Supporting Information

Enantioselective Indole N-H Functionalization Enabled by Addition of Carbene Catalyst to Indole Aldehyde at Remote Site

Xing Yang,[b], + Guoyong Luo,[a], + Liejin Zhou,[b] Bin Liu,[c] Xiaolei Zhang,[b] Hui Gao,[d] Zhichao Jin,[c] and Yonggui Robin Chi*, [b,c]

[a] School of Pharmacy, Guizhou University of Traditional Chinese Medicine, Guiyang 550025, China

[b] Division of Chemistry & Biological Chemistry, School of Physical & Mathematical Sciences, Nanyang Technological University, Singapore 637371, Singapore

[c] Laboratory Breeding Base of Green Pesticide and Agricultural Bioengineering, Key Laboratory of Green Pesticide and Agricultural Bioengineering, Ministry of Education,Guizhou University Huaxi District, Guiyang 550025, China

[d] Key Laboratory of Molecular Target & Clinical Pharmacology and the State Key Laboratory of Respiratory Disease, School of Pharmaceutical Sciences & the Fifth Affiliated Hospital, Guangzhou Medical University, Guangzhou, Guangdong 511436, China

E-mail: robinchi@ntu.edu.sg

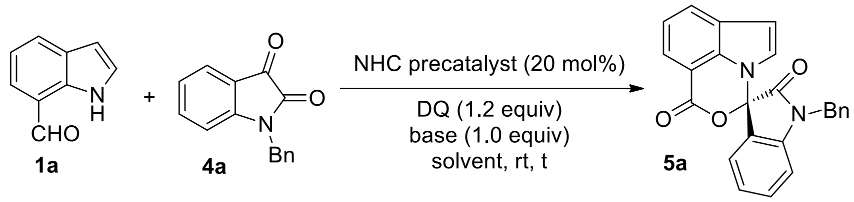
Contents

General methods

All reactions and manipulations involving air-sensitive compounds were carried out using standard Schlenk techniques. Anhydrous toluene, hexane, Et_2O and THF were distilled from sodium benzophenone ketyl. Anhydrous CH_2Cl_2 and $CHCl_3$ were distilled from CaH_2 under an atmosphere of nitrogen. All reactions were monitored by TLC. TLC analysis was performed by illumination with a UV lamp (254 nm). All flash chromatography was packed with silica-gel as the stationary phase. ^{1}H NMR spectra were recorded on a Bruker Avance (300 or 500 MHz) or Bruker BBFO (400 MHz) instrument, and chemical shifts were reported in ppm downfield from internal TMS with the solvent resonance as the internal standard ($CDCl_3$, δ = 7.26 ppm). ^{13}C NMR (126 MHz) spectra were recorded on a Bruker BBFO (101 MHz) instrument, and chemical shifts were reported in ppm downfield from TMS with the solvent resonance as the internal standard ($CDCl_3$, δ = 77.2 ppm). ^{19}F NMR spectra were recorded on a Bruker Avance 300 (282 MHz) or Bruker BBFO (377 MHz) instrument. IR spectra were recorded on a Shimadzu IR Prestige-21FT-IR spectrometer. Optical rotations were measured on a Jasco P-1030 polarimeter. High resolution mass spectra (HRMS) (EI+) were recorded on an a Finnigan MAT 95 XP mass spectrometer. The indole-7-carbaldehydes[1] and fluorinated ketones[2] were synthesized according to the literature procedure.

Optimization of reaction conditions

Table S-1: Optimization of the asymmetric N-H functionalization of **1a** with isatin **4a**[a]



entry	NHC	solvent	base	t/h	yield [%][b]	er [%]
1	**A**	THF	K_2CO_3	12	64	80.5:19.5
2	**B**	THF	K_2CO_3	12	63	85:15
3	**C**	THF	K_2CO_3	12	64	82.5:7.5
4	**D**	THF	K_2CO_3	12	84	89:11
5	**E**	THF	K_2CO_3	12	64	93:7
6	**G**	THF	K_2CO_3	12	trace	-
7	**H**	THF	K_2CO_3	12	57	87:13
8	**I**	THF	K_2CO_3	12	trace	-
9	**J**	THF	K_2CO_3	12	79	76.5:23.5
10	**K**	THF	K_2CO_3	12	trace	-
11	**L**	THF	K_2CO_3	12	trace	-
12	**D**	Et_2O	K_2CO_3	12	58	89:11
13	**D**	CH_2Cl_2	K_2CO_3	12	58	92:8
14	**D**	EA	K_2CO_3	12	90	89.5:10.5
15	**D**	Toluene	K_2CO_3	12	34	92:8
16	**D**	^{t}BuOMe	K_2CO_3	12	53	91.5:8.5
17	**D**	CH_2Cl_2	Cs_2CO_3	2	90	92:8
18	**D**	CH_2Cl_2	DBU	12	trace	-
19	**D**	CH_2Cl_2	DABCO	3	63	92:8
20	**D**	CH_2Cl_2	DIEA	16	93	92:8
21	**E**	CH_2Cl_2	DIEA	24	85	97:3

[a] reaction conditions: **1a** (0.12 mmol), **4a** (0.1 mmol), solvent (1.0 mL);
[b] **I**solated yield.

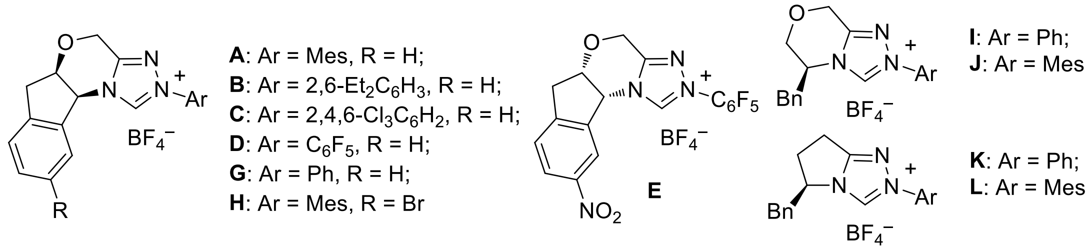
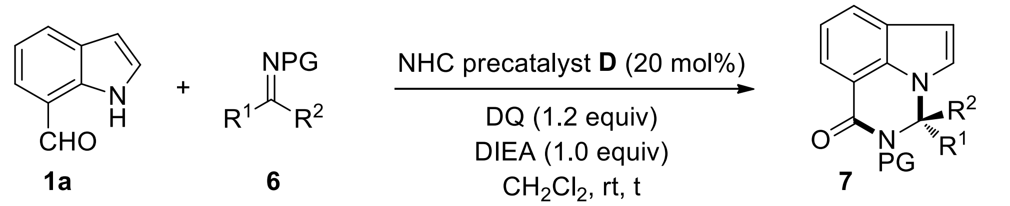
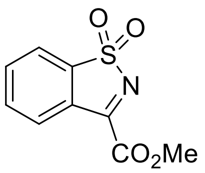


Table S-2: Investigation of the asymmetric N-H functionalization of **1a** with imines [a]

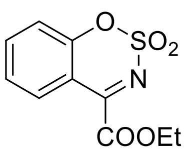


entry	imines	t/h	yield [%][b]	er [%]
1	**6a**	1	95	83:17
2	**6b**	24	NR	-
3	**6c**	24	trace	-
4	**6d**	24	NR	-
5	**6e**	24	trace	-
6	**6f**	24	NR	-
7	**6g**	24	trace	-

[a] Reaction conditions: **1a** (0.12 mmol), **6** (0.1 mmol), CH_2Cl_2 (1.0 mL);
[b] Isolated yield;
[c] NR = No reaction.

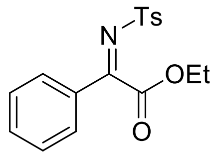


6a

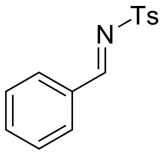


6b

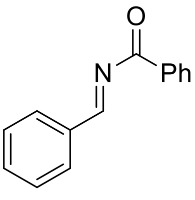
6c



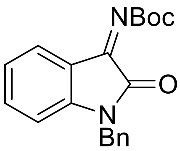
6d



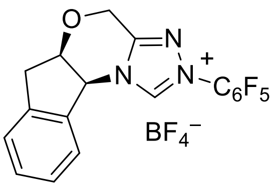
6e



6f



6g



D

General procedure for the asymmetric N-H functionalization

To an dried 3 mL test tube with a stir bar was added the carbene catalyst (20 mol %), indole-7carbaldehydes (0.15 mmol, 1.5 equiv) and DQ (0.12 mmol, 1.2 equive). Then trifluoromethyl ketones (0.1 mmol), isatins (0.1 mmol) or imines (0.1 mmol), anhydrous CH_2Cl_2 (1.0 mL) and DIEA (0.1 mmol, 1.0 equive) was added at r.t. The reaction mixture was stirred at rt for the time indicated in the table, then directly subjected to the preparative thin layer chromatography (Hexane/DCM/EA = 20:20:1).

Mechanism studies

There are two possible pathways for our reaction, one is asymmetric [4+2] annulation pathway, the other is dynamic kinetic resolution (DKR) pathway.

(1) Asymmetric [4+2] annulation pathway:

The proposed [4+2] annulation pathway is shown in Figure S-1. On the basis of known information for NHC catalyzed transformations,[3] we know that the addition of NHC to aldehyde **1a** will form intermediate **INT-1**, which undergoes proton transfer to form Breslow intermediate. Breslow intermediate is then converted to azolium ester intermediate **I** via oxidation. After deprotonation of intermediate **I**, the analogous *aza-o*-QMs intermediate (**II**) is formed. Finanlly, a formal [4+2] annulation reaction between intermediate **II** and trifluoroacetophone **2a** provides the desired product **3a** and regenerates the NHC catalyst.

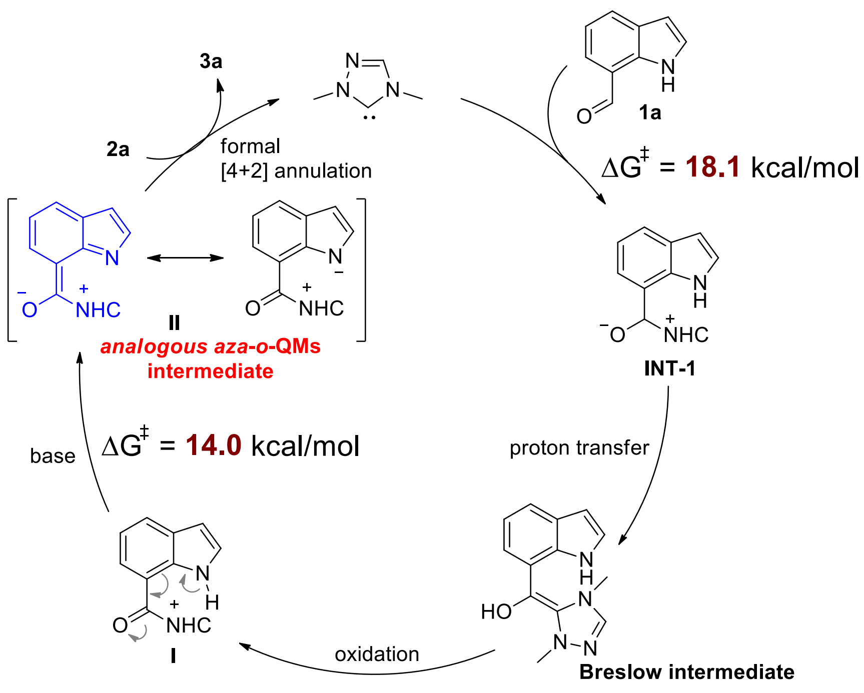


Figure S-1. Asymmetric [4+2] annulation pathway

(2) Dynamic kinetic resolution pathway:

The dynamic kinetic resolution pathway is illustrated in Figure S-2. First, indole-7-carbaldehyde **1a** reacts with trifluoroacetophone **2a** to form racemic compound **4** and **5**. Then the addition of NHC catalyst to (*R*)-**4** is kinetically favored over (*S*)-**4** to give intermediate **I'**, which undergoes hydride shift to form Breslow intermediate. After oxidation reaction, intermediate **II'** is formed. Finally, intramoleculer esterification of intermediate **II'** affords the target product **3a** and regenerates the NHC catalyst.

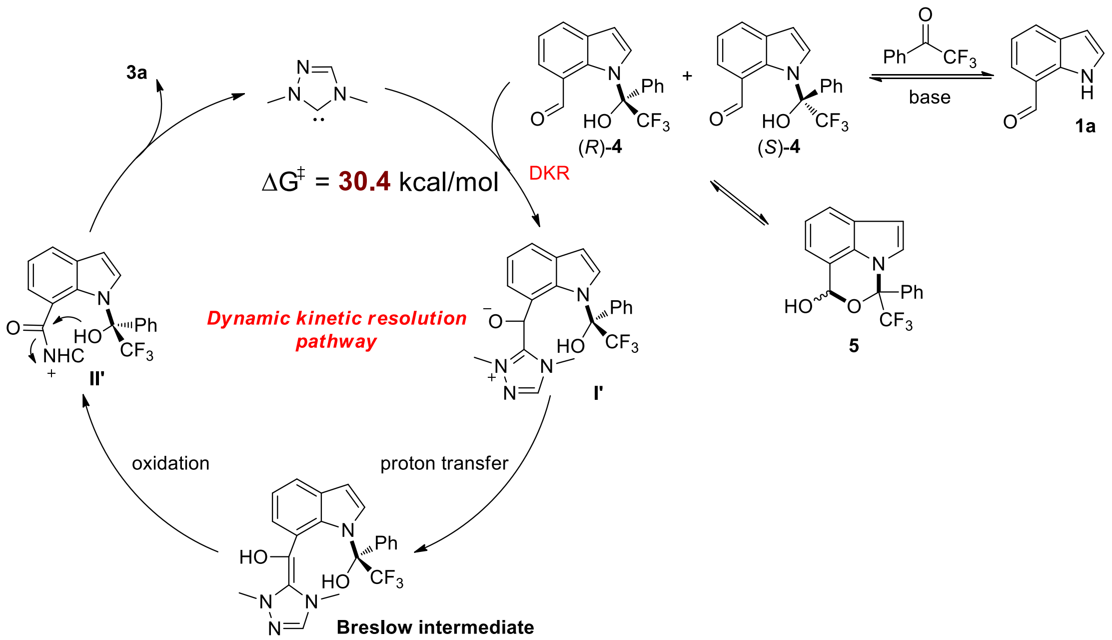


Figure S-2. Dynamic kinetic resolution pathway

In order to provide theoretical insight to support the preferred reaction pathway, we performed some DFT calculations by using Gaussian 09 program (Figure S-3). For the [4+2] annulation pathway, the calculated energy barrier for the first step is 18.1 kcal/mol. We found that there are hydrogen bond interaction between C=O and N-H group and π-π stacking interaction between the C_6F_5 group on NHC and indole ring. In contrast, the calculated energy barrier for the fisrt step in DKR pathway is 30.4 kcal/mol, which is too high for a room temperature reaction to happen. Therefore, the [4+2] annulation pathway is more reasonable than DKR pathway. Moreover, the transformation from intermediate **I** to analogous aza-o-QMs intermediate is energetically feasible (energy barrier is 14.0 kcal/mol). We also calculated Mulliken atomic charges for intermediate **II** and found that the O and N atoms have partial negative charges of -0.481 and -0.631, respectively (Table S-2). These fractional charges imply that **II** cannot be described as either of the two extreme resonance structures depicted in Figure S-1. The real state of analogous *aza*-*o*-QMs intermediate should lie somewhere in between.

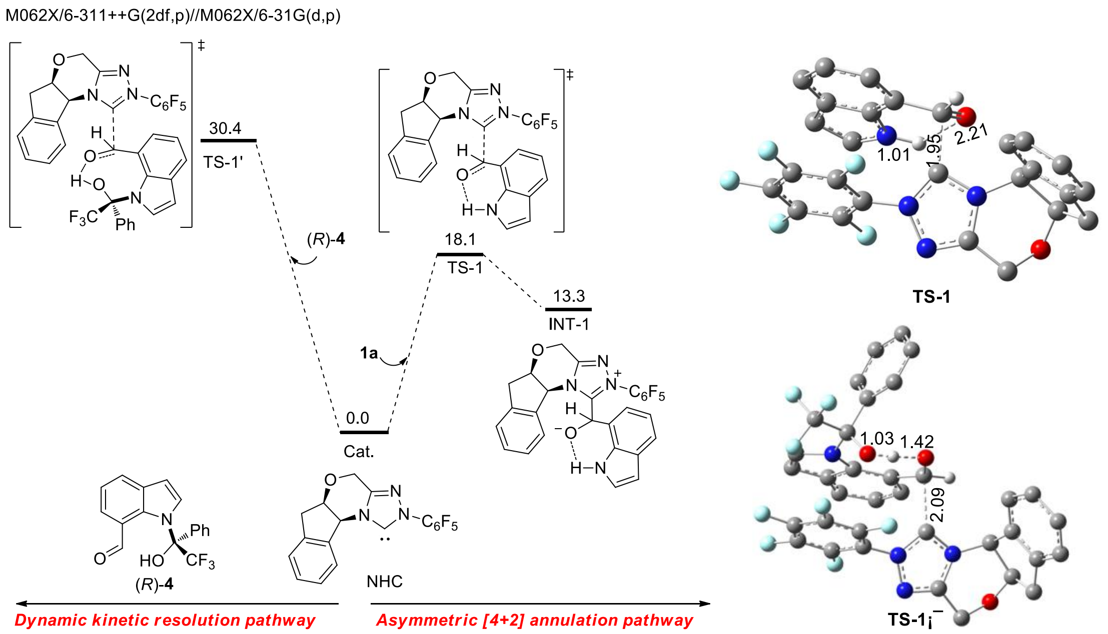
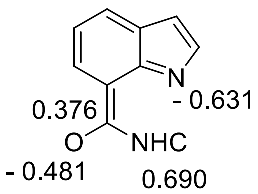


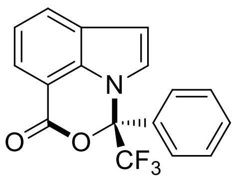
Figure S-3. Key results for DFT calculations

Table S-2: Key Mulliken atomic charges for intermediate II

Group	Mulliken Charge
+NHC	0.690
C1	0.376
O	- 0.481
N	- 0.631



Characterization data of the catalytic reaction products



3a

(*R*)-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3a): slightly yellow oil, 31.0 mg, 99% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.84 (d, *J* = 7.5 Hz, 1H), 7.54 – 7.34 (m, 6H), 7.29 (t, *J* = 7.7 Hz, 1H), 6.78 (d, *J* = 3.4 Hz, 1H);

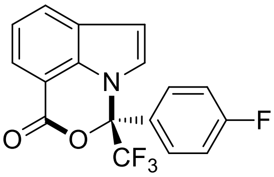
^{13}C NMR (101 MHz, $CDCl_3$) δ 158.5, 137.7, 133.6, 131.2, 129.1, 128.3, 127.1, 126.7, 126.3, 123.4, 122.3 (q, *J* = 289.3 Hz), 122.2, 108.6, 106.2, 93.4 (q, *J* = 33.6 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 318.0736, found: 318.0742;

HPLC analysis: 95.5:4.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 15.3 min, t_{major} = 28.5 min), $[\alpha]_D^{25}$ = +41.82 (c = 1.0, $CHCl_3$).

Note: reproduced by the co-author Dr. Guoyong Luo gave 90% yield and 95.5:4.5 er.



3b

(*R*)-3-(4-fluorophenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3b): slightly yellow oil, 30.8 mg, 92% yield

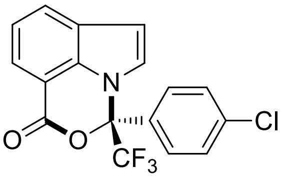
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (dd, *J* = 7.9, 0.6 Hz, 1H), 7.84 (d, *J* = 7.4 Hz, 1H), 7.48 (dd, *J* = 8.8, 5.0 Hz, 2H), 7.36 (dd, *J* = 3.1, 0.9 Hz, 1H), 7.29 (dd, *J* = 16.2, 8.6 Hz, 1H), 7.15 – 7.02 (m, 2H), 6.79 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 164.3 (d, *J* = 253.2 Hz), 158.2, 137.7, 129.7 (d, *J* = 3.2 Hz), 129.1 (dd, *J* = 8.9, 1.6 Hz), 128.5, 127.1, 126.2 (d, *J* = 1.7 Hz), 123.6, 122.3, 122.1 (q, *J* = 289.2 Hz), 116.3 (d, *J* = 22.1 Hz), 108.6, 106.5, 93.0 (q, *J* = 33.8 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.4 (3F), -108.8 (1F);

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 336.0642, found: 336.0654;

HPLC analysis: 96:4 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 16.9 min, t_{major} = 26.2 min), $[\alpha]_D^{25}$ = +63.94 (c = 1.0, $CHCl_3$).



3c

(*R*)-3-(4-chlorophenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3c): slightly yellow oil, 34.8 mg, 99% yield

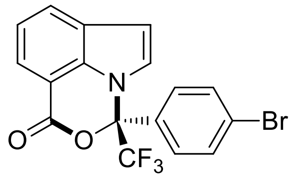
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (d, *J* = 7.9 Hz, 1H), 7.84 (d, *J* = 7.5 Hz, 1H), 7.49 – 7.33 (m, 5H), 7.30 (t, *J* = 7.7 Hz, 1H), 6.80 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.1, 137.7, 137.6, 132.2, 129.4, 128.5, 128.2 (d, *J* = 1.2 Hz), 127.1, 126.1 (d, *J* = 1.5 Hz), 123.6, 122.4, 122.1 (q, *J* = 289.2 Hz), 108.5, 106.6, 93.0 (q, *J* = 33.8 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.3;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 352.0347, found: 352.0348;

HPLC analysis: 95:5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 15.5 min, t_{major} = 21.2 min), $[\alpha]_D^{25}$ = +21.34 (c = 1.0, $CHCl_3$).



3d

(*R*)-3-(4-bromophenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3d): slightly yellow oil, 39.2 mg, 99% yield

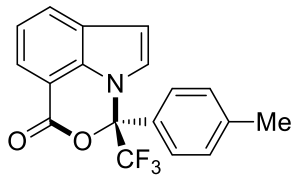
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.91 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.84 (d, *J* = 7.5 Hz, 1H), 7.59 – 7.45 (m, 2H), 7.41 – 7.20 (m, 4H), 6.80 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.1, 137.7, 132.7, 132.4, 128.5, 128.4 (d, *J* = 1.6 Hz), 127.1, 126.2 (d, *J* = 1.7 Hz), 126.0, 123.6, 122.4, 122.0 (q, *J* = 289.3 Hz), 108.5, 106.6, 93.0 (q, *J* = 33.9 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.3;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 395.9842, found: 395.9851;

HPLC analysis: 95:5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 10.4 min, t_{major} = 12.5 min), $[\alpha]_D^{25}$ = +8.04 (c = 1.0, $CHCl_3$).



3e

(*R*)-3-(*p*-tolyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3e): slightly yellow oil, 31.8 mg, 96% yield

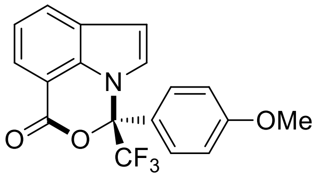
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 7.9, 0.6 Hz, 1H), 7.83 (d, *J* = 7.4 Hz, 1H), 7.37 (d, *J* = 8.3 Hz, 3H), 7.32 – 7.22 (m, 1H), 7.19 (d, *J* = 8.1 Hz, 2H), 6.76 (d, *J* = 3.3 Hz, 1H), 2.34 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.6, 141.5, 137.7, 130.7, 129.7, 128.3, 127.1, 126.6 (d, *J* = 1.5 Hz), 126.4 (d, *J* = 1.6 Hz), 123.3, 122.3 (q, *J* = 289.3 Hz), 122.1, 108.6, 106.1, 93.5 (q, *J* = 33.6 Hz), 21.2;

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 332.0893, found: 332.0897;

HPLC analysis: 96.5:3.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 15.6 min, t_{major} = 32.1 min), $[\alpha]_D^{25}$ = +36.60 (c = 1.0, $CHCl_3$).



3f

(*R*)-3-(4-methoxyphenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3f): slightly yellow oil, 33.3 mg, 96% yield

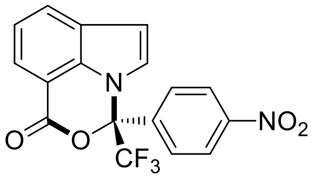
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.90 (dd, *J* = 7.9, 0.6 Hz, 1H), 7.83 (d, *J* = 7.5 Hz, 1H), 7.49 – 7.20 (m, 4H), 6.94 – 6.82 (m, 2H), 6.76 (d, *J* = 3.3 Hz, 1H), 3.79 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6, 158.7, 137.7, 128.3 (d, *J* = 1.6 Hz), 128.2, 127.0, 126.4, 125.5, 123.3, 122.3 (q, *J* = 289.2 Hz), 122.1, 114.4, 108.7, 106.1, 93.5 (q, *J* = 33.6 Hz), 55.5;

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.3;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 348.0842, found: 348.0851;

HPLC analysis: 97.5:2.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 26.6 min, t_{major} = 54.4 min), $[\alpha]_D^{25}$ = +55.50 (c = 1.0, $CHCl_3$).



3g

(*R*)-3-(4-nitrophenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3g): slightly yellow oil, 35.1 mg, 97% yield

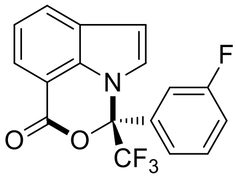
^{1}H NMR (300 MHz, $CDCl_3$) δ 8.34 – 8.18 (m, 2H), 7.95 (d, *J* = 7.9 Hz, 1H), 7.86 (d, *J* = 7.5 Hz, 1H), 7.70 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 2.1 Hz, 1H), 7.33 (t, *J* = 7.7 Hz, 1H), 6.86 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.5, 149.6, 140.0, 137.7, 128.9, 128.2 (d, *J* = 1.4 Hz), 127.2, 125.9, 124.2, 123.9, 122.7, 121.8 (q, *J* = 289.3 Hz), 108.3, 107.2, 92.5 (q, *J* = 34.1 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.0;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 363.0587, found: 363.0578;

HPLC analysis: 93:7 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 51.1 min, t_{minor} = 60.3 min), $[\alpha]_D^{25}$ = +10.42 (c = 1.0, $CHCl_3$).



3h

(*R*)-3-(3-fluorophenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3h): slightly yellow oil, 32.8mg, 98% yield

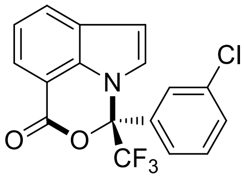
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.85 (d, *J* = 7.5 Hz, 1H), 7.39 (qd, *J* = 8.1, 5.7 Hz, 2H), 7.31 (ddd, *J* = 7.7, 4.1, 3.4 Hz, 2H), 7.24 – 7.11 (m, 2H), 6.81 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 162.9 (d, *J* = 249.7 Hz), 158.0, 137.7, 135.9 (d, *J* = 7.0 Hz), 130.9 (d, *J* = 8.1 Hz), 128.5, 127.1, 126.1 (d, *J* = 1.7 Hz), 123.6, 122.5, 122.4, 122.0 (q, *J* = 289.3 Hz), 118.4 (d, *J* = 21.1 Hz), 114.4 (dd, *J* = 24.5, 1.5 Hz), 108.5, 106.7, 92.7 (q, *J* = 33.9 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.2 (3F), -110.2 (1F);

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 336.0642, found: 336.0630;

HPLC analysis: 93:7 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 14.1 min, t_{major} = 15.0 min), $[\alpha]_D^{25}$ = +44.24 (c = 1.0, $CHCl_3$).



3i

(*R*)-3-(3-chlorophenyl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3i): slightly yellow oil, 31.6 mg, 90% yield

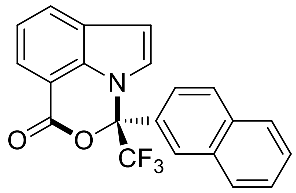
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.92 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.85 (d, *J* = 7.5 Hz, 1H), 7.53 – 7.22 (m, 6H), 6.81 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.0, 137.6, 135.5, 135.4, 131.5, 130.4, 128.6, 127.1, 127.0 (d, J = 1.6 Hz), 126.1 (d, J = 1.7 Hz), 124.9 (d, J = 1.6 Hz), 123.6, 122.4, 122.0 (q, J = 289.4 Hz), 108.4, 106.7, 92.7 (q, J = 33.8 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 352.0347, found: 352.0350;

HPLC analysis: 92.5:7.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 95/5, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 16.5 min, t_{major} = 17.4 min), $[\alpha]_D^{25}$ = +21.12 (c = 1.0, $CHCl_3$).



3j

(*R*)-3-(naphthalen-2-yl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3j): yellow solid, 35.9 mg, 98% yield

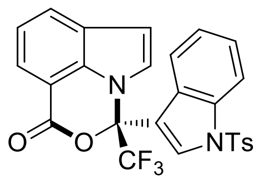
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.97 – 7.82 (m, 6H), 7.62 – 7.47 (m, 3H), 7.41 (d, J = 2.5 Hz, 1H), 7.28 (dd, J = 13.4, 5.7 Hz, 1H), 6.80 (d, J = 3.3 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.5, 137.8, 134.2, 132.5, 130.7, 129.3, 129.1, 128.4, 128.1, 127.7, 127.2, 127.1, 127.0 (d, J = 1.7 Hz), 126.4 (d, J = 1.7 Hz), 123.4, 123.1, 122.4 (q, J = 289.7 Hz), 122.2, 108.6, 106.3, 93.6 (q, J = 33.6 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -77.8;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 368.0893, found: 368.0899;

HPLC analysis: 94.5:5.5 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 99/1, flow rate = 0.5 mL/min, λ = 254 nm, t_{minor} = 13.8 min, t_{major} = 16.0 min), $[\alpha]_D^{25}$ = -46.40 (c = 1.0, $CHCl_3$).

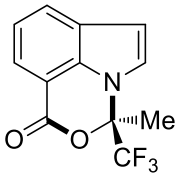


3k

(*R*)-3-(1-tosyl-1H-indol-3-yl)-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3k): white solid, 48.9 mg, 96% yield

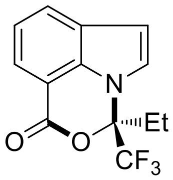
^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 – 7.81 (m, 4H), 7.76 (d, J = 8.4 Hz, 2H), 7.43 – 7.18 (m, 4H), 7.11 – 6.99 (m, 3H), 6.70 (d, J = 3.4 Hz, 1H), 2.37 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.4, 146.1, 137.4, 134.9, 134.5, 130.4, 128.6, 127.3, 127.1, 127.0, 126.4, 126.0, 125.8, 124.3, 123.4, 122.4 (q, *J* = 291.3 Hz), 122.3, 120.7, 113.8, 113.6, 107.9, 106.5, 91.2 (q, *J* = 35.1 Hz), 21.7;
^{19}F NMR (282 MHz, $CDCl_3$) δ -79.6;
HRMS (ESI, m/z): calcd. for $[M+H]^+$: 511.0934, found: 511.0948;
HPLC analysis: 96.5:3.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 35.1 min, t_{major} = 50.9 min), $[\alpha]_D^{25}$ = +90.76 (c = 1.0, $CHCl_3$).



3l

(*R*)-3-methyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3l): slightly yellow oil, 22.7 mg, 89% yield
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 (dd, *J* = 9.5, 7.9 Hz, 2H), 7.36 – 7.16 (m, 2H), 6.74 (d, *J* = 3.3 Hz, 1H), 2.16 (s, 3H);
^{13}C NMR (101 MHz, $CDCl_3$) δ 158.6, 137.0, 128.1, 126.6, 124.3, 123.1, 122.6 (q, *J* = 291.1 Hz), 121.9, 108.0, 106.2, 91.3 (q, *J* = 33.8 Hz), 21.5;
^{19}F NMR (282 MHz, $CDCl_3$) δ -84.3;
HRMS (ESI, m/z): calcd. for $[M+H]^+$: 256.0580, found: 256.0572;
HPLC analysis: 94:6 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 16.7 min, t_{minor} = 23.8 min), $[\alpha]_D^{25}$ = +43.12 (c = 1.0, $CHCl_3$).



3m

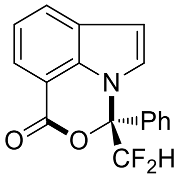
(*R*)-3-ethyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3m): slightly yellow oil, 26.3 mg, 98% yield
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.87 (dd, *J* = 9.6, 7.8 Hz, 2H), 7.37 – 7.24 (m, 1H), 7.20 (d, *J* = 3.1 Hz, 1H), 6.76 (d, *J* = 3.3 Hz, 1H), 2.53 – 2.33 (m, 2H), 1.01 (t, *J* = 7.3 Hz, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.9, 137.5, 128.1, 126.6, 124.2, 123.1, 122.7 (q, J = 291.1 Hz), 121.8, 107.7, 106.3, 94.0 (q, J = 32.6 Hz), 26.2, 5.9;

^{19}F NMR (282 MHz, $CDCl_3$) δ -83.9;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 270.0736, found: 270.0741;

HPLC analysis: 96:4 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 12.6 min, t_{minor} = 14.4 min), $[\alpha]_D^{25}$ = +65.74 (c = 1.0, $CHCl_3$).



3n

(*R*)-3-(difluoromethyl)-3-phenyl-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3n): slightly yellow oil, 25.4 mg, 85% yield

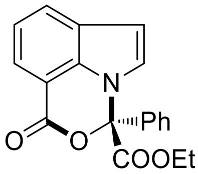
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.90 (d, J = 7.9 Hz, 1H), 7.80 (d, J = 7.5 Hz, 1H), 7.50 – 7.20 (m, 7H), 6.77 (d, J = 3.3 Hz, 1H), 6.42 (t, J = 54.2 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 159.3, 138.1, 135.0, 130.9, 129.2, 128.1, 127.0, 126.8 (t, J = 2.6 Hz), 126.5, 123.0, 121.9, 113.4 (dd, J = 255.3, 3.2 Hz), 108.9, 105.6, 93.8 (dd, J = 26.3, 2.8 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -128.9 (d, J = 285.2 Hz, 1F), -130.3 (d, J = 285.2 Hz, 1F);

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 300.0831, found: 300.0834;

HPLC analysis: 97:3 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 51.8 min, t_{major} = 59.0 min), $[\alpha]_D^{25}$ = +175.50 (c = 1.0, $CHCl_3$).



3o

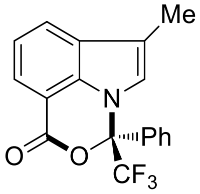
(*R*)-ethyl 1-oxo-3-phenyl-1,3-dihydro-[1,3]oxazino[5,4,3-hi]indole-3-carboxylate (3o): slightly yellow oil, 27.3 mg, 85% yield

^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 (t, J = 7.4 Hz, 2H), 7.64 – 7.38 (m, 5H), 7.38 – 7.17 (m, 2H), 6.68 (d, J = 3.3 Hz, 1H), 4.25 (q, J = 7.1 Hz, 2H), 1.18 (t, J = 7.1 Hz, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 166.9, 160.2, 138.2, 134.9, 130.8, 129.1, 127.9, 127.8, 127.7, 127.0, 122.7, 122.1, 109.4, 105.5, 94.3, 63.5, 14.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 322.1074, found: 322.1080;

HPLC analysis: 97.5:2.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 254 nm, t_{minor} = 35.2 min, t_{major} = 54.5 min), $[\alpha]_D^{25}$ = +131.66 (c = 1.0, $CHCl_3$).



3p

(*R*)-6-methyl-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3p): white solid, 31.7 mg, 96% yield

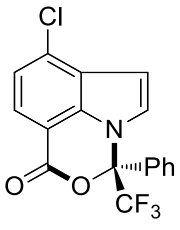
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.82 (t, *J* = 6.5 Hz, 2H), 7.51 – 7.36 (m, 5H), 7.26 (t, *J* = 7.6 Hz, 1H), 7.12 (s, 1H), 2.38 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.6, 138.2, 133.8, 131.1, 129.0, 127.9, 126.7 (d, *J* = 1.6 Hz), 126.6, 123.5, 123.2, 122.3 (q, *J* = 289.5 Hz), 121.6, 116.2, 108.4, 93.4 (q, *J* = 33.6 Hz), 10.0;

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 332.0893, found: 332.0896;

HPLC analysis: 94:6 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 12.7 min, t_{major} = 27.1 min), $[\alpha]_D^{25}$ = +94.54 (c = 1.0, $CHCl_3$).



3q

(*R*)-7-chloro-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3q): slightly yellow oil, 33.7 mg, 96% yield

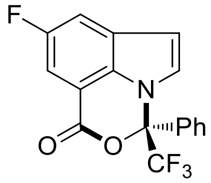
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.8 Hz, 1H), 7.60 – 7.33 (m, 6H), 7.28 (d, *J* = 8.5 Hz, 1H), 6.86 (s, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.8, 137.9, 134.3, 133.2, 131.4, 129.2, 126.9, 126.6 (d, *J* = 1.6 Hz), 126.0, 124.6, 122.5, 122.1 (q, *J* = 289.1 Hz), 107.2, 105.0, 93.5 (q, *J* = 33.7 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -78.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 352.0347, found: 352.0347;

HPLC analysis: 92:8 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 11.8 min, t_{major} = 15.4 min), $[\alpha]_D^{25}$ = +142.24 (c = 1.0, $CHCl_3$).



3r

(*R*)-8-fluoro-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3r): yellow solid, 32.8 mg, 98% yield

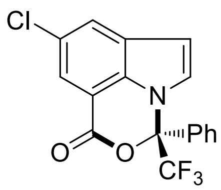
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (td, *J* = 9.6, 2.1 Hz, 2H), 7.52 – 7.35 (m, 6H), 6.76 (d, *J* = 3.3 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ158.9 (d, *J* = 240.4 Hz), 157.6 (d, *J* = 3.1 Hz), 134.5, 133.2, 131.4, 129.2, 127.9, 127.7 (d, *J* = 9.9 Hz), 126.6 (d, *J* = 1.6 Hz), 122.1 (q, *J* = 289.2 Hz), 114.4 (d, *J* = 25.7 Hz), 111.0 (d, *J* = 28.3 Hz), 108.7 (d, *J* = 9.8 Hz), 106.1 (d, *J* = 4.5 Hz), 93.6 (q, *J* = 33.7 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.1 (3F), -119.6 (1F);

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 336.0642, found: 336.0640;

HPLC analysis: 97.5:2.5 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 12.1 min, t_{major} = 25.3 min), $[\alpha]_D^{25}$ = +61.32 (c = 1.0, $CHCl_3$).



3s

(*R*)-8-chloro-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3s): yellow solid, 34.4 mg, 98% yield

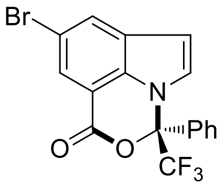
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 (d, *J* = 1.7 Hz, 1H), 7.81 (d, *J* = 1.6 Hz, 1H), 7.54 – 7.35 (m, 6H), 6.74 (d, *J* = 3.3 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.3, 136.1, 133.1, 131.4, 129.2, 128.2, 127.8, 127.7, 126.6, 126.5, 123.2, 122.1 (q, J = 289.3 Hz), 109.3, 105.8, 93.5 (q, J = 33.8 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 352.0347, found: 352.0350;

HPLC analysis: 97:3 er, (CHIRALCEL OJ-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 220 nm, t_{minor} = 11.9 min, t_{major} = 34.1 min), $[\alpha]_D^{25}$ = +28.02 (c = 1.0, $CHCl_3$).



3t

(*R*)-8-bromo-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3t): yellow solid, 37.6 mg, 95% yield

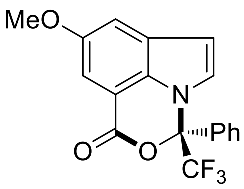
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, J = 1.6 Hz, 1H), 7.94 (d, J = 1.5 Hz, 1H), 7.52 – 7.33 (m, 6H), 6.74 (d, J = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 157.2, 136.4, 133.1, 131.4, 130.7, 129.2, 128.7, 127.6 (d, J = 1.6 Hz), 126.6 (d, J = 1.5 Hz), 125.8, 122.1 (q, J = 289.1 Hz), 115.1, 109.7, 105.7, 93.5 (q, J = 33.8 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 395.9842, found: 395.9856;

HPLC analysis: 95:5 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 10.1 min, t_{minor} = 10.9 min), $[\alpha]_D^{25}$ = +14.50 (c = 1.0, $CHCl_3$).



3u

(*R*)-8-methoxy-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3u): white solid, 32.2 mg, 93% yield

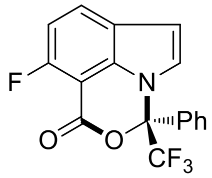
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 – 7.29 (m, 8H), 6.69 (d, J = 3.2 Hz, 1H), 3.85 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 158.4, 156.1, 133.7, 133.6, 131.2, 129.1, 127.9, 127.1, 126.6 (d, *J* = 1.4 Hz), 122.2 (q, *J* = 289.1 Hz), 113.4, 110.4, 108.5, 105.8, 93.5 (q, *J* = 33.7 Hz), 56.5;

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 348.0842, found: 348.0851;

HPLC analysis: 96:4 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 12.8 min, t_{minor} = 14.0 min), $[\alpha]_D^{25}$ = +45.96 (c = 1.0, $CHCl_3$).



3v

(*R*)-9-fluoro-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3v): slightly yellow oil, 30.1 mg, 90% yield

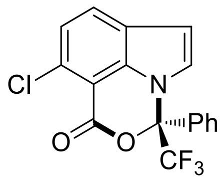
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (dd, *J* = 8.7, 4.2 Hz, 1H), 7.53 – 7.31 (m, 6H), 7.00 (dd, *J* = 10.6, 8.7 Hz, 1H), 6.75 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ159.2 (d, *J* = 264.4 Hz), 154.5 (d, *J* = 3.6 Hz), 137.4 (d, *J* = 5.8 Hz), 133.2, 131.3, 129.8 (d, *J* = 10.4 Hz), 129.2, 126.7 (d, *J* = 1.5 Hz), 123.2 (d, *J* = 2.3 Hz), 122.1 (q, *J* = 289.1 Hz), 111.4, 111.2, 106.3, 97.1 (d, *J* = 14.2 Hz), 93.4 (q, *J* = 31.6 Hz);

^{19}F NMR (377 MHz, $CDCl_3$) δ -78.0 (3F), -113.8 (1F);

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 336.0642, found: 336.0647;

HPLC analysis: 97:3 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 12.8 min, t_{minor} = 14.3 min), $[\alpha]_D^{25}$ = +40.70 (c = 1.0, $CHCl_3$).

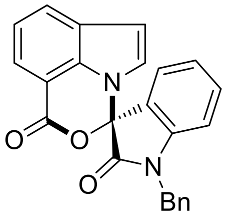


3w

(*R*)-9-chloro-3-phenyl-3-(trifluoromethyl)-[1,3]oxazino[5,4,3-hi]indol-1(3H)-one (3w): slightly yellow oil, 33.7 mg, 96% yield

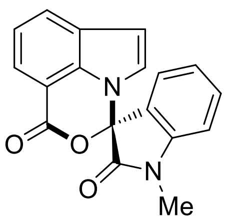
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (d, *J* = 8.4 Hz, 1H), 7.53 – 7.32 (m, 6H), 7.27 (d, *J* = 8.4 Hz, 1H), 6.75 (d, *J* = 3.4 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 155.4, 138.4, 133.3, 131.4, 131.3, 129.2, 128.4, 126.7, 126.6, 125.9, 125.1, 122.1 (q, *J* = 289.4 Hz), 106.4, 106.3, 93.0 (q, *J* = 33.6 Hz);
^{19}F NMR (377 MHz, $CDCl_3$) δ -78.0;
HRMS (ESI, m/z): calcd. for $[M+H]^+$: 352.0347, found: 352.0357;
HPLC analysis: 96.5:3.5 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 11.4 min, t_{minor} = 12.2 min), $[\alpha]_D^{25}$ = -48.46 (c = 1.0, $CHCl_3$).



5a

(*R*)-1'-benzyl-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5a): white solid, 32.3 mg, 85% yield
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.98 – 7.74 (m, 2H), 7.60 (dd, *J* = 7.4, 0.7 Hz, 1H), 7.51 – 7.08 (m, 8H), 6.82 (d, *J* = 7.9 Hz, 1H), 6.65 (s, 2H), 4.87 (d, *J* = 15.7 Hz, 1H), 4.72 (d, *J* = 15.7 Hz, 1H);
^{13}C NMR (101 MHz, $CDCl_3$) δ 169.7, 160.7, 143.8, 138.7, 134.6, 133.3, 129.1, 128.2, 127.8, 127.5, 127.4, 126.4, 124.3, 123.4, 122.9 (2C), 122.1, 110.6, 109.9, 106.6, 89.9, 44.1;
HRMS (ESI, m/z): calcd. for $[M+H]^+$: 381.1234, found: 381.1233;
HPLC analysis: 97:3 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 15.0 min, t_{major} = 16.3 min), $[\alpha]_D^{25}$ = -493.92 (c = 1.0, $CHCl_3$).
Note: reproduced by the co-author Dr. Guoyong Luo gave 83% yield and 97:3 er.



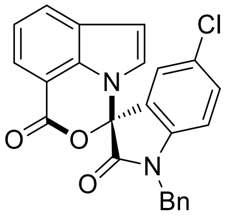
5b

(*R*)-1'-methyl-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5b): slightly yellow solid, 25.8 mg, 85% yield
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.87 (t, *J* = 8.3 Hz, 2H), 7.65 – 7.48 (m, 2H), 7.33 – 7.20 (m, 2H), 6.96 (d, *J* = 7.9 Hz, 1H), 6.63 (dd, *J* = 9.7, 3.3 Hz, 2H), 3.15 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.5, 160.7, 144.8, 138.6, 133.4, 127.7, 127.4, 126.3, 124.2, 123.5, 122.9, 122.8, 122.0, 109.9, 109.4, 106.3, 89.8, 26.5;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 305.0921, found: 305.0932;

HPLC analysis: 97:3 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{major} = 15.3 min, t_{minor} = 30.9 min), $[\alpha]_D^{25}$ = -498.92 (c = 1.0, $CHCl_3$).



5c

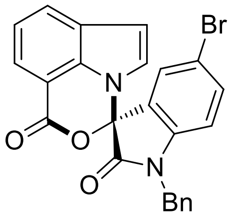
(*R*)-1'-benzyl-5'-chloro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5c): slightly yellow solid, 34.0 mg, 82% yield

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (dd, *J* = 12.6, 7.7 Hz, 2H), 7.60 (d, *J* = 2.0 Hz, 1H), 7.46 – 7.10 (m, 7H), 6.75 (d, *J* = 8.5 Hz, 1H), 6.68 (dd, *J* = 10.1, 3.2 Hz, 2H), 4.87 (d, *J* = 15.7 Hz, 1H), 4.72 (d, *J* = 15.7 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.3, 160.1, 142.3, 138.6, 134.2, 133.2, 129.8, 129.2, 128.4, 127.9, 127.5, 127.4, 126.8, 124.5, 123.2, 123.1, 122.3, 111.7, 109.7, 107.1, 89.6, 44.3;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 415.0844, found: 415.0845;

HPLC analysis: 94:6 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 27.3 min, t_{major} = 36.0 min), $[\alpha]_D^{25}$ = -253.10 (c = 1.0, $CHCl_3$).



5d

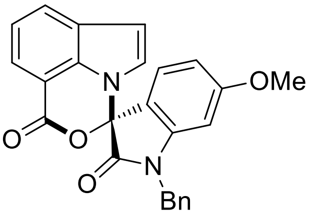
(*R*)-1'-benzyl-5'-bromo-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5d): yellow solid, 33.5 mg, 73% yield

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.90 (dd, *J* = 12.0, 7.7 Hz, 2H), 7.74 (d, *J* = 1.9 Hz, 1H), 7.53 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.41 – 7.12 (m, 6H), 6.71 – 6.66 (m, 3H), 4.86 (d, *J* = 15.7 Hz, 1H), 4.72 (d, *J* = 15.7 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.2, 160.1, 142.8, 138.6, 136.1, 134.1, 129.5, 129.2, 128.4, 127.9, 127.5, 127.4, 124.8, 123.3, 123.2, 122.3, 116.9, 112.1, 109.7, 107.1, 89.5, 44.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 459.0339, found: 459.0339;

HPLC analysis: 94:6 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 28.2 min, t_{major} = 37.4 min), $[\alpha]_D^{25}$ = -351.78 (c = 1.0, $CHCl_3$).



5e

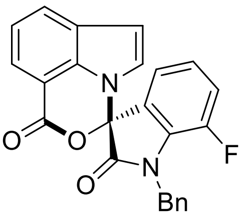
(*R*)-1'-benzyl-6'-methoxy-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5e): slightly yellow solid, 33.2 mg, 81% yield

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.88 (dd, *J* = 16.6, 7.6 Hz, 2H), 7.52 (d, *J* = 8.3 Hz, 1H), 7.41 – 7.12 (m, 6H), 6.77 – 6.56 (m, 3H), 6.37 (d, *J* = 2.1 Hz, 1H), 4.83 (d, *J* = 15.7 Hz, 1H), 4.69 (d, *J* = 15.7 Hz, 1H), 3.79 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.2, 163.8, 161.1, 145.5, 138.7, 134.7, 129.1, 128.2, 127.6, 127.5, 127.4, 123.5, 122.8, 122.0, 114.4, 110.0, 107.8, 106.4, 98.5, 89.9, 55.8, 44.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 411.1339, found: 411.1346;

HPLC analysis: 98:2 er, (CHIRALCEL OD column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.5 mL/min, λ = 254 nm, t_{major} = 29.2 min, t_{minor} = 33.4 min), $[\alpha]_D^{25}$ = -440.12 (c = 1.0, $CHCl_3$).



5f

(*R*)-1'-benzyl-7'-fluoro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5f): slightly yellow solid, 35.8 mg, 90% yield

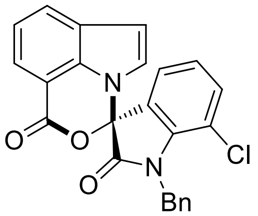
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 14.8, 7.7 Hz, 2H), 7.41 (d, *J* = 7.3 Hz, 1H), 7.37 – 7.09 (m, 8H), 6.63 (dd, *J* = 20.2, 3.2 Hz, 2H), 4.98 (d, *J* = 15.3 Hz, 1H), 4.88 (d, *J* = 15.3 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.5, 160.3, 147.6 (d, *J* = 248.0 Hz), 138.6, 135.8, 130.5 (d, *J* = 9.6 Hz), 128.9, 128.1, 127.9, 127.6 (d, *J* = 1.5 Hz), 127.5, 125.6 (d, *J* = 3.0 Hz), 125.3 (d, *J* = 6.3 Hz), 123.3, 123.0, 122.4 (d, *J* = 3.5 Hz), 122.3, 121.5 (d, *J* = 19.6 Hz), 109.8, 106.9, 89.5 (d, *J* = 3.2 Hz), 45.8 (d, *J* = 4.6 Hz);

^{19}F NMR (282 MHz, $CDCl_3$) δ -131.3;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 399.1139, found: 399.1141;

HPLC analysis: 95:5 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 18.8 min, t_{major} = 19.8 min), $[\alpha]_D^{25}$ = -471.34 (c = 1.0, $CHCl_3$).



5g

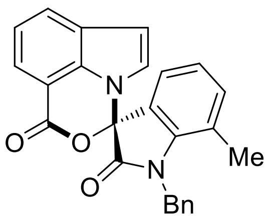
(*R*)-1'-benzyl-7'-chloro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5g): yellow solid, 36.0 mg, 87% yield

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.89 (dd, *J* = 14.0, 7.7 Hz, 2H), 7.55 (d, *J* = 7.4 Hz, 1H), 7.41 (d, *J* = 8.2 Hz, 1H), 7.36 – 7.05 (m, 7H), 6.67 (d, *J* = 3.0 Hz, 2H), 5.23 (s, 2H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.4, 160.2, 140.0, 138.7, 136.2, 135.7, 128.9, 127.9, 127.8, 127.5, 126.6, 125.8, 125.3, 125.2, 123.2, 123.1, 122.2, 116.8, 109.8, 107.0, 89.0, 45.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 415.0844, found: 415.0847;

HPLC analysis: 95:5 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 12.1 min, t_{major} = 14.0 min), $[\alpha]_D^{25}$ = -340.66 (c = 1.0, $CHCl_3$).



5h

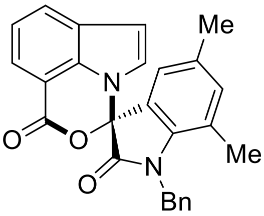
(*R*)-1'-benzyl-7'-methyl-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5h): slightly yellow solid, 27.6 mg, 70% yield

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.88 (dd, *J* = 16.2, 7.7 Hz, 2H), 7.50 (d, *J* = 7.3 Hz, 1H), 7.38 – 7.03 (m, 8H), 6.72 (d, *J* = 3.2 Hz, 1H), 6.66 (d, *J* = 3.2 Hz, 1H), 5.17 – 4.96 (m, 2H), 2.31 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 160.8, 141.8, 138.7, 137.2, 136.3, 129.2, 127.8, 127.7, 127.4, 125.7, 124.5, 124.4, 123.6, 123.5, 122.8, 122.0, 121.4, 110.1, 106.5, 89.5, 45.3, 18.8;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 395.1390, found: 395.1394;

HPLC analysis: 97.5:2.5 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 13.8 min, t_{major} = 14.7 min), $[\alpha]_D^{25}$ = -473.88 (c = 1.0, $CHCl_3$).



5i

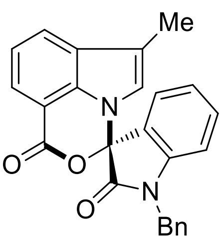
(*R*)-1'-benzyl-5',7'-dimethyl-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5i): yellow solid, 35.5 mg, 87% yield

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.87 (dd, *J* = 15.6, 7.7 Hz, 2H), 7.35 – 7.21 (m, 5H), 7.11 (d, *J* = 7.5 Hz, 2H), 7.00 (s, 1H), 6.73 (d, *J* = 3.1 Hz, 1H), 6.66 (d, *J* = 3.2 Hz, 1H), 5.11 – 4.92 (m, 2H), 2.29 (s, 3H), 2.26 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8, 160.8, 139.3, 138.7, 137.6, 136.4, 134.2, 129.1, 127.7, 127.6, 127.4, 125.8, 124.9, 123.6, 123.5, 122.8, 122.0, 121.1, 110.0, 106.4, 89.7, 45.3, 20.7, 18.7;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 409.1547, found: 409.1550;

HPLC analysis: 98:2 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 12.4 min, t_{major} = 13.8 min), $[\alpha]_D^{25}$ = -508.14 (c = 1.0, $CHCl_3$).



5j

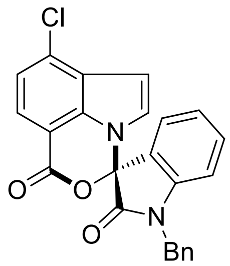
(*R*)-1'-benzyl-6-methyl-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5j): slightly yellow solid, 32.3 mg, 82% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.4 Hz, 1H), 7.80 (dd, *J* = 7.9, 0.7 Hz, 1H), 7.60 (dd, *J* = 7.5, 0.8 Hz, 1H), 7.40 (td, *J* = 7.8, 1.3 Hz, 1H), 7.35 – 7.21 (m, 6H), 7.17 (td, *J* = 7.7, 0.8 Hz, 1H), 6.81 (d, *J* = 7.9 Hz, 1H), 6.41 (d, *J* = 1.0 Hz, 1H), 4.83 (d, *J* = 15.7 Hz, 1H), 4.73 (d, *J* = 15.7 Hz, 1H), 2.27 (d, *J* = 1.1 Hz, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.9, 160.8, 143.8, 139.4, 134.7, 133.1, 129.1, 128.4, 128.1, 127.4, 126.3, 126.1, 124.2, 123.1, 122.7, 121.5, 120.8, 117.0, 110.4, 109.8, 90.0, 44.1, 10.0;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 395.1390, found: 395.1384;

HPLC analysis: 96:4 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 20.3 min, t_{major} = 22.8 min), $[\alpha]_D^{25}$ = -481.06 (c = 1.0, $CHCl_3$).



5k

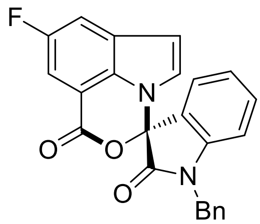
(*R*)-1'-benzyl-7-chloro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5k): yellow solid, 38.1 mg, 92% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 8.0 Hz, 1H), 7.59 (dd, *J* = 7.5, 0.7 Hz, 1H), 7.42 (td, *J* = 7.9, 1.2 Hz, 1H), 7.36 – 7.14 (m, 7H), 6.84 (d, *J* = 7.9 Hz, 1H), 6.72 (d, *J* = 3.3 Hz, 1H), 6.68 (d, *J* = 3.3 Hz, 1H), 4.86 (d, *J* = 15.7 Hz, 1H), 4.72 (d, *J* = 15.7 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.5, 160.0, 143.9, 138.9, 134.5, 133.4 (2C), 129.1, 128.2, 127.3, 126.4, 126.3, 124.4, 124.0, 123.9, 122.4, 122.3, 110.7, 108.7, 105.3, 89.9, 44.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 415.0844, found: 415.0846;

HPLC analysis: 95:5 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 21.8 min, t_{major} = 23.0 min), $[\alpha]_D^{25}$ = -308.00 (c = 1.0, $CHCl_3$).



5l

(*R*)-1'-benzyl-8-fluoro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5l): slightly yellow solid, 31.8 mg, 80% yield

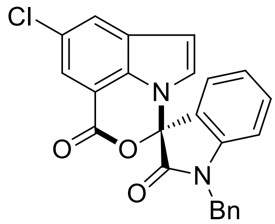
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (dd, *J* = 12.9, 4.6 Hz, 2H), 7.55 (dd, *J* = 9.4, 2.1 Hz, 1H), 7.43 (t, *J* = 7.8 Hz, 1H), 7.36 – 7.15 (m, 6H), 6.84 (d, *J* = 7.9 Hz, 1H), 6.70 (d, *J* = 3.2 Hz, 1H), 6.62 (d, *J* = 3.2 Hz, 1H), 4.86 (d, *J* = 15.7 Hz, 1H), 4.73 (d, *J* = 15.7 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.5, 159.9 (d, *J* = 23.5 Hz), 159.1 (d, *J* = 239.7 Hz), 143.9, 135.5, 134.5, 133.4, 129.2, 128.2, 128.0 (d, *J* = 9.9 Hz), 127.3, 126.4, 125.0, 124.4, 122.4, 113.7, 113.5, 110.6, 110.2 (d, *J* = 10.0 Hz), 106.5 (d, *J* = 4.6 Hz), 90.0, 44.2;

^{19}F NMR (377 MHz, $CDCl_3$) δ -120.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 399.1139, found: 399.1141;

HPLC analysis: 98:2 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 21.0 min, t_{major} = 22.7 min), $[\alpha]_D^{25}$ = -475.22 (c = 1.0, $CHCl_3$).



5m

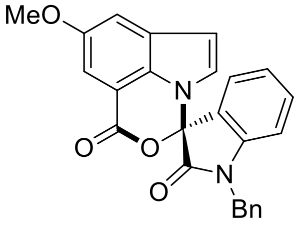
(*R*)-1'-benzyl-8-chloro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5m): slightly yellow solid, 37.7 mg, 91% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 1.5 Hz, 1H), 7.82 (d, *J* = 1.6 Hz, 1H), 7.60 (dd, *J* = 7.4, 0.7 Hz, 1H), 7.43 (td, *J* = 7.9, 1.2 Hz, 1H), 7.37 – 7.13 (m, 6H), 6.84 (d, *J* = 7.9 Hz, 1H), 6.68 (d, *J* = 3.2 Hz, 1H), 6.59 (d, *J* = 3.2 Hz, 1H), 4.85 (d, *J* = 15.7 Hz, 1H), 4.72 (d, *J* = 15.7 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.4, 159.6, 143.9, 137.1, 134.5, 133.5, 129.2, 128.6, 128.2, 128.0, 127.3, 127.1, 126.4, 124.8, 124.4, 122.7, 122.3, 110.8, 110.7, 106.2, 90.0, 44.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 415.0844, found: 415.0840;

HPLC analysis: 97.5:2.5 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 23.2 min, t_{major} = 24.3 min), $[\alpha]_D^{25}$ = -338.82 (c = 1.0, $CHCl_3$).



5n

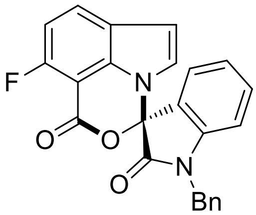
(*R*)-1'-benzyl-8-methoxy-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5n): white solid, 34.0 mg, 83% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (dd, *J* = 7.4, 0.7 Hz, 1H), 7.54 (d, *J* = 2.1 Hz, 1H), 7.44 – 7.10 (m, 8H), 6.81 (d, *J* = 7.9 Hz, 1H), 6.62 (d, *J* = 3.2 Hz, 1H), 6.56 (d, *J* = 3.2 Hz, 1H), 4.85 (d, *J* = 15.7 Hz, 1H), 4.71 (d, *J* = 15.7 Hz, 1H), 3.89 (s, 3H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.6, 160.7, 156.1, 143.8, 134.6, 134.5, 133.2, 129.1, 128.2, 128.1, 127.3, 126.4, 124.3, 124.2, 122.7, 112.5, 110.5, 110.4, 109.9, 106.3, 90.1, 56.6, 44.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 411.1339, found: 411.1347;

HPLC analysis: 96:4 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 12.8 min, t_{minor} = 14.0 min), $[\alpha]_D^{25}$ = -474.92 (c = 1.0, $CHCl_3$).



5o

(*R*)-1'-benzyl-9-fluoro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5o): white solid, 37.8 mg, 95% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (dd, *J* = 8.7, 4.2 Hz, 1H), 7.64 – 7.56 (m, 1H), 7.42 (td, *J* = 7.9, 1.2 Hz, 1H), 7.36 – 7.14 (m, 6H), 7.01 (dd, *J* = 10.6, 8.7 Hz, 1H), 6.83 (d, *J* = 7.9 Hz, 1H), 6.62 (q, *J* = 3.3 Hz, 2H), 4.86 (d, *J* = 15.7 Hz, 1H), 4.72 (d, *J* = 15.7 Hz, 1H);

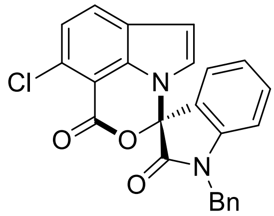
^{13}C NMR (101 MHz, $CDCl_3$) δ 169.6, 158.8 (d, *J* = 263.1 Hz), 156.9, 143.9, 138.4 (d, *J* = 6.0 Hz), 134.5, 133.4, 129.3, 129.2, 128.2, 127.3, 126.4, 124.3, 123.8 (d, *J* = 4.1

Hz), 123.7 (d, J = 2.0 Hz), 122.4, 111.3 (d, J = 23.1 Hz), 110.6, 106.7, 98.1 (d, J = 14.1 Hz), 89.83, 44.2;

^{19}F NMR (377 MHz, $CDCl_3$) δ -115.1;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 399.1139, found: 399.1150;

HPLC analysis: 97:3 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 12.8 min, t_{minor} = 14.3 min), $[\alpha]_D^{25}$ = -532.12 (c = 1.0, $CHCl_3$).



5p

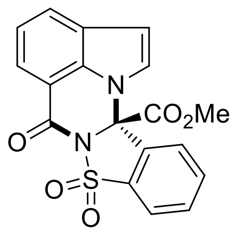
(*R*)-1'-benzyl-9-chloro-1H-spiro[[1,3]oxazino[5,4,3-hi]indole-3,3'-indoline]-1,2'-dione (5p): white solid, 37.3 mg, 90% yield

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74 (d, J = 8.4 Hz, 1H), 7.61 (dd, J = 7.5, 0.8 Hz, 1H), 7.43 (td, J = 7.9, 1.3 Hz, 1H), 7.38 – 7.14 (m, 7H), 6.83 (d, J = 7.9 Hz, 1H), 6.63 (q, J = 3.3 Hz, 2H), 4.87 (d, J = 15.7 Hz, 1H), 4.73 (d, J = 15.7 Hz, 1H);

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.6, 157.7, 143.9, 139.4, 134.5, 133.4, 130.7, 129.2, 128.2, 127.8, 127.4, 126.5, 126.4, 125.0, 124.4, 123.8, 122.4, 110.6, 107.6, 106.6, 89.5, 44.2;

HRMS (ESI, m/z): calcd. for $[M+H]^+$: 415.0844, found: 415.0848;

HPLC analysis: 97:3 er, (CHIRALPAK IC column, *n*-hexane/*i*-PrOH = 90/10, flow rate = 0.5 mL/min, λ = 220 nm, t_{major} = 11.4 min, t_{minor} = 12.3 min), $[\alpha]_D^{25}$ = -367.72 (c = 1.0, $CHCl_3$).



7

(*R*)-methyl 6-oxo-6,12b-dihydrobenzo[4,5]isothiazolo[3,2-b]pyrrolo[3,2,1-ij]quinazoline-12b-carboxylate 8,8-dioxide (7): white solid, 34.7 mg, 95% yield

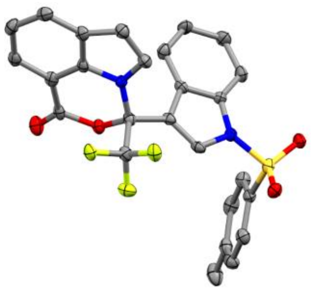
^{1}H NMR (400 MHz, DMSO) δ 8.62 (d, J = 7.9 Hz, 1H), 8.36 (d, J = 7.6 Hz, 1H), 8.22 (d, J = 3.4 Hz, 1H), 8.17 – 8.08 (m, 1H), 8.04 (t, J = 7.3 Hz, 2H), 7.89 (d, J = 7.5 Hz, 1H), 7.43 (t, J = 7.7 Hz, 1H), 6.94 (d, J = 3.4 Hz, 1H), 3.62 (s, 3H);

^{13}C NMR (101 MHz, DMSO) δ 165.8, 158.3, 137.5, 135.7, 133.6, 133.4, 128.3, 127.9, 127.8, 126.7, 126.5, 122.6, 122.5, 121.6, 111.7, 106.5, 78.8, 55.0;

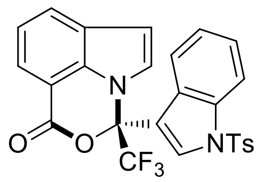
HRMS (ESI, m/z): calcd. for $[M+H]^+$: 369.0540, found: 369.0545;

HPLC analysis: 83:17 er, (CHIRALCEL OD-H column, *n*-hexane/*i*-PrOH = 80/20, flow rate = 0.8 mL/min, λ = 220 nm, t_{minor} = 33.4 min, t_{major} = 36.0 min), $[\alpha]_D^{25}$ = -84.10 (c = 0.6, $CHCl_3$).

X-ray structure of 3k, 5a and 7

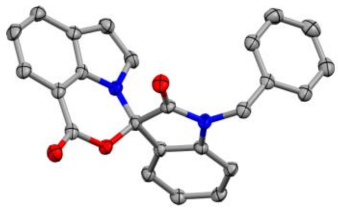


≡

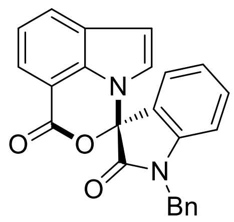


3k

Deposition No. CCDC 1902524

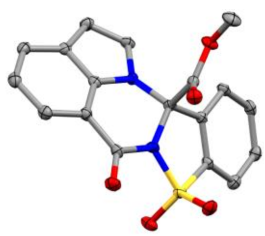


≡

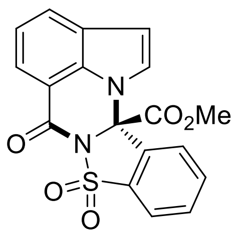


Deposition No. CCDC 1902527

5a



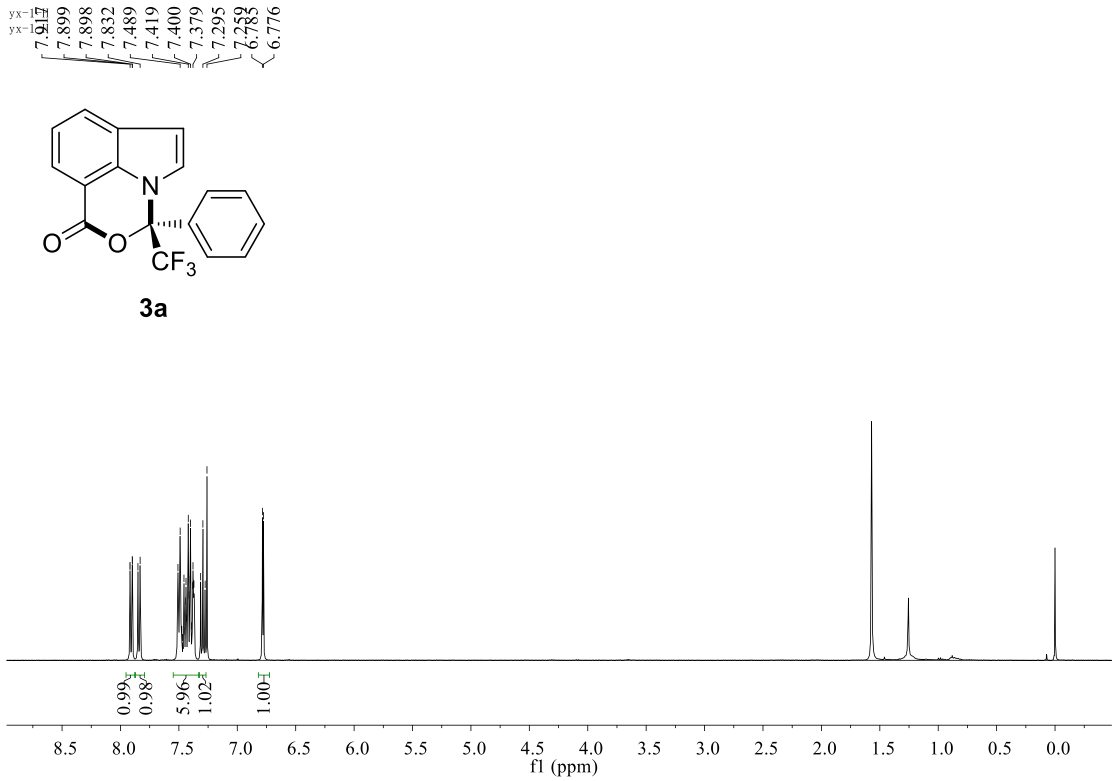
≡

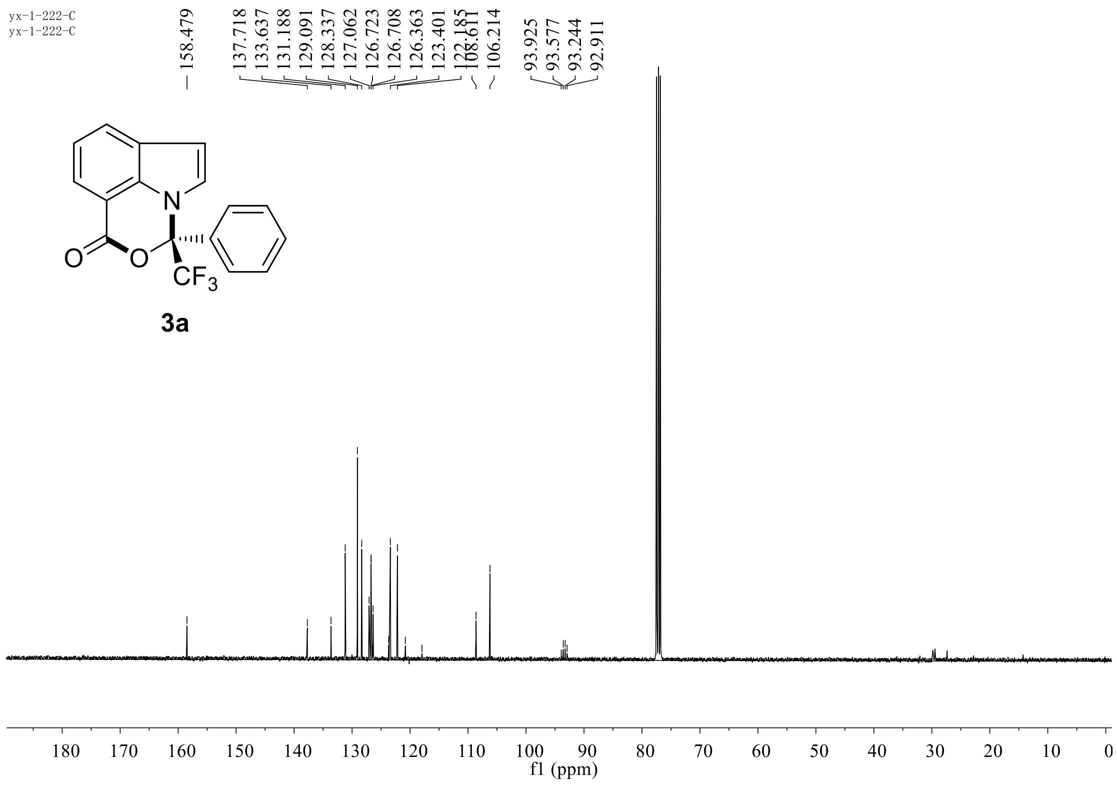


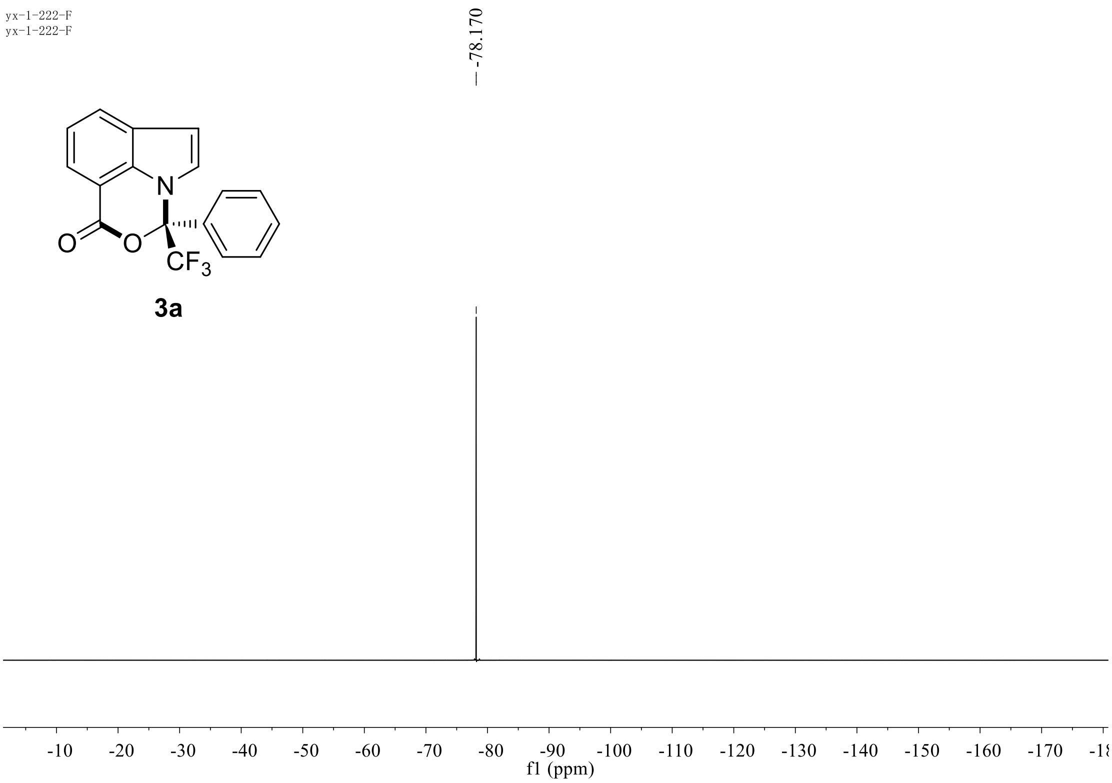
Deposition No. CCDC 1902526

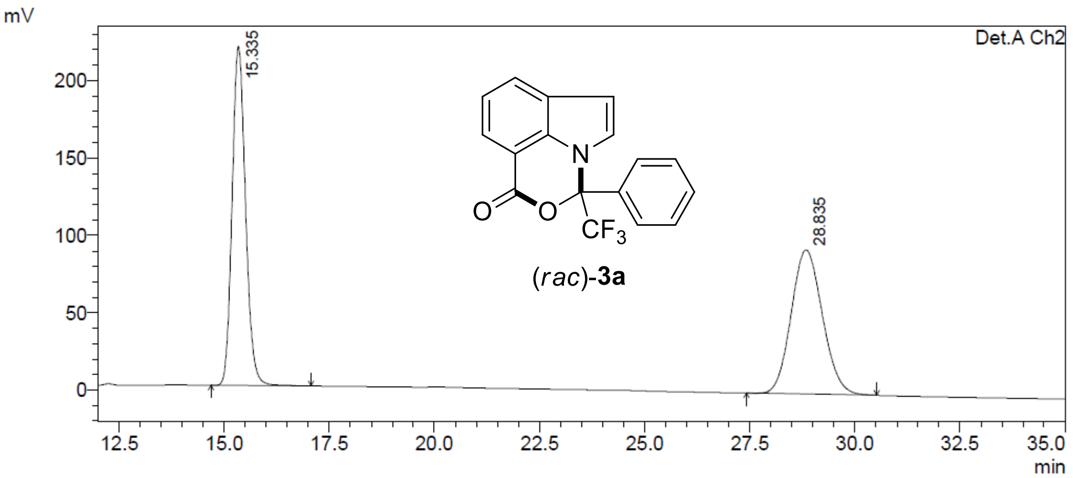
7

^1H, ^{13}C and ^{19}F spectra and HPLC charts



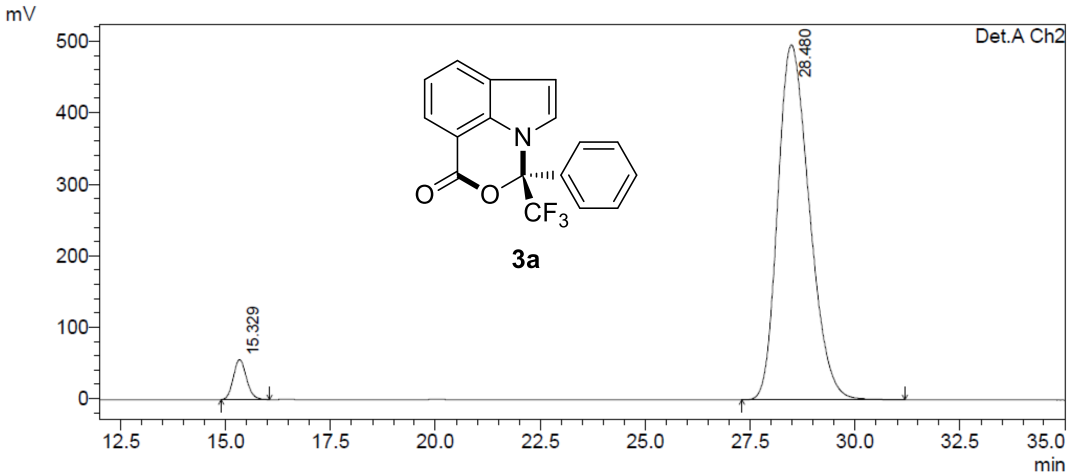






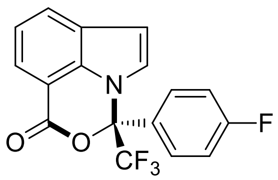
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.335	4867729	219104	50.178	70.170
2	28.835	4833121	93141	49.822	29.830
Total		9700850	312246	100.000	100.000

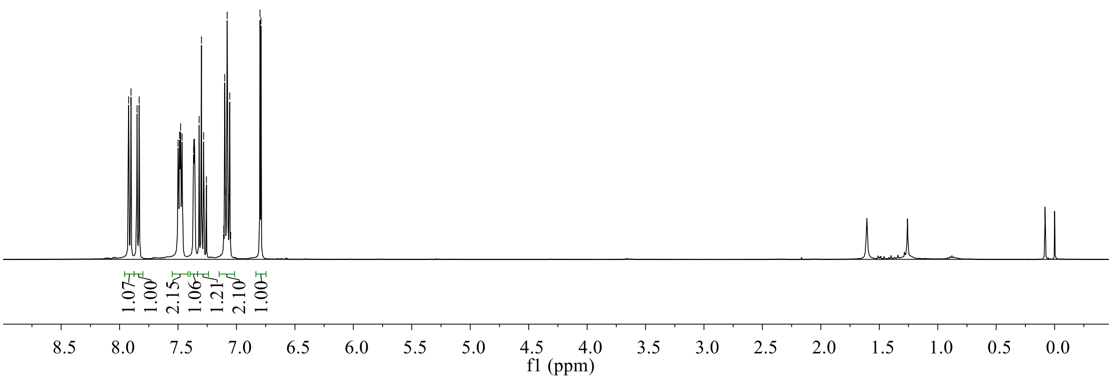


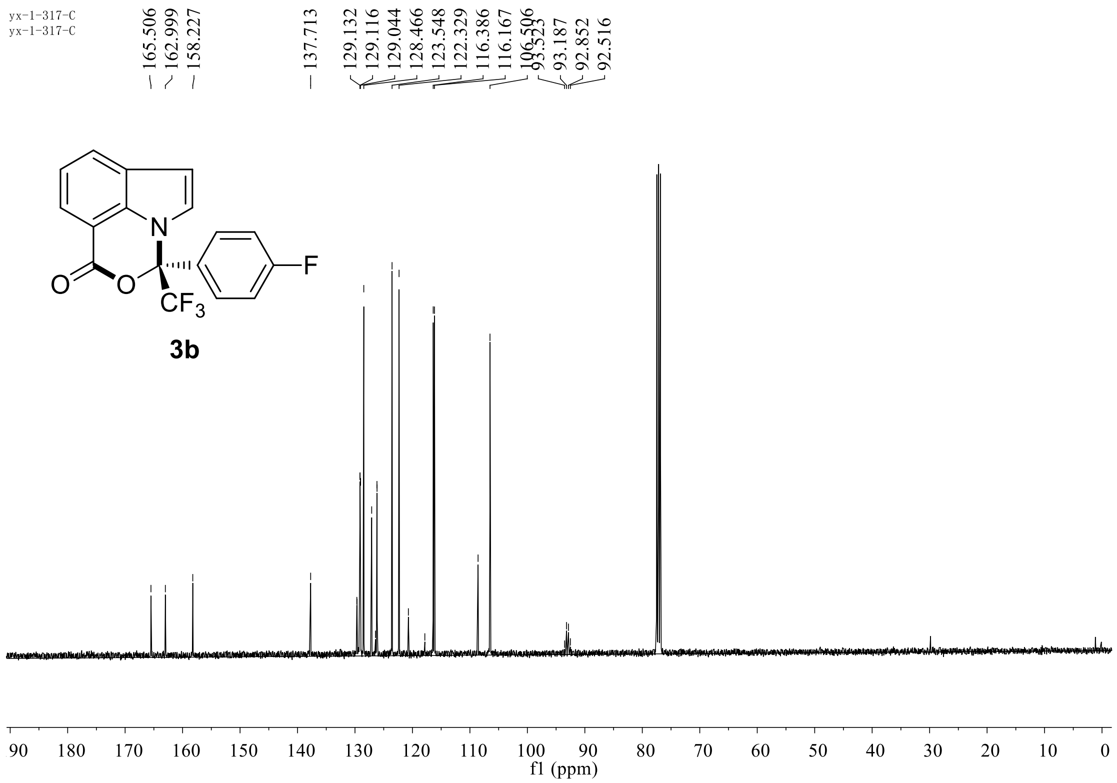
UV Detector Ch2 220nm

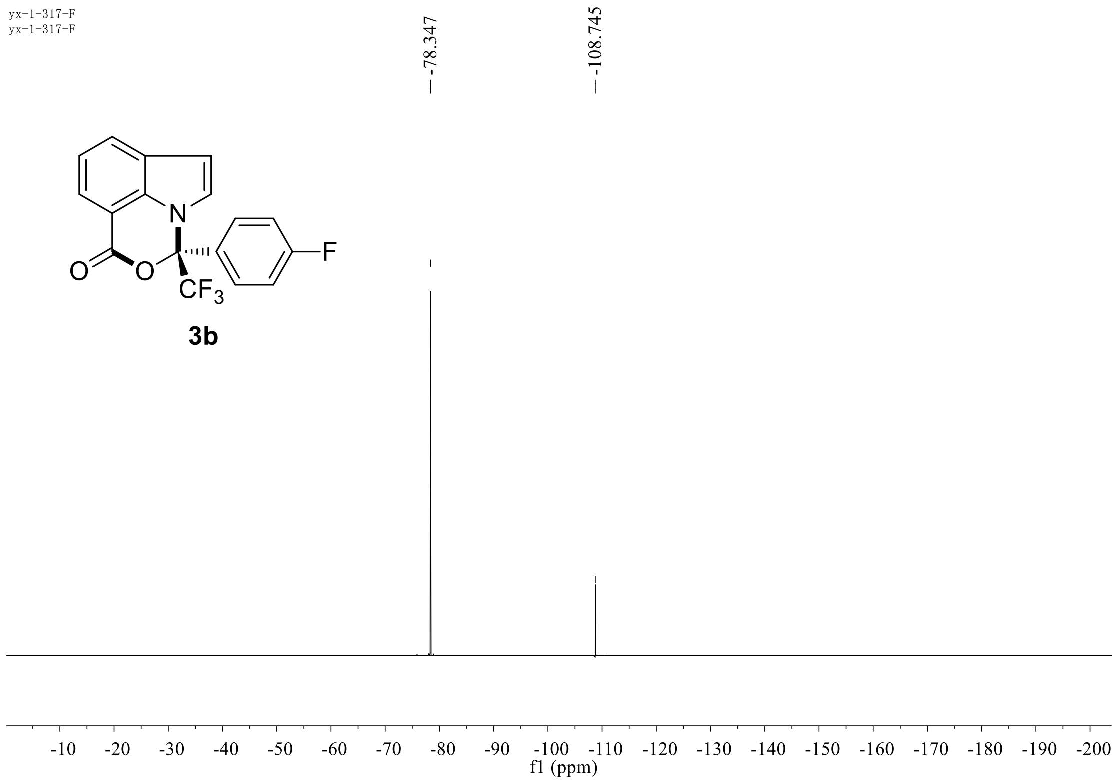
Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.329	1220612	56255	4.472	10.165
2	28.480	26075993	497139	95.528	89.835
Total		27296605	553394	100.000	100.000

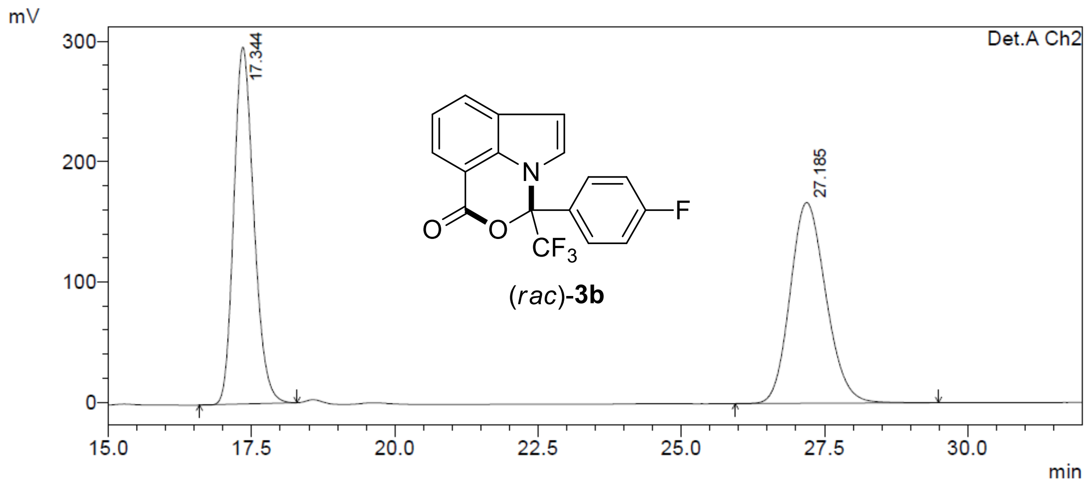


3b



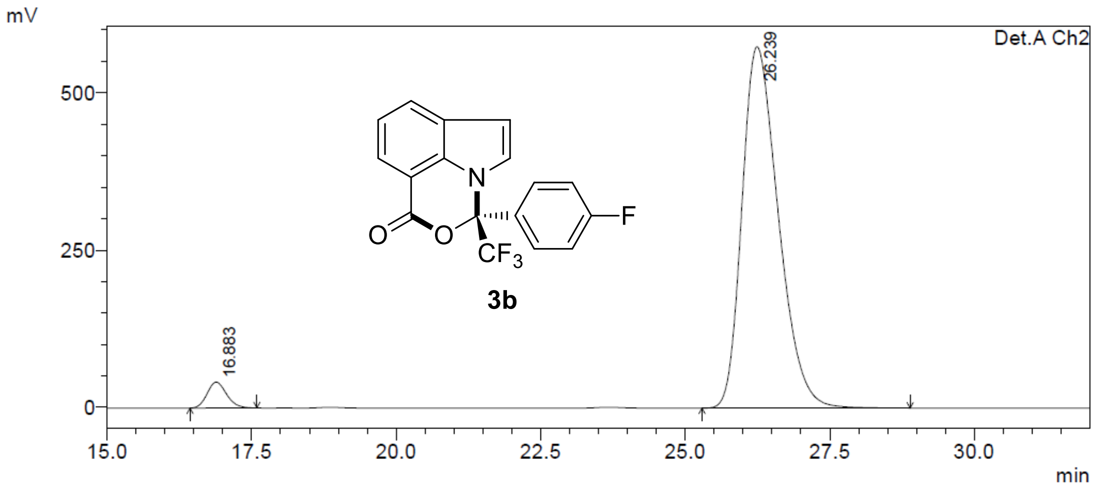

yx-1-317-C
yx-1-317-C
165.506
162.999
158.227
137.713
129.132
129.116
129.044
128.466
123.548
122.329
116.386
116.167
106.506
93.523
93.187
92.852
92.516
N
O
O
F
CF3
3b
90
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


yx-1-317-F
yx-1-317-F
-78.347
-108.745
N
O
O
F
CF3
3b
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
f1 (ppm)

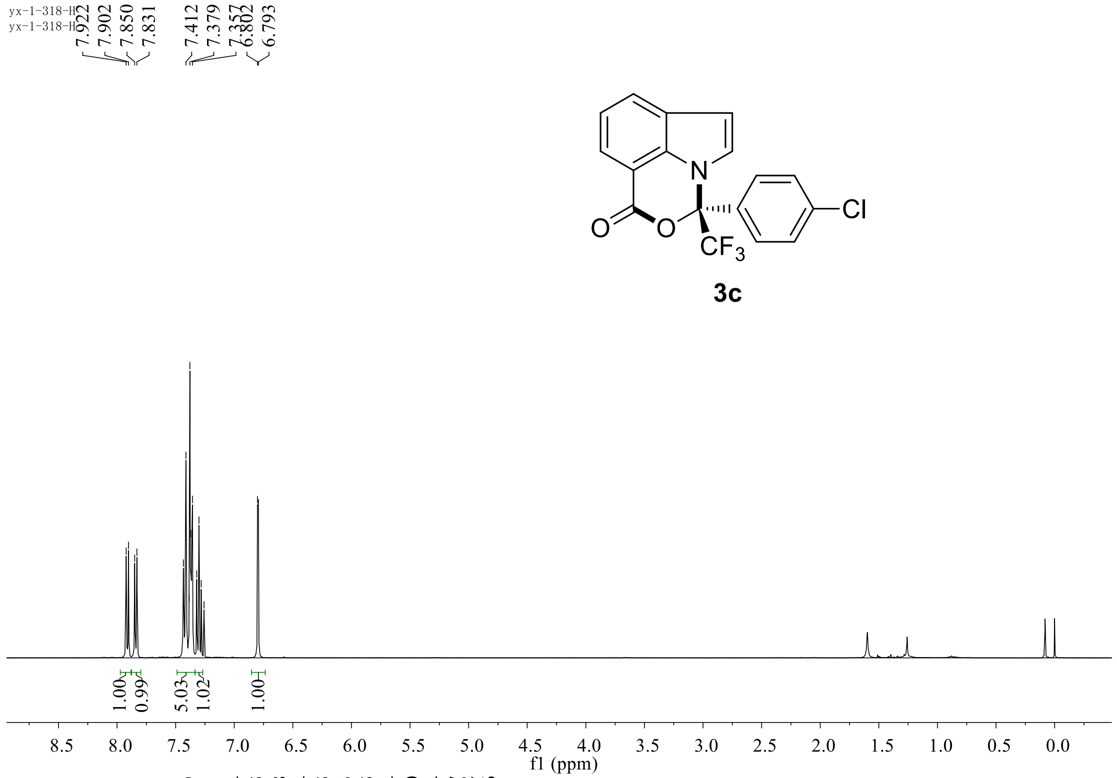


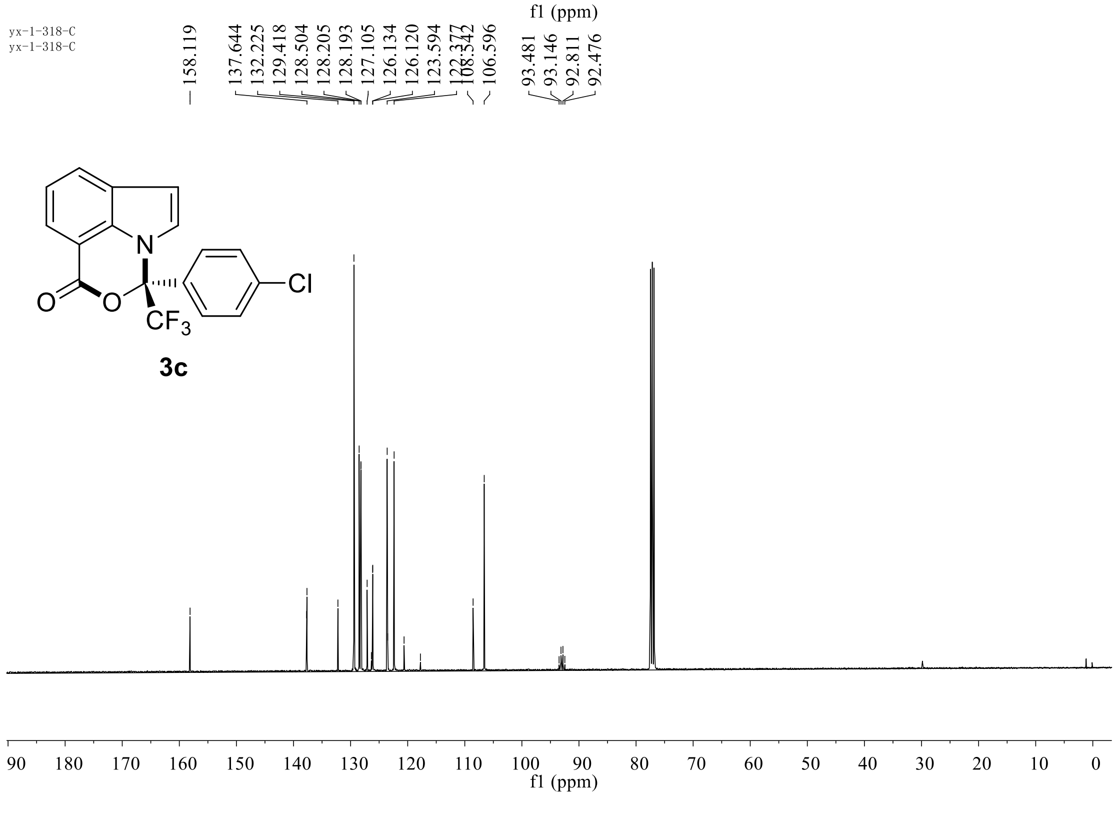
Detector A Ch2 220nm

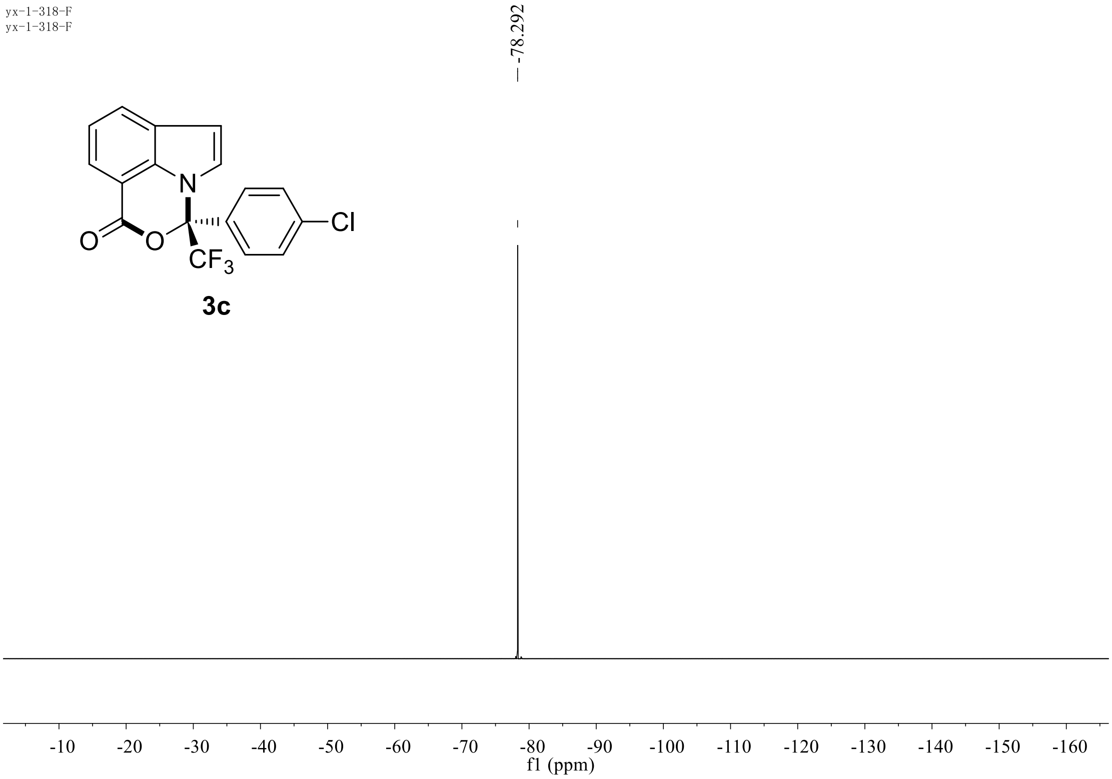
Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.344	7219996	296540	49.860	64.001
2	27.185	7260432	166798	50.140	35.999
Total		14480429	463338	100.000	100.000

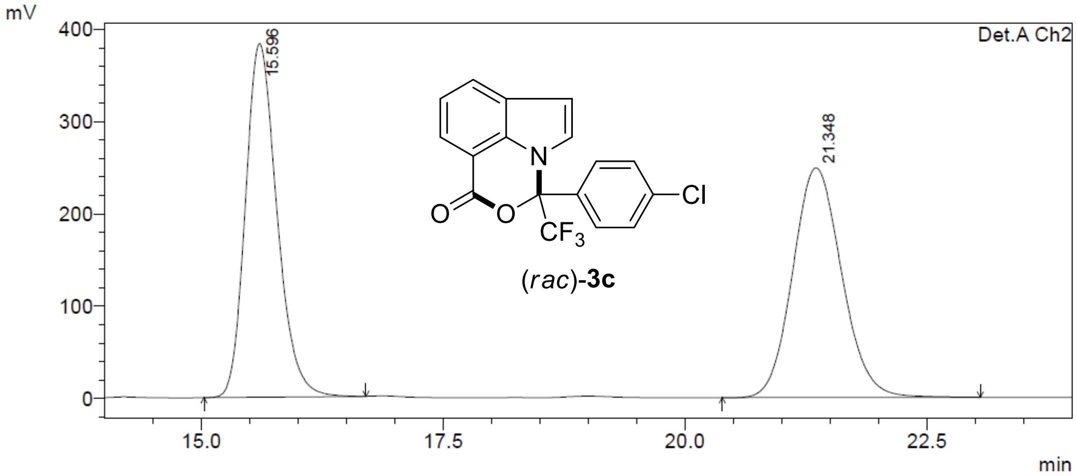


Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.883	959292	41054	3.671	6.669
2	26.239	25174939	574533	96.329	93.331
Total		26134231	615588	100.000	100.000


yx-1-318-H
7.922
7.902
7.850
7.831
7.412
7.379
7.357
6.802
6.793
1.00
0.99
5.03
1.02
1.00
f1 (ppm)
3c

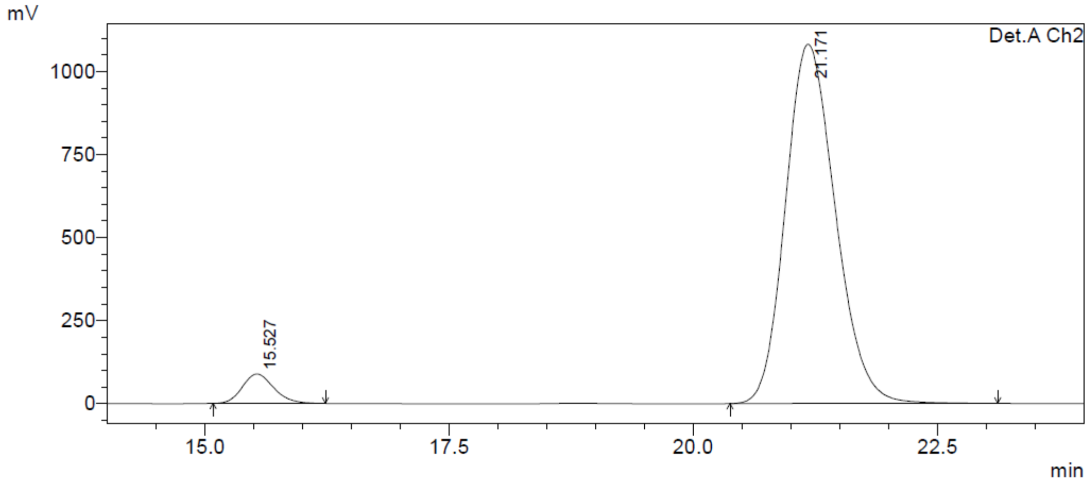

yx-1-318-C
158.119
137.644
132.225
129.418
128.504
128.205
128.193
127.105
126.134
126.120
123.594
122.377
108.542
106.596
93.481
93.146
92.811
92.476
f1 (ppm)
3c





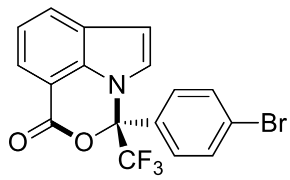
Detector A Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.596	8696086	383324	49.806	60.640
2	21.348	8763894	248809	50.194	39.360
Total		17459980	632133	100.000	100.000

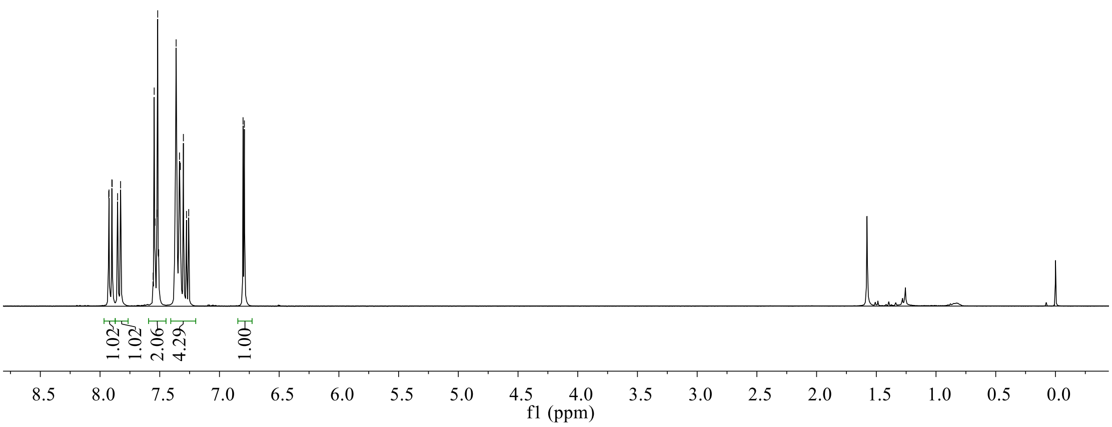


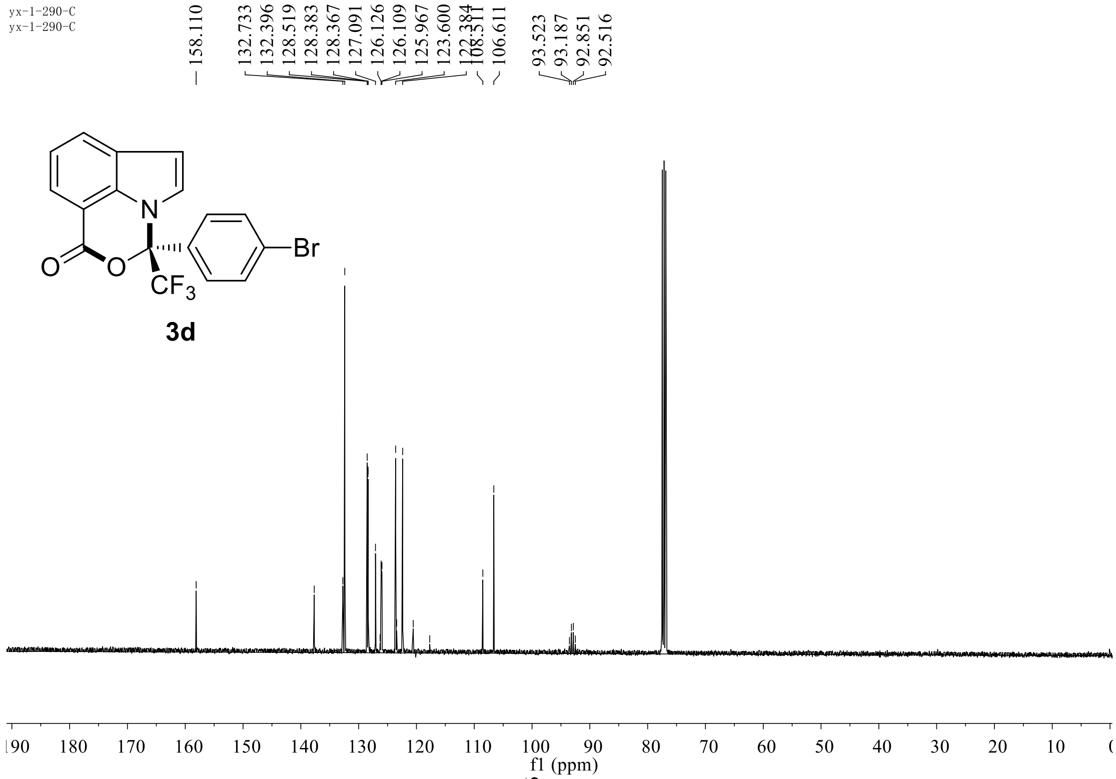
Detector A Ch2 220nm

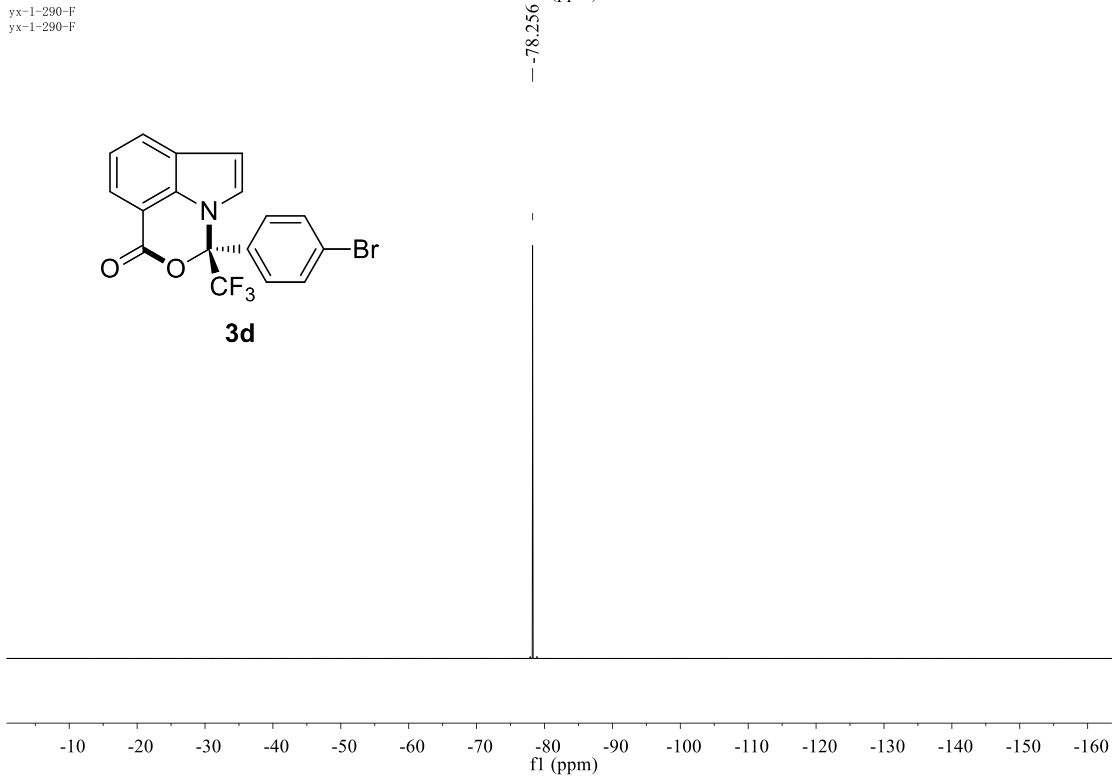
Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.527	1967892	88183	4.875	7.535
2	21.171	38402304	1082207	95.125	92.465
Total		40370196	1170390	100.000	100.000

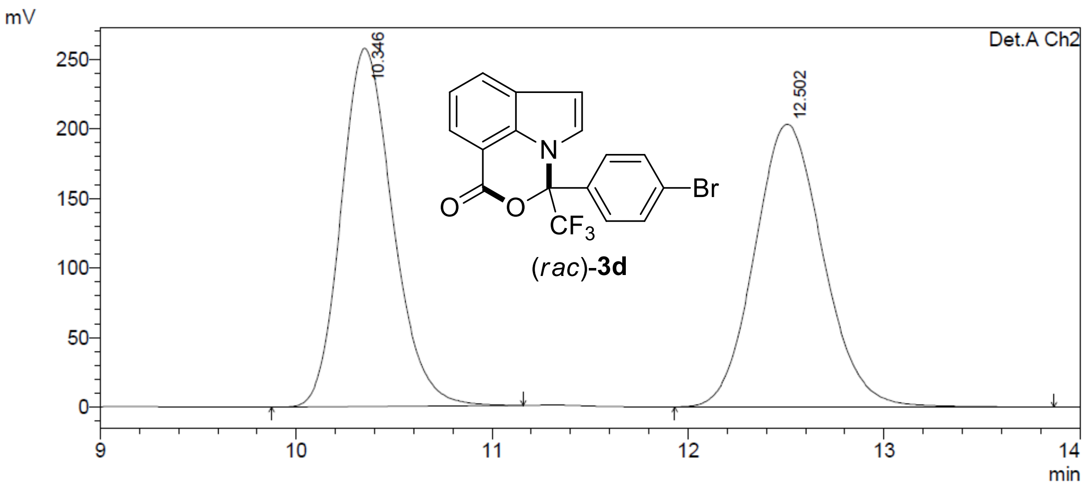


3d



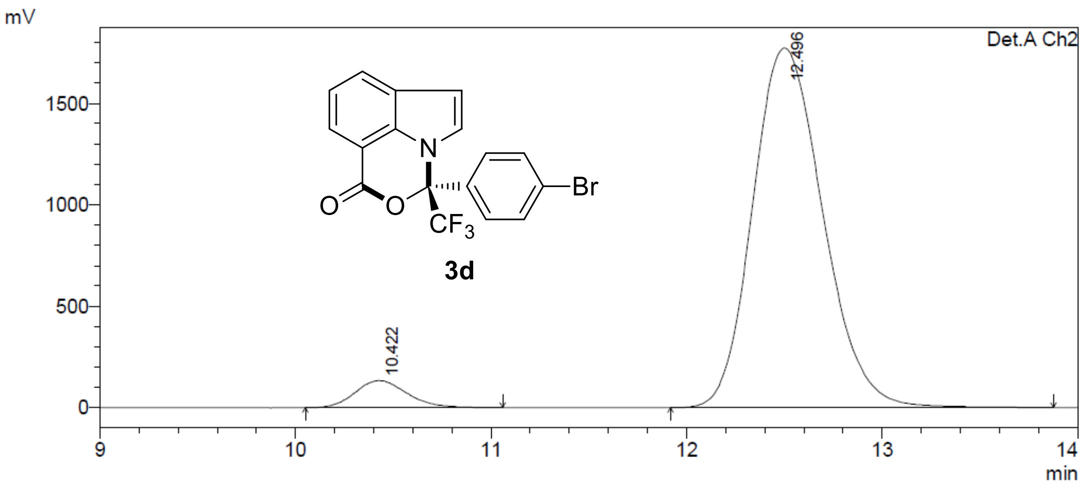

yx-1-290-C
yx-1-290-C
158.110
132.733
132.396
128.519
128.383
128.367
127.091
126.126
126.109
125.967
123.600
122.384
108.511
106.611
93.523
93.187
92.851
92.516
N
O
O
Br
CF_3
3d
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-1-290-F
yx-1-290-F
-78.256
N
O
O
Br
CF_3
3d
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160
f1 (ppm)



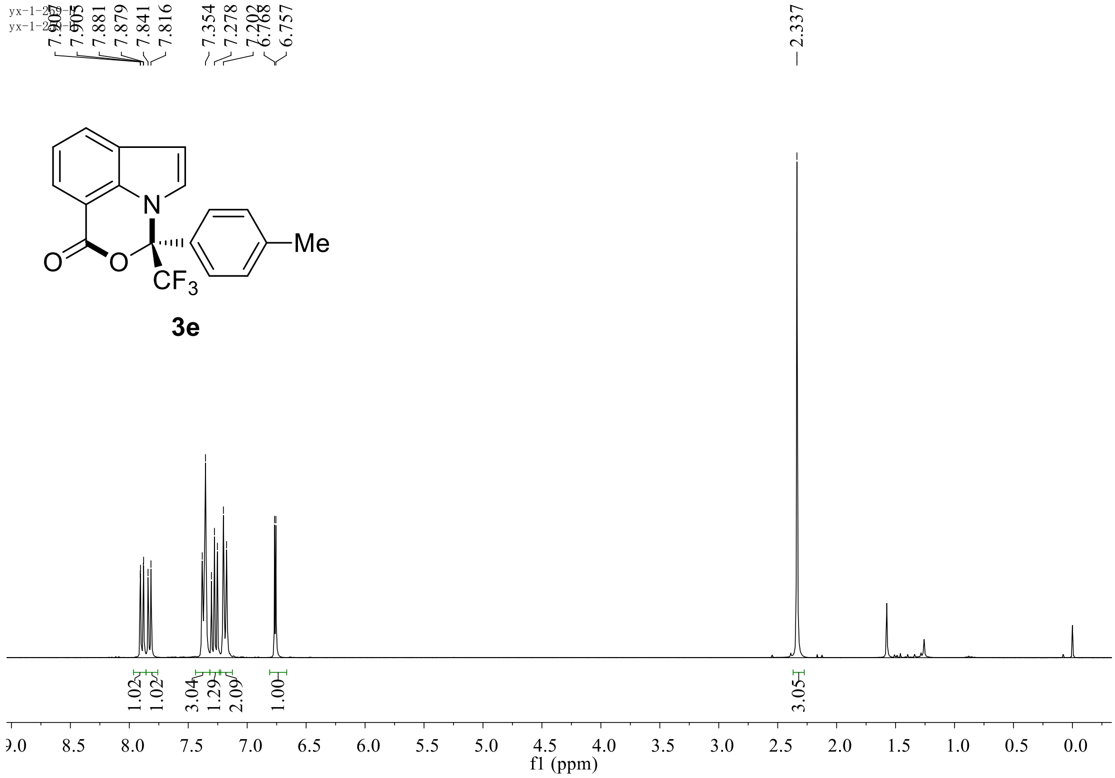
UV Detector Ch2 220nm

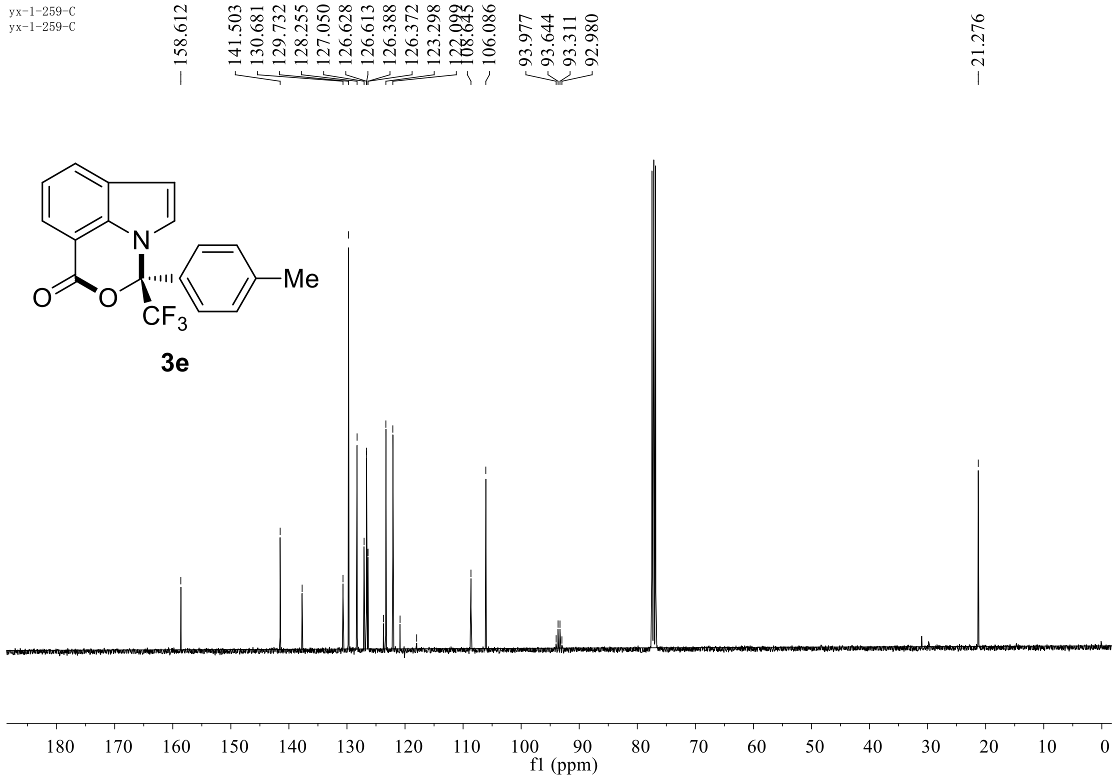
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.346	4719196	257406	48.847	55.886
2	12.502	4941910	203187	51.153	44.114
Total		9661107	460594	100.000	100.000

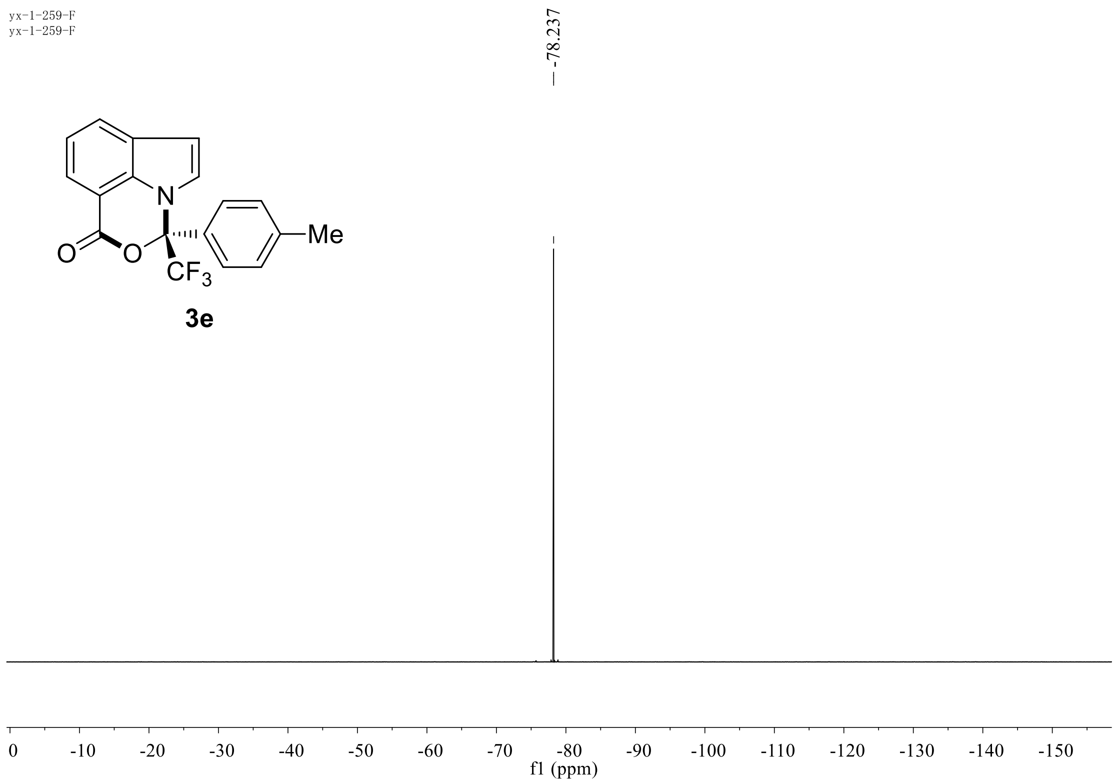


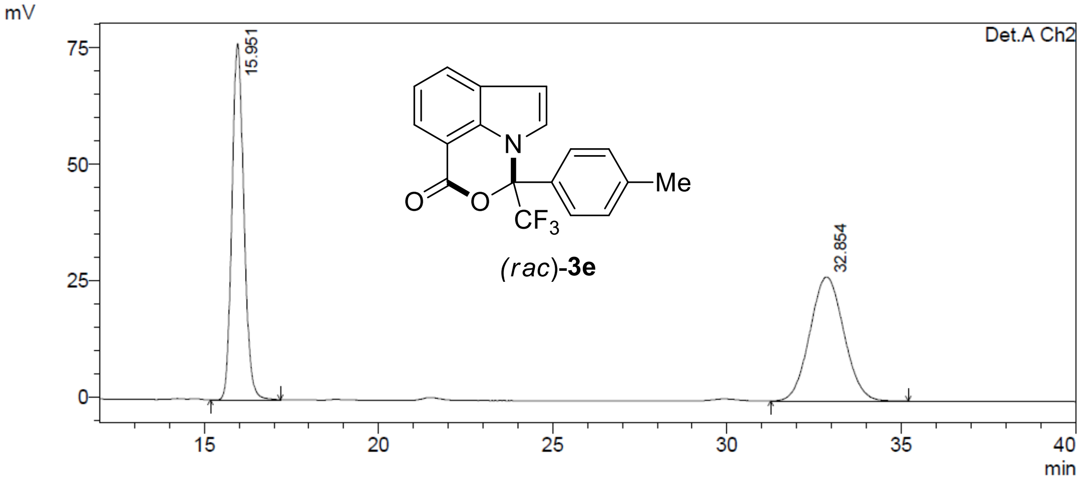
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.422	2471081	133623	5.291	7.015
2	12.496	44228967	1771268	94.709	92.985
Total		46700048	1904891	100.000	100.000



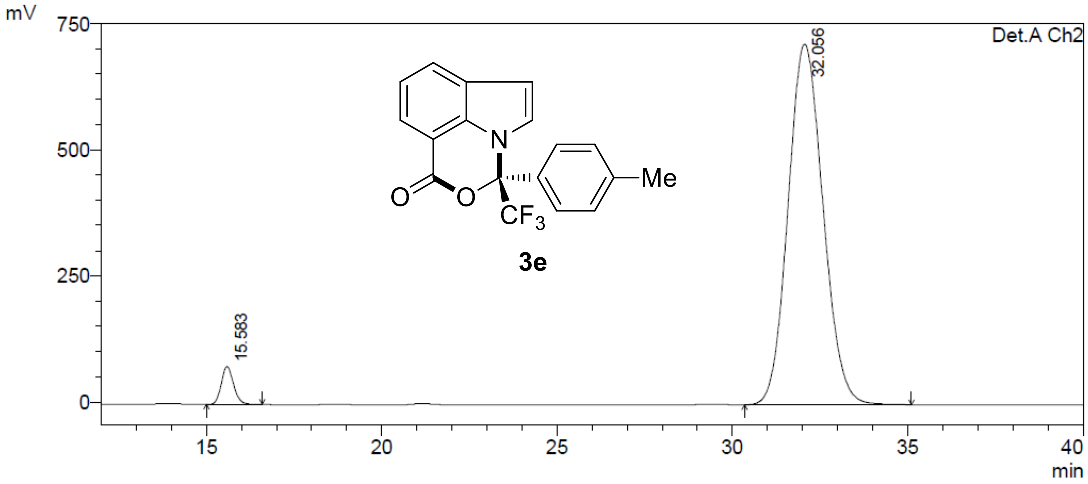






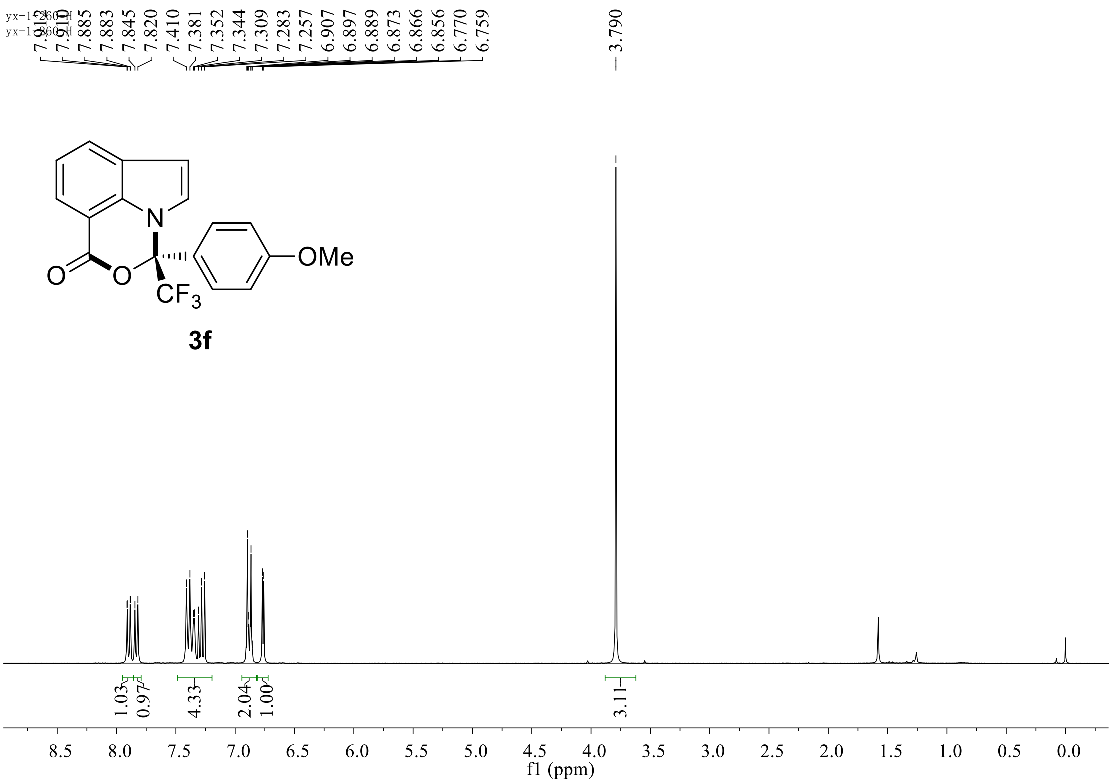
UV Detector Ch2 220nm

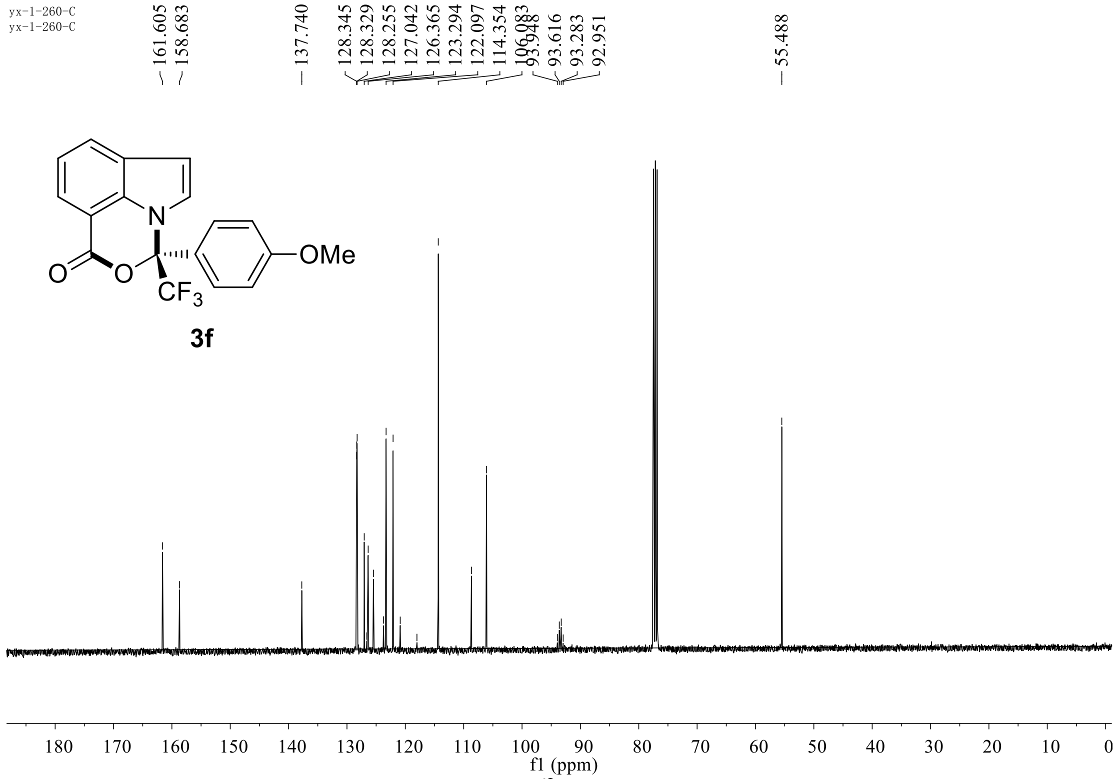
Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.951	1825056	76453	50.143	74.143
2	32.854	1814614	26662	49.857	25.857
Total		3639670	103115	100.000	100.000

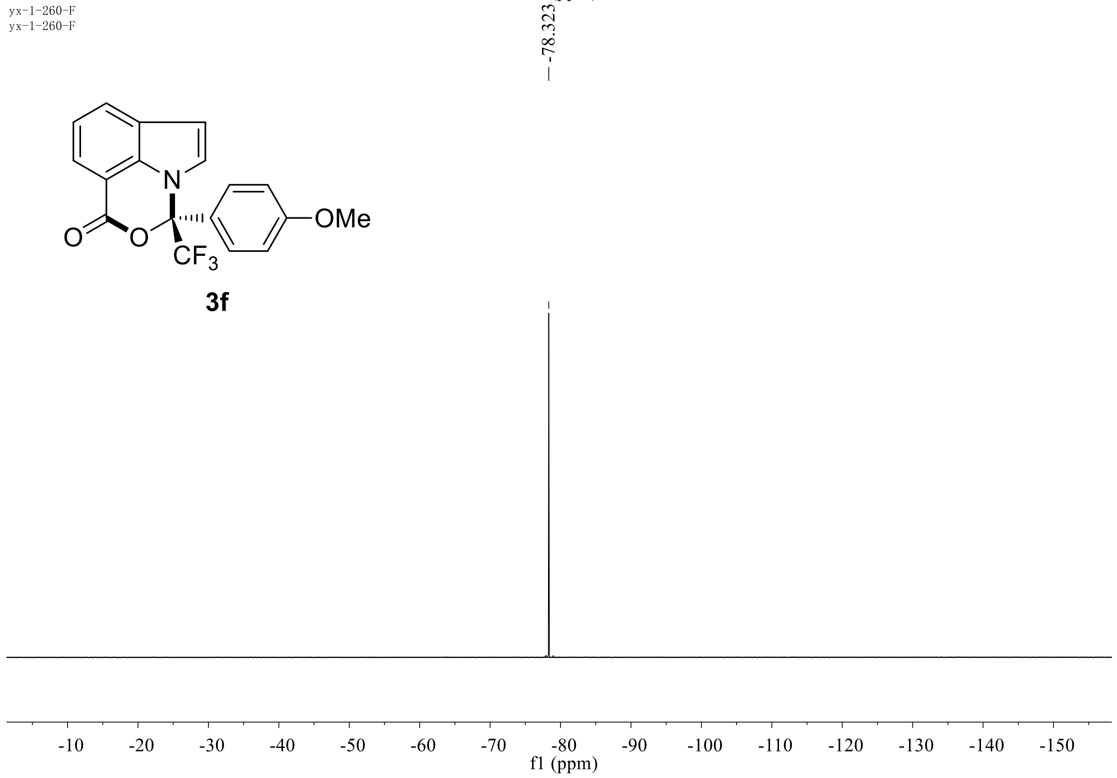


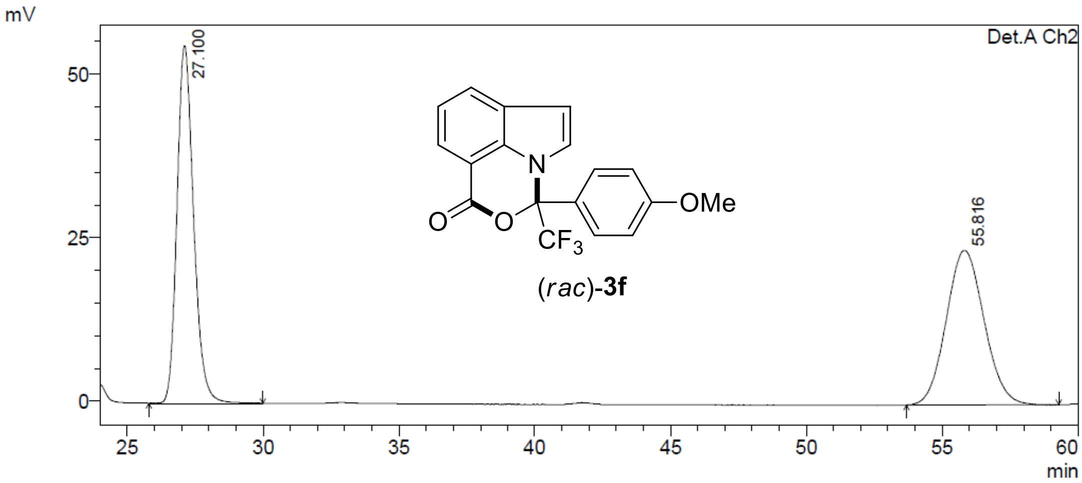
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.583	1830244	75079	3.564	9.509
2	32.056	49522018	714443	96.436	90.491
Total		51352262	789522	100.000	100.000



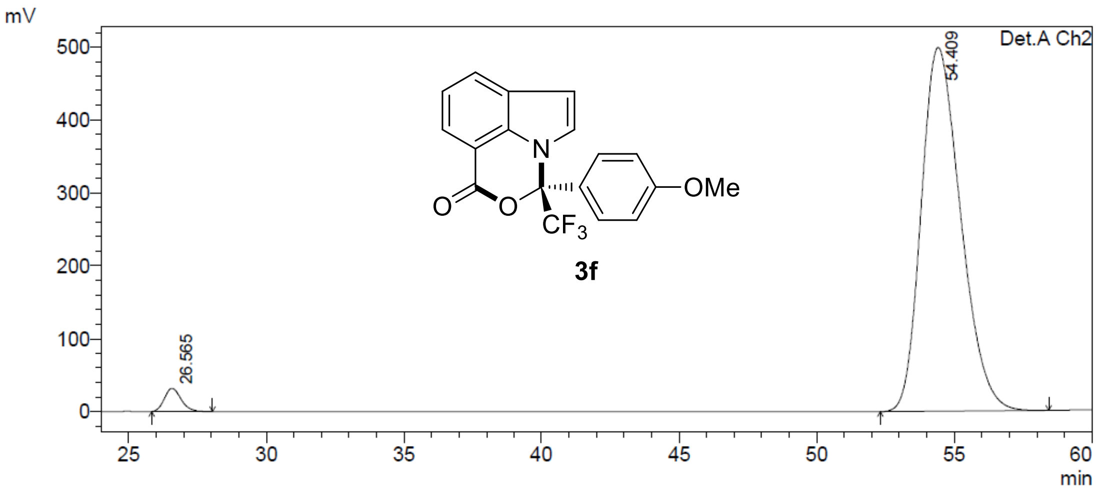

yx-1-260-C
yx-1-260-C
161.605
158.683
137.740
128.345
128.329
128.255
127.042
126.365
123.294
122.097
114.354
106.083
93.948
93.616
93.283
92.951
55.488
OMe
CF3
3f
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-1-260-F
yx-1-260-F
-78.323
OMe
CF3
3f
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150
f1 (ppm)



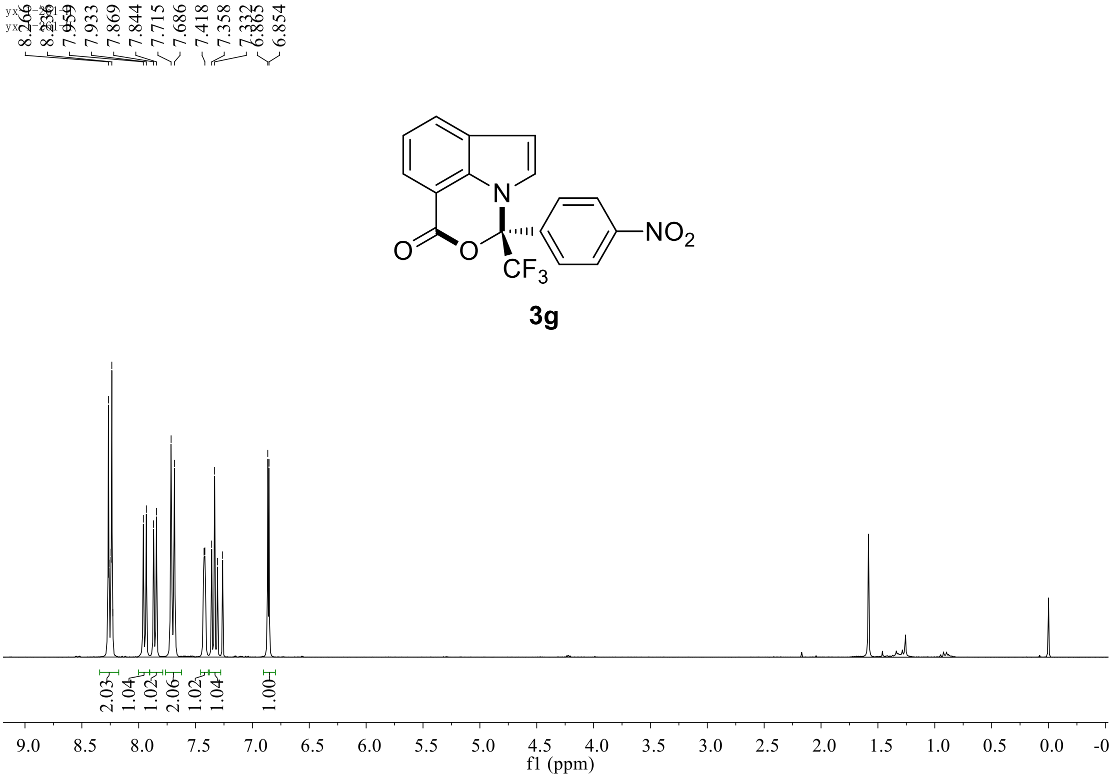
UV Detector Ch2 220nm

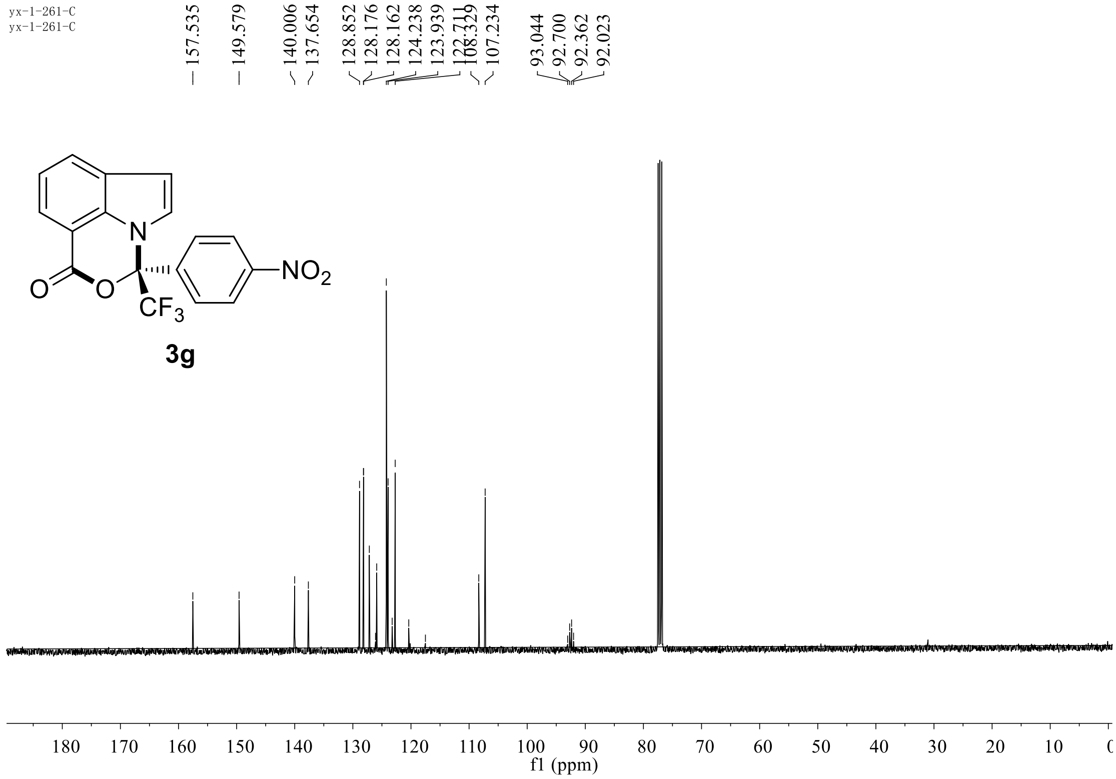
Peak#	Ret. Time	Area	Height	Area %	Height %
1	27.100	2327538	54735	50.379	69.819
2	55.816	2292484	23660	49.621	30.181
Total		4620022	78396	100.000	100.000

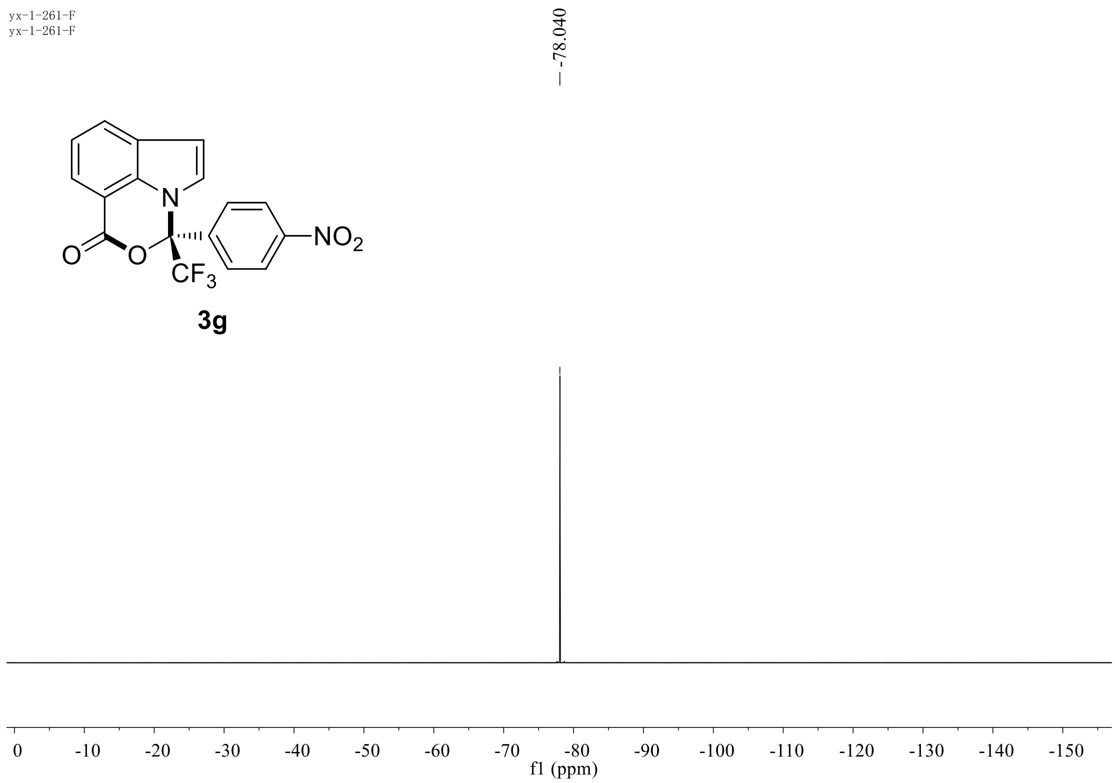


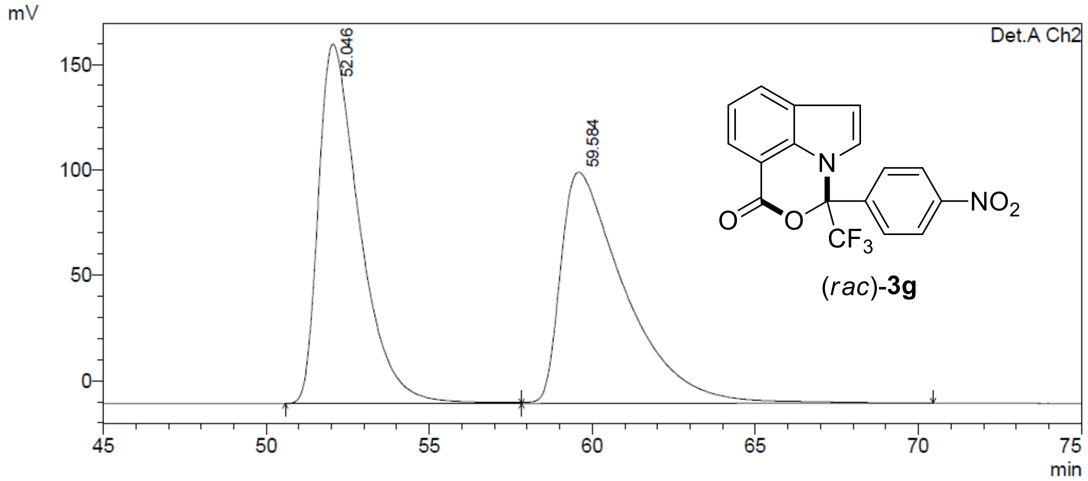
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	26.565	1338683	31808	2.616	5.993
2	54.409	49838422	498973	97.384	94.007
Total		51177105	530781	100.000	100.000


8.266
7.959
7.933
7.869
7.844
7.715
7.686
7.418
7.358
7.332
6.865
6.854
NO2
O
O
N
CF3
3g
2.03
1.04
1.02
2.06
1.02
1.04
1.00
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)

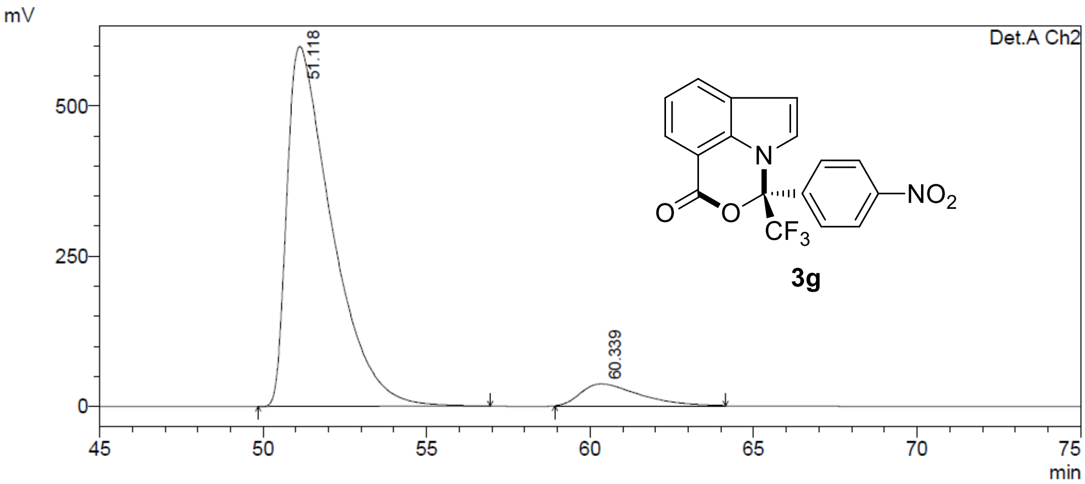

yx-1-261-C
yx-1-261-C
157.535
149.579
140.006
137.654
128.852
128.176
128.162
124.238
123.939
122.711
108.329
107.234
93.044
92.700
92.362
92.023
NO2
O
O
N
CF3
3g
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)





UV Detector Ch2 220nm

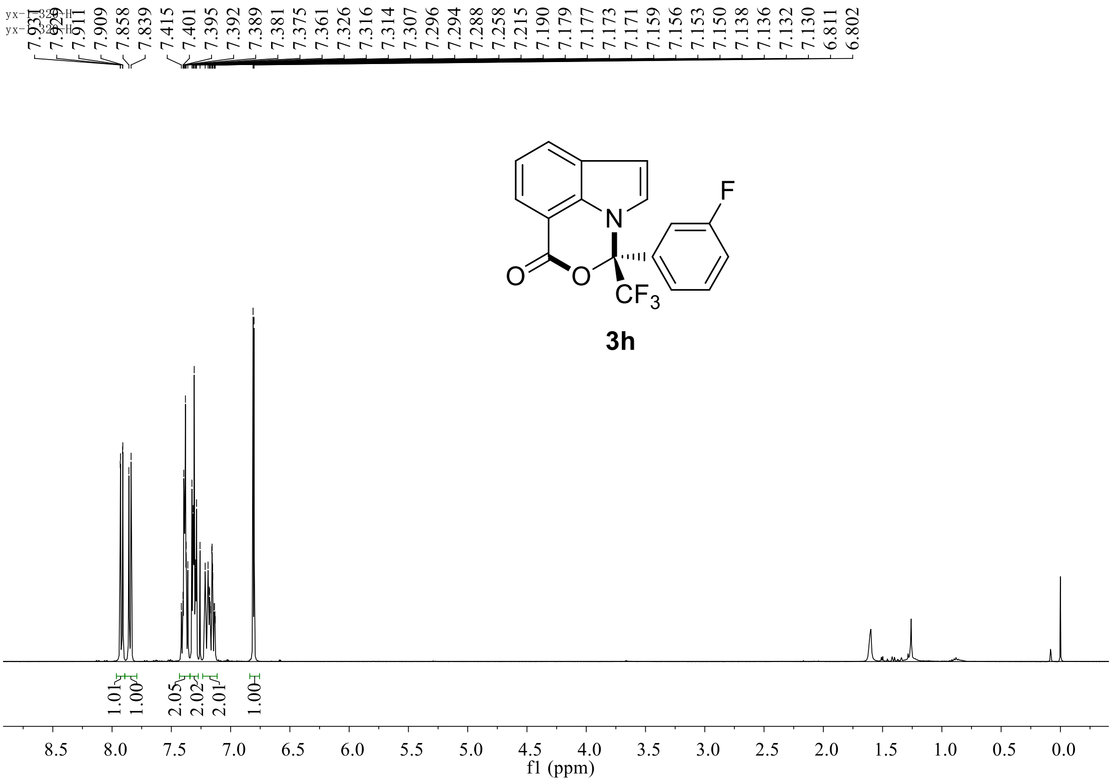
Peak#	Ret. Time	Area	Height	Area %	Height %
1	52.046	14975373	170352	49.746	60.850
2	59.584	15128383	109600	50.254	39.150
Total		30103756	279952	100.000	100.000



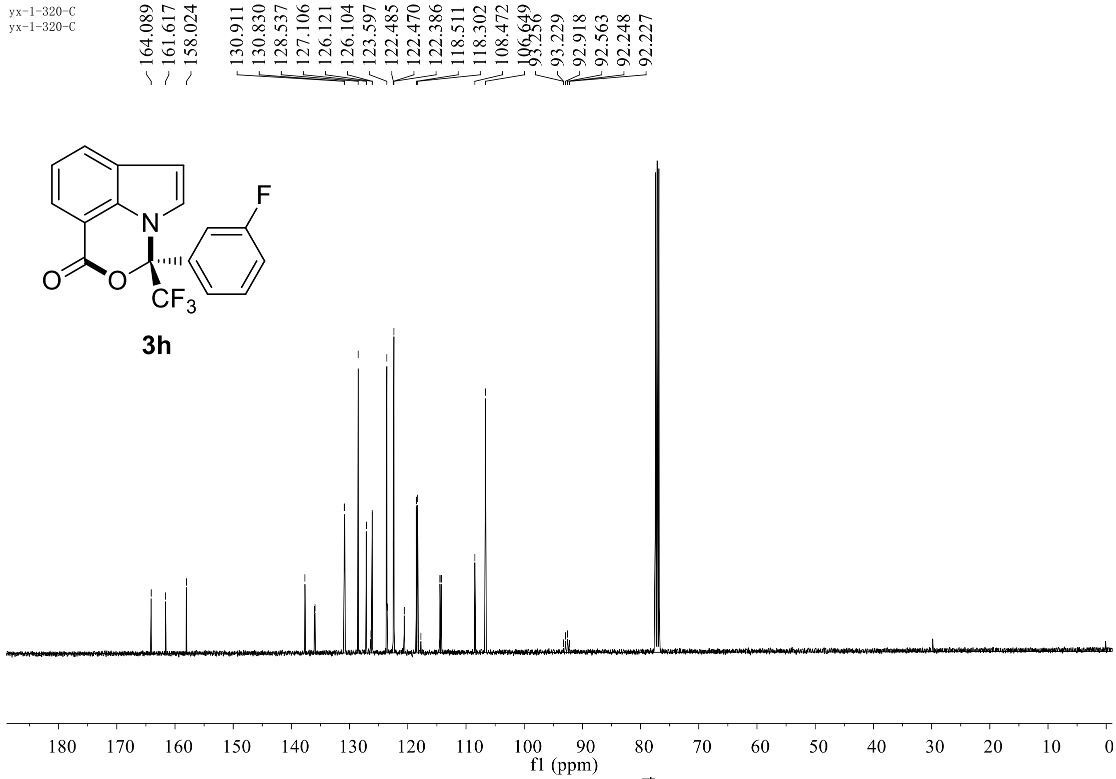
3g

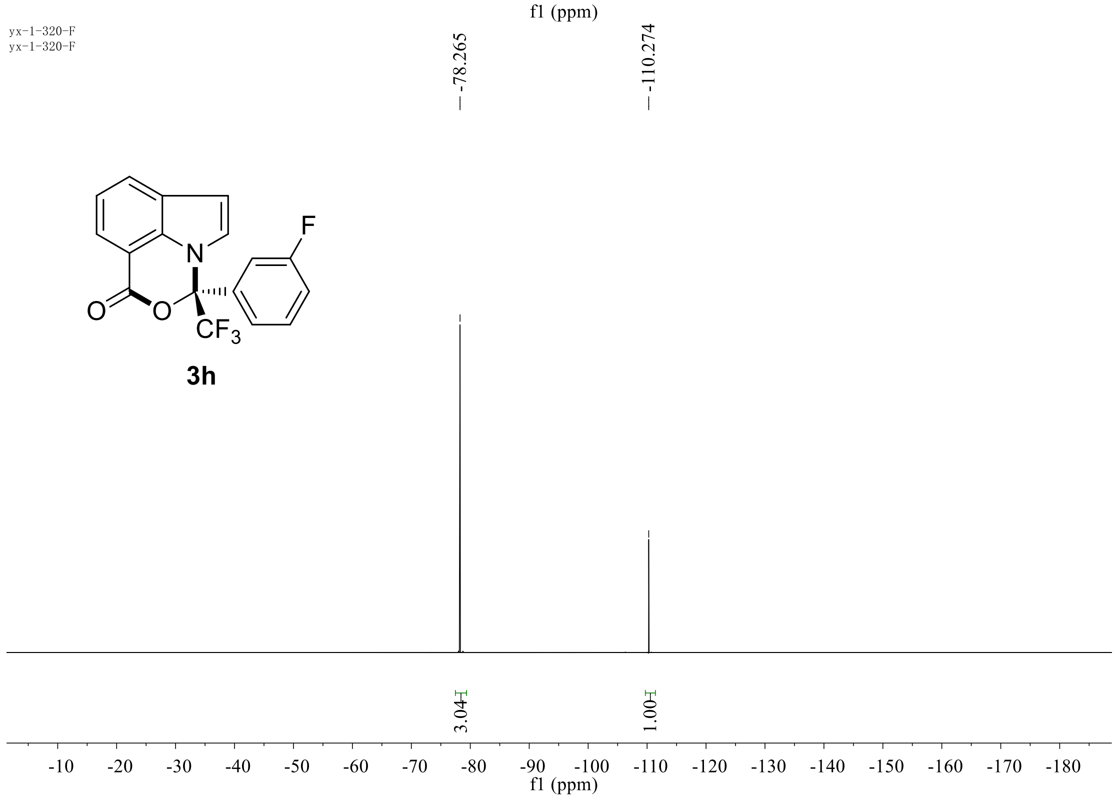
UV Detector Ch2 220nm

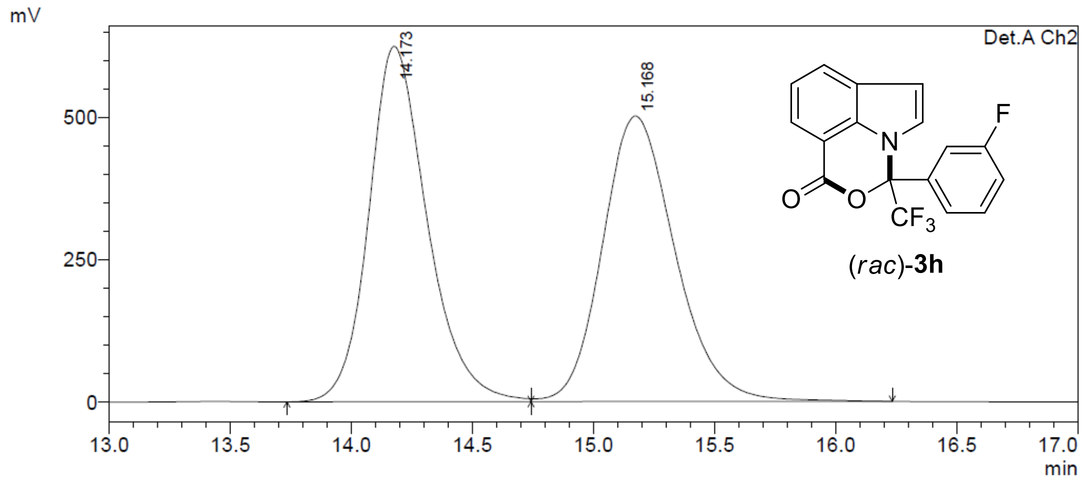
Peak#	Ret. Time	Area	Height	Area %	Height %
1	51.118	57227504	599122	92.716	94.277
2	60.339	4495673	36370	7.284	5.723
Total		61723177	635492	100.000	100.000



3h

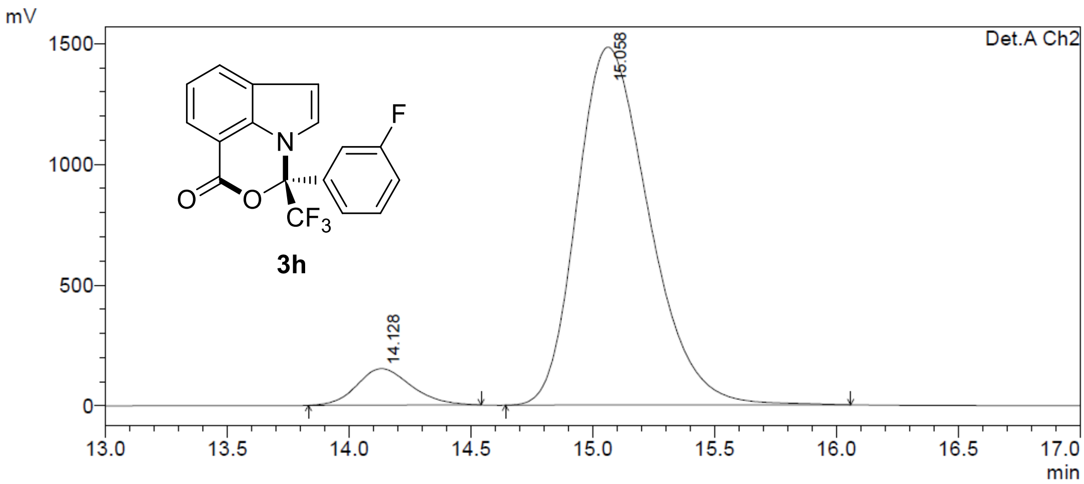

yx-1-320-C
yx-1-320-C
164.089
161.617
158.024
130.911
130.830
128.537
127.106
126.121
126.104
123.597
122.485
122.470
122.386
118.511
118.302
108.472
106.649
93.256
93.229
92.918
92.563
92.248
92.227
F
N
O
O
CF_3
3h
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-1-320-F
yx-1-320-F
-78.265
-110.274
F
N
O
O
CF_3
3h
3.04
1.00
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180
f1 (ppm)



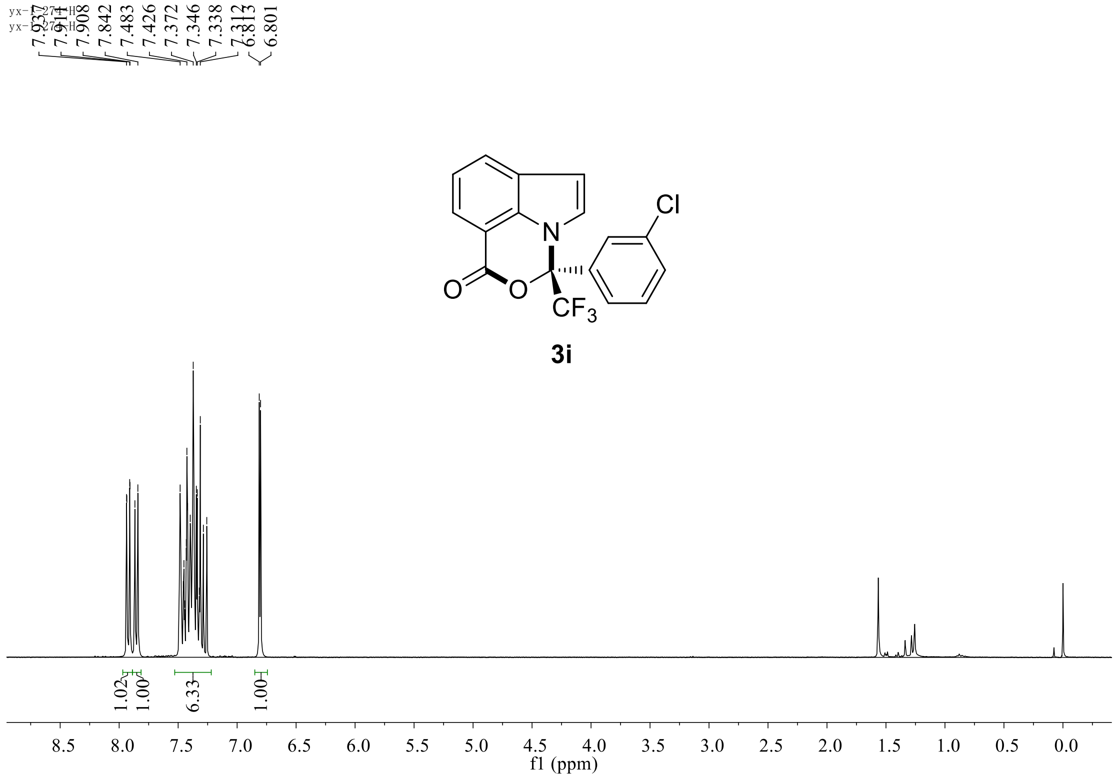
Detector A Ch2 220nm

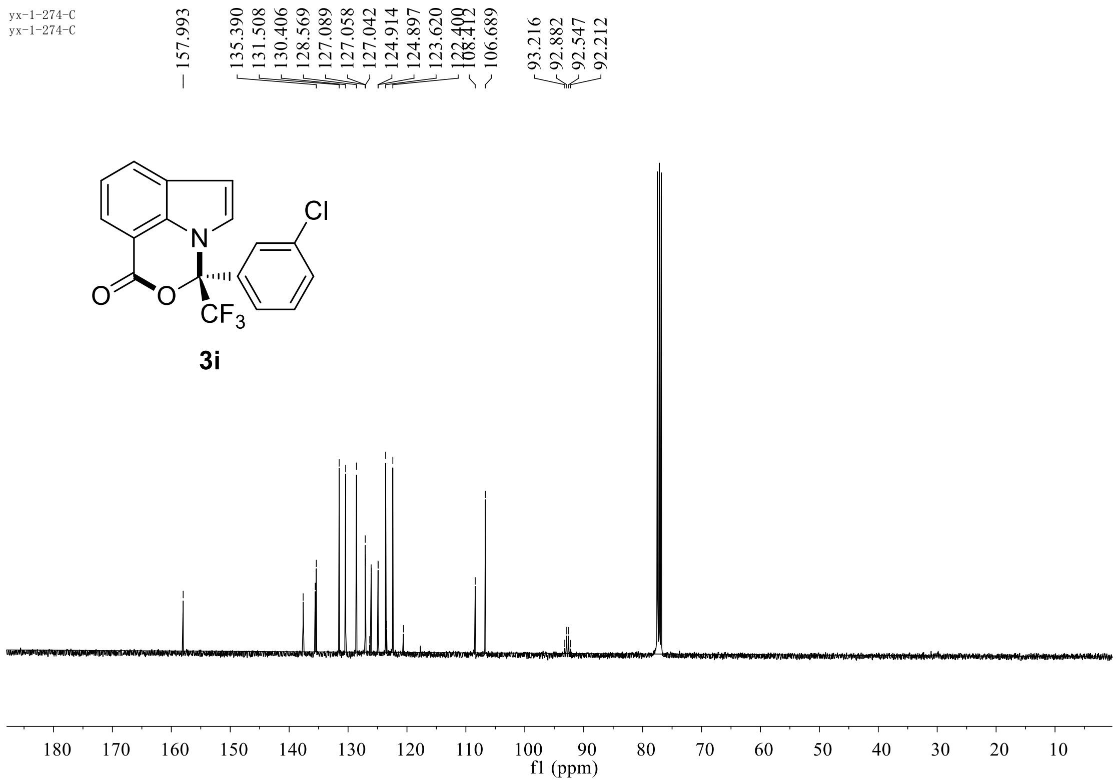
Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.173	10454745	623968	49.973	55.461
2	15.168	10466123	501080	50.027	44.539
Total		20920869	1125048	100.000	100.000

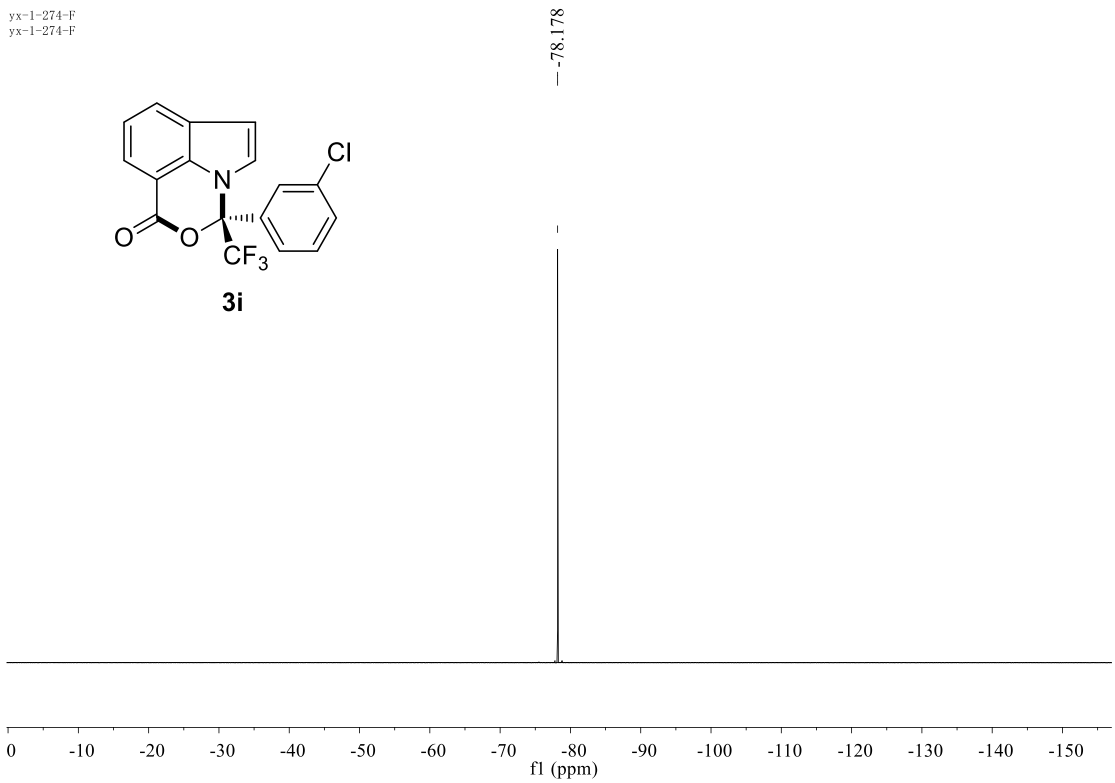


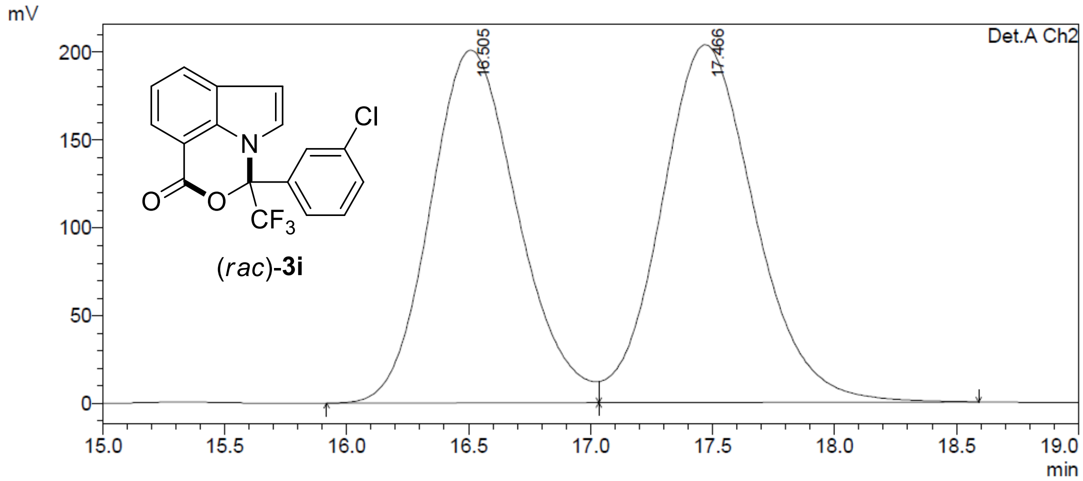
Detector A Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.128	2336742	151036	7.101	9.250
2	15.058	30572497	1481863	92.899	90.750
Total		32909239	1632899	100.000	100.000


7.937
7.908
7.842
7.483
7.426
7.372
7.346
7.338
7.312
6.813
6.801
Cl
N
O
O
CF_3
3i
1.02
1.00
6.33
1.00
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)

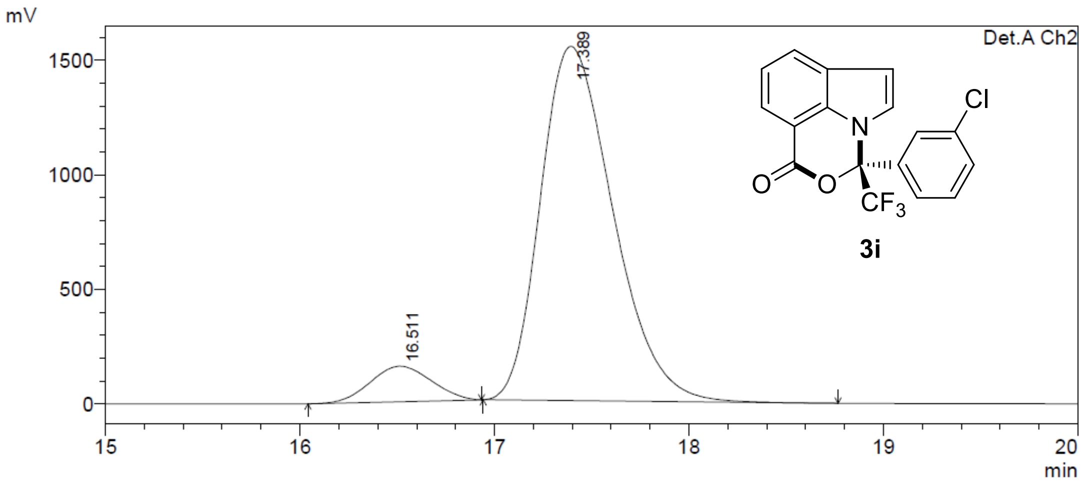

yx-1-274-C
yx-1-274-C
157.993
135.390
131.508
130.406
128.569
127.089
127.058
127.042
124.914
124.897
123.620
122.400
108.412
106.689
93.216
92.882
92.547
92.212
Cl
N
O
O
CF_3
3i
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)





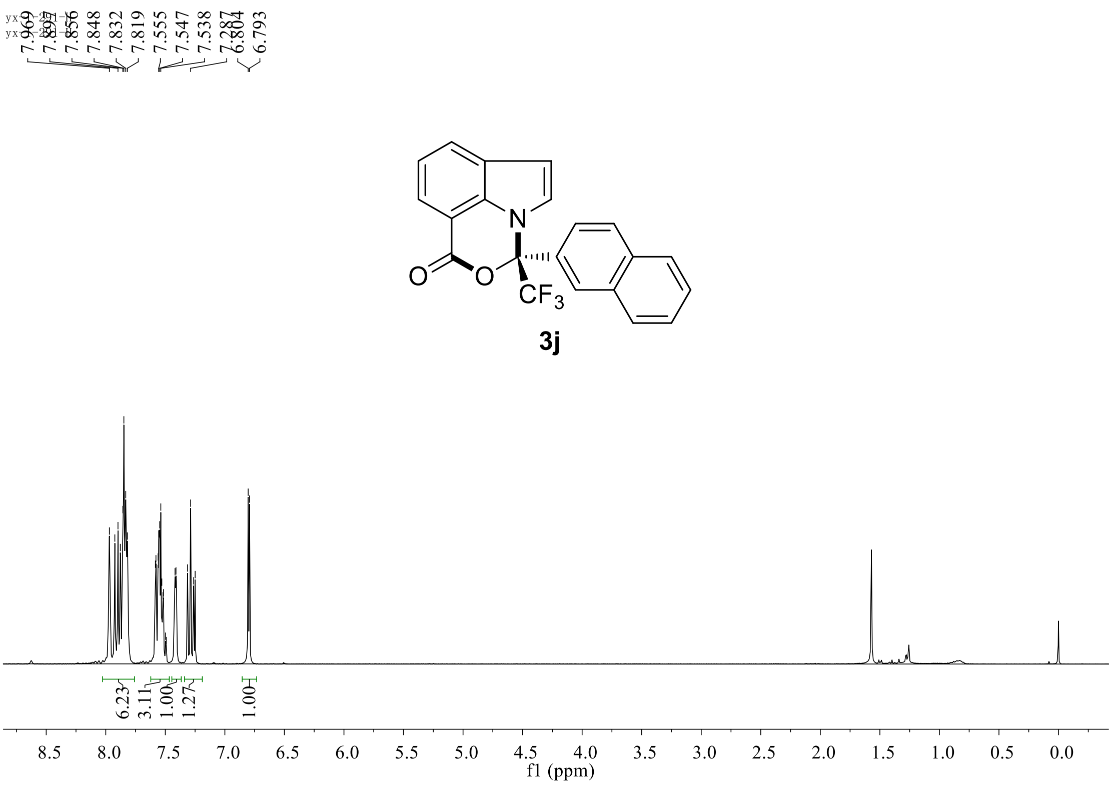
UV Detector Ch2 220nm

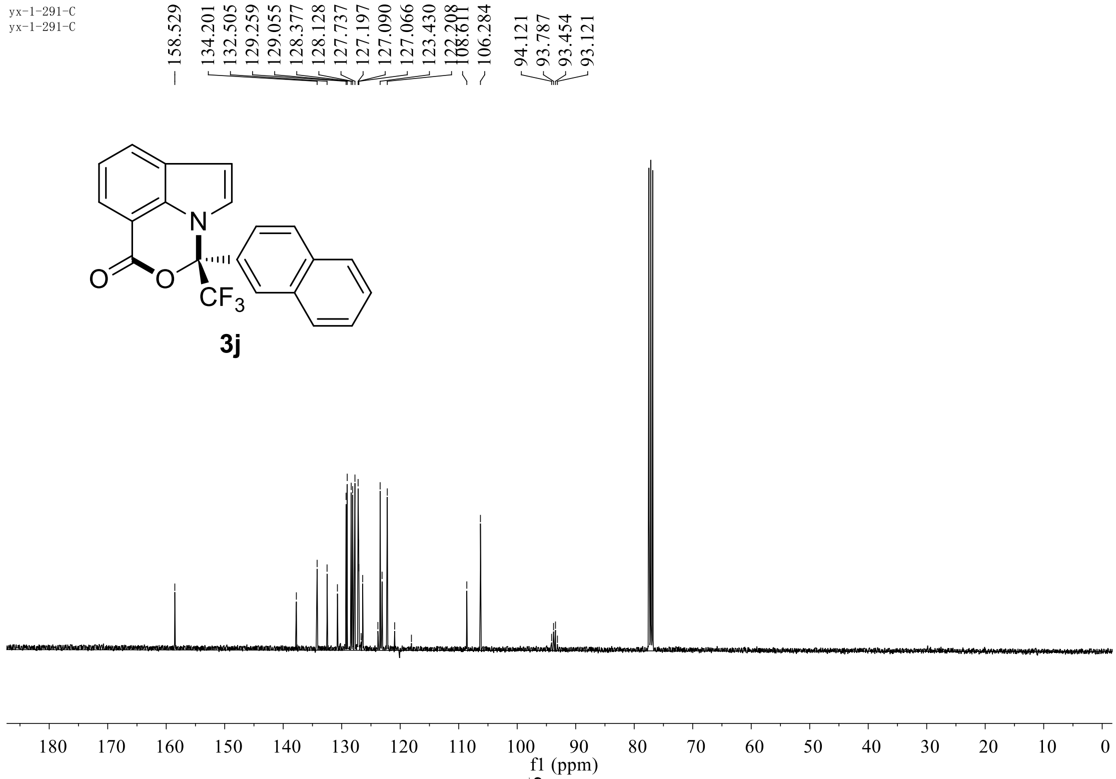
Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.505	5016879	200866	47.954	49.660
2	17.466	5444996	203618	52.046	50.340
Total		10461875	404485	100.000	100.000

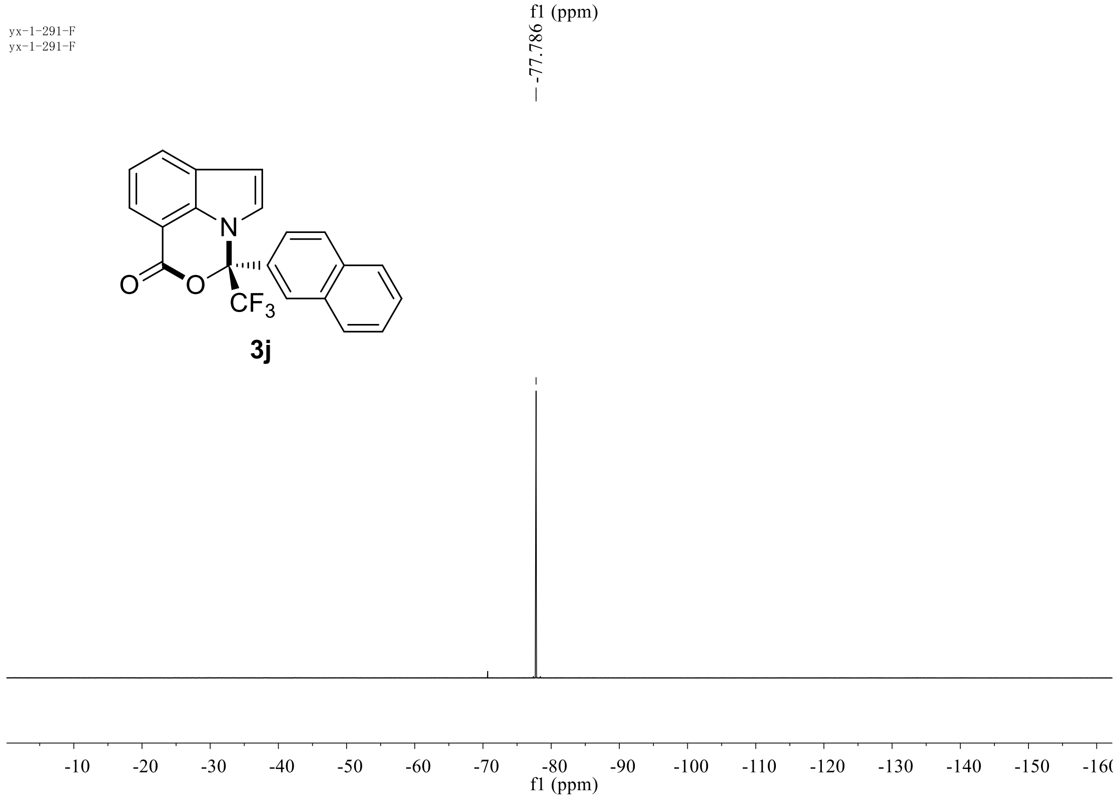


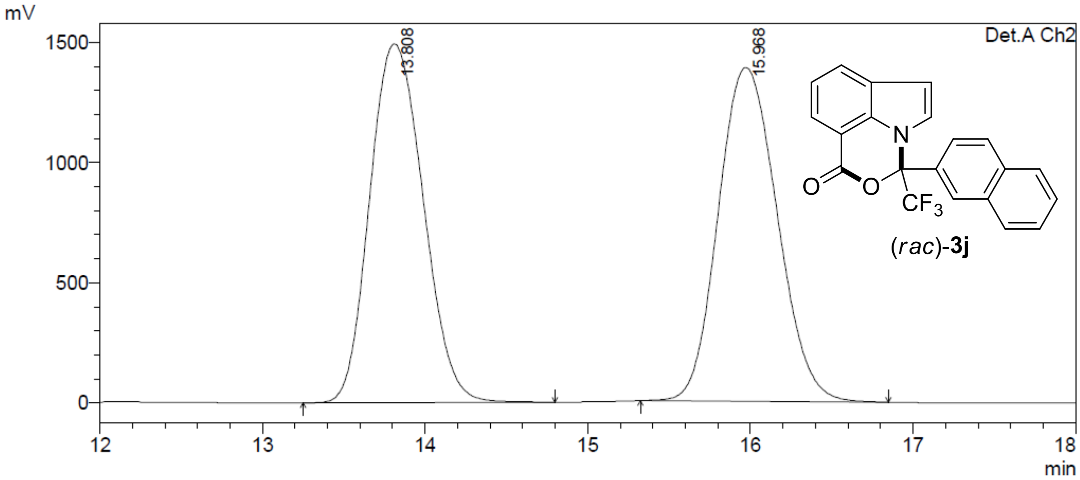
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.511	3373258	154516	7.751	9.091
2	17.389	40148902	1545151	92.249	90.909
Total		43522160	1699667	100.000	100.000



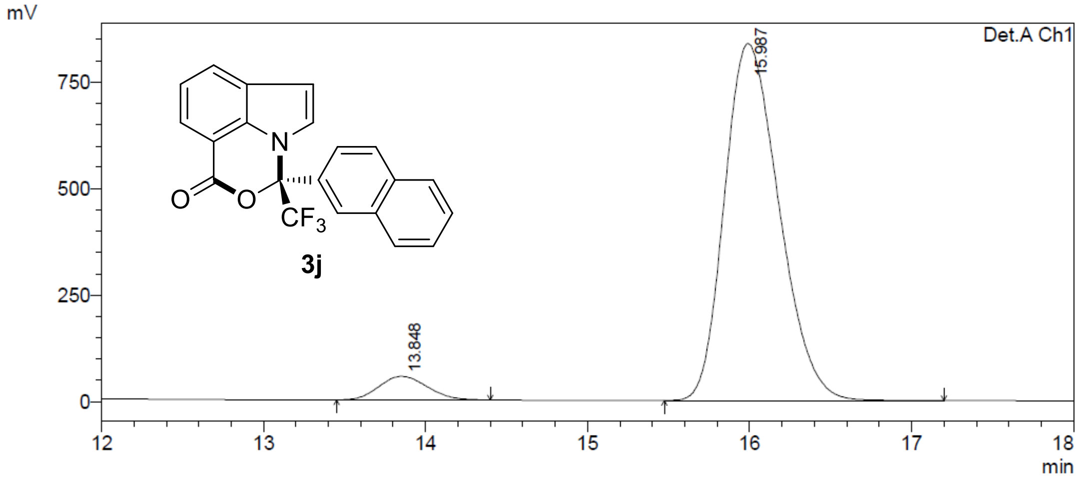

yx-1-291-C
yx-1-291-C
158.529
134.201
132.505
129.259
129.055
128.377
128.128
127.737
127.197
127.090
127.066
123.430
122.208
108.611
106.284
94.121
93.787
93.454
93.121
N
O
O
CF3
3j
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-1-291-F
yx-1-291-F
-77.786
N
O
O
CF3
3j
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160
f1 (ppm)



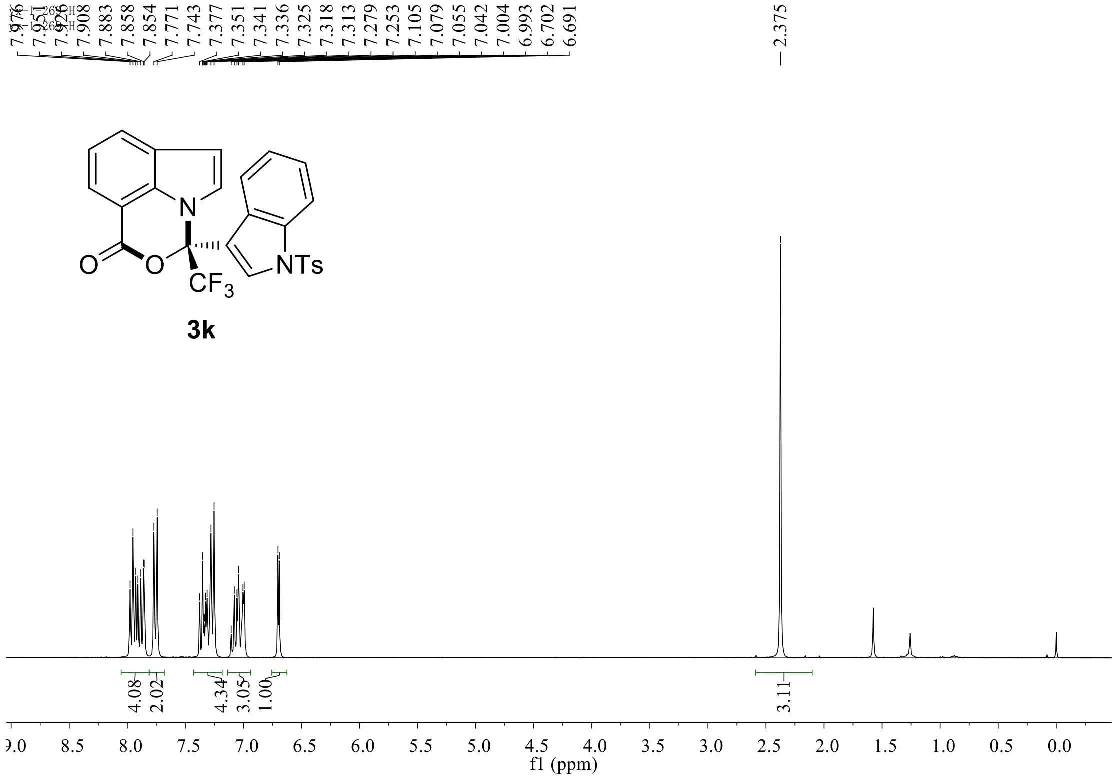
UV Detector Ch2 220nm

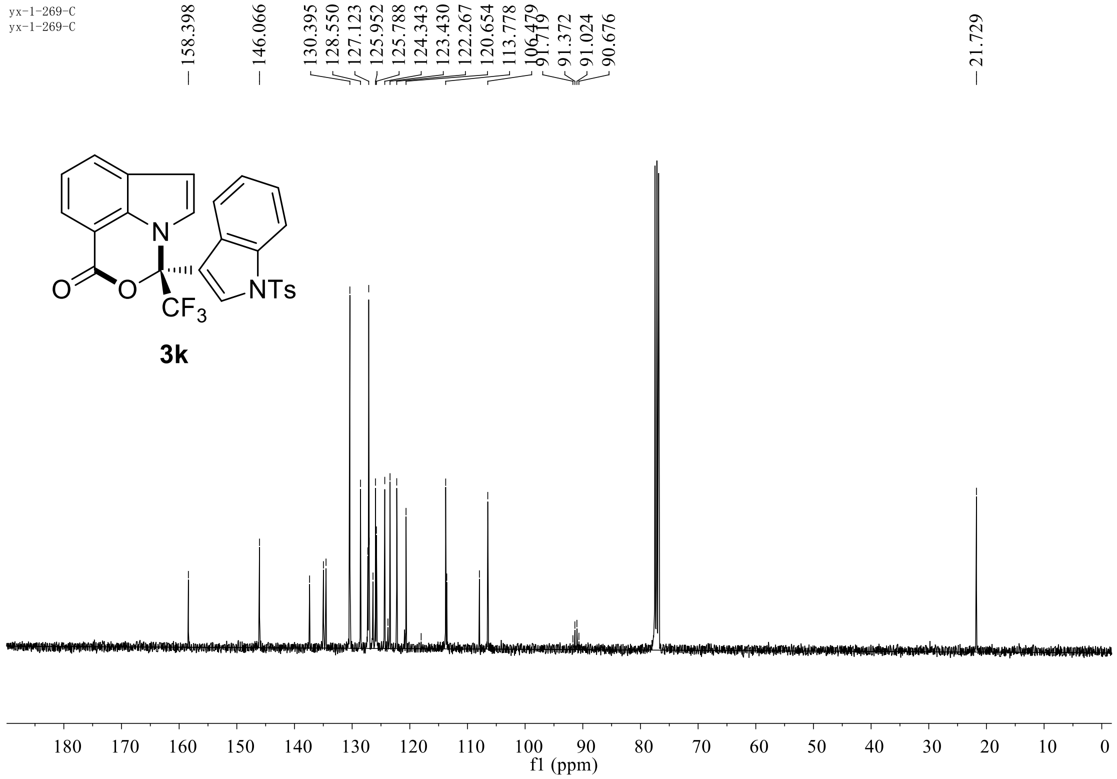
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.808	34107107	1490639	49.307	51.773
2	15.968	35066150	1388560	50.693	48.227
Total		69173258	2879199	100.000	100.000

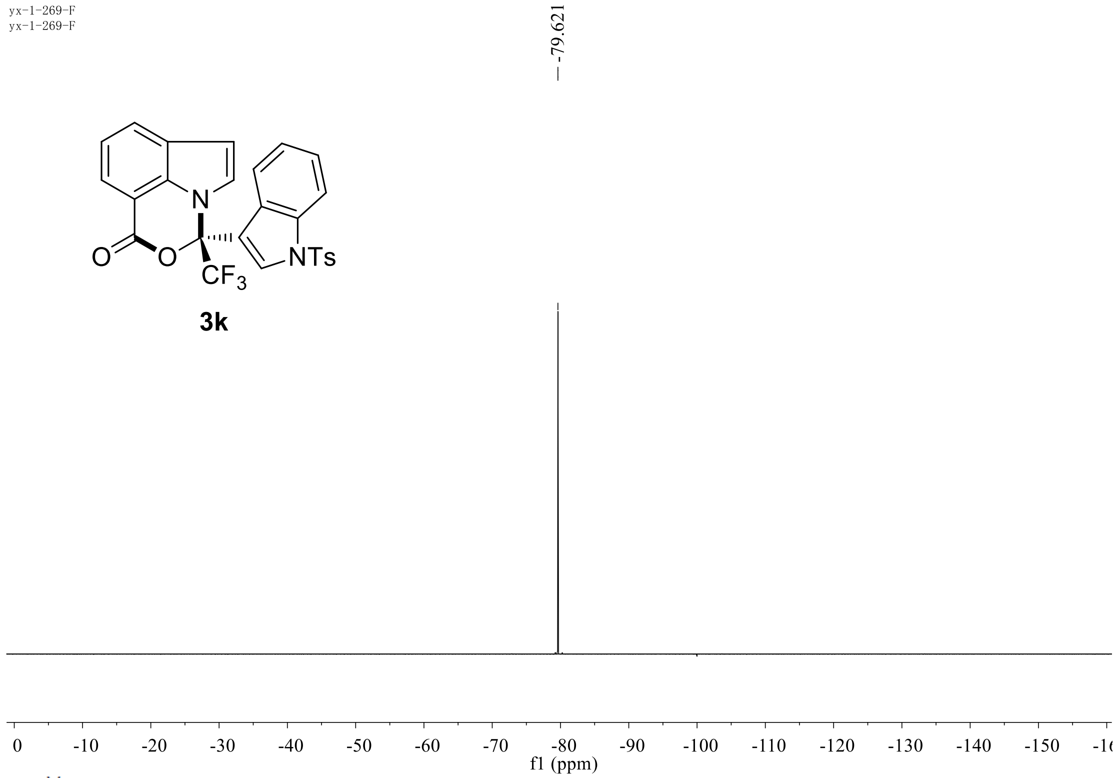


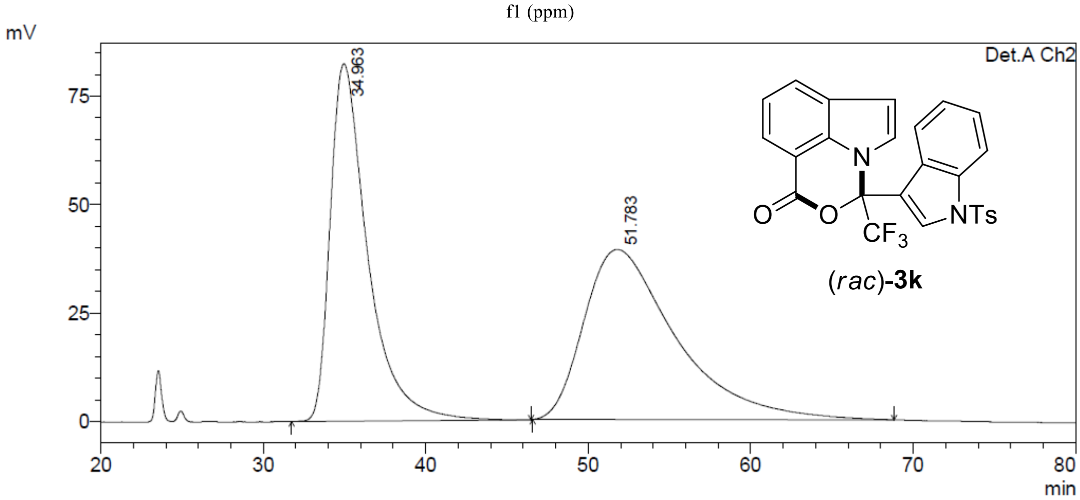
UV Detector Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.848	1150281	55320	5.523	6.189
2	15.987	19677714	838541	94.477	93.811
Total		20827995	893861	100.000	100.000


7.976
7.951
7.926
7.908
7.883
7.858
7.854
7.771
7.743
7.377
7.351
7.341
7.336
7.325
7.318
7.313
7.279
7.253
7.105
7.079
7.055
7.042
7.004
6.993
6.702
6.691
2.375
N
O
O
CF3
NTs
3k
4.08
2.02
4.34
3.05
1.00
3.11
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)

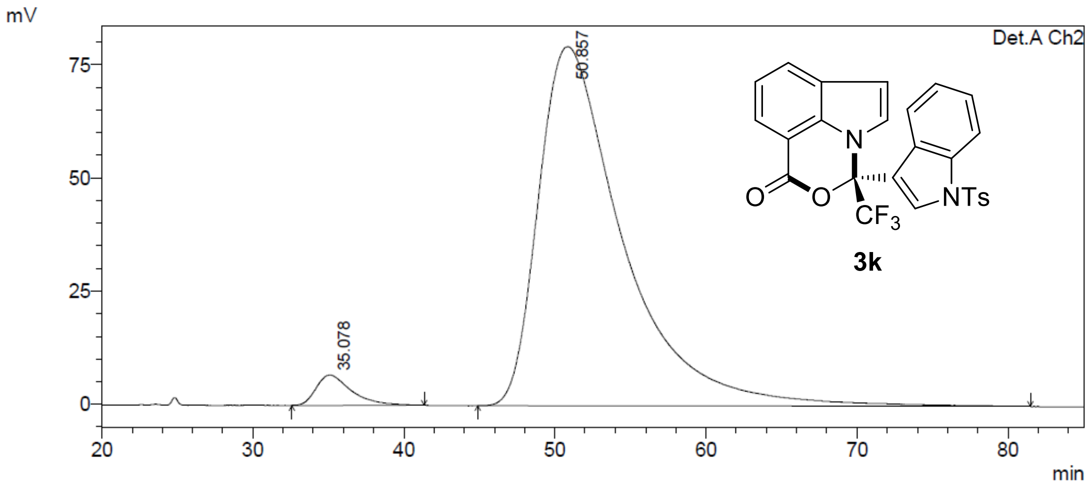

yx-1-269-C
yx-1-269-C
158.398
146.066
130.395
128.550
127.123
125.952
125.788
124.343
123.430
122.267
120.654
113.778
106.479
91.719
91.372
91.024
90.676
21.729
N
O
O
CF3
NTs
3k
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)





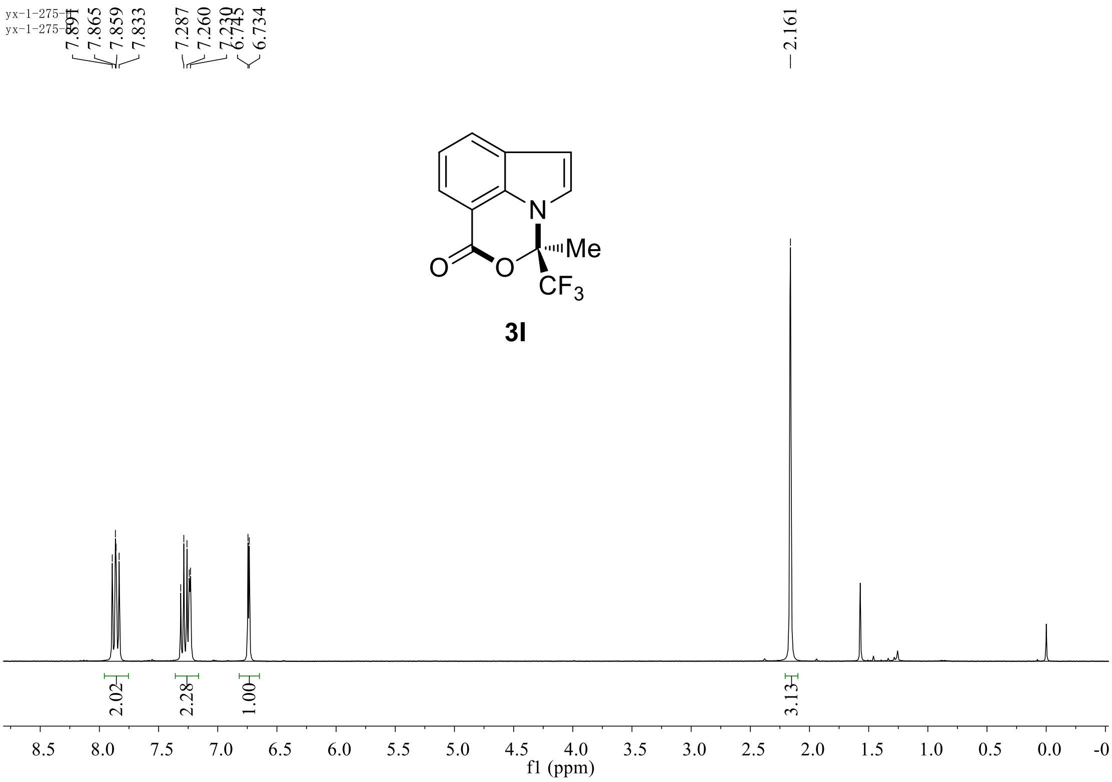
UV Detector Ch2 220nm

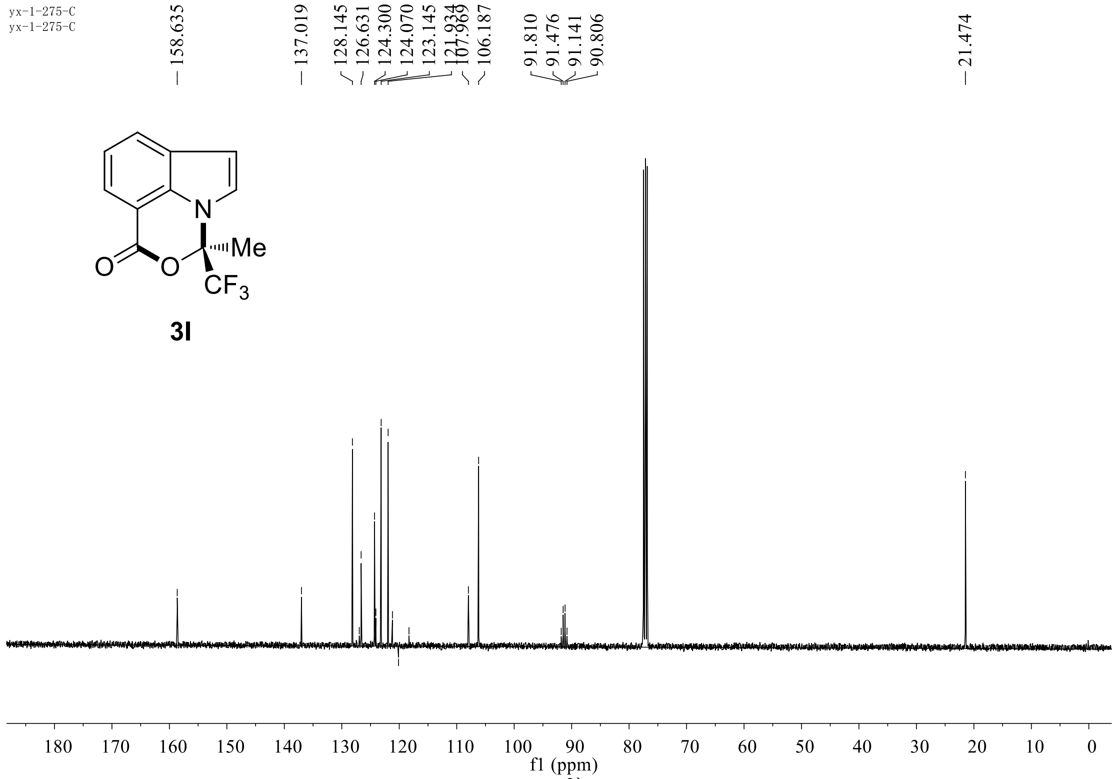
Peak#	Ret. Time	Area	Height	Area %	Height %
1	34.963	13182905	82333	45.995	67.735
2	51.783	15478620	39218	54.005	32.265
Total		28661525	121551	100.000	100.000

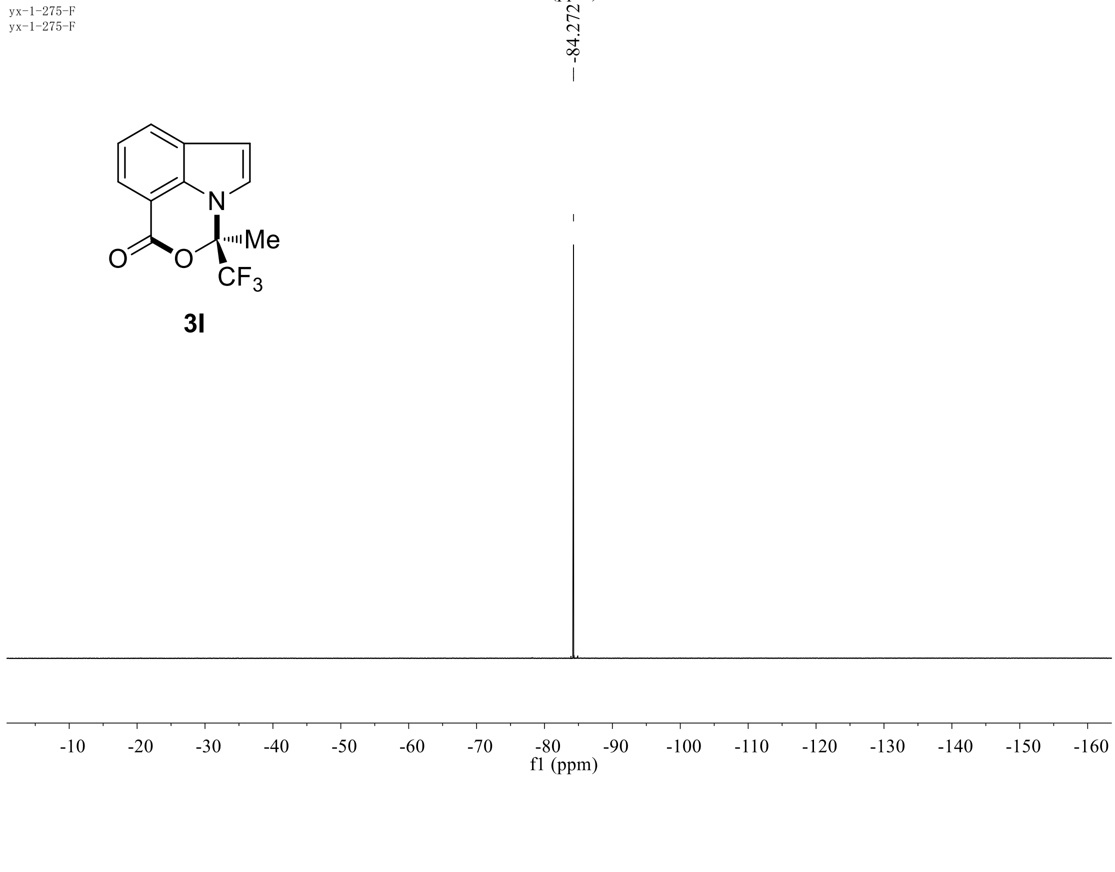


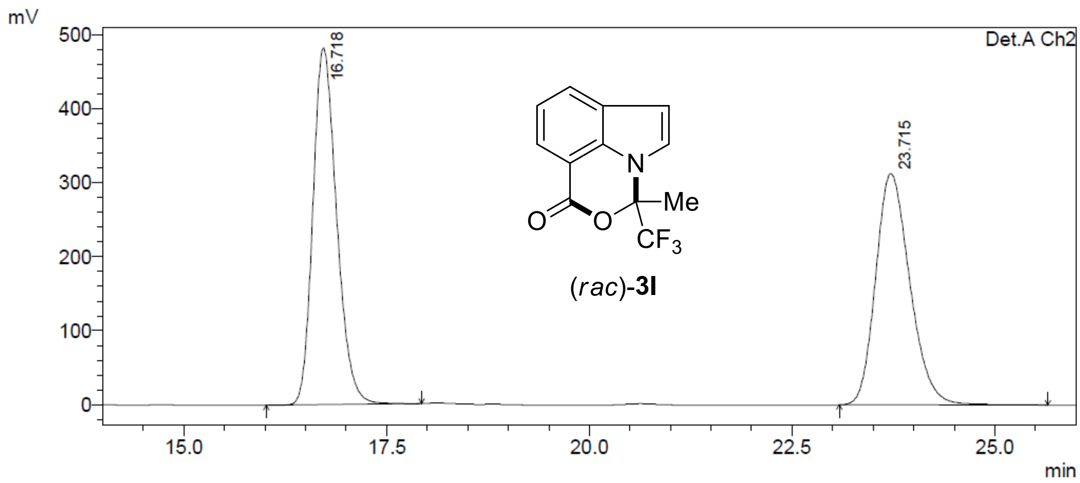
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	35.078	1092402	6693	3.393	7.769
2	50.857	31103727	79460	96.607	92.231
Total		32196129	86153	100.000	100.000



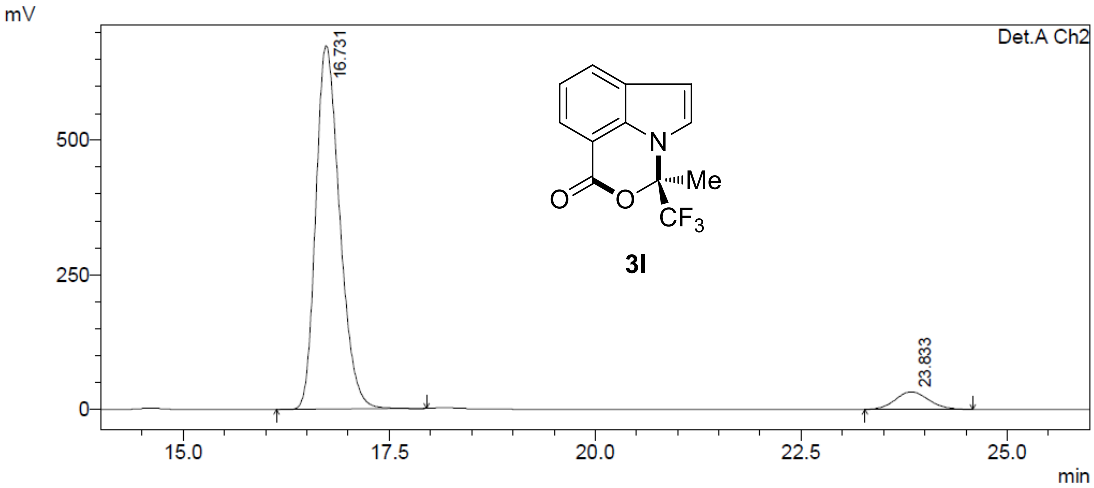

yx-1-275-C
yx-1-275-C
158.635
137.019
128.145
126.631
124.300
124.070
123.145
121.934
107.969
106.187
91.810
91.476
91.141
90.806
21.474
N
Me
O
O
CF3
3l
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-1-275-F
yx-1-275-F
-84.272
N
Me
O
O
CF3
3l
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160
f1 (ppm)



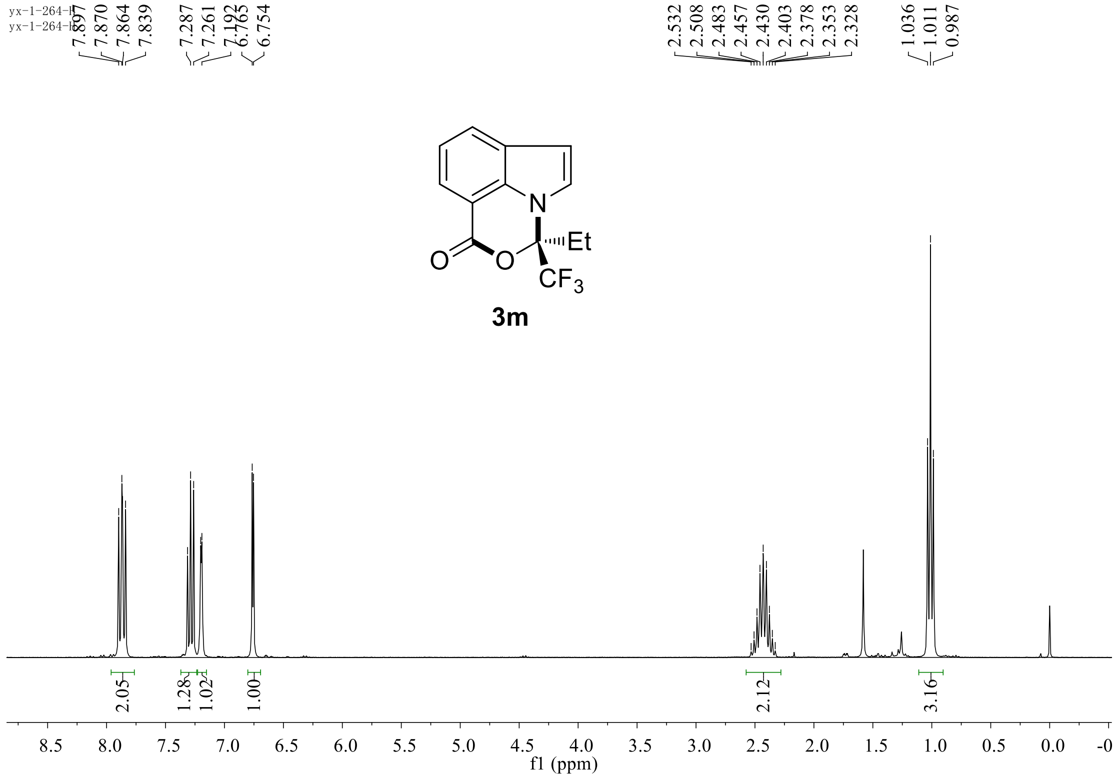
UV Detector Ch2 220nm

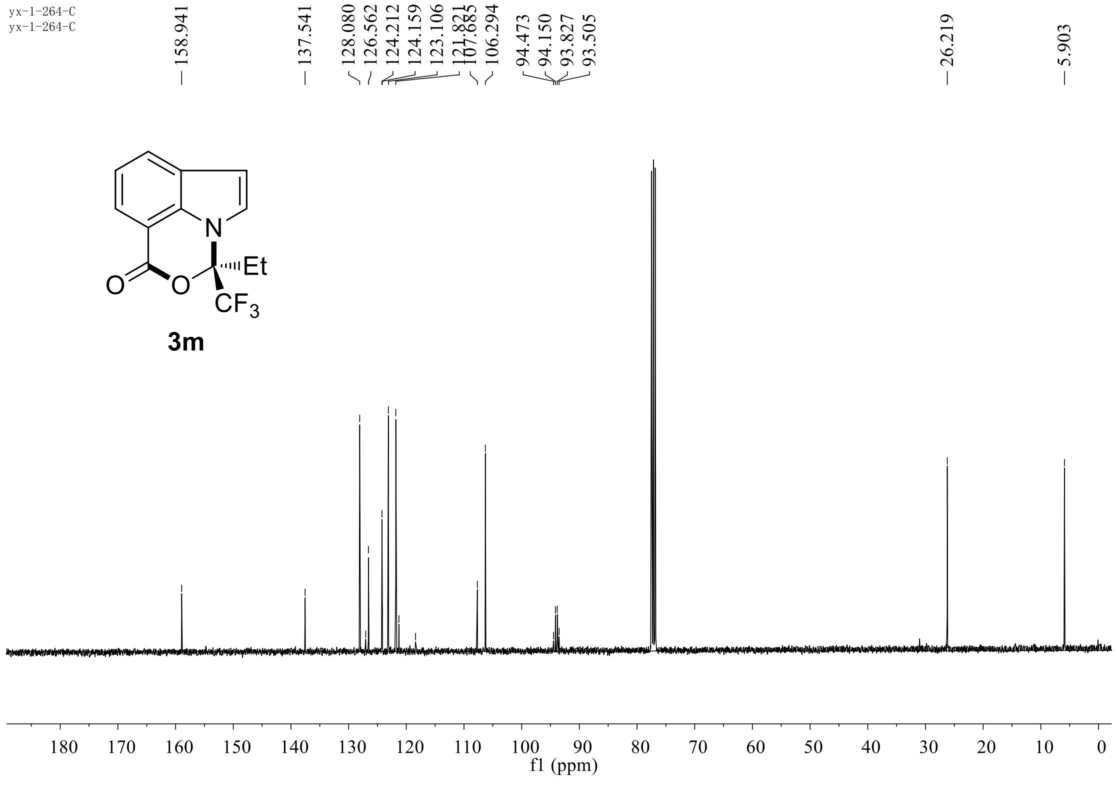
Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.718	9814809	481128	51.742	60.647
2	23.715	9153802	312196	48.258	39.353
Total		18968611	793324	100.000	100.000

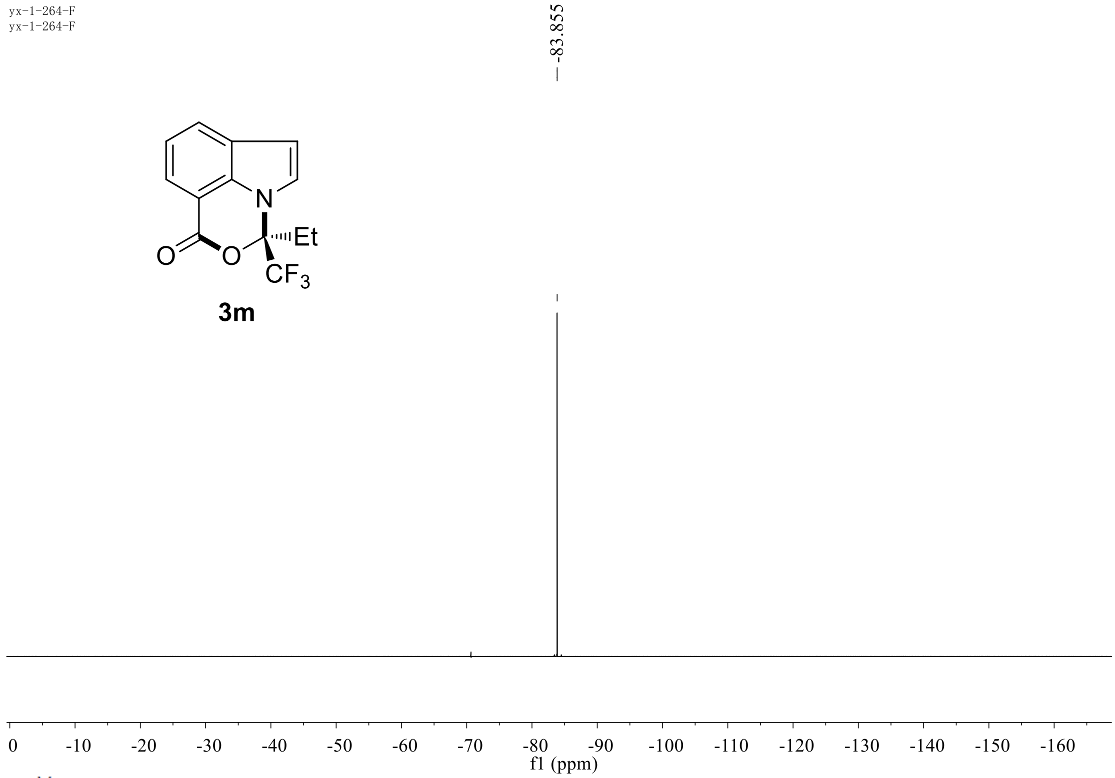


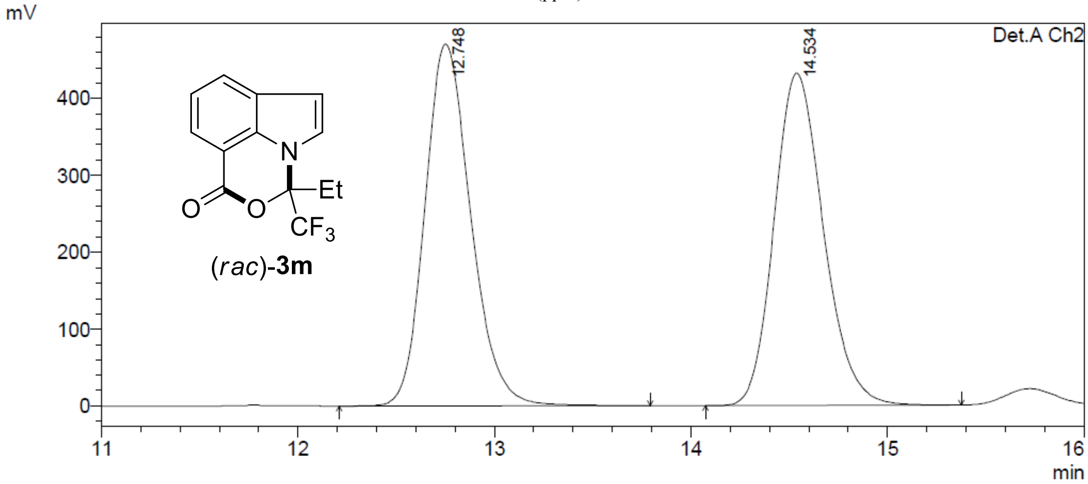
UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.731	13659965	675481	93.705	95.396
2	23.833	917662	32597	6.295	4.604
Total		14577626	708078	100.000	100.000


yx-1-264-H
7.897
7.870
7.864
7.839
7.287
7.261
7.192
6.765
6.754
2.532
2.508
2.483
2.457
2.430
2.403
2.378
2.353
2.328
1.036
1.011
0.987
3m
2.05
1.28
1.02
1.00
2.12
3.16
f1 (ppm)

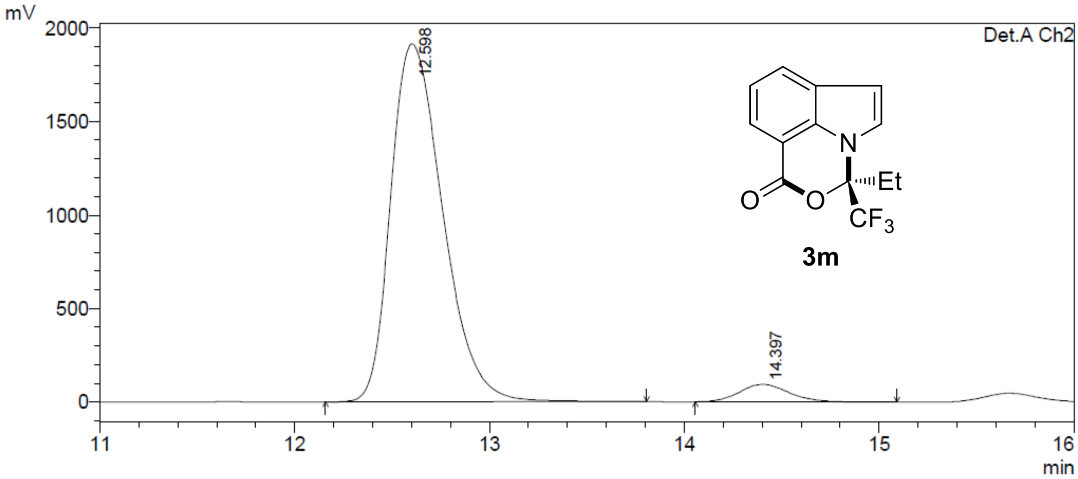

yx-1-264-C
158.941
137.541
128.080
126.562
124.212
124.159
123.106
121.821
107.685
106.294
94.473
94.150
93.827
93.505
26.219
5.903
3m
f1 (ppm)





UV Detector Ch2 220nm

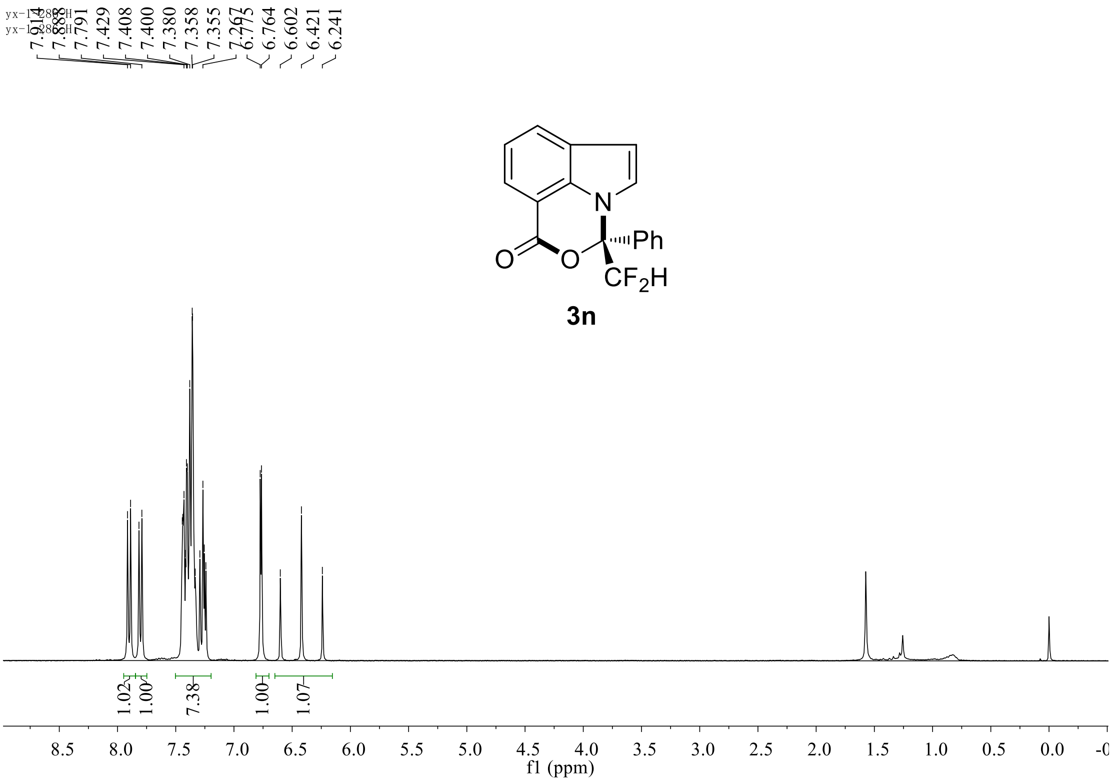
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.748	7629498	470318	50.275	52.107
2	14.534	7546061	432289	49.725	47.893
Total		15175559	902607	100.000	100.000



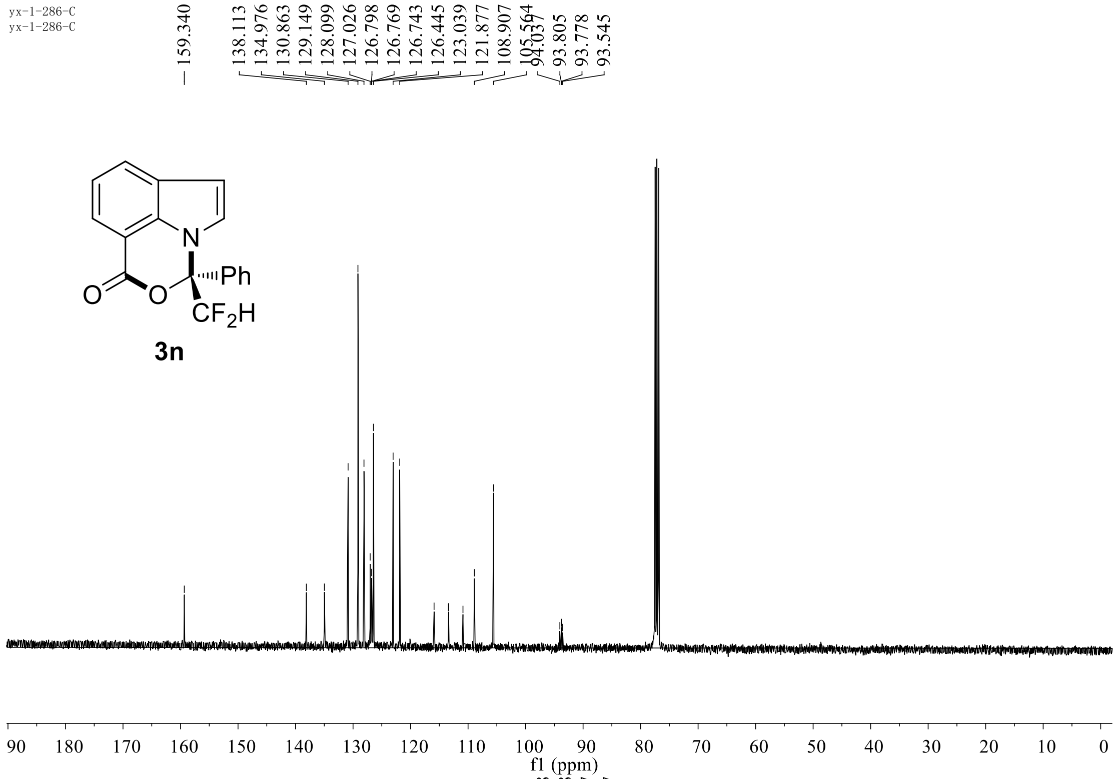
3m

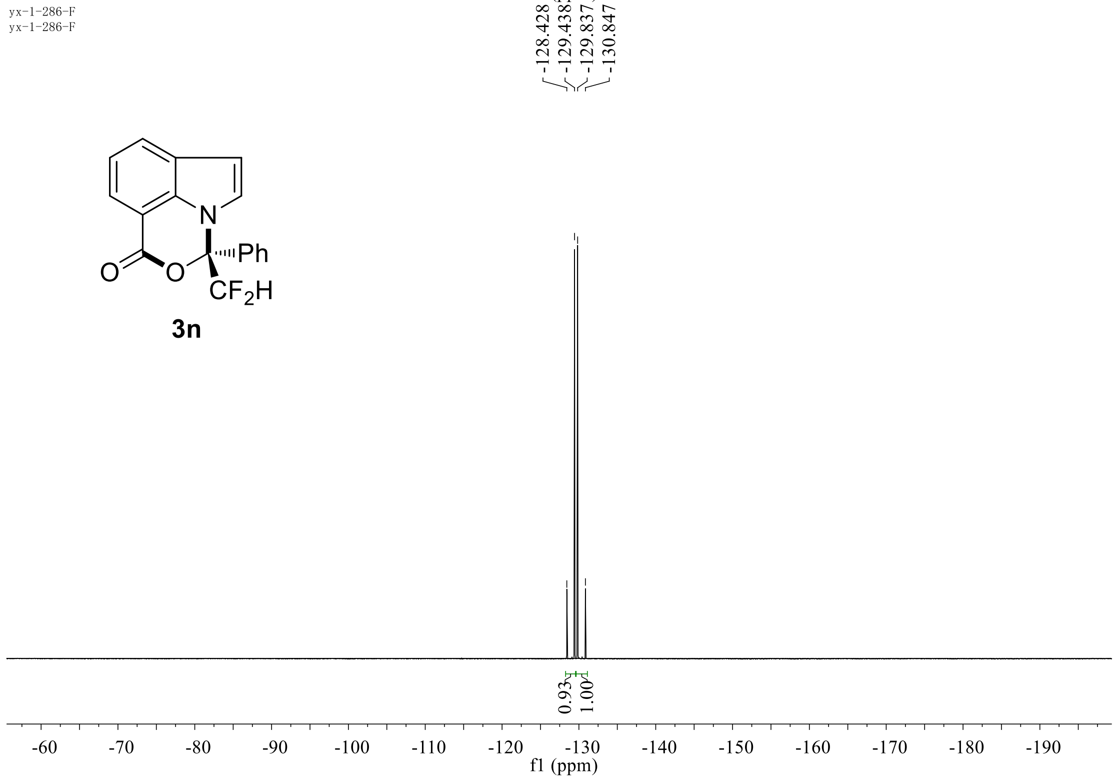
UV Detector Ch2 220nm

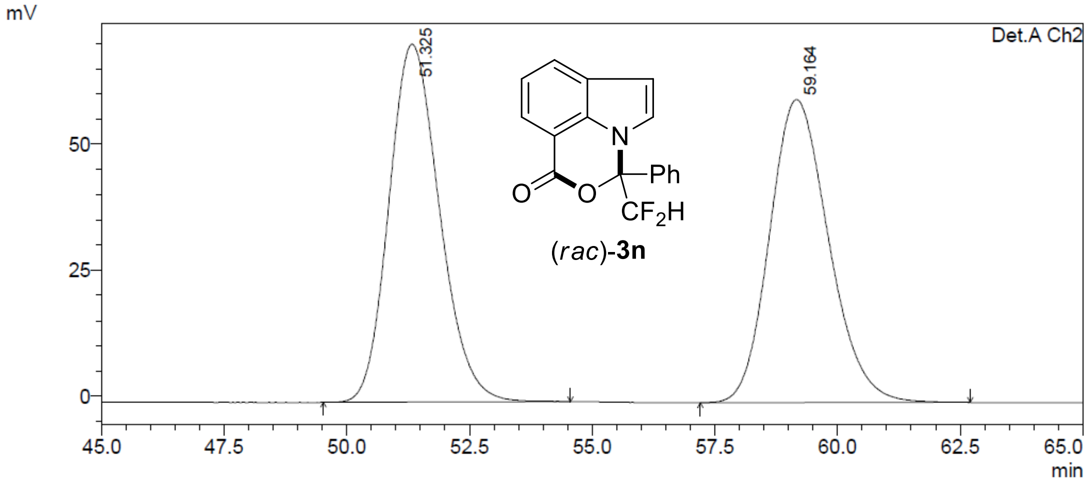
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.598	35490524	1912627	95.560	95.341
2	14.397	1649128	93464	4.440	4.659
Total		37139651	2006090	100.000	100.000



3n

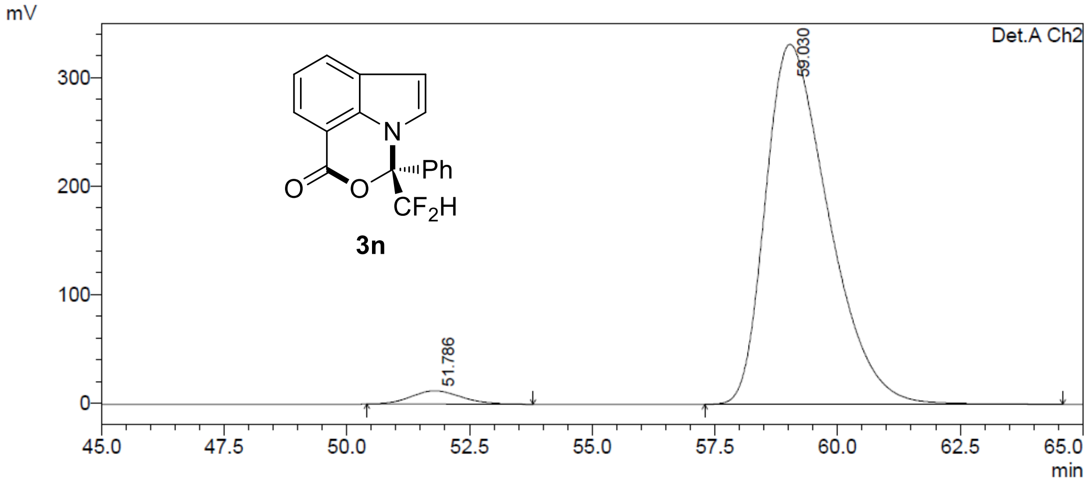

yx-1-286-C
yx-1-286-C
159.340
138.113
134.976
130.863
129.149
128.099
127.026
126.798
126.769
126.743
126.445
123.039
121.877
108.907
105.564
94.037
93.805
93.778
93.545
N
Ph
O
O
CF2H
3n
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-1-286-F
yx-1-286-F
-128.428
-129.438
-129.837
-130.847
N
Ph
O
O
CF2H
3n
0.93
1.00
-60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190
f1 (ppm)



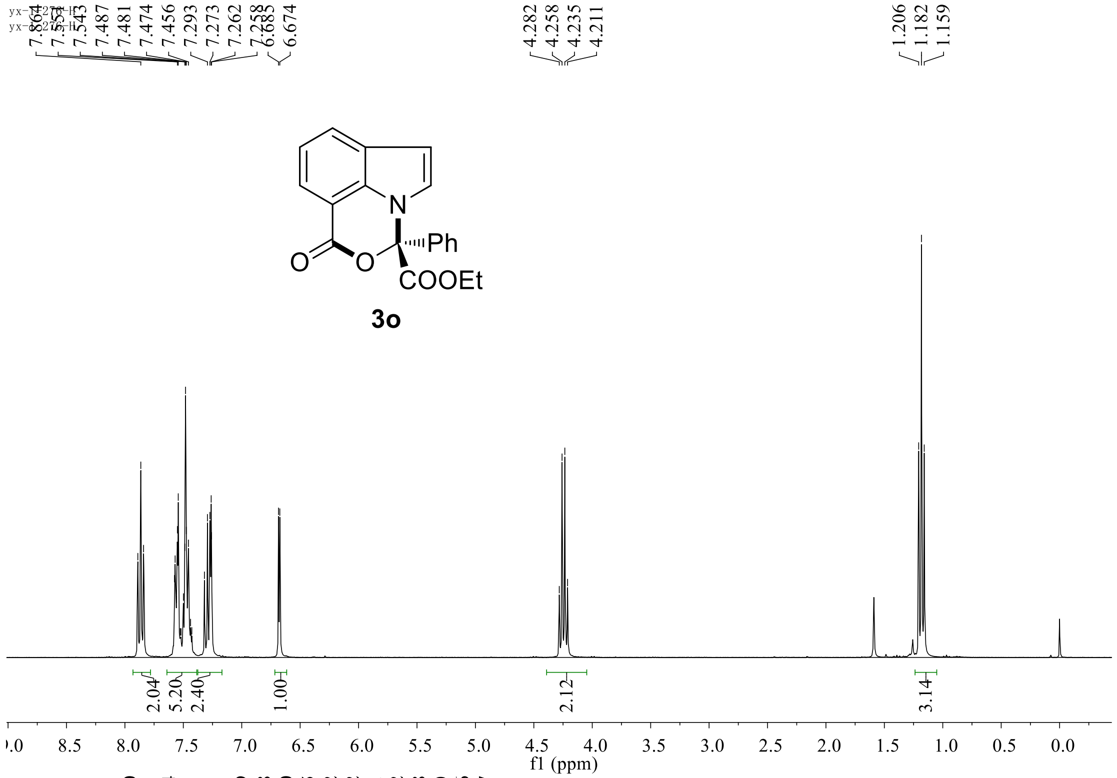
UV Detector Ch2 220nm

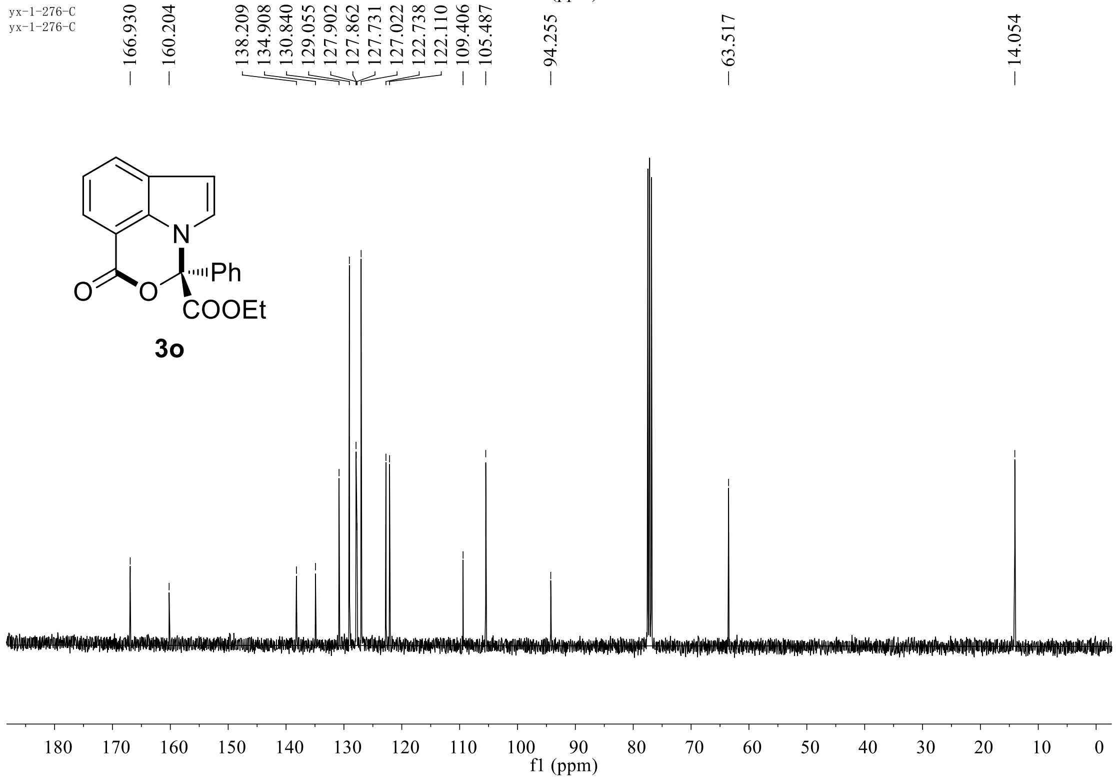
Peak#	Ret. Time	Area	Height	Area %	Height %
1	51.325	5107010	71077	50.299	54.161
2	59.164	5046335	60155	49.701	45.839
Total		10153344	131231	100.000	100.000

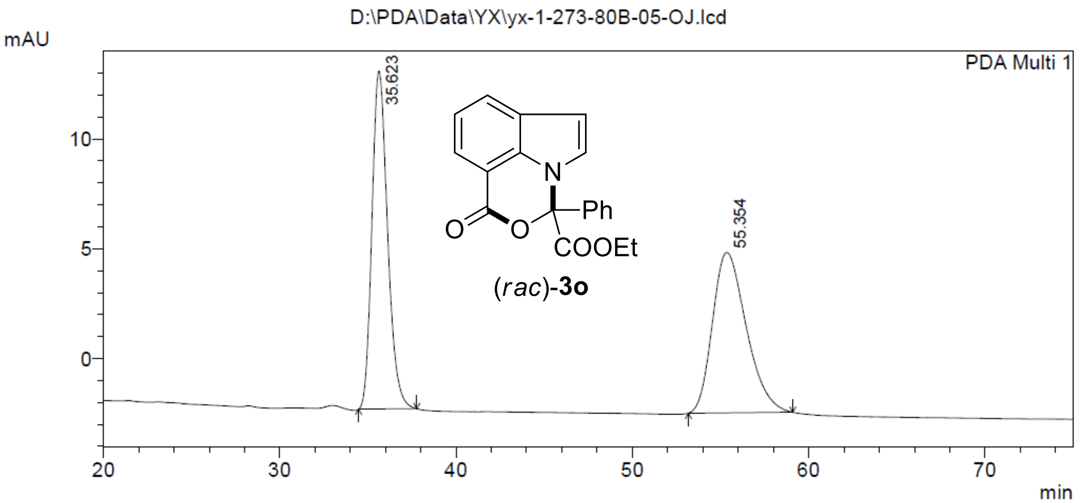


UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	51.786	870031	12141	2.850	3.531
2	59.030	29656036	331742	97.150	96.469
Total		30526067	343883	100.000	100.000

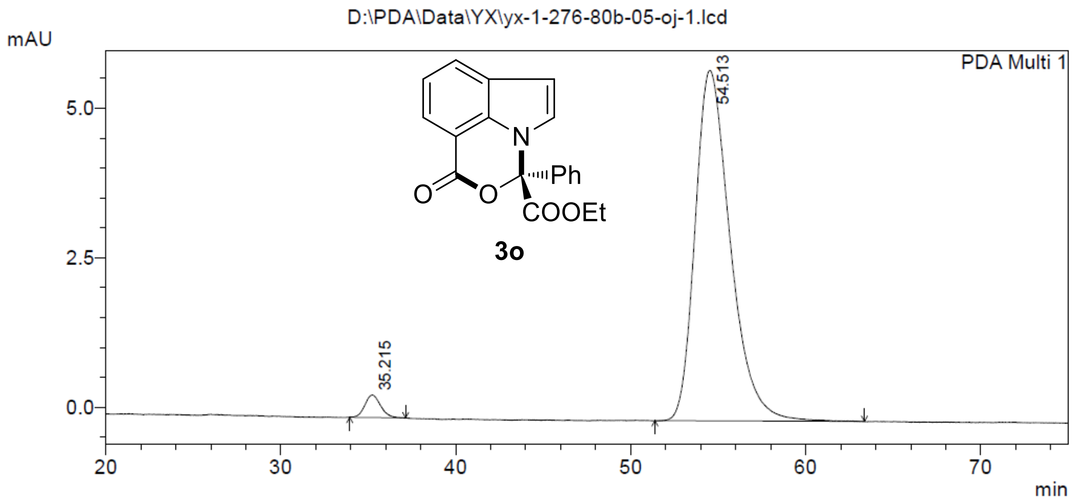

7.864
7.554
7.543
7.487
7.481
7.474
7.456
7.293
7.273
7.262
7.258
6.685
6.674
4.282
4.258
4.235
4.211
1.206
1.182
1.159
N
Ph
O
O
COOEt
3o
2.04
5.20
2.40
1.00
2.12
3.14
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


yx-1-276-C
yx-1-276-C
166.930
160.204
138.209
134.908
130.840
129.055
127.902
127.862
127.731
127.022
122.738
122.110
109.406
105.487
94.255
63.517
14.054
N
Ph
O
O
COOEt
3o
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

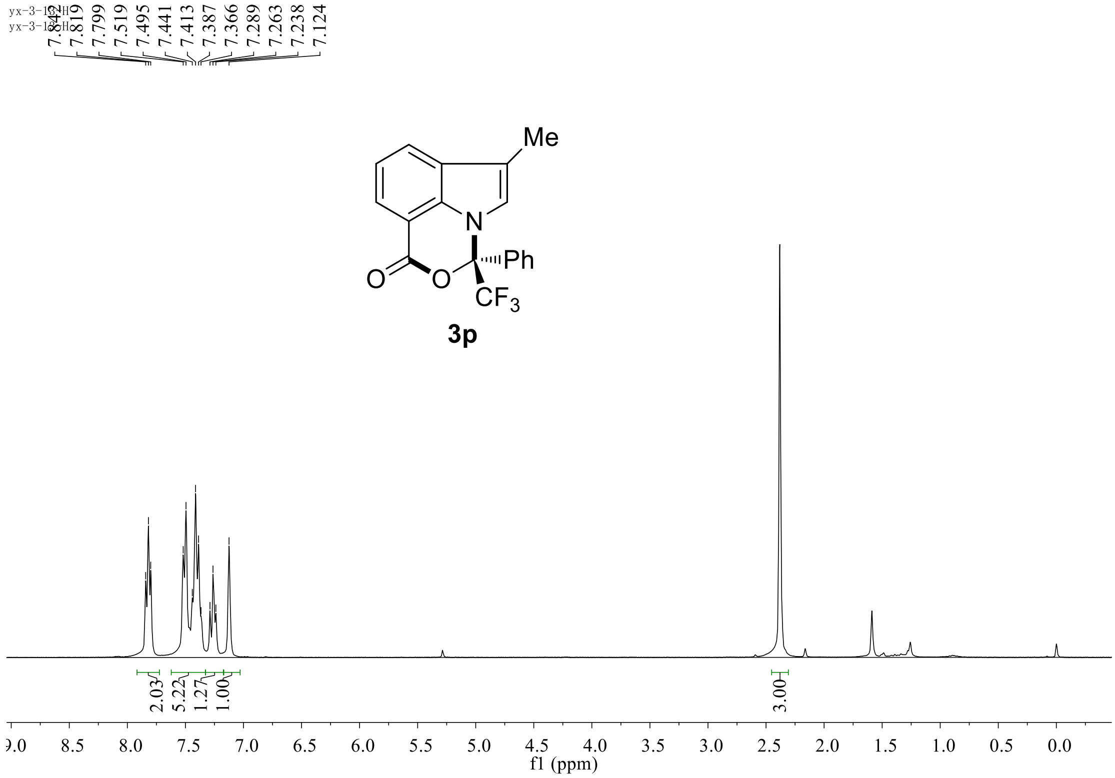


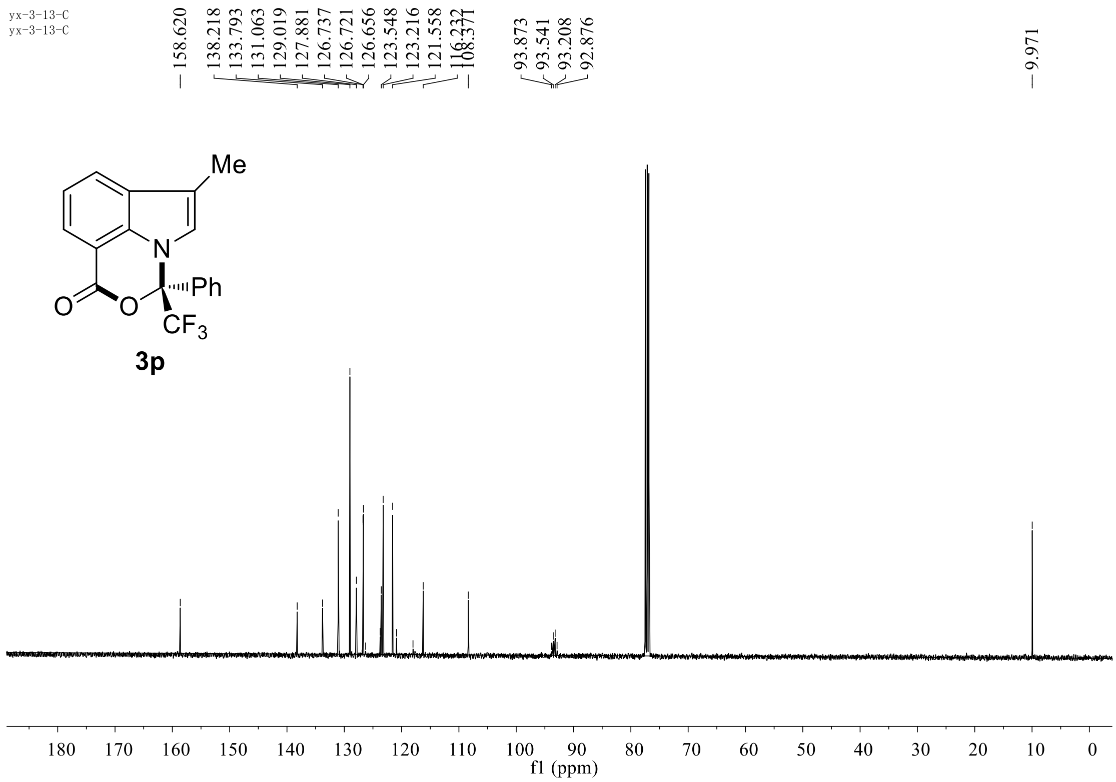
PDA Ch1 254nm 4nm

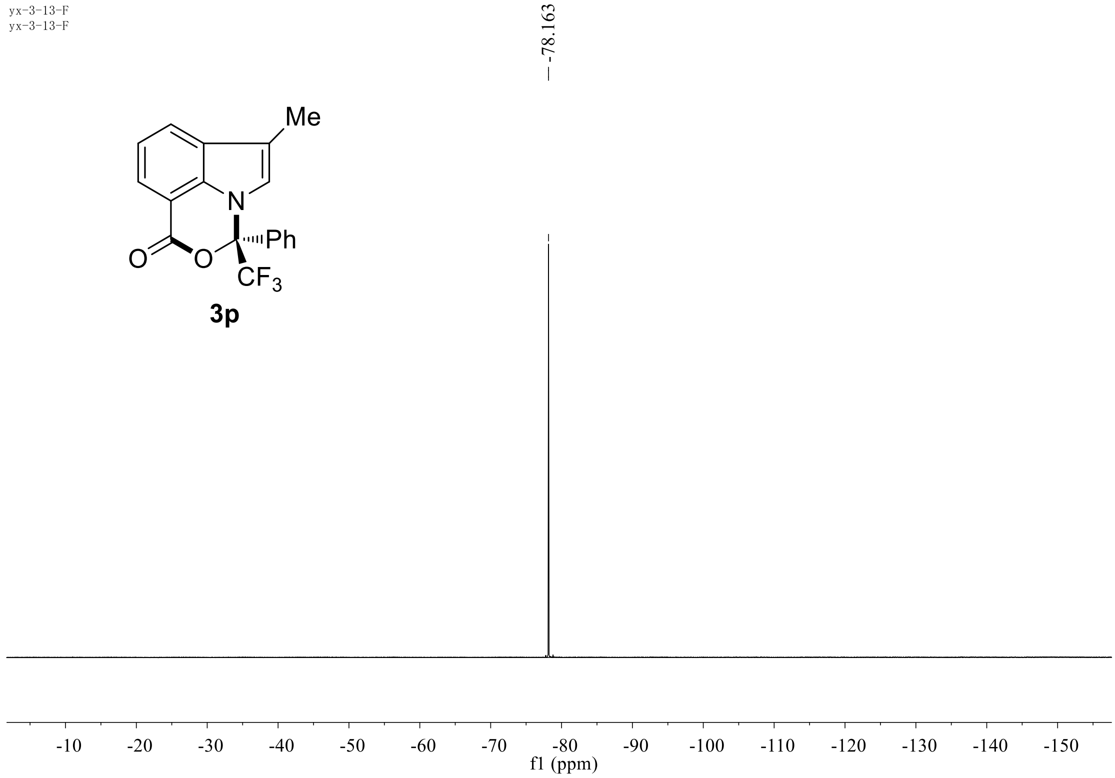
Peak#	Ret. Time	Area	Height	Area %	Height %
1	35.623	947937	15389	49.334	67.805
2	55.354	973519	7307	50.666	32.195
Total		1921456	22696	100.000	100.000

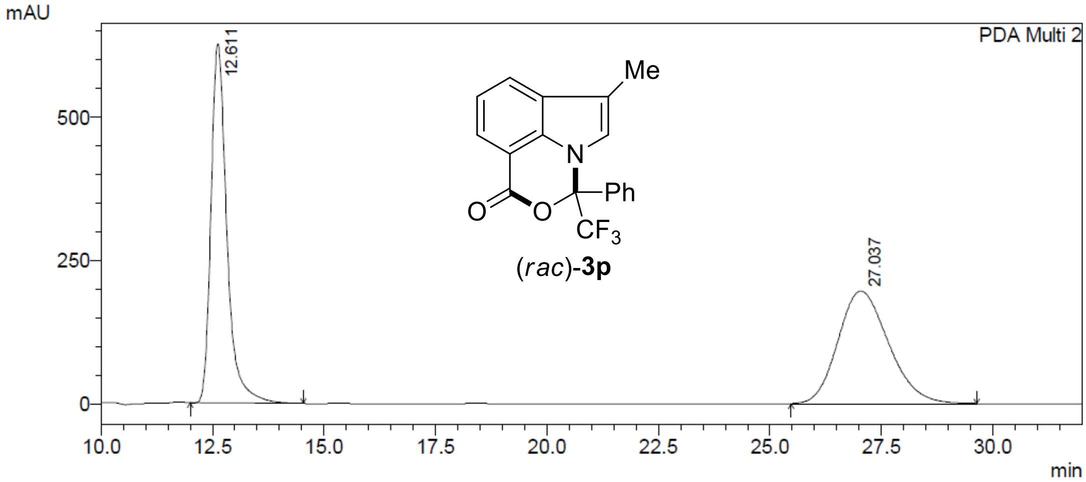


Peak#	Ret. Time	Area	Height	Area %	Height %
1	35.215	23378	378	2.776	6.062
2	54.513	818827	5853	97.224	93.938
Total		842205	6231	100.000	100.000


yx-3-13-C
7.842
7.819
7.799
7.519
7.495
7.441
7.413
7.387
7.366
7.289
7.263
7.238
7.124
Me
N
Ph
O
O
CF_3
3p
2.03
5.22
1.27
1.00
3.00
f1 (ppm)

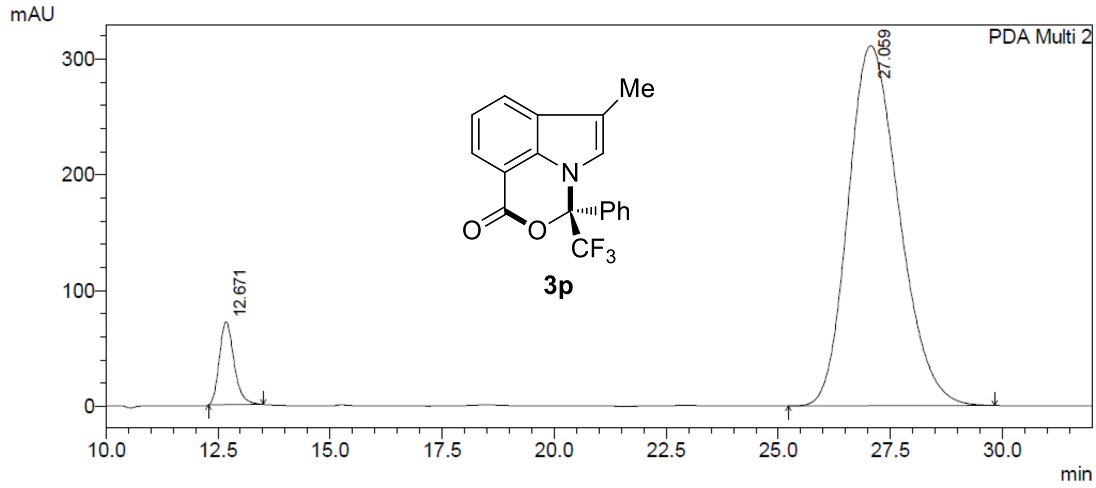

yx-3-13-C
158.620
138.218
133.793
131.063
129.019
127.881
126.737
126.721
126.656
123.548
123.216
121.558
116.232
108.371
93.873
93.541
93.208
92.876
9.971
Me
N
Ph
O
O
CF_3
3p
f1 (ppm)





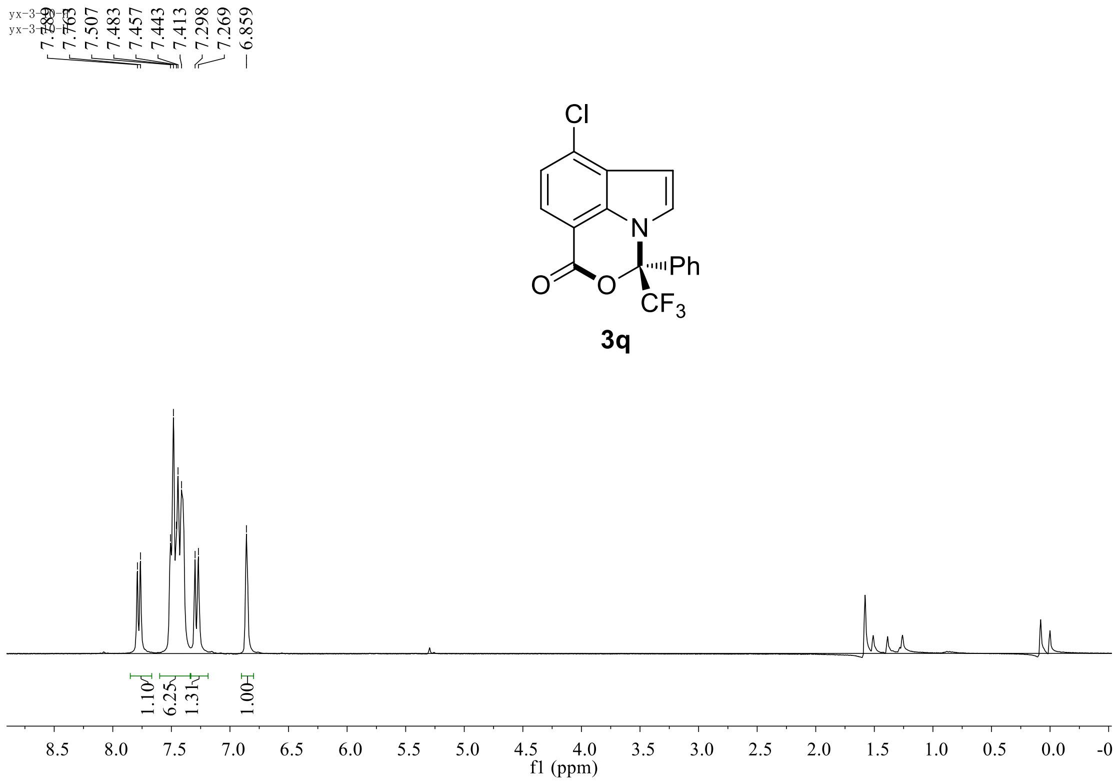
PDA Ch2 220nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.611	15526832	626016	50.078	76.128
2	27.037	15478291	196304	49.922	23.872
Total		31005123	822320	100.000	100.000

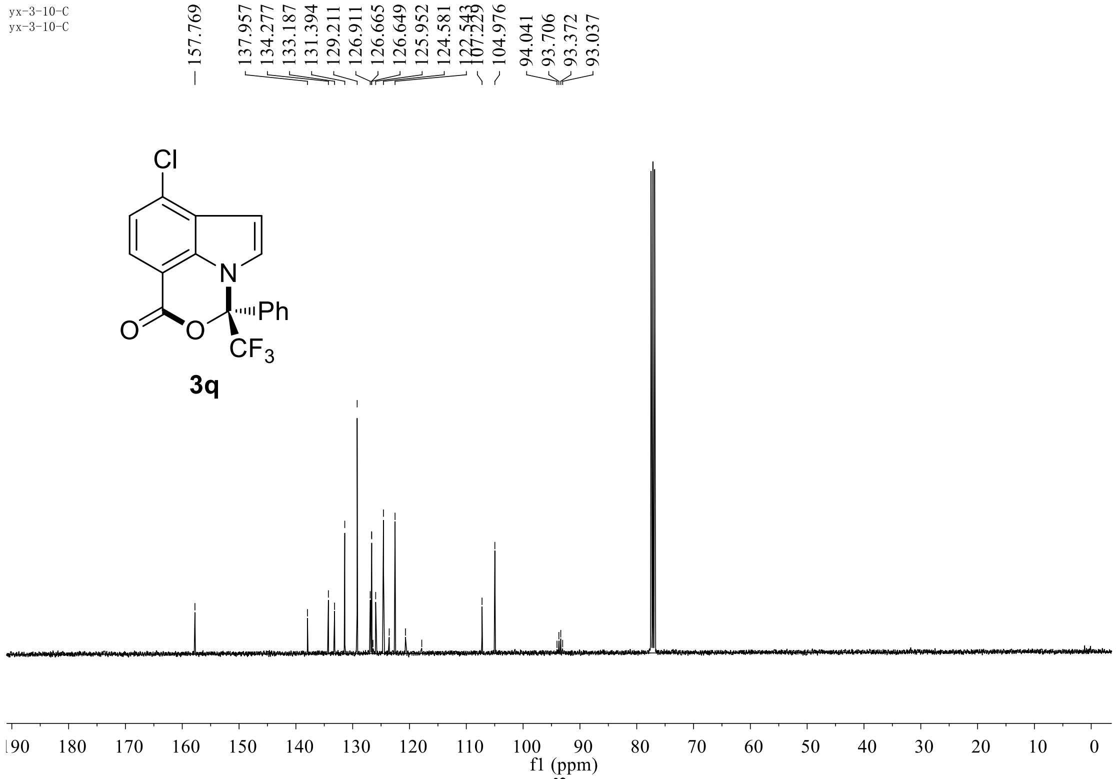


PDA Ch2 220nm 4nm

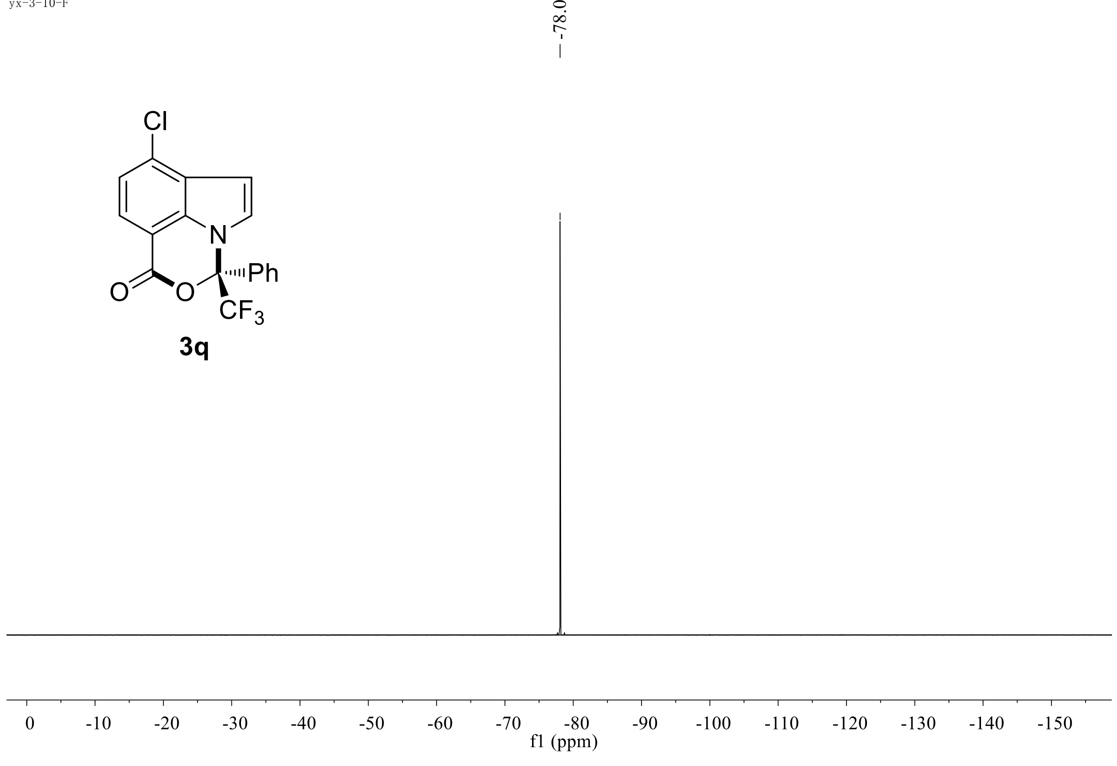
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.671	1637413	71590	6.221	18.698
2	27.059	24682060	311293	93.779	81.302
Total		26319473	382882	100.000	100.000

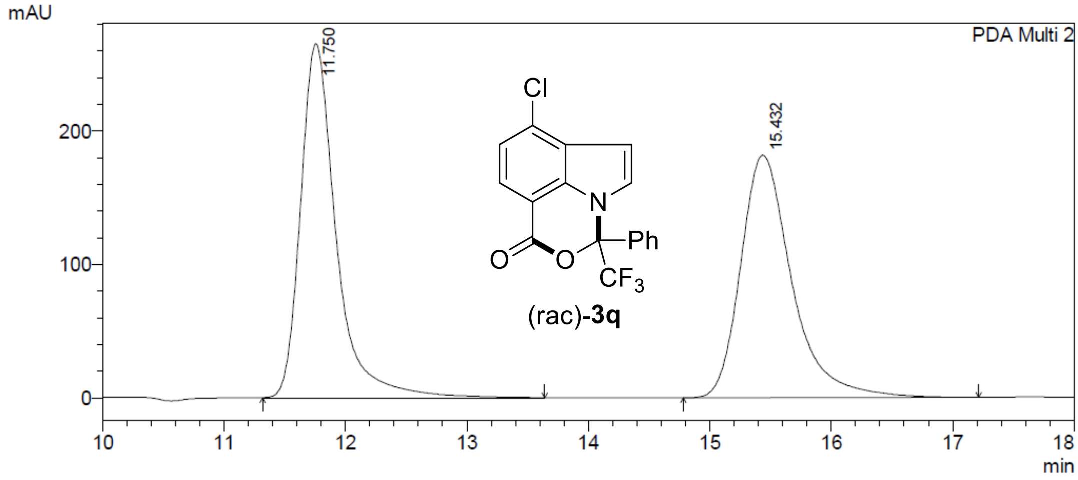


yx-3-10-C
yx-3-10-C



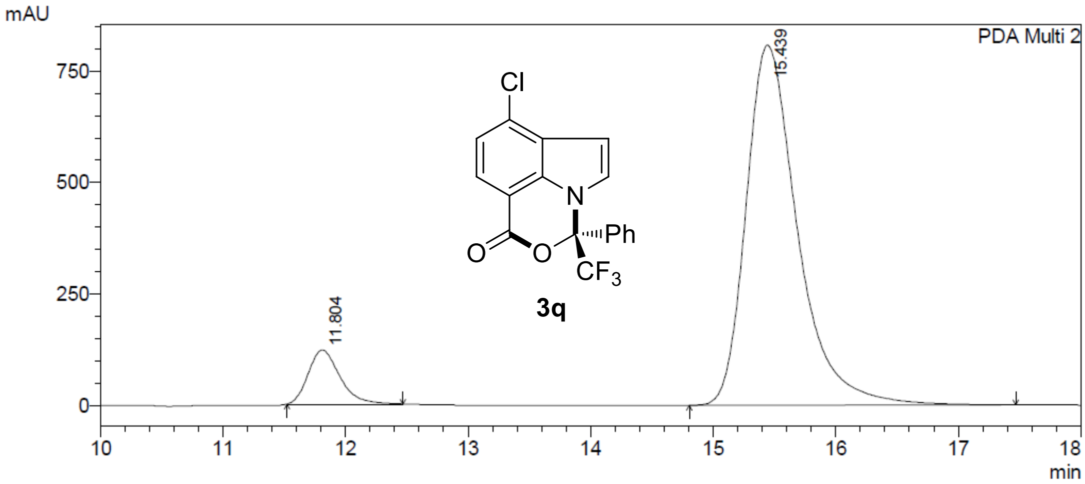
yx-3-10-F
yx-3-10-F





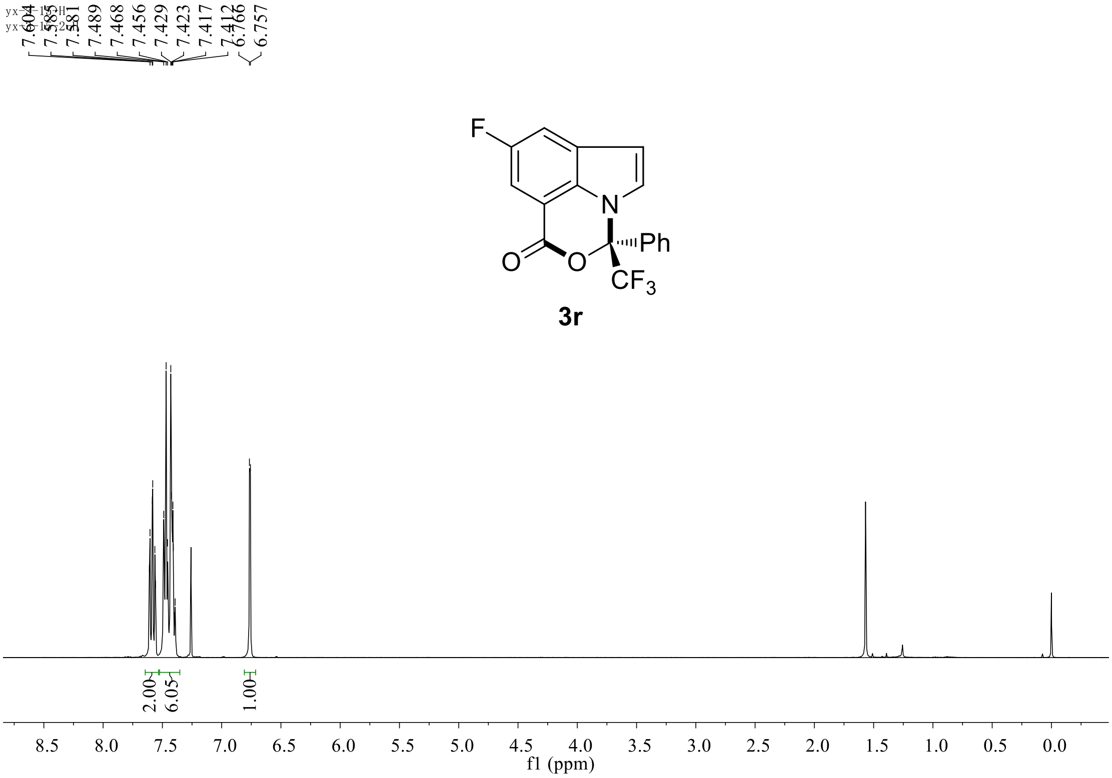
PDA Ch2 220nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.750	5428430	265606	50.373	59.322
2	15.432	5348072	182126	49.627	40.678
Total		10776502	447732	100.000	100.000



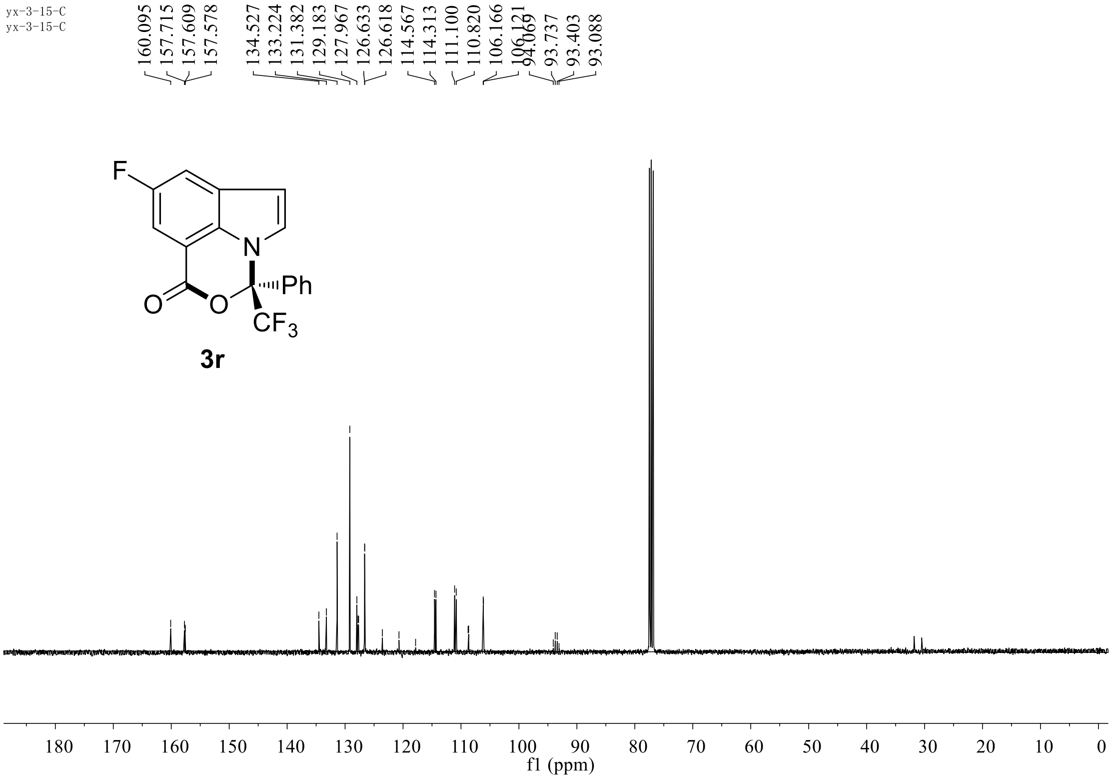
PDA Ch2 220nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.804	2182979	121292	8.464	13.063
2	15.439	23607762	807243	91.536	86.937
Total		25790741	928536	100.000	100.000



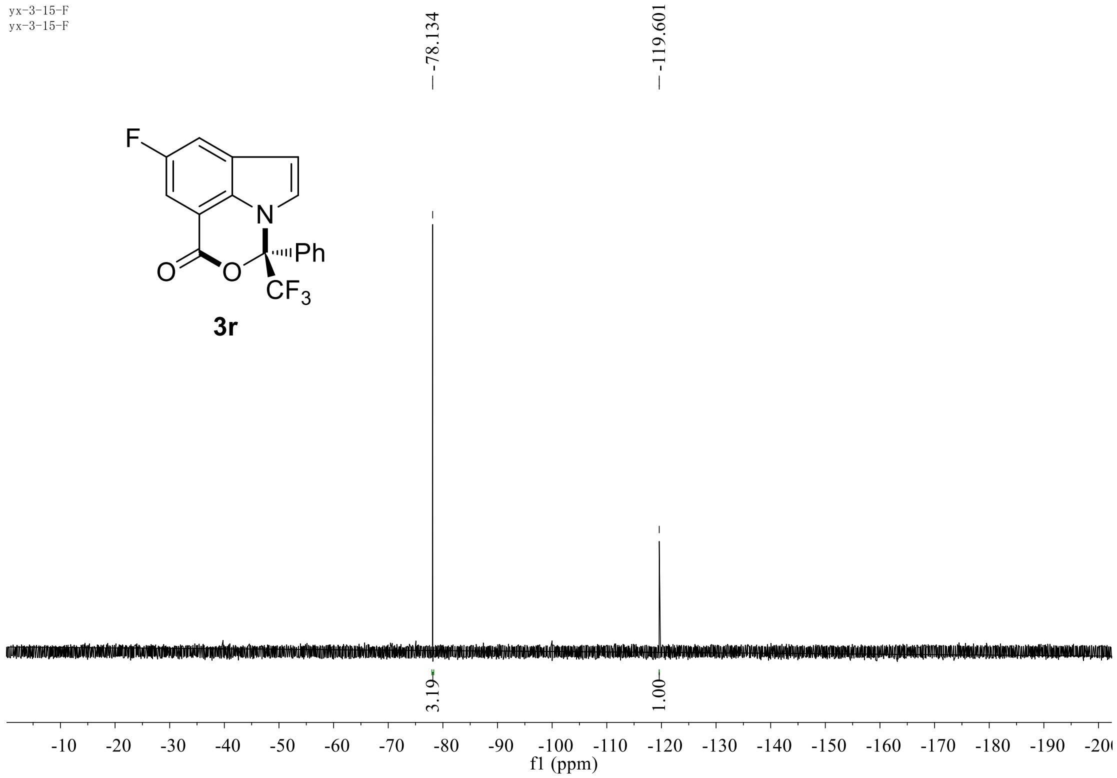
7.604
7.585
7.581
7.489
7.468
7.456
7.429
7.423
7.417
7.412
6.766
6.757
F
N
Ph
O
O
CF3
2.00
6.05
1.00
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

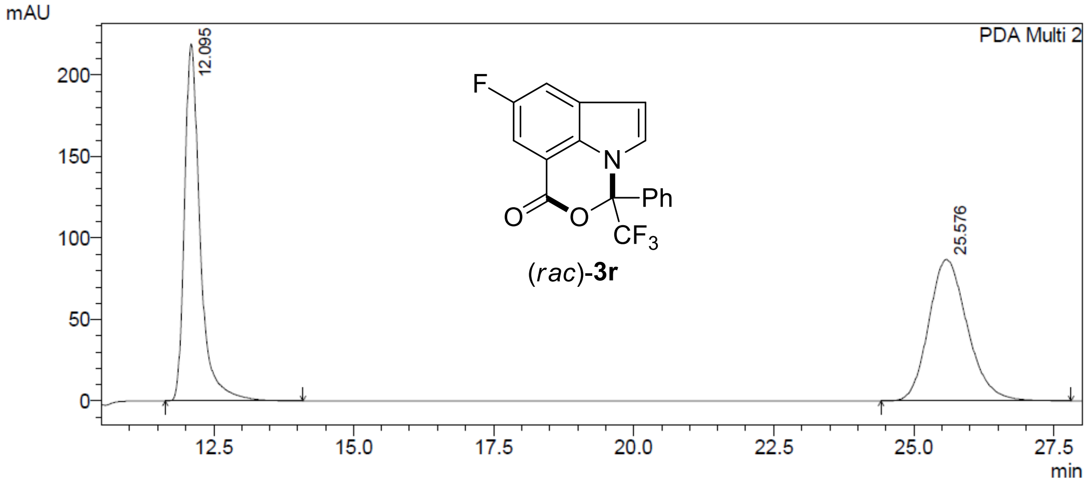
3r



yx-3-15-C
160.095
157.715
157.609
157.578
134.527
133.224
131.382
129.183
127.967
126.633
126.618
114.567
114.313
111.100
110.820
106.166
106.121
94.069
93.737
93.403
93.088
F
N
Ph
O
O
CF3
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

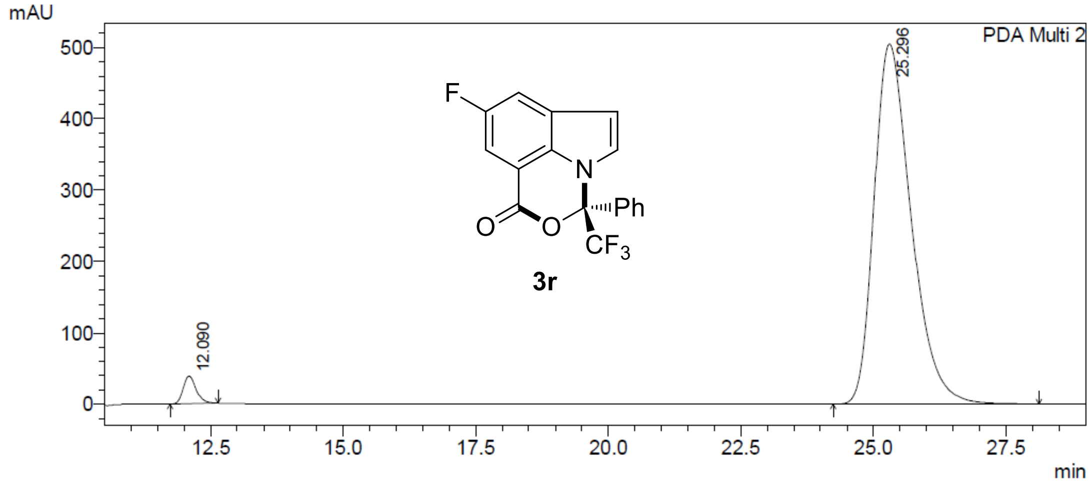
3r





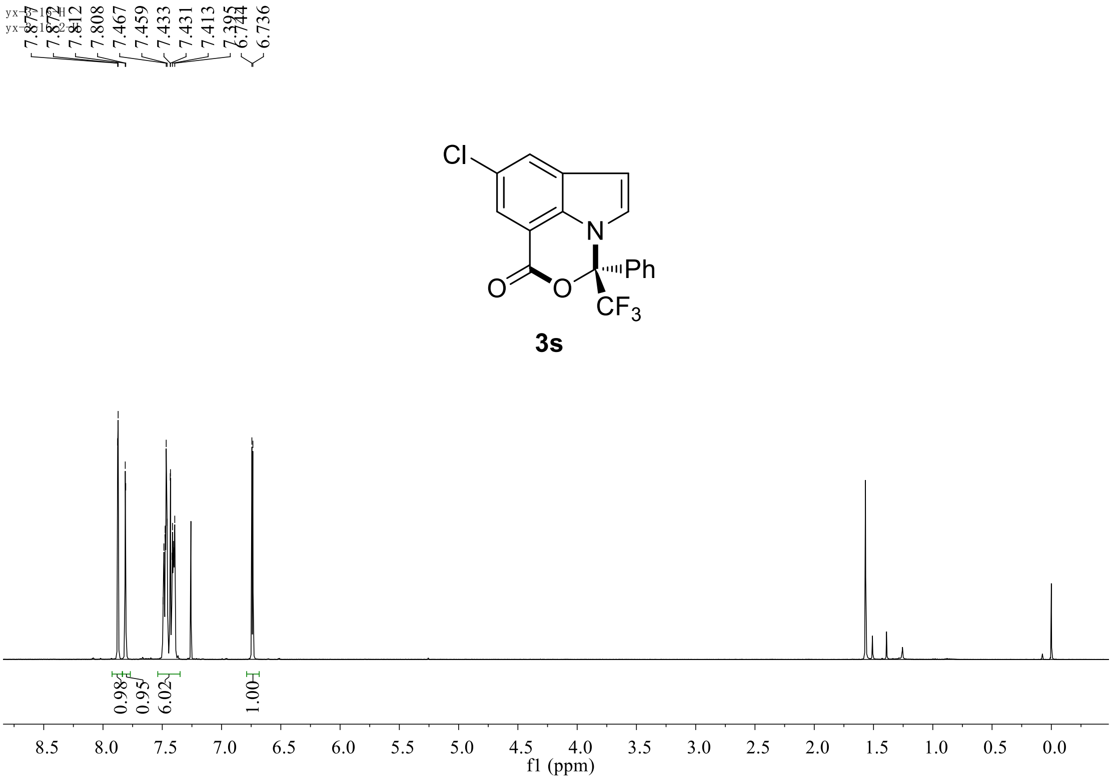
PDA Ch2 220nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.095	4256968	218999	50.474	71.602
2	25.576	4176990	86858	49.526	28.398
Total		8433957	305857	100.000	100.000

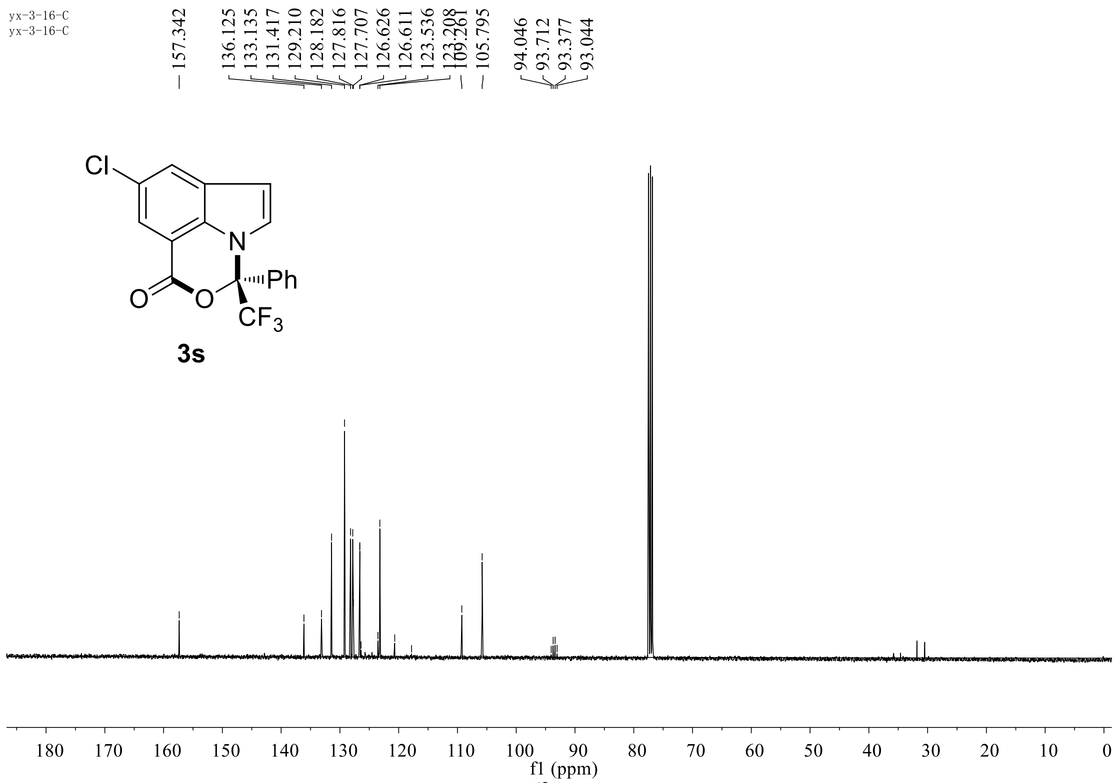


PDA Ch2 220nm 4nm

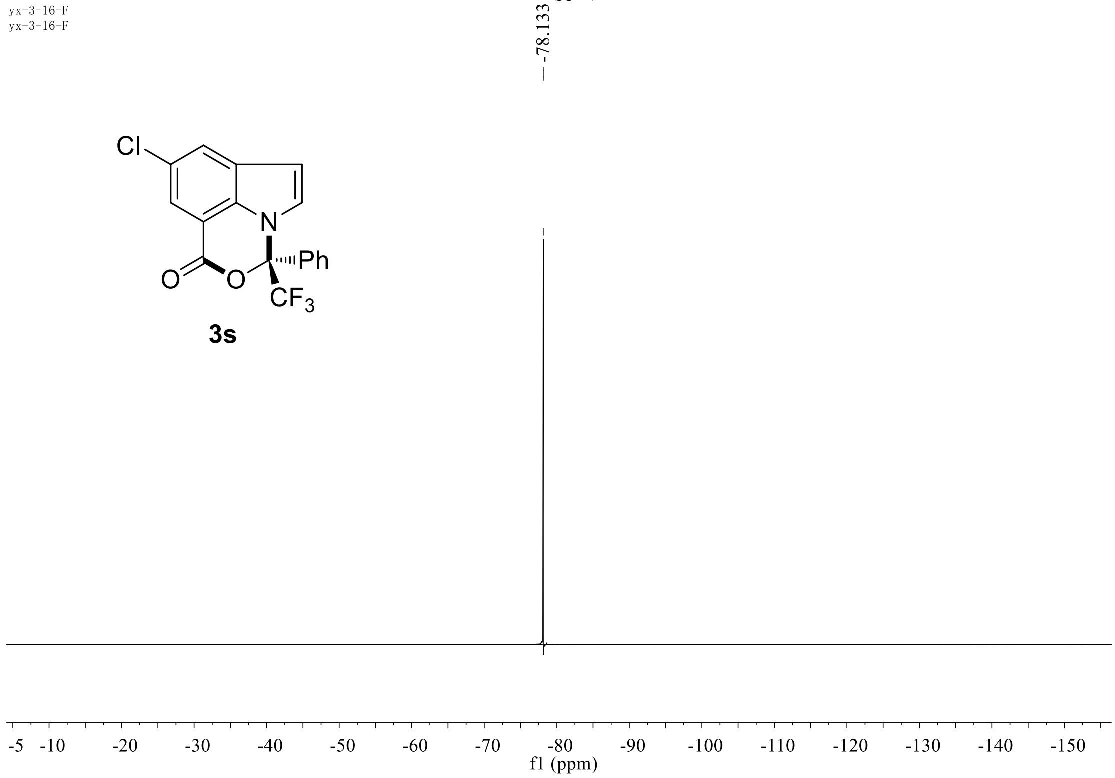
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.090	669277	39049	2.651	7.183
2	25.296	24578982	504613	97.349	92.817
Total		25248259	543661	100.000	100.000

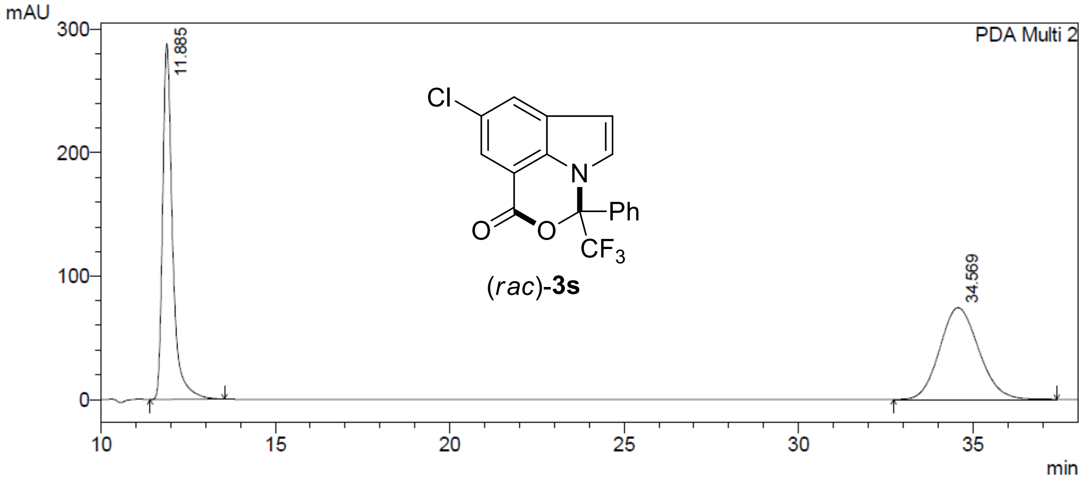


yx-3-16-C
yx-3-16-C



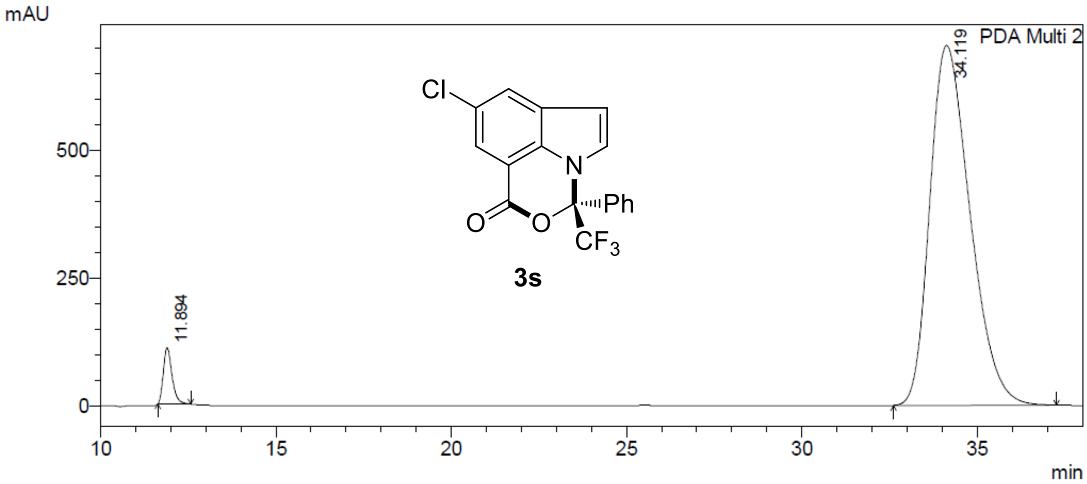
yx-3-16-F
yx-3-16-F





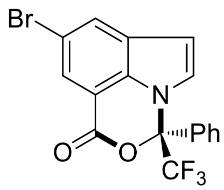
PDA Ch2 220nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.885	5687054	288306	49.614	79.508
2	34.569	5775609	74307	50.386	20.492
Total		11462663	362613	100.000	100.000



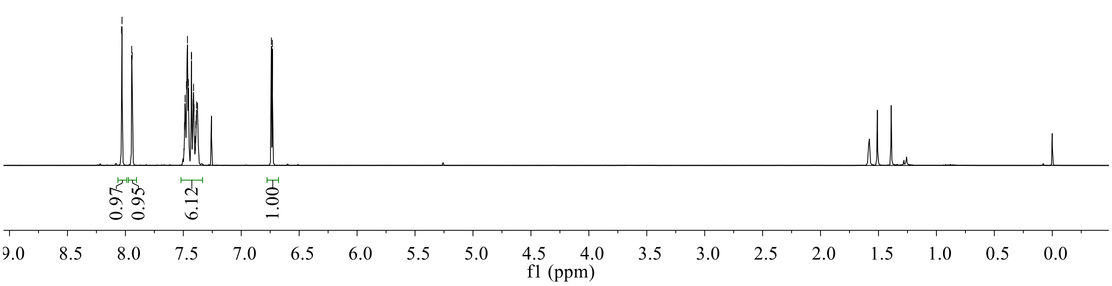
PDA Ch2 220nm 4nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.894	1901319	110465	3.271	13.540
2	34.119	56217311	705360	96.729	86.460
Total		58118630	815824	100.000	100.000

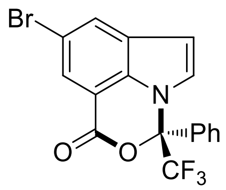


Br
N
Ph
O
O
CF3

3t

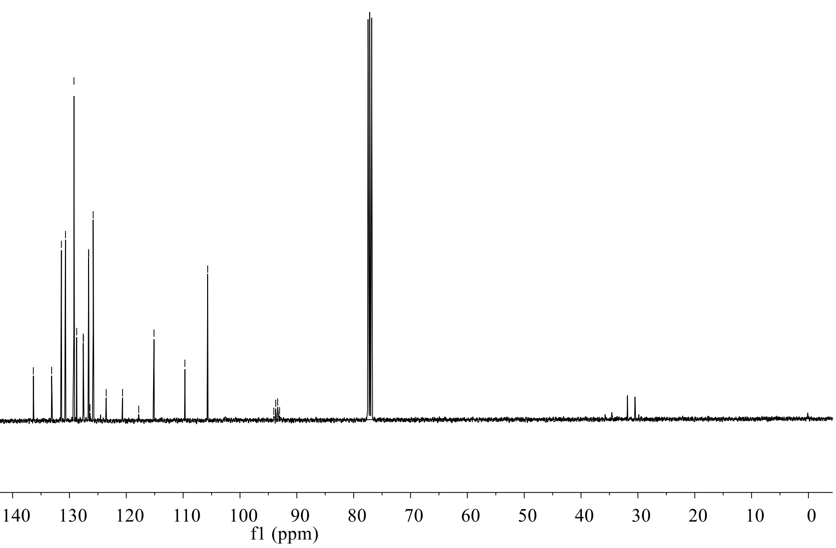


yx-1-325-H
8.033
8.029
7.945
7.942
7.465
7.457
7.430
7.429
6.740
6.732
0.97
0.95
6.12
1.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

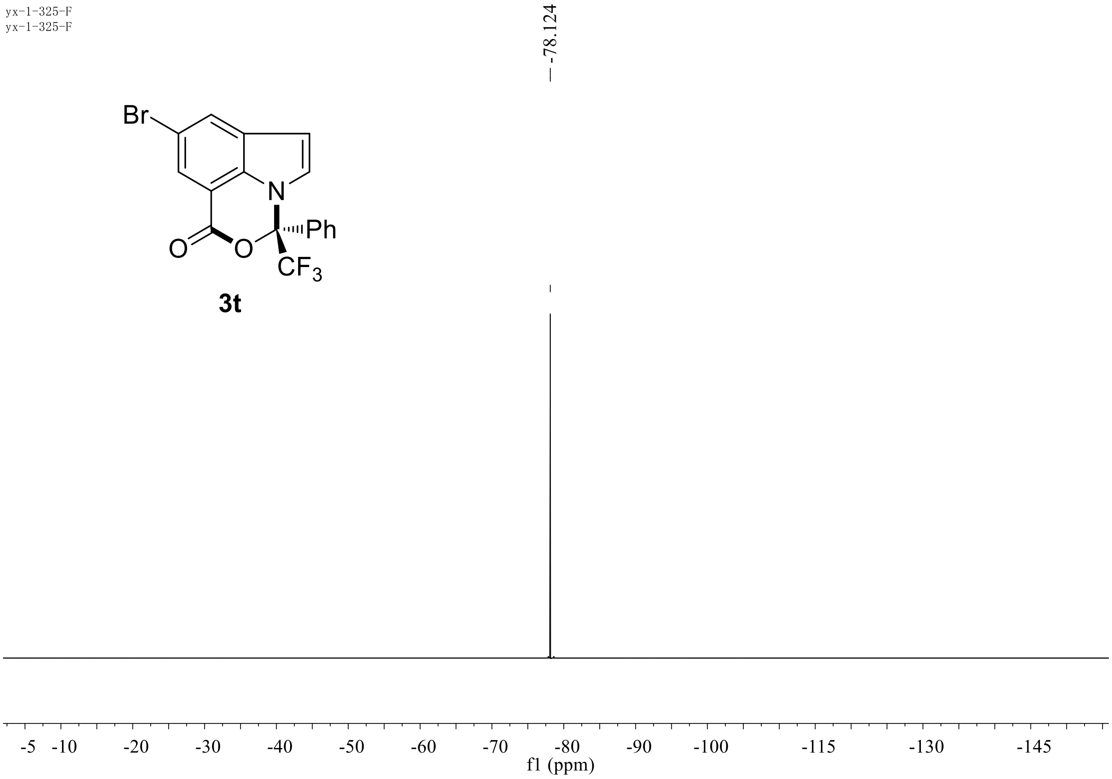


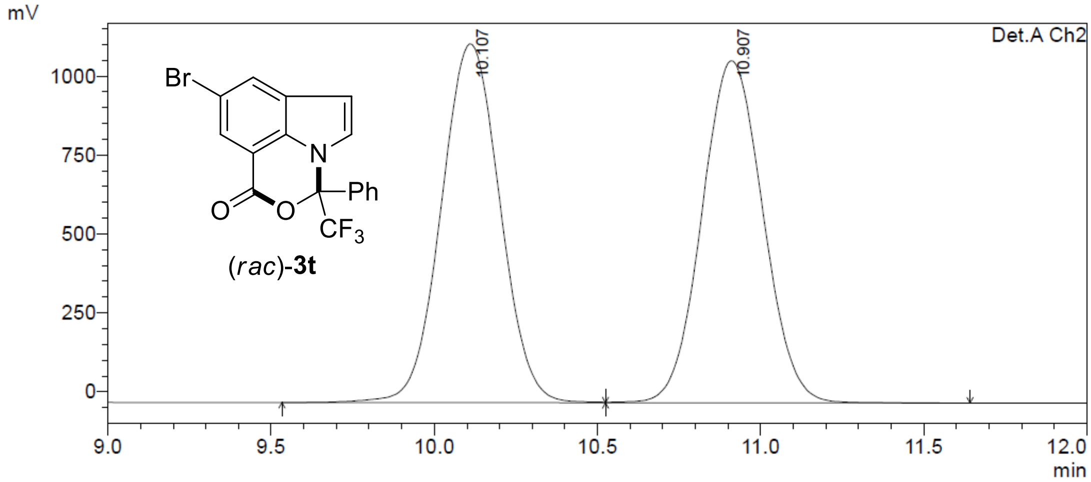
Br
N
Ph
O
O
CF3

3t



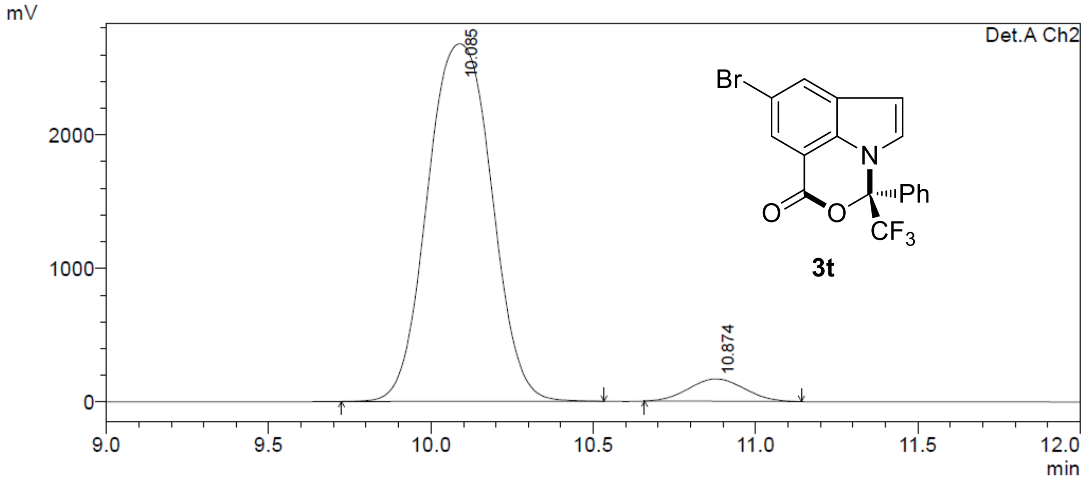
yx-1-325-C
157.179
136.354
133.129
131.422
130.707
129.215
128.722
127.569
127.553
126.625
126.610
125.824
115.134
109.696
105.681
94.045
93.710
93.375
93.042
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)





Detector A Ch2 220nm

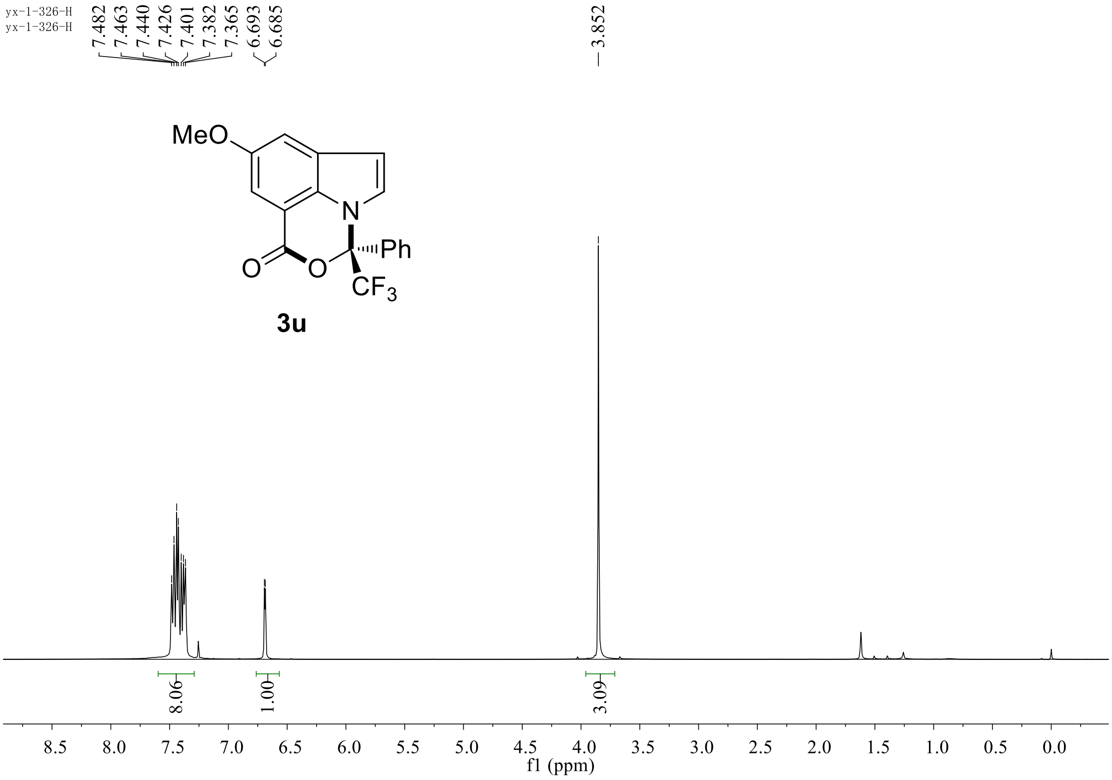
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.107	14231307	1136902	50.241	51.201
2	10.907	14094698	1083580	49.759	48.799
Total		28326005	2220482	100.000	100.000



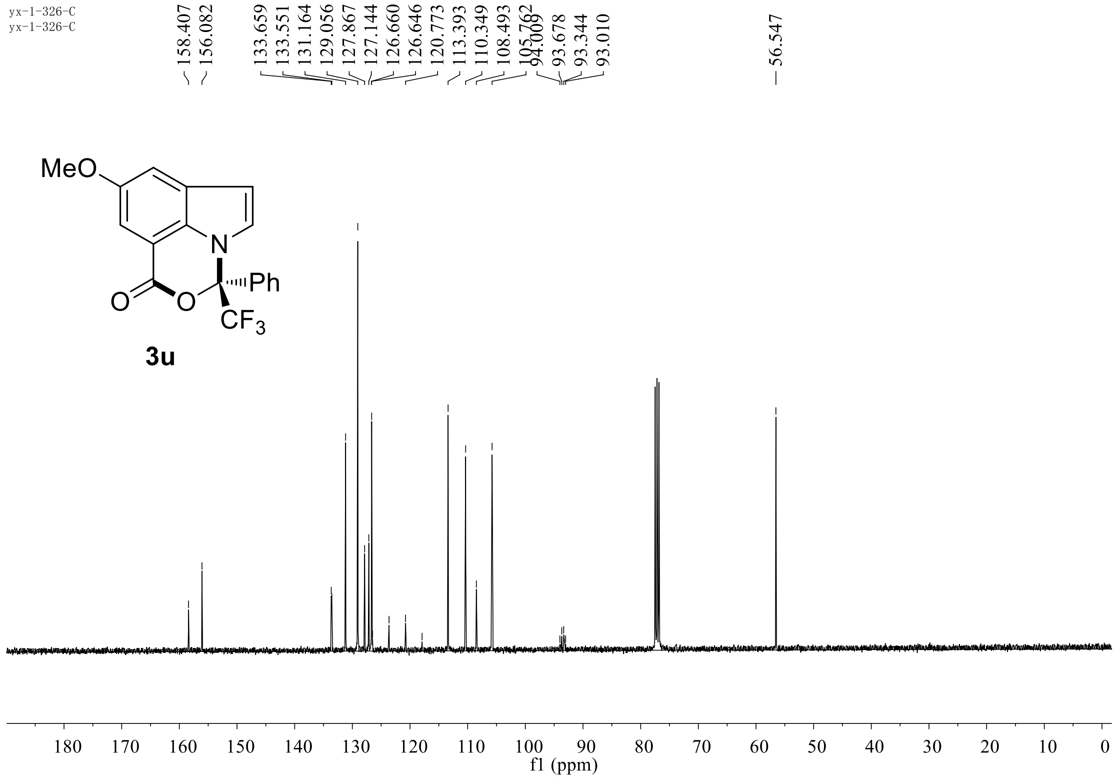
3t

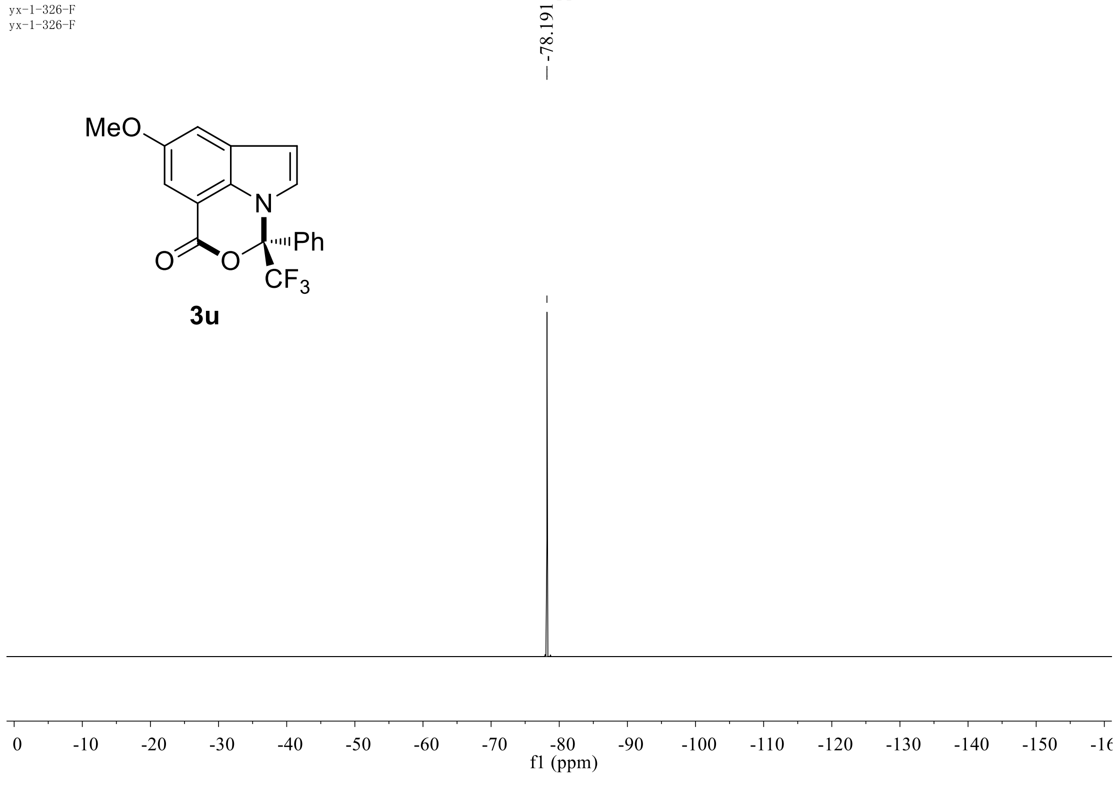
Detector A Ch2 220nm

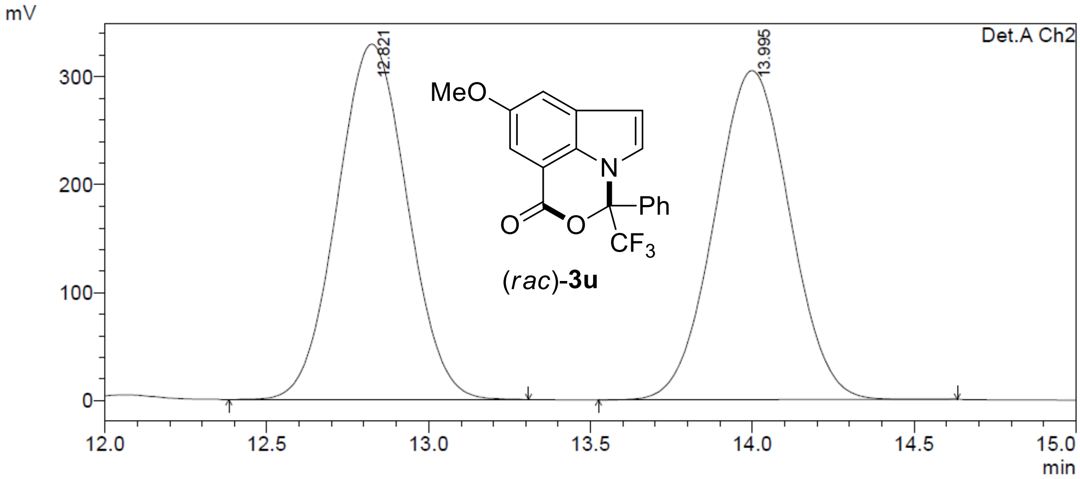
Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.085	36850331	2677111	94.851	94.114
2	10.874	2000265	167417	5.149	5.886
Total		38850595	2844528	100.000	100.000



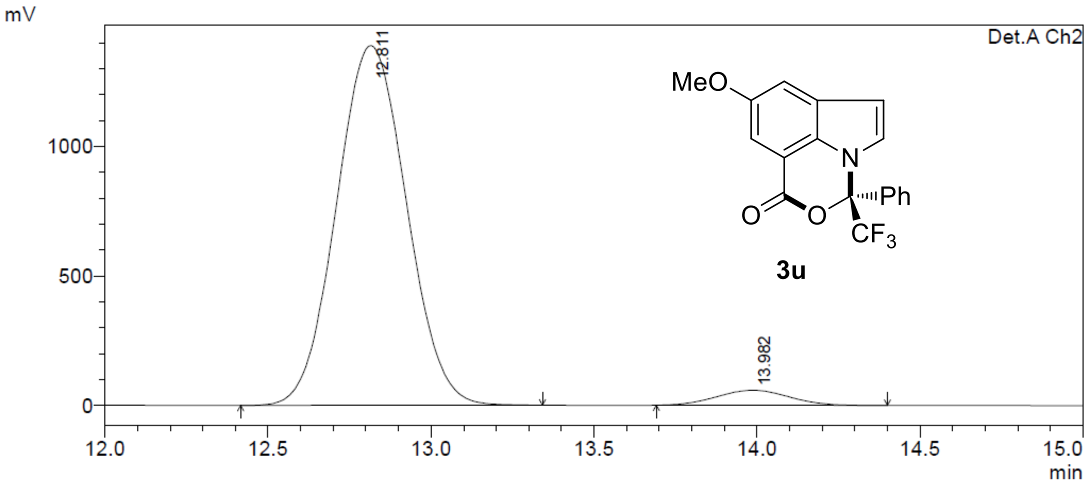
3u


yx-1-326-C
yx-1-326-C
158.407
156.082
133.659
133.551
131.164
129.056
127.867
127.144
126.660
126.646
120.773
113.393
110.349
108.493
105.762
94.009
93.678
93.344
93.010
56.547
MeO
N
Ph
O
O
CF3
3u
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

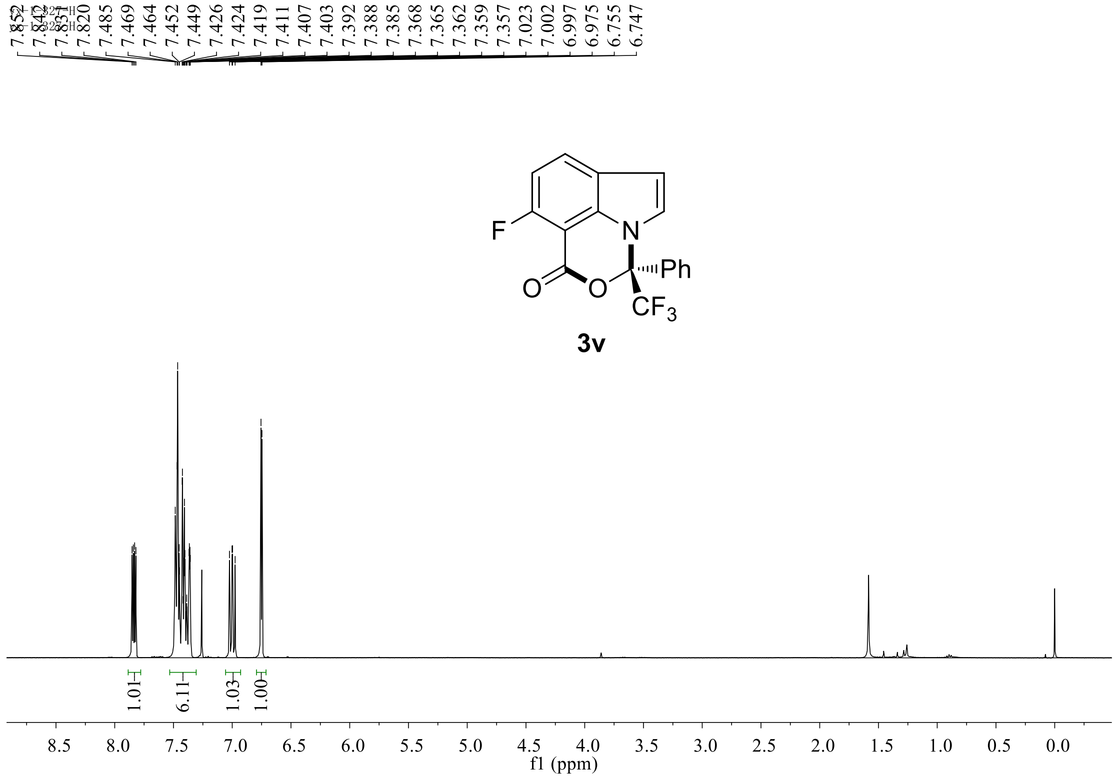

yx-1-326-F
yx-1-326-F
-78.191
MeO
N
Ph
O
O
CF3
3u
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
f1 (ppm)

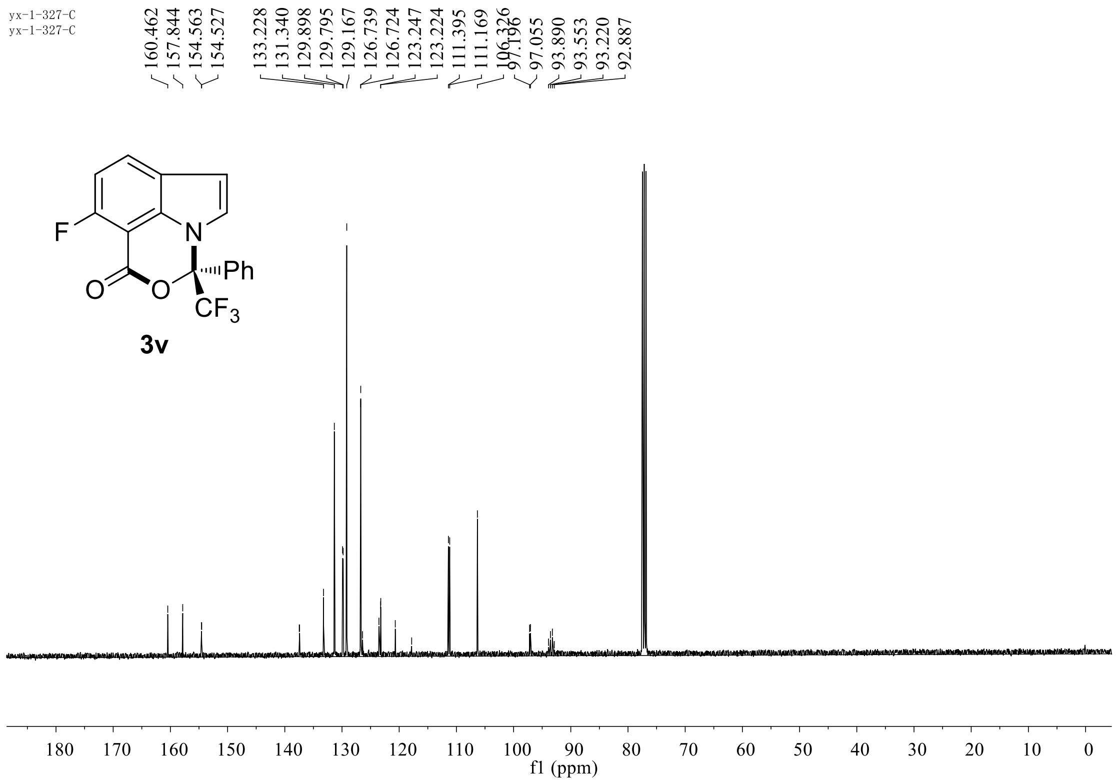


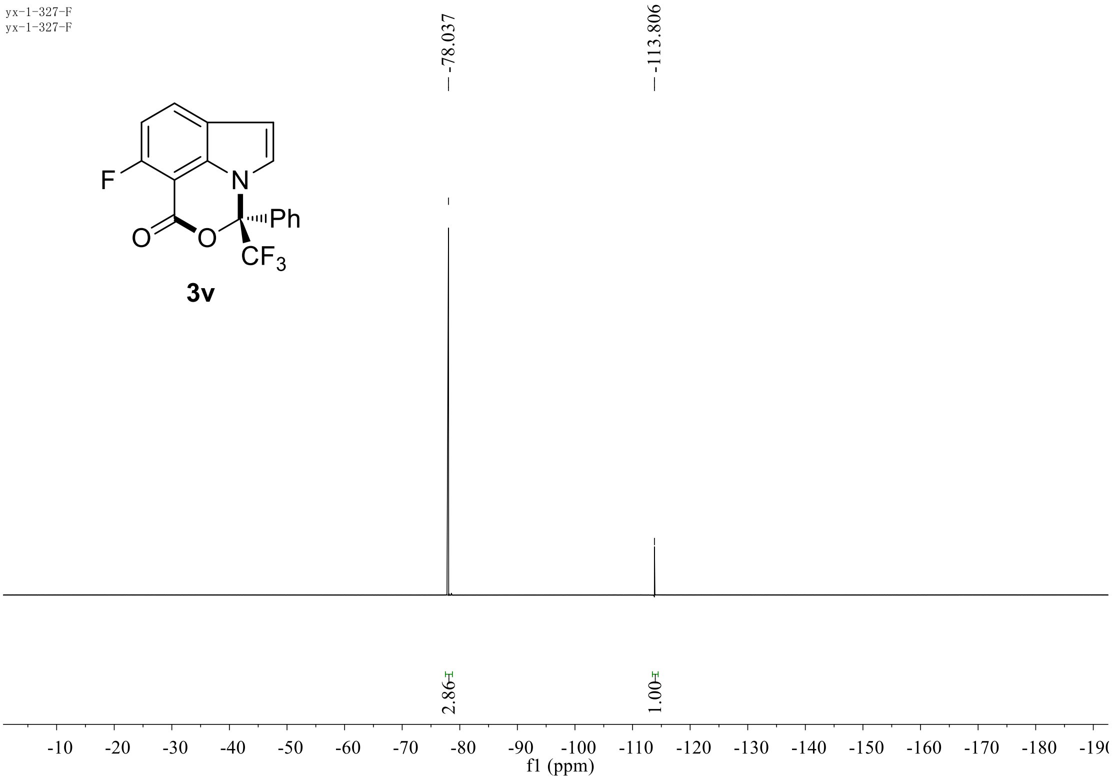
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.821	4967541	329363	50.080	51.933
2	13.995	4951623	304845	49.920	48.067
Total		9919164	634208	100.000	100.000

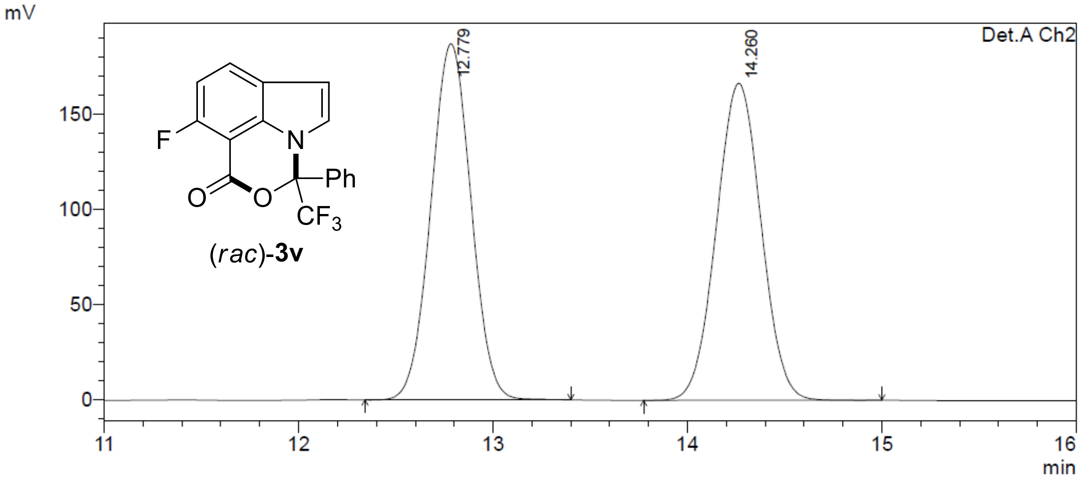


Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.811	20752661	1387720	95.869	95.996
2	13.982	894217	57878	4.131	4.004
Total		21646878	1445598	100.000	100.000


7.852
7.820
7.485
7.469
7.464
7.452
7.449
7.426
7.424
7.419
7.411
7.407
7.403
7.392
7.388
7.385
7.368
7.365
7.362
7.359
7.357
7.023
7.002
6.997
6.975
6.755
6.747
F
N
Ph
O
O
CF3
3v
1.01
6.11
1.03
1.00
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)

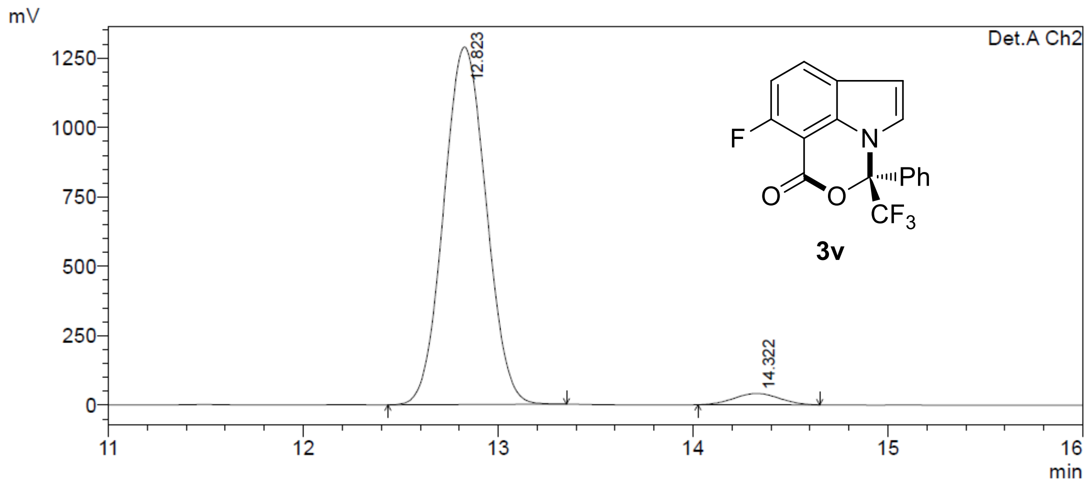

yx-1-327-C
yx-1-327-C
160.462
157.844
154.563
154.527
133.228
131.340
129.898
129.795
129.167
126.739
126.724
123.247
123.224
111.395
111.169
106.326
97.196
97.055
93.890
93.553
93.220
92.887
F
N
Ph
O
O
CF3
3v
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



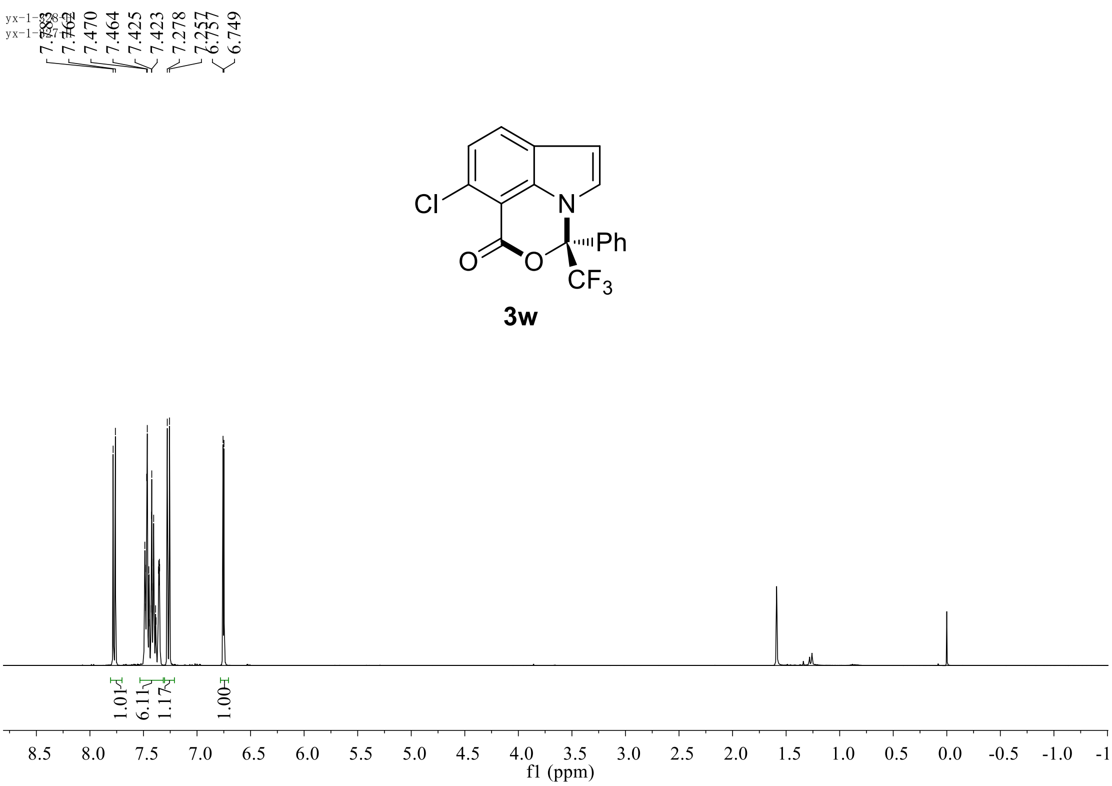


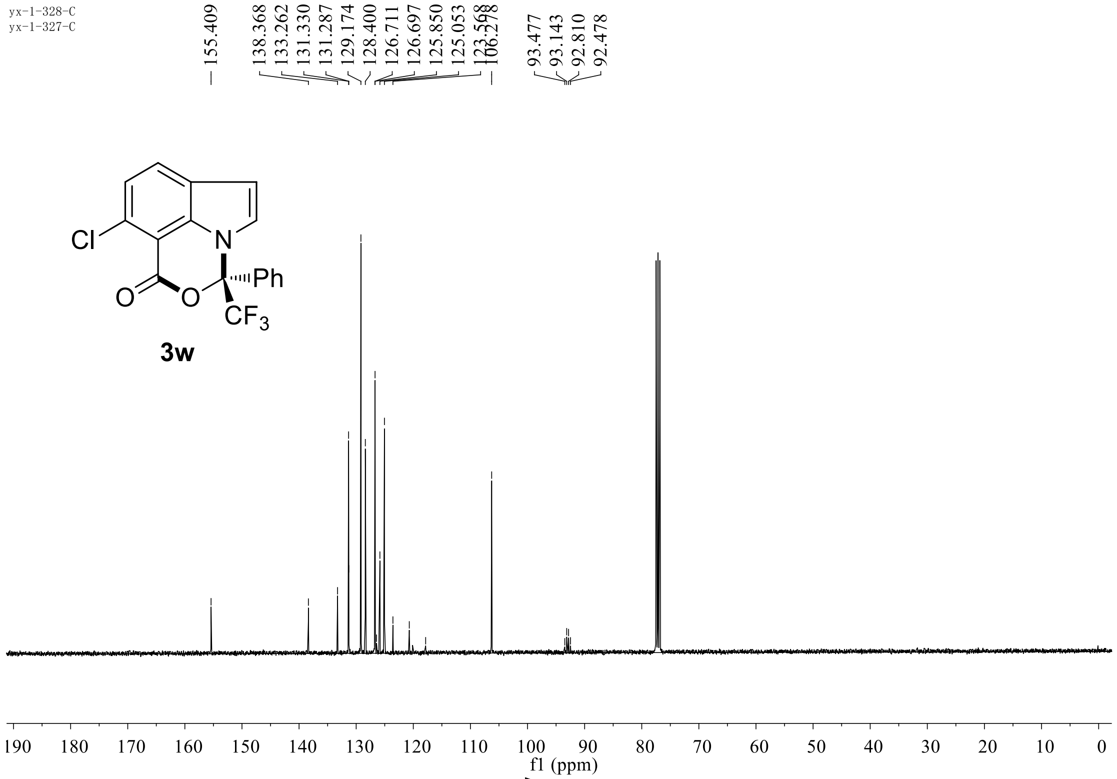
Detector A Ch2 220nm

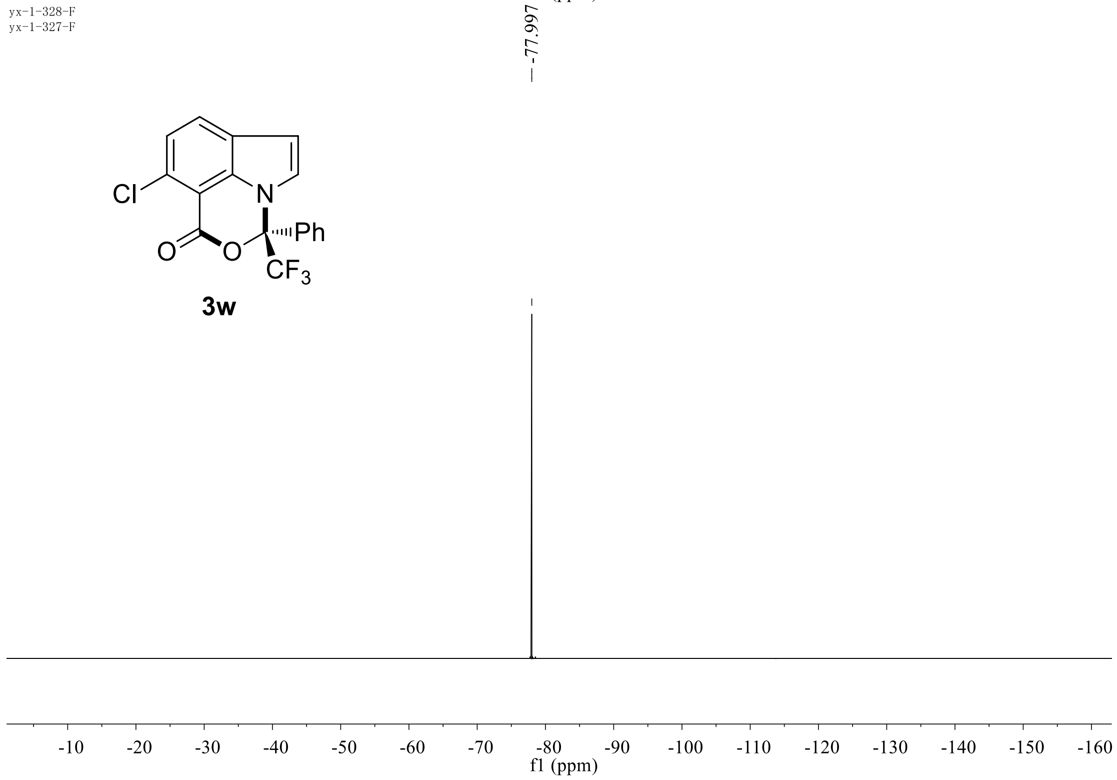
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.779	2687980	187311	50.212	52.932
2	14.260	2665255	166557	49.788	47.068
Total		5353235	353868	100.000	100.000

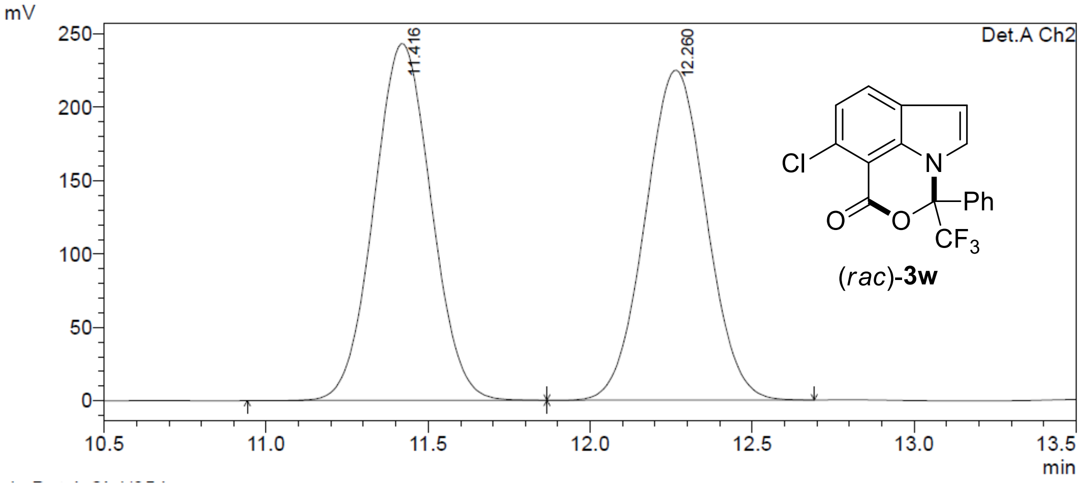


Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.823	19495443	1287799	96.743	96.946
2	14.322	656333	40567	3.257	3.054
Total		20151776	1328366	100.000	100.000

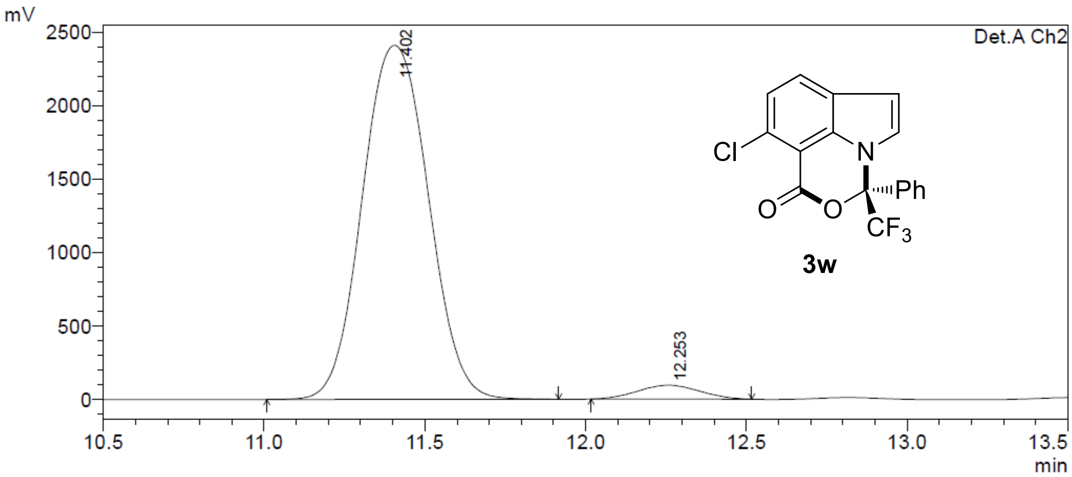



yx-1-328-C
yx-1-327-C
155.409
138.368
133.262
131.330
131.287
129.174
128.400
126.711
126.697
125.850
125.053
123.568
106.278
93.477
93.143
92.810
92.478
Cl
N
Ph
O
O
CF3
3w
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

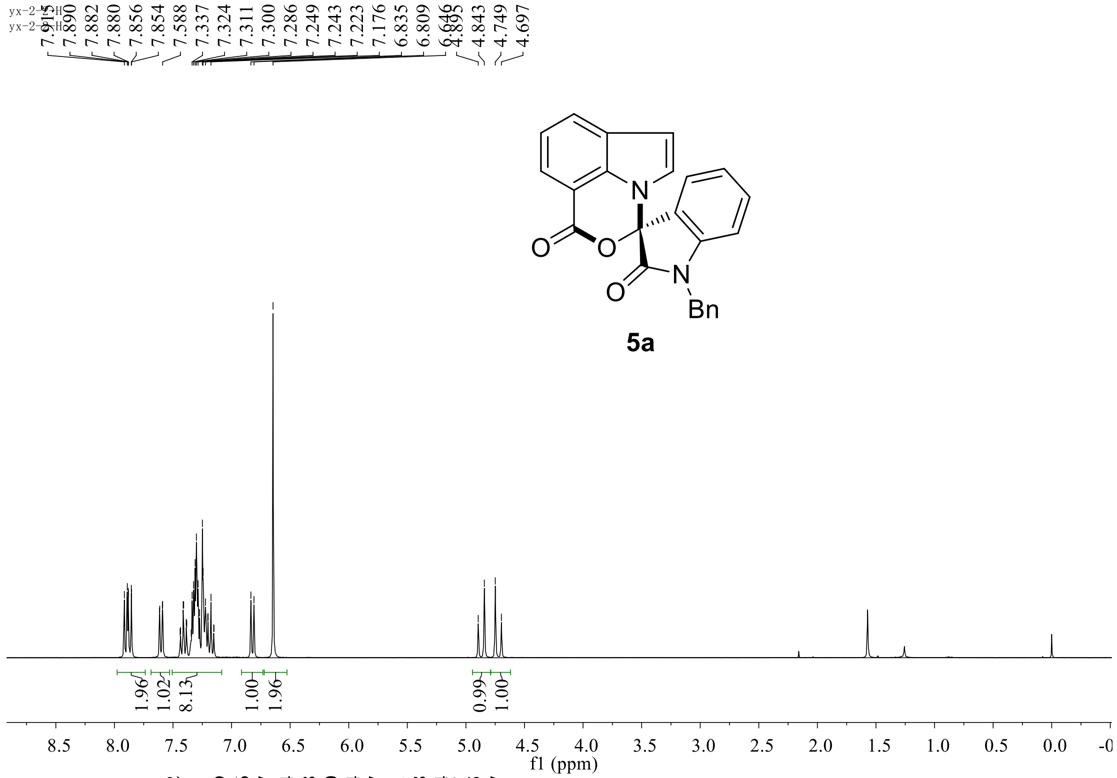

yx-1-328-F
yx-1-327-F
-77.997
Cl
N
Ph
O
O
CF3
3w
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160
f1 (ppm)



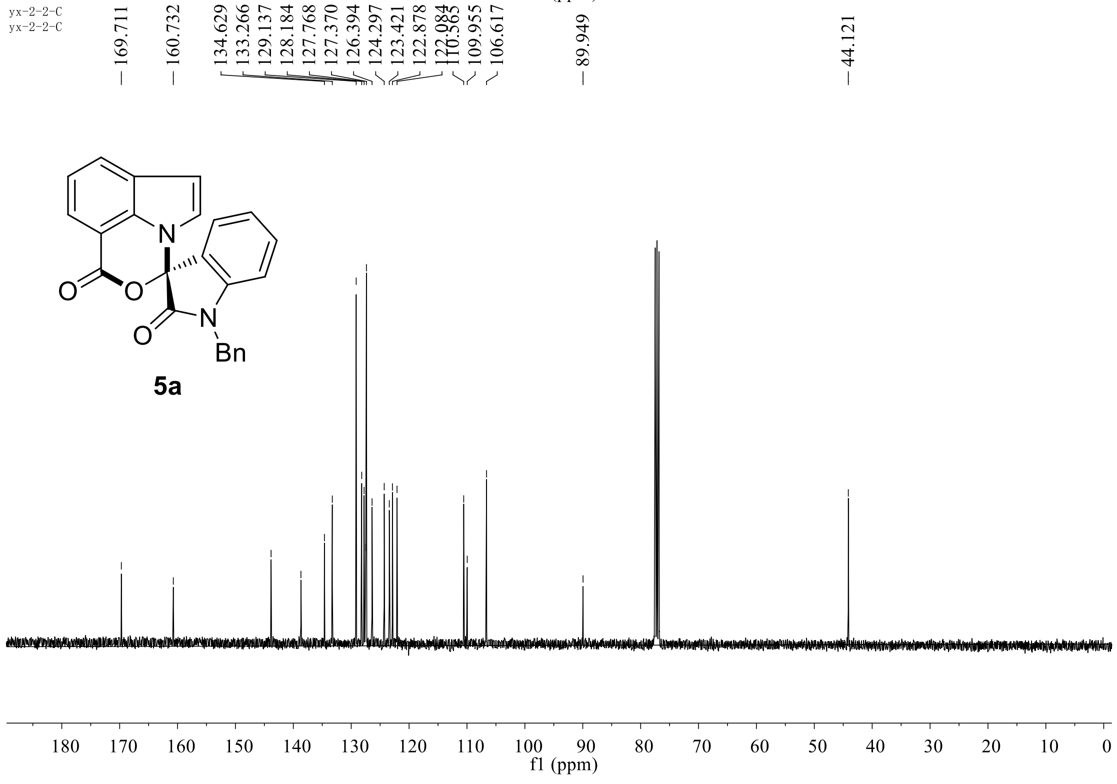
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.416	2996943	243043	50.309	51.950
2	12.260	2960145	224795	49.691	48.050
Total		5957088	467837	100.000	100.000



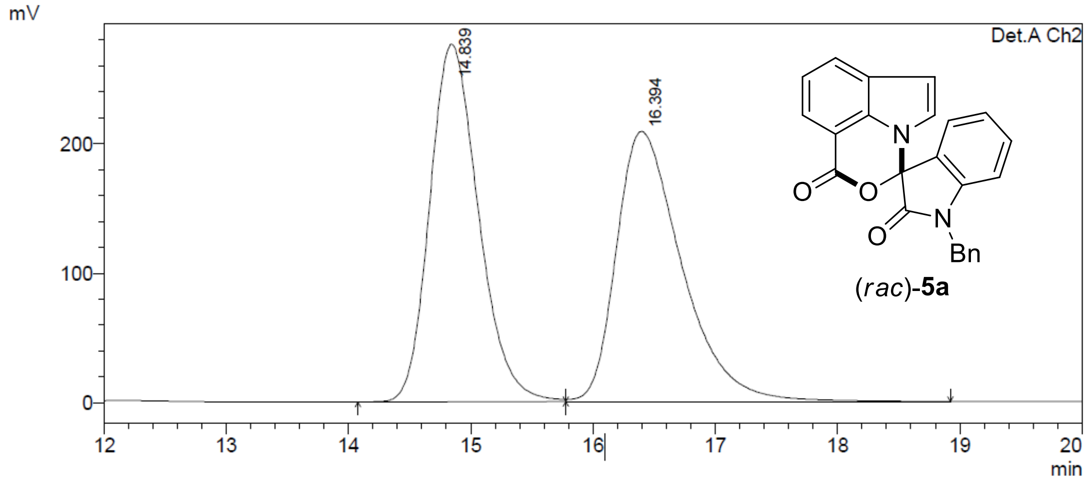
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.402	34445577	2407907	96.464	96.248
2	12.253	1262488	93872	3.536	3.752
Total		35708065	2501779	100.000	100.000


7.915
7.890
7.882
7.880
7.856
7.854
7.588
7.337
7.324
7.311
7.300
7.286
7.249
7.243
7.223
7.176
6.835
6.809
6.646
4.895
4.843
4.749
4.697
1.96
1.02
8.13
1.00
1.96
0.99
1.00
f1 (ppm)

5a

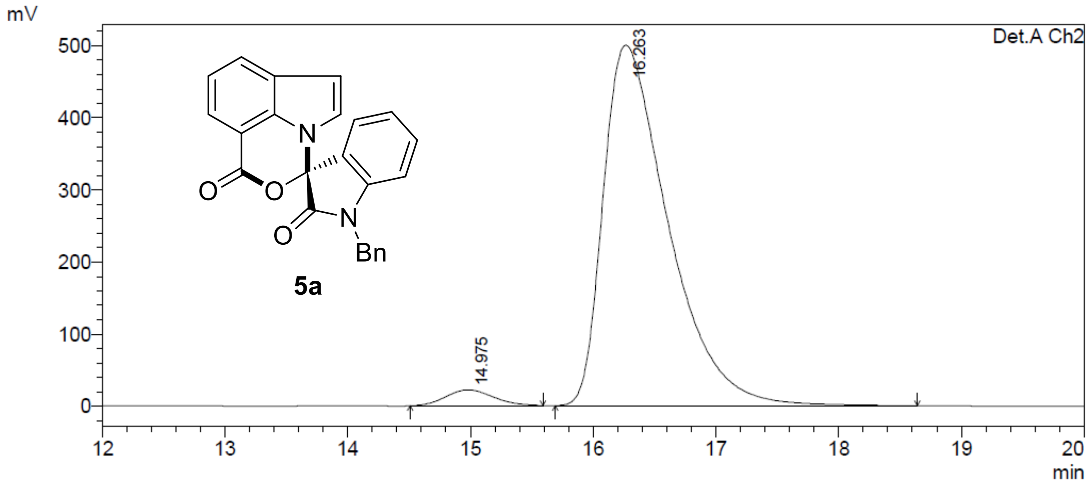

169.711
160.732
134.629
133.266
129.137
128.184
127.768
127.370
126.394
124.297
123.421
122.878
110.565
109.955
106.617
89.949
44.121
f1 (ppm)

5a



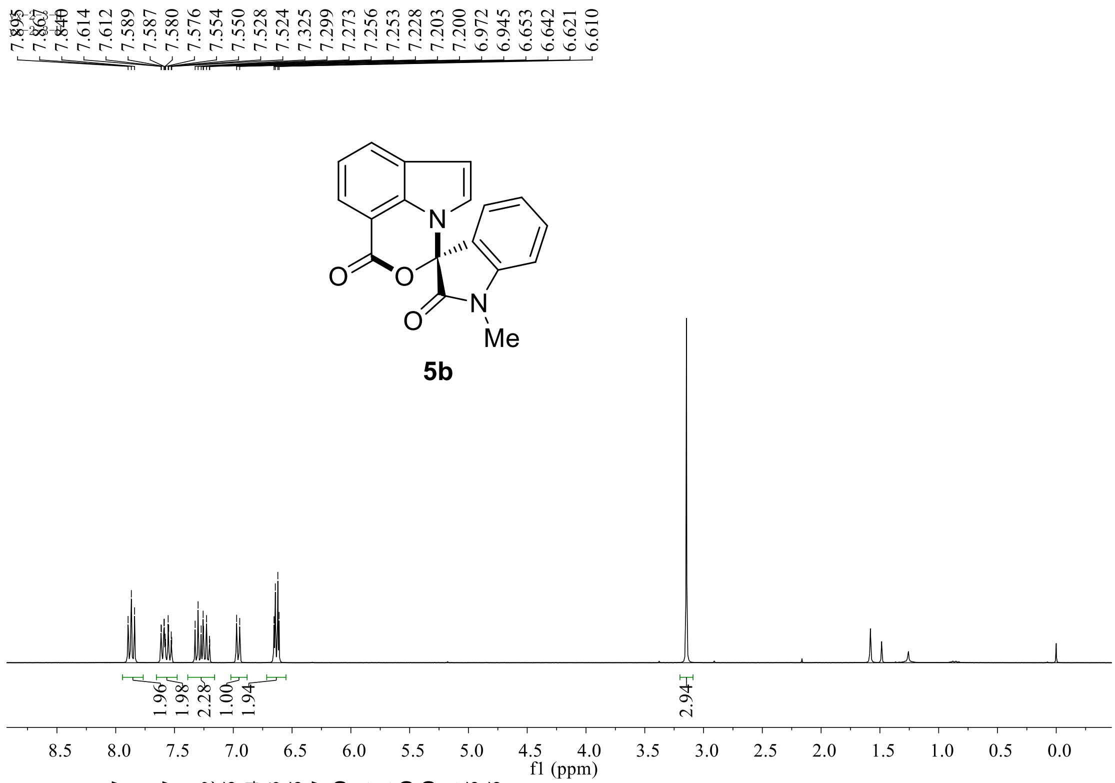
UV Detector Ch1 254nm

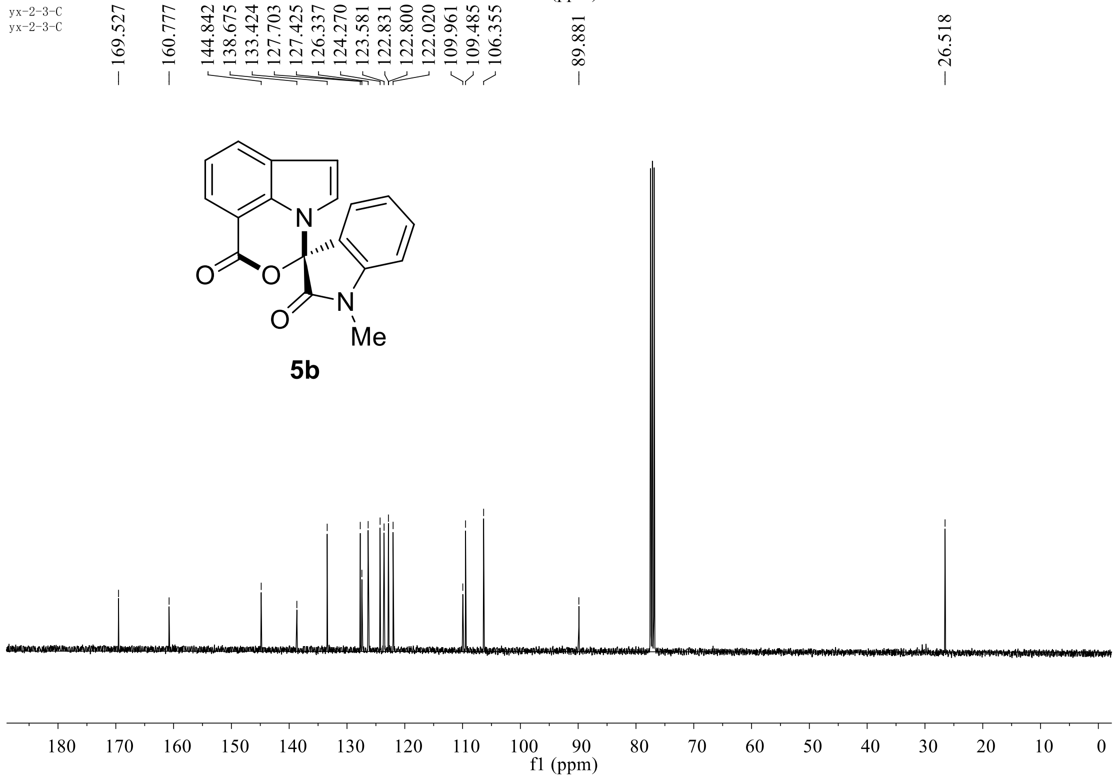
Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.838	1183203	42669	49.334	56.750
2	16.394	1215143	32518	50.666	43.250
Total		2398346	75187	100.000	100.000

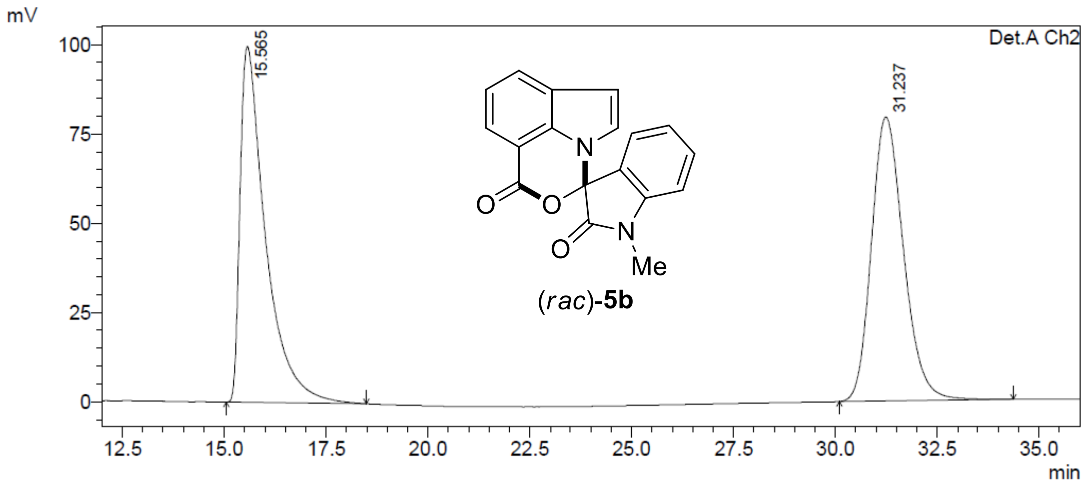


UV Detector Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.975	90518	3365	3.041	4.148
2	16.262	2885849	77764	96.959	95.852
Total		2976367	81129	100.000	100.000

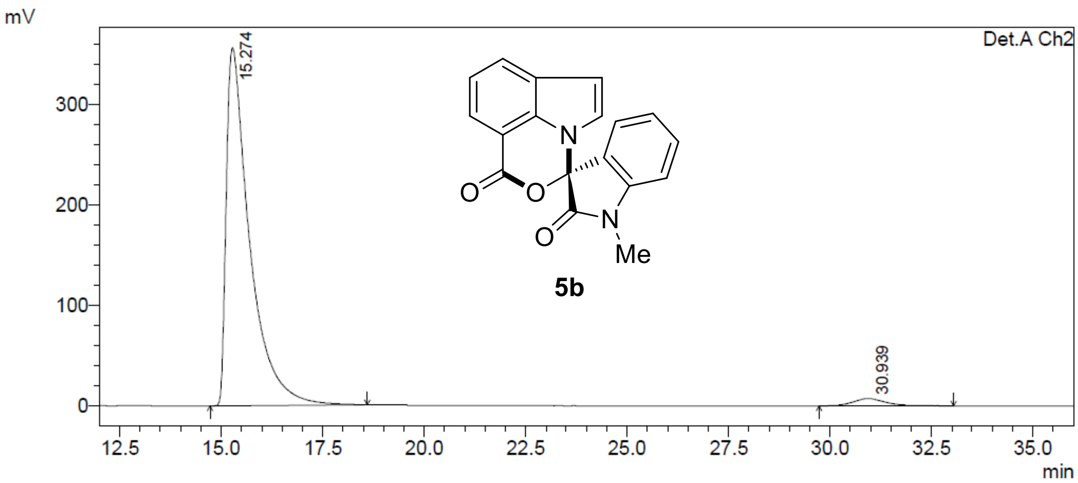

7.840
7.614
7.612
7.589
7.587
7.580
7.576
7.554
7.550
7.528
7.524
7.325
7.299
7.273
7.256
7.253
7.228
7.203
7.200
6.972
6.945
6.653
6.642
6.621
6.610
N
O
O
N
O
Me
5b
1.96
1.98
2.28
1.00
1.94
2.94
f1 (ppm)


yx-2-3-C
yx-2-3-C
169.527
160.777
144.842
138.675
133.424
127.703
127.425
126.337
124.270
123.581
122.831
122.800
122.020
109.961
109.485
106.355
89.881
26.518
N
O
O
N
O
Me
5b
f1 (ppm)



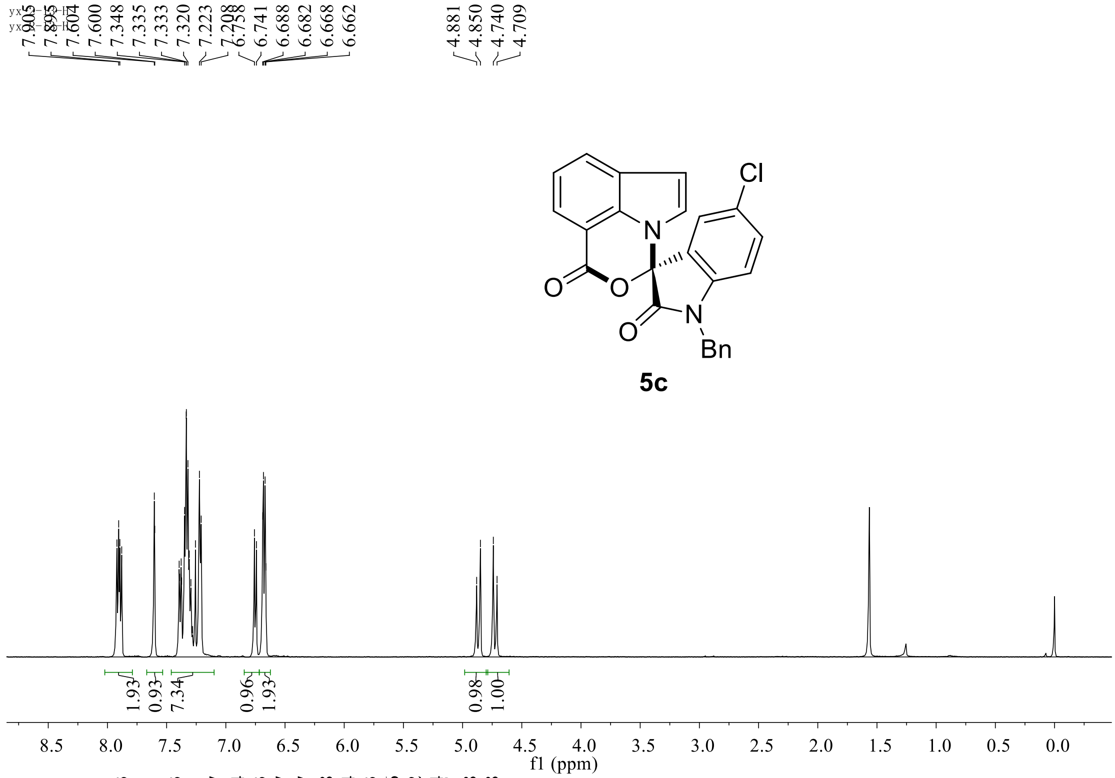
UV Detector Ch2 220nm

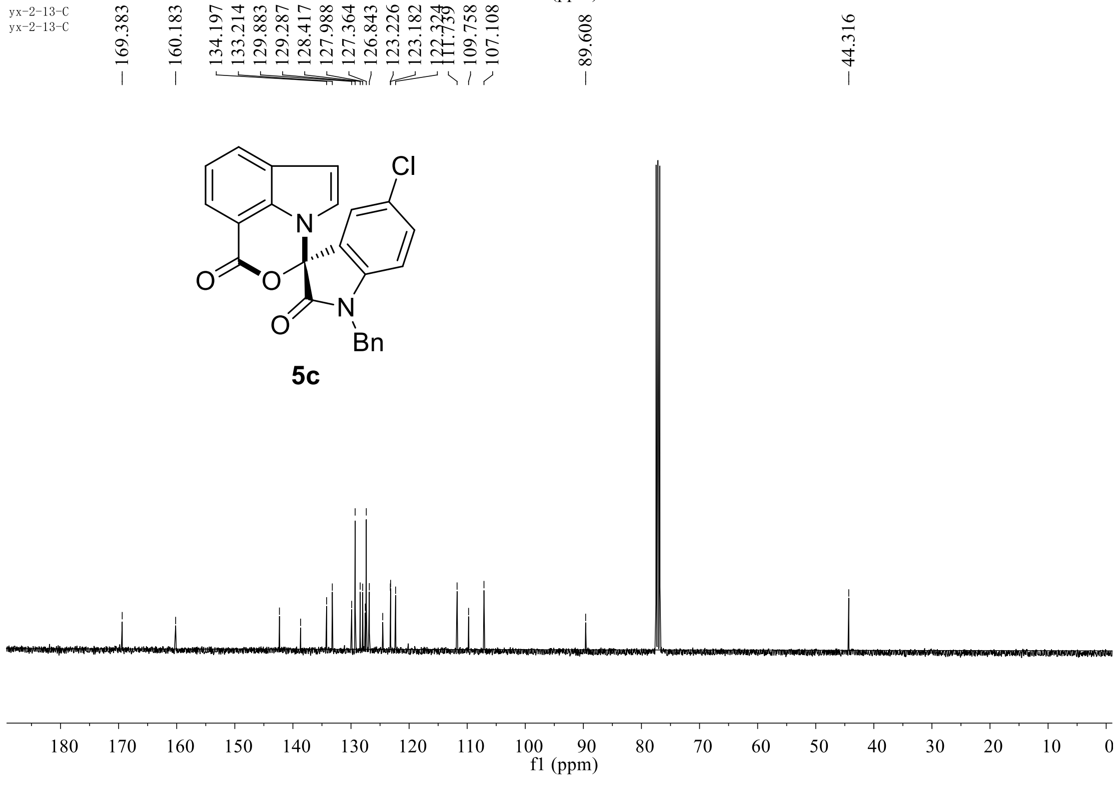
Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.565	4325314	99634	49.744	55.625
2	31.237	4369765	79482	50.256	44.375
Total		8695079	179116	100.000	100.000

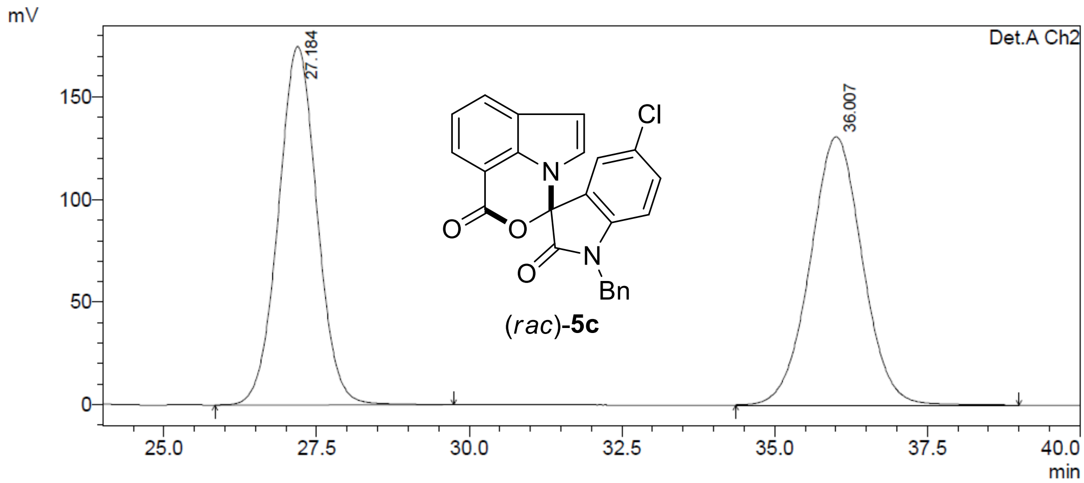


UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.274	14240477	356068	97.417	98.086
2	30.939	377533	6948	2.583	1.914
Total		14618010	363016	100.000	100.000

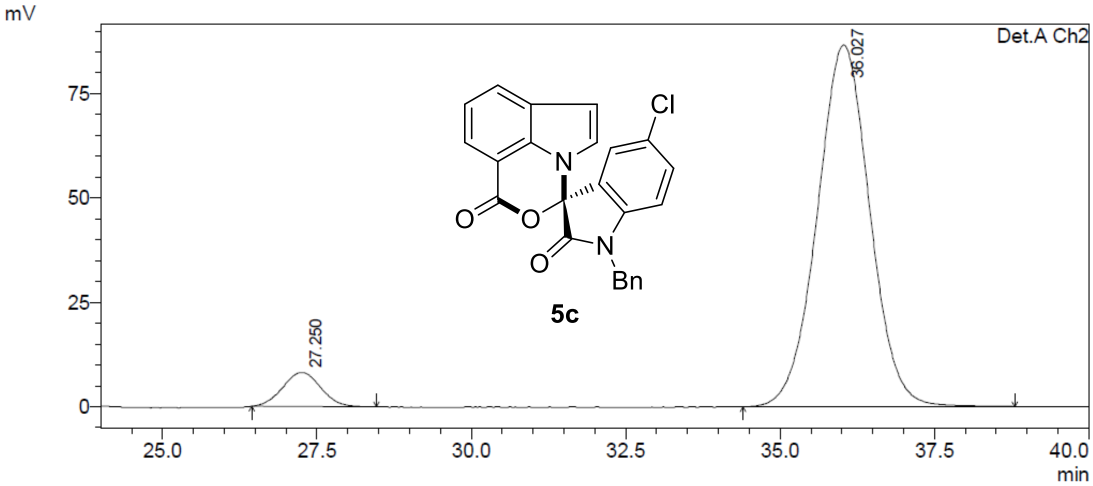

7.905
7.895
7.604
7.600
7.348
7.335
7.333
7.320
7.223
7.208
6.758
6.741
6.688
6.682
6.668
6.662
4.881
4.850
4.740
4.709
Cl
N
O
O
O
N
Bn
5c
1.93
0.93
7.34
0.96
1.93
0.98
1.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


yx-2-13-C
yx-2-13-C
169.383
160.183
134.197
133.214
129.883
129.287
128.417
127.988
127.364
126.843
123.226
123.182
122.324
111.739
109.758
107.108
89.608
44.316
Cl
N
O
O
O
N
Bn
5c
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



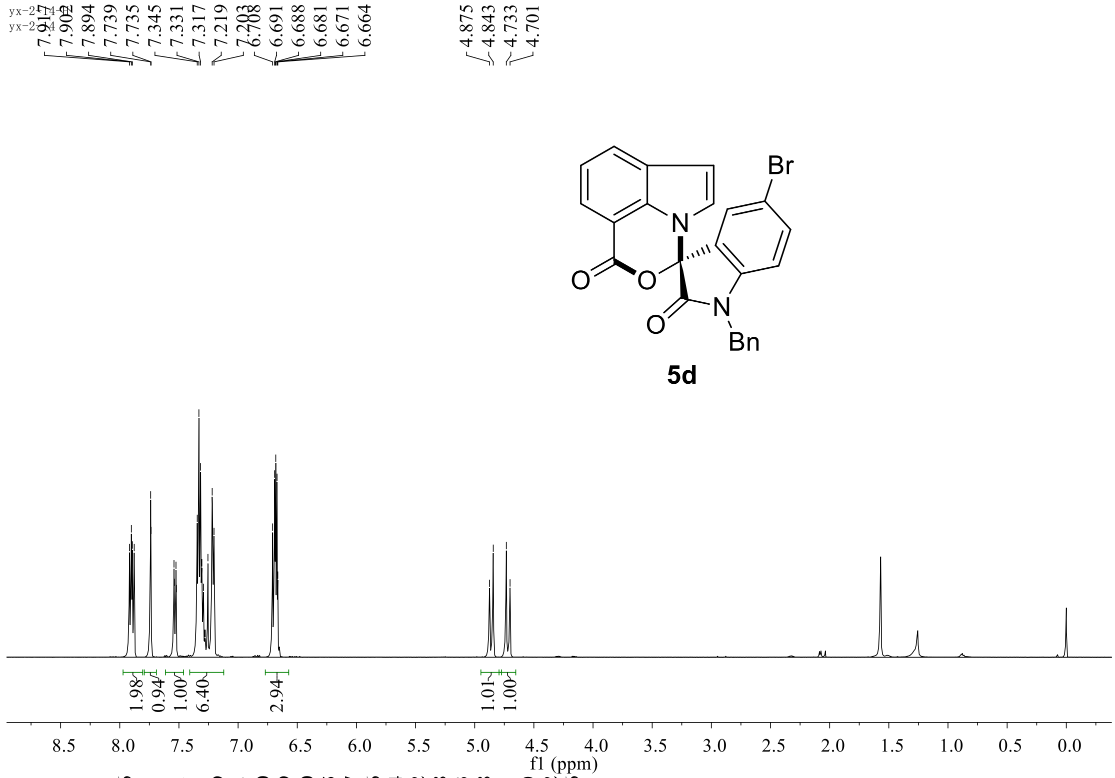
UV Detector Ch2 220nm

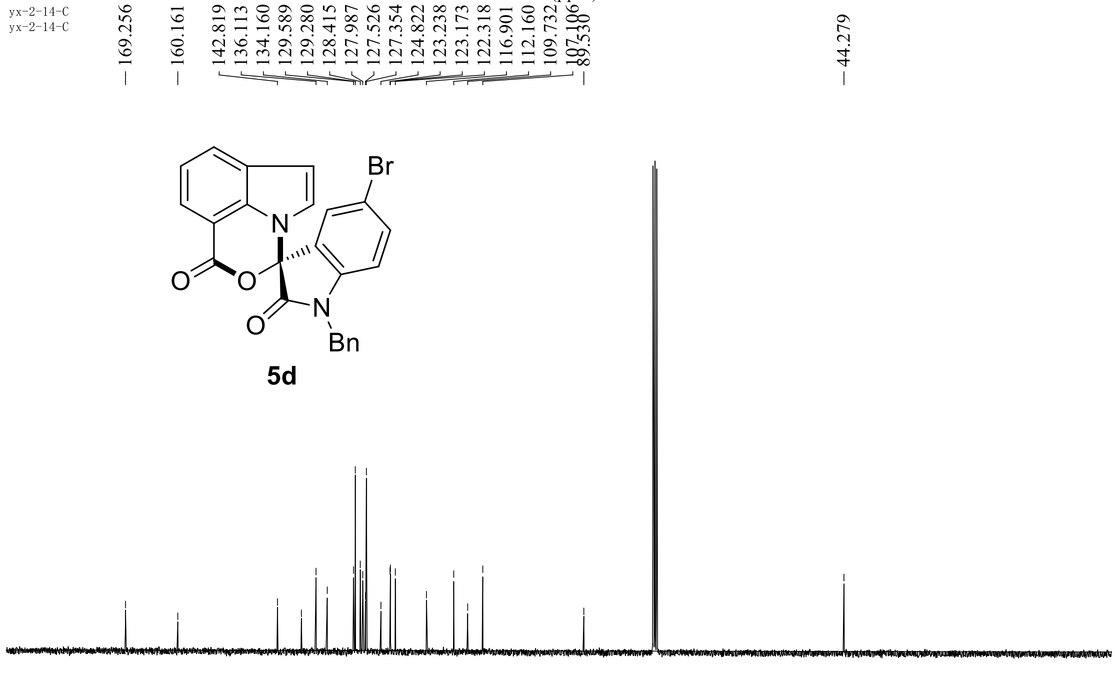
Peak#	Ret. Time	Area	Height	Area %	Height %
1	27.184	7717588	174788	49.791	57.205
2	36.007	7782470	130760	50.209	42.795
Total		15500058	305548	100.000	100.000

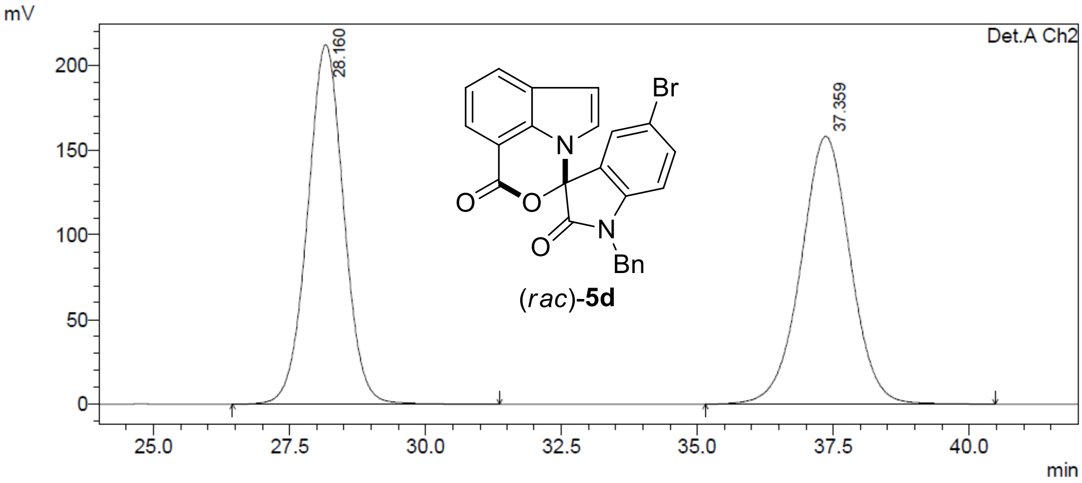


UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	27.250	352117	8196	6.415	8.643
2	36.027	5136643	86636	93.585	91.357
Total		5488761	94833	100.000	100.000

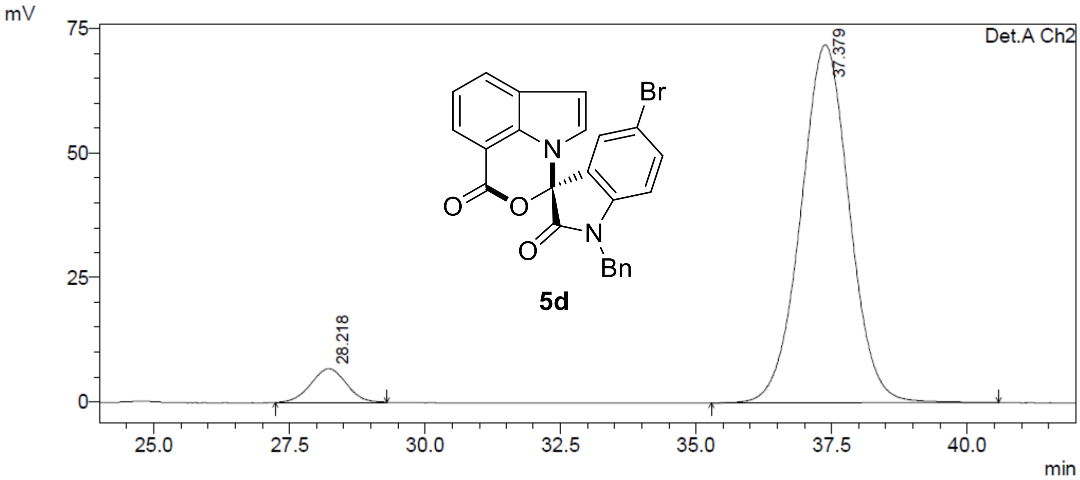

yx-2-14-H
7.917
7.902
7.894
7.739
7.735
7.345
7.331
7.317
7.219
7.203
6.708
6.691
6.688
6.681
6.671
6.664
4.875
4.843
4.733
4.701
Br
N
O
O
O
N
Bn
5d
1.98
0.94
1.00
6.40
2.94
1.01
1.00
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


yx-2-14-C
169.256
160.161
142.819
136.113
134.160
129.589
129.280
128.415
127.987
127.526
127.354
124.822
123.238
123.173
122.318
116.901
112.160
109.732
107.106
89.530
44.279
Br
N
O
O
O
N
Bn
5d
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



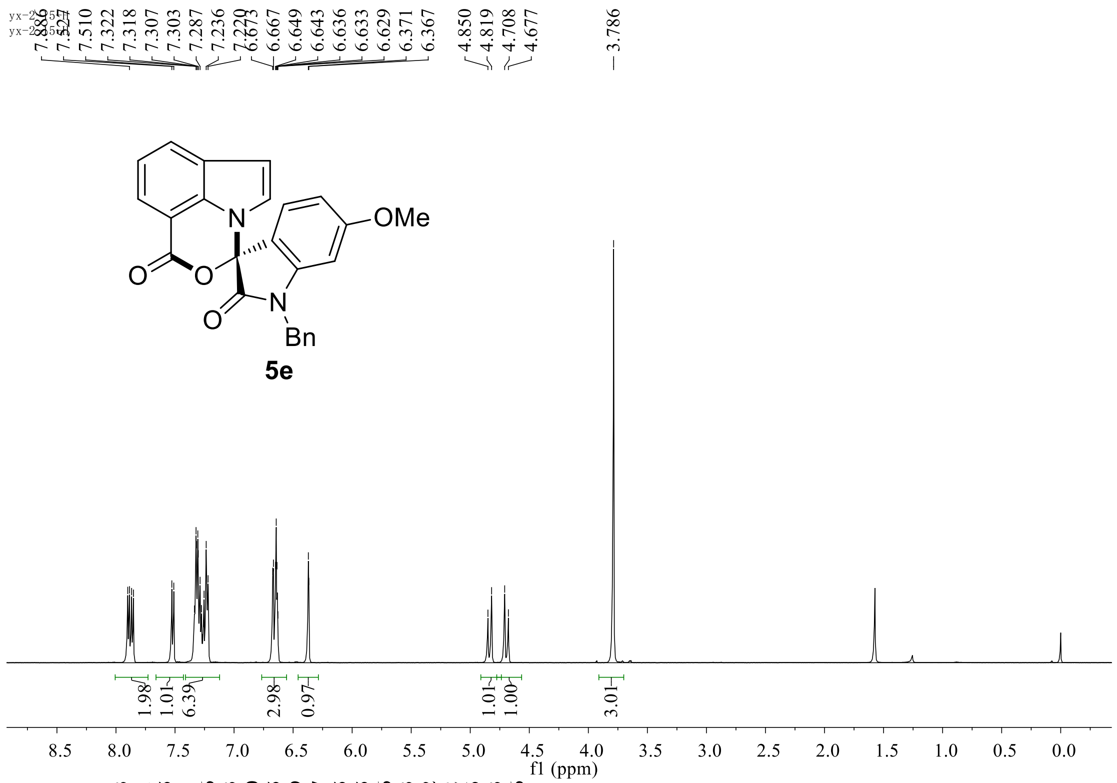
UV Detector Ch2 220nm

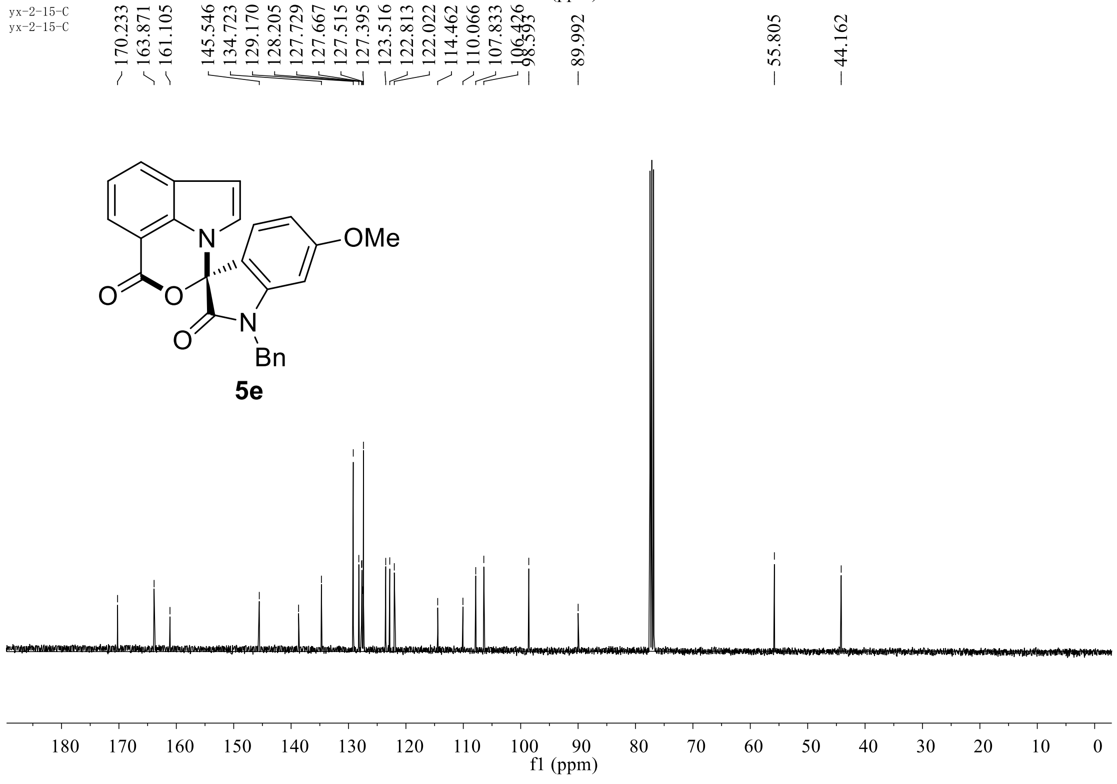
Peak#	Ret. Time	Area	Height	Area %	Height %
1	28.160	9849327	212238	49.610	57.315
2	37.359	10004316	158062	50.390	42.685
Total		19853643	370300	100.000	100.000

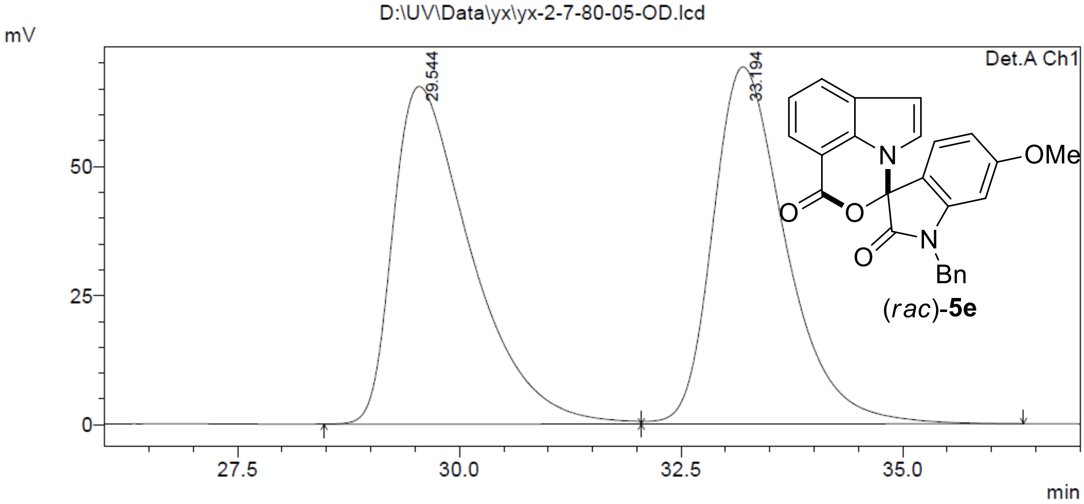


UV Detector Ch2 220nm

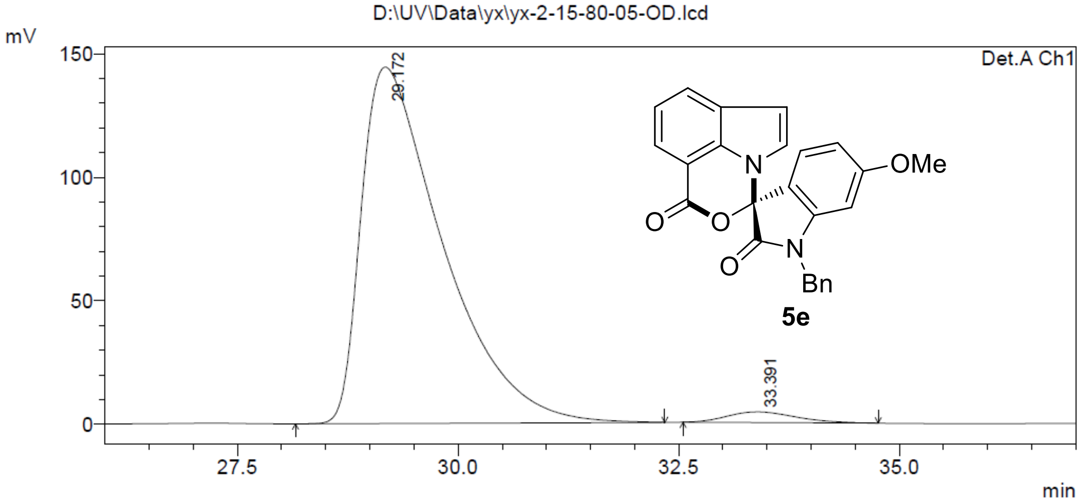
Peak#	Ret. Time	Area	Height	Area %	Height %
1	28.218	304768	6741	6.366	8.578
2	37.379	4482579	71835	93.634	91.422
Total		4787347	78575	100.000	100.000


7.510
7.322
7.318
7.307
7.303
7.287
7.236
7.220
6.673
6.667
6.649
6.643
6.636
6.633
6.629
6.371
6.367
4.850
4.819
4.708
4.677
3.786
OMe
N
O
Bn
5e
1.98
1.01
6.39
2.98
0.97
1.01
1.00
3.01
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)


yx-2-15-C
yx-2-15-C
170.233
163.871
161.105
145.546
134.723
129.170
128.205
127.729
127.667
127.515
127.395
123.516
122.813
122.022
114.462
110.066
107.833
106.426
98.593
89.992
55.805
44.162
OMe
N
O
Bn
5e
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

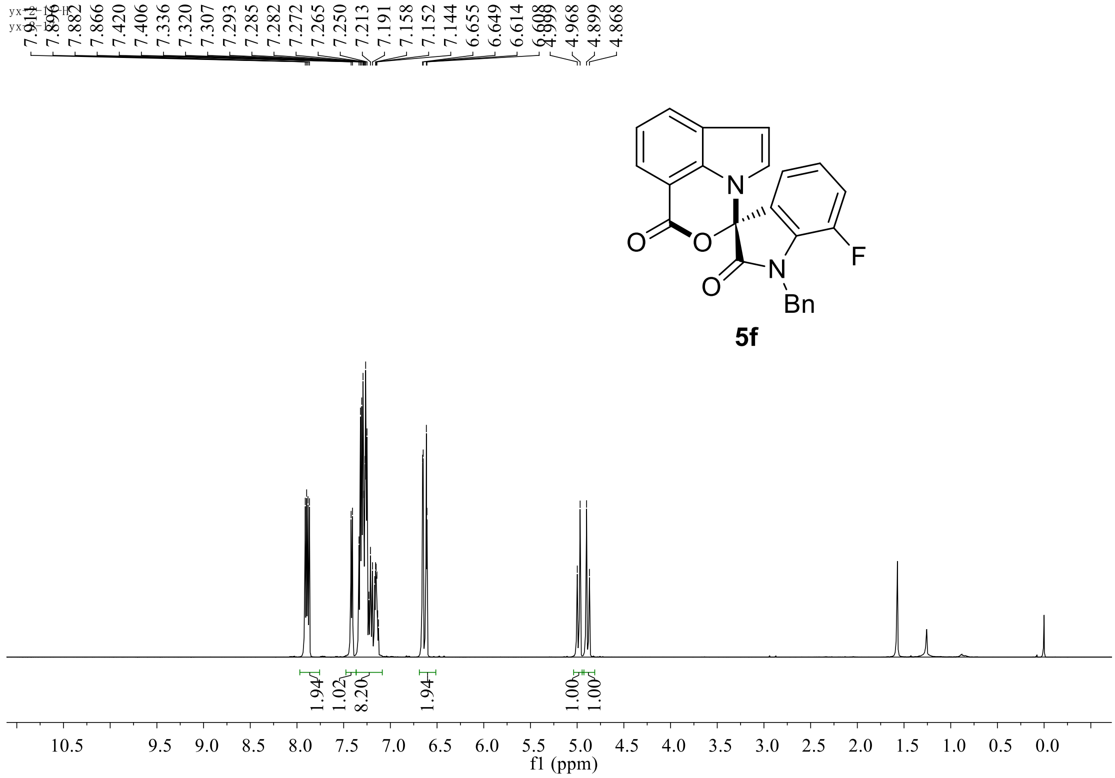


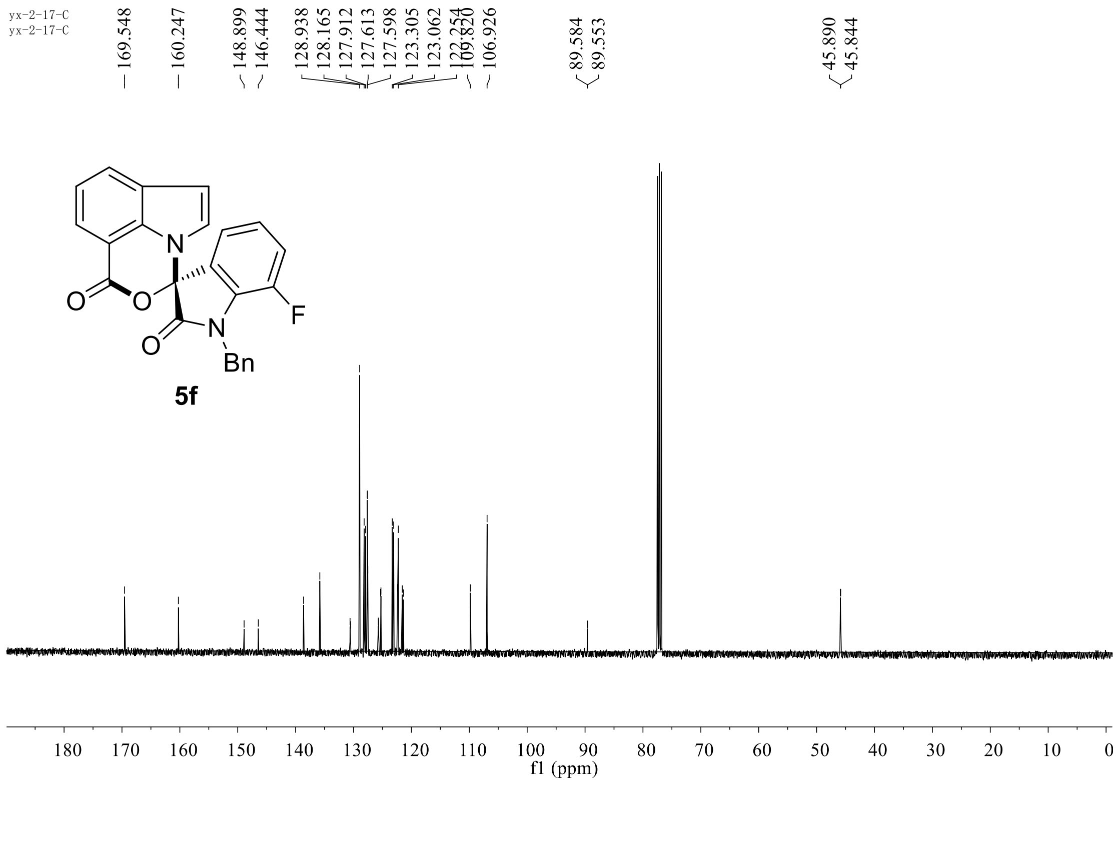
Peak#	Ret. Time	Area	Height	Area %	Height %
1	29.544	4023646	65362	50.372	48.608
2	33.194	3964160	69107	49.628	51.392
Total		7987806	134468	100.000	100.000

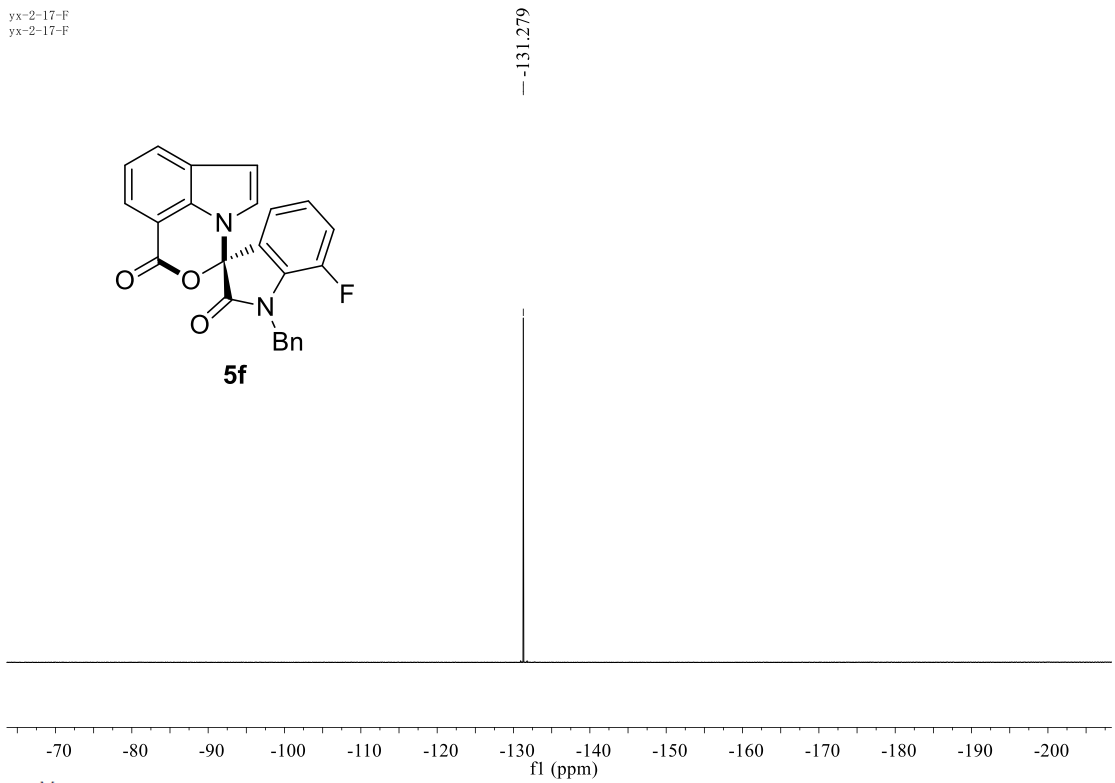


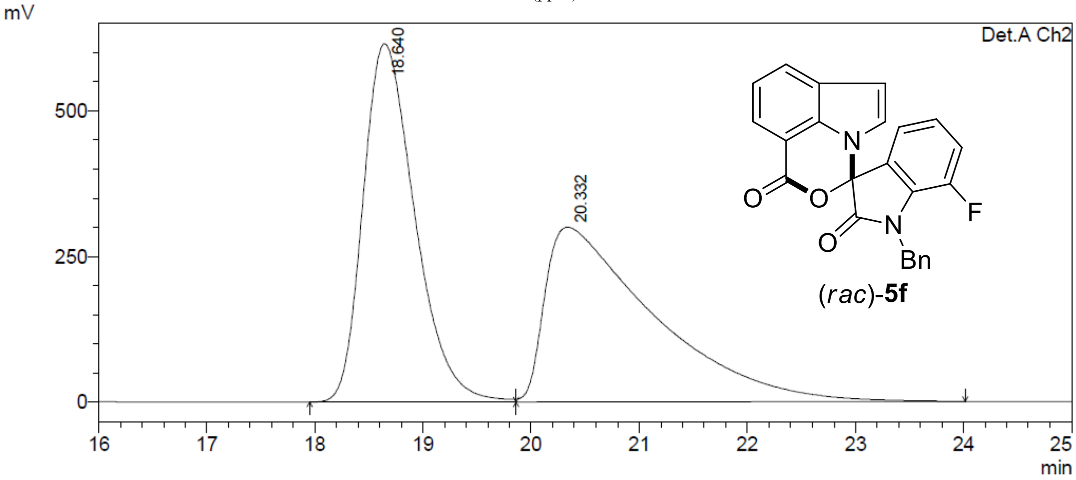
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	29.172	9255285	144290	97.526	97.063
2	33.391	234778	4366	2.474	2.937
Total		9490063	148656	100.000	100.000


7.896
7.882
7.866
7.420
7.406
7.336
7.320
7.307
7.293
7.285
7.282
7.272
7.265
7.250
7.213
7.191
7.158
7.152
7.144
6.655
6.649
6.614
4.968
4.899
4.868
N
O
O
O
N
F
Bn
5f
1.94
1.02
8.20
1.94
1.00
1.00
10.5
9.5
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)

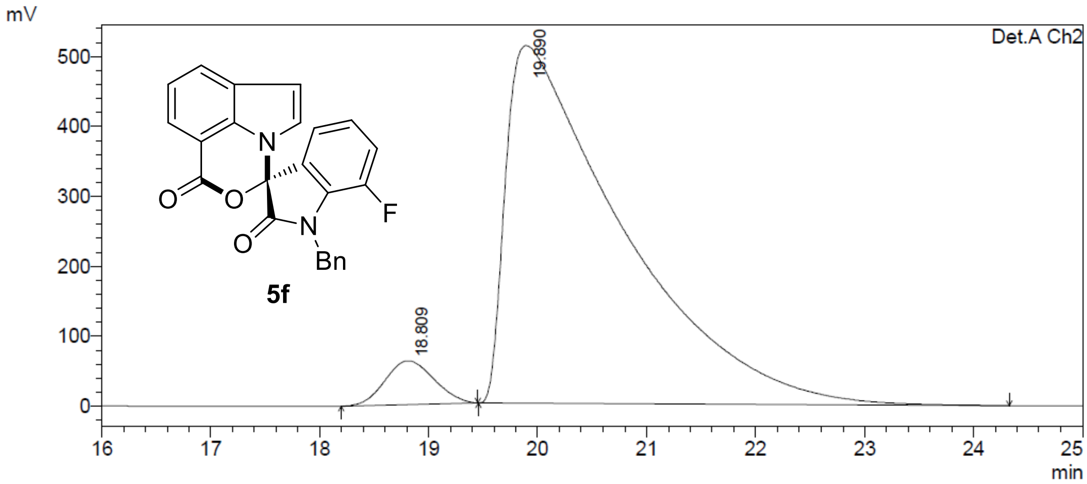

yx-2-17-C
yx-2-17-C
169.548
160.247
148.899
146.444
128.938
128.165
127.912
127.613
127.598
123.305
123.062
106.926
89.584
89.553
45.890
45.844
N
O
O
O
N
F
Bn
5f
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)





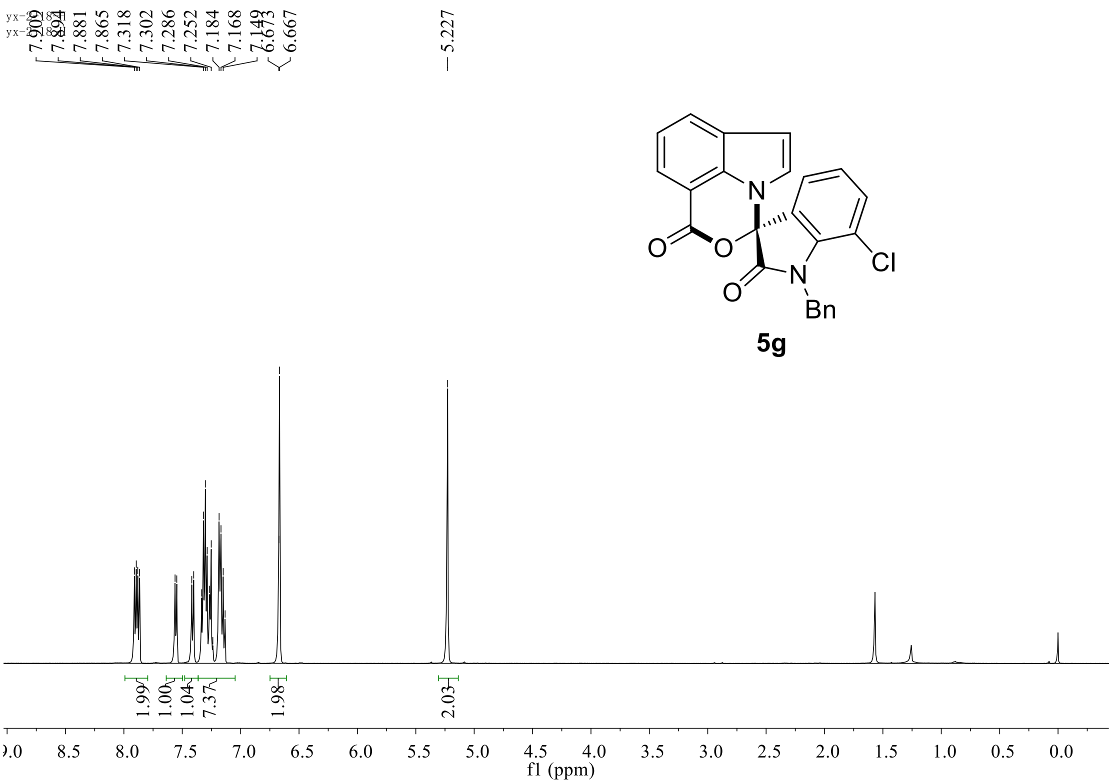
UV Detector Ch2 220nm

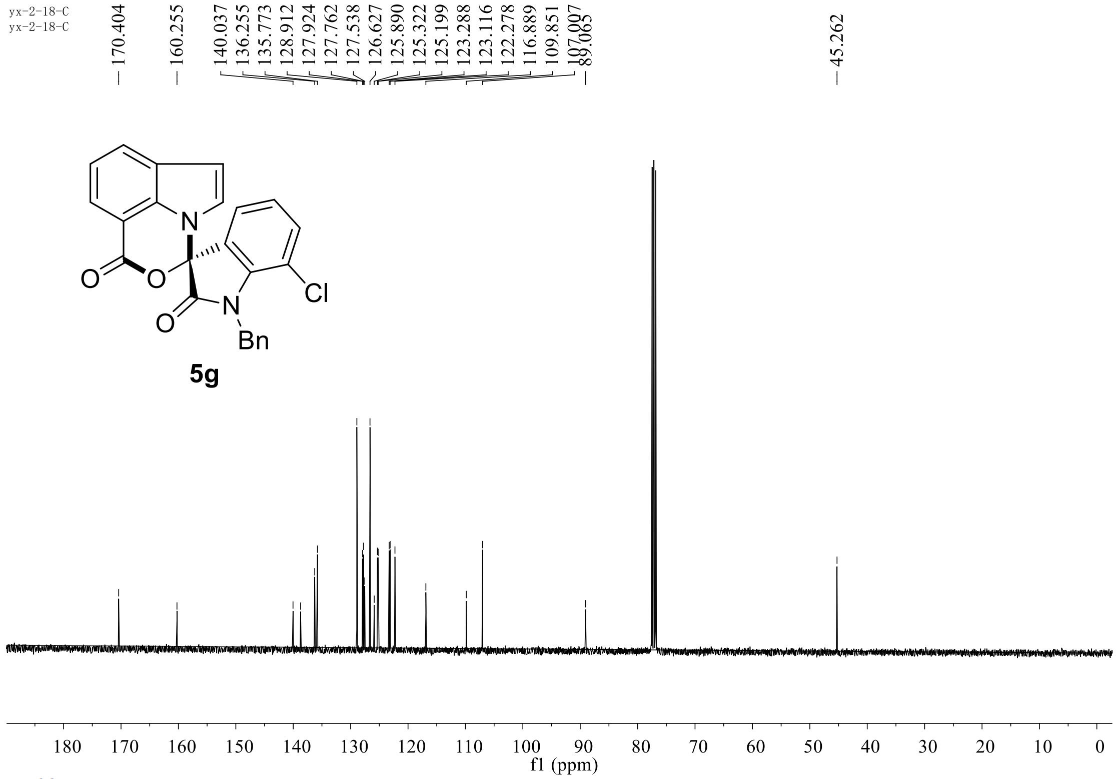
Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.640	20452345	615176	49.396	67.230
2	20.332	20952815	299857	50.604	32.770
Total		41405159	915032	100.000	100.000

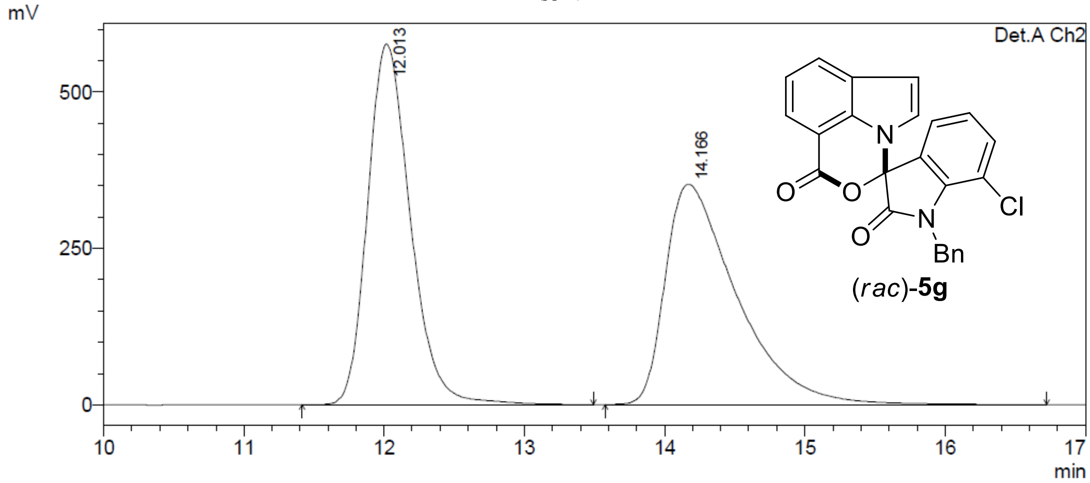


UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.809	1966022	62821	4.899	10.934
2	19.890	38164840	511700	95.101	89.066
Total		40130862	574521	100.000	100.000

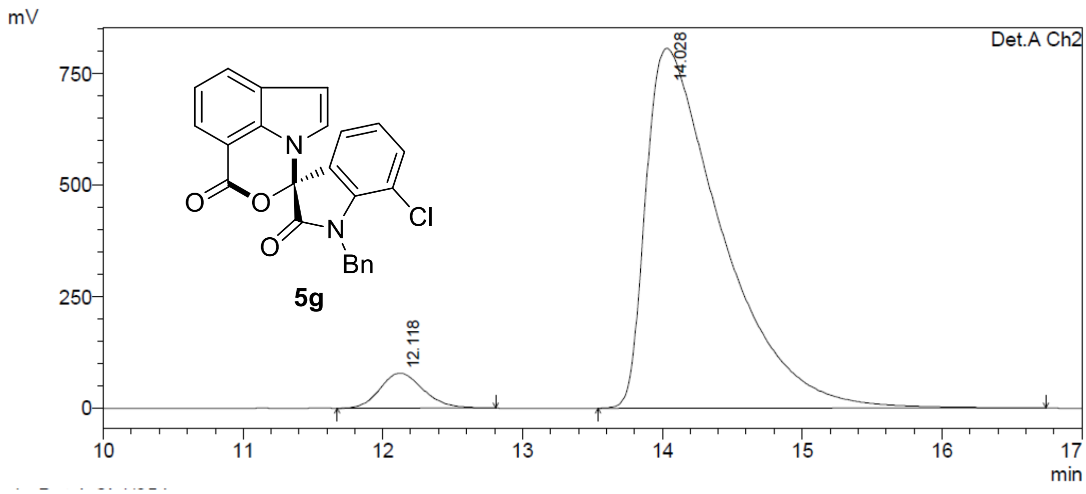






UV Detector Ch2 220nm

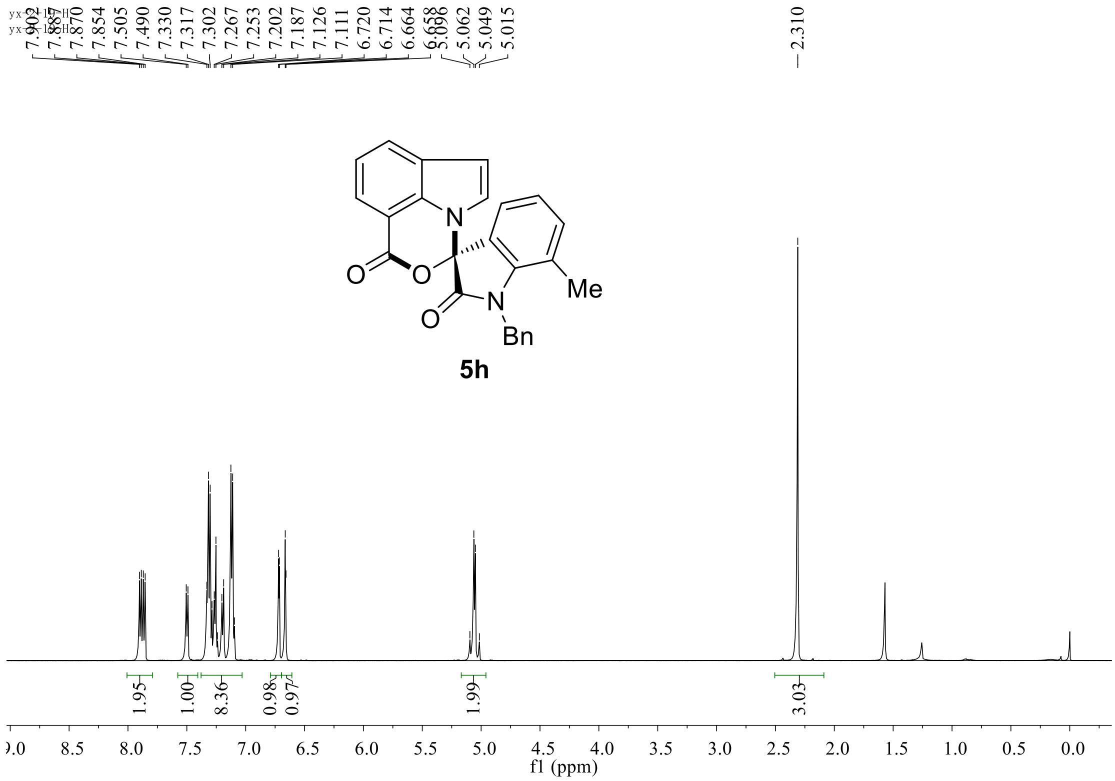
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.013	12189057	575317	49.450	62.082
2	14.166	12460185	351390	50.550	37.918
Total		24649242	926708	100.000	100.000

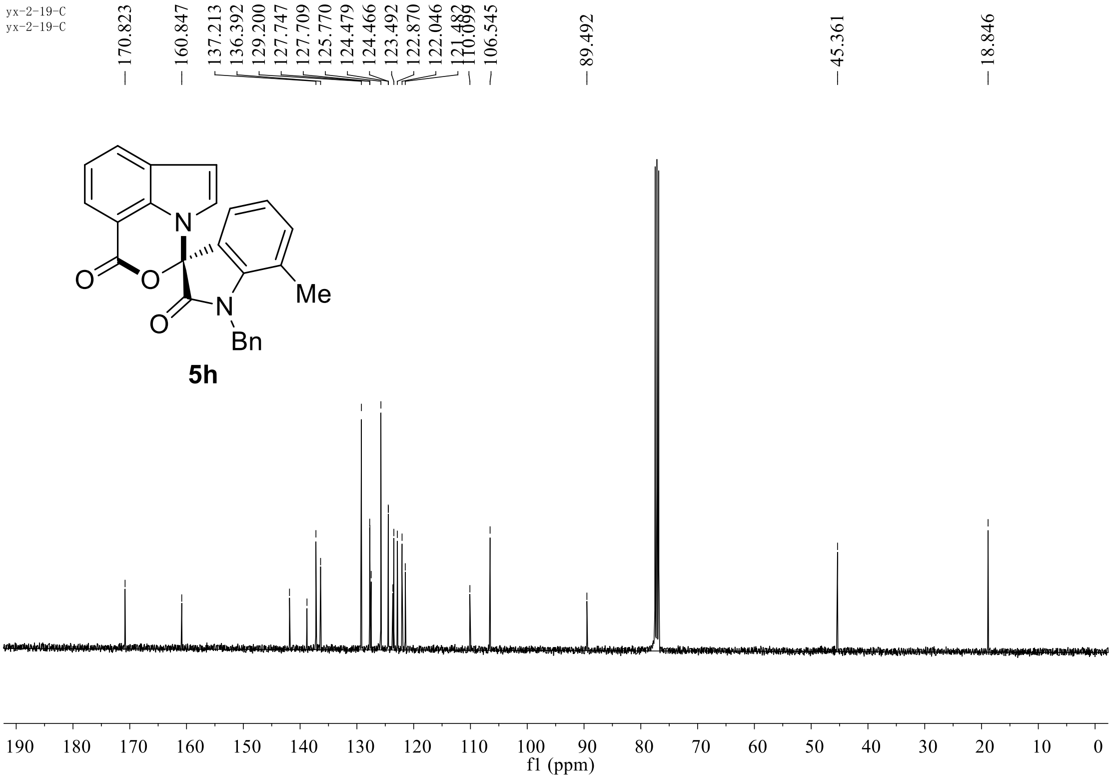


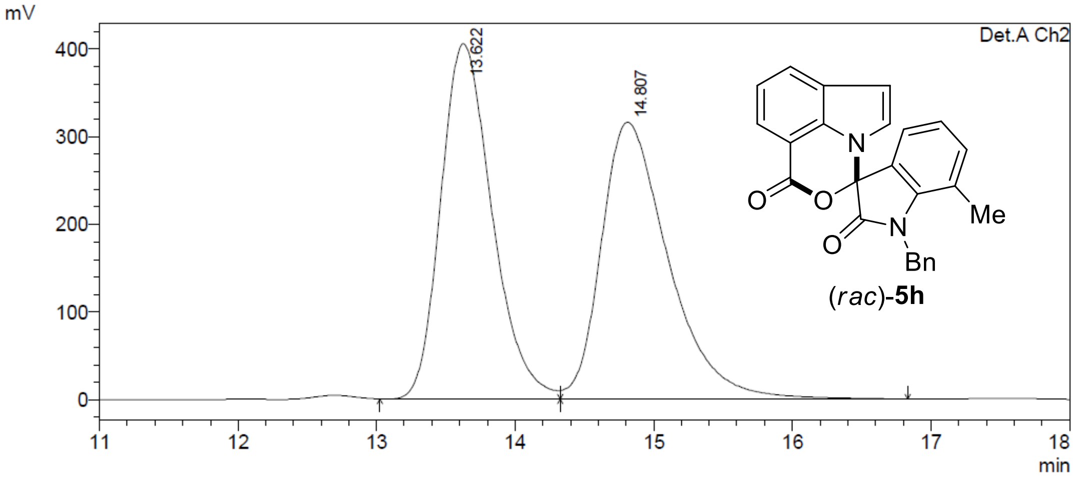
5g

UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.118	1672536	78064	5.203	8.835
2	14.028	30473422	805506	94.797	91.165
Total		32145958	883570	100.000	100.000

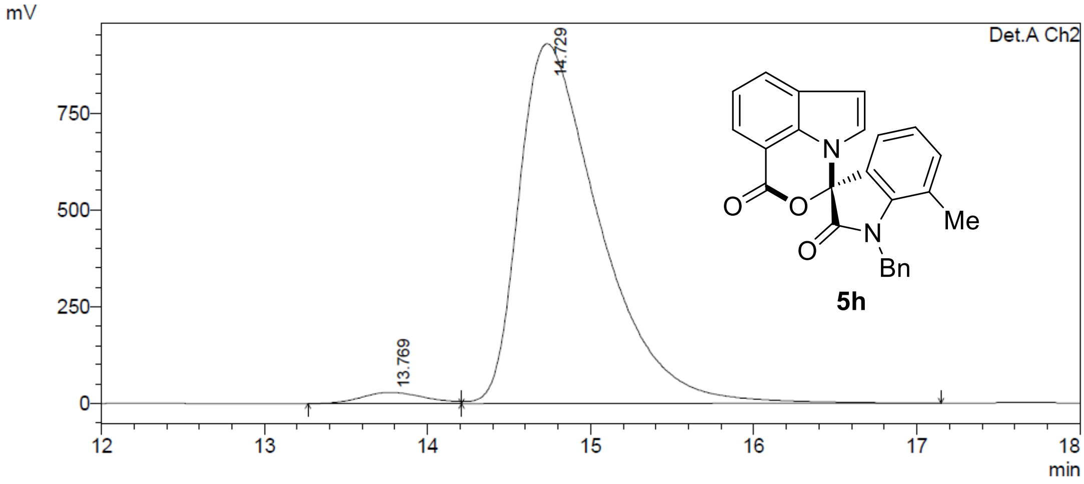






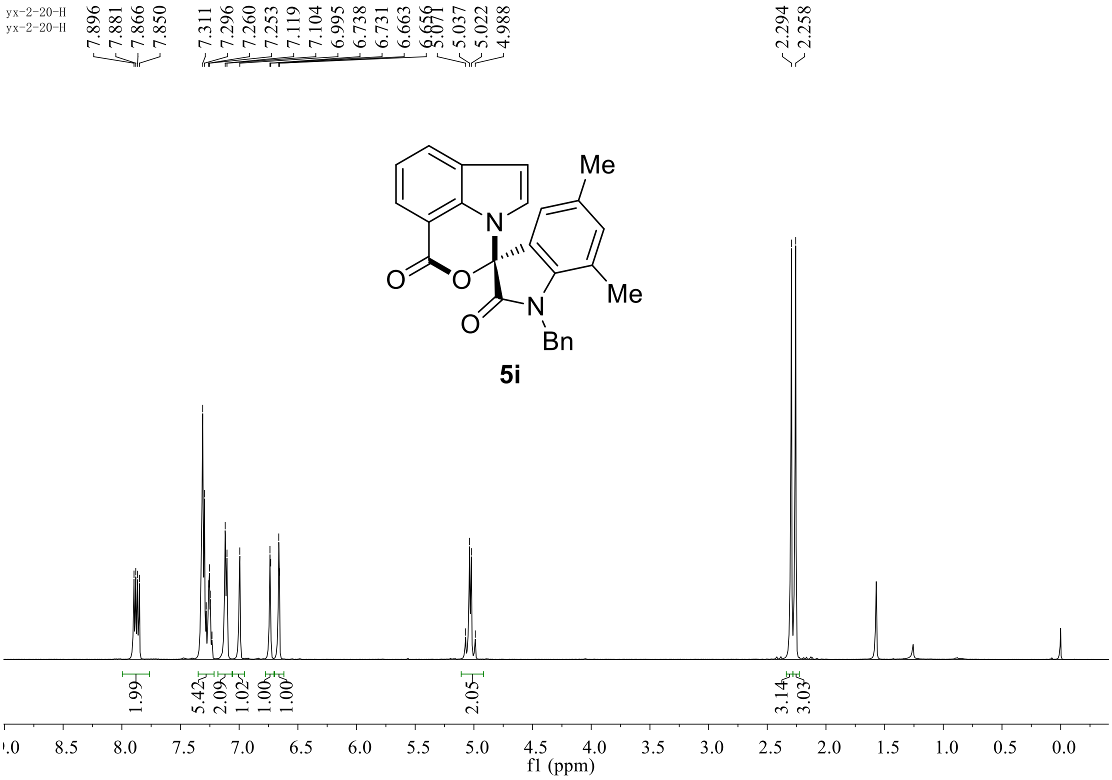
UV Detector Ch2 220nm

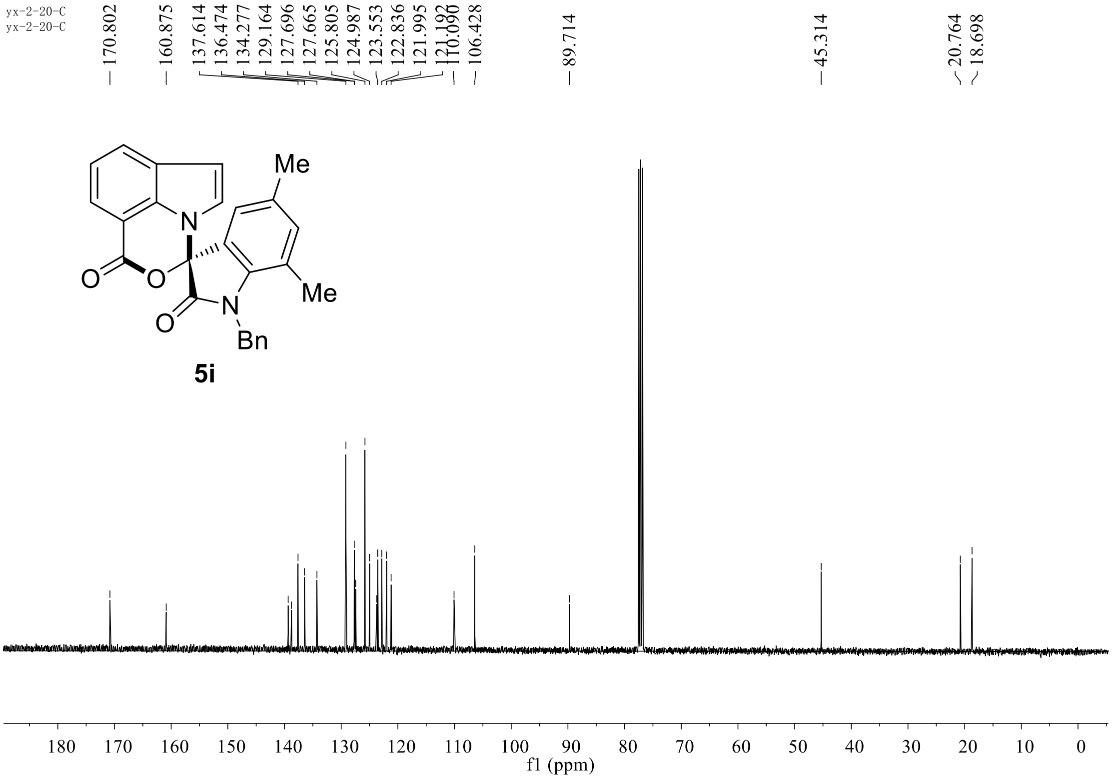
Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.622	10447597	405242	49.525	56.208
2	14.807	10648094	315730	50.475	43.792
Total		21095691	720973	100.000	100.000

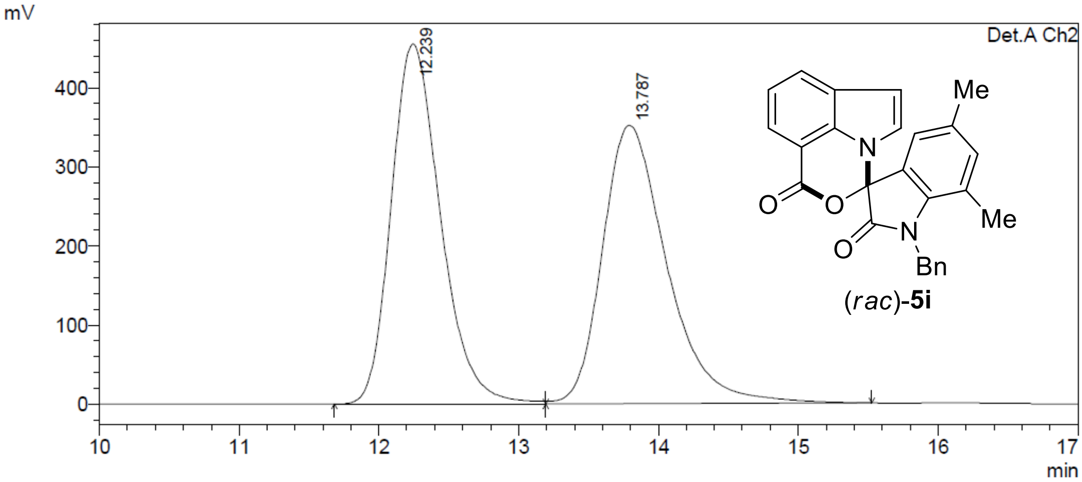


UV Detector Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.769	771474	28957	2.348	3.027
2	14.729	32085895	927709	97.652	96.973
Total		32857369	956666	100.000	100.000

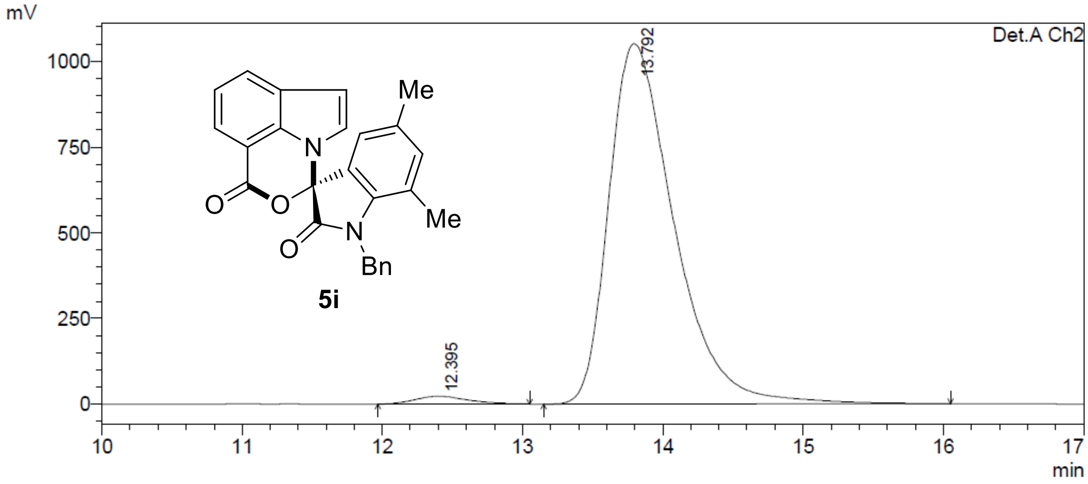






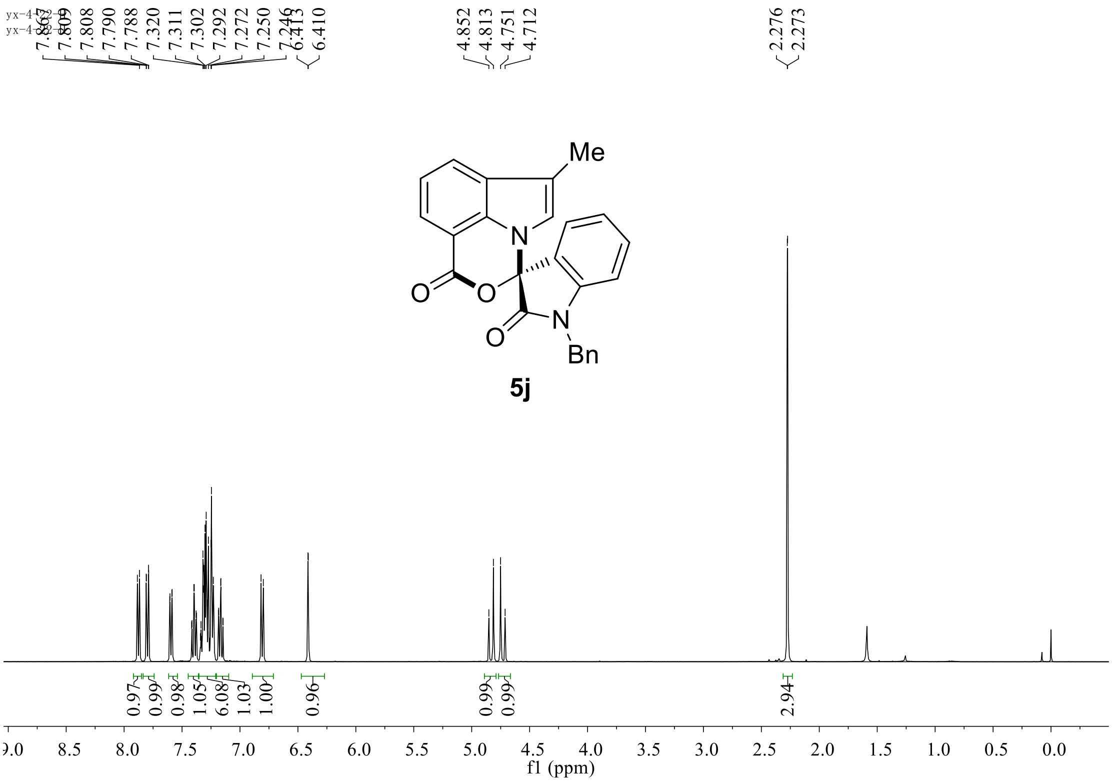
UV Detector Ch2 220nm

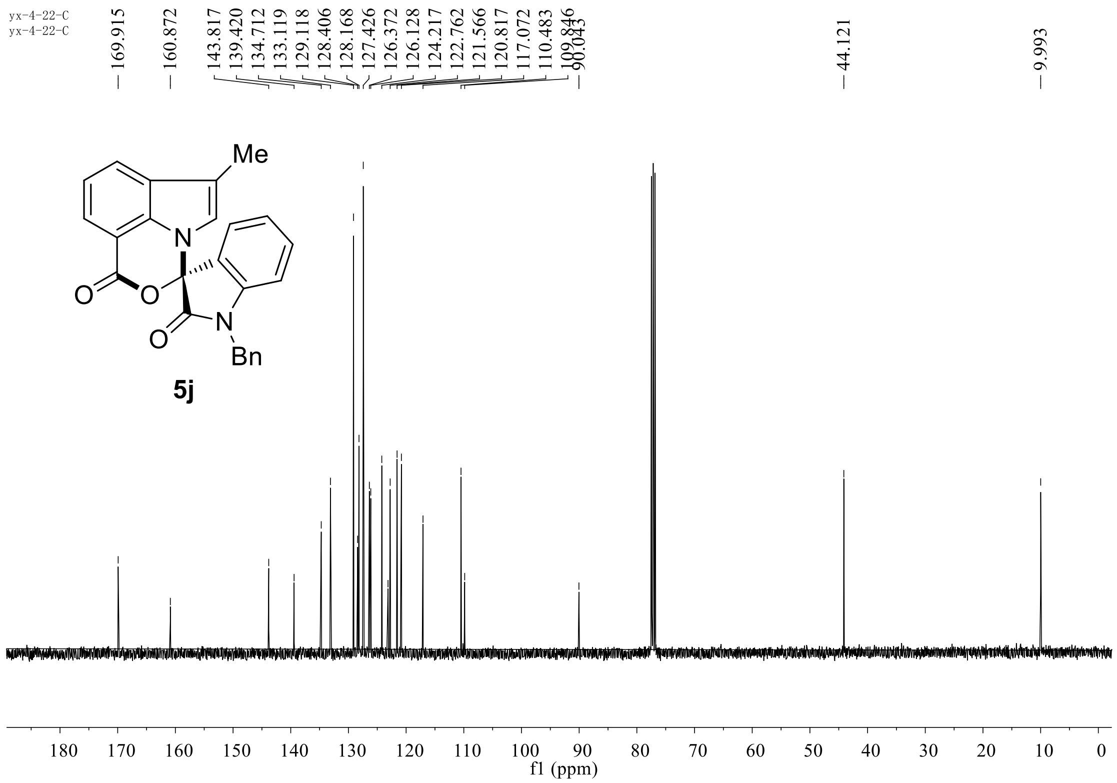
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.239	11162109	455006	49.779	56.404
2	13.787	11261429	351680	50.221	43.596
Total		22423538	806686	100.000	100.000

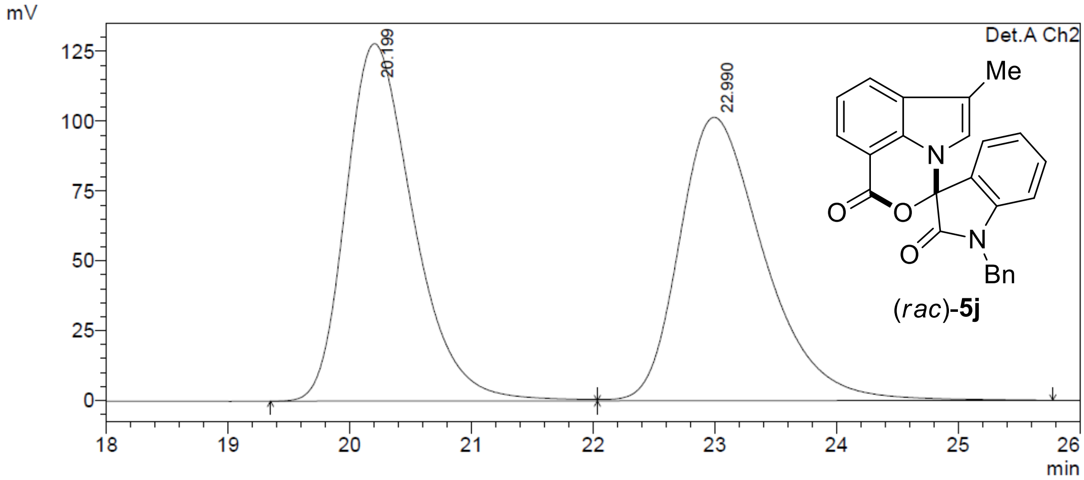


UV Detector Ch2 220nm

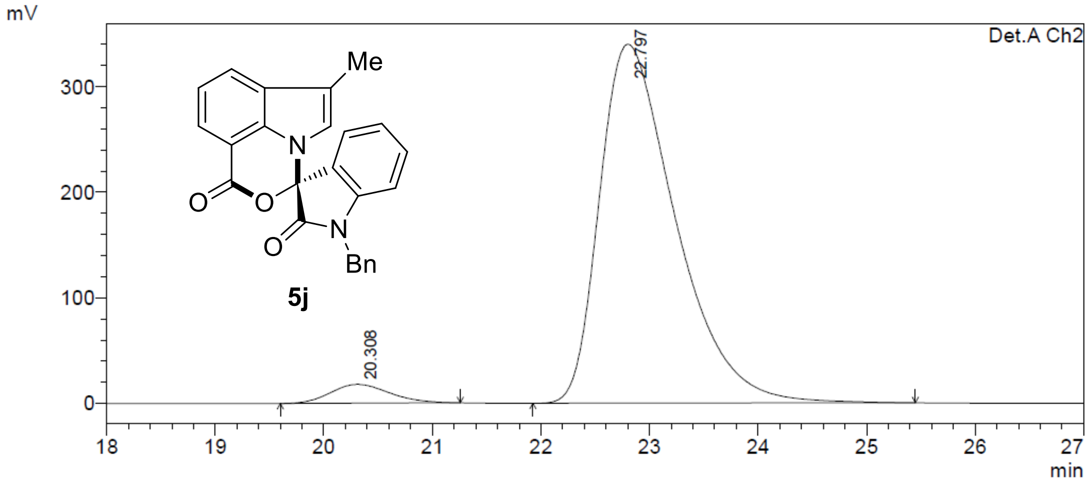
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.395	589940	22490	1.709	2.097
2	13.792	33934860	1049874	98.291	97.903
Total		34524799	1072363	100.000	100.000



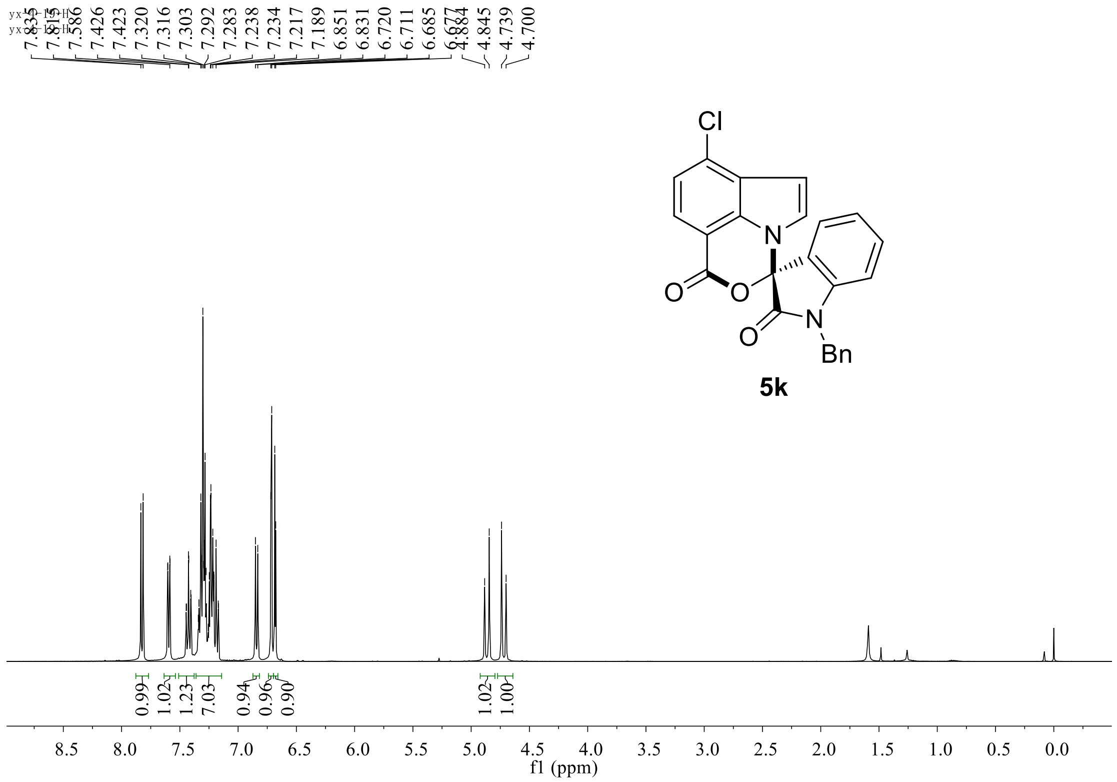


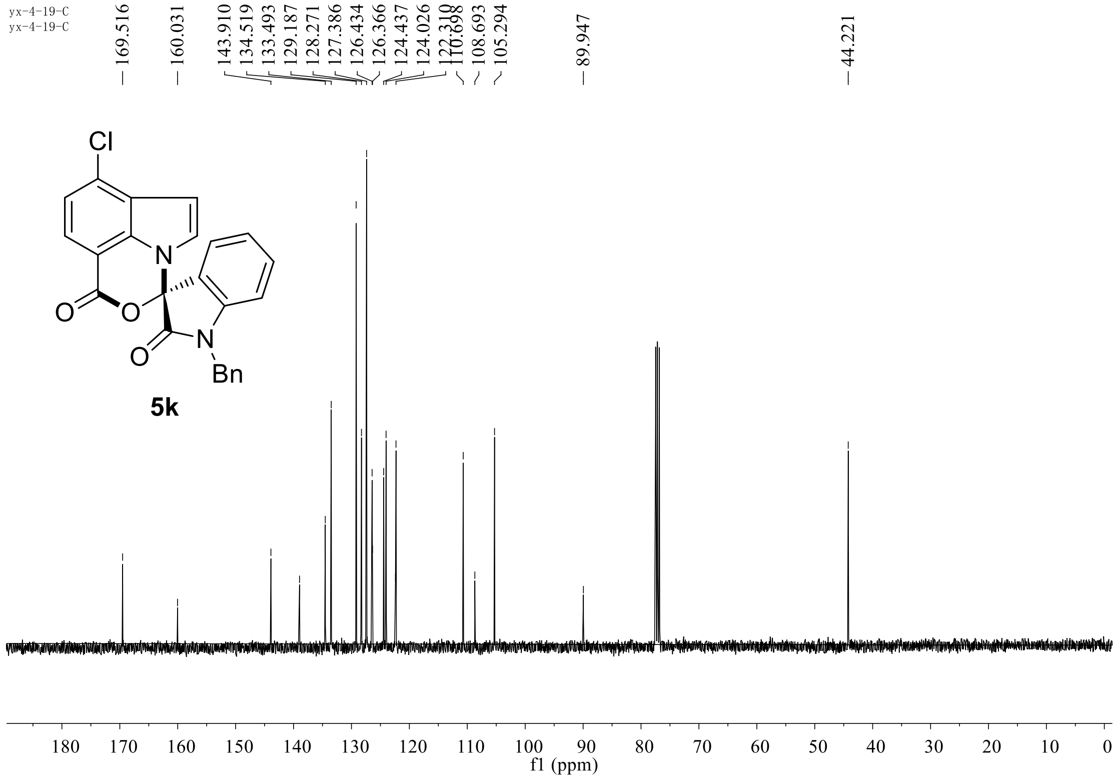


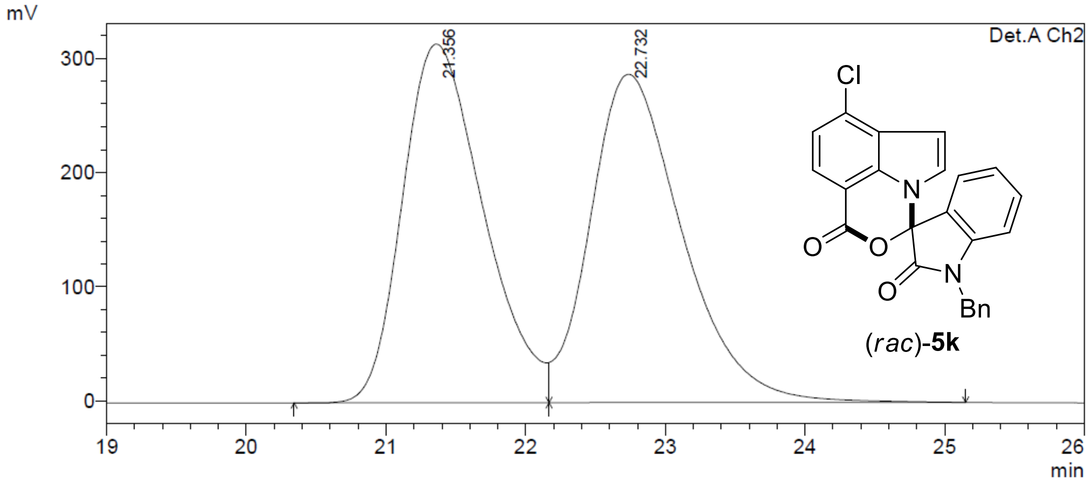
Peak#	Ret. Time	Area	Height	Area %	Height %
1	20.199	4937276	128025	50.035	55.776
2	22.990	4930273	101510	49.965	44.224
Total		9867548	229536	100.000	100.000



Peak#	Ret. Time	Area	Height	Area %	Height %
1	20.308	671099	17771	3.894	4.968
2	22.797	16560931	339924	96.106	95.032
Total		17232030	357695	100.000	100.000

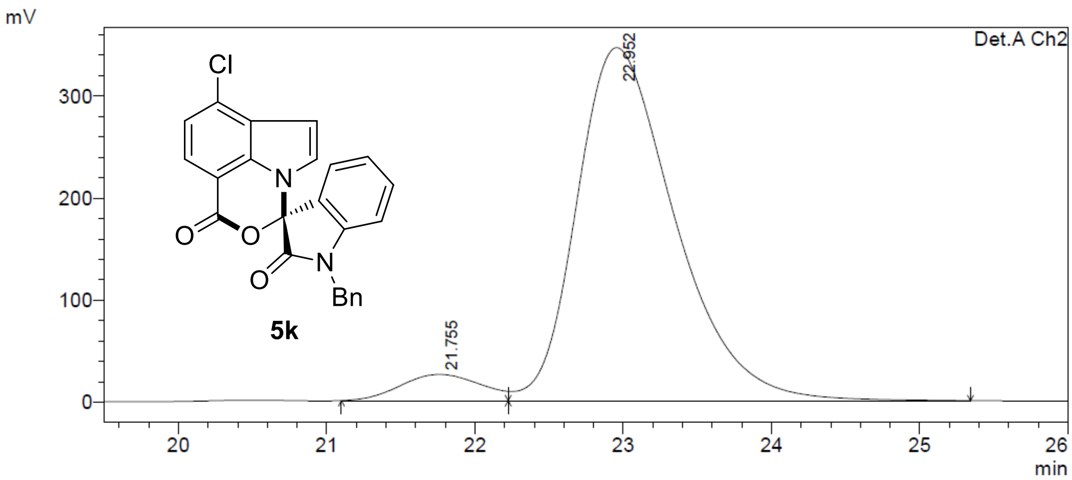






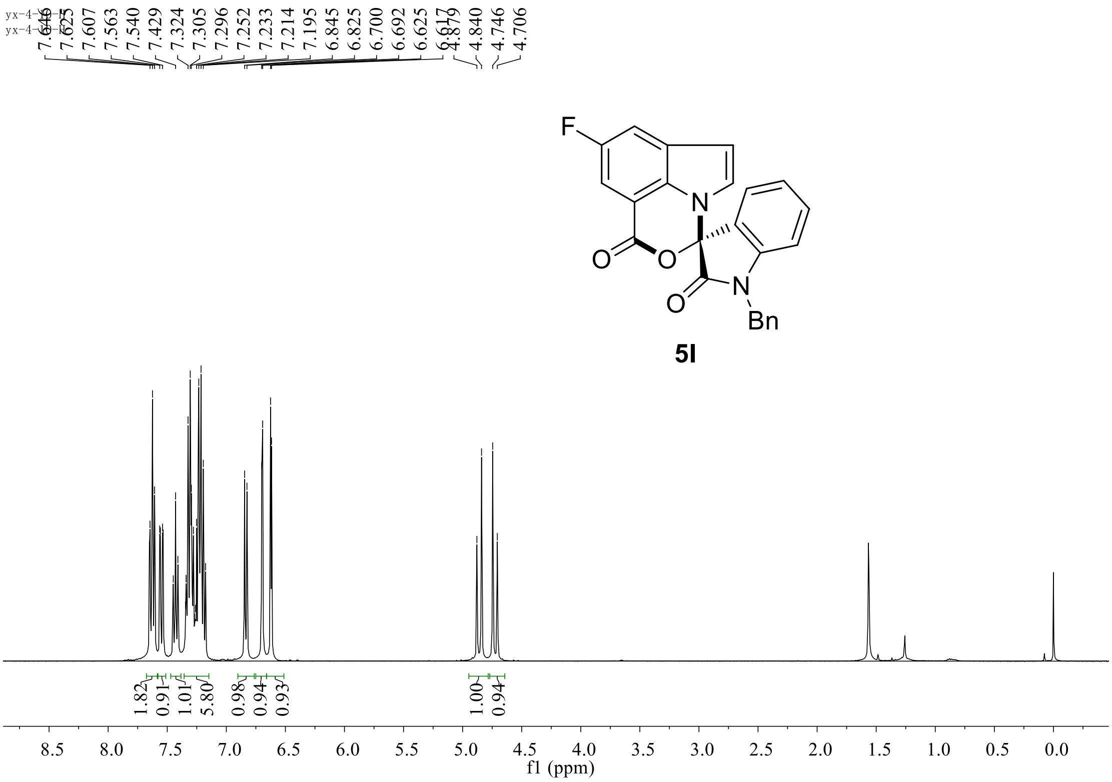
Detector A Ch2 220nm

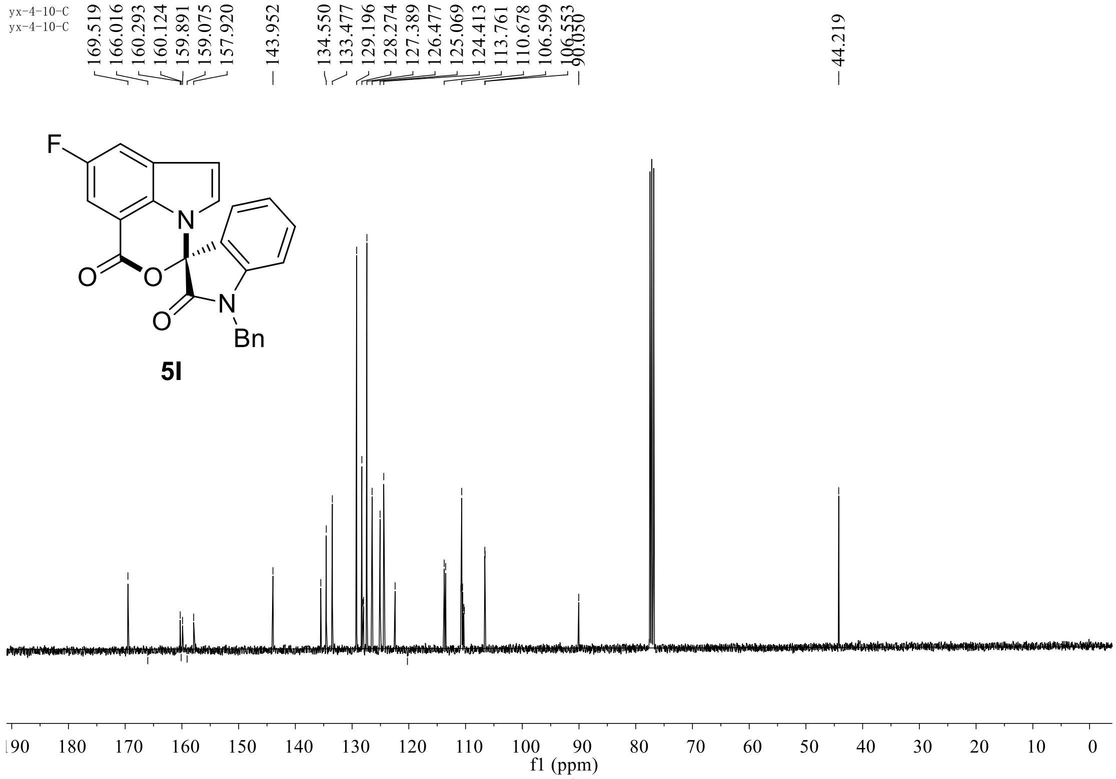
Peak#	Ret. Time	Area	Height	Area %	Height %
1	21.356	12643001	313871	48.989	52.211
2	22.732	13164805	287286	51.011	47.789
Total		25807807	601157	100.000	100.000

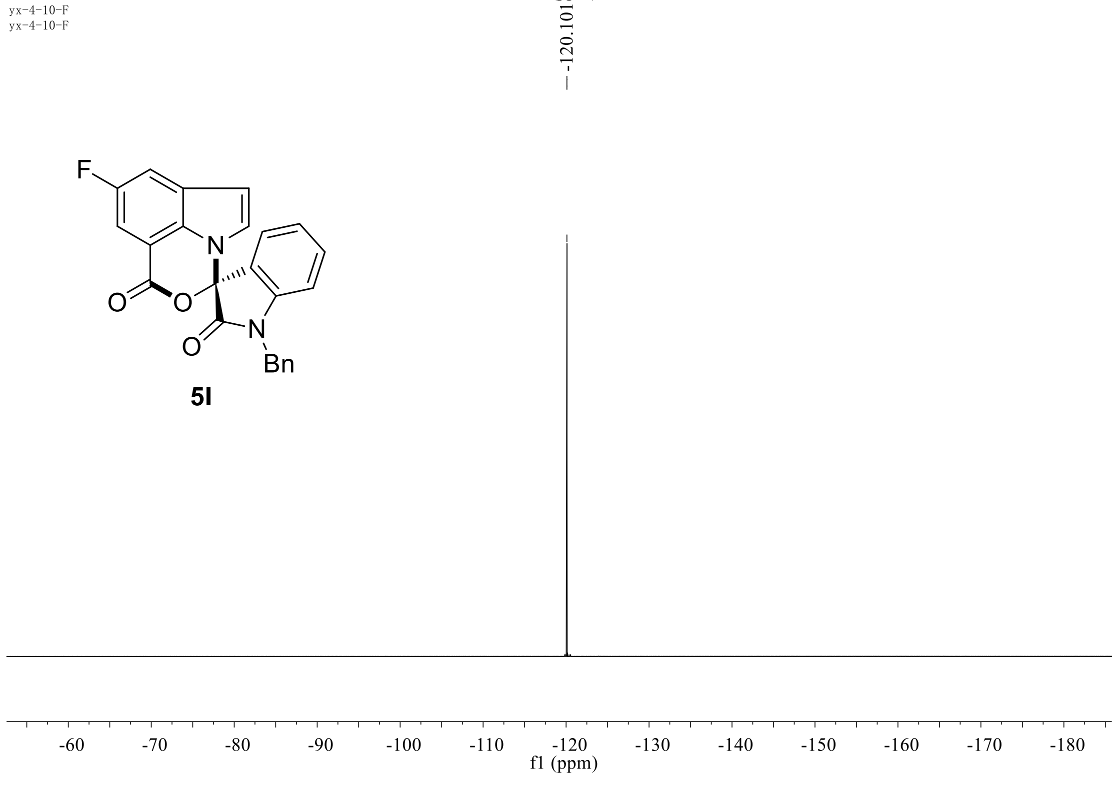


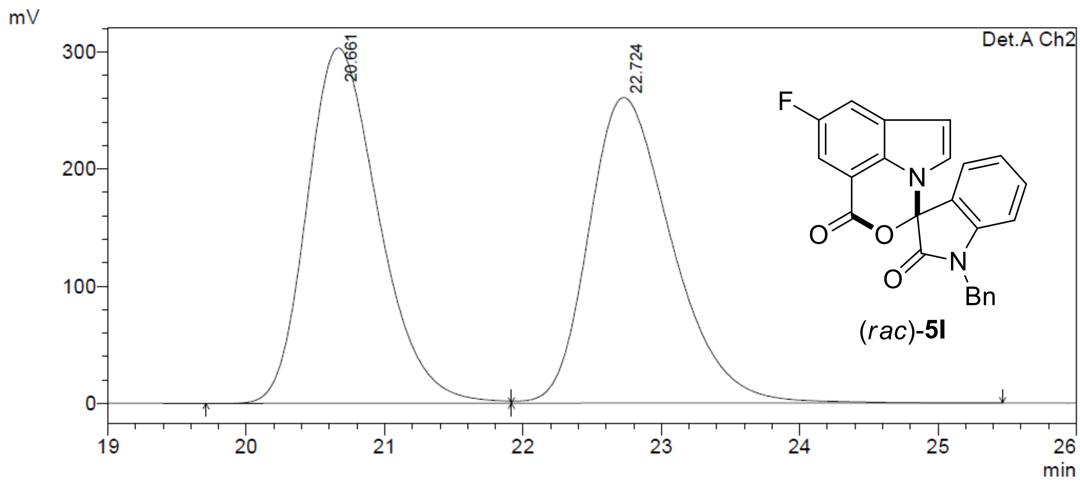
Detector A Ch2 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	21.755	963311	25650	5.717	6.909
2	22.952	15885399	345611	94.283	93.091
Total		16848710	371261	100.000	100.000



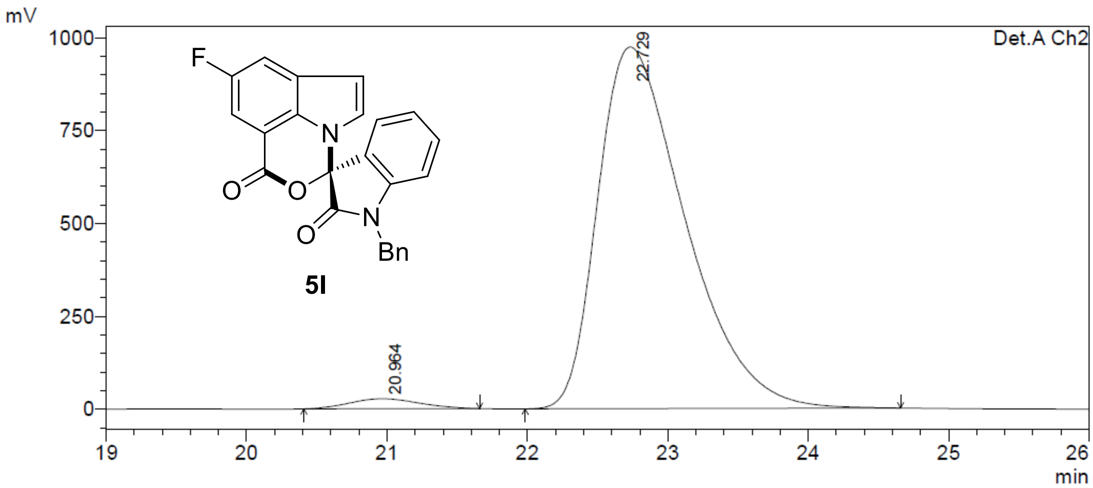

yx-4-10-C
yx-4-10-C
169.519
166.016
160.293
160.124
159.891
159.075
157.920
143.952
134.550
133.477
129.196
128.274
127.389
126.477
125.069
124.413
113.761
110.678
106.599
106.553
90.050
44.219
F
N
O
O
O
N
Bn
5l
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


yx-4-10-F
yx-4-10-F
-120.101
F
N
O
O
O
N
Bn
5l
-60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180
f1 (ppm)

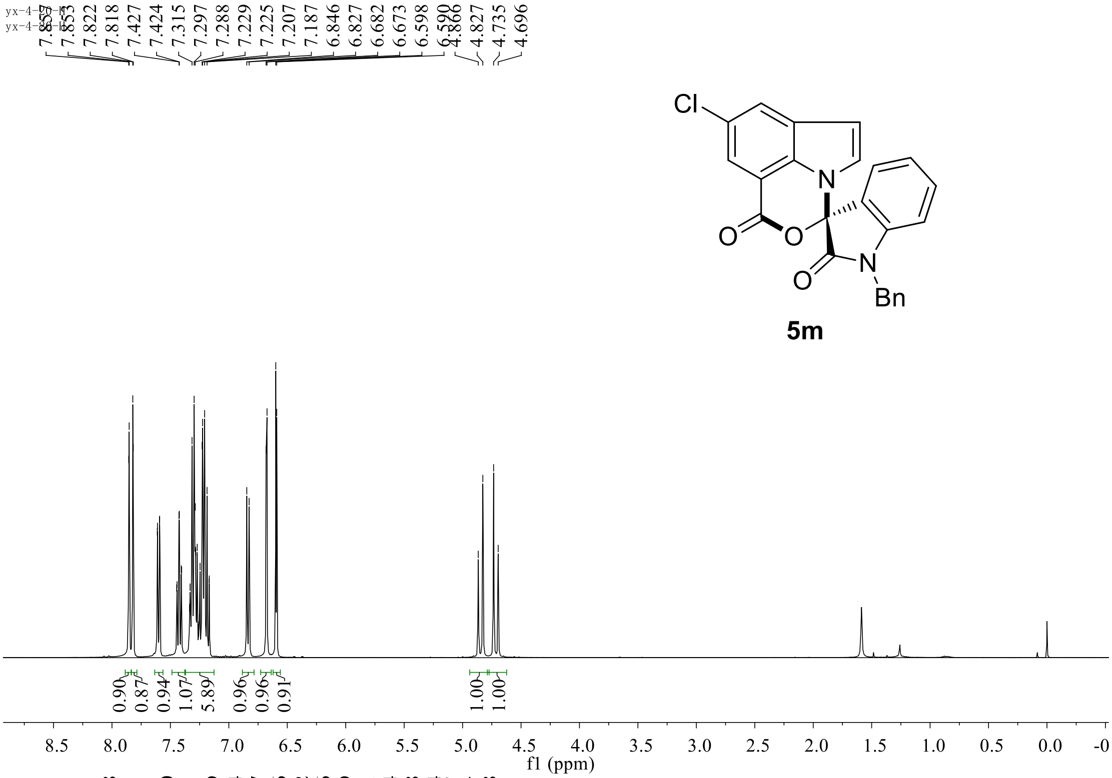


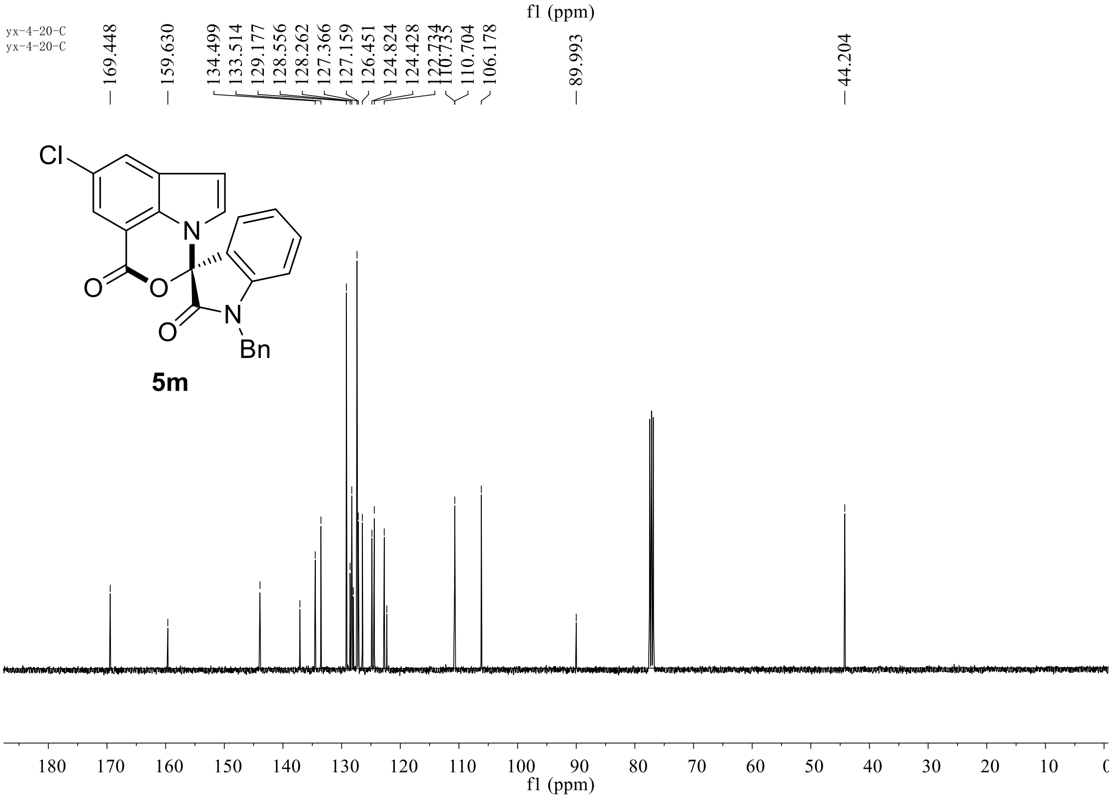
Detector A Ch2 220nm

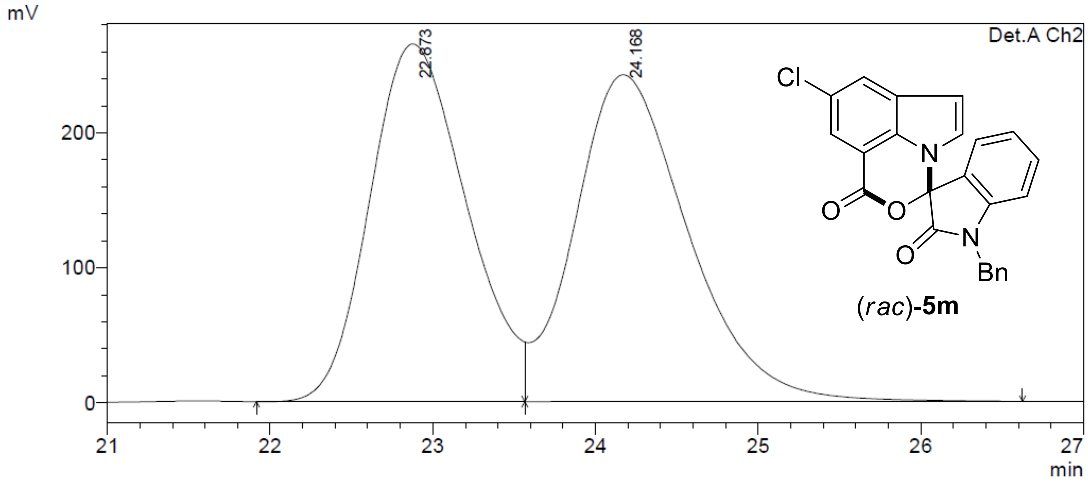
Peak#	Ret. Time	Area	Height	Area %	Height %
1	20.661	10937354	302976	49.986	53.761
2	22.724	10943408	260582	50.014	46.239
Total		21880762	563559	100.000	100.000



Peak#	Ret. Time	Area	Height	Area %	Height %
1	20.964	910753	26565	2.115	2.657
2	22.729	42154502	973359	97.885	97.343
Total		43065256	999924	100.000	100.000

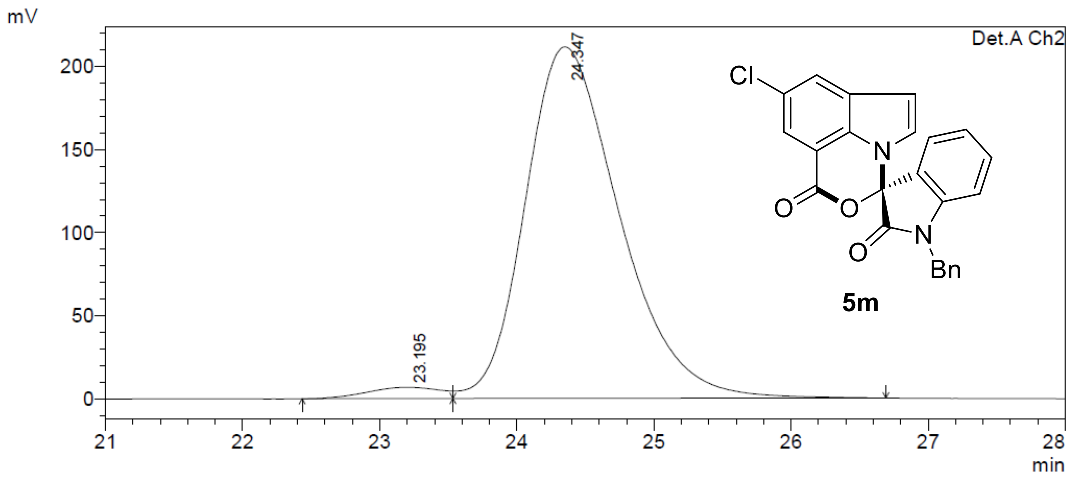




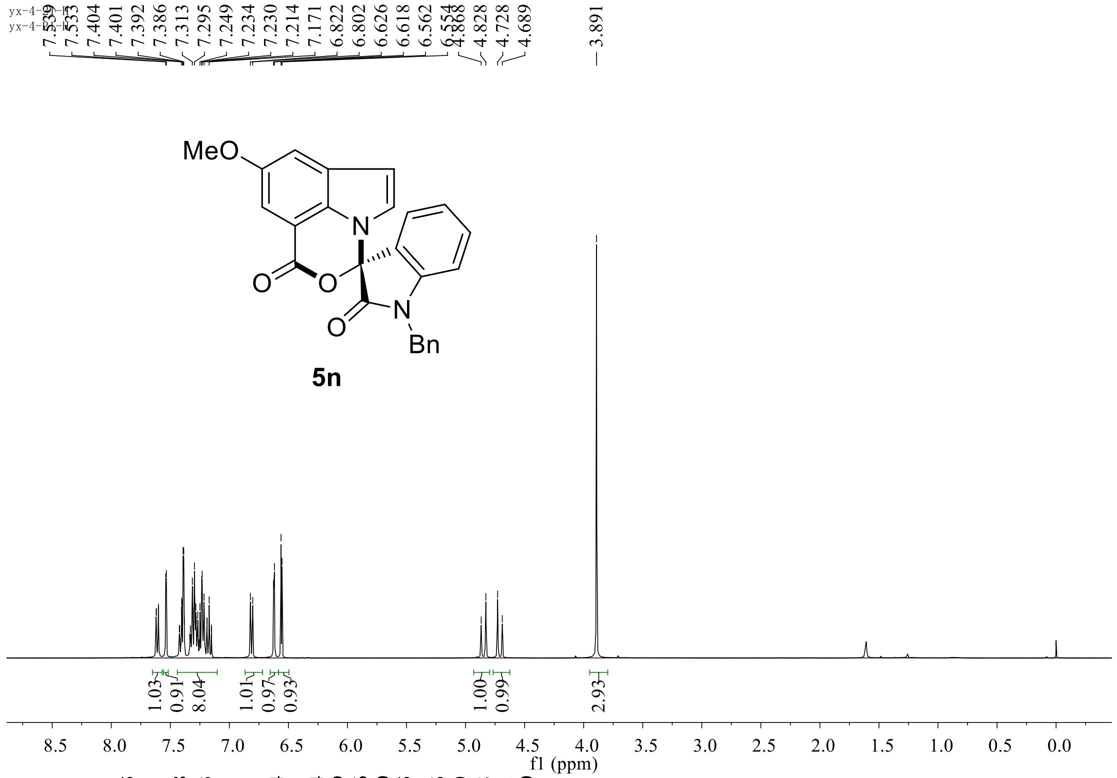


Detector A Ch2 220nm

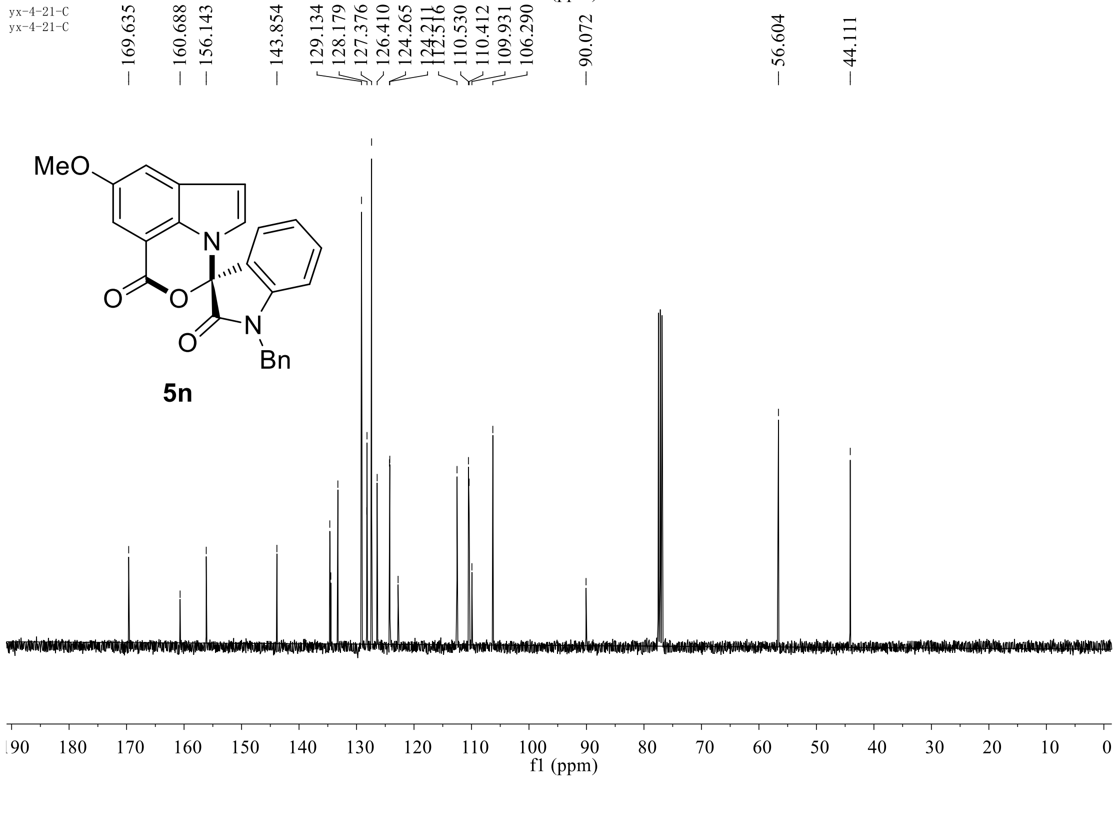
Peak#	Ret. Time	Area	Height	Area %	Height %
1	22.873	10923047	264852	48.286	52.259
2	24.168	11698491	241952	51.714	47.741
Total		22621538	506804	100.000	100.000



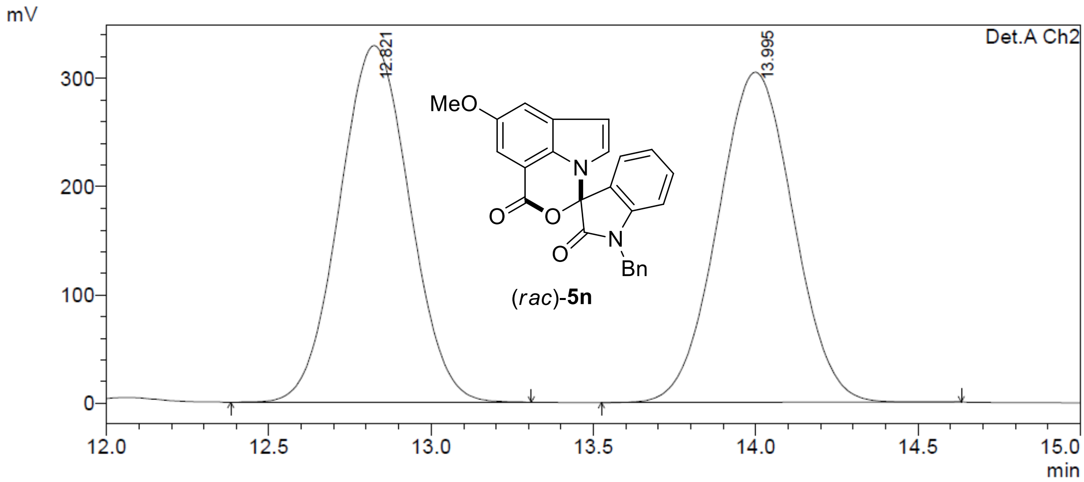
Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.195	253135	6825	2.442	3.129
2	24.347	10112974	211302	97.558	96.871
Total		10366110	218127	100.000	100.000



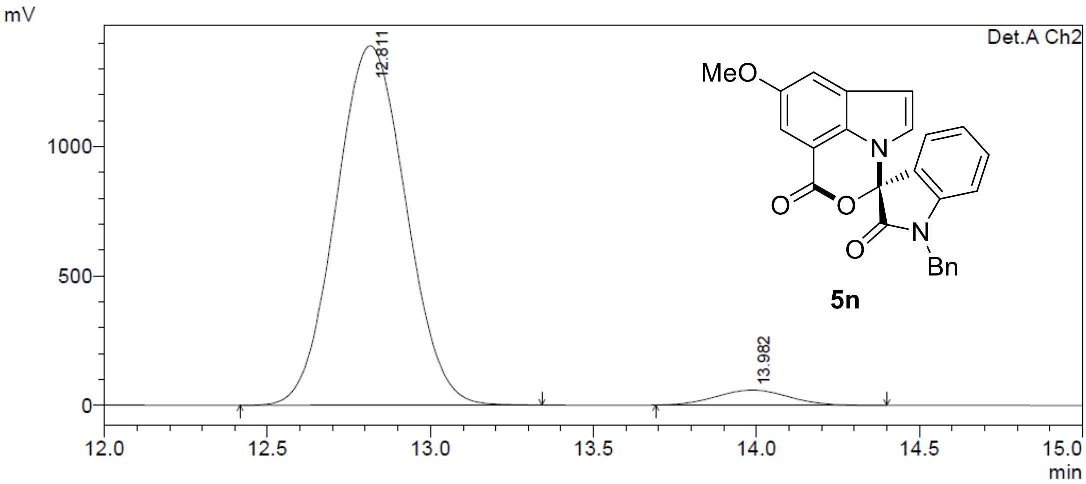
5n



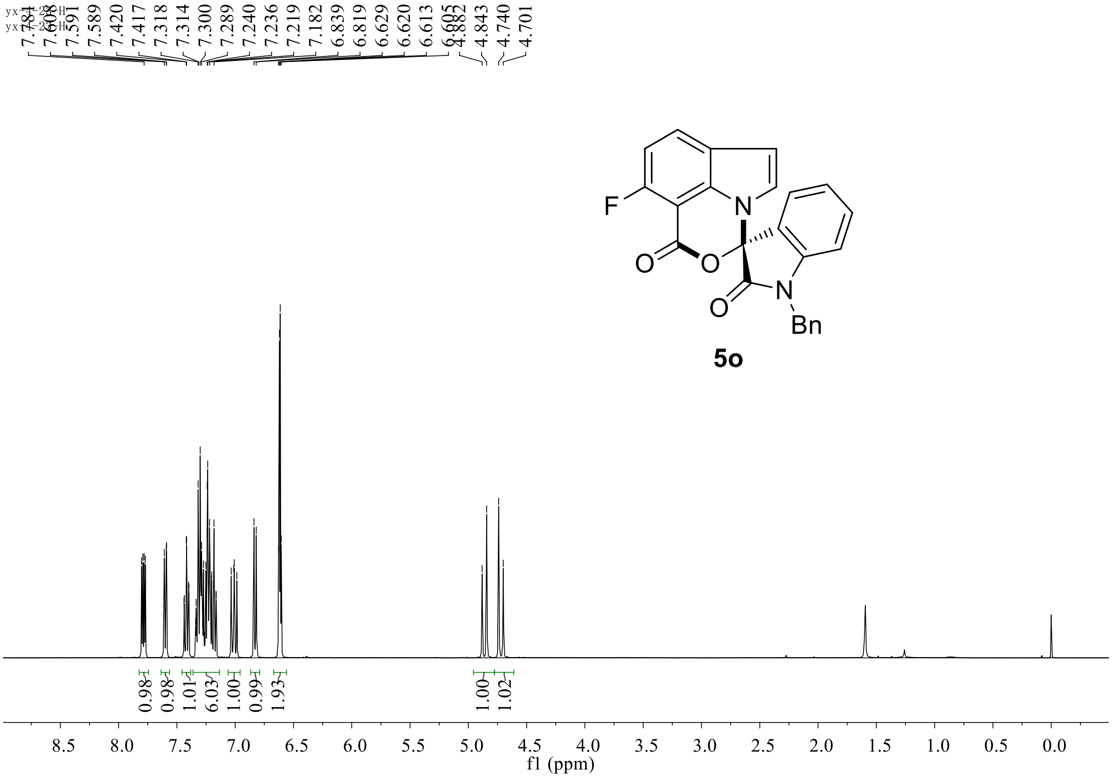
5n



Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.821	4967541	329363	50.080	51.933
2	13.995	4951623	304845	49.920	48.067
Total		9919164	634208	100.000	100.000

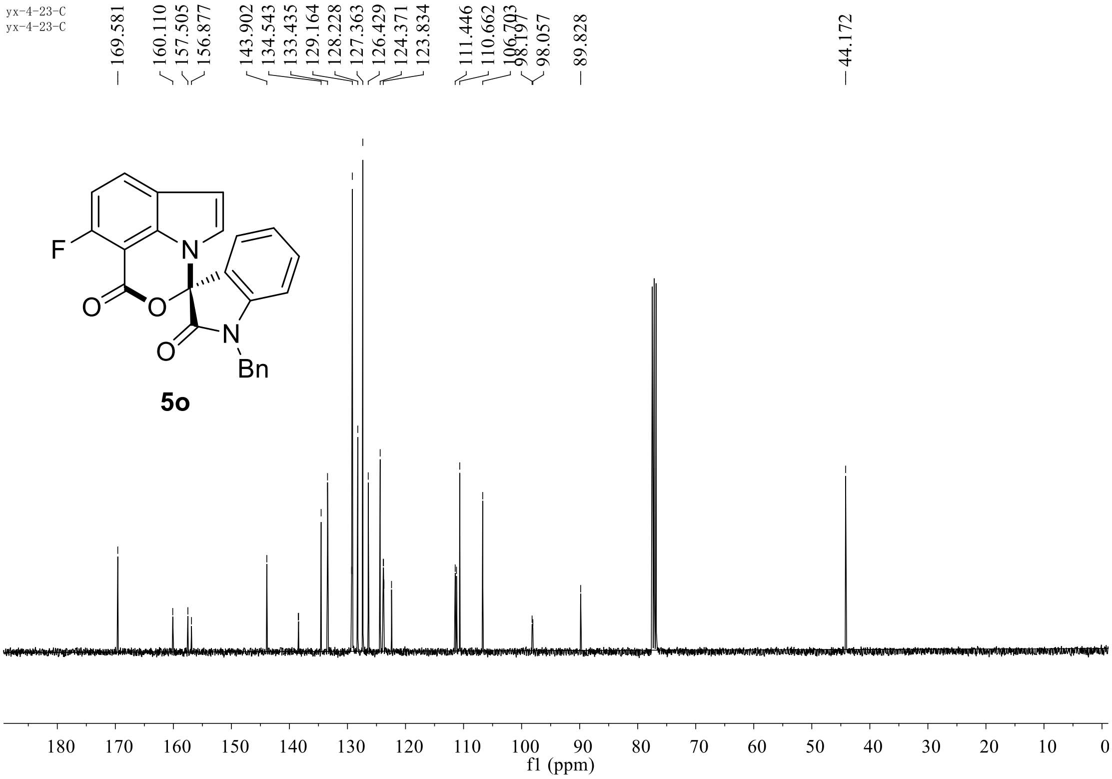


Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.811	20752661	1387720	95.869	95.996
2	13.982	894217	57878	4.131	4.004
Total		21646878	1445598	100.000	100.000



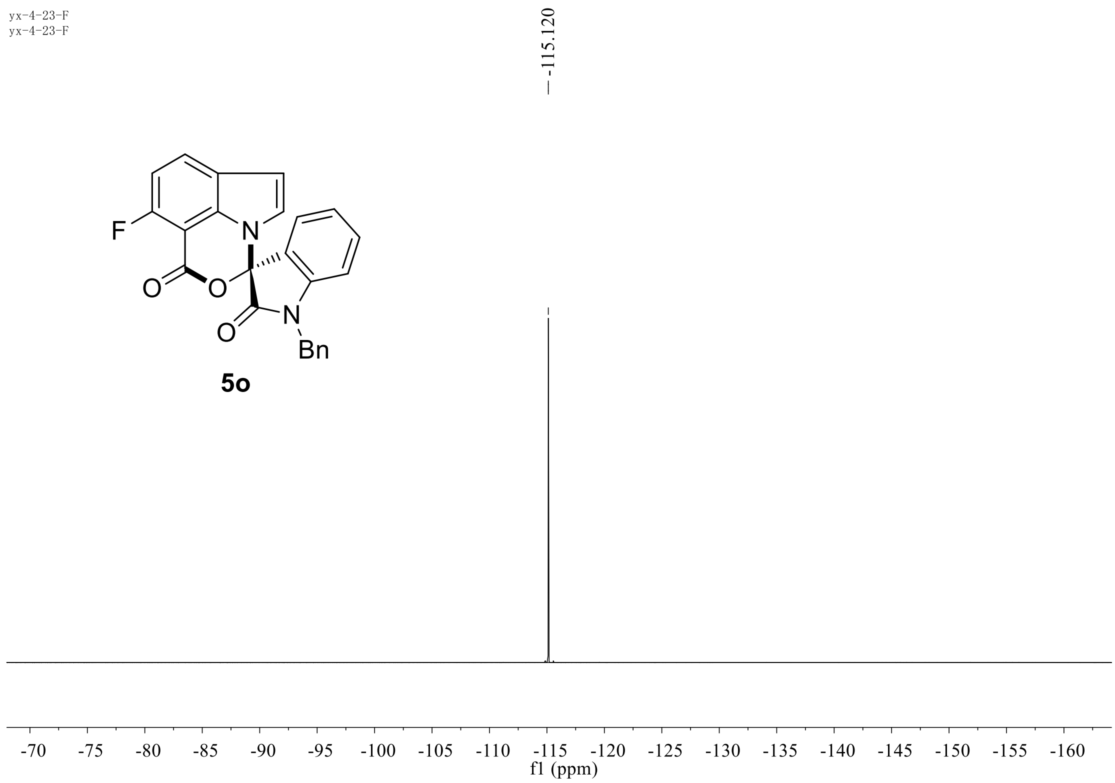
7.591
7.589
7.420
7.417
7.318
7.314
7.300
7.289
7.240
7.236
7.219
7.182
6.839
6.819
6.629
6.620
6.613
4.843
4.740
4.701
F
N
O
O
O
N
Bn
0.98
0.98
1.01
6.03
1.00
0.99
1.93
1.00
1.02
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

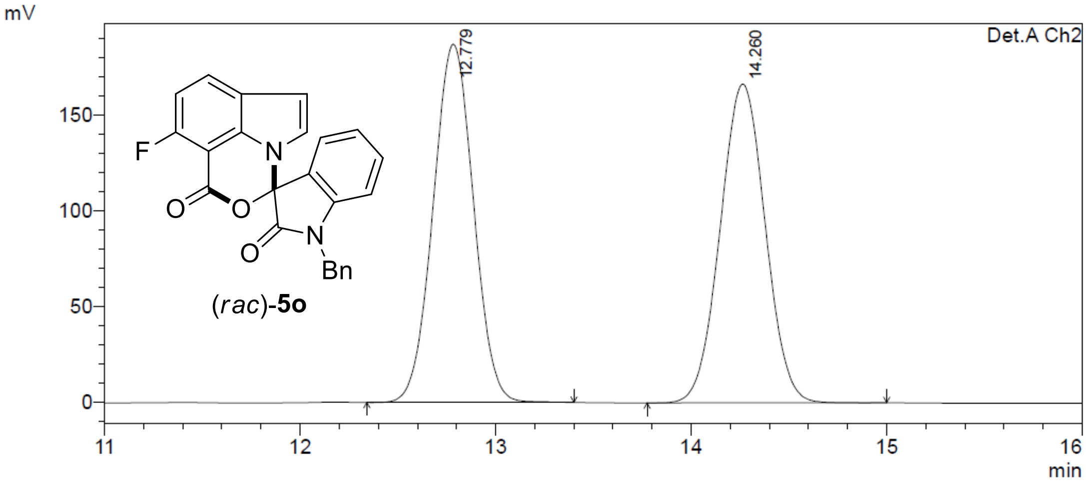
5o



yx-4-23-C
yx-4-23-C
169.581
160.110
157.505
156.877
143.902
134.543
133.435
129.164
128.228
127.363
126.429
124.371
123.834
111.446
110.662
98.057
89.828
44.172
F
N
O
O
O
N
Bn
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

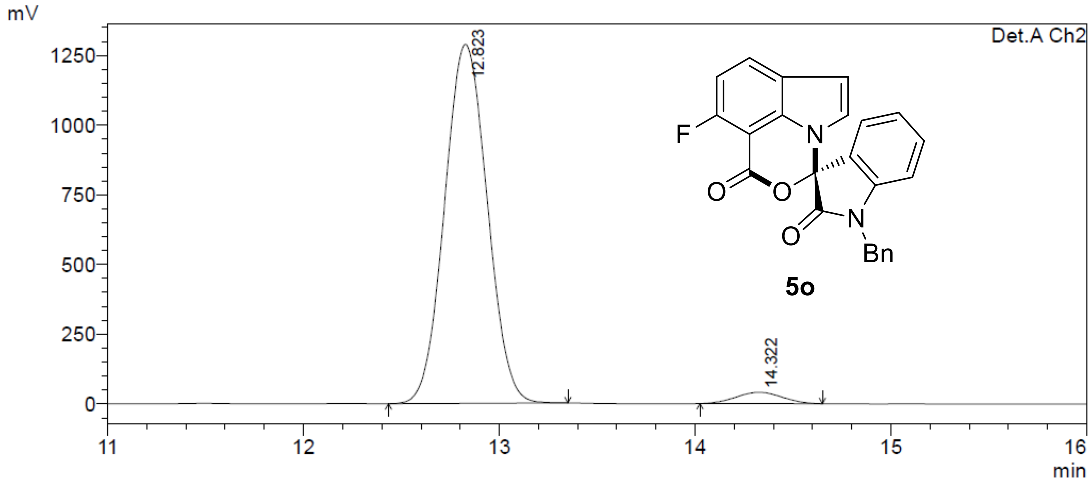
5o



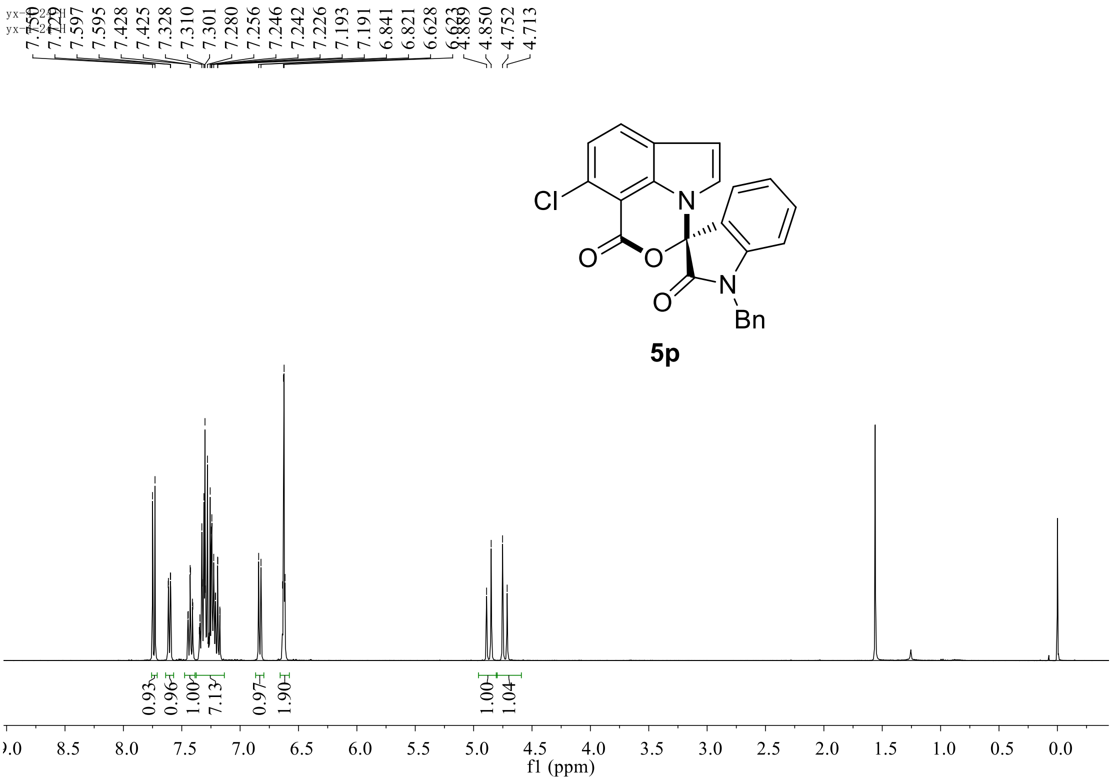


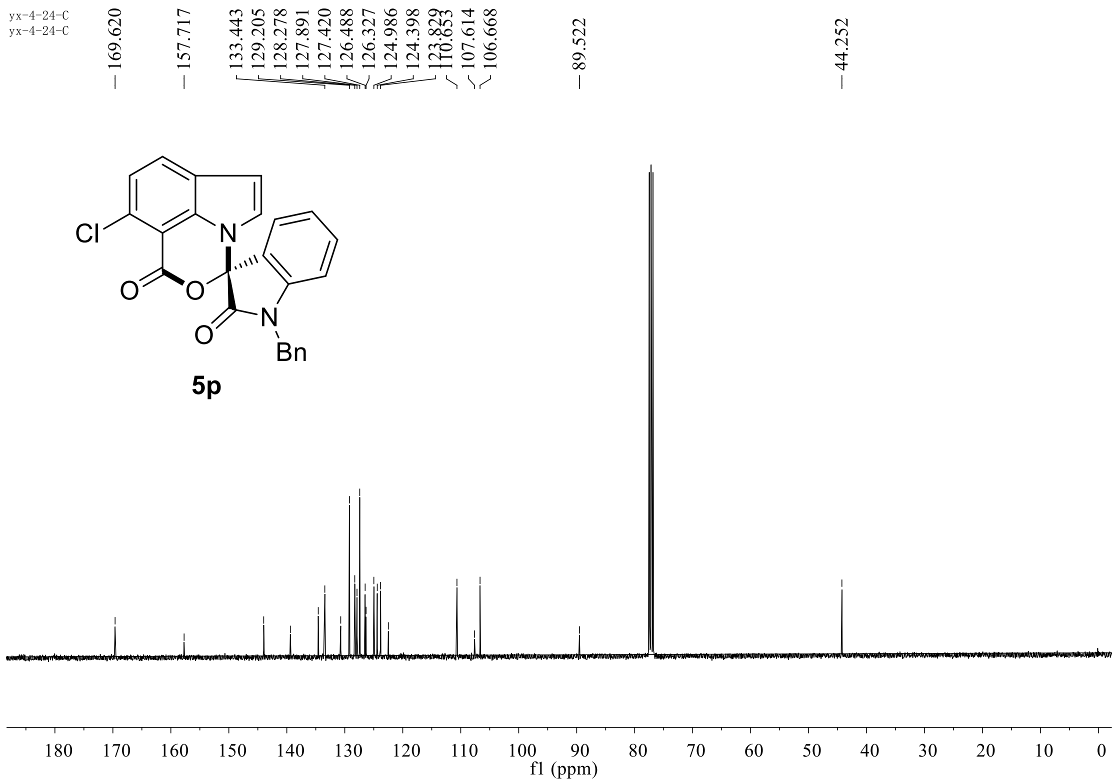
Detector A Ch2 220nm

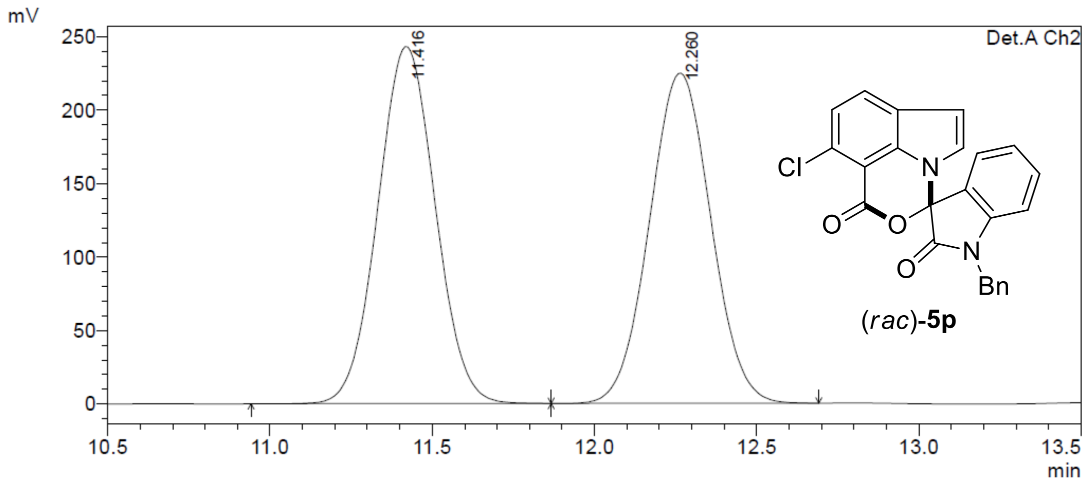
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.779	2687980	187311	50.212	52.932
2	14.260	2665255	166557	49.788	47.068
Total		5353235	353868	100.000	100.000



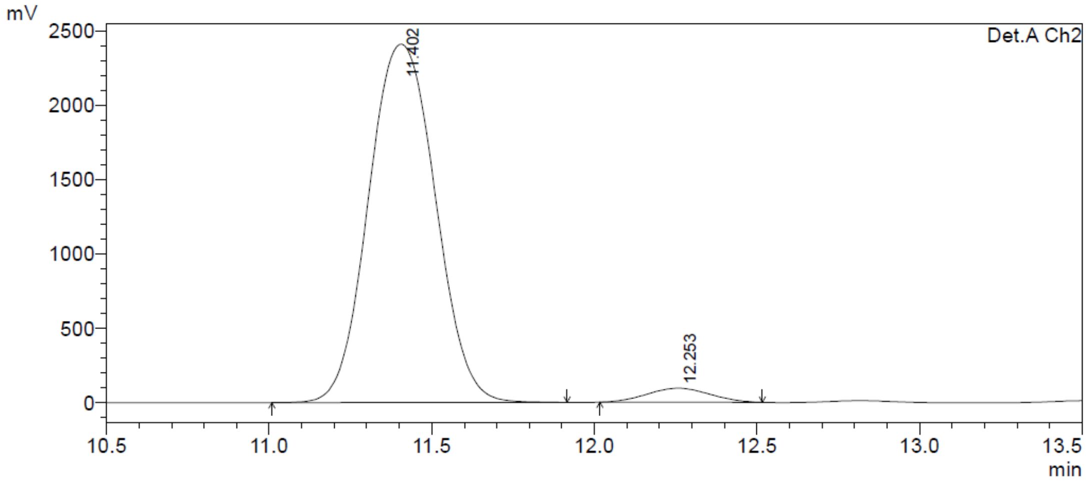
Peak#	Ret. Time	Area	Height	Area %	Height %
1	12.823	19495443	1287799	96.743	96.946
2	14.322	656333	40567	3.257	3.054
Total		20151776	1328366	100.000	100.000



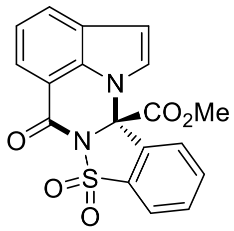




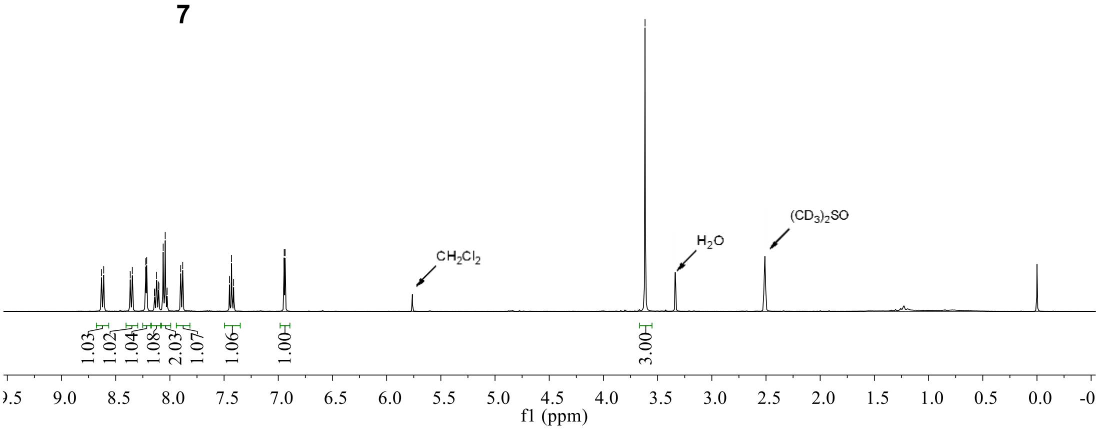
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.416	2996943	243043	50.309	51.950
2	12.260	2960145	224795	49.691	48.050
Total		5957088	467837	100.000	100.000

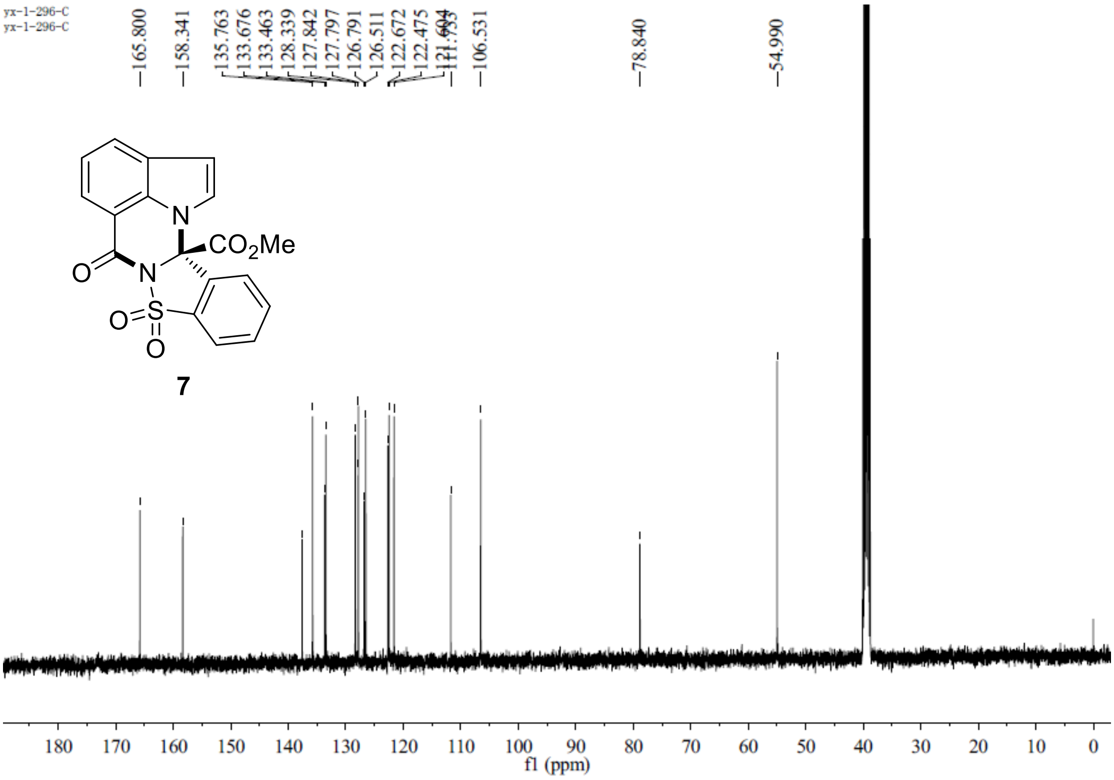


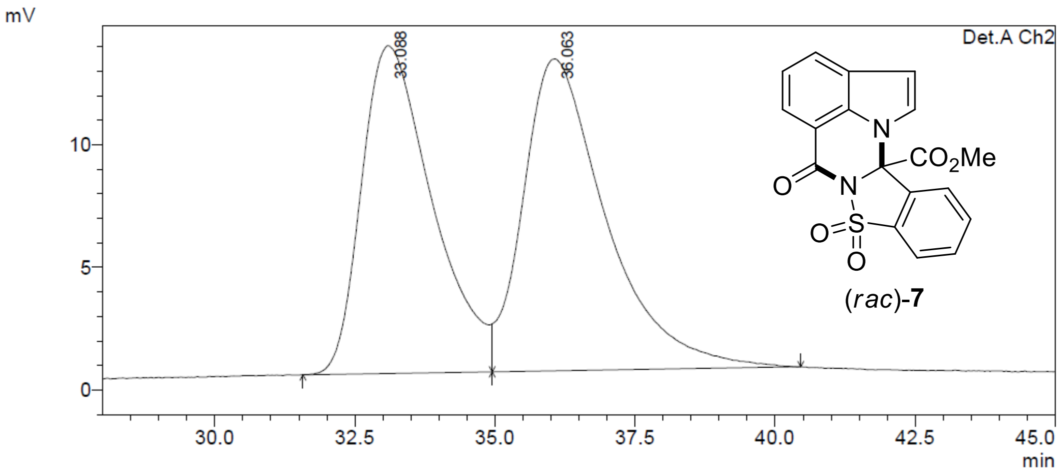
Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.402	34445577	2407907	96.464	96.248
2	12.253	1262488	93872	3.536	3.752
Total		35708065	2501779	100.000	100.000



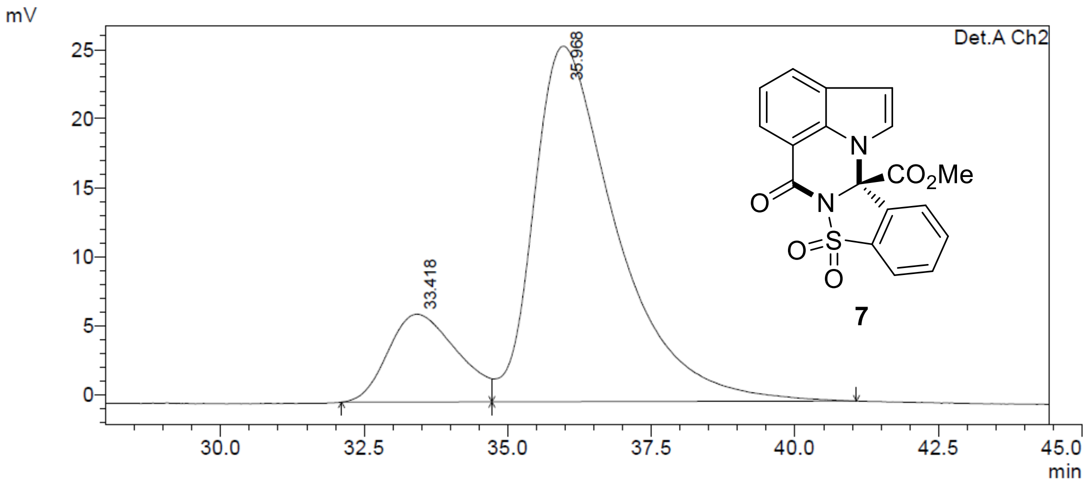
7





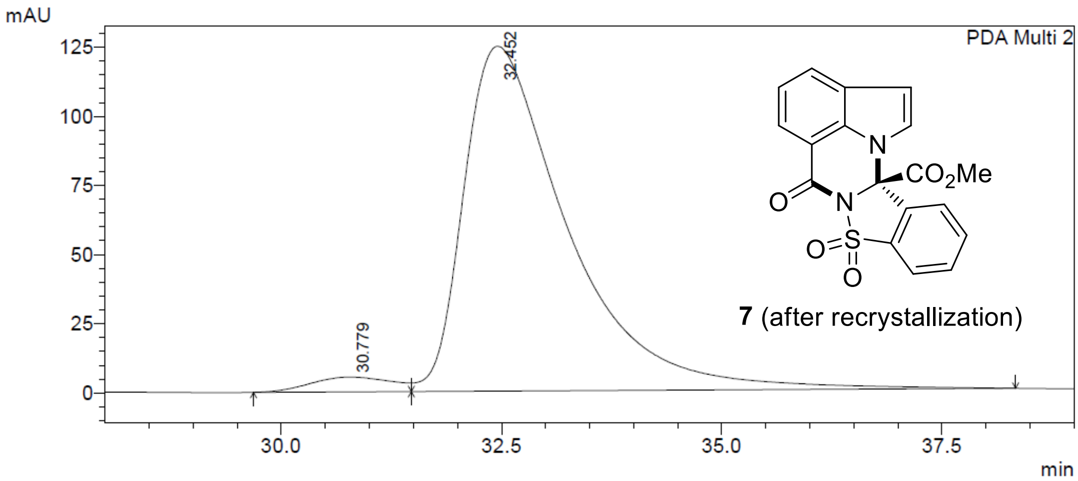


Peak#	Ret. Time	Area	Height	Area %	Height %
1	33.088	1175265	13362	47.307	51.251
2	36.063	1309065	12710	52.693	48.749
Total		2484331	26071	100.000	100.000



Peak#	Ret. Time	Area	Height	Area %	Height %
1	33.418	532825	6362	17.020	19.798
2	35.968	2597780	25773	82.980	80.202
Total		3130605	32135	100.000	100.000

After recrystallization



Peak#	Ret. Time	Area	Height	Area %	Height %
1	30.779	341026	5293	3.208	4.074
2	32.452	10288873	124650	96.792	95.926
Total		10629898	129943	100.000	100.000

Computational Details

The theoretical calculations were carried out by using Gaussian 09 program. Geometry optimizations were performed using the M062X functional with a standard 6-31G(d,p) basis set using SMD solvation model (solvent = DCM). Frequency analyses were done to obtain the thermodynamic energy corrections and to ensure that the optimized structures were at either a minimum or transition state. Single point energies were further refined at the M062X functional with a higher standard 6-311++G(2df,p) basis set level using SMD solvation model (solvent = DCM).

Various energy values for all of the relevant species

1a

Zero-point correction= 0.141434 (Hartree/Particle)

Thermal correction to Energy= 0.149378

Thermal correction to Enthalpy= 0.150322

Thermal correction to Gibbs Free Energy= 0.108685

Sum of electronic and zero-point Energies= -476.838757

Sum of electronic and thermal Energies= -476.830812

Sum of electronic and thermal Enthalpies= -476.829868

Sum of electronic and thermal Free Energies= -476.871505

SCF Done: E(RM062X) = -477.128034642 A.U. after 13 cycles

NFock= 13 Conv=0.19D-08 -V/T= 2.0042

SMD-CDS (non-electrostatic) energy (kcal/mol) = -3.48

(included in total energy above)

2a

Zero-point correction= 0.116797 (Hartree/Particle)

Thermal correction to Energy= 0.126445

Thermal correction to Enthalpy= 0.127390

Thermal correction to Gibbs Free Energy= 0.080552

Sum of electronic and zero-point Energies= -682.253876

Sum of electronic and thermal Energies= -682.244227

Sum of electronic and thermal Enthalpies= -682.243283

Sum of electronic and thermal Free Energies= -682.290121

SCF Done: E(RM062X) = -682.610836853 A.U. after 13 cycles

NFock= 13 Conv=0.58D-08 -V/T= 2.0034

SMD-CDS (non-electrostatic) energy (kcal/mol) = -2.18

(included in total energy above)

Cat. (NHC)

Zero-point correction= 0.259434 (Hartree/Particle)

Thermal correction to Energy= 0.279820

Thermal correction to Enthalpy= 0.280764

Thermal correction to Gibbs Free Energy= 0.208309

Sum of electronic and zero-point Energies= -1429.755887

Sum of electronic and thermal Energies= -1429.735501

Sum of electronic and thermal Enthalpies= -1429.734557

Sum of electronic and thermal Free Energies= -1429.807013

SCF Done: E(RM062X) = -1430.50581958 A.U. after 14 cycles

NFock= 14 Conv=0.90D-09 -V/T= 2.0036

SMD-CDS (non-electrostatic) energy (kcal/mol) = -6.74

(included in total energy above)

DQ

Zero-point correction= 0.622538 (Hartree/Particle)

Thermal correction to Energy= 0.655003

Thermal correction to Enthalpy= 0.655947

Thermal correction to Gibbs Free Energy= 0.561165

Sum of electronic and zero-point Energies= -1240.394238

Sum of electronic and thermal Energies= -1240.361774

Sum of electronic and thermal Enthalpies= -1240.360829

Sum of electronic and thermal Free Energies= -1240.455611

SCF Done: E(RM062X) = -1241.36131774 A.U. after 11 cycles

NFock= 11 Conv=0.56D-08 -V/T= 2.0046

SMD-CDS (non-electrostatic) energy (kcal/mol) = -8.22

(included in total energy above)

DQ-H$^-$

Zero-point correction= 0.632260 (Hartree/Particle)

Thermal correction to Energy= 0.664740

Thermal correction to Enthalpy= 0.665684

Thermal correction to Gibbs Free Energy= 0.571831

Sum of electronic and zero-point Energies= -1241.132733

Sum of electronic and thermal Energies= -1241.100253

Sum of electronic and thermal Enthalpies= -1241.099309

Sum of electronic and thermal Free Energies= -1241.193162

SCF Done: E(RM062X) = -1242.11813038 A.U. after 13 cycles

NFock= 13 Conv=0.42D-08 -V/T= 2.0046

SMD-CDS (non-electrostatic) energy (kcal/mol) = -8.28

(included in total energy above)

Base: N,N-Diisopropylethylamine

Zero-point correction= 0.263853 (Hartree/Particle)

Thermal correction to Energy= 0.275744

Thermal correction to Enthalpy= 0.276688

Thermal correction to Gibbs Free Energy= 0.227377

Sum of electronic and zero-point Energies= -370.608290

Sum of electronic and thermal Energies= -370.596399

Sum of electronic and thermal Enthalpies= -370.595455

Sum of electronic and thermal Free Energies= -370.644766

SCF Done: E(RM062X) = -370.972036478 A.U. after 11 cycles

NFock= 11 Conv=0.40D-08 -V/T= 2.0049

SMD-CDS (non-electrostatic) energy (kcal/mol) = -2.95

(included in total energy above)

Base-H$^+$

Zero-point correction= 0.281217 (Hartree/Particle)

Thermal correction to Energy= 0.292629

Thermal correction to Enthalpy= 0.293574

Thermal correction to Gibbs Free Energy= 0.245704

Sum of electronic and zero-point Energies= -371.061922

Sum of electronic and thermal Energies= -371.050509

Sum of electronic and thermal Enthalpies= -371.049565

Sum of electronic and thermal Free Energies= -371.097435

SCF Done: E(RM062X) = -371.438353662 A.U. after 9 cycles

NFock= 9 Conv=0.98D-08 -V/T= 2.0052

SMD-CDS (non-electrostatic) energy (kcal/mol) = -2.88

(included in total energy above)

3a

Zero-point correction= 0.239657 (Hartree/Particle)

Thermal correction to Energy= 0.256551

Thermal correction to Enthalpy= 0.257495

Thermal correction to Gibbs Free Energy= 0.194323

Sum of electronic and zero-point Energies= -1157.940556

Sum of electronic and thermal Energies= -1157.923662

Sum of electronic and thermal Enthalpies= -1157.922718

Sum of electronic and thermal Free Energies= -1157.985890

SCF Done: E(RM062X) = -1158.56003623 A.U. after 14 cycles

NFock= 14 Conv=0.25D-08 -V/T= 2.0037

SMD-CDS (non-electrostatic) energy (kcal/mol) = -5.31

(included in total energy above)

(*R*)-4

Zero-point correction= 0.261506 (Hartree/Particle)

Thermal correction to Energy= 0.279275

Thermal correction to Enthalpy= 0.280219

Thermal correction to Gibbs Free Energy= 0.216061

Sum of electronic and zero-point Energies= -1159.102011

Sum of electronic and thermal Energies= -1159.084242

Sum of electronic and thermal Enthalpies= -1159.083297

Sum of electronic and thermal Free Energies= -1159.147456

SCF Done: E(RM062X) = -1159.74526111 A.U. after 13 cycles

NFock= 13 Conv=0.34D-08 -V/T= 2.0037

SMD-CDS (non-electrostatic) energy (kcal/mol) = -4.86

(included in total energy above)

TS-1

Zero-point correction= 0.402428 (Hartree/Particle)

Thermal correction to Energy= 0.431296

Thermal correction to Enthalpy= 0.432241

Thermal correction to Gibbs Free Energy= 0.342291

Sum of electronic and zero-point Energies= -1906.593568

Sum of electronic and thermal Energies= -1906.564699

Sum of electronic and thermal Enthalpies= -1906.563755

Sum of electronic and thermal Free Energies= -1906.653705

SCF Done: E(RM062X) = -1907.63030727 A.U. after 14 cycles

NFock= 14 Conv=0.22D-08 -V/T= 2.0038

SMD-CDS (non-electrostatic) energy (kcal/mol) = -7.37

(included in total energy above)

INT-1

Zero-point correction= 0.404028 (Hartree/Particle)

Thermal correction to Energy= 0.432808

Thermal correction to Enthalpy= 0.433752

Thermal correction to Gibbs Free Energy= 0.345016

Sum of electronic and zero-point Energies= -1906.599247

Sum of electronic and thermal Energies= -1906.570466

Sum of electronic and thermal Enthalpies= -1906.569522

Sum of electronic and thermal Free Energies= -1906.658259

SCF Done: E(RM062X) = -1907.64069597 A.U. after 14 cycles

NFock= 14 Conv=0.40D-08 -V/T= 2.0038

SMD-CDS (non-electrostatic) energy (kcal/mol) = -7.68

(included in total energy above)

INT-2

Zero-point correction= 0.394646 (Hartree/Particle)

Thermal correction to Energy= 0.423549

Thermal correction to Enthalpy= 0.424493

Thermal correction to Gibbs Free Energy= 0.333413

Sum of electronic and zero-point Energies= -1905.884038

Sum of electronic and thermal Energies= -1905.855135

Sum of electronic and thermal Enthalpies= -1905.854191

Sum of electronic and thermal Free Energies= -1905.945271

SCF Done: E(RM062X) = -1906.90327060 A.U. after 13 cycles

NFock= 13 Conv=0.79D-08 -V/T= 2.0038

SMD-CDS (non-electrostatic) energy (kcal/mol) = -8.10

(included in total energy above)

INT-3

Zero-point correction= 0.380644 (Hartree/Particle)

Thermal correction to Energy= 0.409190

Thermal correction to Enthalpy= 0.410134

Thermal correction to Gibbs Free Energy= 0.321752

Sum of electronic and zero-point Energies= -1905.418964

Sum of electronic and thermal Energies= -1905.390418

Sum of electronic and thermal Enthalpies= -1905.389474

Sum of electronic and thermal Free Energies= -1905.477856

SCF Done: E(RM062X) = -1906.43167459 A.U. after 14 cycles

NFock= 14 Conv=0.44D-08 -V/T= 2.0038

SMD-CDS (non-electrostatic) energy (kcal/mol) = -7.36

(included in total energy above)

TS-1’

Zero-point correction= 0.522783 (Hartree/Particle)

Thermal correction to Energy= 0.561091

Thermal correction to Enthalpy= 0.562035

Thermal correction to Gibbs Free Energy= 0.452462

Sum of electronic and zero-point Energies= -2588.864474

Sum of electronic and thermal Energies= -2588.826166

Sum of electronic and thermal Enthalpies= -2588.825222

Sum of electronic and thermal Free Energies= -2588.934795

SCF Done: E(RM062X) = -2590.25110864 A.U. after 14 cycles

NFock= 14 Conv=0.22D-08 -V/T= 2.0037

SMD-CDS (non-electrostatic) energy (kcal/mol) = -8.72

(included in total energy above)

6. Cartesian Coordinates

1a

C	-6.11953800	0.03692100	0.00018300
C	-4.70141700	0.04802100	0.00025100
C	-3.96482800	1.24746000	-0.00084500
C	-4.67918500	2.44299500	-0.00203200
C	-6.08196000	2.45165500	-0.00220700
C	-6.80237500	1.26292700	-0.00110900
C	-6.51715100	-1.34392900	0.00174600
C	-5.36715000	-2.08348100	0.00212600
H	-4.12948600	3.38073600	-0.00286600
H	-6.60939000	3.39950800	-0.00320000
H	-7.88856100	1.28265100	-0.00120500
H	-7.52554400	-1.73098500	0.00221900

H	-5.22922800	-3.15509200	0.00308700
H	-3.29930500	-1.51407400	0.00248900
N	-4.27392500	-1.24602400	0.00185400
C	-2.50173500	1.23397000	-0.00064000
O	-1.83729300	0.21060100	0.00023300
H	-2.01190000	2.22590400	-0.00130600

2a

C	-2.60881700	-0.30597400	-0.00023600
C	-1.21898600	-0.35956100	-0.00072900
C	-0.48159400	0.83120200	-0.00126900
C	-1.14240900	2.06640100	-0.00118200
C	-2.52908600	2.11215400	-0.00041200
C	-3.26241600	0.92458000	-0.00000700
H	-3.18188800	-1.22699200	0.00000000
H	-0.72649300	-1.32521100	-0.00084500
H	-0.55216000	2.97692200	-0.00152400
H	-3.04025900	3.06905500	-0.00011000
H	-4.34741900	0.95934800	0.00052300
C	0.99894000	0.85653800	-0.00196700
O	1.66548600	1.86471600	-0.00574100
C	1.75022500	-0.49463300	0.00300300
F	1.43011200	-1.21516100	1.08669900
F	1.43354300	-1.22146400	-1.07751900
F	3.06393200	-0.30551900	0.00451800

Cat. (NHC)

C	-7.19302900	-0.81099200	-0.30595800
C	-5.80497000	-0.70546000	-0.27253700

C	-5.15717300	0.46490900	-0.65648600
C	-5.92913700	1.54692900	-1.07318600
C	-7.32344600	1.45010600	-1.10330400
C	-7.96429300	0.27288600	-0.72167300
C	-7.65019900	-2.17368000	0.14675100
C	-5.16583200	-1.98585800	0.22109000
H	-4.07270100	0.52823000	-0.63650100
H	-5.44602900	2.47007600	-1.37717900
H	-7.91290400	2.30069400	-1.43154700
H	-9.04767100	0.19999000	-0.75339600
H	-8.19062800	-2.11281700	1.09655700
H	-4.69726200	-1.84713700	1.19766300
H	-8.31785800	-2.65860800	-0.57297900
C	-2.79396500	-2.18625800	-0.63705900
C	-4.44713700	-3.20421400	-1.79290800
N	-2.40379600	-2.80946100	-1.77786100
C	-1.08213700	-2.86033100	-2.26359900
C	-0.48300200	-4.08304500	-2.55611900
C	-0.35114900	-1.69329500	-2.46712800
C	0.81304000	-4.14208900	-3.04446300
C	0.95277800	-1.74540600	-2.93776800
C	1.53299700	-2.97069900	-3.23096000
F	-0.89340900	-0.50555800	-2.22145900
F	1.64237200	-0.62282100	-3.12392000
F	2.77841300	-3.02359900	-3.68936300
F	1.37357700	-5.31711400	-3.31873300
F	-1.14830300	-5.21656600	-2.36099200
N	-3.39367100	-3.45081100	-2.50292900
N	-4.12767400	-2.46304700	-0.68358900

C	-5.85910100	-3.67325300	-1.92451500
H	-6.50100400	-2.87987800	-2.33134300
H	-5.91911200	-4.54385100	-2.57808300
C	-6.35815600	-3.00965200	0.31525600
H	-6.33400200	-3.51024900	1.28313300
O	-6.27039500	-4.06966200	-0.62702200

DQ

C	-2.01961800	-0.25773500	0.00789500
C	-0.63473400	-0.17530200	-0.42625300
C	0.08763000	0.96613900	-0.41669600
C	-0.55875900	2.22290800	0.06376800
C	-1.98637900	2.16671500	0.49624900
C	-2.63361600	0.98156900	0.45660400
C	-2.71880200	-1.45734900	-0.00714700
C	-2.10478500	-2.69664100	-0.45585600
C	-2.75200200	-3.88179900	-0.49550400
C	-4.17962200	-3.93801400	-0.06302200
C	-4.82603100	-2.68125600	0.41744100
C	-4.10368700	-1.53980300	0.42699700
H	-0.15906100	-1.07823400	-0.77773100
H	-3.66592100	0.95300300	0.77201900
H	-1.07248000	-2.66805500	-0.77127200
H	-4.57937800	-0.63688100	0.77847200
C	-2.66112500	3.45506500	0.96948700
C	-4.12294200	3.21475100	1.36418800
C	-1.92770900	4.00835800	2.20585200
C	-2.64843900	4.50007200	-0.16193600
H	-4.71840400	2.84341700	0.52340700

H	-4.21157100	2.50569200	2.19408700
H	-4.56248600	4.16216700	1.68964700
H	-0.89271000	4.26373900	1.97757200
H	-2.43938300	4.91019200	2.55885500
H	-1.93751700	3.27446100	3.01871800
H	-3.16899000	5.40380300	0.17280700
H	-1.63175300	4.77179800	-0.44664400
H	-3.17068500	4.11771000	-1.04545200
C	1.54547600	1.01968300	-0.87668000
C	1.68908300	1.99461900	-2.06056900
C	2.44695300	1.47257700	0.28769700
C	2.03990100	-0.35459500	-1.34342500
H	1.05730300	1.68102900	-2.89843100
H	1.41659000	3.01196200	-1.77894500
H	2.72885500	1.99595600	-2.40483500
H	2.36123700	0.78163800	1.13306600
H	3.49157500	1.47420800	-0.04173400
H	2.18945900	2.47592800	0.62795700
H	3.08232900	-0.26732300	-1.66376300
H	2.00031500	-1.09919400	-0.54120600
H	1.46126300	-0.72919400	-2.19449800
C	-2.07722900	-5.17013400	-0.96874500
C	-0.61541600	-4.92978400	-1.36343600
C	-2.08989400	-6.21514800	0.16267300
C	-2.81062400	-5.72343600	-2.20511900
H	-0.52680100	-4.22071700	-2.19333000
H	-0.01996800	-4.55844100	-0.52265000
H	-0.17584800	-5.87718700	-1.68889900
H	-3.10657500	-6.48690400	0.44737300

H	-1.56931600	-7.11886200	-0.17207200
H	-1.56766500	-5.83277700	1.04619400
H	-2.29892500	-6.62525500	-2.55812500
H	-3.84561800	-5.97884600	-1.97684800
H	-2.80082900	-4.98953300	-3.01797900
C	-6.28387700	-2.73483900	0.87741900
C	-6.77836800	-1.36057200	1.34412500
C	-7.18532100	-3.18780900	-0.28695300
C	-6.42744900	-3.70975600	2.06132800
H	-6.19975300	-0.98592400	2.19519300
H	-6.73881200	-0.61599100	0.54188800
H	-7.82079400	-1.44788400	1.66445900
H	-6.92776900	-4.19115400	-0.62718700
H	-8.22994600	-3.18948900	0.04247000
H	-7.09963600	-2.49688600	-1.13233900
H	-7.46722400	-3.71113500	2.40558300
H	-6.15490300	-4.72709200	1.77972700
H	-5.79569100	-3.39611800	2.89918800
O	0.06812500	3.27805200	0.10026100
O	-4.80649100	-4.99316800	-0.09949500

DQ-H$^-$

C	-1.97333700	-0.24748500	0.01512800
C	-0.77658900	-0.08045700	-0.69841300
C	-0.05633400	1.10690700	-0.70515200
C	-0.53475700	2.25320000	0.04868100
C	-1.77100300	2.07362000	0.79063200
C	-2.43515000	0.85467500	0.75065000
C	-2.71563000	-1.52731700	-0.00655200

C	-2.05016900	-2.75444800	-0.08712700
C	-2.71851600	-3.98161900	-0.11640100
C	-4.12708000	-3.95665500	-0.04523600
C	-4.84733700	-2.74671300	0.04551100
C	-4.11439400	-1.55988100	0.05564800
H	-0.42428600	-0.91948800	-1.29285300
H	-3.34452300	0.72600400	1.33165400
H	-0.96704900	-2.74000700	-0.10407800
H	-4.63980500	-0.61286400	0.08915900
C	-2.31815500	3.24971100	1.61194500
C	-3.61890400	2.90248800	2.34616800
C	-1.28736000	3.67927800	2.67113900
C	-2.61442300	4.43813500	0.67929300
H	-4.41929500	2.62133600	1.65269200
H	-3.48160200	2.08079300	3.05775600
H	-3.96168100	3.77677800	2.91087500
H	-0.34820400	3.94925900	2.18680700
H	-1.66016200	4.53788900	3.24401000
H	-1.09858400	2.86153000	3.37641100
H	-2.97838400	5.29880000	1.25496400
H	-1.70876600	4.72182100	0.14125400
H	-3.38840000	4.16886900	-0.04876900
C	1.23911500	1.24705200	-1.51707800
C	1.07379300	2.35189800	-2.57613700
C	2.40756700	1.60737900	-0.58148100
C	1.61872500	-0.04505200	-2.25043700
H	0.28578500	2.08220000	-3.28885600
H	0.80442800	3.29255900	-2.09378100
H	2.00515100	2.48781800	-3.14058900

H	2.57797300	0.80333800	0.14411700
H	3.33225600	1.74107400	-1.15725400
H	2.18196900	2.52746200	-0.04065600
H	2.55388700	0.11075400	-2.80003200
H	1.77651400	-0.87811800	-1.55618600
H	0.85434700	-0.34575900	-2.97535800
C	-1.93163700	-5.30412000	-0.20678300
C	-0.41568200	-5.06321200	-0.25267600
C	-2.18497900	-6.18019000	1.03848100
C	-2.27962500	-6.05781000	-1.50872700
H	-0.12368800	-4.46726200	-1.12255000
H	-0.05695400	-4.55946400	0.64966900
H	0.09509000	-6.02867900	-0.32257900
H	-3.23319500	-6.43873700	1.21185700
H	-1.62702100	-7.11842300	0.95177400
H	-1.83658900	-5.65830100	1.93494200
H	-1.71398200	-6.99417900	-1.55756800
H	-3.33689500	-6.31226300	-1.62905900
H	-2.00451300	-5.44766000	-2.37444700
C	-6.38500000	-2.73143100	0.10910900
C	-6.93479600	-1.30178000	0.20832800
C	-6.98015300	-3.35896200	-1.16474500
C	-6.87839600	-3.49089900	1.35439800
H	-6.57804900	-0.78708900	1.10634000
H	-6.66820100	-0.69750300	-0.66454400
H	-8.02743300	-1.34466700	0.26056700
H	-6.67849700	-4.40014500	-1.28337700
H	-8.07470900	-3.31894900	-1.12122200
H	-6.65877300	-2.80160500	-2.05124900

H	-7.97238000	-3.44646500	1.40448900
H	-6.57720300	-4.53859100	1.33824300
H	-6.48111500	-3.02964500	2.26494200
O	0.09803500	3.36247000	0.05633500
O	-4.87520200	-5.10759900	-0.05943200
H	-4.30538300	-5.87563700	-0.16652300

Base: N,N-Diisopropylethylamine

N	1.54589500	-1.13617400	0.23521200
C	2.14244500	-0.31063300	1.29805300
C	3.24549000	-0.98475000	2.12861200
C	1.03920500	0.21565200	2.21703300
H	2.59330400	0.55398400	0.79844400
H	4.02595100	-1.42178400	1.50144100
H	3.71549600	-0.24740700	2.78724300
H	2.83838800	-1.77624600	2.76617200
H	0.29775600	0.77650500	1.64147400
H	0.52361900	-0.61070900	2.71978700
H	1.45091900	0.87061100	2.99179200
C	2.16052500	-1.00780200	-1.09349300
C	3.67512500	-1.24707300	-1.14303200
C	1.80449500	0.33679200	-1.72808300
H	1.69085100	-1.78360200	-1.70918100
H	3.94604600	-2.20890700	-0.69637600
H	4.02112100	-1.25219700	-2.18161800
H	4.21952200	-0.45552600	-0.61646300
H	0.72196300	0.49027700	-1.71306000
H	2.27564000	1.17218500	-1.19928400

H	2.14841100	0.37262600	-2.76648400
C	1.26603100	-2.51715600	0.61801100
C	0.02105600	-3.06876400	-0.07035400
H	1.09182600	-2.54301900	1.69781500
H	2.12570100	-3.18476100	0.42958900
H	-0.18185200	-4.08999100	0.26661500
H	-0.84512900	-2.44452100	0.16807700
H	0.12749600	-3.09643000	-1.15861700

Base-H$^+$

N	1.46919100	-1.10252200	0.26240300
C	2.16418900	-0.25755600	1.33508100
C	3.21029400	-1.03697100	2.12008000
C	1.09814800	0.33983400	2.24202500
H	2.65503600	0.54592000	0.78405900
H	3.92799100	-1.55142000	1.47914100
H	3.76174000	-0.31819000	2.73088600
H	2.75191800	-1.76340200	2.79527900
H	0.38610100	0.94569400	1.67303700
H	0.55243900	-0.43938000	2.78328900
H	1.58103900	0.98543300	2.97896700
C	2.06978600	-0.96351800	-1.13217200
C	3.54328100	-1.33095300	-1.16874300
C	1.80450400	0.43840100	-1.66473200
H	1.50277800	-1.67259500	-1.73765400
H	3.73579500	-2.33710900	-0.78809200
H	3.86518600	-1.30568800	-2.21262300
H	4.15251000	-0.61062500	-0.61586700
H	0.75155600	0.71716100	-1.55520200

H	2.42474100	1.19495000	-1.17740500
H	2.04459400	0.45115000	-2.73021900
C	1.23616700	-2.52799900	0.69112800
C	0.23026000	-3.24286600	-0.19311800
H	0.86146300	-2.47324900	1.71472700
H	2.20178400	-3.03384800	0.70248900
H	-0.04252900	-4.18184800	0.29339000
H	-0.68285100	-2.65100900	-0.31204100
H	0.62856100	-3.48538700	-1.17962900
H	0.52918200	-0.69936800	0.17212600

3a

C	0.28295400	0.95021600	2.83980400
C	1.29384700	0.51531900	1.96966600
C	2.56578400	1.06326200	1.87943300
C	2.85511000	2.13657600	2.71192400
C	1.86881900	2.60981800	3.59562000
C	0.60146600	2.03405600	3.67485800
C	-0.84527200	0.08701500	2.58006200
C	-0.47416900	-0.79162800	1.60116000
H	3.83843400	2.59394100	2.68141000
H	2.10696300	3.44833800	4.24112200
H	-0.12838600	2.42709800	4.37590500
H	-1.80936000	0.11006200	3.06655600
H	-1.02734400	-1.58995000	1.12649300
N	0.84302300	-0.53972900	1.23544400
C	3.49768900	0.39791000	0.96034700
O	4.64441700	0.69022000	0.76448900
C	0.70001900	-4.54835700	-1.08378600

C	0.81086600	-3.15814900	-1.05966300
C	1.49067700	-2.54071300	-0.01093000
C	2.04670400	-3.31204800	1.01375100
C	1.93482400	-4.69583900	0.98245500
C	1.26058800	-5.31675500	-0.06943200
H	0.17327800	-5.02590600	-1.90326900
H	0.36515200	-2.58192300	-1.86160900
H	2.56845100	-2.82141500	1.83026800
H	2.37296200	-5.28998000	1.77762600
H	1.17273300	-6.39818700	-0.09512800
C	1.63308200	-1.03520800	0.12749200
O	3.01183300	-0.74488700	0.33589400
C	1.23917100	-0.24847700	-1.14107500
F	1.89887200	-0.68532100	-2.21260900
F	-0.07312300	-0.34323600	-1.38061600
F	1.53123000	1.04791900	-0.97819500

(*R*)-4

C	-6.35623400	-1.30238300	-1.76499700
C	-5.74166600	-1.58912900	-0.51467000
C	-5.30430600	-0.50816500	0.30297800
C	-5.59027600	0.78961800	-0.13893500
C	-6.21506400	1.06248800	-1.35873600
C	-6.58077300	0.01547500	-2.18406400
C	-6.67838300	-2.54820000	-2.38790800
C	-6.29649000	-3.52422400	-1.52784300
H	-5.27155400	1.61900500	0.48621100
H	-6.39397800	2.08984700	-1.65529200
H	-7.05165900	0.19863900	-3.14541500

H	-7.14387400	-2.69078900	-3.35202200
H	-6.38190600	-4.59059700	-1.64832200
H	-3.70546200	-2.92020400	1.28896300
N	-5.74179000	-2.97256300	-0.37497600
C	-4.42968400	-0.50783200	1.48336700
O	-3.68638600	-1.39603300	1.87296100
H	-4.41736900	0.45547600	2.01927700
C	-6.23236800	-2.83522100	4.44088500
C	-5.53948100	-3.27320700	3.31657900
C	-6.12620100	-3.17870500	2.05435400
C	-7.42011000	-2.67265700	1.92564800
C	-8.11232700	-2.23728300	3.05315600
C	-7.51836300	-2.31382200	4.31075700
H	-5.76683600	-2.90186900	5.41896800
H	-4.53804600	-3.67980500	3.41051800
H	-7.88743500	-2.61419500	0.94643300
H	-9.11563100	-1.83773100	2.94624500
H	-8.05744900	-1.97064900	5.18820800
C	-5.37467100	-3.72925400	0.83683400
O	-4.00646800	-3.81511700	1.00086500
C	-5.79774100	-5.21017700	0.69335700
F	-5.51164100	-5.86248300	1.82054700
F	-7.11059900	-5.34391500	0.46796500
F	-5.14375800	-5.82808100	-0.29804200

TS-1

C	7.90991400	-3.64600900	1.41220600
C	7.02548800	-2.60027100	1.66672800
C	7.45257600	-1.42376100	2.27642800

C	8.79530900	-1.30125900	2.62479300
C	9.68991300	-2.34337000	2.36350000
C	9.25434400	-3.52000400	1.75822500
C	7.21774300	-4.81873000	0.76982400
C	5.62465300	-2.93443000	1.20925100
H	6.74902500	-0.62109200	2.48436100
H	9.15013800	-0.39216000	3.09963300
H	10.73459100	-2.23472100	2.63822100
H	9.95163700	-4.32953100	1.56249800
H	7.64663800	-5.05781000	-0.20720300
H	5.24008800	-2.23928400	0.45801700
H	7.29559300	-5.72591900	1.37927100
C	4.01045200	-1.79189500	2.76648800
C	4.27410000	-3.98483600	3.02830400
N	3.25791000	-2.30815000	3.75345400
C	2.33905600	-1.60537300	4.56262800
C	0.99725900	-1.97444200	4.56811000
C	2.74671700	-0.51176900	5.31710100
C	0.07571700	-1.26586200	5.32127800
C	1.82591000	0.21264200	6.05747700
C	0.49268700	-0.16846300	6.06095600
F	4.02080600	-0.13346400	5.31925000
F	2.21314400	1.28434600	6.74305700
F	-0.39634400	0.54628100	6.74140300
F	-1.21079700	-1.60145900	5.29750700
F	0.58029600	-2.98809700	3.81693200
N	3.39679000	-3.66919800	3.93024900
N	4.66259500	-2.88383600	2.31312800
C	4.81199700	-5.31246600	2.61306200

H	5.81266800	-5.47244400	3.03635600
H	4.15454700	-6.11412900	2.94993800
C	5.73590400	-4.39272000	0.62208600
H	5.44951300	-4.35748700	-0.42893600
O	4.82868000	-5.31943500	1.19779800
C	0.49000200	1.11692400	2.95220200
C	1.41093900	0.31529000	2.23490300
C	2.79153700	0.56010800	2.22837200
C	3.23867800	1.65742400	2.94538100
C	2.34236200	2.48573000	3.65476200
C	0.98071700	2.22565300	3.66779100
C	-0.79967600	0.50727700	2.77677300
C	-0.61103700	-0.60034400	1.99069700
H	4.30437500	1.87408000	2.96668000
H	2.73190200	3.33511000	4.20721700
H	0.30335400	2.85849500	4.23481300
H	-1.74085700	0.84113100	3.19001000
H	-1.32807700	-1.32388400	1.62946800
N	0.71908400	-0.72156100	1.66939600
C	3.70523700	-0.36416800	1.46921000
O	3.26144200	-0.99415100	0.47012800
H	4.75189400	0.00020000	1.47122300
H	1.15650700	-1.37519100	1.03129500

INT-1

C	7.91585100	-3.61045700	1.25778400
C	7.00235400	-2.60477700	1.56549900
C	7.42155400	-1.38589700	2.09212900
C	8.78318500	-1.18126700	2.30067400

C	9.70494600	-2.18353400	1.98496800
C	9.27841000	-3.40258200	1.46331400
C	7.23198900	-4.83815700	0.71872700
C	5.58712500	-3.03567700	1.25157900
H	6.70251400	-0.60932600	2.33900700
H	9.13091300	-0.23770800	2.70868100
H	10.76356500	-2.01018700	2.15167400
H	9.99596200	-4.18236100	1.22495300
H	7.51878200	-5.02905400	-0.31958000
H	5.10523500	-2.44173000	0.46910400
H	7.47731800	-5.73974500	1.29007400
C	3.88871800	-1.90053600	2.73095200
C	4.52055800	-3.92091900	3.32485400
N	3.26517200	-2.31924300	3.84049600
C	2.22326000	-1.67147700	4.54824900
C	0.90720800	-2.04913600	4.30477500
C	2.49233200	-0.64134800	5.43999800
C	-0.13729800	-1.38881100	4.92946800
C	1.45120500	0.03347100	6.05689000
C	0.14047200	-0.34240500	5.79806400
F	3.74418900	-0.26879400	5.67452500
F	1.70112700	1.05420200	6.87125800
F	-0.85749400	0.32826300	6.35844000
F	-1.39701200	-1.72633800	4.67346300
F	0.64759200	-3.02194000	3.43928800
N	3.63509500	-3.59131300	4.21478300
N	4.70455000	-2.91755900	2.41460600
C	5.21660300	-5.21223900	3.05326900
H	6.27757100	-5.14994700	3.32958100

H	4.74646600	-6.02395100	3.60814600
C	5.71561700	-4.54700900	0.81411600
H	5.22543000	-4.67463300	-0.15060000
O	5.03773000	-5.45597100	1.66961800
C	0.62067200	1.34962200	2.99522000
C	1.43441200	0.39856900	2.33197800
C	2.83353500	0.38433400	2.41647000
C	3.41818200	1.39202600	3.16512400
C	2.63658000	2.36178600	3.83316100
C	1.25255500	2.34927400	3.76066100
C	-0.73873900	0.97254200	2.72176700
C	-0.68837500	-0.14965300	1.93030000
H	4.50200500	1.42374000	3.25718000
H	3.13520700	3.12811500	4.41888900
H	0.66558300	3.09184400	4.29413500
H	-1.63567200	1.46455300	3.07046400
H	-1.49486800	-0.73396000	1.50988000
N	0.61692700	-0.49933400	1.70258600
C	3.60472300	-0.74339400	1.73005400
O	2.99501400	-1.34425900	0.70232300
H	4.62430600	-0.33909700	1.51717600
H	1.03479900	-1.21910100	1.11350800

INT-2

C	5.29730400	-3.25125500	-2.14264500
C	4.29683700	-2.48240900	-1.55126700
C	2.99869200	-2.46435700	-2.05460600
C	2.71438300	-3.23897600	-3.17649600
C	3.71111000	-4.01641000	-3.77266900

C	5.00655100	-4.02972700	-3.26054200
C	6.60905700	-3.10675100	-1.41759900
C	4.84105700	-1.73454500	-0.35184700
H	2.22783200	-1.86325600	-1.58260900
H	1.71098500	-3.23960300	-3.58953700
H	3.47302900	-4.61410600	-4.64695400
H	5.78006000	-4.63124300	-3.72847000
H	6.85739800	-4.02386300	-0.87453800
H	4.43650900	-2.09908300	0.59369800
H	7.44781700	-2.88457500	-2.08411200
C	3.56701800	0.43188300	0.12943600
C	5.25473800	0.54413900	-1.24164900
N	3.70776100	1.66432400	-0.36969100
C	2.85298800	2.78043300	-0.18761800
C	3.38623000	4.00830900	0.19070400
C	1.48218400	2.65154500	-0.38355300
C	2.55286000	5.10158900	0.36587100
C	0.64290100	3.73682000	-0.19455800
C	1.18364500	4.96285200	0.17216000
F	0.97089800	1.47169400	-0.71935900
F	-0.66422200	3.61087900	-0.37329500
F	0.38830400	6.00432000	0.34839300
F	3.05547400	6.27284900	0.72999400
F	4.68589500	4.12401700	0.41780700
N	4.76584800	1.75041800	-1.22210400
N	4.53038800	-0.29593400	-0.43668200
C	6.50642400	-0.01239300	-1.83954700
H	6.28204600	-0.61256700	-2.72999300
H	7.18425200	0.79687300	-2.11062000

C	6.40177600	-1.94350700	-0.42483700
H	6.78589100	-2.17940400	0.56678300
O	7.10599200	-0.76992300	-0.80549000
C	0.56727300	1.02959900	4.10670400
C	0.98182400	0.30129100	2.95785500
C	2.15085900	0.64938000	2.24648700
C	2.92003700	1.71486700	2.73996500
C	2.52620800	2.42389300	3.87364300
C	1.35251300	2.09575200	4.55252100
C	-0.65505400	0.42517900	4.55759400
C	-0.91944400	-0.60441800	3.70250300
H	3.85123100	1.98439300	2.24976100
H	3.14574100	3.23866000	4.23060800
H	1.05506800	2.66270400	5.42963300
H	-1.25030900	0.72214300	5.40813500
H	-1.73576400	-1.31191600	3.69288100
N	0.06699000	-0.67796900	2.73871300
C	2.49671100	-0.10653800	1.06020400
O	1.98389300	-1.16035000	0.72024200
H	0.12740500	-1.36901400	2.00330400

INT-3

C	4.96944800	-3.37791600	-1.80978700
C	4.37798500	-2.50107900	-0.90352900
C	3.05454500	-2.64183300	-0.49763000
C	2.32430200	-3.71287100	-1.00910800
C	2.91370500	-4.61186800	-1.90259200
C	4.23606600	-4.44976800	-2.31295300
C	6.39116900	-2.97791600	-2.11164200

C	5.36187900	-1.43480000	-0.47645500
H	2.58739700	-1.91467600	0.16540400
H	1.28769900	-3.84454600	-0.71607300
H	2.32926900	-5.43969000	-2.29216600
H	4.68324100	-5.14082200	-3.02143200
H	7.10063600	-3.68324700	-1.66729700
H	5.69113400	-1.55084000	0.55705700
H	6.60617700	-2.93017000	-3.18353200
C	4.13750200	0.65608100	0.30844800
C	4.66429800	0.53462300	-1.80422300
N	3.70597300	1.72488700	-0.36797500
C	2.90476700	2.77444700	0.14091600
C	3.31345800	3.48375300	1.26379000
C	1.62908100	2.96984200	-0.37873700
C	2.44520400	4.36236600	1.89004200
C	0.76100100	3.85651500	0.23718700
C	1.16956600	4.54472200	1.37263100
F	1.22817500	2.29235400	-1.44292000
F	-0.46448500	4.03650700	-0.24194400
F	0.33161300	5.37957300	1.97089600
F	2.82520600	5.02053500	2.97953500
F	4.52277700	3.27295200	1.77749900
N	4.02526000	1.66224900	-1.69009900
N	4.76822800	-0.09730800	-0.59330600
C	5.38159800	-0.09841900	-2.95270200
H	4.78710300	-0.91787200	-3.37650500
H	5.57649500	0.64086400	-3.72953500
C	6.56650300	-1.58077500	-1.47493500
H	7.50779200	-1.49771200	-0.93243700

O	6.62612700	-0.53784200	-2.43996400
C	0.49022500	1.25450700	2.56655600
C	1.64219500	0.68543600	1.90790800
C	2.91227500	0.75804800	2.53470300
C	3.01556000	1.31736900	3.81716900
C	1.89244100	1.85148300	4.45021100
C	0.63764500	1.83309300	3.82856400
C	-0.58052000	1.06157100	1.64211500
C	-0.00829900	0.41265000	0.56100000
H	3.99555900	1.38533300	4.28036000
H	1.99981600	2.31104700	5.42728000
H	-0.21612400	2.28122100	4.33184400
H	-1.61833500	1.33985800	1.76681100
H	-0.51667000	0.09875200	-0.34559800
N	1.33535700	0.17128900	0.69985200
C	4.12958100	0.42926300	1.81979000
O	5.20085300	0.08245500	2.28645200

TS-1’

C	-5.00919900	-2.76324000	-1.70261600
C	-4.97314500	-2.62807700	-0.28030100
C	-4.03212400	-1.72990000	0.29887500
C	-3.24410000	-0.99217300	-0.58970500
C	-3.29636900	-1.11725800	-1.98040200
C	-4.17127100	-2.02371700	-2.54441000
C	-5.99732200	-3.74315300	-2.02774000
C	-6.53563800	-4.15777100	-0.85485800
H	-2.52331000	-0.29901500	-0.15992700
H	-2.64151700	-0.51474900	-2.60061600

H	-4.22529100	-2.16802200	-3.61923200
H	-6.25535400	-4.10070400	-3.01387100
H	-7.30556700	-4.89519000	-0.70410300
H	-5.01129200	-3.00370900	2.71054000
N	-5.93863900	-3.50915300	0.22312000
C	-3.65422500	-1.46077800	1.74156200
O	-4.31417800	-1.76475900	2.76251400
H	-3.06252800	-0.53393400	1.79666500
C	-8.02348000	-0.50843400	3.43880700
C	-7.35260900	-1.69735100	3.17028300
C	-7.18970900	-2.12732300	1.85245800
C	-7.71541400	-1.36799600	0.80692800
C	-8.38441900	-0.17628600	1.07818400
C	-8.53947600	0.25546600	2.39307500
H	-8.14092100	-0.17718100	4.46578700
H	-6.94178200	-2.29364700	3.97810800
H	-7.60215400	-1.70096200	-0.22132300
H	-8.78401400	0.41351500	0.25930400
H	-9.06087300	1.18429100	2.60275700
C	-6.51140800	-3.47878300	1.59017200
O	-5.59219100	-3.83845900	2.54153100
C	-7.60349700	-4.56801300	1.72207400
F	-8.02837600	-4.61860500	2.98431800
F	-8.67908600	-4.33399600	0.95470100
F	-7.13633900	-5.78498800	1.40470900
C	0.82366900	-0.64094800	4.30050200
C	-0.43365700	-0.59457500	3.69217300
C	-1.60217800	-0.57220200	4.44825200
C	-1.49212400	-0.57669900	5.83826300

C	-0.23768900	-0.60081200	6.45163300
C	0.92847400	-0.63644000	5.68822100
C	1.92541600	-0.72953500	3.27616100
C	-0.29521200	-0.58816200	2.18774100
H	-2.58298800	-0.57284800	3.97958300
H	-2.38982400	-0.55879800	6.44785100
H	-0.17059800	-0.59634400	7.53525000
H	1.90227700	-0.66422900	6.16855600
H	2.78254800	-0.09027900	3.49934300
H	-0.92313000	0.15967600	1.69645700
H	2.29233500	-1.76010300	3.20982000
C	-1.84247900	-2.49767600	1.63292400
C	0.25031400	-2.67565400	0.89133100
N	-1.60198100	-3.63773500	0.96852800
C	-2.55581800	-4.64453500	0.71059700
C	-2.85844000	-5.00635800	-0.60115400
C	-3.24985800	-5.23850600	1.75512600
C	-3.83262300	-5.95376100	-0.85860300
C	-4.22831000	-6.18972500	1.50505800
C	-4.52152700	-6.53930600	0.19856600
F	-3.00917900	-4.87744700	3.00884800
F	-4.89989100	-6.73286800	2.51176300
F	-5.49302400	-7.40840200	-0.05527000
F	-4.14093000	-6.28012400	-2.11099000
F	-2.23276700	-4.41676800	-1.61390600
N	-0.31958200	-3.77089700	0.48992200
N	-0.63209900	-1.89339200	1.59427900
C	1.66044700	-2.22968800	0.66411700
H	2.33410500	-2.73293000	1.36771900

H	1.96892200	-2.49320200	-0.34886400
C	1.21781800	-0.29295700	1.97653400
H	1.31400000	0.78966200	1.87228400
O	1.73561700	-0.82286200	0.77302400

7. Mulliken charges for II:

1	C	0.607566
2	C	0.437703
3	C	-0.092780
4	C	-0.347781
5	C	-0.394492
6	C	-0.639183
7	C	-0.941887
8	C	-0.536792
9	H	0.197212
10	H	0.266450
11	H	0.251097
12	H	0.267798
13	H	0.221076
14	H	0.287492
15	H	0.249564
16	C	-0.393896
17	C	0.648304
18	N	0.497636
19	C	-0.002858
20	C	0.045717
21	C	0.255441
22	C	0.050028
23	C	-0.247459
24	C	0.426723

25	F	-0.142665
26	F	-0.157464
27	F	-0.176390
28	F	-0.153592
29	F	-0.125999
30	N	-0.152044
31	N	0.412169
32	C	-0.738882
33	H	0.249732
34	H	0.281859
35	C	0.042603
36	H	0.277607
37	O	-0.070702
38	C	0.223167
39	C	0.136149
40	C	0.206110
41	C	-0.197602
42	C	-0.574327
43	C	-0.422219
44	C	-0.530375
45	C	-0.110250
46	H	0.257895
47	H	0.242583
48	H	0.255778
49	H	0.243898
50	H	0.240535
51	N	-0.311160
52	C	-0.010488
53	O	-0.308603

References

[1] Giardinetti, M.; Moreau, X.; Coeffard, V.; Greck, C. Aminocatalyzed Cascade Synthesis of Enantioenriched 1,7-annulated indoles from indole-7-carbaldehyde derivatives and α,β-unsaturated aldehydes. *Adv. Synth. Catal.* **2015**, *357*, 3501-3506.

[2] a) Cheng, H.-F.; Pei, Y.; Leng, F.-Q.; Li, J.-Y.; Liang, A.-P.; Zou, D.-P.; Wu, Y.J.; Wu, Y.-S. Highly efficient synthesis of aryl and heteroaryl trifluoromethyl ketones via o-iodobenzoic acid (IBX). *Tetrahedron Lett*. **2013**, *54*, 4483-4486. b) Khodakovskiy, P. V.; Volochnyuk, D. M.; Panov, D. M.; Pervak, I. I.; Zarudnitskii, E. V.; Shishkin, O. V.; Yurchenko, A. A.; Shivanyuk, A.; Tolmachev, A. A. 2-(trifluoroacetyl)imidazoles, 2-trifluoroacetyl-1,3-thiazoles, and 2-trifluoroacetyl-1,3-oxazoles. *Synthesis* **2008**, 948-956. c) Bos, M.; Huang, W. S.; Poisson, T.; Pannecoucke, X.; Charette, A. B.; Jubault, P. Catalytic enantioselective synthesis of highly functionalized difluoromethylated cyclopropanes. *Angew. Chem. Int. Ed.* **2017**, *56*, 13319-13323.

[3] a) Breslow, R. On the mechanism of thiamine action. IV. Evidence from studies on model systems. *J. Am. Chem. Soc.* **1958**, *80*, 3719-3726. b) Stetter, H. Catalyzed addition of aldehydes to activated double bonds-A new synthetic approach. *Angew. Chem. Int. Ed.* **1976**, *15*, 639-647.