

Supporting Information

Transition Metal-Free Synthesis of α -Aryl Ketones via Oxyallyl Cation Capture with Arylboronic Acids

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Table of Content

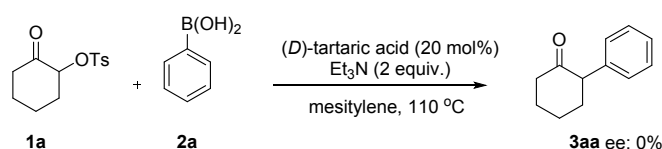
1. General Information.....	S2
2. General Procedure for the Synthesis of Substrates and Products.....	S2
3. General Procedure for the Synthesis of Compounds 4-6.....	S3
4. Control Experiments.....	S4
5. Unsuccessful Results.....	S4
6. Characterization of Substrates and Products.....	S5
7. References.....	S16
8. Copies of ¹H and ¹³C NMR Spectra of Substrates and Products.....	S17

1. General Information

All the commercial reagents were used as such without further purification. All solvents were used as commercial anhydrous grade without further purification. The flash column chromatography was carried out over silica gel (230-400 mesh). ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance-400 MHz spectrometer or Bruker Avance-500 MHz spectrometer. Chemical shifts in ^1H NMR spectra were reported in parts per million (ppm, δ) downfield from the internal standard Me_4Si (TMS, $\delta = 0$ ppm). Chemical shifts in ^{13}C NMR spectra were reported relative to the central line of the chloroform signal ($\delta = 77.0$ ppm). Peaks were labeled as singlet (s), doublet (d), triplet (t), quartet (q), and multiplet (m). High resolution mass spectra were obtained with a Shimadzu LCMS-IT-TOF mass spectrometer. Chemical yields refer to pure isolated substances.

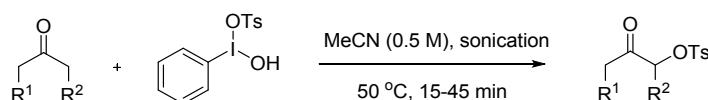
2. General Procedure for the Synthesis of Substrates and Products

(a) Synthesis of product 3a



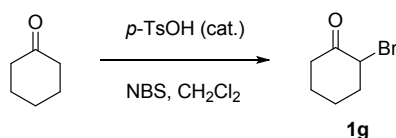
To a solution of **1** (0.2 mmol) and **2** (0.4 mmol) in mesitylene (2 mL), TEA (40.4 mg, 0.4 mmol) and (*D*)-tartaric acid (6 mg, 0.04 mmol) were added. The reaction mixture was then stirred at 110 °C for 24 hours. Upon completion, the reaction mixture was concentrated via rotary evaporation. The crude mixture was purified by flash column chromatography on silica gel to provide the desired product.

(b) Synthesis of α -tosyloxy ketones



The following procedure is adapted from the work of Tuncay *et al.*¹ To the ketone (15.3 mmol, 1.5 equiv.) dissolved in MeCN (20 mL, 0.5 M) was added [hydroxy(tosyloxy)iodo]benzene (4 g, 10.2 mmol, 1 equiv.), and the heterogeneous suspension was sonicated at 50 °C until a homogeneous solution was noted. The MeCN was removed under reduced pressure. The crude products were purified by flash column chromatography, affording the desired α -tosyloxyketone **1a-1f**.

(c) Synthesis of 2-bromocyclohexanone²

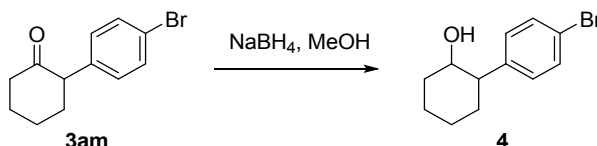


A solution of cyclohexanone (1.04 mL, 10.0 mmol) in CH_2Cl_2 (5 mL) was added dropwise to a solution of *n*-bromosuccinimide (NBS, 2.14 g, 12.0 mmol, 1.2 equiv.) and *p*-TsOH (190 mg, 1.0

mmol, 0.1 equiv.) in CH₂Cl₂ (10 mL) at 0 °C. The reaction mixture was then brought to reflux for 4 h. After addition of H₂O (10 mL), the organic layer was separated, and the aqueous layer was extracted with CH₂Cl₂ (3×10 mL). The combined organic layers were washed with saturated aqueous NaHCO₃ (20 mL) and brine (20 mL), dried over anhydrous Na₂SO₄, and concentrated under reduced pressure. Column chromatography on silica gel provided 2-bromocyclohexanone **1g** (1.6 g, 90% yield).

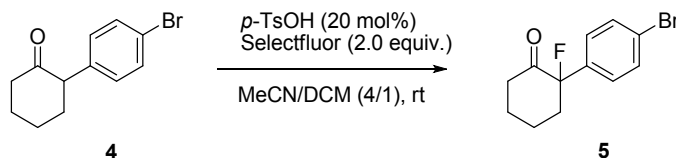
3. General Procedure for the Synthesis of Compounds 4-6

(a) Synthesis of 2-(4-bromophenyl)-cyclohexanol **4**⁴



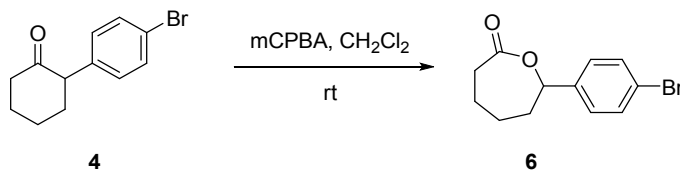
To a round bottom flask fitted with stirring bar was added 2-(4-bromophenyl)cyclohexanone **3am** (50.6 mg, 0.20 mmol) and methanol (1 mL) to a concentration of 0.2 M. The solution was treated with NaBH₄ (15.1 mg, 0.40 mmol) and stirred at room temperature for 2 hours. The reaction was then quenched with saturated NH₄Cl, and the aqueous layer was extracted with diethyl ether (3×5 mL). The organic layers were then combined, dried over anhydrous Na₂SO₄, filtered and concentrated. The crude mixture was purified on silica gel chromatography to give **4** as a white solid (40.8 mg, 80% yield).

(b) Synthesis of 2-(4-bromophenyl)-2-fluorocyclohexan-1-one **5**⁴



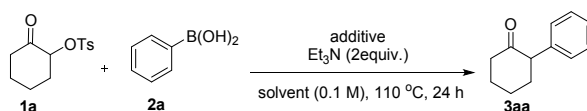
Under argon atmosphere, to a 10 mL reaction tube charged with a magnetic stirring bar was added 2-(4-bromophenyl)cyclohexanone **4** (50.6 mg, 0.20 mmol), Selectfluor (141.8 mg, 0.40 mmol), *p*-TsOH (7.6 mg, 0.04 mmol), CH₂Cl₂ (0.2 mL) and MeCN (0.8 mL). The reaction mixture was stirred at 25 °C until the complete consumption of the starting material (monitored by TLC). The mixture was diluted with ethyl acetate, the resulting organic phase was washed successively with water and brine, dried over Na₂SO₄, filtered, and concentrated *in vacuo*. The crude product was purified by flash column chromatography on silica gel (petroleum ether/ethyl acetate) to give **5** as a white solid (46.0 mg, 83% yield).

(c) Synthesis of 7-(4-bromophenyl)oxepan-2-one **6**¹⁷



To a solution of 2-(4-bromophenyl)cyclohexanone **4** (50.6 mg, 0.20 mmol) in 4 mL CH₂Cl₂ was added mCPBA (69 mg, 0.40 mmol) at 0°C. After stirring at rt overnight, the reaction mixture was quenched with 10% K₂CO₃ solution and a saturated aqueous solution of Na₂S₂O₃. The aqueous layer was separated and extracted with CH₂Cl₂. The combined organic layer was dried over MgSO₄, filtered and concentrated under reduced pressure. The resulting crude product was purified by column chromatography (petroleum ether/ethyl acetate) to afford **6** as a colorless solid (47.9 mg, 89%).

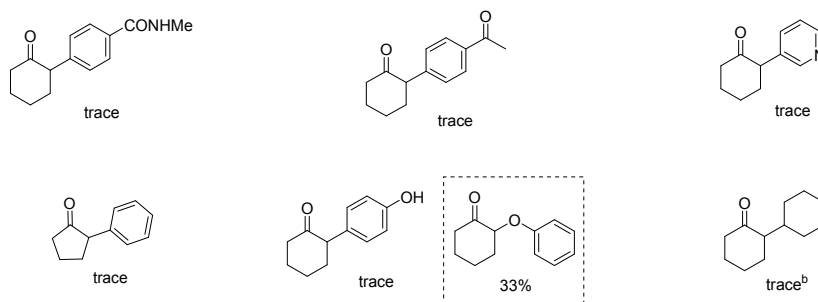
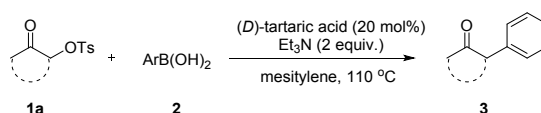
4. Control Experiments^a



Entry	Solvent	Additive	Add. Equiv.	Yield ^c
1	mesitylene	(<i>D</i>)-tartaric acid	0.2	74%
2	mesitylene	(<i>D</i>)-diethyl tartarate	0.2	54%
3	mesitylene	succinic acid	0.2	68%
4	mesitylene	HFIP ^b	-	70%
5	mesitylene	-	-	52%

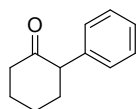
^a Reaction conditions: **1a** (0.2 mmol), **2a** (0.4 mmol), additive and Et₃N (2 equiv.) in mesitylene (2 mL) at 110 °C for 24 h; ^b mesitylene: HFIP (10:1, V/V); ^c Isolated yield.

5. Unsuccessful Results



^a Reaction conditions: **1a** (0.2 mmol), **2** (0.4 mmol), (*D*)-tartaric acid (0.04 mmol) and Et₃N (2 equiv.) in mesitylene (2 mL) at 110 °C for 24 h; ^b Pi system is necessary to engage the cationic electrophile.

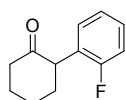
6. Characterization of Substrates and Products



3aa

2-phenylcyclohexan-1-one (**3aa**)³

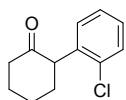
Colorless oil. R_F : 0.43 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.36 (t, $J = 7.5$ Hz, 2H), 7.31-7.27 (m, 1H), 7.17 (d, $J = 7.1$ Hz, 2H), 3.64 (dd, $J = 12.2, 5.4$ Hz, 1H), 2.59-2.45 (m, 2H), 2.33-2.27 (m, 1H), 2.21-2.14 (m, 1H), 2.11-2.00 (m, 2H), 1.91-1.81 (m, 2H); ^{13}C NMR (126 MHz, CDCl_3) δ : 210.4, 138.8, 128.6, 128.4, 127.0, 57.5, 42.3, 35.2, 27.9, 25.4.



3ab

2-(2-fluorophenyl)cyclohexan-1-one (**3ab**)⁴

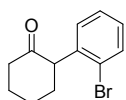
Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.31-7.20 (m, 1H), 7.20-7.08 (m, 2H), 7.09-6.97 (m, 1H), 3.85 (dd, $J = 9.3, 3.7$ Hz, 1H), 2.71-2.37 (m, 2H), 2.33-2.12 (m, 2H), 2.13-1.93 (m, 2H), 1.94-1.69 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 208.4, 159.5 (d), 129.7 (d, $J = 4.8$ Hz), 128.5 (d, $J = 8.3$ Hz), 126.1 (d, $J = 14.4$ Hz), 123.9 (d, $J = 3.3$ Hz), 115.2 (d, $J = 22.4$ Hz), 51.0, 42.1, 33.7, 27.4, 25.5; ^{19}F NMR (376 MHz, CDCl_3) δ : -109.56.



3ac

2-(2-chlorophenyl)cyclohexan-1-one (**3ac**)⁵

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.37 (d, $J = 8.0$ Hz, 1H), 7.29-7.17 (m, 3H), 4.10 (dd, $J = 12.7, 5.3$ Hz, 1H), 2.63-2.50 (m, 2H), 2.30-2.17 (m, 2H), 2.08-1.97 (m, 2H), 1.91-1.77 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 208.8, 136.7, 134.2, 129.4, 129.4, 128.1, 126.7, 54.0, 42.3, 33.9, 27.6, 25.6.

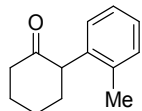


3ad

2-(2-bromophenyl)cyclohexan-1-one (**3ad**)⁵

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.56 (d, $J = 8.0$ Hz, 1H), 7.31 (t, $J = 7.5$ Hz, 1H), 7.21 (d, $J = 7.7$ Hz, 1H), 7.12 (t, $J = 7.6$ Hz, 1H),

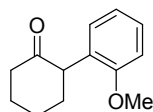
4.12 (dd, $J = 12.7, 5.1$ Hz, 1H), 2.61-2.48 (m, 2H), 2.35-2.25 (m, 1H), 2.24-2.15 (m, 1H), 2.10-1.96 (m, 2H), 1.95-1.77 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 209.0, 138.5, 132.7, 129.6, 128.5, 127.5, 125.3, 56.7, 42.5, 34.3, 27.8, 25.8.



3ae

2-(*o*-tolyl)cyclohexan-1-one (**3ae**)³

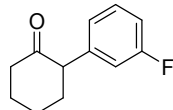
Colorless oil. R_F : 0.43 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.27-7.11 (m, 4H), 3.80 (dd, $J = 12.9, 4.9$ Hz, 1H), 2.59-2.46 (m, 2H), 2.31-2.19 (m, 5H), 2.11-2.02 (m, 2H), 1.93-1.79 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 210.0, 137.3, 136.1, 130.3, 127.6, 126.8, 126.0, 53.8, 42.5, 34.2, 27.8, 25.9, 19.7.



3af

2-(2-methoxyphenyl)cyclohexan-1-one (**3af**)⁶

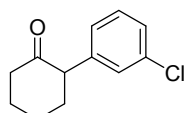
White solid. R_F : 0.40 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.23 (t, $J = 9.1$ Hz, 1H), 7.14-7.07 (m, 1H), 6.98-6.81 (m, 2H), 3.93 (m, 1H), 3.76 (s, 3H), 2.59-2.40 (m, 2H), 2.27-2.10 (m, 2H), 2.10-1.93 (m, 2H), 1.91-1.71 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 209.9, 156.9, 128.7, 127.9, 127.8, 120.5, 110.5, 55.4, 51.0, 42.3, 33.4, 27.5, 25.7.



3ag

2-(3-fluorophenyl)cyclohexan-1-one (**3ag**)³

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.33-7.26 (m, 1H), 7.01-6.78 (m, 3H), 3.61 (dd, $J = 12.1, 5.5$ Hz, 1H), 2.55-2.41 (m, 2H), 2.32-2.13 (m, 2H), 2.04-1.94 (m, 2H), 1.87-1.77 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 209.7, 162.9 (d, $J = 245.2$ Hz), 141.3 (d, $J = 7.4$ Hz), 129.8 (d, $J = 8.3$ Hz), 124.4 (d, $J = 2.8$ Hz), 115.6 (d, $J = 21.6$ Hz), 113.9 (d, $J = 21.0$ Hz), 57.2, 42.3, 35.1, 26.6, 25.4; ^{19}F NMR (471 MHz, CDCl_3) δ : -113.48.

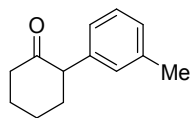


3ah

2-(3-chlorophenyl)cyclohexan-1-one (**3ah**)⁴

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.25-7.18 (m, 2H), 7.11 (s, 1H), 7.02-6.96 (m, 1H), 3.56 (dd, $J = 12.1, 5.4$ Hz, 1H), 2.57-2.38 (m,

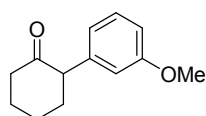
2H), 2.31-2.08 (m, 2H), 2.04-1.91 (m, 2H), 1.86-1.72 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 209.4, 140.7, 134.1, 129.5, 128.7, 127.0, 126.8, 57.0, 42.1, 35.0, 27.7, 25.3.



3ai

2-(*m*-tolyl)cyclohexan-1-one (**3ai**)⁷

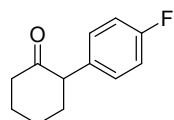
Colorless oil. R_F : 0.42 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.22 (t, $J = 7.5$ Hz, 1H), 7.06 (d, $J = 7.6$ Hz, 1H), 6.94 (d, $J = 8.4$ Hz, 2H), 3.57 (dd, $J = 12.0, 5.4$ Hz, 1H), 2.57-2.39 (m, 2H), 2.34 (s, 3H), 2.29-2.11 (m, 2H), 2.10-1.96 (m, 2H), 1.89-1.75 (m, 2H); ^{13}C NMR (126 MHz, CDCl_3) δ : 210.3, 138.7, 137.8, 129.2, 128.2, 127.6, 125.5, 57.3, 42.1, 34.9, 27.7, 25.2, 21.4.



3aj

2-(3-methoxyphenyl)cyclohexan-1-one (**3aj**)⁸

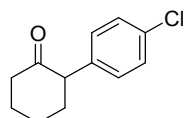
Colorless oil. R_F : 0.43 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.28 (t, $J = 3.9$ Hz, 1H), 6.83 (dd, $J = 8.0, 2.2$ Hz, 1H), 6.76 (d, $J = 7.6$ Hz, 1H), 6.72 (d, $J = 1.9$ Hz, 1H), 3.82 (s, 3H), 3.61 (dd, $J = 12.0, 5.4$ Hz, 1H), 2.63-2.38 (m, 2H), 2.34-2.23 (m, 1H), 2.22-2.12 (m, 1H), 2.10-1.97 (m, 2H), 1.91-1.77 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 210.2, 159.5, 140.3, 129.3, 120.9, 114.5, 112.1, 57.3, 55.1, 42.1, 34.9, 27.7, 25.2.



3ak

2-(4-fluorophenyl)cyclohexan-1-one (**3ak**)³

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.20-6.93 (m, 4H), 3.60 (dd, $J = 11.8, 5.3$ Hz, 1H), 2.64-2.36 (m, 2H), 2.33-2.09 (m, 2H), 2.08-1.91 (m, 2H), 1.90-1.70 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 210.1, 161.8 (d, $J = 244.7$ Hz), 134.4 (d, $J = 2.4$ Hz), 130.0 (d, $J = 7.9$ Hz), 115.1 (d, $J = 21.3$ Hz), 56.6, 42.2, 35.4, 27.8, 25.4; ^{19}F NMR (376 MHz, CDCl_3) δ : -116.20.

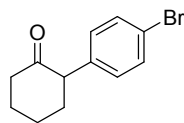


3al

2-(4-chlorophenyl)cyclohexan-1-one (**3al**)⁷

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.35-7.24 (m, 2H), 7.11-7.01 (m, 2H), 3.65-3.55 (m, 1H), 2.61-2.38 (m, 2H), 2.34-2.09 (m, 2H),

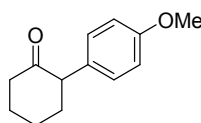
2.09-1.90 (m, 2H), 1.91-1.68 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 209.8, 137.2, 132.7, 129.9, 128.5, 56.8, 42.2, 35.2, 27.8, 25.3.



3am

2-(4-bromophenyl)cyclohexan-1-one (3am)⁹

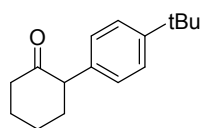
White solid. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.45 (d, $J = 8.3$ Hz, 2H), 7.01 (d, $J = 8.4$ Hz, 2H), 3.57 (dd, $J = 12.1, 5.3$ Hz, 1H), 2.56-2.39 (m, 2H), 2.29-2.11 (m, 2H), 2.04-1.91 (m, 2H), 1.88-1.75 (m, 2H); ^{13}C NMR (126 MHz, CDCl_3) δ : 209.7, 137.7, 131.4, 130.3, 120.8, 56.8, 42.2, 35.2, 27.7, 25.3.



3an

2-(4-methoxyphenyl)cyclohexan-1-one (3an)³

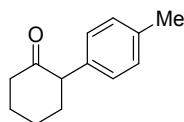
White solid. R_F : 0.43 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.15-7.00 (m, 2H), 6.94-6.85 (m, 2H), 3.79 (s, 3H), 3.57 (dd, $J = 12.2, 5.4$ Hz, 1H), 2.59-2.37 (m, 2H), 2.34-2.08 (m, 2H), 2.07-1.91 (m, 2H), 1.90-1.72 (m, 2H); ^{13}C NMR (126 MHz, CDCl_3) δ : 210.7, 158.4, 130.8, 129.4, 113.8, 56.5, 55.2, 42.2, 35.3, 27.9, 25.4.



3ao

2-(4-(tert-butyl)phenyl)cyclohexan-1-one (3ao)³

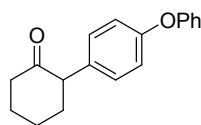
White solid. R_F : 0.40 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.36 (d, $J = 7.8$ Hz, 2H), 7.08 (d, $J = 8.0$ Hz, 2H), 3.65-3.54 (m, 1H), 2.57-2.42 (m, 2H), 2.31-2.13 (m, 2H), 2.03 (dd, $J = 18.7, 6.7$ Hz, 2H), 1.88-1.77 (m, 2H), 1.32 (s, 9H); ^{13}C NMR (101 MHz, CDCl_3) δ : 210.7, 149.6, 135.7, 128.2, 125.4, 57.0, 42.3, 35.2, 34.5, 31.5, 28.0, 25.4.



3ap

2-(p-tolyl)cyclohexan-1-one (3ap)³

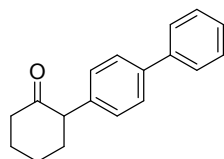
Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.15 (d, $J = 7.9$ Hz, 2H), 7.04 (d, $J = 8.0$ Hz, 2H), 3.58 (dd, $J = 12.1, 5.4$ Hz, 1H), 2.57-2.39 (m, 2H), 2.34 (s, 3H), 2.31-2.11 (m, 2H), 2.10-1.94 (m, 2H), 1.94-1.74 (m, 2H); ^{13}C NMR (126 MHz, CDCl_3) δ : 210.4, 136.4, 135.7, 129.0, 128.3, 57.0, 42.1, 35.0, 27.8, 25.3, 21.0



3aq

2-(4-phenoxyphenyl)cyclohexan-1-one (*3aq*)

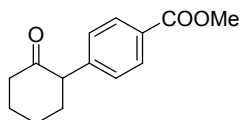
Colorless oil. R_F : 0.50 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 35:1). $^1\text{H NMR}$ (400 MHz, CDCl_3) δ : 7.45-7.28 (m, 2H), 7.18-6.92 (m, 7H), 3.59 (dd, $J = 12.2, 5.5$ Hz, 1H), 2.61-2.38 (m, 2H), 2.35-2.11 (m, 2H), 2.06-1.91 (m, 2H), 1.89-1.74 (m, 2H); $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ : 210.4, 157.2, 156.1, 133.5, 129.7, 129.7, 123.2, 119.0, 118.6, 56.7, 42.2, 35.4, 27.9, 25.4. HRMS (ESI): m/z $[\text{M}+\text{H}]^+$ calcd. for $[\text{C}_{18}\text{H}_{19}\text{O}_2]^+$: 267.1380, found: 267.1380.



3ar

2-([1,1'-biphenyl]-4-yl)cyclohexan-1-one (*3ar*)¹¹

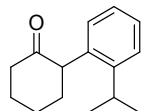
White solid. R_F : 0.55 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 35:1). $^1\text{H NMR}$ (500 MHz, CDCl_3) δ : 7.61-7.55 (m, 4H), 7.43 (t, $J = 7.7$ Hz, 2H), 7.34 (t, $J = 7.4$ Hz, 1H), 7.22 (d, $J = 8.2$ Hz, 2H), 3.67 (dd, $J = 12.3, 5.4$ Hz, 1H), 2.59-2.46 (m, 2H), 2.36-2.29 (m, 1H), 2.22-2.15 (m, 1H), 2.11-2.02 (m, 2H), 1.90-1.82 (m, 2H); $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ : 210.4, 141.0, 139.8, 137.8, 128.9, 128.7, 127.1, 127.1, 57.1, 42.2, 35.2, 27.8, 25.4.



3as

methyl 4-(2-oxocyclohexyl)benzoate (*3as*)⁶

Colorless oil. R_F : 0.43 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). $^1\text{H NMR}$ (400 MHz, CDCl_3) δ : 8.00 (d, $J = 8.3$ Hz, 2H), 7.21 (d, $J = 8.3$ Hz, 2H), 3.90 (s, 3H), 3.67 (dd, $J = 12.3, 5.5$ Hz, 1H), 2.57-2.42 (m, 2H), 2.31-2.14 (m, 2H), 2.08-1.97 (m, 2H), 1.90-1.79 (m, 2H); $^{13}\text{C NMR}$ (101 MHz, CDCl_3) δ : 209.4, 166.9, 144.0, 129.6, 128.7, 128.6, 57.4, 52.0, 42.2, 35.0, 27.7, 25.3.

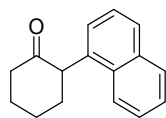


3at

2-(2-isopropylphenyl)cyclohexan-1-one (*3at*)

Colorless oil. R_F : 0.40 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). $^1\text{H NMR}$ (400 MHz, CDCl_3) δ : 7.33 (dd, $J = 7.7, 1.3$ Hz, 1H), 7.31-7.25 (m, 1H), 7.25-7.18 (m, 1H), 7.14 (d, $J = 7.6$ Hz, 1H), 3.92 (dd, $J = 12.7, 5.4$ Hz, 1H), 3.00-2.84 (m, 1H), 2.67-2.45 (m, 2H), 2.37-2.17 (m, 2H), 2.19-2.01 (m, 2H), 1.97-1.80 (m, 2H), 1.32-1.15 (m, 6H); $^{13}\text{C NMR}$ (126 MHz, CDCl_3) δ : 210.2, 146.4,

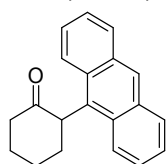
136.0, 128.3, 127.1, 125.6, 125.3, 53.2, 42.5, 35.3, 29.3, 27.6, 25.9, 24.0, 23.8. HRMS (ESI): m/z $[M+H]^+$ calcd. for $[C_{15}H_{21}O]^+$: 217.1587, found: 217.1584.



3au

2-(naphthalen-1-yl)cyclohexan-1-one (**3au**)¹²

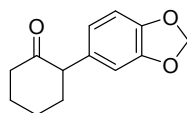
White solid. R_F : 0.39 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). 1H NMR (400 MHz, $CDCl_3$) δ : 7.90-7.84 (m, 1H), 7.78 (d, $J = 8.2$ Hz, 1H), 7.75-7.68 (m, 1H), 7.51-7.42 (m, 3H), 7.36 (d, $J = 7.1$ Hz, 1H), 4.36 (dd, $J = 12.5, 5.3$ Hz, 1H), 2.71-2.60 (m, 2H), 2.47-2.38 (m, 1H), 2.36-2.23 (m, 2H), 2.18-2.10 (m, 1H), 2.02-1.88 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ : 210.0, 135.2, 133.8, 131.8, 129.0, 127.6, 125.9, 125.3, 125.3, 123.2, 53.3, 42.6, 34.3, 27.9, 25.9.



3av

2-(anthracen-9-yl)cyclohexan-1-one (**3av**)³

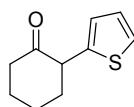
White solid. R_F : 0.55 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 35:1). 1H NMR (400 MHz, $CDCl_3$) δ : 8.42 (s, 1H), 8.11-7.98 (m, 2H), 7.98-7.82 (m, 2H), 7.56-7.37 (m, 4H), 4.88 (dd, $J = 12.3, 6.7$ Hz, 1H), 2.98-2.77 (m, 1H), 2.80-2.46 (m, 2H), 2.41-2.28 (m, 2H), 2.26-2.10 (m, 2H), 2.08-1.86 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ : 209.3, 132.5, 132.0, 130.0, 129.5, 127.5, 125.5, 124.6, 51.3, 41.9, 33.4, 25.7, 25.5.



3aw

2-(benzo[d][1,3]dioxol-5-yl)cyclohexan-1-one (**3aw**)³

Colorless oil. R_F : 0.40 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). 1H NMR (400 MHz, $CDCl_3$) δ : 6.77 (d, $J = 7.9$ Hz, 1H), 6.64 (d, $J = 1.4$ Hz, 1H), 6.58 (dd, $J = 7.9, 1.4$ Hz, 1H), 5.93 (s, 2H), 3.53 (dd, $J = 12.0, 5.3$ Hz, 1H), 2.59-2.38 (m, 2H), 2.30-2.08 (m, 2H), 2.03-1.92 (m, 2H), 1.88-1.75 (m, 2H); ^{13}C NMR (126 MHz, $CDCl_3$) δ : 210.5, 147.7, 146.5, 132.7, 121.6, 109.1, 108.3, 101.0, 57.2, 42.3, 35.5, 27.9, 25.5.

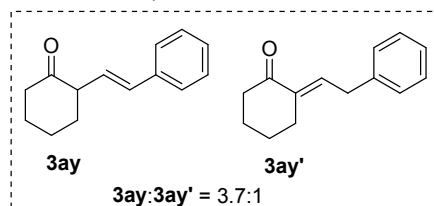


3ax

2-(thiophen-2-yl)cyclohexan-1-one (**3ax**)¹⁰

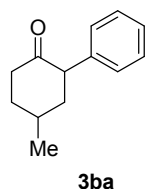
Colorless oil. R_F : 0.30 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 20:1). 1H NMR (400 MHz, $CDCl_3$) δ :

7.24 (d, $J = 5.1$ Hz, 1H), 6.99-6.90 (m, 1H), 6.86 (d, $J = 3.2$ Hz, 1H), 3.92 (dd, $J = 11.1, 5.4$ Hz, 1H), 2.60-2.53 (m, 1H), 2.50-2.36 (m, 2H), 2.18-1.92 (m, 3H), 1.94-1.73 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 208.9, 141.1, 126.5, 125.1, 124.4, 52.0, 41.6, 36.2, 27.7, 25.0.



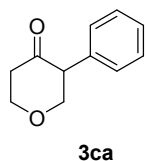
(E)-2-styrylcyclohexanone (3ay) and (E)-2-(2-phenylethylidene)cyclohexanone (3ay') as a mixture (3ay:3ay' = 3.7:1)

White solid. R_F : 0.65 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 40:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.38 (d, $J = 7.5$ Hz, 7.4H), 7.32-7.15 (m, 16.1H), 6.78 (t, $J = 7.6$ Hz, 1H), 6.47-6.35 (m, 7.4H), 3.45 (d, $J = 7.6$ Hz, 2H), 3.19 (dt, $J = 10.4, 6.4$ Hz, 3.7H), 2.61 (t, $J = 6.0$ Hz, 2H), 2.50-2.43 (m, 5.7H), 2.40-2.32 (m, 3.7H), 2.22-2.16 (m, 3.7H), 2.09-2.03 (m, 3.7H), 1.97-1.85 (m, 6.7H), 1.82-1.72 (m, 12.1H); ^{13}C NMR (101 MHz, CDCl_3) δ : 211.2, 137.1, 136.6, 131.4, 128.6, 128.5, 127.5, 127.3, 126.3, 126.3, 54.0, 41.7, 40.2, 34.4, 33.9, 27.6, 26.8, 24.4, 23.6, 23.3.



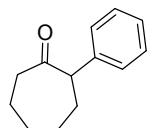
4-methyl-2-phenylcyclohexan-1-one (3ba)

Colorless oil. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.37-7.29 (m, 2H), 7.28-7.21 (m, 1H), 7.15-7.07 (m, 2H), 3.64 (dt, $J = 13.4, 4.5$ Hz, 1H), 2.59-2.45 (m, 2H), 2.26-2.04 (m, 3H), 1.80-1.66 (m, 1H), 1.62-1.46 (m, 1H), 1.11-1.01 (m, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ : 210.3, 138.8, 128.7, 128.3, 126.9, 56.7, 43.7, 41.6, 35.7, 32.4, 21.3. HRMS (ESI): m/z $[\text{M}+\text{H}]^+$ calcd. for $[\text{C}_{13}\text{H}_{17}\text{O}]^+$: 189.1274, found: 189.1289.



3-phenyltetrahydro-4H-pyran-4-one (3ca)¹³

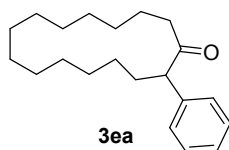
White solid. R_F : 0.25 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 20:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.35 (t, $J = 7.4$ Hz, 2H), 7.32-7.27 (m, 1H), 7.27-7.21 (m, 2H), 4.30-4.20 (m, 2H), 4.03-3.93 (m, 2H), 3.79 (dd, $J = 8.7, 6.1$ Hz, 1H), 2.71-2.63 (m, 1H), 2.63-2.54 (m, 1H); ^{13}C NMR (126 MHz, CDCl_3) δ : 205.7, 134.9, 128.9, 128.6, 127.5, 73.1, 68.5, 58.0, 41.9.



3da

2-phenylcycloheptan-1-one (3da)¹⁴

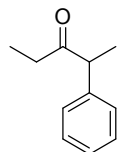
White solid. R_F : 0.50 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 30:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.34-7.28 (m, 2H), 7.27-7.19 (m, 3H), 3.80-3.65 (m, 1H), 2.69 (t, $J = 12.7$ Hz, 1H), 2.52 (d, $J = 12.1$ Hz, 1H), 2.21-2.09 (m, 1H), 2.08-1.90 (m, 4H), 1.71-1.55 (m, 1H), 1.53-1.40 (m, 2H); ^{13}C NMR (126 MHz, CDCl_3) δ : 213.4, 140.4, 128.5, 127.8, 126.9, 58.8, 42.7, 32.0, 30.0, 28.5, 25.3.



3ea

2-phenylcyclopentadecan-1-one (3ea)¹⁵

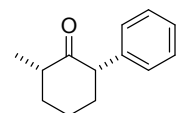
Colorless oil. R_F : 0.40 in 20% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 45:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.38-7.16 (m, 5H), 3.77 (dd, $J = 9.3, 5.3$ Hz, 1H), 2.55-2.38 (m, 1H), 2.33-2.13 (m, 2H), 1.78-1.66 (m, 1H), 1.66-1.50 (m, 3H), 1.42-1.19 (m, 19H); ^{13}C NMR (101 MHz, CDCl_3) δ : 211.9, 139.5, 128.8, 128.2, 127.1, 58.1, 41.6, 32.3, 27.6, 27.1, 26.9, 26.9, 26.5, 26.5, 26.3, 23.6.



3fa

2-phenylpentan-3-one (3fa)¹⁶

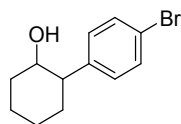
Colorless oil. R_F : 0.50 in 20% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 50:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.35-7.29 (m, 2H), 7.27-7.24 (m, 1H), 7.24-7.19 (m, 2H), 3.81-3.71 (m, 1H), 2.45-2.28 (m, 2H), 1.39 (d, $J = 7.0$ Hz, 3H), 0.97 (t, $J = 7.3$ Hz, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ : 211.5, 140.9, 128.8, 127.8, 127.0, 52.7, 34.2, 17.5, 7.9.



3ha (*cis:trans* 5: 1)

***cis*-2-methyl-6-phenylcyclohexanone (3ha)**

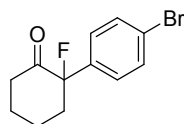
Colorless oil. R_F : 0.43 in 15% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.36-7.29 (m, 2H), 7.26-7.22 (m, 1H), 7.15-7.11 (m, 2H), 3.62 (dd, $J = 12.4, 5.1$ Hz, 1H), 2.64-2.53 (m, 1H), 2.33-2.16 (m, 2H), 2.03-1.86 (m, 3H), 1.56-1.46 (m, 1H), 1.06 (d, $J = 6.5$ Hz, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ : 211.2, 138.8, 128.7, 128.2, 126.8, 57.7, 45.8, 37.2, 36.3, 25.8, 14.7. HRMS (ESI): m/z $[\text{M}+\text{H}]^+$ calcd. for $[\text{C}_{13}\text{H}_{17}\text{O}]^+$: 189.1274, found: 189.1295.



4

2-(4-bromophenyl)cyclohexan-1-ol (4)⁴

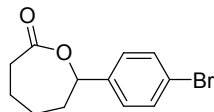
White solid. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.48-7.42 (m, 2H), 7.16-7.11 (m, 2H), 3.69-3.54 (m, 1H), 2.46-2.33 (m, 1H), 2.14-2.04 (m, 1H), 1.91-1.70 (m, 3H), 1.61-1.22 (m, 5H); ^{13}C NMR (101 MHz, CDCl_3) δ : 142.5, 131.7, 129.6, 120.4, 74.2, 52.6, 34.6, 33.3, 25.9, 25.0.



5

2-(4-bromophenyl)-2-fluorocyclohexan-1-one (5)⁴

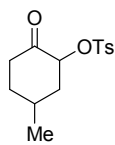
White solid. R_F : 0.48 in 20% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 30:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.53 (d, $J = 8.1$ Hz, 2H), 7.24 (d, $J = 7.9$ Hz, 2H), 2.87-2.72 (m, 1H), 2.51-2.27 (m, 3H), 2.13-1.97 (m, 2H), 1.93-1.75 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 205.6 (d, $J = 23.5$ Hz), 135.5 (d, $J = 22.0$ Hz), 131.6, 127.9 (d, $J = 7.1$ Hz), 123.1 (d, $J = 2.7$ Hz), 97.8 (d, $J = 183.3$ Hz), 39.6, 38.4 (d, $J = 22.8$ Hz), 27.4, 21.7 (d, $J = 5.8$ Hz); ^{19}F NMR (376 MHz, CDCl_3) δ : -146.45.



6

7-(4-bromophenyl)oxepan-2-one (6)¹⁷

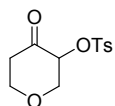
White solid. R_F : 0.36 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 20:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.44-7.40 (m, 2H), 7.22-7.18 (m, 2H), 5.20 (d, $J = 9.4$ Hz, 1H), 2.81-2.71 (m, 2H), 2.11-1.95 (m, 4H), 1.82-1.68 (m, 2H); ^{13}C NMR (101 MHz, CDCl_3) δ : 174.5, 139.8, 131.6, 127.5, 121.9, 81.2, 37.5, 34.9, 28.5, 22.7.



1b

5-methyl-2-oxocyclohexyl 4-methylbenzenesulfonate (1b)

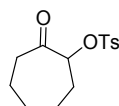
Colorless liquid. R_F : 0.20 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 10:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.83 (d, $J = 8.2$ Hz, 2H), 7.32 (d, $J = 8.1$ Hz, 2H), 5.01 (dd, $J = 12.6, 6.5$ Hz, 1H), 2.53-2.26 (m, 6H), 2.16-1.92 (m, 2H), 1.77-1.53 (m, 1H), 1.45-1.20 (m, 1H), 1.12-0.95 (m, 3H); ^{13}C NMR (126 MHz, CDCl_3) δ : 202.4, 144.8, 133.8, 129.7, 127.9, 80.7, 42.3, 39.7, 34.6, 31.0, 21.6, 20.7. HRMS (ESI): m/z $[\text{M}+\text{H}]^+$ calcd. for $[\text{C}_{14}\text{H}_{19}\text{O}_4\text{S}]^+$: 283.0999, found: 283.0938.



1c

4-oxotetrahydro-2H-pyran-3-yl 4-methylbenzenesulfonate (*1c*)¹⁸

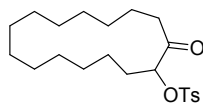
White solid. R_F : 0.20 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 10:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.84 (d, $J = 8.3$ Hz, 2H), 7.35 (d, $J = 8.1$ Hz, 2H), 4.92 (dd, $J = 9.2, 6.7$ Hz, 1H), 4.30 (ddd, $J = 11.1, 6.6, 1.3$ Hz, 1H), 4.23-4.10 (m, 1H), 3.73-3.56 (m, 2H), 2.72-2.53 (m, 2H), 2.45 (s, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ : 198.4, 145.3, 133.0, 129.8, 128.0, 77.9, 71.0, 68.2, 42.3, 21.7.



1d

2-tosylxycycloheptanone (*1d*)¹⁸

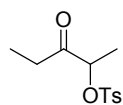
White solid. R_F : 0.20 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 10:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.83 (d, $J = 8.3$ Hz, 2H), 7.36 (d, $J = 8.2$ Hz, 2H), 5.11-4.93 (m, 1H), 2.65-2.39 (m, 5H), 1.97-1.48 (m, 8H); ^{13}C NMR (126 MHz, CDCl_3) δ : 206.3, 145.0, 133.4, 129.8, 127.9, 84.0, 40.3, 31.2, 27.8, 25.1, 22.6, 21.6.



1e

2-tosylxycyclopentadecanone (*1e*)¹⁹

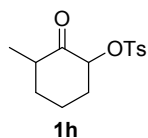
White solid. R_F : 0.30 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 15:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.80 (d, $J = 7.3$ Hz, 2H), 7.35 (d, $J = 7.5$ Hz, 2H), 4.72-4.65 (m, 1H), 2.78-2.61 (m, 1H), 2.53-2.30 (m, 4H), 1.87-1.65 (m, 3H), 1.59-1.44 (m, 1H), 1.44-1.01 (m, 20H); ^{13}C NMR (101 MHz, CDCl_3) δ : 207.5, 145.2, 133.1, 129.9, 127.9, 84.1, 37.7, 31.5, 27.3, 26.9, 26.6, 26.5, 26.5, 26.4, 26.1, 26.1, 25.9, 22.5, 21.7, 21.7.



1f

3-oxopentan-2-yl 4-methylbenzenesulfonate (*1f*)¹⁸

White solid. R_F : 0.45 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 25:1). ^1H NMR (500 MHz, CDCl_3) δ : 7.81 (d, $J = 8.0$ Hz, 2H), 7.37 (d, $J = 8.0$ Hz, 2H), 4.85-4.77 (m, 1H), 2.67-2.53 (m, 2H), 2.46 (s, 3H), 1.35 (d, $J = 7.0$ Hz, 3H), 1.02 (t, $J = 7.2$ Hz, 3H); ^{13}C NMR (126 MHz, CDCl_3) δ : 207.7, 145.3, 133.2, 130.0, 127.9, 80.7, 31.2, 21.6, 17.6, 7.0.



3-methyl-2-oxocyclohexyl 4-methylbenzenesulfonate (*1h*)

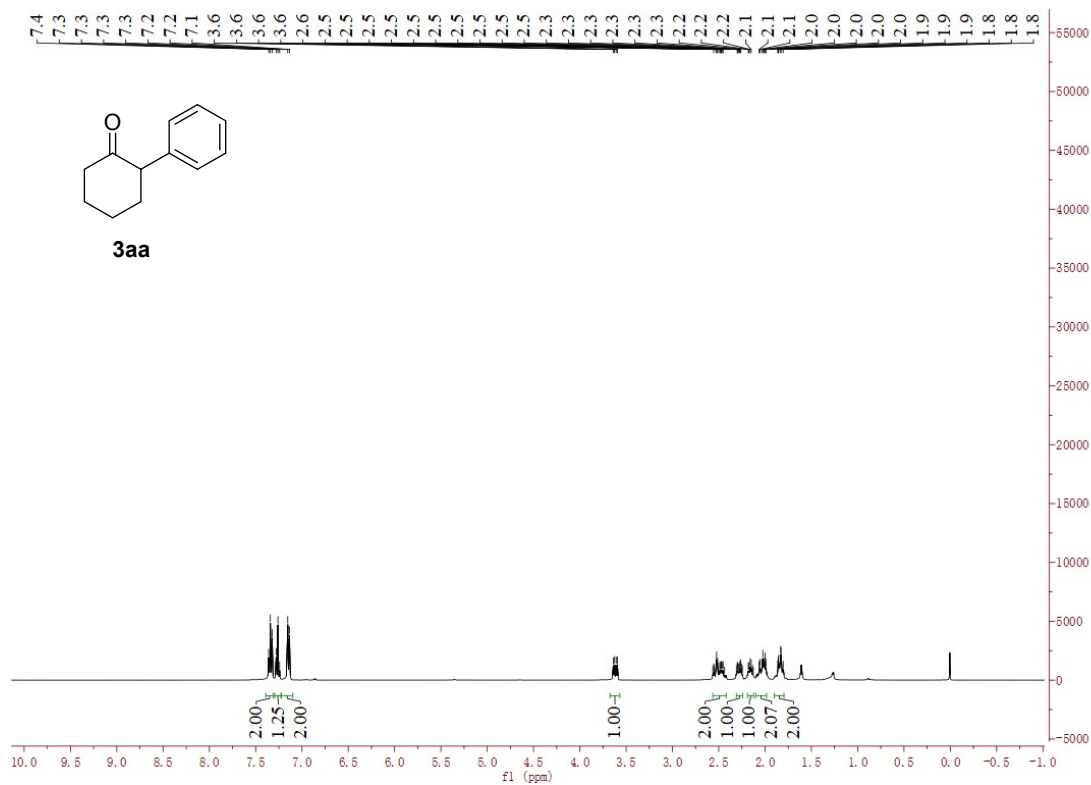
White solid. R_F : 0.18 in 10% ethyl acetate in hexane. The crude mixture was purified by column chromatography on silica gel (petroleum ether/ethyl acetate 10:1). ^1H NMR (400 MHz, CDCl_3) δ : 7.84 (d, $J = 8.3$ Hz, 2H), 7.32 (d, $J = 8.1$ Hz, 2H), 4.99 (dd, $J = 11.3, 6.7$ Hz, 1H), 2.45-2.33 (m, 5H), 2.09-2.02 (m, 1H), 1.93-1.87 (m, 1H), 1.83-1.74 (m, 2H), 1.34-1.24 (m, 1H), 1.02 (d, $J = 6.5$ Hz, 3H); ^{13}C NMR (101 MHz, CDCl_3) δ : 203.8, 144.7, 134.0, 129.6, 127.8, 81.8, 44.6, 35.6, 35.1, 23.1, 21.6, 13.8. HRMS (ESI): m/z $[\text{M}+\text{H}]^+$ calcd. for $[\text{C}_{14}\text{H}_{19}\text{O}_4\text{S}]^+$: 283.0999, found: 283.1015.

7. References

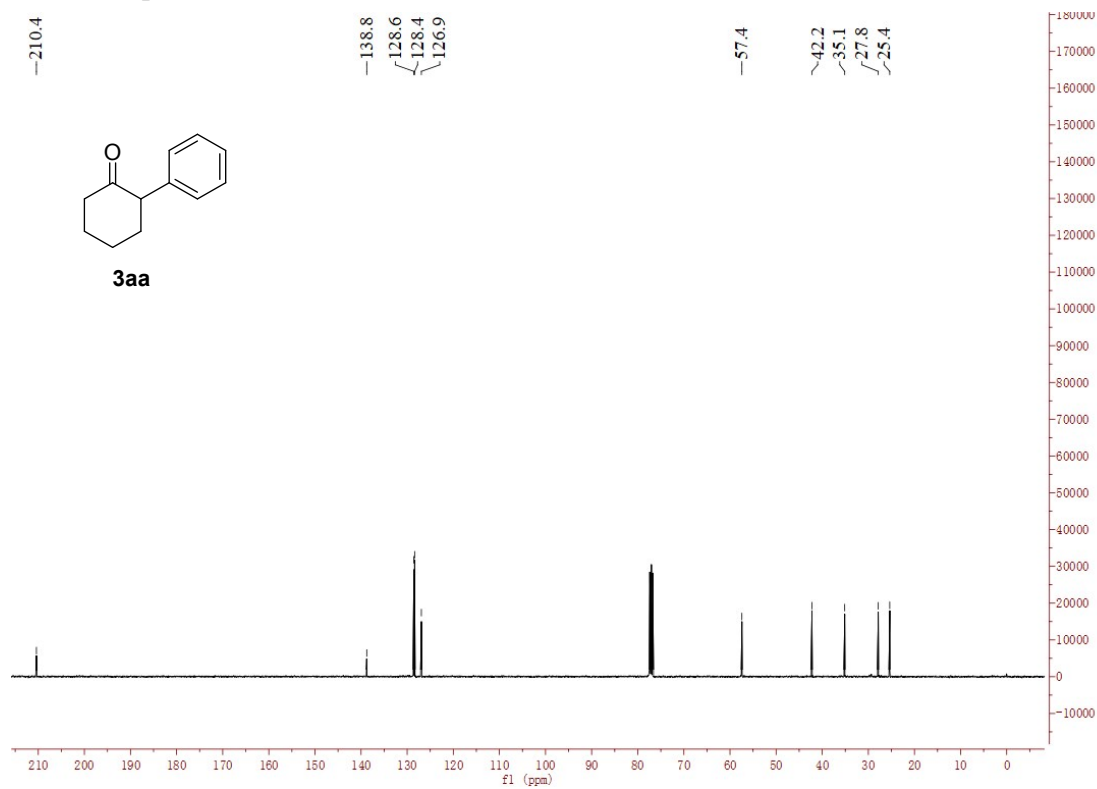
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8. Copies of ^1H and ^{13}C NMR Spectra of Substrates and Products

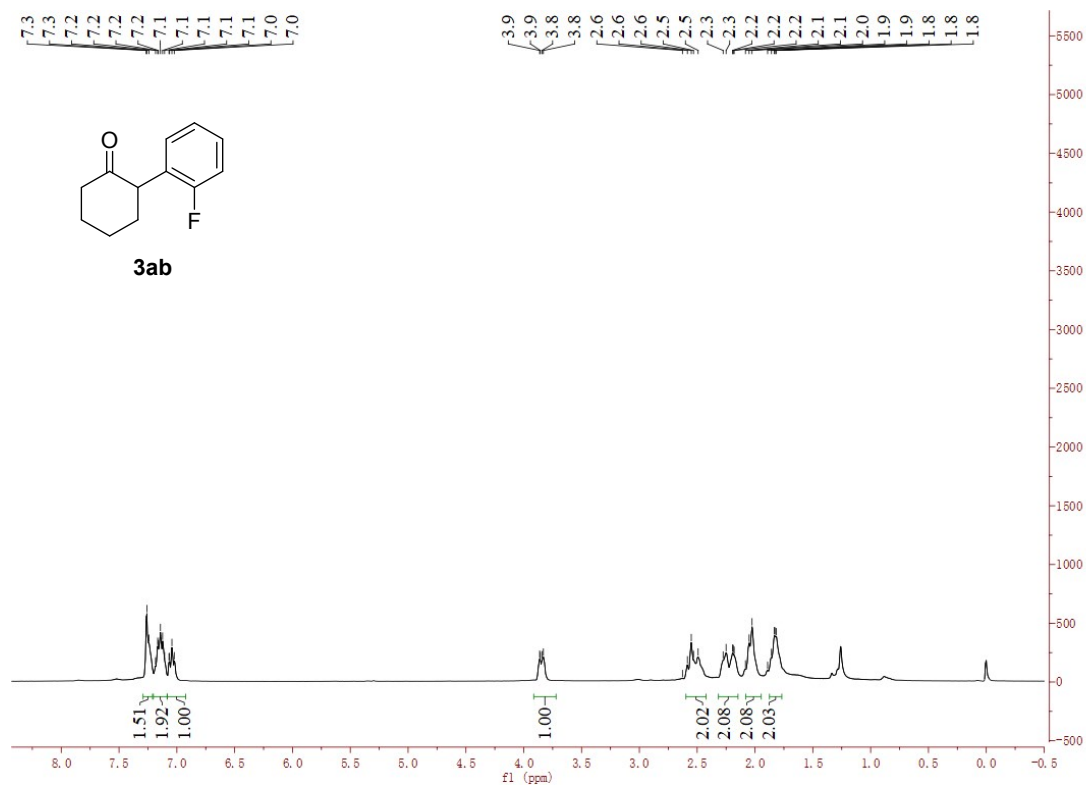
^1H NMR spectrum of 3aa in CDCl_3



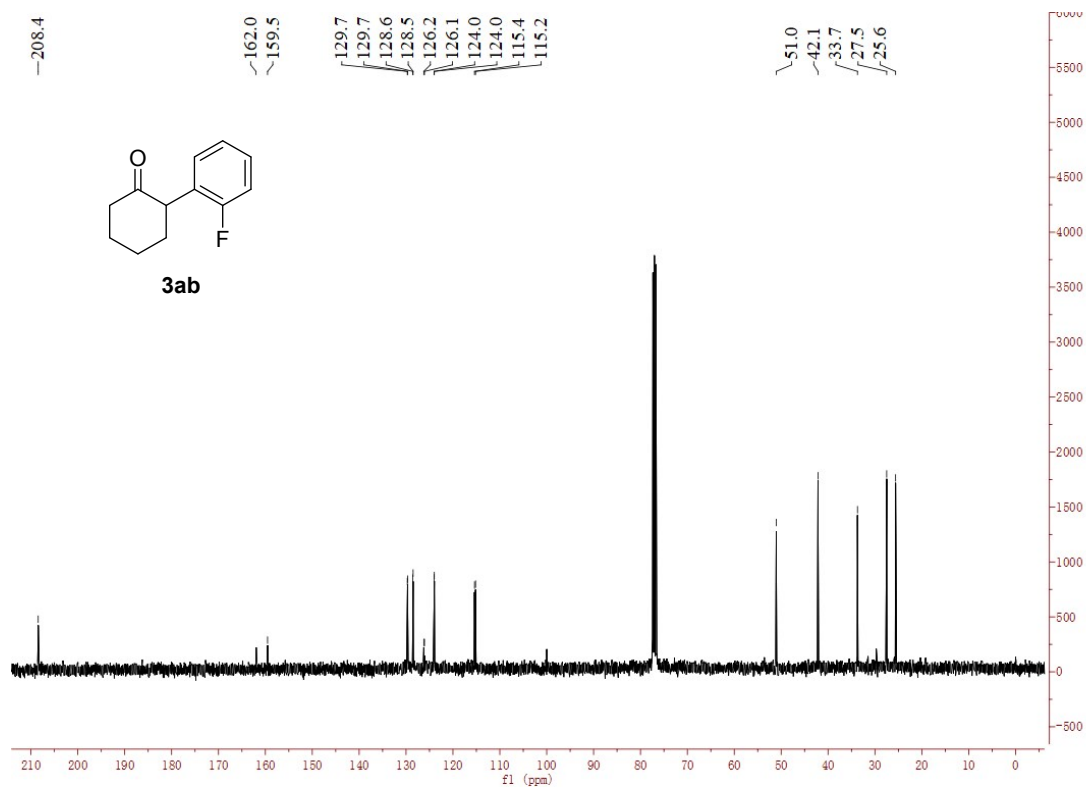
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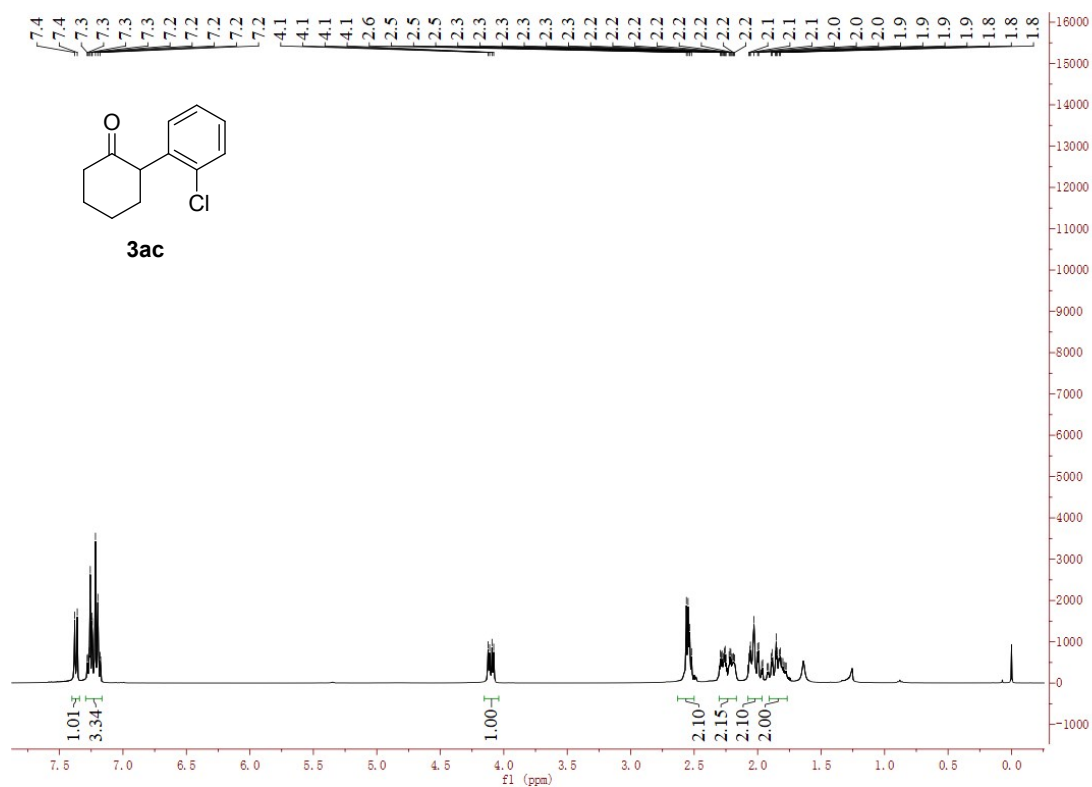
¹H NMR spectrum of 3ab in CDCl₃



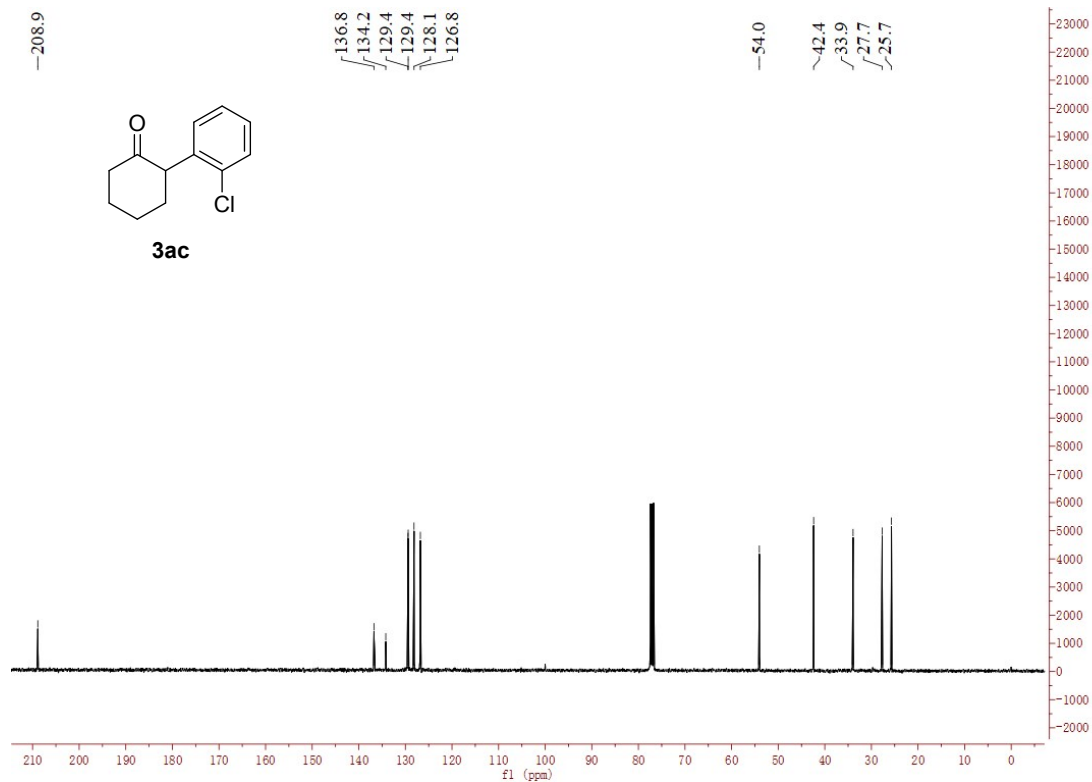
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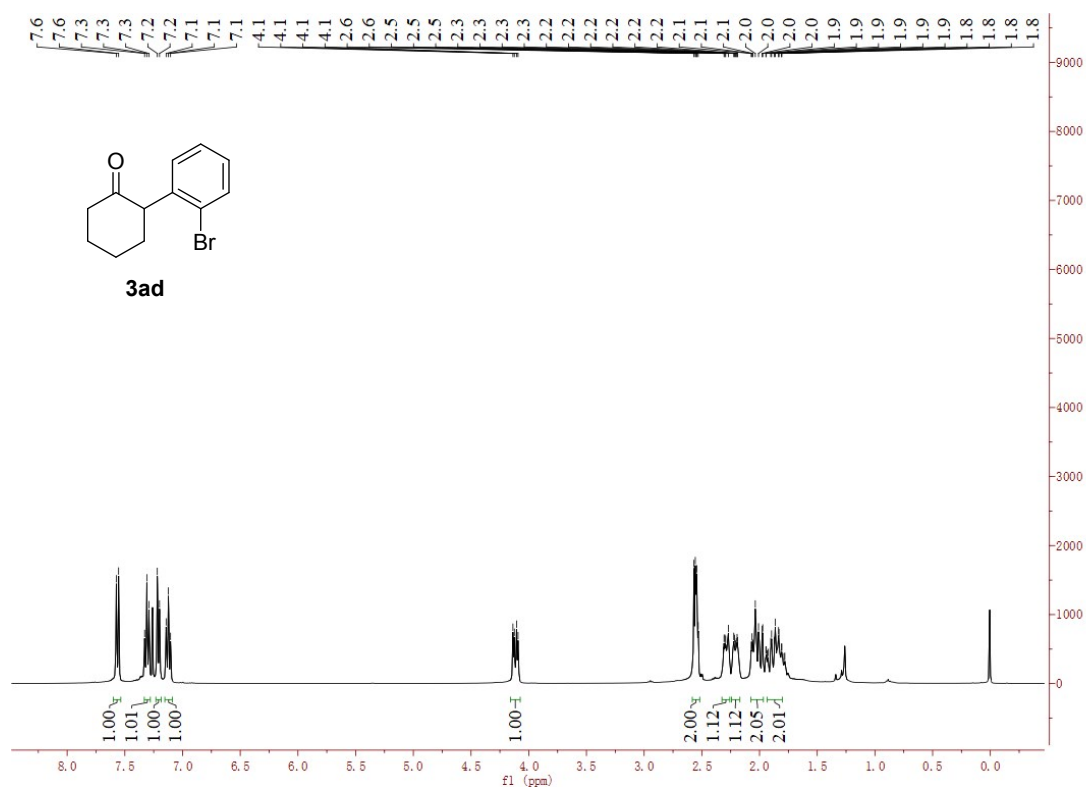
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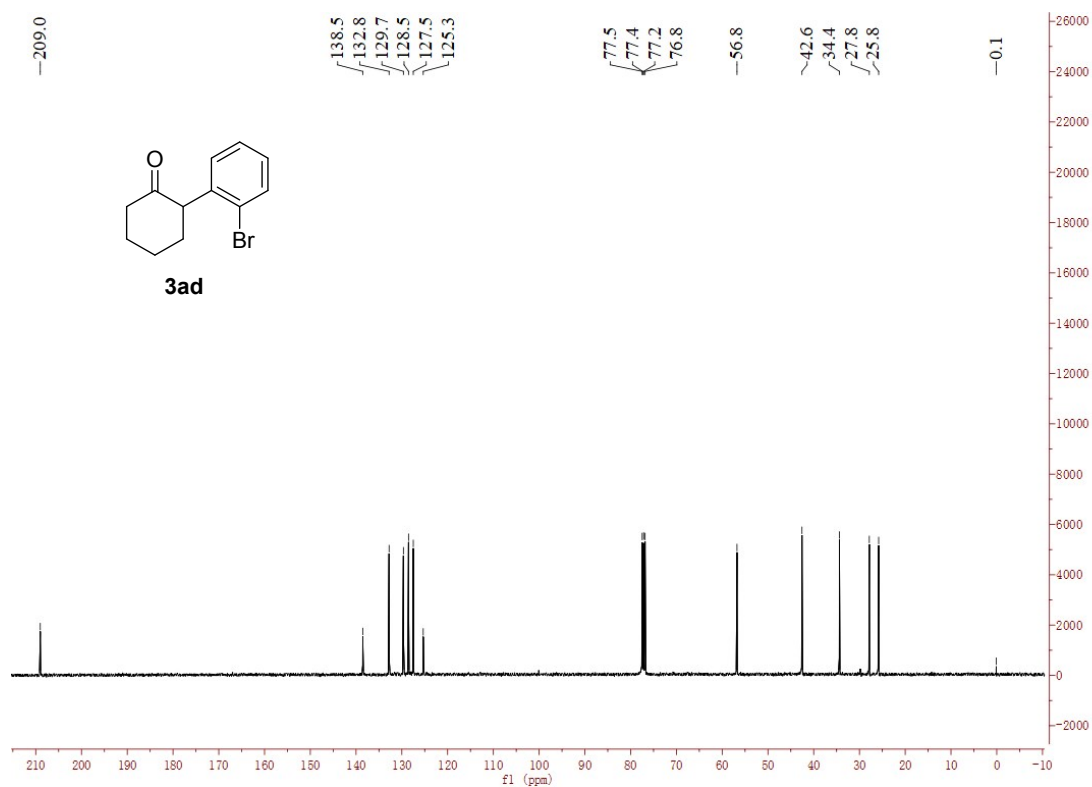
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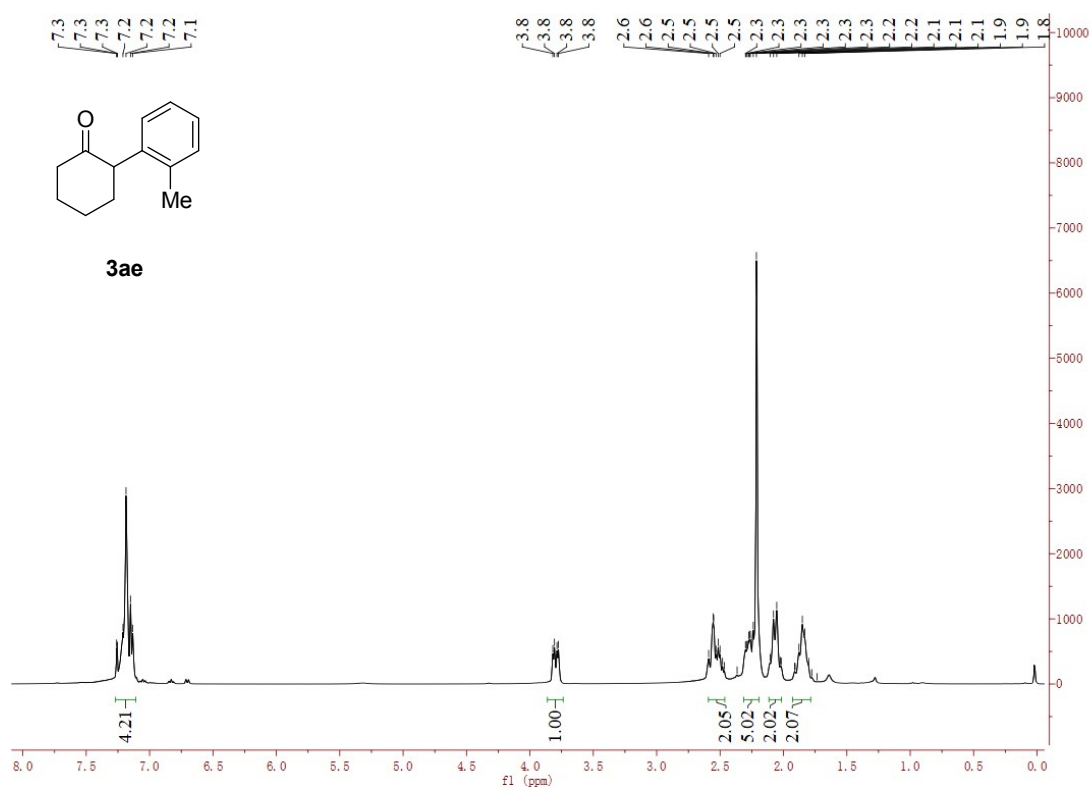
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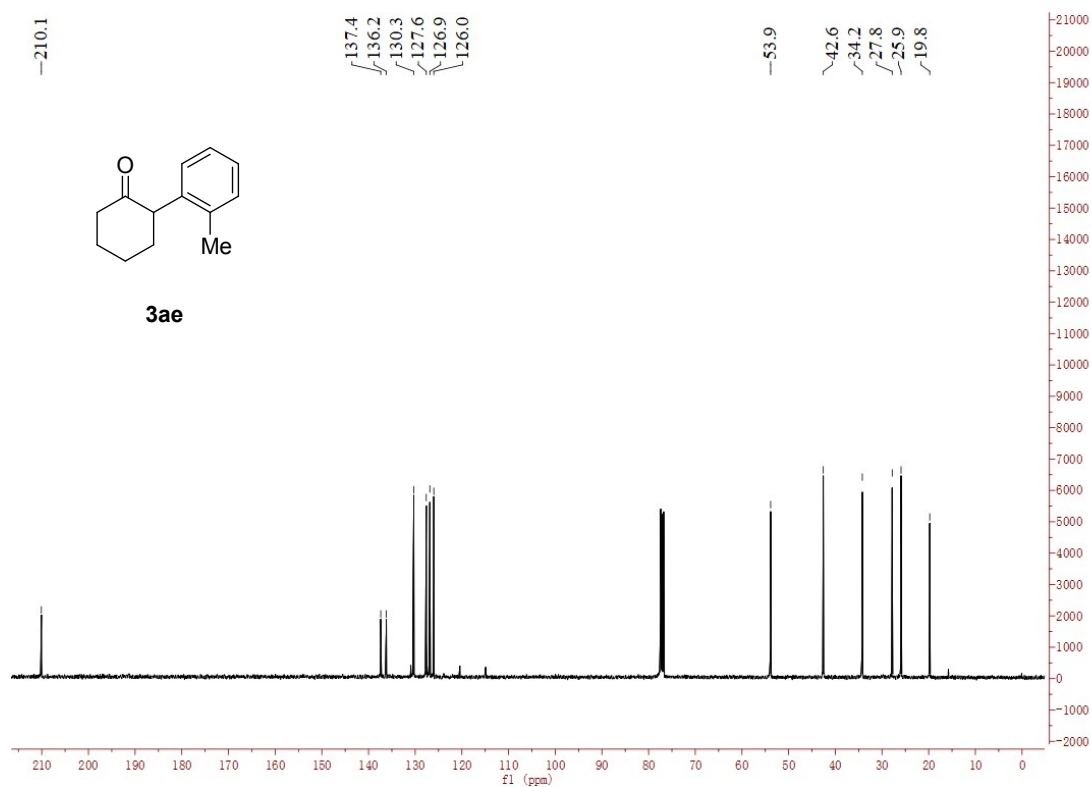
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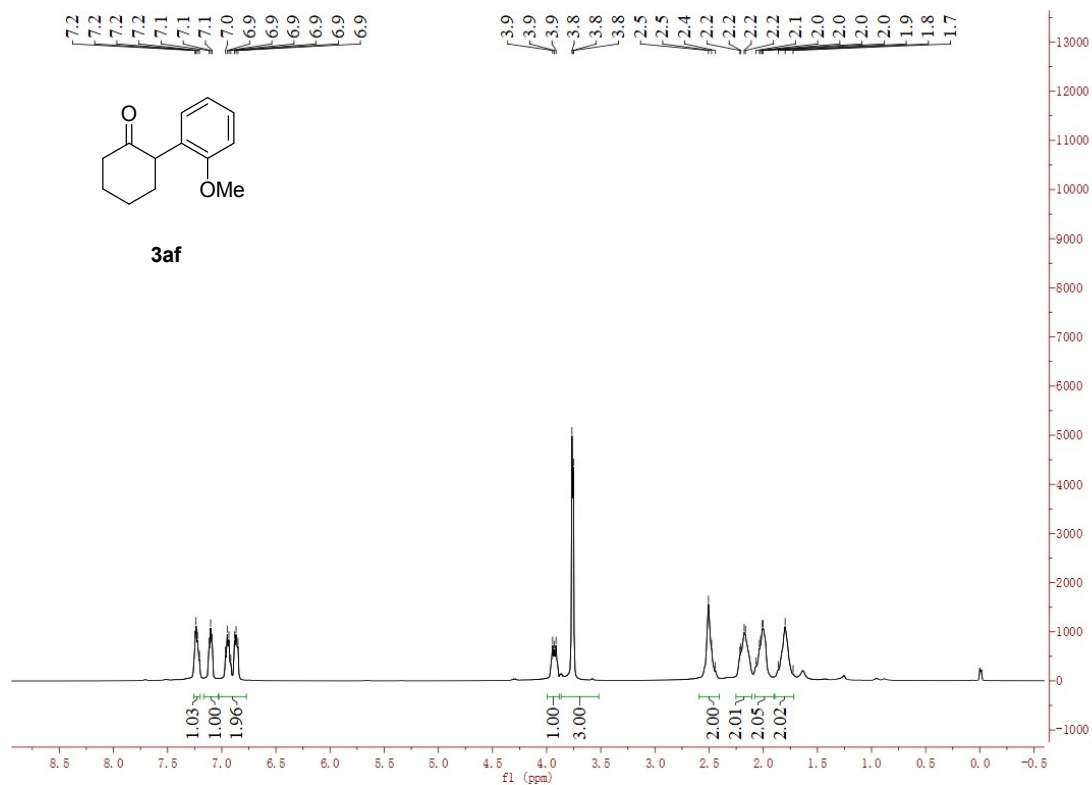
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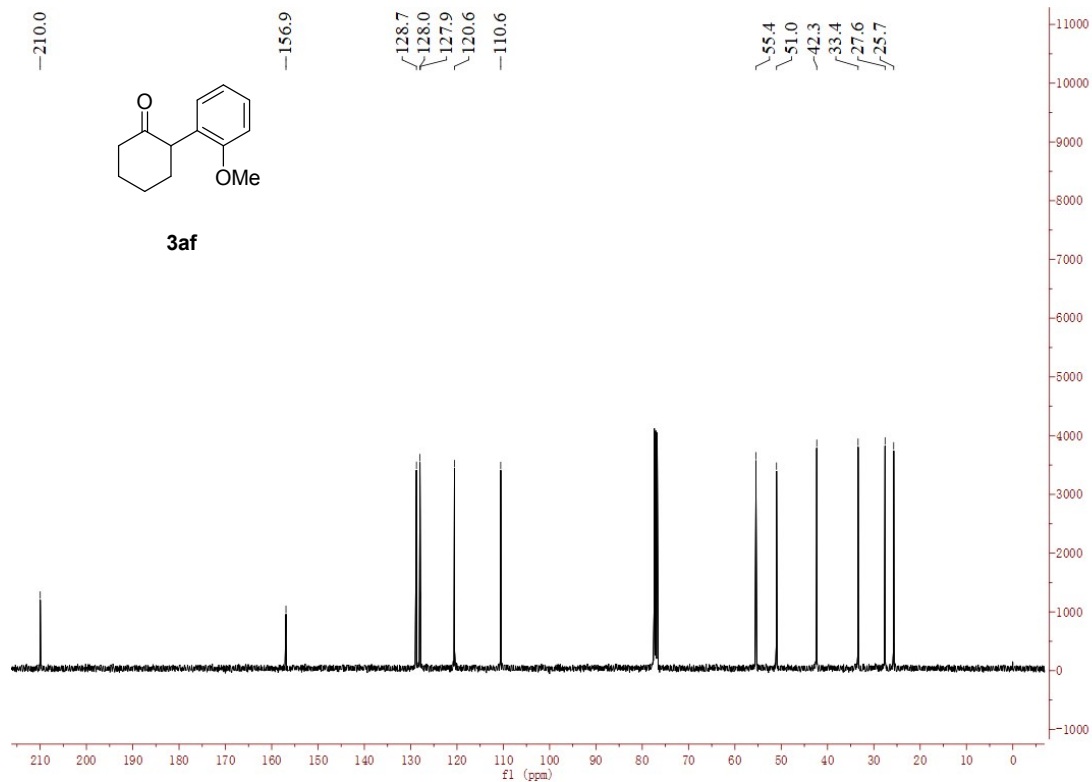
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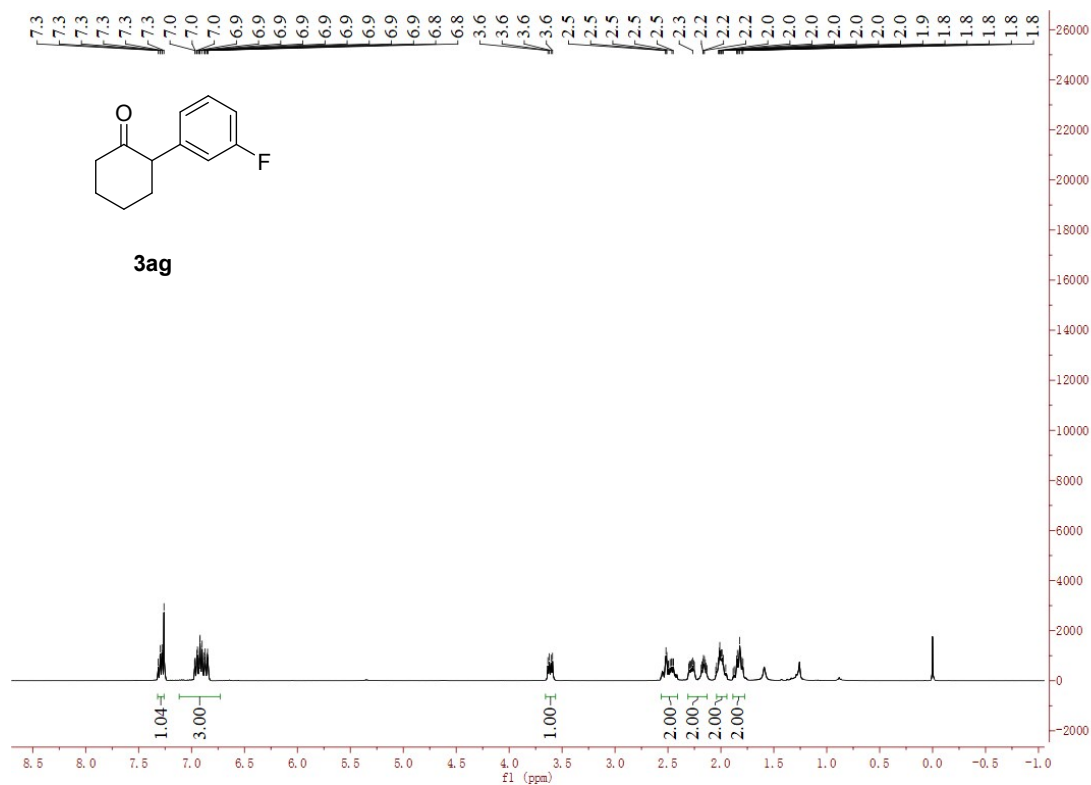
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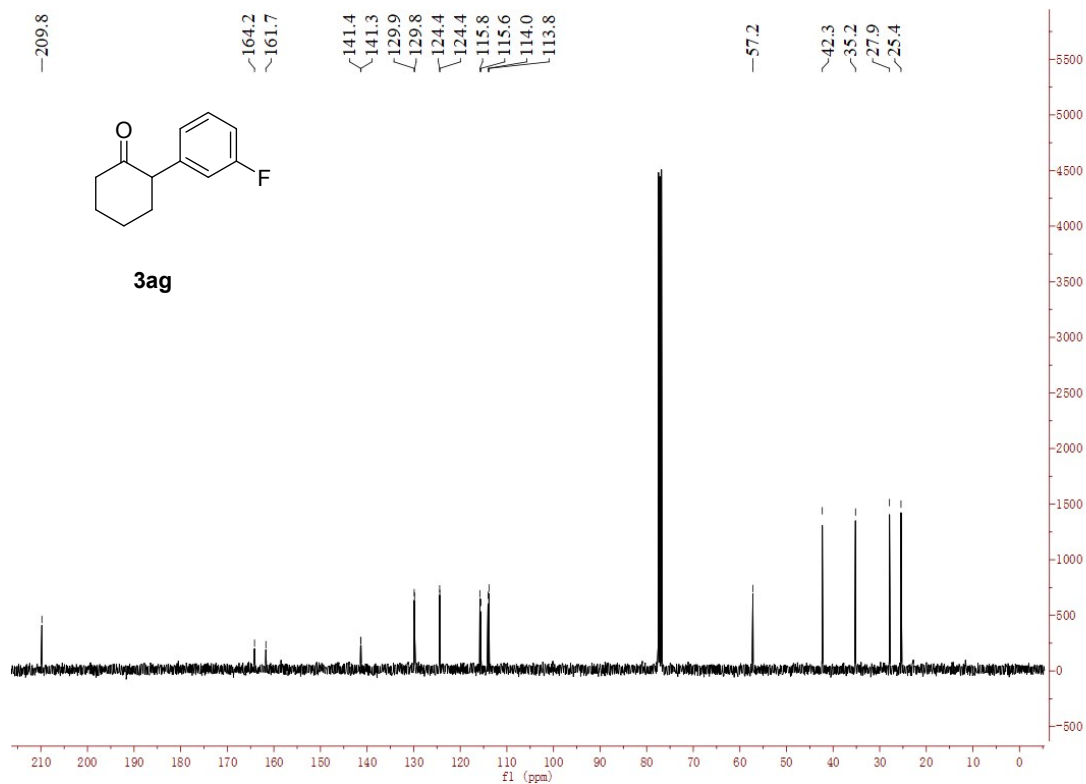
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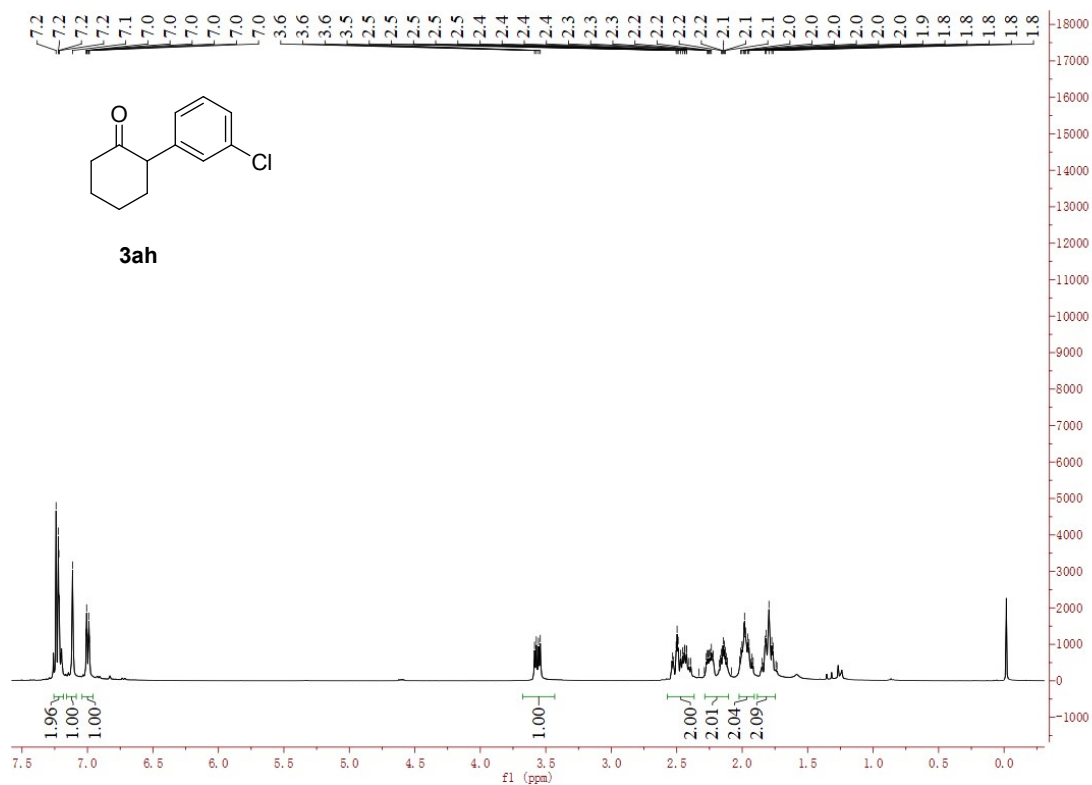
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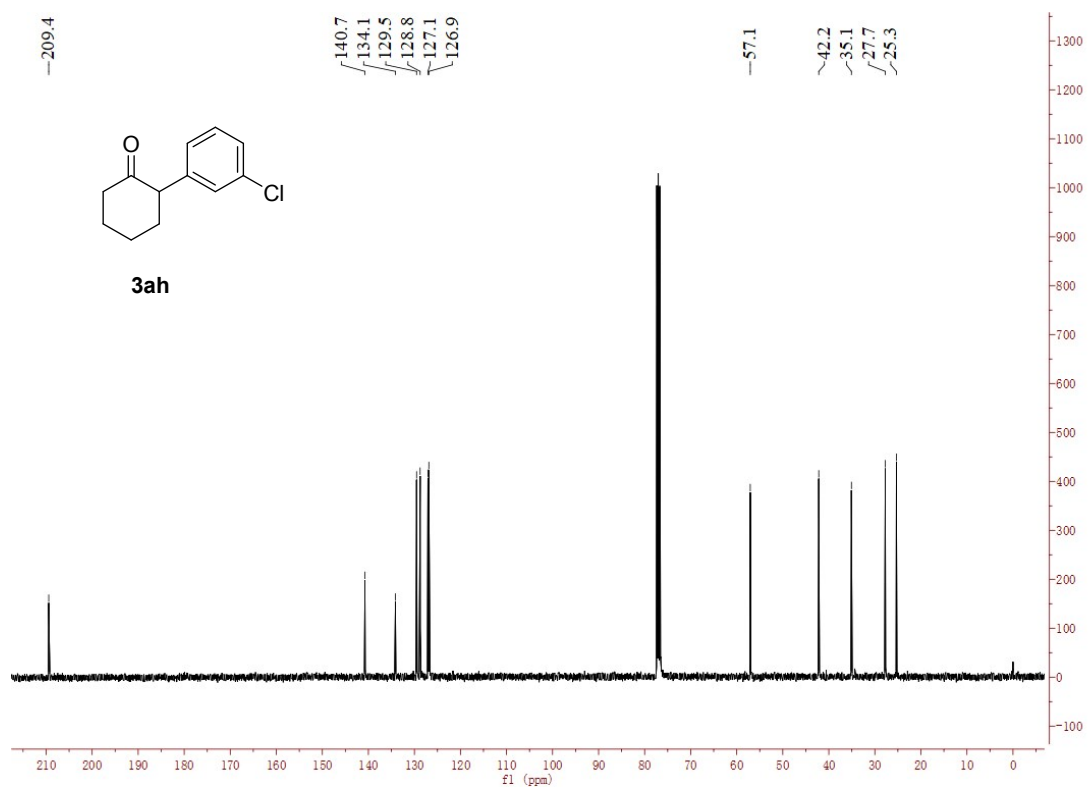
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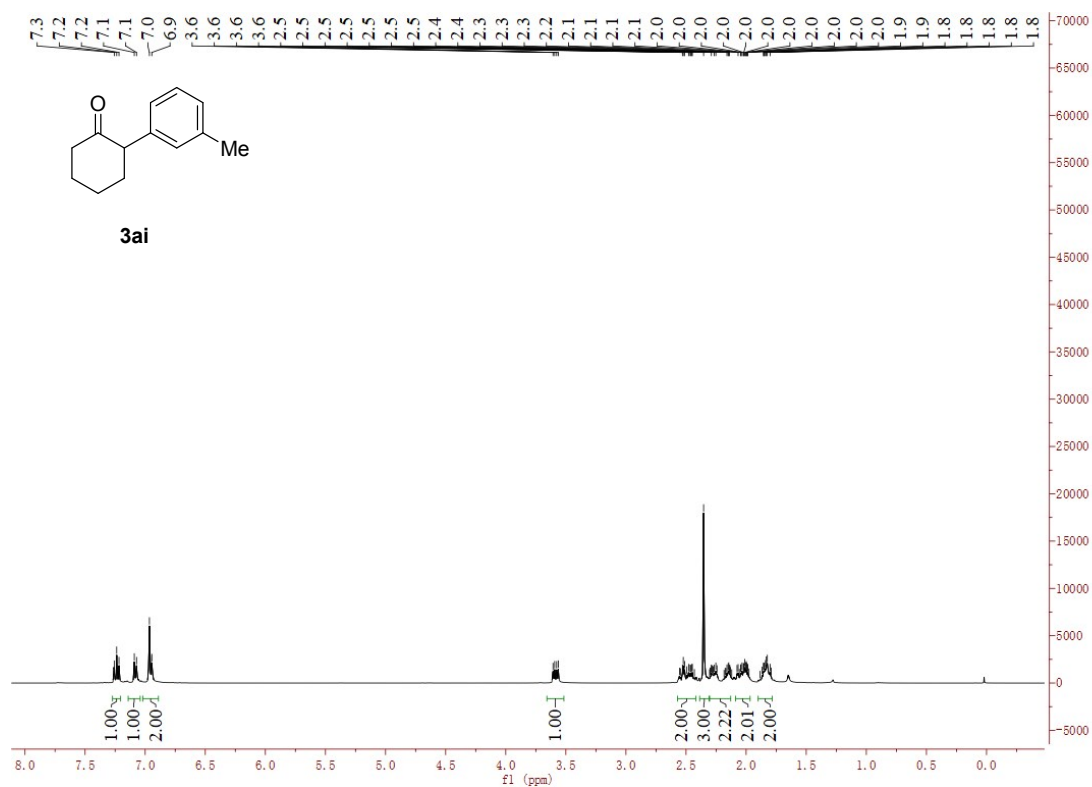
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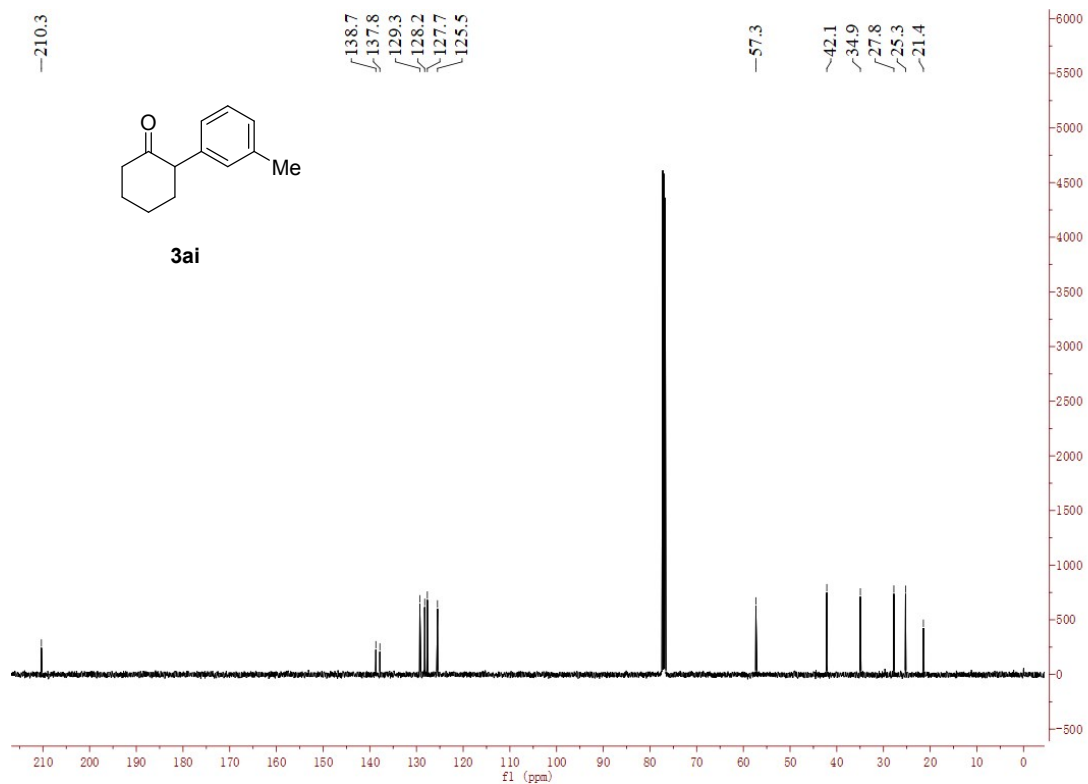
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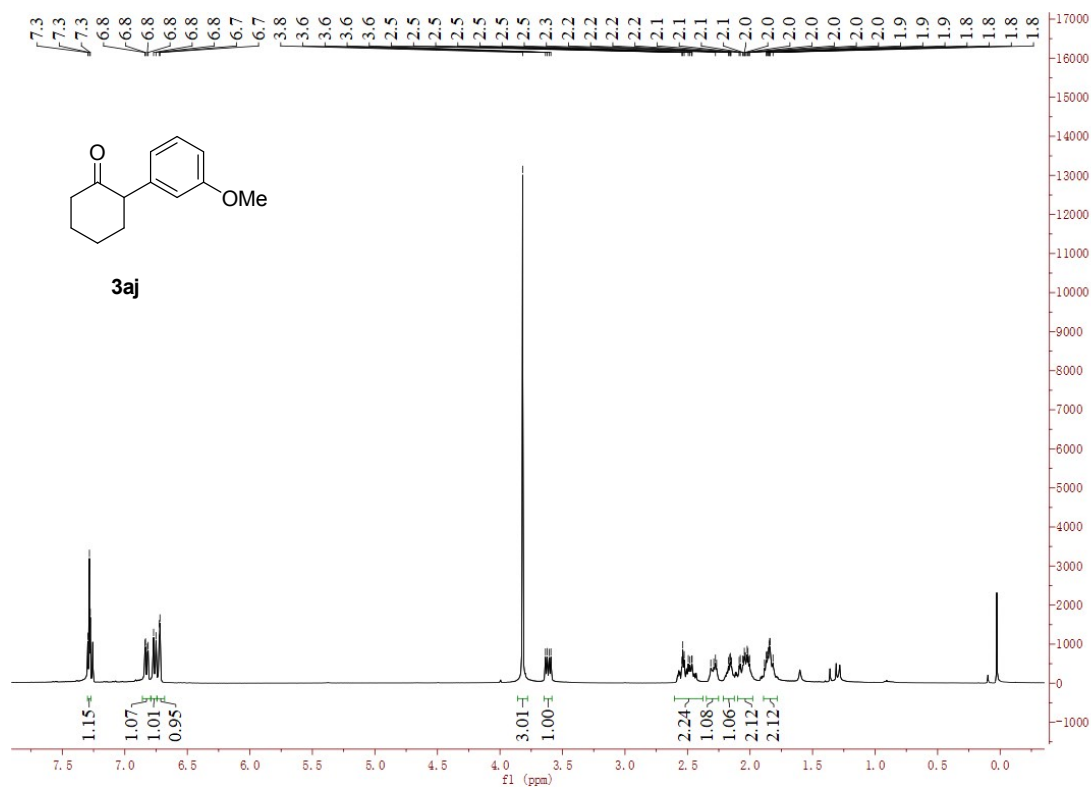
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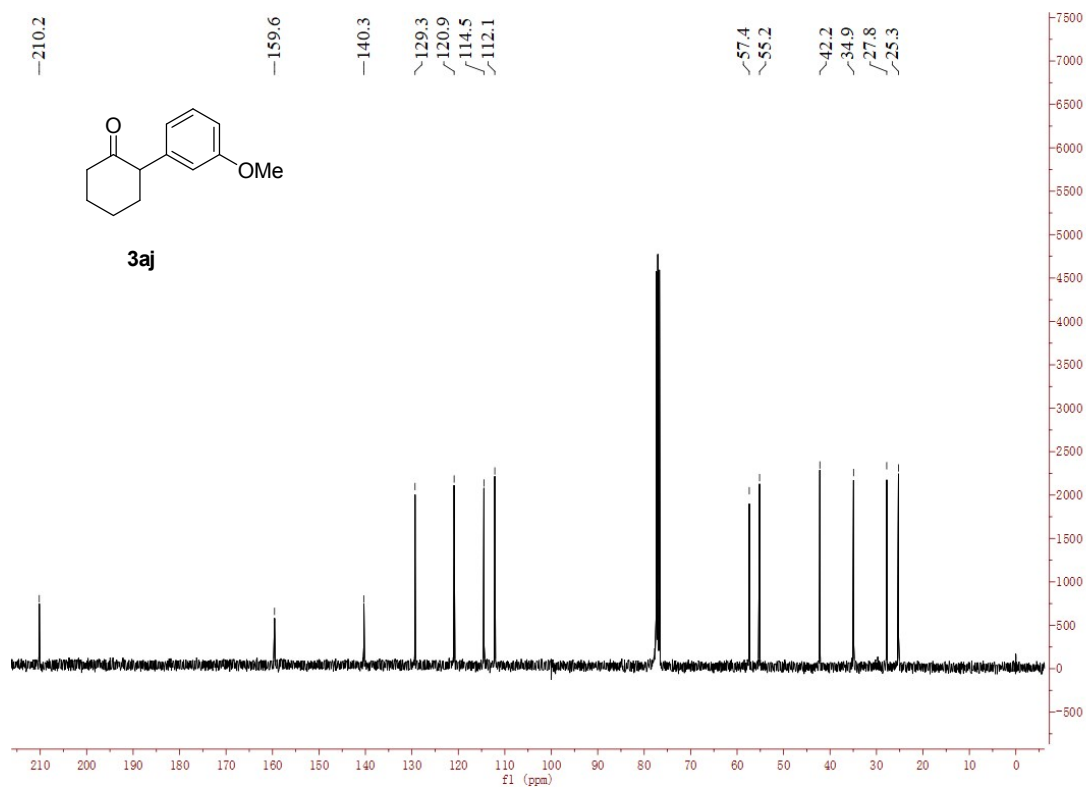
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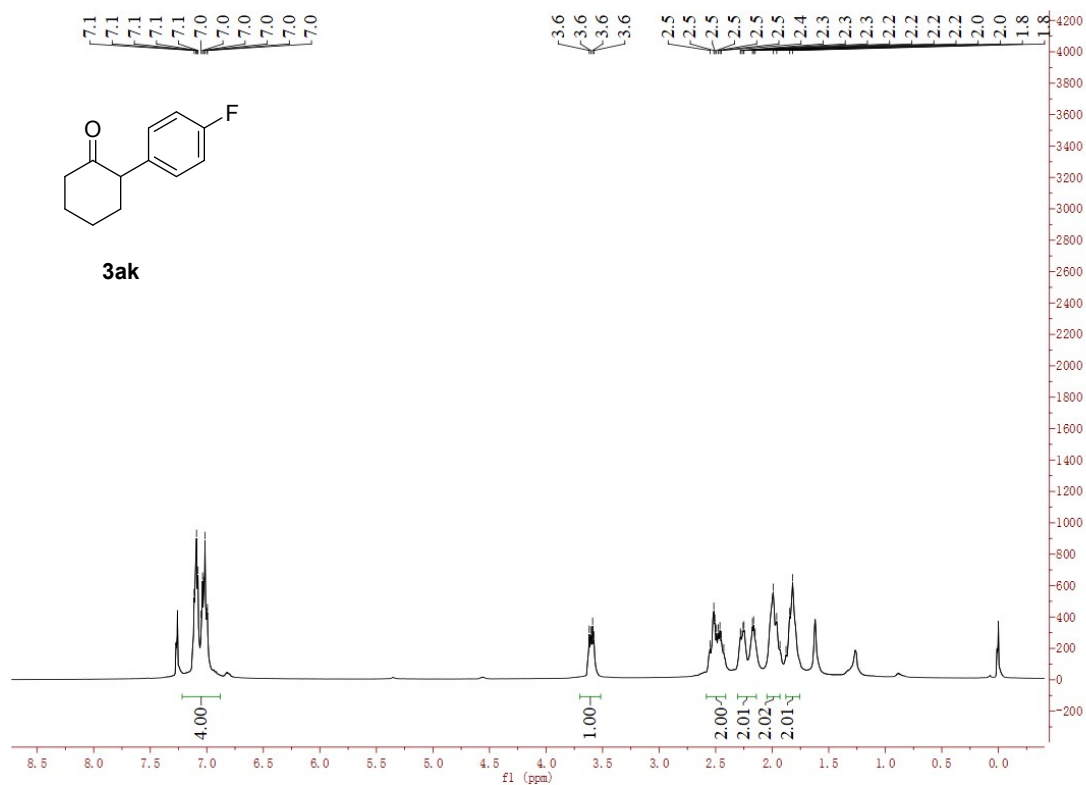
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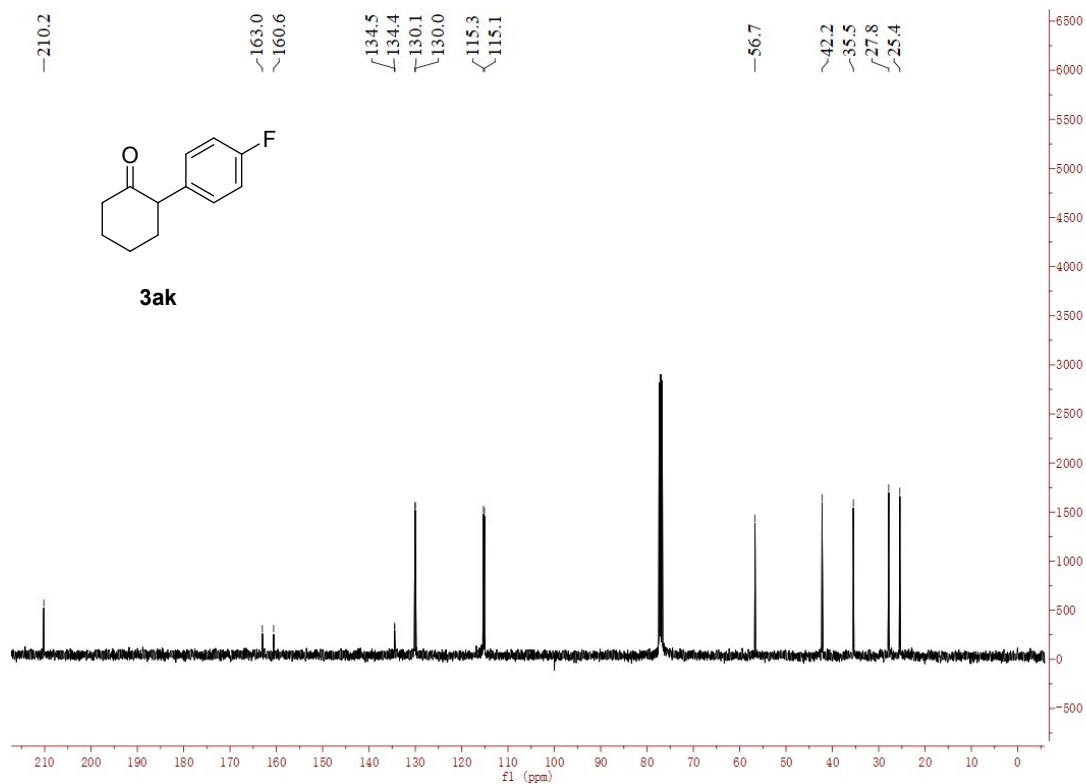
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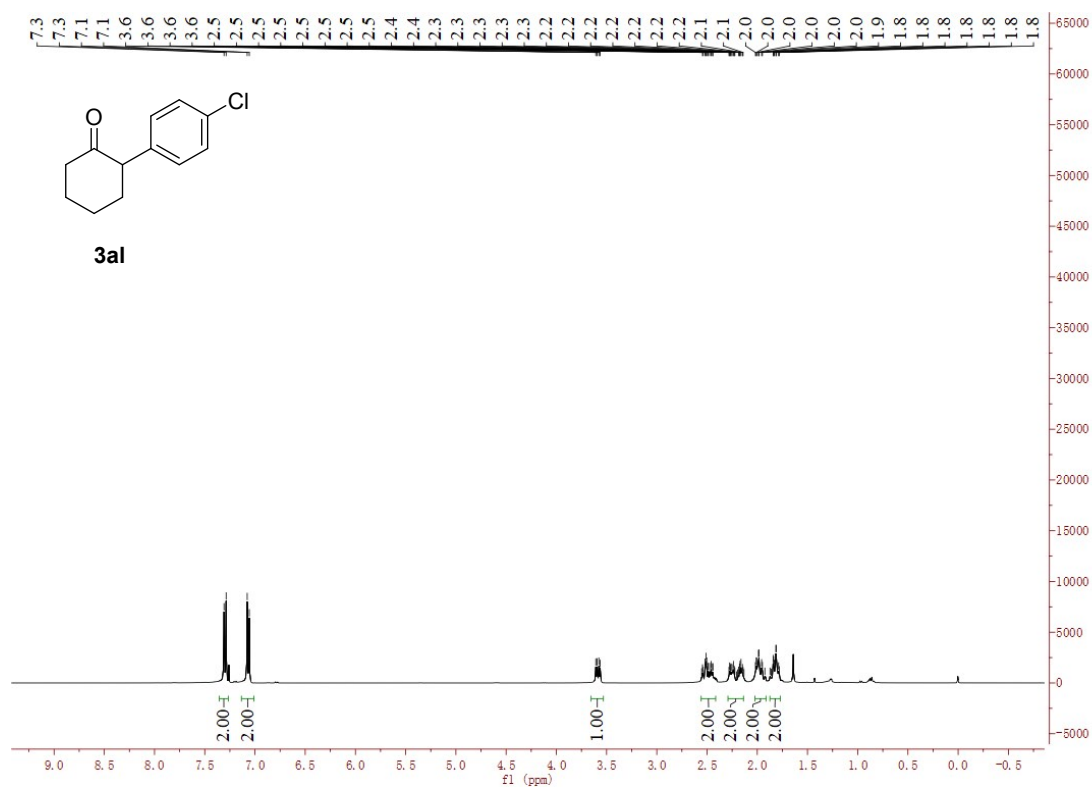
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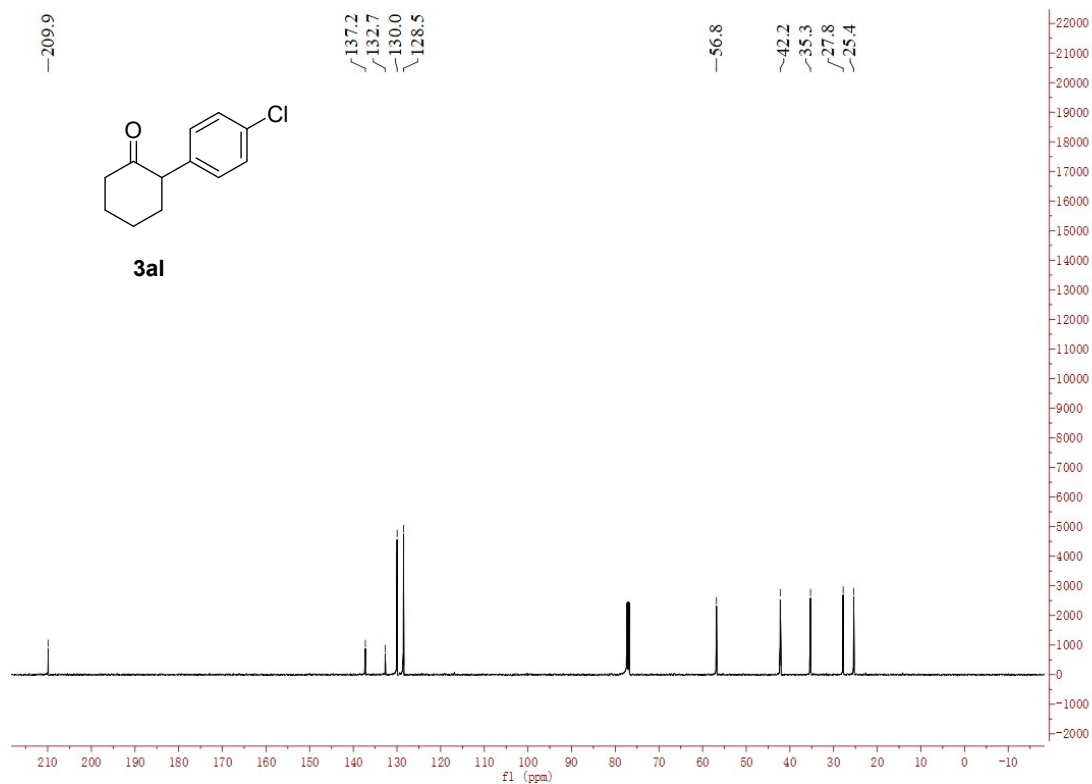
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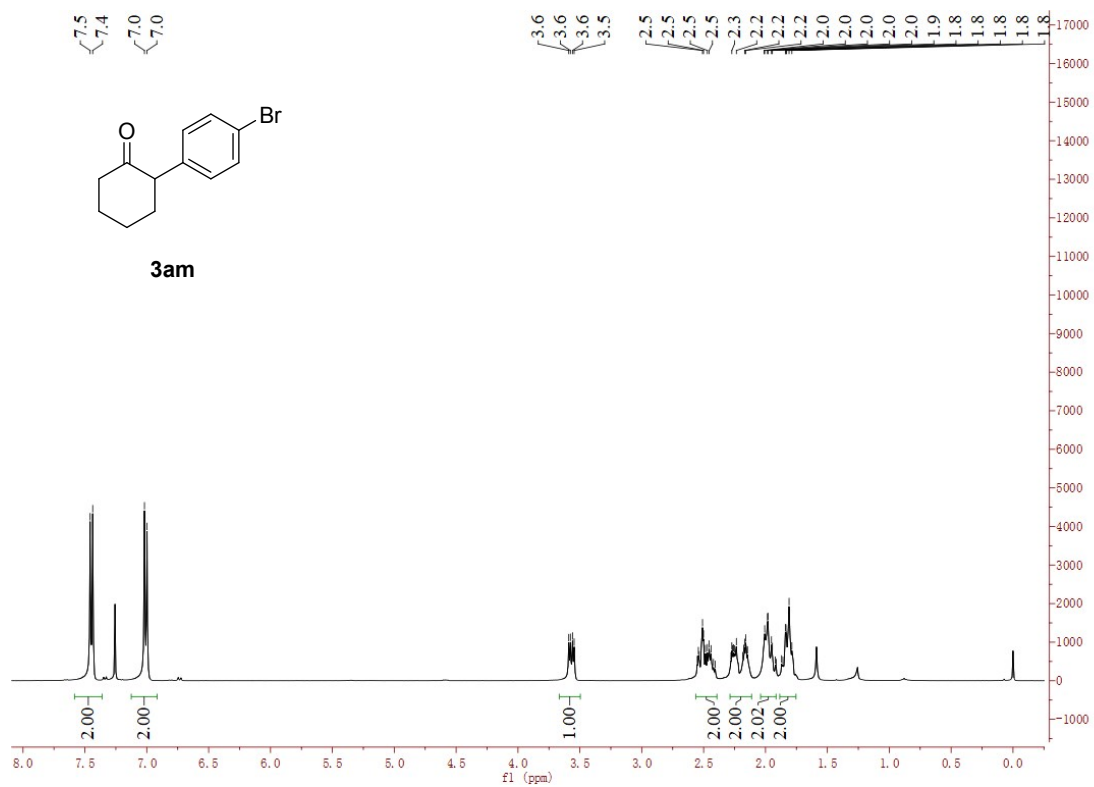
¹H NMR spectrum of 3al in CDCl₃



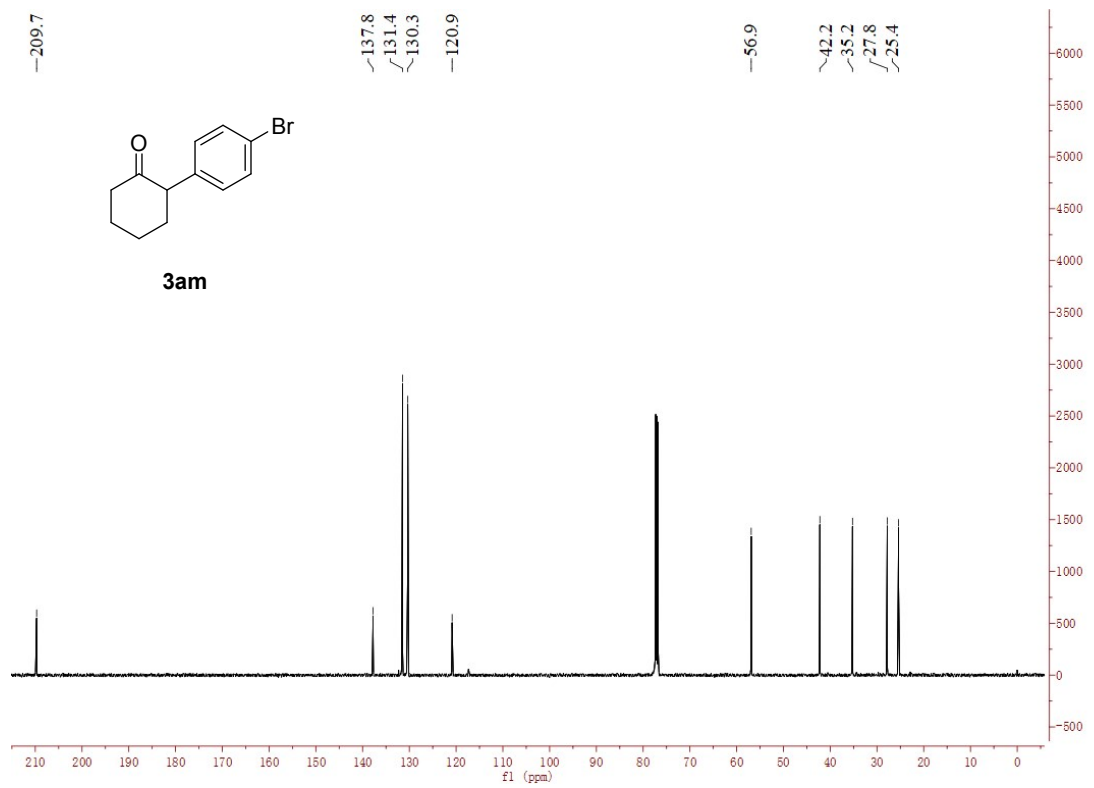
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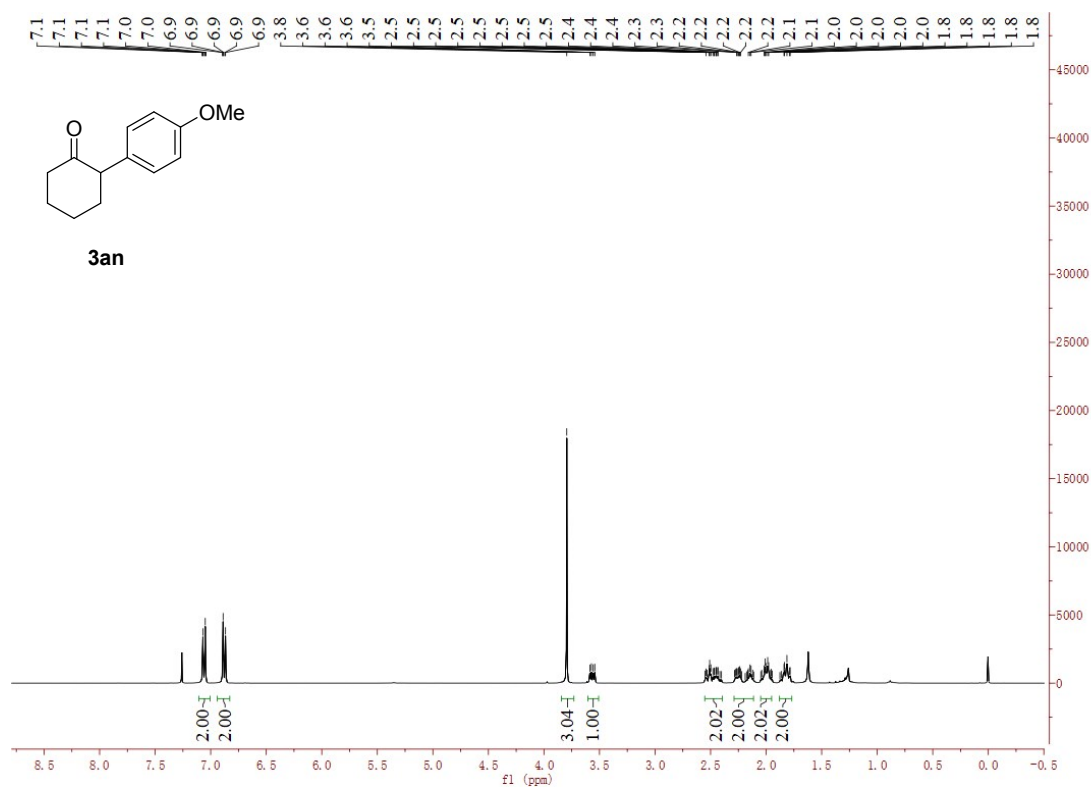
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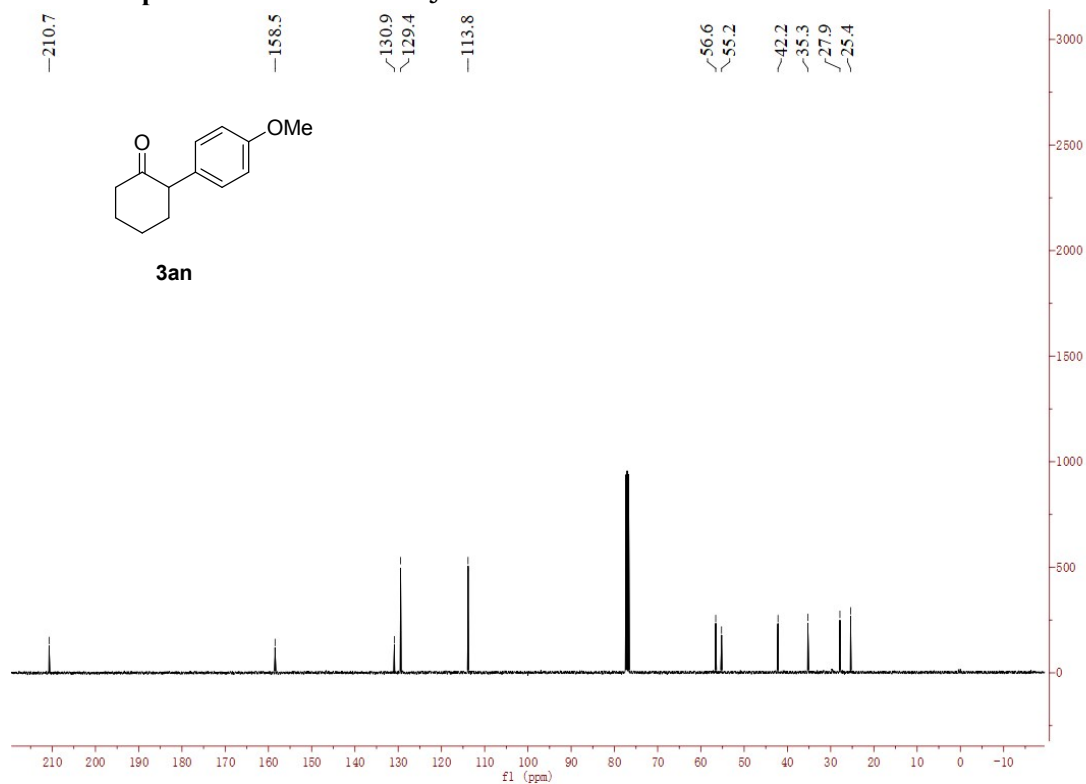
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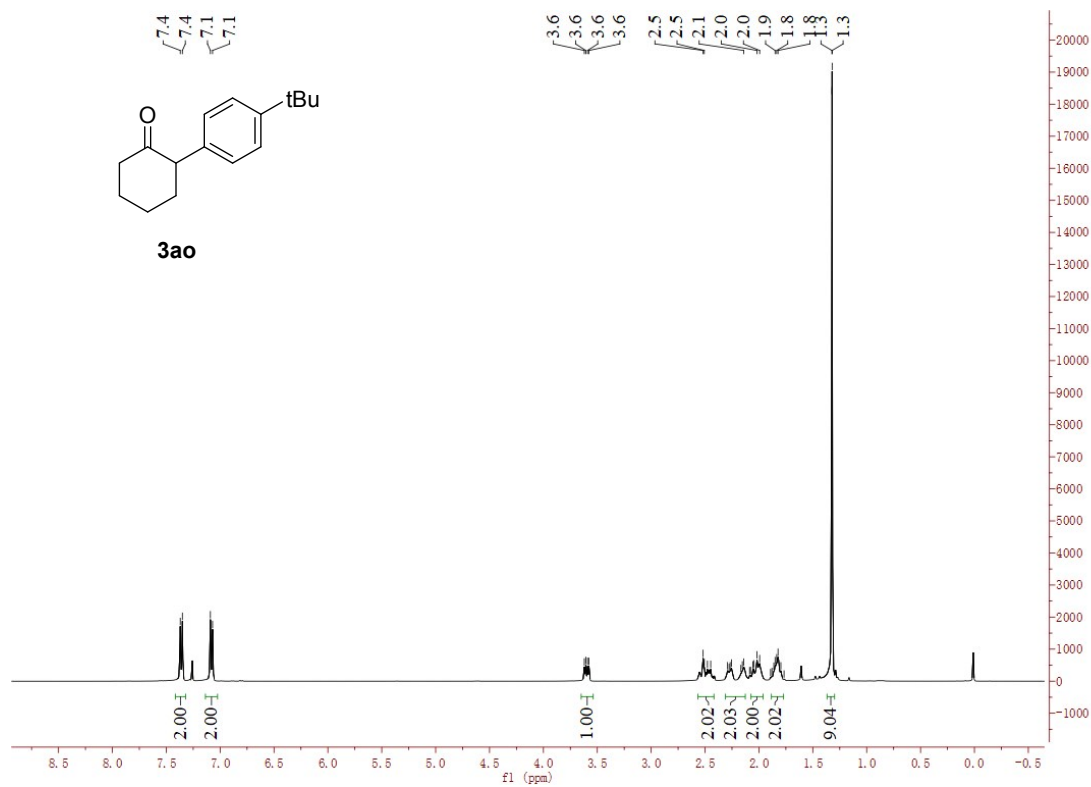
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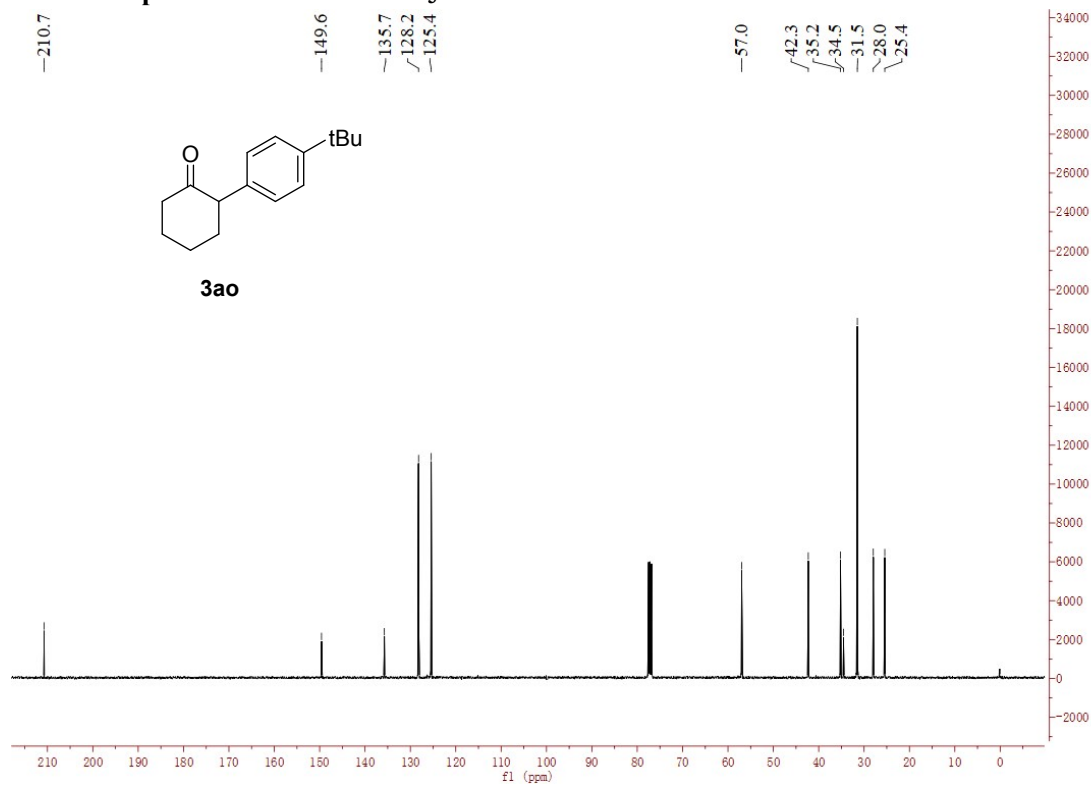
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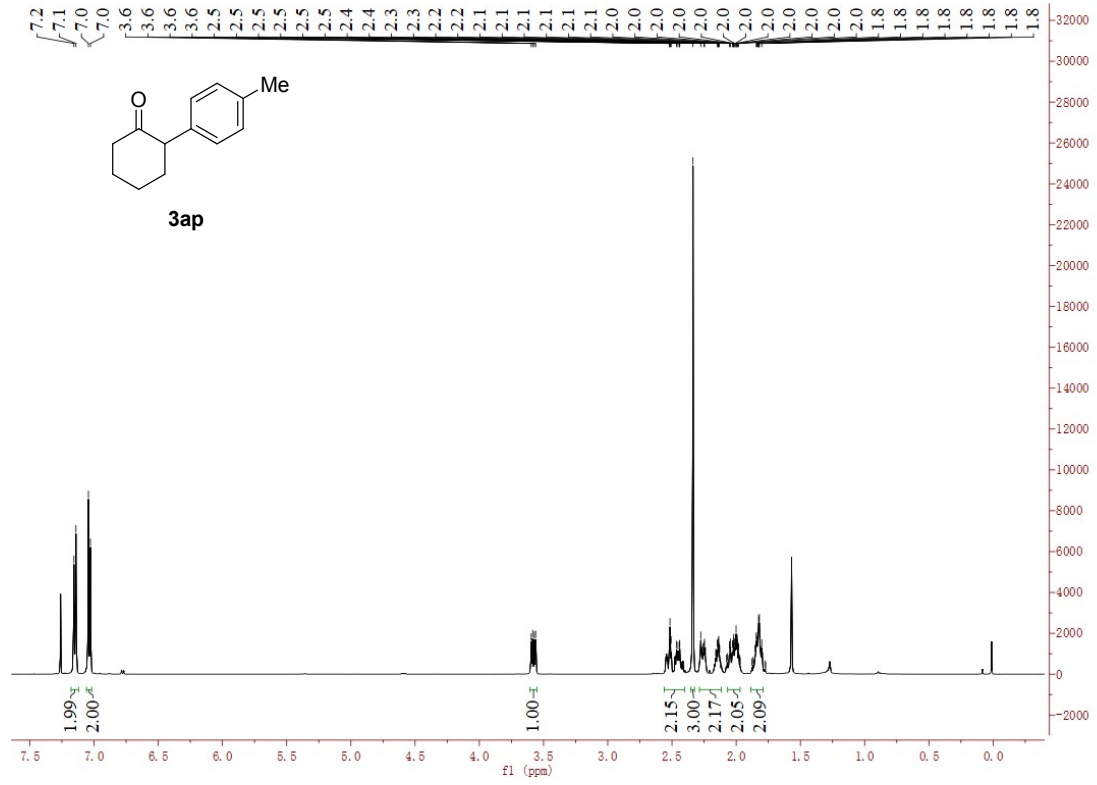
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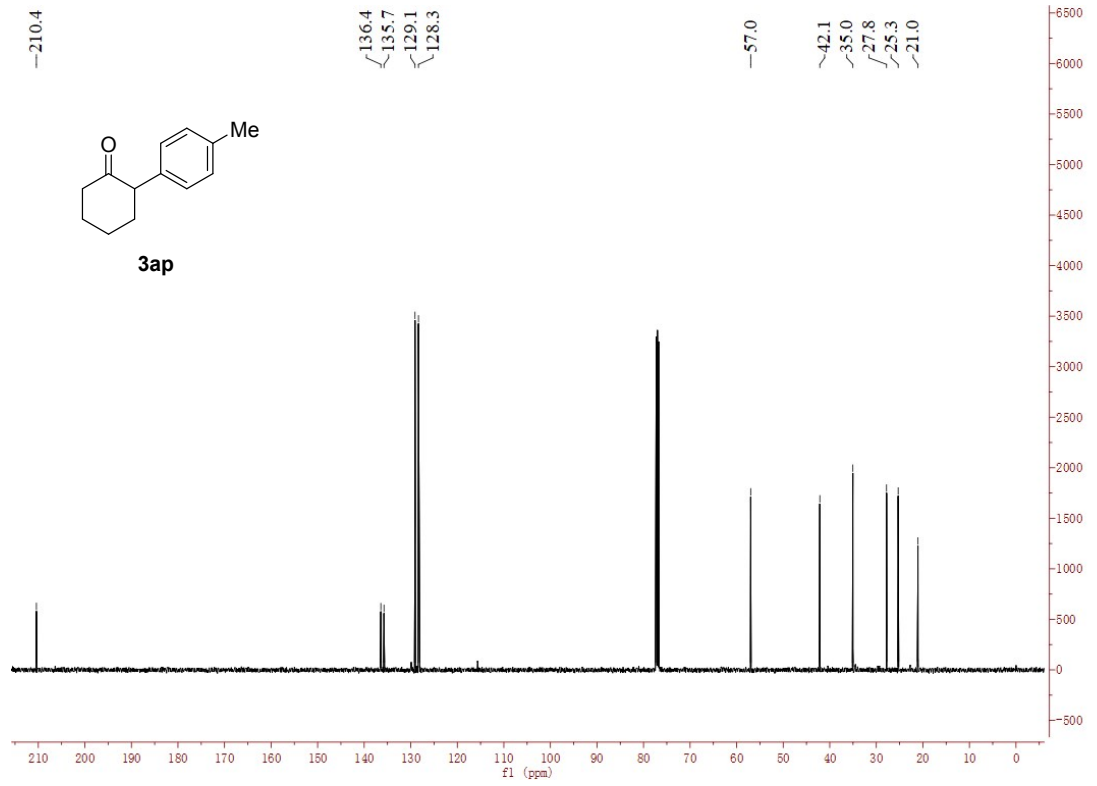
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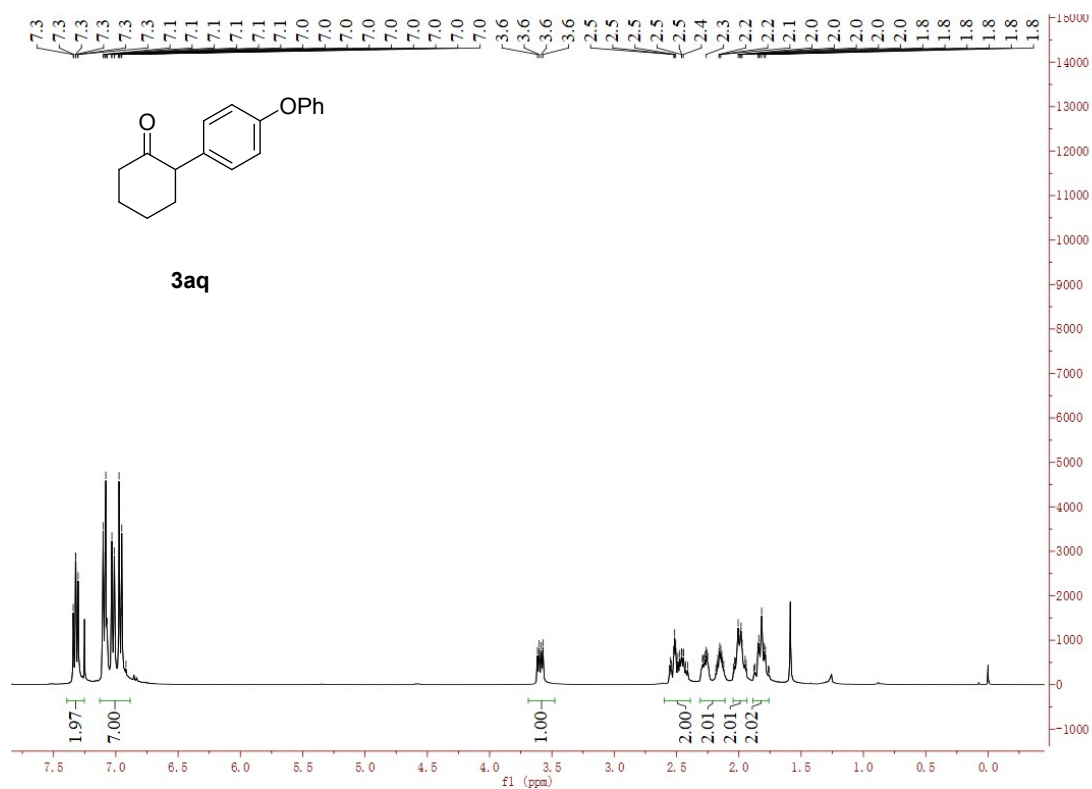
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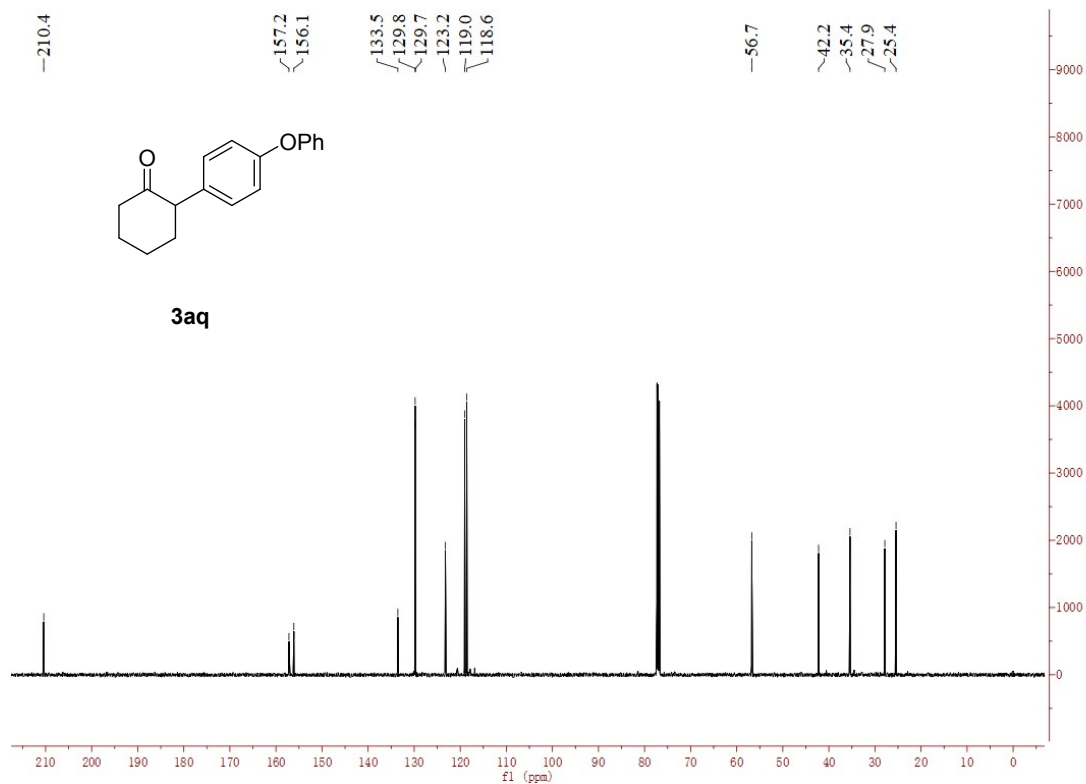
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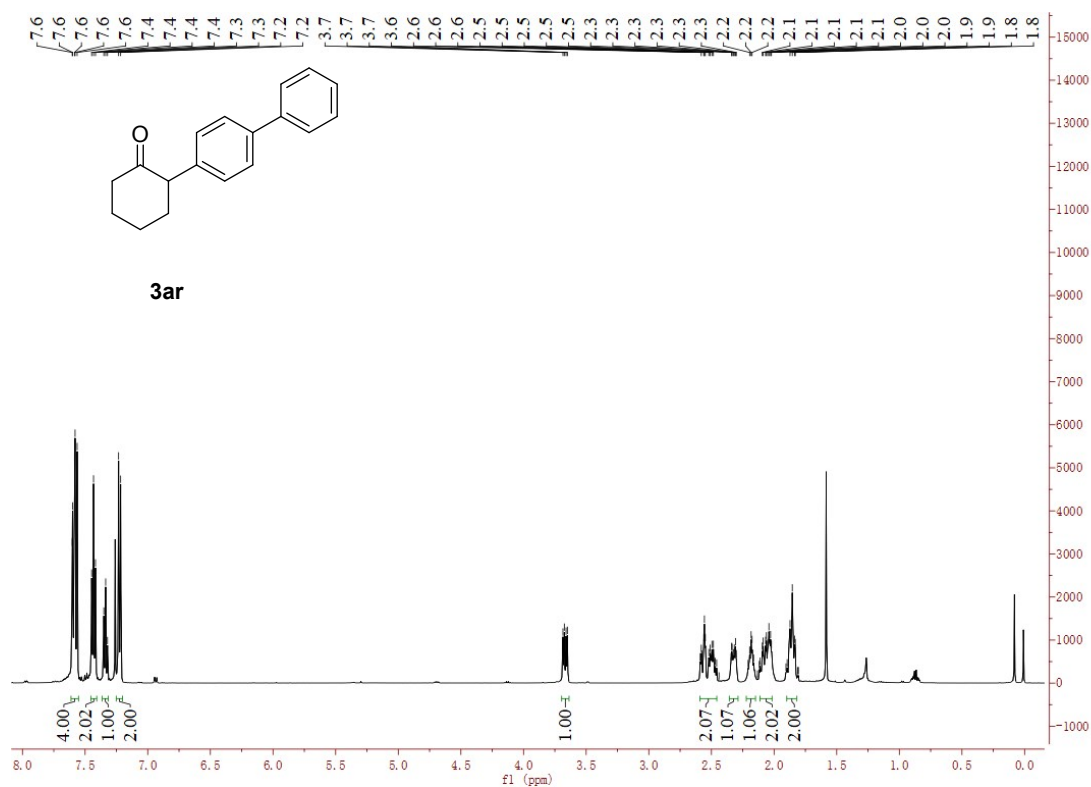
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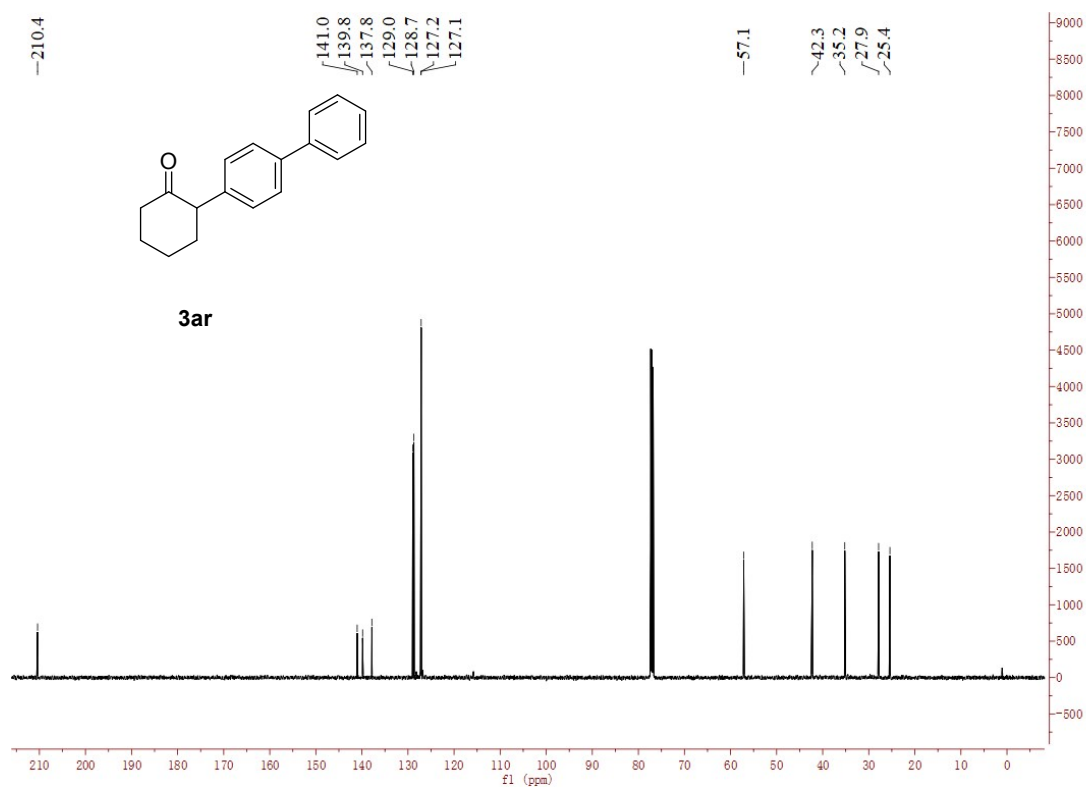
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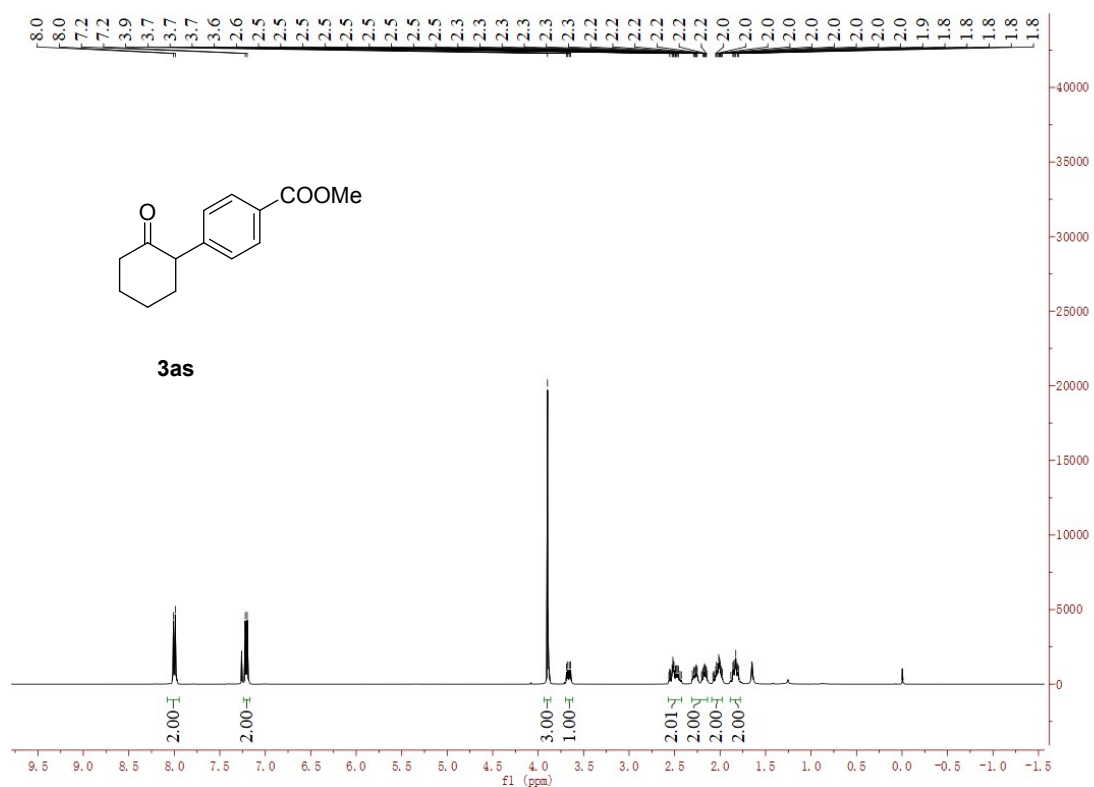
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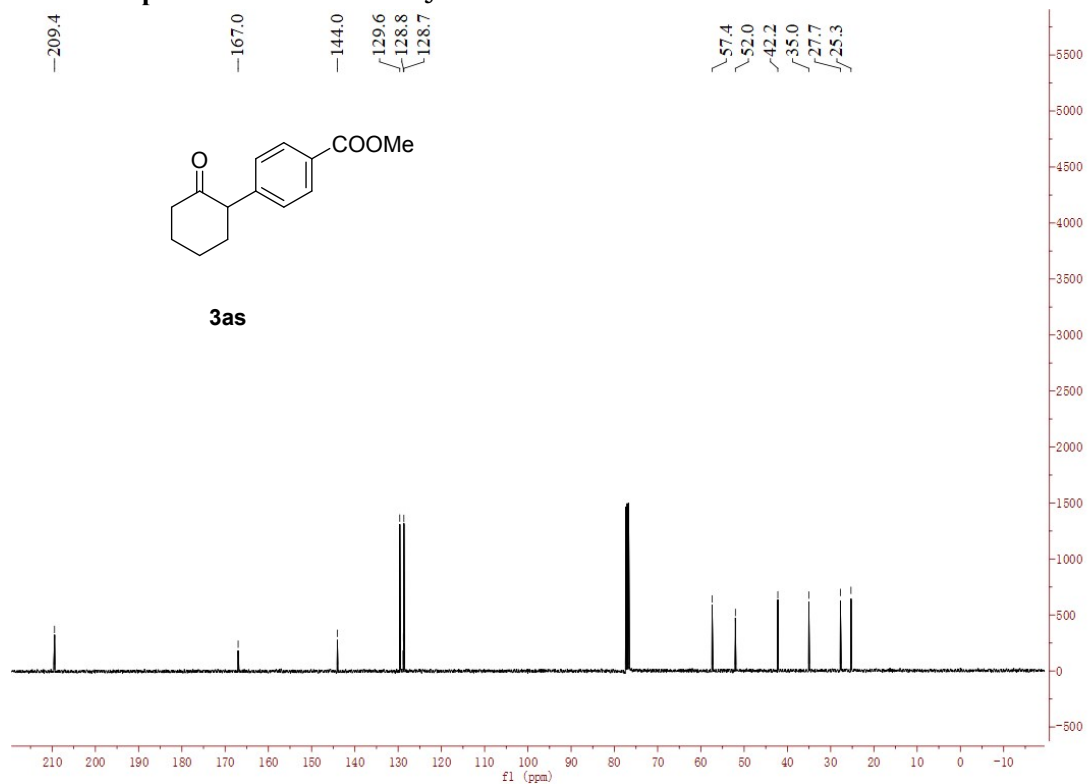
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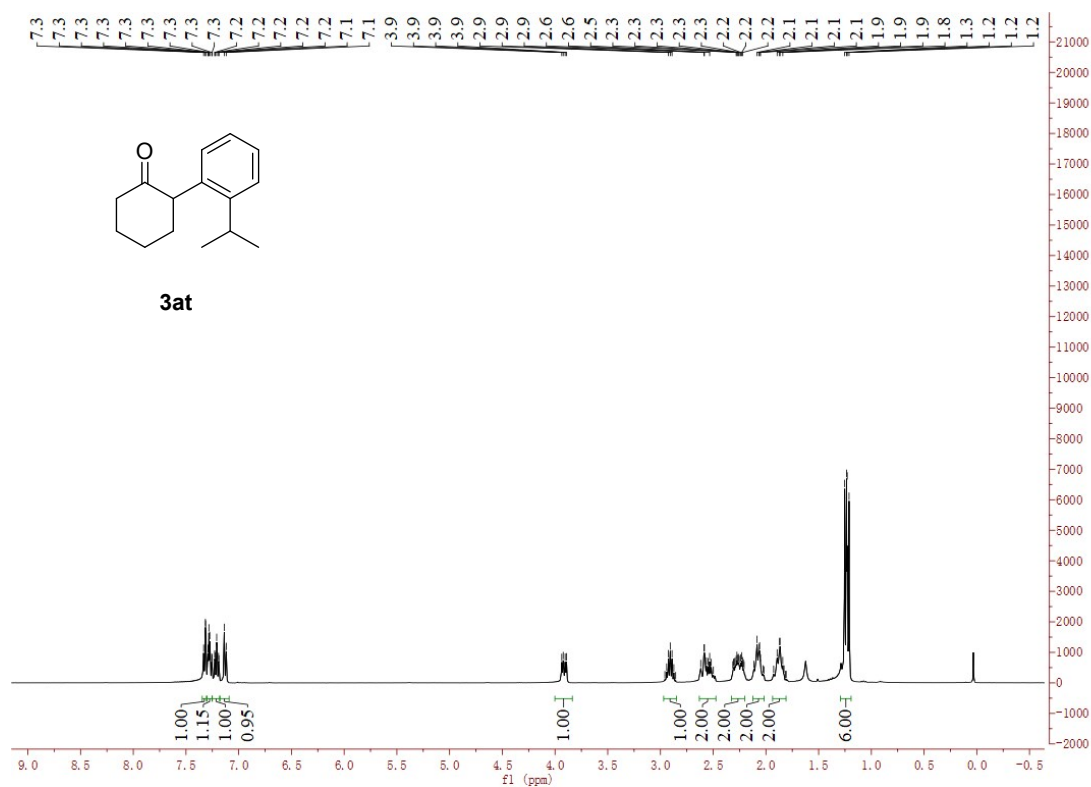
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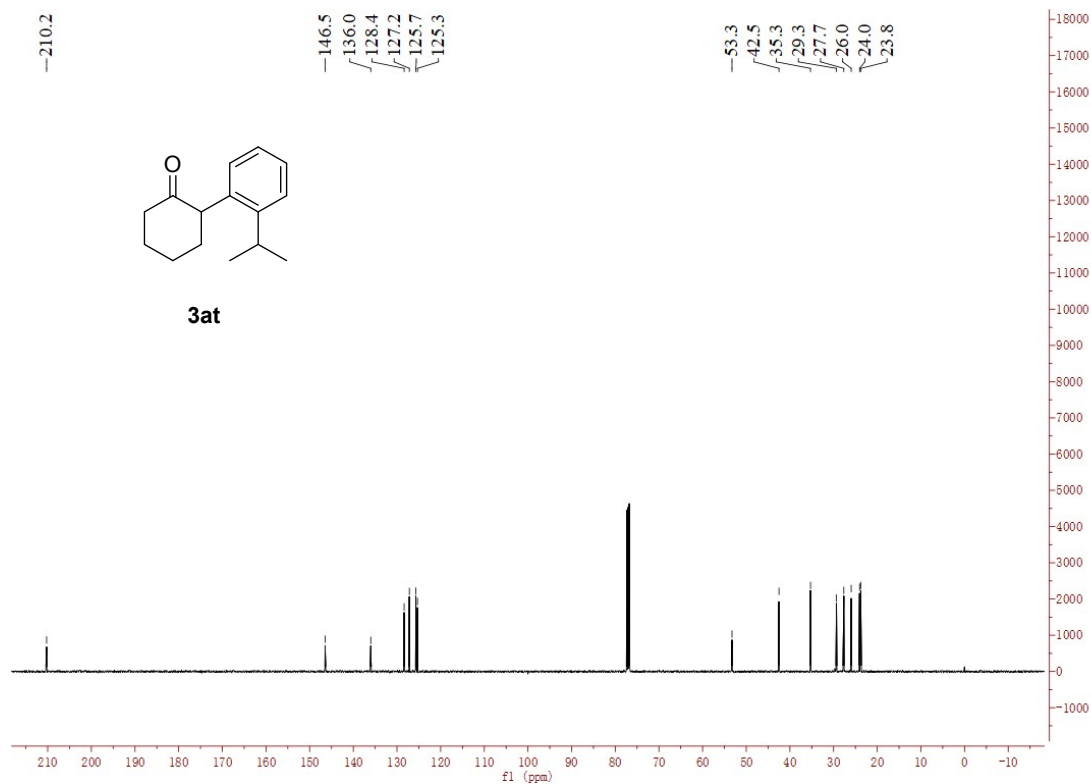
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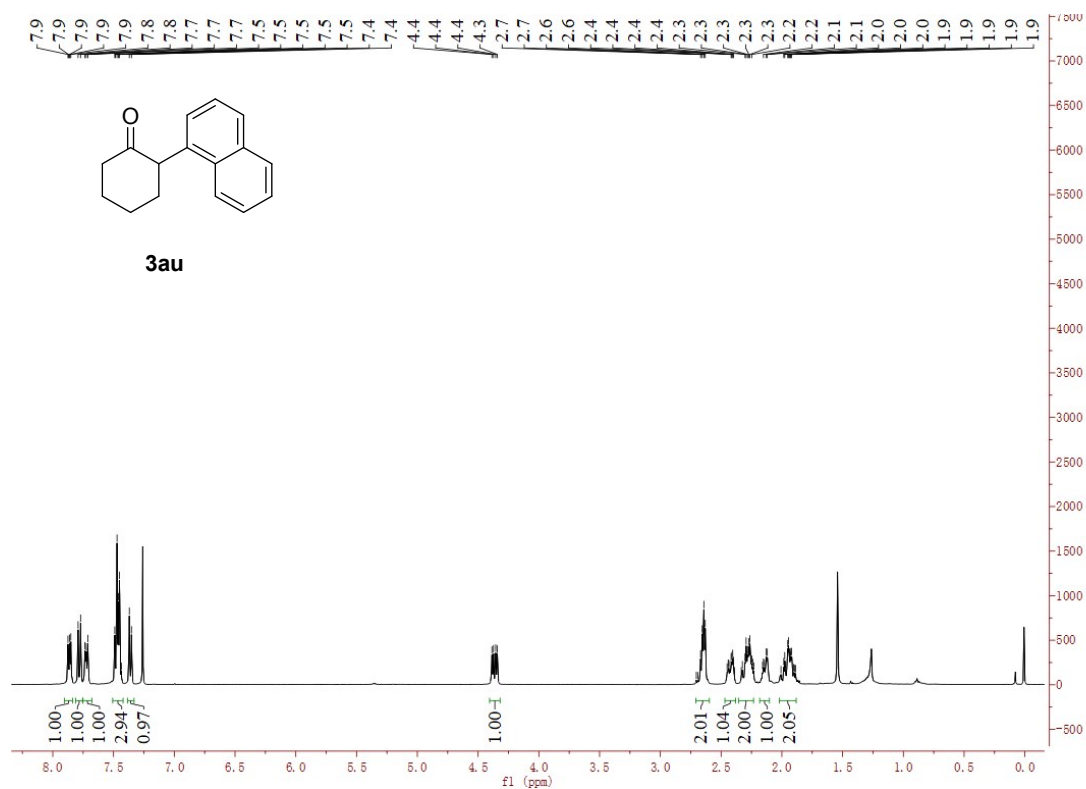
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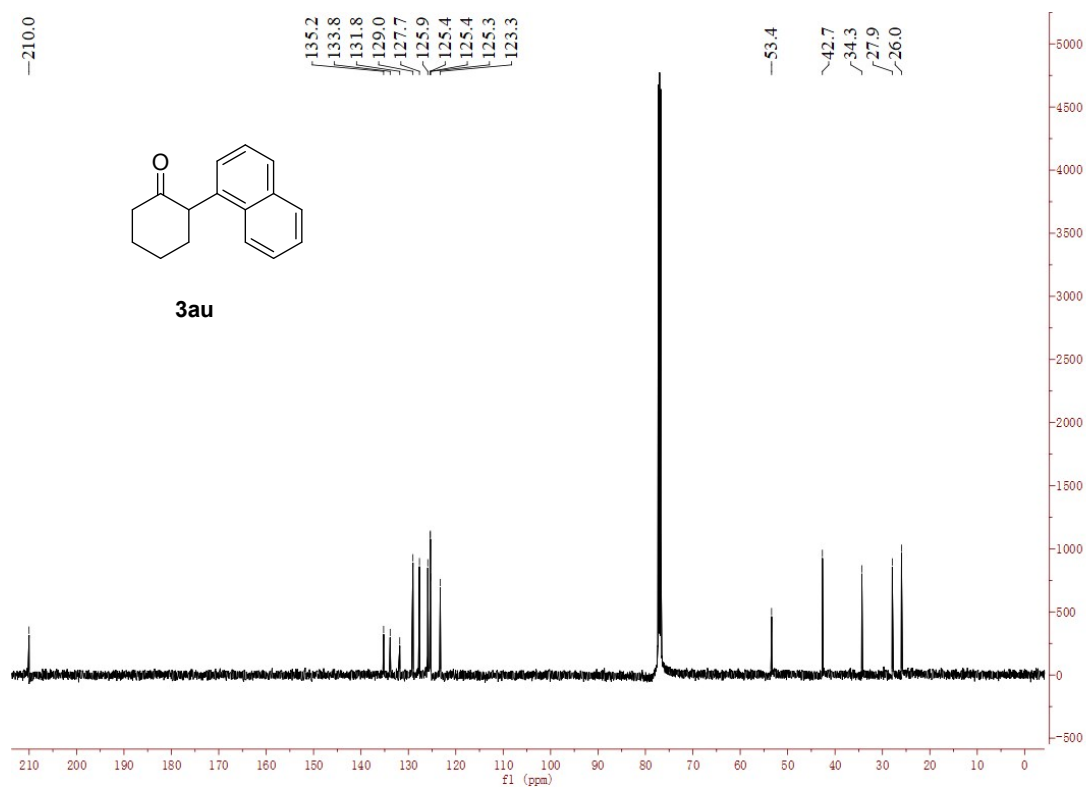
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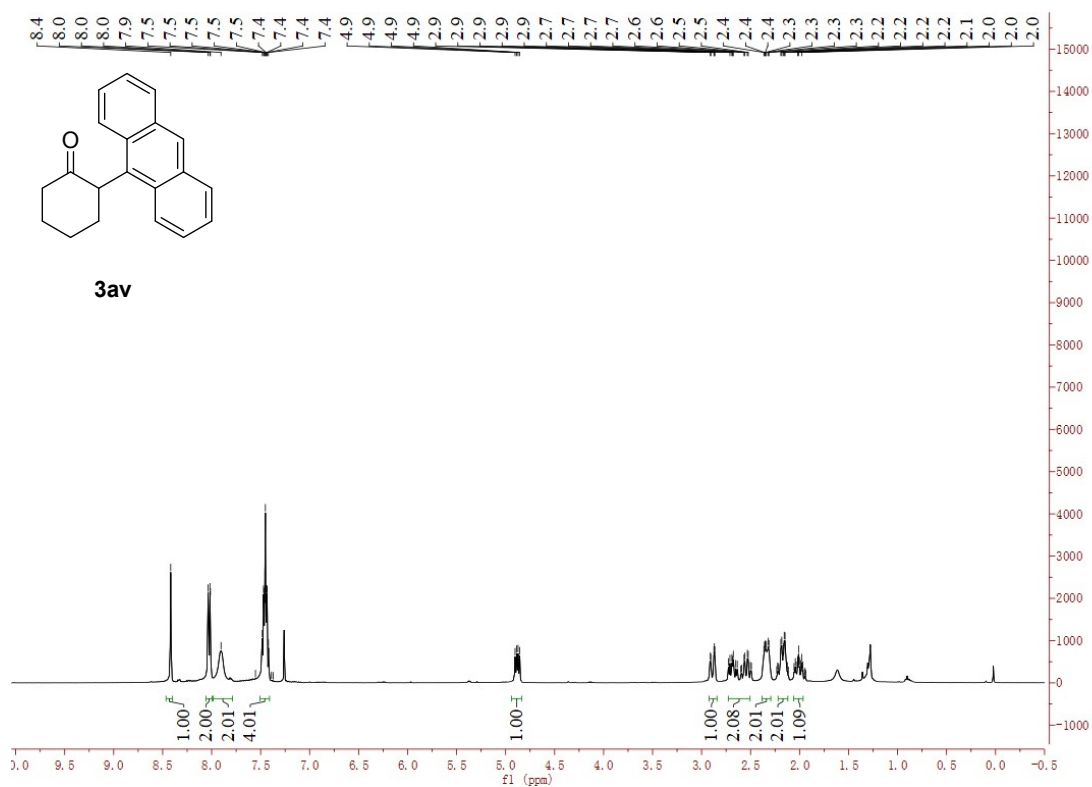
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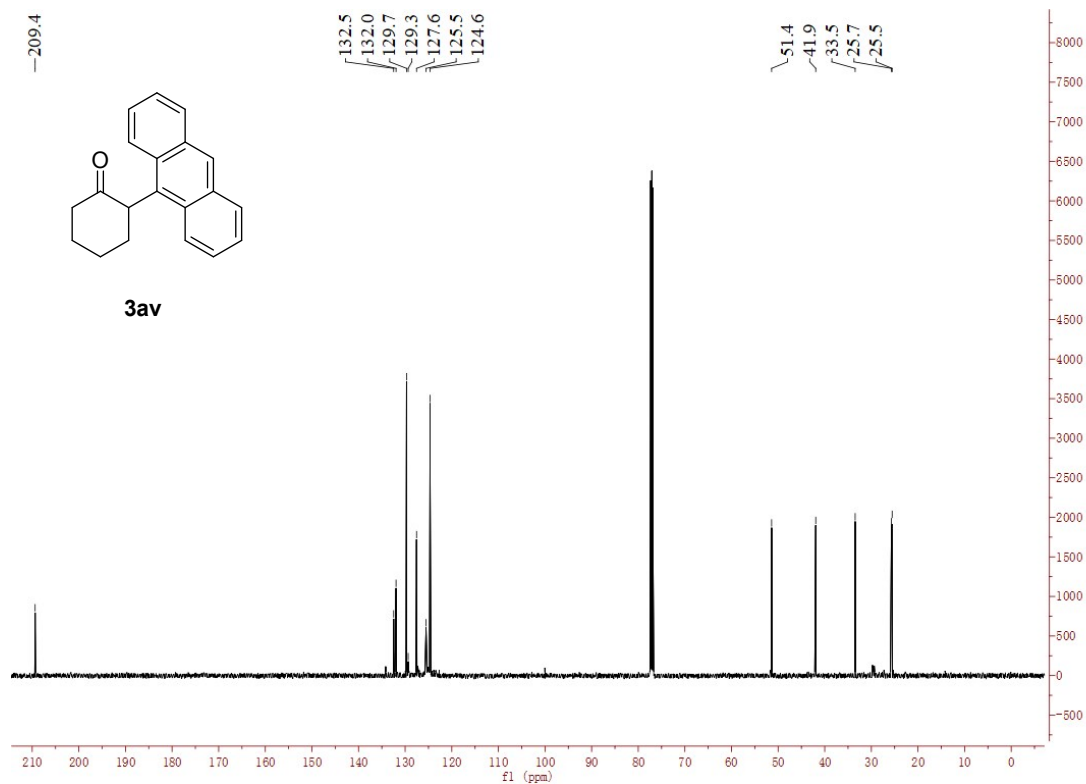
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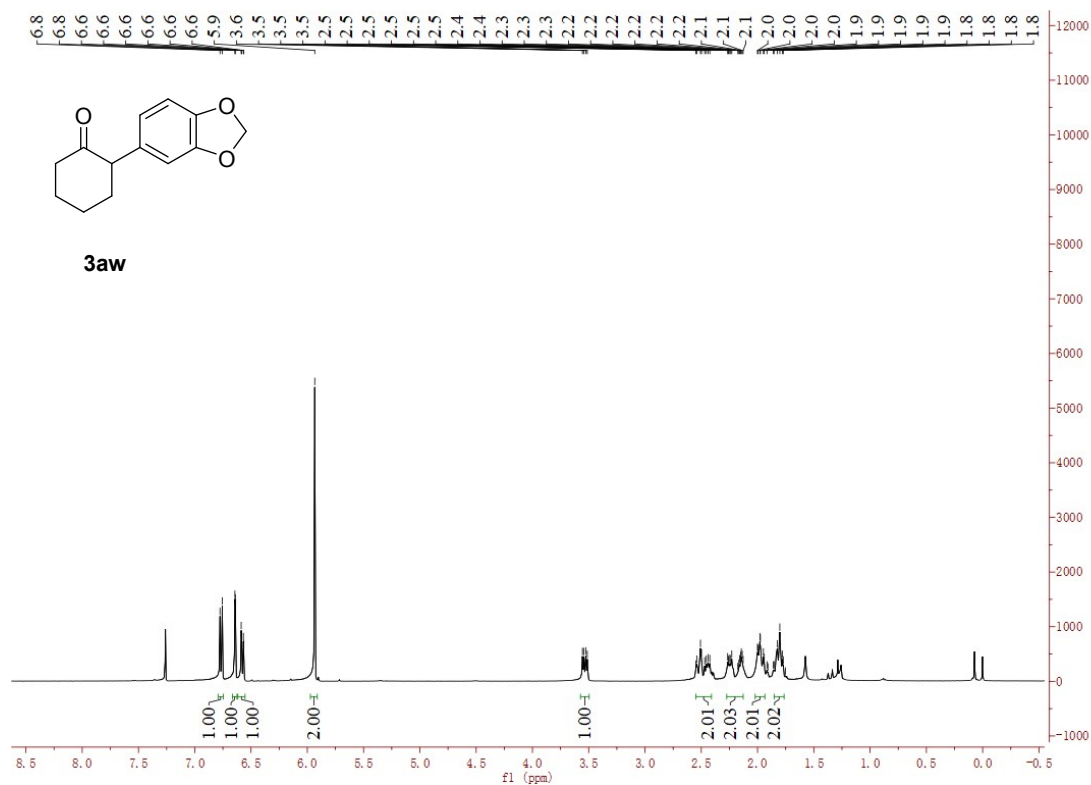
^1H NMR spectrum of 3av in CDCl_3



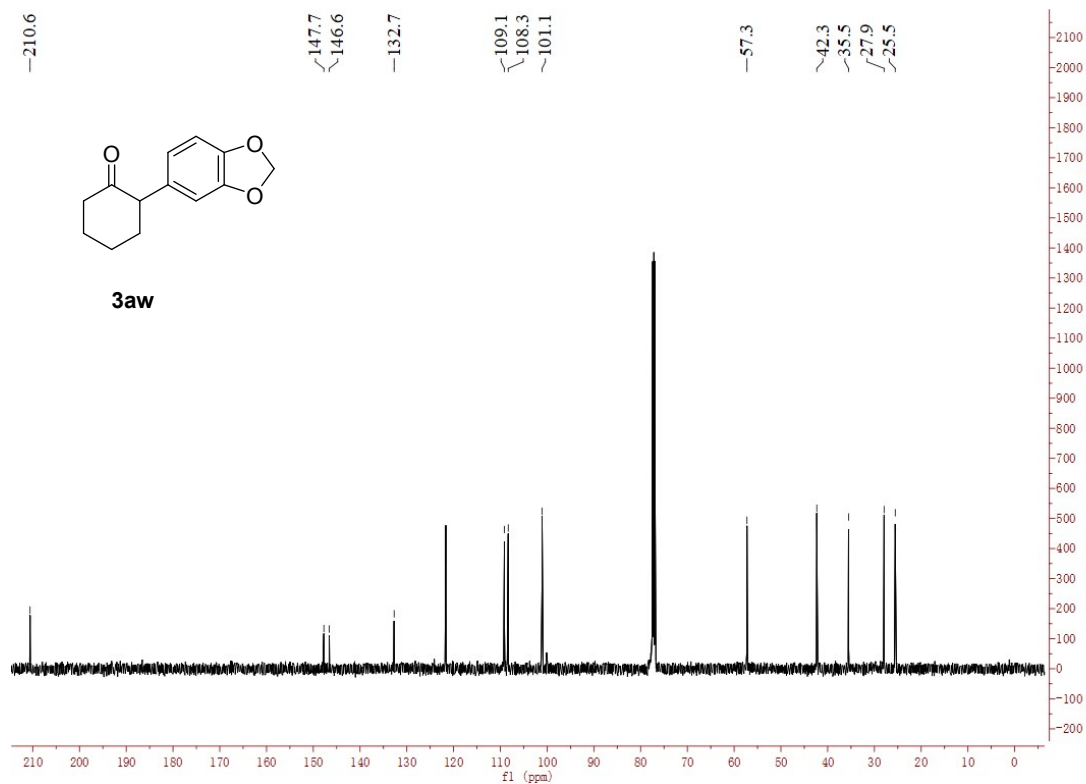
^{13}C NMR spectrum of 3av in CDCl_3



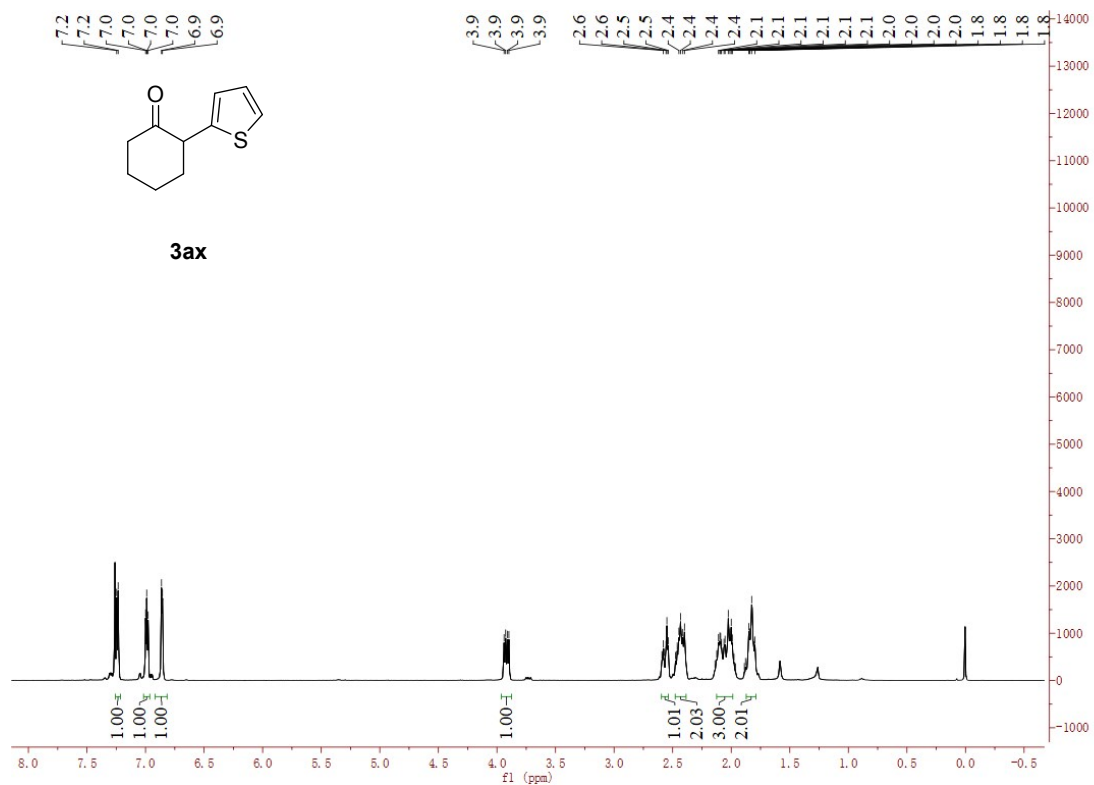
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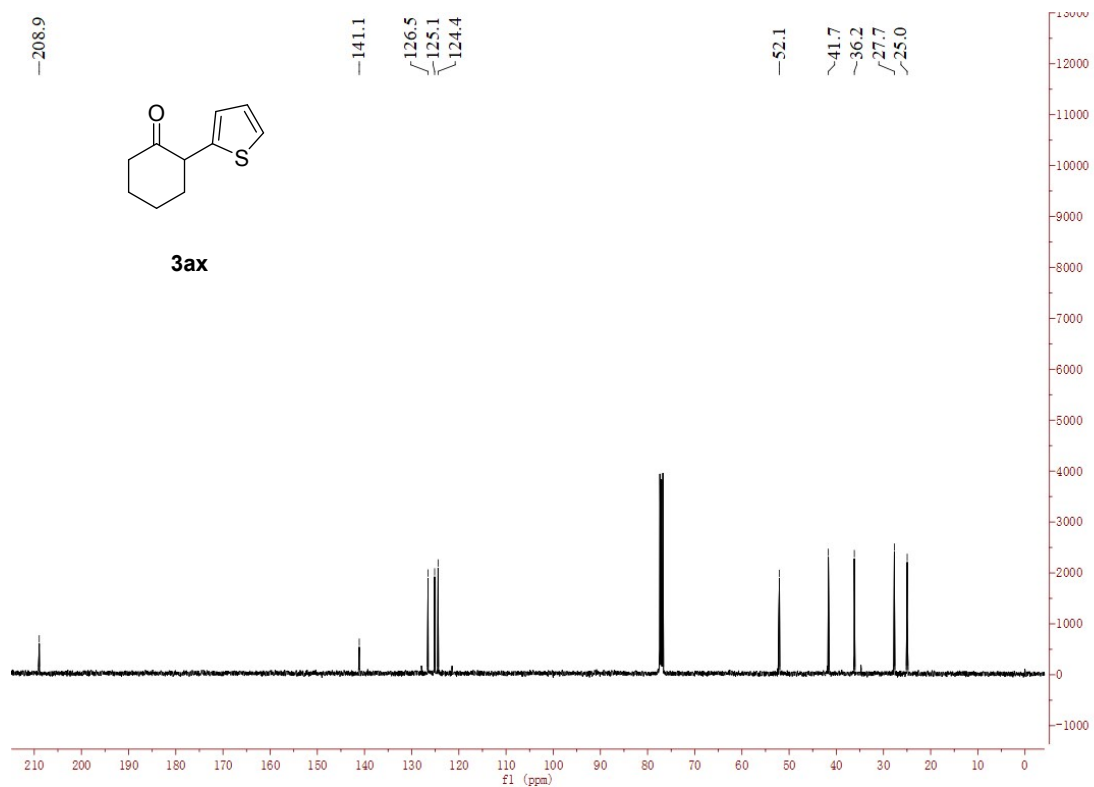
¹³C NMR spectrum of 3aw in CDCl₃



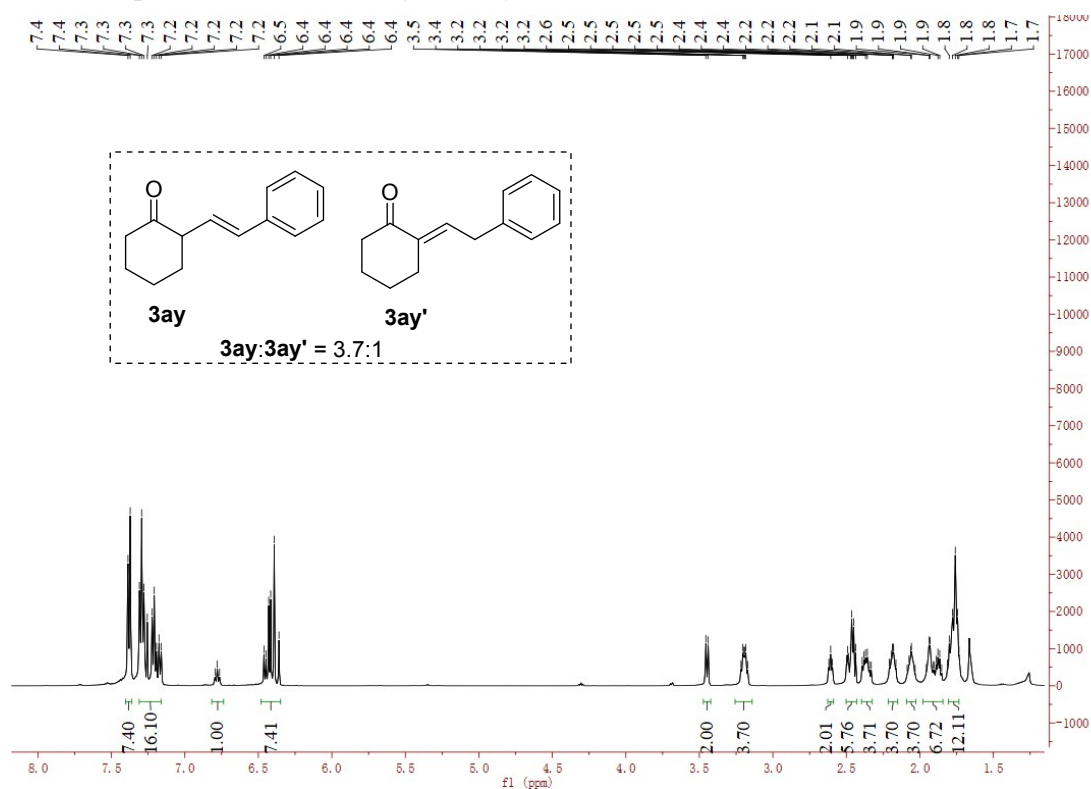
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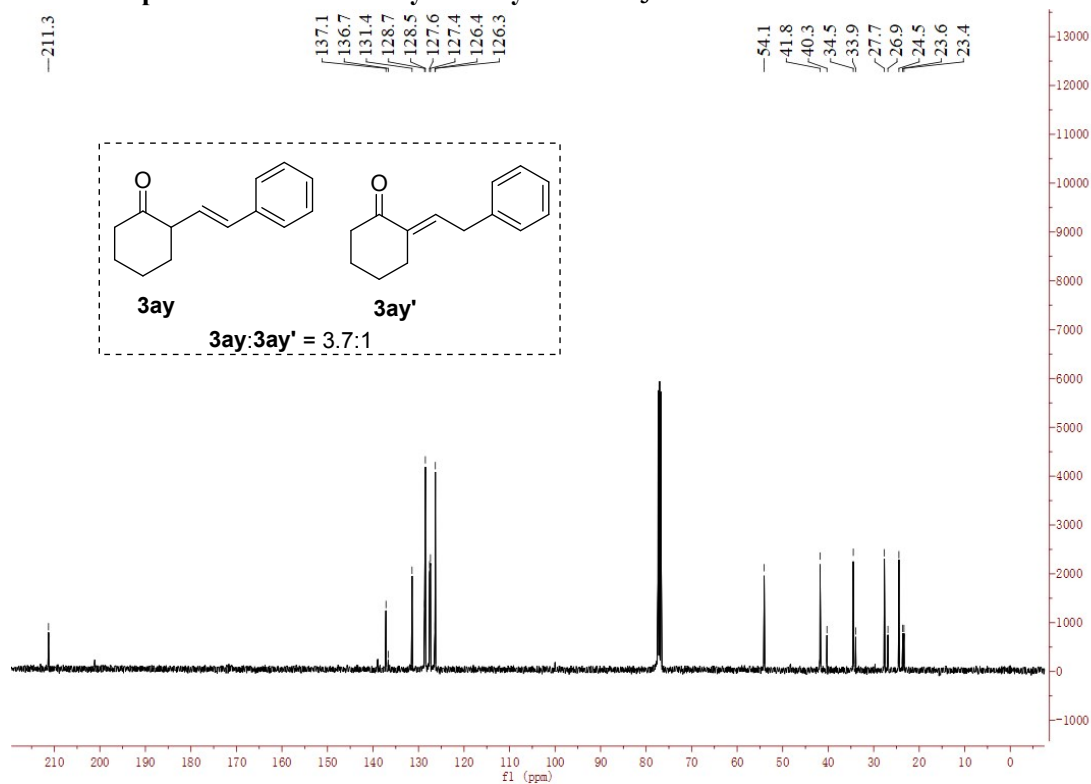
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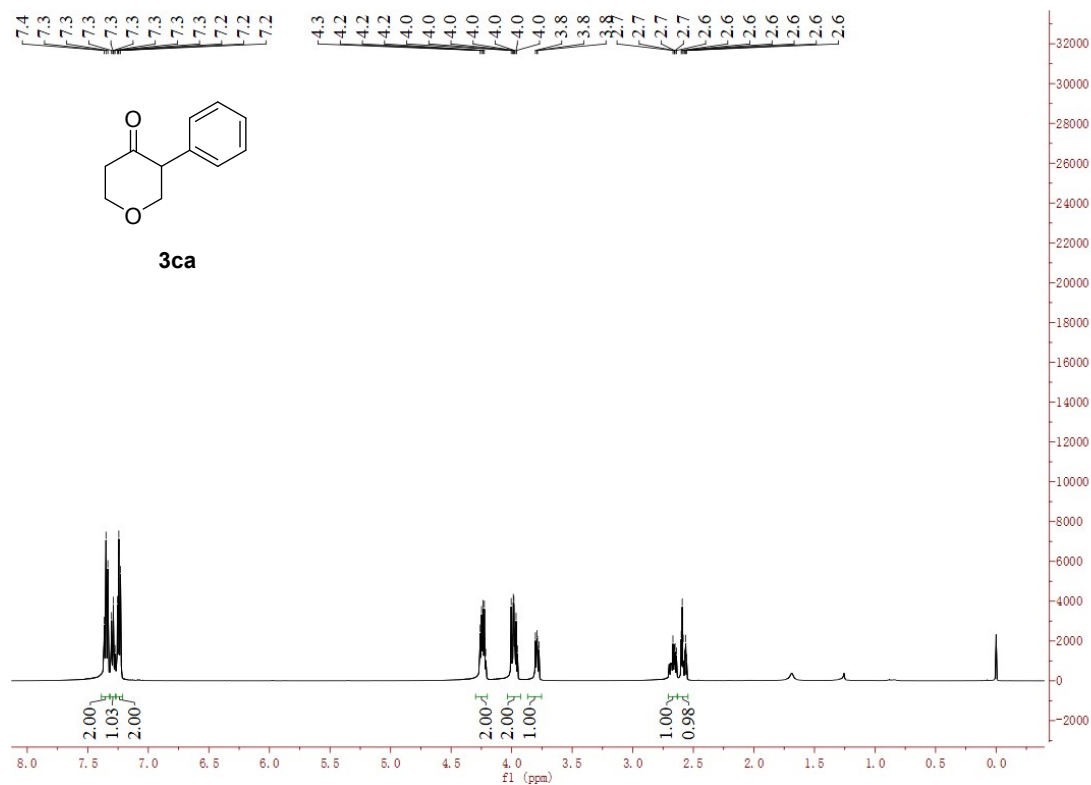
¹H NMR spectrum of mixture 3ay and 3ay' in CDCl₃



¹³C NMR spectrum of mixture 3ay and 3ay' in CDCl₃



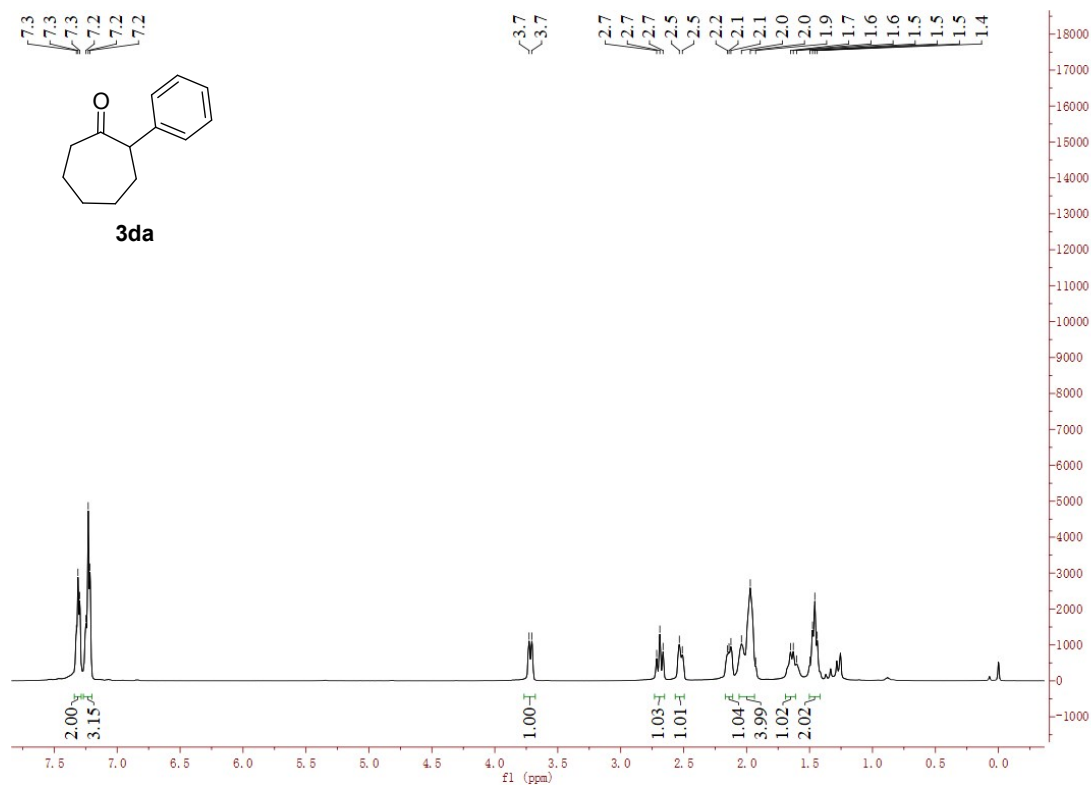
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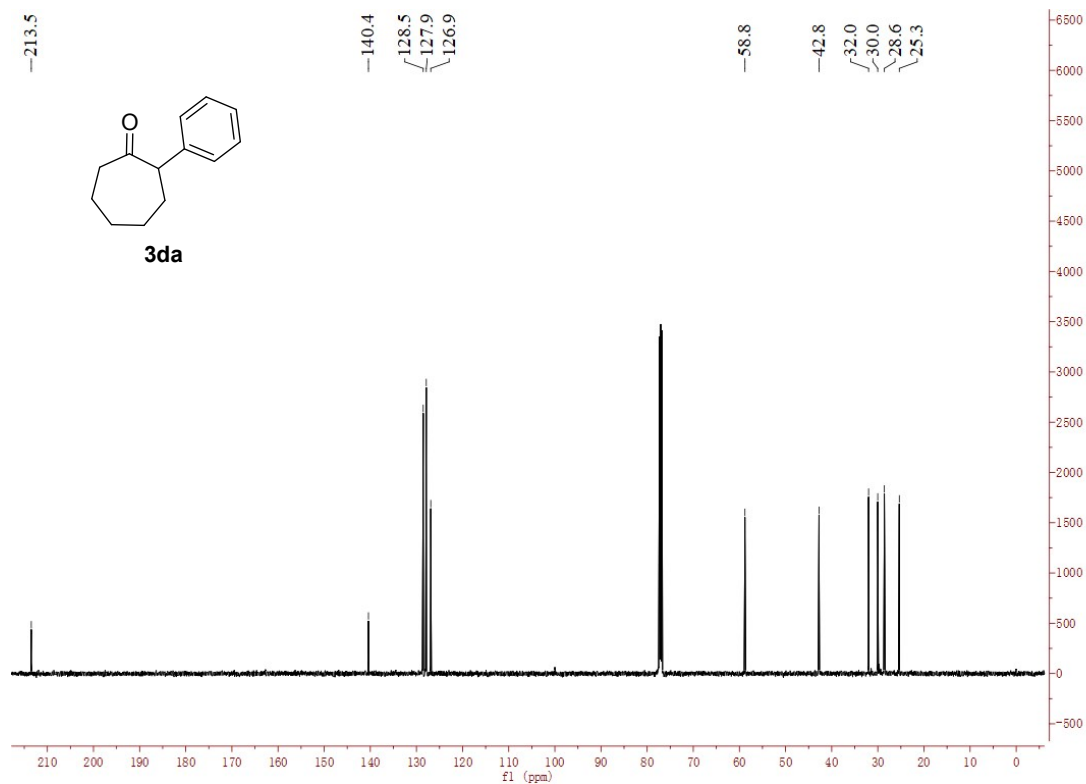
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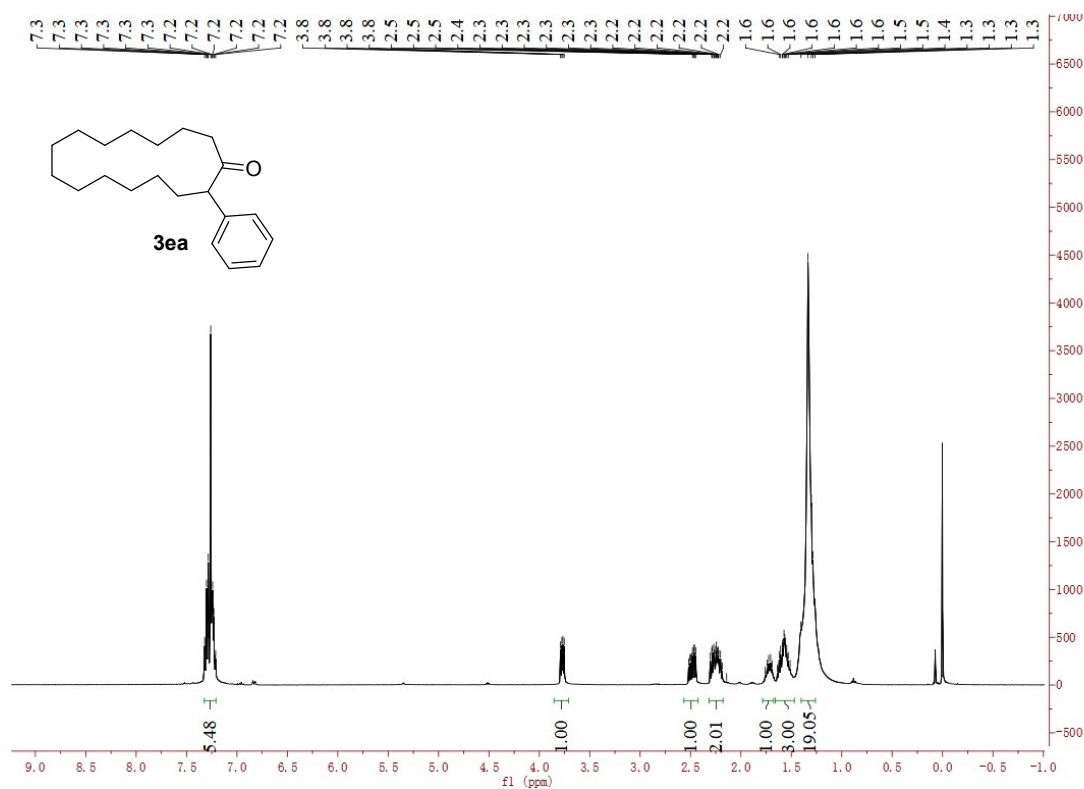
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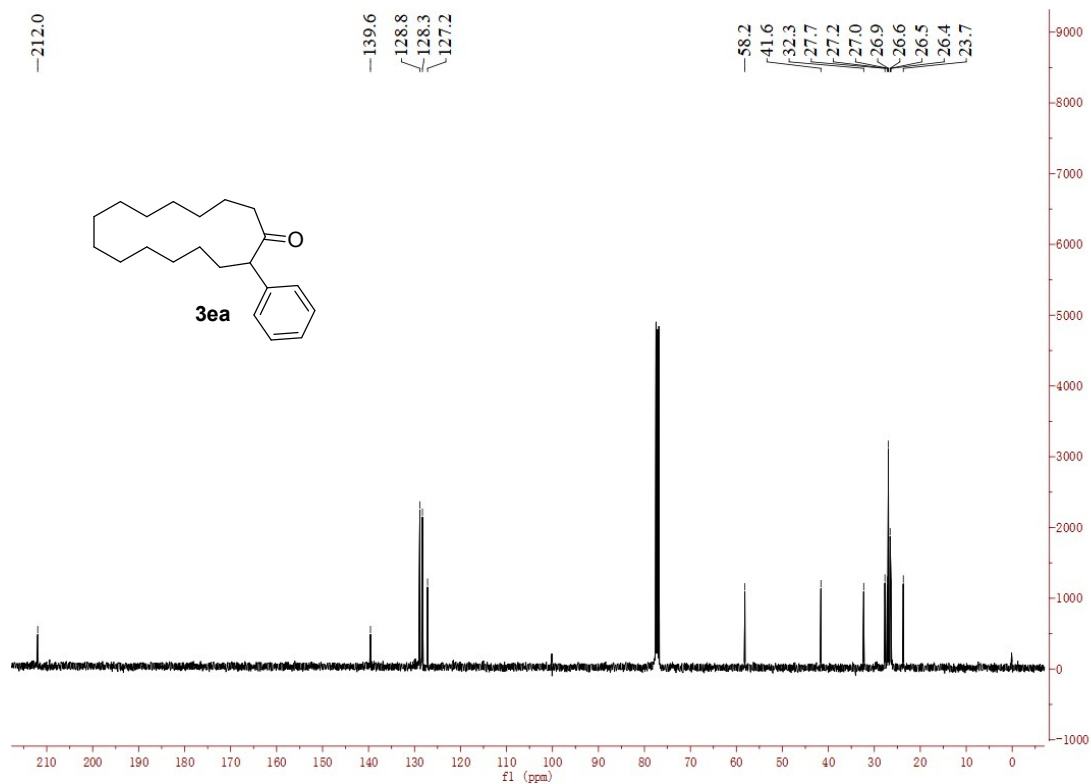
¹³C NMR spectrum of 3da in CDCl₃



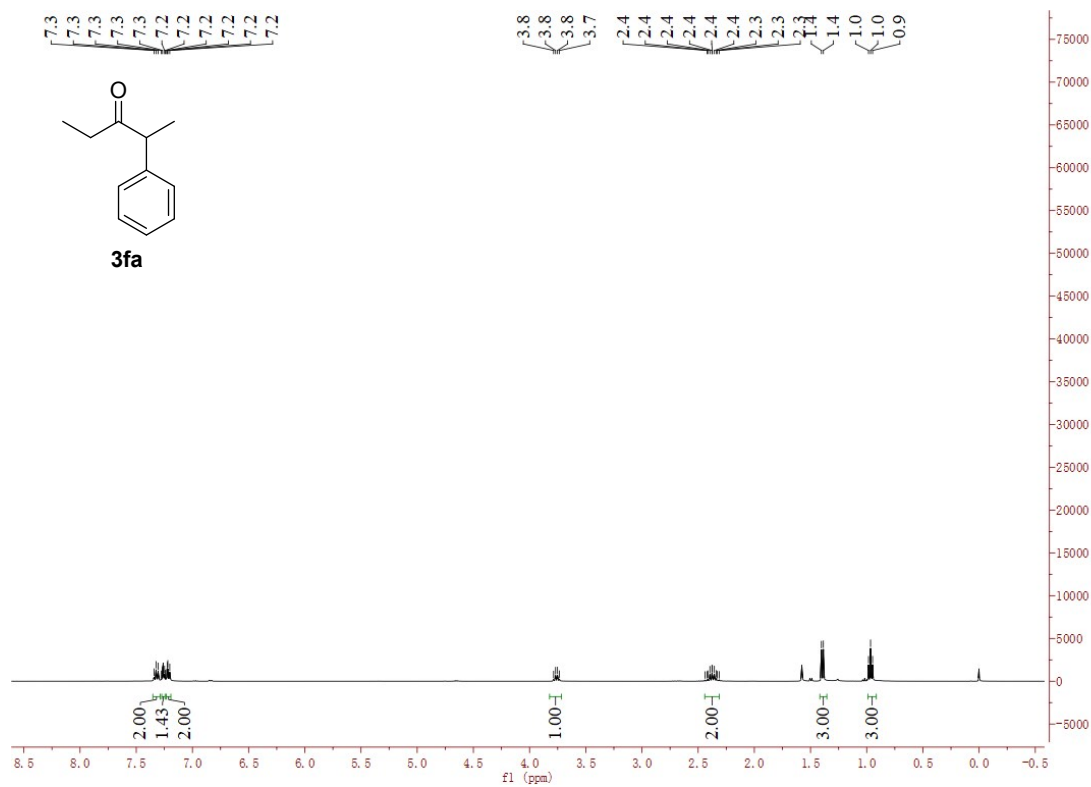
¹H NMR spectrum of 3ea in CDCl₃



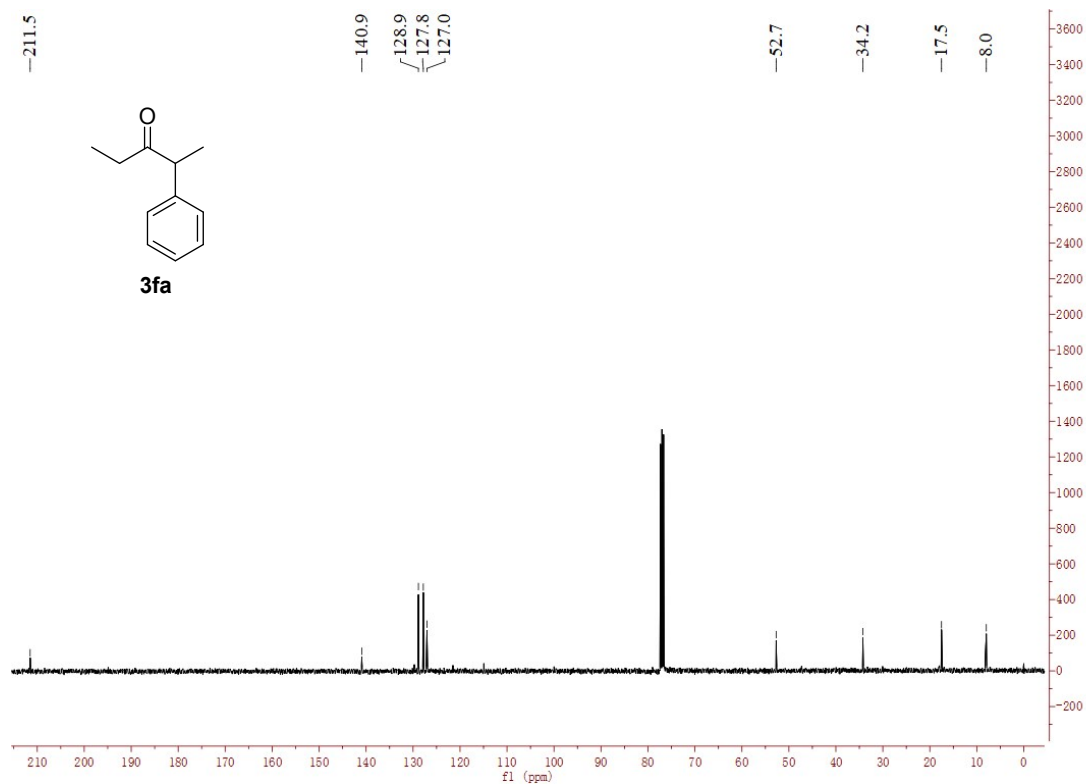
¹³C NMR spectrum of 3ea in CDCl₃



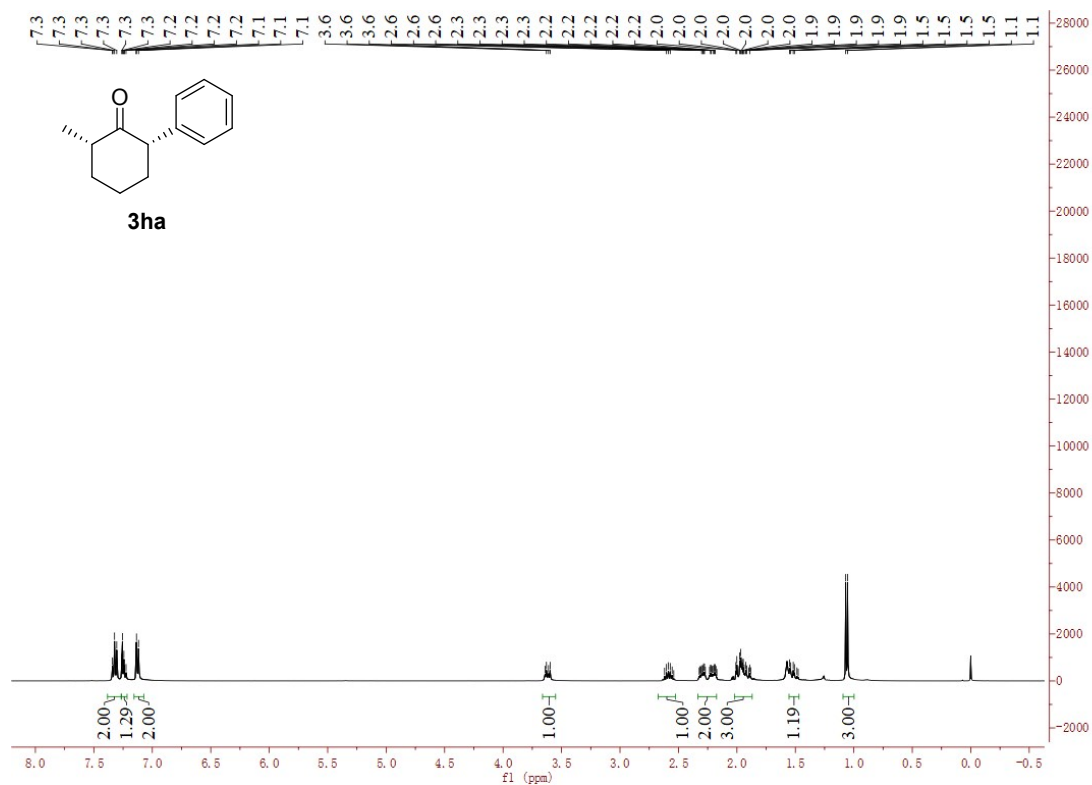
¹H NMR spectrum of 3fa in CDCl₃



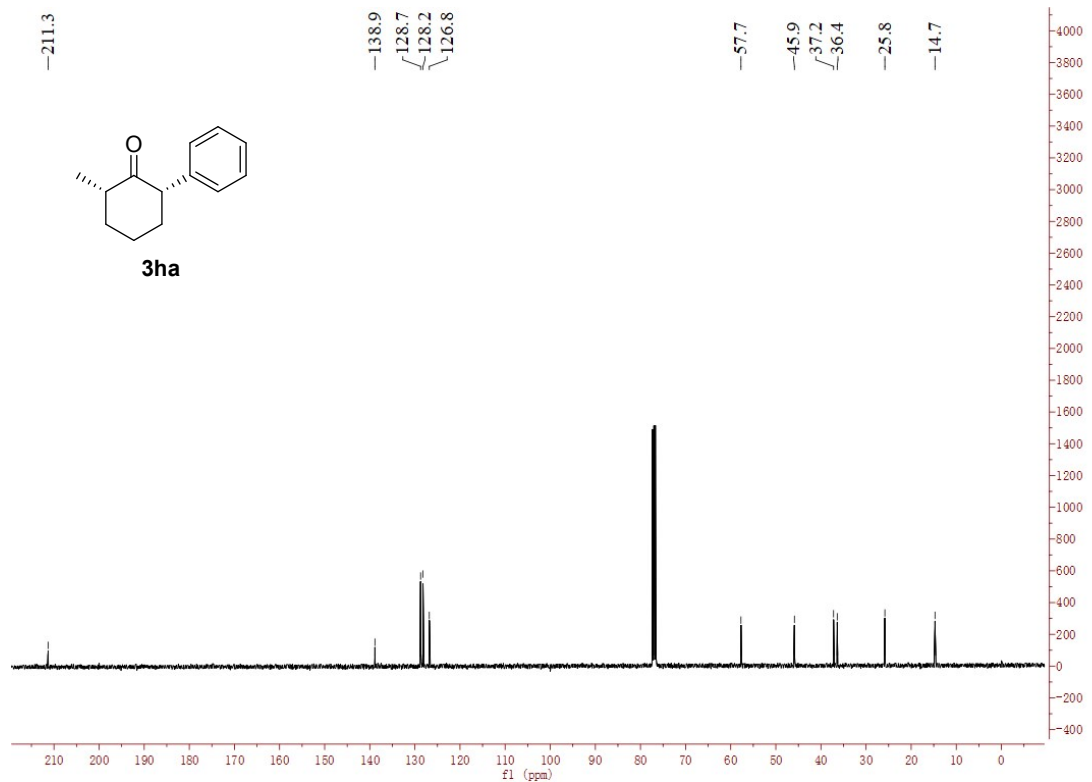
¹³C NMR spectrum of 3fa in CDCl₃



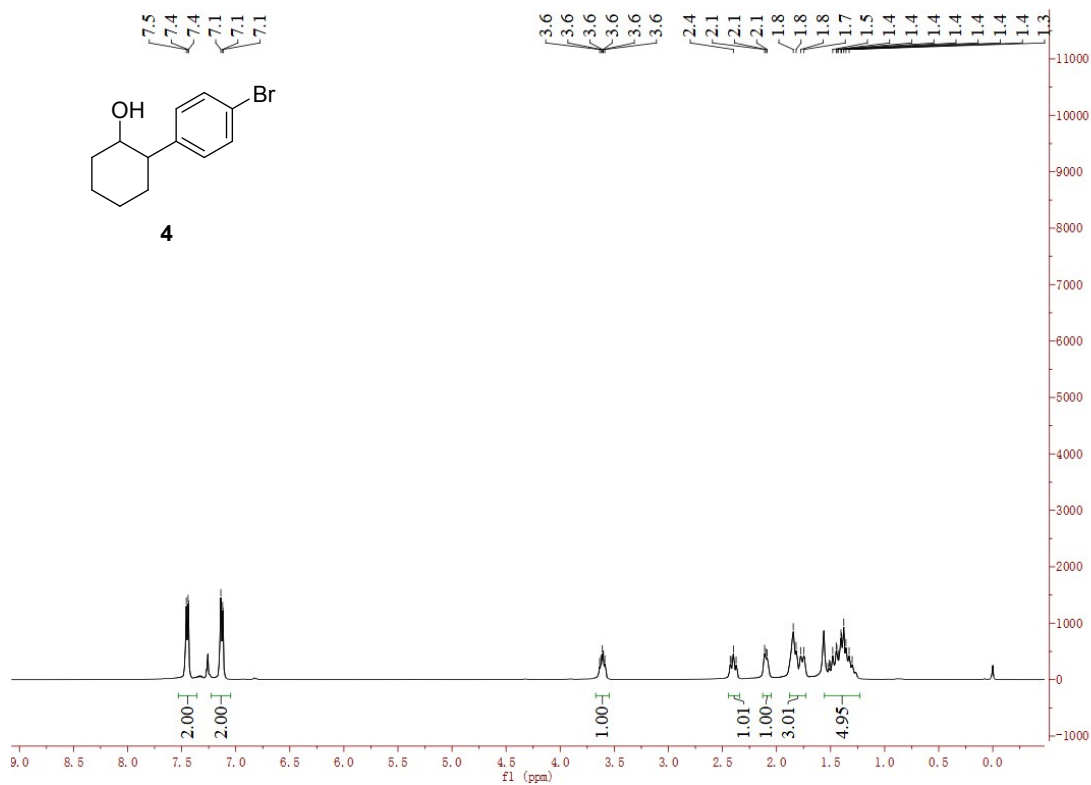
¹H NMR spectrum of 3ha in CDCl₃



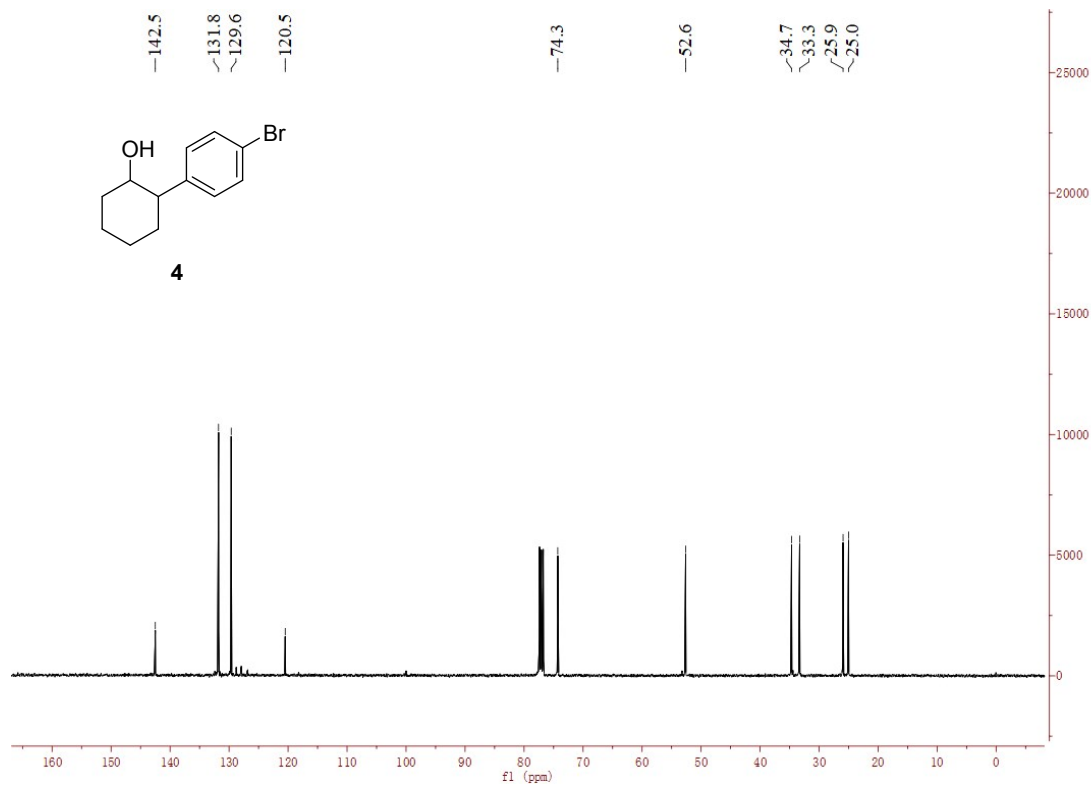
¹³C NMR spectrum of 3ha in CDCl₃



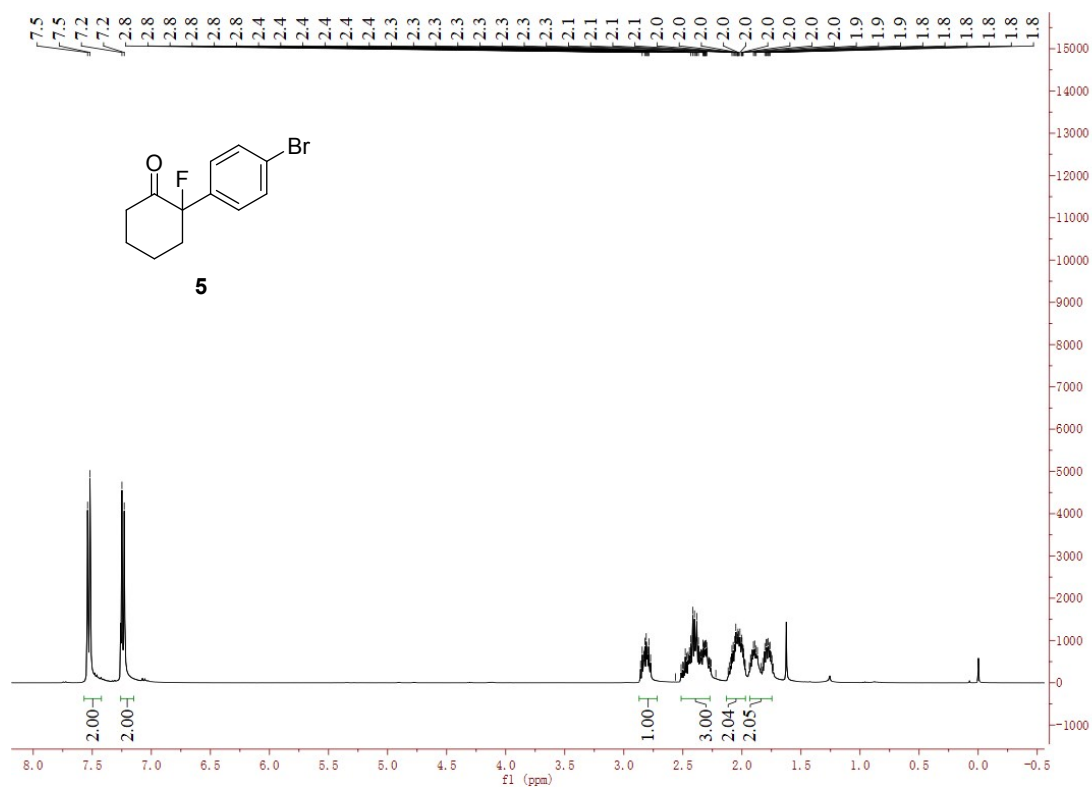
¹H NMR spectrum of 4 in CDCl₃



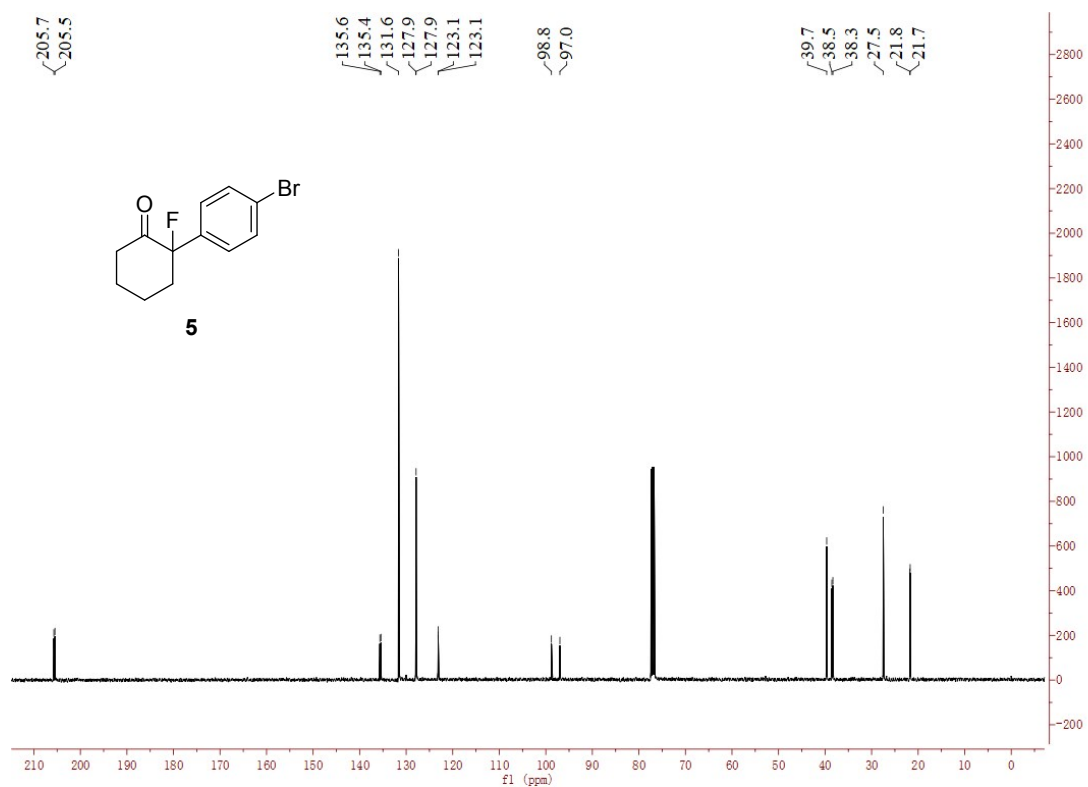
¹³C NMR spectrum of 4 in CDCl₃



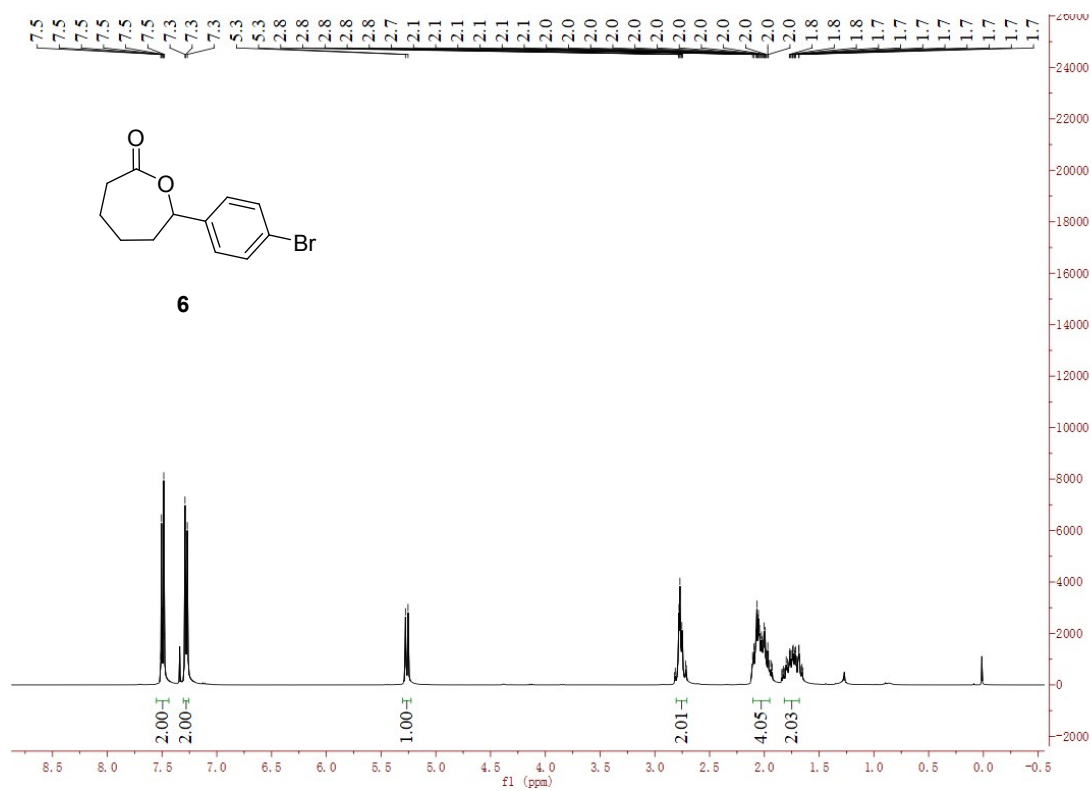
¹H NMR spectrum of 5 in CDCl₃



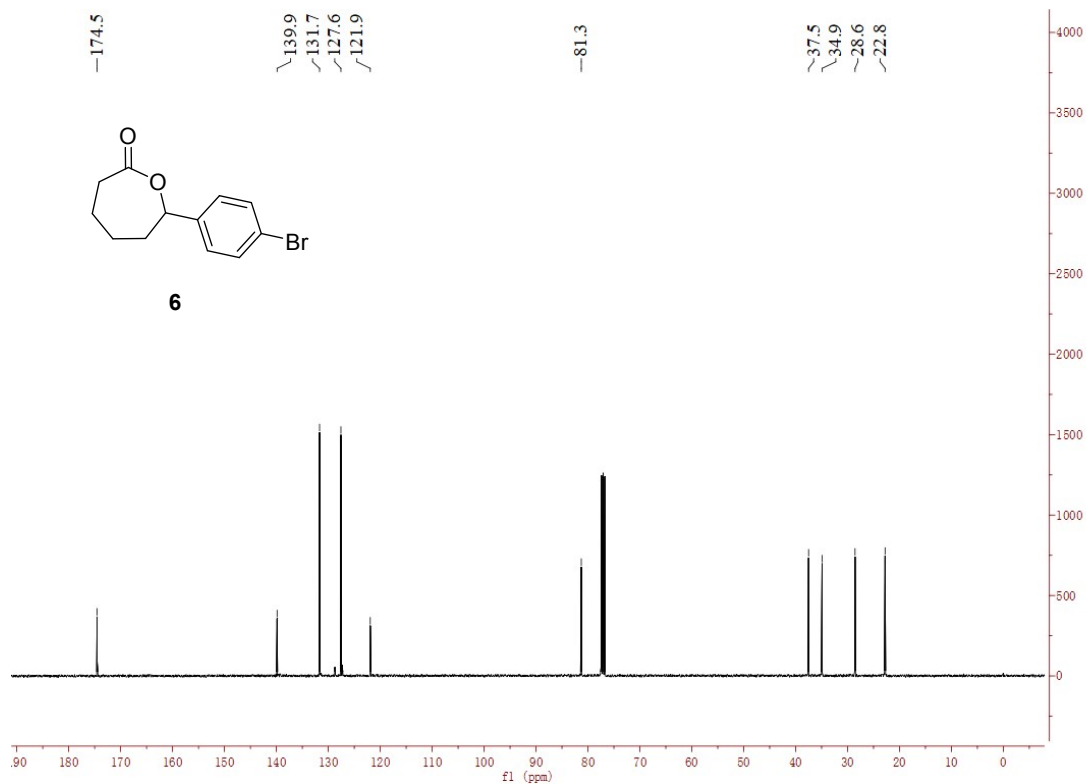
¹³C NMR spectrum of 5 in CDCl₃



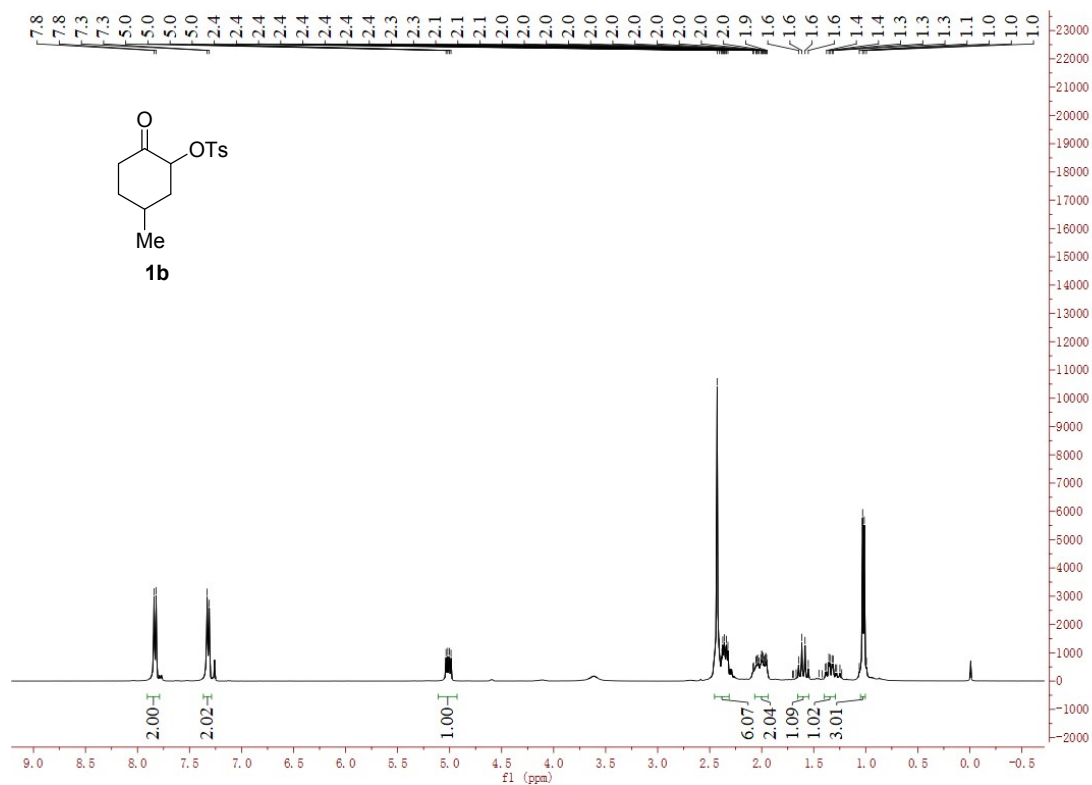
^1H NMR spectrum of 6 in CDCl_3



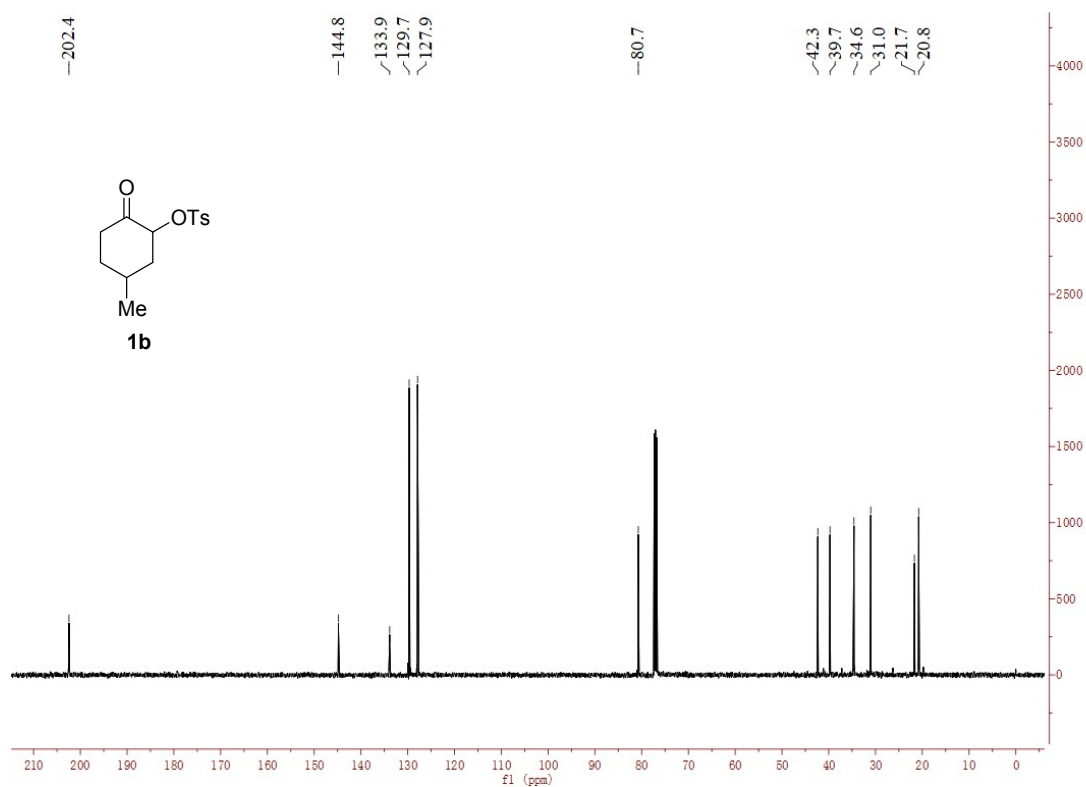
^{13}C NMR spectrum of 6 in CDCl_3



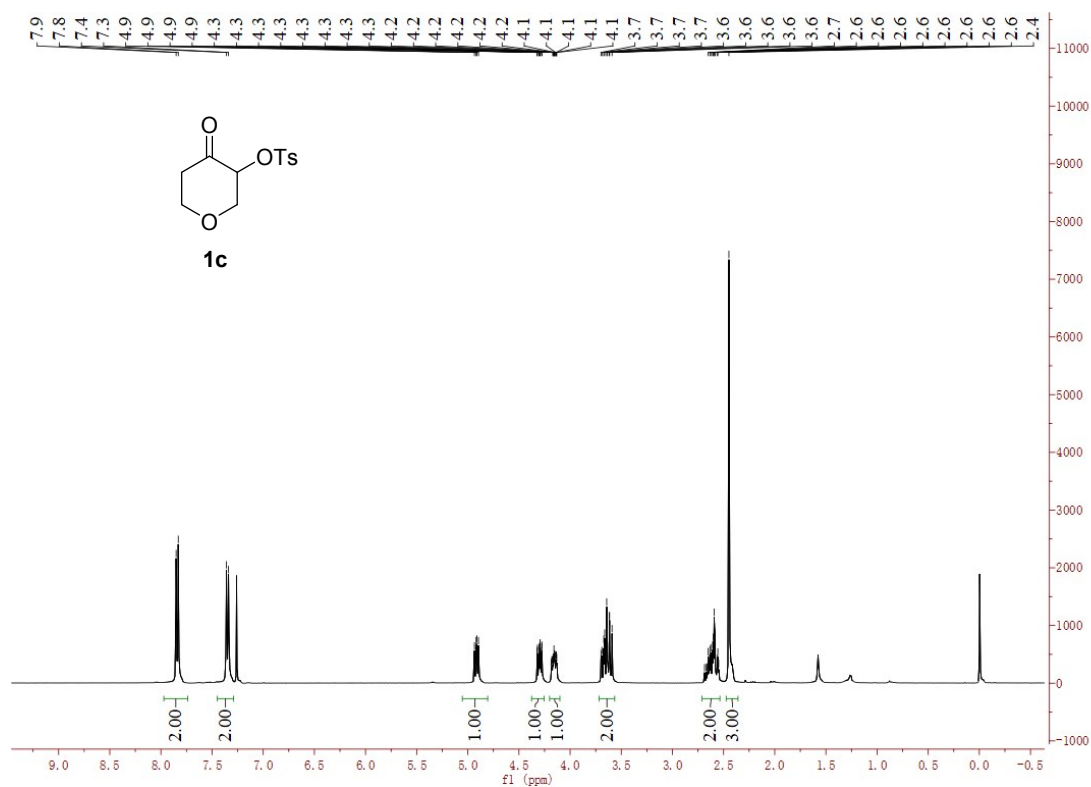
¹H NMR spectrum of 1b in CDCl₃



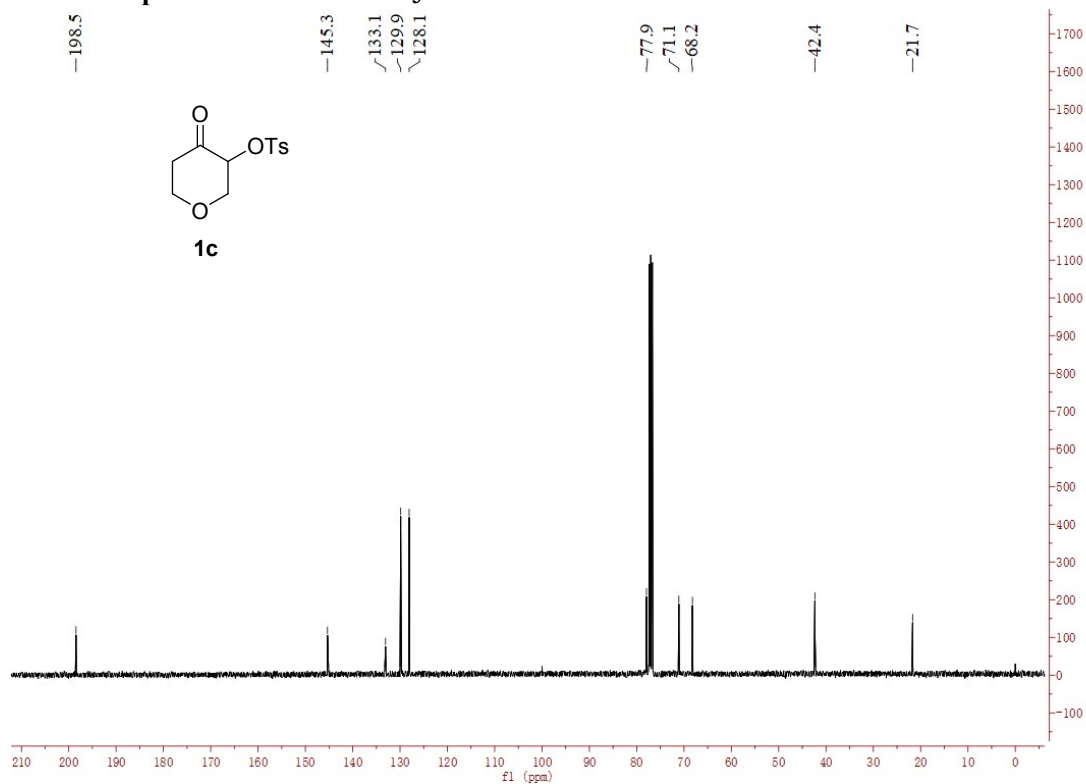
¹³C NMR spectrum of 1b in CDCl₃



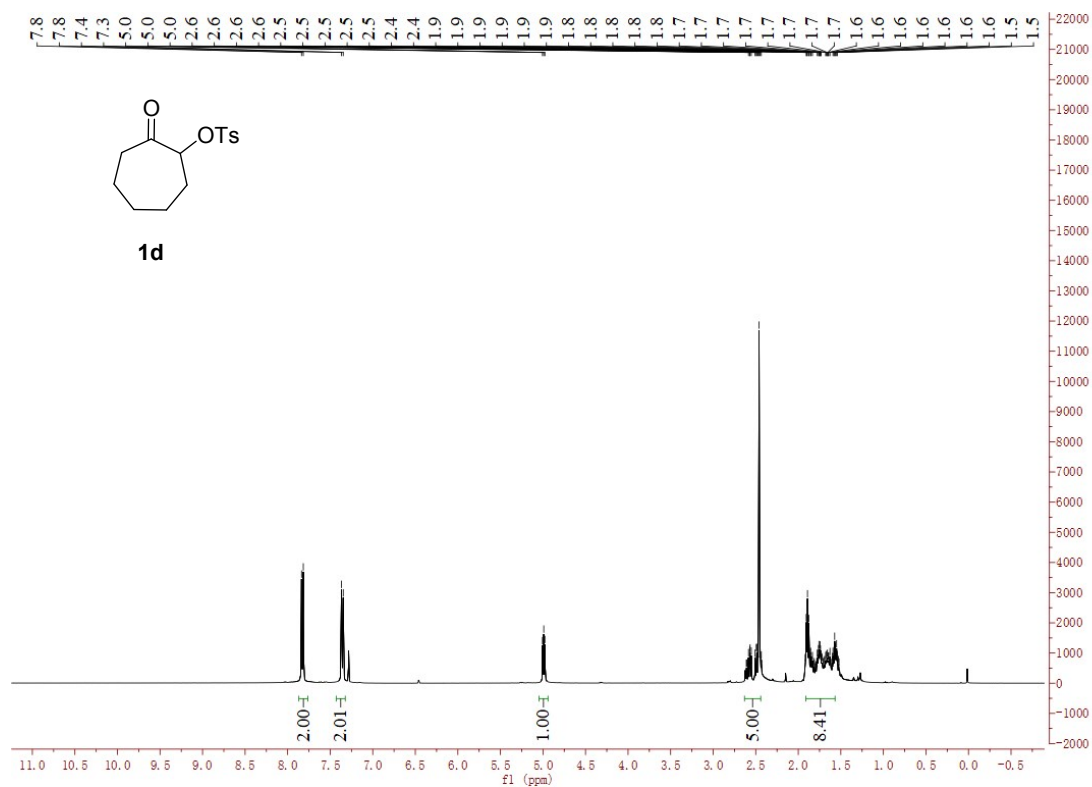
¹H NMR spectrum of 1c in CDCl₃



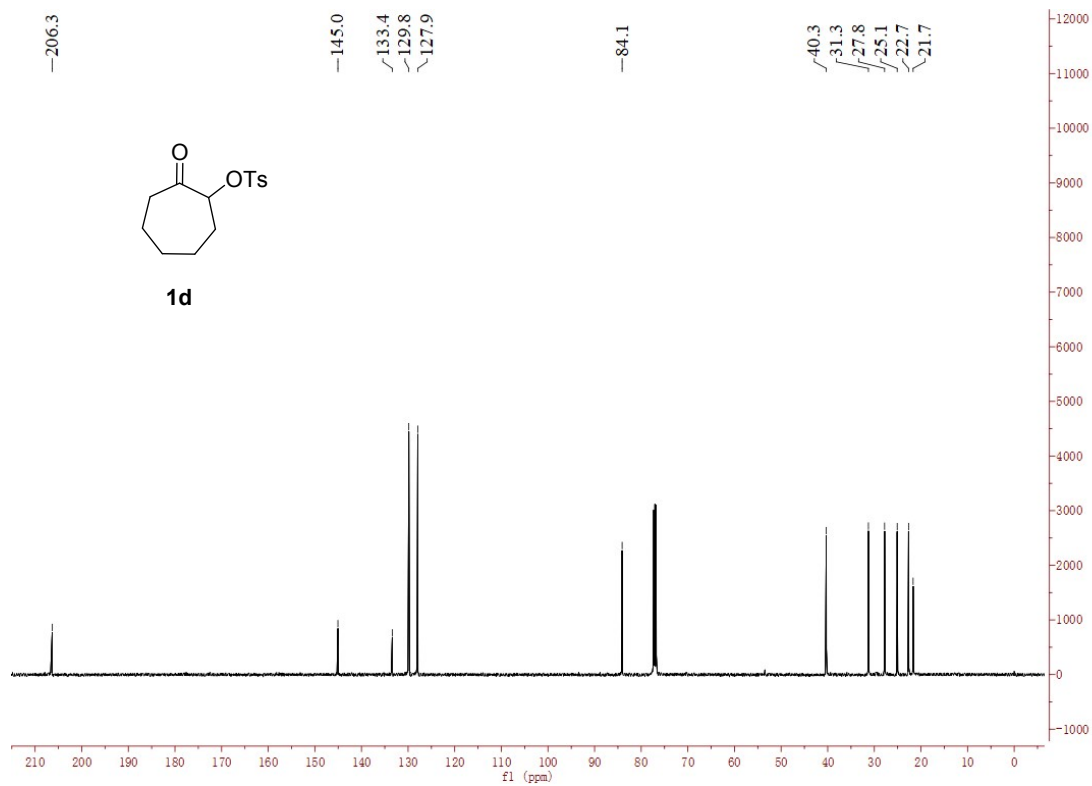
¹³C NMR spectrum of 1c in CDCl₃



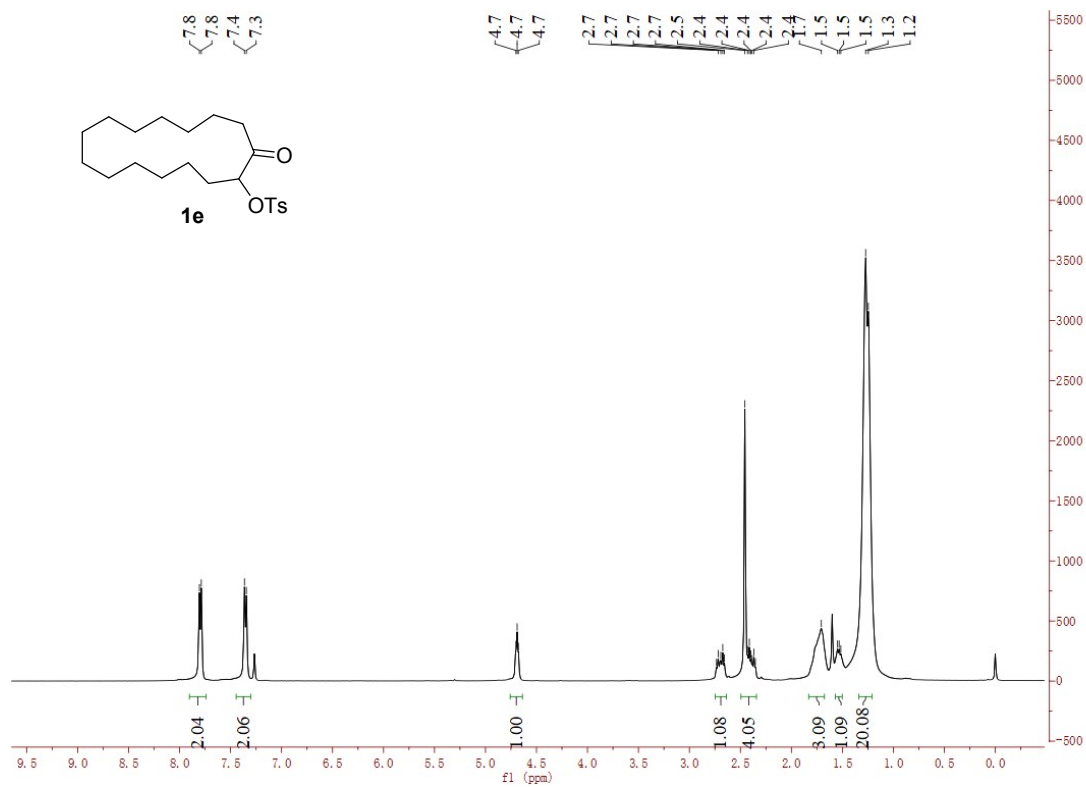
^1H NMR spectrum of **1d** in CDCl_3



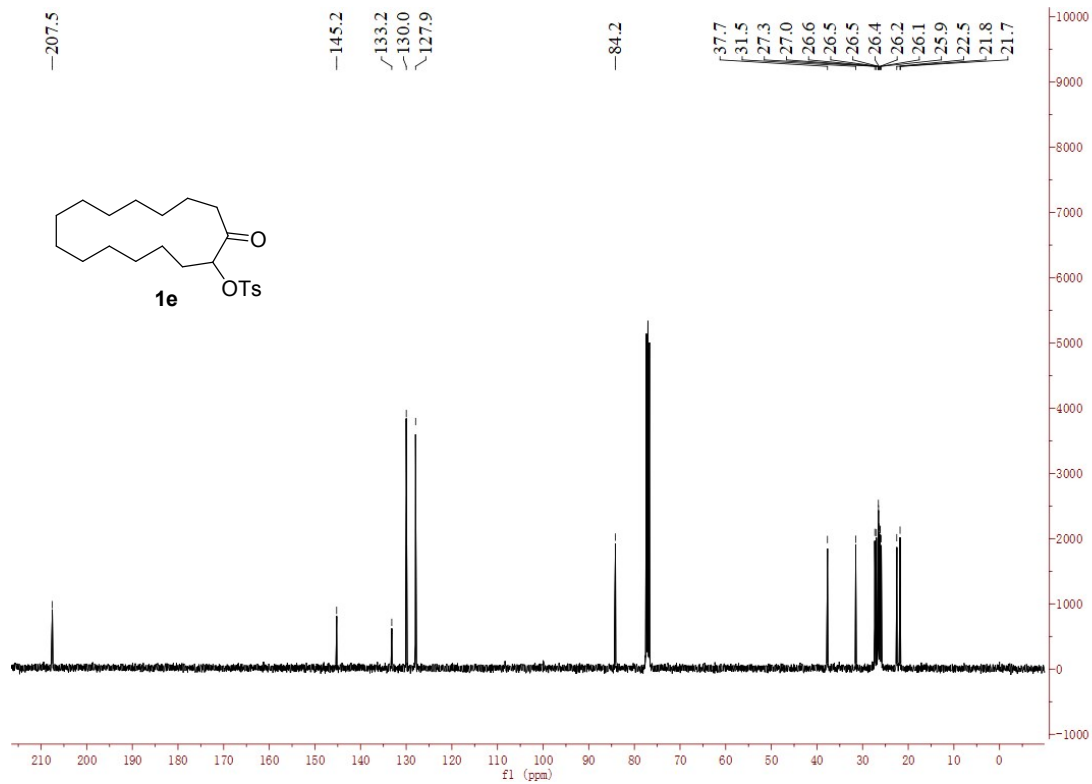
^{13}C NMR spectrum of **1d** in CDCl_3



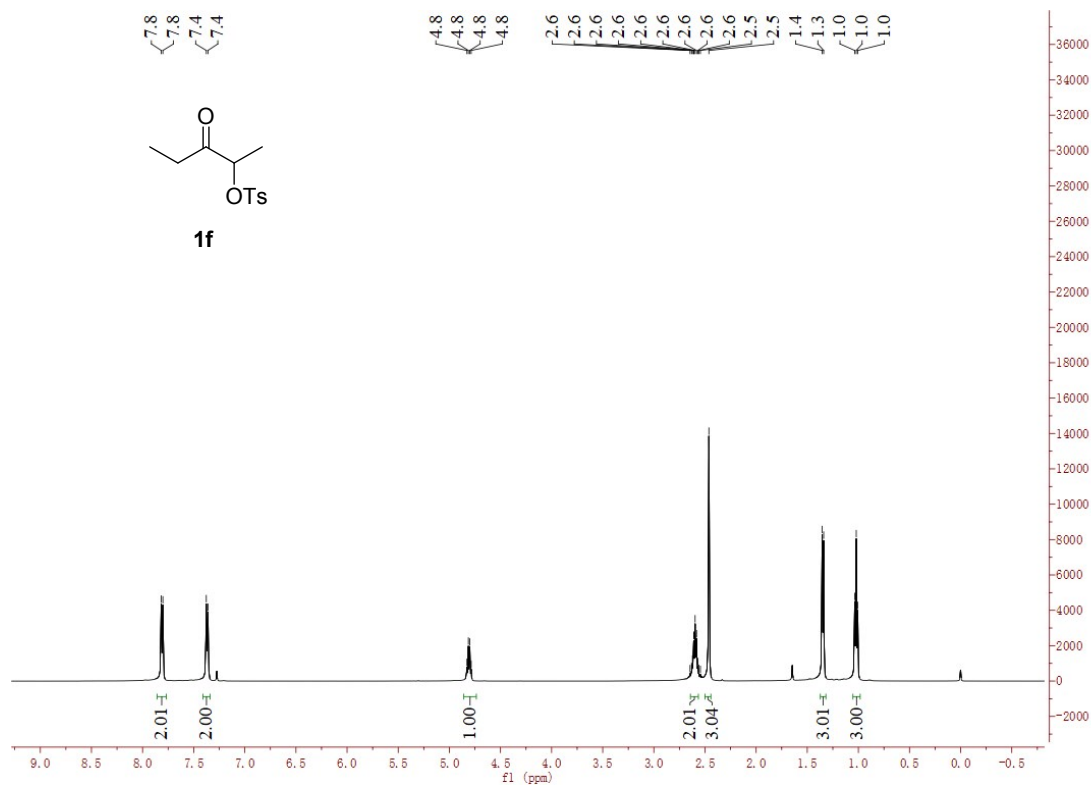
¹H NMR spectrum of **1e** in CDCl₃



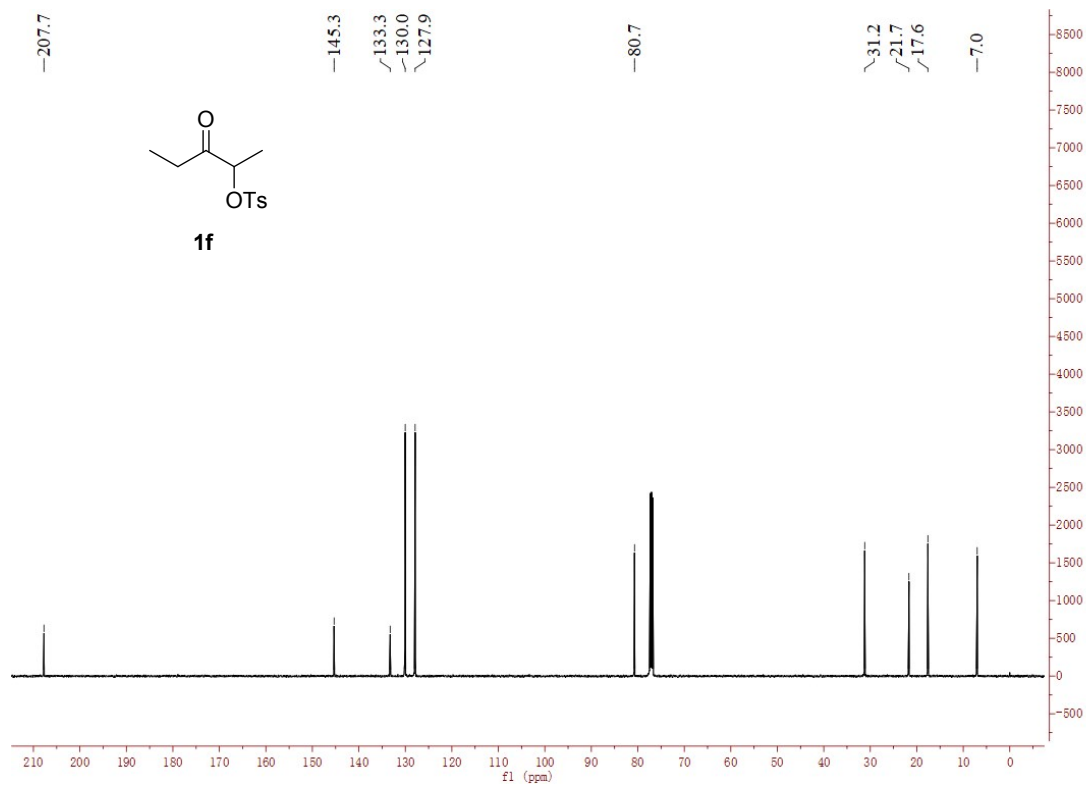
¹³C NMR spectrum of **1e** in CDCl₃



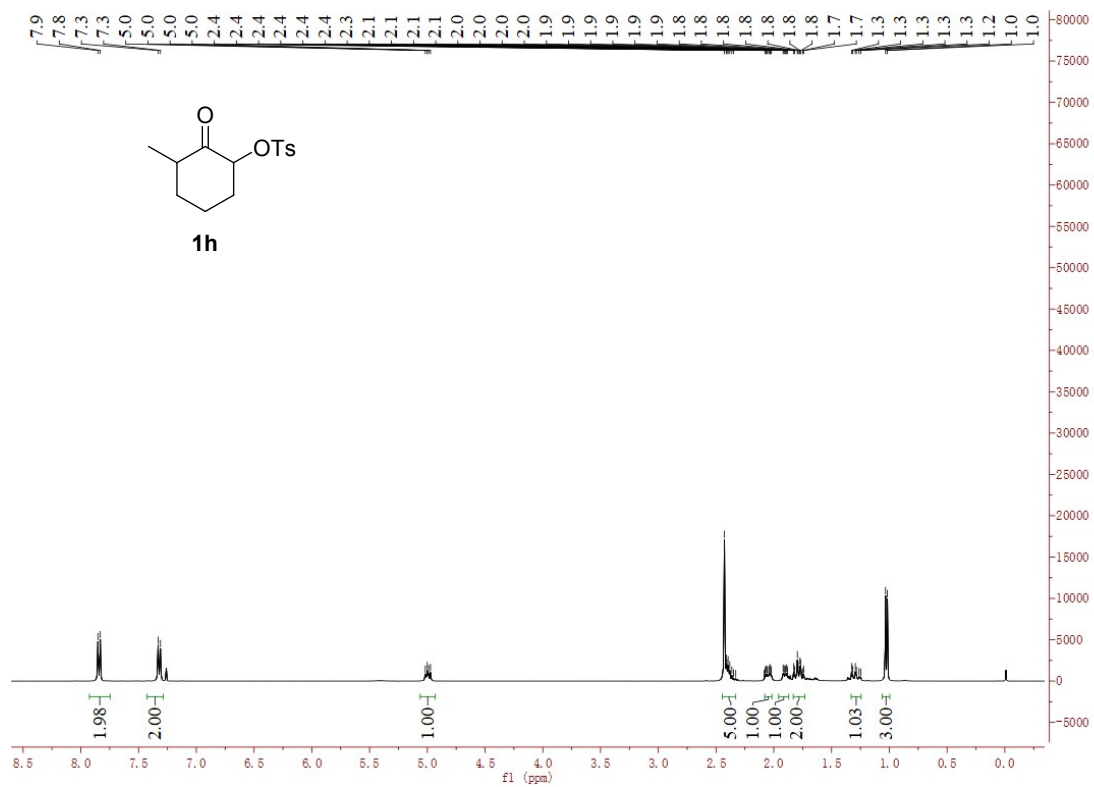
¹H NMR spectrum of 1f in CDCl₃



¹³C NMR spectrum of 1f in CDCl₃



¹H NMR spectrum of 1h in CDCl₃



¹³C NMR spectrum of 1h in CDCl₃

