Catalyst-free racemic and H_2O/CPA-catalyzed asymmetric regio-reversed domino processes of triketone enones with azlactones

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Supporting Information

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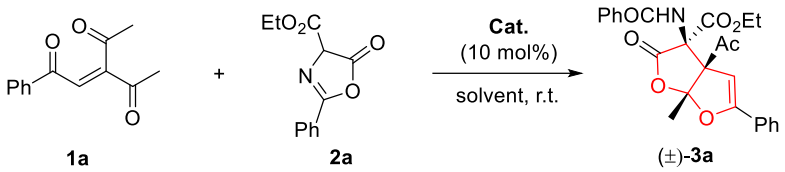
1. General Methods

Unless otherwise specified, all reactions were conducted under an inert atmosphere and anhydrous conditions. All the solvents were purified according to the standard procedures. All chemicals which are commercially available were employed without further purification. Thin-layer chromatography (TLC) was performed on silica gel plates (60F-254) using UV-light (254 nm). Flash chromatography was conducted on silica gel (200–300 mesh). ^{1}H and ^{13}C NMR spectra were recorded at ambient temperature in $CDCl_3$ on a 400 MHz NMR spectrometer. Chemical shifts were reported in parts per million (ppm). The data are reported as follows: for ^{1}H NMR, chemical shift in ppm from tetramethylsilane with the solvent as internal standard ($CDCl_3$ δ 7.26 ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet or overlap of non-equivalent resonances), integration; for ^{13}C NMR, chemical shift in ppm from tetramethylsilane with the solvent as internal indicator ($CDCl_3$ δ 77.1 ppm), multiplicity with respect to protons. All high-resolution mass spectra were obtained on a Q-TOF Micro LC/MS System ESI spectrometer to be given in m/z. Enantiomeric excesses values were determined with HPLC (chiral column; Mobile phase hexane/i-PrOH). Trione alkenes **1** were synthesized according to modified literature-reported procedures[1]; Azlactone **2** were either employed directly from commercial sources or prepared according to the literature[2-3].

2. Representative Procedures

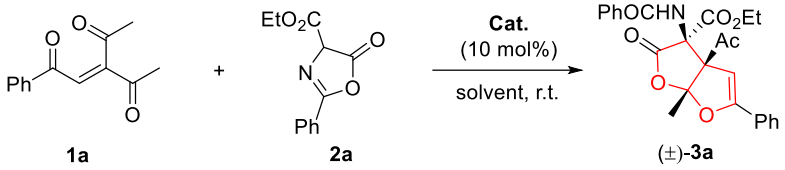
Table S1. Optimization of the reaction conditions[a]



entry	**Cat.**	solvent	yield (%)[b]	dr[c]
1	AcOH	CH_2Cl_2	81	>20:1
2	$PhCO_2H$	CH_2Cl_2	73	>20:1
3	H_3PO_4	CH_2Cl_2	84	>20:1
4	TFA	CH_2Cl_2	78	>20:1
5	TsOH	CH_2Cl_2	64	>20:1
6	-	CH_2Cl_2	89	>20:1
7	-	toluene	82	>20:1
8	-	CH_3CN	78	>20:1
9	-	THF	43	>20:1

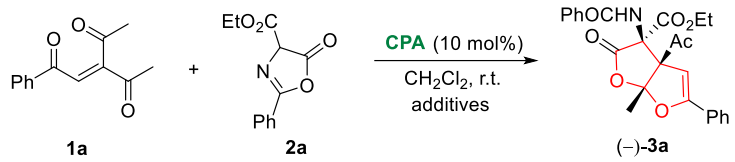
a) Reaction conditions: **1a** (0.05 mmol), **2a** (0.05 mmol.), **Cat.** (10 mol%), solvent (1 mL), and at room temperature (r.t.) for 24 h. b) Isolated yields. c) Determined by ^{1}H NMR.

General Procedures for the synthesis of target products

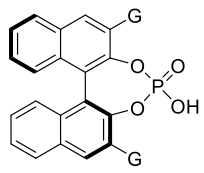


Trione alkenes **1** (0.15 mmol) and azlactone **2** (0.15 mmol) was dissolved in DCM (3 ml), rac-PA (10 mol%) was added. The reaction mixture was stirred for 24 h at room temperature. The solvents were removed in vacuo and the crude product was separated by flash column chromatography on silica gel (petroleum ether/ethyl acetate 5:1–3:1) to afford colorless solid (±)-**3a**.

Table S2. Optimization of the catalytic asymmetric reaction conditions.[a]

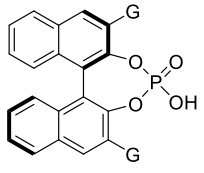


1a 2a (−)-3a



(*S*)-**CPA**

CPA-1, G = 9-anthracenyl
CPA-2, G = 2,4,6-(*i*-Pr)$_3$C$_6$H$_2$
CPA-3, G = 4-ClC$_6$H$_4$
CPA-4, G = SiPh$_3$
CPA-5, G = 2-naphthyl
CPA-6, G = 9-phenanthrenyl
CPA-8, G = 1-Naphthyl
CPA-9, G = 3,5-(CF$_3$)$_2$C$_6$H$_3$
CPA-11, G = 3,5-(CF$_3$)$_2$C$_6$H$_3$

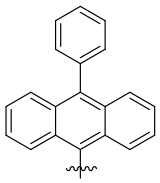


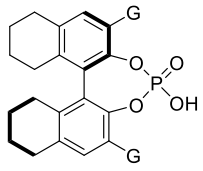
(***R***)-**CPA**

CPA-10, G = 3,5-Ph$_2$-C$_6$H$_3$

CPA-12,

G =





(*R*)-**CPA**

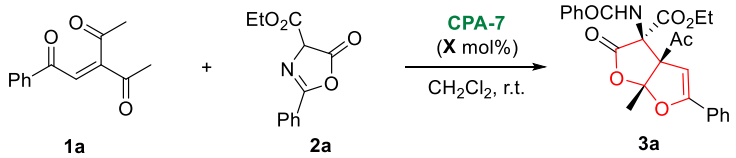
CPA-7, G = 9-anthracenyl
CPA-13, G = 2-Naphthyl
CPA-14, G = 9-phenanthrenyl
CPA-15, G = 9-anthracenyl

Entry	Solvent	Cat.	T(h)	t(°C)	Y(%)[b]	ee%[c]	dr[c]
1	DCM	**CPA-2**	24	r.t	75	-24	>20:1
2	DCM	**CPA-3**	24	r.t	82	-30	>20:1
3	DCM	**CPA-1**	24	r.t	82	-40	>20:1
4	DCM	**CPA-8**	24	r.t	75	-54	>20:1
5	DCM	**CPA-4**	24	r.t	82	0	>20:1
6	THF	**CPA-8**	24	r.t	45	-24	>20:1
7	MeCN	**CPA-8**	24	r.t	82	-20	>20:1
8	Toluene	**CPA-8**	24	r.t	80	-22	>20:1
9	DCE	**CPA-8**	24	r.t	65	-44	>20:1
10	$CHCl_3$	**CPA-8**	24	r.t	Trace	-	>20:1
11	CCl_4	**CPA-8**	24	r.t	45	-14	>20:1
12	DCM	**CPA-9**	24	r.t	63	-64	>20:1
13	DCM	**CPA-10**	24	r.t	75	34	>20:1
14	DCM	**CPA-5**	24	r.t	80	-44	>20:1
15	DCM	**CPA-11**	24	r.t	75	16	>20:1
16	DCM	**CPA-6**	24	r.t	75	-64	>20:1

17	DCM	**CPA-12**	24	r.t	78	-72	>20:1
18	DCM	**CPA-13**	24	r.t	80	40	>20:1
19	DCM	**CPA-14**	24	r.t	76	72	>20:1
20	DCM	**CPA-15**	24	r.t	82	50	>20:1
21	DCM	**CPA-7**	24	r.t	81	74	>20:1

a) Reaction conditions: **1a** (0.05 mmol), **2a** (0.05 mmol.), **Cat.** (10 mol%), solvent and at room temperature (r.t.) for 24 h. b) Isolated yields. c) Determined by chiral HPLC analysis.

Table S3. Catalyst-loading screening.[a]

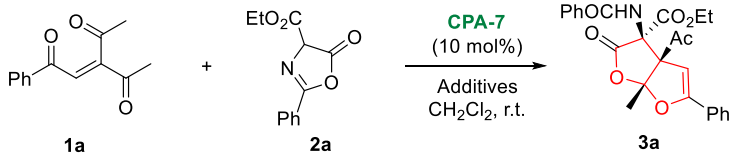


1a 2a 3a

Entry	Solvent	X	Concentration	Y(%)[b]	ee%[c]	dr[c]
1	DCM	15	0.0017M	71	90	>20:1
2	DCM	10	0.0017M	70	90	>20:1
3	DCM	8	0.0017M	68	81	>20:1
4	DCM	6	0.0017M	68	52	>20:1
5	DCM	4	0.0017M	66	43	>20:1

a) Reaction conditions: **1a** (0.15 mmol), **2a** (0.15 mmol), **CPA-7** (X mol%), solvent and at room temperature (r.t.) for 24 h. b) Isolated yields. c) Determined by chiral HPLC analysis.

Table S4. Additive screening.[a]



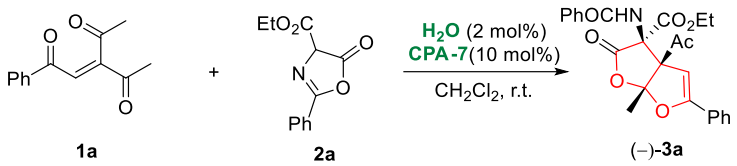
1a 2a 3a

Entry	Additive	Concentration	Y(%)[b]	ee%[c]	dr[c]
1	-	0.005M	81	74	>20:1
2	H_2O (0.5 mol%)	0.005M	80	80	>20:1
3	H_2O (1 mol%)	0.005M	73	86	>20:1
4	H_2O (2 mol%)	0.005M	72	86	>20:1
5	H_2O (4 mol%)	0.005M	70	86	>20:1
6	H_2O (2 mol%)	0.0025M	75	86	>20:1

7	H_2O (2 mol%)	0.0017M	70	90	>20:1
8	H_2O (2 mol%)	0.0013M	65	90	>20:1
9	H_2O (2 mol%)	0.0008M	52	88	>20:1
10	H_2O (2 mol%)	0.0006M	45	84	>20:1

a) Reaction conditions: **1a** (0.05 mmol), **2a** (0.05 mmol.), **CPA-7** (10 mol%), CH_2Cl_2 (10 mL) at room temperature (r.t.) for 24 h. b) Isolated yields. c) Determined by chirl HPLC analysis.

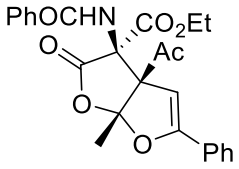
General Procedure for the catalytic asymmetric synthesis of target products



Trione alkenes **1a** (0.15 mmol)、 H_2O (2 mol%) and **CPA-7** (10 mol%) was dissolved in DCM (88 ml), azlactone **2a** (0.15 mmol) was added in 5 minutes. The reaction mixture was stirred for 24 h at room temperature. The solvents were removed in vacuo and the crude product was separated by flash column chromatography on silica gel (petroleum ether/ethyl acetate 5:1–3:1) to afford colorless solid (-)-**3a**. Then recrystallization of the target products were conducted in EA/PE.

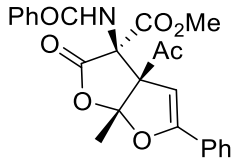
3. Characterization of Products

Ethyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro [2,3-b] furan-3-carboxylate **(±)-3a**:



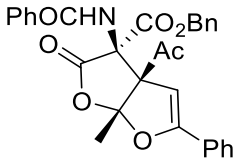
Colorless solid; 89% isolated yield = 60.02 mg; m.p. 120.9-121.8℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.73 (m, 2H), 7.68 – 7.60 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.43 – 7.32 (m, 4H), 5.55 (s, 1H), 4.31 – 4.11 (m, 2H), 2.38 (s, 3H), 2.07 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.5, 166.9, 166.8, 166.5, 158.0, 132.4, 132.4, 130.4, 128.8, 128.7, 128.1, 127.2, 125.7, 116.7, 95.7, 72.8, 69.6, 63.6, 29.6, 22.1, 13.75; HRMS(ESI) m/z Calcd for $C_{25}H_{23}NO_7$ $[M+Na]^+$ = 472.1367 , found: 472.1373.

Methyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro [2,3-b]furan-3-carboxylate (±)-**3b**:



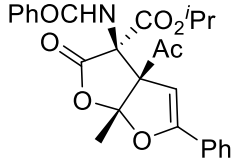
Colorless solid; 90% isolated yield = 58.8 mg; m.p. 122.2-123.1 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.76 (m, 2H), 7.66 – 7.59 (m, 2H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.44 – 7.35 (m, 4H), 5.58 (s, 1H), 3.72 (s, 3H), 2.39 (s, 3H), 2.03 (s, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.1, 167.2, 166.9, 166.6, 158.3, 132.5, 132.4, 130.5, 128.8, 128.7, 128.1, 127.2, 125.7, 116.4, 95.6, 72.5, 69.8, 53.7, 29.7, 22.1; HRMS(ESI) m/z Calcd for $C_{24}H_{21}NO_7$ $[M+Na]^+$ = 458.1210 , found: 458.1217.

Benzyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro [2,3-b]furan-3-carboxylate (±)-**3c**:



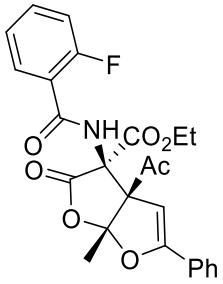
Colorless solid; 82% isolated yield = 62.9 mg; m.p. 128.1-129.2°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.76 (m, 2H), 7.58 – 7.51 (m, 2H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.43 – 7.38 (m, 3H), 7.37 – 7.31 (m, 2H), 7.31 – 7.26 (m, 1H), 7.25 – 7.17 (m, 4H), 5.30 (s, 1H), 5.18 (s, 2H), 2.31 (s, 3H), 2.04 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 201.5, 166.7, 166.4, 166.3, 158.1, 133.8, 132.5, 132.4, 130.3, 128.8, 128.7, 128.6, 128.5, 127.9, 127.2, 125.8, 116.3, 95.5, 72.5, 69.3, 69.0, 29.8, 22.0; HRMS(ESI) m/z Calcd for $C_{30}H_{25}NO_7$ $[M+Na]^+$ = 534.1523, found: 534.1525.

Isopropyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro [2,3-b]furan-3-carboxylate (±)-**3d**:



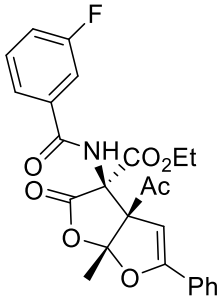
Colorless solid; 81% isolated yield = 56.3 mg; m.p. 111.1-112.1°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.75 (m, 2H), 7.67 – 7.60 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.43 – 7.34 (m, 4H), 5.49 (s, 1H), 5.14 – 4.98 (m, 1H), 2.37 (s, 3H), 2.11 (s, 3H), 1.22 (d, *J* = 6.2 Hz, 3H), 1.04 (d, *J* = 6.3 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.0, 166.8, 166.5, 166.4, 157.7, 132.4, 132.4, 130.3, 128.8, 128.6, 128.1, 127.2, 125.7, 116.8, 95.7, 72.9, 72.4, 69.3, 29.5, 22.1, 21.3, 21.3; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_7$ $[M+Na]^+$ = 486.1523, found: 486.1528.

Ethyl 3a-acetyl-3-(2-fluorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3e**::



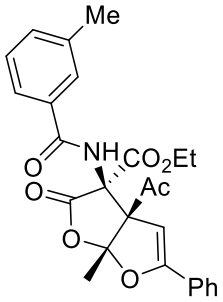
Colorless solid; 88% isolated yield =60.70 mg; m.p. 101.5-102.3℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.00 (m, 2H), 7.66 – 7.57 (m, 2H), 7.56 – 7.49 (m, 1H), 7.45 – 7.38 (m, 3H), 7.31 – 7.26 (m, 1H), 7.21 – 7.12 (m, 1H), 5.46 (s, 1H), 4.29 – 4.19 (m, 2H), 2.36 (s, 3H), 2.14 (s, 3H), 1.13 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.7, 166.8, 166.4,162.3 (d, *J* = 3.2 Hz), 160.9 (d, *J* = 248.6 Hz)， 157.8, 134.4 (d, *J* = 9.6 Hz), 132.3, 130.4, 128.6, 128.1, 125.7, 125.0 (d, *J* = 3.2 Hz), 119.1 (d, *J* = 11.0 Hz) 117.0, 116.1 (d, *J* = 24.5 Hz), 112.0, 95.3, 73.1, 69.5, 63.7, 29.3, 22.0, 13.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -111.16; HRMS(ESI) m/z Calcd for $C_{25}H_{22}FNO_7$ = $[M+Na]^+$ 490.1272 , found: 490.1282.

Ethyl 3a-acetyl-3-(3-fluorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3f**:



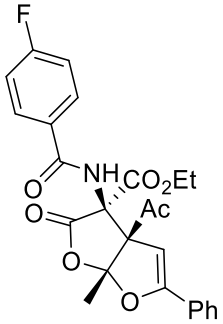
Colorless solid; 87% isolated yield = 61.00 mg; m.p. 150.3-151.2.℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.60 (m, 2H), 7.58 – 7.48 (m, 2H), 7.48 – 7.39 (m, 4H), 7.35 (s, 1H), 7.26 – 7.22 (m, 1H), 5.56 (s, 1H), 4.26 – 4.11 (m, 2H), 2.38 (s, 3H), 2.04 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.9, 166.8, 166.5, 165.3 (d, *J* = 2.5 Hz), 162.7 (d, *J* = 248.5 Hz), 158.2, 134.7 (d, *J* = 7.0 Hz), 130.6, 130.5, 128.7, 128.0, 125.7, 122.6 (d, *J* = 3.1 Hz), 119.5 (d, *J* = 21.3 Hz), 116.5, 114.7 (d, *J* = 23.2 Hz), 95.6, 72.6, 69.7, 63.7, 29.6, 22.1, 13.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -108.9; HRMS(ESI) m/z Calcd for $C_{25}H_{22}FNO_7$ $[M+Na]^+$ = 490.1272, found: 490.1275.

Ethyl 3a-acetyl-6a-methyl-3-(3-methylbenzamido)-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3g**:



Colorless solid; 87% isolated yield = 60.48 mg; m.p. 122.9-123.5℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 – 7.59 (m, 3H), 7.56 (d, *J* = 6.4 Hz, 1H), 7.44 – 7.39 (m, 3H), 7.38 – 7.29 (m, 3H), 5.55 (s, 1H), 4.27 – 4.10 (m, 2H), 2.40 (s, 3H), 2.38 (s, 3H), 2.07 (s, 3H), 1.10 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3, 167.0, 166.8, 166.7, 157.9, 138.7, 133.2, 132.4, 130.4, 128.7, 128.6, 128.1, 127.9, 125.7, 124.1, 116.7, 95.7, 72.8, 69.7, 63.6, 29.5, 22.1, 21.3, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_7$ $[M+Na]^+$ = 486.1523, found: 486.1530.

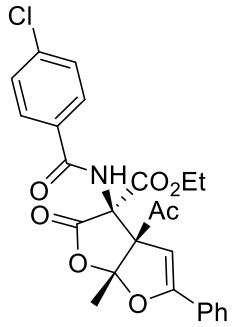
Ethyl 3a-acetyl-3-(4-fluorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3h**:



Colorless solid; 87% isolated yield = 61.00 mg; m.p. 111.1-112.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 – 7.74 (m, 2H), 7.63 (d, *J* = 4.2 Hz, 2H), 7.42 (s, 3H), 7.32 (s, 1H), 7.14 (t, *J* = 8.4 Hz, 2H), 5.55 (s, 1H), 4.28 – 4.10 (m, 2H), 2.37 (s, 3H), 2.05 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.8, 166.9, 166.7, 165.5, 165.3 (d, *J* = 253.6 Hz)， 158.1, 130.5, 129.7 (d, *J* = 9.2 Hz), 128.7, 128.0, 125.7, 116.6, 115.9 (d, *J* = 22.1 Hz), 95.6, 72.6, 69.7, 63.7, 29.6, 22.1, 13.7; ^{19}F NMR (376 MHz,

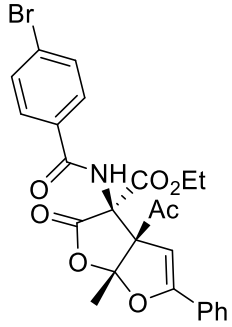
$CDCl_3$) δ -112.4; HRMS(ESI) m/z Calcd for $C_{25}H_{22}FNO_7$ $[M+Na]^+$ = 490.1272, found: 490.1278.

Ethyl 3a-acetyl-3-(4-chlorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3i**:



Colorless solid; 91% isolated yield = 66.04 mg; m.p. 134.5-135.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, *J* = 8.5 Hz, 2H), 7.66 – 7.59 (m, 2H), 7.48 – 7.39 (m, 5H), 7.33 (s, 1H), 5.55 (s, 1H), 4.27 – 4.10 (m, 2H), 2.37 (s, 3H), 2.04 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.8, 166.8, 166.6, 165.5, 158.1, 138.8, 130.8, 130.5, 129.1, 128.7, 128.6, 128.0, 125.7, 116.5, 95.6, 72.6, 69.7, 63.7, 29.6, 22.1, 13.7; HRMS(ESI) m/z Calcd for $C_{25}H_{22}ClNO_7$ $[M+Na]^+$ = 506.0977, found: 506.0980.

Ethyl 3a-acetyl-3-(4-bromobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3j**:

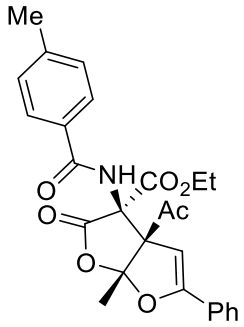


Colorless solid; 92% isolated yield = 72.92. mg; m.p. 126.3-127.1 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.58 (m, 6H), 7.44 – 7.38 (m, 3H), 7.34 (s, 1H), 5.55 (s, 1H), 4.26 – 4.11 (m, 2H), 2.37 (s, 3H), 2.04 (s, 3H), 1.11 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.8, 166.8, 166.6, 165.7, 158.1, 132.0, 131.3, 130.5, 128.8, 128.7, 128.0, 127.3, 125.7, 116.5, 95.6, 72.6, 69.7, 63.7, 29.6, 22.1, 13.7; HRMS(ESI) m/z

Calcd for $C_{25}H_{22}BrNO_7$ $[M+Na]^+$ = 550.0472, found: 550.0479.

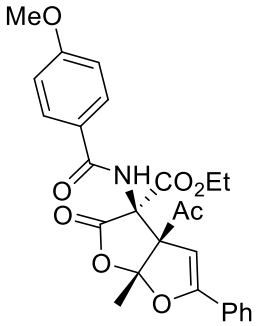
Ethyl 3a-acetyl-6a-methyl-3-(4-methylbenzamido)-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate(±)-**3k**:

:



Colorless solid; 89% isolated yield = 61.87 mg; m.p. 165.5-166.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.2 Hz, 2H), 7.65 – 7.59 (m, 2H), 7.44 – 7.37 (m, 3H), 7.25 (d, *J* = 7.5 Hz, 2H), 5.53 (s, 1H), 4.25 – 4.12 (m, 2H), 2.41 (s, 3H), 2.36 (s, 3H), 2.08 (s, 3H), 1.11 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3, 167.0, 166.9, 166.4, 157.9, 143.1, 130.4, 129.5, 129.4, 128.7, 128.1, 127.2, 125.7, 116.7, 95.7, 72.8, 69.5, 63.6, 29.5, 22.1, 21.5, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_7$ $[M+Na]^+$ = 486.1523, found: 486.1526.

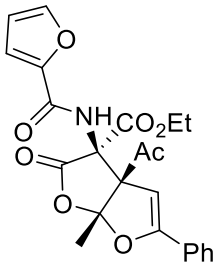
Ethyl 3a-acetyl-3-(3-methoxybenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3l**:



Colorless solid; 87% isolated yield = 62.57 mg; m.p. 158.5-159.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, *J* = 8.7 Hz, 2H), 7.69 – 7.58 (m, 2H), 7.49 – 7.36 (m, 3H), 7.28 (s, 1H), 6.94 (d, *J* = 8.7 Hz, 2H), 5.52 (s, 1H), 4.32 – 4.14 (m, 2H), 3.86 (s, 3H), 2.36 (s, 3H), 2.09 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3,

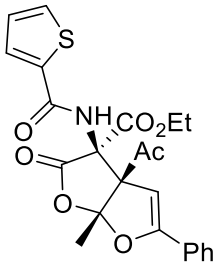
167.0, 165.9, 163.0, 157.9, 130.4, 129.2, 128.7, 128.1, 125.7, 124.6, 116.7, 113.9, 95.7, 72.8, 69.5, 63.6, 55.5, 29.5, 22.1, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_8$ $[M+Na]^+$ = 502.1472, found: 502.1479.

Ethyl 3a-acetyl-3-(furan-2-carboxamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3m**:



Colorless solid; 76% isolated yield = 50.09 mg; m.p. 114.4-115.3℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.58 (m, 2H), 7.49 (d, *J* = 11.2 Hz, 2H), 7.44 – 7.35 (m, 3H), 7.17 (d, *J* = 3.5 Hz, 1H), 6.56 – 6.50 (m, 1H), 5.54 (s, 1H), 4.26 – 4.11 (m, 2H), 2.37 (s, 3H), 2.05 (s, 3H), 1.10 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.2, 166.6, 158.0, 157.2, 146.3, 144.9, 130.4, 128.7, 128.1, 125.6, 116.8, 116.2, 112.5, 95.5, 72.9, 69.2, 63.7, 29.5, 22.1, 13.7; HRMS(ESI) m/z Calcd for $C_{23}H_{21}NO_8$ $[M+Na]^+$ = 462.1159, found: 462.1161.

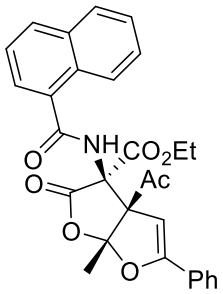
Ethyl 3a-acetyl-6a-methyl-2-oxo-5-phenyl-3-(thiophene-2-carboxamido)-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3n**:



Colorless solid; 78% isolated yield = 53.28 mg; m.p. 107.4-108.2 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.60 (m, 2H), 7.59 (dd, *J* = 3.7, 0.8 Hz, 1H), 7.55 (dd, *J* = 5.0, 0.8 Hz, 1H), 7.44 – 7.37 (m, 3H), 7.19 (s, 1H), 7.14 – 7.08 (m, 1H), 5.55 (s, 1H), 4.27 – 4.09 (m, 2H), 2.38 (s, 3H), 2.04 (s, 3H), 1.10 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz,

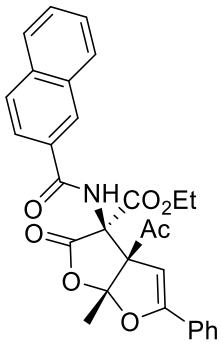
$CDCl_3$) δ 200.6, 166.9, 166.6, 161.0, 158.0, 136.6, 131.5, 130.4, 129.6, 128.7, 128.1, 127.9, 125.7, 116.6, 95.7, 72.7, 69.6, 63.7, 29.5, 22.1, 13.7; HRMS(ESI) m/z Calcd for $C_{23}H_{21}NO_7S$ = $[M+Na]^+$ 478.0931, found: 478.0931.

Ethyl 3-(1-naphthamido)-3a-acetyl-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3o**:



Colorless solid; 91% isolated yield = 68.18 mg; m.p. 110.5-111.2℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31 (d, *J* = 8.4 Hz, 1H), 7.95 (d, *J* = 8.2 Hz, 1H), 7.87 (d, *J* = 8.0 Hz, 1H), 7.72 – 7.63 (m, 3H), 7.61 – 7.46 (m, 3H), 7.45 – 7.37 (m, 3H), 7.15 (s, 1H), 5.68 (s, 1H), 4.27 – 4.06 (m, 2H), 2.45 (s, 3H), 2.07 (s, 3H), 1.10 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.5, 169.0, 167.4, 166.5, 158.1, 133.6, 132.1, 131.4, 130.4, 130.1, 128.7, 128.2, 128.1, 127.6, 126.7, 125.7, 125.2, 124.6, 116.8, 95.8, 72.8, 70.2, 63.7, 29.7, 22.3, 13.7; HRMS(ESI) m/z Calcd for $C_{29}H_{25}NO_7$ $[M+Na]^+$ = 522.1523, found: 522.1527.

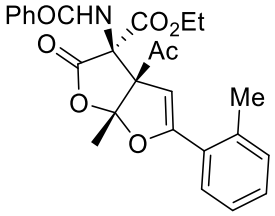
Ethyl 3a-acetyl-3-benzamido-6a-methyl-5-(naphthalen-2-yl)-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate(±)-**3p**:



Colorless solid; 80% isolated yield = 59.94 mg; m.p. 117.3-118.1℃; ^{1}H NMR (400

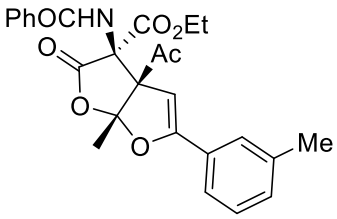
MHz, $CDCl_3$) δ 8.16 (s, 1H), 7.94 – 7.87 (m, 1H), 7.88 – 7.82 (m, 2H), 7.80 (d, *J* = 7.3 Hz, 2H), 7.63 (dd, *J* = 8.6, 1.4 Hz, 1H), 7.59 – 7.52 (m, 3H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.37 (s, 1H), 5.68 (s, 1H), 4.25 – 4.10 (m, 2H), 2.42 (s, 3H), 2.12 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3, 167.0, 166.8, 166.6, 158.0, 134.0, 132.9, 132.5, 132.4, 128.8, 128.7, 128.5, 127.8, 127.4, 127.2, 126.9, 125.7, 125.2, 122.5, 116.8, 96.4, 72.9, 69.7, 63.7, 29.6, 22.2, 13.7; HRMS(ESI) m/z Calcd for $C_{29}H_{25}NO_7$ $[M+Na]^+$ = 522.1523, found: 522.1526.

Ethyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-(o-tolyl)-2,3,3a,6a-tetrahydrofuro [2,3-b]furan-3-carboxylate (±)-**3q**:



Colorless solid; 83% isolated yield = 57.69 mg; m.p. 134.3-135.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.78 (m, 2H), 7.59 – 7.51 (m, 2H), 7.46 (t, *J* = 7.5 Hz, 3H), 7.35 – 7.29 (m, 1H), 7.26 – 7.21 (m, 2H), 5.28 (s, 1H), 4.37 – 4.16 (m, 2H), 2.47 (s, 3H), 2.39 (s, 3H), 2.09 (s, 3H), 1.17 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.8, 167.0, 166.5, 166.3, 158.6, 136.7, 132.5, 132.4, 131.2, 130.1, 128.8, 128.3, 127.8, 127.2, 126.0, 116.1, 99.8, 72.8, 69.2, 63.7, 29.6, 21.9, 21.4, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_7$ $[M+Na]^+$ = 486.1523, found: 486.1528.

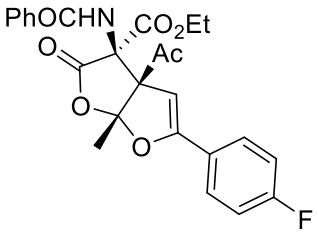
Ethyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-(m-tolyl)-2,3,3a,6a-tetrahydrofuro [2,3-b]furan-3-carboxylate (±)-**3r**:



Colorless solid; 86% isolated yield = 59.78 mg; m.p. 123.5-124.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.76 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.50 – 7.40 (m, 4H), 7.37

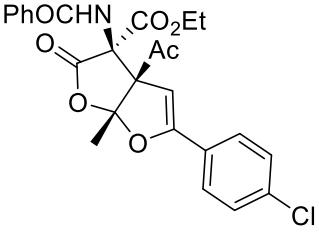
(s, 1H), 7.29 (t, *J* = 7.6 Hz, 1H), 7.23 (d, *J* = 7.5 Hz, 1H), 5.53 (s, 1H), 4.27 – 4.14 (m, 2H), 2.38 (s, 3H), 2.38 (s, 3H), 2.06 (s, 3H), 1.12 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.6, 166.9, 166.8, 166.5, 158.2, 138.5, 132.4, 131.2, 128.8, 128.5, 128.0, 127.2, 126.3, 122.8, 116.6, 95.5, 72.7, 69.6, 63.6, 29.6, 22.1, 21.3, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_7$ $[M+Na]^+$ = 486.1523, found: 486.1533.

Ethyl 3a-acetyl-3-benzamido-5-(4-fluorophenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3s**:



Colorless solid; 90% isolated yield = 61.13 mg; m.p. 134.5-135.3℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 – 7.72 (m, 2H), 7.65 – 7.58 (m, 2H), 7.59 – 7.53 (m, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.35 (s, 1H), 7.15 – 7.02 (m, 2H), 5.49 (s, 1H), 4.26 – 4.14 (m, 2H), 2.37 (s, 3H), 2.06 (s, 3H), 1.11 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3, 166.8, 166.7, 166.5, 163.8 (d, *J* = 251.6 Hz), 157.0, 132.5, 132.4, 128.8, 127.8, 127.8 (d, *J* = 8.5 Hz), 124.4 (d, *J* = 3.4 Hz), 116.7, 115.9 (d, *J* = 22.1 Hz), 95.4 (d, *J* = 1.8 Hz), 72.8, 69.6, 63.6, 29.5, 22.1, 13.7; ^{19}F NMR (376 MHz, $CDCl_3$) δ -108.9; HRMS(ESI) m/z [M+ Na] Calcd for $C_{25}H_{22}FNO_7$ $[M+Na]^+$ = 490.1272, found: 490.1276

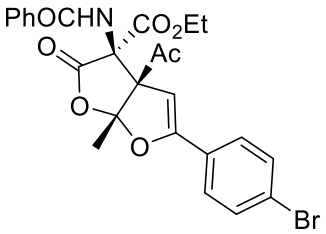
Ethyl 3a-acetyl-3-benzamido-5-(4-chlorophenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3t**:



Colorless solid; 87% isolated yield = 63.15 mg; m.p. 143.5-143.9℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.76 (m, 2H), 7.59 – 7.51 (m, 3H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.42

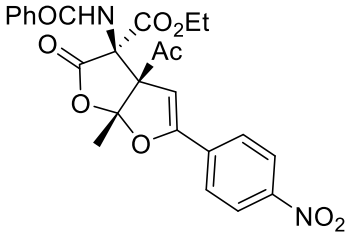
– 7.37 (m, 2H), 7.34 (s, 1H), 5.55 (s, 1H), 4.26 – 4.10 (m, 2H), 2.37 (s, 3H), 2.06 (s, 3H), 1.11 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.1, 166.8, 166.7, 166.5, 156.9, 136.4, 132.5, 132.3, 129.0, 128.8, 127.2, 127.0, 126.6, 116.7, 96.2, 72.8, 69.6, 63.7, 29.5, 22.1, 13.8; HRMS(ESI) m/z Calcd for $C_{25}H_{22}ClNO_7$ $[M+Na]^+$ = 506.0977, found: 506.0986.

Ethyl 3a-acetyl-3-benzamido-5-(4-bromophenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3u**:



Colorless solid; 91% isolated yield = 74.14 mg; m.p. 145.4-146.3 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 – 7.76 (m, 2H), 7.58 – 7.52 (m, 3H), 7.51 – 7.44 (m, 4H), 7.34 (s, 1H), 5.57 (s, 1H), 4.26 – 4.08 (m, 2H), 2.37 (s, 3H), 2.06 (s, 3H), 1.12 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.0, 166.8, 166.7, 166.5, 157.0, 132.5, 132.3, 132.0, 128.8, 127.2, 127.1, 127.0, 124.7, 116.7, 96.3, 72.8, 69.5, 63.7, 29.5, 22.1, 13.8; HRMS(ESI) m/z Calcd for $C_{25}H_{22}BrNO_7$ $[M+Na]^+$ = 550.0472, found: 550.0480.

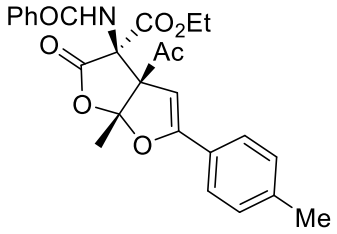
Ethyl 3a-acetyl-3-benzamido-6a-methyl-5-(4-nitrophenyl)-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3v**:



Colorless solid; 75% isolated yield = 55.62 mg; m.p. 145.2-146.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28 (d, *J* = 8.8 Hz, 2H), 7.86 – 7.76 (m, 4H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.32 (s, 1H), 5.81 (s, 1H), 4.29 – 4.14 (m, 2H), 2.40 (s, 3H), 2.09 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 199.2, 166.6, 166.6, 166.5, 155.7, 148.6, 133.9, 132.6, 132.2, 128.8, 127.2, 126.5, 124.0, 117.0, 99.9,

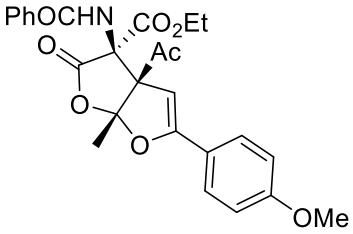
73.0, 69.5, 63.8, 29.6, 22.1, 13.8; HRMS(ESI) m/z Calcd for $C_{25}H_{22}N_2O_9$ $[M+Na]^+$ = 517.1217, found: 517.1220.

Ethyl 3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-(p-tolyl)-2,3,3a,6a-tetrahydrofuro [2,3-b]furan-3-carboxylate (±)-**3w**:



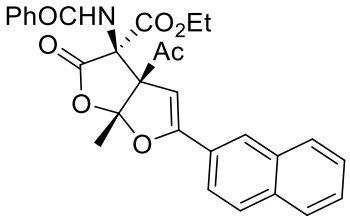
Colorless solid; 85% isolated yield = 59.11 mg; m.p. 125.5-126.1°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 – 7.73 (m, 2H), 7.59 – 7.42 (m, 5H), 7.37 (s, 1H), 7.21 (d, *J* = 8.1 Hz, 2H), 5.47 (s, 1H), 4.27 – 4.12 (m, 2H), 2.39 (s, 3H), 2.37 (s, 3H), 2.06 (s, 3H), 1.12 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.7, 166.9, 166.8, 166.5, 158.1, 140.7, 132.5, 132.4, 129.4, 128.7, 127.2, 125.6, 125.3, 116.6, 94.7, 72.7, 69.6, 63.6, 29.6, 22.1, 21.5, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_7$ $[M+Na]^+$ = 486.1523, found: 486.1528.

Ethyl 3a-acetyl-3-benzamido-5-(4-methoxyphenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3x**:



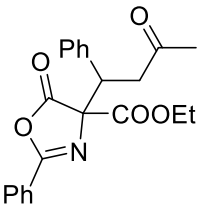
Colorless solid; 87 % isolated yield = 62.57 mg; m.p. 101.9-102.6°C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 – 7.75 (m, 2H), 7.55 (t, *J* = 7.8 Hz, 3H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.37 (s, 1H), 6.91 (d, *J* = 8.9 Hz, 2H), 5.38 (s, 1H), 4.26 – 4.14 (m, 2H), 3.85 (s, 3H), 2.37 (s, 3H), 2.06 (s, 3H), 1.12 (t, *J* = 7.2 Hz, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.8, 167.0, 166.8, 166.5, 161.2, 157.8, 132.5, 132.4, 128.7, 127.3, 127.2, 120.7, 116.6, 114.0, 93.6, 72.8, 69.7, 63.6, 55.4, 29.5, 22.1, 13.7; HRMS(ESI) m/z Calcd for $C_{26}H_{25}NO_8$ $[M+Na]^+$ = 502.1472, found: 502.1479.

Ethyl 3-(2-naphthamido)-3a-acetyl-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (±)-**3y**:



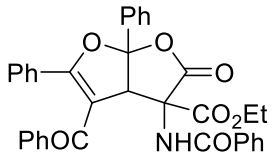
Colorless solid; 92% isolated yield = 68.93 mg; m.p. 111.4-112.3℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 (s, 1H), 7.98 – 7.86 (m, 3H), 7.85 – 7.80 (m, 1H), 7.68 – 7.61 (m, 2H), 7.60 – 7.53 (m, 2H), 7.50 (s, 1H), 7.45 – 7.35 (m, 3H), 5.59 (s, 1H), 4.31 – 4.08 (m, 2H), 2.41 (s, 3H), 2.10 (s, 3H), 1.12 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.4, 167.1, 166.8, 166.6, 158.0, 135.1, 132.5, 130.4, 129.6, 129.1, 128.7, 128.7, 128.2, 128.2, 128.1, 127.8, 127.0, 125.7, 123.3, 116.7, 95.7, 72.8, 69.8, 63.7, 29.6, 22.2, 13.7; HRMS(ESI) m/z Calcd for $C_{29}H_{25}NO_7$ $[M+Na]^+$ = 522.1523, found: 522.1530.

Ethyl 5-oxo-4-(3-oxo-1-phenylbutyl)-2-phenyl-4,5-dihydrooxazole-4-carboxylate (±)-**7:**



Colorless solid; 65% isolated yield = 22.74 mg; m.p. 132.6-133.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.5 Hz, 2H), 7.60 (t, *J* = 7.4 Hz, 1H), 7.47 (t, *J* = 7.7 Hz, 2H), 7.24 – 7.17 (m, 2H), 7.17 – 7.08 (m, 3H), 4.43 – 4.36 (m, 1H), 4.36 – 4.20 (m, 2H), 3.34 – 3.15 (m, 2H), 2.08 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 2H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 205.2, 172.3, 165.1, 163.4, 136.1, 133.3, 129.2, 128.8, 128.3, 128.2, 128.0, 125.0, 80.0, 63.3, 45.4, 44.8, 30.2, 13.9; HRMS(ESI) m/z Calcd for $C_{22}H_{21}NO_5$ $[M+Na]^+$ = 402.1312, found: 402.1317.

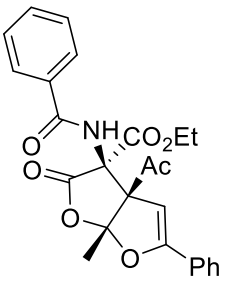
Ethyl 3-benzamido-4-benzoyl-2-oxo-5,6a-diphenyl-2,3,3a,6a-tetrahydrofuro[2,3-b] furan-3-carboxylate (+)-**10:**



Colorless solid; 40% isolated yield = 14.00 mg; m.p. 124.7-125.1℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.05 – 7.82 (m, 2H), 7.77 – 7.52 (m, 4H), 7.51 – 7.29 (m, 7H), 7.22 – 7.05 (m, 5H), 7.00 (t, *J* = 7.8 Hz, 1H), 6.83 (t, *J* = 7.8 Hz, 1H), 4.64 (d, *J* = 83.4 Hz, 1H), 4.39 – 3.98 (m, 2H), 1.22 – 1.02 (m, 3H) ; ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.0, 168.7, 168.5, 166.9, 166.4, 137.9, 137.4, 132.3, 132.3, 132.1, 131.9, 131.7, 131.4, 130.8, 129.9, 129.7, 129.5, 129.0, 128.8, 128.7, 128.6, 128.5, 128.1, 128.0, 127.7, 127.4, 127.4, 125.4, 125.0, 113.0, 110.9, 66.5, 64.1, 61.5, 13.7; HRMS(ESI) m/z Calcd for $C_{35}H_{27}NO_7$ $[M+Na]^+$ = 596.1680, found: 596.1690.

Catalytic asymmetric version:

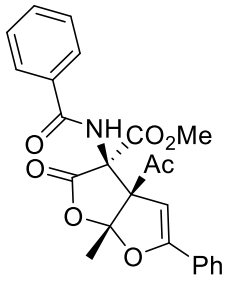
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3a**:



Before recrystallization：Colorless solid; 70% isolated yield = 47.19 mg; HPLC (IC column, *i*-propanol/hexane = 20/80, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 17.05 min (major), t_2 = 20.59 min (minor), ee = 90%;

After recrystallization：Colorless solid; 60% isolated yield = 40.45 mg; HPLC (IC column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 12.78 min (major), t_2 = 14.57 min (minor), ee > 99%; $[\alpha]^{20.0}_D$ = -58.0 (*c* 0.2, CH_2Cl_2).

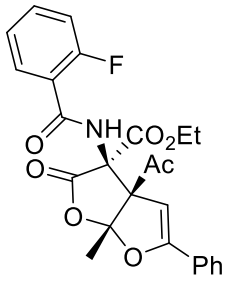
Methyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3b**:



Before recrystallization：Colorless solid; 72% isolated yield = 47.03 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.59 min (major), t_2 = 10.59 min (minor), ee = 88%;

After recrystallization：Colorless solid; 65% isolated yield = 42.45 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.53 min (major), t_2 = 10.52 min (minor), ee = 96%; $[\alpha]^{20.0}_D$ = -54.2 (*c* 0.2, CH_2Cl_2).

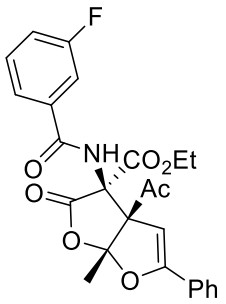
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-(2-fluorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3e**:



Before recrystallization：Colorless solid; 68% isolated yield = 47.68 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 7.80 min (major), t_2 = 10.66 min (minor), ee = 70%;

After recrystallization：Colorless solid; 35% isolated yield = 31.55 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 9.04 min (major), t_2 = 13.84 min (minor), ee = 92%; $[\alpha]^{20.0}_D$ = -43.8 (*c* 0.2, CH_2Cl_2).

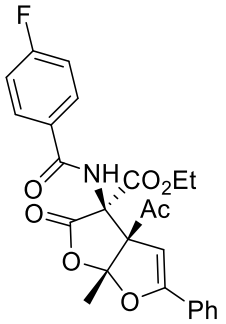
Ethyl(3*R*,3a*S*,6a*R*)-3a-acetyl-3-(3-fluorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3f**:



Before recrystallization：Colorless solid; 70% isolated yield = 49.08 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 6.60 min (major), t_2 = 7.73 min (minor), ee = 82%;

After recrystallization：Colorless solid; 50% isolated yield = 35.06 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 17.05 min (major), t_2 = 20.59 min (minor), ee = 98%; $[\alpha]^{20.0}_D$ = -36.0 (*c* 0.1, CH_2Cl_2).

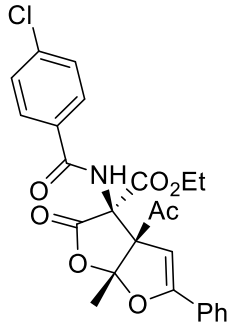
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-(4-fluorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate **(-)-3h**:



Before recrystallization：Colorless solid; 73% isolated yield = 51.19 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 7.16 min (major), t_2 = 9.54 min (minor), ee = 84%;

After recrystallization：Colorless solid; 48% isolated yield = 33.66 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 6.97 min (major), t_2 = 8.98 min (minor), ee = 98%; $[\alpha]^{20.0}_D$ = -47.1 (*c* 0.17, CH_2Cl_2).

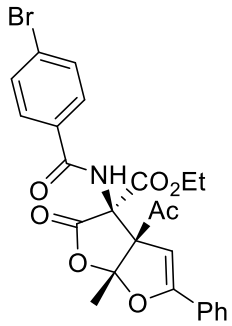
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-(4-chlorobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate **(-)-3i**:



Before recrystallization：Colorless solid; 73% isolated yield = 52.99 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 7.63 min (major), t_2 = 9.68 min (minor), ee = 80%;

After recrystallization：Colorless solid; 54% isolated yield = 39.20 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.33 min (major), t_2 = 10.83 min (minor), ee > 99%; $[\alpha]^{20.0}_D$ = -44.8 (*c* 0.25, CH_2Cl_2).

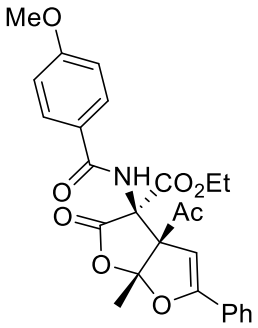
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-(4-bromobenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3j**:



Before recrystallization：Colorless solid; 73% isolated yield = 57.85 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.69 min (major), t_2 = 11.41 min (minor), ee = 88%;

After recrystallization：Colorless solid; 48% isolated yield = 38.04 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 9.04 min (major), t_2 = 11.74 min (minor), ee > 99%; $[\alpha]^{20.0}_D$ = -48.5 (*c* 0.17, CH_2Cl_2).

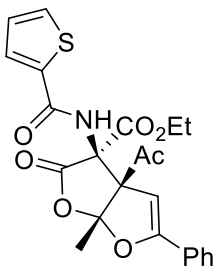
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-(4-methoxybenzamido)-6a-methyl-2-oxo-5-phenyl-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3l**:



Before recrystallization：Colorless solid; 66% isolated yield = 47.47 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 14.29 min (major), t_2 = 28.69 min (minor), ee = 84%;

After recrystallization：Colorless solid; 46% isolated yield = 33.08 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 14.82 min (major), t_2 = 30.28 min (minor), ee = 98%; $[\alpha]^{20.0}_D$ = -52.7 (*c* 0.15, CH_2Cl_2).

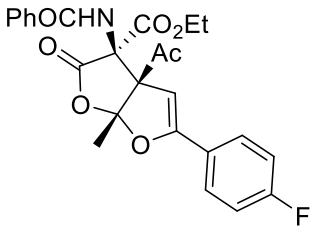
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-6a-methyl-2-oxo-5-phenyl-3-(thiophene-2-carboxamido)-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3n**:



Before recrystallization：Colorless solid; 69% isolated yield = 47.14 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.62 min (major), t_2 = 12.36 min (minor), ee = 86%;

After recrystallization：Colorless solid; 68% isolated yield = 46.46 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.56 min (major), t_2 = 11.91 min (minor), ee = 94%; $[\alpha]^{20.0}_D$ = -54.0 (*c* 0.1, CH_2Cl_2).

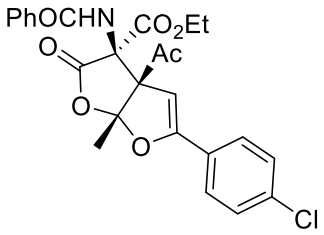
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-5-(4-fluorophenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3s**:



Before recrystallization：Colorless solid; 90% isolated yield = 63.11 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.18 min (major), t_2 = 11.31 min (minor), ee = 78%;

After recrystallization：Colorless solid; 48% isolated yield = 33.66 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.19 min (major), t_2 = 11.38 min (minor), ee = 90%; $[\alpha]^{20.0}_D$ = -37.2 (*c* 0.17, CH_2Cl_2).

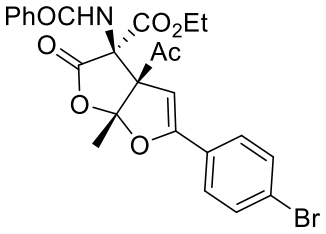
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-5-(4-chlorophenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3t**:



Before recrystallization：Colorless solid; 87% isolated yield = 63.15 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.39 min (major), t_2 = 11.32 min (minor), ee = 78%;

After recrystallization：Colorless solid; 45% isolated yield = 32.66 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.41 min (major), t_2 = 11.36 min (minor), ee = 92%; $[\alpha]^{20.0}_D$ = -19.2 (*c* 0.18, CH_2Cl_2).

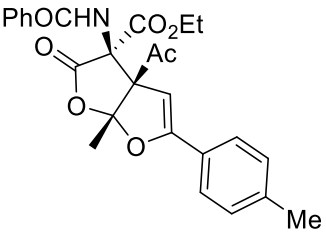
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-5-(4-bromophenyl)-6a-methyl-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3u**:



Before recrystallization：Colorless solid; 91% isolated yield = 72.12 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.31 min (major), t_2 = 11.18 min (minor), ee = 80%;

After recrystallization：Colorless solid; 48% isolated yield = 38.04 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 8.96 min (major), t_2 = 12.09 min (minor), ee = 94%; $[\alpha]^{20.0}_D$ = -49.2 (*c* 0.23, CH_2Cl_2).

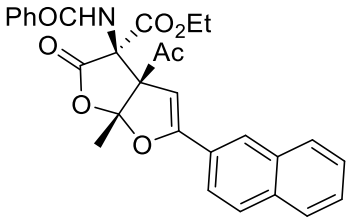
Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-6a-methyl-2-oxo-5-(p-tolyl)-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3w**:



Before recrystallization：Colorless solid; 85% isolated yield = 59.09 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 9.29 min (major), t_2 = 12.78 min (minor), ee = 82%;

After recrystallization：Colorless solid; 55% isolated yield = 38,24 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 9.39 min (major), t_2 = 12.55 min (minor), ee = 90%; $[\alpha]^{20.0}_D$ = -47.1 (*c* 0.23, CH_2Cl_2).

Ethyl (3*R*,3a*S*,6a*R*)-3a-acetyl-3-benzamido-6a-methyl-5-(naphthalen-2-yl)-2-oxo-2,3,3a,6a-tetrahydrofuro[2,3-b]furan-3-carboxylate (-)-**3y**:

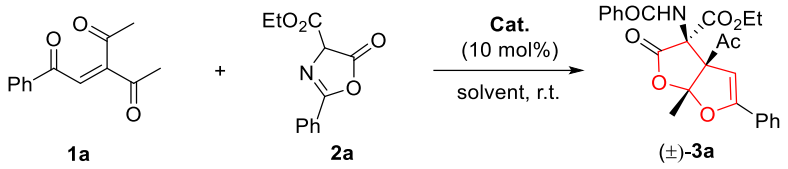


Before recrystallization：Colorless solid; 92% isolated yield = 69.93 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 9.91 min (major), t_2 = 13.22 min (minor), ee = 84%;

After recrystallization：Colorless solid; 60% isolated yield = 44.96 mg; HPLC (IF column, *i*-propanol/hexane = 30/70, flow rate 1.0 mL/min, λ = 254 nm), product: t_1 = 10.62 min (major), t_2 = 14.10 min (minor), ee = 92%; $[\alpha]^{20.0}_{D}$ = -44.5 (*c* 0.25, CH_2Cl_2).

4. Chemical kinetics studies

Kinetic profiles analyzed by ^{1}H NMR at two different concentrations. (0.05 M or 0.005M)



Investigation of the reaction at 0.05 M without catalyst[a]

Time (min)	**1a** (%)	**3a** (%)
0	100	0
4	63.97695	23.79863
6	53.60231	27.00229
8	49.85591	38.44394
10	44.3804	44.39359
14	38.9049	52.40275
18	34.87032	54.23341
22	33.14121	54.46224
26	27.95389	55.60641
30	27.37752	58.3524

a) Reaction conditions: **1a** (0.05 mmol), **2a** (0.05 mmol.), solvent (1 mL), and at room temperature (r.t.).

Investigation of the reaction at 0.05 M with **CPA-7** (10 mol%)[a]

Time (min)	1a (%)	3a (%)
0	100	0
4	71.19705	23.054755
6	64.95973	26.224784
8	55.93524	31.700288
10	51.04975	35.158501
14	49.75675	40.92219
18	44.85126	42.651297
22	43.47826	48.126801
26	41.48876	50.144092
30	40.06577	51.585014

a) Reaction conditions: **1a** (0.05 mmol), **2a** (0.05 mmol.), **CPA-7** (10 mol%), solvent (1 mL), and at room temperature (r.t.).

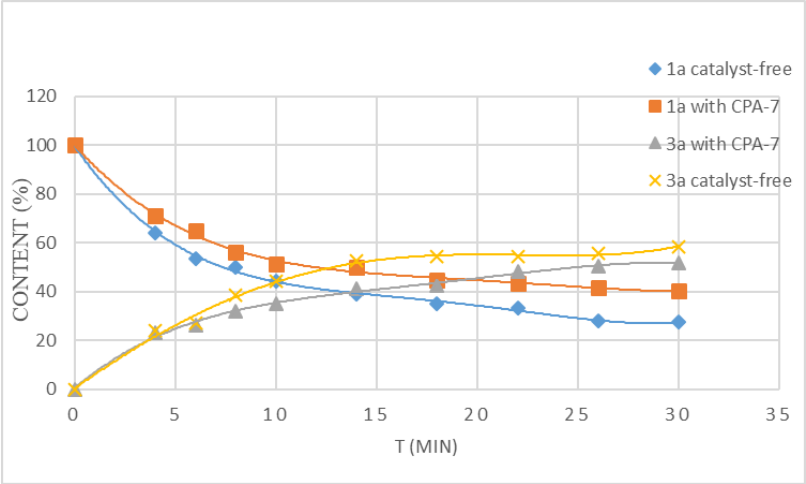
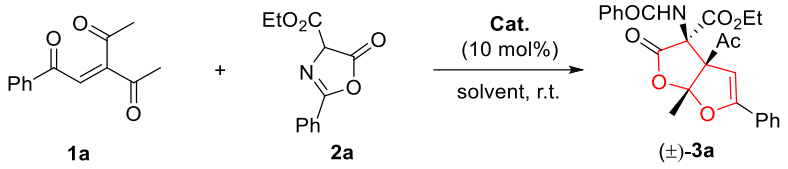


Figure S1. Kinetic profiles analyzed by ^{1}H NMR at the concentration of 0.05 M[a].

a) Reaction conditions: **1a** (0.05 mmol), **2a** (0.05 mmol.), solvent (1 mL), catalyst-free or **CPA-7** (10 mol%), and at room temperature (r.t.).



Investigation of the reaction at 0.005 M without catalyst[a]

Time (min)	1a (%)	3a (%)
0	100	0
8	83.39483	23.98524
16	77.12177	27.67528
24	69.37269	31.73432
32	67.52768	35.42435
40	61.25461	40.2214
48	58.67159	41.32841
56	56.08856	42.06642

a) Reaction conditions: **1a** (0.005 mmol), **2a** (0.005 mmol.), solvent (1 mL), and at room temperature r.t.).

Investigation of the reaction at 0.005 M with **CPA-7** (10 mol%)[a]

Time (min)	1a (%)	3a (%)
0	100	0
8	71.16705	23.79863
16	64.75973	27.00229
24	55.83524	38.44394
32	51.02975	44.39359

40	49.65675	52.40275
48	41.41876	55.60641
56	40.04577	58.3524

a) Reaction conditions: **1a** (0.005 mmol), **2a** (0.005 mmol.), **CPA-7** (10 mol%), solvent (1 mL), and at room temperature (r.t.).

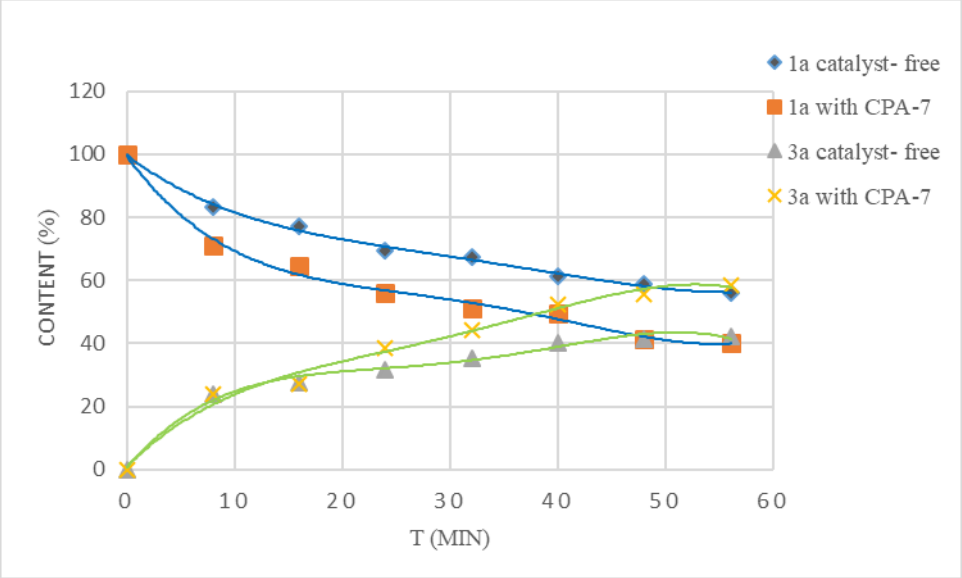
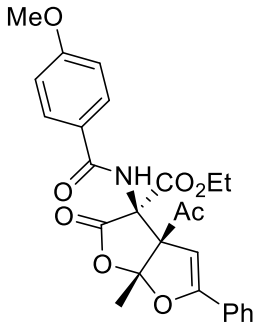


Figure S2. Kinetic profiles analyzed by ^{1}H NMR at the concentration of 0.005 M[a]

a) Reaction conditions: **1a** (0.005 mmol), **2a** (0.005 mmol.), solvent (1 mL), catalyst-free or CPA-7 (10mol%), and at room temperature (r.t.).

5. X-ray single crystal data for compounds (-)-3l

Compound : (-)-**3l**



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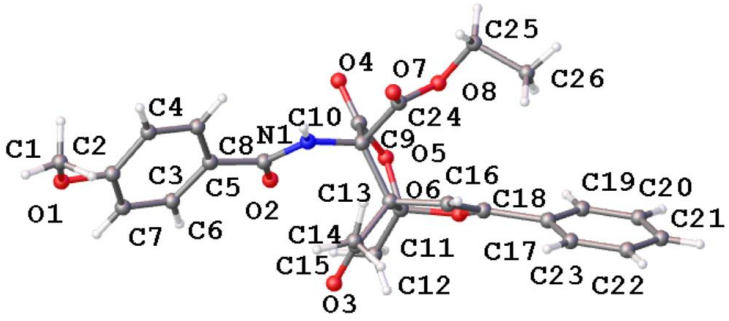
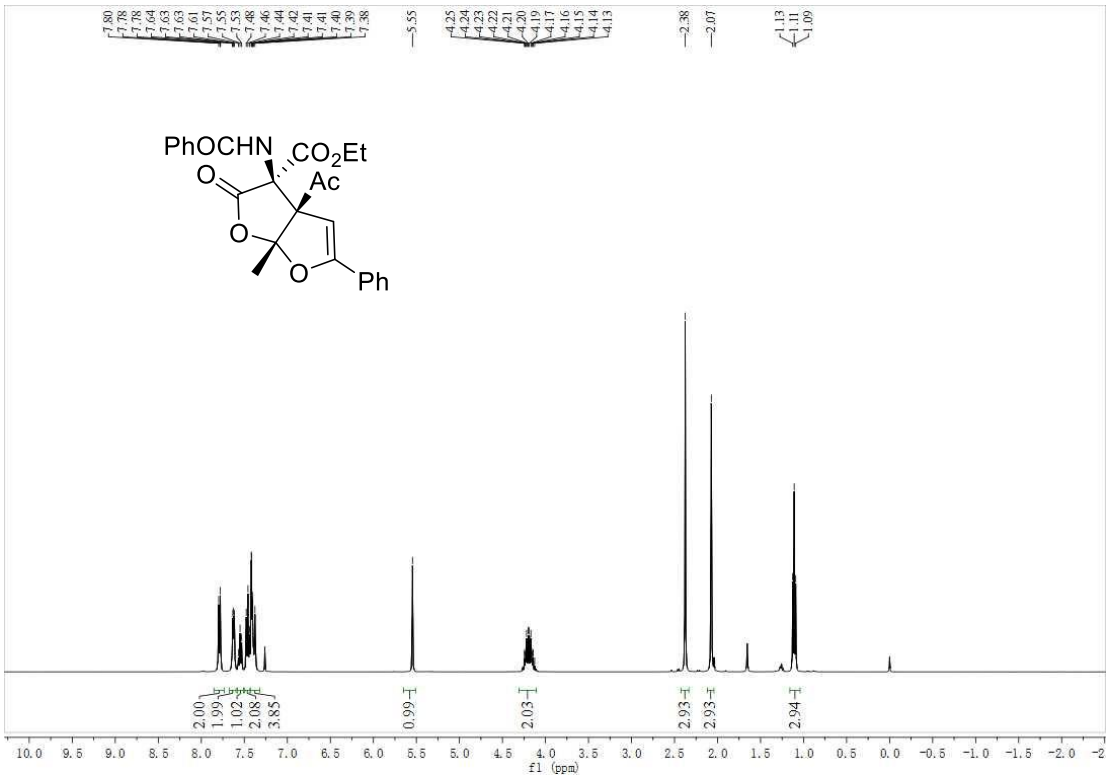


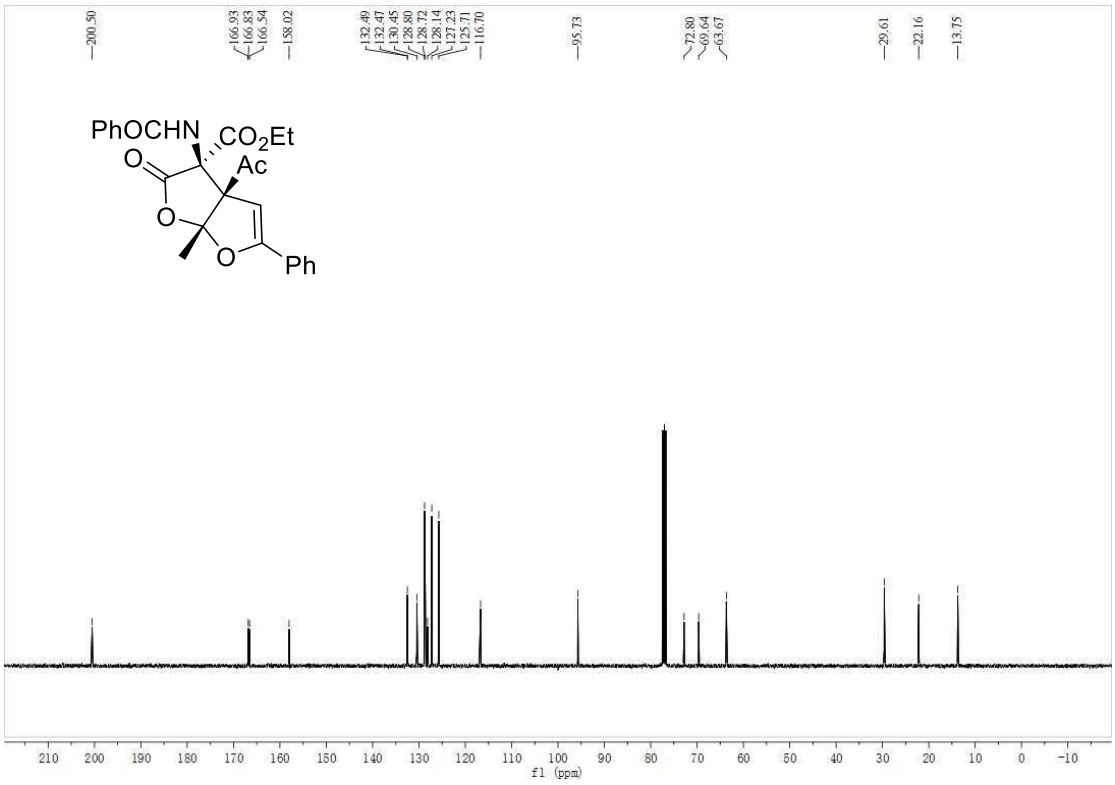
Identification code	230318LU_LGPZ144707_0m
Empirical formula	$C_{26}H_{25}NO_8$
Formula weight	479.47
Temperature/K	193.00
Crystal system	orthorhombic
Space group	$P2_12_12_1$
a/Å	7.6044(5)
b/Å	9.6671(6)
c/Å	31.908(2)
α/°	90
β/°	90
γ/°	90
Volume/Å^3	2345.6(3)
Z	4
ρ_{calc}g/cm^3	1.358
μ/mm^{-1}	0.538
F(000)	1008.0
Crystal size/mm^3	0.13 × 0.12 × 0.1
Radiation	GaKα (λ = 1.34139)

2Θ range for data collection/°	8.314 to 120.906
Index ranges	$-9 \leq h \leq 9$, $-11 \leq k \leq 12$, $-40 \leq l \leq 41$
Reflections collected	39600
Independent reflections	5280 [R_{int} = 0.0634, R_{sigma} = 0.0324]
Data/restraints/parameters	5280/71/391
Goodness-of-fit on F^2	1.091
Final R indexes [I>=2σ (I)]	R_1 = 0.0521, wR_2 = 0.1154
Final R indexes [all data]	R_1 = 0.0623, wR_2 = 0.1214
Largest diff. peak/hole / e $Å^{-3}$	0.17/-0.22
Flack parameter	0.18(14)

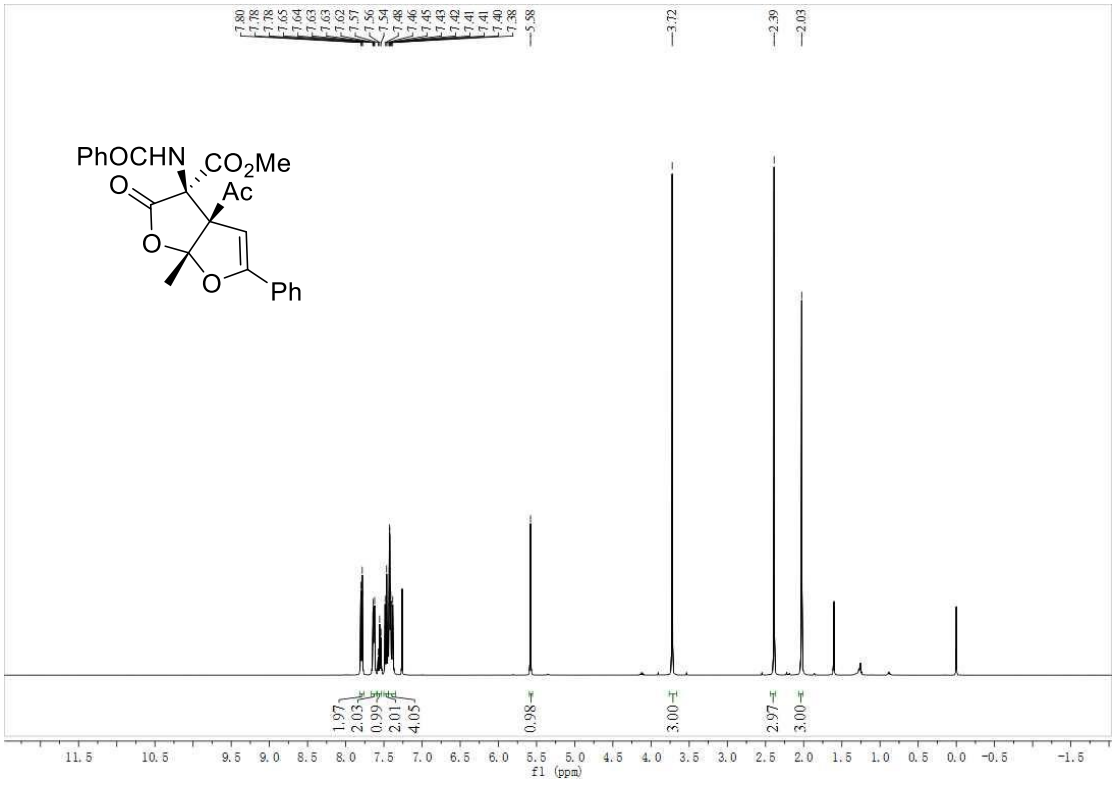
6. NMR Spectra

(±)-3a





(±)-3b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CO2Me
Ac
O
O
O
Ph
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7.78
7.78
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7.64
7.63
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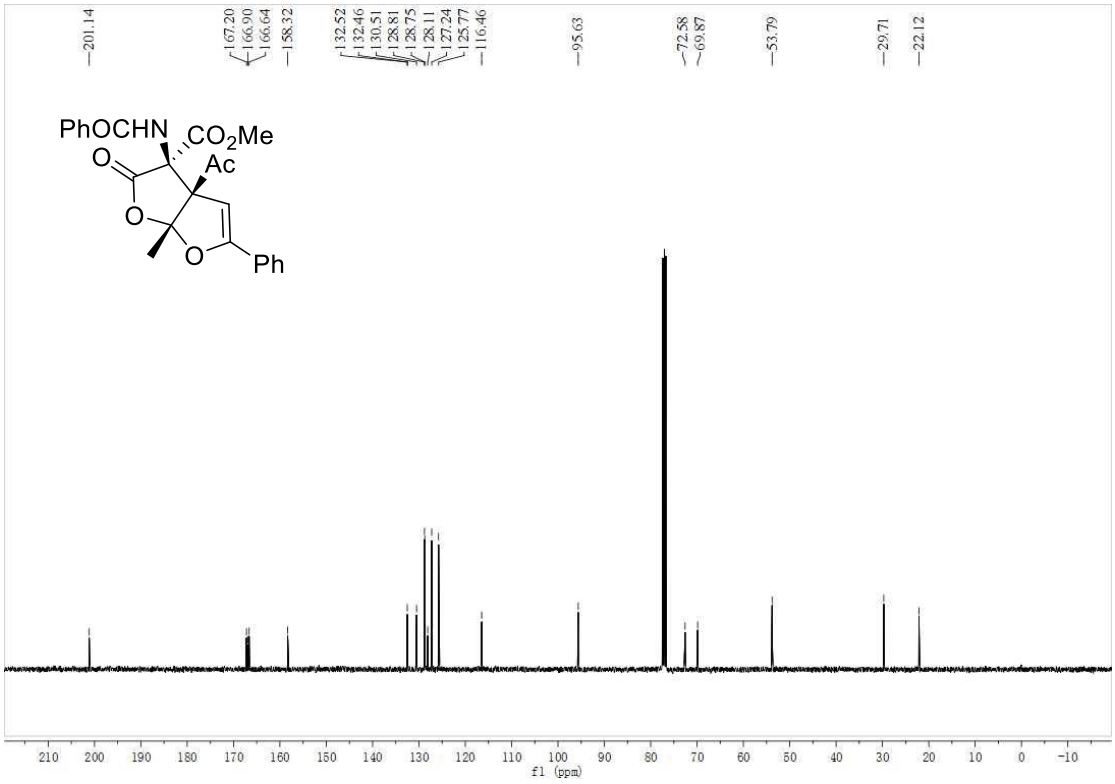
7.57
7.56
7.54
7.48
7.46
7.45
7.43
7.42
7.41
7.41
7.40
7.38
5.58
3.72
2.39
2.03
1.97
2.03
0.99
2.01
4.05
0.98
3.00
2.97
3.00
f1 (ppm)


PhOCHN
CO2Me
Ac
O
O
O
Ph
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167.20
166.90
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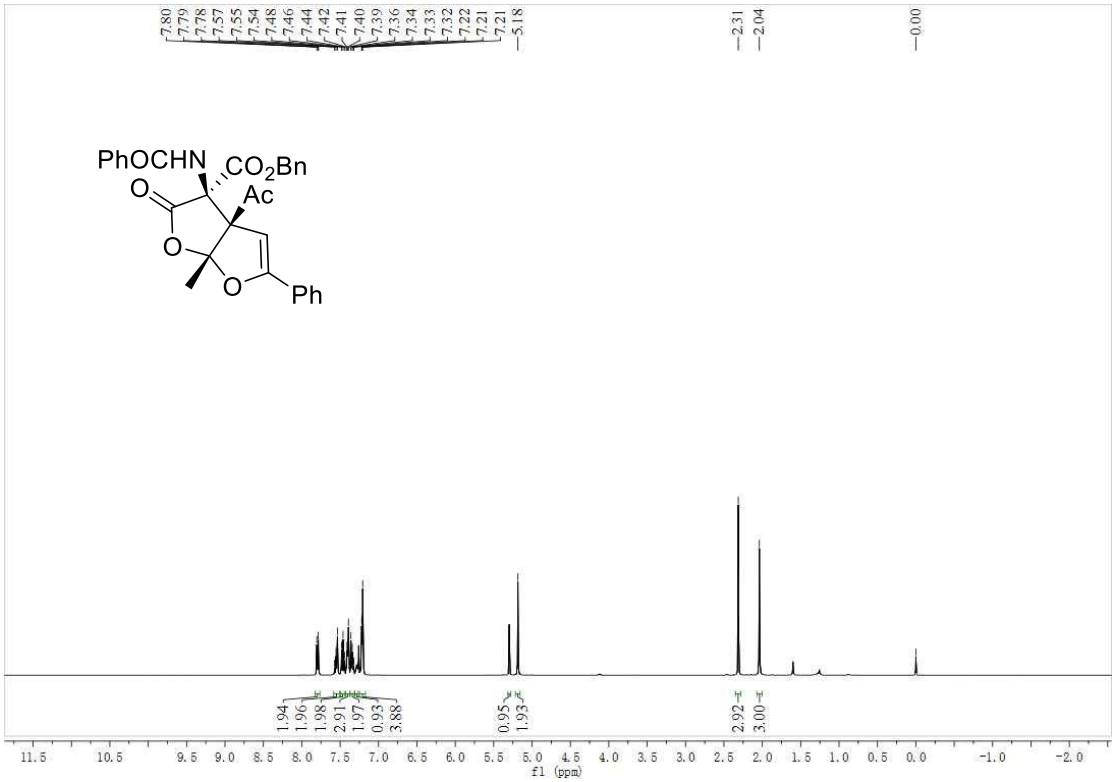
158.32
132.52
132.46
130.51
128.81
128.75
128.11
127.24
125.77
116.46
95.63
72.58
69.87
53.79
29.71
22.12
f1 (ppm)

(±)-3c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7.46
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7.42
7.41
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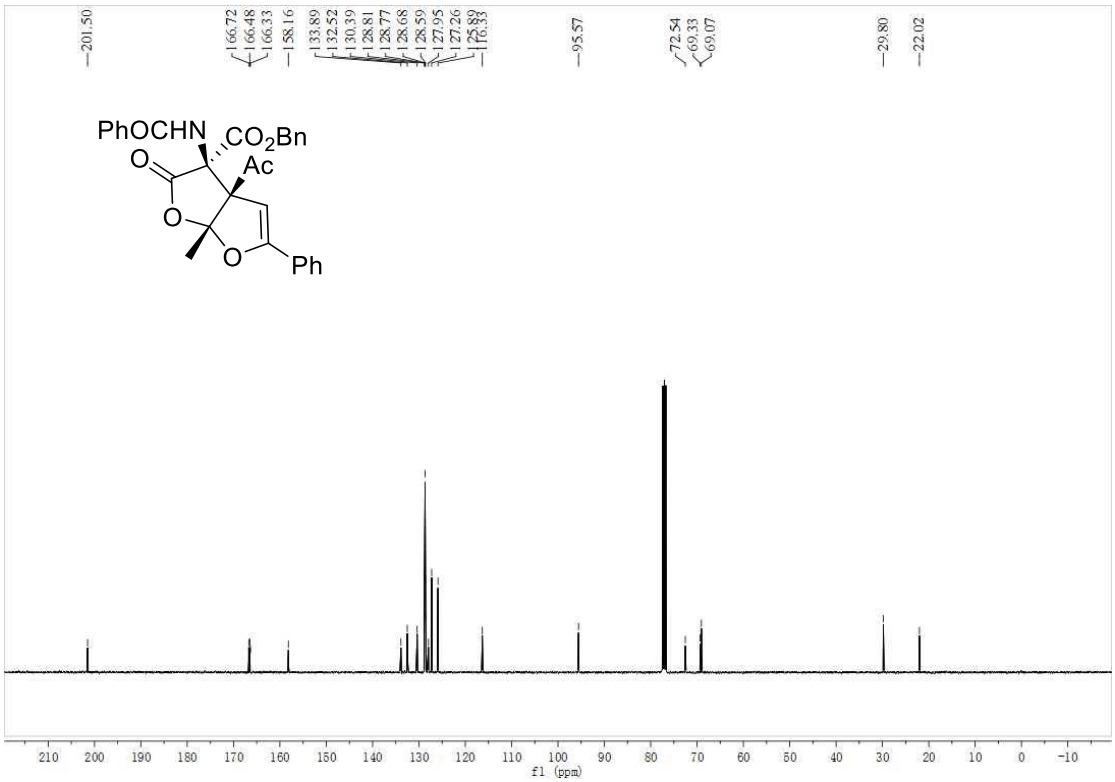
7.39
7.36
7.34
7.33
7.32
7.22
7.21
5.18
2.31
2.04
0.00
PhOCHN
CO2Bn
Ac
O
O
O
Ph
1.94
1.96
1.98
2.91
1.97
0.93
3.88
0.95
1.93
2.92
3.00
f1 (ppm)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132.52
130.39
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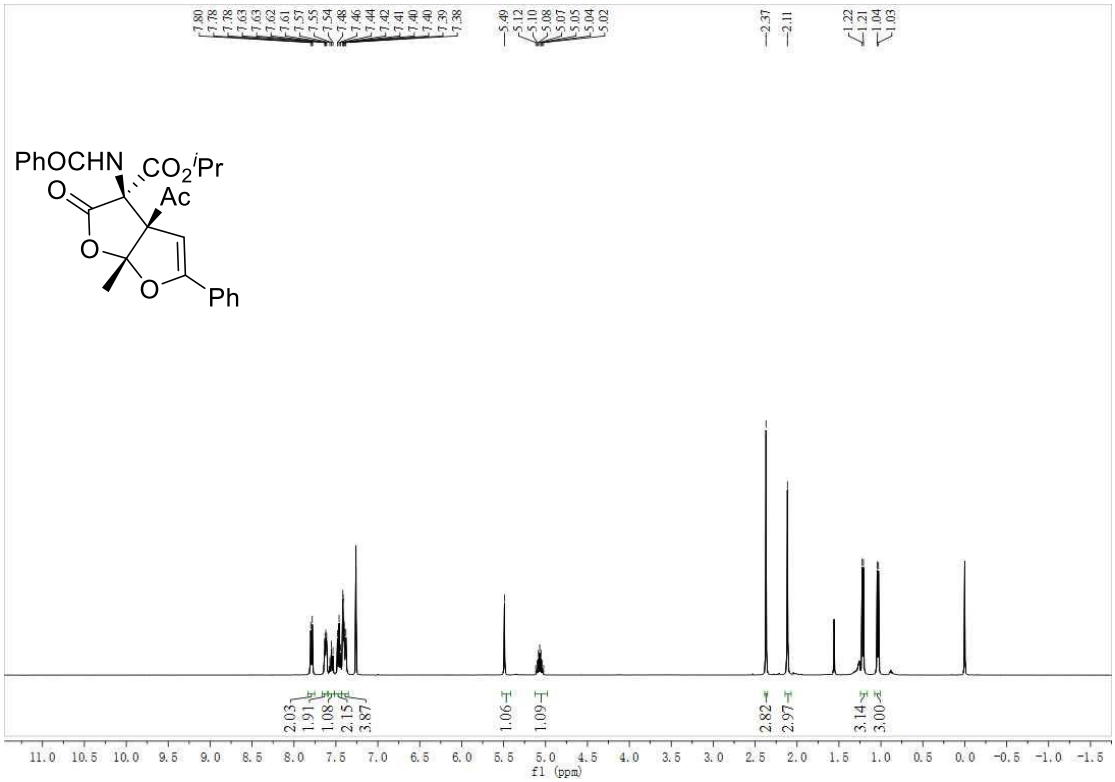
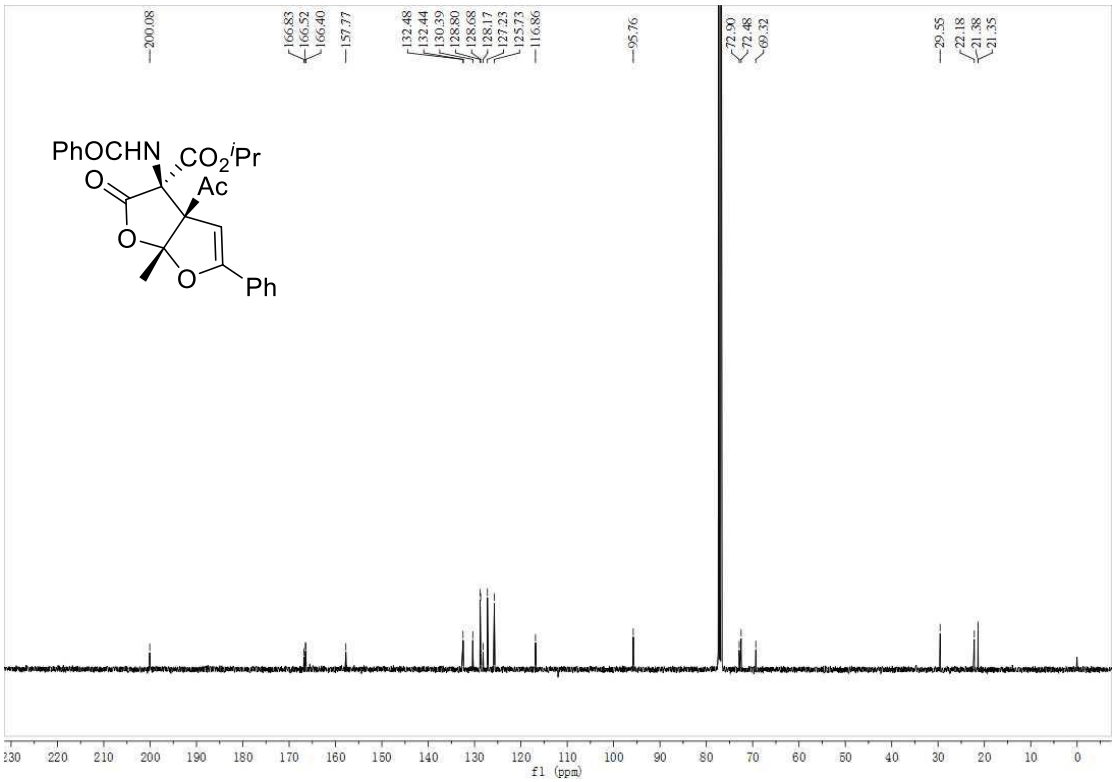
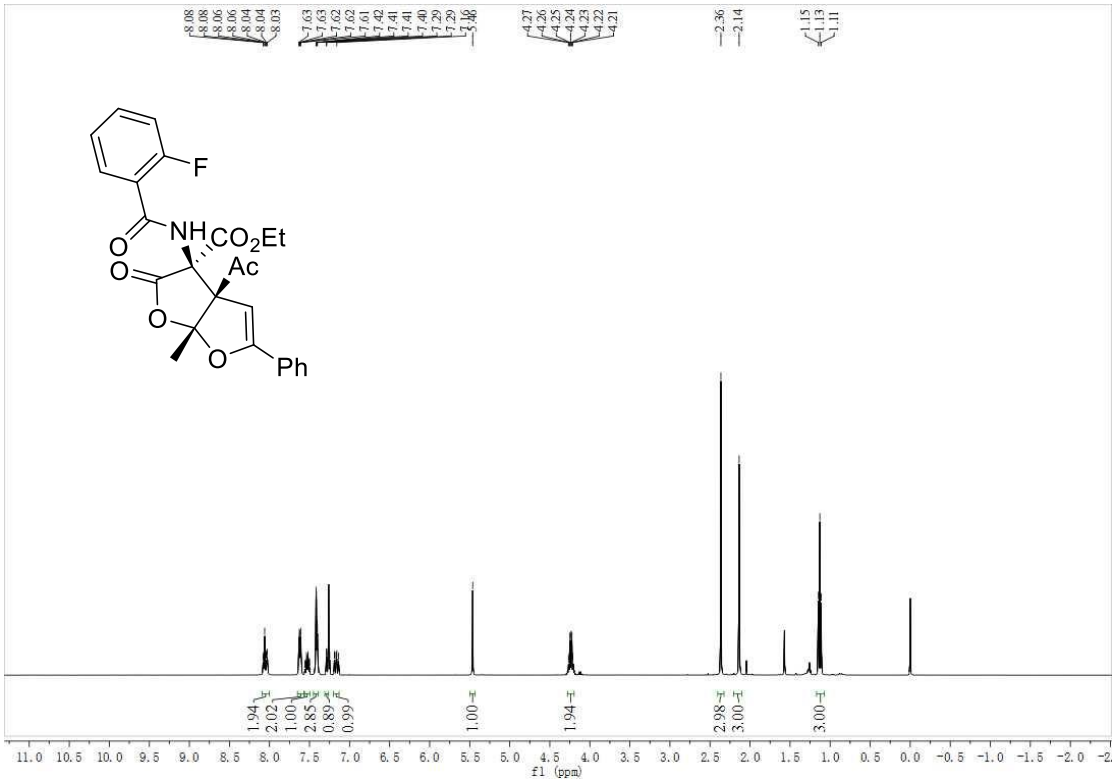
128.77
128.68
128.59
127.95
127.26
125.89
116.33
95.57
72.54
69.33
69.07
29.80
22.02
PhOCHN
CO2Bn
Ac
O
O
O
Ph
f1 (ppm)

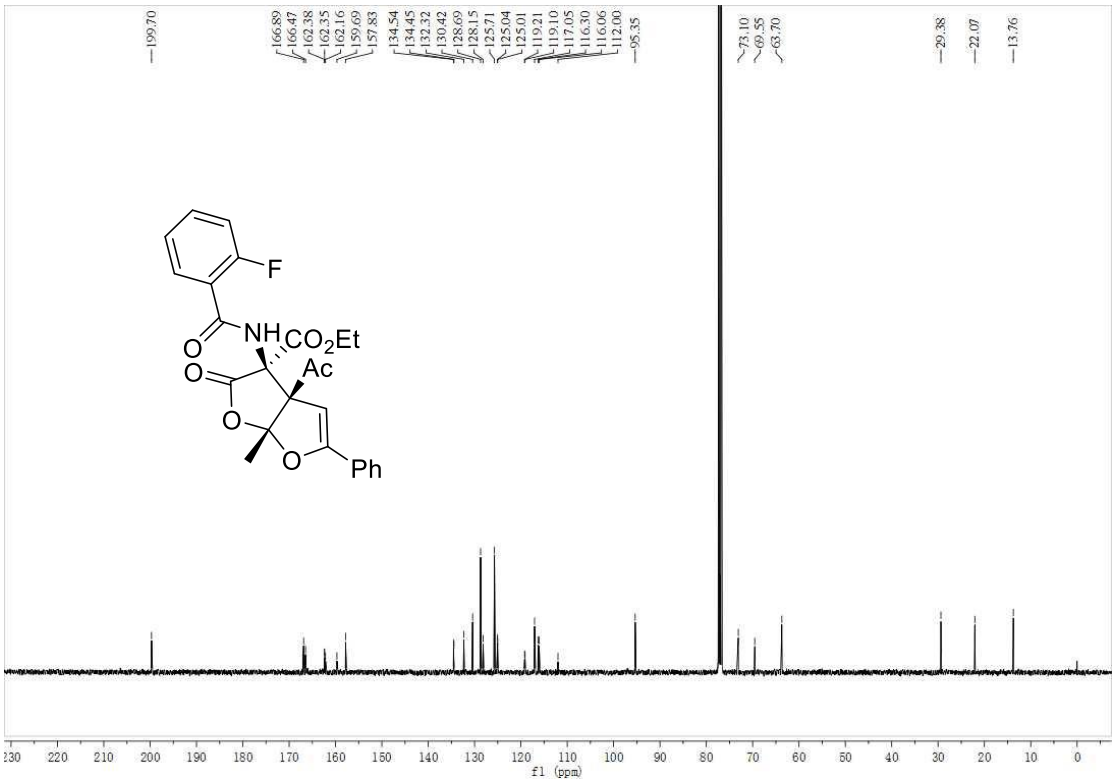
(±)-3d

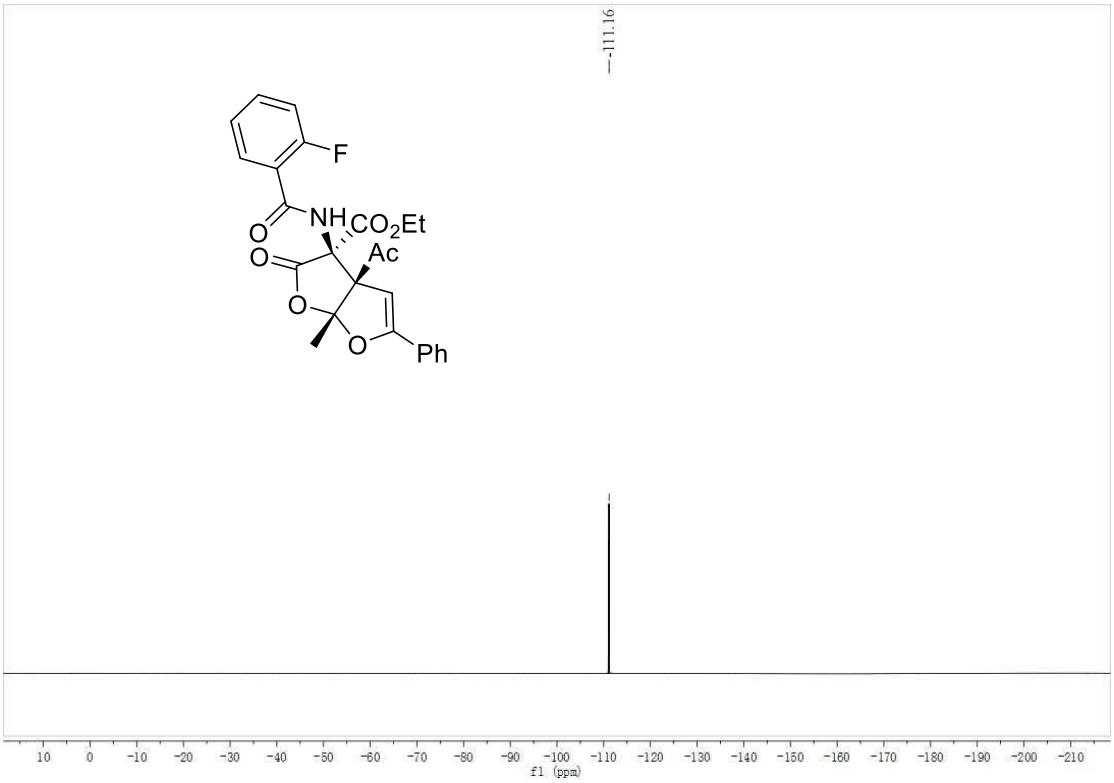




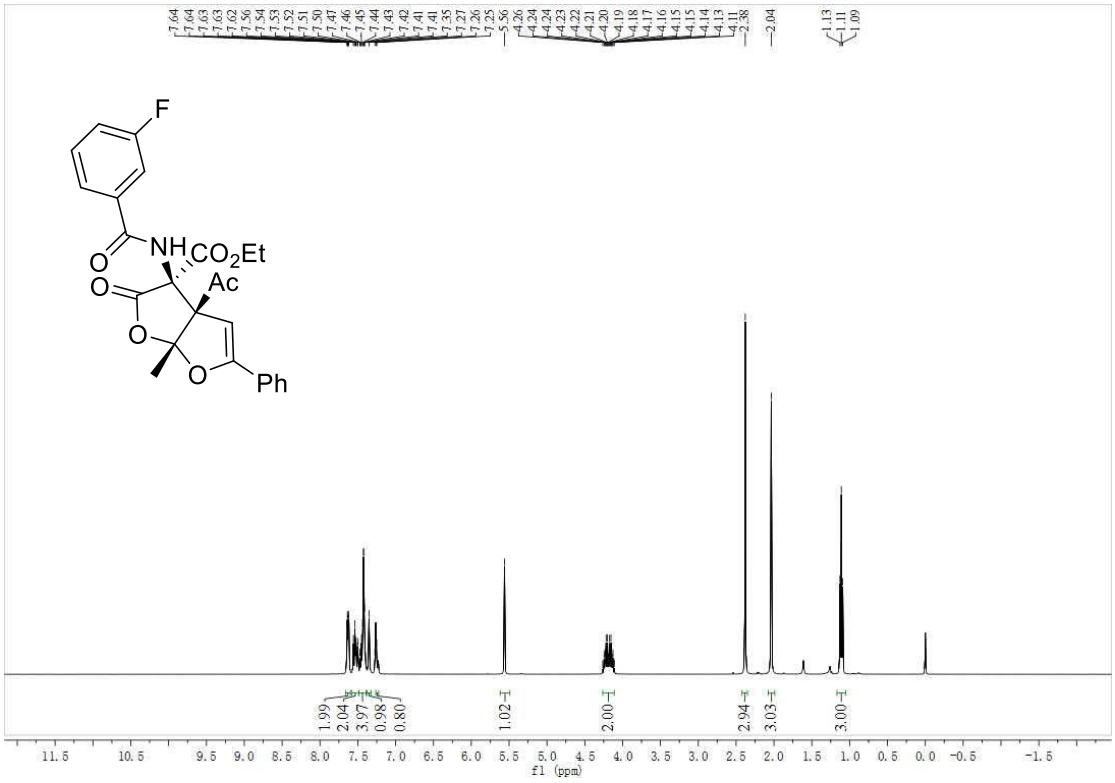
(±)-3e

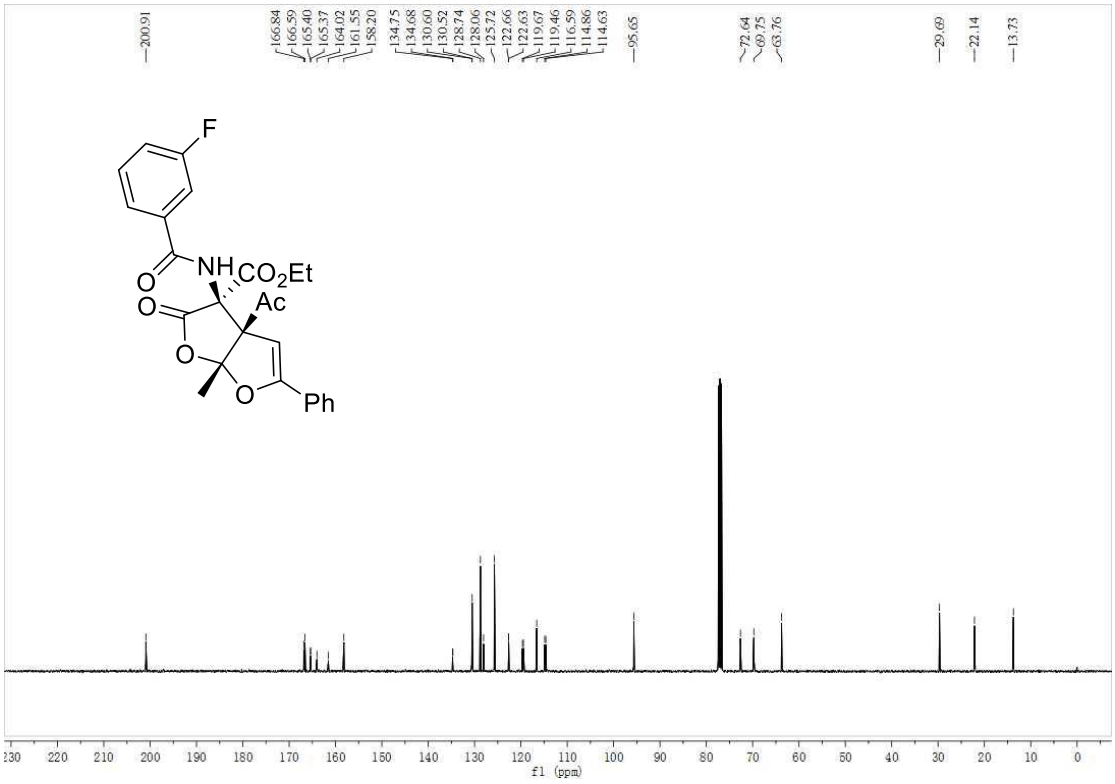


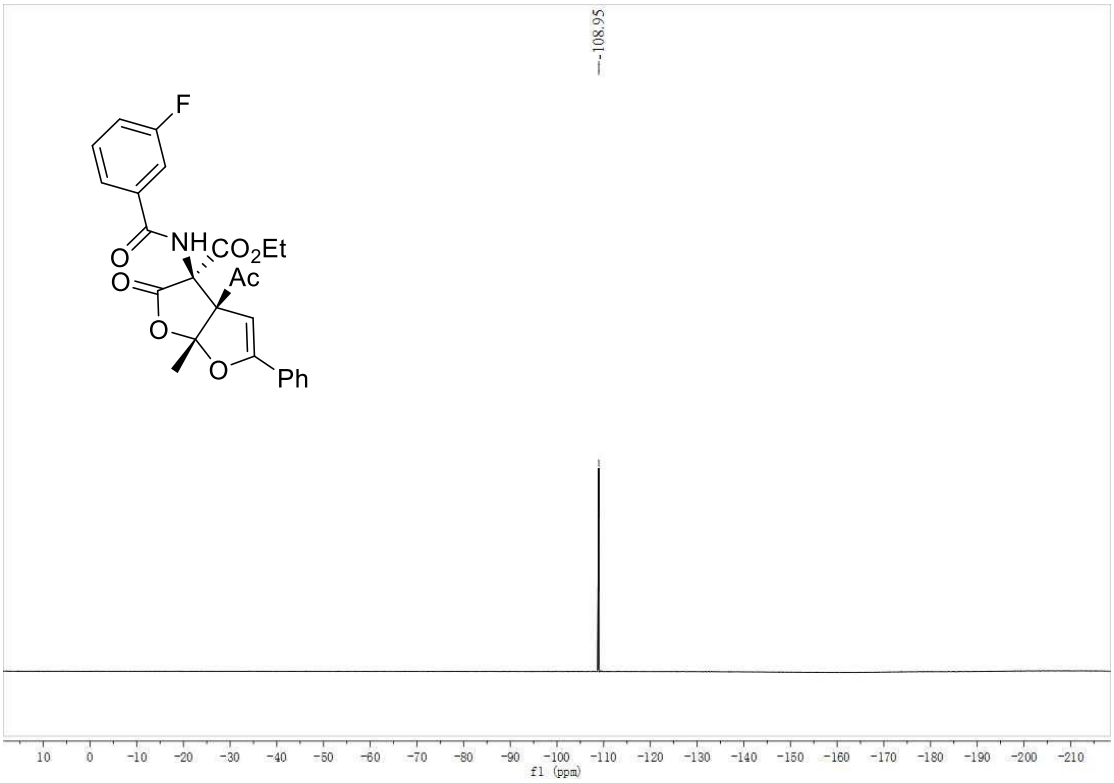



-111.16
F
NH
CO2Et
Ac
O
O
O
O
Ph
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

(±)-3f






-108.95
F
NH
CO2Et
Ac
O
O
O
O
Ph
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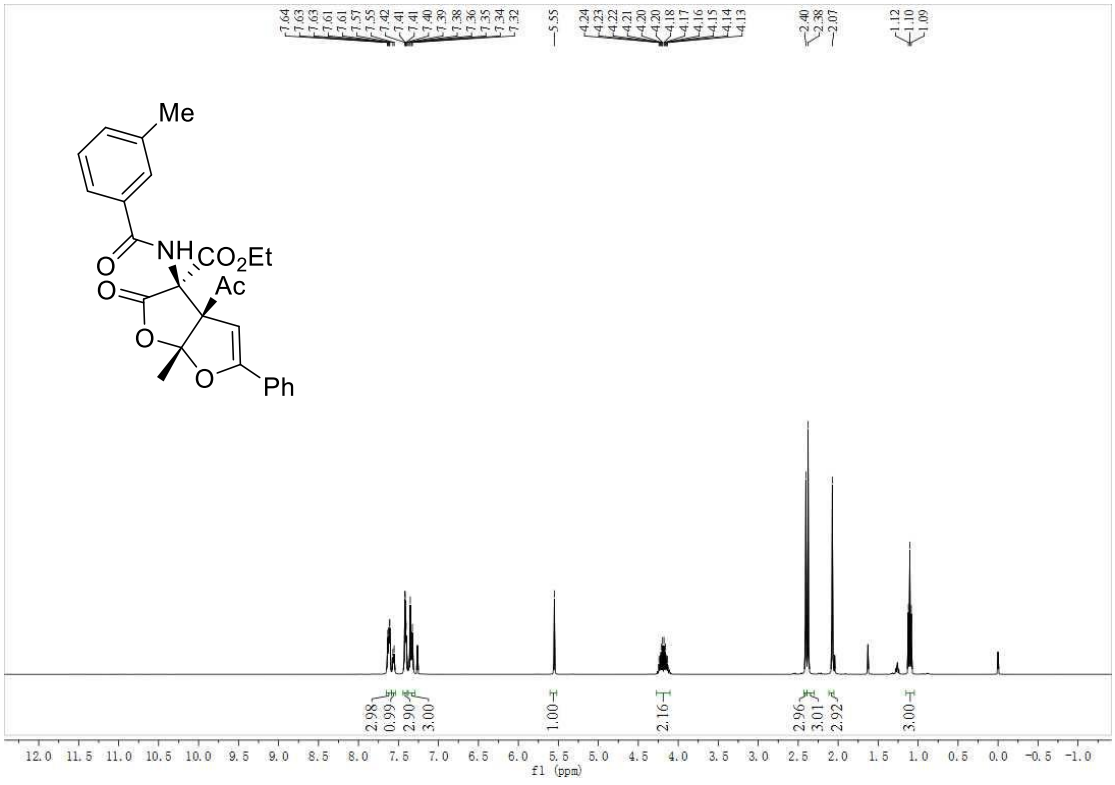
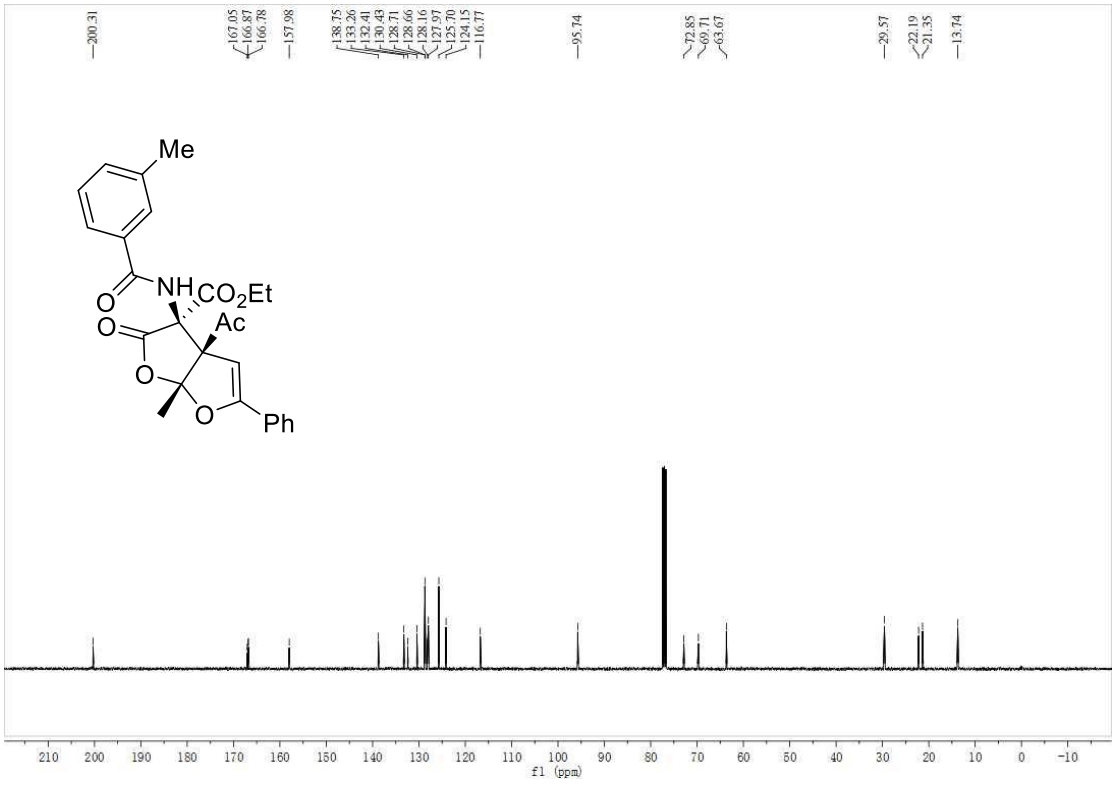
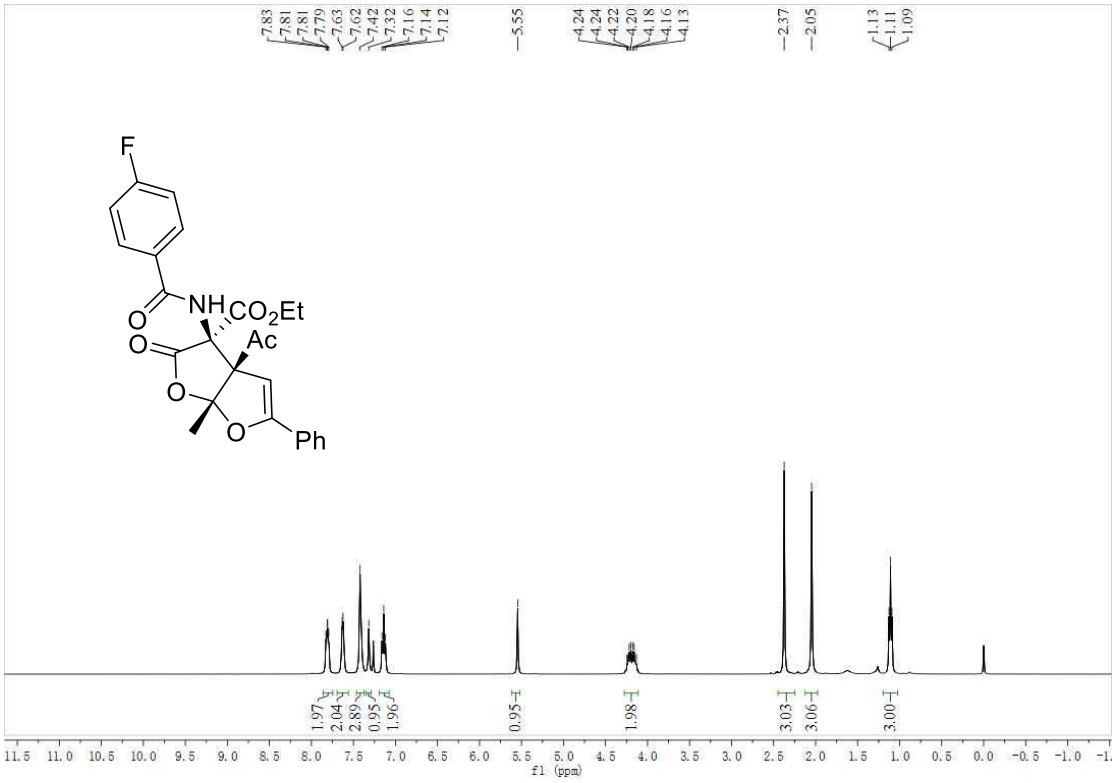
f1 (ppm)

(±)-3g





(±)-3h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7.79
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7.16
7.14
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4.24
4.24
4.22
4.20
4.18
4.16
4.13
2.37
2.05
1.13
1.11
1.09
F
NH
CO2Et
Ac
O
O
O
O
Ph
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2.89
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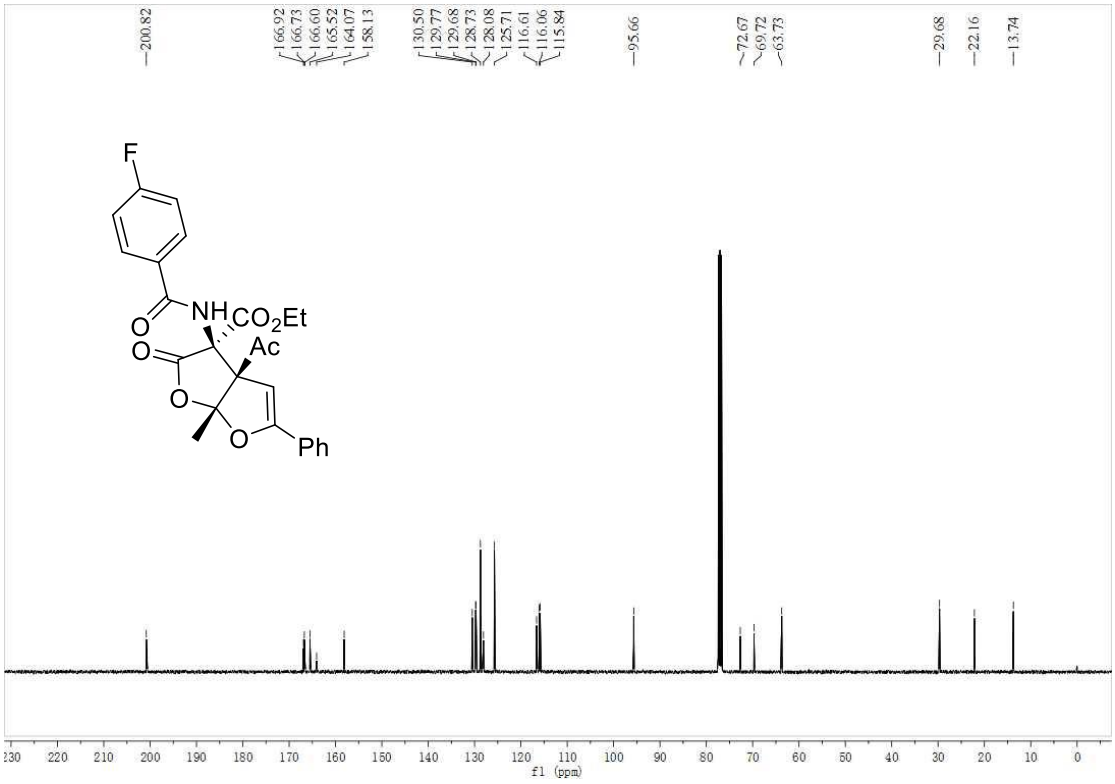
1.96
0.95
1.98
3.03
3.06
3.00
f1 (ppm)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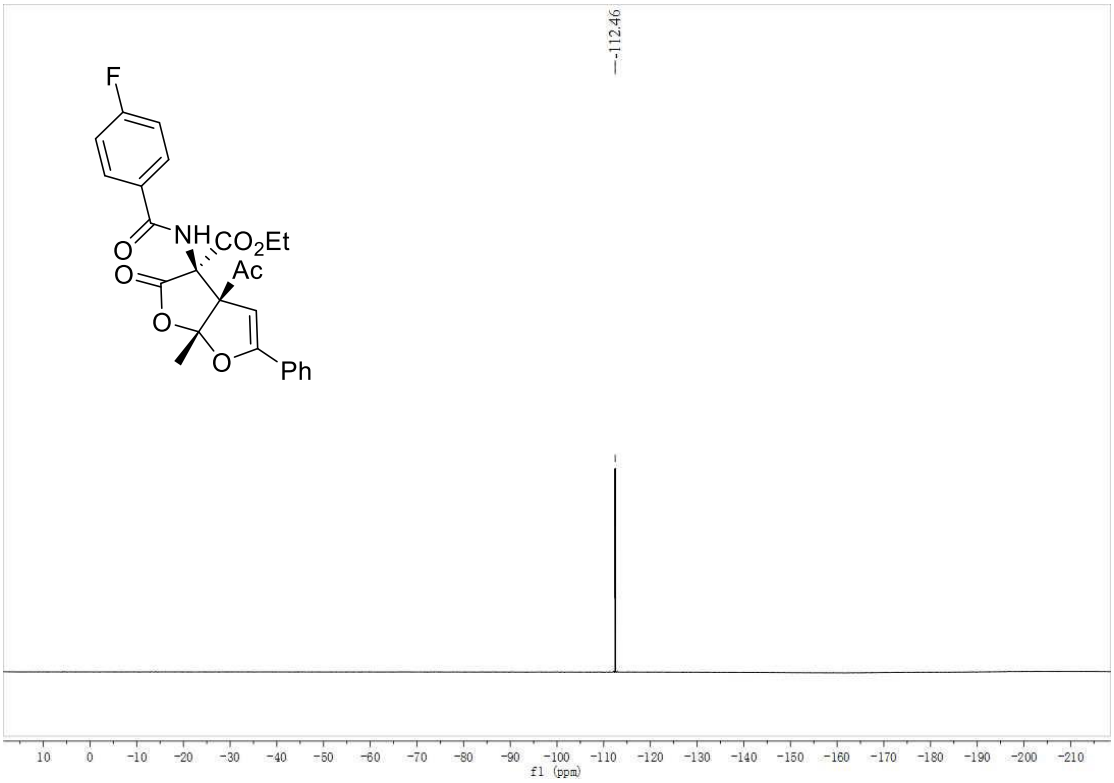
128.73
128.08
125.71
116.61
116.06
115.84
95.66
72.67
69.72
63.73
29.68
22.16
13.74
F
NH
CO2Et
Ac
O
O
O
O
Ph
f1 (ppm)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CO2Et
Ac
O
O
O
O
Ph
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10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
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-130
-140
-150
-160
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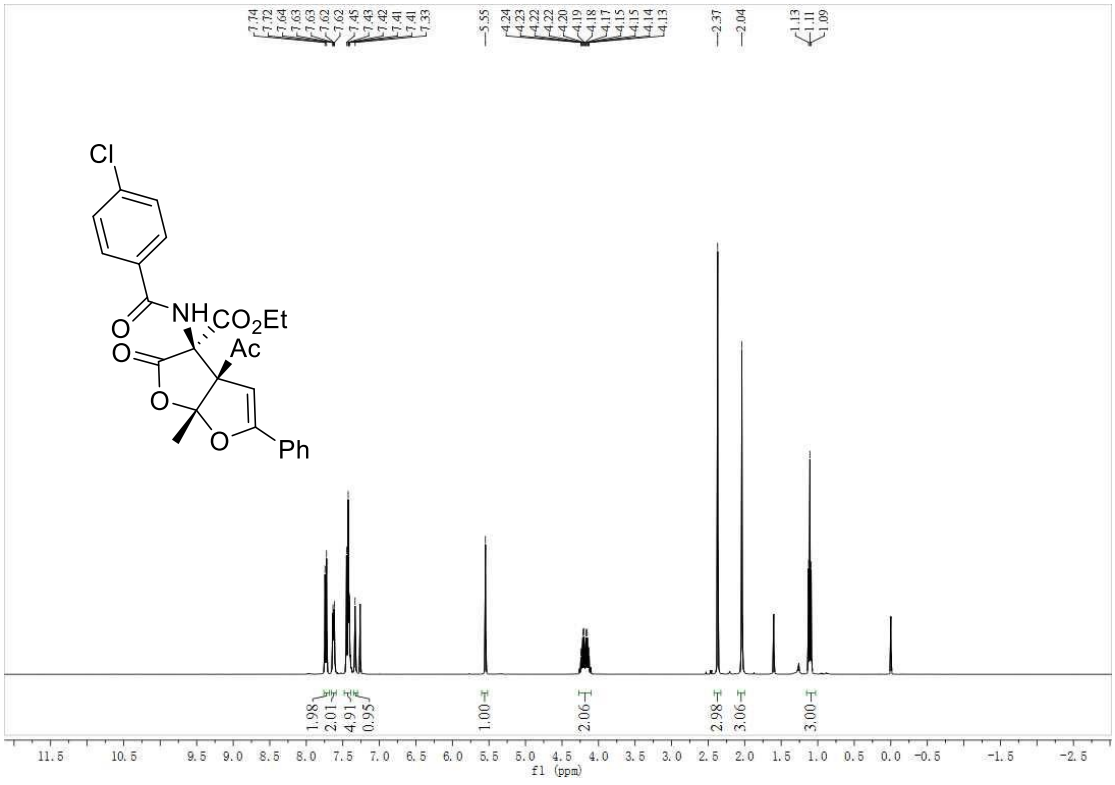
-180
-190
-200
-210
f1 (ppm)

(±)-3i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5.55
4.24
4.23
4.22
4.22
4.20
4.19
4.18
4.17
4.15
4.15
4.14
4.13
2.37
2.04
1.13
1.11
1.09
Cl
NH
CO2Et
Ac
O
O
O
O
Ph
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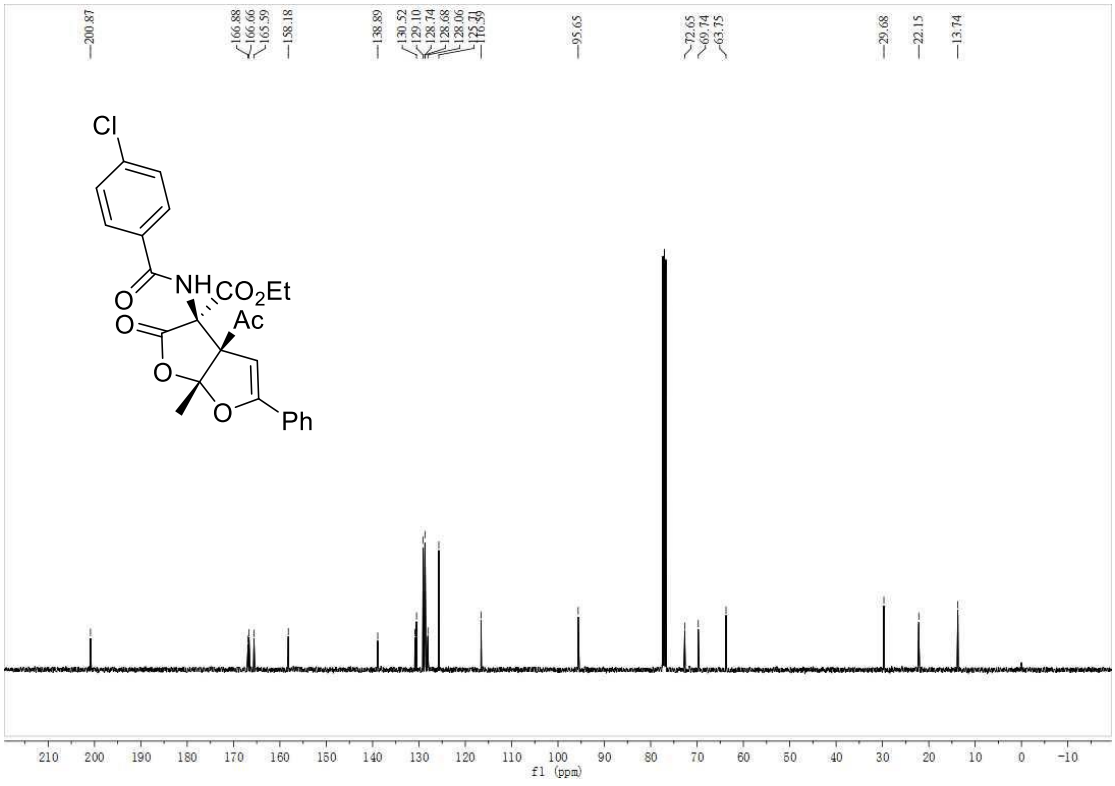
0.95
1.00
2.06
2.98
3.06
3.00
f1 (ppm)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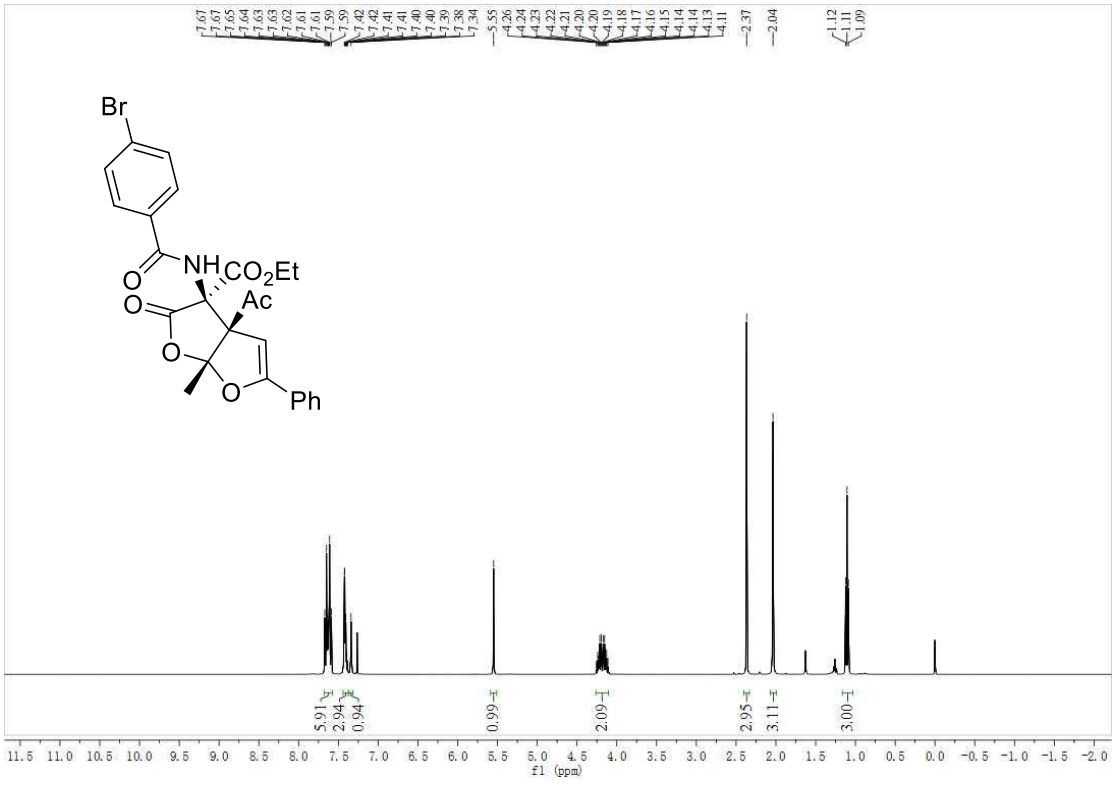
72.65
69.74
63.75
29.68
22.15
13.74
Cl
NH
CO2Et
Ac
O
O
O
O
Ph
f1 (ppm)

(±)-3j


Br
NH
CO2Et
Ac
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O
O
O
Ph
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7.42
7.41
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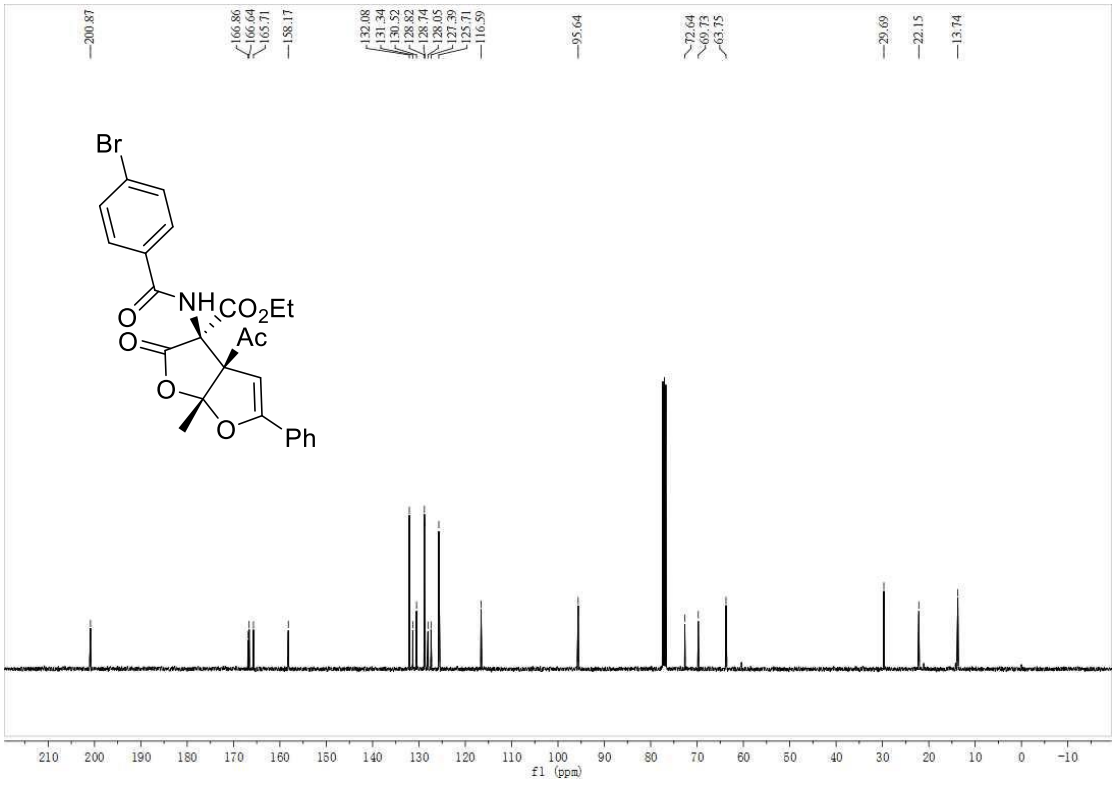
7.39
7.38
7.34
5.55
4.26
4.24
4.23
4.22
4.21
4.20
4.19
4.18
4.17
4.16
4.15
4.14
4.13
4.11
2.37
2.04
1.12
1.11
1.09
5.91
2.94
0.94
0.99
2.09
2.95
3.11
3.00
f1 (ppm)


Br
NH
CO2Et
Ac
O
O
O
O
Ph
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158.17
132.08
131.34
130.52
128.82
128.74
128.05
127.39
125.71
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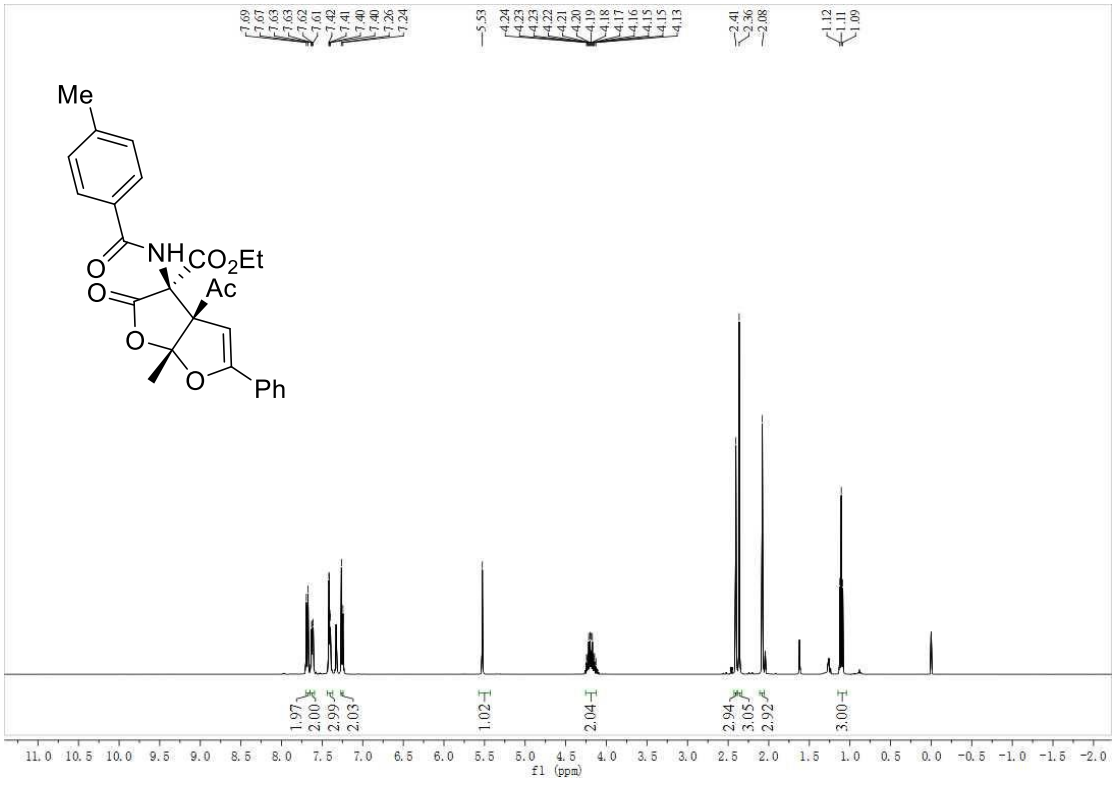
95.64
72.64
69.73
63.75
29.69
22.15
13.74
f1 (ppm)

(±)-3k


Me
NH
CO2Et
Ac
O
O
O
O
Ph
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7.62
7.61
7.42
7.41
7.40
7.40
7.26
7.24
5.53
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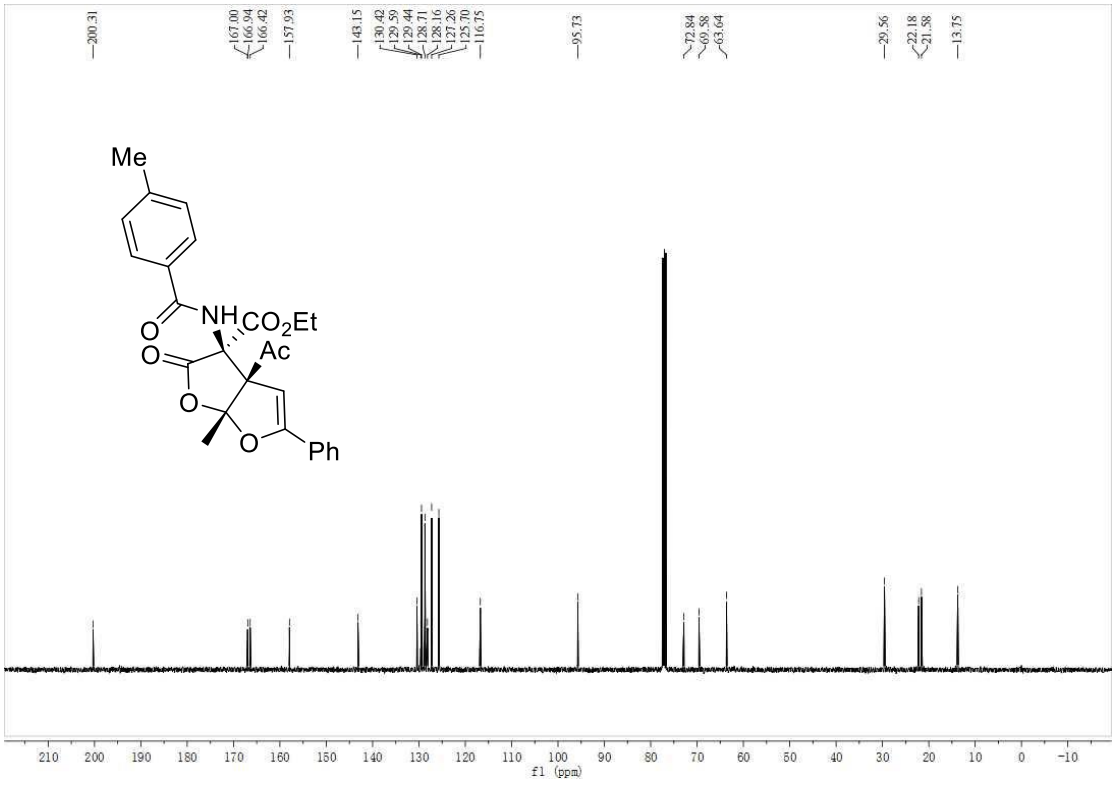
4.23
4.23
4.22
4.21
4.20
4.19
4.18
4.17
4.16
4.15
4.15
4.13
2.41
2.36
2.08
1.12
1.11
1.09
1.97
2.00
2.99
2.03
1.02
2.04
2.94
3.05
2.92
3.00
f1 (ppm)


Me
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O
O
O
Ph
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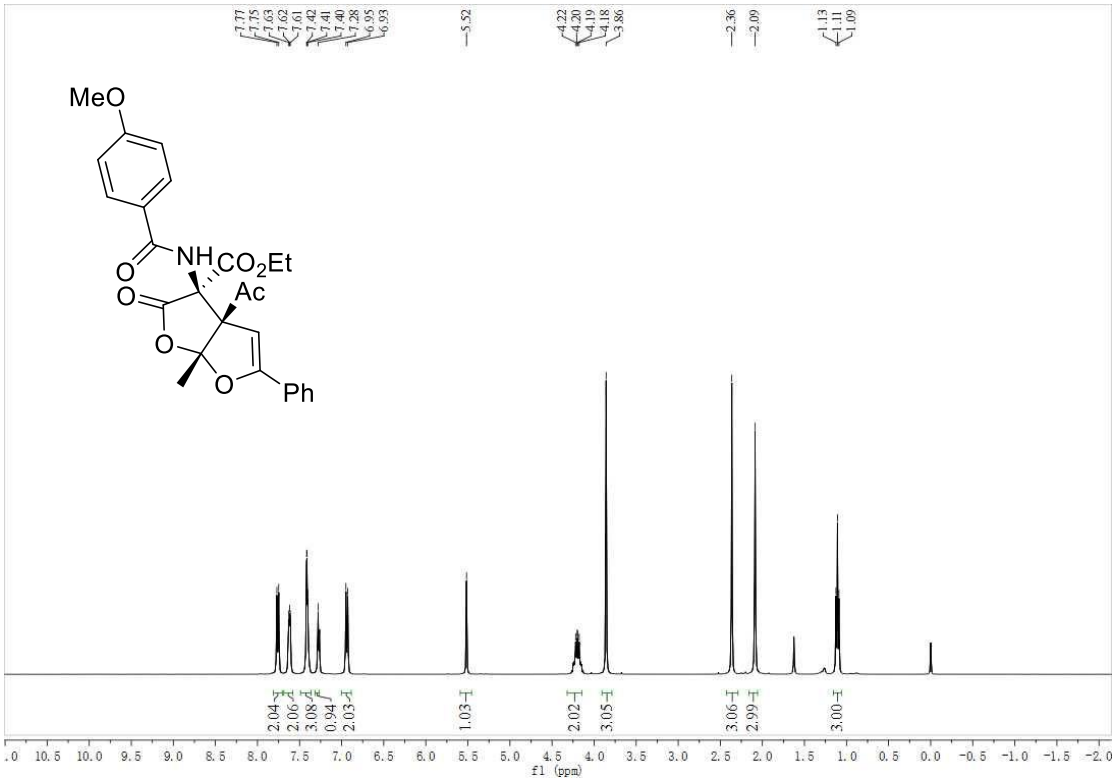
130.42
129.59
129.44
128.71
128.16
127.26
125.70
116.75
95.73
72.84
69.58
63.64
29.56
22.18
21.58
13.75
f1 (ppm)

(±)-3l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NH
CO2Et
Ac
O
O
O
O
Ph
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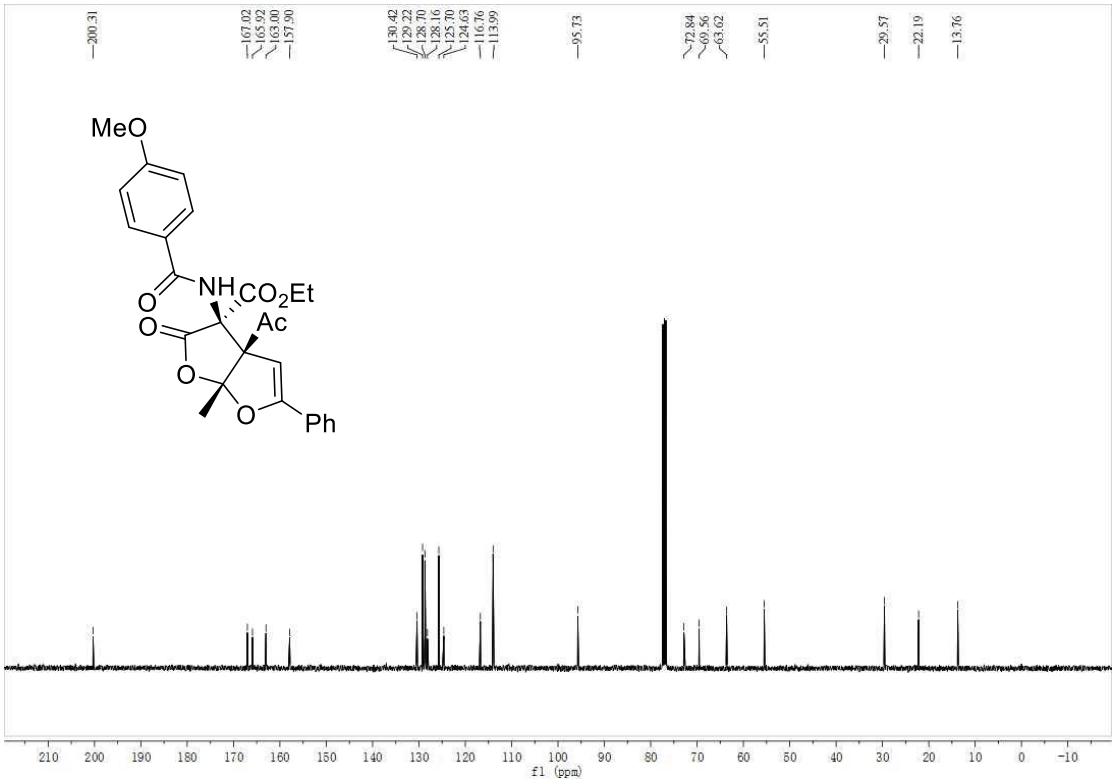
7.62
7.61
7.42
7.41
7.40
7.28
6.95
6.93
5.52
4.22
4.20
4.19
4.18
3.86
2.36
2.09
1.13
1.11
1.09
2.04
2.06
3.08
0.94
2.03
1.03
2.02
3.05
3.06
2.99
3.00
f1 (ppm)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CO2Et
Ac
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O
O
O
Ph
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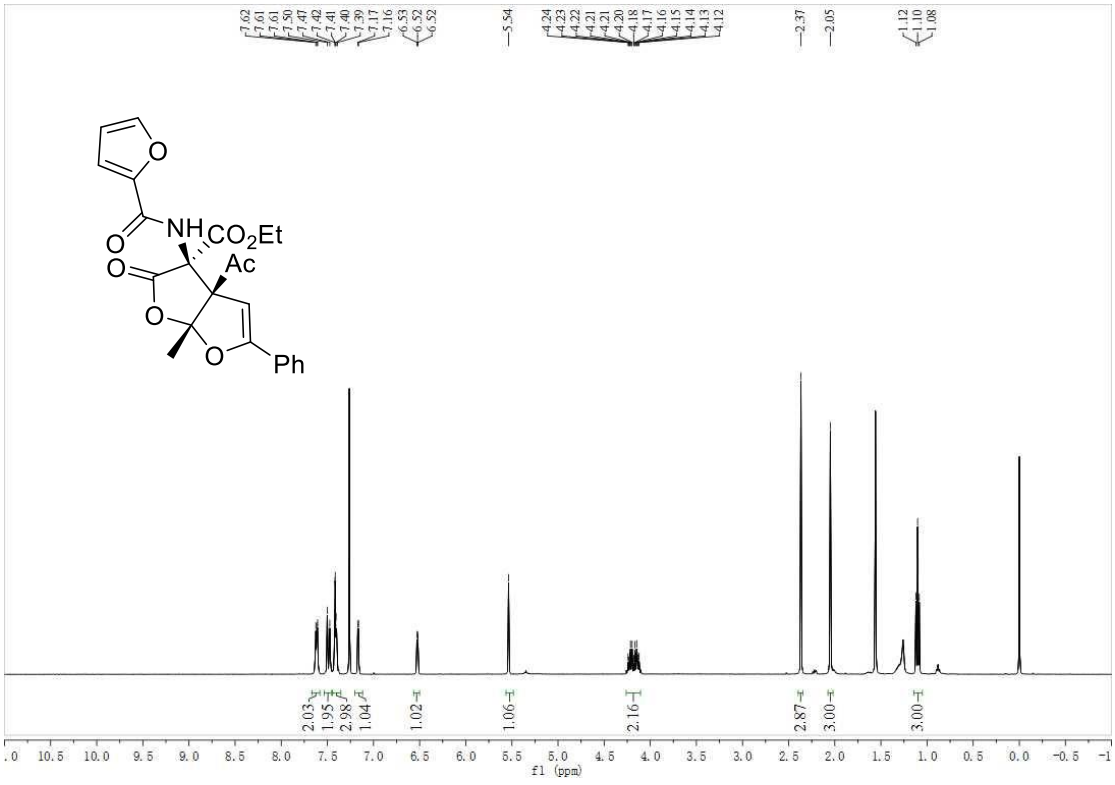
165.92
163.00
157.90
130.42
129.22
128.70
128.16
125.70
124.63
116.76
113.99
95.73
72.84
69.56
63.62
55.51
29.57
22.19
13.76
f1 (ppm)

(±)-3m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7.61
7.61
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7.42
7.41
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7.39
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7.16
6.53
6.52
6.52
5.54
4.24
4.23
4.22
4.21
4.21
4.20
4.18
4.17
4.16
4.15
4.14
4.13
4.12
2.37
2.05
1.12
1.10
1.08
NH
CO2Et
Ac
Ph
2.03
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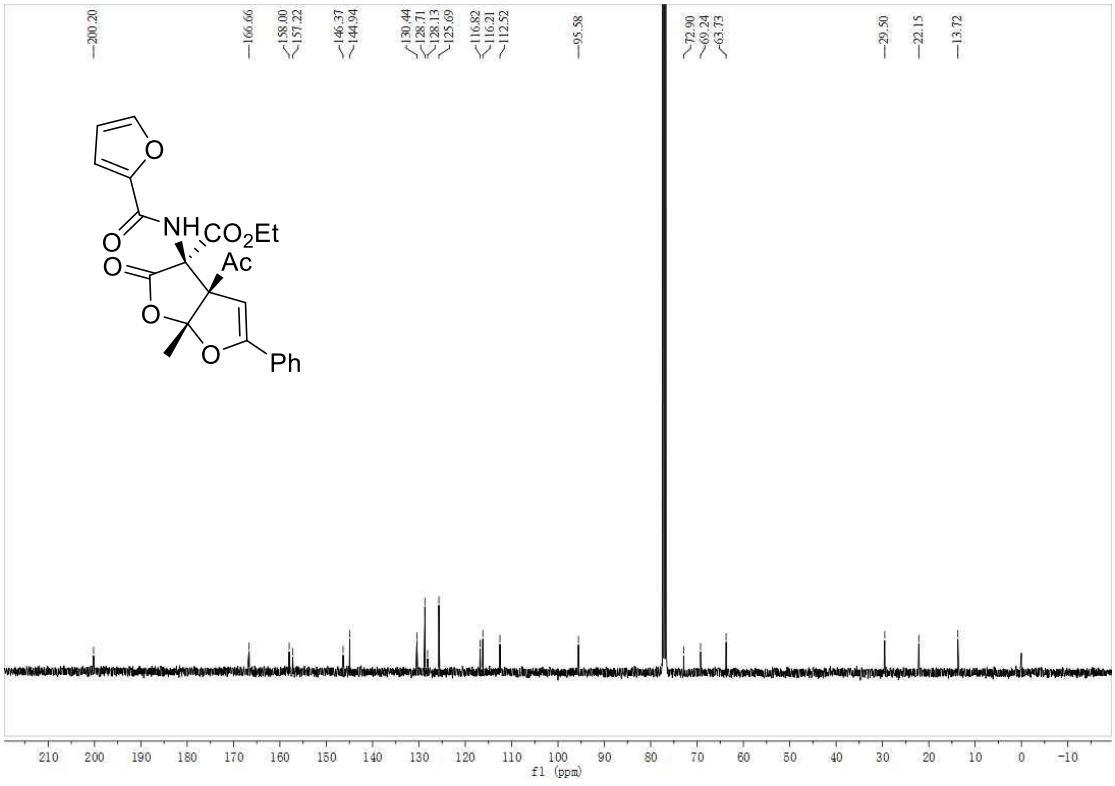
2.98
1.04
1.02
1.06
2.16
2.87
3.00
3.00
f1 (ppm)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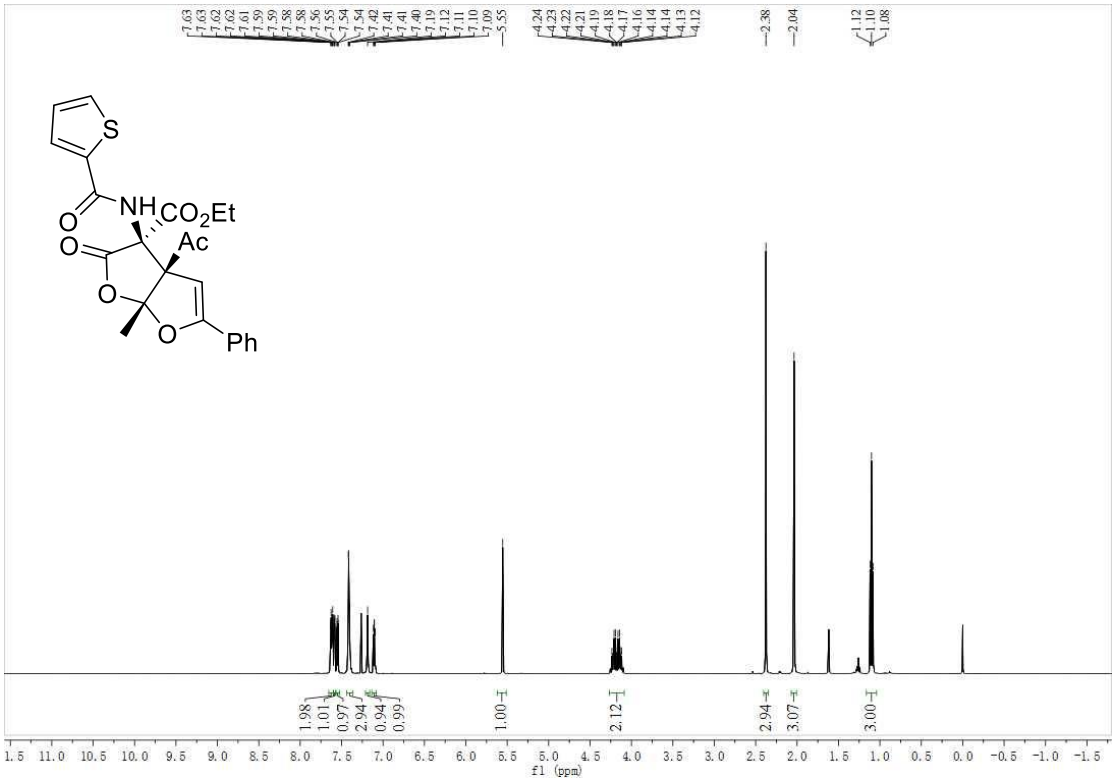
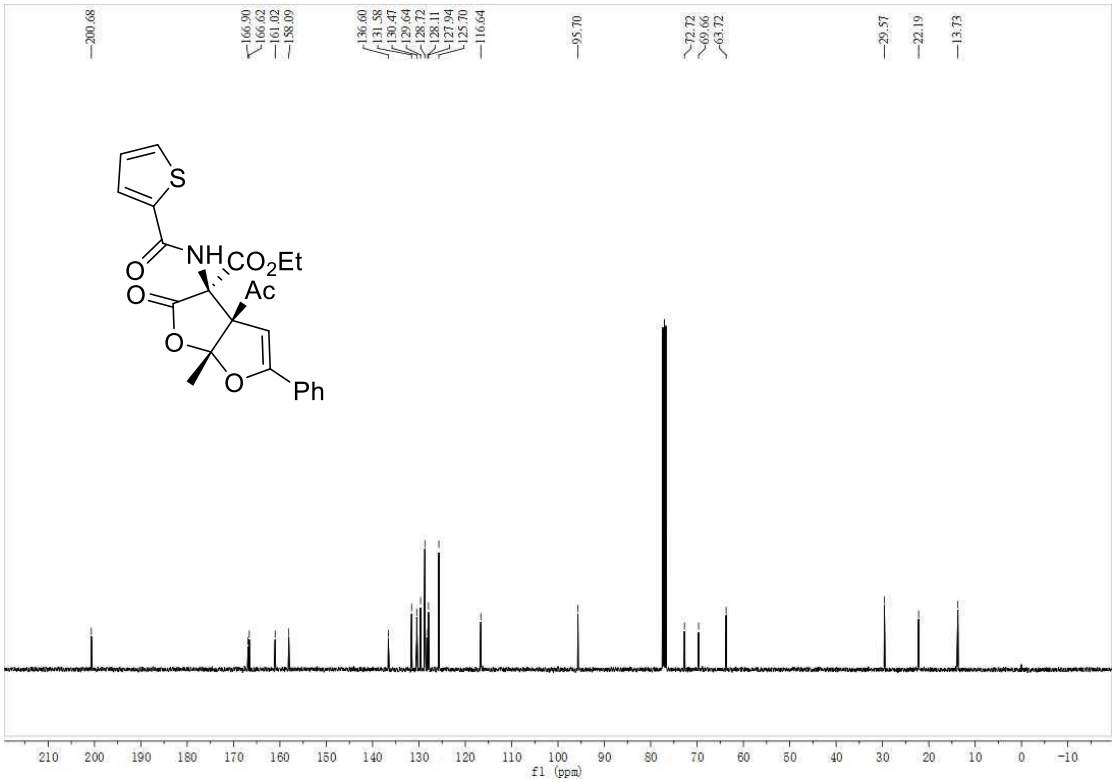
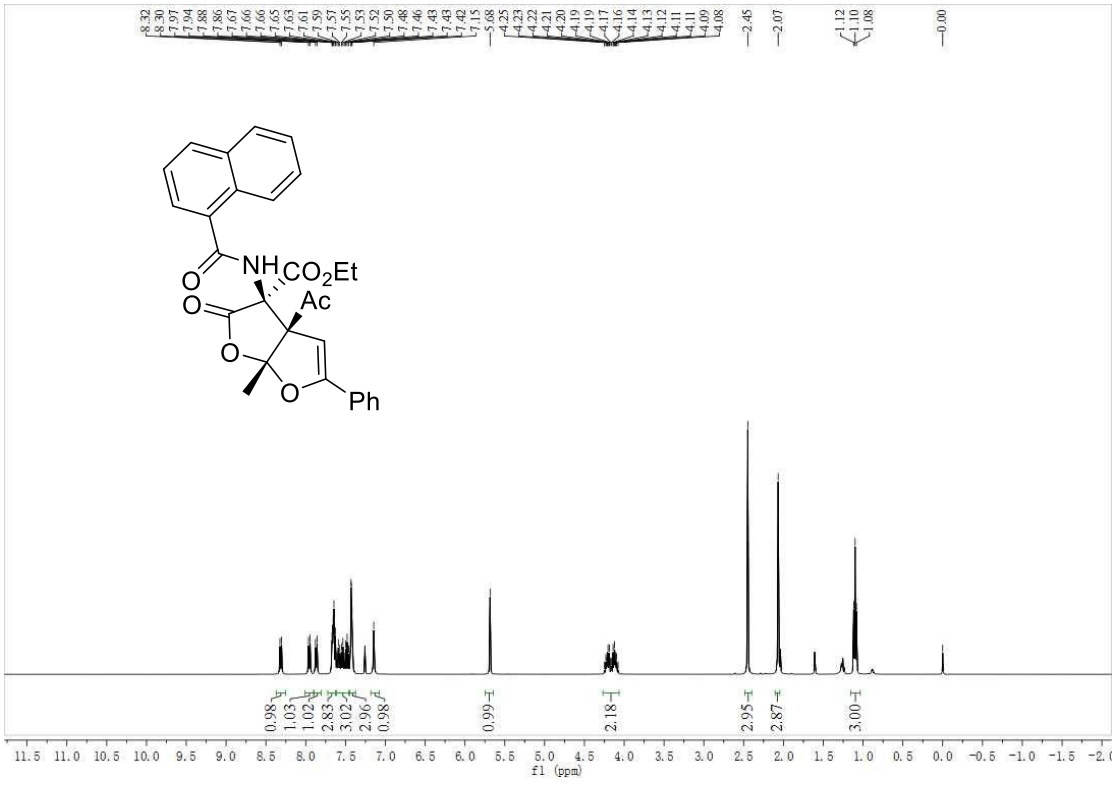
128.71
128.13
125.69
116.82
116.21
112.52
95.58
72.90
69.24
63.73
29.50
22.15
13.72
NH
CO2Et
Ac
Ph
f1 (ppm)

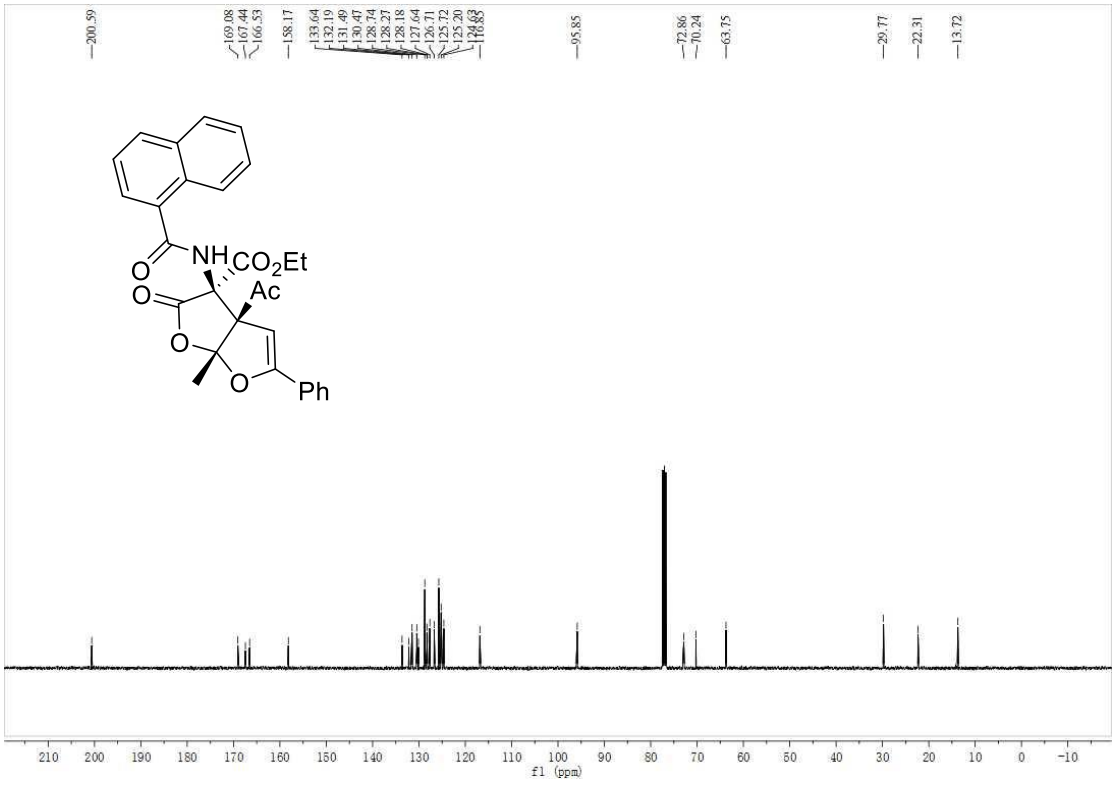
(±)-3n



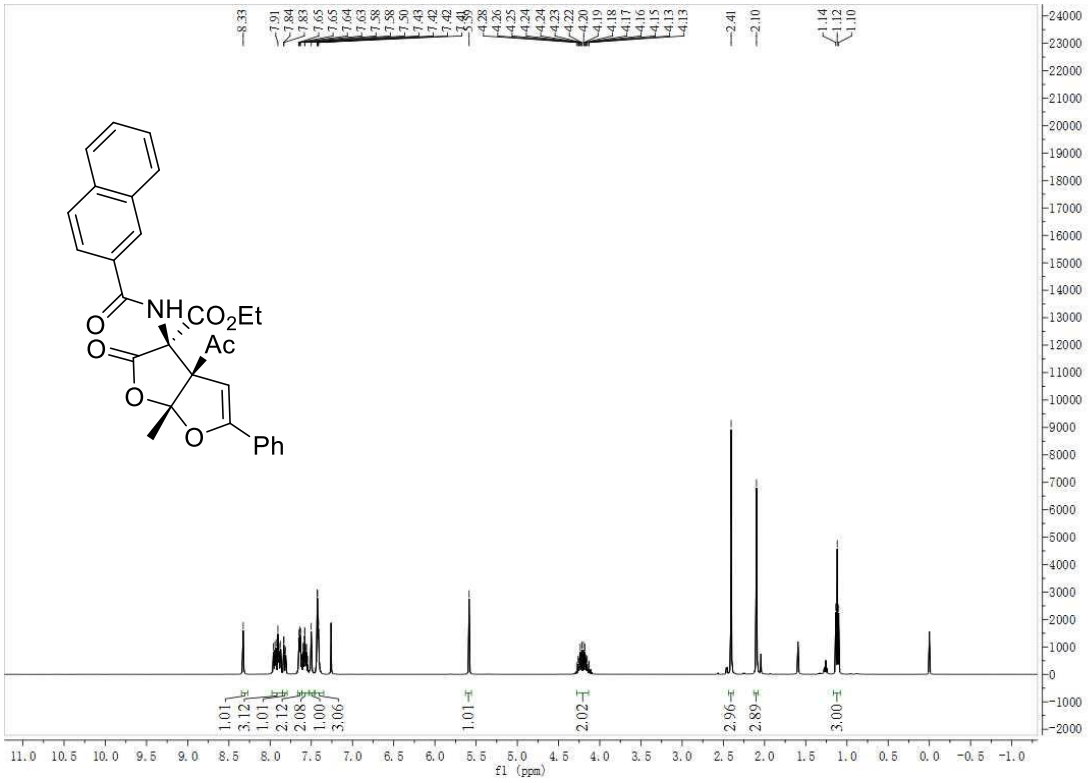


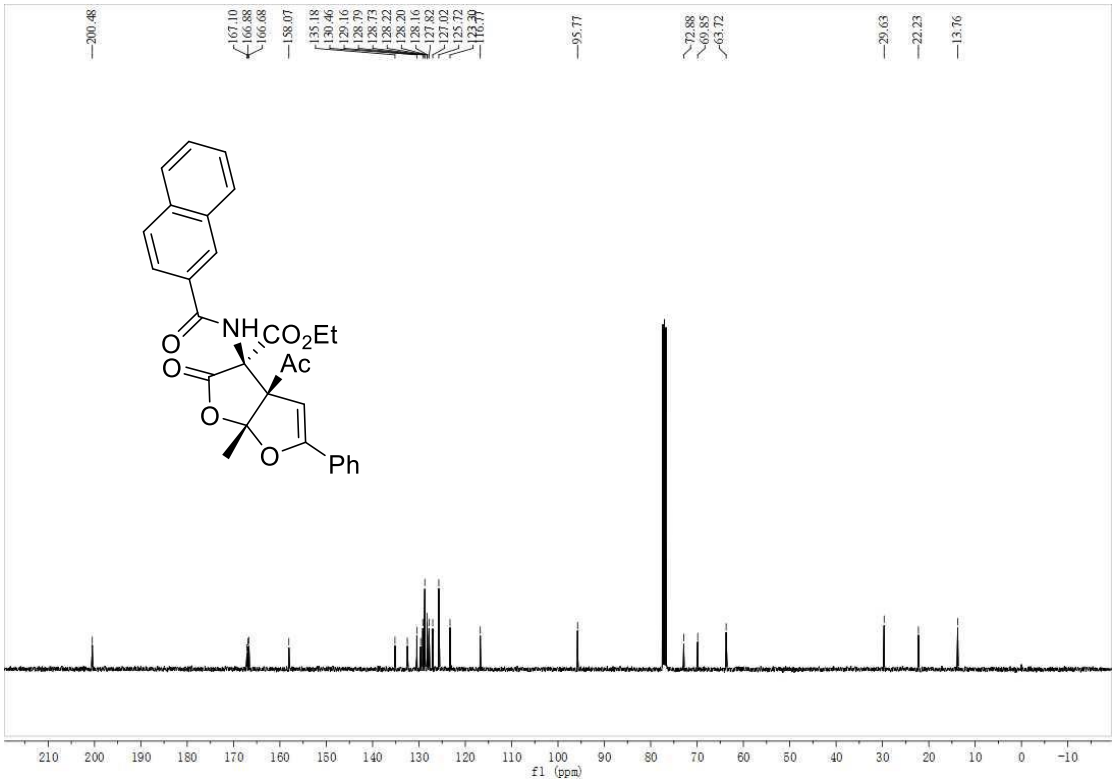
(±)-3o



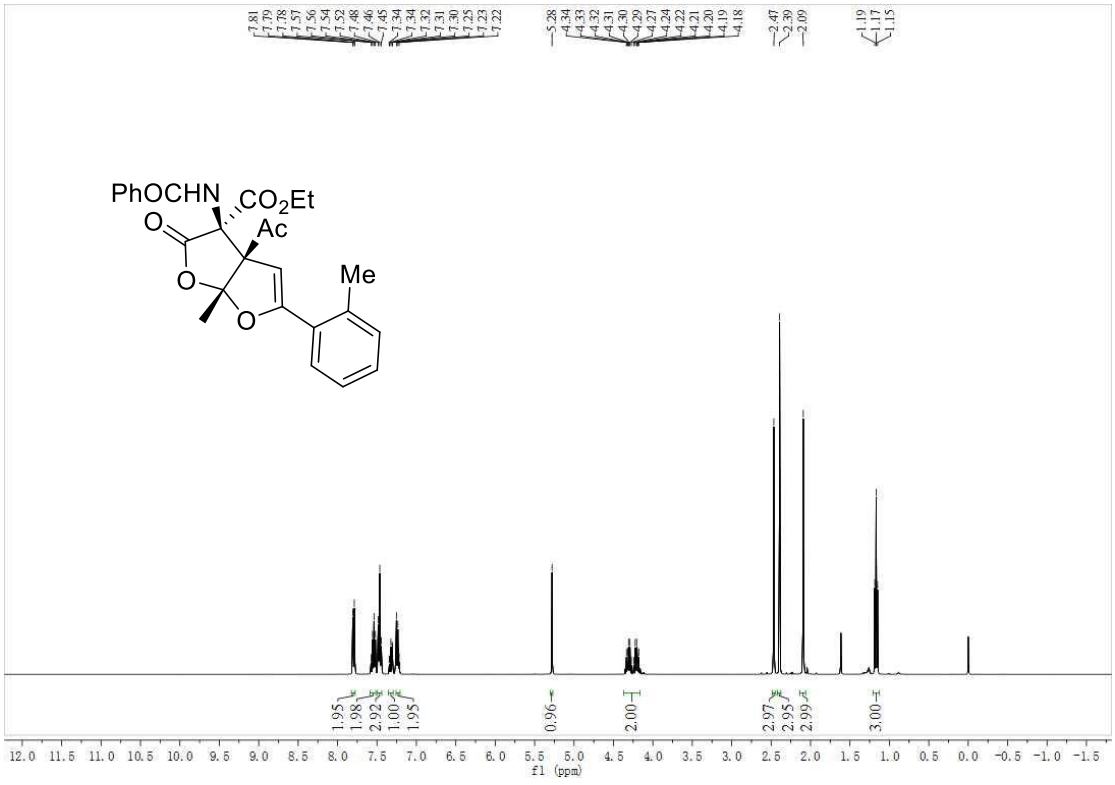


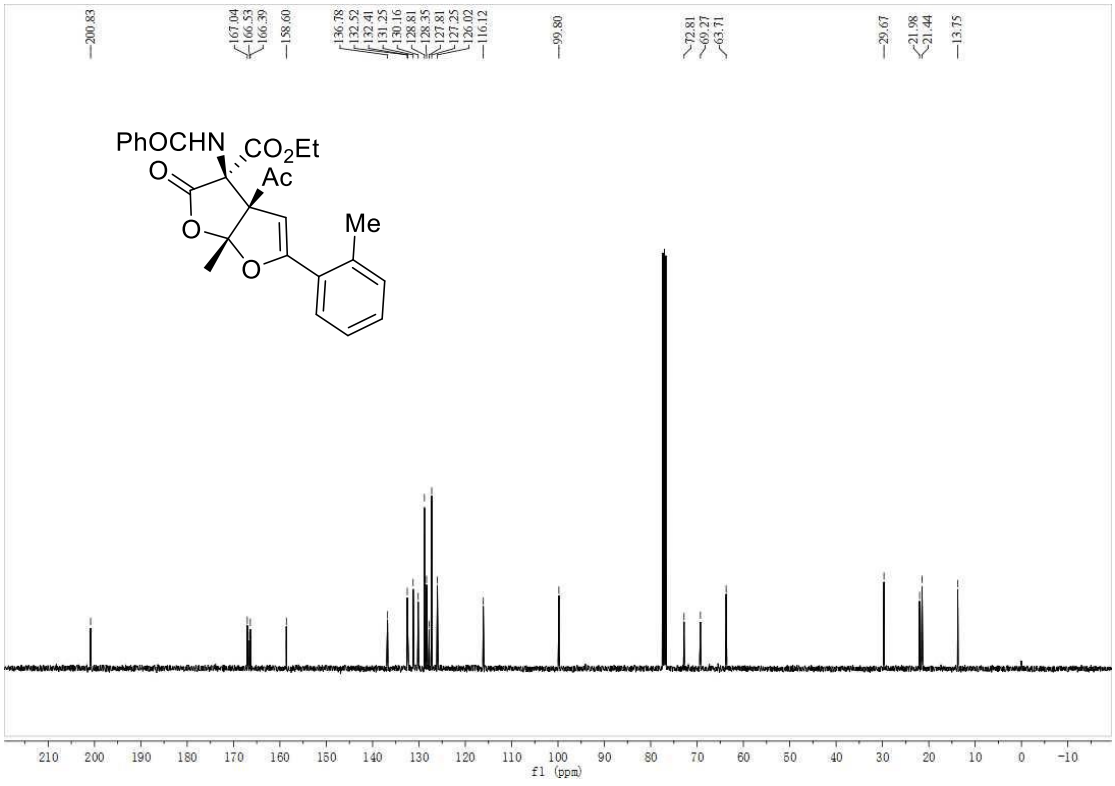
(±)-3p



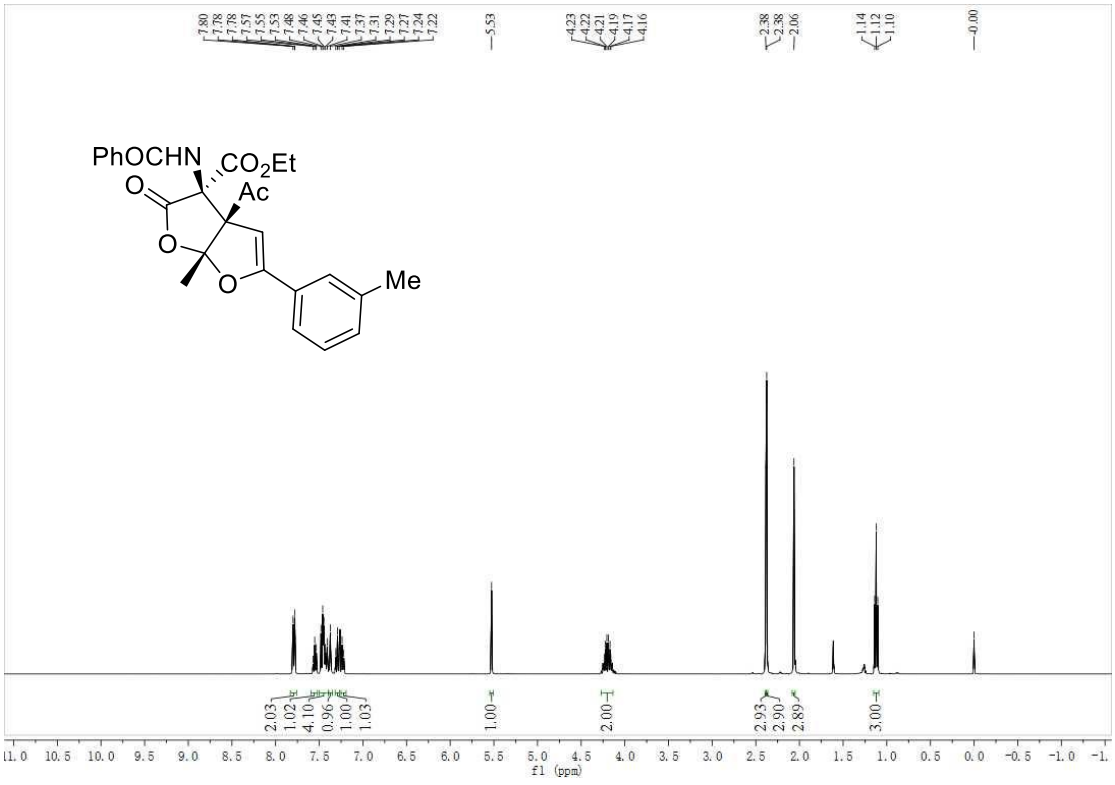


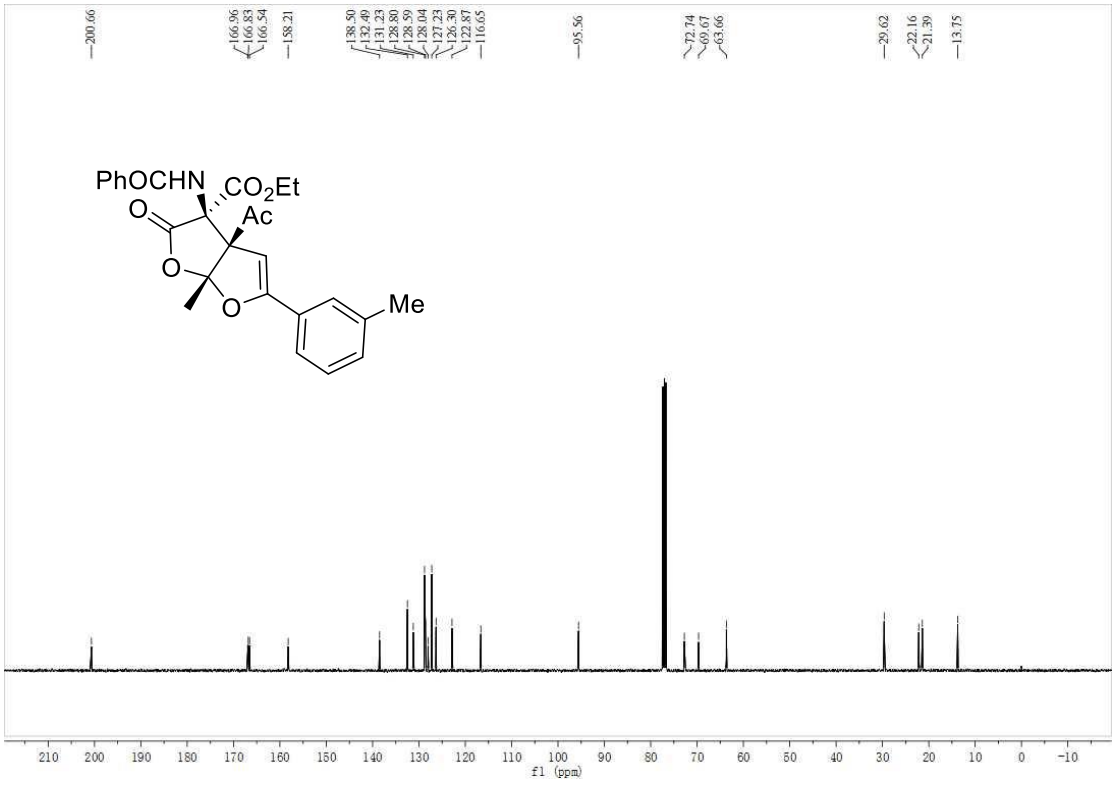
(±)-3q



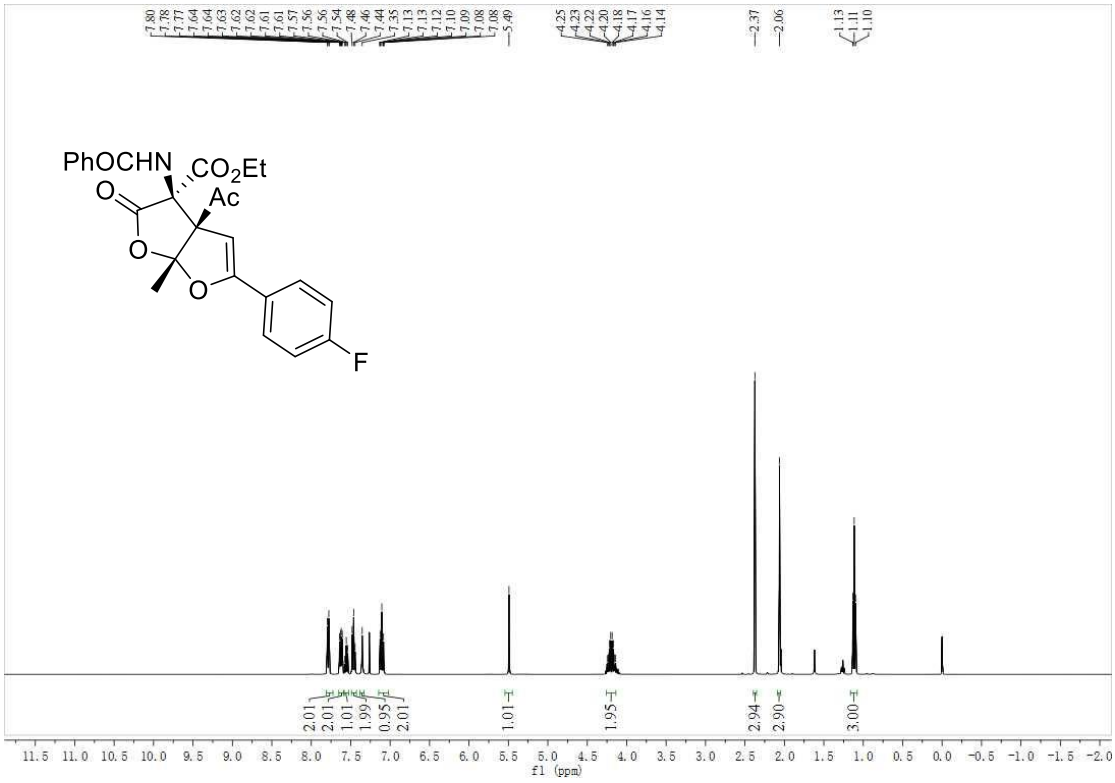


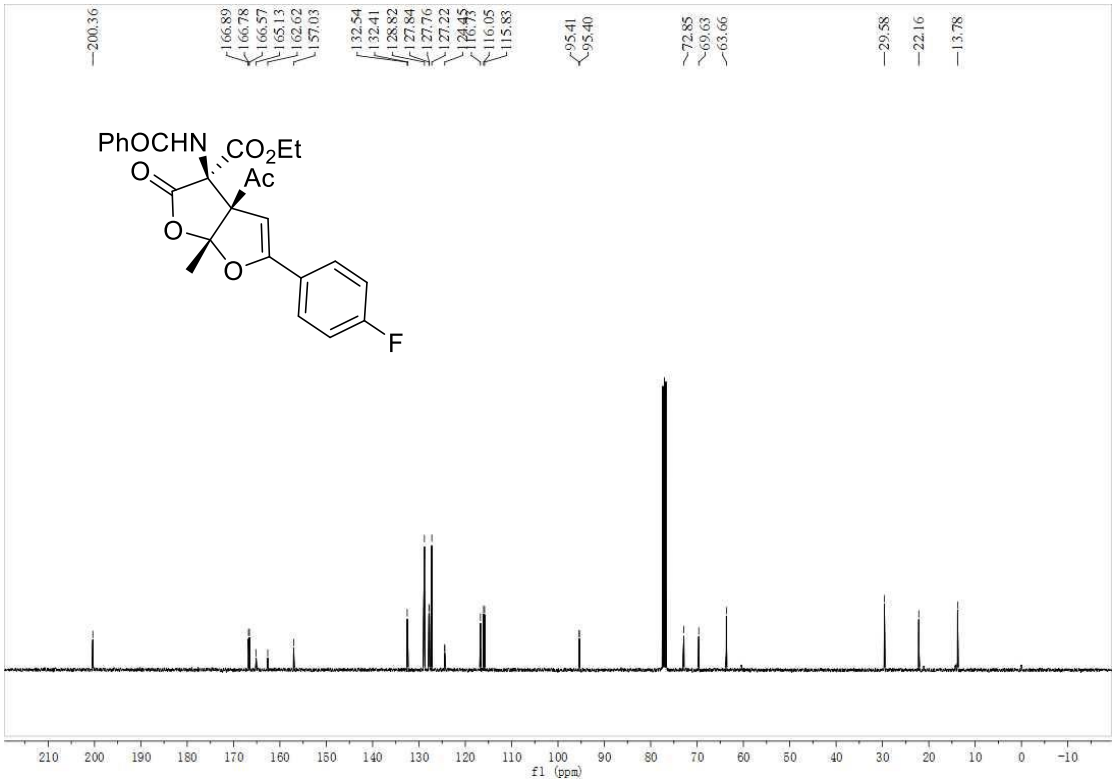
(±)-3r

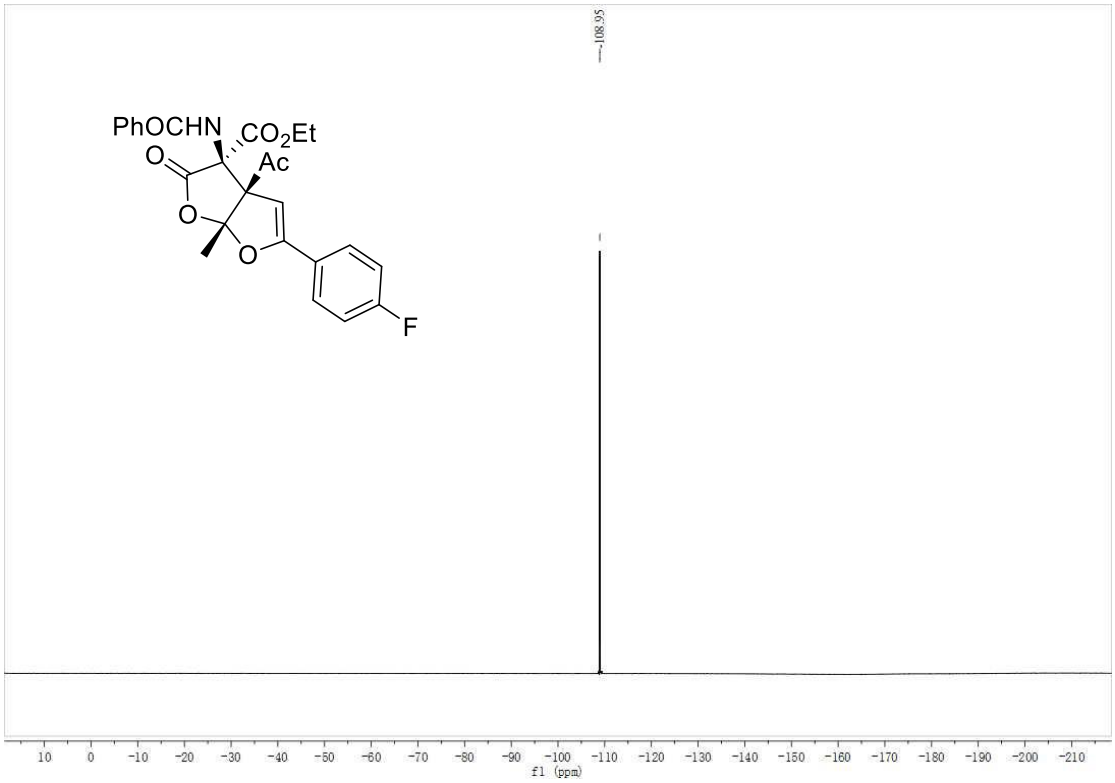




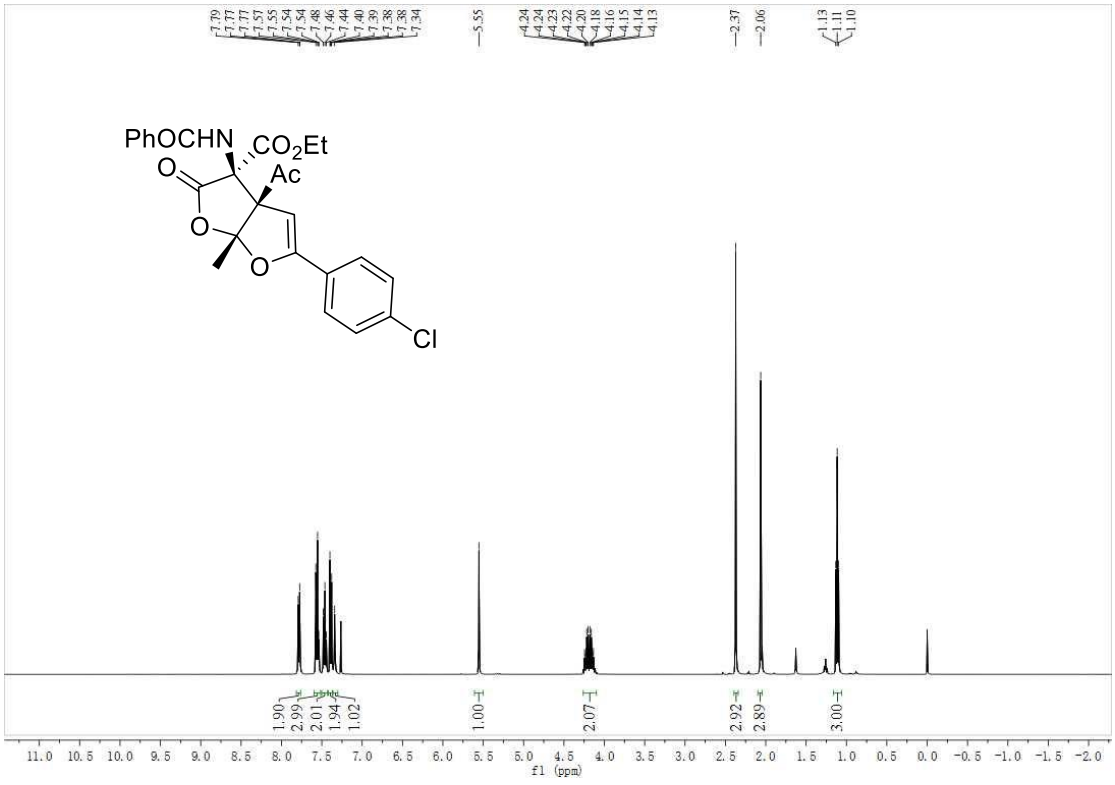
(±)-3s

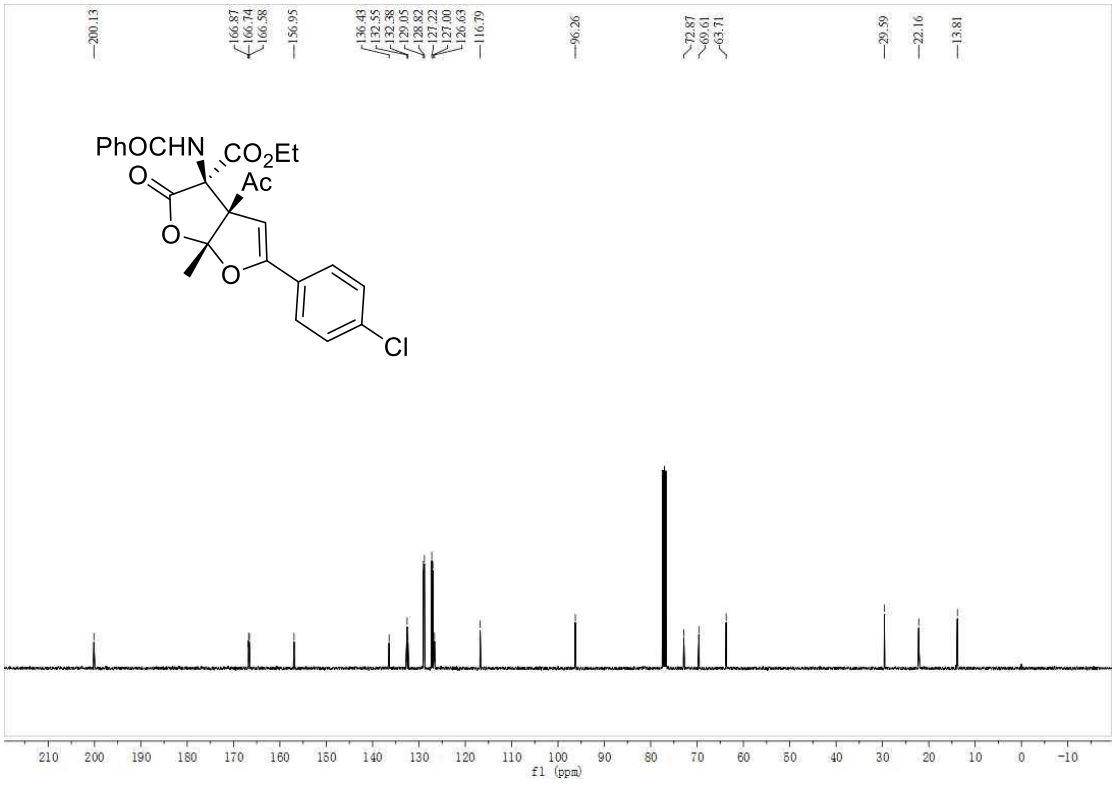




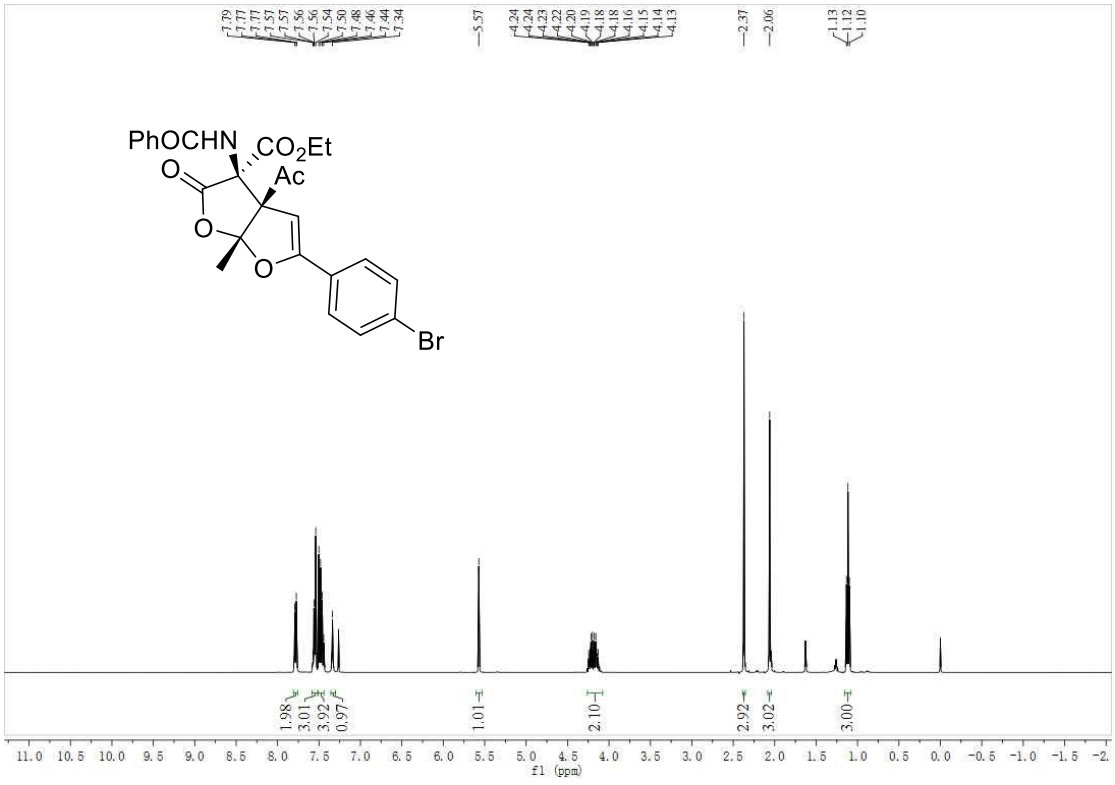

-108.95
PhOCHN
CO2Et
Ac
O
O
O
F
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

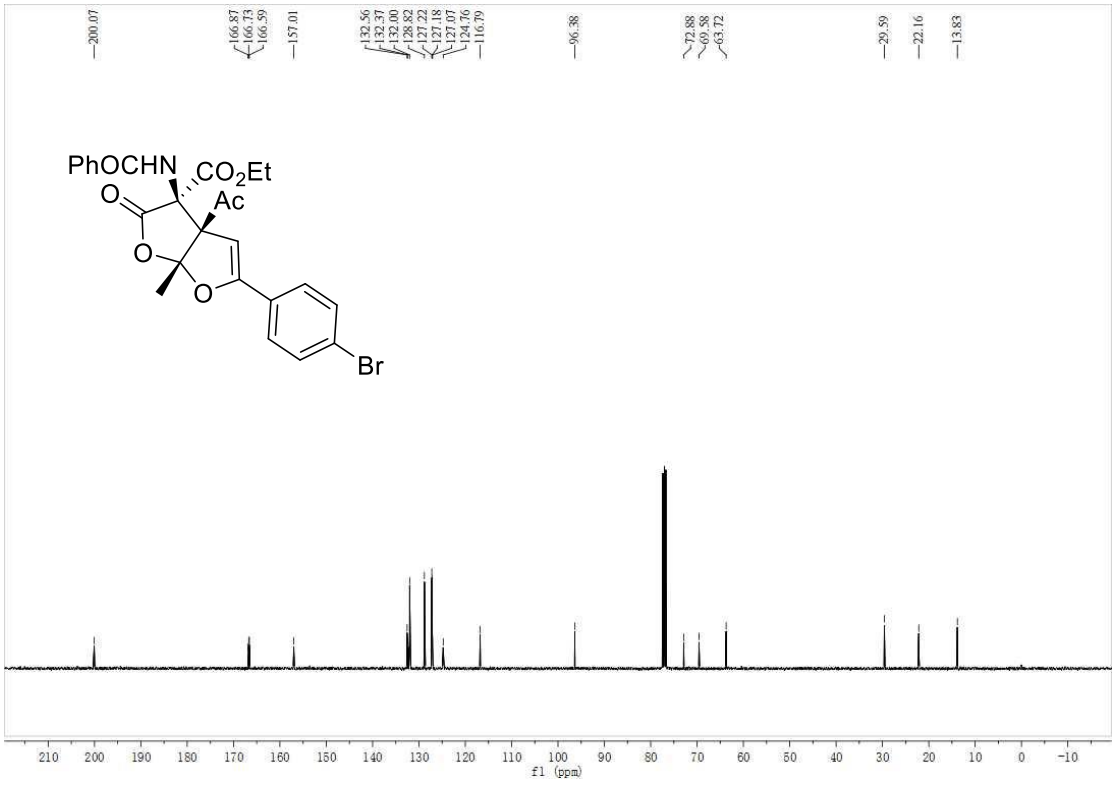
(±)-3t



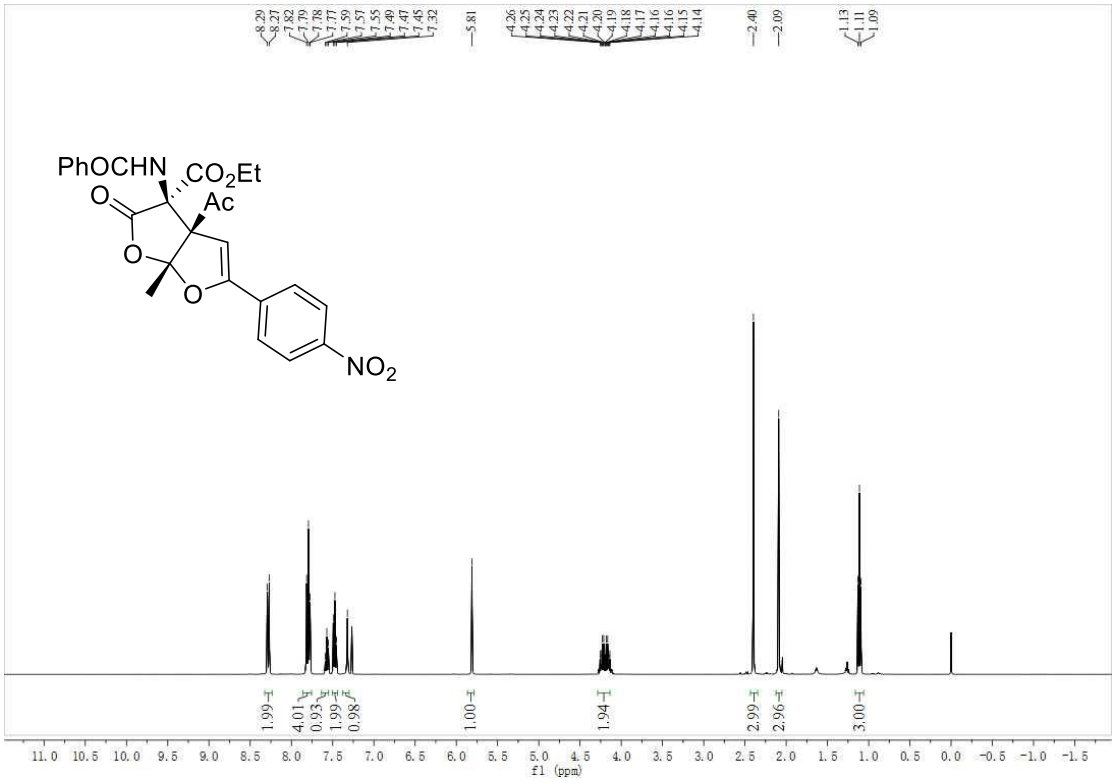


(±)-3u





(±)-3v


8.29
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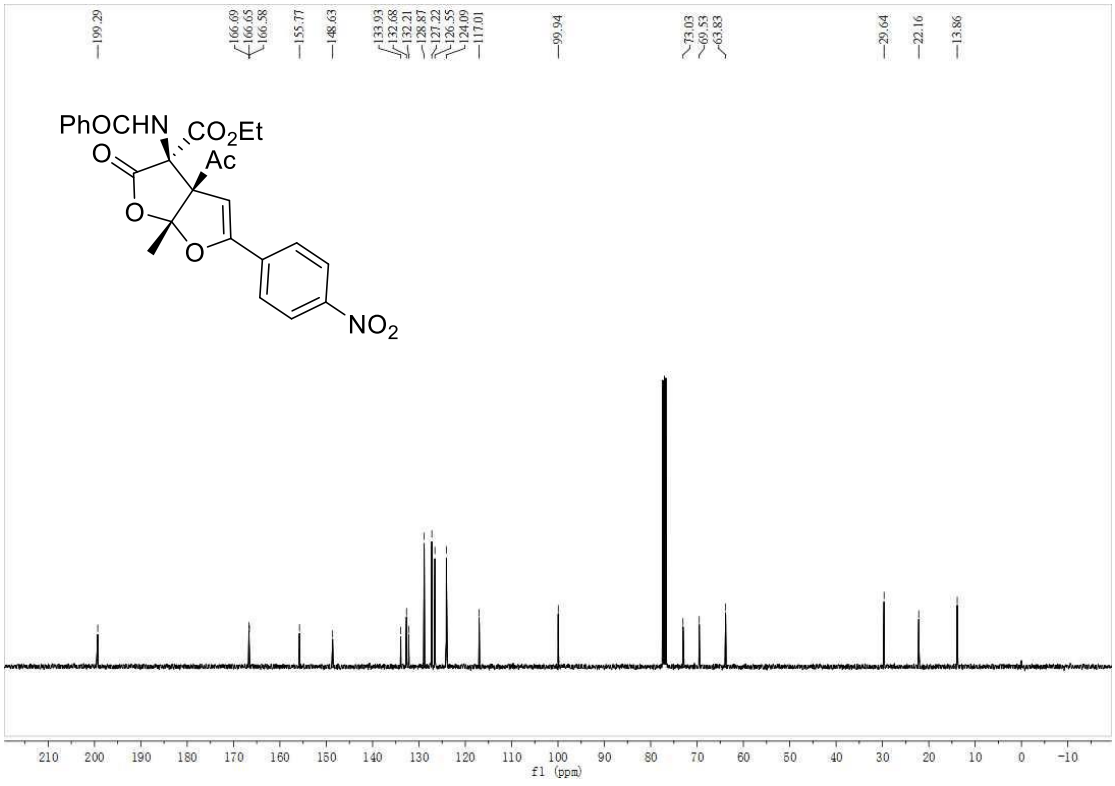
7.78
7.77
7.59
7.57
7.55
7.49
7.47
7.45
7.32
5.81
4.26
4.25
4.24
4.23
4.22
4.21
4.20
4.19
4.18
4.17
4.16
4.16
4.15
4.14
2.40
2.09
1.13
1.11
1.09
PhOCHN
CO2Et
Ac
O
O
O
NO2
1.99
4.01
0.93
1.99
0.98
1.00
1.94
2.99
2.96
3.00
f1 (ppm)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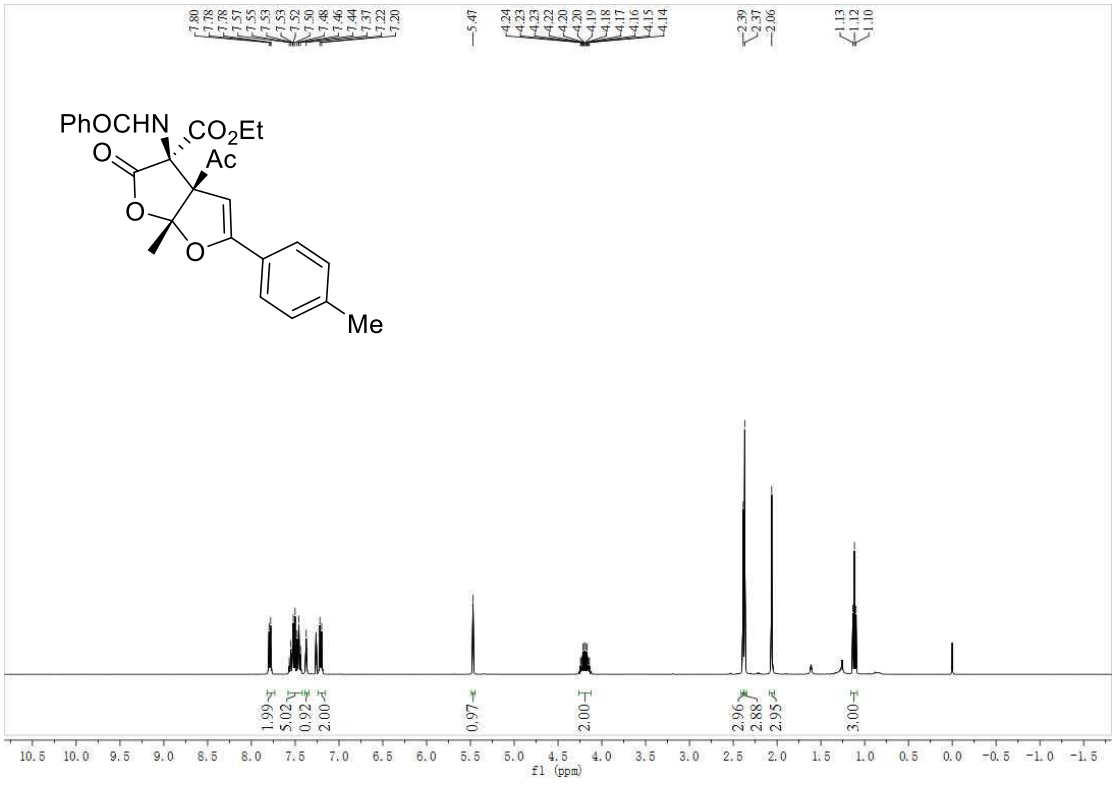
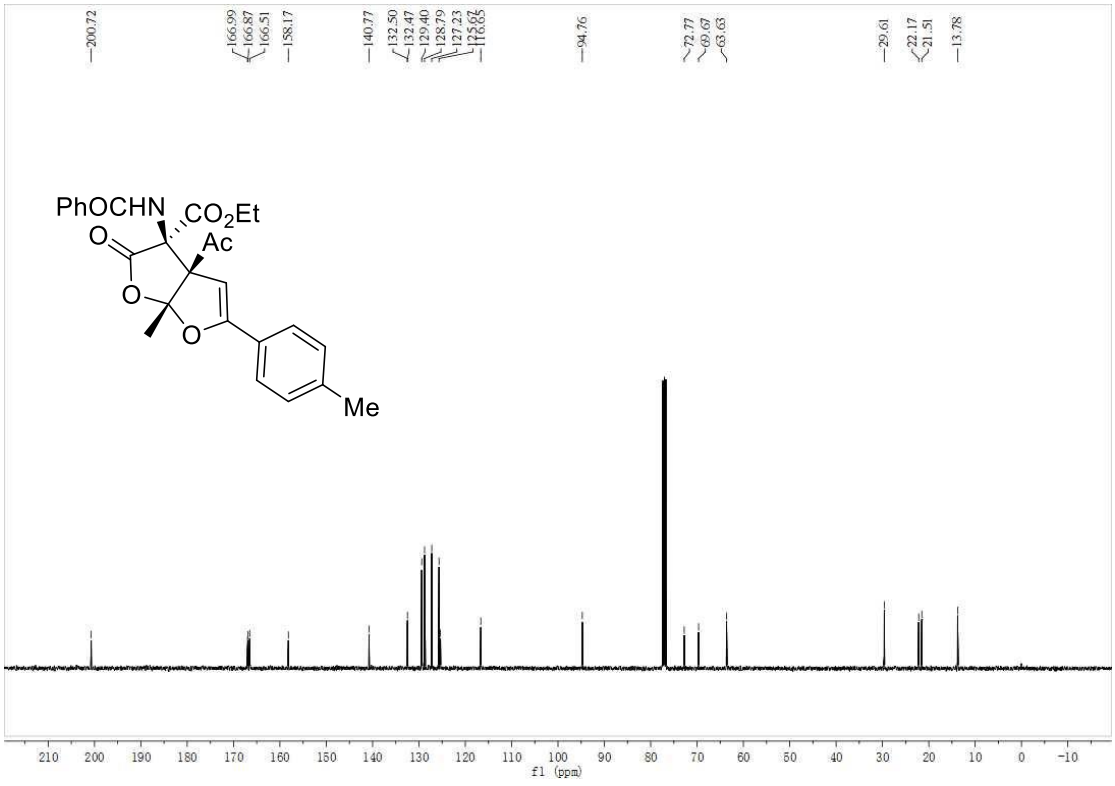
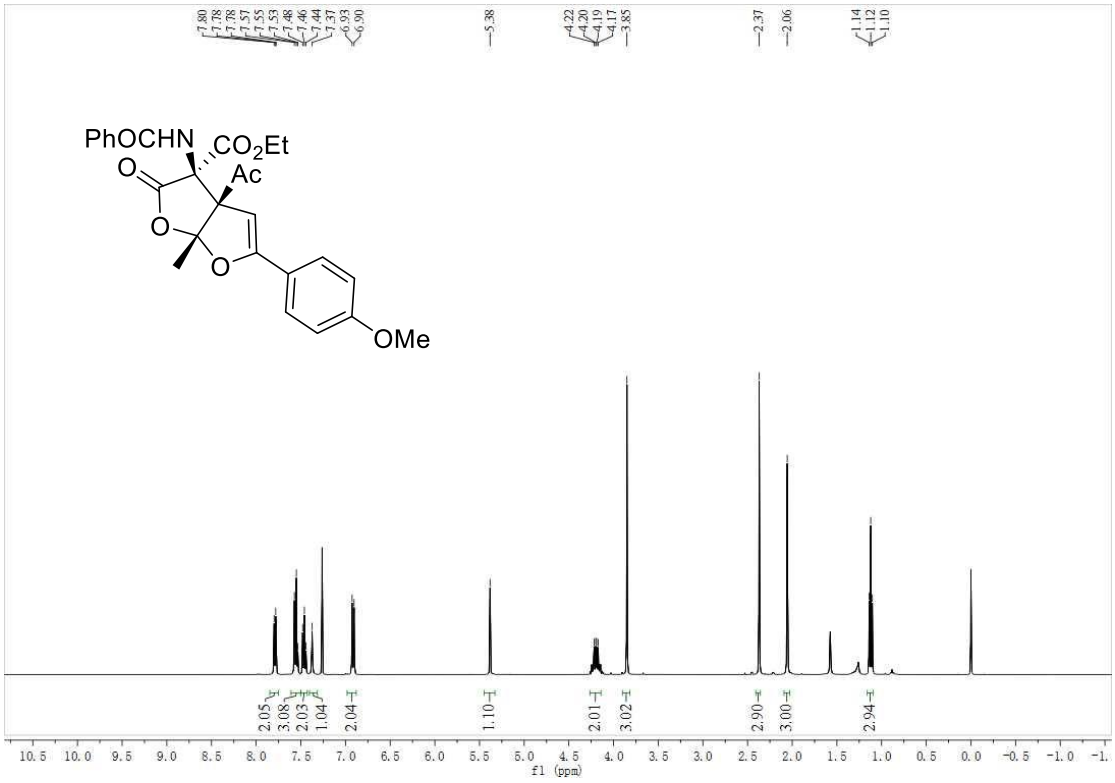
133.93
132.68
132.21
128.87
127.22
126.55
124.09
117.01
99.94
73.03
69.53
63.83
29.64
22.16
13.86
PhOCHN
CO2Et
Ac
O
O
O
NO2
f1 (ppm)

(±)-3w





(±)-3x


7.80
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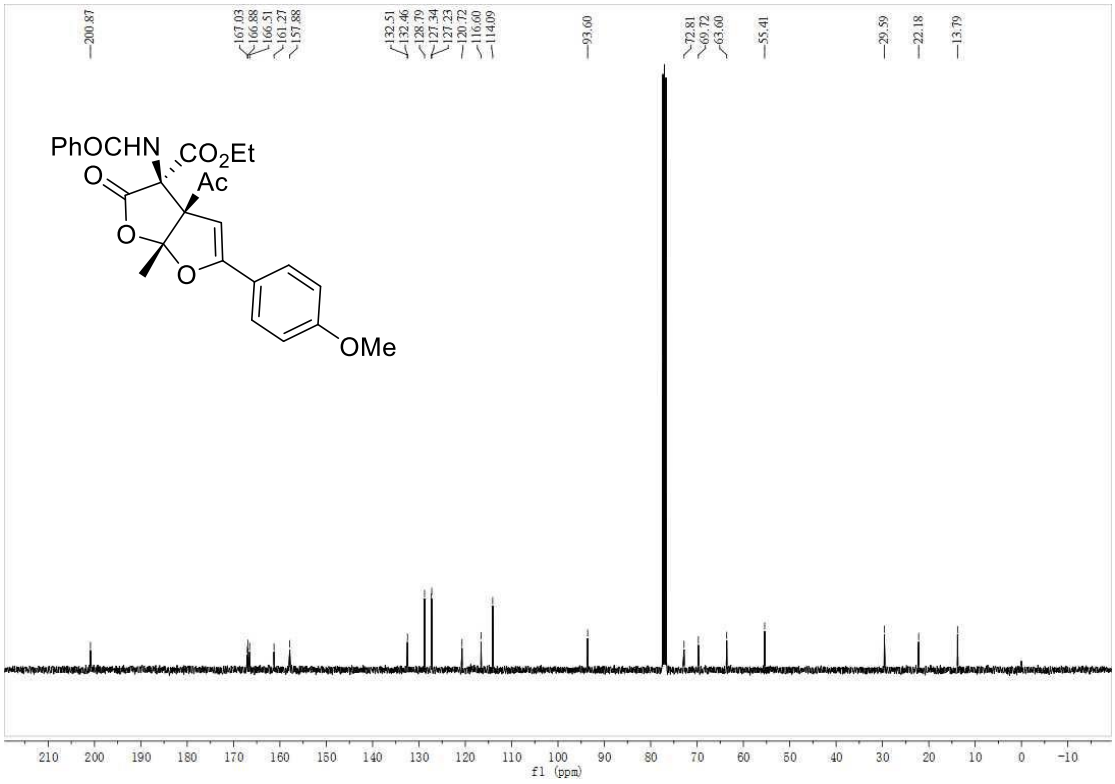
7.78
7.57
7.55
7.53
7.48
7.46
7.44
7.37
6.93
6.90
5.38
4.22
4.20
4.19
4.17
3.85
2.37
2.06
1.14
1.12
1.10
PhOCHN
CO2Et
Ac
O
O
O
O
OMe
2.05
3.08
2.03
1.04
2.04
1.10
2.01
3.02
2.90
3.00
2.94
f1 (ppm)


200.87
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166.88
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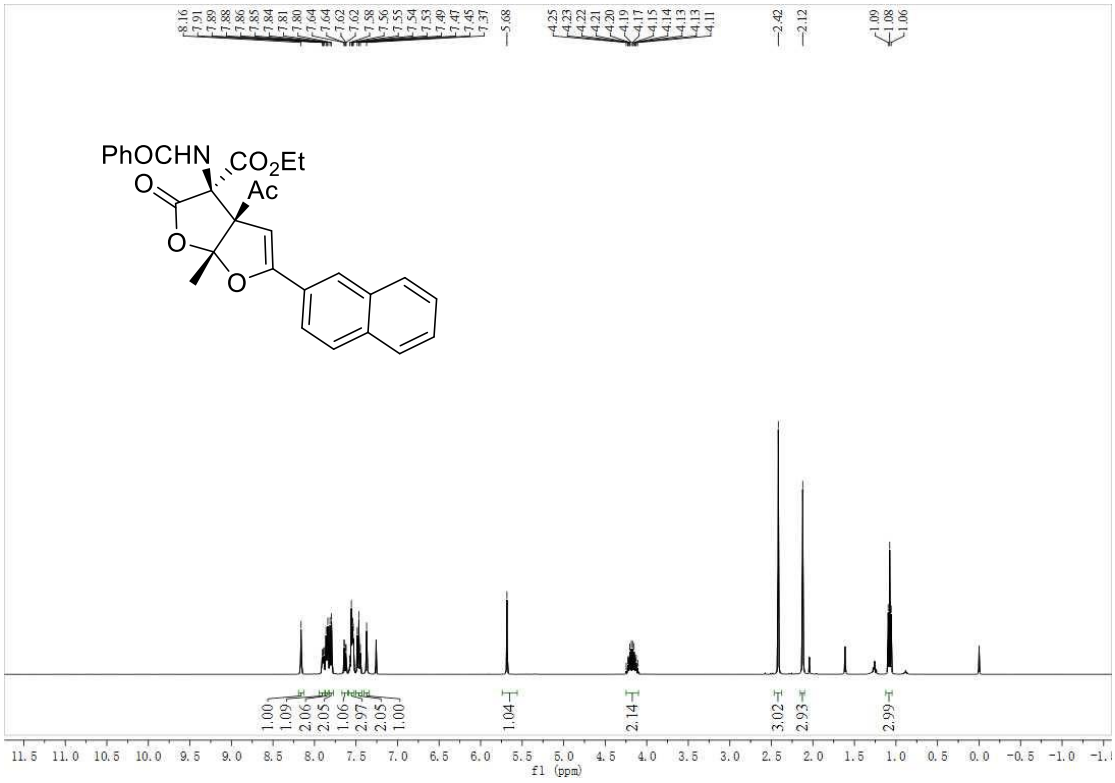
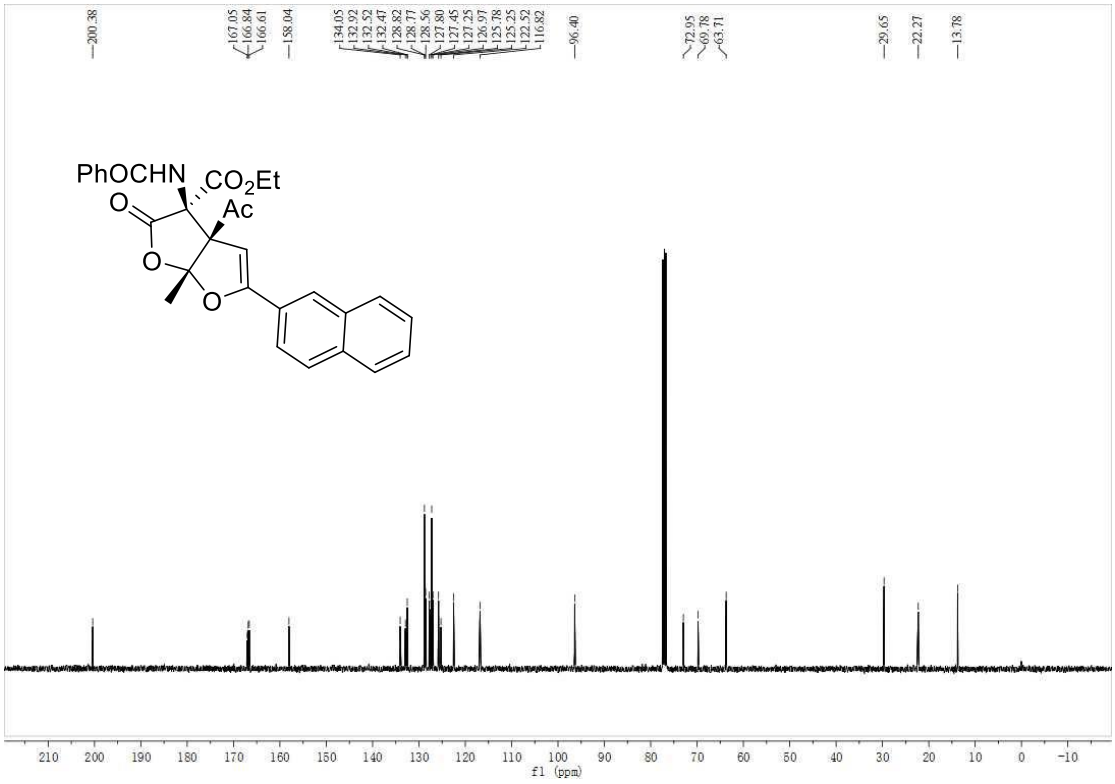
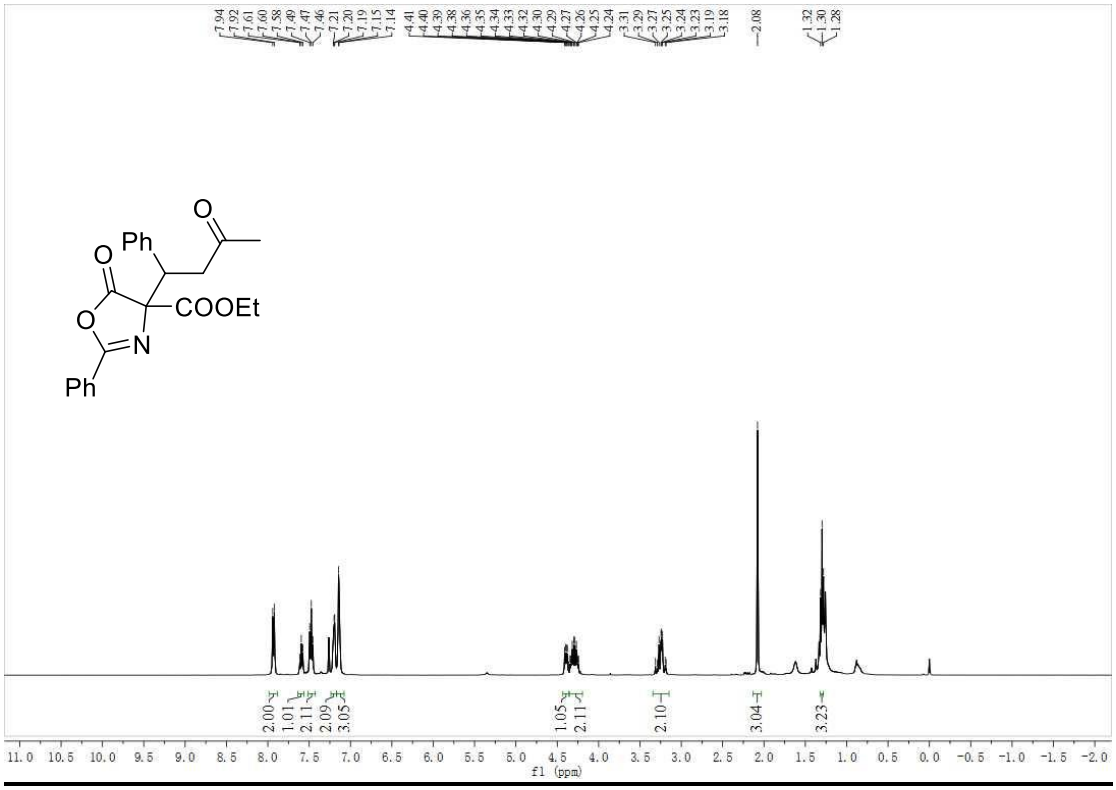
161.27
157.88
132.51
132.46
128.79
127.34
127.23
120.72
116.60
114.09
93.60
72.81
69.72
63.60
55.41
29.59
22.18
13.79
PhOCHN
CO2Et
Ac
O
O
O
O
OMe
f1 (ppm)

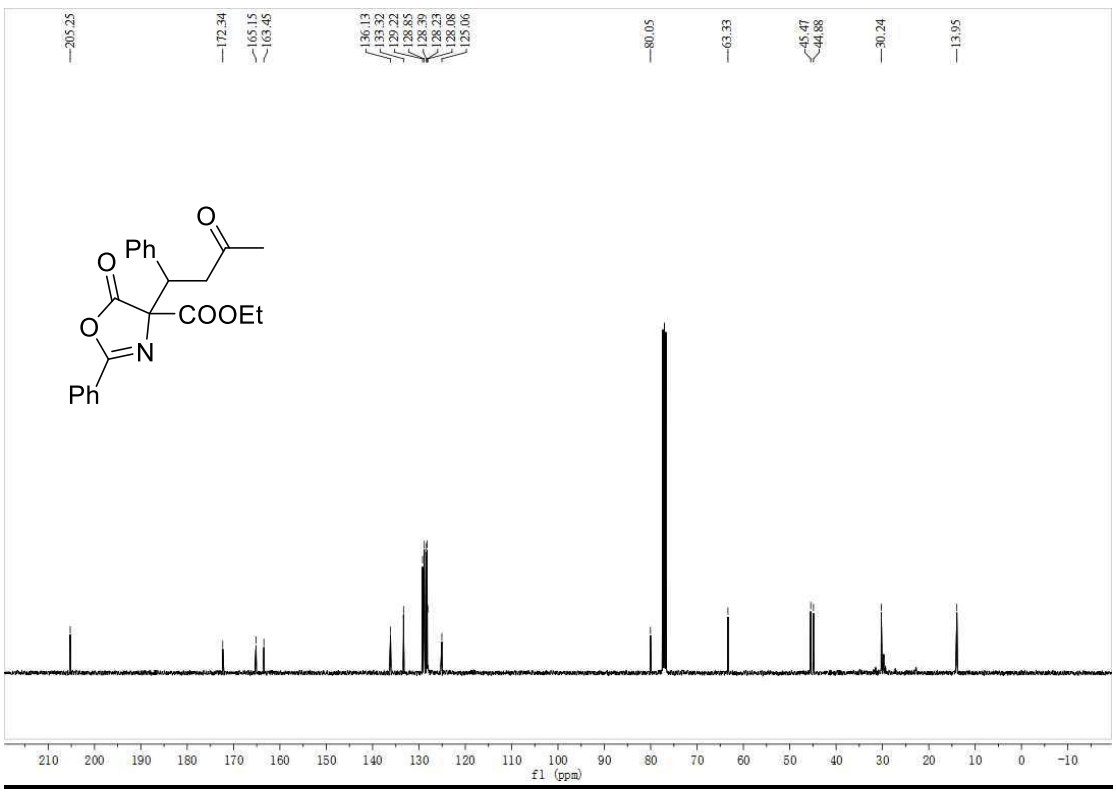
(±)-3y



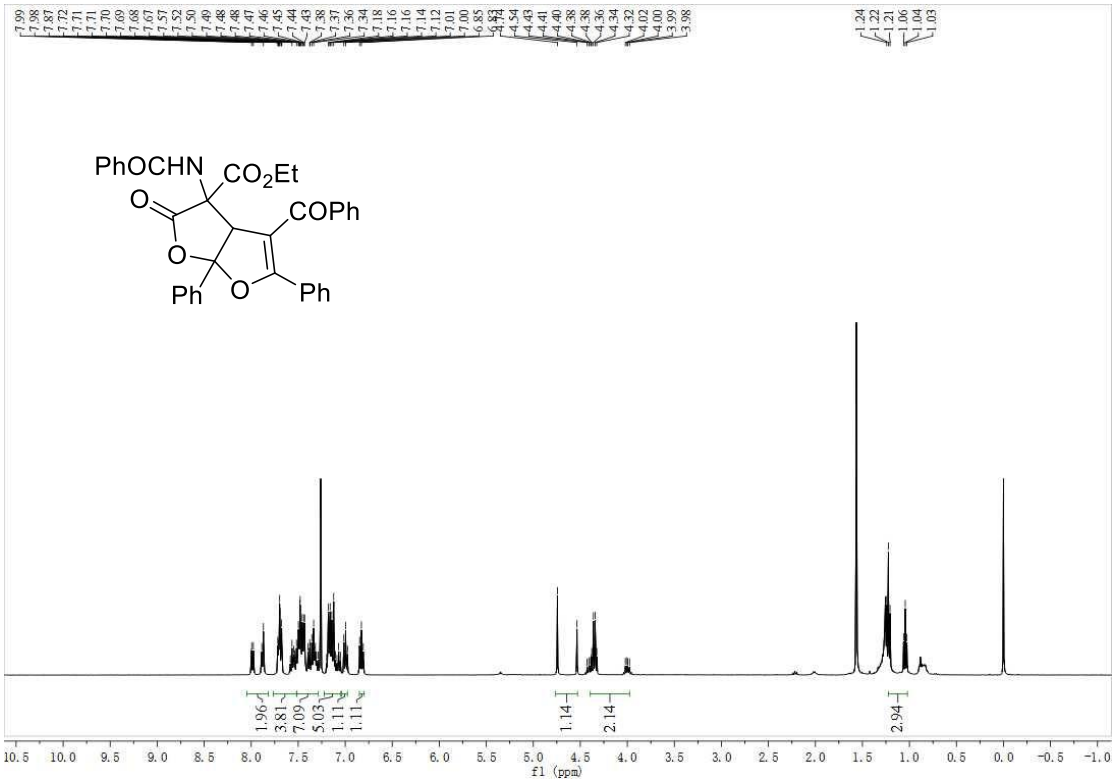


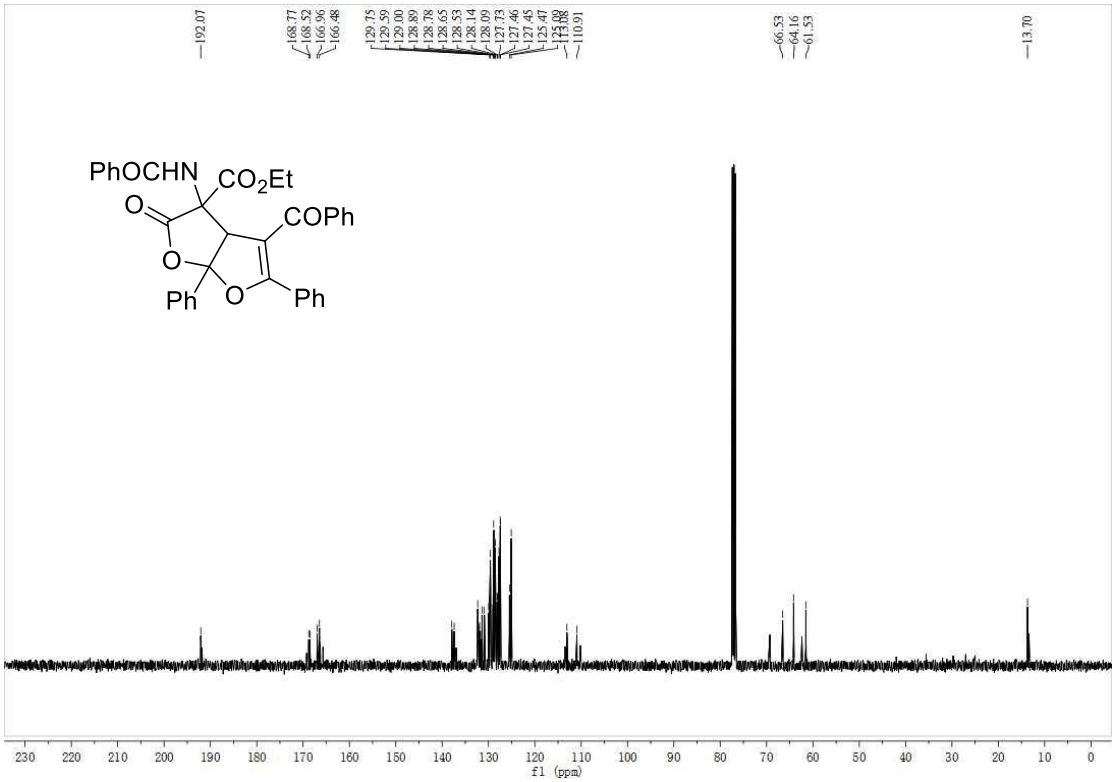
(±)-**7:**





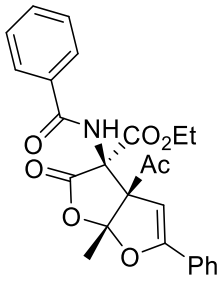
(±)-**10:**


PhOCHN
CO2Et
COPh
O
O
Ph
O
Ph
f1 (ppm)

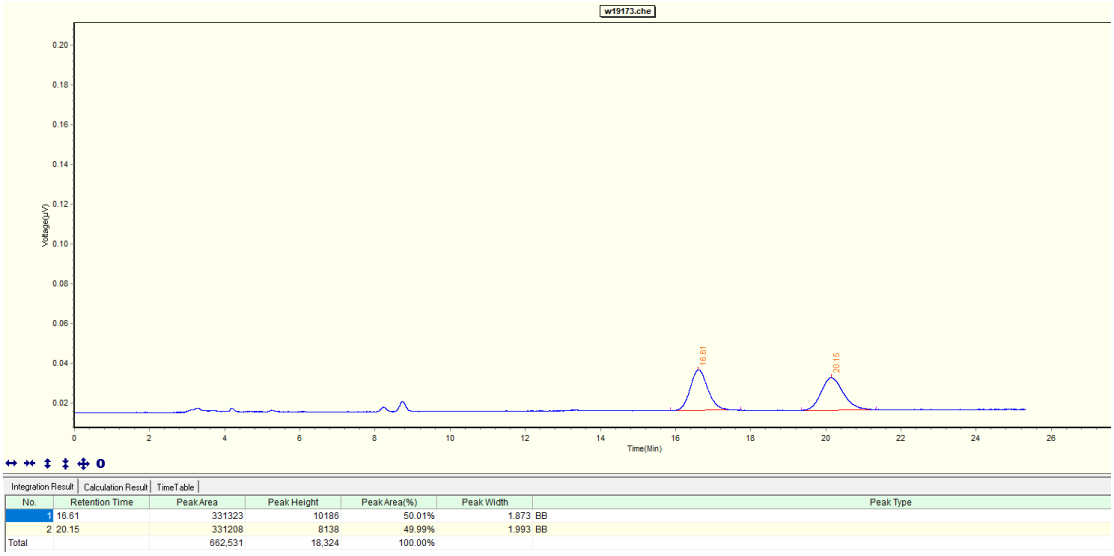

PhOCHN
CO2Et
COPh
O
O
Ph
O
Ph
f1 (ppm)

7. HPLC spectra

3a

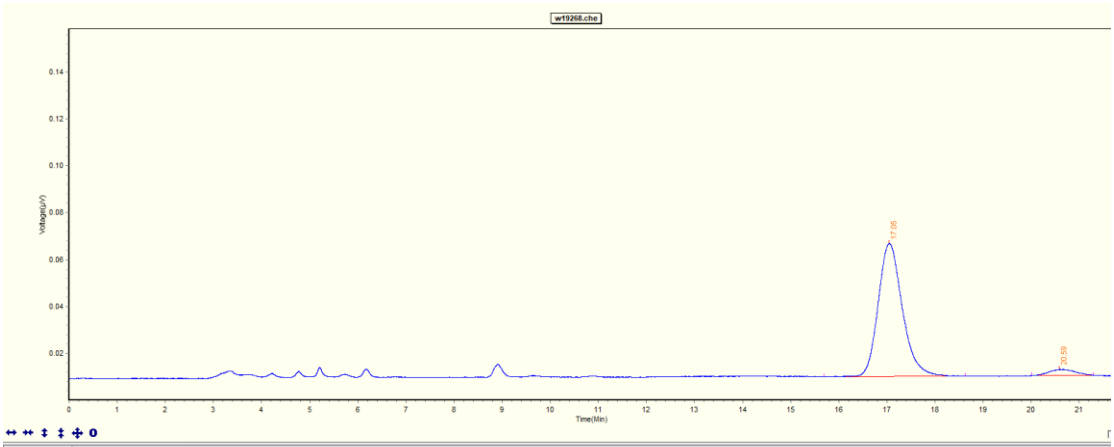


Before recrystallization：



Integration Result | Calculation Result | TimeTable

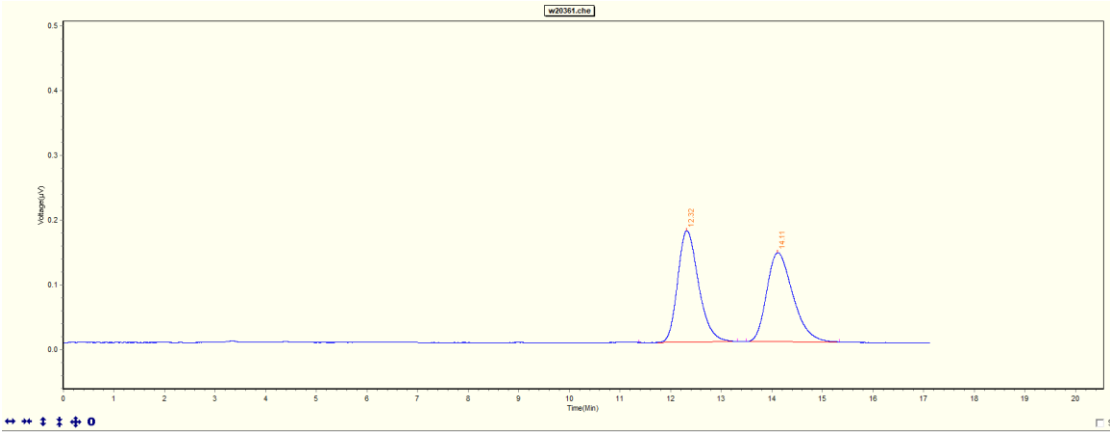
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	16.61	331323	10186	50.01%	1.873	BB
2	20.15	331208	8138	49.99%	1.993	BB
Total		662,531	18,324	100.00%		



Integration Result | Calculation Result | TimeTable

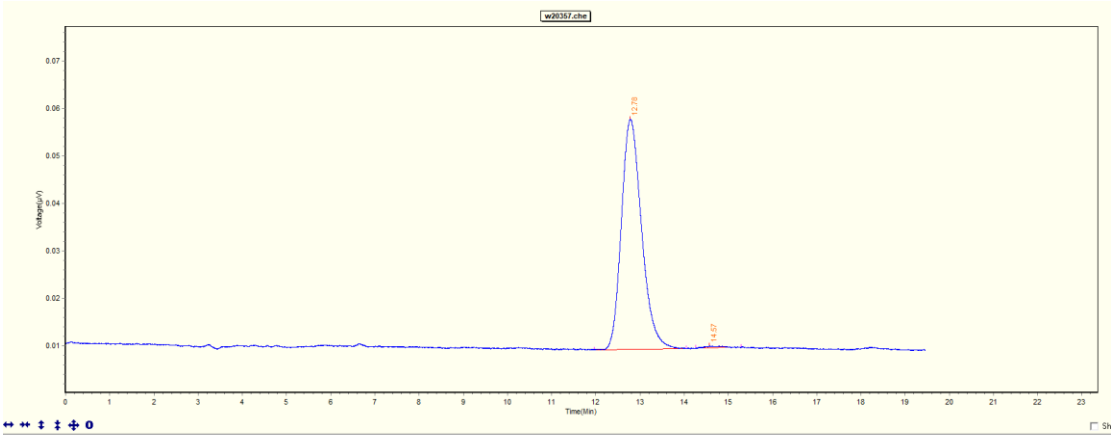
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	17.05	983353	28327	95.35%	2.938	BB
2	20.59	47967	1270	4.65%	1.294	BB
Total		1,031,320	29,597	100.00%		

After recrystallization.



Integration Result | Calculation Result | TimeTable

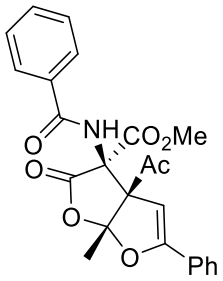
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	12.32	2457985	85920	49.92%	1.947	BB
2	14.11	2465709	68862	50.08%	1.839	BB
Total		4,923,694	154,782	100.00%		



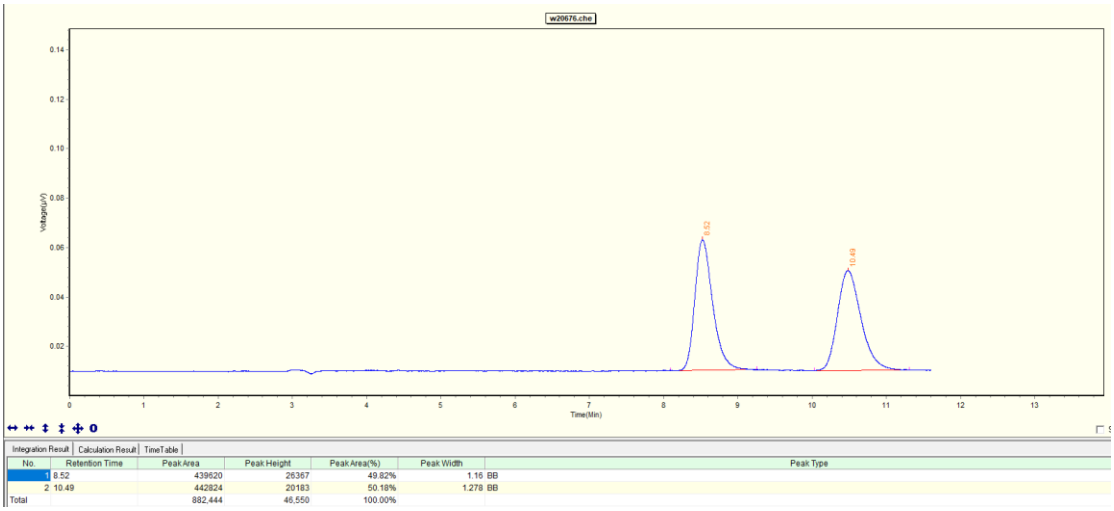
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	12.78	771361	24268	99.34%	2.083	BB
2	14.57	5152	178	0.66%	1.027	BB
Total		776,513	24,446	100.00%		

3b

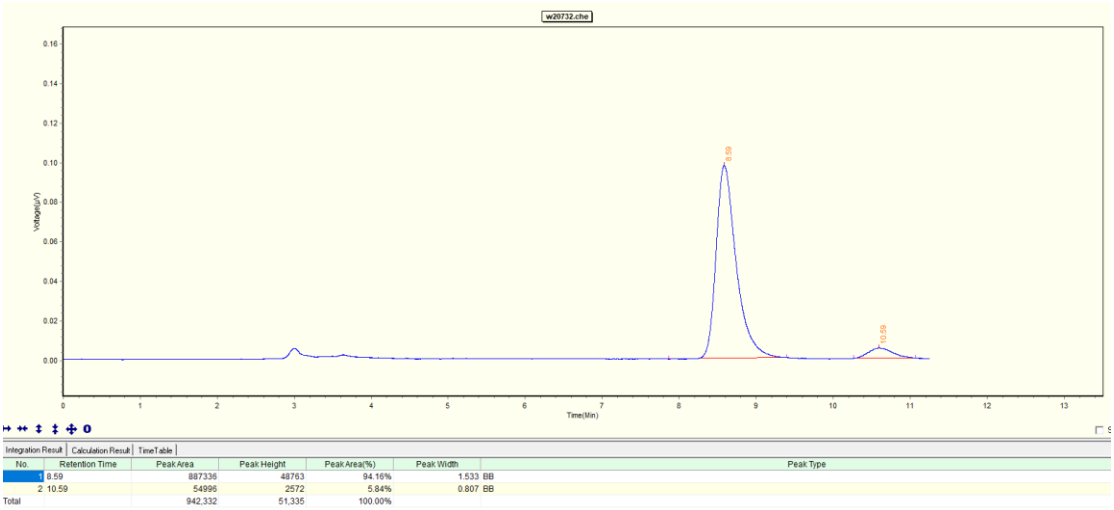


Before recrystallization



Integration Result | Calculation Result | TimeTable

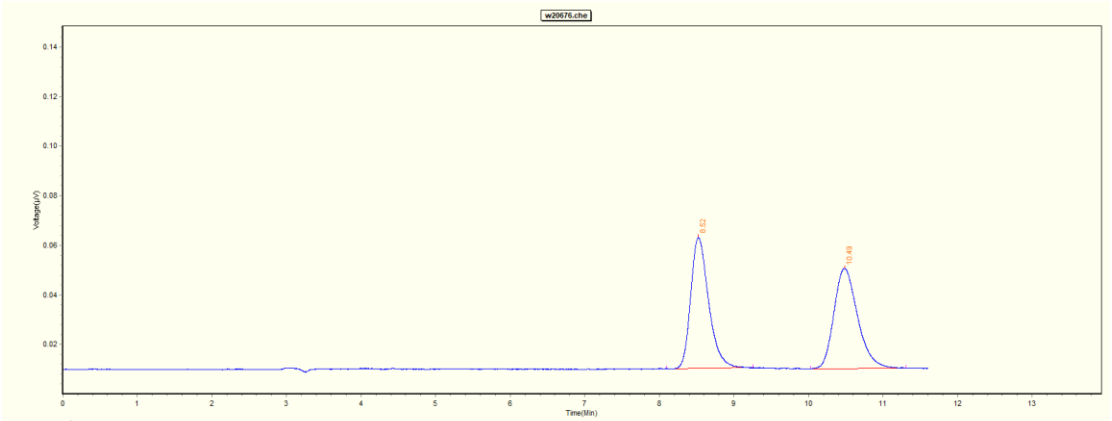
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.52	439620	26367	49.82%	1.16	BB
2	10.49	442824	20183	50.18%	1.278	BB
Total		882,444	46,550	100.00%		



Integration Result | Calculation Result | TimeTable

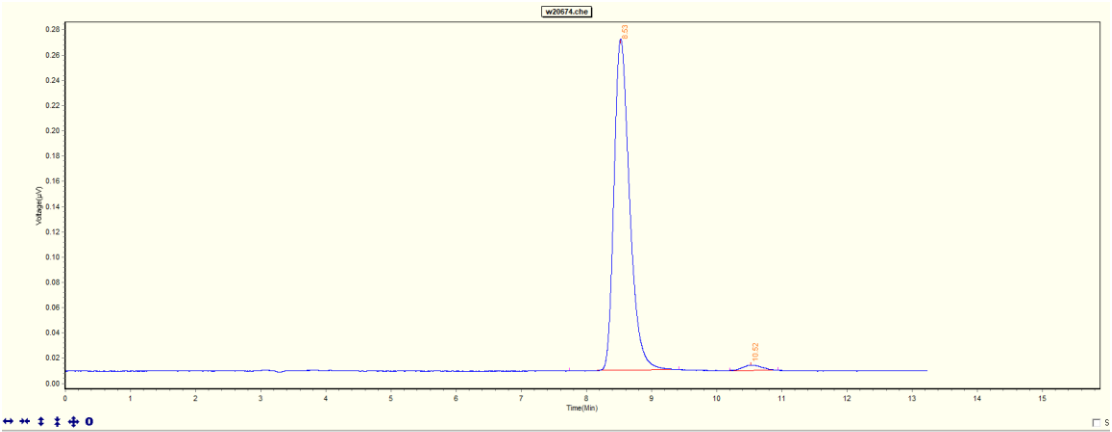
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.59	887336	48763	94.16%	1.533	BB
2	10.59	54996	2572	5.84%	0.807	BB
Total		942,332	51,335	100.00%		

After recrystallization.



Integration Result | Calculation Result | TimeTable

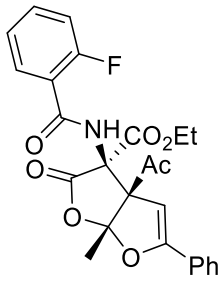
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.52	439620	26367	49.82%	1.16	BB
2	10.49	442824	20183	50.18%	1.278	BB
Total		882,444	46,550	100.00%		



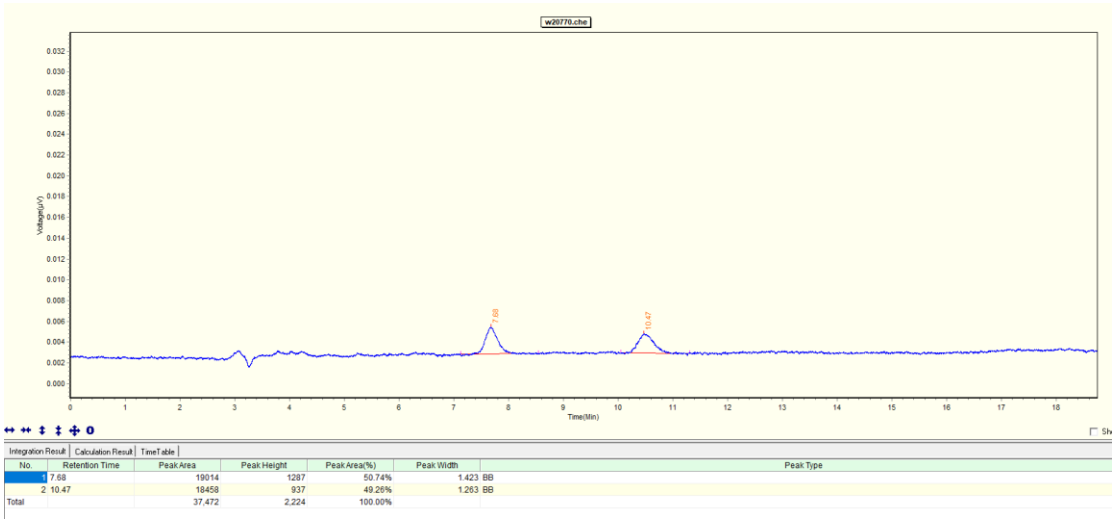
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.53	2184799	131320	98.07%	1.677	BB
2	10.52	43053	2073	1.93%	0.739	BB
Total		2,227,852	133,393	100.00%		

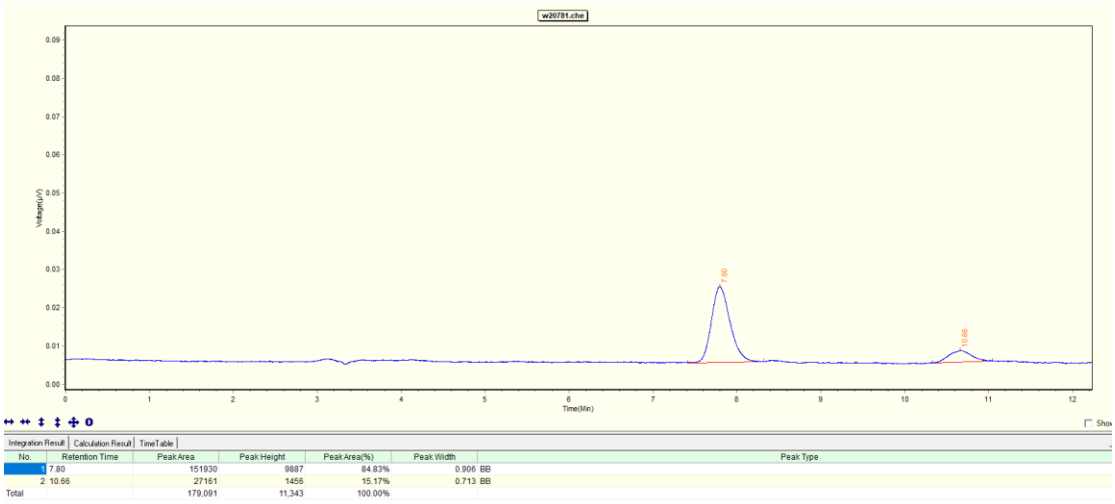
3e



Before recrystallization

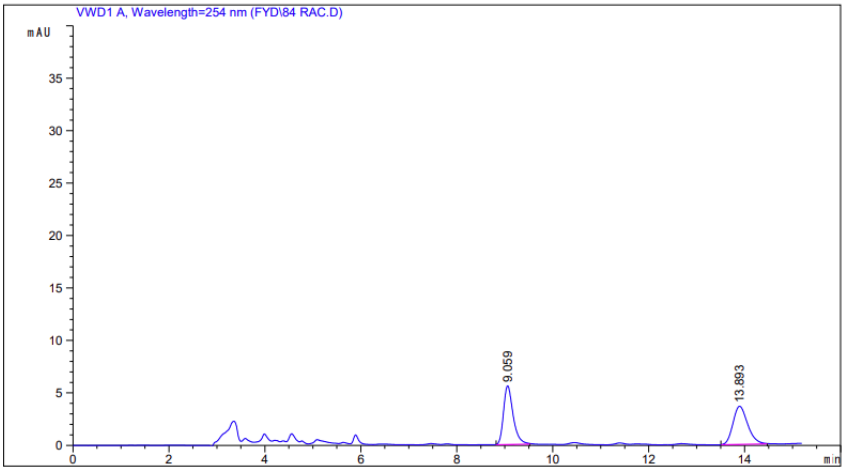


No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.68	19014	1287	50.74%	1.423	BB
2	10.47	18458	937	49.26%	1.263	BB
Total		37,472	2,224	100.00%		



No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.80	151930	9887	84.83%	0.906	BB
2	10.66	27161	1456	15.17%	0.713	BB
Total		179,091	11,343	100.00%		

After recrystallization.

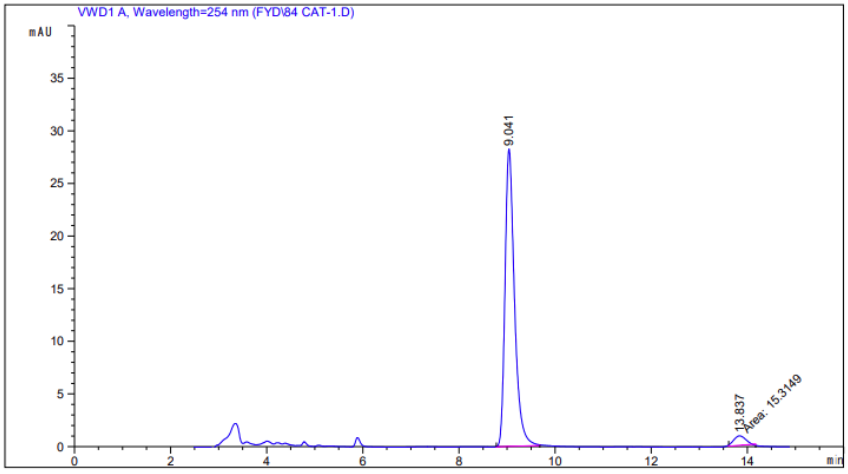



```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1   9.059 BB    0.2118   77.86799    5.59749  50.2228
   2  13.893 BB    0.3249   77.17713    3.63493  49.7772
```

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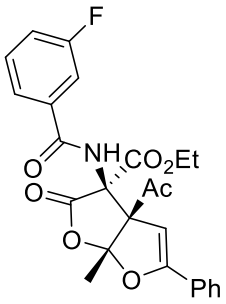
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs

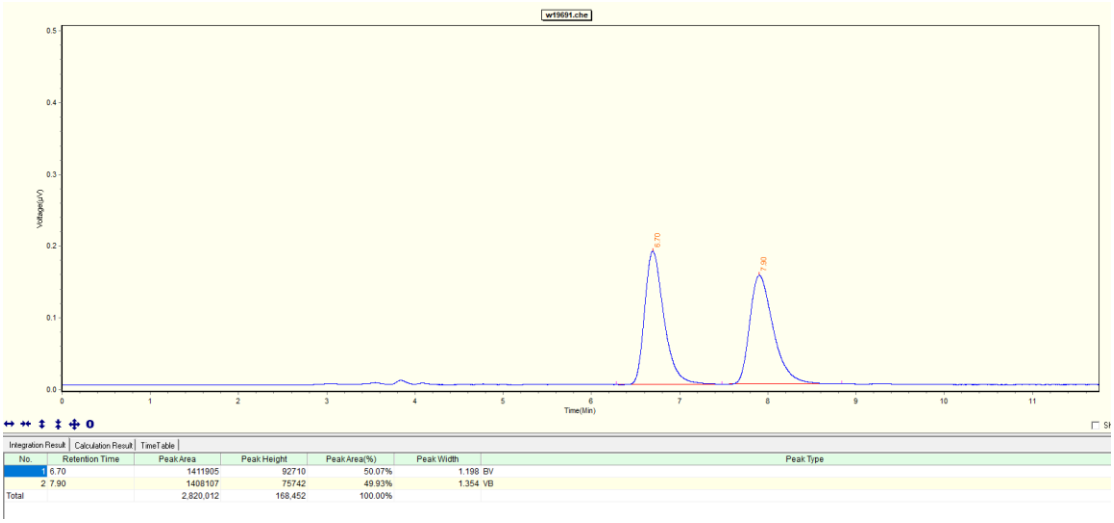

Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1   9.041 BB    0.2060  385.81775   28.24062  96.1821
   2  13.837 MM    0.2837   15.31486 8.99570e-1   3.8179
```

3f

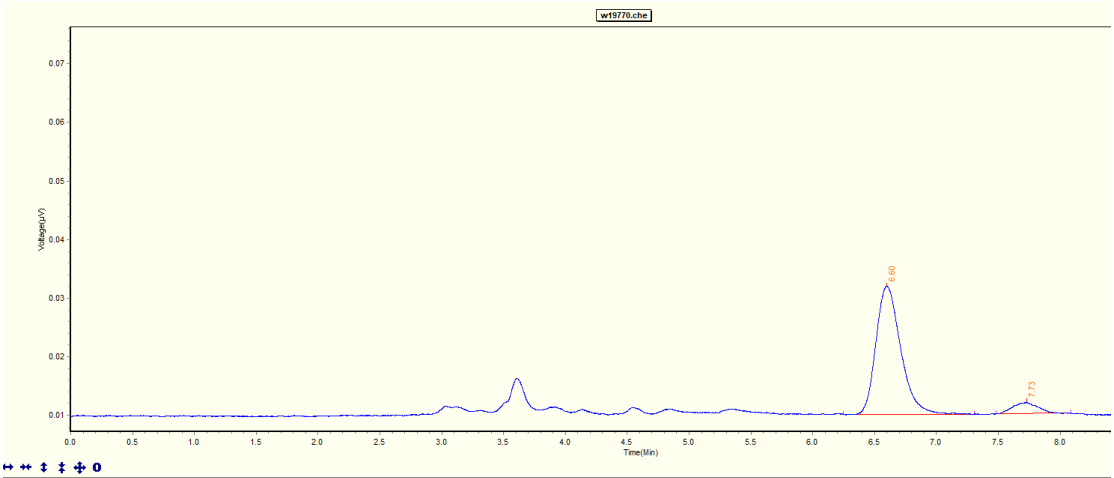


Before recrystallization



Integration Result | Calculation Result | TimeTable

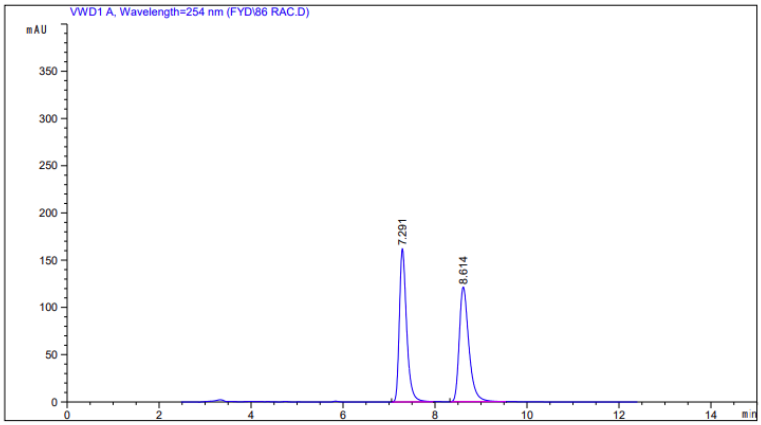
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	6.70	1411905	92710	50.07%	1.198	BV
2	7.90	1408107	75742	49.93%	1.354	VB
Total		2,820,012	168,452	100.00%		



Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	6.60	152162	10949	92.21%	1.059	BB
2	7.73	12847	964	7.79%	0.603	BB
Total		165,009	11,913	100.00%		

After recrystallization.

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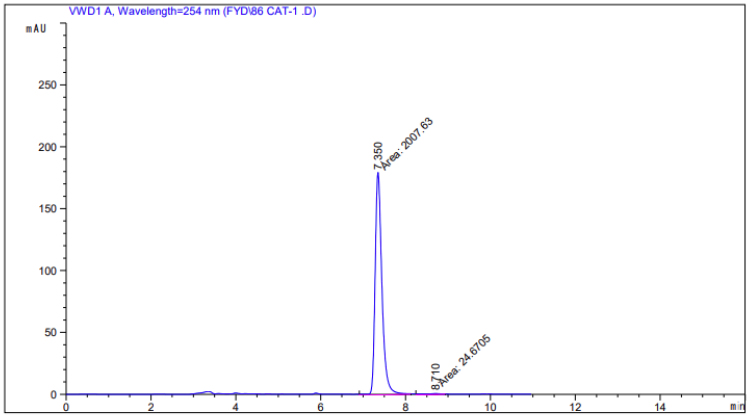
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1   7.291 BB    0.1654 1770.99622  162.01620  50.0874
   2   8.614 BB    0.2206 1764.81274  121.40273  49.9126
```

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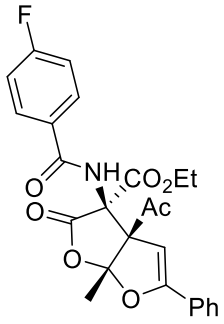
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs

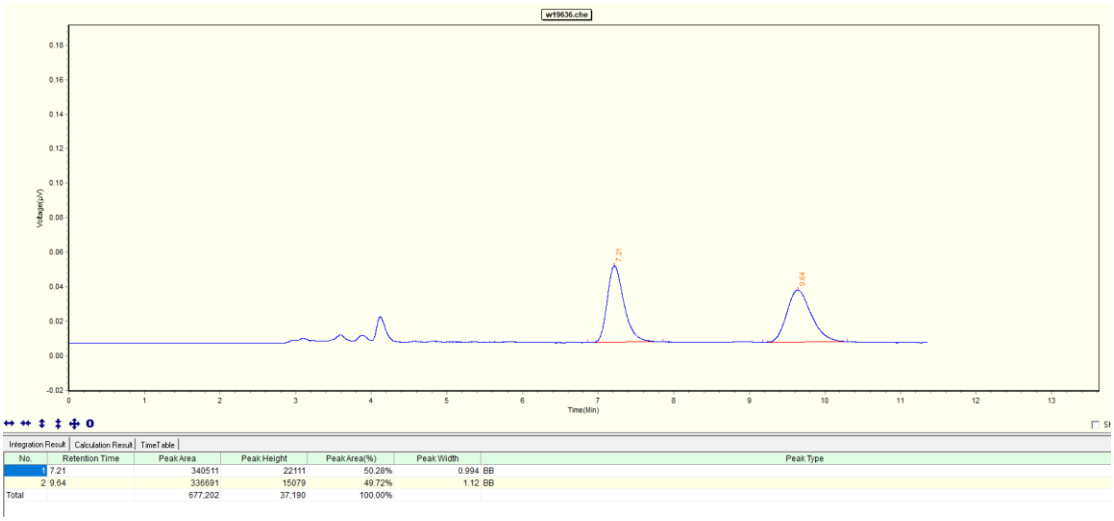

Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1   7.350 MM    0.1861 2007.62585  179.82129  98.7861
   2   8.710 MM    0.3706   24.67053 7.79884e-1   1.2139
```

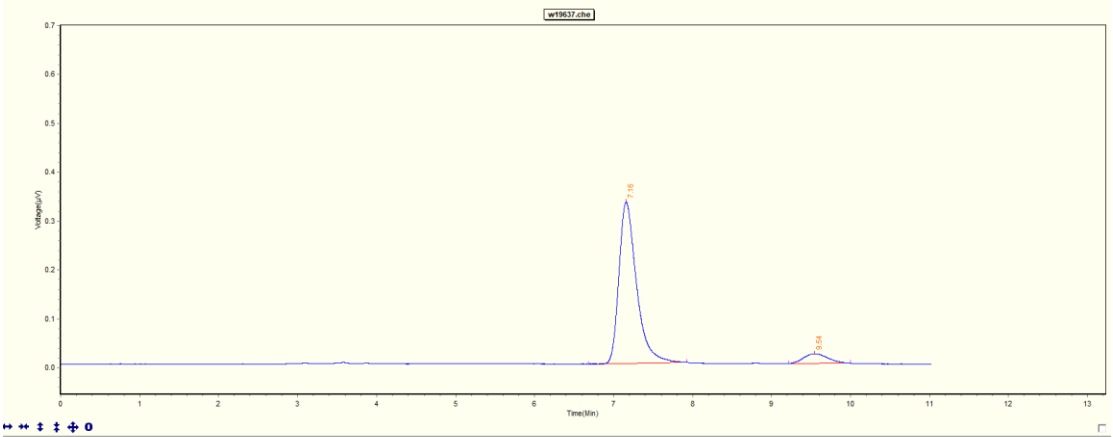
3h



Before recrystallization

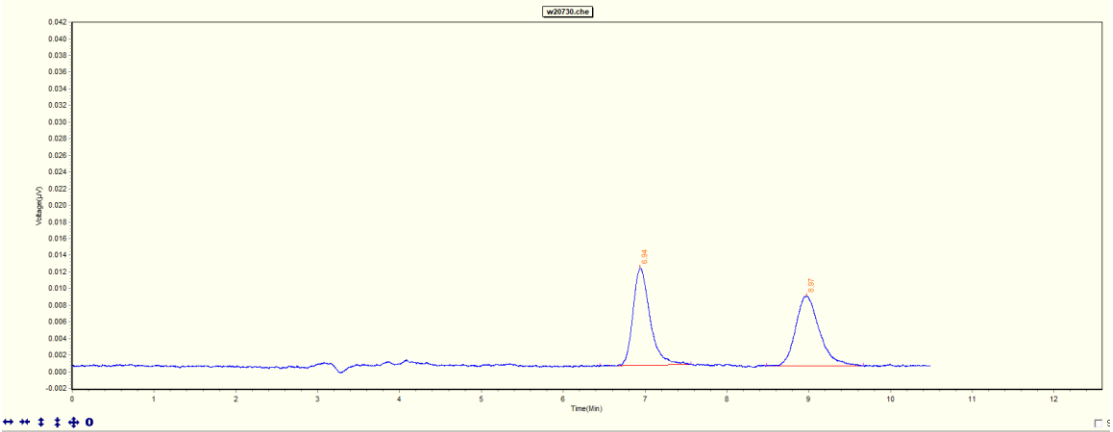


No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.21	340511	22111	50.28%	0.994	BB
2	9.64	336691	15079	49.72%	1.12	BB
Total		677,202	37,190	100.00%		



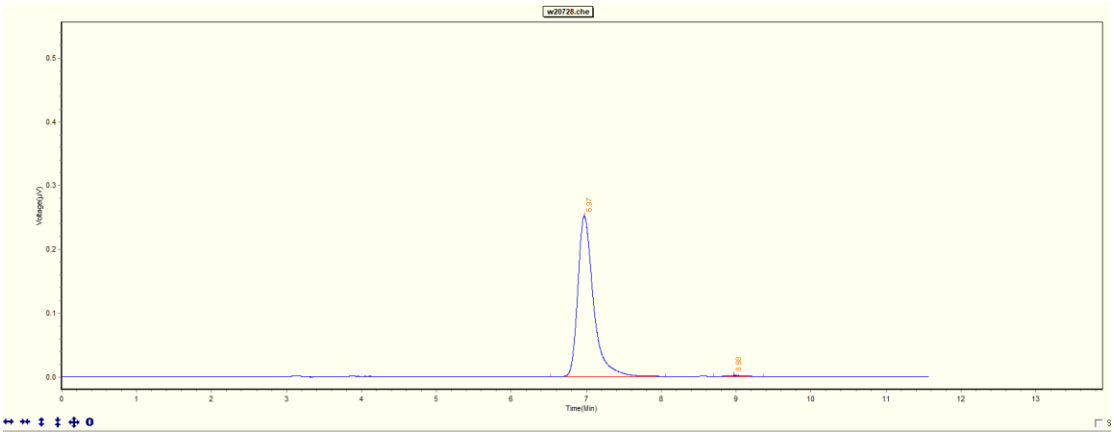
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.16	2545583	164831	92.35%	1.244	BB
2	9.54	210929	9928	7.65%	0.787	BB
Total		2,756,512	174,759	100.00%		

After recrystallization.



Integration Result | Calculation Result | TimeTable

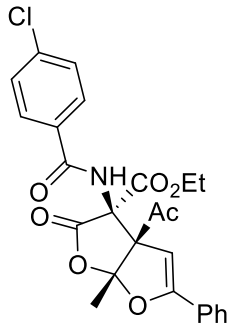
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	6.94	84462	5834	49.86%	1.113	BB
2	8.97	84944	4191	50.14%	1.188	BB
Total		169,406	10,025	100.00%		



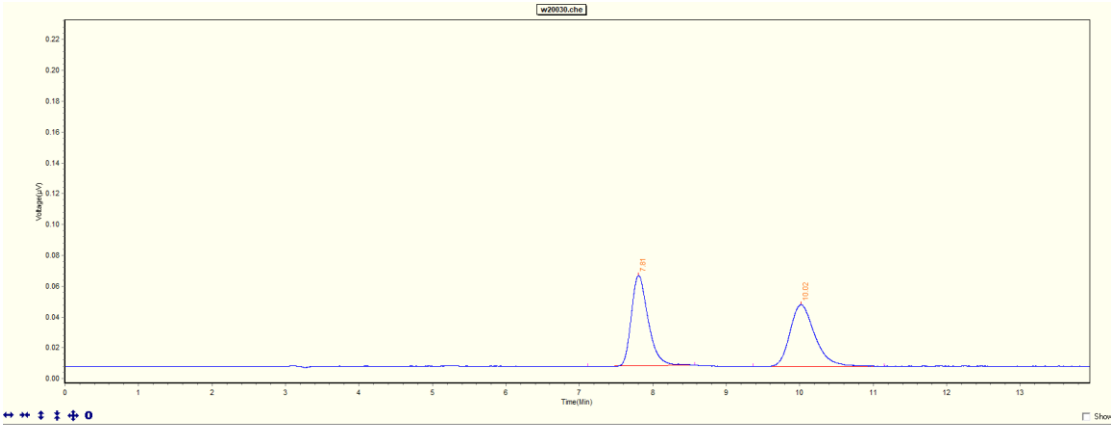
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	6.97	1829463	125927	99.32%	1.534	BB
2	8.98	12614	748	0.68%	0.658	BB
Total		1,842,077	126,675	100.00%		

3i

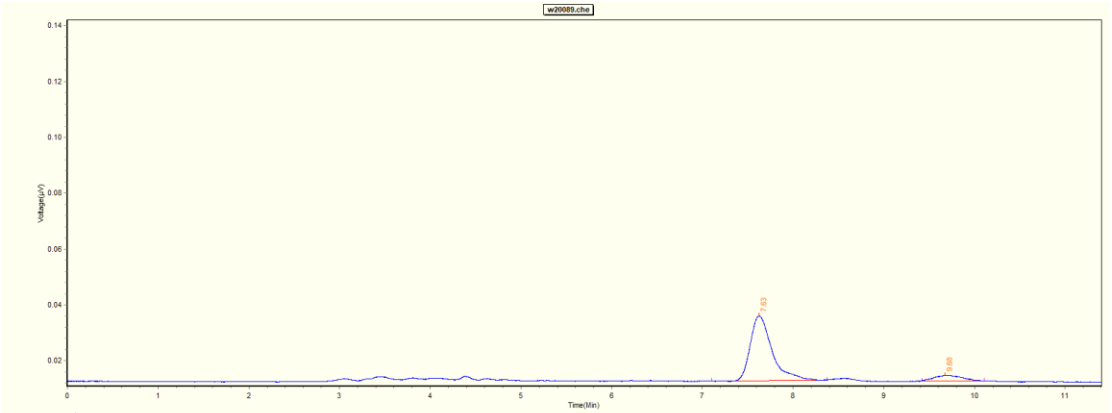


Before recrystallization



Integration Result | Calculation Result | TimeTable

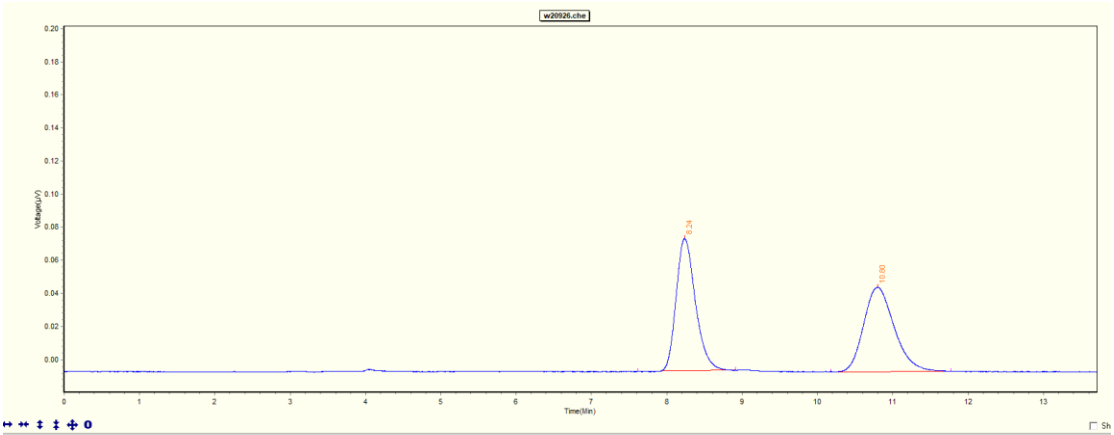
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.81	465625	29292	49.99%	1.46	BB
2	10.02	465894	19975	50.01%	1.789	BB
Total		931,519	49,267	100.00%		



Integration Result | Calculation Result | TimeTable

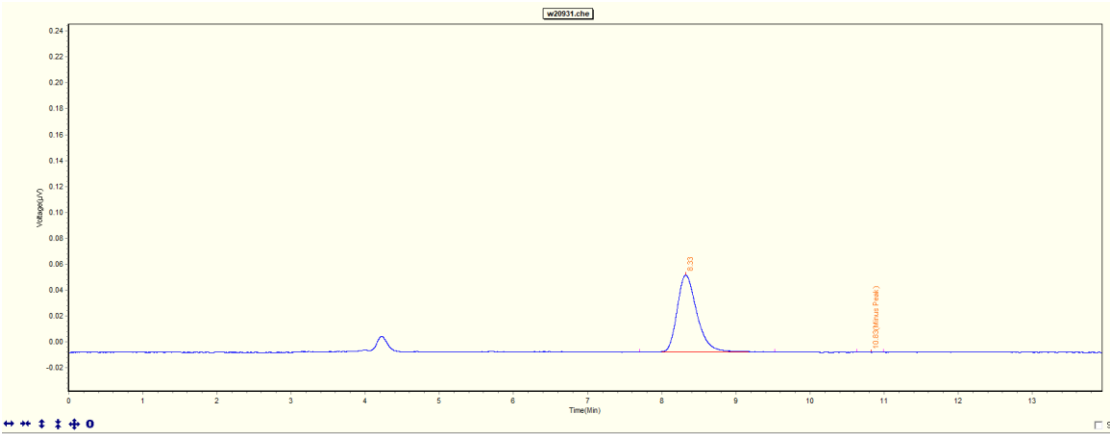
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.63	190270	11572	90.07%	1.265	BB
2	9.68	20967	1002	9.93%	0.691	BB
Total		211,237	12,574	100.00%		

After recrystallization.



Integration Result | Calculation Result | TimeTable

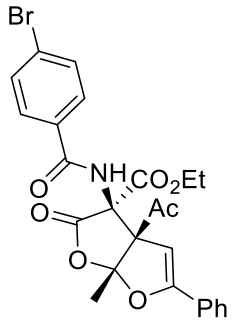
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.24	713637	40023	49.97%	1.298	BB
2	10.80	714571	25413	50.03%	1.591	BB
Total		1,428,208	65,436	100.00%		



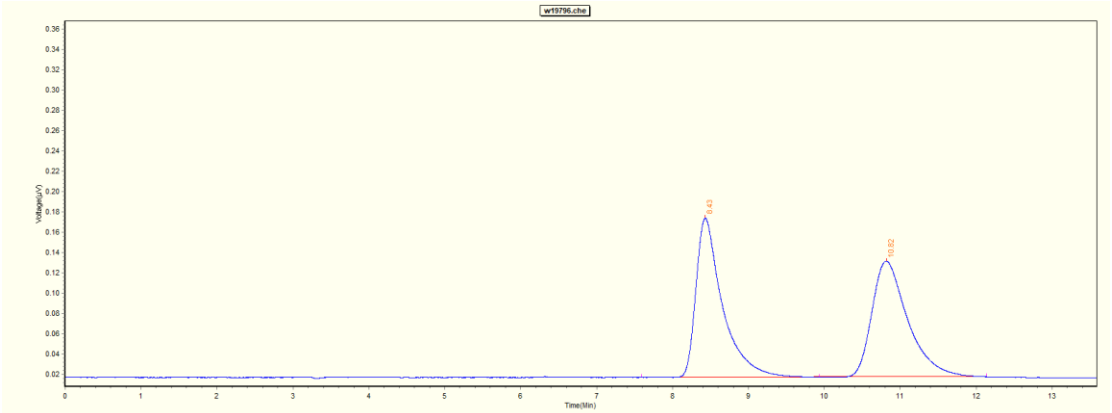
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.33	549499	29697	99.99%	1.825	BB
2	10.83	63	87	0.01%	0.353	BB
Total		549,562	29,784	100.00%		

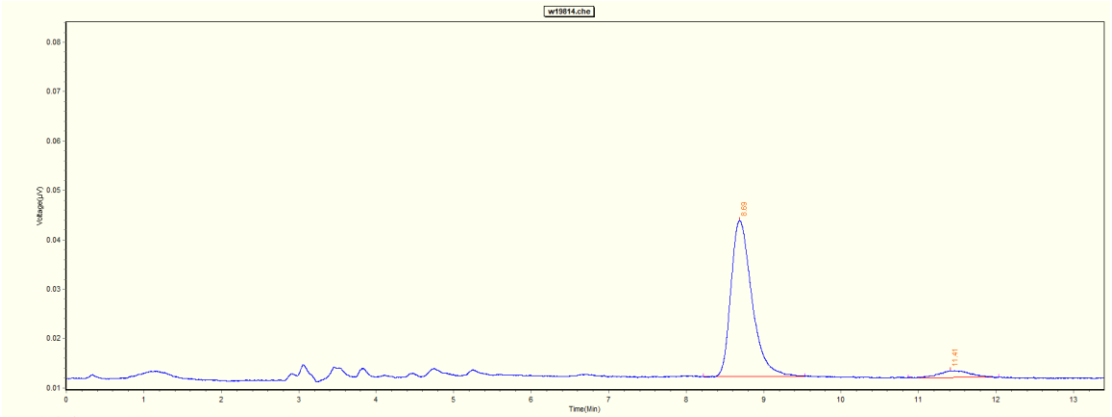
3j



Before recrystallization

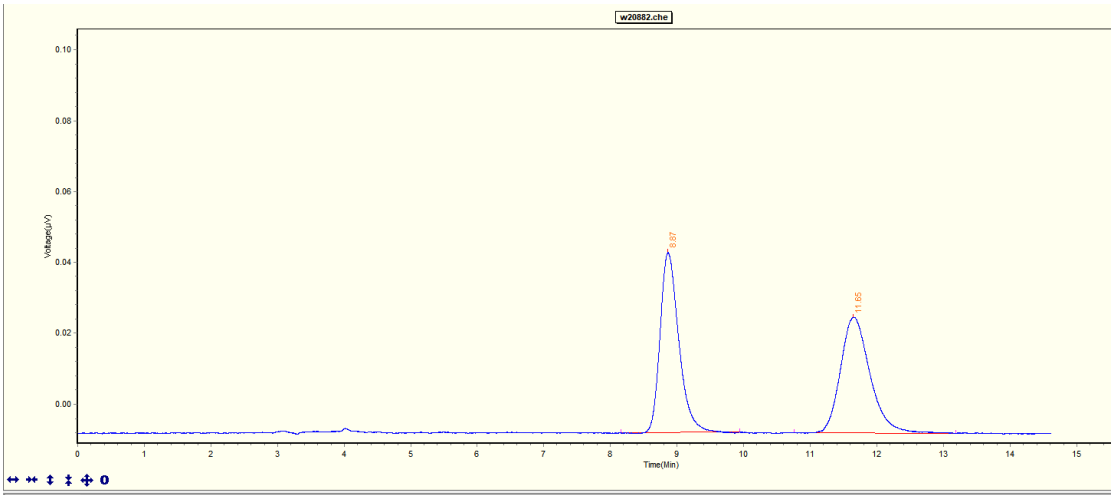


No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.43	1896135	78249	50.32%	2.344	BV
2	10.82	1872239	56994	49.68%	2.2	VB
Total		3,768,374	135,243	100.00%		



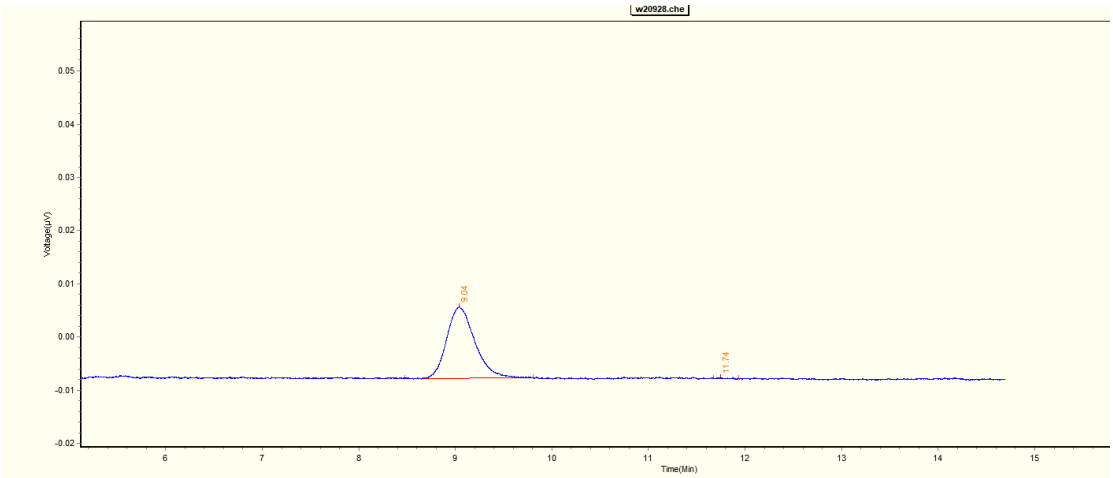
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.69	295409	15776	94.03%	1.312	BB
2	11.41	18749	688	5.97%	1.164	BB
Total		314,158	16,464	100.00%		

After recrystallization.



Integration Result | Calculation Result | TimeTable

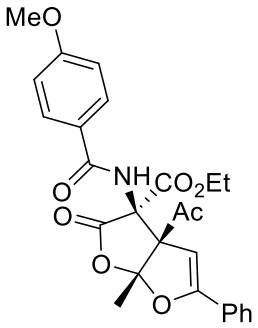
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.87	494837	25409	49.80%	1.788	BB
2	11.65	498815	16282	50.20%	2.423	BB
Total		993,652	41,691	100.00%		



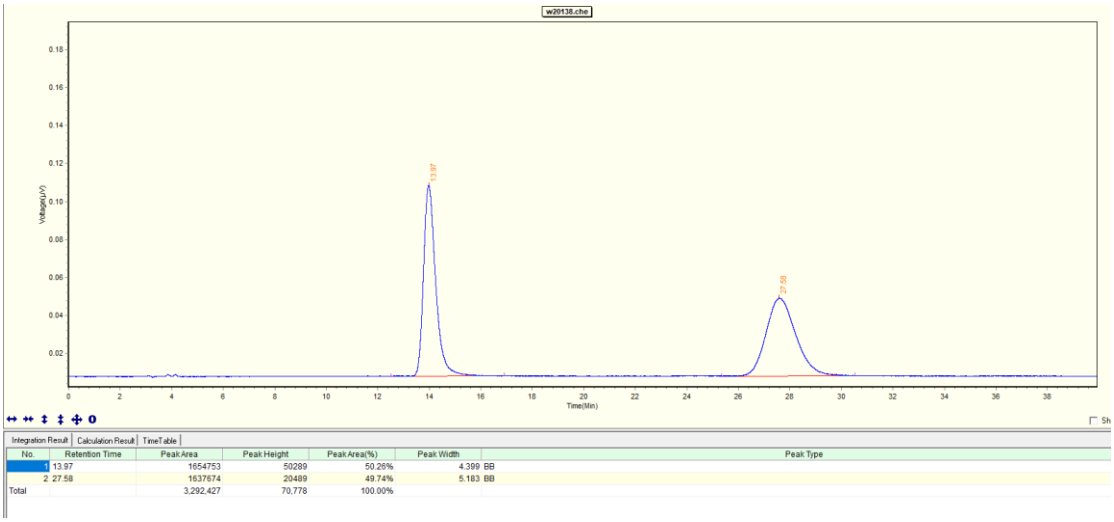
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	9.04	134285	6686	99.88%	1.333	BB
2	11.74	161	66	0.12%	0.262	BB
Total		134,446	6,752	100.00%		

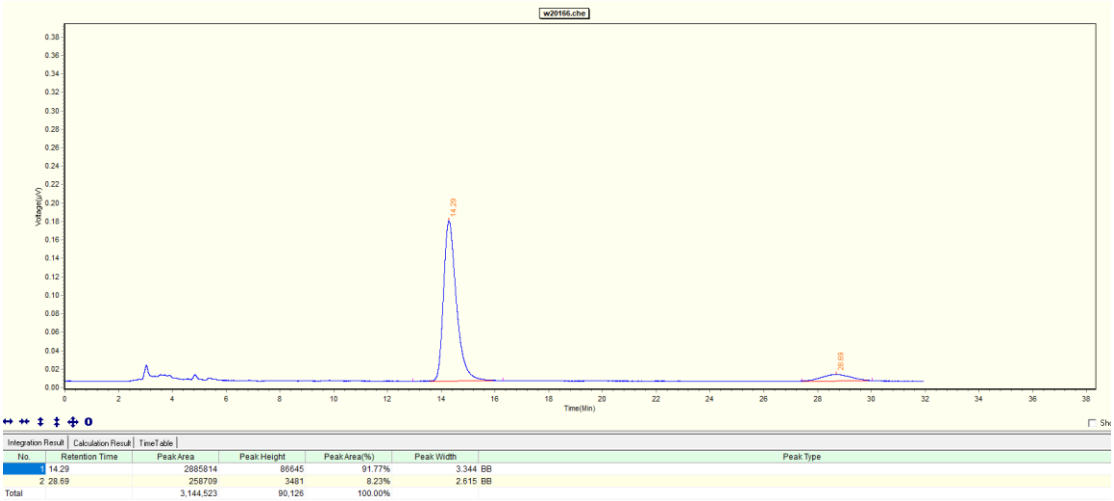
3l



Before recrystallization:

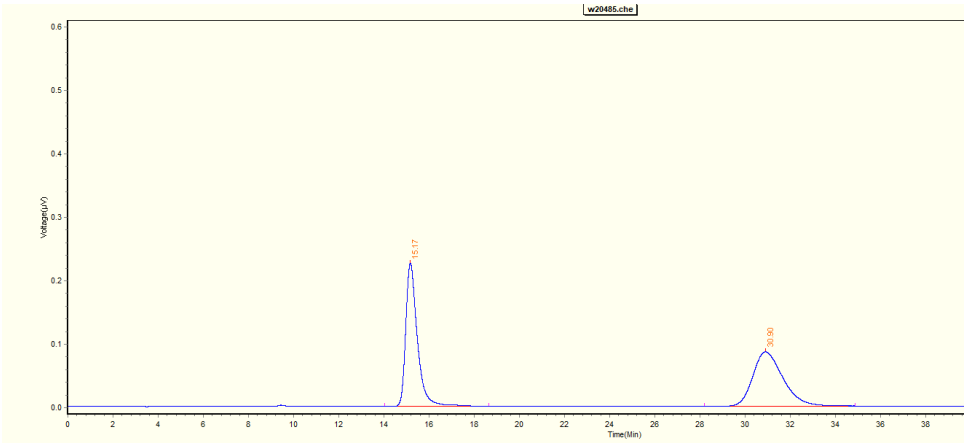


No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	13.97	1654753	50289	50.26%	4.399	BB
2	27.58	1637674	20489	49.74%	5.183	BB
Total		3,292,427	70,778	100.00%		



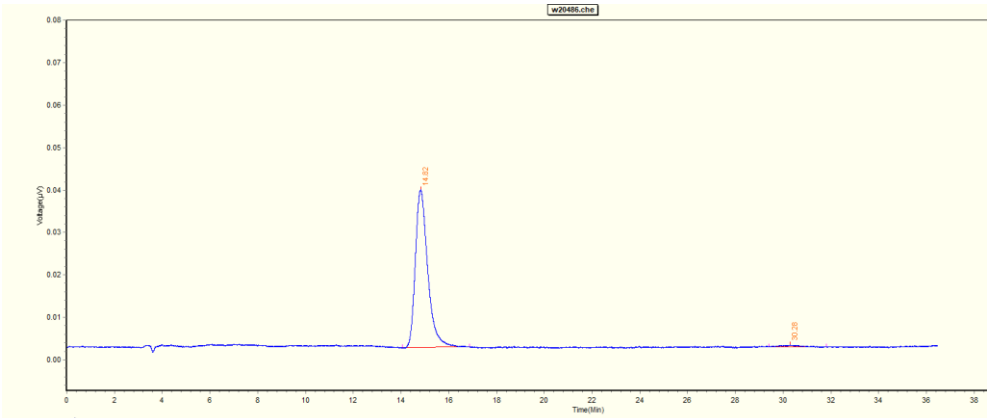
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	14.29	2885814	86645	91.77%	3.344	BB
2	28.69	258709	3481	8.23%	2.615	BB
Total		3,144,523	90,126	100.00%		

After recrystallization:



Integration Result | Calculation Result | TimeTable

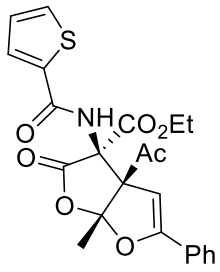
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	15.17	4016420	112843	50.41%	4.589	BB
2	30.90	3951138	42816	49.59%	6.66	BB
Total		7,967,558	155,659	100.00%		



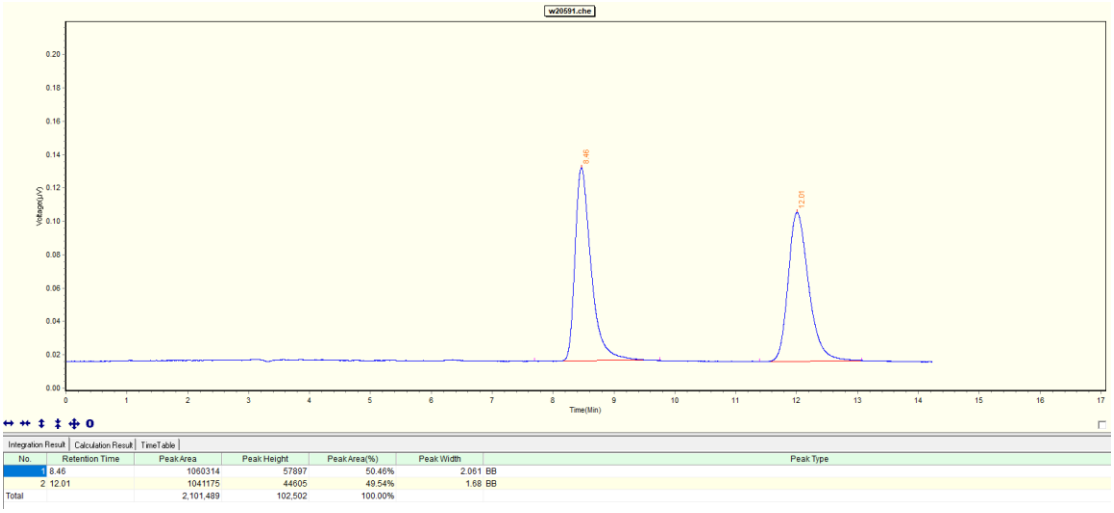
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	14.82	666820	18568	98.96%	2.822	BB
2	30.28	7041	195	1.04%	2.419	BB
Total		673,861	18,763	100.00%		

3n

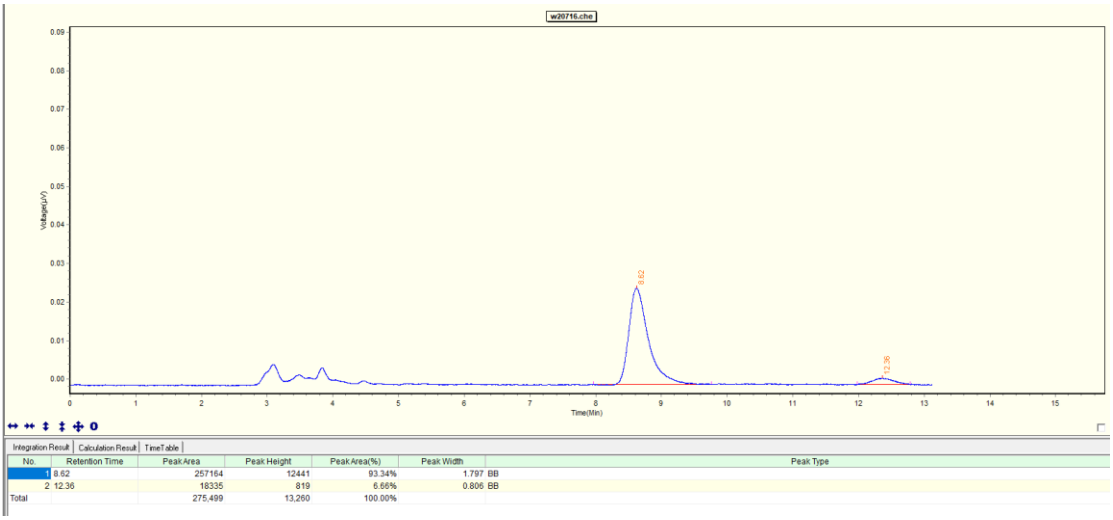


Before recrystallization:



Integration Result | Calculation Result | TimeTable

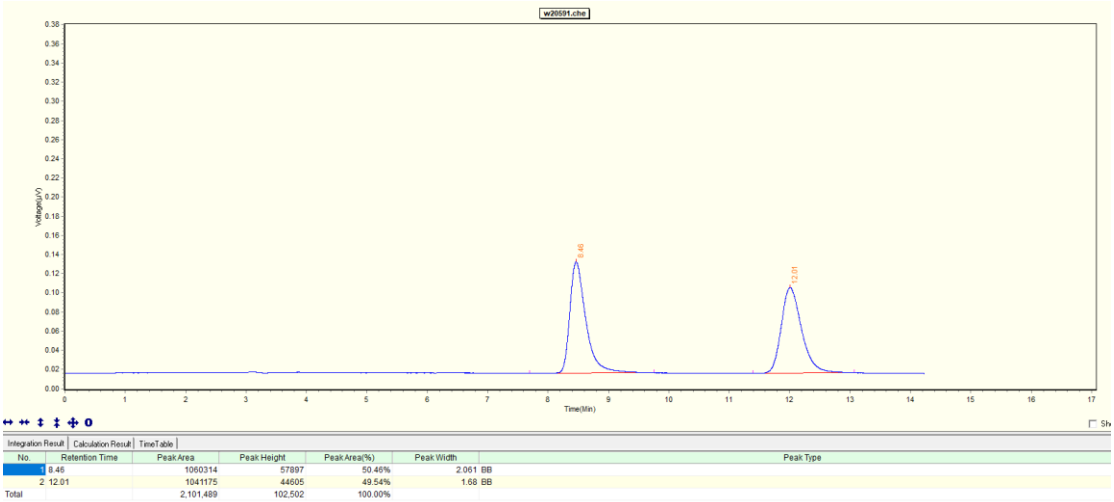
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.46	1060314	57897	50.46%	2.061	BB
2	12.01	1041175	44605	49.54%	1.68	BB
Total		2,101,489	102,502	100.00%		



Integration Result | Calculation Result | TimeTable

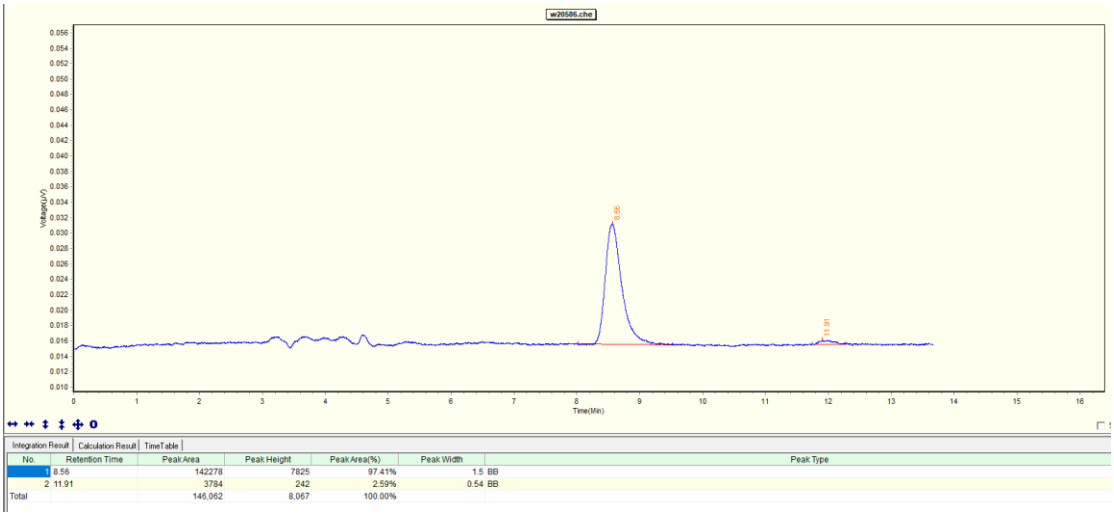
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.62	257164	12441	93.34%	1.797	BB
2	12.36	18335	819	6.66%	0.806	BB
Total		275,499	13,260	100.00%		

After recrystallization:



Integration Result | Calculation Result | TimeTable

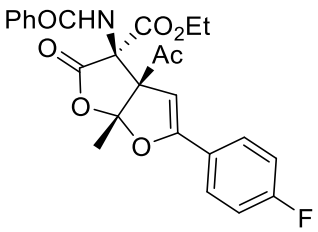
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.46	1060314	57897	50.46%	2.061	BB
2	12.01	1041175	44605	49.54%	1.68	BB
Total		2,101,489	102,502	100.00%		



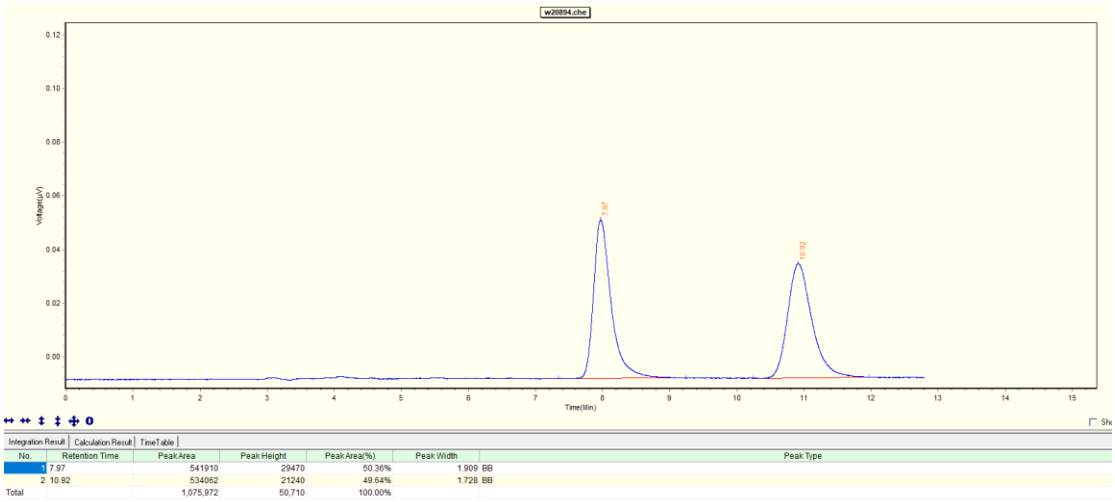
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.56	142278	7825	97.41%	1.5	BB
2	11.91	3784	242	2.59%	0.54	BB
Total		146,062	8,067	100.00%		

3s

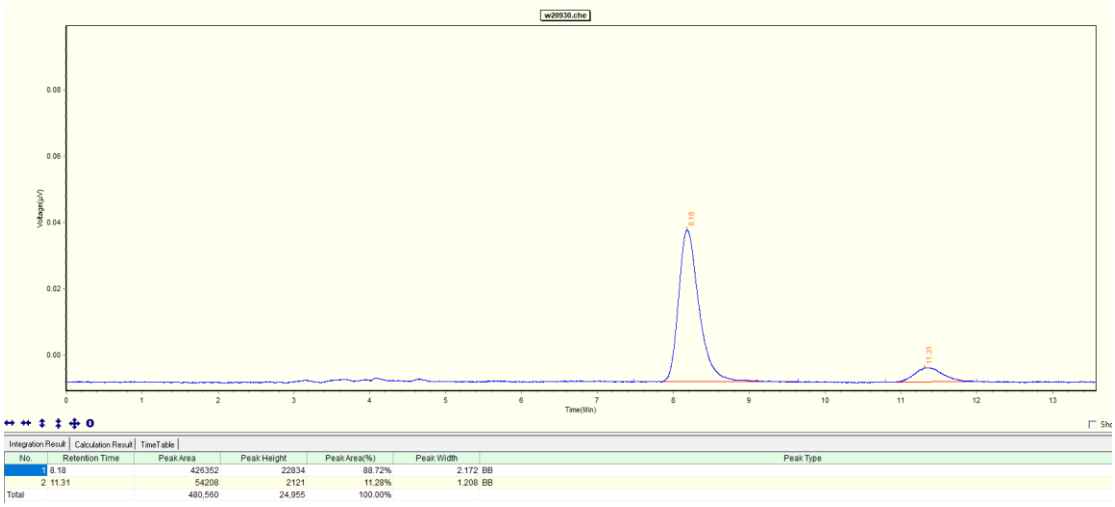


Before recrystallization:



Integration Result | Calculation Result | TimeTable

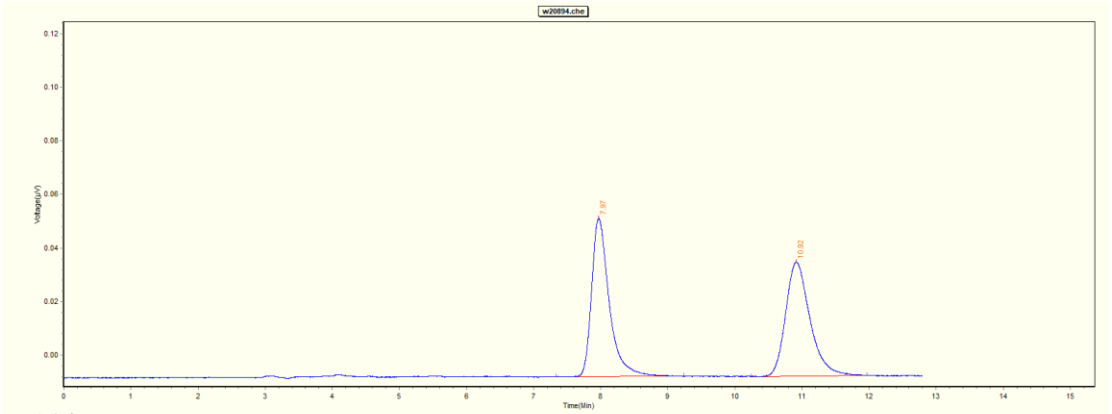
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.97	541910	29470	50.36%	1.909	BB
2	10.92	534062	21240	49.64%	1.728	BB
Total		1,075,972	50,710	100.00%		



Integration Result | Calculation Result | TimeTable

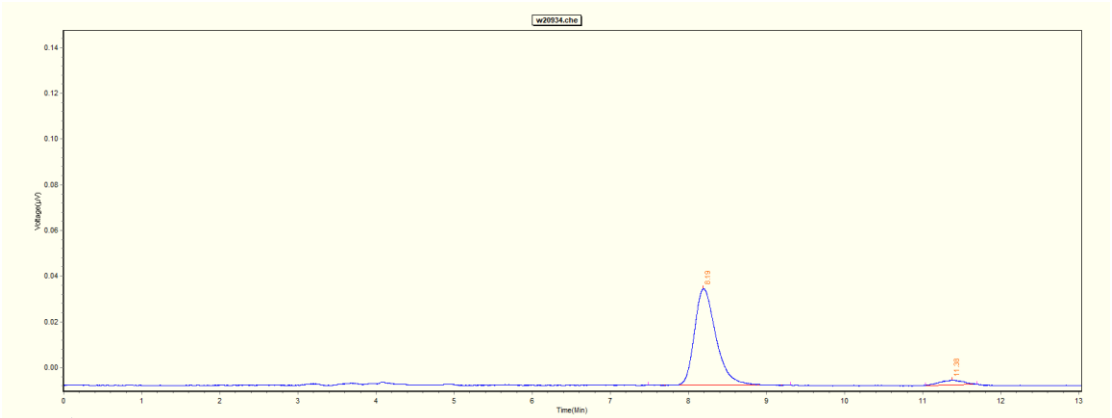
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.18	426352	22834	88.72%	2.172	BB
2	11.31	54208	2121	11.28%	1.208	BB
Total		480,560	24,955	100.00%		

After recrystallization:



Integration Result | Calculation Result | TimeTable

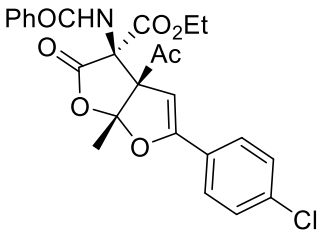
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	7.97	541910	29470	50.36%	1.909	BB
2	10.92	534062	21240	49.64%	1.728	BB
Total		1,075,972	50,710	100.00%		



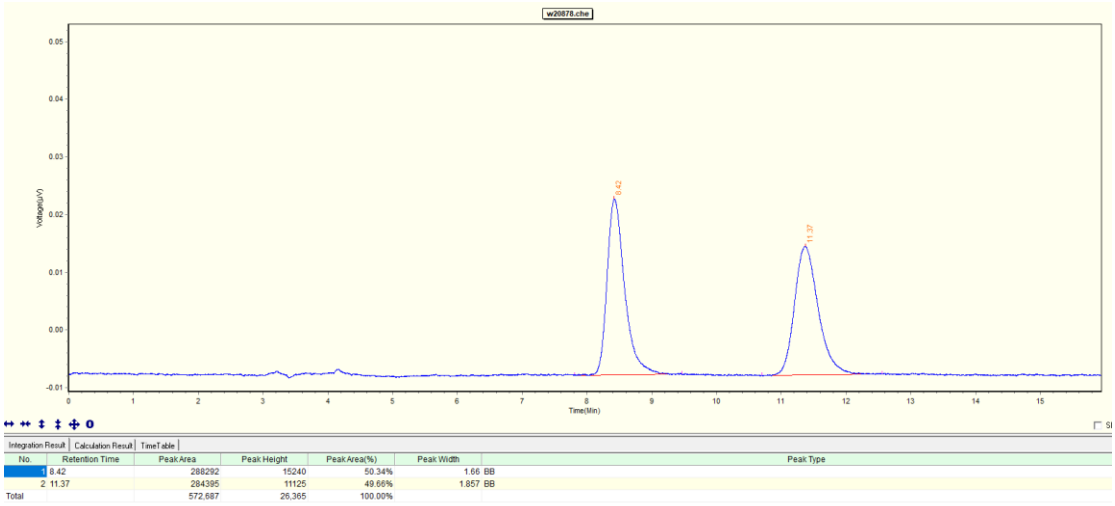
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.19	401703	21106	95.26%	1.82	BB
2	11.38	19995	976	4.74%	0.658	BB
Total		421,698	22,082	100.00%		

3t

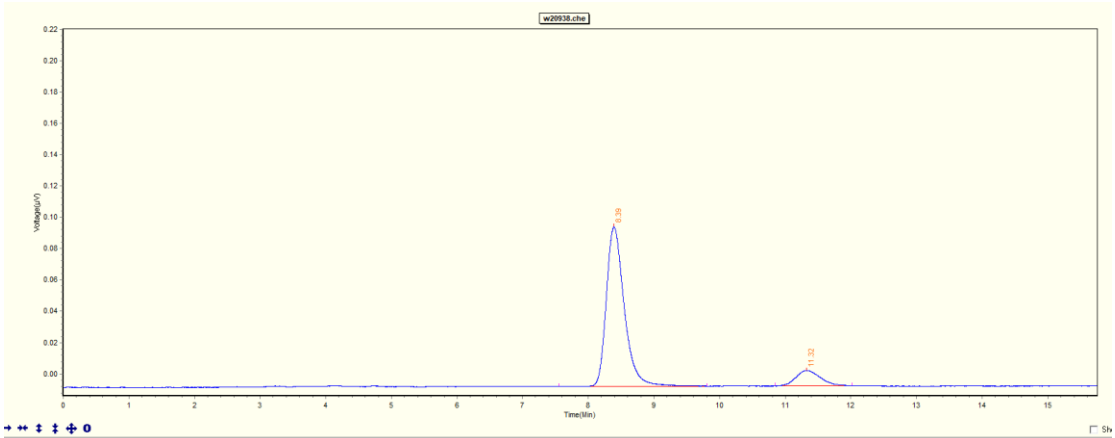


Before recrystallization



Integration Result | Calculation Result | TimeTable

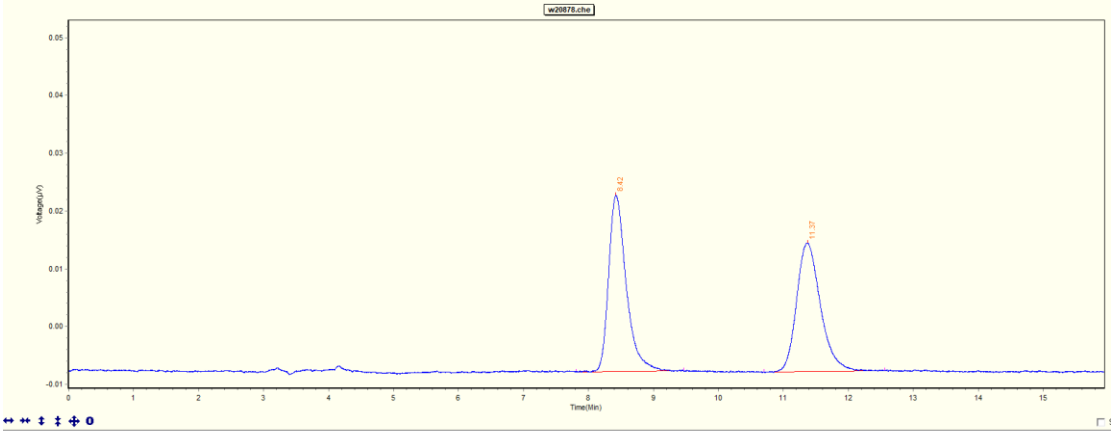
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.42	288292	15240	50.34%	1.66	BB
2	11.37	284395	11125	49.66%	1.857	BB
Total		572,687	26,365	100.00%		



Integration Result | Calculation Result | TimeTable

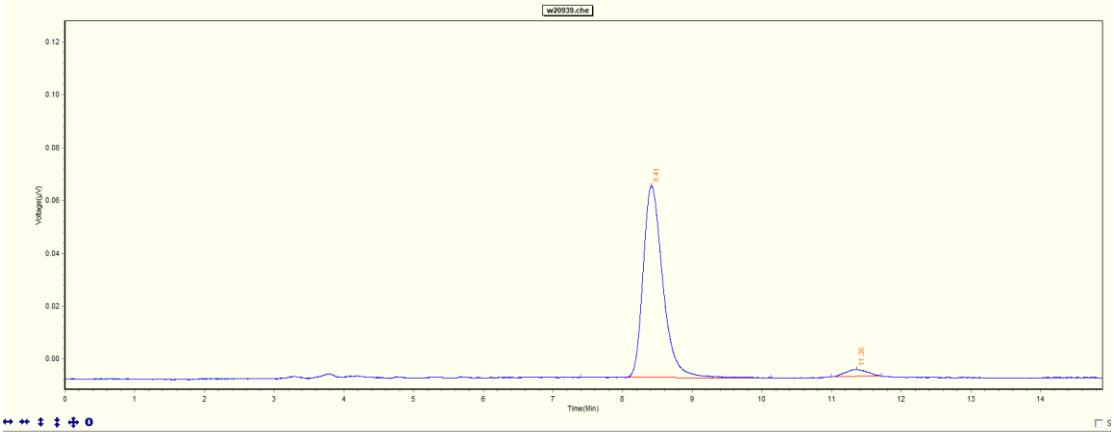
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.39	967683	50927	88.74%	2.257	BB
2	11.32	122778	4855	11.26%	1.166	BB
Total		1,090,461	55,782	100.00%		

After recrystallization.



Integration Result | Calculation Result | TimeTable

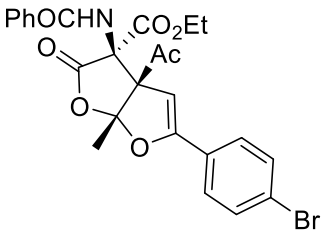
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.42	288292	15240	50.34%	1.66	BB
2	11.37	284395	11125	49.66%	1.857	BB
Total		572,687	26,365	100.00%		



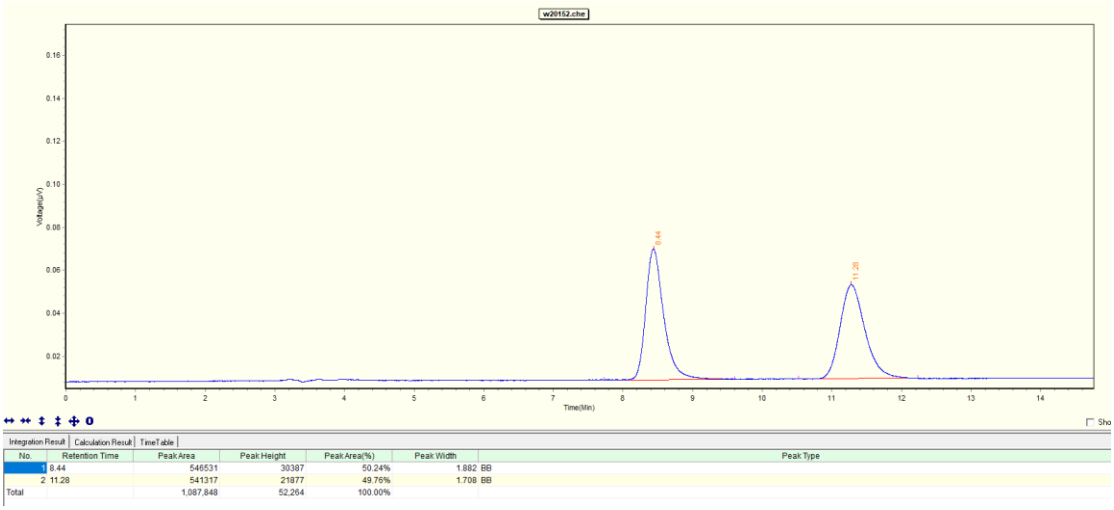
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.41	706871	36250	96.35%	2.737	BB
2	11.36	26756	1251	3.65%	0.717	BB
Total		733,627	37,501	100.00%		

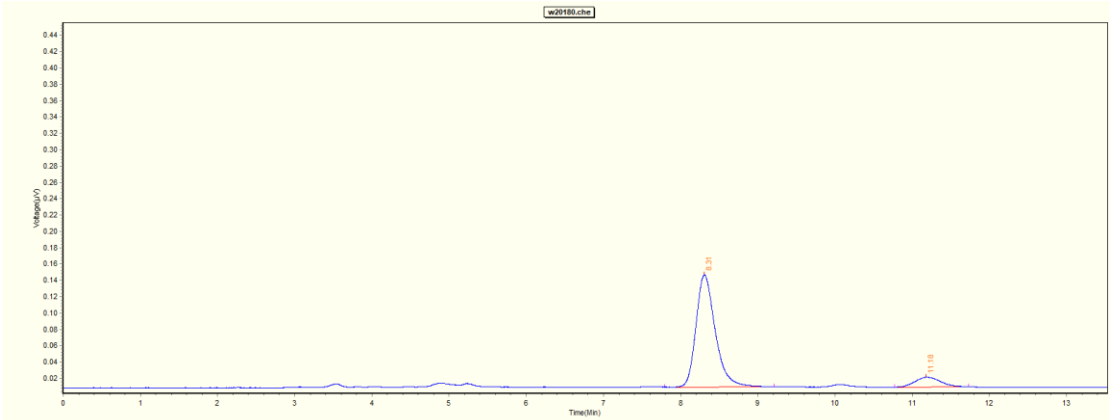
3u



Before recrystallization

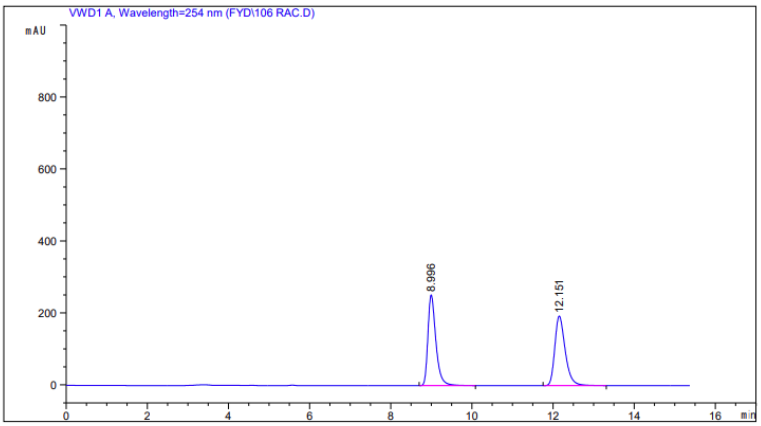


No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.44	546531	30387	50.24%	1.882	BB
2	11.28	541317	21877	49.76%	1.708	BB
Total		1,087,848	52,264	100.00%		



No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	8.31	1190512	68561	89.68%	1.418	BB
2	11.18	137048	5971	10.32%	0.958	BB
Total		1,327,560	74,532	100.00%		

After recrystallization:

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=====================================================================
                      Area Percent Report
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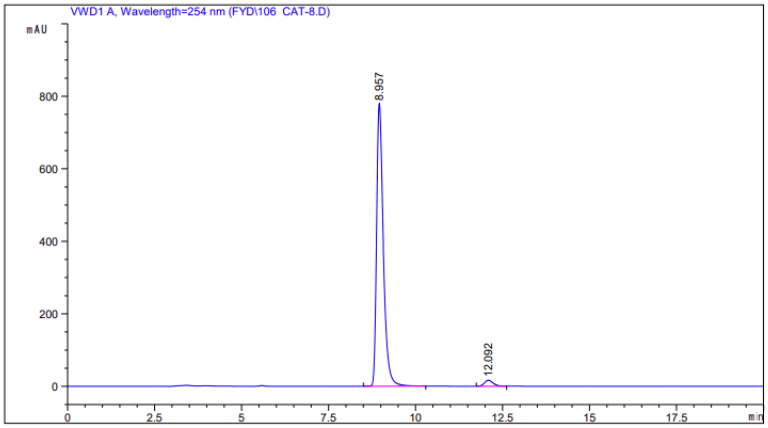
Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s   [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1   8.996 BB    0.2080 3460.24634  252.32442  49.9926
   2  12.151 BB    0.2728 3461.26904  193.46725  50.0074
```

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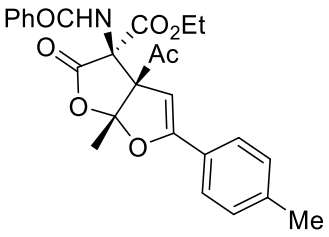
=====================================================================
                      Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs

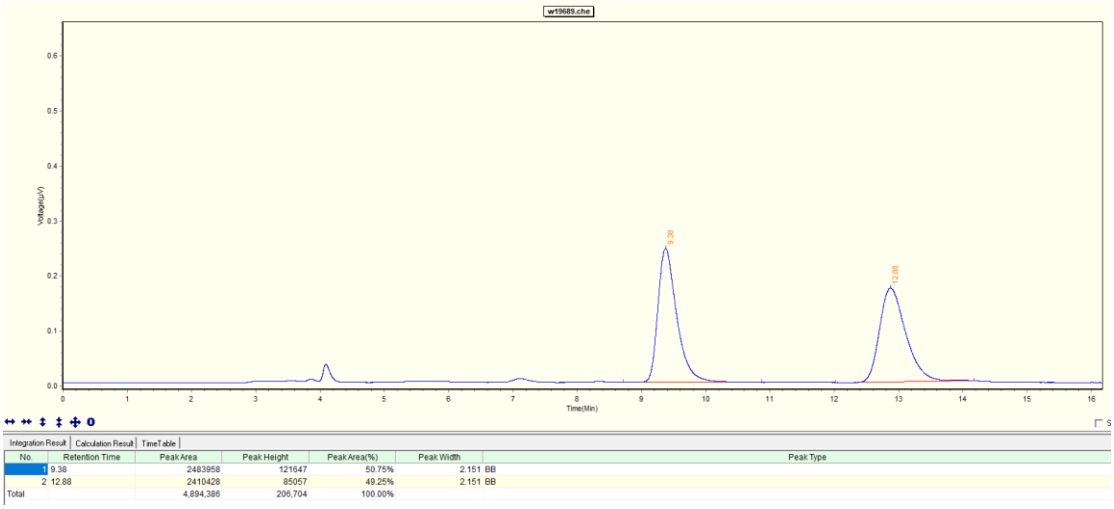

Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s   [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1   8.957 BB    0.2040 1.05255e4   779.91101  97.2426
   2  12.092 BB    0.2716  298.45779   16.77649   2.7574
```

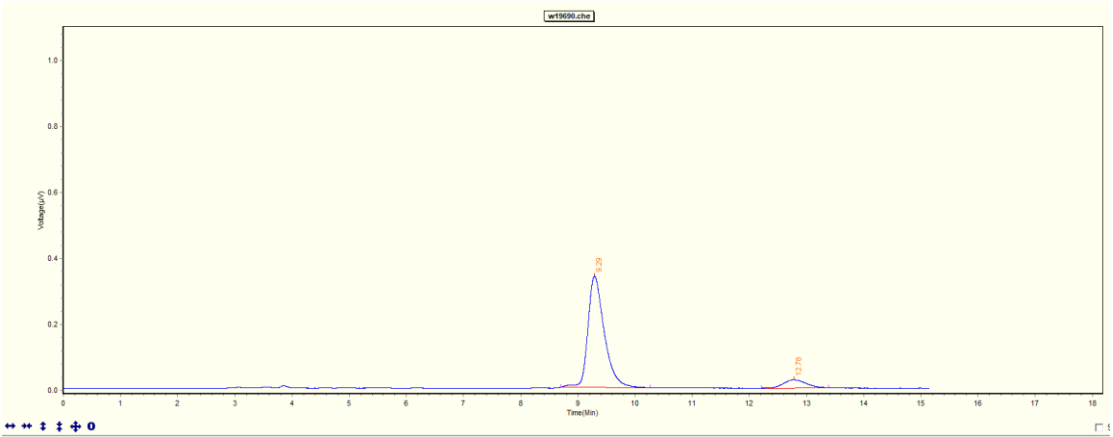
3w



Before recrystallization:

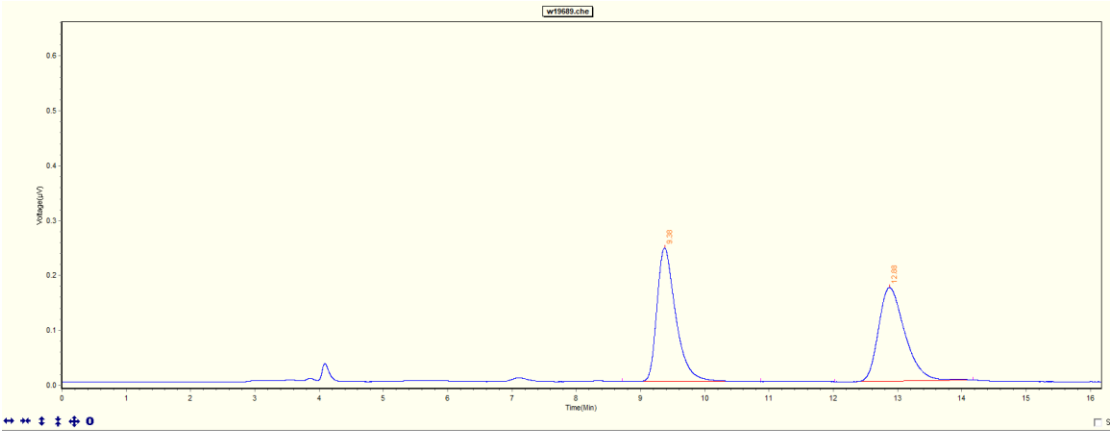


Integration Result	Calculation Result	TimeTable					
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type	
1	9.38	2483958	121647	50.75%	2.151	BB	
2	12.88	2410428	85057	49.25%	2.151	BB	
Total		4,894,386	206,704	100.00%			



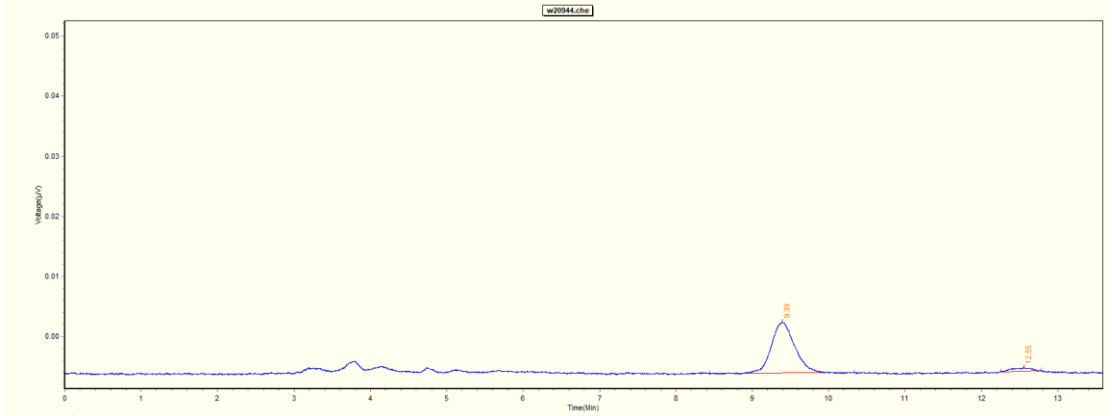
Integration Result	Calculation Result	TimeTable					
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type	
1	9.29	3339828	167860	90.90%	1.556	BB	
2	12.78	334354	12345	9.10%	1.176	BB	
Total		3,674,182	180,205	100.00%			

After recrystallization:



Integration Result | Calculation Result | TimeTable

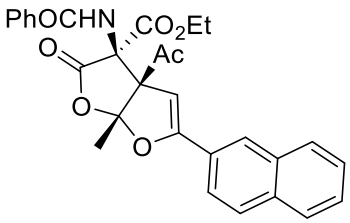
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	9.38	2483958	121647	50.75%	2.151	BB
2	12.88	2410428	85057	49.25%	2.151	BB
Total		4,894,386	206,704	100.00%		



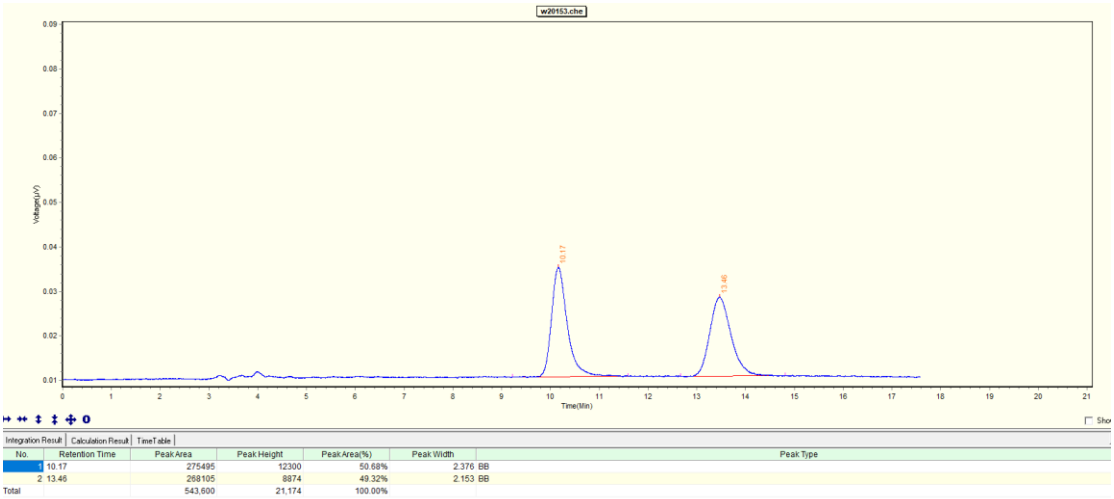
Integration Result | Calculation Result | TimeTable

No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	9.39	88903	4227	95.08%	1.903	BB
2	12.55	4597	294	4.92%	0.531	BB
Total		93,500	4,521	100.00%		

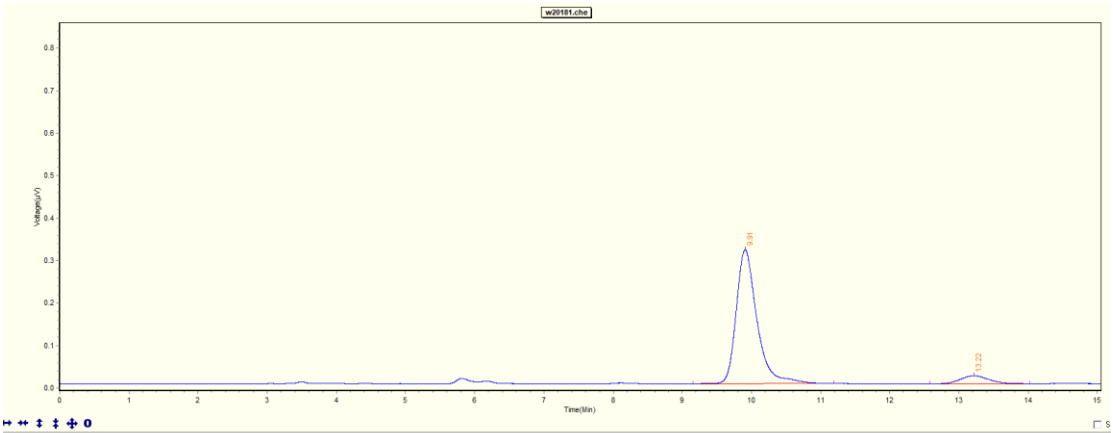
3y



Before recrystallization:

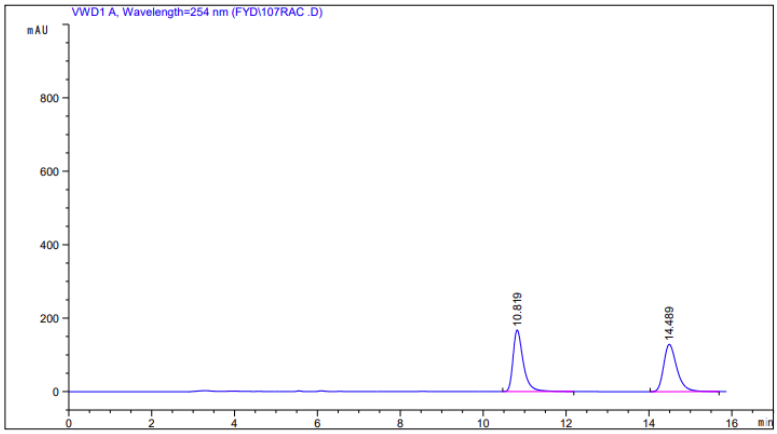


Integration Result	Calculation Result	TimeTable				
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	10.17	275495	12300	50.68%	2.376	BB
2	13.46	268105	8874	49.32%	2.153	BB
Total		543,600	21,174	100.00%		



Integration Result	Calculation Result	TimeTable				
No.	Retention Time	Peak Area	Peak Height	Peak Area(%)	Peak Width	Peak Type
1	9.91	3299351	157896	92.25%	2.038	BB
2	13.22	277292	9534	7.75%	1.446	BB
Total		3,576,643	167,430	100.00%		

After recrystallization:

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=====================================================================
                      Area Percent Report
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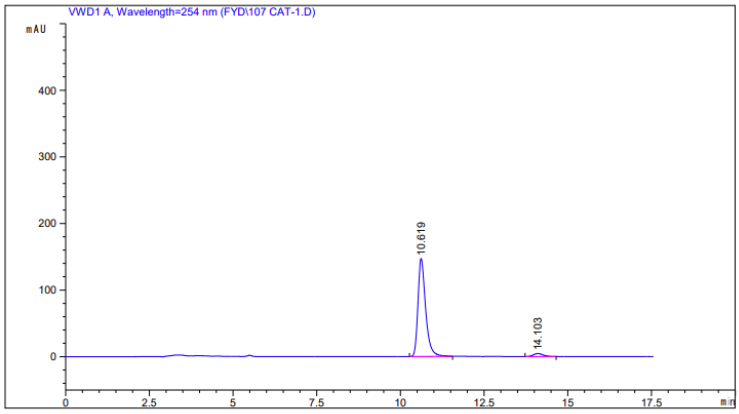
Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1  10.819 BB    0.2581 2869.20801  167.49533  50.1753
   2  14.489 BB    0.3366 2849.15381  128.87137  49.8247
```

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=====================================================================
                      Area Percent Report
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Sorted By             :      Signal
Multiplier            :      1.0000
Dilution              :      1.0000
Use Multiplier & Dilution Factor with ISTDs


Signal 1: VWD1 A, Wavelength=254 nm

Peak RetTime Type  Width     Area      Height     Area
  #   [min]        [min]  mAU   *s    [mAU   ]      %
----|-------|----|-------|----------|----------|--------|
   1  10.619 BB    0.2427 2344.58447  147.13242  96.2266
   2  14.103 BB    0.3116   91.94094    4.51924   3.7734
```

8. References

1. M. Gao, Y. Yang, Y.-D. Wu, C. Deng, L.-P. Cao, X.-G. Meng, A.-X. Wu, *Org. Lett.*, **2010**, 12, 1856-1859.

2. X. P. Chen, J. X. Liu, H. Y. Li, Y. C. Xiao, F. E. Chen, *Adv. Synth. Catal.*, **2022**, 364 (12), 2067-2071.

3 R. A. Mosey, J. S. Fisk, T. L. Friebe, J. J. Tepe, J. *Org. Lett.*, **2008**, 10 (5), 825-828.