

# Catalytic asymmetric [3+2] cycloaddition of isomünchnones with methyleneindolinones

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## 1. General Information

**NMR characterization data** were collected on Bruker ASCEND™ 400M and 600M. <sup>1</sup>H NMR and <sup>13</sup>C{<sup>1</sup>H} NMR: chemical shifts  $\delta$  were recorded in ppm relative to tetramethylsilane and internally referenced to the residual solvent signal (for <sup>1</sup>H NMR: CDCl<sub>3</sub> = 7.26 ppm; for <sup>13</sup>C NMR: CDCl<sub>3</sub> = 77.16 ppm). Data were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd = doublet of doublets, td = triplet of doublets, dt = doublet of triplets, ddd = doublet of doublet of doublets, m = multiplet), coupling constants (Hz), integration.

**Enantiomeric excesses (ee)** were determined by HPLC (High performance liquid chromatography) analysis using the corresponding commercial chiralpak column (IG, IF, IA, etc.) as stated in the experimental procedures at 25 °C.

**Optical rotations** measured on Rudolph Research Analytic Automatic Polarimeter were reported as follows:  $[\alpha]_D^{25}$  (c: g/100 mL, in CH<sub>2</sub>Cl<sub>2</sub>).

**HRMS** (High resolution mass spectra) were performed on Thermo Q-Exactive Focus (FTMS+c ESI) and data were reported as (m/z).

**Infrared spectra (IR)** were recorded on Shimadzu IRTracer-100 or Bruker Tensor II spectrometer with Plantium ATR accessory. The peaks are reported as absorption maxima ( $\tilde{\nu}$ , cm<sup>-1</sup>).

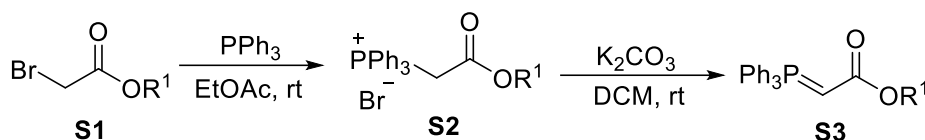
**Circular dichroism spectrum (CD)** were recorded on Applied Photophysics Chirascan.

**X-Ray crystallographic data** were collected by a Bruker D8 Venture Photon II.

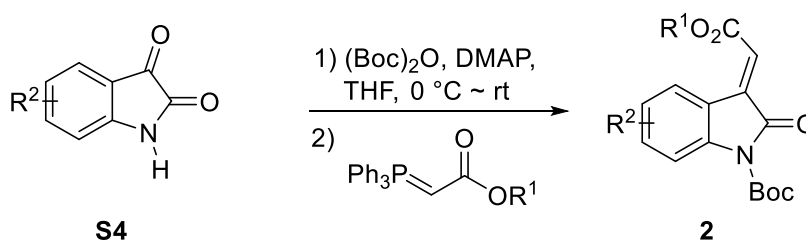
The *N,N'*-dioxides were prepared according to the methods reported in the literature.<sup>1</sup>

## 2. General Procedure for the Preparation of Substrates

### 2.1 General Procedure for the Preparation of Methyleneindolinones<sup>2</sup>



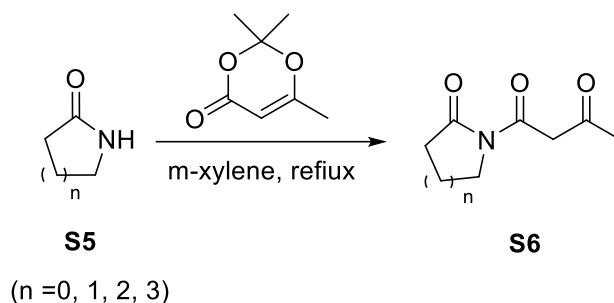
To a solution of triphenylphosphine (20 mmol) in ethyl acetate (20.0 mL) was added **S1** (20 mmol) at room temperature, and the mixture was stirred overnight. The resulting mixture was filtered (solvent: ethyl acetate), and the crude product **S2** (white solid) was directly subjected to the next reaction without further purification. To a solution of **S2** in DCM (10.0 mL) was added K<sub>2</sub>CO<sub>3</sub> (20 mmol) at room temperature. The reaction mixture was stirred for at least 30 minutes and then washed with H<sub>2</sub>O. The aqueous layer was extracted with DCM in three times. The combined organic mixtures were washed with brine (20.0 mL), dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>, filtered (solvent: DCM), and concentrated under reduced pressure. The obtained product **S3** was used directly for the next step.



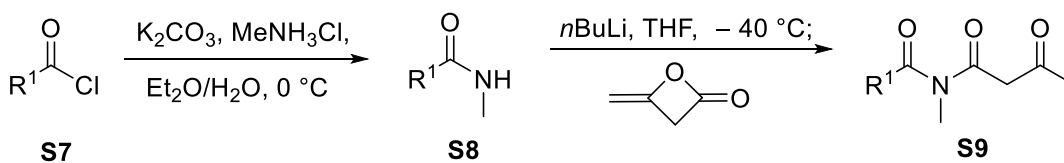
(Boc)<sub>2</sub>O (Di-*tert*-butyl dicarbonate, 24 mmol) was added to a solution of Isatin **S4** (20 mmol) and DMAP (*N,N*-

dimethylpyridin-4-amine, 2 mmol) in THF (20.0 mL) at 0 °C. After stirring for 2 h at room temperature, a solution of **S3** from general procedure 2.1 was added to the reaction mixture. Keep stirring until the reaction solution was fully transparent. Then the solvent was removed under reduced pressure. 20.0 mL water and 20.0 mL ethyl acetate were added to the mixture. The aqueous layer was washed with ethyl acetate (3x 20.0 mL). The combined organic phases was washed with brine (20.0 mL) and dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>. After being filtered and concentrated under reduced pressure, the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 15/1 (v/v). The product **2** was obtained as a yellow solid.

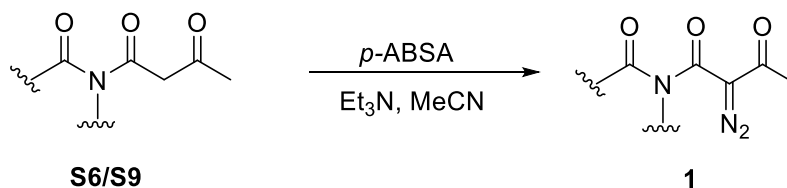
## 2.2 General Procedure for the Preparation of Diazoimides<sup>3</sup>



A solution containing **S5** (50 mmol) and 2,2,6-trimethyl-1,3-dioxin-4-one (55 mmol) in 30 mL of *m*-xylene was heated at reflux for 1 ~ 2 h. The solvent was removed under reduced pressure, and the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 4/1 (v/v). The product **S6** was obtained in 60 ~ 70% yield as a yellow oil.



K<sub>2</sub>CO<sub>3</sub> (15 mmol) was added to a solution of **S7** (10 mmol) and MeNH<sub>3</sub>Cl (15 mmol) in mixed solvent of 10.0 mL Et<sub>2</sub>O and 10.0 mL H<sub>2</sub>O. After the reaction was completed, the reaction mixture was extracted with ethyl acetate in three times. The combined organic mixtures were dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>, filtered (solvent: ethyl acetate), and concentrated under reduced pressure to afford crude product **S9**. After the following recrystallization (ethyl acetate / petroleum ether = 10/1, v/v), the product **S9** was dissolved in 20.0 mL to an over dried 100 mL round-bottom flask under N<sub>2</sub> atmosphere. At -40 °C, 5 mL 2.5 mol/L <sup>n</sup>BuLi was added dropwise to the solution of **S9**. Keep stirring until the reaction mixture became red and then 4-methyleneoxetan-2-one was added dropwise. When the reaction was completed, the solvent was removed under reduced pressure. 20.0 mL water was added and the aqueous layer was extracted with ethyl acetate (3x 20.0 mL). The combined organic phases was washed with brine (20.0 mL), and dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>. After being filtered and concentrated under reduced pressure, the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 6/1 (v/v). The product **S9** was obtained in 30 ~ 50% yield as a yellow oil.

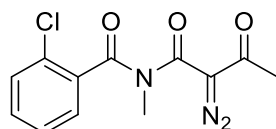


To a solution of **S6/S9** (5 mmol) and *p*-ABSA (*p*-Acetamidobenzenesulfonyl azide, 5 mmol) in 10 mL MeCN was added Et<sub>3</sub>N

(5.5 mmol) at room temperature, and the mixture was stirred overnight. After the reaction was completed, the solvent was removed under reduced pressure, and the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate =2/1 (v/v). The product **1** was obtained in 85 ~ 97% yield as a light yellow oil or solid.

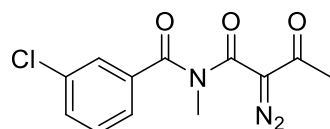
### 3. Characters of diazo compounds **2f**, **2g**, **2i**, **2k**, **2m**

#### 2-Chloro-*N*-(2-diazo-3-oxobutanoyl)-*N*-methylbenzamide (**2f**)



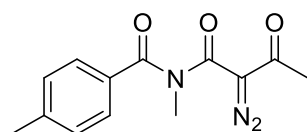
Yellow oil.  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46 – 7.35 (m, 4H), 3.20 (s, 3H), 2.44 (s, 3H).  $^{13}\text{C NMR}$  (101 MHz,  $\text{CDCl}_3$ )  $\delta$  169.58, 164.41, 134.97, 131.86, 130.07, 128.77, 127.60, 77.48, 77.16, 76.84, 34.06, 28.56. **ESI-HRMS** scaled for  $[\text{C}_{12}\text{H}_{11}\text{Cl}^{34,9689}\text{N}_3\text{O}_3+\text{H}^+]$ : 280.0483, found 280.0486.  $[\text{C}_{12}\text{H}_{11}\text{Cl}^{36,9659}\text{N}_3\text{O}_3+\text{H}^+]$ : 282.0454, found 280.0457. **IR** (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 2957.89, 2927.51, 2136.44, 1661.94, 1592.26, 1475.57, 1436.03, 1301.01, 1187.45, 1073.16, 1024.46, 966.11, 930.91, 774.67, 635.07.

#### 3-Chloro-*N*-(2-diazo-3-oxobutanoyl)-*N*-methylbenzamide (**2g**)



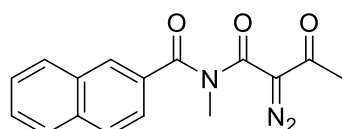
Yellow oil.  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.47 (s, 1H), 7.38 – 7.34 (m, 2H), 7.24 (t,  $J = 7.9$  Hz, 1H), 3.16 (s, 3H), 2.10 (s, 3H).  $^{13}\text{C NMR}$  (151 MHz,  $\text{CDCl}_3$ )  $\delta$  170.79, 164.80, 136.08, 134.20, 131.96, 129.60, 128.23, 126.31, 80.43, 43.45, 33.85, 27.11. **ESI-HRMS** scaled for  $[\text{C}_{12}\text{H}_{11}\text{Cl}^{34,9689}\text{N}_3\text{O}_3+\text{H}^+]$ : 280.0483, found 280.0485.  $[\text{C}_{12}\text{H}_{11}\text{Cl}^{36,9659}\text{N}_3\text{O}_3+\text{H}^+]$ : 282.0454, found 280.0453. **IR** (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 2976.7, 2122.94, 1700.04, 1662.43, 1423.25, 1343.44, 1296.19, 1045.68, 938.87, 803.85.

#### *N*-(2-Diazo-3-oxobutanoyl)-*N*,4-dimethylbenzamide (**2i**)



Yellow oil.  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.44 (d,  $J = 8.2$  Hz, 2H), 7.14 (d,  $J = 8.0$  Hz, 2H), 3.24 (s, 3H), 2.30 (s, 3H), 2.15 (s, 3H).  $^{13}\text{C NMR}$  (151 MHz,  $\text{CDCl}_3$ )  $\delta$  172.30, 165.18, 143.15, 131.51, 129.04, 128.55, 77.37, 77.16, 76.95, 34.02, 27.39, 21.41. **ESI-HRMS** scaled for  $[\text{C}_{13}\text{H}_{13}\text{N}_3\text{O}_3+\text{H}^+]$ : 260.1030, found 260.1031. **IR** (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 2956.44, 2925.34, 2122.22, 1662.43, 1609.62, 1363.46, 1297.63, 1177.8, 1039.17, 1016.02, 966.35, 932.6, 834.71, 789.62, 738.27, 627.84.

#### *N*-(2-Diazo-3-oxobutanoyl)-*N*-methyl-2-naphthamide (**2k**)

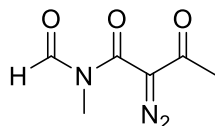


Dark yellow oil.  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.17 – 8.13 (m, 1H), 7.86 (m, 3H), 7.65 (dd,  $J = 8.5, 1.8$  Hz, 1H), 7.55 (m, 2H), 3.38 (s, 3H), 2.17 (s, 3H).  $^{13}\text{C NMR}$  (151 MHz,  $\text{CDCl}_3$ )  $\delta$  172.67, 165.39, 134.96, 132.25, 131.72, 129.76, 129.01, 128.51,



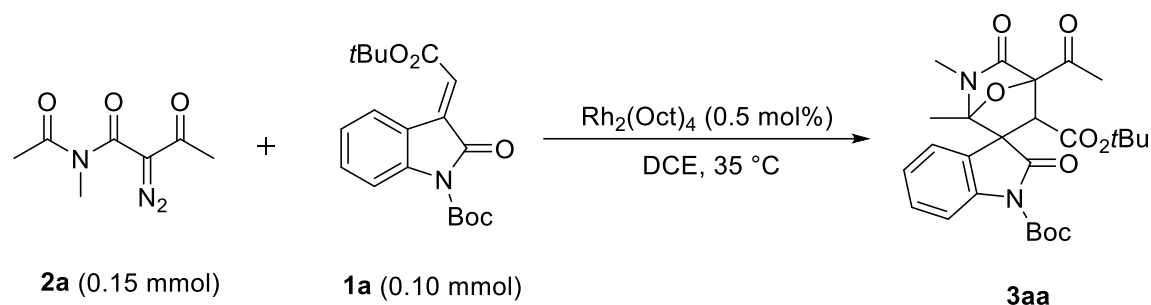
127.89, 127.22, 124.54, 77.37, 77.16, 76.95, 34.35, 27.50. **ESI-HRMS** scaled for  $[C_{16}H_{13}N_3O_3+H^+]$ : 296.1030, found 296.1033. **IR** (film):  $\tilde{\nu}$  ( $cm^{-1}$ ) 2956.68, 2925.58, 2121.49, 1659.53, 1609.38, 1419.39, 1295.22, 1177.8, 1114.87, 1087.63, 1038.69, 1016.02, 966.35, 932.60, 834.71, 789.86, 738.27, 627.84.

#### 2-Diazo-N-formyl-N-methyl-3-oxobutanamide (2m)



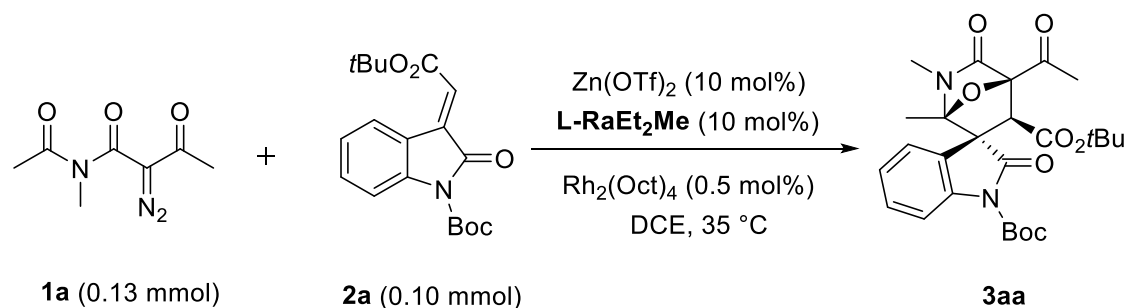
Yellow oil. **<sup>1</sup>H NMR** (400 MHz,  $CDCl_3$ )  $\delta$  8.69 (s, 1H), 3.14 (s, 3H), 2.38 (s, 3H). **<sup>13</sup>C NMR** (101 MHz,  $CDCl_3$ )  $\delta$  186.70, 163.39, 162.80, 28.70, 27.57. **ESI-HRMS** scaled for  $[C_6H_7N_3O_3+H^+]$ : 170.0560, found 170.0562. **IR** (film):  $\tilde{\nu}$  ( $cm^{-1}$ ) 2955.72, 2931.85, 2133.79, 1715.71, 1659.29, 1417.7, 965.87, 901.01, 790.10, 742.12

#### 4. General Procedure for the Preparation of Racemic Products



An oven-dried test tube was charged with **1a** (0.15 mmol), **2a** (0.15 mmol),  $Rh_2(Oct)_4$  (0.5 mol %) and DCE (1.0 mL) under  $N_2$  atmosphere. The resulted solution was stirred at 35 °C for 4 h. The reaction mixture was subjected to flash column chromatography on silica gel and eluted with petroleum ether/ethyl acetate = 4/1 (v/v) to afford the corresponding racemic product **3aa** (white solid, 41.1 mg, 82% yield). And other racemic products **3** were prepared according to the procedure described for **3aa**.

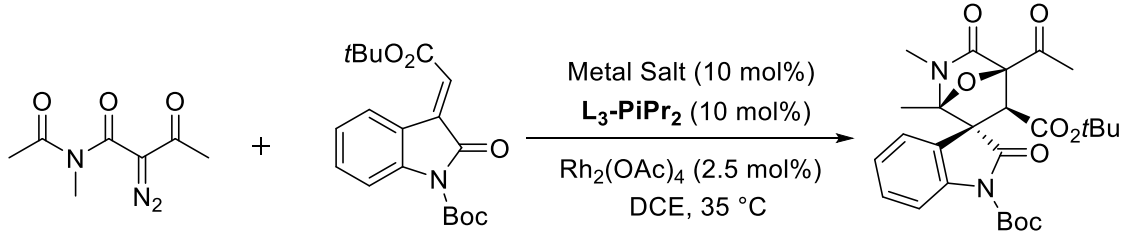
#### 5. General Procedure for the Catalytic Asymmetric Reaction



An oven-dried test tube was charged with catalyst **L-RaEt<sub>2</sub>Me**/ $Zn(OTf)_2$  (1:1, 10 mol %), **1a** (0.13 mmol) and **2a** (0.10 mmol) in 0.5 mL DCE under  $N_2$  atmosphere. At 35 °C, a solution of  $Rh_2(Oct)_4$  (0.5 mol %) in 0.5 mL DCE was added and the reaction was stirred at 35 °C for 4 h. The reaction mixture was subjected to flash column chromatography on silica gel and eluted with petroleum ether/ethyl acetate = 4/1 (v/v) to afford the corresponding product **3aa** (white solid, 44.7 mg, 89% yield, 98% ee, 98:2 dr).

## 6. The Optimization of Reaction Conditions

**Table S1** Optimization of Metal Salt

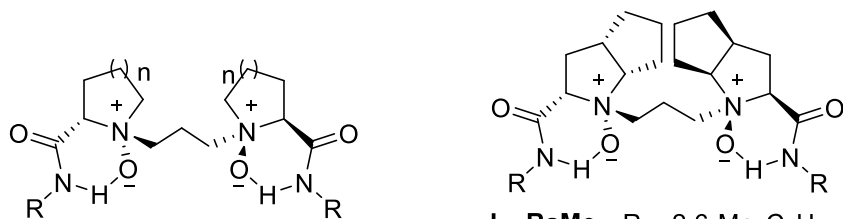
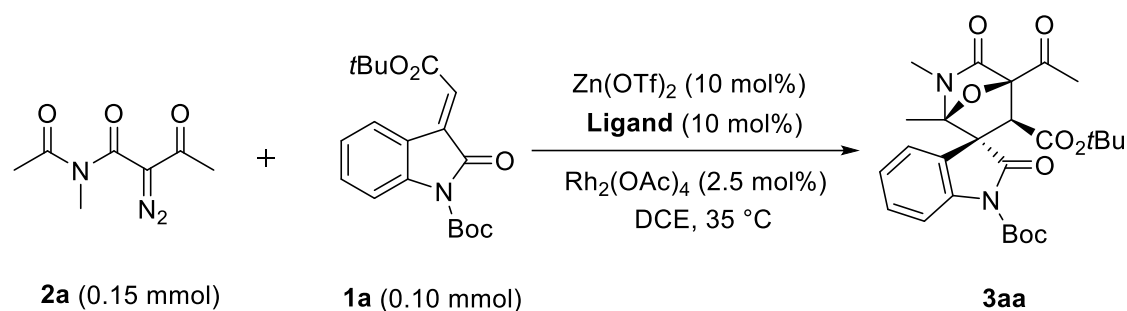


Reaction scheme showing the synthesis of **3aa** from **2a** and **1a**. Reagents: Metal Salt (10 mol%),  $L_3\text{-PiPr}_2$  (10 mol%),  $\text{Rh}_2(\text{OAc})_4$  (2.5 mol%), DCE, 35 °C.

entry <sup>[a]</sup>	Metal Salt	yield [%] <sup>[b]</sup>	dr <sup>[c]</sup>	ee [%] <sup>[c]</sup>
1	Mg(OTf) <sub>2</sub>	39	81/19	97/90
2	Fe(OTf) <sub>2</sub>	68	85/15	75/75
3	Co(OTf) <sub>2</sub>	71	88/12	75/78
4	Ni(OTf) <sub>2</sub>	62	72/28	85/90
5	Cu(OTf) <sub>2</sub>	60	88/12	74/80
6	Zn(OTf) <sub>2</sub>	68	76:24	98/95
7	Sc(OTf) <sub>3</sub>	48	93:7	4/26
8	Y(OTf) <sub>3</sub>	78	75:25	4/38
9	La(OTf) <sub>3</sub>	25	19:81	11/58
10	Ce(OTf) <sub>4</sub>	28	10:90	9/20
11	Ce(OTf) <sub>3</sub>	56	40:60	37/25
12	Nd(OTf) <sub>3</sub>	34	19:81	36/75
13	Sm(OTf) <sub>3</sub>	60	46:54	5/46
14	Eu(OTf) <sub>3</sub>	62	73:27	2/45
15	Gd(OTf) <sub>3</sub>	82	71:29	19:69
16	Tb(OTf) <sub>3</sub>	61	77:23	1/35
17	Dy(OTf) <sub>3</sub>	60	79:21	2/34
18	Ho(OTf) <sub>3</sub>	56	76:24	4/30
19	Er(OTf) <sub>3</sub>	70	74:26	3/30
20	Tm(OTf) <sub>3</sub>	70	75:25	4/29
21	Yb(OTf) <sub>3</sub>	71	53:47	15/56

<sup>a</sup>The reactions were performed with **2a** (0.15 mmol), **1a** (0.10 mmol),  $\text{Rh}_2(\text{OAc})_4$  (2.5 mol%) and Metal Salt/ $L_3\text{-PiPr}_2$  (1:1, 10 mol%) in DCE (0.1 M) at 35 °C for 4 h under  $\text{N}_2$  atmosphere. <sup>b</sup>Yield of the isolated product. <sup>c</sup>Determined by HPLC analysis on a chiral stationary phase.

**Table S2** Optimization of Ligand



**L<sub>3</sub>-PrPr<sub>2</sub>**: R = 2,6-*i*-Pr<sub>2</sub>C<sub>6</sub>H<sub>3</sub>, n = 1

**L<sub>3</sub>-PiPr<sub>2</sub>**: R = 2,6-*i*-Pr<sub>2</sub>C<sub>6</sub>H<sub>3</sub>, n = 2

**L<sub>3</sub>-RaMe<sub>2</sub>**: R = 2,6-Me<sub>2</sub>C<sub>6</sub>H<sub>3</sub>

**L<sub>3</sub>-RaEt<sub>2</sub>**: R = 2,6-Et<sub>2</sub>C<sub>6</sub>H<sub>3</sub>

**L<sub>3</sub>-RaPr<sub>2</sub>**: R = 2,6-*i*-Pr<sub>2</sub>C<sub>6</sub>H<sub>3</sub>

**L<sub>3</sub>-RaEt<sub>2</sub>Me**: R = 2,6-Et<sub>2</sub>-4-MeC<sub>6</sub>H<sub>2</sub>

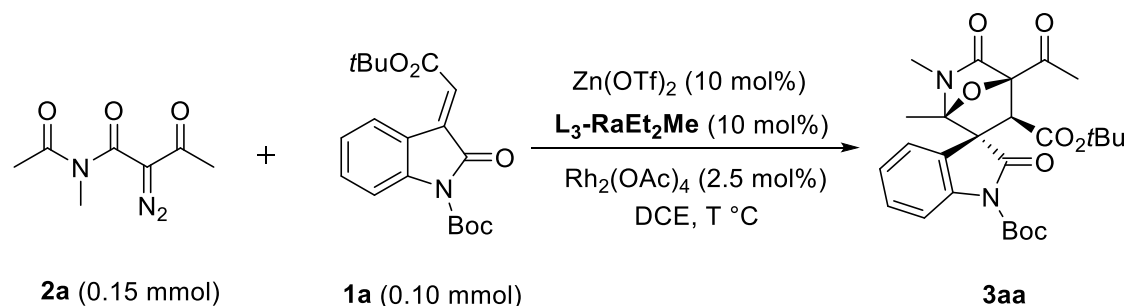
**L<sub>3</sub>-RaEt<sub>3</sub>**: R = 2,4,6-Et<sub>3</sub>C<sub>6</sub>H<sub>2</sub>

**L<sub>3</sub>-RaPr<sub>3</sub>**: R = 2,4,6-Pr<sub>3</sub>C<sub>6</sub>H<sub>2</sub>

entry <sup>[a]</sup>	Ligand	yield [%] <sup>[b]</sup>	dr <sup>[c]</sup>	ee [%] <sup>[c]</sup>
1	<b>L<sub>3</sub>-PrPr<sub>2</sub></b>	73	75/25	95/93
2	<b>L<sub>3</sub>-PiPr<sub>2</sub></b>	68	76/24	98/95
3	<b>L<sub>3</sub>-RaPr<sub>2</sub></b>	97	66/34	97/94
4	<b>L<sub>3</sub>-RaMe<sub>2</sub></b>	24	80/20	98/95
5	<b>L<sub>3</sub>-RaEt<sub>2</sub></b>	72	85/15	98/97
6	<b>L<sub>3</sub>-RaEt<sub>2</sub>Me</b>	96	89/11	98/90
7	<b>L<sub>3</sub>-RaEt<sub>3</sub></b>	81	89/11	98/90
8	<b>L<sub>3</sub>-RaPr<sub>3</sub></b>	64	85/15	97/85

<sup>a</sup>The reactions were performed with **2a** (0.15 mmol), **1a** (0.10 mmol),  $\text{Rh}_2(\text{OAc})_4$  (2.5 mol%) and  $\text{Zn(OTf)}_2$ /**Ligand** (1:1, 10 mol%) in DCE (0.1 M) at 35 °C for 4 h under N<sub>2</sub> atmosphere. <sup>b</sup>Yield of the isolated product. <sup>c</sup>Determined by HPLC analysis on a chiral stationary phase.

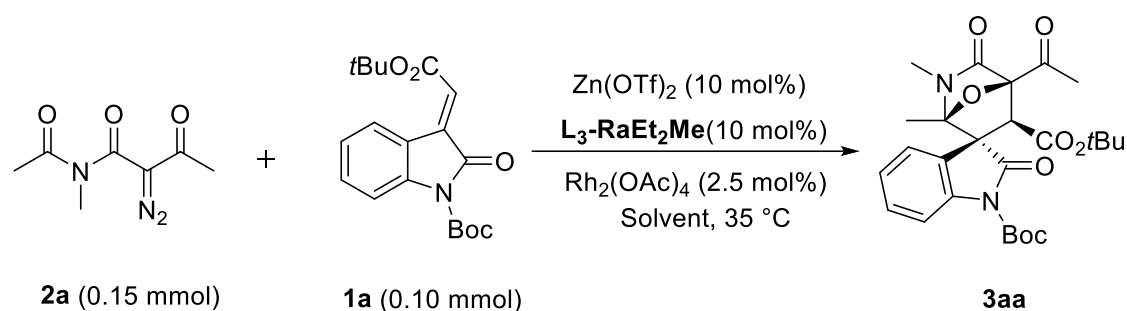
**Table S3** Optimization of Temperature



Entry <sup>[a]</sup>	T [°C]	yield [%] <sup>[b]</sup>	dr <sup>[c]</sup>	ee [%] <sup>[c]</sup>
1 <sup>d</sup>	0	91	84/16	95/97
2 <sup>e</sup>	10	85	83/17	98/98
3	20	87	80/20	98/95
4	30	91	84/16	97/92
5	35	96	89/11	98/90
6	45	85	95/5	95/-

<sup>a</sup>The reactions were performed with **2a** (0.15 mmol), **1a** (0.10 mmol), Rh<sub>2</sub>(OAc)<sub>4</sub> (2.5 mol%) and Zn(OTf)<sub>2</sub>/L<sub>3</sub>-RaEt<sub>2</sub>Me (1:1, 10 mol%) in DCE (0.1 M) at T °C for 4 h under N<sub>2</sub> atmosphere. <sup>b</sup>Yield of the isolated product. <sup>c</sup>Determined by HPLC analysis on a chiral stationary phase. <sup>d</sup>The reactions was carried out in 15 h. <sup>e</sup>The reactions was carried out in 24 h.

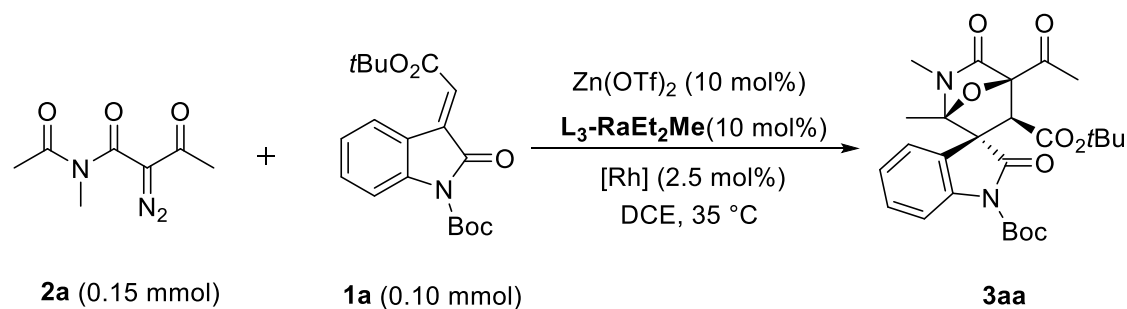
**Table S4** Optimization of Solvent



Entry <sup>[a]</sup>	Solvent	yield [%] <sup>[b]</sup>	dr <sup>[c]</sup>	ee [%] <sup>[c]</sup>
1	Et <sub>2</sub> O	36	96:4	93/54
2	THF	trace	-	-
3	Toluene	54	91:9	96/73
4	DCM	63	85:15	98/84
5	CHCl <sub>3</sub>	72	87:13	98/90
6	DCE	96	89:11	98/90
7	EA	18	83:17	90/73
8	MeCN	N.R.	-	-

<sup>a</sup>The reactions were performed with **2a** (0.15 mmol), **1a** (0.10 mmol), Rh<sub>2</sub>(OAc)<sub>4</sub> (2.5 mol%) and Zn(OTf)<sub>2</sub>/L<sub>3</sub>-RaEt<sub>2</sub>Me (1:1, 10 mol%) in Solvent (0.1 M) at 35 °C for 4 h under N<sub>2</sub> atmosphere. <sup>b</sup>Yield of the isolated product. <sup>c</sup>Determined by HPLC analysis on a chiral stationary phase.

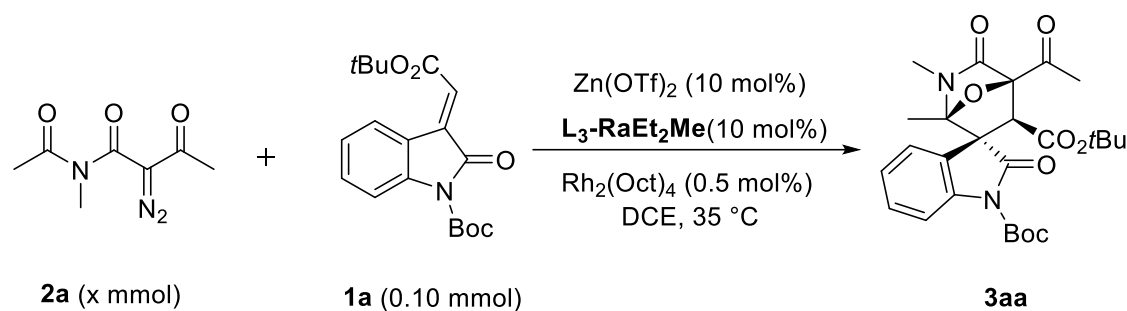
**Table S5** Optimization of [Rh]



Entry <sup>[a]</sup>	[Rh]	yield [%] <sup>[b]</sup>	dr <sup>[c]</sup>	ee [%] <sup>[c]</sup>
1	Rh <sub>2</sub> (OAc) <sub>4</sub>	96	89:11	98/90
2	Rh <sub>2</sub> (CO <sub>2</sub> CF <sub>3</sub> ) <sub>4</sub>	76	88:12	98/90
3	Rh <sub>2</sub> (Piv) <sub>4</sub>	99	78:22	98/91
4	Rh <sub>2</sub> (Oct) <sub>4</sub>	94	90:10	98/90
5 <sup>d</sup>	Rh <sub>2</sub> (OAc) <sub>4</sub>	64	89:11	98/90
6 <sup>d</sup>	Rh <sub>2</sub> (Oct) <sub>4</sub>	91	90:10	98/90

<sup>a</sup>The reactions were performed with **2a** (0.15 mmol), **1a** (0.10 mmol), [Rh] (2.5 mol%) and Zn(OTf)<sub>2</sub>/L<sub>3</sub>-RaEt<sub>2</sub>Me (1:1, 10 mol%) in Solvent (0.1 M) at 35 °C for 4 h under N<sub>2</sub> atmosphere. <sup>b</sup>Yield of the isolated product. <sup>c</sup>Determined by HPLC analysis on a chiral stationary phase. <sup>d</sup>[Rh] (0.5 mol%).

**Table S6** Optimization of the ratio of **2a** and **1a**

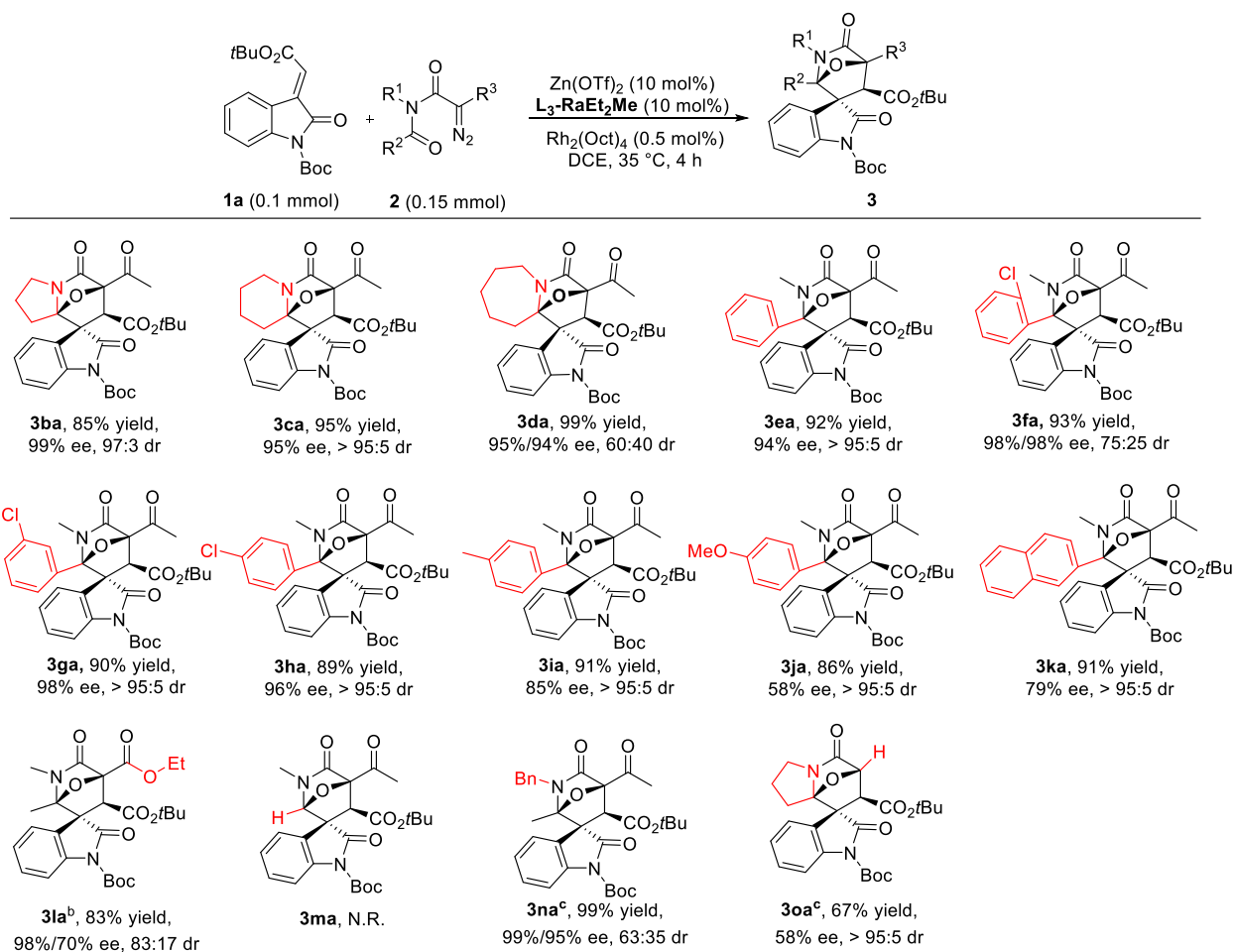


Entry <sup>[a]</sup>	x (mmol)	yield [%] <sup>[b]</sup>	dr <sup>[c]</sup>	ee [%] <sup>[c]</sup>
1	0.10	63	98:2	98/90
2	0.11	72	98:2	98/90
4	0.13	89	98:2	98/90
5 <sup>d</sup>	0.15	91	89:11	98/90
6 <sup>d</sup>	0.20	97	83:17	95/90

<sup>a</sup>The reactions were performed with **1a** (0.10 mmol), **2a** (x mmol), Rh<sub>2</sub>(Oct)<sub>4</sub> (0.5 mol%) and Zn(OTf)<sub>2</sub>/L<sub>3</sub>-RaEt<sub>2</sub>Me (1:1, 10 mol%) in Solvent (0.1 M) at 35 °C for 4 h under N<sub>2</sub> atmosphere. <sup>b</sup>Yield of the isolated product. <sup>c</sup>Determined by HPLC analysis on a chiral stationary phase.



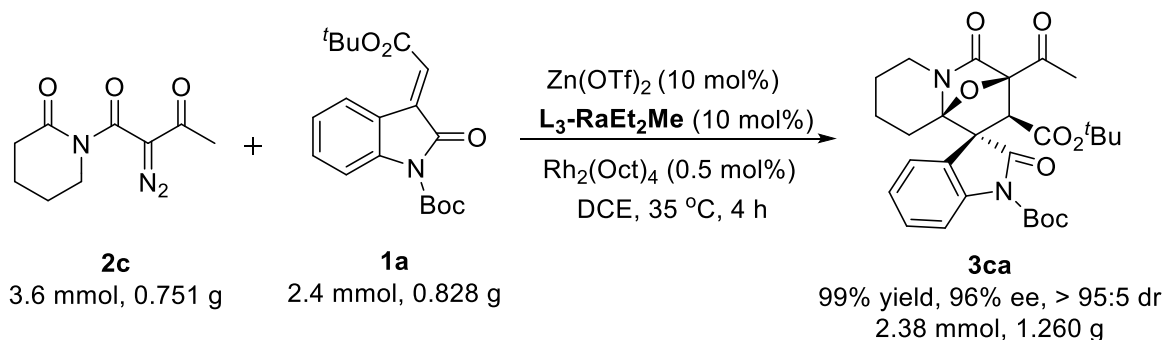
**Table S8** Substrate Scope for Diazoimides<sup>a</sup>



<sup>a</sup>Unless otherwise noted, all reactions were carried out with **1a** (0.10 mmol), **2** (0.15 mmol),  $\text{Rh}_2(\text{Oct})_4$  (0.5 mol%),  $\text{L}_3\text{-RaEt}_2\text{Me}/\text{Zn}(\text{OTf})_2$  (1:1, 10 mol%) in 1.0 mL DCE at 35 °C for 4 h. Diastereoselectivity ratios were determined by <sup>1</sup>H NMR analysis and ee values were determined by chiral HPLC analysis. <sup>b</sup>**2l** (0.13 mmol). <sup>c</sup>The reaction was treated at 10 °C for 10 h.

## 8. Experimental Procedures for Gram-Scale Synthesis and Derivatizations of **3ca**

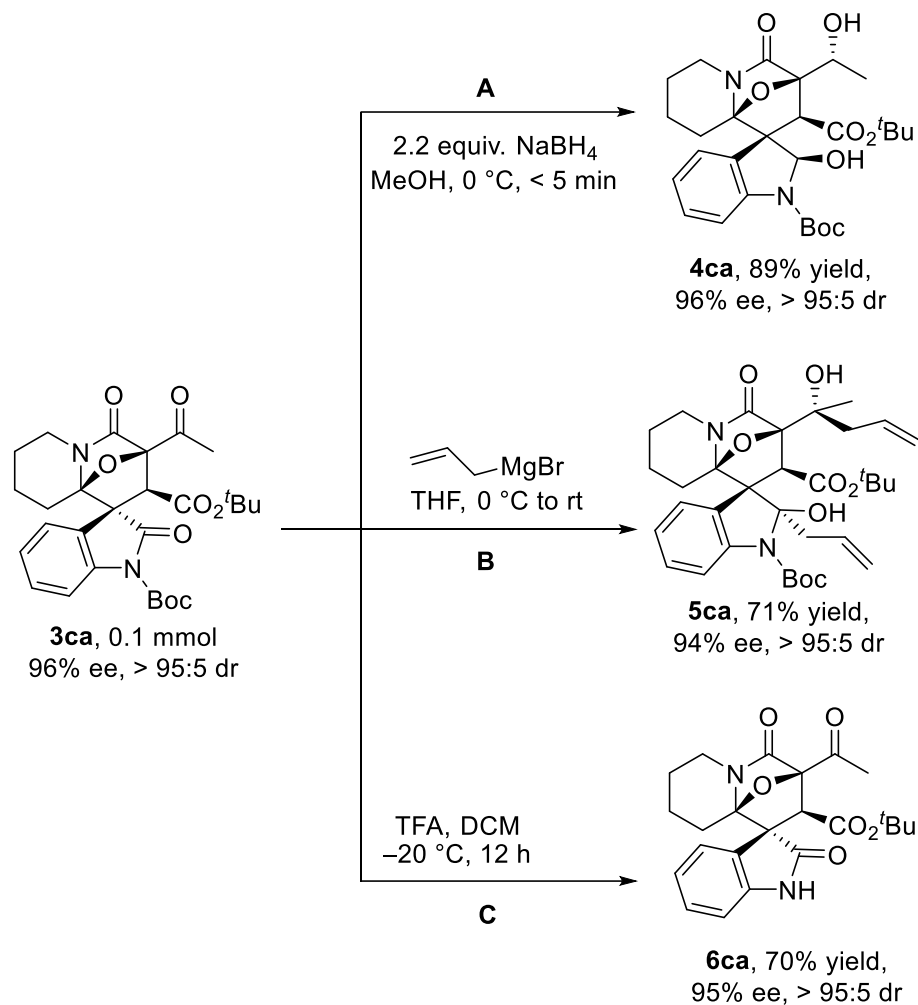
### 8.1 Experimental Procedure for Gram-Scale Synthesis of **3ca**



Procedure: An over dried 100 mL round-bottom flask charged with **2c** (0.751 g, 4.0 mmol), **1a** (0.828 g, 2.4 mmol),  $\text{Rh}_2(\text{Oct})_4$  (9.3 mg, 0.012 mmol, 0.5 mol%) and the catalyst  $\text{Zn}(\text{OTf})_2/\text{L}_3\text{-RaEt}_2\text{Me}$  (0.249 mg, 0.24 mmol, 10 mol%) in anhydrous DCE

(14.0 mL) under nitrogen atmosphere. Then Rh<sub>2</sub>(Oct)<sub>4</sub> (9.3 mg, 0.012 mmol, 0.5 mol%) dissolved in anhydrous DCE (10.0 mL) was added and the reaction was stirred at 35 °C for 4 h. After the reaction was completed, 25.0 mL water was added. The mixture was extracted by DCM, and the aqueous layer was washed with DCM (2 x 20.0 mL). The combined organic phases was washed with brine (20.0 mL), and dried over Na<sub>2</sub>SO<sub>4</sub>. After evaporation of the solvent, the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 2/1 (v/v). The product **3ca** was obtained in 99% yield (1.260 g) with 96% ee and > 95:5 dr.

## 8.2 Experimental Procedures for Derivatizations of **3ca**



Procedure A: 52.6 mg (0.1 mmol) **3ca** was weighed into a reaction tube and 1.0 mL MeOH was added to dissolve the substrate. When the temperature was cooled down 0 °C, 8.5 mg (2.2 equiv.) NaBH<sub>4</sub> was added. After the reaction was completed, the solvent was evaporated under vacuum. Then, 2.0 mL water was added and the mixture was extracted by ethyl acetate. The organic phases was washed with brine (5.0 mL) and dried over Na<sub>2</sub>SO<sub>4</sub>. After evaporation of the solvent, the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 1/1 (v/v). The product **4ca** was obtained in 89% yield (47.1 mg) with 96% ee and > 95:5 dr. The newly generated chiral center was determined by X-ray diffraction crystal analysis (CCDC 2081111).

Procedure B: 52.6 mg (0.1 mmol) **3ca** was weighed into an oven-dried reaction tube. And then make sure it filled with nitrogen. Next, 1.0 ml anhydrous THF was added to dissolve the substrate. When the temperature was cooled down 0 °C, a solution of allyl magnesium bromide (0.22 mL, 0.22 mmol, 1.0 M in THF) was slowly added. The reaction was allowed to warm up to room



temperature. After the reaction was completed, a saturated aqueous solution of  $\text{NH}_4\text{Cl}$  (1 mL) was added. The mixture was extracted by ethyl acetate. The organic phases was washed with brine (5.0 mL), and dried over  $\text{Na}_2\text{SO}_4$ . After evaporation of the solvent, the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 1/1 (v/v). The product **5ca** was obtained in 71 % yield (43.2 mg) with 94% ee and > 95:5 dr.

Procedure C: 52.6 mg (0.1 mmol) **3ca** was weighted into a reaction tube and 1.0 mL DCM was added to dissolve the substrate. When the temperature was cooled down  $-20\text{ }^\circ\text{C}$ , 0.1 mL (10 equiv.) TFA (trifluoroacetic acid) was added slowly. After the reaction was completed, 10.0 mL water and 10 mL DCM was added. The mixture was treated by  $\text{K}_2\text{CO}_3$  until the PH value became over 8. And then the aqueous layer was washed with DCM (2 x 10.0 mL). The combined organic phases was washed with brine (5.0 mL), and dried over  $\text{Na}_2\text{SO}_4$ . After evaporation of the solvent, the residue was subjected to column chromatography on silica gel with petroleum ether/ethyl acetate = 1:1 (v/v). The product **6ca** was obtained in 70% yield (29.8 mg) with 95% ee and > 95:5 dr. The absolute configuration of the major enantiomer of **6ca** was determined by comparison of the CD spectra with that of **3aa**.

## 9. Operando IR experiments

Operando IR experiments were performed to determine the process of the reaction. Initially, the infrared absorption spectra of each reactant and product **3aa** in DCE were collected. The following figure shows the absorption of each participant minus the absorption of solvent. Peak at  $1477\text{ cm}^{-1}$  was identified as the characteristic absorption of product **3aa**. Peak at  $1461\text{ cm}^{-1}$  was for **1a** and Peak at  $1667\text{ cm}^{-1}$  was for **2a**.

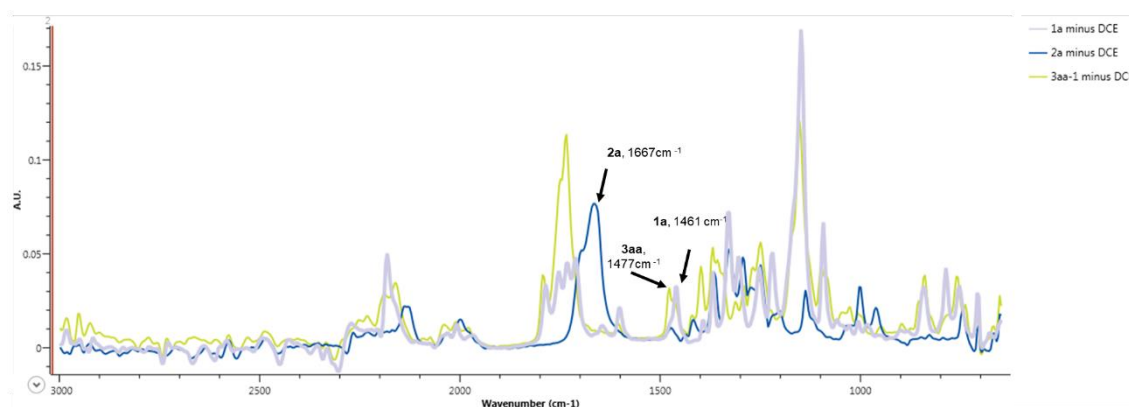
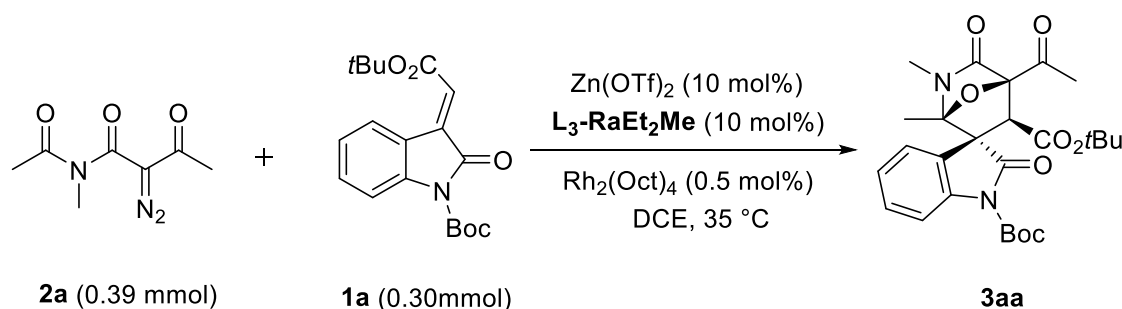


Figure1. The IR spectra of each component.

For the reaction, the solution of 0.39 mmol **2a** and 0.5 mol %  $\text{Rh}_2(\text{Oct})_4$  in the presence of 10 mol %  $\text{Zn}(\text{OTf})_2/\text{L}_3\text{-RaEt}_2\text{Me}$  was monitored firstly. Then, 0.30 mmol **1a** was added into the reaction system. A newly absorption peak at  $1704\text{ cm}^{-1}$  increased first and then decreased before and after adding the substrate **1a**. It implied that this newly generated species at  $1704\text{ cm}^{-1}$  could be the isomünchnone.



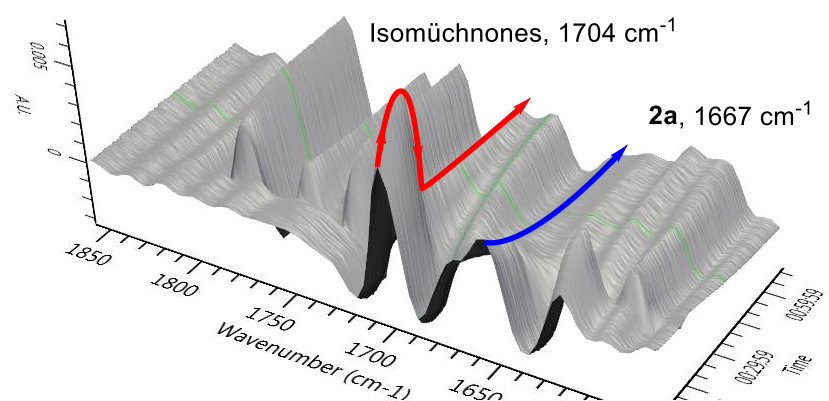
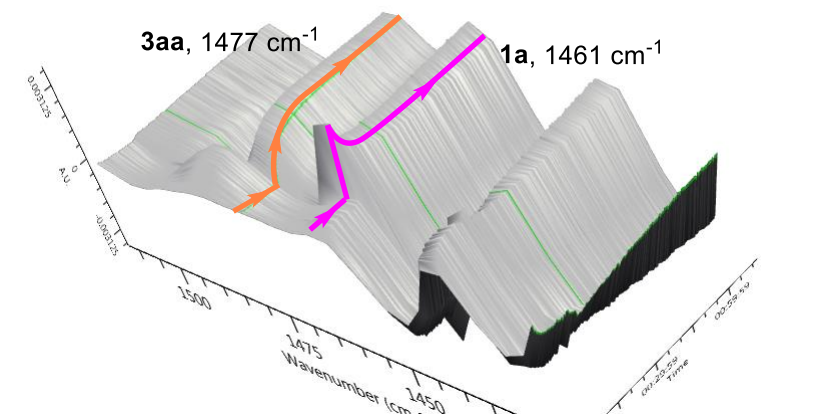


Figure 2. 3D ATR-FTIR profile of the catalytic asymmetric cascade reaction of each component.

The variation of peak height with reaction time represented the changing of concentration with reaction time. So comparison of the reaction rate could be detected by comparing the changing rate of peak height in both reactions. A formula shows the increasing of peak height of **3aa** with reaction time in Figure 3. Operando IR experiments show that the reaction with chiral Lewis acid has a much higher reaction rate than the reaction without Lewis acid.

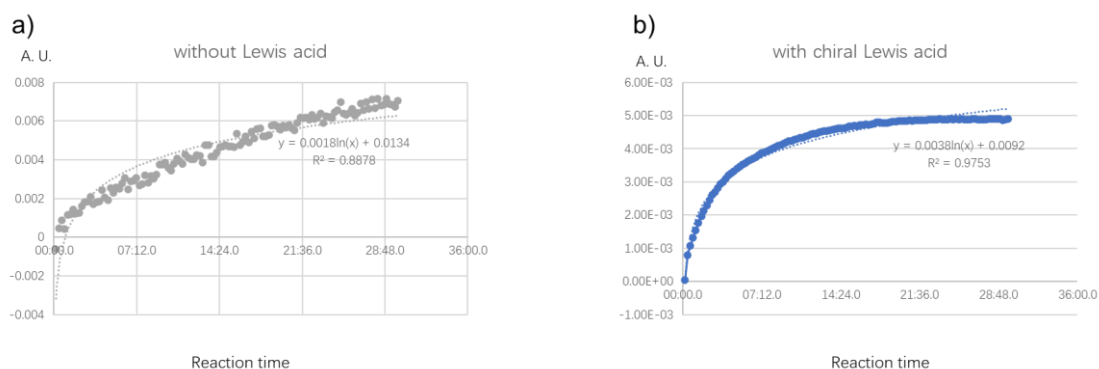


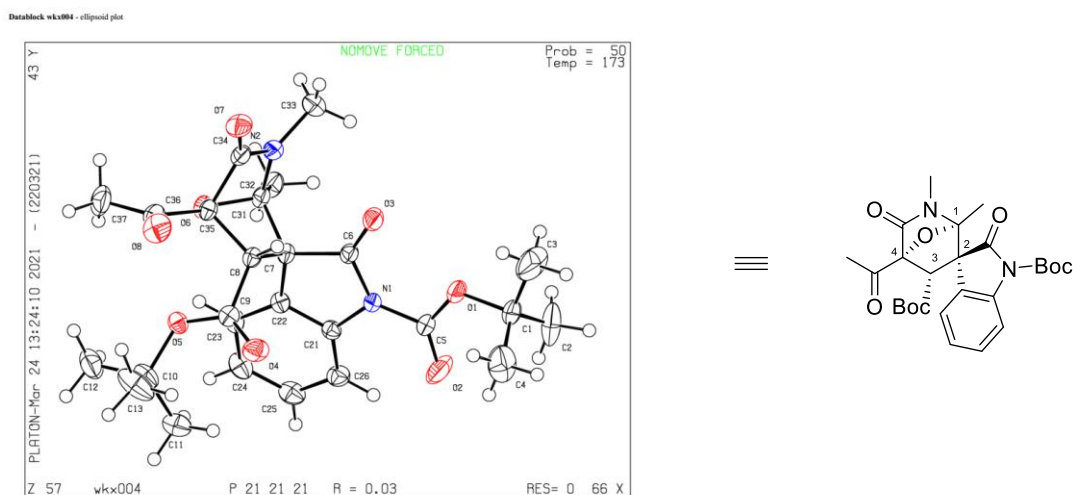
Figure 3. Variation of peak height with reaction time with chiral Lewis acid or without Lewis acid.

## 10. Crystal Data of Products

### 10.1 Crystal Data of Product 3aa

The absolute configuration of product **3aa** was determined to be (1*R*,2*R*,3*S*,4*R*) by X-ray chromatography analysis. Single crystal of **3aa** [C<sub>26</sub>H<sub>32</sub>N<sub>2</sub>O<sub>8</sub>] was obtained by recrystallization in hexane/DCM at room temperature. CCDC 2055996 contains the supplementary crystallographic data which can be obtained free of charge from The Cambridge Crystallographic Data Center.

The colourless crystal in block-shape, with approximate dimensions of 0.454 × 0.218 × 0.216 mm<sup>3</sup>, was selected and mounted for the single-crystal X-ray diffraction. The data set was collected by Bruker D8 Venture Photon II diffractometer at 170(2)K equipped with micro-focus Cu radiation source ( $K_{\alpha} = 1.54178\text{\AA}$ ). Applied with face-indexed numerical absorption correction, the structure solution was solved and refinement was processed by SHELXTL (version 6.14) and OLEX 2.3 program package<sup>a, b, c, d</sup>. Since attempts to refine peaks of residual electron density attributed by disordered or partial-occupancy solvent were unsuccessful, the data were corrected for unsolvable electron density using the SQUEEZE procedure as implemented in PLATON suite<sup>d</sup>. The structure was analyzed by ADDSYM routine implemented in PLATON suite and no higher symmetry was suggested<sup>e</sup>.



### Crystallographic Data for C<sub>26</sub>H<sub>32</sub>N<sub>2</sub>O<sub>8</sub>.

Formula	C <sub>26</sub> H <sub>32</sub> N <sub>2</sub> O <sub>8</sub>
Formula mass (amu)	500.53
Space group	P2 <sub>1</sub> 2 <sub>1</sub> 2 <sub>1</sub>
<i>a</i> (Å)	10.2902(3)
<i>b</i> (Å)	13.8257(4)
<i>c</i> (Å)	18.5139(6)
$\alpha$ (deg)	90
$\beta$ (deg)	90
$\gamma$ (deg)	90
<i>V</i> (Å <sup>3</sup> )	2633.96(14)
<i>Z</i>	4

$\lambda$ (Å)	1.54178
$T$ (K)	173 K(2)
$\rho_{\text{calcd}}$ (g cm <sup>-3</sup> )	1.262
$\mu$ (mm <sup>-1</sup> )	0.780
Transmission factors	0.765–0.904
$\theta_{\text{max}}$ (deg)	72.364
No. of unique data, including $F_o^2 < 0$	5198
No. of unique data, with $F_o^2 > 2\sigma(F_o^2)$	5182
No. of variables	334
$R(F)$ for $F_o^2 > 2\sigma(F_o^2)$ <sup>a</sup>	0.0277
$R_w(F_o^2)$ <sup>b</sup>	0.0736
Goodness of fit	1.081

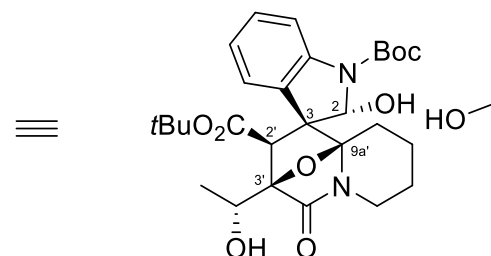
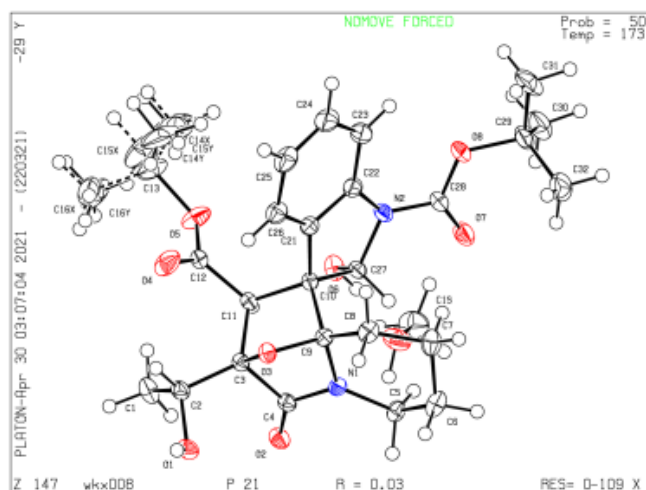
$$^a R(F) = \sum ||F_o| - |F_c|| / \sum |F_o|.$$

$$^b R_w(F_o^2) = [\sum [w(F_o^2 - F_c^2)^2] / \sum wF_o^4]^{1/2}; w^{-1} = [\sigma^2(F_o^2) + (Ap)^2 + Bp], \text{ where } p = [\max(F_o^2, 0) + 2F_c^2] / 3.$$

## 10.2 Crystal Data of Product 4ca

The absolute configuration of product **4ca** and the newly generated hydroxy chiral center was determined to be (2*R*,2'*S*,3*S*,3'*R*,9*a*'*R*) and (*R*) by X-ray chromatography analysis. Single crystal of **4ca** [C<sub>28</sub>H<sub>38</sub>N<sub>2</sub>O<sub>8</sub>] was obtained by recrystallization in *d*<sub>4</sub>-MeOH at room temperature. CCDC 2081111 contains the supplementary crystallographic data which can be obtained free of charge from The Cambridge Crystallographic Data Center.

The colourless crystal in flake-shape, with approximate dimensions of 0.200 × 0.308 × 0.743 mm<sup>3</sup>, was selected and mounted for the single-crystal X-ray diffraction. The data set was collected by Bruker D8 Venture Photon II diffractometer at 173(2)K equipped with micro-focus Cu radiation source ( $K_{\alpha} = 1.54178\text{\AA}$ ). Applied with face-indexed numerical absorption correction, the structure solution was solved and refinement was processed by SHELXTL (version 6.14) and OLEX 2.3 program package<sup>a, b, c, d</sup>. The structure was analyzed by ADDSYM routine implemented in PLATON suite and no higher symmetry was suggested<sup>e</sup>.



### Crystallographic Data for C<sub>29</sub>H<sub>42</sub>N<sub>2</sub>O<sub>9</sub>

Formula	C <sub>29</sub> H <sub>42</sub> N <sub>2</sub> O <sub>9</sub>
Formula mass (amu)	562.64
Space group	P2 <sub>1</sub>
<i>a</i> (Å)	9.7907(5)
<i>b</i> (Å)	11.0235(6)
<i>c</i> (Å)	14.4145(8)
<i>α</i> (deg)	90
<i>β</i> (deg)	107.747(2)
<i>γ</i> (deg)	90
<i>V</i> (Å <sup>3</sup> )	1481.69(14)
<i>Z</i>	2
<i>λ</i> (Å)	1.54178
<i>T</i> (K)	173 K(2)
<i>ρ</i> <sub>calcd</sub> (g cm <sup>-3</sup> )	1.261
<i>μ</i> (mm <sup>-1</sup> )	0.772
Transmission factors	0.689–1.000
2 <i>θ</i> <sub>max</sub> (deg)	68.376
No. of unique data, including <i>F</i> <sub>o</sub> <sup>2</sup> < 0	5382
No. of unique data, with <i>F</i> <sub>o</sub> <sup>2</sup> > 2σ( <i>F</i> <sub>o</sub> <sup>2</sup> )	5310
No. of variables	412
<i>R</i> ( <i>F</i> ) for <i>F</i> <sub>o</sub> <sup>2</sup> > 2σ( <i>F</i> <sub>o</sub> <sup>2</sup> ) <sup>a</sup>	0.0311
<i>R</i> <sub>w</sub> ( <i>F</i> <sub>o</sub> <sup>2</sup> ) <sup>b</sup>	0.0807

$$^a R(F) = \sum ||F_o| - |F_c|| / \sum |F_o|.$$

$$^b R_w(F_o^2) = [\sum [w(F_o^2 - F_c^2)^2] / \sum wF_o^4]^{1/2}; w^{-1} = [\sigma^2(F_o^2) + (Ap)^2 + Bp], \text{ where } p = [\max(F_o^2, 0) + 2F_c^2] / 3.$$

## References:

<sup>a</sup> Sheldrick, G. M. *Acta Cryst.* **2008**, *A64*, 112–122.

<sup>b</sup> Sheldrick, G. M. *Acta Cryst.* **2015**, *A71*, 3–8.

<sup>c</sup> Sheldrick, G. M. *Acta Cryst.* **2015**, *C71*, 3–8.

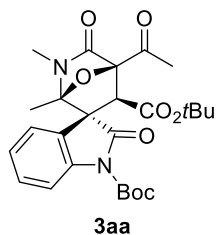
<sup>d</sup> Dolomanov, O.V., Bourhis, L.J., Gildea, R.J., Howard, J. A. K., Puschmann, H. *J. Appl. Cryst.* **2009**, *42*, 339-341.

<sup>e</sup> Spek, A. L. *J. Appl. Cryst.* **2003**, *36*, 7–13.

## 11. Characterization of Products

Tips: All of the spiro piperidine oxindole products (**3aa-3aq**, **3ba-3oa**, **4ca**, **5ca**, **6ca**) will decompose in high temperature under air so that the melting points can't be obtained veritably. (**3aa-3aq**, **3ba-3da**, **3la-3oa**, **6ca** will decompose above 130 °C; **3ea-3ka** will decompose above 60 °C; **4ca** and **5ca** will decompose around 100 °C)

### Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate



White solid; 89% yield, 98% ee, 98:2 dr; 44.6 mg;  $[\alpha]_D^{19} = -73.0$  ( $c = 0.20$ ,  $\text{CH}_2\text{Cl}_2$ ); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.01$  min,  $t_2 = 8.98$  min,  $t_3 = 10.10$  min,  $t_4 = 12.20$  min].

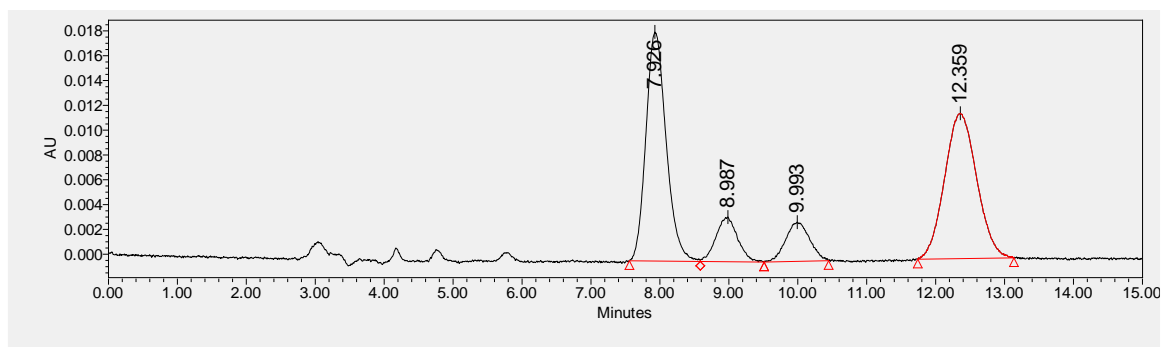
$^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.81 (d,  $J = 8.2$  Hz, 1H), 7.40 (d,  $J = 7.6$  Hz, 1H), 7.36 (t,  $J = 8.4$  Hz, 1H), 7.15 (t,  $J = 7.6$  Hz, 1H), 3.83 (s, 1H), 2.89 (s, 3H), 2.45 (s, 3H), 1.63 (s, 9H), 1.30 (s, 3H), 0.92 (s, 9H).

$^{13}\text{C NMR}$  (101 MHz,  $\text{CDCl}_3$ )  $\delta$  198.49, 171.90, 168.74, 166.35, 148.64, 140.34, 129.87, 126.46, 124.93, 124.84, 114.81, 98.29, 90.87, 85.33, 83.10, 77.48, 77.16, 76.84, 63.43, 60.02, 28.17, 28.02, 27.68, 27.38,

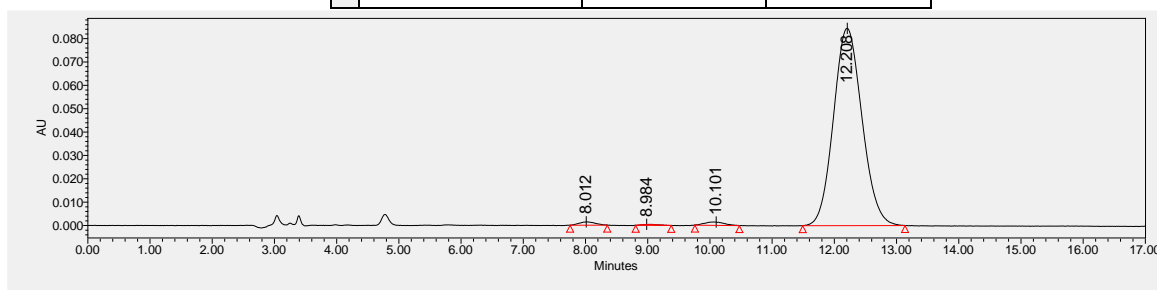
14.69.

ESI-HRMS calcd for  $[\text{C}_{26}\text{H}_{32}\text{N}_2\text{O}_8 + \text{H}^+]$ : 501.2231, found 501.2235.

IR (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 2981, 2937, 2362, 2334, 1793, 1739, 1471, 1399, 1363, 1267, 1153, 1094, 1030, 892, 845, 756.



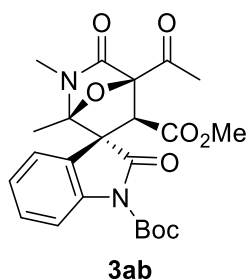
	Retention Time	Area	% Area
1	7.926	375847	41.32
2	8.987	78579	8.64
3	9.993	76616	8.42
4	12.359	378632	41.62



	Retention Time	Area	% Area
1	8.012	25969	0.94
2	8.984	6792	0.25
3	10.101	32062	1.17

4	12.208	2686641	97.64
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**1'-(*Tert*-butyl) 3-methyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



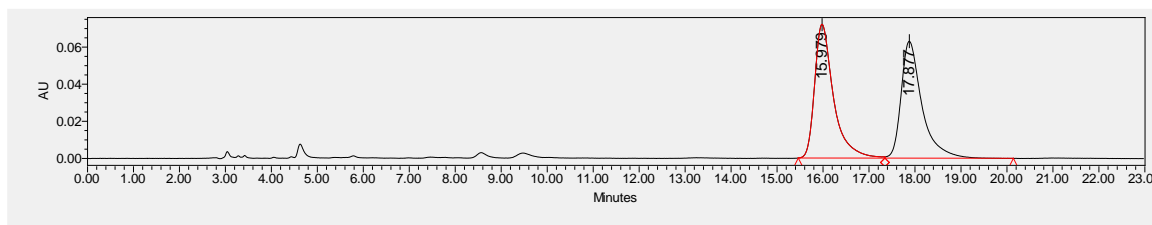
White solid; 63% yield (*exo*), 94% ee, 85:15 dr (determined by raw <sup>1</sup>H NMR spectra of reaction mixture); 29.0 mg; [ $\alpha$ ]<sub>D</sub><sup>22</sup> = -105.5 (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda$  = 230 nm, *t*<sub>1</sub> = 16.00 min, *t*<sub>2</sub> = 17.85 min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.84 (d, *J* = 8.2 Hz, 1H), 7.37 (t, *J* = 7.9 Hz, 1H), 7.29 (d, *J* = 7.5 Hz, 1H), 7.16 (t, *J* = 7.5 Hz, 1H), 3.91 (s, 1H), 3.15 (s, 3H), 2.87 (s, 3H), 2.46 (s, 3H), 1.64 (s, 9H), 1.28 (s, 3H).

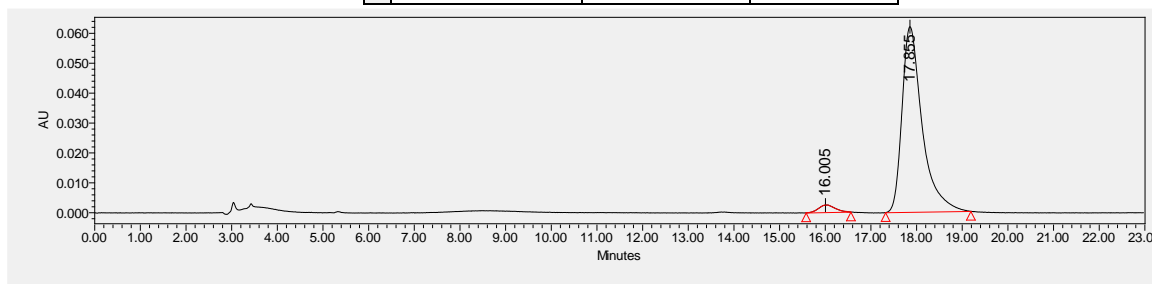
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  199.09, 171.53, 168.38, 168.24, 148.74, 140.00, 130.05, 125.17, 124.85, 124.74, 114.99, 98.82, 91.20, 85.54, 77.48, 77.16, 76.84, 63.45, 58.75, 52.54, 28.24, 28.01, 27.77, 14.72.

ESI-HRMS calcd for [C<sub>23</sub>H<sub>26</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 459.1762, found 459.1760;

IR (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3006, 2985, 2360, 2341, 1748, 1653, 1558, 1541, 1507, 1457, 1275, 1260, 1152, 764, 420.

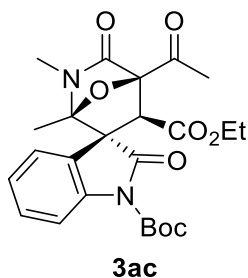


	Retention Time	Area	% Area
1	15.979	2053883	50.99
2	17.877	1973985	49.01



	Retention Time	Area	% Area
1	16.005	64728	3.21
2	17.855	1904136	96.79

**1'-(*Tert*-butyl) 3-ethyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



White solid; 75% yield (*exo*), 96% ee, 87:13 dr (determined by raw <sup>1</sup>H NMR spectra of reaction mixture); 35.3 mg; [ $\alpha$ ]<sub>D</sub><sup>21</sup> = -115.5 (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda$  = 230 nm, *t*<sub>1</sub> = 13.38 min, *t*<sub>2</sub> = 15.76 min].

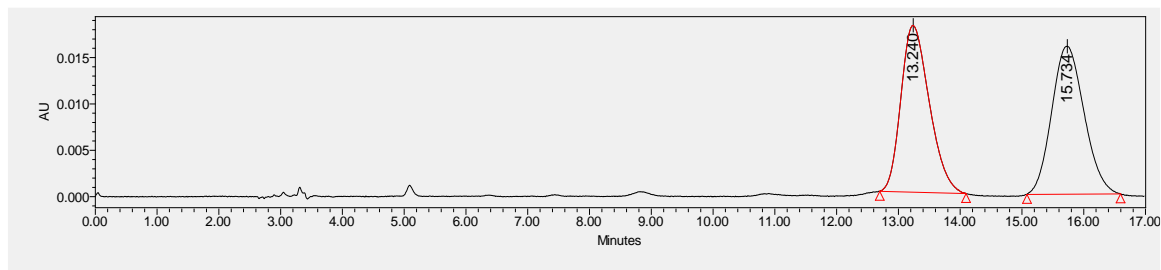
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.80 (d, *J* = 8.2 Hz, 1H), 7.35 (t, *J* = 8.5 Hz, 1H), 7.31 (d, *J* = 7.6 Hz, 1H), 7.13 (t, *J* = 7.6 Hz, 1H), 3.87 (s, 1H), 3.70 – 3.52 (m, 2H), 2.86 (s, 3H), 2.45 (s, 3H), 1.62 (s, 9H), 1.27 (s, 3H), 0.61 (t, *J* = 7.1 Hz, 3H).



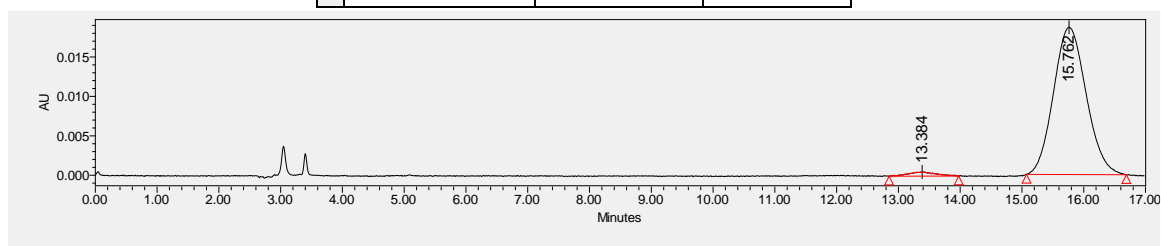
$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  198.94, 171.64, 168.32, 167.72, 148.64, 140.10, 129.97, 125.47, 124.83, 124.71, 114.87, 98.63, 91.04, 85.47, 77.48, 77.16, 76.84, 63.41, 61.80, 58.90, 28.18, 27.98, 27.71, 14.69, 13.42.

ESI-HRMS calcd for  $[\text{C}_{24}\text{H}_{28}\text{N}_2\text{O}_8+\text{H}^+]$ : 473.1918, found 473.1921;

IR (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 3004, 2985, 2941, 2360, 2340, 1794, 1740, 1718, 1478, 1466, 1458, 1400, 1371, 1349, 1275, 1260, 1172, 1152, 764.

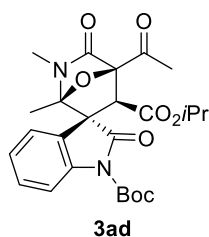


	Retention Time	Area	% Area
1	13.240	574388	49.72
2	15.734	580939	50.28



	Retention Time	Area	% Area
1	13.384	16485	2.25
2	15.762	685753	97.75

**1'-(*Tert*-butyl) 3-isopropyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



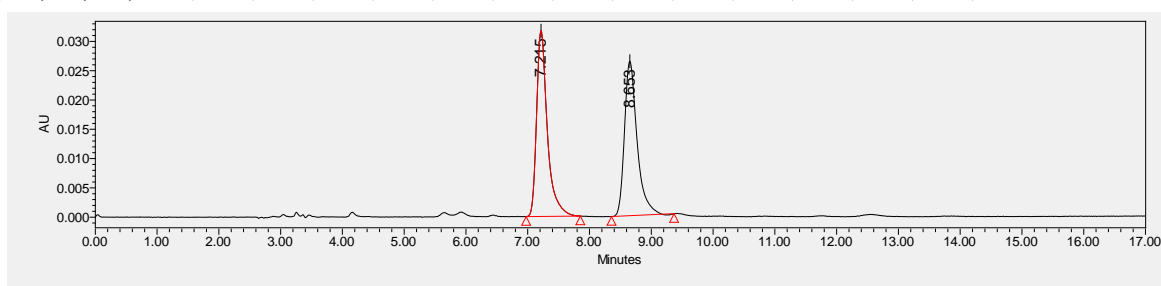
White solid; 67% yield (*exo*), 96% ee, 83:17 dr (determined by raw  $^1\text{H}$  NMR spectra of reaction mixture); 32.6 mg;  $[\alpha]^{22}_{\text{D}} = -103.5$  (*c* 0.20,  $\text{CH}_2\text{Cl}_2$ ); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 16.00$  min,  $t_2 = 17.85$  min].

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.81 (d,  $J = 8.0$  Hz, 1H), 7.36 (m, 2H), 7.15 (t,  $J = 7.6$  Hz, 1H), 4.48 (m, 1H), 3.86 (s, 1H), 2.88 (s, 3H), 2.46 (s, 3H), 1.64 (s, 10H), 1.28 (s, 3H), 1.00 (d,  $J = 6.3$  Hz, 3H), 0.36 (d,  $J = 6.3$  Hz, 3H).

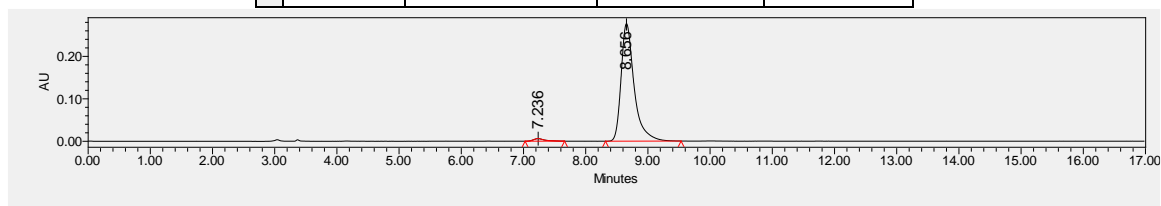
$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  198.77, 171.58, 168.23, 167.04, 148.46, 140.02, 129.77, 125.59, 124.73, 124.54, 114.73, 98.42, 90.85, 85.28, 77.32, 77.00, 76.68, 69.79, 63.25, 58.87, 28.02, 27.85, 27.55, 21.55, 20.30, 14.51.

ESI-HRMS calcd for  $[\text{C}_{25}\text{H}_{30}\text{N}_2\text{O}_8+\text{H}^+]$ : 487.2075, found 487.2077;

IR (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 2984, 2939, 2362, 2334, 1793, 1742, 1468, 1399, 1369, 1347, 1268, 1204, 1151, 1102, 755.

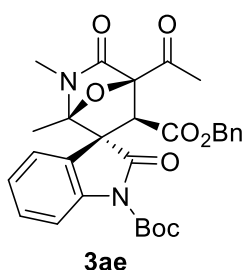


	Name	Retention Time	Area	% Area
1		7.215	383718	50.59
2		8.653	374808	49.41



	Name	Retention Time	Area	% Area
1		7.236	77446	1.89
2		8.656	4029927	98.11

**3-Benzyl 1'-(*tert*-butyl) (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



White solid; 60% yield (*exo*), 97% ee, 84:16 dr (determined by raw <sup>1</sup>H NMR spectra of reaction mixture); 32.1 mg; [ $\alpha$ ]<sub>D</sub><sup>21</sup> = -97.5 (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda$  = 230 nm, *t*<sub>1</sub> = 10.29 min, *t*<sub>2</sub> = 16.15 min].

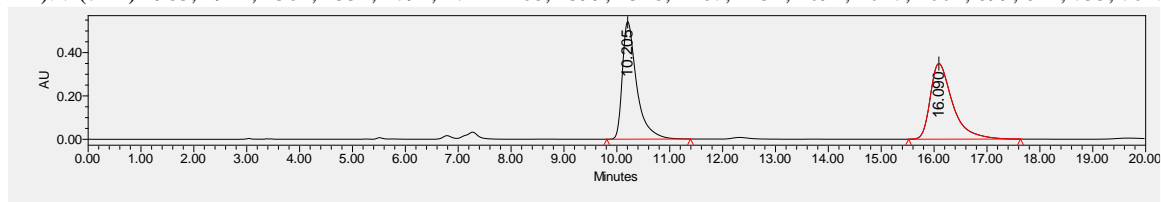
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.79 (d, *J* = 8.1 Hz, 1H), 7.37 – 7.31 (m, 2H), 7.24 – 7.15 (m, 3H), 7.12 (t, *J* = 7.9 Hz, 1H), 6.77 (d, *J* = 6.7 Hz, 2H), 4.68 (d, *J* = 11.9 Hz, 1H), 4.36 (d, *J* = 11.9 Hz, 1H), 3.94 (s, 1H), 2.88 (s, 3H), 2.46 (s, 3H), 1.61 (s, 9H), 1.28 (s, 3H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.93, 171.51, 168.23, 167.65, 148.50, 140.06, 134.08, 130.06, 128.50, 128.46, 125.34, 124.87, 124.58, 115.02, 98.71, 91.07, 85.39, 77.48, 77.16, 76.84, 67.84, 63.40,

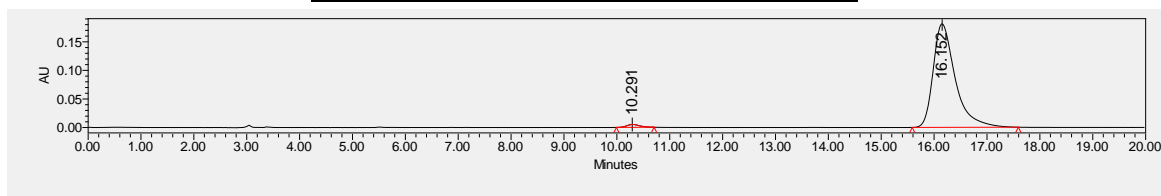
58.79, 28.15, 28.00, 27.74, 14.66.

**ESI-HRMS** calcd for [C<sub>29</sub>H<sub>30</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 535.2075, found 535.2076;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2983, 2941, 2362, 2334, 1792, 1744 1468, 1399, 1348, 1267, 1151, 1092, 1027, 1004, 899, 844, 755, 704.

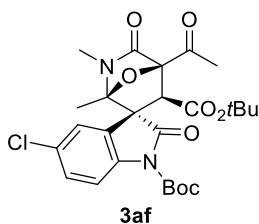


	Retention Time	Area	% Area
1	10.205	10200089	49.97
2	16.090	10210732	50.03



	Retention Time	Area	% Area
1	10.291	84165	1.58
2	16.152	5238274	98.42

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-5'-chloro-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



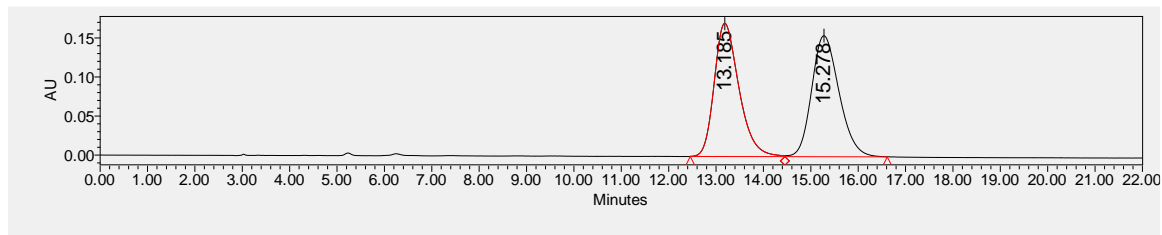
White solid; 86% yield, 97% ee, > 95:5 dr; 46.0 mg;  $[\alpha]_D^{21} = -45.6$  (*c* 0.068, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 13.22$  min,  $t_2 = 15.25$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.82 (d, *J* = 8.7 Hz, 1H), 7.40 (d, *J* = 2.2 Hz, 1H), 7.36 (dd, *J* = 8.7, 2.3 Hz, 1H), 3.83 (s, 1H), 2.90 (s, 3H), 2.47 (s, 3H), 1.64 (s, 10H), 1.34 (s, 3H), 1.02 (s, 9H).

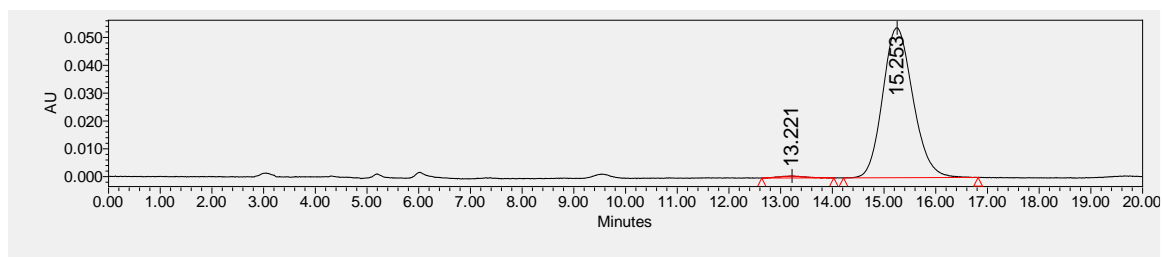
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.28, 171.17, 168.54, 166.14, 148.50, 138.82, 130.67, 129.90, 126.66, 126.36, 116.14, 100.13, 98.34, 91.10, 85.77, 83.67, 77.48, 77.16, 76.84, 63.47, 59.87, 28.17, 28.07, 27.72, 27.43, 14.78.

**ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>34.9689</sup>ClN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 557.1661, found 557.1653; **ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>36.9659</sup>ClN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 559.1632, found 559.1641;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2998, 2986, 2361, 2334, 1740, 1548, 1515, 1466, 1397, 1366, 1335, 1268, 1152, 755.

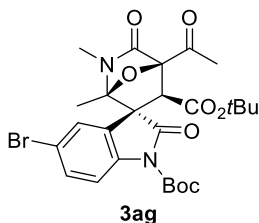


	Retention Time	Area	% Area
1	13.185	6176891	49.81
2	15.278	6223233	50.19



	Retention Time	Area	% Area
1	13.221	31172	1.41
2	15.253	2173169	98.59

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-5'-bromo-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



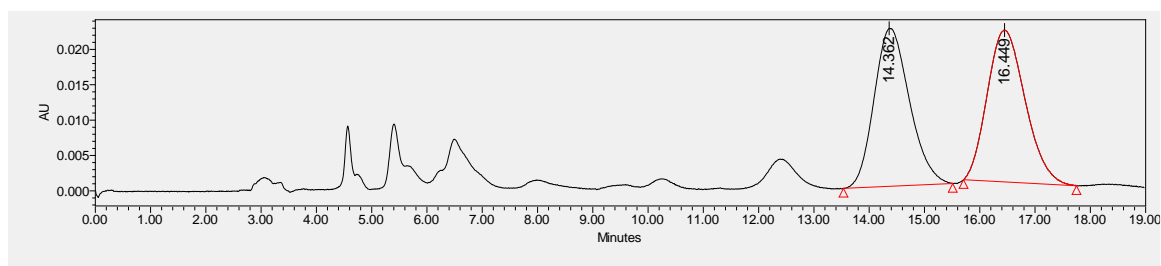
White solid; 71% yield, 96% ee, > 95:5 dr; 41.0 mg;  $[\alpha]_D^{21} = -25.0$  (*c* 0.060, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 13.86$  min,  $t_2 = 15.79$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.76 – 7.72 (m, 1H), 7.53 – 7.48 (m, 2H), 3.80 (s, 1H), 2.87 (s, 3H), 2.45 (s, 3H), 1.62 (s, 9H), 1.33 (s, 3H), 1.01 (s, 9H).

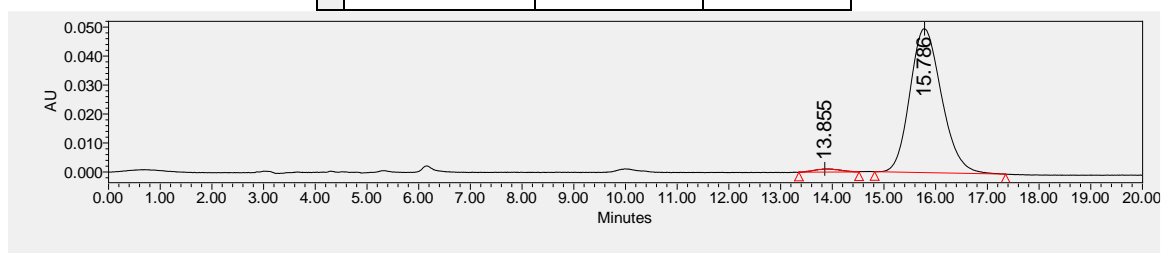
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.28, 171.03, 168.49, 166.09, 148.41, 139.27, 132.82, 129.01, 126.93, 118.10, 116.50, 98.33, 91.06, 85.79, 83.69, 77.48, 77.16, 76.84, 63.34, 59.82, 59.81, 28.13, 28.08, 27.70, 27.41, 14.77.

**ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>78.9183</sup>BrN<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 579.1337, found 579.1338; **ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>80.9163</sup>BrN<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 581.1316, found 581.1321;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2983, 2361, 2334, 1794, 1740, 1467, 1398, 1367, 1334, 1300, 1268, 1153, 1105, 893, 836, 755, 678.

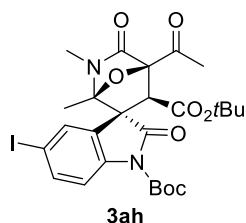


	Retention Time	Area	% Area
1	14.362	992451	49.25
2	16.449	1022778	50.75



	Retention Time	Area	% Area
1	13.855	37246	1.73
2	15.786	2112042	98.27

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-5'-iodo-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



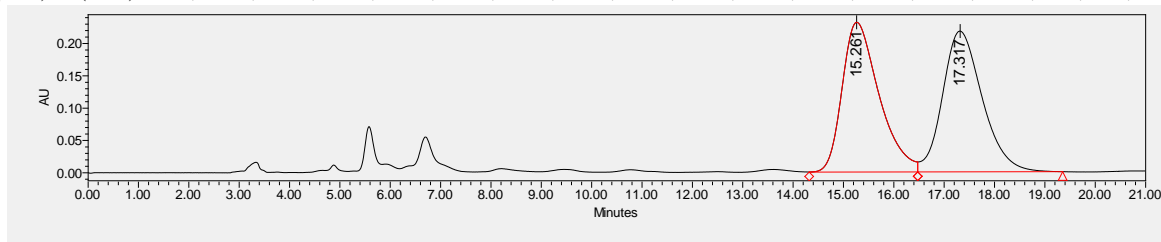
White solid; 64% yield, 97% ee, > 95:5 dr; 39.8 mg;  $[\alpha]_D^{25} = -23.5$  (*c* 0.068, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 15.00$  min,  $t_2 = 16.80$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.74 – 7.67 (m, 2H), 7.62 (d, *J* = 8.6 Hz, 1H), 3.81 (s, 1H), 2.88 (s, 3H), 2.46 (s, 3H), 1.62 (s, 9H), 1.33 (s, 3H), 1.02 (s, 9H).

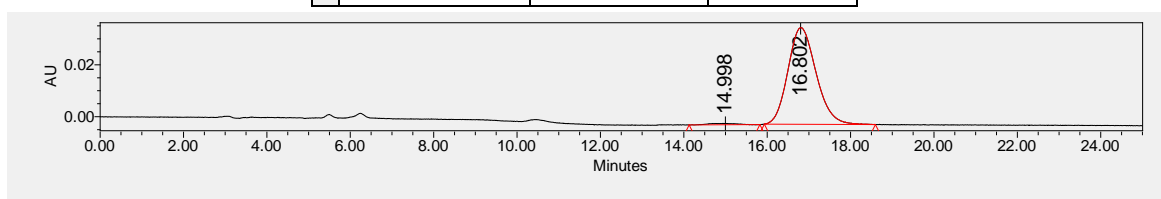
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.23, 170.92, 168.56, 166.11, 148.45, 140.05, 138.87, 134.59, 127.26, 116.87, 98.37, 91.14, 88.50, 85.80, 83.75, 77.48, 77.16, 76.84, 63.24, 28.17, 27.72, 27.51, 14.82.

ESI-HRMS calcd for [C<sub>26</sub>H<sub>31</sub>IN<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 627.1198, found 627.1198;

IR (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2999, 2986, 2361, 2334, 1740, 1646, 1563, 1532, 1515, 1465, 1397, 1367, 1331, 1268, 1152, 894, 755, 677.

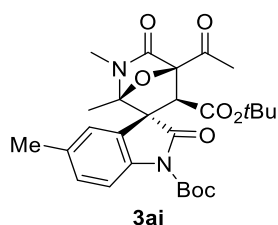


	Retention Time	Area	% Area
1	15.261	11779046	49.69
2	17.317	11927288	50.31



	Retention Time	Area	% Area
1	14.998	24309	1.37
2	16.802	1744946	98.63

**Di-tert-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,5',6-trimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



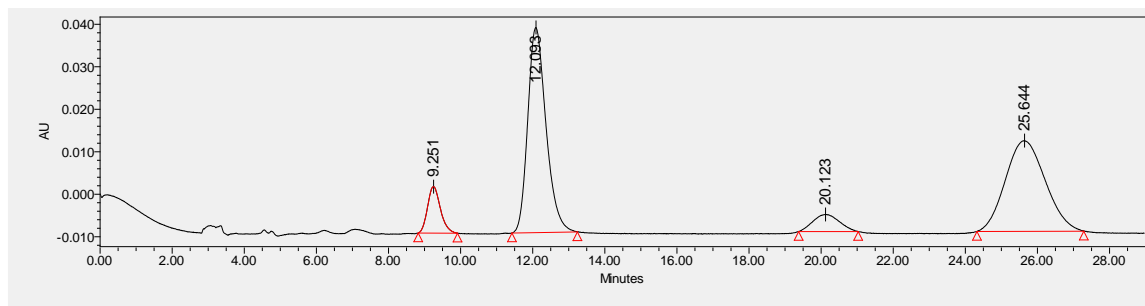
White solid; 91% yield, 98% ee, 96:4 dr; 46.8 mg;  $[\alpha]_D^{21} = -74$  (*c* 0.2, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 9.21$  min,  $t_2 = 11.88$  min,  $t_3 = 19.50$  min,  $t_4 = 24.66$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.68 (d, *J* = 8.3 Hz, 1H), 7.20 – 7.12 (m, 2H), 3.81 (s, 1H), 2.88 (s, 3H), 2.45 (s, 3H), 2.29 (s, 3H), 1.62 (s, 9H), 1.30 (s, 3H), 0.93 (s, 9H).

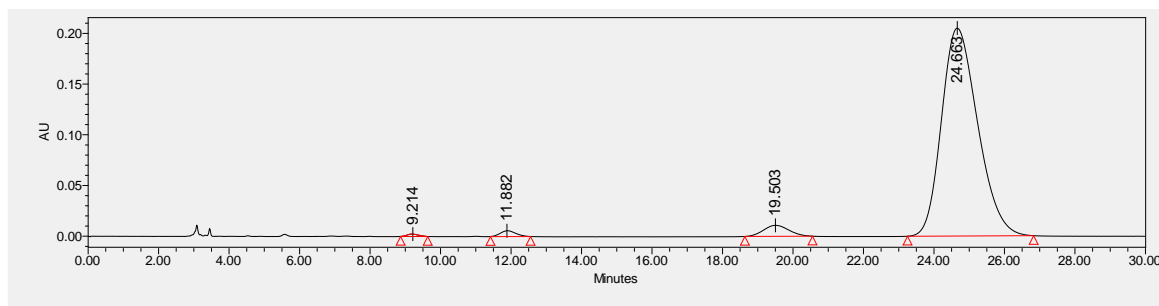
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.39, 172.04, 168.78, 166.37, 148.68, 137.89, 134.74, 130.24, 126.68, 124.77, 114.63, 98.30, 91.00, 85.12, 83.06, 77.48, 77.16, 76.84, 63.49, 59.78, 59.76, 28.16, 28.02, 27.67, 27.29, 21.12, 14.70.

ESI-HRMS calcd for [C<sub>27</sub>H<sub>34</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 515.2388, found 515.2394;

IR (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2981, 2937, 2361, 2334, 1791, 1739, 1485, 1463, 1393, 1366, 1338, 1308, 1271, 1151, 1109, 1027, 896, 843, 755, 679.

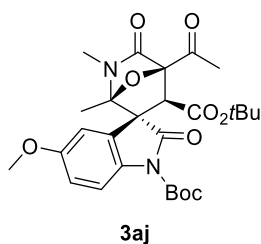


	Name	Retention Time	Area	% Area
1		9.251	271829	7.12
2		12.093	1699116	44.53
3		20.123	204910	5.37
4		25.644	1639724	42.97



	Name	Retention Time	Area	% Area
1		9.214	54089	0.35
2		11.882	175134	1.14
3		19.503	543245	3.53
4		24.663	14596729	94.97

**Di-tert-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-5'-methoxy-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



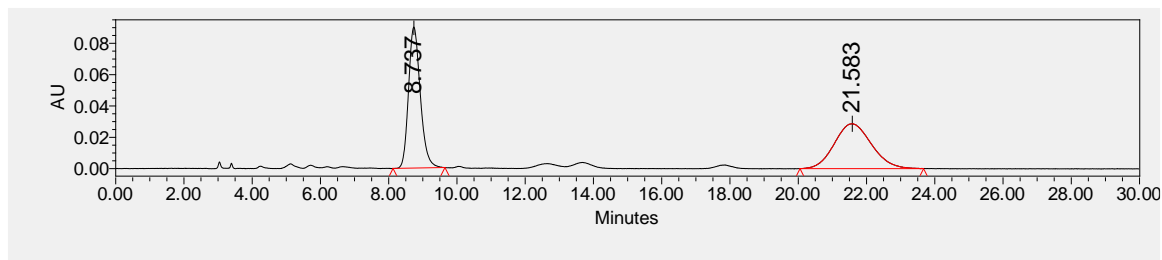
White solid; 82% yield, 97% ee, >95:5 dr; 43.5 mg;  $[\alpha]_D^{21} = -93.5$  (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.85$  min,  $t_2 = 22.17$  min].

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.73 (d, *J* = 8.9 Hz, 1H), 6.96 (d, *J* = 2.7 Hz, 1H), 6.91 – 6.85 (m, 1H), 3.81 (s, 1H), 3.76 (s, 3H), 2.88 (s, 3H), 2.44 (s, 3H), 1.62 (s, 9H), 1.32 (s, 3H), 0.96 (s, 9H).

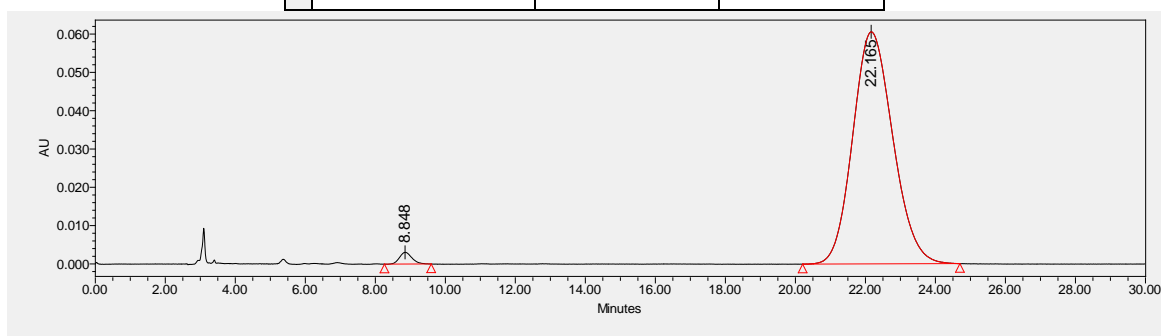
**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.44, 171.93, 168.70, 166.39, 157.10, 148.70, 133.57, 125.95, 115.82, 115.18, 112.12, 98.29, 90.91, 85.10, 83.08, 77.48, 77.16, 76.84, 63.69, 59.90, 59.89, 55.88, 55.86, 28.18, 28.03, 27.68, 27.39, 14.70.

**ESI-HRMS** calcd for [C<sub>27</sub>H<sub>34</sub>N<sub>2</sub>O<sub>9</sub>+H<sup>+</sup>]: 531.2337, found 531.2338;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3004, 2982, 2939, 2360, 2341, 1798, 1770, 1738, 1623, 1497, 1448, 1398, 1372, 1276, 1260, 1152, 1109, 853, 800, 764, 750, 683.

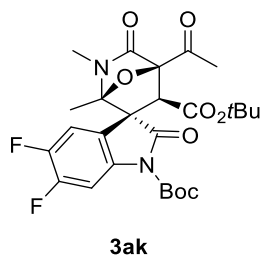


	Retention Time	Area	% Area
1	8.737	2155468	49.90
2	21.583	2163731	50.10



	Name	Retention Time	Area	% Area
1		8.848	75191	1.54
2		22.165	4812168	98.46

**Di-tert-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-5',6'-difluoro-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



White solid; 70% yield, 95% ee, > 95:5 dr; 37.4 mg;  $[\alpha]_D^{21} = -67.0$  (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 10.34$  min,  $t_2 = 12.48$  min].

**<sup>1</sup>H NMR** (600 MHz, CDCl<sub>3</sub>)  $\delta$  7.82 (dd, *J* = 11.1, 6.9 Hz, 1H), 7.29 (dd, *J* = 9.4, 8.0 Hz, 1H), 3.81 (s, 1H), 2.90 (s, 3H), 2.46 (s, 3H), 1.64 (s, 9H), 1.33 (s, 3H), 1.04 (s, 9H).

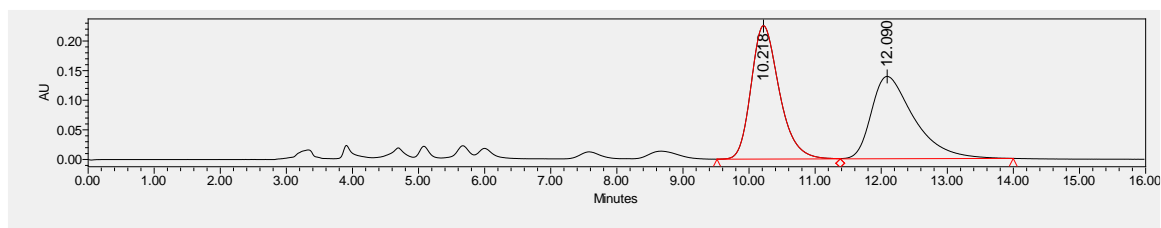
**<sup>13</sup>C NMR** (151 MHz, CDCl<sub>3</sub>)  $\delta$  198.28, 171.04, 168.44, 166.23, 151.85 (d, *J* = 6.80 Hz), 150.20 (d, *J* = 6.80 Hz), 148.61 (d, *J* = 6.80 Hz), 148.35, 146.98 (d, *J* = 6.80 Hz), 136.45 (dd, *J* = 6.80 Hz, *J* = 1.51 Hz), 120.60 (dd, *J* = 6.80 Hz, *J* = 1.51 Hz), 115.71 (d, *J* = 10.57 Hz), 105.69 (d, *J* = 12.84 Hz), 98.28, 91.04, 86.16, 83.68, 77.40, 77.19, 76.98, 63.30, 59.89, 28.16, 28.05, 27.73, 27.53,

14.74.

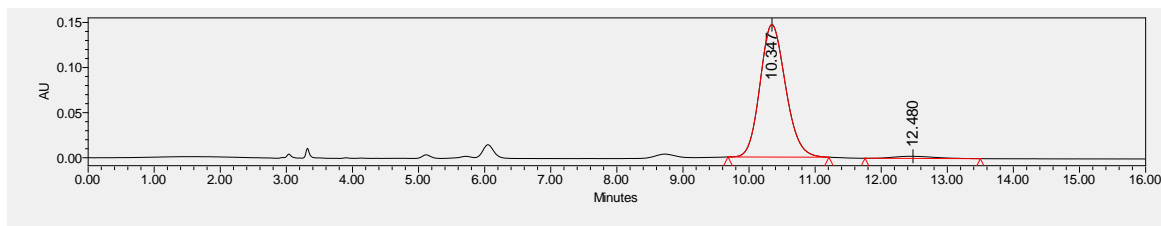
**<sup>19</sup>F{<sup>1</sup>H} NMR** (565 MHz, CDCl<sub>3</sub>)  $\delta$  -132.97, -141.12.

**ESI-HRMS** calcd for [C<sub>26</sub>H<sub>30</sub>F<sub>2</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 537.2043, found 537.2040;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2989, 2362, 2334, 1792, 1740, 1646, 1547, 1515, 1484, 1464, 1426, 1397, 1365, 1268, 1154, 755, 677.

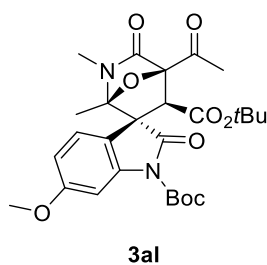


	Name	Retention Time	Area	% Area
1		10.218	6663254	51.67
2		12.090	6232217	48.33



	Name	Retention Time	Area	% Area
1		10.347	3944806	97.51
2		12.480	100766	2.49

**Di-tert-butyl (1R,2R,3S,4R)-4-acetyl-6'-methoxy-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro [bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



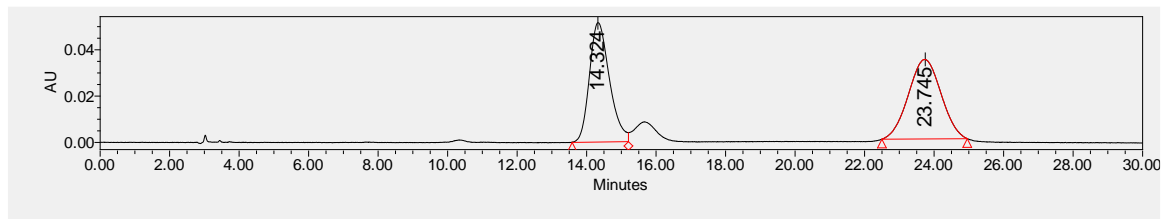
White solid; 82% yield, 96% ee, > 95:5 dr; 44.1 mg;  $[\alpha]_D^{25} = -119.4$  ( $c$  0.072,  $\text{CH}_2\text{Cl}_2$ ); determined by HPLC analysis [Daicel chiralpak IG,  $n$ -hexane/ $i$ -PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.76$  min,  $t_2 = 10.48$  min,  $t_3 = 12.70$  min,  $t_4 = 15.20$  min].

**$^1\text{H}$  NMR** (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.43 (d,  $J = 2.4$  Hz, 1H), 7.28 (d,  $J = 8.5$  Hz, 1H), 6.67 (dd,  $J = 8.5, 2.4$  Hz, 1H), 3.81 (s, 3H), 3.79 (s, 1H), 2.88 (s, 3H), 2.44 (s, 3H), 1.63 (s, 9H), 1.29 (s, 3H), 0.96 (s, 9H).

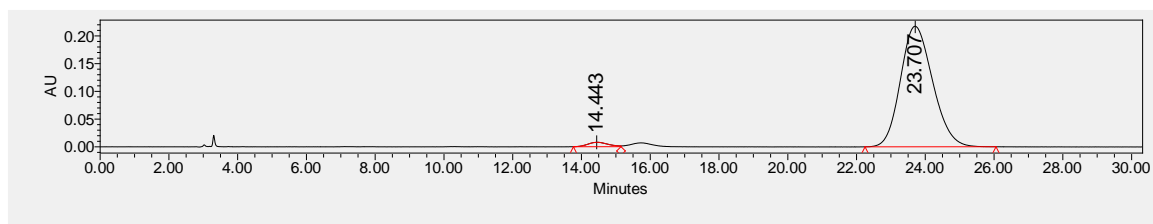
**$^{13}\text{C}$  NMR** (101 MHz,  $\text{CDCl}_3$ )  $\delta$  198.70, 172.38, 168.77, 166.49, 161.11, 148.58, 141.37, 127.23, 116.43, 110.10, 101.76, 98.30, 90.85, 85.33, 83.01, 77.48, 77.16, 76.84, 63.11, 59.87, 55.75, 28.15, 28.00, 27.64, 27.47, 14.64.

**ESI-HRMS** calcd for  $[\text{C}_{27}\text{H}_{34}\text{N}_2\text{O}_9 + \text{H}^+]$ : 531.2337, found 531.2338;

**IR** (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 3005, 2988, 2361, 2337, 1753, 1737, 1501, 1478, 1467, 1450, 1400, 1368, 1358, 1275, 1260, 1152, 1103, 1023, 845, 764, 750.

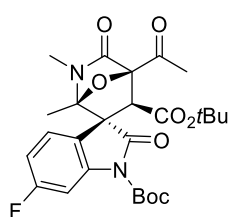


	Retention Time	Area	% Area
1	14.324	2067296	47.97
2	23.745	2242484	52.03



	Retention Time	Area	% Area
1	14.443	328077	2.27
2	23.707	14141297	97.73

**Di-tert-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6'-fluoro-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



**3am**

White solid; 86% yield, 96% ee, 97:3 dr; 44.5 mg;  $[\alpha]_D^{25} = -95.5$  (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 9.11$  min,  $t_2 = 11.05$  min,  $t_3 = 12.49$  min,  $t_4 = 13.68$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.63 (dd, *J* = 9.9, 2.3 Hz, 1H), 7.38 (dd, *J* = 8.5, 5.7 Hz, 1H), 6.87 (td, *J* = 8.7, 2.3 Hz, 1H), 3.80 (s, 1H), 2.89 (s, 3H), 2.44 (s, 3H), 1.63 (s, 10H), 1.30 (s, 3H), 0.97 (s, 9H).

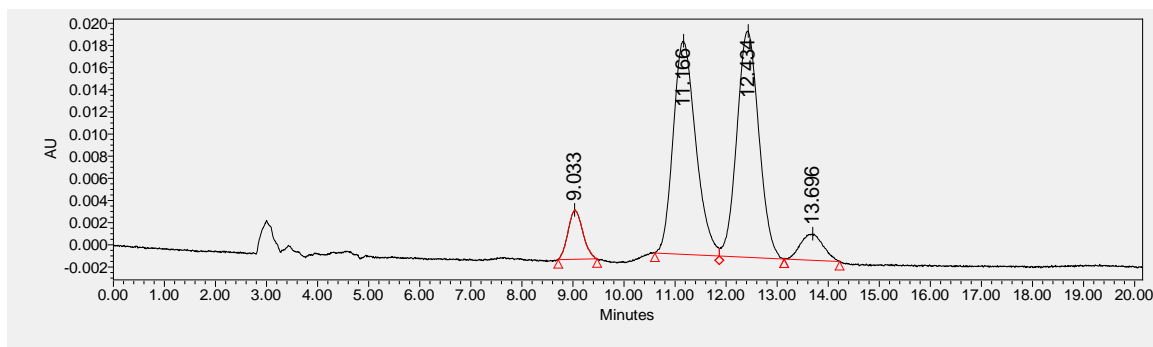
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.23, 171.58, 168.48, 166.21, 164.69, 162.23, 148.24, 141.47 (*J* = 12.1 Hz), 127.67 (*J* = 10.1 Hz), 120.20 (*J* = 3.0 Hz), 111.56 (*J* = 23.2 Hz), 103.75 (*J* = 29.3 Hz), 98.11,

90.78, 85.76, 83.17, 77.35, 77.04, 76.72, 63.02, 59.83, 28.00, 27.86, 27.54, 27.35, 14.55.

<sup>19</sup>F{<sup>1</sup>H} NMR (376 MHz, CDCl<sub>3</sub>)  $\delta$  -108.56.

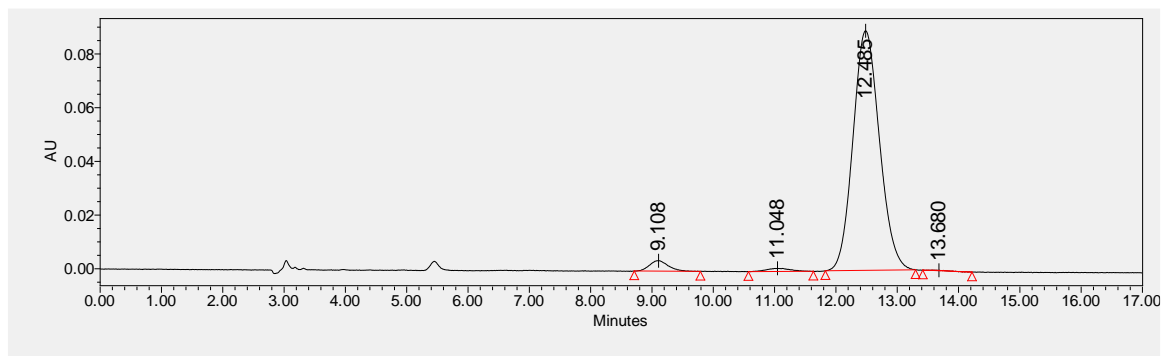
ESI-HRMS calcd for [C<sub>26</sub>H<sub>31</sub>FN<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 519.2137, found 519.2142;

IR (film):  $\tilde{\nu}$  (cm<sup>-1</sup>): 3006, 295, 2361, 2334, 1794, 1740, 1548, 1515, 465, 1397, 1365, 1268, 1153, 1094, 899, 858, 755, 679.



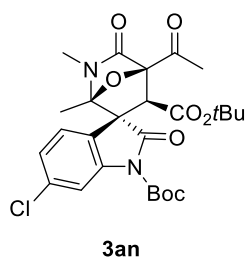
	Retention Time	Area	% Area
1	9.033	89066	6.53
2	11.166	591102	43.34
3	12.434	610242	44.75
4	13.696	73397	5.38





	Retention Time	Area	% Area
1	9.108	82861	2.97
2	11.048	31140	1.12
3	12.485	2671718	95.80
4	13.680	3269	0.12

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6'-chloro-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



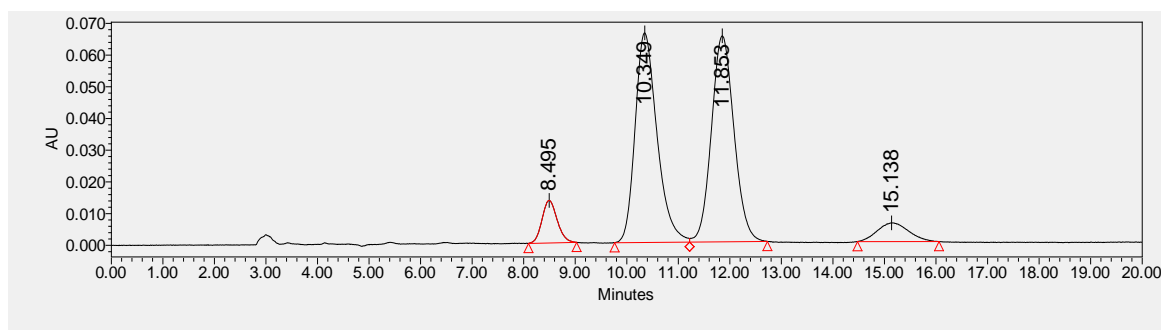
White solid; 81% yield, 98% ee, 98:2 dr; 43.3 mg;  $[\alpha]_D^{25} = -87.9$  (*c* 0.14, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.51$  min,  $t_2 = 10.17$  min,  $t_3 = 11.83$  min,  $t_4 = 15.17$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.92 (d, *J* = 1.7 Hz, 1H), 7.34 (d, *J* = 8.2 Hz, 1H), 7.15 (dd, *J* = 8.2, 1.8 Hz, 1H), 3.81 (s, 1H), 2.89 (s, 3H), 2.44 (s, 3H), 1.63 (s, 9H), 1.31 (s, 3H), 0.97 (s, 9H).

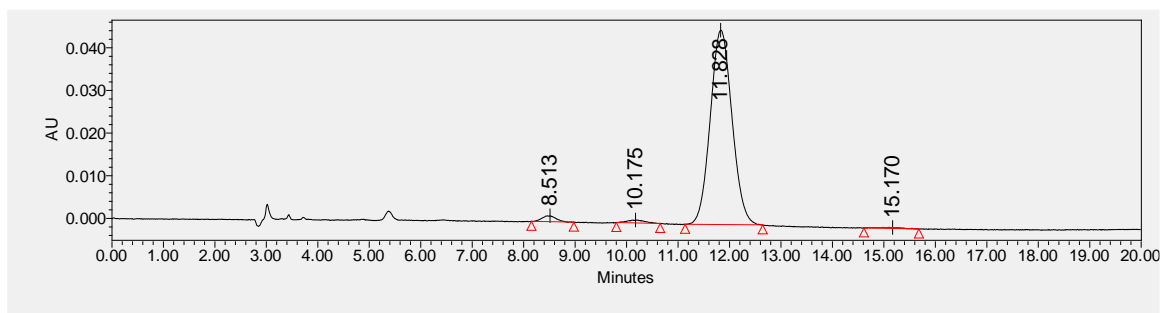
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.28, 171.41, 168.59, 166.27, 148.39, 141.24, 135.94, 127.37, 124.93, 123.23, 115.62, 98.23, 90.93, 85.93, 83.43, 77.48, 77.16, 76.84, 63.24, 59.96, 28.13, 28.00, 27.69, 27.46, 14.72.

**ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>34,9689</sup>CIN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 535.1842, found 535.1836; **ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>36,9659</sup>CIN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 537.1812, found 537.1821.

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3004, 2985, 2360, 2341, 1799, 1738, 1604, 1558, 1541, 1473, 1457, 1424, 1398, 1370, 1339, 1275, 1260, 1152, 1105, 1081, 1024, 841, 764, 750.

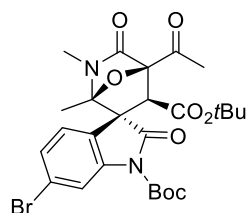


	Retention Time	Area	% Area
1	8.495	274521	6.17
2	10.349	1951194	43.82
3	11.853	1976441	44.39
4	15.138	250105	5.62



	Retention Time	Area	% Area
1	8.513	25530	1.84
2	10.175	15825	1.14
3	11.828	1336536	96.56
4	15.170	6192	0.45

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6'-bromo-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



**3ao**

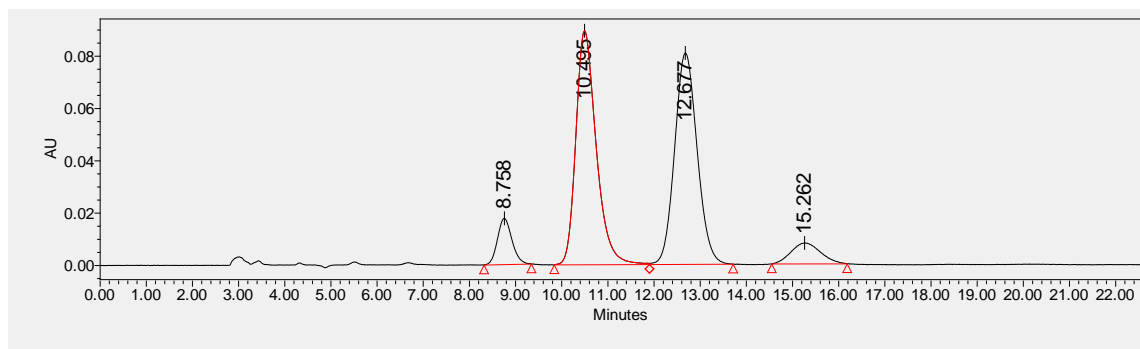
White solid; 81% yield, 97% ee, 98:2 dr; 47.0 mg;  $[\alpha]_D^{23} = -85.7$  (*c* 0.056, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.76$  min,  $t_2 = 10.48$  min,  $t_3 = 12.70$  min,  $t_4 = 15.20$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  8.09 – 8.06 (m, 1H), 7.34 – 7.27 (m, 2H), 3.81 (s, 1H), 2.89 (s, 3H), 2.45 (s, 3H), 1.63 (s, 9H), 1.31 (s, 3H), 0.98 (s, 9H).

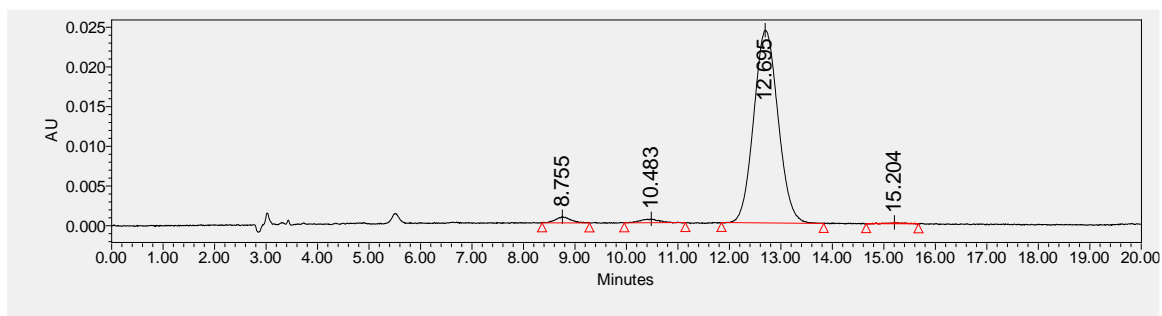
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.26, 171.30, 168.59, 166.25, 148.40, 141.36, 127.89, 127.67, 123.81, 123.78, 118.40, 100.12, 98.16, 90.93, 85.95, 83.46, 77.48, 77.36, 77.16, 76.84, 63.31, 59.93, 28.13, 28.01, 27.69, 27.46, 14.74.

**ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>78,9183</sup>BrN<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 579.1337, found 579.1333; **ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>80,9163</sup>BrN<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 581.1316, found 581.1316;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3006, 2989, 2359, 2341, 1771, 1748, 1734, 1716, 1698, 1558, 1541, 1534, 1507, 1473, 1457, 1396, 1275, 1260, 1153, 750, 699.

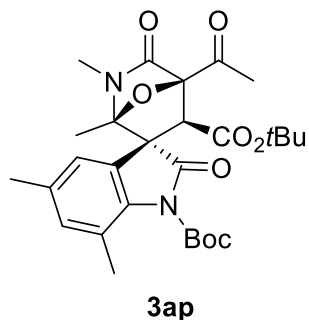


	Retention Time	Area	% Area
1	8.758	385553	6.21
2	10.495	2735990	44.05
3	12.677	2732491	44.00
4	15.262	356389	5.74



	Retention Time	Area	% Area
1	8.755	15394	1.86
2	10.483	12040	1.46
3	12.695	795606	96.28
4	15.204	3333	0.40

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1,5',6,7'-tetramethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



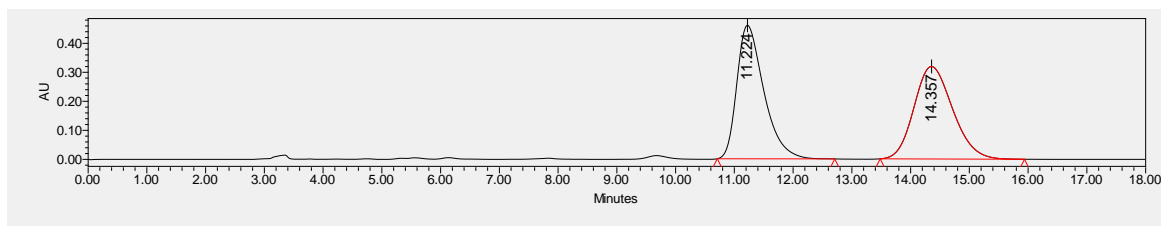
White solid; 68% yield, 60% ee, > 95:5 dr; 35.9 mg;  $[\alpha]_D^{25} = -76.0$  (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 254$  nm,  $t_1 = 11.07$  min,  $t_2 = 13.97$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.02 (s, 1H), 6.97 (s, 1H), 3.82 (s, 1H), 2.87 (s, 3H), 2.46 (s, 3H), 2.26 (s, 3H), 2.21 (s, 3H), 1.60 (s, 9H), 1.26 (s, 3H), 0.95 (s, 9H).

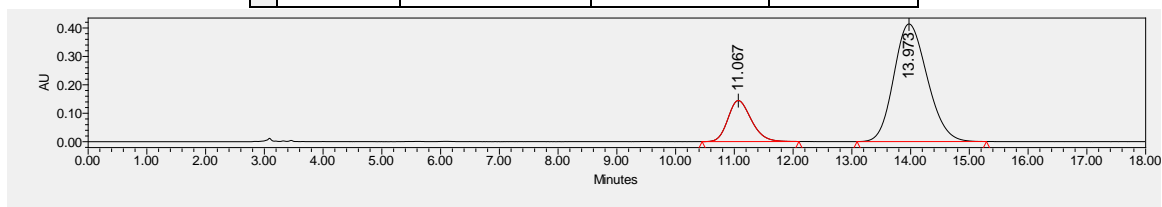
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.50, 173.07, 168.84, 166.53, 148.87, 136.65, 134.51, 133.09, 126.11, 124.35, 123.26, 98.27, 90.98, 85.44, 83.04, 77.48, 77.16, 76.84, 63.93, 59.79, 28.00, 27.85, 27.58, 27.36, 21.01, 19.39, 14.59.

ESI-HRMS calcd for [C<sub>28</sub>H<sub>36</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 529.2544, found 529.2546;

IR (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2981, 2933, 2361, 2334, 1744, 1477, 1399, 1366, 1267, 1149, 1081, 1029, 892, 848, 755, 690.

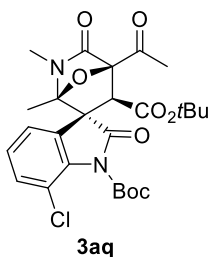


	Name	Retention Time	Area	% Area
1		11.224	14666630	50.23
2		14.357	14530872	49.77



	Name	Retention Time	Area	% Area
1		11.067	3995555	19.65
2		13.973	16341756	80.35

**Di-tert-butyl (1R,2R,3S,4R)-4-acetyl-7'-chloro-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



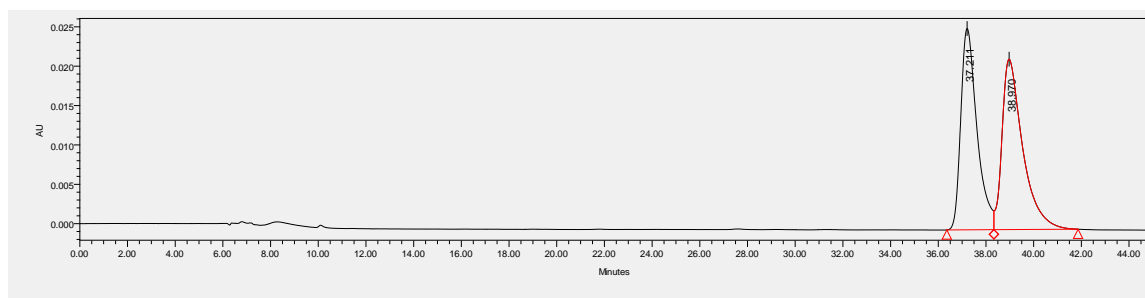
White solid; 77% yield, 58% ee, > 95:5 dr; 41.2 mg;  $[\alpha]_D^{22} = -93.5$  (*c* 0.2, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 90/10, 0.5 mL/min,  $\lambda = 230$  nm,  $t_1 = 37.07$  min,  $t_2 = 39.08$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.34 (dd, *J* = 17.8, 7.9 Hz, 2H), 7.10 (t, *J* = 7.9 Hz, 1H), 3.85 (s, 1H), 2.88 (s, 3H), 2.44 (s, 3H), 1.60 (s, 9H), 1.28 (s, 3H), 0.97 (s, 9H).

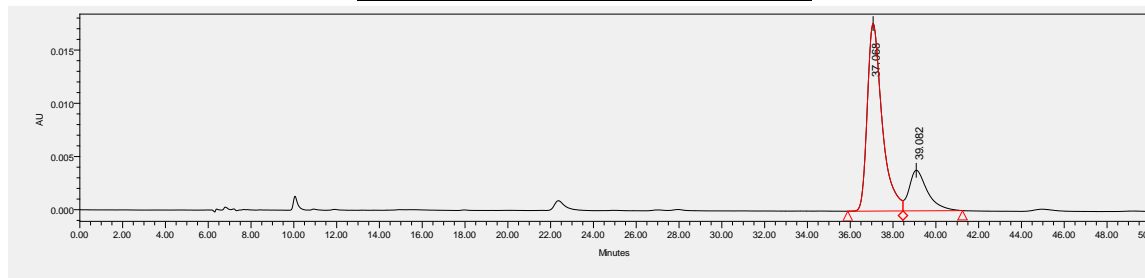
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.29, 172.14, 168.55, 166.33, 147.46, 137.79, 131.41, 128.25, 125.47, 125.02, 118.67, 98.21, 90.82, 86.46, 83.38, 77.48, 77.16, 76.84, 64.08, 59.92, 27.97, 27.71, 27.61, 27.49, 14.59.

**ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>34,9689</sup>ClN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 557.1661, found 557.1663; **ESI-HRMS** calcd for [C<sub>26</sub>H<sub>31</sub><sup>36,9659</sup>ClN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 559.1632, found 559.1640.

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>): 3004, 2983, 2360, 2341, 1752, 1740, 1718, 1466, 1457, 1422, 1398, 1371, 1275, 1260, 1233, 1151, 1119, 841, 764, 750.

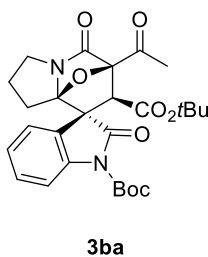


	Retention Time	Area	% Area
1	37.211	1202705	48.06
2	38.970	1299635	51.94



	Retention Time	Area	% Area
1	37.068	848055	78.86
2	39.082	227379	21.14

**Di-tert-butyl (3R,6'R,7'S,8a'R)-6'-acetyl-2,5'-dioxo-2',3',6',7'-tetrahydro-1'H,5'H-spiro[indoline-3,8'-[6,8a]epoxyindolizine]-1,7'-dicarboxylate**



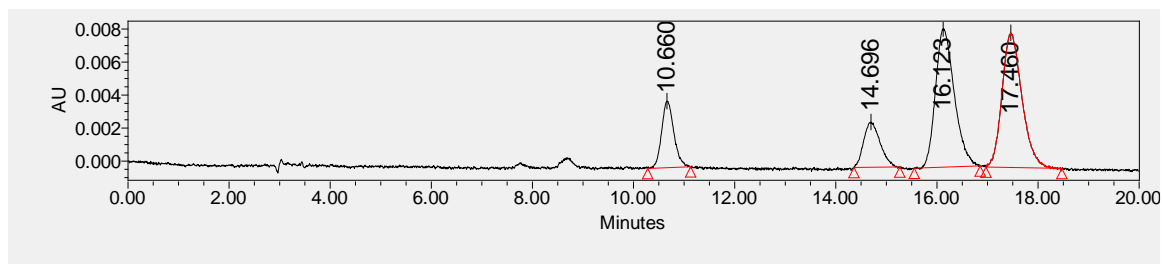
White solid; 85% yield, 99% ee, 97:3 dr; 43.5 mg;  $[\alpha]_D^{20} = -136.7$  (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 85/15, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 10.53$  min,  $t_2 = 14.40$  min,  $t_3 = 15.83$  min,  $t_4 = 16.95$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.84 (d, *J* = 8.2 Hz, 1H), 7.47 (d, *J* = 7.0 Hz, 1H), 7.42 – 7.34 (m, 1H), 7.14 (t, *J* = 7.6 Hz, 1H), 4.04 (s, 1H), 3.77 (ddd, *J* = 11.0, 7.8, 2.7 Hz, 1H), 3.15 (ddd, *J* = 11.5, 8.8, 6.7 Hz, 1H), 2.44 (s, 3H), 2.15 – 1.86 (m, 3H), 1.64 (s, 9H), 1.47 – 1.31 (m, 1H), 0.91 (s, 9H).

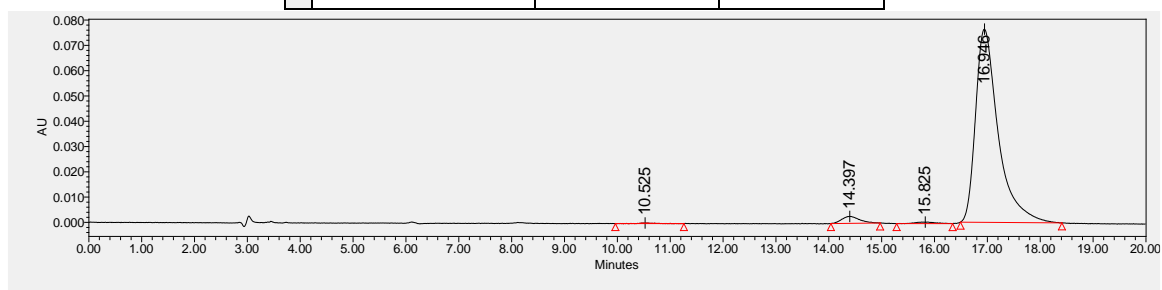
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.61, 171.29, 169.08, 166.37, 148.78, 140.40, 129.95, 126.24, 125.01, 114.73, 105.56, 93.22, 85.27, 83.09, 77.48, 77.16, 76.84, 60.63, 60.12, 43.38, 28.17, 27.94, 27.33, 26.80, 25.65.

**ESI-HRMS** calcd for  $[C_{27}H_{32}N_2O_8+H^+]$ : 513.2231, found 513.2227.

**IR** (film):  $\tilde{\nu}$  ( $cm^{-1}$ ): 2994, 2361, 2334, 1740, 1548, 1515, 1465, 1394, 1364, 1351, 1268, 1154, 755.



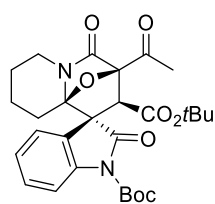
	Retention Time	Area	% Area
1	10.660	67885	11.92
2	14.696	61669	10.83
3	16.123	217089	38.13
4	17.460	222756	39.12



	Retention Time	Area	% Area
1	10.525	4513	0.19
2	14.397	64220	2.73
3	15.825	15710	0.67
4	16.946	2271047	96.42

### Di-*tert*-butyl

### (2'*S*,3*R*,3'*R*,9*a*'*R*)-3'-acetyl-2,4'-dioxo-3',4',6',7',8',9'-hexahydro-2'*H*-spiro[indoline-3,1'-[3,9a]epoxyquinolizine]-1,2'-dicarboxylate



**3ca**

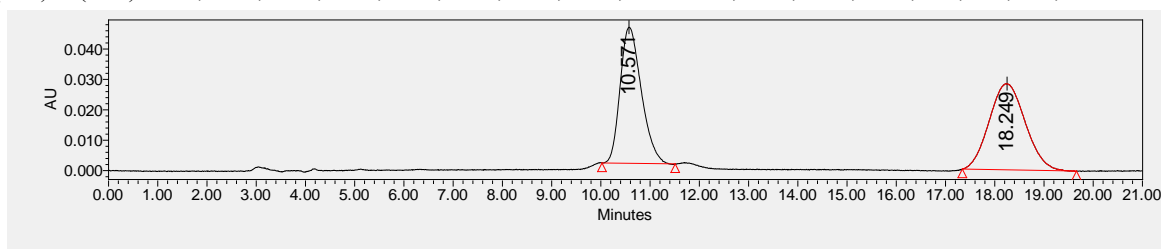
White solid; 95% yield, 95% ee, > 95:5 dr; 46.8 mg;  $[\alpha]_D^{20} = -139.0$  (*c* 0.20,  $CH_2Cl_2$ ); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 10.17$  min,  $t_2 = 17.37$  min].

**$^1H$  NMR** (400 MHz,  $CDCl_3$ )  $\delta$  7.80 (d,  $J = 8.0$  Hz, 1H), 7.40 – 7.32 (m, 2H), 7.14 (td,  $J = 7.7, 1.0$  Hz, 1H), 3.88 (s, 2H), 3.29 (td,  $J = 13.3, 12.8, 4.6$  Hz, 1H), 2.45 (s, 3H), 1.73 (td,  $J = 12.4, 11.3, 5.7$  Hz, 3H), 1.62 (s, 9H), 1.59 – 1.43 (m, 2H), 1.12 – 1.02 (m, 1H), 0.91 (s, 9H).

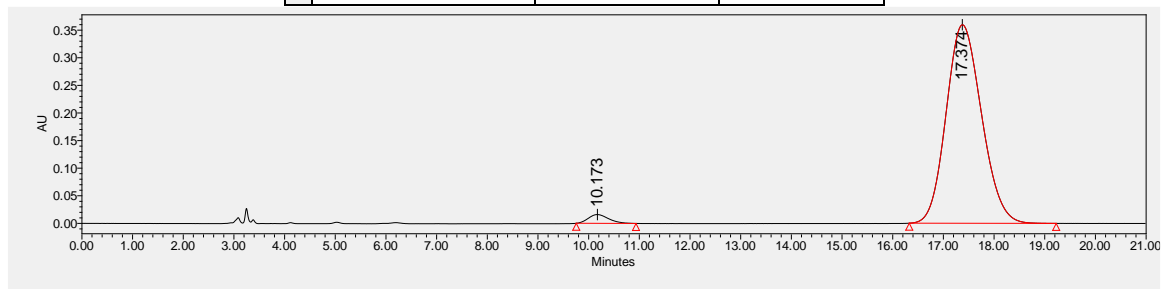
**$^{13}C$  NMR** (101 MHz,  $CDCl_3$ )  $\delta$  198.60, 172.62, 168.32, 166.40, 148.61, 140.28, 129.83, 126.55, 125.11, 124.96, 114.73, 96.84, 90.42, 85.28, 83.04, 77.48, 77.16, 76.84, 62.87, 60.39, 40.96, 28.16, 28.07, 27.35, 26.81, 22.81, 20.20.

**ESI-HRMS** calcd for  $[C_{28}H_{34}N_2O_8+H^+]$ : 527.2388, found 527.2390;

**IR** (film):  $\tilde{\nu}$  ( $cm^{-1}$ ): 2979, 2940, 2361, 2334, 1792, 1739, 1469, 1400, 1362 1350, 1267, 1154, 1096, 987, 955, 836, 756.

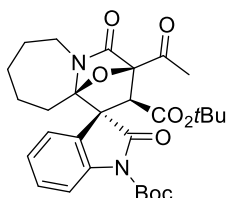


	Retention Time	Area	% Area
1	10.571	1336162	48.15
2	18.249	1438721	51.85



	Retention Time	Area	% Area
1	10.173	440179	2.46
2	17.374	17460302	97.54

**Di-*tert*-butyl (2'*S*,3*R*,3'*R*,10*a*'*R*)-3'-acetyl-2,4'-dioxo-3',4',7',8',9',10'-hexahydro-2'*H*,6'*H*-spiro[indoline-3,1'-[3,10a]epoxyprido[1,2-*a*]azepine]-1,2'-dicarboxylate**



**3da**

White solid; 99% yield, 95%/94 ee, 60:40 dr; 53.4 mg; [ $\alpha$ ]<sub>D</sub><sup>20</sup> = -41.5 (*c* 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda$  = 254 nm, *t*<sub>1</sub> = 8.71 min, *t*<sub>2</sub> = 11.40 min, *t*<sub>3</sub> = 14.12 min, *t*<sub>4</sub> = 17.96 min].

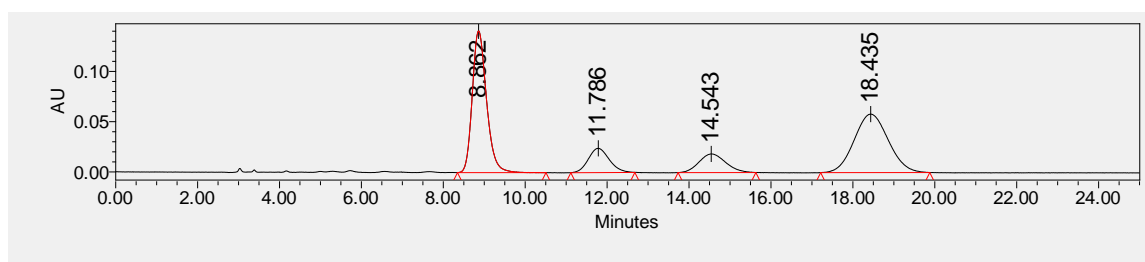
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.88 (m, 1H), 7.46 – 7.33 (m, 2H), 7.20 – 7.01 (m, 1H), 4.18 (s, 1H), 3.83 (m, 1H), 2.72 – 2.59 (m, 1H), 2.48 (m, 3H), 2.35 – 2.19 (m, 1H), 1.99 – 1.75 (m, 3H), 1.65 (s, 9H), 1.63 – 1.53 (m, 1H), 1.44 – 1.13 (m, 3H), 1.11 (s, 4H), 0.93 (s, 5H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  199.44, 198.75, 173.86, 171.87, 169.43, 168.21, 166.36, 166.06,

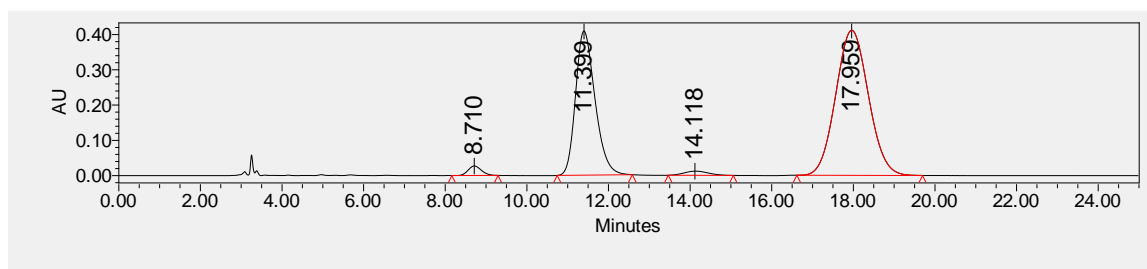
148.93, 148.65, 140.89, 140.27, 129.98, 129.69, 126.53, 126.23, 124.91, 124.79, 124.23, 121.79, 114.94, 114.71, 102.57, 101.17, 90.51, 89.67, 85.26, 85.20, 82.97, 82.54, 77.48, 77.16, 76.84, 63.11, 63.01, 60.29, 56.07, 43.68, 42.43, 30.78, 30.42, 30.37, 29.99, 29.67, 28.53, 28.17, 28.05, 27.72, 27.64, 27.37, 23.19, 23.11.

**ESI-HRMS** calcd for [C<sub>29</sub>H<sub>36</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 541.2544, found 541.2548;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>): 2982, 2935, 2361, 2334, 1792, 1738, 1467, 1410, 1360, 1351, 1267, 1154, 1067, 1004, 837, 755.

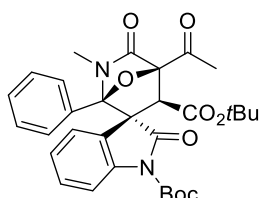


	Retention Time	Area	% Area
1	8.862	3398152	40.14
2	11.786	854721	10.10
3	14.543	841347	9.94
4	18.435	3372038	39.83



	Retention Time	Area	% Area
1	8.710	609342	1.63
2	11.399	13511682	36.05
3	14.118	490478	1.31
4	17.959	22869859	61.02

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6-methyl-2',5-dioxo-1-phenyl-7-oxa-6-azaspiro[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



**3ea**

White solid; 92% yield, 94% ee, > 95:5 dr; 51.7 mg;  $[\alpha]_D^{21} = +13.9$  确认 ( $c$  0.46,  $\text{CH}_2\text{Cl}_2$ );

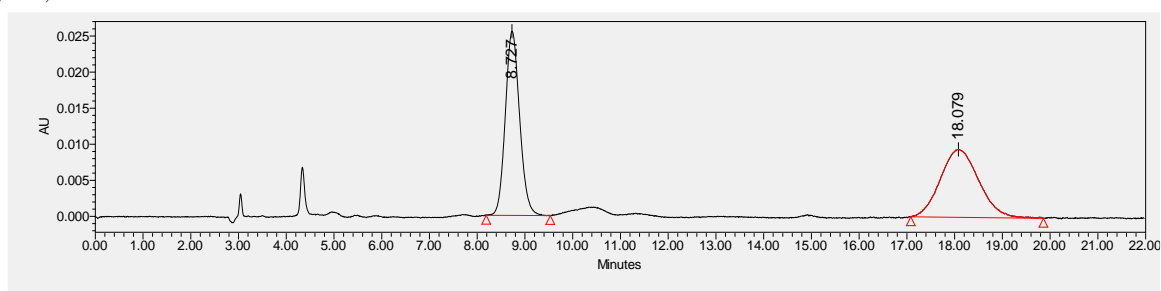
determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 9.01$  min,  $t_2 = 18.97$  min].

$^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.66 (d,  $J = 7.8$  Hz, 1H), 7.24 (dd,  $J = 9.9, 5.7$  Hz, 5H), 7.15 (t,  $J = 7.7$  Hz, 2H), 6.84 (td,  $J = 7.7, 1.0$  Hz, 1H), 3.96 (s, 1H), 2.72 (s, 3H), 2.57 (s, 3H), 1.68 (s, 9H), 0.90 (s, 9H).

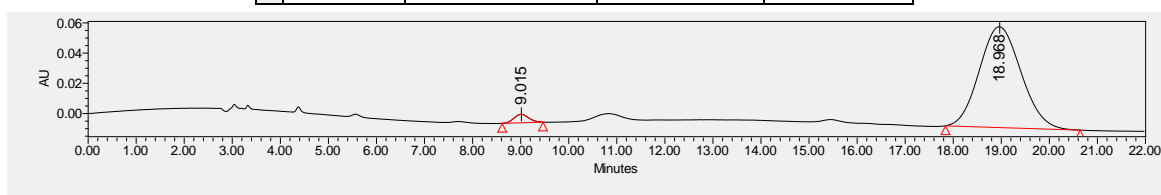
$^{13}\text{C NMR}$  (101 MHz,  $\text{CDCl}_3$ )  $\delta$  198.65, 172.95, 168.26, 166.15, 148.77, 140.10, 130.14, 129.92, 129.47, 128.76, 126.87, 126.32, 124.97, 124.72, 114.40, 100.48, 90.45, 85.41, 83.04, 77.48, 77.16, 76.84, 63.00, 61.39, 28.58, 28.55, 28.22, 28.14, 28.12, 27.25.

**ESI-HRMS** calcd for  $[\text{C}_{32}\text{H}_{36}\text{N}_2\text{O}_8 + \text{H}^+]$ : 563.2388, found 563.2386.

**IR** (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ): 2980, 2935, 2361, 2335, 1791, 1737, 1604, 1472, 1424, 1362, 1282, 1254, 1151, 1103, 1080, 1029, 965, 949, 935, 754, 702.

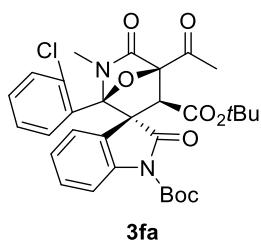


	Name	Retention Time	Area	% Area
1		8.727	532007	50.23
2		18.079	527059	49.77



	Name	Retention Time	Area	% Area
1		9.015	119765	2.89
2		18.968	4029570	97.11

**Di-tert-butyl (1*S*,2*R*,3*S*,4*R*)-4-acetyl-1-(2-chlorophenyl)-6-methyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



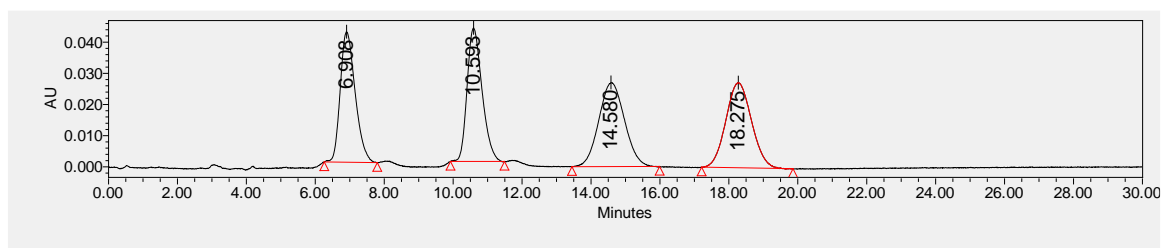
White solid; 93% yield, 98%/98% ee, 75:25 dr; 55.3 mg;  $[\alpha]^{22}_{\text{D}} = +15.3$  (*c* 0.46, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 6.80$  min,  $t_2 = 10.67$  min,  $t_3 = 14.36$  min,  $t_4 = 18.25$  min].

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  8.11 (d, *J* = 8.0 Hz, 1H), 7.71 (d, *J* = 8.2 Hz, 1H), 7.36 (t, *J* = 7.7 Hz, 1H), 7.27 (d, *J* = 14.9 Hz, 1H), 7.27 (s, 2H), 7.16 (d, *J* = 7.9 Hz, 2H), 6.96 (t, *J* = 7.6 Hz, 2H), 6.79 (t, *J* = 7.6 Hz, 1H), 3.97 (s, 1H), 2.96 (s, 3H), 2.68 (s, 1H), 2.56 (s, 4H), 1.68 (s, 3H), 0.89 (d, *J* = 6.9 Hz, 12H).

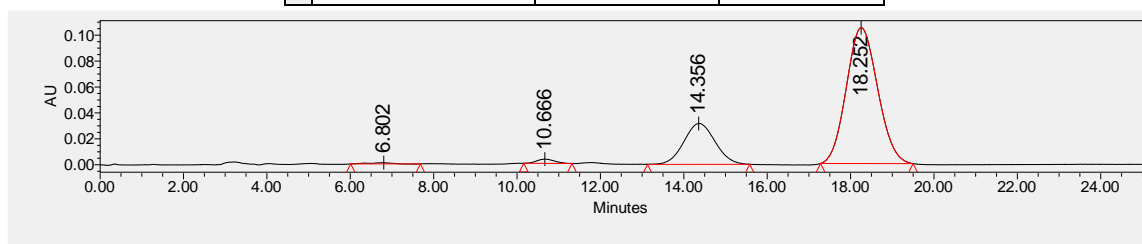
**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.64, 173.89, 168.15, 166.19, 148.99, 140.80, 131.80, 131.71, 131.55, 130.53, 129.54, 128.73, 127.56, 126.42, 124.12, 123.90, 114.62, 100.21, 89.47, 84.88, 83.01, 77.48, 77.16, 76.84, 63.49, 62.15, 28.23, 28.20, 28.07, 27.20.

**ESI-HRMS** calcd for [C<sub>32</sub>H<sub>35</sub><sup>34,9689</sup>ClN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 619.1818, found 619.1813; **ESI-HRMS** calcd for [C<sub>32</sub>H<sub>35</sub><sup>36,9659</sup>ClN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 620.1851, found 620.1847;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>): 2980, 2935, 2361, 2335, 1791, 1737, 1604, 1472, 1424, 1362, 1282, 1254, 1151, 1103, 1080, 1029, 965, 949, 935, 754, 702.



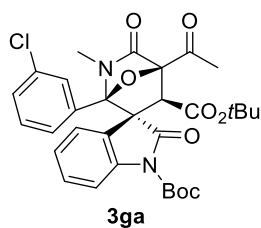
	Retention Time	Area	% Area
1	6.908	501396	25.55
2	10.593	477902	24.36
3	14.578	484276	24.68
4	18.273	498517	25.41



	Retention Time	Area	% Area
1	6.802	37143	0.51
2	10.666	95766	1.32
3	14.356	1647679	22.76
4	18.252	5459685	75.41

**Di-tert-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1-(3-chlorophenyl)-6-methyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**





White solid; 90% yield, 98% ee, 98:2 dr; 53.7 mg;  $[\alpha]^{23}_D = +41.9$  (*c* 0.50, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.05$  min,  $t_2 = 9.65$  min,  $t_3 = 10.61$  min,  $t_4 = 13.53$  min].

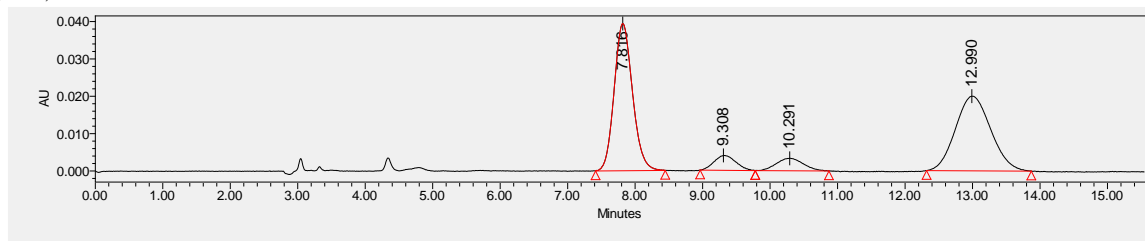
**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.66 (d, *J* = 8.1 Hz, 1H), 7.33 (s, 1H), 7.25 – 7.21 (m, 1H), 7.20 – 7.11 (m, 3H), 6.97 (d, *J* = 7.3 Hz, 1H), 6.87 (td, *J* = 7.7, 1.0 Hz, 1H), 3.95 (s, 1H), 2.73 (s, 3H), 2.56 (s, 3H), 1.67 (s, 9H), 0.89 (s, 9H).

**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.29, 172.66, 168.05, 165.99, 148.64, 140.06, 135.09, 131.84, 130.45, 130.04, 129.75, 126.80, 126.72, 124.89, 124.56, 124.18, 114.45, 99.69, 90.47, 85.61, 83.22,

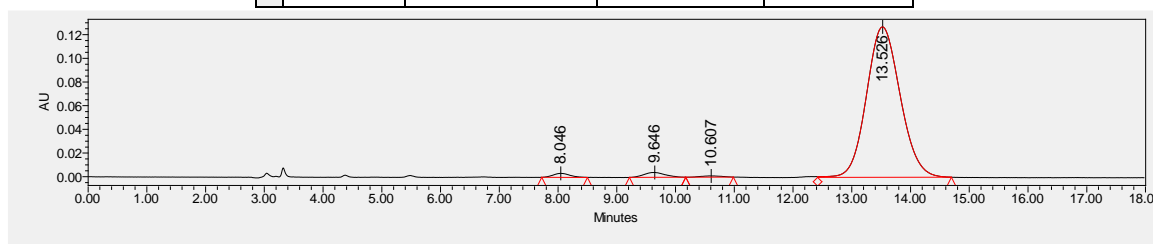
77.48, 77.16, 76.84, 62.97, 61.10, 61.08, 28.59, 28.21, 28.21, 28.15, 27.28, 27.28.

**ESI-HRMS** calcd for [C<sub>32</sub>H<sub>35</sub><sup>34.9689</sup>CIN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 619.1818, found 619.1815; **ESI-HRMS** calcd for [C<sub>32</sub>H<sub>35</sub><sup>36.9659</sup>CIN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 620.1851, found 620.1844;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2980, 2935, 2361, 2334, 1793, 1741, 1605, 1571, 1473, 1424, 1379, 1364, 1282, 1255, 1153, 1101, 1024, 861, 756, 681, 582.

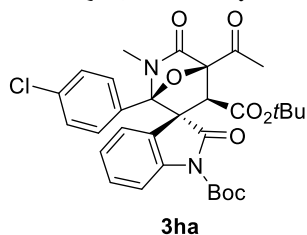


	Name	Retention Time	Area	% Area
1		7.816	743097	44.95
2		9.308	89108	5.39
3		10.291	93216	5.64
4		12.990	727799	44.02



	Name	Retention Time	Area	% Area
1		8.046	67659	1.29
2		9.646	103614	1.97
3		10.607	26207	0.50
4		13.526	5057097	96.24

**Di-tert-butyl (1R,2R,3S,4R)-4-acetyl-1-(4-chlorophenyl)-6-methyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



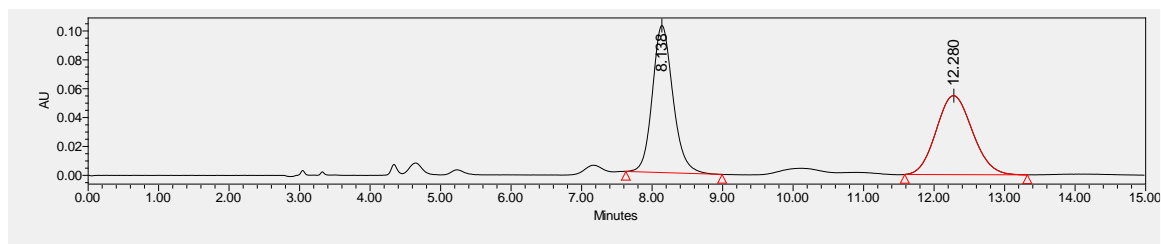
White solid; 89% yield, 96% ee, > 95:5 dr; 53.1 mg;  $[\alpha]^{23}_D = +29.0$  (*c* 0.53, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 8.41$  min,  $t_2 = 12.74$  min].

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.66 (d, *J* = 8.1 Hz, 1H), 7.24 – 7.11 (m, 6H), 6.87 (td, *J* = 7.7, 0.9 Hz, 1H), 3.95 (s, 1H), 2.70 (s, 3H), 2.55 (s, 3H), 1.67 (s, 9H), 0.88 (s, 9H).

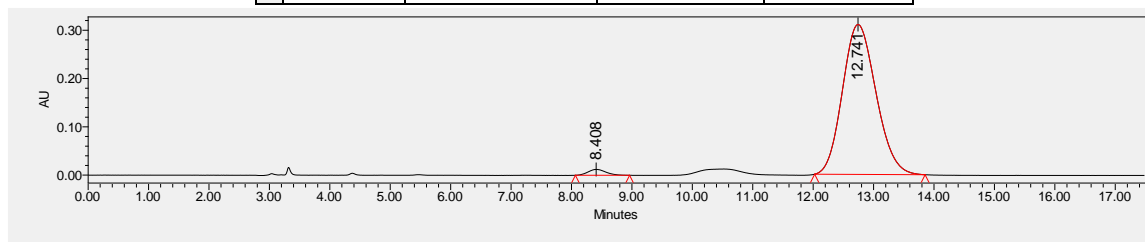
**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.26, 172.75, 168.11, 165.99, 148.66, 140.05, 136.35, 129.73, 129.15, 128.52, 127.79, 126.78, 124.94, 124.68, 114.52, 99.90, 90.46, 85.60, 83.19, 77.48, 77.16, 76.84, 62.91, 61.36, 61.34, 28.54, 28.53, 28.21, 28.12, 28.10, 27.24.

**ESI-HRMS** calcd for [C<sub>32</sub>H<sub>35</sub><sup>34.9689</sup>CIN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 619.1818, found 619.1816; **ESI-HRMS** calcd for [C<sub>32</sub>H<sub>35</sub><sup>36.9659</sup>CIN<sub>2</sub>O<sub>8</sub>+Na<sup>+</sup>]: 620.1851, found 620.1845;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2980, 2936, 2360, 1792, 1742, 1604, 1471, 1381, 1282, 1282, 1251, 1153, 1095, 1046, 1014, 968, 835, 756.

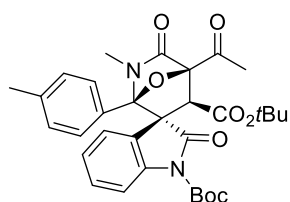


	Name	Retention Time	Area	% Area
1		8.138	2064666	51.44
2		12.280	1949271	48.56



	Name	Retention Time	Area	% Area
1		8.408	247535	2.03
2		12.741	11955911	97.97

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6-methyl-2',5-dioxo-1-(*p*-tolyl)-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



**3ia**

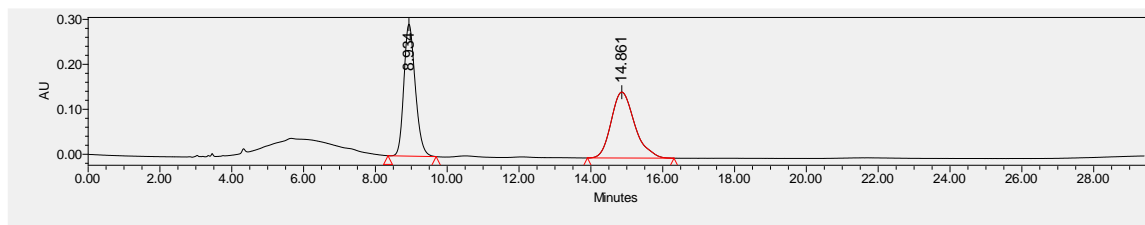
White solid; 91% yield, 85% ee, > 95:5 dr; 52.6 mg;  $[\alpha]_D^{23} = +10.7$  (*c* 0.46, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 80/20, 1.0 mL/min,  $\lambda = 230$  nm,  $t_1 = 9.38$  min,  $t_2 = 15.64$  min].

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.66 (d, *J* = 8.5 Hz, 1H), 7.19 – 7.12 (m, 2H), 7.09 – 6.99 (m, 4H), 6.85 (t, *J* = 7.6 Hz, 1H), 3.94 (s, 1H), 2.69 (s, 3H), 2.56 (s, 3H), 2.23 (s, 3H), 1.67 (s, 9H), 0.88 (s, 9H).

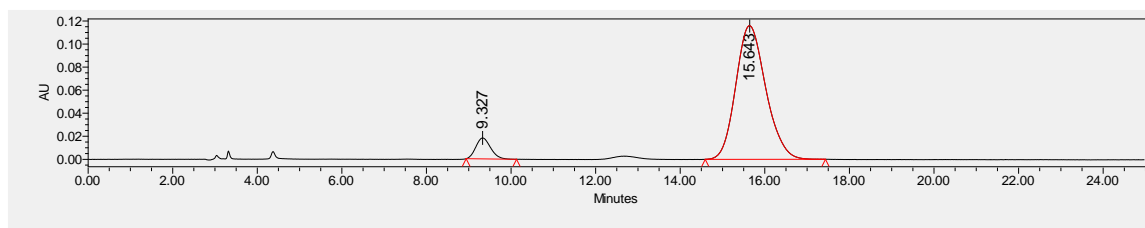
**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.75, 173.02, 168.29, 166.19, 148.80, 140.19, 140.09, 129.44, 129.40, 126.96, 126.91, 126.25, 125.12, 124.76, 114.37, 100.60, 90.45, 85.36, 82.98, 77.48, 77.16, 76.84, 62.96, 61.51, 28.50, 28.22, 28.15, 27.25, 21.32.

**ESI-HRMS** calcd for [C<sub>33</sub>H<sub>38</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 577.2544, found 577.2546;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2981, 2935, 2360, 2336, 1791, 1738, 1609, 1471, 1423, 1385, 1361, 1276, 1258, 1153, 1099, 1048, 1022, 966, 830, 755, 697, 428.

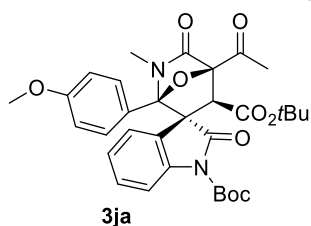


	Name	Retention Time	Area	% Area
1		8.934	6493348	49.40
2		14.861	6649916	50.60



	Name	Retention Time	Area	% Area
1		9.327	437290	7.13
2		15.643	5697246	92.87

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-1-(4-methoxyphenyl)-6-methyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



White solid; 86% yield, 58% ee, > 95:5 dr; 50.8 mg;  $[\alpha]_D^{23} = +4.0$  (*c* 0.22, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 85/15, 1.0 mL/min,  $\lambda = 210$  nm,  $t_1 = 21.89$  min,  $t_2 = 26.77$  min].

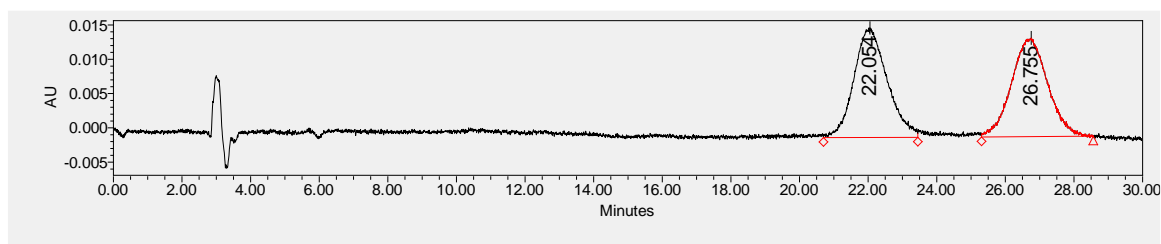
**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.67 (d, *J* = 8.1 Hz, 1H), 7.16 (t, *J* = 8.0 Hz, 2H), 7.09 (d, *J* = 7.7 Hz, 2H), 6.86 (t, *J* = 7.6 Hz, 1H), 6.73 (d, *J* = 8.6 Hz, 2H), 3.94 (s, 1H), 3.72 (s, 3H), 2.68 (s, 3H), 2.56 (s, 3H), 1.67 (s, 9H), 0.88 (s, 9H).

**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.81, 173.01, 168.26, 166.18, 160.57, 148.79, 140.04, 129.45, 127.89, 126.93, 125.14, 124.82, 121.94, 114.42, 114.10, 100.52, 90.48, 85.40, 82.99, 77.48, 77.16,

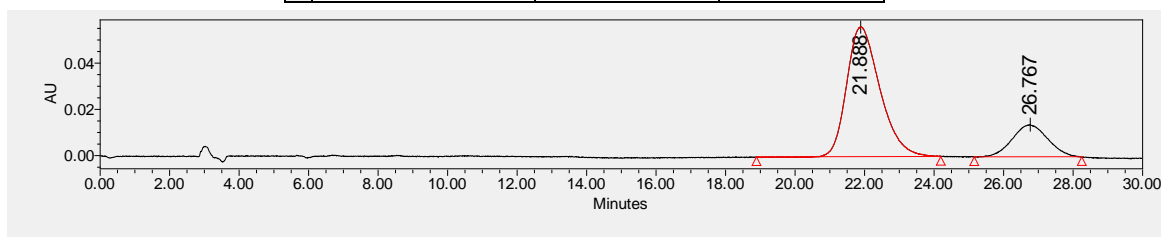
76.84, 62.99, 61.60, 55.34, 28.48, 28.22, 28.17, 27.23.

**ESI-HRMS** calcd for [C<sub>33</sub>H<sub>38</sub>N<sub>2</sub>O<sub>9</sub>+H<sup>+</sup>]: 593.2494, found 593.2487;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3005, 2983, 2360, 2337, 1793, 1735, 1610, 1519, 1462, 1390, 1367, 1333, 1274, 1259, 1151, 1094, 1028, 838, 751, 439, 425.

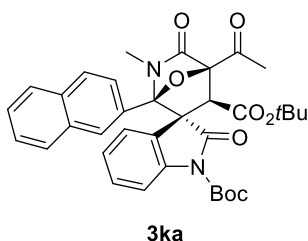


	Retention Time	Area	% Area
1	22.054	1070467	50.55
2	26.755	1047109	49.45



	Retention Time	Area	% Area
1	21.888	3735684	79.20
2	26.767	981278	20.80

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6-methyl-1-(naphthalen-2-yl)-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



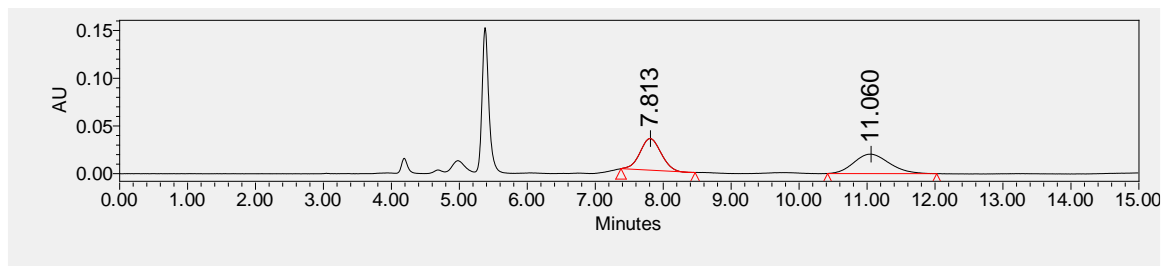
White solid; 91% yield, 79% ee, > 95:5 dr; 55.7mg;  $[\alpha]_D^{23} = +59.5$  (*c* 0.34, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda = 210$  nm,  $t_1 = 7.80$  min,  $t_2 = 11.01$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.83 (s, 1H), 7.80 – 7.71 (m, 2H), 7.66 (dd, *J* = 15.1, 8.3 Hz, 2H), 7.54 – 7.47 (m, 2H), 7.21 – 7.12 (m, 2H), 7.08 (td, *J* = 8.2, 1.3 Hz, 1H), 6.76 (td, *J* = 7.7, 0.9 Hz, 1H), 4.02 (s, 1H), 2.73 (s, 3H), 2.62 (s, 3H), 1.71 (s, 9H), 1.60 (s, 3H), 0.90 (s, 9H).

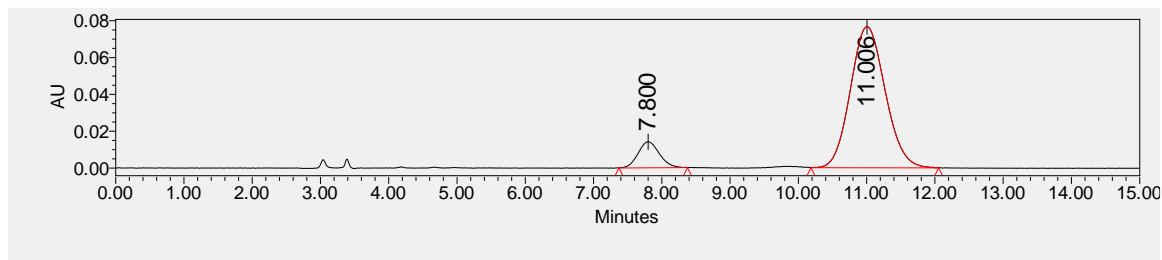
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  198.69, 173.13, 168.31, 166.17, 148.83, 140.10, 133.61, 132.65, 129.54, 128.77, 128.55, 127.81, 127.55, 127.26, 127.05, 126.87, 124.90, 124.86, 122.48, 114.37, 100.65, 90.58, 85.51, 83.13, 77.48, 77.16, 76.84, 63.07, 61.45, 28.68, 28.26, 28.24, 27.27.

**ESI-HRMS** calcd for [C<sub>36</sub>H<sub>38</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 613.2544, found 613.2545;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3056, 2979, 2932, 1791, 1738, 1604, 1474, 1423, 1389, 1361, 1287, 1248, 1154, 1101, 1028, 959, 856, 823, 790, 757, 620, 476.

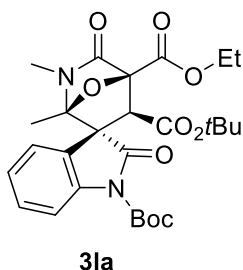


	Retention Time	Area	% Area
1	7.813	713719	49.15
2	11.060	738440	50.85



	Retention Time	Area	% Area
1	7.800	306720	10.16
2	11.006	2710841	89.84

**1',3-Di-tert-butyl 4-ethyl (1*R*,2*R*,3*S*,4*S*)-1,6-dimethyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3,4-tricarboxylate**



White solid; 83% yield, 98%/70% ee, 87:13 dr; 44.0 mg;  $[\alpha]_D^{26} = -91.5$  (*c* 0.28, CH<sub>2</sub>Cl<sub>2</sub>);

determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 70/30, 0.5 mL/min,  $\lambda = 230$  nm,  $t_1 = 15.80$  min,  $t_2 = 16.69$  min,  $t_3 = 18.01$  min,  $t_4 = 19.00$  min].

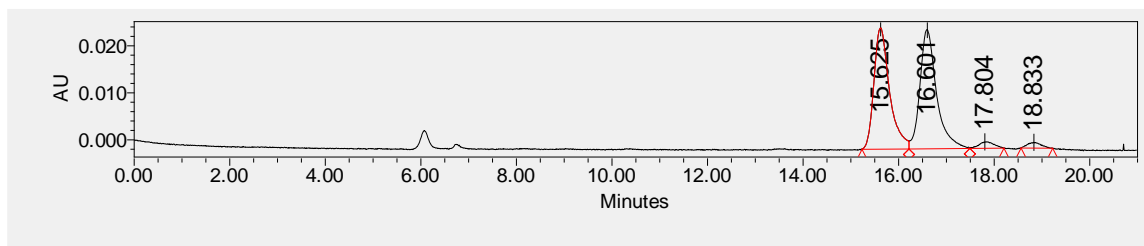
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.80 (d, *J* = 8.2 Hz, 1H), 7.45 (d, *J* = 7.6 Hz, 1H), 7.36 (t, *J* = 7.9 Hz, 1H), 7.14 (t, *J* = 7.6 Hz, 1H), 4.48 (dt, *J* = 10.7, 7.2 Hz, 1H), 4.41 – 4.32 (m, 1H), 3.76 (s, 1H), 2.90 (s, 3H), 1.63 (s, 9H), 1.33 (t, *J* = 7.1 Hz, 3H), 1.30 (s, 3H), 0.93 (s, 9H).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  171.89, 168.59, 166.15, 164.07, 148.67, 140.28, 129.85, 126.81, 124.96, 124.67, 114.70, 98.61, 86.52, 85.31, 82.75, 77.48, 77.16, 76.84, 63.20, 62.35, 58.84, 28.17,

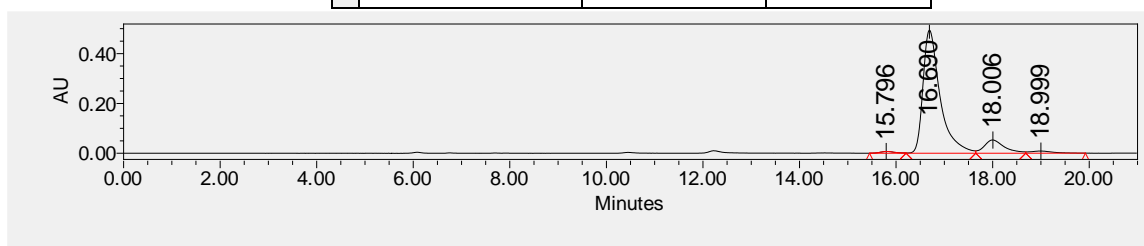
27.78, 27.66, 27.38, 14.68, 14.20.

**ESI-HRMS** calcd for [C<sub>27</sub>H<sub>34</sub>N<sub>2</sub>O<sub>9</sub>+H<sup>+</sup>]: 531.2337, found 531.2338;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2987, 2937, 1760, 1736, 1604, 1472, 1400, 1366, 1344, 1281, 1256, 1149, 1092, 1048, 1005, 855, 756, 584, 509.

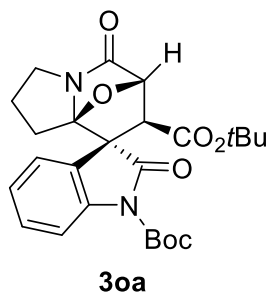


	Retention Time	Area	% Area
1	15.625	587237	46.81
2	16.601	612359	48.82
3	17.804	30228	2.41
4	18.833	24573	1.96



	Retention Time	Area	% Area
1	15.796	146023	1.03
2	16.690	12164369	86.17
3	18.006	1530901	10.84
4	18.999	275426	1.95

**Di-*tert*-butyl (3*R*,6'*S*,7'*S*,8*a*'*R*)-2,5'-dioxo-2',3',6',7'-tetrahydro-1'*H*,5'*H*-spiro[indoline-3,8']-[6,8*a*]epoxyindolizine]-1,7'-dicarboxylate**



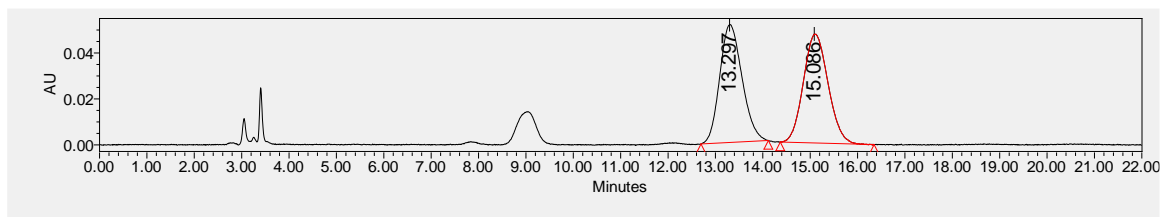
White solid; 67% yield, 58% ee, > 95:5 dr; 31.4 mg;  $[\alpha]_D^{23} = -47.9$  (*c* 0.096, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 70/30, 0.5 mL/min,  $\lambda = 230$  nm,  $t_1 = 13.26$  min,  $t_2 = 15.09$  min].

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.92 (d,  $J = 8.0$  Hz, 1H), 7.40 – 7.33 (m, 1H), 7.20 (dd,  $J = 7.7, 1.0$  Hz, 1H), 7.10 (td,  $J = 7.6, 1.0$  Hz, 1H), 4.87 (d,  $J = 5.1$  Hz, 1H), 3.87 (d,  $J = 5.1$  Hz, 1H), 3.79 (ddd,  $J = 10.5, 7.9, 1.8$  Hz, 1H), 2.76 – 2.65 (m, 1H), 2.15 (ddd,  $J = 14.0, 7.7, 2.0$  Hz, 1H), 2.00 (dd,  $J = 21.0, 10.6$  Hz, 1H), 1.75 – 1.68 (m, 1H), 1.65 (s, 9H), 1.42 – 1.35 (m, 1H), 1.11 (s, 9H).

**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  174.79, 174.13, 166.87, 149.01, 140.92, 129.79, 126.33, 124.59, 122.92, 114.92, 108.17, 85.20, 82.85, 80.88, 77.48, 77.16, 76.84, 59.65, 55.58, 44.25, 28.21, 27.83, 26.10, 25.70.

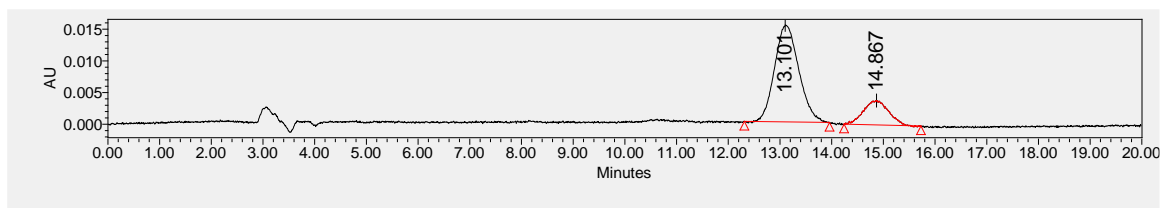
**ESI-HRMS** calcd for [C<sub>25</sub>H<sub>30</sub>N<sub>2</sub>O<sub>7</sub>+H<sup>+</sup>]: 471.2126, found 471.2131;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2982, 2938, 2361, 23344, 1742, 1528, 1468, 1398, 1345, 1303, 1269, 1150, 1116, 1028, 895, 846, 755, 679.



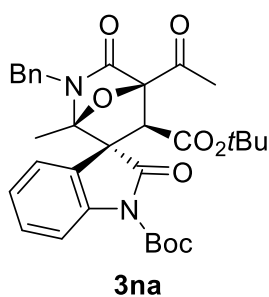
	Retention Time	Area	% Area
1	13.297	1679840	49.50

2	15.086	1713955	50.50
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	Retention Time	Area	% Area
1	13.101	497847	79.27
2	14.867	130200	20.73

**Di-*tert*-butyl (1*R*,2*R*,3*S*,4*R*)-4-acetyl-6-benzyl-1-methyl-2',5-dioxo-7-oxa-6-azaspiro[bicyclo[2.2.1]heptane-2,3'-indoline]-1',3-dicarboxylate**



White solid; 99% yield, 99%/95% ee, 65:35 dr; 57.0 mg;  $[\alpha]_D^{23} = +15.9$  (*c* 0.088, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IF, *n*-hexane/*i*-PrOH = 70/30, 0.5 mL/min,  $\lambda = 230$  nm,  $t_1 = 12.79$  min,  $t_2 = 16.69$  min,  $t_3 = 17.67$  min,  $t_4 = 18.14$  min].

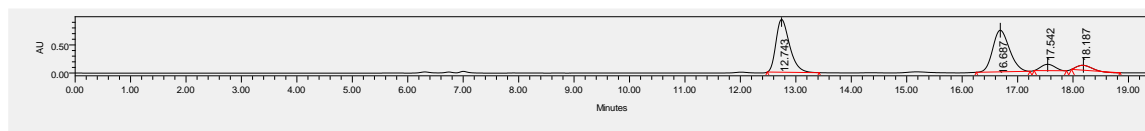
**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.97 (d, *J* = 8.2 Hz, 1H), 7.47 – 7.31 (m, 2H), 7.32 – 7.27 (m, 2H), 7.18 (dt, *J* = 28.5, 8.5 Hz, 5H), 5.17 (t, *J* = 15.6 Hz, 1H), 3.89 (d, *J* = 1.5 Hz, 1H), 3.41 (d, *J* = 16.3 Hz, 1H), 2.52 (m, 3H), 1.65 (m, 9H), 1.27 (s, 2H), 1.16 (s, 1H), 1.13 (s, 6H), 0.94 (s, 3H).

**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>)  $\delta$  199.05, 173.62, 170.18, 166.05, 148.89, 140.94, 137.23, 130.22, 129.00, 127.85, 126.94, 126.24, 125.04, 124.41, 115.16, 100.34, 90.09, 85.31, 82.80, 77.48, 77.16,

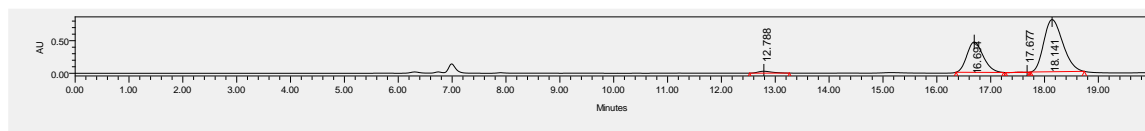
76.84, 63.83, 55.57, 46.49, 28.23, 28.18, 27.78, 27.39, 13.99.

**ESI-HRMS** calcd for [C<sub>32</sub>H<sub>36</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 577.2544, found 577.2542;

**IR** (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 2980, 2929, 2360, 2333, 1792, 1735, 1605, 1471, 1402, 1361, 1351, 1286, 1255, 1151, 1100, 1004, 845, 756, 706, 624, 597, 467.

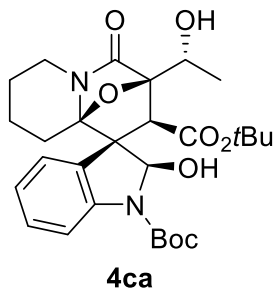


	Retention Time	Area	% Area
1	12.743	15896915	45.49
2	16.687	15489402	44.32
3	17.542	1915069	5.48
4	18.187	1648045	4.72



	Retention Time	Area	% Area
1	12.788	526737	1.76
2	16.694	9720802	32.56
3	17.677	26658	0.09
4	18.141	19576312	65.58

**Di-tert-butyl (2R,2'S,3S,3'R,9a'R)-2-hydroxy-3'-(R)-1-hydroxyethyl)-4'-oxo-3',4',6',7',8',9'-hexahydro-2'H-spiro[indoline-3,1'-[3,9a]epoxyquinolizine]-1,2'-dicarboxylate**



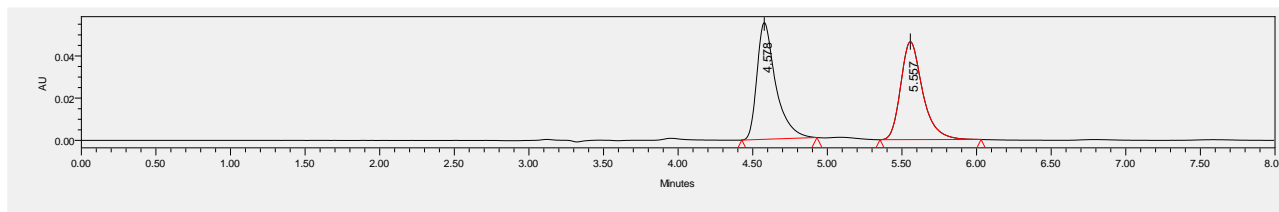
White solid; 89% yield, 96% ee, > 95:5 dr; 47.0 mg;  $[\alpha]^{23}_D = +59.4$  (c 0.096, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IA, *n*-hexane/*i*-PrOH = 90/10, 1.0 mL/min,  $\lambda = 254$  nm,  $t_1 = 4.57$  min,  $t_2 = 5.54$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.31 (d,  $J = 7.6$  Hz, 1H), 7.26 (d,  $J = 3.2$  Hz, 2H), 6.97 (t,  $J = 7.6$  Hz, 1H), 5.73 (s, 1H), 4.83 (p,  $J = 6.5$  Hz, 1H), 4.05 – 3.88 (m, 2H), 3.23 (d,  $J = 7.3$  Hz, 1H), 3.12 (ddd,  $J = 15.4, 11.1, 4.8$  Hz, 1H), 1.78 – 1.66 (m, 3H), 1.60 (s, 9H), 1.54 (d,  $J = 6.7$  Hz, 3H), 1.03 (s, 9H).

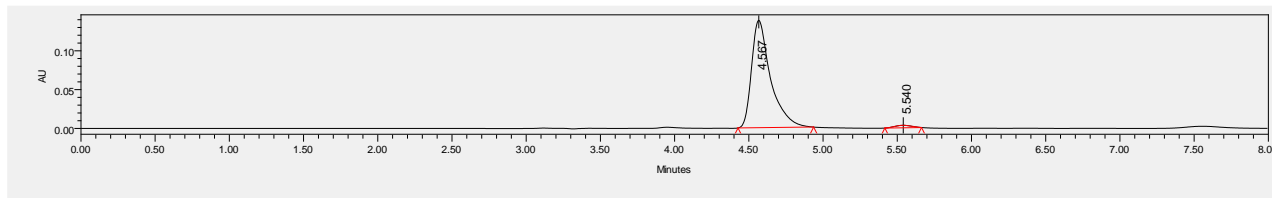
<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$  172.76, 171.28, 168.88, 141.13, 129.71, 127.93, 127.15, 123.19, 114.35, 111.16, 100.09, 94.83, 88.95, 84.30, 77.48, 77.16, 76.84, 65.35, 51.41, 40.01, 28.51, 27.47, 26.11, 22.72, 19.79, 18.30.

ESI-HRMS calcd for [C<sub>28</sub>H<sub>36</sub>N<sub>2</sub>O<sub>8</sub>+H<sup>+</sup>]: 529.2544, found 529.2546;

IR (film):  $\tilde{\nu}$  (cm<sup>-1</sup>) 3463, 2978, 2938, 2360, 2339, 1790, 1726, 1603, 1470, 1458, 1405, 1367, 1346, 1259, 1151, 1109, 897, 799, 755, 511, 459.

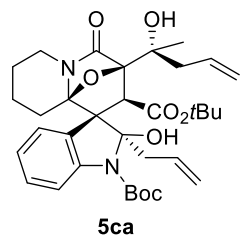


	Retention Time	Area	% Area
1	4.578	487191	50.79
2	5.557	472028	49.21



	Retention Time	Area	% Area
1	4.567	1227873	98.02
2	5.540	24845	1.98

**Di-tert-butyl (2R,2'S,3S,3'R,9a'R)-2-allyl-2-hydroxy-3'-(S)-2-hydroxypent-4-en-2-yl)-4'-oxo-3',4',6',7',8',9'-hexahydro-2'H-spiro[indoline-3,1'-[3,9a]epoxyquinolizine]-1,2'-dicarboxylate**



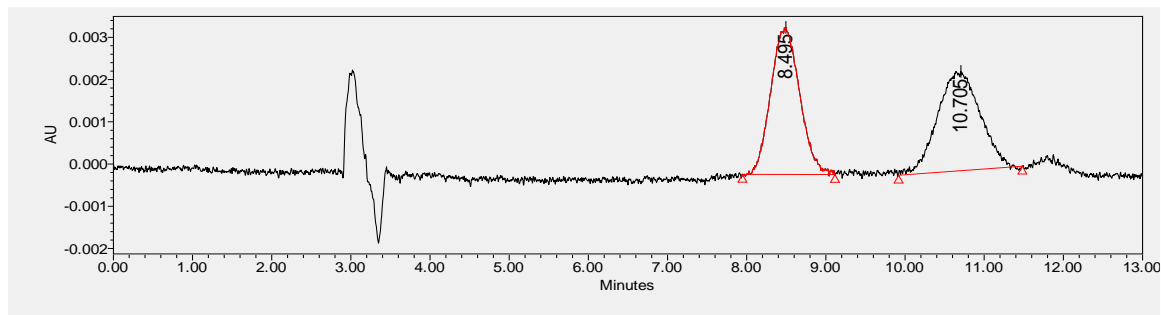
White solid; 71% yield; 94% ee, > 95:5 dr; 43.3 mg;  $[\alpha]^{25}_D = -81.5$  (c 0.20, CH<sub>2</sub>Cl<sub>2</sub>); determined by HPLC analysis [Daicel chiralpak IG, *n*-hexane/*i*-PrOH] = 90/10, 1.0 ml/min,  $\lambda = 254$  nm.  $t_1 = 8.50$  min,  $t_2 = 10.36$  min].

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$  7.51 (t,  $J = 7.3$  Hz, 2H), 7.19 (t,  $J = 7.2$  Hz, 1H), 6.93 (t,  $J = 7.6$  Hz, 1H), 6.07 – 5.96 (m, 2H), 5.85 (m, 1H), 5.15 (m, 2H), 5.09 (m, 2H), 4.64 (s, 1H), 3.79 (s, 1H), 3.64 (dt,  $J = 13.0, 6.7$  Hz, 1H), 3.29 – 3.19 (m, 2H), 3.07 (dd,  $J = 16.1, 6.6$  Hz, 1H), 2.84 (dd,  $J = 13.8, 7.7$  Hz, 1H), 2.34 (dd,  $J = 13.8, 6.8$  Hz, 1H), 1.97 – 1.87 (m, 2H), 1.72 – 1.64 (m, 4H), 1.61 (s, 9H), 1.39 (s, 3H), 0.97 (s, 9H).

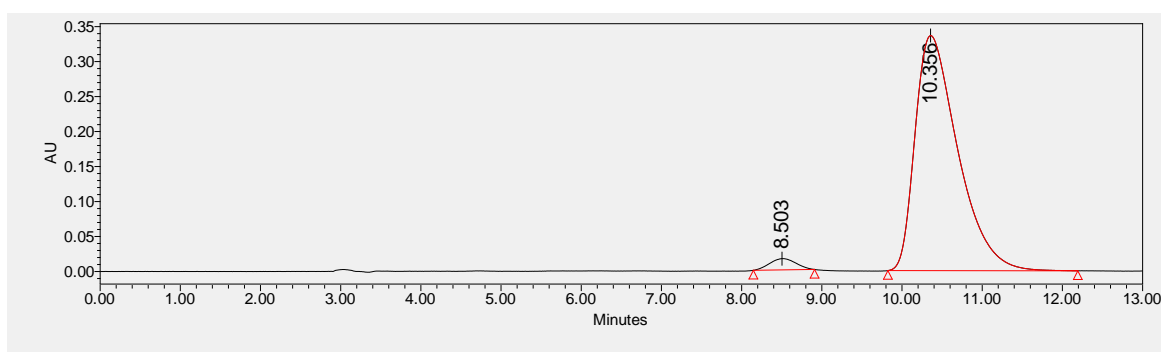
$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  173.29, 171.77, 153.56, 142.37, 133.76, 133.24, 129.34, 128.34, 127.60, 122.83, 118.62, 117.96, 113.66, 96.80, 95.80, 90.56, 83.64, 83.49, 77.48, 77.16, 76.84, 71.83, 71.63, 55.23, 43.05, 42.19, 38.30, 28.59, 27.61, 27.15, 23.61, 21.72, 18.80.

ESI-HRMS calcd for  $[\text{C}_{34}\text{H}_{46}\text{N}_2\text{O}_8+\text{H}^+]$ : 611.3327, found 611.3330;

IR (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 3405.86, 3054.57, 2984.89, 2306.18, 1713.3, 1645.31, 1594.92, 1482.8, 1371.41, 1345.61, 1265.57, 1156.34, 1080.16, 919.58, 896.19, 841.22, 739.95, 705.72.

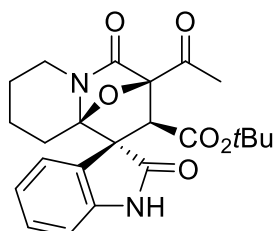


	Retention Time	Area	% Area
1	8.495	88308	49.97
2	10.705	88412	50.03



	Retention Time	Area	% Area
1	8.503	360942	2.82
2	10.356	12454570	97.18

***Tert*-butyl (2'*S*,3*R*,3'*R*,9*a*'*R*)-3'-acetyl-2,4'-dioxo-3',4',6',7',8',9'-hexahydro-2'*H*-spiro[indoline-3,1'-[3,9*a*]epoxyquinolizine]-2'-carboxylate**



**6ca**

White solid; 70% yield, 95% ee, > 95:5 dr; 29.8 mg;  $[\alpha]_D^{26} = -28.3$  ( $c$  0.060,  $\text{CH}_2\text{Cl}_2$ ); determined by HPLC analysis [Daicel chiralpak IA, *n*-hexane/*i*-PrOH = 70/30, 1.0 mL/min,  $\lambda = 254$  nm,  $t_1 = 5.21$  min,  $t_2 = 7.70$  min].

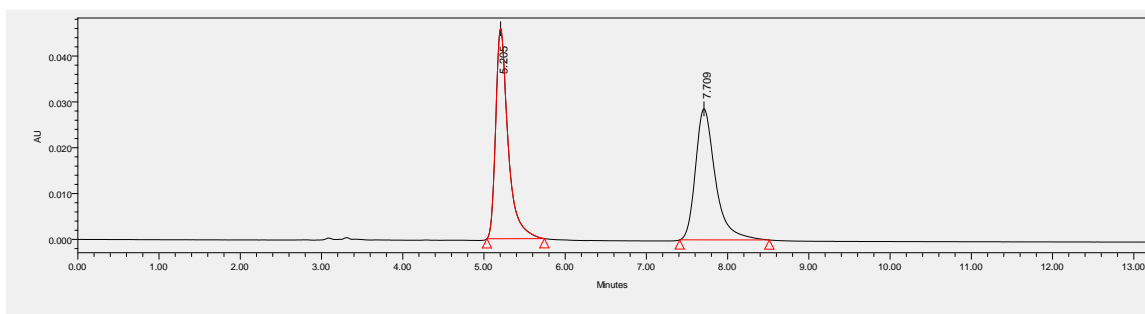
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.15 (s, 1H), 7.32 (d,  $J = 7.6$  Hz, 1H), 7.29 (td,  $J = 7.8, 1.3$  Hz, 1H), 7.03 (td,  $J = 7.7, 1.0$  Hz, 1H), 6.94 (d,  $J = 7.7$  Hz, 1H), 3.86 (s, 2H), 3.36 (td,  $J = 13.4, 12.8, 4.6$  Hz, 1H), 2.48 (s, 3H), 1.84 – 1.67 (m, 4H), 1.51 (td,  $J = 16.7, 15.7, 5.1$  Hz, 1H), 1.25 – 1.15 (m, 1H), 0.95 (s, 9H).

$^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  199.20, 175.56, 168.56, 166.82, 141.19, 129.70, 127.24, 126.62, 123.28, 109.81, 96.58, 90.69, 82.91, 77.48, 77.16, 76.84, 62.72, 59.34, 41.10, 28.14, 27.52, 27.08, 22.86, 20.42.

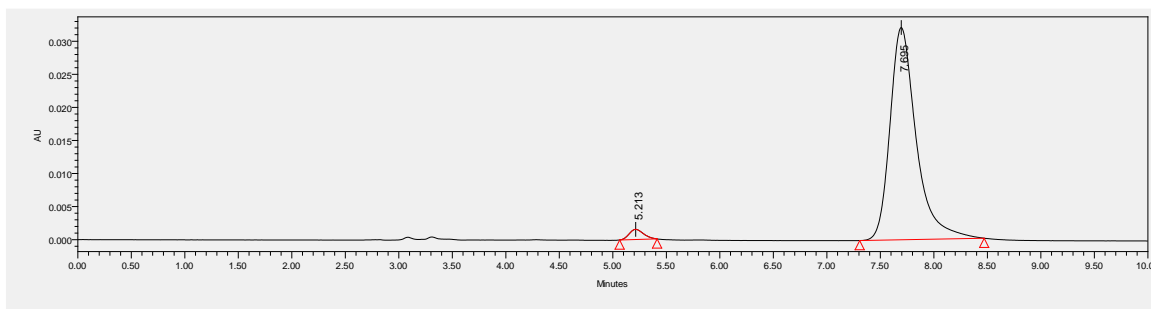
ESI-HRMS calcd for  $[\text{C}_{23}\text{H}_{26}\text{N}_2\text{O}_6+\text{H}^+]$ : 427.1864, found 427.1862;

IR (film):  $\tilde{\nu}$  ( $\text{cm}^{-1}$ ) 3261, 2981, 2363, 2330, 1732, 1619, 1471, 1406, 1363, 1268, 1154, 863, 755, 454.





	Retention Time	Area	% Area
1	5.205	484248	49.97
2	7.709	484760	50.03

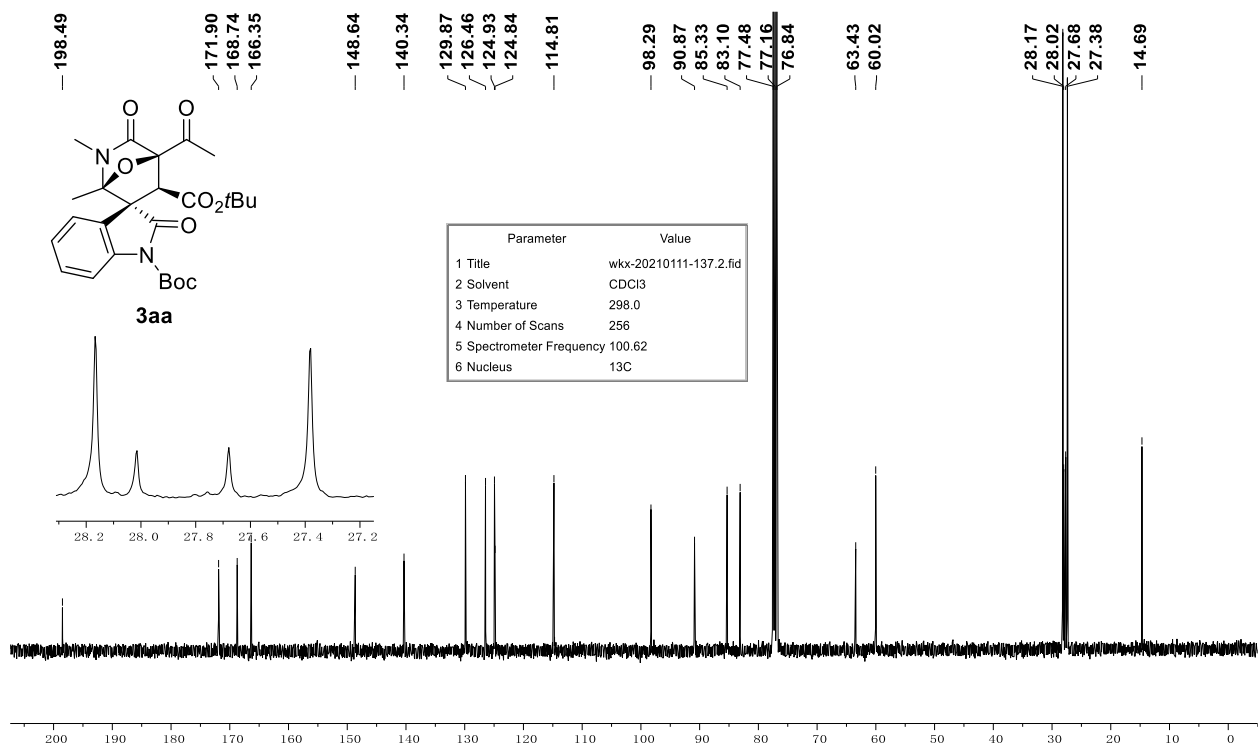
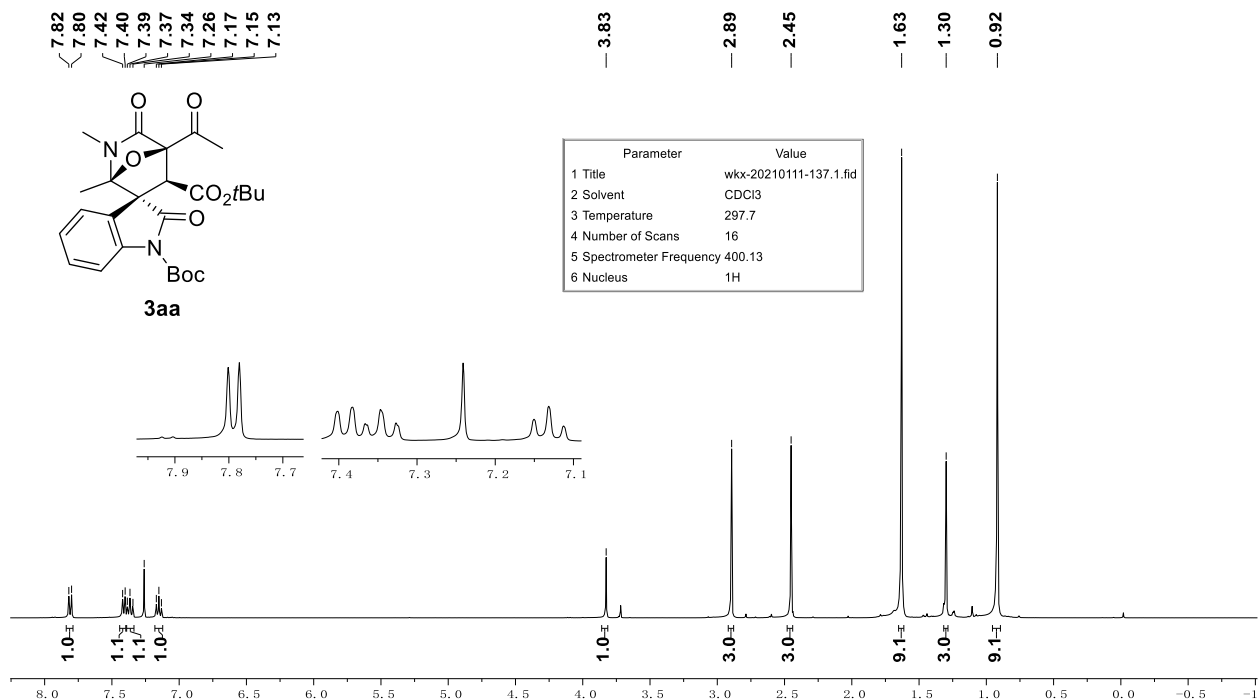


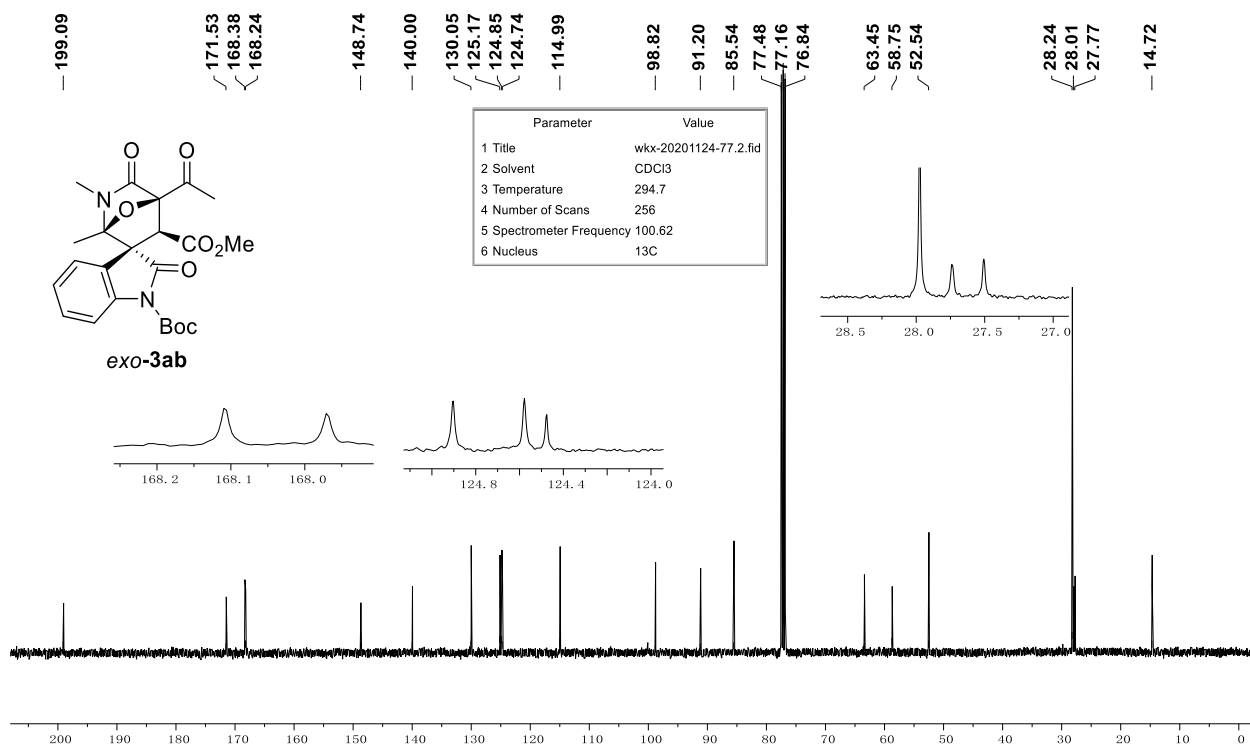
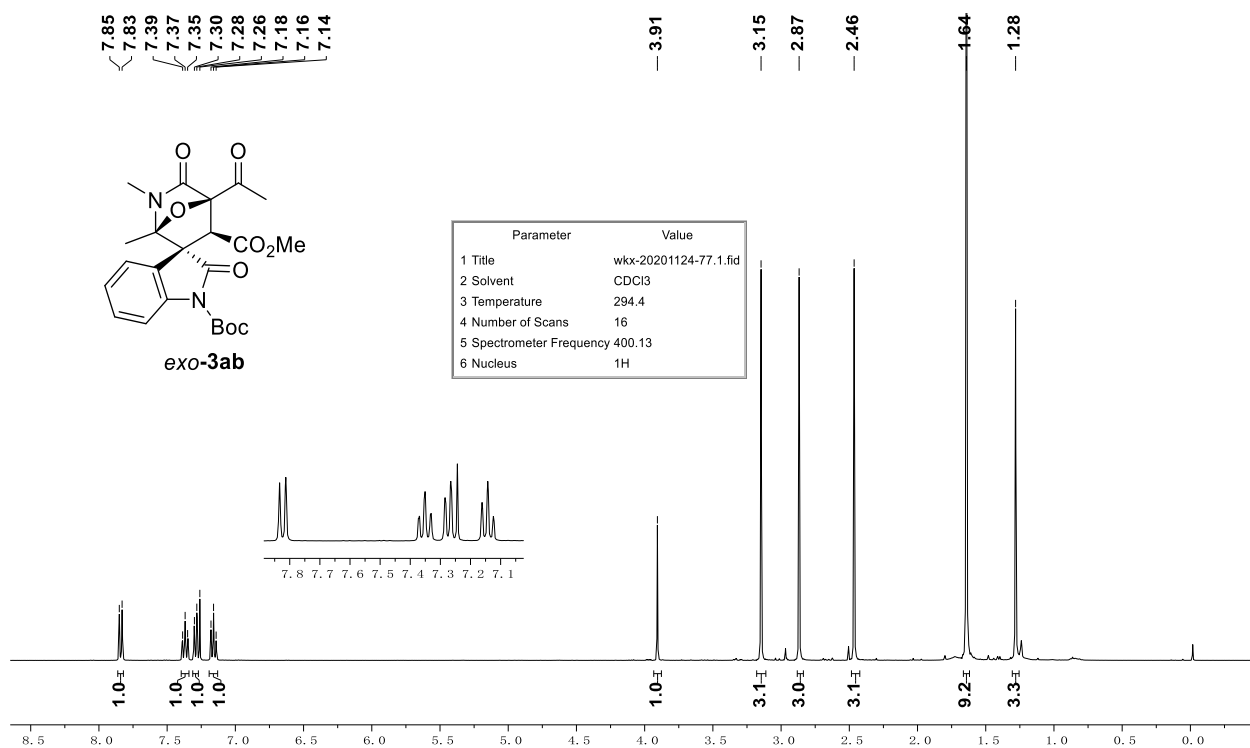
	Retention Time	Area	% Area
1	5.213	14296	2.55
2	7.695	547066	97.45

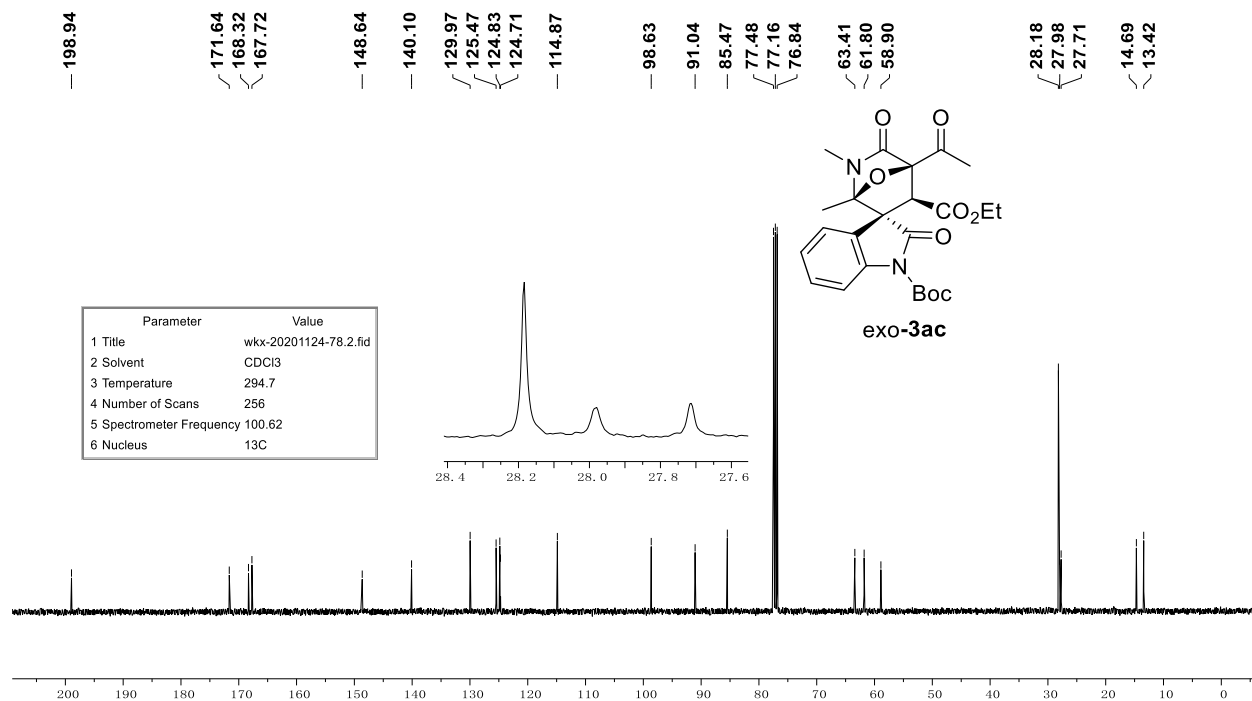
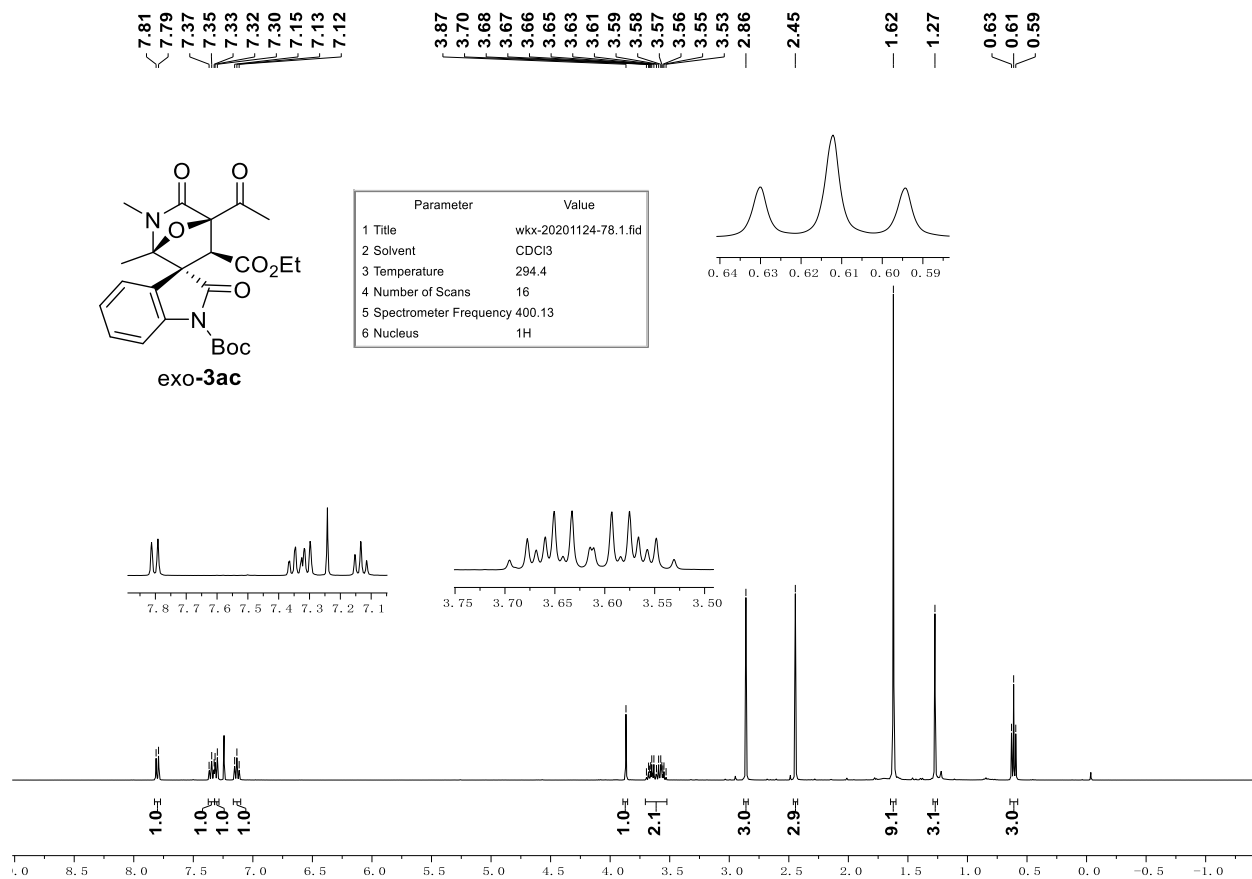
## 12. Reference

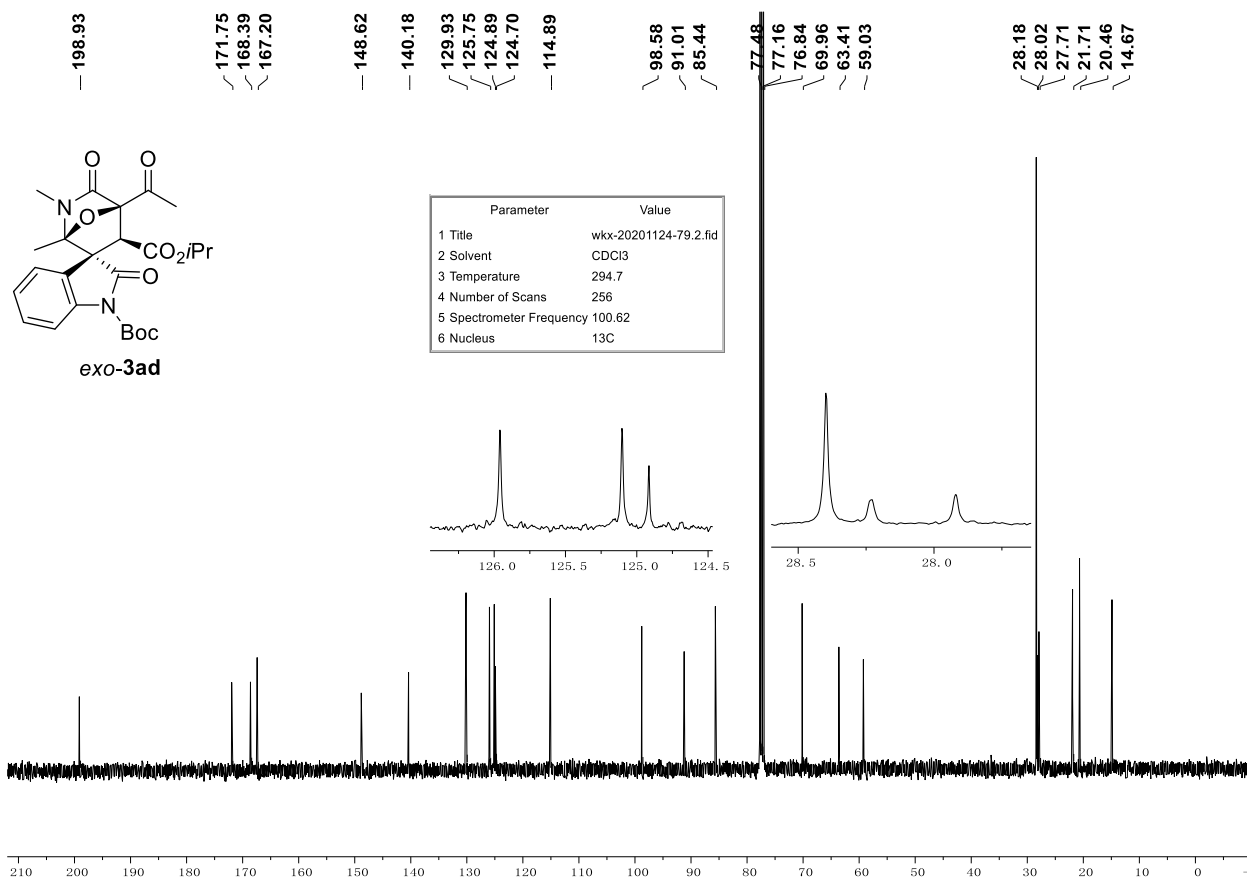
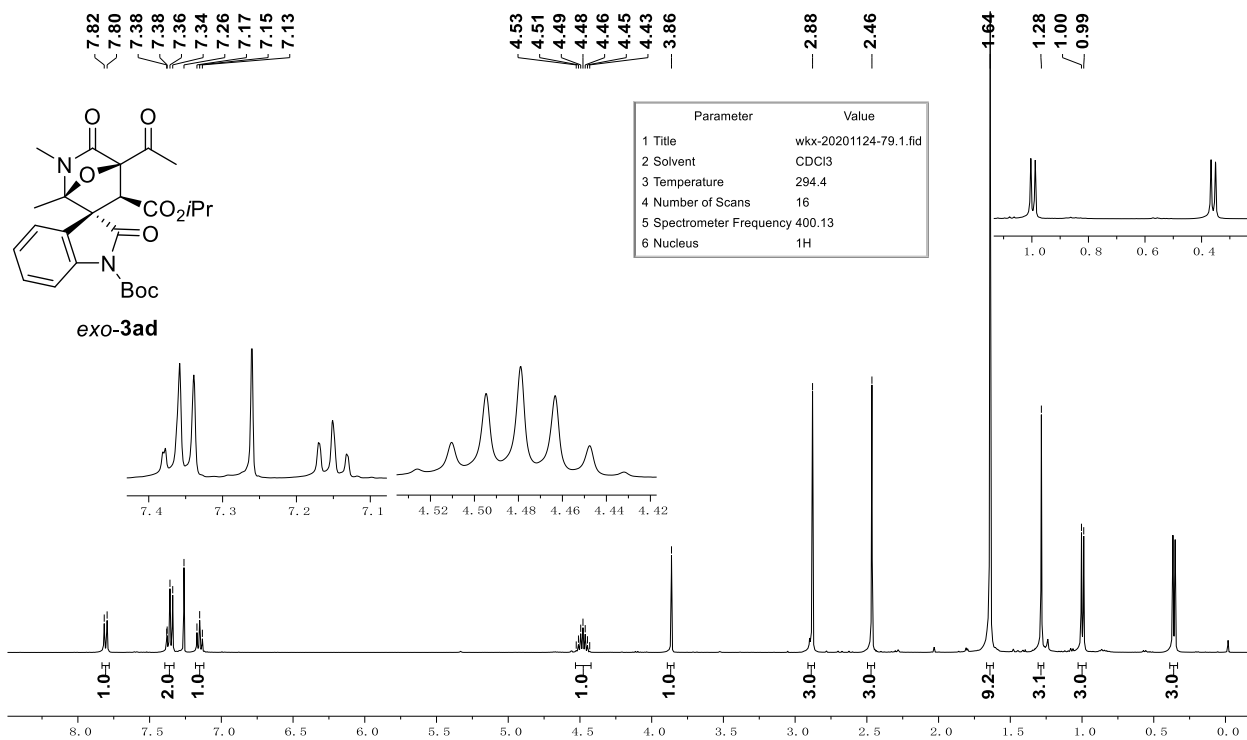
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- (3) (a) Doyle, M. P.; Dorow, R. L.; Terpstra, J. W.; Rodenhouse, R. A. Synthesis and Catalytic Reactions of Chiral *N*-(Diazoacetyl)oxazolidones. *J. Org. Chem.* **1985**, *50*, 1663-1666. (b) Padwa, A.; Hertzog, D. L.; Chinn, R. L. Synthesis of Aza Substituted Polycycles via Rhodium (II) Carboxylate induced cyclization of Diazoimides. *Tetrahedron Lett.* **1989**, *30*, 4077-4080. (c) Doyle, M. P.; Pieters, R. J.; Taunton, J.; Padwa, A.; Hertzog, D. L.; Precedo, L. Synthesis of Nitrogen-containing Polycycles via Rhodium(II)-induced Cyclization-cycloaddition and Insertion Reactions of *N*-(Diazoacetoacetyl)amides. Conformational Control of Reaction Selectivity. *J. Org. Chem.* **1991**, *56*, 820-829. (d) Padwa, A.; Hertzog, D. L.; Nadler, W. R.; Osterhout, M. H.; Price, A. T. *J. Org. Chem.* **1994**, *59*, 1418-1427; (d) Savinov, S. N.; Austin, D. J. Modular Evolution of a Chiral Auxiliary for the 1,3-Dipolar Cycloaddition of Isomülchnones with Vinyl Ethers *Org. Lett.* **2002**, *4*, 1415-1418. (e) Xu, C. R.; Wang, K. X.; Li, D. W.; Lin, L. L.; Feng, X. M. Asymmetric Synthesis of Oxa-Bridged Oxazocines through a Catalytic Rh<sup>II</sup>/Zn<sup>II</sup> Relay [4+3] Cycloaddition Reaction. *Angew. Chem. Int. Ed.* **2019**, *58*, 1-6.

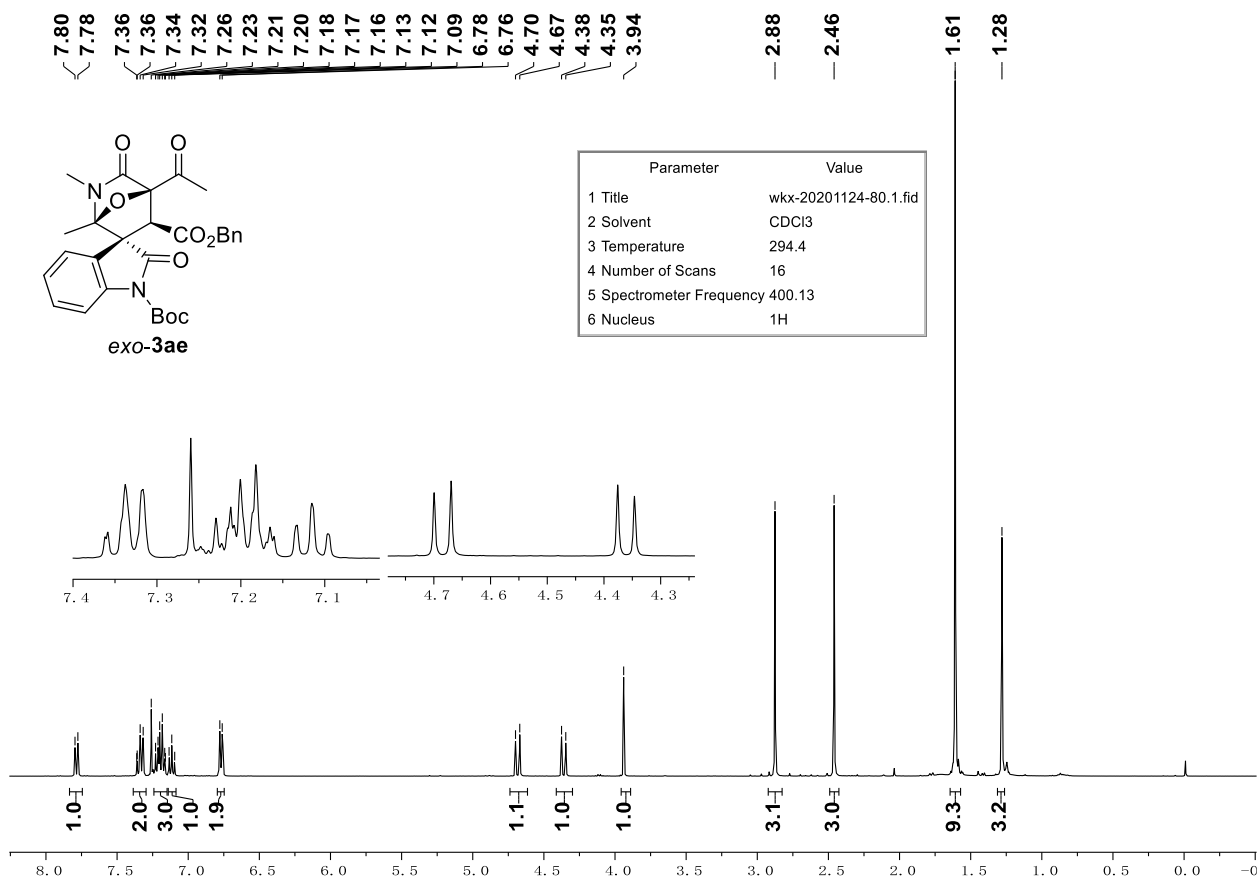
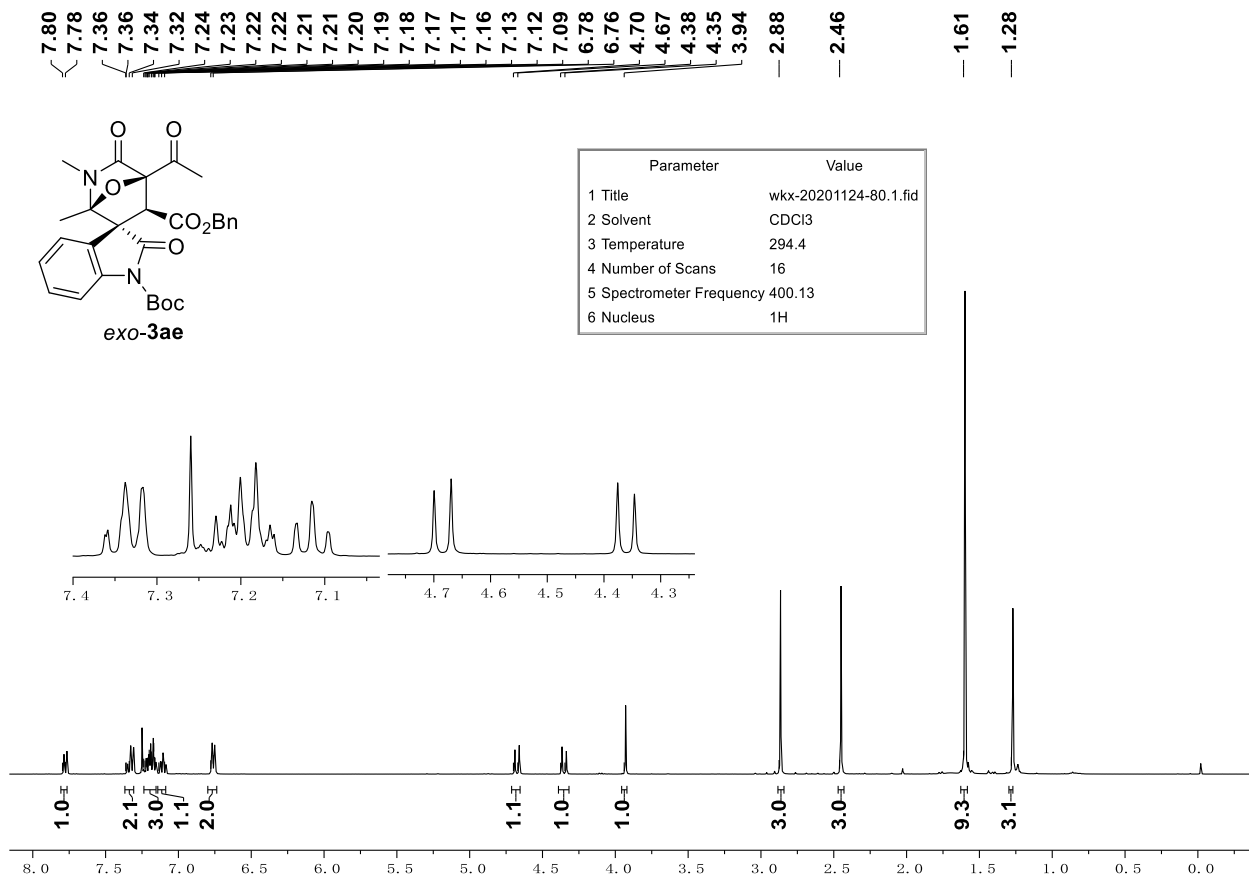
### 13. Copies of NMR-Spectra of Products

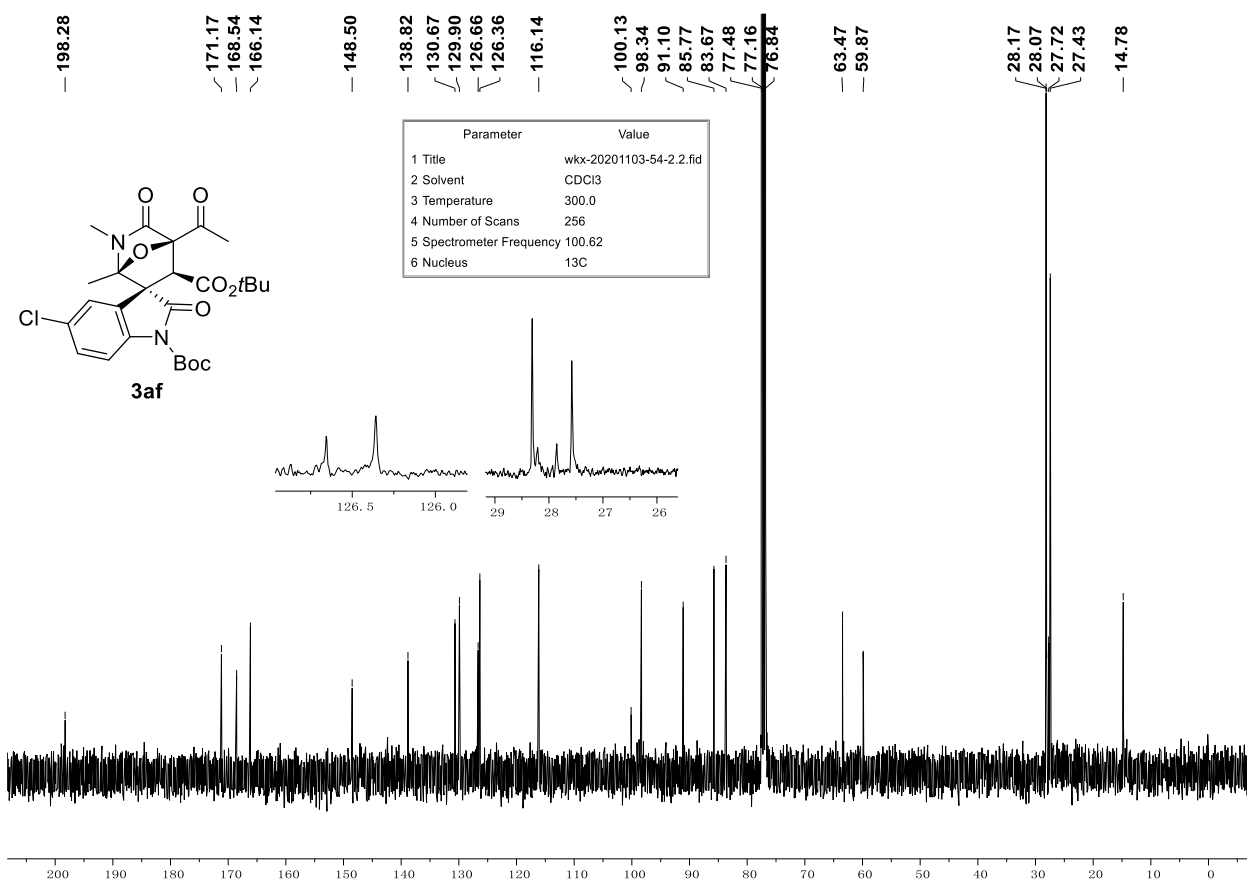
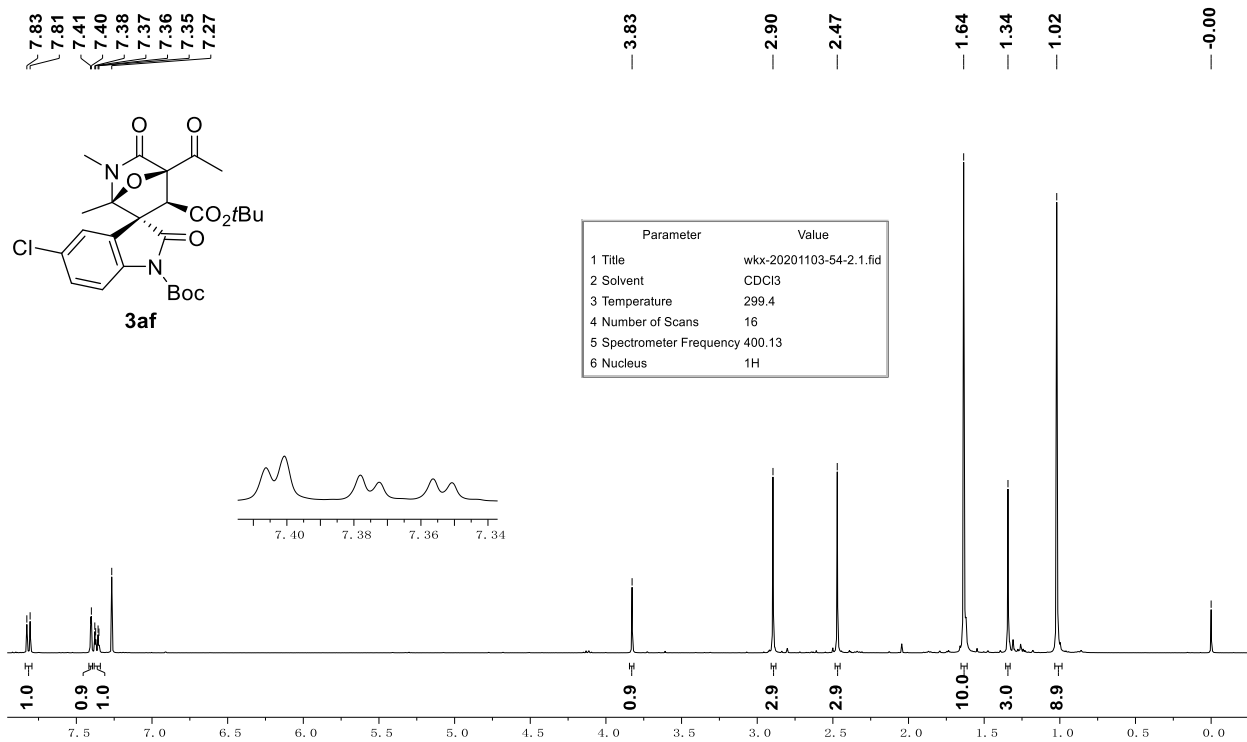




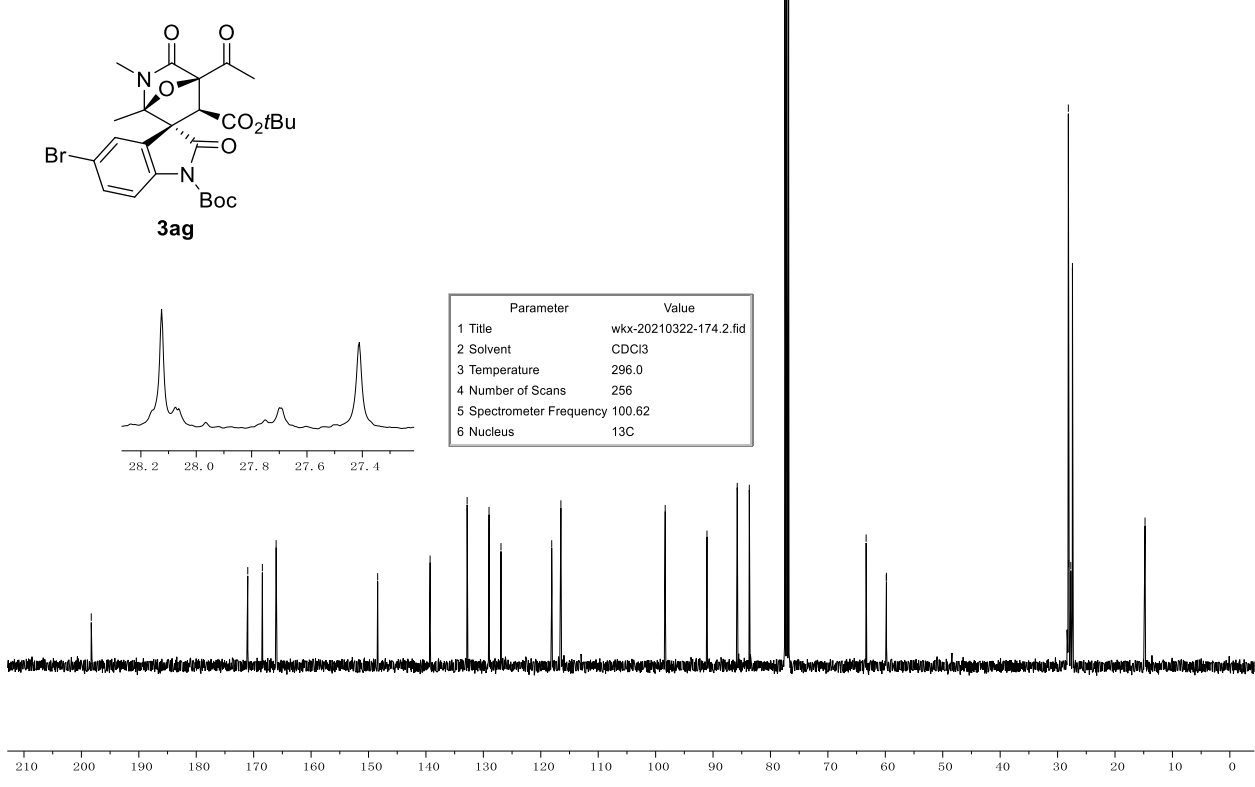
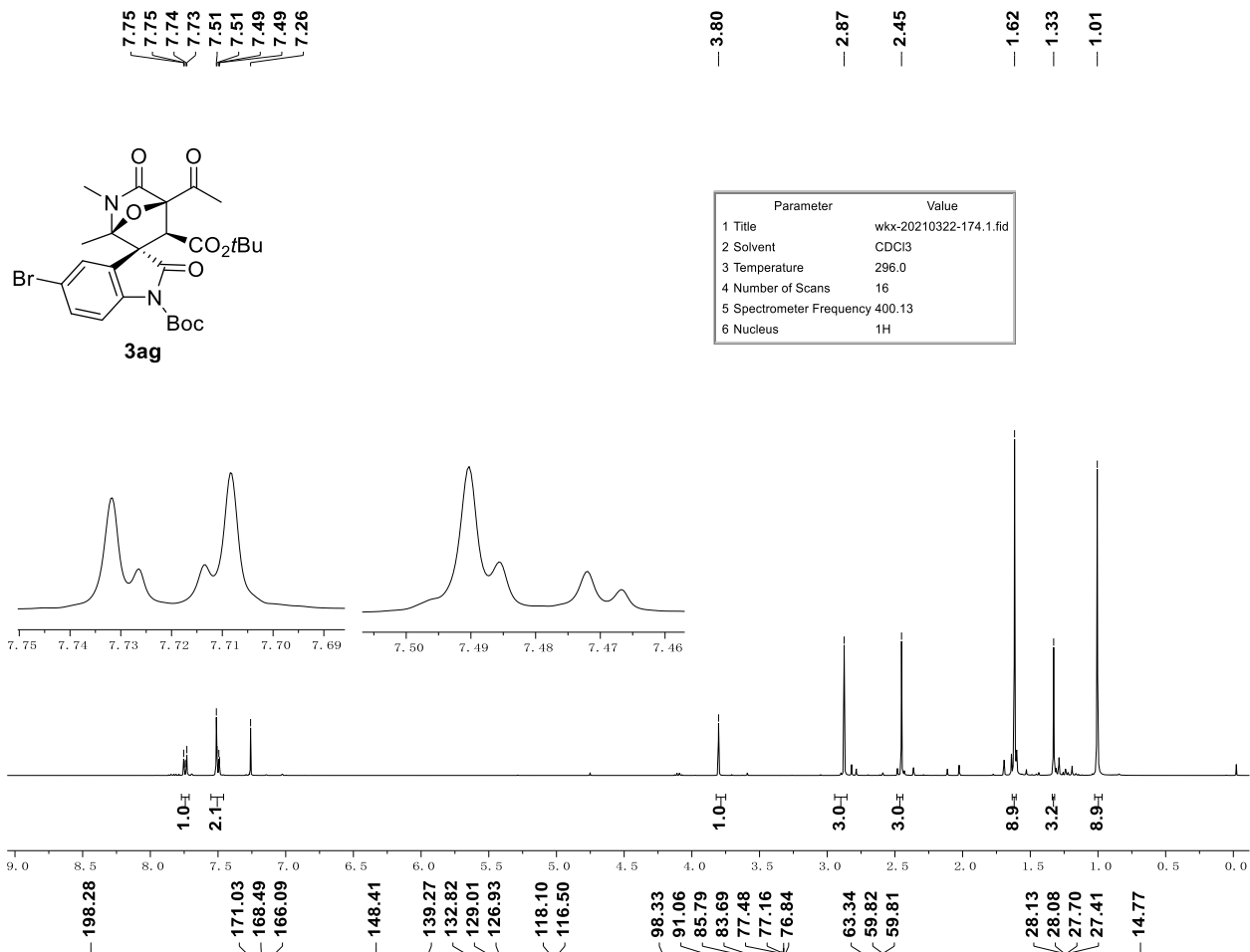


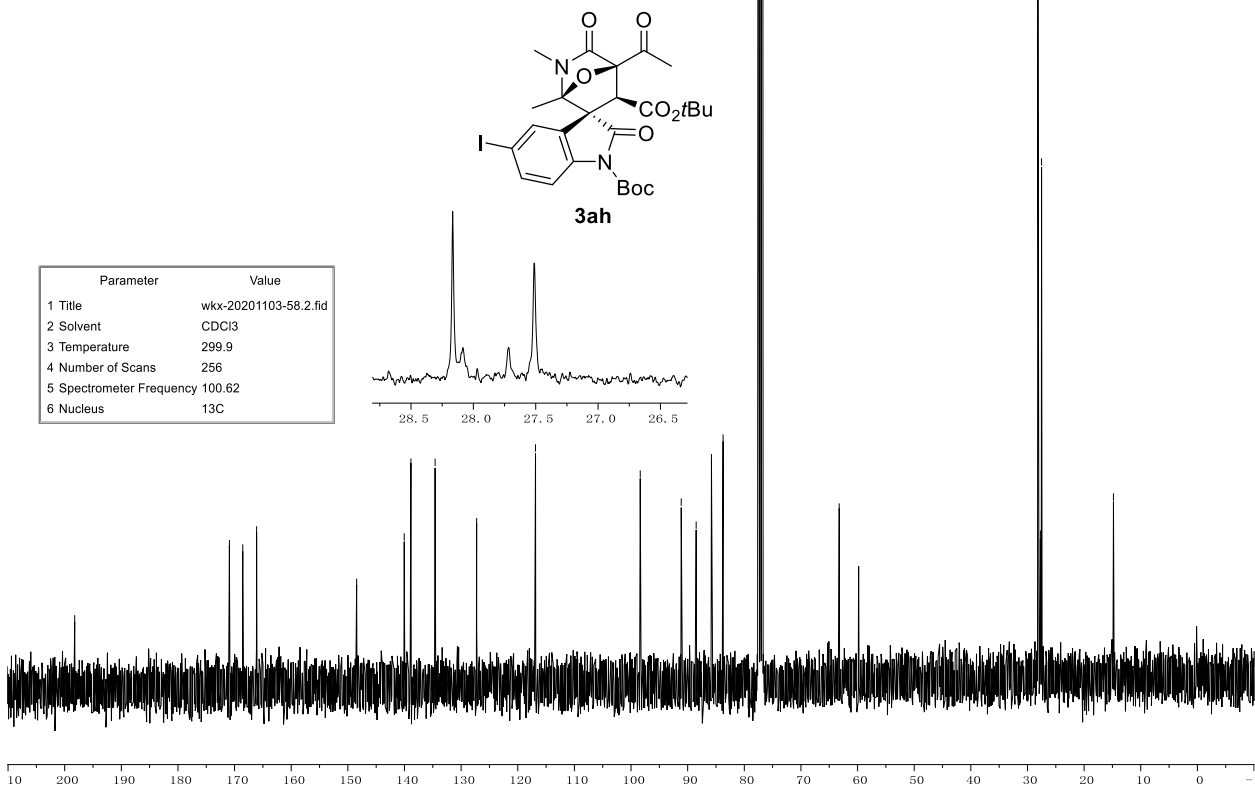
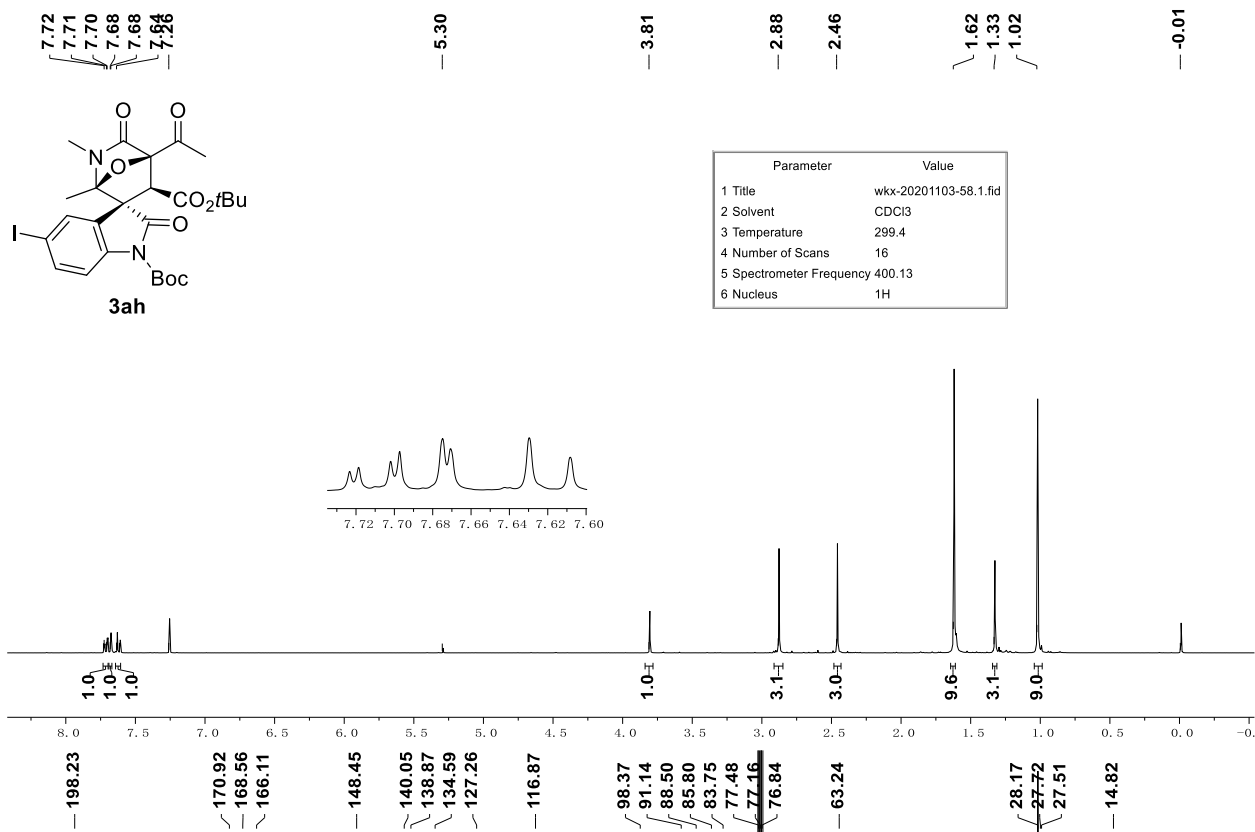


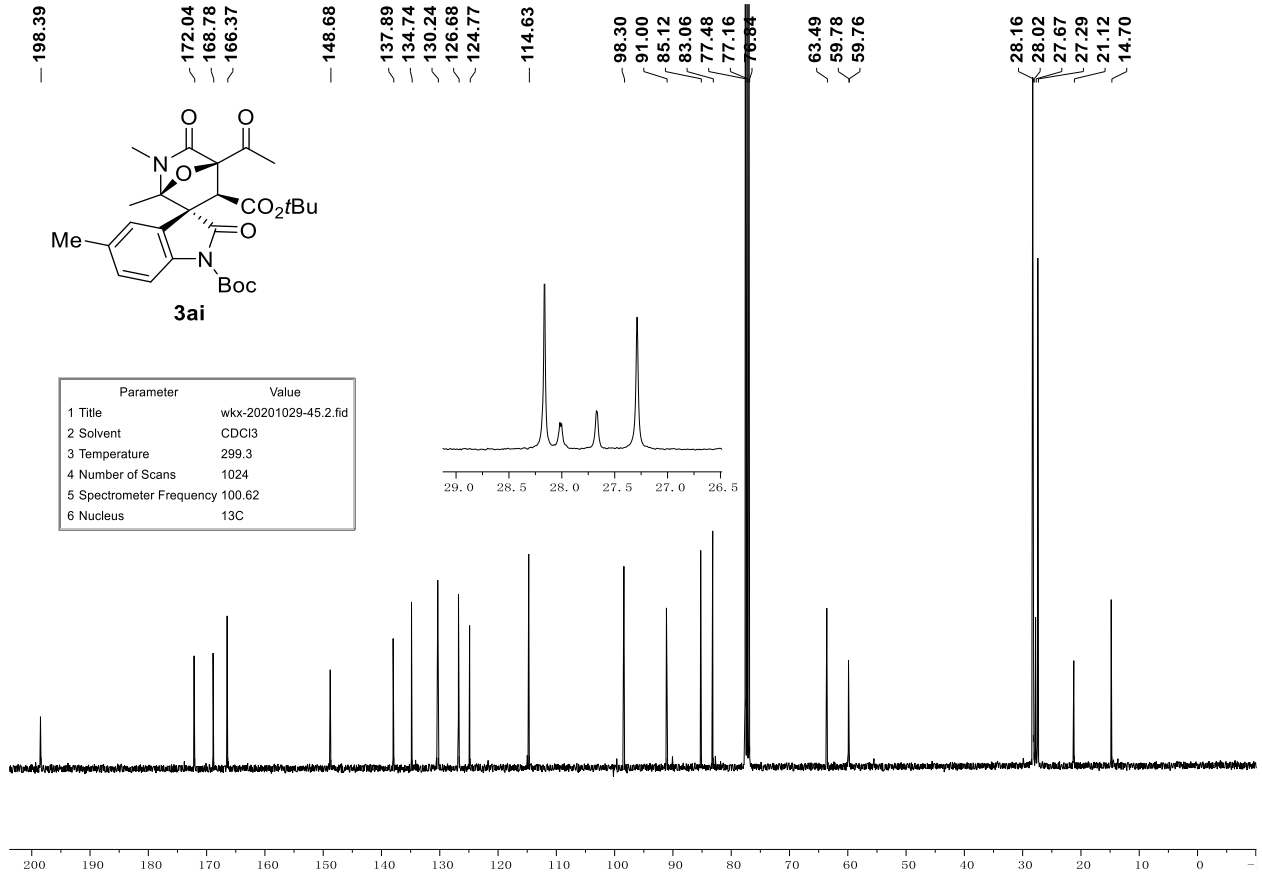
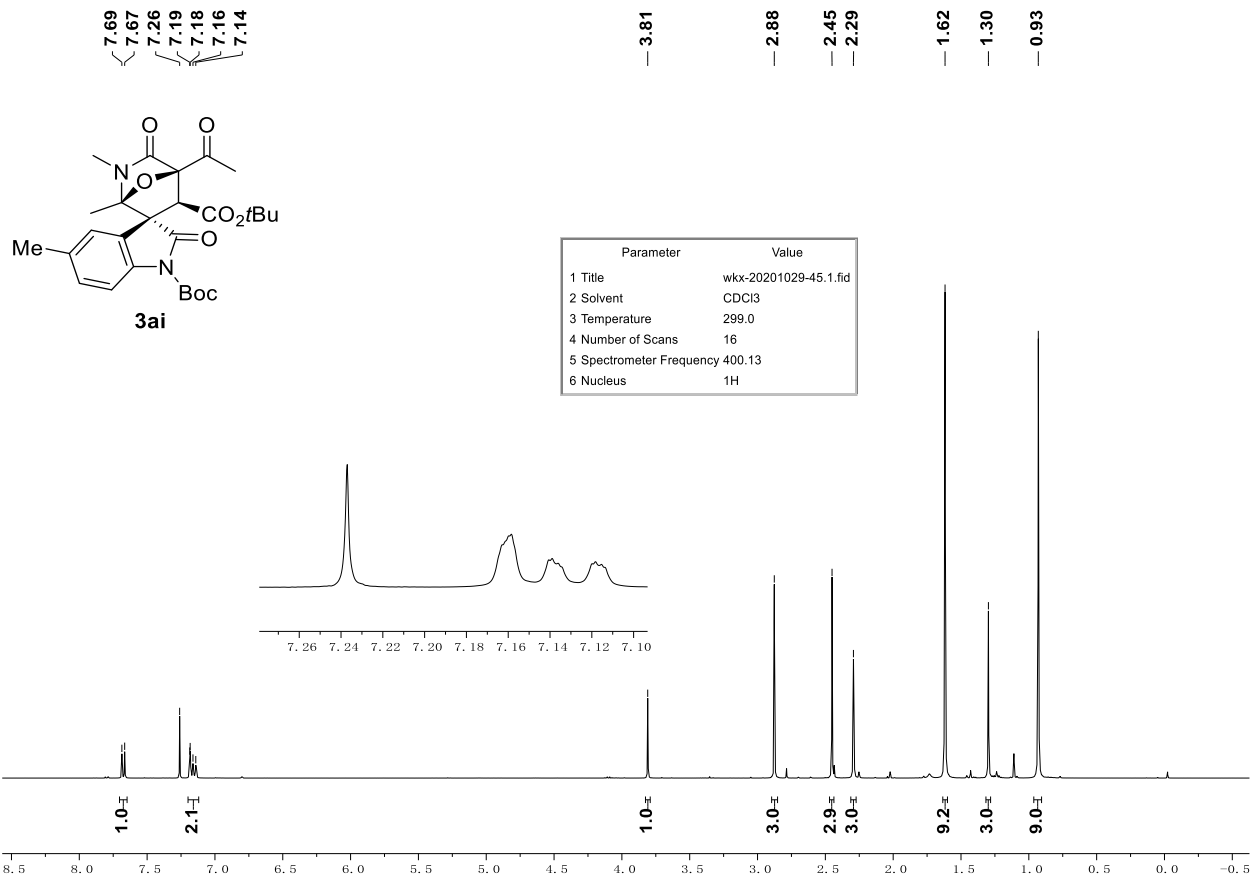


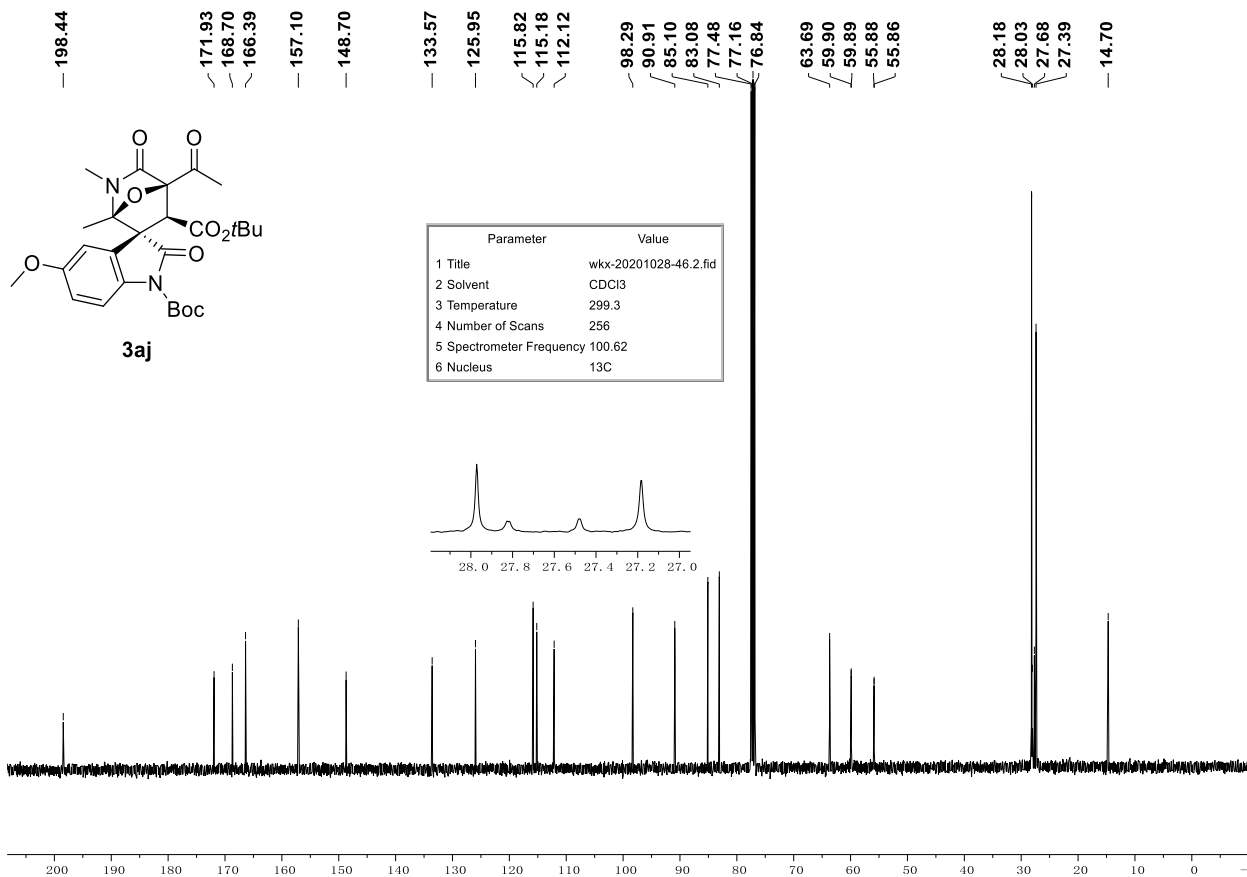
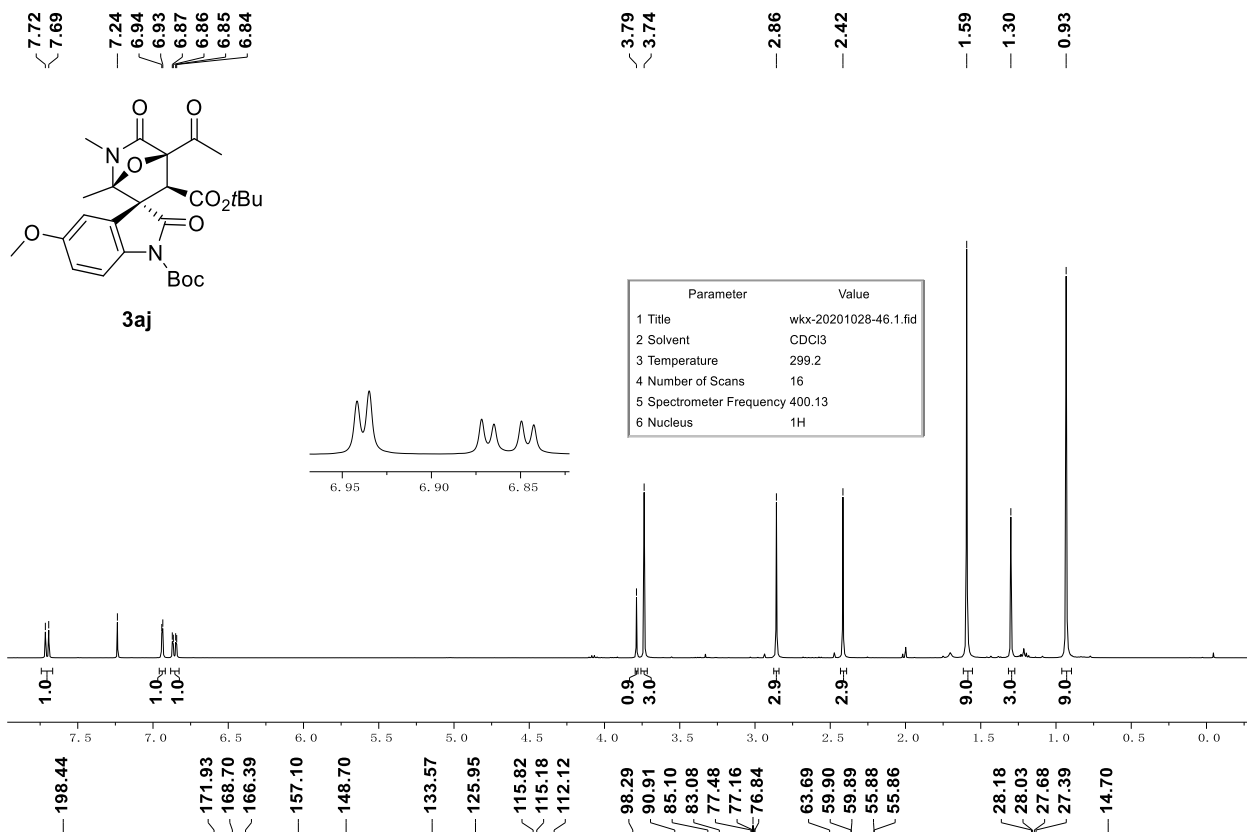


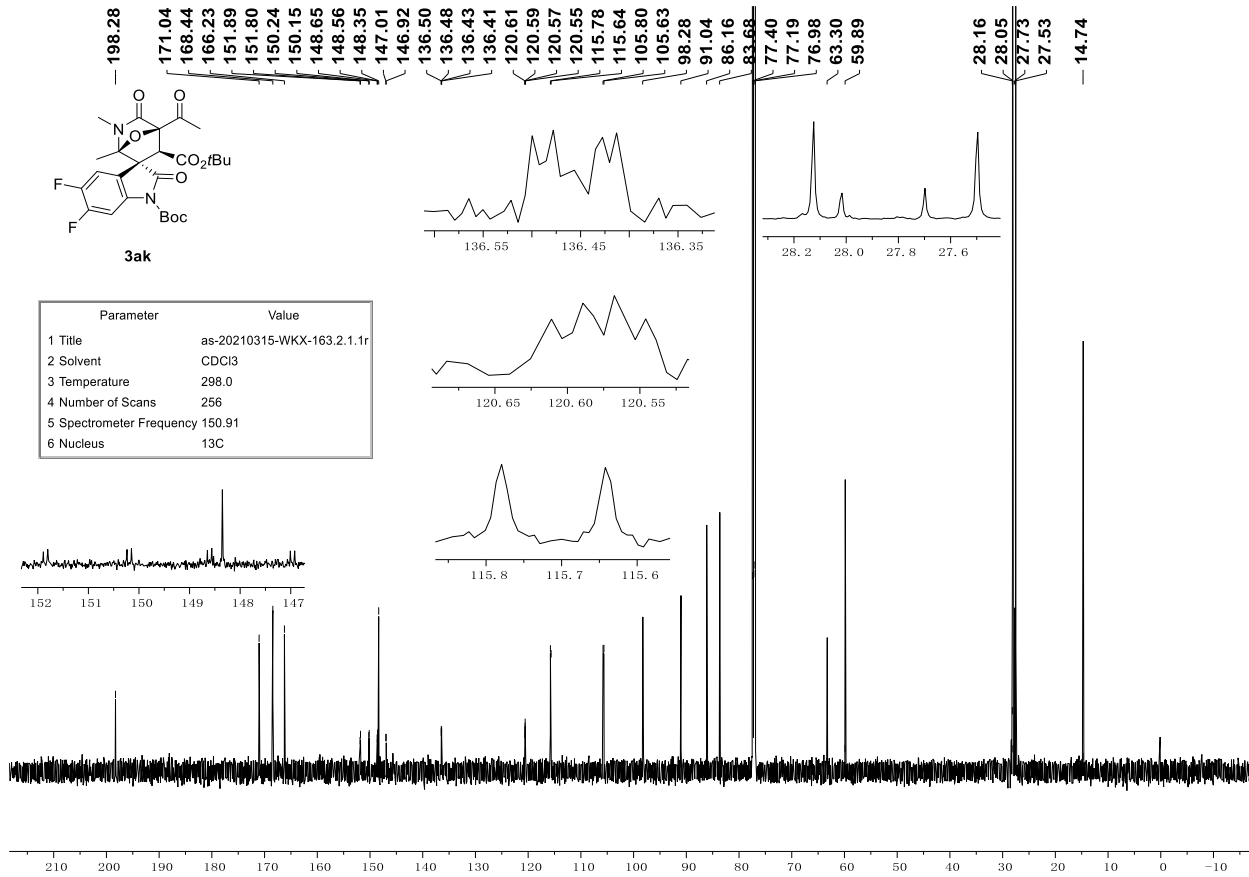
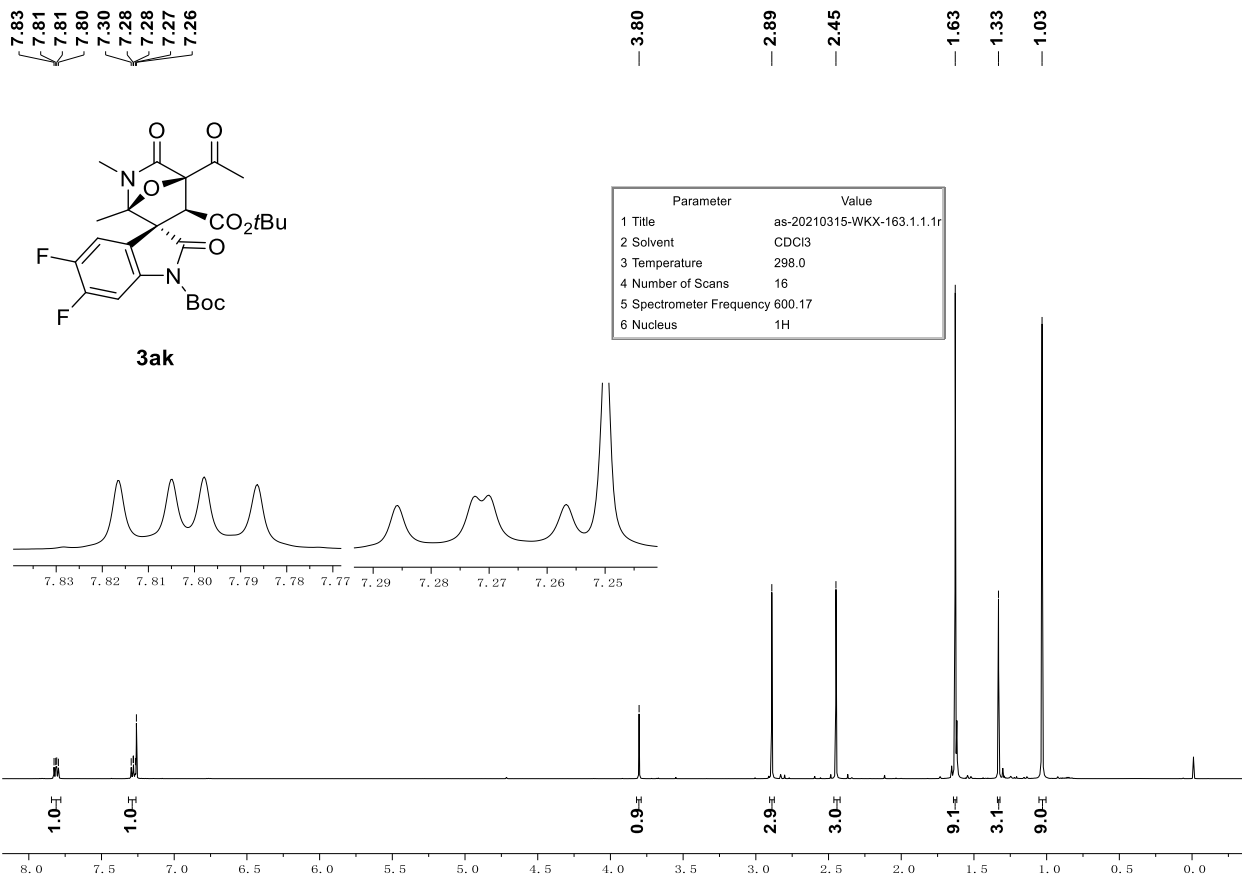


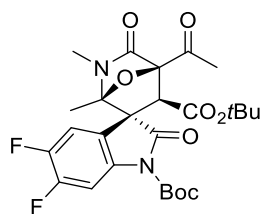












**3ak**

Parameter	Value
1 Title	as-20210315-WKX-163.3.1.1r
2 Solvent	CDCl3
3 Temperature	298.1
4 Number of Scans	16
5 Spectrometer Frequency	564.72
6 Nucleus	19F

— -132.97  
— -141.12



10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210

7.26  
7.02  
6.97

3.82

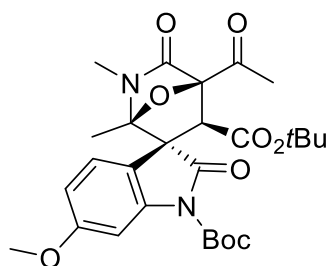
2.87

2.46  
2.26  
2.21

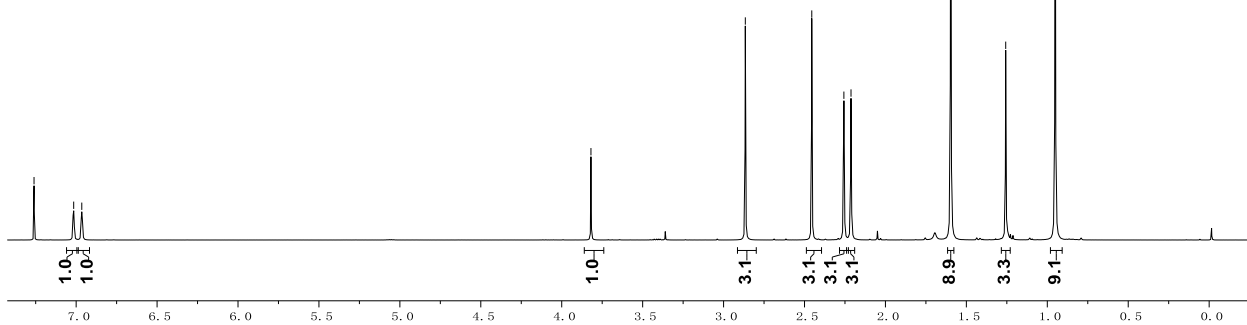
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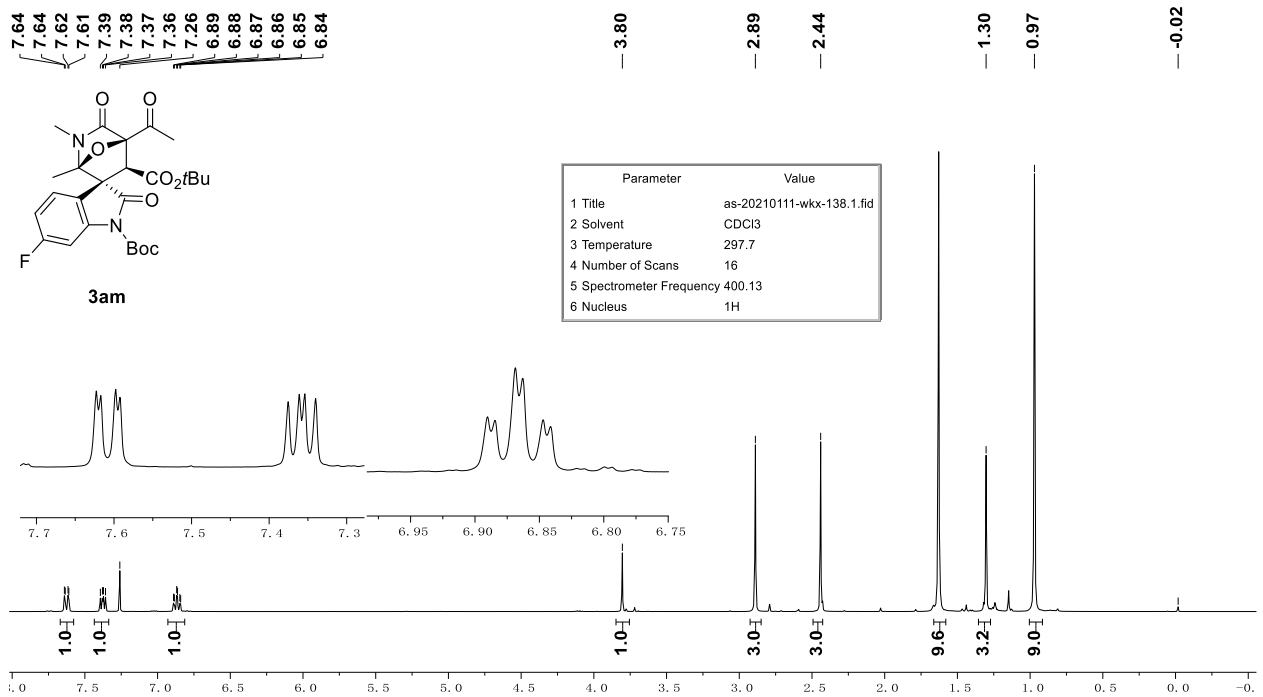
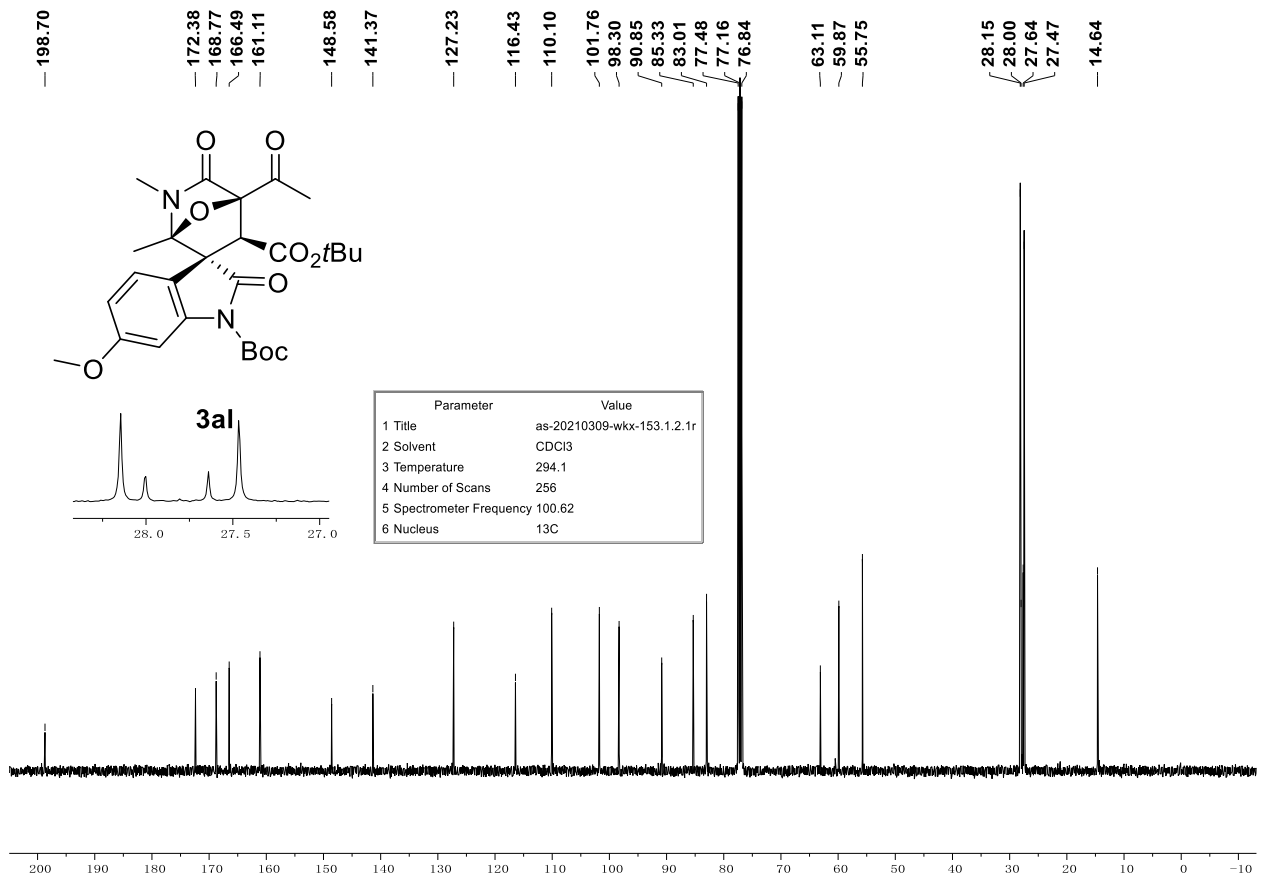
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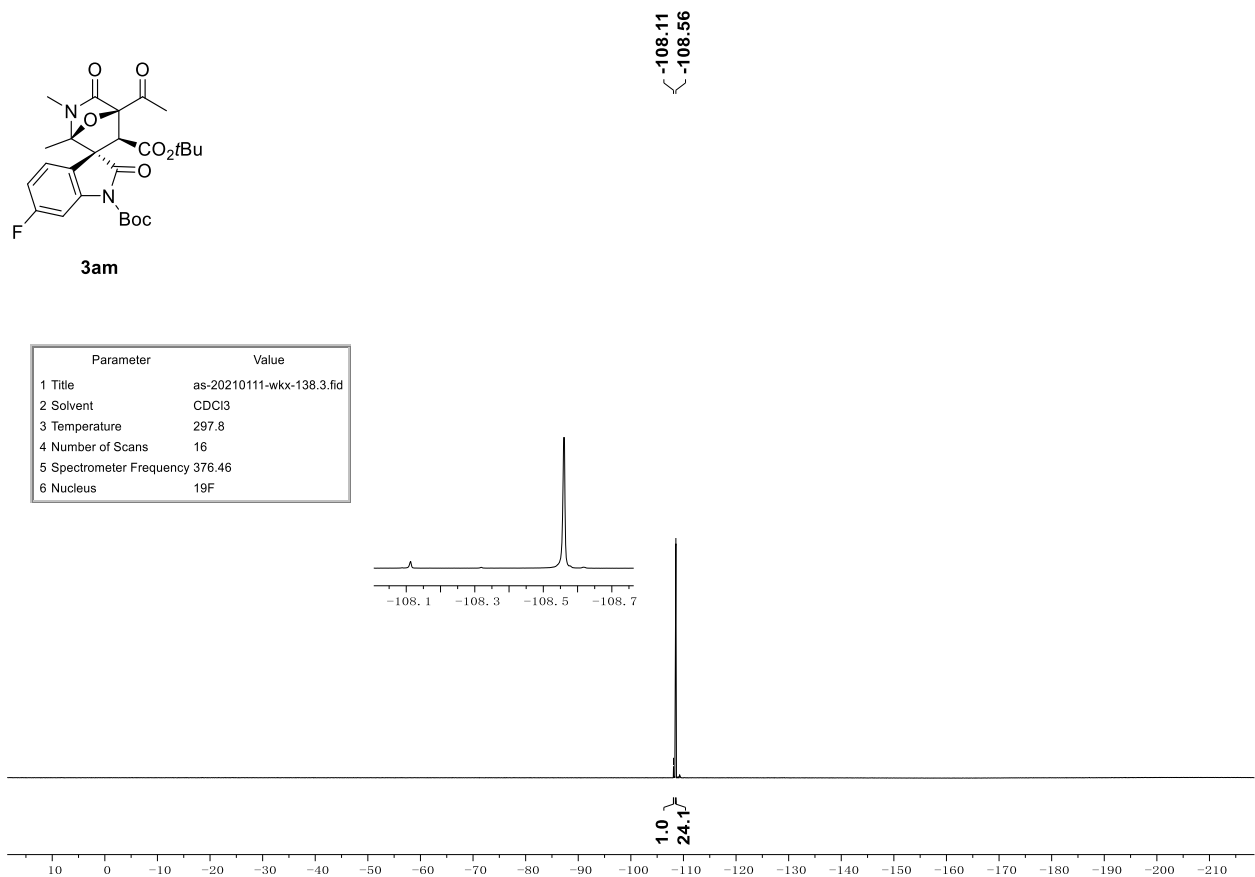
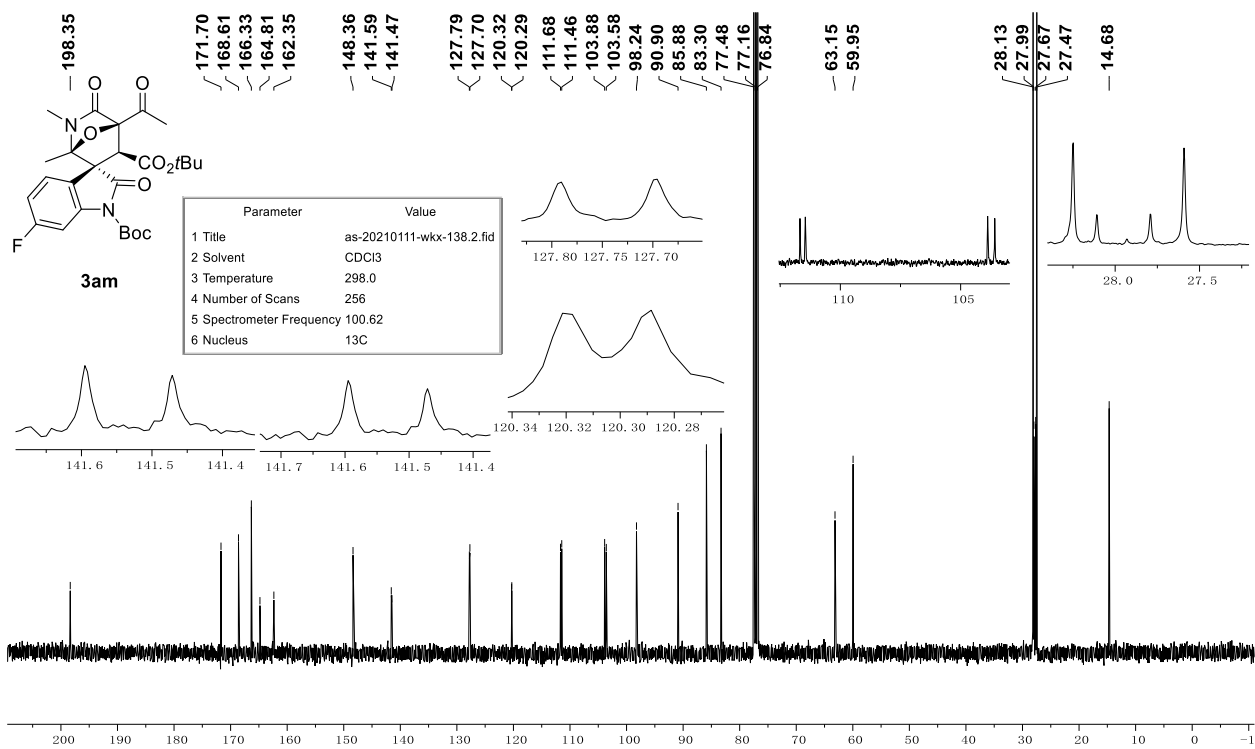
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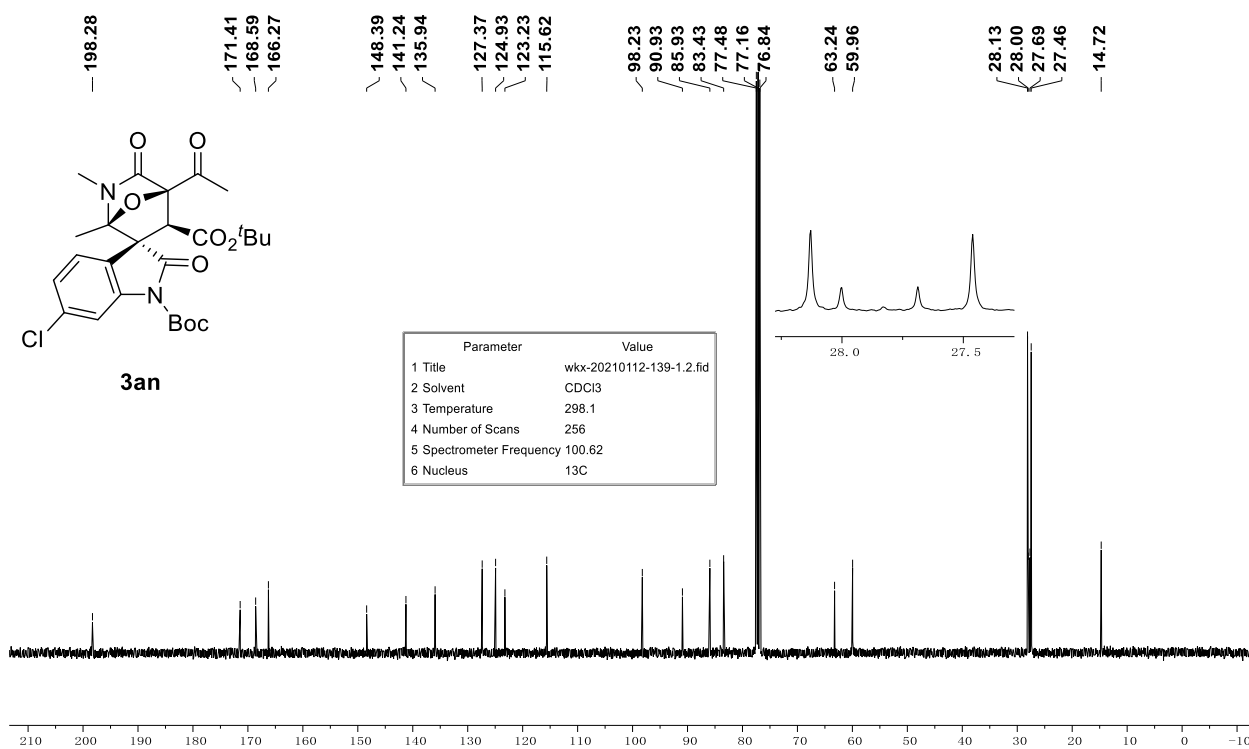
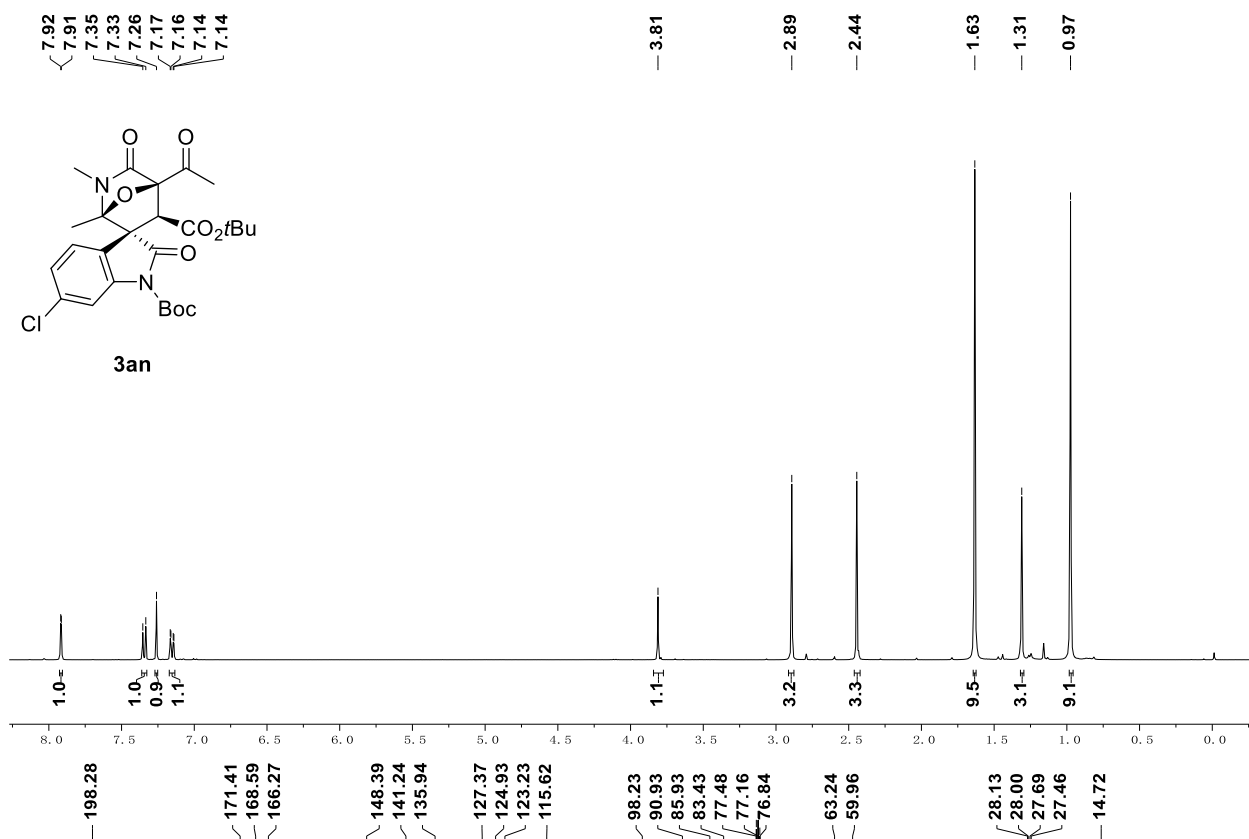
**3al**

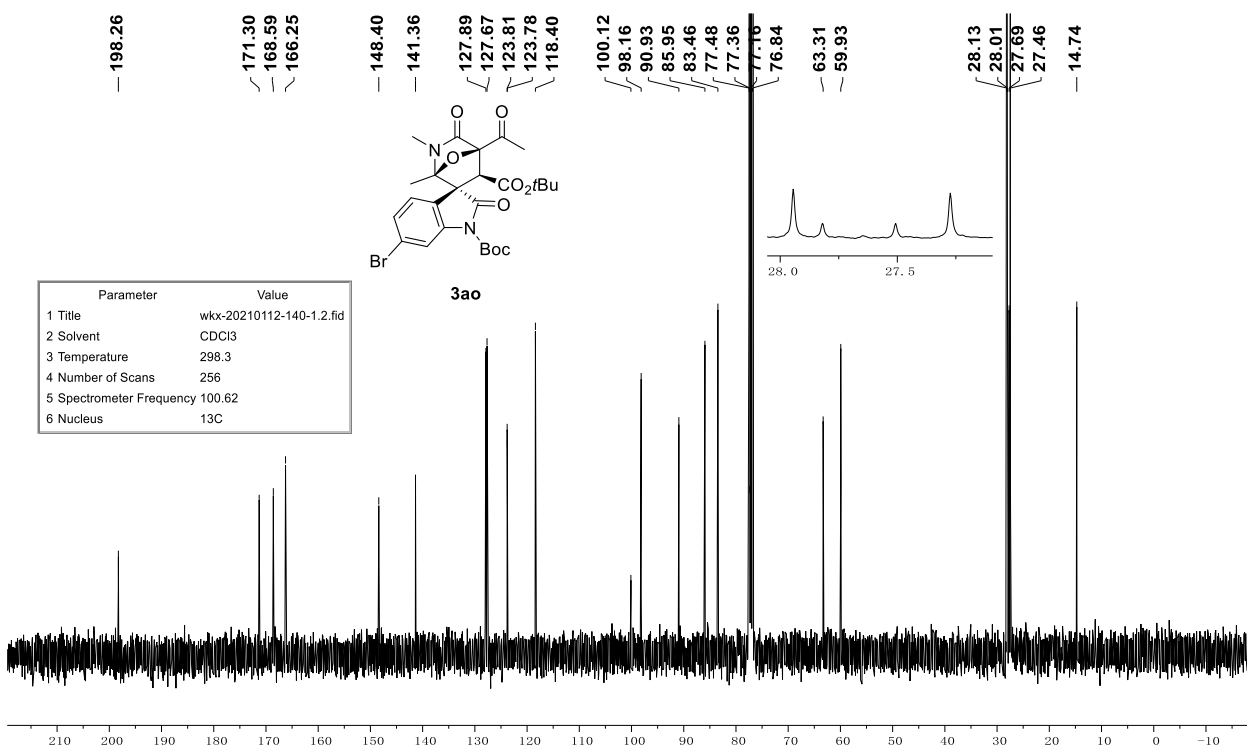
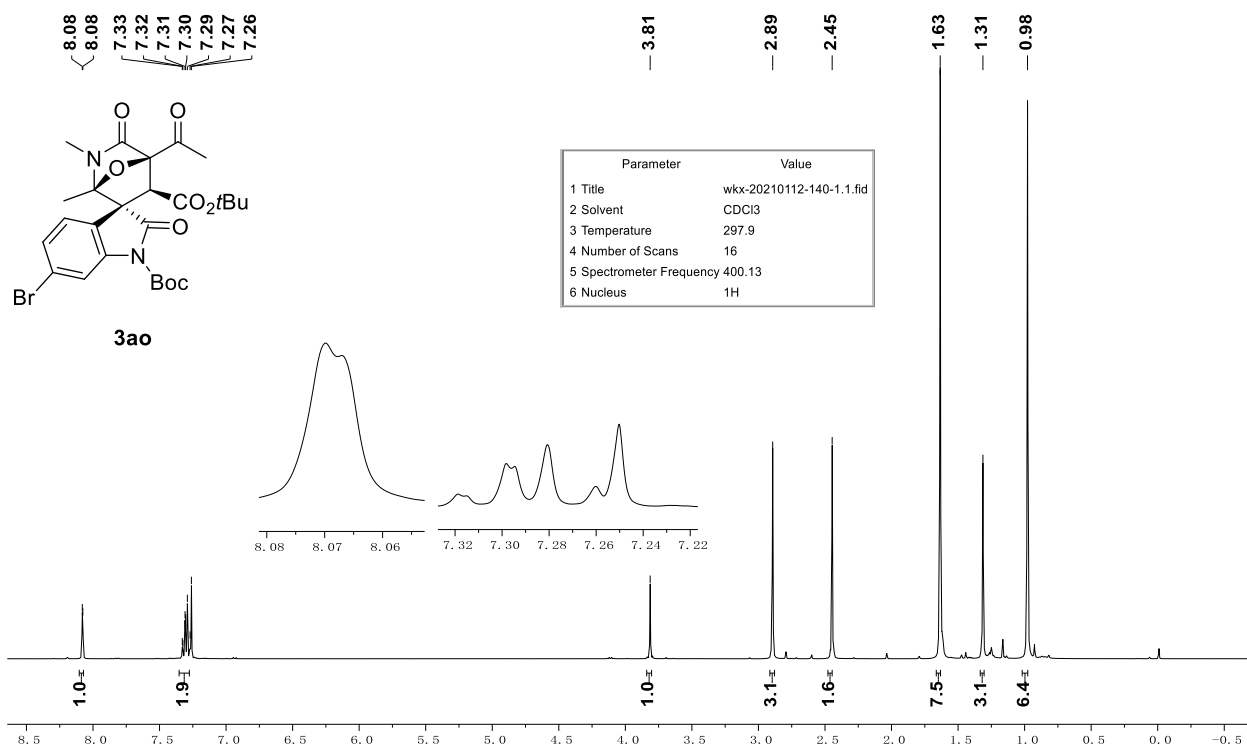


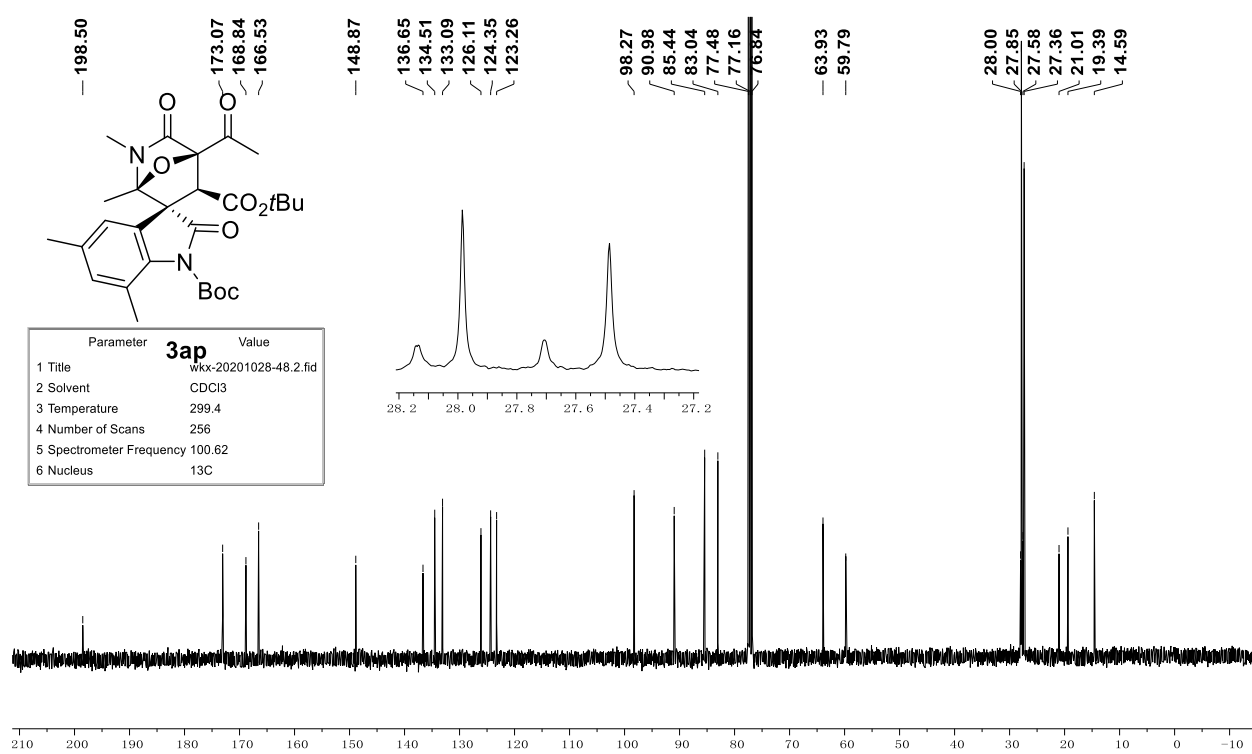
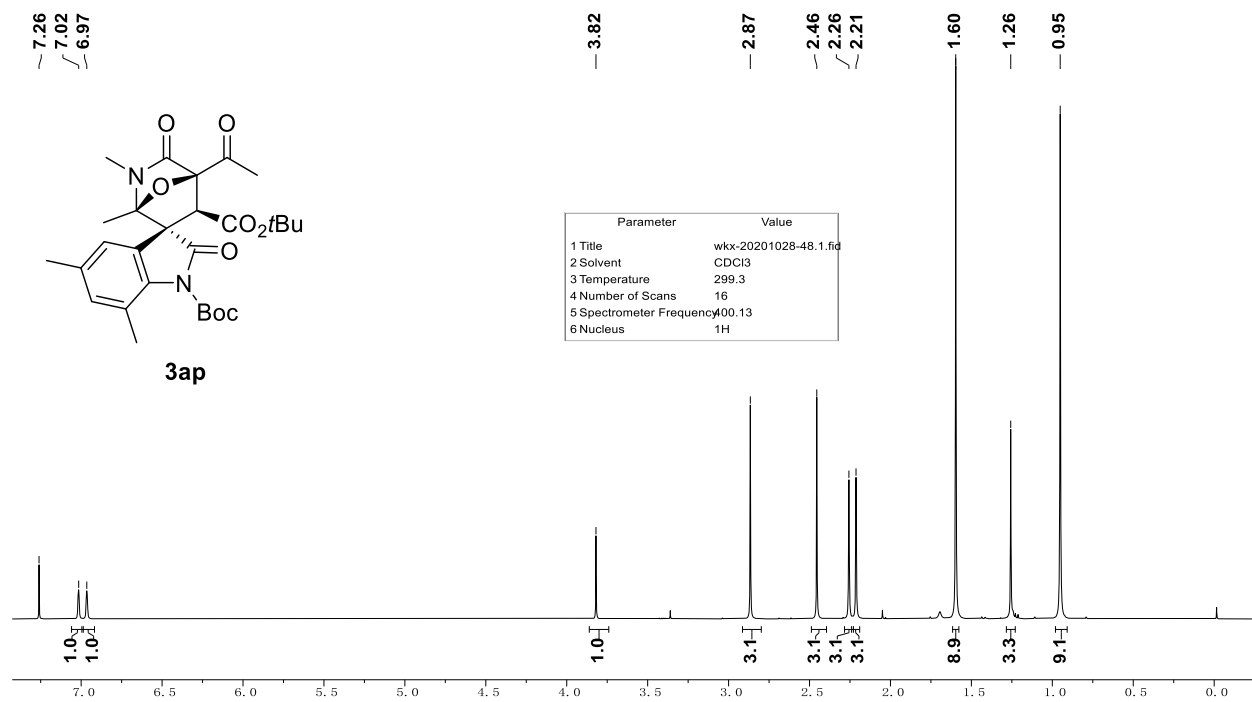


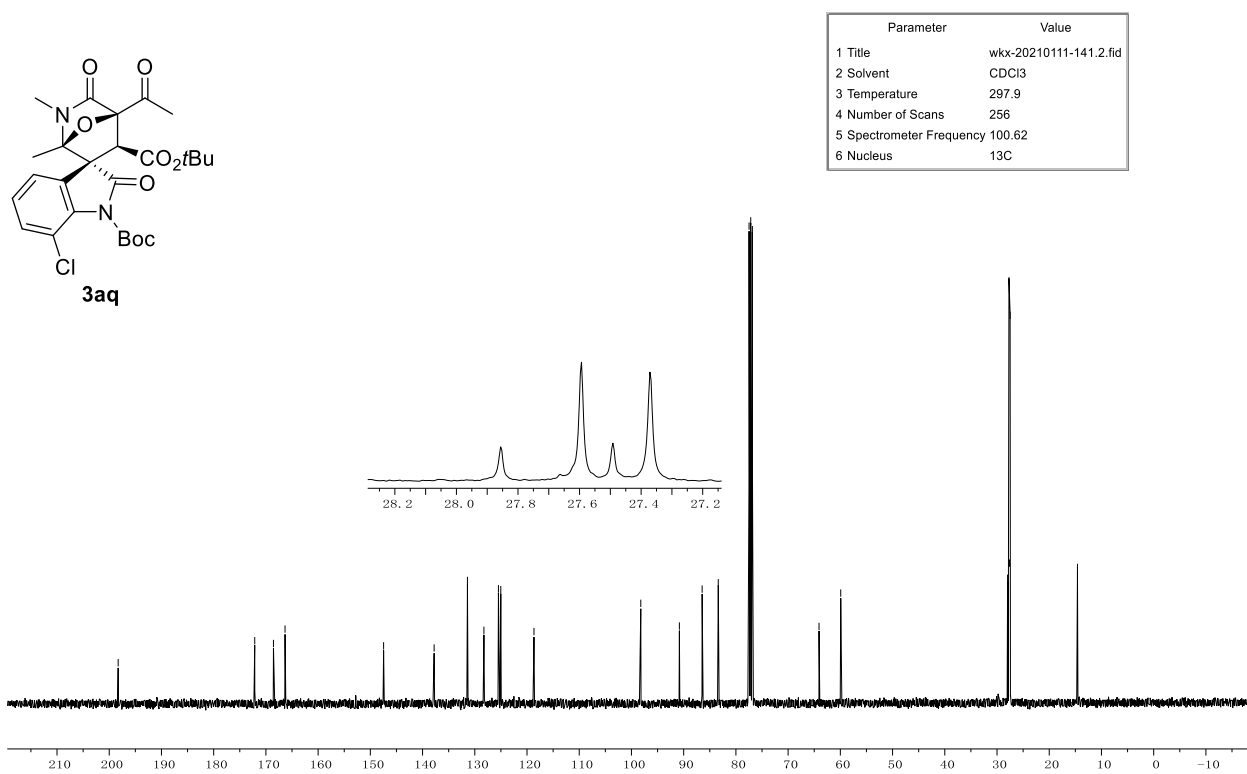
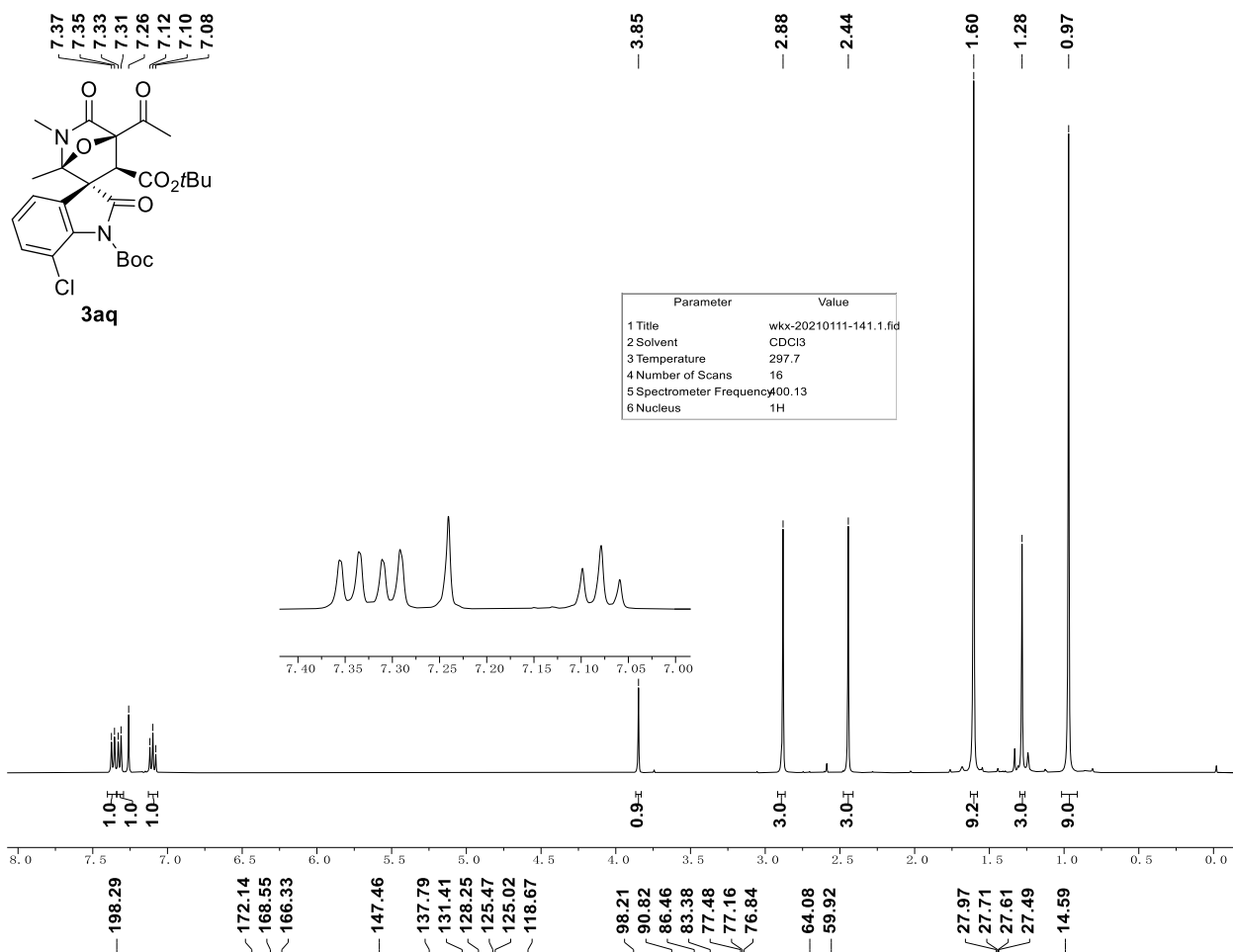


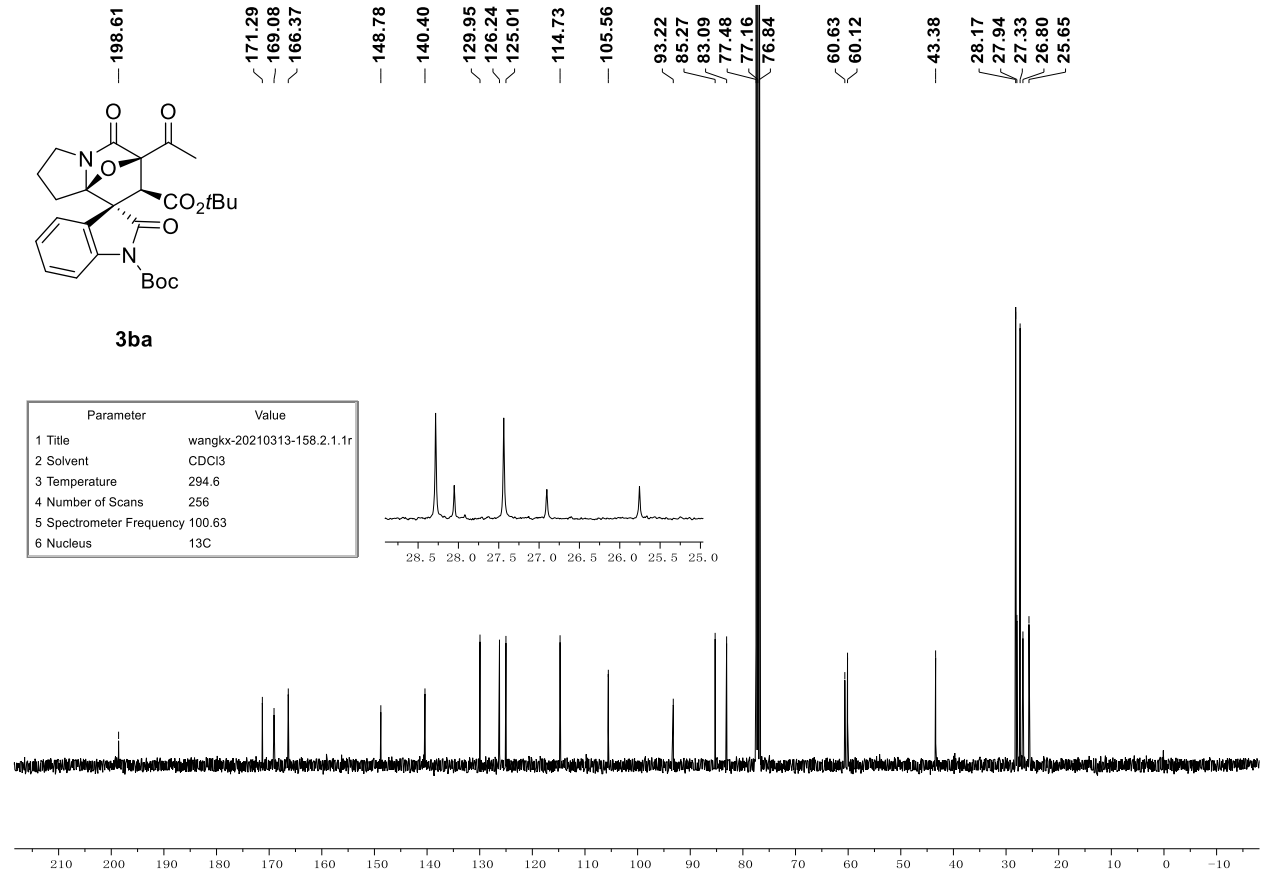
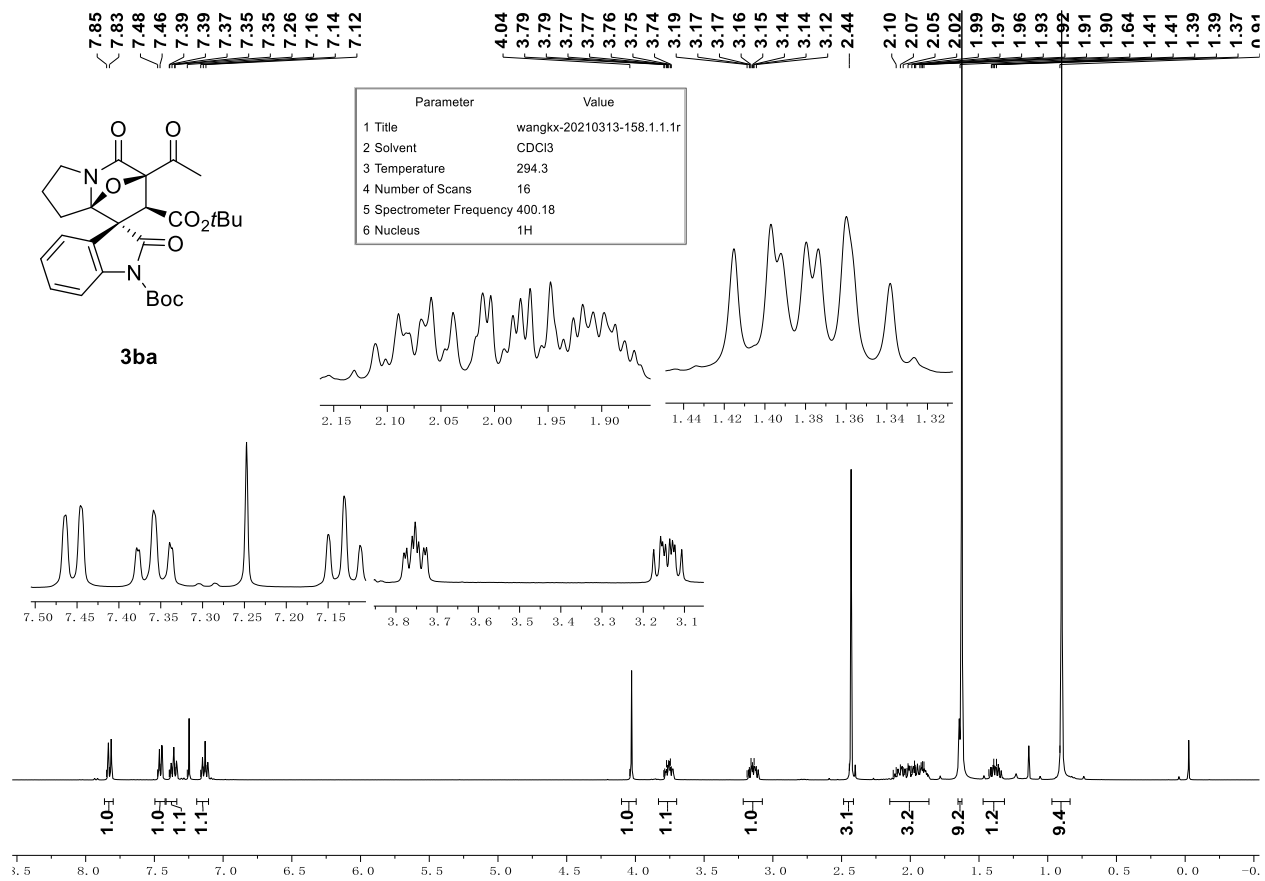


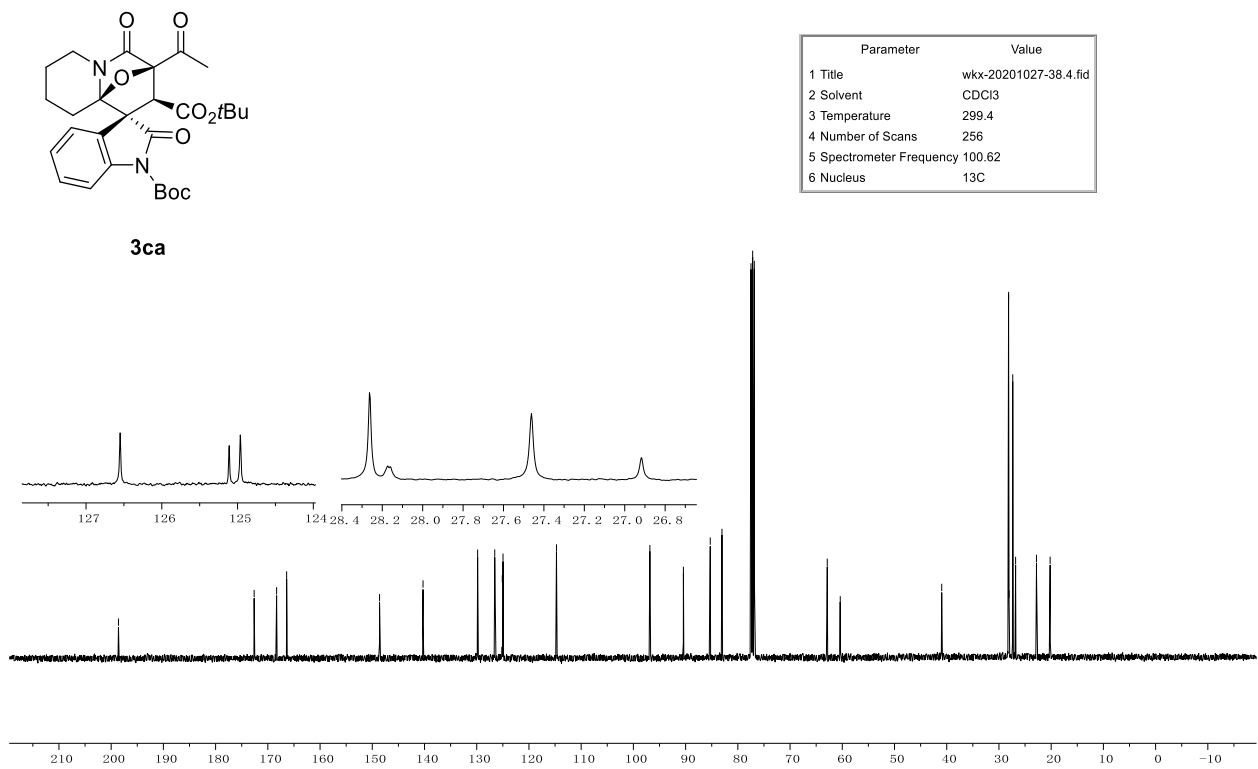
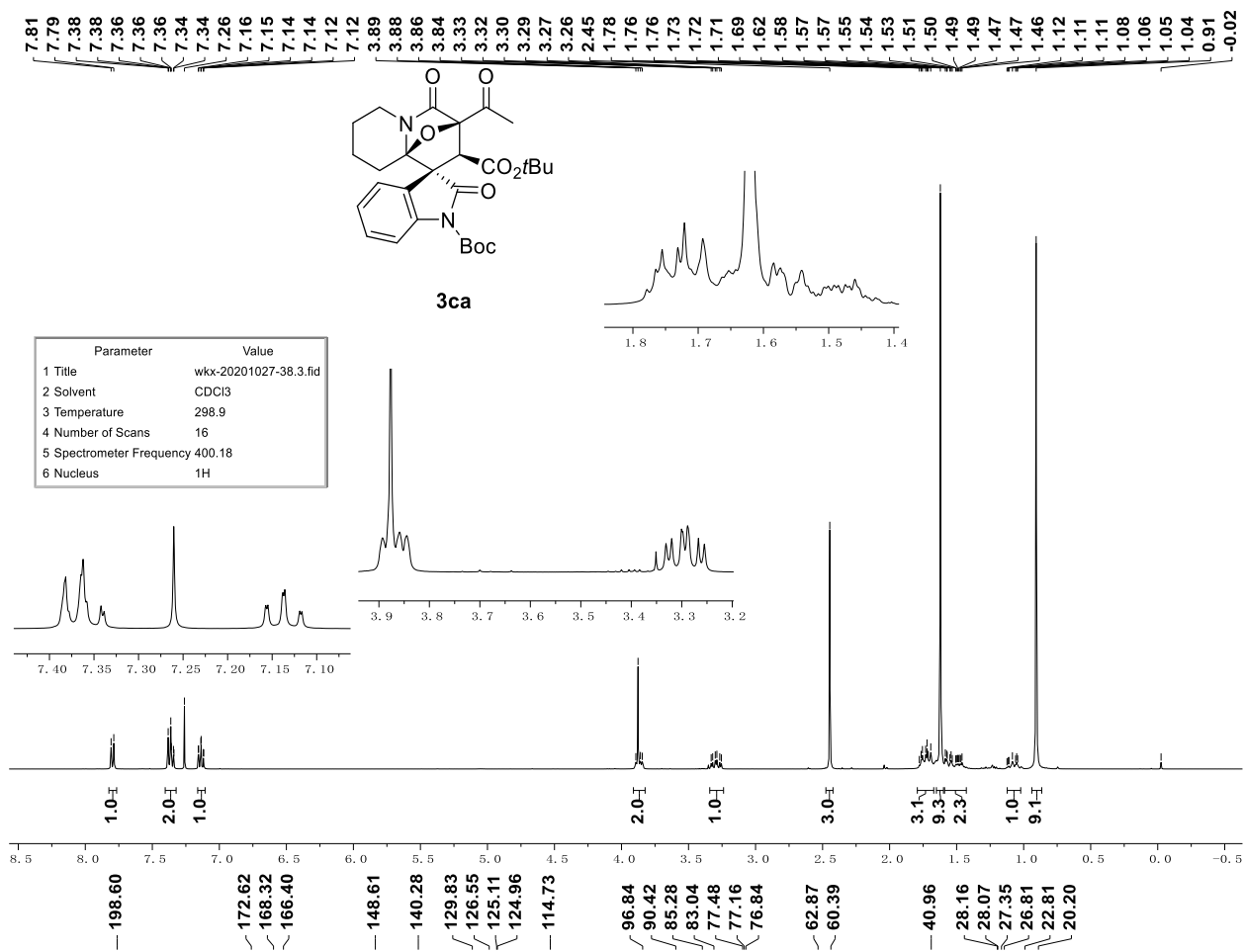


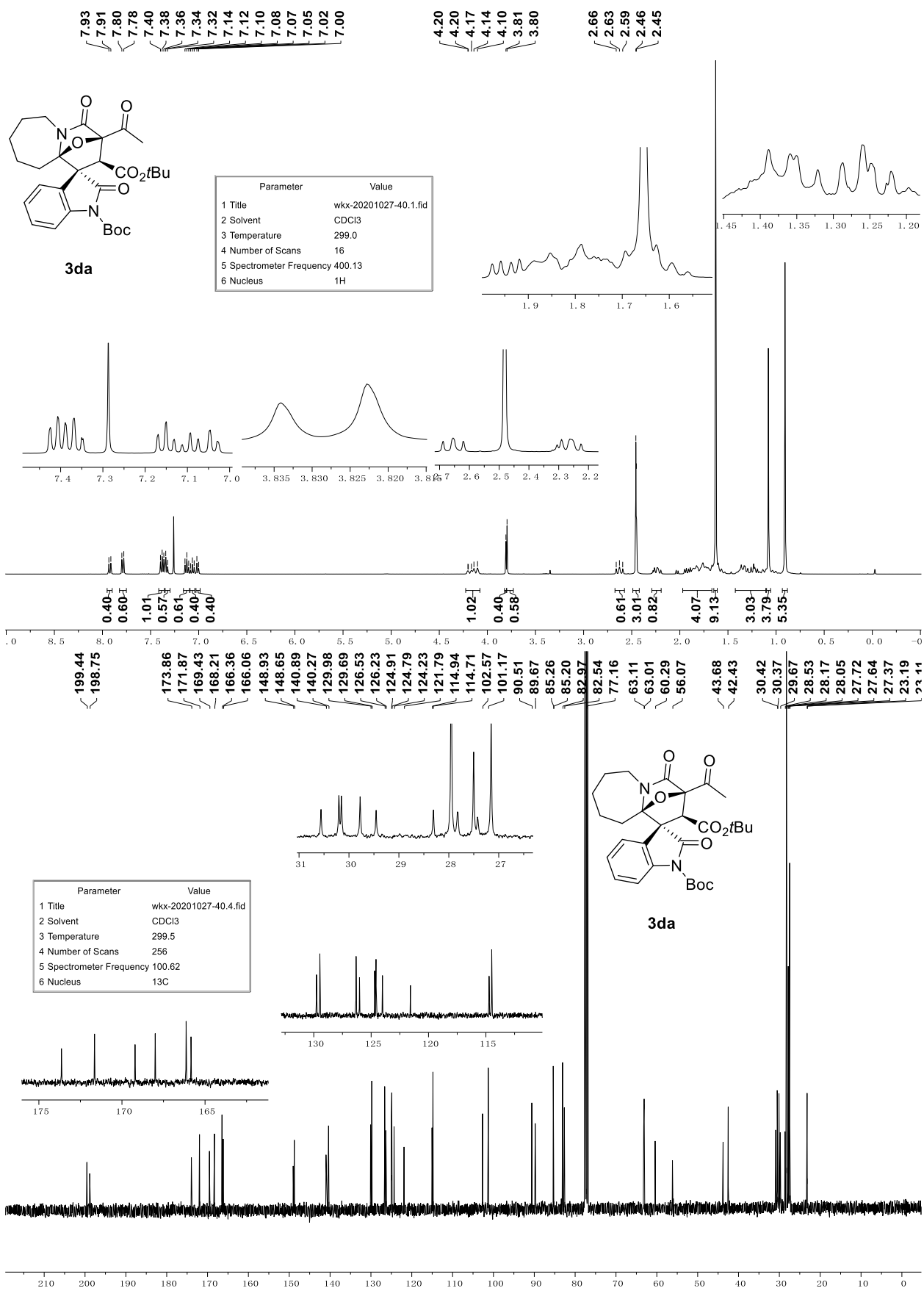


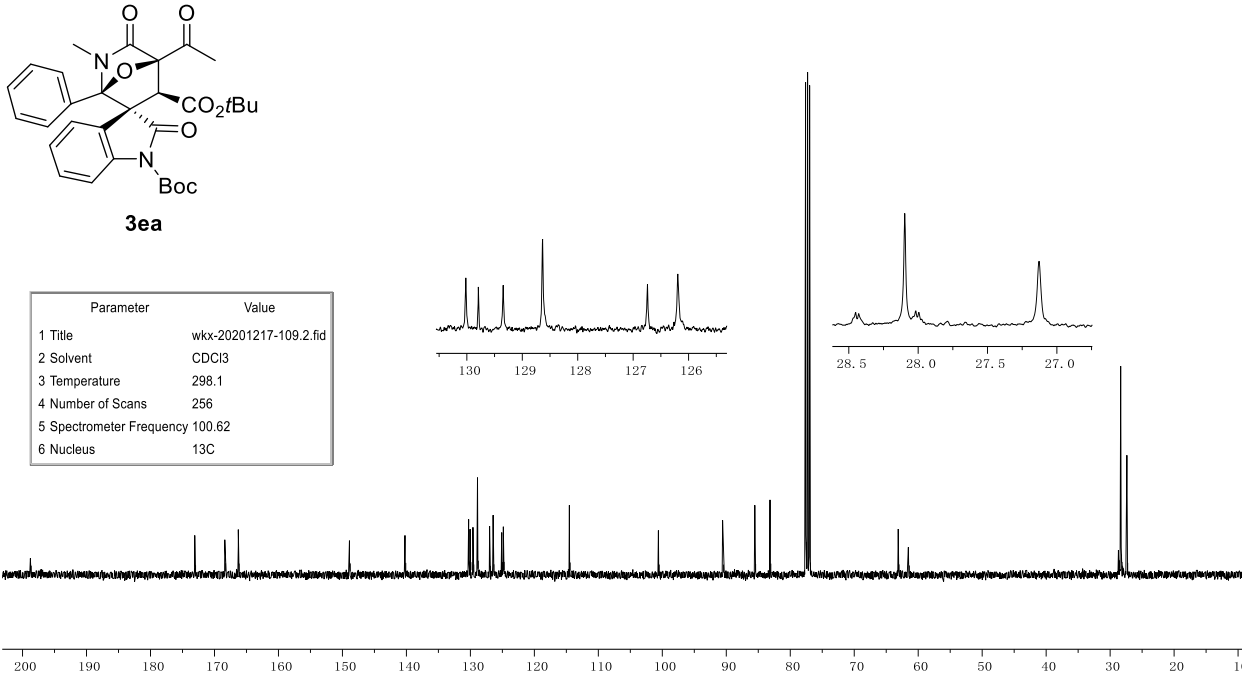
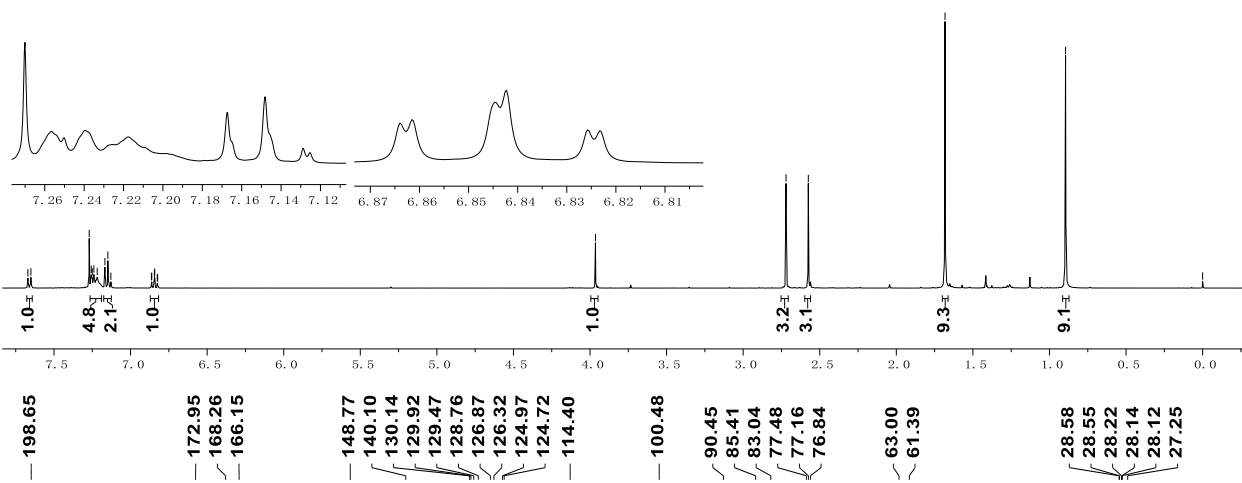
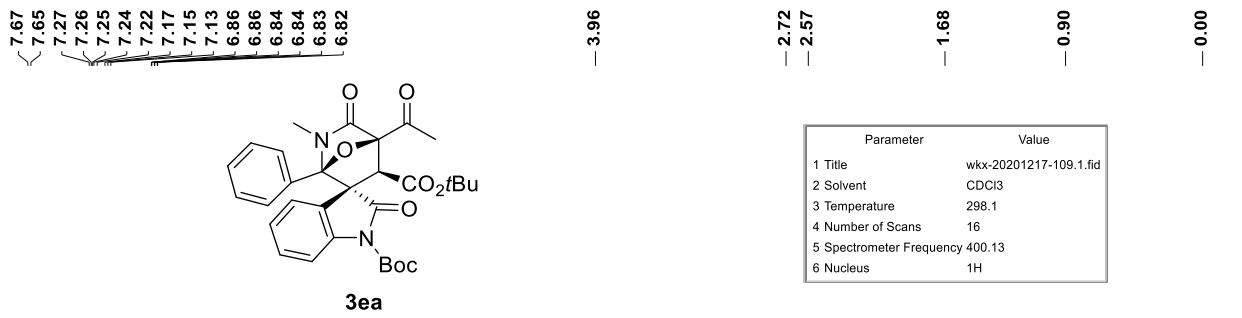




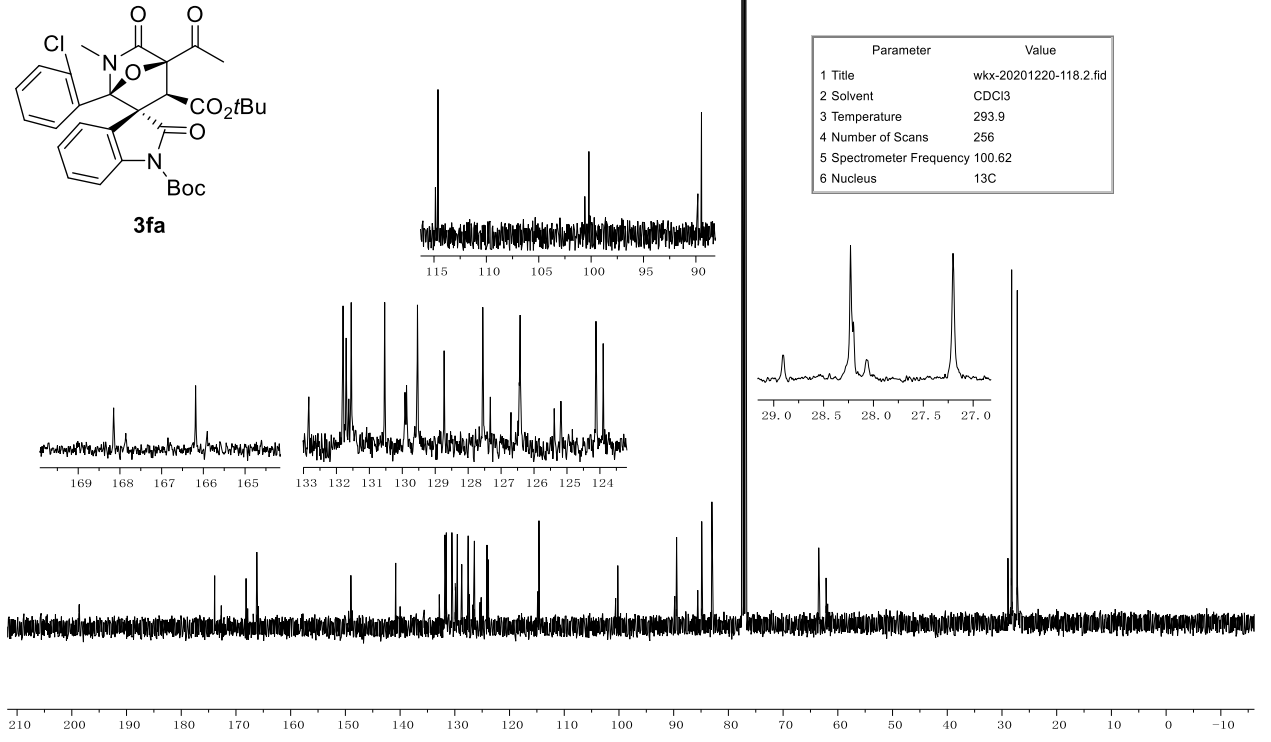
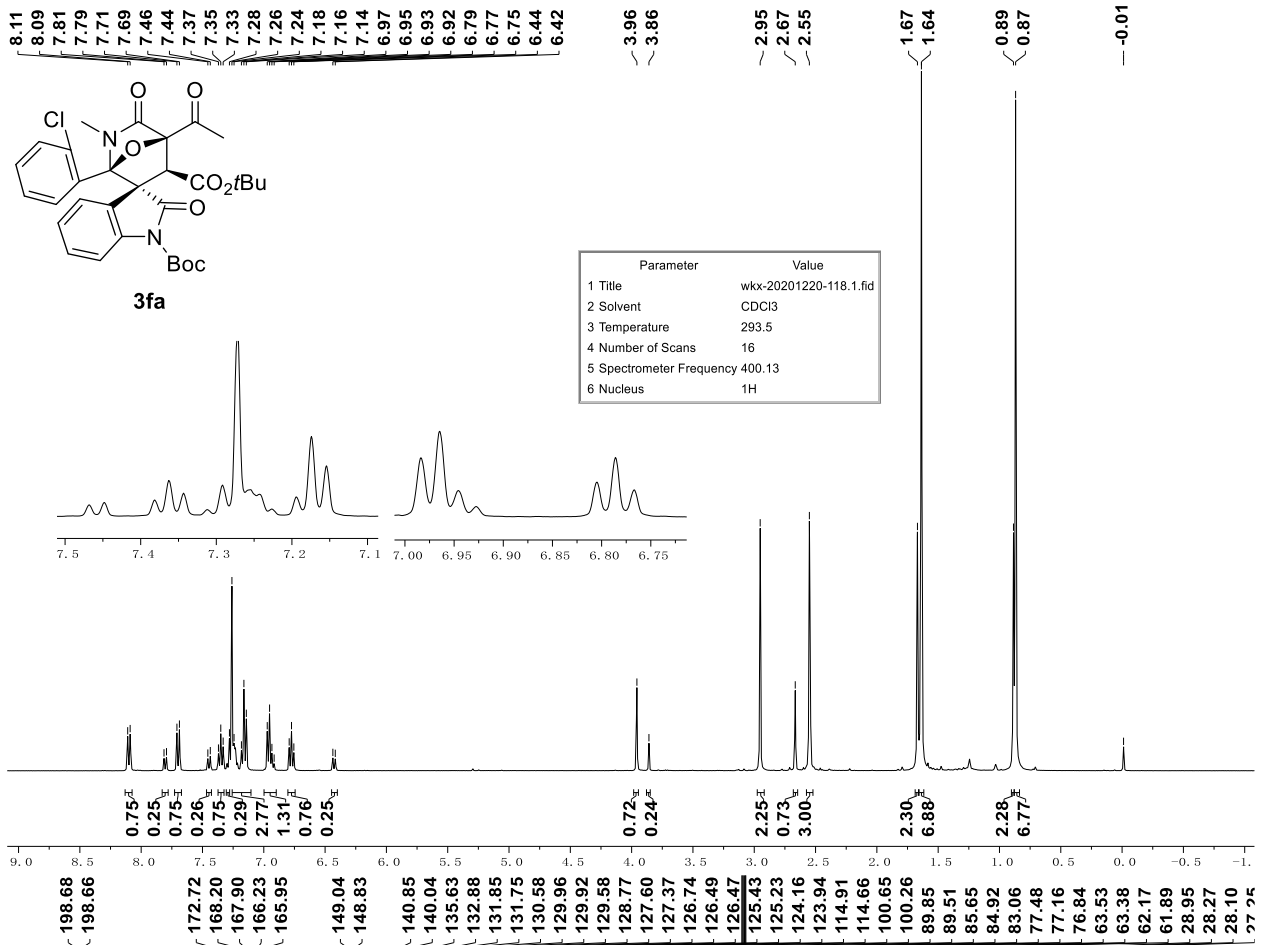


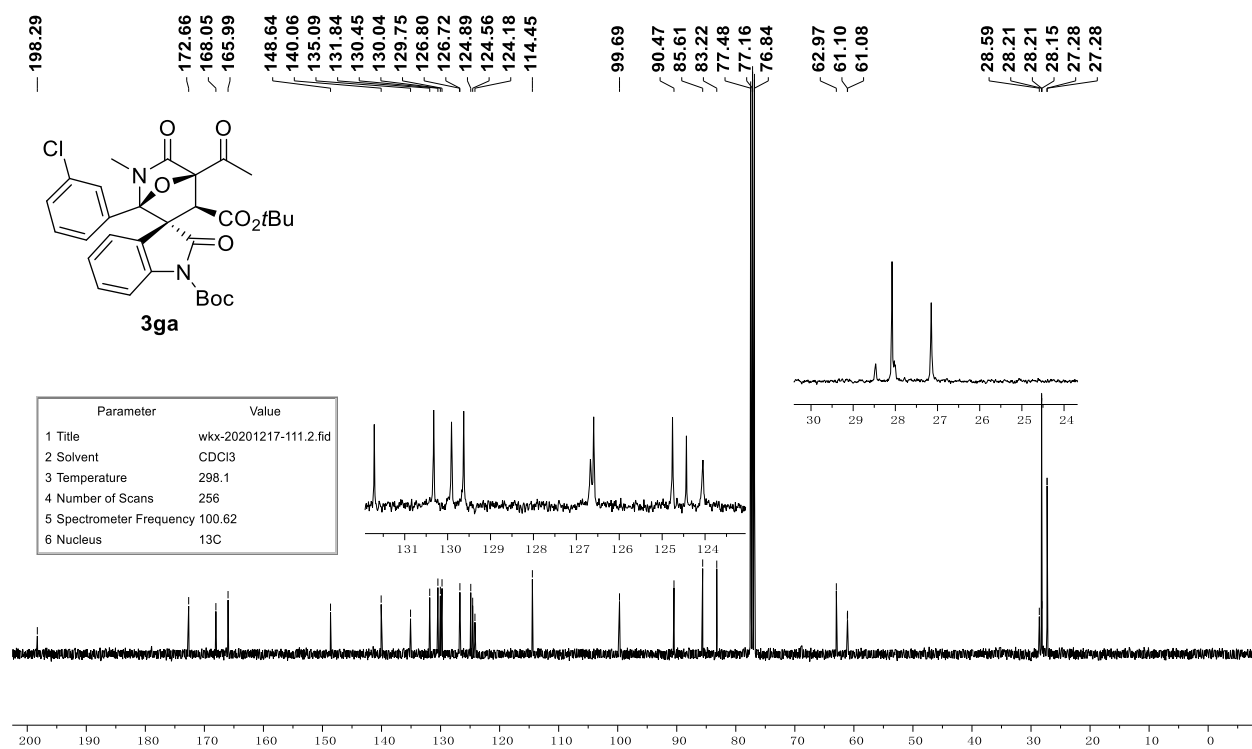
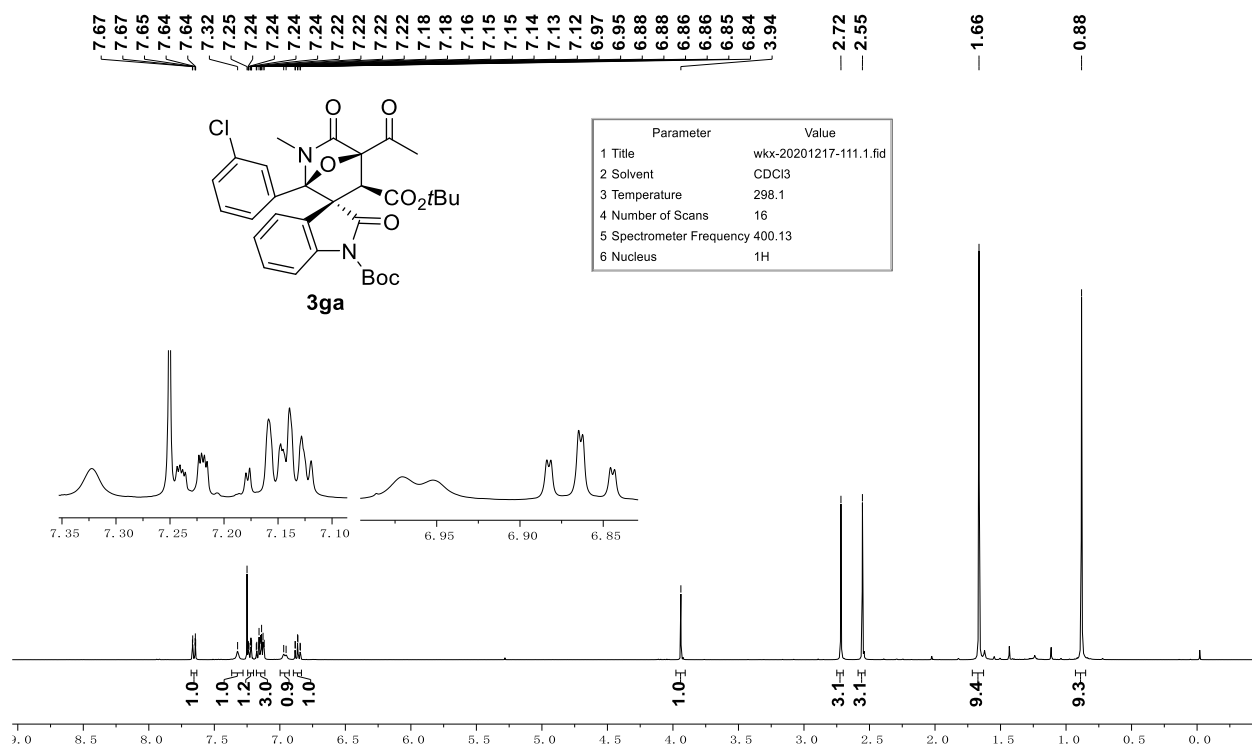


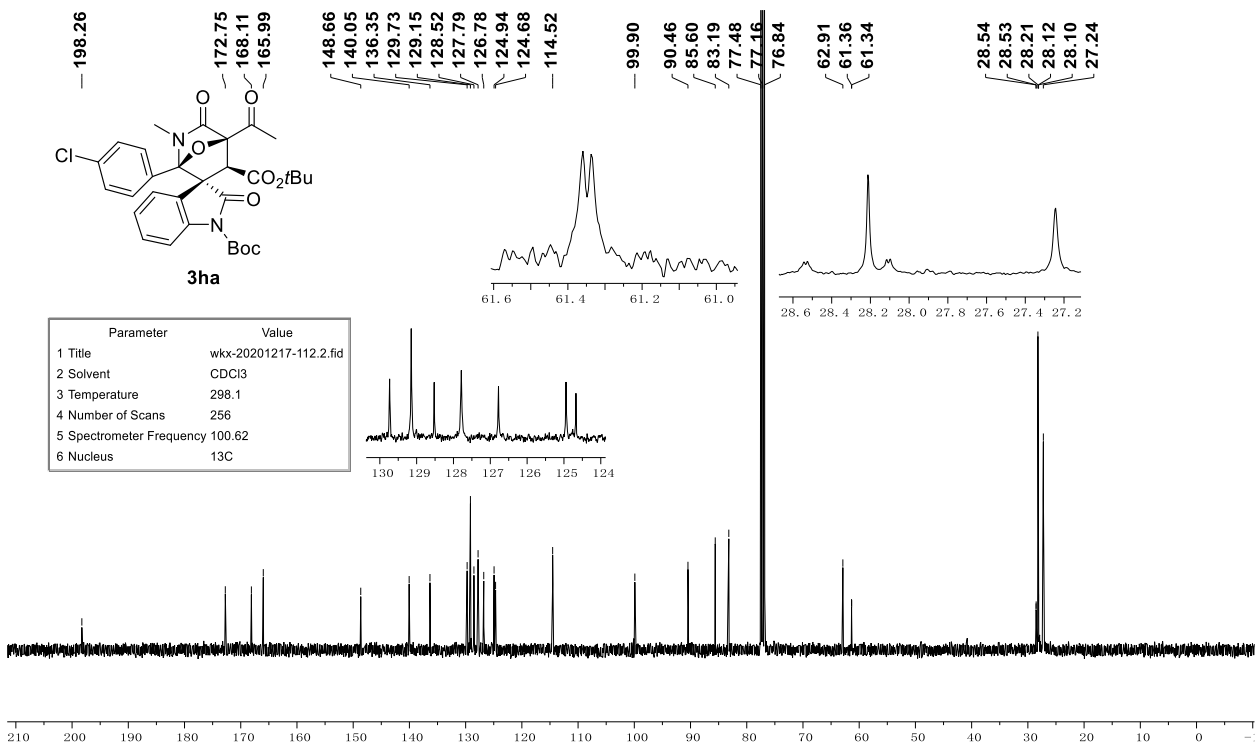
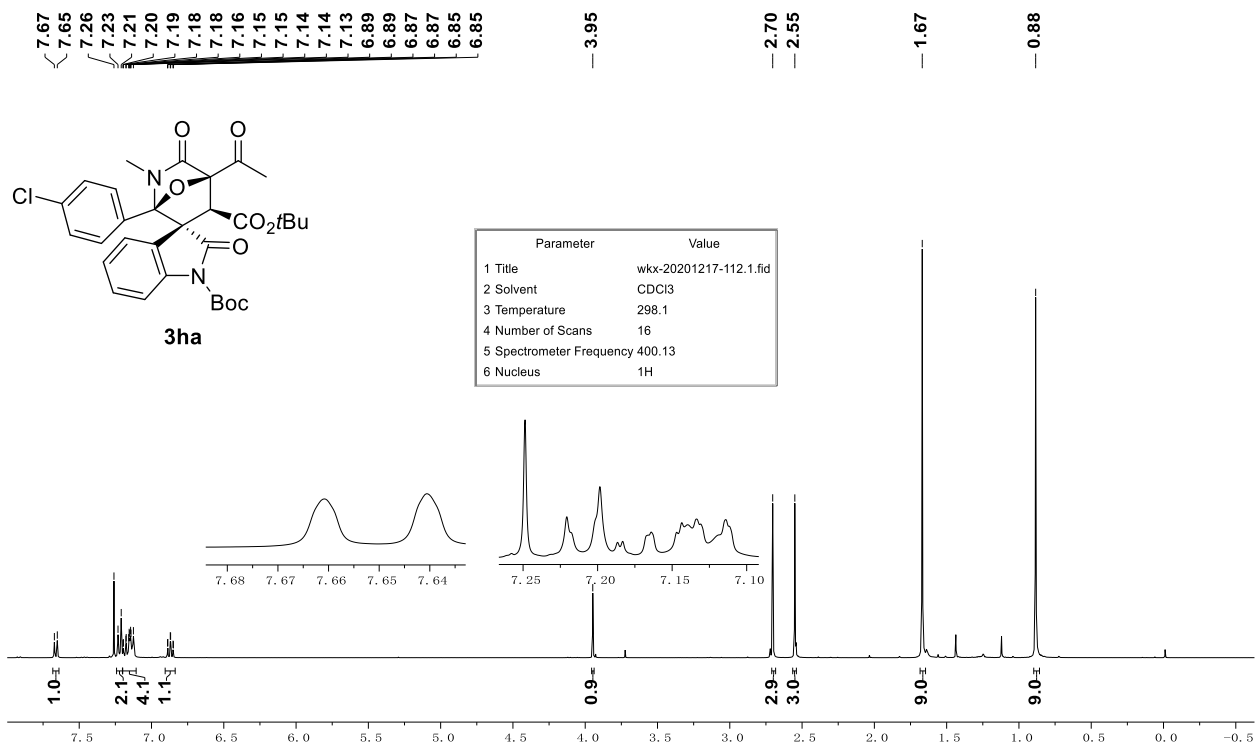


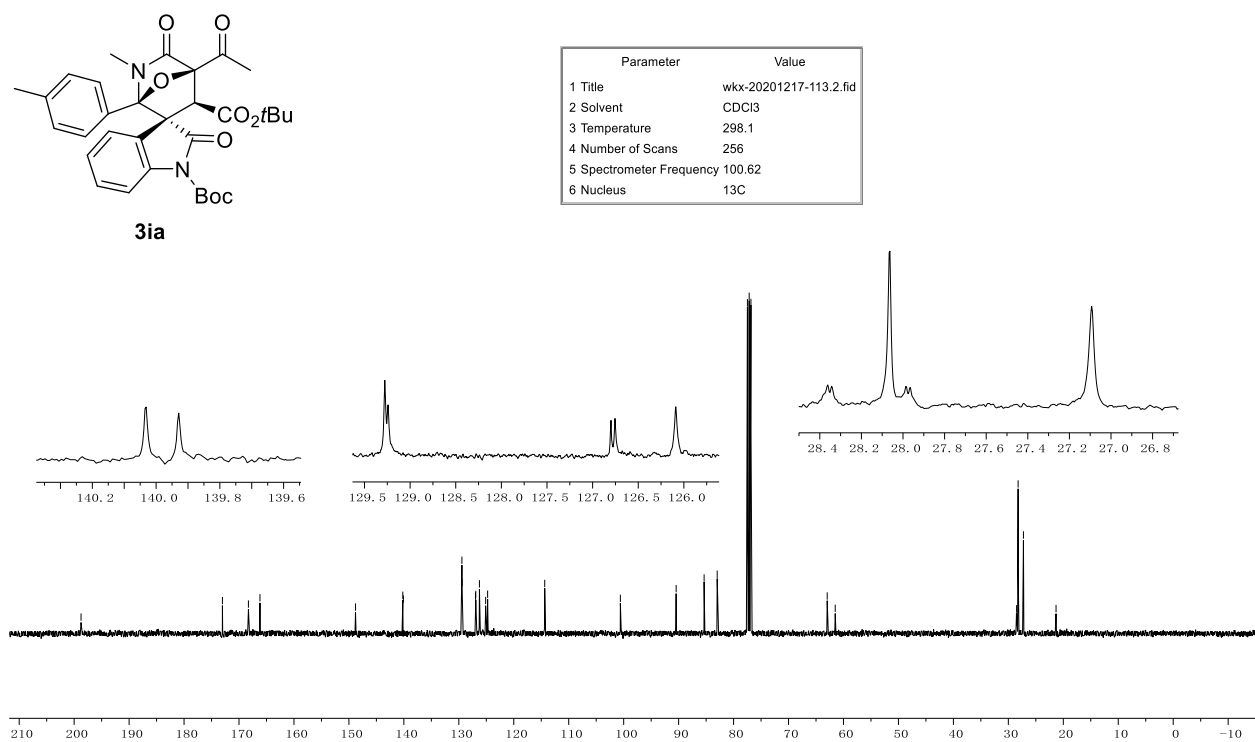
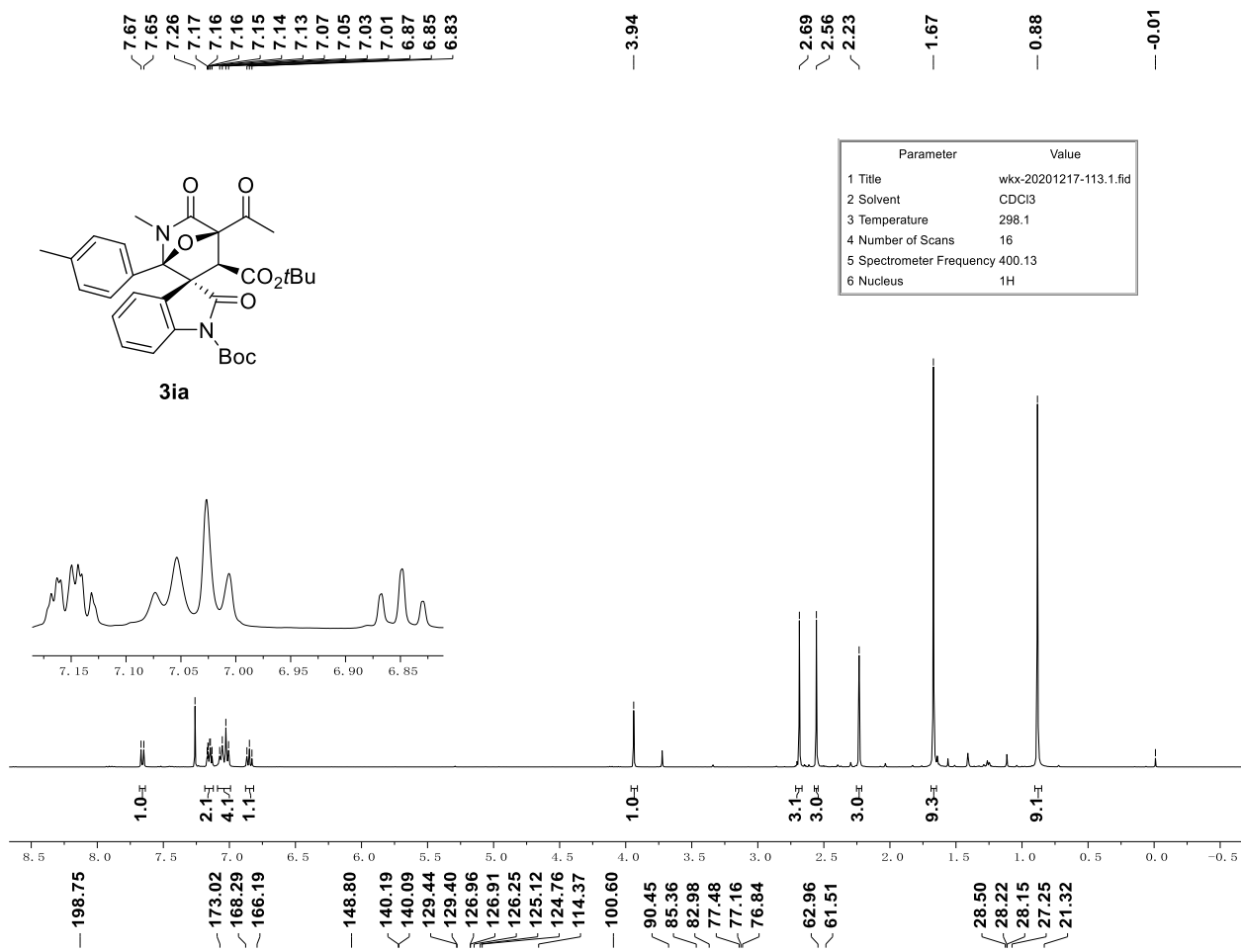












7.68  
7.66  
7.26  
7.18  
7.16  
7.14  
7.10  
7.08  
6.88  
6.86  
6.84  
6.74  
6.71

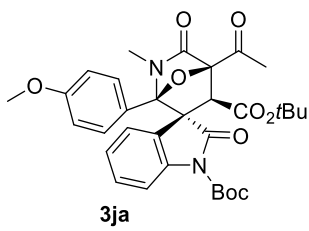
3.94  
3.72

2.68  
2.56

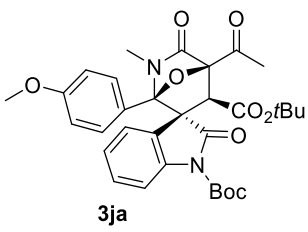
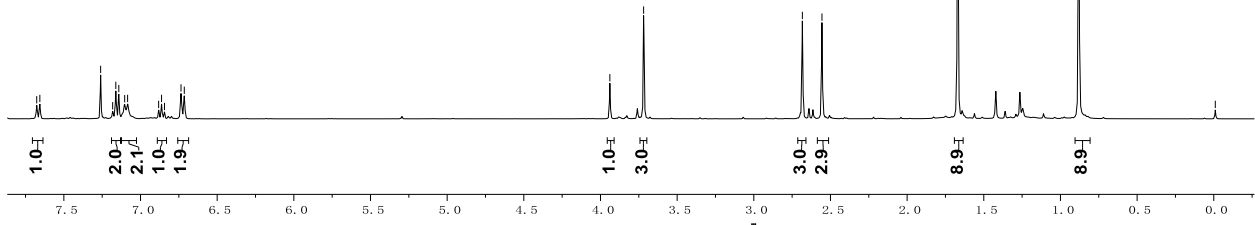
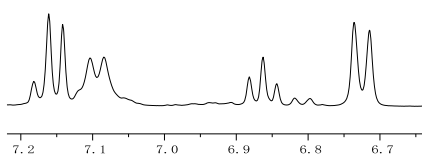
1.67

0.88

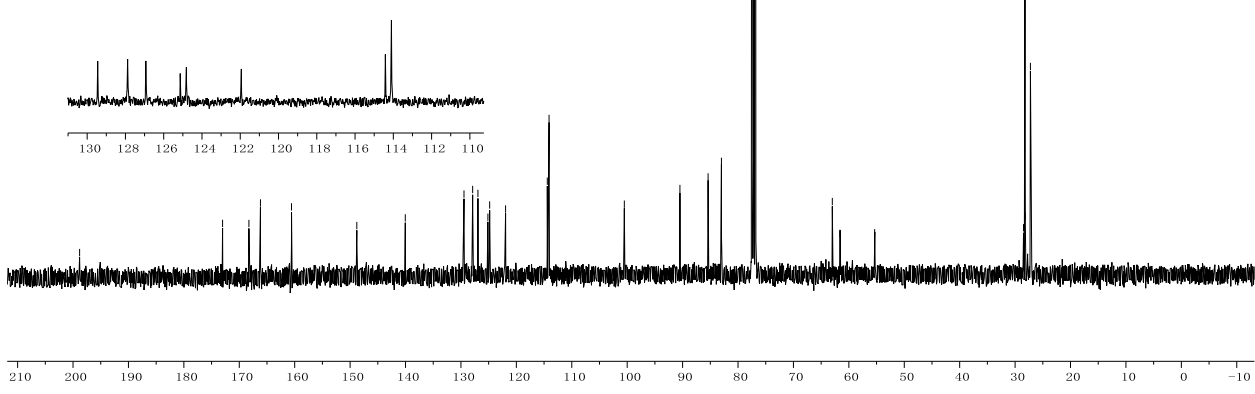
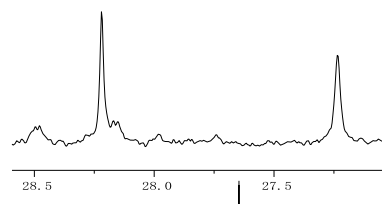
-0.01



Parameter	Value
1 Title	wkx-20201222-121.1.fid
2 Solvent	CDCl3
3 Temperature	293.3
4 Number of Scans	16
5 Spectrometer Frequency	400.13
6 Nucleus	13C



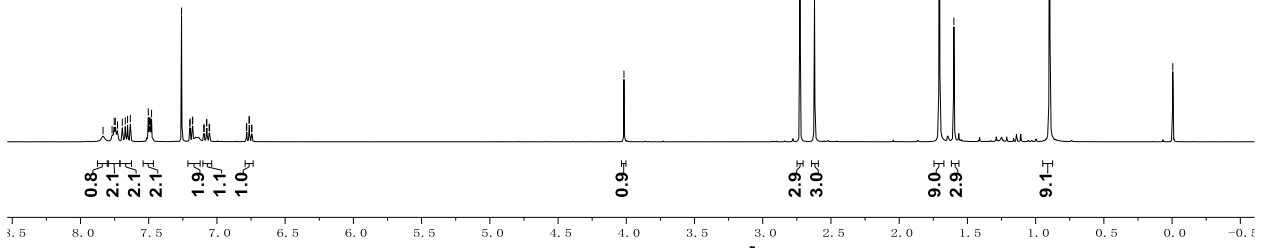
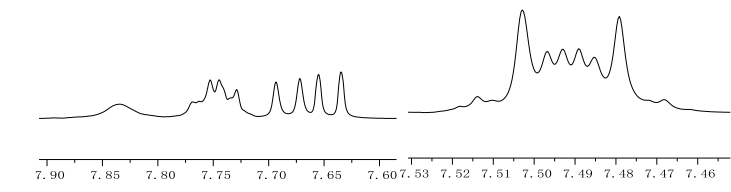
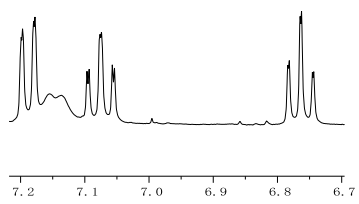
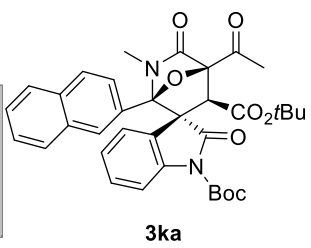
Parameter	Value
1 Title	wkx-20201222-121.2.fid
2 Solvent	CDCl3
3 Temperature	293.3
4 Number of Scans	256
5 Spectrometer Frequency	100.62
6 Nucleus	13C



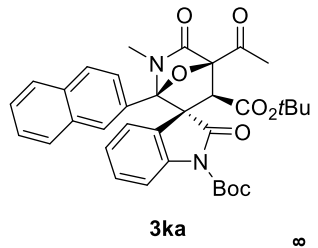
7.83  
7.77  
7.75  
7.74  
7.73  
7.69  
7.67  
7.65  
7.63  
7.50  
7.50  
7.49  
7.49  
7.48  
7.48  
7.26  
7.20  
7.20  
7.18  
7.18  
7.10  
7.09  
7.08  
7.07  
7.06  
7.05  
6.78  
6.78  
6.76  
6.76  
6.75  
6.74  
4.02

2.73  
2.62  
1.71  
1.60  
0.90  
-0.01

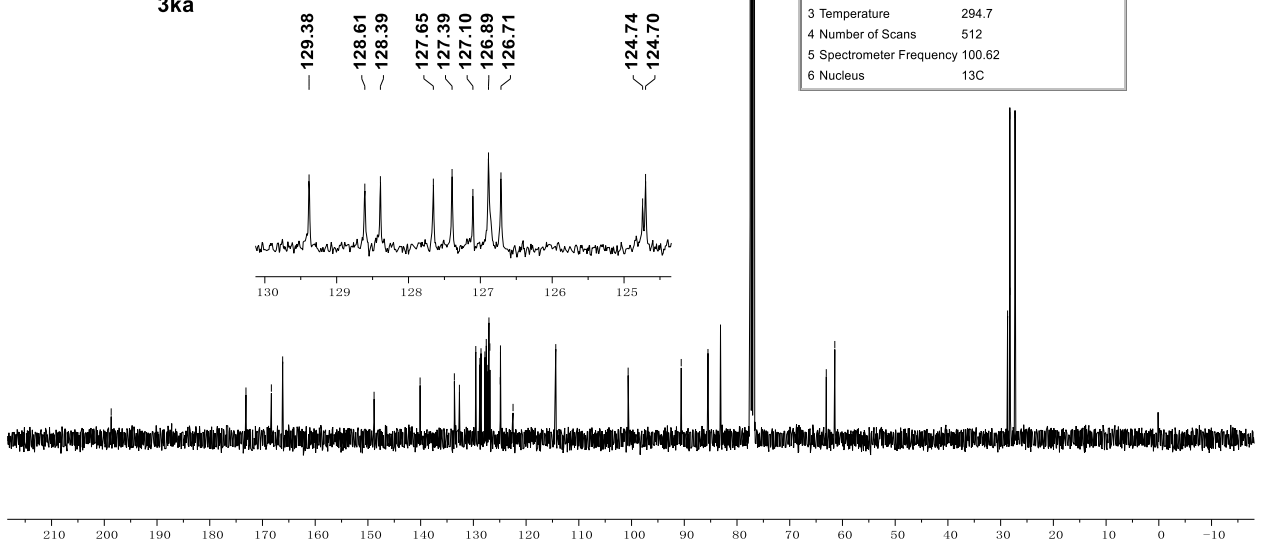
Parameter	Value
1 Title	wangxx-20210313-155.1.fid
2 Solvent	CDCl3
3 Temperature	294.1
4 Number of Scans	16
5 Spectrometer Frequency	400.13
6 Nucleus	1H

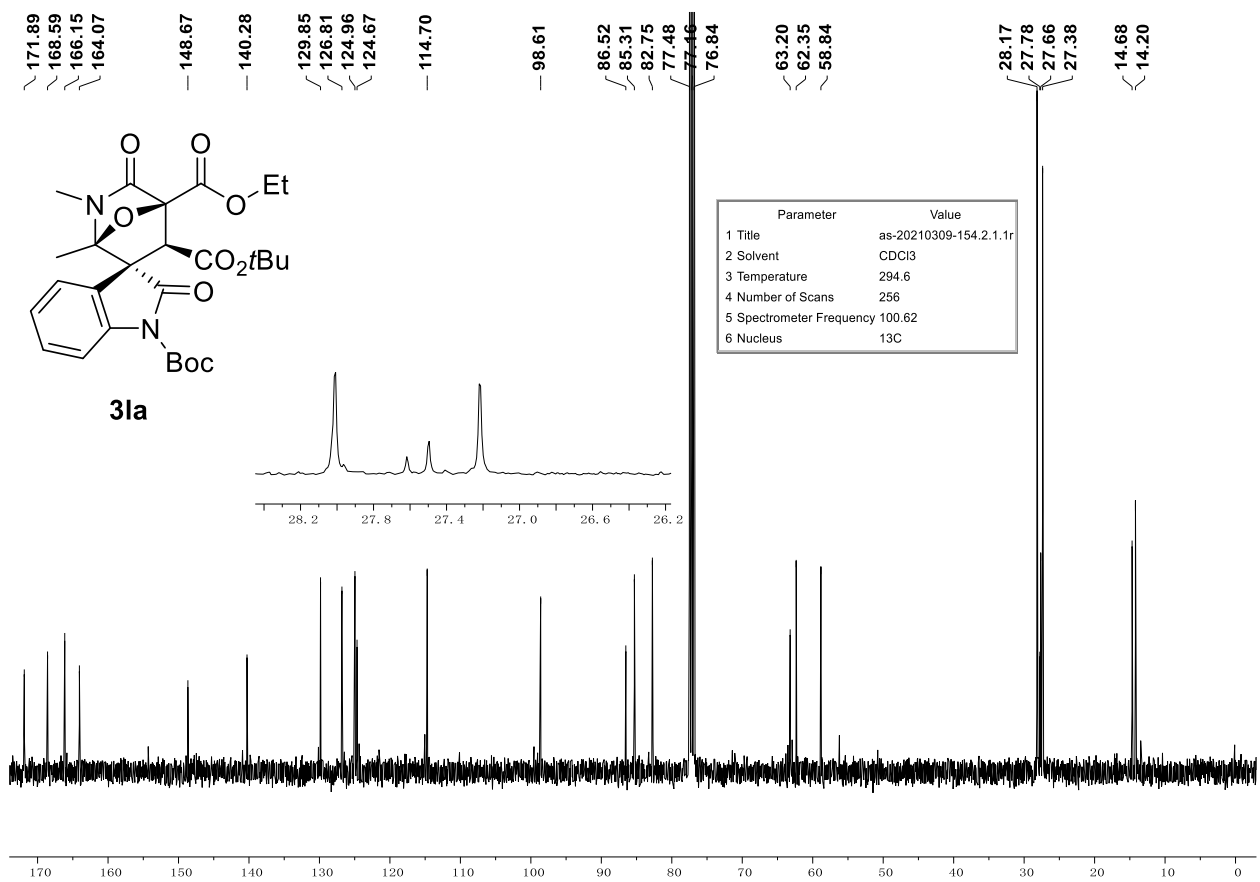
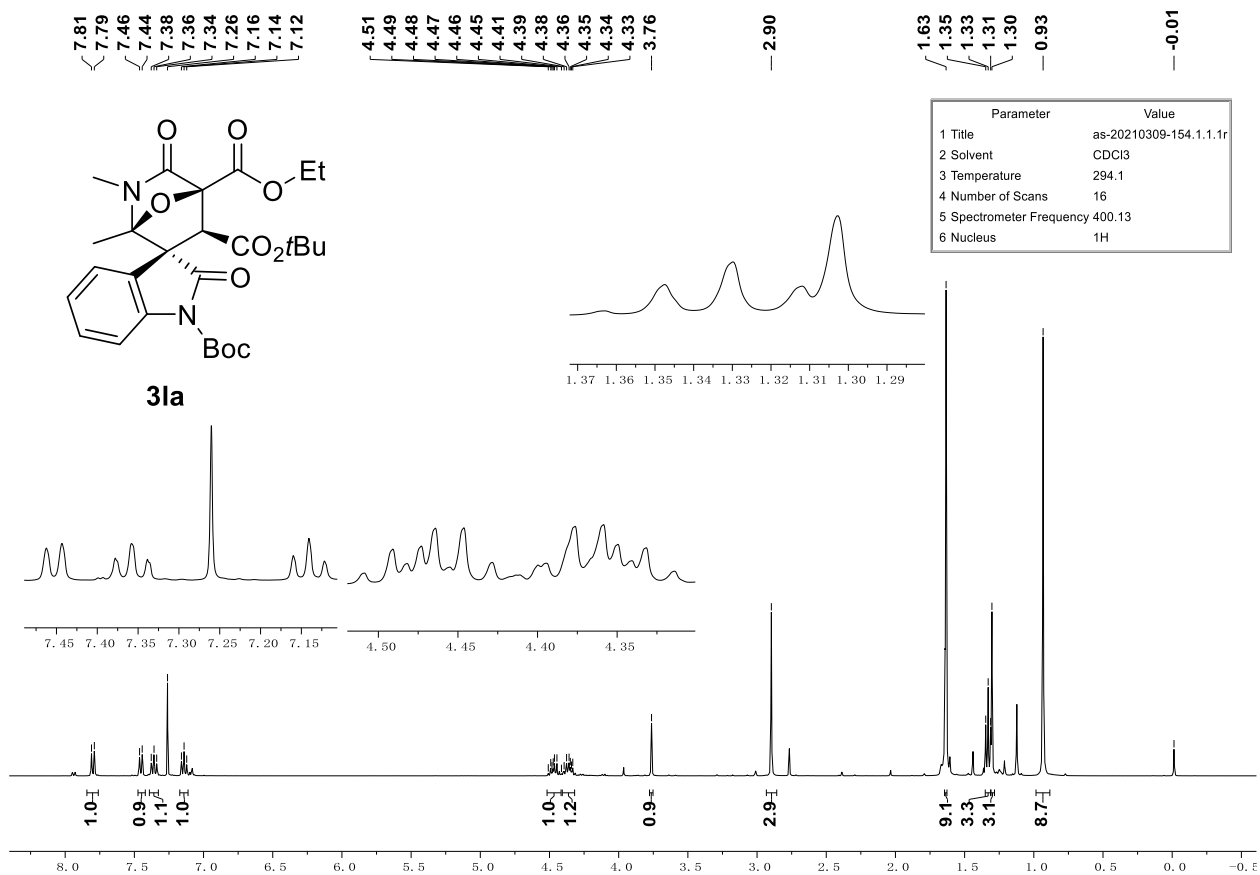


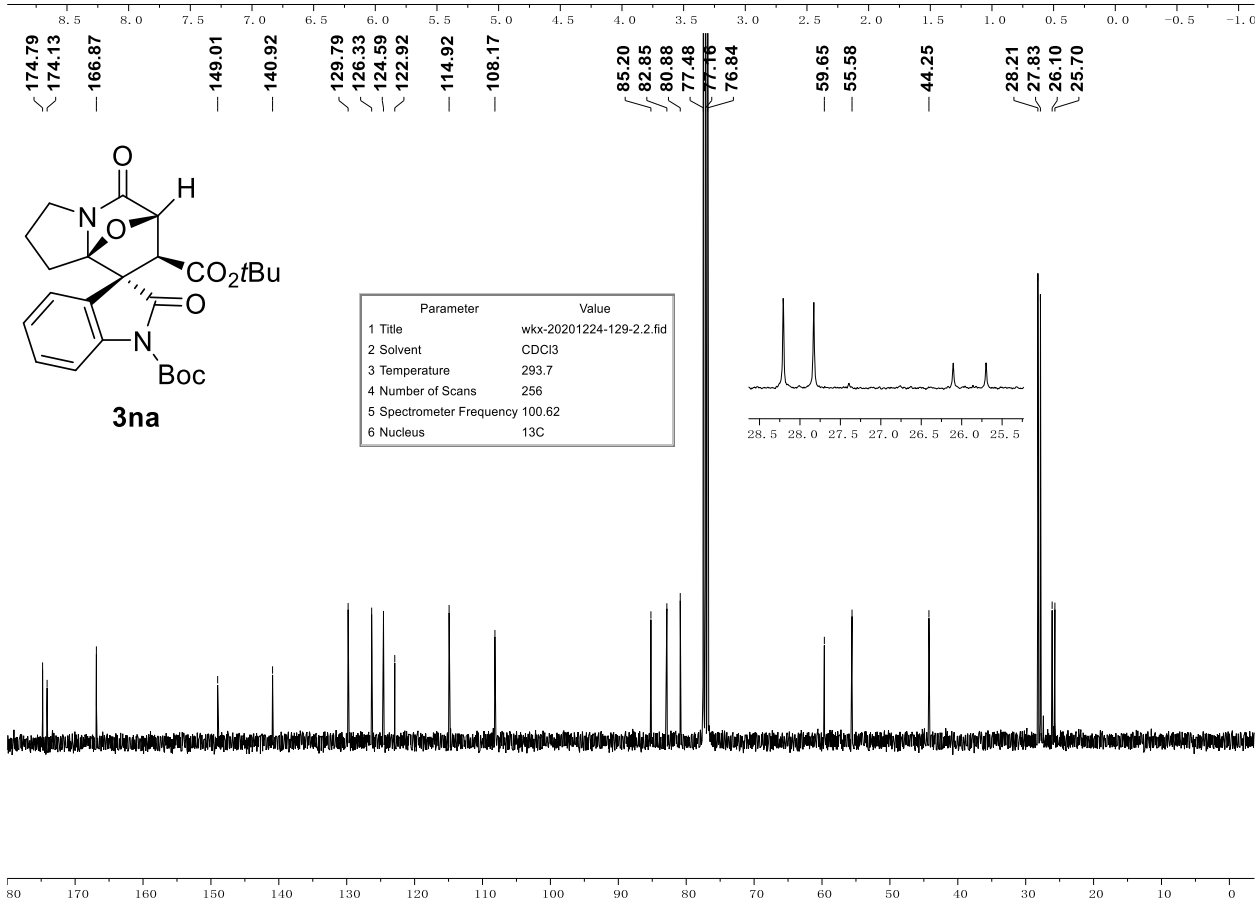
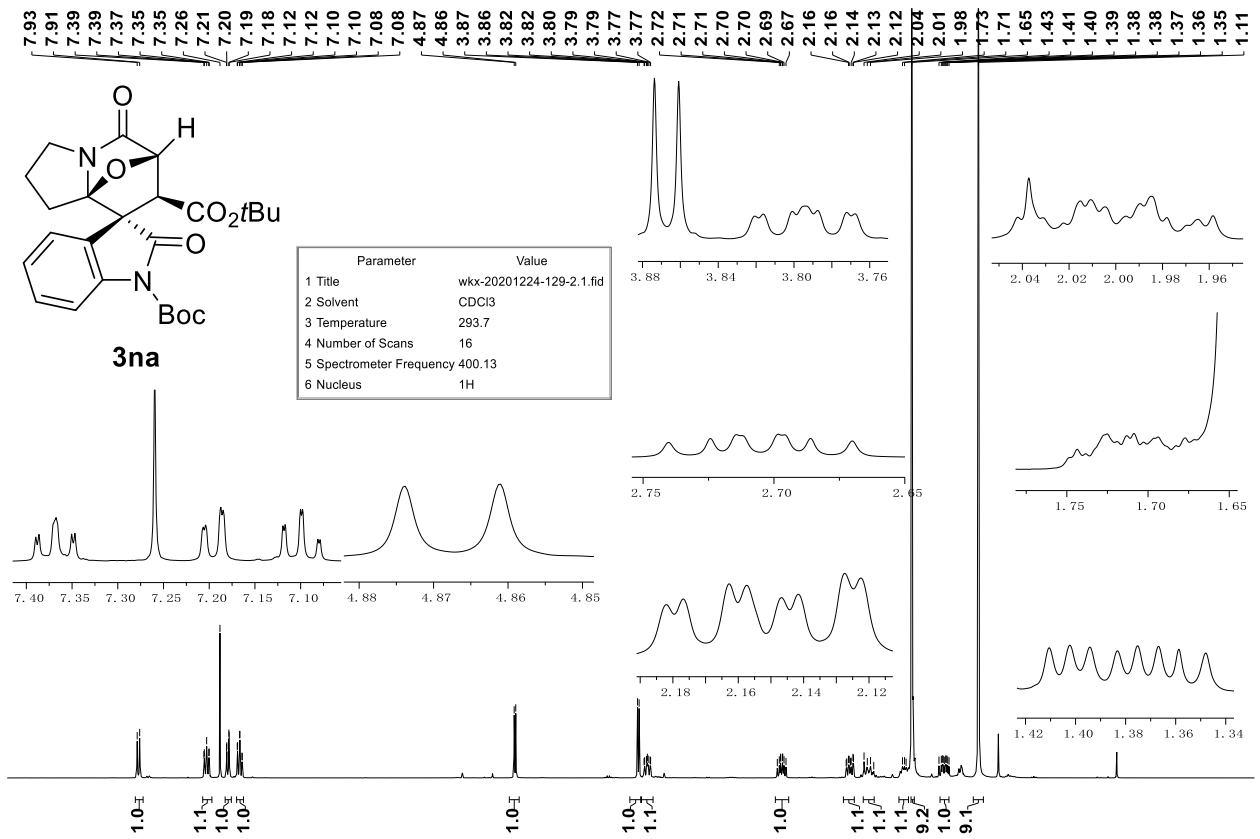
198.69  
173.13  
168.31  
166.17  
148.83  
140.10  
133.61  
132.65  
129.54  
128.77  
128.55  
127.81  
127.55  
127.26  
127.05  
126.87  
124.90  
124.86  
122.48  
114.37  
100.65  
90.58  
85.51  
83.13  
77.46  
77.16  
76.84  
63.07  
61.45  
28.68  
28.26  
28.24  
27.27



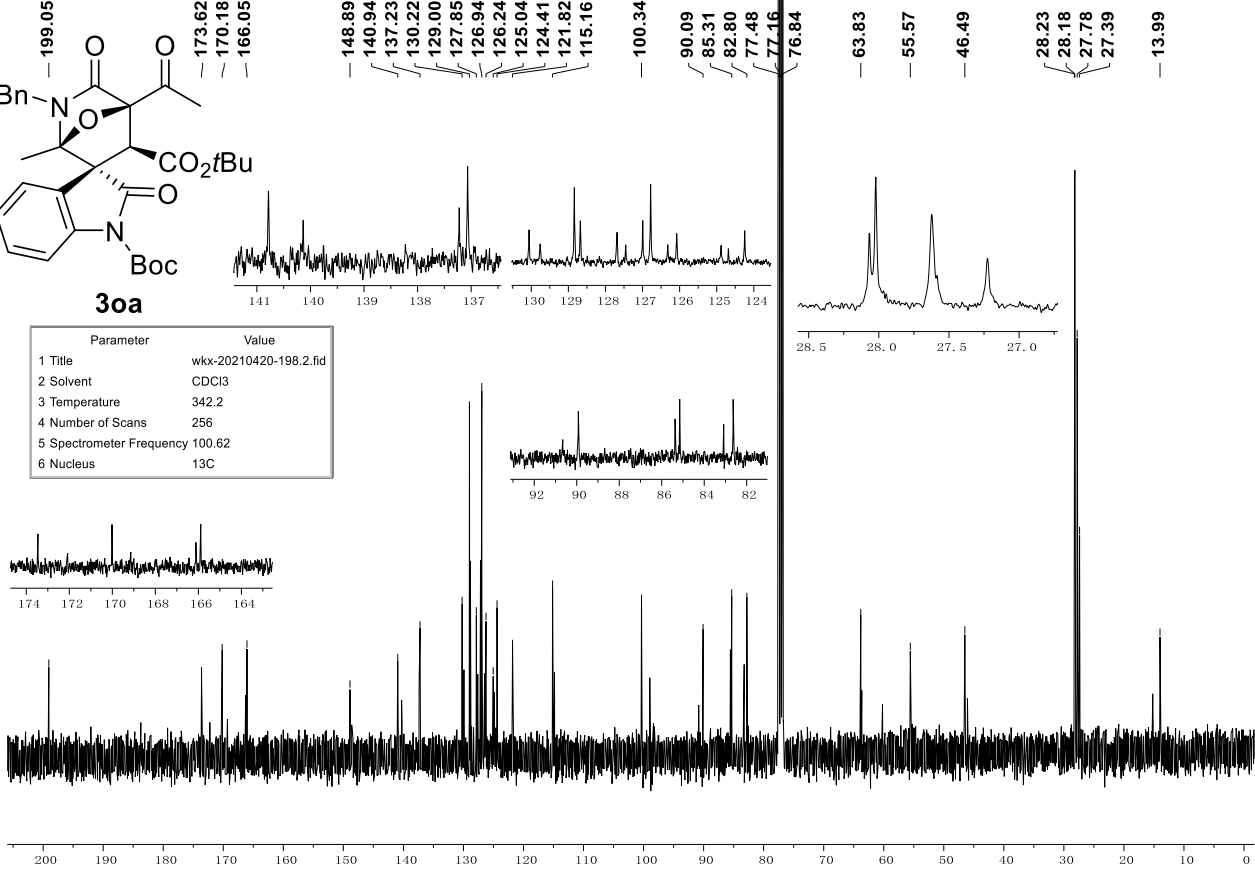
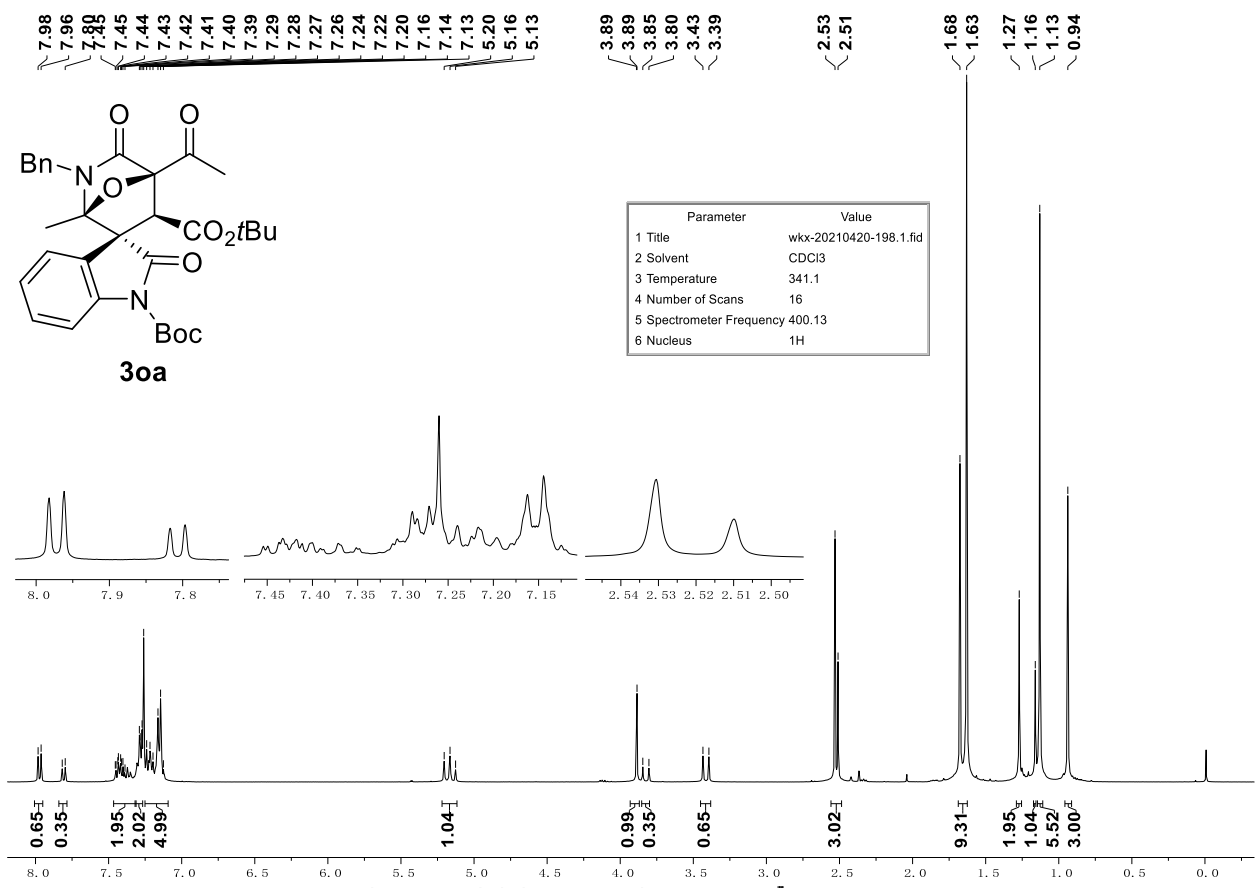
Parameter	Value
1 Title	wangxx-20210313-155.2.fid
2 Solvent	CDCl3
3 Temperature	294.7
4 Number of Scans	512
5 Spectrometer Frequency	100.62
6 Nucleus	13C

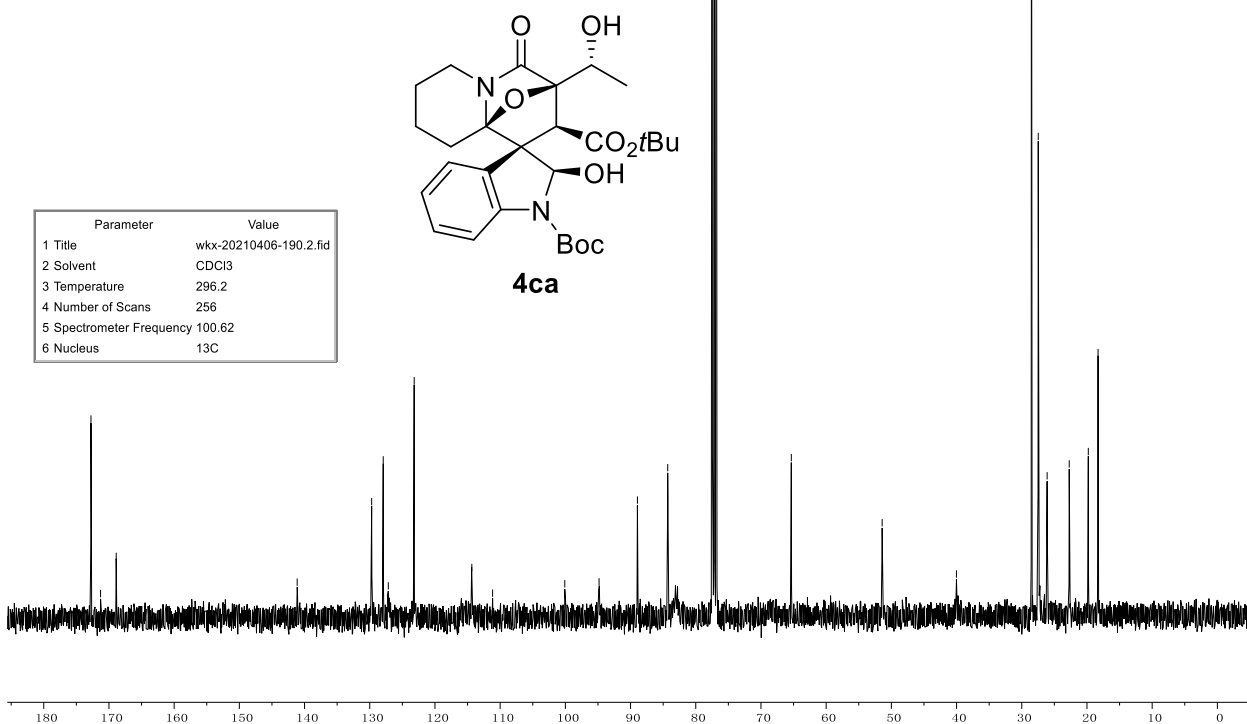
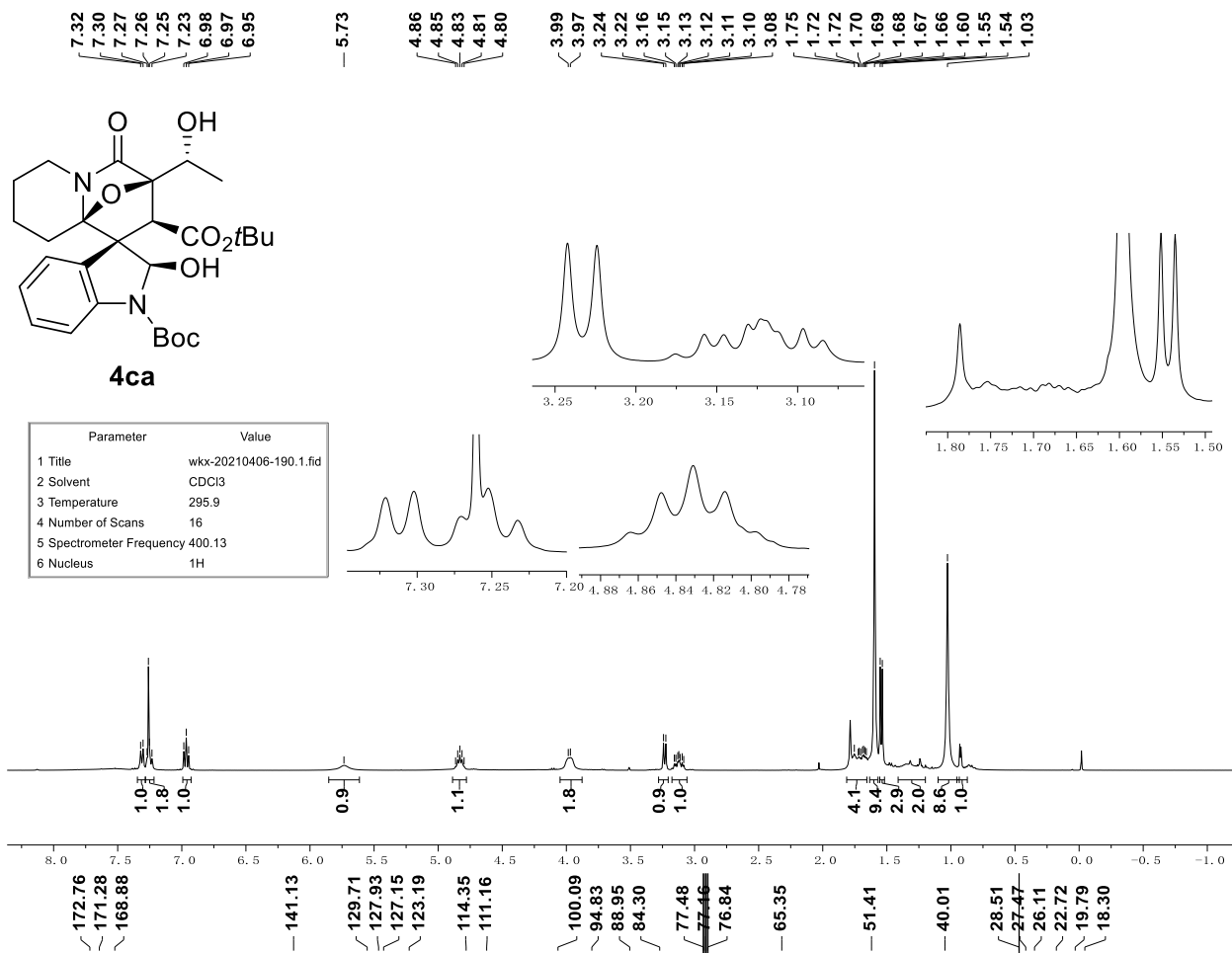


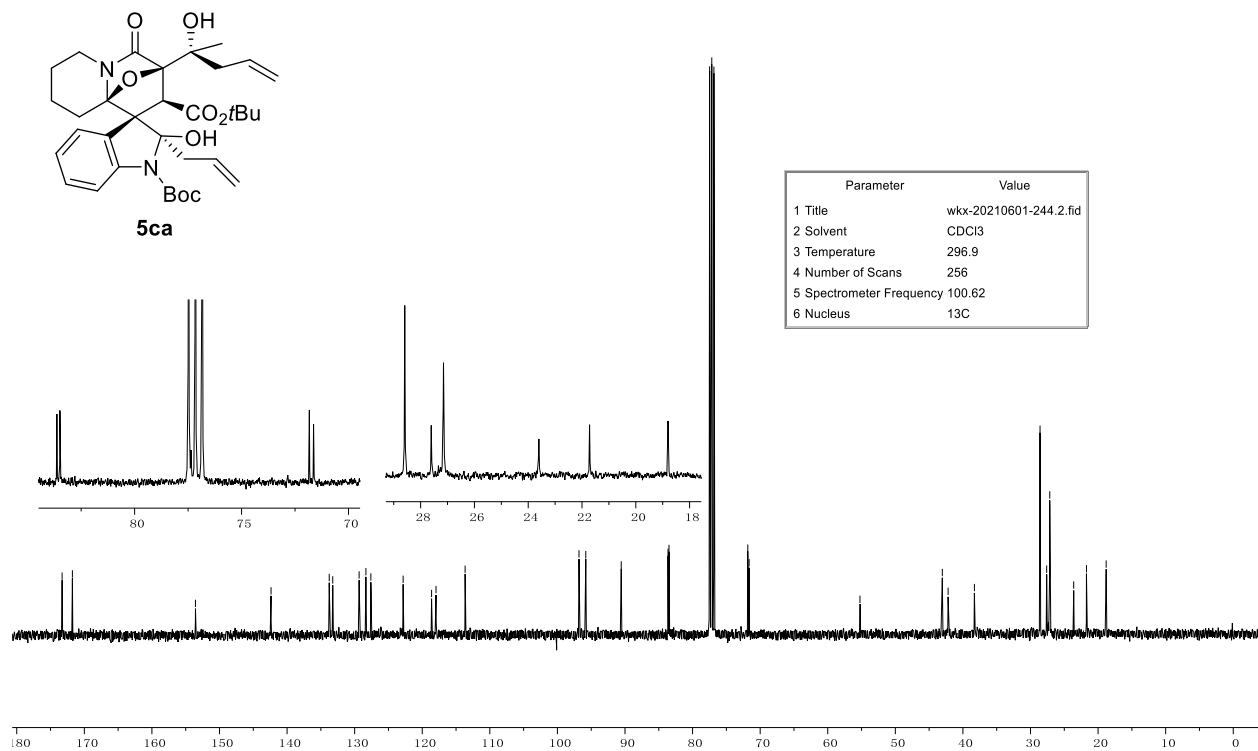
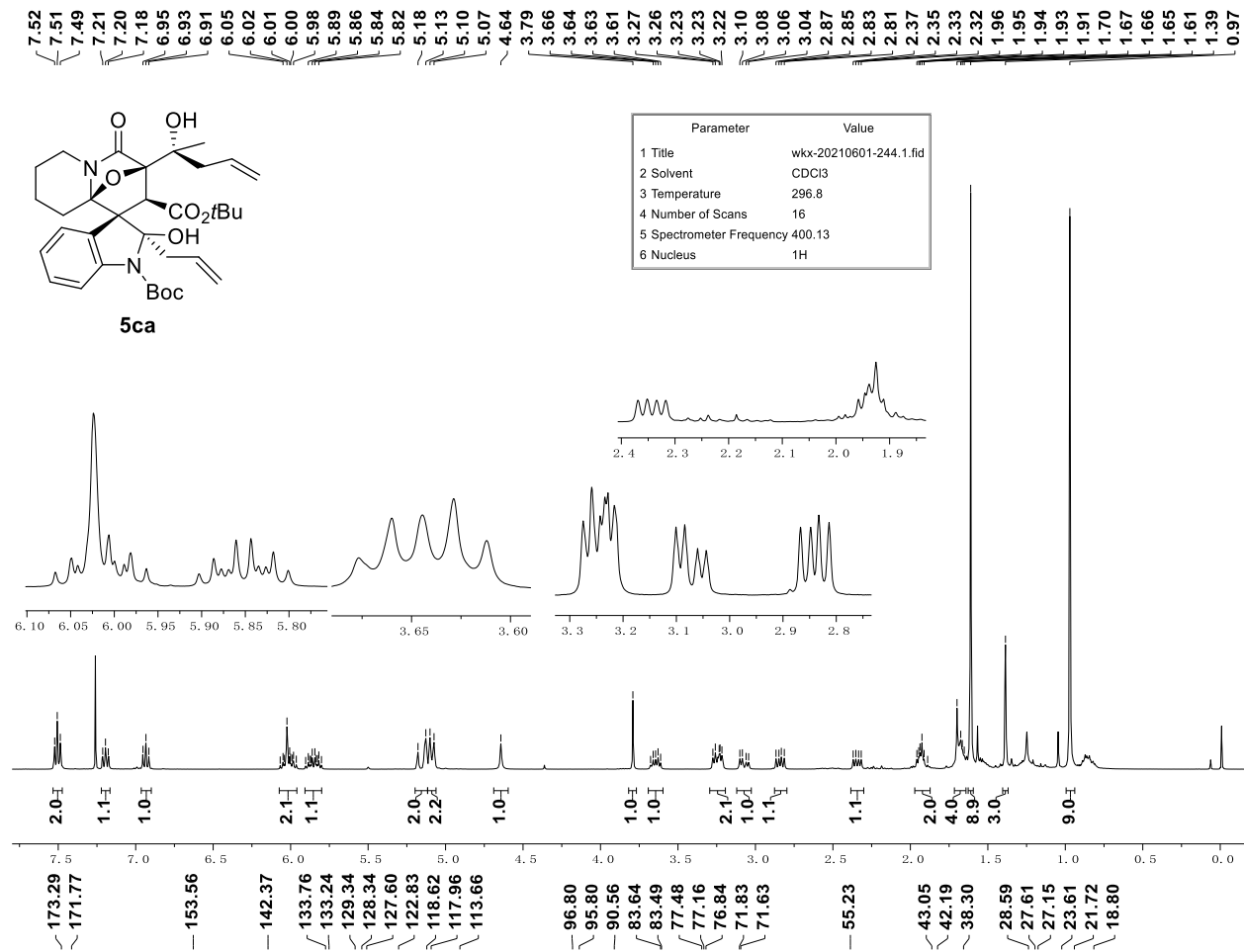


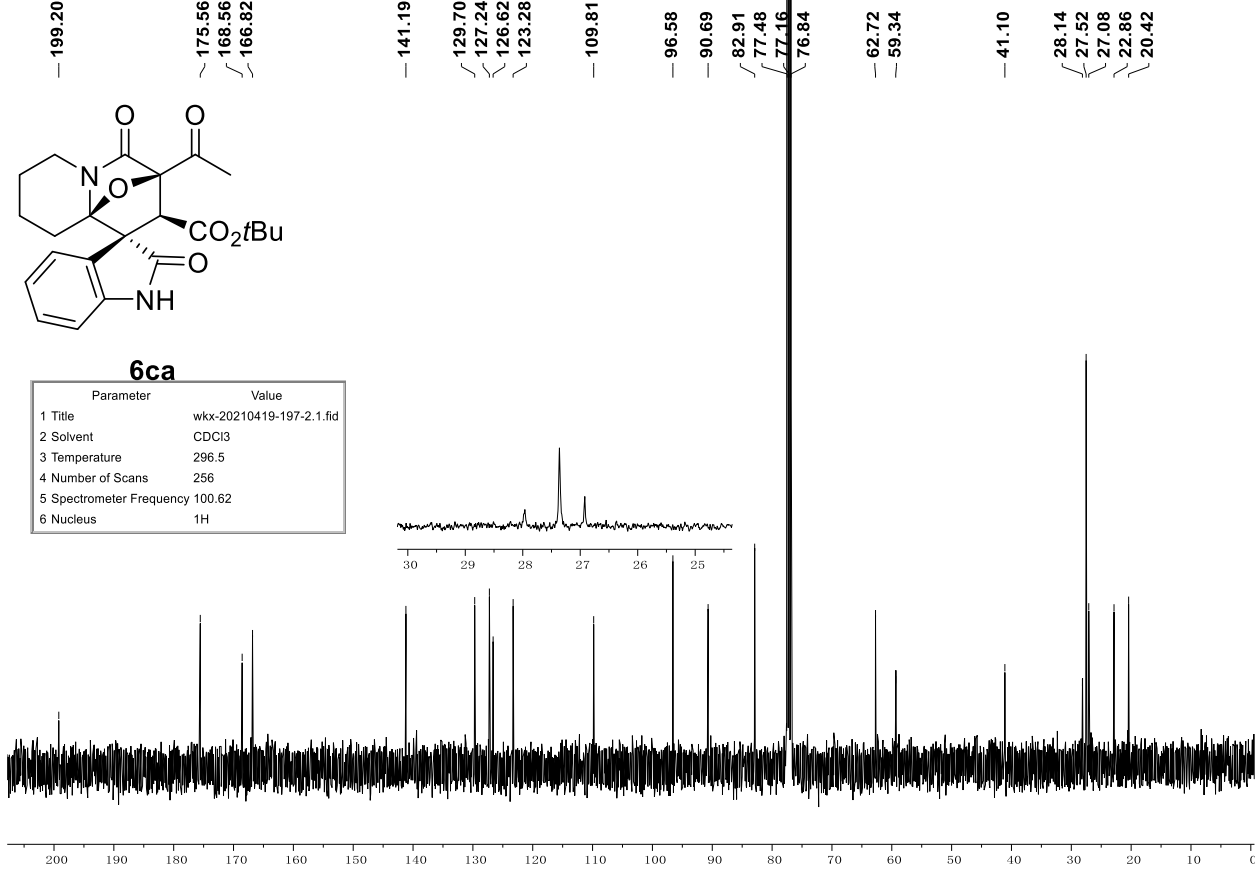
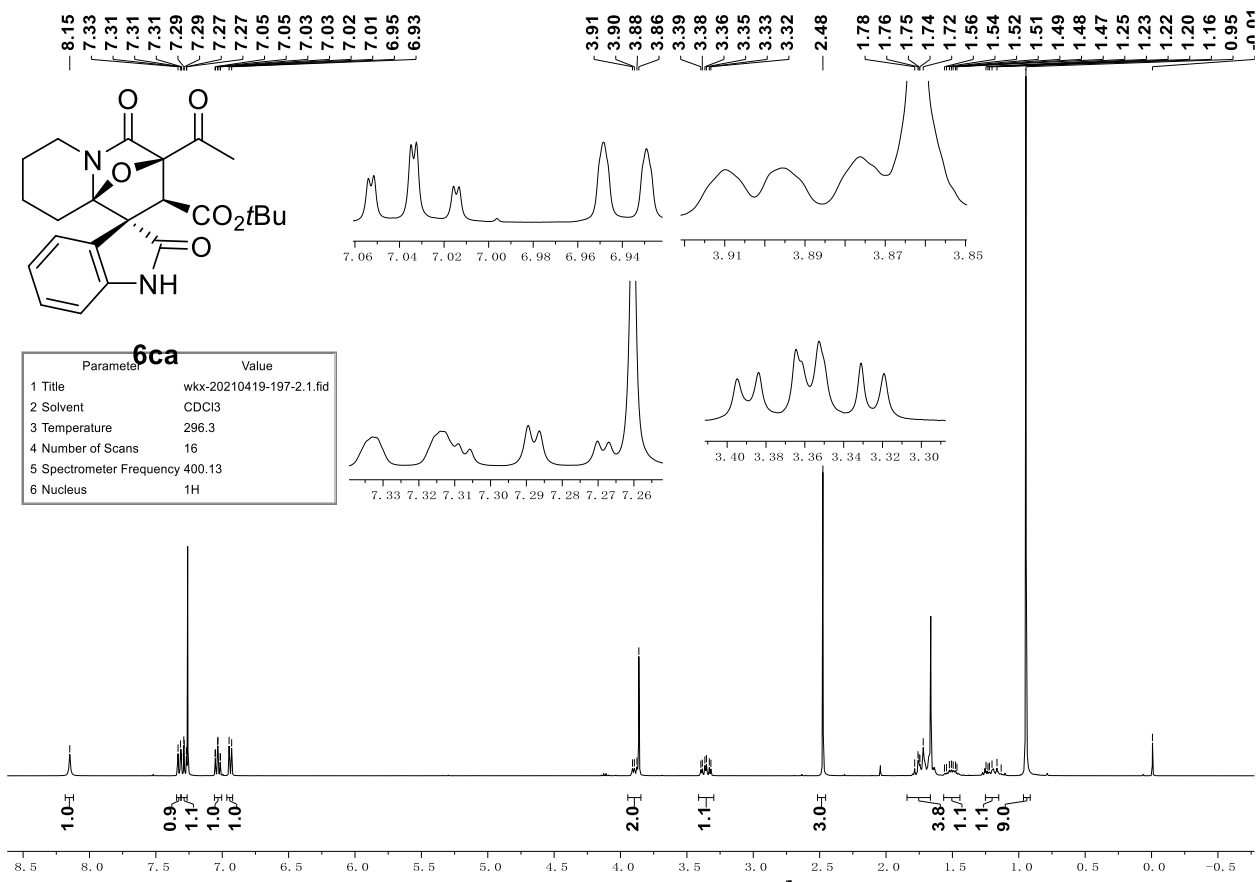


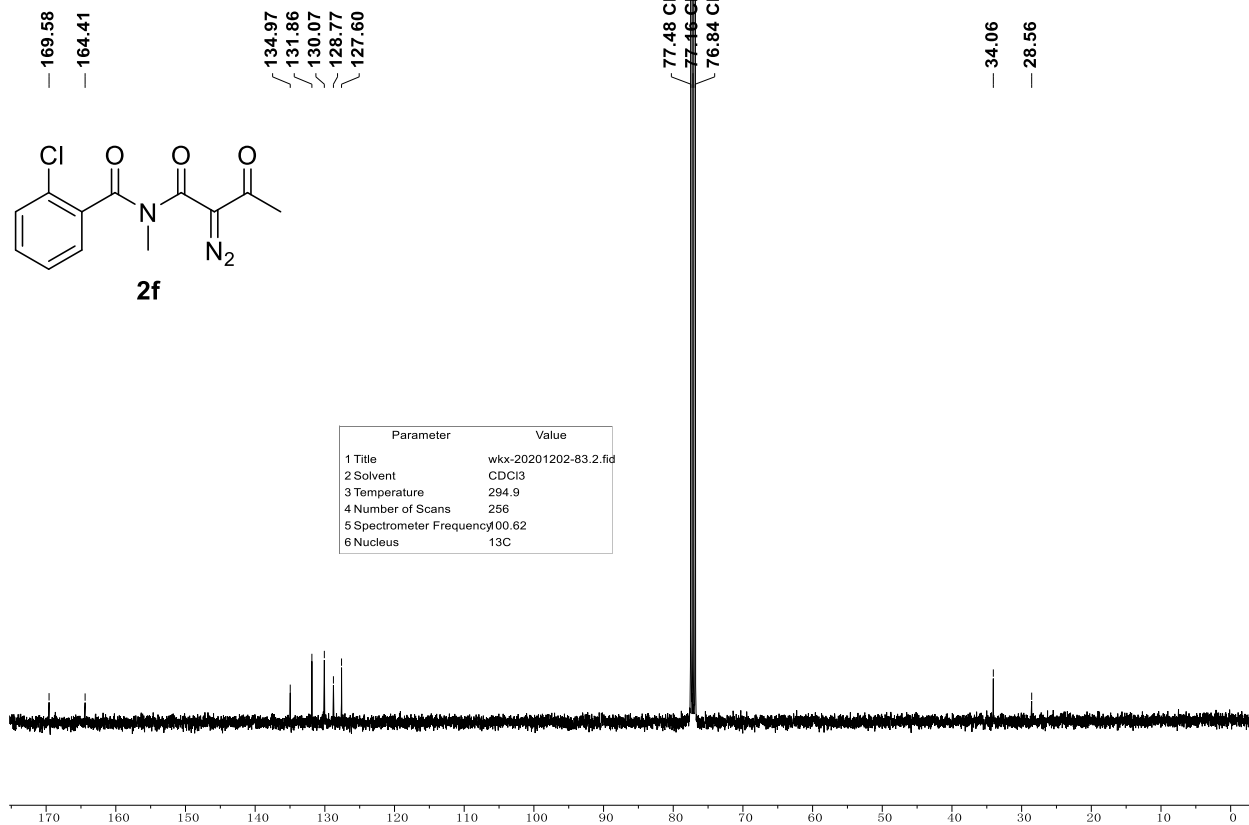
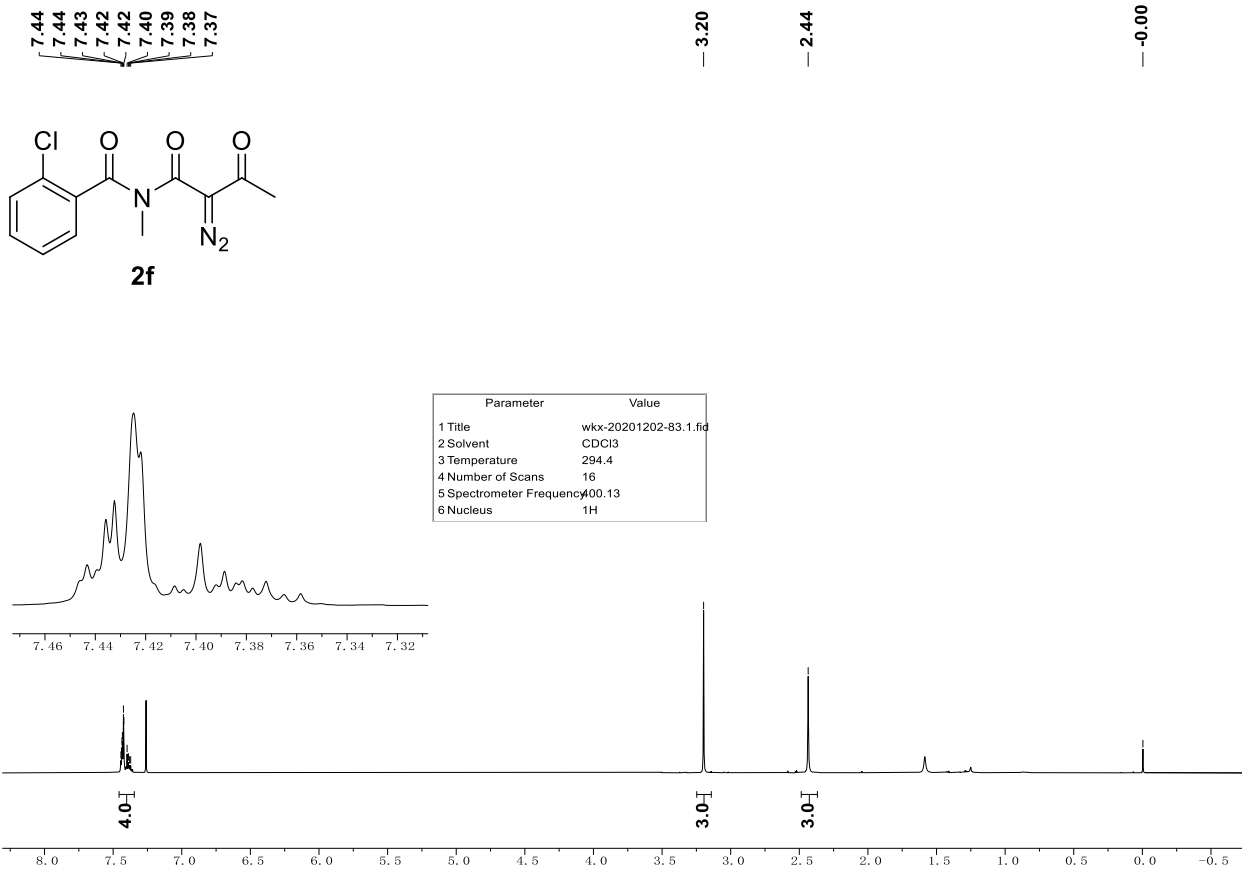




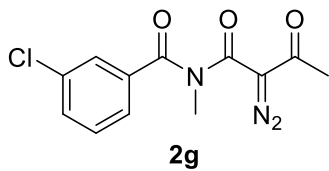








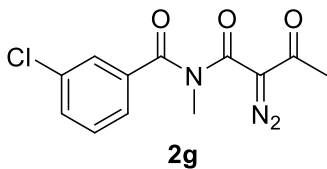
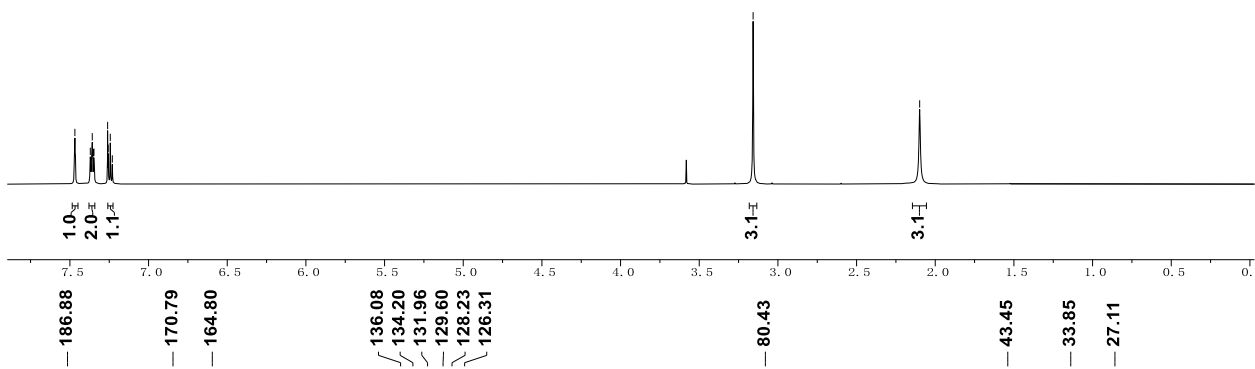
7.47  
7.37  
7.36  
7.35  
7.35  
7.26  
7.26  
7.24  
7.23



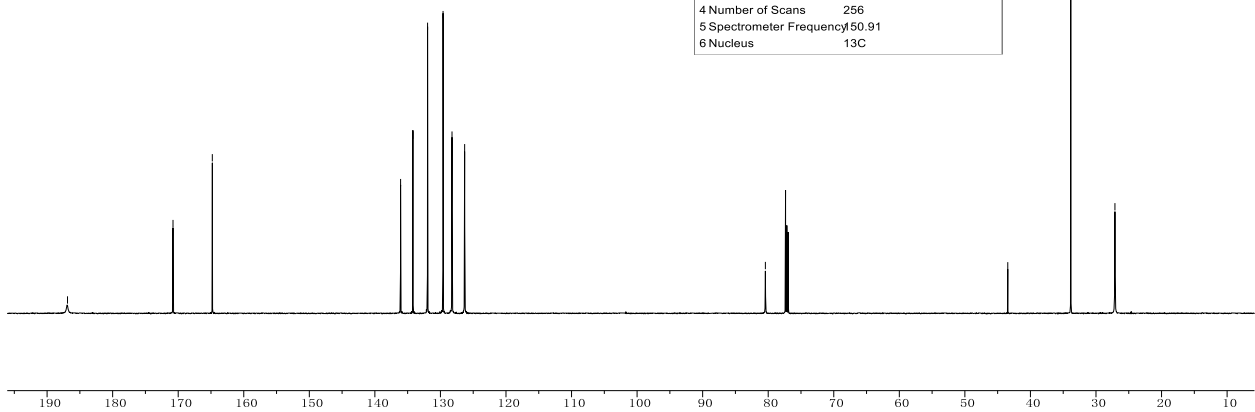
3.16

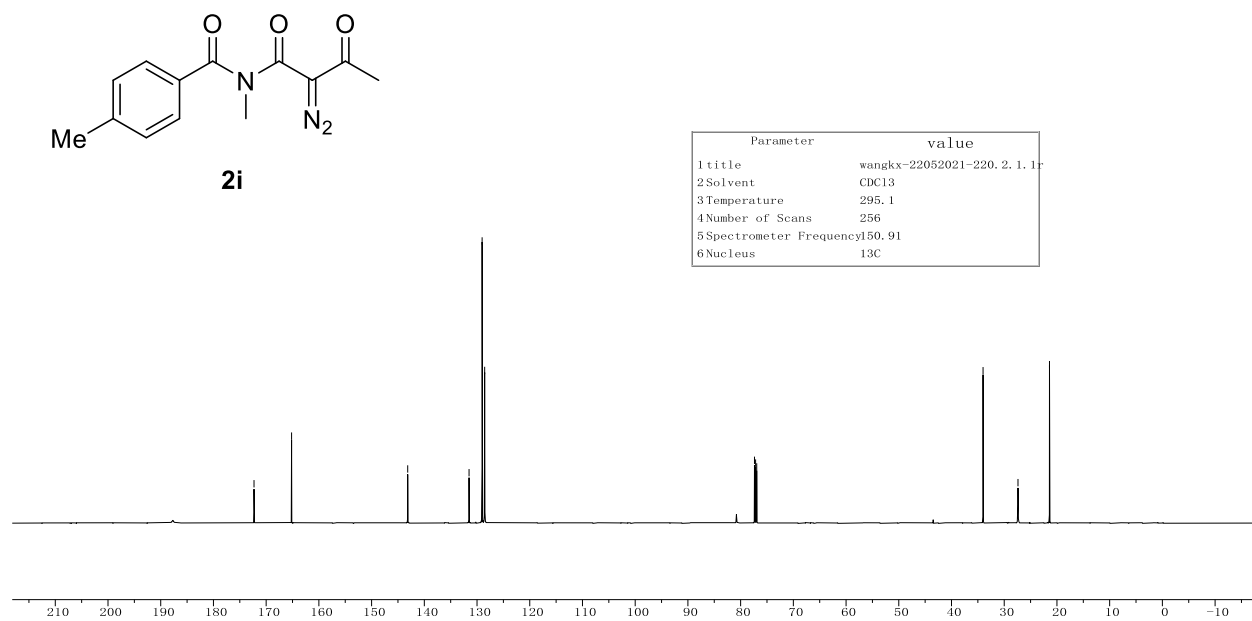
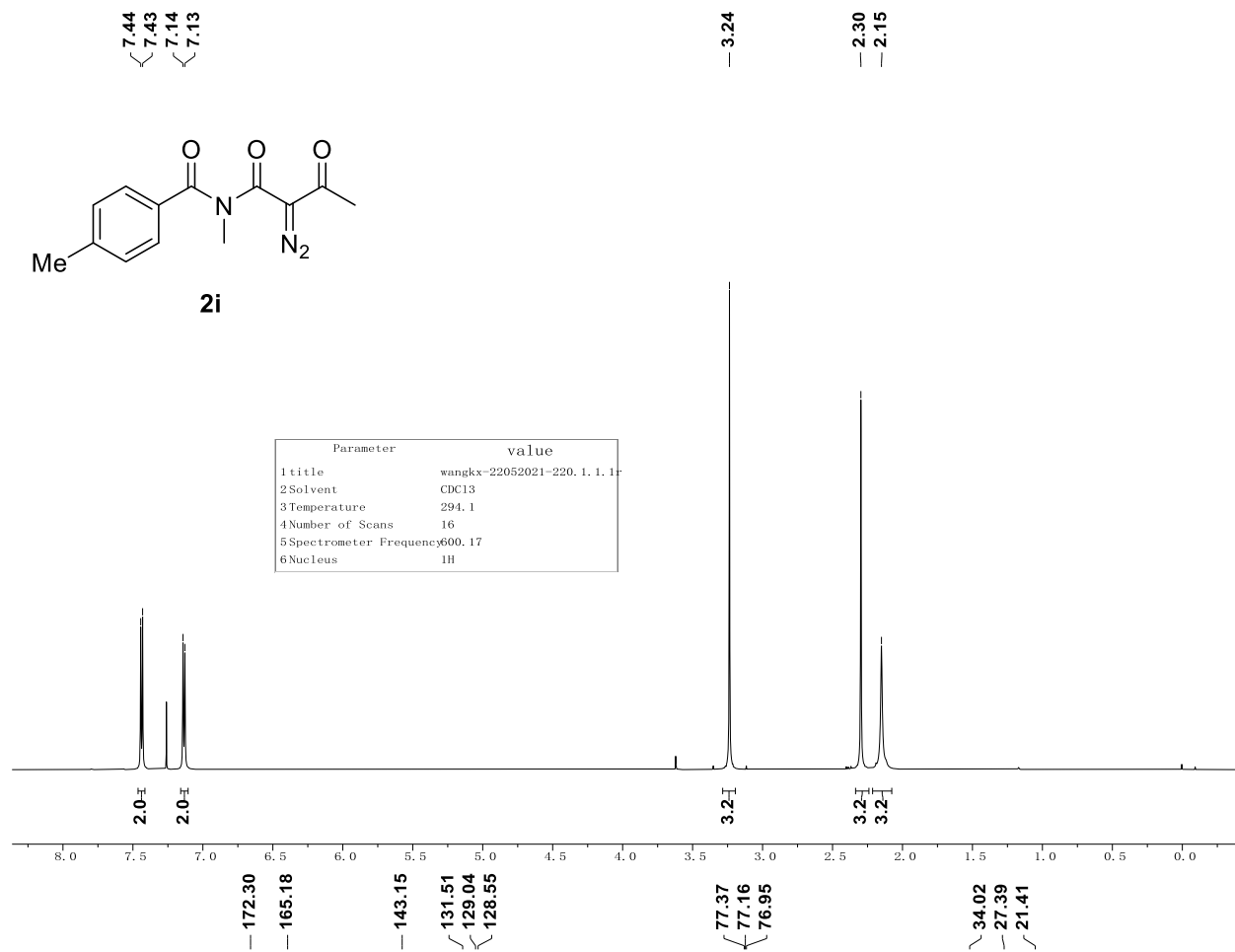
2.10

Parameter	Value
1 Title	wangkx-22052021-219.1.1.1r
2 Solvent	CDCl3
3 Temperature	294.1
4 Number of Scans	16
5 Spectrometer Frequency	600.17
6 Nucleus	1H



Parameter	Value
1 Title	wangkx-22052021-219.2.1.1r
2 Solvent	CDCl3
3 Temperature	295.0
4 Number of Scans	256
5 Spectrometer Frequency	150.91
6 Nucleus	13C

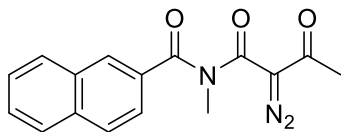




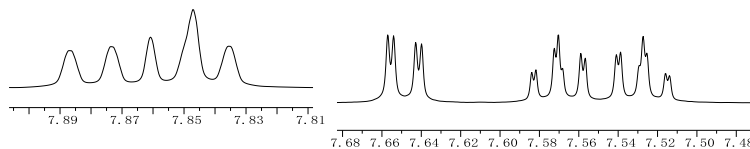
8.15  
7.89  
7.87  
7.86  
7.85  
7.84  
7.66  
7.65  
7.64  
7.64  
7.58  
7.58  
7.57  
7.57  
7.56  
7.56  
7.54  
7.54  
7.53  
7.53  
7.52  
7.51  
7.26

3.38

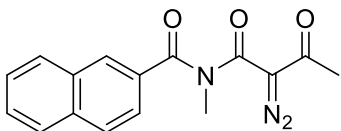
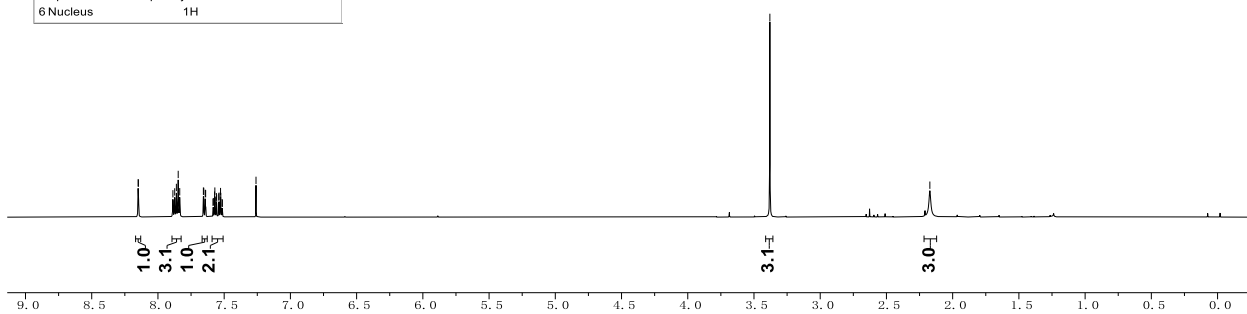
2.17



2k

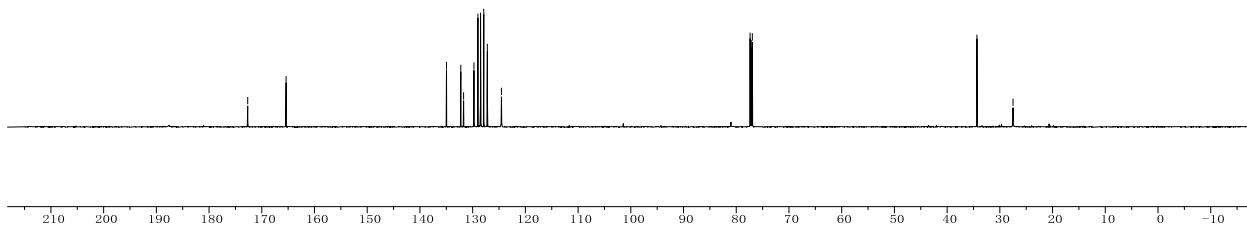
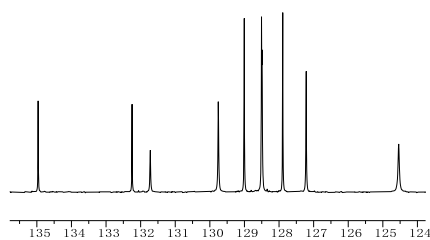


Parameter	Value
1 Title	wangkx-22052021-222.1.1.1r
2 Solvent	CDCl3
3 Temperature	293.9
4 Number of Scans	16
5 Spectrometer Frequency	600.17
6 Nucleus	1H

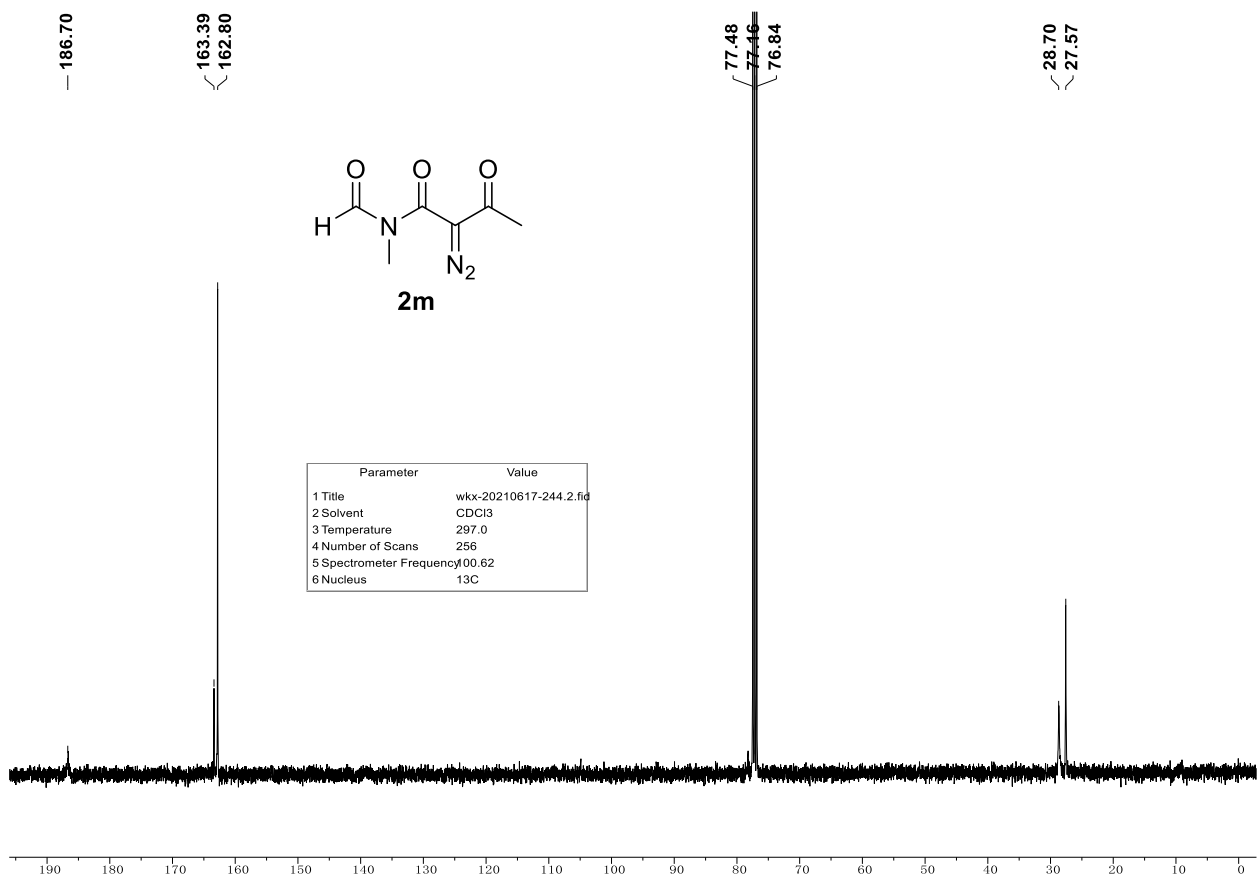
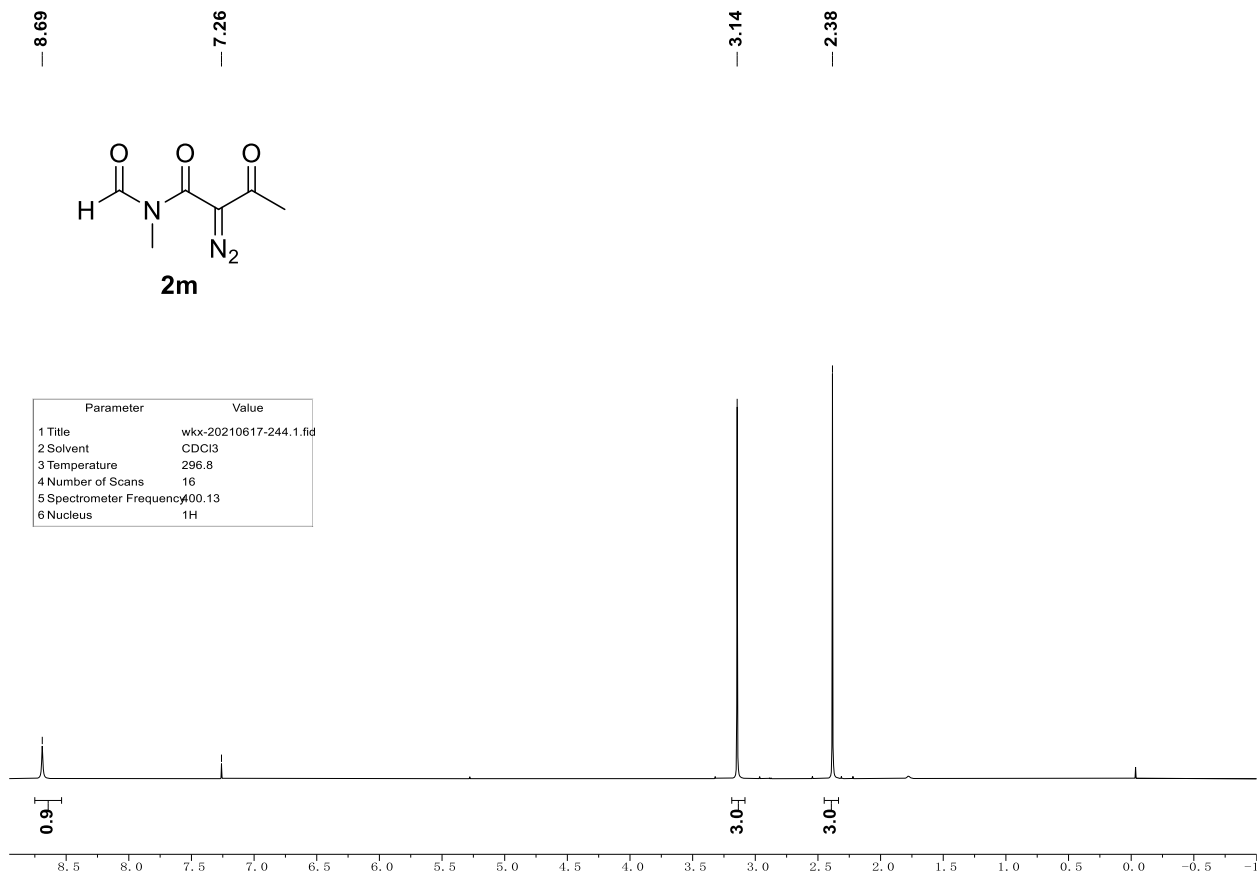


2k

Parameter	Value
1 Title	wangkx-22052021-222.2.1.1r
2 Solvent	CDCl3
3 Temperature	294.7
4 Number of Scans	256
5 Spectrometer Frequency	150.91
6 Nucleus	13C







## 14. Copies of CD Spectra for the Products

