Supplementary Information (SI) for ChemComm.
This journal is © The Royal Society of Chemistry 2024

Electronic Supporting Information

Pd-Catalyzed CO-Free Double Carbonylation for the Synthesis of 1,4-Ketoesters with $Mo(CO)_6$ as Carbonyl Source

Wenting Guo, Houhong Gong, Wei Yuan, Hualan Zhou, Li Tao and Jing Zhu*

Jiangsu Key Laboratory of Function Control Technology for Advanced Materials, School of Environmental and Chemical Engineering, Jiangsu Ocean University, Lianyungang 222005, Jiangsu, China;

E-mail: 2016000019@jou.edu.cn

Table of Contents

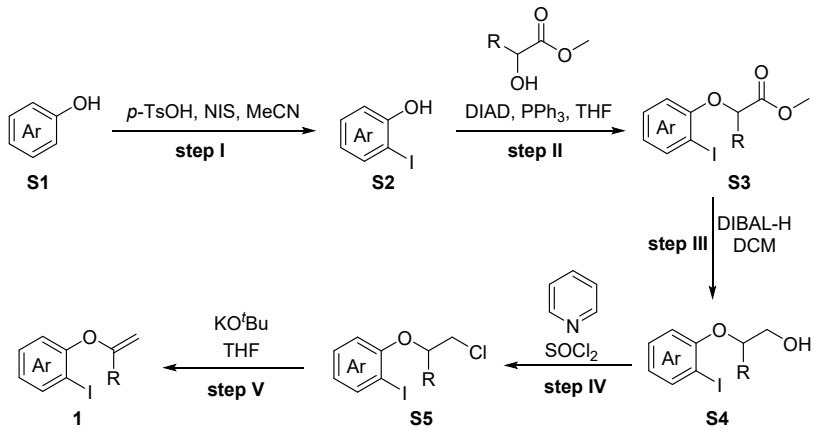
I. General Information

Unless otherwise noted, all chemicals were purchased from commercial suppliers and used without further purification. ^{1}H NMR、^{13}C NMR spectra were recorded at ambient temperature on a 500 MHz (125 MHz for ^{13}C) NMR spectrometer. NMR experiments are reported in δ units, parts per million (ppm), and were referenced to $CDCl_3$ (δ 7.26 or 77.0 ppm) as the internal standard. The coupling constants J are given in Hz. Column chromatography was performed using EM Silica gel 60 (300-400 mesh). High-resolution mass spectra (HRMS) were obtained using a Bruker micro TOF II focus spectrometer (ESI). All melting points were uncorrected.

II. Synthesis and Reaction

Preparation of the substrates

General procedures for the synthesis of 1



Step I:[1] *p*-TsOH (10 mmol) was added to a stirred solution (50 mL of CH_3CN) containing the corresponding phenol **S1** (10 mmol) at r.t. After 5 min, 1.1 equivalent of NIS (11 mmol) was added and the mixture was stirred overnight. After the completion of the reaction, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 30:1) as the eluent to give the desired product **S2**.

Step II:[2] To a solution of **S2** (10 mmol, 1.0 equiv), PPh_3 (10 mmol, 1.0 equiv) and *s*-methyl lactate (0.95 equiv) in THF (10 mL) at room temperature was added dropwise a solution of DIAD (1.05 equiv) in THF (4.0 mL) over 30 min. Then the solution was stirred overnight. After the completion of the reaction, the solvent was evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 30:1) as the eluent to give the desired product **S3**.

Step III:[2] To the solution of **S3** (10 mmol, 1.0 equiv) in DCM (10 mL) under nitrogen at -78 °C was added dropwise a solution of DIBAL-H (2.3 equiv) in DCM (1.0 M). After the addition, the reaction mixture was stirred for 1 h at -78 °C, and

warmed to room temperature and stirred for another 2 h. Then the reaction was quenched by 20 mL of saturated brines slowly and extracted with DCM (10 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 8:1) as the eluent to give the desired product **S4**.

Step IV:[2] To the solution of **S4** (10 mmol, 1.0 equiv) and pyridine (1.0 equiv) in anhydrous $CHCl_3$ (15 mL) under nitrogen at 0 °C was added a solution of $SOCl_2$ (1.5 equiv) in anhydrous $CHCl_3$ (5 mL). After the addition, the reaction mixture was slowly warmed to reflux and stirred for 6 h. Afterwards, the reaction was quenched with aqueous $NaHCO_3$ solution in an ice bath and extracted with DCM (10 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 30:1) as the eluent to give the desired product **S5**.

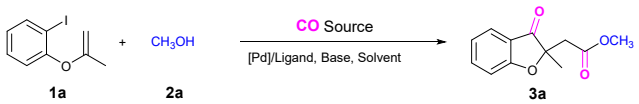
Step V:[2] To an ice cooled solution of KO^{t}Bu (23 mmol, 2.3 equiv) in anhydrous THF (30 mL) under nitrogen at 0 °C was added the solution of **S5** (10 mmol) in anhydrous THF (10 mL). After 30 min the reaction mixture was allowed to warm to room temperature and stirred for 3 h. After the completion of the reaction, 20 mL of saturated brines was added to the mixture, and extracted with ethyl acetate (15 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether as the eluent to give the desired product **1**.

Optimization of the reaction conditions

Initially, we selected 2-iodophenyl alkenyl ether **1a** and methanol **2a** as model substrates to react with different metal carbonyl and organic carbonyl sources for identifying the optimal conditions (Table S1, entries 1-7). Delightedly, when the reaction was conducted in the presence of 10 mol % of $Pd(OAc)_2$, 20 mol% of Ad_2P^nBu, Na_2CO_3 (2.0 equiv) in toluene (1.0 mL) under 80 °C for 24 h with $Mo(CO)_6$ (1.0 equiv) as the carbonyl source, the desired 1,4-ketoester product **3a** was formed smoothly in 6% isolated yield (Table S1, entry 2). Subsequently, the yield of **3a** was further increased to 22% by replacing $Pd(OAc)_2$ with $PdCl_2$ (Table S1, entry 10) while other tested catalysts obtained no better results (Table S1, entries 8-9 & 11-12). Unfortunately, various screened phosphine ligands including PPh_3, PCy_3, dppp and XantPhos were all inferior to Ad_2P^nBu (Table S1, entries 13-16). To further improve the reaction efficiency, a large variety of inorganic bases and organic bases, including KOH, Cs_2CO_3, DABCO and DIPEA were evaluated carefully (Table S1, entries 17-20). Dramatically, the yield of **3a** was increased to 40% by using DABCO as the base (Table S1, entries 19). Afterwards, a higher isolated yield of 45% was obtained by investigating the reaction solvents like PhCl, $PhCF_3$, xylene and 1,2-DCE (Table S1, entries 21-24). We were pleased to find higher reaction temperatures are favorable to increase the reaction efficiency, and the yield reached 76% under 100 °C (Table S1, entry 25). Further variation of the amount of $Mo(CO)_6$ demonstrated that 0.4 equivalent of $Mo(CO)_6$ was the most suitable, where the product **3a** was formed in 73% yield (Table S1, entry 26). Then control experiments in the absence of palladium or the ligand have been carried out. We found no reaction took place neither in the absence of palladium or the ligand (Table S1, entries 27 & 28). Besides, although the reactions could take place by decreasing the loading amount of palladium to 5%, 3% and 1%, the yields, the yields decreased dramatically to 43%, 26% and 5%, respectively (Table S1, entry 29). Finally, the optimized conditions were established as follows: **1a** (0.2 mmol, 1.0 equiv), **2a** (2.0 equiv), $Mo(CO)_6$ (0.4 equiv), $PdCl_2$ (10

mol%), Ad_2P^nBu (20 mol%), DABCO (2.0 equiv), in xylene (1.0 mL) at 100 °C for 24 h, where the yield of **3a** reached 73% (Table S1, entry 26).

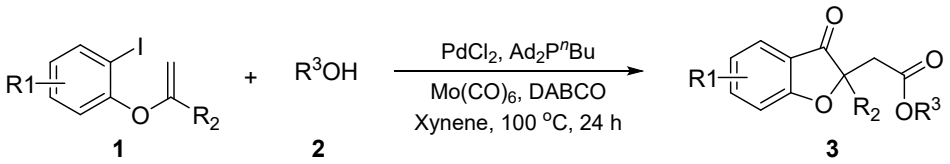
Table S1. Optimization of the reaction conditions.[a]



Entry	CO Source	[Pd]	Ligand	Base	Solvent	Yield (%)[b]
1	$Co_2(CO)_8$	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	trace
2	$Mo(CO)_6$	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	6
3	$W(CO)_6$	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	3
4	$Cr(CO)_6$	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	trace
5	HCOOH	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	N.R.
6	DMF	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	N.R.
7	TFBen	$Pd(OAc)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	N.R.
8	$Mo(CO)_6$	$Pd(dba)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	5
9	$Mo(CO)_6$	$Pd(TFA)_2$	Ad_2P^nBu	Na_2CO_3	Toluene	10
10	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	Na_2CO_3	Toluene	22
11	$Mo(CO)_6$	$Pd(MeCN)_2Cl_2$	Ad_2P^nBu	Na_2CO_3	Toluene	trace
12	$Mo(CO)_6$	$Pd(PPh_3)_2Cl_2$	Ad_2P^nBu	Na_2CO_3	Toluene	8
13	$Mo(CO)_6$	$PdCl_2$	PPh_3	Na_2CO_3	Toluene	17
14	$Mo(CO)_6$	$PdCl_2$	PCy_3	Na_2CO_3	Toluene	12
15	$Mo(CO)_6$	$PdCl_2$	dppp	Na_2CO_3	Toluene	trace
16	$Mo(CO)_6$	$PdCl_2$	XantPhos	Na_2CO_3	Toluene	trace
17	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	KOH	Toluene	N.R.
18	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	Cs_2CO_3	Toluene	19
19	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	Toluene	40
20	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DIPEA	Toluene	13
21	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	PhCl	30
22	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	$PhCF_3$	32
23	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	Xylene	45
24	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	1,2-DCE	5
25	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	Xylene	59[c], 76[d]
26[d]	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	Xylene	73[e], 75[f], 72[g], 18[h]
27[d,e]	$Mo(CO)_6$	\	Ad_2P^nBu	DABCO	Xylene	N.R.
28[d,e]	$Mo(CO)_6$	$PdCl_2$	\	DABCO	Xylene	N.R.
29[d,e]	$Mo(CO)_6$	$PdCl_2$	Ad_2P^nBu	DABCO	Xylene	43,[i] 26,[j] 5[k]

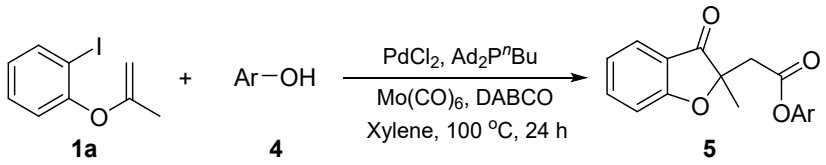
[a] Reaction conditions: **1a** (0.2 mmol, 1.0 equiv), methanol **2a** (0.4 mmol, 2.0 equiv), CO source (0.2 mmol, 1.0 equiv), palladium catalyst (10 mol%), ligand (20 mol%), base (2.0 equiv), solvent (1.0 mL), 80 °C, 24 h. [b] Isolated yield. [c] Under 90 °C. [d] Under 100 °C. [e] 0.4 Equiv of $Mo(CO)_6$ was used. [f] 0.5 Equiv of $Mo(CO)_6$ was used. [g] 2.0 Equiv of $Mo(CO)_6$ was used. [h] 1 Atm. of CO gas was used instead of $Mo(CO)_6$, [i] 5 mol% of $PdCl_2$. [j] 3 mol% of $PdCl_2$. [k] 1 mol% of $PdCl_2$. N.R. is no reaction.

General procedure for the synthesis of 3



A 20 mL of Schlenk tube equipped with a stir bar was charged with **1** (0.20 mmol, 1.0 equiv), alcohol **2** (0.4 mmol, 2.0 equiv), $Mo(CO)_6$ (0.4 equiv), $PdCl_2$ (10 mol%), Ad_2P^nBu (20 mol%), DABCO (2.0 equiv) and xylene (1.0 mL). The tube was sealed with a Teflon lined cap. The reaction mixture was stirred at 100 °C for 24 h in oil bath. After the completion of the reaction, 6.0 mL of saturated brines was added to the mixture, and extracted with ethyl acetate (5 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 8:1) as the eluent to give the desired product **3**.

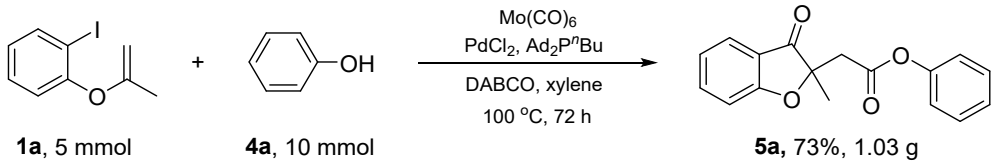
General procedure for the synthesis of 5



A 20 mL of Schlenk tube equipped with a stir bar was charged with **1a** (0.20 mmol, 1.0 equiv), phenol **4** (0.4 mmol, 2.0 equiv), $Mo(CO)_6$ (0.4 equiv), $PdCl_2$ (10 mol%), Ad_2P^nBu (20 mol%), DABCO (2.0 equiv) and xylene (1.0 mL). The tube was sealed with a Teflon lined cap. The reaction mixture was stirred at 100 °C for 24 h in oil bath. After the completion of the reaction, 6.0 mL of EtOAc was added to the mixture, and the mixture was washed with saturated aqueous sodium carbonate (5 mL × 3). Then 20 mL of saturated brines was added to the organic phase, and extracted with ethyl acetate (10 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel

with petroleum ether-EtOAc (PE/EA, v/v, 8:1) as the eluent to give the desired product **5**.

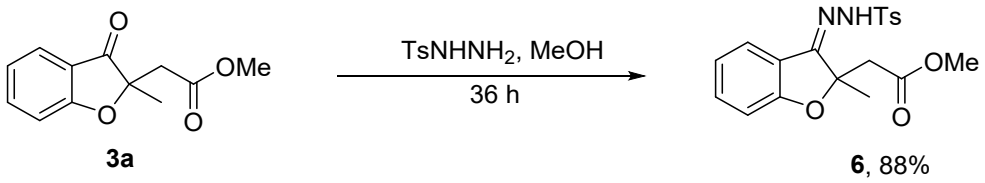
Gram-scale synthesis of 5a



1a, 5 mmol **4a**, 10 mmol **5a,** 73%, 1.03 g

A 150 mL of Schlenk tube equipped with a stir bar was charged with **1a** (5 mmol, 1.0 equiv), phenol **4a** (10 mmol, 2.0 equiv), $Mo(CO)_6$ (0.4 equiv), $PdCl_2$ (10 mol%), Ad_2P^nBu (20 mol%), DABCO (2.0 equiv) and xylene (50 mL). The tube was sealed with a Teflon lined cap. The reaction mixture was stirred at 100 °C for 72 h in oil bath. After the completion of the reaction, 50 mL of EtOAc was added to the mixture, and the mixture was washed with saturated aqueous sodium carbonate (20 mL × 3). Then 50 mL of saturated brines was added to the organic phase, and extracted with ethyl acetate (30 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 8:1) as the eluent to give the desired product **5a** in 73% yield (1.03 g).

General procedure for the preparation of hydrazone 6[3]

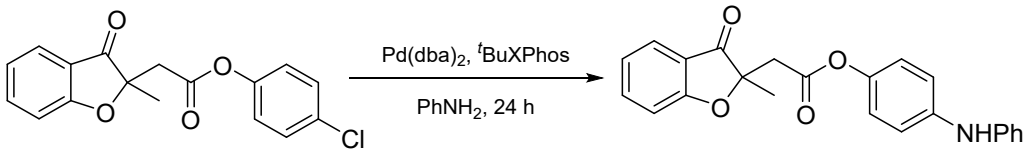


3a **6**, 88%

To a solution of tosylhydrazide (37.2 mg, 0.2 mmol, 1.0 equiv.) in MeOH (0.5 M) was added **3a** (44.0 mg, 0.2 mmol, 1.0 equiv). The reaction mixture was stirred at 36 °C for 24 hours, and then stirred at 100 °C until complete conversion was observed by TLC. Then the solvent was removed in vacuo, the residue was purified by flash column chromatography on silica gel (PE/EA=4:1) to afford the desired product **6** as a

yellowish solid (68.6 mg, 88%).

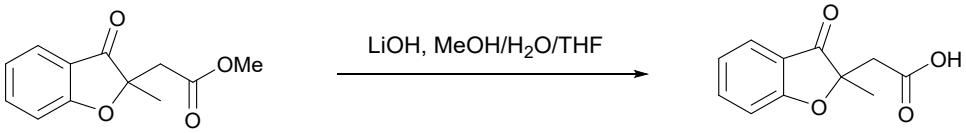
General procedure of Buchwald–Hartwig cross-coupling[4]



5f **7**, 58%

An oven-dried Schlenk tube (25 mL) charged with a magnetic stirring bar, $Pd(dba)_2$ (5.8 mg, 5 mol%), ^{t}BuXPhos (8.6 mg, 10 mol%), NaO^{t}Bu (28 mg, 1.4 equiv), **6d** (62 mg, 0.2 mmol) and aniline (38 μL, 2.0 equiv) was vacuumed and refilled with argon for 3 times. The solvent-free reaction mixture was stirred at 110 °C for 24 h. Subsequently, the reaction mixture was transferred to a column directly for chromatography purification (PE/EA = 4:1) with minimum amount of CH_2Cl_2 to obtain product **7** in 58% yield as a yellow oil.

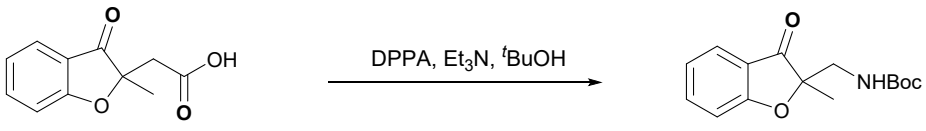
General procedure for the hydrolysis 3a[5]



3a **8**, 95%

A solution of **3a** (44.0 mg, 0.2 mmol) and LiOH (24.0 mg, 1 mmol, 5.0 equiv) in $MeOH/H_2O/THF$ (2.0 mL, 5/1/1) was stirred at room temperature for 15 h. The resulting mixture was neutralized with 1M hydrochloric acid solution and then extracted with DCM (5.0 mL × 3). The organic layer was dried over Na_2SO_4, concentrated to afford the desired carboxylic acid **8** in 95% yield (39.1 mg).

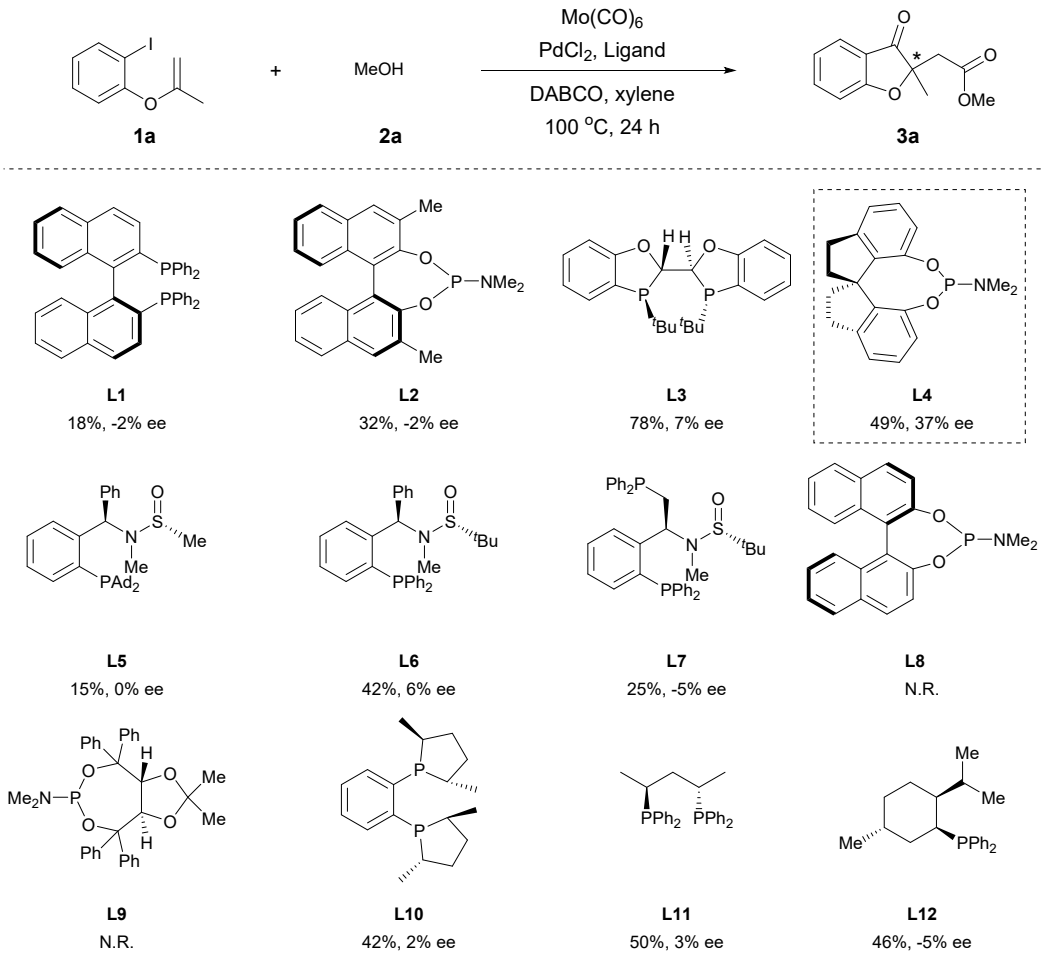
General procedure for Curtius rearrangement of acid 8[5]



8 **9**, 55%

To a solution of **8** (41.2 mg, 0.2 mmol) and Et_3N (14 μL, 0.22 mmol), anhydrous ^{t}BuOH (2.0 mL) was added diphenylphosphoryl azide (21 μL, 0.22 mmol) dropwise. The reaction was heated at 80℃ and stirred for 48 h before cooling down to room temperature and concentrating in vacuo. Et_2O (5.0 mL) and H_2O (10.0 mL) were added. The layers were separated and the aqueous portion was extracted with Et_2O (2 × 5.0 mL). The organic extracts were combined, washed with saturated $NaHCO_3$ solution, brine, dried over anhydrous Na_2SO_4, filtered, concentrated and purified by column chromatography on silica gel (PE/EA = 4/1) to afford the desired product **9** in 55% yield (30.5 mg).

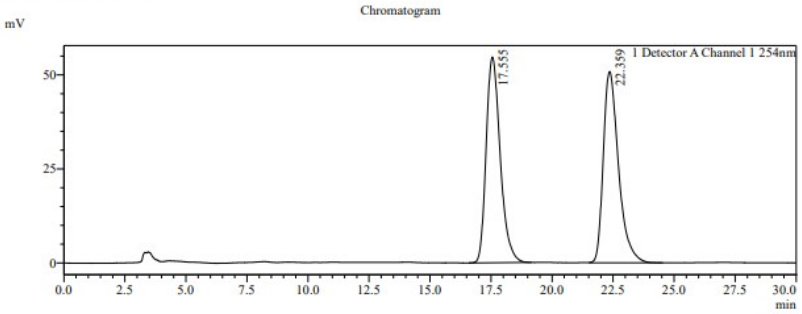
Studies of the asymmetric reaction



A 20 mL of Schlenk tube equipped with a stir bar was charged with **1a** (0.20 mmol, 1.0 equiv), methanol **2a** (0.4 mmol, 2.0 equiv), $Mo(CO)_6$ (0.4 equiv), $PdCl_2$ (10

mol%), L4 (20 mol%), DABCO (2.0 equiv) and xylene (1.0 mL). The tube was sealed with a Teflon lined cap. The reaction mixture was stirred at 100 °C for 24 h in oil bath. After the completion of the reaction, 6.0 mL of saturated brines was added to the mixture, and extracted with ethyl acetate (5 mL × 3). The combined organic extracts were dried over anhydrous Na_2SO_4. Subsequently, the solvent was filtered and evaporated under reduced pressure, and the residue was purified by flash column chromatography on silica gel with petroleum ether-EtOAc (PE/EA, v/v, 8:1) as the eluent to give the chiral product **3a** in 49% yield with 37% ee value. The ee (37%) of compound **3a** was determined by HPLC using an OD-H column (0.46 cm x 25 cm), *n*-hexane/*i*-PrOH = 98/2, flow rate = 1.0 mL/min, λ = 254 nm, t(minor) = 17.831min, t(major) = 23.067 min.

<Chromatogram>



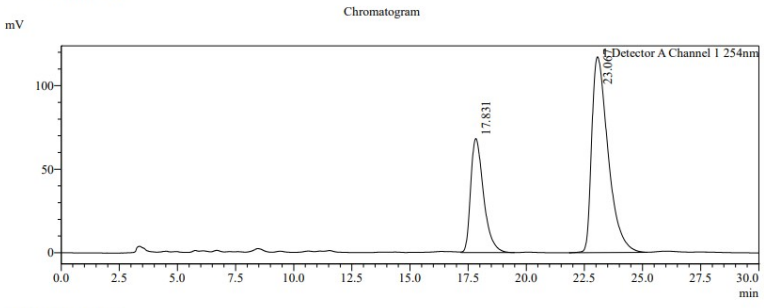
<Peak Table>

Peak Table

Detector A Channel 1 254nm

Peak#	Ret. Time	Area	Height	Area%
1	17.555	2190399	54620	49.885
2	22.359	2200521	50786	50.115
Total		4390920	105406	100.000

<Chromatogram>



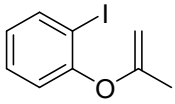
<Peak Table>

Peak Table

Detector A Channel 1 254nm

Peak#	Ret. Time	Area	Height	Area%
1	17.831	2631120	68245	31.385
2	23.067	5752162	117139	68.615
Total		8383282	185384	100.000

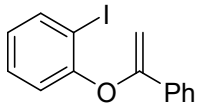
III. Characterization Data



1a

1-iodo-2-(prop-1-en-2-yloxy)benzene (1a)

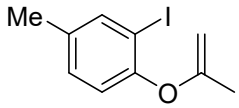
Flash column chromatography on a silica gel (PE) gives **1a** (75% yield) as a colorless liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (dd, J_1 = 7.9 Hz, J_2 = 1.6 Hz, 1H), 7.33 (dt, J_1 = 7.7 Hz, J_2 = 1.5 Hz, 1H), 7.08 (dd, J_1 = 8.1 Hz, J_2 = 1.6 Hz, 1H), 6.90-6.87 (m, 1H), 4.16 (d, J = 2.1 Hz, 1H), 3.77 (d, J = 2.0 Hz, 1H), 2.05 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 158.8 (C=C), 154.9 (O-C(Ar)), 139.7 (Ar), 129.5 (Ar), 126.0 (Ar), 122.0 (Ar), 90.5 (=CH_2), 89.0 (Ar), 20.1 (CH_3). HRMS(ESI) m/z: $[M+H]^+$ Calcd. for $C_9H_{10}IO^+$ 260.9771, found 260.9770.



1r

1-iodo-2-((1-phenylvinyl)oxy)benzene (1r)

Flash column chromatography on a silica gel (PE) gives **1r** (76% yield) as a colorless liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (dd, J_1 = 7.9 Hz, J_2 = 1.6 Hz, 1H), 7.82-7.79 (m, 2H), 7.46-7.40 (m, 3H), 7.36-7.32 (m, 1H), 7.13 (dd, J_1 = 8.2 Hz, J_2 = 1.5 Hz, 1H), 6.92 (dt, J_1 = 7.8 Hz, J_2 = 1.6 Hz, 1H), 5.09 (d, J = 2.8 Hz, 1H), 4.36 (d, J = 2.8 Hz, 1H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 158.5 (C=C), 155.2 (O-C(Ar)), 139.7 (Ar), 134.6 (Ar), 129.5 (Ar), 128.9 (Ar), 128.3 (Ar), 125.7 (Ar), 120.7 (2C, Ar), 91.5 (=CH_2), 89.4 (Ar). HRMS(ESI) m/z: $[M+H]^+$ Calcd. for $C_{14}H_{12}IO^+$ 322.9927, found 322.9934.

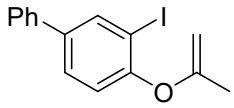


1s

2-iodo-4-methyl-1-(prop-1-en-2-yloxy)benzene (1s)

Flash column chromatography on a silica gel (PE) gives **1s** (73% yield) as a as a

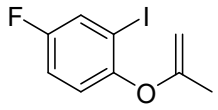
colorless liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 (s, 1H), 7.12 (d, *J* = 8.3 Hz, 1H), 6.95 (d, *J* = 8.2 Hz, 1H), 4.10 (d, *J* = 2.2 Hz, 1H), 3.72 (d, *J* = 1.9 Hz, 1H), 2.30 (s, 3H), 2.04 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 159.0 (C=C), 152.6 (O-C(Ar)), 139.8 (Ar), 136.0 (Ar), 130.1 (Ar), 121.8 (Ar), 90.3 (=CH_2), 88.1 (Ar), 20.3 (CH_3), 20.2 (Ar-CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{10}H_{11}INaO^+$ 296.9747, found 296.9749.



1t

3-iodo-4-(prop-1-en-2-yloxy)-1,1'-biphenyl (1t)

Flash column chromatography on a silica gel (PE) gives **1t** (82% yield) as a colorless liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.06 (d, *J* = 2.2 Hz, 1H), 7.56-7.54 (m, 3H), 7.46-7.43 (m, 2H), 7.39-7.35 (m, 1H), 7.14 (d, *J* = 8.4 Hz, 1H), 4.22 (d, *J* = 2.2 Hz, 1H), 3.89 (d, *J* = 2.0 Hz, 1H), 2.09 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 158.8 (C=C), 154.3 (O-C(Ar)), 139.2 (Ar), 139.0 (Ar), 138.1 (Ar), 128.8 (Ar), 128.2 (Ar), 127.6 (Ar), 126.9 (Ar), 121.9 (Ar), 90.8 (=CH_2), 89.2 (Ar), 20.1 (CH_3). HRMS(ESI) m/z: $[M+H]^+$ Calcd. for $C_{15}H_{14}IO^+$ 337.0084, found 337.0096.

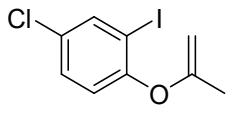


1u

4-fluoro-2-iodo-1-(prop-1-en-2-yloxy)benzene (1u)

Flash column chromatography on a silica gel (PE) gives **1u** (52% yield) as a colorless liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53 (dd, J_1 = 7.7 Hz, J_2 = 2.8 Hz, 1H), 7.05-7.00 (m, 2H), 4.12 (d, *J* = 2.2 Hz, 1H), 3.69 (d, *J* = 2.2 Hz, 1H), 2.04 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 158.8 (d, *J* = 246.3 Hz, C=C), 157.8 (O-C(Ar)), 151.2 (d, *J* = 2.5 Hz, Ar), 126.1 (d, *J* = 25.0 Hz, Ar), 122.6 (d, *J* = 8.8 Hz, Ar), 116.2 (d, *J* = 22.5 Hz, Ar), 90.2 (d, *J* = 8.8 Hz, =CH_2), 88.3 (Ar), 20.1 (CH_3). ^{19}F NMR (471 MHz, $CDCl_3$) δ -117.0. HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_9H_8FINaO^+$ 300.9496, found

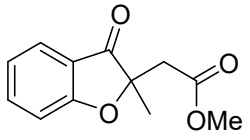
300.9491.



1v

4-chloro-2-iodo-1-(prop-1-en-2-yloxy)benzene (1v)

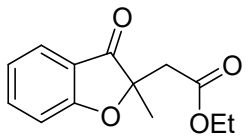
Flash column chromatography on a silica gel (PE) gives **1v** (63% yield) as a colorless liquid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 2.5 Hz, 1H), 7.30 (dd, J_1 = 8.6 Hz, J_2 = 2.5 Hz, 1H), 6.99 (d, J = 8.6 Hz, 1H), 4.17 (d, J = 2.1 Hz, 1H), 3.78 (d, J = 2.1 Hz, 1H), 2.03 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 158.6 (C=C), 153.8 (O-C(Ar)), 138.8 (Ar), 130.2 (Ar), 129.5 (Ar), 122.4 (Ar), 90.7 (=CH_2), 89.4 (Ar), 20.0 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_9H_8ClINaO^+$ 316.9201, found 316.9207.



3a

methyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3a)[6]

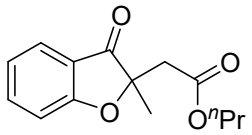
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3a** (32.1 mg, 73% yield) as a yellow solid: m.p. 80-81 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, J = 8.40 Hz, 1H), 7.62-7.59 (m, 1H), 7.10-7.07 (m, 2H), 3.54 (s, 3H), 3.03 (d, J = 16.5 Hz, 1H), 2.94 (d, J = 16.4 Hz, 1H), 1.47 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.6 (Ar-C=O), 170.9 (O-C(Ar)), 169.1 (COOR), 137.8 (Ar), 124.6 (Ar), 121.9 (Ar), 120.4 (Ar), 113.3 (Ar), 86.2 (O-C(4°)), 51.8 (O-CH_3), 41.2 (CH_2C=O), 22.3 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{12}H_{12}NaO_4^+$ 243.0628, found 243.0635.



3b

ethyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3b)

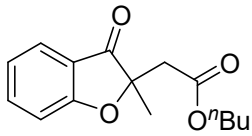
Flash column chromatography on a silica gel (PE:EA=8:1) gives **3b** (35.5 mg, 76% yield) as a yellow solid: m.p. 80-81 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.7 Hz, 1H), 7.61-7.58 (m, 1H), 7.09-7.05 (m, 2H), 4.01-3.89 (m, 2H), 3.04 (d, *J* = 16.4 Hz, 1H), 2.91 (d, *J* = 16.4 Hz, 1H), 1.45 (s, 3H), 0.97 (t, *J* = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.6 (Ar-C=O), 170.9 (O-C(Ar)), 168.4 (COOR), 137.7 (Ar), 124.5 (Ar), 121.8 (Ar), 120.6 (Ar), 113.2 (Ar), 86.3 (O-C(4°)), 60.8 (O-CH_2), 41.6 (CH_2C=O), 22.5 (CH_3), 13.6 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{13}H_{14}NaO_4^+$ 257.0784, found 257.0792.



3c

propyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3c)

Flash column chromatography on a silica gel (PE:EA=8:1) gives **3c** (37.2 mg, 75% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.7 Hz, 1H), 7.60-7.57 (m, 1H), 7.09-7.05 (m, 2H), 3.90-3.82 (m, 2H), 3.05 (d, *J* = 16.3 Hz, 1H), 2.92 (d, *J* = 16.3 Hz, 1H), 1.45 (s, 3H), 1.41-1.31 (m, 2H), 0.77 (t, *J* = 7.5 Hz, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.9 (O-C(Ar)), 168.5 (COOR), 137.7 (Ar), 124.5 (Ar), 121.8 (Ar), 120.5 (Ar), 113.2 (Ar), 86.3 (O-C(4°)), 66.4 (O-CH_2), 41.6 (CH_2C=O), 22.5 (CH_3), 21.5 (CH_2), 10.2 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{14}H_{16}NaO_4^+$ 271.0941, found 271.0950.

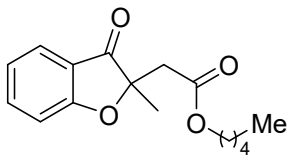


3d

butyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3d)

Flash column chromatography on a silica gel (PE:EA=8:1) gives **3d** (36.7 mg, 70% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.7 Hz, 1H), 7.61-7.57 (m, 1H), 7.09-7.05 (m, 2H), 3.94-3.85 (m, 2H), 3.04 (d, *J* = 16.4 Hz, 1H), 2.92 (d,

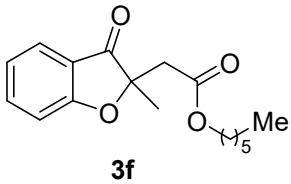
J = 16.4 Hz, 1H), 1.45 (s, 3H), 1.34-1.28 (m, 2H), 1.21-1.14 (m, 2H), 0.80 (t, *J* = 7.4 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.9 (O-C(Ar)), 168.5 (COOR), 137.7 (Ar), 124.5 (Ar), 121.8 (Ar), 120.5 (Ar), 113.3 (Ar), 86.3 (O-C(4°)), 64.7 (O-CH_2), 41.6 (CH_2C=O), 30.2 (CH_2), 22.5 (CH_3), 18.9 (CH_2), 13.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{15}H_{18}NaO_4^+$ 285.1097, found 285.1106.



3e

pentyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3e)

Flash column chromatography on a silica gel (PE:EA=8:1) gives **3e** (39.2 mg, 71% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.1 Hz, 1H), 7.61-7.57 (m, 1H), 7.09-7.05 (m, 2H), 3.93-3.85 (m, 2H), 3.05 (d, *J* = 16.3 Hz, 1H), 2.92 (d, *J* = 16.4 Hz, 1H), 1.45 (s, 3H), 1.36-1.30 (m, 2H), 1.23-1.11 (m, 4H), 0.83 (t, *J* = 7.2 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.9 (O-C(Ar)), 168.5 (COOR), 137.7 (Ar), 124.5 (Ar), 121.8 (Ar), 120.5 (Ar), 113.3 (Ar), 86.3 (O-C(4°)), 65.0 (O-CH_2), 41.6 (CH_2C=O), 27.9 (CH_2), 27.8 (CH_2), 22.5 (CH_3), 22.2 (CH_2), 13.8 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{16}H_{20}NaO_4^+$ 299.1254, found 299.1263.

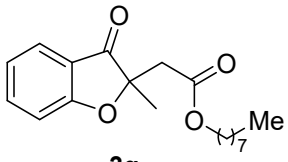


3f

hexyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3f)

Flash column chromatography on a silica gel (PE:EA=30:1) gives **3f** (39.2 mg, 68% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.6 Hz, 1H), 7.60-7.57 (m, 1H), 7.09-7.05 (m, 2H), 3.93-3.85 (m, 2H), 3.04 (d, *J* = 16.3 Hz, 1H), 2.92 (d, *J* = 16.3 Hz, 1H), 1.45 (s, 3H), 1.35-1.13 (m, 8H), 0.85 (t, *J* = 7.1 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.9 (O-C(Ar)), 168.5 (COOR), 137.7

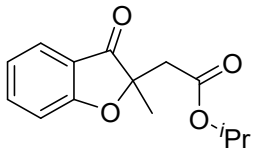
(Ar), 124.5 (Ar), 121.8 (Ar), 120.5 (Ar), 113.2 (Ar), 86.3 (O-C(4°)), 65.0 (O-CH_2), 41.6 (CH_2C=O), 31.3 (CH_2), 28.1 (CH_2), 25.3 (CH_2), 22.5 (CH_3), 22.4 (CH_2), 13.9 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{17}H_{22}NaO_4^+$ 313.1410, found 313.1419.



3g

octyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3g)

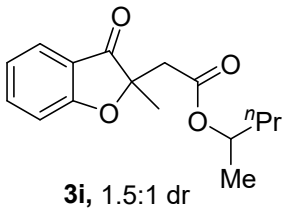
Flash column chromatography on a silica gel (PE/EA, v/v, 30:1) gives **3g** (44.6 mg, 70% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.8 Hz, 1H), 7.60–7.57 (m, 1H), 7.09–7.05 (m, 2H), 3.93–3.84 (m, 2H), 3.04 (d, *J* = 16.4 Hz, 1H), 2.92 (d, *J* = 16.4 Hz, 1H), 1.45 (s, 3H), 1.34–1.14 (m, 12H), 0.86 (t, *J* = 6.9 Hz, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.9 (O-C(Ar)), 168.5 (COOR), 137.7 (Ar), 124.5 (Ar), 121.8 (Ar), 120.5 (Ar), 113.3 (Ar), 86.3 (O-C(4°)), 65.1 (O-CH_2), 41.6 (CH_2C=O), 31.7 (CH_2), 29.1 (CH_2), 29.0 (CH_2), 28.2 (CH_2), 25.7 (CH_2), 22.6 (CH_2), 22.5 (CH_3), 14.0 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{19}H_{26}NaO_4^+$ 341.1723, found 341.1731.



3h

isopropyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3h)

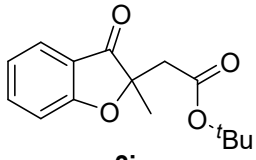
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3h** (33.2 mg, 67% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.7 Hz, 1H), 7.61–7.57 (m, 1H), 7.09–7.05 (m, 2H), 4.83–4.78 (m, 1H), 3.04 (d, *J* = 16.2 Hz, 1H), 2.88 (d, *J* = 16.2 Hz, 1H), 1.44 (s, 3H), 1.02 (d, *J* = 6.3 Hz, 3H), 0.86 (d, *J* = 6.2 Hz, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.6 (Ar-C=O), 171.0 (O-C(Ar)), 167.8 (COOR), 137.7 (Ar), 124.5 (Ar), 121.8 (Ar), 120.7 (Ar), 113.3 (Ar), 86.4 (O-C(4°)), 68.5 (O-CH), 42.1 (CH_2C=O), 22.6 (CH_3), 21.4 (CH_3), 21.1 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{14}H_{16}NaO_4^+$ 271.0941, found 271.0950.



3i, 1.5:1 dr

pentan-2-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3i)

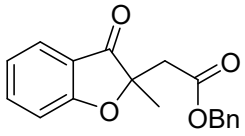
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3i** (35.9 mg, 65% yield, 1.5:1 dr) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.6 Hz, 1H), 7.59–7.57 (m, 1H), 7.09–7.04 (m, 2H), 4.78–4.69 (m, 1H), 3.04 (t, *J* = 16.3 Hz, 1H), 2.91 (d, *J* = 5.6 Hz, 0.6H), 2.87 (d, *J* = 5.4 Hz, 0.4H), 1.44 (d, *J* = 2.0 Hz, 3H), 1.32–1.01 (m, 6H), 0.83–0.75 (m, 4H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.5 (2C, Ar-C=O), 171.0 (O-C(Ar)), 170.9 (O-C(Ar)), 168.0 (COOR), 167.9 (COOR), 137.6 (2C, Ar), 124.53 (Ar), 124.50 (Ar), 121.79 (Ar), 121.76 (Ar), 120.7 (Ar), 120.6 (Ar), 113.29 (Ar), 113.25 (Ar), 86.4(2C, O-C(4^{o})), 71.7 (O-CH), 71.6 (O-CH), 42.1 (CH_2C=O), 42.0 (CH_2C=O), 37.64 (CH_2), 37.56 (CH_2), 22.7 (CH_3), 22.6 (CH_3), 19.6 (CH_3), 19.3 (CH_3), 18.37 (CH_2), 18.35 (CH_2), 13.8 (2C, CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{16}H_{20}NaO_4^+$ 299.1254, found 299.1263.



3j

***tert*-butyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3j)**

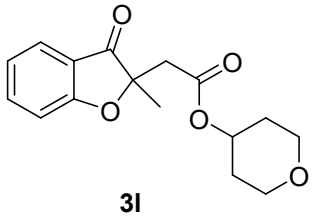
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3j** (21.5 mg, 41% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.8 Hz, 1H), 7.62–7.58 (m, 1H), 7.09–7.06 (m, 2H), 3.03 (d, *J* = 15.7 Hz, 1H), 2.80 (d, *J* = 15.8 Hz, 1H), 1.43 (s, 3H), 1.13 (s, 9H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.6 (Ar-C=O), 171.0 (O-C(Ar)), 167.4 (COOR), 137.7 (Ar), 124.6 (Ar), 121.8 (Ar), 120.8 (Ar), 113.3 (Ar), 86.7 (O-C(4^{o})), 81.5 (O-C), 43.3 (CH_2C=O), 27.5 (CH_3), 22.8 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{15}H_{18}NaO_4^+$ 285.1097, found 285.1106.



3k

benzyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3k)

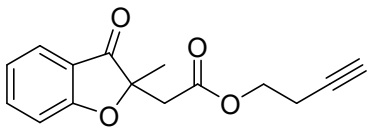
Flash column chromatography on a silica gel (PE/EA, v/v, 30:1) gives **3k** (46.2 mg, 78% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.7 Hz, 1H), 7.59–7.56 (m, 1H), 7.30–7.27 (m, 3H), 7.17–7.15 (m, 2H), 7.07–7.02 (m, 2H), 4.96 (d, *J* = 3.1 Hz, 2H), 3.10 (d, *J* = 16.4 Hz, 1H), 2.99 (d, *J* = 16.4 Hz, 1H), 1.47 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.4 (Ar-C=O), 170.8 (O-C(Ar)), 168.3 (COOR), 137.7 (Ar), 135.1 (Ar), 128.4 (Ar), 128.19 (Ar), 128.16 (Ar), 124.6 (Ar), 121.9 (Ar), 120.4 (Ar), 113.2 (Ar), 86.2 ((O-C(4^{o})), 66.7 (O-CH_2), 41.4 (CH_2C=O), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{18}H_{16}NaO_4^+$ 319.0941, found 319.0950.



3l

tetrahydro-*2H*-pyran-4-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3l)

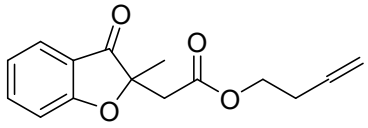
Flash column chromatography on a silica gel (PE/EA, v/v, 4:1) gives **3l** (41.2 mg, 71% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70–7.68 (m, 1H), 7.62–7.58 (m, 1H), 7.10–7.05 (m, 2H), 4.80–4.74 (m, 1H), 3.75–3.71 (m, 1H), 3.67–3.62 (m, 1H), 3.41–3.31 (m, 2H), 3.08 (d, *J* = 16.2 Hz, 1H), 2.93 (d, *J* = 16.3 Hz, 1H), 1.75–1.70 (m, 1H), 1.62–1.57 (m, 1H), 1.48–1.43 (m, 4H), 1.22–1.16 (m, 1H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.4 (Ar-C=O), 170.9 (O-C(Ar)), 167.7 (COOR), 137.8 (Ar), 124.6 (Ar), 122.0 (Ar), 120.6 (Ar), 113.3 (Ar), 86.3 (O-C(4^{o})), 69.9 (O-CH), 65.1 (O-CH_2), 41.9 (CH_2C=O), 31.3 (CH_2), 22.7 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{16}H_{18}NaO_5^+$ 313.1046, found 313.1056.



3m

but-3-yn-1-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3m)

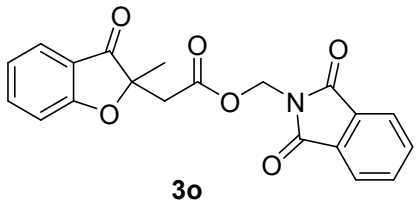
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3m** (36.1 mg, 70% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, J = 7.6 Hz, 1H), 7.62–7.59 (m, 1H), 7.11–7.06 (m, 2H), 4.08–3.99 (m, 2H), 3.06 (d, J = 16.4 Hz, 1H), 2.96 (d, J = 16.5 Hz, 1H), 2.27 (td, J_1 = 7.0 Hz, J_2 = 2.8 Hz, 2H), 1.94 (t, J = 2.7 Hz, 1H), 1.47 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ ^{13}C NMR (126 MHz, $CDCl_3$) δ 202.4 (Ar-C=O), 170.9 (O-C(Ar)), 168.2 (COOR), 137.8 (Ar), 124.6 (Ar), 121.9 (Ar), 120.4 (Ar), 113.3 (Ar), 86.2 (O-C(4^{o})), 79.6 (C≡CH), 70.0 (≡CH), 62.5 (O-CH_2), 41.3 (CH_2C=O), 22.4 (CH_3), 18.5 (CH_2). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{15}H_{14}NaO_4^+$ 281.0784, found 281.0794.



3n

but-3-en-1-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3n)

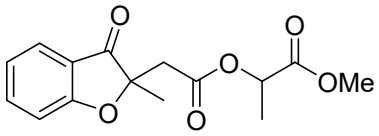
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3n** (37.4 mg, 72% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, J = 7.7 Hz, 1H), 7.62–7.58 (m, 1H), 7.10–7.06 (m, 2H), 5.65–5.57 (m, 1H), 5.03–4.99 (m, 2H), 3.97 (td, J_1 = 6.8 Hz, J_2 = 2.1 Hz, 2H), 3.04 (d, J = 16.3 Hz, 1H), 2.93 (d, J = 16.3 Hz, 1H), 2.13 (q, J = 6.9 Hz, 2H), 1.46 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.9 (O-C(Ar)), 168.5 (COOR), 137.8 (CH=CH_2), 133.6 (Ar), 124.6 (Ar), 121.9 (Ar), 120.5 (Ar), 117.2 (=CH_2), 113.3 (Ar), 86.3 (O-C(4^{o})), 64.0 (O-CH_2), 41.5 (CH_2C=O), 32.6 (CH_2), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{15}H_{16}NaO_4^+$ 283.0941, found 283.0950.



3o

(1,3-dioxoisoindolin-2-yl)methyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3o)

Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3o** (32.9 mg, 45% yield) as a white solid: m.p. 116-117 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89–7.85 (m, 2H), 7.79–7.76 (m, 2H), 7.56 (d, *J* = 7.7 Hz, 1H), 7.43–7.40 (m, 1H), 6.99 (d, *J* = 8.4 Hz, 1H), 6.87 (t, *J* = 7.7 Hz, 1H), 5.63 (d, *J* = 10.5 Hz, 1H), 5.50 (d, *J* = 10.5 Hz, 1H), 3.05 (d, *J* = 16.6 Hz, 1H), 2.93 (d, *J* = 16.7 Hz, 1H), 1.43 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.1 (Ar-C=O), 170.8 (O-C(Ar)), 167.2 (COOR), 166.2 (N-C=O), 137.6 (Ar), 134.6 (Ar), 131.6 (Ar), 124.4 (Ar), 123.9 (Ar), 121.8 (Ar), 120.2 (Ar), 113.3 (Ar), 85.9 (O-C(4^{o})), 60.9 (O-CH_2), 41.0 (CH_2C=O), 22.4 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{20}H_{15}NNaO_6^+$ 388.0792, found 388.0799.

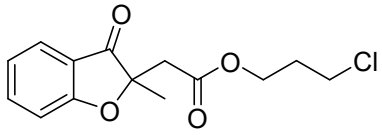


3p 1:1 dr

methyl 2-(2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetoxy)propanoate (3p)

Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3p** (43.8 mg, 75% yield, 1:1 dr) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.3 Hz, 1H), 7.61–7.57 (m, 1H), 7.08–7.05 (m, 2H), 4.97–4.91 (m, 1H), 3.65 (d, *J* = 4.6 Hz, 3H), 3.12–2.98 (m, 2H), 1.47 (d, *J* = 5.0 Hz, 3H), 1.29 (d, *J* = 7.1 Hz, 1.58H), 1.20 (d, *J* = 7.2 Hz, 1.57H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.3 (2C, Ar-C=O), 171.1 (O-C(Ar)), 171.0 (O-C(Ar)), 170.6 (COOR), 170.5 (COOR), 167.9 ($COOCH_3$), 167.8 ($COOCH_3$), 137.9 (Ar), 137.8 (Ar), 124.62 (Ar), 124.60 (Ar), 121.93 (Ar), 121.90 (Ar), 120.4 (Ar), 113.4 (Ar), 86.2 (O-C(4^{o})), 86.1 (O-C(4^{o})), 69.0 (O-CH), 68.8 (O-CH), 52.3 (2C, O-CH_3), 41.13 (CH_2C=O), 41.08 (CH_2C=O), 22.44 (CH_3), 22.39

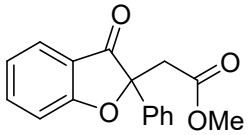
(CH_3), 16.7 (CH_3), 16.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{15}H_{16}NaO_6^+$ 315.0839, found 315.0848.



3q

3-chloropropyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3q)

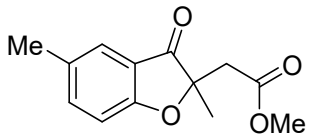
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3q** (40.0 mg, 71% yield) as a yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, J = 7.7 Hz, 1H), 7.62–7.59 (m, 1H), 7.10–7.06 (m, 2H), 4.05 (t, J = 6.0 Hz, 2H), 3.38 (td, J_1 = 6.5 Hz, J_2 = 2.7 Hz, 2H), 3.06 (d, J = 16.3 Hz, 1H), 2.93 (d, J = 16.3 Hz, 1H), 1.84–1.74 (m, 2H), 1.46 (s, 3H). $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 202.4 (Ar-C=O), 170.8 (O-C(Ar)), 168.2 (COOR), 137.9 (Ar), 124.5 (Ar), 122.0 (Ar), 120.4 (Ar), 113.3 (Ar), 86.2 (O-C(4°)), 61.6 (O-CH_2), 41.5 (CH_2C=O), 40.8 (CH_2Cl), 31.2 (CH_2), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{14}H_{15}ClNaO_4^+$ 305.0551, found 305.0561.



3r

methyl 2-(3-oxo-2-phenyl-2,3-dihydrobenzofuran-2-yl)acetate (3r)

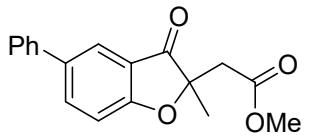
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3r** (37.8 mg, 67% yield) as a yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ 7.69–7.59 (m, 4H), 7.37–7.28 (m, 3H), 7.24 (d, J = 8.4 Hz, 1H), 7.10 (t, J = 7.4 Hz, 1H), 3.54 (s, 3H), 3.49 (d, J = 16.8 Hz, 1H), 3.25 (d, J = 16.8 Hz, 1H). $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ 199.8 (Ar-C=O), 171.2 (O-C(Ar)), 168.8 (COOR), 137.8 (Ar), 136.4 (Ar), 128.7 (Ar), 128.4 (Ar), 124.9 (Ar), 124.6 (Ar), 122.3 (Ar), 120.6 (Ar), 112.9 (Ar), 88.1 (O-C(4°)), 51.8 (O-CH_3), 43.0 (CH_2C=O). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{17}H_{14}NaO_4^+$ 305.0784, found 305.0791.



3s

methyl 2-(2,5-dimethyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3s)

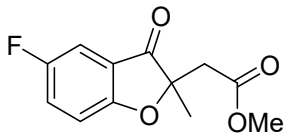
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3s** (37.5 mg, 80% yield) as a white solid: m.p. 69-70 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.47 (s, 1H), 7.41 (d, J = 8.5 Hz, 1H), 6.96 (d, J = 8.5 Hz, 1H), 3.53 (s, 3H), 3.00 (d, J = 17.0 Hz, 1H), 2.91 (d, J = 16.7 Hz, 1H), 2.34 (s, 3H), 1.44 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.6 (Ar-C=O), 169.3 (O-C(Ar)), 169.1 (COOR), 139.0 (Ar), 131.5 (Ar), 123.9 (Ar), 120.2 (Ar), 112.8 (Ar), 86.4 (O-C(4^{o})), 51.7 (O-CH_3), 41.2 (CH_2C=O), 22.3 (CH_3), 20.6 (Ar-CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{13}H_{14}NaO_4^+$ 257.0784, found 257.0792.



3t

methyl 2-(2-methyl-3-oxo-5-phenyl-2,3-dihydrobenzofuran-2-yl)acetate (3t)

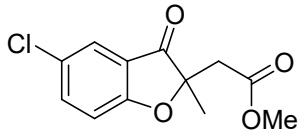
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3t** (48.6 mg, 82% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.91 (d, J = 2.0 Hz, 1H), 7.86 (dd, J_1 = 8.6 Hz, J_2 = 2.1 Hz, 1H), 7.57–7.55 (m, 2H), 7.44 (t, J = 7.6 Hz, 2H), 7.36–7.33 (m, 1H), 7.16 (d, J = 8.6 Hz, 1H), 3.57 (s, 3H), 3.08 (d, J = 16.6 Hz, 1H), 2.98 (d, J = 16.6 Hz, 1H), 1.51 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 170.3 (O-C(Ar)), 169.0 (COOR), 139.7 (Ar), 137.0 (Ar), 135.5 (Ar), 128.9 (Ar), 127.3 (Ar), 126.8 (Ar), 122.5 (Ar), 120.8 (Ar), 113.5 (Ar), 86.9 (O-C(4^{o})), 51.8 (O-CH_3), 41.2 (CH_2C=O), 22.4 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{18}H_{16}NaO_4^+$ 319.0941, found 319.0950.



3u

methyl 2-(5-fluoro-2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3u)

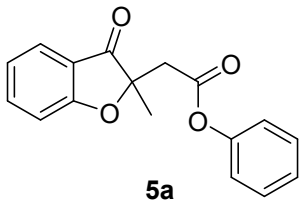
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3u** (29.9 mg, 63% yield) as a white solid: m.p. 95-96 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34–7.31 (m, 2H), 7.05–7.01 (m, 1H), 3.54 (s, 3H), 3.05 (d, J = 16.6 Hz, 1H), 2.94 (d, J = 16.7 Hz, 1H), 1.45 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.2 (Ar-C=O), 169.0 (O-C(Ar)), 167.0 (COOR), 157.7 (d, J = 241.3 Hz, Ar), 125.3 (d, J = 26.3 Hz, Ar), 121.0 (d, J = 8.8 Hz, Ar), 114.3 (d, J = 7.5 Hz, Ar), 109.6 (d, J = 23.8 Hz, Ar), 87.4 (O-C(4^{o})), 51.9 (O-CH_3), 41.3 (CH_2C=O), 22.4 (CH_3). ^{19}F NMR (471 MHz, $CDCl_3$) δ -121.1. HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{12}H_{11}FNaO_4^+$ 261.0534, found 261.0544.



3v

methyl 2-(5-chloro-2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3v)

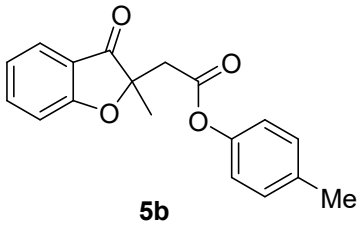
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **3v** (33.1 mg, 65% yield) as a white solid: m.p. 94-95 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, J = 2.2 Hz, 1H), 7.53 (dd, J_1 = 8.8 Hz, J_2 = 2.3 Hz, 1H), 7.02 (d, J = 8.8 Hz, 1H), 3.54 (s, 3H), 3.06 (d, J = 16.8 Hz, 1H), 2.95 (d, J = 16.8 Hz, 1H), 1.45 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 201.3 (Ar-C=O), 169.2 (O-C(Ar)), 168.9 (COOR), 137.5 (Ar), 127.3 (Ar), 123.9 (Ar), 121.7 (Ar), 114.5 (Ar), 87.3 (O-C(4^{o})), 51.9 (O-CH_3), 41.3 (CH_2C=O), 22.4 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{12}H_{11}ClNaO_4^+$ 277.0238, found 277.0245.



5a

phenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5a)

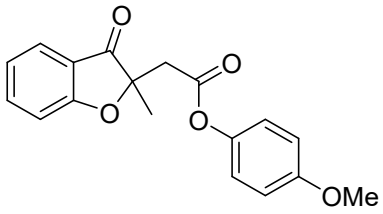
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5a** (44.0 mg, 78% yield) as a white solid: m.p. 117-118 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71 (d, *J* = 7.8 Hz, 1H), 7.63–7.60 (m, 1H), 7.29–7.26 (m, 2H), 7.17–7.07 (m, 3H), 6.87–6.84 (m, 2H), 3.32 (d, *J* = 16.3 Hz, 1H), 3.18 (d, *J* = 16.2 Hz, 1H), 1.56 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.2 (Ar-C=O), 170.9 (O-C(Ar)), 166.9 (COOR), 150.1 (O-C(Ar)), 137.9 (Ar), 129.3 (Ar), 125.9 (Ar), 124.7 (Ar), 122.0 (Ar), 121.2 (Ar), 120.3 (Ar), 113.3 (Ar), 86.1 (O-C(4°)), 41.6 (CH_2C=O), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{17}H_{14}NaO_4^+$ 305.0784, found 305.0791.



5b

***p*-tolyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5b)**

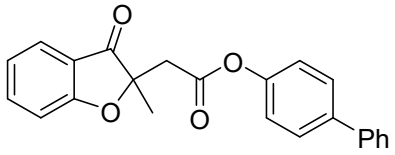
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5b** (48.0 mg, 81% yield) as a white solid: m.p. 80-81 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, *J* = 7.7 Hz, 1H), 7.62–7.58 (m, 1H), 7.11 (d, *J* = 8.4 Hz, 1H), 7.09–7.05 (m, 3H), 6.73 (d, *J* = 8.5 Hz, 2H), 3.29 (d, *J* = 16.2 Hz, 1H), 3.16 (d, *J* = 16.2 Hz, 1H), 2.27 (s, 3H), 1.55 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.2 (Ar-C=O), 170.9 (O-C(Ar)), 167.1 (COOR), 147.8 (O-C(Ar)), 137.8 (Ar), 135.5 (Ar), 129.7 (Ar), 124.6 (Ar), 121.9 (Ar), 120.8 (Ar), 120.3 (Ar), 113.3 (Ar), 86.1 (O-C(4°)), 41.5 (CH_2C=O), 22.5 (CH_3), 20.7 (Ar-CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{18}H_{16}NaO_4^+$ 319.0941, found 319.0950.



5c

4-methoxyphenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5c)

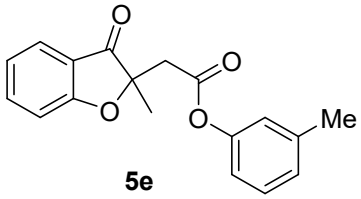
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5c** (57.8 mg, 83% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.7 Hz, 1H), 7.60 (t, *J* = 8.6 Hz, 1H), 7.11–7.06 (m, 2H), 6.78–6.74 (m, 4H), 3.72 (s, 3H), 3.28 (d, *J* = 16.3 Hz, 1H), 3.14 (d, *J* = 16.2 Hz, 1H), 1.54 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.2 (Ar-C=O), 170.9 (O-C(Ar)), 167.3 (COOR), 157.2 (O-C(Ar)), 143.5 (Ar), 137.9 (Ar), 124.7 (Ar), 122.0 (Ar), 121.9 (Ar), 120.3 (Ar), 114.3 (Ar), 113.3 (Ar), 86.2 (O-C(4^{o})), 55.4 (Ar-OCH_3), 41.5 (CH_2C=O), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{18}H_{16}NaO_5^+$ 335.0890, found 335.0899.



5d

[1,1'-biphenyl]-4-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5d)

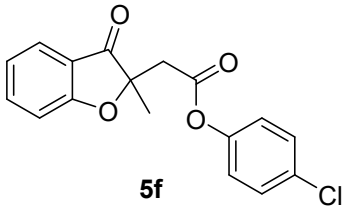
Flash column chromatography on a silica gel (PE:EA=8:1) gives **5d** (50.1 mg, 70% yield) as a white oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.71 (d, *J* = 7.7 Hz, 1H), 7.64-7.61 (m, 1H), 7.50-7.46 (m, 4H), 7.40 (t, *J* = 7.5 Hz, 2H), 7.34-7.31 (m, 1H), 7.14-7.08 (m, 2H), 6.93-6.90 (m, 2H), 3.33 (d, *J* = 16.3 Hz, 1H), 3.20 (d, *J* = 16.3 Hz, 1H), 1.57 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.2 (Ar-C=O), 171.0 (O-C(Ar)), 167.1 (COOR), 149.5 (O-C(Ar)), 140.3 (Ar), 139.2 (Ar), 138.0 (Ar), 128.7 (Ar), 128.1 (Ar), 127.3 (Ar), 127.1 (Ar), 124.8 (Ar), 122.1 (Ar), 121.5 (Ar), 120.4 (Ar), 113.4 (Ar), 86.2 (O-C(4^{o})), 41.7 (CH_2C=O), 22.6 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{23}H_{18}NaO_4^+$ 381.1097, found 381.1102.



5e

***m*-tolyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5e)**

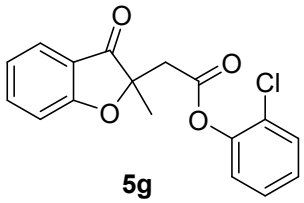
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5e** (40.9 mg, 69% yield) as a white solid: m.p. 95-96 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, *J* = 7.8 Hz, 1H), 7.63–7.60 (m, 1H), 7.16–7.07 (m, 3H), 6.96 (d, *J* = 7.0 Hz, 1H), 6.64 (d, *J* = 11.1 Hz, 2H), 3.29 (d, *J* = 16.3 Hz, 1H), 3.16 (d, *J* = 16.2 Hz, 1H), 2.27 (s, 3H), 1.55 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.3 (Ar-C=O), 171.0 (O-C(Ar)), 167.1 (COOR), 150.0 (O-C(Ar)), 139.5 (Ar), 137.9 (Ar), 127.0 (Ar), 126.7 (Ar), 124.8 (Ar), 122.0 (Ar), 121.8 (Ar), 120.4 (Ar), 118.2 (Ar), 113.4 (Ar), 86.2 (O-C(4°)), 41.6 (CH_2C=O), 22.5 (CH_3), 21.2 (Ar-CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{18}H_{16}NaO_4^+$ 319.0941, found 319.0950.



5f

4-chlorophenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5f)

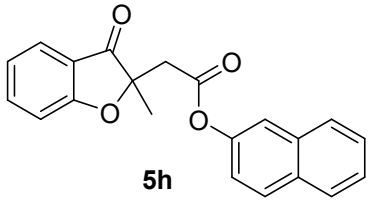
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5f** (42.3 mg, 67% yield) as a white solid: m.p. 79-80 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.5 Hz, 1H), 7.61 (t, *J* = 8.6 Hz, 1H), 7.24–7.20 (m, 2H), 7.11–7.07 (m, 2H), 6.80–6.76 (m, 2H), 3.29 (d, *J* = 16.2 Hz, 1H), 3.15 (d, *J* = 16.3 Hz, 1H), 1.55 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.1 (Ar-C=O), 170.9 (O-C(Ar)), 166.8 (COOR), 148.5 (O-C(Ar)), 138.0 (Ar), 131.3 (Ar), 129.3 (Ar), 124.7 (Ar), 122.6 (Ar), 122.1 (Ar), 120.3 (Ar), 113.3 (Ar), 86.1 (O-C(4°)), 41.5 (CH_2C=O), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{17}H_{13}ClNaO_4^+$ 339.0395, found 339.0404.



5g

2-chlorophenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5g)

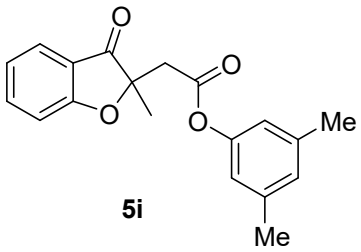
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5g** (39.8 mg, 63% yield) as a white solid: m.p. 103-104 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.7 Hz, 1H), 7.60 (t, *J* = 7.9 Hz, 1H), 7.35 (d, *J* = 7.9 Hz, 1H), 7.17 (t, *J* = 7.7 Hz, 1H), 7.13–7.05 (m, 3H), 6.92 (d, *J* = 8.0 Hz, 1H), 3.34 (d, *J* = 16.6 Hz, 1H), 3.25 (d, *J* = 16.5 Hz, 1H), 1.57 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.1 (Ar-C=O), 171.0 (O-C(Ar)), 166.2 (COOR), 146.5 (O-C(Ar)), 137.9 (Ar), 130.2 (Ar), 127.6 (Ar), 127.1 (Ar), 126.7 (Ar), 124.7 (Ar), 123.4 (Ar), 122.0 (Ar), 120.2 (Ar), 113.4 (Ar), 86.0 (O-C(4^{o})), 40.9 (CH_2C=O), 22.4 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{17}H_{13}ClNaO_4^+$ 339.0395, found 339.0404.



5h

naphthalen-2-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5h)

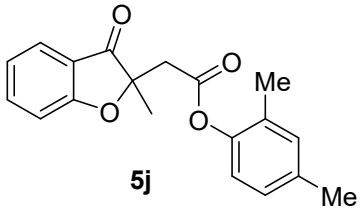
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5h** (47.2 mg, 71% yield) as a yellowish solid: m.p. 100-102 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83–7.80 (m, 2H), 7.70–7.68 (m, 2H), 7.61–7.57 (m, 1H), 7.52–7.46 (m, 2H), 7.37 (t, *J* = 7.9 Hz, 1H), 7.15 (d, *J* = 8.4 Hz, 1H), 7.07–7.03 (m, 2H), 3.49 (d, *J* = 16.3 Hz, 1H), 3.37 (d, *J* = 16.2 Hz, 1H), 1.63 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.2 (Ar-C=O), 170.9 (O-C(Ar)), 167.2 (COOR), 146.1 (O-C(Ar)), 137.9(2C, Ar), 134.5 (Ar), 127.9 (Ar), 126.43 (Ar), 126.37 (Ar), 126.1 (Ar), 125.2 (Ar), 124.7 (Ar), 122.1 (Ar), 121.1 (Ar), 120.3 (Ar), 117.8 (Ar), 113.3 (Ar), 86.2 (O-C(4^{o})), 41.4 (CH_2C=O), 22.5 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for C21H16NaO4$^+$ 355.0941, found 355.0950.



5i

3,5-dimethylphenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5i)

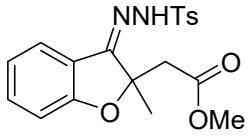
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5i** (46.5 mg, 75% yield) as a white solid: m.p. 117-118 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.70 (d, *J* = 7.7 Hz, 1H), 7.63–7.60 (m, 1H), 7.13–7.07 (m, 2H), 6.78 (s, 1H), 6.45 (s, 2H), 3.29 (d, *J* = 16.3 Hz, 1H), 3.15 (d, *J* = 16.2 Hz, 1H), 2.22 (s, 6H), 1.55 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.3 (Ar-C=O), 171.0 (O-C(Ar)), 167.2 (COOR), 150.0 (Ar), 139.1 (Ar), 137.8 (Ar), 127.6 (Ar), 124.7 (Ar), 121.9 (Ar), 120.4 (Ar), 118.8 (Ar), 113.4 (Ar), 86.2 (O-C(4^{o})), 41.6 (CH_2C=O), 22.5 (CH_3), 21.1 (Ar-CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{19}H_{18}NaO_4^+$ 333.1097, found 333.1106.



5j

2,4-dimethylphenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5j)

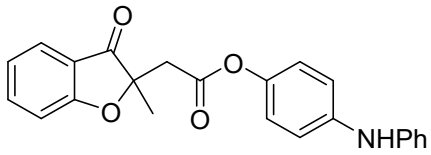
Flash column chromatography on a silica gel (PE/EA, v/v, 8:1) gives **5j** (44.7 mg, 72% yield) as a white solid: m.p. 90-91 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.68 (d, *J* = 7.7 Hz, 1H), 7.61–7.58 (m, 1H), 7.11–7.05 (m, 2H), 6.95 (s, 1H), 6.90 (d, *J* = 8.1 Hz, 1H), 6.65 (d, *J* = 8.2 Hz, 1H), 3.31 (d, *J* = 16.4 Hz, 1H), 3.20 (d, *J* = 16.3 Hz, 1H), 2.24 (s, 3H), 2.04 (s, 3H), 1.56 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.3 (Ar-C=O), 170.9 (O-C(Ar)), 167.1 (COOR), 146.6 (Ar), 137.8 (Ar), 135.7 (Ar), 131.6 (Ar), 129.5 (Ar), 127.3 (Ar), 124.7 (Ar), 122.0 (Ar), 121.1 (Ar), 120.4 (Ar), 113.3 (Ar), 86.2 (O-C(4^{o})), 41.2 (CH_2C=O), 22.5 (CH_3), 20.7 (Ar-CH_3), 15.9 (Ar-CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{19}H_{18}NaO_4^+$ 333.1097, found 333.1106.



6

methyl (*E*)-2-(2-methyl-3-(2-tosylhydrazineylidene)-2,3-dihydrobenzofuran-2-yl)acetate (6)

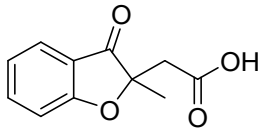
Flash column chromatography on a silica gel (PE:EA=4:1) gives **6** (68.3 mg, 88% yield) as a yellow solid: m.p. 136-137 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.96-7.79 (m, 4H), 7.39 (t, *J* = 7.9 Hz, 1H), 7.27 (s, 1H), 6.99-6.91 (m, 2H), 3.37 (s, 3H), 2.82 (d, *J* = 16.1 Hz, 1H), 2.75 (d, *J* = 16.2 Hz, 1H), 2.39 (s, 3H), 1.45 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 169.1 (O-C(Ar)), 164.3 (COOR), 160.0 (C=N), 144.0 (S-C(Ar)), 134.7 (Ar), 134.4 (Ar), 129.2 (Ar), 128.3 (Ar), 126.3 (Ar), 121.3 (Ar), 117.6 (Ar), 112.1 (Ar), 86.0 (O-C(4^{o})), 51.4 (O-CH_3), 43.5 (CH_2C=O), 25.4 (CH_3), 21.5 (CH_3). HRMS(ESI) m/z: $[M+K]^+$ Calcd. for $C_{19}H_{20}KN_2O_5S^+$ 427.0725, found 427.0736.



7

propyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (7)

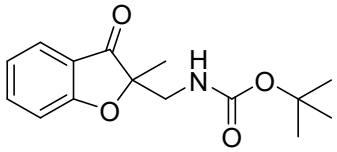
Flash column chromatography on a silica gel (PE:EA=8:1) gives **7** (43.3 mg, 58% yield) as a yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.73 (d, *J* = 7.5 Hz, 1H), 7.66-7.62 (m, 1H), 7.27-7.24 (m, 2H), 7.15-7.09 (m, 2H), 7.03-6.92 (m, 5H), 6.77-6.74 (m, 2H), 3.31 (d, *J* = 16.2 Hz, 1H), 3.18 (d, *J* = 16.3 Hz, 1H), 1.58 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.3 (Ar-C=O), 171.0 (O-C(Ar)), 167.4 (COOR), 144.0 (Ar), 143.1 (Ar), 141.0 (Ar), 137.9 (Ar), 129.4 (Ar), 124.8 (Ar), 122.04 (Ar), 121.99 (Ar), 121.1 (Ar), 120.4 (Ar), 118.6 (Ar), 117.7 (Ar), 113.4 (Ar), 86.2 (O-C(4^{o})), 41.6 (CH_2C=O), 22.6 (CH_3). HRMS(ESI) m/z: $[M+H]^+$ Calcd. for $C_{23}H_{20}NO_4^+$ 374.1387, found 374.1396.



8

2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetic acid (8)

Flash column chromatography on a silica gel (EA:MeOH=10:1) gives **8** (39.1 mg, 95% yield) as a white solid: m.p. 165-166 ^{o}C; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (d, J = 7.7 Hz, 1H), 7.62-7.58 (m, 1H), 7.09-7.05 (m, 2H), 2.99 (d, J = 16.6 Hz, 1H), 2.91 (d, J = 16.6 Hz, 1H), 1.46 (s, 3H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 202.5 (Ar-C=O), 173.8 (O-C(Ar)), 170.9 (COOH), 138.0 (Ar), 124.7 (Ar), 122.0 (Ar), 120.1 (Ar), 113.4 (Ar), 86.0 (O-C(4^{o})), 40.8 (CH_2C=O), 22.2 (CH_3). HRMS(ESI) m/z: $[M-H]^-$ Calcd. for $C_{11}H_9O_4^-$ 205.0506, found 205.0506.



9

***tert*-butyl ((2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)methyl)carbamate (9)**

Flash column chromatography on a silica gel (PE:EA=8:1) gives **9** (28.3 mg, 55% yield) as a colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65-7.60 (m, 2H), 7.11-7.06 (m, 2H), 4.76 (s, 1H), 3.54-3.45 (m, 2H), 1.44 (s, 3H), 1.37 (s, 9H). ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ 201.3 (Ar-C=O), 171.5 (O-C(Ar)), 156.7 (N-C=O), 138.3 (Ar), 124.7 (Ar), 122.0 (Ar), 120.3 (Ar), 113.5 (Ar), 89.1 (O-C(4^{o})), 79.7 (O-C), 45.3 (CH_2NH), 28.2 (CH_3), 19.1 (CH_3). HRMS(ESI) m/z: $[M+Na]^+$ Calcd. for $C_{15}H_{19}NNaO_4^+$ 300.1206, found 300.1215.

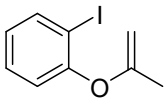
IV. References

1. Bovonsombat, P.; Leykajarakul, J.; Khan, C.; Pla-on, K.; Krause, M. M.; Khanthapura, P.; Ali, R.; Doowa, N. Regioselective iodination of phenol and analogues using *N*-iodosuccinimide and *p*-toluenesulfonic acid. *Tetrahedron Lett*. **2009**, *50*, 2664-2667.
2. García-Lacuna, J.; Alonso, M.; Domíngueza, G.; Pérez Castells, J. Study of the Pauson–Khand reaction in flow over alkynylphenyl vinyl ethers: towards the synthesis of tricyclic multisubstituted benzofurans. *RSC Adv*. **2022**, *12*, 7313-7317.
3. Allwood, D. M.; Blakemore, D. C.; Ley, S. V. Preparation of Unsymmetrical Ketones from Tosylhydrazones and Aromatic Aldehydes via Formyl C–H Bond Insertion. *Org. Lett.* **2014**, *16*, 3064–3067.
4. Hu, W.; Teng, F.; Hu, H.; Luo, S.; Zhu, Q. Pd-Catalyzed C(sp^2)–H Imidoylative Annulation: A General Approach to Construct Dibenzoox(di)azepines. *J. Org. Chem*. **2019**, *84*, 6524–6535.
5. Li, Q.; Zhang, Y.; Zeng, Y.; Fan, Y.; Lin, A.; Yao, H. Palladium-Catalyzed Asymmetric Dearomative Carbonylation of Indoles. *Org. Lett*. **2022**, *24*, 3033−3037.
6. Rafiński, Z. NHC-Catalyzed Organocatalytic Asymmetric Approach to 2,2-Disubstituted Benzofuran-3(2*H*)-ones Containing Fully Substituted Quaternary Stereogenic Center. *Catalysts* **2019**, *9*, 192-213.

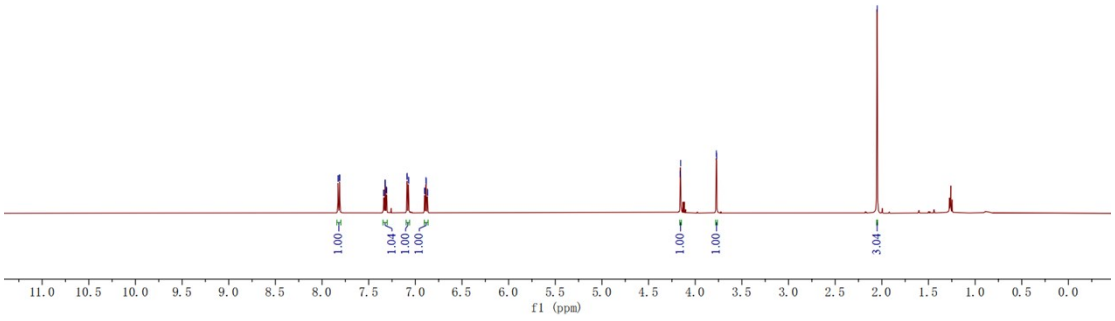
V. Copies NMR Spectra

1-iodo-2-(prop-1-en-2-yloxy)benzene (1a)

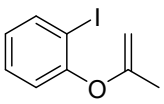
^{1}H NMR (500 MHz, $CDCl_3$)



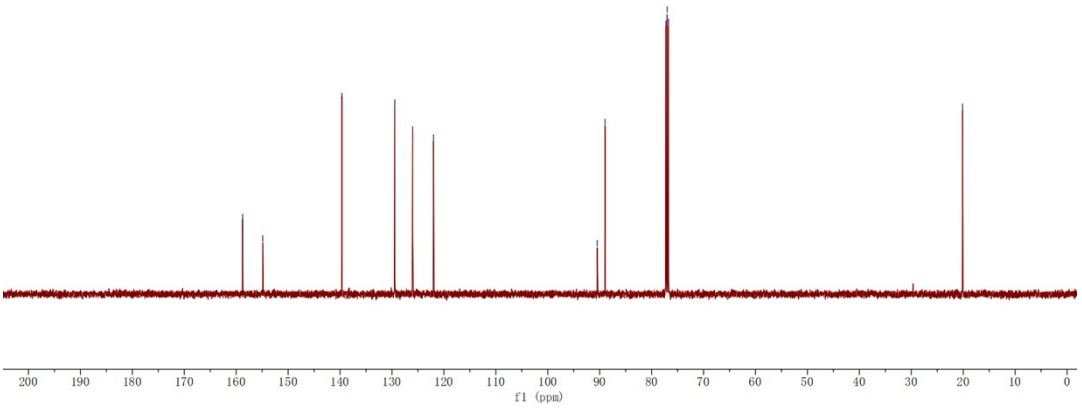
1a



$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

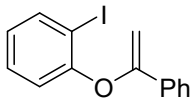


1a

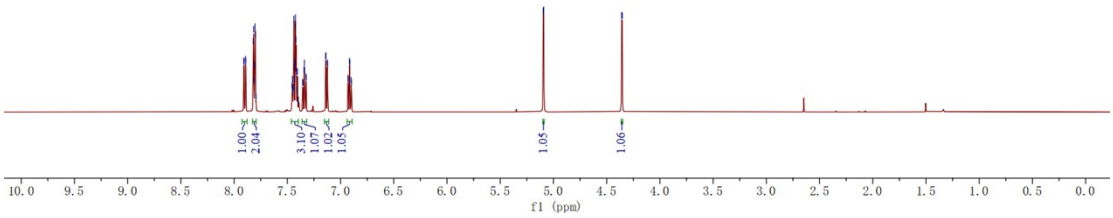


1-iodo-2-(prop-1-en-2-yloxy)benzene (1r)

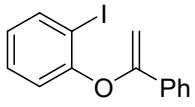
^{1}H NMR (500 MHz, $CDCl_3$)



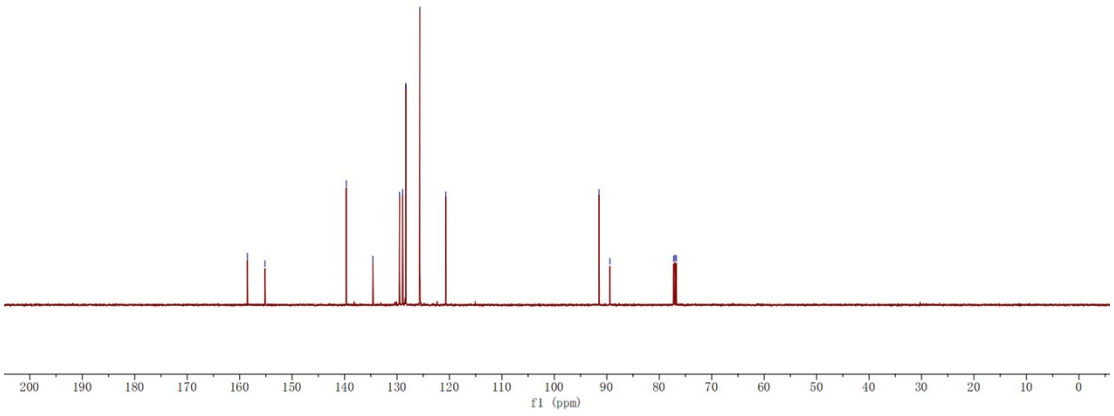
1r



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

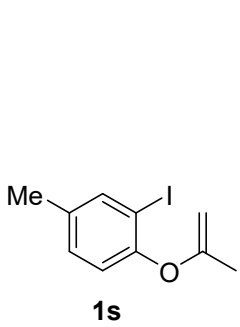


1r



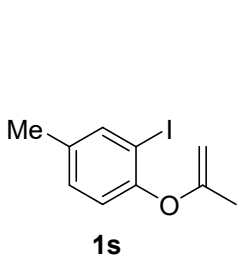
2-iodo-4-methyl-1-(prop-1-en-2-yloxy)benzene (1s)

^{1}H NMR (500 MHz, $CDCl_3$)



1s

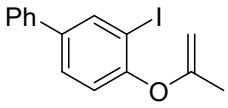
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



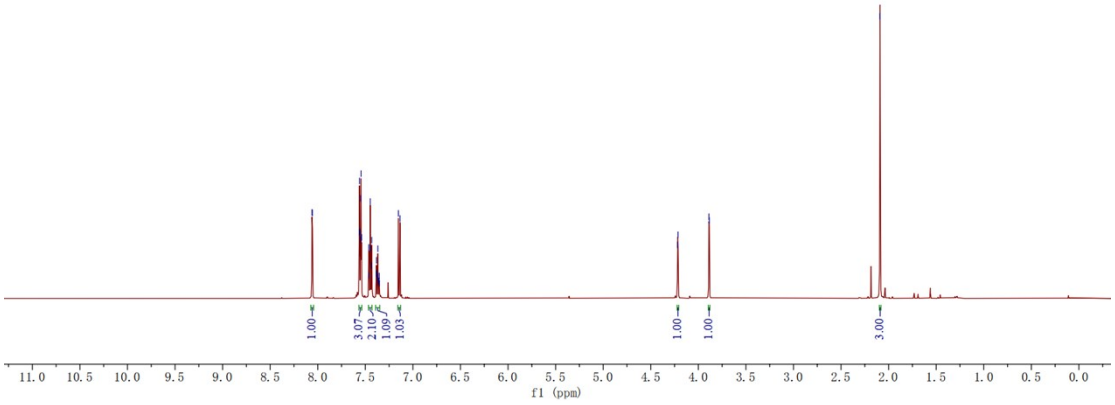
1s

3-iodo-4-(prop-1-en-2-yloxy)-1,1'-biphenyl (1t)

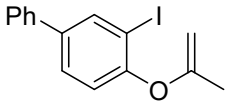
^{1}H NMR (500 MHz, $CDCl_3$)



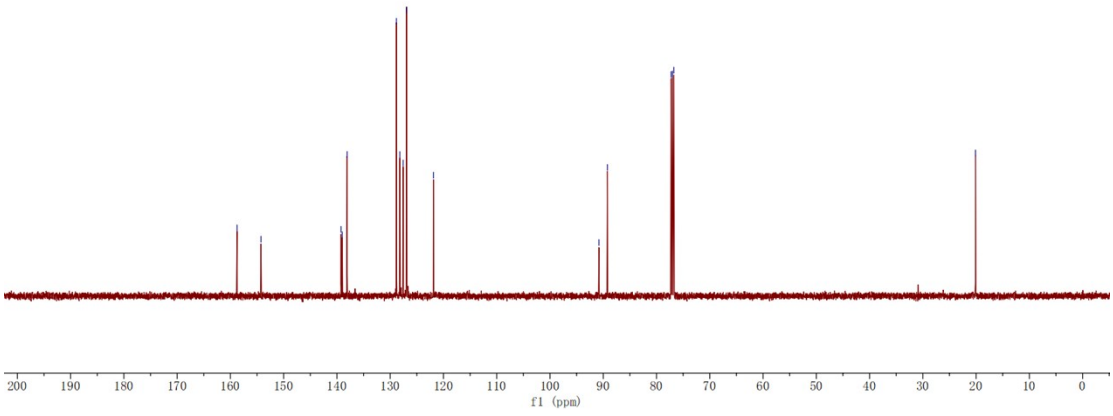
1t



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

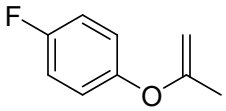


1t

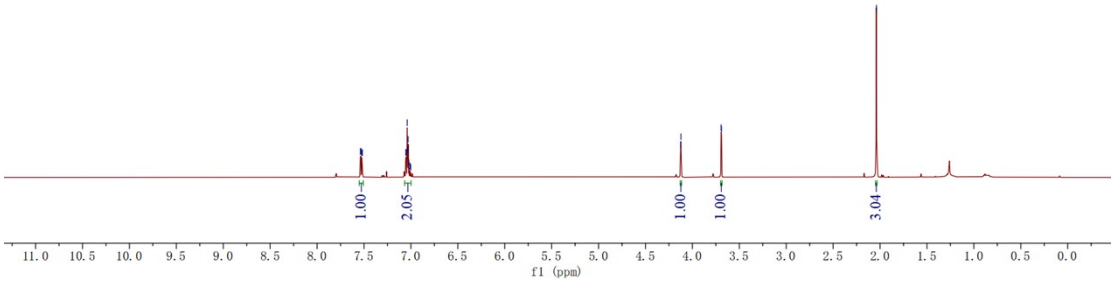


4-fluoro-2-iodo-1-(prop-1-en-2-yloxy)benzene (1u)

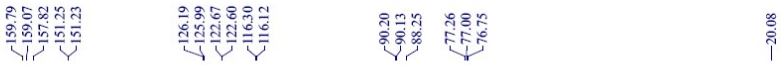
^{1}H NMR (500 MHz, $CDCl_3$)

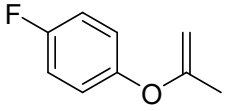


1u

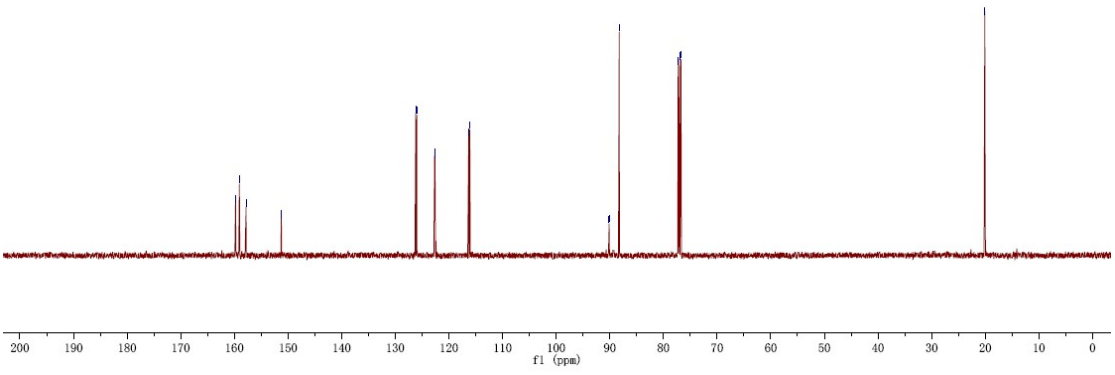


$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

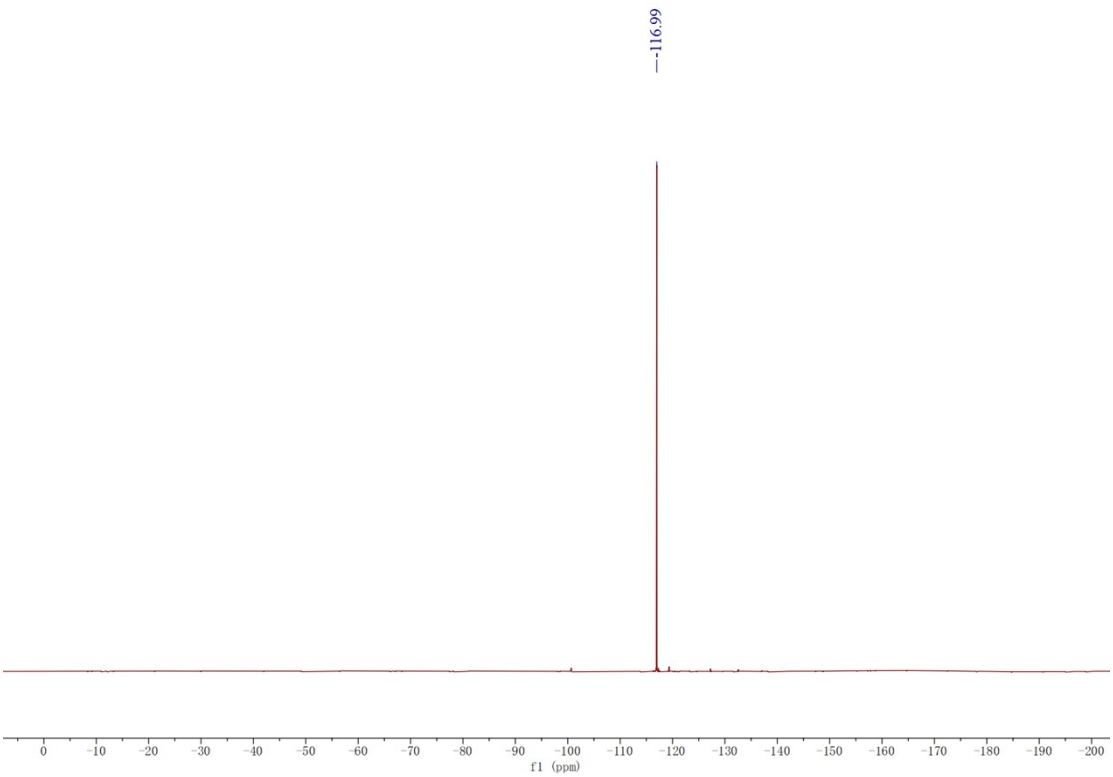




1u

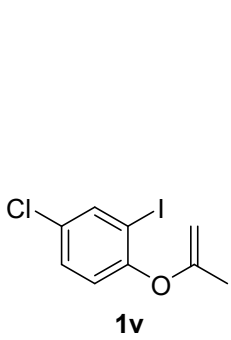


^{19}F NMR (471 MHz, $CDCl_3$)



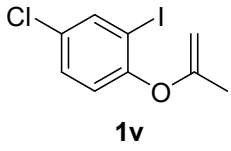
4-chloro-2-iodo-1-(prop-1-en-2-yloxy)benzene (1v)

^{1}H NMR (500 MHz, $CDCl_3$)



1v

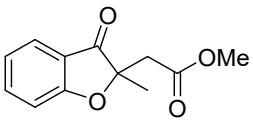
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



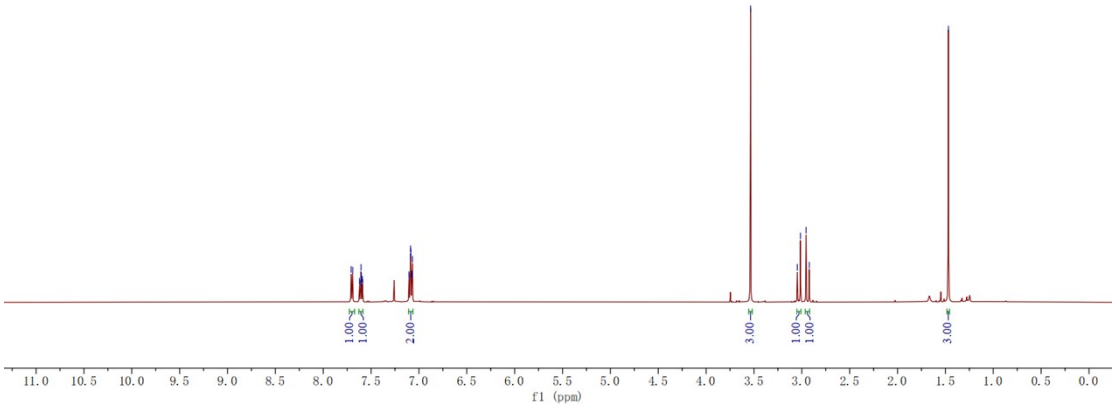
1v

methyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3a)

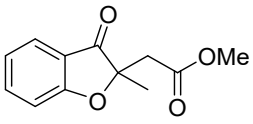
^{1}H NMR (500 MHz, $CDCl_3$)



3a



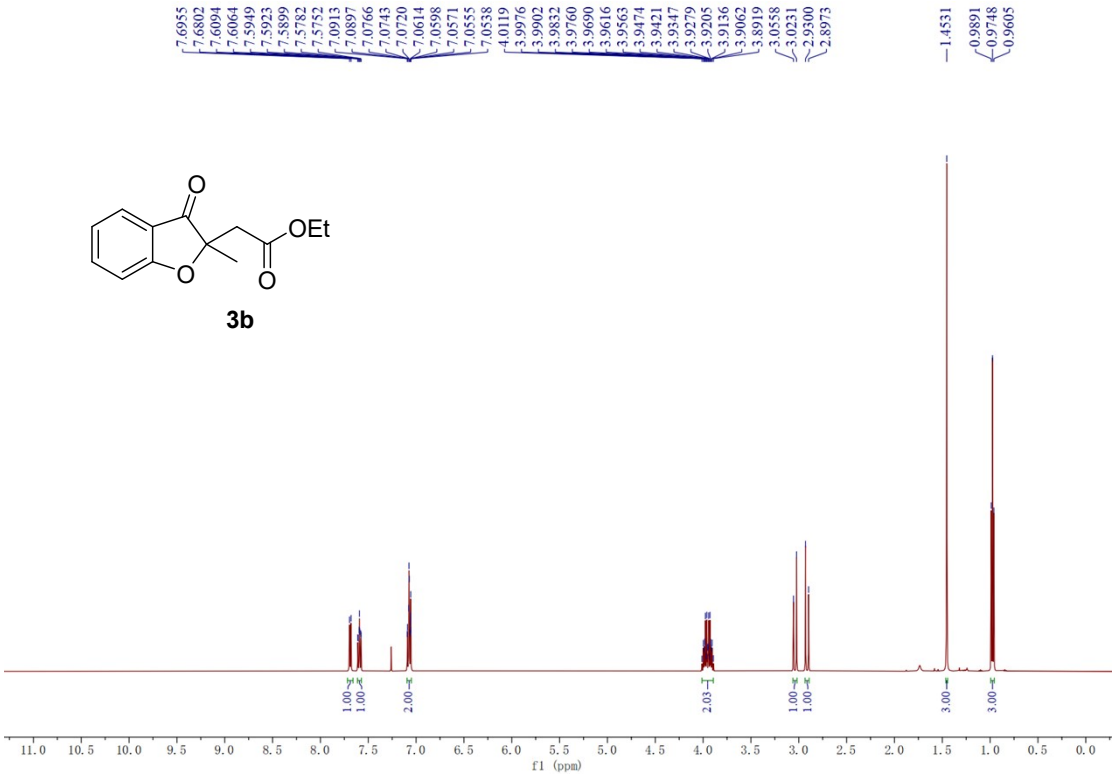
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



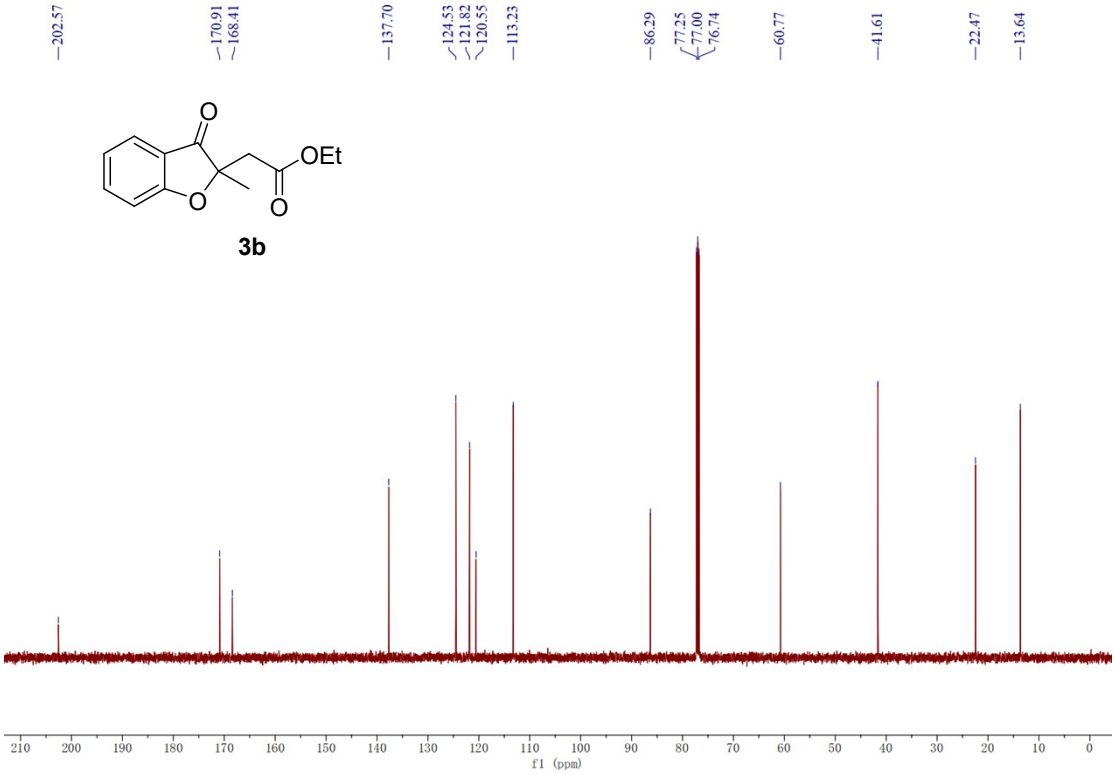
3a

ethyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3b)

^{1}H NMR (500 MHz, $CDCl_3$)

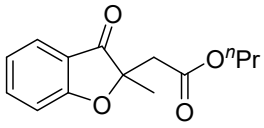


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

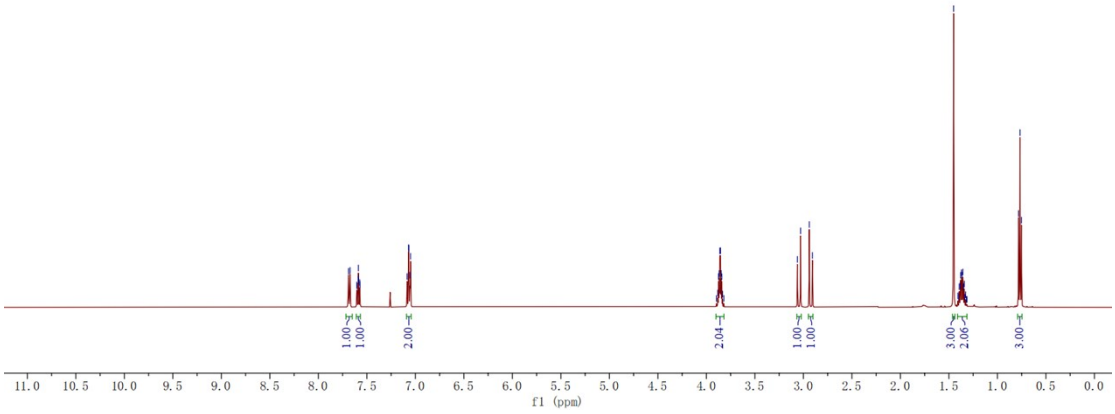


propyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3c)

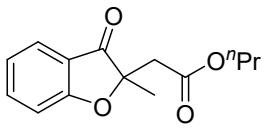
^{1}H NMR (500 MHz, $CDCl_3$)



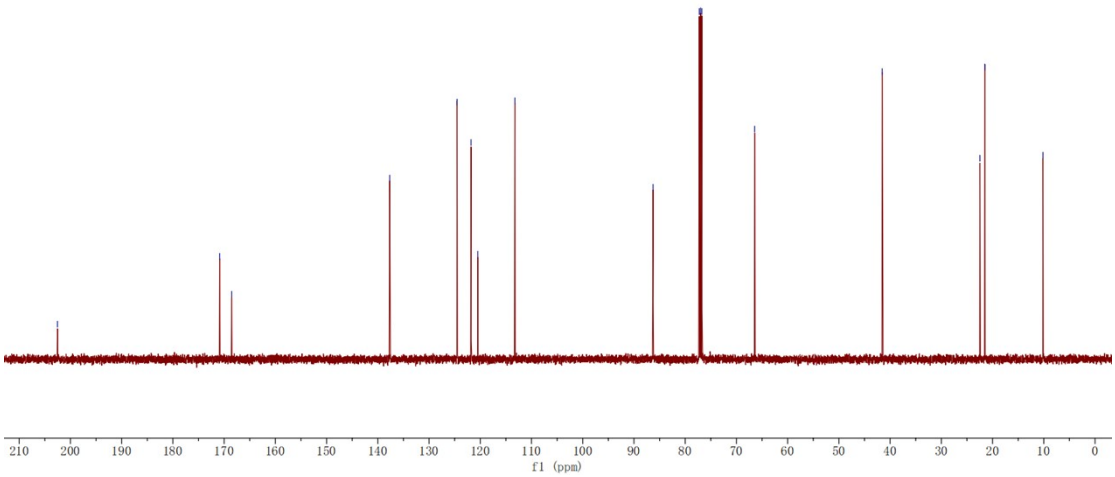
3c



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

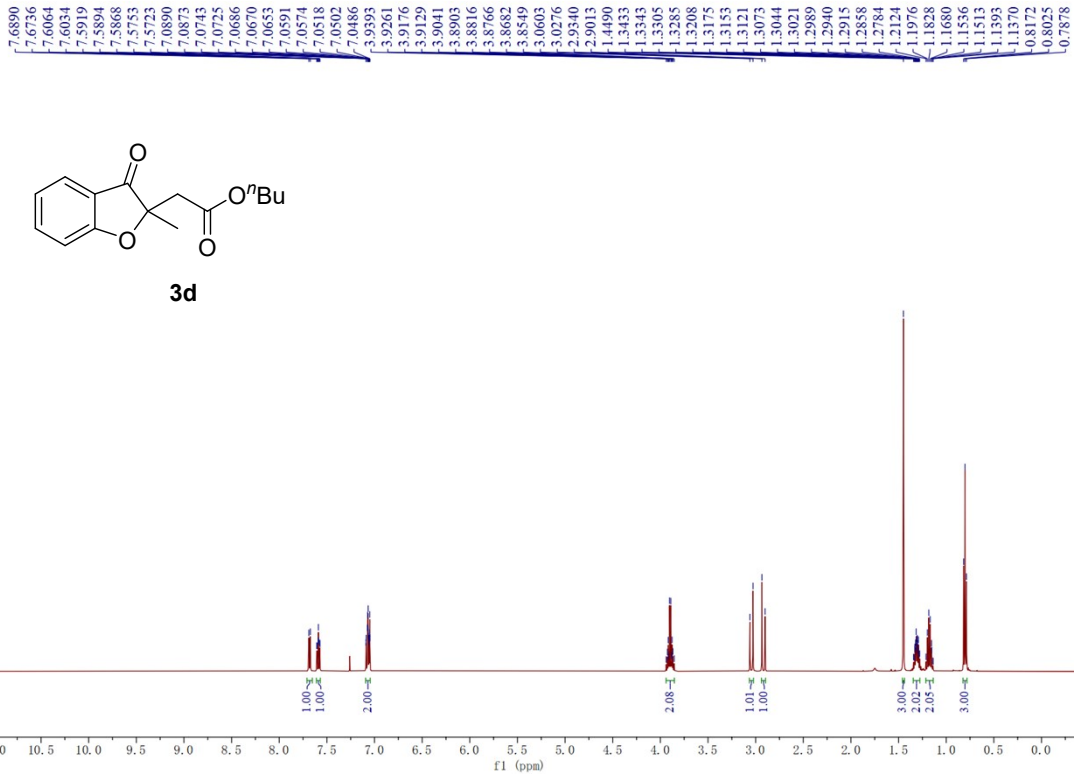


3c



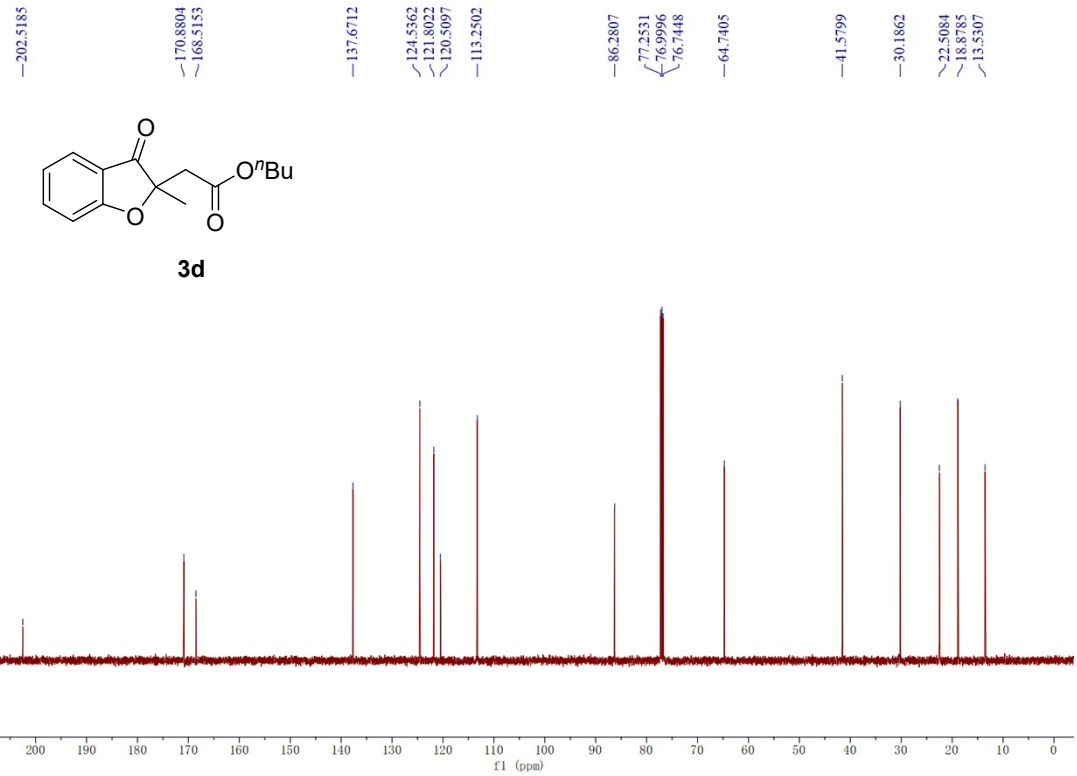
butyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3d)

^{1}H NMR (500 MHz, $CDCl_3$)



3d

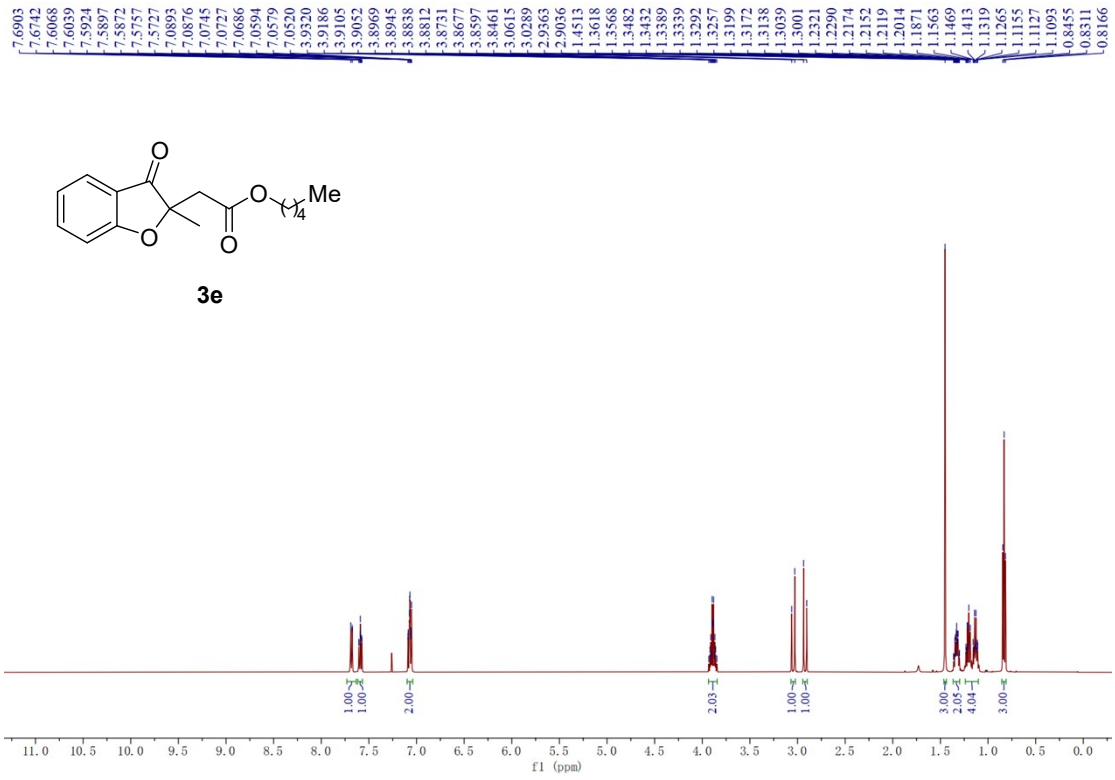
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



3d

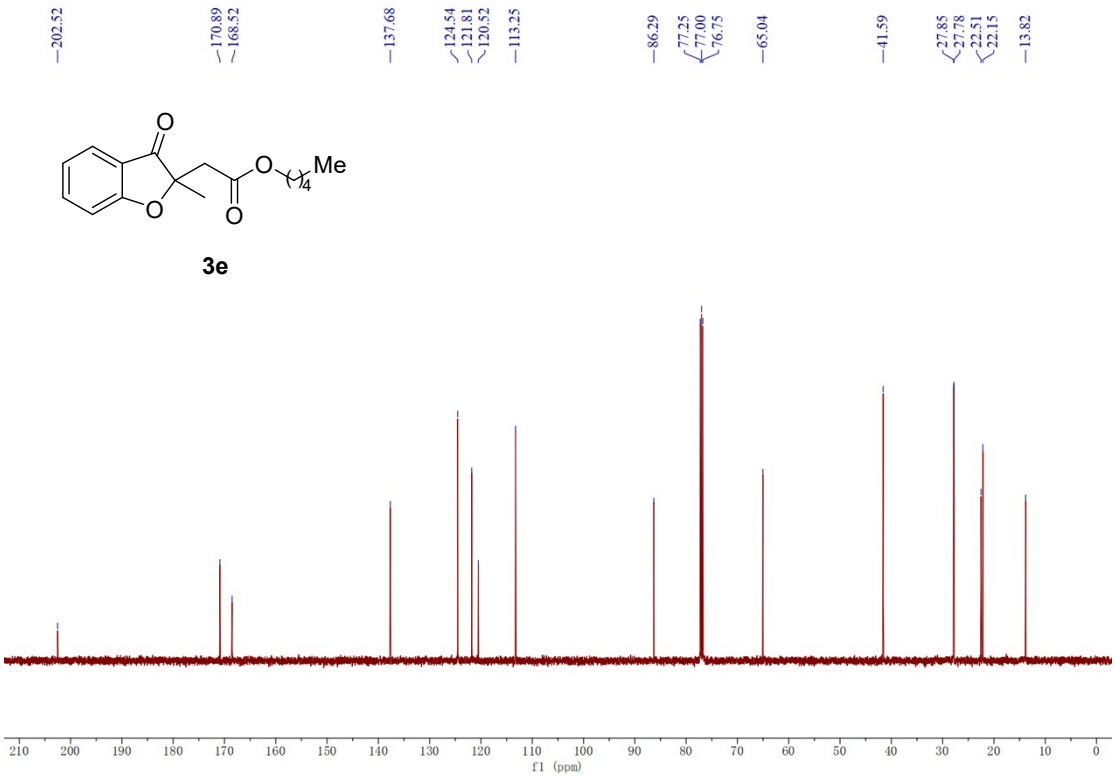
pentyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3e)

^{1}H NMR (500 MHz, $CDCl_3$)



3e

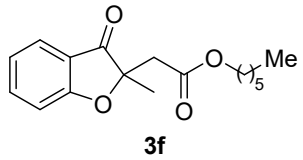
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



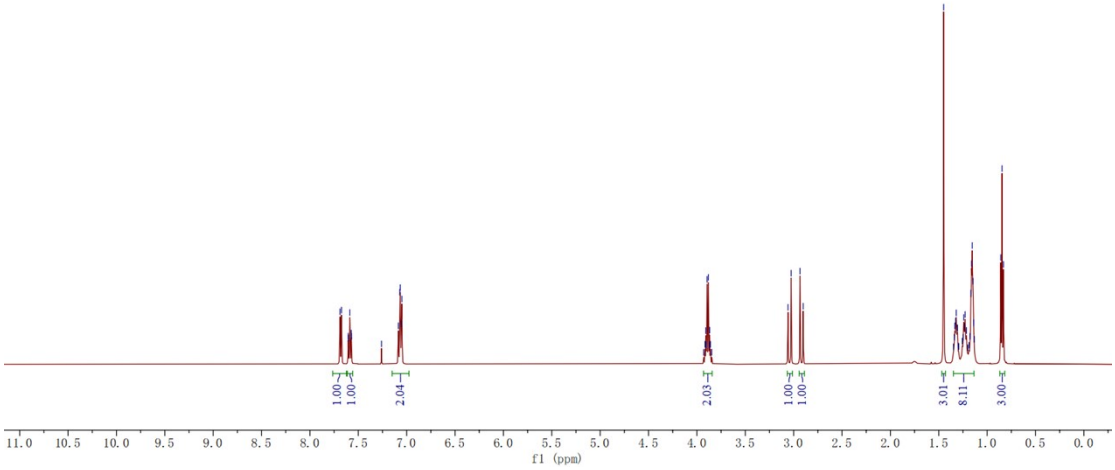
3e

hexyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3f)

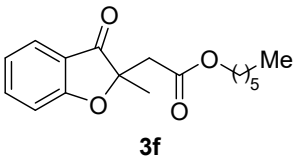
^{1}H NMR (500 MHz, $CDCl_3$)



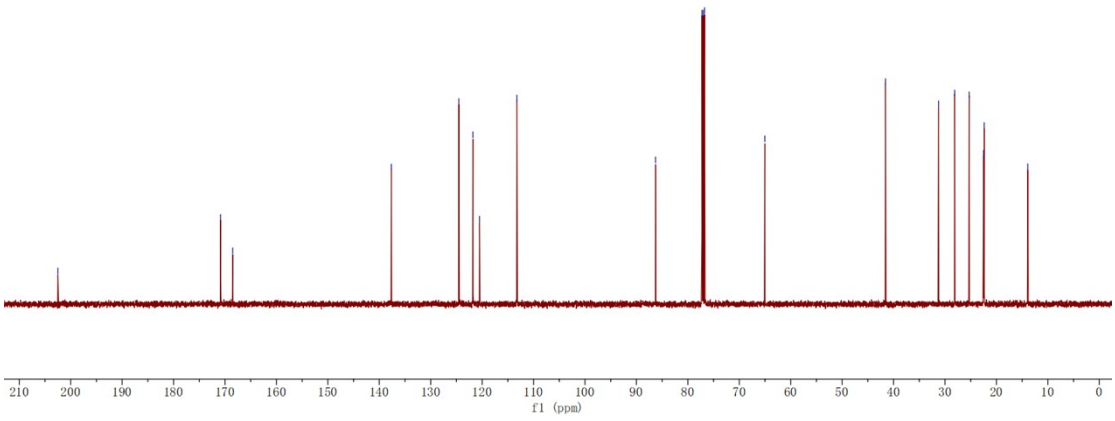
3f



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

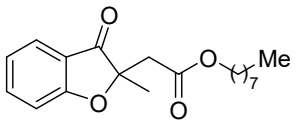


3f

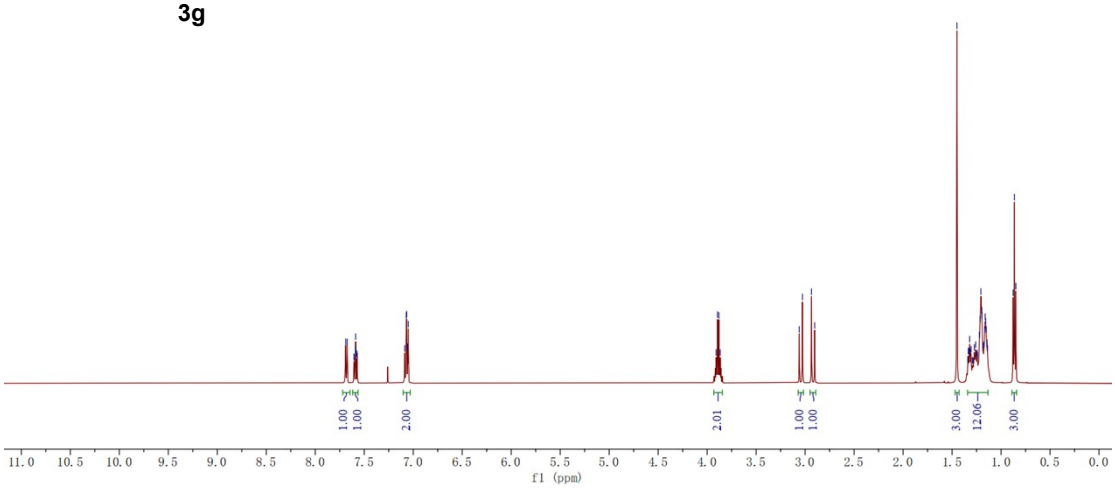


octyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3g)

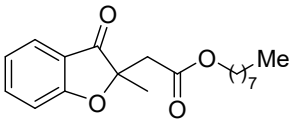
^{1}H NMR (500 MHz, $CDCl_3$)



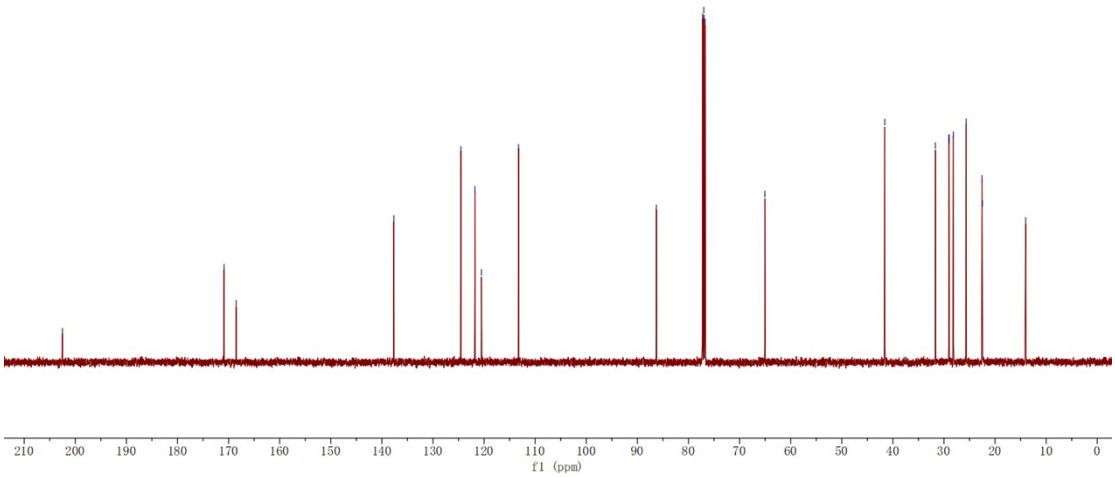
3g



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

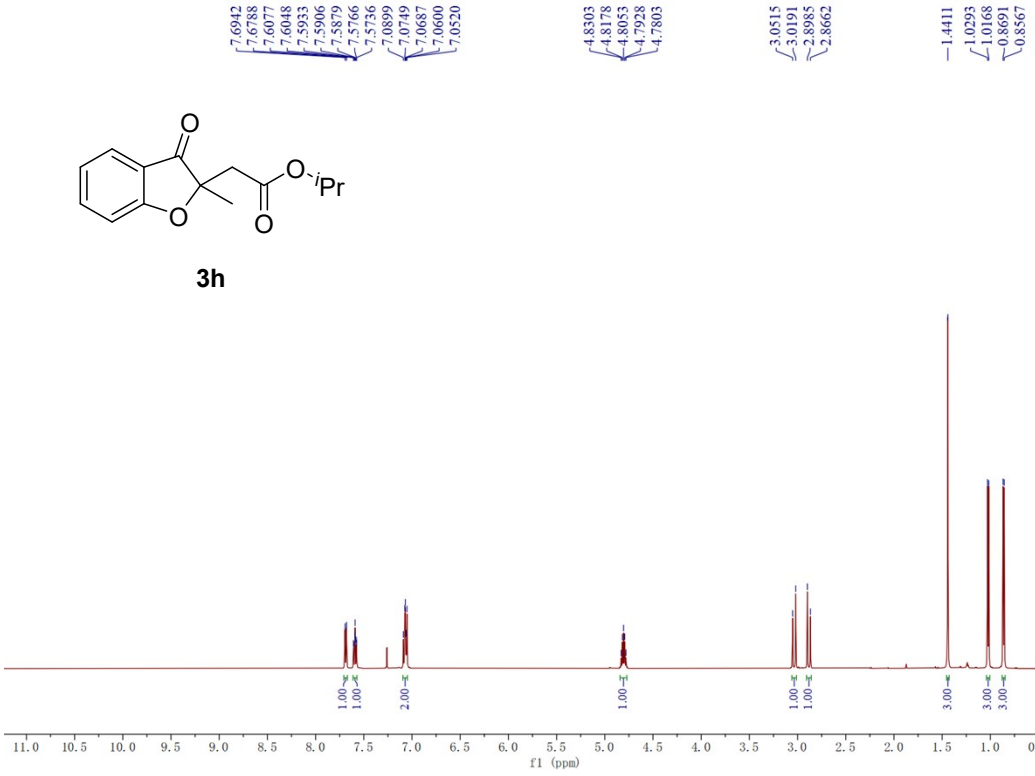


3g

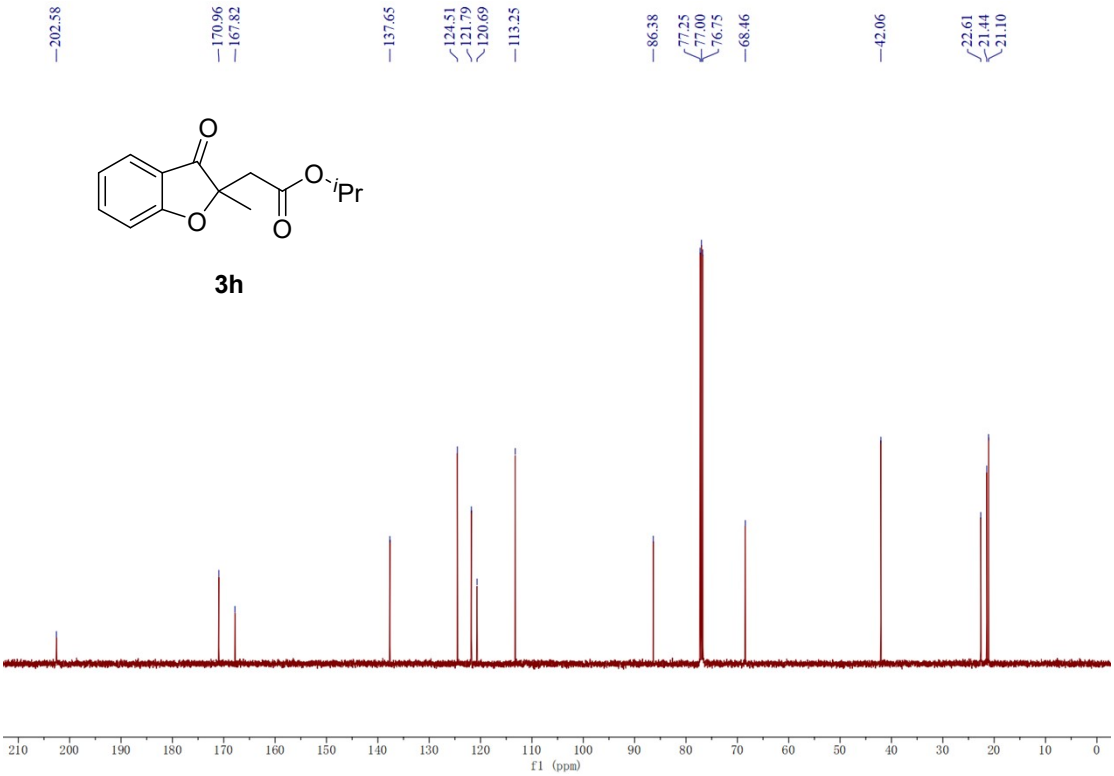


isopropyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3h)

^{1}H NMR (500 MHz, $CDCl_3$)

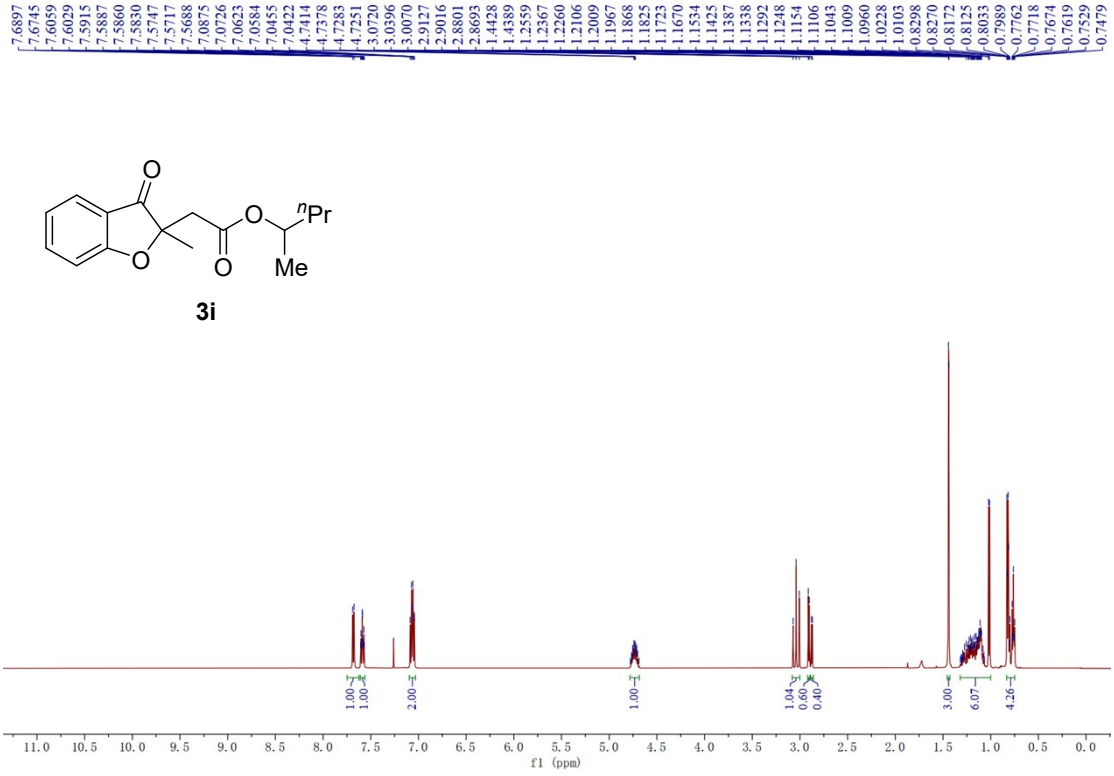


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



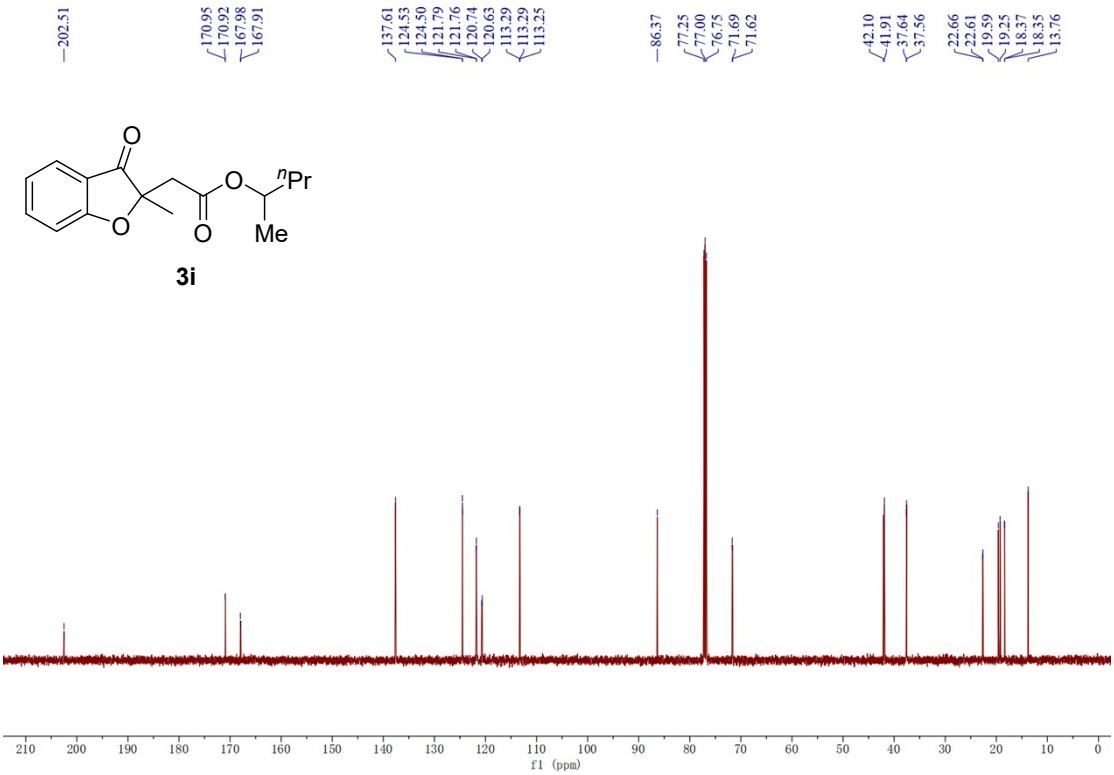
pentan-2-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3i)

^{1}H NMR (500 MHz, $CDCl_3$)



3i

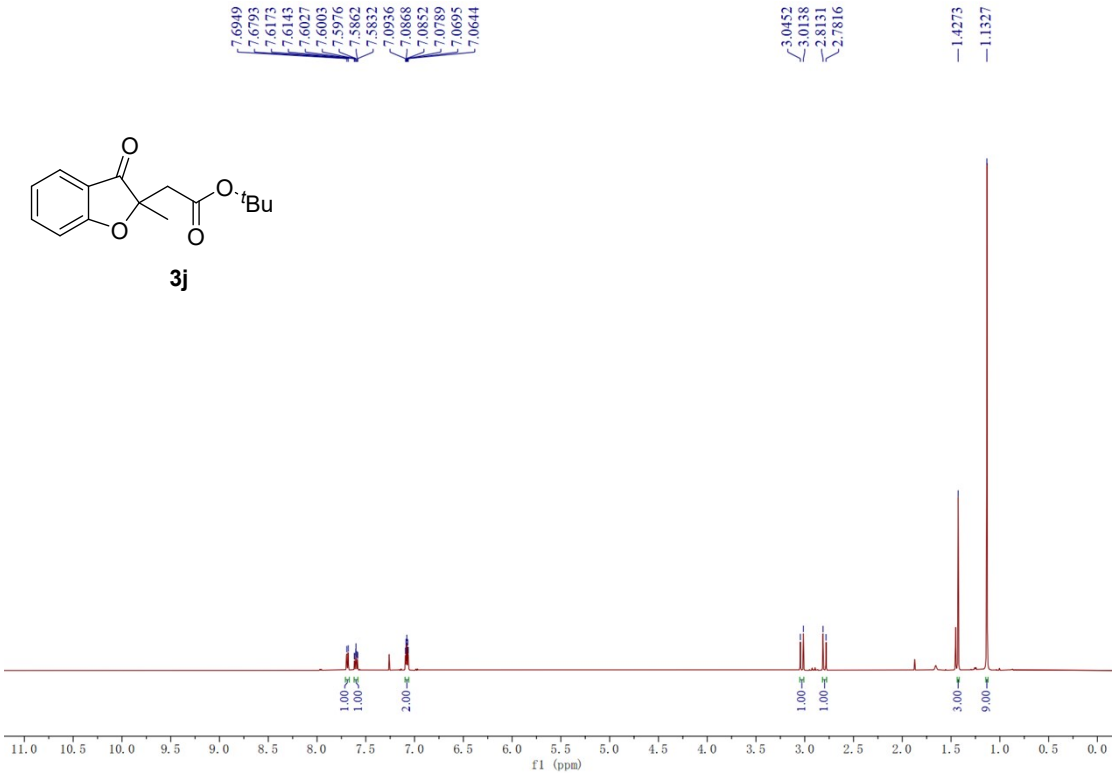
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



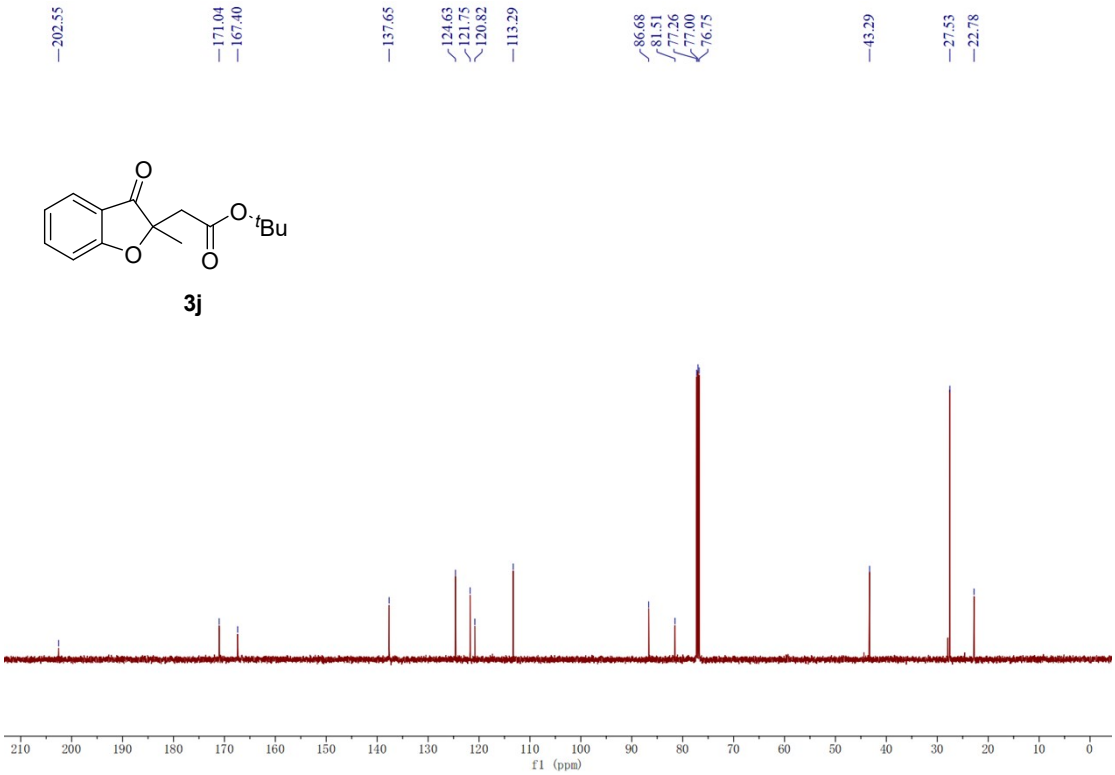
3i

tert-butyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3j)

^{1}H NMR (500 MHz, $CDCl_3$)

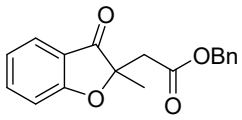


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

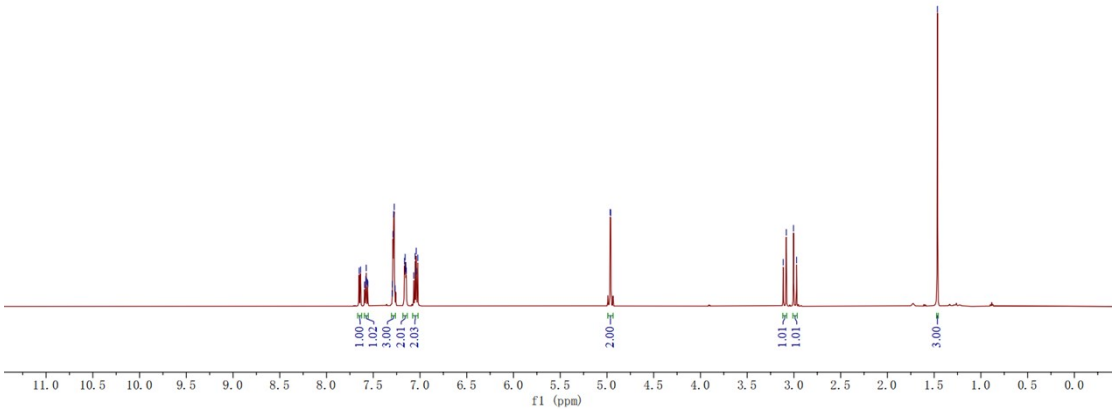


benzyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3k)

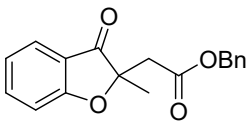
^{1}H NMR (500 MHz, $CDCl_3$)



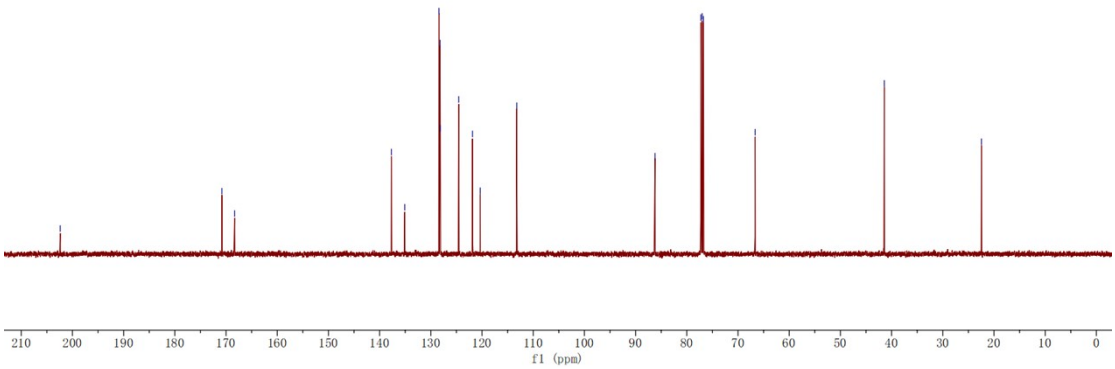
3k



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

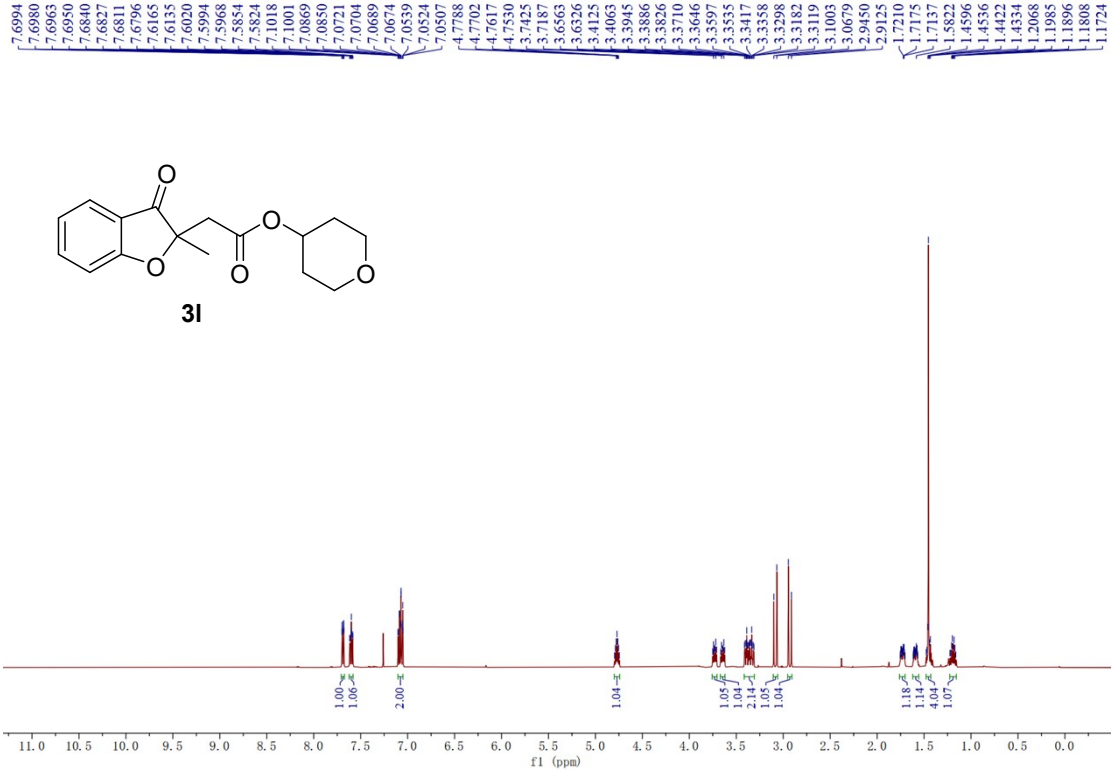


3k



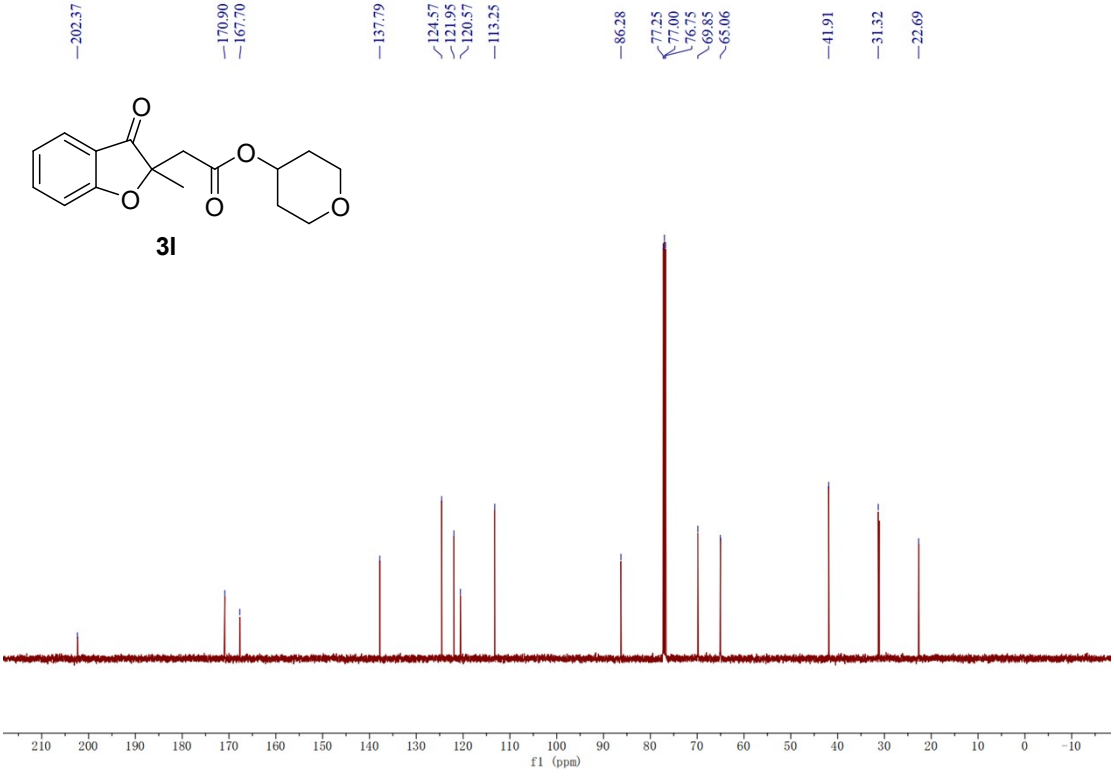
tetrahydro-*2H*-pyran-4-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3l)

^{1}H NMR (500 MHz, $CDCl_3$)



3l

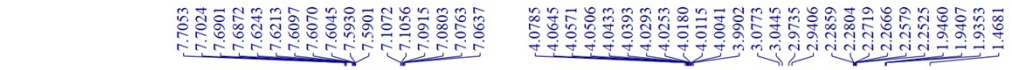
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

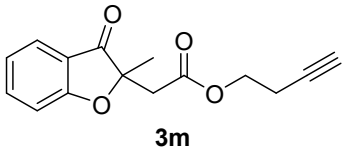


3l

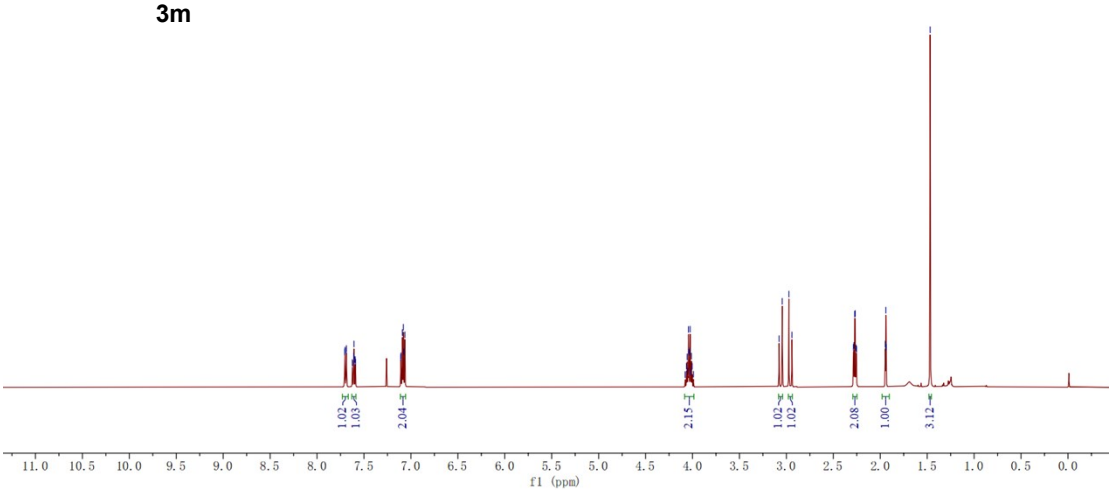
but-3-yn-1-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3m)

^{1}H NMR (500 MHz, $CDCl_3$)

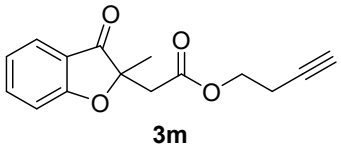




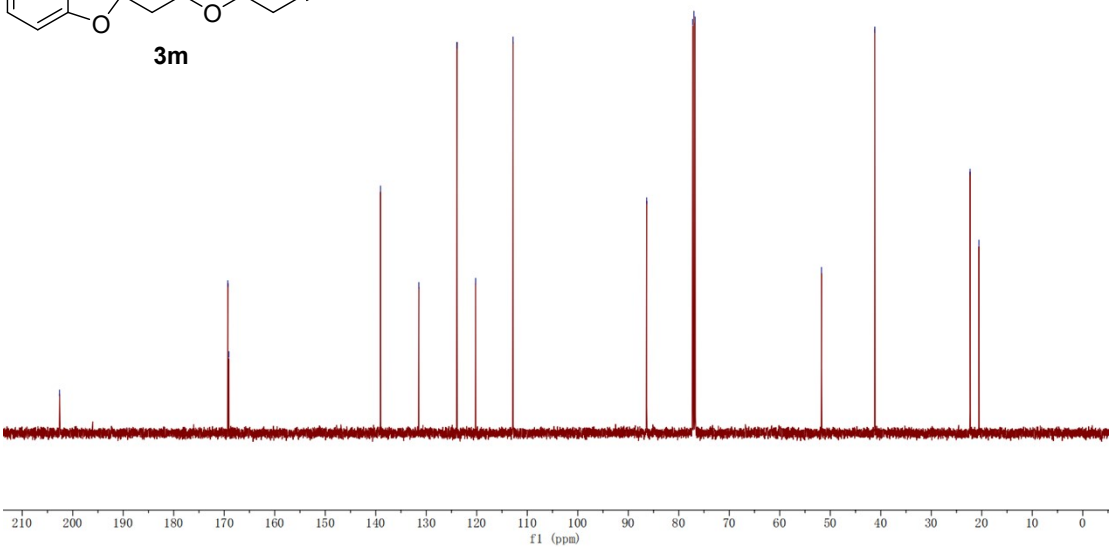
3m



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

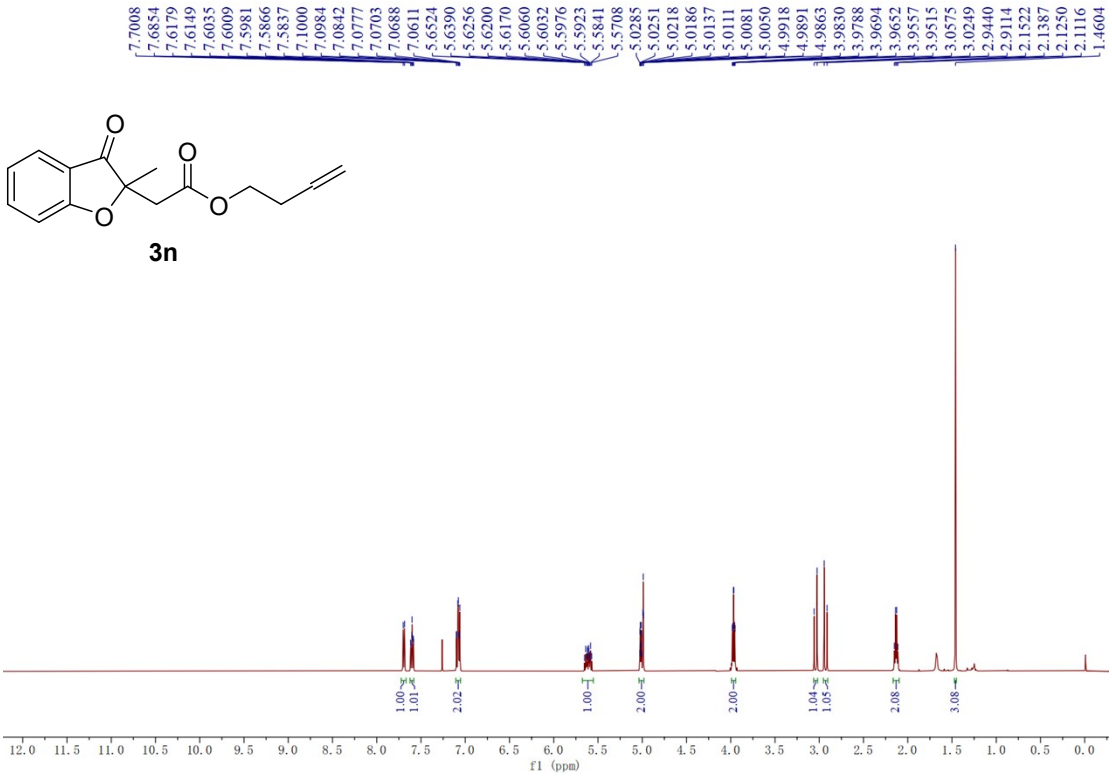


3m

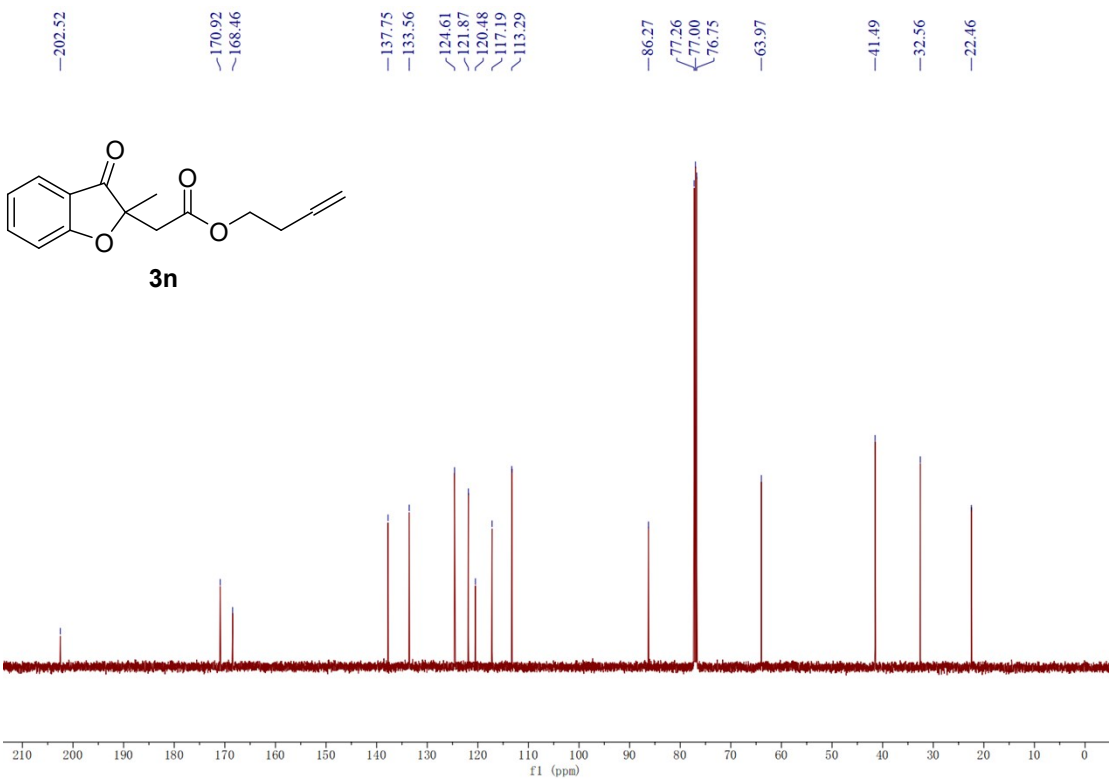


but-3-en-1-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3n)

^{1}H NMR (500 MHz, $CDCl_3$)

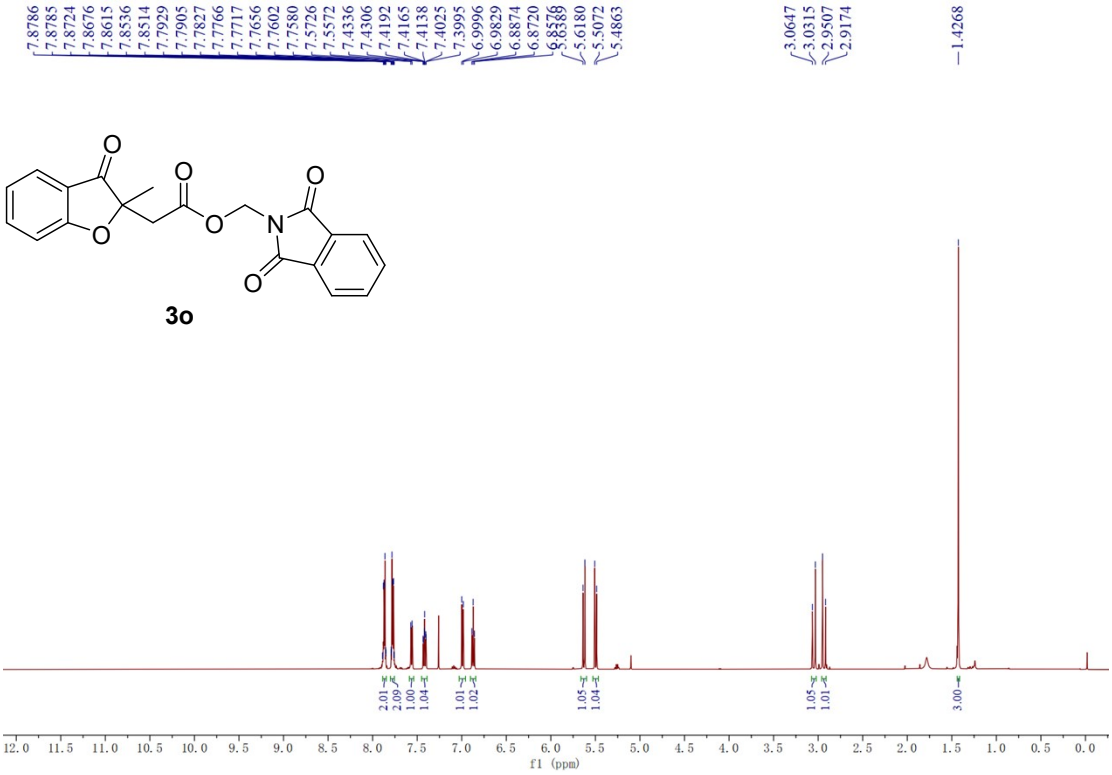


$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

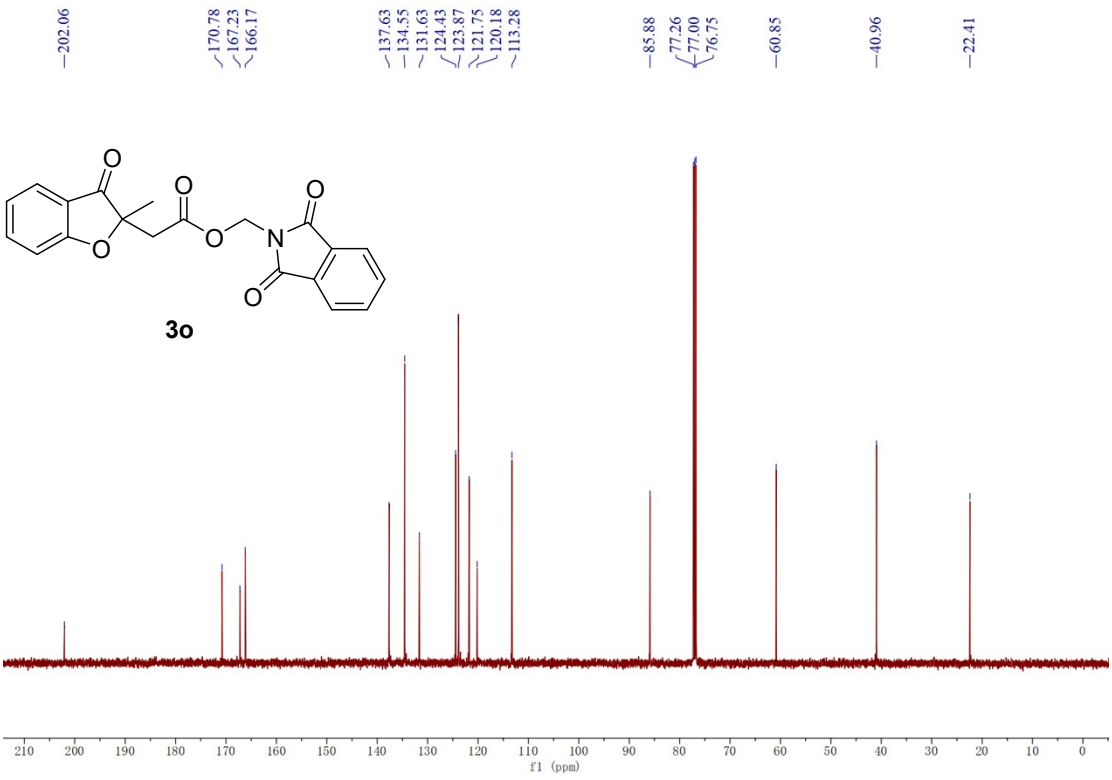


(1,3-dioxoisoindolin-2-yl)methyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3o)

^{1}H NMR (500 MHz, $CDCl_3$)

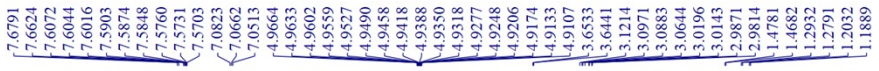


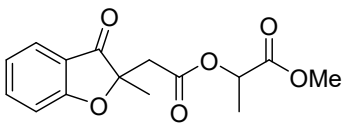
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



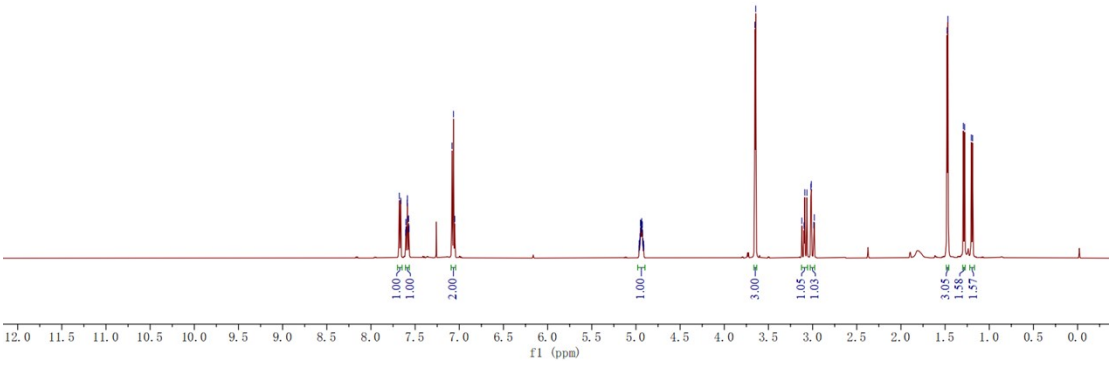
methyl 2-(2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetoxy)propanoate (3p)

^{1}H NMR (500 MHz, $CDCl_3$)

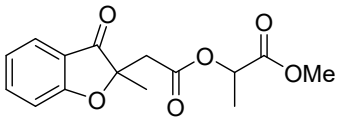




3p



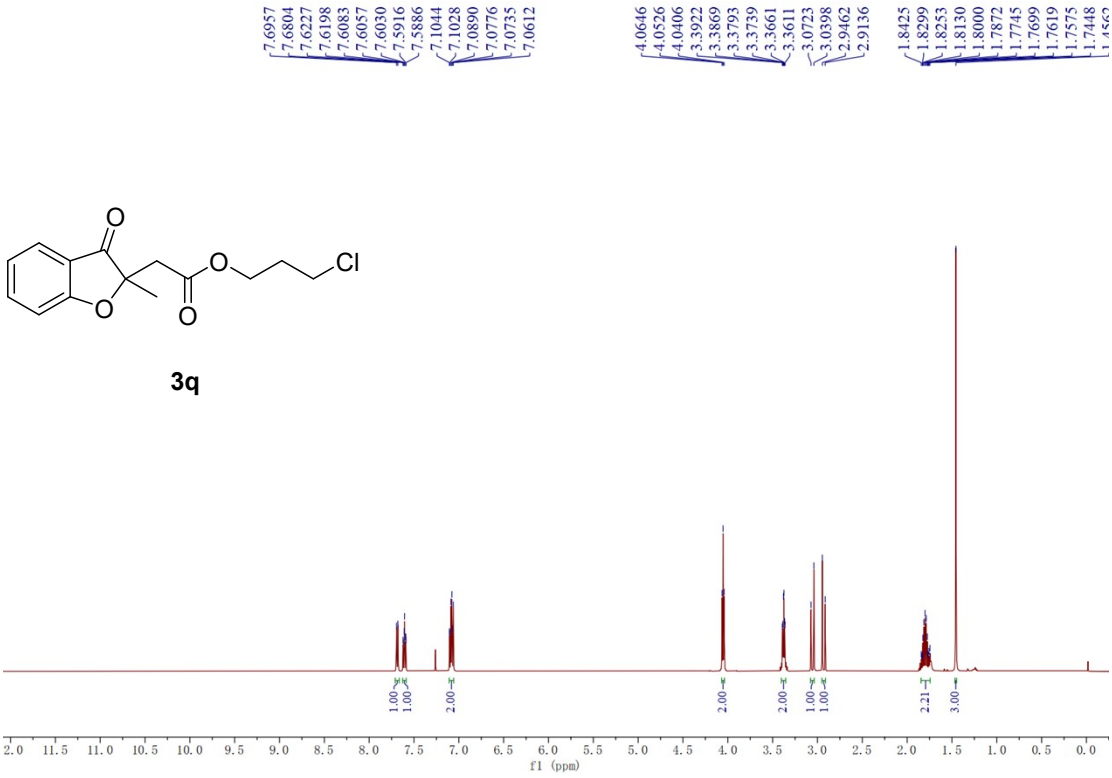
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



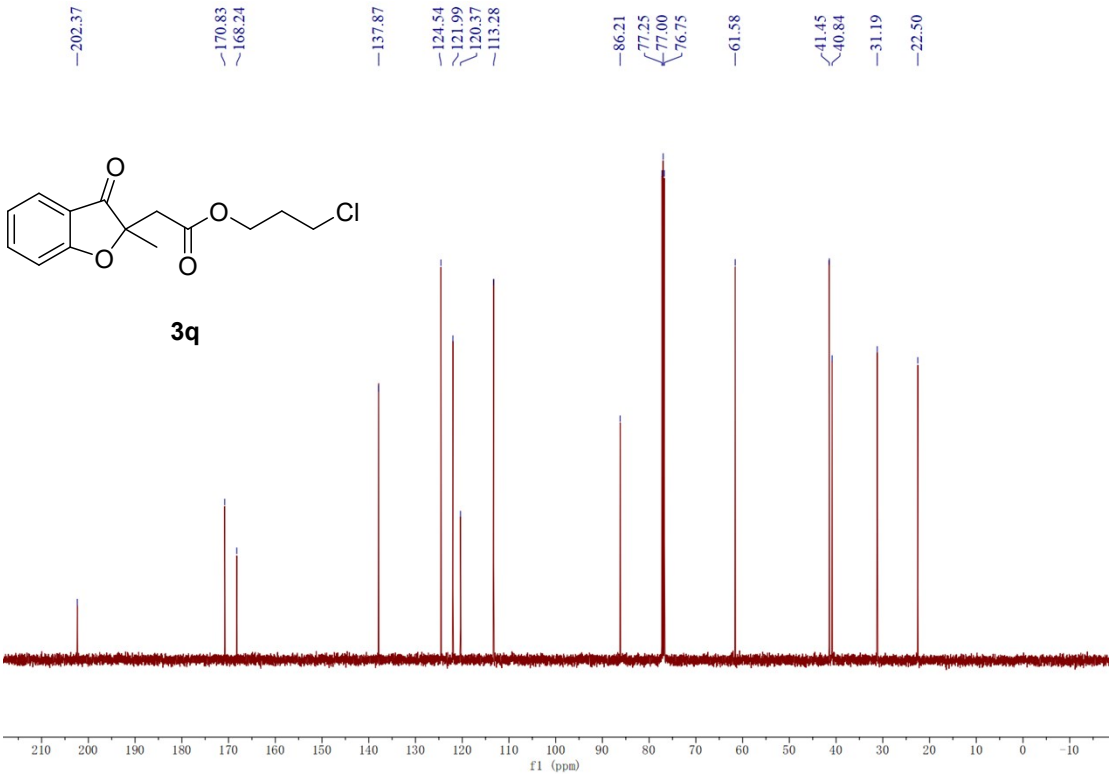
3p

3-chloropropyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3q)

^{1}H NMR (500 MHz, $CDCl_3$)

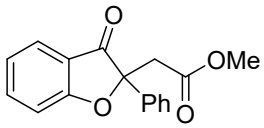


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

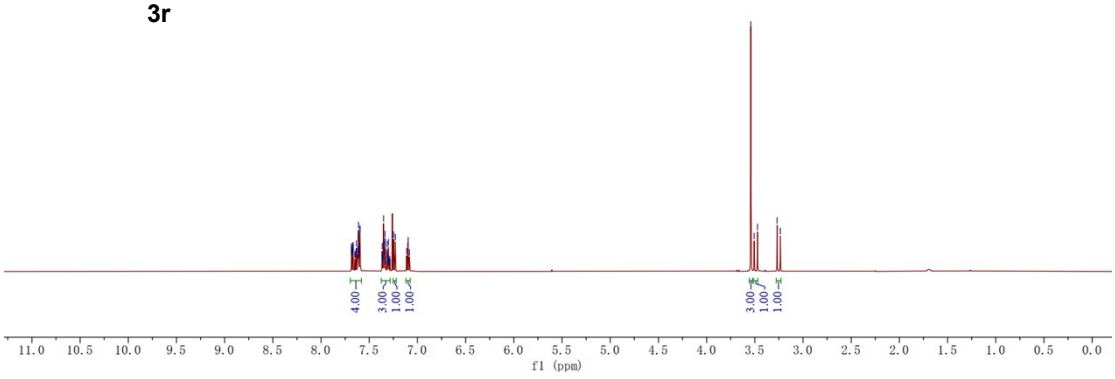


methyl 2-(3-oxo-2-phenyl-2,3-dihydrobenzofuran-2-yl)acetate (3r)

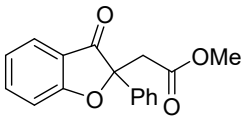
^{1}H NMR (500 MHz, $CDCl_3$)



3r



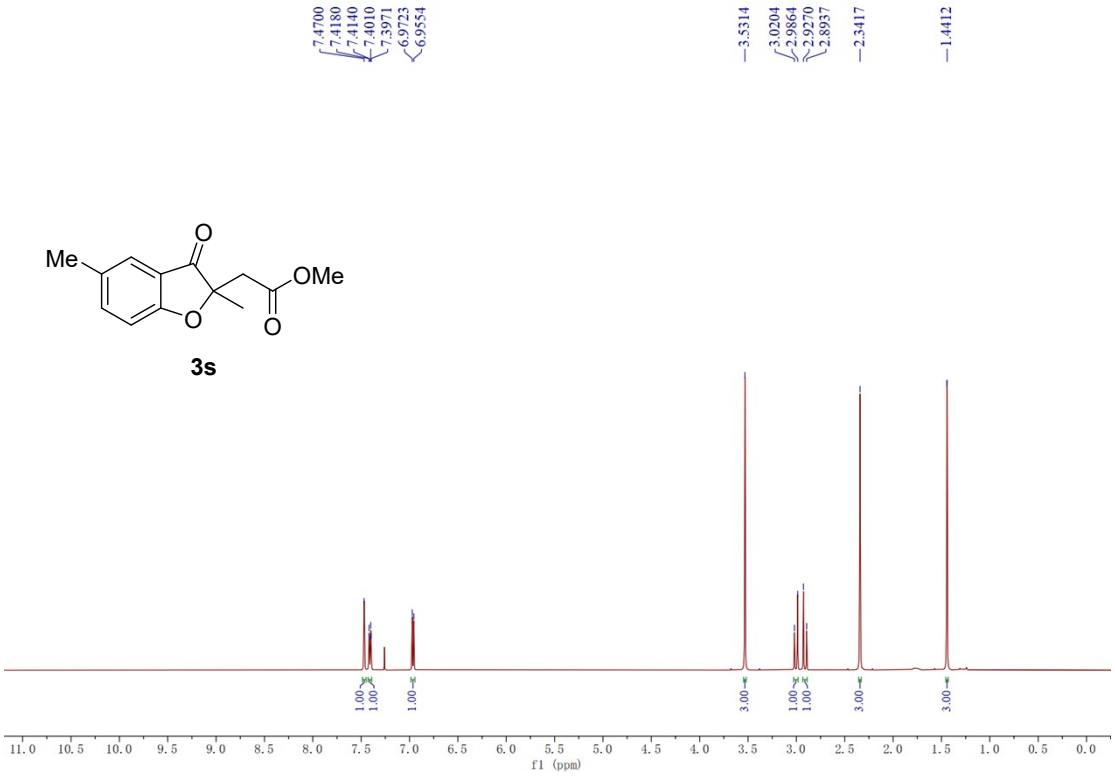
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



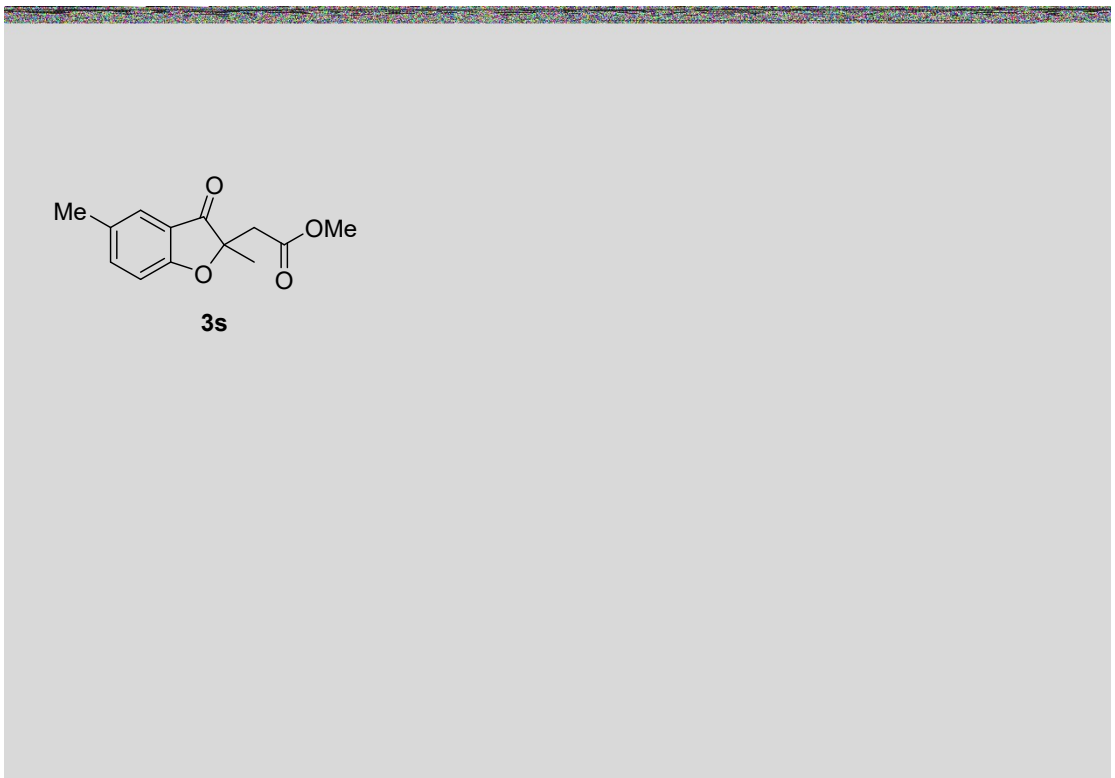
3r

methyl 2-(2,5-dimethyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3s)

^{1}H NMR (500 MHz, $CDCl_3$)

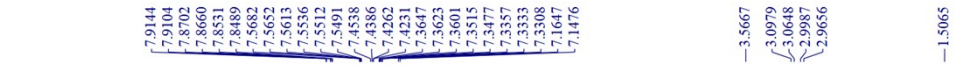


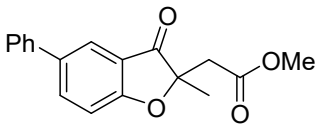
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



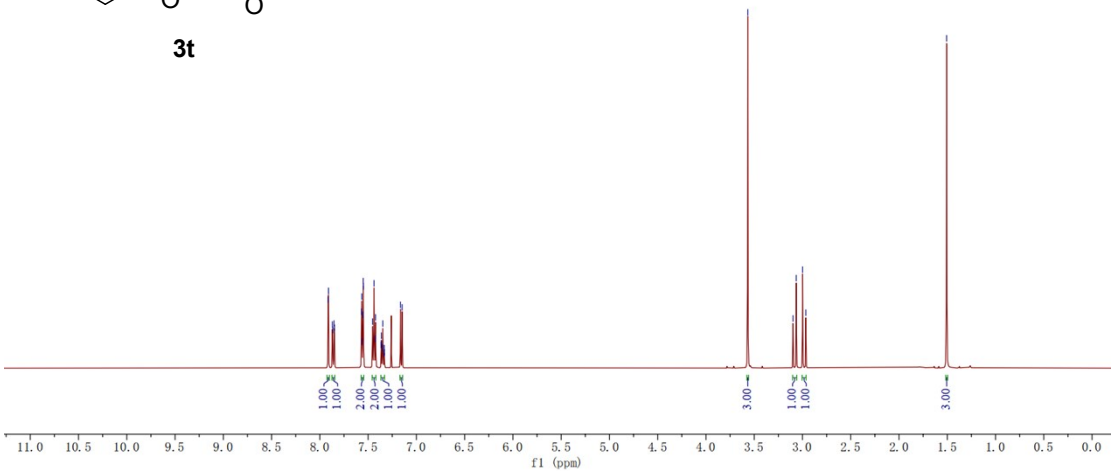
methyl 2-(2-methyl-3-oxo-5-phenyl-2,3-dihydrobenzofuran-2-yl)acetate (3t)

^{1}H NMR (500 MHz, $CDCl_3$)

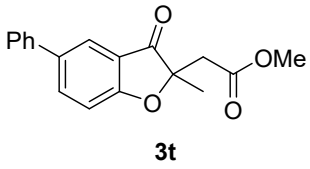




3t



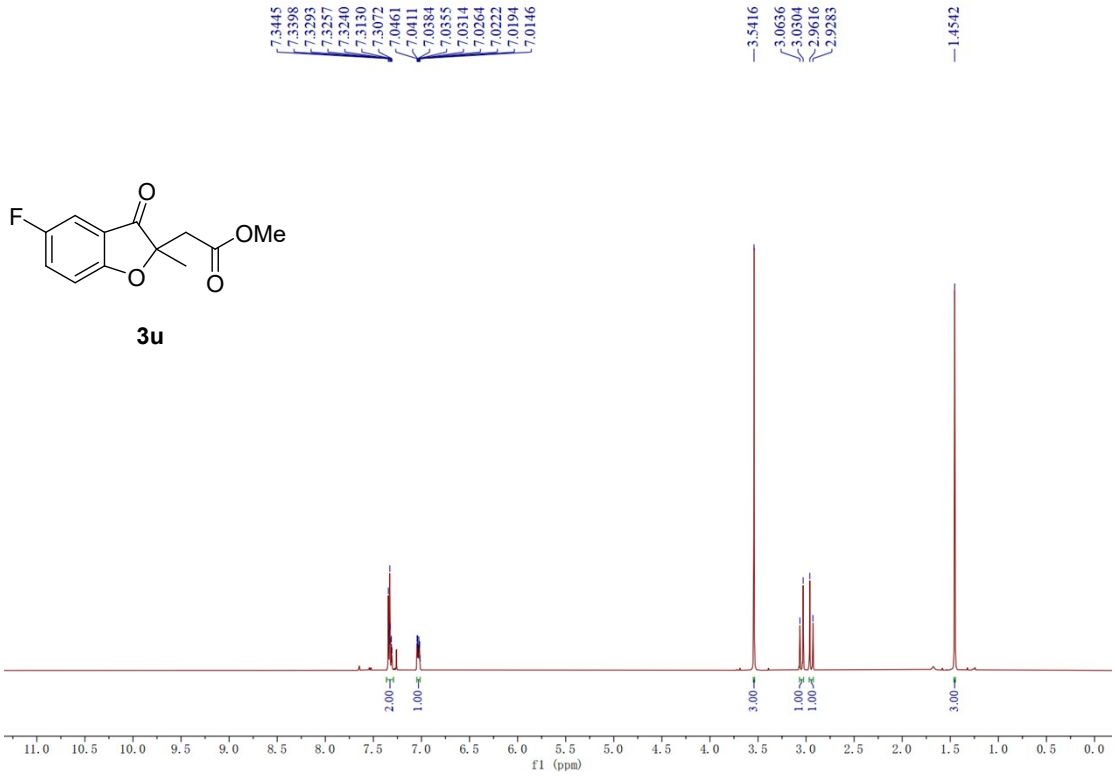
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



3t

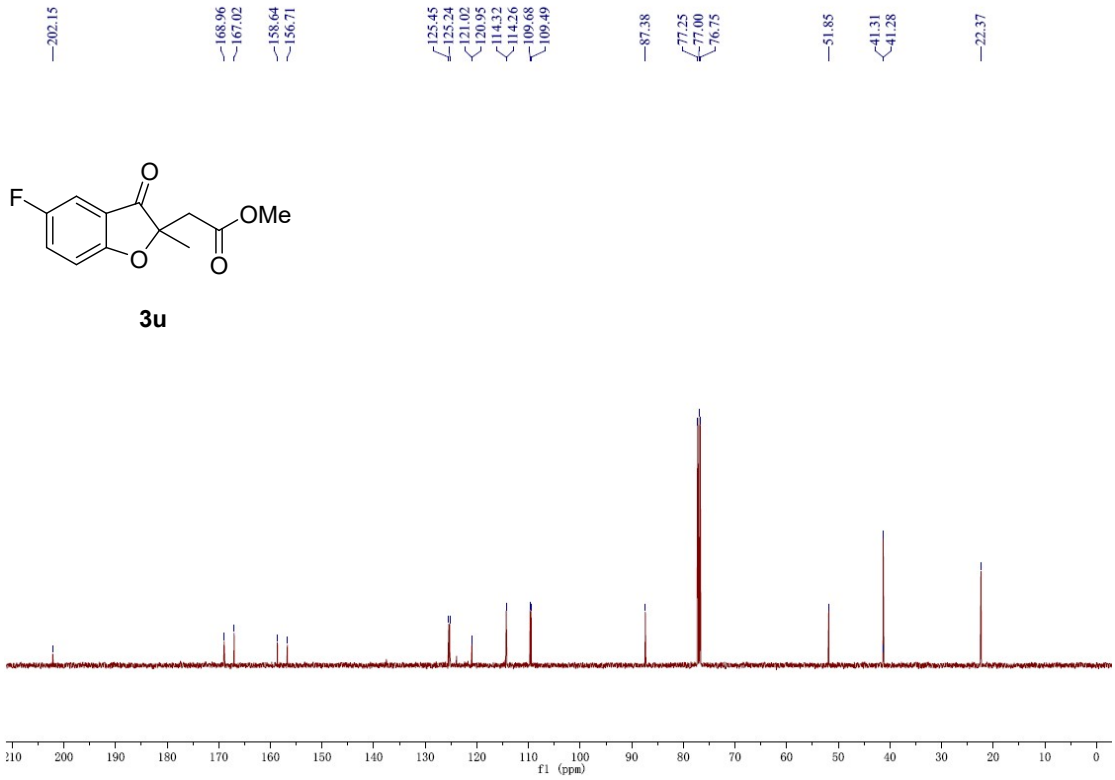
methyl 2-(5-fluoro-2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (3u)

^{1}H NMR (500 MHz, $CDCl_3$)



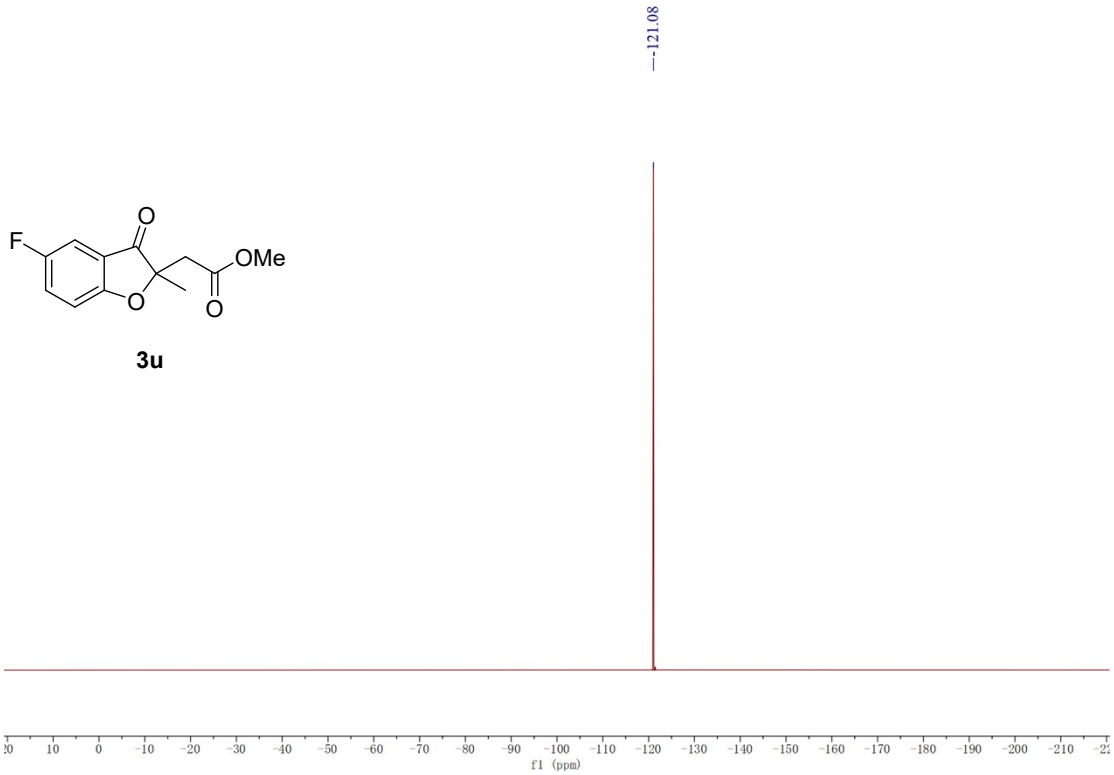
3u

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



3u

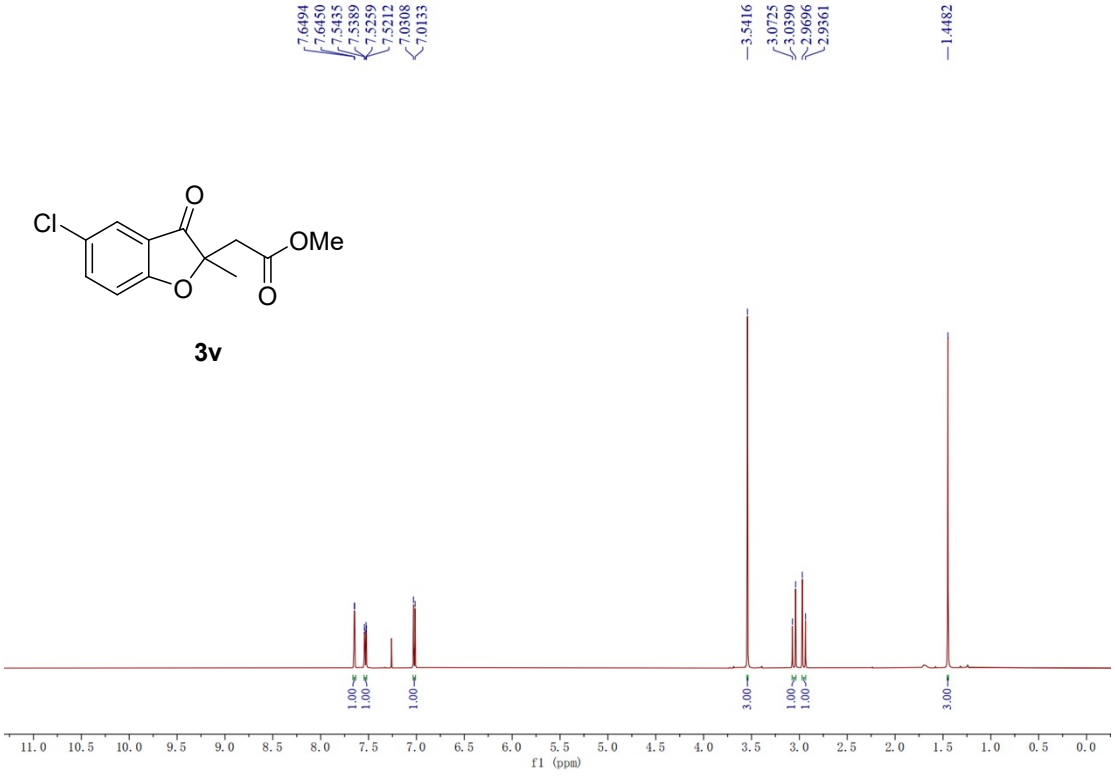
^{19}F NMR (471 MHz, $CDCl_3$)



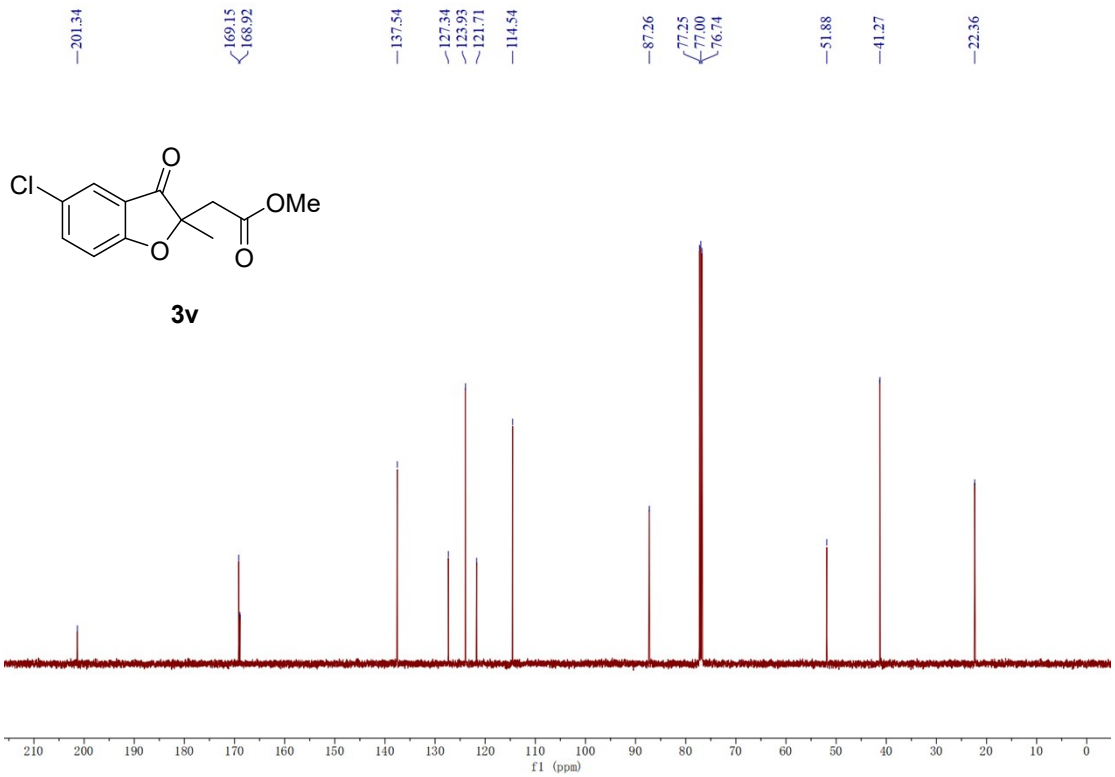
3u

methyl 2-(5-chloro-2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate(3v)

^{1}H NMR (500 MHz, $CDCl_3$)

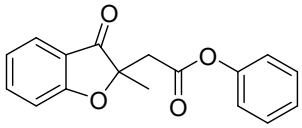


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

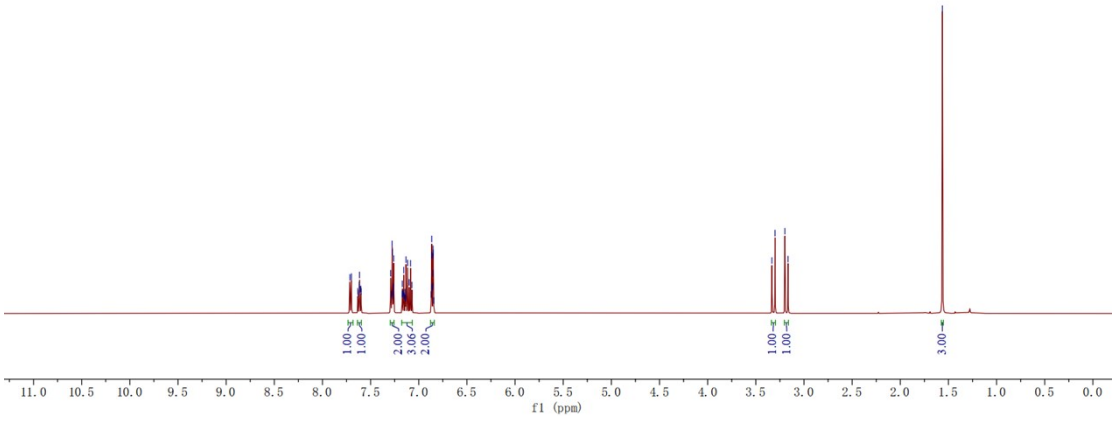


phenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5a)

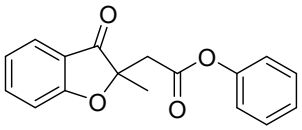
^{1}H NMR (500 MHz, $CDCl_3$)



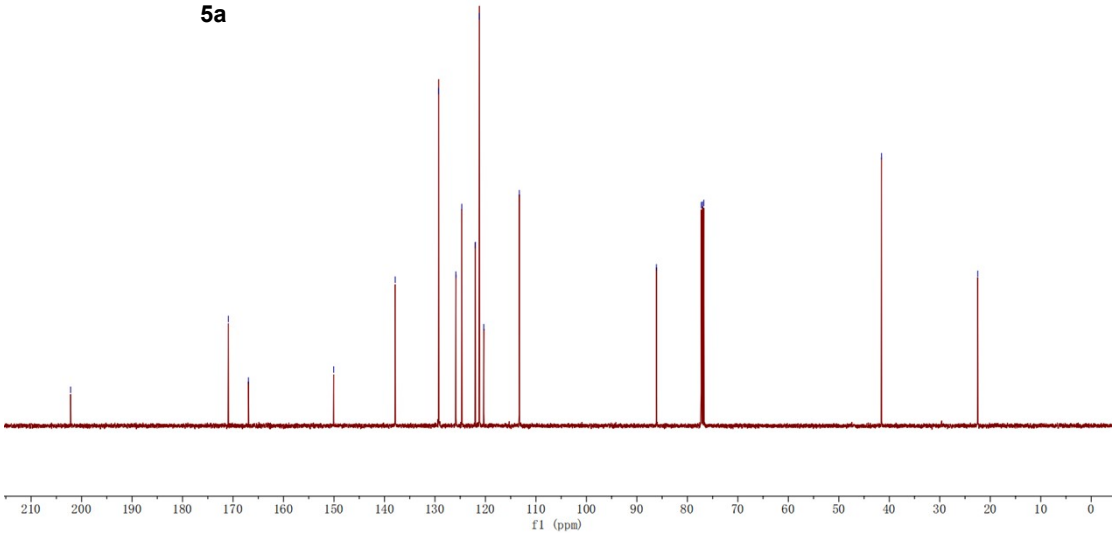
5a



$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

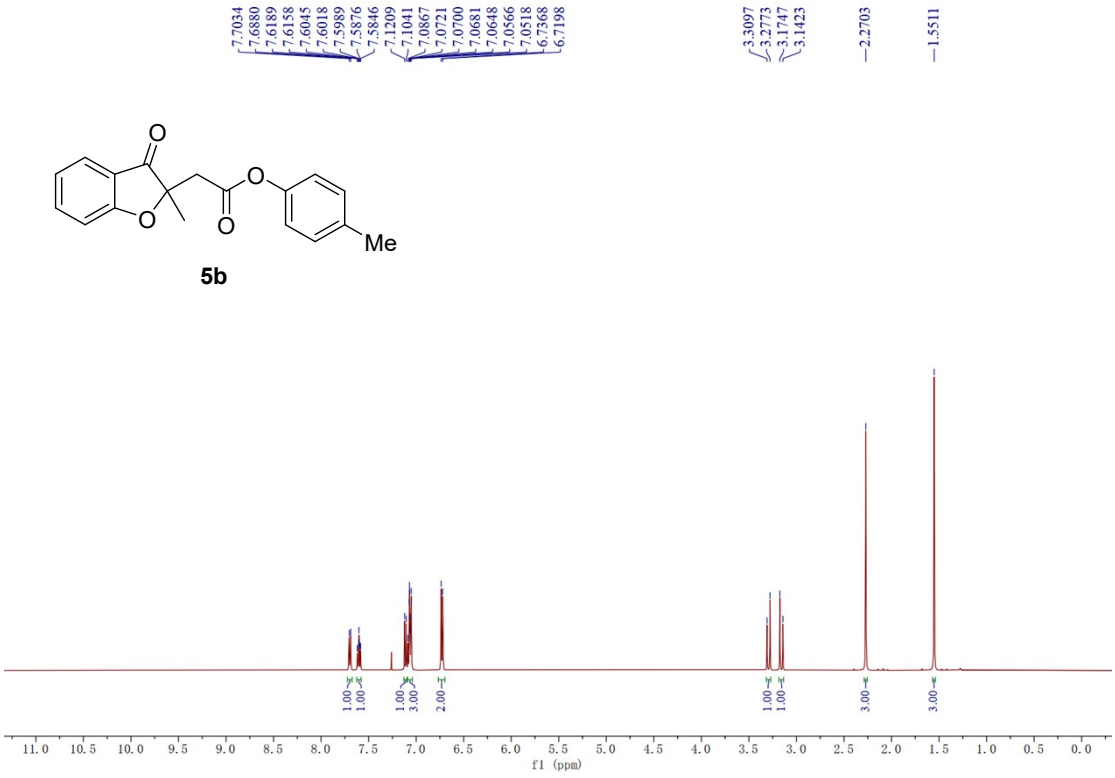


5a



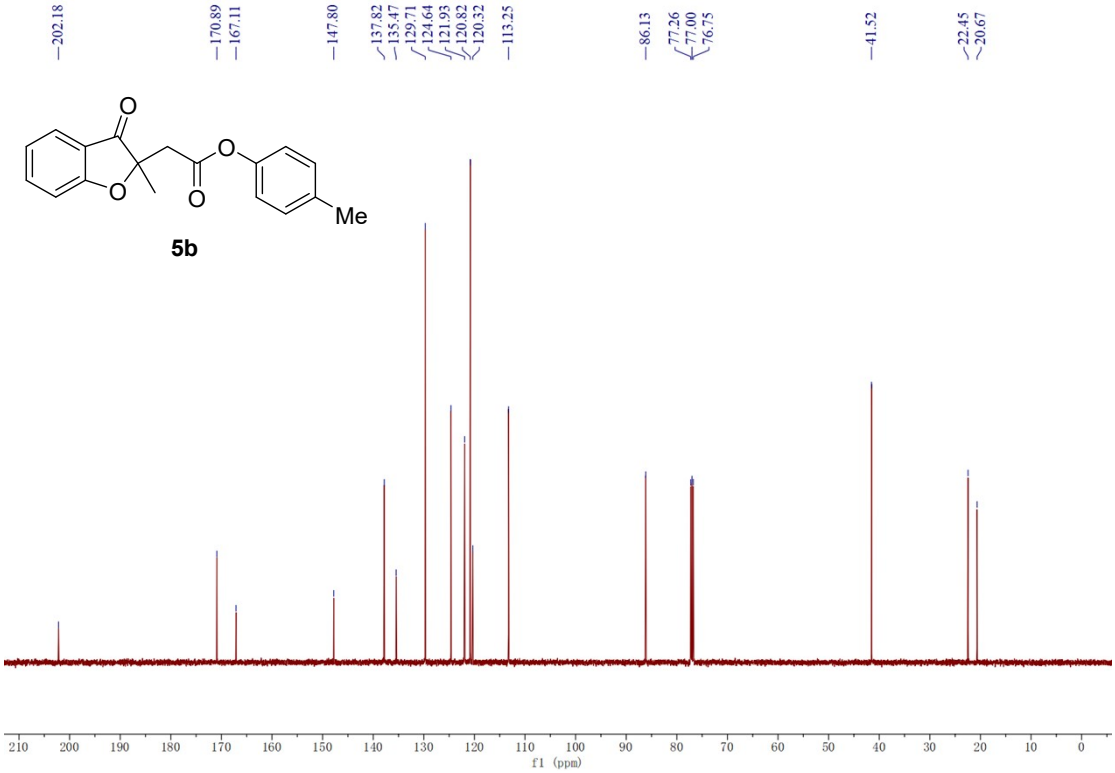
p-tolyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5b)

^{1}H NMR (500 MHz, $CDCl_3$)



5b

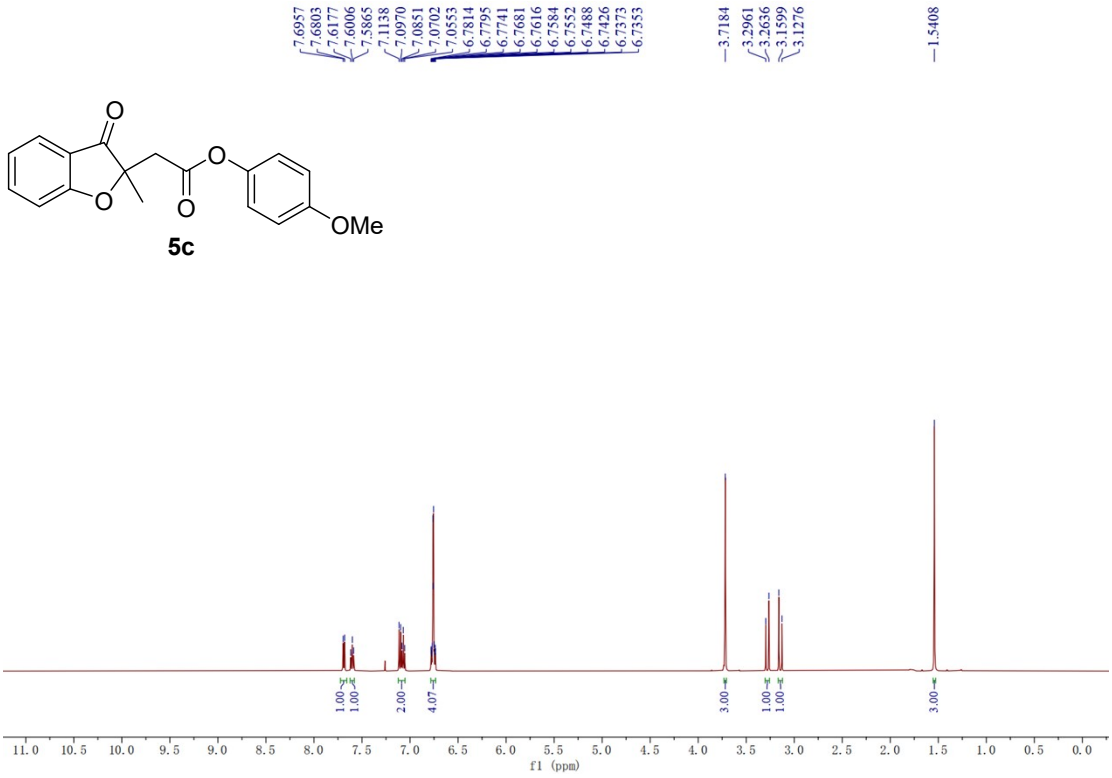
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



5b

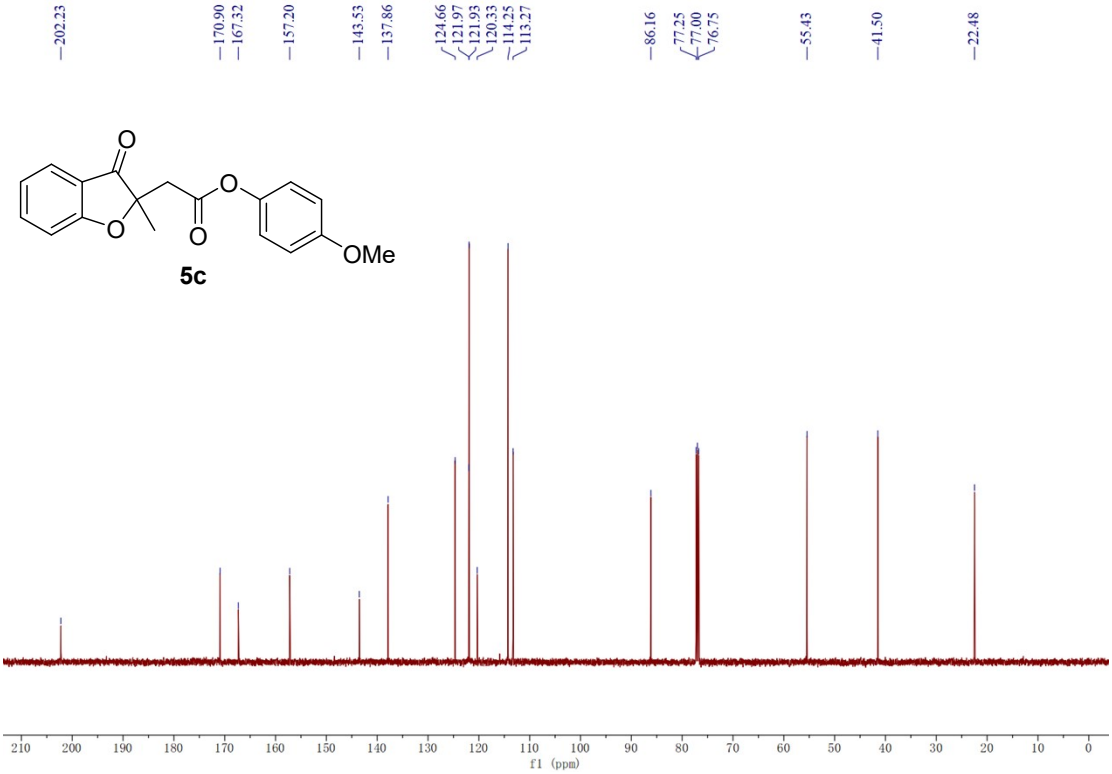
4-methoxyphenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5c)

^{1}H NMR (500 MHz, $CDCl_3$)



5c

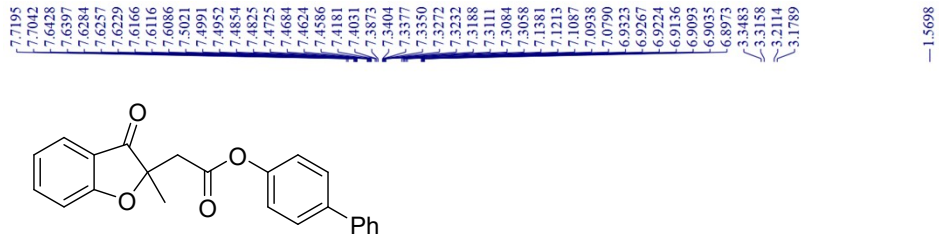
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



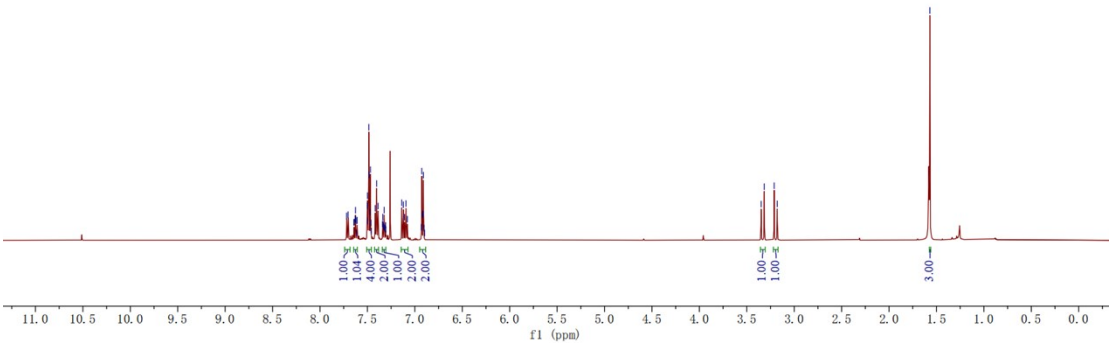
5c

[1,1'-biphenyl]-4-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5d)

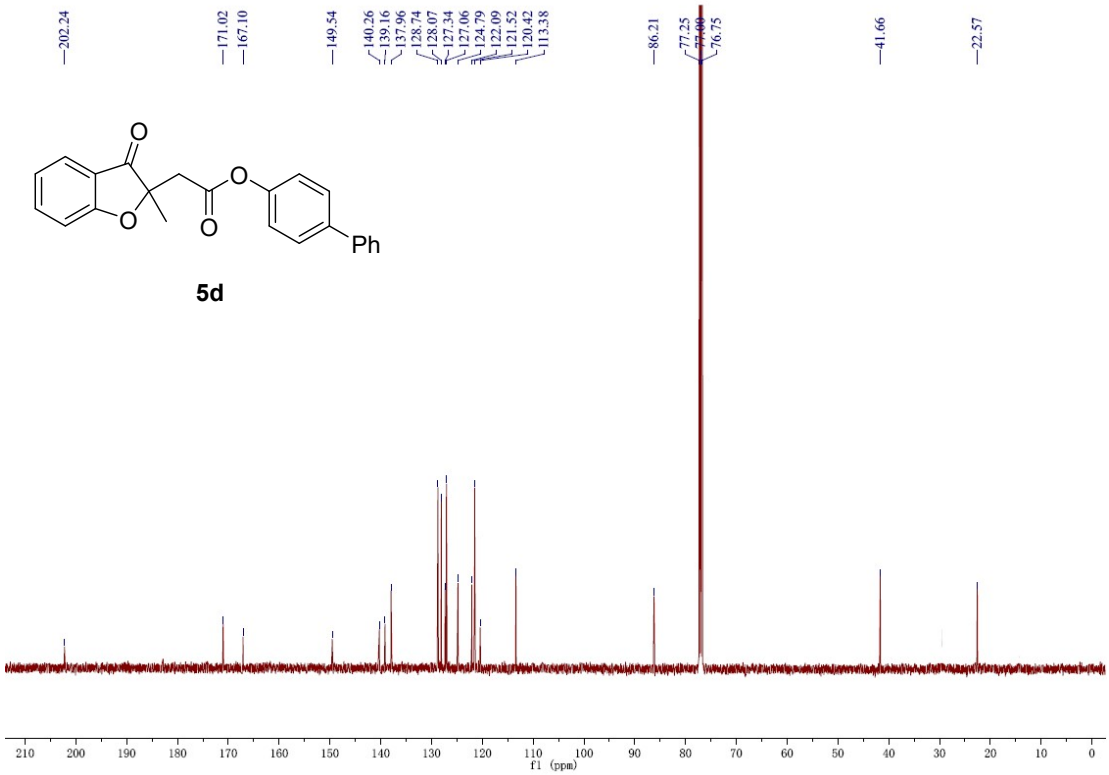
^{1}H NMR (500 MHz, $CDCl_3$)



5d



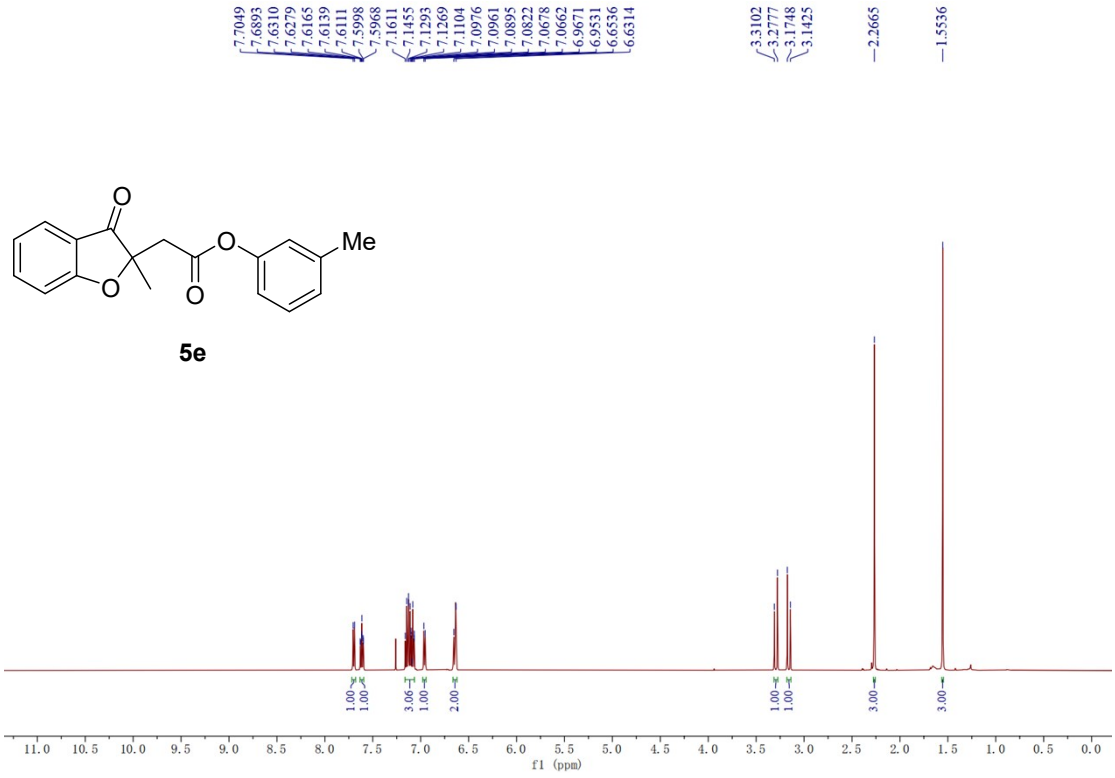
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



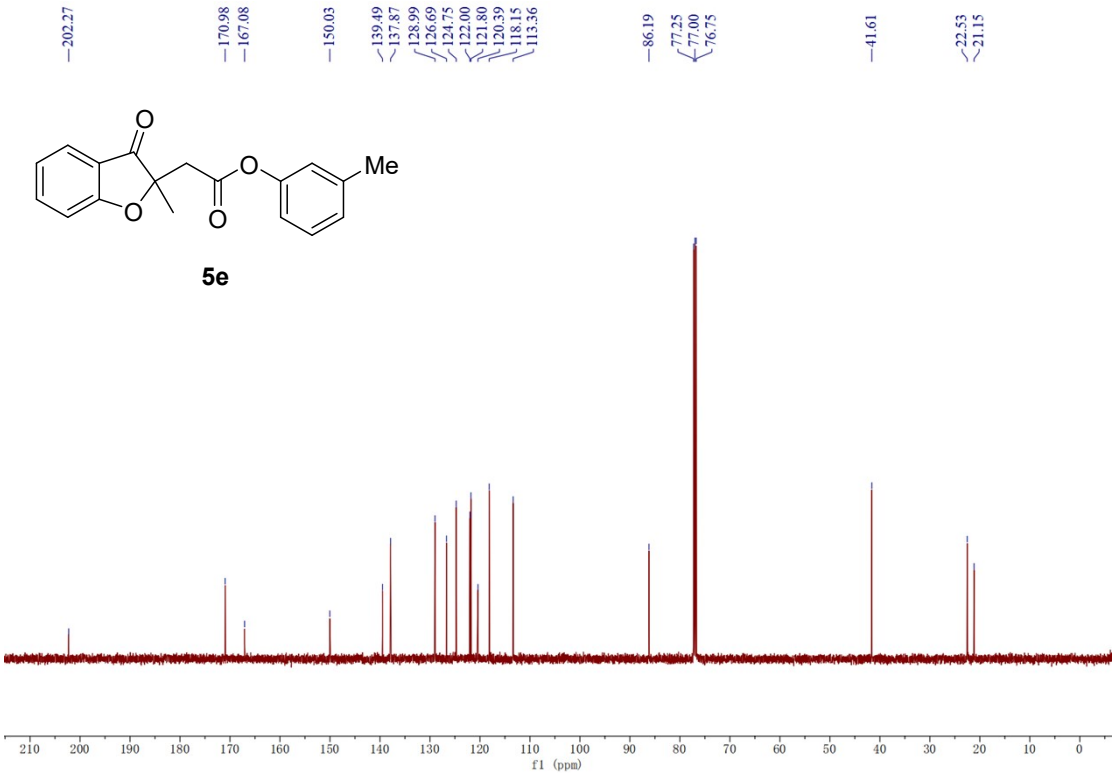
5d

m-tolyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5e)

^{1}H NMR (500 MHz, $CDCl_3$)

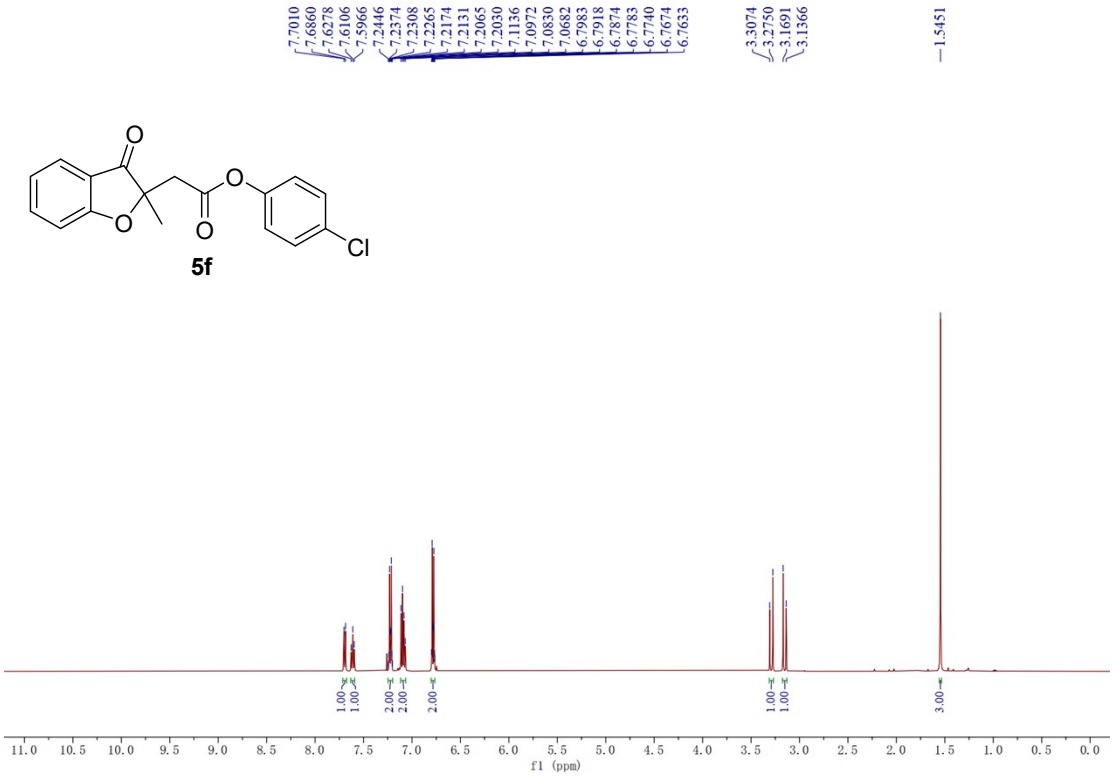


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

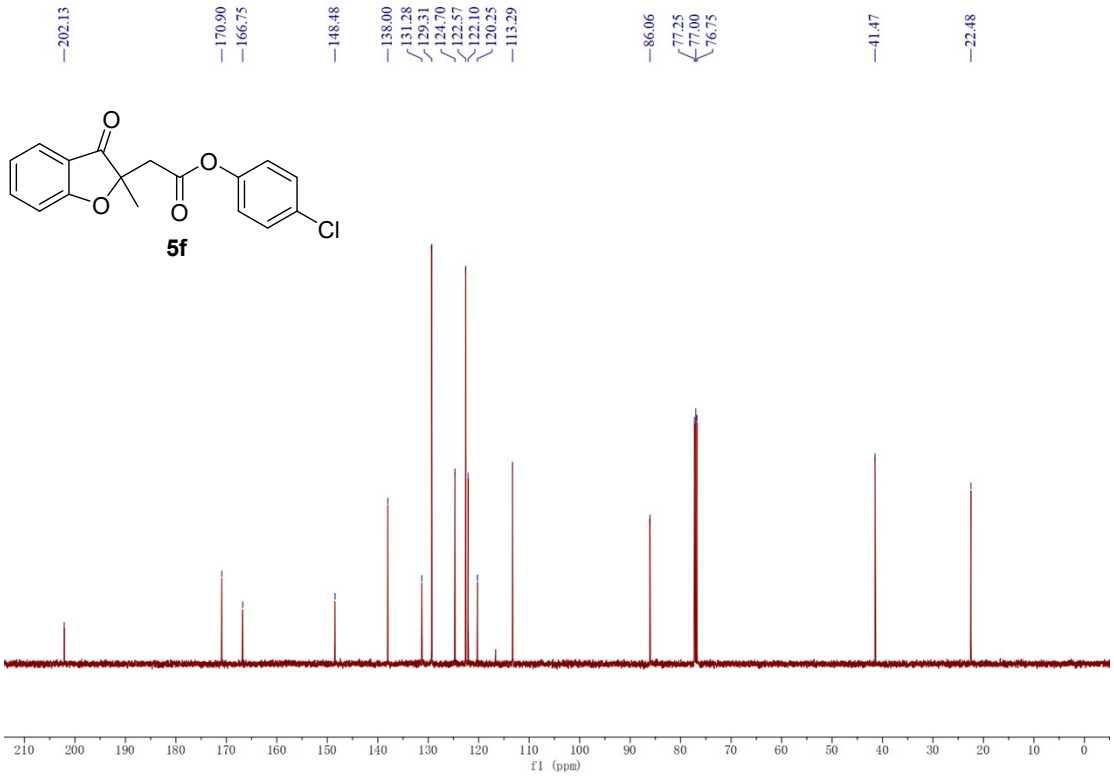


4-chlorophenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5f)

^{1}H NMR (500 MHz, $CDCl_3$)

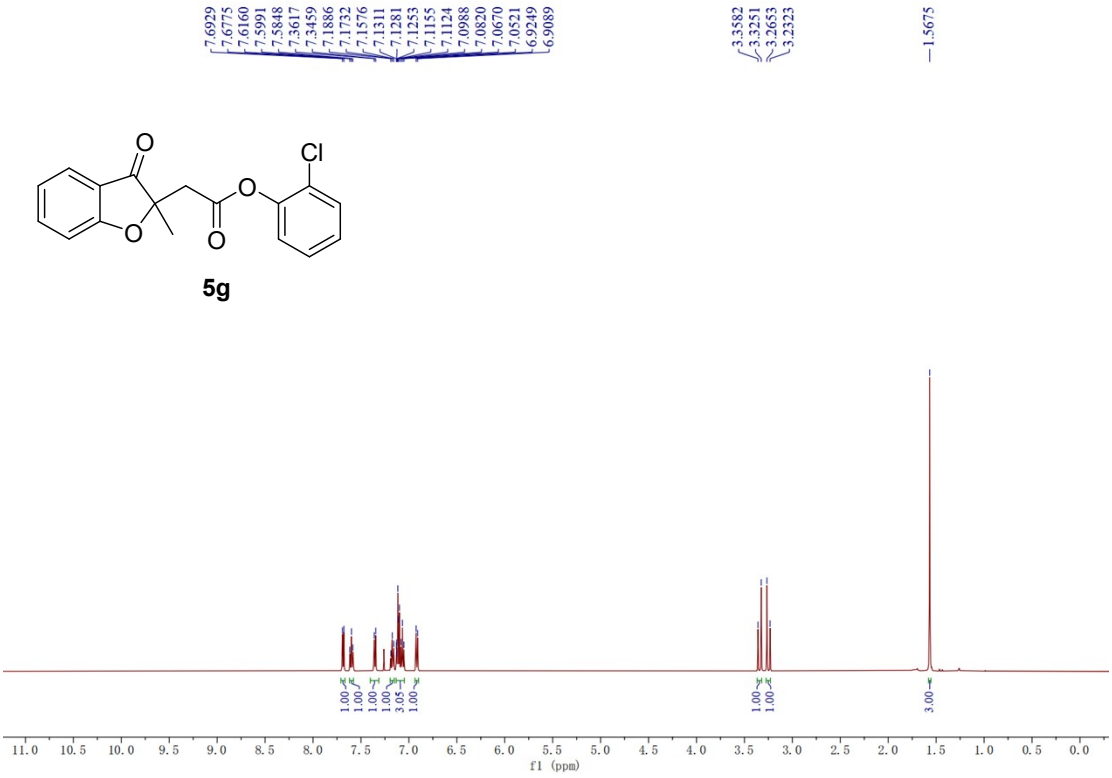


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



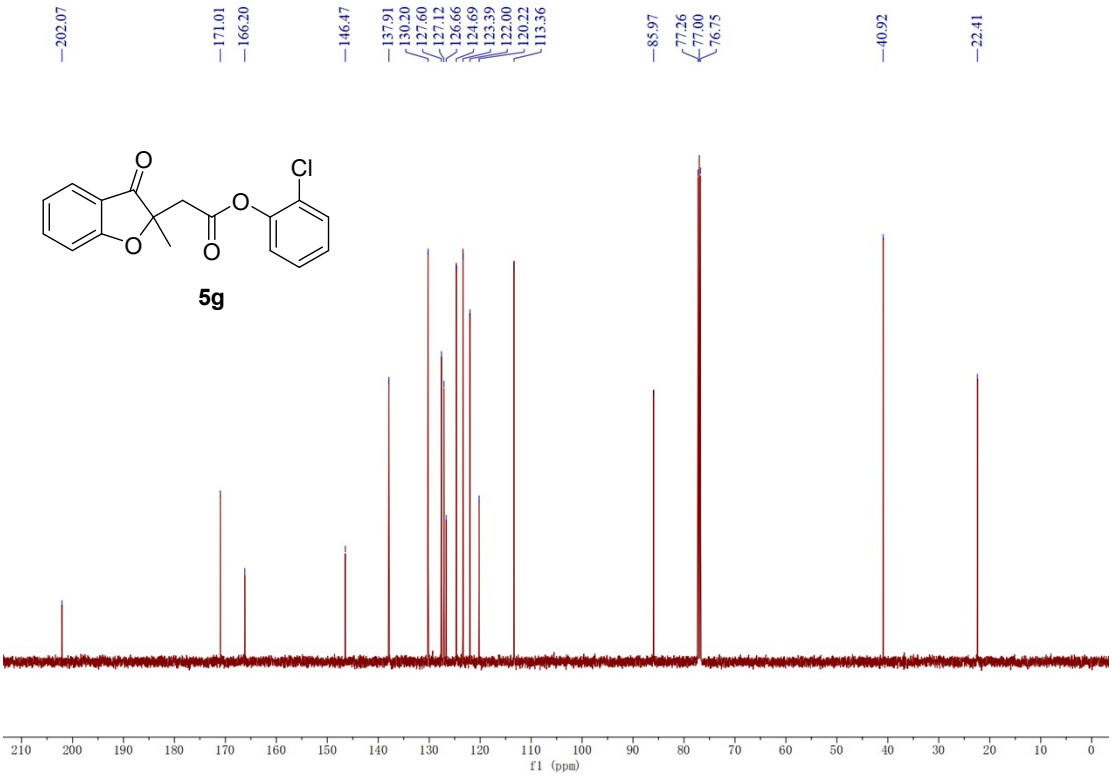
2-chlorophenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5g)

^{1}H NMR (500 MHz, $CDCl_3$)



5g

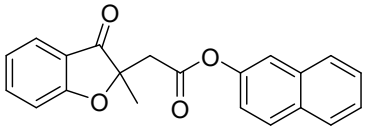
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



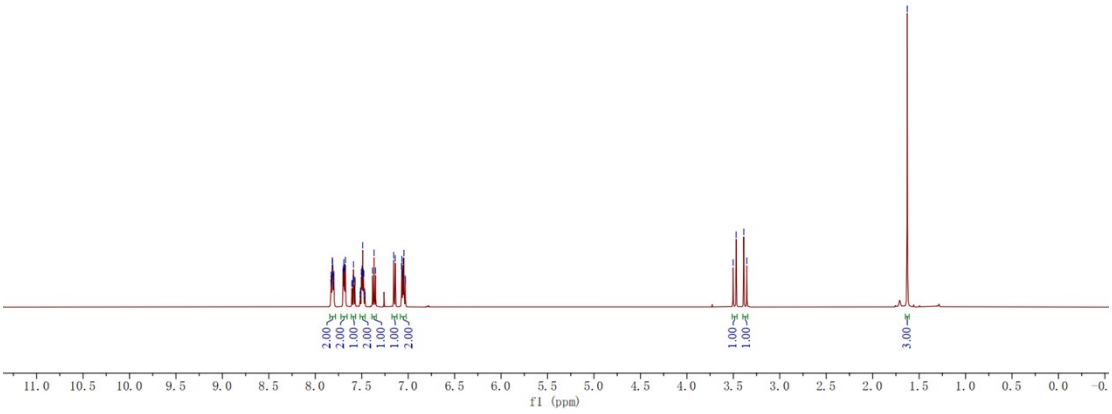
5g

naphthalen-2-yl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5h)

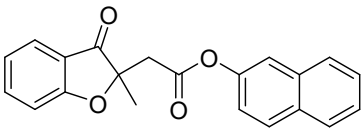
^{1}H NMR (500 MHz, $CDCl_3$)



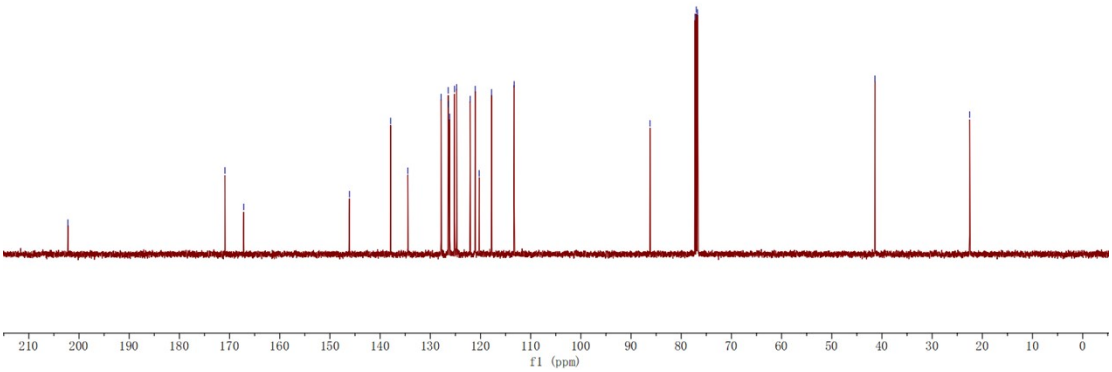
5h



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

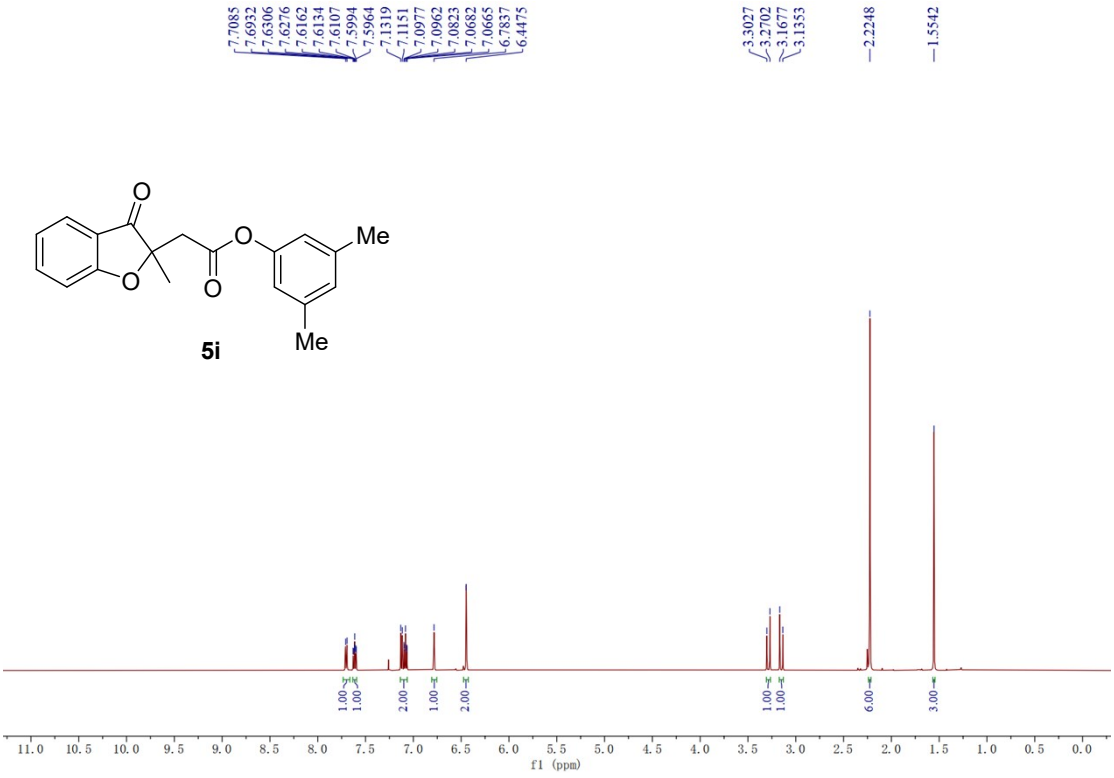


5h

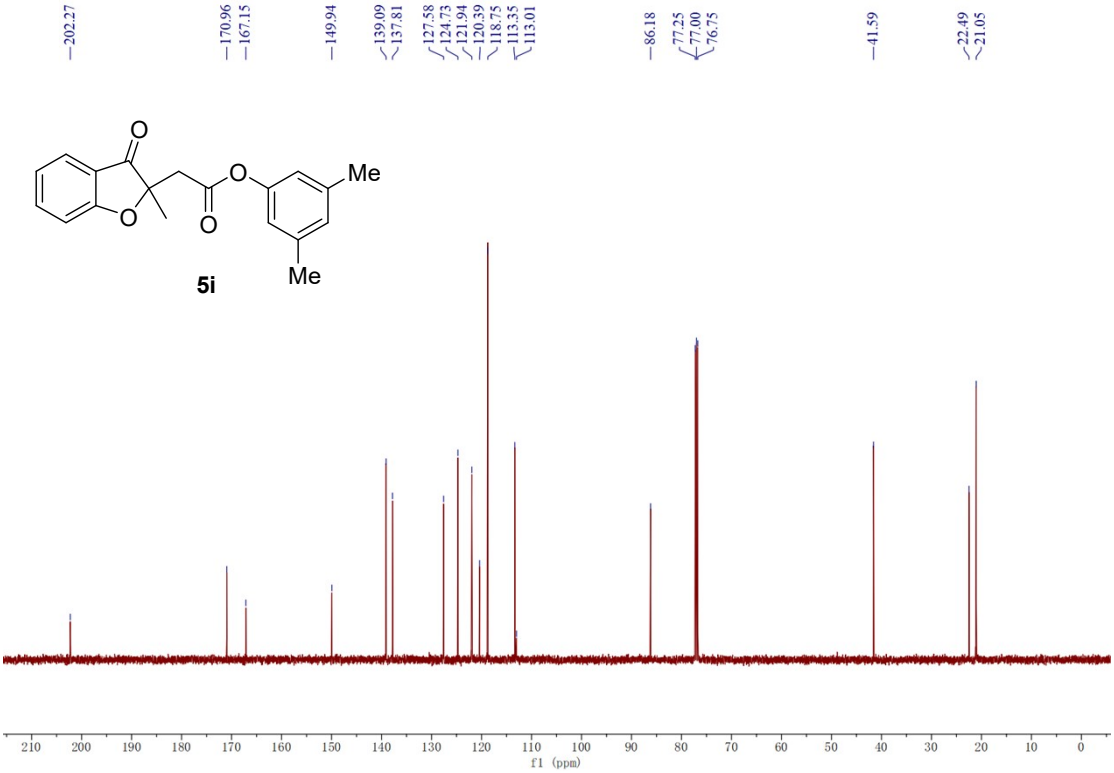


3,5-dimethylphenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5i)

^{1}H NMR (500 MHz, $CDCl_3$)

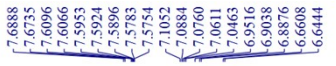


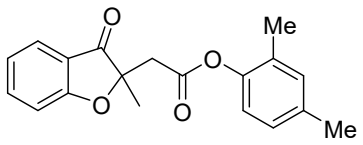
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



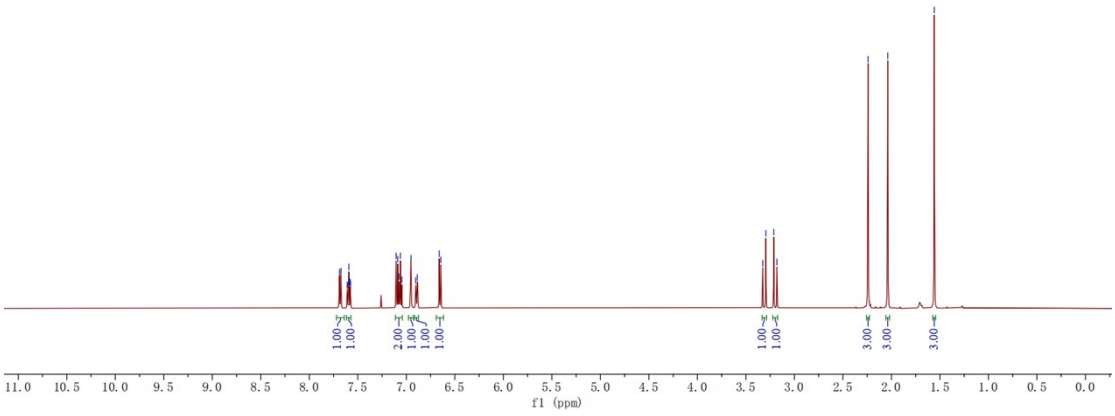
2,4-dimethylphenyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (5j)

^{1}H NMR (500 MHz, $CDCl_3$)

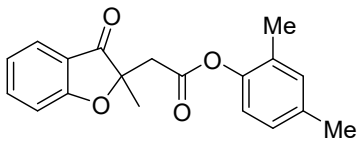




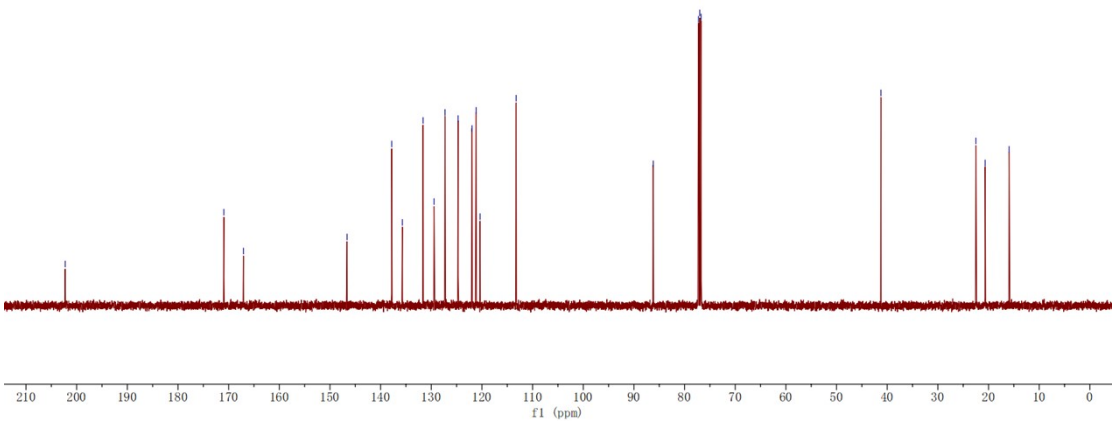
5j



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

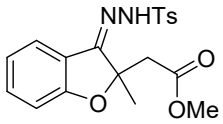


5j

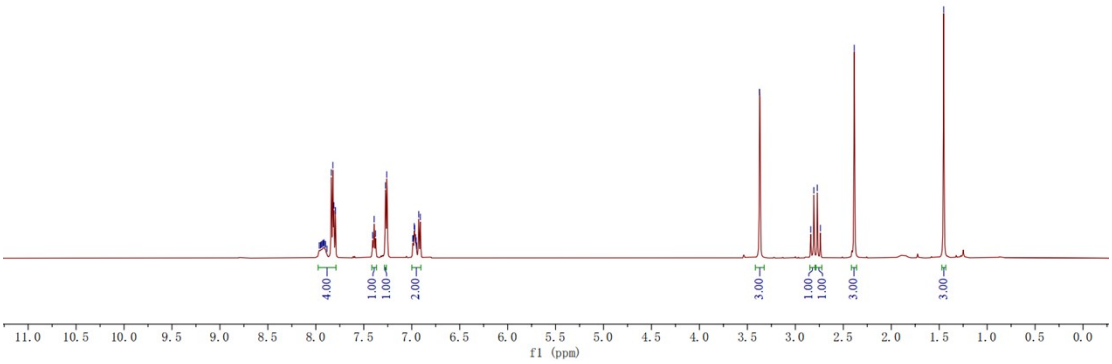


methyl (*E*)-2-(2-methyl-3-(2-tosylhydrazineylidene)-2,3-dihydrobenzofuran-2-yl)acetate (6)

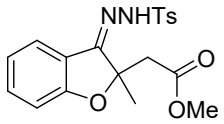
^{1}H NMR (500 MHz, $CDCl_3$)



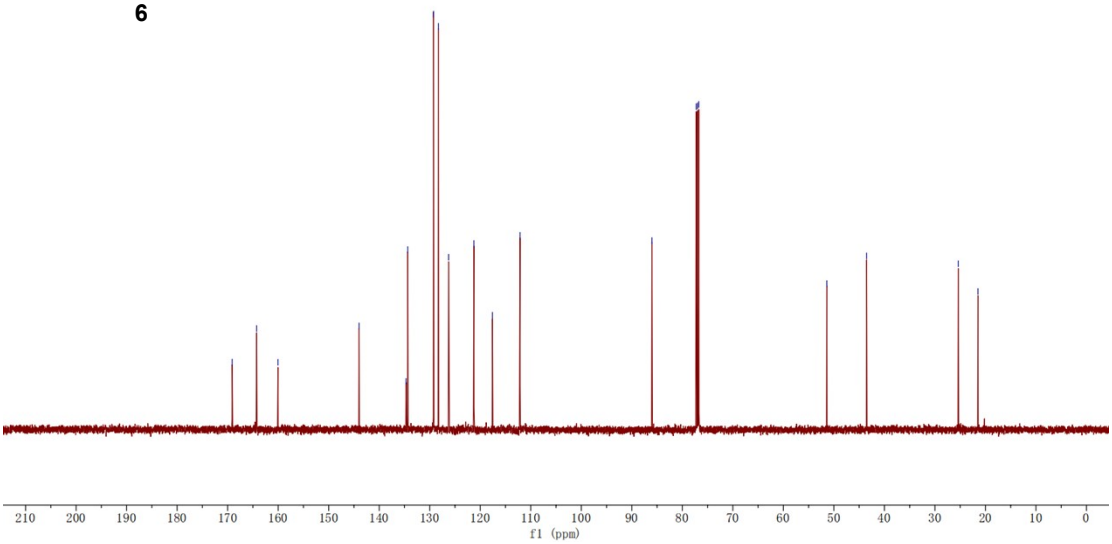
6



^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

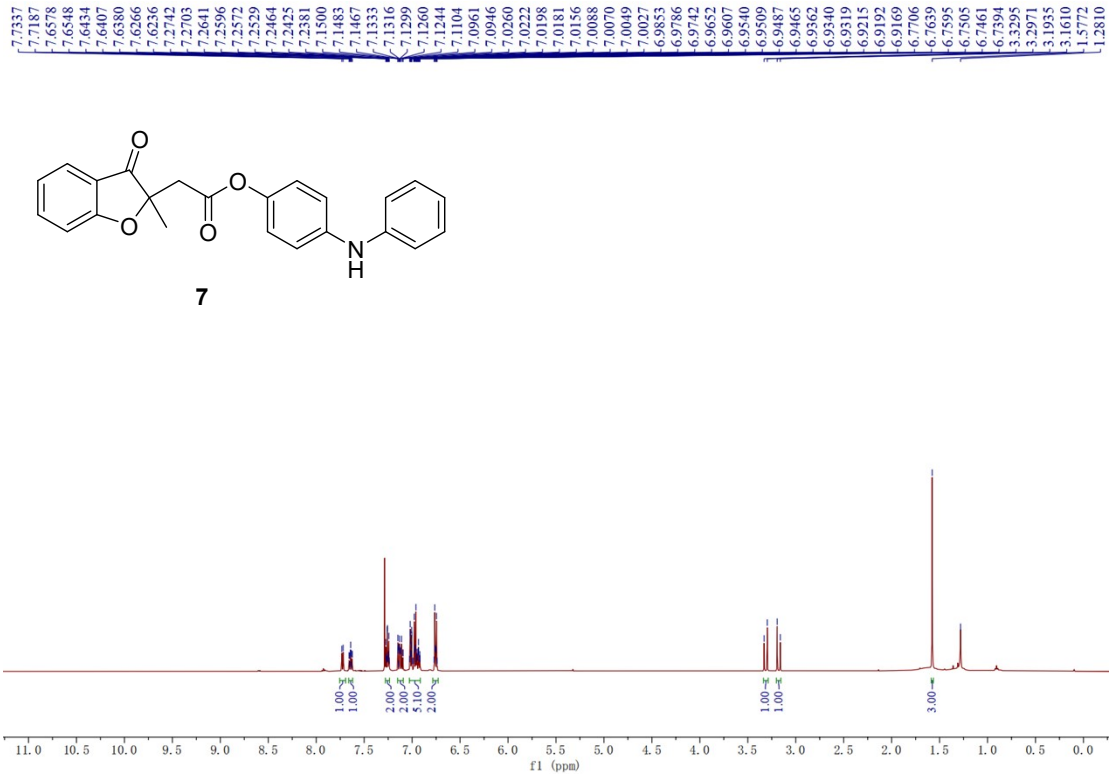


6

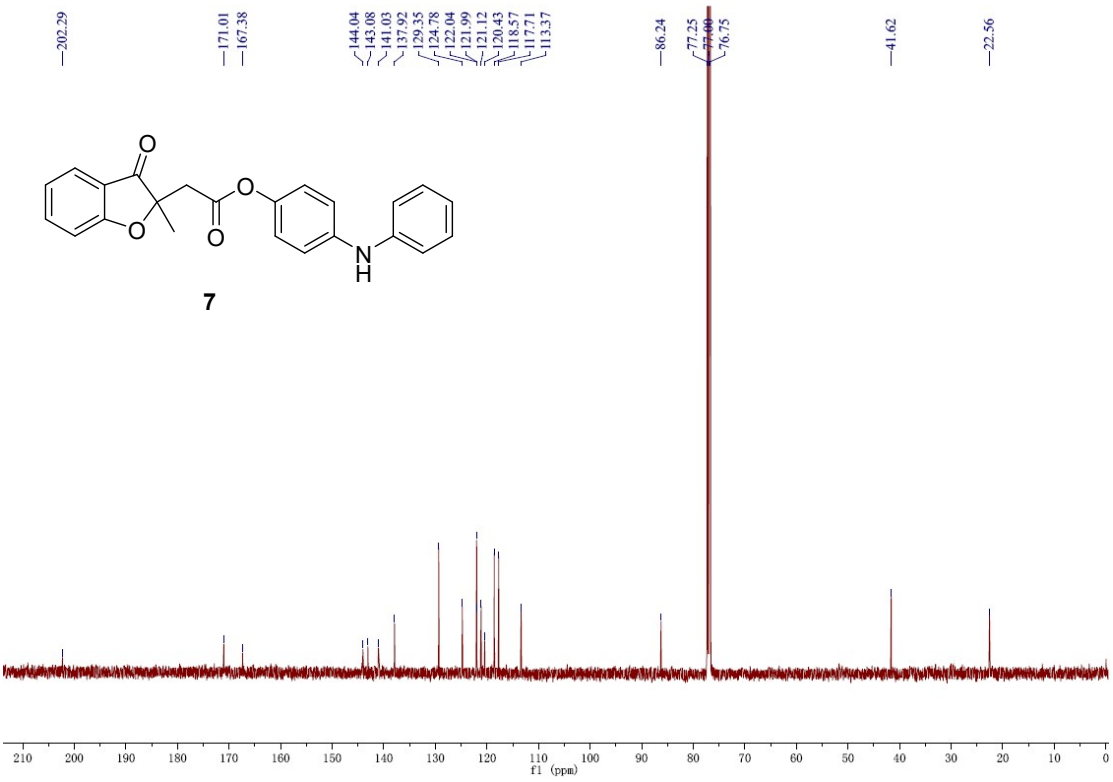


propyl 2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetate (7)

^{1}H NMR (500 MHz, $CDCl_3$)

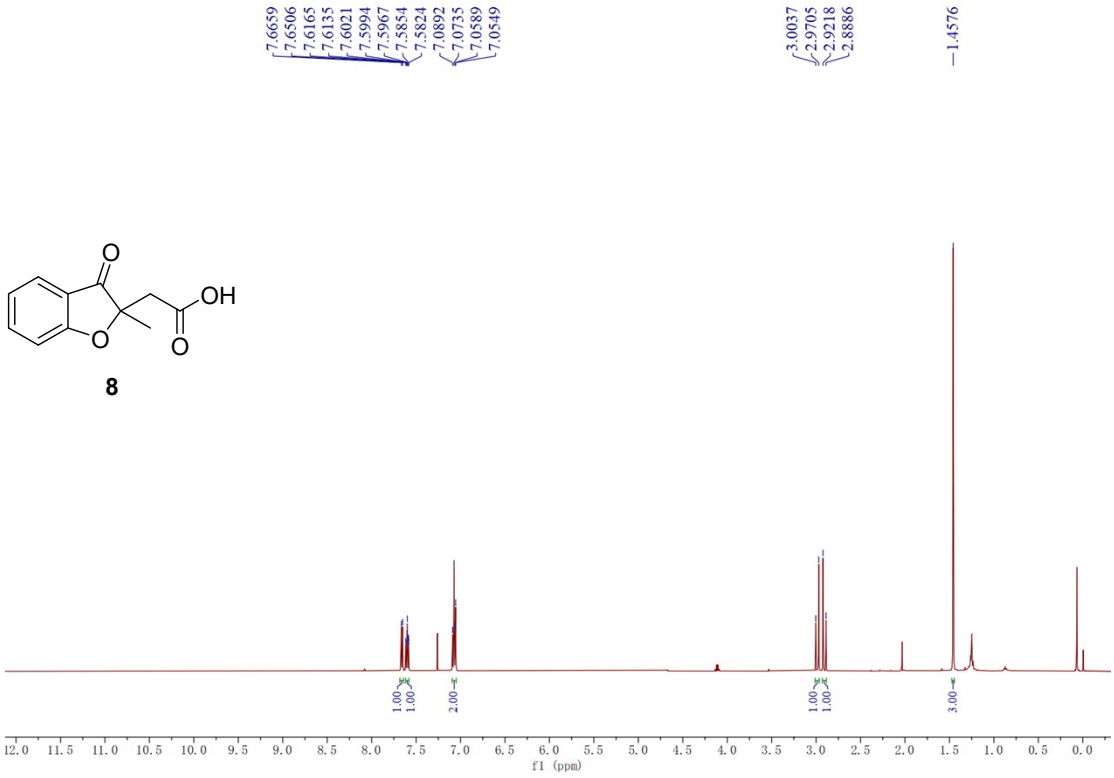


^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



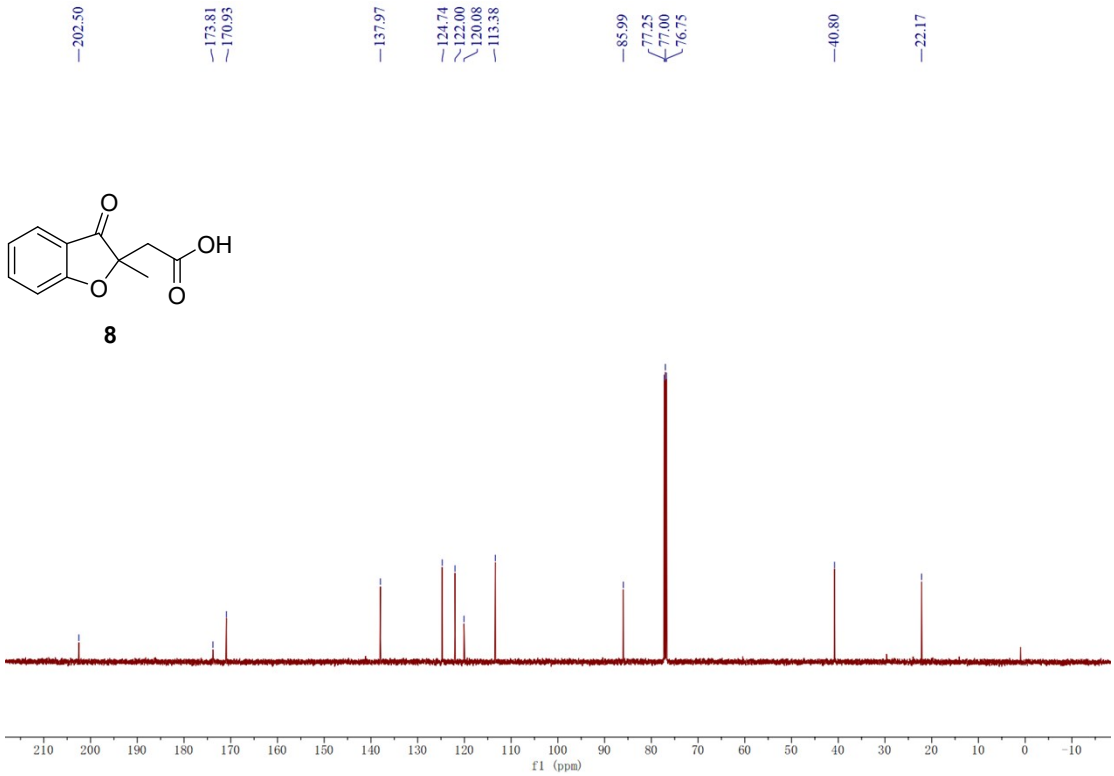
2-(2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)acetic acid (8)

^{1}H NMR (500 MHz, $CDCl_3$)



8

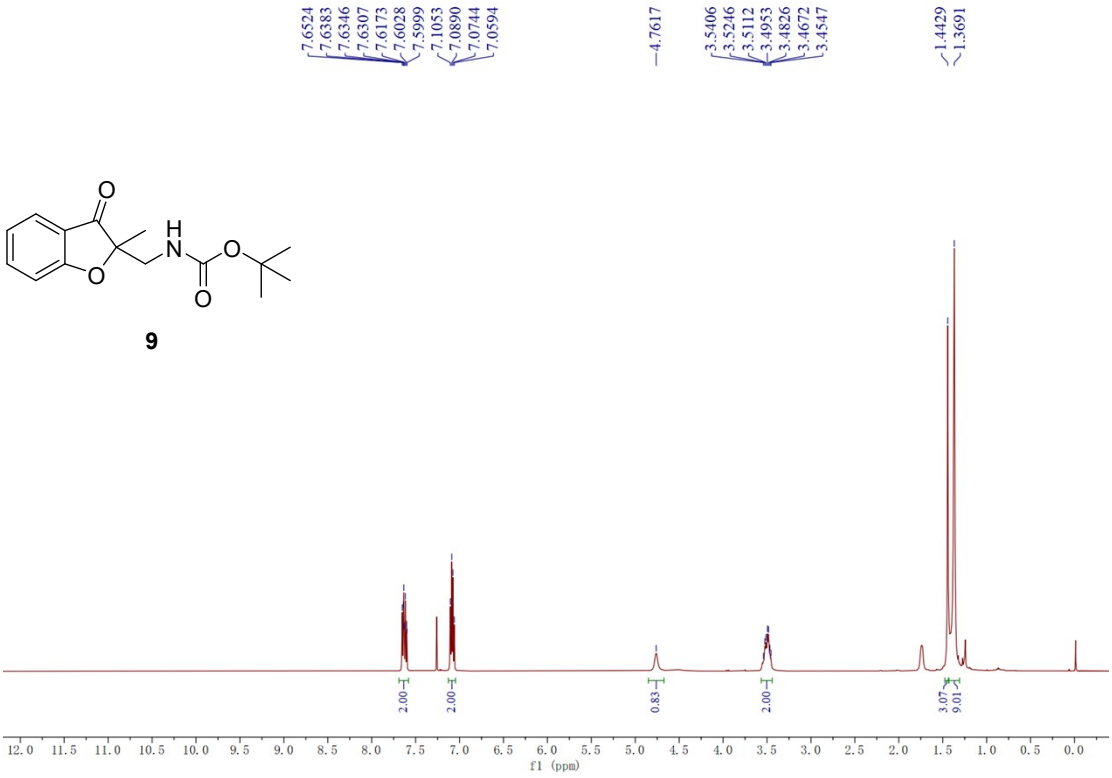
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



8

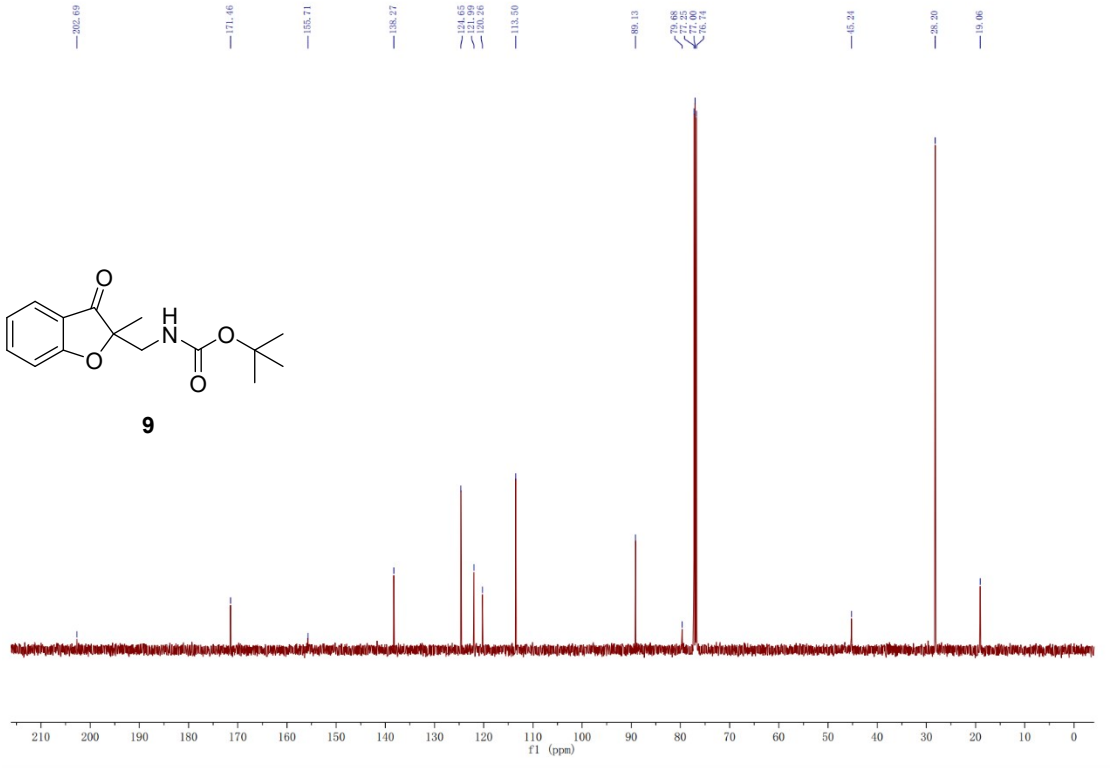
tert-butyl ((2-methyl-3-oxo-2,3-dihydrobenzofuran-2-yl)methyl)carbamate (9)

^{1}H NMR (500 MHz, $CDCl_3$)



9

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



9