Supporting Information

Electrochemical synthesis of γ-keto sulfones containing β-quaternary carbon center via 1,2-migration

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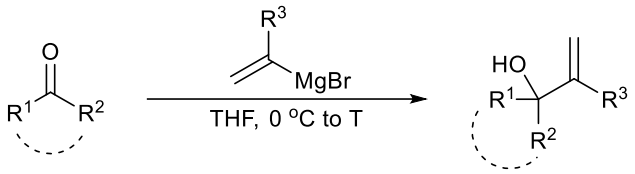
1. General information

^{1}H-NMR and ^{13}C-NMR spectra were recorded in $CDCl_3$ solution on a Bruker Avance 400 spectrometer at 20~25 ℃. ^{1}H NMR spectra were reported in parts per million using tetramethylsilane TMS (δ = 0.00 ppm) as an internal standard. The data of ^{1}H NMR were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd= doublet of doublets, dt = doublet of triplets, m = multiplet), coupling constants (*J*, Hz), and integration. ^{13}C NMR spectra were reported in parts per million using solvent $CDCl_3$ (δ = 77.2 ppm) as an internal standard. The data of ^{13}C NMR are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet), and coupling constants (*J*, Hz). Reactions were monitored by TLC and column chromatography was performed using silica gel. Commercially available reagents were used without further purification unless otherwise specified.

1.1 Preparation of allylic alcohols

The raw materials (**1**) were prepared according to literature procedures.[1-6] To a two-necked flask under argon atmosphere loaded with a solution of ketone (5 mmol) in anhydrous THF (5 mL), then Grignard reagent (1.0 M in THF, 5.5 mL, 5.5 mmol, 1.1 eq.) was dropwise added via syringe under vigorous stirring in ice-bath. After continuously stirring for 0.5 h, the mixture was warmed to room temperature (or 50 ℃) and stirred for 5 h. Then it was detected by TLC and aqueous NH_4Cl (6 mL) was added at 0 ℃ to quench the reaction. Removed THF solvent. Subsequently, the mixture was extracted with EtOAc (5 mL × 3) and the combined organic layer was dried with anhydrous magnesium. The solvent was removed in vacuo by a rotary evaporator and the final crude was purified by chromatography on silica gel to yield desired allylic alcohol.



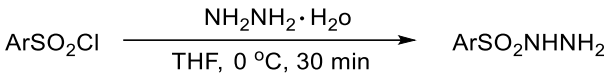
R^1 = Aryl, Alkyl
R^2 = Aryl, Alkyl
R^3 = H, Me

For α, α-diaryl allylic alcohols (1a-m): 0 ℃ to rt.

For α-alkyl, α-aryl allylic alcohols (1m-r) and α, α-dialkyl allylic alcohols (1s-z): 0 ℃ to 50 ℃.

1.2 Preparation of aryl sulfonhydrazides

The raw materials (**2**) were prepared according to literature procedures.[7-10] To a two-necked flask under argon atmosphere charged with arylsulfonyl chloride (5 mmol) in THF solution (25 mL), and subsequently added hydrazine hydrate (15 mmol, 3 eq.) dropwise under ice bath conditions. After stirring at 0 ℃ for 30 minutes, detected by TLC. Then evaporated THF solution in vacuum, and extracted the aqueous solution of crudes with ethyl acetate (30 mL × 3). Organic layer was dried over anhydrous magnesium and removed solvents. Then the crude was purified by chromatography on silica gel to obtain desired aryl sulfonhydrazides.



1.3 Preparation of γ-keto sulfones

An undivided cell was equipped with graphite plate anode (10 × 10 × 3 mm) and foamed nickel cathode (10 × 10 × 2 mm). Allyl alcohols **1** (0.25 mmol), sulfonyl hydrazines **2** (0.5 mmol, 2 eq.) and Bu_4NBF_4 electrolyte (0.5 mmol) were respectively added into the cell with a 6 mL solution of MeCN/H_2O (5/1). The mixture exposed to air was stirred and electrolyzed under constant current conditions (15 mA) at room temperature for 4 hours. Then it was extracted with ethyl acetate (15 mL × 3), and

dried over anhydrous $MgSO_4$. After concentrating in vacuum, the residue was purified by column chromatography on silica gel to get target γ-keto sulfone possessing β-quaternary carbon center.

1.4 Gram-scale reaction

An undivided round-bottomed flask (250 mL) was equipped with graphite plate anode (10 × 10 × 3 mm) and foamed nickel cathode (10 × 10 × 2 mm), which were connected to a power supply. 2-methyl-1,1-diphenylprop-2-en-1-ol **1a** (5 mmol), 4-methylbenzenesulfonhydrazide **2a** (10 mmol, 2 eq.) and Bu_4NBF_4 electrolyte (10 mmol) were respectively added into the cell with a solution of $MeCN/H_2O$ (120 mL, 5/1). The mixture exposed to air was stirred and electrolyzed under constant current conditions (15 mA) at room temperature for 72 hours. Then evaporated MeCN solvent in vacuum and extracted with ethyl acetate (50 mL × 3). After drying over anhydrous $MgSO_4$ and concentrating in vacuum, the residue was purified by column chromatography on silica gel to obtain target γ-keto sulfone **3aa** (1.27 g, 84%).

1.5 Reductive reaction

A round bottomed flask was filled with γ-keto sulfone (**3aa**, 0.5 mmol, 189.2 mg) in ethanol solution (2 mL). Added sodium borohydride (1.0 mmol, 2 eq.) slowly to it under ice bath conditions. The mixture was continuously stirred for 2 hours at room temperature and detected by TLC. Quenched the reaction by adding dilute hydrochloric acid dropwise under ice bath condition. Washed with saturated salt water and ethyl acetate (15 mL × 3). After drying with anhydrous $MgSO_4$ and concentrating in vacuum, the mixture was purified by column chromatography on silica gel and obtained γ-hydroxyl sulfone **6** (129.2 mg, 68%).

1.6 Control experiments

Add three equivalents of 2,2,6,6-tetramethylpiperidinyl-1-oxide (TEMPO) or butylated hydroxytoluene (BHT) to the standard reaction system, and other operations are the same as **1.3**.

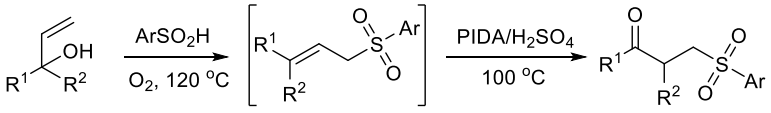
1.7 Cyclic voltammetry (CV) experiments

Cyclic voltammetry experiments were carried out in a three-electrode cell (25 mL) at room temperature. A steady glassy carbon electrode was used as the working electrode, while a platinum wire was used as the counter electrode and an Ag/AgCl electrode was used as reference. A mixed CH_3CN/H_2O (12 mL, 5/1) solution containing 1 mmol nBu_4NBF_4 was added into the cell. 0.5 mmol **1a** was added to determine the oxidation potential of itself. 0.1 mmol **2a** was added to determine the oxidation potential of **2a**. The scan rate was 0.1 V/s, ranging from 0 V to 3 V.

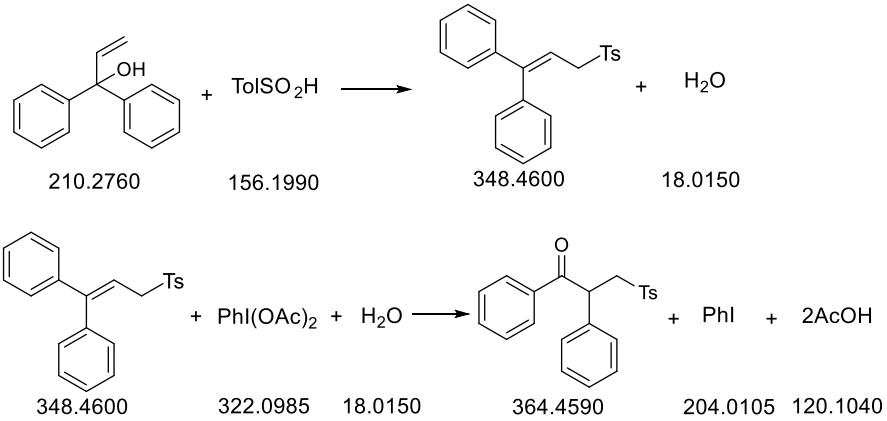
2. Green metrics

Taking standard reactions as examples and calculations are conducted using atom economy (atom efficiency) and theoretical environmental factor (E-factor) as representative green metrics[11-13].

(a) Ji's work[14]: two steps, unstable PIDA, heating and other by-products (PhI, AcOH, etc.).

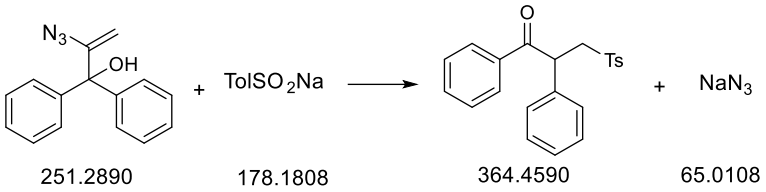


While $R^1 = R^2$ = Ph: Atom efficiency = 0.53, E_{theor} = 0.89.

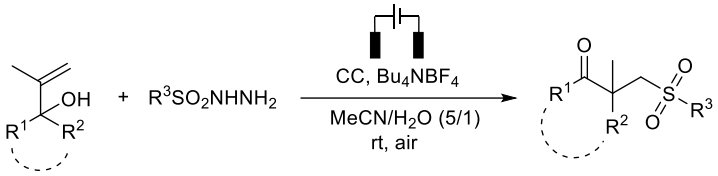


(b) Wang's work[15]: unstable and toxic azides, high temperature, 6 equivalents of sodium p-toluenesulfonate, and many by-products ($TsNH_2$, TMSOH,NaN_3,etc.)

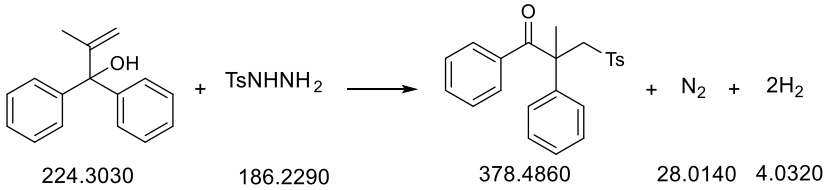
While R^1 = R^2 = Ph: Atom efficiency = 0.85, E_{theor} = 0.18.



(c) Our work: room tempreture, one step, without oxidants and catalysts, only H_2 and N_2 by-products.



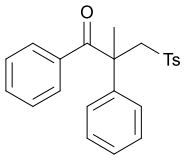
While R^1 = R^2 = Ph: Atom efficiency = 0.92, E_{theor} = 0.08.



Overall, this electrochemical strategy for constructing γ-keto sulfones has higher atom economy and lower theoretical environmental factor, which is in line with the concept of green chemistry.

3. Characterization of the products

2-methyl-1,2-diphenyl-3-tosylpropan-1-one (3aa)



3aa

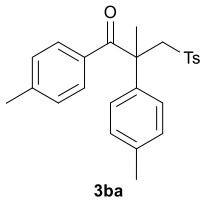
White solid, 84.2 mg, 89% yield, mp 102-104 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49 (d, *J* = 8.0 Hz, 2H), 7.32-7.26 (m, 2H), 7.25-7.20 (m, 6H), 7.16-7.12 (m, 4H),4.00 (d, *J* = 14.4 Hz, 1H), 3.72 (d, *J* = 14.4 Hz, 1H), 2.32 (s, 3H), 2.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.31, 144.14, 139.52, 138.81, 136.35, 131.95, 129.74, 129.37, 129.36, 128.22, 128.08, 127.68, 126.77, 65.70, 53.81, 22.26, 21.71.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{22}O_3SNa$ 401.1182, found 401.1186.

2-methyl-1,2-di-*p*-tolyl-3-tosylpropan-1-one (3ba)



3ba

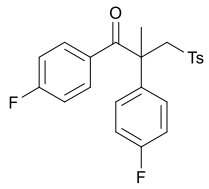
White solid, 87.4 mg, 86% yield, mp 88-90 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52 (d, *J* = 8.4 Hz, 2H), 7.29 (d, *J* = 8.4 Hz, 2H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.13 (d, *J* = 8.0 Hz, 2H), 7.02 (t, *J* = 8.0 Hz, 4H), 3.99 (d, *J* = 14.8 Hz, 1H), 3.84 (d, *J* = 14.8 Hz, 1H), 2.38 (s, 3H), 2.29 (s, 3H), 2.28 (s, 3H), 2.09 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$):δ 200.77, 143.86, 142.65, 138.79, 137.73, 136.50, 133.26, 129.90, 129.73, 129.53, 128.84, 127.64, 126.66, 65.81, 53.37, 22.27, 21.66, 21.57, 21.14.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{25}H_{26}O_3SNa$ 429.1495, found 429.1497.

1,2-bis(4-fluorophenyl)-2-methyl-3-tosylpropan-1-one (3ca)



3ca

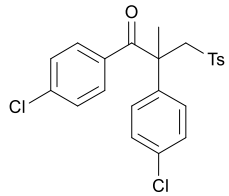
White solid, 82.9 mg, 80% yield, mp 134-136 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (d, *J* = 8.0 Hz, 2H), 7.41-7.38 (m, 2H), 7.26-7.21 (m, 4H), 6.98-6.90 (m, 4H), 3.94 (d, *J* = 14.8 Hz, 1H), 3.83 (d, *J* = 14.8 Hz, 1H), 2.34 (s, 3H), 2.02 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 199.42, 164.99 (d, *J* = 242.6 Hz), 162.49 (d, *J* = 236.1 Hz), 144.36, 138.64, 135.03 (d, *J* = 3.4 Hz), 132.23 (d, *J* = 9.1 Hz), 131.89 (d, *J* = 3.3 Hz), 129.79, 128.70 (d, *J* = 8.2 Hz), 127.64, 116.39 (d, *J* = 21.5 Hz), 115.51 (d, *J* = 21.8 Hz), 65.60, 53.26, 22.50, 21.72.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{20}F_2O_3SNa$ 437.0993, found 437.0996.

1,2-bis(4-chlorophenyl)-2-methyl-3-tosylpropan-1-one (3da)



3da

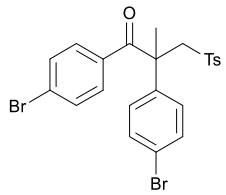
White solid, 88.3 mg, 79% yield mp 100-102 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42 (d, *J* = 8.4 Hz, 2H), 7.23 (d, *J* = 8.8 Hz, 2H), 7.16-7.08 (m, 8H), 3.85 (d, *J* = 14.4 Hz, 1H), 3.78 (d, *J* = 14.8 Hz, 1H), 2.41 (s, 3H), 2.11 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 199.59, 144.41, 138.77, 138.38, 137.48, 134.56, 133.86, 130.96, 129.79, 129.57, 128.72, 128.35, 127.60, 65.37, 53.33, 22.18, 21.75.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{20}Cl_2O_3SNa$ 469.0402, found 469.0405.

1,2-bis(4-bromophenyl)-2-methyl-3-tosylpropan-1-one (3ea)



3ea

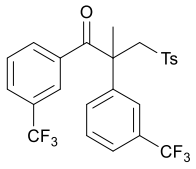
White solid, 88.5 mg, 66% yield, mp 118-119 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48 (d, *J* = 8.0 Hz, 2H), 7.38 (d, *J* = 7.2 Hz, 2H), 7.23-7.19 (m, 4H), 7.09 (d, *J* = 8.8 Hz, 2H), 3.89 (dd, *J* = 18.0, 14.8 Hz, 2H), 2.42 (s, 3H), 2.08 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 199.67, 144.39, 138.25, 137.87, 134.23, 132.48, 131.70, 131.04, 129.79, 128.66, 127.55, 127.43, 122.77, 65.22, 53.34, 22.08, 21.77.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{20}Br_2O_3SNa$ 558.9372, found 558.9373.

2-methyl-3-tosyl-1,2-bis(3-(trifluoromethyl)phenyl)propan-1-one (3fa)



3fa

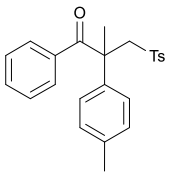
Colourless oil, 115.7 mg, 90% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56 (d, *J* = 7.6 Hz, 1H), 7.51 (s, 1H), 7.46-7.40 (m, 5H), 7.37 (d, *J* = 8.0 Hz, 1H), 7.33-7.26 (m, 2H), 7.10 (d, *J* = 8.0 Hz, 2H), 3.95 (d, *J* = 14.8 Hz, 1H), 3.82 (d, *J* = 14.8 Hz, 1H), 2.29 (s, 3H), 2.07 (s, 3H).

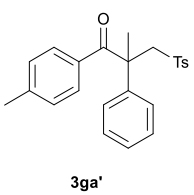
^{13}C NMR (101 MHz, $CDCl_3$): δ 199.36, 144.64, 139.86, 138.12, 136.32, 132.19, 131.91 (q, *J* = 32.7 Hz), 131.10 (q, *J* = 24.0 Hz), 130.45, 130.11, 129.86, 129.04, 128.76 (q, *J* = 3.5 Hz), 127.57, 126.21 (q, *J* = 4.0 Hz), 125.30 123.62 (q, *J* = 3.7 Hz), 123.71 (q, *J* = 271.0 Hz), 123.62 (q, *J* = 3.7 Hz), 123.49 (q, *J* = 273.6 Hz), 65.01, 53.66, 22.04, 21.59.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{25}H_{20}F_6O_3SNa$ 537.0930, found 537.0932.

2-methyl-1-phenyl-2-(p-tolyl)-3-tosylpropan-1-one (3ga) and 2-methyl-2-phenyl-1-(p-tolyl)-3-tosylpropan-1-one (3ga')



3ga



3ga'

Colourless oil, 90.3 mg, 92% yield.

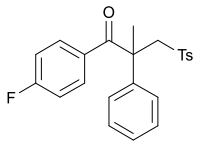
^{1}H NMR (400 MHz, $CDCl_3$): First isomer: δ 7.46 (d, *J* = 7.6 Hz, 2H), 7.30-7.25 (overlapped, 2H), 7.19-7.15 (overlapped,3H), 7.13-7.06 (overlapped, 4H), 6.97 (d, *J* = 7.6 Hz, 2H), 3.95 (d, *J* = 14.4 Hz, 1H), 3.73 (d, *J* = 14.8 Hz, 1H), 2.31 (s, 3H), 2.22 (s, 3H), 2.00 (s, 3H). Second isomer: δ 7.46 (d, *J* = 7.6 Hz, 2H), 7.30-7.25 (overlapped, 2H), 7.19-7.15 (overlapped,3H), 7.13-7.06 (overlapped, 4H), 6.93 (d, *J* =

7.6 Hz, 2H), 3.95 (d, *J* = 14.4 Hz, 1H), 3.73 (d, *J* = 14.8 Hz, 1H), 2.30 (s, 3H), 2.20 (s, 3H), 2.04 (s, 3H).

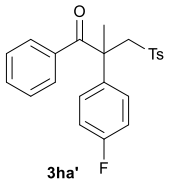
^{13}C NMR (101 MHz, $CDCl_3$): First isomer: δ 201.42, 143.97, 142.74, 138.74, 137.87, 136.26, 131.85, 129.98, 129.59, 129.34, 128.16, 127.65, 126.59, 65.69, 53.39, 22.20, 21.67, 21.14. Second isomer: δ 200.59, 144.01, 139.70, 138.80, 136.39, 133.17, 129.70, 129.66, 129.25, 128.87, 127.93, 127.62, 126.78, 65.76, 53.74, 22.30, 21.67, 21.57.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{24}H_{24}O_3SNa$ 415.1338, found 415.1337.

1-(4-fluorophenyl)-2-methyl-2-phenyl-3-tosylpropan-1-one (3ha) and 2-(4-fluorophenyl)-2-methyl-1-phenyl-3-tosylpropan-1-one (3ha')



3ha



3ha'

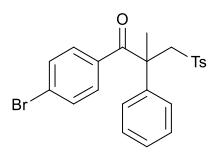
White solid, 86.1 mg, 87% yield, mp 99-107 °C.

^{1}H NMR (400 MHz, $CDCl_3$): First isomer: δ 7.55 (t, *J* = 8.8 Hz, 2H), 7.41-7.38 (overlapped, 2H), 7.33 (d, *J* = 6.8 Hz, 2H), 7.28 (overlapped, 2H), 7.22 (t, *J* = 8.0 Hz, 2H), 6.90 (t, *J* = 8.4 Hz, 3H), 4.04 (d, *J* = 14.4 Hz, 1H), 3.78 (d, *J* = 14.4 Hz, 1H), 2.39 (s, 3H), 2.11 (s, 3H). Second isomer: δ 7.55 (t, *J* = 8.8 Hz, 2H), 7.41-7.38 (overlapped, 1H), 7.28 (overlapped, 3H), 7.26 (d, *J* = 2.8 Hz, 2H), 7.23 (t, *J* = 8.0 Hz, 2H), 6.96 (t, *J* = 8.4 Hz, 3H), 3.97 (d, *J* = 14.8 Hz, 1H), 3.85 (d, *J* = 14.4 Hz, 1H), 2.40 (s, 3H), 2.10 (s, 3H).

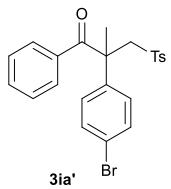
^{13}C NMR (101 MHz, $CDCl_3$): First isomer: δ 199.61, 164.78 (d, *J* = 255.1 Hz), 144.20, 139.44, 138.62, 132.25(d, *J* = 3.5 Hz), 132.19, 132.13 (d, *J* = 6.8 Hz), 129.76, 129.46, 127.66, 126.72, 115.36 (d, *J* = 21.8 Hz), 65.68, 53.79, 22.32, 21.71. Second isomer: δ 201.07, 162.48 (d, *J* = 249.1 Hz), 144.28, 138.75, 135.92, 135.03 (d, *J* = 3.5 Hz), 129.75, 129.39, 128.71 (d, *J* = 8.2 Hz), 128.31, 128.20, 127.62, 116.25 (d, *J* = 21.5 Hz), 65.56, 53.23, 22.41, 21.69.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{21}FO_3SNa$ 419.1088, found 419.1089.

1-(4-bromophenyl)-2-methyl-2-phenyl-3-tosylpropan-1-one (3ia) and 2-(4-bromophenyl)-2-methyl-1-phenyl-3-tosylpropan-1-one (3ia')



3ia



3ia'

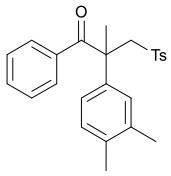
Colourless oil, 94.9 mg, 83% yield.

^{1}H NMR (400 MHz, $CDCl_3$): First isomer: δ 7.47 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.32-7.43 (overlapped, 3H), 7.20-7.16 (overlapped, 3H), 7.14-7.09 (overlapped, 5H), 3.97 (d, *J* = 14.8 Hz, 1H), 3.68 (d, *J* = 14.8 Hz, 1H), 2.30 (s, 3H), 2.00 (s, 3H). Second isomer: δ 7.39 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.32-7.43 (overlapped, 3H), 7.20-7.16 (overlapped, 3H), 7.14-7.09 (overlapped, 3H), 7.03 (dt, *J* = 8.8, 2.0 Hz, 2H), 3.84 (s, 2H), 2.32 (s, 3H), 2.00 (s, 3H).

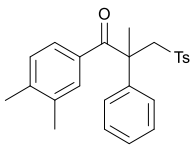
^{13}C NMR (101 MHz, $CDCl_3$): First isomer: δ 200.13, 144.18, 139.22, 138.10, 134.90, 131.46, 130.91, 129.73, 129.44, 128.19, 127.60, 126.90, 126.63, 65.51, 53.73, 22.18, 21.65. Second isomer: δ 200.64, 144.21, 138.66, 138.30, 135.62, 132.27, 132.22, 129.69, 129.38, 128.68, 128.30, 127.49, 122.48, 65.27, 53.29, 22.09, 21.68.

HRMS (ESI) m/z: $[M + H]^+$ Calcd for $C_{23}H_{22}BrO_3S$ 457.0468, found 457.0468.

2-(3,4-dimethylphenyl)-2-methyl-1-phenyl-3-tosylpropan-1-one (3ja) and 1-(3,4-dimethylphenyl)-2-methyl-2-phenyl-3-tosylpropan-1-one (3ja')



3ja



3ja'

White solid, 76.2 mg, 75% yield, mp 132-137 °C.

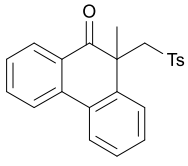
^{1}H NMR (400 MHz, $CDCl_3$): First isomer: δ 7.41 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.29-7.25 (m, 3H), 7.21-7.15 (overlapped, 4H), 7.08-7.05 (m, 3H), 3.93 (d, *J* = 14.8 Hz, 1H), 3.78 (d, *J* = 14.4 Hz, 1H), 2.29 (s, 3H), 2.10 (s, 3H), 2.00 (s, 3H), 1.97 (s, 3H). Second isomer: δ 7.46 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.21-7.15 (overlapped, 1H), 7.14-7.10 (m, 3H), 6.98-6.90 (m, 3H), 6.88-6.80 (m, 3H), 3.95 (d, *J* = 14.4 Hz, 1H), 3.72 (d, *J* = 14.8 Hz, 1H), 2.29 (s, 3H), 2.09 (s, 3H), 2.05 (s, 3H), 2.03 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): First isomer: δ 201.46, 143.74, 139.77, 138.66, 137.38, 136.48, 136.36, 131.78, 130.50, 129.38, 129.18, 128.11, 127.62, 127.59, 127.08, 65.67, 53.22, 22.12, 21.62, 19.90, 19.45. Second isomer: δ 200.78, 143.95, 141.45, 138.82, 136.65, 136.49, 133.60, 130.86, 127.95, 129.62, 129.33, 127.87, 127.62, 126.78, 123.97, 65.79, 53.74, 22.26, 21.62, 19.87, 19.79.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{25}H_{26}O_3SNa$ 429.1495, found 429.1496.

10-methyl-10-(tosylmethyl)phenanthren-9(10*H*)-one (3ka)

White solid, 82.8 mg, 88% yield, mp 127-128 °C.



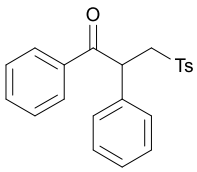
3ka

^{1}H NMR (400 MHz, $CDCl_3$): δ 8.09 (d, *J* = 8.0 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 2H), 7.62 (t, *J* = 8.0 Hz, 1H), 7.38-7.26 (m, 5H), 7.19-7.14 (m, 1H), 7.03 (d, *J* = 8.4 Hz, 2H), 4.51 (d, *J* = 14.4 Hz, 1H), 3.91 (d, *J* = 14.4 Hz, 1H), 2.26 (s, 3H), 1.35 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 198.62, 144.26, 138.83, 137.84, 137.03, 134.89, 129.58, 129.31, 128.92, 128.51, 128.34, 128.11, 128.08, 127. 93, 127.85, 124.02, 123.22, 64.83, 49.12, 30.78, 21.67.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{20}O_3SNa$ 399.1025, found 399.1024.

1,2-diphenyl-3-tosylpropan-1-one (3la)[15]



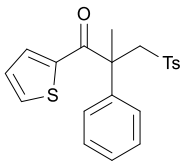
3la

White solid, 56.5 mg, 62% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (d, *J* = 7.6 Hz, 2H), 7.62 (d, *J* = 8.0 Hz, 2H), 7.42 (t, *J* = 7.2 Hz, 1H), 7.31 (t, *J* = 7.6 Hz, 2H), 7.19-7.10 (m, 7H), 5.21 (dd, *J* = 8.8, 3.6 Hz, 1H), 4.34 (dd, *J* = 14.0, 8.8 Hz, 1H), 3.35 (dd, *J* = 14.0, 3.6 Hz, 1H), 2.31 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 196.03, 144.86, 136.66, 136.54, 135.64, 133.58, 129.96, 129.53, 129.03, 128.74, 128.29, 128.26, 128.11, 59.46, 47.68, 21.76.

2-methyl-2-phenyl-1-(thiophen-2-yl)-3-tosylpropan-1-one (3ma)



3ma

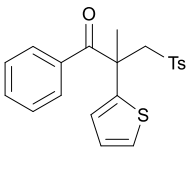
Colourless oil, 39.5 mg, 41% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.39-7.35 (m, 3H), 7.18-7.12 (m, 5H), 7.06 (d, *J* = 8.4 Hz, 2H), 6.90 (dd, *J* = 4.0, 1.2 Hz, 1H), 6.76 (dd, *J* = 4.8, 4.0 Hz, 1H), 3.89 (d, *J* = 15.2 Hz, 1H), 3.83 (d, *J* = 14.8 Hz, 1H), 2.30 (s, 3H), 2.12 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 193.81, 143.97, 140.51, 139.16, 138.53, 133.97, 133.51, 129.66, 129.01, 128.18, 127.78, 127.74, 127.60, 64.96, 53.80, 22.78, 21.69.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{21}H_{20}O_3S_2Na$ 407.0746, found 407.0746.

2-methyl-1-phenyl-2-(thiophen-2-yl)-3-tosylpropan-1-one (3ma')



3ma'

Colourless oil, 19.2 mg, 20% yield.

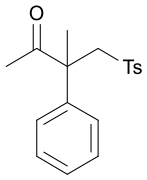
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61 (d, *J* = 8.0 Hz, 2H), 7.37-7.32 (m, 3H), 7.23-7.18 (m, 5H), 6.87 (d, *J* = 4.4 Hz, 1H), 6.83 (dd, *J* =

3.6, 1.2 Hz, 2H), 4.19 (d, *J* = 14.4 Hz, 1H), 3.63 (d, *J* = 14.0 Hz, 1H), 2.35 (s, 3H), 2.08 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 200.73, 144.47, 138.70, 136.83, 131.78, 129.88, 128.78, 128.27, 127.81, 126.27, 126.06, 66.08, 51.74, 24.02, 21.76.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{21}H_{20}O_3S_2Na$ 407.0746, found 407.0746.

3-methyl-3-phenyl-4-tosylbutan-2-one (3na)



3na

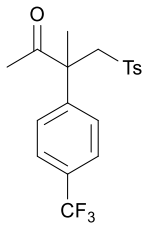
Colourless oil, 64.9 mg, 82% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (dt, *J* = 8.0, 1.8 Hz, 2H), 7.25-7.21 (m, 3H), 7.18 (d, *J* = 7.6 Hz, 2H), 7.16-7.13 (m,2H), 3.92 (d, *J* = 14.8 Hz, 1H), 3.66 (d, *J* = 14.4 Hz, 1H), 2.38(s, 3H), 2.03 (s, 3H), 1.96 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 207.44, 144.15, 138.57, 138.44, 129.70, 129.03, 127.85, 127.61, 126.56, 63.88, 54.26, 25.11, 21.63, 20.06.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{18}H_{20}O_3SNa$ 339.1025, found 339.1024.

3-methyl-4-tosyl-3-(4-(trifluoromethyl)phenyl)butan-2-one (3oa)



3oa

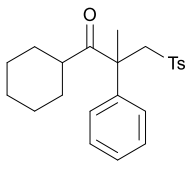
White solid, 63.4 mg, 66% yield, mp 89-91 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 (t, *J* = 7.2 Hz, 4H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.08 (d, *J* = 7.6 Hz, 2H), 3.74 (dd, *J* = 16.4, 15.2 Hz, 2H), 2.30(s, 3H), 1.98 (s, 3H), 1.86 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 206.82, 144.45, 142.09, 137.90, 129.79, 129.32 (q, *J* = 160.1 Hz), 127.56, 127.38, 125.89 (q, *J* = 3.7 Hz), 123.95 (q, *J* = 273.2 Hz) 63.44, 54.31, 25.13, 21.58, 19.99.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{19}H_{19}F_3O_3SNa$ 407.0899, found 407.0897.

1-cyclohexyl-2-methyl-2-phenyl-3-tosylpropan-1-one (3pa)



3pa

White solid, 81.7 mg, 85% yield, mp 92-94 °C.

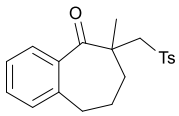
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41 (d, *J* = 8.0 Hz, 2H), 7.13-7.11 (m, 3H), 7.08 (s, 1H), 7.06-7.03 (m, 3H), 3.79 (d, *J* = 14.8 Hz, 1H), 3.63 (d, *J* = 14.8 Hz, 1H), 2.32-2.25 (m, 4H), 1.99 (s, 3H), 1.68-1.62

(m, 2H), 1.49-1.40 (m, 2H), 1.35-1.16 (m, 2H), 1.09-1.03 (m, 2H), 0.90-0.78 (m, 2H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 212.34, 143.96, 138.55, 137.41, 129.63, 128.76, 127.82, 127.61, 127.17, 63.91, 54.45, 45.94, 30.92, 30.84, 25.65, 25.63, 25.56, 21.64, 19.16.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{28}O_3SNa$ 407.1651, found 407.1649.

6-methyl-6-(tosylmethyl)-6,7,8,9-tetrahydro-5*H*-benzo[7]annulen-5-one (3qa)



3qa

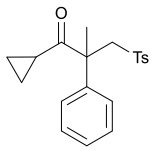
Colourless oil, 55.6 mg, 65% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 (d, *J* = 8.0 Hz, 2H), 7.35-7.19 (m, 5H), 7.68 (d, *J* = 6.4 Hz, 1H), 3.46 (d, *J* = 14.0 Hz, 1H), 3.37 (d, *J* = 14.0 Hz, 1H), 2.78-2.71 (m, 1H), 2.69-2.62 (m, 1H), 2.36 (s, 3H), 2.21-2.13 (m, 1H), 1.93-1.84 (m, 1H), 1.37 (s, 3H).

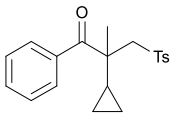
^{13}C NMR (101 MHz, $CDCl_3$): δ 210.97, 144.67, 140.20, 138.83, 136.96, 131.19, 130.00, 128.69, 128.67, 127.73, 126.80, 63.97, 49.47, 35.08, 33.29, 22.93, 22.83, 21.74.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{20}H_{22}O_3SNa$ 365.1182, found 365.1182.

1-cyclopropyl-2-methyl-2-phenyl-3-tosylpropan-1-one (3ra) and 2-cyclopropyl-2-methyl-1-phenyl-3-tosylpropan-1-one (3ra')



3ra



3ra'

Colourless oil, 70.8 mg, 82% yield.

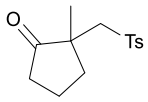
^{1}H NMR (400 MHz, $CDCl_3$): First isomer: δ 7.40-7.30 (overlapped, 2H), 7.15-7.12 (m, 3H), 7.07-7.04 (m, 4H), 3.79 (d, *J* = 14.8 Hz, 1H), 3.66 (d, *J* = 14.8 Hz, 1H), 2.28 (s, 3H), 2.00 (s, 3H), 1.55-1.49 (m, 1H), 0.89 (t, *J* = 4.4 Hz, 2H), 0.50-0.44 (m, 2H). Second isomer: δ 7.71-7.68 (m, 2H), 7.64-7.62 (m, 2H), 7.40-7.30 (overlapped, 3H), 7.25 (d, *J* = 8.4 Hz, 2H), 3.87 (d, *J* = 13.6 Hz, 1H), 3.45 (d, *J* = 14.0 Hz, 1H), 2.36 (s, 3H), 1.22 (s, 3H), 1.16-1.12 (m, 1H), 0.78-0.73 (m, 1H), 0.56-0.52 (m, 2H), 0.36-0.31 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) First isomer: δ 209.90, 143.92, 139.38, 138.74, 129.92, 129.59, 128.84, 127.72, 127.68 , 63.79, 54.31, 21.61, 20.33, 17.40, 11.46, 2.41.

Second isomer: δ 207.08, 144.49, 138.92, 138.44, 130.70, 128.04, 127.76, 127.56, 127.20, 65.64, 49.53, 21.71, 19.31, 18.70, 12.73, 3.19.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{20}H_{22}O_3SNa$ 365.1182, found 365.1181.

2-methyl-2-(tosylmethyl)cyclopentan-1-one (3sa)



3sa

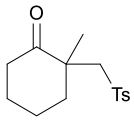
Colourless oil, 48.6 mg, 73% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 3.24 (s, 2H), 2.50-2.42 (m, 1H), 2.37 (s, 3H), 2.33-2.23 (m, 2H), 2.06-1.97 (m, 2H), 1.90-1.79 (m, 1H), 1.08 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 219.60, 144.84, 138.46, 130.05, 127.78, 62.51, 47.27, 36.28, 34.36, 22.41, 21.77, 18.90.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{14}H_{18}O_3SNa$ 289.0869, found 289.0870.

2-methyl-2-(tosylmethyl)cyclohexan-1-one (3ta)



3ta

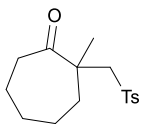
Colourless oil, 51.9 mg, 74% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 3.45 (d, *J* = 14.4 Hz, 1H), 3.27 (d, *J* = 14.4 Hz, 1H), 2.49-2.40 (m, 1H), 2.37-2.32 (m, 4H), 2.13-2.10 (m, 2H), 1.94-1.86 (m, 1H), 1.77-1.68 (m, 3H), 1.30 (s, 3H)

^{13}C NMR (101 MHz, $CDCl_3$): δ 212.13, 144.58, 139.02, 129.94, 127.73, 63.47, 48.67, 38.06, 37.73, 26.60, 23.30, 21.72, 21.05.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{15}H_{20}O_3SNa$ 303.1025, found 303.1025.

2-methyl-2-(tosylmethyl)cycloheptan-1-one (3ua)



3ua

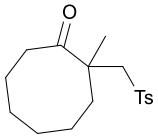
Colourless oil, 52.2 mg, 71% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 7.6 Hz, 2H), 3.30 (dd, *J* = 18.8, 14.4 Hz, 2H), 2.66-2.60 (m, 1H), 2.56-2.47 (m, 2H), 2.37 (s, 3H), 1.69 (dd, *J* = 14.4, 8.8 Hz, 1H), 1.63-1.52 (m, 5H), 1.46-1,39 (m, 1H), 1.27 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 214.88, 144.69, 138.81, 130.01, 127.77, 63.24, 50.74, 40.83, 35.22, 30.47, 25.91, 24.54, 24.21, 21.76.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{16}H_{22}O_3SNa$ 317.1182, found 317.1181.

2-methyl-2-(tosylmethyl)cyclooctan-1-one (3va)



3va

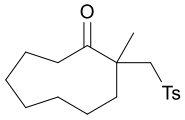
Colourless oil, 51.7 mg, 67% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 7.6 Hz, 2H), 3.49 (d, *J* = 14.8 Hz, 1H), 3.08 (d, *J* = 14.4 Hz, 1H), 2.71 (td, *J* = 11.6, 3.2 Hz, 1H), 2.37-2.30 (m, 4H), 2.18-2.05 (m, 2H), 1.84-1.76 (m, 1H), 1.71-1.58 (m. 3H), 1.55-1.42 (m, 2H), 1.37 (s, 3H), 1.31-1.21 (m, 1H), 0.84-0.74 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 217.48, 144.62, 139.07, 129.99, 127.69, 59.12, 50.56, 35.86, 32.45, 30.16, 26.18, 25.03, 24.37, 22.66, 21.72.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{24}O_3SNa$ 331.1338, found 331.1339.

2-methyl-2-(tosylmethyl)cyclononan-1-one (3wa)



3wa

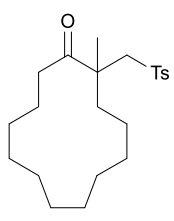
Colourless oil, 52.4 mg, 65% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.72 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 7.6 Hz, 2H), 3.46 (d, *J* = 14.4 Hz, 1H), 3.14 (d, *J* = 14.4 Hz, 1H), 2.85-2.78 (m, 1H), 2.37 (s, 3H), 2.23-2.17 (m, 1H), 2.06-1.99 (m, 1H), 1.80-1.65 (m, 3H), 1.50-1.43 (m, 4H), 1.37-1.30 (m, 4H), 1.29-1.22 (m, 2H), 1.16-1.08 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 215.23, 144.59, 139.09, 129.98, 127.70, 61.07, 51.99, 34.20, 33.69, 25.31, 24.62, 23.16, 22.38, 21.73, 21.27, 20.29.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{18}H_{26}O_3SNa$ 345.1495, found 345.1496.

2-methyl-2-(tosylmethyl)cyclotridecan-1-one (3xa)



3xa

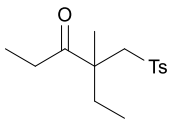
White solid, 56.8 mg, 60% yield, mp 112-114 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.68 (d, *J* = 8.4 Hz, 2H), 7.26 (d, *J* = 8.4 Hz, 2H), 3.83 (d, *J* = 14.0 Hz, 1H), 2.94 (d, *J* = 13.6 Hz, 1H), 2.80-2.72 (m, 1H), 2.53-2.46 (m, 1H), 2.36 (s, 3H), 2.01-1.94 (m, 1H), 1.61 (s, 3H), 1.48-1.39 (m, 2H), 1.31-1.05 (m, 17H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 212.95, 144.53, 138.92, 129.96, 127.73, 64.42, 50.21, 40.68, 37.03, 26.81, 26.36, 26.20, 25.22, 24.71, 23.81, 23.23, 21.87, 21.76, 20.95, 20.62.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{34}O_3SNa$ 401.2121, found 401.2123.

4-methyl-4-(tosylmethyl)hexan-3-one (3ya)



3ya

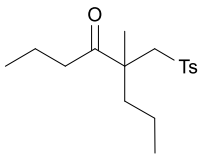
Colourless oil, 48.0 mg, 68% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.27 (d, *J* = 8.4 Hz, 2H), 3.66 (d, *J* = 14.0 Hz, 1H), 3.10 (d, *J* = 14.0 Hz, 1H), 2.66-2.57 (m, 1H), 2.50-2.42 (m, 1H), 2.37 (s, 3H), 1.67-1.60 (m, 1H), 1.54-1.47 (m, 4H), 1.00 (t, *J* = 7.2 Hz, 3H), 0.74 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 213.37, 144.60, 138.81, 129.98, 127.78, 63.17, 50.34, 32.62, 31.46, 21.75, 20.80, 8.54, 7.90.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{15}H_{22}O_3SNa$ 305.1182, found 305.1184.

5-methyl-5-(tosylmethyl)octan-4-one (3za)



3za

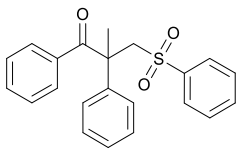
Colourless oil, 50.4 mg, 65% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69 (d, *J* = 8.0 Hz, 2H), 7.26 (d, *J* = 8.0 Hz, 2H), 3.64 (d, *J* = 14.0 Hz, 1H), 3.11 (d, *J* = 14.0 Hz, 1H), 2.60-2.52 (m, 1H), 2.44-2.39 (m, 1H), 2.37 (s, 3H), 1.61-1.52 (m, 3H), 1.49 (s, 3H), 1.44-1.36 (m, 1H), 1.16-1.06 (m, 2H), 0.86 (t, *J* = 7.2 Hz, 3H), 0.79 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 212.69, 144.57, 138.86, 129.97, 127.76, 63.18, 50.25, 41.90, 39.93, 21.76, 21.33, 17.43, 16.99, 14.52, 13.84.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{26}O_3SNa$ 333.1495, found 333.1497.

2-methyl-1,2-diphenyl-3-(phenylsulfonyl)propan-1-one (3ab)



3ab

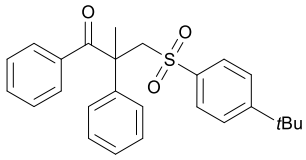
White solid, 78.4 mg, 86% yield, mp 109-111 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.59 (d, *J* = 8.0 Hz, 2H), 7.43 (t, *J* = 7.2 Hz, 1H), 7.33 (d, *J* = 6.4 Hz, 2H), 7.29-7.24 (m, 3H), 7.22-7.17 (m, 5H), 7.13 (t, *J* = 8.0 Hz, 2H), 3.99 (d, *J* = 14.4 Hz, 1H), 3.76 (d, *J* = 14.4 Hz, 1H), 2.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.19, 141.58, 139.25, 136.19, 133.19, 131.98, 129.35, 129.10, 128.21, 128.15, 127.58, 126.76, 65.60, 53.75, 22.20.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{20}O_3SNa$ 387.1025, found 387.1025.

3-((4-(*tert*-butyl)phenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ac)



3ac

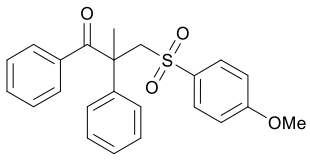
Colourless oil, 96.7 mg, 92% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.30 (dt, *J* = 8.8, 2.0 Hz, 2H), 7.27-7.09 (m, 10H), 3.97 (d, *J* = 14.8 Hz, 1H), 3.77 (d, *J* = 14.8 Hz, 1H), 2.03 (s, 3H), 1.22 (s, 9H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.19, 156.86, 139.21, 138.46, 136.22, 131.90, 129.31, 129.26, 128.15, 128.04, 127.43, 126.77, 126.05, 65.44, 53.66, 35.20, 31.14, 22.14.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{26}H_{28}O_3SNa$ 443.1651, found 443.1651.

3-((4-methoxyphenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ad)



3ad

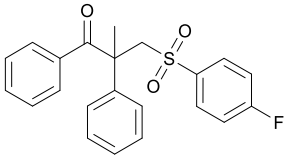
Colourless oil, 51.3 mg, 52% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.52 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.32-7.28 (m, 1H), 7.26 (s, 1H), 7.24-7.19 (m, 6H), 7.17-7.13 (m, 2H), 6.79 (dt, *J* = 10.0, 2.4 Hz, 2H), 3.99 (d, *J* = 14.4 Hz, 1H), 3.77 (s, 3H), 3.72 (d, *J* = 14.4 Hz, 1H), 2.03 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.37, 163.40, 139.56, 136.39, 133.46, 131.95, 129.84, 129.40, 129.36, 128.23, 128.11, 126.80, 114.32, 65.86, 55.81, 53.82, 22.28.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{22}O_4SNa$ 417.1131, found 417.1133.

3-((4-fluorophenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ae)



3ae

Colourless oil, 92.7 mg, 97% yield.

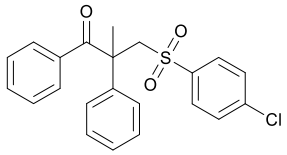
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.60-7.57 (m, 2H), 7.30 (t, *J* = 7.2 Hz, 1H), 7.25 (d, *J* = 8.4 Hz, 2H), 7.20 (s, 5H), 7.14 (t, *J* = 8.0 Hz, 2H), 6.98 (t, *J* = 8.4 Hz, 2H), 3.97 (d, *J* = 14.4 Hz,

1H), .3.79 (d, *J* = 14.8 Hz, 1H), 2.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.14, 164.47 (d, *J* = 256.5 Hz), 139.08, 137.66 (d, *J* = 3.1 Hz), 136.04, 132.12, 130.51 (d, *J* = 9.7 Hz), 129.43, 129.41, 128.28, 128.26, 126.87, 116.32 (d, *J* = 22.6 Hz), 65.90, 53.80, 22.13.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{19}FO_3SNa$ 405.0931, found 405.0932.

3-((4-chlorophenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3af)



3af

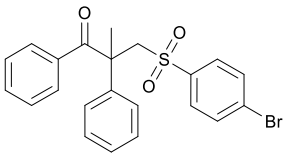
White solid, 85.8 mg, 86% yield, mp 89-91 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49 (dt, *J* = 8.4, 2.4 Hz, 2H), 7.31-7.23 (m, 5H), 7.19 (s, 5H), 7.14 (t, *J* = 8.0 Hz, 2H), 3.96 (d, *J* = 14.8 Hz, 1H), .3.79 (d, *J* = 14.4 Hz, 1H), 2.03 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.03, 139.93, 139.81, 138.98, 135.94, 132.10, 129.40, 129.38, 129.33, 129.12, 128.24, 128.22, 126.83, 65.80, 53.75, 22.10.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{19}ClO_3SNa$ 421.0636, found 421.0635.

3-((4-bromophenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ag)



3ag

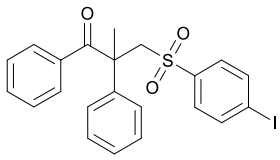
White solid, 92.0 mg, 83% yield, mp 109-111 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47-7.41 (m, 4H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.25 (d, *J* = 8.0 Hz, 2H), 7.20 (s, 5H), 7.15 (t, *J* = 7.6 Hz, 2H), 3.96 (d, *J* = 14.8 Hz, 1H), .3.80 (d, *J* = 14.4 Hz, 1H), 2.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.10, 140.51, 139.02, 135.99, 132.38, 132.17, 129.47, 129.44, 129.25, 128.48, 128.30, 128.28, 126.90, 65.86, 53.81, 22.13.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{19}BrO_3SNa$ 465.0130, found 465.0130.

3-((4-iodophenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ah)



3ah

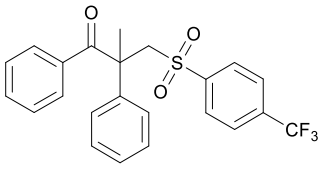
White solid, 90.7 mg, 74% yield, mp 96-97 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.33-7.23 (m, 5H), 7.21-7.18 (m, 5H), 7.15 (t, *J* = 8.0 Hz, 2H), 3.95 (d, *J* = 14.8 Hz, 1H), .3.79 (d, *J* = 14.8 Hz, 1H), 2.03 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.06, 141.14, 139.01, 138.34, 136.00, 132.13, 129.46, 129.42, 129.06, 128.28, 128.24, 126.88, 101.05, 65.79, 53.78, 22.12.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{19}IO_3SNa$ 512.9992, found 512.9990.

2-methyl-1,2-diphenyl-3-((4-(trifluoromethyl)phenyl)sulfonyl)propan-1-one (3ai)



3ai

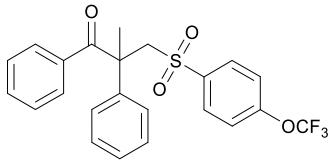
White solid, 103.7 mg, 96% yield, mp 87-89 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.4 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.33-7.29 (m, 1H), 7.27-7.23 (m, 2H), 7.16-7.13 (m, 7H), 3.96 (d, *J* = 14.8 Hz, 1H), 3.89 (d, *J* = 14.8 Hz, 1H), 2.06 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 200.94, 144.76, 138.66, 135.78, 134.71 (q, *J* = 22.6 Hz), 132.26, 129.48, 129.43, 128.40, 128.32, 128.28, 126.97, 126.18 (q, *J* = 3.7 Hz), 123.31 (q, *J* = 274.2 Hz), 65.75, 53.78, 22.05.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{19}F_3O_3SNa$ 455.0899, found 455.0899.

2-methyl-1,2-diphenyl-3-((4-(trifluoromethoxy)phenyl)sulfonyl)propan-1-one (3aj)



3aj

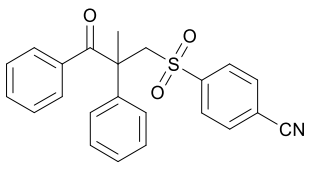
White solid, 95.3 mg, 85% yield, mp 99-101 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.58 (dt, *J* = 8.8, 2.8 Hz, 2H), 7.30 (t, *J* = 7.2 Hz, 1H), 7.25-7.23 (m, 2H), 7.19-7.15 (m, 6H), 7.12 (t, *J* = 8.4 Hz, 3H), 3.94 (d, *J* = 14.8 Hz, 1H), 3.87 (d, *J* = 15.2 Hz, 1H), 2.05 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.04, 152.46, 139.74, 138.75, 135.88, 132.19, 129.91, 129.46, 129.40, 128.31, 128.30, 126.99, 120.98, 120.36 (q, *J* = 260.4 Hz), 65.81, 53.75, 22.06.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{19}F_3O_4SNa$ 471.0848, found 471.0848.

4-((2-methyl-3-oxo-2,3-diphenylpropyl)sulfonyl)benzonitrile (3ak)



3ak

White solid, 79.8 mg, 82% yield, mp 139-140 °C.

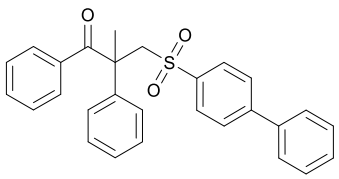
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.25 (d, *J*

= 8.0 Hz, 2H), 7.17-7.12 (m, 7H), 3.95 (d, *J* = 14.8 Hz, 1H), 3.88 (d, *J* = 13.2 Hz, 1H), 2.05 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 200.81, 145.37, 138.64, 135.60, 132.76, 132.30, 129.44, 128.42, 128.33, 128.31, 126.95, 117.35, 116.73, 65.86, 53.80, 22.01.

HRMS (ESI) m/z: [M + Na] + Calcd for $C_{23}H_{19}NO_3SNa$ 412.0978, found 412.0984.

3-([1,1'-biphenyl]-4-ylsulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3al)



3al

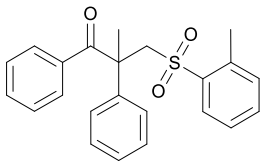
White solid, 41.8 mg, 38% yield, , mp 58-60 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.52-7.47 (m, 4H), 7.42-7.37 (m, 2H), 7.36-7.33 (m, 1H), 7.32-7.17 (m, 8H), 7.16-7.12 (m, 2H), 4.02 (d, *J* = 14.8 Hz, 1H), 3.83 (d, *J* = 14.4 Hz, 1H), 2.06 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.24, 146.11, 140.05, 139.48, 139.26, 136.20, 132.03, 129.41, 129.39, 129.22, 128.70, 128.25, 128.18, 128.13, 127.76, 127.50, 126.88, 65.72, 53.80, 22.23.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{28}H_{24}O_3SNa$ 463.1338, found 463.1339.

2-methyl-1,2-diphenyl-3-(*o*-tolylsulfonyl)propan-1-one (3am)



3am

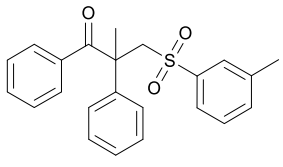
Colourless oil, 73.8 mg, 78% yield.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.63 (dd, *J* = 8.4, 0.8 Hz, 1H), 7.33-7.26 (m, 2H), 7.25-7.17 (m, 7H), 7.14-7.10 (m, 4H), 3.99 (d, *J* = 14.4 Hz, 1H), 3.74 (d, *J* = 14.4 Hz, 1H), 2.53 (s, 3H), 2.03 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.26, 139.53, 139.49, 137.66, 136.24, 133.35, 132.60, 131.96, 129.75, 129.35, 129.33, 128.21, 128.16, 126.66, 126.56, 64.49, 53.73, 22.28, 20.42.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{22}O_3SNa$ 401.1182, found 401.1182.

2-methyl-1,2-diphenyl-3-(*m*-tolylsulfonyl)propan-1-one (3an)



3an

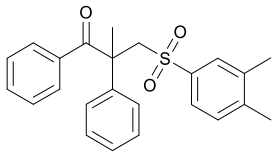
White solid, 81.4 mg, 86% yield, mp 99-101 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42 (dt, *J* = 6.8, 2.0 Hz, 1H), 7.32-7.12 (m, 13H), 3.96 (d, *J* = 14.8 Hz, 1H), 3.79 (d, *J* = 14.4 Hz, 1H), 2.26 (s, 3H), 2.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.27, 141.45, 139.29, 136.27, 134.04, 132.00, 129.42, 129.28, 129.02, 128.25, 128.13, 127.98, 126.87, 124.72, 65.58, 53.76, 22.31, 21.41.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{23}H_{22}O_3SNa$ 401.1182, found 401.1180.

3-((3,4-dimethylphenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ao)



3ao

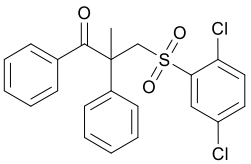
White solid, 85.4 mg, 87% yield, mp 135-136 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 (dd, *J* = 8.0, 2.0 Hz, 1H), 7.30 (t, *J* = 7.6 Hz, 1H), 7.26-7.24 (m, 3H), 7.22-7.19 (m, 5H), 7.15 (t, *J* = 8.0 Hz, 2H), 7.09 (d, *J* = 8.0 Hz, 1H), 3.97 (d, *J* = 14.8 Hz, 1H), 3.75 (d, *J* = 14.4 Hz, 1H), 2.21 (s, 3H), 2.16 (s, 3H), 2.03 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.31, 142.86, 139.52, 138.88, 137.78, 136.38, 131.92, 130.24, 129.39, 129.25, 128.46, 128.21, 128.00, 126.82, 125.14, 65.64, 53.77, 22.36, 20.08, 19.88.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{24}H_{24}O_3SNa$ 415.1338, found 415.1335.

3-((2,5-dichlorophenyl)sulfonyl)-2-methyl-1,2-diphenylpropan-1-one (3ap)



3ap

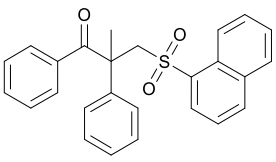
White solid, 81.3 mg, 75% yield, mp 143-145 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.39-7.38 (m, 1H), 7.36-7.33 (m, 3H), 7.30-7.26 (m, 2H), 7.25-7.21 (m, 3H), 7.19 (s, 1H), 7.17-7.14 (m, 3H), 4.70 (d, *J* = 15.6 Hz, 1H), 3.89 (d, *J* = 15.6 Hz, 1H), 2.10 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 200.60, 139.43, 137.71, 135.28, 133.91, 133.49, 132.46, 132.37, 131.09, 130.31, 129.74, 129.06, 128.67, 128.31, 127.10, 63.36, 53.59, 22.44.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{22}H_{18}Cl_2O_3SNa$ 455.0246, found 455.0248.

2-methyl-3-(naphthalen-1-ylsulfonyl)-1,2-diphenylpropan-1-one (3aq)



3aq

White solid, 63.2mg, 61% yield, mp 83-85 °C.

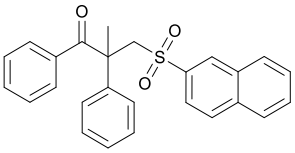
^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51 (d, *J* = 8.4 Hz, 1H), 7.90 (t, *J* = 7.6 Hz, 2H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.58-7.54 (m, 1H), 7.51-7.47 (m, 1H), 7.34-7.24 (m, 4H), 7.14-7.08 (m, 7H), 4.14 (d, *J* = 14.8 Hz, 1H), 3.98 (d, *J* = 14.8 Hz, 1H), 2.09 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.17, 139.21, 136.22, 136.13, 134.88, 134.15, 132.01, 130.17, 129.45, 129.23, 129.14, 128.79, 128.52, 128.23, 128.09, 126.95, 126.72, 124.49, 124.25, 64.68, 53.87, 22.45.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{26}H_{22}O_3SNa$ 437.1182, found 437.1181.

2-methyl-3-(naphthalen-2-ylsulfonyl)-1,2-diphenylpropan-1-one (3ar)

Colourless oil, 56.0 mg, 54% yield.



3ar

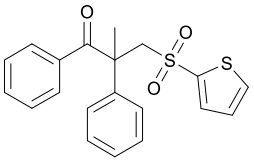
^{1}H NMR (400 MHz, $CDCl_3$): δ 8.12 (d, *J* = 1.6 Hz, 1H), 7.87-7.84 (m, 3H), 7.69 (dd, *J* = 8.8, 2.0 Hz, 1H), 7.65-7.55 (m, 2H), 7.39-7.32 (m, 3H), 7.30-7.26 (m, 2H), 7.22-7.15 (m, 4H), 7.10-7.06 (m, 1H), 4.12 (d, *J* = 14.4 Hz, 1H), 3.96 (d, *J* = 14.8 Hz, 1H), 2.15 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.21, 139.08, 138.32, 136.19, 135.09, 132.13, 132.01, 129.61, 129.45, 129.42, 129.41, 129.24, 129.17, 128.24, 128.19, 127.99, 127.56, 126.82, 122.45, 65.45, 53.81, 22.32.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{26}H_{22}O_3SNa$ 437.1182, found 437.1180.

2-methyl-1,2-diphenyl-3-(thiophen-2-ylsulfonyl)propan-1-one (3as)

Colourless oil, 52.8 mg, 57% yield.



3as

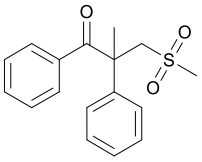
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (dd, *J* = 7.2, 1.6 Hz, 1H), 7.32-7.27 (m, 3H), 7.26-7.24 (m, 5H), 7.23-7.20 (m, 1H), 7.16-7.13 (m, 2H), 6.89 (dd, *J* = 5.2, 4.0 Hz, 1H), 4.10 (d, *J* = 14.8 Hz, 1H), 3.89 (d, *J* = 14.8 Hz, 1H), 2.04 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.05, 142.99, 139.22, 136.04, 133.70, 133.61, 132.10, 129.46, 129.44, 128.26, 128.24, 127.72, 126.85, 67.17, 53.97, 22.13.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{20}H_{18}O_3S_2Na$ 393.0590, found 393.0588.

2-methyl-3-(methylsulfonyl)-1,2-diphenylpropan-1-one (3at)

White solid, 64.3 mg, 85% yield, mp 118-120 °C.



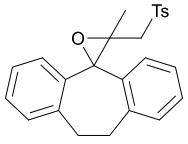
3at

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.46-7.36 (m, 8H), 7.26-7.23 (m, 2H), 3.75 (dd, *J* = 17.2, 15.2 Hz, 2H), 2.37 (s, 3H), 2.08 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 201.16, 139.44, 135.42, 132.43, 129.82, 129.74, 128.64, 128.35, 127.07, 65.03, 53.71, 43.47, 21.71.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{18}O_3SNa$ 325.0869, found 325.0869.

3'-methyl-3'-(tosylmethyl)-10,11-dihydrospiro[dibenzo[*a,d*][7]annulene-5,2'-oxirane] (4)



4

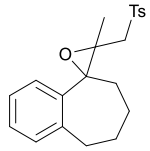
White solid, 73.8 mg, 73% yield, mp 167-169 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.60 (dt, *J* = 8.4, 2.0 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 2H), 7.24-7.22 (m, 1H), 7.13-7.00 (m, 5H), 6.85 (t, *J* = 7.6 Hz, 1H), 6.69 (d, *J* = 7.6 Hz, 1H), 3.34-3.27 (m, 1H), 3.23-3.15 (m, 2H), 2.94 (d, *J* = 14.4 Hz, 1H), 2.90-2.78 (m, 2H), 2.41 (s, 3H), 1.32 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 144.77, 137.90, 137.86, 137.69, 137.41, 135.94, 129.95, 129.76, 128.89, 128.58, 128.25, 128.17, 126.21, 126.07, 125.89, 125.71, 68.76, 64.07, 59.87, 32.64, 31.77, 21.87, 18.14.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{18}O_3SNa$ 427.1338, found 427.1332.

(5S)-3'-methyl-3'-(tosylmethyl)-6,7,8,9-tetrahydrospiro[benzo[7]annulene-5,2'-oxirane] (5)



5

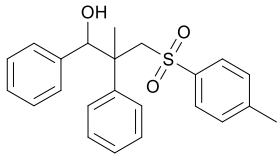
White solid, 54.3 mg, 61% yield, mp 95-97 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (d, *J* = 8.4 Hz, 2H), 7.25 (d, *J* = 8.4 Hz, 2H), 7.05 (t, *J* = 7.2 Hz, 1H), 6.98 (d, *J* = 6.0 Hz, 1H), 6.84 (t, *J* = 7.6 Hz, 1H), 6.43 (d, *J* = 7.6 Hz, 1H), 3.07 (d, *J* = 15.6 Hz, 1H), 2.70-2.54 (m, 3H), 2.40 (s, 3H), 1.93-1.63 (m, 8H), 1.31-1.25 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 144.64, 139.93, 139.27, 137.63, 129.60, 129.22, 128.62, 128.03, 126.26, 125.91, 68.69, 61.54, 60.04, 36.08, 33.36, 27.32, 27.28, 21.85, 18.67.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{18}O_3SNa$ 379.1338, found 379.1333.

2-methyl-1,2-diphenyl-3-tosylpropan-1-ol (6)



6

White solid, 129.4 mg, 68% yield, mp 115-117 °C.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (dd, *J* = 8.0, 2.0 Hz, 2H), 7.15-7.04 (m, 10H), 6.79 (d, *J* = 7.6 Hz, 2H), 4.99 (s, 1H), 3.74 (d, *J* = 14.4 Hz, 1H), 3.60 (d, *J* = 14.4 Hz, 1H), 2.54 (s, 1H), 2.33 (s, 3H), 1.61 (s, 3H).

^{13}C NMR (101 MHz, $CDCl_3$): δ 144.42, 140.49, 139.54, 138.54, 129.86, 128.25, 127.98, 127.84, 127.63, 127.10, 80.63, 64.33, 47.03, 21.74, 20.71.

HRMS (ESI) m/z: $[M + Na]^+$ Calcd for $C_{17}H_{18}O_3SNa$ 403.1338, found 403.1337.

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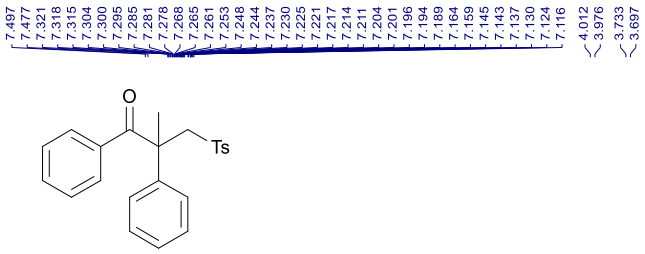
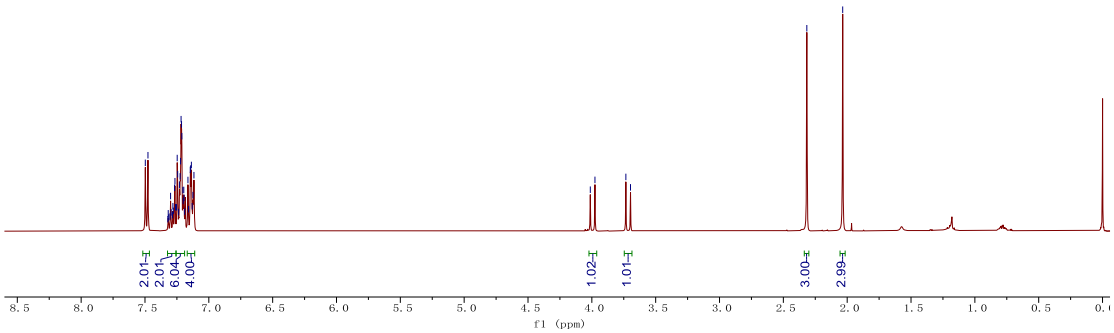
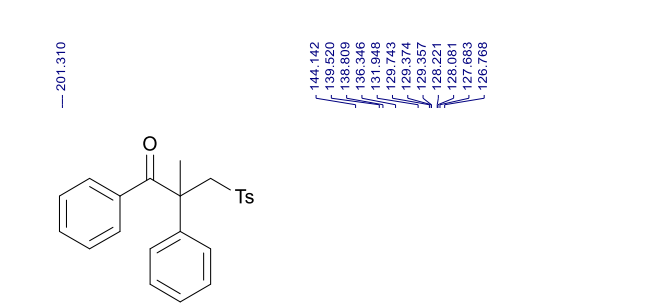
5. ^{1}H NMR and ^{13}C NMR of products

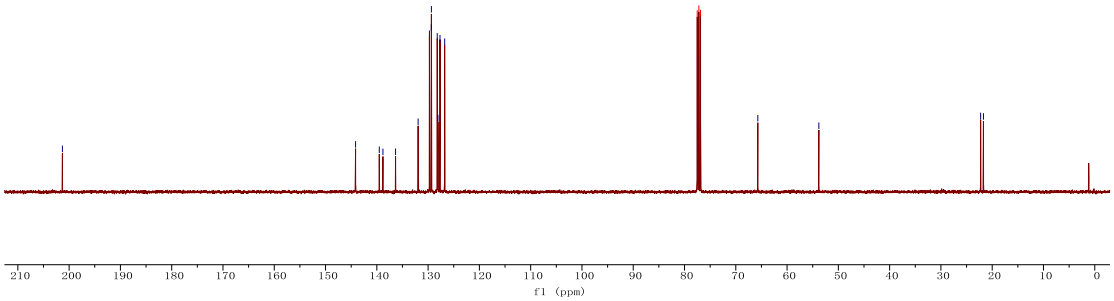


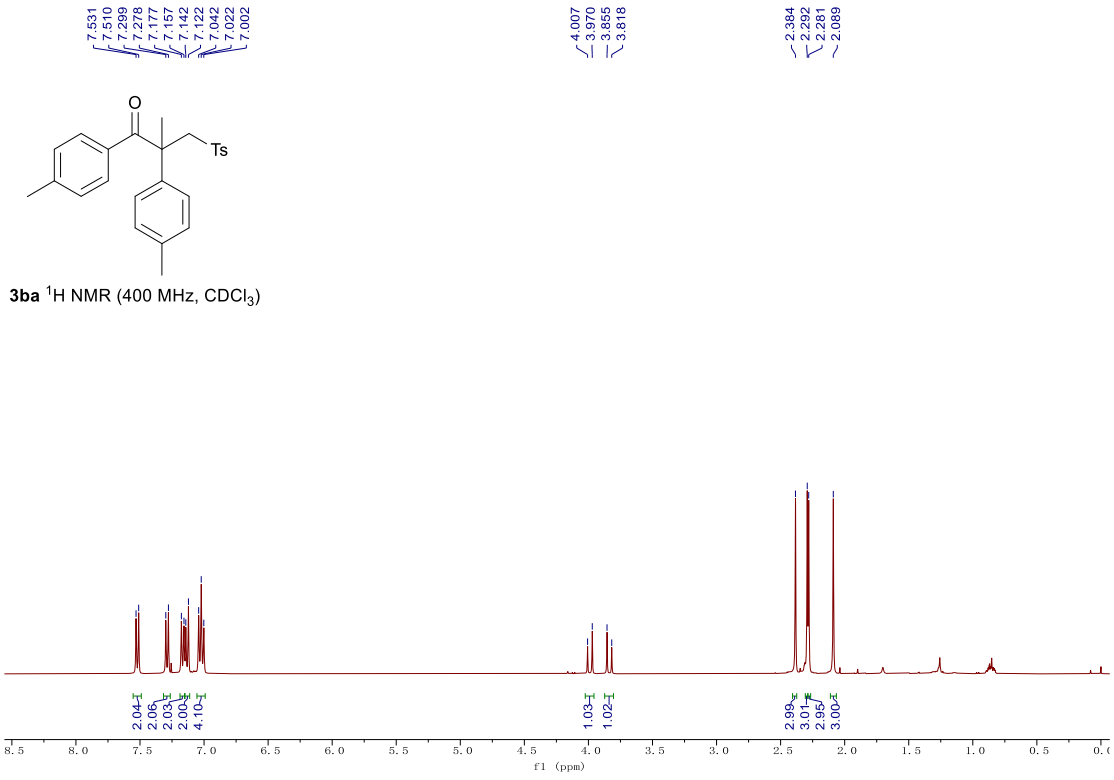
3aa ^{1}H NMR (400 MHz, $CDCl_3$)



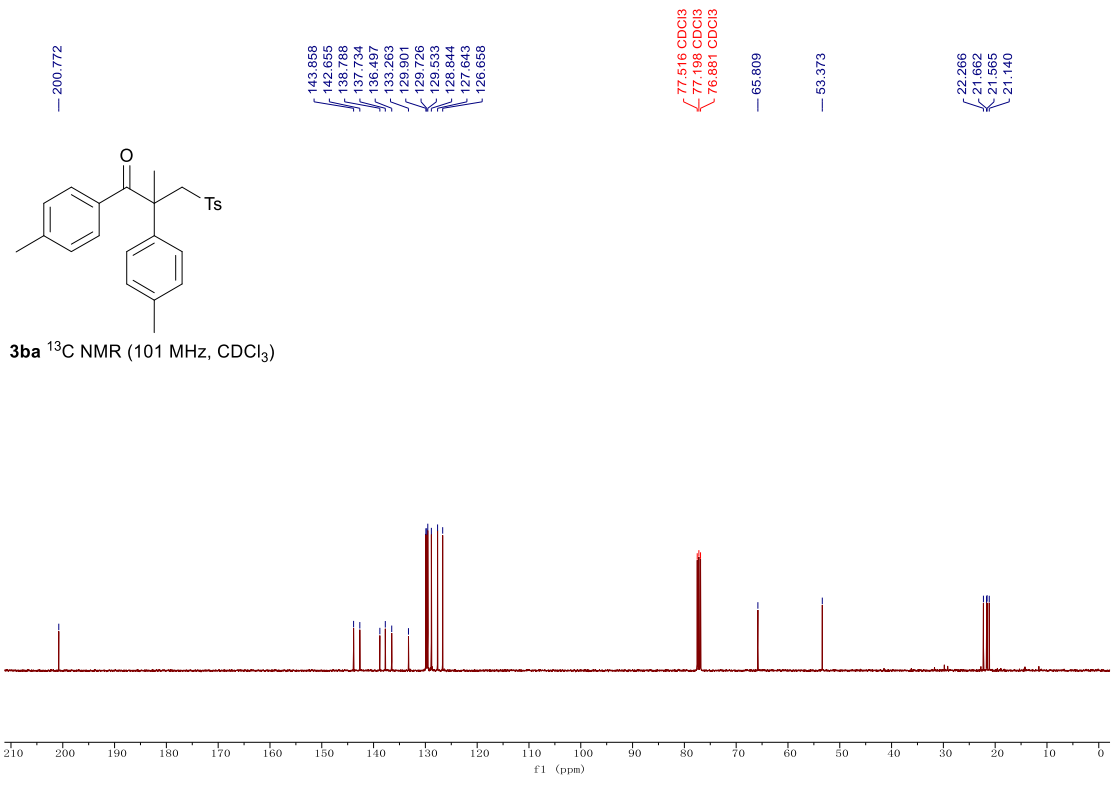


3aa ^{13}C NMR (101 MHz, $CDCl_3$)

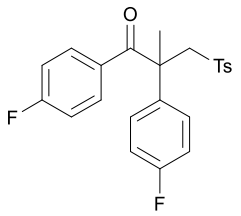




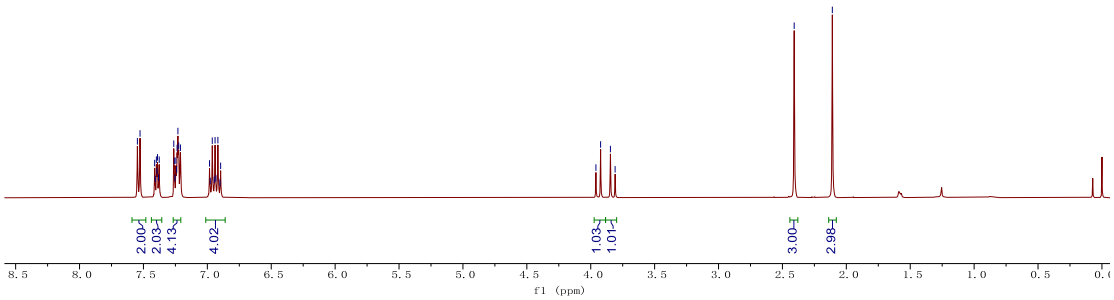
3ba ^{1}H NMR (400 MHz, $CDCl_3$)

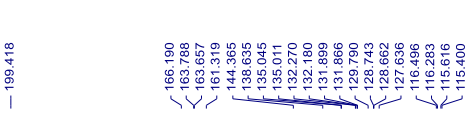


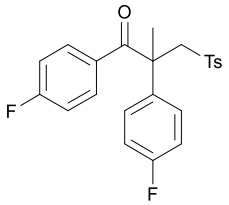
3ba ^{13}C NMR (101 MHz, $CDCl_3$)



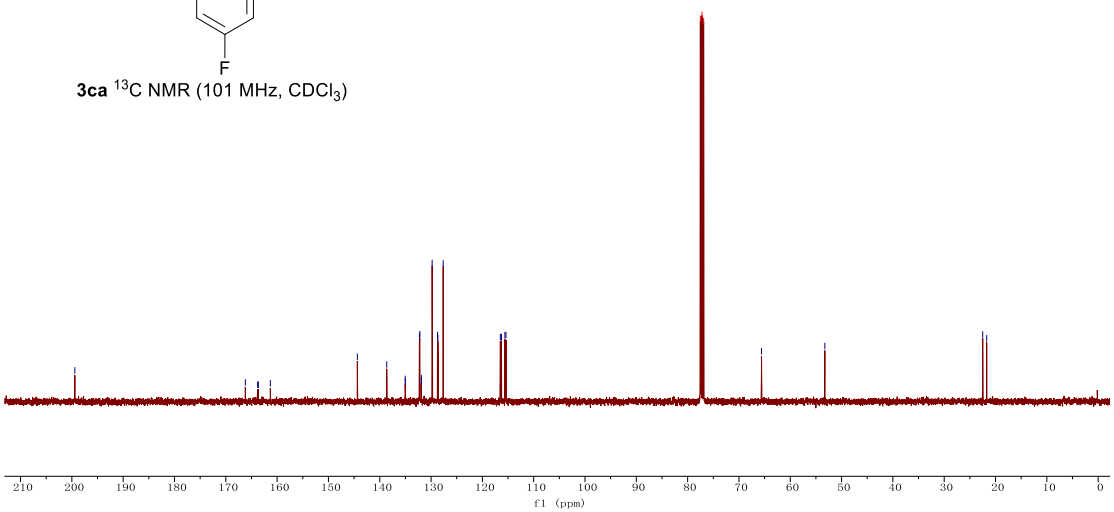
3ca ^{1}H NMR (400 MHz, $CDCl_3$)

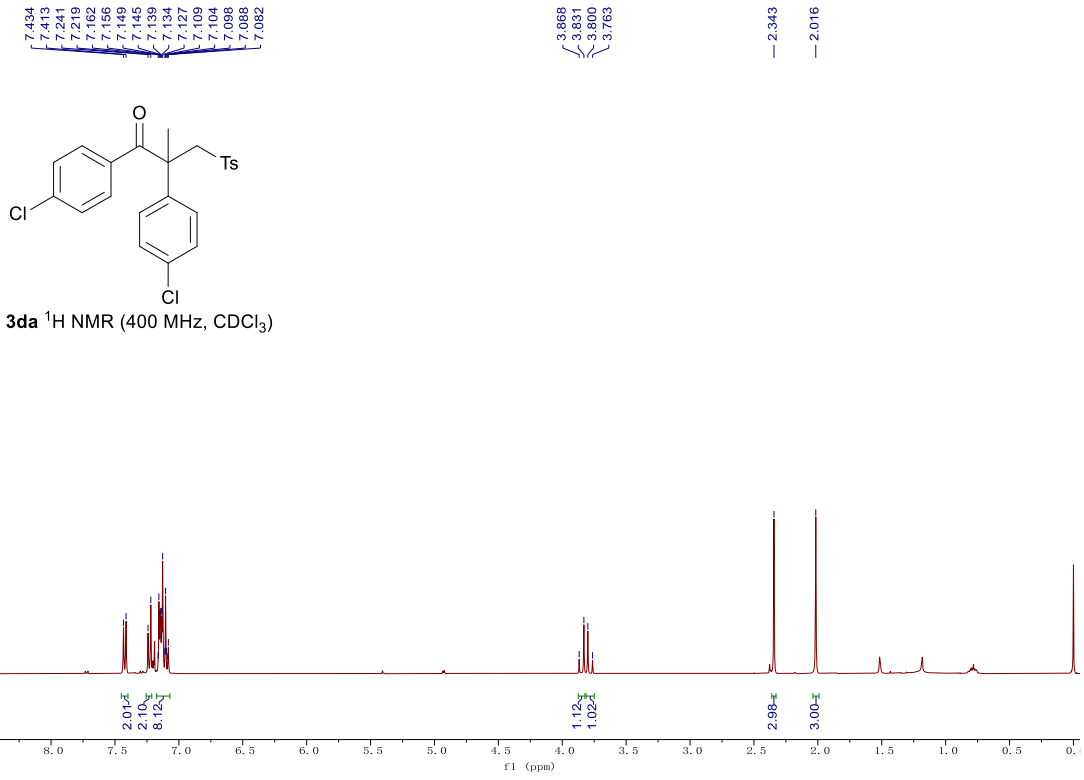




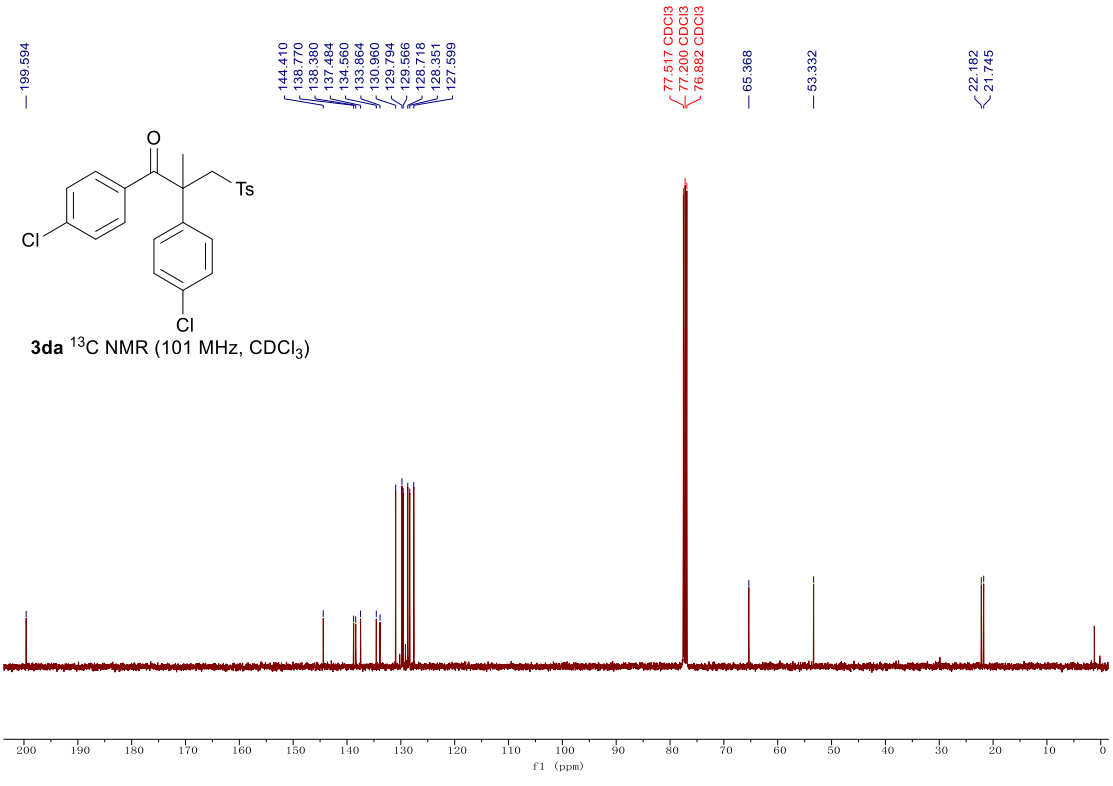


3ca ^{13}C NMR (101 MHz, $CDCl_3$)

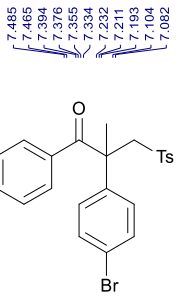




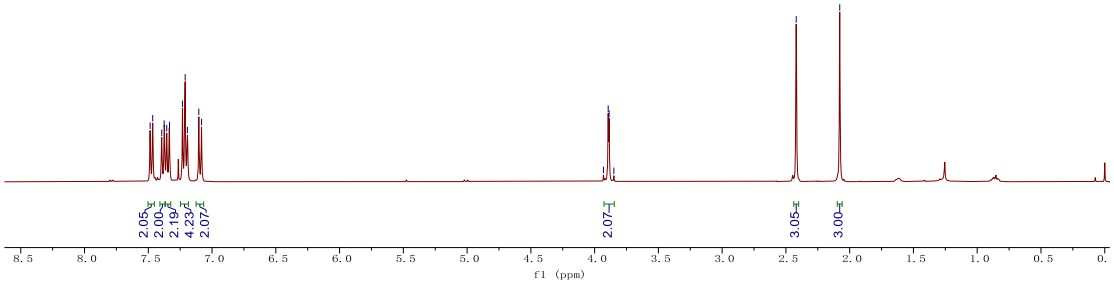
3da ^{1}H NMR (400 MHz, $CDCl_3$)

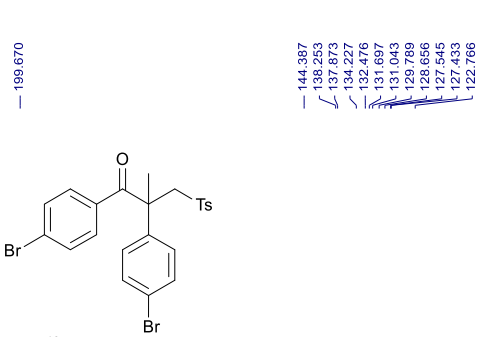


3da ^{13}C NMR (101 MHz, $CDCl_3$)

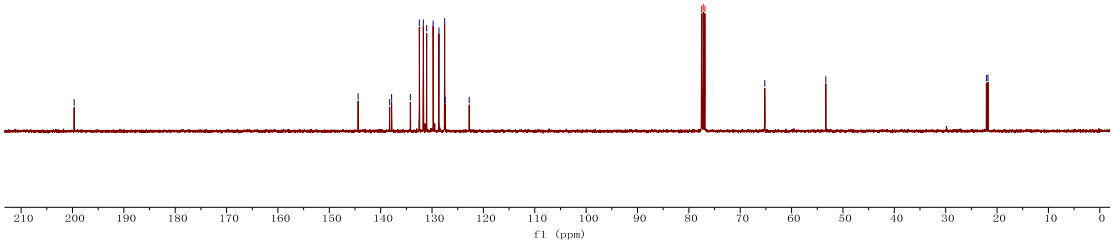


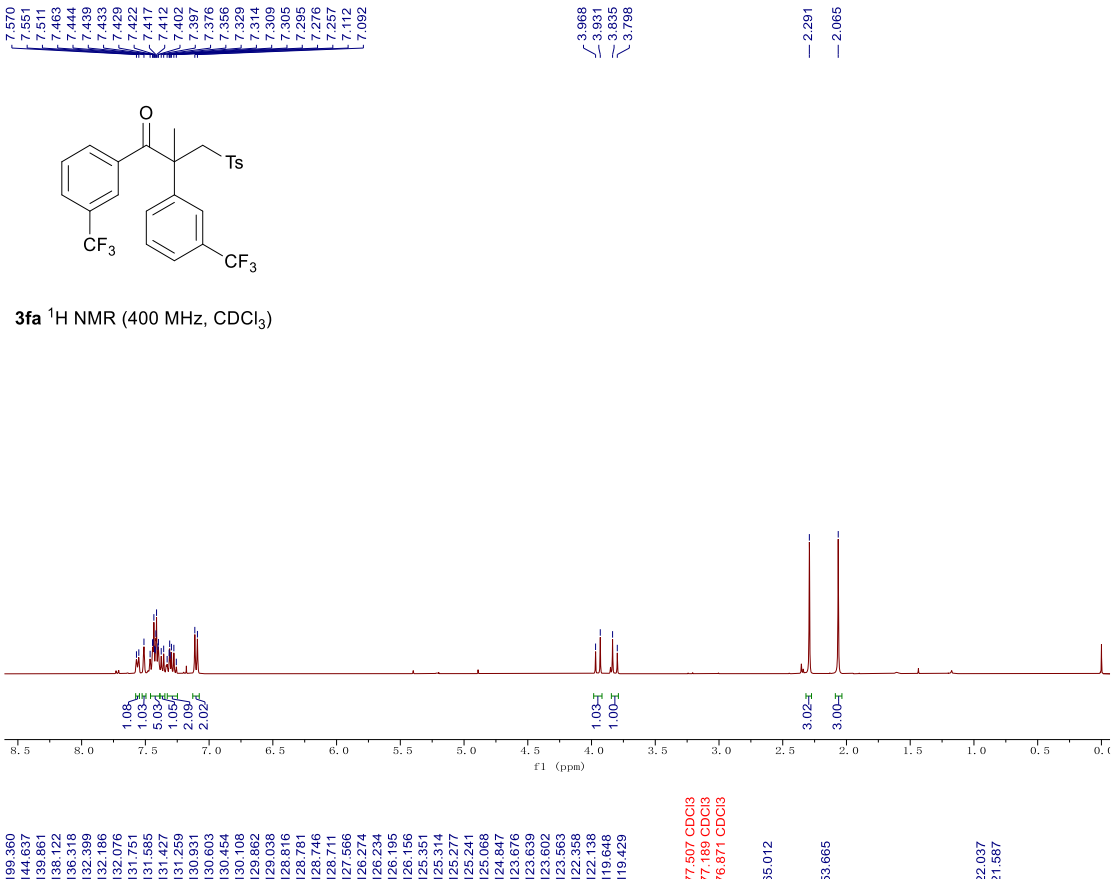
3ea ^{1}H NMR (400 MHz, $CDCl_3$)



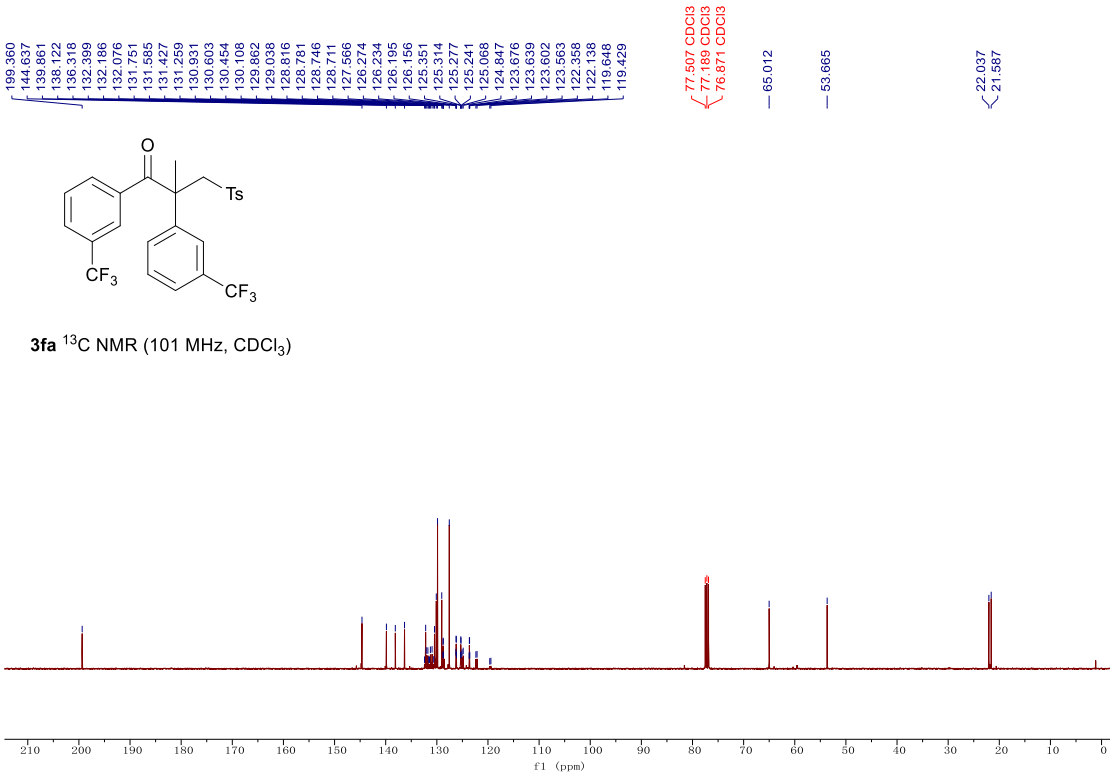


3ea ^{13}C NMR (101 MHz, $CDCl_3$)

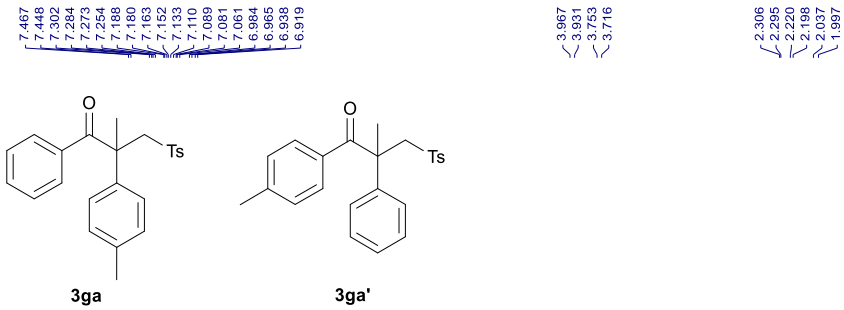




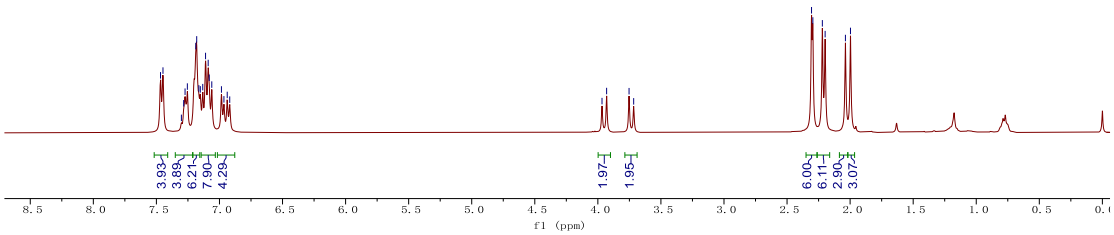
3fa ^{1}H NMR (400 MHz, $CDCl_3$)

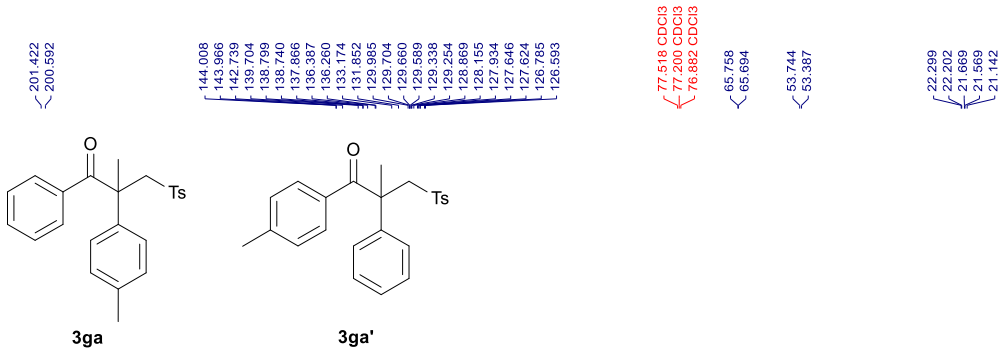


3fa ^{13}C NMR (101 MHz, $CDCl_3$)

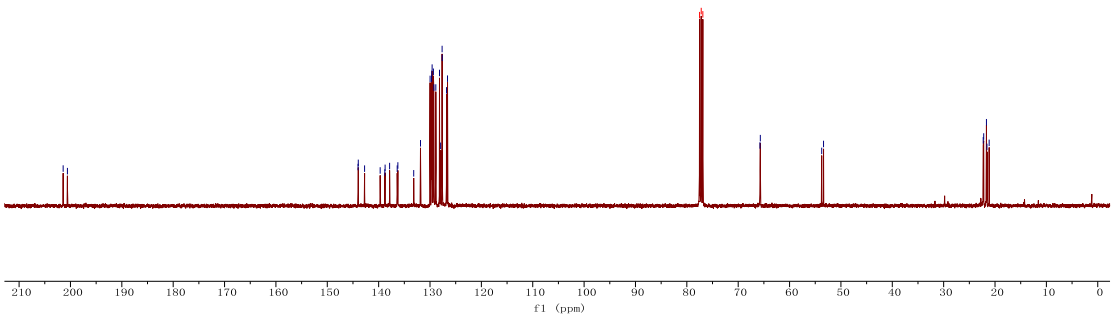


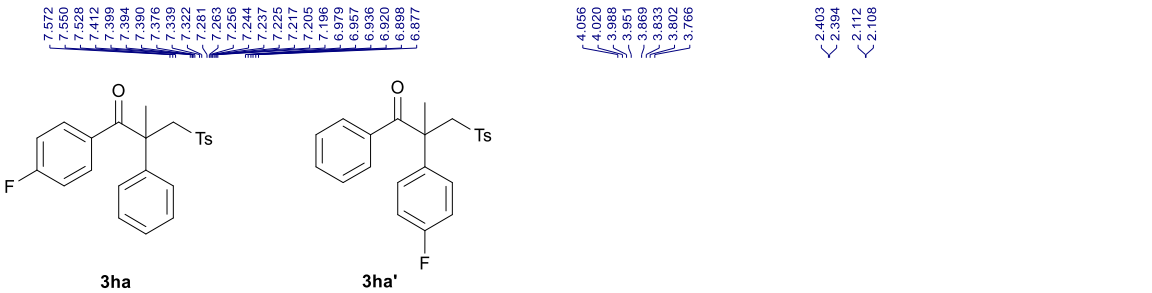
^{1}H NMR (400 MHz, CDCl3)



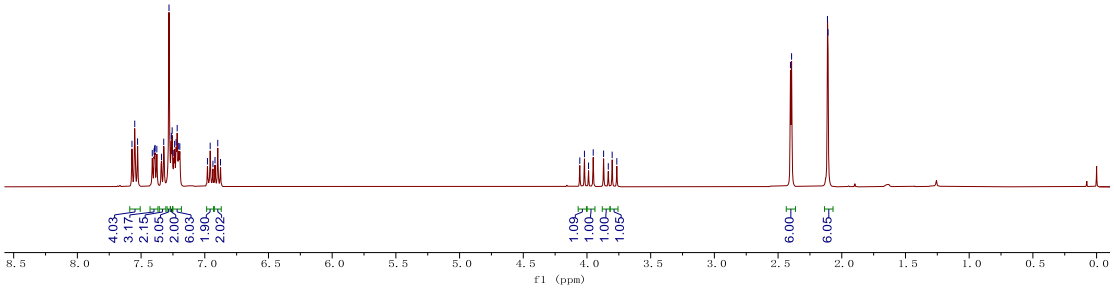


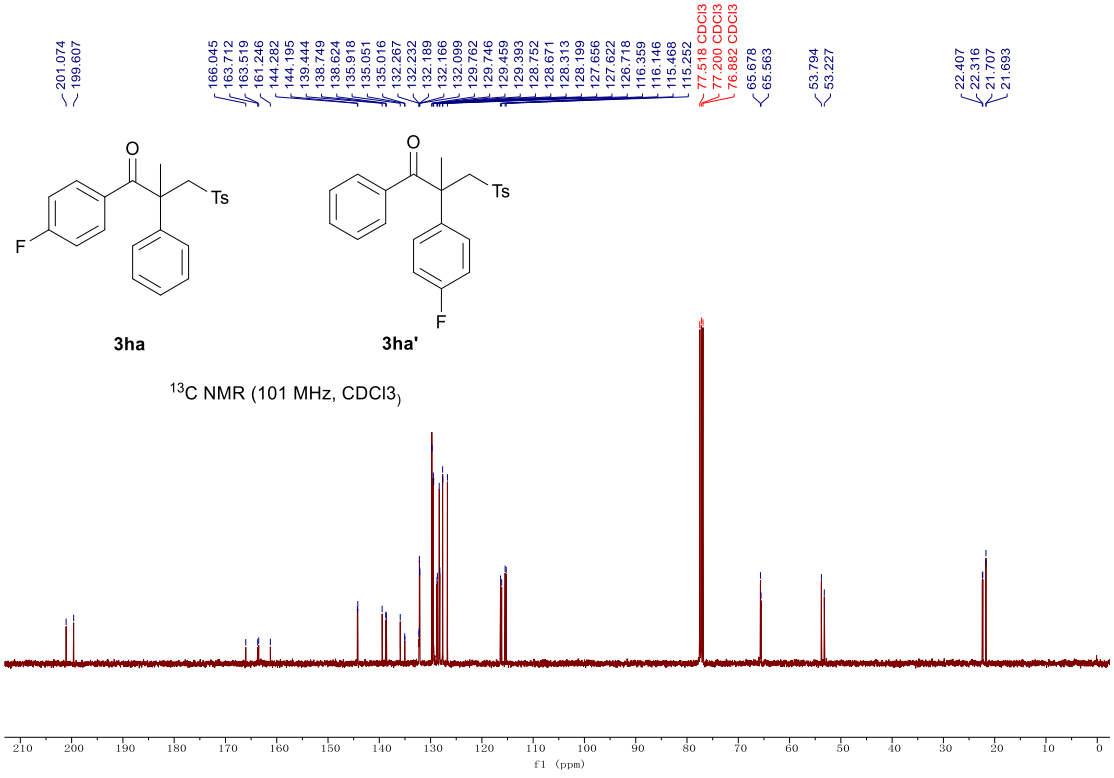
^{13}C NMR (101 MHz, CDCl3)



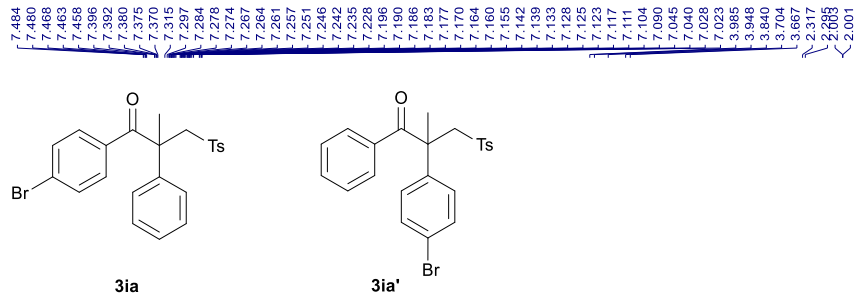


^{1}H NMR (400 MHz, CDCl3)

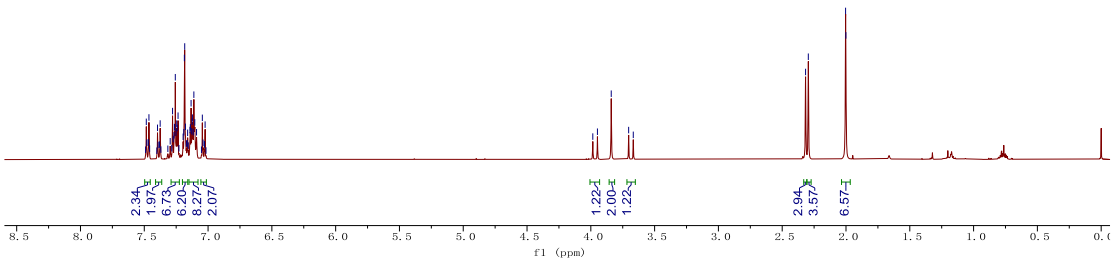


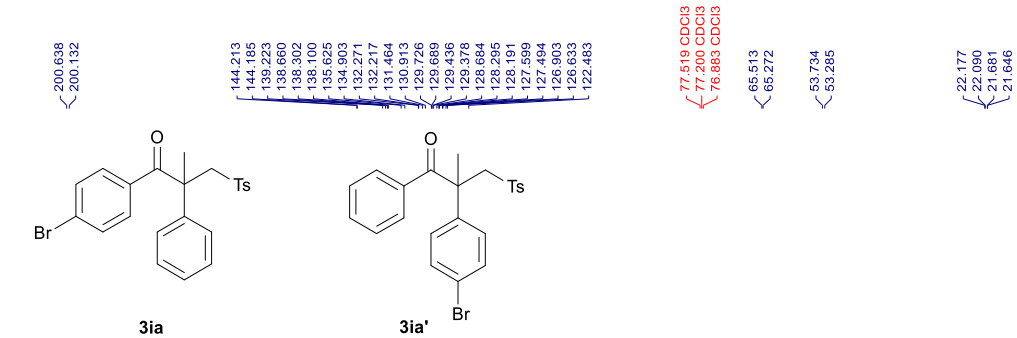


^{13}C NMR (101 MHz, CDCl3)

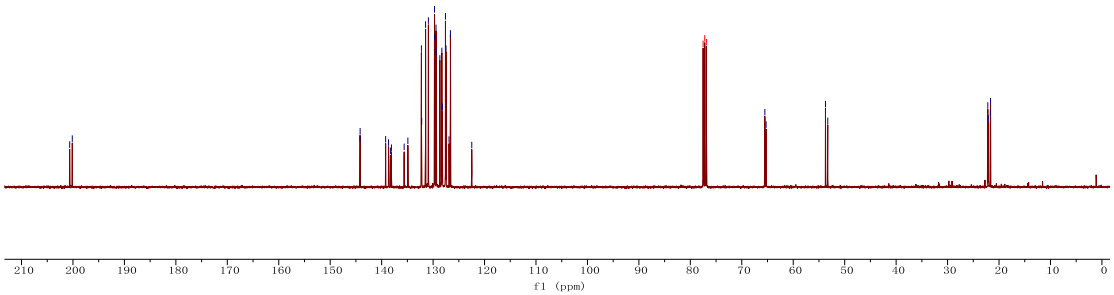


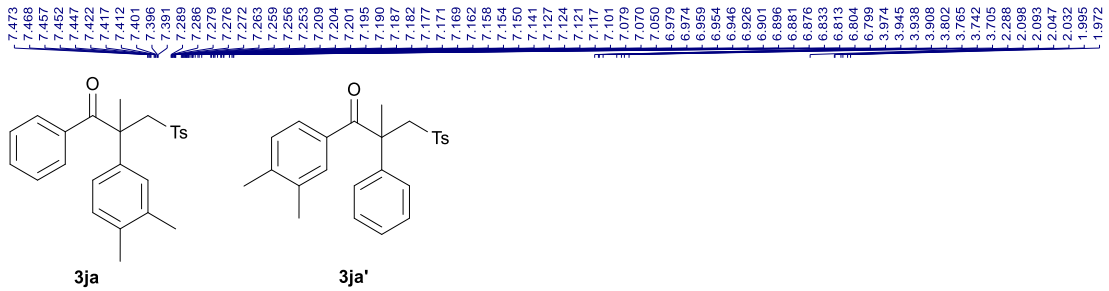
^{1}H NMR (400 MHz, CDCl3)





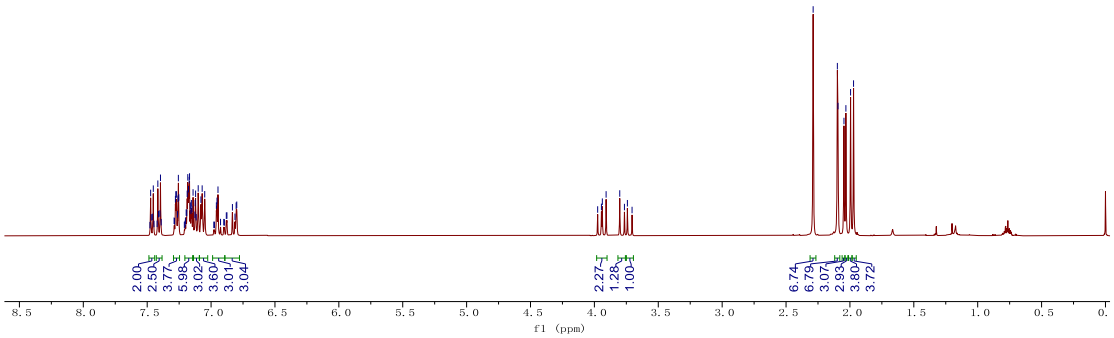
^{13}C NMR (101 MHz, CDCl3)

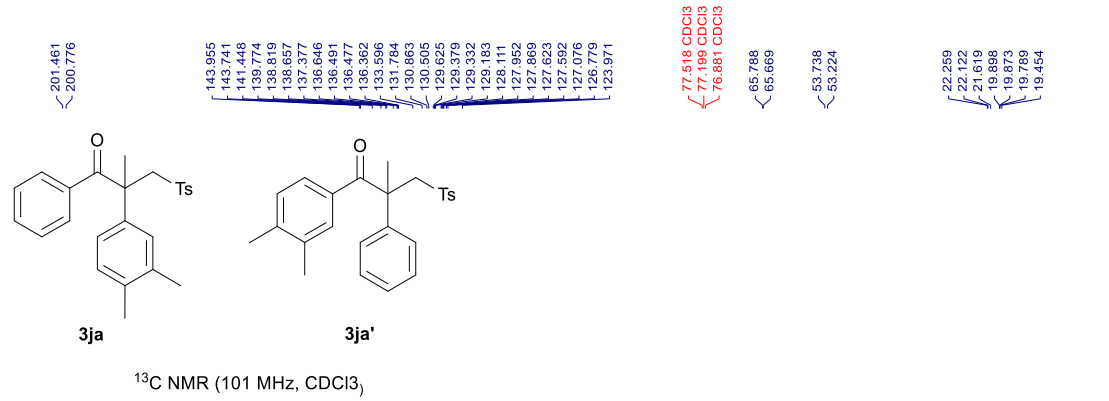




3ja **3ja'**

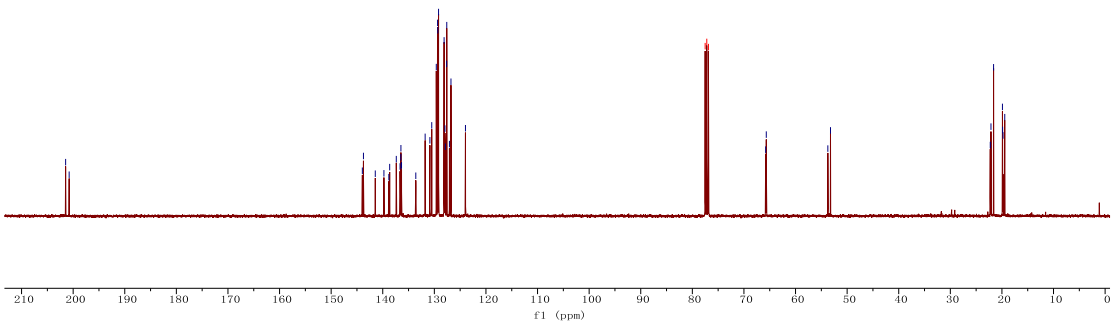
^{1}H NMR (400 MHz, CDCl3)

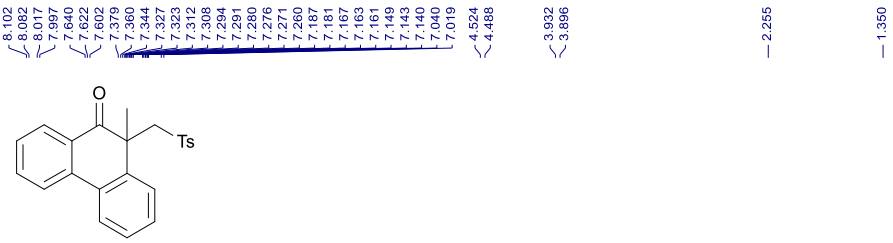




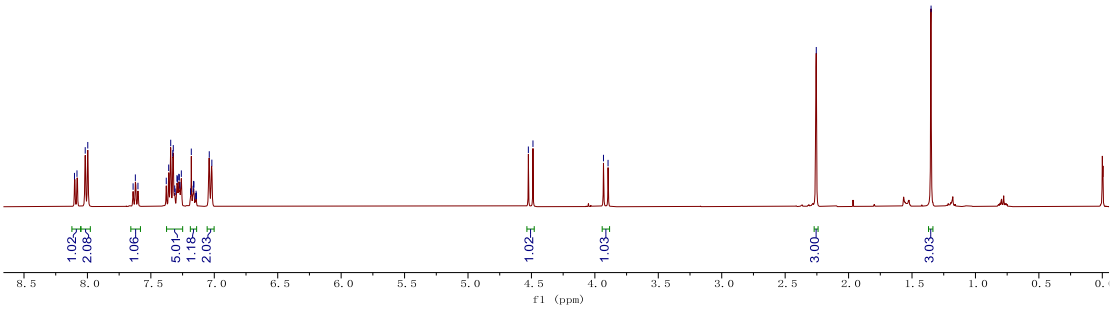
3ja **3ja'**

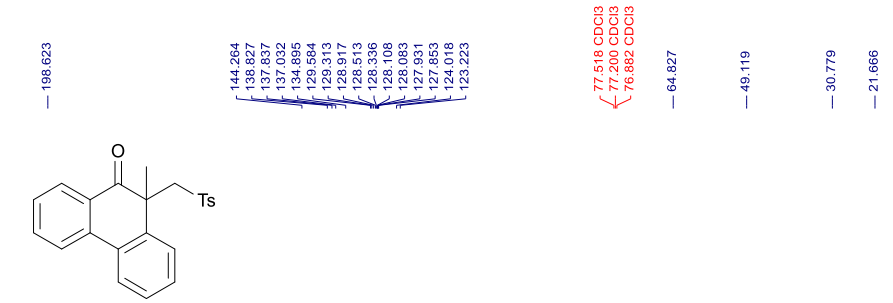
^{13}C NMR (101 MHz, CDCl3)



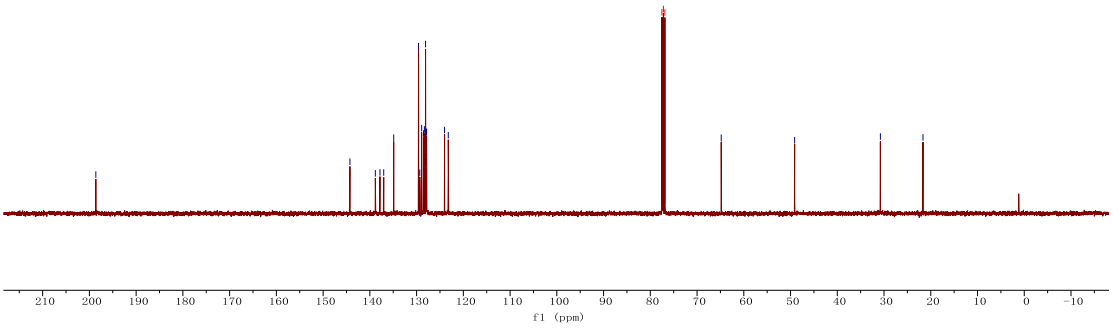


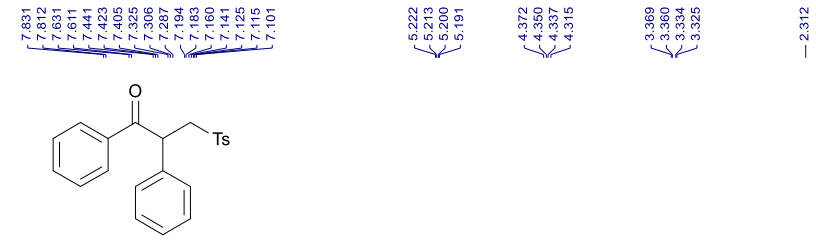
3ka ^{1}H NMR (400 MHz, $CDCl_3$)



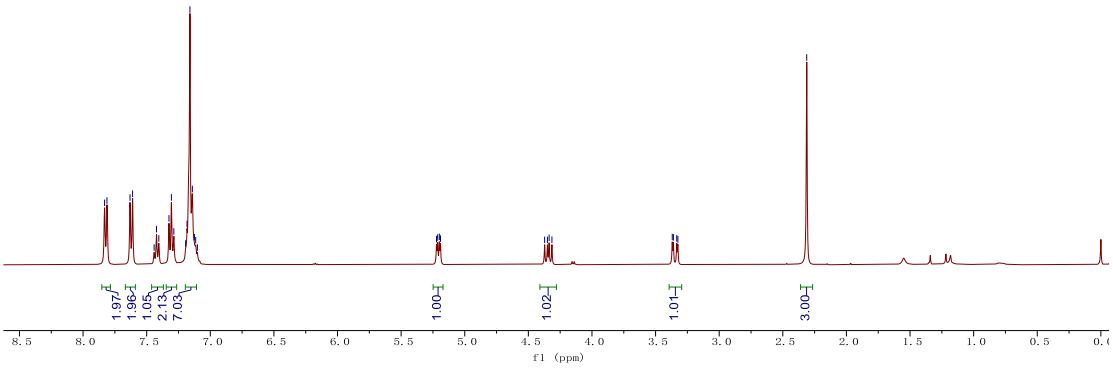


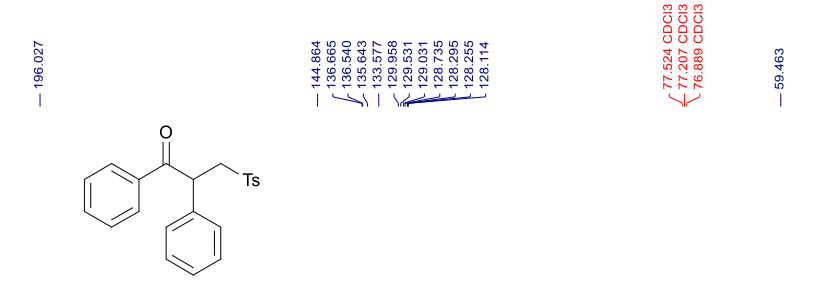
3ka ^{13}C NMR (101 MHz, $CDCl_3$)



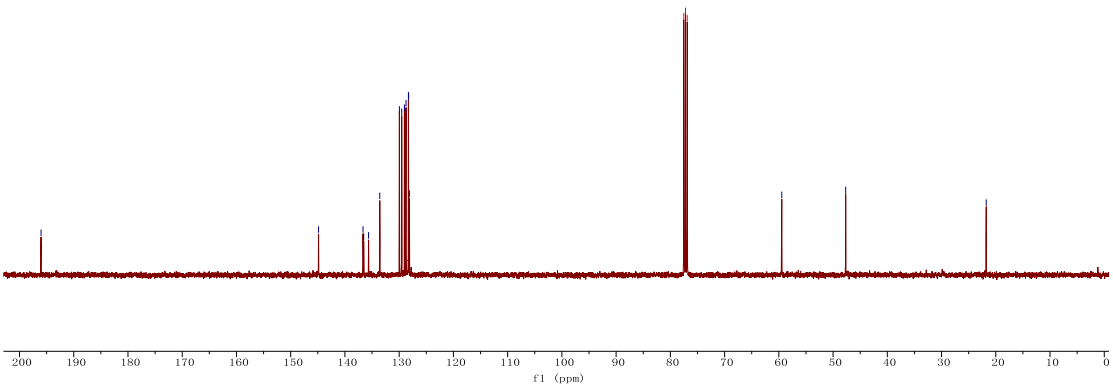


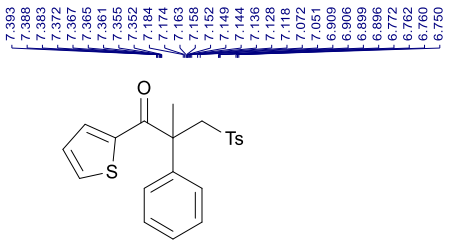
3la ^{1}H NMR (400 MHz, $CDCl_3$)



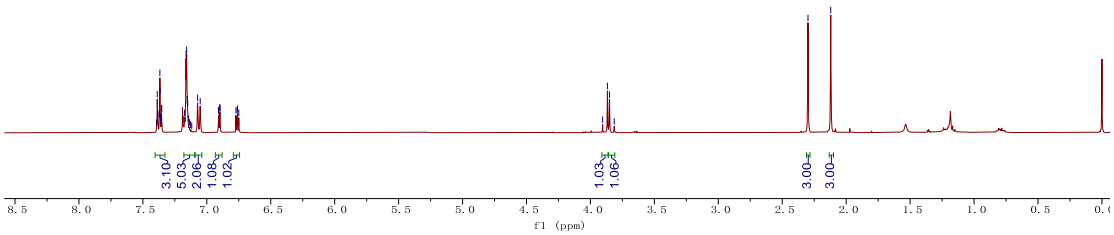


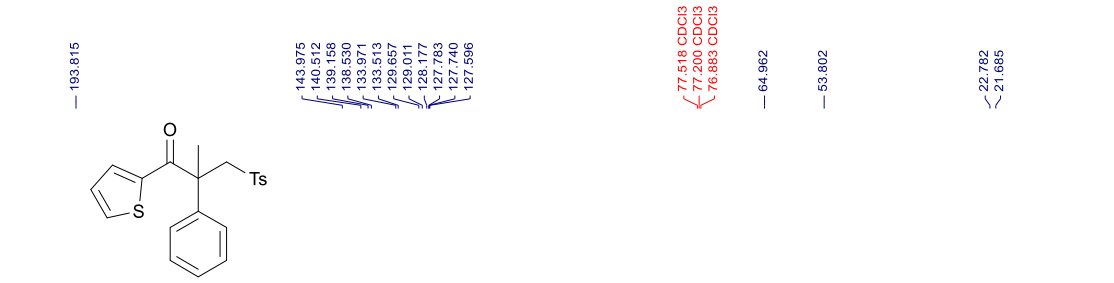
3la ^{13}C NMR (101 MHz, $CDCl_3$)



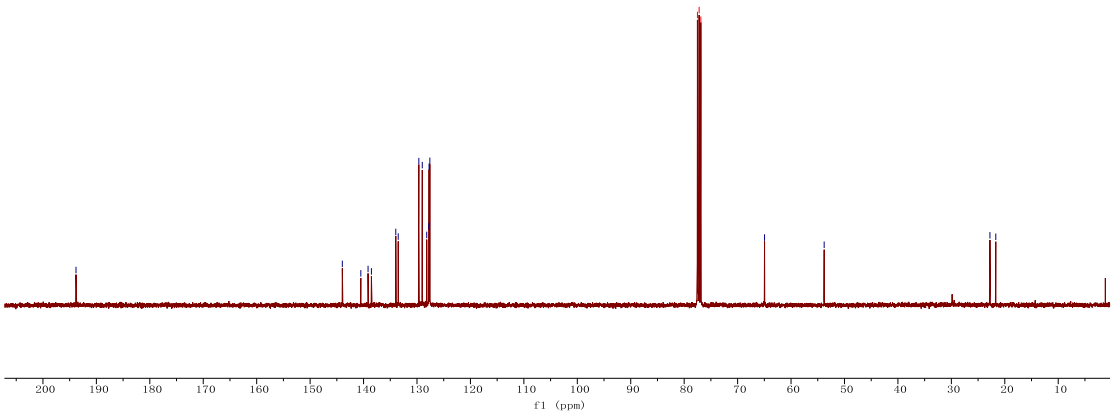


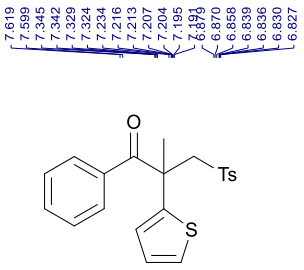
3ma ^{1}H NMR (400 MHz, $CDCl_3$)



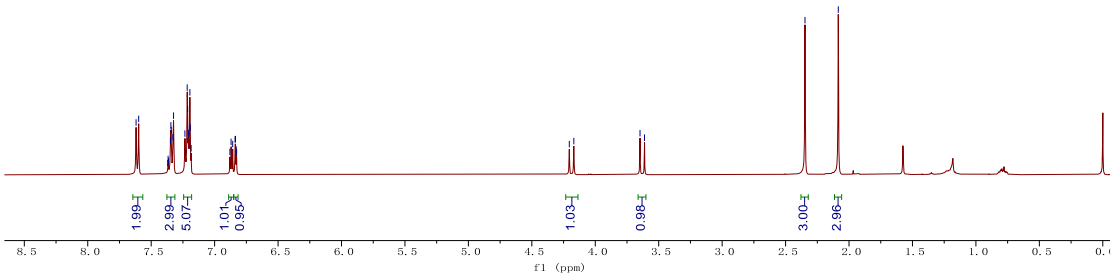


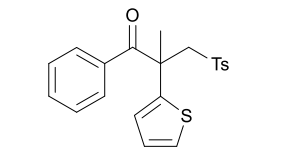
3ma ^{13}C NMR (101 MHz, $CDCl_3$)



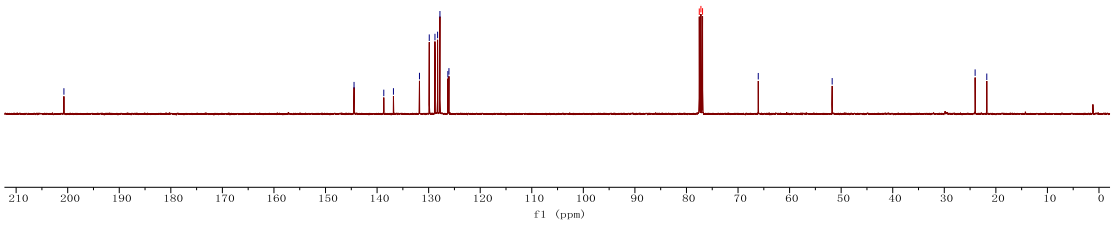


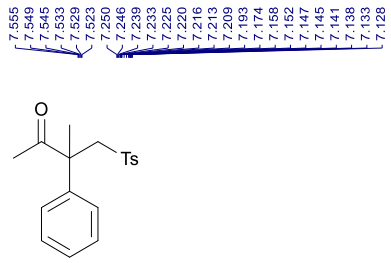
3ma' ^{1}H NMR (400 MHz, $CDCl_3$)



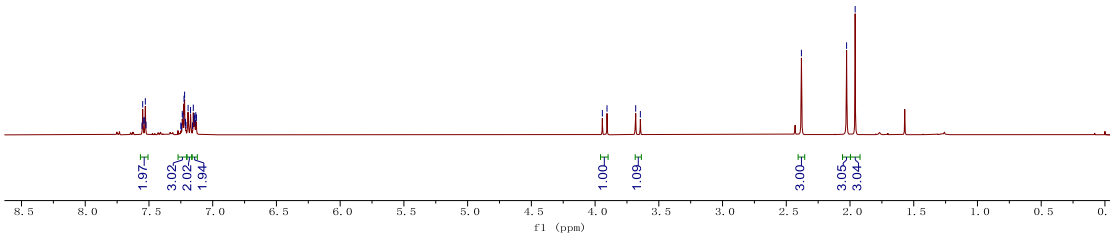


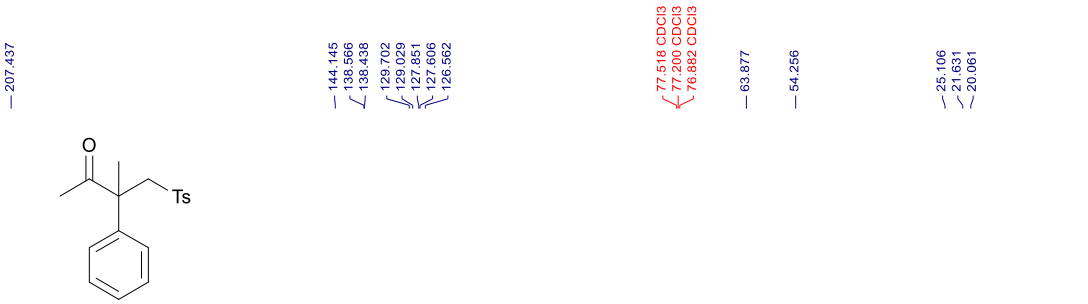
3ma' ^{13}C NMR (101 MHz, $CDCl_3$)



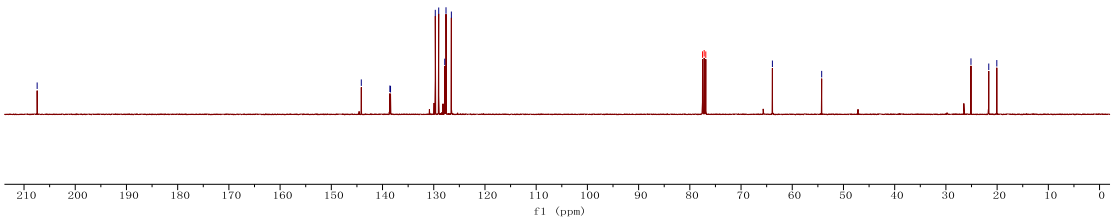


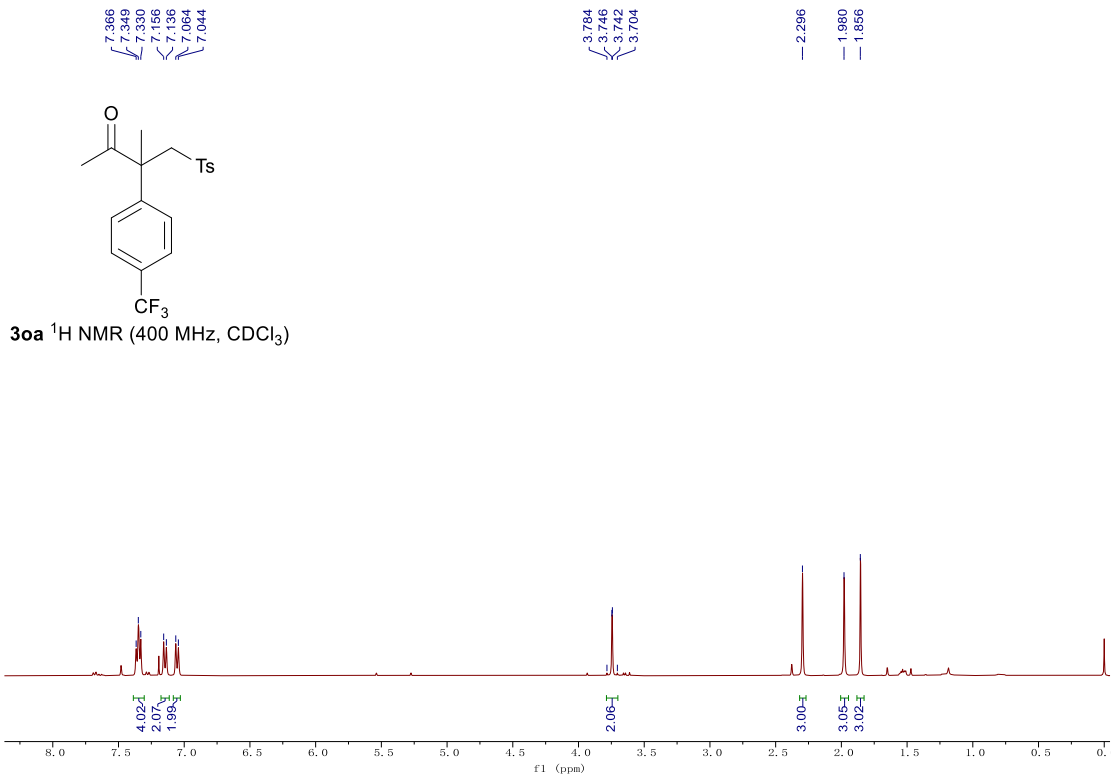
3na ^{1}H NMR (400 MHz, $CDCl_3$)



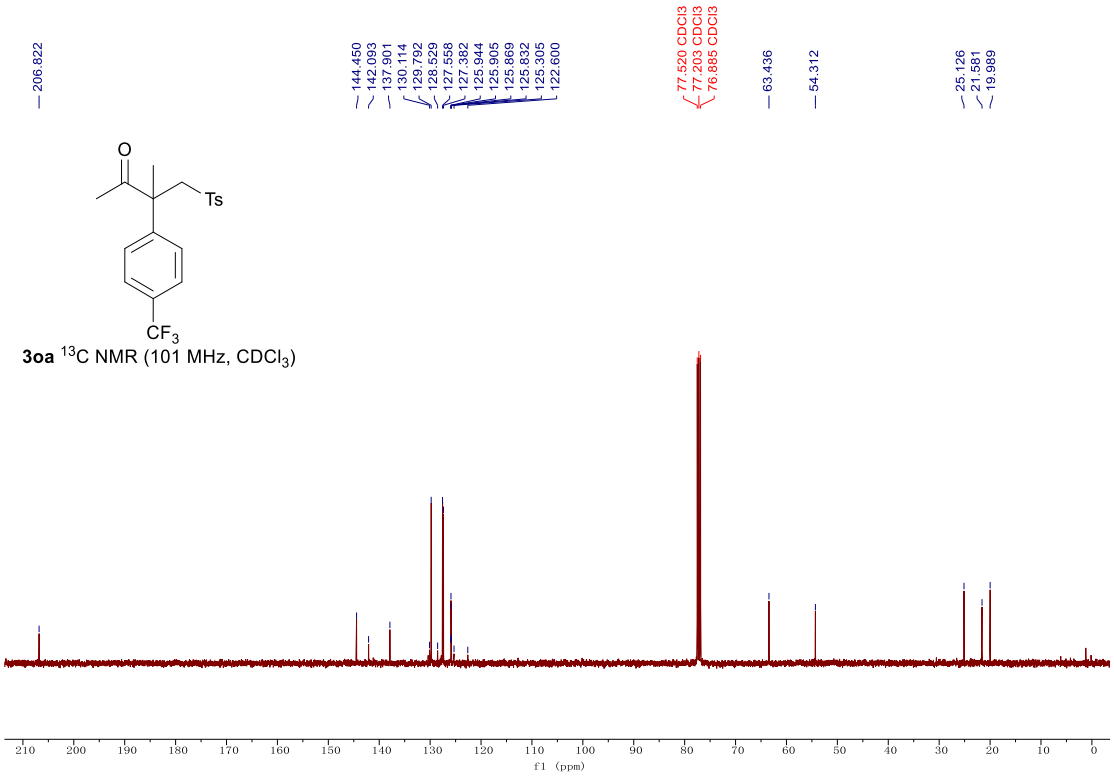


3na ^{13}C NMR (101 MHz, $CDCl_3$)

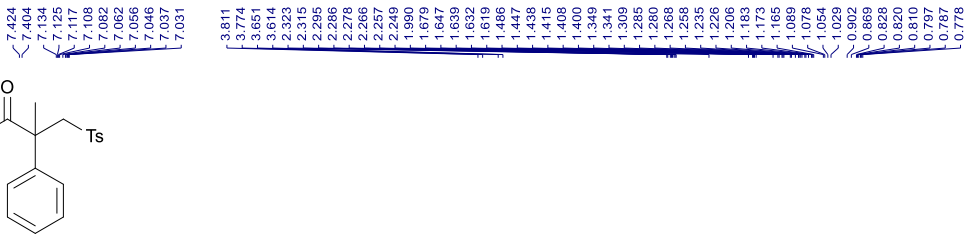




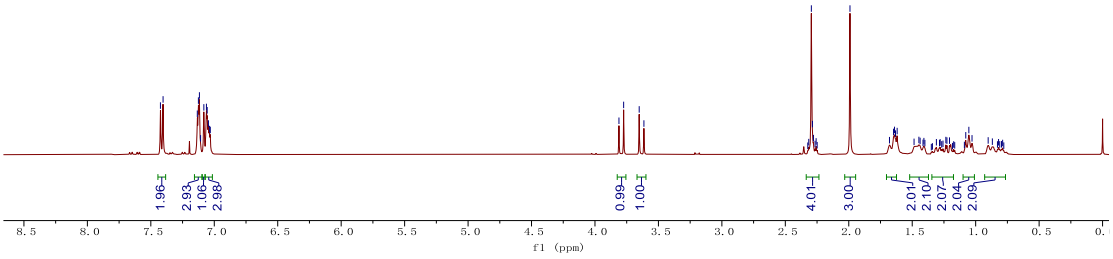
3oa ^{1}H NMR (400 MHz, $CDCl_3$)

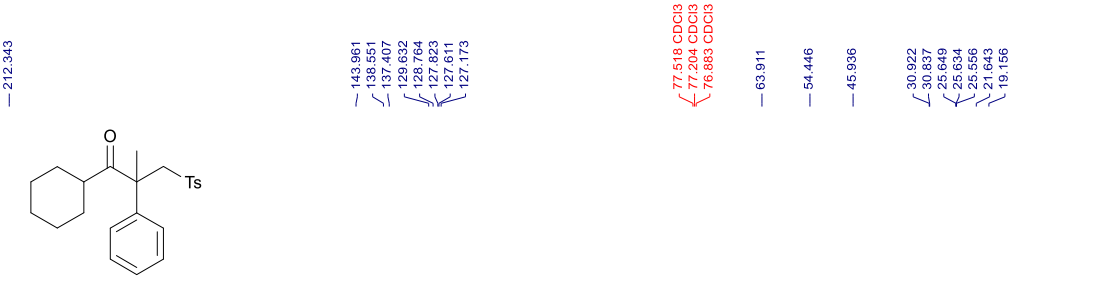


3oa ^{13}C NMR (101 MHz, $CDCl_3$)

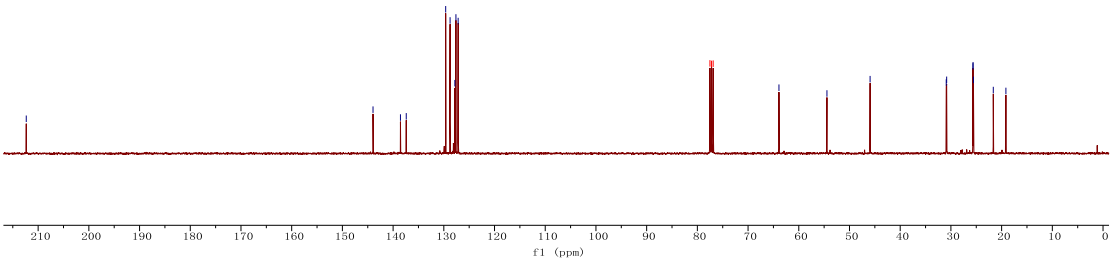


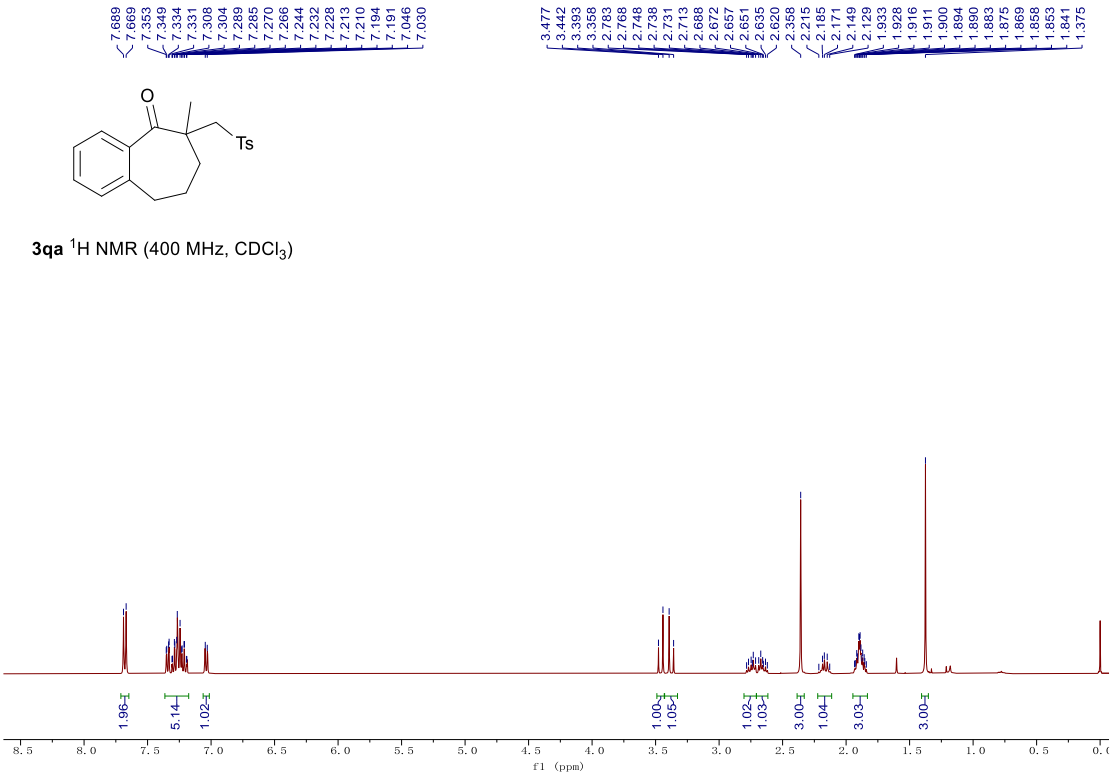
3pa ^{1}H NMR (400 MHz, $CDCl_3$)



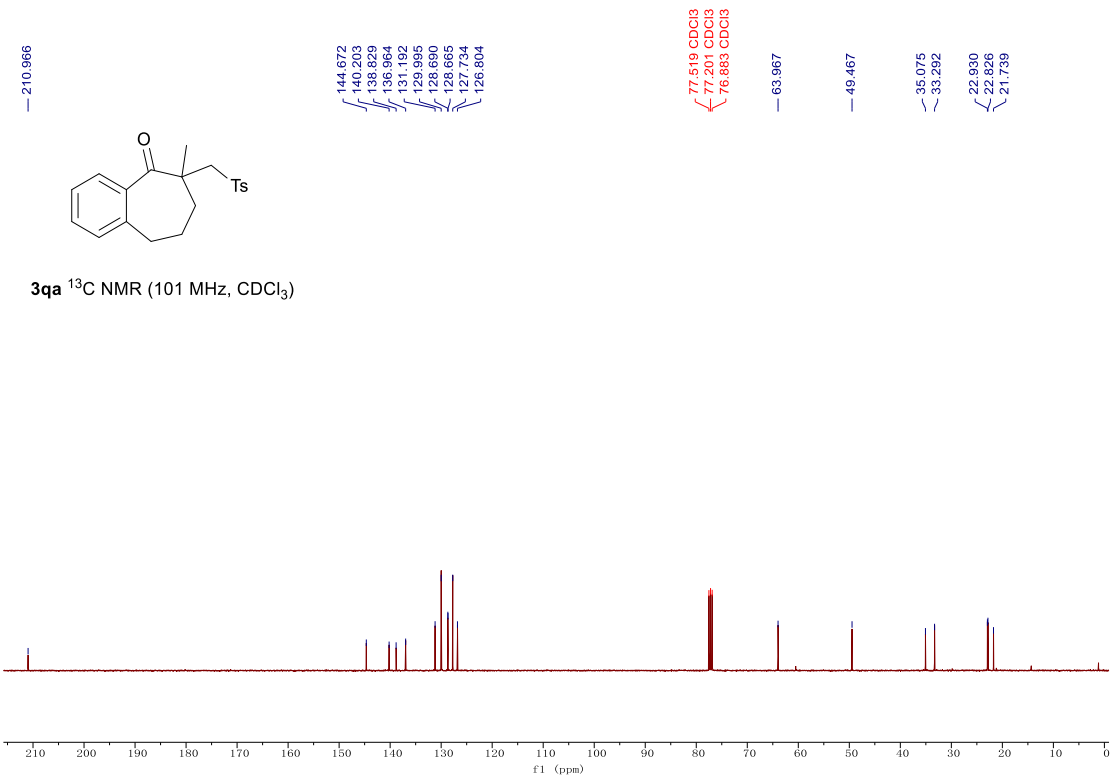


3pa ^{13}C NMR (101 MHz, $CDCl_3$)

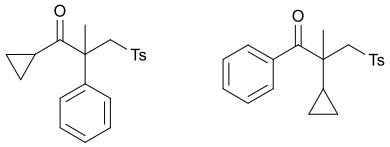




3qa ^{1}H NMR (400 MHz, $CDCl_3$)

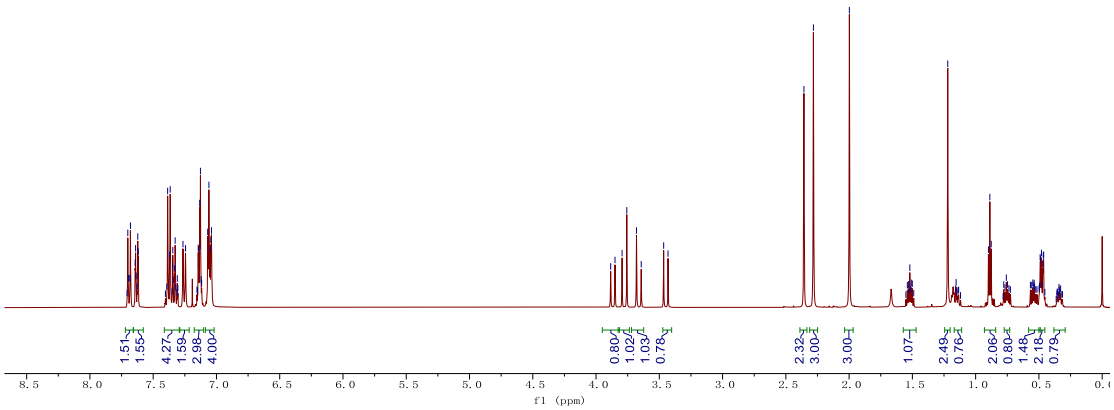


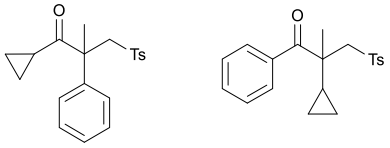
3qa ^{13}C NMR (101 MHz, $CDCl_3$)



3ra **3ra'**

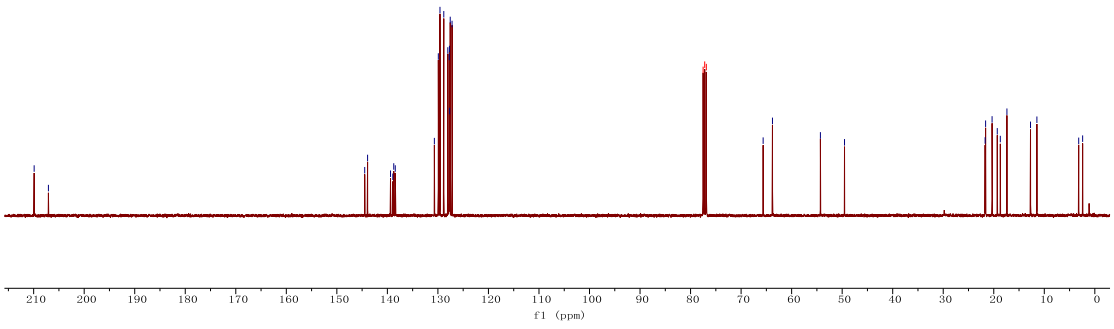
^{1}H NMR (400 MHz, CDCl3)

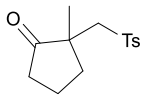




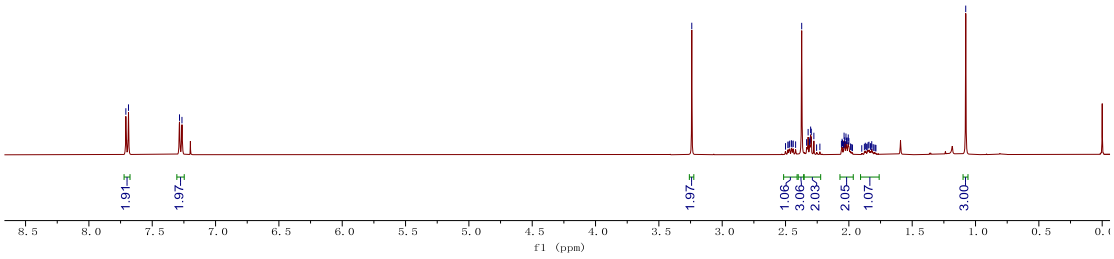
3ra **3ra'**

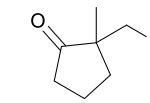
^{13}C NMR (101 MHz, CDCl3)



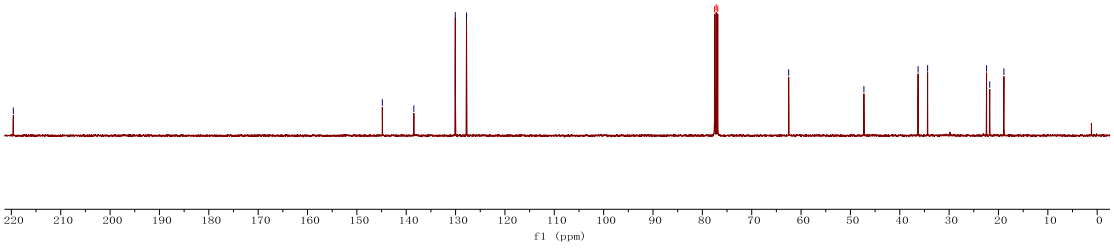


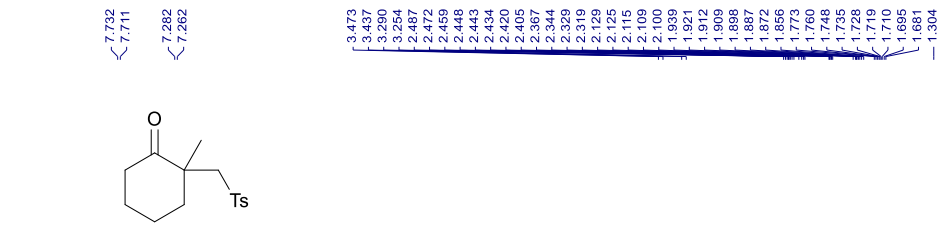
3sa ^{1}H NMR (400 MHz, $CDCl_3$)



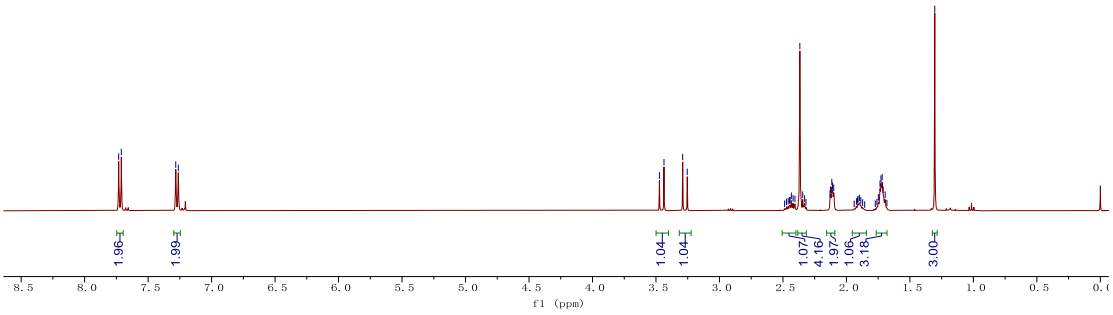


3sa ^{13}C NMR (101 MHz, $CDCl_3$)

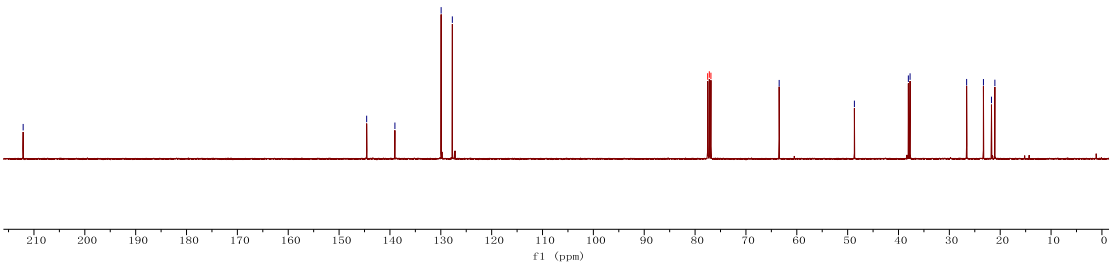


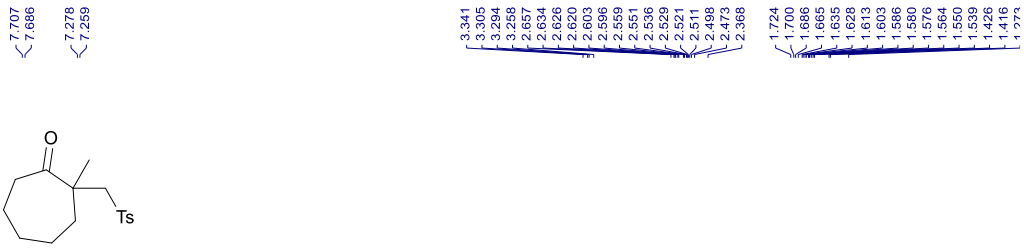


3ta ^{1}H NMR (400 MHz, $CDCl_3$)

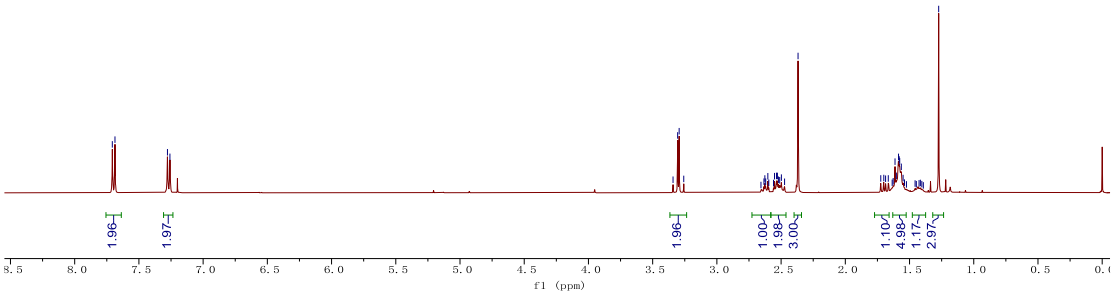


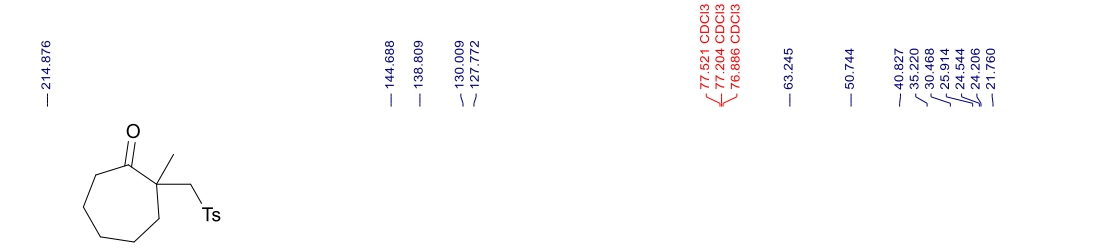
3ta ^{13}C NMR (101 MHz, $CDCl_3$)



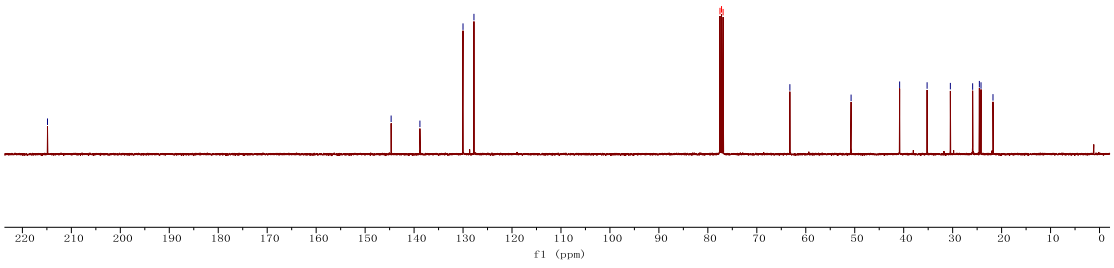


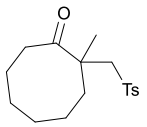
3ua ^{1}H NMR (400 MHz, $CDCl_3$)



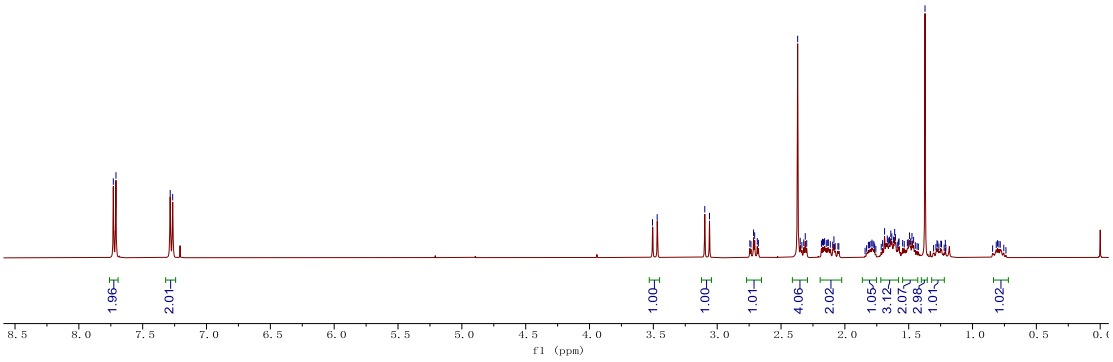


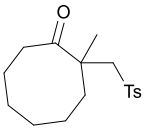
3ua ^{13}C NMR (101 MHz, $CDCl_3$)



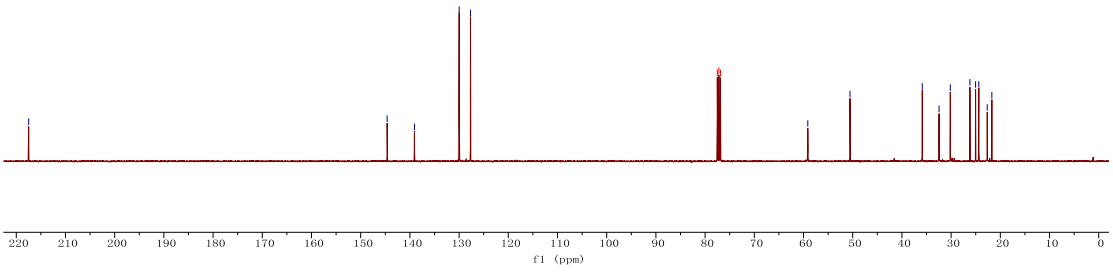


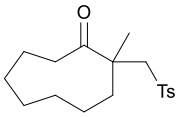
3va ^{1}H NMR (400 MHz, $CDCl_3$)



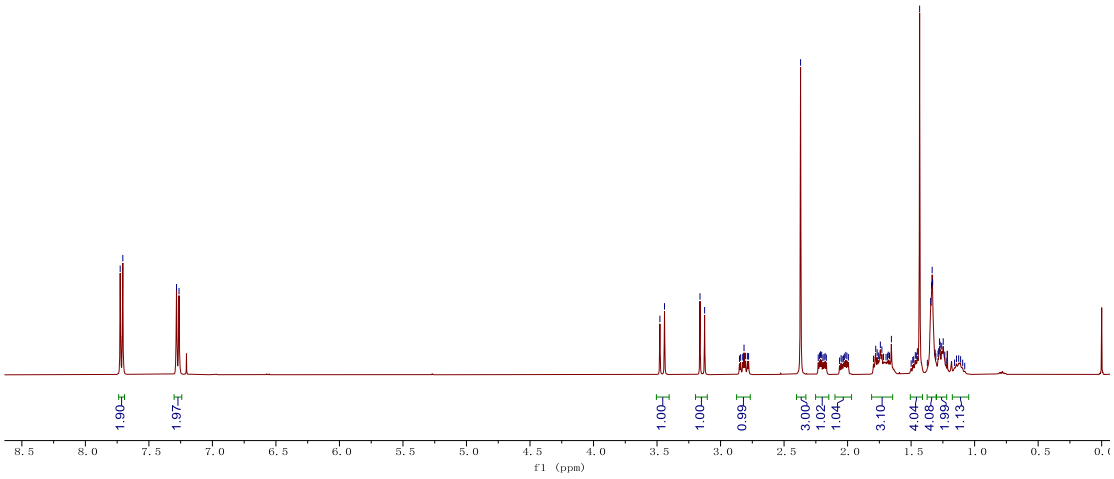


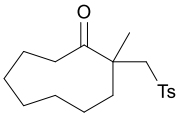
3va ^{13}C NMR (101 MHz, $CDCl_3$)



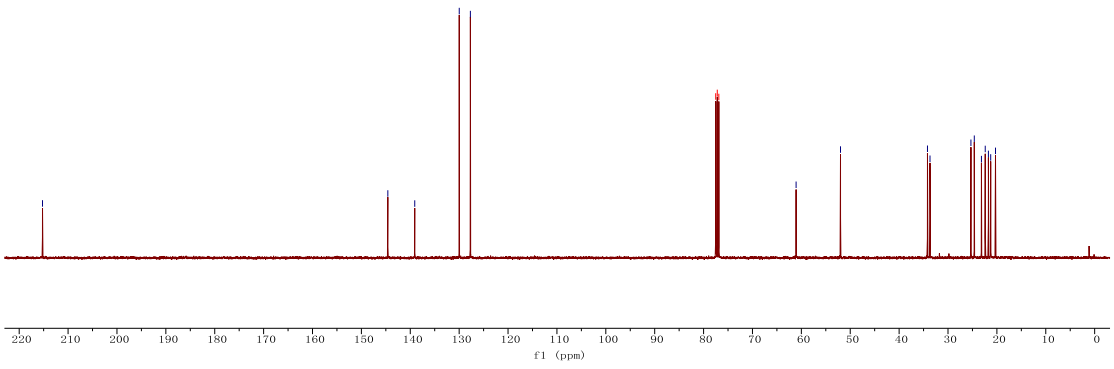


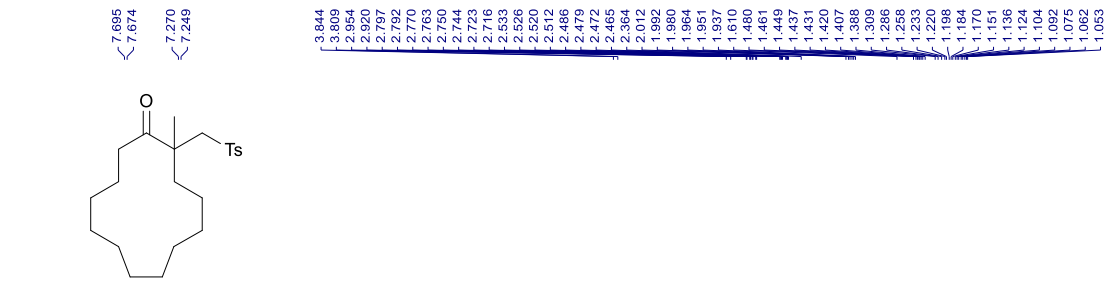
3wa ^{1}H NMR (400 MHz, $CDCl_3$)



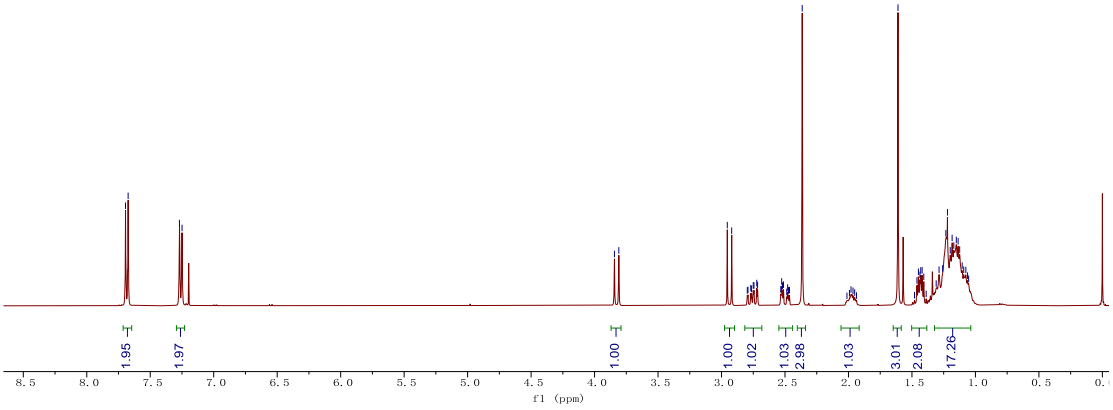


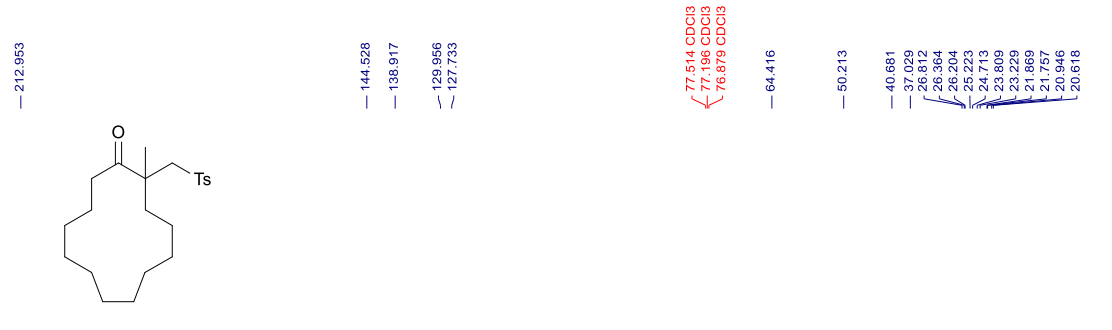
3wa ^{13}C NMR (101 MHz, $CDCl_3$)



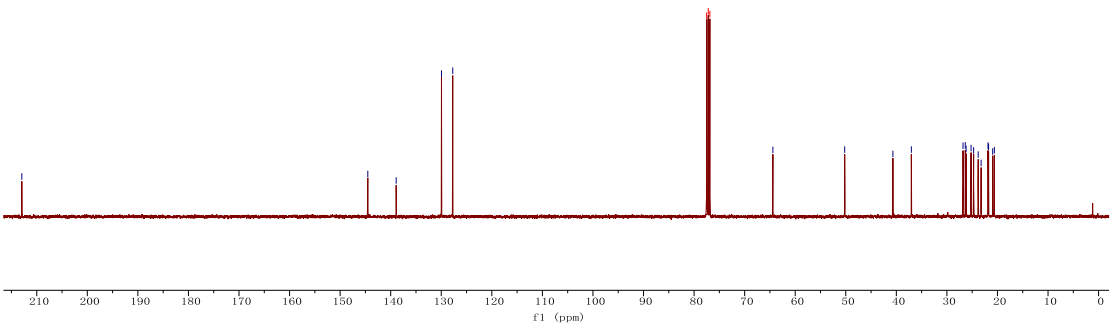


3xa ^{1}H NMR (400 MHz, $CDCl_3$)

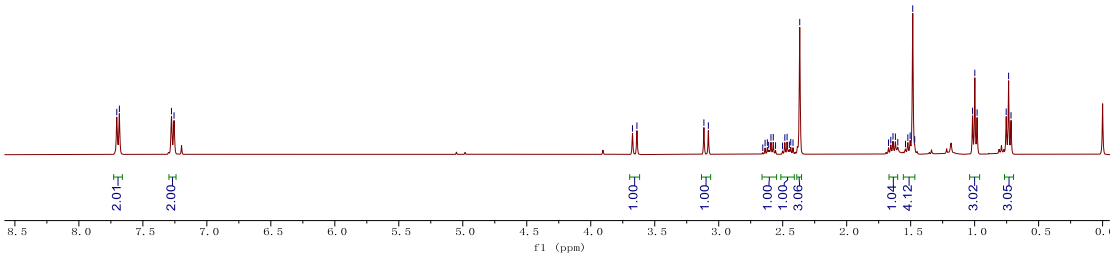




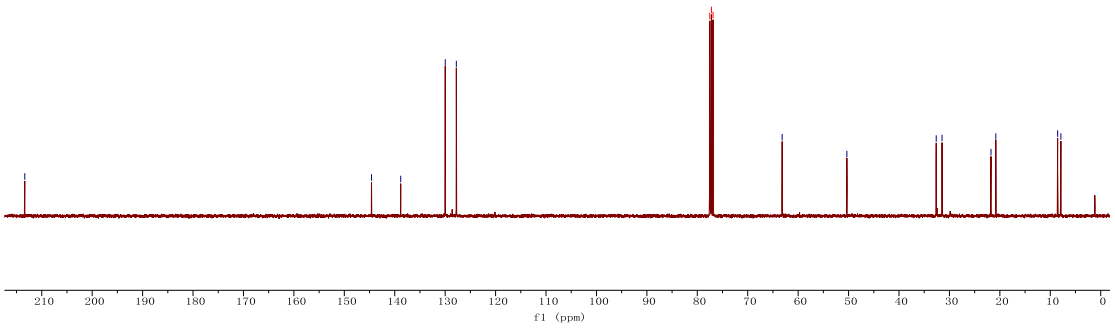
3xa ^{13}C NMR (101 MHz, $CDCl_3$)

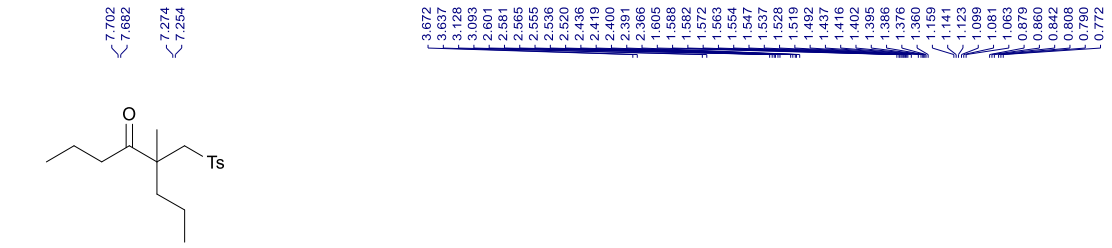


3ya ^{1}H NMR (400 MHz, $CDCl_3$)

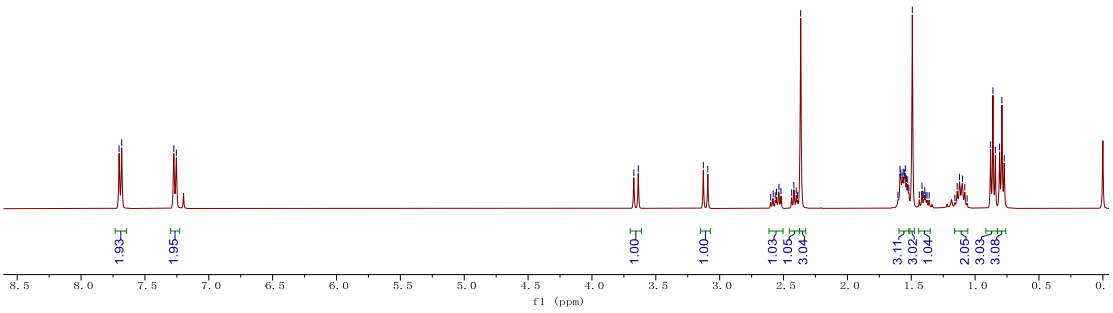


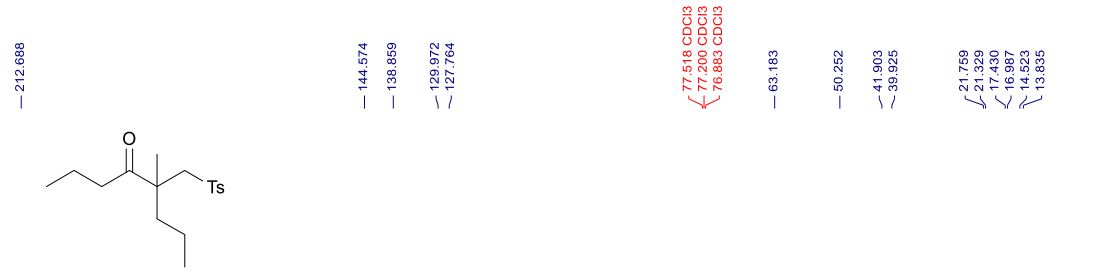
3ya ^{13}C NMR (101 MHz, $CDCl_3$)



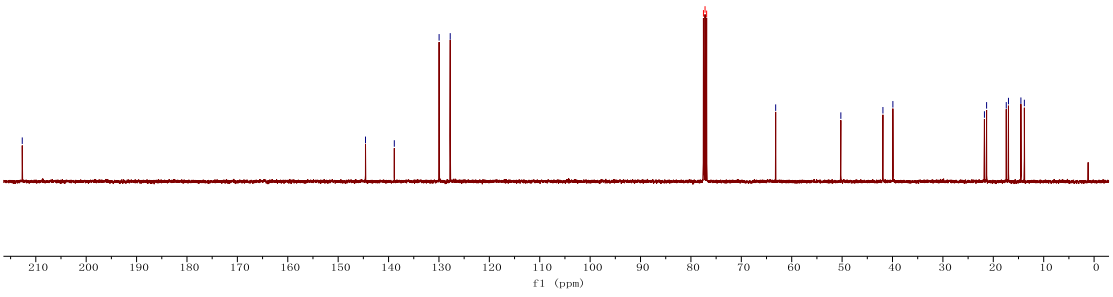


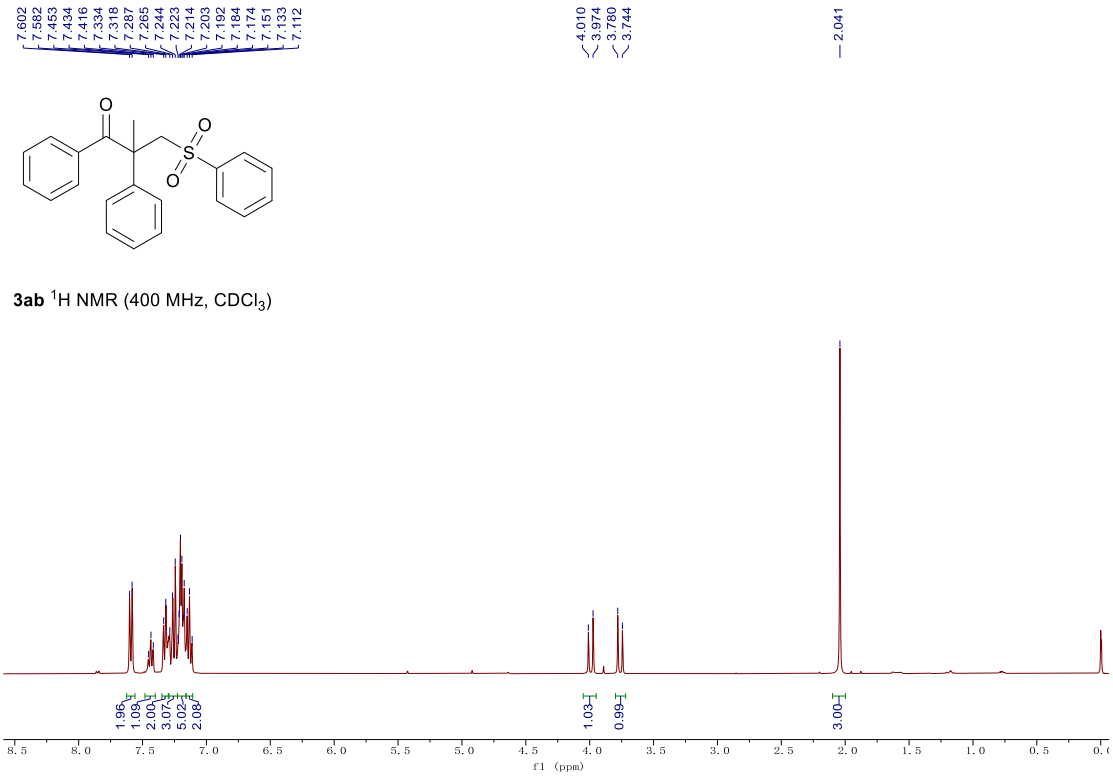
3za ^{1}H NMR (400 MHz, $CDCl_3$)



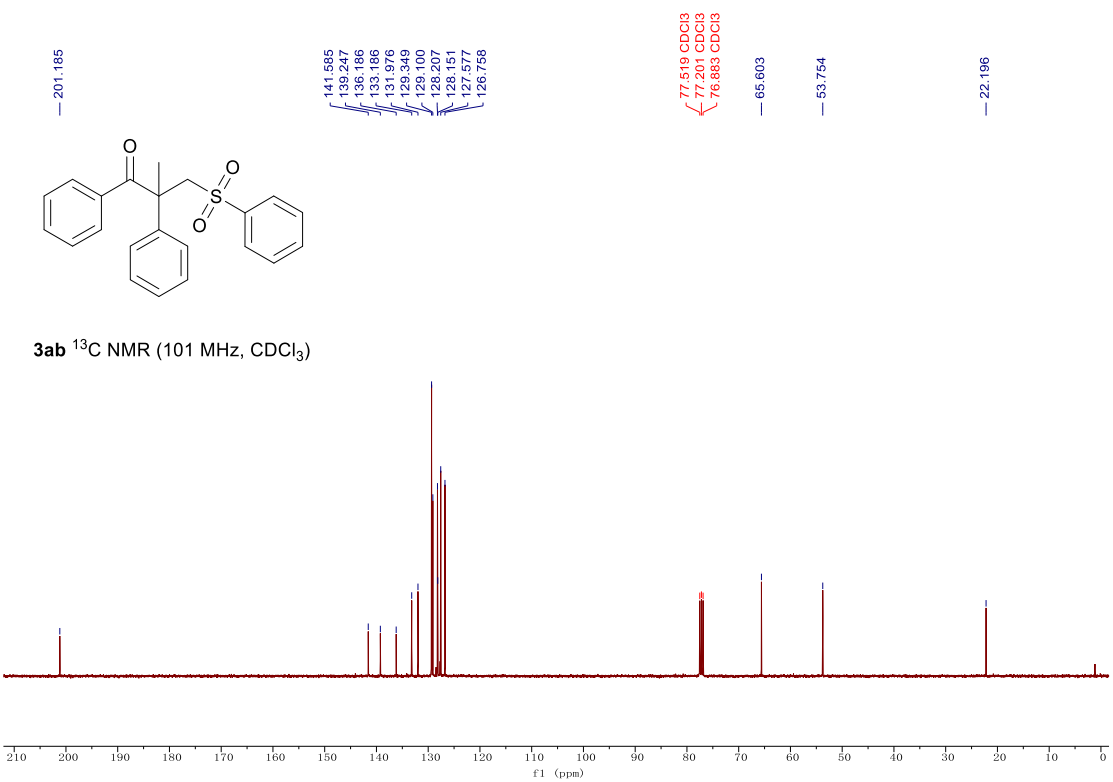


3za ^{13}C NMR (101 MHz, $CDCl_3$)

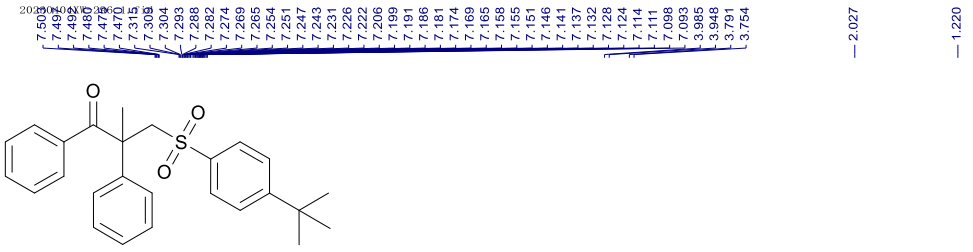




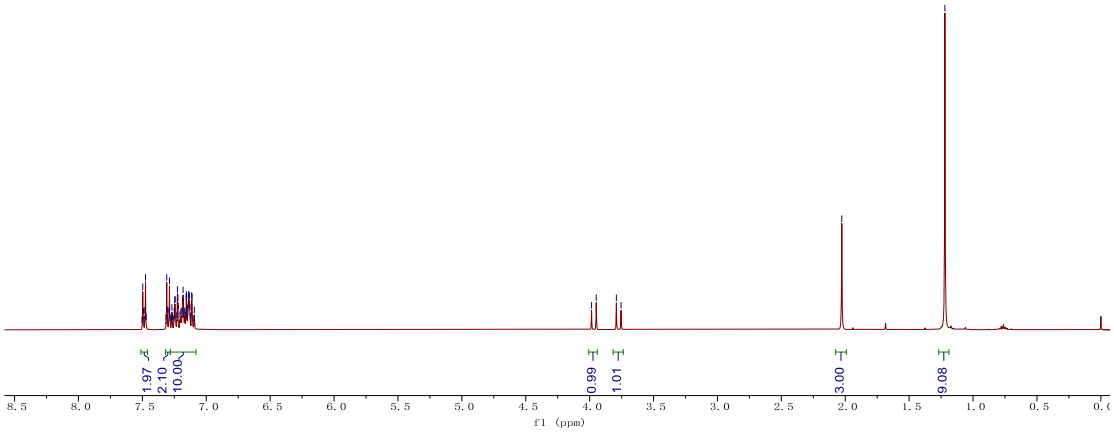
3ab ^{1}H NMR (400 MHz, $CDCl_3$)

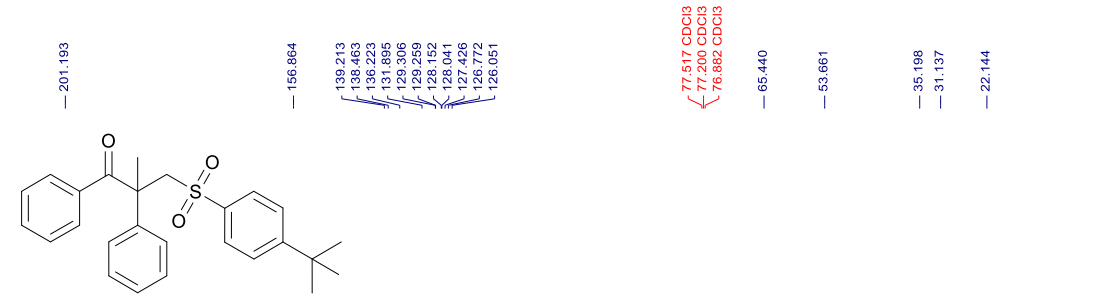


3ab ^{13}C NMR (101 MHz, $CDCl_3$)

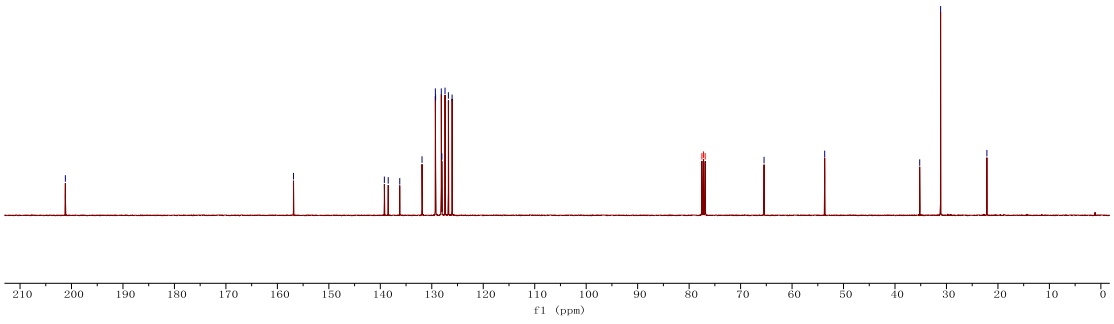


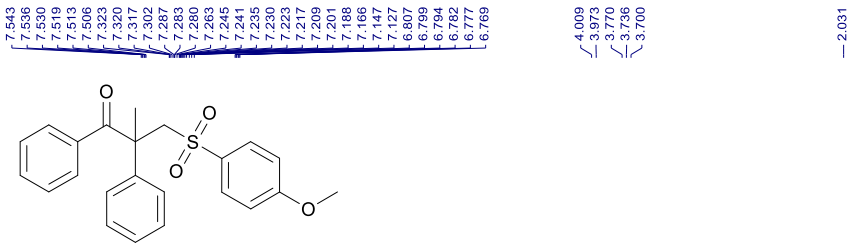
3ac ^{1}H NMR (400 MHz, $CDCl_3$)



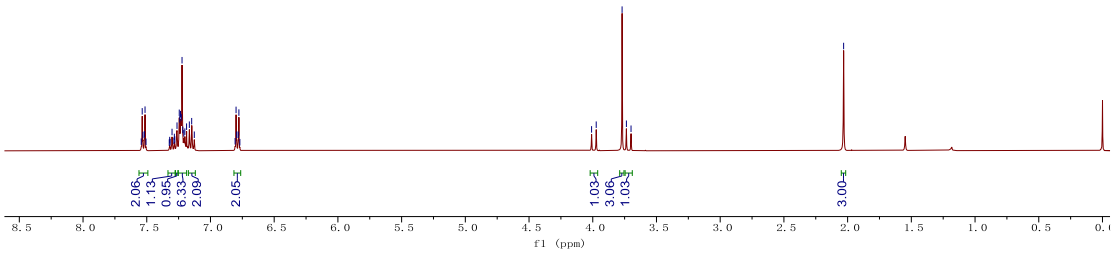


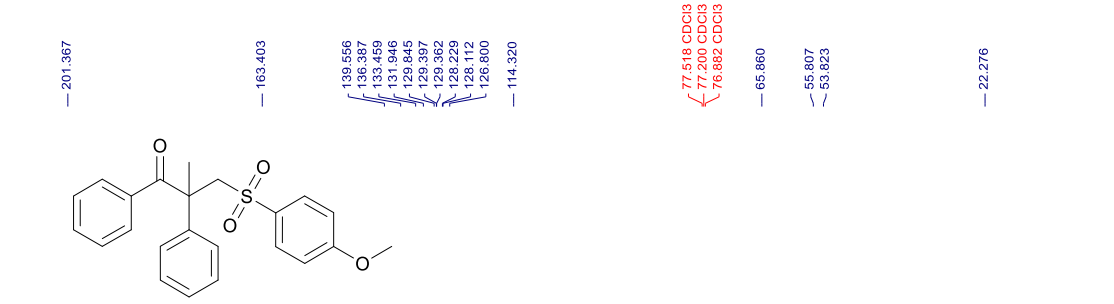
3ac ^{13}C NMR (101 MHz, $CDCl_3$)



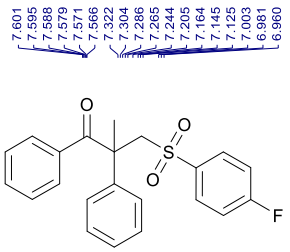


3ad ^{1}H NMR (400 MHz, $CDCl_3$)

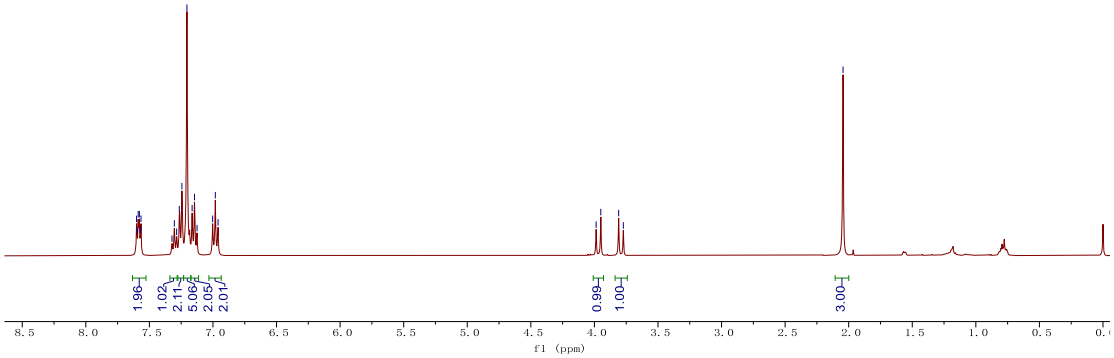


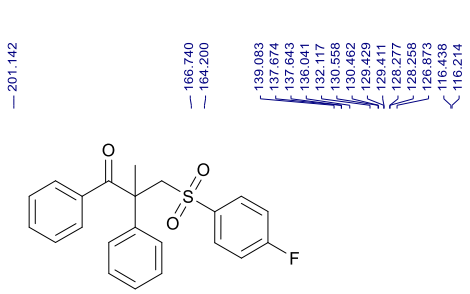


3ad ^{13}C NMR (101 MHz, $CDCl_3$)

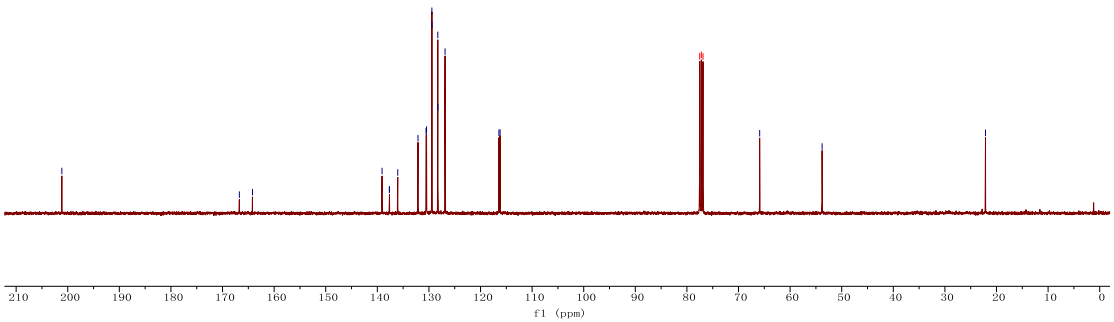


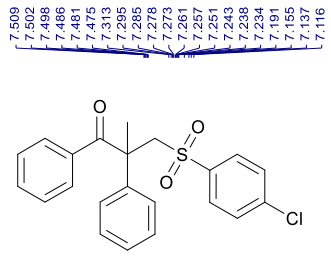
3ae ^{1}H NMR (400 MHz, $CDCl_3$)





3ae ^{13}C NMR (101 MHz, $CDCl_3$)





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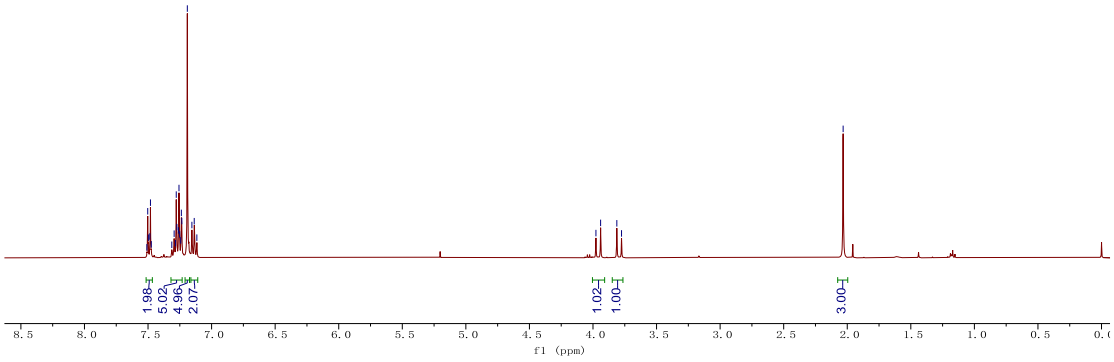

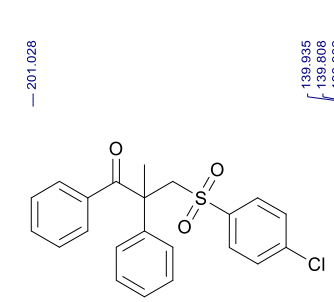

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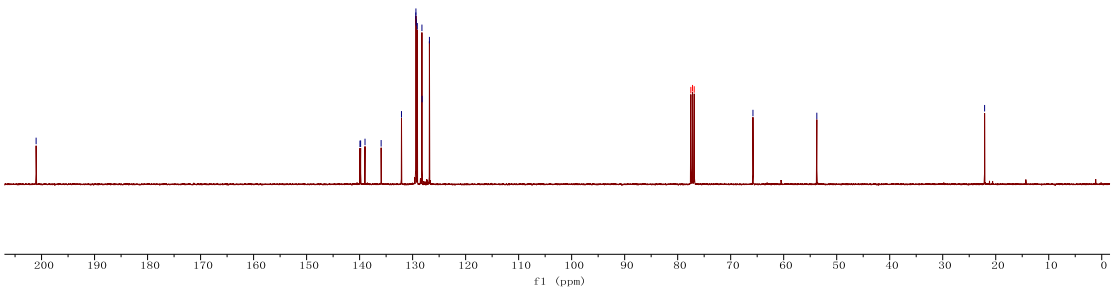
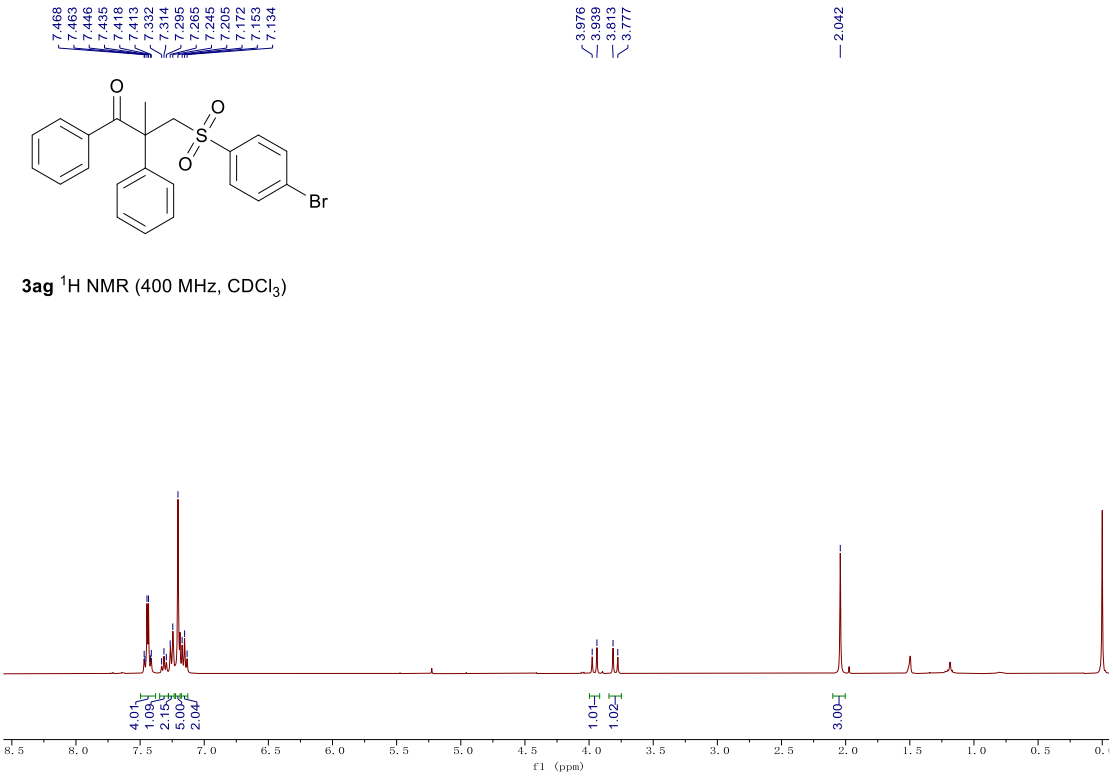
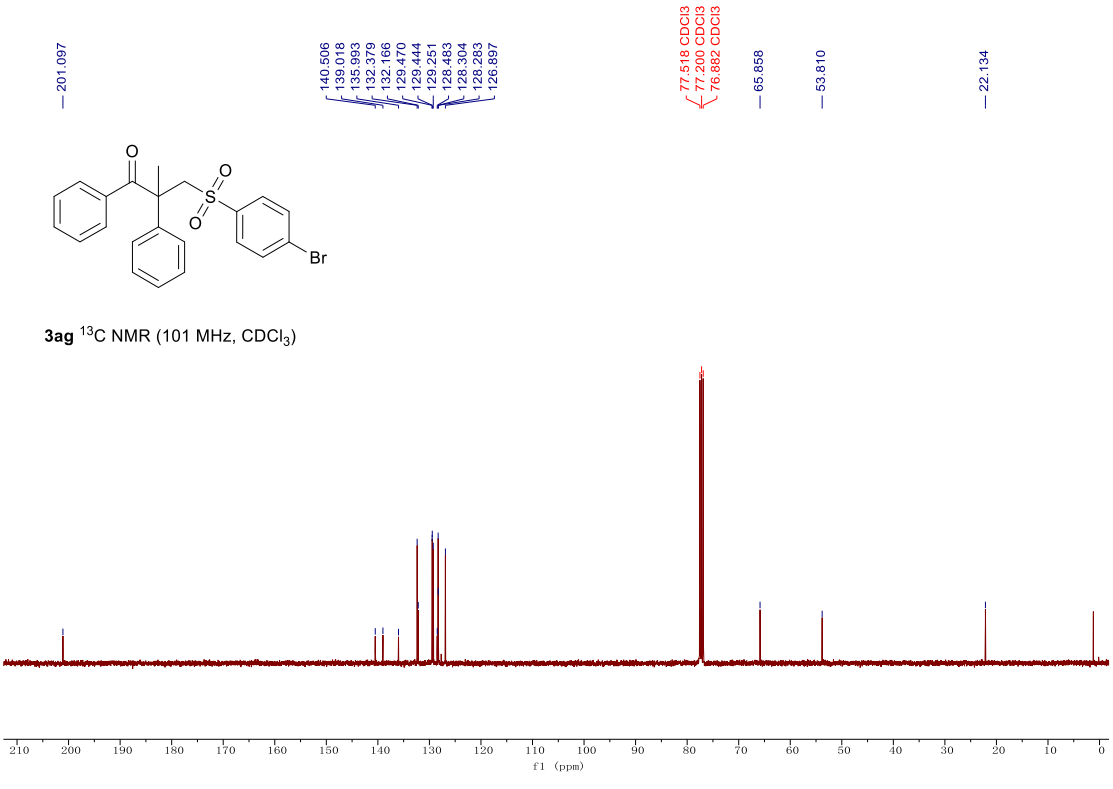
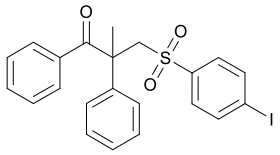




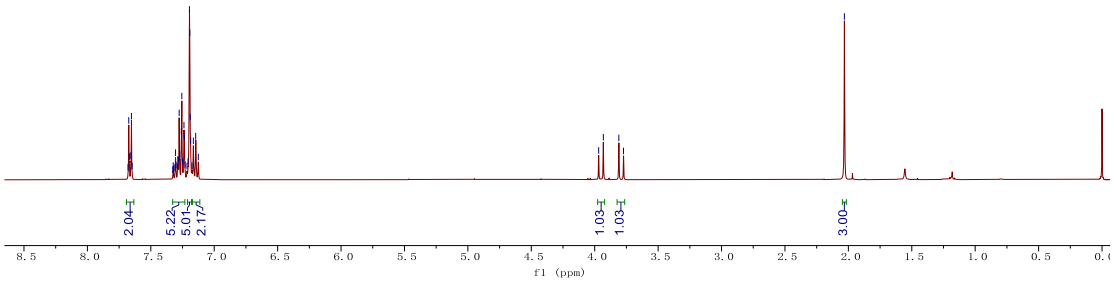
3ag ^{1}H NMR (400 MHz, $CDCl_3$)

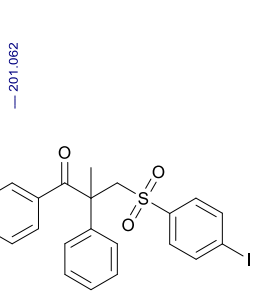


3ag ^{13}C NMR (101 MHz, $CDCl_3$)

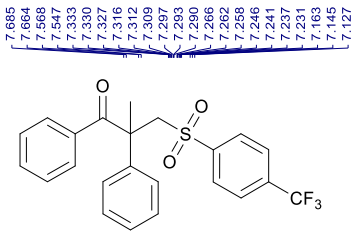


3ah^{1}H NMR (400 MHz, $CDCl_3$)

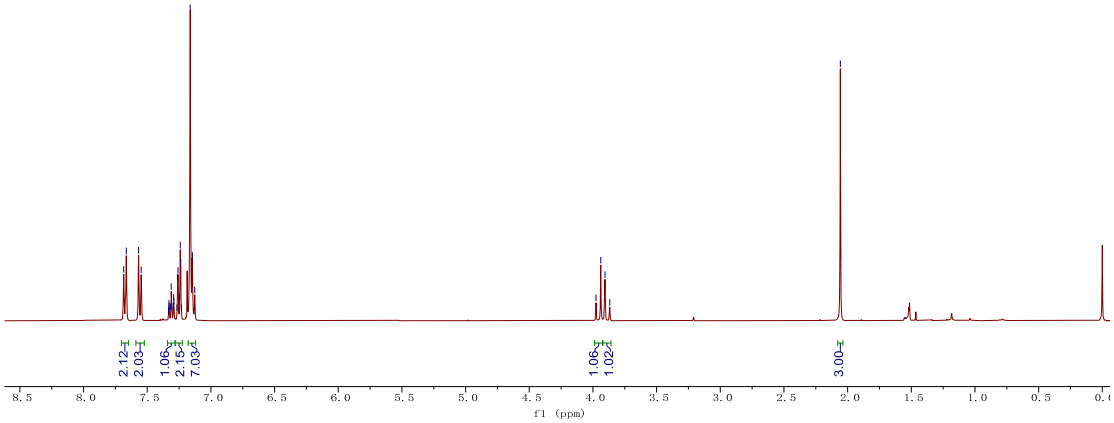


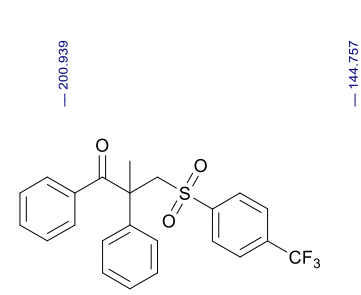


3ah ^{13}C NMR (101 MHz, $CDCl_3$)

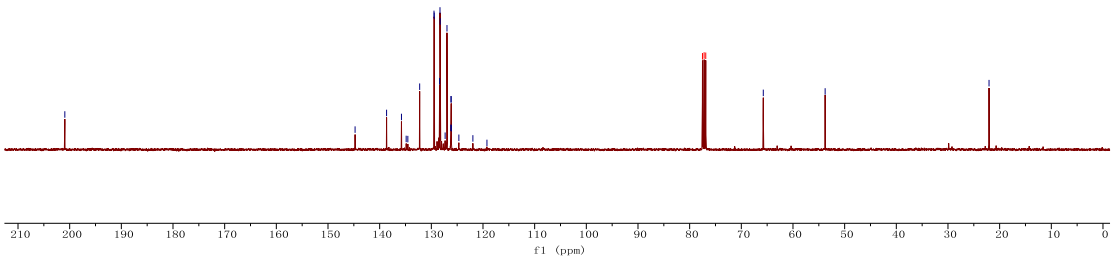


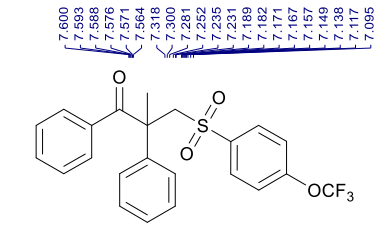
3ai ^{1}H NMR (400 MHz, $CDCl_3$)



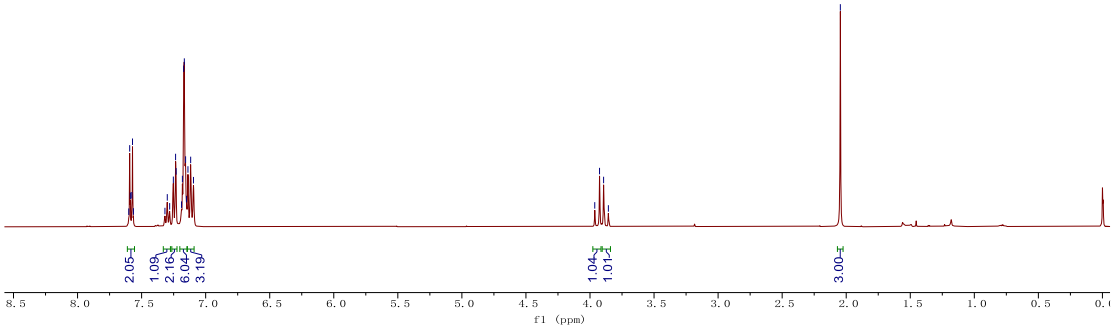


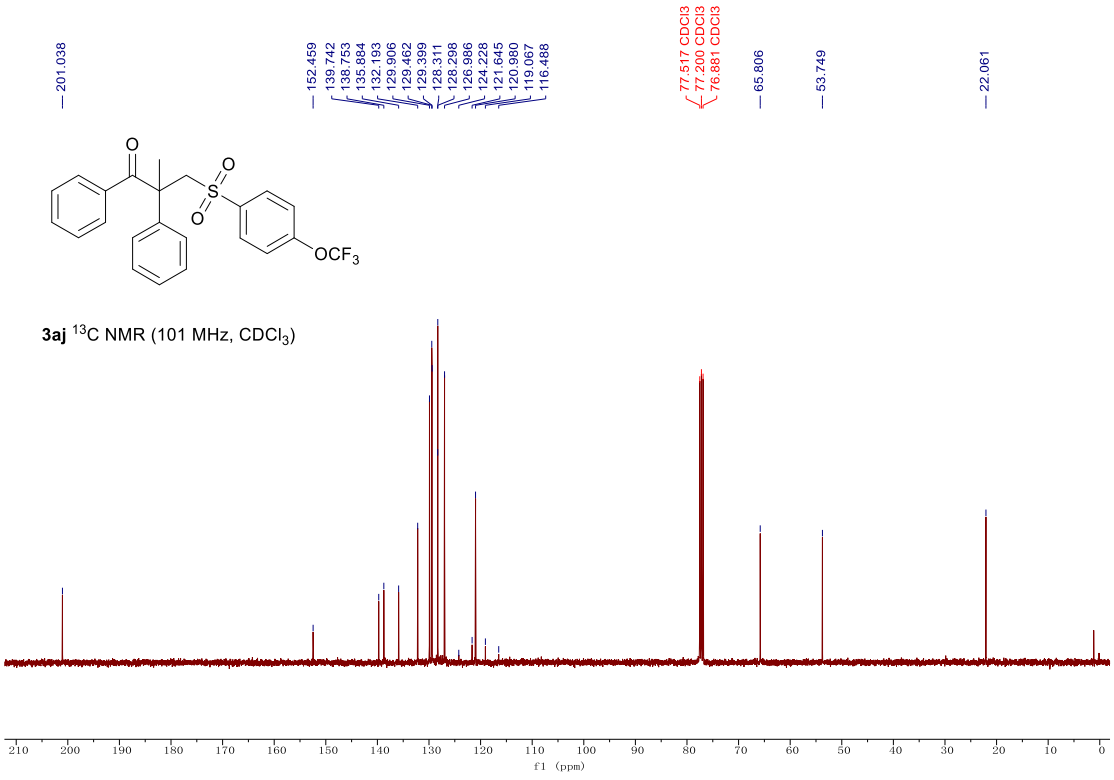
3ai ^{13}C NMR (101 MHz, $CDCl_3$)



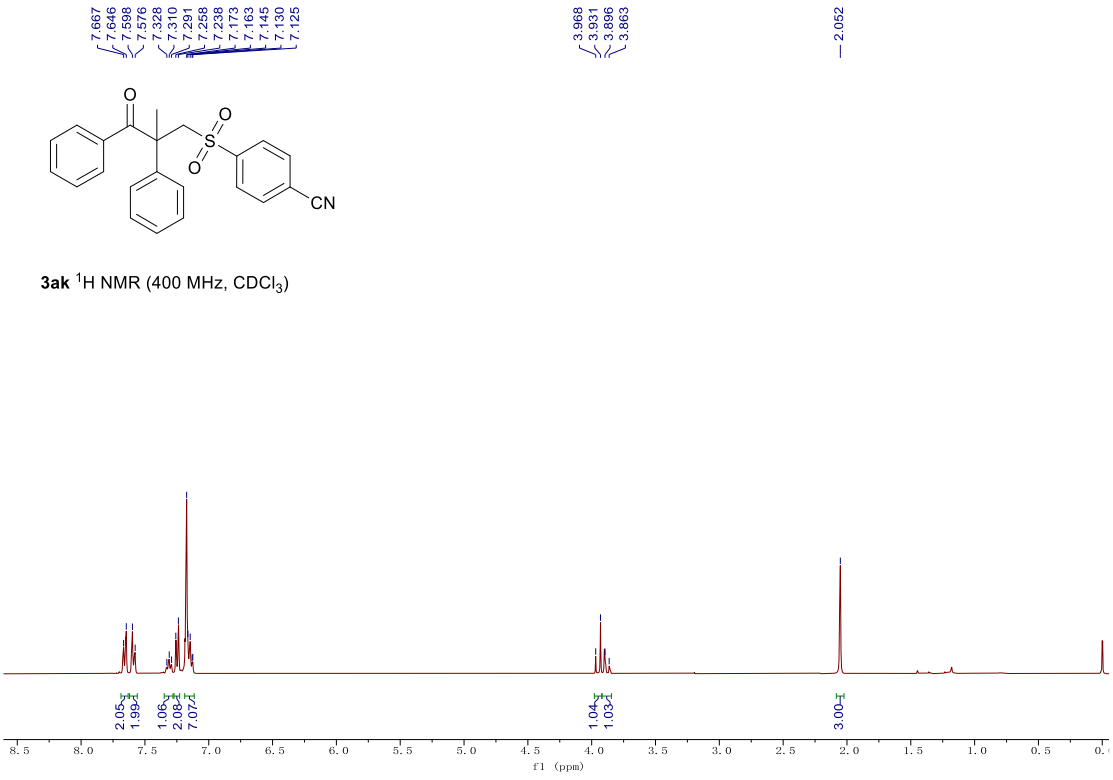


3aj ^{1}H NMR (400 MHz, $CDCl_3$)

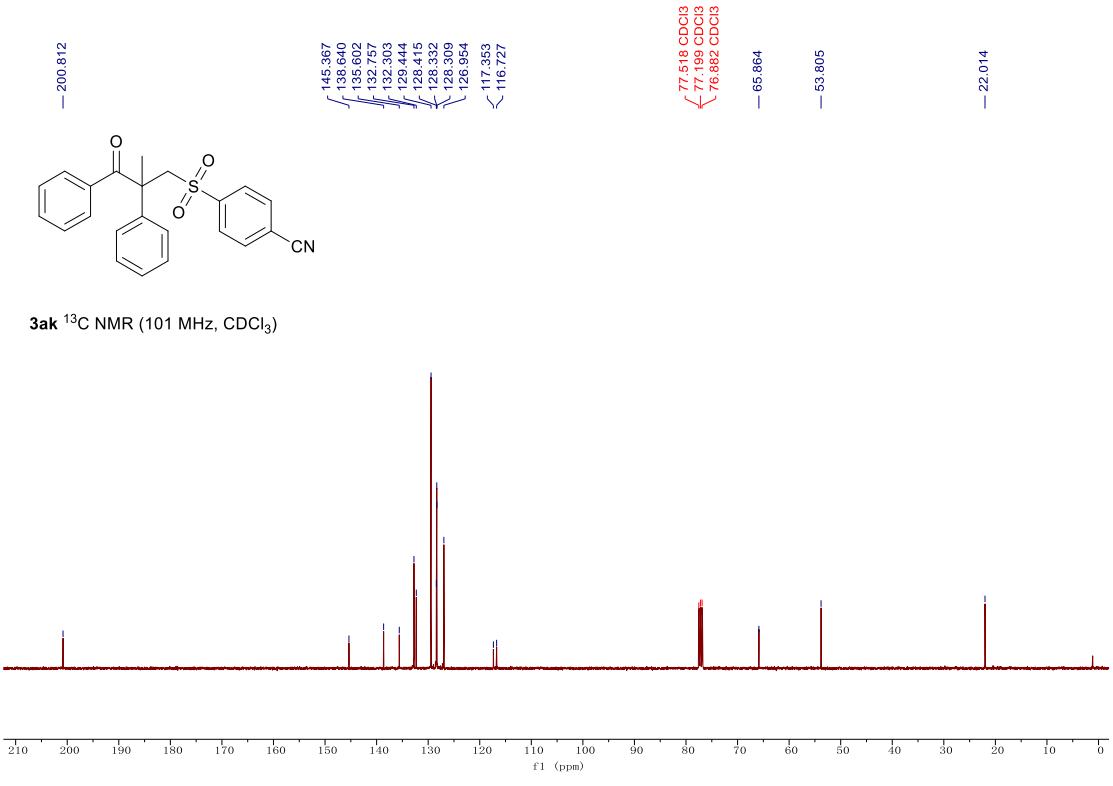




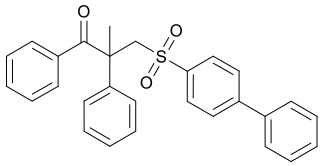
3aj ^{13}C NMR (101 MHz, $CDCl_3$)



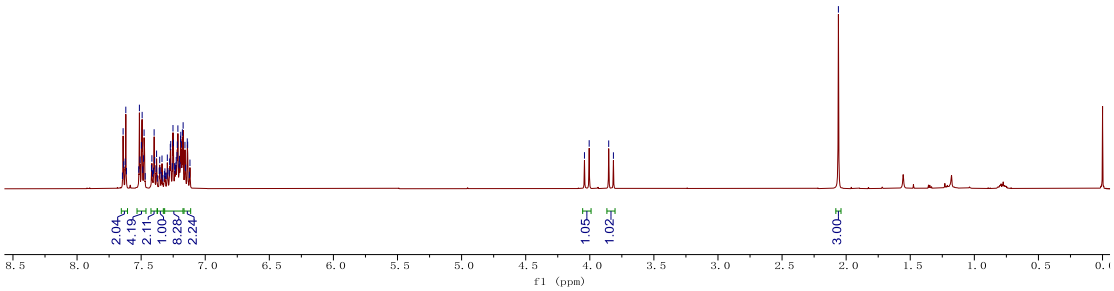
3ak ^{1}H NMR (400 MHz, $CDCl_3$)

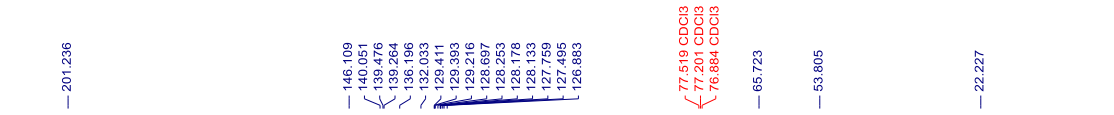


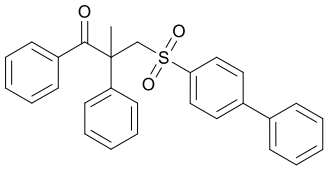
3ak ^{13}C NMR (101 MHz, $CDCl_3$)



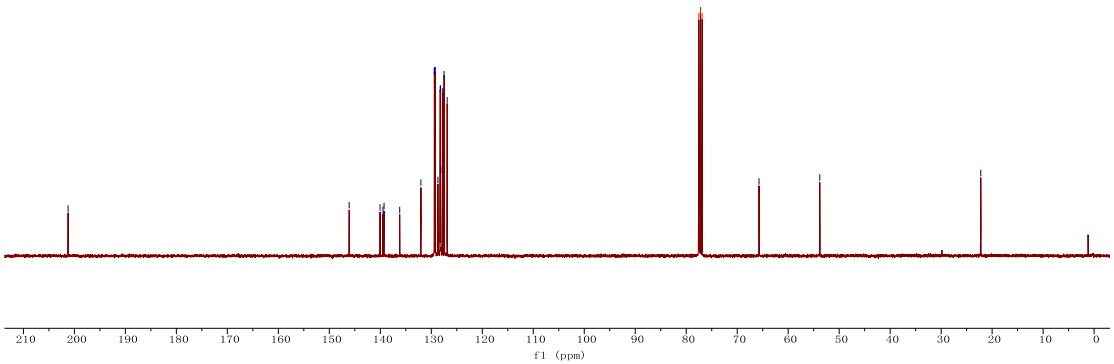
3al ^{1}H NMR (400 MHz, $CDCl_3$)

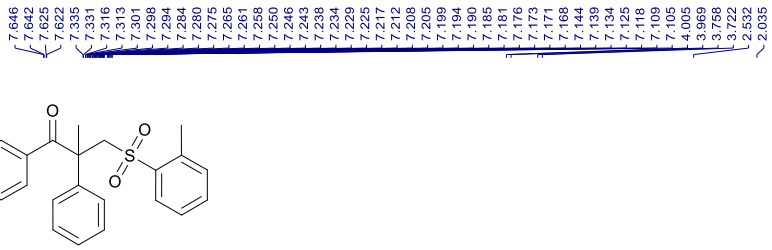




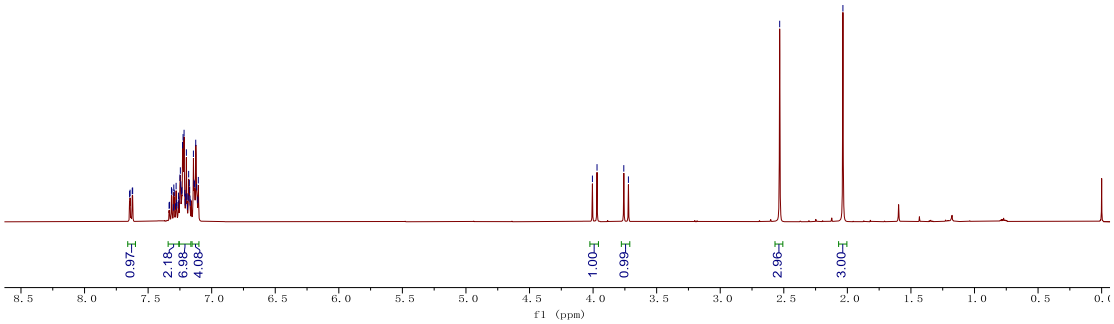


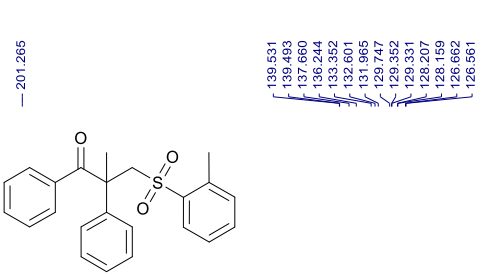
3al ^{13}C NMR (101 MHz, $CDCl_3$)



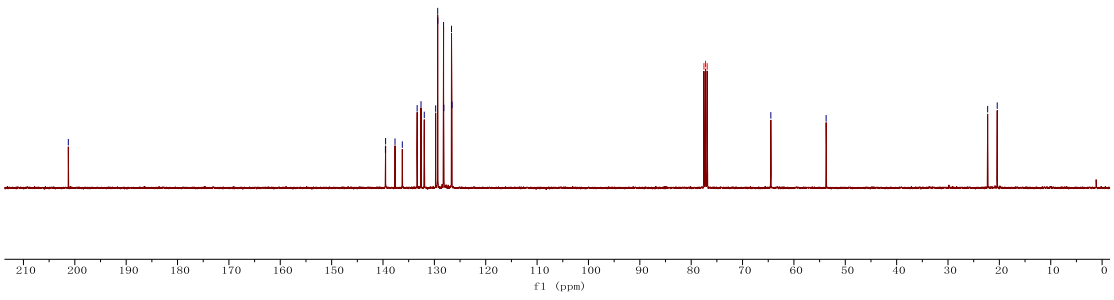


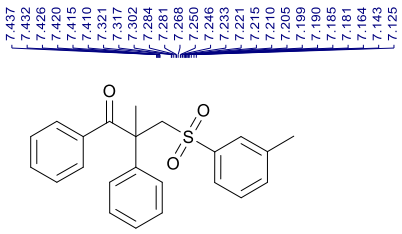
3am ^{1}H NMR (400 MHz, $CDCl_3$)



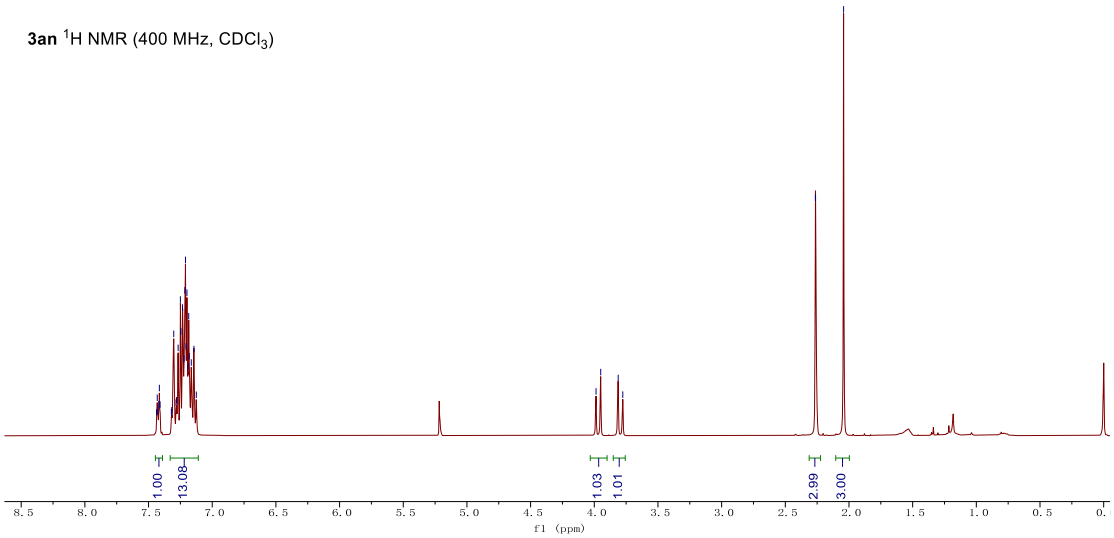


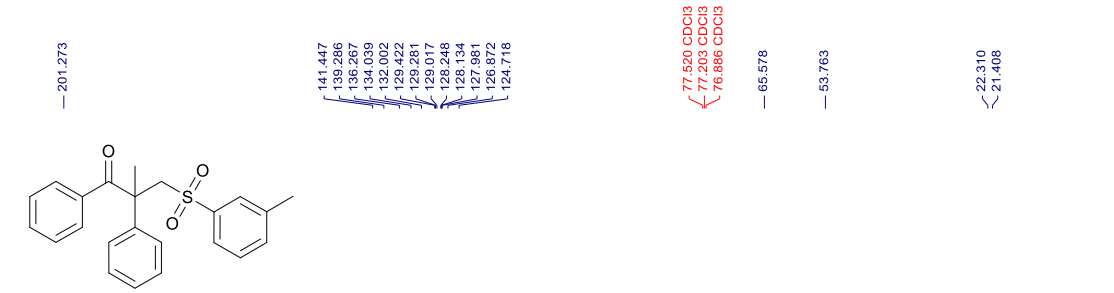
3am ^{13}C NMR (101 MHz, $CDCl_3$)



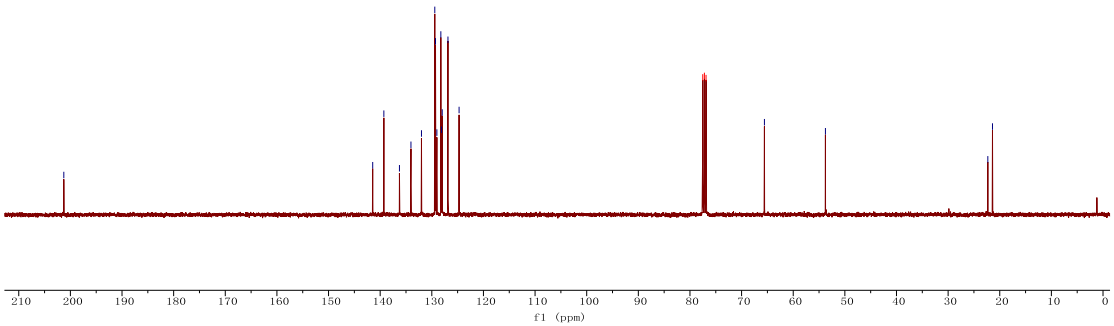


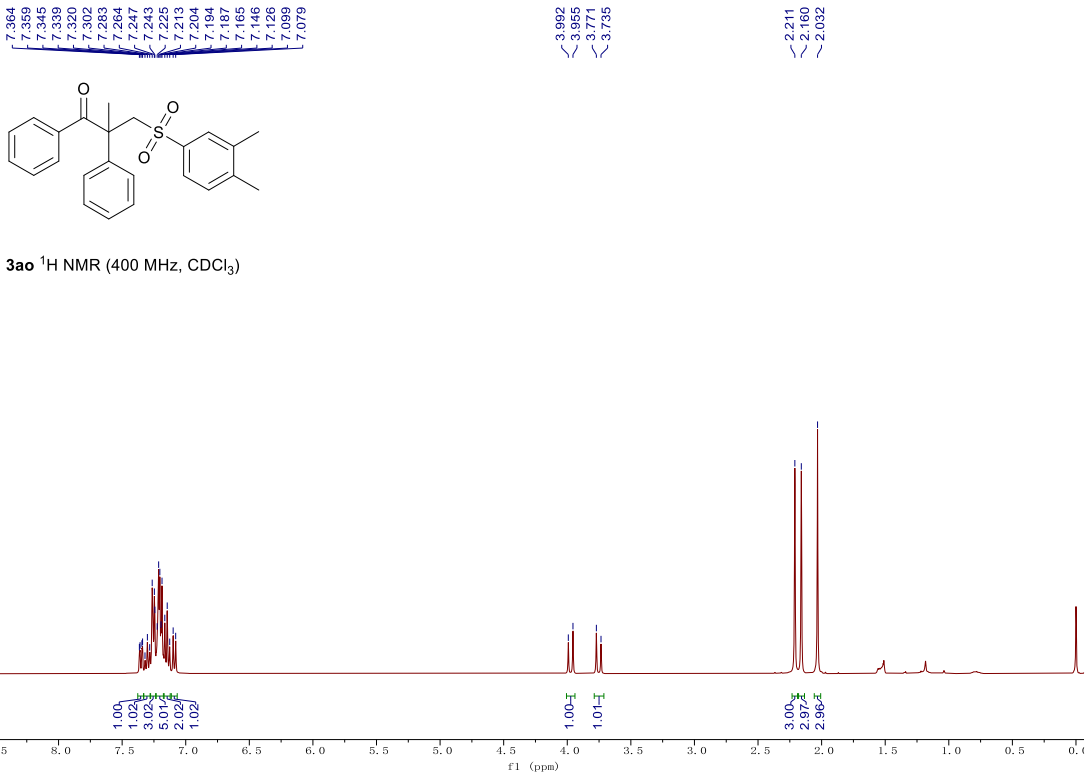
3an ^{1}H NMR (400 MHz, $CDCl_3$)



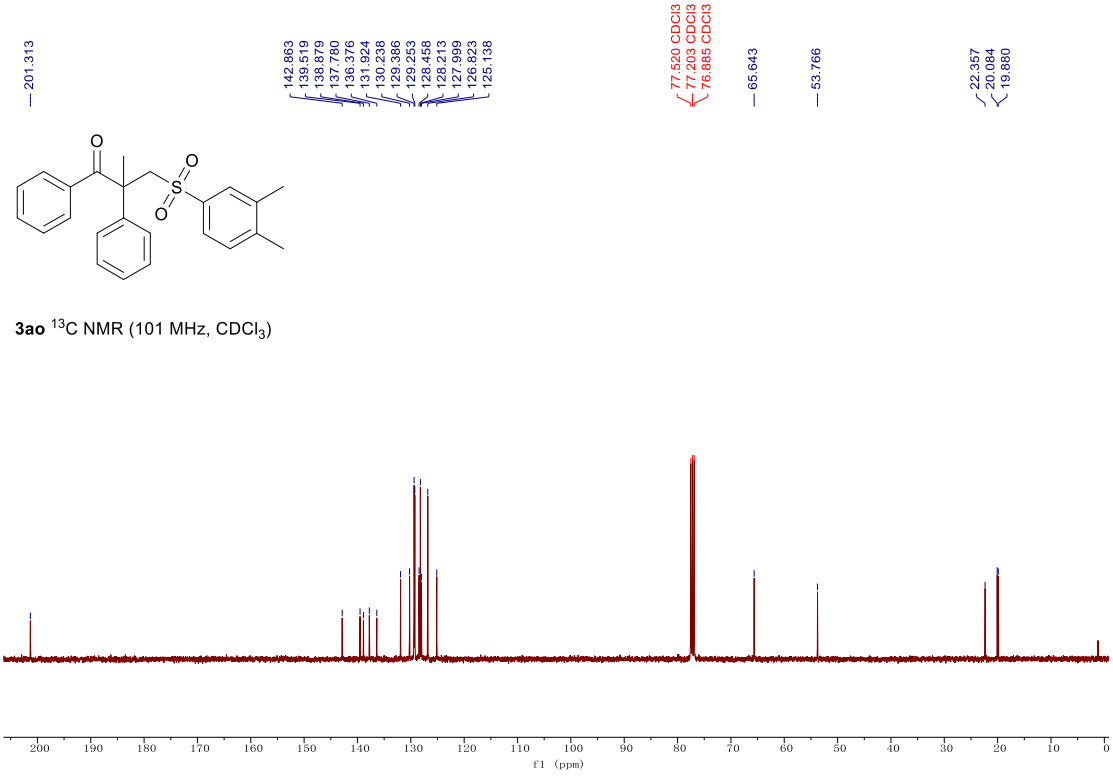


3an ^{13}C NMR (101 MHz, $CDCl_3$)

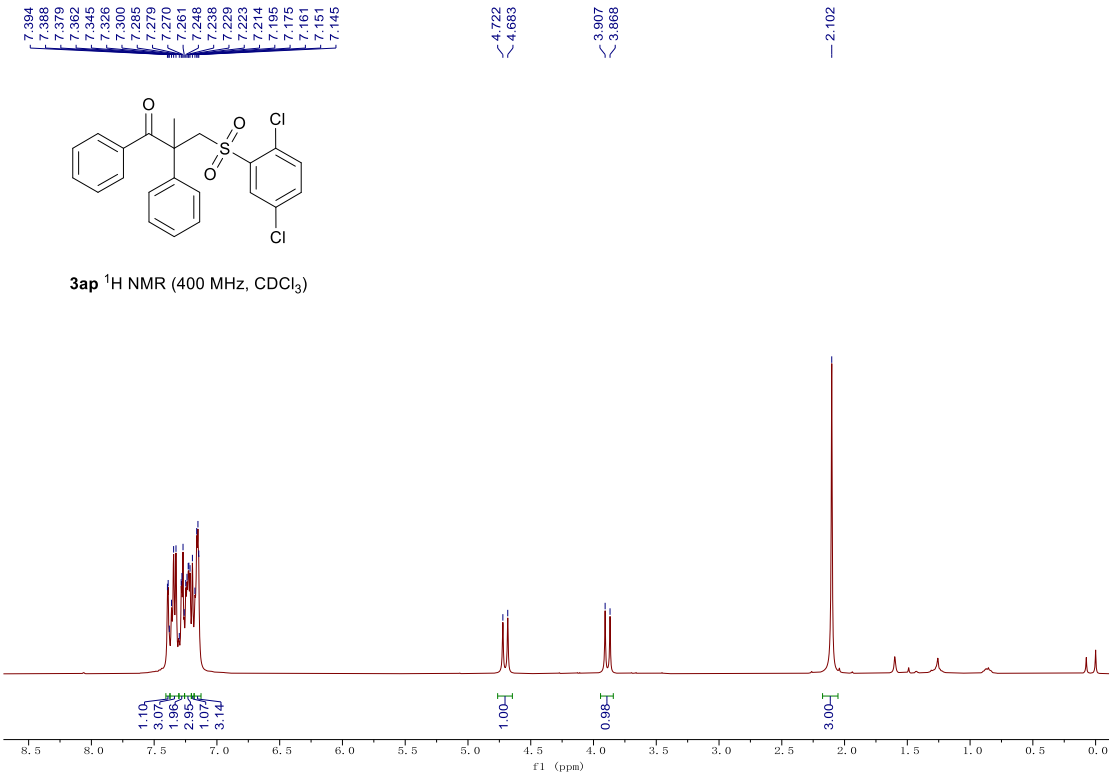




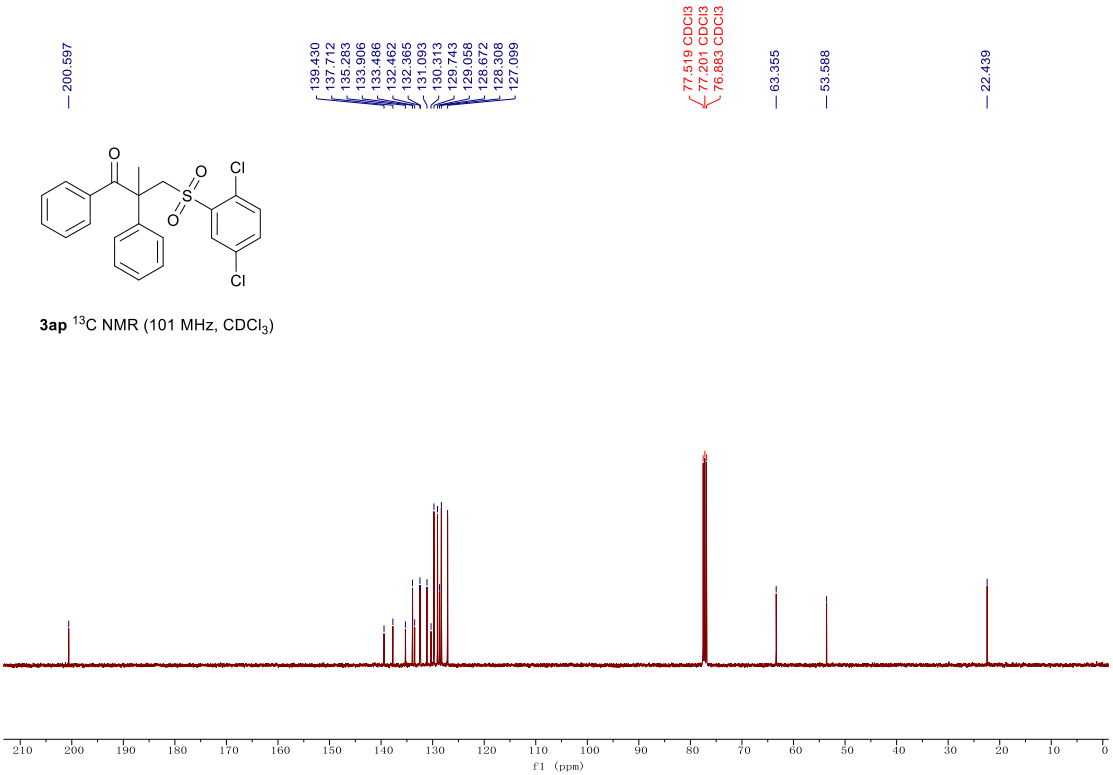
3ao ^{1}H NMR (400 MHz, $CDCl_3$)



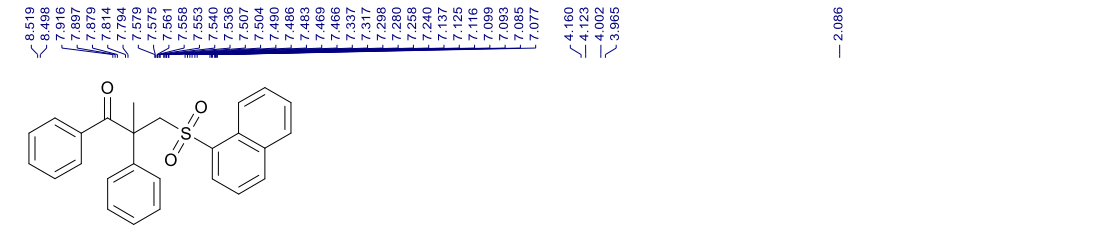
3ao ^{13}C NMR (101 MHz, $CDCl_3$)



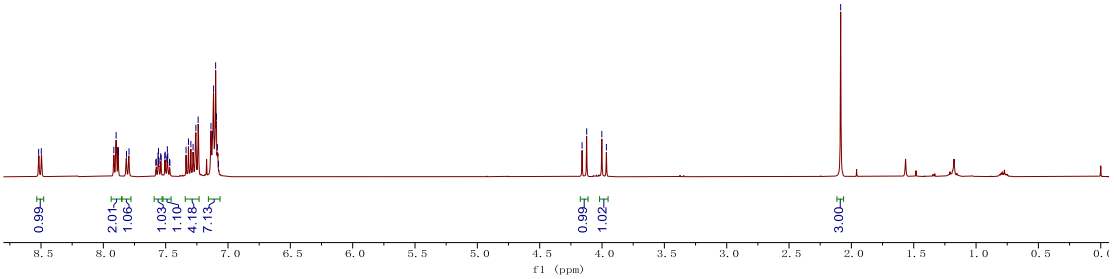
3ap ^{1}H NMR (400 MHz, $CDCl_3$)

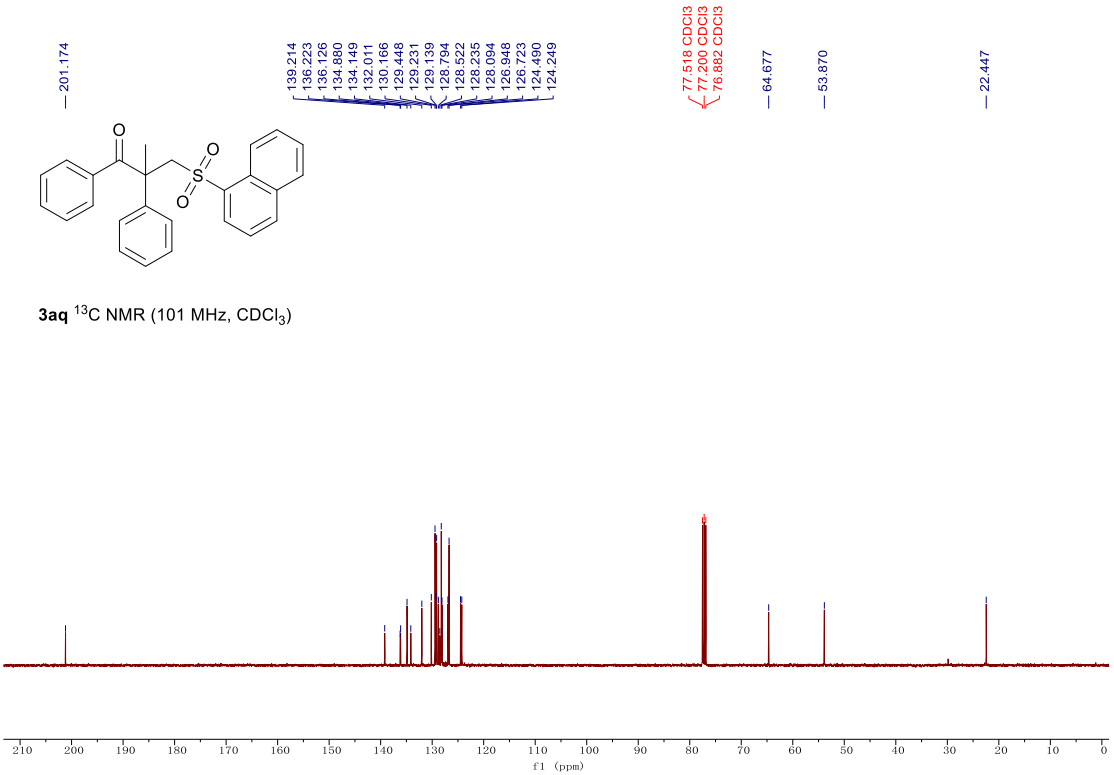


3ap ^{13}C NMR (101 MHz, $CDCl_3$)

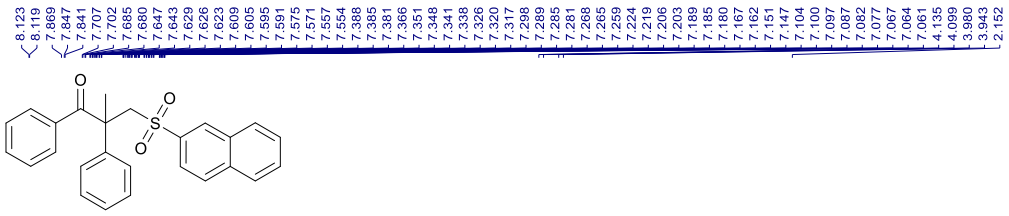


3aq ^{1}H NMR (400 MHz, $CDCl_3$)

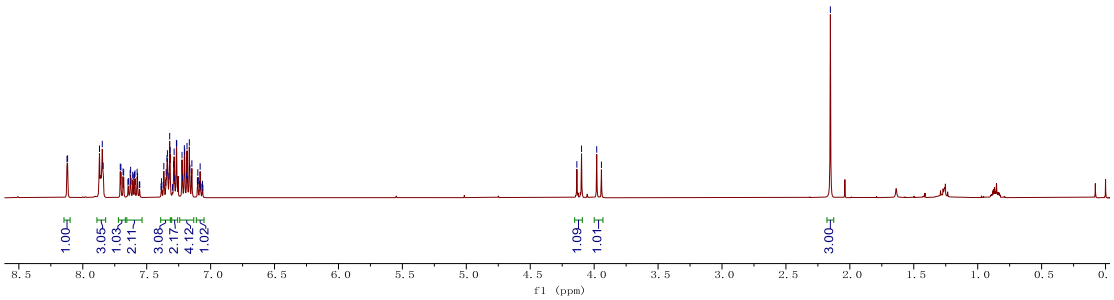


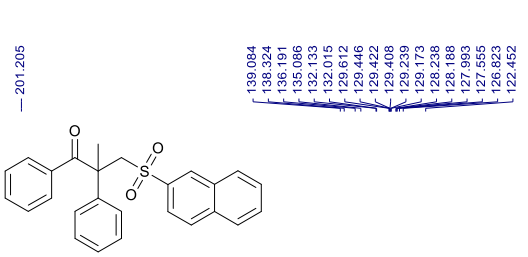


3aq ^{13}C NMR (101 MHz, $CDCl_3$)

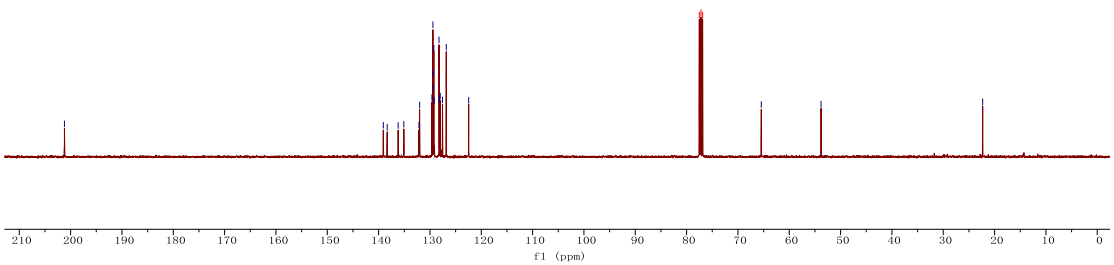


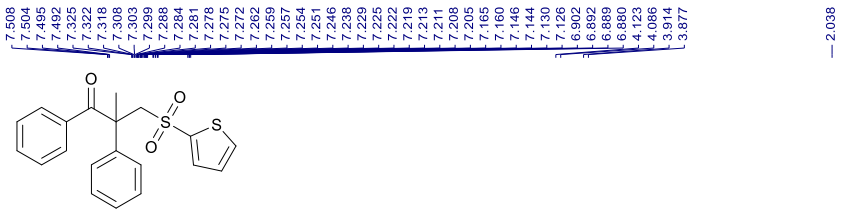
3ar ^{1}H NMR (400 MHz, $CDCl_3$)



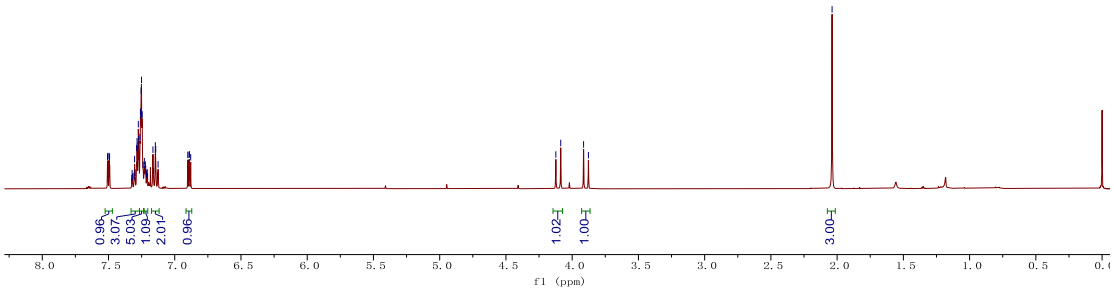


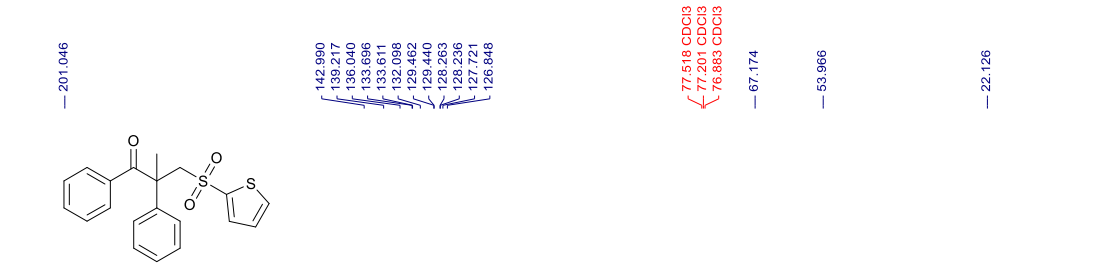
3ar ^{13}C NMR (101 MHz, $CDCl_3$)



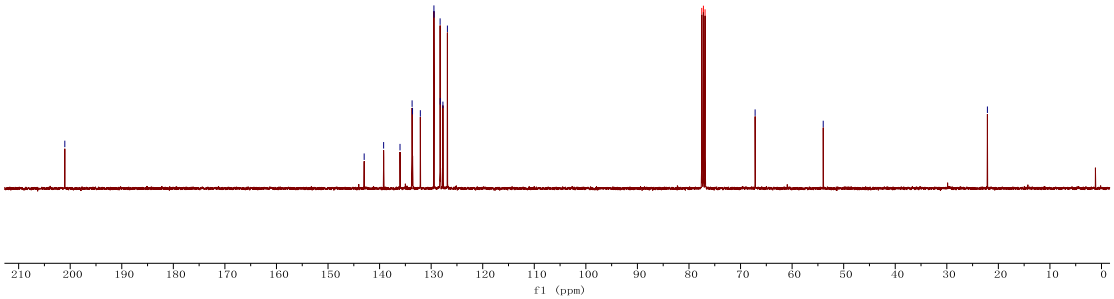


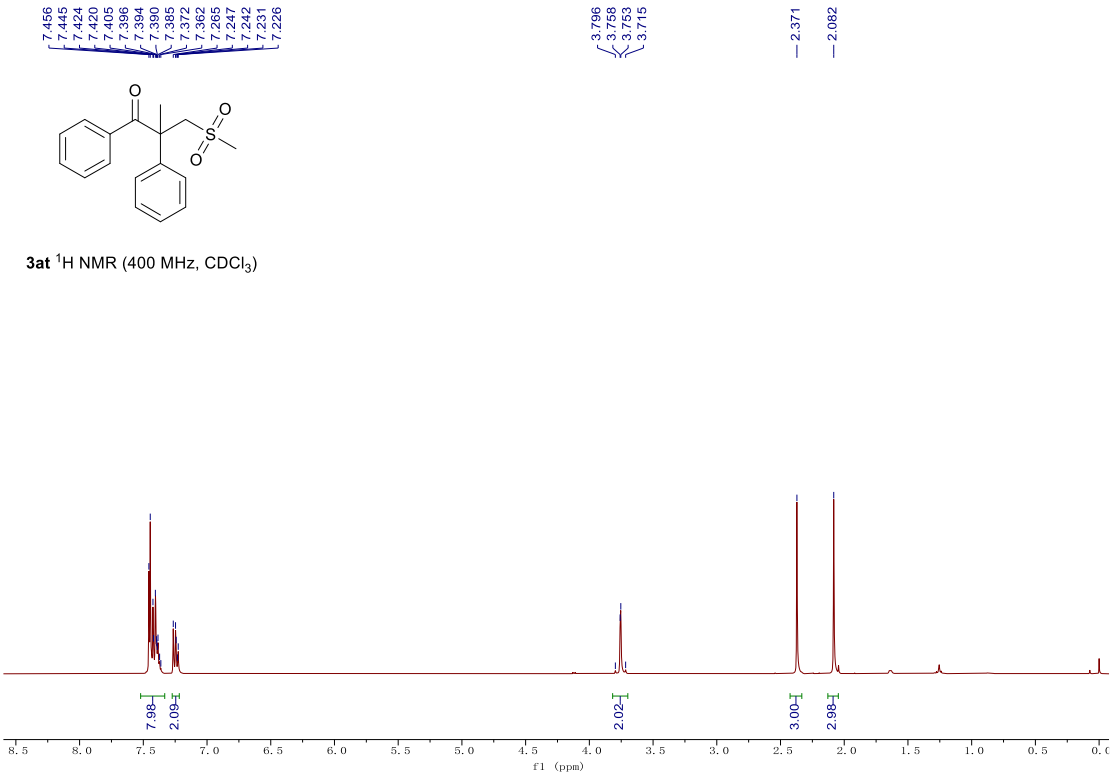
3as ^{1}H NMR (400 MHz, $CDCl_3$)



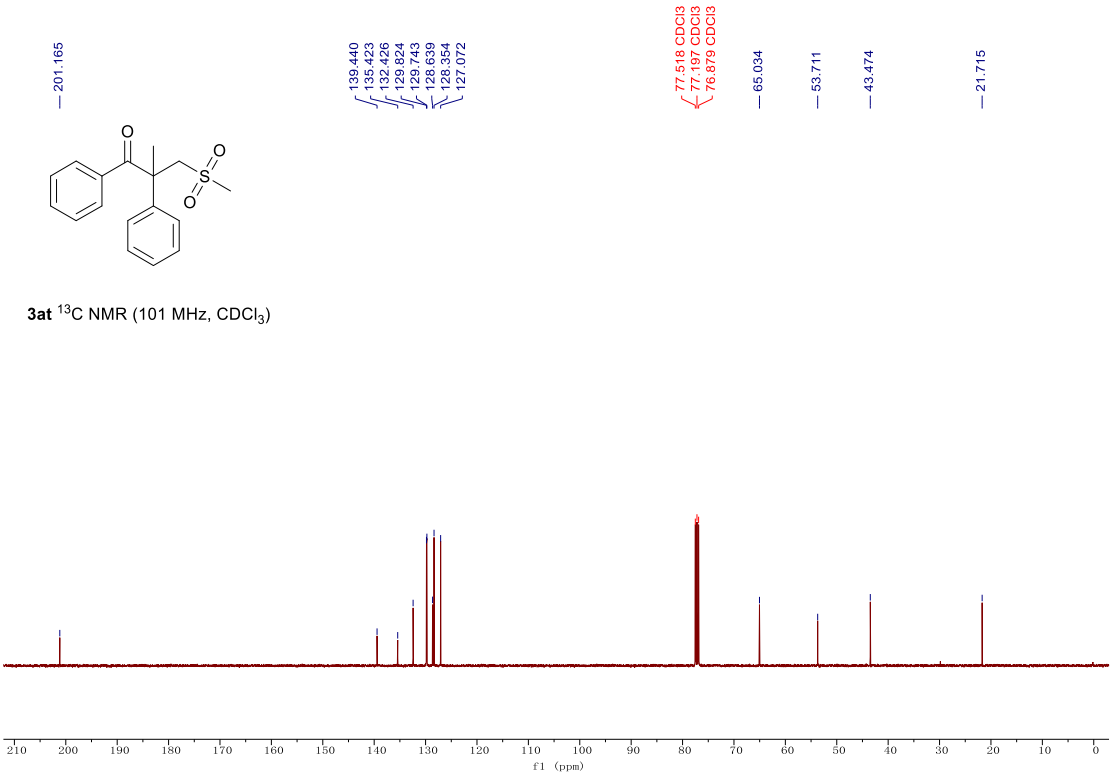


3as ^{13}C NMR (101 MHz, $CDCl_3$)

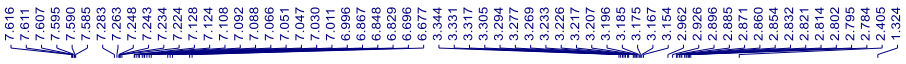


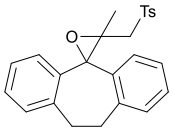


3at ^{1}H NMR (400 MHz, $CDCl_3$)

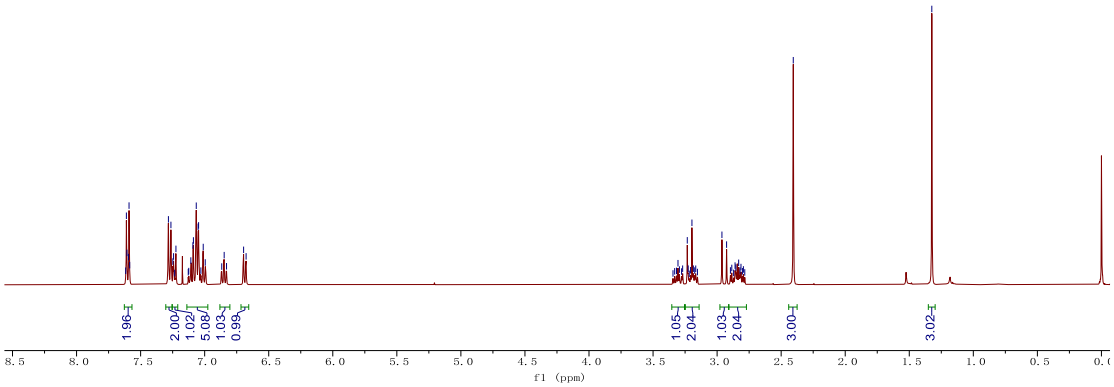


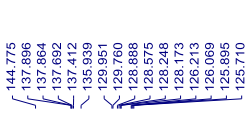
3at ^{13}C NMR (101 MHz, $CDCl_3$)

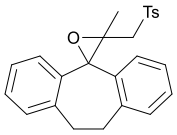




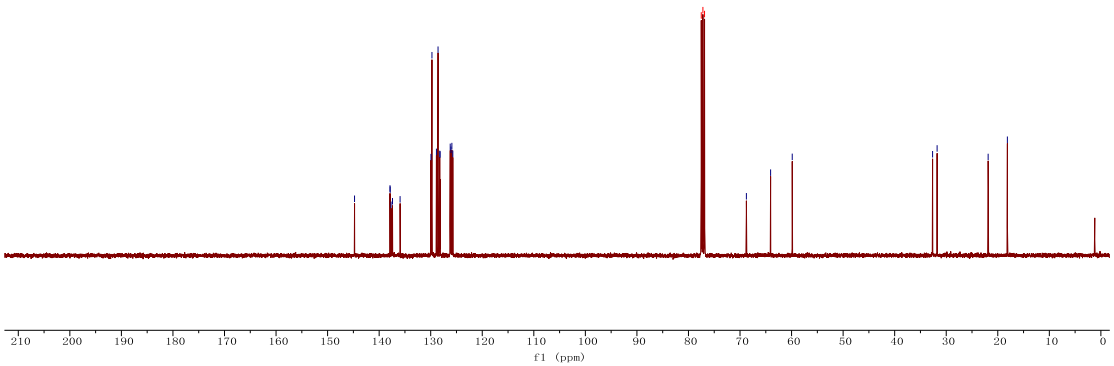
4 ^{1}H NMR (400 MHz, $CDCl_3$)

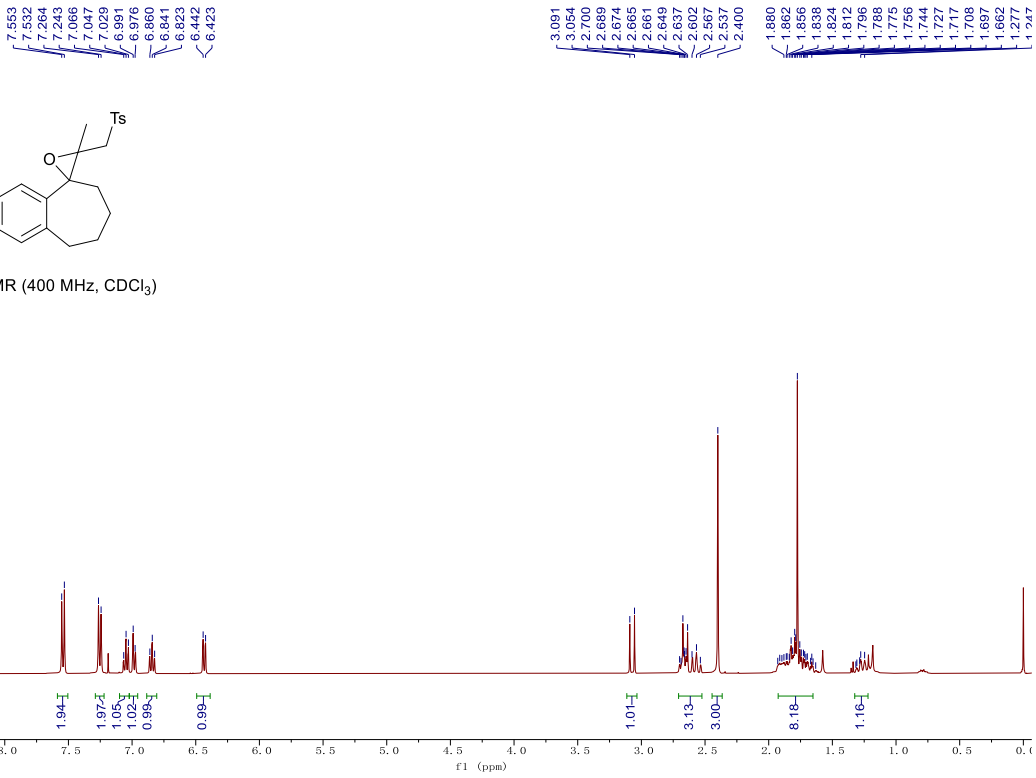




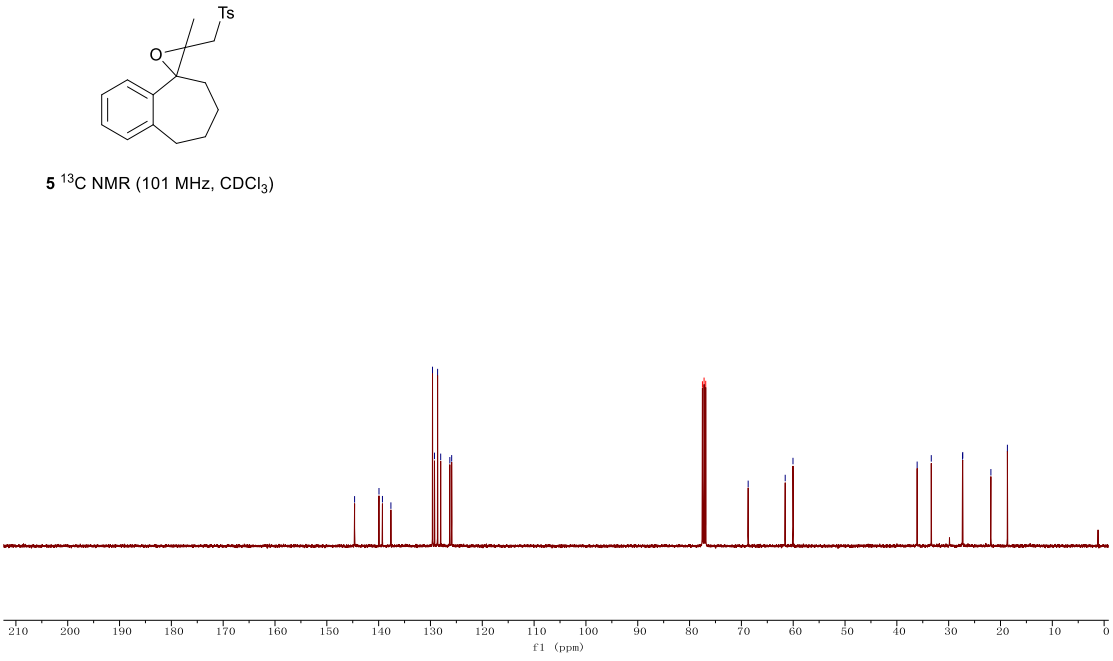


4 ^{13}C NMR (101 MHz, $CDCl_3$)

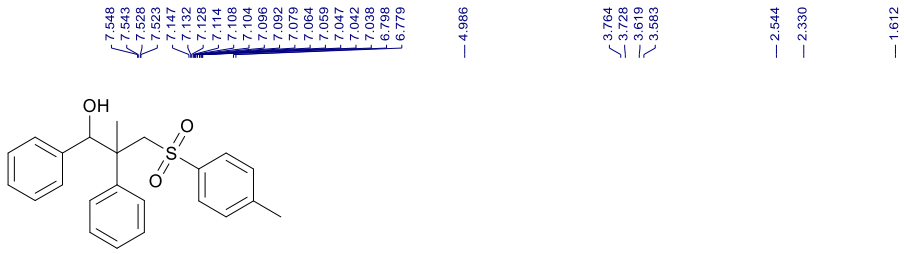




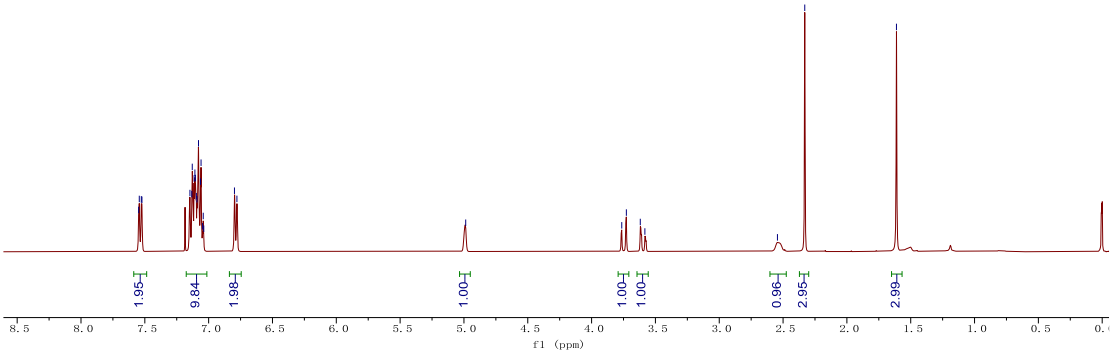
5 ^{1}H NMR (400 MHz, $CDCl_3$)

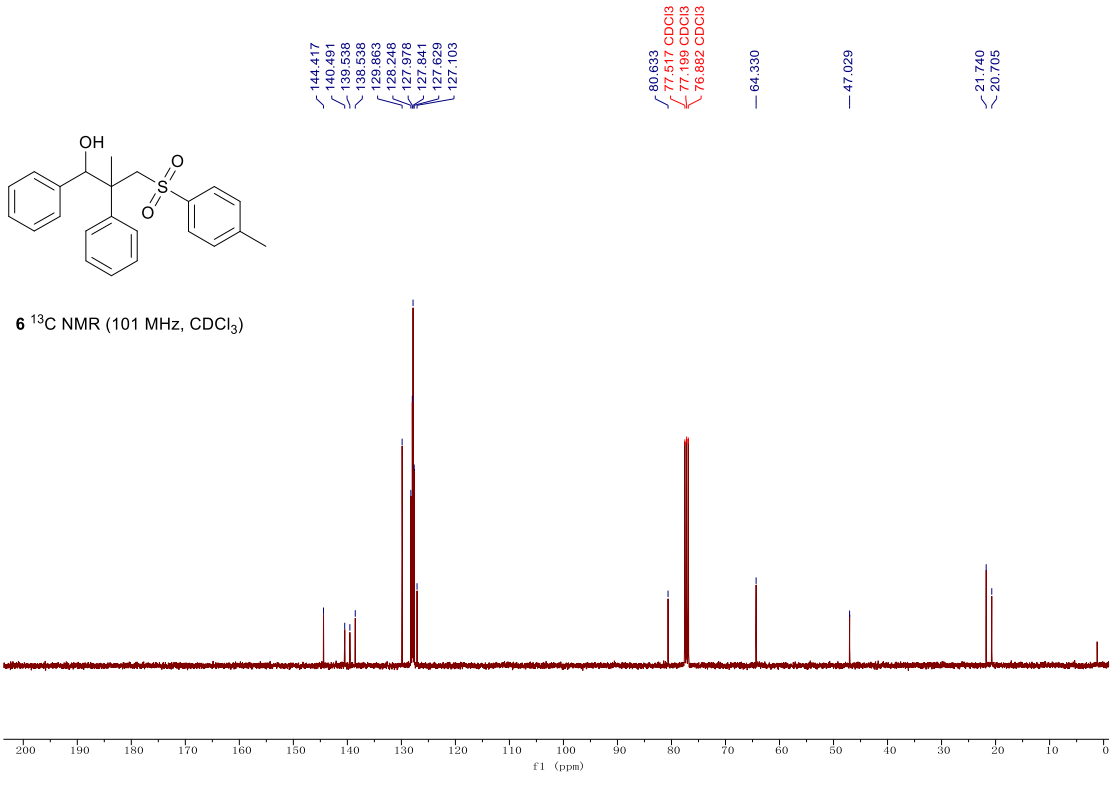


5 ^{13}C NMR (101 MHz, $CDCl_3$)



6 ^{1}H NMR (400 MHz, $CDCl_3$)





6 ^{13}C NMR (101 MHz, $CDCl_3$)