

Supporting information

**Pd-Catalyzed Enantioselective Double Heck
Reaction**

Baihang Ju, Shigui Chen* and Wangqing Kong*

E-mail: wqkong@whu.edu.cn

The Center for Precision Synthesis, Institute for Advanced Studies, Wuhan
University, 299 Bayi Road, Wuhan, Hubei 430072, P. R. China

Contents

1. General information	S3
2. General procedures	S4
3. Optimization of reaction conditions	S5
4. General procedure for the synthesis of starting materials	S6
5. Characterization data of products	S8
6. Copies of the ^1H , ^{19}F and ^{13}C NMR spectra	S64
7. References	S100

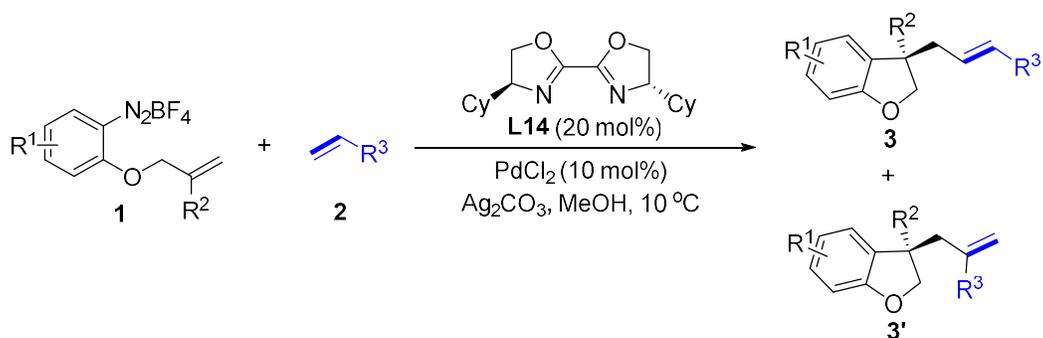
1. General Information

^1H and ^{13}C NMR data were recorded with Bruker ADVANCE III (400 MHz) or JNM-ECZ400S/L1 (400 MHz) spectrometers. Chemical shifts are given in ppm. The spectra are calibrated to the residual ^1H and ^{13}C signals of the solvents. Multiplicities are abbreviated as follows: singlet (s), doublet (d), triplet (t), quartet (q), doublet-doublet (dd), quintet (quint), septet (sept), multiplet (m), and broad (b). ^{19}F NMR spectra were recorded using CFCl_3 as internal standard. Gas chromatography were determined with a SHIMADZU Nexis GC 2030 gas chromatography instrument with a FID detector. High-resolution mass spectra (HRMS) were recorded on DIONEX UltiMate 3000 & Bruker Compact TOF mass spectrometer. Enantiomeric excesses were determined with a SHIMADZU LC-20ADXR system using chiral stationary phase columns (DAICEL) by comparing the samples with the corresponding racemic samples. Column and elution details were specified in each entry.

Materials and Methods: Unless otherwise stated, starting materials were purchased from commercial suppliers (Adamas-beta[®], Alfa, Aldrich and so on). All reactions dealing with air- or moisture-sensitive compounds were performed in the argon-filled glove box or by standard Schlenk techniques in oven-dried reaction vessels under argon atmosphere. Solvents were purchased in HPLC quality, degassed by purging thoroughly with argon and dried over activated molecular sieves of appropriate size. More sensitive compounds were stored in a desiccator or in a glove-box if required. Reactions were monitored by thin layer chromatography (TLC) using glass 0.25 mm silica gel plates. Compounds were visualized by UV-light at 254 nm and by dipping the plates in an aqueous potassium permanganate solution followed by heating. Flash column chromatography was performed over silica gel (200-400 mesh).

2. General Procedure

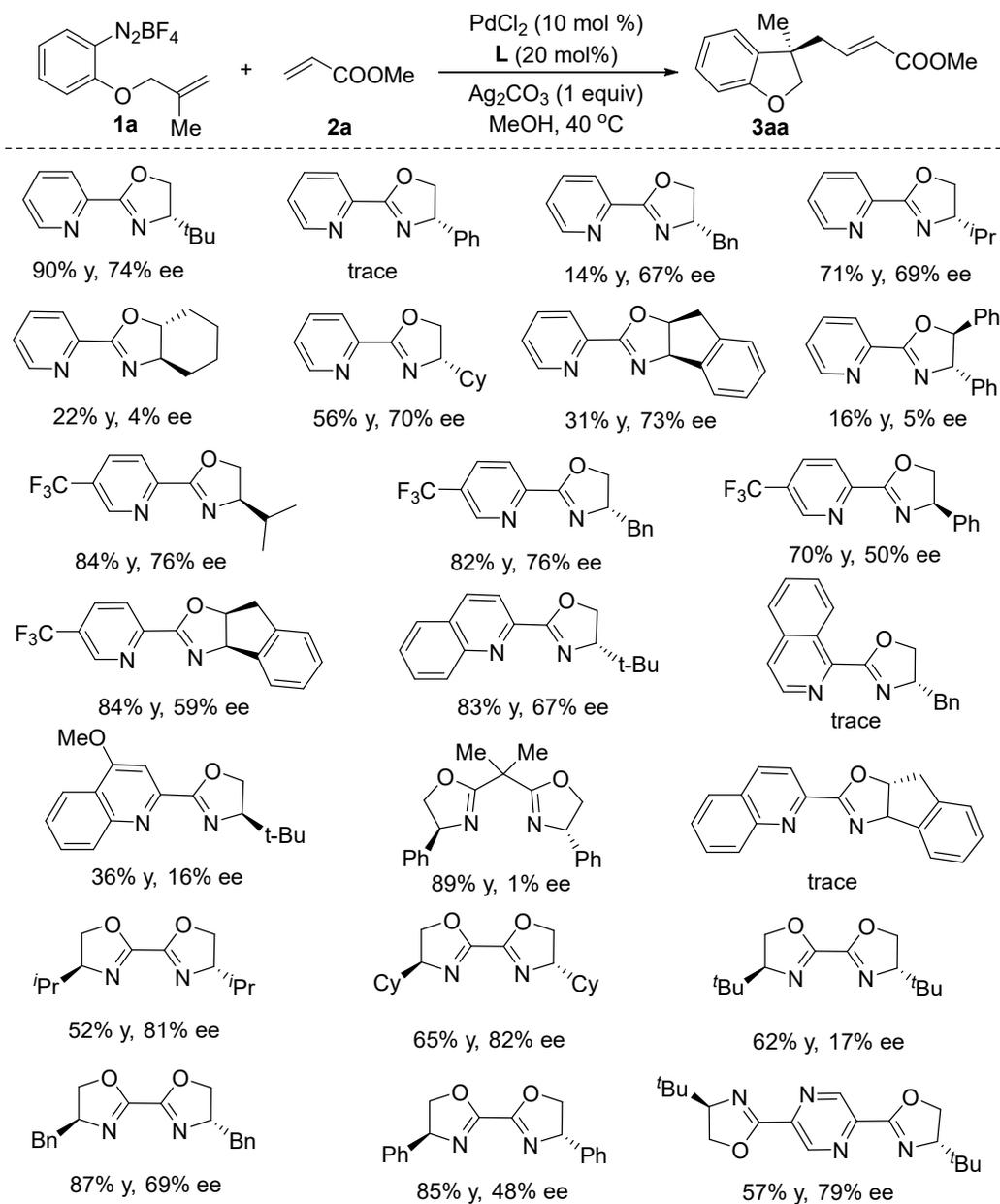
General procedure for the enantioselective aryl-alkenylation of arenediazonium salts **1** with alkenes **2**:



A mixture of PdCl₂ (10 mol %, 1.7 mg), (4*S*, 4'*S*)-BOX **L14** (20 mol %, 6.0 mg) and MeOH (1.0 mL) was stirred in an oven-dried vial at room temperature for 15 minutes to form the precatalyst. The resulting solution was cooled to 10 °C and charged with arenediazonium salt **1** (0.1 mmol, 1.0 equiv), alkene **2** (0.2 mmol, 0.2 equiv) and Ag₂CO₃ (0.1 mmol, 27.5 mg). Then the reaction mixture was stirred at the same temperature until the reaction was completed. The solvent was removed under vacuum and the residue was then purified by column chromatography on silica gel, eluting with petroleum ether/EtOAc = 100:1~5/1 to afford the desired dihydrobenzofuran **3** (This reaction show high regioselectivity and in almost all cases only < 5% of regioisomers **3'** were detected).

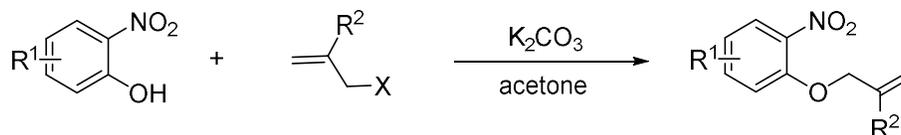
3. Optimization of Reaction Conditions

Ligand screening:



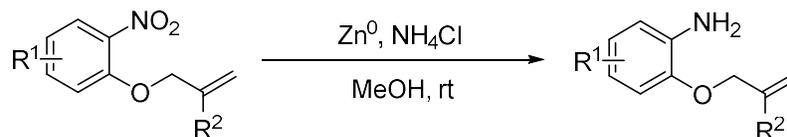
4. General procedure for the synthesis of starting materials

4.1 General procedure for allylation of 2-nitrophenols



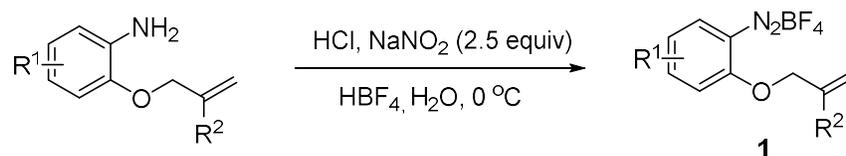
To an oven-dried sealed tube containing 2-nitrophenol (20 mmol, 1.0 equiv), K_2CO_3 (3.0 equiv, 8.29 g) in acetone (60 mL) at 0 °C was added the corresponding allyl halide (X = Br, 1.2 equiv; X = Cl, 1.5 equiv). The tube was sealed and the reaction mixture was heated at 65 °C until the reaction was completed. The mixture was cooled to room temperature, quenched by the addition of H_2O and extracted with EtOAc. The combined organic layers was washed with saturated NH_4Cl and dried over Na_2SO_4 . The solvent was then removed under vacuum to give the desired alkylation product in an almost pure form, which was used in the next step without further purification.

4.2 General procedure for reduction of nitro to aniline



To a vigorously stirred solution of the above prepared allylated nitro compound (10 mmol, 1.0 equiv) in MeOH (60 mL) and saturated NH_4Cl aqueous solution (5 mL) was added Zn dust (15 equiv, 9.75 g). After the reaction was completed, the reaction mixture was filtered through a short pad of celite and washed with EtOAc. The filtrate was dried over Na_2SO_4 and the solvent was then removed under vacuum to give the corresponding aniline derivative, which was used in the next step without further purification.

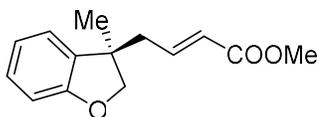
4.3 General procedure for the synthesis of arenediazonium tetrafluoroborates **1**¹



A mixture of the above aniline (10 mmol, 1 equiv) and HCl (3 equiv, 3.0 mol/L, 10 mL) was stirred at 0 °C for 10 minutes. To the vigorously stirred suspension was added a solution of NaNO₂ (2.5 equiv, 1.73 g) in 2.0 mL of H₂O at the same temperature for 20 minutes. The reaction mixture was washed with cold Et₂O, followed by the addition of HBF₄ (48% w/w, 4.5 equiv, 5.9 mL). This solution was extracted with DCM, the organic phase was washed with H₂O and dried over anhydrous Na₂SO₄. The solvent was evaporated under vacuum to furnish the corresponding arenediazonium salt. Depending on the purity of the salt, it was recrystallized by dissolution in acetone followed by the addition of cold Et₂O at 0 °C. All the arenediazonium tetrafluoroborate salts were stored in a freezer at -25 °C.

5. Characterization data of products

Methyl (*R*, *E*)-4-(3-methyl-2,3-dihydrobenzofuran-3-yl)but-2-enoate (**3aa**)



Chemical Formula: C₁₄H₁₆O₃

Exact Mass: 232.1099

3aa was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2a** (0.2 mmol, 18 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 50/1~10/1) to obtain **3aa** as colorless oil (18.4 mg, 79% yield). The ¹H NMR data matched those reported in the literature²: ¹H NMR (400 MHz, CDCl₃): δ 7.17-7.08 (m, 2H), 6.92-6.78 (m, 3H), 5.85 (dt, *J* = 15.5, 1.4 Hz, 1H), 4.35 (d, *J* = 8.8 Hz, 1H), 4.15 (d, *J* = 8.8 Hz, 1H), 3.72 (s, 3H), 2.50 (dd, *J* = 7.8, 1.4 Hz, 2H), 1.38 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 166.5, 159.2, 144.3, 133.9, 128.5, 124.2, 122.8, 120.7, 109.9, 81.7, 51.5, 45.2, 43.3, 24.8.

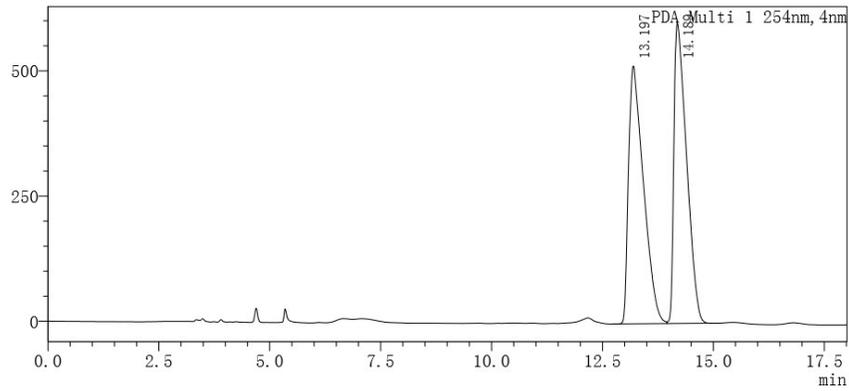
The enantiomeric purity was established by HPLC analysis using a chiral column: OJ-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. t_R = 13 min (minor), 14 min (major).

Optical Rotation: $[\alpha]_D^{30}$ 25.2 (c 0.1, CHCl₃) for 94% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	13.197	12094583	515148	0.000		M	
2	14.189	11882682	599546	0.000		V M	
总计		23977266	1114694				

peak number

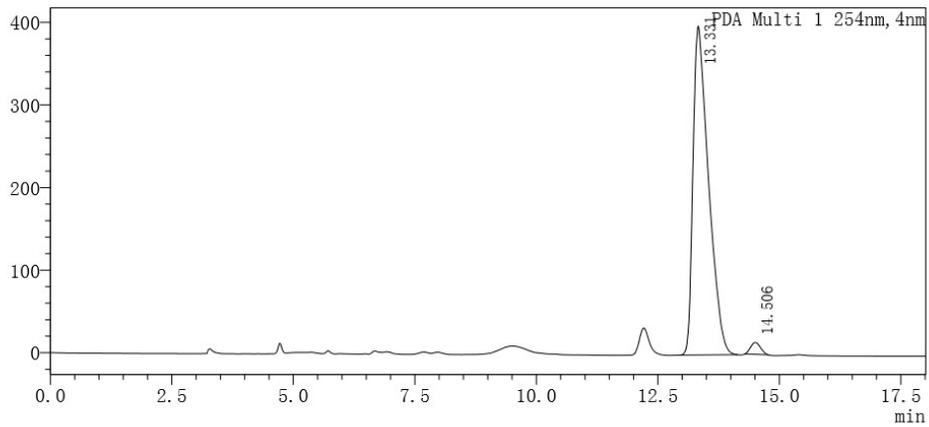
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	13.331	8822898	398286	0.000		M	
2	14.506	203547	14333	0.000		M	
总计		9026444	412619				

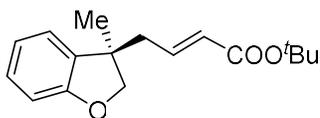
peak number

area

height

retention time

tert-butyl (*R, E*)-4-(3-methyl-2,3-dihydrobenzofuran-3-yl)but-2-enoate (**3ab**)



Chemical Formula: C₁₇H₂₂O₃

Exact Mass: 274.1569

3ab was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2b** (0.2 mmol, 29 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 50/1~10/1) to obtain **3ab** as colorless oil (20.6 mg, 75% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.16-7.08 (m, 2H), 6.91-6.87 (td, *J* = 7.4, 0.8 Hz, 1H), 6.81-6.72 (m, 2H), 5.79 (d, *J* = 15.5 Hz, 1H), 4.35 (d, *J* = 8.8 Hz, 1H), 4.14 (d, *J* = 8.8 Hz, 1H), 2.47 (d, *J* = 7.7 Hz, 2H), 1.47 (s, 9H), 1.37 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 165.5, 159.3, 142.8, 134.2, 128.4, 126.3, 122.8, 120.6, 109.9, 81.8, 80.3, 45.2, 43.1, 28.1, 24.7;

HRMS: (ESI) calcd for C₁₇H₂₂NaO₃⁺[M+Na]⁺ 297.1461; found 297.1456.

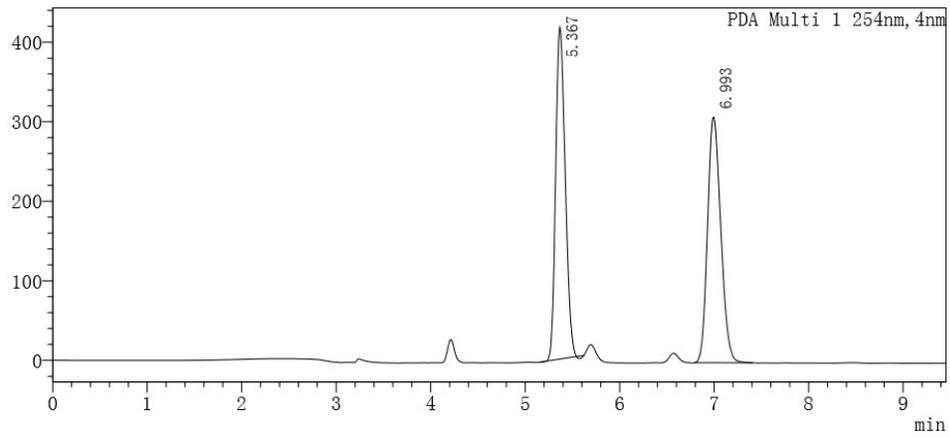
The enantiomeric purity was established by HPLC analysis using a chiral column: OJ-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. t_R = 5.3 min (major), 6.9 min (minor).

Optical Rotation: [α]_D²⁸ 8.0 (c 0.3, CHCl₃) for 99% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.367	2912162	418331	0.000		M	
2	6.993	3018466	308815	0.000		M	
总计		5930628	727146				

peak number

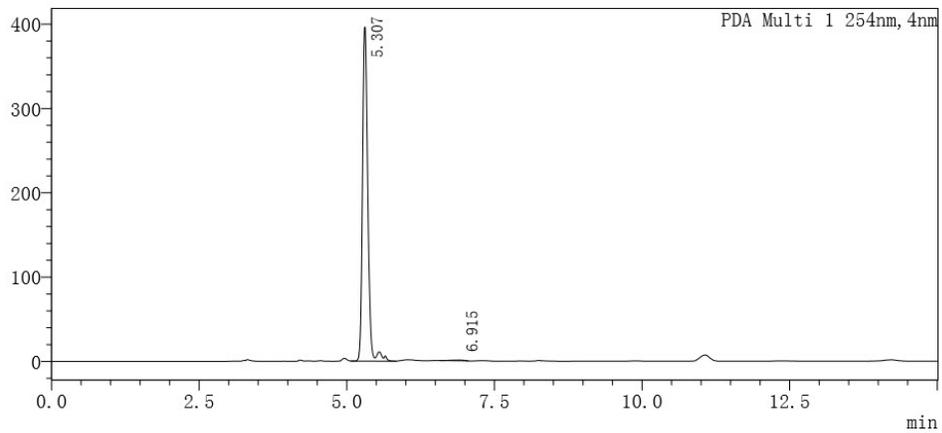
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.307	2494425	396323	0.000		M	
2	6.915	12717	922	0.000		M	
总计		2507142	397245				

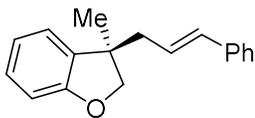
peak number

area

height

retention time

(*R*)-3-cinnamyl-3-methyl-2,3-dihydrobenzofuran (**3ac**)



Chemical Formula: C₁₈H₁₈O

Exact Mass: 250.1358

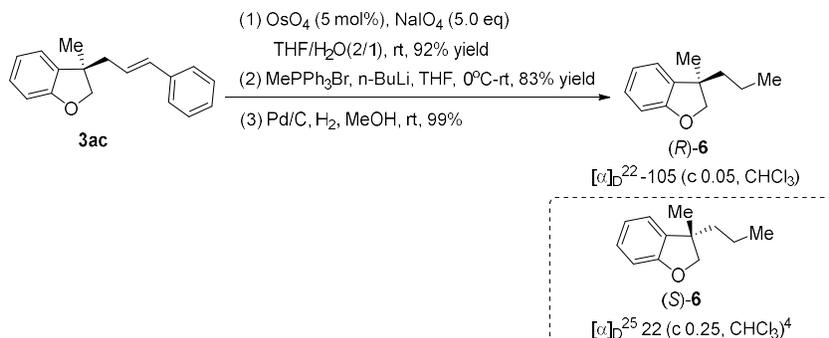
3ac was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2c** (0.2 mmol, 23 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ac** as colorless oil (19.0 mg, 76% yield). The ¹H NMR data matched those reported in the literature³: ¹H NMR (400 MHz, CDCl₃): δ 7.34-7.28 (m, 4H), 7.25-7.20 (m, 1H), 7.19-7.12 (m, 2H), 6.91 (td, *J* = 7.4, 0.9 Hz, 1H), 6.82 (dt, *J* = 7.9, 0.8 Hz, 1H), 6.43 (dt, *J* = 15.7, 1.3 Hz, 1H), 6.12 (dt, *J* = 15.8, 7.5 Hz, 1H), 4.46 (d, *J* = 8.6 Hz, 1H), 4.17 (d, *J* = 8.6 Hz, 1H), 2.52 (dd, *J* = 7.5, 1.4 Hz, 2H), 1.41 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 137.3, 134.8, 133.4, 128.5, 128.2, 127.2, 126.1, 125.6, 122.9, 120.5, 109.7, 82.0, 45.6, 44.2, 25.0.

The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 1 mL/min. tR = 5.6 min (minor), 5.8 min (major).

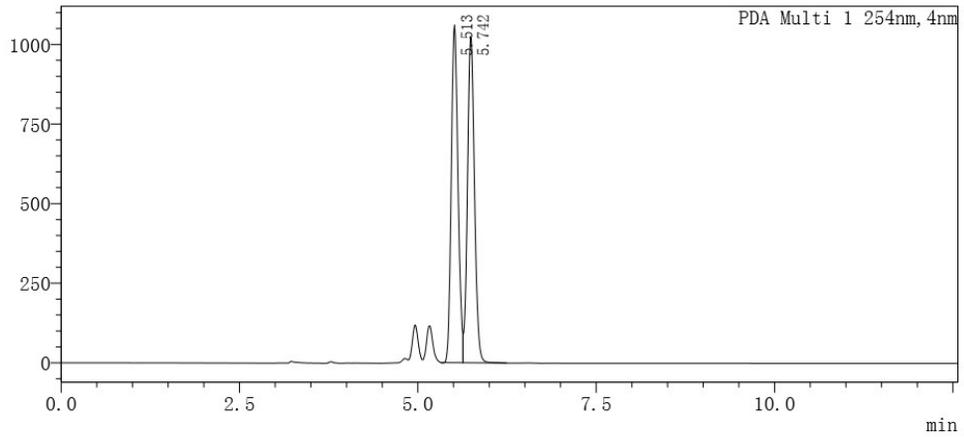
Optical Rotation: $[\alpha]_D^{30}$ 21.3 (c 0.1, CHCl₃) for 94% ee.

The absolute configuration of product **3ac** was determined by converting **3ac** into the corresponding known compound **6** by ozonolysis of alkene to aldehyde, followed by olefination of the resulting aldehyde to terminal alkene and hydrogenation. All other dihydrobenzofurans **3** were attributed accordingly.



<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.513	6925224	1060933	0.000		M	
2	5.742	7072695	1025268	0.000		V M	
总计		13997920	2086201				

peak number

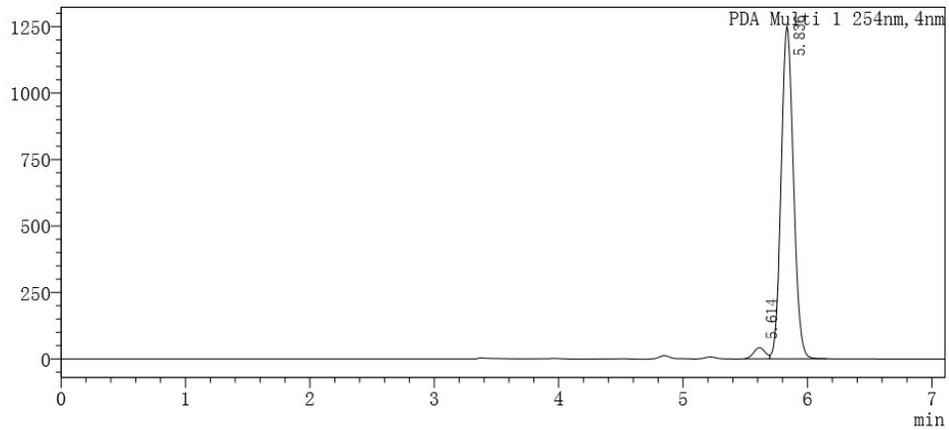
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.614	272153	41758	0.000		M	
2	5.836	8610817	1253693	0.000		V M	
总计		8882970	1295452				

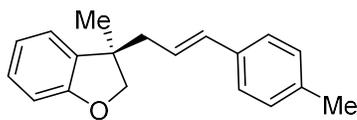
peak number

area

height

retention time

(*R, E*)-3-methyl-3-(3-(*p*-tolyl)allyl)-2,3-dihydrobenzofuran (**3ad**)



Chemical Formula: C₁₉H₂₀O

Exact Mass: 264.1514

3ad was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2d** (0.2 mmol, 26 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ad** as colorless oil (18.1 mg, 66% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.33-7.07 (m, 6H), 6.98-6.90 (m, 1H), 6.84 (d, *J* = 7.9 Hz, 1H), 6.42 (d, *J* = 15.7 Hz, 1H), 6.18-5.99 (m, 1H), 4.48 (dd, *J* = 8.6, Hz, 1H), 4.19 (dd, *J* = 8.6, Hz, 1H), 2.53 (d, *J* = 7.3 Hz, 2H), 2.37 (s, 3H), 1.43 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.4, 137.0, 134.9, 134.5, 133.2, 129.2, 128.1, 125.9, 124.5, 122.9, 120.4, 109.7, 81.9, 45.6, 44.2, 24.9, 21.2;

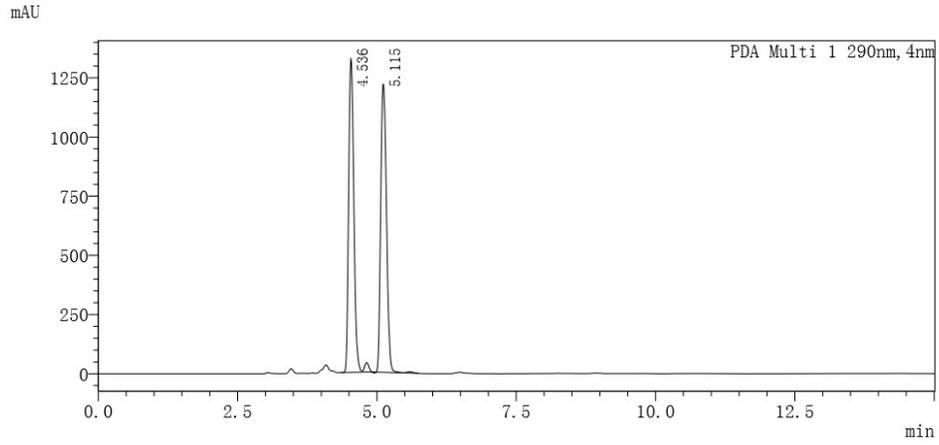
HRMS: (ESI) calcd for C₁₉H₂₀NaO⁺[M+Na]⁺ 287.1406; found 287.1407.

The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. tR = 4.5 min (minor), 5.0 min (major).

Optical Rotation: [α]_D³⁰ -9.3 (c 0.2, CHCl₃) for 94% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>



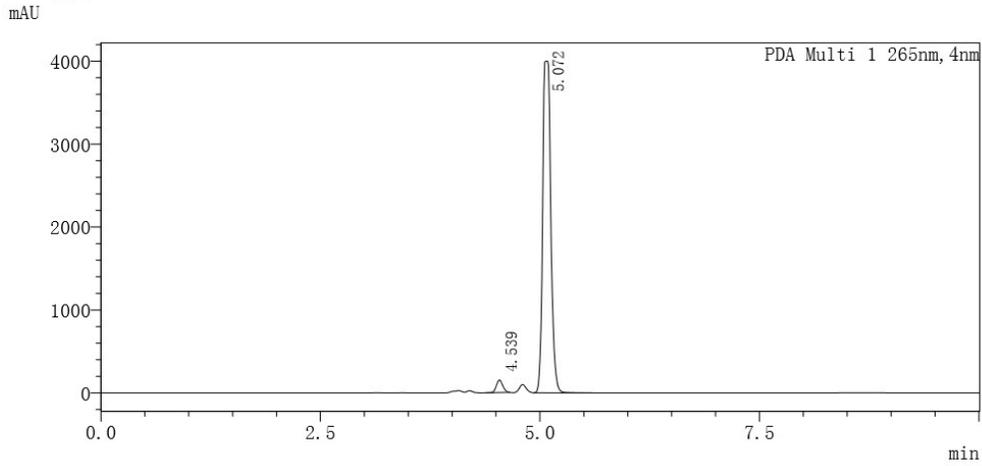
<峰表>

PDA Ch1 290nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.536	8782919	1327577	0.000		M	
2	5.115	8791332	1216670	0.000		M	
总计		17574252	2544247				



<色谱图>



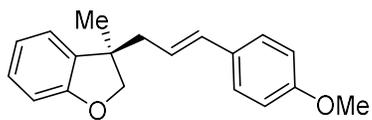
<峰表>

PDA Ch1 265nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.539	762200	149626	0.000		M	
2	5.072	25622591	3998210	0.000		M	
总计		26384791	4147836				



(*R, E*)-3-(3-(4-methoxyphenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ae**)



Chemical Formula: C₁₉H₂₀O₂

Exact Mass: 280.1463

3ae was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2e** (0.2 mmol, 26.6 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~20/1) to obtain **3ae** as colorless oil (19.1 mg, 68% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.25-7.23 (m, 1H), 7.17-7.11 (m, 2H), 6.91-6.80 (m, 5H), 6.36 (d, *J* = 15.7 Hz, 1H), 6.01-5.93 (m, 1H), 4.44 (d, *J* = 8.6 Hz, 1H), 4.15 (d, *J* = 8.6 Hz, 1H), 3.80 (s, 3H), 2.48 (dd, *J* = 7.5, 1.2 Hz, 2H), 1.39 (s, 3H);

¹³C NMR (101 MHz, CDCl₃) δ 159.5, 158.9, 134.9, 132.8, 130.2, 128.1, 127.2, 123.4, 122.9, 120.4, 113.9, 109.7, 82.0, 55.3, 45.7, 44.2, 25.0;

HRMS: (ESI) calcd for C₁₉H₂₁O₂⁺[M+H]⁺ 281.1536; found 281.1540.

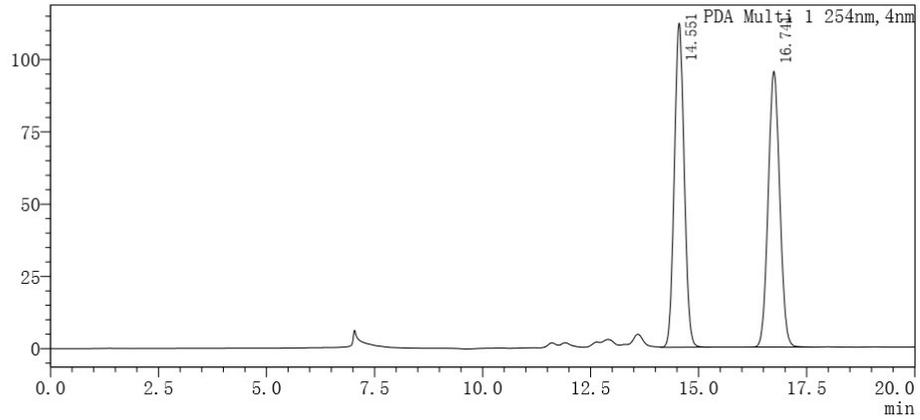
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 99/1 as eluent, 254 nm, 0.5 mL/min. t_R = 14 min (minor), 16 min (major).

Optical Rotation: [α]_D²⁸ 18.4 (c 0.2, CHCl₃) for 94% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	14.551	1782162	112163	0.000			
2	16.741	1774978	95341	0.000			
总计		3557140	207503				

peak number

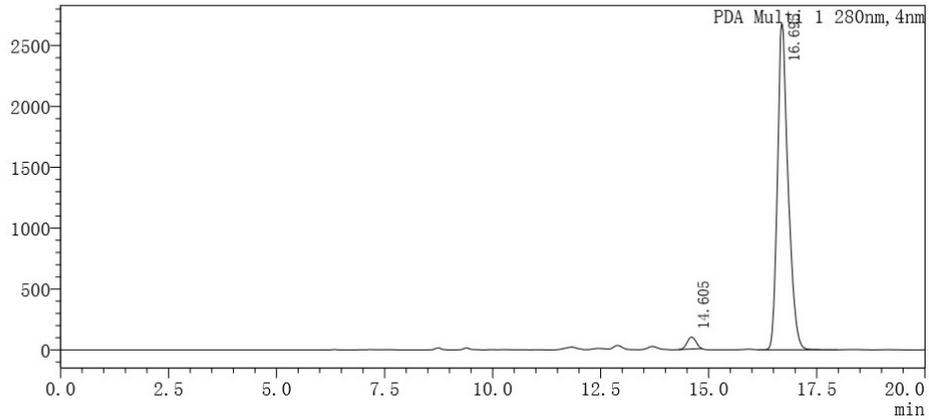
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 280nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	14.605	1395048	98174	0.000		M	
2	16.695	45769675	2679976	0.000		M	
总计		47164724	2778151				

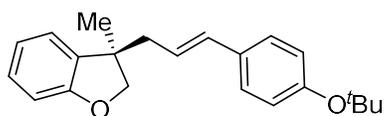
peak number

area

height

retention time

(*R, E*)-3-(3-(4-(*tert*-butoxy)phenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3af**)



Chemical Formula: C₂₂H₂₆O₂

Exact Mass: 322.1933

3af was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2f** (0.2 mmol, 37.7 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~20/1) to obtain **3af** as colorless oil (22.5 mg, 70% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.23-7.19 (m, 2H), 7.17-7.12 (m, 2H), 6.93-6.88 (m, 3H), 6.82-6.80 (m, 1H), 6.39 (d, *J* = 15.7 Hz, 1H), 6.01 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.45 (d, *J* = 8.6 Hz, 1H), 4.15 (d, *J* = 8.6 Hz, 1H), 2.50 (dd, *J* = 7.5, 1.2 Hz, 2H), 1.40 (s, 3H), 1.34 (s, 9H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 154.7, 134.9, 132.9, 132.5, 128.1, 126.6, 124.3, 124.2, 122.9, 120.5, 109.7, 81.9, 78.6, 45.6, 44.2, 28.8, 25.0;

HRMS: (ESI) calcd for C₂₂H₂₆NaO₂⁺[M+Na]⁺ 345.1825; found 345.1825.

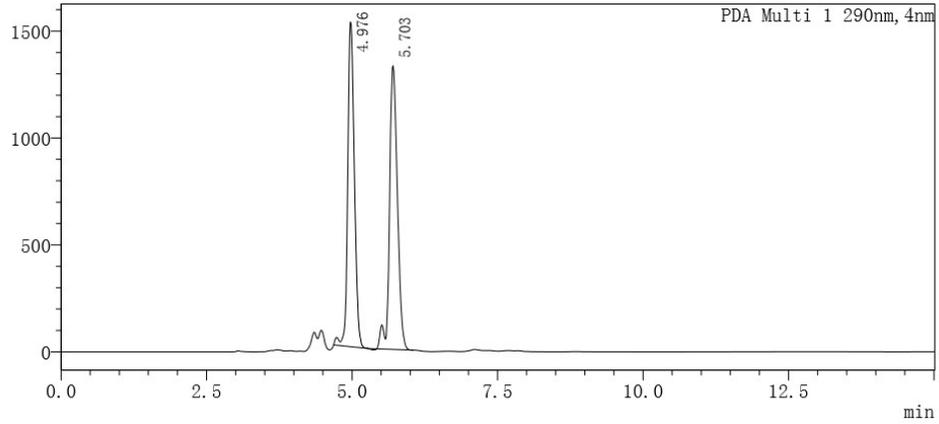
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. t_R = 4.9 min (minor), 5.7 min (major).

Optical Rotation: [α]_D²⁸ -1.9 (c 0.5, CHCl₃) for 95% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 290nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.976	12076864	1517268	0.000		M	
2	5.703	12475247	1326529	0.000		M	
总计		24552111	2843797				

peak number

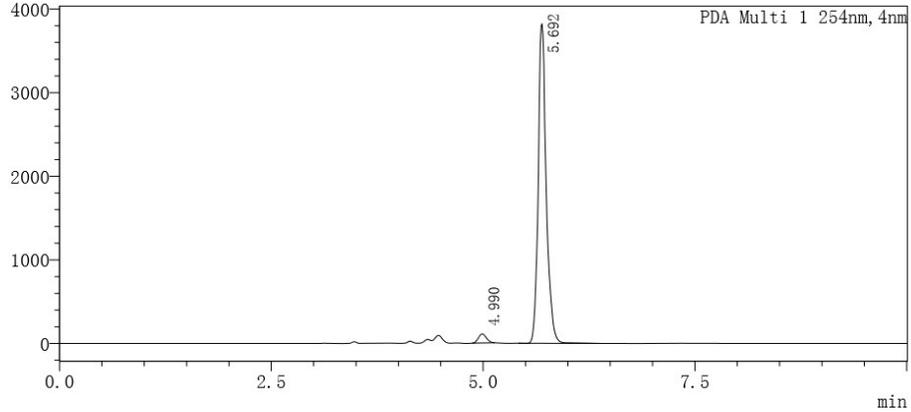
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.990	713609	108605	0.000		M	
2	5.692	25177426	3823207	0.000		M	
总计		25891035	3931812				

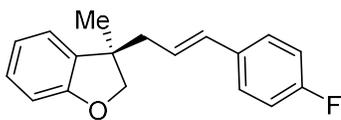
peak number

area

height

retention time

(*R, E*)-3-(3-(4-fluorophenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ag**)



Chemical Formula: C₁₈H₁₇FO

Exact Mass: 268.1263

3ag was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2g** (0.2 mmol, 24 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ag** as colorless oil (19.0 mg, 71% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.34-7.26 (m, 2H), 7.21-7.15 (m, 2H), 7.04-6.98 (m, 2H), 6.94 (td, *J* = 7.4, 1.0 Hz, 1H), 6.85 (dt, *J* = 7.8, 0.8 Hz, 1H), 6.40 (dt, *J* = 15.7, 1.4 Hz, 1H), 6.04 (dt, *J* = 15.3, 7.5 Hz, 1H), 4.47 (d, *J* = 8.6 Hz, 1H), 4.20 (d, *J* = 8.7 Hz, 1H), 2.53 (dd, *J* = 7.4, 1.4 Hz, 2H), 1.44 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 16 (d, *J* = 246.2 Hz), 159.5, 134.8, 133.5 (d, *J* = 3.3 Hz), 132.2, 128.3, 127.6 (d, *J* = 7.9 Hz), 125.4 (d, *J* = 2.2 Hz), 122.9, 120.5, 115.4 (d, *J* = 21.5 Hz), 109.7, 81.9, 45.7, 44.3, 25.0;

¹⁹F NMR (376 MHz, CDCl₃): δ -114.95;

HRMS: (APCI) calcd for C₁₈H₁₈FO⁺[M+H]⁺ 269.1337; found 269.1347.

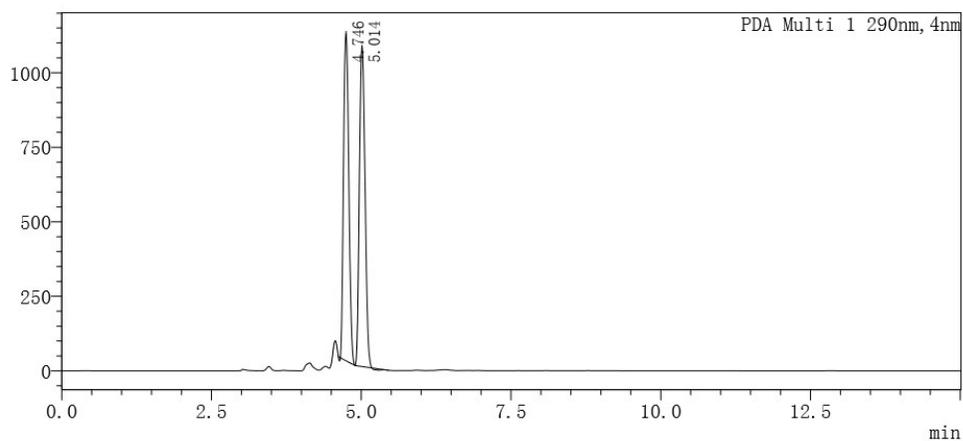
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. tR = 4.7 min (minor), 5.0 min (major).

Optical Rotation: [α]_D³⁰ -18.1 (c 0.3, CHCl₃) for 94% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 290nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.746	6663655	1104358	0.000		M	
2	5.014	7010128	1077400	0.000		M	
总计		13673783	2181757				

peak number

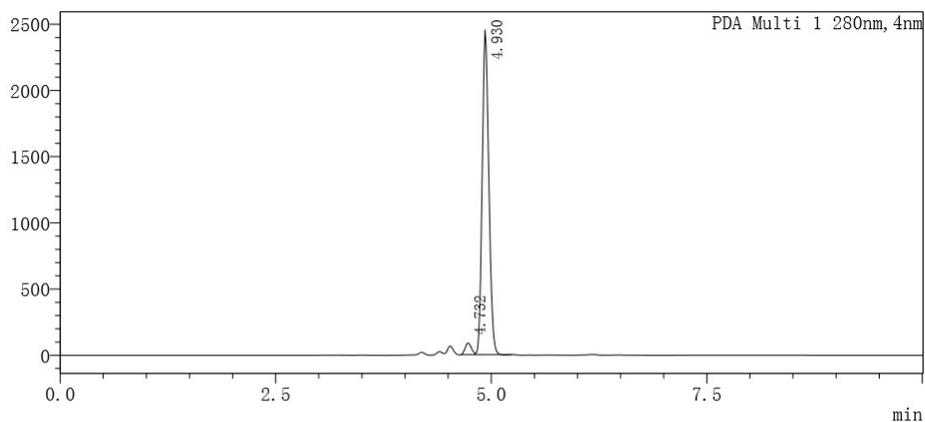
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 280nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.732	439931	87852	0.000		M	
2	4.930	13070014	2453227	0.000		V M	
总计		13509946	2541079				

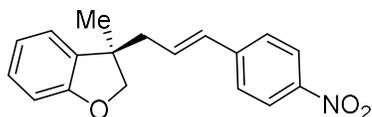
peak number

area

height

retention time

(*R, E*)-3-methyl-3-(3-(4-nitrophenyl)allyl)-2,3-dihydrobenzofuran (**3ah**)



Chemical Formula: C₁₈H₁₇NO₃

Exact Mass: 295.1208

3ah was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2h** (0.2 mmol, 25.6 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~5/1) to obtain **3ah** as colorless oil (25.1 mg, 85% yield). ¹H NMR (400 MHz, CDCl₃): δ 8.15-8.13 (m, 2H), 7.42-7.38 (m, 2H), 7.18-7.11 (m, 2H), 6.91 (td, *J* = 7.4, 0.9 Hz, 1H), 6.81 (d, *J* = 8.0 Hz, 1H), 6.45 (d, *J* = 15.8 Hz, 1H), 6.31-6.23 (m, 1H), 4.43 (d, *J* = 8.7 Hz, 1H), 4.18 (d, *J* = 8.7 Hz, 1H), 2.55 (dd, *J* = 7.5, 1.1 Hz, 2H), 1.43 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.4, 146.6, 143.6, 134.1, 131.5, 131.1, 128.4, 126.6, 123.9, 122.8, 120.6, 109.8, 81.8, 45.7, 44.5, 25.0;

HRMS: (ESI) calcd for C₁₈H₁₇NNaO₃⁺[M+Na]⁺ 318.1101; found 318.1104.

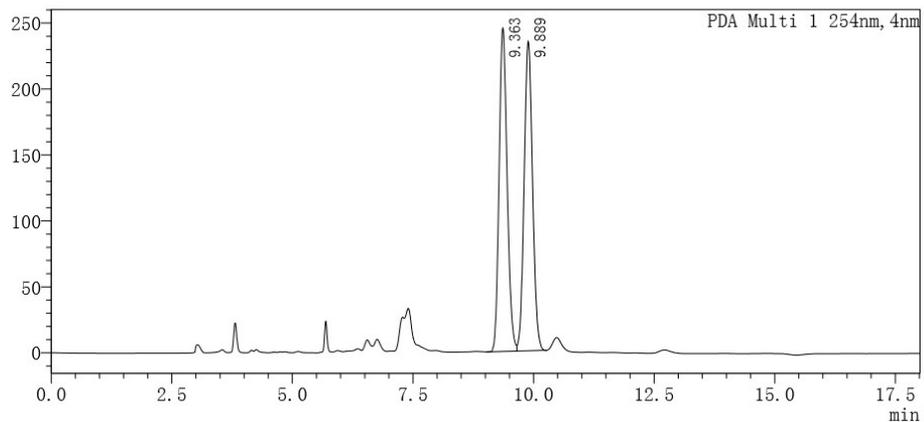
The enantiomeric purity was established by HPLC analysis using a chiral column: AD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 95/5 as eluent, 254 nm, 1 mL/min. tR = 9.4 min (minor), 9.9 min (major).

Optical Rotation: $[\alpha]_D^{28}$ 19.7 (c 0.4, CHCl₃) for 90% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	9.363	2842439	245569	0.000		M	
2	9.889	2843259	234994	0.000		V M	
总计		5685698	480563				

peak number

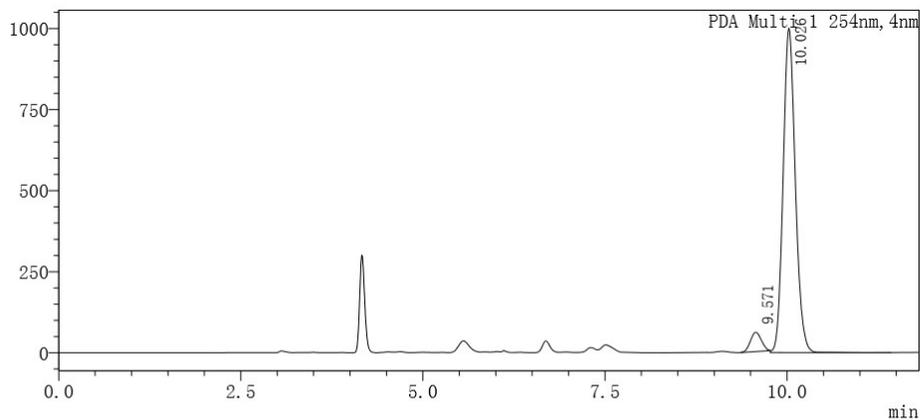
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	9.571	620294	59378	0.000		M	
2	10.026	11605064	1001106	0.000		M	
总计		12225359	1060484				

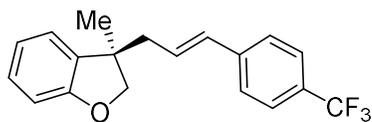
peak number

area

height

retention time

(*R, E*)-3-methyl-3-(3-(4-(trifluoromethyl)phenyl)allyl)-2,3-dihydrobenzofuran (**3ai**)



Chemical Formula: C₁₉H₁₇F₃O

Exact Mass: 318.1231

3ai was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2i** (0.2 mmol, 30 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ai** as colorless oil (20.0 mg, 63% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.54 (d, *J* = 8.2 Hz, 2H), 7.44-7.34 (m, 2H), 7.22-7.08 (m, 2H), 6.91 (td, *J* = 7.4, 1.0 Hz, 1H), 6.82 (ddd, *J* = 8.0, 0.6 Hz, 1H), 6.43 (d, *J* = 15.8 Hz, 1H), 6.28-6.13 (m, 1H), 4.44 (d, *J* = 8.7 Hz, 1H), 4.17 (d, *J* = 8.7 Hz, 1H), 2.54 (dd, *J* = 7.5, 1.2 Hz, 2H), 1.42 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 140.7, 134.5, 132.2, 129.2, 128.9, 128.6, 128.3, 126.2, 125.45 (q, *J* = 3.8 Hz), 122.9, 120.6, 109.8, 81.9, 45.6, 44.3, 25.0;

¹⁹F NMR (376 MHz, CDCl₃): δ -62.35;

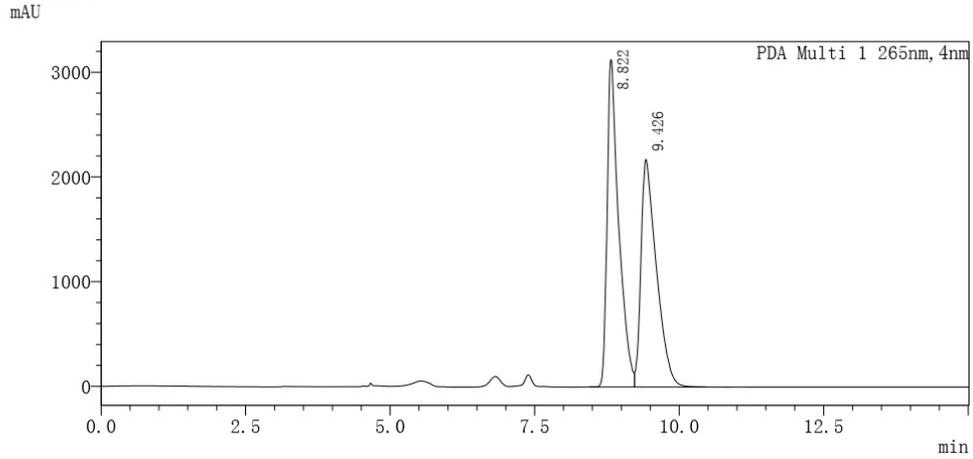
HRMS: (APCI) calcd for C₁₉H₁₈F₃O⁺[M+H]⁺ 319.1304; found 319.1298.

The enantiomeric purity was established by HPLC analysis using a chiral column: OJ-H column, 30 °C, *n*-Hexane/*i*-Propanol = 95/5 as eluent, 254 nm, 1 mL/min. tR = 8.8 min (major), 9.4 min (minor).

Optical Rotation: [α]_D³⁰ -12.5 (c 0.3, CHCl₃) for 93% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>



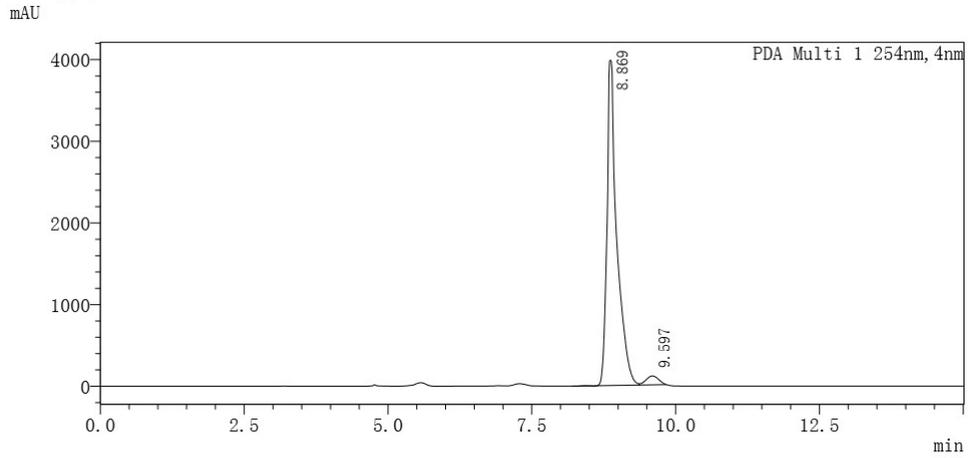
<峰表>

PDA Ch1 265nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.822	43382201	3127304	51.800		M	
2	9.426	40366799	2174500	48.200		V M	
总计		83749001	5301804				



<色谱图>



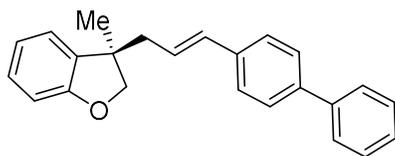
<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.869	47325142	3981982	0.000		M	
2	9.597	1645092	109696	0.000		V M	
总计		48970234	4091679				



(*R, E*)-3-(3-([1,1'-biphenyl]-4-yl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3aj**)



Chemical Formula: C₂₄H₂₂O

Exact Mass: 326.1671

3aj was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2j** (0.2 mmol, 36 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3aj** as colorless oil (28.0 mg, 86% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.71-7.52 (m, 4H), 7.48-7.31 (m, 5H), 7.23-7.11 (m, 2H), 6.92 (td, *J* = 7.4, 1.0 Hz, 1H), 6.83 (dt, *J* = 7.8, 0.9 Hz, 1H), 6.58-6.39 (m, 1H), 6.17 (dt, *J* = 15.8, 7.5 Hz, 1H), 4.47 (d, *J* = 8.6 Hz, 1H), 4.18 (d, *J* = 8.6 Hz, 1H), 2.55 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.43 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 140.7, 140.0, 136.3, 134.8, 133.0, 128.8, 128.2, 127.2, 126.9, 126.5, 125.8, 122.9, 120.5, 109.7, 82.0, 45.7, 44.3, 25.0;

HRMS: (APCI) calcd for C₂₄H₂₃O⁺[M+H]⁺ 327.1743; found 327.1739.

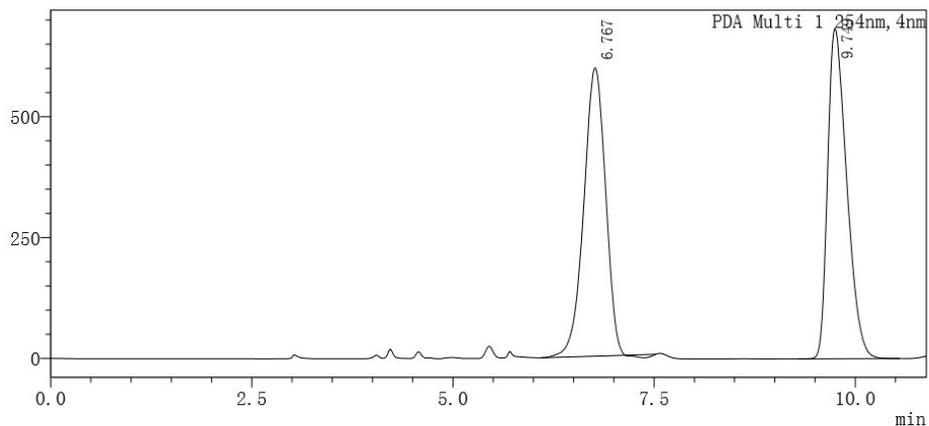
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 0.5 mL/min. t_R = 6 min (minor), 9 min (major).

Optical Rotation: [α]_D²⁸ 36.8 (c 0.1, CHCl₃) for 93% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	6.767	11183404	596254	0.000		M	
2	9.749	11308727	683491	0.000		M	
总计		22492131	1279745				

peak number

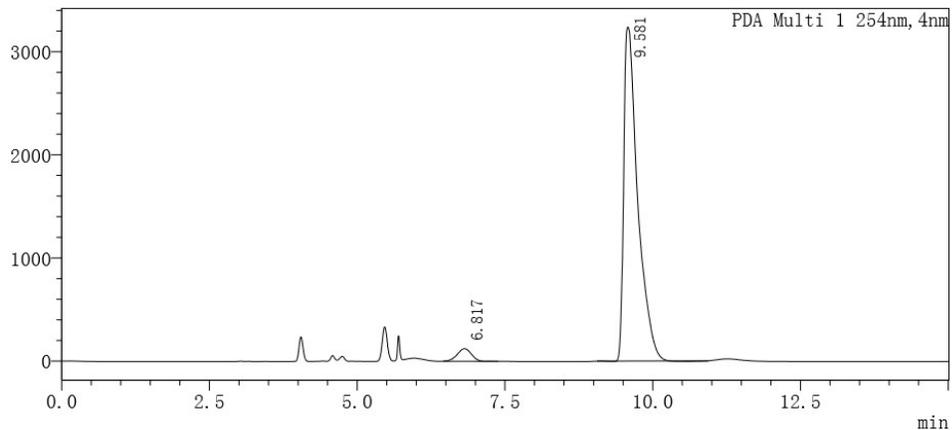
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	6.817	2038190	122933	0.000		M	
2	9.581	52945538	3239850	0.000		M	
总计		54983727	3362783				

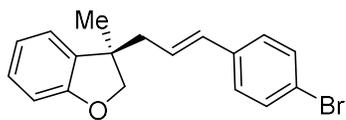
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ak**)



Chemical Formula: C₁₈H₁₇BrO

Exact Mass: 328.0463

3ak was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2k** (0.2 mmol, 26 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ak** as colorless oil (29.0 mg, 88% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.48-7.38 (m, 2H), 7.22-7.10 (m, 4H), 6.90 (td, *J* = 7.4, 1.0 Hz, 1H), 6.85-6.79 (m, 1H), 6.43-6.27 (m, 1H), 6.09 (dt, *J* = 15.8, 7.5 Hz, 1H), 4.43 (d, *J* = 8.7 Hz, 1H), 4.16 (d, *J* = 8.7 Hz, 1H), 2.50 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.40 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.4, 136.2, 134.6, 132.2, 131.5, 128.2, 127.6, 126.5, 122.9, 120.9, 120.5, 109.7, 81.9, 45.6, 44.3, 24.9;

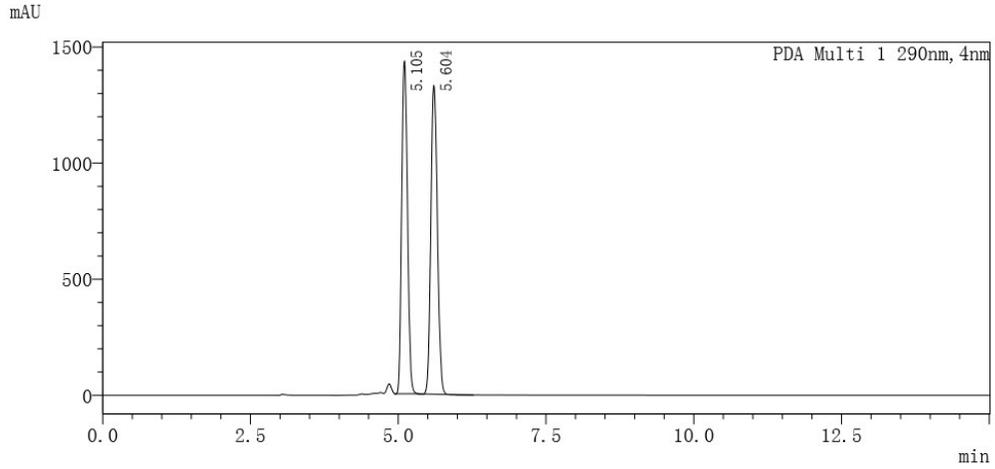
HRMS: (APCI) calcd for C₁₈H₁₈BrO⁺[M+H]⁺ 329.0536; found 329.0543.

The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. tR = 5.0 min (minor), 5.5 min (major).

Optical Rotation: [α]_D³⁰ -1 (c 0.3, CHCl₃) for 94% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>



<峰表>

PDA Ch1 290nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.105	9694000	1434717	0.000		M	
2	5.604	10235645	1330338	0.000		M	
总计		19929644	2765055				

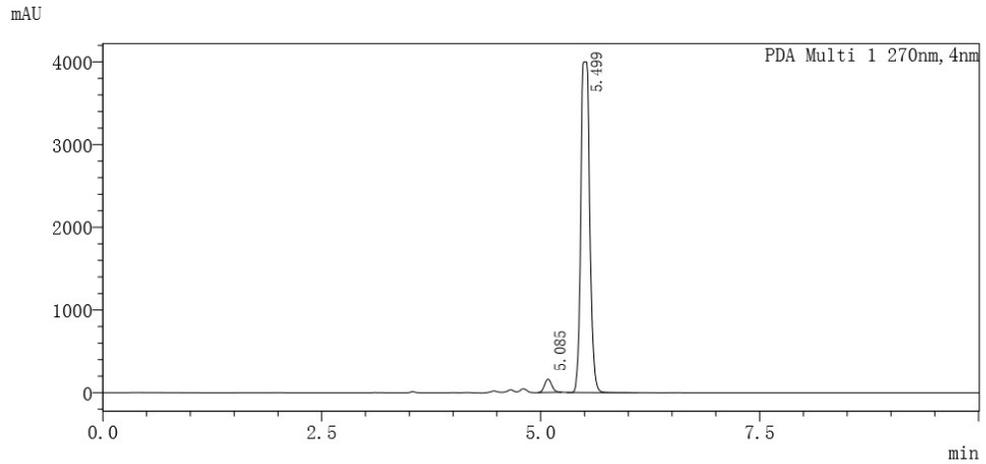
peak number

area

height

retention time

<色谱图>



<峰表>

PDA Ch1 270nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.085	922215	160948	0.000		M	
2	5.499	28371824	3997458	0.000		M	
总计		29294039	4158407				

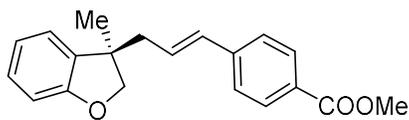
peak number

area

height

retention time

Methyl (*R*, *E*)-4-(3-(3-methyl-2,3-dihydrobenzofuran-3-yl)prop-1-en-1-yl)benzoate (**3al**)



Chemical Formula: C₂₀H₂₀O₃

Exact Mass: 308.1412

3al was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2I** (0.2 mmol, 32.4 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3al** as colorless oil (21.2 mg, 69% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.96 (d, *J* = 8.4 Hz, 2H), 7.35 (d, *J* = 8.3 Hz, 2H), 7.17-7.08 (m, 2H), 6.90 (td, *J* = 7.4, 1.0 Hz, 1H), 6.85-6.78 (m, 1H), 6.52-6.38 (m, 1H), 6.31-6.15 (m, 1H), 4.44 (d, *J* = 8.7 Hz, 1H), 4.17 (d, *J* = 8.6 Hz, 1H), 3.91 (s, 3H), 2.53 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.42 (s, 3H);

¹³C NMR NMR (101 MHz, CDCl₃): δ 166.9, 159.5, 141.7, 134.5, 132.6, 129.9, 128.7, 128.6, 128.3, 125.9, 122.9, 120.5, 109.8, 81.9, 52.0, 45.6, 44.4, 25.0;

HRMS: (ESI) calcd for C₂₀H₂₀NaO₃⁺[M+Na]⁺ 331.1305; found 331.1310.

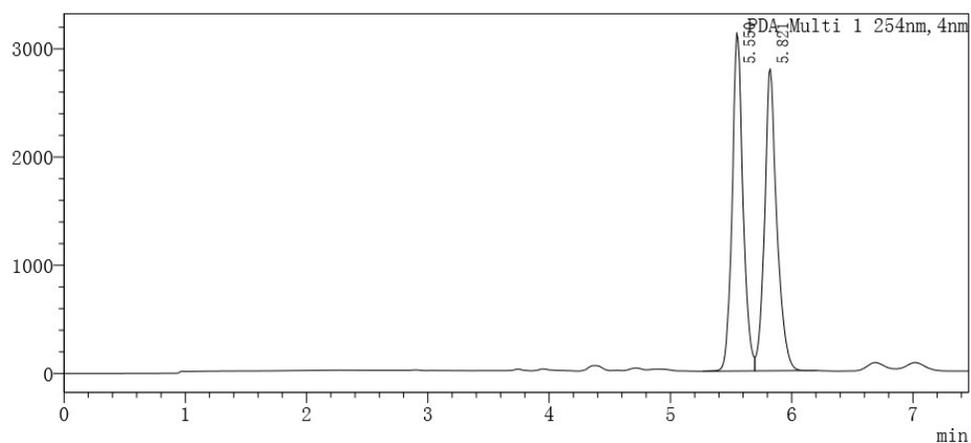
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 85/15 as eluent, 254 nm, 1 mL/min. t_R = 5.5 min (minor), 5.8 min (major).

Optical Rotation: [α]_D²⁸ 13.9 (c 0.3, CHCl₃) for 93% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

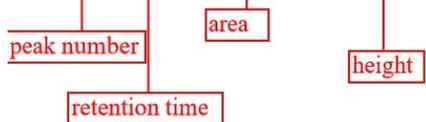
mAU



<峰表>

PDA Ch1 254nm

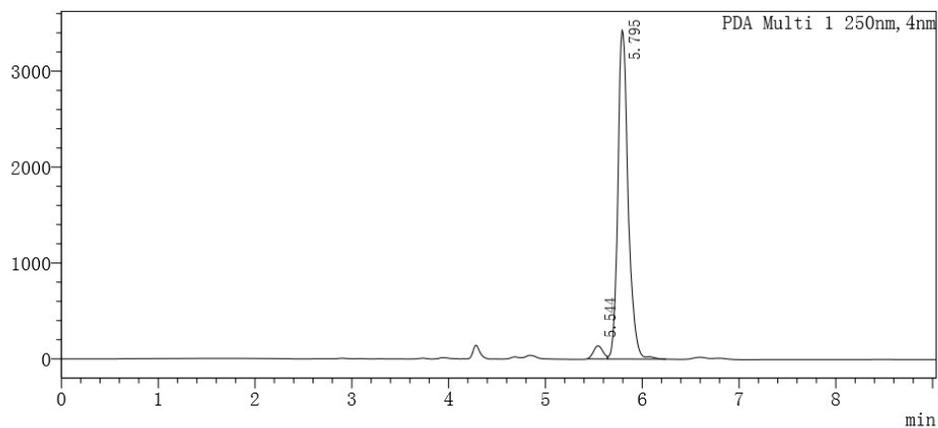
峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.550	19462861	3127287	0.000		M	
2	5.821	19580238	2790792	0.000		V M	
总计		39043099	5918079				



retention time

<色谱图>

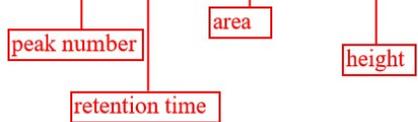
mAU



<峰表>

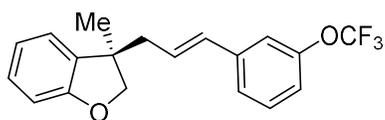
PDA Ch1 250nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.544	927686	137277	0.000		M	
2	5.795	25137890	3434145	0.000		V M	
总计		26065576	3571422				



retention time

(*R, E*)-3-methyl-3-(3-(3-(trifluoromethoxy)phenyl)allyl)-2,3-dihydrobenzofuran (**3am**)



Chemical Formula: C₁₉H₁₇F₃O₂

Exact Mass: 334.1181

3am was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2m** (0.2 mmol, 37.6 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3am** as colorless oil (17.4 mg, 52% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.30 (t, *J* = 7.9 Hz, 1H), 7.25-7.20 (m, 1H), 7.19-7.10 (m, 3H), 7.09-7.04 (m, 1H), 6.91 (td, *J* = 7.5, 1.0 Hz, 1H), 6.81 (dt, *J* = 8.0, 0.8 Hz, 1H), 6.54-6.30 (m, 1H), 6.13 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.44 (d, *J* = 8.7 Hz, 1H), 4.17 (d, *J* = 8.7 Hz, 1H), 2.52 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.41 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 149.6, 139.5, 134.6, 13, 129.8, 128.3, 127.7, 124.4, 122.9, 120.6, 120.0 (q, *J* = 115.1 Hz), 119.4, 118.5, 109.8, 81.9, 45.6, 44.2, 24.9;

¹⁹F NMR (376 MHz, CDCl₃): δ -57.58;

HRMS: (ESI) calcd for C₁₉H₁₇F₃NaO₂⁺[M+Na]⁺ 357.1073; found 357.1072.

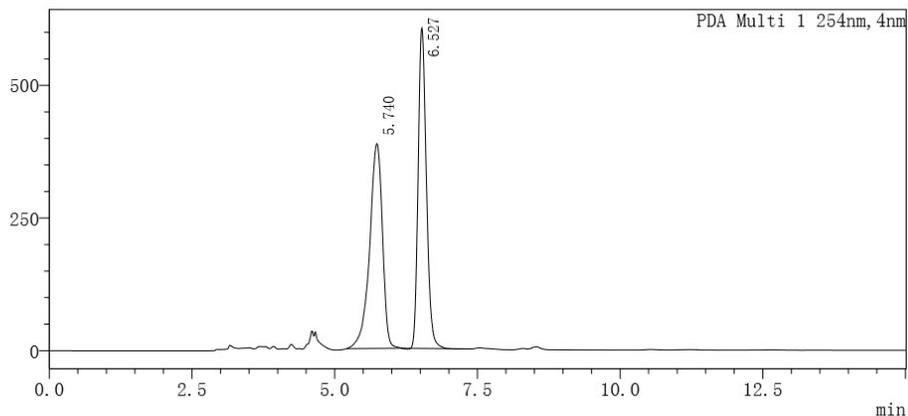
The enantiomeric purity was established by HPLC analysis using a chiral column: OJ-H column, 30 °C, *n*-Hexane/*i*-Propanol = 95/5 as eluent, 254 nm, 1 mL/min. tR = 5.7 min (minor), 6.5 min (major).

Optical Rotation: [α]_D²⁸ 39.2 (c 0.1, CHCl₃) for 97% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.740	6017651	386204	0.000		M	
2	6.527	6028539	605173	0.000		M	
总计		12046189	991378				

peak number

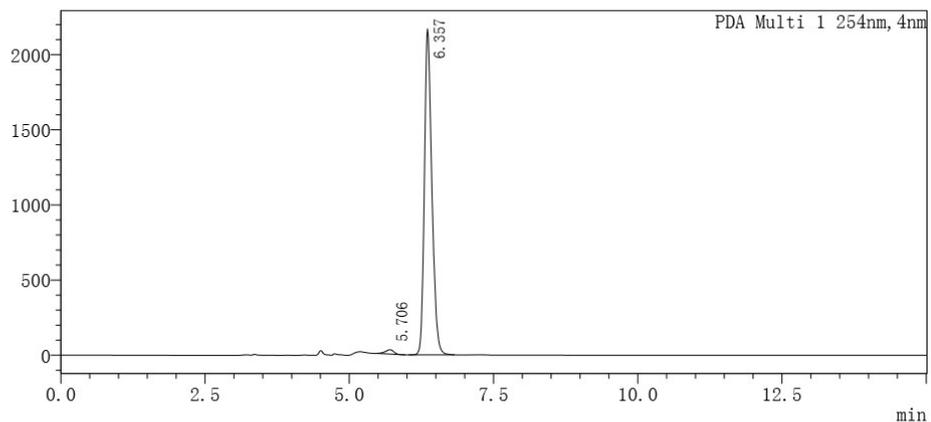
retention time

area

height

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.706	297449	29050	0.000		M	
2	6.357	19451479	2170269	0.000		M	
总计		19748928	2199318				

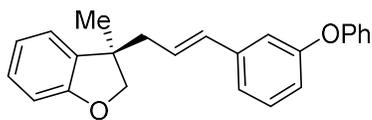
peak number

retention time

area

height

(*R, E*)-3-methyl-3-(3-(3-phenoxyphenyl)allyl)-2,3-dihydrobenzofuran (**3an**)



Chemical Formula: C₂₄H₂₂O₂

Exact Mass: 342.1620

3an was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2n** (0.2 mmol, 39 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~20/1) to obtain **3an** as colorless oil (28.4 mg, 83% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.38-7.31 (m, 2H), 7.29-7.21 (m, 1H), 7.17-7.08 (m, 3H), 7.08-6.94 (m, 4H), 6.92-6.83 (m, 2H), 6.80 (dt, *J* = 8.0, 0.8 Hz, 1H), 6.37 (dt, *J* = 15.7, 1.3 Hz, 1H), 6.09 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.42 (d, *J* = 8.6 Hz, 1H), 4.15 (d, *J* = 8.7 Hz, 1H), 2.49 (dd, *J* = 7.5, 1.4 Hz, 2H), 1.39 (s, 3H);

¹³C NMR NMR (101 MHz, CDCl₃): δ 159.5, 157.4, 157.2, 139.3, 134.7, 132.8, 129.7 (d, *J* = 1.9 Hz), 128.2, 126.6, 123.2, 122.9, 121.2, 120.5, 118.8, 117.6, 116.5, 109.7, 82.0, 45.6, 44.2, 25.0;

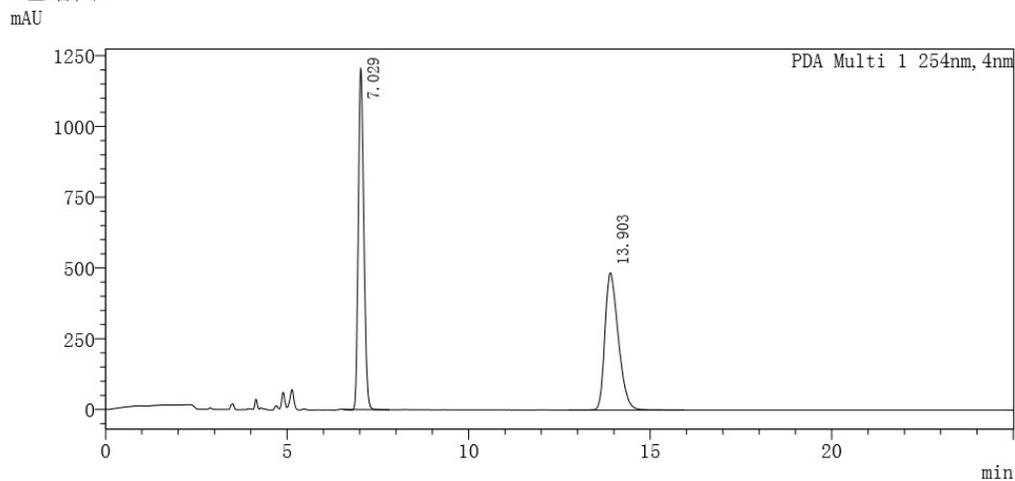
HRMS: (ESI) calcd for C₂₄H₂₃O₂⁺[M+H]⁺ 343.1693; found 343.1686.

The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 85/15 as eluent, 254 nm, 1 mL/min. t_R = 7 min (minor), 13 min (major).

Optical Rotation: [α]_D²⁸ 6.5 (c 0.6, CHCl₃) for 93% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>



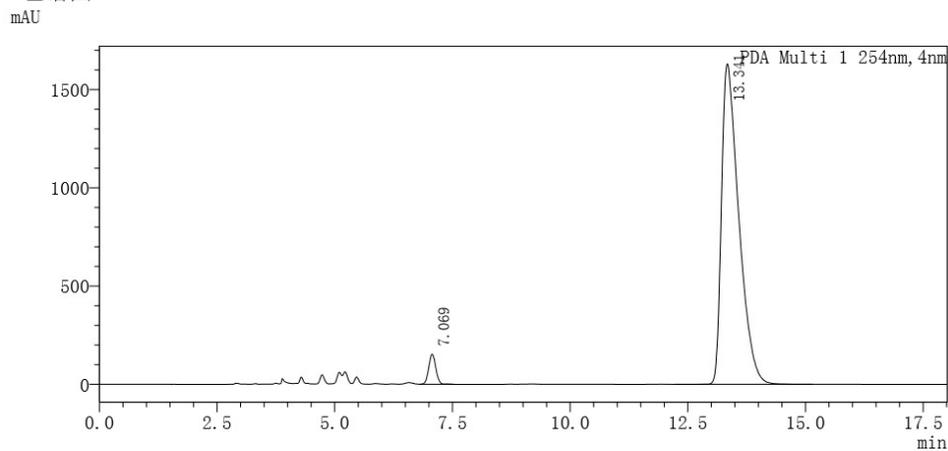
<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	7.029	12566218	1207354	0.000		M	
2	13.903	12425729	484135	0.000		M	
总计		24991947	1691489				



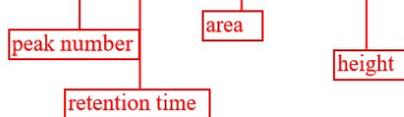
<色谱图>



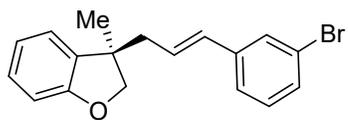
<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	7.069	1606988	153232	0.000		M	
2	13.341	41623070	1631342	0.000		M	
总计		43230058	1784574				



(*R, E*)-3-(3-(3-bromophenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ao**)



Chemical Formula: C₁₈H₁₇BrO

Exact Mass: 328.0463

3ao was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2o** (0.2 mmol, 26 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ao** as colorless oil (28.6 mg, 87% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.45 (t, *J* = 1.8 Hz, 1H), 7.34 (ddd, *J* = 7.7, 1.9, 1.3 Hz, 1H), 7.24-7.09 (m, 4H), 6.91 (td, *J* = 7.4, 1.0 Hz, 1H), 6.82 (ddd, *J* = 8.0, 0.6 Hz, 1H), 6.33 (d, *J* = 15.7 Hz, 1H), 6.11 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.43 (d, *J* = 8.7 Hz, 1H), 4.16 (d, *J* = 8.7 Hz, 1H), 2.51 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.41 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 139.4, 134.6, 13, 130.1, 130.0, 128.9, 128.3, 127.4, 124.8, 122.9, 122.7, 120.5, 109.8, 81.9, 45.6, 44.2, 24.9;

HRMS: (APCI) calcd for C₁₈H₁₈BrO⁺[M+H]⁺ 329.0536; found 329.0528.

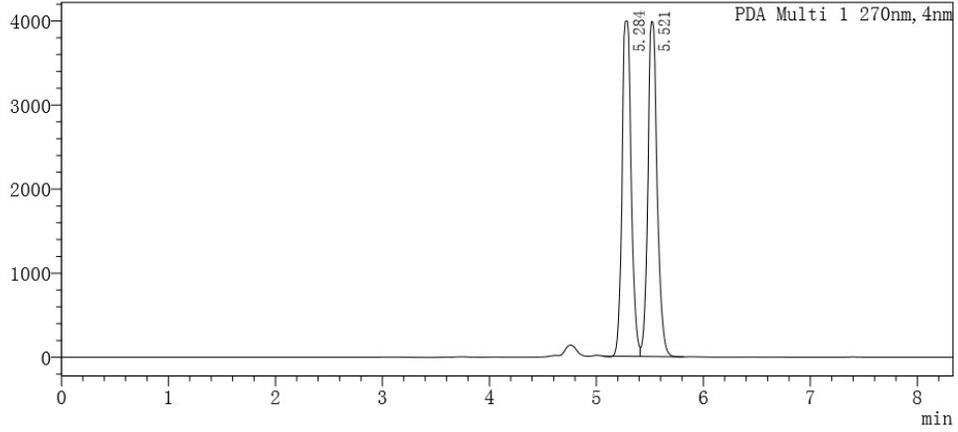
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. tR = 5.2 min (minor), 5.4 min (major).

Optical Rotation: [α]_D³⁰ -7.1 (c 0.4, CHCl₃) for 93% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

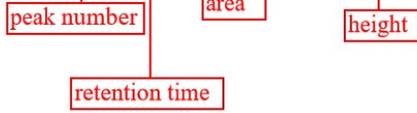
mAU



<峰表>

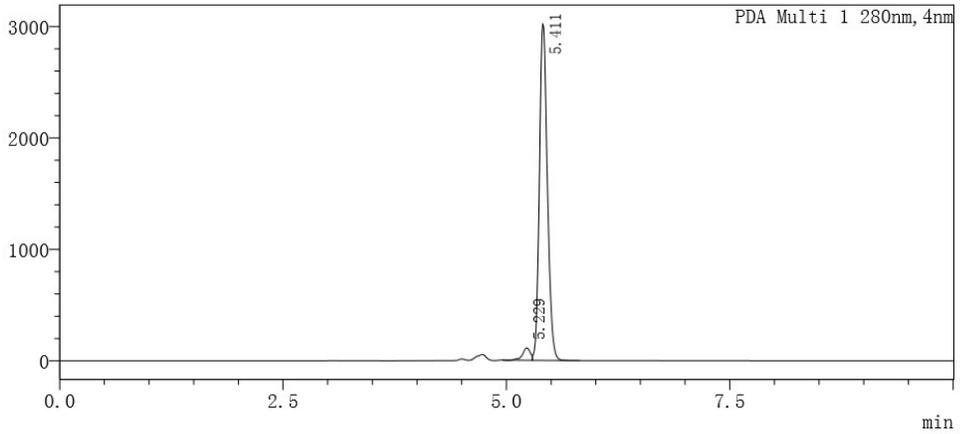
PDA Ch1 270nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.284	23812838	3988483	0.000		M	
2	5.521	24198315	3987131	0.000		V M	
总计		48011154	7975614				



<色谱图>

mAU



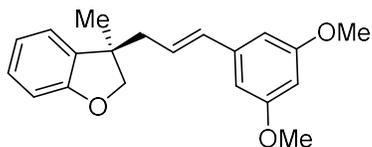
<峰表>

PDA Ch1 280nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.229	665043	110766	0.000		M	
2	5.411	18859320	3022716	0.000		V M	
总计		19524363	3133482				



(*R, E*)-3-(3-(3,5-dimethoxyphenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ap**)



Chemical Formula: C₂₀H₂₂O₃

Exact Mass: 310.1569

3ap was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2p** (0.2 mmol, 33 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~20/1) to obtain **3ap** as colorless oil (10.9 mg, 35% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.20-7.07 (m, 2H), 6.89 (td, *J* = 7.4, 1.0 Hz, 1H), 6.80 (dt, *J* = 7.9, 0.8 Hz, 1H), 6.47 (d, *J* = 2.2 Hz, 2H), 6.40-6.30 (m, 2H), 6.16-6.02 (m, 1H), 4.43 (d, *J* = 8.6 Hz, 1H), 4.15 (d, *J* = 8.7 Hz, 1H), 3.79 (s, 6H), 2.49 (dd, *J* = 7.5, 1.2 Hz, 2H), 1.40 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 160.9, 159.5, 139.4, 134.8, 133.4, 128.2, 126.3, 122.9, 120.5, 109.7, 104.3, 99.3, 82.0, 55.3, 45.6, 44.2, 24.9;

HRMS: (ESI) calcd for C₂₀H₂₃O₃⁺[M+H]⁺ 311.1642; found 311.1633.

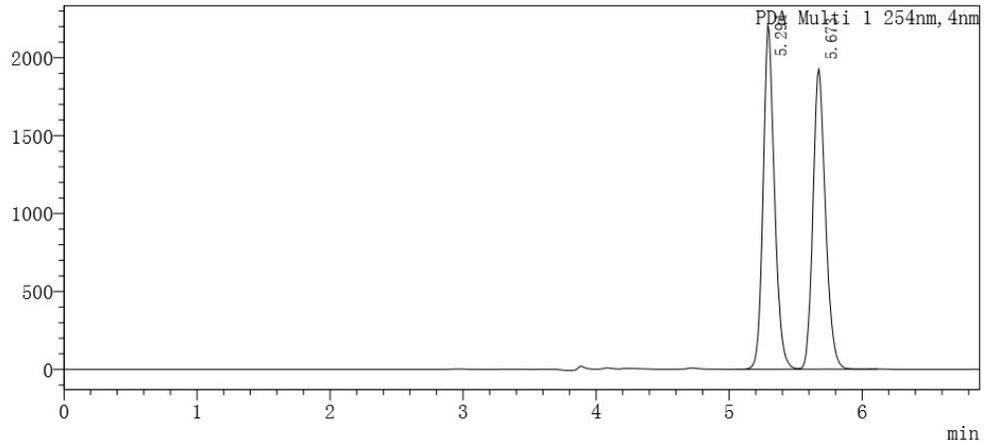
The enantiomeric purity was established by HPLC analysis using a chiral column: AD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 85/15 as eluent, 254 nm, 1 mL/min. t_R = 5.3 min (major), 5.7 min (minor).

Optical Rotation: [α]_D³⁰ -22.3 (c 0.1, CHCl₃) for 96% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.294	13052027	2210178	0.000		M	
2	5.673	12552447	1930180	0.000		V M	
总计		25604474	4140358				

peak number

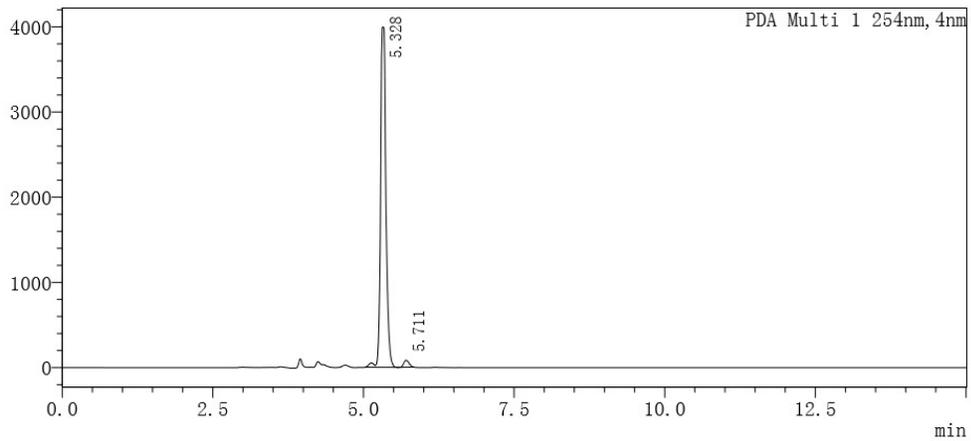
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.328	24629140	3995901	0.000		M	
2	5.711	502532	82332	0.000		M	
总计		25131671	4078234				

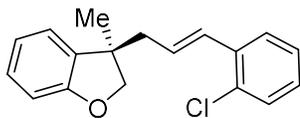
peak number

area

height

retention time

(*R, E*)-3-(3-(2-chlorophenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3aq**)



Chemical Formula: C₁₈H₁₇ClO

Exact Mass: 284.0968

3aq was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2q** (0.2 mmol, 26 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3aq** as colorless oil (21.7 mg, 76% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.41 (dd, *J* = 7.5, 2.0 Hz, 1H), 7.33 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.24-7.09 (m, 4H), 6.91 (td, *J* = 7.4, 1.0 Hz, 1H), 6.86-6.75 (m, 2H), 6.06 (dt, *J* = 15.4, 7.5 Hz, 1H), 4.47 (d, *J* = 8.6 Hz, 1H), 4.18 (d, *J* = 8.7 Hz, 1H), 2.56 (dd, *J* = 7.5, 1.4 Hz, 2H), 1.43 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 135.5, 134.6, 132.7, 129.8, 129.6, 128.8, 128.2, 126.9, 126.8, 122.9, 120.6, 109.7, 81.9, 45.6, 44.4, 25.1;

HRMS: (ESI) calcd for C₁₈H₁₇ClNaO⁺[M+Na]⁺ 307.0860; found 307.0867.

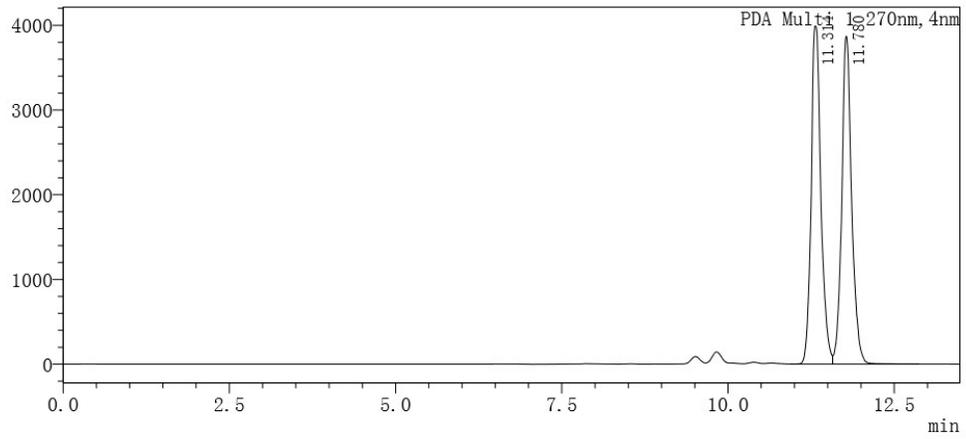
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 0.5 mL/min. t_R = 11.3 min (minor), 11.7 min (major).

Optical Rotation: [α]_D³⁰ -3.8 (c 0.3, CHCl₃) for 92% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 270nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.314	40675722	3992904	0.000		M	
2	11.780	40029148	3871651	0.000		V M	
总计		80704870	7864555				

peak number

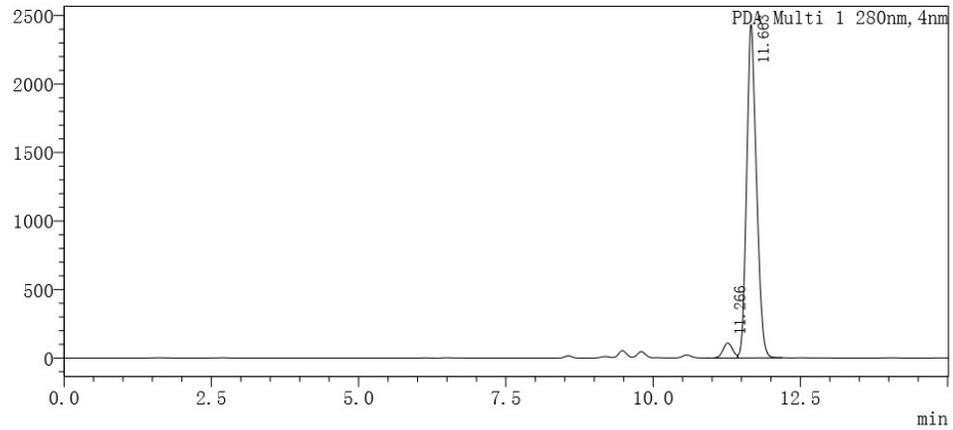
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 280nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.266	1244840	109702	0.000		M	
2	11.663	28053332	2432887	0.000		V M	
总计		29298172	2542589				

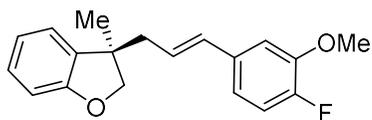
peak number

area

height

retention time

(*R, E*)-3-(3-(4-fluoro-3-methoxyphenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ar**)



Chemical Formula: C₁₉H₁₉FO₂

Exact Mass: 298.1369

3ar was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2r** (0.1 mmol, 30.4 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~20/1) to obtain **3ar** as colorless oil (16.1 mg, 54% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.19-7.09 (m, 2H), 6.99 (dd, *J* = 11.1, 8.3 Hz, 1H), 6.93-6.86 (m, 2H), 6.85-6.79 (m, 2H), 6.34 (dd, *J* = 15.7, 1.4 Hz, 1H), 5.99 (dtd, *J* = 15.7, 7.5, 0.6 Hz, 1H), 4.44 (d, *J* = 8.7 Hz, 1H), 4.16 (d, *J* = 8.7 Hz, 1H), 3.89 (s, 3H), 2.49 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.41 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 151.9 (d, *J* = 246.0 Hz), 147.6 (d, *J* = 11.0 Hz), 134.7, 133.9, 132.5, 128.2, 125.6, 122.9, 120.5, 118.7 (d, *J* = 6.7 Hz), 116.0 (d, *J* = 18.8 Hz), 111.1, 109.7, 81.9, 56.2, 45.6, 44.2, 24.9;

¹⁹F NMR (376 MHz, CDCl₃): δ -136.63;

HRMS: (APCI) calcd for C₁₉H₂₀FO₂⁺[M+H]⁺ 299.1442; found 299.1443.

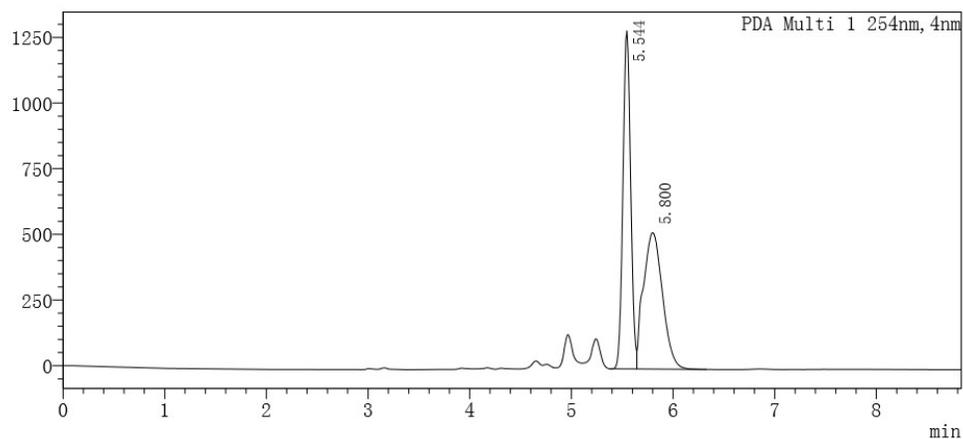
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 95/5 as eluent, 254 nm, 1 mL/min. t_R = 5.5 min (minor), 5.8 min (major).

Optical Rotation: [α]_D²⁸ 14.3 (c 0.3, CHCl₃) for 93% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.544	6810429	1287663	0.000		M	
2	5.800	6777237	519817	0.000		V M	
总计		13587666	1807480				

peak number

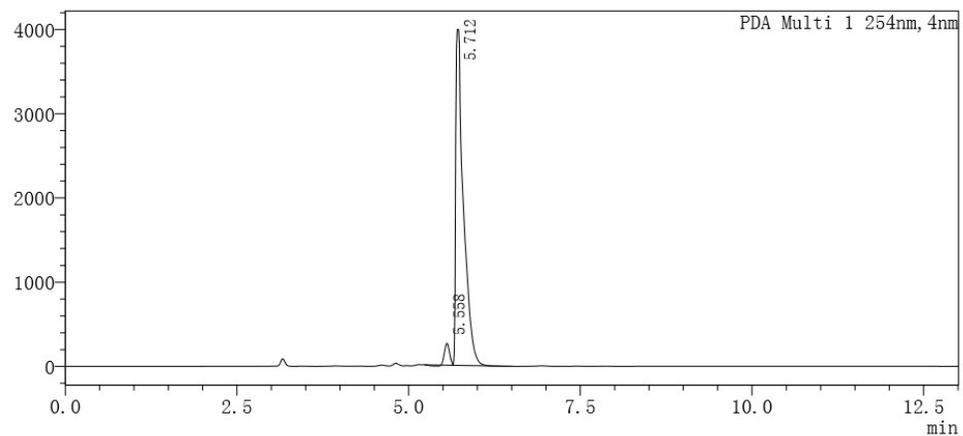
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.558	1212451	261455	0.000		M	
2	5.712	31305311	3987314	0.000		V M	
总计		32517762	4248770				

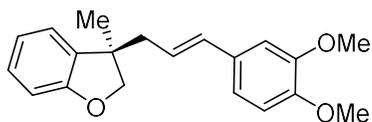
peak number

area

height

retention time

(*R, E*)-3-(3-(3,4-dimethoxyphenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3as**)



Chemical Formula: C₂₀H₂₂O₃

Exact Mass: 310.1569

3as was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2s** (0.1 mmol, 32.8 mg) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~20/1) to obtain **3as** as colorless oil (19.0 mg, 61% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.20-7.08 (m, 2H), 6.98-6.76 (m, 5H), 6.35 (dt, *J* = 15.5, 1.3 Hz, 1H), 6.06-5.88 (m, 1H), 4.45 (d, *J* = 8.6 Hz, 1H), 4.16 (d, *J* = 8.7 Hz, 1H), 3.89 (s, 3H), 3.87 (s, 3H), 2.49 (dd, *J* = 7.5, 1.3 Hz, 2H), 1.40 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.5, 148.9, 148.5, 134.9, 133.1, 130.5, 128.1, 123.7, 122.9, 120.4, 119.0, 111.1, 109.6, 108.8, 81.9, 55.9, 55.8, 45.7, 44.2, 24.9;

HRMS: (ESI) calcd for C₂₀H₂₃O₃⁺[M+H]⁺ 311.1642; found 311.1635.

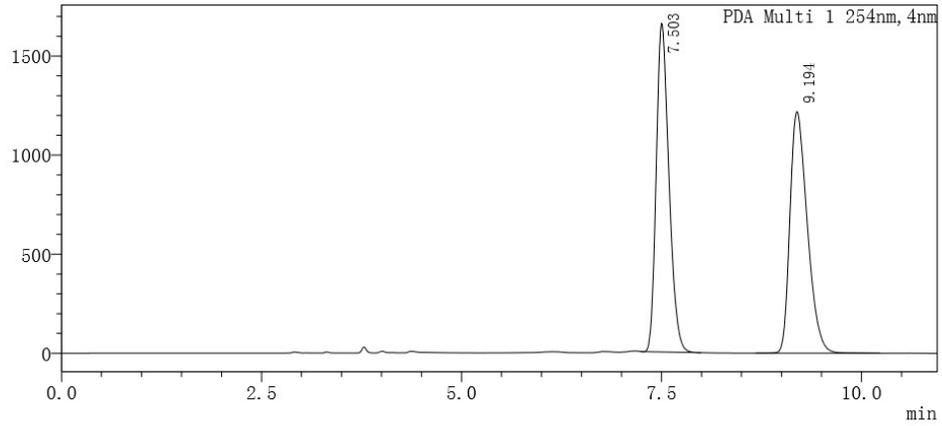
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 90/10 as eluent, 254 nm, 1 mL/min. t_R = 7.5 min (minor), 9.1 min (major).

Optical Rotation: [α]_D²⁸ 11.1 (c 0.3, CHCl₃) for 91% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	7.503	18458602	1658995	0.000		M	
2	9.194	18401408	1219726	0.000			
总计		36860010	2878721				

peak number

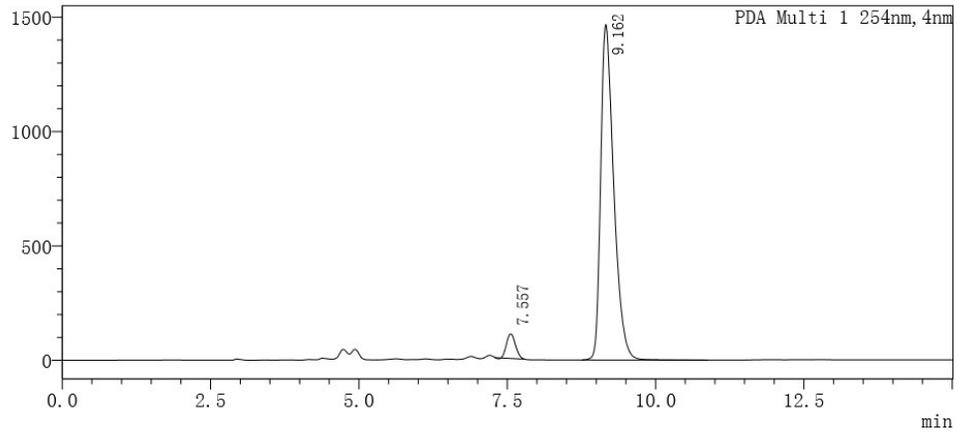
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	7.557	1109782	107561	0.000		M	
2	9.162	22503792	1468023	0.000		M	
总计		23613574	1575585				

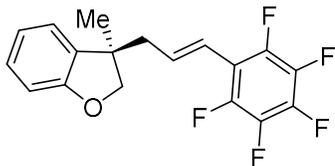
peak number

area

height

retention time

(*R, E*)-3-methyl-3-(3-(perfluorophenyl)allyl)-2,3-dihydrobenzofuran (**3at**)



Chemical Formula: C₁₈H₁₃F₅O

Exact Mass: 340.0887

3at was prepared according to general procedure using **1a** (0.1 mmol, 1.0 equiv, 26.2 mg) and **2t** (0.5 mmol, 69 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3at** as colorless oil (21.1 mg, 62% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.24-7.07 (m, 2H), 6.90 (td, *J* = 7.5, 1.0 Hz, 1H), 6.81 (dt, *J* = 8.0, 0.8 Hz, 1H), 6.42 (dt, *J* = 16.2, 7.4 Hz, 1H), 6.28 (dt, *J* = 16.3, 1.3 Hz, 1H), 4.42 (d, *J* = 8.7 Hz, 1H), 4.17 (d, *J* = 8.8 Hz, 1H), 2.73-2.43 (m, 2H), 1.42 (s, 3H); ¹³C NMR (101 MHz, CDCl₃): δ 159.5, 136.0, 134.1, 128.4, 122.8, 120.6, 117.4, 109.8, 81.9, 45.6, 45.5, 24.7;

¹⁹F NMR (376 MHz, CDCl₃): δ -143.40 (m), -156.90 (t, *J* = 20.9 Hz), -163.02 (m);

HRMS: (APCI) calcd for C₁₈H₁₄F₅O⁺[M+H]⁺ 341.0959; found 341.0958.

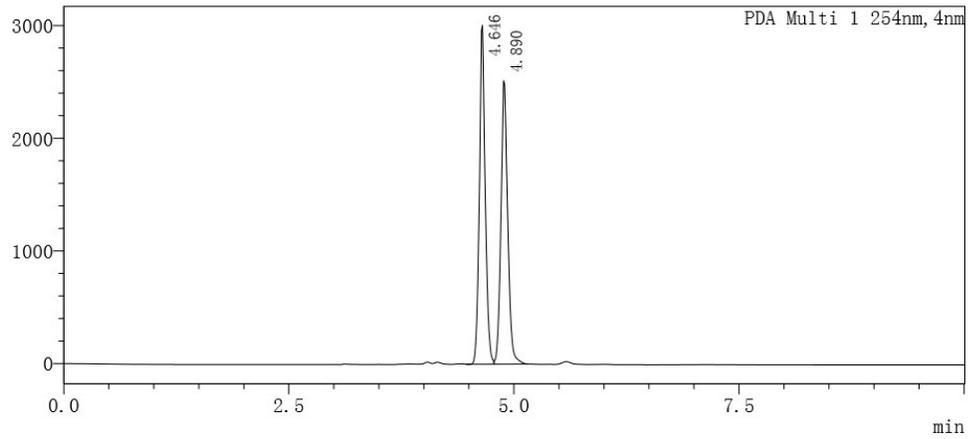
The enantiomeric purity was established by HPLC analysis using a chiral column: OJ-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. tR = 4.7 min (minor), 4.9 min (major).

Optical Rotation: [α]_D³⁰ -14.2 (c 0.4, CHCl₃) for 90% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.646	13651633	3009043	0.000		M	
2	4.890	13161968	2516941	0.000		V M	
总计		26813601	5525984				

peak number

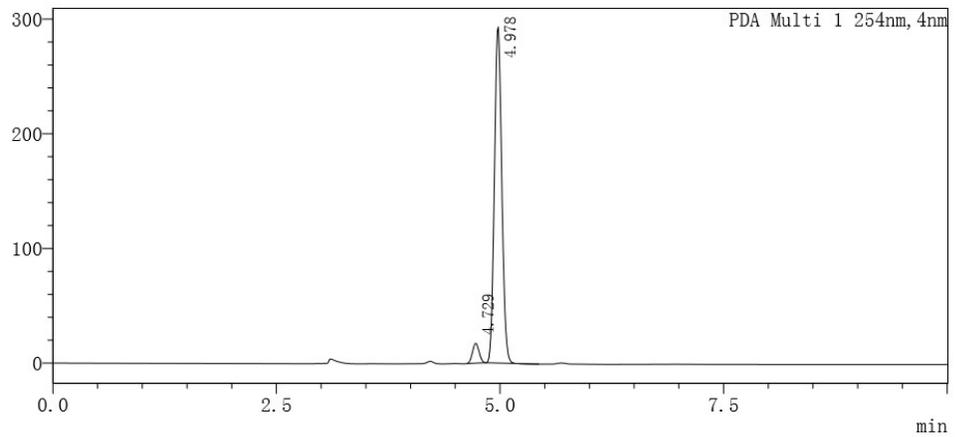
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	4.729	89012	17352	0.000		M	
2	4.978	1680718	293169	0.000		M	
总计		1769730	310521				

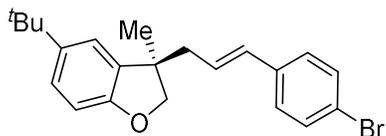
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-5-(*tert*-butyl)-3-methyl-2,3-dihydrobenzofuran (**3bk**)



Chemical Formula: C₂₂H₂₅BrO
Exact Mass: 384.1089

3bk was prepared according to general procedure using **1b** (0.1 mmol, 1.0 equiv, 31.8 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3bk** as colorless oil (18.4 mg, 48% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.50-7.38 (m, 2H), 7.17 (dd, *J* = 8.5, Hz, 3H), 7.11 (d, *J* = Hz, 1H), 6.74 (d, *J* = 8.4 Hz, 1H), 6.38-6.27 (m, 1H), 6.12 (dt, *J* = 15.8, 7.5 Hz, 1H), 4.41 (d, *J* = 8.6 Hz, 1H), 4.15 (d, *J* = 8.6 Hz, 1H), 2.49 (dd, *J* = 7.5, 1.4 Hz, 2H), 1.41 (s, 3H), 1.30 (s, 9H);

¹³C NMR (101 MHz, CDCl₃): δ 157.2, 143.5, 136.3, 134.1, 132.2, 131.6, 127.6, 126.7, 124.9, 120.9, 119.8, 108.8, 82.3, 45.8, 44.3, 34.4, 31.7, 24.6;

HRMS: (APCI) calcd for C₂₂H₂₆BrO⁺[M+H]⁺ 385.1162; found 385.1165.

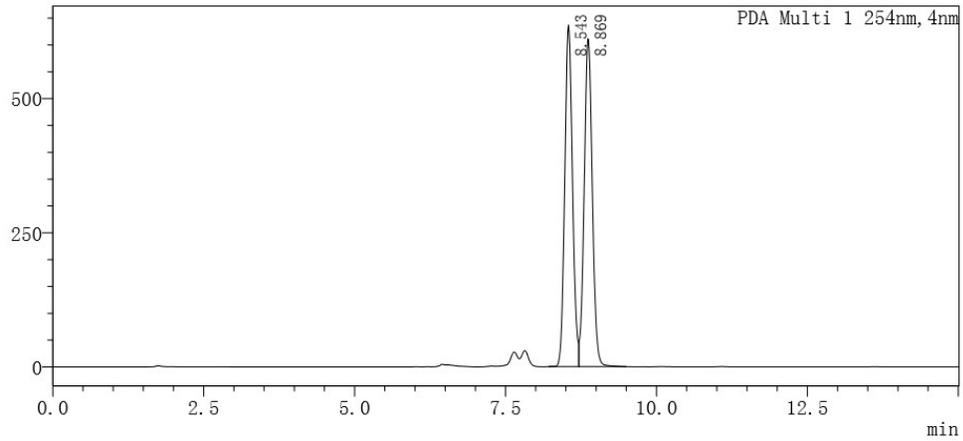
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 0.5 mL/min. tR = 8.5 min (minor), 8.9 min (major).

Optical Rotation: [α]_D³⁰ 30.1 (c 0.5, CHCl₃) for 92% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.543	5709187	636653	0.000		M	
2	8.869	5737434	611096	0.000		V M	
总计		11446621	1247749				

peak number

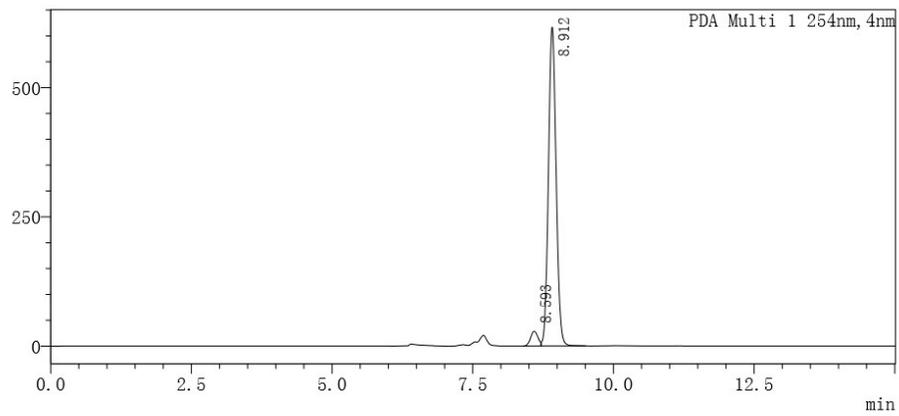
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.593	260198	28743	0.000		M	
2	8.912	5862908	616476	0.000		V M	
总计		6123106	645220				

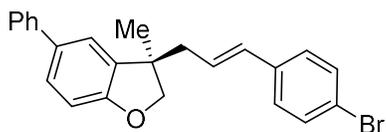
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-3-methyl-5-phenyl-2,3-dihydrobenzofuran (**3ck**)



Chemical Formula: C₂₄H₂₁BrO

Exact Mass: 404.0776

3ck was prepared according to general procedure using **1c** (0.1 mmol, 1.0 equiv, 33.8 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ck** as colorless oil (22.7 mg, 56% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.59-7.51 (m, 2H), 7.48-7.37 (m, 5H), 7.36-7.28 (m, 2H), 7.22-7.15 (m, 2H), 6.88 (d, *J* = 8.3 Hz, 1H), 6.60-6.31 (m, 1H), 6.13 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.50 (d, *J* = 8.7 Hz, 1H), 4.22 (d, *J* = 8.7 Hz, 1H), 2.55 (ddd, *J* = 7.7, 3.1, 1.3 Hz, 2H), 1.46 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 159.2, 141.3, 136.2, 135.3, 134.1, 132.5, 131.6, 128.7, 127.7, 127.4, 126.8, 126.6, 126.4, 121.8, 121.0, 109.9, 82.3, 45.7, 44.3, 25.0;

HRMS: (APCI) calcd for C₂₄H₂₂BrO⁺[M+H]⁺ 405.0849; found 405.0848.

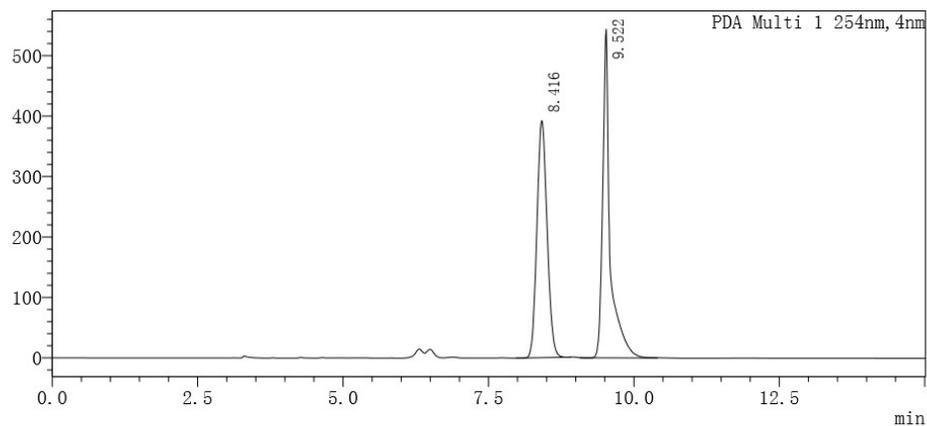
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 1 mL/min. tR = 8.4 min (minor), 9.5 min (major).

Optical Rotation: [α]_D²⁸ 153.1 (c 0.5, CHCl₃) for 91% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.416	4771836	392464	0.000		M	
2	9.522	4797221	543848	0.000		M	
总计		9569058	936312				

peak number

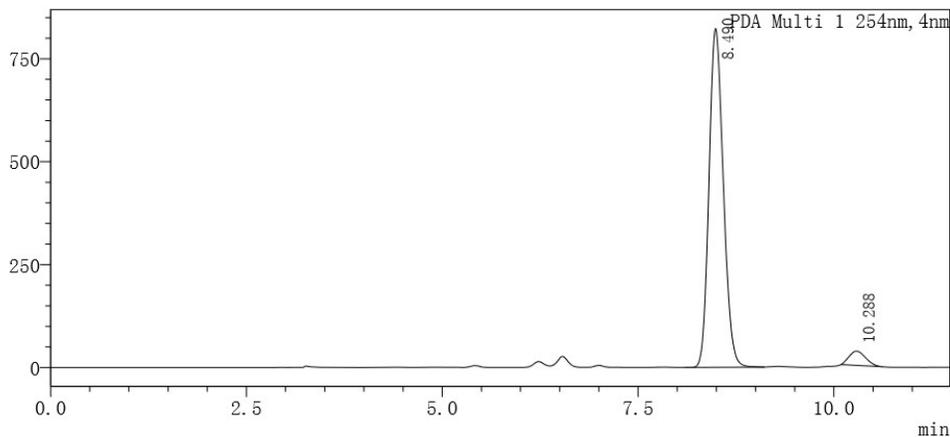
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.490	10470183	823419	0.000		M	
2	10.288	508286	34696	0.000		M	
总计		10978469	858115				

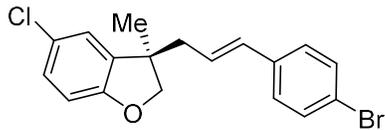
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-5-chloro-3-methyl-2,3-dihydrobenzofuran (**3dk**)



Chemical Formula: C₁₈H₁₆BrClO

Exact Mass: 362.0073

3dk was prepared according to general procedure using **1d** (0.1 mmol, 1.0 equiv, 29.6 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3dk** as colorless oil (19.3 mg, 53% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.54-7.34 (m, 2H), 7.19-7.12 (m, 2H), 7.08 (dd, *J* = 8.4, 2.3 Hz, 1H), 7.04 (d, *J* = 2.0 Hz, 1H), 6.70 (d, *J* = 8.5 Hz, 1H), 6.44-6.25 (m, 1H), 6.03 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.43 (d, *J* = 8.7 Hz, 1H), 4.16 (d, *J* = 8.7 Hz, 1H), 2.46 (ddd, *J* = 7.7, 2.3, 1.3 Hz, 2H), 1.38 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 158.2, 136.6, 136.0, 132.7, 131.6, 128.2, 127.7, 125.9, 125.2, 123.1, 121.1, 110.7, 82.3, 45.9, 44.1, 25.0;

HRMS: (APCI) calcd for C₁₈H₁₇BrClO⁺[M+H]⁺ 363.0146; found 363.0158.

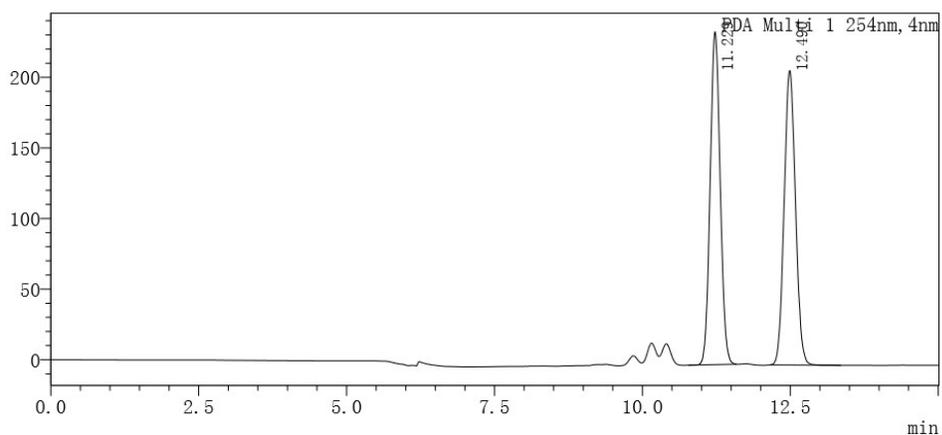
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 0.5 mL/min. t_R = 11.2 min (minor), 12.4 min (major).

Optical Rotation: [α]_D³⁰ 71.4 (c 0.5, CHCl₃) for 90% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.229	2766907	235714	0.000		M	
2	12.490	2772553	208661	0.000		M	
总计		5539460	444374				

peak number

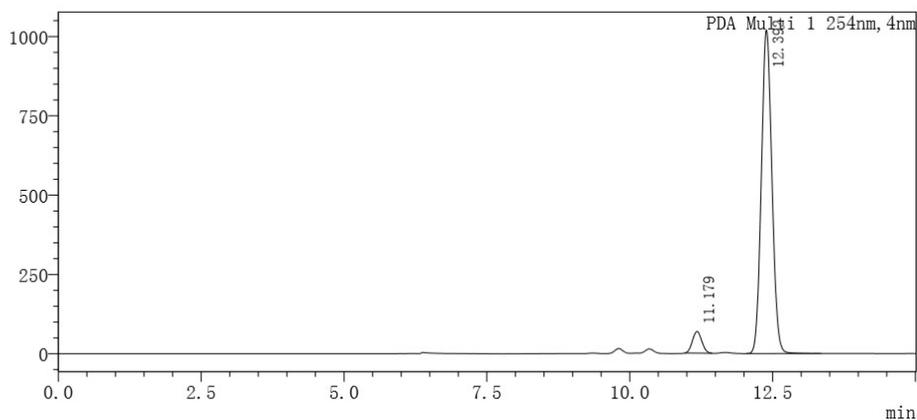
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.179	779201	68666	0.000		M	
2	12.392	13133568	1020302	0.000		M	
总计		13912769	1088968				

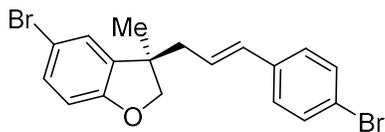
peak number

area

height

retention time

(*R, E*)-5-bromo-3-(3-(4-bromophenyl)allyl)-3-methyl-2,3-dihydrobenzofuran (**3ek**)



Chemical Formula: C₁₈H₁₆Br₂O

Exact Mass: 405.9568

3ek was prepared according to general procedure using **1e** (0.1 mmol, 1.0 equiv, 34 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3ek** as colorless oil (18.4 mg, 45% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.49-7.38 (m, 2H), 7.23 (dd, *J* = 8.4, Hz, 1H), 7.20-7.13 (m, 3H), 6.67 (d, *J* = 8.4 Hz, 1H), 6.50-6.26 (m, 1H), 6.03 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.44 (d, *J* = 8.8 Hz, 1H), 4.16 (d, *J* = 8.8 Hz, 1H), 2.47 (ddd, *J* = 7.7, 2.7, 1.3 Hz, 2H), 1.39 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 158.7, 137.2, 136.0, 132.7, 131.6, 131.1, 127.7, 126.0, 125.9, 121.1, 112.3, 111.4, 82.3, 45.9, 44.1, 25.0;

HRMS: (APCI) calcd for C₁₈H₁₇Br₂O⁺[M+H]⁺ 406.9641; found 406.9639.

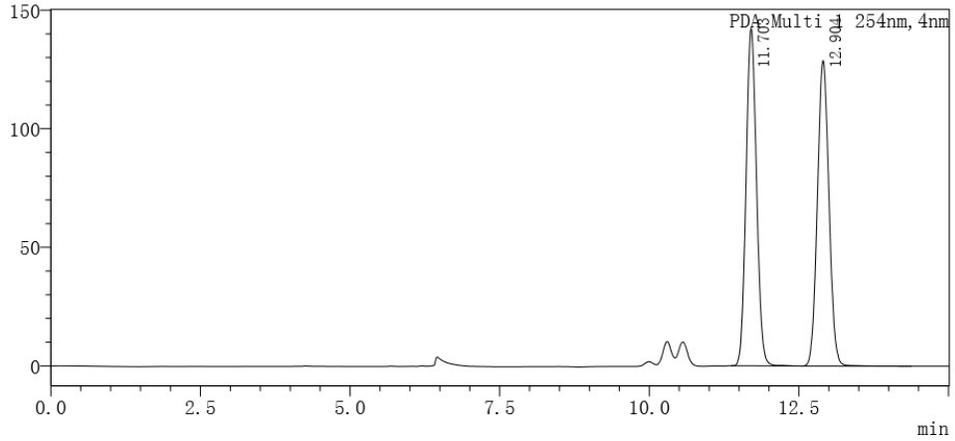
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 0.5 mL/min. t_R = 11.7 min (minor), 12.9 min (major).

Optical Rotation: [α]_D²⁸ 112.9 (c 0.4, CHCl₃) for 90% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.703	1725245	142428	0.000		M	
2	12.904	1730555	128832	0.000		M	
总计		3455799	271260				

peak number

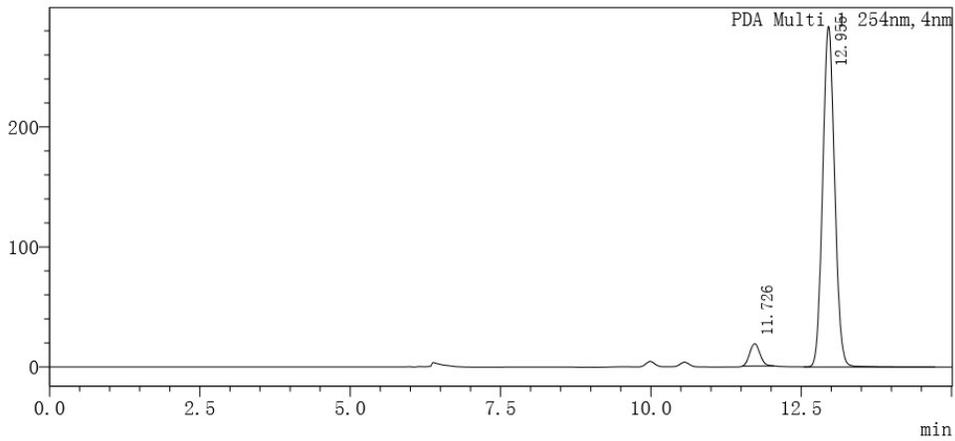
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.726	219604	18639	0.000		M	
2	12.955	3927873	283851	0.000		M	
总计		4147478	302490				

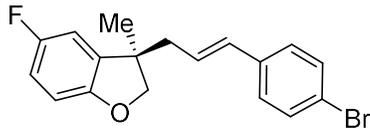
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-5-fluoro-3-methyl-2,3-dihydrobenzofuran (**3fk**)



Chemical Formula: C₁₈H₁₆BrFO

Exact Mass: 346.0369

3fk was prepared according to general procedure using **1f** (0.1 mmol, 1.0 equiv, 28 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3fk** as colorless oil (24.3 mg, 70% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.53-7.37 (m, 2H), 7.22-7.11 (m, 2H), 6.90-6.77 (m, 2H), 6.70 (ddd, *J* = 8.3, 4.1, 0.7 Hz, 1H), 6.41-6.29 (m, 1H), 6.06 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.44 (d, *J* = 8.7 Hz, 1H), 4.17 (d, *J* = 8.7 Hz, 1H), 2.48 (dt, *J* = 7.9, 1.0 Hz, 2H), 1.39 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 157.6 (d, *J* = 237.4 Hz), 155.34, 136.1, 136.05, 132.6, 131.6, 127.7, 126.0, 121.1, 114.4 (d, *J* = 24.3 Hz), 109.98 (d, *J* = 31.4 Hz), 109.9, 82.4, 46.1, 44.0, 24.8;

¹⁹F NMR (376 MHz, CDCl₃) δ -123.77;

HRMS: (APCI) calcd for C₁₈H₁₇BrFO⁺[M+H]⁺ 347.0441; found 347.0439.

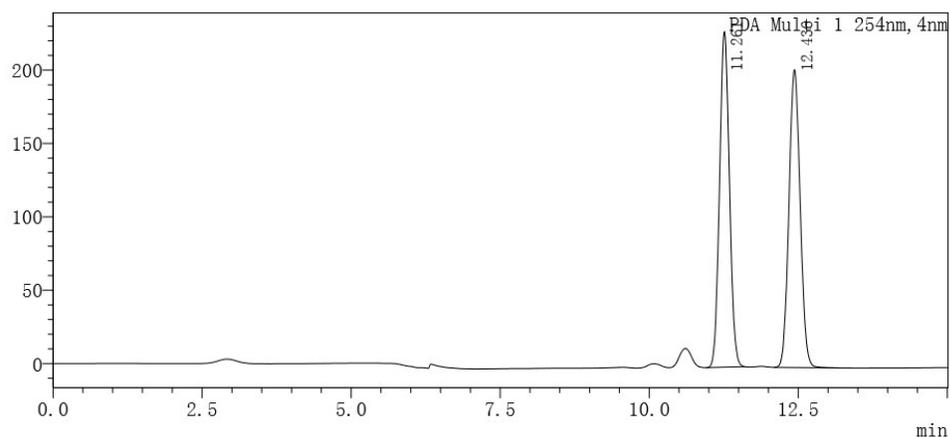
The enantiomeric purity was established by HPLC analysis using a chiral column: OD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 98/2 as eluent, 254 nm, 0.5 mL/min. t_R = 11.2 min (minor), 12.4 min (major).

Optical Rotation: [α]_D²⁸ 12.4 (c 0.6, CHCl₃) for 91% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.261	2644190	228778	0.000		M	
2	12.436	2645848	203212	0.000		M	
总计		5290037	431989				

peak number

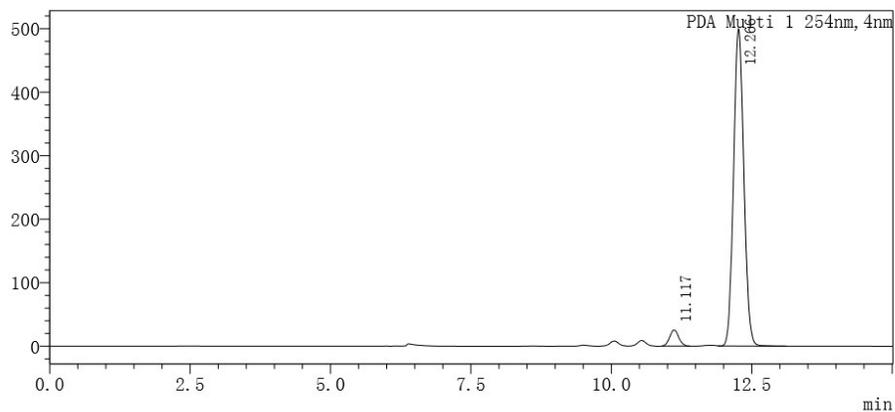
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	11.117	284317	25505	0.000		M	
2	12.266	6317892	500394	0.000		M	
总计		6602209	525899				

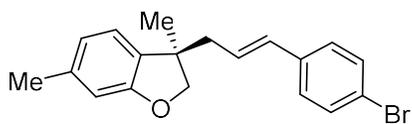
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-3,6-dimethyl-2,3-dihydrobenzofuran (**3gk**)



Chemical Formula: C₁₉H₁₉BrO

Exact Mass: 342.0619

3gk was prepared according to general procedure using **1g** (0.1 mmol, 1.0 equiv, 27.6 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3gk** as colorless oil (28.1 mg, 82% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.49-7.36 (m, 2H), 7.23-7.14 (m, 2H), 6.99 (d, *J* = 7.5 Hz, 1H), 6.72 (ddd, *J* = 7.5, 1.5, 0.8 Hz, 1H), 6.64 (dt, *J* = 1.5, 0.7 Hz, 1H), 6.34 (dd, *J* = 15.7, 1.5 Hz, 1H), 6.10 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.41 (d, *J* = 8.7 Hz, 1H), 4.15 (d, *J* = 8.7 Hz, 1H), 2.48 (dd, *J* = 7.5, 1.3 Hz, 2H), 2.33 (d, *J* = 0.8 Hz, 3H), 1.38 (s, 3H); ¹³C NMR (101 MHz, CDCl₃): δ 159.7, 138.4, 136.3, 13, 131.7, 131.6, 127.7, 126.8, 122.5, 121.2, 120.9, 110.4, 82.2, 45.3, 44.3, 25.0, 21.5;

HRMS: (APCI) calcd for C₁₉H₂₀BrO⁺[M+H]⁺ 343.0692; found 343.0696.

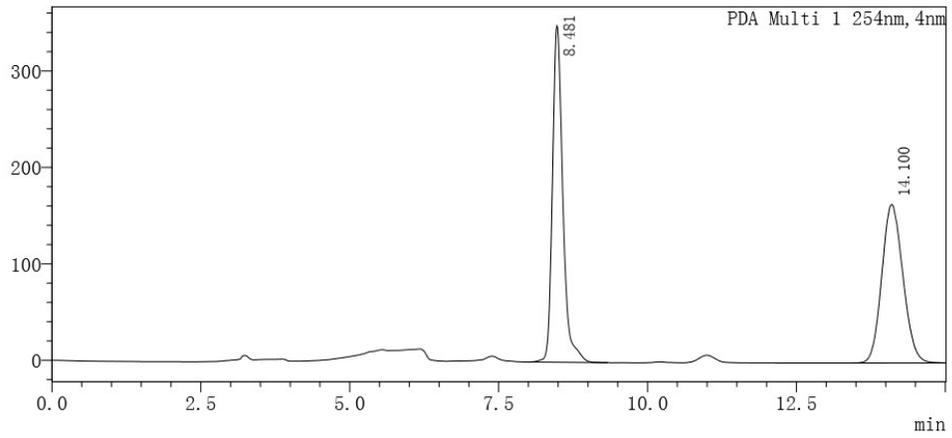
The enantiomeric purity was established by HPLC analysis using a chiral column: OJ-H column, 30 °C, *n*-Hexane/*i*-Propanol = 95/5 as eluent, 254 nm, 1 mL/min. tR = 8.4 min (minor), 14.1 min (major).

Optical Rotation: [α]_D³⁰ -7.2 (c 0.7, CHCl₃) for 91% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.481	4242570	349237	0.000			
2	14.100	4058659	164286	0.000			
总计		8301229	513523				

peak number

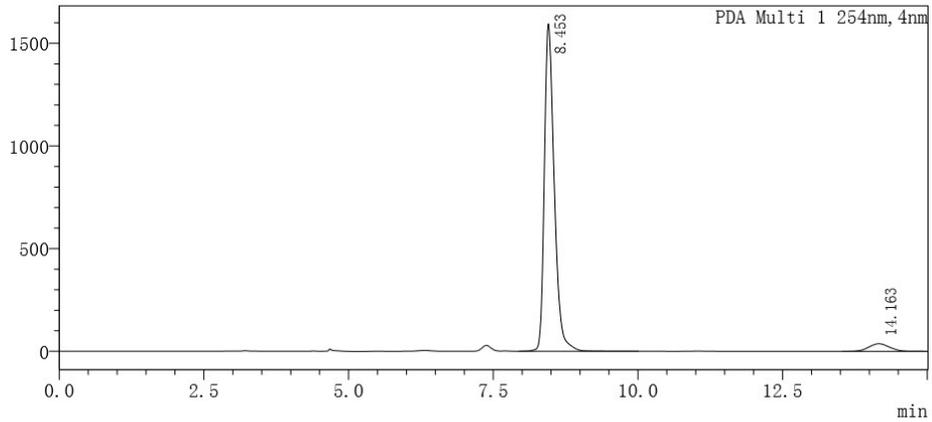
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	8.453	19072650	1594529	0.000			
2	14.163	922376	37393	0.000			
总计		19995026	1631922				

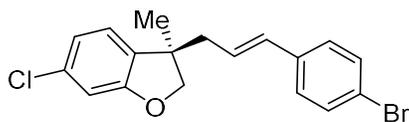
peak number

area

height

retention time

(*R, E*)-3-(3-(4-bromophenyl)allyl)-6-chloro-3-methyl-2,3-dihydrobenzofuran (**3hk**)



Chemical Formula: C₁₈H₁₆BrClO

Exact Mass: 362.0073

3hk was prepared according to general procedure using **1h** (0.1 mmol, 1.0 equiv, 29.6 mg) and **2k** (0.2 mmol, 26.2 μ L) and was purified by silica gel column chromatography (petroleum ether/EtOAc = 100/1~30/1) to obtain **3hk** as colorless oil (24.3 mg, 67% yield). ¹H NMR (400 MHz, CDCl₃): δ 7.54-7.37 (m, 2H), 7.16 (d, *J* = 8.4 Hz, 2H), 6.99 (d, *J* = 7.9 Hz, 1H), 6.87 (dd, *J* = 7.9, 1.8 Hz, 1H), 6.79 (d, *J* = 1.8 Hz, 1H), 6.33 (dt, *J* = 15.7, 1.4 Hz, 1H), 6.05 (dt, *J* = 15.7, 7.5 Hz, 1H), 4.45 (d, *J* = 8.7 Hz, 1H), 4.18 (d, *J* = 8.8 Hz, 1H), 2.47 (dt, *J* = 7.8, 1.3 Hz, 2H), 1.38 (s, 3H);

¹³C NMR (101 MHz, CDCl₃): δ 160.4, 136.0, 133.5, 133.4, 132.6, 131.6, 127.7, 126.0, 123.5, 121.1, 120.7, 110.5, 82.7, 45.3, 44.2, 25.0;

HRMS: (APCI) calcd for C₁₈H₁₇BrClO⁺[M+H]⁺ 363.0146; found 363.0144.

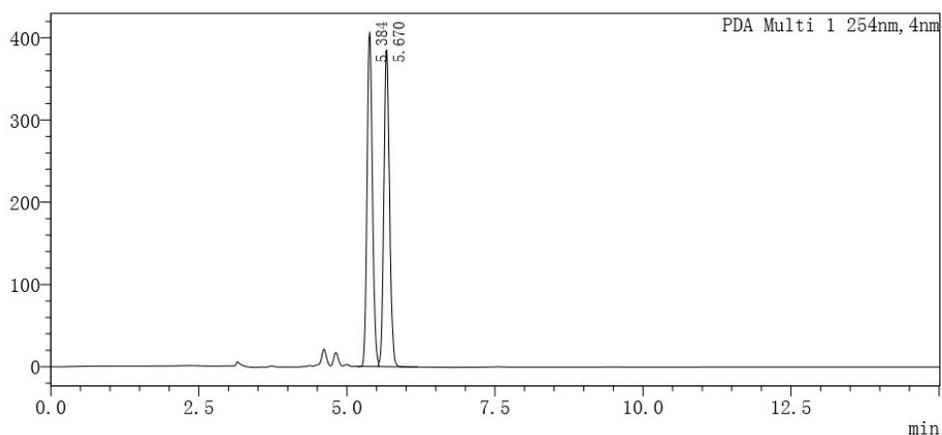
The enantiomeric purity was established by HPLC analysis using a chiral column: AD-H column, 30 °C, *n*-Hexane/*i*-Propanol = 97/3 as eluent, 254 nm, 1 mL/min. tR = 5.3 min (minor), 5.6 min (major).

Optical Rotation: [α]_D³⁰ -8.6 (c 0.7, CHCl₃) for 94% ee.

Absolute stereochemistry was determined through analogy with **3ac**.

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.384	2553968	406927	0.000		M	
2	5.670	2563348	384431	0.000		V M	
总计		5117316	791358				

peak number

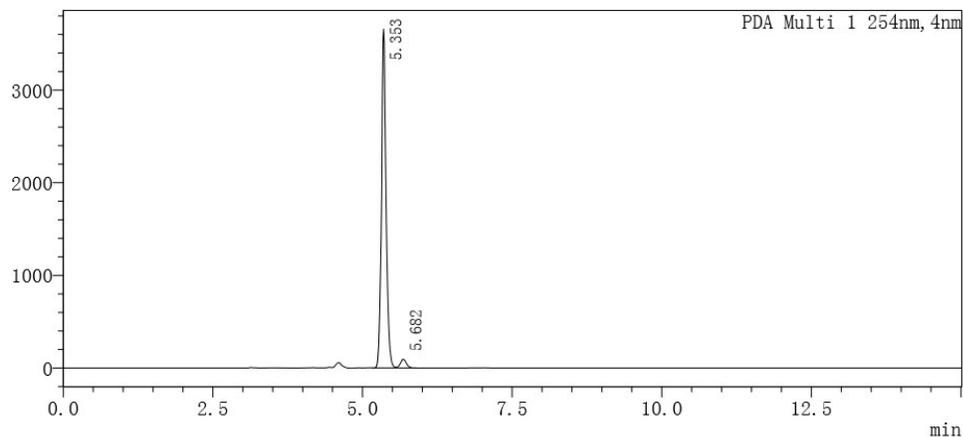
area

height

retention time

<色谱图>

mAU



<峰表>

PDA Ch1 254nm

峰号	保留时间	面积	高度	浓度	浓度单位	标记	化合物名
1	5.353	19394260	3657241	0.000		M	
2	5.682	650103	93174	0.000		V M	
总计		20044363	3750415				

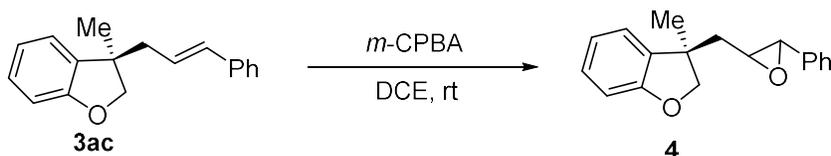
peak number

area

height

retention time

(3*R*)-3-methyl-3-((3-phenyloxiran-2-yl)methyl)-2,3-dihydrobenzofuran (**4**)



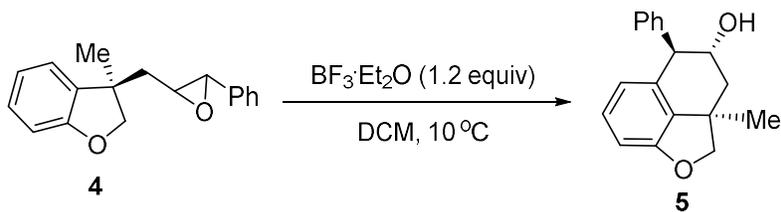
To a stirred solution of **3ac** (0.4 mmol, 120.1 mg) in DCE (2.0 mL) was added *m*-CPBA (0.48 mmol, 84.0 mg) in three pots. The mixture was then stirred at room temperature for 24 hours. After the reaction was completed, the solid was filtrated and the solvent was removed under vacuum. The residue was then purified by column chromatography on silica gel, eluting with petroleum ether/EtOAc = 50/1~20/1 to afford the desired epoxide **4** (85.2 mg, 80% yield, d.r. = 1.1/1).

¹H NMR (400 MHz, CDCl₃): δ 7.41-7.21 (m, 8H), 7.20-7.05 (m, 6H), 6.97-6.87 (m, 2H), 6.85-6.73 (m, 2H), 4.60 (d, *J* = 8.8 Hz, 1H), 4.51 (d, *J* = 8.8 Hz, 1H), 4.25 (d, *J* = 1.1 Hz, 1H), 4.23 (d, *J* = 1.2 Hz, 1H), 3.55 (d, *J* = Hz, 1H), 3.44 (d, *J* = Hz, 1H), 3.05-2.94 (m, 1H), 2.93-2.83 (m, 1H), 0-1.90 (m, 4H), 1.49 (s, 3H), 1.47(s, 3H);

¹³C NMR (100 MHz, CDCl₃): δ 159.5, 159.2, 137.2, 137.1, 134.4, 133.9, 128.4, 128.4, 128.3, 128.1, 127.9, 125.5, 125.4, 122.97, 122.7, 120.7, 120.6, 109.9, 109.9, 82.8, 81.8, 59.9, 59.8, 58.6, 58.1, 44.7, 44.6, 43.6, 42.9, 26.1, 24.6;

HRMS: (ESI) calcd for C₁₈H₁₈NaO₂⁺[M+Na]⁺ 289.1199; found 289.1201.

(2a*R*,4*R*,5*R*)-2a-methyl-5-phenyl-2a,3,4,5-tetrahydro-2H-naphtho[1,8-*bc*]furan-4-ol (**5**)



To a solution of **4** (0.1 mmol, 26.6 mg) in dry DCM (2 mL) at 10°C under an argon atmosphere was added $\text{BF}_3 \cdot \text{Et}_2\text{O}$ (0.12 mmol) slowly. After the reaction was completed, the reaction was quenched by the addition of saturated aqueous NaHCO_3 and extracted with DCM. The combined organic layers was washed with saturated NH_4Cl and dried over Na_2SO_4 . The solvent was then removed under vacuum and the residue was purified by column chromatography on silica gel, eluting with petroleum ether/EtOAc = 20:1~5/1 to afford the desired tricyclic dihydrobenzofuran **5** (16.0 mg, 60%) with d.r. (100/13).

^1H NMR (400 MHz, CDCl_3): δ 7.47-7.40 (m, 2H), 7.39-7.32 (m, 1H), 7.31-7.24 (m, 2H), 6.99 (t, $J = 7.8$ Hz, 1H), 6.72-6.67 (m, 1H), 6.23-6.17 (m, 1H), 4.50 (d, $J = 8.2$ Hz, 1H), 4.22 (d, $J = 8.1$ Hz, 1H), 4.18-4.08 (m, 1H), 3.94 (d, $J = 8.9$ Hz, 1H), 2.33 (dd, $J = 14.2$, 8.0 Hz, 1H), 1.99 (dd, $J = 14.1$, 6.8 Hz, 1H), 1.74 (bs, 1H), 1.45 (s, 3H);

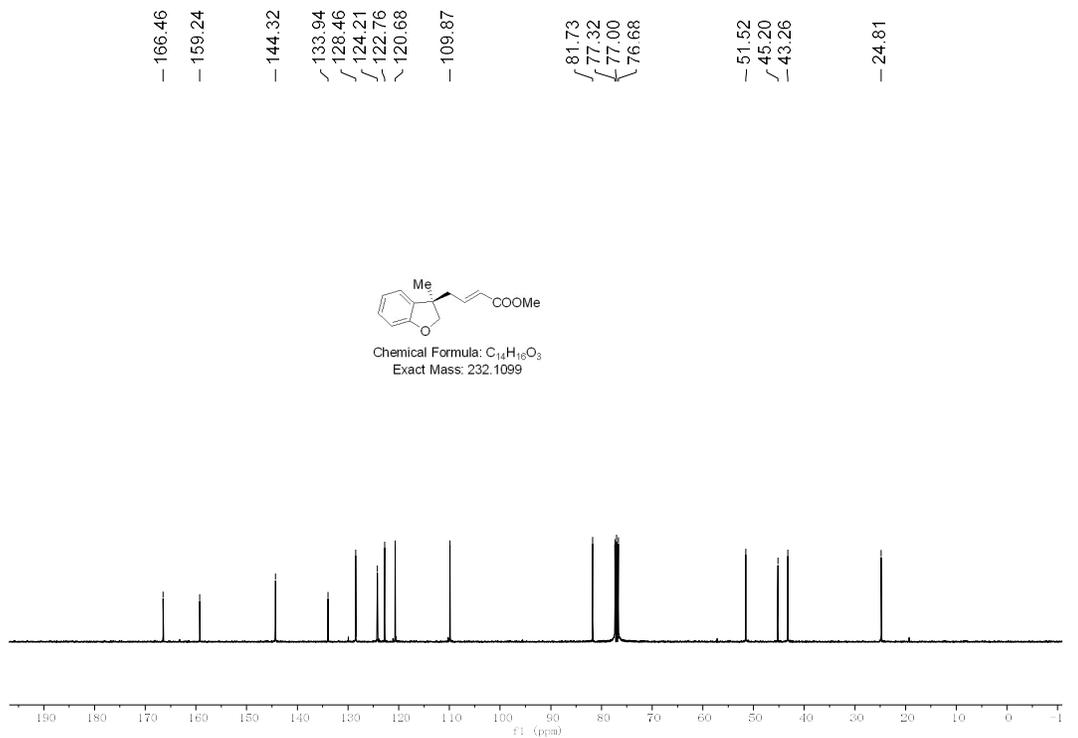
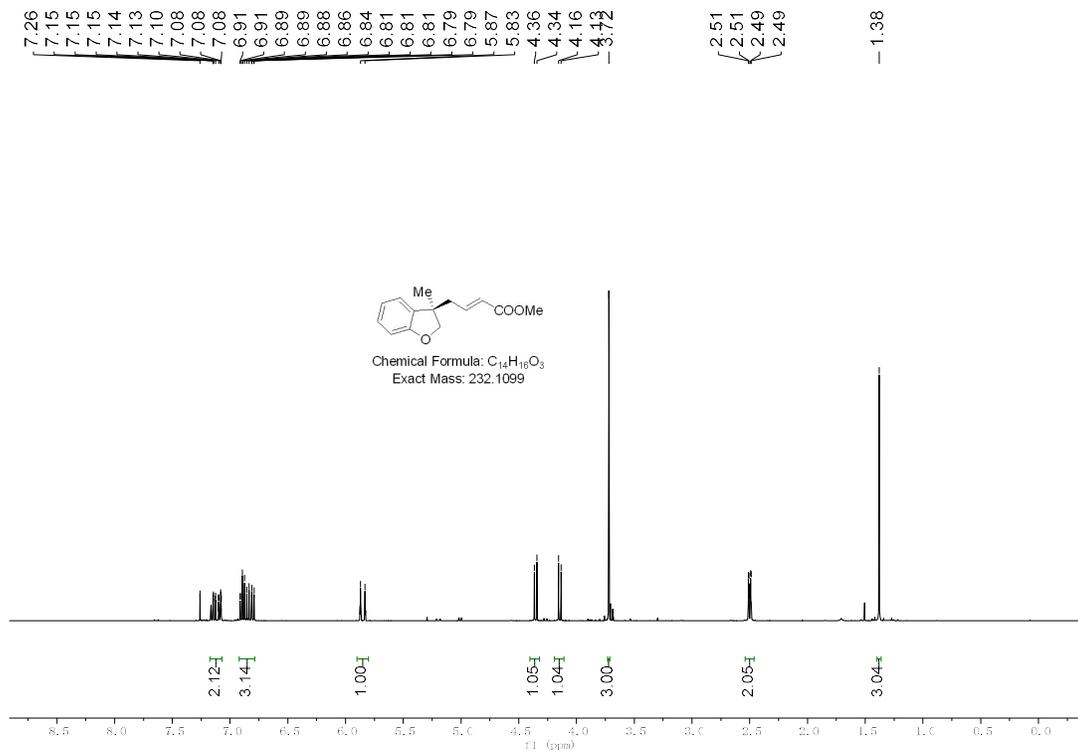
^{13}C NMR (100 MHz, CDCl_3): δ 157.1, 139.2, 136.2, 132.6, 129.7, 129.0, 128.3, 127.5, 118.5, 107.7, 87.1, 75.1, 5, 41.0, 40.3, 27.7;

HRMS: (ESI) calcd for $\text{C}_{18}\text{H}_{18}\text{NaO}_2^+[\text{M}+\text{Na}]^+$ 289.1199; found 289.1201.

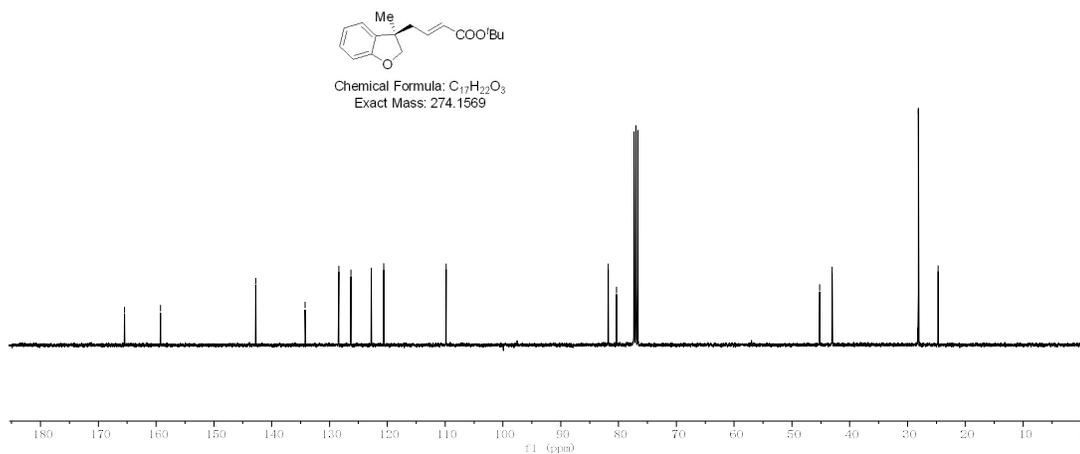
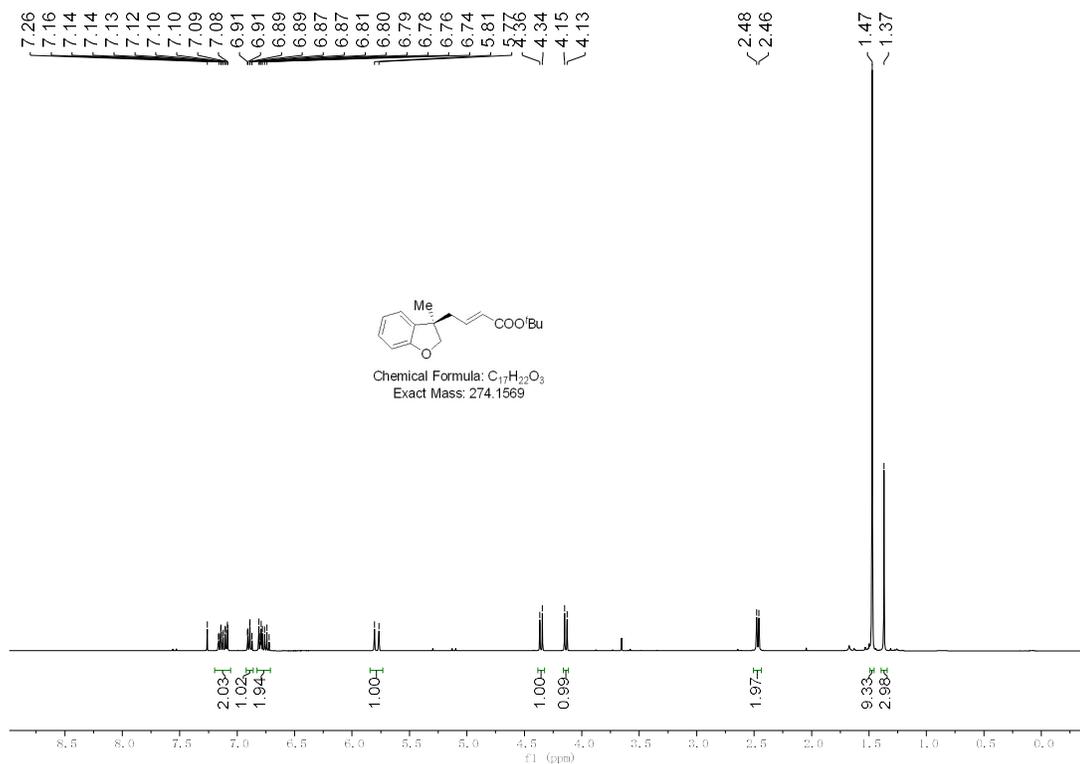
Optical Rotation: $[\alpha]_{\text{D}}^{30}$ 23.0 (c 0.3, CHCl_3).

6. Copies of the ^1H , ^{13}C and ^{19}F NMR spectra

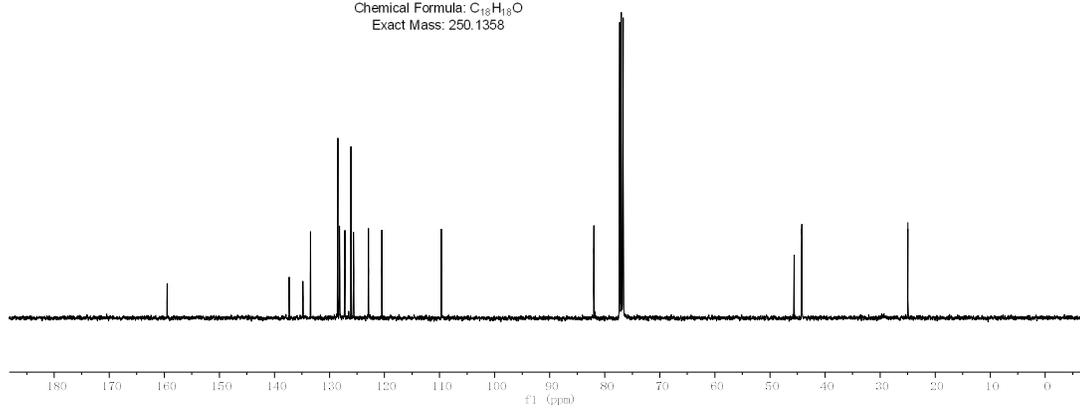
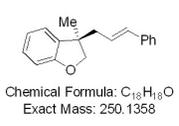
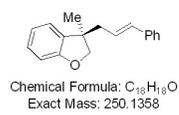
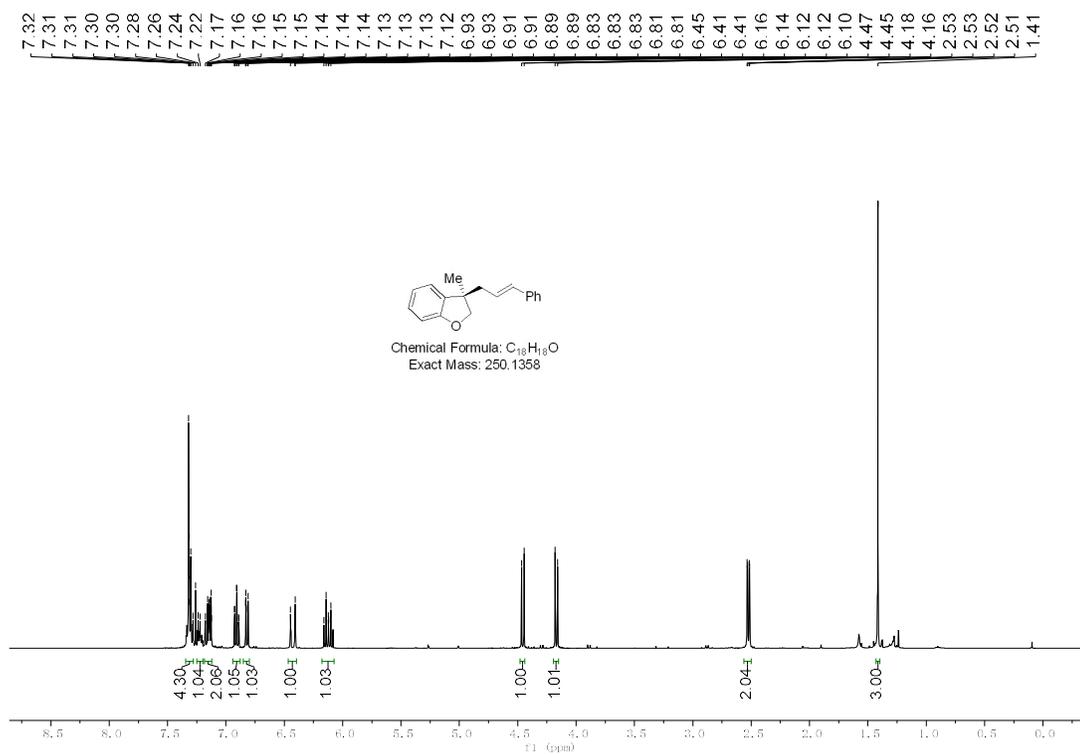
3aa



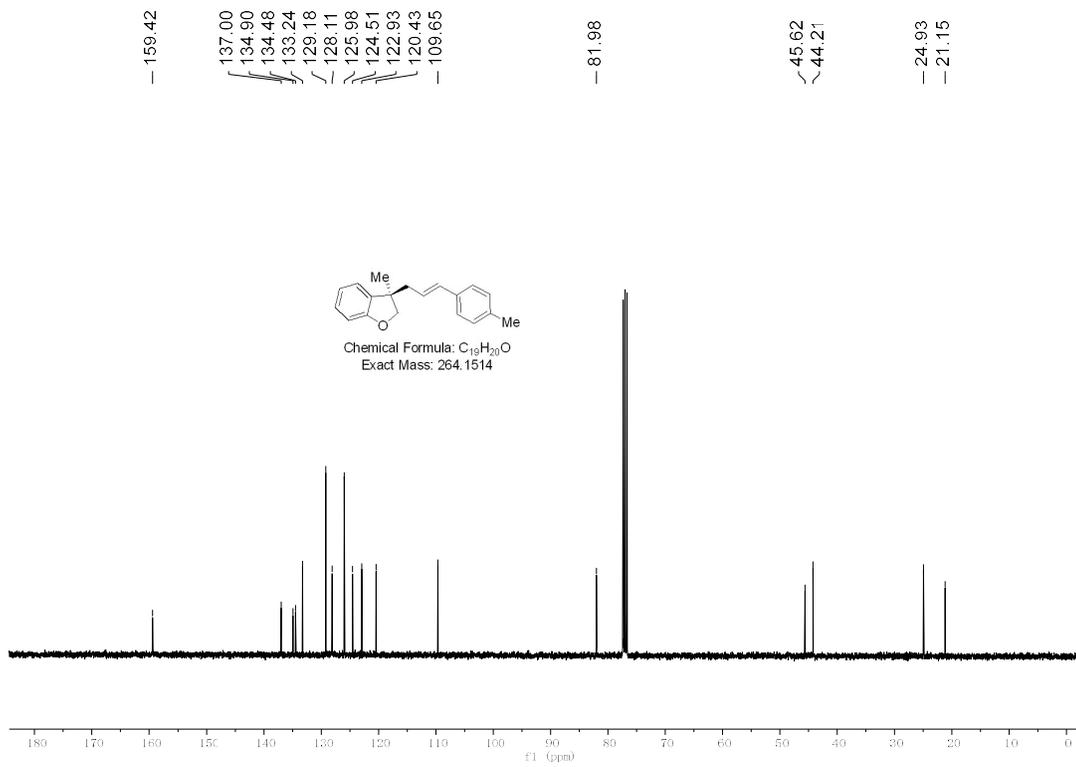
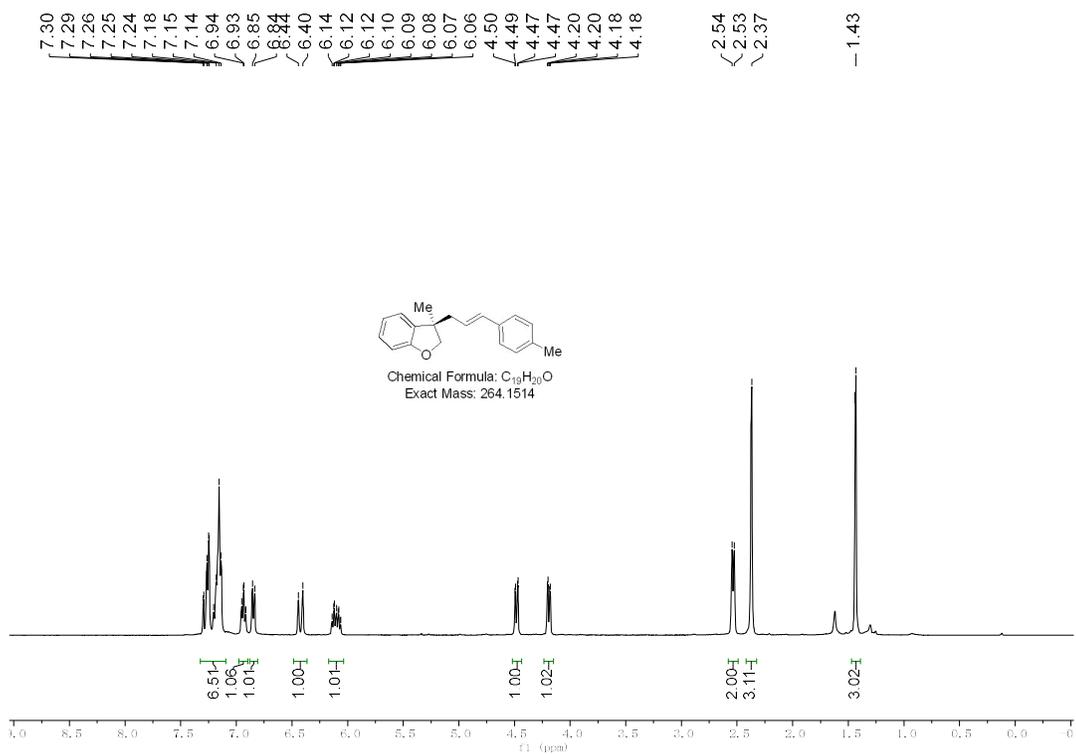
3ab



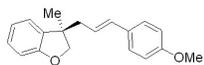
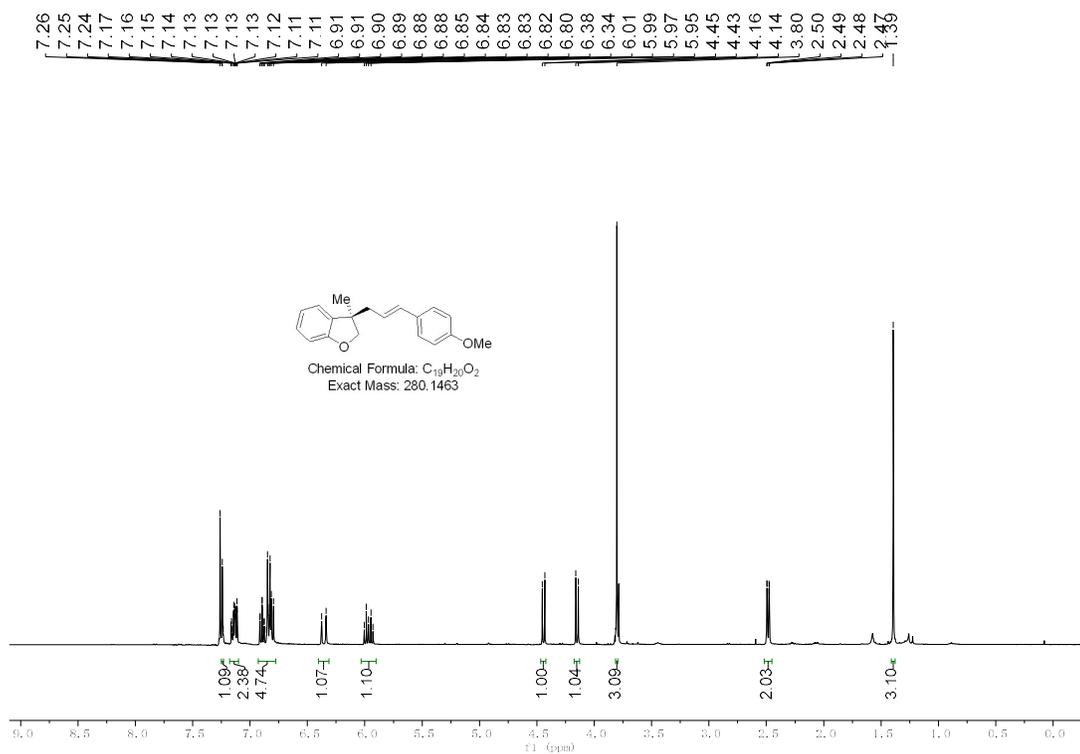
3ac



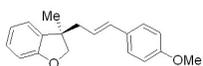
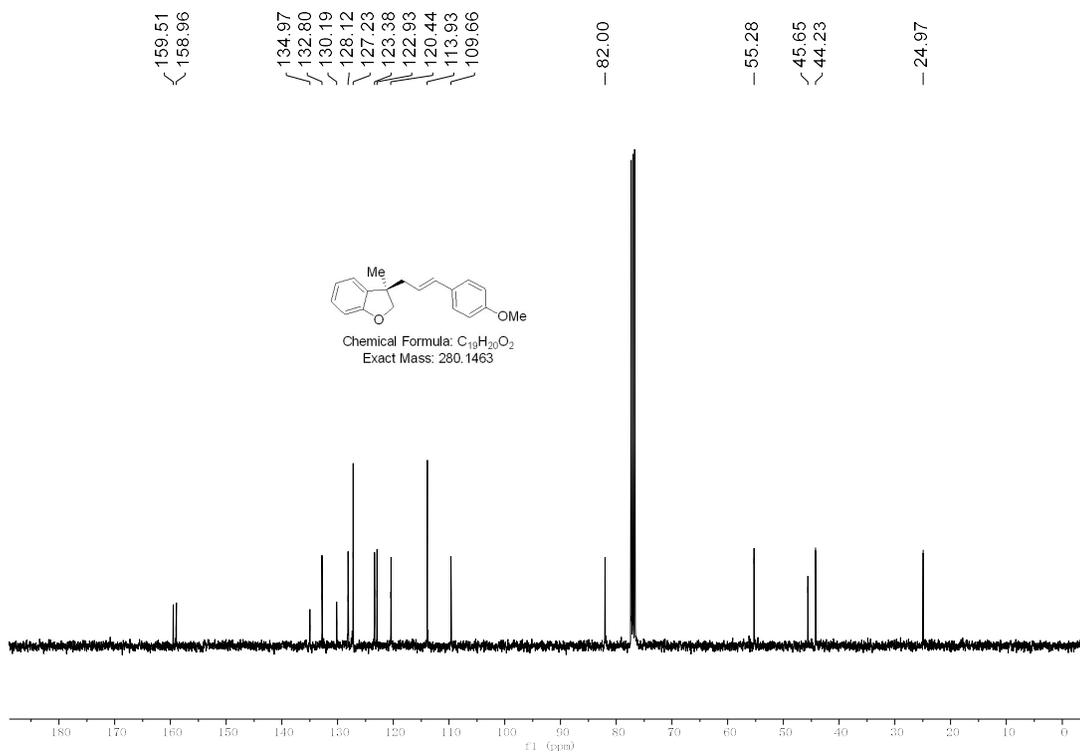
3ad



3ae

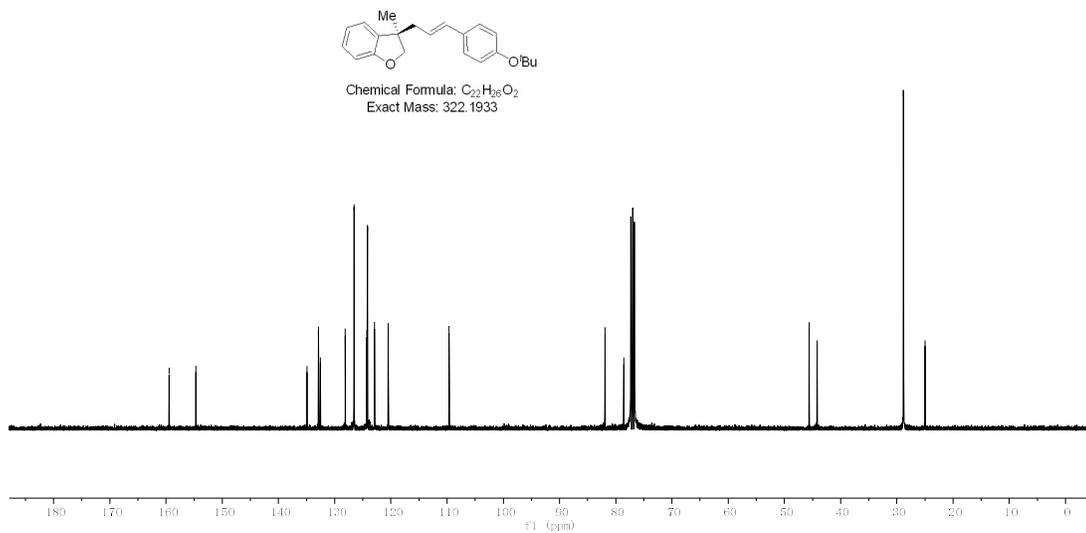
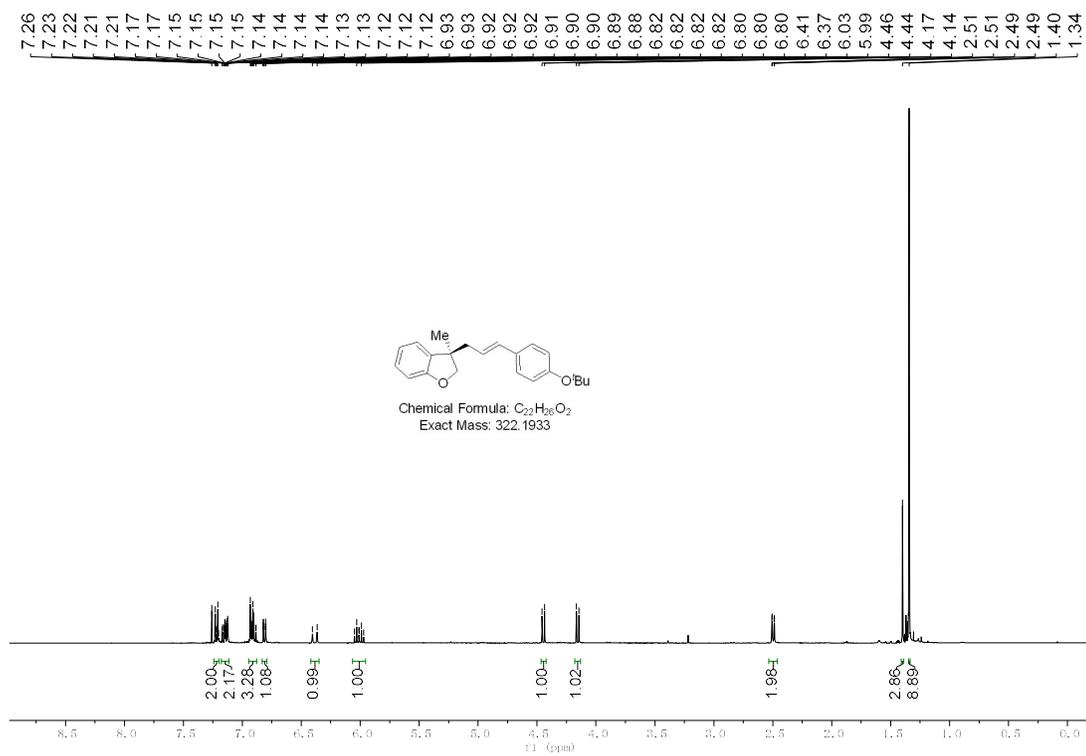


Chemical Formula: C₁₉H₂₀O₂
Exact Mass: 280.1463

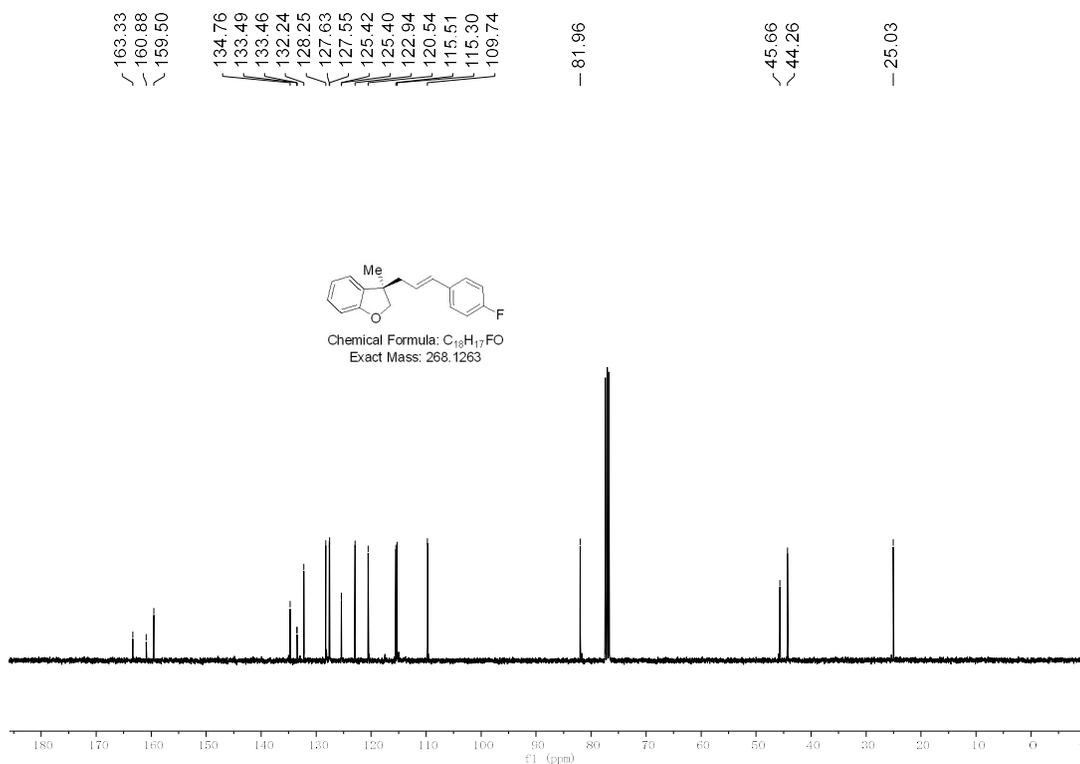
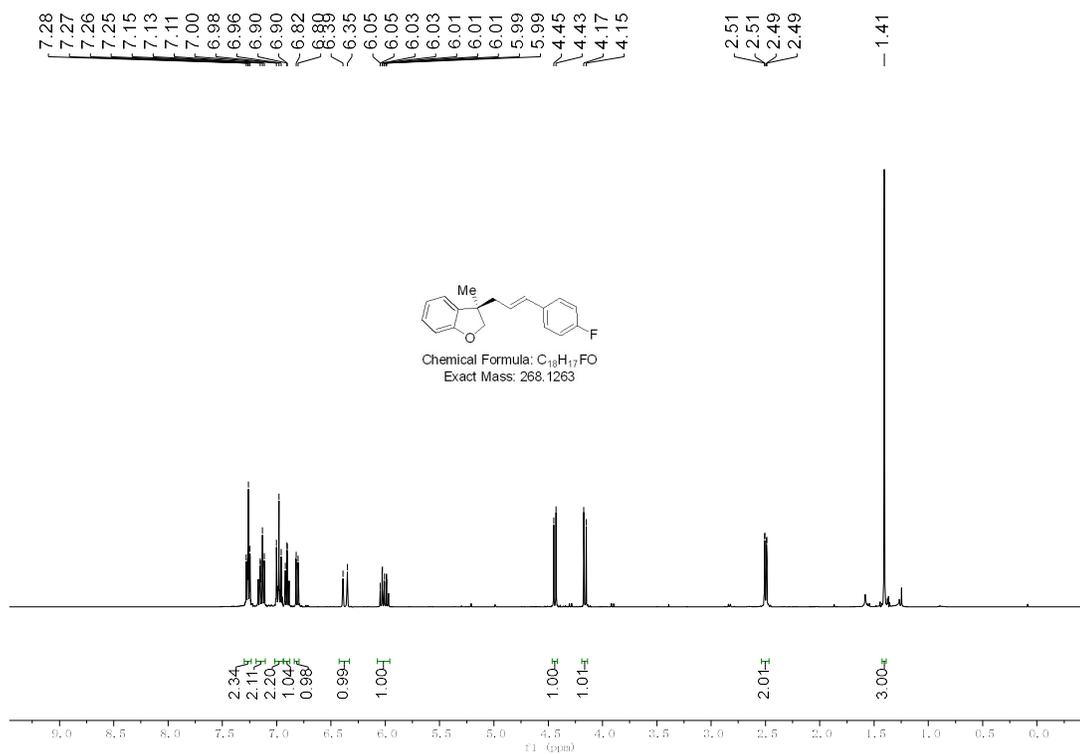


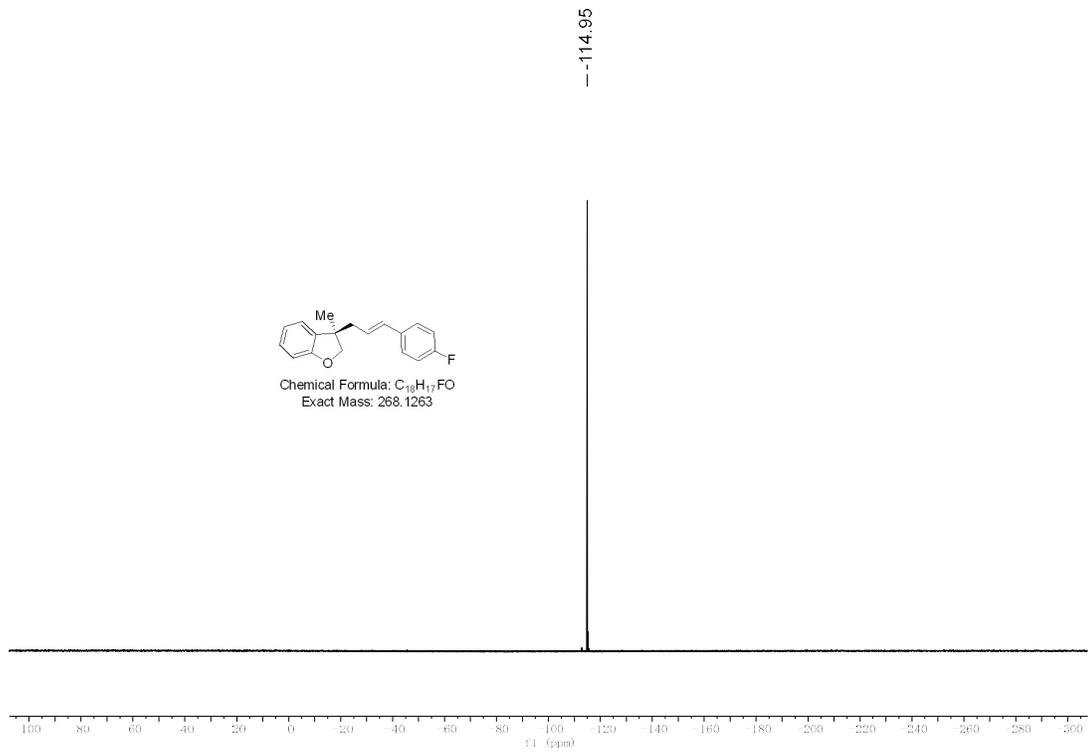
Chemical Formula: C₁₉H₂₀O₂
Exact Mass: 280.1463

3af

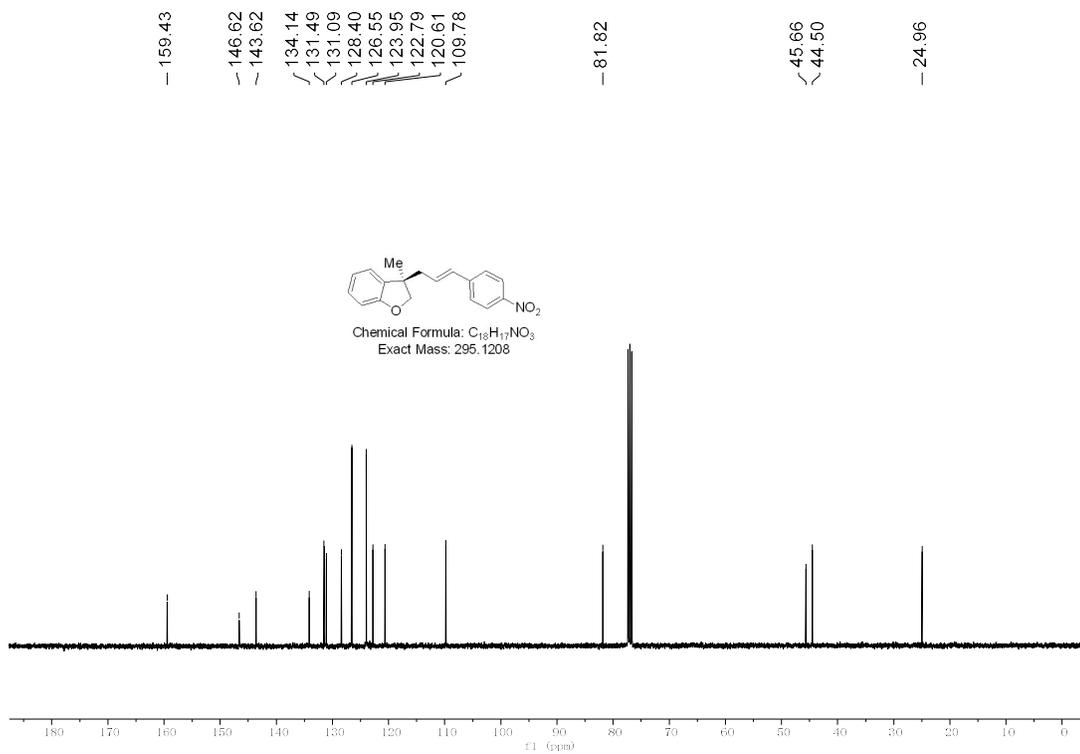
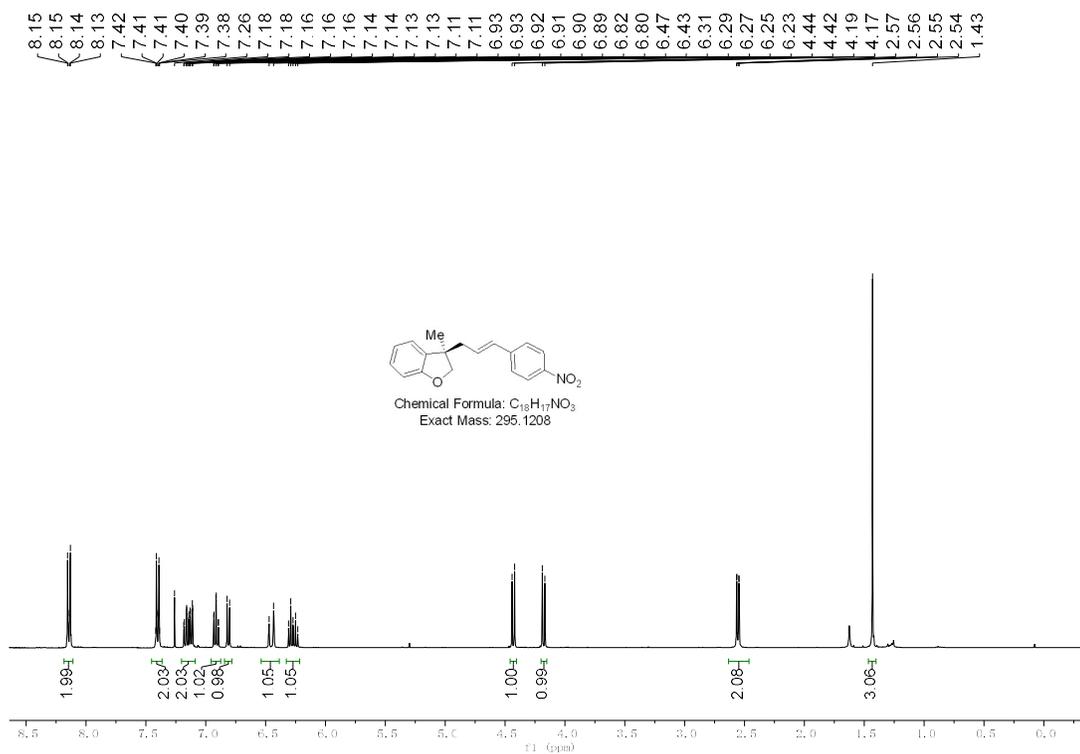


3ag

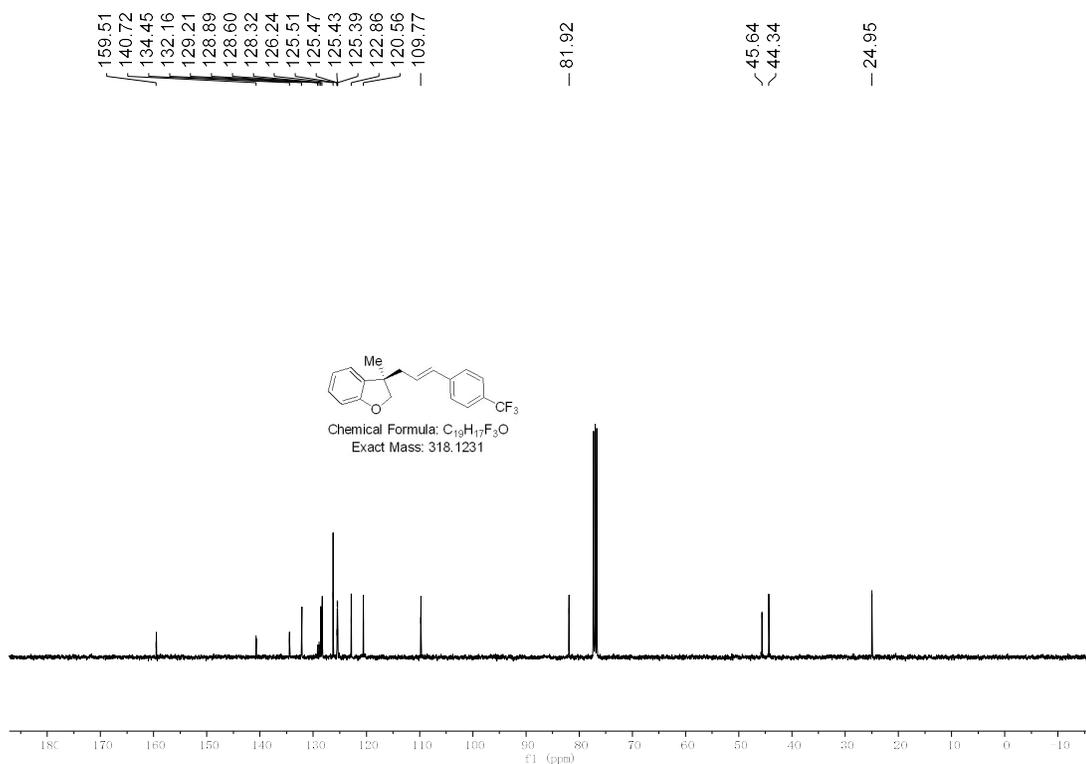
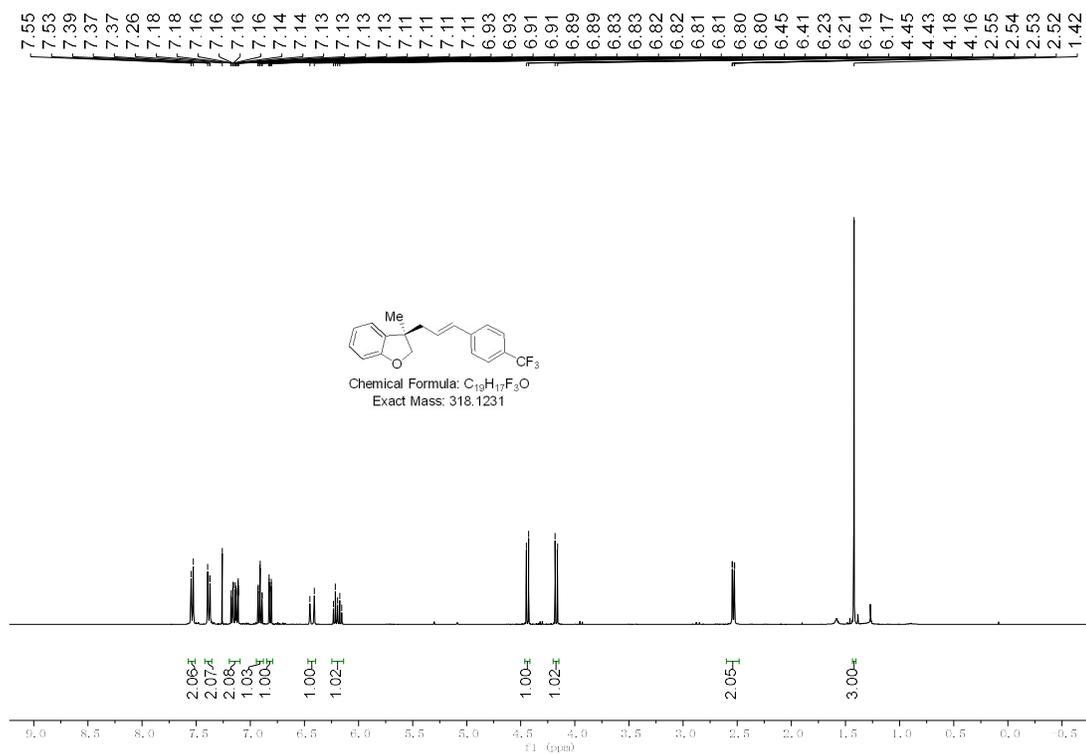


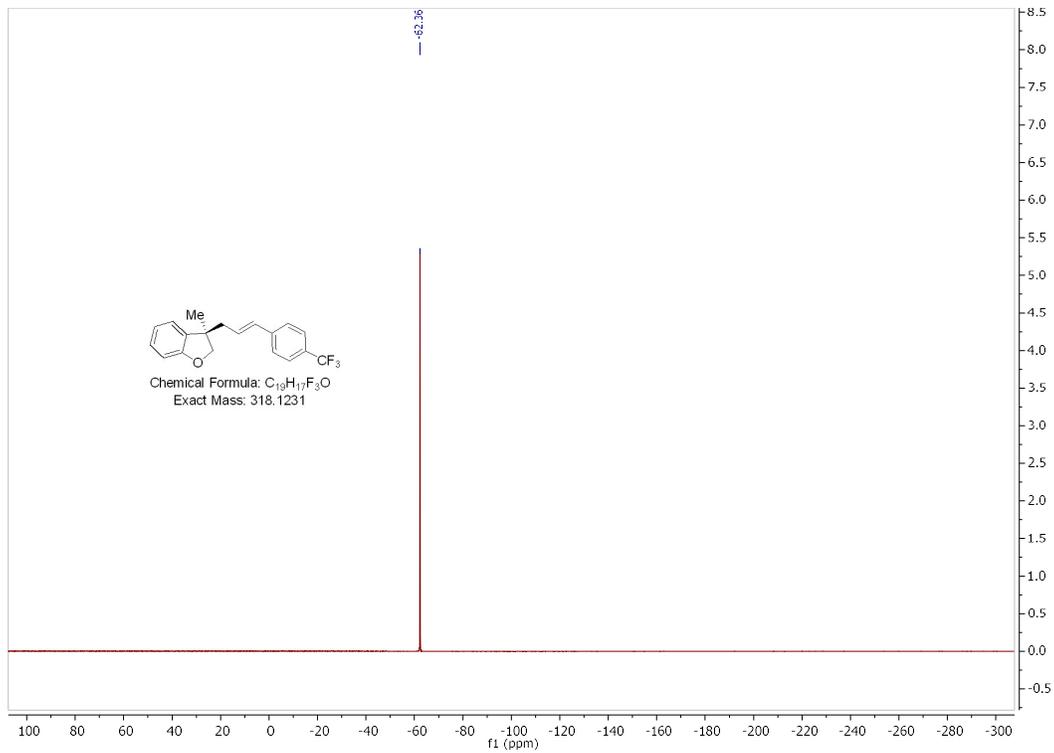


3ah

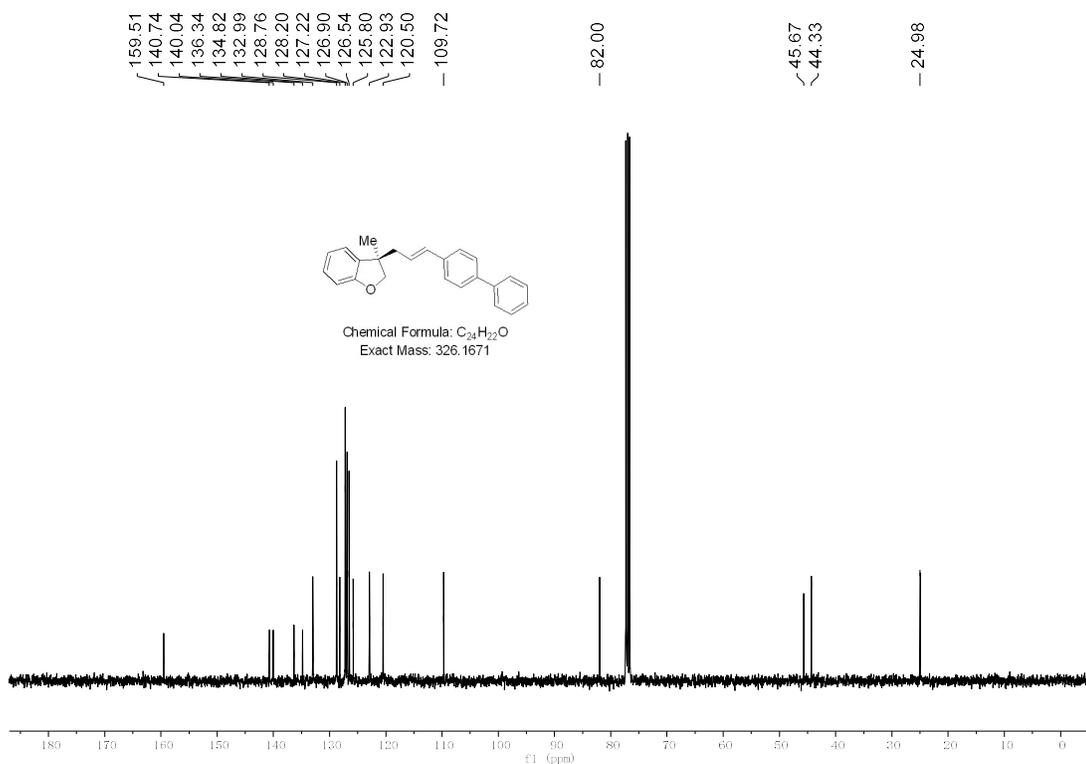
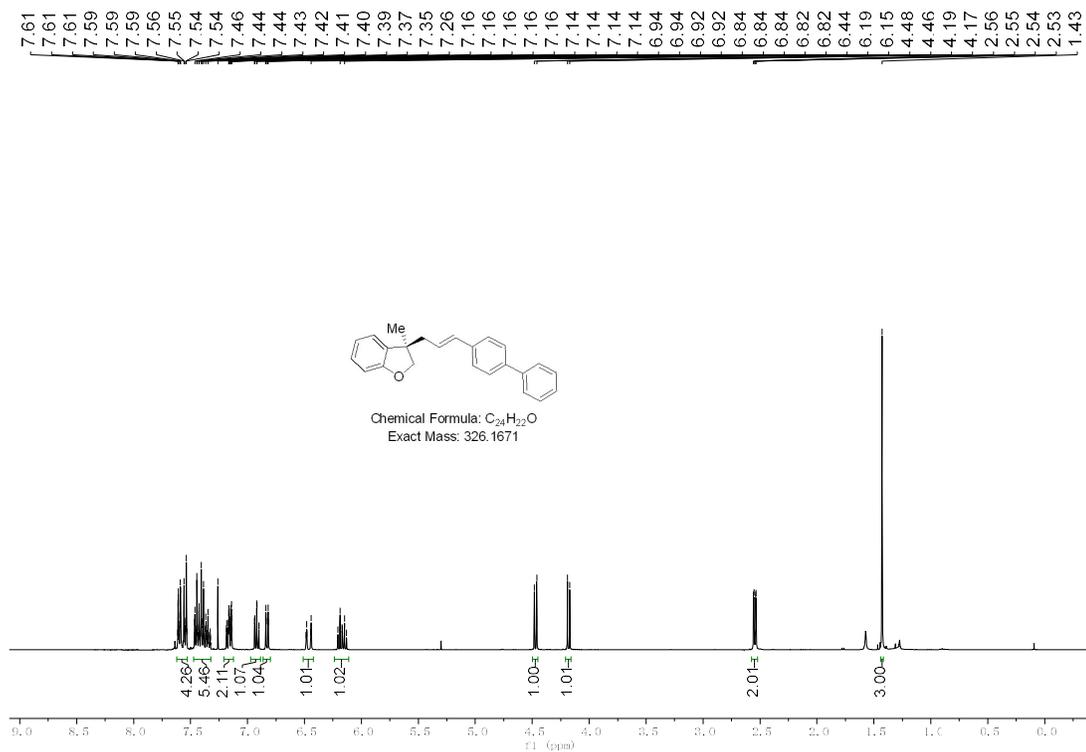


3ai

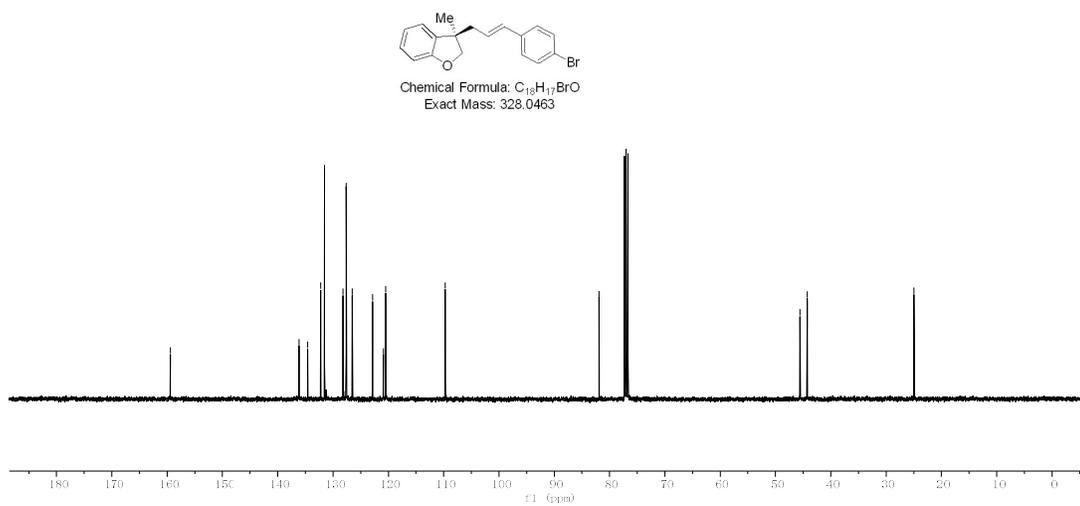
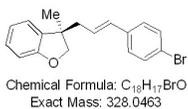
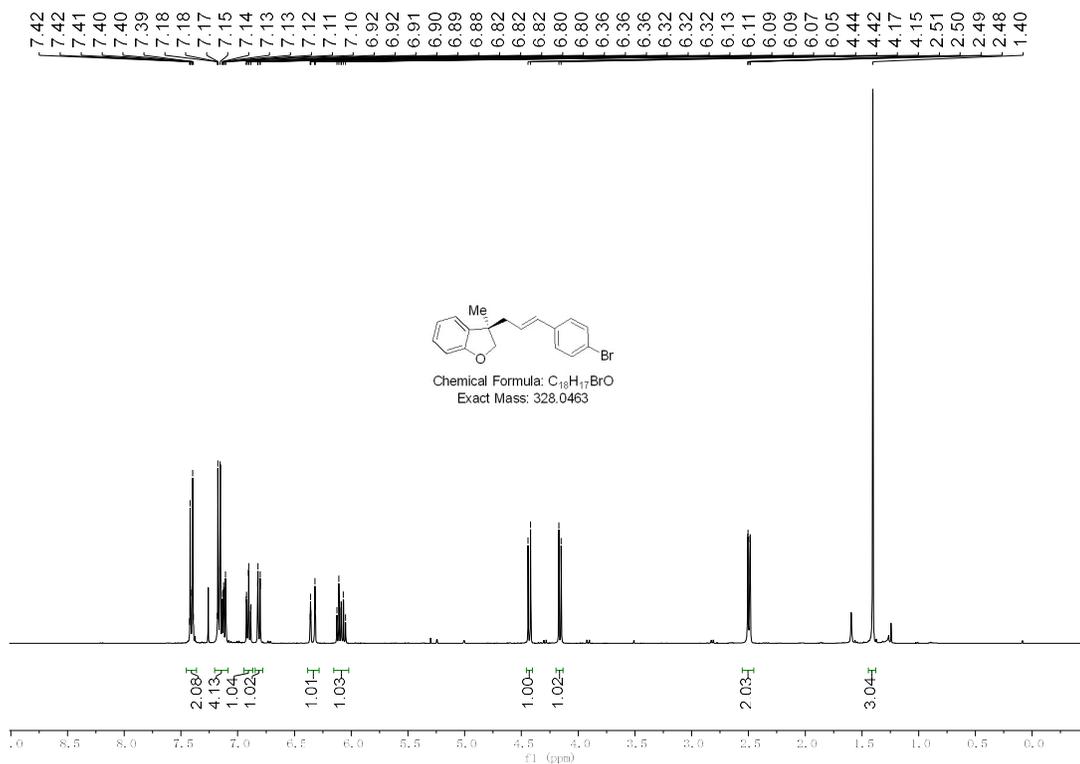




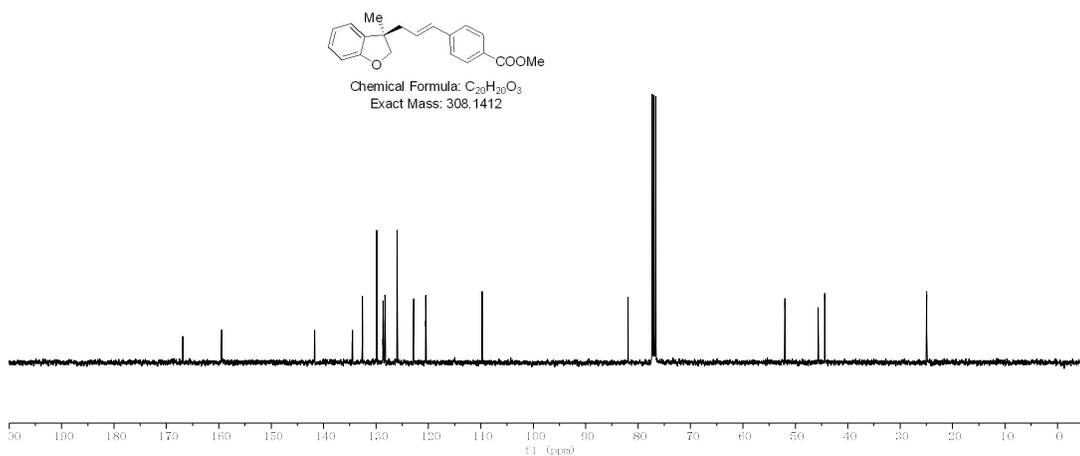
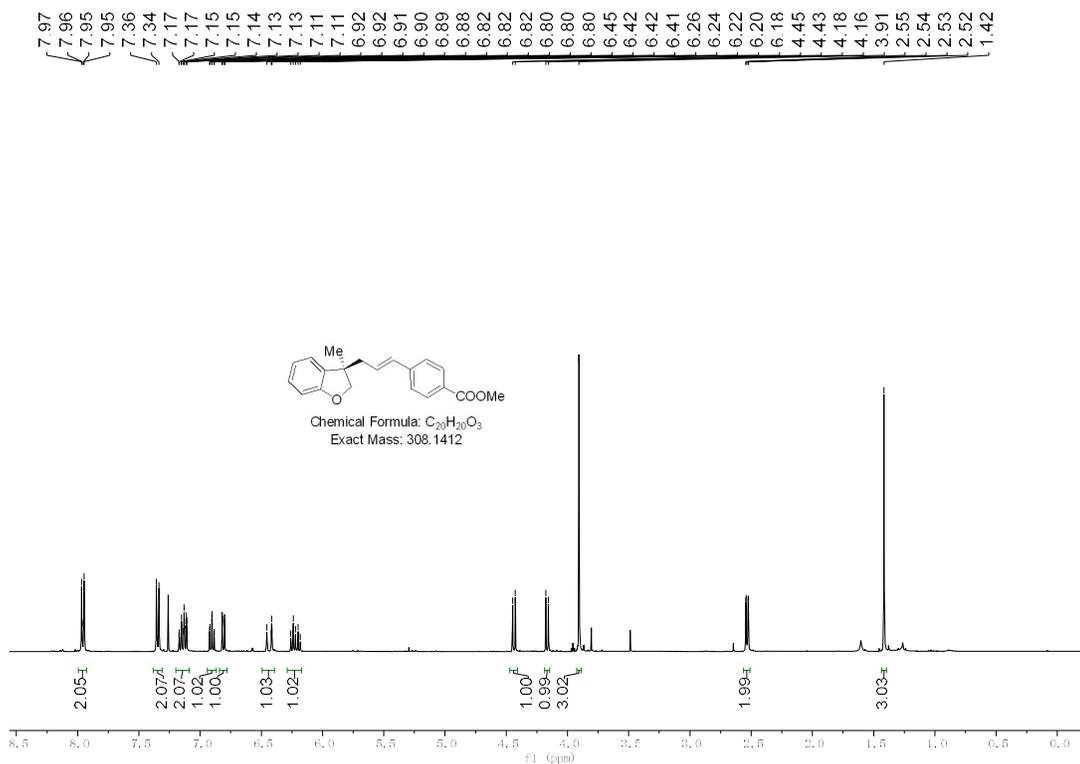
3aj



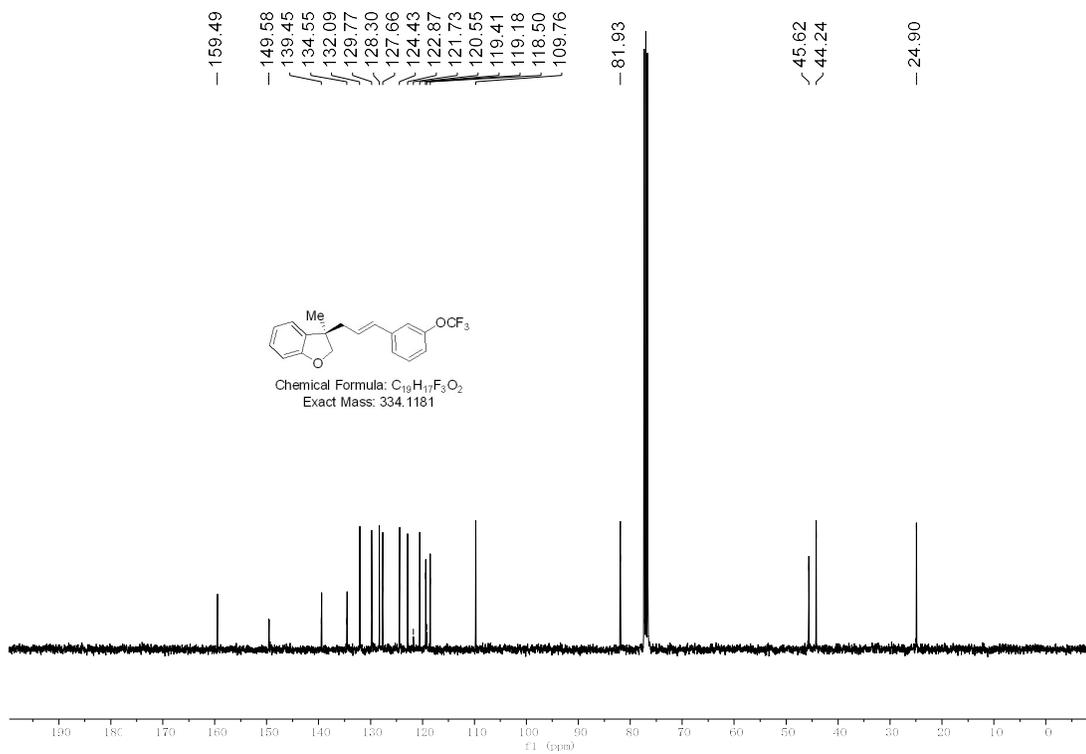
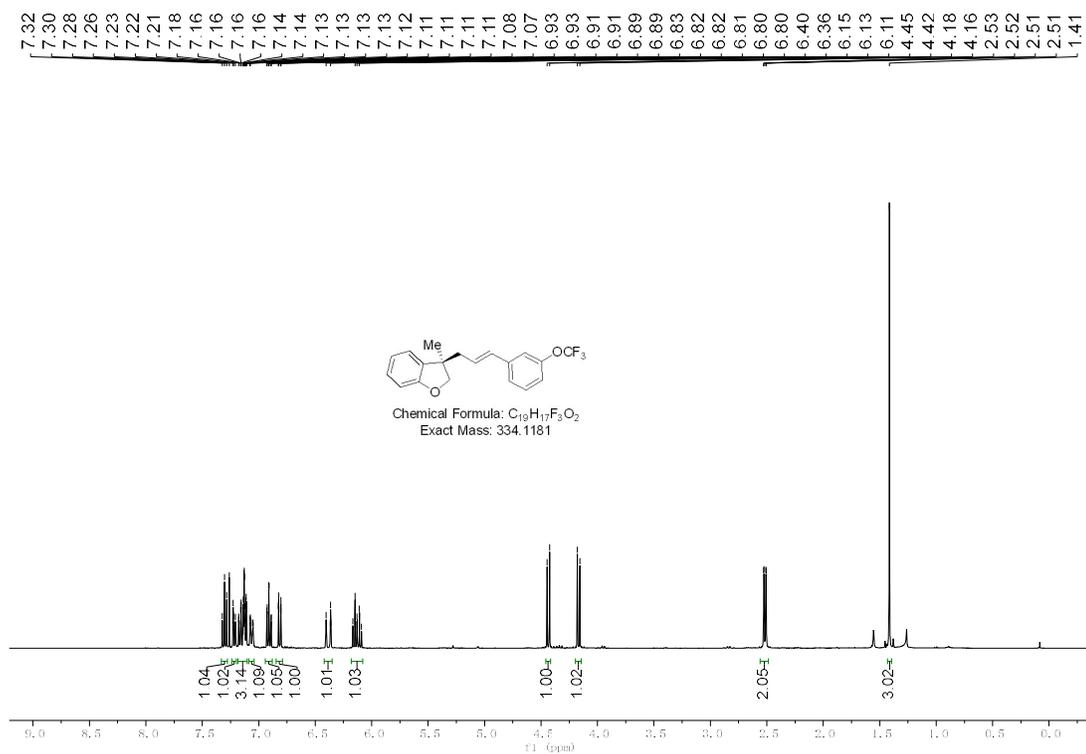
3ak

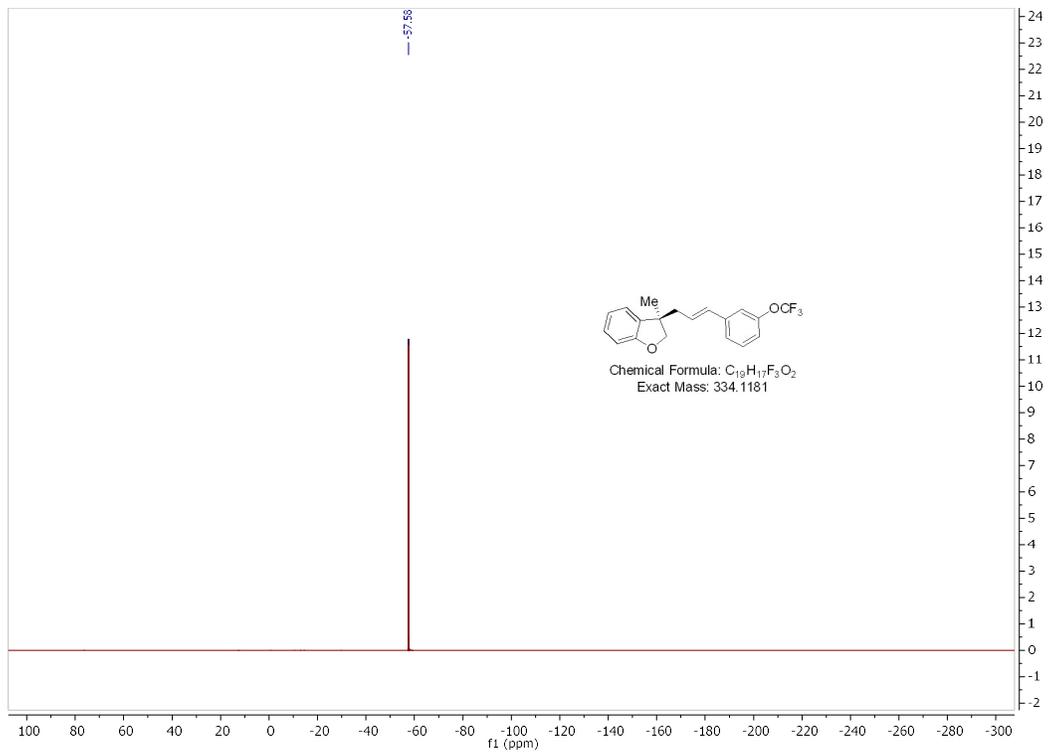


3al

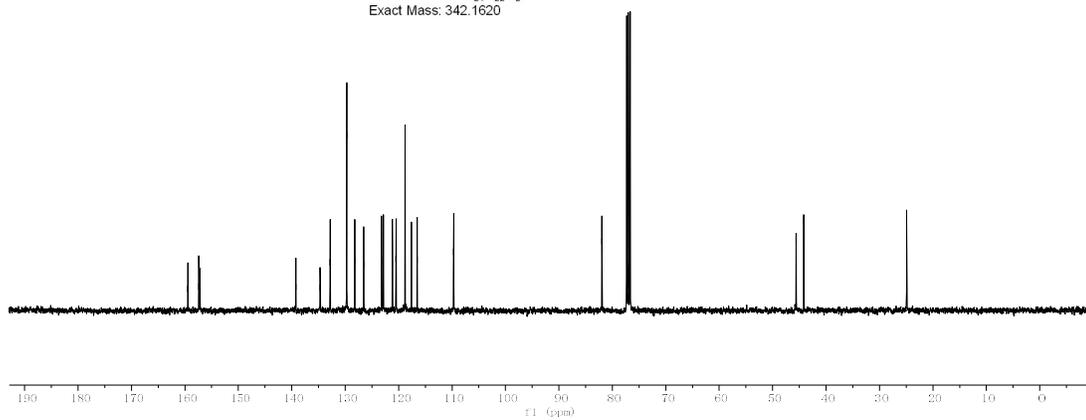
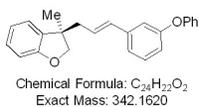
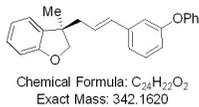
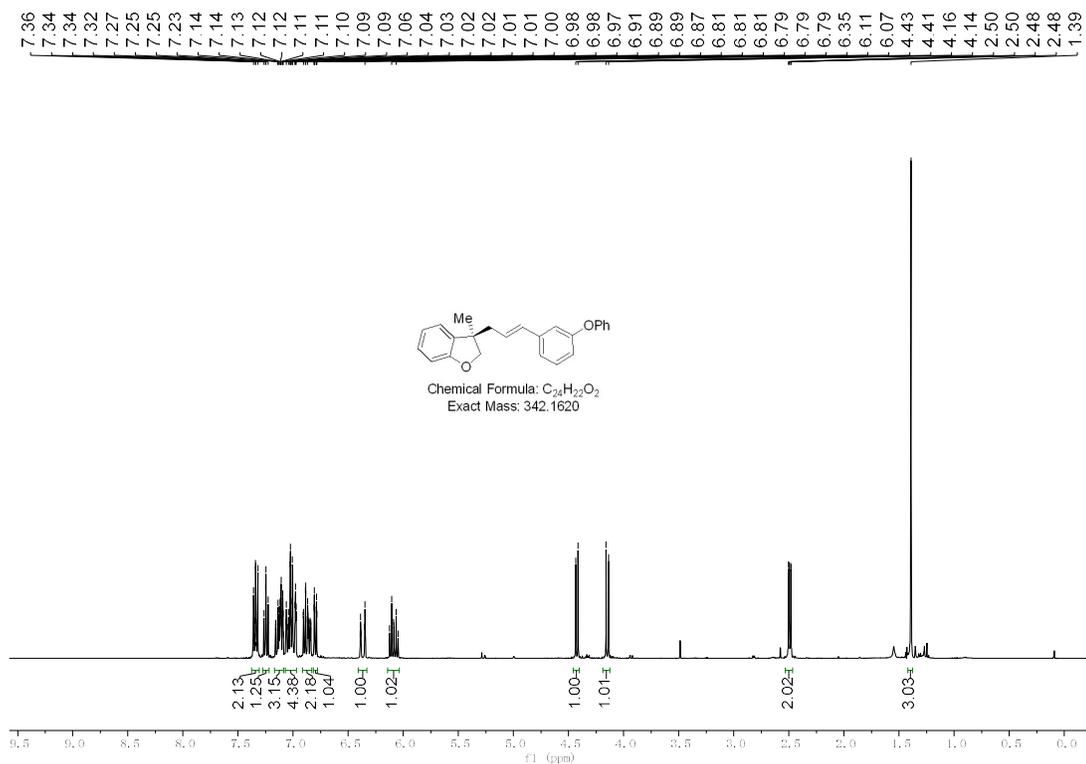


3am

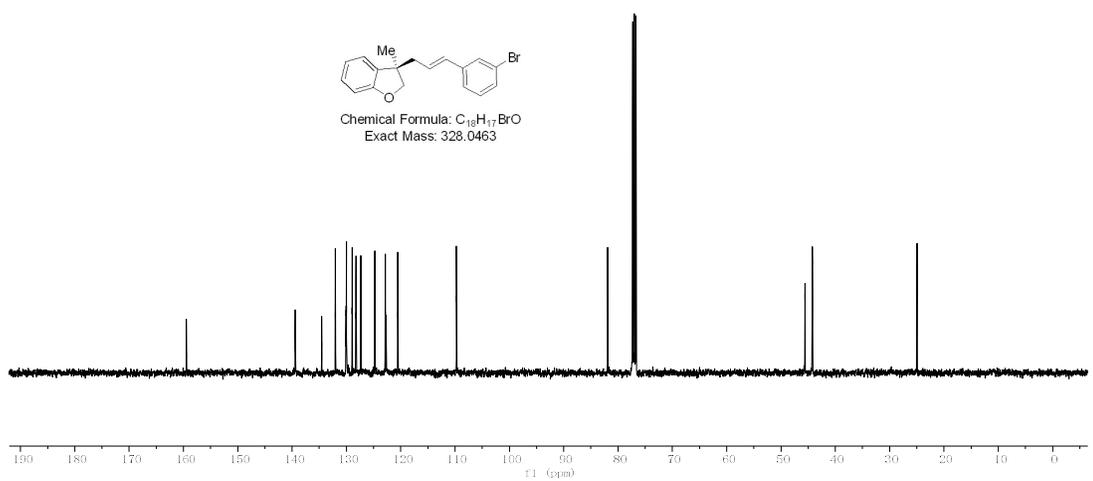
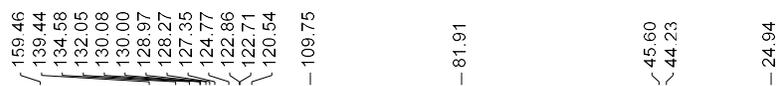
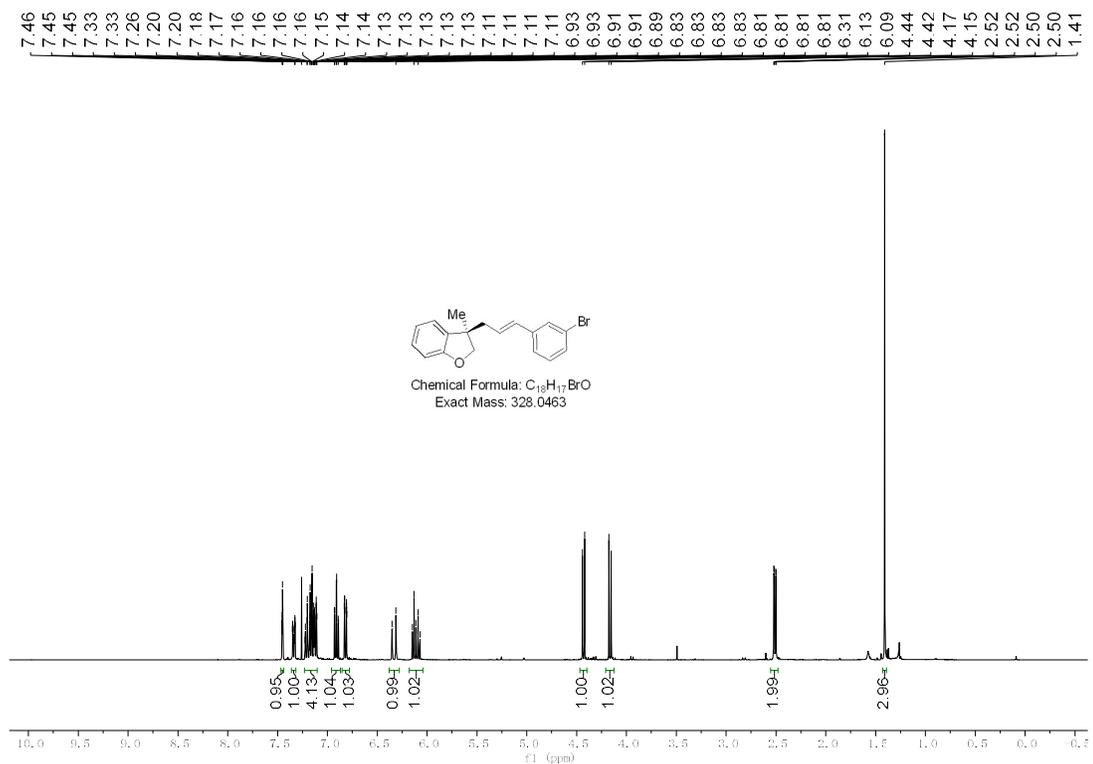




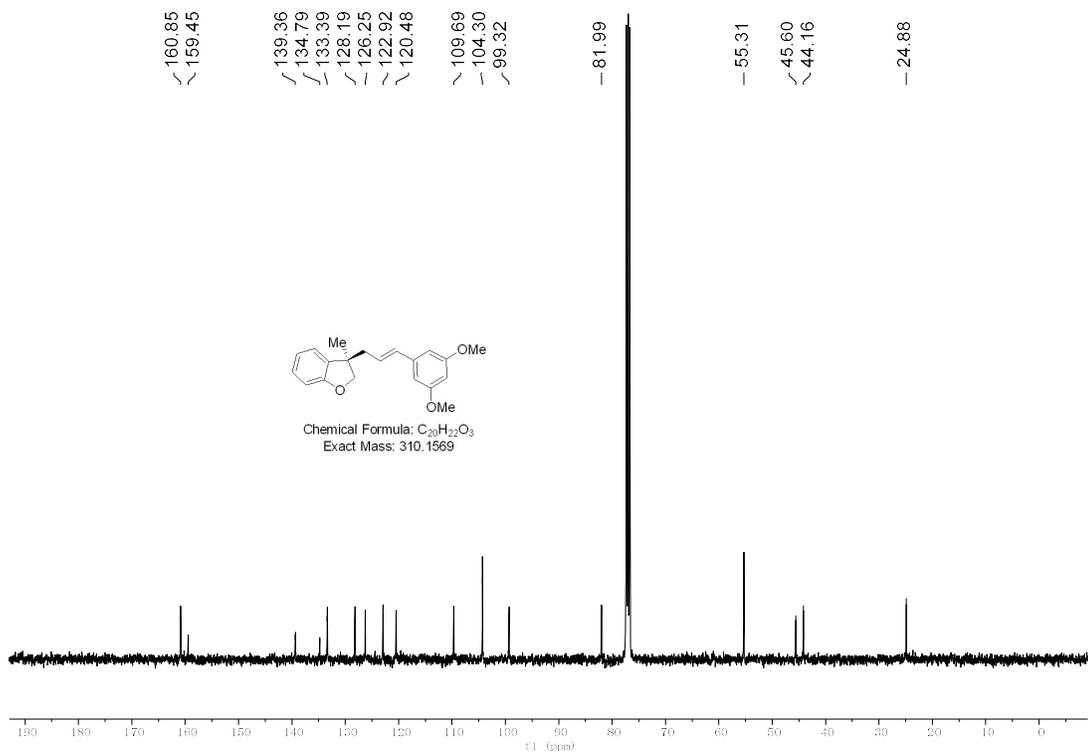
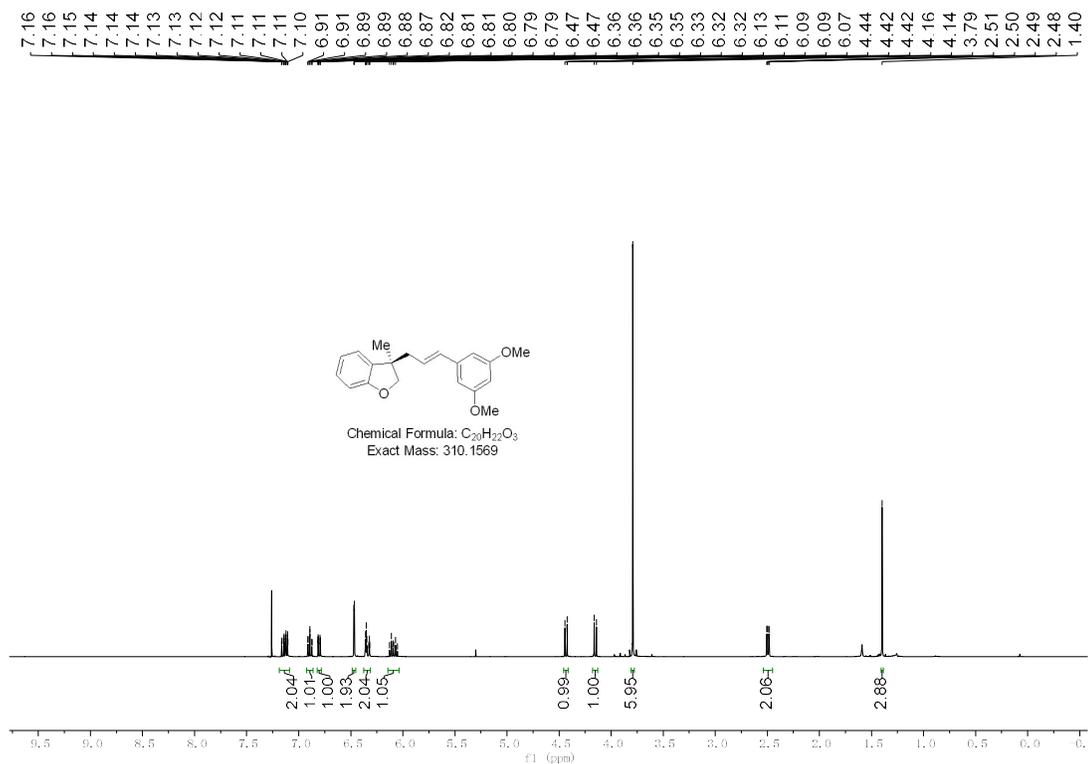
3an



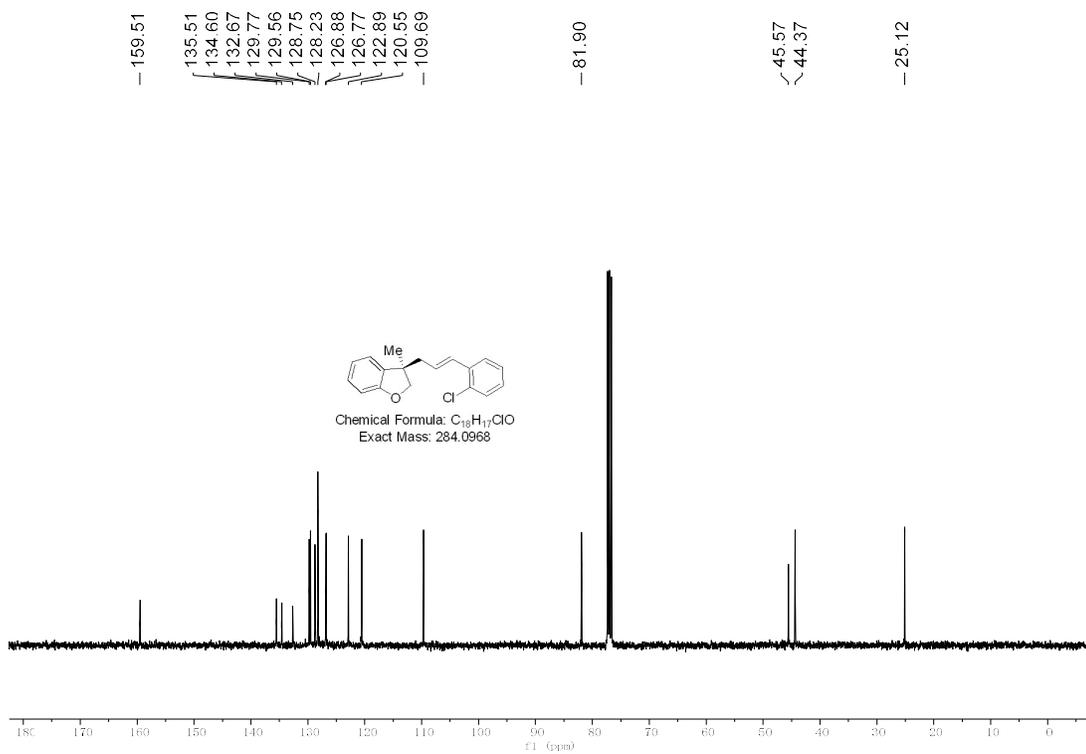
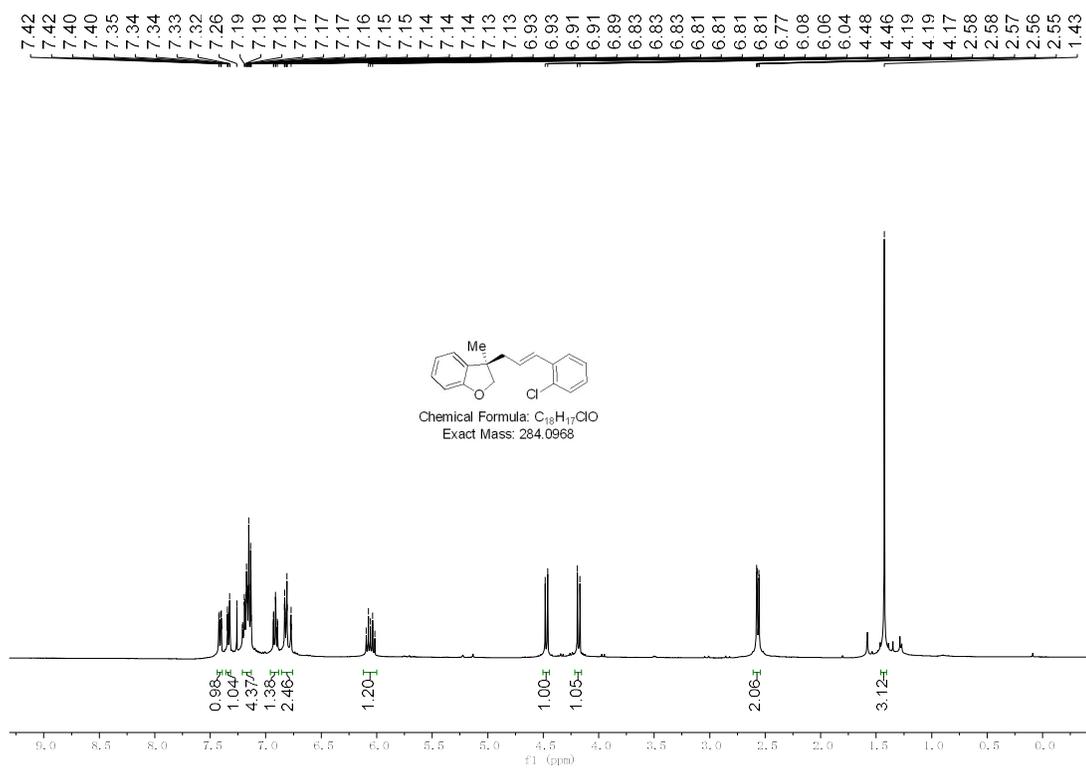
3ao



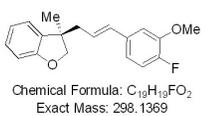
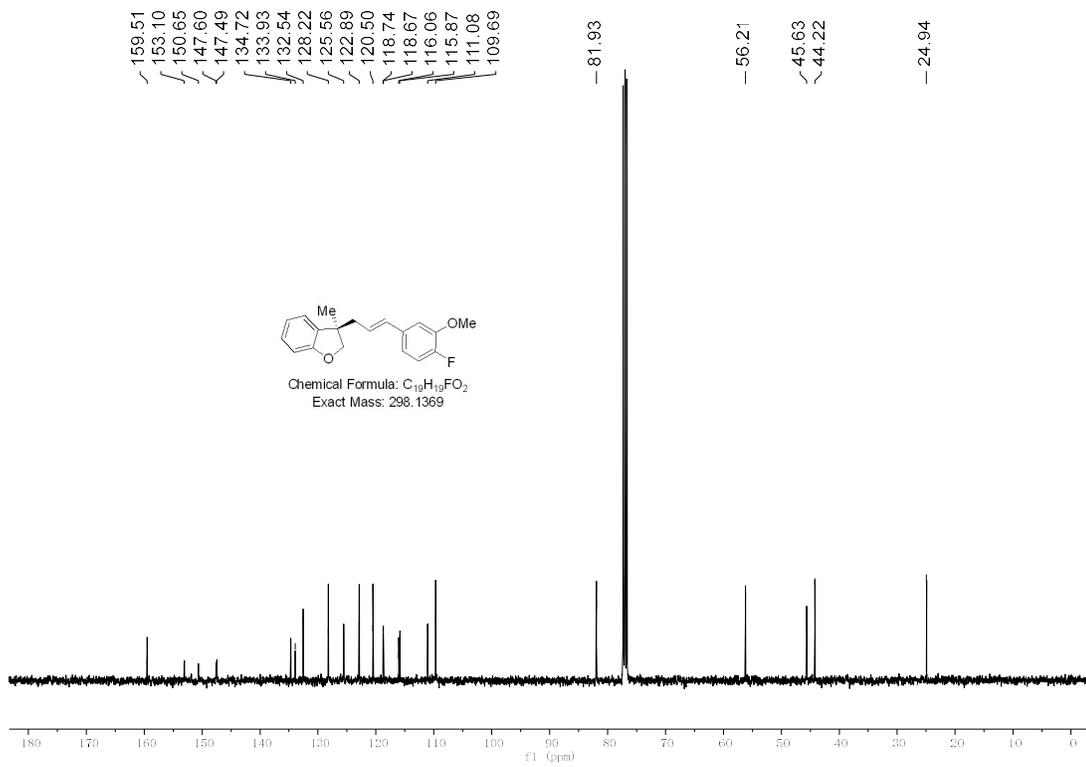
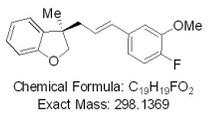
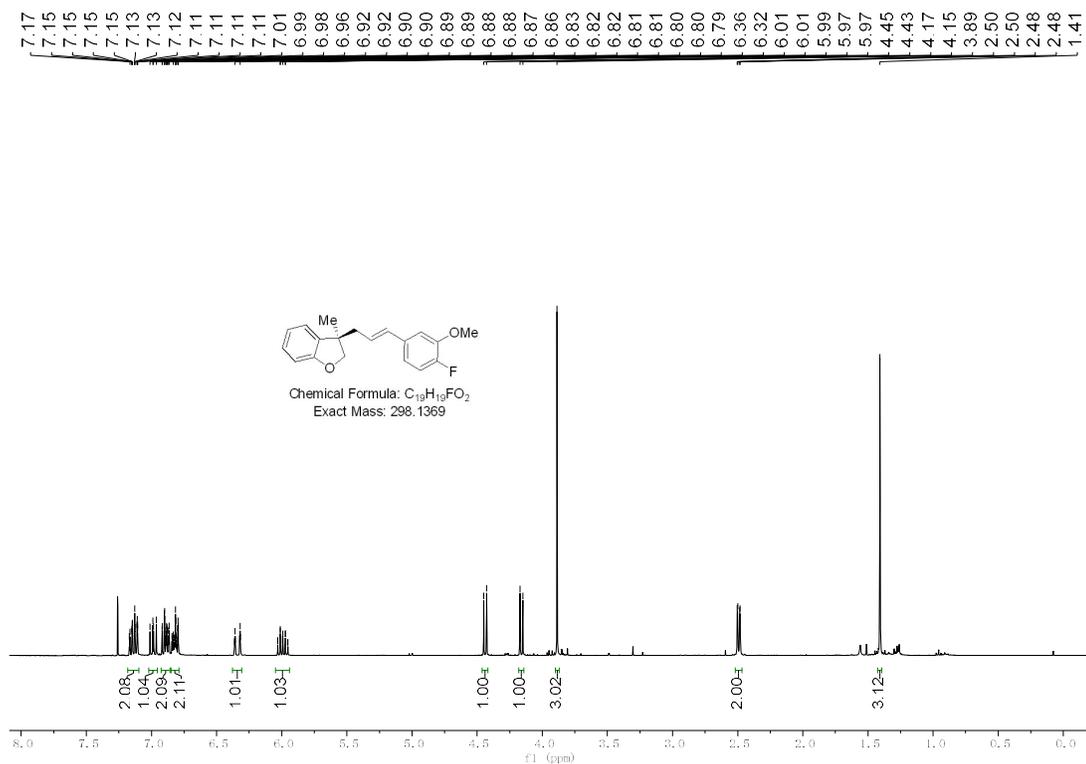
3ap

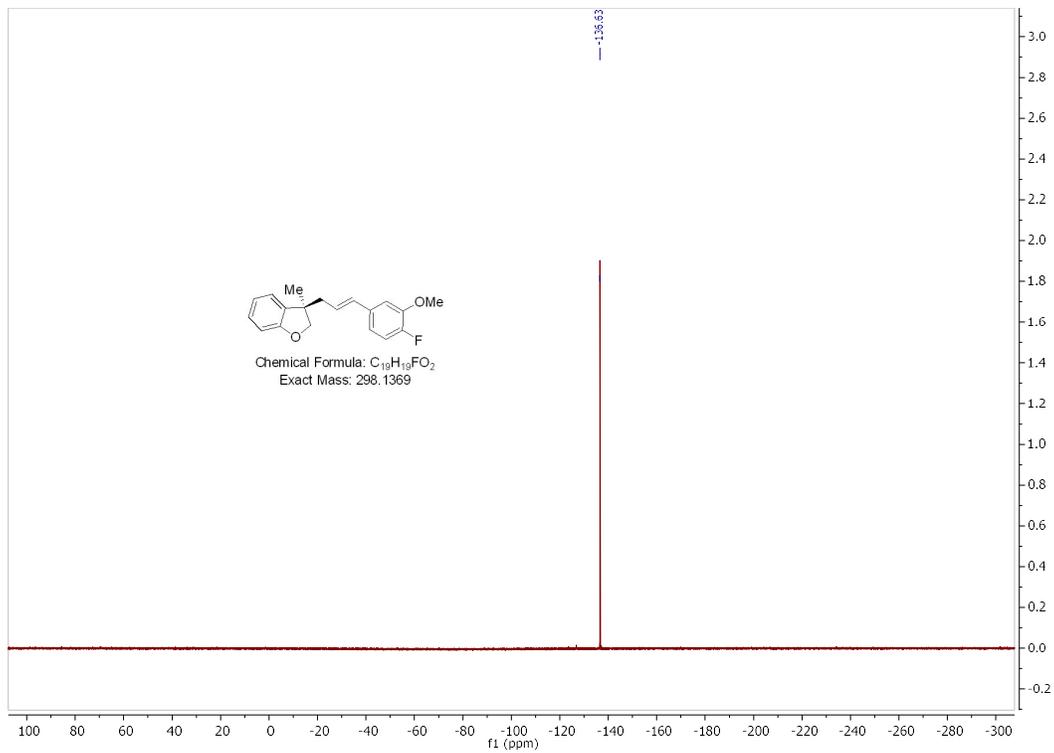


3aq

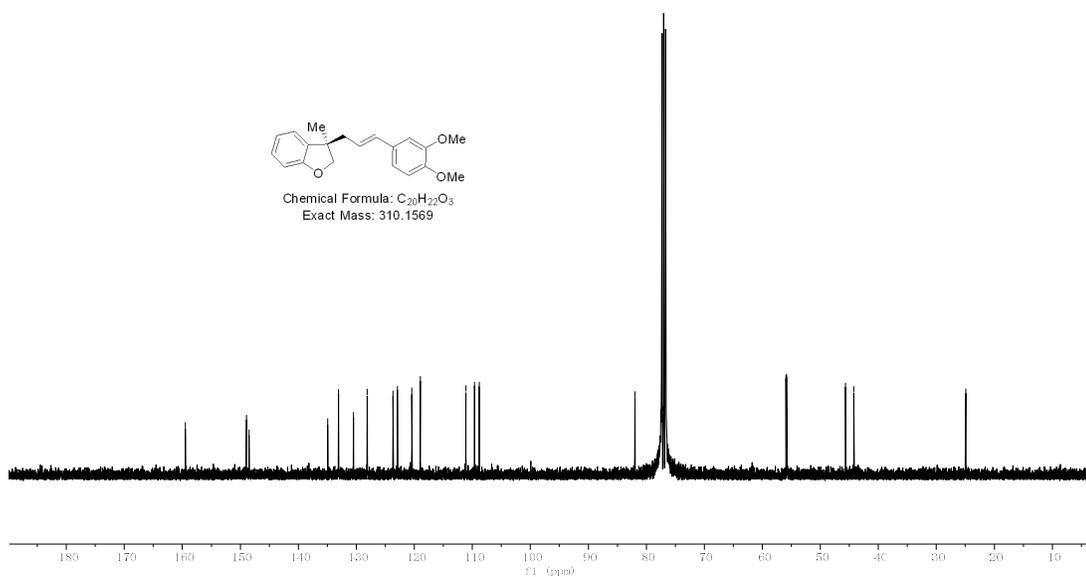
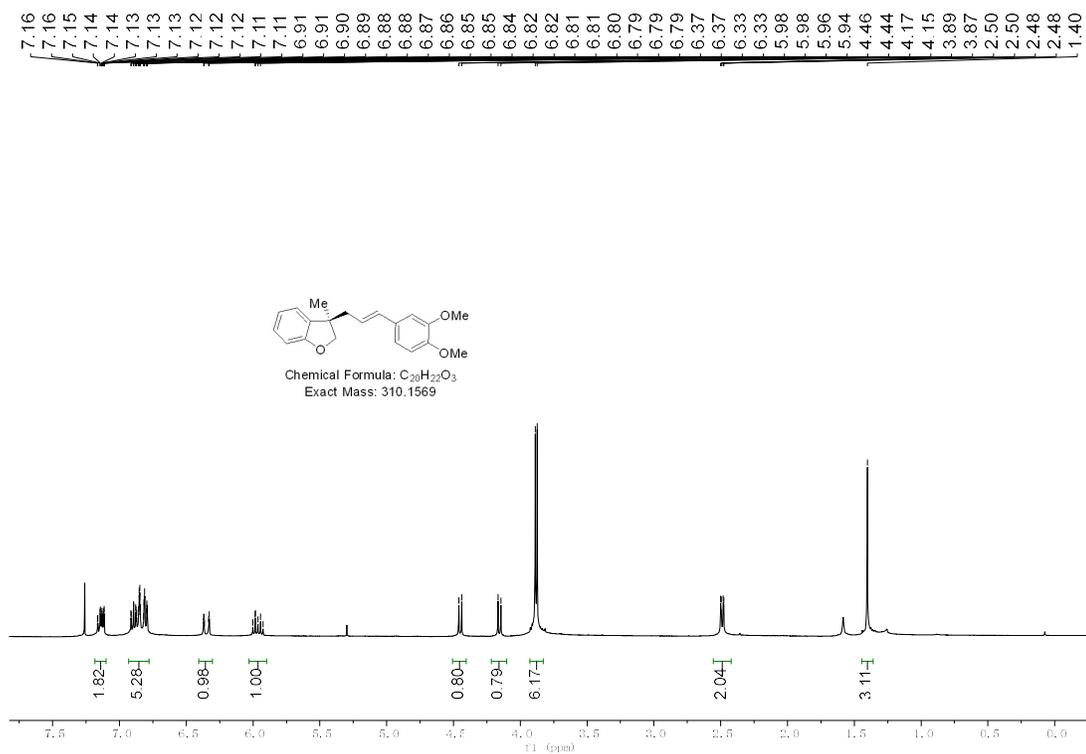


3ar

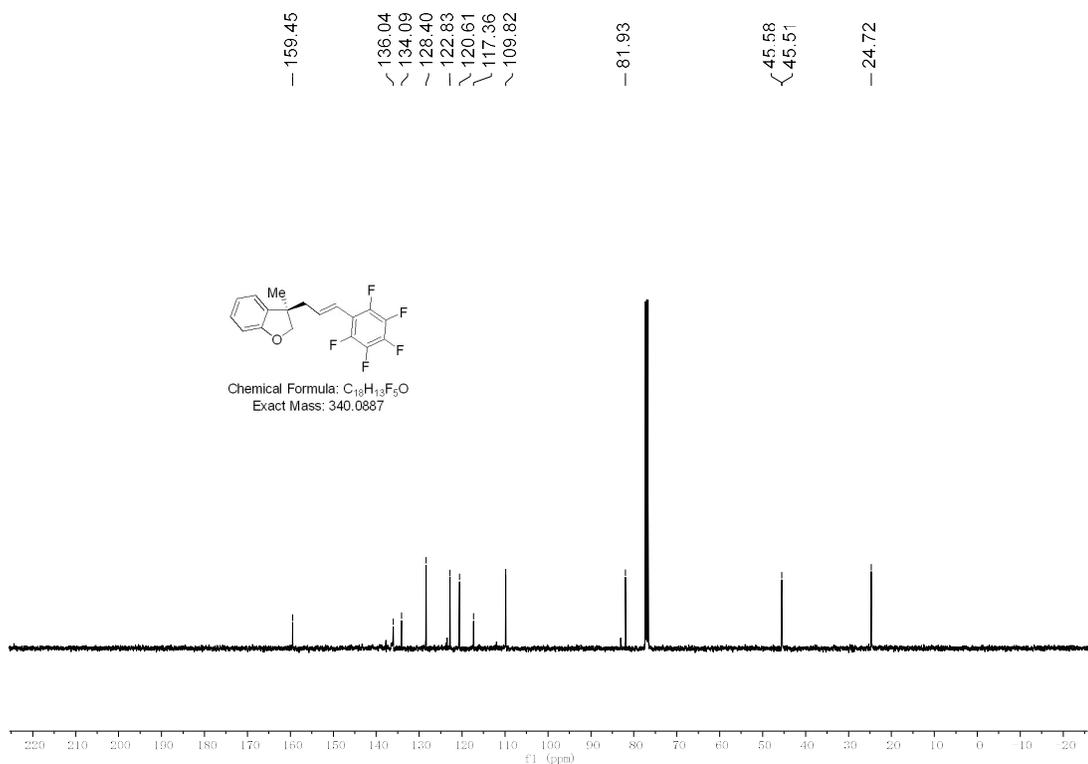
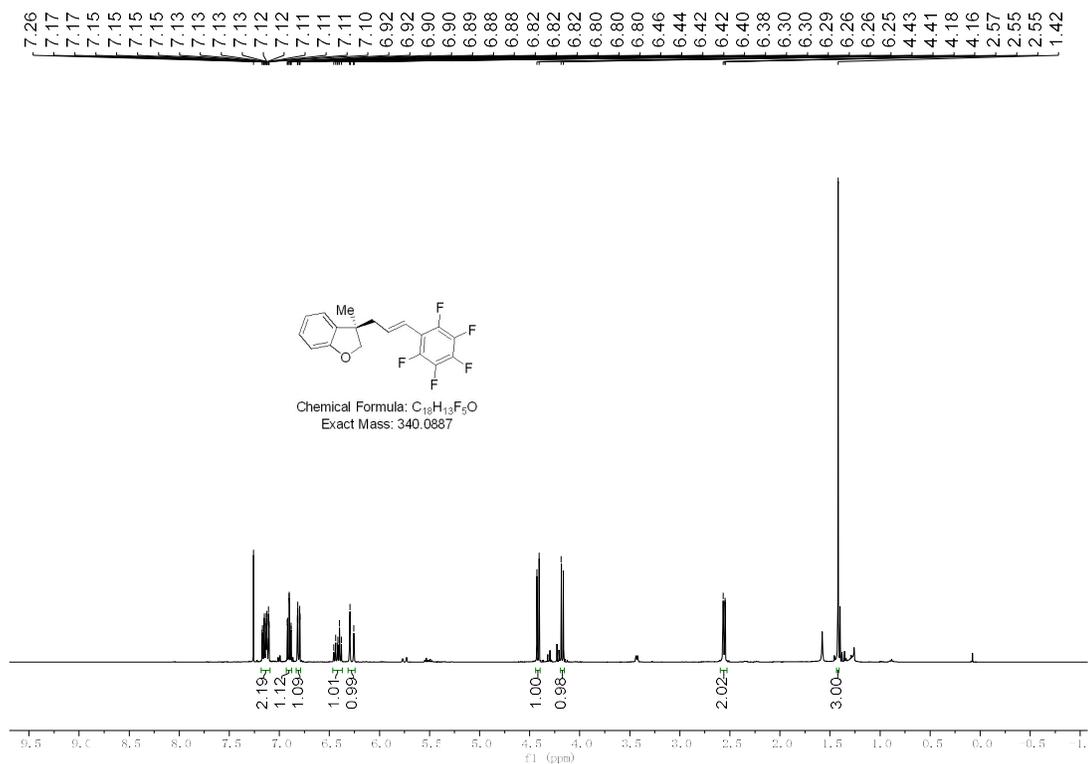


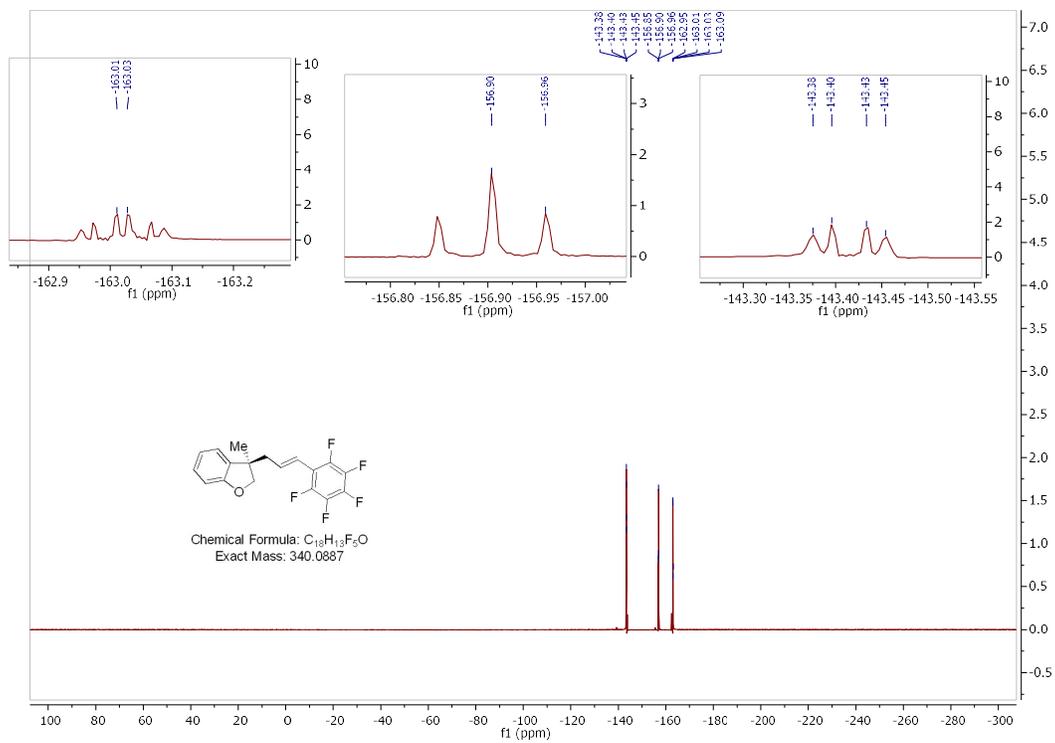


3as

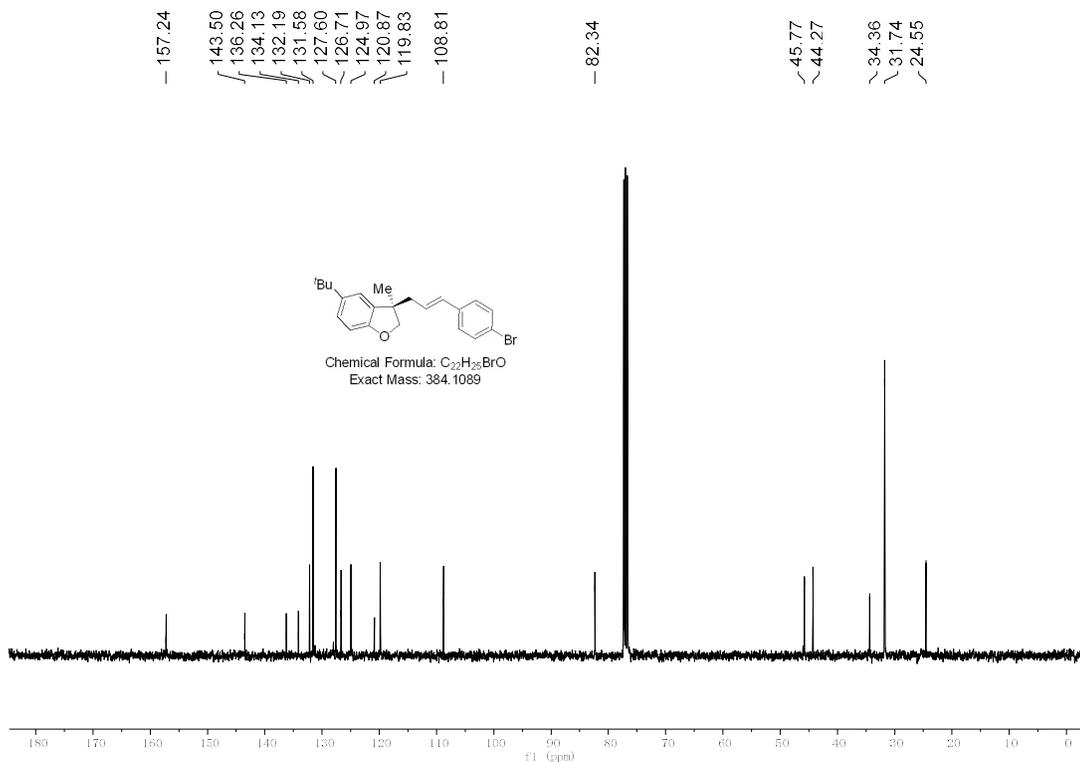
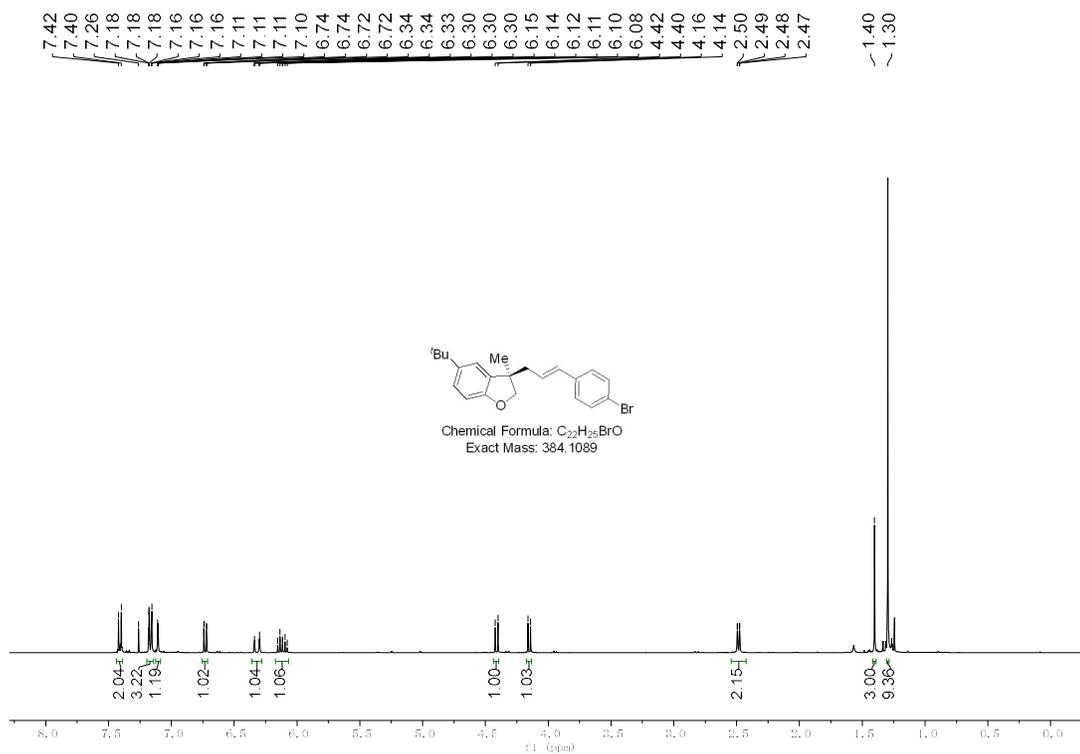


3at

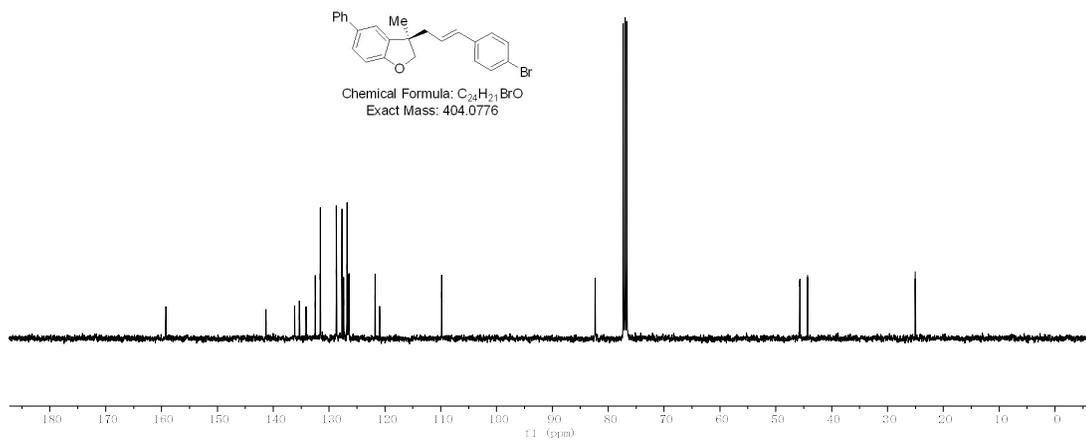
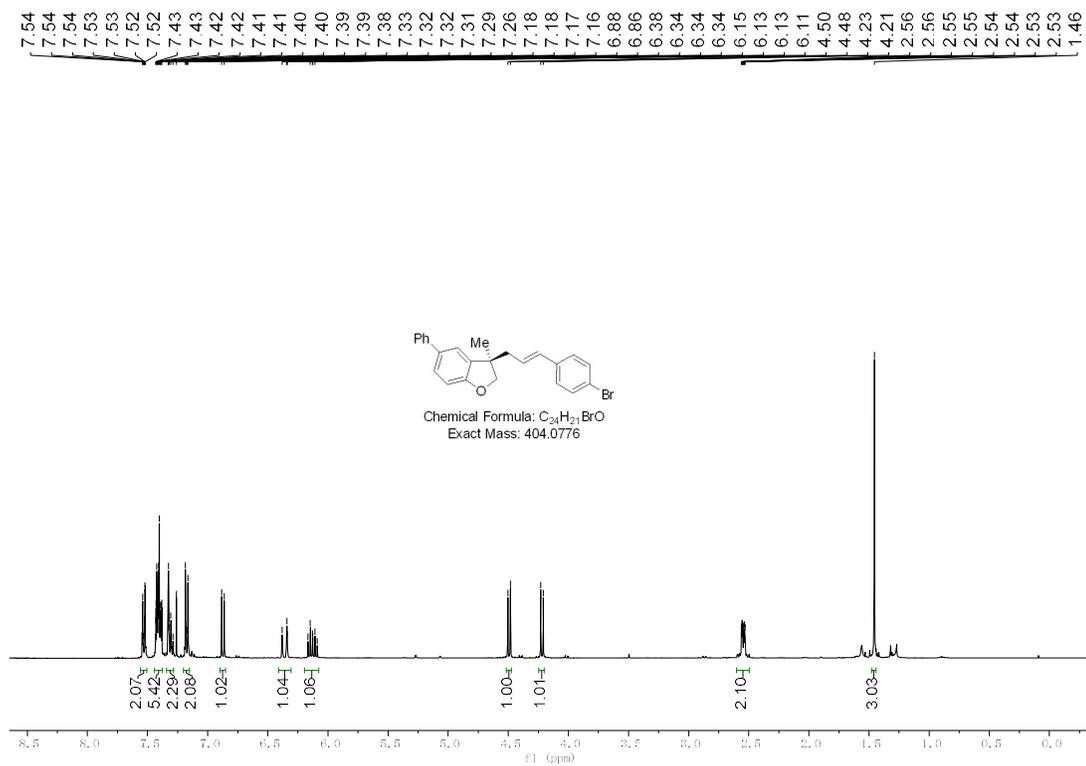




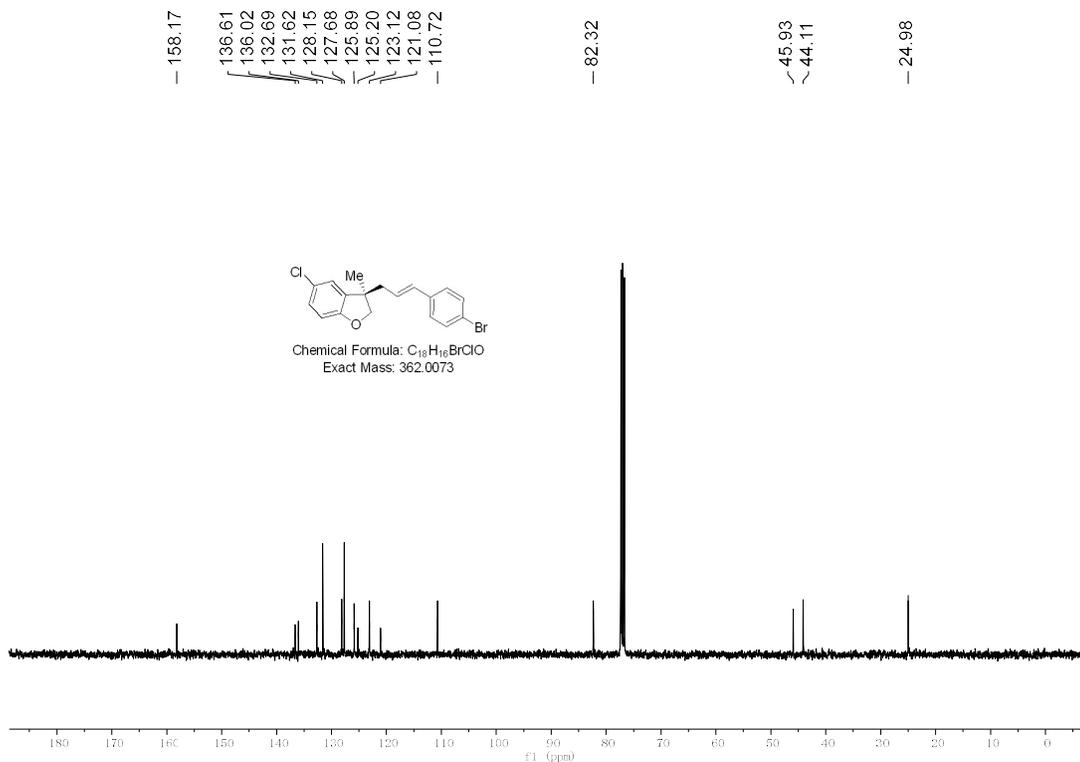
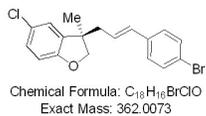
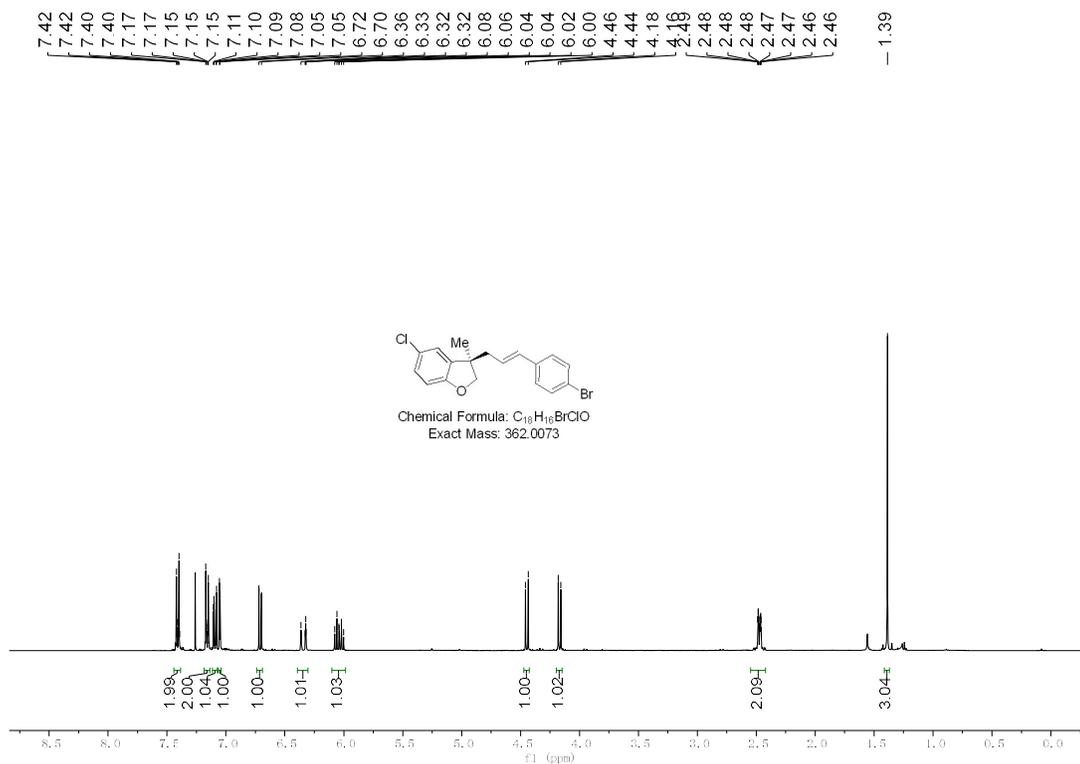
3bk



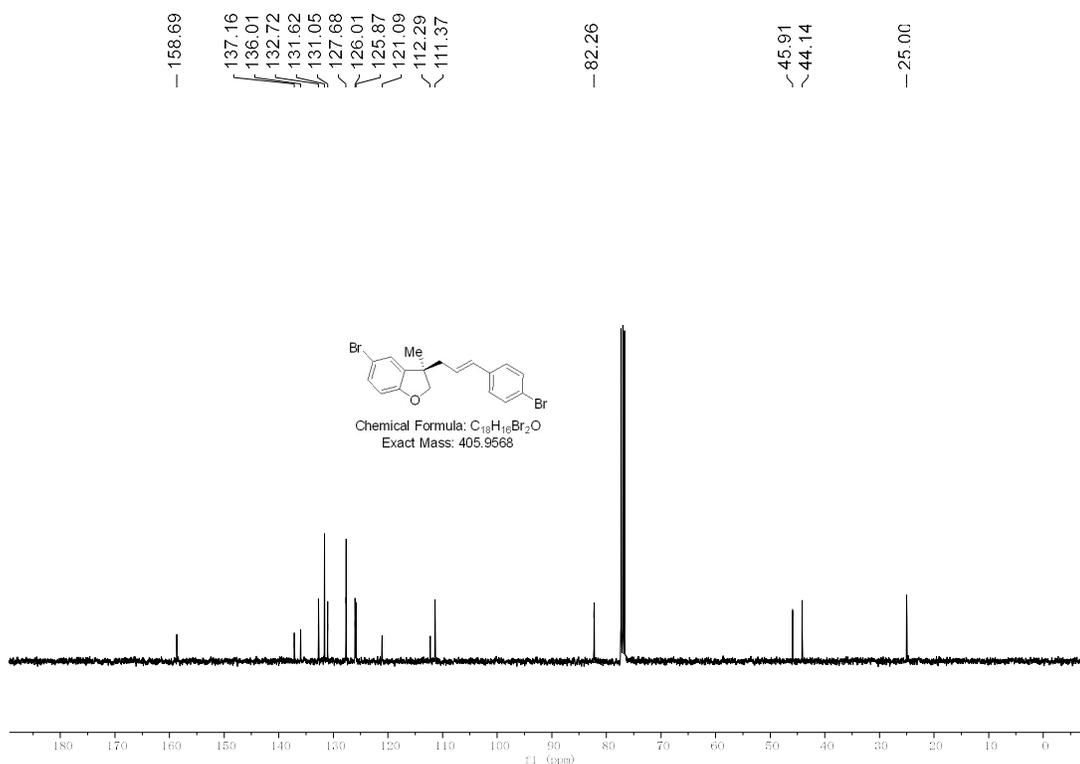
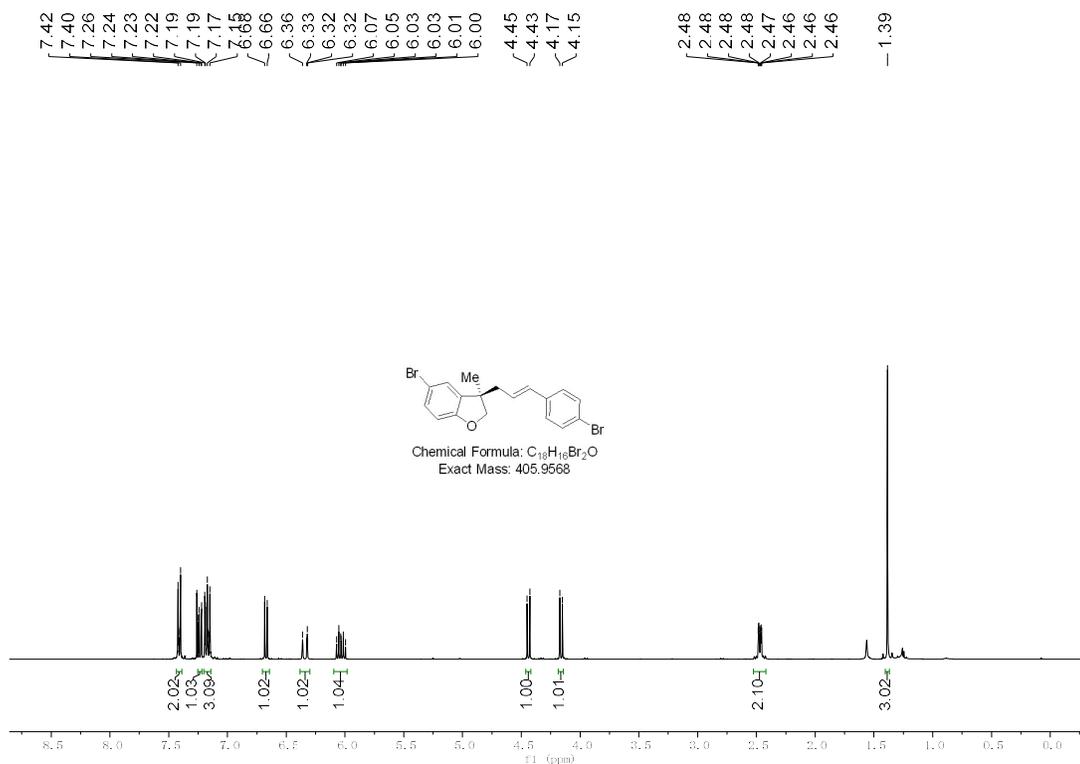
3ck



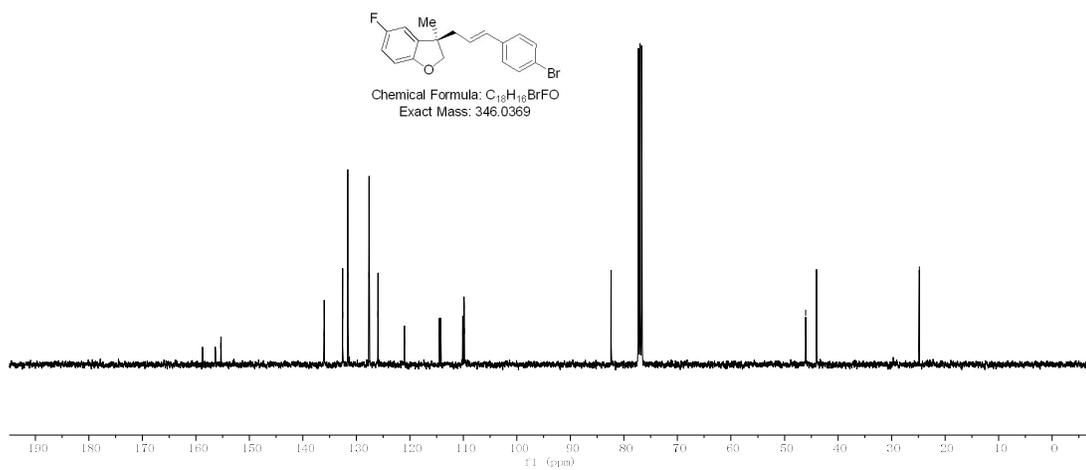
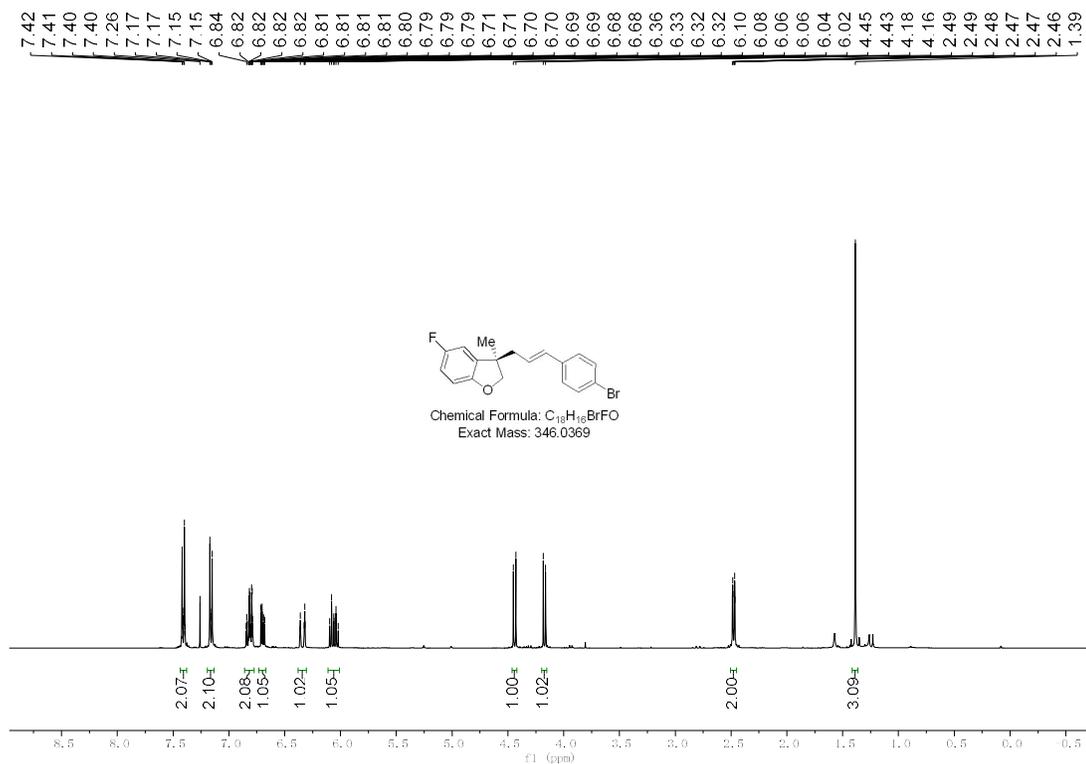
3dk



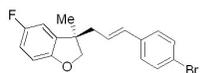
3ek



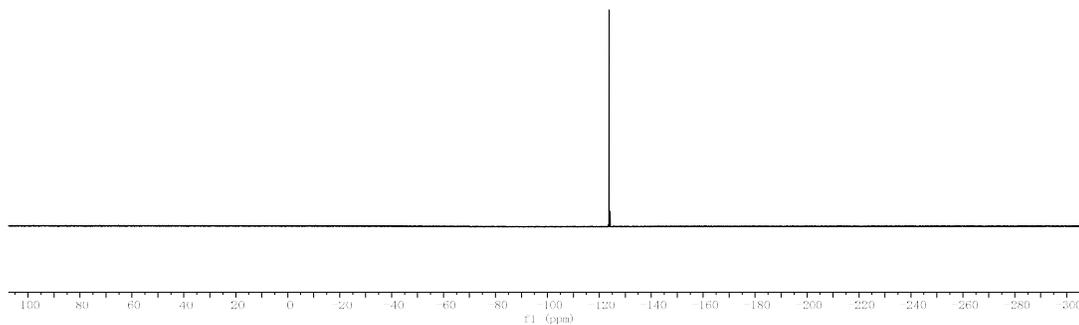
3fk



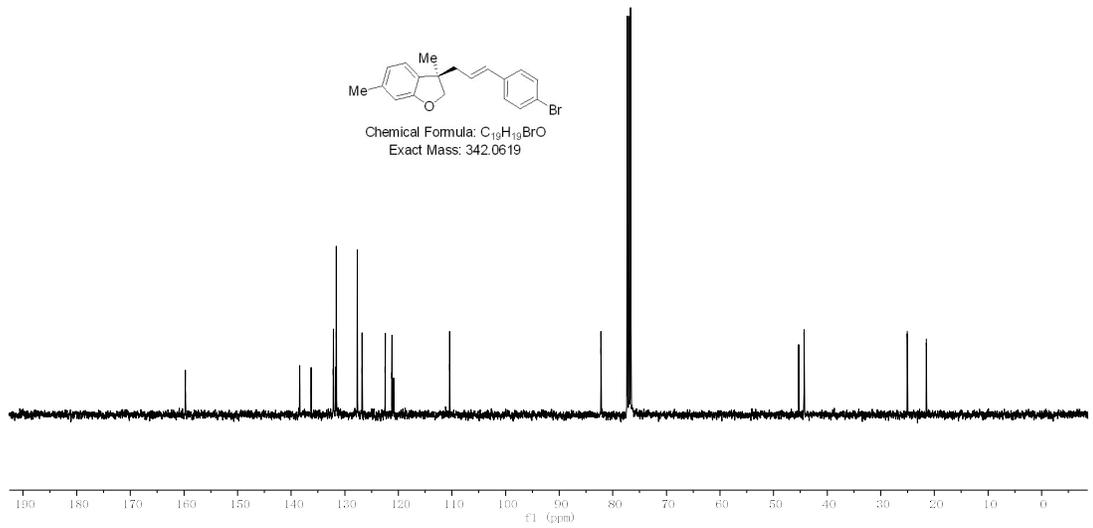
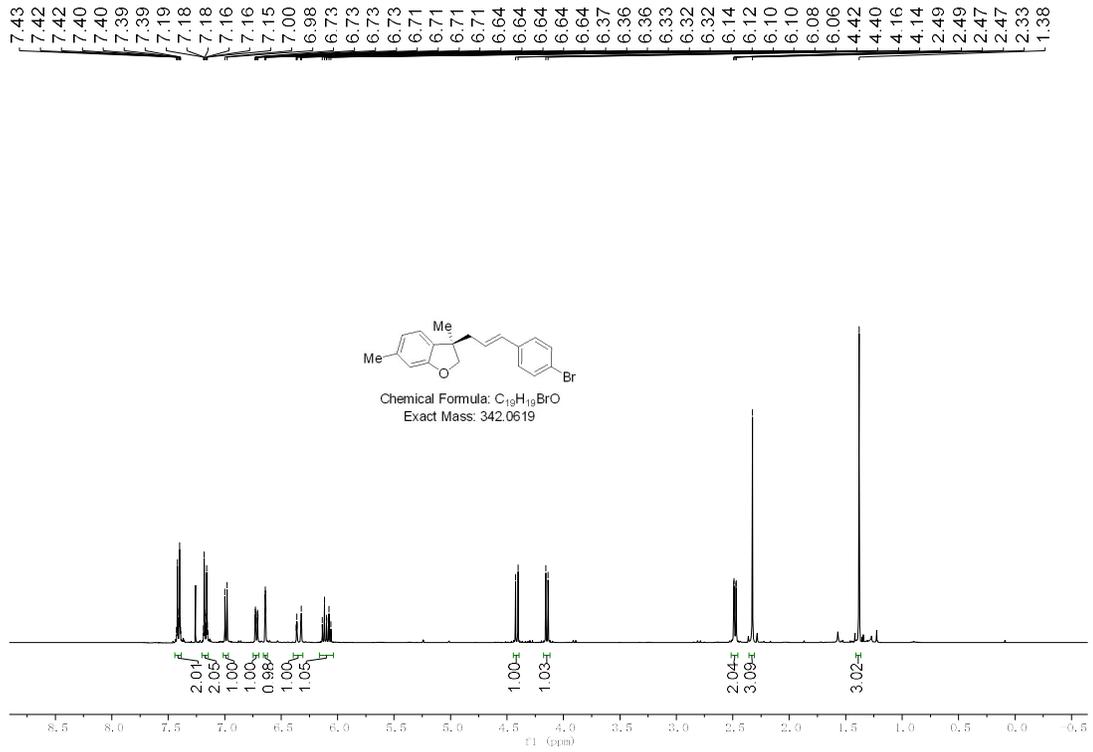
--123.77



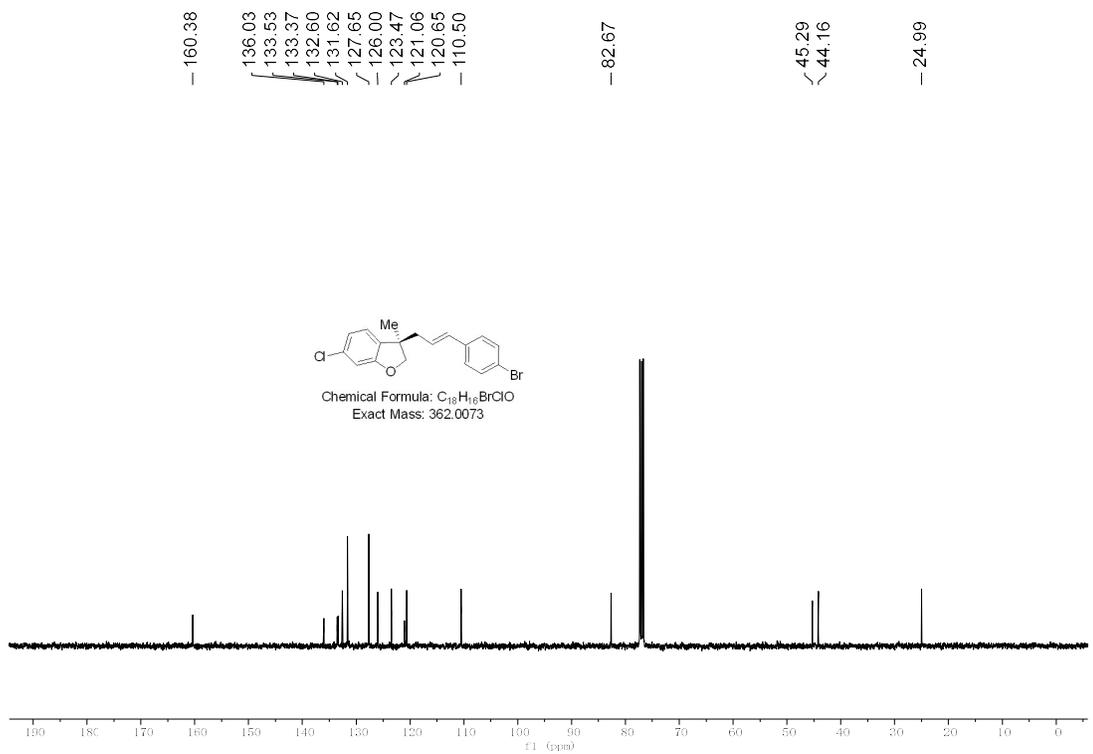
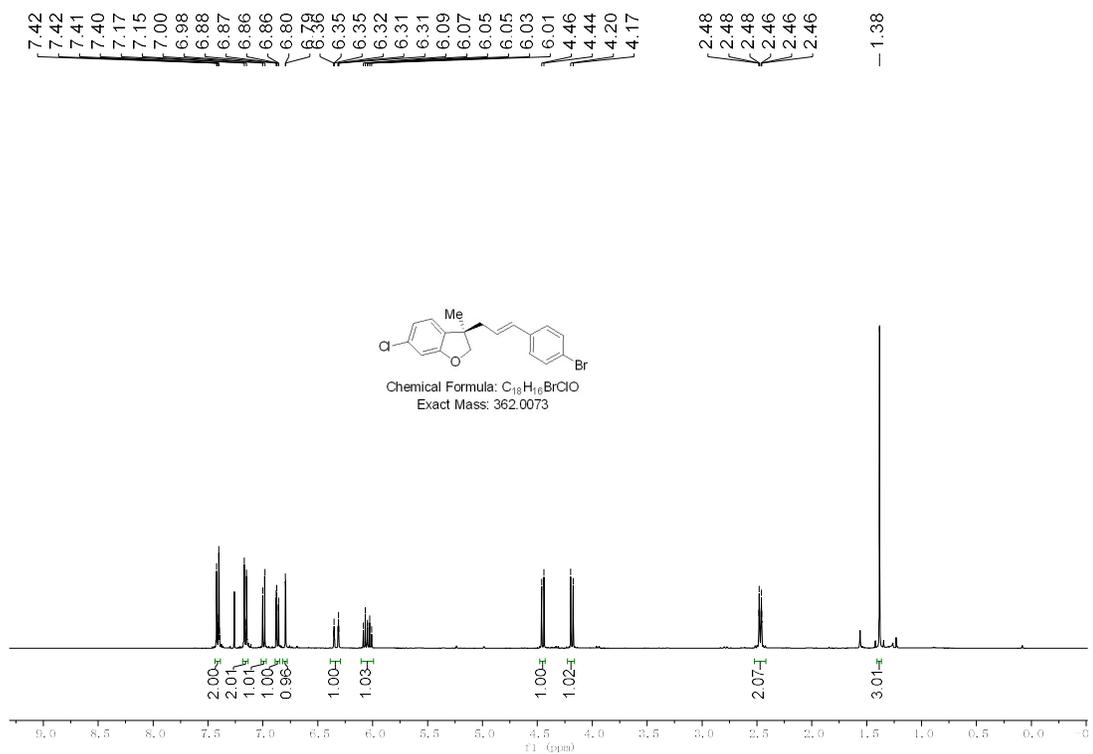
Chemical Formula: C₁₈H₁₆BrFO
Exact Mass: 346.0369



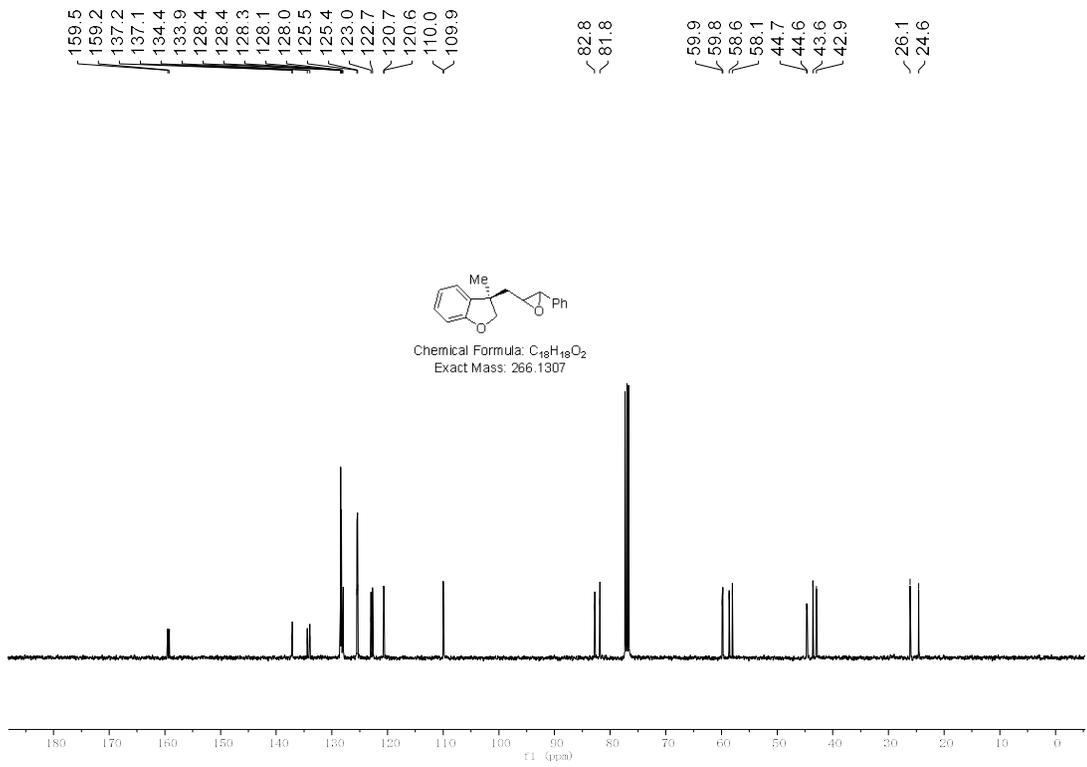
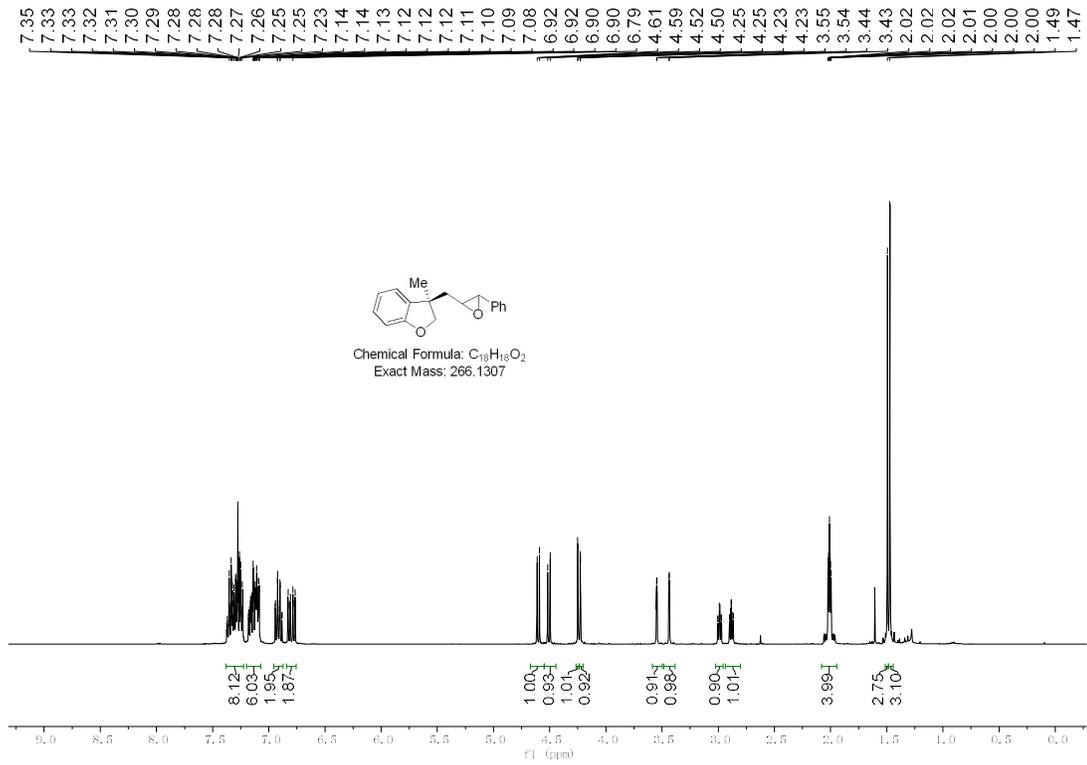
3gk



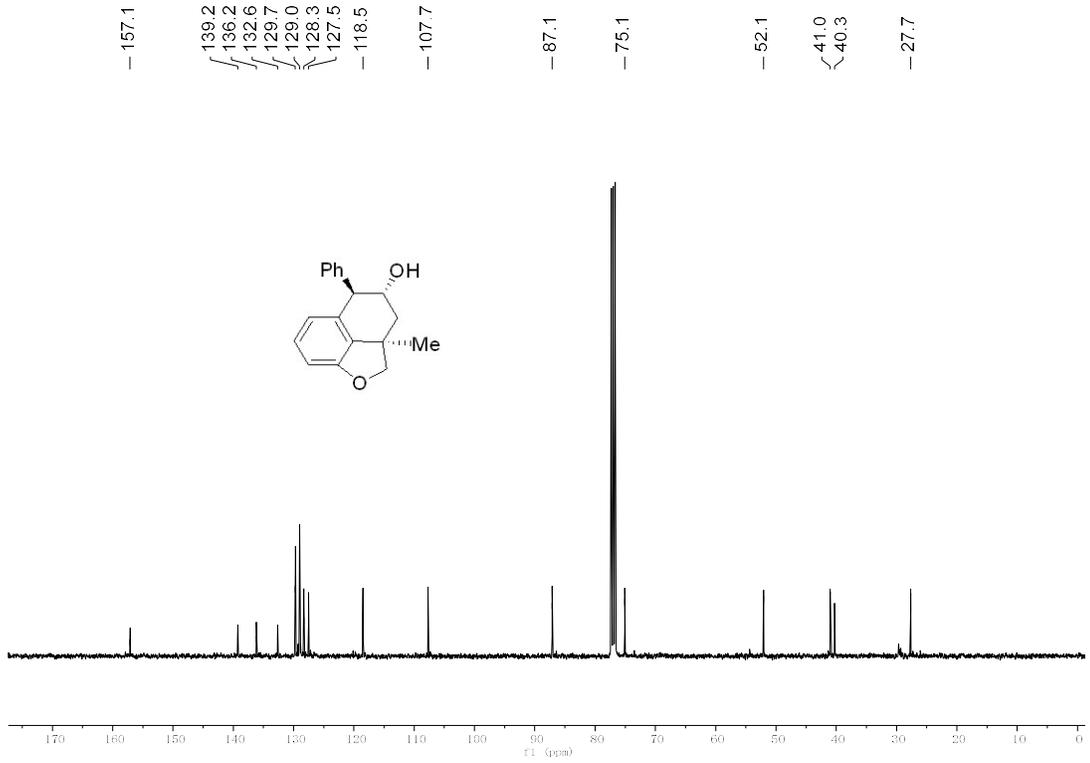
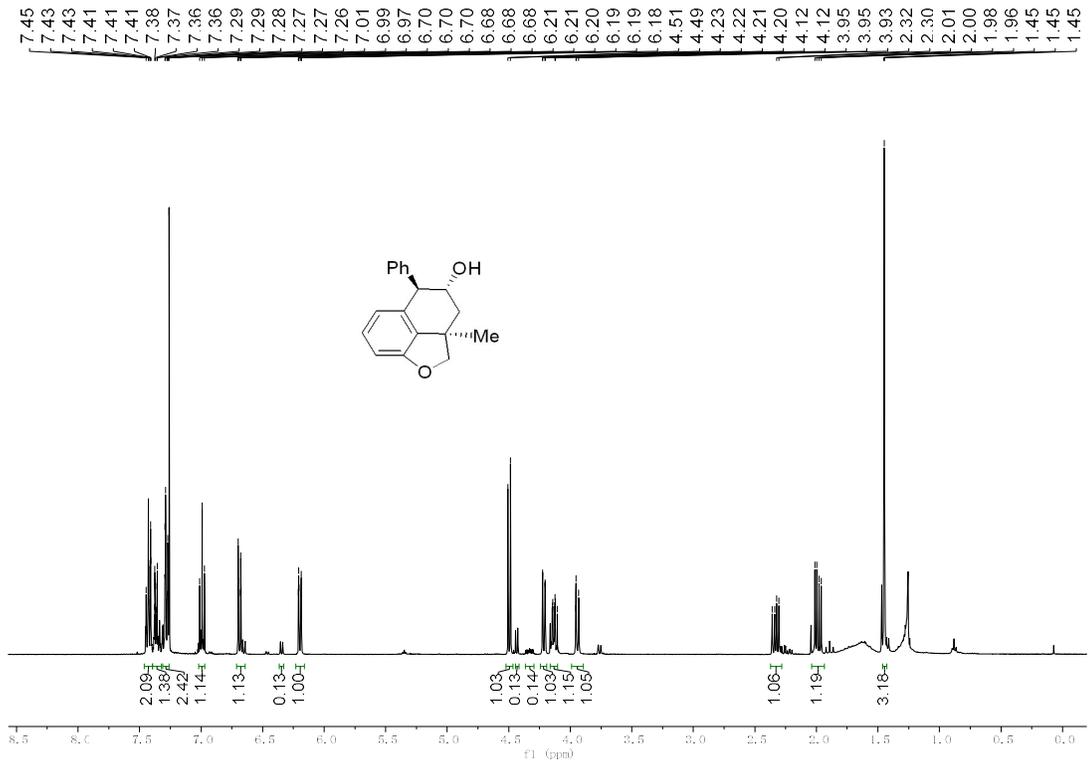
3hk

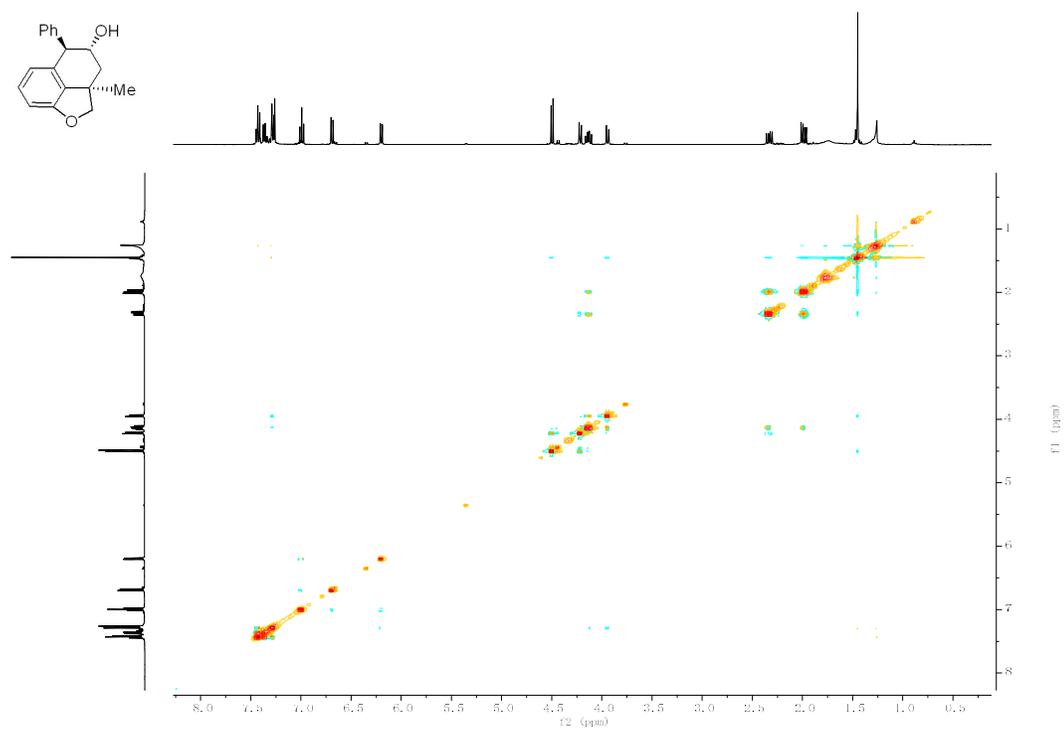
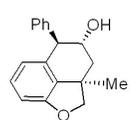


4



5





7. References

1. Micic, N.; Polyzos, A. Radical Carbonylation Mediated by Continuous-Flow Visible-Light Photocatalysis: Access to 2,3-Dihydrobenzofurans. *Org. Lett.* **2018**, *20*, 4663.
2. Gao, Y.; Gao, Y.; Wu, W.; Jiang, H.; Yang, X.; Liu, W.; Li, C.-J. Palladium-Catalyzed Tandem Oxidative Arylation/Olefination of Aromatic Tethered Alkenes/Alkynes. *Chem. Eur. J.* **2017**, *23*, 793.
3. Grigg, R.; Sansano, J. M.; Santhakumar, V.; Sridharan, V.; Thangavelanthum, R.; Thornton-Pett, M.; Wilson, D. Palladium catalysed tandem cyclisation-anion capture processes. Part 3. Organoboron anion transfer agents. *Tetrahedron*, **1997**, *53*, 11803.
4. Zhang, Z.; Xu, B.; Qian, Y.; Wu, L.; Wu, Y.; Zhou, L.; Liu, Y.; Zhang, L. Palladium-Catalyzed Enantioselective Reductive Heck Reactions: Convenient Access to 3,3-Disubstituted 2,3-Dihydrobenzofuran. *Angew. Chem. Int. Ed.* **2018**, *57*, 10373-10377.