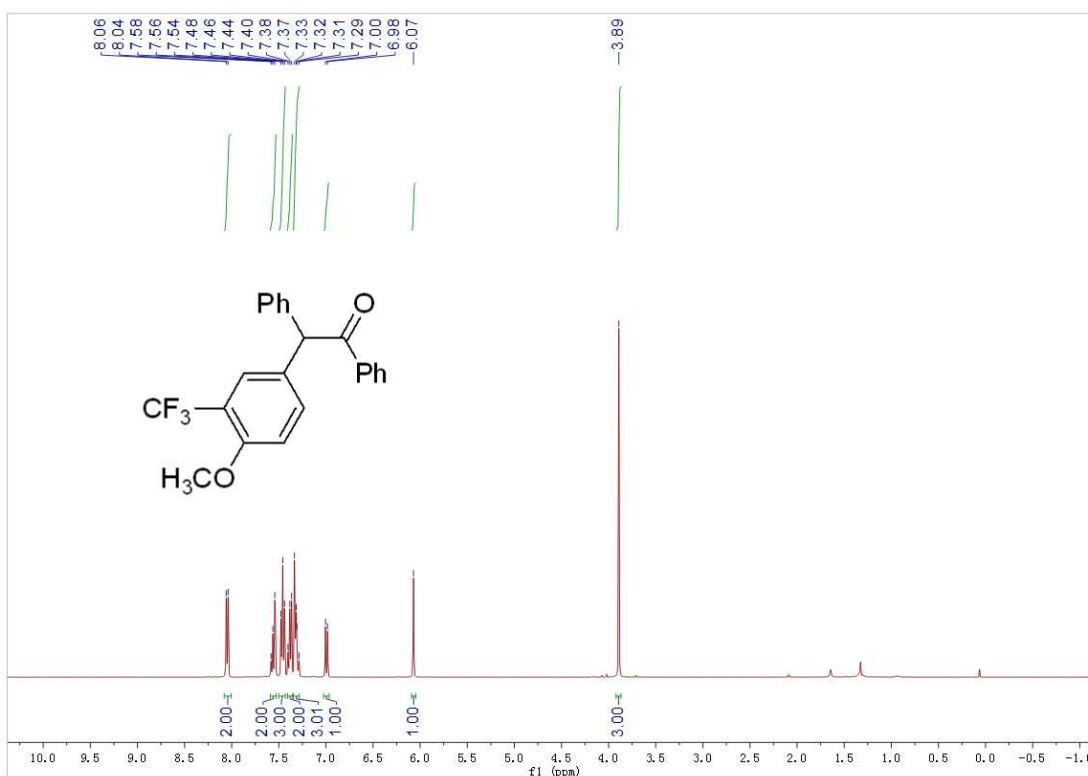
**<sup>13</sup>C NMR Spectrum of Compound 2m**



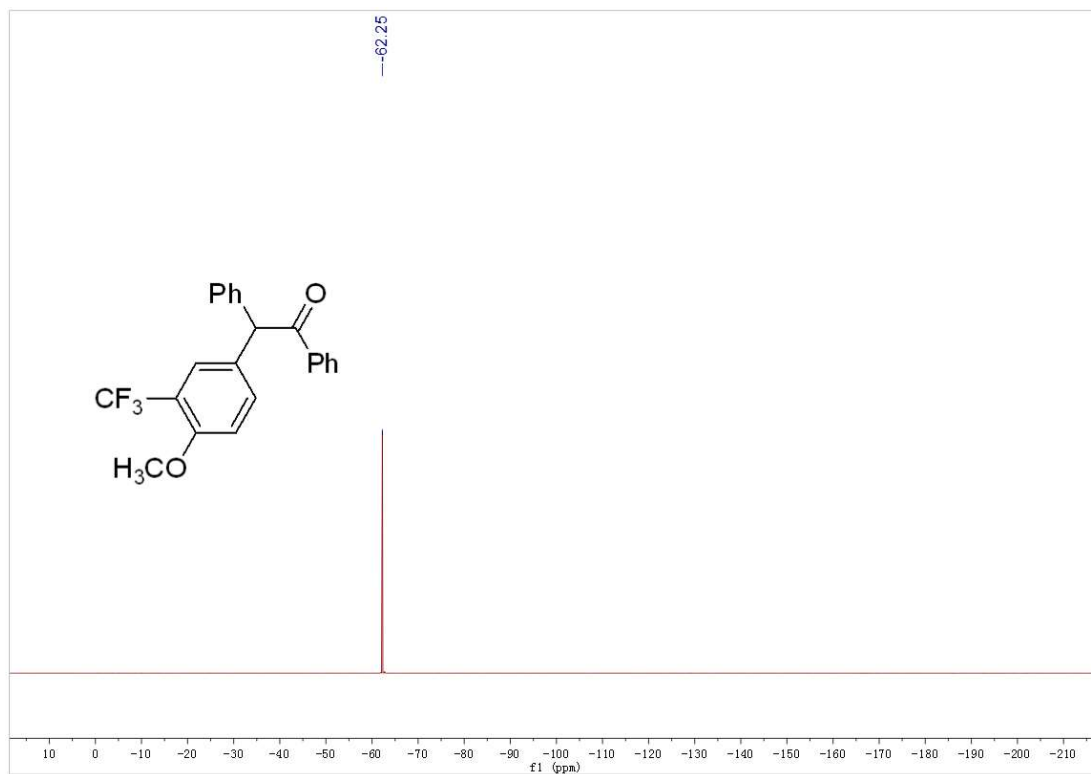
**<sup>1</sup>H NMR Spectrum of Compound 2n**



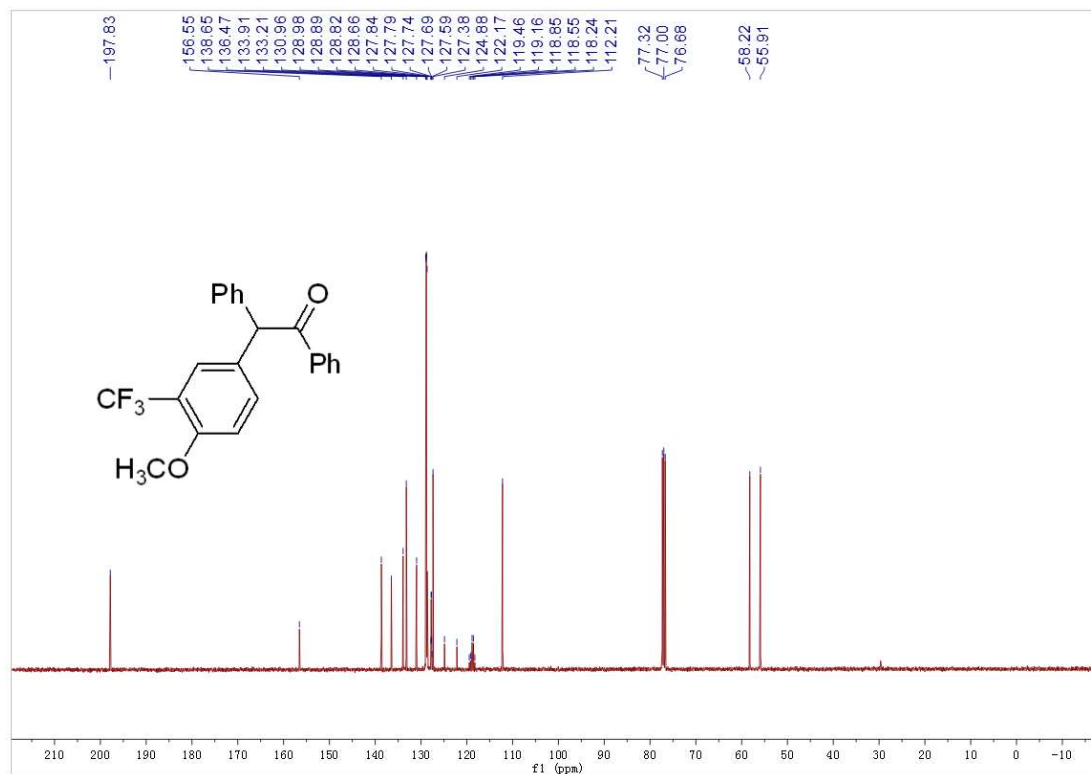
**<sup>13</sup>C NMR Spectrum of Compound 2n**



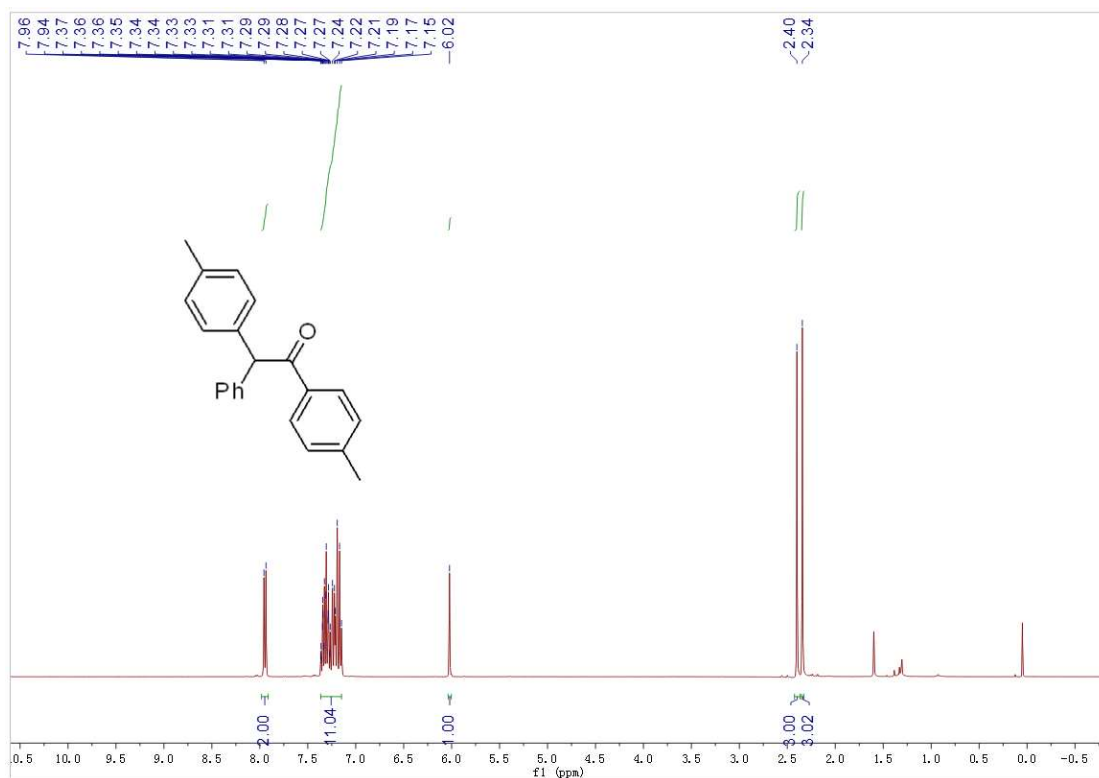
**<sup>1</sup>H NMR Spectrum of Compound 2o**



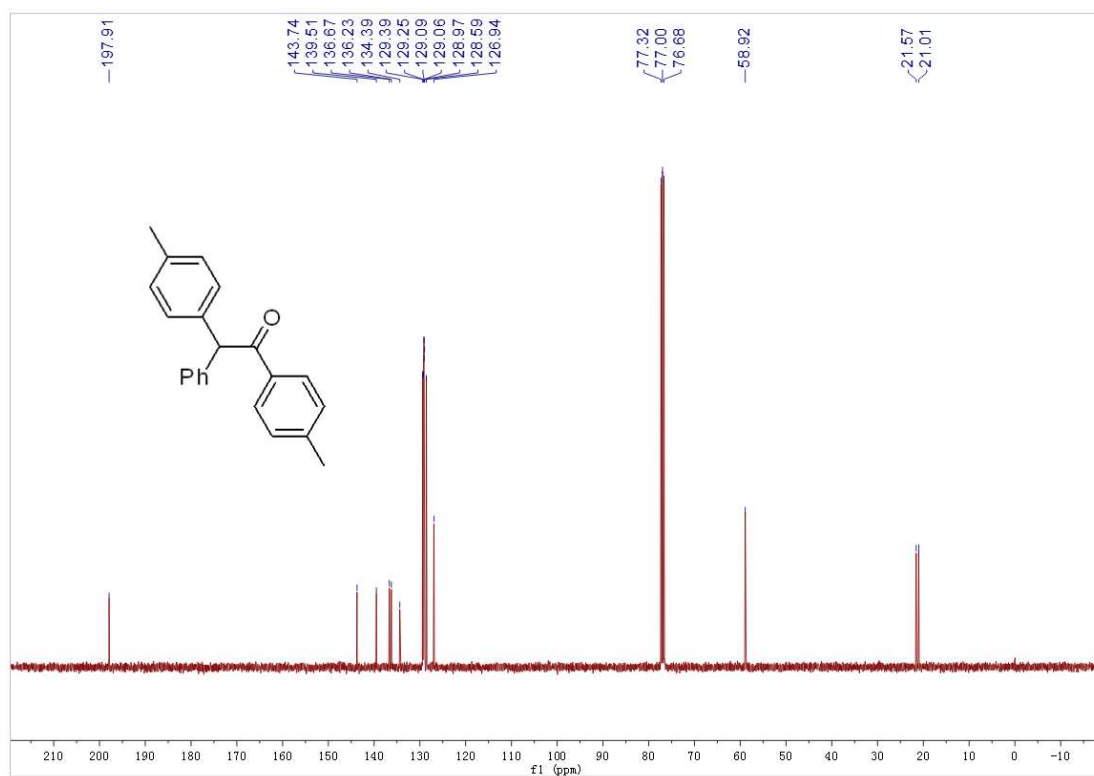
$^{19}\text{F}$  NMR Spectrum of Compound 2o



$^{13}\text{C}$  NMR Spectrum of Compound 2o

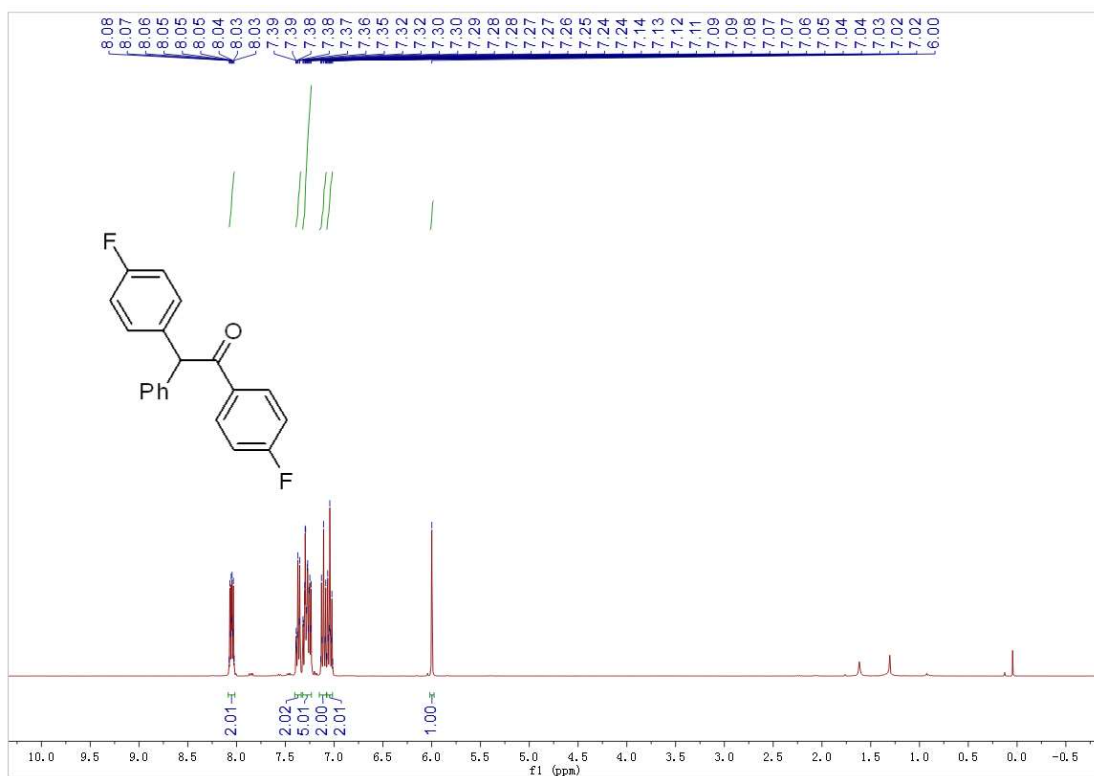


**<sup>1</sup>H NMR Spectrum of Compound 2p**

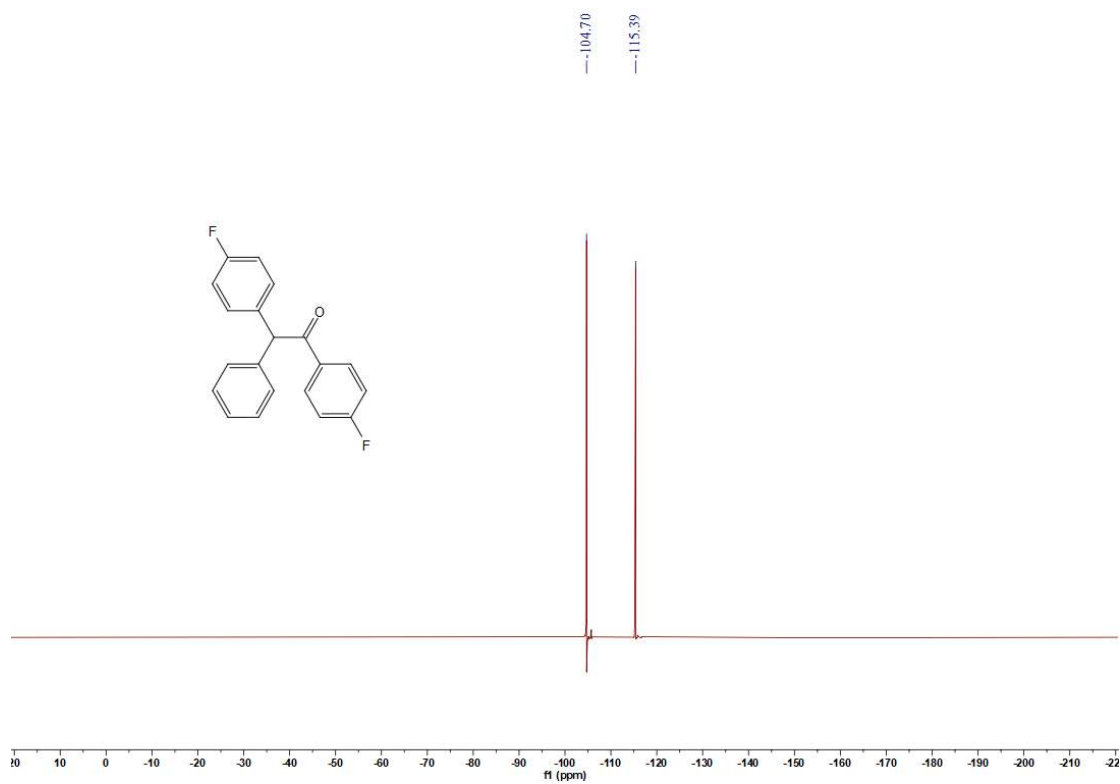


**<sup>13</sup>C NMR Spectrum of Compound 2p**

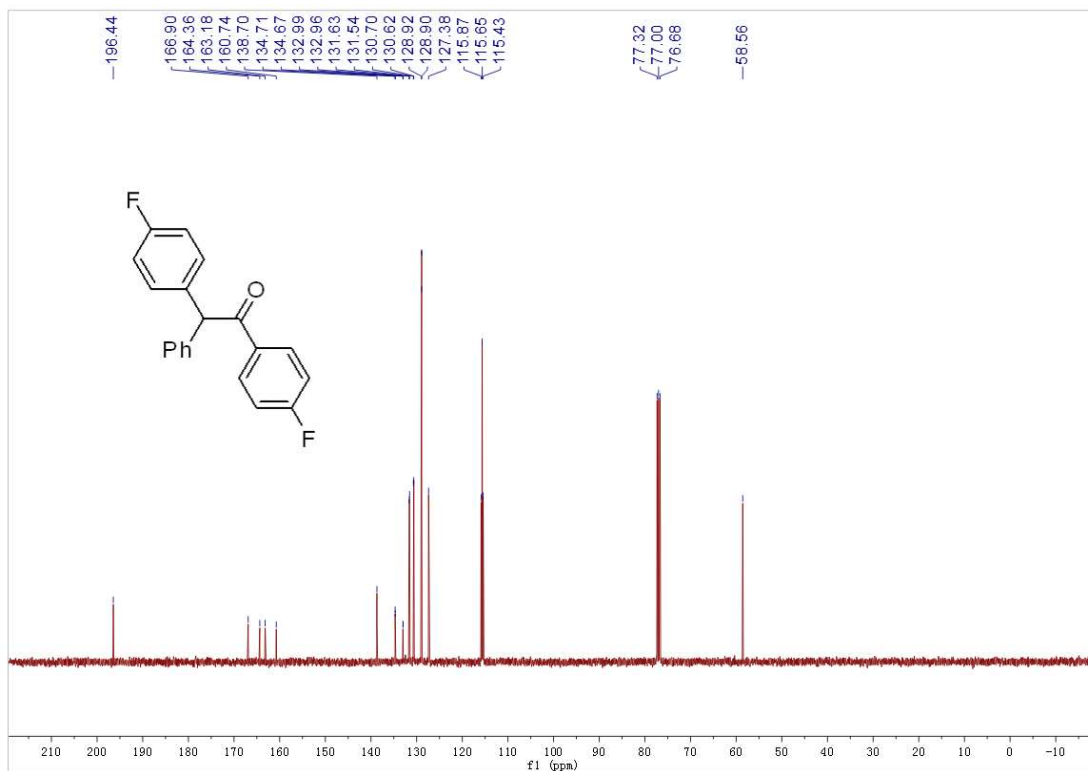




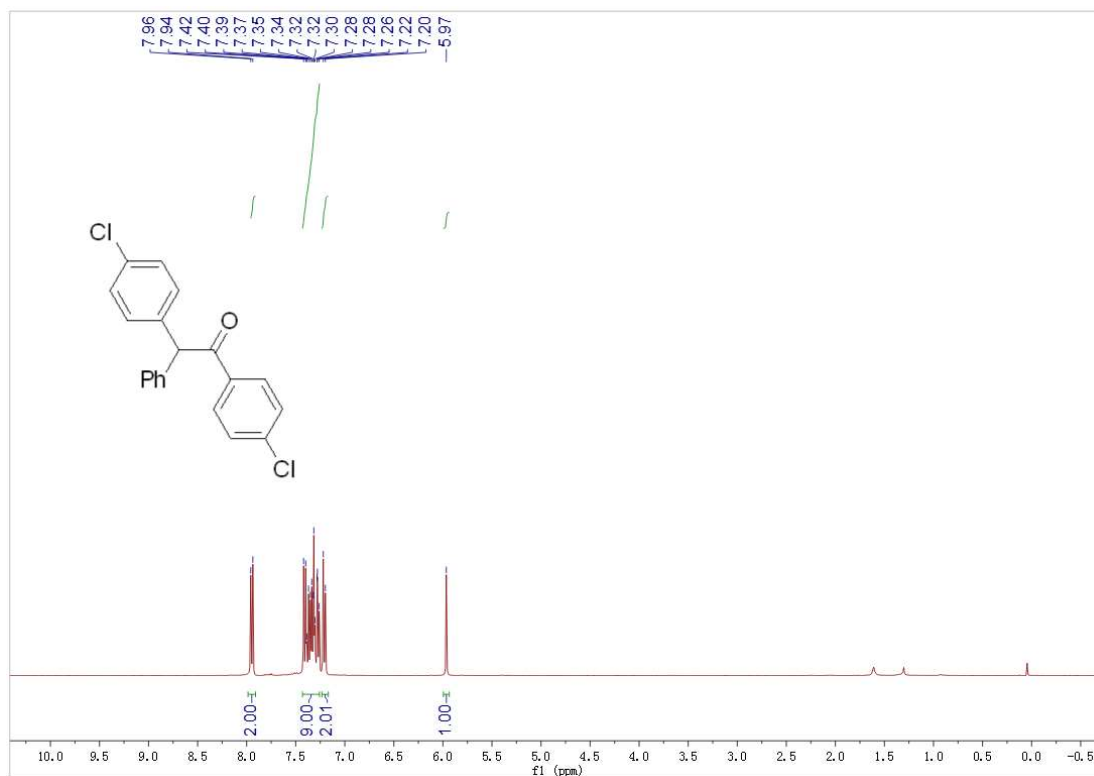
**<sup>1</sup>H NMR Spectrum of Compound 2q**



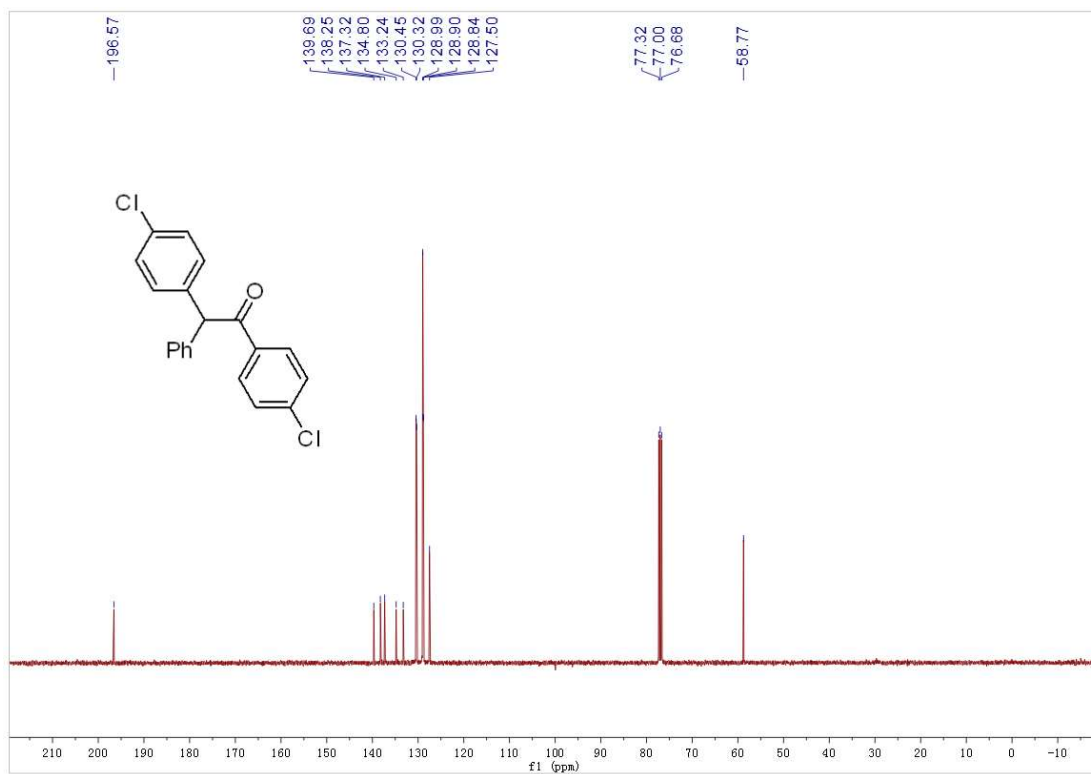
**<sup>19</sup>F NMR Spectrum of Compound 2q**



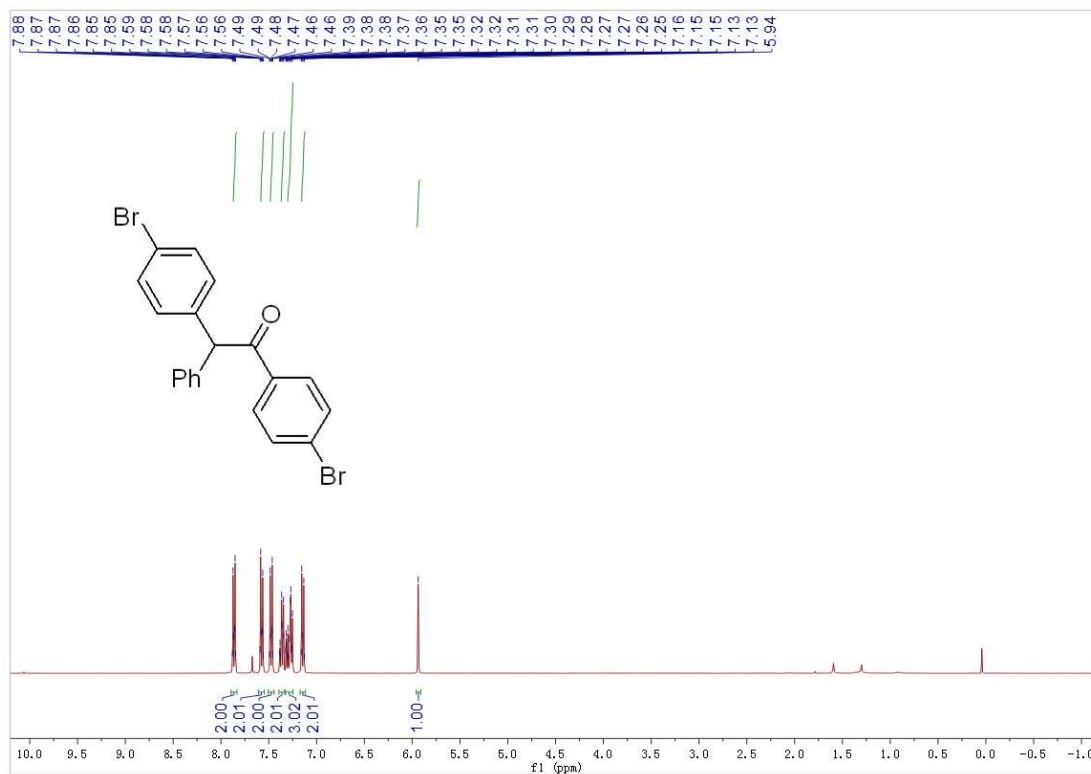
**<sup>13</sup>C NMR Spectrum of Compound 2p**



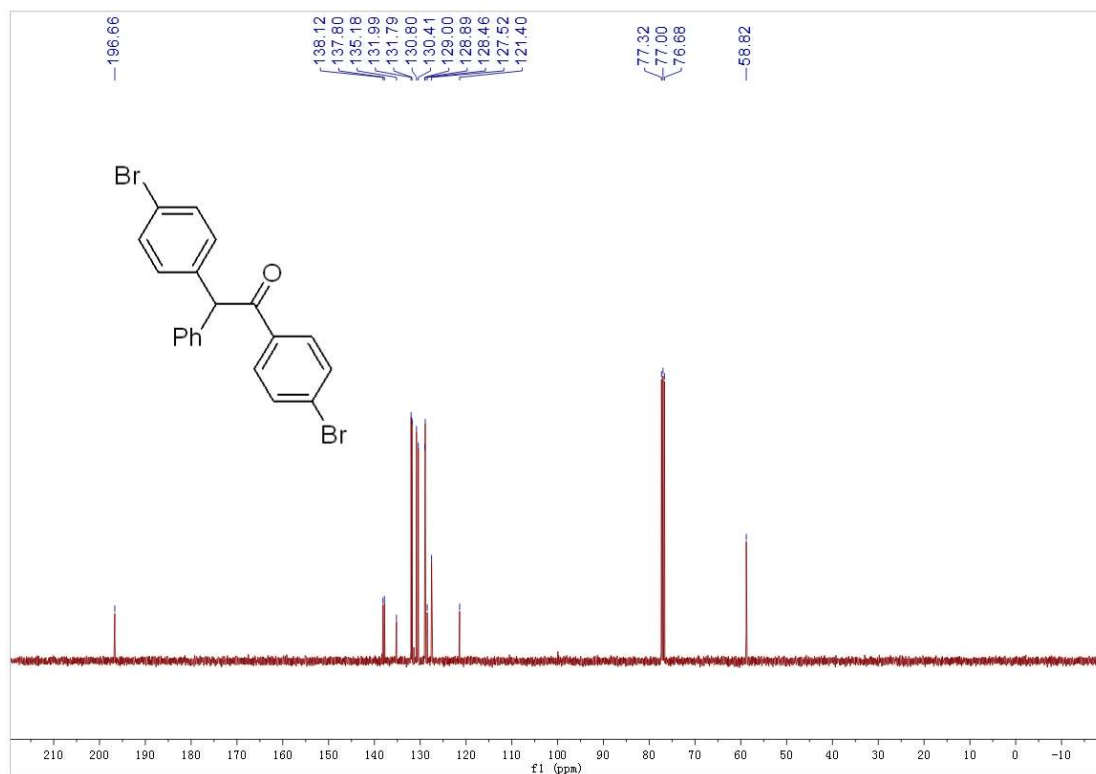
**<sup>1</sup>H NMR Spectrum of Compound 2r**



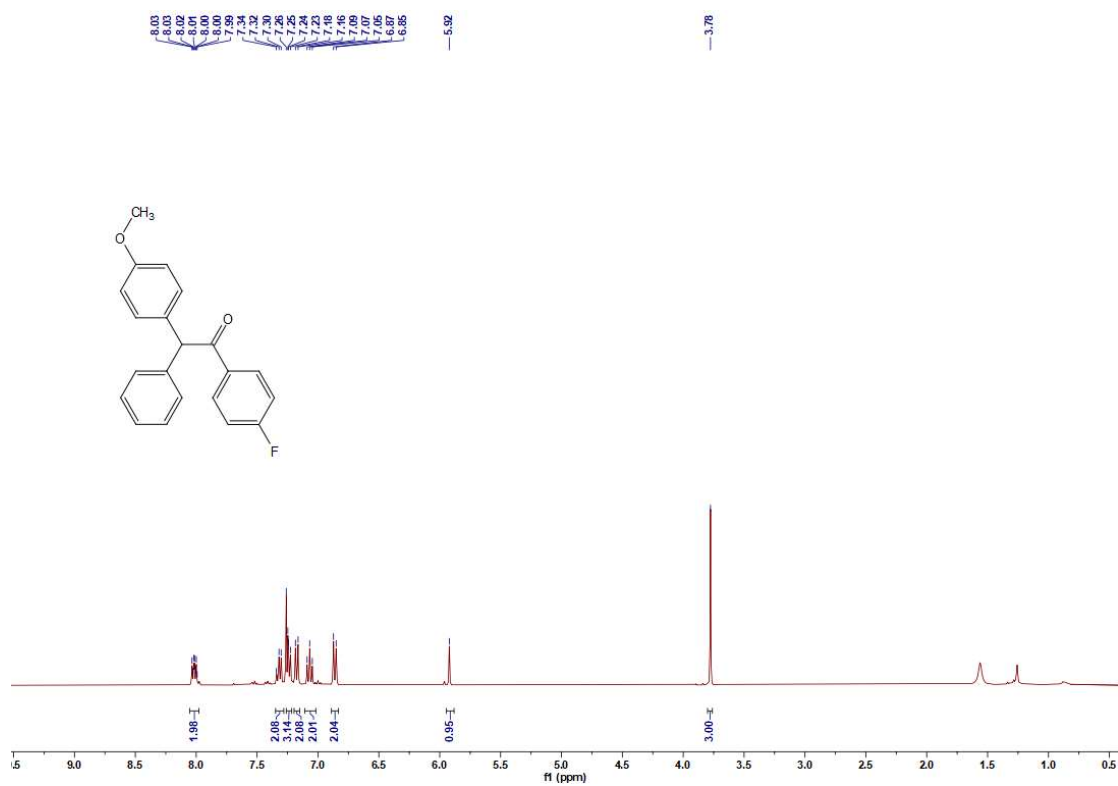
**<sup>13</sup>C NMR Spectrum of Compound 2r**



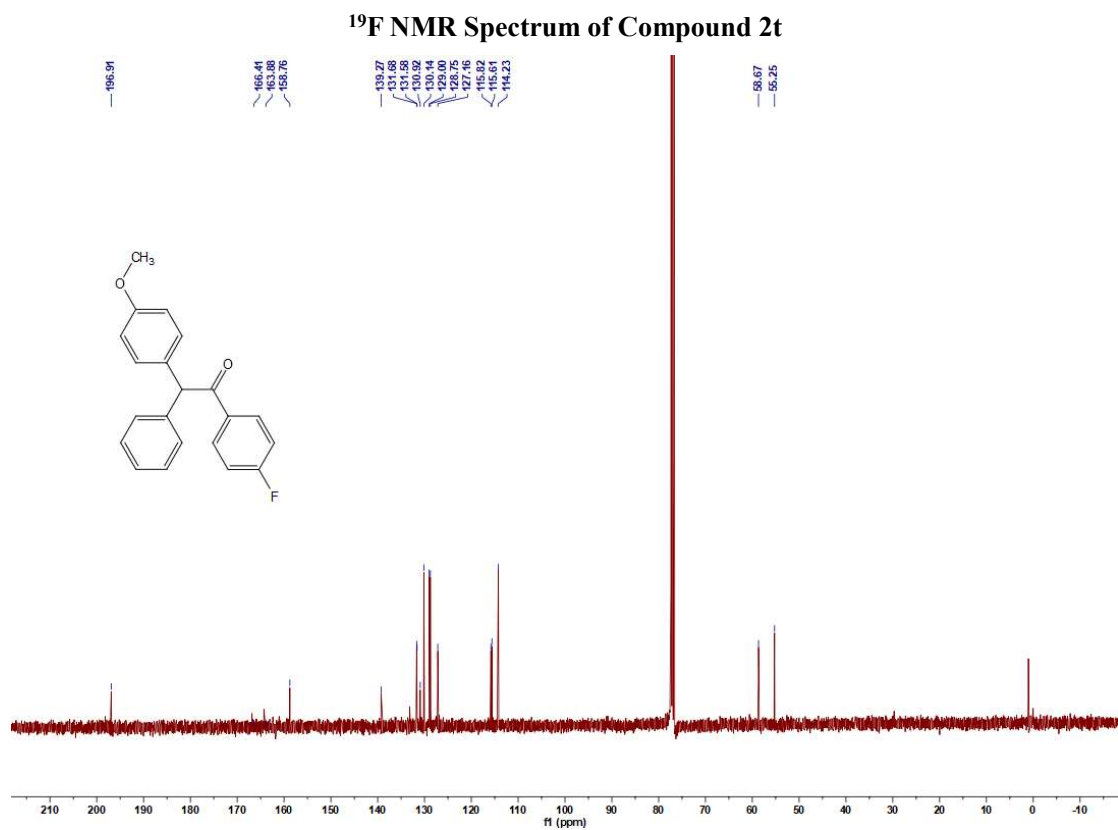
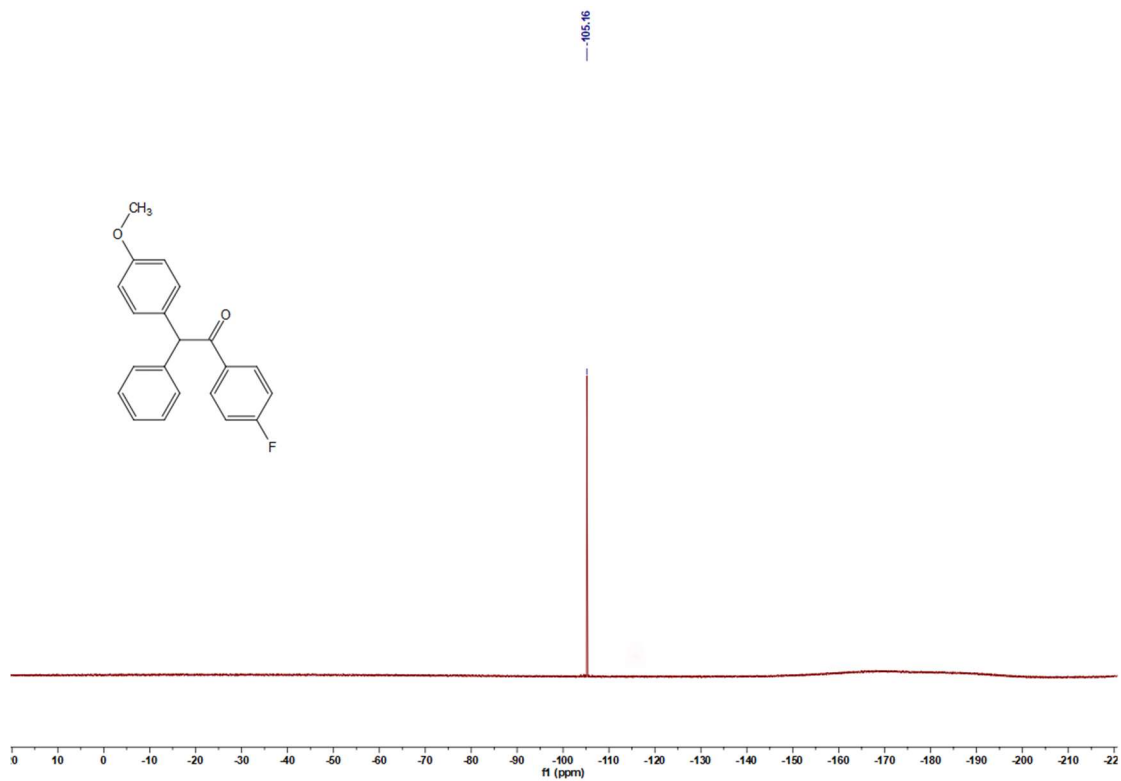
**<sup>1</sup>H NMR Spectrum of Compound 2s**



**<sup>13</sup>C NMR Spectrum of Compound 2s**



**<sup>1</sup>H NMR Spectrum of Compound 2t**



## 11. References

- [1] O. V. Dolomanov, L. J. Bourhis, R. J. Gildea, J. A. K. Howard and H. Puschmann, *Journal of Applied Crystallography* 2009, 42, 339-341.
- [2] G. Sheldrick, *Acta Crystallographica Section C* 2015, 71, 3-8.
- [3] G. Sheldrick, *Acta Crystallographica Section A* 2008, 64, 112-122.
- [4] a) J. Li, L. He, X. Liu, X. Cheng and G. Li, *Angew Chem Int Ed Engl* 2019, 58, 1759-1763; b) J. Li, W. Huang, J. Chen, L. He, X. Cheng and G. Li, *Angew Chem Int Ed Engl* 2018, 57, 5695-5698.