Electronic Supplementary Information

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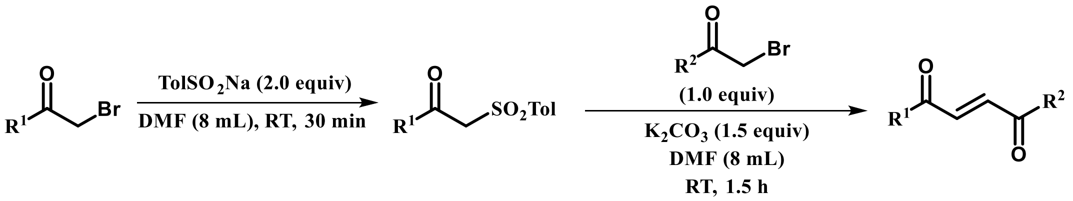
1. General information

All reactions were carried out in sealed air using oven dried glassware. 1,1,1,3,3,3-hexafluoro-2-propanol, 1,2-dichloroethane, tetrabutylammonium perchlorate, and graphite felt are all available from commercial sources. Deionized water is obtained by ultra pure water machine. The electrochemical instrument is HONGSHENGFENGC DPS-305BM. Column chromatography was performed on silica gel (200-300 mesh). NMR spectra were recorded in $CDCl_3$ on 500 MHz spectrometers. ^1H NMR chemical shifts (δ) are reported in parts per million relative to tetramethylsilane (0 ppm). The following abbreviations are used for multiplicities: s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, dt = doublet of triplets, and m = multiplet. HRMS were obtained on an Ultima Global spectrometer with an ESI source. Melting points are uncorrected.

2. General preparation of 1,4-enedione compounds

Method :



Scheme S1. General preparation of 1,4-enedione compounds

Method:

Generally procedure for the 1,4-enedione compounds: add DMF (8 mL) into a 25 mL flask α-Bromoacetophenone (4.0 mmol), and then aromatic sodium sulfonate (8.0 mmol) was added at room temperature. The reaction mixture was stirred for 30 min. Dilute with brine (50 mL) and extract the mixture with EtOAc (3 x 20 mL). The combined organic layers were washed with brine, dried, filtered, and evaporated to afford intermediates in nearly quantitative yields. Without further purification, K_2CO_3 (7.5 mmol), the resulting intermediates (4.0 mmol), α- Bromoacetophenone (4.0 mmol) was added to DMF (8 mL) at RT. The reaction mixture was stirred at RT for 2 h. The solvent was diluted with water (50 mL) and the mixture was extracted with EtOAc (3 x 20 mL). The combined organic layers were washed with brine, dried, filtered, and evaporated to afford crude product. Purification on silica gel (PE/ EA = 20/1~10/1) afforded the desired 1,4-enedione as a yellow solid.

3. General preparation of 1,4-dione compounds

Figure S1. Components required for the reaction

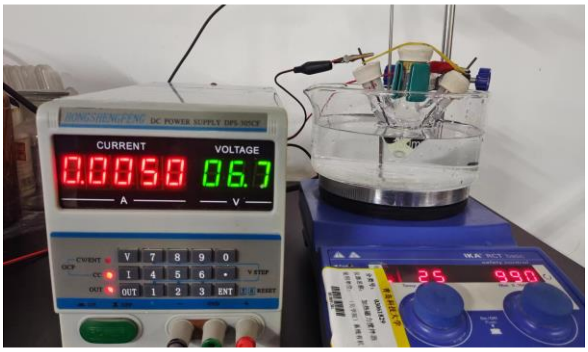
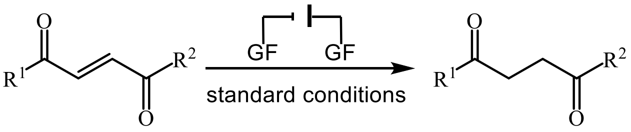


Figure S2. Typical reaction set up



1a **1b**

To the mixed solution of dichloroethane (4.5 mL), HFIP (0.5 mL), and 100 μL water, 1,4-enedione **1a** (0.1 mmol, 1.0 eq.) and tetrabutylammonium perchlorate (0.2 mmol, 2.0 eq.) were added. Equipped with graphite felt (10 × 10 × 5 mm) as an anode, graphite felt (10 × 10 × 5 mm) as a cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 5 mA at 20 °C in the Air for 2 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate (PE/ EA = 15:1).

4. Optimization of reaction conditions

Table S1. Screening of solvents

Entry	**Deviation from standard conditions** [a]	**Yield (%)** [b]
1	HFIP instead of solvent	70%
2	DCE instead of solvent	15%
3	CH_3CN instead of solvent	8%
4	THF instead of solvent	11%
5	acetone instead of solvent	trace
6	DMSO instead of solvent	n.r.[c]
7	CH_3NO_2 instead of solvent	10%
8	DMF instead of solvent	n.d.[d]
9	HFIP : DCM = 0.5 : 4.5	83%
10	HFIP : acetone = 0.5 : 4.5	60%
11	Acetone : DCE = 0.5 : 4.5	20%
12	DMSO : DCE = 0.5 : 4.5	28%
13	HFIP : DCE = 1 : 4	92%
14	HFIP : DCE = 2 : 3	89%
15	HFIP : DCE = 3 : 2	68%
16	HFIP : DCE = 4 : 1	69%

[a]Standard condition: graphite felt anode (10 mm × 10 mm × 5 mm), graphite felt cathode (10 mm × 10 mm × 5 mm), undivided cell, constant current = 5 mA, **1a** (0.1 mmol), electrolyte (2.0 eq.), DCE = 4.5 mL, HFIP = 0.5 mL, H_2O = 0.1 mL, 20 ^{o}C, Air, RT, 2 h (3.73 $F\cdot mol^{-1}$), [b]Isolated yields, [c]n.r. = not reaction, [d]n.d. = not detected.

Table S2. Screening of H_2O

Entry	**Deviation from standard conditions** [a]	**Yield (%)** [b]
1	No H_2O	68%
2	10 μL H_2O	83%
3	50 μL H_2O	92%
4	150 μL H_2O	86%

[a]Standard condition: graphite felt anode (10 mm × 10 mm × 5 mm), graphite felt cathode (10 mm × 10 mm × 5 mm), undivided cell, constant current = 5 mA, **1a** (0.1 mmol), electrolyte (2.0 eq.), DCE = 4.5 mL, HFIP = 0.5 mL, H_2O = 0.1 mL, 20 ^{o}C, Air, 2 h (3.73 $F\cdot mol^{-1}$), [b]Isolated yields.

Table S3. Screening of electrode

Entry	**Deviation from standard conditions** [a]	**Yield (%)** [b]
1	GF(+) / Pt(-)	67%
2	GF(+) / C(-)	83%

[a]Standard condition: graphite felt anode (10 mm × 10 mm × 5 mm), graphite felt cathode (10 mm × 10 mm × 5 mm), undivided cell, constant current = 5 mA, **1a** (0.1 mmol), electrolyte (2.0 eq.), DCE = 4.5 mL, HFIP = 0.5 mL, H_2O = 0.1 mL, 20 ^{o}C, Air, RT, 2 h (3.73 $F\cdot mol^{-1}$), [b]Isolated yields.

Table S4. Screening of electrolyte

Entry	Deviation from standard conditions [a]	Yield (%) [b]
1	*n*-Bu_4NPF_6 instead of *n*-Bu_4NClO_4	68%
2	*n*-Bu_4NBF_4 instead of *n*-Bu_4NClO_4	62%
3	*n*-Bu_4NI instead of *n*-Bu_4NClO_4	trace
4	*n*-Bu_4NBr instead of *n*-Bu_4NClO_4	trace
5	*n*-Bu_4NOAc instead of *n*-Bu_4NClO_4	55%
6	Et_4NPF_6 instead of *n*-Bu_4NClO_4	52%
7	Me_4NPF_6 instead of n *n*-Bu_4NClO_4	24%

[a]Standard condition: graphite felt anode (10 mm × 10 mm × 5 mm), graphite felt cathode (10 mm × 10 mm × 5 mm), undivided cell, constant current = 5 mA, **1a** (0.1 mmol), electrolyte (2.0 eq.), DCE = 4.5 mL, HFIP = 0.5 mL, H_2O = 0.1 mL, 20 ^{o}C, Air, RT, 2 h (3.73 F·mol^{-1}), [b]Isolated yields.

Table S5. Screening of other hydrogen donor

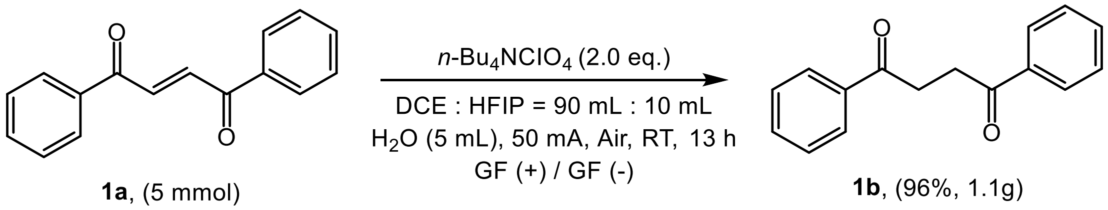
Entry	Deviation from standard conditions [a]	Yield (%) [b]
1	Cheng's condition: [12a] D_2O as hydrogen donor	trace
2	Cheng's condition: [12b] NH_3 as hydrogen donor	trace
3	Xia's condition: [12c] MeOH and NH_4Cl as hydrogen donor	trace
4	Huang's condition: [12d] DMSO and H_2O as hydrogen donor	trace
5	Wen's condition: [12e] MeOH as hydrogen donor	trace

[a]Standard condition: graphite felt anode (10 mm × 10 mm × 5 mm), graphite felt cathode (10 mm × 10 mm × 5 mm), undivided cell, constant current = 5 mA, **1a** (0.1 mmol), electrolyte (2.0 eq.), DCE = 4.5 mL, HFIP = 0.5 mL, H_2O = 0.1 mL, 20 ^{o}C, Air, RT, 2 h (3.73 F·mol^{-1}), [b]Isolated yields.

5. Gram-scale reaction

Figure S3. Components required for gram-scale reaction

Figure S4. Typical reaction set up for gram-scale reaction



1a, (5 mmol)

1b, (96%, 1.1g)

To the mixed solution of dichloroethane (90 mL), HFIP (10 mL), and 5 mL water, 1,4-enedione **1a** (5 mmol, 1.0 eq.) and tetrabutylammonium perchlorate (10 mmol, 2.0 eq.) were added. Equipped with graphite felt (20mm × 10mm × 5 mm) as anode, graphite felt (20mm × 10mm × 5 mm) as cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 50 mA at 20 ^{o}C in the Air for 13 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous MgSO$_4$, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate (PE/ EA = 15:1).

Figure S5. Pure product

6. Decagram-scale reaction

Figure S6. Components required for decagram-scale reaction

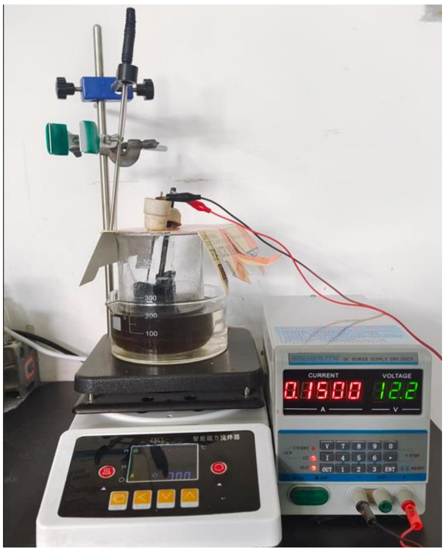
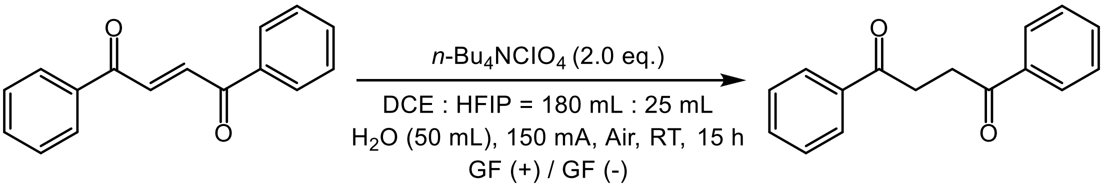


Figure S7. Typical reaction set up for decagram-scale reaction



1a, (50 mmol)

1b, (90%, 10.7g)

To the mixed solution of dichloroethane (180 mL), HFIP (25 mL), and 50 mL water, 1,4-enedione **1a** (50 mmol, 1.0 eq.) and tetrabutylammonium perchlorate (100 mmol, 2.0 eq.) were added. Equipped with graphite felt (40mm × 20mm × 10 mm) as anode, graphite felt (40mm × 20mm × 10 mm) as cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 150 mA at 20 ^{o}C in Air for 15 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate (PE/ EA = 15:1).

Figure S8. Pure product

7. Deuteration gram-scale reaction

Figure S9. Components required for deuteration gram-scale reaction

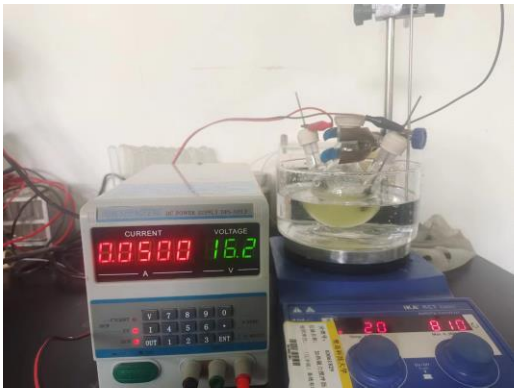
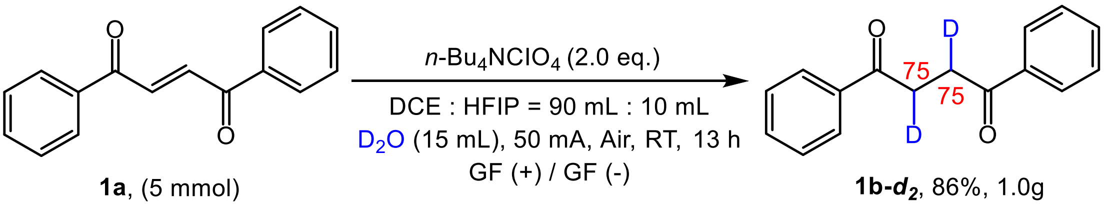


Figure S10. Typical reaction set up for deuteration gram-scale reaction



1a, (5 mmol)

1b-*d*$_2$, 86%, 1.0g

To the mixed solution of dichloroethane (90 mL), HFIP (10 mL), and 15 mL D_2O, 1,4-enedione **1a** (5 mmol, 1.0 eq.) and tetrabutylammonium perchlorate (10 mmol, 2.0 eq.) were added. Equipped with graphite felt (20mm × 10mm × 5 mm) as anode, graphite felt (20mm × 10mm × 5 mm) as cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 50 mA at 20 ^{o}C in Air for 13 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate (PE/ EA = 15:1).

Figure S11. Pure product

8. Cyclic voltammetry study

The cyclic voltammetry experiments were carried out with a computer-controlled electrochemical analyzer for electrochemical measurements. The data was collected with the CS300H potentiostat (Wuhan Coster Instrument Co., LTD).

Working electrode: The working electrode is a 3 mm diameter glassy carbon working electrode. Polished with 0.05 μm aluminum oxide and then sonicated in distilled water and ethanol before measurements.

Reference electrode: The reference electrode is SCE (saturated aqueous KCl) that was washed with water and ethanol before measurements.

Counter electrode: The counter electrode is a platinum wire that was polished with 0.05 μm aluminum oxide and then sonicated in distilled water and ethanol before measurements.

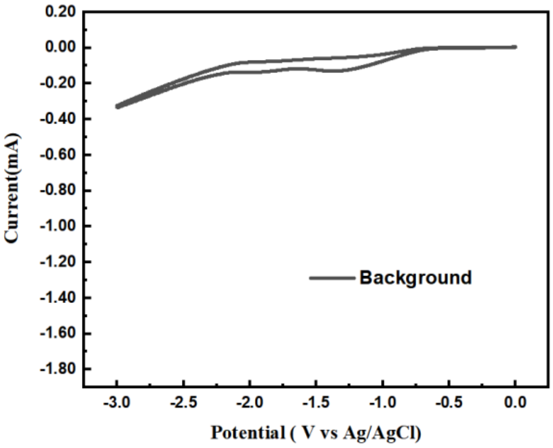


Figure S12. Cyclic voltammogram of **blank** sample

General procedure for cyclic voltammetry (CV): Cyclic voltammogram of **blank** sample was performed in a three-electrode cell at room temperature. The working electrode was a steady glassy carbon, the counter electrode was a platinum wire, and the reference was an Ag/AgCl electrode submerged in saturated aqueous KCl solution. A solution of *n*-Bu_4NClO_4 (0.2 mmol) in 5 mL DCE and 0.1 mL H_2O was subject to cyclic voltammetry experiment. The scan rate was 100 mV/s, ranging from -3.0 V to 0.0 V.

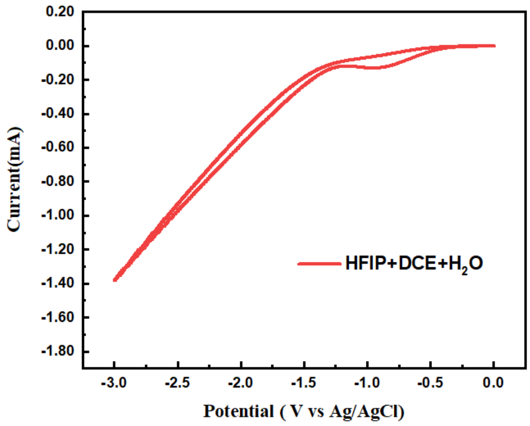


Figure S13. Cyclic voltammogram of HFIP

General procedure for cyclic voltammetry (CV): Cyclic voltammogram of HFIP was performed in a three-electrode cell at room temperature. The working electrode was a steady glassy carbon, the counter electrode was a platinum wire, and the reference was an Ag/AgCl electrode submerged in saturated aqueous KCl solution. A solution of *n*-Bu_4NClO_4 (0.2 mmol) in 4.5 mL DCE, 0.5 mL HFIP and 0.1 mL H_2O was subject to cyclic voltammetry experiment. The scan rate was 100 mV/s, ranging from -3.0 V to 0.0 V.

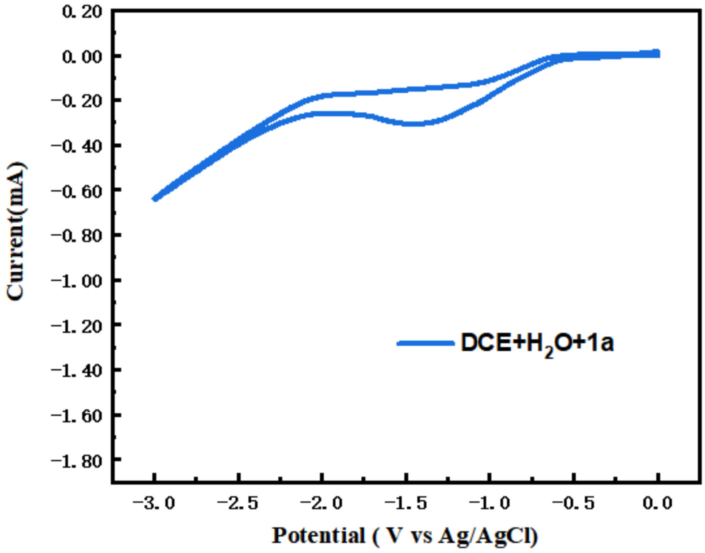


Figure S14. Cyclic voltammogram of **1a**

General procedure for cyclic voltammetry (CV): Cyclic voltammogram of **1a** was performed in a three-electrode cell at room temperature. The working electrode was a steady glassy carbon, the counter electrode was a platinum wire, and the reference was an Ag/AgCl electrode submerged in saturated aqueous KCl solution. A solution of **1a** (0.1 mmol) and *n*-Bu_4NClO_4 (0.2 mmol) in 5.0 mL DCE and 0.1 mL H_2O was subject to cyclic voltammetry experiment. The scan rate was 100 mV/s, ranging from -3.0 V to 0.0 V.

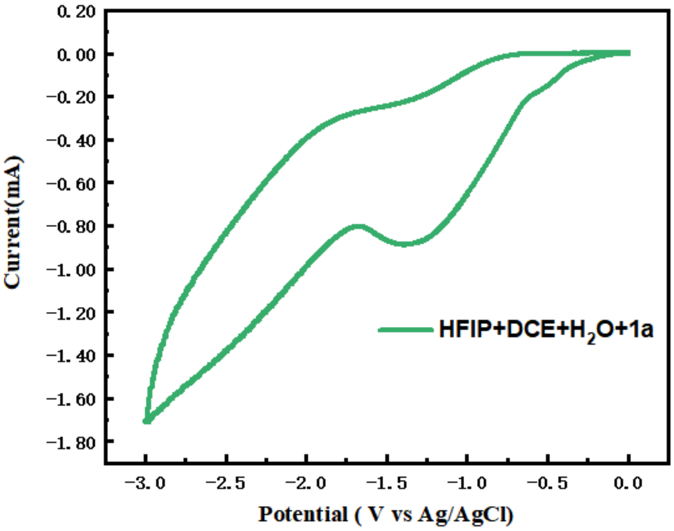


Figure S15. Cyclic voltammograms of **1a** and HFIP

General procedure for cyclic voltammetry (CV): Cyclic voltammograms of **1a** and **HFIP** were performed in a three-electrode cell at room temperature. The working electrode was a steady glassy carbon, the counter electrode was a platinum wire, and the reference was an Ag/AgCl electrode submerged in saturated aqueous KCl solution. A solution of **1a** (0.1 mmol) and *n*-Bu_4NClO_4 (0.2 mmol) in 4.5 mL DCE, 0.5 mL HFIP and 0.1 mL H_2O was subject to cyclic voltammetry experiment. The scan rate was 100 mV/s, ranging from -3.0 V to 0.0 V.

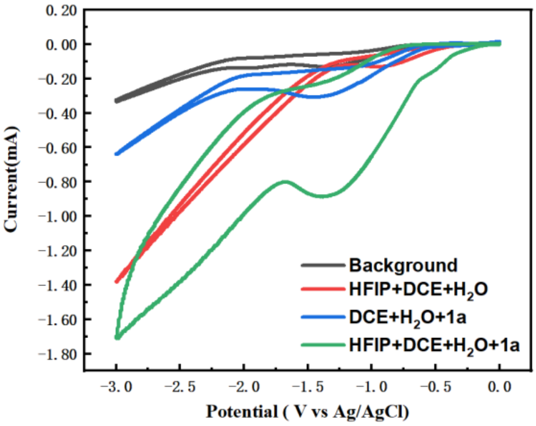
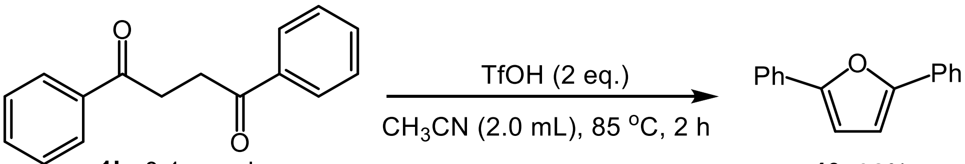


Figure S16. Cyclic voltammograms of HFIP, DCE, H_2O and **1a**

9. Synthetic applications

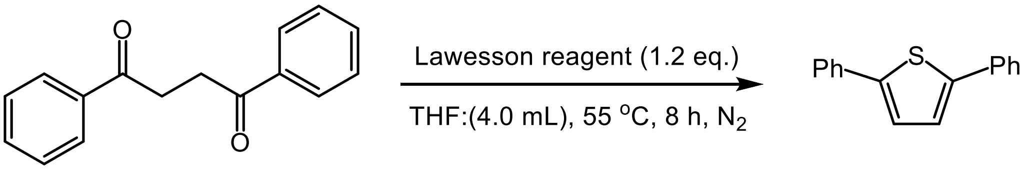
Conversions of 1b to Compounds 40–46, 40-*d*₂, and 41-*d*₂



1b, 0.1 mmol

40, 92%

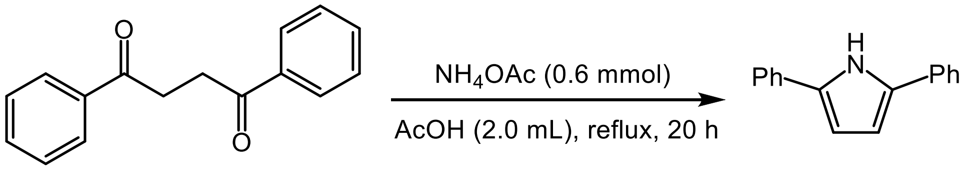
2,5-diphenylfuran (40).[14] To a dry schlenk tube that charged with nitrogen, 1,4-diketone **1b** (0.1 mmol, 24 mg) was added, then freshly distilled CH_3CN (2.0 mL) was injected through a syringe. Subsequently, TfOH (17.3 μL, 0.2 mmol, 30 mg) was added to the mixture, and the resulting solution was stirred at 85 °C for 2 h. Then the resulting solution was cooled to room temperature, and solvent was evaporated under vacuum, the residue was purified by flash column chromatography on silica gel (eluent: PE/ EA= 100:1) to give the furan **40** as a yellow solid (20.3 mg, 92% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.77 (d, *J* = 7.4 Hz, 4H), 7.42 (t, *J* = 7.8 Hz, 4H), 7.29 (t, *J* = 7.3 Hz, 2H), 6.75 (s, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 153.4, 130.8, 128.7, 127.4, 123.7, 107.2.



1b, 0.1 mmol

41, 92%

2,5-diphenylthiophene (41). [14] A schlenk tube was charged under N_2 atmosphere with 1,4-diketones **1b** (0.1 mmol, 24 mg), Lawesson's reagent (0.12 mmol, 49 mg), THF (4 mL), and heated to 55 °C. After 8 h, when the reaction was completed as determined by TLC, 2 g alumina was added and the THF was evaporated. The resulting solid was placed on a short column packed with silica which was eluted with acetonitrile to give **41** as a white solid (21.7 mg, 92% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.6 Hz, 4H), 7.40 (t, *J* = 7.7 Hz, 4H), 7.31 – 7.28 (m, 4H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 143.6, 134.3, 128.9, 127.5, 125.6, 124.0.

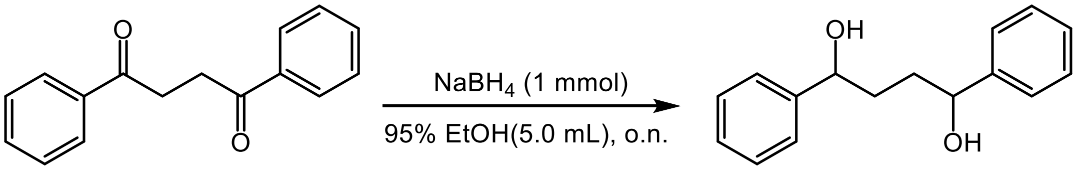


1b, 0.1 mmol

42, 82%

2,5-diphenyl-1H-pyrrole (42).[14] A mixture of 1,4-diketone **1b** (0.1 mmol, 24 mg), ammonium acetate (0.6 mmol, 47 mg), and acetic acid (2 mL) was heated to reflux for 20 h. After cooling, the reaction mixture was poured into ice-water. The formed solid was collected and washed with H_2O and dried to give pure product **42** as a white solid (18.0 mg, 82% yield). **^{1}H NMR** (500 MHz,

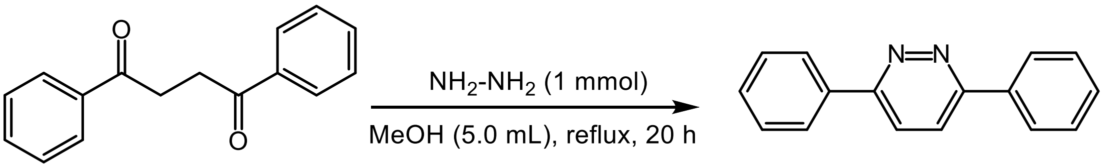
$CDCl_3$) δ 8.55 (s, 1H), 7.51 (d, *J* = 7.7 Hz, 4H), 7.37 (t, *J* = 7.7 Hz, 4H), 7.21 (t, *J* = 7.2 Hz, 2H), 6.57 (d, *J* = 2.6 Hz, 2H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 133.2, 132.5, 129.0, 126.4, 123.8, 108.0.



1b, 0.1 mmol

43, 83%

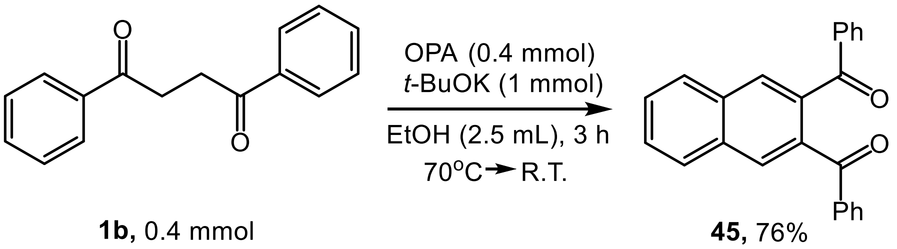
1,4-diphenylbutane-1,4-diol (43).[16] 1,4-diketone **1b** (0.1 mmol, 24 mg) was added to a flask containing ethanol (95%) in an ice bath at 0 °C. $NaBH_4$ (1 mmol, 38 mg) was added and the mixture was kept stirring at 0 °C for 1 h. After that time, the ice bath was removed and the mixture was stirred at room temperature overnight. Water (40 mL) and aqueous HCl (2 M) were added to the mixture until pH 7 was reached. The resulting aqueous phase was washed with ethyl acetate (3 x 20 mL) and the combined organic phases were dried over $MgSO_4$ and filtered off. The organic solvent was removed under vacuum and the residue was purified by column chromatography using petroleum ether and ethyl acetate (9:1 v/v) as eluent. (20.1 mg, 83% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.25 – 7.19 (m, 10H), 4.57 (d, *J* = 4.8 Hz, 1H), 4.53 (d, *J* = 7.7 Hz, 1H), 3.65 (s, 1H), 3.42 (s, 1H), 1.82 – 1.68 (m, 4H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 144.7, 144.6, 128.4, 128.4, 127.4, 127.4, 125.9, 74.4, 74.0, 36.0, 35.0.



1b, 0.2 mmol

44, 60%

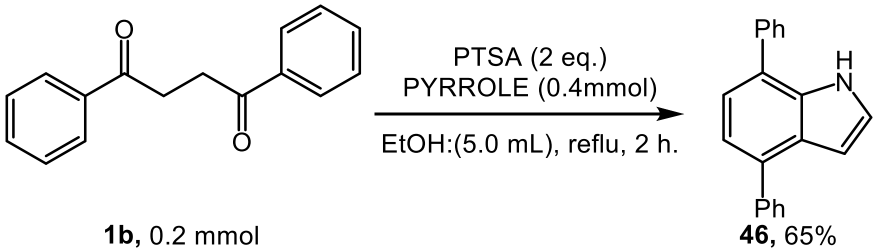
3,6-diphenylpyridazine (44).[17] A hot methanolic solution of 1,4-diketone **1b** (24mg, 0.1 mmol) was dropped in excess hydrazine hydrate (12.5 mg, 0.25 mmol) and the mixture was refluxed at 70 °C in oil bath for 12 hours. After being cooled to room temperature, the mixture was filtered and the residue was washed with methanol to give the desired **44**. (27.9 mg, 60% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.16 (d, *J* = 7.2 Hz, 4H), 7.93 (s, 2H), 7.56 – 7.49 (m, 6H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 157.7, 136.2, 130.0, 129.0, 127.0, 124.2.



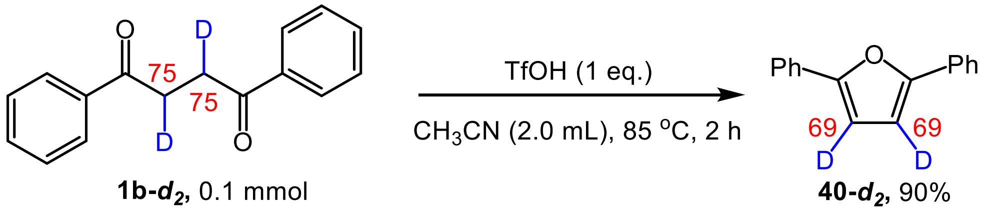
1b, 0.4 mmol

45, 76%

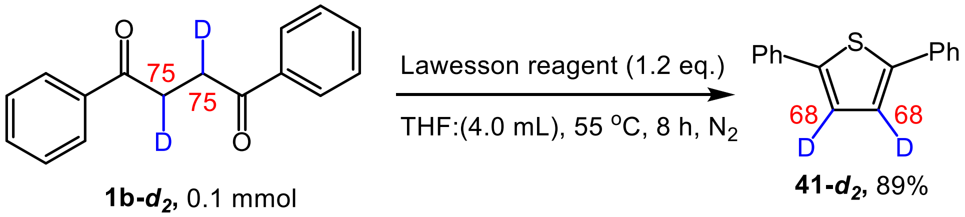
Naphthalene-2,3-diylbis(phenylmethanone) (45).[15] The 1,4-diketone **1b** (0.4 mmol, 95.2 mg) and phthaladehyde (0.4 mmol, 53.7 mg) were dissolved in hot ethanol (5 mL). To this, *t*-BuOK (1 mmol, 1.122 mg) was slowly added and the reaction mixture was stirred for 3 h at room temperature. The solid obtained was filtered and washed with methanol to afford **45** (102.3 mg, 76%) as a colorless solid. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.10 (s, 2H), 7.92 (dd, *J* = 6.2, 3.3 Hz, 2H), 7.84 – 7.82 (m, 4H), 7.64 (dd, *J* = 6.2, 3.3 Hz, 2H), 7.53 (t, *J* = 7.3 Hz, 2H), 7.41 (t, *J* = 7.3 Hz, 4H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 196.4, 137.4, 137.0, 133.0, 133.0, 130.9, 130.0, 128.8, 128.8, 128.4.



4,7-diphenyl-1H-indole (46).[18] Add 1,4-diketone **1b** (0.2 mmol, 48 mg), *p*-toluenesulfonic acid (0.4 mmol, 47 mg), and pyrrole (0.4mmol, 47 mg) to ethanol (5 mL), heat and reflux for 2 hours. Then the resulting solution was cooled to room temperature, and solvent was evaporated under vacuum, the residue was purified by flash column chromatography on silica gel (eluent: PE/ EA = 15:1) to give **46**. (35.0 mg, 65% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.47 (s, 1H), 7.73 (d, *J* = 7.3 Hz, 2H), 7.65 (d, *J* = 7.5 Hz, 2H), 7.49 (dt, *J* = 12.2, 7.6 Hz, 4H), 7.38 (dd, *J* = 13.3, 7.4 Hz, 2H), 7.28 (d, *J* = 2.5 Hz, 2H), 7.21 (dd, *J* = 5.6, 2.8 Hz, 1H), 6.78 – 6.77 (m, 1H). **^{13}C NMR** (125 MHz, $CDCl_3$) δ 140.3, 138.2, 133.2, 133.0, 128.4, 127.9, 127.7, 127.4, 126.6, 126.1, 125.6, 123.9, 123.8, 121.5, 119.5, 101.8.



2,5-diphenylfuran-3,4-d2 (40-d_2). [14] To a dry schlenk tube that charged with nitrogen, 1,4-diphenylbutane-1,4-dione-2,3-d_2 **1b-d_2** (0.1 mmol, 24 mg) was added, then freshly distilled CH_3CN (2.0 mL) was injected through a syringe. Subsequently, TfOH (17.3 μL, 0.2 mmol, 30 mg) was added to the mixture, and the resulting solution was stirred at 85 °C for 2 h. Then the resulting solution was cooled to room temperature, and solvent was evaporated under vacuum, the residue was purified by flash column chromatography on silica gel (eluent: PE/ EA = 100:1) to give the furan **40-d_2** as a yellow solid (20.0 mg, 90% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.74 (d, *J* = 7.6 Hz, 4H), 7.40 (t, *J* = 7.3 Hz, 4H), 7.26 (t, *J* = 7.3 Hz, 2H), 6.73 (s, 1H).



1b-*d*$_2$, 0.1 mmol

41-*d*$_2$, 89%

2,5-diphenylthiophene-3,4-d2 (41-*d*$_2$). [14] A schlenk tube was charged under N_2 atmosphere with 1,4-diphenylbutane-1,4-dione-2,3-*d*$_2$ **1b-*d*$_2$** (0.1 mmol, 24 mg), Lawesson's reagent (0.12 mmol, 49 mg), THF (4 mL), and heated to 55°C. After 8 h, when the reaction was completed as determined by TLC, 2 g alumina was added and the THF was evaporated. The resulting solid was placed on a short column packed with silica which was eluted with acetonitrile to give **41-*d*$_2$** as a white solid (21.2 mg, 89% yield). **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 7.6 Hz, 4H), 7.41 (t, *J* = 7.7 Hz, 4H), 7.31 (t, *J* = 3.8 Hz, 3H).

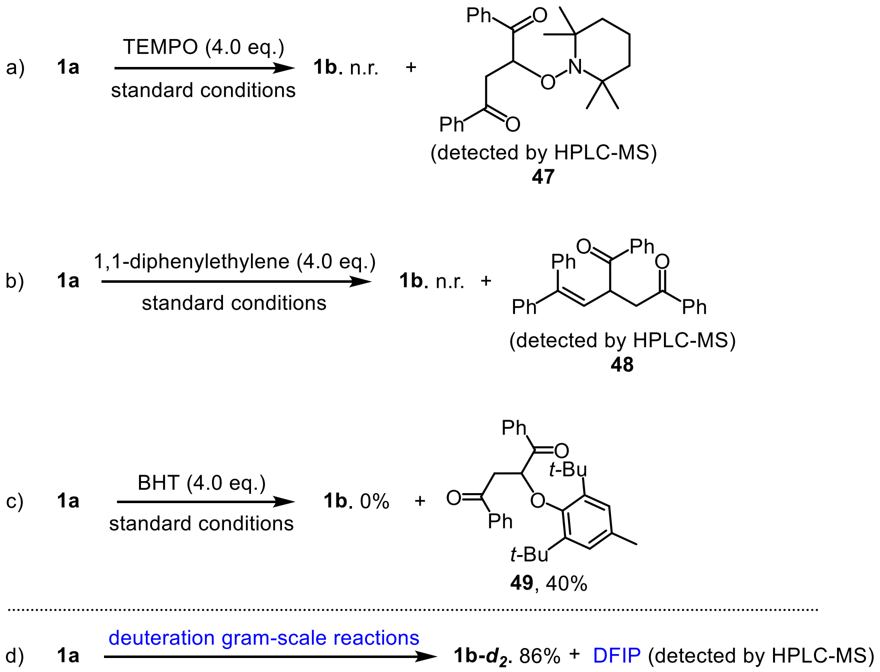
10. Proposed reaction mechanism

1) pH:

Figure S17. **pH** in the decagram-scale reaction water

The water phase is separated after the completion of the decagram-scale reaction, and the measured pH value is 2.10, which is acidic.

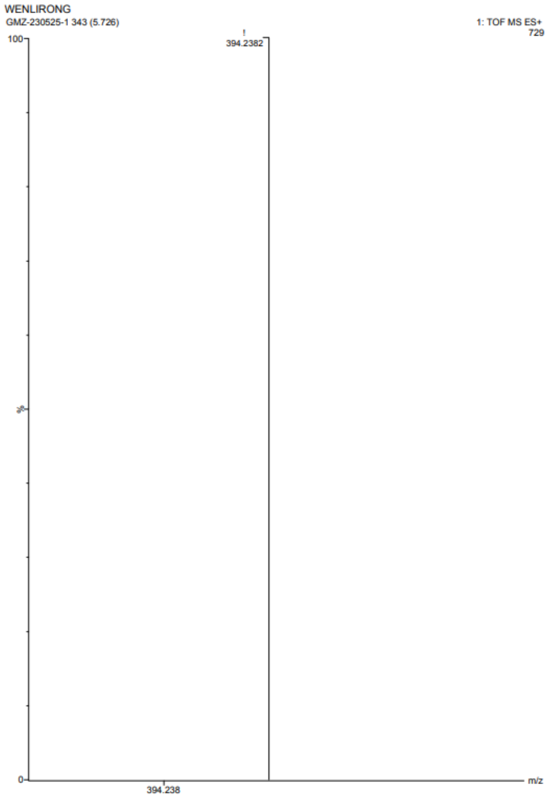
2) Control experiments



Scheme S2. Control experiments

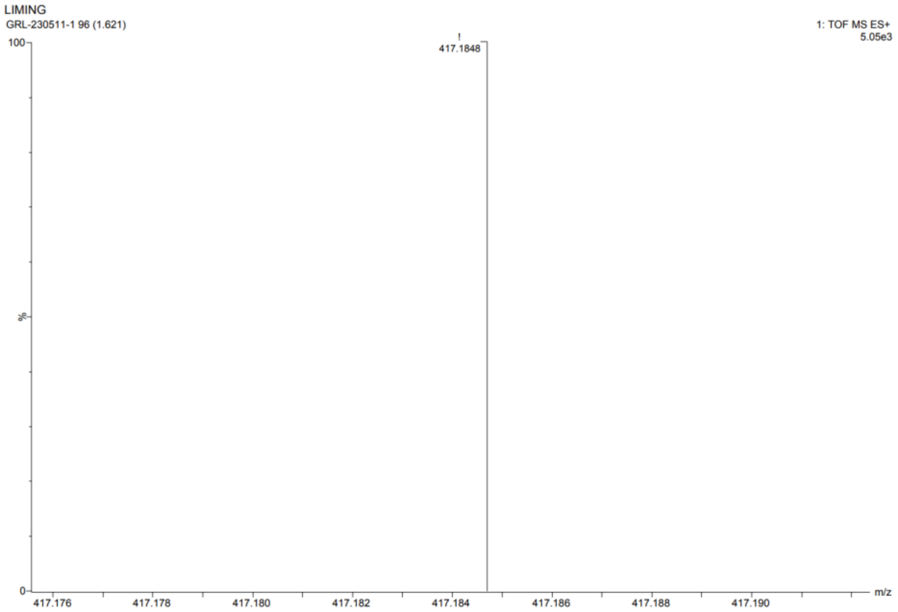
a) To the mixed solution of DCE (4.5 mL), HFIP (0.5 mL) and H_2O (0.1 mL), 1,4-enedione **1a** (0.1 mmol, 1.0 eq.), TEMPO (0.4 mmol, 4.0 eq.) and *n*-Bu_4NClO_4 (0.2 mmol, 2.0 eq.) were added. Equipped with graphite felt (10 × 10 × 5 mm) as anode and graphite felt (10 × 10 × 5 mm) as cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 5 mA at 20 °C in Air for 2 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate. The target product was not obtained, and free radical capture products **47** detected under HRMS.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{25}H_{31}NO_3$ 394.2377, found 394.2382



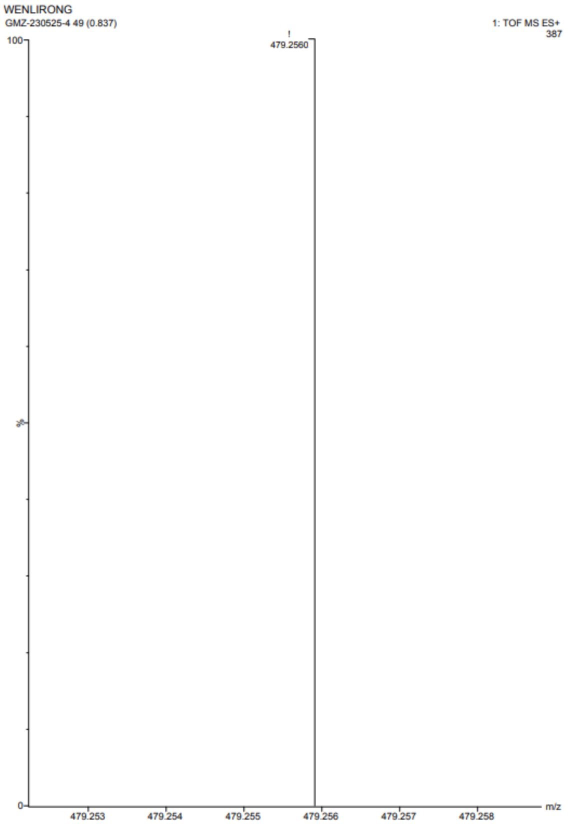
b) To the mixed solution of DCE (4.5 mL), HFIP (0.5 mL) and H_2O (0.1 mL), 1,4-enedione **1a** (0.1 mmol, 1.0 eq.), 1,1-diphenylethylene (0.4 mmol, 4.0 eq.) and *n*-Bu_4NClO_4 (0.2 mmol, 2.0 eq.) were added. Equipped with graphite felt (10 × 10 × 5 mm) as anode and graphite felt (10 × 10 × 5 mm) as cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 5 mA at 20 ^{o}C in Air for 2 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate. The target product was not obtained, and free radical capture products **48** detected under HRMS.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{30}H_{24}O_2$ 417.1849, found 417.1848



c) To the mixed solution of DCE (4.5 mL), HFIP (0.5 mL) and H_2O (0.1 mL), 1,4-enedione **1a** (0.1 mmol, 1.0 eq.), BHT (0.4 mmol, 4.0 eq.) and *n*-Bu_4NClO_4 (0.2 mmol, 2.0 eq.) were added. Equipped with graphite felt (10 × 10 × 5 mm) as anode and graphite felt (10 × 10 × 5 mm) as cathode, non-separating electrolytic cell device. The reaction mixture was stirred at constant current of 5 mA at 20 ^{o}C in Air for 2 hours. After the reaction (monitored by TLC), the reaction system was dried with anhydrous $MgSO_4$, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography and eluted with petroleum ether and ethyl acetate. The target product was not obtained and free radical capture product **49** was obtained in 40% yield. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 8.12 (d, *J* = 7.5 Hz, 2H), 7.83 (d, *J* = 7.1 Hz, 2H), 7.59 (t, *J* = 7.3 Hz, 1H), 7.54 – 7.50 (m, 3H), 7.42 (t, *J* = 7.7 Hz, 2H), 6.70 (d, *J* = 3.0 Hz, 1H), 6.48 (d, *J* = 3.0 Hz, 1H), 4.40 (dd, *J* = 10.0, 3.2 Hz, 1H), 3.55 (dd, *J* = 18.1, 9.9 Hz, 1H), 3.03 (dd, *J* = 18.1, 3.2 Hz, 1H), 1.20 (s, 9H), 1.18 (s, 9H), 1.16 (s, 3H).

HRMS (ESI-TOF, [M + Na$^+$]): calcd for $C_{31}H_{36}O_3$ 479.2557, found 479.2560



d) DFIP detection in the system

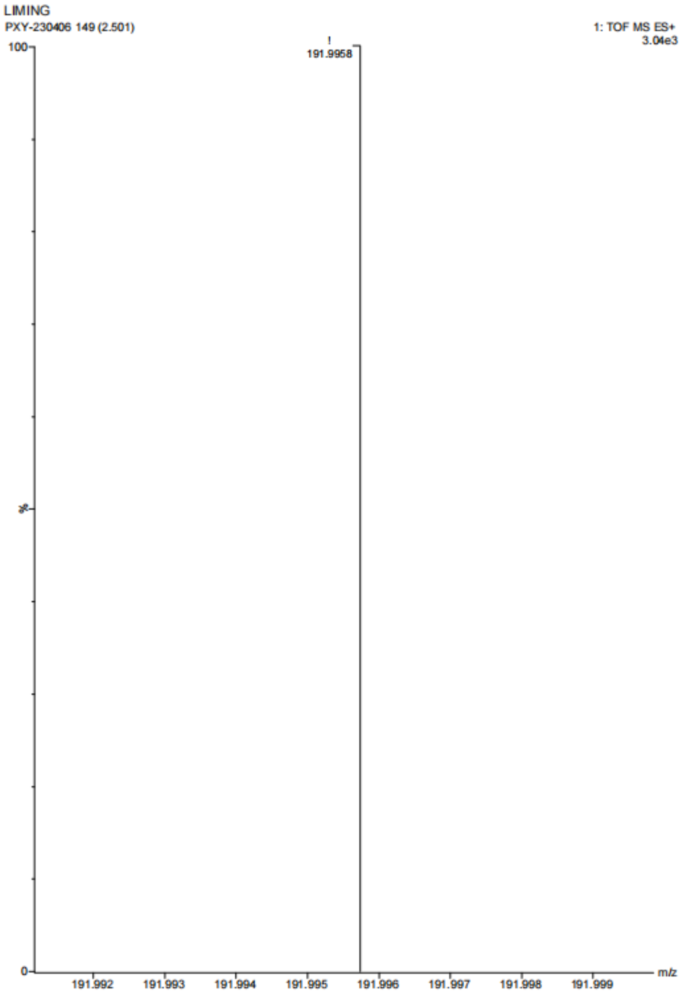
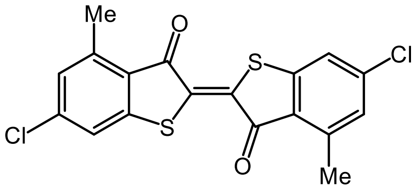


Figure S18. HRMS (ESI-TOF, [M + Na$^+$]) of DFIP

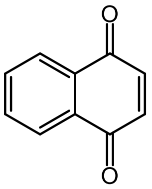
the organic phase was separated in the deuterium gram-scale reaction and perform HRMS testing to obtain [M + Na$^+$] data for DFIP.

HRMS (ESI-TOF, [M + Na$^+$]): calcd for C_3HDF_6O, 191.9965, found 191.9958

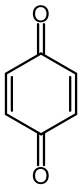
11. Unsuccessful substrates



n.r.



n.r.



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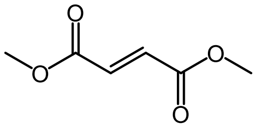

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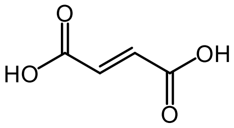

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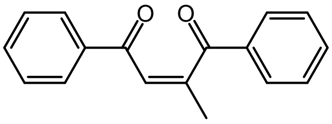

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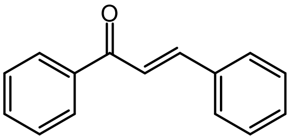
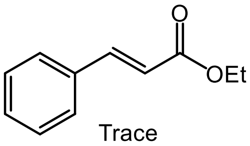


mass



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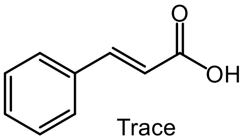

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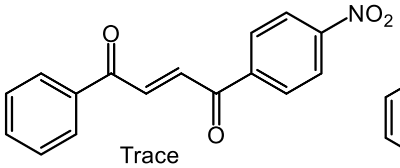

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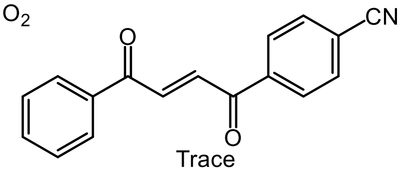

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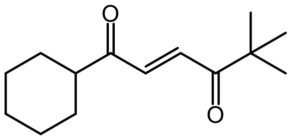

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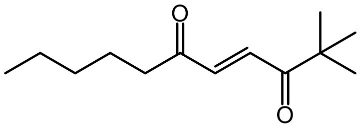

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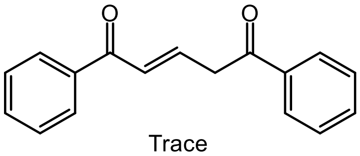
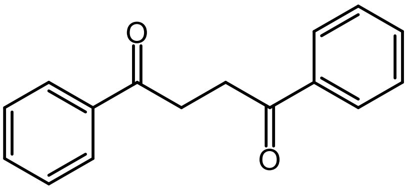


Trace

12. NMR spectra for the obtained compound



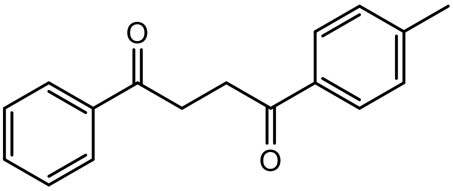
1b

22.9 mg, 96% yield. The spectra matched with the previous report. [1]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.2 Hz, 4H), 7.58 (t, *J* = 7.0 Hz, 2H), 7.48 (t, *J* = 6.8 Hz, 4H), 3.47 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.8, 136.9, 133.3, 128.7, 128.3, 32.7.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{14}O_2$ 239.1067, found 239.1070



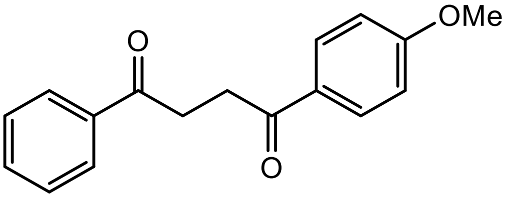
2b

24.0 mg, 95% yield. The spectra matched with the previous report.[2]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.6 Hz, 2H), 7.94 (d, *J* = 8.0 Hz, 2H), 7.57 (t, *J* = 7.3 Hz, 1H), 7.48 (t, *J* = 7.7 Hz, 2H), 7.27 (d, *J* = 8.2 Hz, 2H), 3.44 (d, *J* = 2.2 Hz, 4H), 2.42 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.8, 198.3, 143.9, 136.8, 134.3, 133.1, 129.3, 128.6, 128.2, 128.1, 32.6, 32.5, 21.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{16}O_2$ 253.1223, found 253.1227



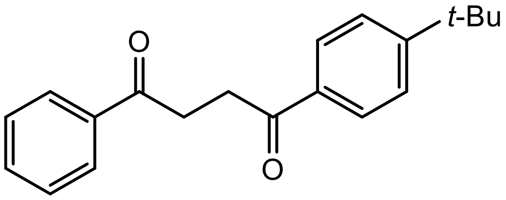
3b

20.9 mg, 78% yield. The spectra matched with the previous report.[2]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (t, *J* = 8.6 Hz, 4H), 7.57 (t, *J* = 7.3 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 6.95 (d, *J* = 8.6 Hz, 2H), 3.87 (s, 3H), 3.52 – 3.16 (m, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.9, 197.2, 163.5, 136.8, 133.1, 130.4, 129.9, 128.6, 128.1, 113.7, 55.5, 32.7, 32.2.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{16}O_3$ 269.1172, found 269.1172



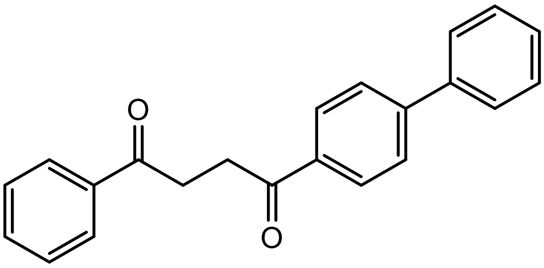
4b

28.3 mg, 96% yield. The spectra matched with the previous report.[9]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.7 Hz, 2H), 7.99 (d, *J* = 8.4 Hz, 2H), 7.57 (t, *J* = 7.3 Hz, 1H), 7.50 – 7.48 (m, 4H), 3.46 (s, 4H), 1.35 (s, 9H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.8, 198.4, 156.9, 136.8, 134.2, 133.1, 128.6, 128.1, 128.1, 125.5, 35.1, 32.7, 32.5, 31.1.

HRMS (ESI-TOF, [M + Na^+]): calcd for $C_{20}H_{22}O_2$ 317.1512, found 317.1514



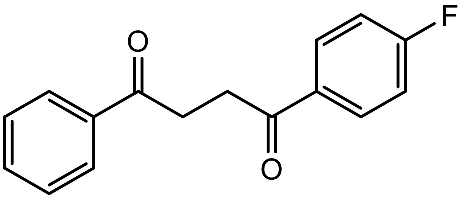
5b

23.6 mg, 75% yield. The spectra matched with the previous report.[10]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.15 (d, *J* = 8.2 Hz, 2H), 8.09 (d, *J* = 7.5 Hz, 2H), 7.74 (d, *J* = 8.1 Hz, 2H), 7.68 (d, *J* = 7.6 Hz, 2H), 7.62 (t, *J* = 7.4 Hz, 1H), 7.52 (q, *J* = 7.4 Hz, 4H), 7.44 (t, *J* = 7.3 Hz, 1H), 3.53 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.7, 198.3, 145.8, 139.9, 136.8, 135.5, 133.2, 129.0, 128.7, 128.6, 128.2, 128.1, 127.3, 127.3, 32.7, 32.6.

HRMS (ESI-TOF, [M + Na^+]): calcd for $C_{22}H_{18}O_2$ 337.1199, found 337.1198



6b

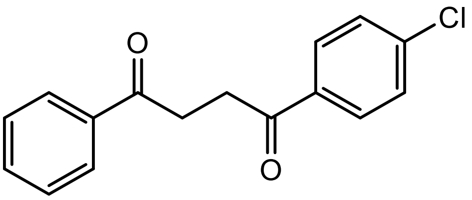
21.5 mg, 84 % yield. The spectra matched with the previous report.[5]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.10 – 8.01 (m, 4H), 7.58 (t, *J* = 7.1 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 2H), 7.15 (t, *J* = 8.5 Hz, 2H), 3.44 (dd, *J* = 14.7, 6.2 Hz, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.6, 197.1, 165.8 (d, *J* = 254.6 Hz), 136.7, 133.2 (d, *J* = 7.8 Hz), 133.2, 130.8 (d, *J* = 9.4 Hz), 128.6, 128.1, 115.7 (d, *J* = 22.0 Hz), 32.6, 32.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.24.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{16}H_{13}FO_2$ 257.0972, found 257.0974



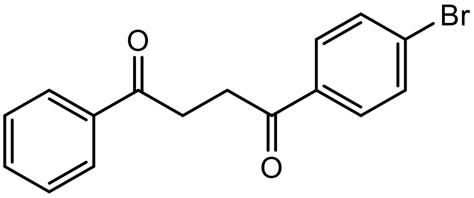
7b

26.2 mg, 96% yield. The spectra matched with the previous report.[5]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (d, *J* = 7.7 Hz, 2H), 7.97 (d, *J* = 7.6 Hz, 2H), 7.57 (d, *J* = 7.2 Hz, 1H), 7.51 – 7.42 (m, 4H), 3.45 (d, *J* = 4.3 Hz, 2H), 3.42 (d, *J* = 5.8 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.5, 197.5, 139.6, 136.7, 135.1, 133.2, 129.6, 128.9, 128.6, 128.1, 32.6, 32.5.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{13}ClO_2$ 273.0677, found 273.0675



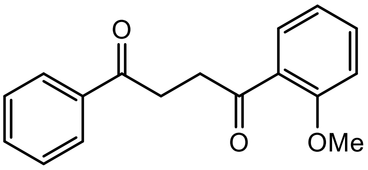
8b

29.8 mg, 94% yield. The spectra matched with the previous report.[7]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (d, *J* = 7.7 Hz, 2H), 7.90 (d, *J* = 8.1 Hz, 2H), 7.62 (d, *J* = 8.6 Hz, 2H), 7.58 (t, *J* = 7.6 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 2H), 3.45 (d, *J* = 5.9 Hz, 2H), 3.41 (d, *J* = 5.5 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.5, 197.7, 136.7, 135.5, 133.2, 131.9, 129.7, 128.6, 128.3, 128.1, 32.5, 32.5.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{13}BrO_2$ 317.0172, found 317.0172



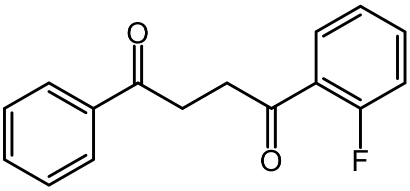
9b

23.6 mg, 88 % yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (d, *J* = 7.6 Hz, 2H), 7.77 (d, *J* = 7.5 Hz, 1H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 3H), 7.04 – 6.95 (m, 2H), 3.92 (s, 3H), 3.46 (d, *J* = 6.0 Hz, 2H), 3.42 (d, *J* = 6.0 Hz, 2H).

^{13}C NMR (125MHz, $CDCl_3$) δ 200.6, 199.1, 158.8, 137.0, 133.6, 133.0, 130.5, 128.6, 128.1, 127.9, 120.7, 111.6, 55.5, 38.0, 33.0.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{16}O_3$ 269.1172, found 269.1178



10b

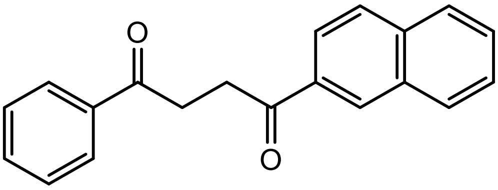
22.0 mg, 86% yield. The spectra matched with the previous report.[7]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.16 – 7.97 (m, 2H), 7.90 (td, *J* = 7.6, 1.9 Hz, 1H), 7.61 – 7.48 (m, 4H), 7.26 – 7.19 (m, 1H), 7.19 – 7.09 (m, 1H), 3.45 (d, *J* = 2.0 Hz, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.6, 197.1 (d, *J* = 4.0 Hz), 162.1 (d, *J* = 254.8 Hz), 136.9, 134.7 (d, *J* = 9.0 Hz), 133.2, 130.8 (d, *J* = 2.6 Hz), 128.7, 128.2, 125.6, 125.5, 124.5 (d, *J* = 3.4 Hz), 116.7 (d, *J* = 23.9 Hz), 37.5, 37.5, 32.7 (d, *J* = 2.2 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -108.96.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{13}FO_2$ 257.0972, found 257.0976



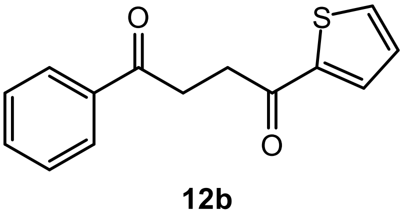
11b

19.3 mg, 67% yield. The spectra matched with the previous report.[5]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (s, 1H), 8.08 (t, *J* = 9.3 Hz, 3H), 7.99 (d, *J* = 8.0 Hz, 1H), 7.93 – 7.85 (m, 2H), 7.63 – 7.53 (m, 3H), 7.49 (t, *J* = 7.6 Hz, 2H), 3.61 (t, *J* = 6.3 Hz, 2H), 3.52 (t, *J* = 6.4 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.8, 198.6, 136.8, 135.7, 134.1, 133.2, 132.6, 129.9, 129.6, 128.6, 128.5, 128.2, 127.8, 126.8, 123.9, 32.7, 32.7.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{20}H_{16}O_2$ 289.1223, found 289.1224



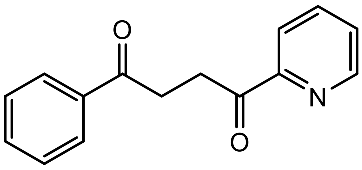
12b

13.2 mg, 54% yield. The spectra matched with the previous report.[5]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 (d, *J* = 7.7 Hz, 2H), 7.83 (d, *J* = 3.8 Hz, 1H), 7.64 (d, *J* = 5.0 Hz, 1H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.15 (t, *J* = 4.4 Hz, 1H), 3.45 (d, *J* = 5.9 Hz, 2H), 3.41 (d, *J* = 5.8 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.6, 191.7, 144.1, 136.8, 133.7, 133.3, 132.2, 128.8, 128.3, 33.3, 32.8.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{14}H_{12}O_2S$ 245.0631, found 245.0631



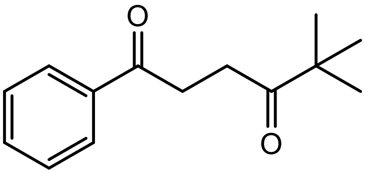
13b

15.3 mg, 64% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.71 (d, *J* = 4.7 Hz, 1H), 8.04 (t, *J* = 6.7 Hz, 3H), 7.83 (t, *J* = 7.5 Hz, 1H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.7 Hz, 3H), 3.69 (t, *J* = 6.3 Hz, 2H), 3.47 (t, *J* = 6.3 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.5, 196.6, 151.3, 147.0, 134.9, 134.8, 131.0, 126.5, 126.1, 125.1, 119.8, 30.7, 30.0.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{15}H_{13}NO_2$ 240.1019, found 240.1019



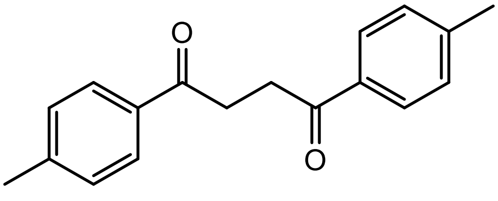
14b

18.8 mg, 86% yield. The spectra matched with the previous report.[7]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (d, *J* = 7.0 Hz, 2H), 7.54 (t, *J* = 7.3 Hz, 1H), 7.45 (t, *J* = 7.7 Hz, 2H), 3.24 (t, *J* = 6.3 Hz, 2H), 2.96 (t, *J* = 6.3 Hz, 2H), 1.21 (s, 9H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 214.7, 199.0, 136.9, 133.1, 128.6, 128.1, 44.1, 32.4, 30.8, 26.6.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{14}H_{18}O_2$ 219.1380, found 219,1383



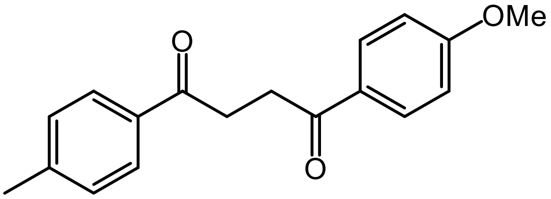
15b

20.8 mg, 78 % yield. The spectra matched with the previous report.[4]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.0 Hz, 4H), 7.30 (d, *J* = 8.1 Hz, 4H), 3.46 (s, 4H), 2.45 (s, 6 H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.5, 143.9, 134.3, 129.3, 128.3, 32.5, 21.7.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{18}H_{18}O_2$ 267.1380, found 267.1380



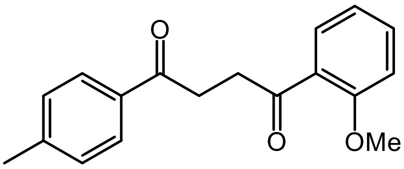
16b

22.0 mg, 78% yield. The spectra matched with the previous report.[4]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.7 Hz, 2H), 7.94 (d, *J* = 8.1 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 6.97 – 6.92 (m, 2H), 3.87 (s, 3H), 3.46 – 3.37 (m, 4H), 2.41 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.5, 197.3, 163.5, 143.9, 134.4, 130.4, 130.0, 129.3, 128.2, 113.7, 55.5, 32.6, 32.3, 21.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{18}H_{18}O_3$ 283.1329, found 283.1331



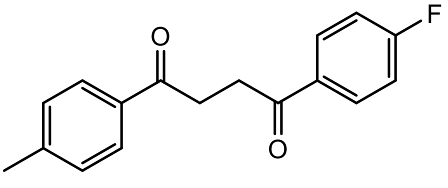
17b

22.0 mg, 78% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.4 Hz, 2H), 7.79 – 7.74 (m, 1H), 7.49 – 7.43 (m, 1H), 7.29 – 7.24 (m, 2H), 7.04 – 6.95 (m, 2H), 3.92 (s, 3H), 3.44 (d, *J* = 6.2 Hz, 2H), 3.39 (d, *J* = 5.8 Hz, 2H), 2.41 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 200.8, 198.7, 158.8, 143.7, 134.5, 133.5, 130.5, 129.2, 128.2, 128.0, 120.6, 111.6, 55.5, 38.0, 32.9, 21.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{18}H_{18}O_3$ 283.1329, found 283.1327



18b

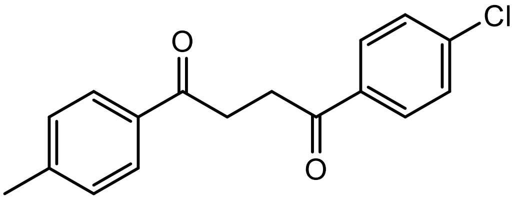
19.2 mg, 71% yield.

^{1}H NMR (500 MHz, CDCl3) δ 8.13 – 8.06 (m, 2H), 7.96 (d, *J* = 8.0 Hz, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 7.17 (t, *J* = 8.6 Hz, 2H), 3.46 – 3.44 (m, 4H), 2.44 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 196.2, 195.2, 163.8 (d, *J* = 254.5 Hz), 142.0, 132.3, 131.3 (d, *J* = 3.1 Hz), 128.7 (d, *J* = 9.4 Hz), 127.3, 126.2, 113.6 (d, *J* = 21.9 Hz), 30.5, 19.6.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.33.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{15}FO_2$ 271.1129, found 271.1130



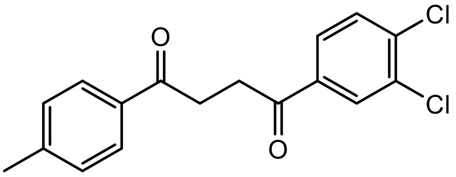
19b

22.1 mg, 77% yield. The spectra matched with the previous report.[8]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.98 (d, *J* = 8.5 Hz, 2H), 7.93 (d, *J* = 8.2 Hz, 2H), 7.45 (d, *J* = 8.6 Hz, 2H), 7.27 (d, *J* = 8.1 Hz, 2H), 3.47 – 3.37 (m, 4H), 2.42 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.1, 196.6, 143.0, 138.5, 134.1, 133.2, 128.5, 128.3, 127.9, 127.2, 31.5, 31.4, 20.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{15}ClO_2$ 287.0833, found 287.0830



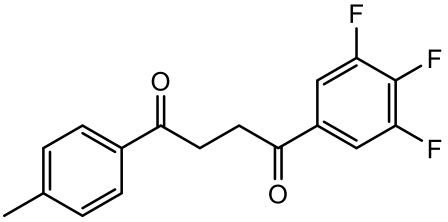
20b

26.3 mg, 82% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 (d, *J* = 2.0 Hz, 1H), 7.92 (d, *J* = 8.1 Hz, 2H), 7.86 (dd, *J* = 8.3, 2.1 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.28 (d, *J* = 8.0 Hz, 2H), 3.44 (d, *J* = 6.2 Hz, 2H), 3.38 (d, *J* = 6.2 Hz, 2H), 2.42 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.9, 196.7, 144.1, 137.7, 136.4, 134.1, 133.3, 130.7, 130.2, 129.3, 128.2, 127.2, 32.6, 32.4, 21.7.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{14}C_{l2}O_2$ 321.0444, found 321.0444



21b

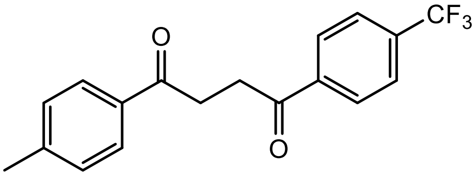
25.7 mg, 84% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.0 Hz, 2H), 7.68 (t, *J* = 7.1 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 3.45 (t, *J* = 6.1 Hz, 2H), 3.33 (t, *J* = 6.2 Hz, 2H), 2.42 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.7, 195.4, 152.2 (d, *J* = 10.9 Hz), 150.2 (d, *J* = 7.0 Hz), 144.2, 142.2 (d, *J* = 15.5 Hz), 134.0, 132.4 (d, *J* = 4.9 Hz), 129.3, 128.2, 125.6, 112.8 (d, *J* = 5.4 Hz), 112.6 (d, *J* = 5.3 Hz), 32.5, 32.3, 21.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ -137.01, -137.07, -157.18, -157.24, -157.29.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{13}F_3O_2$ 307.0940, found 307.0946



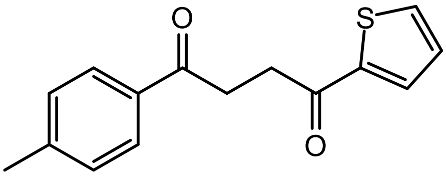
22b

22.4 mg, 70% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.0 Hz, 2H), 7.93 (d, *J* = 7.9 Hz, 2H), 7.75 (d, *J* = 8.0 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 3.47 – 3.45 (m, 4H), 2.42 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.0, 144.1, 139.5, 134.5, 134.3, 134.1, 129.3, 128.5, 128.2, 125.7, 125.7, 124.7, 122.5, 32.8, 32.5, 21.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{18}H_{15}F_3O_2$ 321.1097, found 321.1096



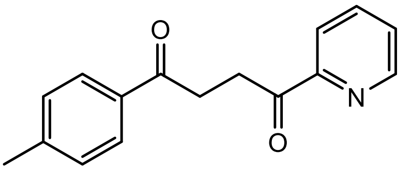
23b

17.6 mg, 68% yield. The spectra matched with the previous report.[5]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.95 (d, *J* = 8.0 Hz, 2H), 7.86 (d, *J* = 3.8 Hz, 1H), 7.66 (d, *J* = 5.0 Hz, 1H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.17 (t, *J* = 4.4 Hz, 1H), 3.44 (dd, *J* = 16.9, 5.5 Hz, 4H), 2.44 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.1, 191.8, 144.0, 144.0, 134.2, 133.5, 132.0, 129.3, 128.2, 128.1, 33.2, 32.5, 21.7.

HRMS (ESI-TOF, [M + H$^+$]): calcd for, found $C_{15}H_{14}O_2S$ 259.0787, found 259.0787



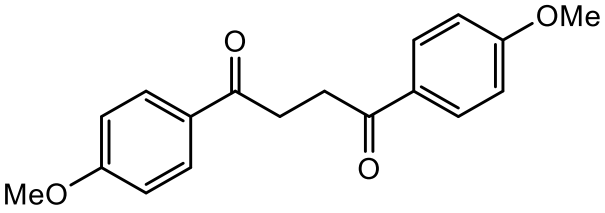
24b

22.0 mg, 87% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.71 (d, *J* = 4.4 Hz, 1H), 8.04 (d, *J* = 7.8 Hz, 1H), 7.93 (d, *J* = 8.2 Hz, 2H), 7.85 – 7.82 (m, 1H), 7.49 – 7.46 (m, 1H), 7.27 (d, *J* = 5.8 Hz, 2H), 3.68 (t, *J* = 6.3 Hz, 2H), 3.45 (t, *J* = 6.3 Hz, 2H), 2.42 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 200.6, 198.3, 153.3, 149.0, 143.8, 136.8, 134.4, 129.2, 128.2, 127.1, 121.8, 32.6, 32.0, 21.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{15}NO_2$ 254.1176, found 254.1176



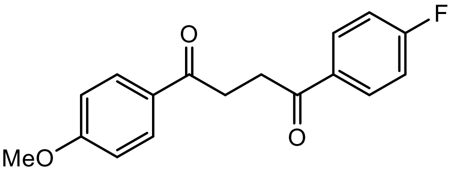
25b

19.7 mg, 66 % yield. The spectra matched with the previous report.[3]

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.02 (d, *J* = 8.5 Hz, 4H), 6.95 (d, *J* = 8.5 Hz, 4H), 3.87 (s, 6H), 3.40 (s, 4H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 197.4, 163.5, 130.4, 130.0, 113.7, 55.5, 32.3.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{18}H_{18}O_4$ 299.1278, found 299.1282



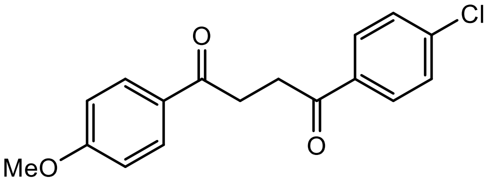
26b

22.0 mg, 77% yield. The spectra matched with the previous report.[4]

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.09 – 8.04 (m, 2H), 8.01 (d, *J* = 8.9 Hz, 2H), 7.18 – 7.10 (m, 2H), 6.99 – 6.90 (m, 2H), 3.87 (s, 3H), 3.41 (d, *J* = 2.4 Hz, 4H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 197.3, 197.1, 166.8, 164.8, 163.6, 133.3, 130.8, 130.7, 130.4, 129.8, 115.8, 115.6, 113.8, 55.5, 32.5, 32.2.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{15}FO_3$ 287.1078, found 287.1078



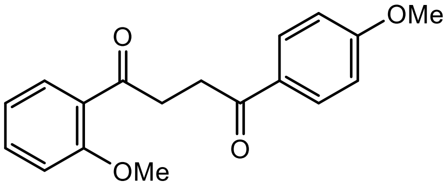
27b

22.4 mg, 74% yield. The spectra matched with the previous report.[4]

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.02 – 7.97 (m, 4H), 7.45 (d, *J* = 8.6 Hz, 2H), 6.95 (d, *J* = 9.0 Hz, 2H), 3.88 (s, 3H), 3.42 – 3.40 (m, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 197.7, 197.0, 163.6, 139.5, 135.2, 130.4, 129.8, 129.6, 128.9, 113.8, 55.5, 32.6, 32.2.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{17}H_{15}ClO_3$ 303.0782, found 303.0785



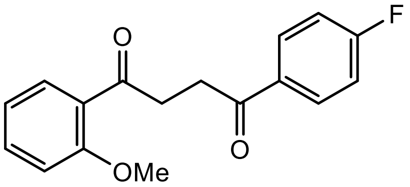
28b

23.0 mg, 77% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.8 Hz, 2H), 7.77 – 7.75 (m, 1H), 7.48 – 7.44 (m, 1H), 7.03 – 6.91 (m, 4H), 3.91 (s, 3H), 3.86 (s, 3H), 3.44 (t, *J* = 6.3 Hz, 2H), 3.36 (t, *J* = 6.1 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 200.9, 197.6, 163.4, 158.8, 133.5, 130.5, 130.4, 130.1, 128.0, 120.6, 113.7, 111.6, 55.5, 55.5, 38.0, 32.6.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{18}H_{18}O_4$ 299.1278, found 299.1282



29b

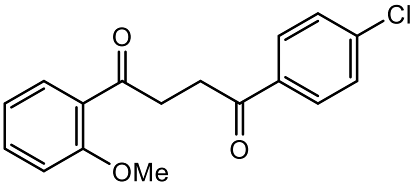
21.8 mg, 76% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 8.04 (m, 2H), 7.77 – 7.75 (m, 1H), 7.49 – 7.45 (m, 1H), 7.13 (t, *J* = 8.6 Hz, 2H), 7.02 – 6.97 (m, 2H), 3.92 (s, 3H), 3.46 (t, *J* = 6.3 Hz, 2H), 3.37 (t, *J* = 6.3 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 200.5, 197.5, 165.7 (d, *J* = 254.3 Hz), 158.9, 133.7, 133.4 (d, *J* = 3.1 Hz), 130.7 (d, *J* = 9.4 Hz), 130.5, 127.7, 120.7, 115.6 (d, *J* = 21.8 Hz), 111.6, 55.5, 37.9, 32.9.

^{19}F NMR (376 MHz, $CDCl_3$) δ -104.51.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{17}H_{15}FO_3$ 287.1078, found 287.1180



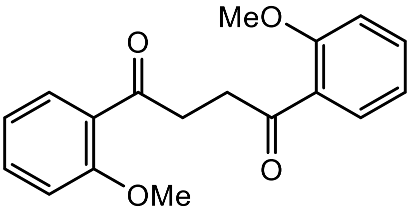
30b

23.0 mg, 76% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.5 Hz, 2H), 7.77 – 7.75 (m, 1H), 7.51 – 7.45 (m, 1H), 7.44 (d, *J* = 8.5 Hz, 2H), 7.04 – 6.95 (m, 2H), 3.92 (s, 3H), 3.46 (t, *J* = 6.3 Hz, 2H), 3.36 (t, *J* = 6.4 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 200.4, 197.9, 158.9, 139.4, 135.3, 133.7, 130.5, 129.6, 128.9, 127.7, 120.7, 111.6, 55.5, 37.9, 32.9.

HRMS (ESI-TOF, [M + H^+]): calcd for $C_{17}H_{15}ClO_3$ 303.0782, found 303.0792



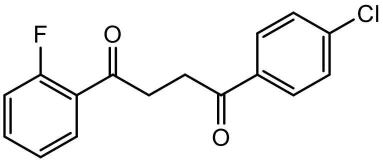
31b

26.0 mg, 87 % yield. The spectra matched with the previous report.[12]

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.75 (d, *J* = 7.7 Hz, 2H), 7.46 (t, *J* = 7.1 Hz, 2H), 6.99 (q, *J* = 9.6, 9.1 Hz, 4H), 3.91 (s, 6H), 3.41 (s, 4H).

^{13}C NMR (125MHz, CDCl$_3$) δ 201.2, 158.7, 133.4, 130.4, 128.2, 120.6, 111.5, 55.5, 38.3.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{18}H_{18}O_4$ 299.1278, found 299.1281



32b

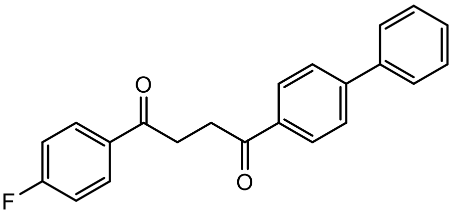
20.9 mg, 76% yield. The spectra matched with the previous report.[13]

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.97 (d, *J* = 8.4 Hz, 2H), 7.91 – 7.88 (m, 1H), 7.57 – 7.49 (m, 1H), 7.45 (d, *J* = 8.4 Hz, 1H), 7.24 (t, *J* = 7.6 Hz, 1H), 7.16 (dd, *J* = 11.3, 8.3 Hz, 1H), 3.45 (dd, *J* = 6.3, 3.2 Hz, 1H), 3.41 (d, *J* = 5.9 Hz, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 197.3, 196.8 (d, *J* = 4.1 Hz), 162.1 (d, *J* = 254.9 Hz), 139.5, 135.1, 134.7 (d, *J* = 9.1 Hz), 130.7 (d, *J* = 2.7 Hz), 129.6, 128.9, 125.4, 125.2, 124.5 (d, *J* = 3.4 Hz), 116.7 (d, *J* = 23.8 Hz), 37.4 (d, *J* = 8.5 Hz), 32.5.

^{19}F NMR (376 MHz, CDCl$_3$) δ -108.87.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{12}ClFO_2$ 291.0583, found 291.0583



33b

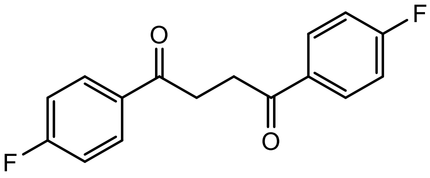
25.3 mg, 76% yield.

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.12 – 8.06 (m, 4H), 7.71 (d, *J* = 8.1 Hz, 2H), 7.64 (d, *J* = 7.2 Hz, 2H), 7.48 (t, *J* = 7.6 Hz, 2H), 7.41 (t, *J* = 7.3 Hz, 1H), 7.15 (t, *J* = 8.5 Hz, 2H), 3.48 (d, *J* = 5.5 Hz, 2H), 3.45 (d, *J* = 5.4 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.2, 197.1, 165.8 (d, *J* = 254.7 Hz), 145.9, 139.9, 135.4, 133.3 (d, *J* = 3.1 Hz), 130.8 (d, *J* = 9.2 Hz), 129.0, 128.7, 128.3, 127.3 (d, *J* = 2.4 Hz), 115.7 (d, *J* = 21.9 Hz), 32.6, 32.5.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.22.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{22}H_{17}FO_2$ 333.1285, found 333.1289



34b

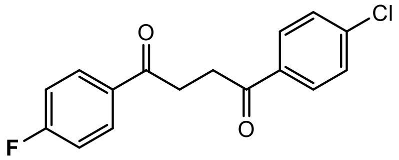
22.5 mg, 82% yield. The spectra matched with the previous report.[4]

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 8.05 (m, 4H), 7.15 (t, *J* = 8.5 Hz, 4H), 3.42 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.0, 165.8 (d, *J* = 254.9 Hz), 133.2, 130.8 (d, *J* = 9.4 Hz), 115.7 (d, *J* = 21.9 Hz), 32.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.11.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{12}F_2O_2$ 275.0878, found 275.0878



35b

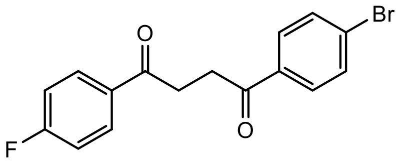
23.3 mg, 80% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.07 – 8.04 (m, 2H), 7.97 (d, *J* = 8.6 Hz, 2H), 7.45 (d, *J* = 8.6 Hz, 2H), 7.15 (t, *J* = 8.6 Hz, 2H), 3.42 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.4, 196.9, 165.9 (d, *J* = 254.8 Hz), 139.7, 135.0, 133.1, 130.8 (d, *J* = 9.2 Hz), 129.5, 128.9, 115.7 (d, *J* = 22.0 Hz), 32.5, 32.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.06.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{12}ClFO_2$ 291.0583, found 291.0588



36b

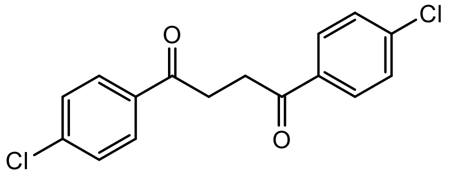
29.8 mg, 89% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.05 (dd, *J* = 8.7, 5.6 Hz, 2H), 7.89 (d, *J* = 8.5 Hz, 2H), 7.62 (d, *J* = 8.6 Hz, 2H), 7.14 (t, *J* = 8.6 Hz, 2H), 3.41 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.6, 196.9, 165.9 (d, *J* = 254.8 Hz), 135.4, 133.1 (d, *J* = 3.1 Hz), 131.9, 130.8 (d, *J* = 9.2 Hz), 129.7, 128.4, 115.7 (d, *J* = 22.0 Hz), 32.5, 32.4.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.04.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{12}BrFO_2$ 335.0077, found 335.0076



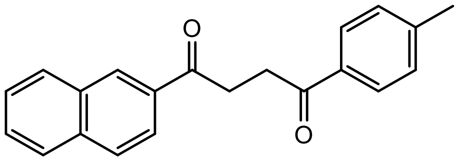
37b

29.5 mg, 96% yield. The spectra matched with the previous report.[4]

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.6 Hz, 4H), 7.45 (d, *J* = 8.6 Hz, 4H), 3.42 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 197.3, 139.7, 135.0, 129.5, 129.0, 32.5.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{12}C_{l2}O_2$ 307.0287, found 307.0287



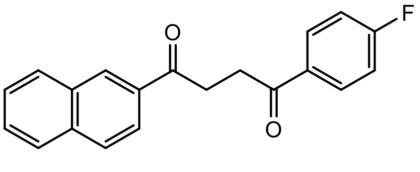
38b

21.2 mg, 70% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (s, 1H), 8.08 (d, *J* = 8.4 Hz, 1H), 7.99 – 7.96 (m, 3H), 7.90 (dd, *J* = 12.4, 8.3 Hz, 2H), 7.58 (dt, *J* = 22.7, 7.0 Hz, 2H), 7.29 (d, *J* = 7.9 Hz, 2H), 3.60 (t, *J* = 6.4 Hz, 2H), 3.50 (t, *J* = 6.4 Hz, 2H), 2.43 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.8, 198.4, 144.0, 135.7, 134.3, 134.2, 132.6, 129.9, 129.6, 129.3, 128.4, 128.3, 127.8, 126.7, 123.9, 32.7, 32.6, 21.7.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{21}H_{18}O_2$ 303.1380, found 303.1383



39b

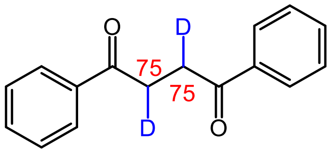
20.5 mg, 67% yield.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.59 (s, 1H), 8.11 – 8.07 (m, 3H), 7.99 (d, *J* = 8.0 Hz, 1H), 7.92 – 7.88 (m, 2H), 7.63 – 7.55 (m, 2H), 7.16 (t, *J* = 8.6 Hz, 2H), 3.61 (t, *J* = 6.3 Hz, 2H), 3.48 (t, *J* = 6.3 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.5, 197.2, 165.8 (d, *J* = 254.8 Hz), 135.7, 134.0, 133.2, 132.5, 130.8 (d, *J* = 9.3 Hz), 129.9, 129.6, 128.5 (d, *J* = 3.3 Hz), 127.8, 126.8, 123.8, 115.7 (d, *J* = 21.9 Hz), 32.7, 32.6.

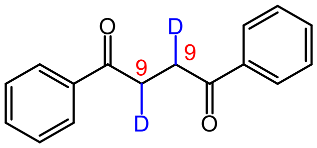
^{19}F NMR (376 MHz, $CDCl_3$) δ -105.20.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{20}H_{15}FO_2$ 307.1129, found 307.1133



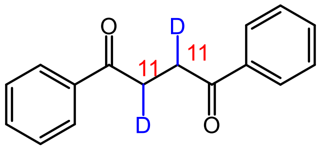
1b-d_2

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.2 Hz, 4H), 7.58 (t, *J* = 7.4 Hz, 2H), 7.48 (t, *J* = 7.6 Hz, 4H), 3.47 – 3.43 (m, 2.66H).



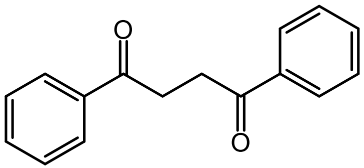
[9% D]**1b-d_2**

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.8 Hz, 4H), 7.58 (t, *J* = 7.4 Hz, 2H), 7.48 (t, *J* = 7.4 Hz, 4H), 3.47 (s, 3.83H).



[11% D]**1b-d_2**

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.04 (d, *J* = 7.4 Hz, 4H), 7.58 (t, *J* = 7.4 Hz, 2H), 7.48 (t, *J* = 7.6 Hz, 4H), 3.47 (s, 3.79H).



1b-gram-scale

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 (d, *J* = 7.4 Hz, 4H), 7.61 (t, *J* = 7.3 Hz, 2H), 7.52 (t, *J* = 7.8 Hz, 4H), 3.51 (s, 4H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 198.7, 136.8, 133.2, 128.6, 128.1, 32.6.

HRMS (ESI-TOF, [M + H$^+$]): calcd for $C_{16}H_{14}O_2$ 239.1067, found 239.1066

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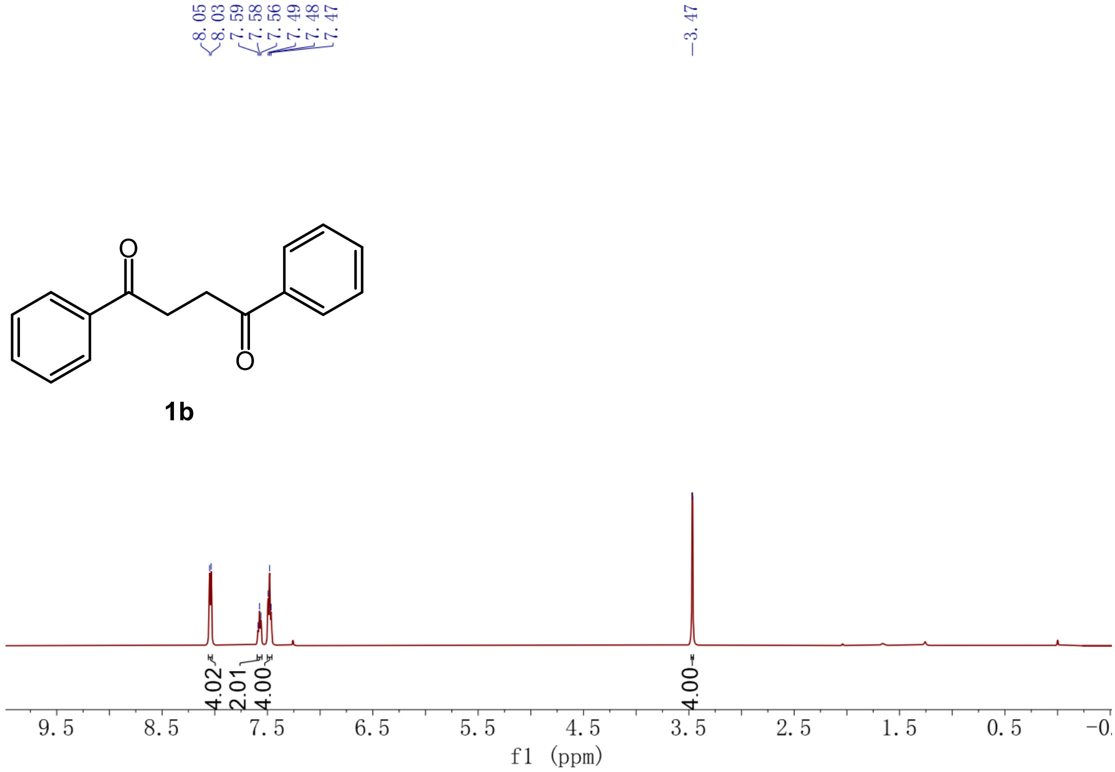
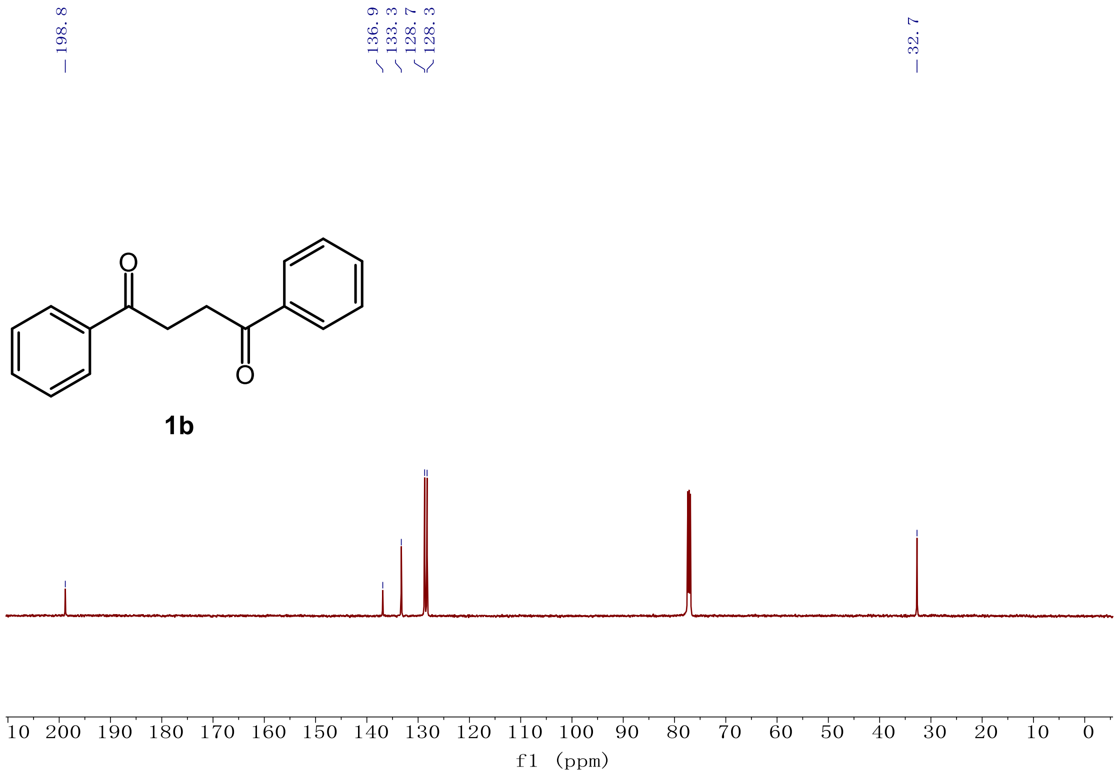
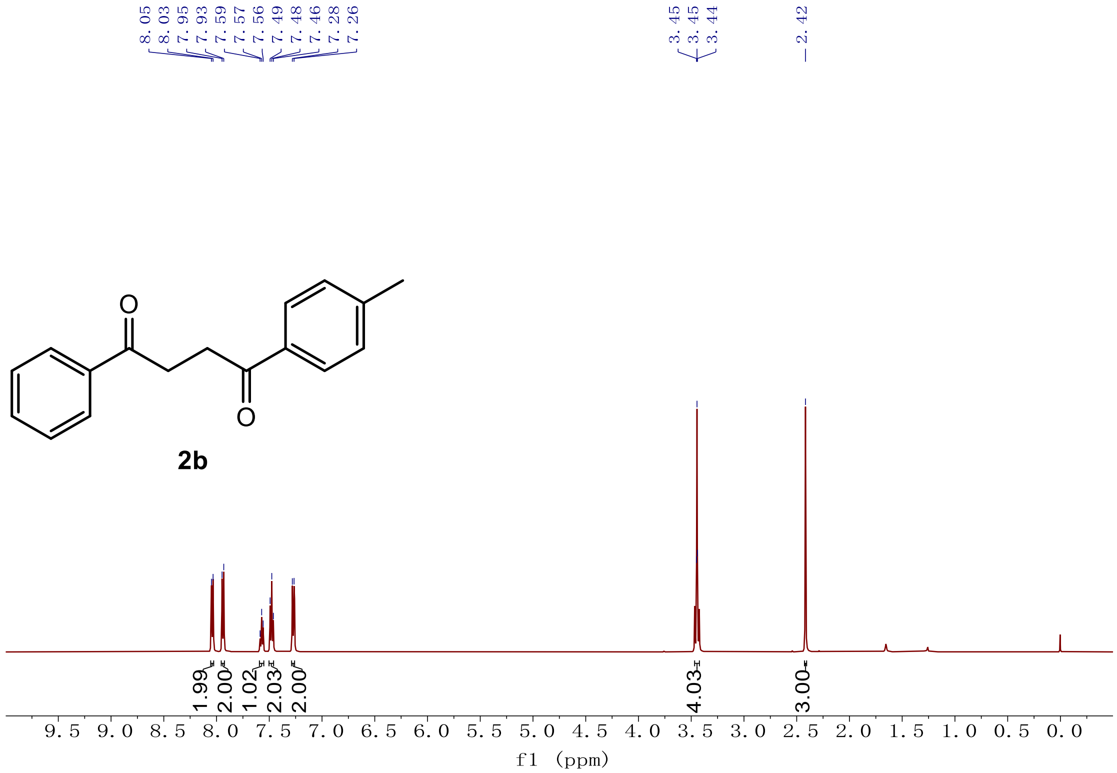
14. NMR spectra



1b


198.8
136.9
133.3
128.7
128.3
32.7
1b
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.57
7.56
7.49
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7.46
7.28
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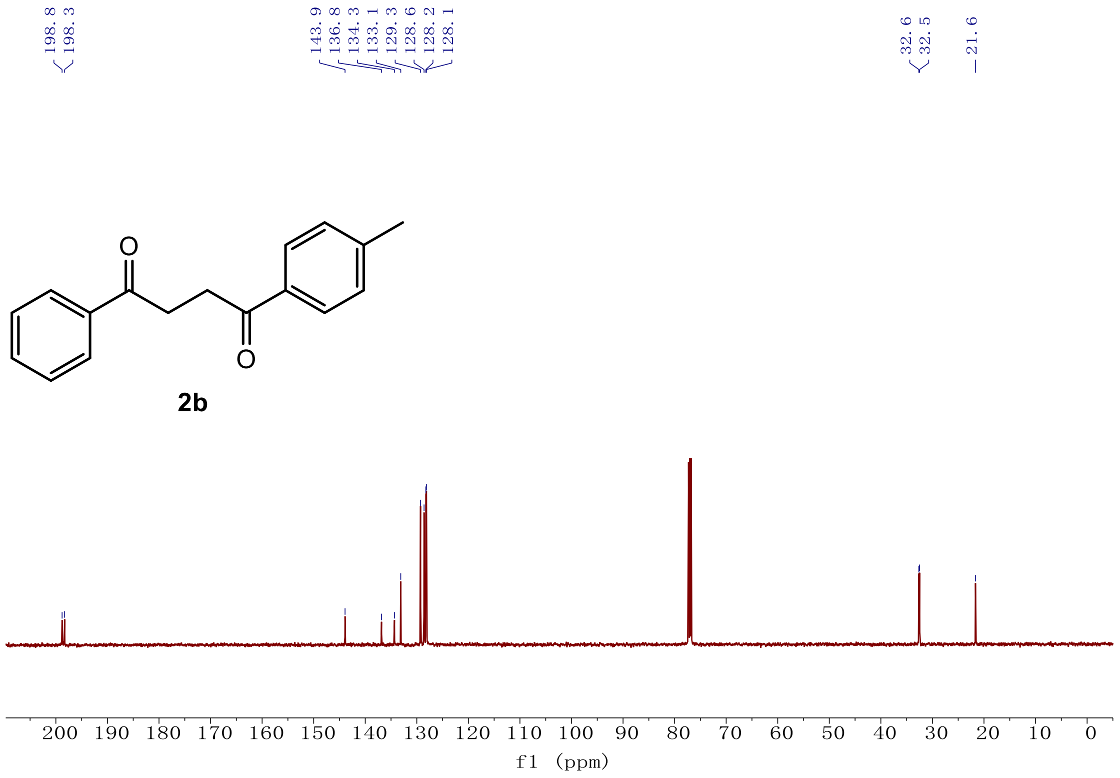
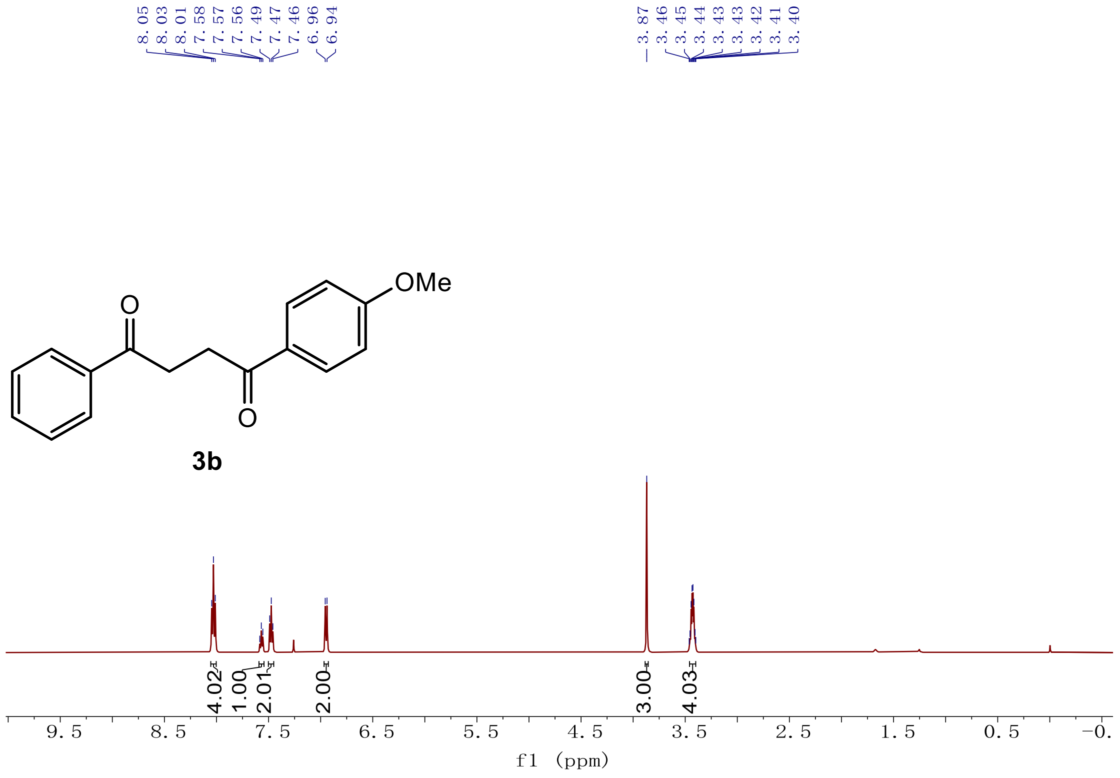
3.45
3.45
3.44
2.42
2b
1.99
2.00
1.02
2.03
2.00
4.03
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


2b

198.8
198.3
143.9
136.8
134.3
133.1
129.3
128.6
128.2
128.1
32.6
32.5
21.6
O
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


3b

8.05
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8.01
7.58
7.57
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7.46
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3.46
3.45
3.44
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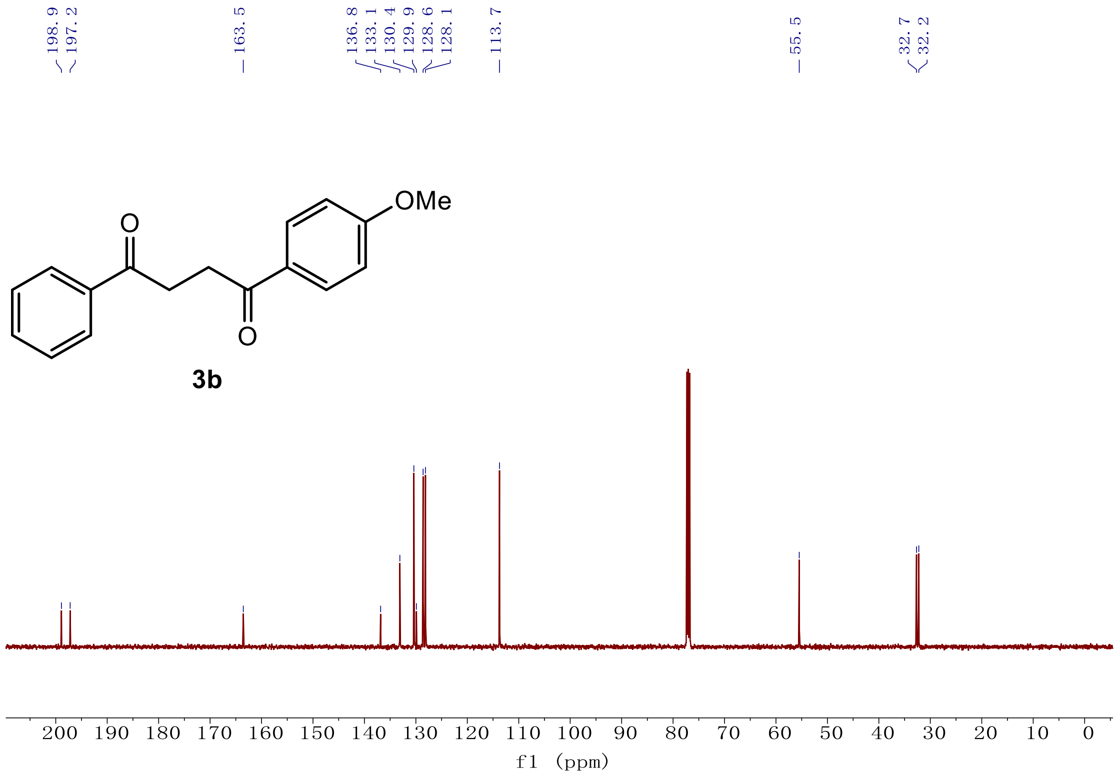
3.42
3.41
3.40
O
O
OMe
4.02
1.00
2.01
2.00
3.00
4.03
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.
f1 (ppm)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197.2
163.5
136.8
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32.2
O
OMe
O
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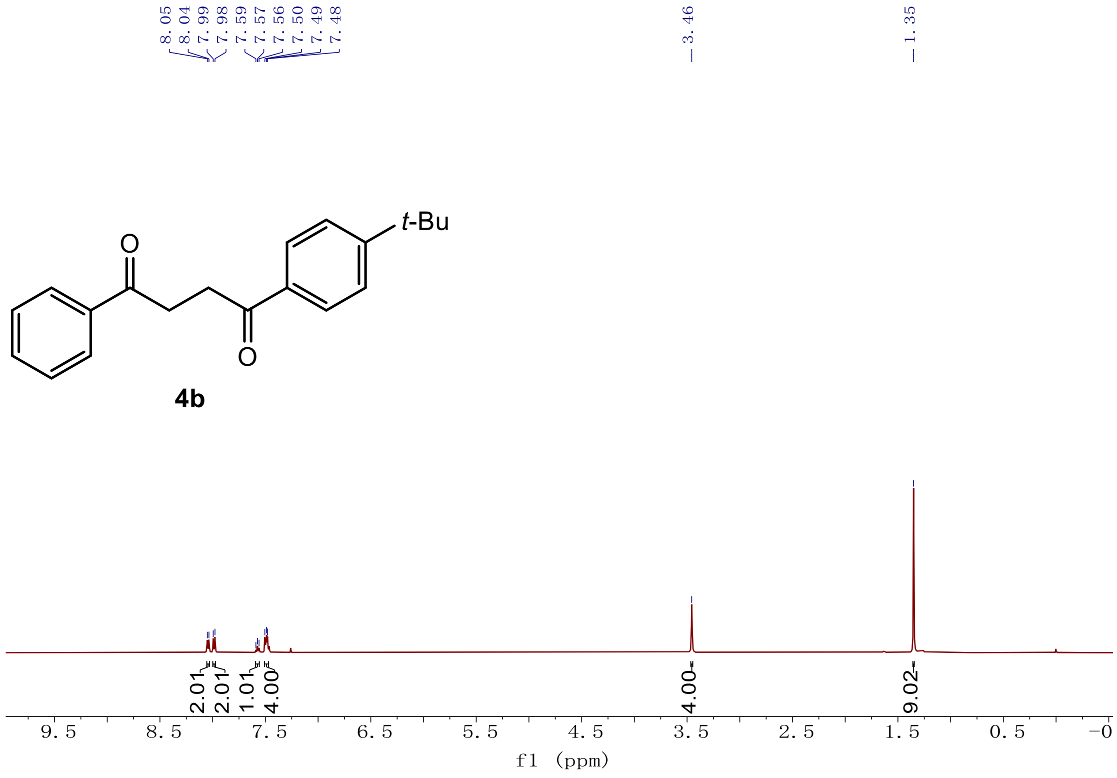
f1 (ppm)

3b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O
2.01
2.01
1.01
4.00
4.00
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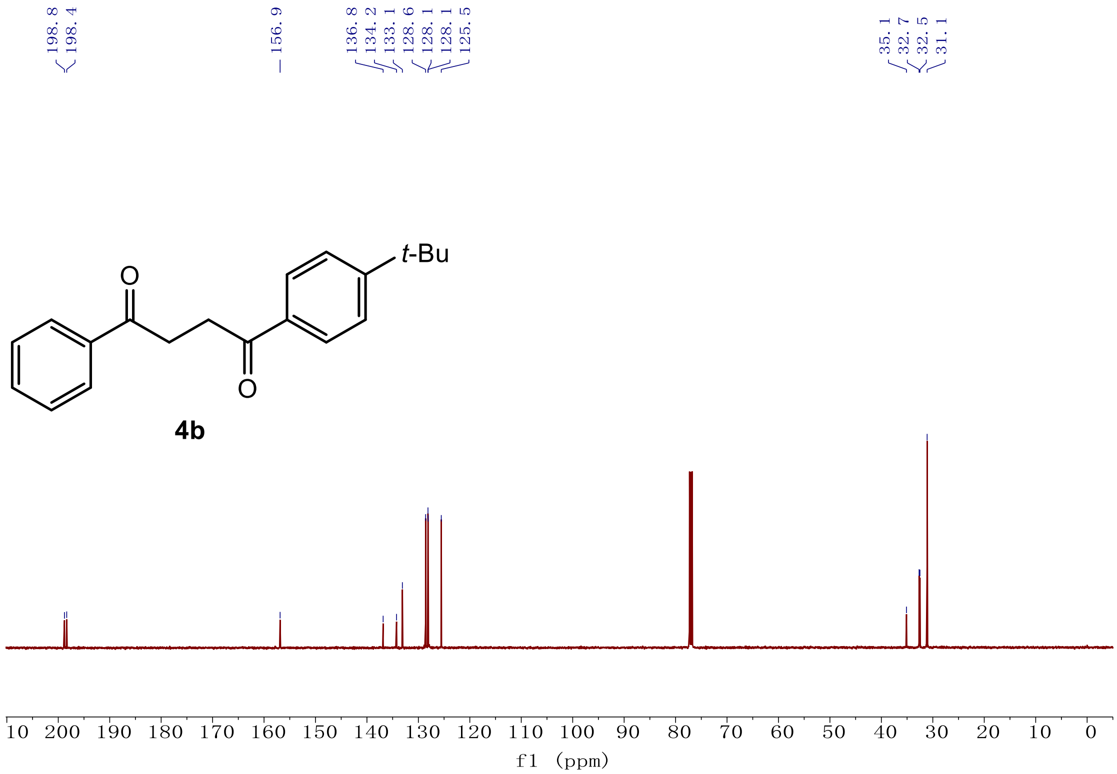
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

4b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128.6
128.1
128.1
125.5
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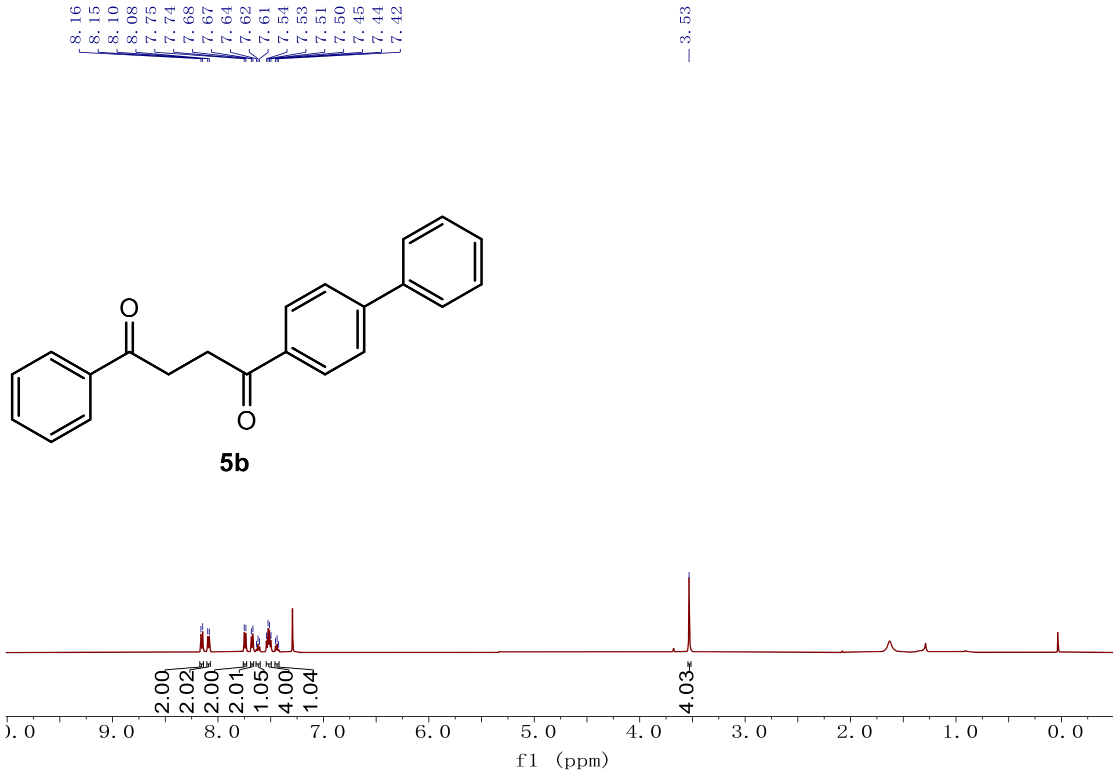
31.1
O
t-Bu
O
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

4b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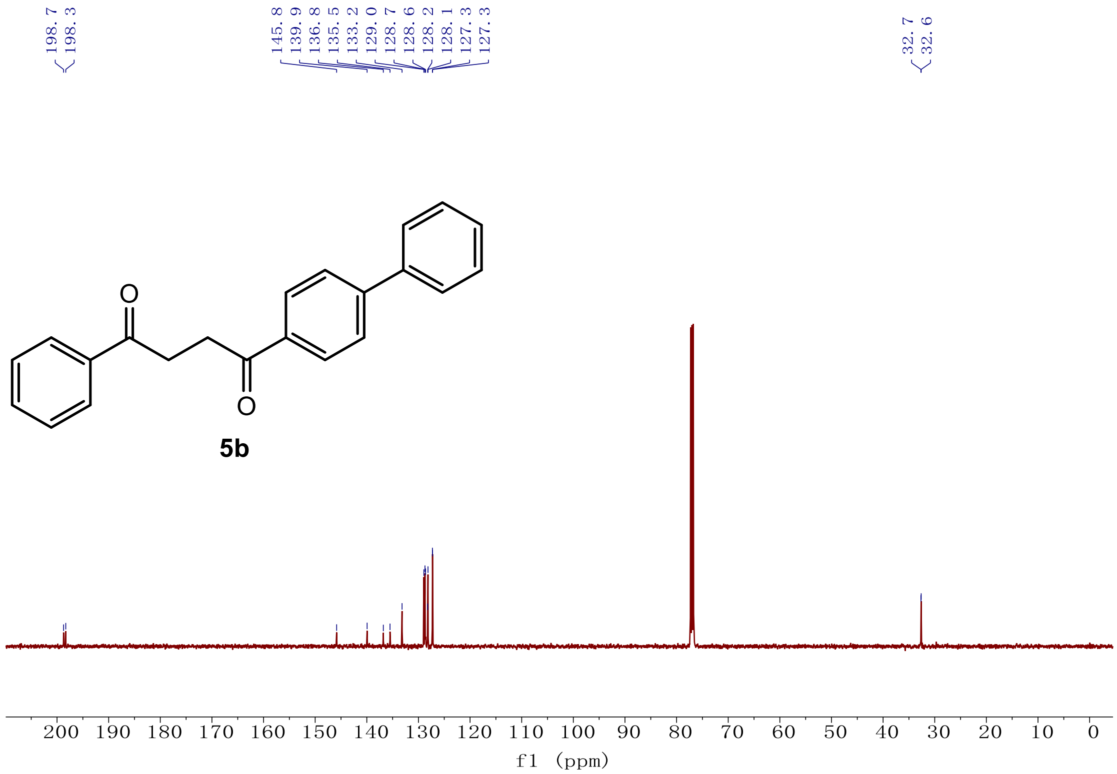
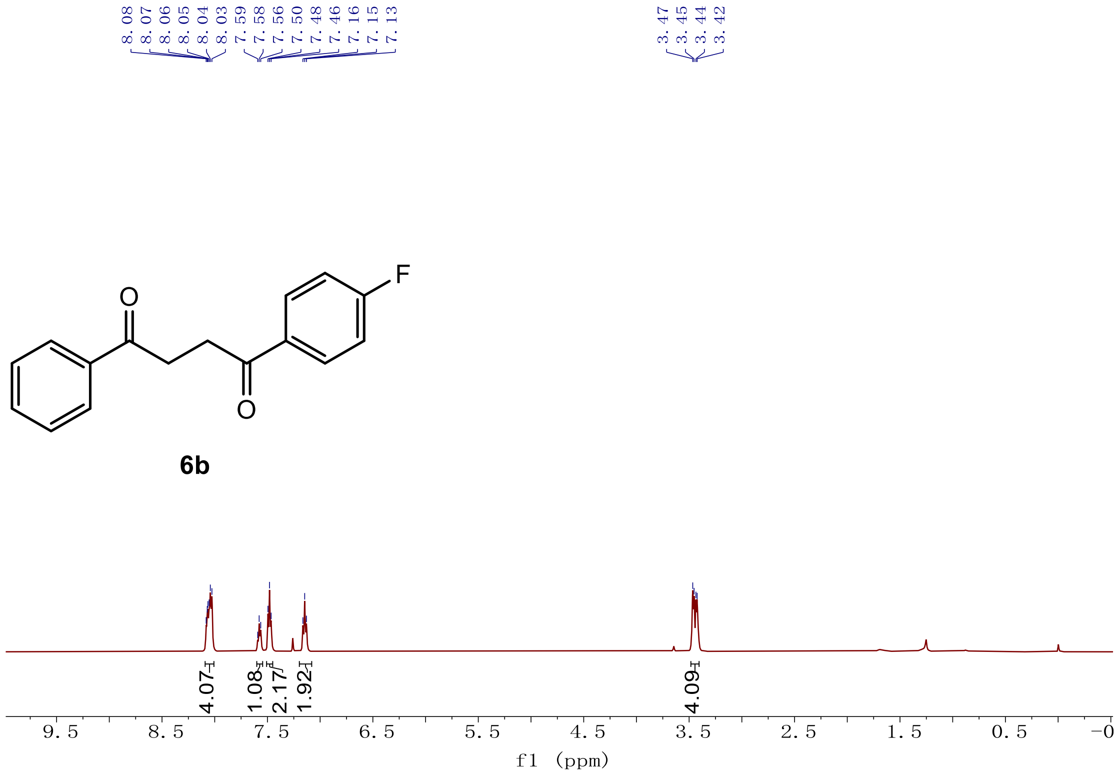
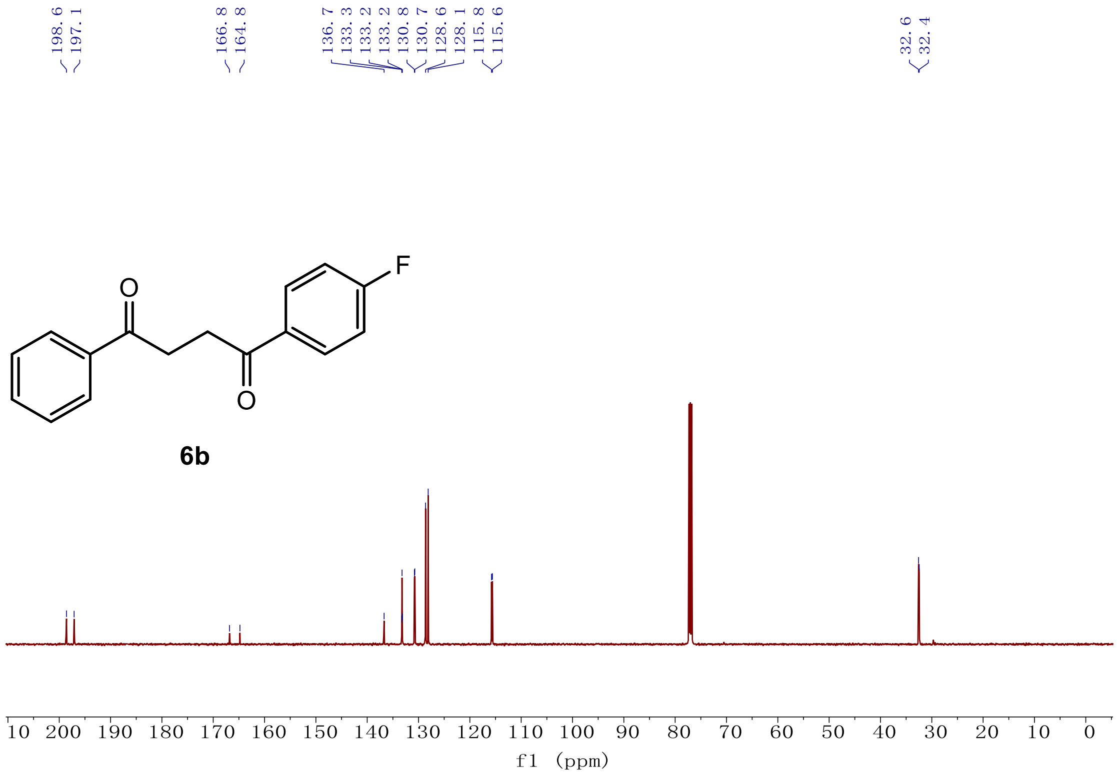
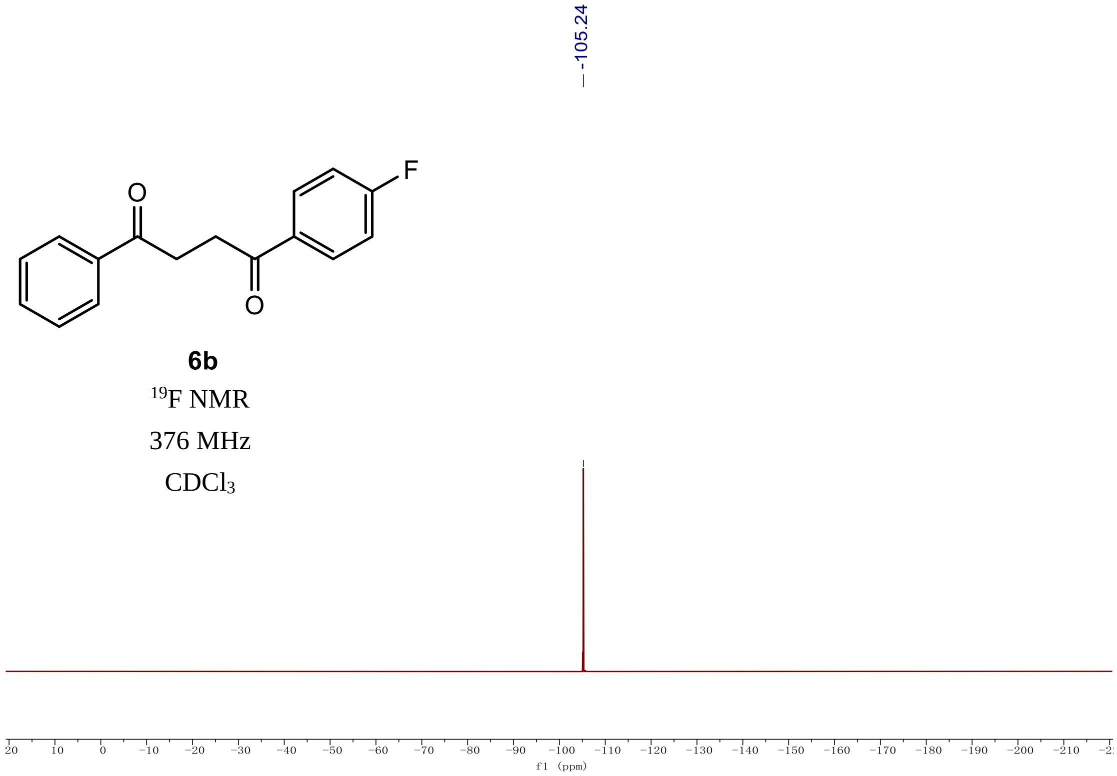
7.53
7.51
7.50
7.45
7.44
7.42
3.53
O
O
2.00
2.02
2.00
2.01
1.05
4.00
1.04
4.03
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

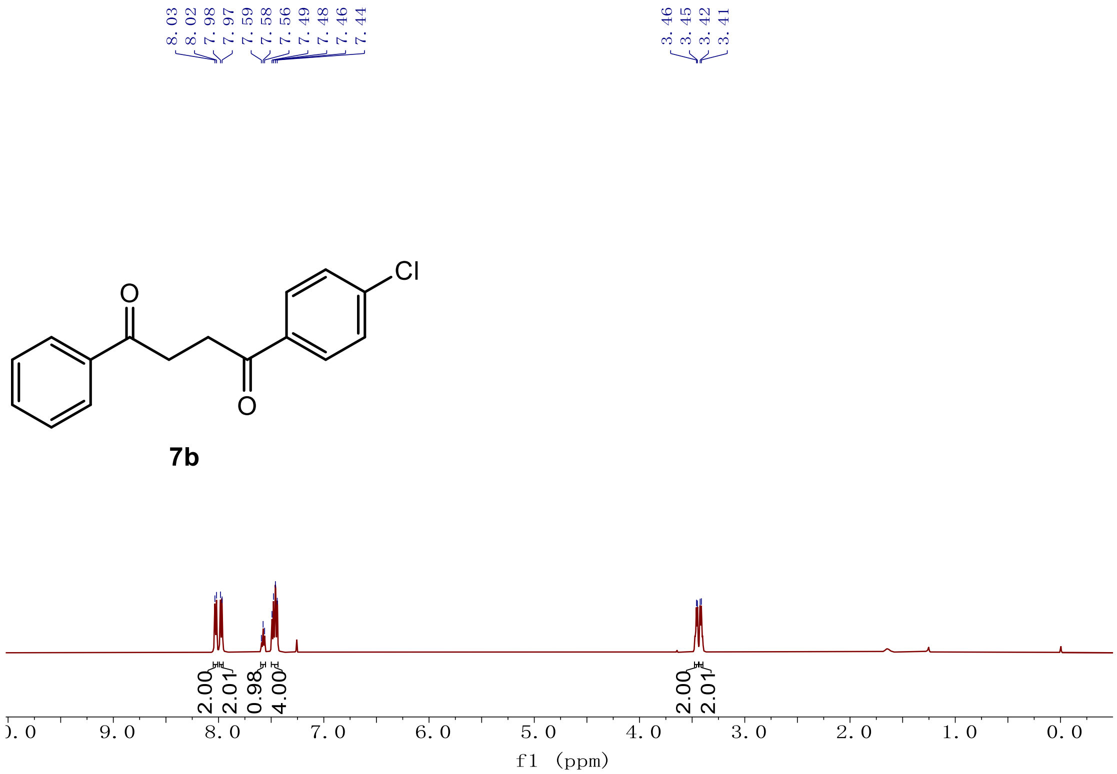
5b


198.7
198.3
145.8
139.9
136.8
135.5
133.2
129.0
128.7
128.6
128.2
128.1
127.3
127.3
32.7
32.6
O
O
5b
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.08
8.07
8.06
8.05
8.04
8.03
7.59
7.58
7.56
7.50
7.48
7.46
7.16
7.15
7.13
3.47
3.45
3.44
3.42
O
F
O
6b
4.07
1.08
2.17
1.92
4.09
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

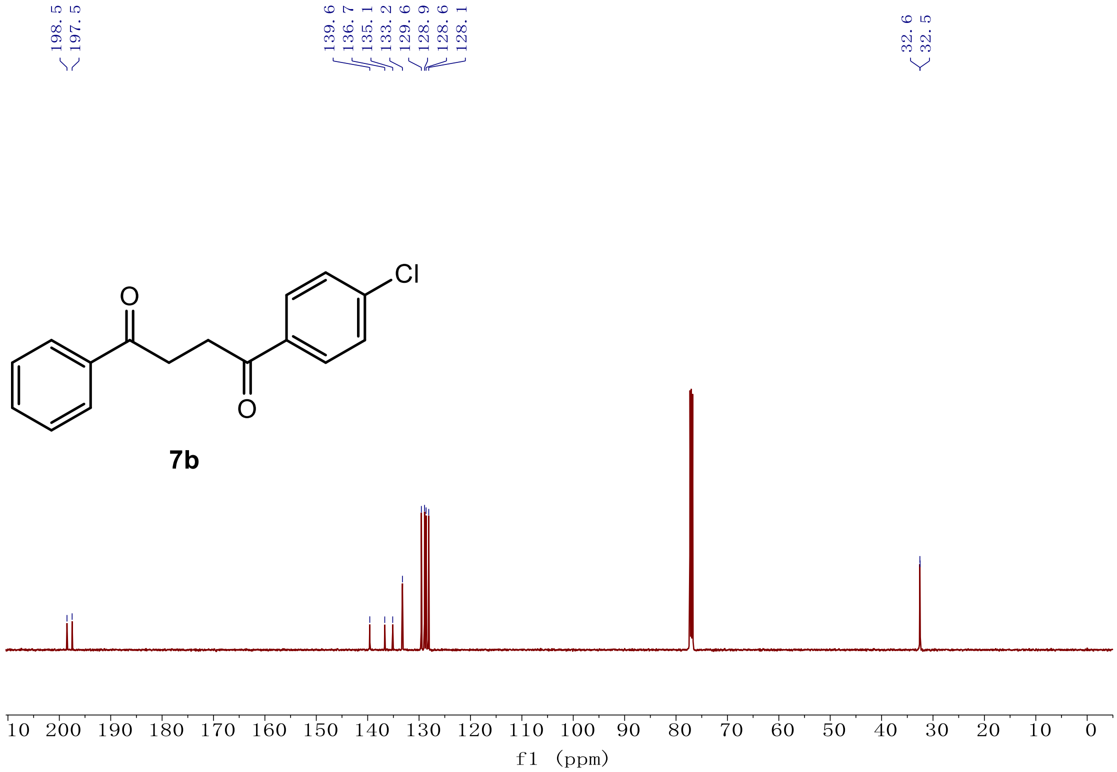

198.6
197.1
166.8
164.8
136.7
133.3
133.2
133.2
130.8
130.7
128.6
128.1
115.8
115.6
32.6
32.4
O
O
F
6b
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-105.24
O
O
F
6b
19F NMR
376 MHz
CDCl3
20
10
0
−10
−20
−30
−40
−50
−60
−70
−80
−90
−100
−110
−120
−130
−140
−150
−160
−170
−180
−190
−200
−210
f1 (ppm)



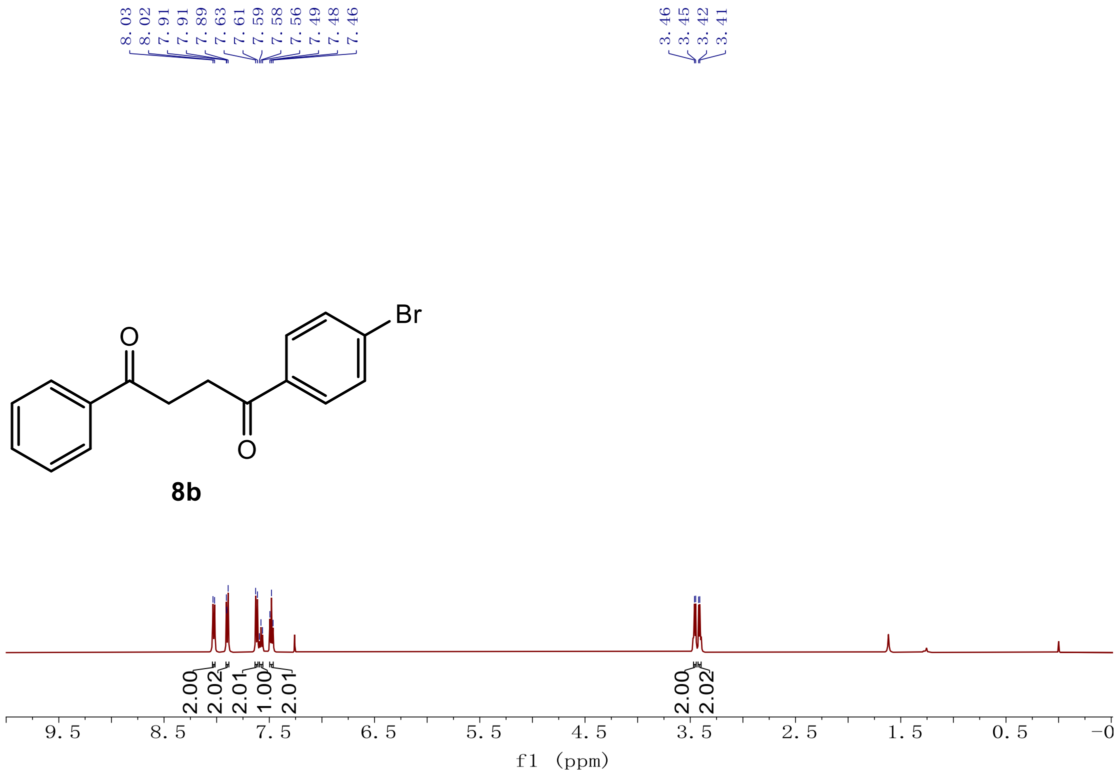
7b

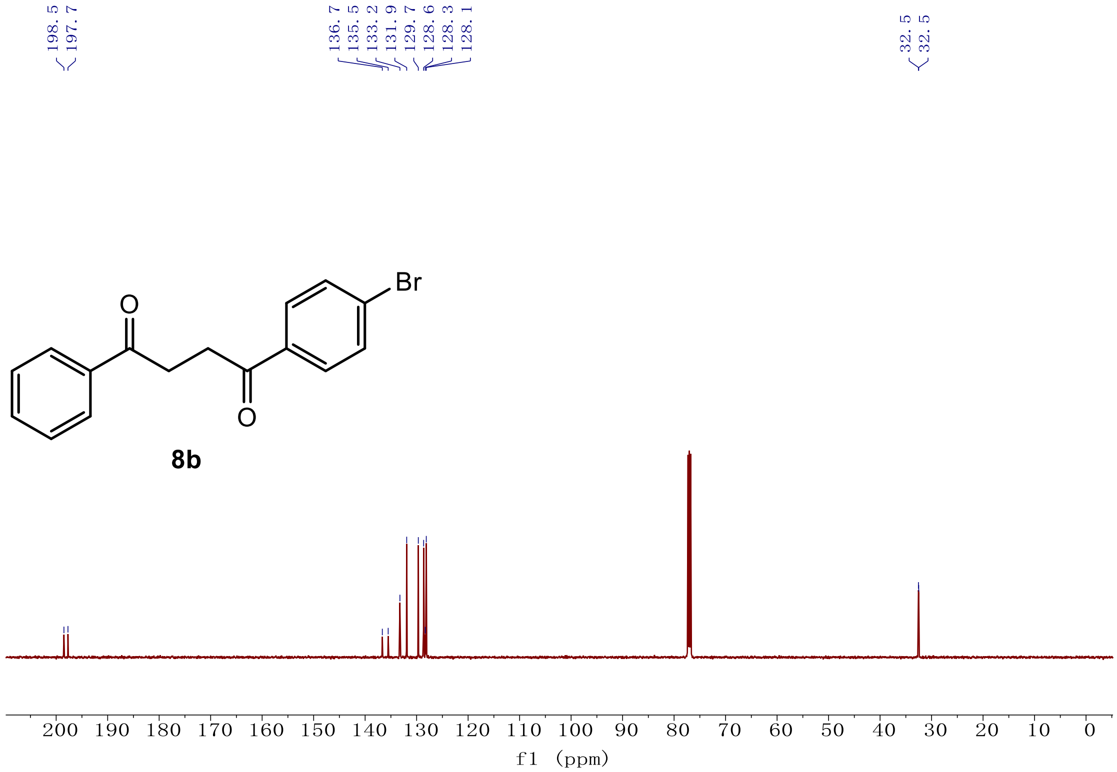
8.03
8.02
7.98
7.97
7.59
7.58
7.56
7.49
7.48
7.46
7.44
3.46
3.45
3.42
3.41
O
O
Cl
2.00
2.01
0.98
4.00
2.00
2.01
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

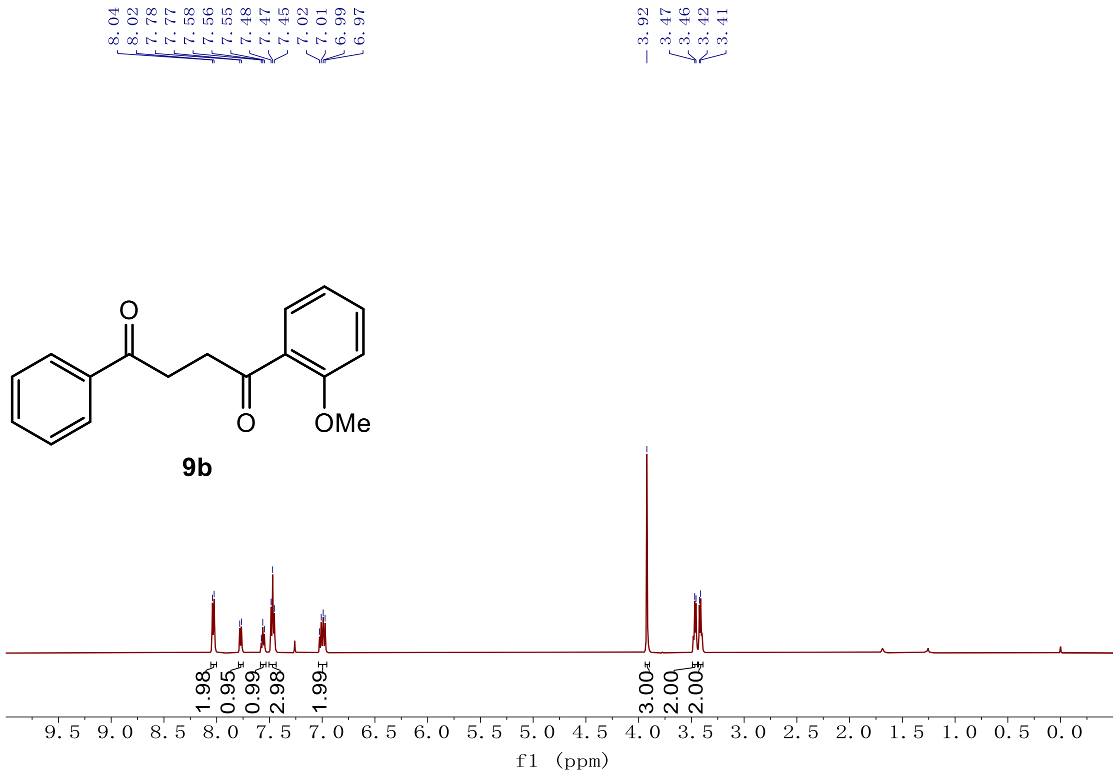


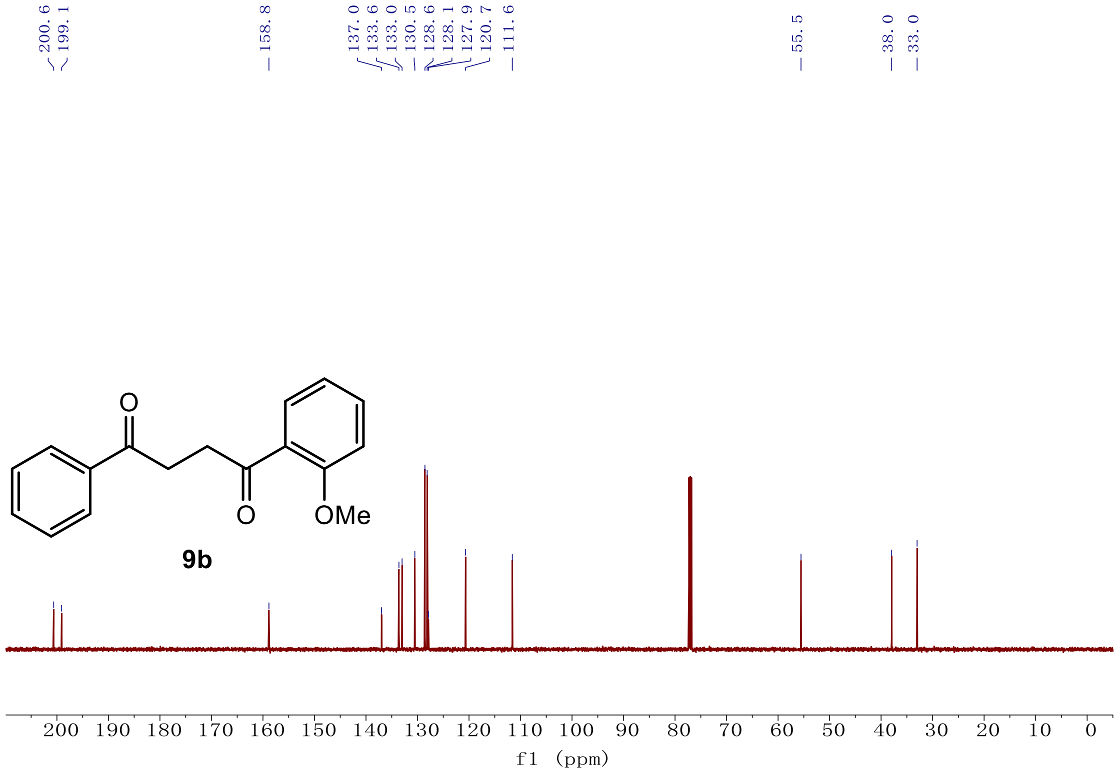
7b

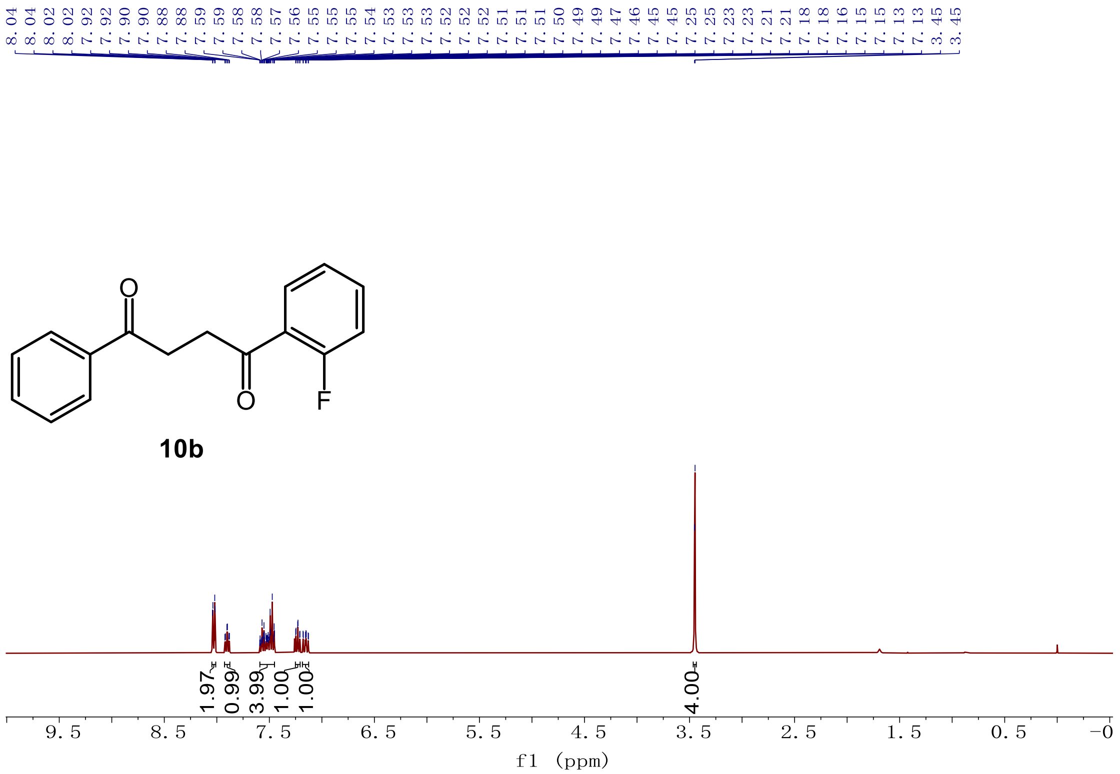
198.5
197.5
139.6
136.7
135.1
133.2
129.6
128.9
128.6
128.1
32.6
32.5
O
O
Cl
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.03
8.02
7.91
7.91
7.89
7.63
7.61
7.59
7.58
7.56
7.49
7.48
7.46
3.46
3.45
3.42
3.41
O
Br
O
8b
2.00
2.02
2.01
1.00
2.01
2.00
2.02
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
−0
f1 (ppm)

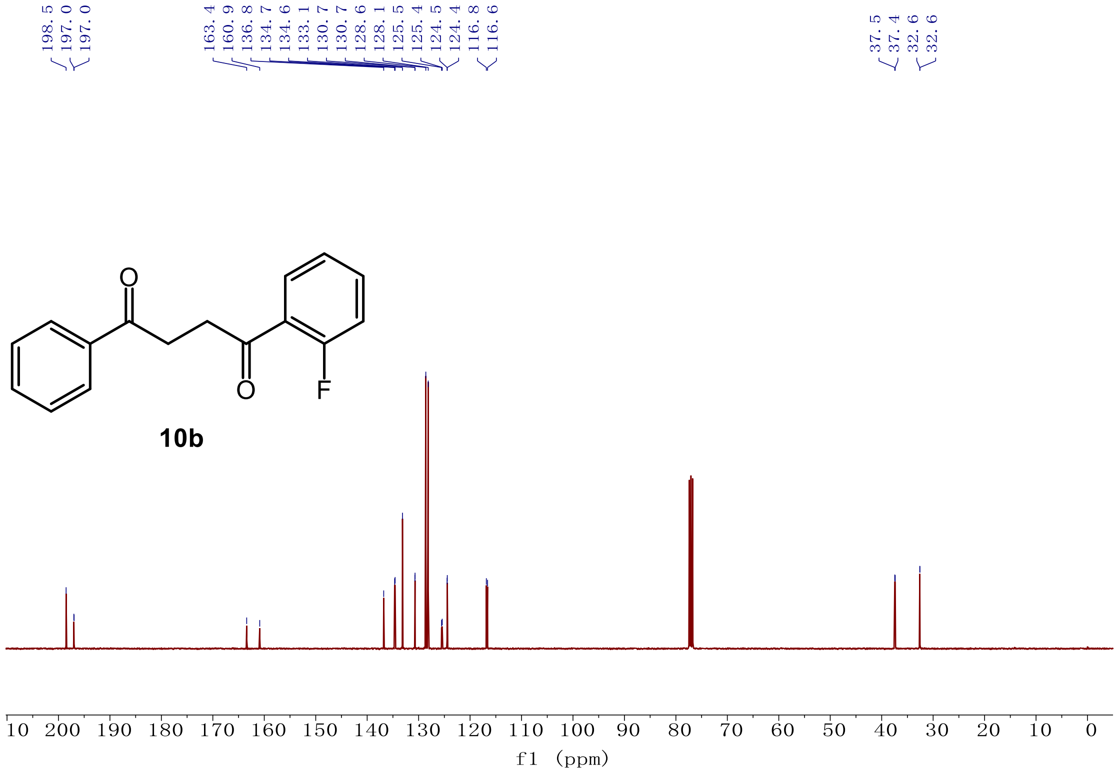

198.5
197.7
136.7
135.5
133.2
131.9
129.7
128.6
128.3
128.1
32.5
32.5
O
Br
O
8b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.04
8.02
7.78
7.77
7.58
7.56
7.55
7.48
7.47
7.45
7.02
7.01
6.99
6.97
3.92
3.47
3.46
3.42
3.41
O
O
OMe
9b
1.98
0.95
0.99
2.98
1.99
3.00
2.00
2.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

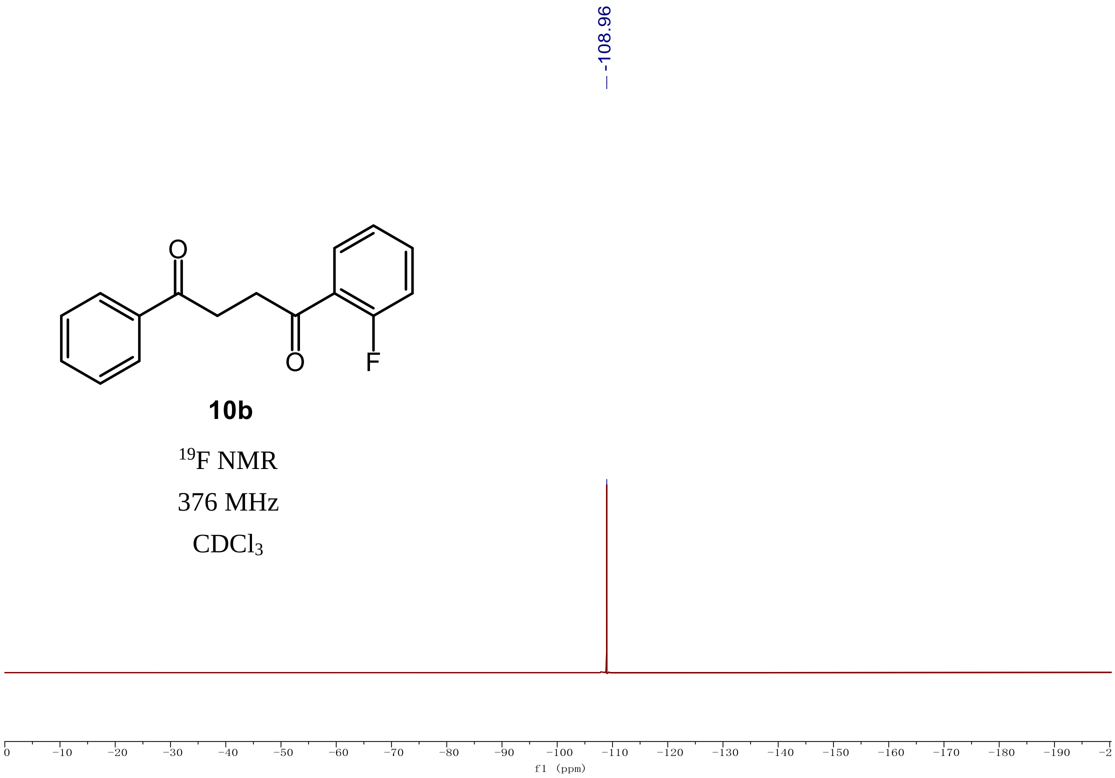

200.6
199.1
158.8
137.0
133.6
133.0
130.5
128.6
128.1
127.9
120.7
111.6
55.5
38.0
33.0
O
O
OMe
9b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.04
8.04
8.02
8.02
7.92
7.92
7.90
7.90
7.88
7.88
7.59
7.59
7.58
7.58
7.57
7.56
7.55
7.55
7.55
7.54
7.53
7.53
7.53
7.52
7.52
7.52
7.51
7.51
7.51
7.50
7.49
7.47
7.46
7.45
7.45
7.45
7.25
7.25
7.23
7.23
7.21
7.21
7.18
7.18
7.16
7.15
7.15
7.13
7.13
3.45
3.45
O
O
F
1.97
0.99
3.99
1.00
1.00
4.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
−0
f1 (ppm)

10b


198.5
197.0
197.0
163.4
160.9
136.8
134.7
134.6
133.1
130.7
130.7
128.6
128.1
125.5
125.4
124.5
124.4
116.8
116.6
37.5
37.4
32.6
32.6
O
O
F
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

10b

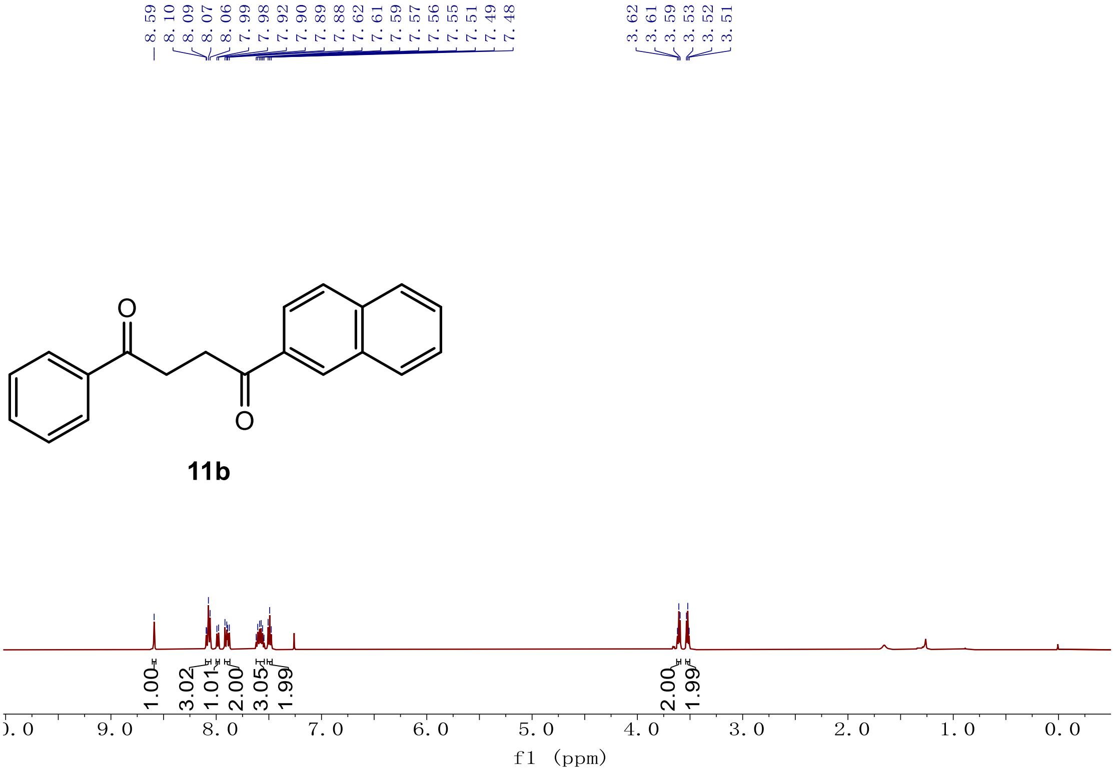


10b

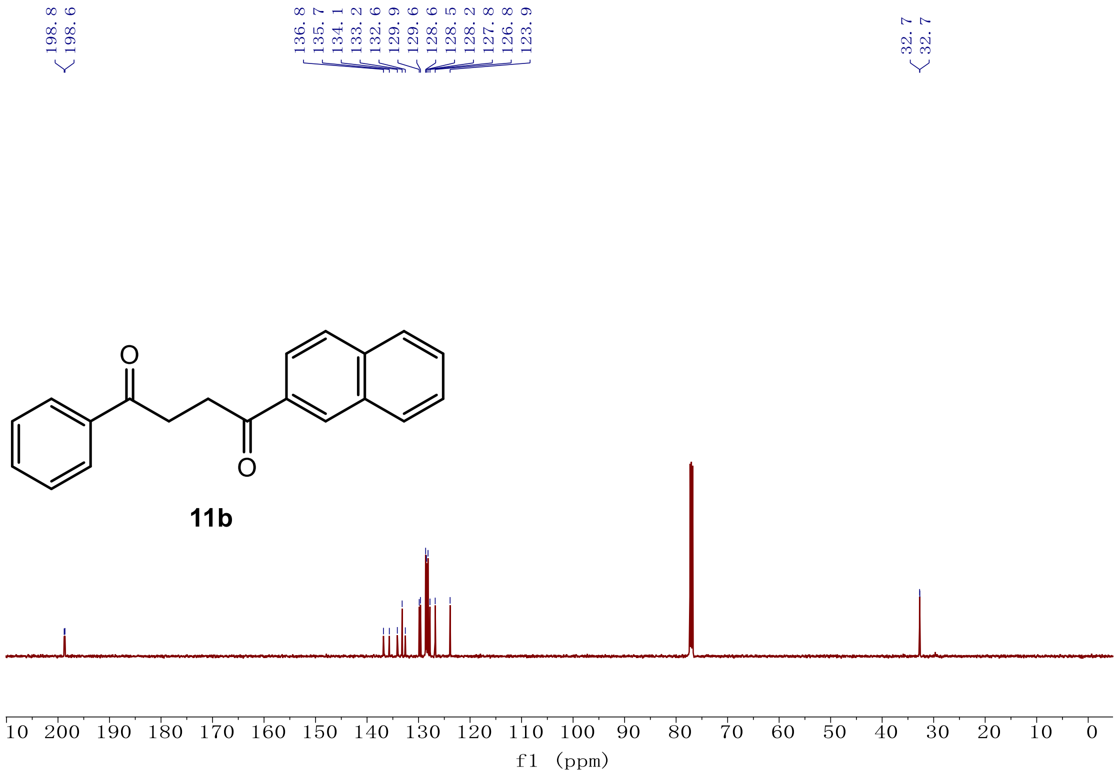
^{19}F NMR

376 MHz

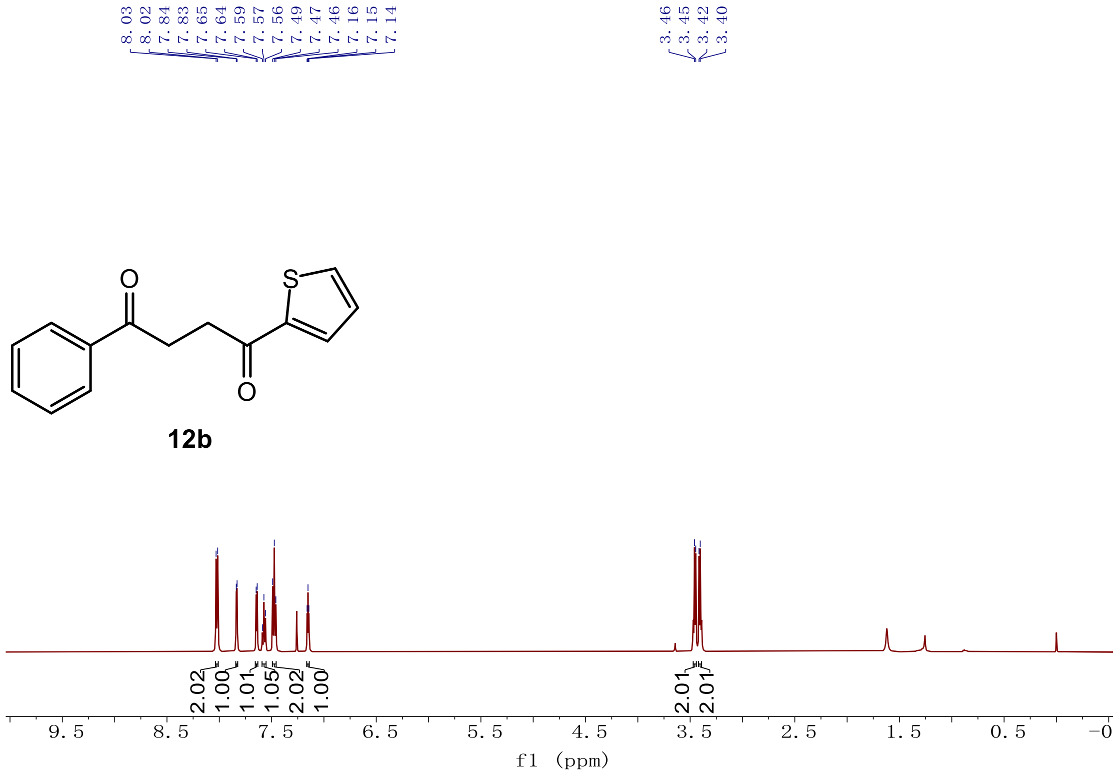
$CDCl_3$



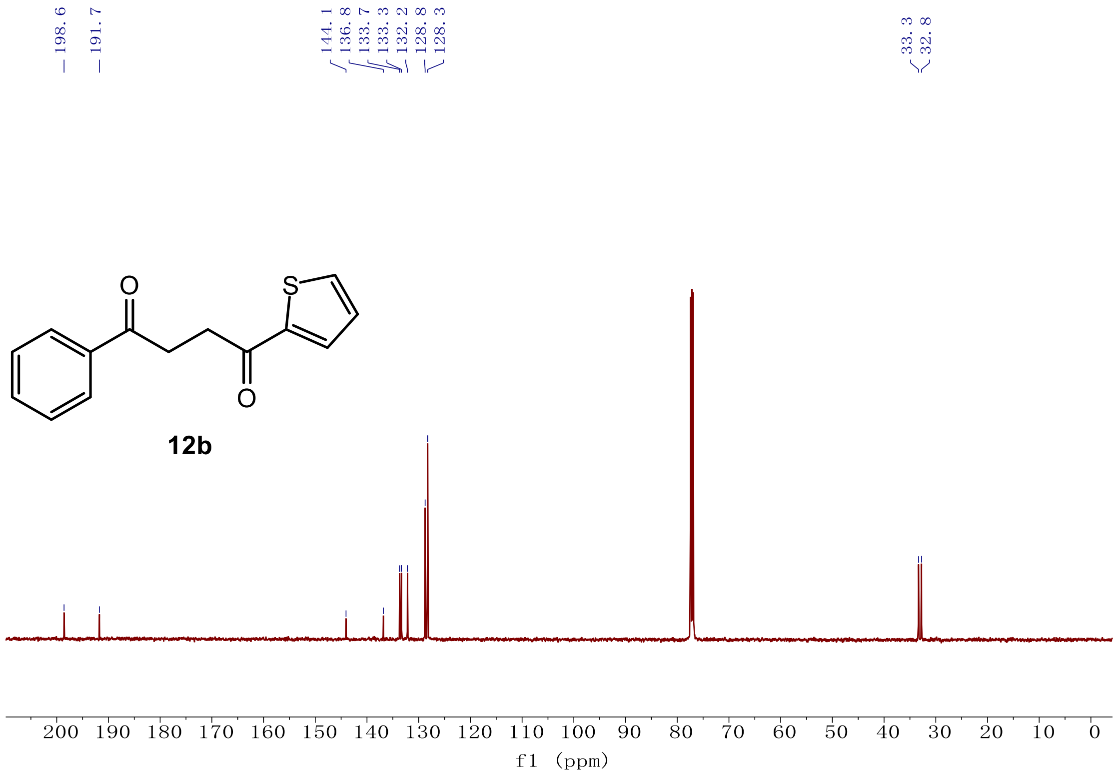
11b


198.8
198.6
136.8
135.7
134.1
133.2
132.6
129.9
129.6
128.6
128.5
128.2
127.8
126.8
123.9
32.7
32.7
O
O
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

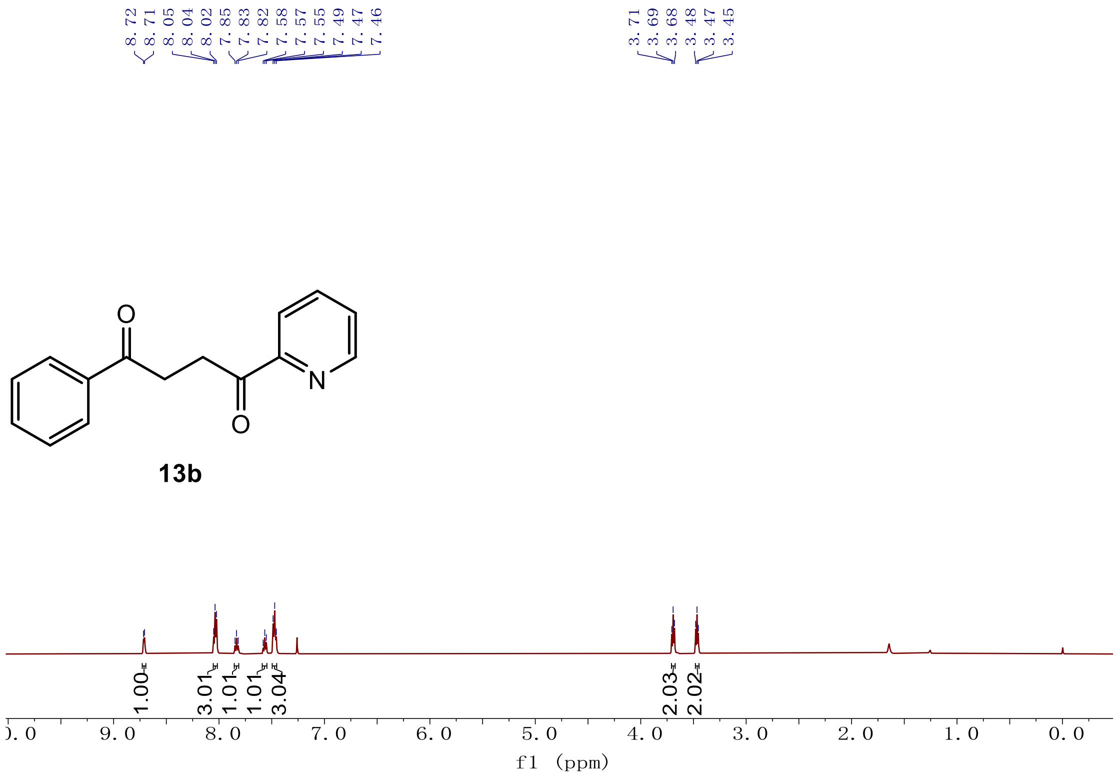
11b


8.03
8.02
7.84
7.83
7.65
7.64
7.59
7.57
7.56
7.49
7.47
7.46
7.16
7.15
7.14
3.46
3.45
3.42
3.40
O
S
O
2.02
1.00
1.01
1.05
2.02
1.00
2.01
2.01
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 −0
f1 (ppm)

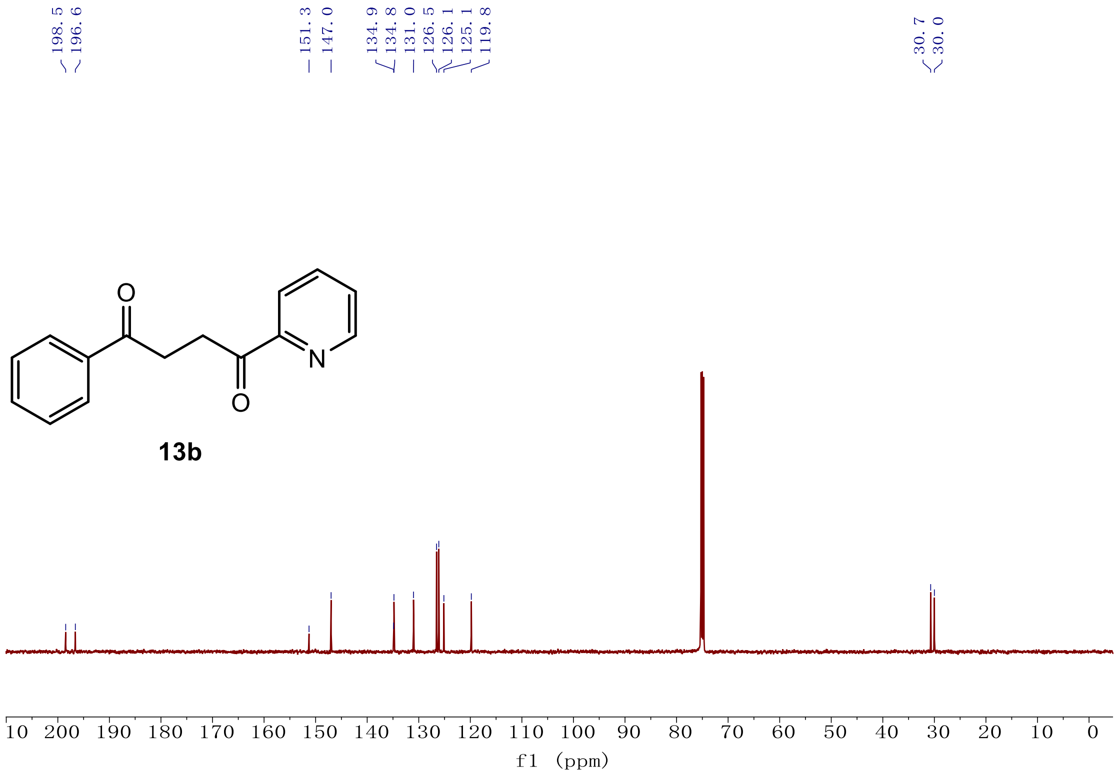
12b

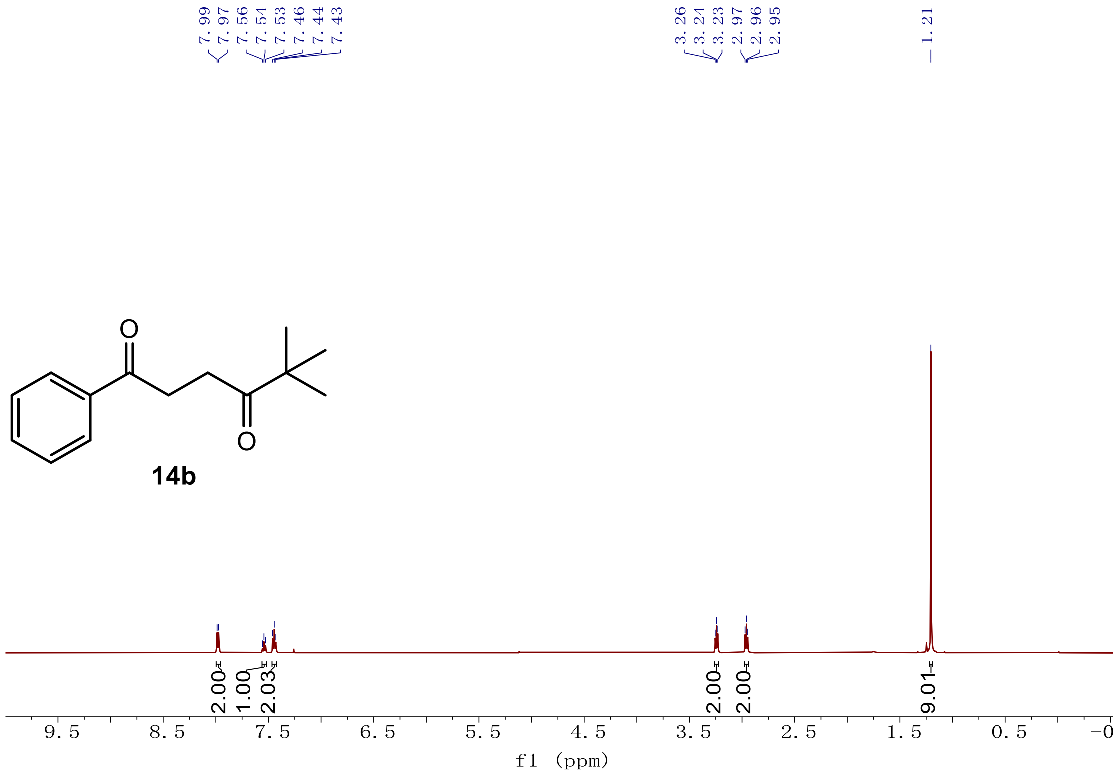

198.6
191.7
144.1
136.8
133.7
133.3
132.2
128.8
128.3
33.3
32.8
O
S
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

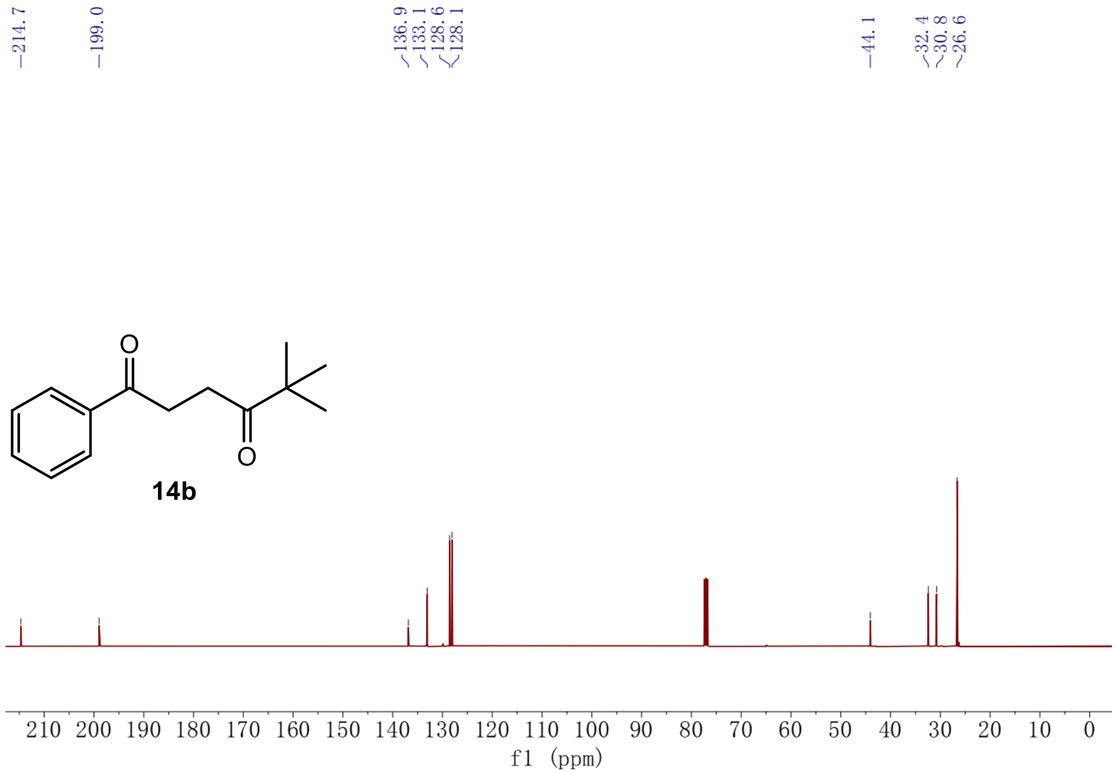
12b


8.72
8.71
8.05
8.04
8.02
7.85
7.83
7.82
7.58
7.57
7.55
7.49
7.47
7.46
3.71
3.69
3.68
3.48
3.47
3.45
O
N
O
1.00
3.01
1.01
1.01
3.04
2.03
2.02
9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)

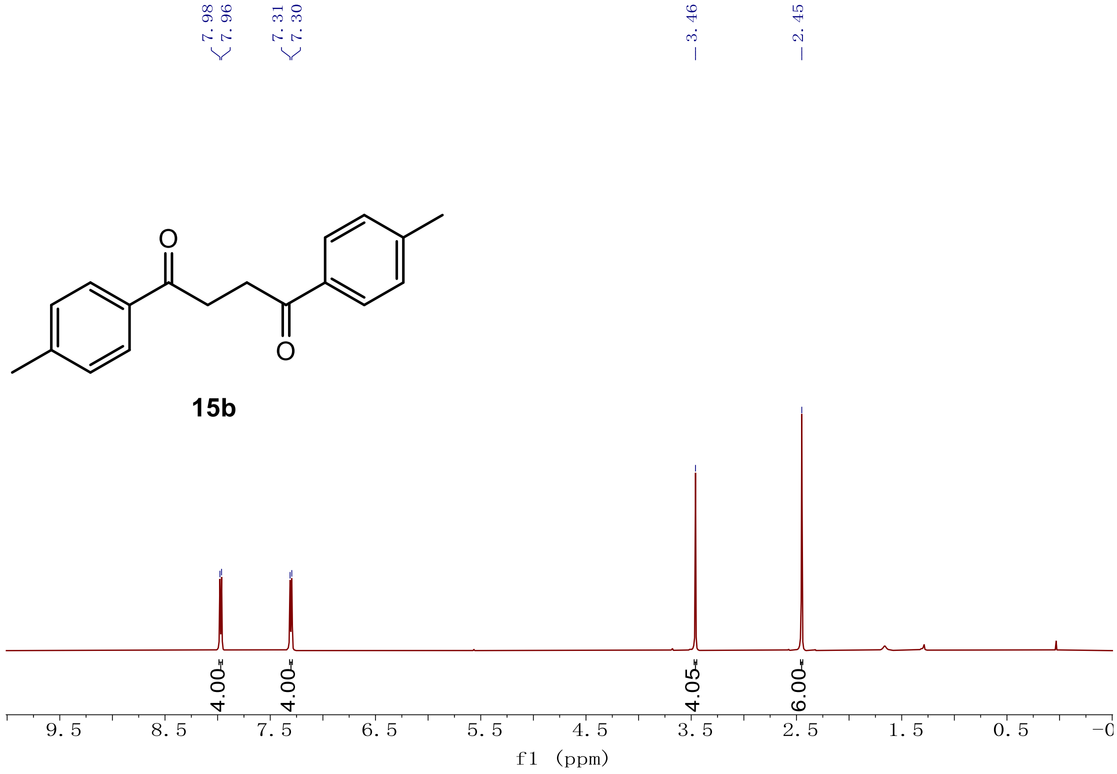
13b


13b
198.5
196.6
151.3
147.0
134.9
134.8
131.0
126.5
126.1
125.1
119.8
30.7
30.0
O
O
N
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

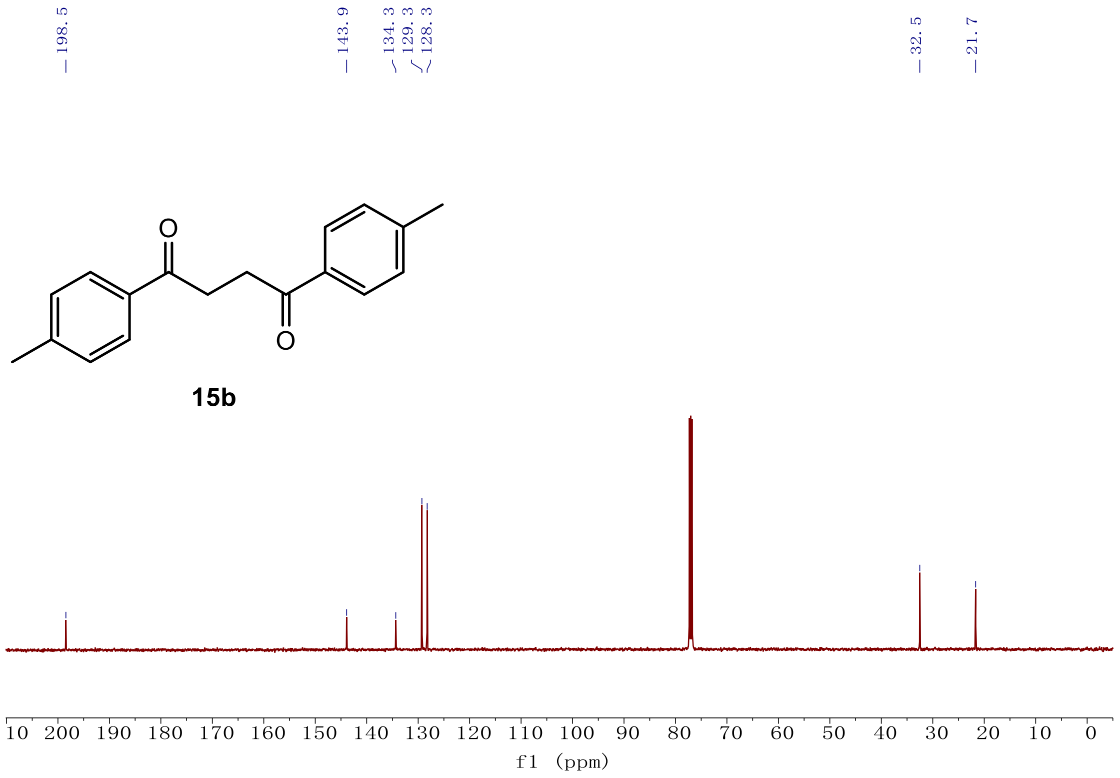

14b
7.99
7.97
7.56
7.54
7.53
7.46
7.44
7.43
3.26
3.24
3.23
2.97
2.96
2.95
1.21
O
O
2.00
1.00
2.03
2.00
2.00
9.01
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
−0
f1 (ppm)


14b

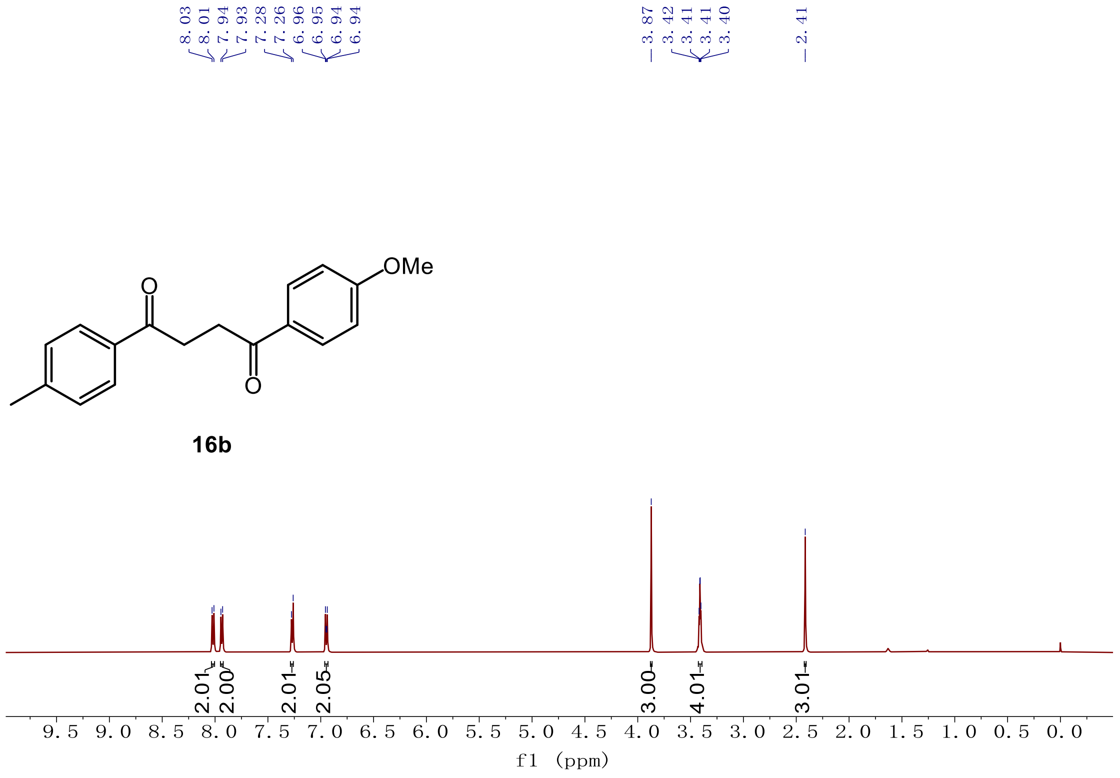
214.7
199.0
136.9
133.1
128.6
128.1
44.1
32.4
30.8
26.6
O
O
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


15b

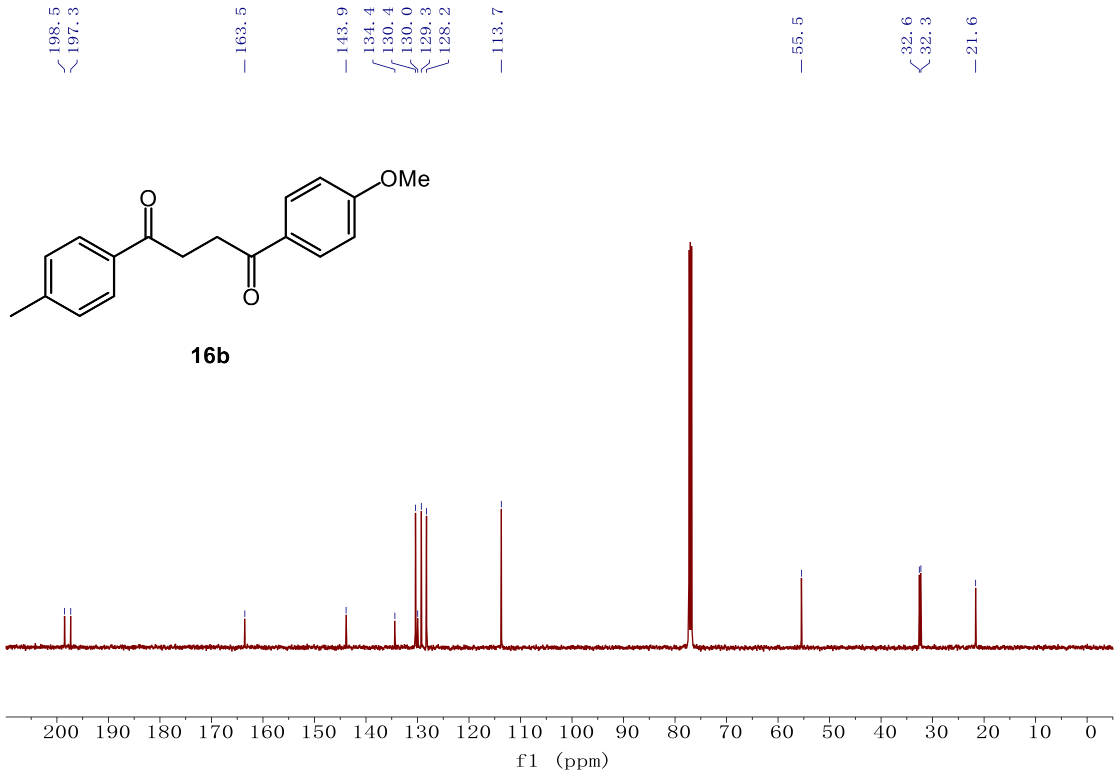
7.98
7.96
7.31
7.30
3.46
2.45
O
O
4.00
4.00
4.05
6.00
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)


198.5
143.9
134.3
129.3
128.3
32.5
21.7
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

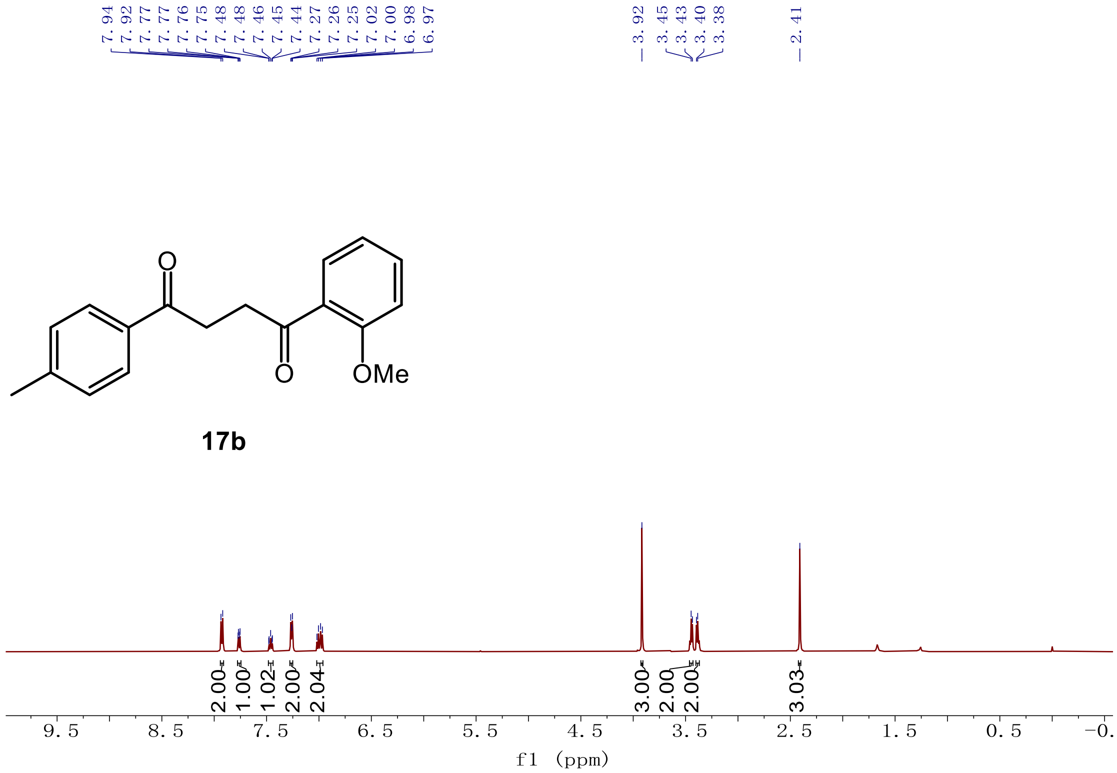
15b


8.03
8.01
7.94
7.93
7.28
7.26
6.96
6.95
6.94
6.94
3.87
3.42
3.41
3.41
3.40
2.41
OMe
2.01
2.00
2.01
2.05
3.00
4.01
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
0.0
f1 (ppm)

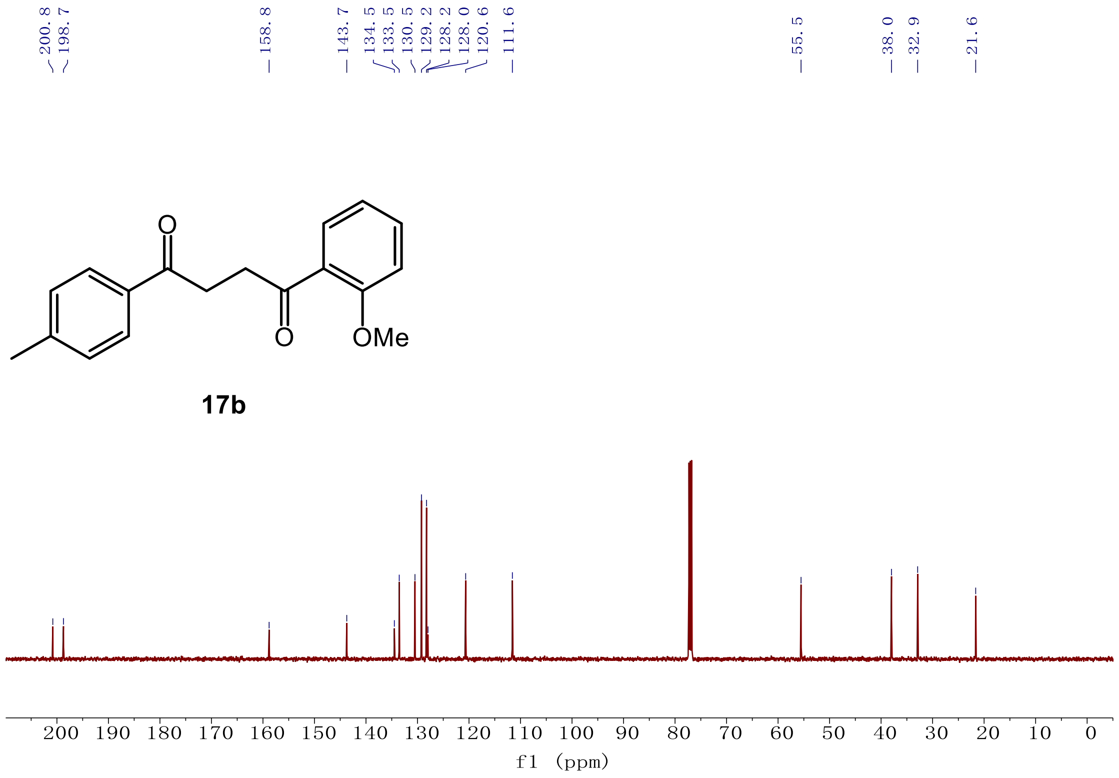
16b


198.5
197.3
163.5
143.9
134.4
130.4
130.0
129.3
128.2
113.7
55.5
32.6
32.3
21.6
OMe
O
O
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

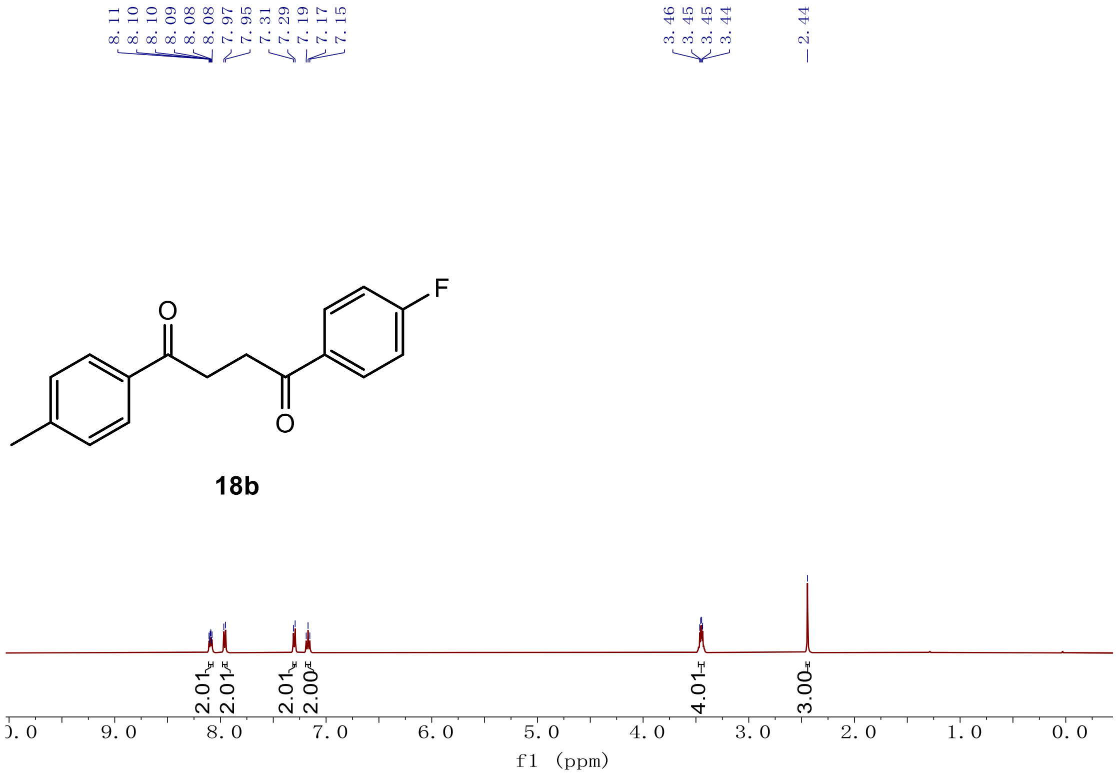
16b


7.94
7.92
7.77
7.77
7.76
7.75
7.48
7.48
7.46
7.45
7.44
7.27
7.26
7.25
7.02
7.00
6.98
6.97
3.92
3.45
3.43
3.40
3.38
2.41
O
O
OMe
2.00
1.00
1.02
2.00
2.04
3.00
2.00
2.00
3.03
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.
f1 (ppm)

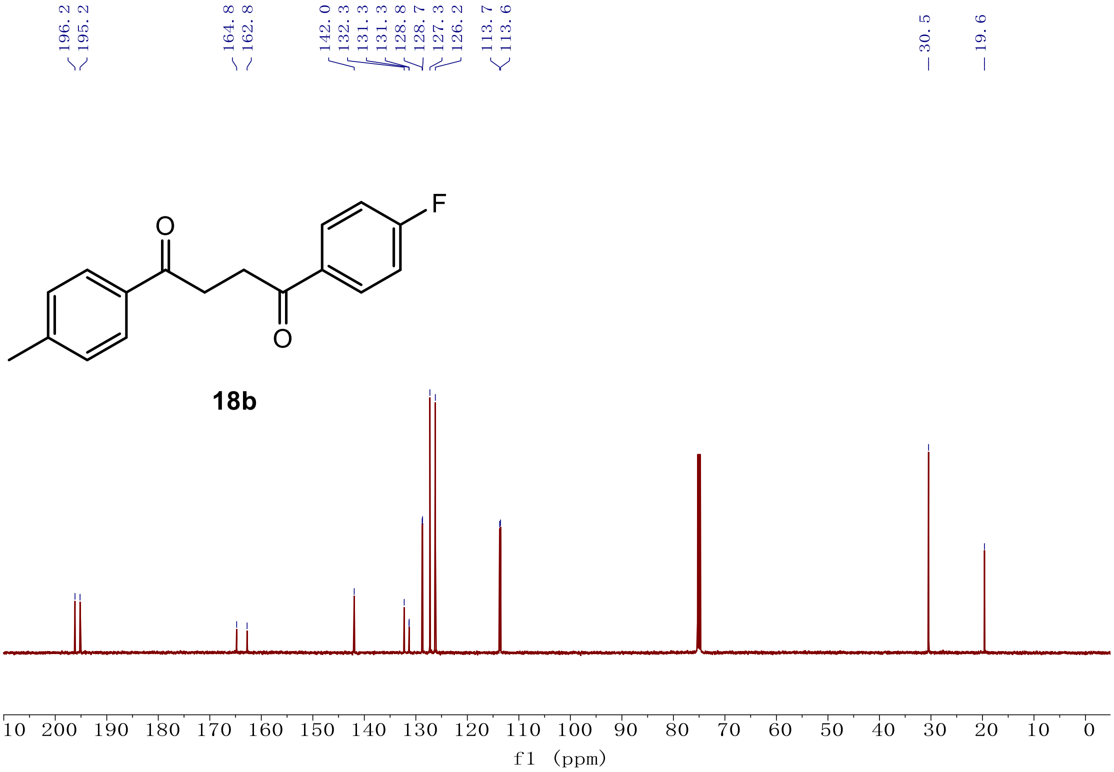
17b


200.8
198.7
158.8
143.7
134.5
133.5
130.5
129.2
128.2
128.0
120.6
111.6
55.5
38.0
32.9
21.6
O
O
OMe
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

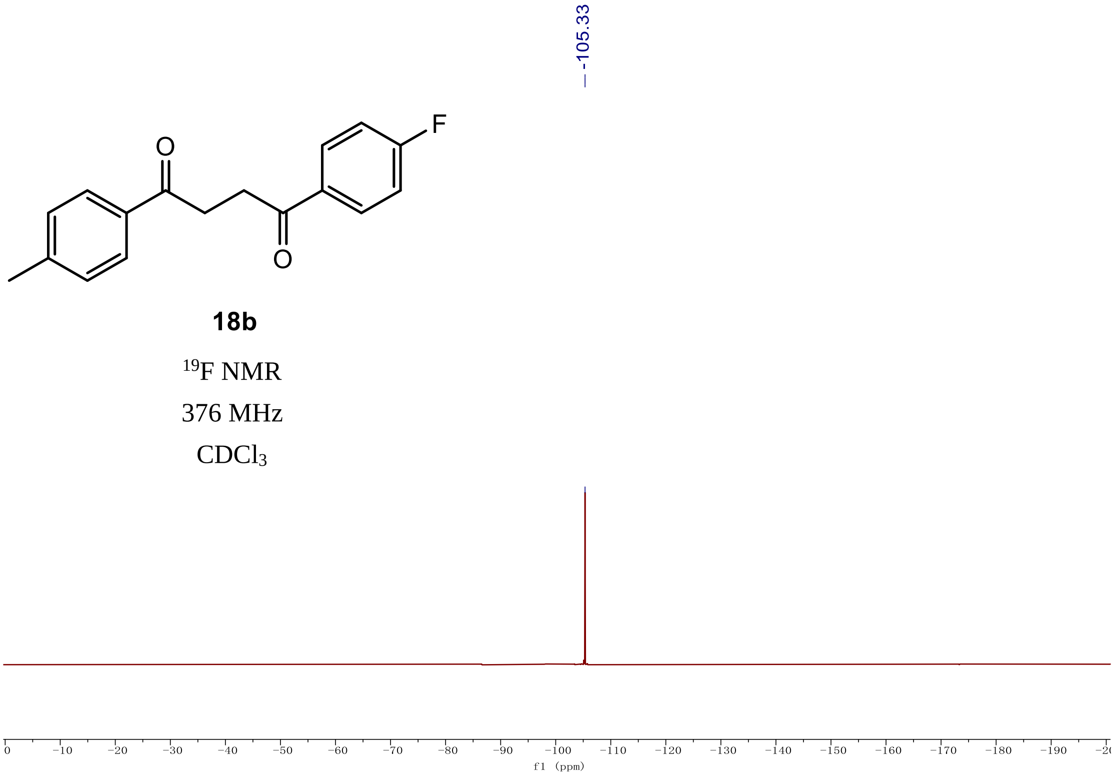
17b


8.11
8.10
8.10
8.09
8.08
8.08
7.97
7.95
7.31
7.29
7.19
7.17
7.15
3.46
3.45
3.45
3.44
2.44
O
O
F
2.01
2.01
2.01
2.00
4.01
3.00
0.0 9.0 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0
f1 (ppm)

18b



18b

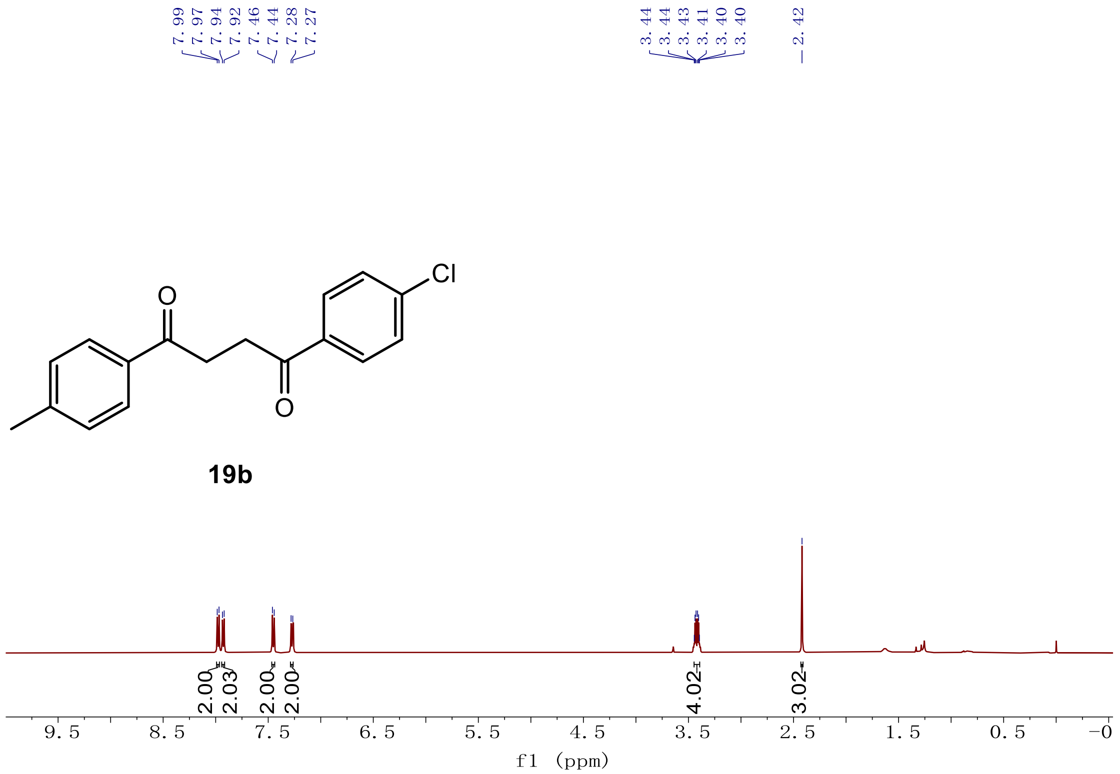


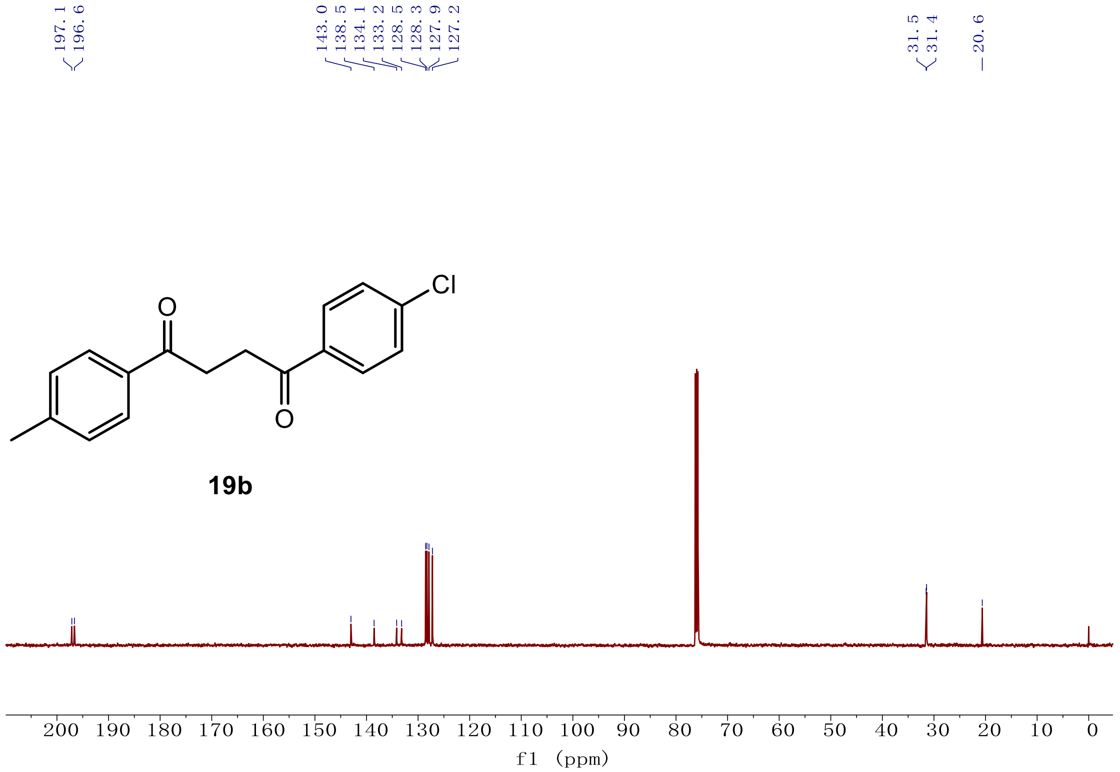
18b

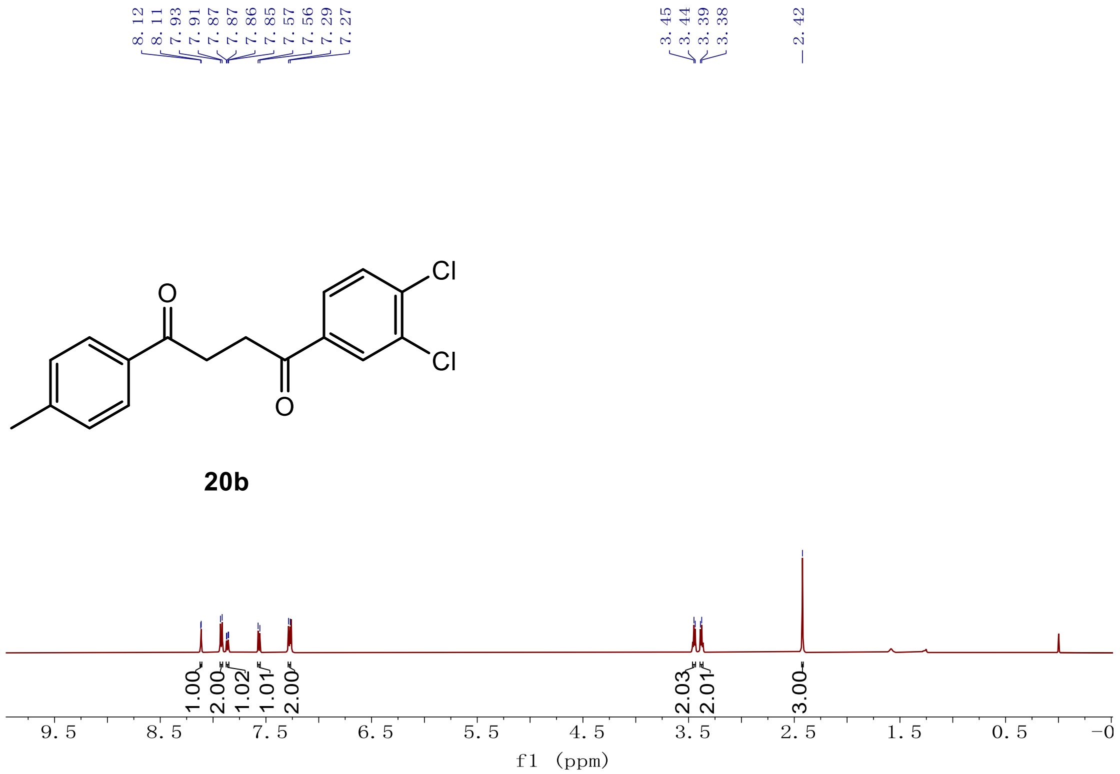
^{19}F NMR

376 MHz

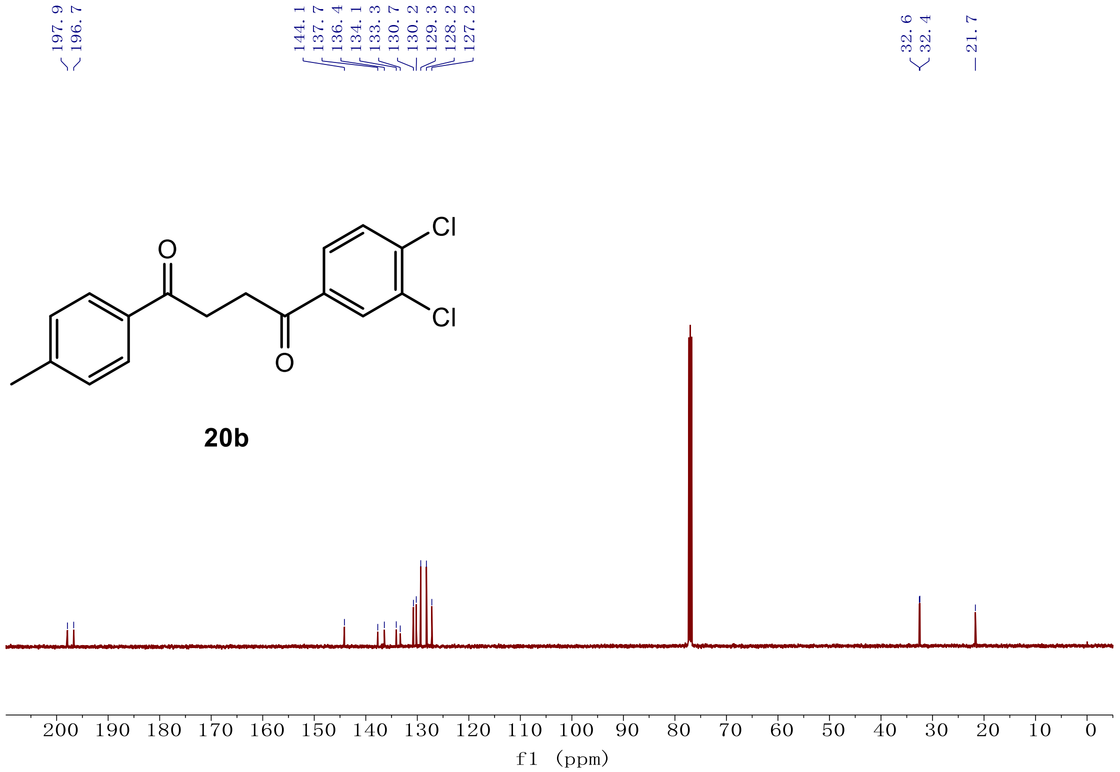
$CDCl_3$


19b
7.99
7.97
7.94
7.92
7.46
7.44
7.28
7.27
3.44
3.44
3.43
3.41
3.40
3.40
2.42
O
O
Cl
2.00
2.03
2.00
2.00
4.02
3.02
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
−0
f1 (ppm)

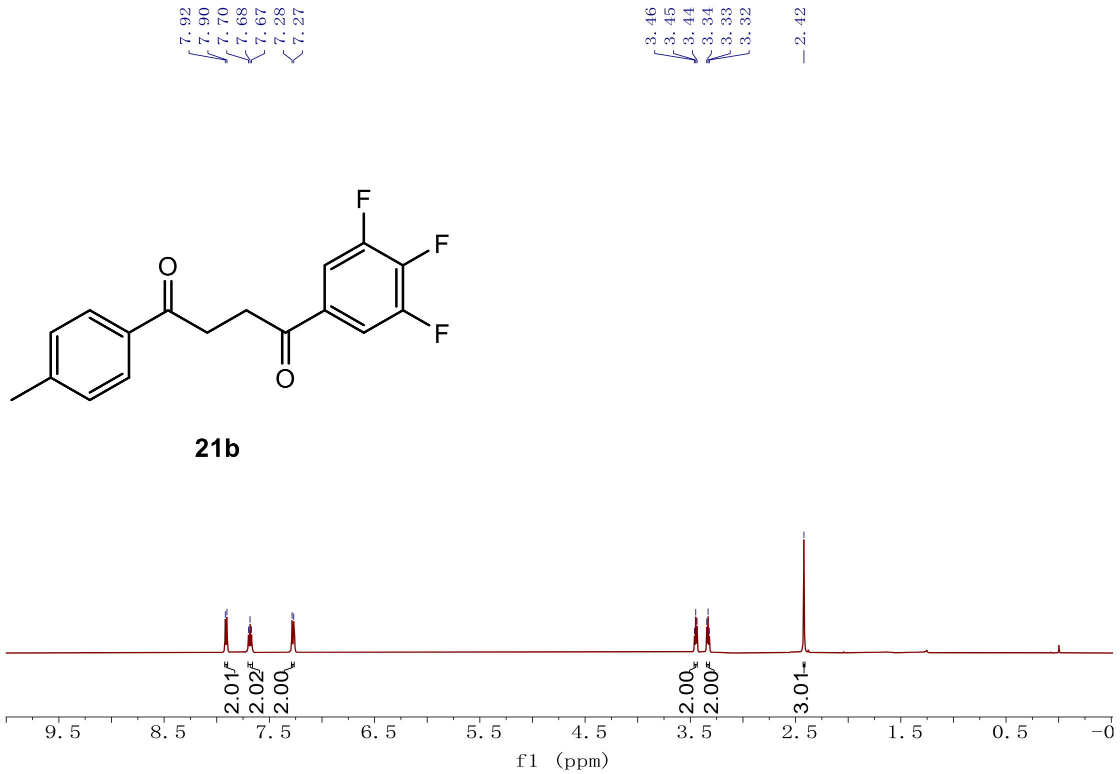

19b
197.1
196.6
143.0
138.5
134.1
133.2
128.5
128.3
127.9
127.2
31.5
31.4
20.6
O
O
Cl
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.12
8.11
7.93
7.91
7.87
7.87
7.86
7.85
7.57
7.56
7.29
7.27
3.45
3.44
3.39
3.38
2.42
O
O
Cl
Cl
1.00
2.00
1.02
1.01
2.00
2.03
2.01
3.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)

20b

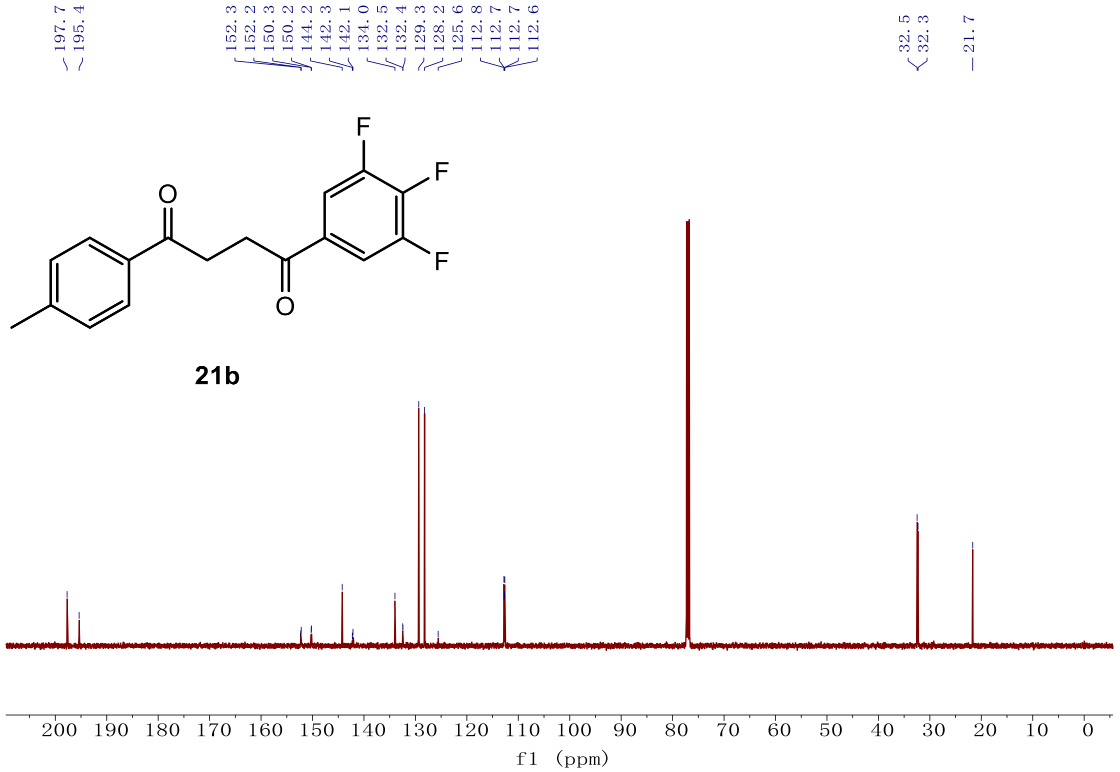

197.9
196.7
144.1
137.7
136.4
134.1
133.3
130.7
130.2
129.3
128.2
127.2
32.6
32.4
21.7
O
O
Cl
Cl
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

20b



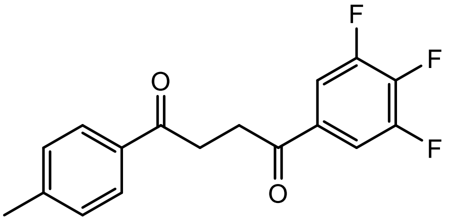
21b

7.92
7.90
7.70
7.68
7.67
7.28
7.27
3.46
3.45
3.44
3.34
3.33
3.32
2.42
F
F
F
O
O
2.01
2.02
2.00
2.00
2.00
3.01
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
−0
f1 (ppm)



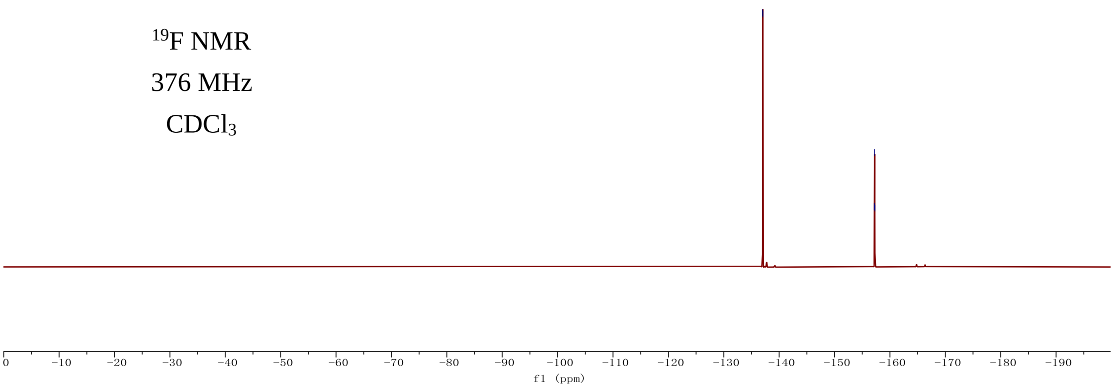
21b

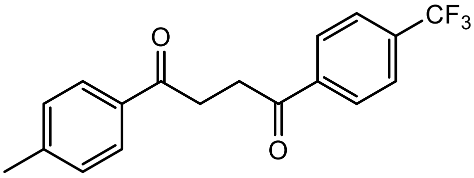
197.7
195.4
152.3
152.2
150.3
150.2
144.2
142.3
142.1
134.0
132.5
132.4
129.3
128.2
125.6
112.8
112.7
112.7
112.6
32.5
32.3
21.7
F
F
F
O
O
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



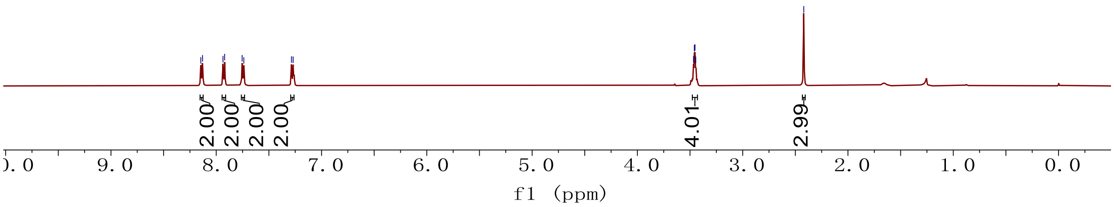
21b

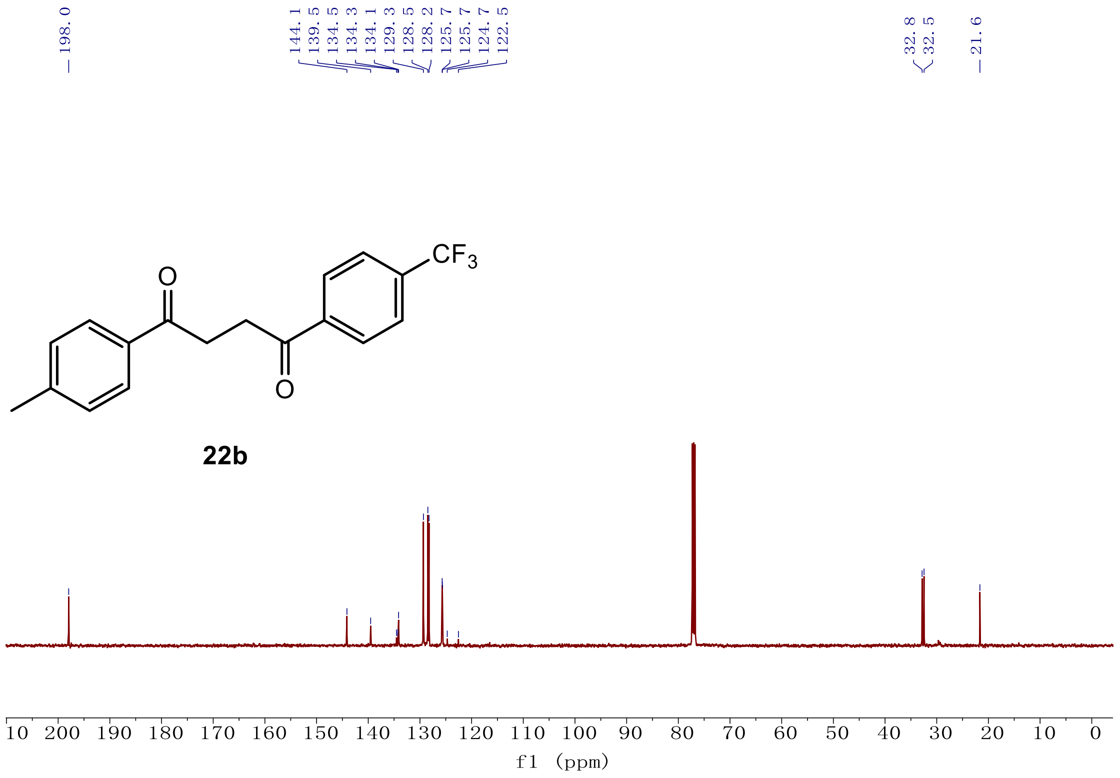
^{19}F NMR
376 MHz
CDCl$_3$



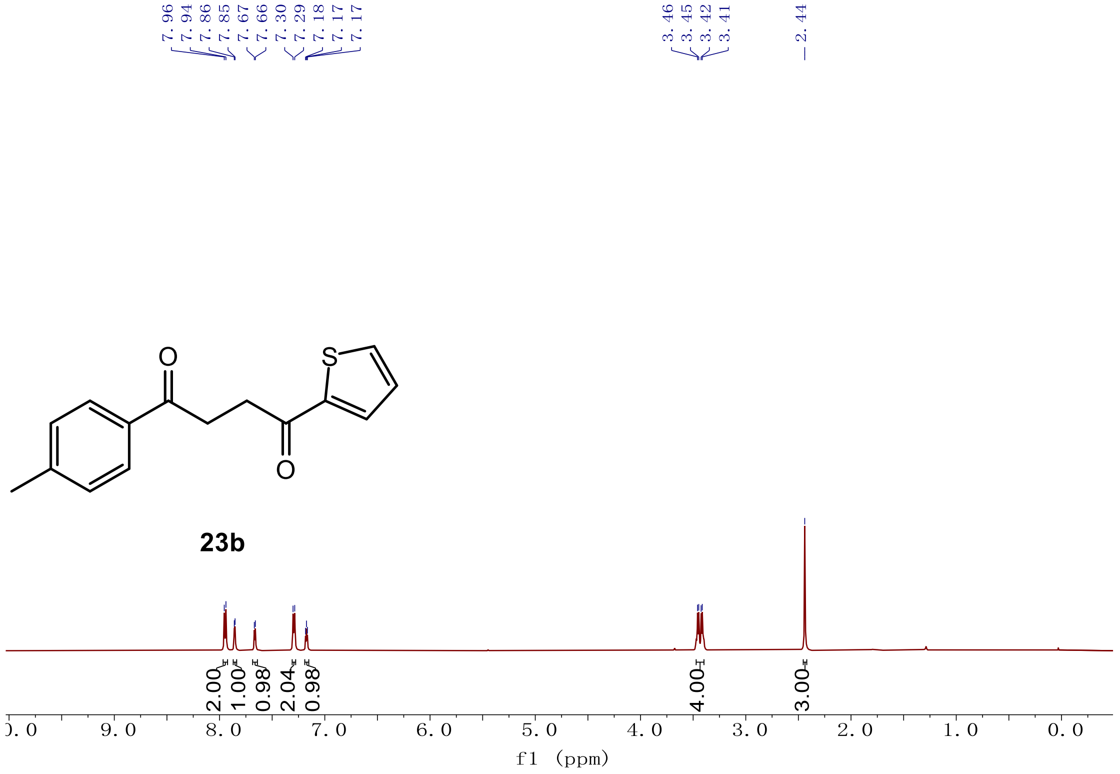


22b

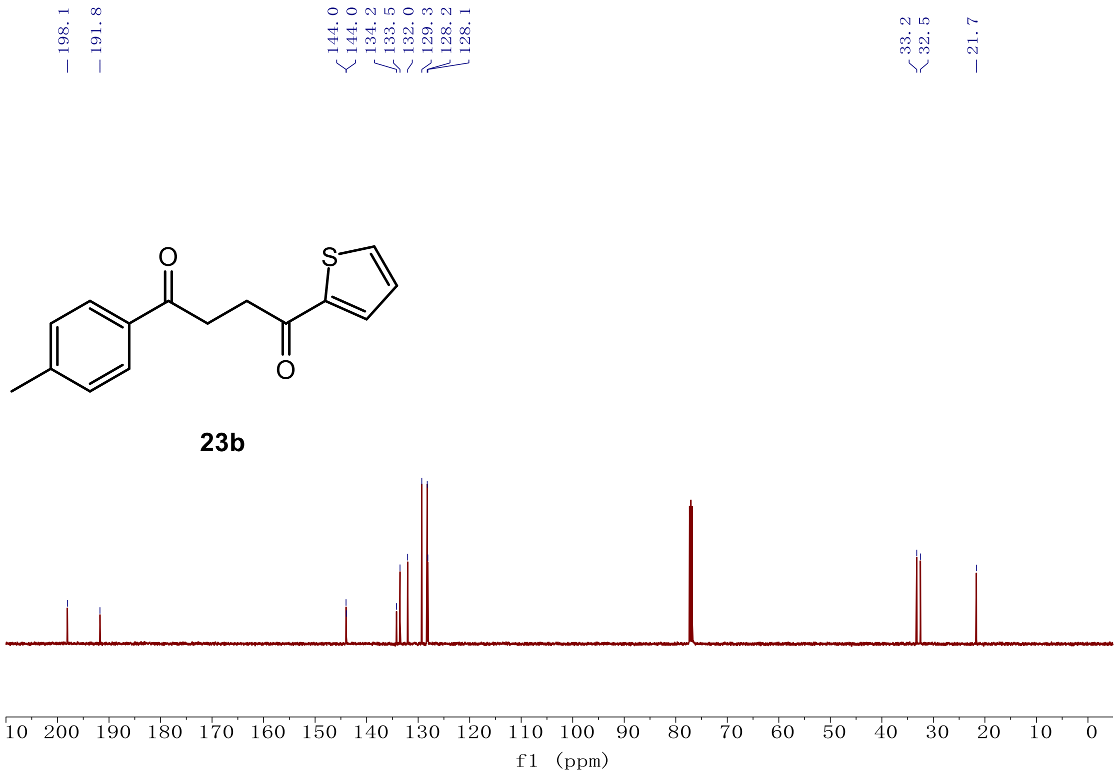



198.0
144.1
139.5
134.5
134.3
134.1
129.3
128.5
128.2
125.7
125.7
124.7
122.5
32.8
32.5
21.6
O
O
CF3
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

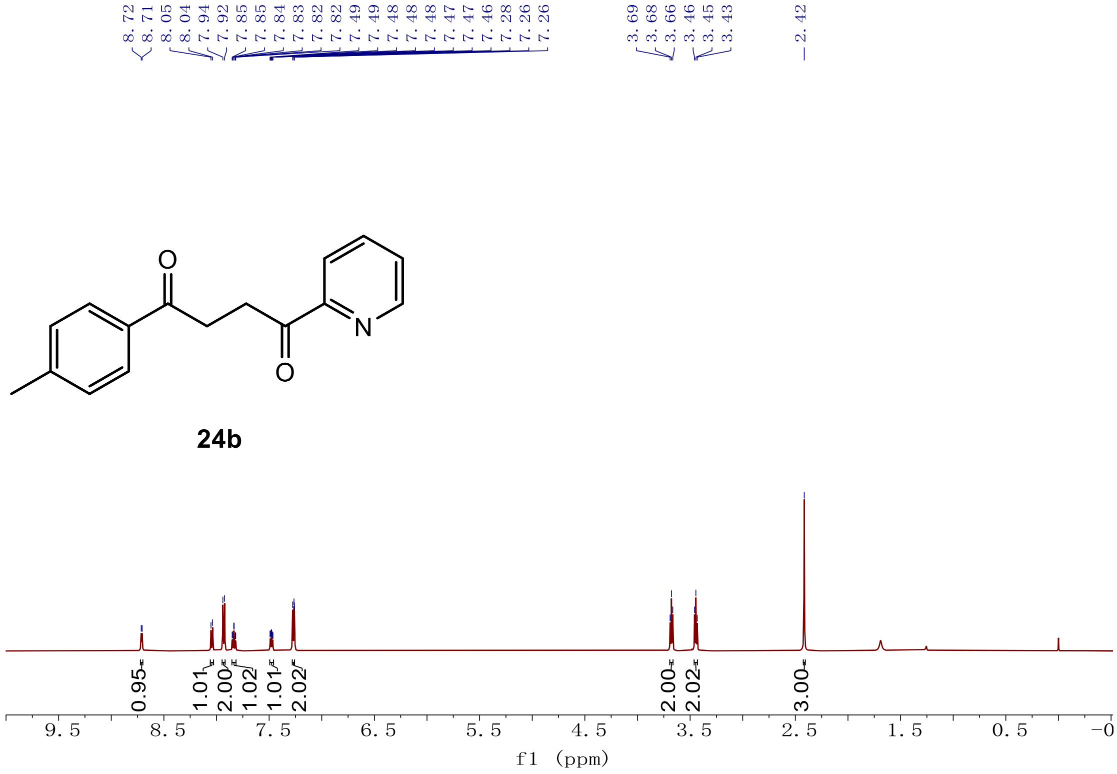
22b


7.96
7.94
7.86
7.85
7.67
7.66
7.30
7.29
7.18
7.17
7.17
7.17
3.46
3.45
3.42
3.41
2.44
O
O
S
2.00
1.00
0.98
2.04
0.98
4.00
3.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

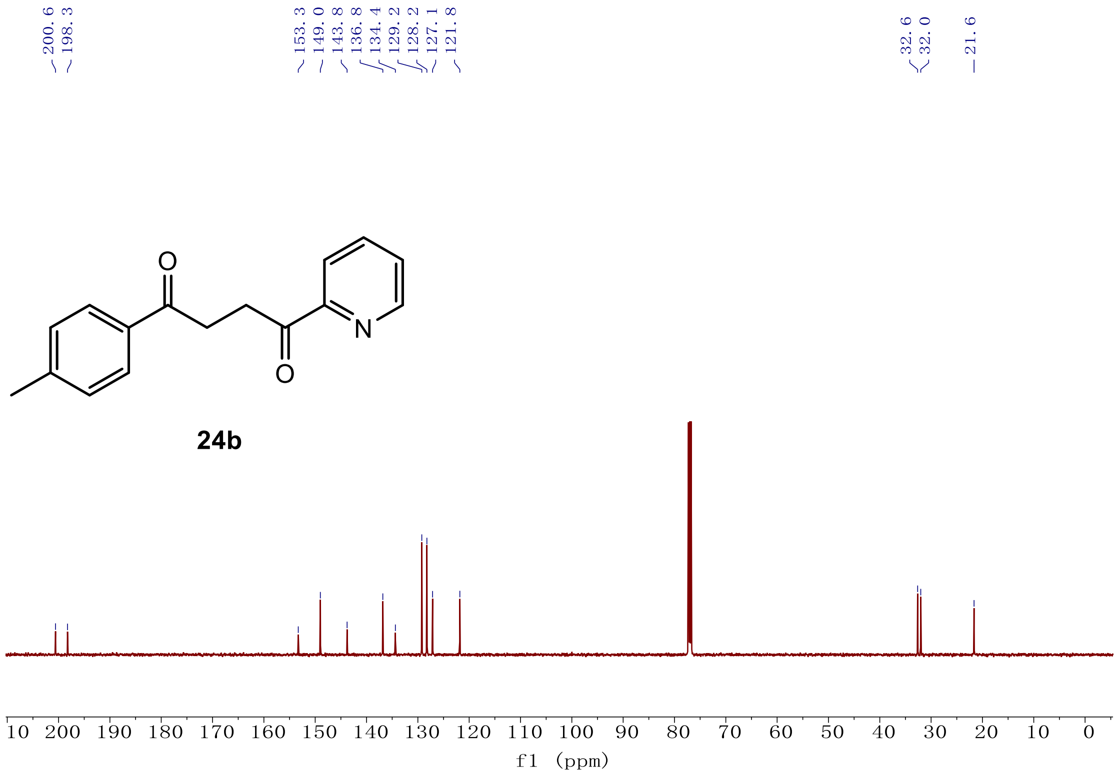
23b


198.1
191.8
144.0
144.0
134.2
133.5
132.0
129.3
128.2
128.1
33.2
32.5
21.7
O
S
O
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

23b

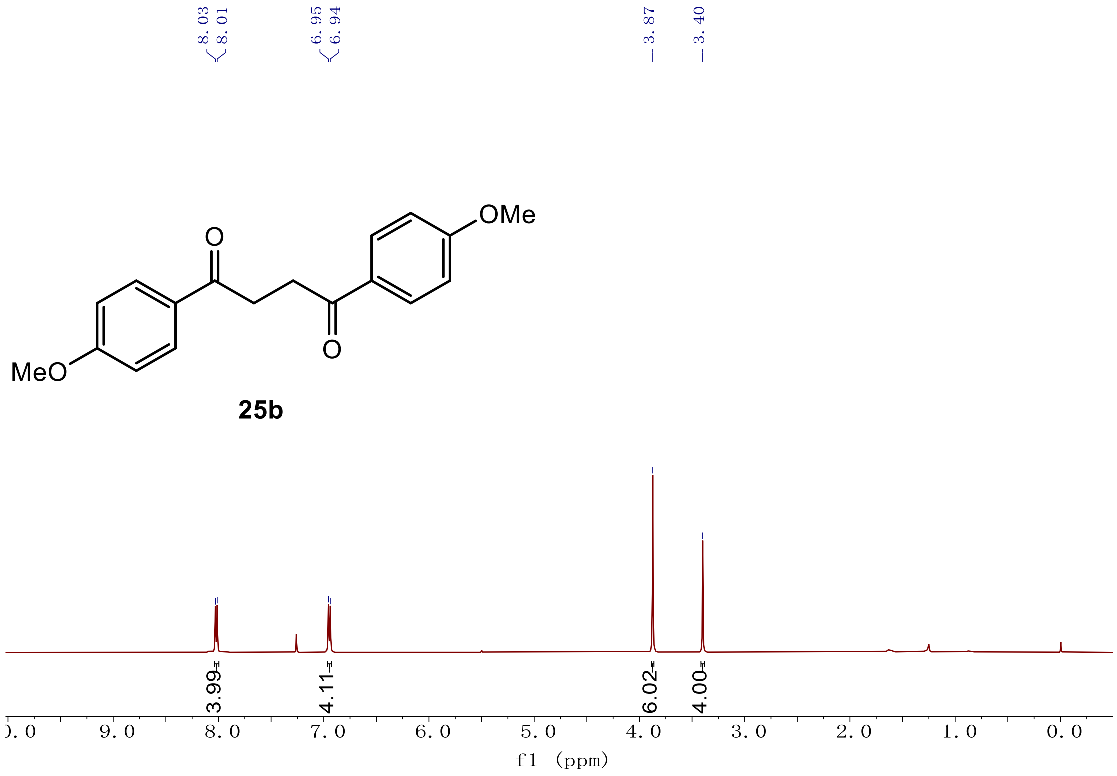

8.72
8.71
8.05
8.04
7.94
7.92
7.85
7.85
7.84
7.83
7.82
7.82
7.49
7.49
7.48
7.48
7.48
7.47
7.47
7.46
7.28
7.26
7.26
3.69
3.68
3.66
3.46
3.45
3.43
2.42
O
N
O
0.95
1.01
2.00
1.02
1.01
2.02
2.00
2.02
3.00
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 −0
f1 (ppm)

24b



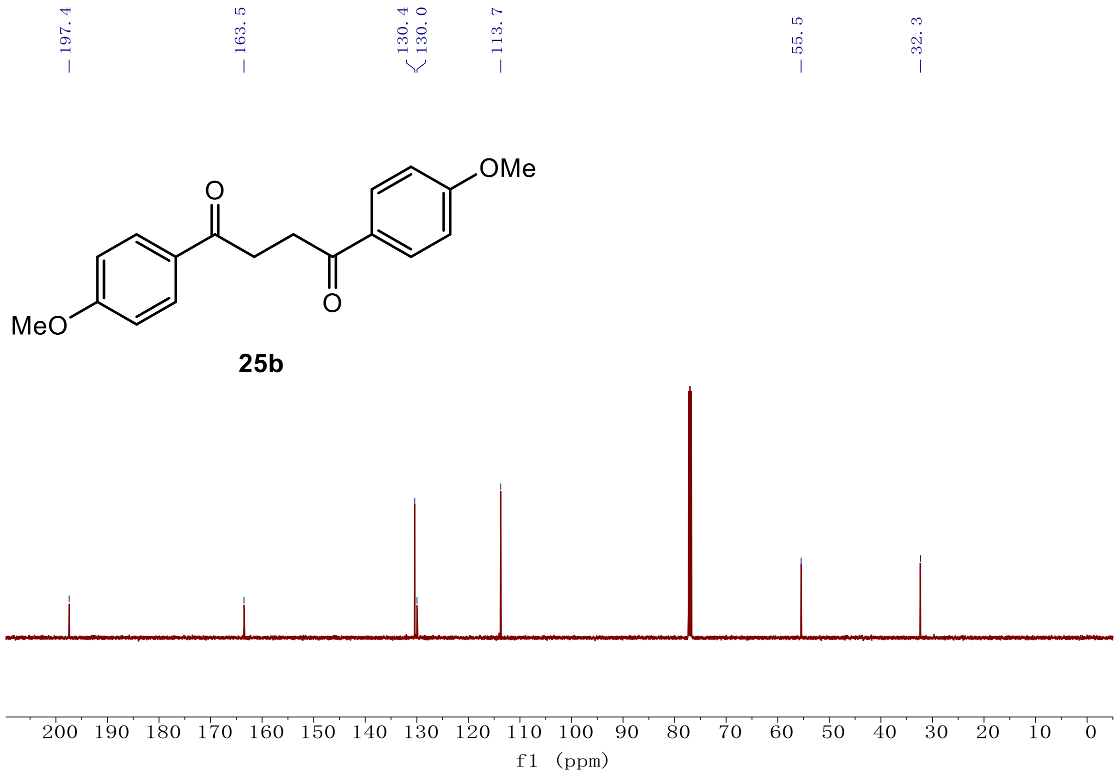
24b

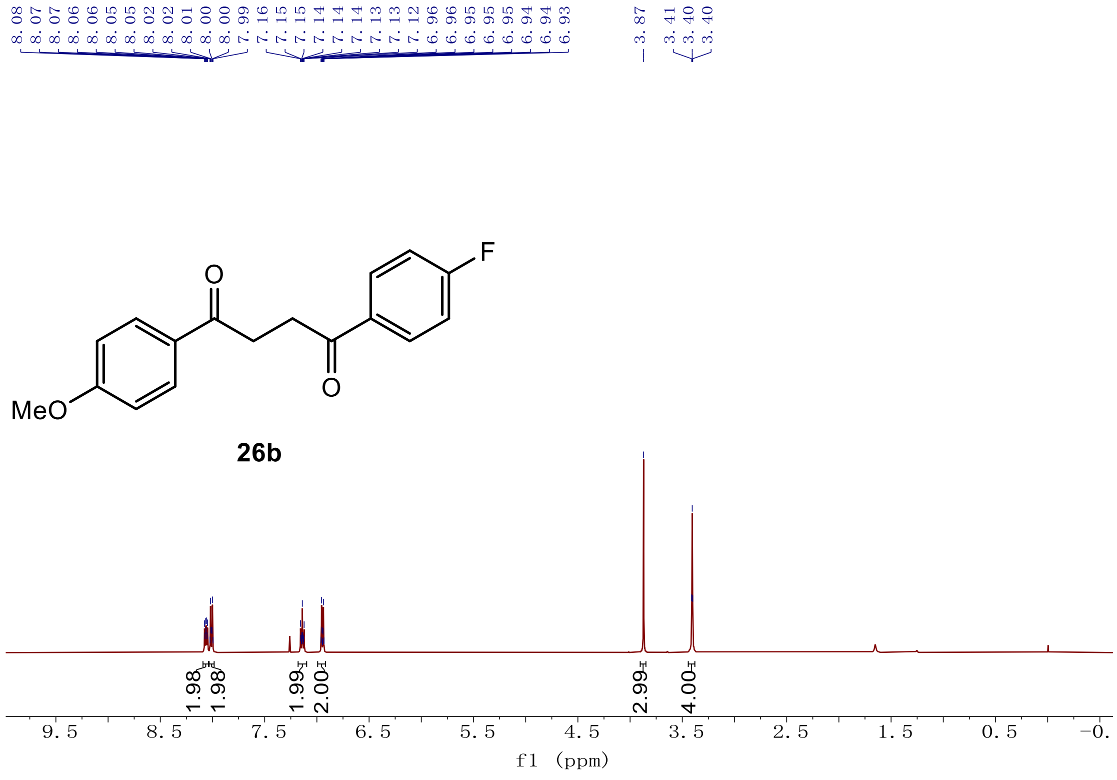
200.6
198.3
153.3
149.0
143.8
136.8
134.4
129.2
128.2
127.1
121.8
32.6
32.0
21.6
O
N
O
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

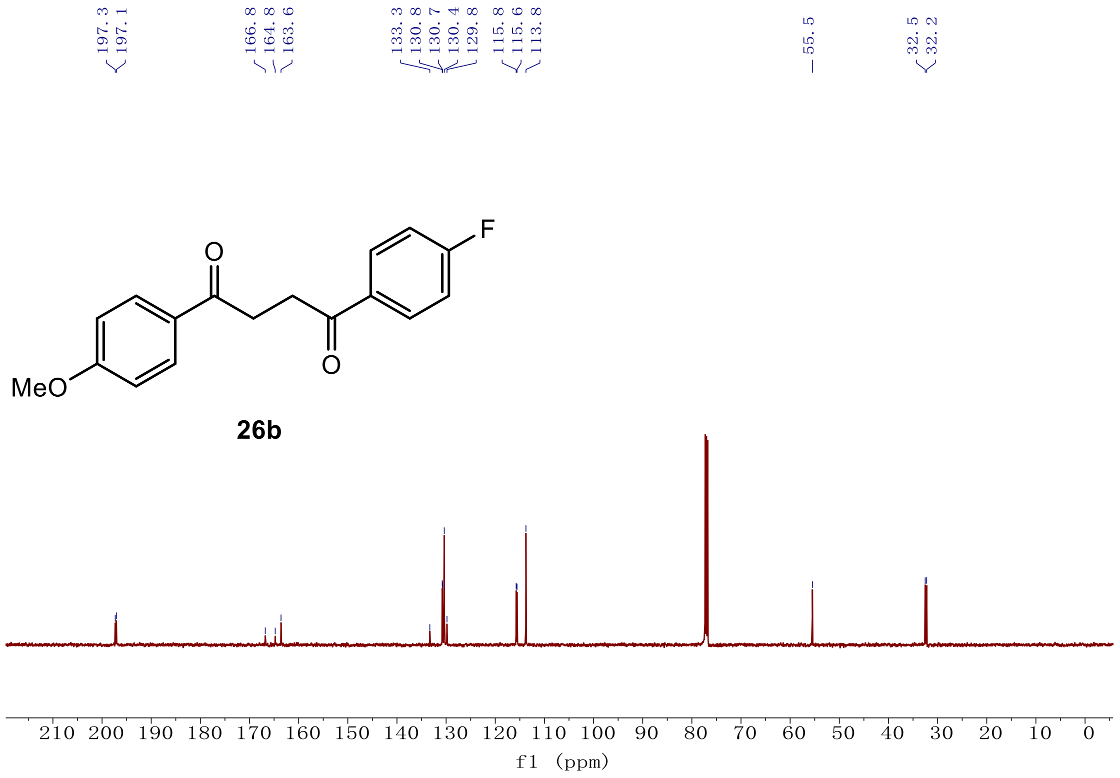


25b

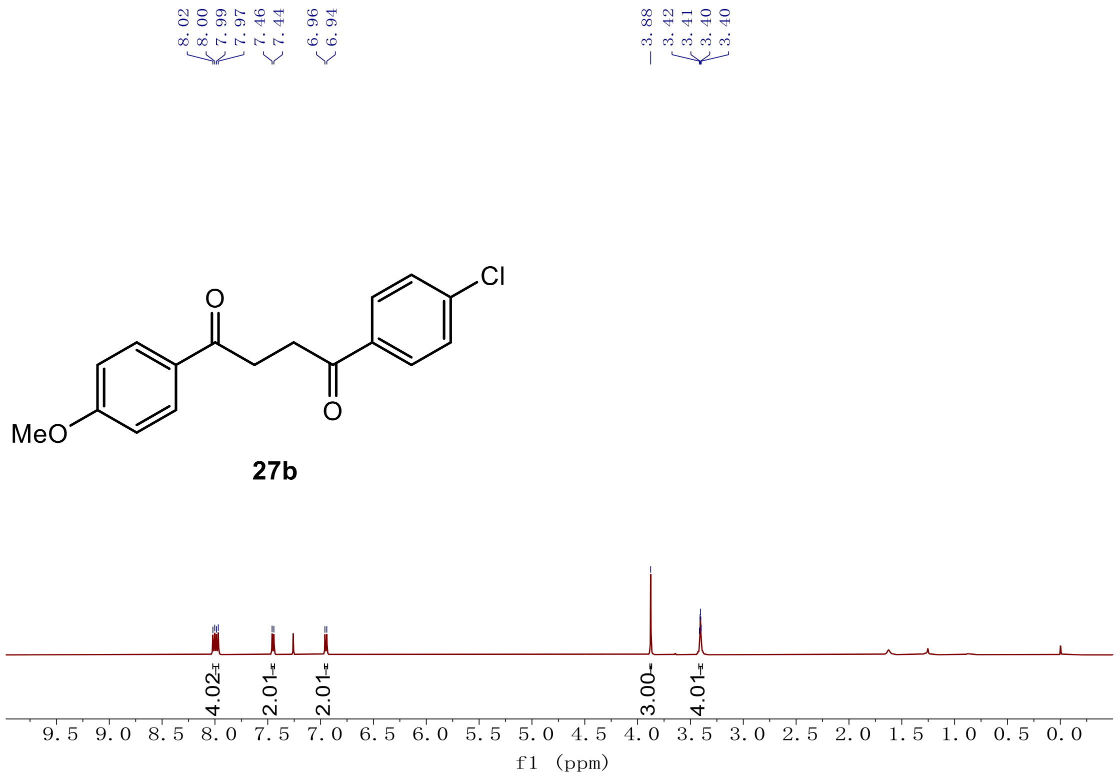
8.03
8.01
6.95
6.94
3.87
3.40
OMe
O
MeO
O
3.99
4.11
6.02
4.00
0.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


25b
197.4
163.5
130.4
130.0
113.7
55.5
32.3
OMe
O
O
MeO
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

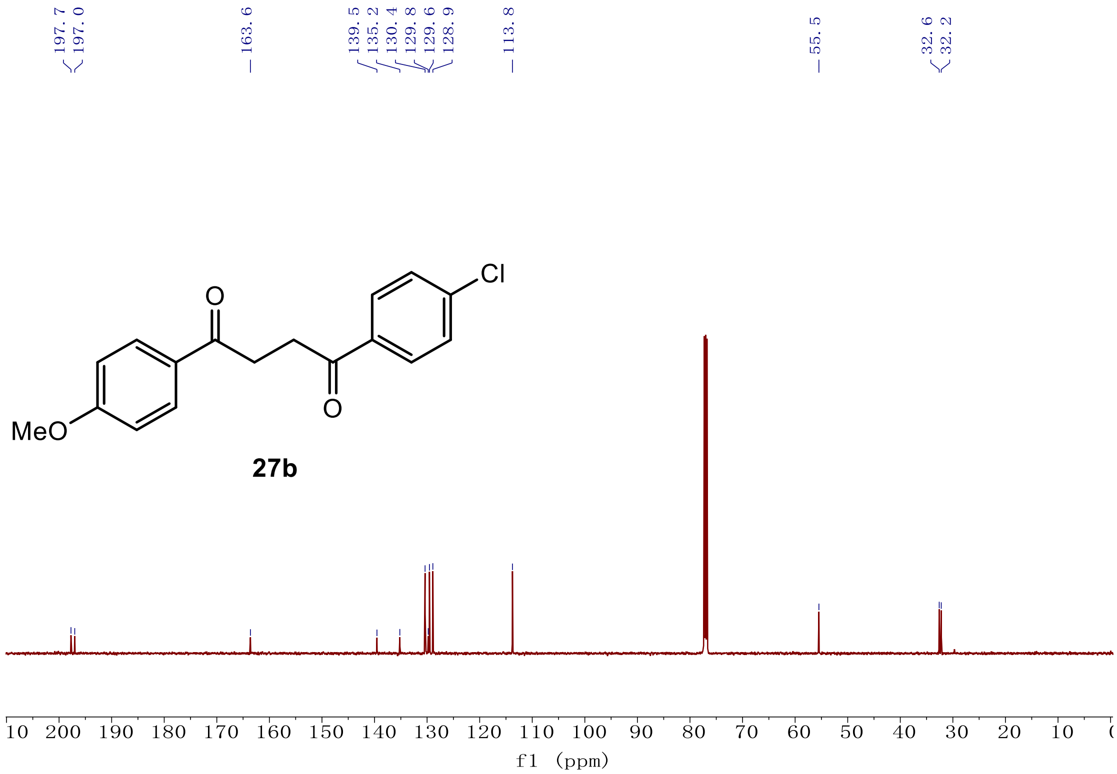

26b
8.08
8.07
8.07
8.06
8.06
8.05
8.05
8.02
8.02
8.01
8.00
8.00
7.99
7.16
7.15
7.15
7.14
7.14
7.14
7.13
7.13
7.12
6.96
6.96
6.95
6.95
6.95
6.94
6.94
6.93
3.87
3.41
3.40
3.40
F
O
O
MeO
1.98
1.98
1.99
2.00
2.99
4.00
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0.
f1 (ppm)


197.3
197.1
166.8
164.8
163.6
133.3
130.8
130.7
130.4
129.8
115.8
115.6
113.8
55.5
32.5
32.2
O
F
O
MeO
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

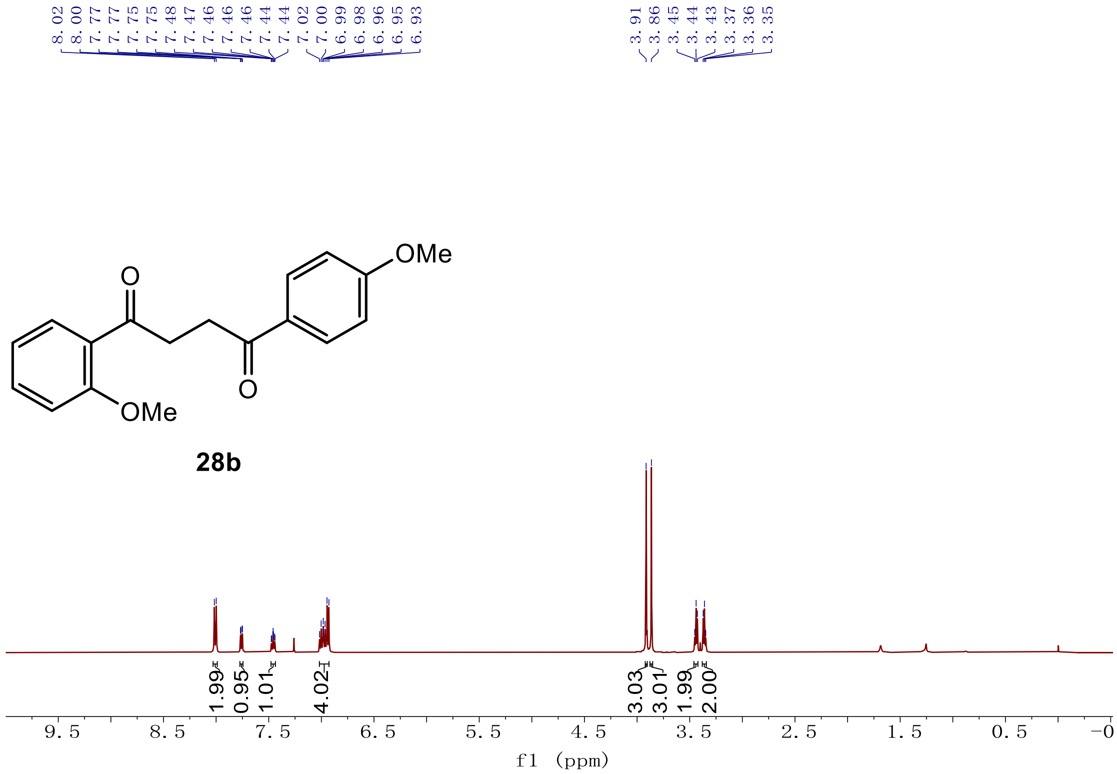
26b


8.02
8.00
7.99
7.97
7.46
7.44
6.96
6.94
3.88
3.42
3.41
3.40
3.40
O
Cl
O
MeO
4.02
2.01
2.01
3.00
4.01
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 0.0
f1 (ppm)

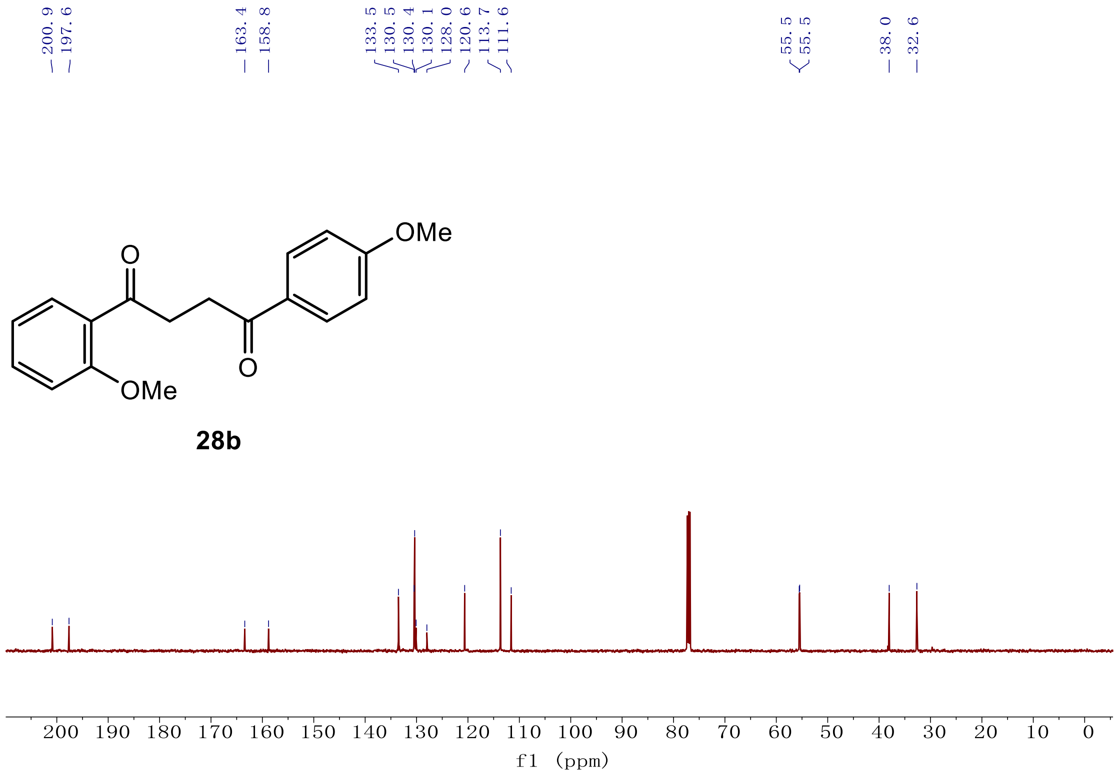
27b


197.7
197.0
163.6
139.5
135.2
130.4
129.8
129.6
128.9
113.8
55.5
32.6
32.2
O
Cl
MeO
O
10 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

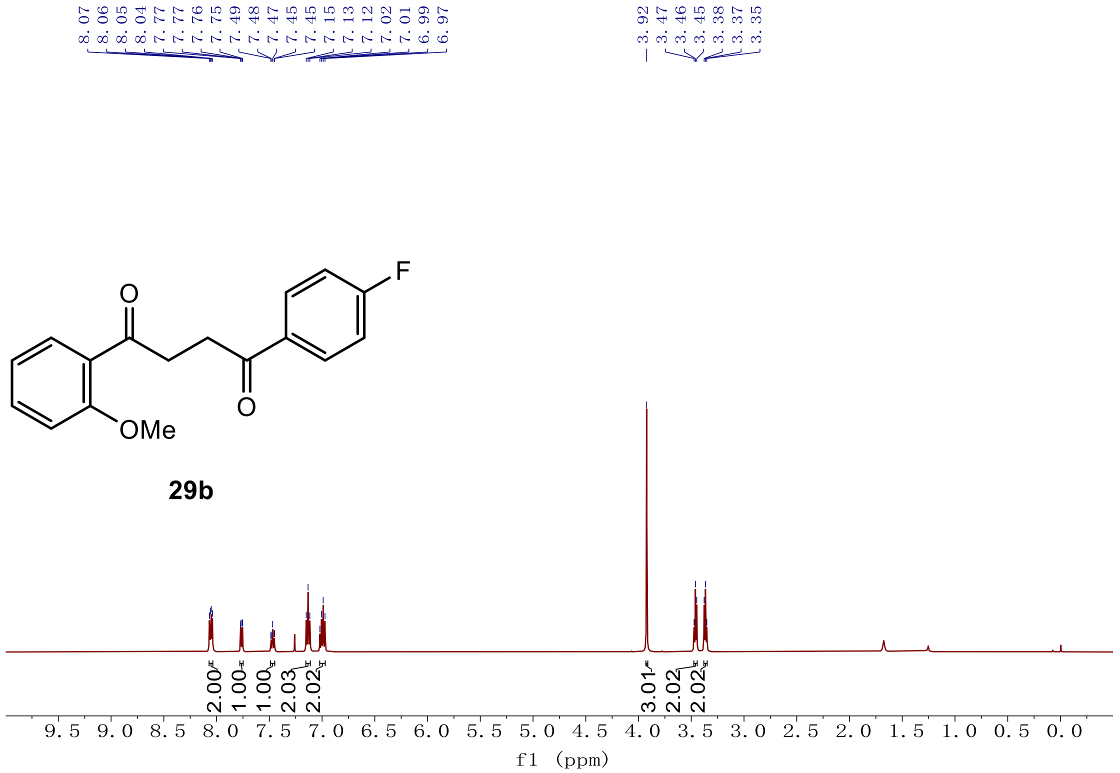
27b


8.02
8.00
7.77
7.77
7.75
7.75
7.48
7.47
7.46
7.46
7.46
7.44
7.44
7.02
7.00
6.99
6.98
6.96
6.95
6.93
3.91
3.86
3.45
3.44
3.43
3.37
3.36
3.35
O
OMe
OMe
O
1.99
0.95
1.01
4.02
3.03
3.01
1.99
2.00
9.5 8.5 7.5 6.5 5.5 4.5 3.5 2.5 1.5 0.5 -0
f1 (ppm)

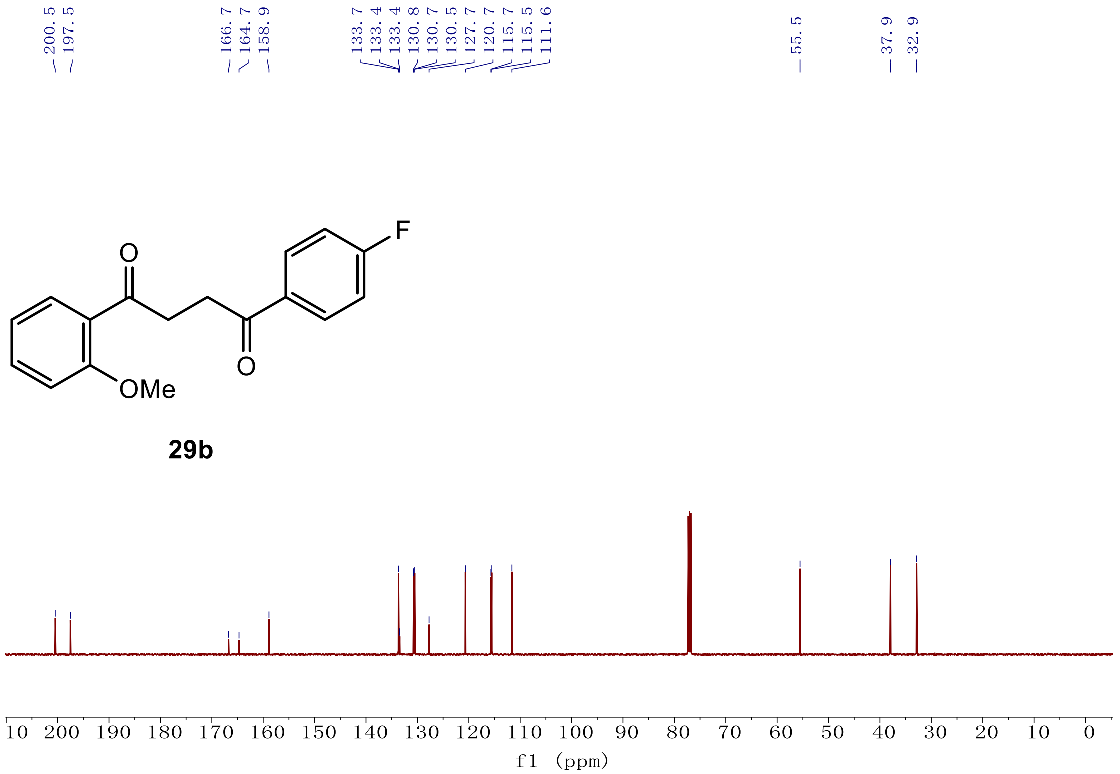
28b


200.9
197.6
163.4
158.8
133.5
130.5
130.4
130.1
128.0
120.6
113.7
111.6
55.5
55.5
38.0
32.6
OMe
O
O
OMe
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

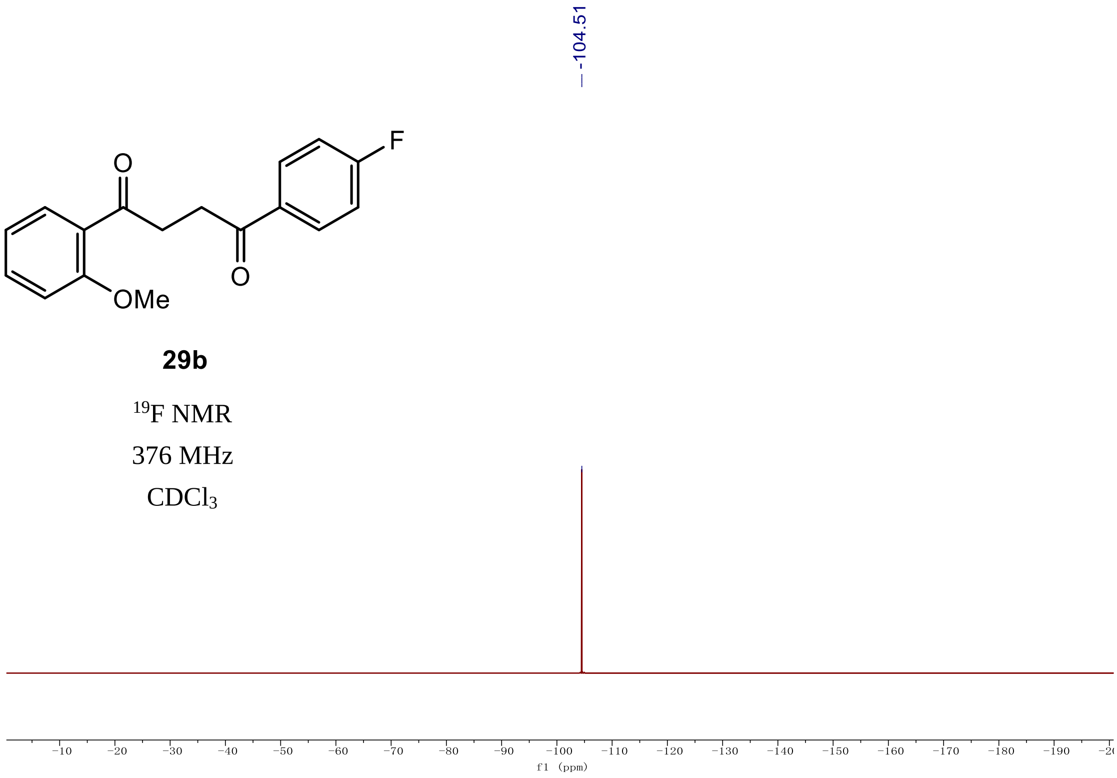
28b


8.07
8.06
8.05
8.04
7.77
7.77
7.76
7.75
7.49
7.48
7.47
7.45
7.45
7.15
7.13
7.12
7.02
7.01
6.99
6.97
3.92
3.47
3.46
3.45
3.38
3.37
3.35
F
O
O
OMe
2.00
1.00
1.00
2.03
2.02
3.01
2.02
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 0.0
f1 (ppm)

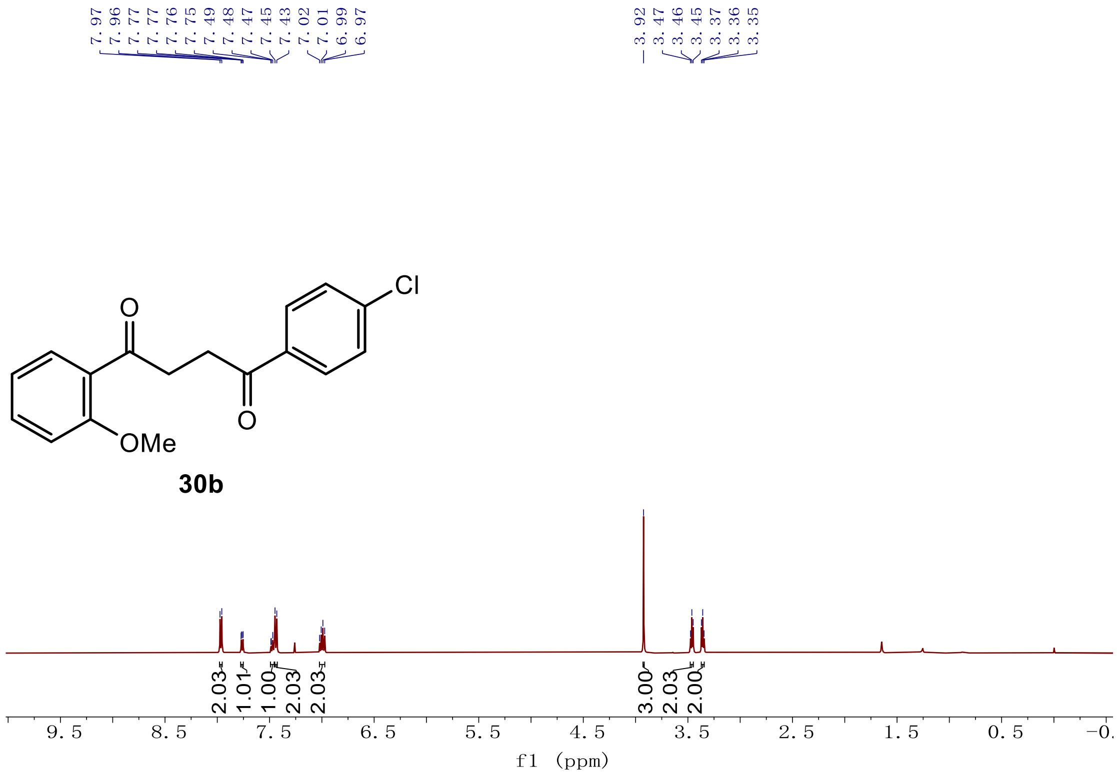
29b

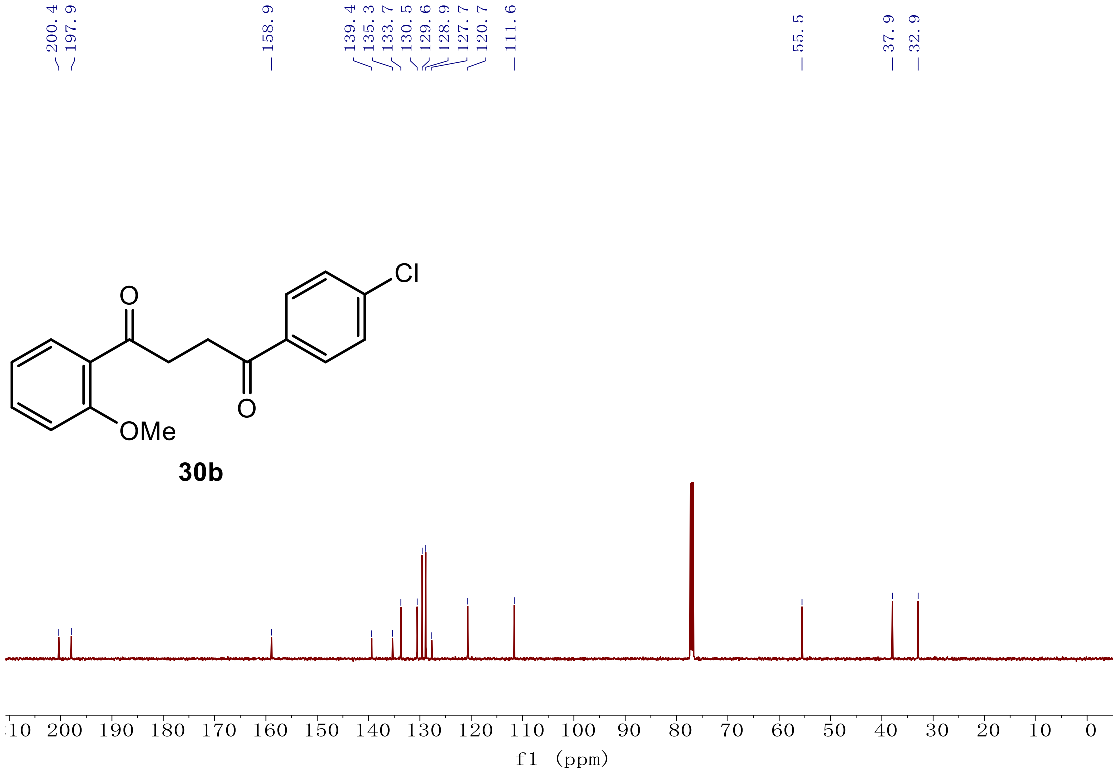

200.5
197.5
166.7
164.7
158.9
133.7
133.4
133.4
130.8
130.7
130.5
127.7
120.7
115.7
115.5
111.6
55.5
37.9
32.9
O
O
F
OMe
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

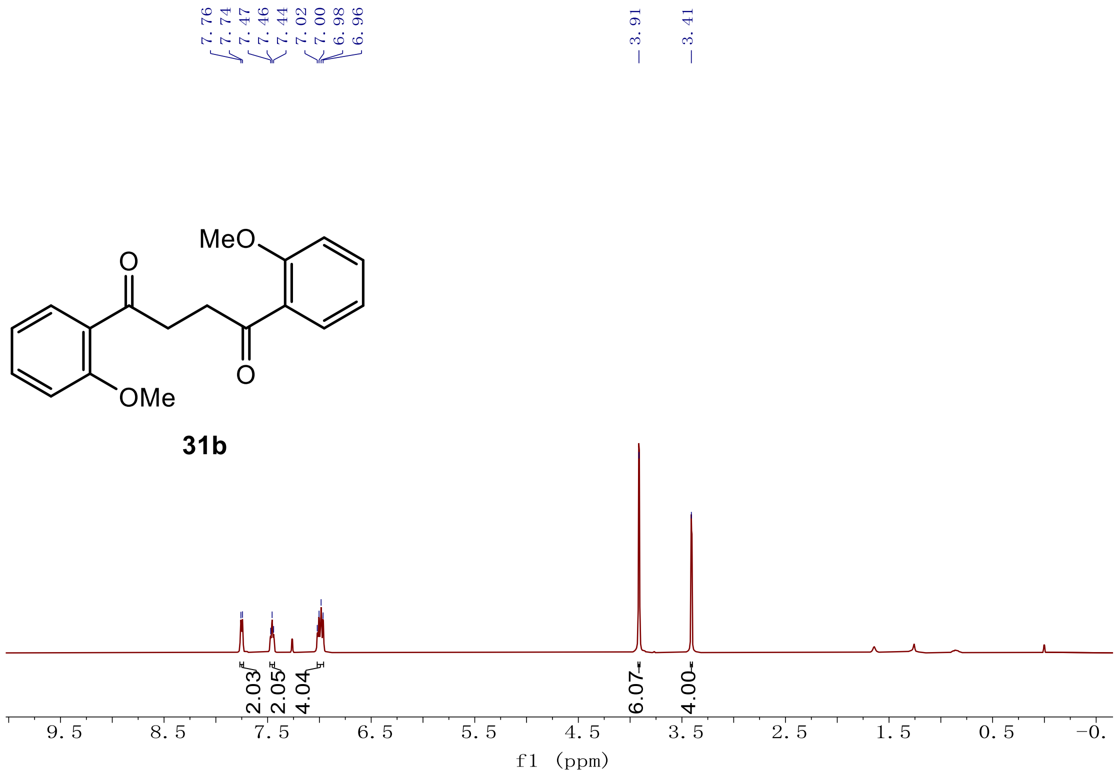
29b


-104.51
O
O
F
OMe
^{19}F NMR
376 MHz
$CDCl_3$
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
f1 (ppm)

29b

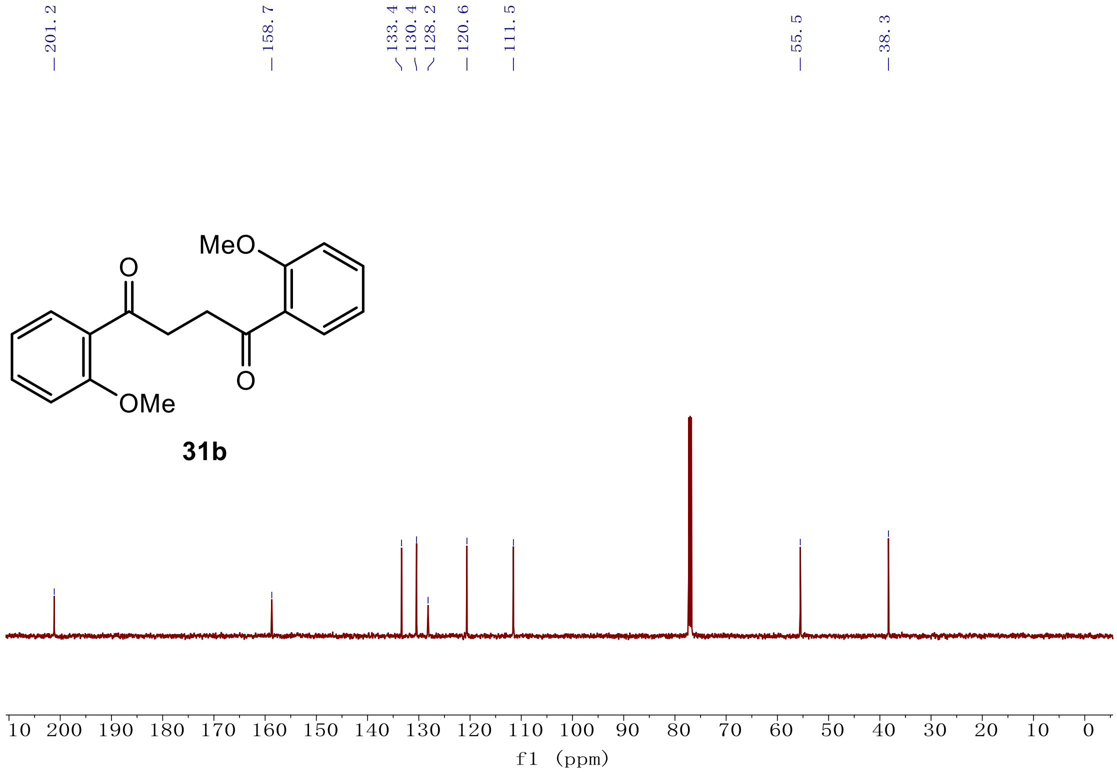

7.97
7.96
7.77
7.77
7.76
7.75
7.49
7.48
7.47
7.45
7.43
7.02
7.01
6.99
6.97
3.92
3.47
3.46
3.45
3.37
3.36
3.35
O
Cl
O
OMe
30b
2.03
1.01
1.00
2.03
2.03
3.00
2.03
2.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.
f1 (ppm)


200.4
197.9
158.9
139.4
135.3
133.7
130.5
129.6
128.9
127.7
120.7
111.6
55.5
37.9
32.9
O
Cl
O
OMe
30b
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



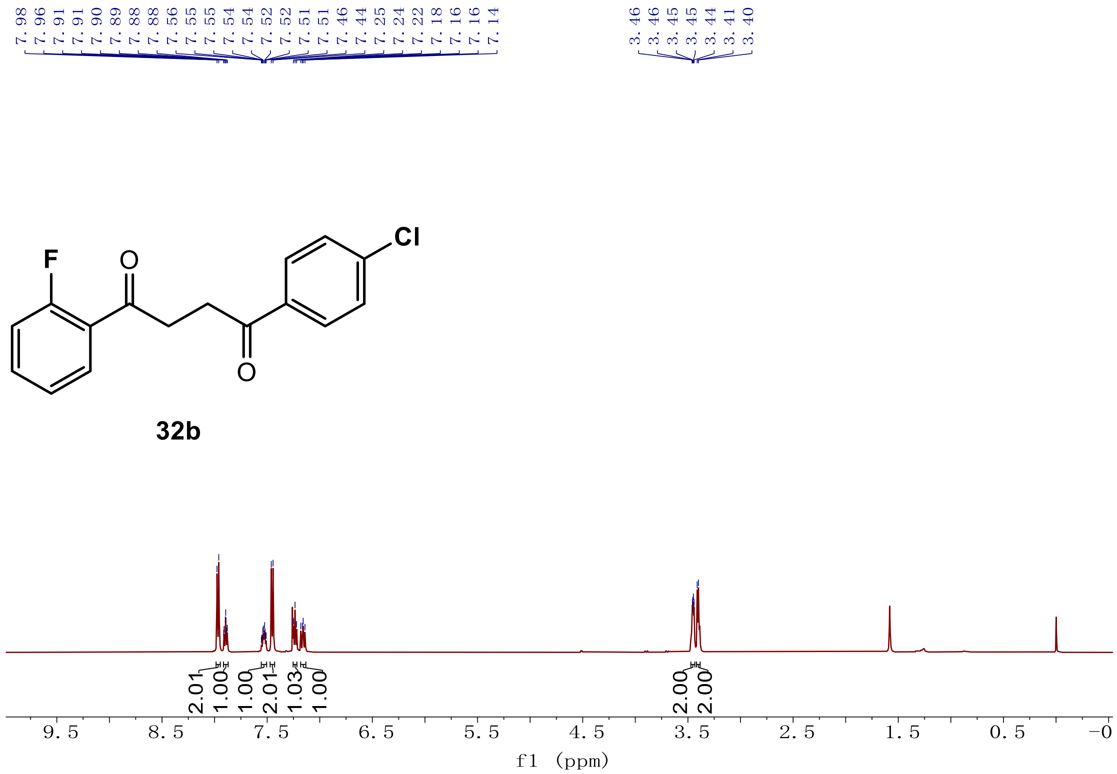
31b

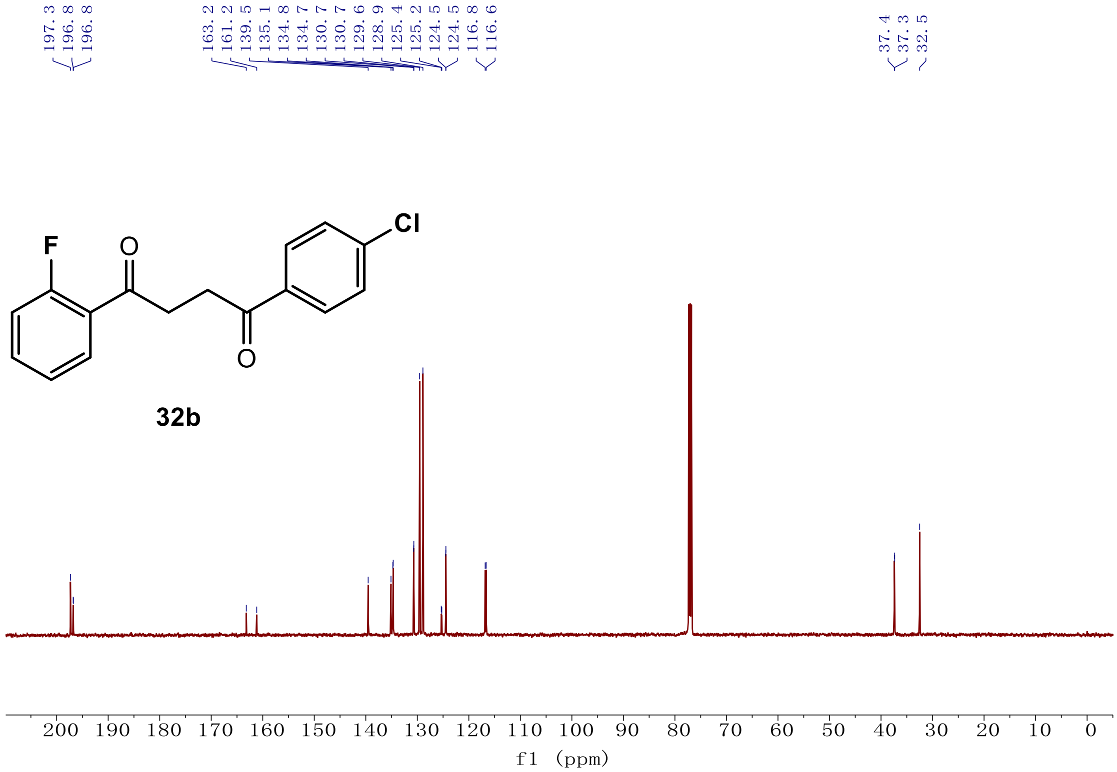
7.76
7.74
7.47
7.46
7.44
7.02
7.00
6.98
6.96
3.91
3.41
MeO
O
O
OMe
2.03
2.05
4.04
6.07
4.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.
f1 (ppm)

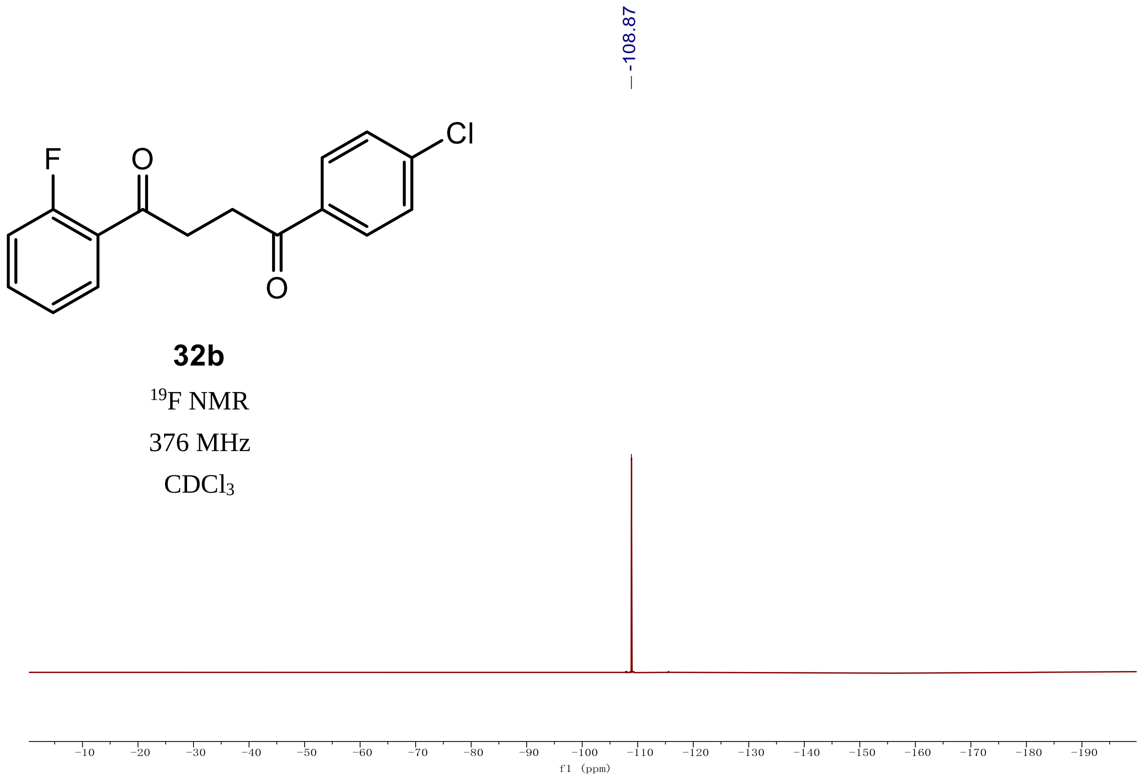


31b

201.2
158.7
133.4
130.4
128.2
120.6
111.5
55.5
38.3
MeO
O
O
OMe
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.98
7.96
7.91
7.91
7.90
7.89
7.88
7.88
7.56
7.55
7.55
7.54
7.54
7.52
7.52
7.51
7.51
7.46
7.44
7.25
7.24
7.22
7.18
7.16
7.16
7.14
3.46
3.46
3.45
3.45
3.44
3.41
3.40
F
O
O
Cl
32b
2.01
1.00
1.00
2.01
1.03
1.00
2.00
2.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)


197.3
196.8
196.8
163.2
161.2
139.5
135.1
134.8
134.7
130.7
130.7
129.6
128.9
125.4
125.2
124.5
124.5
116.8
116.6
37.4
37.3
32.5
F
O
O
Cl
32b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

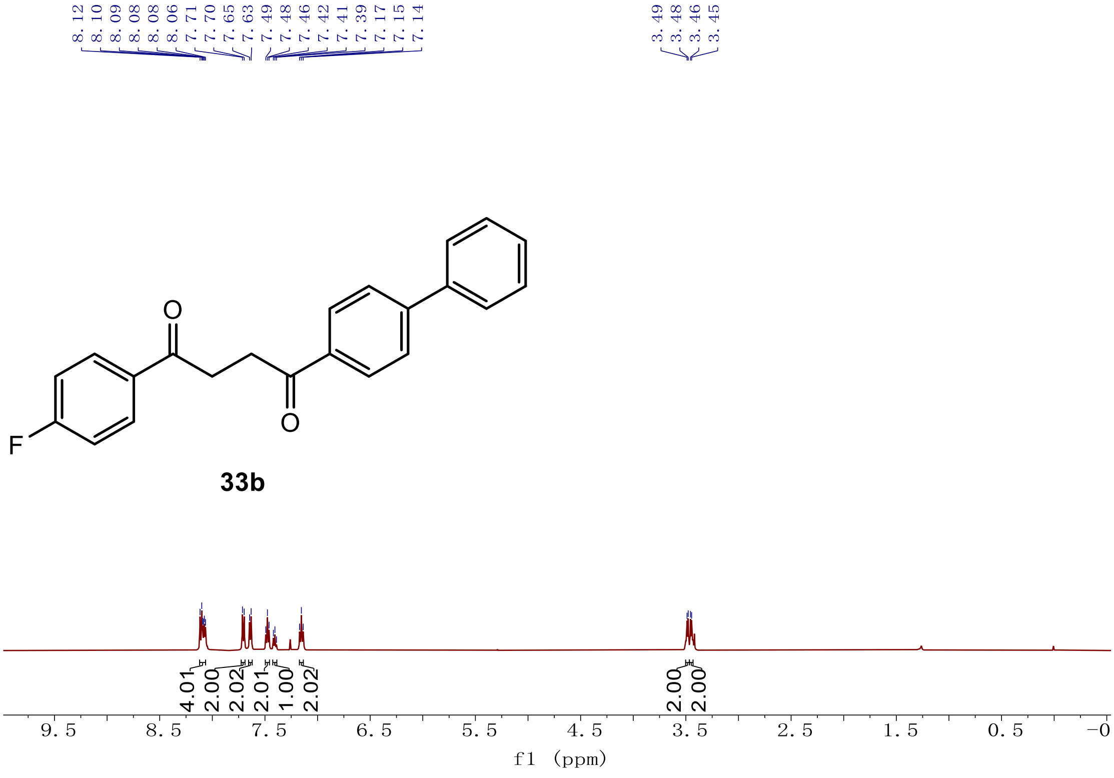


32b

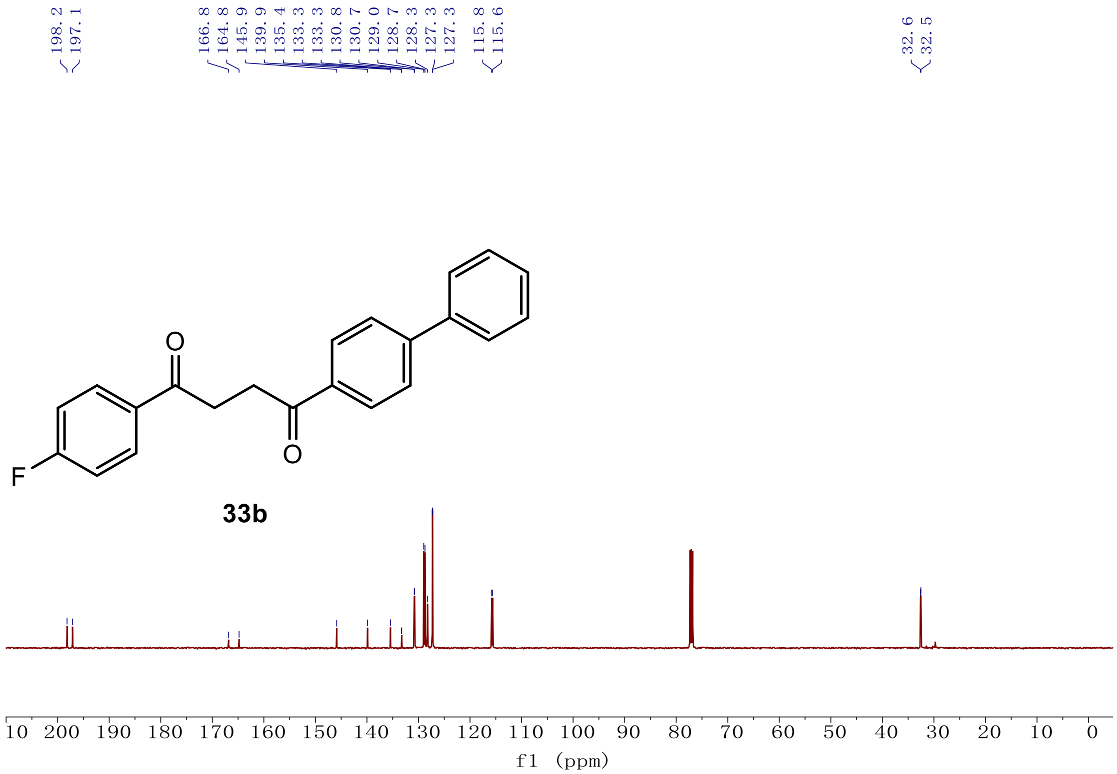
^{19}F NMR

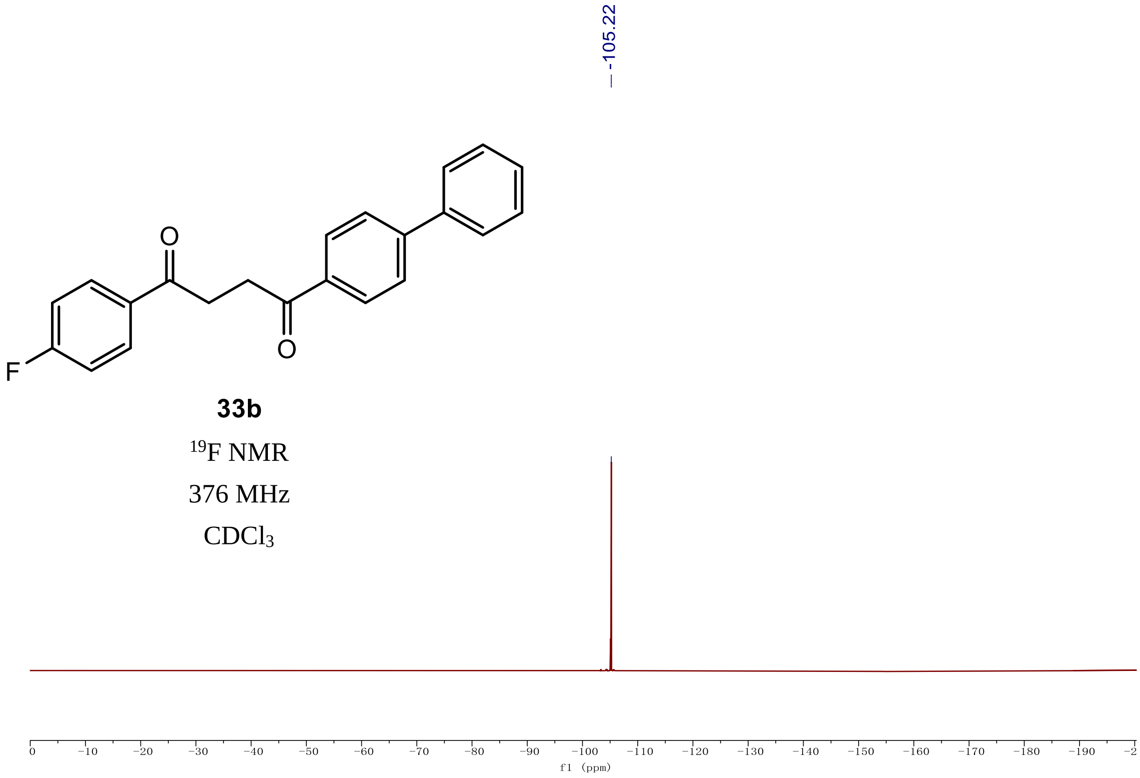
376 MHz

$CDCl_3$



33b

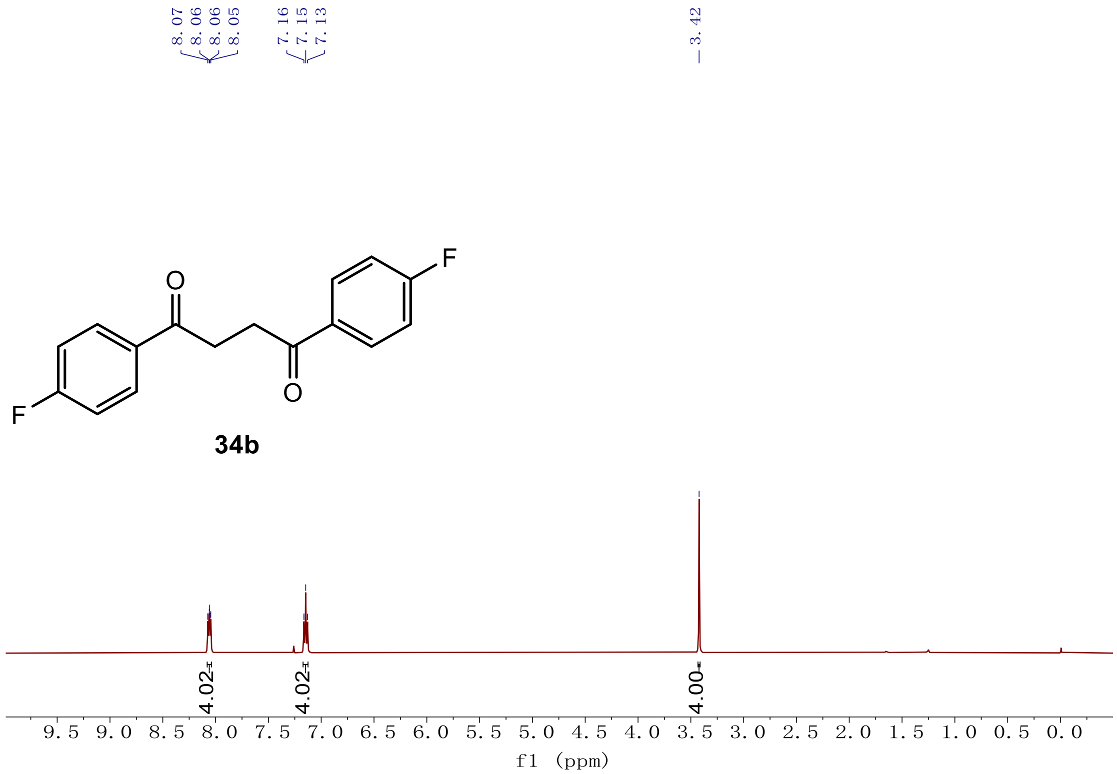

33b

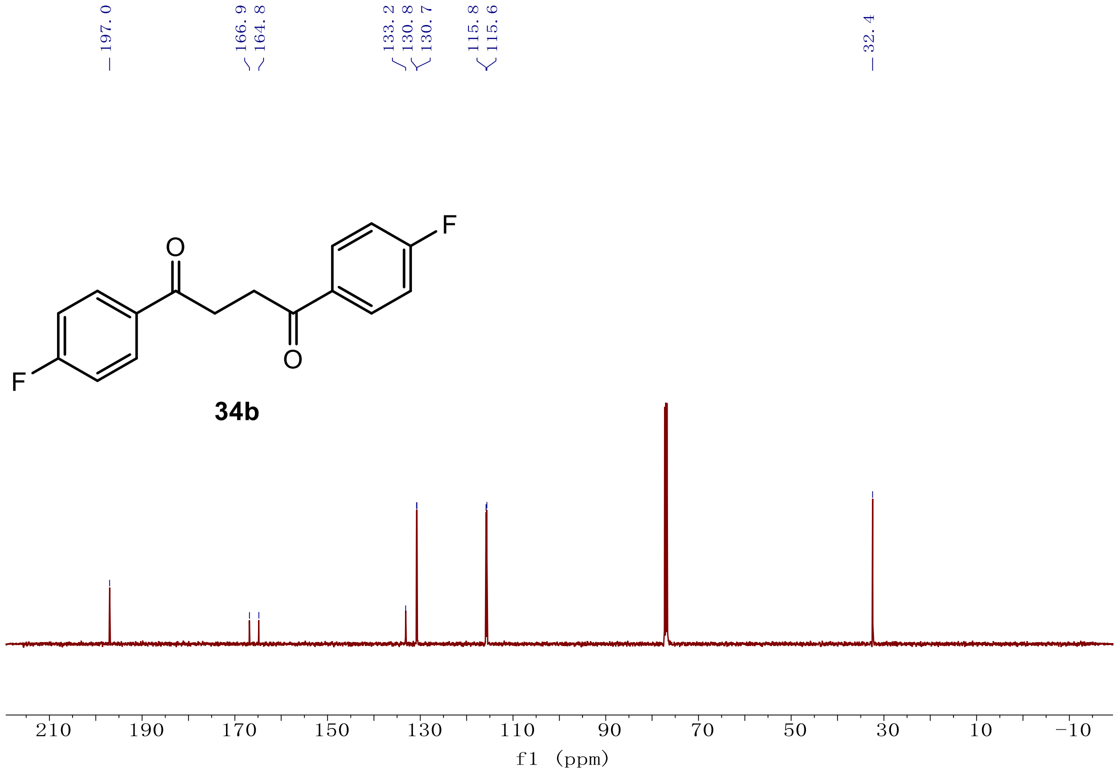

33b

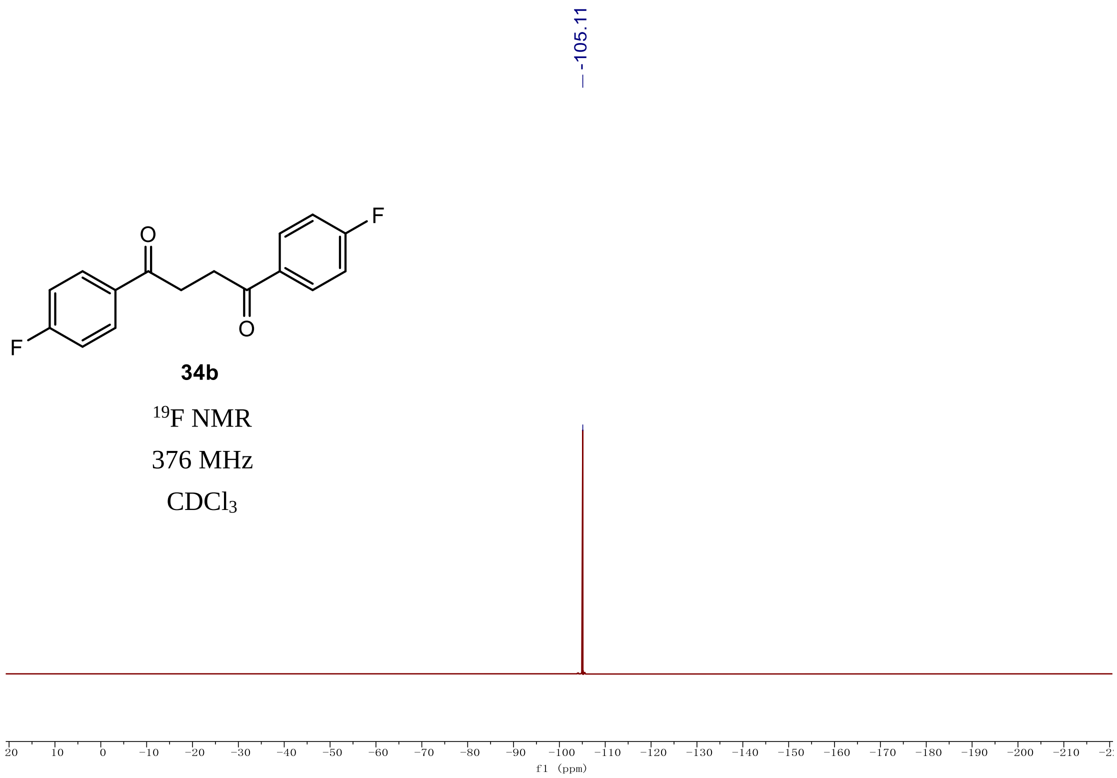
^{19}F NMR

376 MHz

$CDCl_3$


8.07
8.06
8.06
8.05
7.16
7.15
7.13
3.42
O
F
O
F
34b
4.02
4.02
4.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


197.0
166.9
164.8
133.2
130.8
130.7
115.8
115.6
32.4
O
F
O
F
34b
210 190 170 150 130 110 90 70 50 30 10 −10
f1 (ppm)

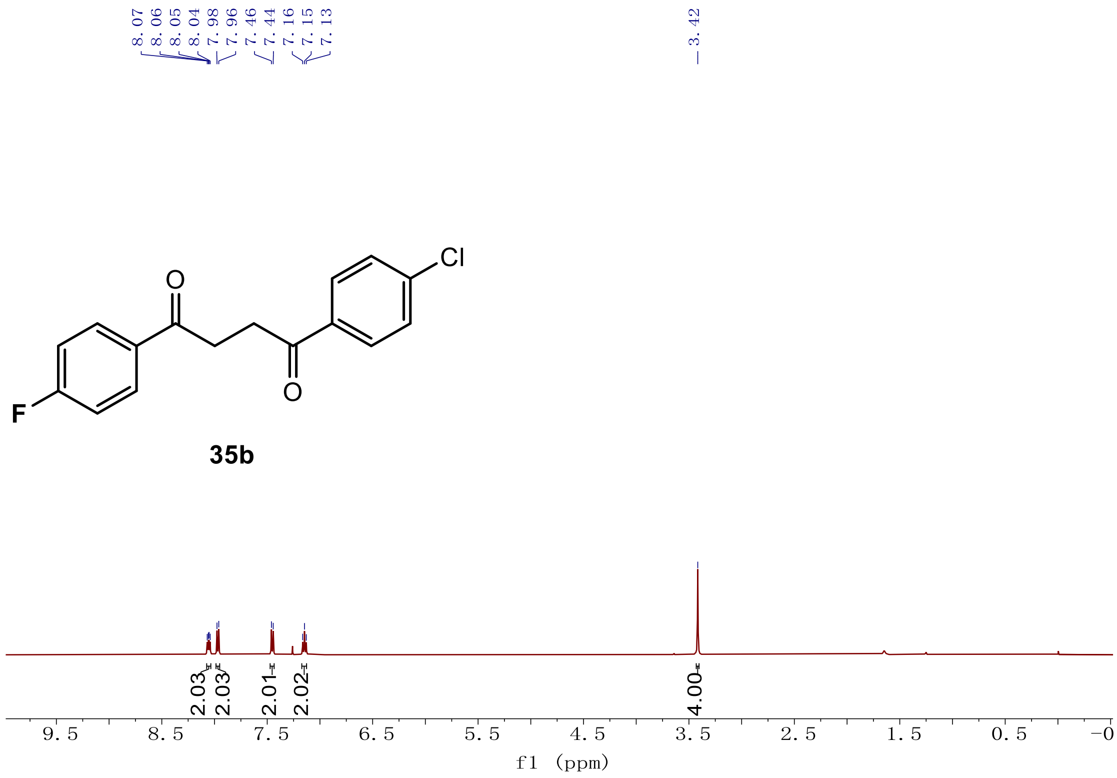


34b

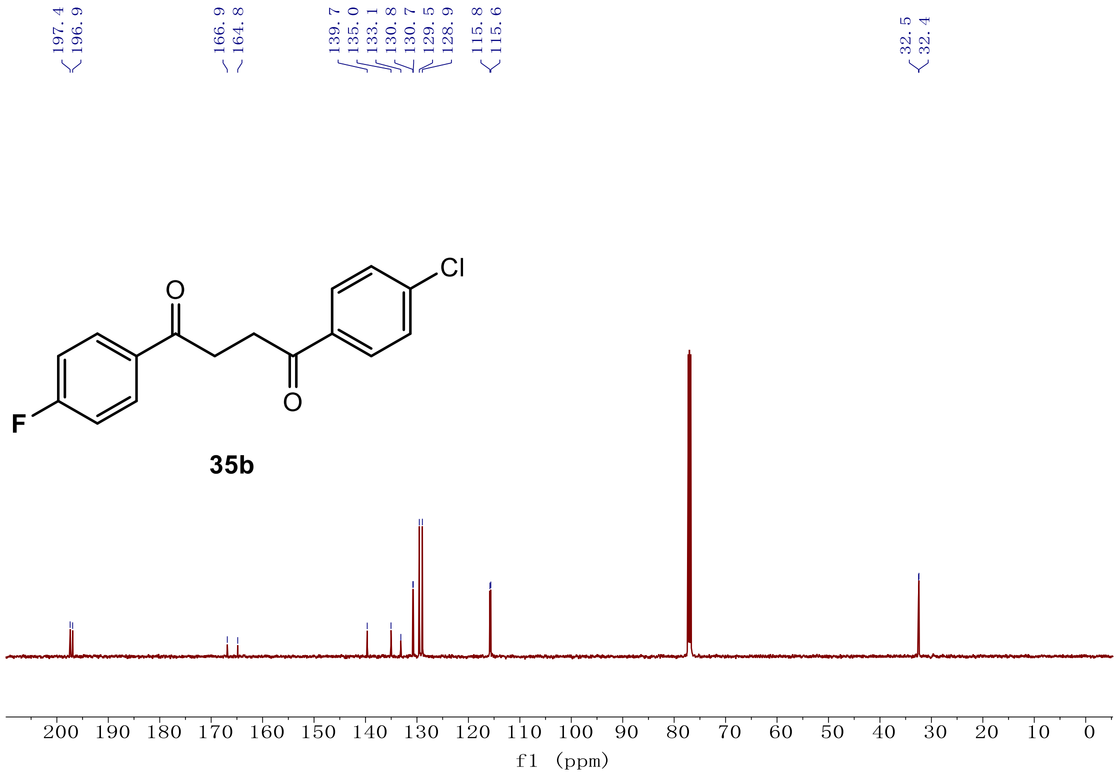
^{19}F NMR

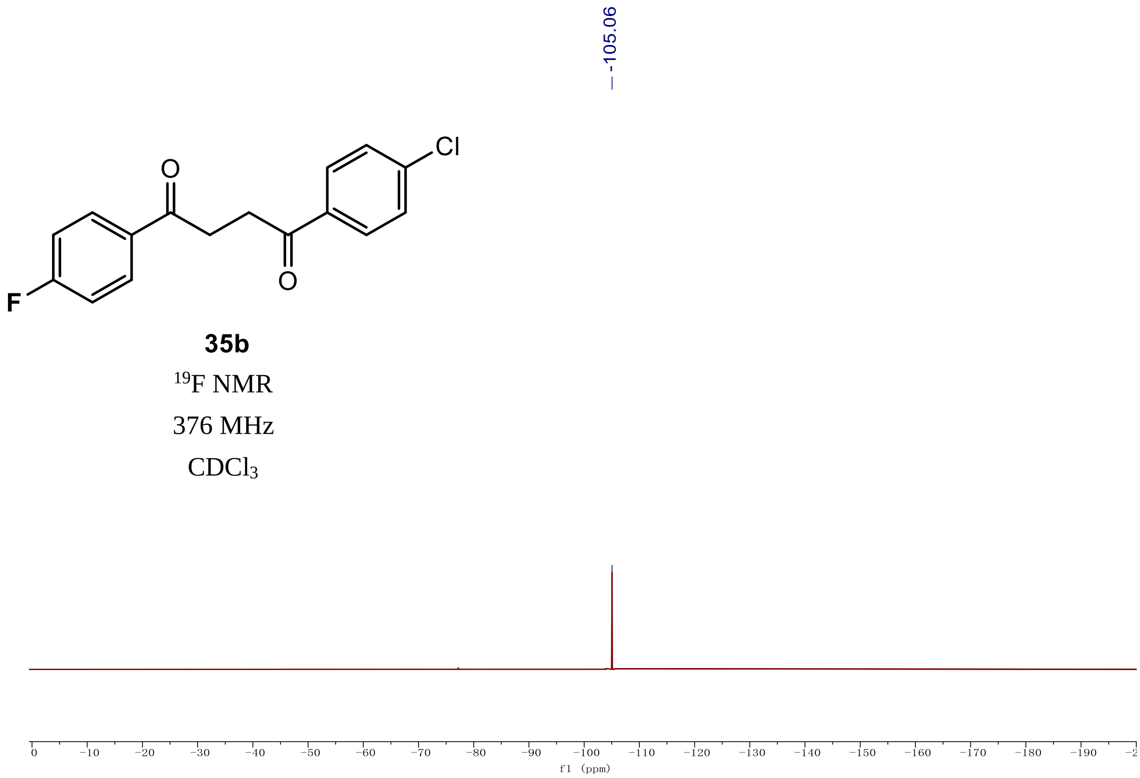
376 MHz

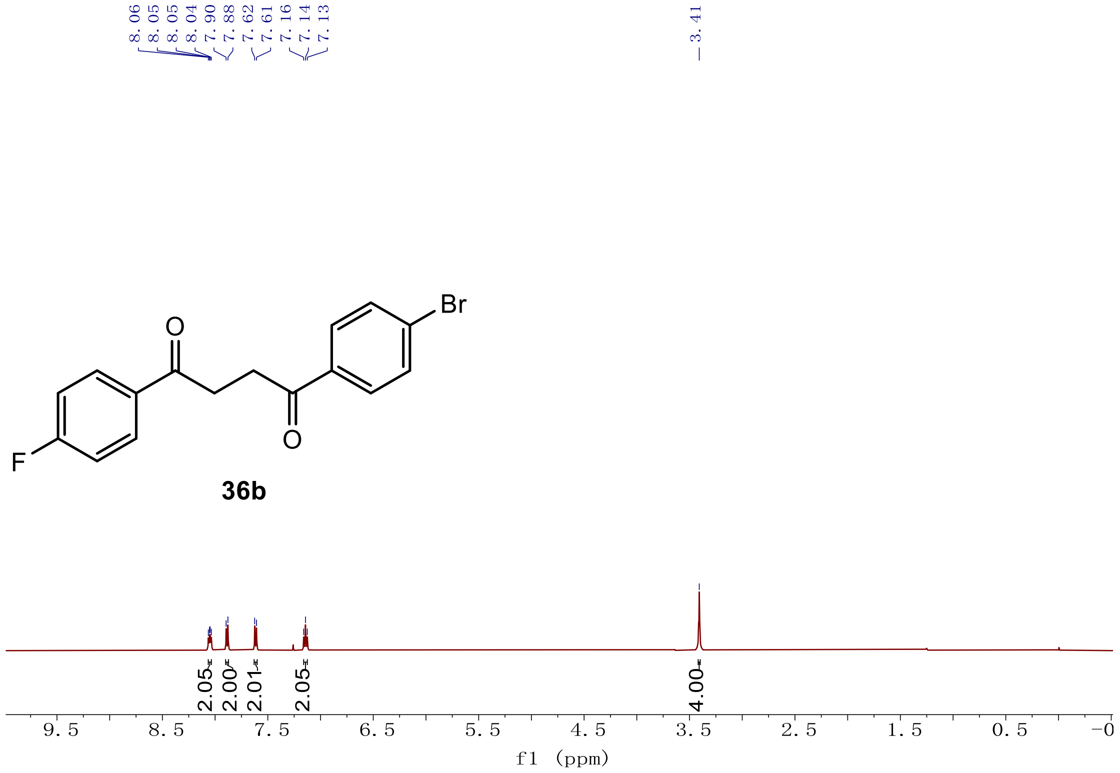
$CDCl_3$

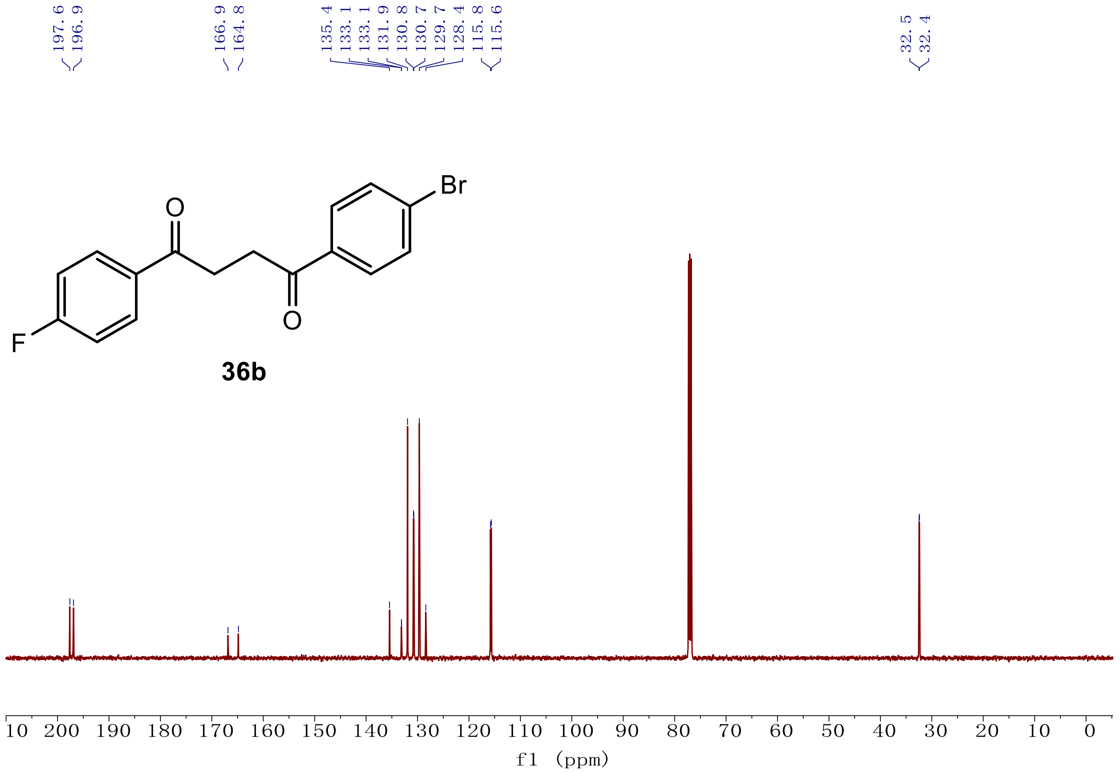


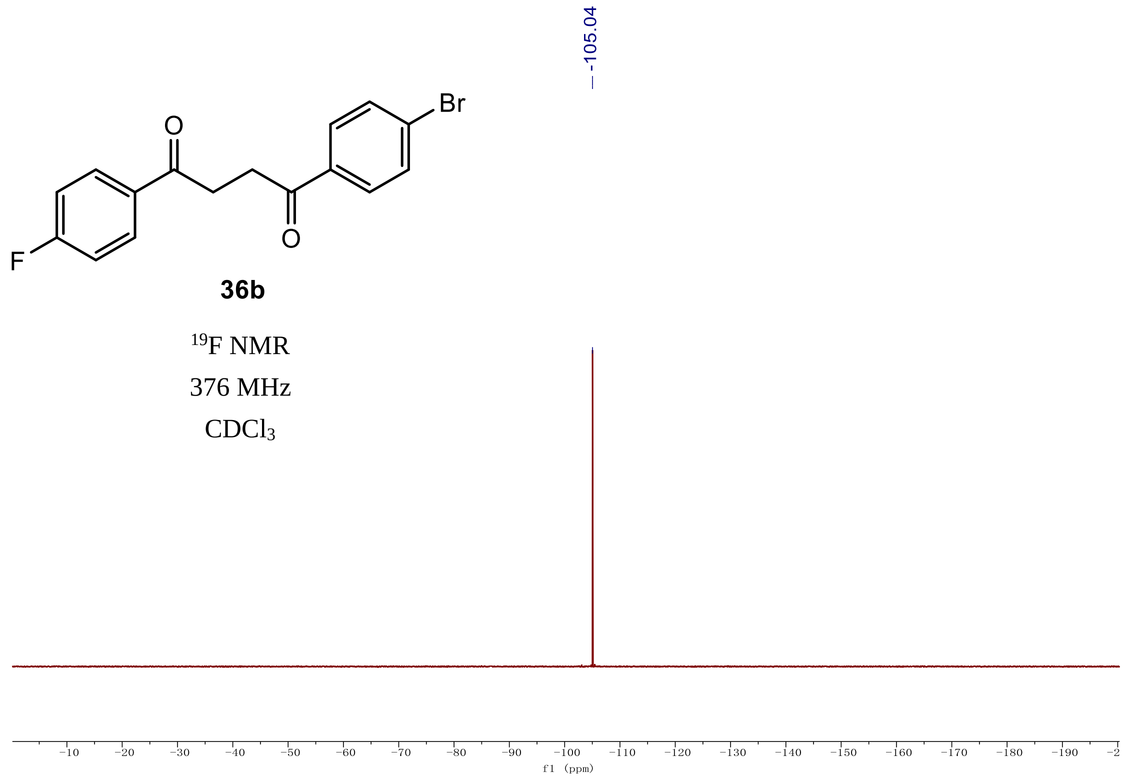
35b


197.4
196.9
166.9
164.8
139.7
135.0
133.1
130.8
130.7
129.5
128.9
115.8
115.6
32.5
32.4
O
Cl
F
O
35b
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-105.06
O
Cl
F
O
35b
^{19}F NMR
376 MHz
CDCl$_3$
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
f1 (ppm)


8.06
8.05
8.05
8.04
7.90
7.88
7.62
7.61
7.16
7.14
7.13
3.41
Br
O
O
F
36b
2.05
2.00
2.01
2.05
4.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)

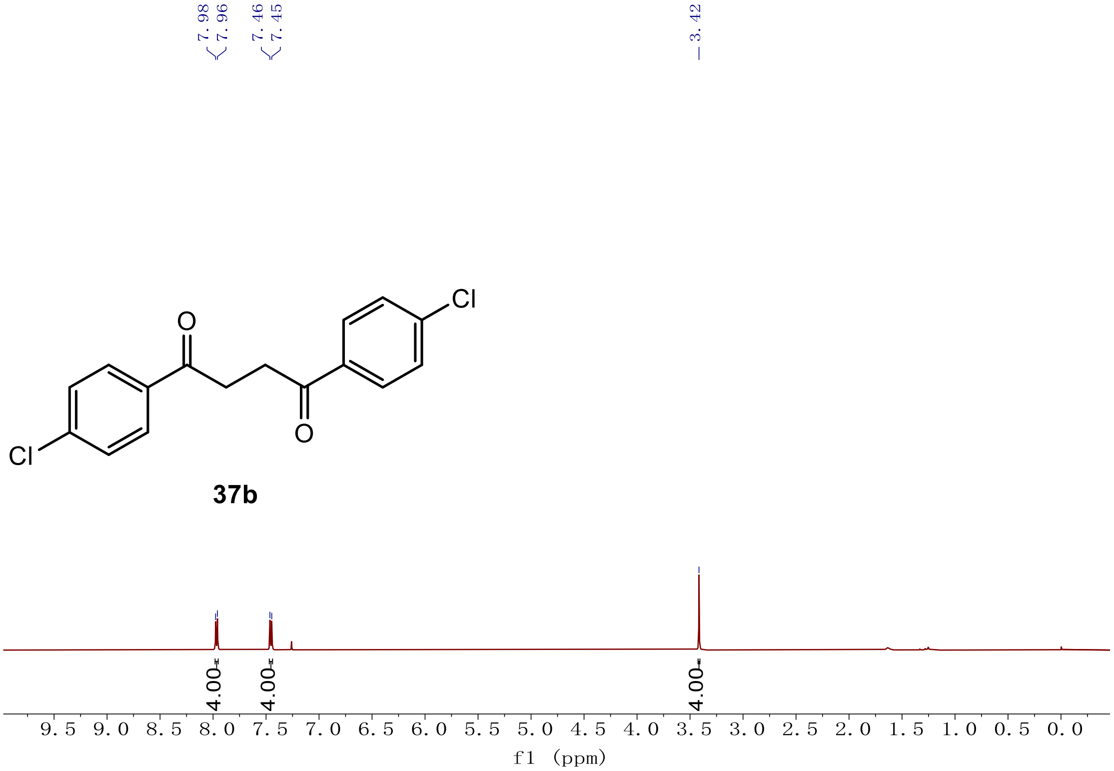

197.6
196.9
166.9
164.8
135.4
133.1
133.1
131.9
130.8
130.7
129.7
128.4
115.8
115.6
32.5
32.4
Br
O
O
F
36b
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

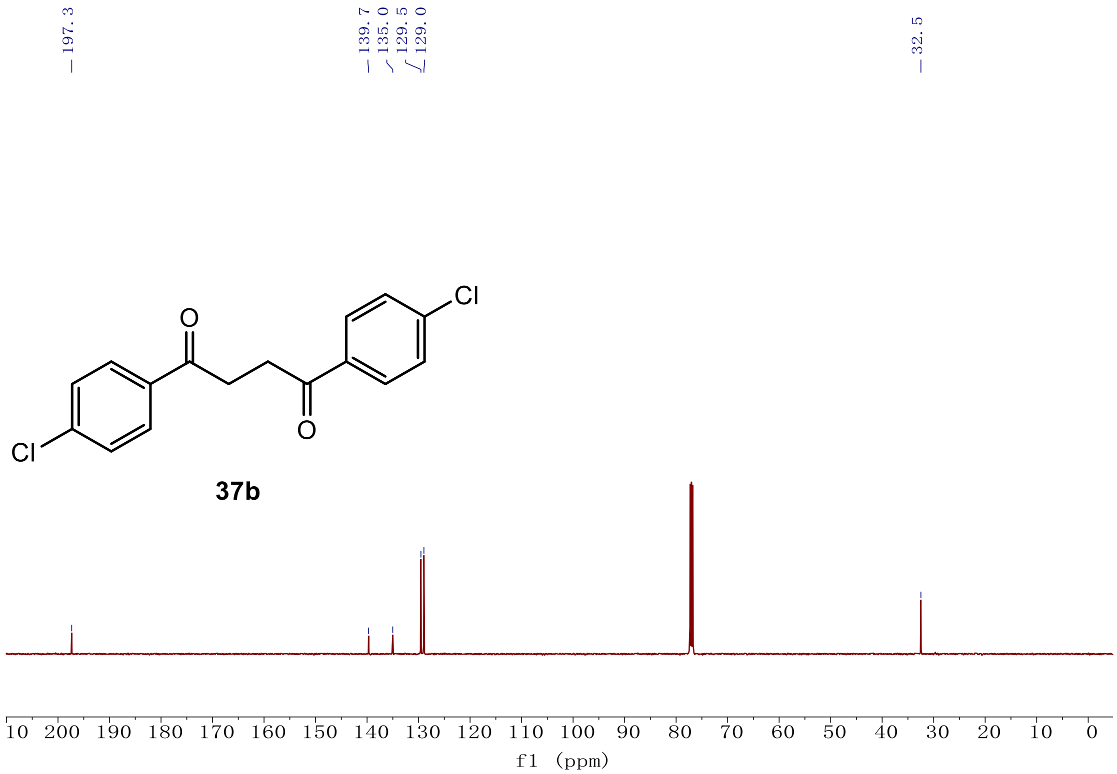

36b

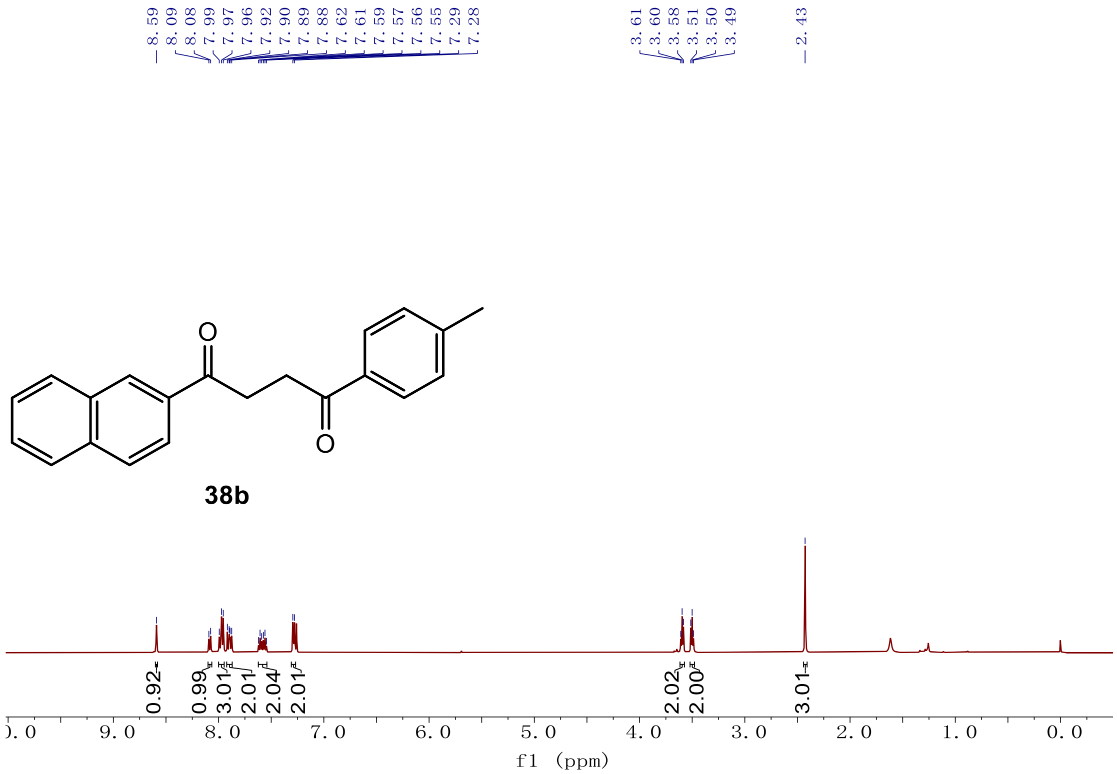
^{19}F NMR

376 MHz

$CDCl_3$

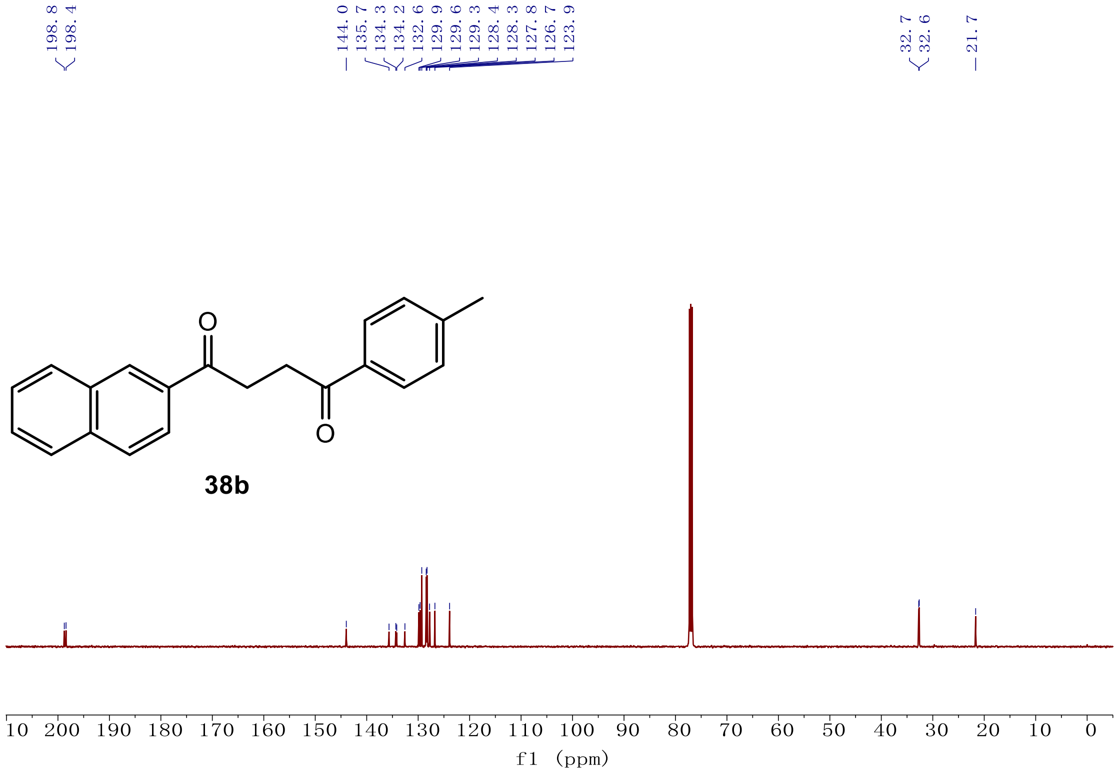

37b


197.3
139.7
135.0
129.5
129.0
32.5
O
O
Cl
Cl
37b
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



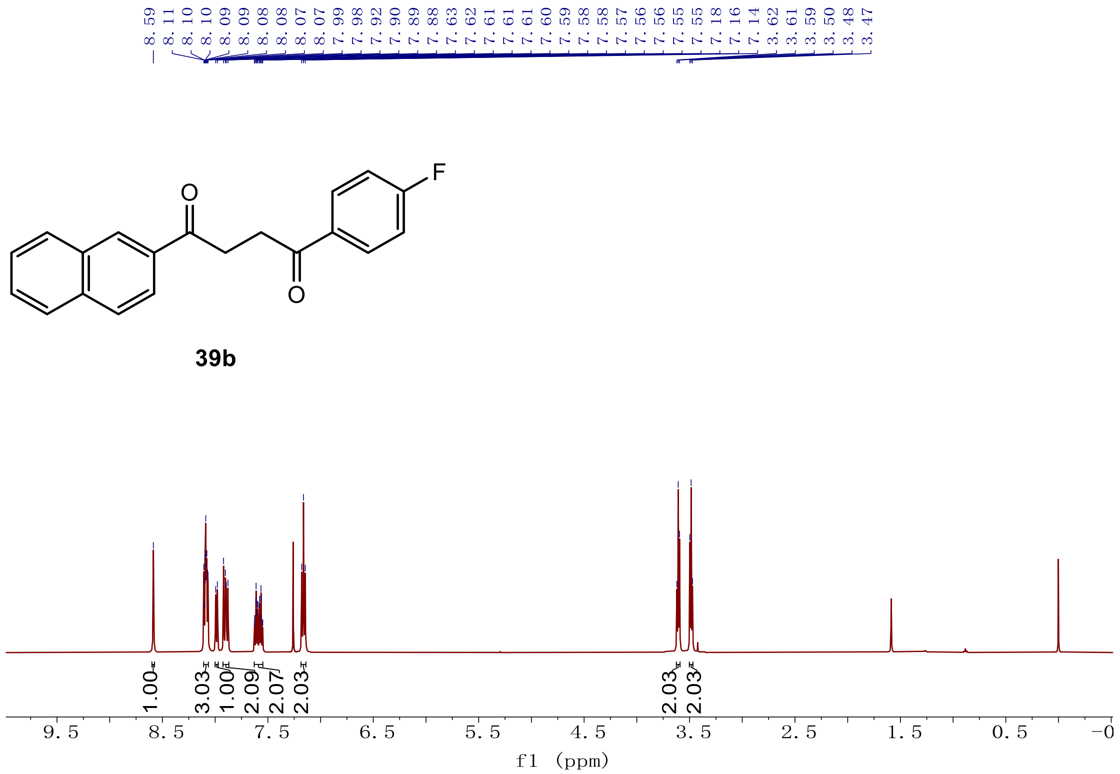
8.59
8.09
8.08
7.99
7.97
7.96
7.92
7.90
7.89
7.88
7.62
7.61
7.59
7.57
7.56
7.55
7.29
7.28
3.61
3.60
3.58
3.51
3.50
3.49
2.43
O
O
0.92
0.99
3.01
2.01
2.04
2.01
2.02
2.00
3.01
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

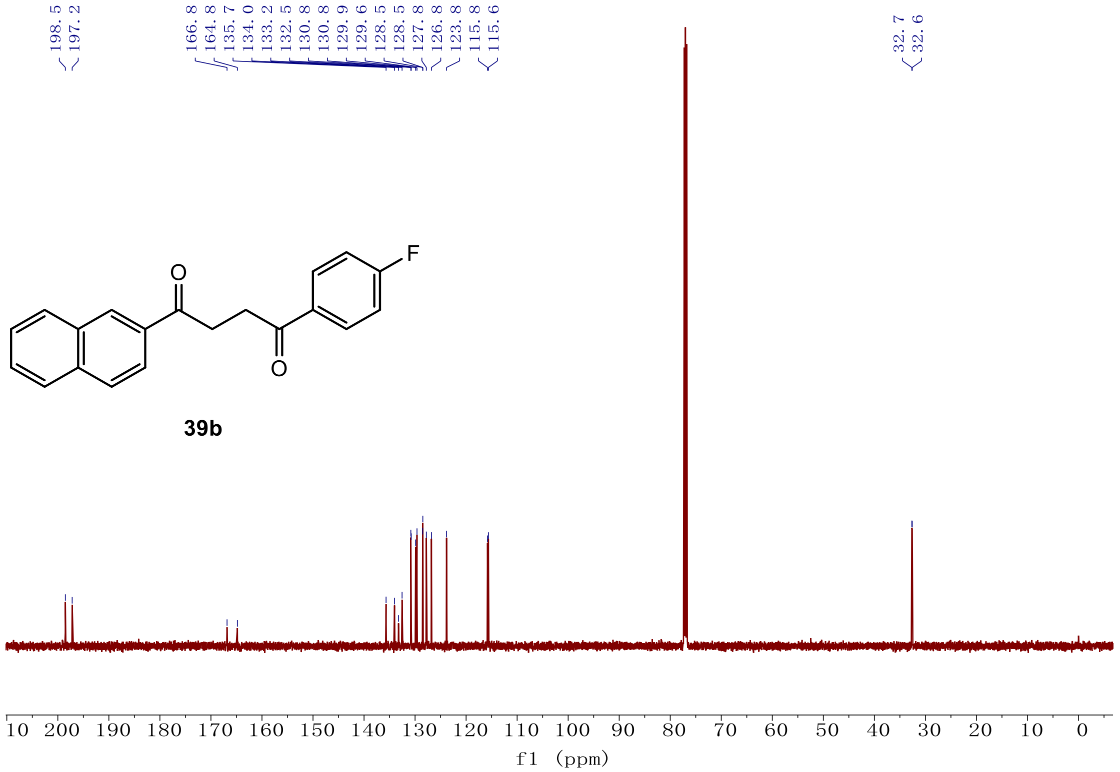
38b

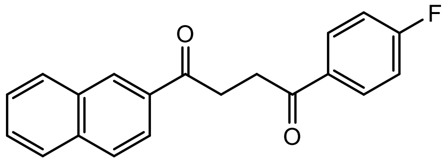


198.8
198.4
144.0
135.7
134.3
134.2
132.6
129.9
129.6
129.3
128.4
128.3
127.8
126.7
123.9
32.7
32.6
21.7
O
O
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

38b


8.59
8.11
8.10
8.10
8.09
8.09
8.08
8.08
8.07
8.07
7.99
7.98
7.92
7.90
7.89
7.88
7.63
7.62
7.61
7.61
7.61
7.60
7.59
7.58
7.58
7.57
7.56
7.56
7.55
7.55
7.55
7.18
7.16
7.14
3.62
3.61
3.59
3.50
3.48
3.47
O
F
O
39b
1.00
3.03
1.00
2.09
2.07
2.03
2.03
2.03
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)


198.5
197.2
166.8
164.8
135.7
134.0
133.2
132.5
130.8
130.8
129.9
129.6
128.5
128.5
127.8
126.8
123.8
115.8
115.6
32.7
32.6
O
F
O
39b
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

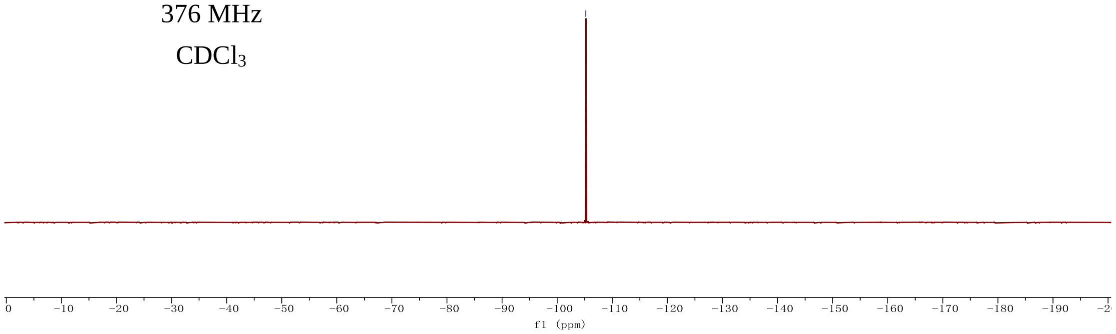


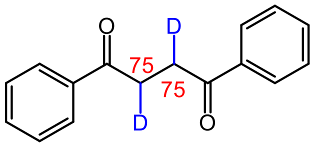
39b

^{19}F NMR

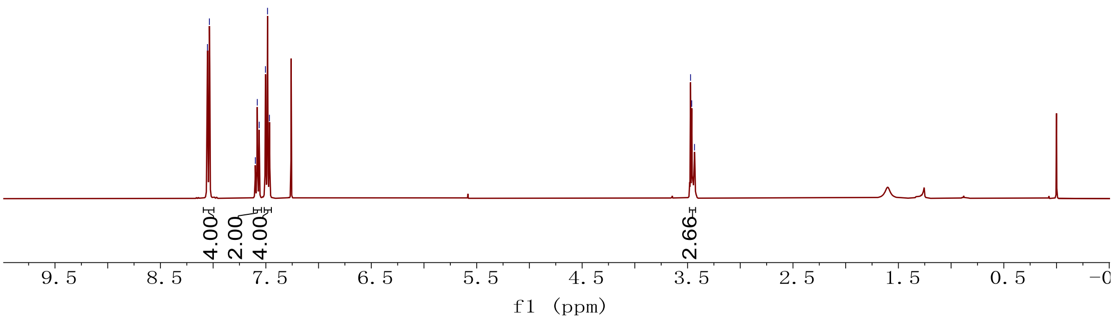
376 MHz

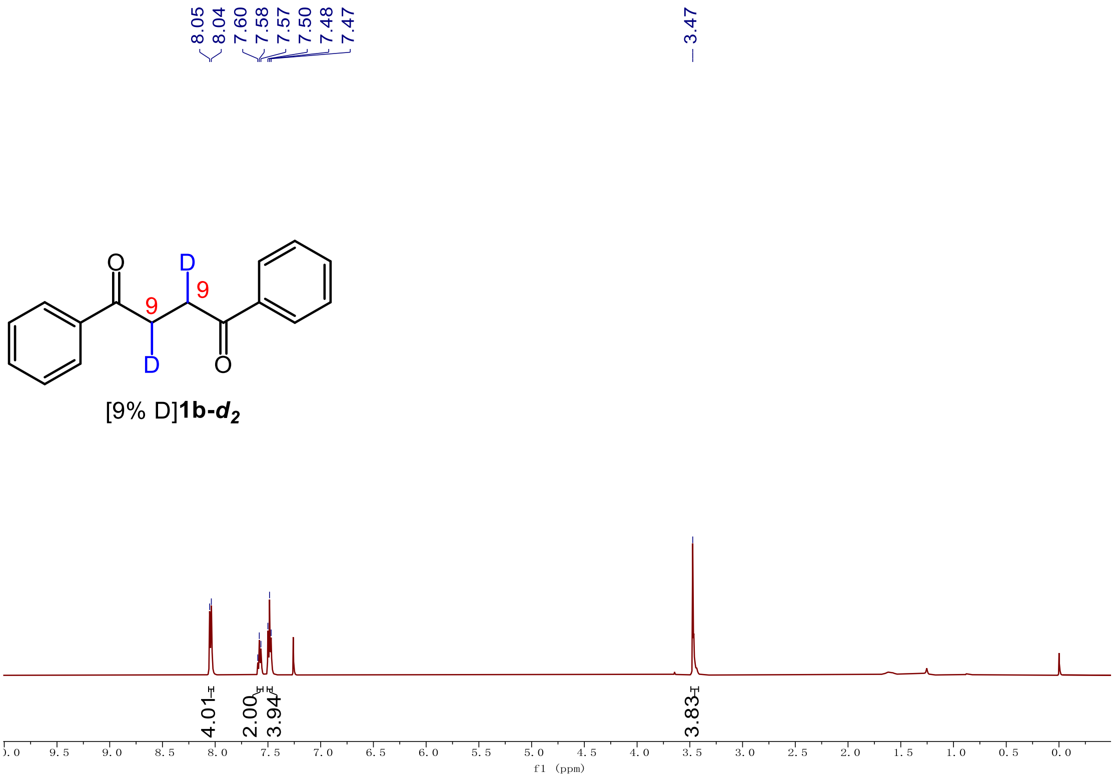
$CDCl_3$



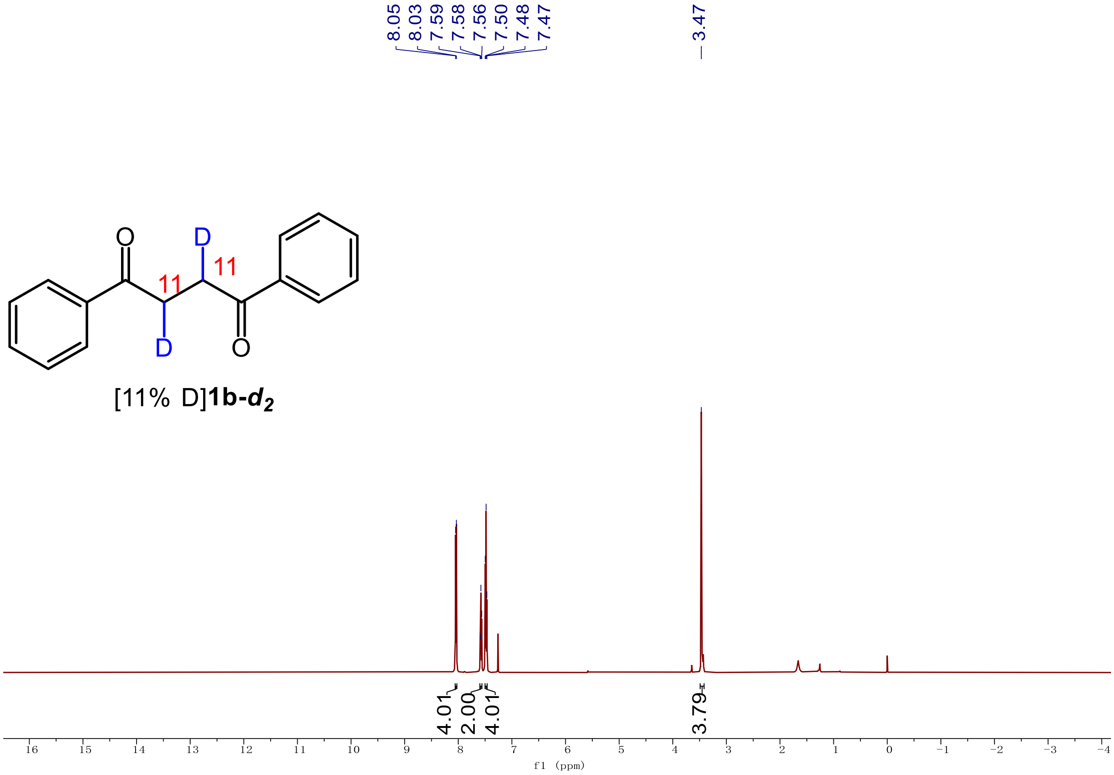


1b-d_2

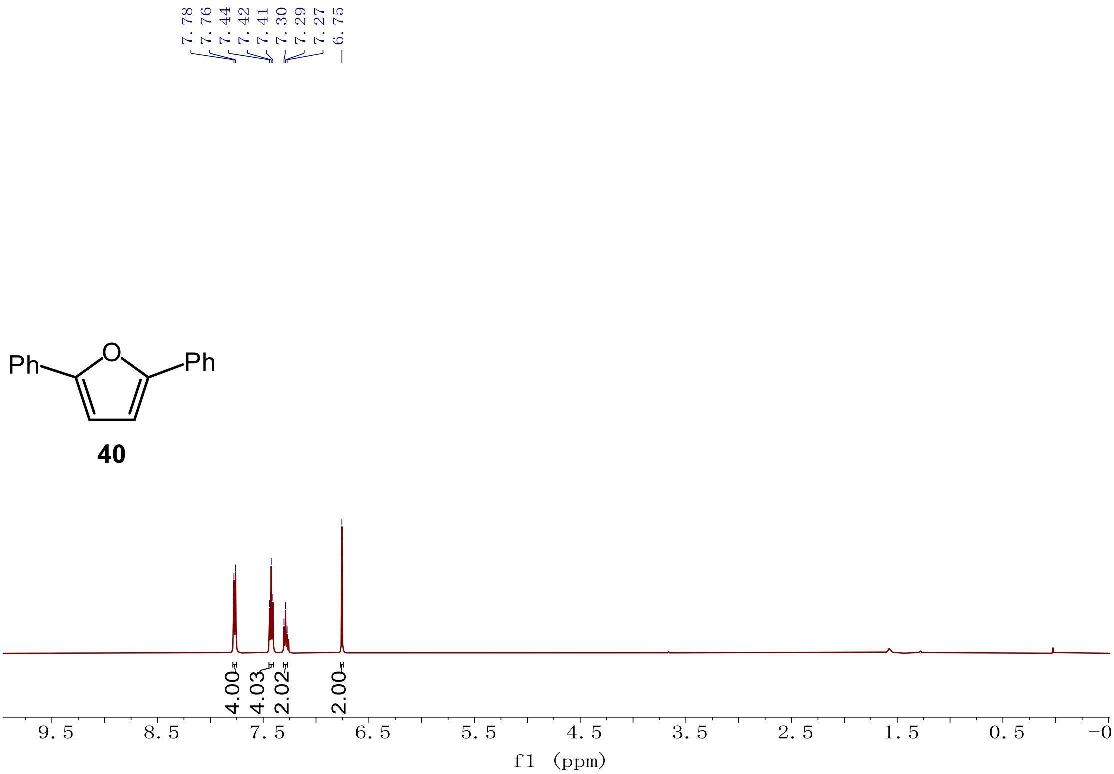




[9% D]**1b-*d*$_2$**

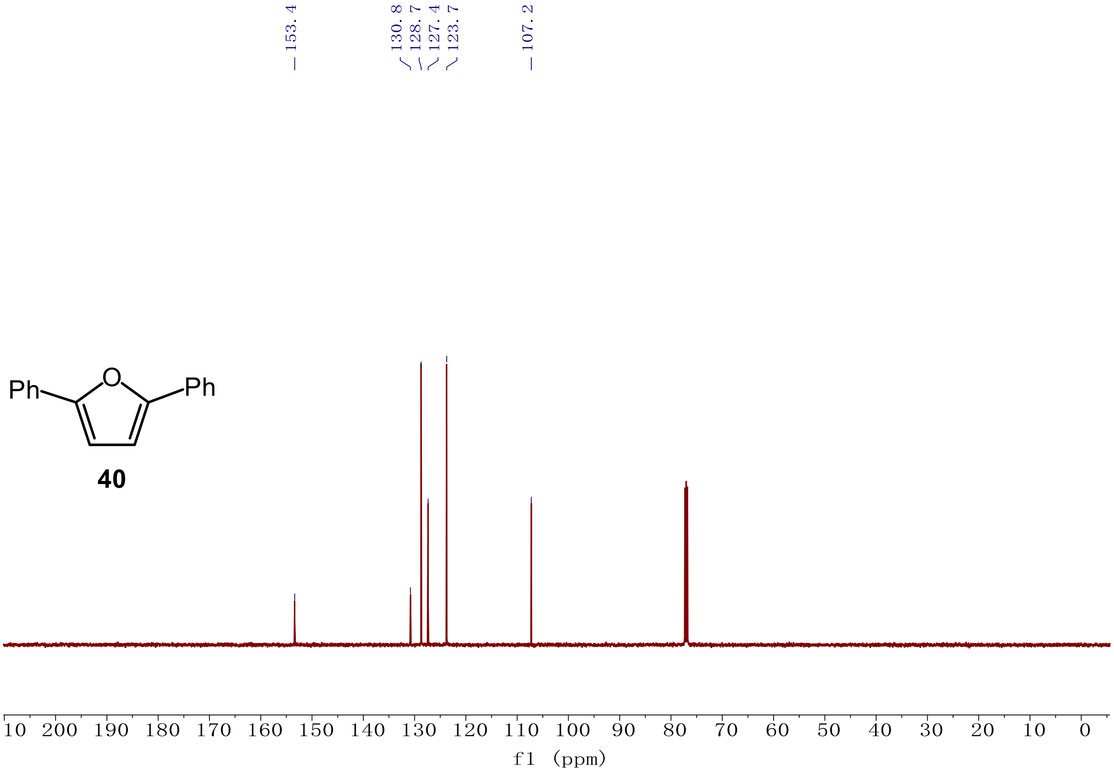


[11% D]**1b-*d*$_2$**



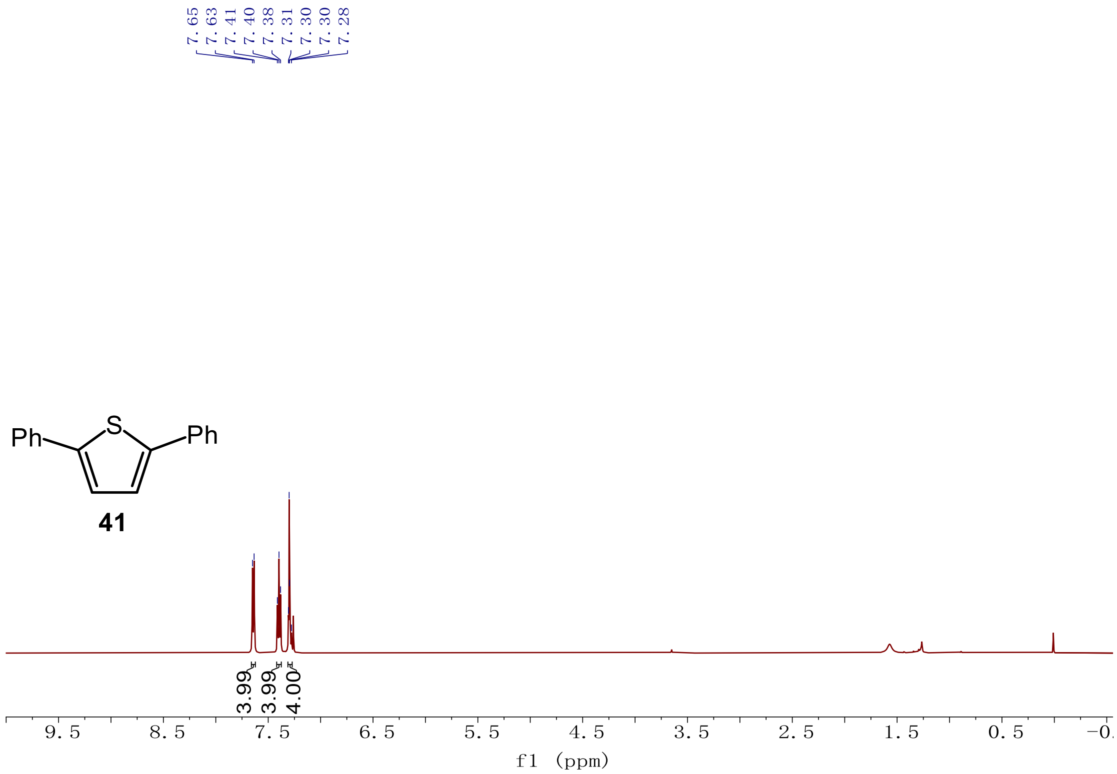
40

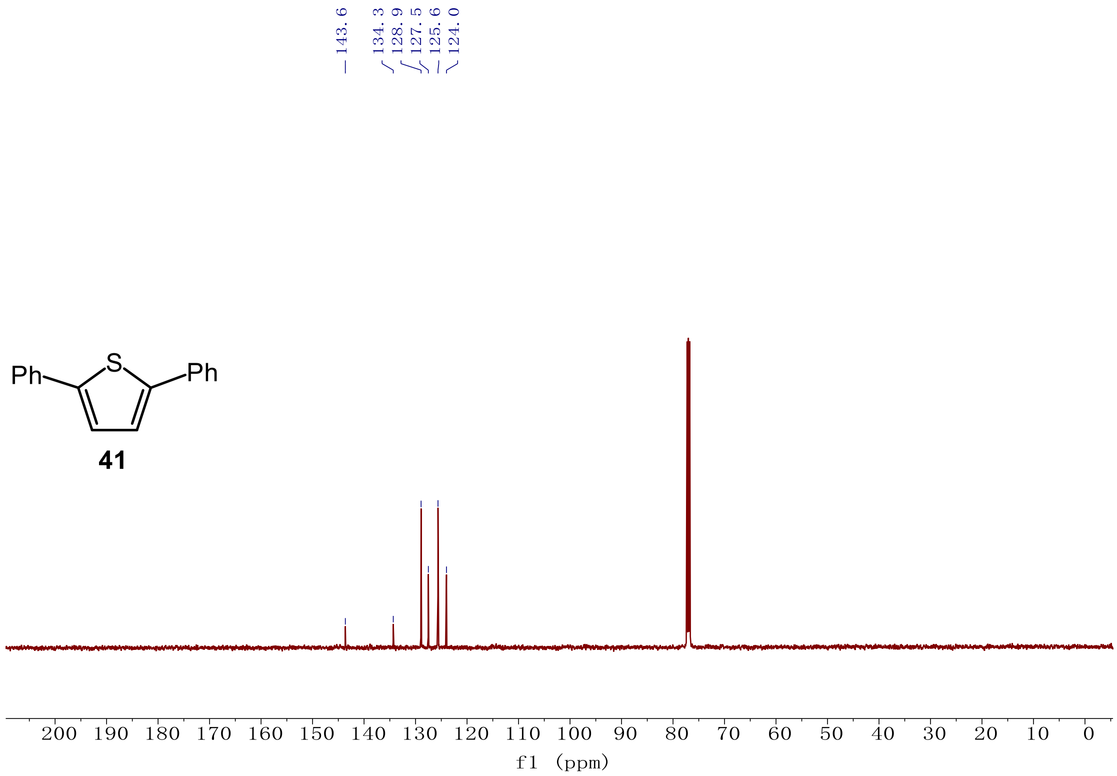
7.78
7.76
7.44
7.42
7.41
7.30
7.29
7.27
6.75
Ph
O
Ph
4.00
4.03
2.02
2.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)

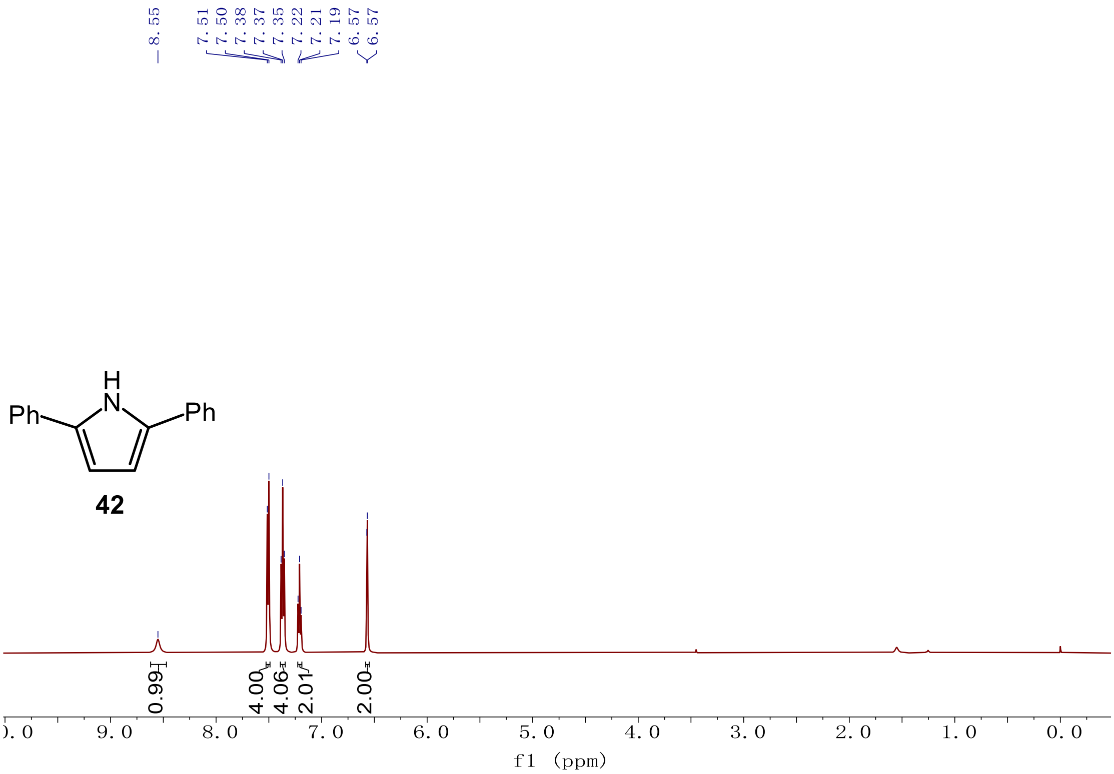


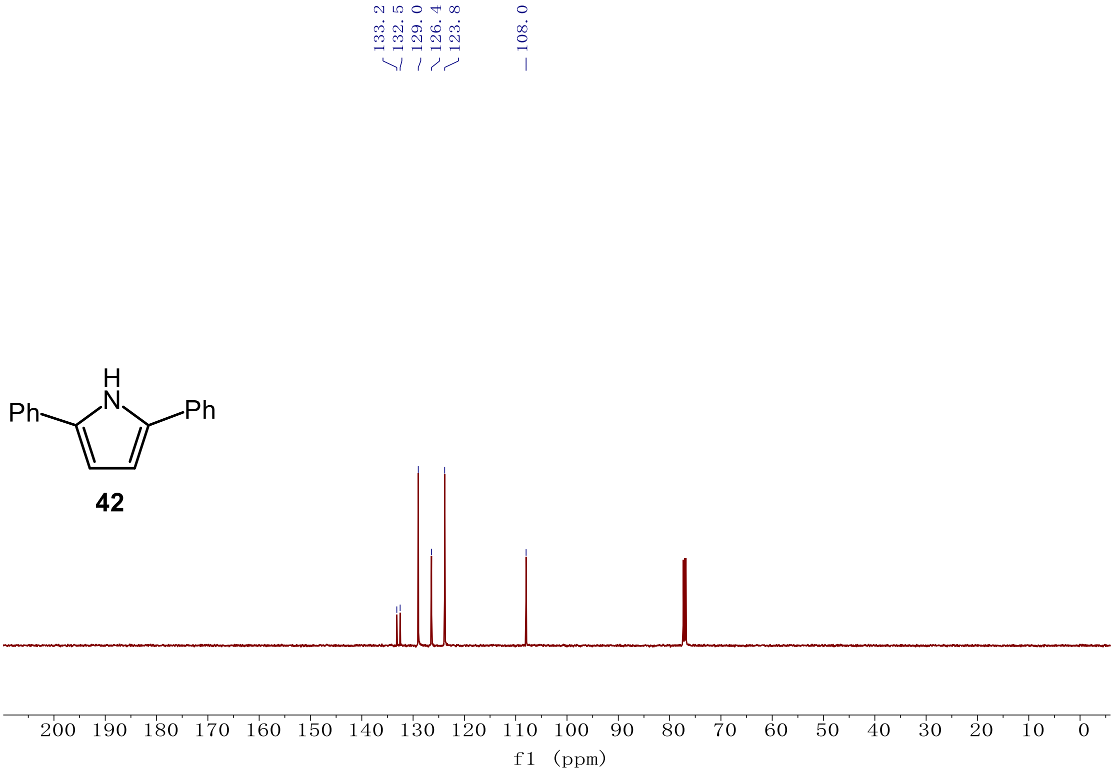
40

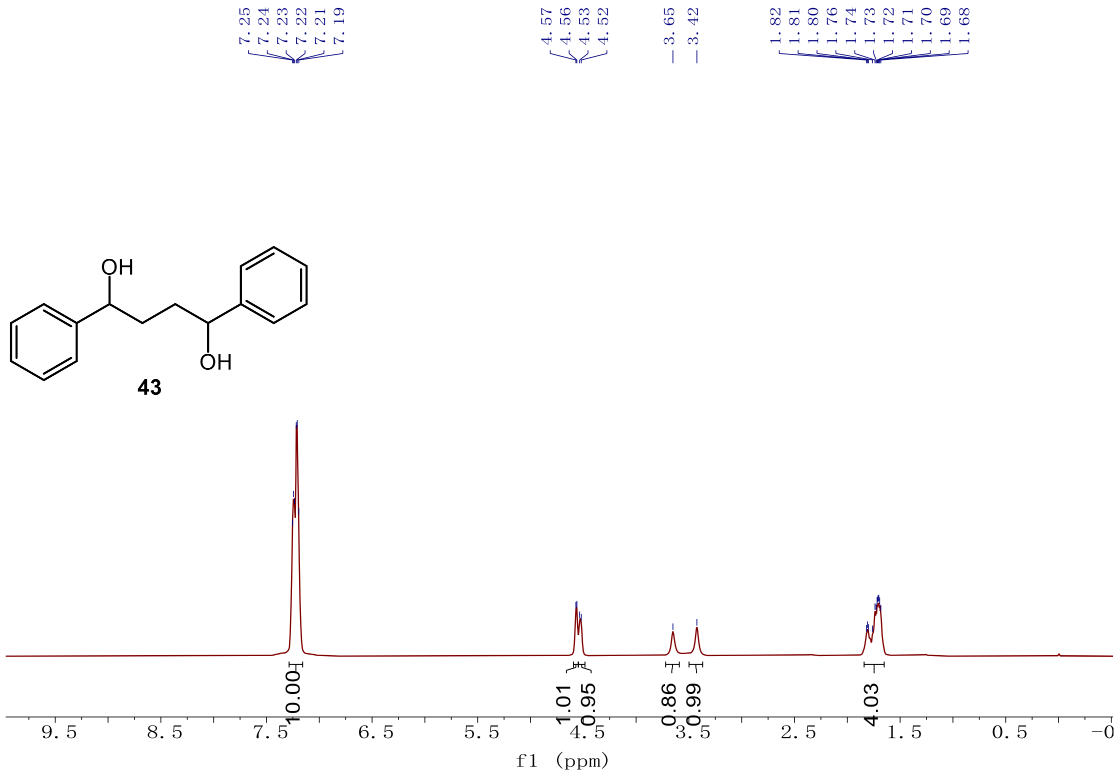
153.4
130.8
128.7
127.4
123.7
107.2
Ph
O
Ph
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

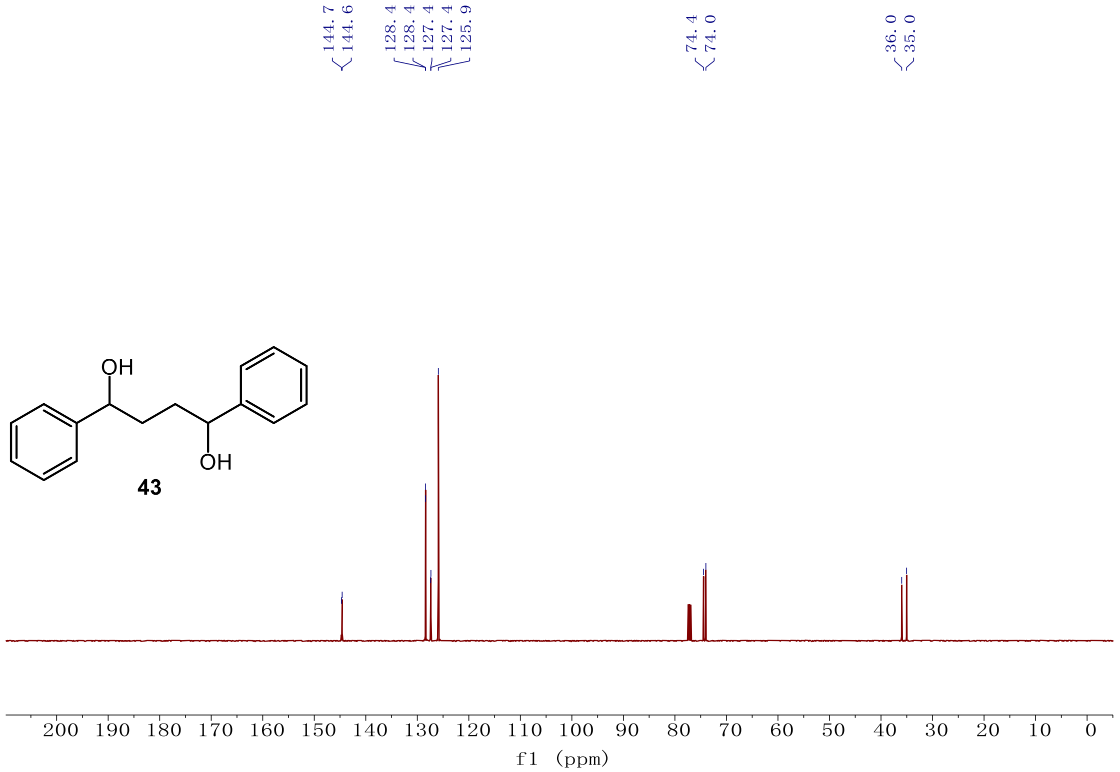

7.65
7.63
7.41
7.40
7.38
7.31
7.30
7.30
7.28
Ph
S
Ph
41
3.99
3.99
4.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.
f1 (ppm)

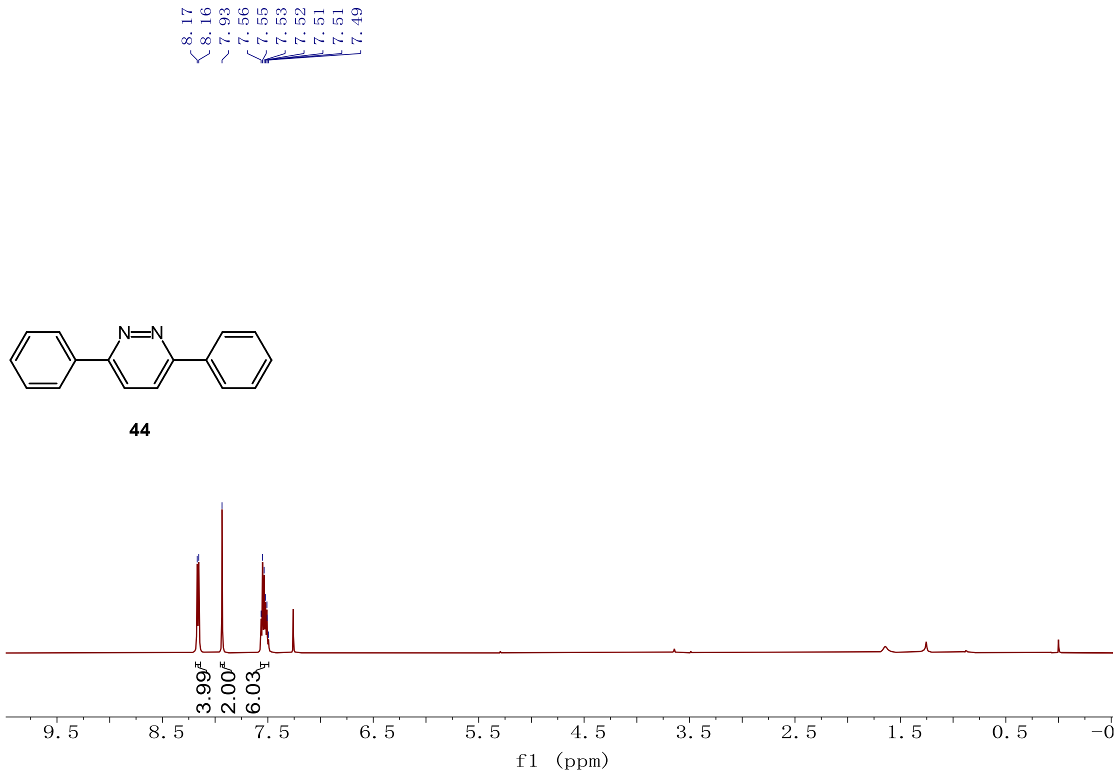

143.6
134.3
128.9
127.5
125.6
124.0
Ph
S
Ph
41
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

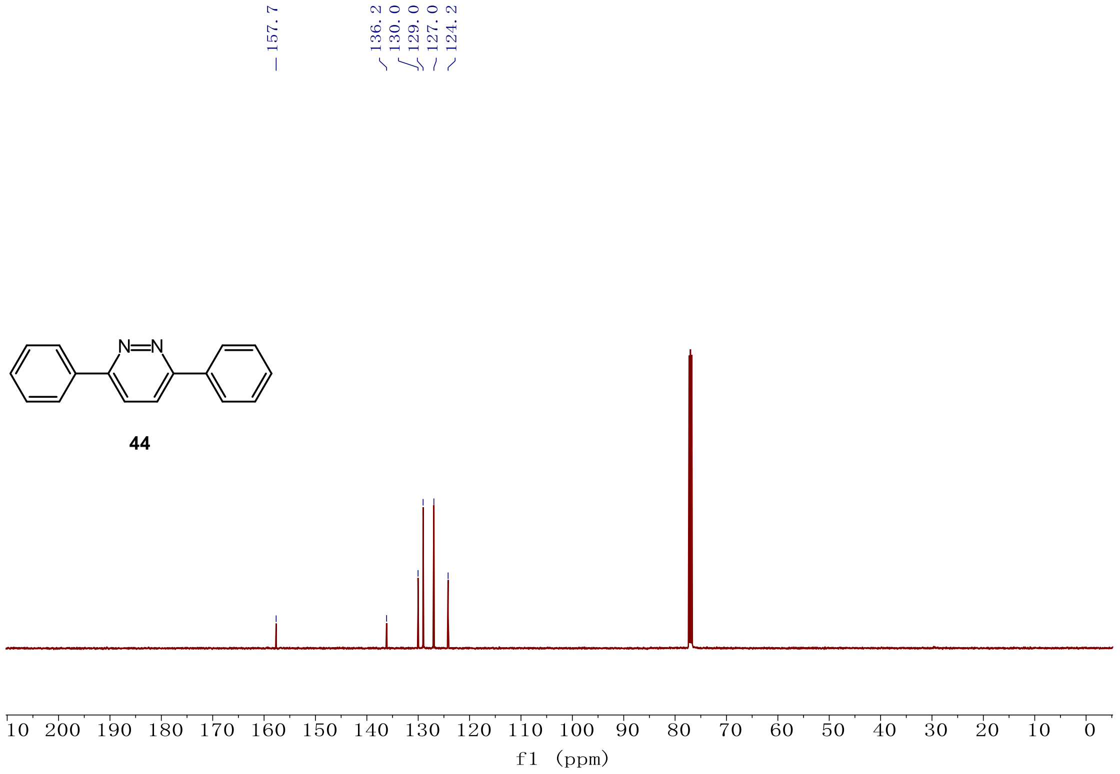

8.55
7.51
7.50
7.38
7.37
7.35
7.22
7.21
7.19
6.57
6.57
H
N
Ph
Ph
42
0.99
4.00
4.06
2.01
2.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

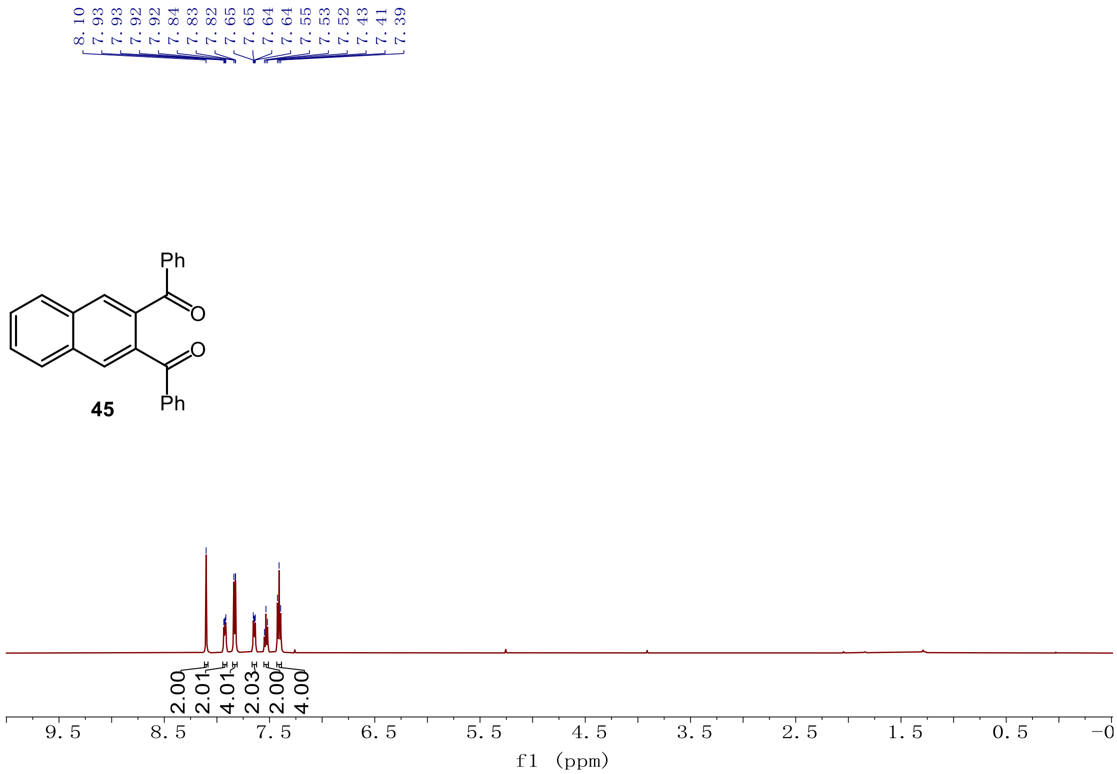

133.2
132.5
129.0
126.4
123.8
108.0
H
N
Ph
Ph
42
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

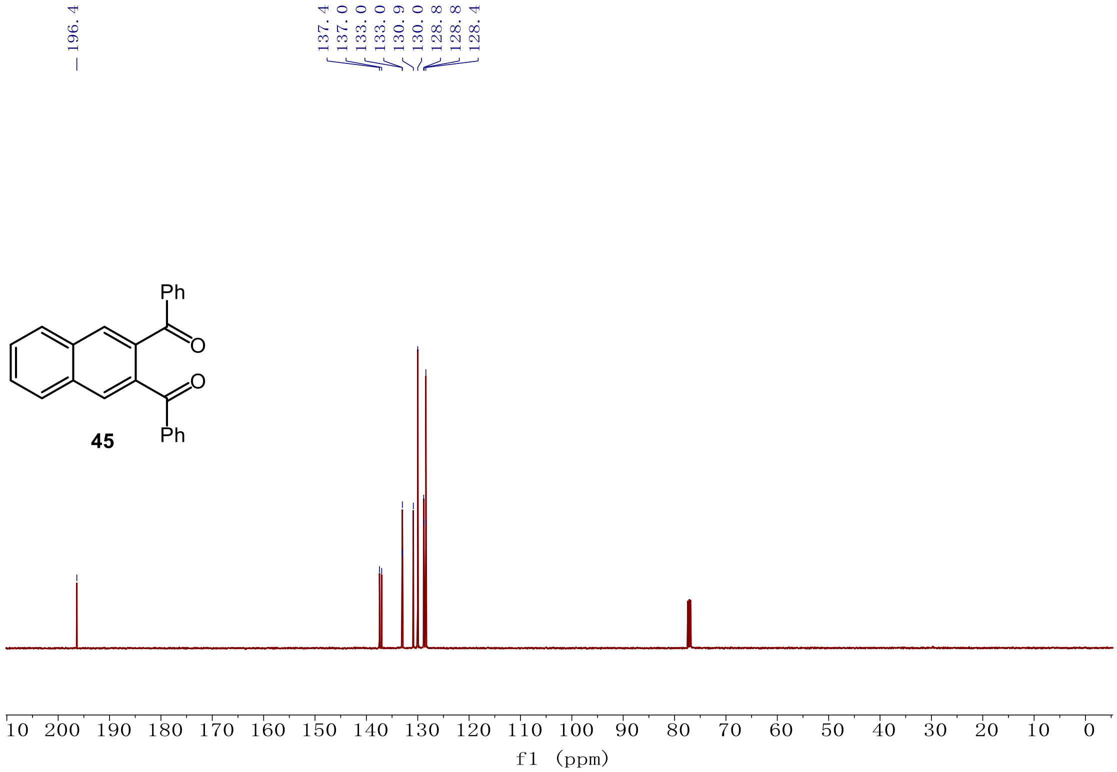

7.25
7.24
7.23
7.22
7.21
7.19
4.57
4.56
4.53
4.52
3.65
3.42
1.82
1.81
1.80
1.76
1.74
1.73
1.72
1.71
1.70
1.69
1.68
OH
OH
43
10.00
1.01
0.95
0.86
0.99
4.03
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)

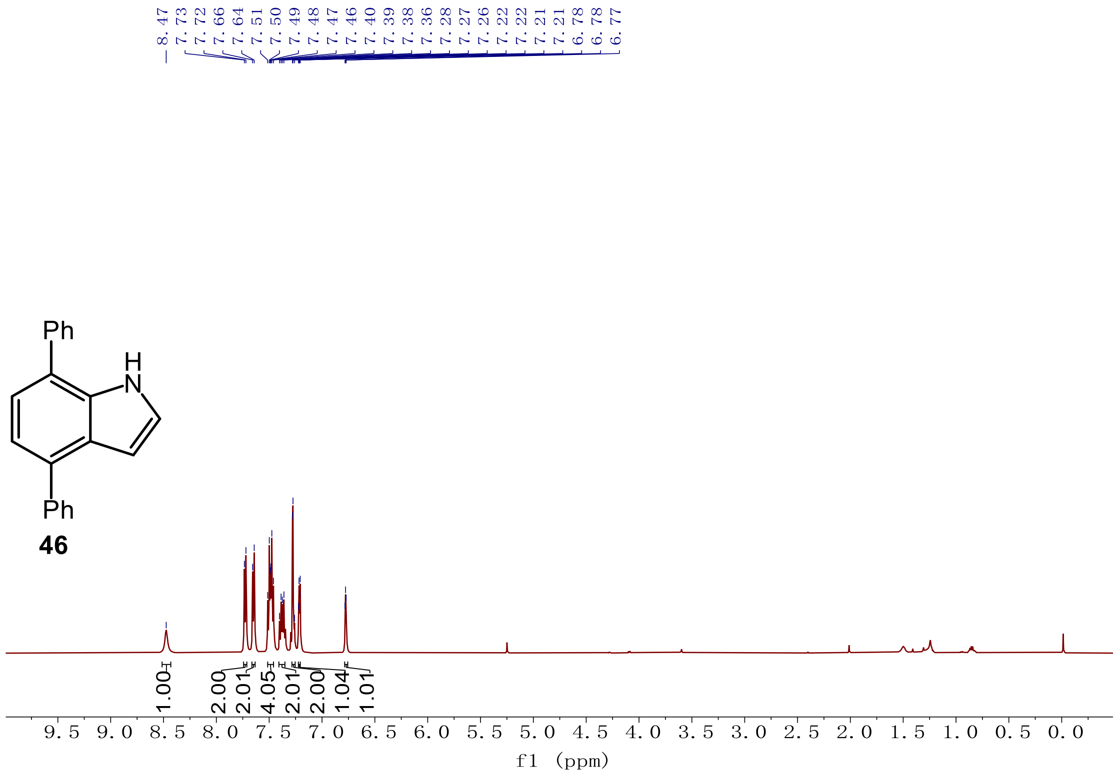

144.7
144.6
128.4
128.4
127.4
127.4
125.9
74.4
74.0
36.0
35.0
OH
OH
43
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

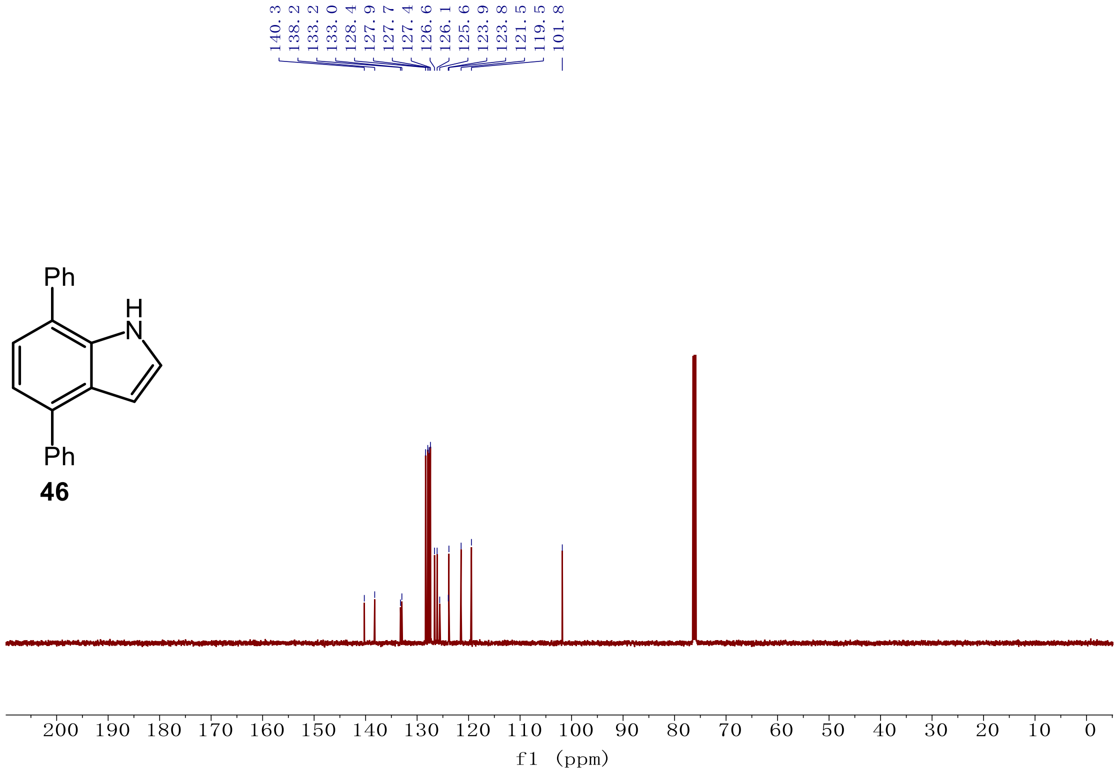

44
8.17
8.16
7.93
7.56
7.55
7.53
7.52
7.51
7.51
7.49
N=N
3.99
2.00
6.03
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0
f1 (ppm)

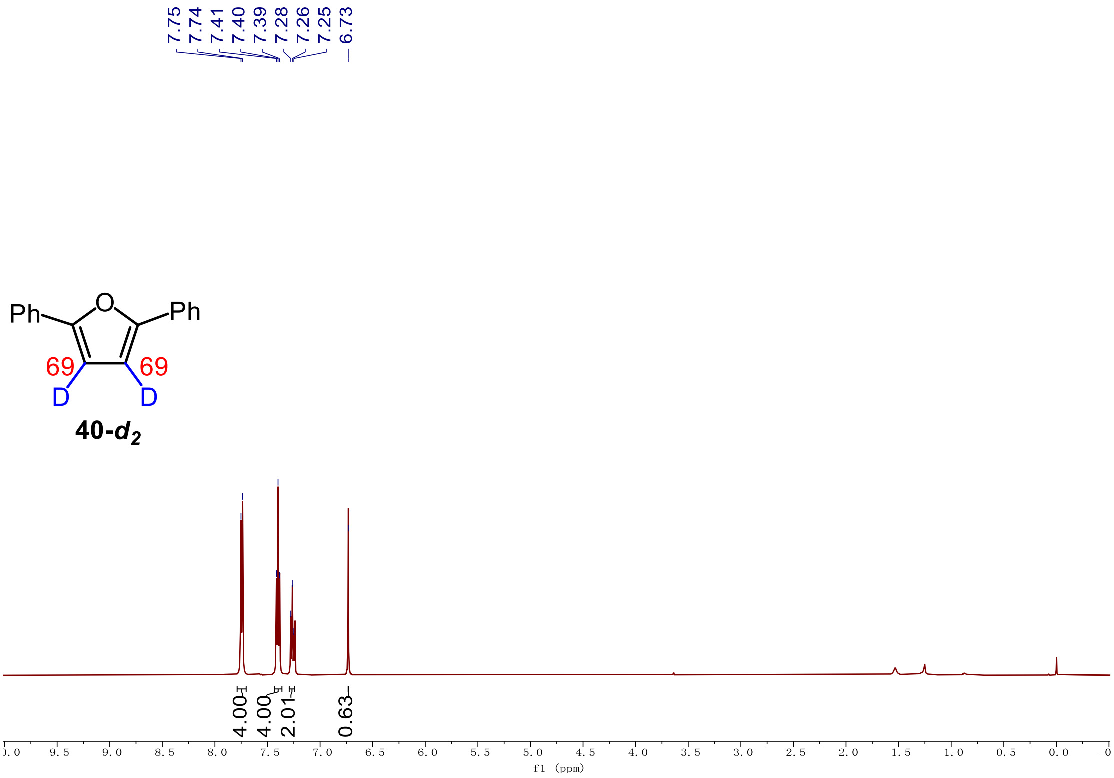

44
157.7
136.2
130.0
129.0
127.0
124.2
N=N
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.10
7.93
7.93
7.92
7.92
7.84
7.83
7.82
7.65
7.65
7.64
7.64
7.55
7.53
7.52
7.43
7.41
7.39
Ph
O
O
Ph
45
2.00
2.01
4.01
2.03
2.00
4.00
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
−0
f1 (ppm)

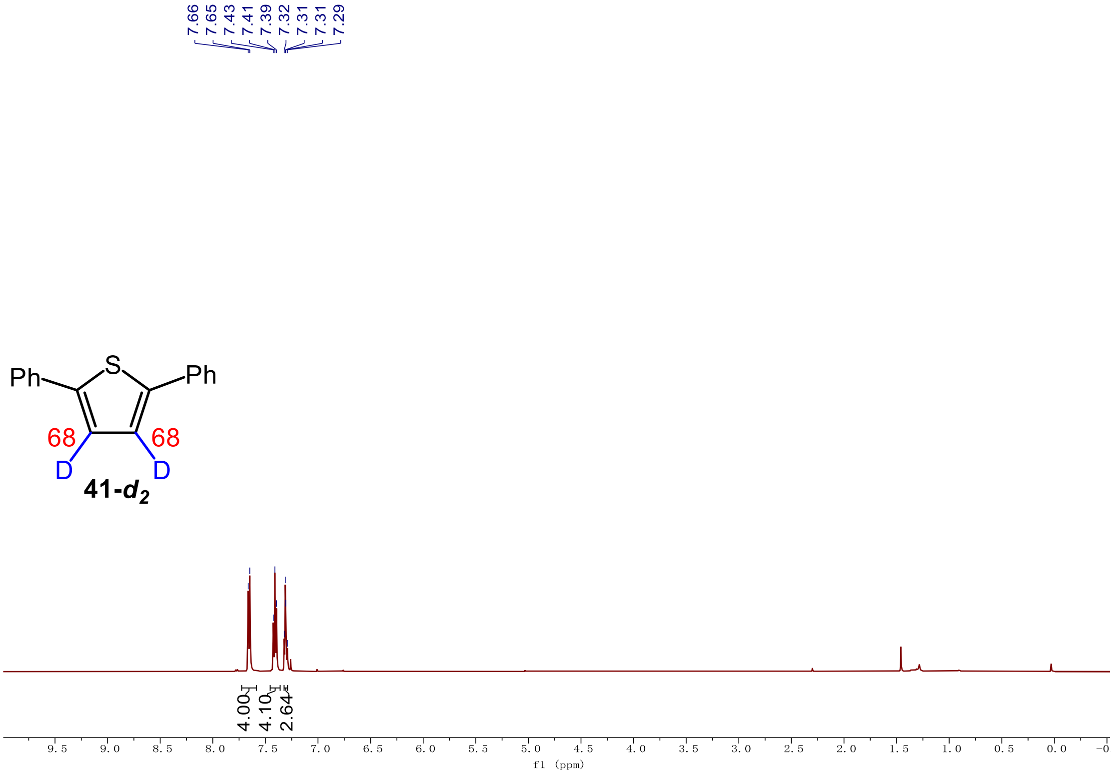

196.4
137.4
137.0
133.0
133.0
130.9
130.0
128.8
128.8
128.4
Ph
O
O
Ph
45
10
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.47
7.73
7.72
7.66
7.64
7.51
7.50
7.49
7.48
7.47
7.46
7.40
7.39
7.38
7.36
7.28
7.27
7.26
7.22
7.22
7.21
7.21
6.78
6.78
6.77
Ph
H
N
Ph
46
1.00
2.00
2.01
4.05
2.01
2.00
1.04
1.01
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 0.0
f1 (ppm)

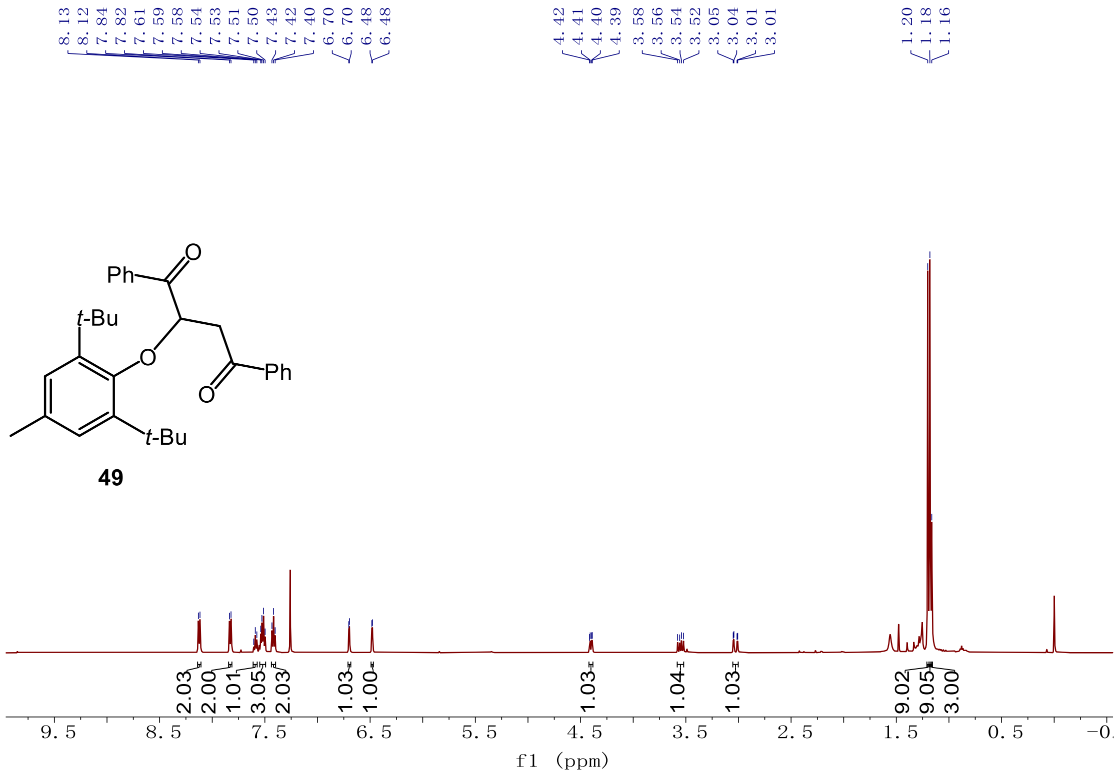

140.3
138.2
133.2
133.0
128.4
127.9
127.7
127.4
126.6
126.1
125.6
123.9
123.8
121.5
119.5
101.8
Ph
H
N
Ph
46
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.75
7.74
7.41
7.40
7.39
7.28
7.26
7.25
6.73
Ph
O
Ph
69
69
D
D
4.00
4.00
2.01
0.63
f1 (ppm)

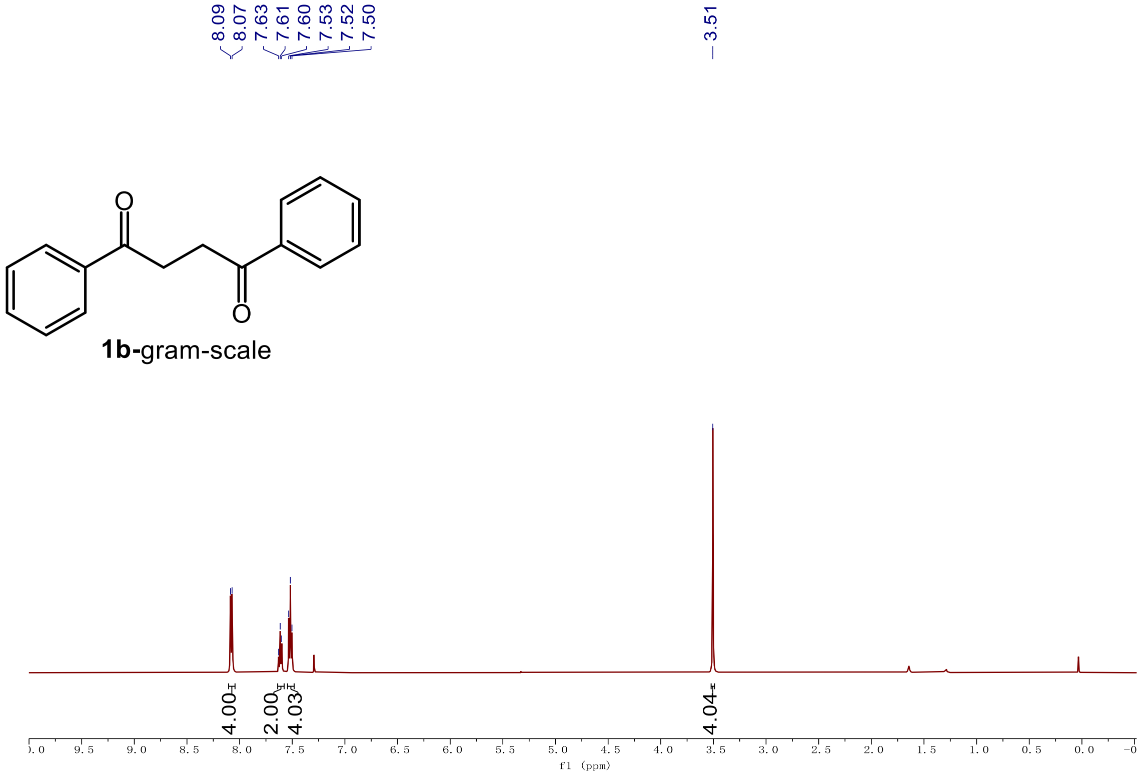
40-d_2


7.66
7.65
7.43
7.41
7.39
7.32
7.31
7.29
Ph
S
Ph
68
68
D
D
4.00
4.10
2.64
f1 (ppm)

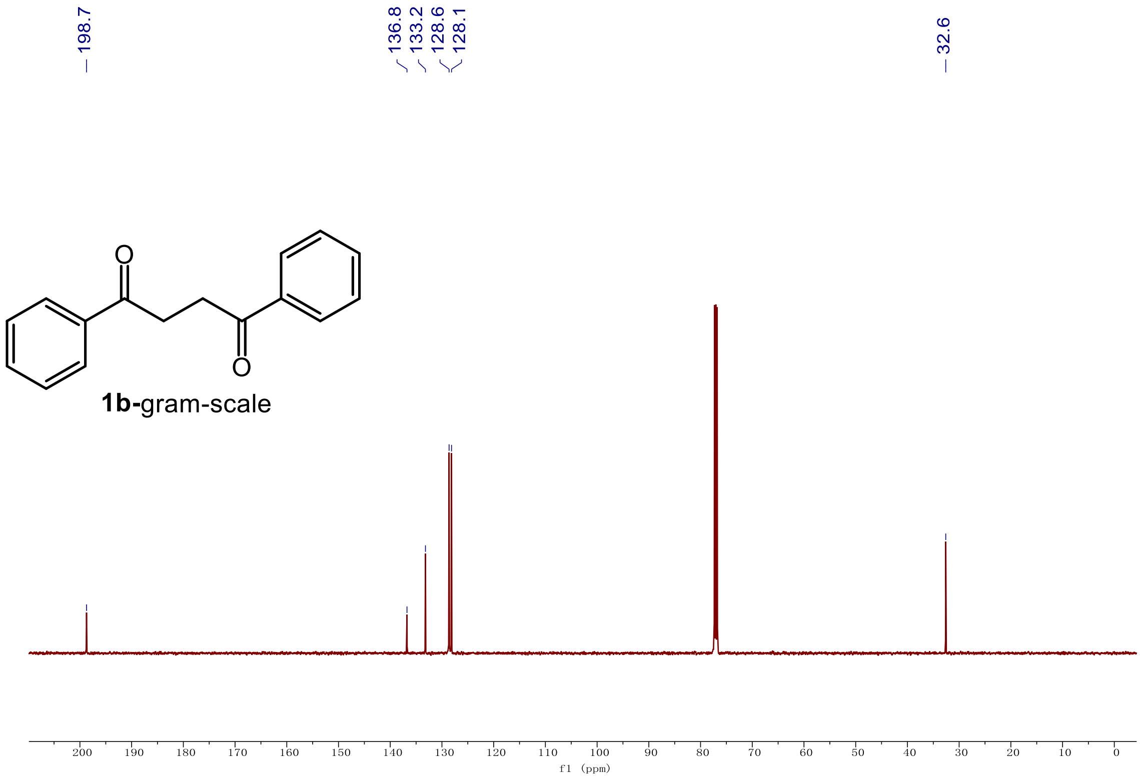
41-d_2



49



1b-gram-scale



1b-gram-scale