Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

Phosphine-catalyzed asymmetric *aza*-Morita-Baylis-Hillman reaction of endocyclic ketimines and activated alkenes

Yue Lu,[a#] Fangfang Zhu,[a#] Xinyu Liu,[a] and De Wang*[,a,b,c]

[a] *Key Laboratory of Marine Drugs, Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, Qingdao 266071, China.*

[b] *State Key Laboratory of Natural and Biomimetic Drugs, Peking University, Beijing 100191, China.*

[c] *Laboratory for Marine Drugs and Bioproducts, Qingdao National Laboratory for Marine Science and Technology, Qingdao 266237, China.*

wangde@ouc.edu.cn

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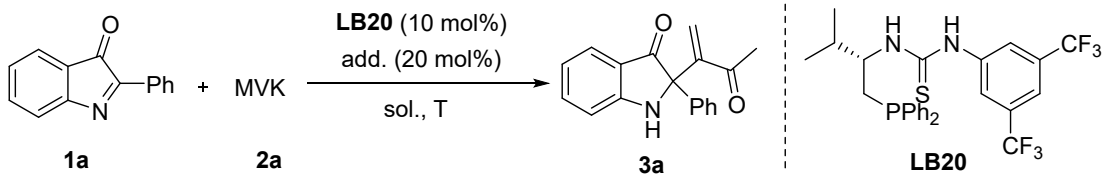
1. General Information

^{1}H (400 MHz) and ^{13}C NMR (100 MHz or 125 MHz) spectra were recorded on JEOL (400 MHz) or Agilent (500 MHz) [7.26 ppm for ^{1}H NMR, 77.00 ppm for ^{13}C NMR as internal references when $CDCl_3$ used]. High-resolution mass spectra were recorded by ESI method. The used organic solvents were dried by standard methods if it was necessary. Optical rotations were determined at 589 nm (sodium D line) by using a Perkin-Elmer-341 MC digital polarimeter; $[\alpha]_D$ values are given in unit of 10 deg^{-1} cm^2 g^{-1}. Chiral HPLC was performed on a SHIMADZU LC-20AT LC System with chiral columns [Chiralpak AD-H, OD-H, IB-H and IF-H columns 4.6*250 mm, (Daicel Chemical Ind., Ltd.)]. Commercially obtained reagents were used without further purification. All these reactions were monitored by TLC with silica-gel-coated plates. Flash column chromatography was carried out by using silica gel at increased pressure.

All the racemic products were carried out with tertiary phosphine ($PMePh_2$, 20 mol%) or tertiary amine (DABCO, 20 mol%) as catalyst in ethyl acetate at room temperature.

2. Screening of reaction conditions

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

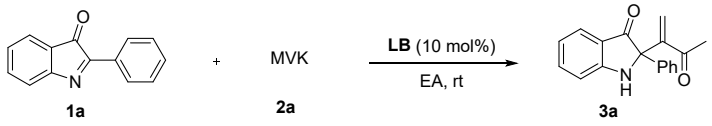


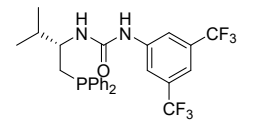
1a **2a** **3a** **LB20**

Entry	Sol.	T [°C]	add.	Yield [%]	ee [%]
1	toluene	25	None	99	75
2	DCM	25	None	27	79
3	MeCN	25	None	79	81
4	fluorobenzene	25	None	trace	-
5	*o*-xylene	25	None	99	79
6	Et_2O	25	None	74	87
7	MTBE	25	None	71	80
8	THF	25	None	24	88
9	EtOAc	25	None	99	88
10	$CH_3CO_2{}^tBu$	25	None	99	83
11	$CH_3CO_2CH_3$	25	None	81	87
12	HCO_2Me	25	None	44	43
13	HCO_2Et	25	None	trace	-
14	$CO(OCH_3)_2$	25	None	99	85
15	EtOAc	25	PhOH	99	81
16	EtOAc	25	2-chlorophenol	99	55
17	EtOAc	25	PhCOOH	trace	-
18	EtOAc	25	MeOH	99	86
19	EtOAc	25	H_2O	99	83
20	EtOAc	25	4Å MS	99	87
21	EtOAc	10	None	99	87
22	EtOAc	0	None	99	88
23	EtOAc	-10	None	82	69

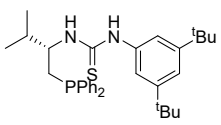
[a] All reactions were run with **1a** (0.05 mmol), **2a** (0.075 mmol) and **LB20** (10 mol%) under argon atmosphere in solvents (1.0 ml) at indicated temperature for 6 h. [b] Isolated yields. [c] ee values were determined by stationary chiral HPLC.

Table S2. The screening of chiral phosphines [a-c]

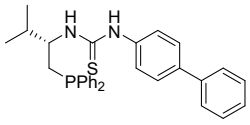




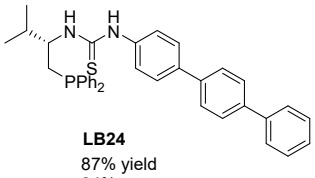
LB21
52% yield
65% ee



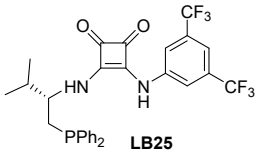
LB22
99% yield
79% ee



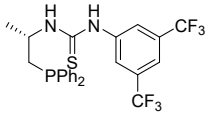
LB23
99% yield
85% ee



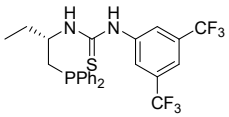
LB24
87% yield
84% ee



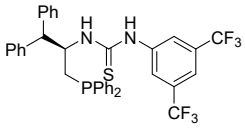
LB25
99% yield
86% ee



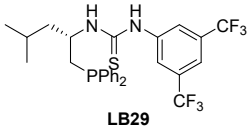
LB26
87% yield
84% ee



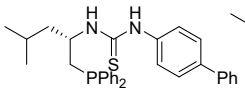
LB27
99% yield
88% ee



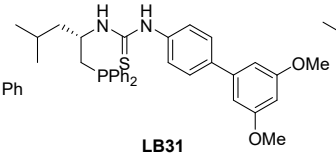
LB28
99% yield
69% ee



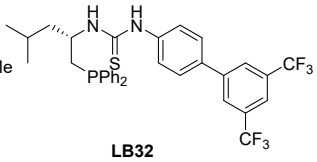
LB29
99% yield
89% ee



LB30
99% yield
86% ee



LB31
94% yield
87% ee

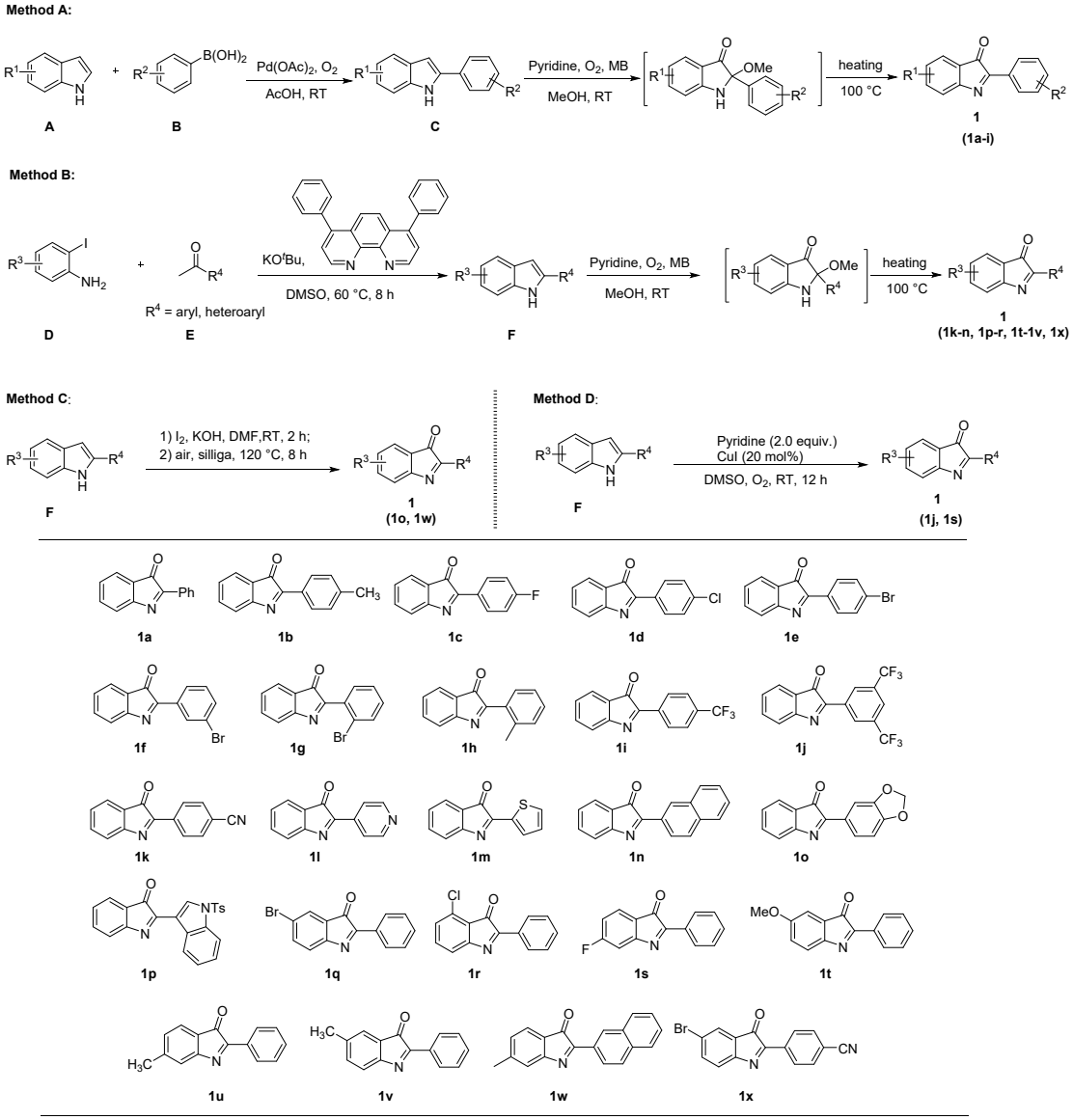


LB32
99% yield
90% ee

[a] All reactions were run with **1a** (0.05 mmol), **2a** (0.075 mmol) and **LB** (10 mol%) under nitrogen atmosphere in EtOAc (1.0 ml) at room temperature for 6h. [b] Isolated yields. [c] ee values were determined by stationary chiral HPLC.

3. Experimental procedure and characterization data

General procedure (*I*) for the synthesis of C2-substituted-*3H*-indol-3-one (1a-1x).



Compounds **1** were prepared according to the modified procedure of literature. [1]

General Procedure I:

Method A: Indole derivatives (**A**) (1.0 equiv.), aryl boronic acid (**B**) (1.3 equiv.) and $Pd(OAc)_2$ (0.1 equiv.) were added to an oven dried Schlenck flask. AcOH was added by syringe and resulting solution was degassed twice and refilled with O_2. The reaction mixture was stirred for 8 hrs at room temperature. Then AcOH was recovered by distillation under reduced pressure, and the residue was dissolved in DCM, washed with aqueous $NaHCO_3$. The organic layer was dried over anhydrous Na_2SO_4. After removal

of the solvent, the product (**C**) was purified by flash chromatography on silica gel.

Irradiation of a methanol solution of 2-arylindoles (**C**, 1.0 equiv.) in the presence of methylene blue (MB, 0.1 equiv.) and pyridine (1 M) was carried out with a lighting operated at 180 V at 20 ℃ under oxygen bubbling. After complete disappearance of the starting 2-arylindoles (TLC monitoring), the reaction mixture was concentrated in vacuo, diluted with ether and washed with water. The ether layer was dried over anhydrous Na_2SO_4, evaporated to dryness and heated at 100 ℃ under reduced pressure for 1 h. The product **1** was purified by flash chromatography on silica gel (Compounds **1a-i** were prepared by method A).

Method B: Reactions were performed in a dry Schlenck flask equipped with a magnetic stirring bar under N_2. Aniline derivatives (**D**) (1.0 equiv.), KO^t-Bu (3.0 equiv.), and bathophenanthroline (0.2 equiv.) were added to the Schlenck tube. A solution of ketone (**E**) (2.0 equiv.) was added through a syringe and the reaction mixture was stirred at 60 ℃ for 8 hrs. After the solution was cooled to room temperature, the reaction was quenched with water. The organic layer was extracted with ethyl acetate and the combineg layer was concentrated under reduced pressure. The product (**F**) was purified by flash chromatography on silica gel. Then the procedure for the preparation of **1** followed method A from compound **F** (Compounds **1k-n**, **1p-r**, **1t-v** and **1x** were prepared by method B).

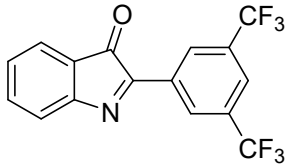
Method C: A solution of I_2 (1.0 equiv.) in DMF was dropped into a solution of **F** (1.0 equiv.) and KOH (2.5 equiv.) in DMF at room temperature and stirred for 2 hrs. The mixture was then purged with air, silica was added and the mixture heated to 120 ℃. Upon cooling, water was added and the mixture extracted with ethyl acetate. The organic extracts were combined, dried over anhydrous Na_2SO_4, filtered and concentrated in vacuum. Purification by flash chromatography on silica get eluting with petroleum ether/ethyl acetate to give product **1** (Compounds **1o** and **1w** were prepared by method C).

Method D: Reactions were performed in a dry Schlenck flask equipped with a magnetic stirring bar under N_2. Compound **F** (1.0 equiv.), CuI (0.2 equiv.) were added to the Schlenck flask, DMSO was added as solvent, then pyridine (2.0 equiv.) was

added through a syringe, the resulting solution was degassed twice and refilled with O_2. The reaction mixture was stirred for 12 hours at room temperature, water was added and the mixture extracted with ethyl acetate. The organic extracts were combined, dried over anhydrous Na_2SO_4, filtered and concentrated in vacuum. The crude materials were purified by flash chromatography on silica gel eluting with petroleum ether/ethyl acetate to give product **1** (Compounds **1j** and **1s** were prepared by method D).

Compounds **1a-1i**, **1m-1n** and **1p-1v** were known compounds. The spectra data were correspondence with the literature data. [1]

2-(3,5-bis(trifluoromethyl)phenyl)-*3H*-indol-3-one (1j)

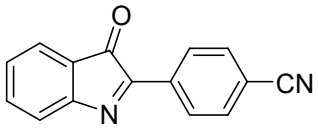


1j

Compound **1j** (175 mg, 73% yield) was obtained as a red solid following the *general procedure I* (Method D) from **F** (0.70 mmol, 240 mg), CuI (0.14 mmol, 26.7 mg), pyridine (1.4 mmol, 110.6 mg, 110 μL) in DMSO.

^{1}H NMR (400 MHz, DMSO-d_6) δ 8.73 (s, 2H), 8.36 (s, 1H), 7.70-7.63 (m, 2H), 7.55 (d, J = 7.6 Hz, 1H), 7.42 (t, J = 7.6 Hz, 1H); **^{13}C NMR** (100 MHz, DMSO-d_6) δ 191.0, 159.2, 158.1, 136.9, 132.6, 130.8 (q, J = 33.1 Hz), 129.4, 128.7, 124.9, 124.7, 123.1, 123.0 (q, J = 271.4 Hz), 122.5; **^{19}F NMR** (376 MHz, DMSO-d_6) δ -61.5 (s); **HRMS** Calcd. for $C_{16}H_8ONF_6^+$ $[M+H]^+$: 344.0505, found: 344.0500; **M.p.**: 102-104 ºC.

4-(3-oxo-3*H*-indol-2-yl)benzonitrile (1k)



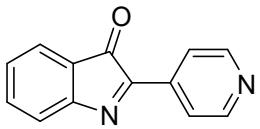
1k

Compound **1k** (206 mg, 34% yield) was obtained as a red solid following the *general procedure I* (Method B) from **F** (2.65 mmol, 578 mg), MB (0.265 mmol, 84.8 mg),

pyridine (2.5 mL) in MeOH.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (d, *J* = 8.4 Hz, 2H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.60-7.56 (m, 2H), 7.45 (d, *J* = 8.0 Hz, 1H), 7.32 (t, *J* = 7.6 Hz, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 192.4, 159.6, 159.0, 137.0, 134.0, 132.4, 129.4, 129.3, 125.0, 122.8, 122.6, 118.3, 115.1; **HRMS** Calcd. for $C_{15}H_9ON_2^+$ $[M+H]^+$: 233.0709, found: 233.0703; **M.p.**: 179-181 ºC.

2-(pyridin-4-yl)-3*H*-indol-3-one (1l)

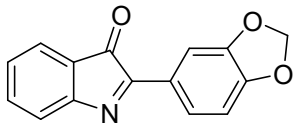


1l

Compound **1l** (51.1 mg, 12% yield) was obtained as a red solid following the *general procedure I* (Method B) from **F** (2 mmol, 388 mg), MB (0.2 mmol, 64 mg), pyridine (2 mL) in MeOH.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.78 (d, *J* = 4.8 Hz, 2H), 8.19 (dd, *J* = 4.8, 1.6 Hz, 2H), 7.61-7.57 (m, 2H), 7.49-7.47 (m, 1H), 7.36-7.32 (m, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 192.1, 159.8, 158.9, 150.5, 137.0, 136.9, 129.5, 125.0, 122.9, 122.8, 122.3; **HRMS** Calcd. for $C_{13}H_9ON_2^+$ $[M+H]^+$: 209.0715, found: 209.0706; **M.p.**: 138-140 ºC.

2-(benzo[*d*][1,3]dioxol-5-yl)-3*H*-indol-3-one (1o).



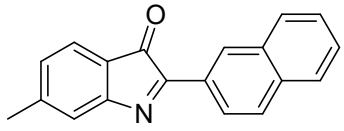
1o

Compound **1o** (106 mg, 37% yield) was obtained as a red solid following the *general procedure I* (Method C) from **F** (1.14 mmol, 270 mg), KOH (2.85 mmol, 160 mg), I_2 (1.14 mmol, 290 mg) and sillica gel (570 mg) in DMF.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (dd, *J* = 8.4, 1.6 Hz, 1H), 7.85 (d, *J* = 1.6 Hz, 1H), 7.53-7.50 (m, 2H), 7.37-7.34 (m, 1H), 7.24-7.20 (m, 1H), 6.91 (d, *J* = 8.0 Hz, 1H), 6.05 (s, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 193.8, 160.7, 159.5, 151.4, 148.3, 136.8, 127.8,

125.6, 124.7, 124.3, 123.2, 121.6, 108.7, 108.4, 101.7; **HRMS** Calcd. for $C_{15}H_{10}NO_3^+$ $[M+H]^+$: 252.0655, found: 252.0653; **M.p.**: 141-143 ºC.

6-Methyl-2-(naphthalen-2-yl)-3*H*-indol-3-one (1w).

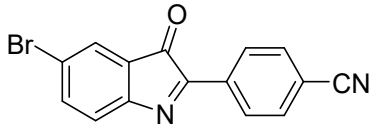


1w

Compound **1w** (64.9 mg, 20% yield) was obtained as a red solid following the *general procedure I* (Method C) from **F** (1.2 mmol, 308 mg), KOH (3 mmol, 168 mg), I_2 (1.2 mmol, 305 mg) and sillica gel (600 mg) in DMF.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.03 (s, 1H), 8.37 (dd, *J* = 8.8, 1.6 Hz, 1H), 8.00 (d, *J* = 7.6 Hz, 1H), 7.92 (d, *J* = 8.4 Hz, 1H), 7.86 (d, *J* = 7.6 Hz, 1H), 7.60-7.52 (m, 2H), 7.48 (d, *J* = 7.2 Hz, 1H), 7.25 (s, 1H), 7.06 (d, *J* = 7.2 Hz, 1H), 2.45 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 193.2, 161.5, 160.4, 148.6, 135.0, 133.0, 131.3, 129.6, 128.7, 128.5, 128.2, 127.8, 127.6, 126.6, 124.8, 124.7, 123.0, 121.0, 22.4; **HRMS** Calcd. for $C_{19}H_{14}ON^+$ $[M+H]^+$: 272.1075, found: 272.1077; **M.p.**: 163-165 ºC.

4-(5-Bromo-1*H*-indol-2-yl)benzonitrile (1x)

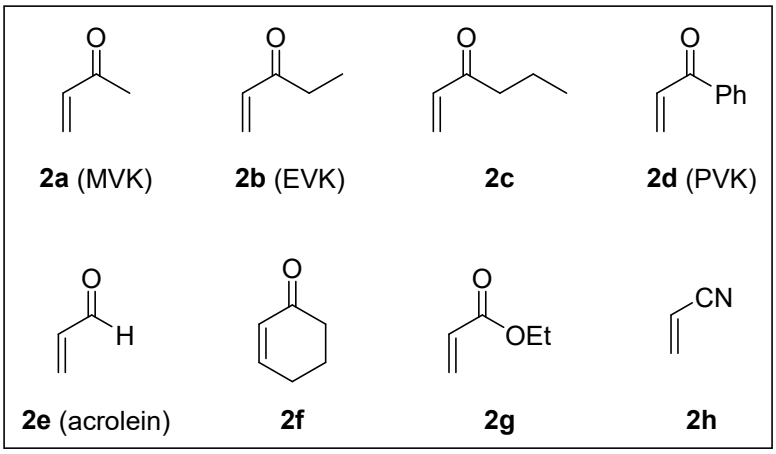


1x

Compound **1x** (185.7 mg, 40% yield) was obtained as a red solid following the *general procedure I* (Method B) from **F** (1.5 mmol, 443 mg), MB (0.15 mmol, 48 mg) and pyridine (1.5 mL) in MeOH.

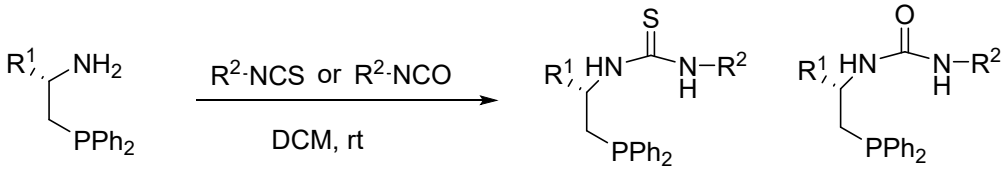
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (d, *J* = 8.4 Hz, 2H), 7.78 (d, *J* = 8.4 Hz, 2H), 7.71 (td, *J* = 8.0, 2.0 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 191.4, 159.3, 157.7, 139.3, 133.6, 132.5, 129.5, 128.2, 124.2, 124.0, 122.9, 118.2, 115.4; **HRMS** Calcd. for $C_{15}H_8N_2OBr^+$ $[M+H]^+$: 310.9815, found: 310.9807; **M.p.**: 259-261 ºC.

Structures of compounds 2



Compounds **2a-2c** and **2e-2h** are commercially available, using directly without any purification. Compound **2d** (PVK) was prepared according to literature. [2]

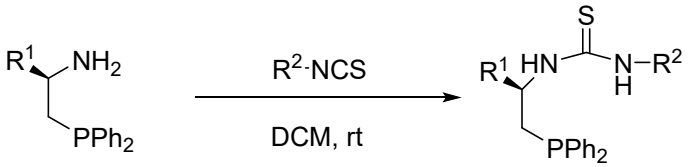
General procedure (*II*) for the synthesis of chiral phosphines.



LBa-d
LBa, R^1 = isopropyl
LBb, R^1 = Me
LBc, R^1 = Et
LBd, R^1 = isopentyl

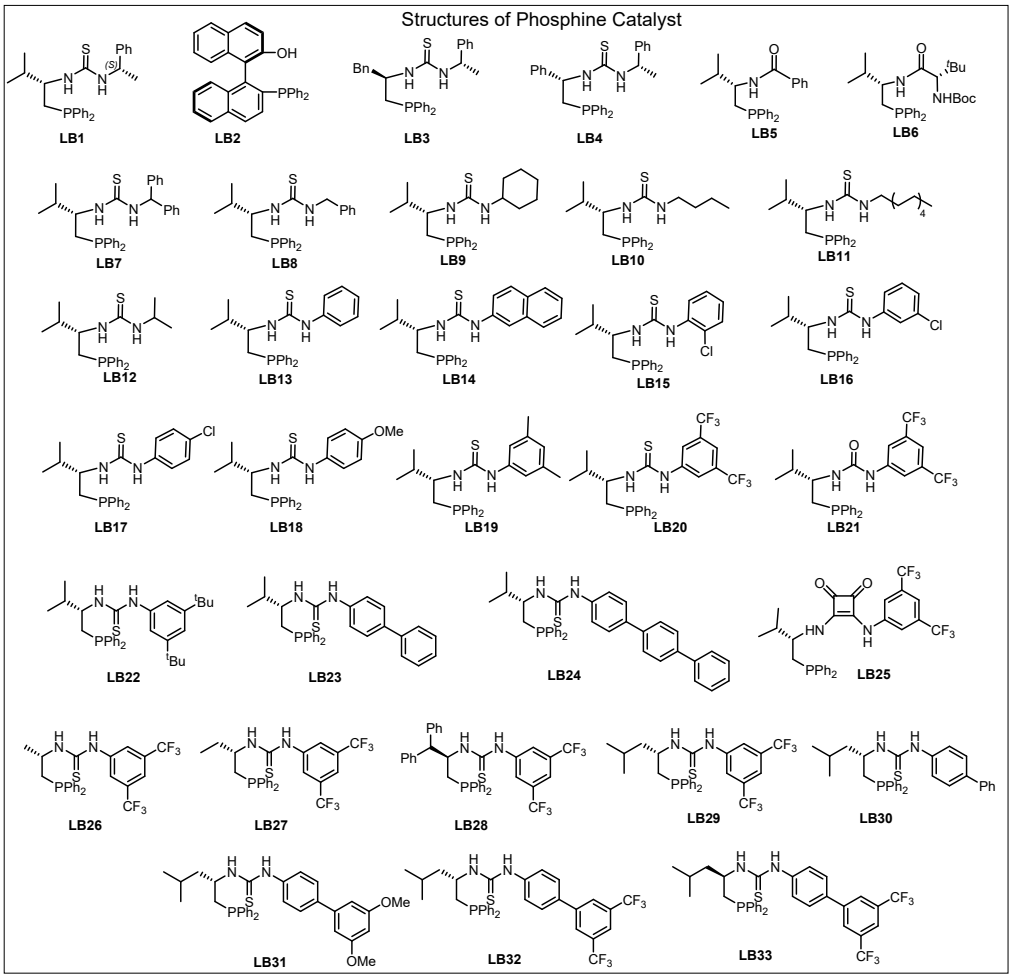
LB12
LB15-16
LB19
LB21-24
LB26-28
LB29-32

LB21



LBe, R^1 = diphenylmethyl
LBf, R^1 = isopentyl

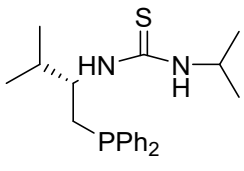
LB28
LB33



LBa-f, isothiocyanate and isocyanate was prepared according to the reported literature.[3,4] **LB1-11, LB13-14, LB17-18, LB20** and **LB25** were known compounds.[5]

Procedure (II): To a solution of **LBa-f** (1.0 eq) in DCM under N_2 atmosphere was added isothiocyanate or isocyanate (1.2 eq), and the reaction mixture was stirred at room temperature for 24 hrs. Solvent was then removed under reduced pressure, and the residue was directly subjected to column chromatographic separation on silica gel (hexane/ethyl acetate = 15:1 to 10:1) to afford chiral phosphines (**LB12, LB15-16, LB19, LB21-24, LB26-33**) as white solid.

(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-isopropylthiourea (LB12)

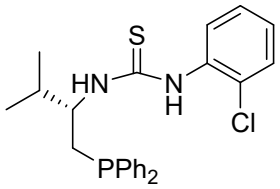


LB12

Compound **LB12** (70 mg, 94% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.2 mmol, 54.2 mg) and 2-isothiocyanatopropane (0.24 mmol, 24 mg, 26 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47-7.41 (m, 4H), 7.35-7.31 (m, 6H), 5.75 (brs, 1H), 4.28 (brs, 1H), 3.79 (brs, 1H), 2.42 (dd, *J* = 14.0, 4.8Hz, 1H), 2.33-2.28 (m, 1H), 2.19-2.10 (m, 1H), 1.09 (dd, *J* = 6.4, 1.6 Hz, 6H), 0.91 (t, *J* = 6.4Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.8, 138.2 (d, *J* = 11.8 Hz), 132.8 (d, *J* = 19.2 Hz), 132.6 (d, *J* = 18.9 Hz), 128.74, 128.66, 128.50 (d, *J* = 6.8 Hz), 128.47 (d, *J* = 6.9 Hz), 99.8, 57.6, 45.4, 32.0 (d, *J* = 8.9 Hz), 31.2 (d, *J* = 12.1 Hz), 22.4 (d, *J* = 9.6 Hz), 18.7, 18.0, 14.0; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -23.7; **HRMS** Calcd. for $C_{21}H_{30}N_2PS^+$ $[M+H]^+$: 373.1862, found: 373.1854; **M.p.**: 105-106 ºC; $[\alpha]^{20}_D$ = +2.0 (c 0.05, CH_2Cl_2).

(*S*)-1-(2-chlorophenyl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB15)

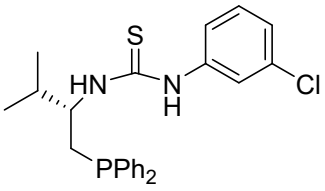


LB15

Compound **LB15** (83.1 mg, 94% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.2 mmol, 54.2 mg) and 1-chloro-2-isothiocyanatobenzene (0.24 mmol, 40.7 mg, 31 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (brs, 1H), 7.49-7.41 (m, 5H), 7.34-7.17 (m, 9H), 6.06 (brs, 1H), 4.60 (brs, 1H), 2.43-2.31 (m, 2H), 2.16 (h, *J* = 6.4 Hz, 1H), 0.87 (dd, *J* = 11.2, 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 180.1, 138.0 (d, *J* = 11.9 Hz), 133.4, 132.8 (d, *J* = 4.8 Hz), 132.6 (d, *J* = 4.8 Hz), 130.6, 129.7, 128.7, 128.5, 128.4, 128.3, 127.8 (d, *J* = 11.1 Hz), 126.8, 58.5 (d, *J* = 14.3 Hz), 31.54 (d, *J* = 8.4 Hz), 31.49 (d, *J* = 14.7 Hz), 18.7, 17.9; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.2; **HRMS** Calcd. for $C_{24}H_{27}ClN_2PS^+$ $[M+H]^+$: 441.1327, found: 441.1319; **M.p.**: 43-45 ºC; $[\alpha]^{20}_D$ = +63.6 (c 0.11, CH_2Cl_2).

(*S*)-1-(3-chlorophenyl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB16)

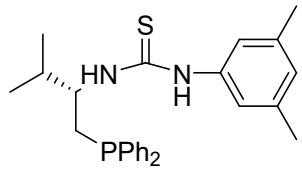


LB16

Compound **LB16** (88 mg, 91% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.22 mmol, 59.6 mg) and 1-chloro-3-isothiocyanatobenzene (0.24 mmol, 40.7 mg, 32 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (brs, 1H) 7.47-7.40 (m, 4H), 7.32-7.29 (m, 6H), 7.24-7.22 (m, 1H), 7.18-7.16 (m, 1H), 7.13-7.11 (m, 1H), 7.00 (d, *J* = 8.0 Hz, 1H), 6.12 (brs, 1H), 4.59 (brs, 1H), 2.47-2.42 (m, 1H), 2.27 (dd, *J* = 11.4, 8.4 Hz, 1H), 2.13 (h, *J* = 6.4Hz, 1H), 0.88 (dd, *J* = 9.2, 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.7, 138.1 (d, *J* = 11.5 Hz), 137.9 (d, *J* = 12.2 Hz), 137.4, 135.4, 132.9 (d, *J* = 6.9 Hz), 132.7 (d, *J* = 7.0 Hz), 130.8, 128.8, 128.5 (d, *J* = 6.8 Hz), 126.7, 124.7, 122.6, 58.6 (d, *J* = 13.9 Hz), 31.8 (d, *J* = 8.4 Hz), 31.0 (d, *J* = 14.5 Hz), 18.7, 18.2; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.2; **HRMS** Calcd. for $C_{24}H_{27}ClN_2PS^+$ $[M+H]^+$: 441.1327, found: 441.1332; **M.p.**: 50-52 ºC; $[a]^{20}_D$ = +52.0 (c 0.10, CH_2Cl_2).

(*S*)-1-(3,5-dimethylphenyl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB19)



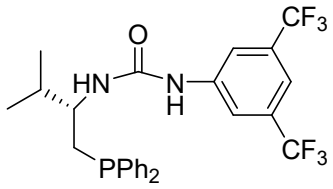
LB19

Compound **LB19** (90.0 mg, 90% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.23 mmol, 62.3 mg) and 1-isothiocyanato-3,5-dimethylbenzene (0.24 mmol, 39.2 mg, 39 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (brs, 1H) 7.50-7.44 (4H, m, ArH), 7.34-7.29 (m,

6H), 6.88 (s, 1H), 6.73 (s, 2H), 6.15 (d, *J* = 8.0 Hz, 1H), 4.60 (brs, 1H), 2.44 (dd, *J* = 14.4, 5.6 Hz, 1H), 2.28 (s, 6H), 2.15 (h, *J* = 6.4 Hz, 1H), 0.87 (dd, *J* = 16.4, 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.8, 139.8, 138.2 (d, *J* = 11.9 Hz), 135.7, 132.8 (d, *J* = 19.3 Hz), 132.7 (d, *J* = 19.1 Hz), 128.6, 128.42, 128.36, 122.6, 58.3 (d, *J* = 14.5 Hz), 31.6 (d, *J* = 8.6 Hz), 31.2 (d, *J* = 14.6 Hz), 21.1, 18.8, 17.9; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.3; **M.p.**: 117-118 ºC; **HRMS** Calcd. for $C_{26}H_{32}N_2PS^+$ $[M+H]^+$: 435.2018, found: 435.2013; $[\alpha]^{20}_D$ = +72.5 (c 0.04, CH_2Cl_2).

(*S*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)urea (**LB21**)

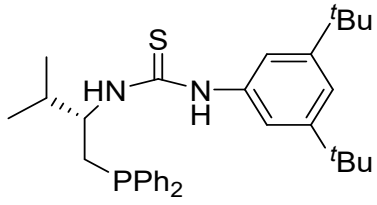


LB21

Compound **LB21** (36.0 mg, 40% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.17 mmol, 46.4 mg) and 1-isothiocyanato-3,5-bis(trifluoromethyl)benzene (0.24 mmol, 61.2 mg, 41 µL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (s, 2H), 7.41-7.38 (m, 5H), 7.30-7.25 (m, 6H), 5.18 (d, *J* = 8.8 Hz, 1H), 3.85 (brs, 1H), 2.36 (d, *J* = 12.8 Hz, 1H), 2.16 (t, *J* = 12.8 Hz, 1H), 1.95-1.89 (m, 1H), 0.87-0.84 (m, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 154.8, 140.4, 138.0 (d, *J* = 10.8 Hz), 137.7 (d, *J* = 11.7 Hz), 132.7 (q, *J* = 8.6 Hz), 132.6 (d, *J* = 8.6 Hz), 132.0 (d, *J* = 33.0 Hz), 131.5, 128.9 (d, *J* = 13.5 Hz), 128.6 (d, *J* = 7.0 Hz), 123.1 (q, *J* = 271.5 Hz), 118.5, 115.6, 53.4 (d, *J* = 14.3 Hz), 32.7 (d, *J* = 7.9 Hz), 32.2 (d, *J* = 12.9 Hz), 18.9, 17.5; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -22.7; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -63.0; **M.p.**: 189-191 ºC; **HRMS** Calcd. for $C_{26}H_{26}ON_2F_6P^+$ $[M+H]^+$: 527.1681, found: 527.1676; $[\alpha]^{20}_D$ = -10.0 (c 0.05, CH_2Cl_2).

(*S*)-1-(3,5-di-tert-butylphenyl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB22)

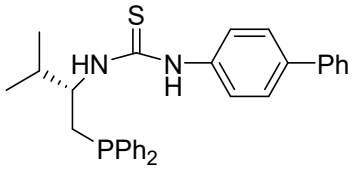


LB22

Compound **LB22** (214.8 mg, 83% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.5 mmol, 136 mg) and 1,3-di-*tert*-butyl-5-isothiocyanatobenzene (0.6 mmol, 148 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.60 (s, 1H), 7.53-7.44 (m, 4H), 7.34-7.28 (m, 7H), 7.09 (s, 2H), 6.17 (d, *J* = 8.4 Hz, 1H), 4.60 (brs, 1H), 2.36 (d, *J* = 6.4 Hz, 2H), 2.21-2.12 (m, 1H), 1.32 (s, 18 H), 0.87 (dd, *J* = 21.6, 6.4 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.6, 152.7, 138.3 (d, *J* = 12.6 Hz), 137.8 (d, *J* = 11.5 Hz), 135.4, 132.7 (d, *J* = 19.2 Hz), 132.6 (d, *J* = 19.1 Hz), 128.4 (d, *J* = 5.6 Hz), 128.3 (d, *J* = 4.2 Hz), 128.2 (d, *J* = 4.1 Hz), 120.8, 119.2, 57.7 (d, *J* = 14.6 Hz), 34.8, 31.4 (d, *J* = 14.5 Hz), 31.2, 18.9,17.5; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.6; **HRMS** Calcd. for $C_{32}H_{44}N_2PS^+$ $[M+H]^+$: 519.2968, found: 519.2965; **M.p.**: 60-62 ºC; $[\alpha]^{20}_D$ = +52.7 (c 0.11, CH_2Cl_2).

(*S*)-1-([1,1'-biphenyl]-4-yl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB23)



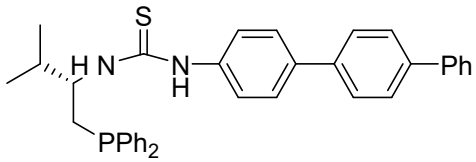
LB23

Compound **LB23** (131.2 mg, 82% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.33 mmol, 71.2 mg) and 4-isothiocyanato-1,1'-biphenyl (0.39 mmol, 83.6 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.23 (s, 1H), 7.59 (d, *J* = 8.0 Hz, 4H), 7.51-7.45 (m, 6H), 7.39 (d, *J* = 7.2 Hz, 1H), 7.36-7.31 (m, 6H), 7.17 (d, *J* = 8.4 Hz, 2H), 6.13 (d, *J* = 8.4 Hz, 1H), 4.65 (brs, 1H), 2.46 (dd, *J* = 14.4, 5.6 Hz, 1H), 2.32 (dd, *J* = 14.4, 8.0 Hz, 1H), 2.22-2.14 (m, 1H), 0.90 (dd, *J* = 14.8, 8.0 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$)

δ 179.9, 139.7 (d, *J* = 11.7 Hz), 138.2 (d, *J* = 12.3 Hz), 135.1, 132.9 (d, *J* = 8.1 Hz), 132.7 (d, *J* = 8.1 Hz), 128.9, 128.73, 128.68, 128.51, 128.47, 128.44, 128.40, 127.6, 126.9, 125.1, 58.5 (d, *J* = 14.3 Hz), 31.7 (d, *J* = 8.6 Hz), 31.1 (d, *J* = 14.4 Hz), 18.8, 18.1; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.2; **HRMS** Calcd. for $C_{30}H_{32}N_2SP^+$ $[M+H]^+$: 483.2018, found: 483.2003; **M.p.**: 60-62 ºC; $[\alpha]^{20}_D$ = +103.0 (c 0.10, CH_2Cl_2).

(*S*)-1-([1,1':4',1''-terphenyl]-4-yl)-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB24)

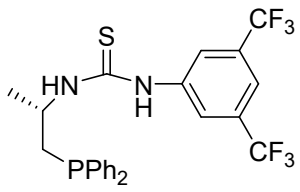


LB24

Compound **LB24** (207 mg, 81% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.46 mmol, 127 mg) and 4-isothiocyanato-1,1':4',1''-terphenyl (0.55 mmol, 158 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (s, 1H), 7.73-7.63 (m, 8H), 7.52-7.47 (m, 6H), 7.40 (d, *J* = 7.6 Hz, 1H), 7.37-7.31 (m, 6H), 7.20 (d, *J* = 8.4 Hz, 2H), 6.15 (d, *J* = 8.4 Hz, 1H), 4.67 (s, 1H), 2.48 (dd, *J* = 14.4, 4.0 Hz, 1H), 2.34 (dd, *J* = 14.4, 8.0 Hz, 1H), 2.24-2.16 (m, 1H), 0.92 (dd, *J* = 14.0, 6.8 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.9, 140.5, 140.4, 139.1, 138.6, 138.2 (d, *J* = 9.3 Hz), 135.2, 132.9 (d, *J* = 8.5 Hz), 132.7 (d, *J* = 8.4 Hz), 128.8, 128.7 (d, *J* = 4.8 Hz), 128.5 (d, *J* = 3.7 Hz), 128.43 (d, *J* = 3.8 Hz), 128.37, 127.9, 127.6, 127.4, 127.2, 126.9, 126.1, 125.1 (d, *J* = 0.8 Hz), 58.5 (d, *J* = 14.3 Hz), 31.8 (d, *J* = 9.2 Hz), 31.2 (d, *J* = 14.8 Hz), 18.8, 18.1; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.1; **HRMS** Calcd. for $C_{36}H_{36}N_2PS^+$ $[M+H]^+$: 559.2331, found: 559.2317; **M.p.**: 136-138 ºC; $[\alpha]^{20}_D$ = +118.0 (c 0.10, CH_2Cl_2).

(*S*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-(1-(diphenylphosphaneyl)propan-2-yl)thiourea (LB26)

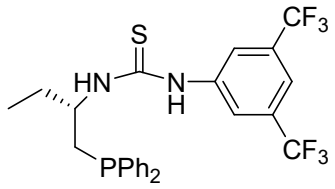


LB26

Compound **LB26** (130 mg, 51% yield) was obtained as a white solid following the *general procedure II* from **LBb** (0.5 mmol, 122 mg) and 1-isothiocyanato-3,5-bis(trifluoromethyl)benzene (0.6 mmol, 162 mg, 110 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.2 Hz, 3H), 7.48-7.39 (m, 4H), 7.34-7.30 (m, 6H), 6.18 (brs, 1H), 4.65 (brs, 1H), 2.53 (dd, *J* = 14.0, 6.0 Hz, 1H), 2.41 (dd, *J* = 14.0, 6.4 Hz, 1H), 1.38 (d, *J* = 6.4 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 178.9, 139.0, 137.2 (d, *J* = 9.8 Hz), 137.1 (d, *J* = 9.6 Hz), 132.7 (d, *J* = 4.6 Hz), 132.5 (d, *J* = 4.6 Hz), 128.9, 128.57 (d, *J* = 7.0 Hz), 128.55 (d, *J* = 7.0 Hz), 123.4, 122.7 (q, *J* = 217.3 Hz), 118.8, 49.3 (d, *J* = 14.8 Hz), 35.8 (d, *J* = 12.4 Hz), 21.6 (d, *J* = 8.6 Hz); **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.9; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.8; **HRMS** Calcd. for $C_{24}H_{22}F_6N_2PS^+$ $[M+H]^+$: 515.1140, found: 515.1129; **M.p.**: 106-108 ºC; $[\alpha]^{20}_D$ = +24.8 (c 0.20, CH_2Cl_2).

(*S*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-(1-(diphenylphosphaneyl)butan-2-yl)thiourea (LB27)



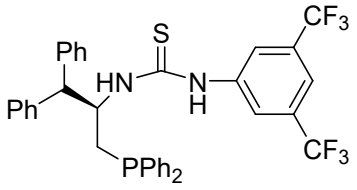
LB27

Compound **LB27** (69.5 mg, 40% yield) was obtained as a white solid following the *general procedure II* from **LBc** (0.33 mmol, 85 mg) and 1-isothiocyanato-3,5-bis(trifluoromethyl)benzene (0.4 mmol, 108 mg, 73 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26 (brs, 1H), 7.67 (d, *J* = 10.4 Hz, 3H), 7.46-7.39 (m, 4H), 7.31-7.30 (m, 6H), 6.25 (brs, 1H), 4.62 (brs, 1H), 2.60 (d, *J* = 12.4 Hz, 1H), 2.37 (dd, *J* = 14.4, 7.2 Hz, 1H), 1.82-1.66 (m, 2H), 0.94 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 179.6, 138.8, 137.6, 137.3, 132.73 (d, *J* = 19.0 Hz), 132.69 (d, *J* = 19.0

Hz), 129.0, 128.6 (d, J = 6.9 Hz), 123.6, 122.8 (q, J = 271.8 Hz), 119.11 (d, J = 3.5 Hz), 119.05 (d, J = 3.8 Hz), 55.0 (d, J = 13.6 Hz), 33.2, 28.4, 10.2; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -25.2 (s); **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.9 (s); **HRMS** Calcd. for $C_{25}H_{24}F_6N_2PS^+$ $[M+H]^+$: 529.1307, found: 529.1302; **M.p.**: 133-135 ºC; $[\alpha]^{20}_D$ = +7.5 (c 0.04, CH_2Cl_2).

(*R*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-(3-(diphenylphosphaneyl)-1,1-diphenylpropan-2-yl)thiourea (LB28)

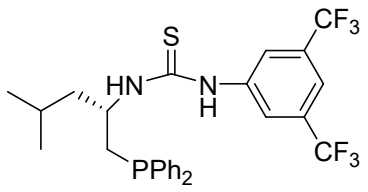


LB28

Compound **LB28** (183.4 mg, 64% yield) was obtained as a white solid following the *general procedure II* from **LBe** (0.43 mmol, 171 mg) and 1-isothiocyanato-3,5-bis(trifluoromethyl)benzene (0.52 mmol, 141 mg, 95 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (brs, 1H), 7.65 (s, 1H), 7.49-7.45 (m, 2H), 7.37-7.29 (m, 9H), 7.25-7.15 (m, 9H), 7.05 (s, 2H), 5.80 (brs, 2H), 4.60 (d, J = 7.6 Hz, 1H), 2.99 (d, J = 10.0 Hz, 1H), 2.12 (d, J = 14.8 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 179.2, 141.0 (d, J = 18.6 Hz), 138.1 (d, J = 9.6 Hz), 137.7, 136.9 (d, J = 11.3 Hz), 133.1 (d, J = 19.9 Hz), 132.8 (d, J = 32.9 Hz), 132.2 (d, J = 18.3 Hz), 129.1, 128.9 (d, J = 9.8 Hz), 128.6 (d, J = 7.3 Hz), 128.5, 128.4 (d, J = 6.8 Hz), 128.3, 127.9, 127.1, 127.0, 123.9 (d, J = 2.9 Hz), 122.6 (q, J = 271.9 Hz), 119.4 (d, J = 6.6 Hz), 56.1 (d, J = 73.9 Hz), 31.6, 22.6; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -27.7; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.6; **M.p.**: 79-81 ºC; **HRMS** Calcd. for $C_{36}H_{30}F_6N_2SP^+$ $[M+H]^+$: 667.1766, found: 667.1749; $[\alpha]^{20}_D$ = -58.0 (c 0.05, CH_2Cl_2).

(*S*)-1-(3,5-bis(trifluoromethyl)phenyl)-3-(1-(diphenylphosphaneyl)-4-methylpentan-2-yl)thiourea (LB29)

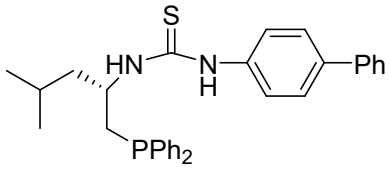


LB29

Compound **LB29** (173.2 mg, 62% yield) was obtained as a white solid following the *general procedure II* from **LBd** (0.5 mmol, 143 mg) and 1-isothiocyanato-3,5-bis(trifluoromethyl)benzene (0.6 mmol, 163 mg, 110 μL) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.95 (brs, 1H), 7.69 (d, *J* = 10.4 Hz, 3H), 7.50-7.42 (m, 4H), 7.34-7.31 (m, 6H), 6.41 (brs, 1H), 4.85 (brs, 1H), 2.68 (s, 1H), 2.40 (dd, *J* = 14.0, 6.0 Hz, 1H), 1.62 (brs, 3H), 0.91-0.87 (m, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.3, 138.8, 137.6 (d, *J* = 10.2 Hz), 132.9, 132.7, 132.5, 129.0, 128.9, 128.6, 128.5, 123.4, 122.8 (q, *J* = 271.6 Hz), 118.9, 51.9 (d, *J* = 12.9 Hz), 44.6 (d, *J* = 8.9 Hz), 34.1, 25.1, 22.4; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -25.4; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.9; **M.p.**: 145-146 ºC; **HRMS** Calcd. for $C_{27}H_{28}F_6N_2SP^+$ $[M+H]^+$: 557.1610, found: 557.1616; $[\alpha]^{20}_D$ = -2.50 (c 0.20, CH_2Cl_2).

(*S*)-1-([1,1'-biphenyl]-4-yl)-3-(1-(diphenylphosphaneyl)-4-methylpentan-2-yl)thiourea (LB30)



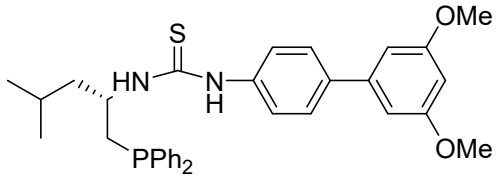
LB30

Compound **LB30** (109 mg, 88% yield) was obtained as a white solid following the *general procedure II* from **LBd** (0.25 mmol, 71 mg) and 4-isothiocyanato-1,1'-biphenyl (0.3 mmol, 63.3 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (brs, 1H), 7.59 (d, *J* = 7.6 Hz, 4H), 7.53-7.44 (m, 6H), 7.40-7.29 (m, 7H), 7.14 (d, *J* = 8.4 Hz, 2H), 6.10 (brs, 1H), 4.87 (brs, 1H), 2.59 (dd, *J* = 14.4, 6.4 Hz, 1H), 2.42 (dd, *J* = 14.0, 6.0 Hz, 1H), 1.62-1.53 (m, 3H), 0.88 (d, *J* = 4.4 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.3, 139.7 (d, *J* = 16.6 Hz), 138.3 (d, *J* = 11.1 Hz), 138.0 (d, *J* = 11.5 Hz), 135.1, 133.0 (d, *J* = 19.3 Hz), 132.6 (d, *J* =

19.0 Hz), 128.8, 128.7, 128.6, 128.49, 128.45, 128.41, 128.38, 127.6, 126.9, 125.1, 52.1 (d, *J* = 14.3 Hz), 44.5 (d, *J* = 9.4 Hz), 34.4 (d, *J* = 14.5 Hz), 25.1, 22.7, 22.4; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.9; **M.p.**: 55-57 ºC; **HRMS** Calcd. for $C_{31}H_{34}N_2SP^+$ $[M+H]^+$: 497.2175, found: 497.2163; $[\alpha]^{20}_D$ = +75.0 (c 0.20, CH_2Cl_2).

(*S*)-1-(3',5'-dimethoxy-[1,1'-biphenyl]-4-yl)-3-(1-(diphenylphosphaneyl)-4-methylpentan-2-yl)thiourea (LB31)

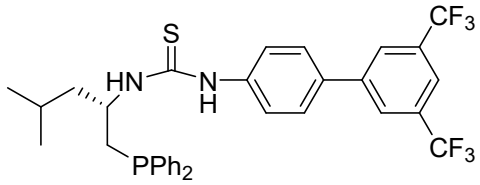


LB31

Compound **LB31** (189.8 mg, 68% yield) was obtained as a white solid following the *general procedure II* from **LBd** (0.5 mmol, 143 mg) and 4'-isothiocyanato-3,5-dimethoxy-1,1'-biphenyl (0.6 mmol, 163 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.60 (s, 1H), 7.58-7.43 (m, 6H), 7.38-7.27 (m, 6H), 7.15 (d, *J* = 8.4 Hz, 2H), 6.72 (d, *J* = 2.0 Hz, 2H), 6.50 (t, *J* = 2.0 Hz, 1H), 6.14 (brs, 1H), 6.88 (brs, 1H), 3.85 (s, 6H), 2.59 (dd, *J* = 14.4, 6.4 Hz, 1H), 2.42 (dd, *J* = 14.0, 4.8 Hz, 1H), 1.63-1.54 (m, 3H), 0.88 (d, *J* = 6.0 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.4, 161.1, 142.0, 139.6, 138.3 (d, *J* = 11.7 Hz), 138.1 (d, *J* = 11.2 Hz), 135.3, 133.0 (d, *J* = 19.5 Hz), 132.6 (d, *J* = 19.1 Hz), 128.8, 128.6, 128.5 (d, *J* = 3.6 Hz), 128.4 (d, *J* = 3.3 Hz), 125.0, 105.3, 99.5, 55.4, 52.2 (d, *J* = 14.1 Hz), 44.5 (d, *J* = 9.5 Hz), 34.4 (d, *J* = 14.6 Hz), 25.1, 22.7, 22.5; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -24.9; **M.p.**: 57-59 ºC; **HRMS** Calcd. for $C_{33}H_{38}N_2O_2SP^+$ $[M+H]^+$: 557.2386, found: 557.2381; $[\alpha]^{20}_D$ = +82.0 (c 0.05, CH_2Cl_2).

(*S*)-1-(3',5'-bis(trifluoromethyl)-[1,1'-biphenyl]-4-yl)-3-(1-(diphenylphosphaneyl)-4-methylpentan-2-yl)thiourea (LB32)

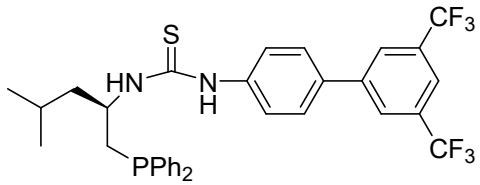


LB32

Compound **LB32** (195.4 mg, 62% yield) was obtained as a white solid following the *general procedure II* from **LBd** (0.5 mmol, 143 mg) and 4'-isothiocyanato-3,5-bis(trifluoromethyl)-1,1'-biphenyl (0.6 mmol, 208 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (s, 2H), 7.88 (s, 1H), 7.60 (d, *J* = 8.4 Hz, 2H), 7.51-7.43 (m, 4H), 7.35-7.29 (m, 6H), 7.21 (d, *J* = 8.4 Hz, 2H), 6.07 (brs, 1H), 4.84 (brs, 1H), 2.61 (dd, *J* = 14.0, 6.0 Hz, 1H), 2.38 (dd, *J* = 14.4, 5.6 Hz, 1H), 1.58-1.53 (m, 3H), 0.87 (dd, *J* = 6.0, 3.6 Hz, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 179.4, 142.0, 138.2 (d, *J* = 9.8 Hz), 138.0 (d, *J* = 11.0 Hz), 136.8, 136.3, 133.0 (d, *J* = 19.4 Hz), 132.6 (d, *J* = 18.9 Hz), 132.3 (d, *J* = 33.1 Hz), 131.9, 128.9 (d, *J* = 10.3 Hz), 128.7 (d, *J* = 16.1 Hz), 128.54, 128.51 (d, *J* = 5.4 Hz), 127.0 (d, *J* = 2.9 Hz), 125.1, 123.2 (q, *J* = 271.4 Hz), 121.2, 52.4 (d, *J* = 14.5 Hz), 44.6 (d, *J* = 9.4 Hz), 34.4 (d, *J* = 14.0 Hz), 25.2, 22.6, 22.5; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -25.2; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.7; **M.p.**: 138-139 ºC; **HRMS** Calcd. for $C_{33}H_{32}F_6N_2SP^+$ $[M+H]^+$: 633.1928, found: 633.1932; $[\alpha]^{20}_D$ = +88.0 (c 0.10, CH_2Cl_2).

(*R*)-1-(3',5'-bis(trifluoromethyl)-[1,1'-biphenyl]-4-yl)-3-(1-(diphenylphosphaneyl)-4-methylpentan-2-yl)thiourea (**LB33**)



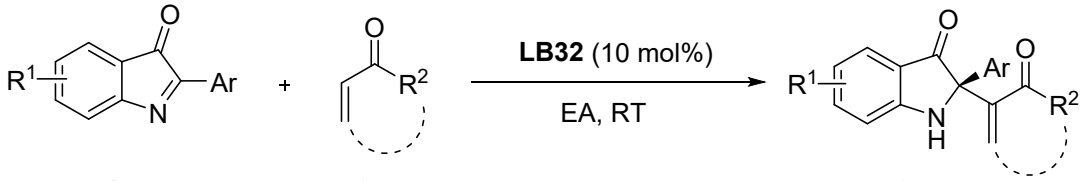
LB33

Compound **LB33** (229 mg, 73% yield) was obtained as a white solid following the *general procedure II* from **LBf** (0.5 mmol, 143 mg) and 4'-isothiocyanato-3,5-bis(trifluoromethyl)-1,1'-biphenyl (0.6 mmol, 208 mg) stirred for 24 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30 (brs, 1H), 7.99 (s, 2H), 7.88 (s, 1H), 7.59 (d, *J* = 8.0 Hz, 2H), 7.52-7.43 (m, 4H), 7.34-7.31 (m, 6H), 7.24 (d, *J* = 8.0 Hz, 2H), 6.15 (brs,

1H), 4.86 (brs, 1H), 2.62 (dd, J = 14.0, 5.6 Hz, 1H), 2.39 (dd, J = 14.4, 6.0 Hz, 1H), 1.56 (d, J = 6.8 Hz, 2H), 1.27 (s, 1H), 0.89-0.86 (m, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.3, 142.0 138.2 (d, J = 10.8 Hz), 138.0 (d, J = 10.9 Hz), 137.0, 136.1, 133.0 (d, J = 19.3 Hz), 132.6 (d, J = 18.9 Hz), 132.3 (q, J = 33.2 Hz), 131.8, 128.9, 128.7, 128.6 (d, J = 4.6 Hz), 128.5 (d, J = 4.5 Hz), 127.0, 125.0, 123.2 (q, J = 271.4 Hz), 121.1, 52.2 (d, J = 14.0 Hz), 44.6 (d, J = 9.1 Hz), 34.4 (d, J = 13.7 Hz), 25.2, 22.6, 22.5; **^{31}P NMR** (160 MHz, $CDCl_3$) δ -25.2; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.7; **M.p.**: 136-138 ºC; **HRMS** Calcd. for $C_{33}H_{32}F_6N_2SP^+$ $[M+H]^+$: 633.1928, found: 633.1926; $[\alpha]^{20}_D$ = -47.0 (c 0.10, CH_2Cl_2).

General procedure (*III*) for the synthesis of C2-quaternary indolin-3-ones (3aa-3xe).

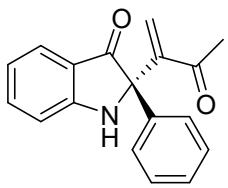


1 **2** **3**

2a, R = Me
2b, R = Et
2c, R = ^{n}Pr
2d, R = Ph
2e, R = H
2f, Cyclohexenone

Procedure (III): To a solution of compound **1** (0.1 mmol, 1.0 equiv.) and chiral phosphine **LB32** (0.01 mmol, 0.1 equiv.) in ethyl acetate (2.0 mL) was added compound **2** (0.15 mmol, 1.5 equiv.) under nitrogen atmosphere at room temperature. TLC monitor until the compound **1** consumed after six hours. The reaction mixture was then concentrated on a rotary evaporator under reduce pressure and the residue was subjected to purification by column chromatography (silica gel, PE/EtOAc: 15/1 to 10/1, R_f = 0.2-0.3) to afford the corresponding product **3**.

(*S*)-2-(3-oxobut-1-en-2-yl)-2-phenylindolin-3-one (**3aa**)



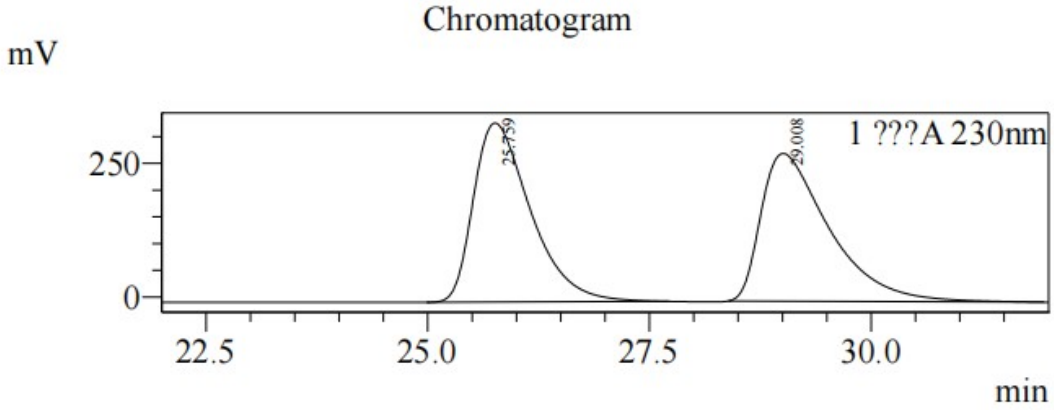
3aa

Compound **3aa** (26.3 mg, 95% yield) was obtained as a yellow solid following the *general procedure III* from **1a** (0.1 mmol, 20.7 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 7.6 Hz, 1H), 7.50-7.42 (m, 3H), 7.32-7.29 (m, 2H), 7.25-7.21 (m, 1H), 6.92-6.90 (m, 1H), 6.79 (t, *J* = 7.6 Hz, 1H), 6.41-6.40 (m, 2H), 6.26 (brs, 1H), 2.36 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 200.1, 198.5, 159.6, 145.4, 137.9, 137.8, 128.58, 128.55, 127.6, 125.4, 125.2, 118.7, 118.4, 111.6, 72.6, 27.1; **HRMS** Calcd. for $C_{18}H_{16}NO_2^+$ $[M+H]^+$: 278.1187, found: 278.1186; **M.p.**: 158-160 ºC.

$[\alpha]^{20}_D$ = -677.0 (c 0.10, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 29.862 min, t_{major} = 26.359 min.

Racemic Sample of 3aa

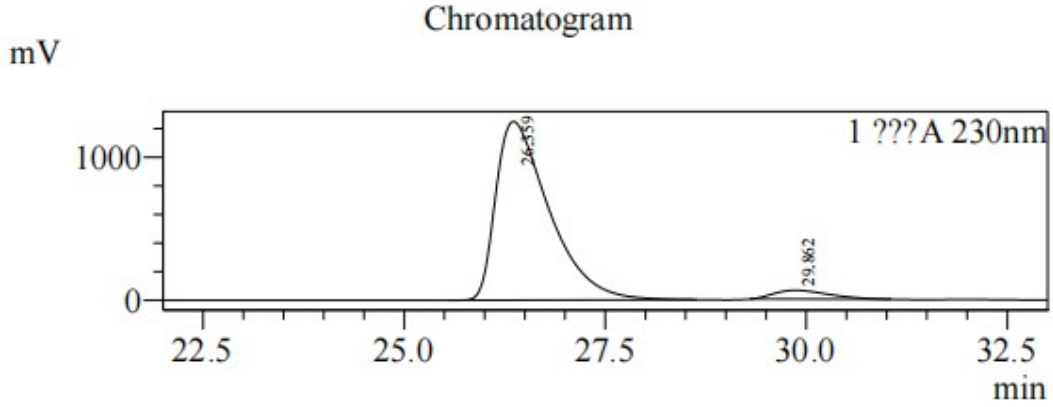


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	25.759	14981922	334691	50.354
2	29.008	14771524	276099	49.646
Total		29753446	610789	100.000

Enantiomeric Sample of 3aa

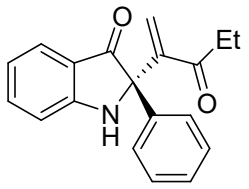


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	26.359	57554823	1250244	95.153
2	29.862	2931544	61266	4.847
Total		60486367	1311510	100.000

(*S*)-2-(3-oxopent-1-en-2-yl)-2-phenylindolin-3-one (3ab)



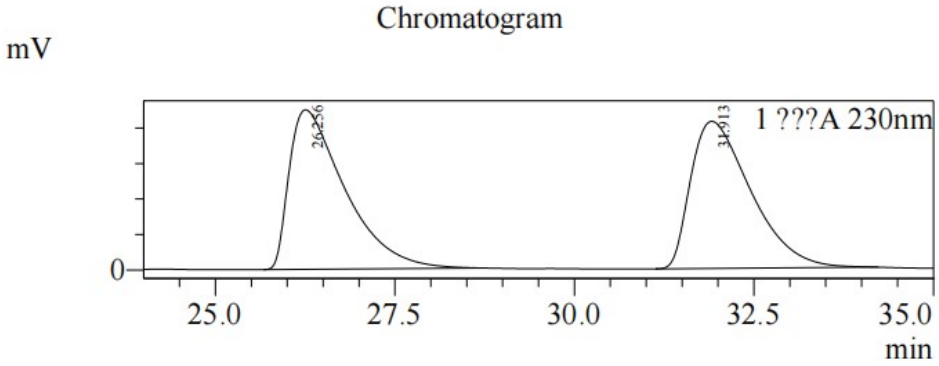
3ab

Compound **3ab** (27.4 mg, 94% yield) was obtained as a yellow solid following the *general procedure III* from **1a** (0.1 mmol, 20.7 mg) and **2b** (0.15 mmol, 12.6 mg, 14.8 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, *J* = 7.6 Hz, 1H), 7.50-7.42 (m, 3H), 7.31-7.27 (m, 2H), 7.25-7.21 (m, 1H), 6.91 (d, *J* = 8.4 Hz, 1H), 6.78 (t, *J* = 7.6 Hz, 1H), 6.38 (s, 1H), 6.34 (s, 1H), 6.27 (brs, 1H), 2.85-2.64 (m, 2H), 1.02 (t, *J* = 7.2Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 202.8, 198.5, 159.6, 145.1, 138.0, 137.8, 128.6, 127.6, 127.2, 125.4, 124.8, 118.7, 118.5, 111.7, 72.9, 32.1, 8.0; **HRMS** Calcd. for $C_{19}H_{18}NO_2^+$ $[M+H]^+$: 292.1332, found: 292.1331; **M.p.**: 131-133 ºC.

$[\alpha]^{20}_D$ = -328.0 (c 0.10, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 26.566 min, t_{major} = 31.697 min.

Racemic Sample of 3ab

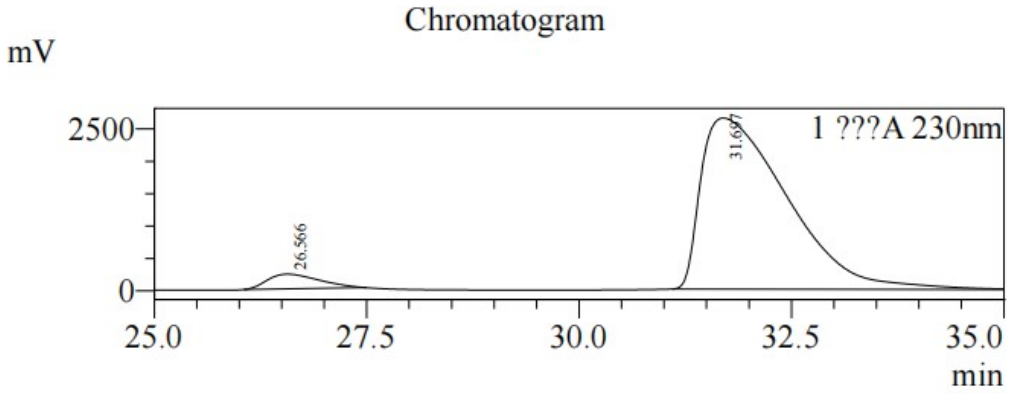


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	26.256	48541672	898281	50.117
2	31.913	48315644	828445	49.883
Total		96857316	1726726	100.000

Enantiomeric Sample of 3ab

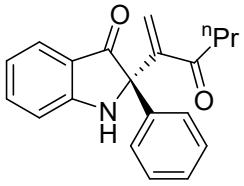


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	26.566	9595773	226576	4.884
2	31.697	186864092	2641594	95.116
Total		196459865	2868170	100.000

(*S*)-2-(3-oxohex-1-en-2-yl)-2-phenylindolin-3-one (3ac)



3ac

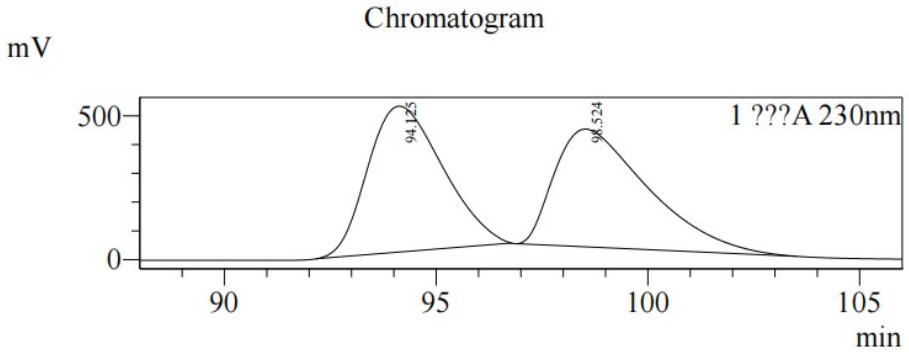
Compound **3ac** (27.4 mg, 90% yield) was obtained as a yellow solid following the

general procedure III from **1a** (0.1 mmol, 20.7 mg) and **2c** (0.15 mmol, 14.7 mg, 17.5 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 8.0 Hz, 1H), 7.50-7.42 (m, 3H), 7.31-7.27 (m, 2H), 7.24-7.21 (m, 1H), 6.91 (d, *J* = 8.4 Hz, 1H), 6.78 (t, *J* = 7.6 Hz, 1H), 6.37 (s, 1H), 6.34 (s, 1H), 6.29 (brs, 1H), 2.74-2.61 (m, 2H), 1.56 (h, *J* = 7.6 Hz, 2H), 0.85 (t, *J* = 7.6 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 202.5, 198.5, 159.6, 145.4, 138.0, 137.8, 128.5, 127.6, 127.2, 125.4, 125.2, 118.7, 118.5, 111.7, 72.9, 40.8, 17.6, 13.6; **HRMS** Calcd. for $C_{20}H_{20}NO_2^+$ $[M+H]^+$: 306.1489, found: 306.1487; **M.p.**: 42-44 ºC.

$[\alpha]^{20}_D$ = -828.0 (c 0.05, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IF-H column, Hexane/^{i}PrOH = 95/5, 0.2 mL/min, 230 nm, t_{minor} = 99.826 min, t_{major} = 93.696 min.

Racemic Sample of 3ac

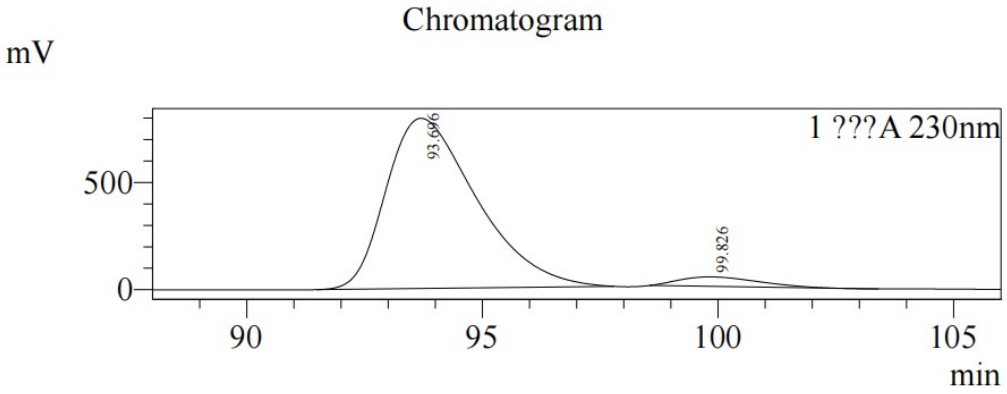


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	94.125	62565488	507630	49.923
2	98.524	62759228	409320	50.077
Total		125324716	916950	100.000

Enantiomeric Sample of 3ac

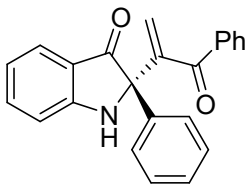


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	93.696	106057757	793893	95.322
2	99.826	5204608	44449	4.678
Total		111262366	838342	100.000

(*S*)-2-(3-oxo-3-phenylprop-1-en-2-yl)-2-phenylindolin-3-one (**3ad**)



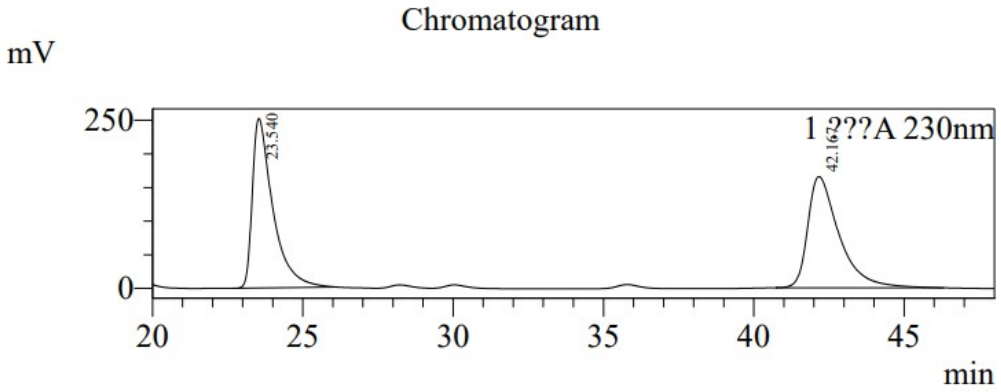
3ad

Compound **3ad** (17.1 mg, 50% yield) was obtained as a yellow solid following the *general procedure III* from **1a** (0.1 mmol, 20.7 mg) and **2d** (0.15 mmol, 19.8 mg, 19.4 μL) stirred for 8 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94-7.92 (m, 2H), 7.68 (d, *J* = 7.6 Hz, 1H), 7.61-7.55 (m, 2H), 7.52-7.46 (m, 4H), 7.41-7.34 (m, 4H), 7.29 (d, *J* = 4.0 Hz, 1H), 7.04 (d, *J* = 8.4 Hz, 1H), 6.96-6.92 (m, 1H), 5.25 (s, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.2, 190.5, 160.1, 145.5, 138.0, 137.9, 137.3, 133.1, 129.1, 128.7, 128.6, 128.5, 126.2, 125.73, 125.66, 120.1, 119.1, 112.6, 73.1; **M.p.**: 125-127 ºC; **HRMS** Calcd. for $C_{23}H_{18}NO_2^+$ $[M+H]^+$: 340.1343, found: 340.1336.

$[\alpha]^{20}_D$ = -4.2 (c 0.13, CH_2Cl_2) for 3% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IB-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 23.500 min, t_{major} = 42.696 min.

Racemic Sample of 3ad

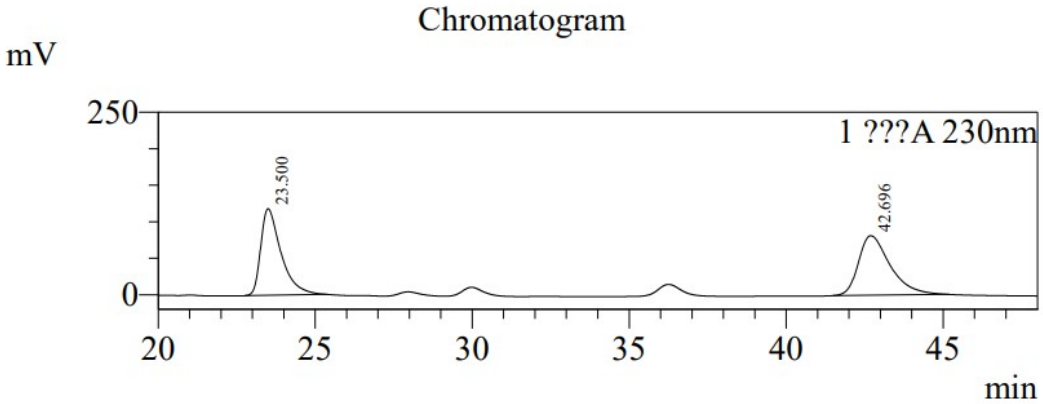


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	23.540	12010462	252321	50.021
2	42.167	12000235	165221	49.979
Total		24010697	417542	100.000

Enantiomeric Sample of 3ad

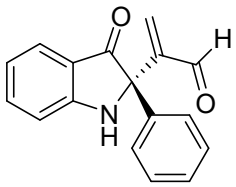


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	23.500	5335510	118611	48.289
2	42.696	5713498	81574	51.711
Total		11049008	200185	100.000

(*S*)-2-(3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3ae)



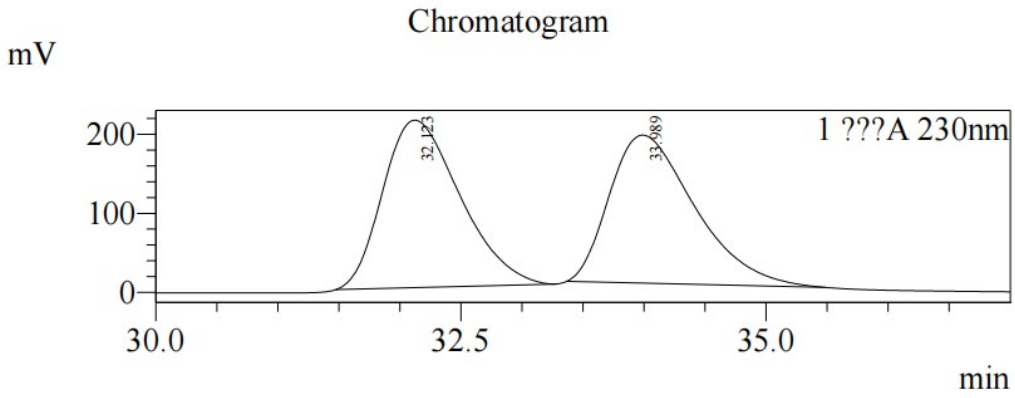
3ae

Compound **3ae** (24.7 mg, 94% yield) was obtained as a yellow solid following the *general procedure III* from **1a** (0.1 mmol, 20.7 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 3 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.58 (d, *J* = 8.8 Hz, 1H), 7.51-7.43 (m, 3H), 7.33-7.24 (m, 3H), 6.93 (d, *J* = 6.4 Hz, 2H), 6.81 (t, *J* = 8.0 Hz, 1H), 6.39 (s, 1H), 6.16(brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.9, 194.4, 159.8, 146.0, 137.9, 137.1, 136.9, 128.6, 127.9, 125.5, 125.4, 119.0, 118.2, 111.7, 71.0; **M.p.**: 154-156 ºC; **HRMS** Calcd. for $C_{17}H_{14}NO_2^+$ $[M+H]^+$: 264.1019, found: 264.1012.

$[\alpha]^{20}_D$ = -439.0 (c 0.20, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 34.447 min, t_{major} = 32.086 min.

Racemic Sample of 3ae

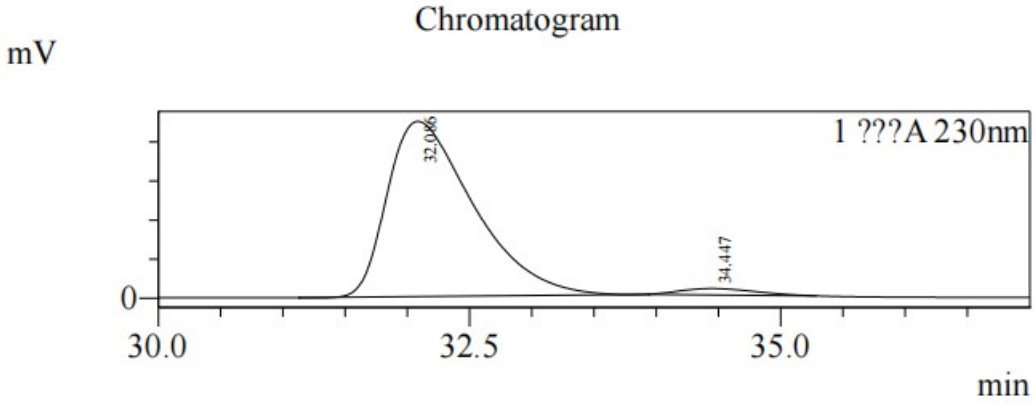


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	32.123	9312471	211723	50.620
2	33.989	9084251	187188	49.380
Total		18396722	398912	100.000

Enantiomeric Sample of 3ae

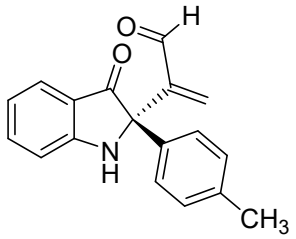


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	32.086	43136270	897638	96.964
2	34.447	1350434	32516	3.036
Total		44486704	930154	100.000

(*S*)-2-(3-oxo-2-(p-tolyl)indolin-2-yl)acrylaldehyde (3be)



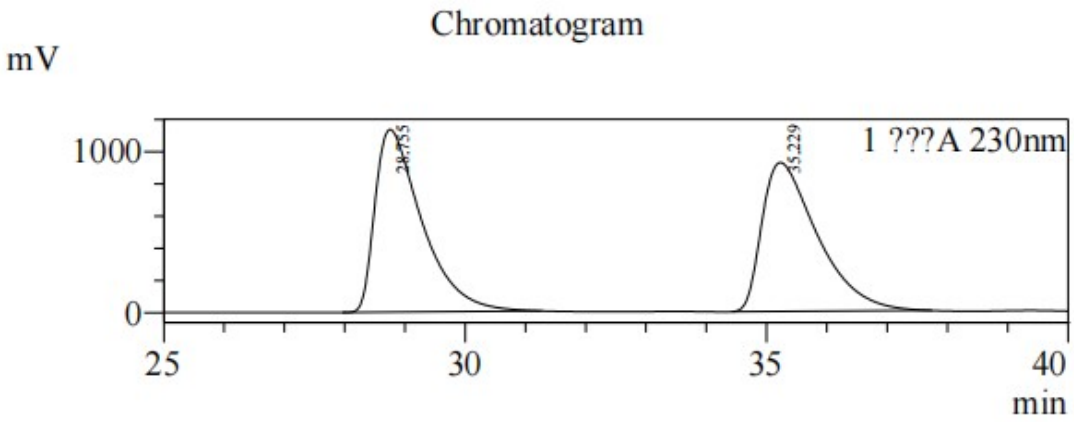
3be

Compound **3be** (18.5 mg, 67% yield) was obtained as a yellow solid following the *general procedure III* from **1b** (0.1 mmol, 22.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 µL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (s, 1H), 7.58 (d, *J* = 7.6 Hz, 1H), 7.49 (t, *J* = 8.0 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 6.92 (d, *J* = 8.0 Hz, 2H), 6.80 (t, *J* = 7.6 Hz, 1H), 6.38 (s, 1H), 6.13 (brs, 1H), 2.29 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.1, 194.5, 159.8, 146.1, 137.9, 137.7, 137.0, 133.9, 129.4, 125.5, 125.3, 118.9, 118.2, 111.7, 70.9, 21.0; **HRMS** Calcd. for $C_{18}H_{16}NO_2^+$ $[M+H]^+$: 278.1176, found: 278.1176; **M.p.**: 119-121 ºC.

$[\alpha]^{20}_D$ = -1160.0 (c 0.04, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 36.846 min, t_{major} = 29.235 min.

Racemic Sample of 3be

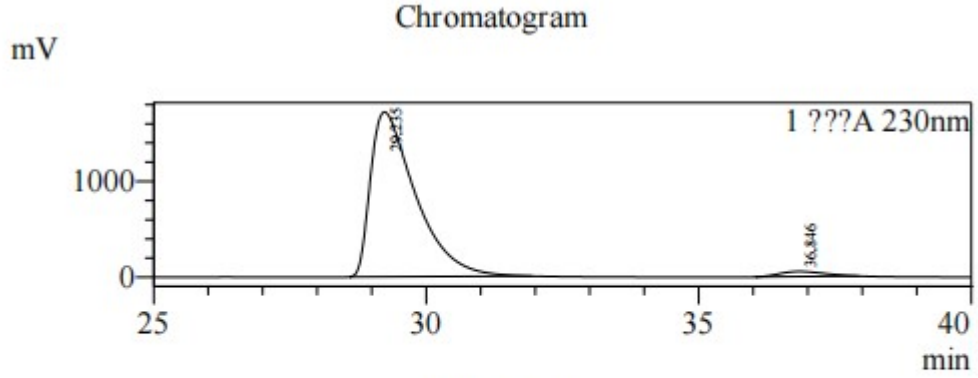


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	28.755	61250538	1133543	50.823
2	35.229	59267686	923784	49.177
Total		120518224	2057327	100.000

Enantiomeric Sample of 3be

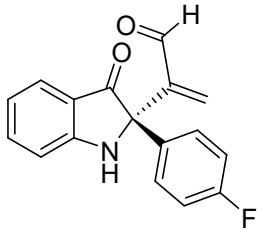


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	29.235	98575696	1717296	97.055
2	36.846	2991589	53068	2.945
Total		101567284	1770364	100.000

(*S*)-2-(2-(4-fluorophenyl)-3-oxoindolin-2-yl)acrylaldehyde (3ce)



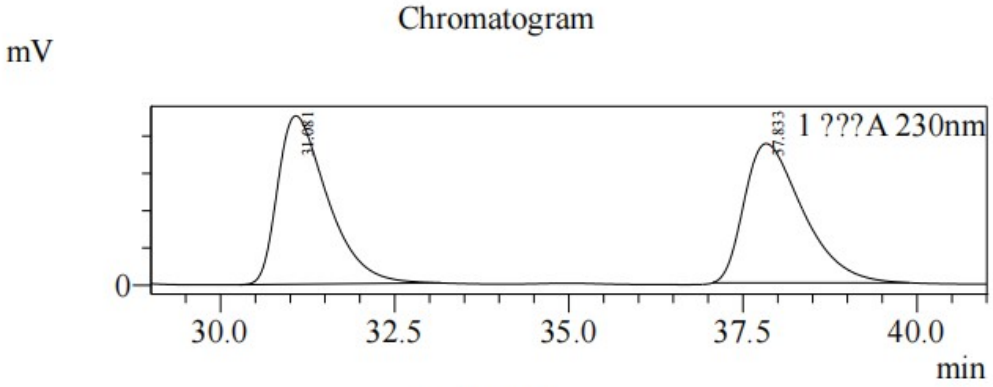
3ce

Compound **3ce** (26.3 mg, 94% yield) was obtained as a yellow solid following the *general procedure III* from **1c** (0.1 mmol, 22.5 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 7.58 (d, *J* = 8.0 Hz, 1H), 7.50 (t, *J* = 8.0 Hz, 1H), 7.45-7.41 (m, 2H), 6.99 (t, *J* = 8.4 Hz, 2H), 6.93-6.90 (m, 2H), 6.82 (t, *J* = 7.6 Hz, 1H), 6.39 (s, 1H), 6.15 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.8, 194.4, 162.5 (d, *J* = 245.5 Hz), 159.7, 145.9, 138.1, 137.3, 132.7 (d, *J* = 2.9 Hz), 127.3 (d, *J* = 8.1 Hz), 125.5, 119.2, 118.1, 115.5 (d, *J* = 21.6 Hz), 111.8, 70.5; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -114.7 (s); **HRMS** Calcd. for $C_{17}H_{13}NO_2F^+$ $[M+H]^+$: 282.0925, found: 282.0922; **M.p.**: 118-120 ºC.

$[\alpha]^{20}_D$ = -480.0 (c 0.04, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 38.129 min, t_{major} = 30.637 min.

Racemic Sample of 3ce

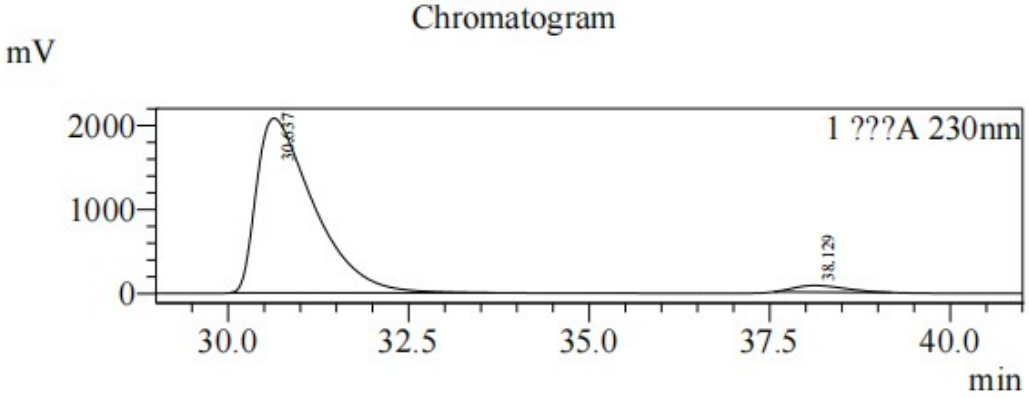


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	31.081	22480732	451120	50.747
2	37.833	21818893	372721	49.253
Total		44299625	823841	100.000

Enantiomeric Sample of 3ce

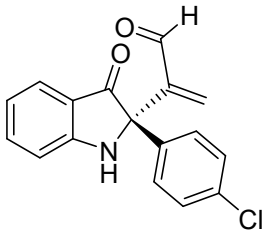


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	30.637	114699328	2077015	96.805
2	38.129	3785617	77356	3.195
Total		118484945	2154371	100.000

(*S*)-2-(2-(4-chlorophenyl)-3-oxoindolin-2-yl)acrylaldehyde (3de)



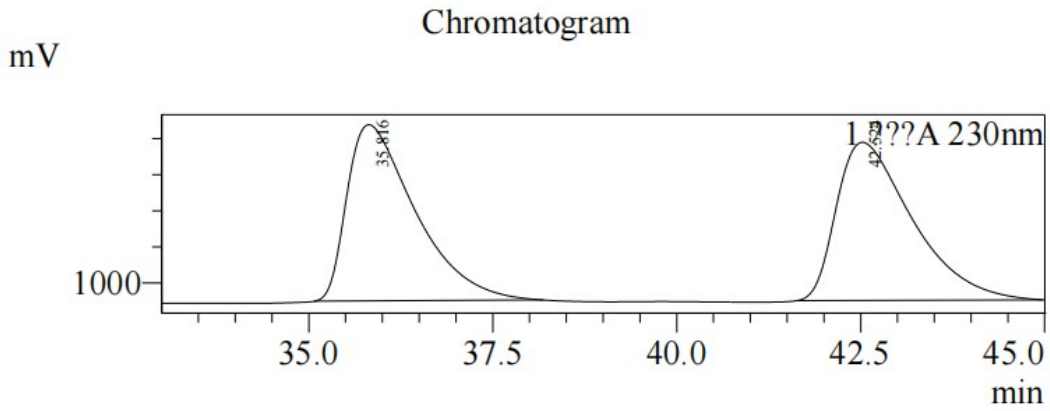
3de

Compound **3de** (25.9 mg, 87% yield) was obtained as a yellow solid following the *general procedure III* from **1d** (0.1 mmol, 24.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 7.58 (d, *J* = 7.6 Hz, 1H), 7.50 (t, *J* = 8.0 Hz, 1H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 6.92 (d, *J* = 8.4 Hz, 1H), 6.89 (s, 1H), 6.82 (t, *J* = 7.6 Hz, 1H), 6.40 (s, 1H), 6.12 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.5, 194.4, 159.7, 145.7, 138.1, 137.4, 135.6, 133.9, 128.8, 127.0, 125.6, 119.3, 118.1, 111.8, 70.5; **HRMS** Calcd. for $C_{17}H_{13}NO_2Cl^+$ $[M+H]^+$: 298.0629, found: 298.0627; **M.p.**: 145-148 ºC.

$[\alpha]^{20}_D$ = -1043.6 (c 0.07, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 41.556 min, t_{major} = 34.505 min.

Racemic Sample of 3de

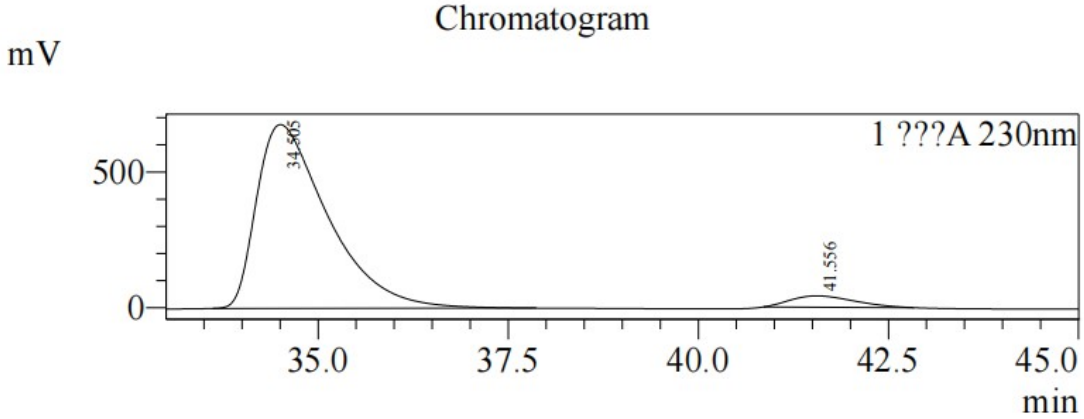


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	35.816	31503862	488140	50.117
2	42.524	31357187	438212	49.883
Total		62861050	926352	100.000

Enantiomeric Sample of 3de

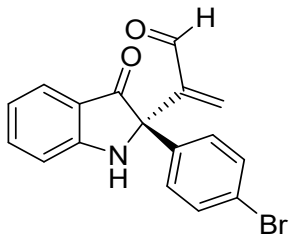


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	34.505	44077070	676629	94.770
2	41.556	2432440	41619	5.230
Total		46509509	718247	100.000

(*S*)-2-(2-(4-bromophenyl)-3-oxoindolin-2-yl)acrylaldehyde (3ee)



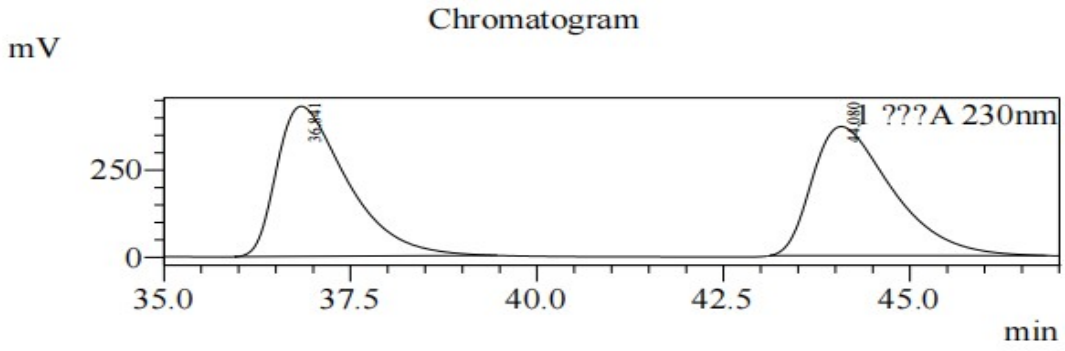
3ee

Compound **3ee** (23 mg, 67% yield) was obtained as a yellow solid following the *general procedure III* from **1e** (0.1 mmol, 28.4 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 7.58 (d, *J* = 7.6 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.43 (d, *J* = 8.8 Hz, 2H), 7.33 (d, *J* = 8.8 Hz, 2H), 6.93 (d, *J* = 8.4 Hz, 1H), 6.89 (s, 1H), 6.83 (t, *J* = 7.6 Hz, 1H), 6.40 (s, 1H), 6.12 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.4, 194.3, 159.7, 145.7, 138.2, 137.4, 136.2, 131.7, 127.3, 125.6, 122.2, 119.3, 118.1, 111.9, 70.6; **HRMS** Calcd. for $C_{17}H_{13}NO_2Br^+$ $[M+H]^+$: 342.0124, found: 342.0123; **M.p.**: 115-117 ºC.

$[\alpha]^{20}_D$ = -815.0 (c 0.04, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 44.565 min, t_{major} = 36.272 min.

Racemic Sample of 3ee

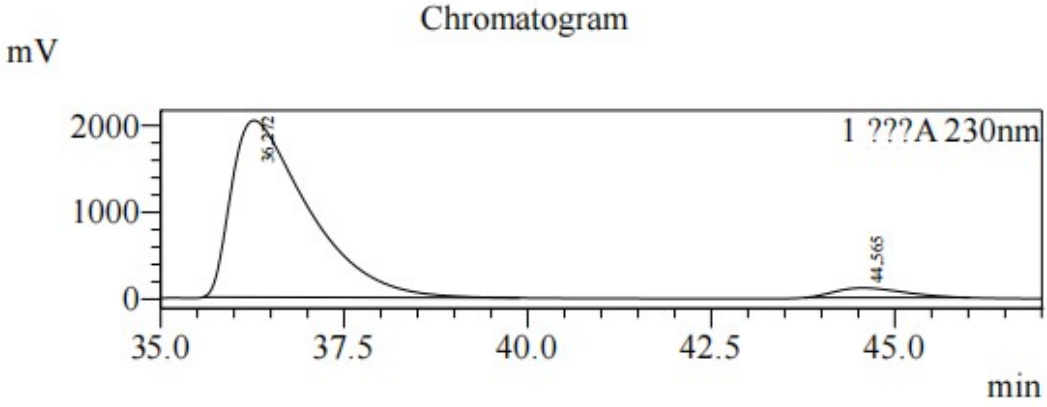


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	36.841	28218864	430560	50.544
2	44.080	27611359	370127	49.456
Total		55830222	800687	100.000

Enantiomeric Sample of 3ee

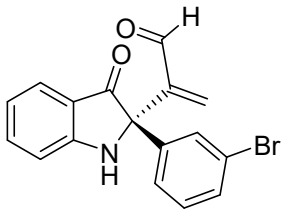


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	36.272	148688277	2035137	95.341
2	44.565	7265240	111244	4.659
Total		155953517	2146381	100.000

(*S*)-2-(2-(3-bromophenyl)-3-oxoindolin-2-yl)acrylaldehyde (**3fe**)



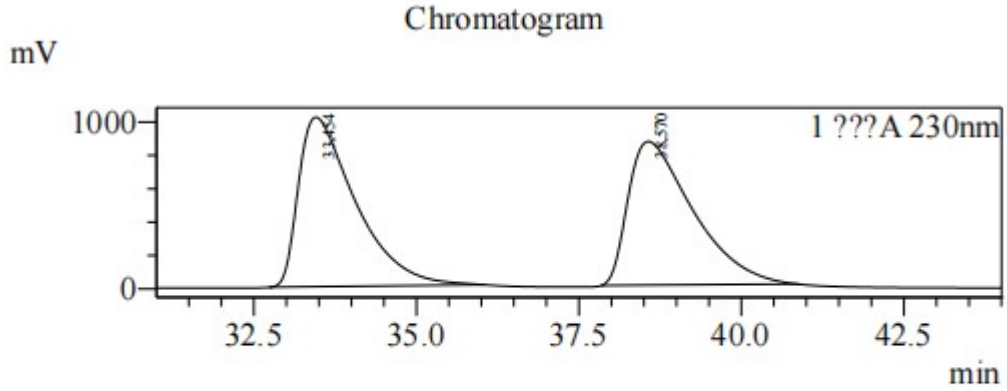
3fe

Compound **3fe** (25.6 mg, 75% yield) was obtained as a yellow solid following the *general procedure III* from **1f** (0.1 mmol, 28.4 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 7.59 (d, *J* = 9.2 Hz, 2H), 7.51 (t, *J* = 8.0 Hz, 1H), 7.38 (d, *J* = 8.0 Hz, 2H), 7.18 (t, *J* = 8.0 Hz, 1H), 6.93 (d, *J* = 8.0 Hz, 1H), 6.90 (s, 1H), 6.83 (t, *J* = 7.6 Hz, 1H), 6.41 (s, 1H), 6.14 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.2, 194.3, 159.7, 145.6, 139.4, 138.2, 137.6, 131.0, 130.1, 128.5, 125.6, 124.3, 122.8, 119.3, 118.0, 111.9, 70.5; **HRMS** Calcd. for $C_{17}H_{13}NO_2Br^+$ $[M+H]^+$: 342.0124, found: 342.0123; **M.p.**: 142-144 ºC.

$[\alpha]^{20}_D$ = -777.5 (c 0.04, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 39.394 min, t_{major} = 33.075 min.

Racemic Sample of 3fe

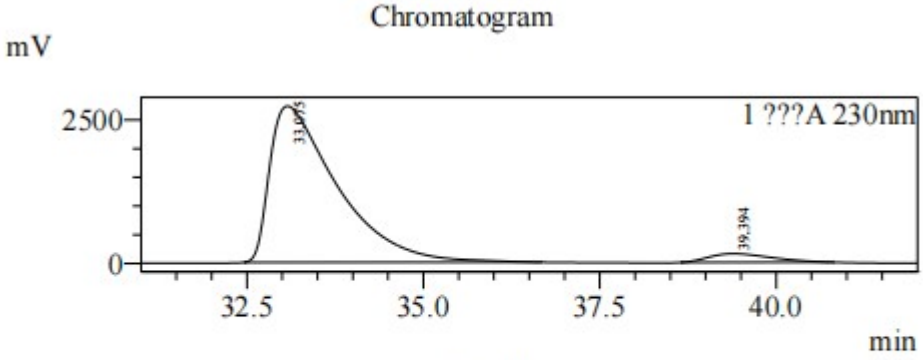


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	33.454	61875702	1015651	50.869
2	38.570	59761028	860719	49.131
Total		121636729	1876369	100.000

Enantiomeric Sample of 3fe

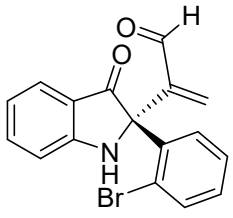


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	33.075	180244203	2715744	95.117
2	39.394	9252187	150420	4.883
Total		189496389	2866164	100.000

(*R*)-2-(2-(2-bromophenyl)-3-oxoindolin-2-yl)acrylaldehyde (3ge)



3ge

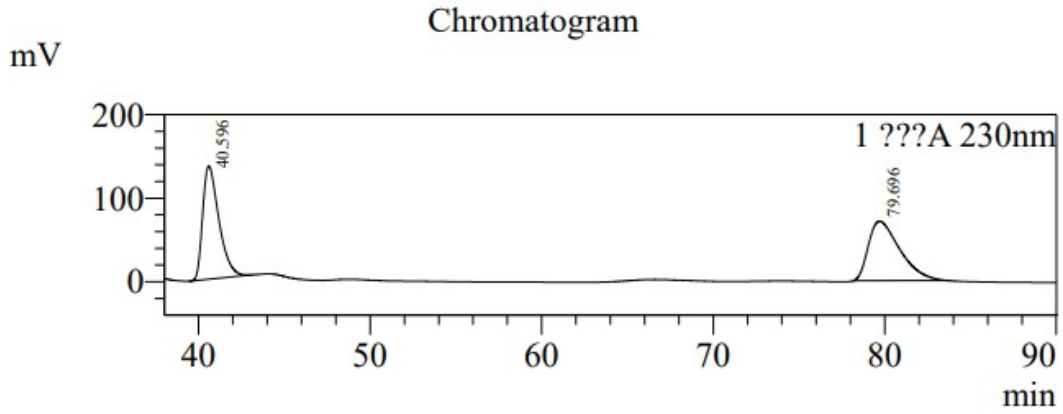
Compound **3ge** (13.7 mg, 40% yield) was obtained as a yellow solid following the

general procedure III from **1g** (0.1 mmol, 28.4 mg) and **2e** (0.15 mmol, 8.4 mg, 10 µL) stirred for 36 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.64 (s, 1H), 7.69 (d, *J* = 7.6 Hz, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 1H), 7.32-7.27 (m, 2H), 7.19-7.16 (m, 1H), 6.89-6.84 (m, 2H), 6.40 (d, *J* = 12.0 Hz, 2H), 6.25 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.0, 193.1, 159.9, 145.5, 137.72, 137.67, 136.3, 135.2, 130.5, 129.8, 127.5, 125.0, 123.0, 120.2, 119.4, 112.5, 73.5; **M.p.:** 169-171 ºC; **HRMS** Calcd. for $C_{17}H_{13}BrNO_2^+$ $[M+H]^+$: 342.0124, found: 342.0132.

$[\alpha]^{20}_D$ = -1.82 (c 0.11, CH_2Cl_2) for 11% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 91.515 min, t_{major} = 43.878 min.

Racemic Sample of 3ge

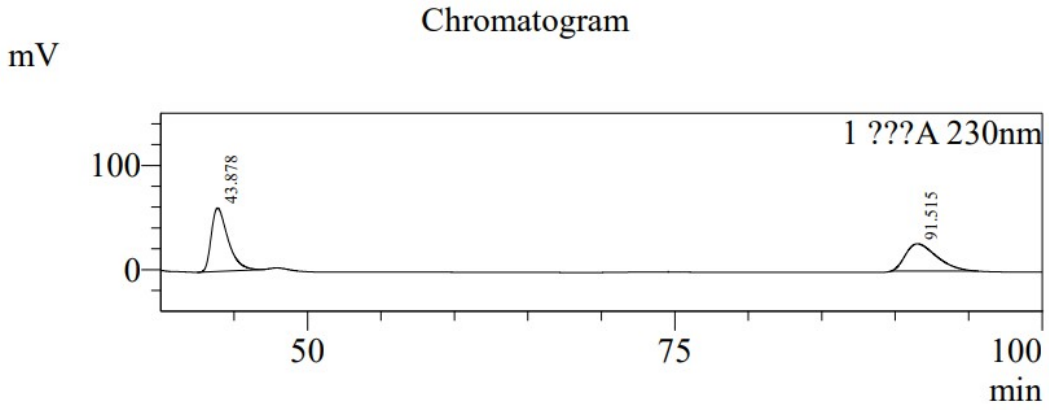


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	40.596	8914589	135499	49.592
2	79.696	9061226	71103	50.408
Total		17975815	206601	100.000

Enantiomeric Sample of 3ge

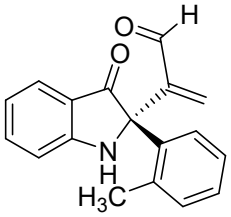


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	43.878	4806142	60920	55.263
2	91.515	3890761	26238	44.737
Total		8696903	87159	100.000

(*S*)-2-(3-oxo-2-(o-tolyl)indolin-2-yl)acrylaldehyde (**3he**)



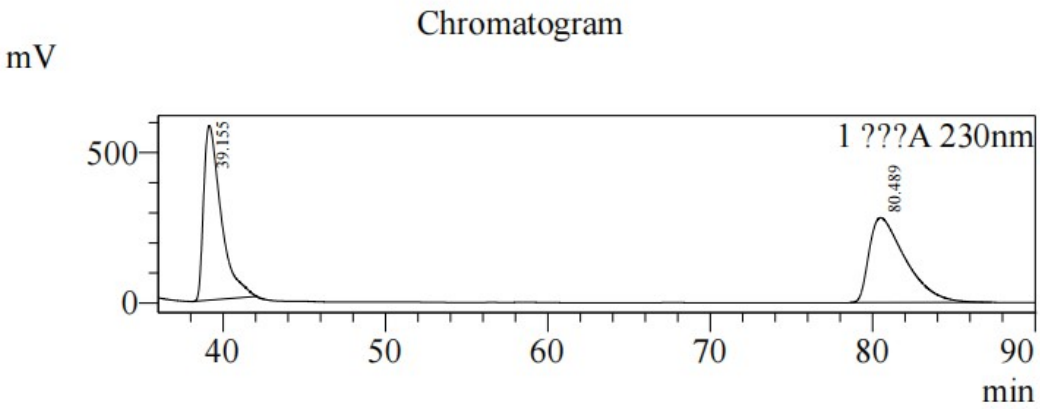
3he

Compound **3he** (11.9 mg, 43% yield) was obtained as a yellow solid following the *general procedure III* from **1h** (0.1 mmol, 22.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.70 (s, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.51-7.47 (m, 1H), 7.21-7.17 (m, 1H), 7.13 (t, *J* = 4.0 Hz, 3H), 6.88-6.83 (m, 2H), 6.62 (s, 1H), 6.41 (s, 1H), 6.03 (brs, 1H), 2.18 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 199.2, 194.4, 159.3, 145.9, 137.8, 137.6, 136.9, 135.3, 132.5, 128.5, 128.3, 125.9, 125.0, 119.8, 119.2, 112.3, 21.0; **M.p.**: 125-127 ºC; **HRMS** Calcd. for $C_{18}H_{16}NO_2^+$ $[M+H]^+$: 278.1176, found: 278.1180.

$[\alpha]^{20}_D$ = -15.0 (c 0.04, CH_2Cl_2) for 9% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 76.915 min, t_{major} = 38.117 min.

Racemic Sample of 3he

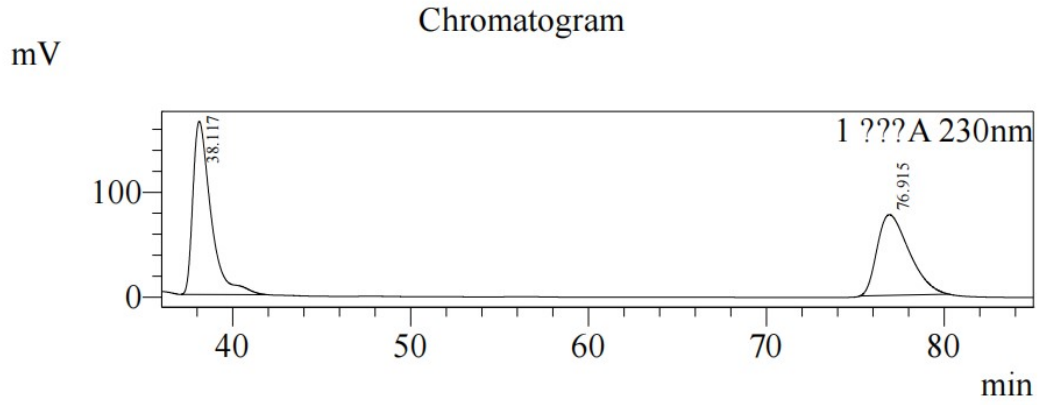


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	39.155	43479462	579871	49.754
2	80.489	43909926	281827	50.246
Total		87389388	861697	100.000

Enantiomeric Sample of 3he

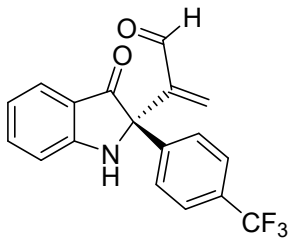


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	38.117	11654307	165168	54.696
2	76.915	9653024	76959	45.304
Total		21307330	242127	100.000

(*S*)-2-(3-oxo-2-(4-(trifluoromethyl)phenyl)indolin-2-yl)acrylaldehyde (3ie)



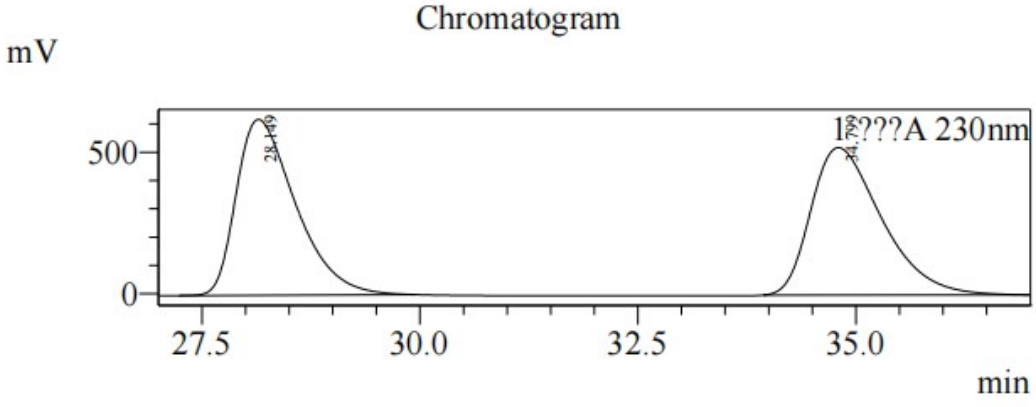
3ie

Compound **3ie** (26.9 mg, 81% yield) was obtained as a yellow solid following the *general procedure III* from **1i** (0.1 mmol, 27.5 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.61-7.51 (m, 6H), 6.97-6.93 (m, 2H), 6.85 (t, *J* = 7.6 Hz, 1H), 6.44 (s, 1H), 6.16 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.1, 194.3, 159.7, 145.7, 141.1, 138.3, 137.6, 130.1 (q, *J* = 32.2 Hz), 126.0, 125.6 (q, *J* = 3.7 Hz), 124.0 (q, *J* = 270.9 Hz), 119.5, 118.0, 111.9, 99.9, 70.8; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.5 (s); **HRMS** Calcd. for $C_{18}H_{13}NO_2F_3^+$ $[M+H]^+$: 332.0893, found: 332.0887; **M.p.**: 115-117 ºC.

$[\alpha]^{20}_D$ = -555.0 (c 0.05, CH_2Cl_2) for 87% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 34.681 min, t_{major} = 27.444 min.

Racemic Sample of 3ie

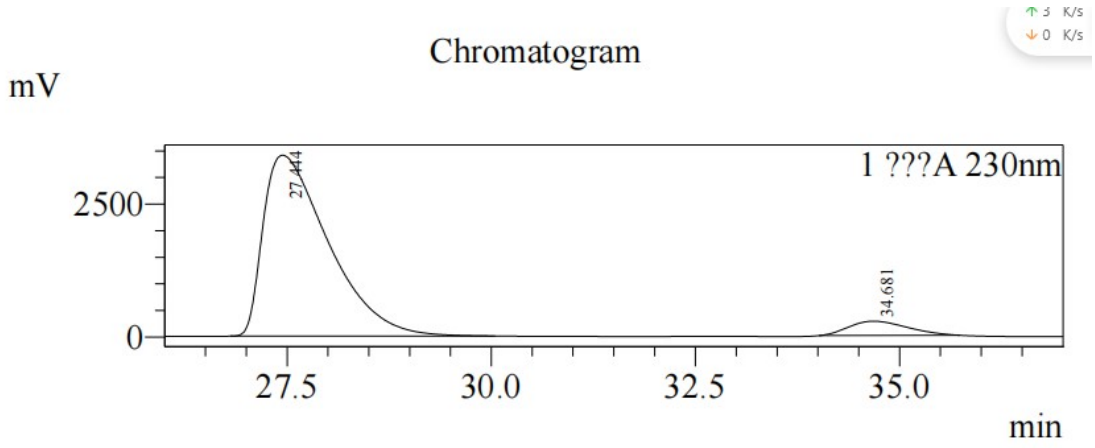


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	28.149	29387205	621245	49.968
2	34.799	29425233	521001	50.032
Total		58812438	1142246	100.000

Enantiomeric Sample of 3ie

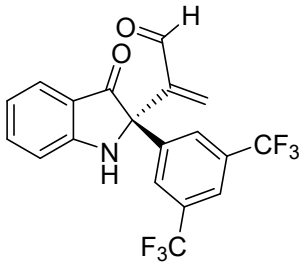


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	27.444	188756040	3404147	93.391
2	34.681	13356971	268050	6.609
Total		202113011	3672197	100.000

(*S*)-2-(2-(3,5-bis(trifluoromethyl)phenyl)-3-oxoindolin-2-yl)acrylaldehyde (3je)



3je

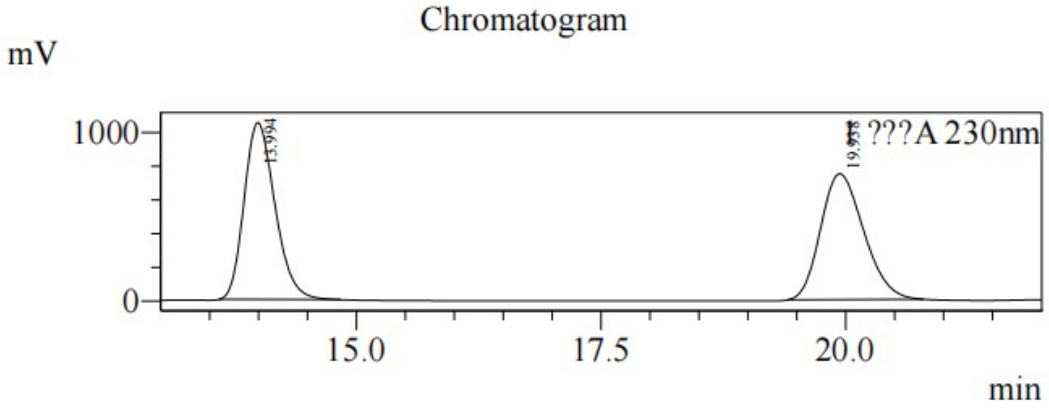
Compound **3je** (25.6 mg, 64% yield) was obtained as a yellow solid following the *general procedure III* from **1j** (0.1 mmol, 34.3 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.96 (s, 2H), 7.79 (s, 1H), 7.62-7.54 (m, 2H), 7.01 (d, *J* = 8.0 Hz, 1H), 6.95 (s, 1H), 6.90 (t, *J* = 7.6 Hz, 1H), 6.49 (s, 1H), 6.14 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.3, 194.2, 159.7, 145.3, 140.1, 138.6, 138.3, 131.8 (q, *J* = 33.3 Hz), 126.1 (q, *J* = 3.5 Hz), 125.6, 123.2 (q, *J* = 271.4 Hz), 122.0 (q, *J* = 3.7 Hz), 120.0, 117.9, 112.4, 70.4; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.5 (s); **HRMS** Calcd. for $C_{19}H_{12}NO_2F_6^+$ $[M+H]^+$: 400.0767, found: 400.0756; **M.p.**: 162-164 ºC.

$[\alpha]^{20}_D$ = -780.0 (c 0.04, CH_2Cl_2) for 88% ee; Enantiomeric excess was determined by

HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 19.957 min, t_{major} = 13.945 min.

Racemic Sample of 3je

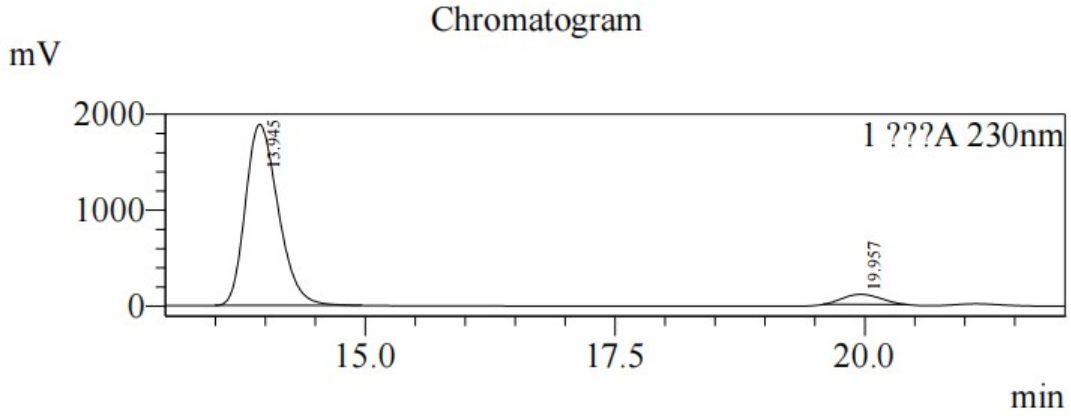


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	13.994	23052224	1049306	50.221
2	19.938	22848925	746126	49.779
Total		45901148	1795432	100.000

Enantiomeric Sample of 3je

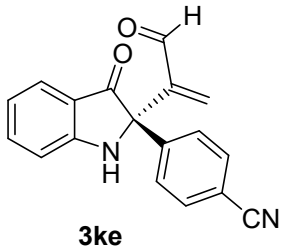


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	13.945	43154932	1886348	93.972
2	19.957	2768208	105255	6.028
Total		45923140	1991602	100.000

(*S*)-4-(3-oxo-2-(3-oxoprop-1-en-2-yl)indolin-2-yl)benzonitrile (3ke)

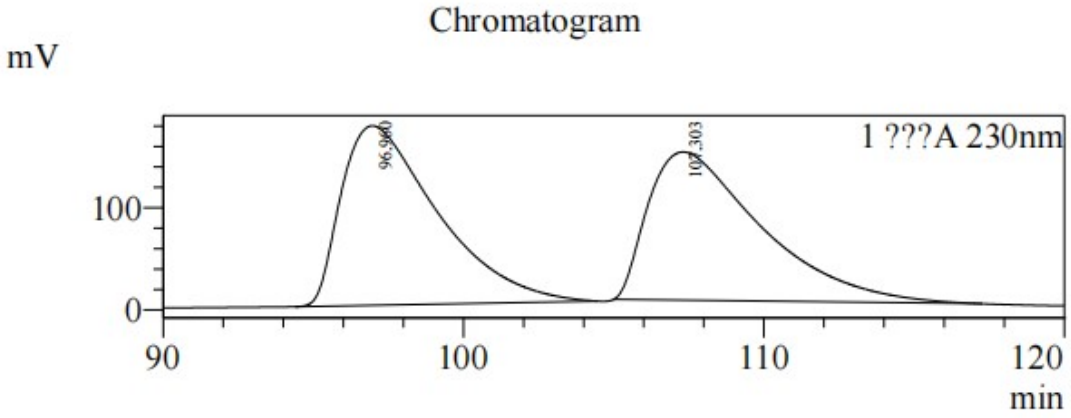


3ke

Compound **3ke** (20.1 mg, 70% yield) was obtained as a yellow solid following the *general procedure III* from **1k** (0.1 mmol, 23.2 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 7.61-7.51 (m, 6H), 6.98-6.84 (m, 3H), 6.45 (s, 1H), 6.14 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.6, 194.2, 159.7, 145.5, 142.5, 138.4, 137.8, 132.3, 126.4, 125.6, 119.7, 118.6, 117.9, 112.1, 111.7, 70.8; **HRMS** Calcd. for $C_{18}H_{13}N_2O_2^+$ $[M+H]^+$: 289.0972, found: 289.0964; **M.p.**: 98-100 ºC. $[\alpha]^{20}_D$ = -737.5 (c 0.40, CH_2Cl_2) for 87% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 110.507 min, t_{major} = 96.747 min.

Racemic Sample of 3ke

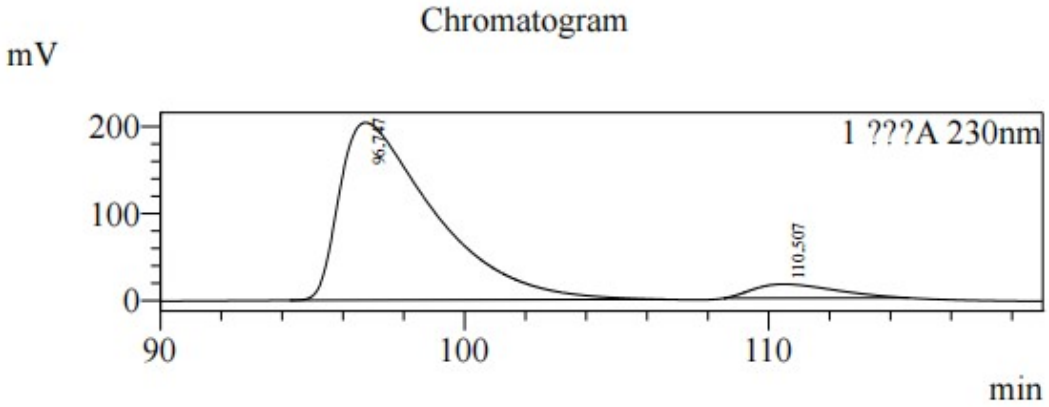


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	96.960	39105651	175787	50.762
2	107.303	37931383	145267	49.238
Total		77037034	321054	100.000

Enantiomeric Sample of 3ke

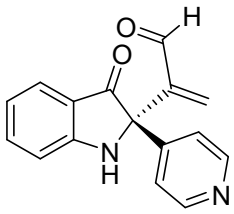


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	96.747	44036993	203920	93.595
2	110.507	3013591	16065	6.405
Total		47050584	219985	100.000

(*S*)-2-(3-oxo-2-(pyridin-4-yl)indolin-2-yl)acrylaldehyde (3le)



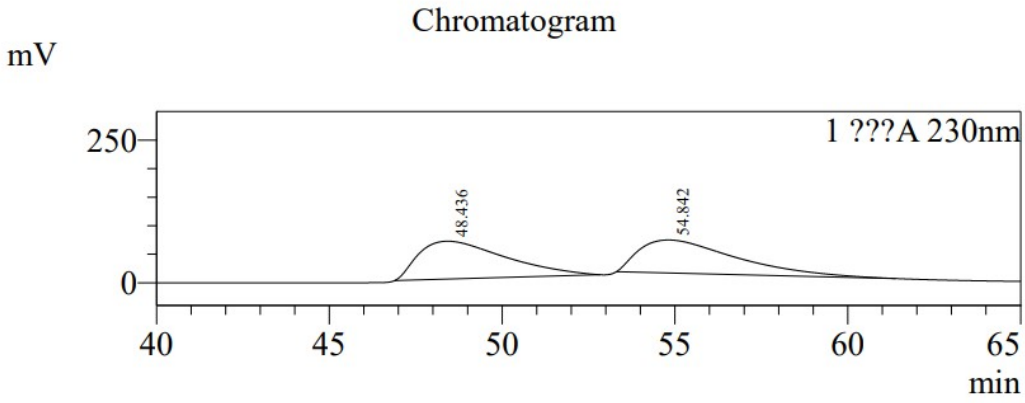
3le

Compound **3le** (16.5 mg, 63% yield) was obtained as a yellow solid following the *general procedure III* from **1l** (0.1 mmol, 20.8 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.53 (s, 1H), 8.54 (d, *J* = 5.6 Hz, 2H), 7.59 (d, *J* = 8.0 Hz, 1H), 7.53 (t, *J* = 6.8 Hz, 1H), 7.39 (d, *J* = 6.4 Hz, 2H), 6.97-6.94 (m, 2H), 6.85 (t, *J* = 7.6 Hz, 1H), 6.45 (s, 1H), 6.13 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.4, 194.1, 159.8, 150.0, 146.4, 145.4, 138.4, 137.7, 125.6, 120.6, 119.6, 118.0, 112.0, 70.4; **HRMS** Calcd. for $C_{16}H_{13}N_2O_2^+$ $[M+H]^+$: 265.0977, found: 265.0972; **M.p.**: 114-115 ºC.

$[\alpha]^{20}_D$ = -676.4 (c 0.18, CH_2Cl_2) for 97% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IB-H column, Hexane/^{i}PrOH = 80/20, 0.5 mL/min, 230 nm, t_{minor} = 51.126 min, t_{major} = 54.844 min.

Racemic Sample of 3le

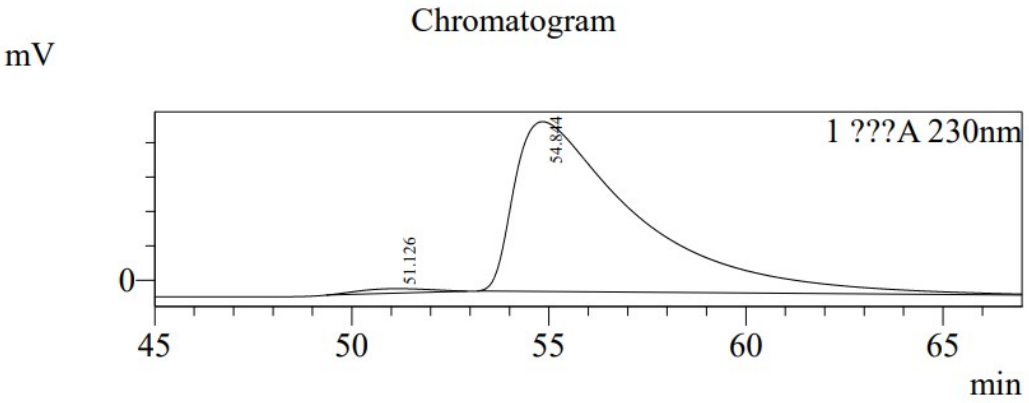


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	48.436	11591436	66381	50.455
2	54.842	11382473	57802	49.545
Total		22973909	124183	100.000

Enantiomeric Sample of 3le

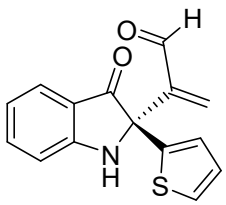


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	51.126	335033	2614	1.549
2	54.844	21300933	98756	98.451
Total		21635966	101370	100.000

(*S*)-2-(3-oxo-2-(thiophen-2-yl)indolin-2-yl)acrylaldehyde (3me)



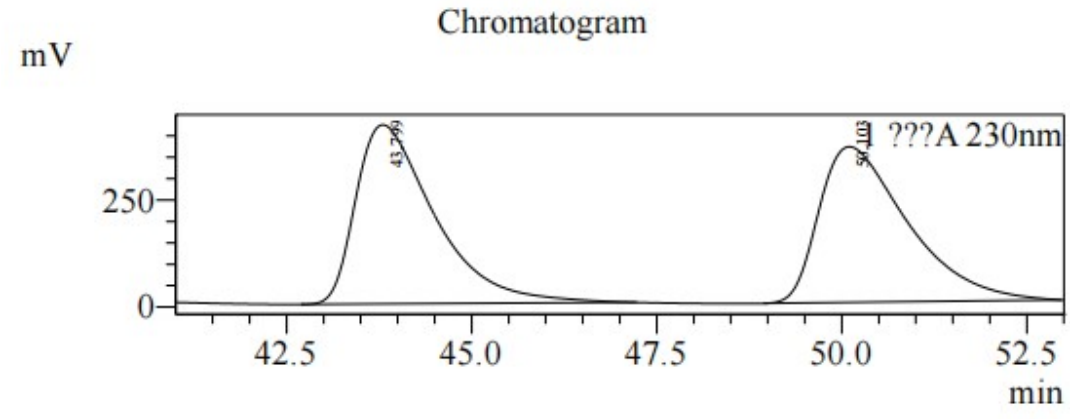
3me

Compound **3me** (16.8 mg, 62% yield) was obtained as a yellow solid following the *general procedure III* from **1m** (0.1 mmol, 21.3 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.56 (s, 1H), 7.62 (d, *J* = 7.6 Hz, 1H), 7.50 (t, *J* = 7.6 Hz, 1H), 7.19 (d, *J* = 5.2 Hz, 1H), 7.03 (d, *J* = 3.2 Hz, 1H), 6.97-6.90 (m, 3H), 6.85 (t, *J* = 7.6 Hz, 1H), 6.36 (s, 1H), 6.29 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.9, 194.1, 159.5, 145.8, 141.9, 138.0, 137.2, 127.6, 125.6, 125.3, 124.8, 119.5, 118.1, 112.0, 69.0; **HRMS** Calcd. for $C_{15}H_{12}NO_2S^+$ $[M+H]^+$: 270.0589, found: 270.0583; **M.p.**: 130-132 ºC.

$[\alpha]^{20}_D$ = -468.0 (c 0.05, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 50.817 min, t_{major} = 43.986 min.

Racemic Sample of 3me

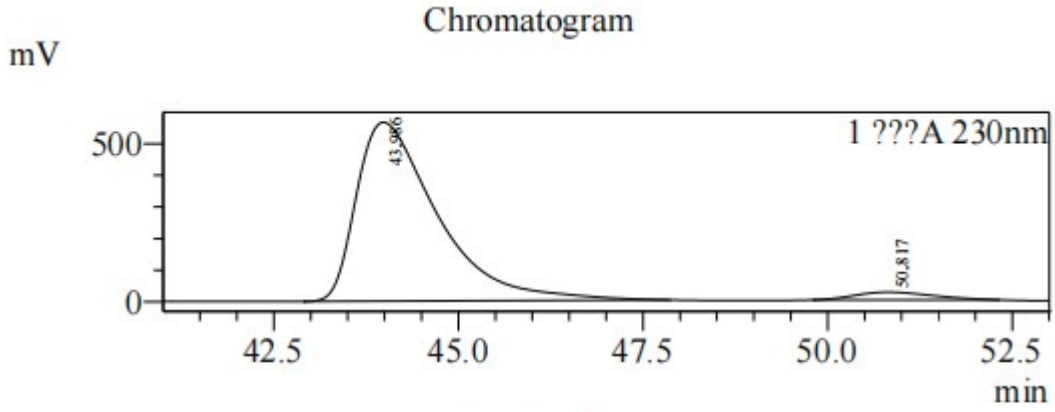


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	43.799	31010242	418694	50.628
2	50.103	30240986	363885	49.372
Total		61251228	782579	100.000

Enantiomeric Sample of 3me

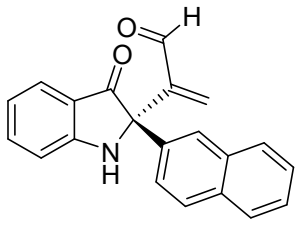


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	43.986	43195569	566485	96.019
2	50.817	1791123	24550	3.981
Total		44986692	591035	100.000

(*S*)-2-(2-(naphthalen-2-yl)-3-oxoindolin-2-yl)acrylaldehyde (3ne)



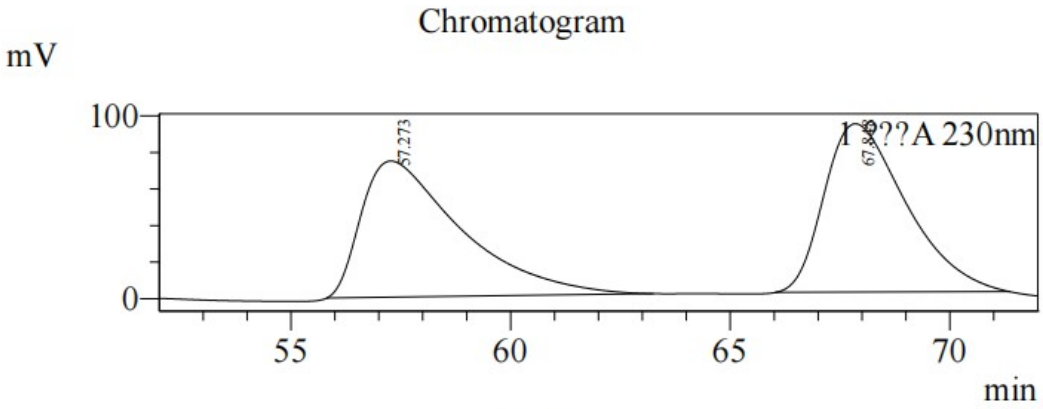
3ne

Compound **3ne** (19.0 mg, 61% yield) was obtained as a yellow solid following the *general procedure III* from **1n** (0.1 mmol, 25.7 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (s, 1H), 7.91 (s, 1H), 7.80-7.79 (m, 3H), 7.61-7.51 (m, 3H), 7.45-7.44 (m, 2H), 6.99 (s, 2H), 6.84 (t, *J* = 7.6 Hz, 1H), 6.46 (s, 1H), 6.27 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.9, 194.4, 159.8, 145.9, 138.0, 137.4, 134.3, 133.2, 132.9, 128.5, 128.1, 127.5, 126.16, 126.15, 125.6, 124.6, 123.3, 119.1, 118.3, 111.8, 71.1; **HRMS** Calcd. for $C_{21}H_{16}NO_2^+$ $[M+H]^+$: 314.1176, found: 314.1174; **M.p.**: 84-86 ºC.

$[\alpha]^{20}_D$ = -423.5 (c 0.04, CH_2Cl_2) for 95% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 64.359 min, t_{major} = 52.177 min.

Racemic Sample of 3ne

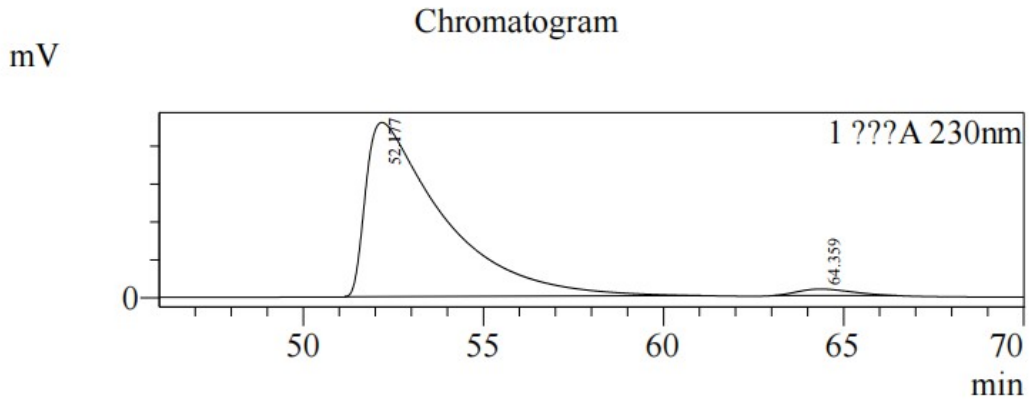


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	57.273	11733615	74393	49.669
2	67.848	11889943	91996	50.331
Total		23623558	166389	100.000

Enantiomeric Sample of 3ne

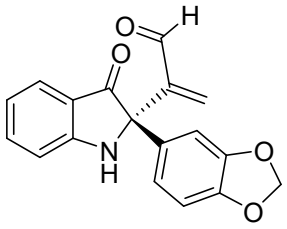


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	52.177	137329473	920716	97.486
2	64.359	3540876	34149	2.514
Total		140870349	954865	100.000

(*S*)-2-(2-(benzo[d][1,3]dioxol-5-yl)-3-oxoindolin-2-yl)acrylaldehyde (3oe)



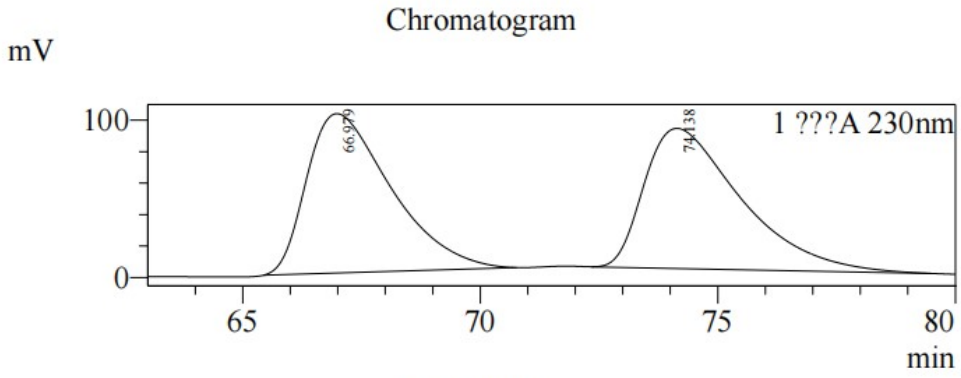
3oe

Compound **3oe** (26.4 mg, 86% yield) was obtained as a yellow solid following the *general procedure III* from **1o** (0.1 mmol, 25.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (s, 1H), 7.58 (d, *J* = 8.0 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 1H), 6.92-6.87 (m, 4H), 6.81 (t, *J* = 7.2 Hz, 1H), 6.74 (d, *J* = 7.2 Hz, 1H), 6.37 (s, 1H), 6.11 (brs, 1H), 5.91 (s, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.9, 194.5, 159.6, 148.0, 147.4, 145.9, 138.0, 137.2, 130.7, 125.5, 119.0, 118.8, 118.1, 111.7, 108.3, 106.2, 101.2, 70.7; **HRMS** Calcd. for $C_{18}H_{14}NO_4^+$ $[M+H]^+$: 308.0917, found: 308.0909; **M.p.**: 147-149 ºC.

$[\alpha]^{20}_D$ = -812.5 (c 0.04, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 66.796 min, t_{major} = 72.289 min.

Racemic Sample of 3oe

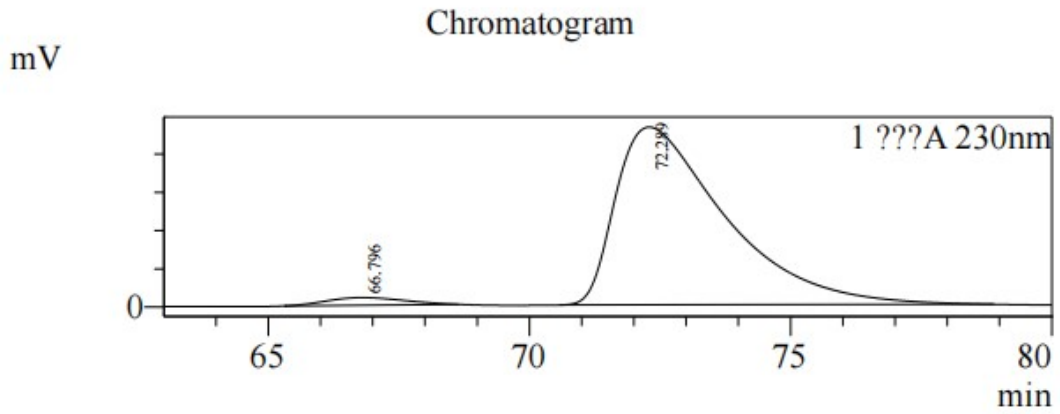


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	66.979	12483628	101163	49.771
2	74.138	12598719	88995	50.229
Total		25082347	190158	100.000

Enantiomeric Sample of 3oe

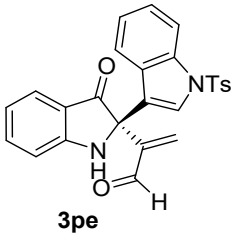


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	66.796	1021862	9909	2.918
2	72.289	33991635	232437	97.082
Total		35013496	242347	100.000

(*S*)-2-(3-oxobut-1-en-2-yl)-2-(1-tosyl-1H-indol-3-yl)indolin-3-one (**3pe**)



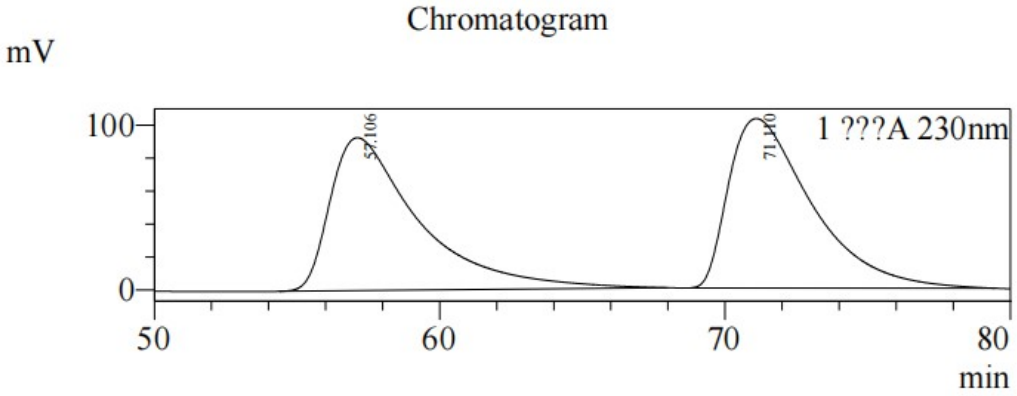
3pe

Compound **3pe** (19.2 mg, 42% yield) was obtained as a yellow solid following the *general procedure III* from **1p** (0.1 mmol, 40 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 8 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.60 (s, 1H), 7.88 (d, *J* = 8.4 Hz, 1H), 7.69 (d, *J* = 8.4 Hz, 2H), 7.63 (d, *J* = 8.0 Hz, 1H), 7.56 (s, 1H), 7.55-7.48 (m, 2H), 7.25-7.23 (m, 1H), 7.21 (s, 1H), 7.19 (s, 1H), 7.15-7.11 (m, 1H), 6.92 (d, *J* = 8.4 Hz, 1H), 6.87 (t, *J* = 8.0 Hz, 1H), 6.78 (s, 1H), 6.42 (s, 1H), 5.99 (brs, 1H), 2.33 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.7, 193.7, 159.6, 145.1, 144.9, 138.1, 137.9, 135.7, 134.7, 129.9, 127.8, 126.8, 125.4, 125.1, 124.9, 123.3, 121.4, 119.44, 119.36, 119.0, 113.7, 112.2, 67.9, 21.6; **M.p.**: 123-125 ºC; **HRMS** Calcd. for $C_{26}H_{21}N_2O_4S^+$ $[M+H]^+$: 457.1228, found: 457.1224.

$[\alpha]^{20}_{D}$ = -362.5 (c 0.04, CH_2Cl_2) for 88% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IF-H column, Hexane/^{i}PrOH = 80/20, 0.5 mL/min, 230 nm, t_{minor} = 58.202 min, t_{major} = 70.844 min.

Racemic Sample of 3pe

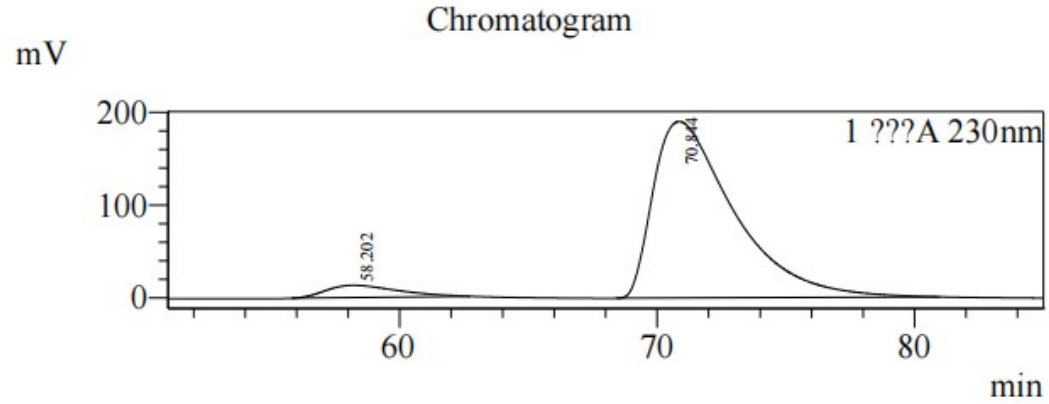


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	57.106	20071371	92700	49.062
2	71.110	20838545	102798	50.938
Total		40909916	195498	100.000

Enantiomeric Sample of 3pe

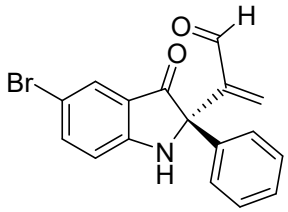


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	58.202	2540345	13211	5.778
2	70.844	41423853	189985	94.222
Total		43964199	203196	100.000

(*S*)-2-(5-bromo-3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3qe)



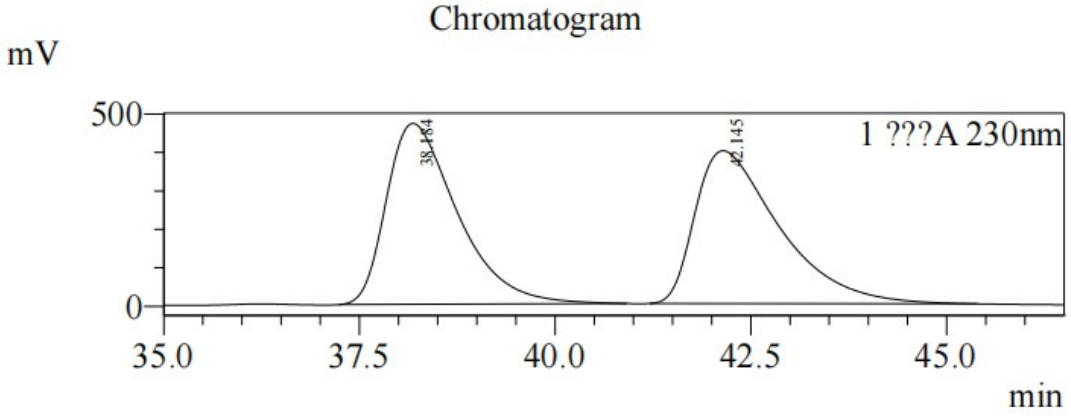
3qe

Compound **3qe** (30.7 mg, 90% yield) was obtained as a yellow solid following the *general procedure III* from **1q** (0.1 mmol, 28.4 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.68 (s, 1H), 7.55 (d, *J* = 8.8 Hz, 1H), 7.41 (d, *J* = 7.2 Hz, 2H), 7.34-7.27 (m, 3H), 6.88 (s, 1H), 6.84 (d, *J* = 8.8 Hz, 1H), 6.41 (s, 1H),6.20 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.6, 194.2, 158.2, 145.7, 140.4, 137.3, 136.3, 128.8, 128.1, 127.9, 125.3, 119.8, 113.3, 111.0, 71.6; **HRMS** Calcd. for $C_{17}H_{13}NO_2Br^+$ $[M+H]^+$: 342.0124, found: 342.0123; **M.p.**: 179-181 ºC.

$[\alpha]^{20}_D$ = -576.0 (c 0.05, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 38.327 min, t_{major} = 41.696 min.

Racemic Sample of 3qe

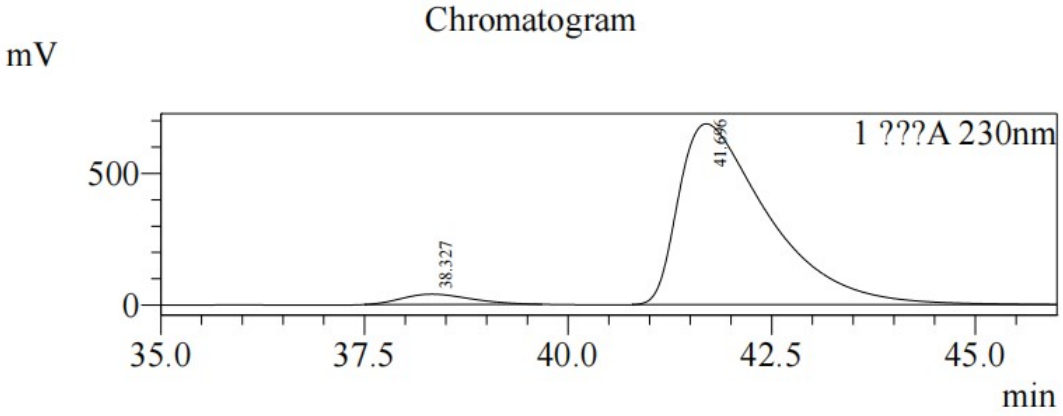


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	38.184	29664294	470192	49.931
2	42.145	29746868	397140	50.069
Total		59411162	867332	100.000

Enantiomeric Sample of 3qe

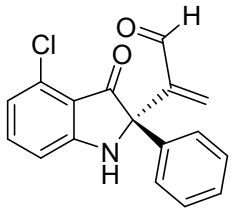


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	38.327	2294397	39078	4.172
2	41.696	52696875	686925	95.828
Total		54991273	726003	100.000

(*S*)-2-(4-chloro-3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3re)



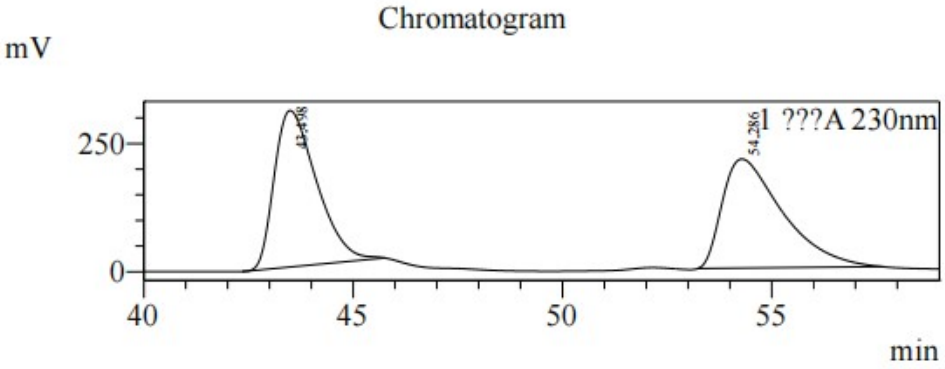
3re

Compound **3re** (18.8 mg, 63% yield) was obtained as a yellow solid following the *general procedure III* from **1r** (0.1 mmol, 24.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.52 (s, 1H), 7.44 (d, *J* = 7.2 Hz, 2H), 7.38-7.27 (m, 4H), 6.98 (s, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 6.73 (d, *J* = 7.6 Hz, 1H) 6.42 (s, 1H), 6.31 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.0, 194.4, 160.9, 145.7, 138.0, 137.5, 136.5, 133.3, 128.7, 128.1, 125.4, 120.0, 114.8, 109.9, 71.2; **HRMS** Calcd. for $C_{17}H_{13}NO_2Cl^+$ $[M+H]^+$: 298.0629, found: 298.0623; **M.p.**: 118-120 ºC.

$[\alpha]^{20}_D$ = -1185.0 (c 0.04, CH_2Cl_2) for 93% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 55.244 min, t_{major} = 43.204 min.

Racemic Sample of 3re

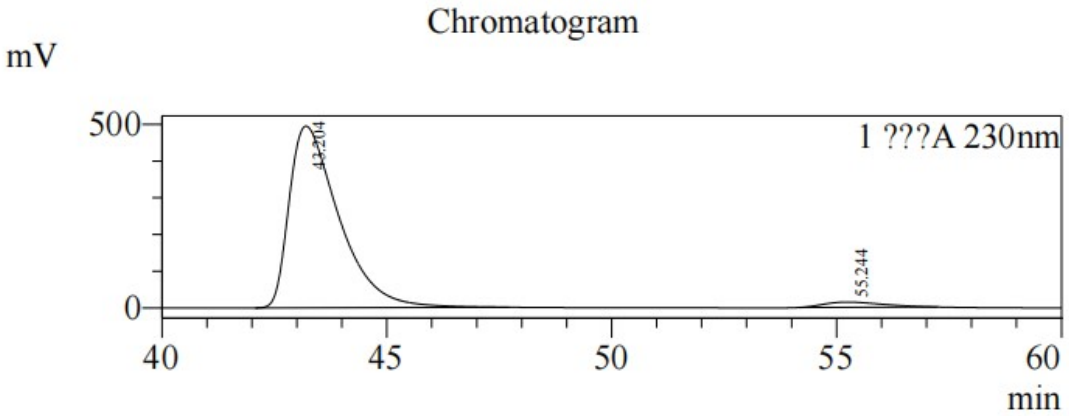


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	43.498	21429594	305188	50.097
2	54.286	21346986	212915	49.903
Total		42776580	518104	100.000

Enantiomeric Sample of 3re

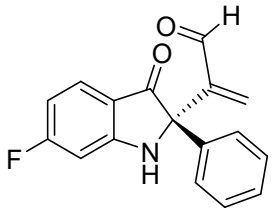


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	43.204	38009900	494960	96.723
2	55.244	1287867	14216	3.277
Total		39297767	509176	100.000

(*S*)-2-(6-fluoro-3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3se)



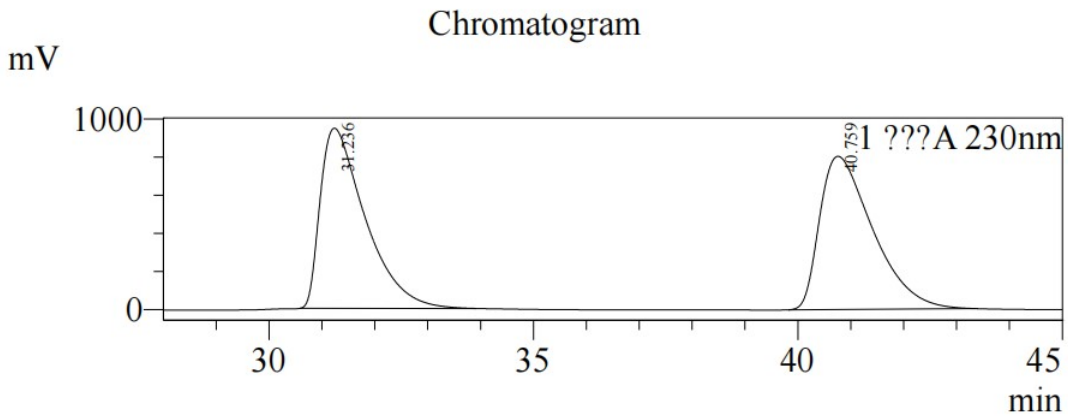
3se

Compound **3se** (27.3 mg, 97% yield) was obtained as a yellow solid following the *general procedure III* from **1s** (0.1 mmol, 22.5 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.57 (dd, *J* = 8.4, 5.6 Hz, 1H), 7.43-7.40 (m, 2H), 7.34-7.24 (m, 3H), 6.94 (s, 1H), 6.58-6.49 (m, 2H), 6.41 (s, 1H), 6.33 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.9, 194.3, 169.9 (d, *J* = 255.3 Hz), 161.2 (d, *J* = 14.3 Hz), 145.8, 137.2, 136.6, 128.7, 128.1, 127.9 (d, *J* = 12.6 Hz), 125.3, 114.8 (d, *J* = 0.9 Hz), 107.9 (d, *J* = 24.8 Hz), 98.0 (d, *J* = 26.0 Hz), 71.6; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -98.1 (s); **M.p.:** 125-127 ºC; **HRMS** Calcd. for $C_{17}H_{11}FNO_2^-$ [M-H]$^-$: 280.0774, found: 280.0783.

$[\alpha]^{20}_D$ = -692.8 (c 0.91, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 31.656 min, t_{major} = 40.417 min.

Racemic Sample of 3se

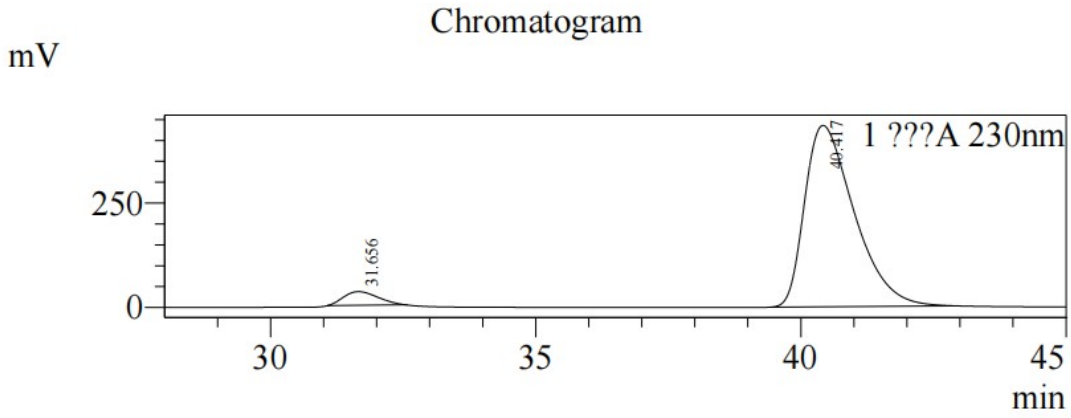


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	31.236	55772458	944060	49.837
2	40.759	56138381	802853	50.163
Total		111910839	1746913	100.000

Enantiomeric Sample of 3se

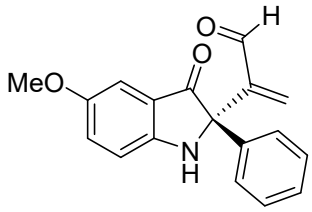


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	31.656	1484609	32833	5.002
2	40.417	28198455	434473	94.998
Total		29683064	467306	100.000

(*S*)-2-(5-methoxy-3-oxo-2-phenylindolin-2-yl)acrylaldehyde (**3te**)



3te

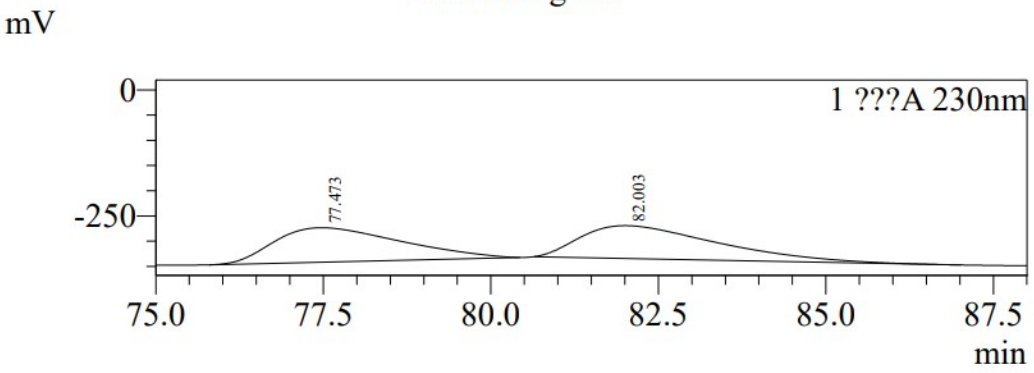
Compound **3te** (19.7 mg, 67% yield) was obtained as a yellow solid following the *general procedure III* from **1t** (0.1 mmol, 23.7 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.55 (s, 1H), 7.44 (d, *J* = 8.4 Hz, 2H), 7.33-7.24 (m, 3H), 7.20-7.17 (m, 1H), 7.00 (s, 1H), 6.91-6.88 (m, 2H), 6.39 (s, 1H), 5.88 (brs, 1H), 3.75 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.2, 194.3, 155.7, 153.4, 146.3, 137.1, 137.0, 128.7, 127.9, 125.4, 118.3, 113.3, 105.0, 72.0, 55.7; **HRMS** Calcd. for $C_{18}H_{16}NO_3^+$ $[M+H]^+$: 294.1125, found: 294.1117; **M.p.**: 169-170 ºC.

$[\alpha]^{20}_D$ = -940.0 (c 0.04, CH_2Cl_2) for 85% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 78.973 min, t_{major} = 82.414 min.

Racemic Sample of 3te

Chromatogram



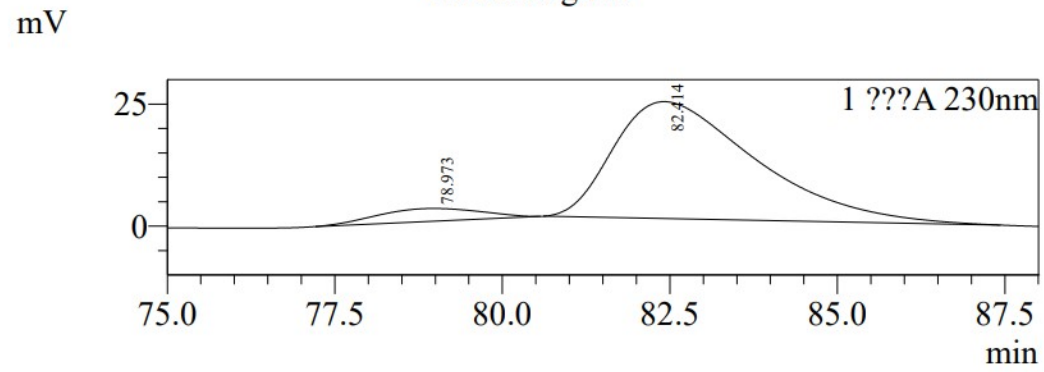
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	77.473	8935858	68207	49.053
2	82.003	9280727	64949	50.947
Total		18216585	133156	100.000

Enantiomeric Sample of 3te

Chromatogram

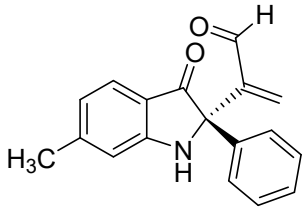


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	78.973	282591	2606	7.376
2	82.414	3548487	23950	92.624
Total		3831078	26556	100.000

(*S*)-2-(6-methyl-3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3ue)



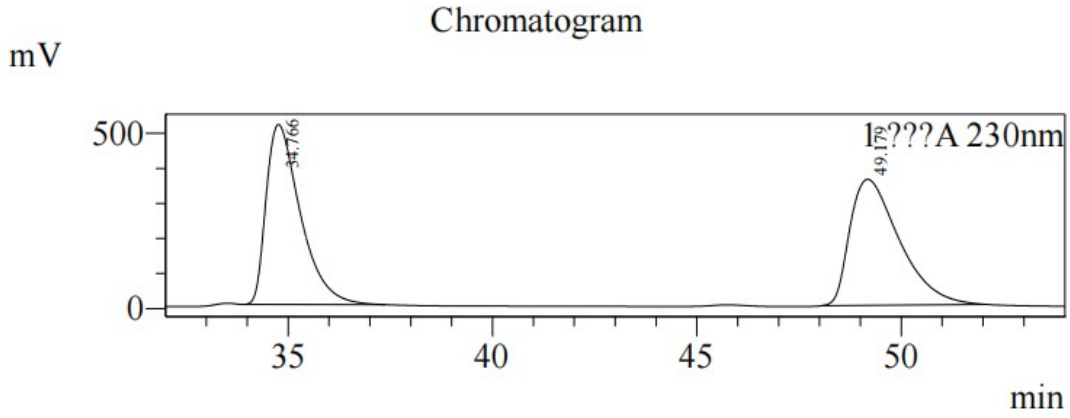
3ue

Compound **3ue** (21.0 mg, 76% yield) was obtained as a yellow solid following the *general procedure III* from **1u** (0.1 mmol, 22.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.45 (dd, *J* = 17.2, 8.0 Hz, 3H), 7.32-7.23 (m, 3H), 6.93 (s, 1H), 6.73 (s, 1H), 6.64 (d, *J* = 8.0 Hz, 1H), 6.38 (s, 1H), 6.10 (brs, 1H), 2.37 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.1, 194.5, 160.2, 149.8, 146.1, 137.13, 137.10, 128.6, 127.8, 125.3, 125.2, 120.9, 115.9, 111.7, 71.2, 22.5; **HRMS** Calcd. for $C_{18}H_{16}NO_2^+$ $[M+H]^+$: 278.1176, found: 278.1167; **M.p.**: 141-143 ºC.

$[\alpha]^{20}_D$ = -1070.0 (c 0.05, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IF-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 35.014 min, t_{major} = 48.313 min.

Racemic Sample of 3ue

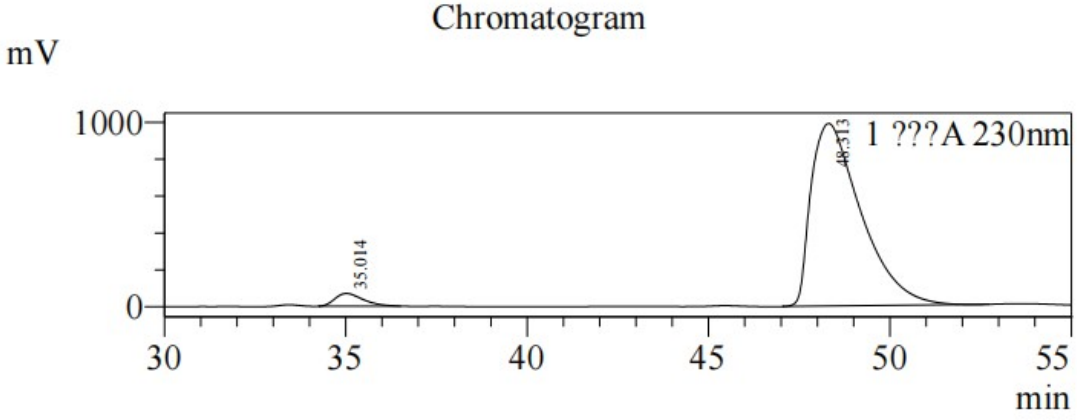


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	34.766	29983951	513831	49.745
2	49.179	30291608	359694	50.255
Total		60275559	873525	100.000

Enantiomeric Sample of 3ue

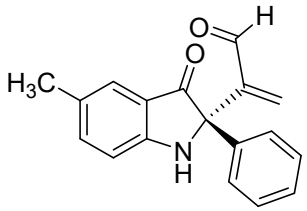


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	35.014	3724088	69098	3.778
2	48.313	94840643	990739	96.222
Total		98564732	1059837	100.000

(*S*)-2-(5-methyl-3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3ve)



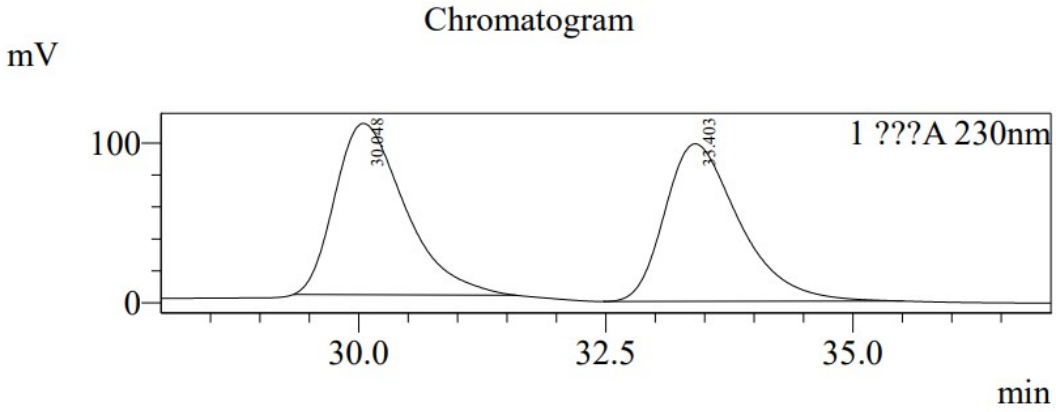
3ve

Compound **3ve** (24.5 mg, 88% yield) was obtained as a yellow solid following the *general procedure III* from **1v** (0.1 mmol, 22.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.43 (d, *J* = 7.6 Hz, 2H), 7.37 (s, 1H), 7.34-7.28 (m, 3H), 7.25-7.23 (m, 1H), 6.89 (s, 1H), 6.86 (d, *J* = 8.4 Hz, 1H), 6.37 (s, 1H), 5.98 (brs, 1H), 2.28 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.0, 194.3, 158.3, 146.3, 139.4, 137.2, 136.9, 128.6, 127.8, 125.5, 124.8, 118.4, 111.7, 71.4, 20.5; **M.p.**: 141-143 ºC; **HRMS** Calcd. for $C_{18}H_{16}NO_2^+$ $[M+H]^+$: 278.1176, found: 278.1174.

$[\alpha]^{20}_D$ = -1461.0 (c 0.05, CH_2Cl_2) for 95% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IF-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 33.131 min, t_{major} = 29.494 min.

Racemic Sample of 3ve

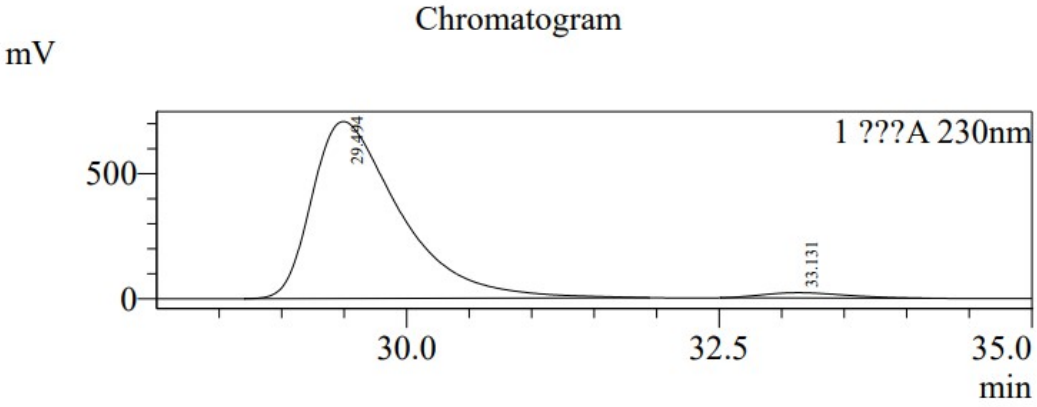


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	30.048	5299058	107213	50.556
2	33.403	5182471	98645	49.444
Total		10481529	205858	100.000

Enantiomeric Sample of 3ve

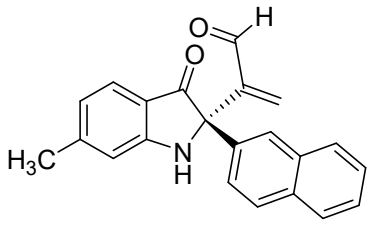


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	29.494	34655083	707790	97.255
2	33.131	977992	21158	2.745
Total		35633074	728948	100.000

(*S*)-2-(6-methyl-2-(naphthalen-2-yl)-3-oxoindolin-2-yl)acrylaldehyde (3we)



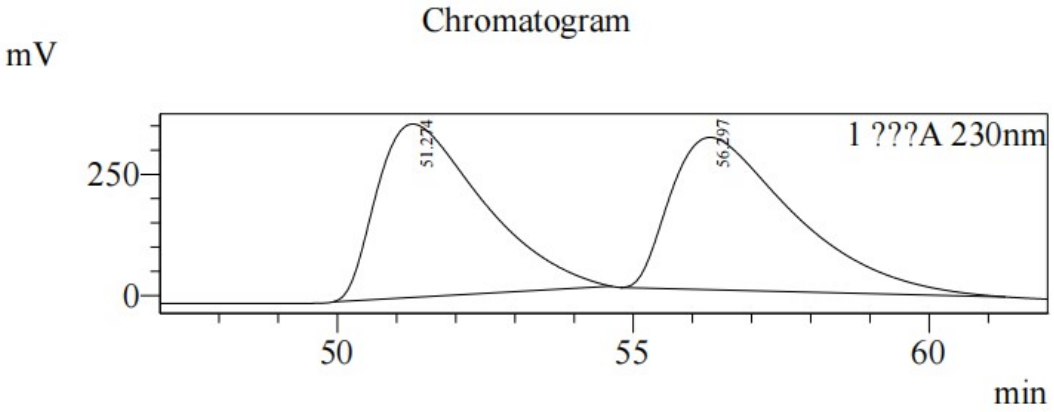
3we

Compound **3we** (15.0 mg, 46% yield) was obtained as a yellow solid following the *general procedure III* from **1w** (0.1 mmol, 27.1 mg) and **2e** (0.15 mmol, 8.4 mg, 10 µL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (s, 1H), 7.89 (s, 1H), 7.79 (d, *J* = 8.0 Hz, 3H), 7.55-7.42 (m, 4H), 6.99 (s, 1H), 6.79 (s, 1H), 6.66 (d, *J* = 8.0 Hz, 1H), 6.45 (s, 1H), 6.19 (brs, 1H), 2.40 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.1, 194.5, 160.3, 149.9, 146.1, 137.4, 134.6, 133.2, 132.9, 128.5, 128.1, 127.5, 126.11, 126.08, 125.3, 124.5, 123.3, 121.0, 116.1, 111.8, 71.3, 22.6; **HRMS** Calcd. for $C_{22}H_{18}NO_2^+$ $[M+H]^+$: 328.1332, found: 328.1326; **M.p.**: 75-77 ºC.

$[\alpha]^{20}_D$ = -836.0 (c 0.05, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 57.515 min, t_{major} = 50.001 min.

Racemic Sample of 3we

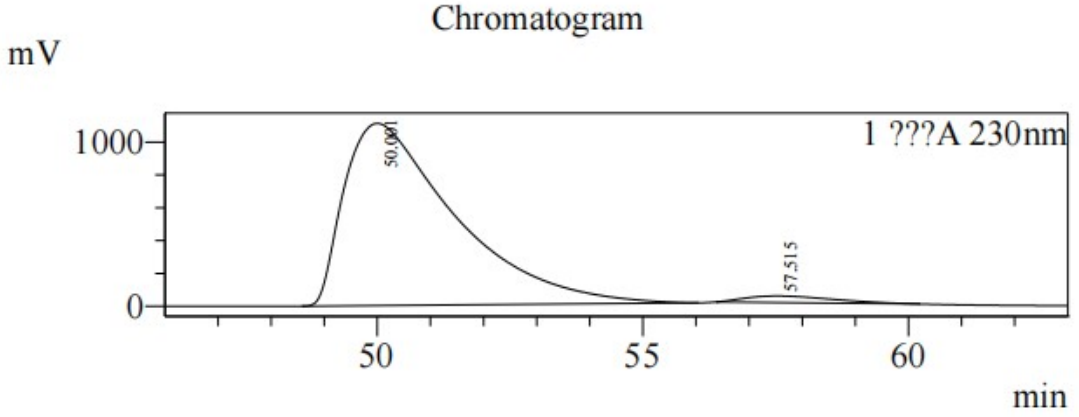


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	51.274	44619768	357370	49.521
2	56.297	45483131	313900	50.479
Total		90102899	671269	100.000

Enantiomeric Sample of 3we

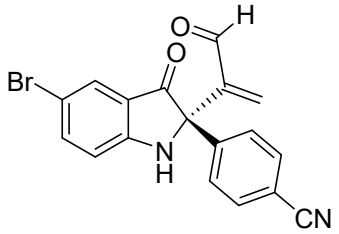


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	50.001	160886728	1110298	97.194
2	57.515	4644033	40297	2.806
Total		165530761	1150594	100.000

(*S*)-4-(5-bromo-3-oxo-2-(3-oxoprop-1-en-2-yl)indolin-2-yl)benzonitrile (3xe)



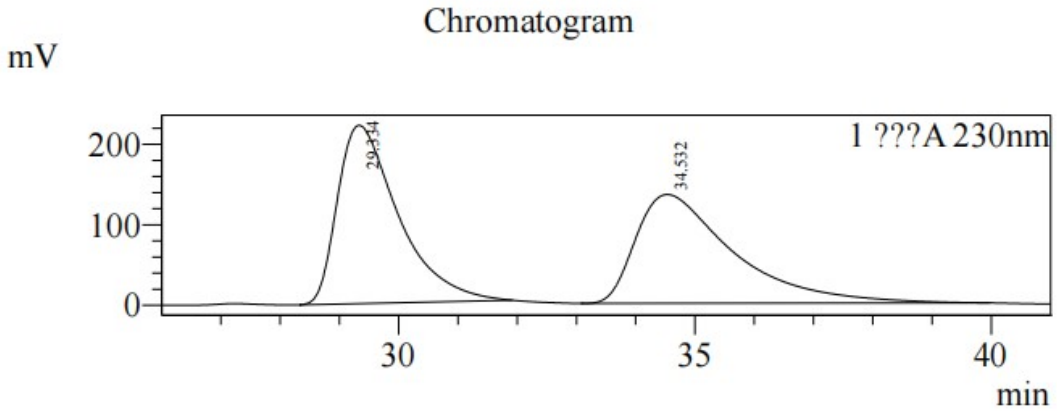
3xe

Compound **3xe** (26.1 mg, 71% yield) was obtained as a yellow solid following the *general procedure III* from **1x** (0.1 mmol, 30.9 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.52 (s, 1H), 7.69 (s, 1H), 7.59 (dd, *J* = 18.8, 8.8 Hz, 5H), 6.88 (t, *J* = 4.8 Hz, 2H), 6.47 (s, 1H), 6.17 (s, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 195.3, 194.0, 158.2, 145.1, 141.8, 140.9, 137.9, 132.4, 128.0, 126.4, 119.5, 118.5, 113.7, 112.0, 111.7, 71.4; **M.p.**: 88-90 ºC; **HRMS** Calcd. for $C_{18}H_{10}N_2O_2Br^-$ [M-H]$^-$: 364.9931, found: 364.9938.

$[\alpha]^{20}_D$ = -652.5 (c 0.04, CH_2Cl_2) for 78% ee; Enantiomeric excess was determined by HPLC with a Chiralcel IF-H column, Hexane/^{i}PrOH = 80/20, 0.5 mL/min, 230 nm, t_{minor} = 34.686 min, t_{major} = 28.998 min.

Racemic Sample of 3xe

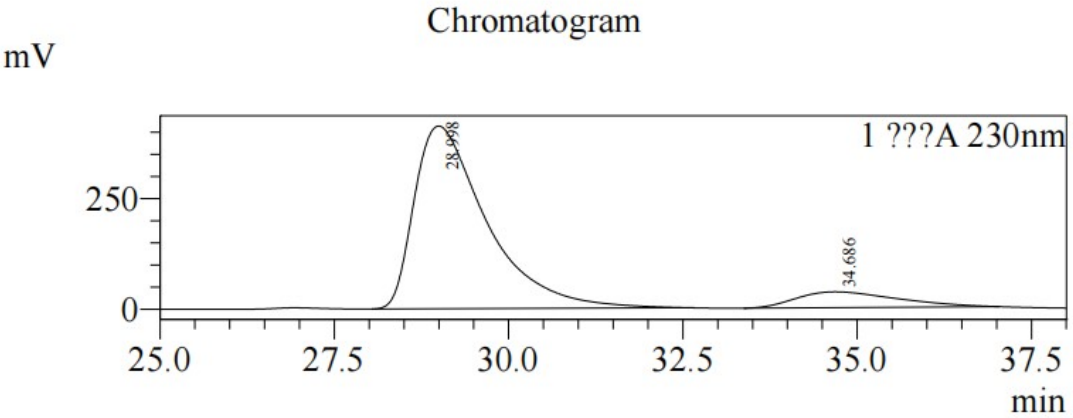


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	29.334	15777285	221386	50.496
2	34.532	15467267	135228	49.504
Total		31244552	356614	100.000

<u>Enantiomeric Sample of 3xe</u>

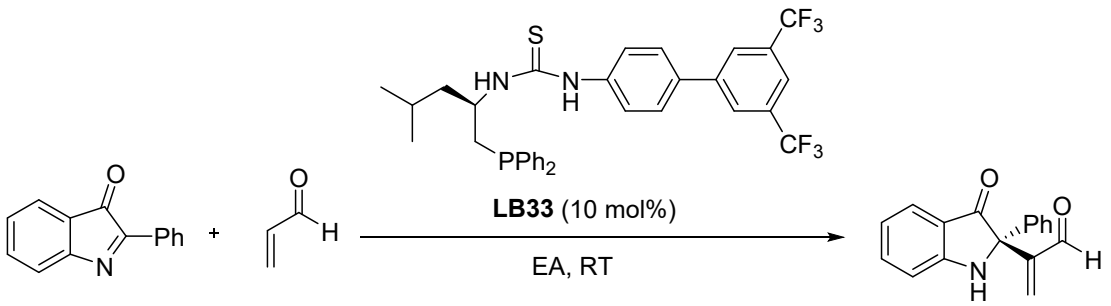


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	28.998	29823111	412678	89.231
2	34.686	3599423	35718	10.769
Total		33422534	448396	100.000

(*R*)-2-(3-oxo-2-phenylindolin-2-yl)acrylaldehyde (3ae')



1a **2e** **3ae'**

Procedure (IIIa): To a solution of compound **1a** (0.1 mmol, 1.0 equiv., 20.7 mg) and chiral phosphine **LB33** (0.01 mmol, 0.1 equiv., 6.3 mg) in ethyl acetate (2.0 mL) was added compound **2e** (0.15 mmol, 1.5 equiv., 10 μL) under nitrogen atmosphere at room temperature. TLC monitor until the compound **1a** was consumed after three hours. The reaction mixture was then concentrated on a rotary evaporator under reduce pressure and the residue was subjected to purification by column chromatography (silica gel, PE/EtOAc: 15/1 to 10/1, R_f = 0.2-0.3) to afford the corresponding product **3ae'**.

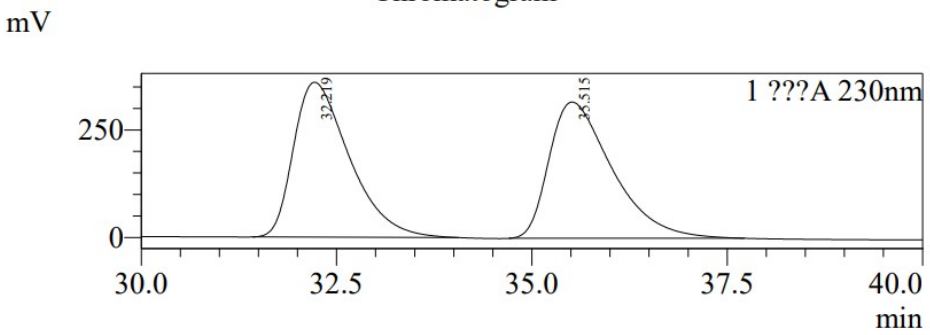
Compound **3ae'** (24.7 mg, 94% yield) was obtained as a yellow solid following the *general procedure IIIa* from **1a** (0.1 mmol, 20.7 mg) and **2e** (0.15 mmol, 8.4 mg, 10 μL) stirred for 6 hours.

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (s, 1H), 7.58 (d, *J* = 7.6 Hz, 1H), 7.51-7.42 (m, 3H), 7.31-7.24 (m, 3H), 6.93-6.91 (m, 2H), 6.81 (t, *J* = 7.2 Hz, 1H), 6.40 (s, 1H), 6.17 (brs, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.9, 194.4, 159.8, 146.0, 137.9, 137.1, 136.9, 128.6, 127.9, 125.5, 125.4, 119.0, 118.2, 111.7, 71.0; **M.p.**: 155-157 ºC.

$[\alpha]^{20}_D$ = +904.0 (c 0.05, CH_2Cl_2) for -95% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 32.868 min, t_{major} = 37.239 min.

Racemic Sample of 3ae'

Chromatogram



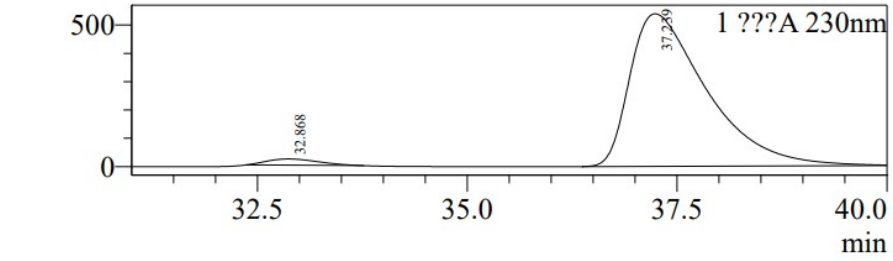
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	32.219	17886753	359635	50.162
2	35.515	17770952	316523	49.838
Total		35657705	676158	100.000

Enantiomeric Sample of 3ae'

Chromatogram



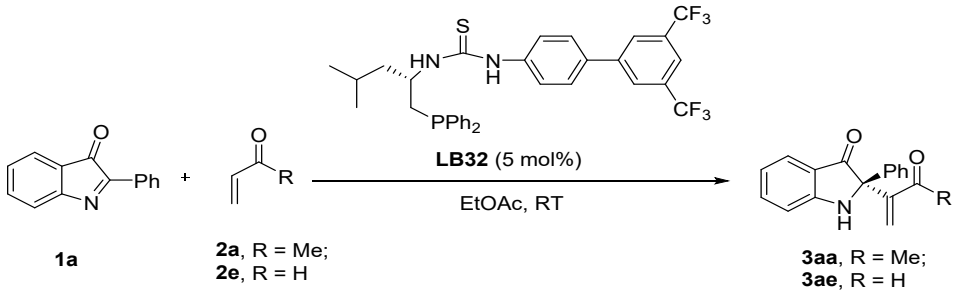
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	32.868	941969	21972	2.669
2	37.239	34354114	539141	97.331
Total		35296083	561113	100.000

4. Synthetic applications

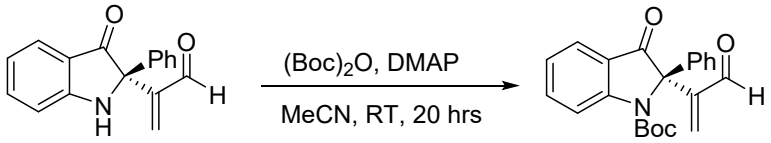
a) Scale-up experiments for the synthesis of 3aa and 3ae



1a **2a**, R = Me; **2e**, R = H **3aa**, R = Me; **3ae**, R = H

The scale up experiment was followed the general *procedure III*. To a solution of compound **1a** (1.0 mmol for **3aa**, 5.0 mmol for **3ae**, 1.0 equiv.) and chiral phosphine **LB32** (5 mol%) in ethyl acetate was added compound **2a** or **2e** (1.5 equiv.) under nitrogen atmosphere at room temperature. TLC monitor until the compound **1a** consumed after six hours. The reaction mixture was then concentrated on a rotary evaporator under reduce pressure and the residue was subjected to purification by column chromatography (silica gel, PE/EtOAc: 20/1 to 15/1, R_f = 0.3) to afford the corresponding product **3aa** (0.21 g, 76% yield, 90% ee) and **3ae** (0.971 g, 74% yield, 94% ee) as yellow solid.

b) Synthesis of *N*-Boc product 3ae



3ae **4**

Procedure (IV): To a solution of **3ae** (1 mmol, 263 mg) and DMAP (3.3 mmol, 720 mg) in MeCN was added $(Boc)_2O$ (2.2 mmol, 489 mg) under nitrogen, then the reaction mixture was stirred at room temperature for 20 hrs. After conversion, the solvent was removed in vacuum and extracted twice with EtOAc and water, the organic layers were dried over anhydrous Na_2SO_4 and purified by column chromatography (Petroleum ether/EtOAc: 30/1 to 20/1) to afford the product **4** in 75% yield with 94% ee.

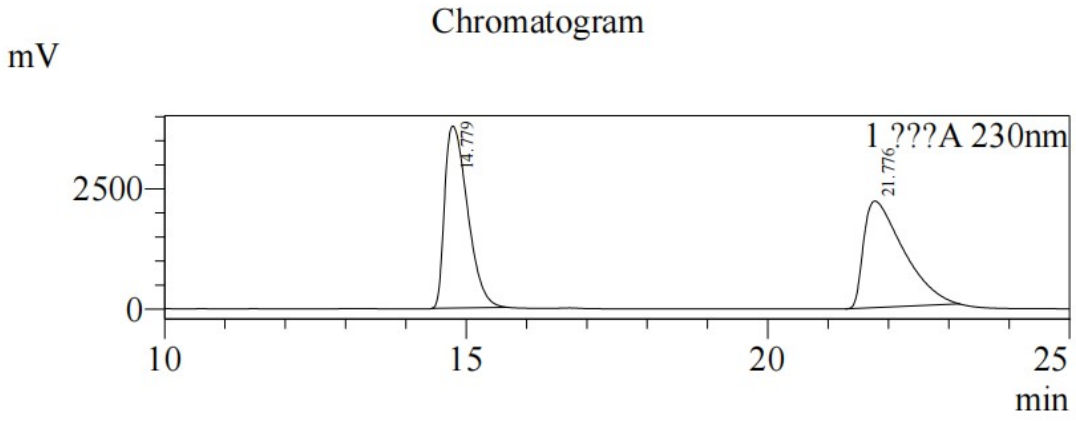
***tert*-Butyl (*S*)-3-oxo-2-(3-oxoprop-1-en-2-yl)-2-phenylindoline-1-carboxylate (4)**

Compound **4** (272.9 mg, 75% yield) was obtained as yellow solid following the

procedure IV from **3ae** (1 mmol, 263 mg), DMAP (3.3 mmol, 720 mg) and $(Boc)_2O$ (2.2 mmol, 489 mg) stirred for 20 hrs. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.56 (s, 1H), 8.27 (s, 1H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.62 (t, *J* = 7.6 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 2H), 7.36-7.30 (m, 3H), 7.13 (t, *J* = 7.6 Hz, 1H), 6.58 (d, *J* = 17.2 Hz, 2H), 1.44 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.0, 191.6, 152.3, 150.7, 149.1, 141.4, 136.6, 133.6, 128.3, 128.2, 127.3, 124.4, 123.4, 122.7, 117.1, 83.0, 74.1, 28.1; **HRMS** Calcd. for $C_{22}H_{21}NO_4Na^+$ $[M+Na]^+$: 386.1368, found: 386.1372; **M.p.**: 49-51 ºC.

$[\alpha]^{20}_D$ = -103.0 (c 0.10, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 22.596 min, t_{major} = 14.894 min.

Racemic Sample of 4

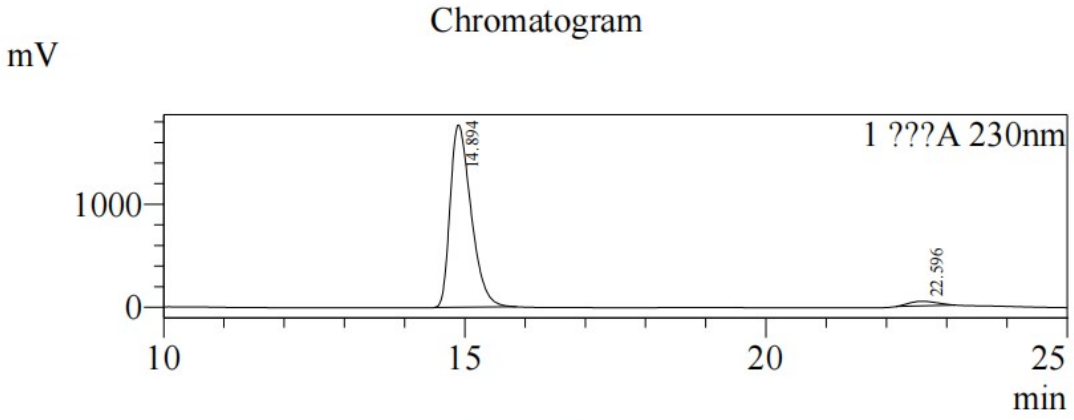


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.779	99981535	3784934	49.518
2	21.776	101927515	2214040	50.482
Total		201909050	5998974	100.000

Enantiomeric Sample of 4

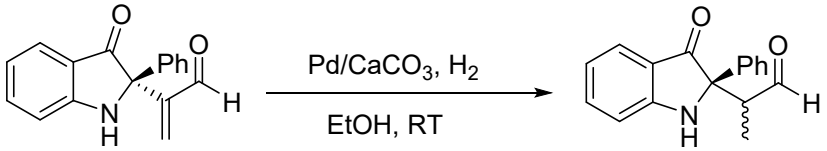


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.894	42802899	1771240	96.750
2	22.596	1437746	44501	3.250
Total		44240644	1815741	100.000

c) Preparation of compound 5



3ae **5**

Procedure (V): Compound **3ae** was dissolved in ethanol, and then 5% $Pd/CaCO_3$ was added. The mixture was stirred overnight under a hydrogen balloon at room temperature. Then the mixture was filtered through a Celite pad and the solvent removed in vacuum, the residue obtained was purified by column chromatography (petroleum ether/EtOAc: 20/1 to 15/1) to afford the product **5** in 91% yield with 91% ee/94% ee and 43/57 dr.

Note: Compound **5** were inseparable diastereoisomers.

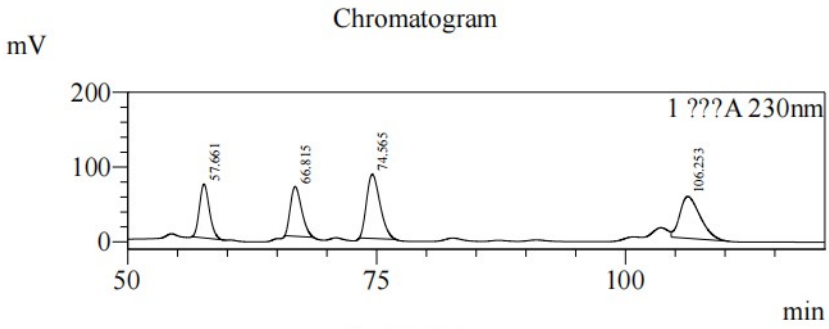
2-((*R*)-3-oxo-2-phenylindolin-2-yl)propanal (5)

Compound **5** (48.1 mg, 91% yield, diastereomers, 43:57 dr) were obtained as yellow solid following the *procedure V* from **3ae** (0.2 mmol, 52.6 mg) and 5% $Pd/CaCO_3$ (0.1 mmol, 41.3 mg) stirred for 24 hrs. **^{1}H NMR** (400 MHz, $CDCl_3$, diastereomers) δ 9.61 (s, 1H), 9.48 (s, 1H), 7.60-7.57 (m, 3H), 7.53-7.51 (m, 3H), 7.49-7.45 (m, 2H), 7.36-7.29 (m, 5H), 7.25-7.22 (m, 1H), 6.98-6.93 (m, 2H), 6.84 (t, J = 7.6 Hz, 1H), 6.78 (t, J

= 7.6 Hz, 1H), 5.70 (brs, 1H), 5.39 (brs, 1H), 3.83 (q, *J* = 7.2 Hz, 1H), 3.59 (q, *J* = 7.2 Hz, 1H), 1.05 (s, 3H), 1.04 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$, diastereomers) δ 202.9, 201.1, 200.2, 200.0, 160.9, 160.0, 137.8, 137.68, 137.65, 136.7, 129.0, 128.8, 128.0, 127.9, 125.43, 125.35, 125.29, 125.25, 119.9, 119.8, 119.0, 112.1, 111.5, 72.6, 71.6, 53.8, 52.5, 9.1, 8.8; **HRMS** Calcd. for $C_{17}H_{16}NO_2^+$ $[M+H]^+$: 266.1176, found: 266.1183; **M.p.**: 167-169 ºC.

$[\alpha]^{20}_D$ = -364.0 (c 0.05, CH_2Cl_2) for 91% and 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 65.593 min, t_{major} = 57.335 min and t_{minor} = 104.012 min, t_{major} = 73.380 min.

Racemic Sample of 5

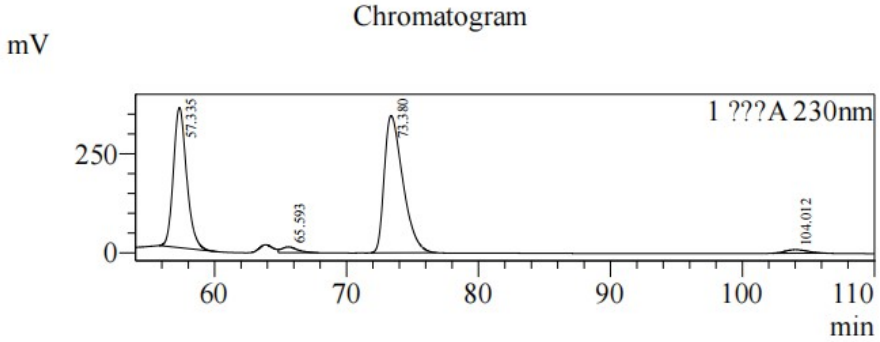


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	57.661	5003239	72057	19.040
2	66.815	5191389	66292	19.756
3	74.565	8071859	85793	30.718
4	106.253	8010428	55973	30.485
Total		26276914	280116	100.000

Enantiomeric Sample of 5

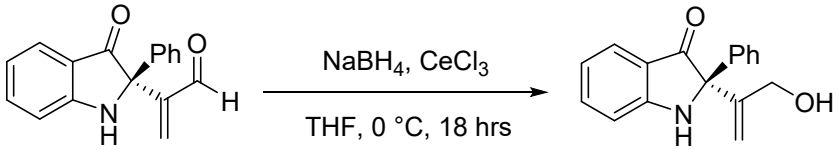


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	57.335	24756013	353621	40.710
2	65.593	1218707	14592	2.004
3	73.380	33815178	346068	55.608
4	104.012	1020382	8861	1.678
Total		60810281	723141	100.000

d) Luche reduction



3ae **6**

Procedure (VI): A solution of $NaBH_4$ and $CeCl_3$ in anhydrous THF was cooled to 0 ℃ under nitrogen atmosphere, the solution of **3ae** in anhydrous THF was added dropwised while maintained temperature at 0 ℃ for full conversion. The mixture was then quenched with saturated NH_4Cl solution and extracted twice with EtOAc, the organic layers were combined and dried over anhydrous Na_2SO_4. The residue obtained was purified by column chromatography (Petroleum ether/EtOAc: 8/1) to afford the product **6** in 93% yield with 94% ee.

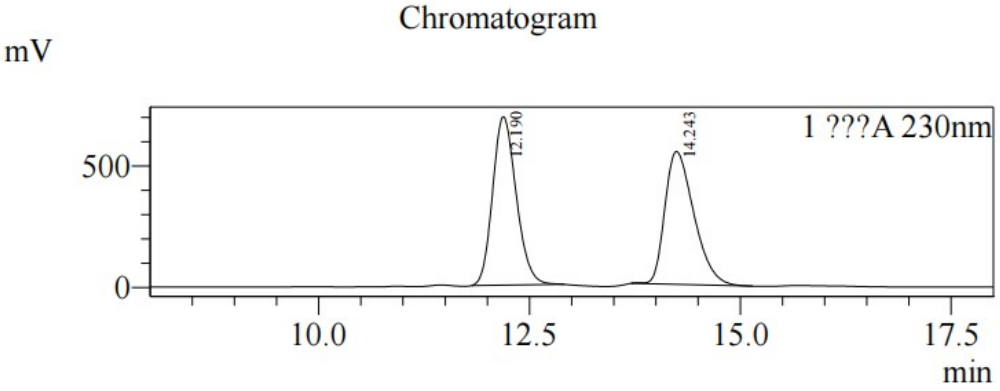
(*S*)-2-(3-hydroxyprop-1-en-2-yl)-2-phenylindolin-3-one (6)

Compound **6** (24.7 mg, 93% yield) were obtained as yellow solid following the *procedure VI* from **3ae** (0.1 mmol, 26.3 mg), $NaBH_4$ (0.11 mmol, 4.2 mg) and $CeCl_3$ (0.1 mmol, 24.6 mg) stirred for 18 hrs. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.61 (d, J = 7.6 Hz, 1H), 7.53 (d, J = 8.0 Hz, 2H), 7.48 (t, J = 8.0 Hz, 1H), 7.36-7.29 (m, 3H), 6.94 (d, J = 8.0 Hz, 1H), 6.84 (t, J = 7.6 Hz, 1H), 5.80 (brs, 1H), 5.40 (d, J = 10.8 Hz, 2H), 4.21 (d, J = 12.8 Hz, 1H), 4.15 (d, J = 12.8 Hz, 1H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 200.0,

160.0, 145.7, 138.4, 137.6, 128.7, 127.9, 126.5, 125.4, 119.8, 119.3, 116.7, 112.6, 75.1, 65.2; **HRMS** Calcd. for $C_{17}H_{16}NO_2^+$ $[M+H]^+$: 266.1176, found: 266.1182; **M.p.**: 47-49 ºC.

$[\alpha]^{20}_D$ = -199.5 (c 0.21, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 80/20, 0.5 mL/min, 230 nm, t_{minor} = 14.368 min, t_{major} = 12.197 min.

Racemic Sample of 6

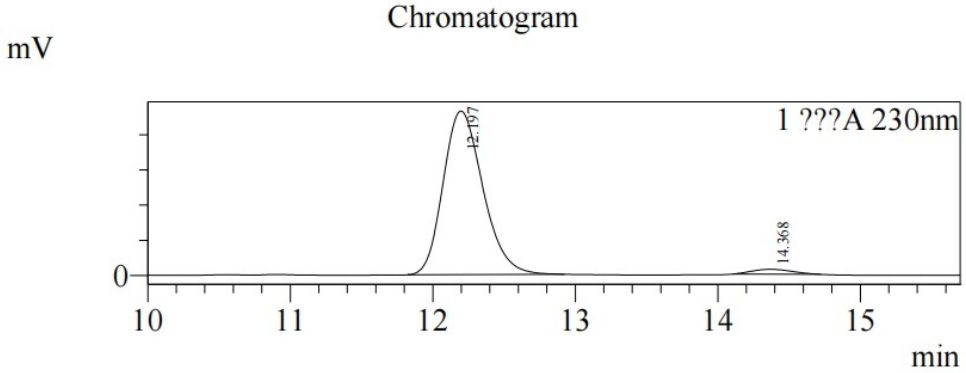


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	12.190	13515518	693656	50.720
2	14.243	13131542	547227	49.280
Total		26647060	1240883	100.000

Enantiomeric Sample of 6

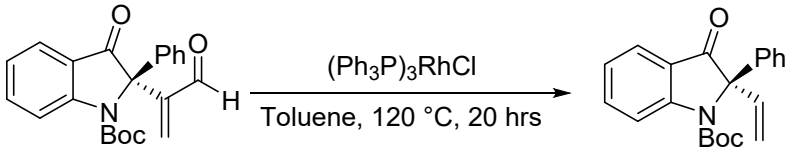


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	12.197	18015067	929766	97.115
2	14.368	535253	27587	2.885
Total		18550320	957353	100.000

e) Tsuji-Wilkinson Decarbonylation



4 **7**

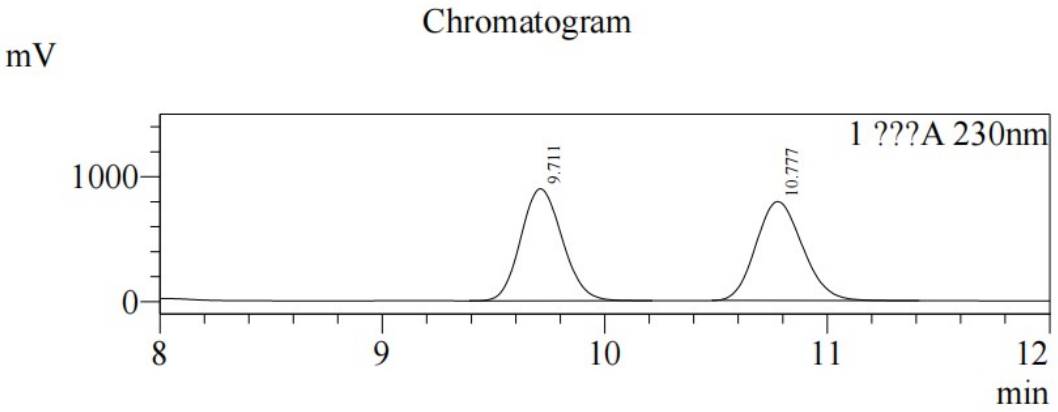
Procedure (VII): The compound **4a** (0.1 mmol, 1 equiv.) in dry toluene (2 mL) was vigorously purged with nitrogen for 30 min. In an inert atmosphere box, the reaction mixture was added $Rh(PPh_3)_3Cl$ (0.1 mmol, 1 equiv.) and then heated at 120 ℃ for 20 hrs. The reaction mixture was cooled to room temperature and quenched with H_2O, Then the mixture was diluted with EtOAc, filtered through a Celite pad and the solvent was extracted twice with EtOAc, the organic layers were combined and dried over anhydrous Na_2SO_4. The residue obtained was purified by column chromatography (petroleum ether/EtOAc: 40/1 to 30/1) to afford the product **7** in 73% yield with 88% ee.

***tert*-Butyl (*R*)-3-oxo-2-phenyl-2-vinylindoline-1-carboxylate (7)**

Compound **7** (24.6 mg, 73% yield) were obtained as yellow solid following the *procedure VII* from **4a** (0.1 mmol, 36.3 mg) and $Rh(PPh_3)_3Cl$ (0.1 mmol, 93 mg) stirred for 20 hrs. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.39 (s, 1H), 7.72 (dd, *J* = 19.2, 8.0 Hz, 2H), 7.34-7.27 (m, 3H), 7.24 (d, *J* = 7.6 Hz, 2H), 7.18 (t, *J* = 7.6 Hz, 1H), 6.54 (dd, *J* = 17.6, 10.8 Hz, 1H), 5.45 (d, *J* = 10.4 Hz, 1H), 5.38 (d, *J* = 17.2 Hz, 1H), 1.23 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.6, 153.3, 150.5, 138.4, 137.4, 133.3, 128.6, 127.8, 125.7, 125.0, 123.4, 121.5, 118.0, 116.8, 82.4, 76.2, 27.8; **HRMS** Calcd. for $C_{21}H_{22}NO_3^+$ $[M+H]^+$: 336.1600, found: 336.1601; **M.p.**: 74-75 ºC.

$[\alpha]^{20}_D$ = -176.7 (c 0.38, CH_2Cl_2) for 88% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 10.745 min, t_{major} = 9.639 min.

Racemic Sample of 7

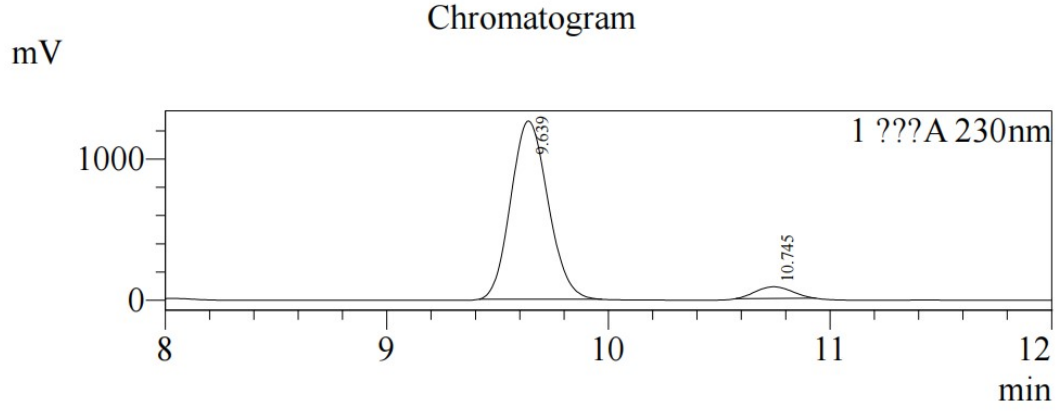


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.711	11639295	896520	50.139
2	10.777	11574560	792510	49.861
Total		23213855	1689029	100.000

Enantiomeric Sample of 7

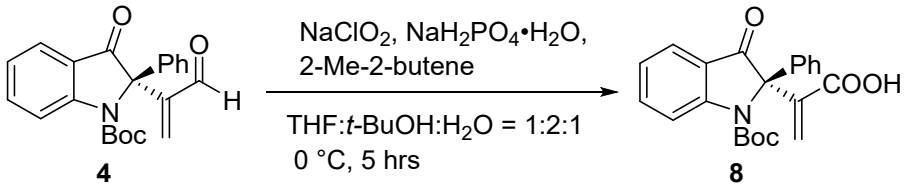


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.639	14782317	1262981	94.016
2	10.745	940957	82847	5.984
Total		15723274	1345827	100.000

f) Pinnick oxidation for the preparation of compound 8

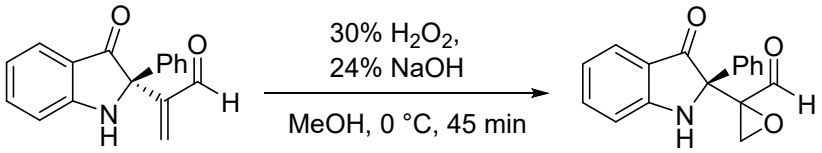


Procedure (VIII): The compound **4** (0.1 mmol, 1 equiv.), NaH_2PO_4 (0.6 mmol, 6 equiv.) was dissolved in the mixture solution of THF, *t*-BuOH and H_2O (1:2:1 mL)，2-Me-2-butene (1 mmol, 10 equiv.) was added dropwised by a syringe at 0 ℃, then NaClO (0.5 mmol, 5 equiv.) was added in above solution while mataining temperature at 0 ℃ for full conversion. After conversion, the reaction solution was quenched with Na_2SO_3 (0.8 mmol, 8 equiv.), then 0.5 M HCl was added for acidification. The obtained mixture was extracted twice with EtOAc and water, the organic layers obtained were dried over anhydrous Na_2SO_4 and purified by column chromatography (DCM/MeOH: 10/1) to afford the product **8** in 95% yield.

(*S*)-2-(1-(*tert*-butoxycarbonyl)-3-oxo-2-phenylindolin-2-yl)acrylic acid (8)

Compound **8** (36 mg, 95% yield) were obtained as yellow solid following the *procedure VIII* from **4a** (0.1 mmol, 36.3 mg), NaH_2PO_4 (0.6 mmol, 93.6 mg), 2-Me-2-butene (1 mmol, 0.11 mL) and $NaClO_2$ (0.5 mmol, 45.2 mg) stirred for 5 hrs. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.23 (d, *J* = 7.2 Hz, 1H), 7.55-7.50 (m, 2H), 7.44 (d, *J* = 6.8 Hz, 2H), 7.32-7.28 (m, 3H), 7.02 (t, *J* = 7.2 Hz, 1H), 6.54 (s, 1H), 5.71 (s, 2H), 1.38 (s, 9H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 197.5, 170.2, 152.4, 151.3, 142.1, 136.1, 134.5, 132.0, 128.0, 127.9, 124.3, 123.1, 117.1, 82.9, 76.3, 28.0; **HRMS** Calcd. for $C_{22}H_{21}NO_5Na^+$ $[M+Na]^+$: 402.1317, found: 402.1321; **M.p.**: 170-172 ºC; $[\alpha]^{20}_D$ = -25.2 (c 0.70, CH_2Cl_2).

g) Preparation of compound 9



3ae **9**

Procedure (IX): A solution of **3ae** (0.1 mmol, 1 equiv.) in MeOH was cooled to 0 ℃ under nitrogen atmosphere, 30% H_2O_2 (0.2 mmol, 2 equiv.) was added dropwised slowly while keeping temperature at 0 ℃, then 24% NaOH (0.03 mmol, 0.3 equiv.) was added in above solution while keeping temperature at 0 ℃ for full conversion. The mixture was then quenched with saturated $Na_2S_2O_3$ solution and extracted twice with

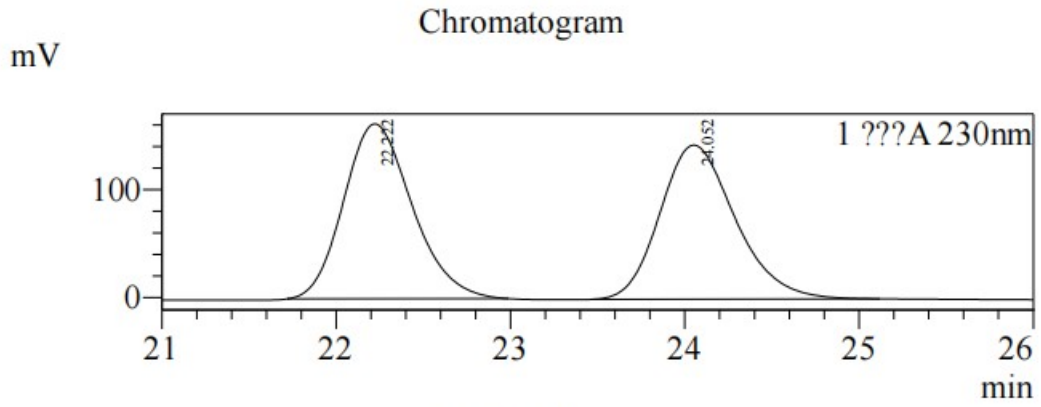
EtOAc, the organic layers were combined and dried over anhydrous Na_2SO_4. The residue obtained was purified by column chromatography (Petroleum ether/EtOAc: 8/1) to afford the product **9** in 44% yield with 93% ee.

2-((*S*)-3-oxo-2-phenylindolin-2-yl)oxirane-2-carbaldehyde (9)

Compound **9** (12.3 mg, 44% yield) were obtained as yellow solid following the *procedure IX* from **3ae** (0.1 mmol, 26.3 mg), 30% H_2O_2 (0.2 mmol, 22.7 mg, 15 µL) and 24% NaOH (0.03 mmol, 5 mg, 5 µL) stirred for 45 mins.

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.93 (s, 1H), 7.50 (dd, *J* = 18.8, 7.6 Hz, 4H), 7.37-7.29 (m, 3H), 6.94 (d, *J* = 8.4 Hz, 1H), 6.83 (t, *J* = 7.6 Hz, 1H), 5.73 (s, 1H), 4.22 (d, *J* = 4.4 Hz, 1H), 3.35 (d, *J* = 4.4 Hz, 1H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 196.9, 196.6, 160.5, 138.0, 136.2, 129.0, 128.4, 125.53, 125.51, 119.5, 118.3, 111.6, 68.8, 61.6, 48.5; **HRMS** Calcd. for $C_{17}H_{14}NO_3^+$ $[M+H]^+$: 280.0968, found: 280.0975; **M.p.**: 166-168 ºC; $[\alpha]^{20}_D$ = -307.8 (c 0.20, CH_2Cl_2). for 93% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 22.317 min, t_{major} = 24.102 min.

Racemic Sample of 9



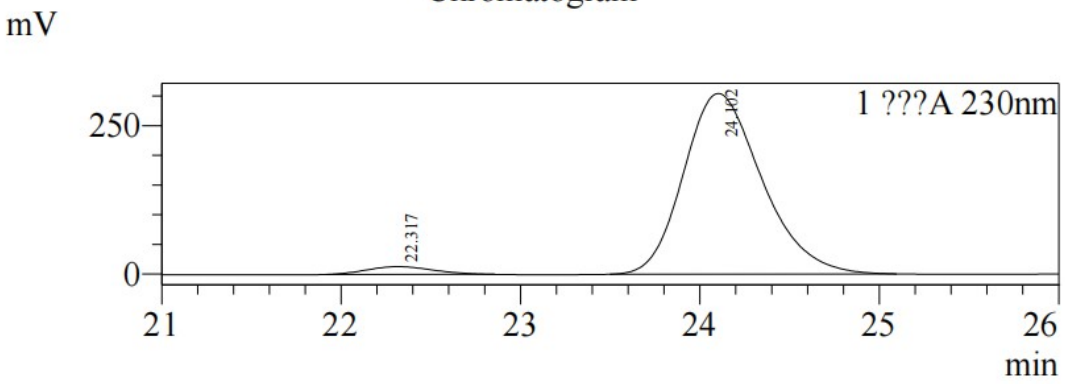
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	22.222	4429509	162145	50.812
2	24.052	4287870	142877	49.188
Total		8717378	305022	100.000

Enantiomeric Sample of 9

Chromatogram



Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	22.317	336879	13128	3.522
2	24.102	9227023	304232	96.478
Total		9563902	317360	100.000

5. References

[1] (a) K.-Q. Ling, *Synth. Commun.*, **1995**, *25*, 3831; (b) H. Chung, J. Kim, G.-A. González-Montiel, P. Ha-Yeon Cheong, H.-G. Lee, *Org. Lett.*, **2021**, *23*, 1096; (c) X. Yuan, X.-D. Wu, F. Peng, H.-J. Yang, C.-J. Zhu, H. Fu, *Chem. Commun.*, **2020**, *56*, 12648. (d) B. Yin, P.-P. Huang, Y.-B. Lu, L.-X. Liu, *RSC Adv.*, **2017**, *7*, 606.

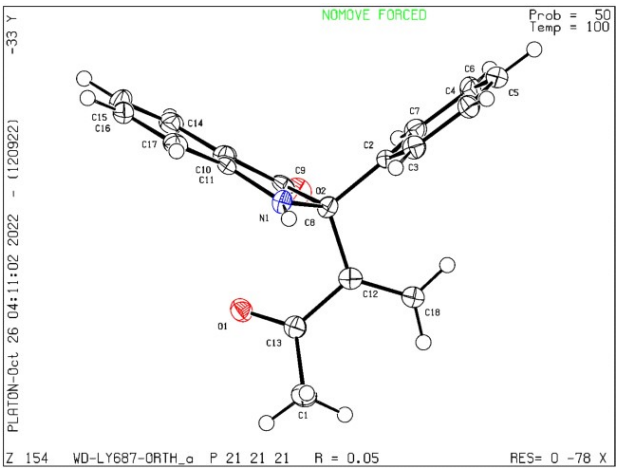
[2] T. Cablewski, A.-F. Faux, C.-R. Strauss, *J. Org. Chem.*, **1994**, *59*, 3408.

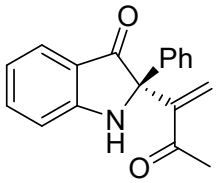
[3] M. Ito, A. Osaku, C. Kobayashi, A. Shibashi, T. Ikariya, *Organometallics*, **2009**, *28*, 390.

[4] G. Bian, W. Shan, W. Su, *Journal of Chemical Research*, **2005**, 585.

[5] (a) J-J. Gong, K. Yuan, X.-Y. Wu, *Tetrahedron: Asymmetry*, **2009**, *20*, 2117; (b) Z. Dong, C. Yan, Y.-Z. Gao, C.-N. Dong, G.-F. Qiu, H.-B. Zhou, *Adv. Synth. Catal.*, **2015**, *357*, 2132; (c) S.-Q. Fang, J.-P. Tan, J.-K. Pan, H.-K. Zhang, Y. Chen, X.-Y. Ren, T.-L. Wang, *Angew. Chem. Int. Ed.*, **2021**, 60, 14921; (d) X.-Y. Han, Y.-Q. Wang, F.-R. Zhong, Y. Lu, *Org. Biomol. Chem.*, **2011**, *9*, 6734. (e) Y. Lu, N. He, X. Miao, D. Wang, *Org. Chem. Front.*, **2022**, *9*, 4840.

6. X-ray data



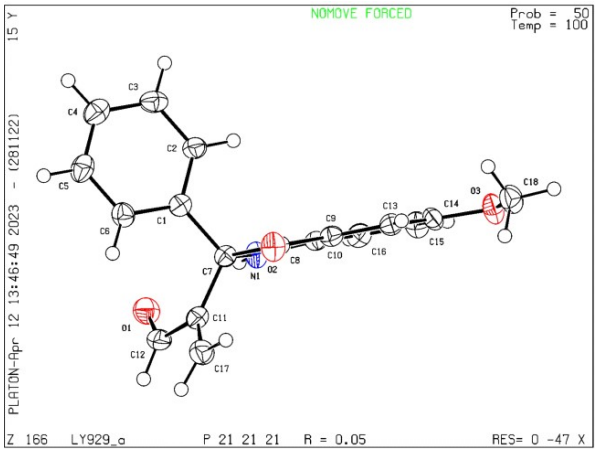


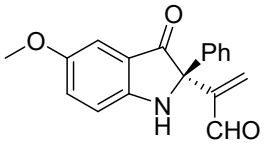
3aa

Table 1. Crystal data and structure refinement for WD-LY687-ORTH_a-finalcif.

Identification code	WD-LY687-ORTH_a	
Empirical formula	C18 H15 N O2	
Formula weight	277.31	
Temperature	100(2) K	
Wavelength	1.54178 Å	
Crystal system	Orthorhombic	
Space group	$P2_12_12_1$	
Unit cell dimensions	a = 8.8982(5) Å	α= 90°.
	b = 12.1235(7) Å	β= 90°.
	c = 13.0719(7) Å	γ = 90°.
Volume	1410.16(14) $Å^3$	
Z	4	
Density (calculated)	1.306 Mg/m^3	
Absorption coefficient	0.683 mm^{-1}	
F(000)	584	
Crystal size	0.15 x 0.12 x 0.1 mm^3	
Theta range for data collection	6.016 to 67.487°.	
Index ranges	-10<=h<=10, -14<=k<=14, -15<=l<=15	
Reflections collected	13582	
Independent reflections	2449 [R(int) = 0.0572]	
Completeness to theta = 67.487°	97.3 %	
Absorption correction	Semi-empirical from equivalents	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	2449 / 0 / 191	
Goodness-of-fit on F^2	1.646	

Final R indices [I>2sigma(I)]	R1 = 0.0541, wR2 = 0.1838
R indices (all data)	R1 = 0.0555, wR2 = 0.1889
Absolute structure parameter	0.05(11)
Extinction coefficient	n/a
Largest diff. peak and hole	0.368 and -0.371 e.Å^{-3}





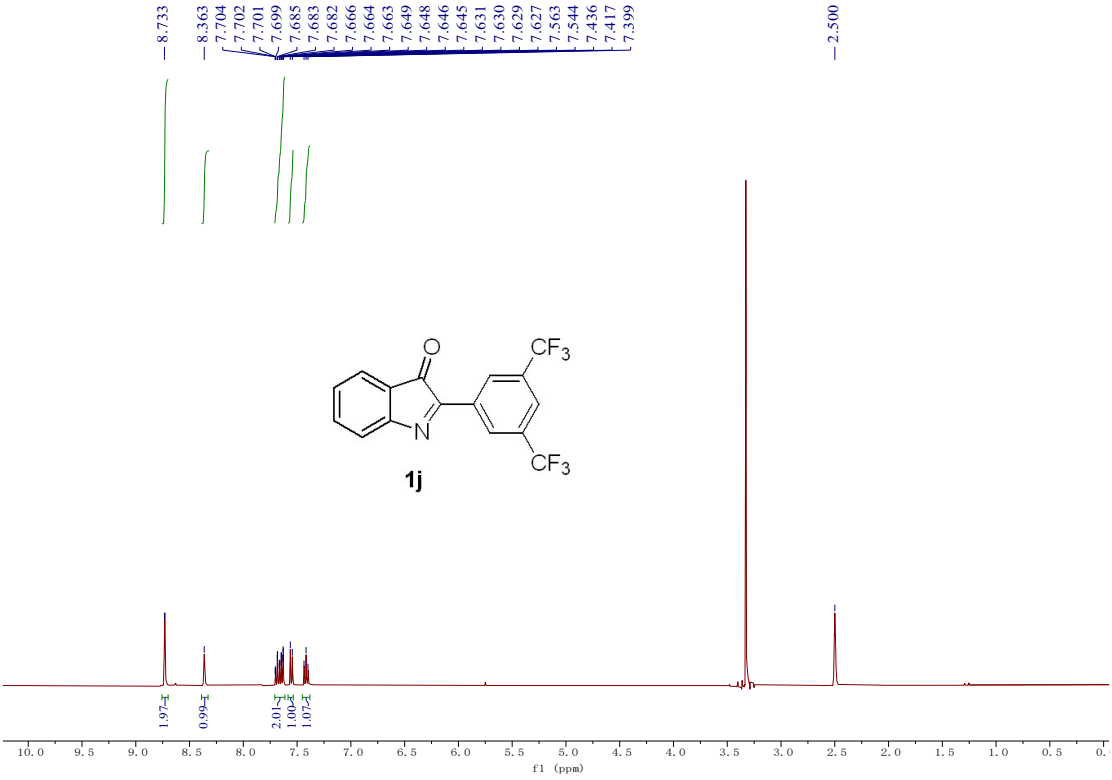
3te

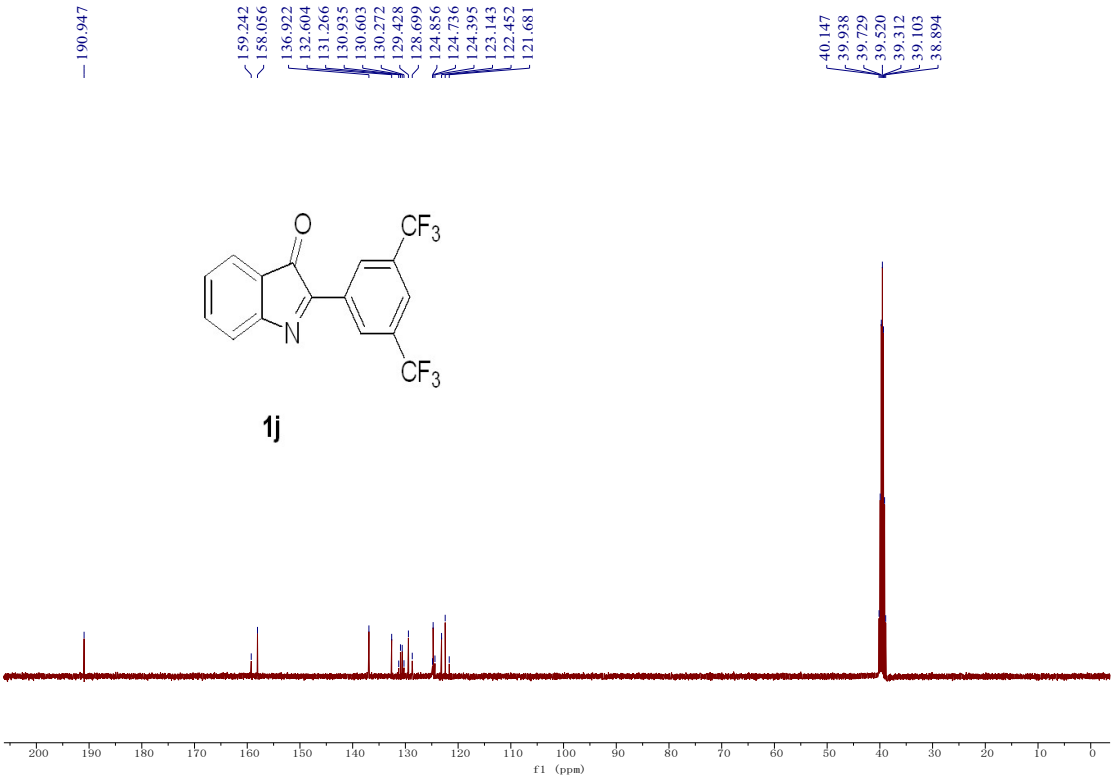
Table 1. Crystal data and structure refinement for LY929_a-finalcif.

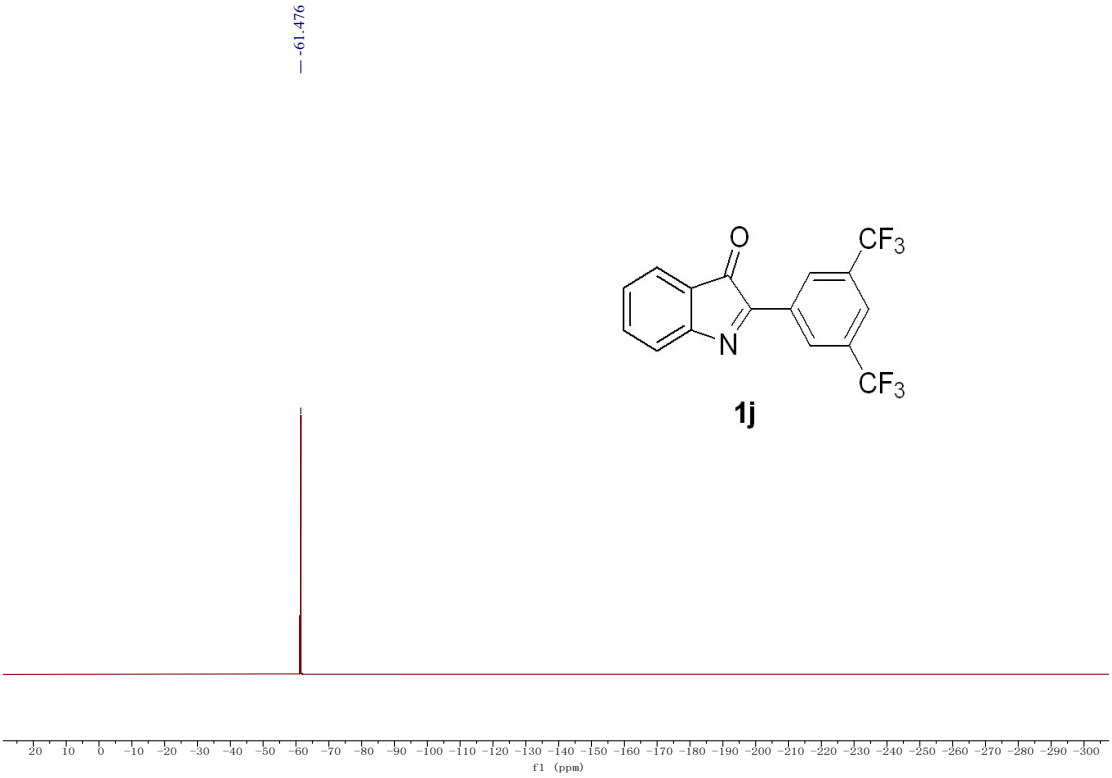
Identification code	LY929_a	
Empirical formula	C18 H15 N O3	
Formula weight	293.31	
Temperature	100(2) K	
Wavelength	1.54178 Å	
Crystal system	Orthorhombic	
Space group	$P2_12_12_1$	
Unit cell dimensions	a = 10.4311(17) Å	α= 90°.
	b = 11.3052(17) Å	β= 90°.
	c = 12.2205(18) Å	γ = 90°.
Volume	1441.1(4) Å^3	
Z	4	
Density (calculated)	1.352 Mg/m^3	
Absorption coefficient	0.753 mm^{-1}	
F(000)	616	
Crystal size	0.10 x 0.09 x 0.07 mm^3	
Theta range for data collection	5.330 to 68.068°.	
Index ranges	-12<=h<=12, -13<=k<=13, -14<=l<=11	
Reflections collected	12864	
Independent reflections	2506 [R(int) = 0.0904]	
Completeness to theta = 67.679°	97.1 %	

Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.7528 and 0.5246
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2506 / 0 / 200
Goodness-of-fit on F^2	1.033
Final R indices [I>2sigma(I)]	R1 = 0.0504, wR2 = 0.1031
R indices (all data)	R1 = 0.0753, wR2 = 0.1184
Absolute structure parameter	0.0(2)
Extinction coefficient	n/a
Largest diff. peak and hole	0.265 and -0.233 e.$Å^{-3}$

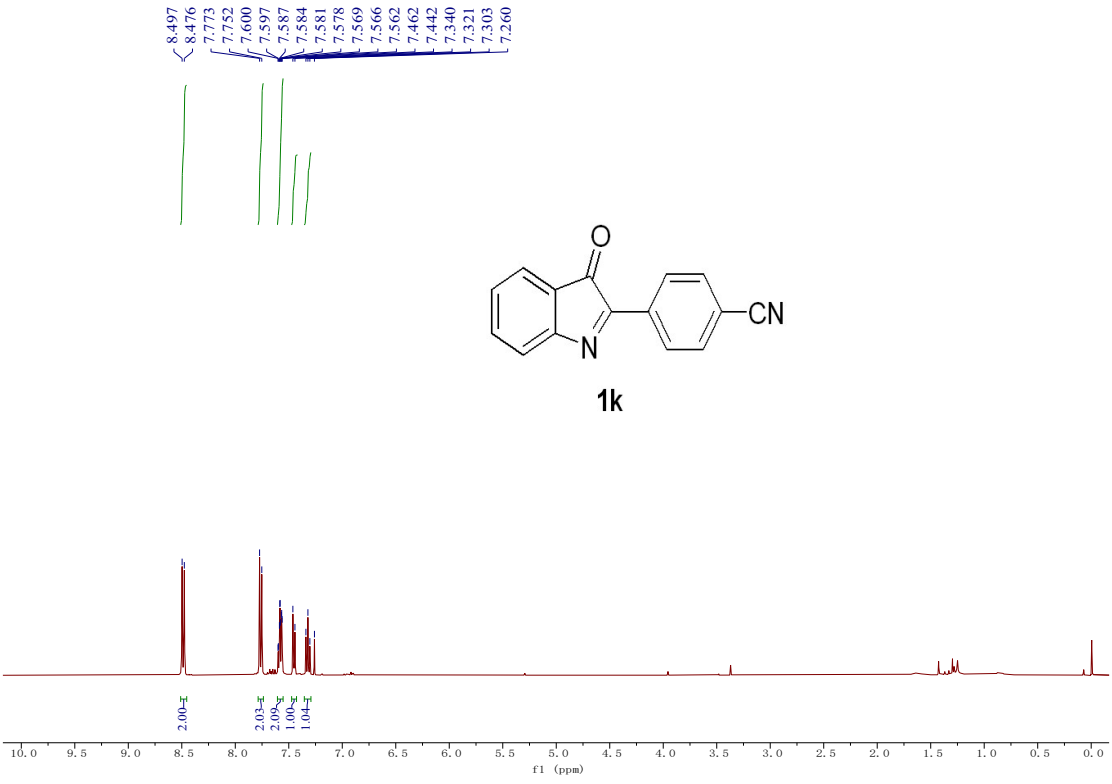
7. NMR Spectra

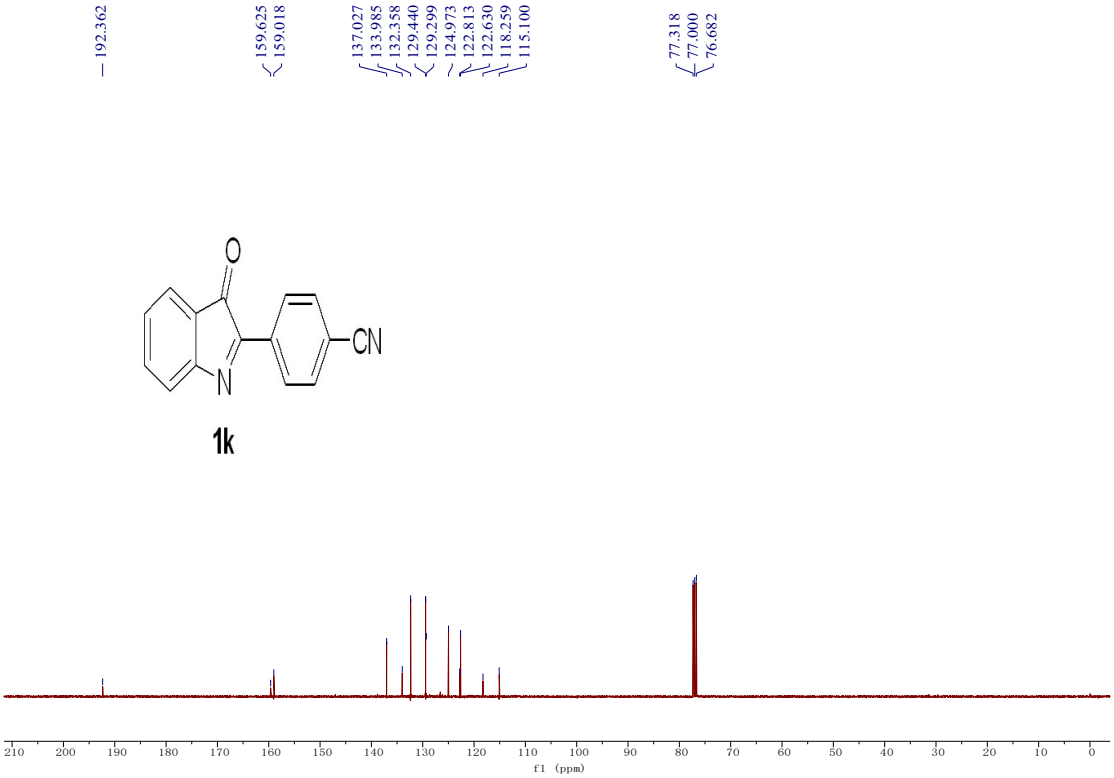




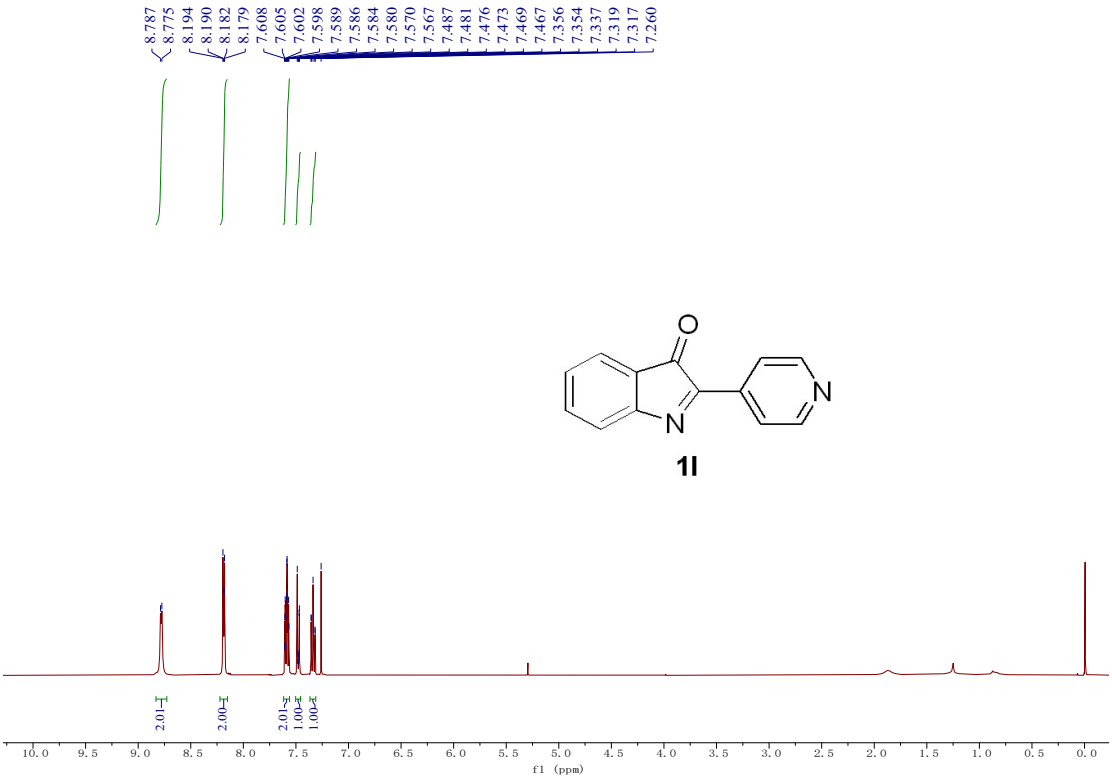


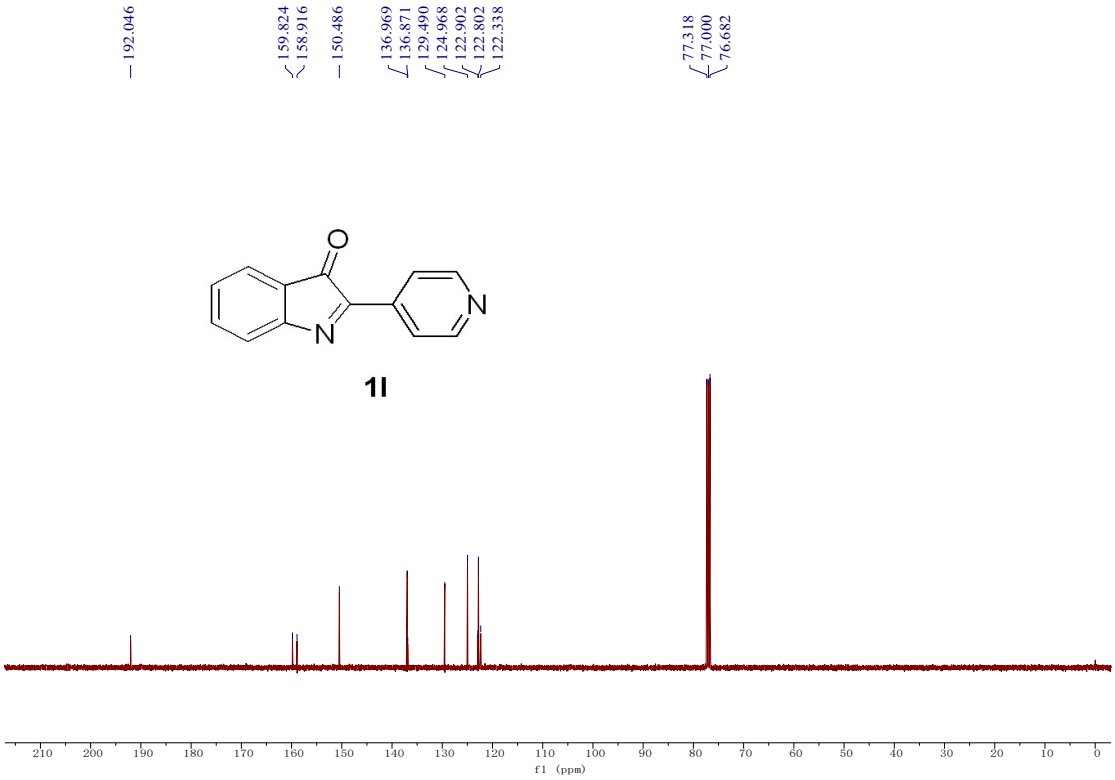
^{1}H, ^{13}C and ^{19}F NMR spectra of compound **1j** (400 MHz, DMSO-d_6)



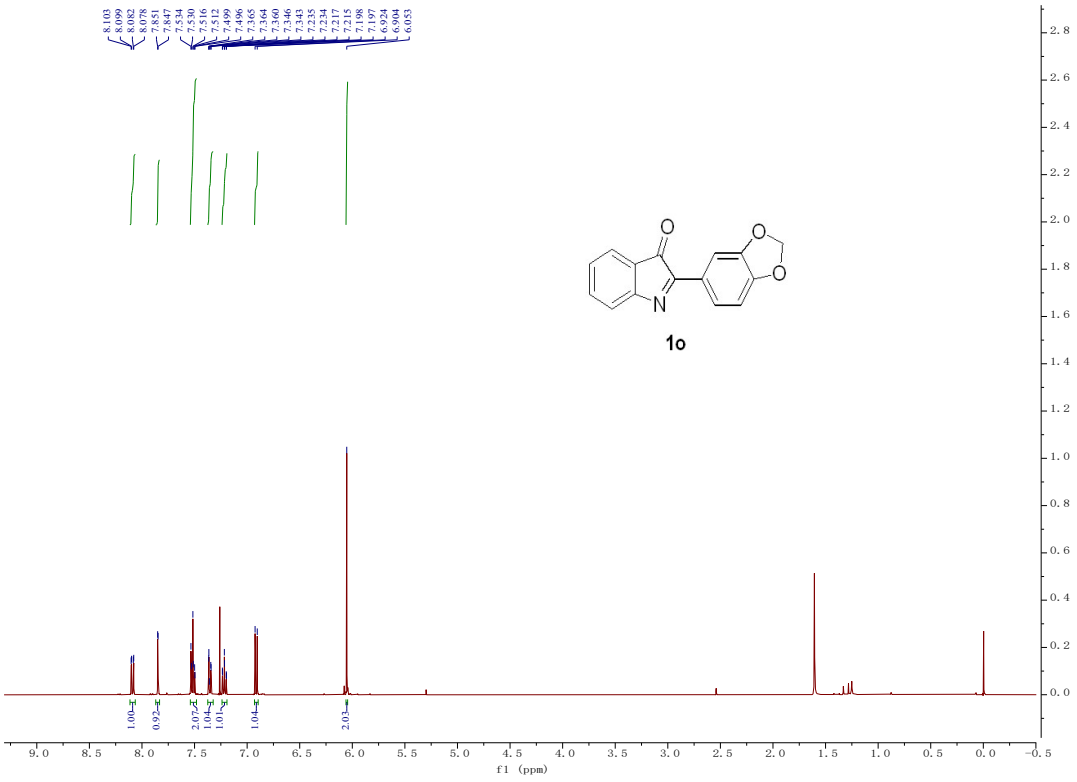


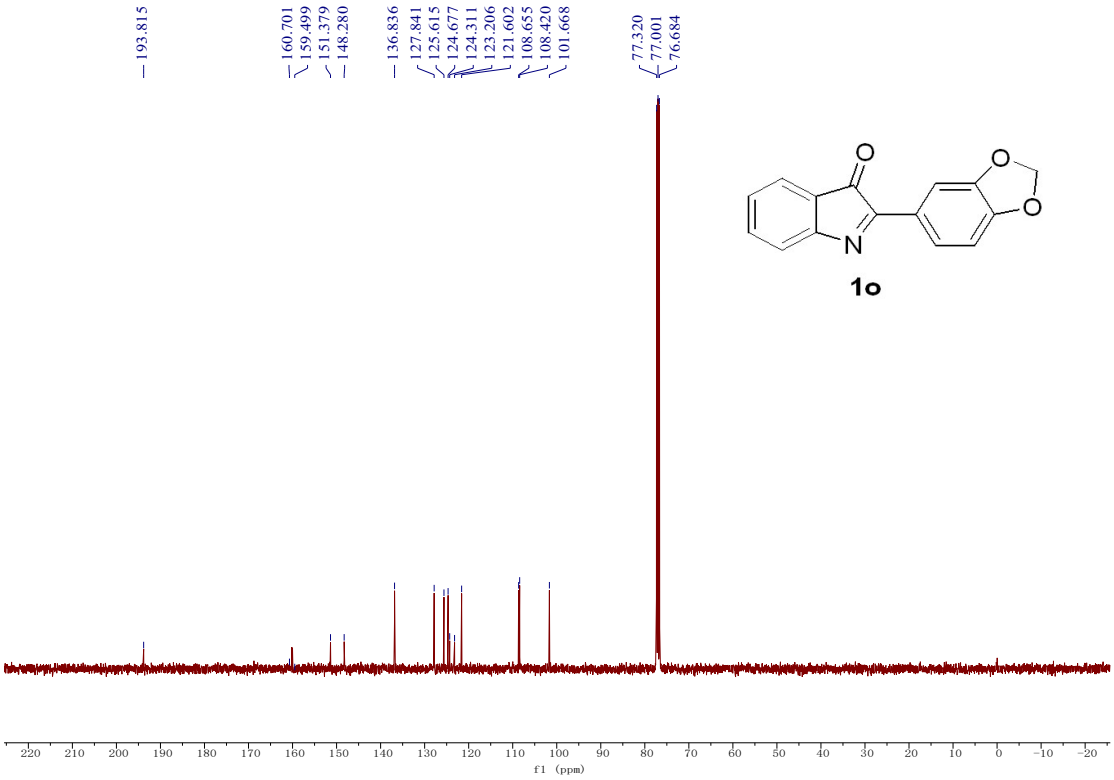
^{1}H and ^{13}C NMR spectra of compound **1k** (400 MHz, $CDCl_3$)



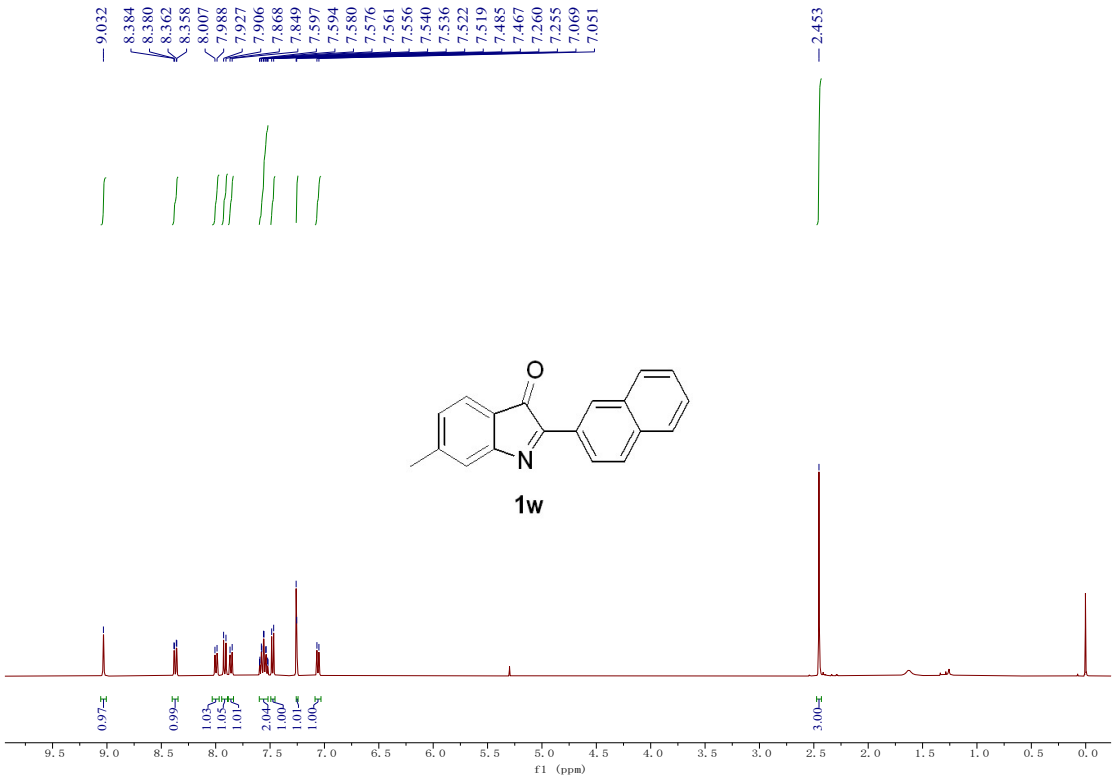


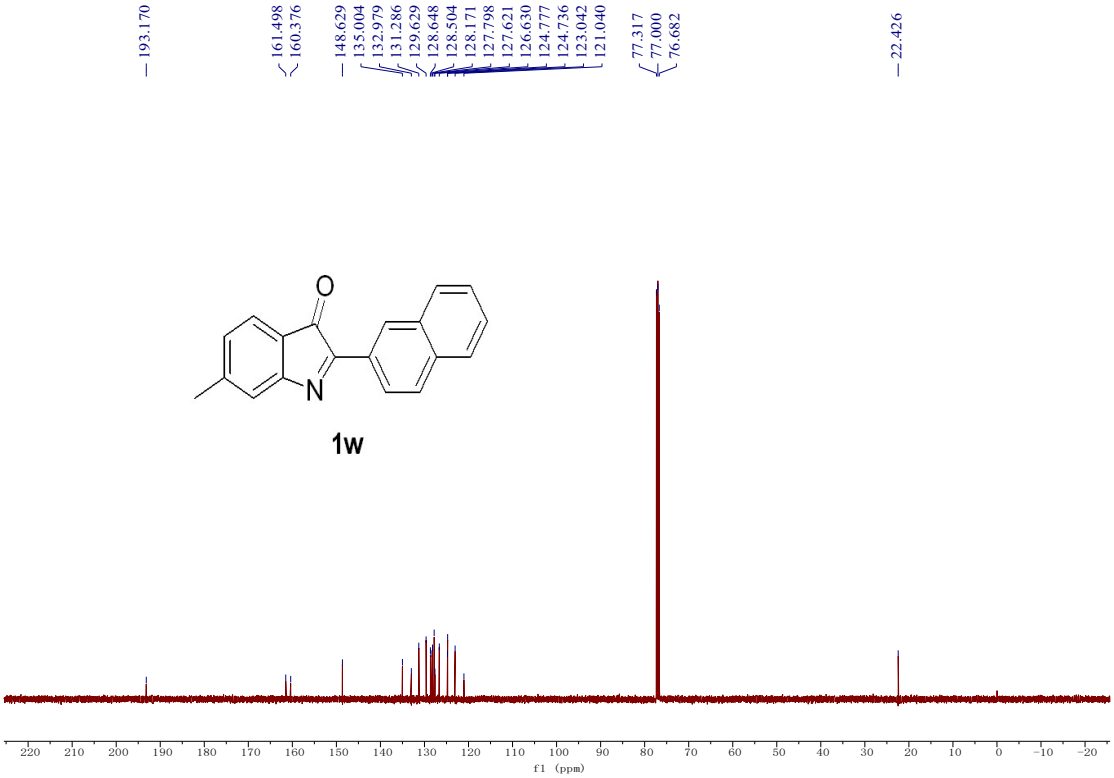
^{1}H and ^{13}C NMR spectra of compound **1l** (400 MHz, $CDCl_3$)



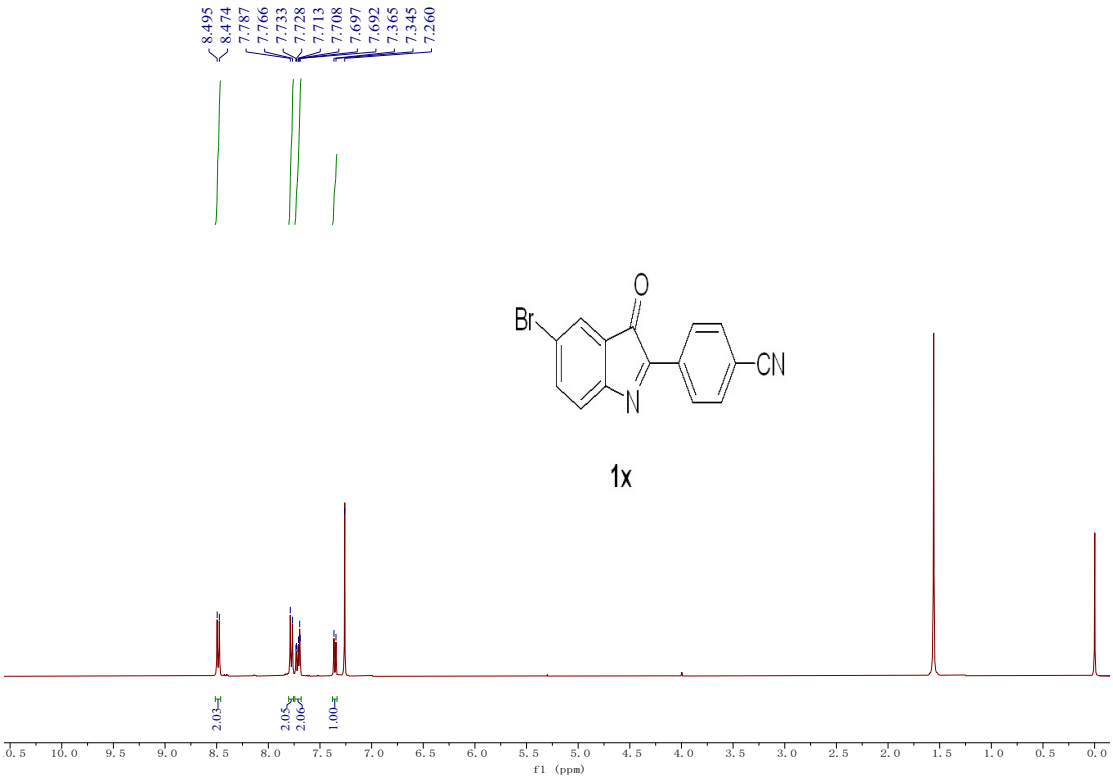


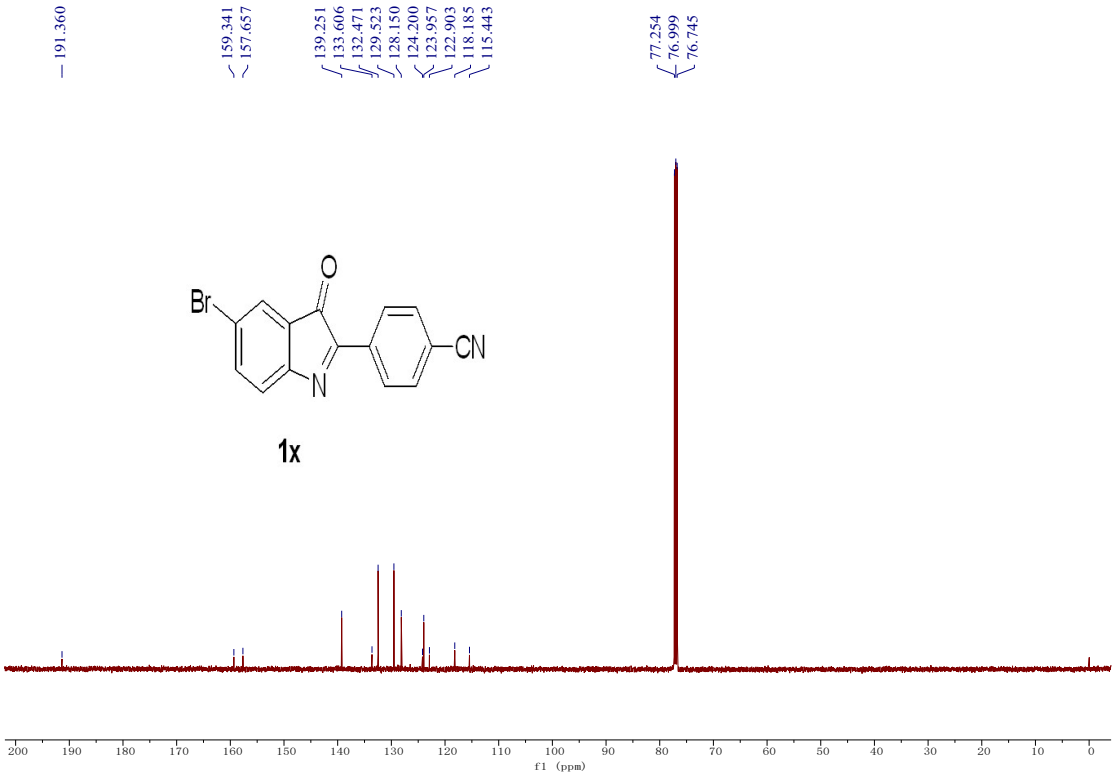
^{1}H and ^{13}C NMR spectra of compound **1o** (400 MHz, $CDCl_3$)



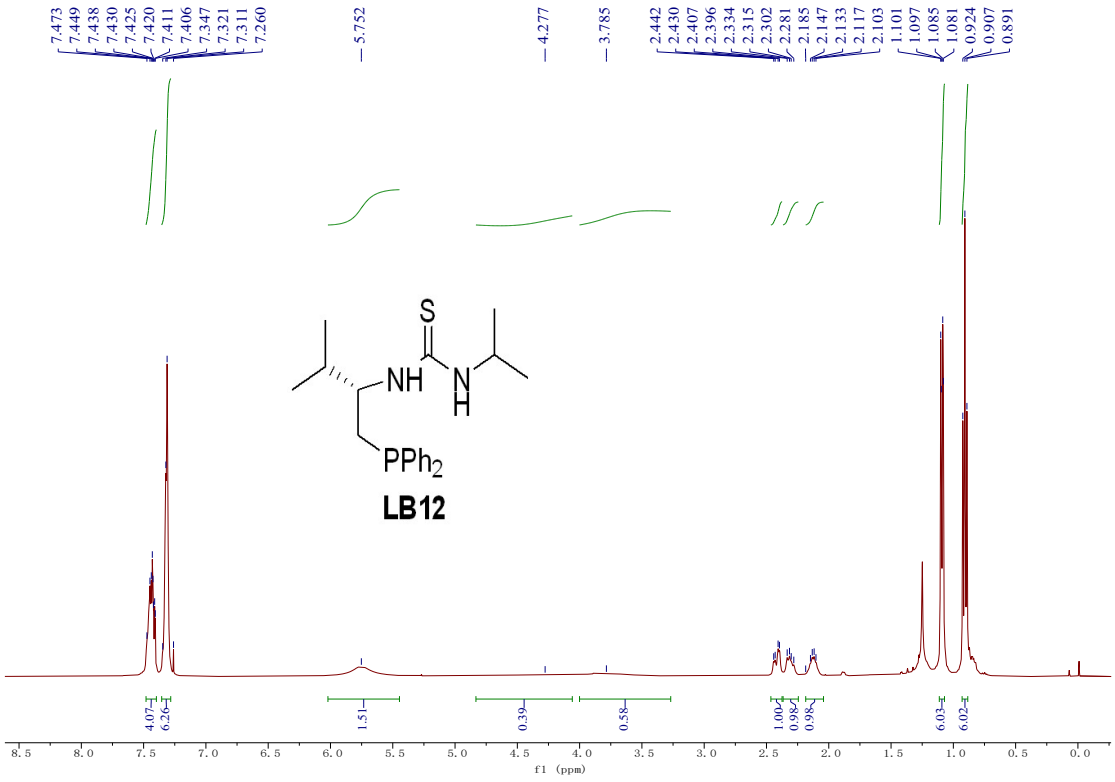


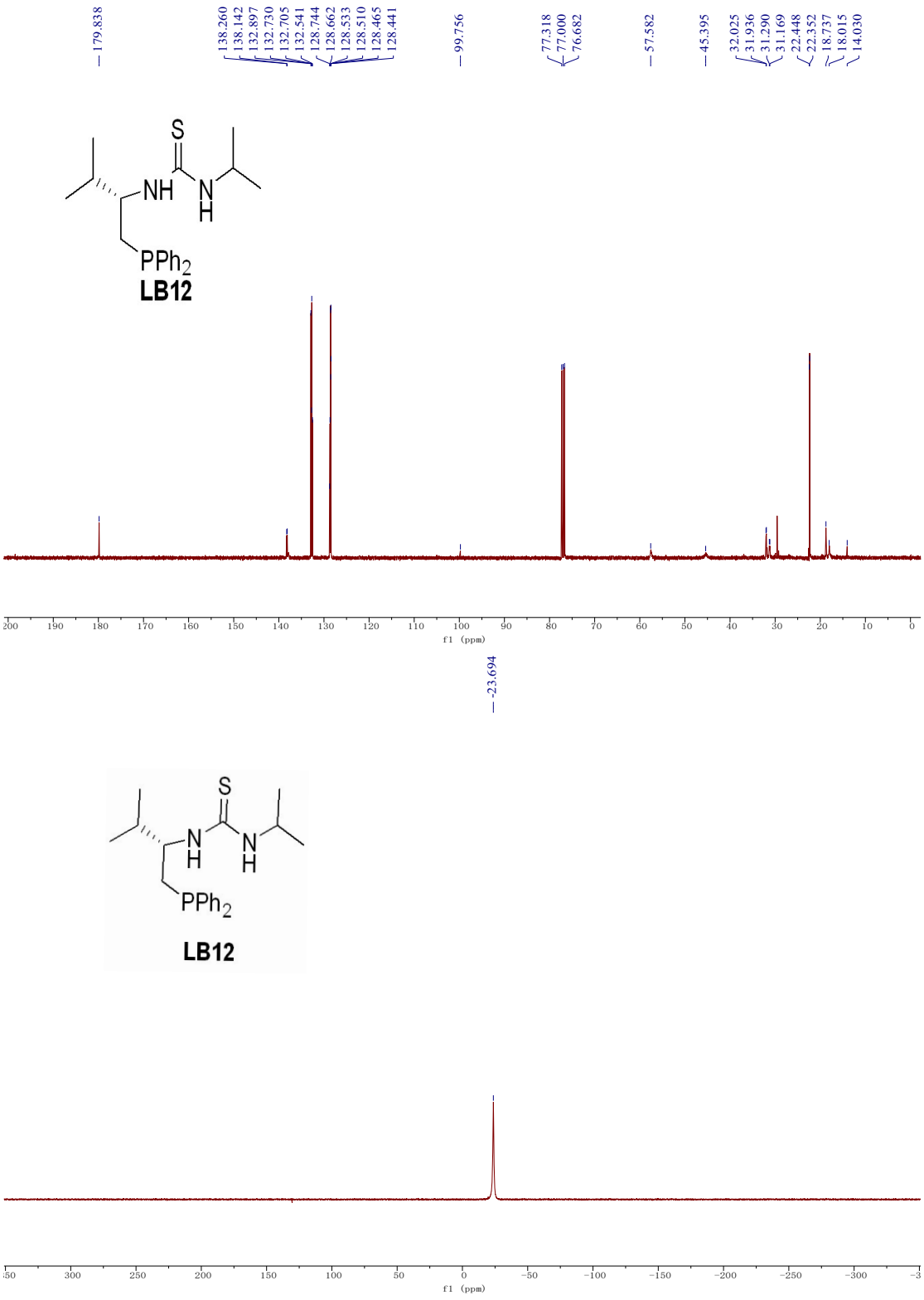
^{1}H and ^{13}C NMR spectra of compound **1w** (400 MHz, $CDCl_3$)



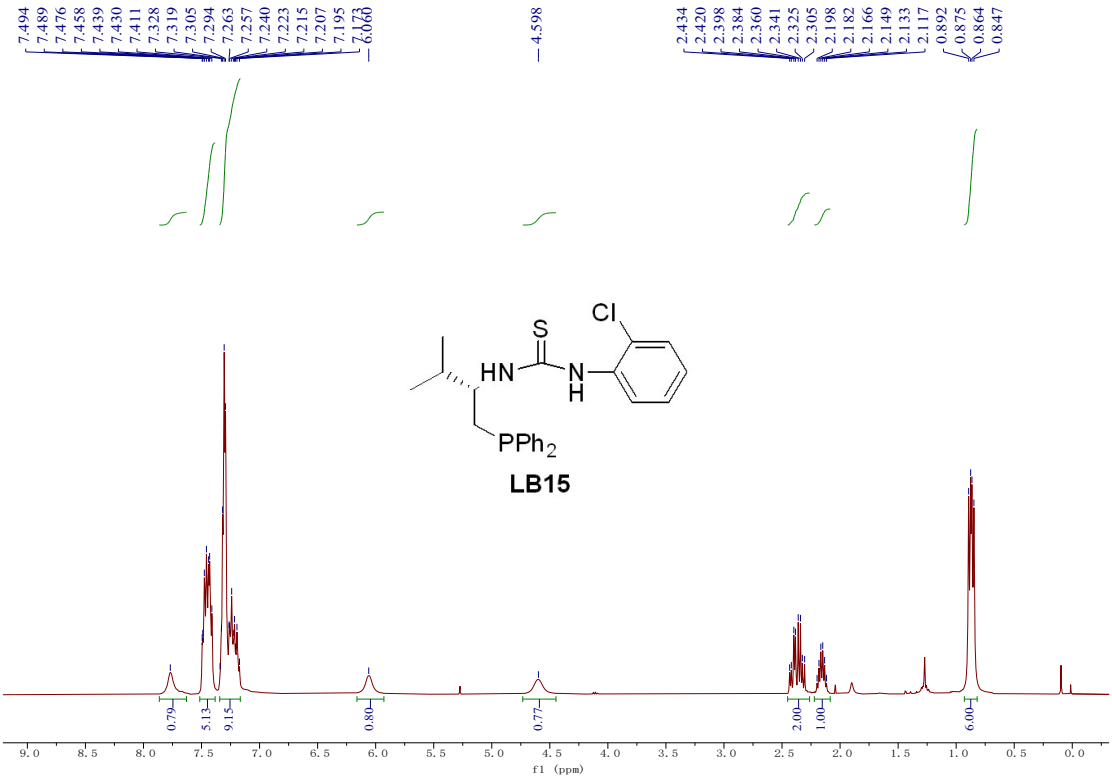


^{1}H and ^{13}C NMR spectra of compound **1x**





^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB12** (400 MHz, $CDCl_3$)


7.494
7.489
7.476
7.458
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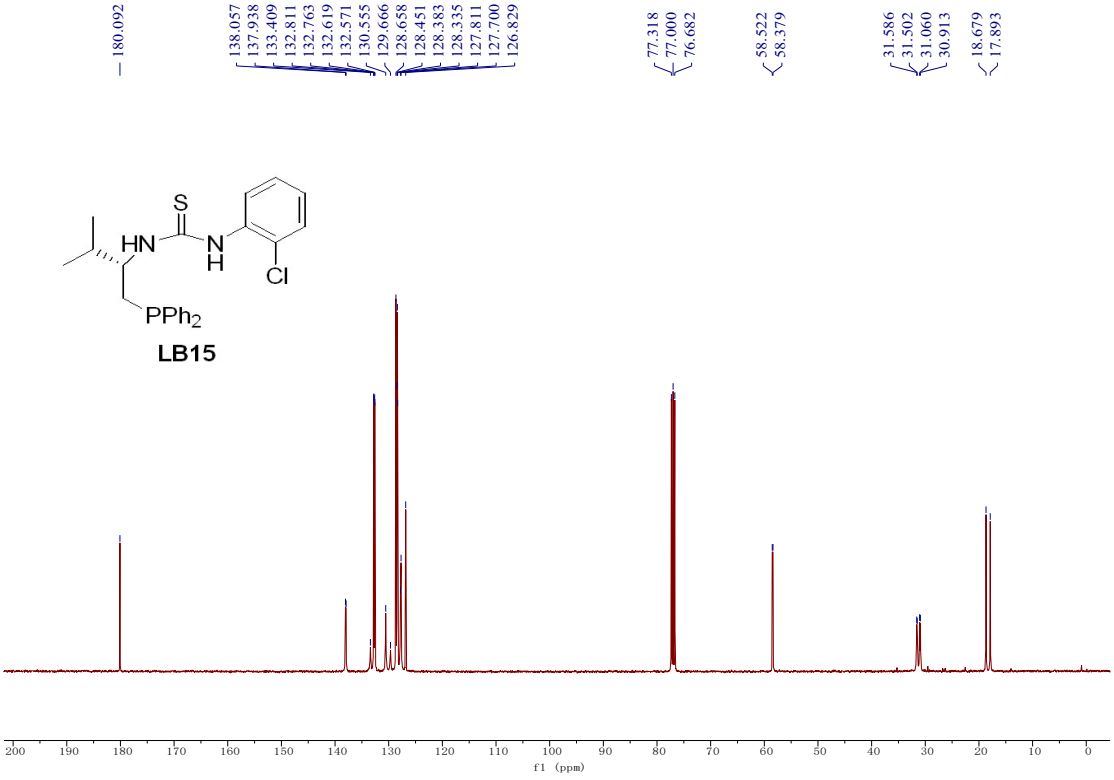
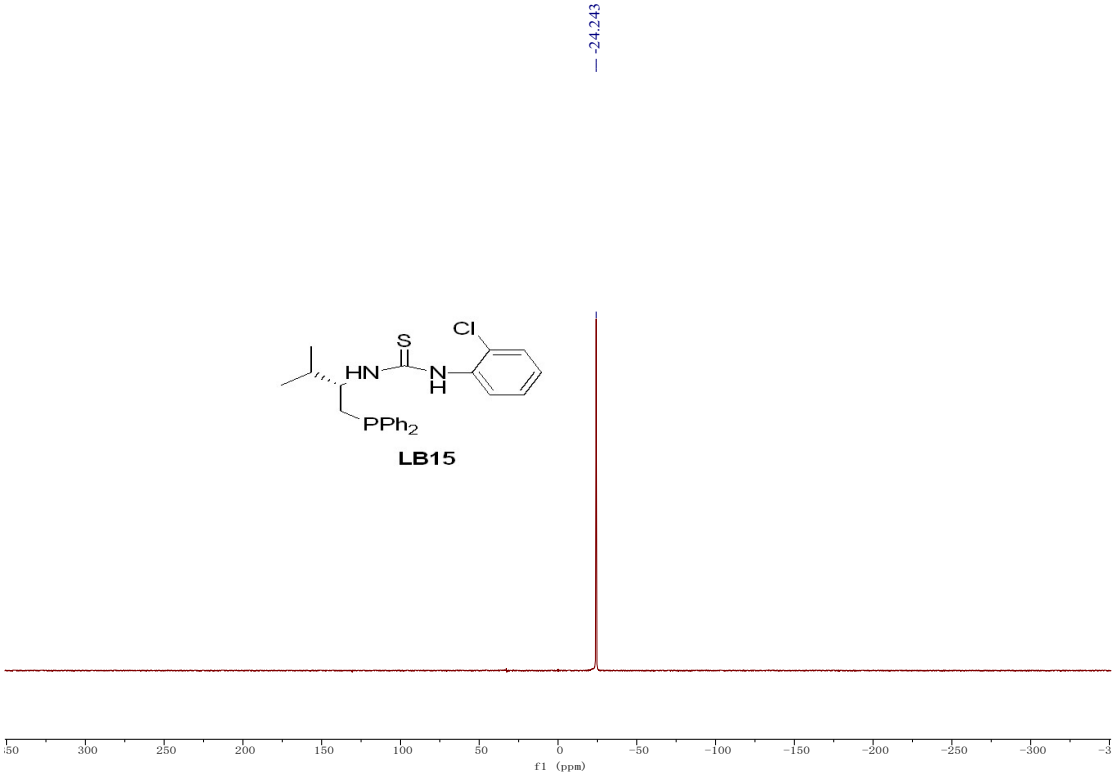
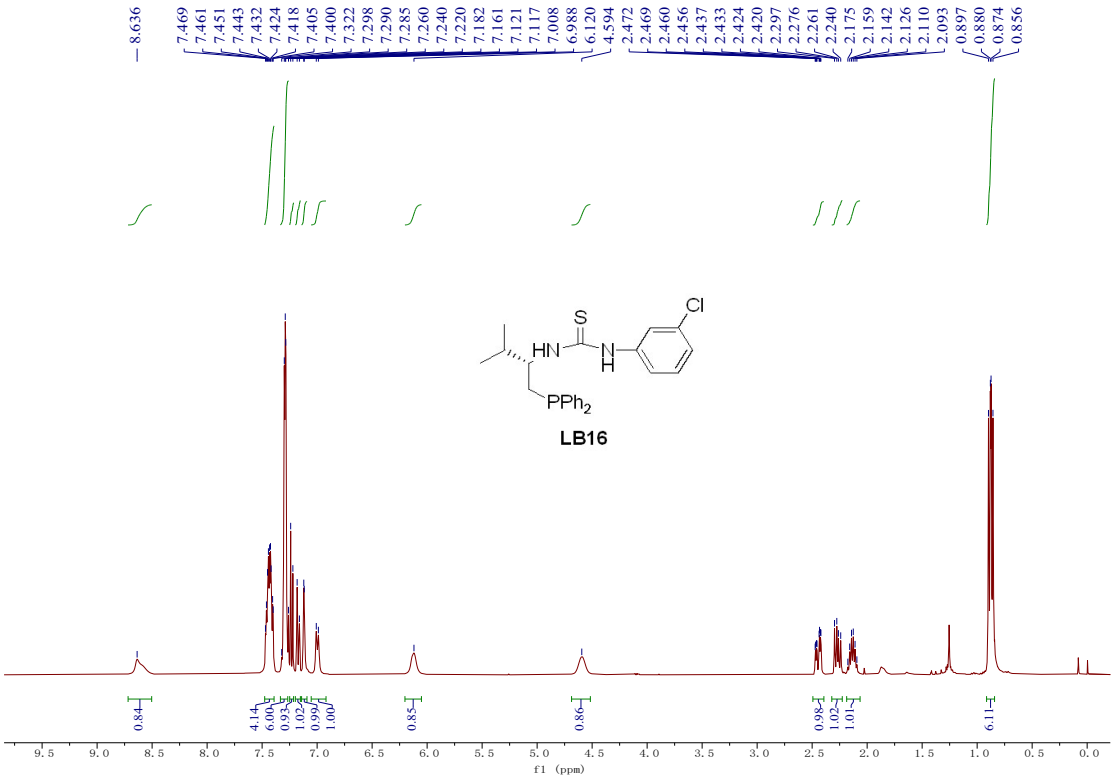
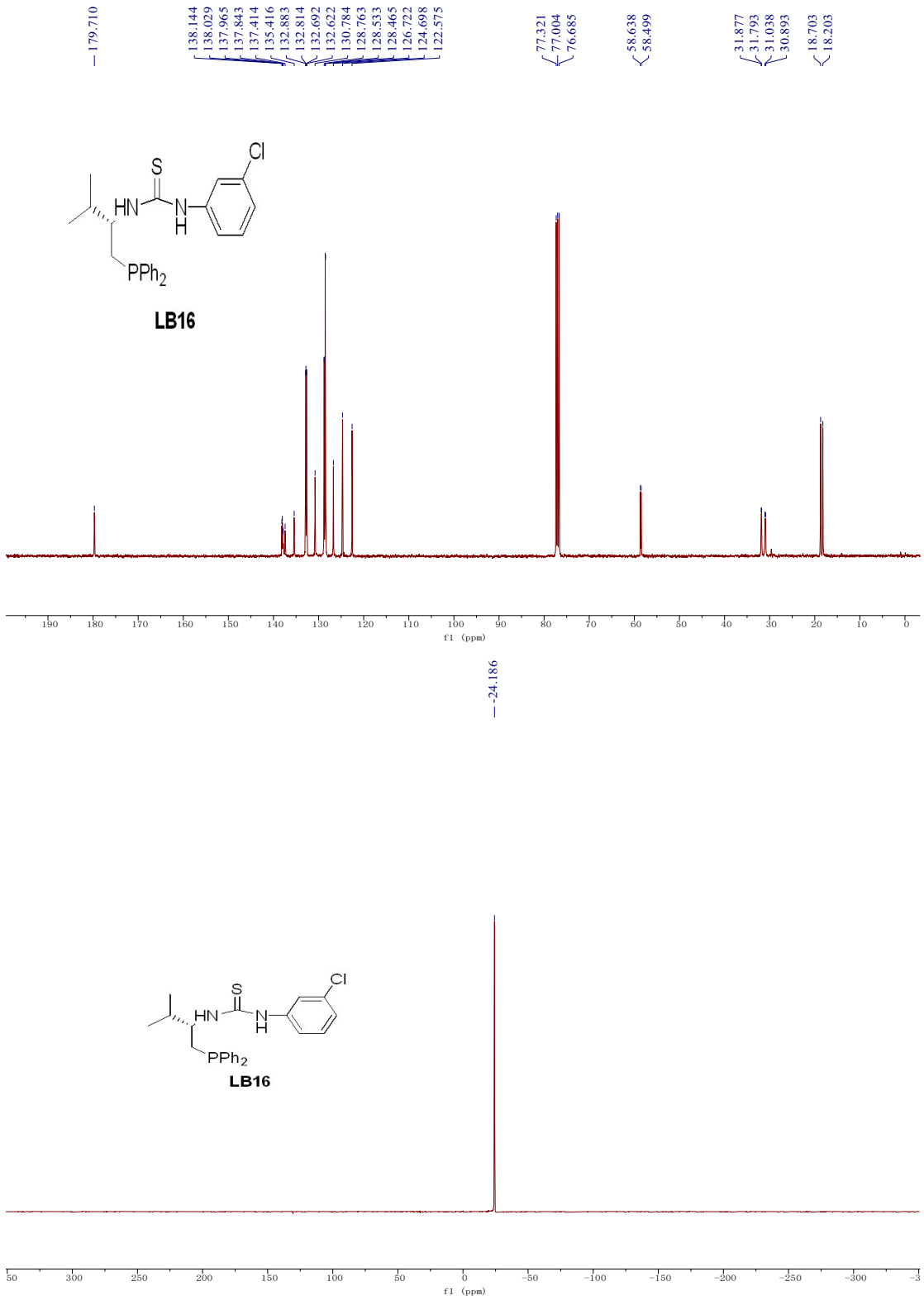
7.430
7.411
7.328
7.319
7.305
7.294
7.263
7.257
7.240
7.223
7.215
7.207
7.195
7.173
6.060
4.598
2.434
2.420
2.398
2.384
2.360
2.341
2.325
2.305
2.198
2.182
2.166
2.149
2.133
2.117
0.892
0.875
0.864
0.847
Cl
S
HN
N
H
PPh2
LB15
0.79
5.13
9.15
0.80
0.77
2.00
1.00
6.00
f1 (ppm)


180.092
138.057
137.938
133.409
132.811
132.763
132.619
132.571
130.555
129.666
128.658
128.451
128.383
128.335
127.811
127.700
126.829
77.318
77.000
76.682
58.522
58.379
31.586
31.502
31.060
30.913
18.679
17.893
S
HN
N
H
Cl
PPh2
LB15
f1 (ppm)

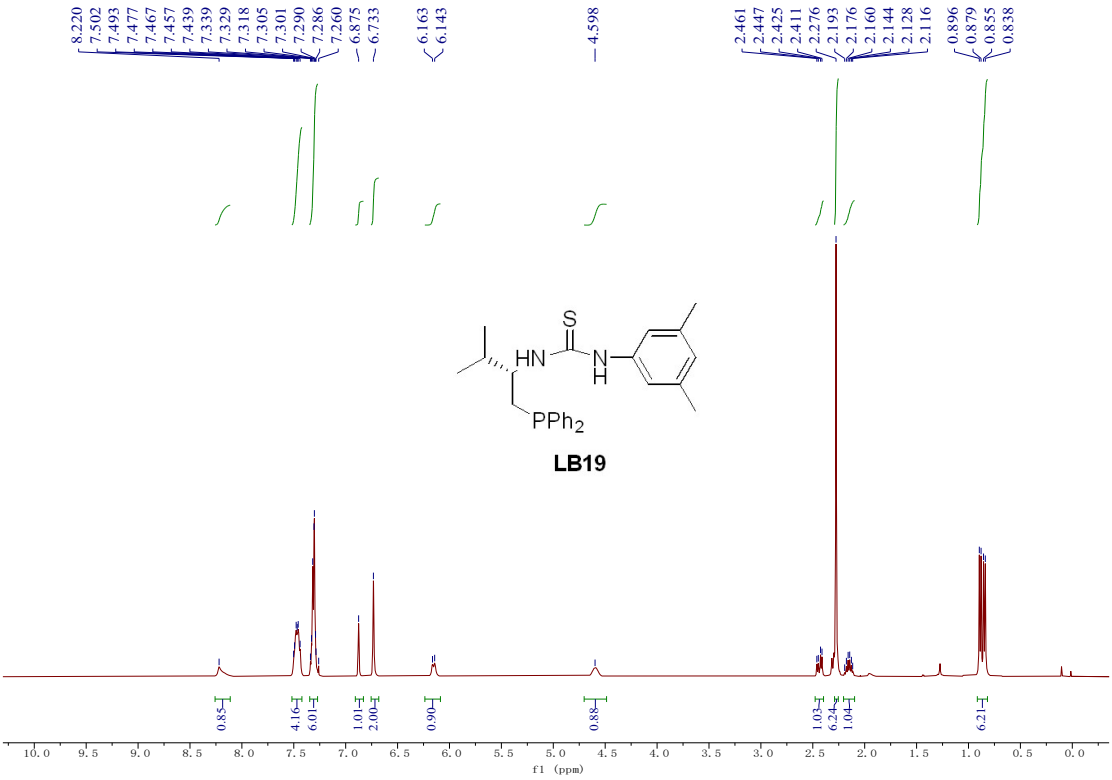


^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB15** (400 MHz, $CDCl_3$)

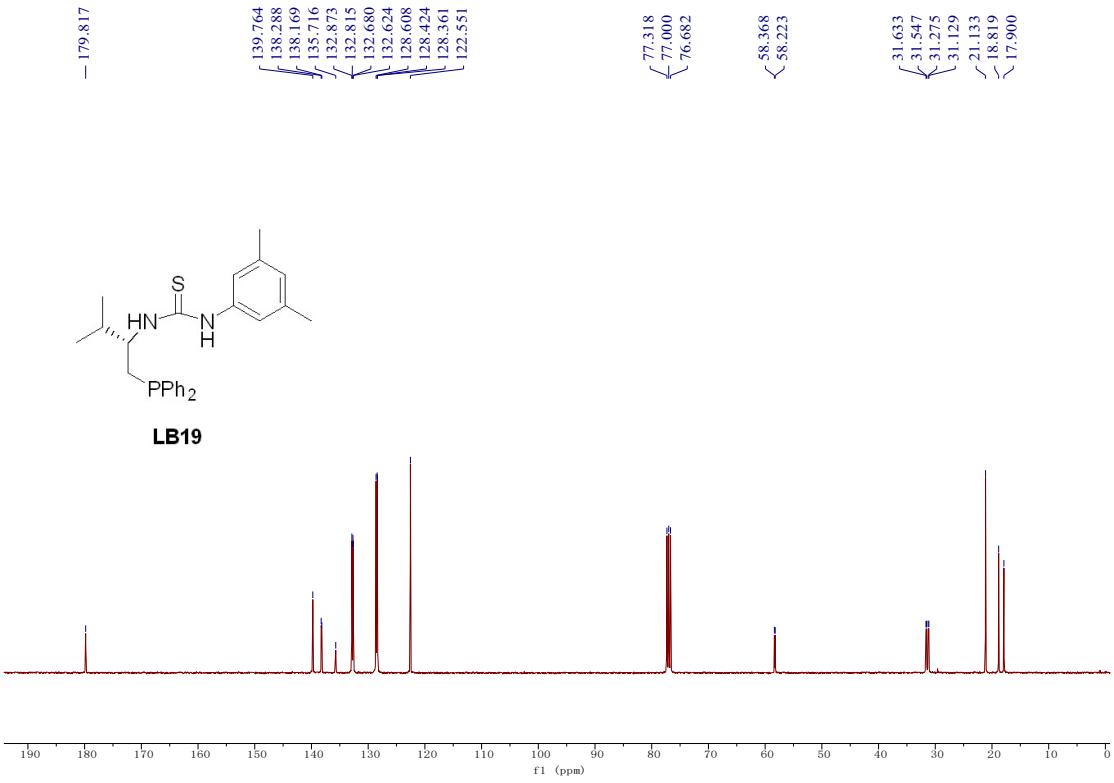




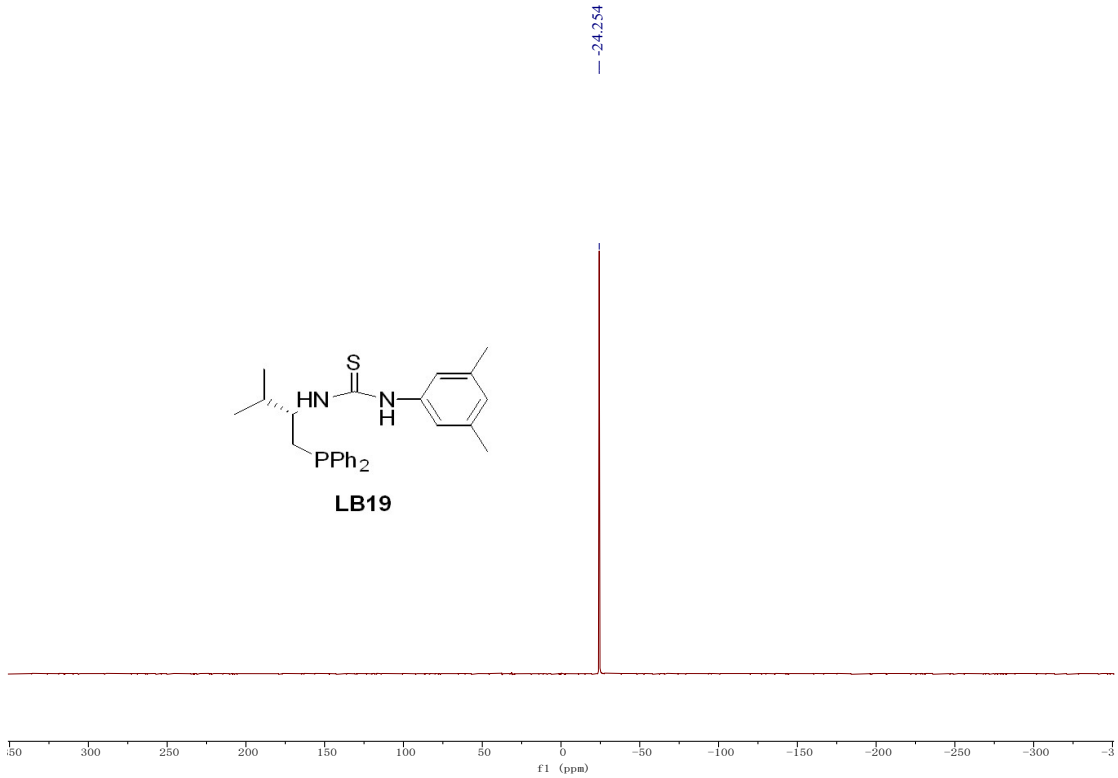
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB16** (400 MHz, $CDCl_3$)


8.220
7.502
7.493
7.477
7.467
7.457
7.439
7.339
7.329
7.318
7.305
7.301
7.290
7.286
7.260
6.875
6.733
6.163
6.143
4.598
2.461
2.447
2.425
2.411
2.276
2.193
2.176
2.160
2.144
2.128
2.116
0.896
0.879
0.855
0.838
S
HN
N
H
PPh2
0.85
4.16
6.01
1.01
2.00
0.90
0.88
1.03
6.24
1.04
6.21
f1 (ppm)

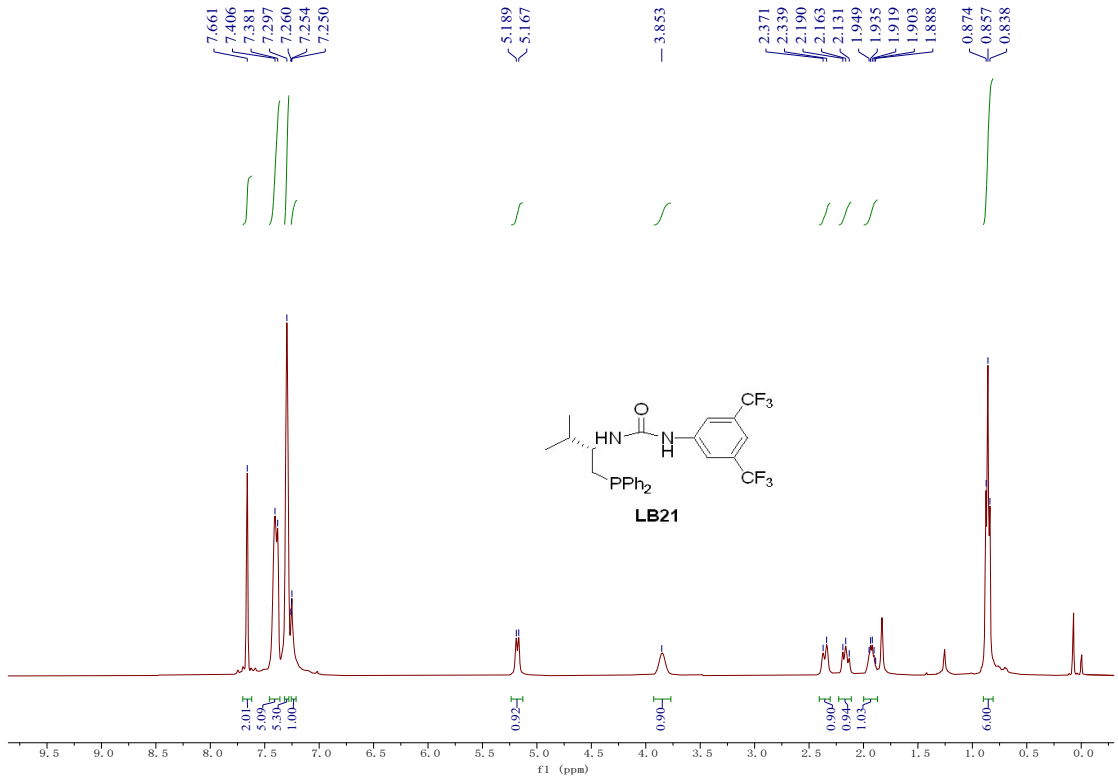
LB19

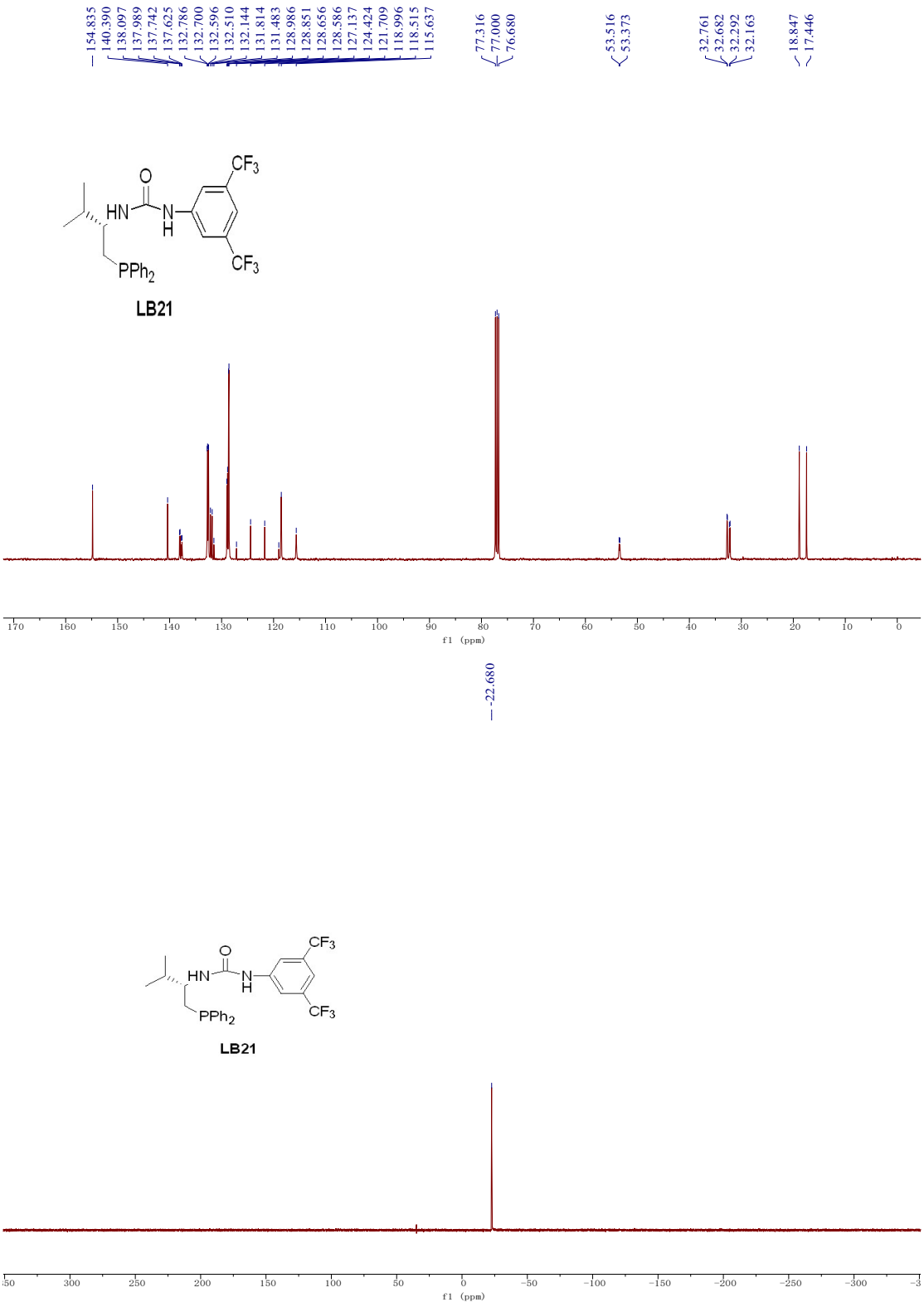

179.817
139.764
138.288
138.169
135.716
132.873
132.815
132.680
132.624
128.608
128.424
128.361
122.551
77.318
77.000
76.682
58.368
58.223
31.633
31.547
31.275
31.129
21.133
18.819
17.900
S
HN
N
H
PPh2
f1 (ppm)

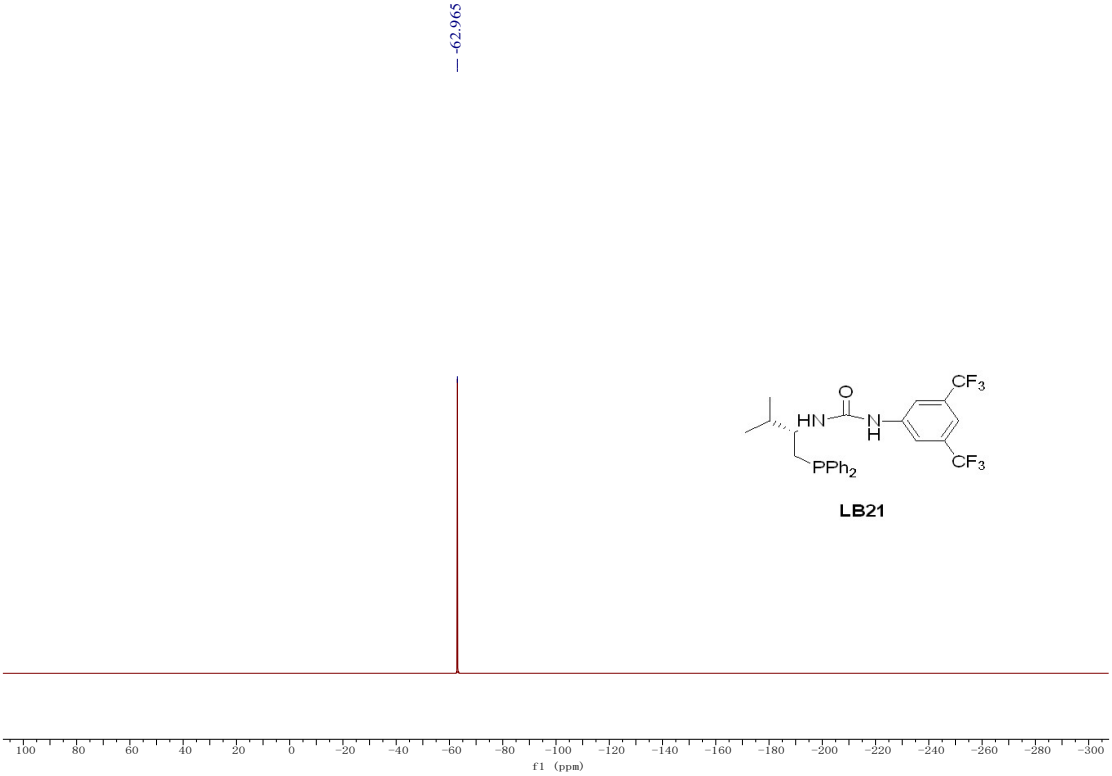
LB19



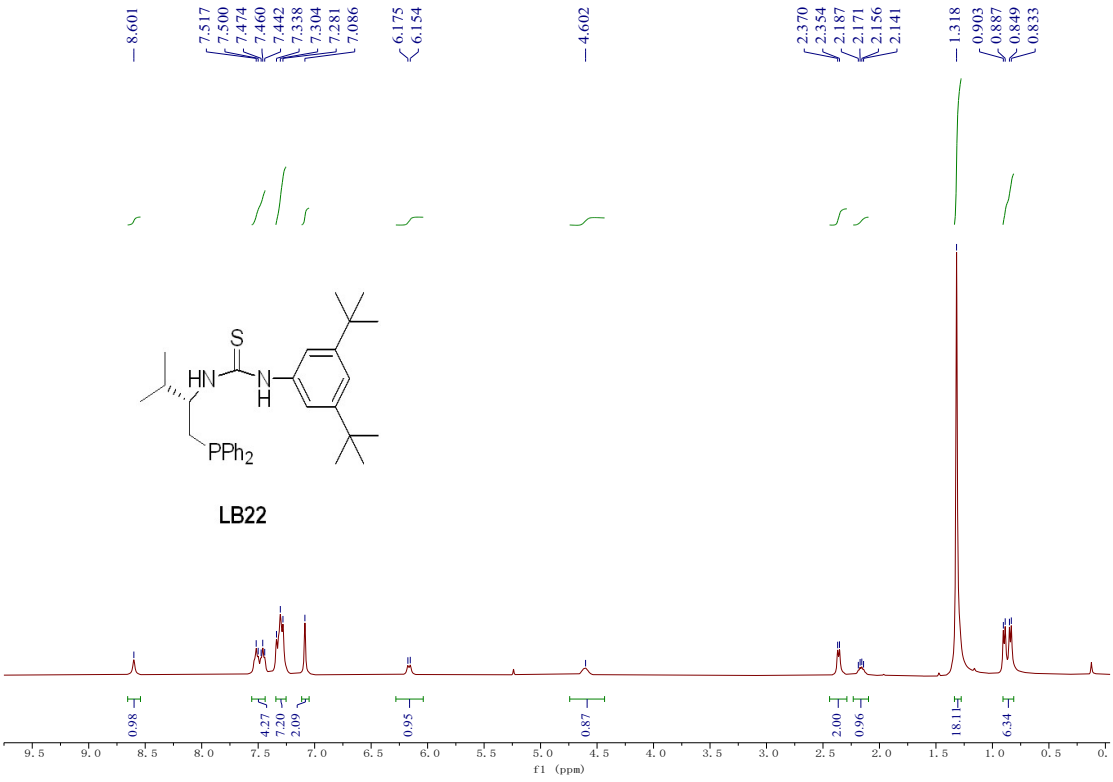
^{1}H, ^{13}C, ^{31}P NMR spectra of compound **LB19** (400 MHz, $CDCl_3$)

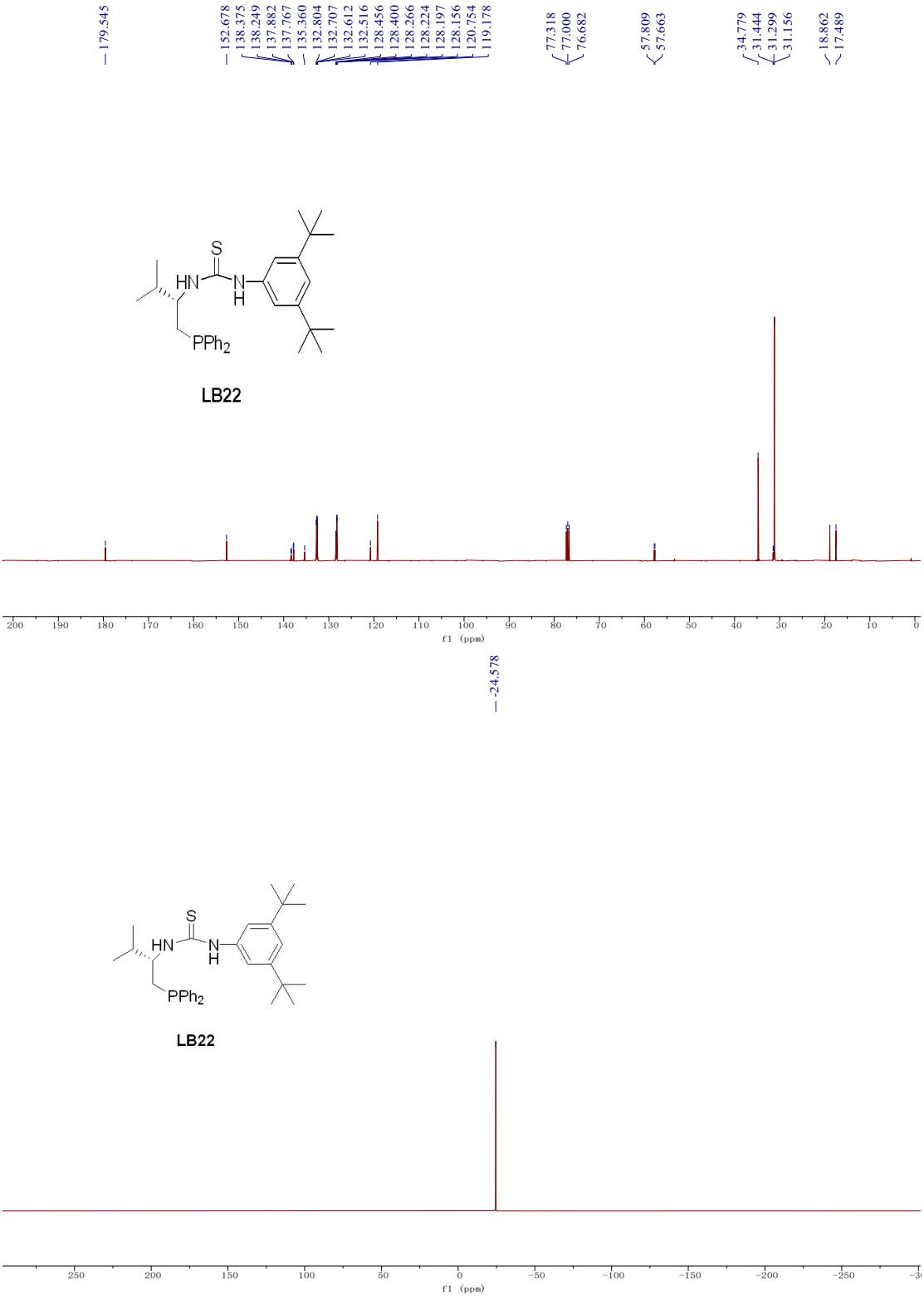



154.835
140.390
138.097
137.989
137.742
137.625
132.786
132.700
132.596
132.510
132.144
131.814
131.483
128.986
128.851
128.656
128.586
127.137
124.424
121.709
118.996
118.515
115.637
77.316
77.000
76.680
53.516
53.373
32.761
32.682
32.292
32.163
18.847
17.446
CF3
O
HN
N
H
PPh2
CF3
LB21
f1 (ppm)
-22.680
CF3
O
HN
N
H
PPh2
CF3
LB21
f1 (ppm)

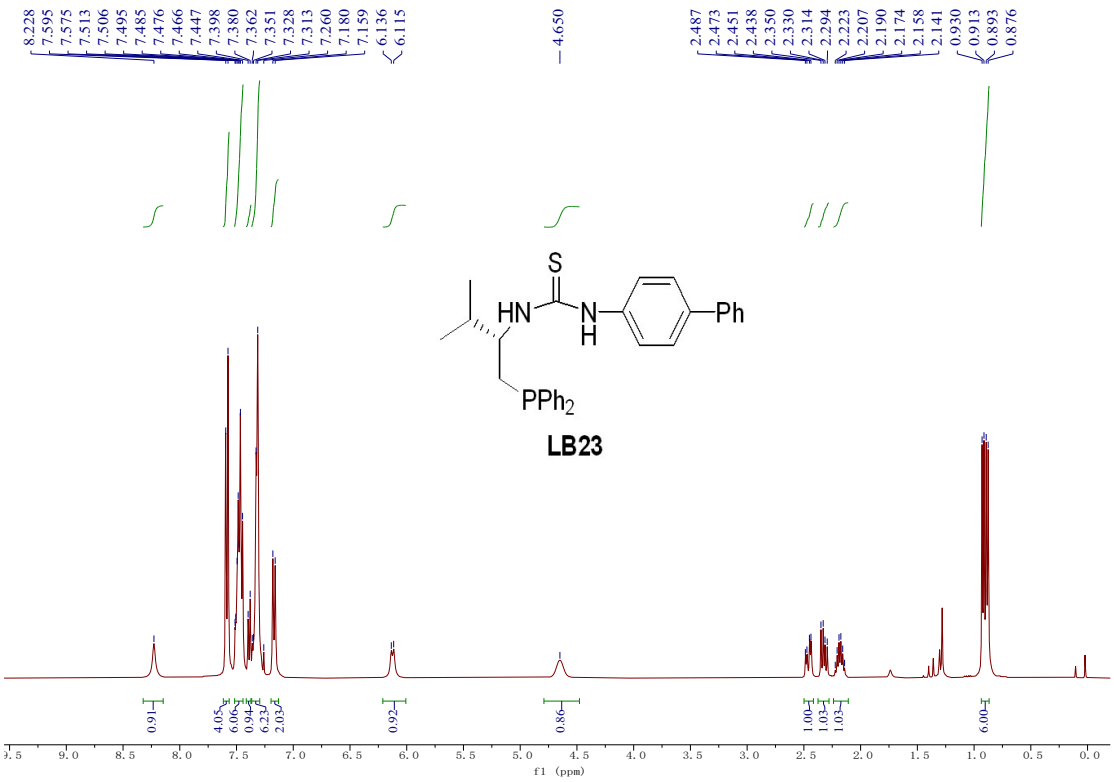


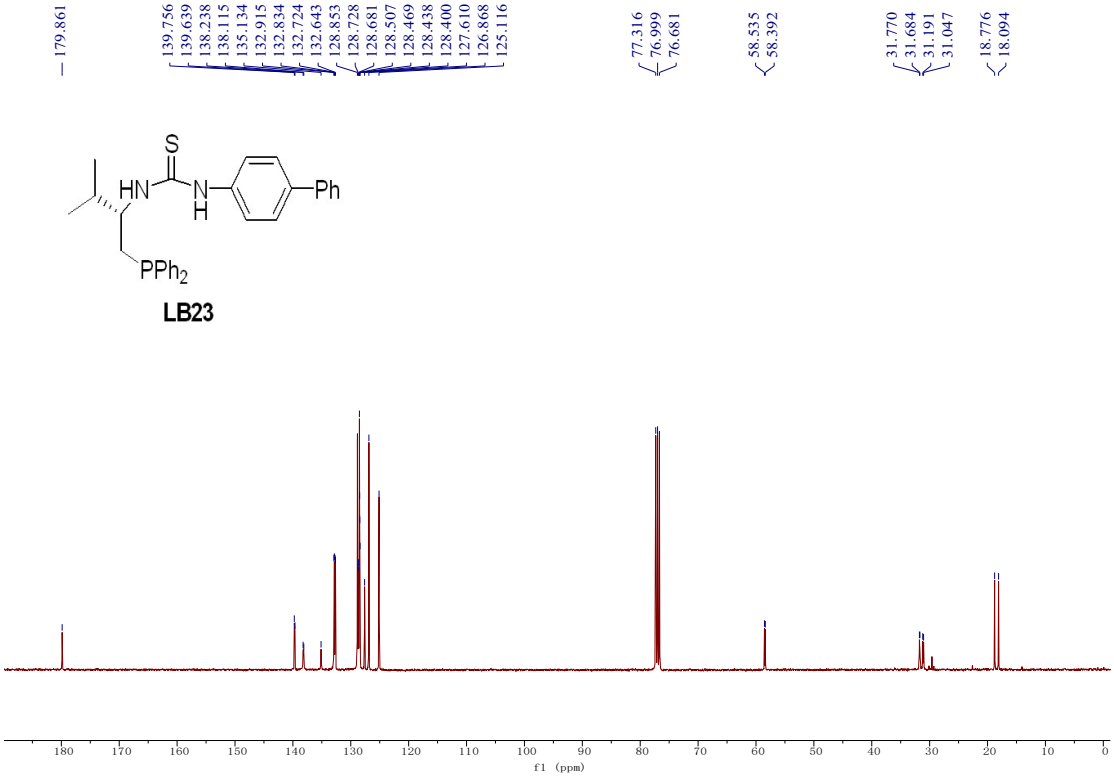
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB21** (400 MHz, $CDCl_3$)

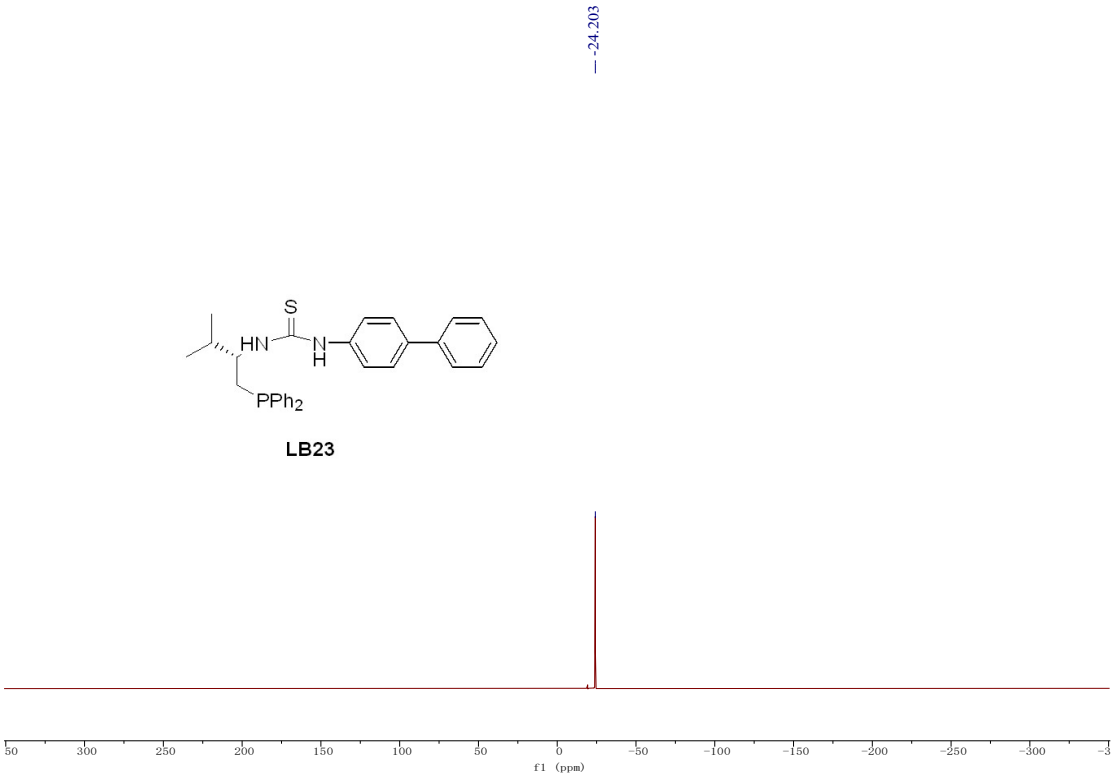




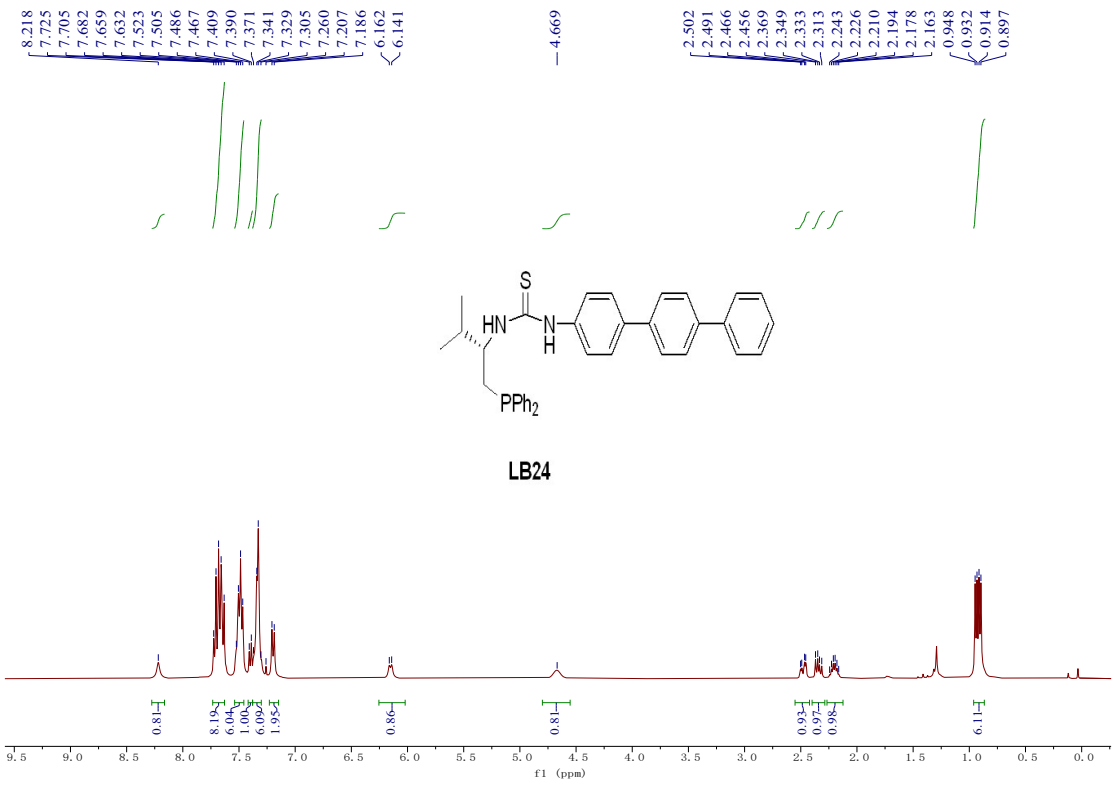
^{1}H, ^{13}C, ^{31}P NMR spectra of compound **LB22** (400 MHz, $CDCl_3$)

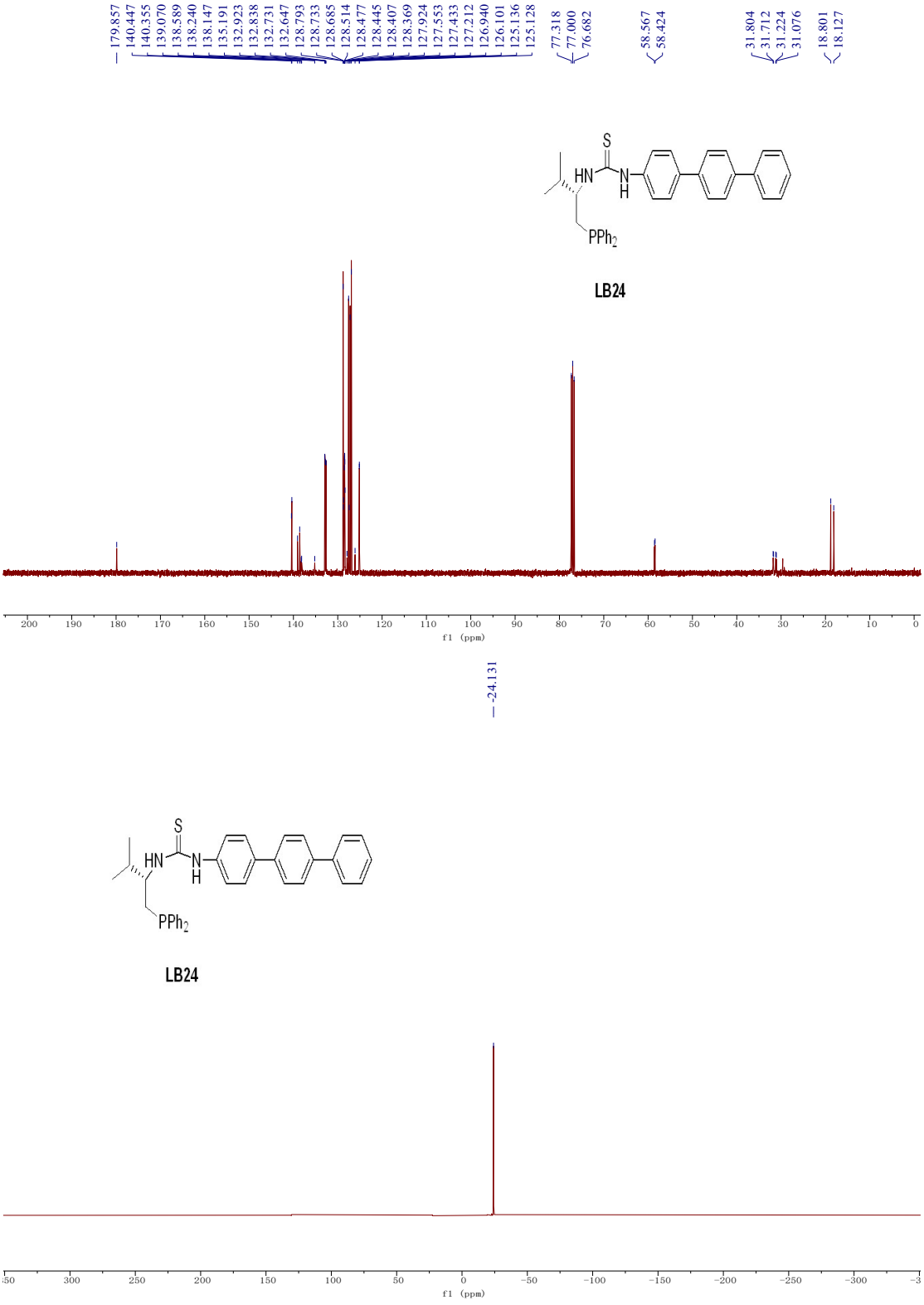

8.228
7.595
7.575
7.513
7.506
7.495
7.485
7.476
7.466
7.447
7.398
7.380
7.362
7.351
7.328
7.313
7.260
7.180
7.159
6.136
6.115
4.650
2.487
2.473
2.451
2.438
2.350
2.330
2.314
2.294
2.223
2.207
2.190
2.174
2.158
2.141
0.930
0.913
0.893
0.876
S
HN
N
H
Ph
PPh2
LB23
0.91
4.05
6.06
0.94
6.23
2.03
0.92
0.86
1.00
1.03
1.03
6.00
f1 (ppm)


179.861
139.756
139.639
138.238
138.115
135.134
132.915
132.834
132.724
132.643
128.853
128.728
128.681
128.507
128.469
128.438
128.400
127.610
126.868
125.116
77.316
76.999
76.681
58.535
58.392
31.770
31.684
31.191
31.047
18.776
18.094
S
HN
N
H
Ph
PPh2
LB23
f1 (ppm)

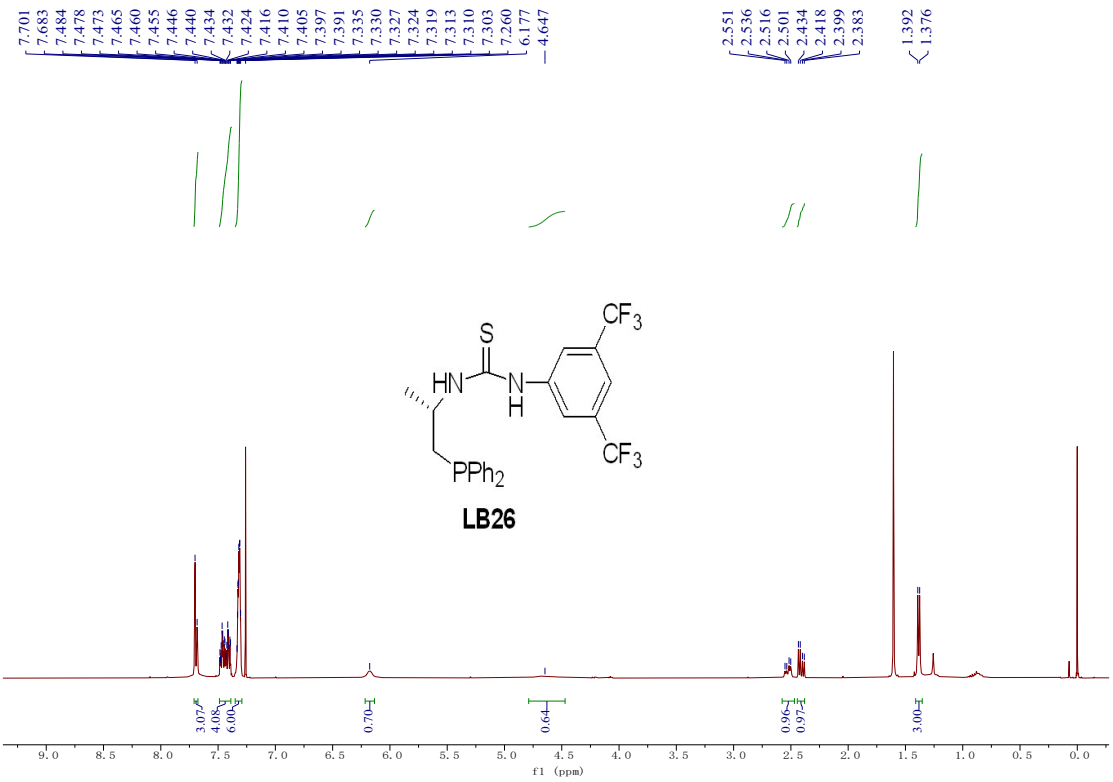


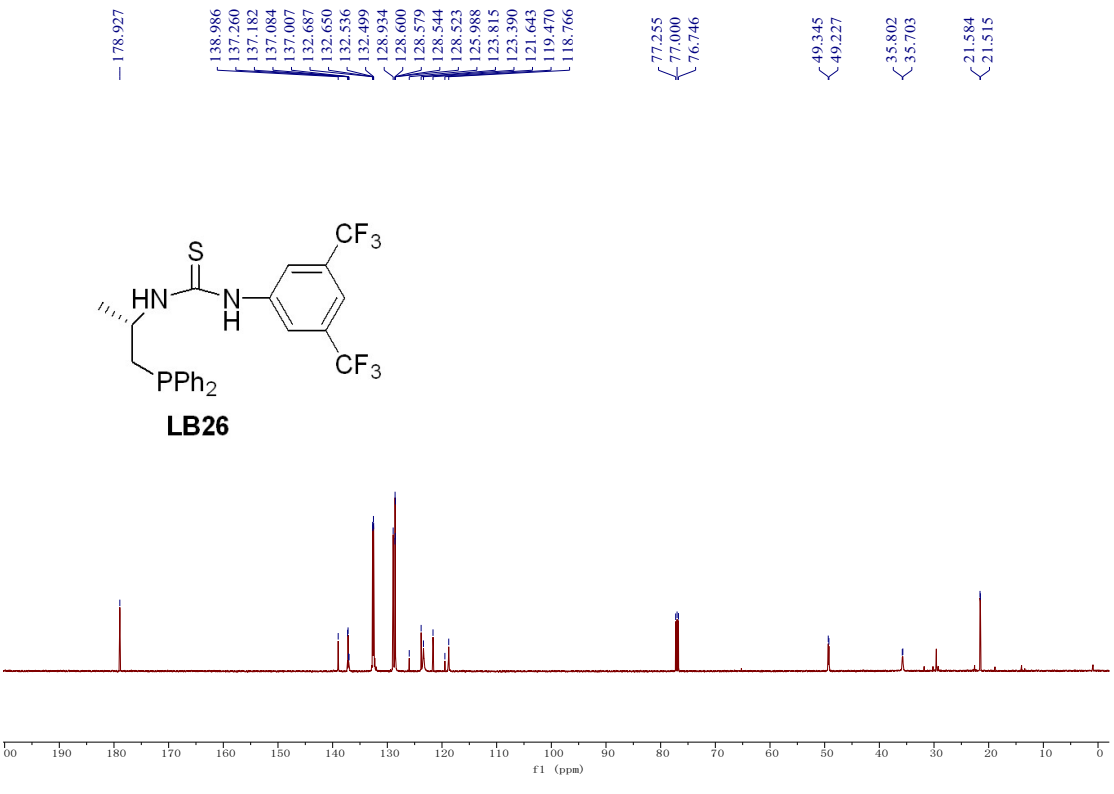
^{1}H, ^{13}C, ^{31}P NMR spectra of compound **LB23** (400 MHz, $CDCl_3$)

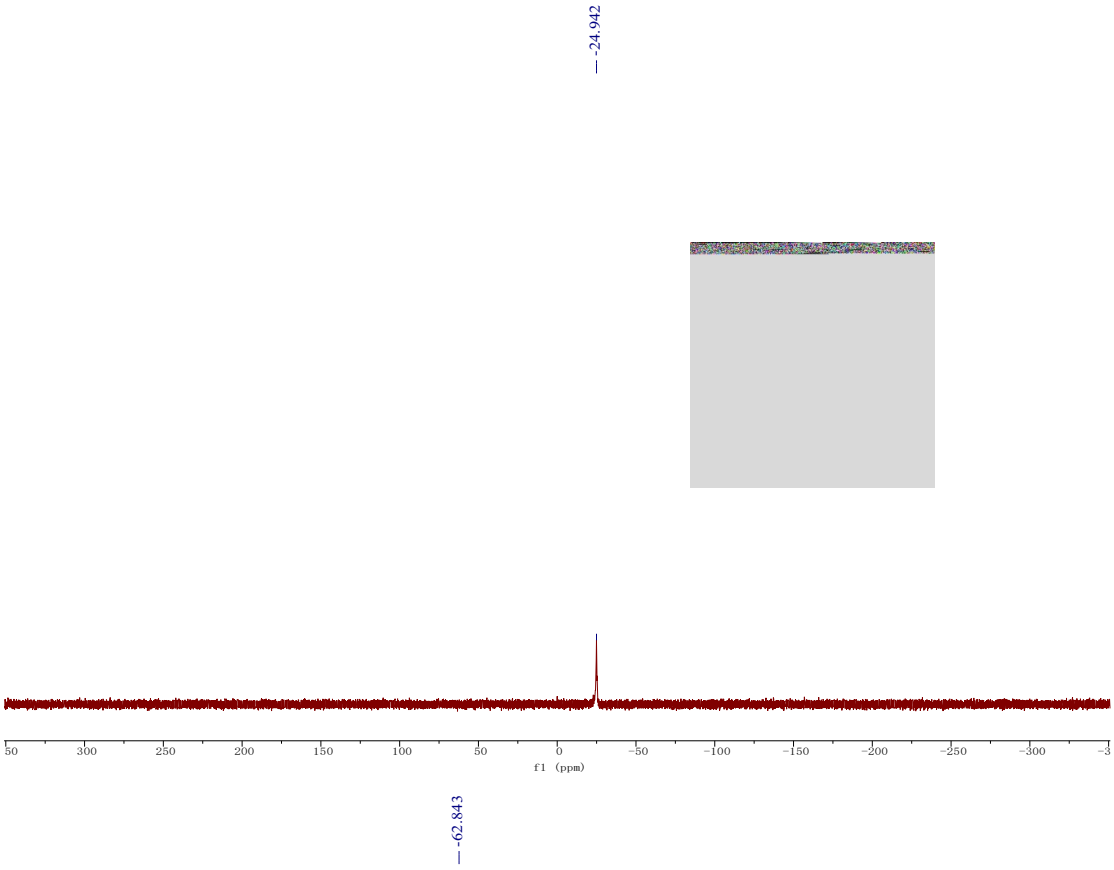


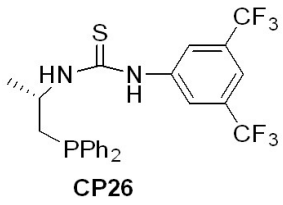


^{1}H, ^{13}C, ^{31}P NMR spectra of compound **LB24** (400 MHz, $CDCl_3$)


7.701
7.683
7.484
7.478
7.473
7.465
7.460
7.455
7.446
7.440
7.434
7.432
7.424
7.416
7.410
7.405
7.397
7.391
7.335
7.330
7.327
7.324
7.319
7.313
7.310
7.303
7.260
6.177
4.647
2.551
2.536
2.516
2.501
2.434
2.418
2.399
2.383
1.392
1.376
S
HN
N
H
CF3
CF3
PPh2
LB26
3.07
4.08
6.00
0.70
0.64
0.96
0.97
3.00
f1 (ppm)

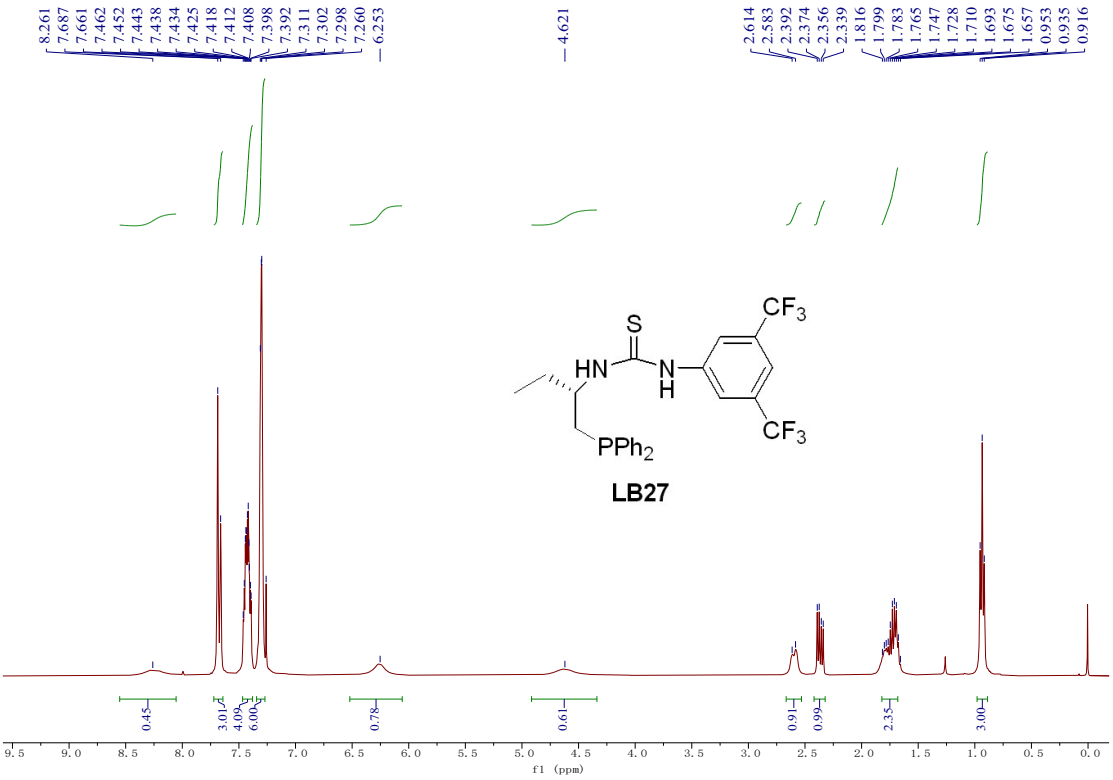

178.927
138.986
137.260
137.182
137.084
137.007
132.687
132.650
132.536
132.499
128.934
128.600
128.579
128.544
128.523
125.988
123.815
123.390
121.643
119.470
118.766
77.255
77.000
76.746
49.345
49.227
35.802
35.703
21.584
21.515
S
HN
N
H
CF3
CF3
PPh2
LB26
f1 (ppm)

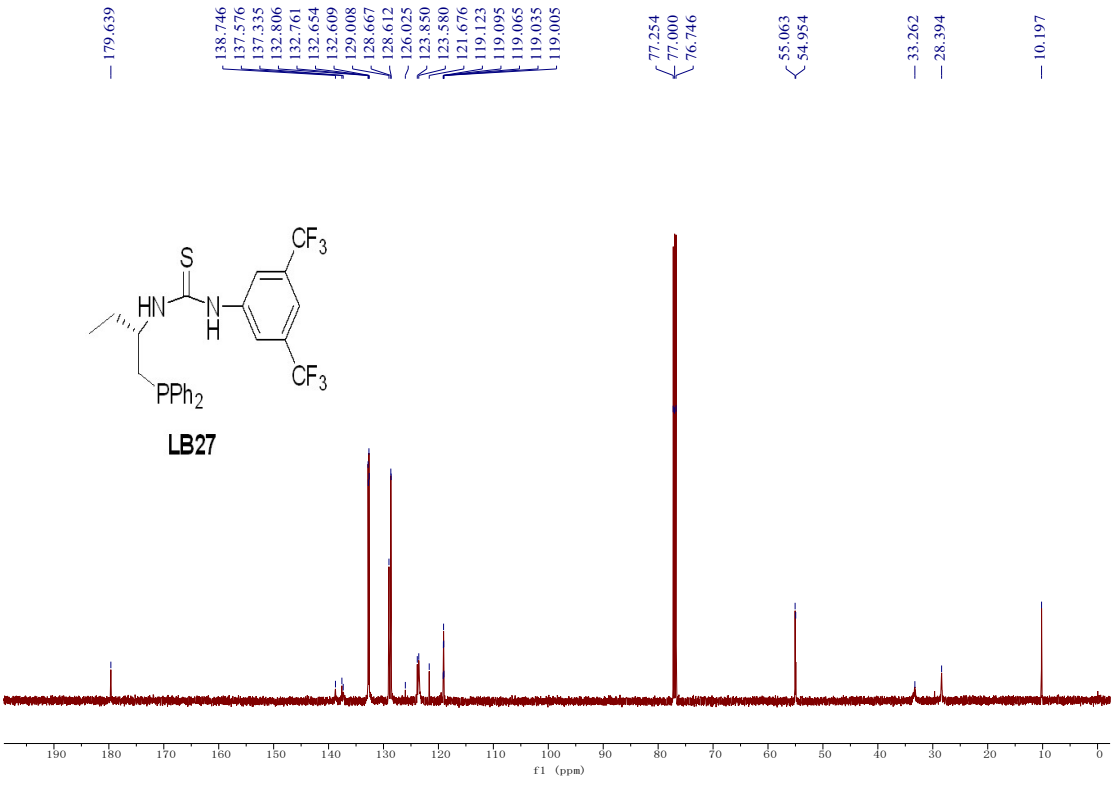


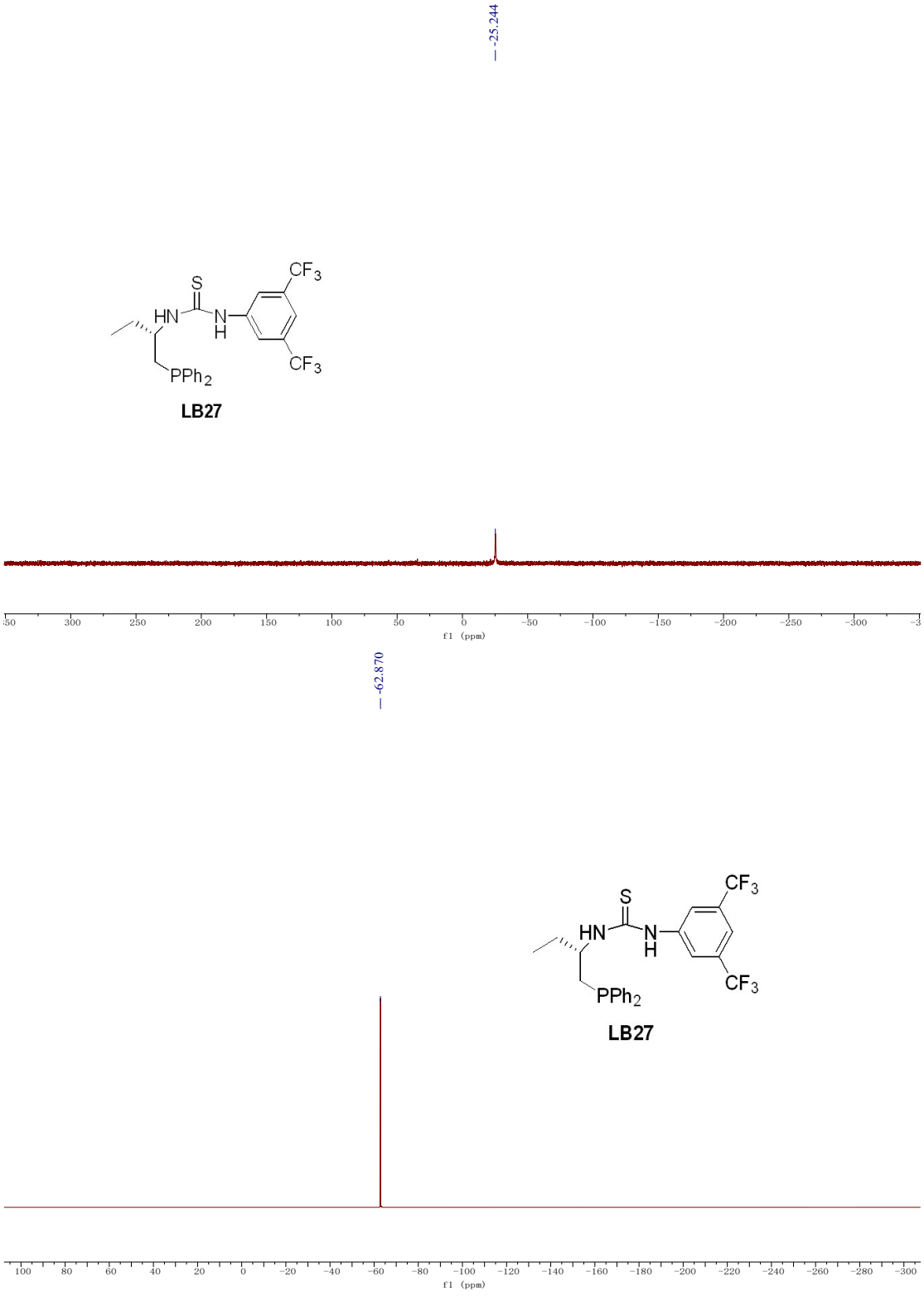


CP26

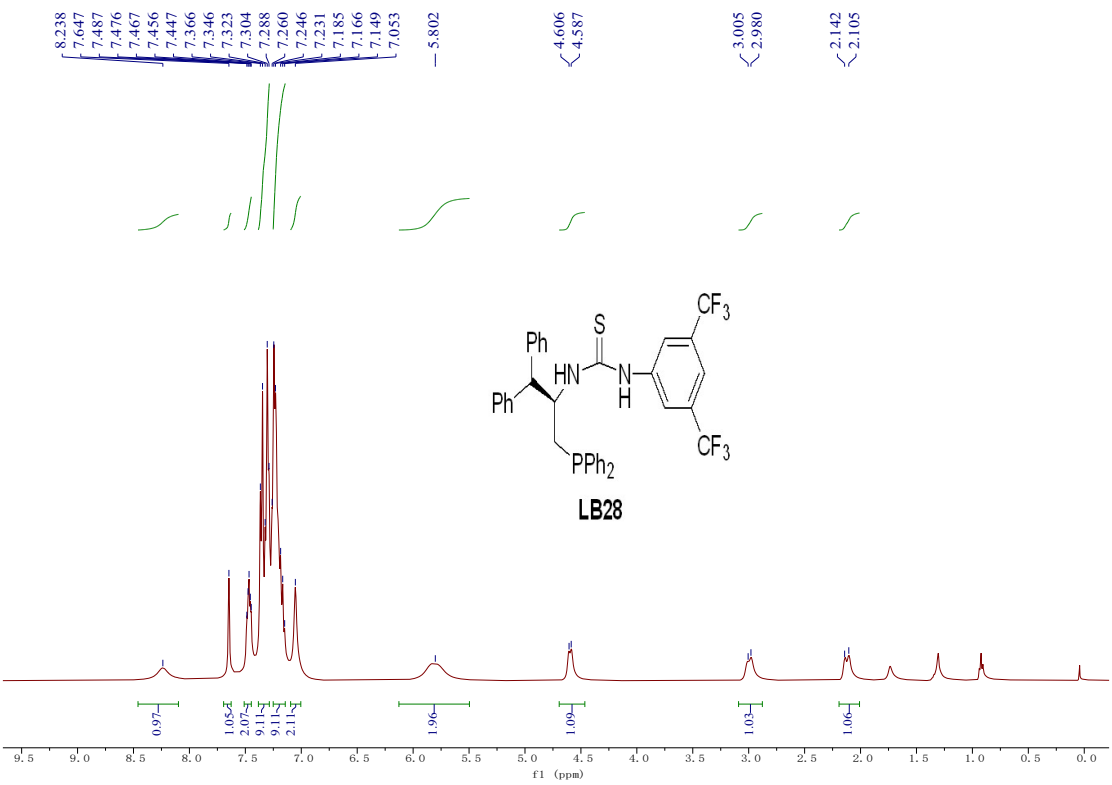
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB26** (400 MHz, $CDCl_3$)

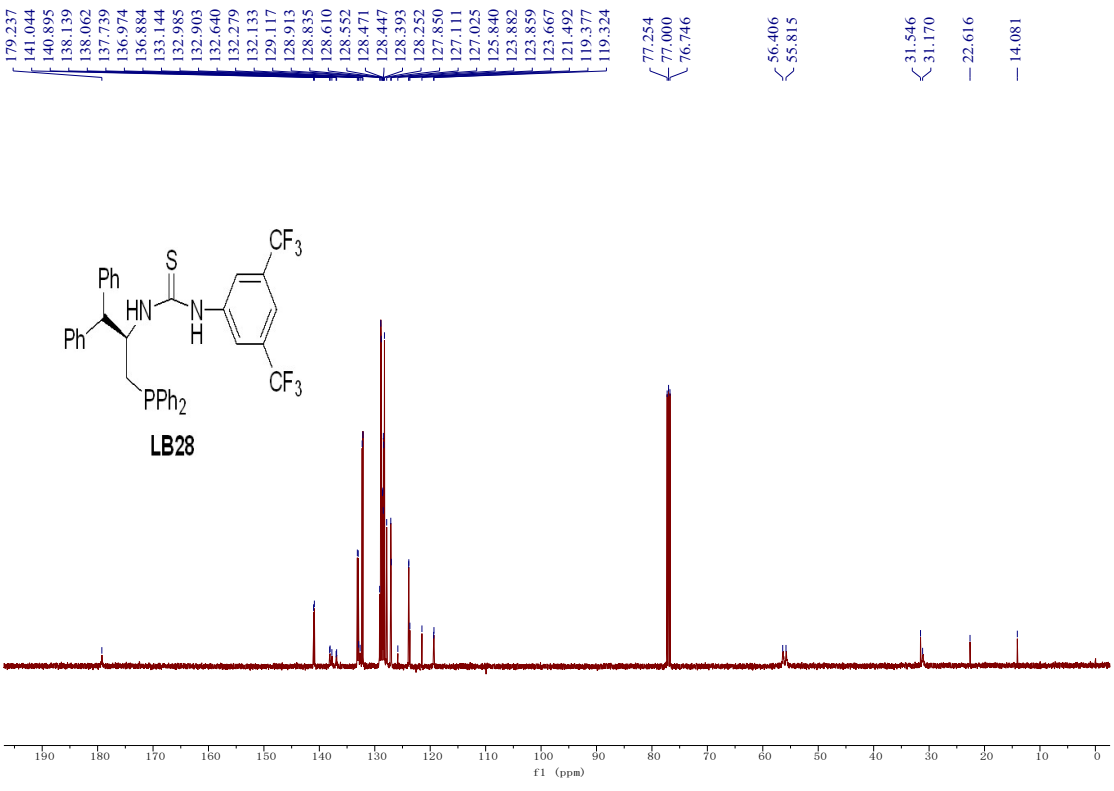

8.261
7.687
7.661
7.462
7.452
7.443
7.438
7.434
7.425
7.418
7.412
7.408
7.398
7.392
7.311
7.302
7.298
7.260
6.253
4.621
2.614
2.583
2.392
2.374
2.356
2.339
1.816
1.799
1.783
1.765
1.747
1.728
1.710
1.693
1.675
1.657
0.953
0.935
0.916
S
HN
N
H
CF3
CF3
PPh2
LB27
0.45
3.01
4.09
6.00
0.78
0.61
0.91
0.99
2.35
3.00
f1 (ppm)

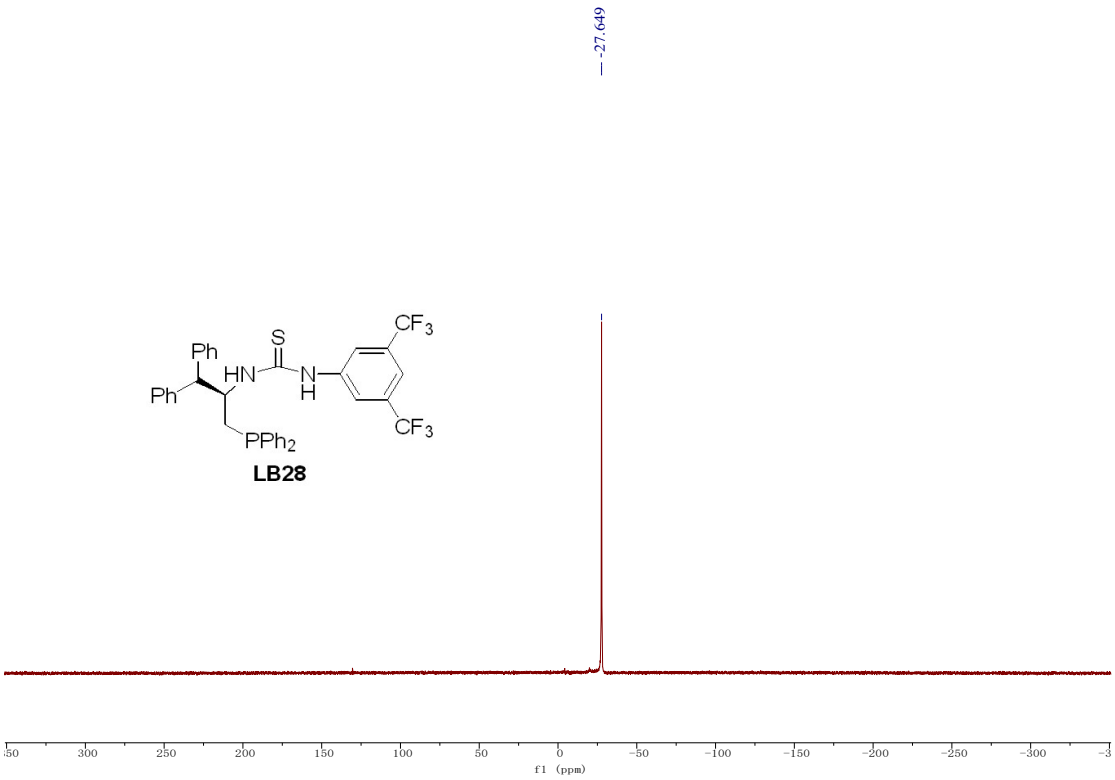

179.639
138.746
137.576
137.335
132.806
132.761
132.654
132.609
129.008
128.667
128.612
126.025
123.850
123.580
121.676
119.123
119.095
119.065
119.035
119.005
77.254
77.000
76.746
55.063
54.954
33.262
28.394
10.197
S
HN
N
H
CF3
CF3
PPh2
LB27
f1 (ppm)

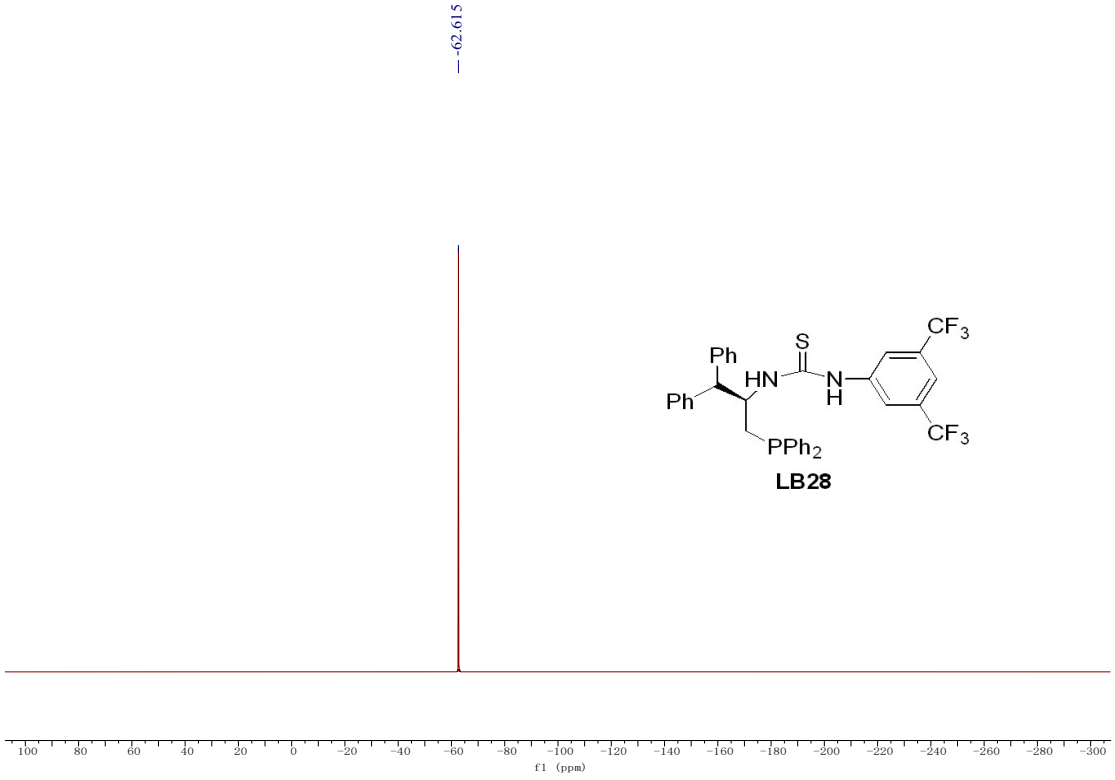


^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB27** (400 MHz, $CDCl_3$)

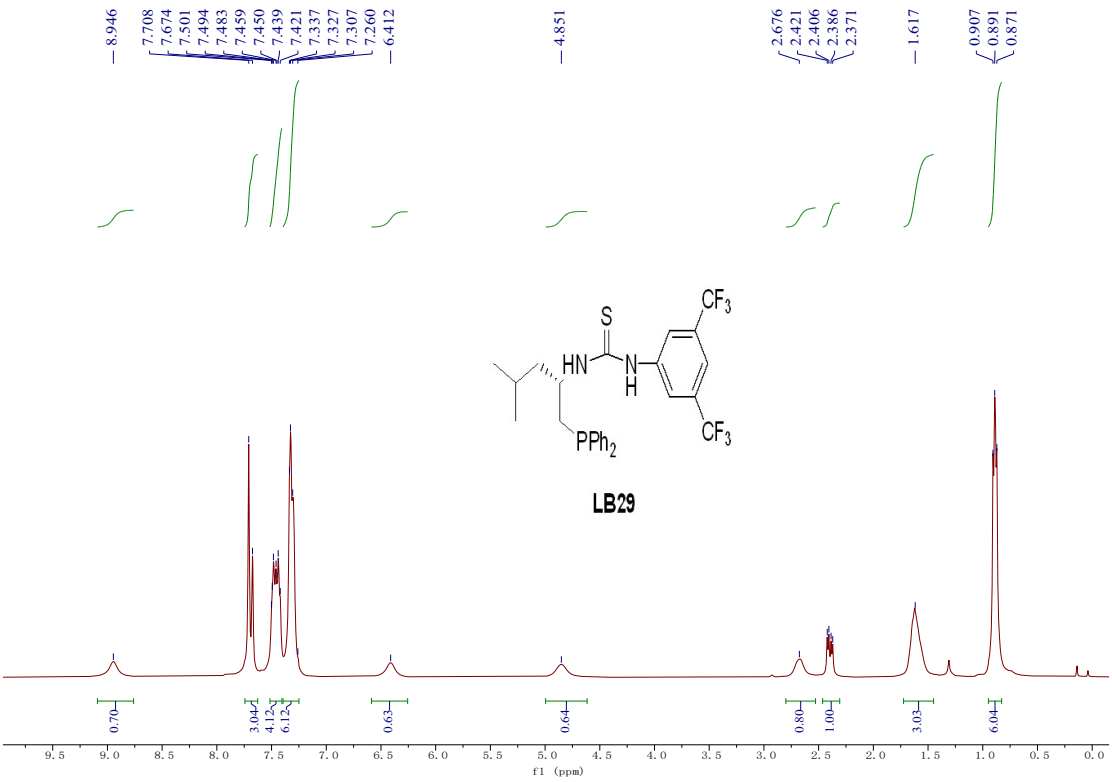

8.238
7.647
7.487
7.476
7.467
7.456
7.447
7.366
7.346
7.323
7.304
7.288
7.260
7.246
7.231
7.185
7.166
7.149
7.053
5.802
4.606
4.587
3.005
2.980
2.142
2.105
CF3
S
Ph
HN
N
H
Ph
CF3
PPh2
LB28
0.97
1.05
2.07
9.11
9.11
2.11
1.96
1.09
1.03
1.06
f1 (ppm)

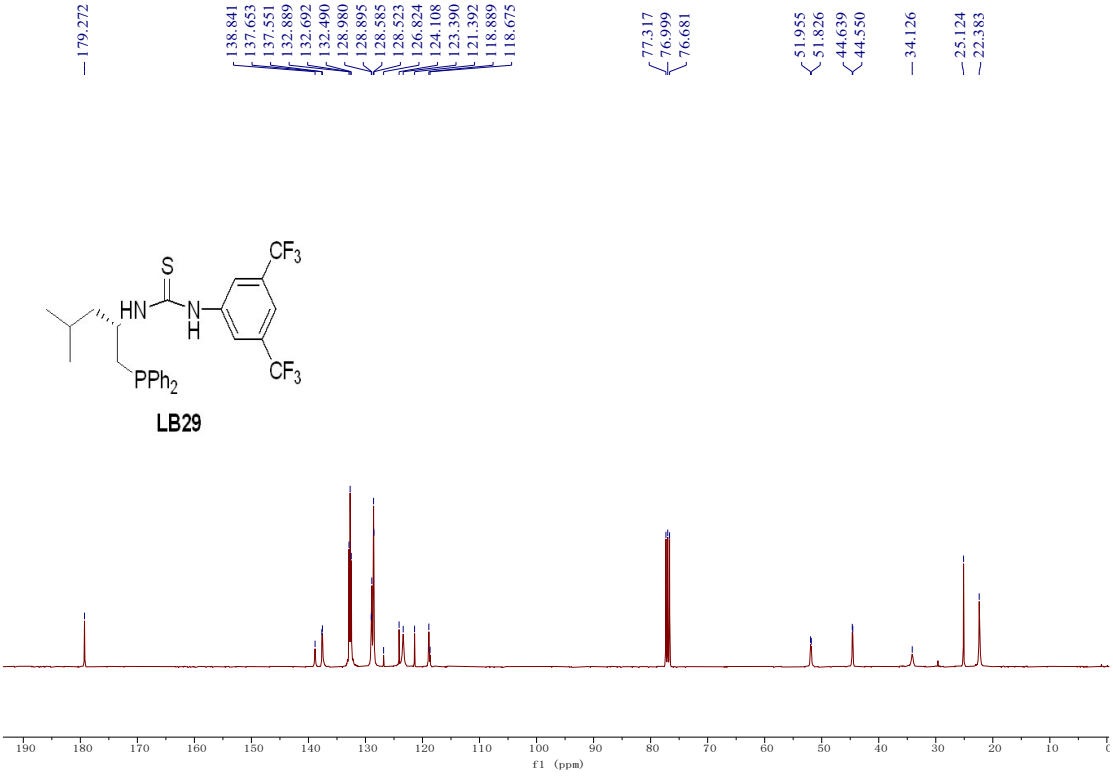

179.237
141.044
140.895
138.139
138.062
137.739
136.974
136.884
133.144
132.985
132.903
132.640
132.279
132.133
129.117
128.913
128.835
128.610
128.552
128.471
128.447
128.393
128.252
127.850
127.111
127.025
125.840
123.882
123.859
123.667
121.492
119.377
119.324
77.254
77.000
76.746
56.406
55.815
31.546
31.170
22.616
14.081
CF3
S
Ph
HN
N
H
Ph
CF3
PPh2
LB28
f1 (ppm)

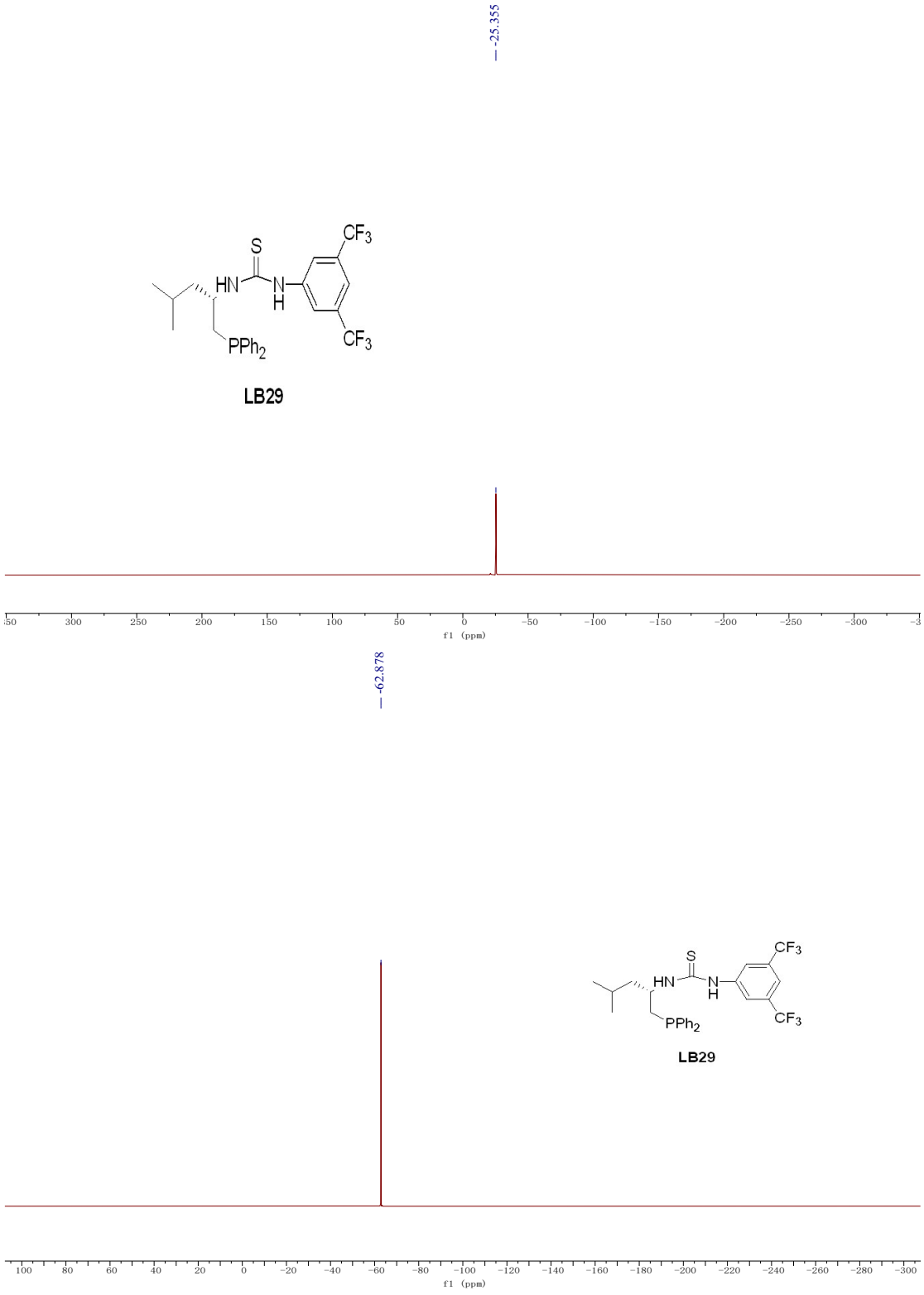




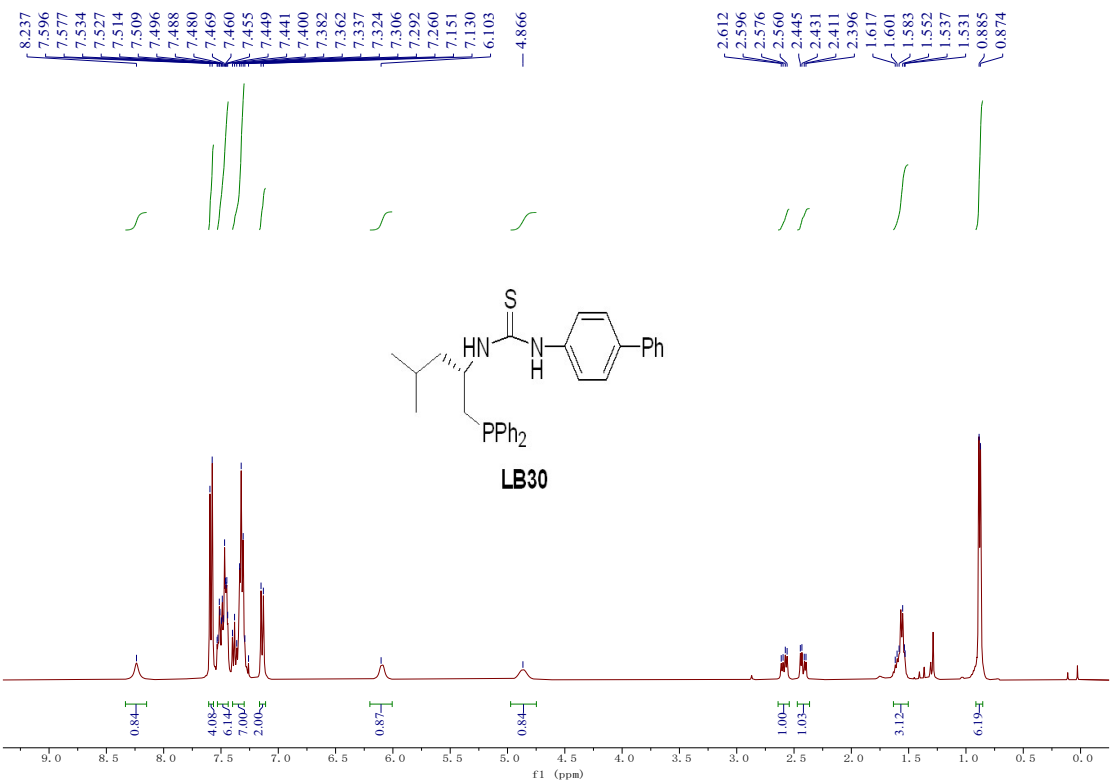
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB28** (400 MHz, $CDCl_3$)

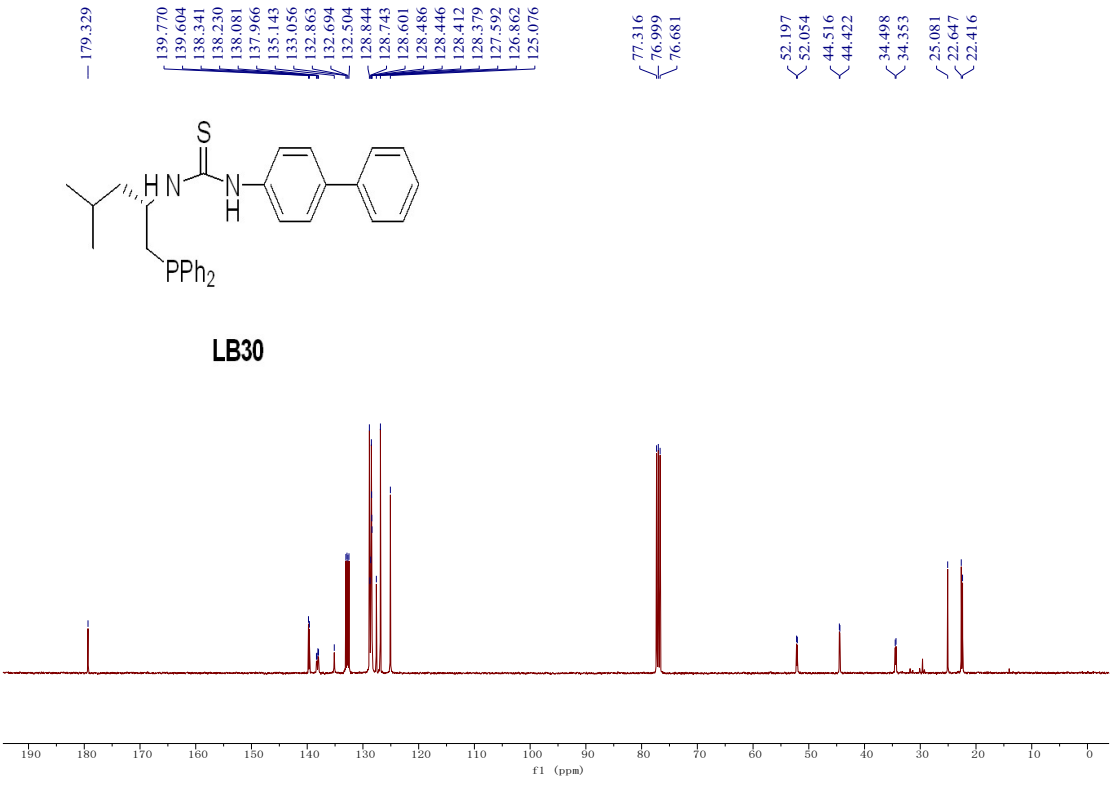

8.946
7.708
7.674
7.501
7.494
7.483
7.459
7.450
7.439
7.421
7.337
7.327
7.307
7.260
6.412
4.851
2.676
2.421
2.406
2.386
2.371
1.617
0.907
0.891
0.871
S
HN
N
H
CF3
CF3
PPh2
LB29
0.70
3.04
4.12
6.12
0.63
0.64
0.80
1.00
3.03
6.04
f1 (ppm)

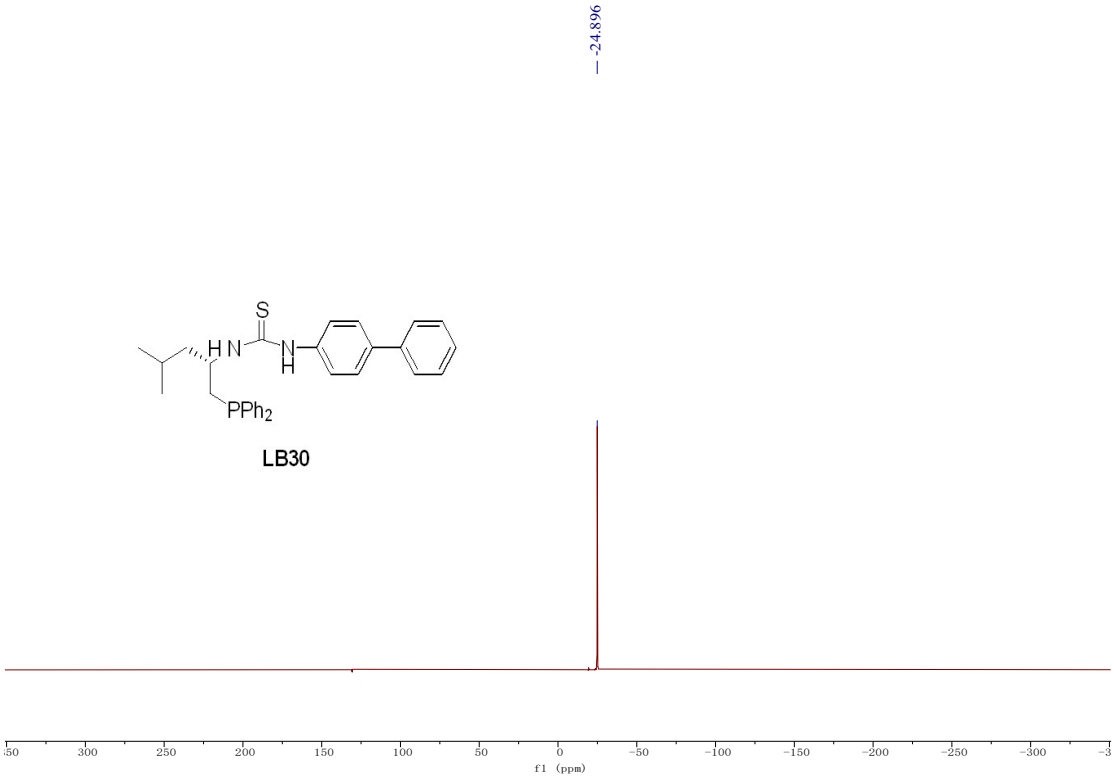

179.272
138.841
137.653
137.551
132.889
132.692
132.490
128.980
128.895
128.585
128.523
126.824
124.108
123.390
121.392
118.889
118.675
77.317
76.999
76.681
51.955
51.826
44.639
44.550
34.126
25.124
22.383
S
HN
N
H
CF3
CF3
PPh2
LB29
f1 (ppm)



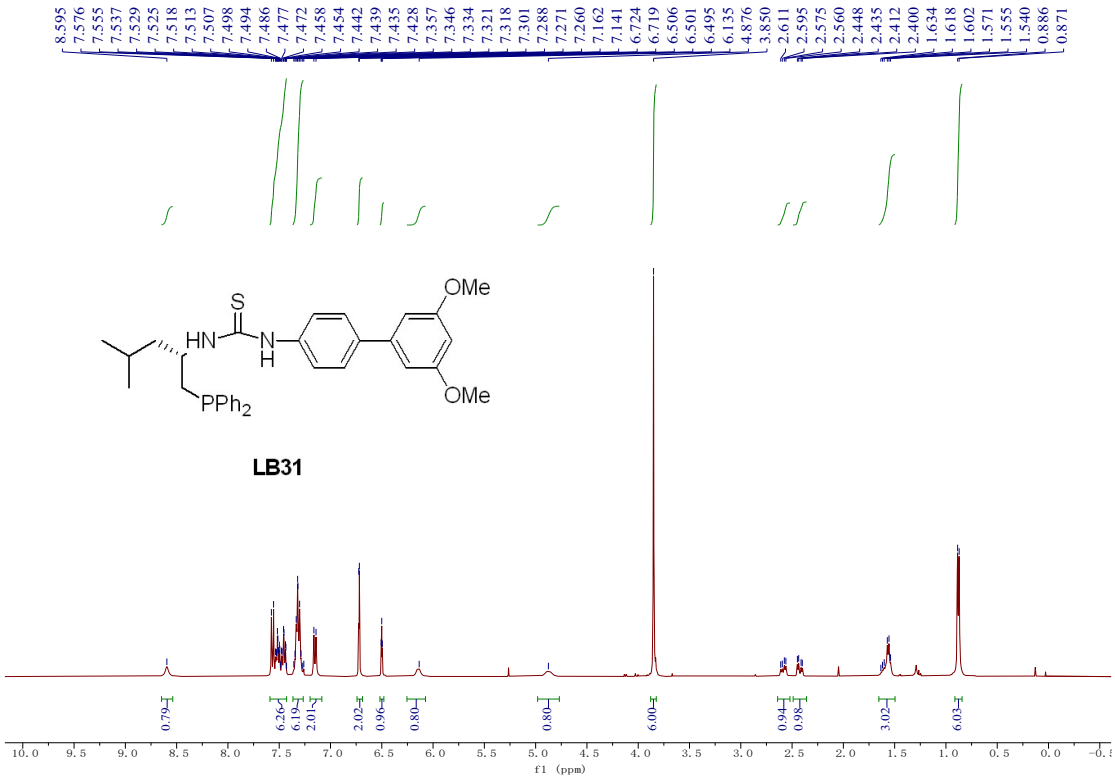
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB29** (400 MHz, $CDCl_3$)

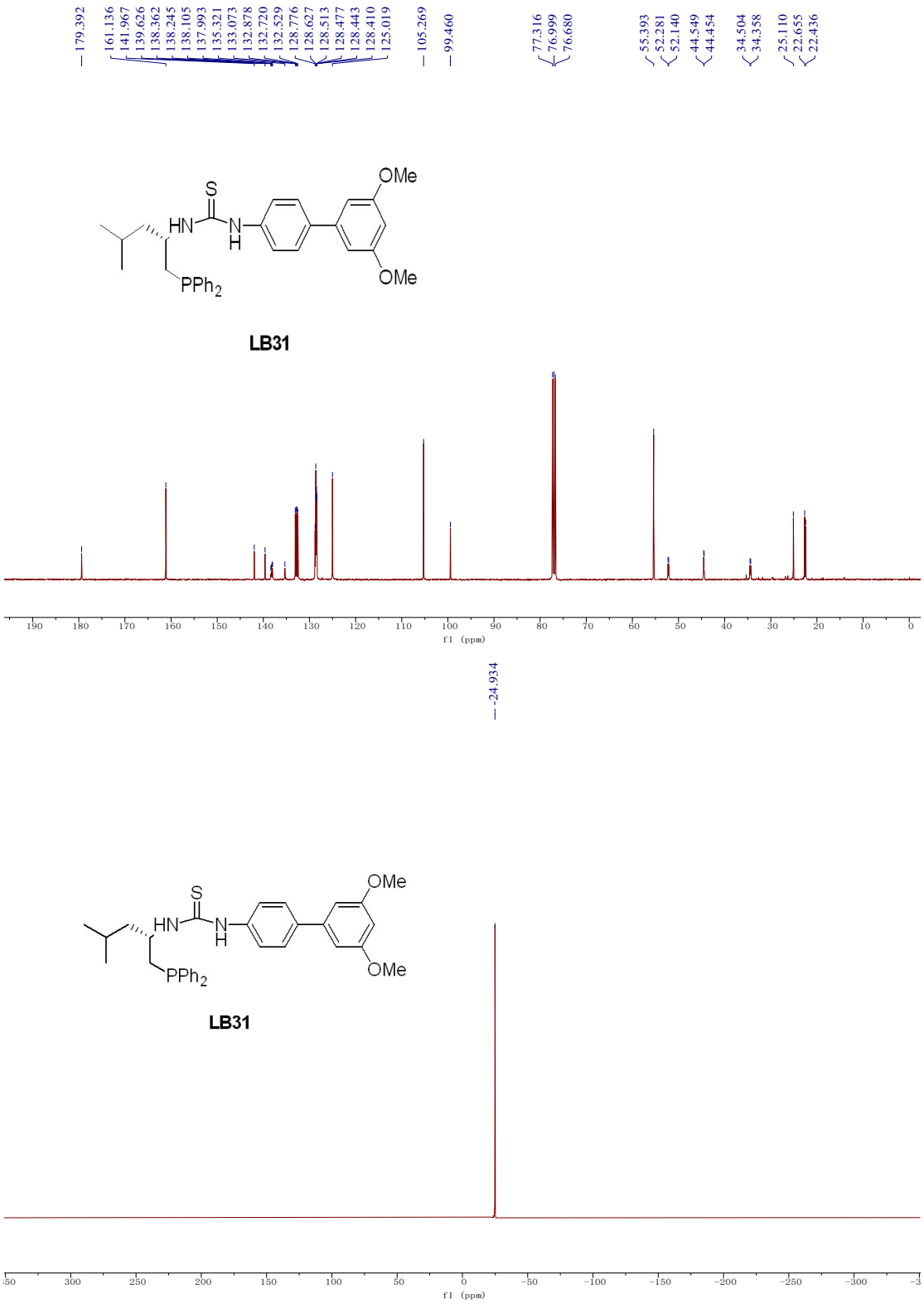

8.237
7.596
7.577
7.534
7.527
7.514
7.509
7.496
7.488
7.480
7.469
7.460
7.455
7.449
7.441
7.400
7.382
7.362
7.337
7.324
7.306
7.292
7.260
7.151
7.130
6.103
4.866
2.612
2.596
2.576
2.560
2.445
2.431
2.411
2.396
1.617
1.601
1.583
1.552
1.537
1.531
0.885
0.874
S
HN
N
H
Ph
PPh2
LB30
0.84
4.08
6.14
7.00
2.00
0.87
0.84
1.00
1.03
3.12
6.19
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


179.329
139.770
139.604
138.341
138.230
138.081
137.966
135.143
133.056
132.863
132.694
132.504
128.844
128.743
128.601
128.486
128.446
128.412
128.379
127.592
126.862
125.076
77.316
76.999
76.681
52.197
52.054
44.516
44.422
34.498
34.353
25.081
22.647
22.416
S
HN
N
H
PPh2
LB30
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

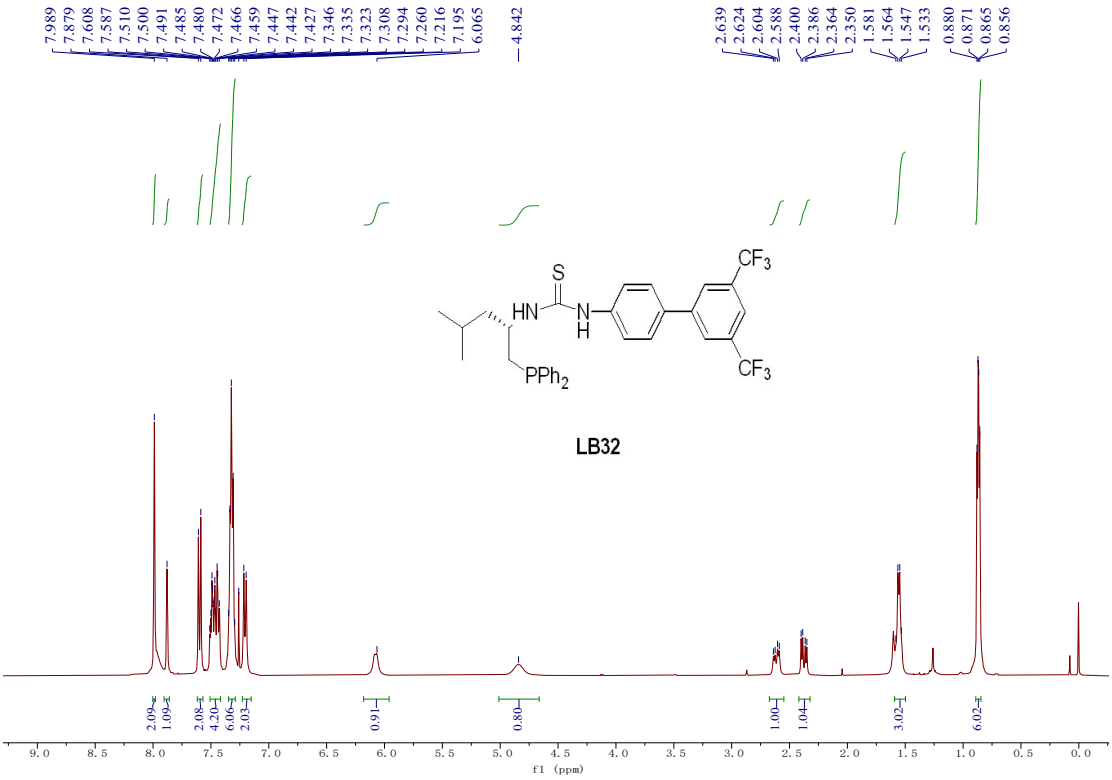


^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB30** (400 MHz, $CDCl_3$)

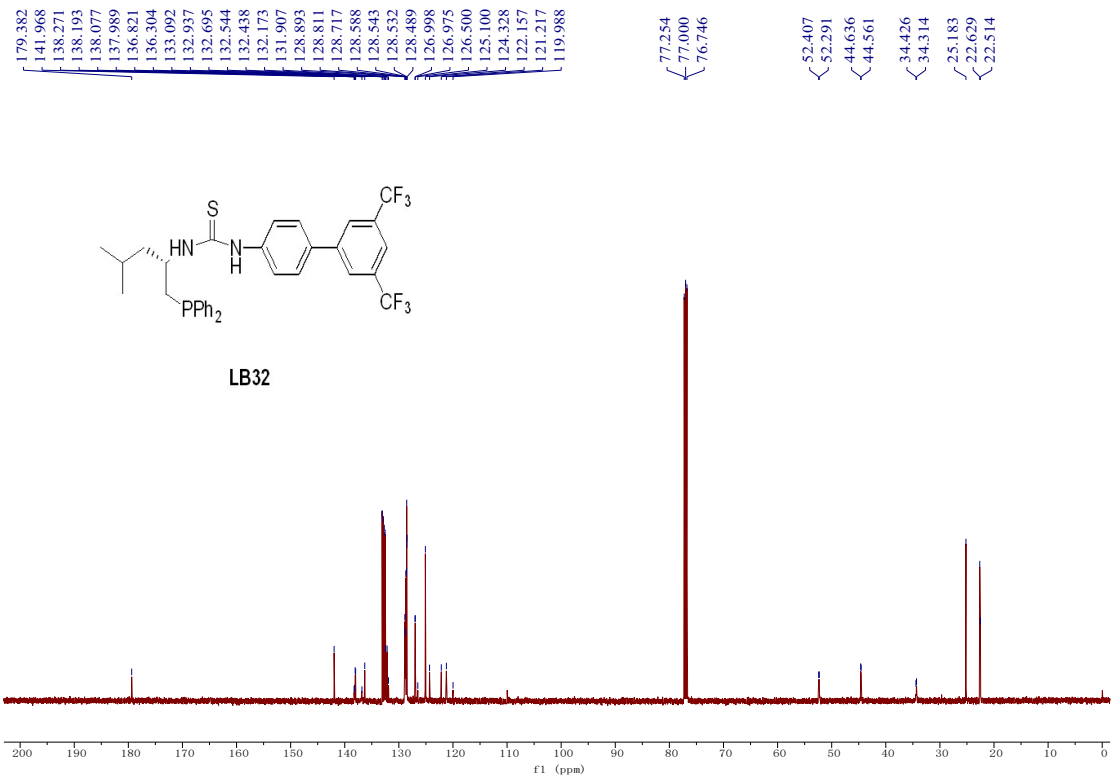




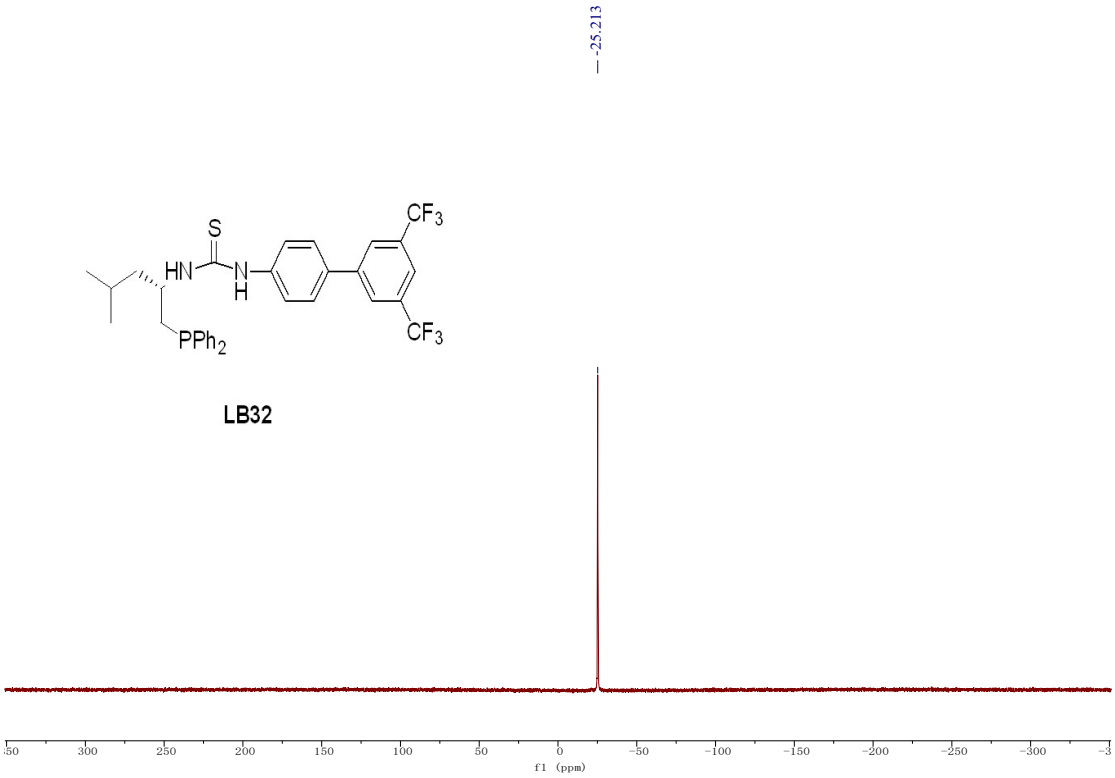
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB31** (400 MHz, $CDCl_3$)

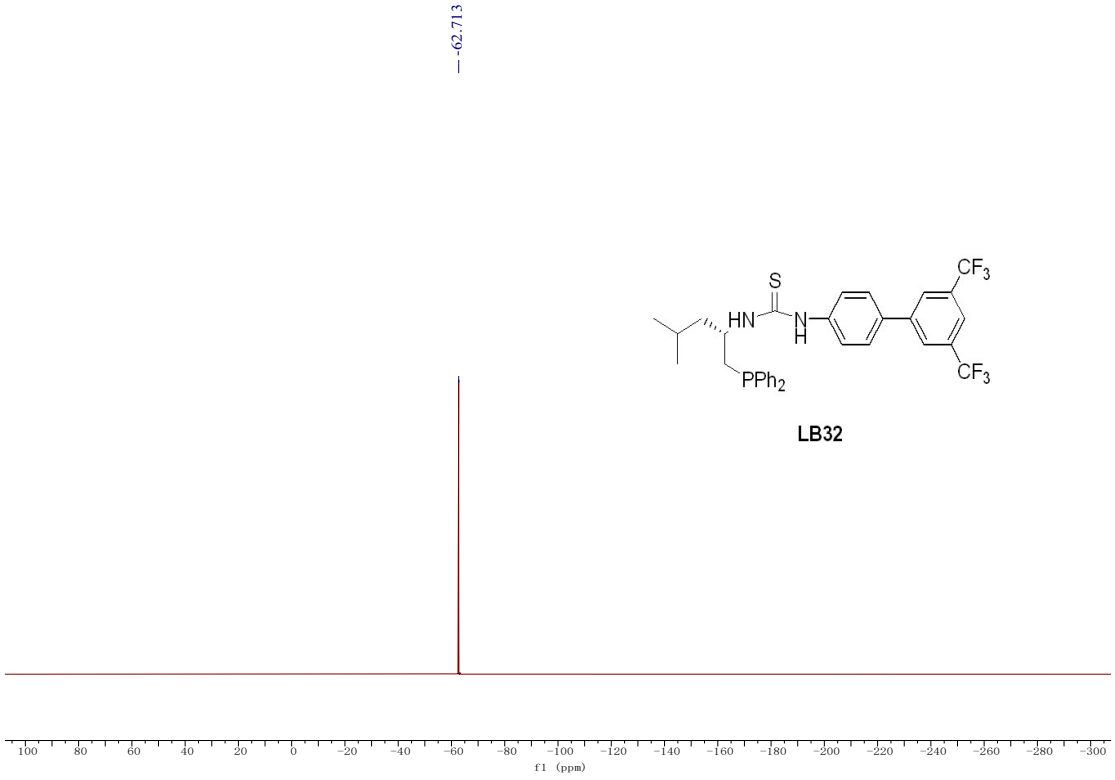

7.989
7.879
7.608
7.587
7.510
7.500
7.491
7.485
7.480
7.472
7.466
7.459
7.447
7.442
7.427
7.346
7.335
7.323
7.308
7.294
7.260
7.216
7.195
6.065
4.842
2.639
2.624
2.604
2.588
2.400
2.386
2.364
2.350
1.581
1.564
1.547
1.533
0.880
0.871
0.865
0.856
S
HN
N
H
PPh2
CF3
CF3
2.09
1.09
2.08
4.20
6.06
2.03
0.91
0.80
1.00
1.04
3.02
6.02
f1 (ppm)

LB32

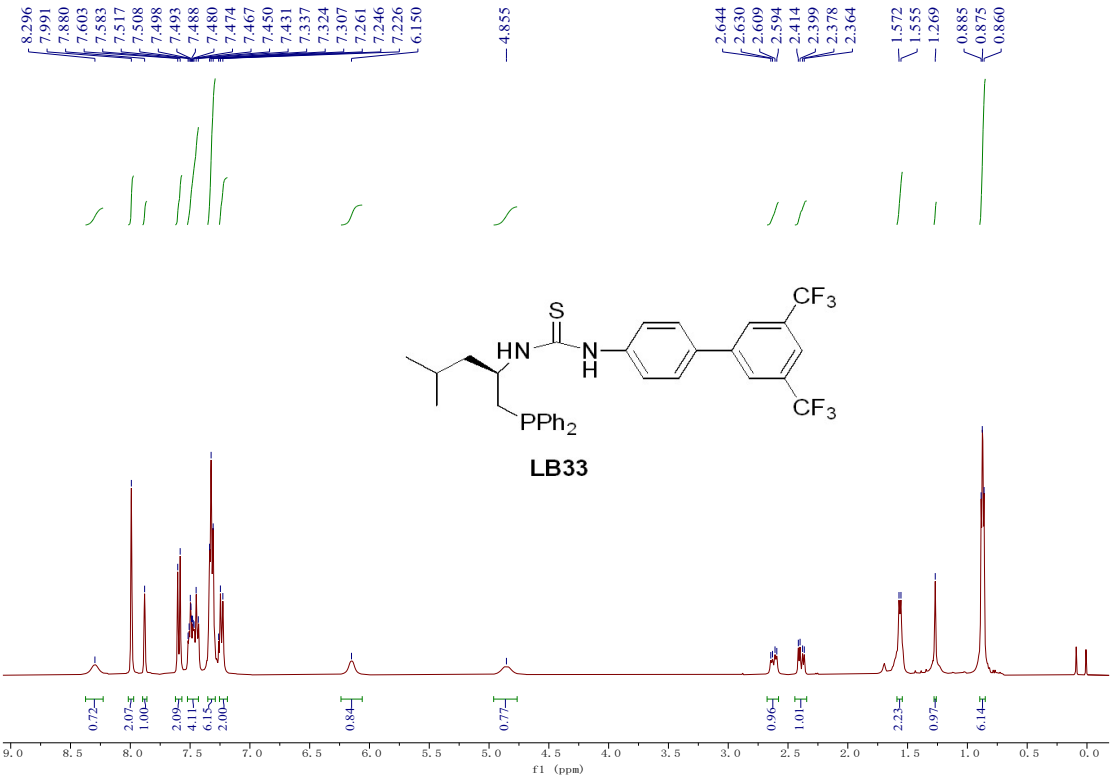

179.382
141.968
138.271
138.193
138.077
137.989
136.821
136.304
133.092
132.937
132.695
132.544
132.438
132.173
131.907
128.893
128.811
128.717
128.588
128.543
128.532
128.489
126.998
126.975
126.500
125.100
124.328
122.157
121.217
119.988
77.254
77.000
76.746
52.407
52.291
44.636
44.561
34.426
34.314
25.183
22.629
22.514
S
HN
N
H
PPh2
CF3
CF3
f1 (ppm)

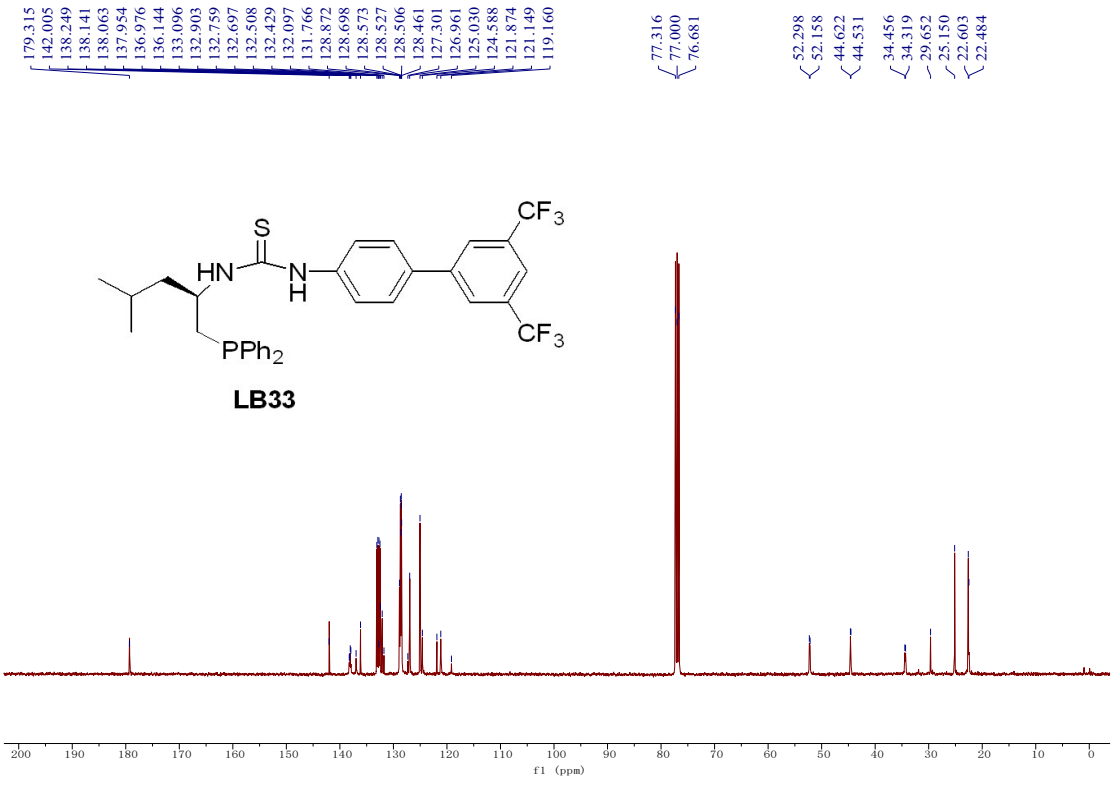
LB32

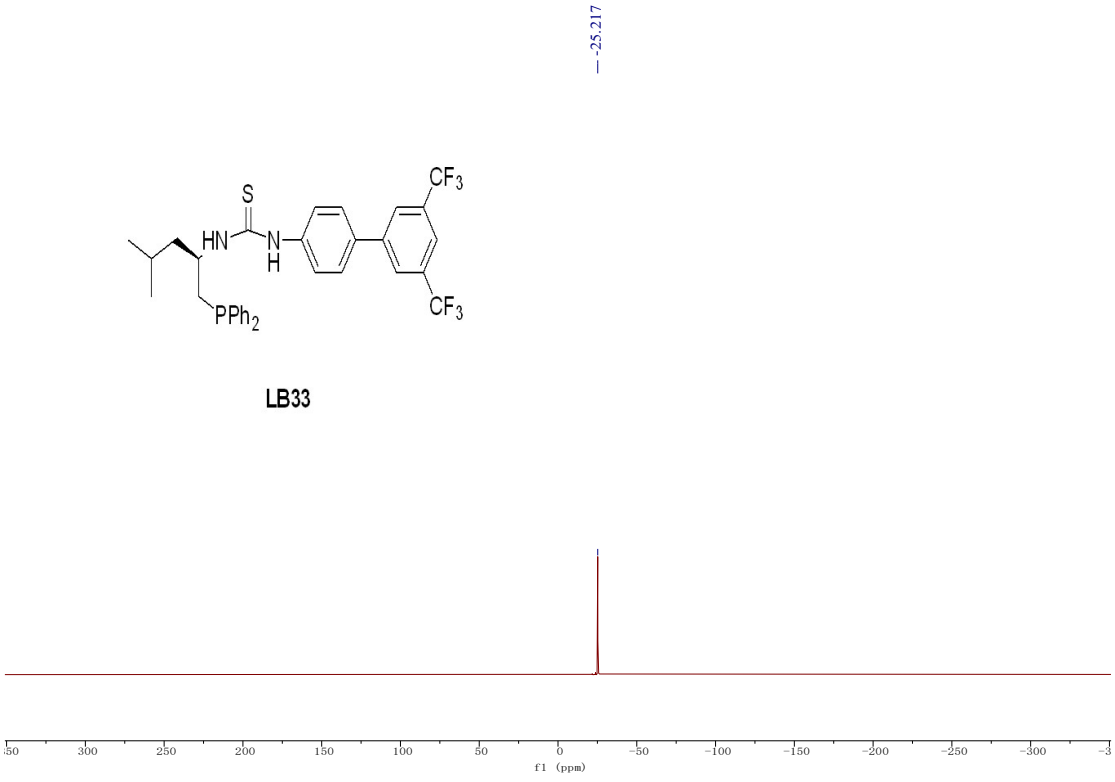




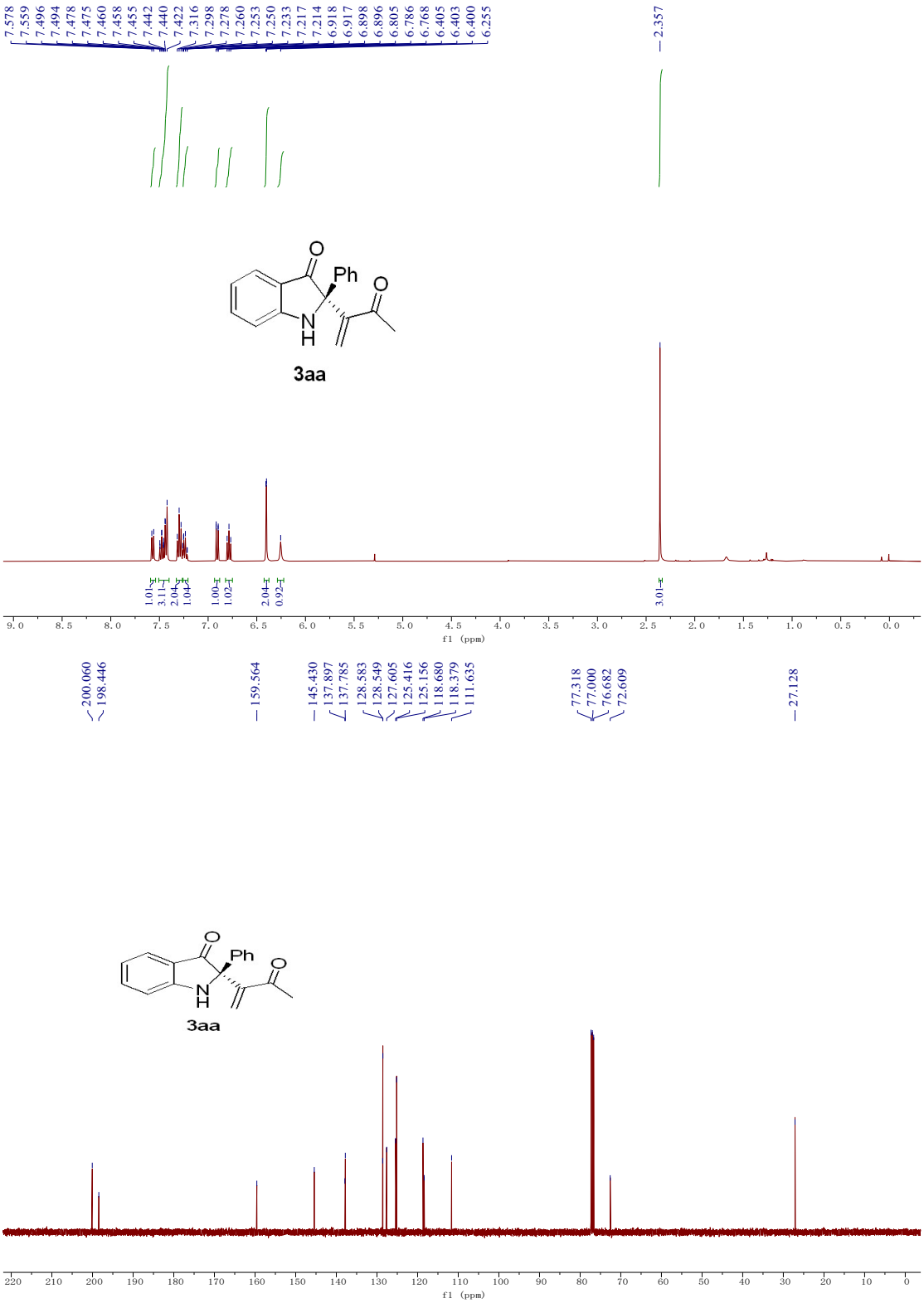
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB32** (400 MHz, $CDCl_3$)


8.296
7.991
7.880
7.603
7.583
7.517
7.508
7.498
7.493
7.488
7.480
7.474
7.467
7.450
7.431
7.337
7.324
7.307
7.261
7.246
7.226
6.150
4.855
2.644
2.630
2.609
2.594
2.414
2.399
2.378
2.364
1.572
1.555
1.269
0.885
0.875
0.860
S
HN
N
H
PPh2
CF3
CF3
LB33
0.72
2.07
1.00
2.09
4.11
6.15
2.00
0.84
0.77
0.96
1.01
2.23
0.97
6.14
f1 (ppm)

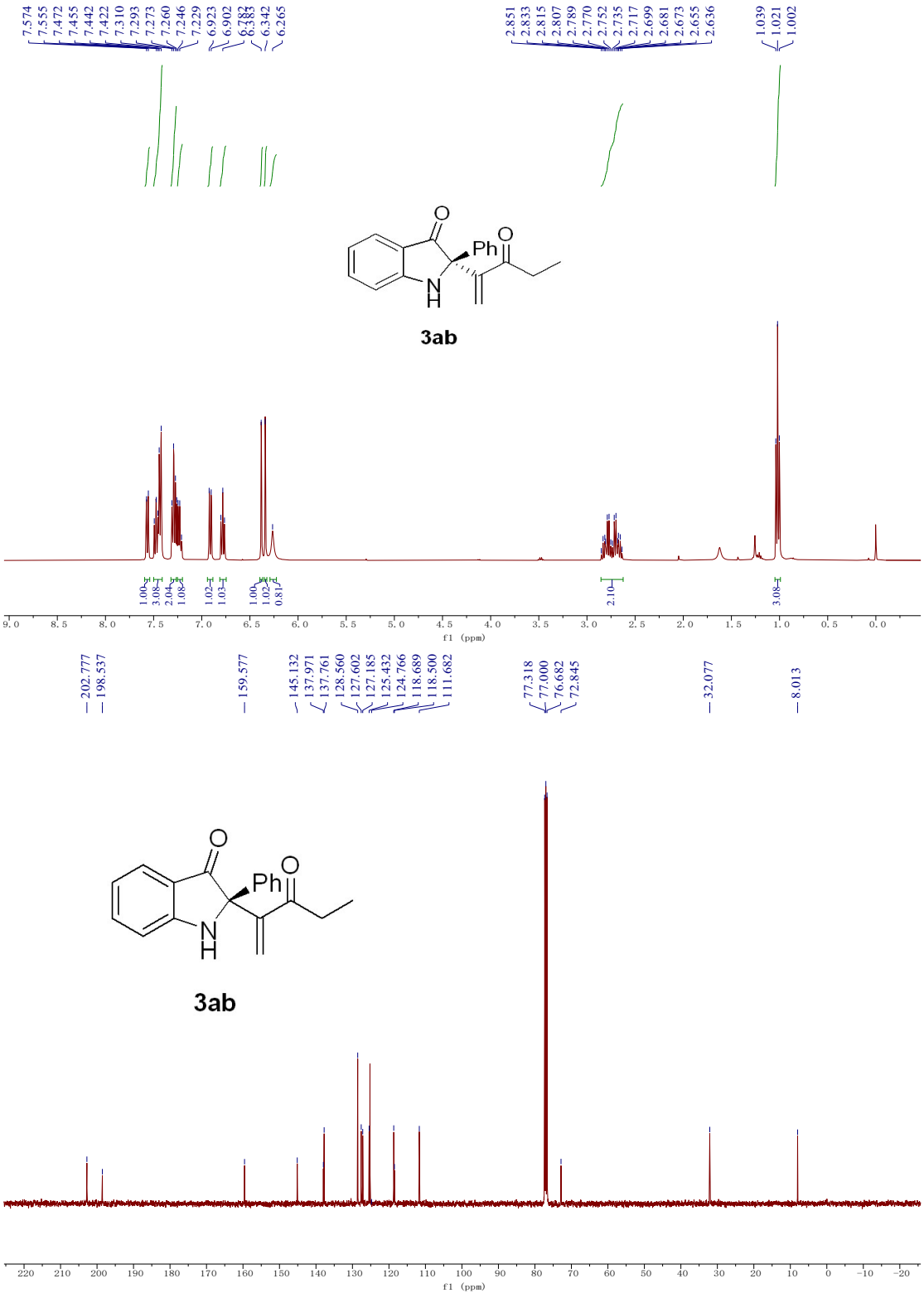

179.315
142.005
138.249
138.141
138.063
137.954
136.976
136.144
133.096
132.903
132.759
132.697
132.508
132.429
132.097
131.766
128.872
128.698
128.573
128.527
128.506
128.461
127.301
126.961
125.030
124.588
121.874
121.149
119.160
77.316
77.000
76.681
52.298
52.158
44.622
44.531
34.456
34.319
29.652
25.150
22.603
22.484
S
HN
N
H
PPh2
CF3
CF3
LB33
f1 (ppm)



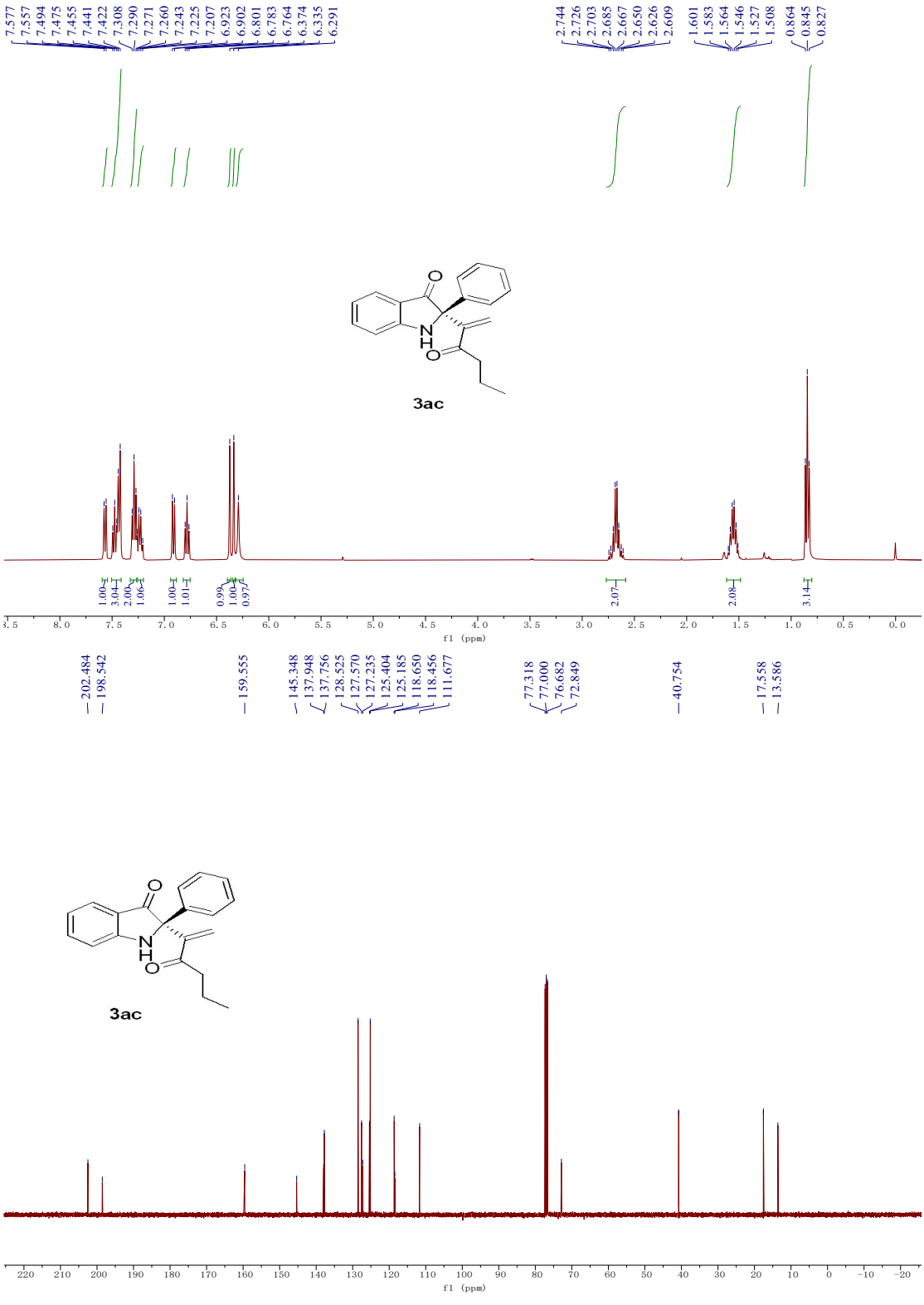
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB33** (400 MHz, $CDCl_3$)



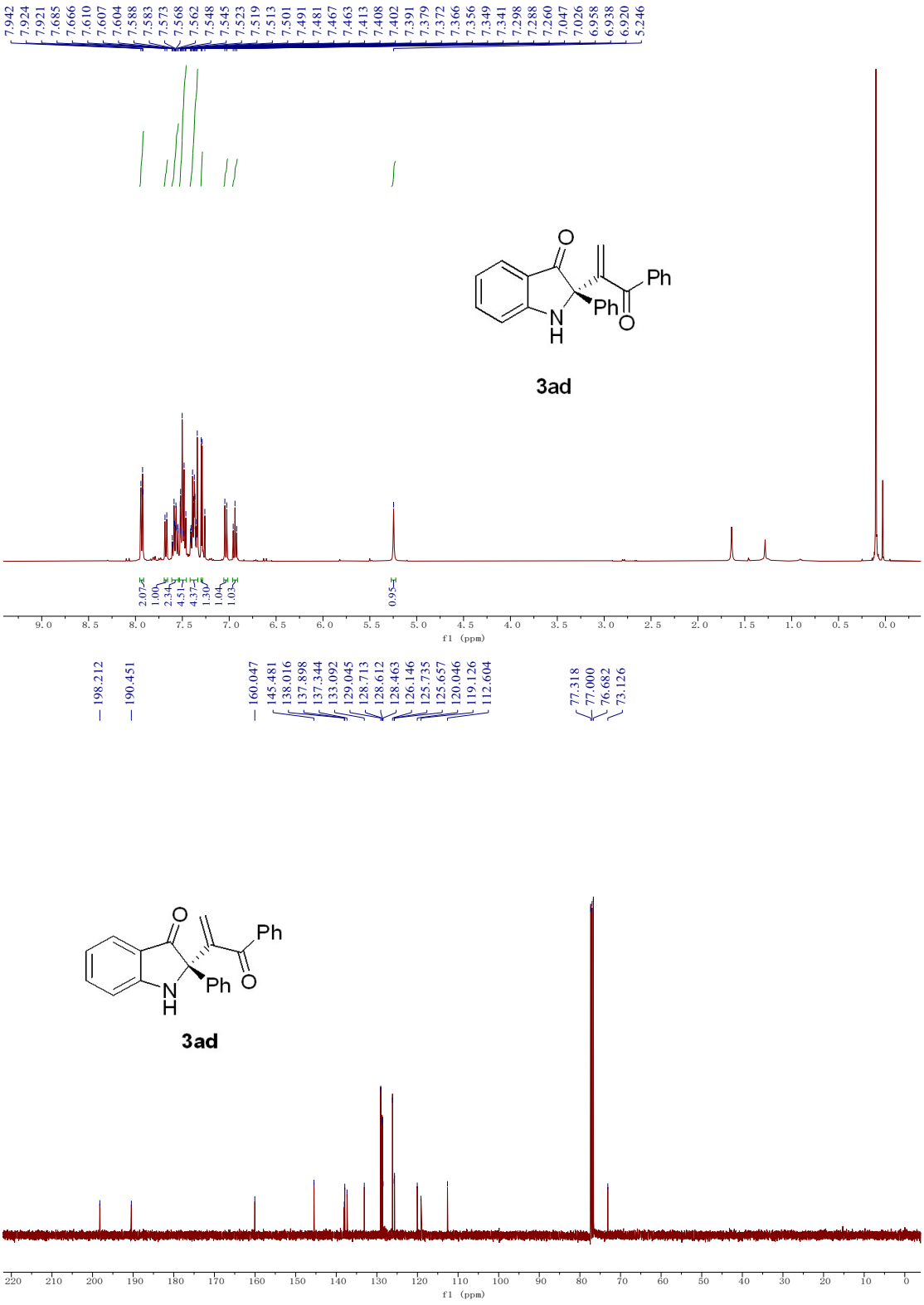
^{1}H and ^{13}C NMR spectra of compound **3aa** (400 MHz, $CDCl_3$)



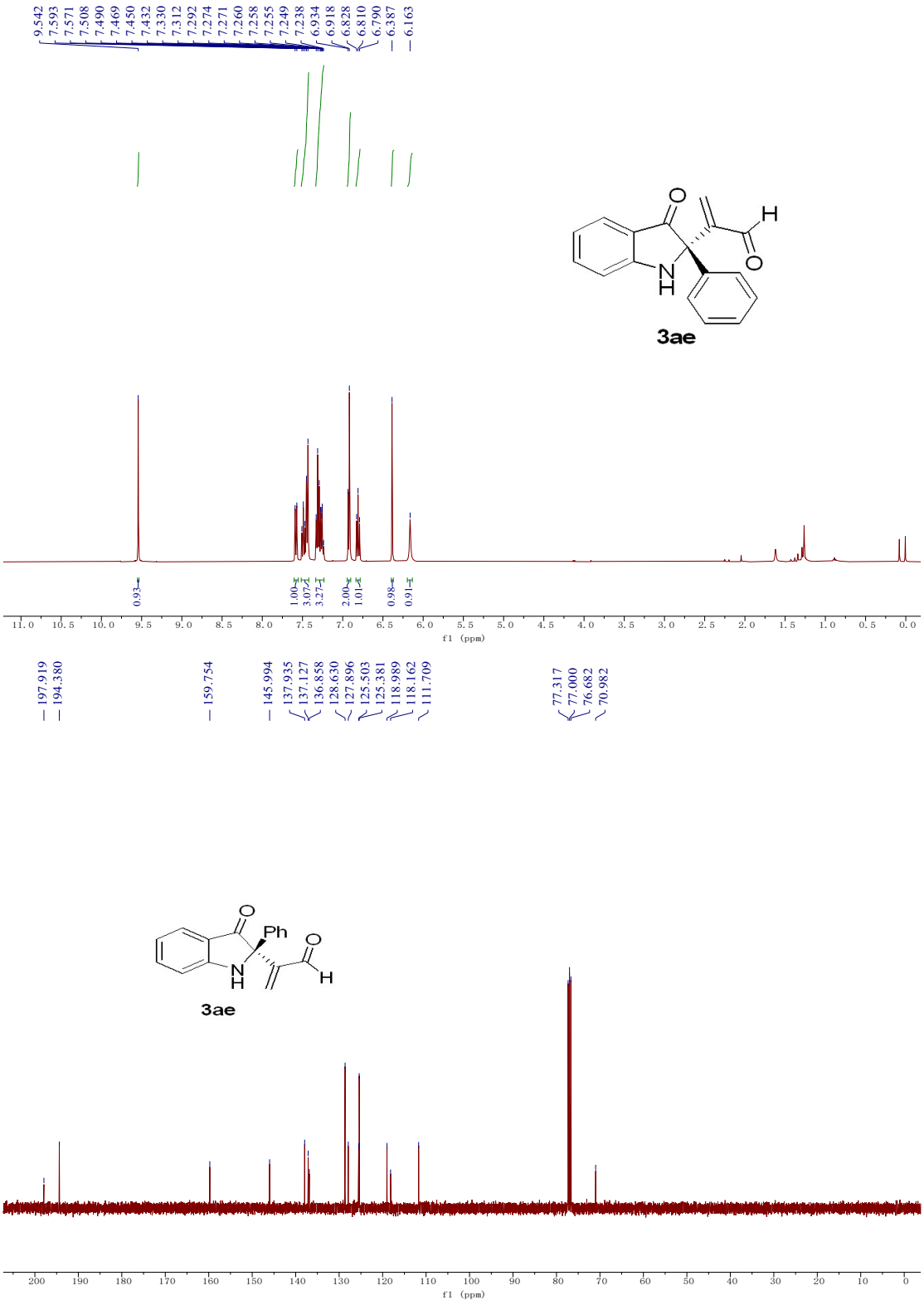
^{1}H and ^{13}C NMR spectra of compound **3ab** (400 MHz, $CDCl_3$)



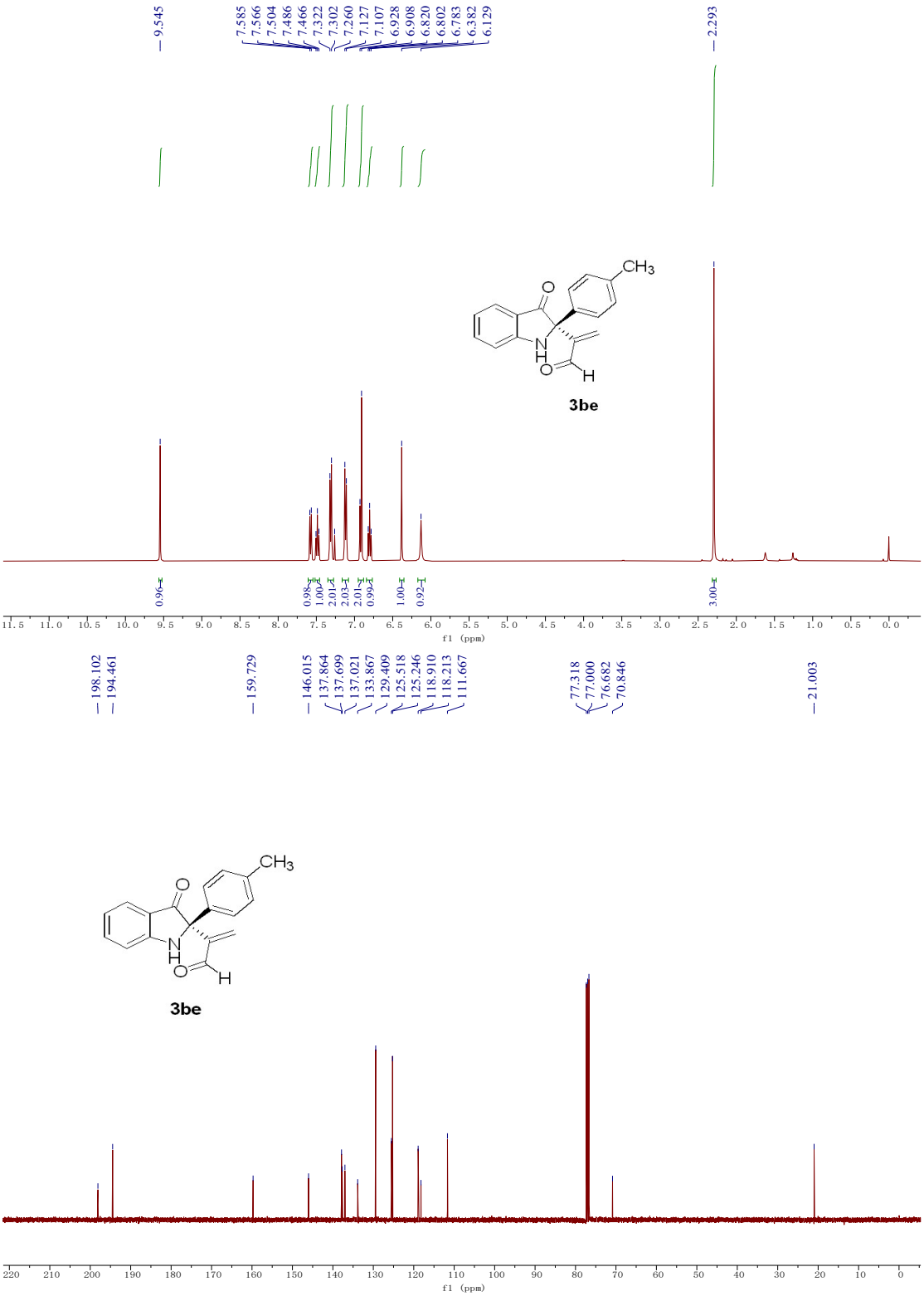
^{1}H and ^{13}C NMR spectra of compound **3ac** (400 MHz, $CDCl_3$)



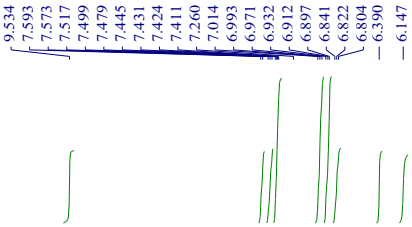
^{1}H and ^{13}C NMR spectra of compound **3ad** (400 MHz, $CDCl_3$)

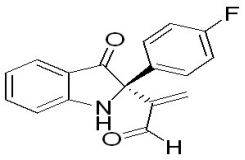


^{1}H and ^{13}C NMR spectra of compound **3ae** (400 MHz, $CDCl_3$)

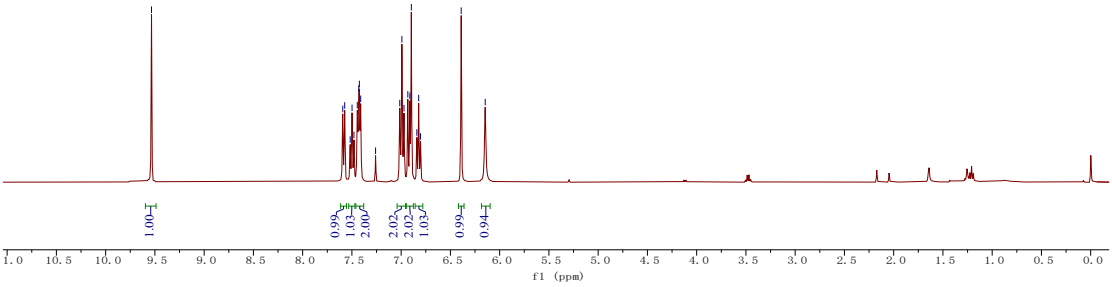


^{1}H and ^{13}C NMR spectra of compound **3be** (400 MHz, $CDCl_3$)

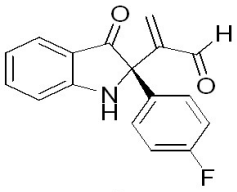

9.534
7.593
7.573
7.517
7.499
7.479
7.445
7.431
7.424
7.411
7.260
7.014
6.993
6.971
6.932
6.912
6.897
6.841
6.822
6.804
6.390
6.147


F
O
N
H
O
H

3ce

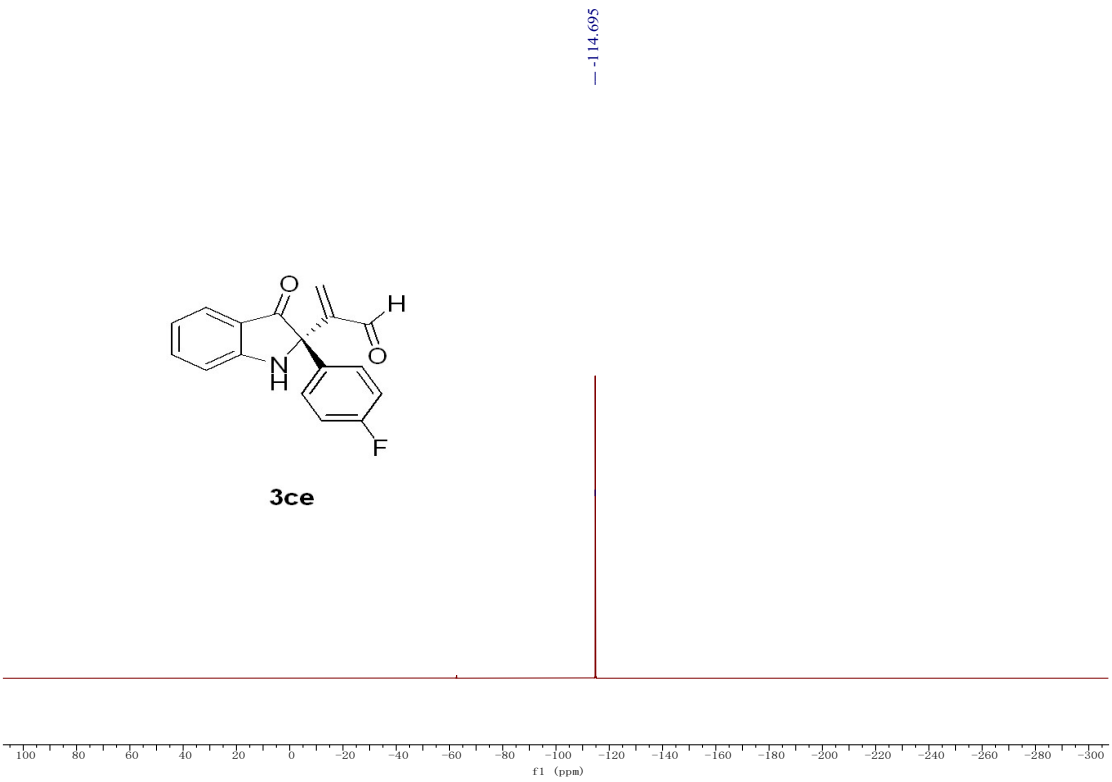

1.00
0.99
1.03
2.00
2.02
2.02
1.03
0.99
0.94
f1 (ppm)


197.839
194.400
163.761
161.306
159.691
145.906
138.078
137.267
132.690
132.661
127.334
127.253
125.531
119.198
118.086
115.599
115.383
111.819
77.318
77.000
76.682
70.477

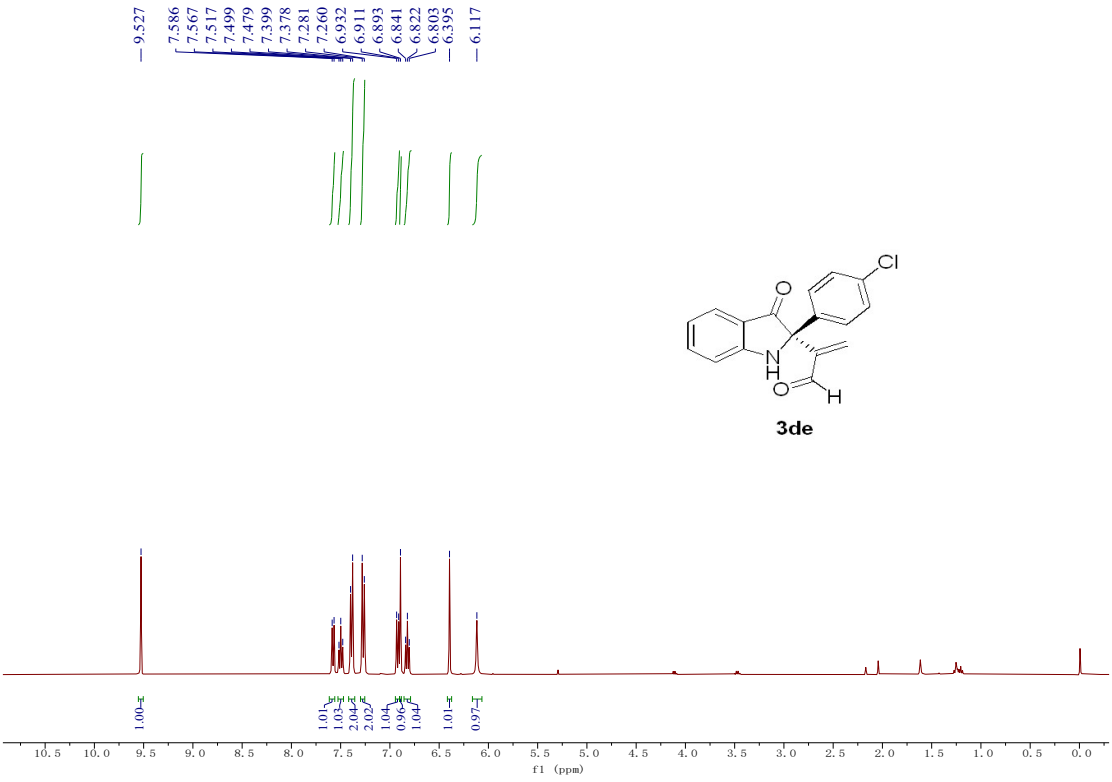

O
H
N
H
O
F

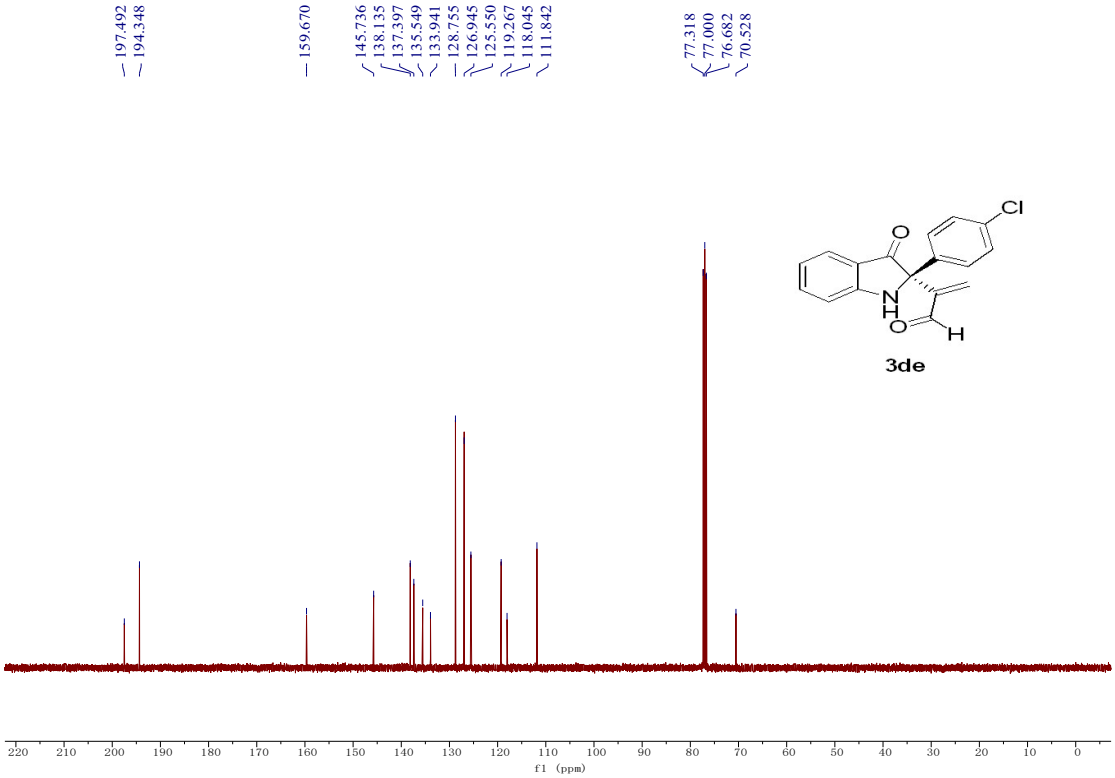
3ce

f1 (ppm)

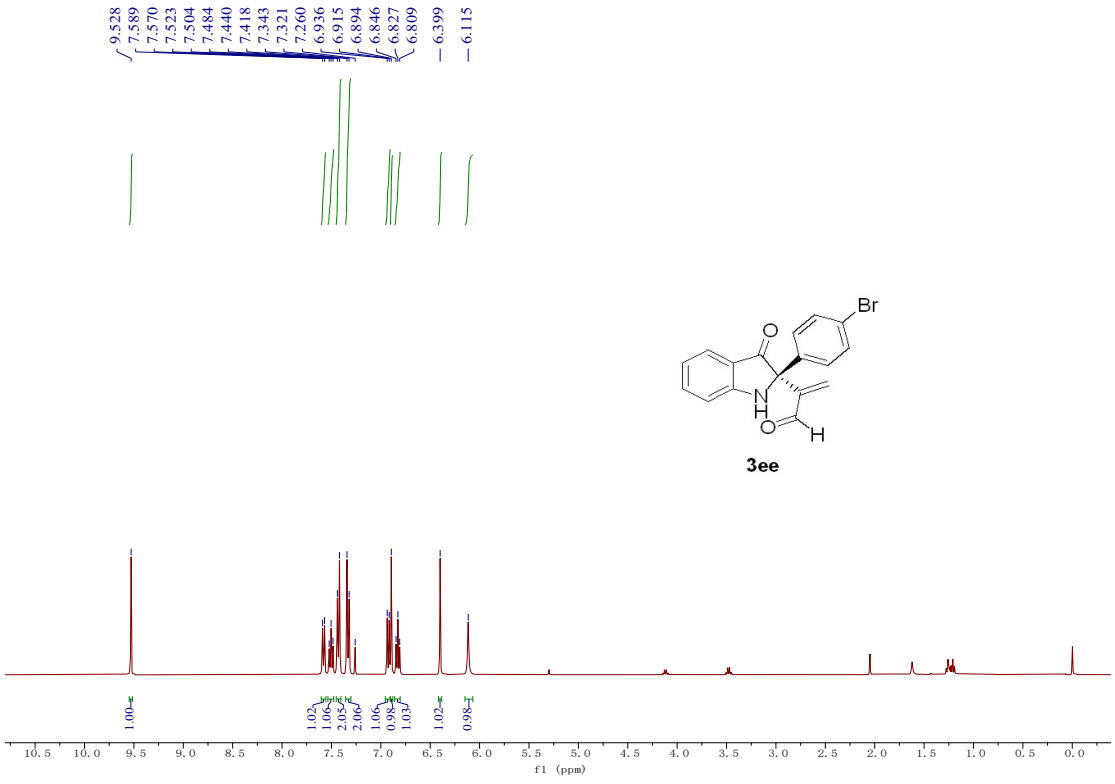


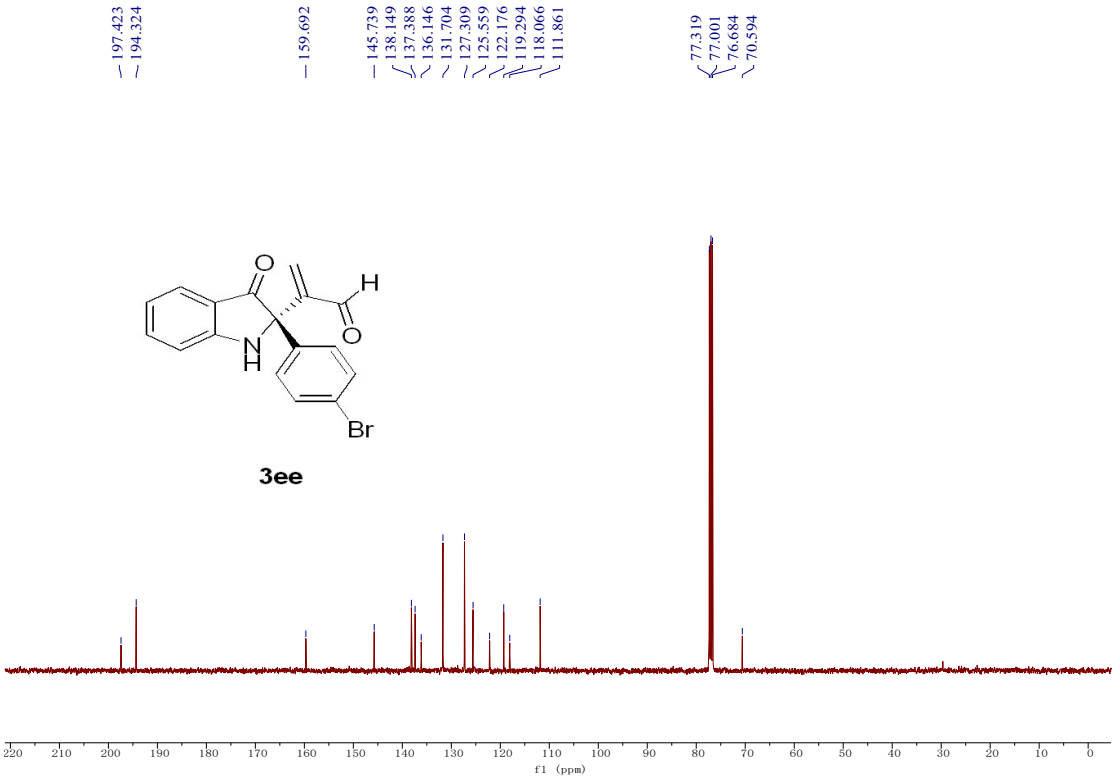
^{1}H, ^{13}C and ^{19}F NMR spectra of compound **3ce** (400 MHz, $CDCl_3$)



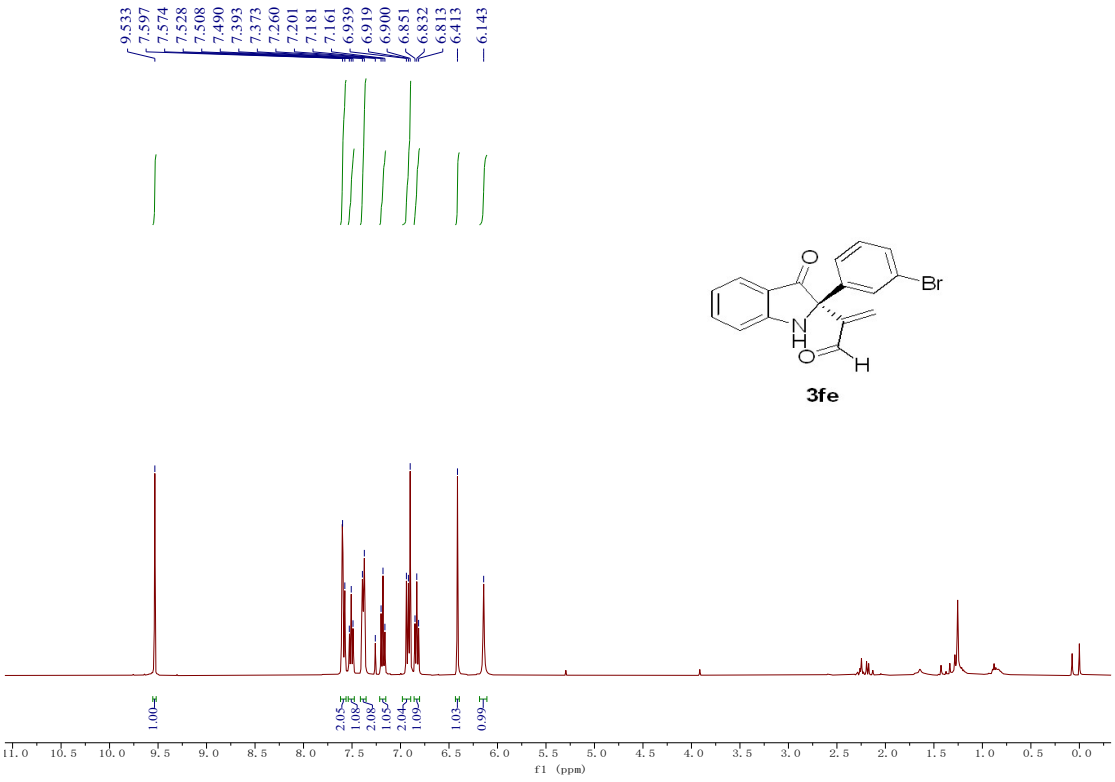


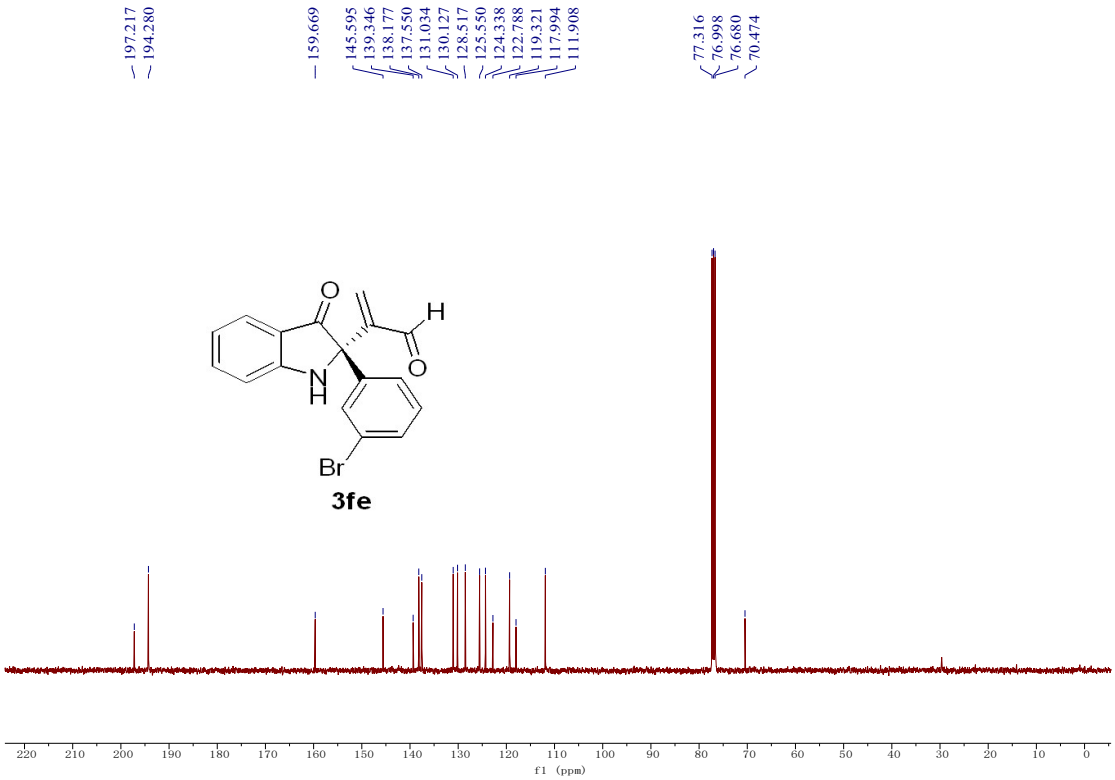
^{1}H and ^{13}C NMR spectra of compound **3de** (400 MHz, $CDCl_3$)



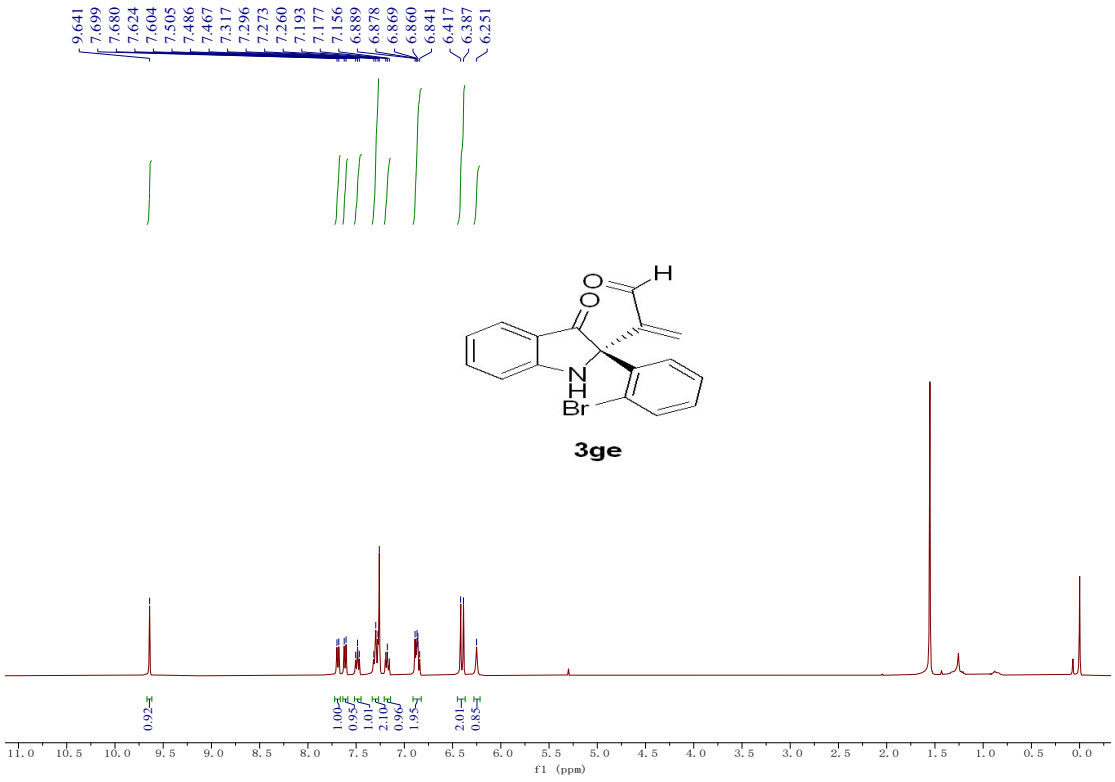


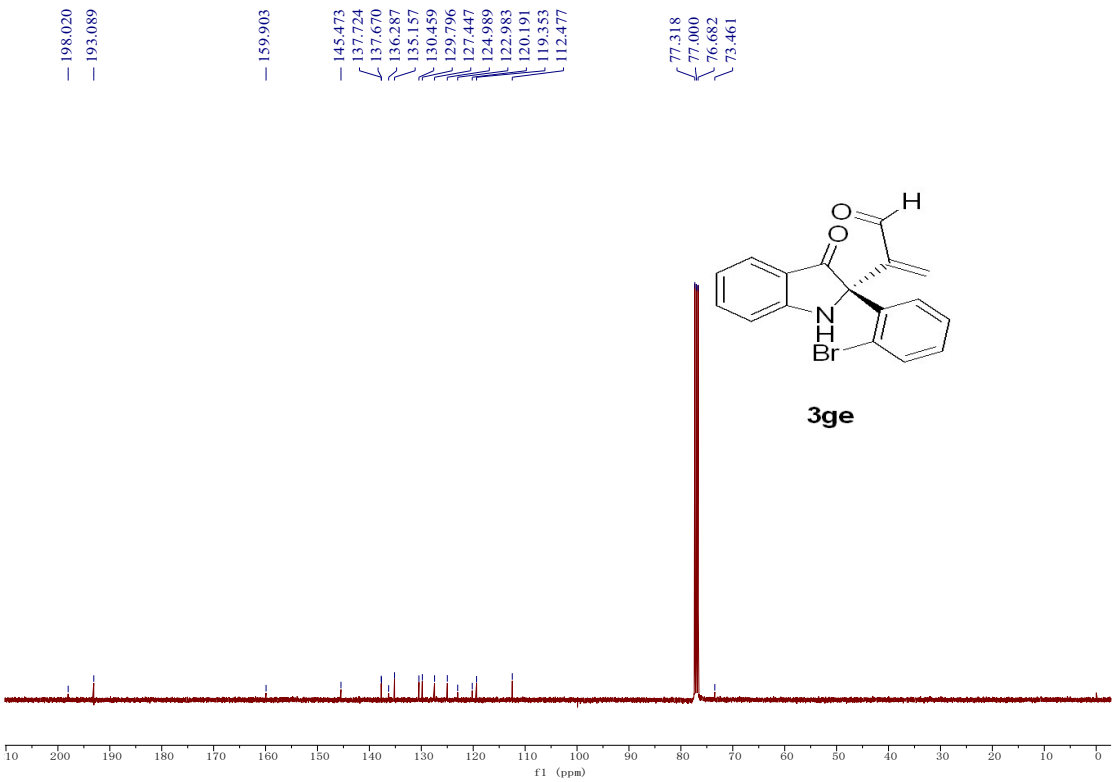
^{1}H and ^{13}C NMR spectra of compound **3ee** (400 MHz, $CDCl_3$)



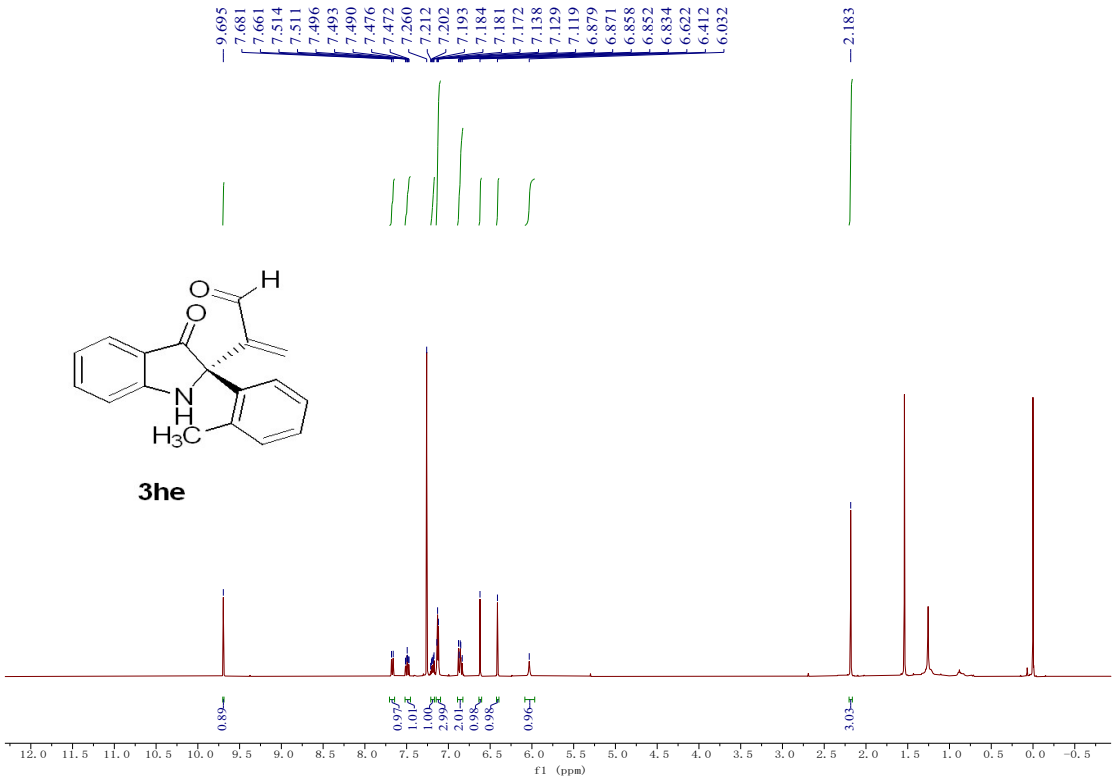


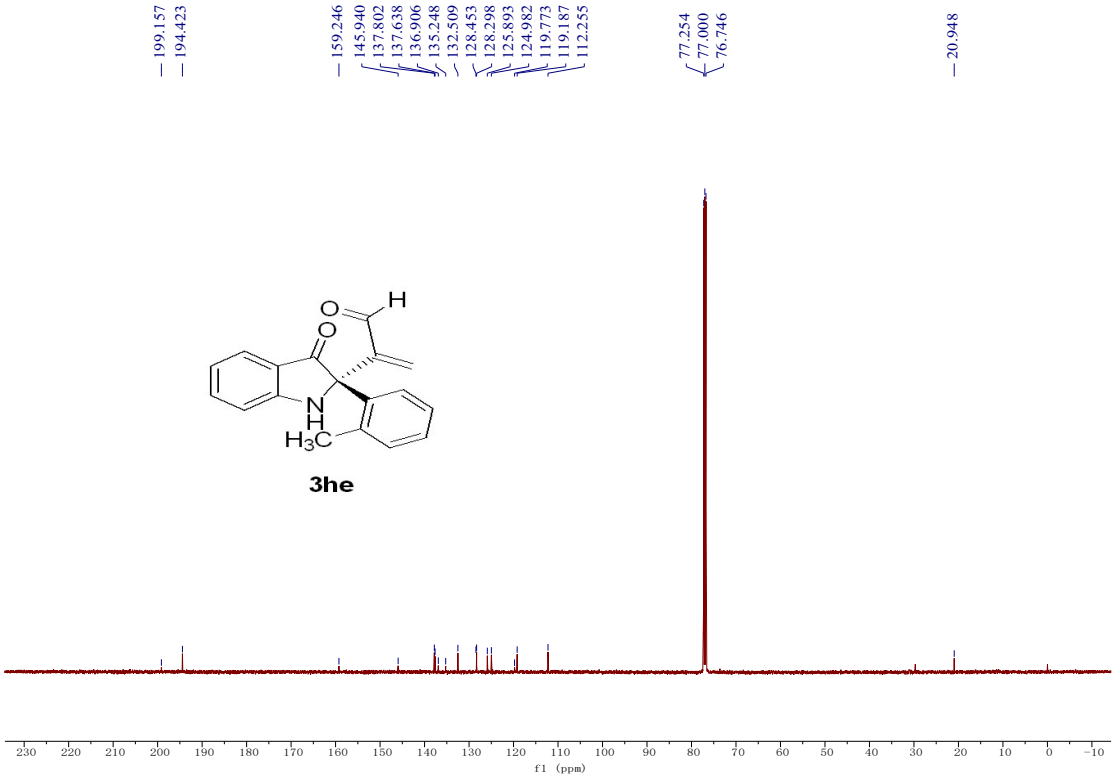
^{1}H and ^{13}C NMR spectra of compound **3fe** (400 MHz, $CDCl_3$)



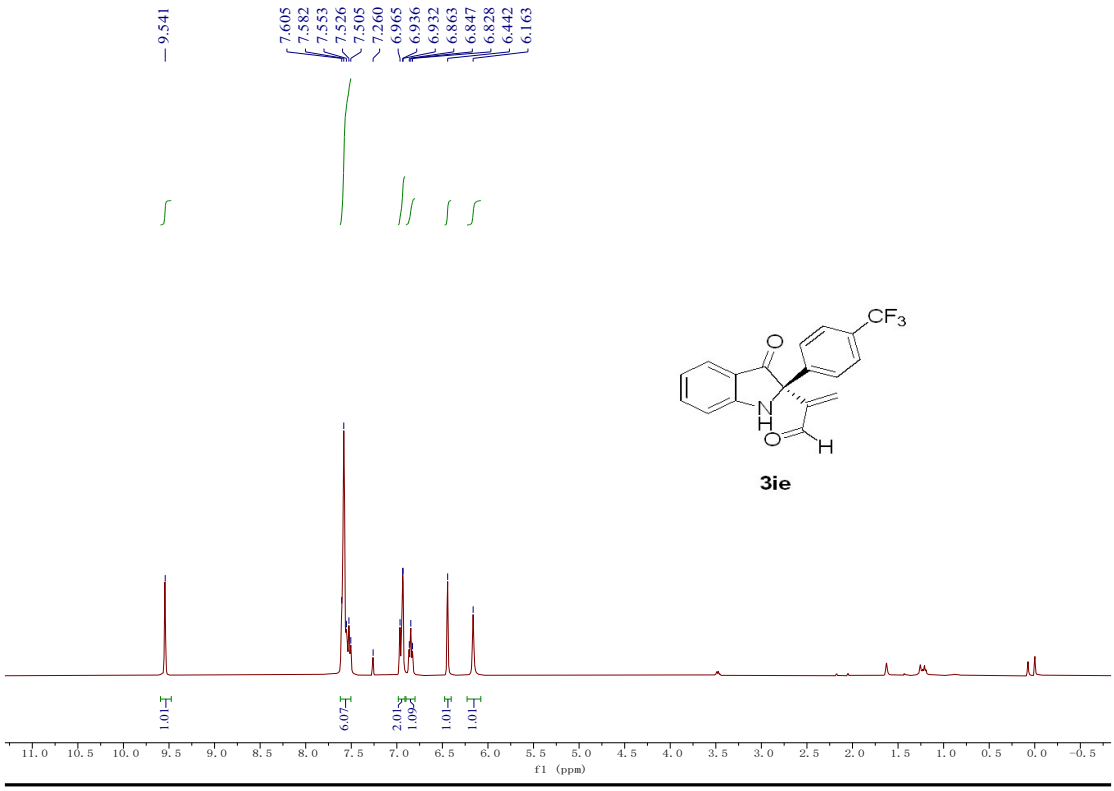


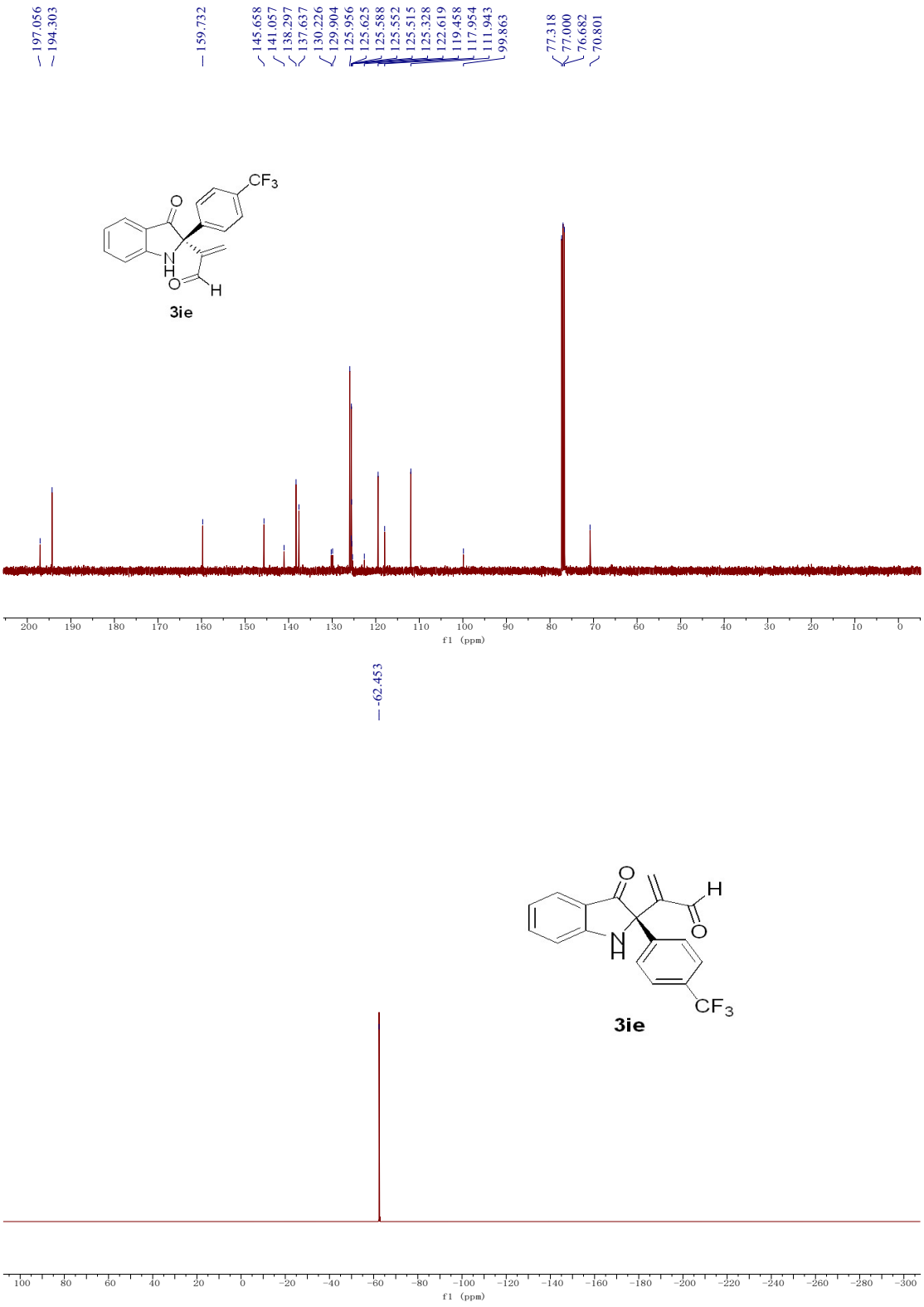
^{1}H and ^{13}C NMR spectra of compound **3ge** (400 MHz, $CDCl_3$)



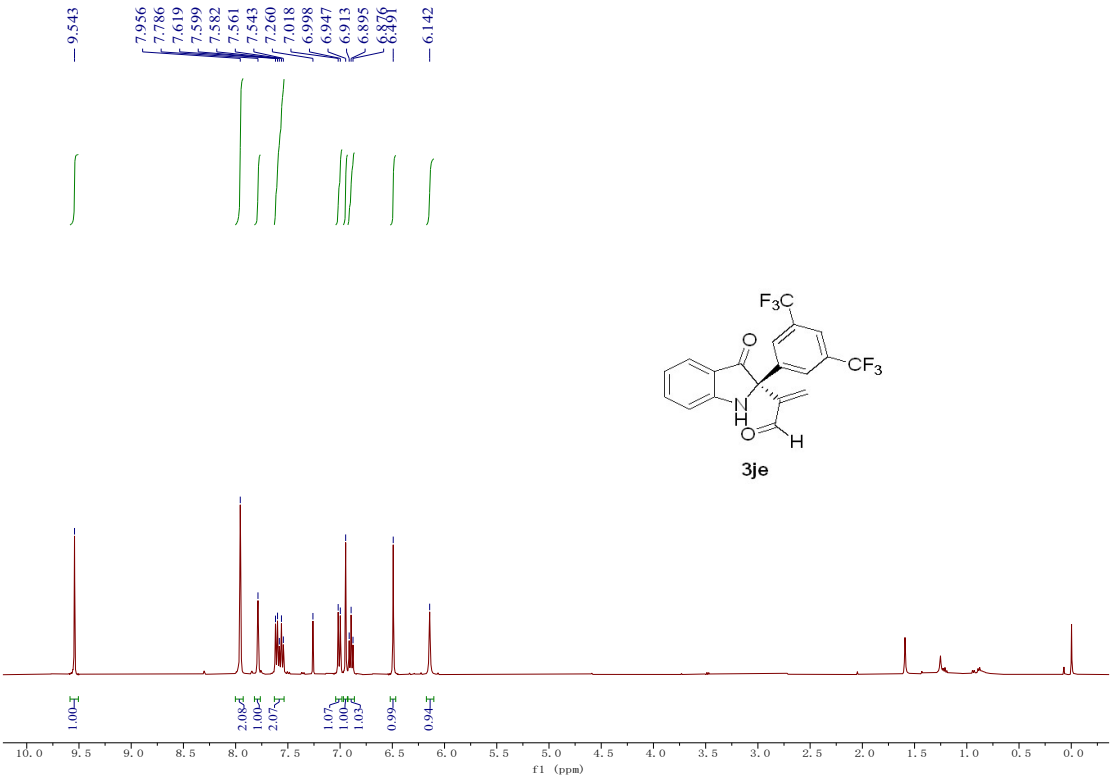


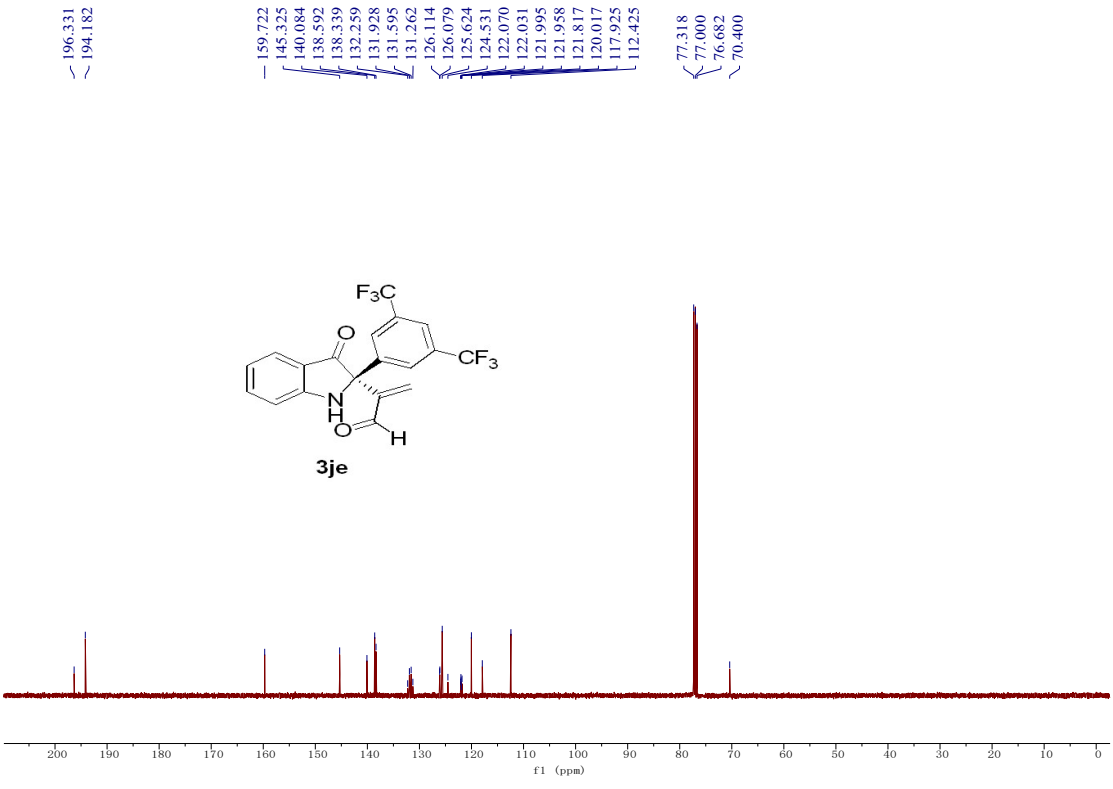
^{1}H and ^{13}C NMR spectra of compound **3he** (400 MHz, $CDCl_3$)

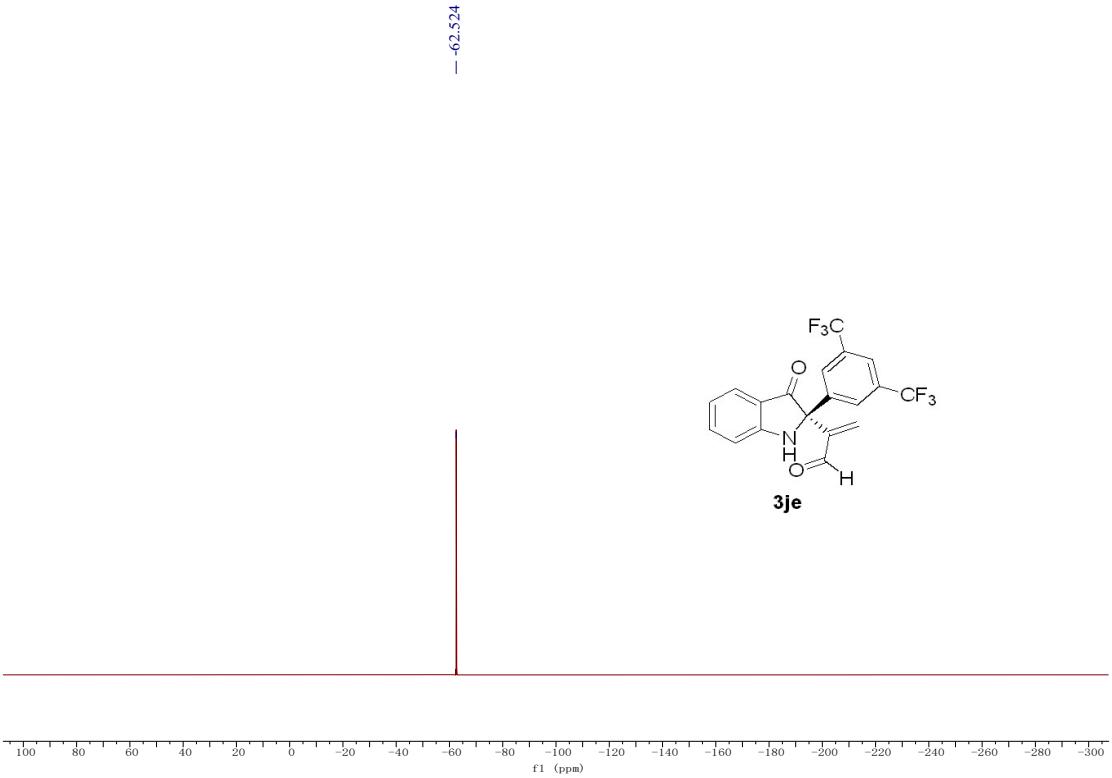




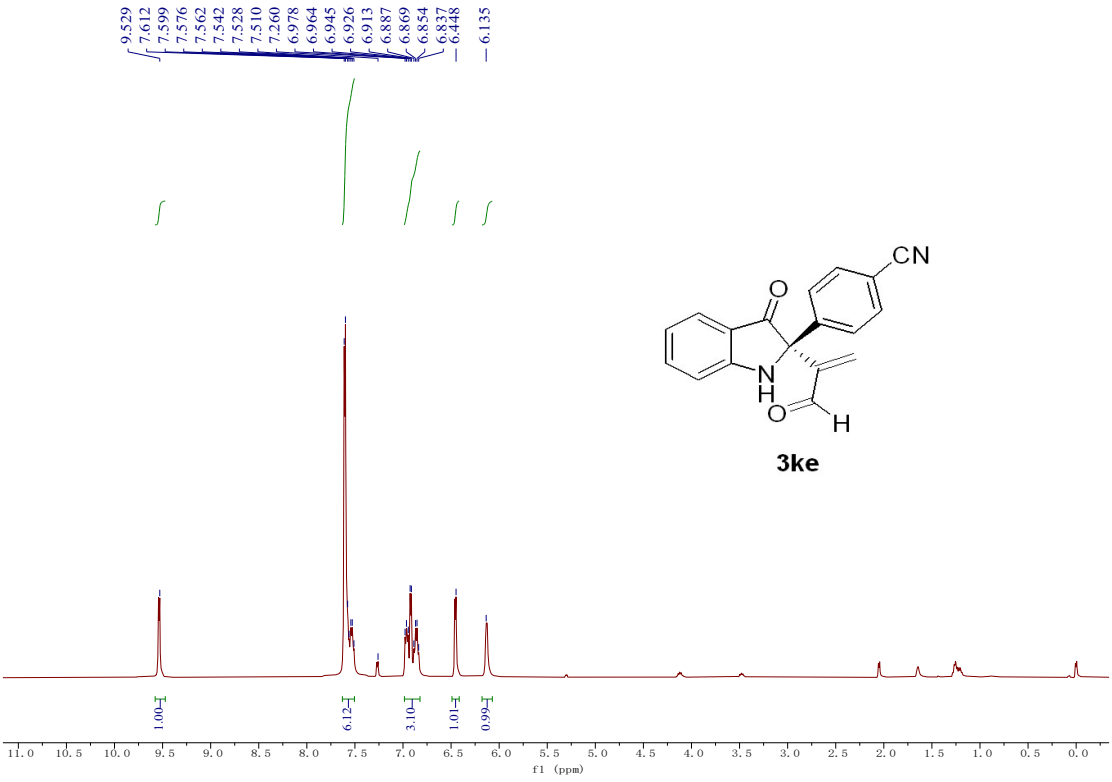
^{1}H, ^{13}C and ^{19}F NMR spectra of compound **3ie** (400 MHz, $CDCl_3$)

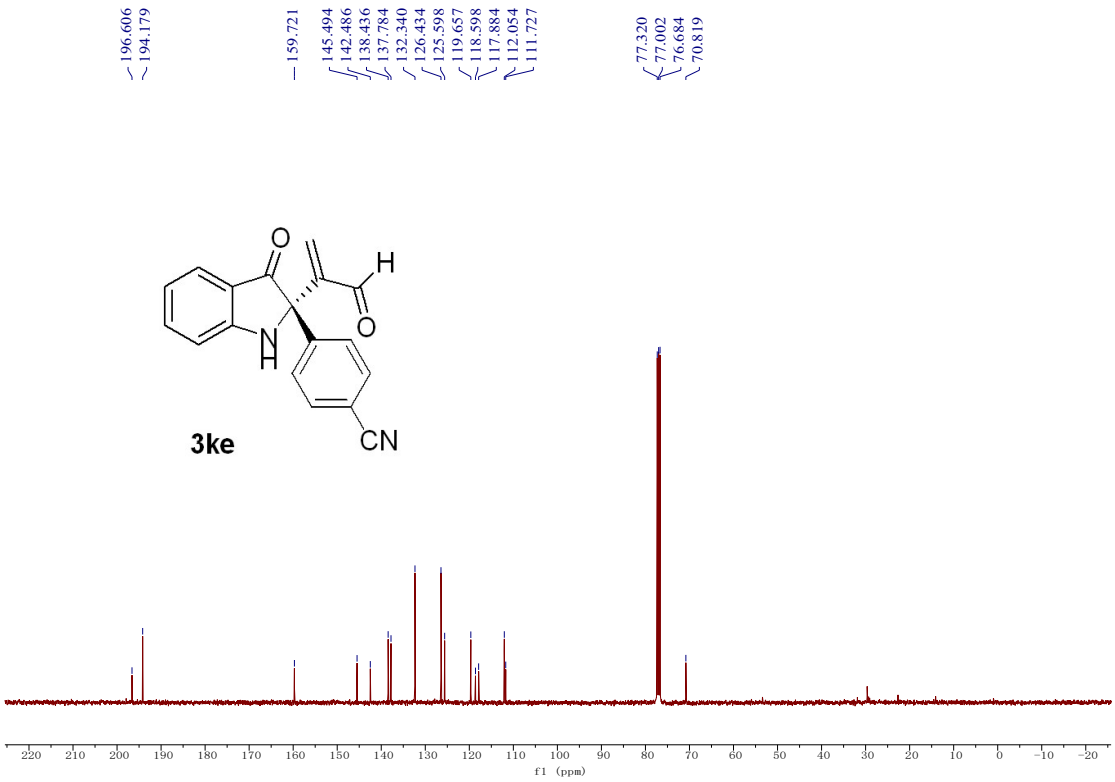

9.543
7.956
7.786
7.619
7.599
7.582
7.561
7.543
7.260
7.018
6.998
6.947
6.913
6.895
6.876
6.491
6.142
F3C
CF3
O
N
H
O
H
3je
1.00
2.08
1.00
2.07
1.07
1.00
1.03
0.99
0.94
f1 (ppm)


196.331
194.182
159.722
145.325
140.084
138.592
138.339
132.259
131.928
131.595
131.262
126.114
126.079
125.624
124.531
122.070
122.031
121.995
121.958
121.817
120.017
117.925
112.425
77.318
77.000
76.682
70.400
F3C
CF3
O
N
H
O
H
3je
f1 (ppm)

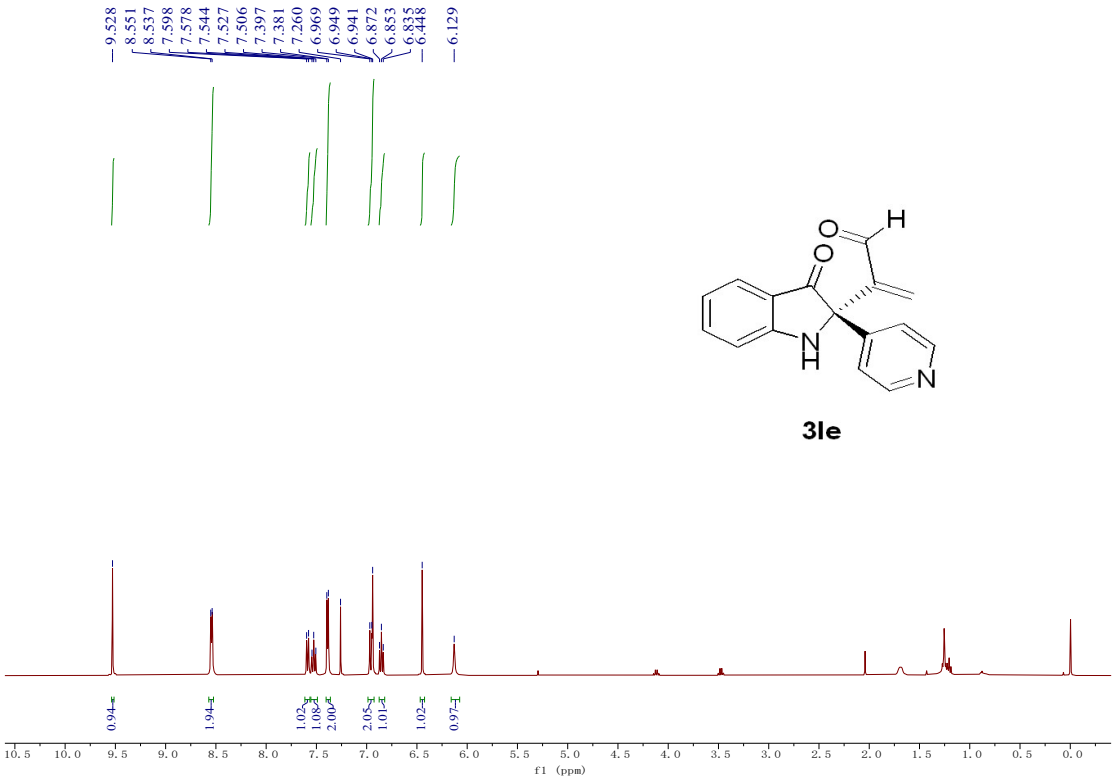


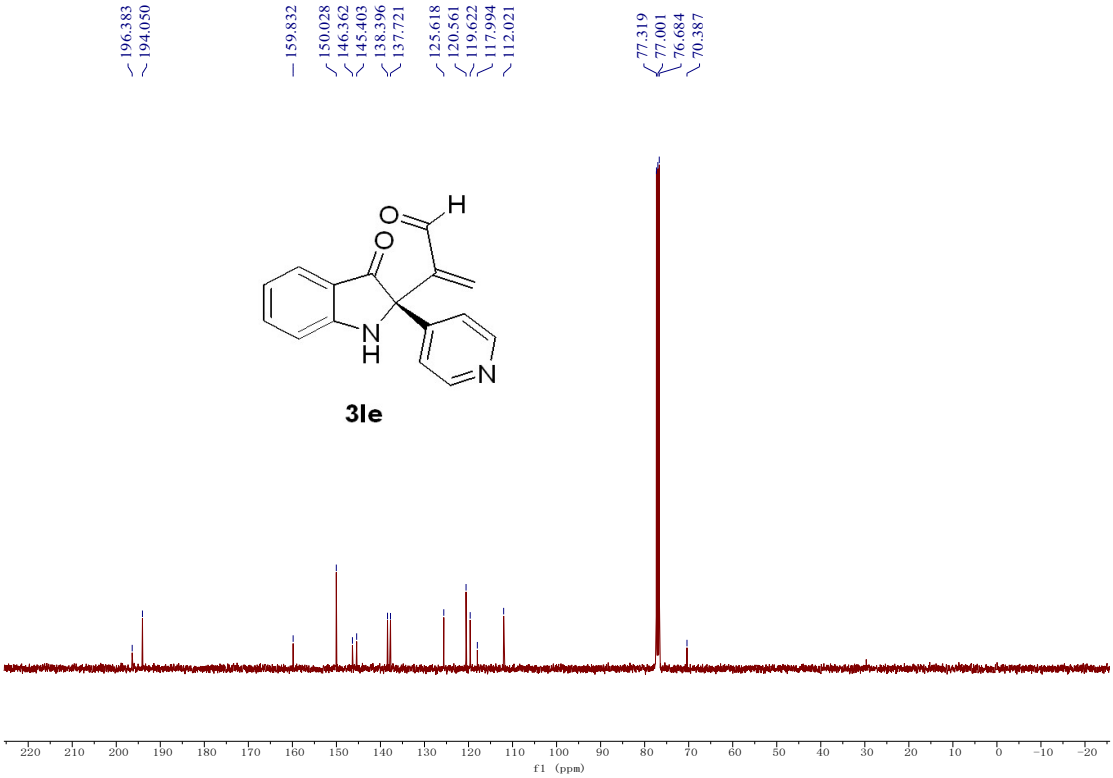
^{1}H ,^{13}C and ^{19}F NMR spectra of compound **3je** (400 MHz, $CDCl_3$)



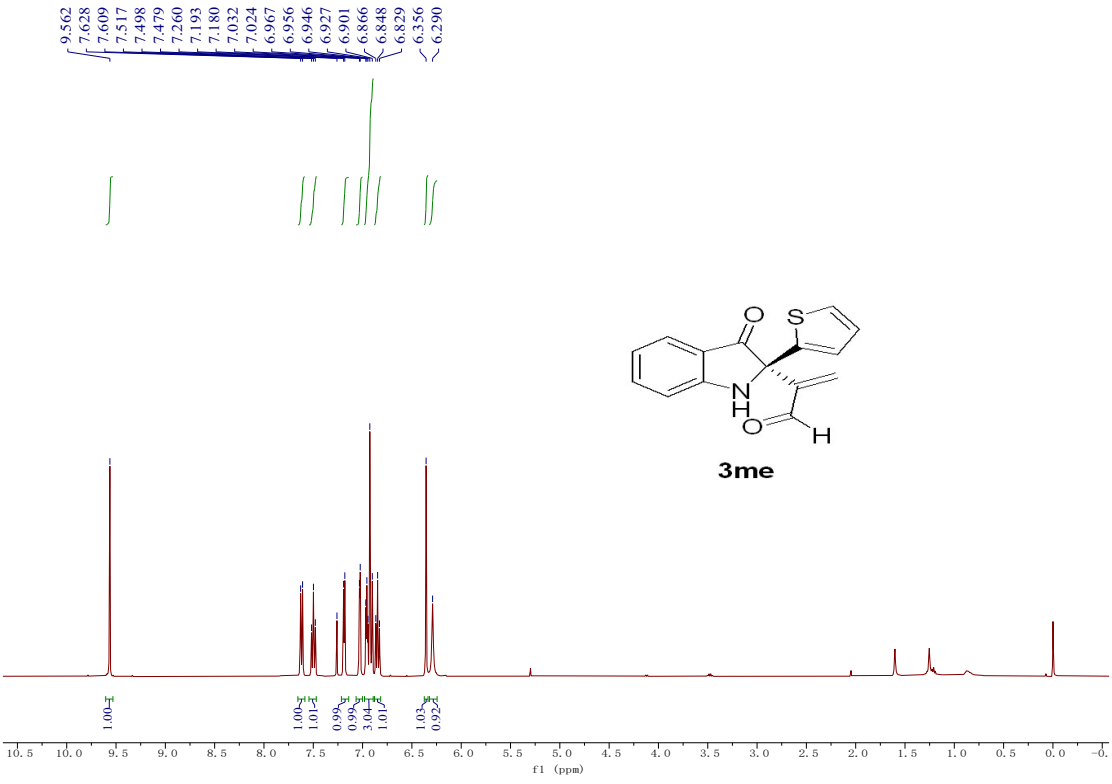


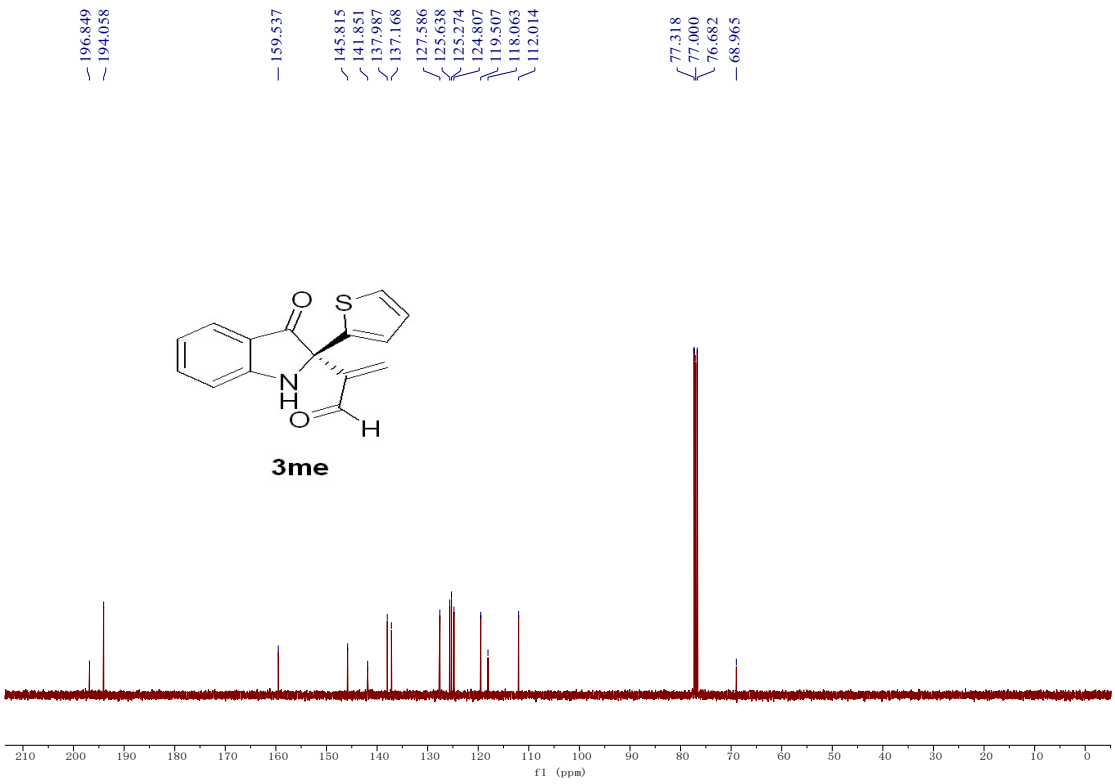
^{1}H and ^{13}C NMR spectra of compound **3ke** (400 MHz, $CDCl_3$)



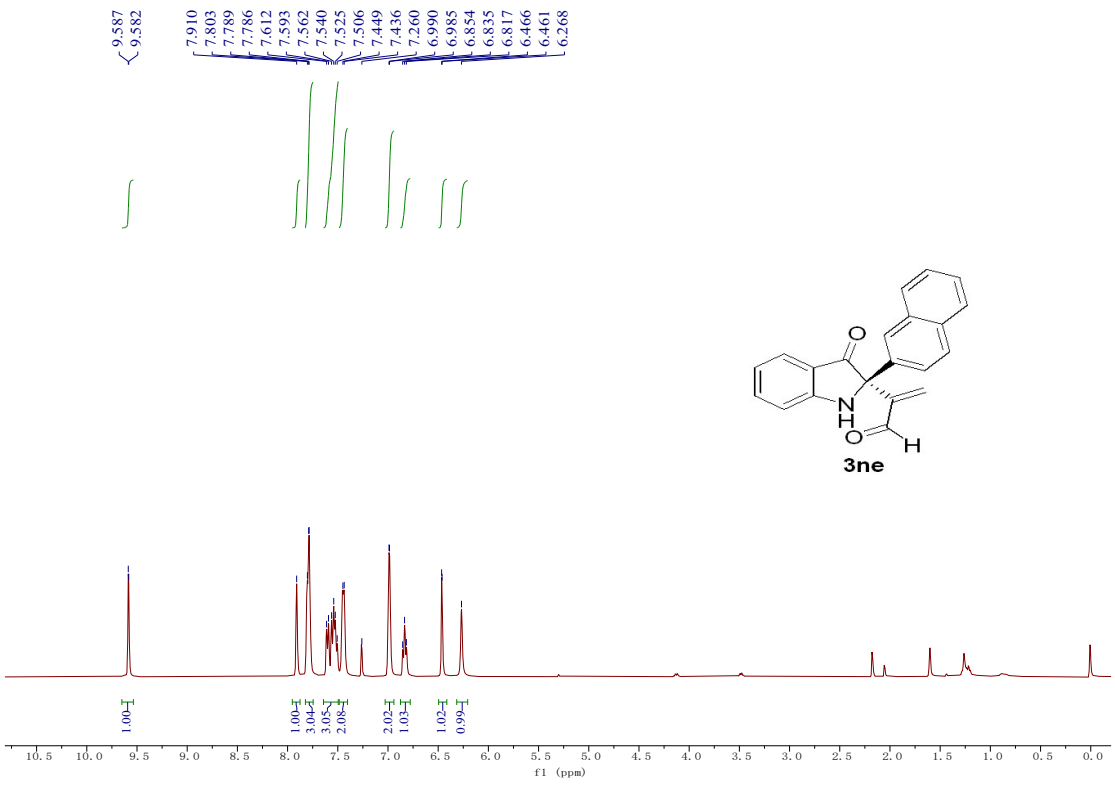


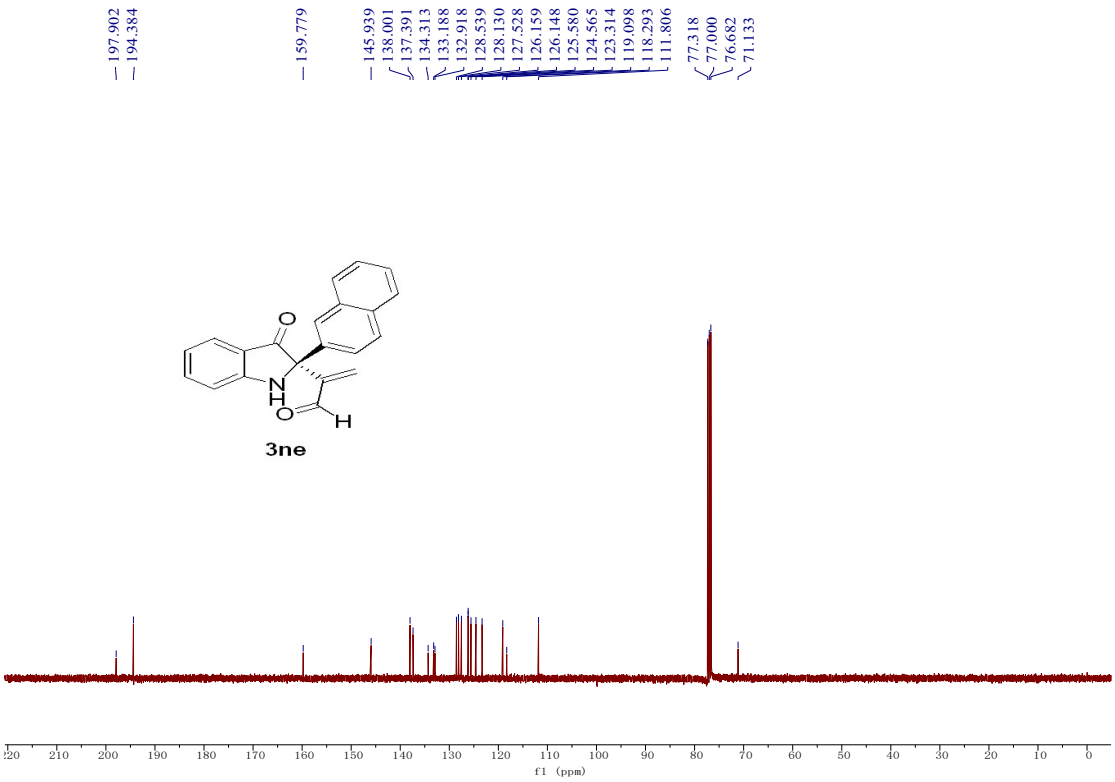
^{1}H and ^{13}C NMR spectra of compound **3le** (400 MHz, $CDCl_3$)



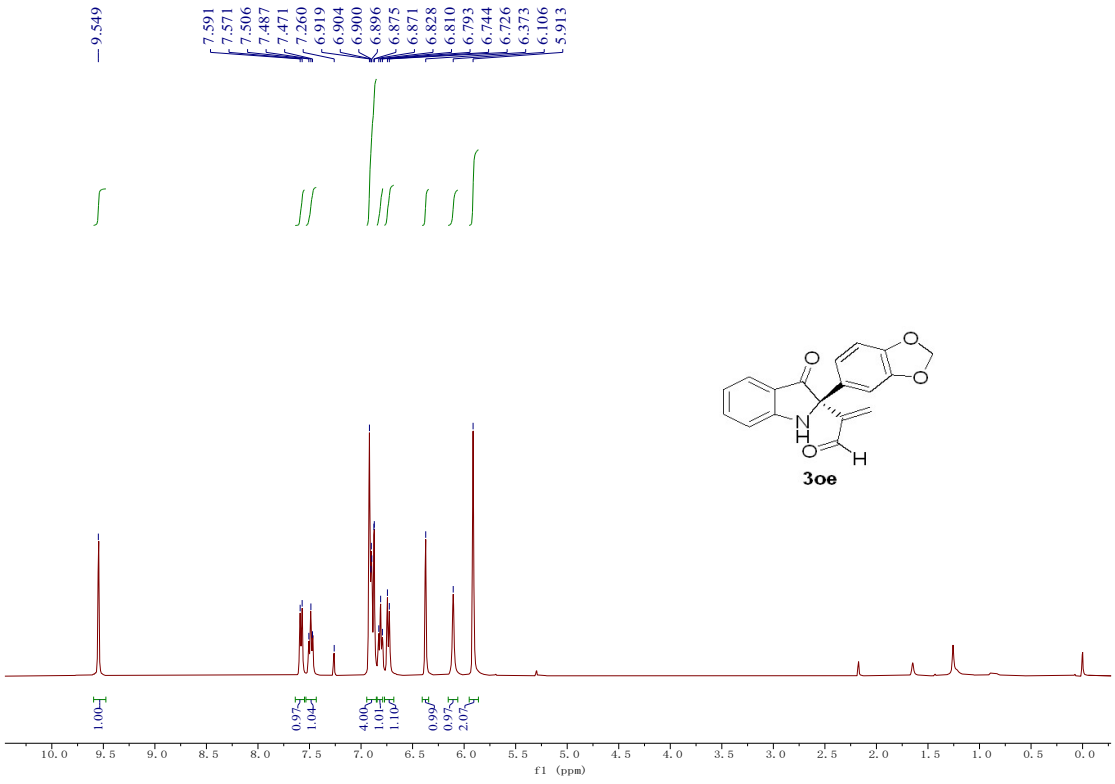


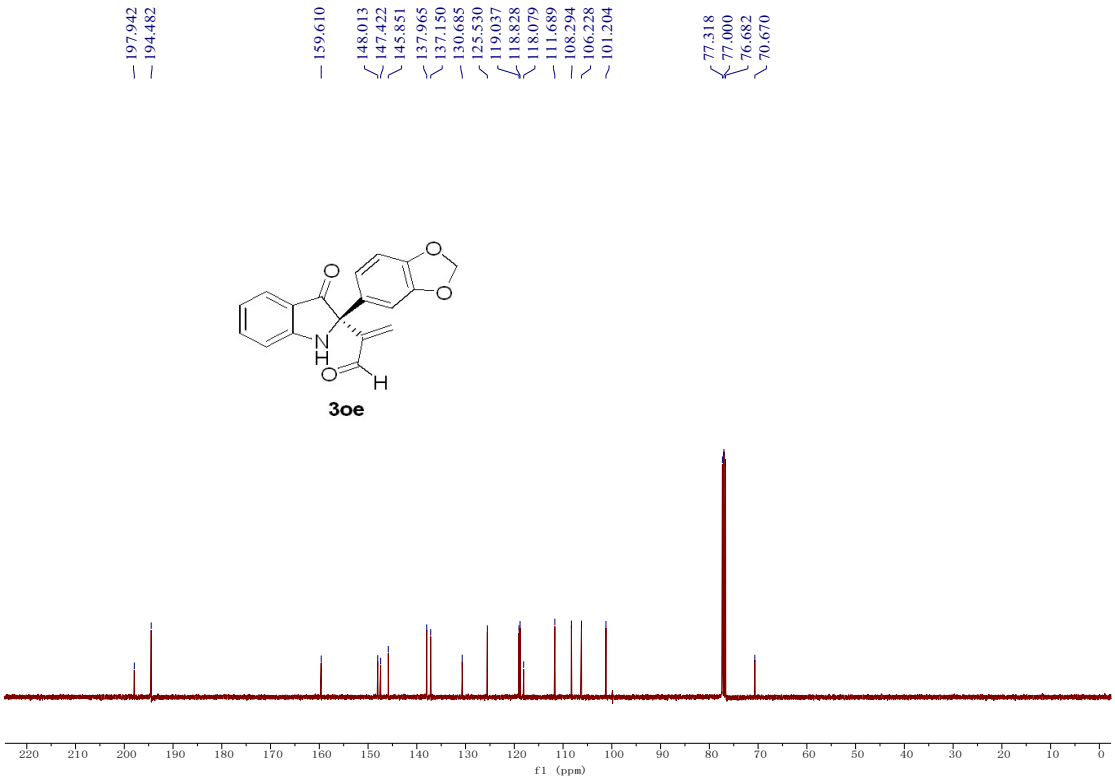
^{1}H and ^{13}C NMR spectra of compound **3me** (400 MHz, $CDCl_3$)



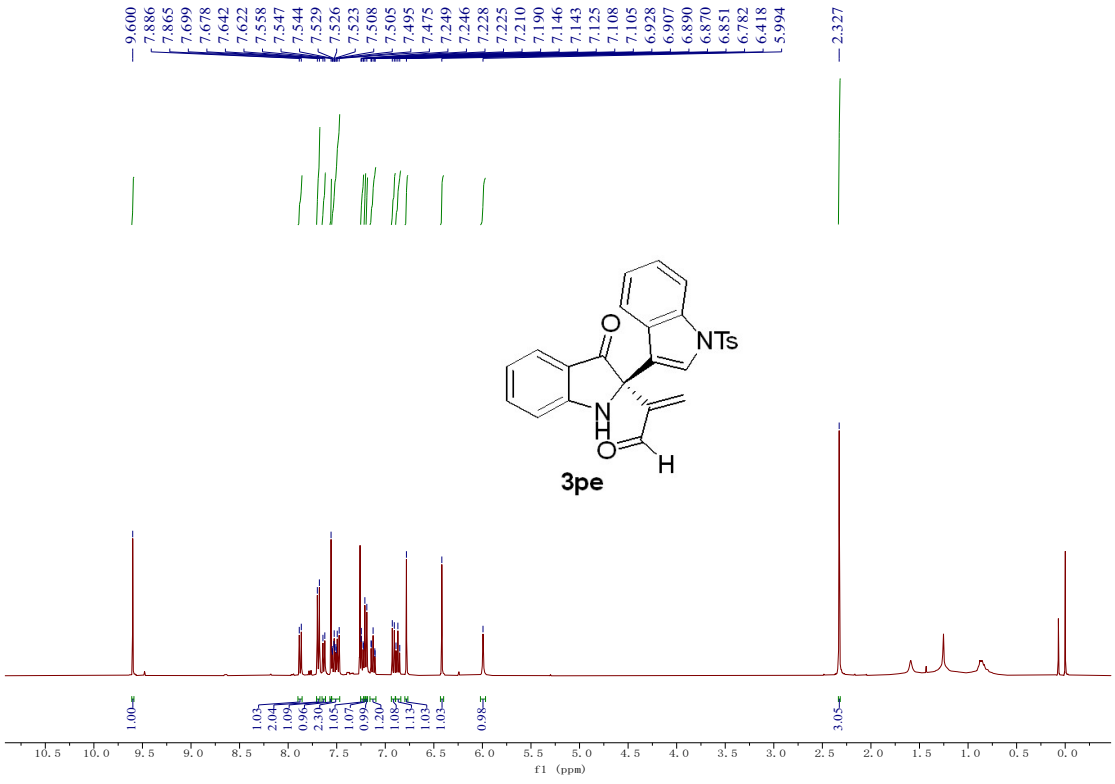


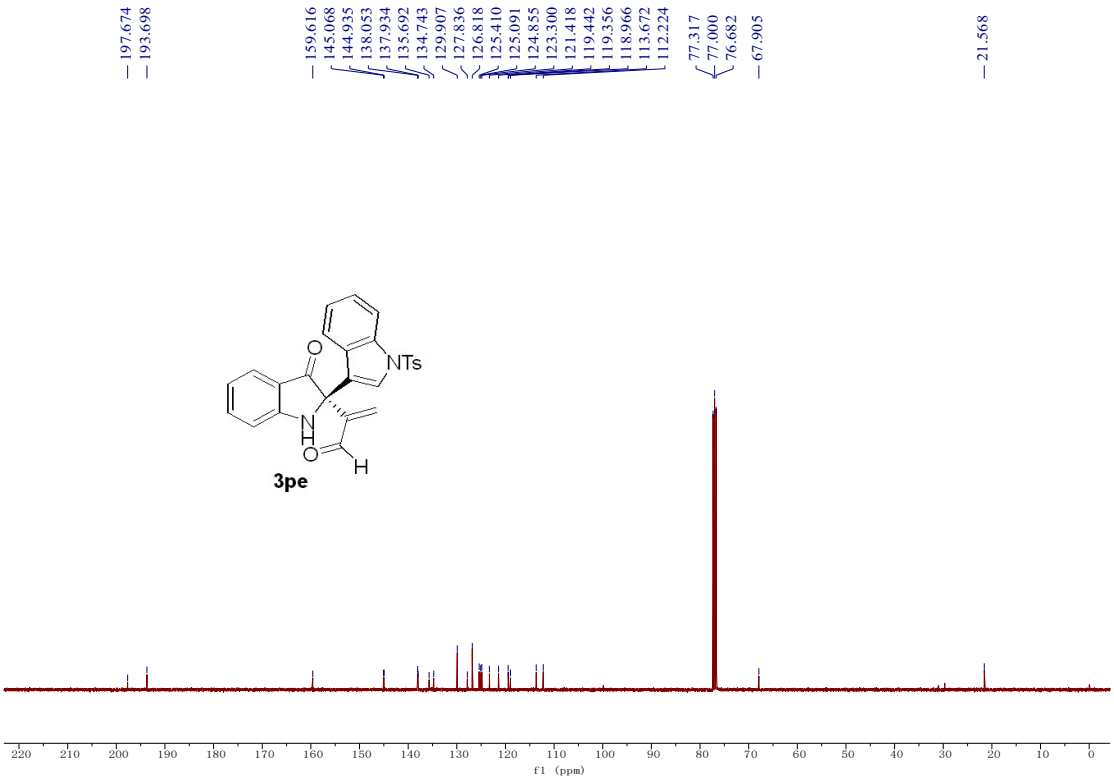
^{1}H and ^{13}C NMR spectra of compound **3ne** (400 MHz, $CDCl_3$)



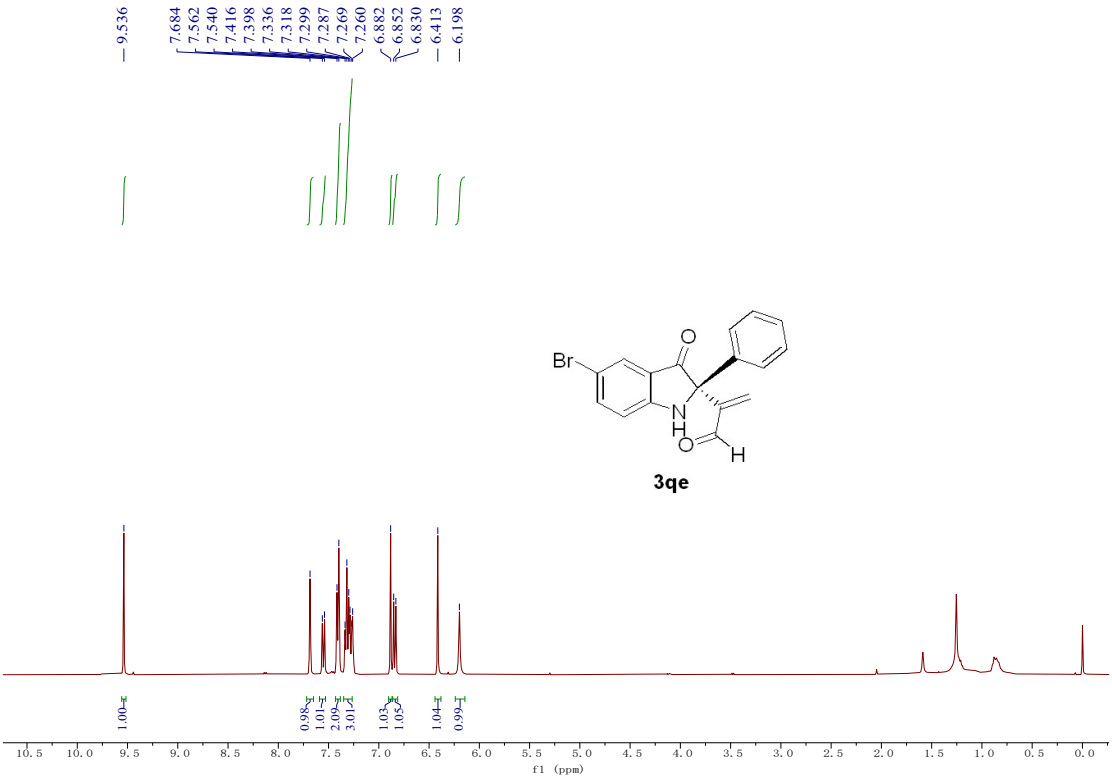


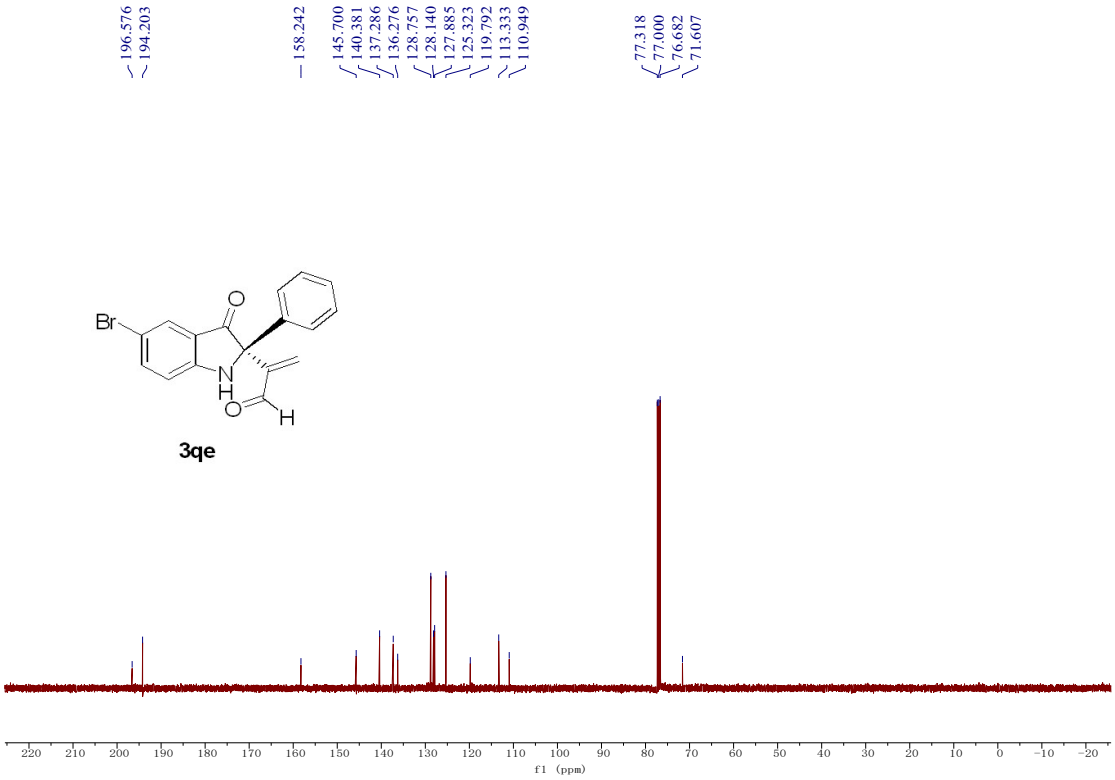
^{1}H and ^{13}C NMR spectra of compound **3oe** (400 MHz, $CDCl_3$)



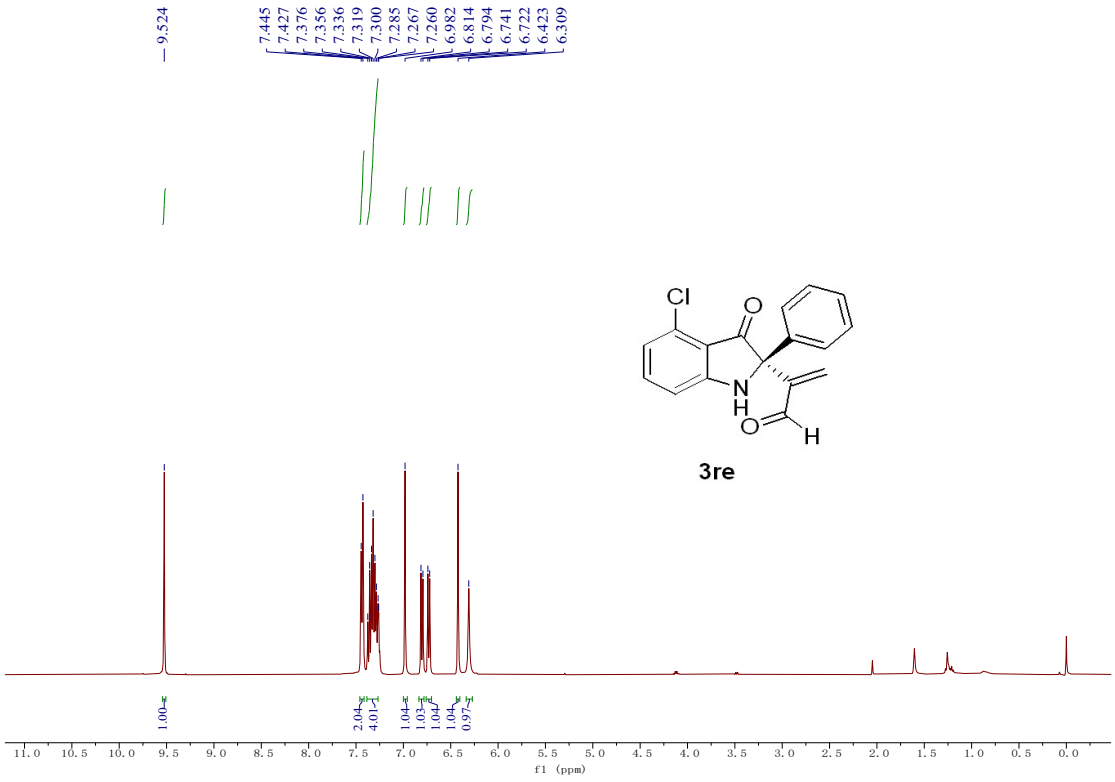


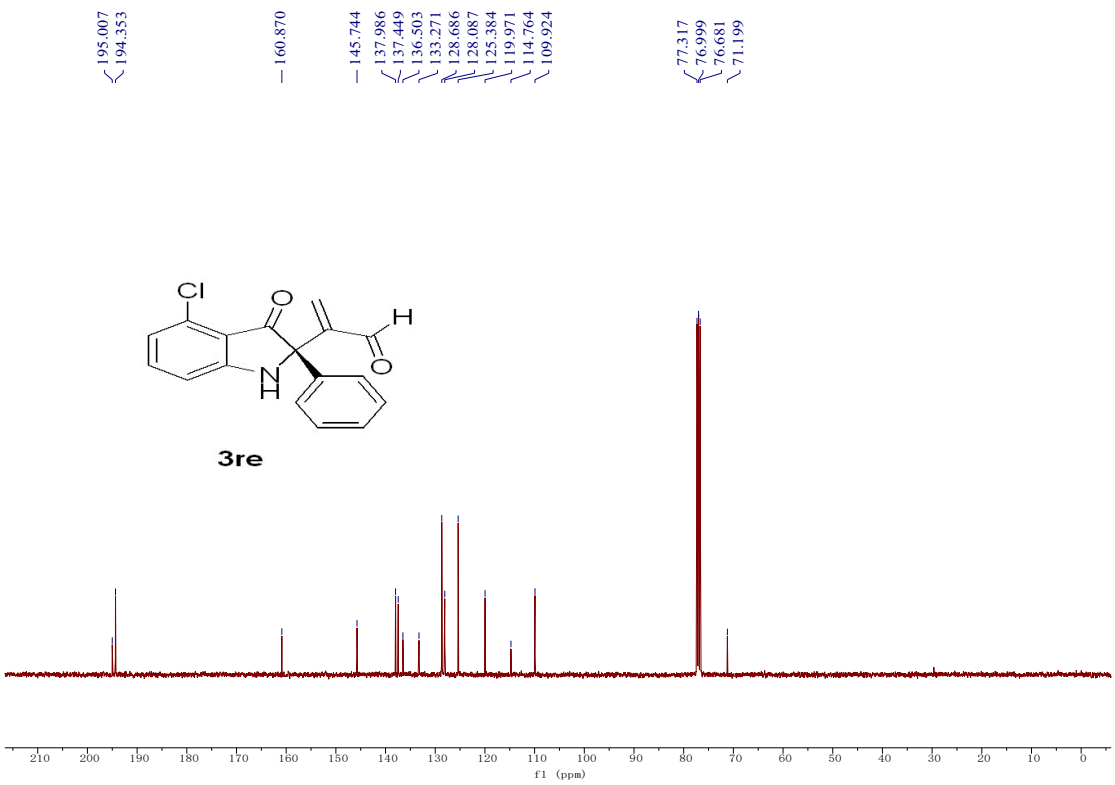
^{1}H and ^{13}C NMR spectra of compound **3pe** (400 MHz, $CDCl_3$)



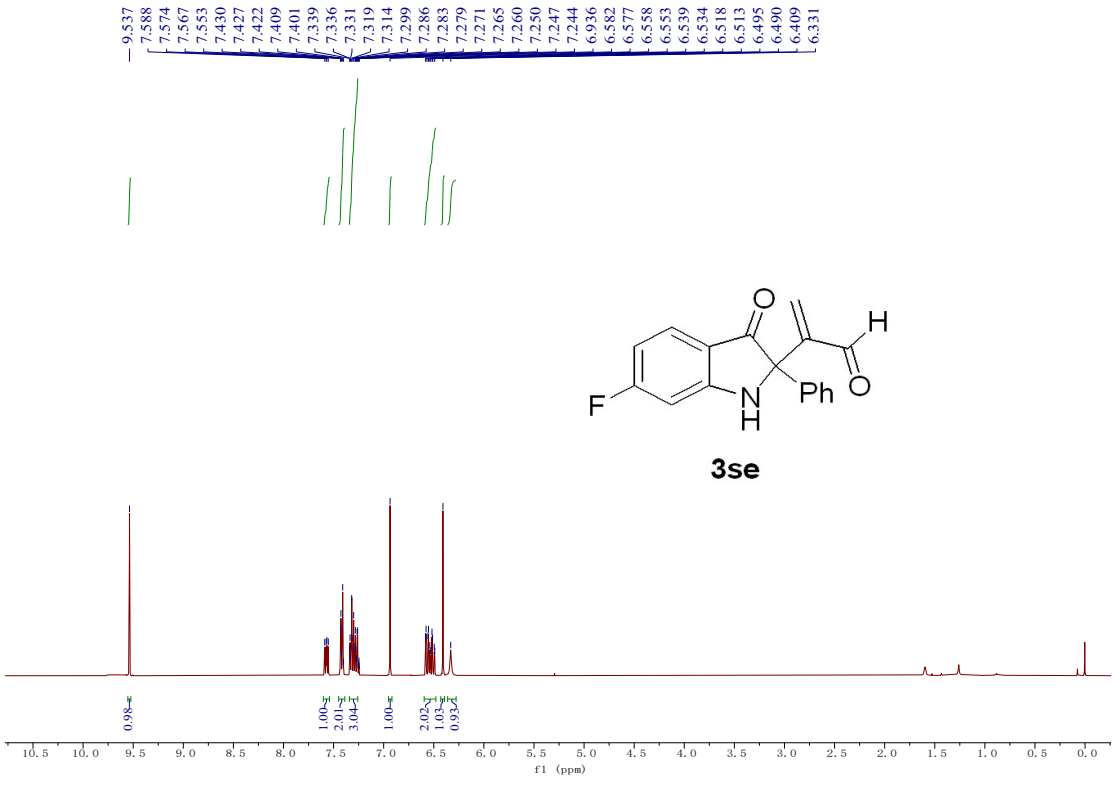


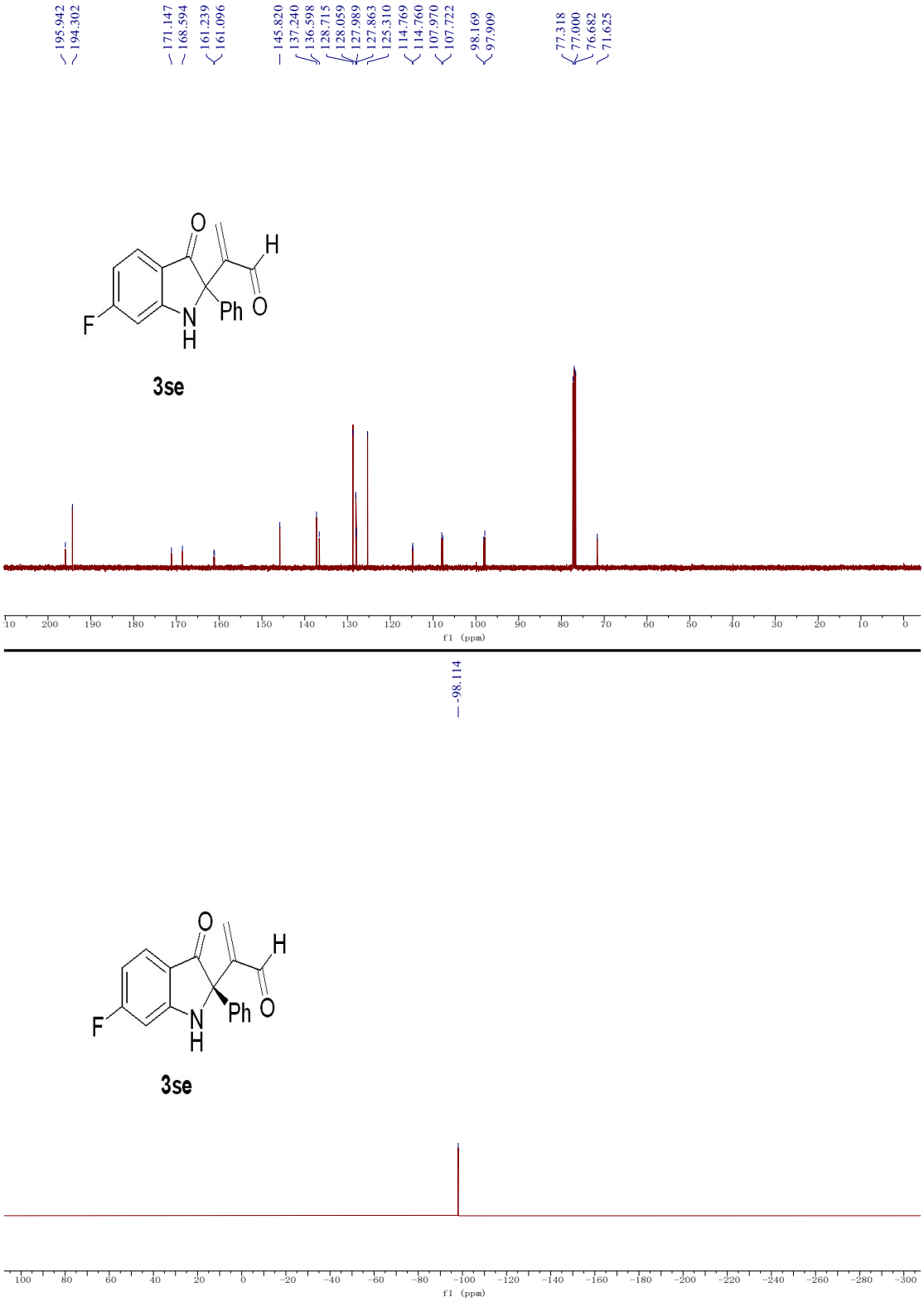
^{1}H and ^{13}C NMR spectra of compound **3qe** (400 MHz, $CDCl_3$)



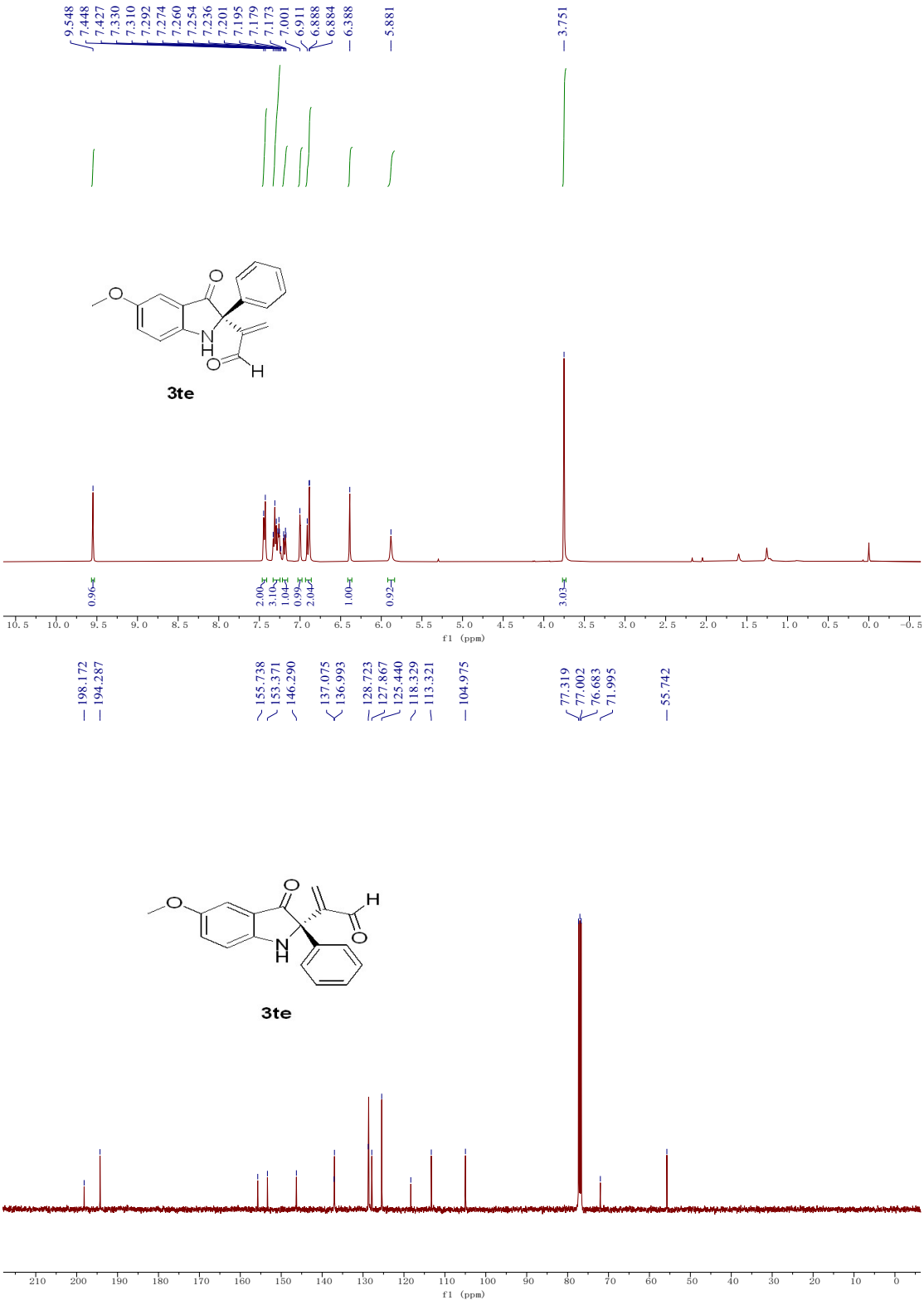


^{1}H and ^{13}C NMR spectra of compound **3re** (400 MHz, $CDCl_3$)

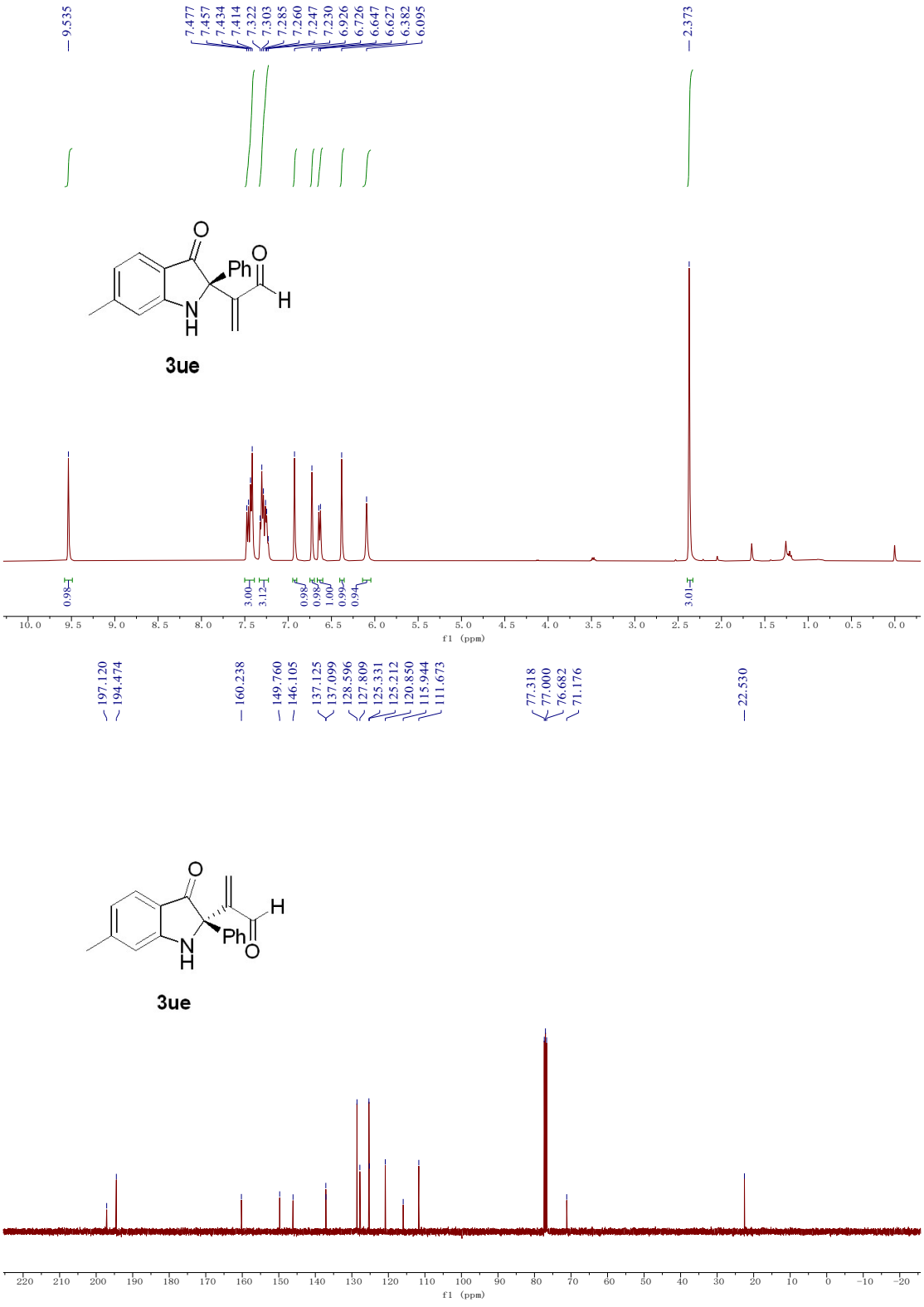




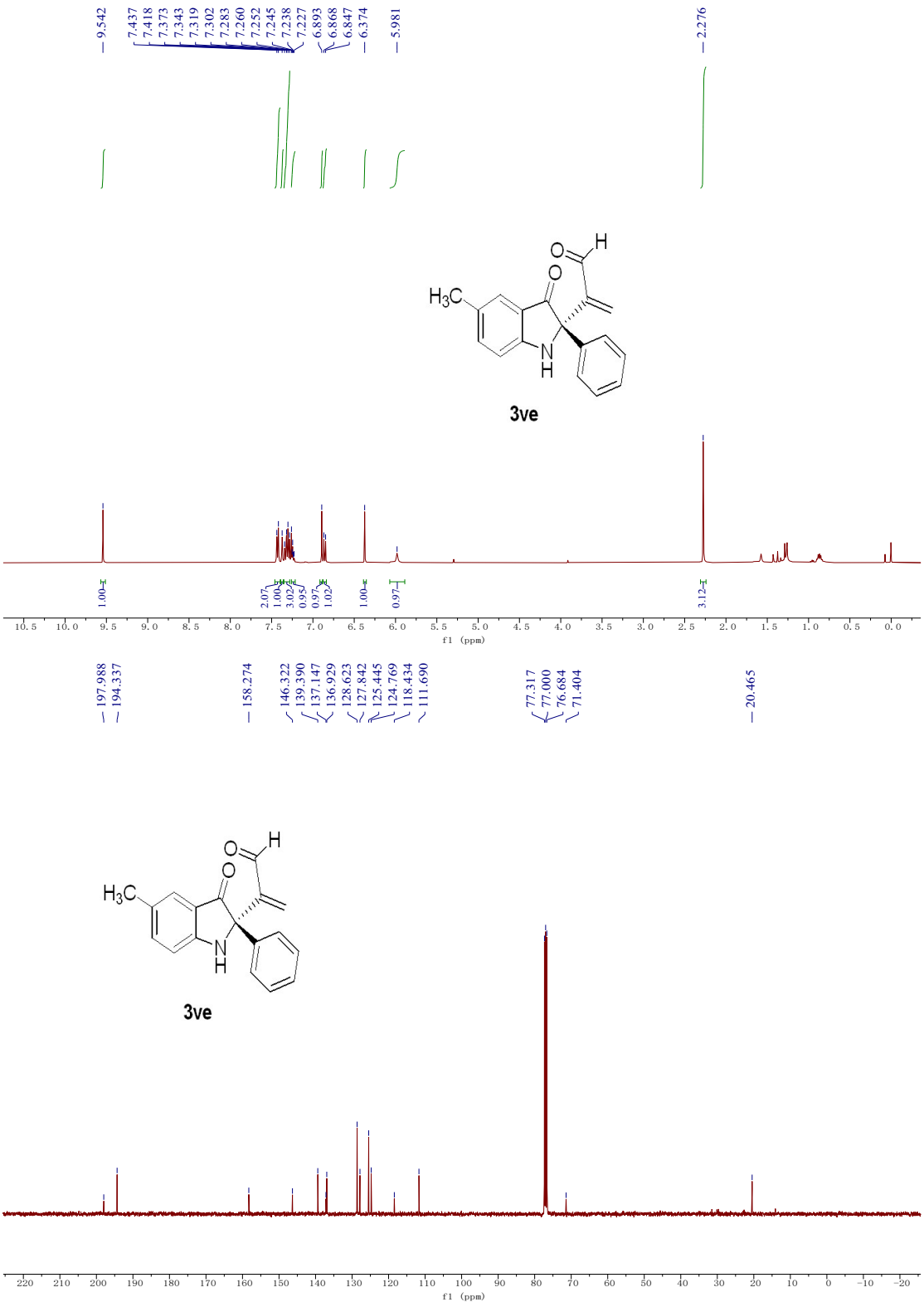
^{1}H ,^{13}C and ^{19}F NMR spectra of compound **3se** (400 MHz, $CDCl_3$)



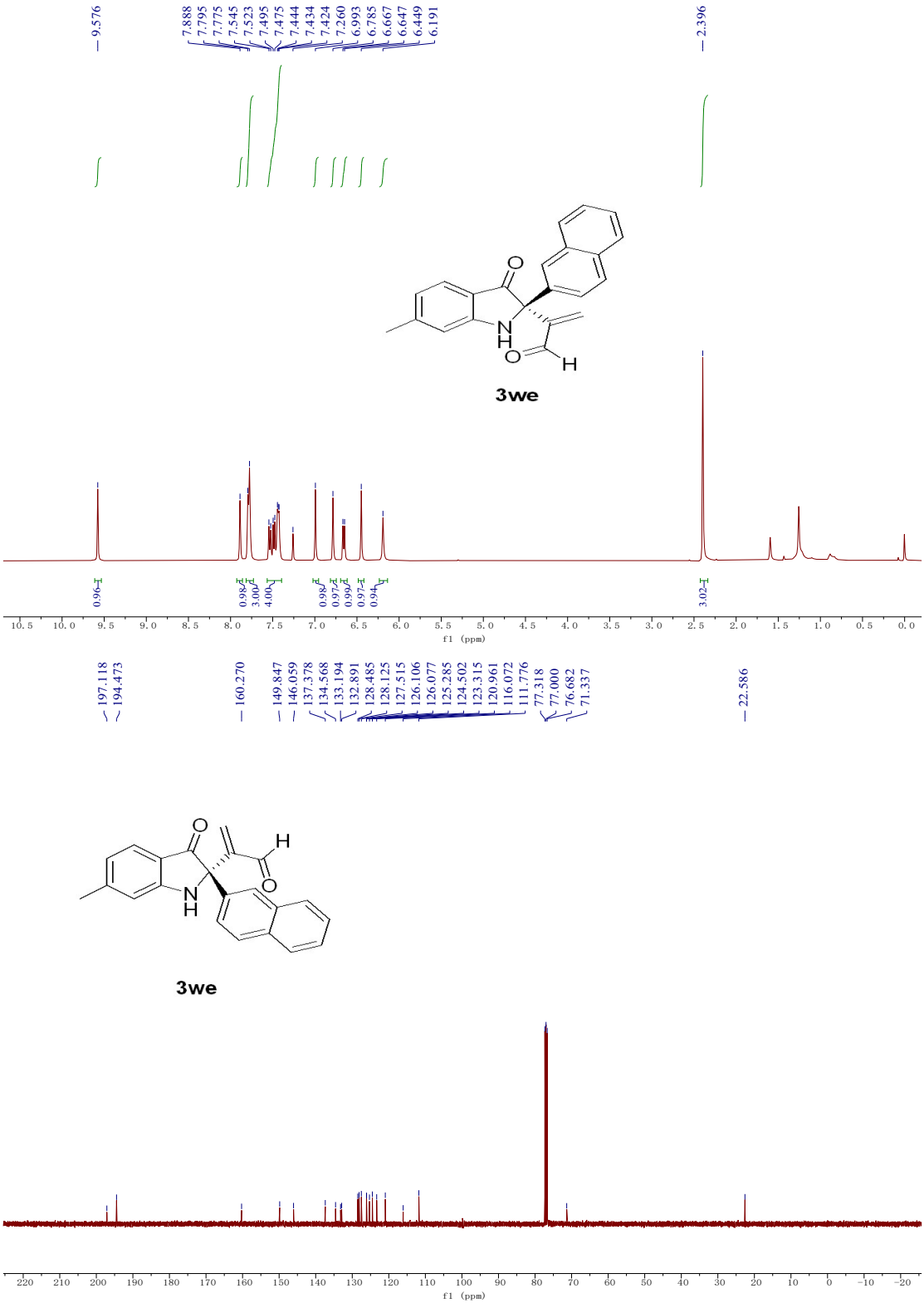
^{1}H and ^{13}C NMR spectra of compound **3te** (400 MHz, $CDCl_3$)



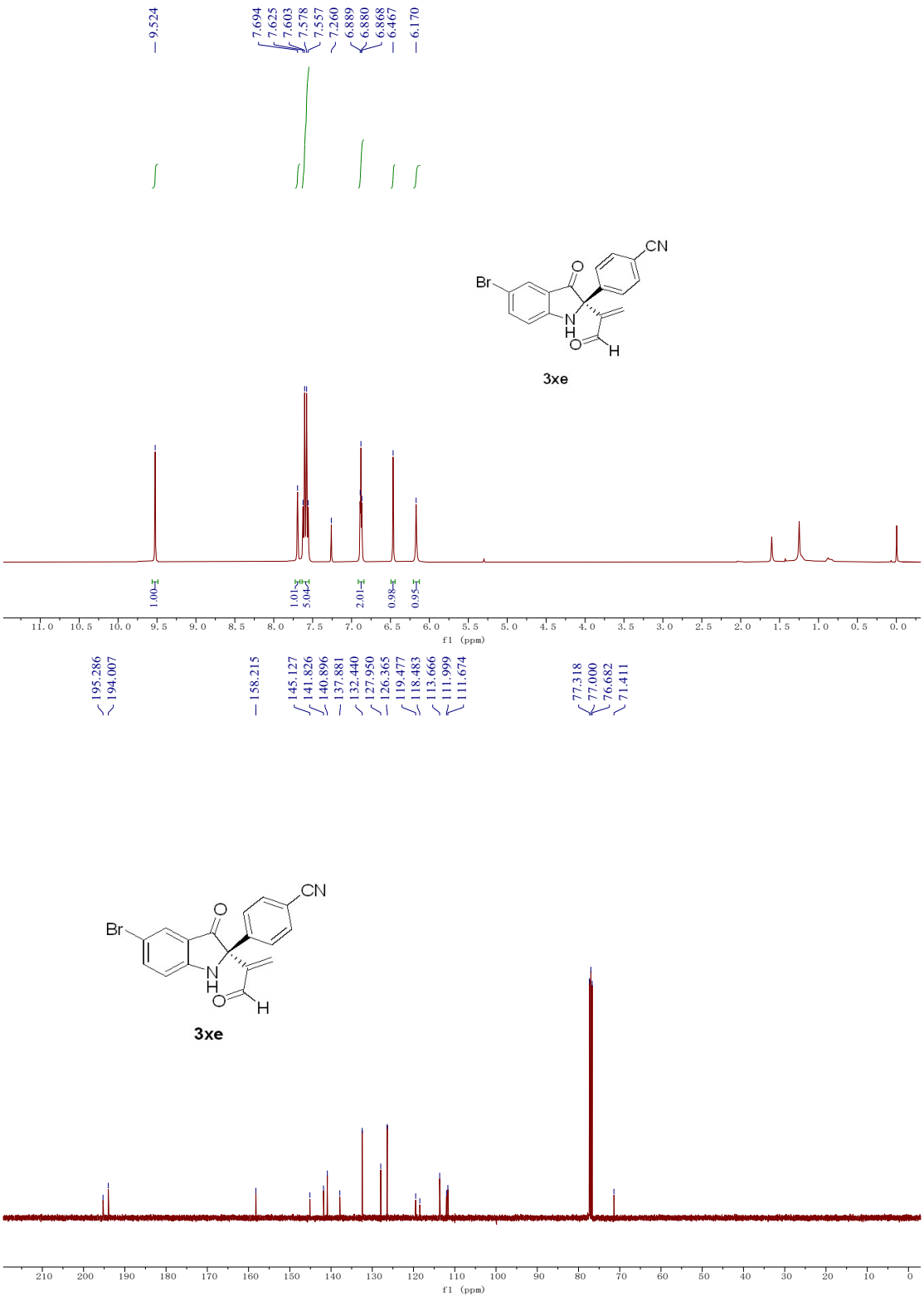
^{1}H and ^{13}C NMR spectra of compound **3ue** (400 MHz, $CDCl_3$)



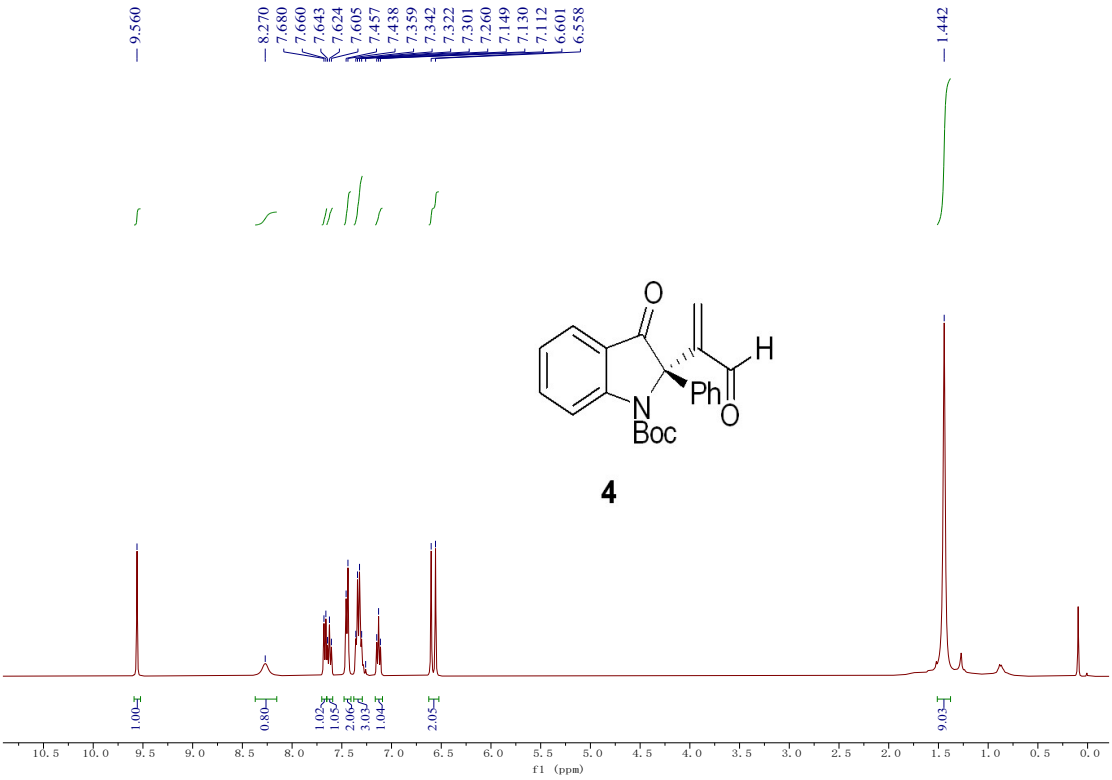
^{1}H and ^{13}C NMR spectra of compound **3ve** (400 MHz, $CDCl_3$)

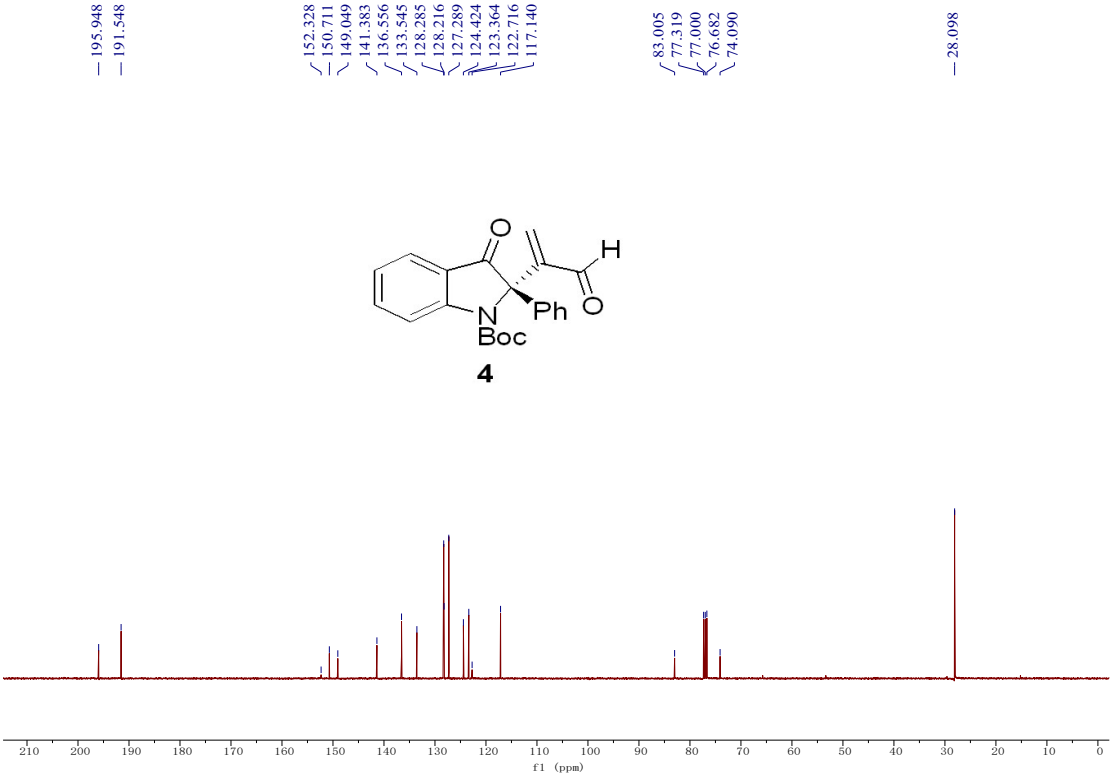


^{1}H and ^{13}C NMR spectra of compound **3we** (400 MHz, $CDCl_3$)

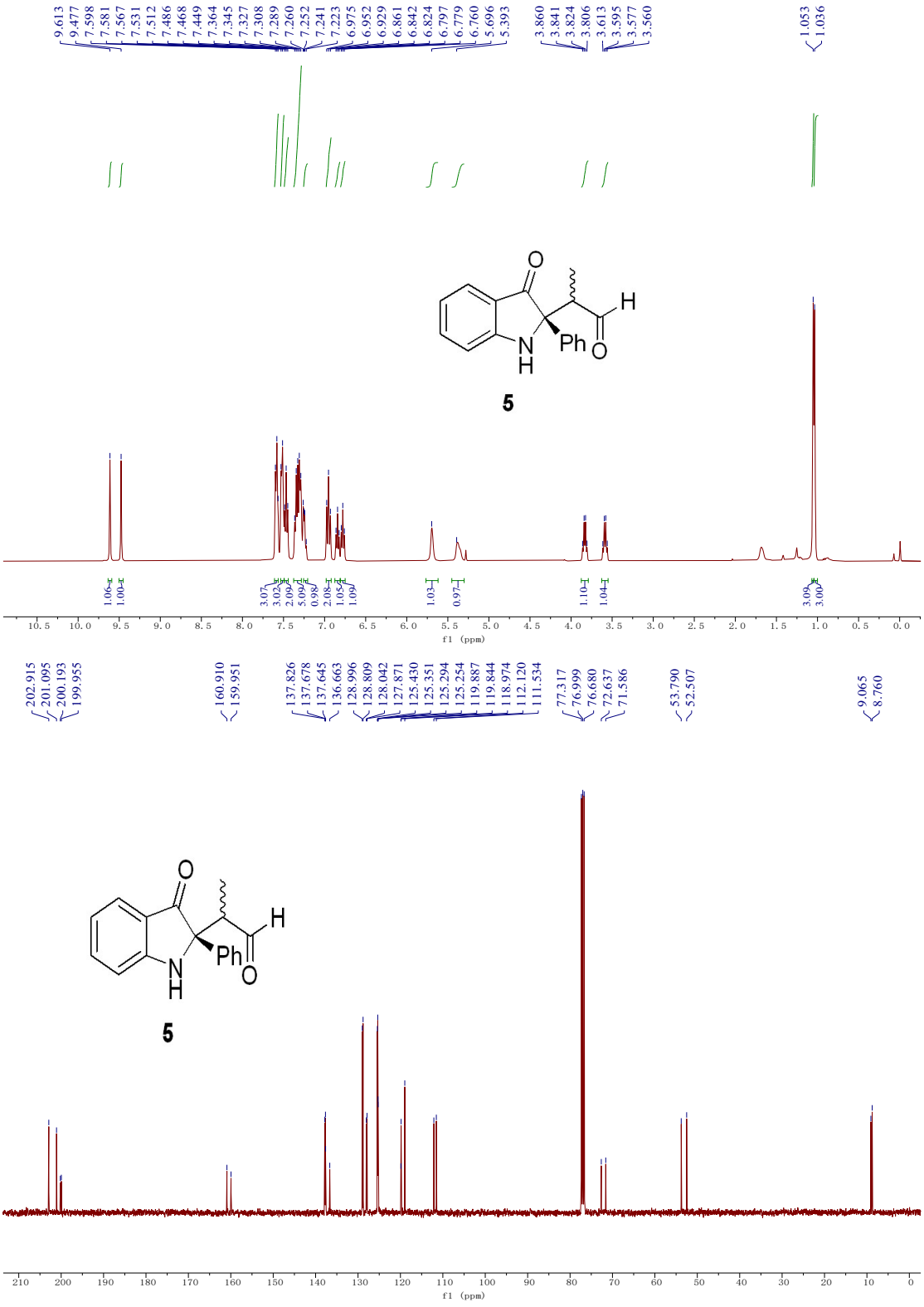


^{1}H and ^{13}C NMR spectra of compound **3xe** (400 MHz, $CDCl_3$)

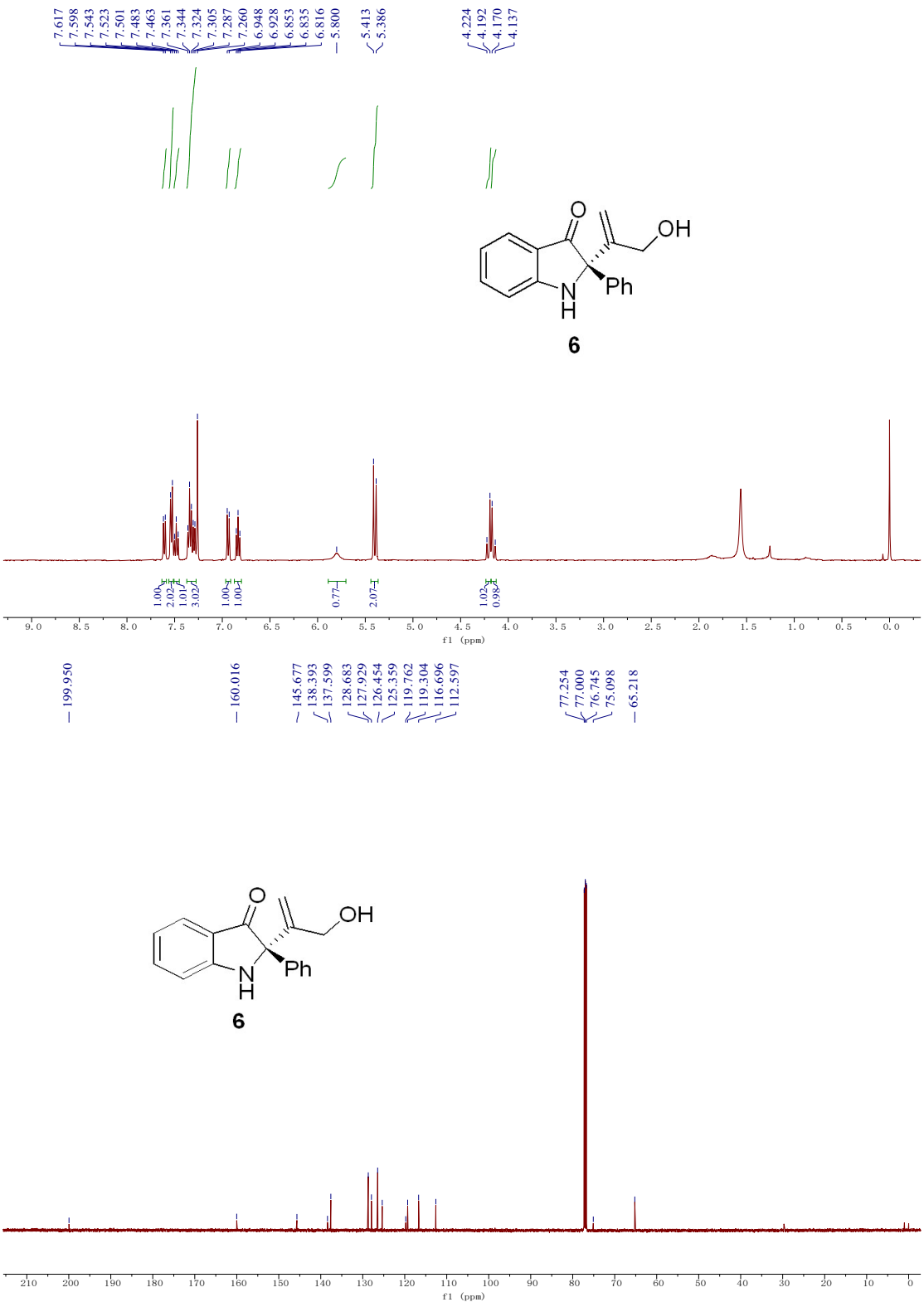




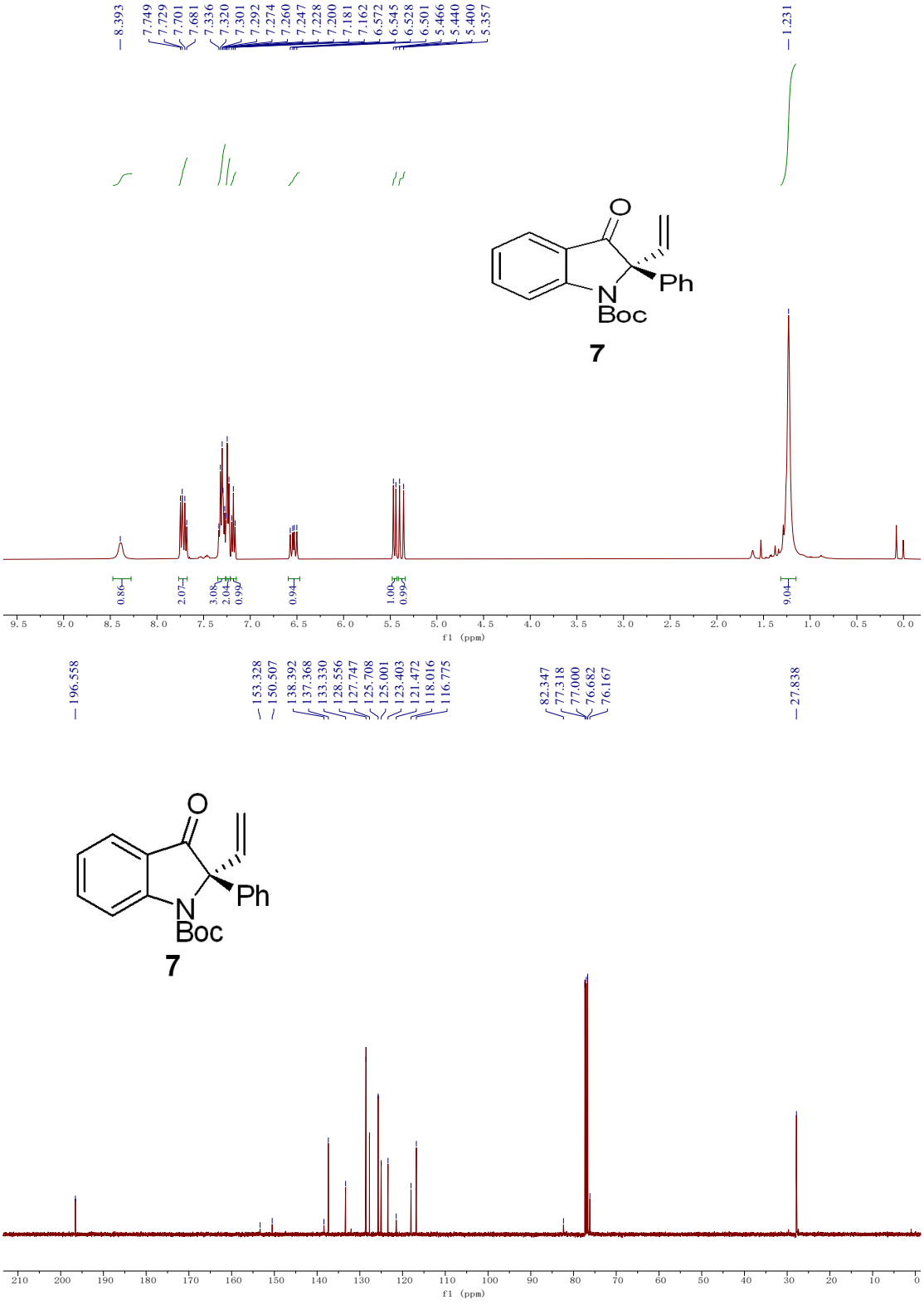
^{1}H and ^{13}C NMR spectra of compound **4** (400 MHz, $CDCl_3$)



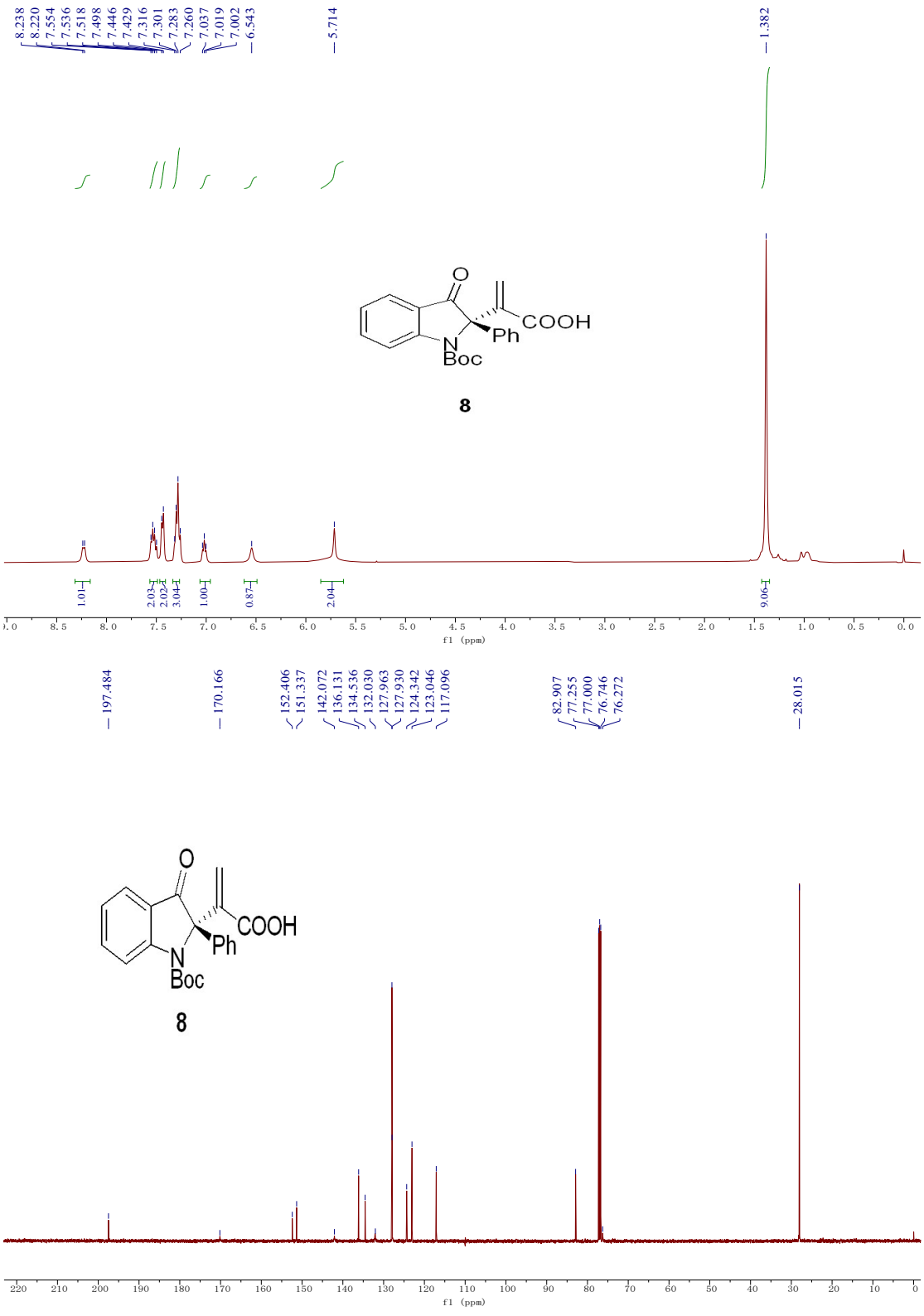
^{1}H and ^{13}C NMR spectra of compound **5** (400 MHz, $CDCl_3$)



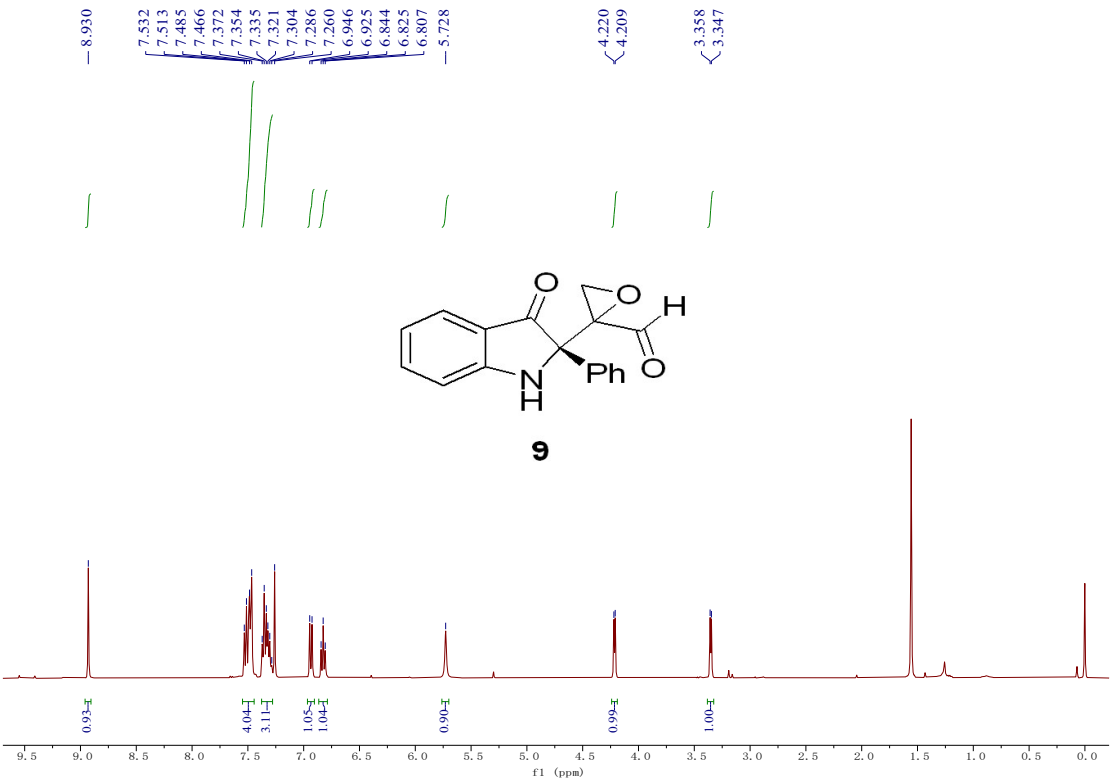
^{1}H and ^{13}C NMR spectra of compound **6** (400 MHz, $CDCl_3$)

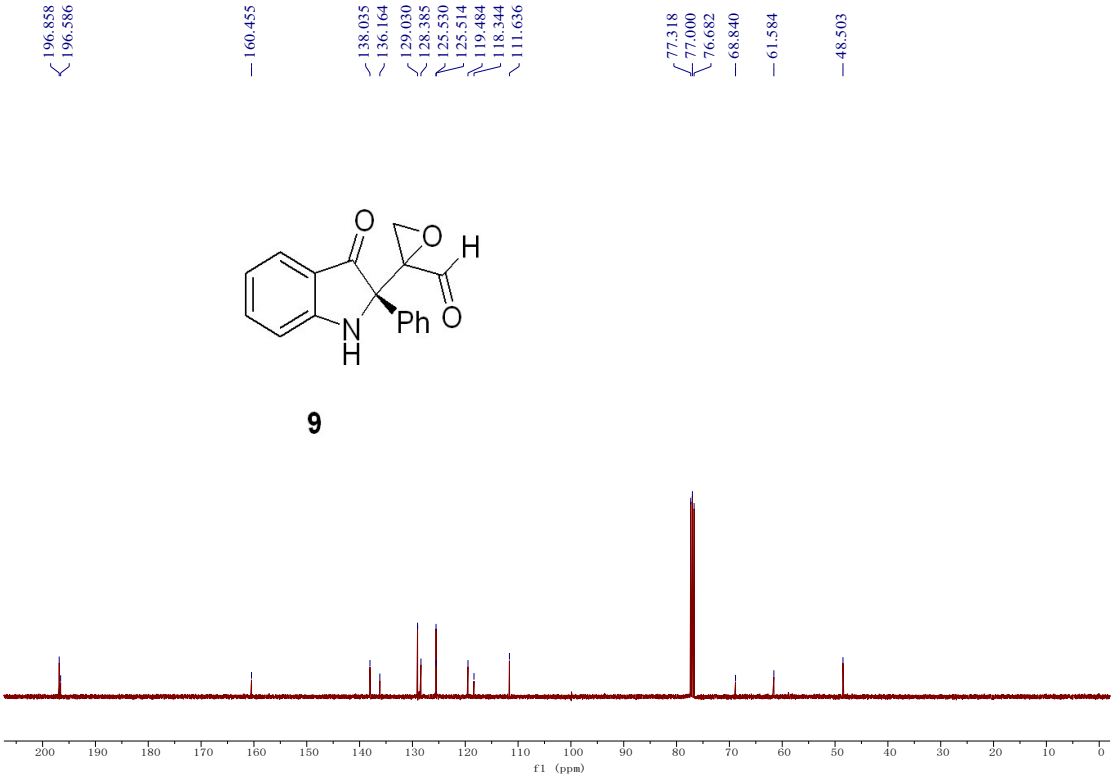


^{1}H and ^{13}C NMR spectra of compound **7** (400 MHz, $CDCl_3$)



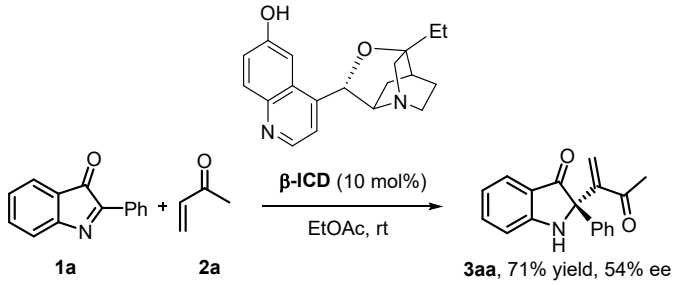
^{1}H and ^{13}C NMR spectra of compound **8** (400 MHz, $CDCl_3$)





^{1}H and ^{13}C NMR spectra of compound **9**

8. Tertiary amine catalyzed the reaction



1a **2a** **3aa**, 71% yield, 54% ee

To a solution of compound **1a** (0.1 mmol, 1.0 equiv.) and tertiary amine catalyst **β-ICD** (0.01 mmol, 0.1 equiv.) in ethyl acetate (2.0 mL) was added compound **2a** (0.15 mmol, 1.5 equiv.) under nitrogen atmosphere at room temperature. TLC monitor until the compound **1a** consumed after six hours. The reaction mixture was then concentrated on a rotary evaporator under reduce pressure and the residue was subjected to purification by column chromatography (silica gel, PE/EtOAc: 15/1 to 10/1, R_f = 0.2-0.3) to afford the corresponding product **3aa** in 71% yield with 54% ee.