Supporting Information:

Synthesis of chiral pyrimidine-substituted diester D-A cyclopropanes via asymmetric cyclopropanation of phenyliodonium ylides

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Contents

1. General information

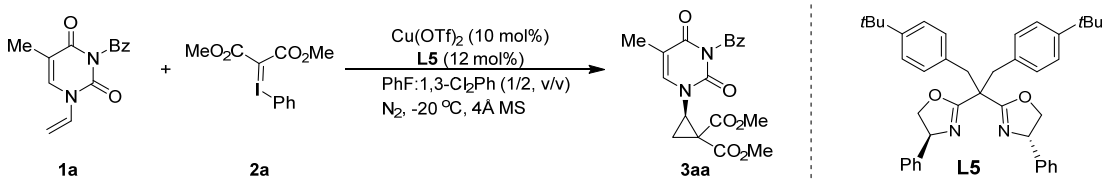
All reactions were carried out in oven-dried Schlenk tube filled nitrogen, and monitored by thin layer chromatography (TLC). All reagents were reagent grade quality and purchased from commercial sources unless otherwise indicated. Molecular sieves powder 3Å MS, 4Å MS, and 5Å MS were dried at 500 ^{o}C for 4 h in vacuum before use. ^{1}H NMR spectra were recorded on commercial instruments (400/600 MHz). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quaternary, m = multiplet, br = broad), coupling constants (Hz), integration. ^{13}C NMR data were collected on commercial instruments (100/150 MHz) with complete proton decoupling. Chemical shifts are reported in ppm from the tetramethylsilane with the solvent resonance as internal standard. Coupling constants (*J*) are reported in Hz. Enantiomer excesses were determined by chiral HPLC analysis on Chiralcel IA/ID in comparison with the authentic racemates. Chiral HPLC analysis recorded on Thermo scientific Dionex Ultimate 3000. Optical rotations were reported as follows: $[\alpha]_D^T$ (c: = g/100mL, in solvent). Optical rotations recorded on Autopol Automatic Polarimeter. All products were further characterized by high-resolution mass spectra (HRMS). The HRMS was obtained using a Q-TOF instrument equipped with an ESI source. The ligands **L1-L8** were purchased from commercial suppliers and used without further purifications.

2. Synthesis of starting materials

N1-vinylthymine (**1a**-**1n**) were prepared according to the literature procedures.[1] N1-vinylthymine were purified by flash chromatography on silica gel using petroleum ether/ethyl acetate as an eluant.

Phenyliodonium ylides were prepared according to the literature precedents.[2]

3. General procedure for the enantioselective cyclopropanation

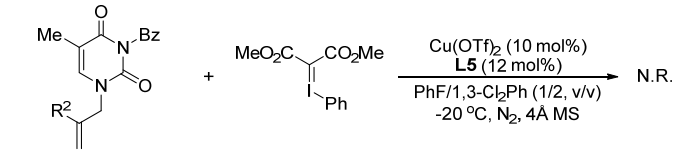


1a 2a 3aa

A mixture of $Cu(OTf)_2$ (0.005 mmol, 0.1 equiv) and the ligand **L5** (0.006 mmol, 0.12 equiv) in PhF:1,3-Cl_2Ph (1/2, v/v, 0.5 mL) with activated 4Å MS was stirred at room temperature for 2 h under an atmosphere of nitrogen. Then, N1-vinylthymine **1a** (0.05 mmol) was added to the mixture under an atmosphere. The mixture was then cooled to -20 °C for 20 minutes and then phenyliodonium ylide **2a** (0.20 mmol) was added to the mixture under an atmosphere of nitrogen in one portion. After the reaction was complete (monitoring by TLC), the reaction was filtered through a glass funnel with a thin layer of silica gel with DCM (approx 15 mL). The filtrate was concentrated under reduced pressure. The residue was purified by flash chromatography (petroleum ether/ethyl acetate = 2:1) to afford the product **3aa**.

4. Asymmetric cyclopropanation of N1-allylthymines

Scheme S1

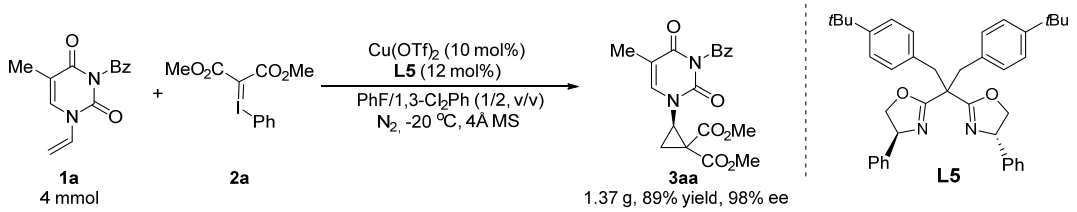


1o-p 2a

1o: R^2 = H; **1p**: R^2 = Ph

5. Gram-scale synthesis of 3aa

Scheme S2



1a
4 mmol

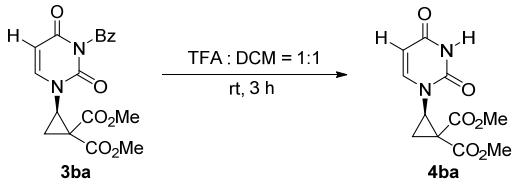
2a

3aa
1.37 g, 89% yield, 98% ee

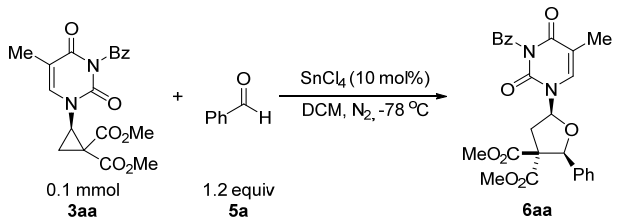
A mixture of $Cu(OTf)_2$ (0.4 mmol, 14.4 mg, 0.1 equiv) and ligand **L5** (0.48 mmol, 28.8 mg, 0.12 equiv) in PhF:1,3-Cl_2Ph (1/2, v/v, 40 mL) with activated 4Å MS was stirred at room temperature for 2

h under an atmosphere of nitrogen. Then, N1-vinylthymine **1a** (4 mmol, 1.024 g) was added to the mixture under an atmosphere of nitrogen. The mixture was then cooled to -20 °C for 20 minutes and phenyliodonium ylide **2a** (24 mmol, 8.016 g) was added to the mixture under an atmosphere of nitrogen in one portion. After the reaction was complete (monitoring by TLC), the reaction was filtered through a glass funnel with a thin layer of silica gel with DCM (approx 100 mL). The filtrate was concentrated under reduced pressure. The residue was purified by flash chromatography (petroleum ether/ethyl acetate = 2:1) to afford the product **3aa** (1.371 g, 89% yield, 98% ee).

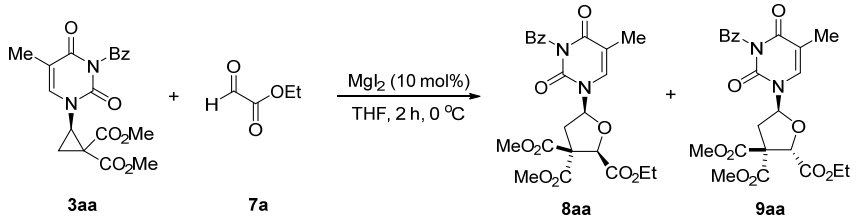
6. Transformation of the chiral cyclopropanes



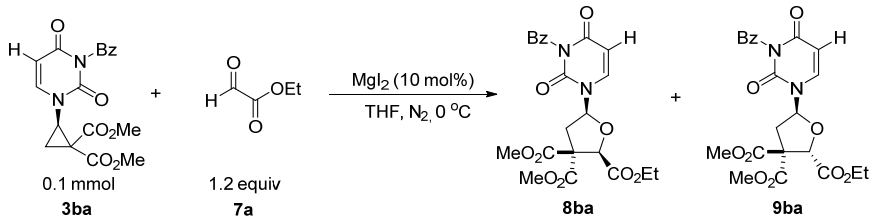
In a test tube, cyclopropane **3ba** (37.2 mg, 0.1 mmol) was dissolved in a mixture of TFA/DCM (1:1, v/v, 1.0 mL) and the resulting solution was stirred at room temperature for 3 h. The progress of the reaction was monitored by TLC. Then, sat. $NaHCO_3$ was added and the mixture was extracted with DCM (3 x 10 mL). The combined organic phase was dried over anhydrous Na_2SO_4. The solvent was removed and purified by column chromatography on silica gel (dichloromethane: methanol = 15:1) to afford the product **4ba** (81% yield, 84% ee).



In a test tube, cyclopropane **3aa** (0.1 mmol) and benzaldehyde **5a** (0.12 mmol, 1.2 equiv) were dissolved in DCM (1 mL) at -78 °C under an atmosphere of nitrogen. The progress of the reaction was monitored by TLC. After overnight, water (2 mL) was added and the mixture was extracted with DCM (5 mL x 3). The organic phases were combined, dried over Na_2SO_4 and concentrated under vacuum. The residue was purified by silica gel flash chromatography (petroleum : ethyl acetate = 2:1) to give the desired product **6aa** (68% yield, >20:1 dr, and 50% ee).

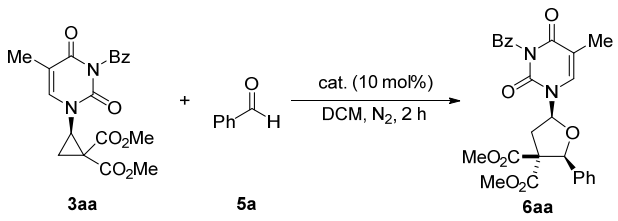


In a test tube, cyclopropane **3aa** (37.2 mg, 0.1 mmol) and ethyl glyoxalate **7a** (approximately 50% solvent in toluene, 0.12 mmol, 23.8 μL) were dissolved in THF (0.5 mL). MgI_2 (2.8 mg, 0.01 mmol) was dissolves in THF (0.5 mL) and added to the above tube via syringe at 0 °C for 2 h under an atmosphere of nitrogen. The progress of the reaction was monitored by TLC. Then, water (2 mL) was added and the mixture was extracted with DCM (5 mL x 3). The organic phases were combined, dried over Na_2SO_4 and concentrated under vacuum. The residue was purified by silica gel flash chromatography (petroleum : ethyl acetate = 1:1) to give the desired products **8aa** (35% yield, 86% ee) and **9aa** (37% yield, 94% ee).



In a test tube, cyclopropane **3ba** (37.2 mg, 0.1 mmol) and ethyl glyoxalate **7a** (approximately 50% solvent in toluene, 0.12 mmol, 23.8 μL) were dissolved in THF (0.5 mL). MgI_2 (2.8 mg, 0.01 mmol) was dissolves in THF (0.5 mL) and added to the above tube via syringe at 0 °C for 2 h under an atmosphere of nitrogen. The progress of the reaction was monitored by TLC. Then, water (2 mL) was added and the mixture was extracted with DCM (5 mL x 3). The organic phases were combined, dried over Na_2SO_4 and concentrated under vacuum. The residue was purified by silica gel flash chromatography (petroleum : ethyl acetate = 1:1) to give the desired products **8ba** (47% yield, 80% ee), **9ba** (24% yield, 88% ee).

Table S1[a]



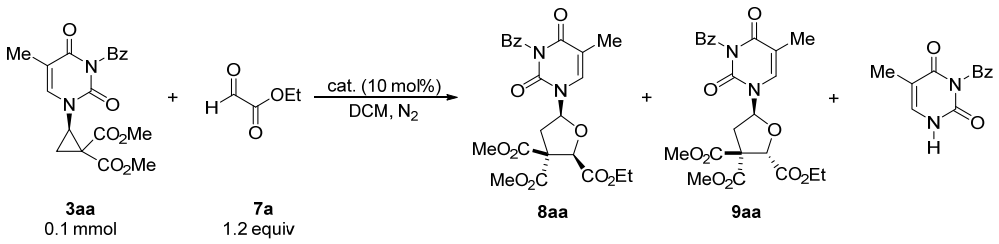
entry	cat.	T (°C)	ee[b] (%)
1	$In(OTf)_3$	0	24
2[c]	$In(OTf)_3$	-20	-
3	$Sn(OTf)_2$	0	24
4[c]	$Sn(OTf)_2$	-20	-
5	$SnCl_4$	-20	12
6	$SnCl_4$	-40	42
7[c,d]	MgI_2	0	-

8[c,d]	MgI_2	rt	-
9[c,d]	MgI_2	65	-

[a] Reaction conditions: cat. (10 mol%), **3aa** (0.1 mmol), **5a** (0.12 mmol), DCM (1 mL) under N_2 atmosphere. [b] ee value of the product was determined by chiral HPLC. [c] No reaction. [d] THF was used as the solvent.

In a test tube, cyclopropane **3aa** (38.6 mg, 0.1 mmol), benzaldehyde **5a** (0.12 mmol, 1.2 equiv) and catalyst (10 mol%) were added in DCM (1 mL) under an atmosphere of nitrogen. The progress of the reaction was monitored by TLC. After overnight, water (2 mL) was added and the mixture was extracted with DCM (5 mL x 3). The organic phases were combined, dried over Na_2SO_4 and concentrated under vacuum. The residue was purified by silica gel flash chromatography (petroleum: ethyl acetate = 2:1) to give the desired product **6aa**.

Table S2[a]



entry	cat.	T (°C)	ee[b] (**8aa**) (%)	ee[b] (**9aa**) (%)
1	$SnCl_2$	rt	11	9
2	$ZnBr_2$	rt	33	51
3[c]	$AlCl_3$	rt	-	-
4[c,d]	$Yb(OTf)_3$	rt	-	-
5[e]	$Mg(OTf)_2$	rt	-	-
6	$Zn(NTf)_2$	rt	10	23
7[f]	$SnCl_4$	-78	-	-
8[f]	$SnCl_4$	-20	-	-
9[g]	$SnCl_4$	rt	14	-

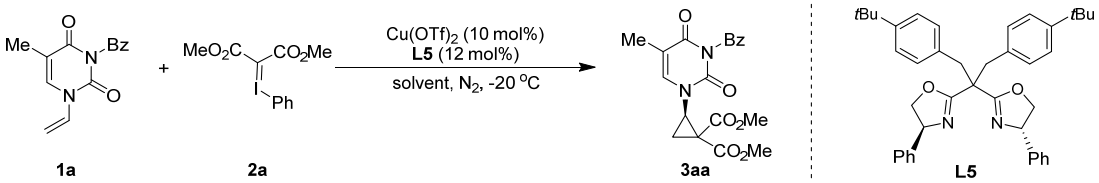
[a] Reaction conditions: cat. (10 mol%), **3aa** (0.1 mmol), **7a** (0.12 mmol), DCM (1 mL) under N_2 atmosphere. [b] ee value of the product was determined by chiral HPLC. [c] Trace of products (**8aa** and **9aa**) was detected. [d] Some of Bz-protected thymine was detected. [e] No reaction. [f] Trace of product **8aa** was detected and the product **9aa** was not detected. [g] Product **9aa** was not detected.

In a test tube, cyclopropane **3aa** (38.6 mg, 0.1 mmol), ethyl glyoxalate **7a** (approximately 50% solvent in toluene, 0.12 mmol, 23.8 μL) were dissolved in DCM (1 mL) at room temperature under an atmosphere of nitrogen. The progress of the reaction was monitored by TLC. After overnight, water (2 mL) was added and the mixture was extracted with DCM (5 mL x 3). The organic phases were

combined, dried over Na_2SO_4 and concentrated under vacuum. The residue was purified by silica gel flash chromatography (petroleum: ethyl acetate = 1:1) to give the corresponding products **8aa** and **9aa**.

7. Condition optimization

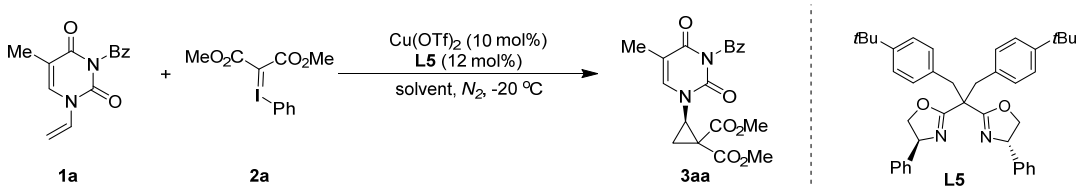
Table S3 [a]



entry	solvent	additive	t (h)	yield[b] (%)	ee[c] (%)
1	THF		48	39	92
2	DCE		48	56	70
3,	$CHCl_3$		48	47	84
4	MeCN		48	32	44
5	toluene		48	52	93
6	toluene	3Å MS (50 mg)	72	73	93
7	toluene	4Å MS (50 mg)	72	94	93
8	toluene	5Å MS (50 mg)	72	85	93

[a]Unless otherwise noted, reaction conditions were: **1a** (0.05 mmol), **2a** (2.0 mmol), solvent (0.5 mL), $Cu(OTf)_2$ (10 mol%), **L5** (12 mol%), N_2 atmosphere. [b]Isolated yields were reported. [c] Determined by chiral HPLC.

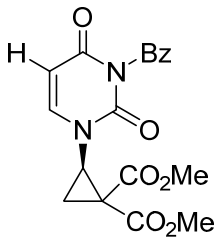
Table S4 [a]



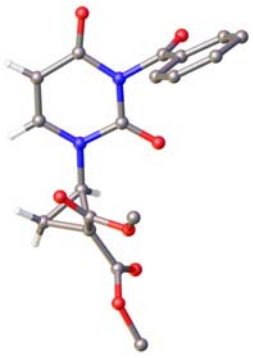
entry	solvent	yield[b] (%)	ee[c] (%)
1	xylene	49	90
2	mesitylene	43	92
3	PhCl	56	90
4	1,3-Cl_2Ph	86	98
5	PhF	97	97
6	$PhCF_3$	96	97
7	PhF/1,3-Cl_2Ph (1/1, v/v)	96	99
8	PhF/1,3-Cl_2Ph (2/1, v/v)	94	98

[a]Unless otherwise noted, reaction conditions were: **1a** (0.05 mmol), **2a** (2.0 mmol), solvent (0.5 mL), $Cu(OTf)_2$ (10 mol%), **L5** (12 mol%), 4Å MS (50 mg) was used under N_2 for 72 h. [b] Isolated yields were reported. [c]Determined by chiral HPLC.

8. The X-ray data for 3ba



3ba



3ba

The product of **3ba** was recrystallized by dichloromethane/ ethyl acetate (1/1).

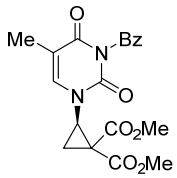
CCDC 2009735 (**3ba)** contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Table 1 Crystal data and structure refinement for 3ba.

Identification code	lwp-20191021
Empirical formula	$C_{18}H_{16}N_2O_7$
Formula weight	372.33
Temperature/K	292.7(2)
Crystal system	orthorhombic
Space group	P212121
a/Å	7.48180(10)
b/Å	10.0714(2)
c/Å	23.3470(3)
α/°	90
β/°	90
γ/°	90
Volume/Å3	1759.25(5)
Z	4
ρcalcg/cm3	1.406
μ/mm-1	0.933
F(000)	776.0
Crystal size/mm3	0.23 × 0.1 × 0.07
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	7.574 to 143.326
Index ranges	-9 ≤ h ≤ 9, -12 ≤ k ≤ 12, -28 ≤ l ≤ 28
Reflections collected	31254
Independent reflections	3434 [Rint = 0.0352, Rsigma = 0.0153]
Data/restraints/parameters	3434/0/246
Goodness-of-fit on F2	1.037
Final R indexes [I>=2σ (I)]	R1 = 0.0398, wR2 = 0.1032
Final R indexes [all data]	R1 = 0.0416, wR2 = 0.1052
Largest diff. peak/hole / e Å-3	0.13/-0.21
Flack parameter	-0.05(7)

9. The analytical and spectral characterization data for the cycloadducts

(*R*)-Dimethyl -2-(3-benzoyl-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3aa)



White solid; m.p.: 181.1 – 183.6 °C. 97% yield, 18.7 mg, 99% ee. $[\alpha]_D^{25}$ = -20.7 (c = 1.4, CH_2Cl_2).

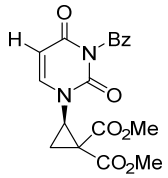
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 13.750 min, 15.275 min.

^{1}H NMR (400 MHz, Methanol-d_4) δ 7.91 (d, *J* = 7.6 Hz, 2H), 7.72 (t, *J* = 6.8 Hz, 1H), 7.56 (t, *J* = 7.6 Hz, 3H), 4.01(t, *J* = 7.6 HZ, 1H), 3.74 (s, 3H), 3.62 (s, 3H), 2.32 (t, *J* = 6.4 Hz, 1H), 2.01 (t, *J* = 7.6 Hz, 1H), 1.92 (s, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.4, 167.6, 166.9, 162.8, 150.2, 139.0, 135.2, 131.6, 130.7, 129.2, 111.1, 53.4, 53.4, 42.8, 35.0, 20.4, 12.7.

HRMS (ESI): m/z calcd. for : $C_{19}H_{18}N_2O_7Na^+$ $[M+Na]^+$:409.1006, found 409.1006.

(*R*)-Dimethyl-2-(3-benzoyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarbox-ylate (3ba)



White solid; m.p.: 174.1 – 179.6 °C. 95% yield, 17.5 mg, 97% ee. $[\alpha]_D^{25}$ = -80.7 (c = 1.2, CH_2Cl_2).

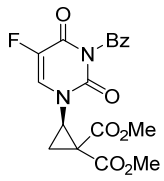
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 50/50, flow rate = 0.9 mL/min, λ = 254 nm, retention time: 23.415 min, 37.742 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 7.8 Hz, 2H), 7.65 (t, *J* = 6.6 Hz, 1H), 7.50 (t, *J* = 7.2 Hz, 2H), 7.27 (s, 1H), 5.83 (d, *J* = 7.8 Hz, 1H), 4.02 (t, *J* = 7.2 Hz, 1H), 3.78 (s, 3H), 3.68 (s, 3H), 2.22 (d, *J* = 6.6 Hz, 1H), 2.01 (t, *J* = 6.6 Hz, 1H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.2, 167.5, 166.8, 162.0, 150.1, 143.1, 135.3, 131.4, 130.7, 129.2, 102.5, 53.4, 53.4, 43.0, 34.8, 20.2.

HRMS (ESI): m/z calcd. for : $C_{18}H_{16}N_2O_7Na^+$ $[M+Na]^+$: 395.0850, found 395.0849.

(*R*)-Dimethyl -2-(3-benzoyl-5-fluoro-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3ca)



Colorless oil; 96% yield, 18.7 mg, 98% ee. $[\alpha]_D^{25}$ = -44.2 (c =1.6, CH_2Cl_2).

HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 14.867 min, 16.927 min.

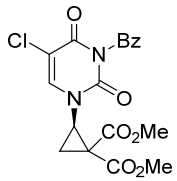
^{1}H NMR (600 MHz, Chloroform-d) δ 7.91 (d, *J* = 7.8 Hz, 2H), 7.66 (t, *J* = 7.2 Hz, 1H), 7.50 (t, *J* = 7.2 Hz, 2H), 7.35 (d, *J* = 5.4 Hz, 1H), 3.98 (t, *J* = 7.2 Hz, 1H), 3.76 (s, 3H), 3.67 (s, 3H), 2.17 (t, *J* = 6.6 Hz, 1H), 2.00 (t, *J* = 7.8 Hz, 1H),

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.2, 166.8, 166.7, 156.1(d, $J_{C\text{-}F}$ = 114.0 Hz), 148.8, 140.7, 139.1, 135.7, 130.9, 130.9, 129.3, 128.0 (d, $J_{C\text{-}F}$ = 138.0 Hz) , 53.5, 53.4, 43.0, 34.9, 20.5.

^{19}F NMR (376 MHz, Chloroform-*d*) δ –163.85.

HRMS (ESI): m/z calcd. for: $C_{18}H_{15}N_2O_7Na^+$ $[M+Na]^+$: 413.0756, found 413.0756.

(*R*)-Dimethyl -2-(3-benzoyl-5-chloro-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3da)



Colorless oil; 93% yield, 18.9 mg, 88% ee. $[\alpha]_D^{25}$ = -32.6 (c = 1.2, CH_2Cl_2).

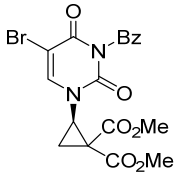
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 14.640 min, 18.120 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.90 (d, *J* = 7.8 Hz , 2H), 7.65 (t, *J* = 7.8 Hz, 1H), 7.49 (t, *J* = 7.8 Hz, 3H), 4.00 (t, *J* = 7.2 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.21 (t, *J* = 6.6 Hz, 1H), 2.02 (t, *J* = 7.2 Hz, 1H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.2, 167.0, 166.8, 158.0, 149.3, 140.1, 135.6, 131.0, 130.9, 129.3, 109.2, 53.5, 53.5, 43.0, 34.8, 20.4.

HRMS (ESI): m/z calcd. for: $C_{18}H_{15}N_2O_7Na^+$ $[M+Na]^+$: 429.0460, found 429.0458.

(*R*)-Dimethyl -2-(3-benzoyl-5-bromo-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1, 1-dicarboxylate (3ea)



Colorless oil; 94% yield, 21.2 mg, 93% ee. $[\alpha]_D^{25}$ = -43.7 (c = 0.6, CH_2Cl_2).

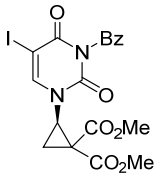
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 15.412 min, 18.795 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.90 (d, *J* = 7.8 Hz, 2H), 7.65 (t, *J* = 7.2 Hz, 1H), 7.60 (s, 1H), 7.49 (t, *J* = 7.2 Hz, 2H), 3.99 (d, *J* = 6.6 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.21 (t, *J* = 6.6 Hz, 1H), 2.02 (t, *J* = 7.2 Hz, 1H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.2, 167.0, 166.7, 149.5, 142.5, 135.5, 131.0, 130.9, 129.3, 96.8, 53.5, 53.5, 43.0, 34.8, 20.5.

HRMS (ESI): m/z calcd. for: $C_{18}H_{15}BrN_2O_7Na^+$ $[M+Na]^+$: 472.9955, found 472.9953

(*R*)-Dimethyl-2-(3-benzoyl-5-iodo-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3fa)



Colorless oil; 96% yield, 23.9 mg , 92% ee. $[\alpha]_D^{25}$ = -81.8 (c = 1.4, CH_2Cl_2).

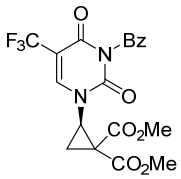
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 14.430 min, 17.960 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.88 (dd, *J* = 1.2, 8.0 Hz, 2H), 7.70 (s, 1H), 7.64 (t, *J* = 7.6 Hz, 1H), 7.48 (t, *J* = 7.6 Hz, 2H), 3.99 (dd, *J* = 8.0, 6.4 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.21 (t, *J* = 6.4 Hz, 1H), 2.02 (dd, *J* = 8.0, 6.8 Hz, 1H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 167.3, 167.2, 166.7, 158.9, 149.8, 147.5, 135.5, 130.9, 130.8, 129.3, 68.0, 53.5, 53.5, 42.8, 34.7, 20.5.

HRMS (ESI): m/z calcd. for: $C_{18}H_{15}N_2O_7Na^+$ $[M+Na]^+$: 520.9816, found 520.9816.

(*R*)-Dimethyl-2-(3-benzoyl-2,4-dioxo-5-(trifluoromethyl)-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1, 1-dicarboxylate (3ga)



Colorless oil; 91% yield, 20.0 mg, 71% ee. $[\alpha]_D^{25}$ = -26.4 (c = 1.2, CH_2Cl_2).

HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 9.917 min, 11.863 min.

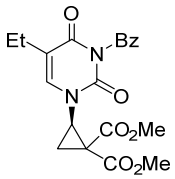
^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.89 (d, *J* = 7.8 Hz, 2H), 7.74 (s, 1H), 7.66 (t, *J* = 7.2 Hz, 1H), 7.50 (t, *J* = 7.8 Hz, 2H), 4.02 (t, *J* = 7.2 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.19 (t, *J* = 6.0 Hz, 1H), 2.06 (t, *J* = 7.4 Hz, 1H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.0, 166.8, 157.4, 149.2, 144.2(q, $J_{C\text{-}F}$ = 24.0 Hz), 135.7, 130.9, 130.8, 129.4, 122.4, 120.6, 105.5(q, $J_{C\text{-}F}$ =132.0 Hz), 53.5, 43.1, 34.6 , 20.4 .

^{19}F NMR (376 MHz, Chloroform-*d*) δ –63.28 (s)

HRMS (ESI): m/z calcd. for: $C_{19}H_{15}F_3N_2O_7Na^+$ $[M+Na]^+$: 463.0724, found 463.0724.

(*R*)-Dimethyl-2-(3-benzoyl-5-ethyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3ha)



White solid; m.p.: 186.1 – 188.7°C. 96% yield, 19.2 mg, 93% ee. $[\alpha]_D^{25}$ = -127.1 (c = 0.8, CH_2Cl_2).

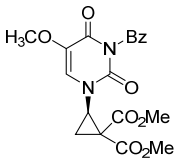
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 12.213 min, 13.250 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.90 – 7.87 (m, 2H), 7.62 (t, *J* = 7.2 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.01 (s, 1H), 3.98 (dd, *J* = 8.0, 6.4 Hz, 1H), 3.76 (s, 3H), 3.65 (s, 3H), 2.43 – 2.35 (m, 2H), 2.24 (t, *J* = 6.4 Hz, 1H), 1.98 (dd, *J* = 8.4, 6.4 Hz, 1H), 1.16 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 168.5, 167.6, 166.8, 150.1, 138.3, 135.1, 131.6, 130.65, 129.2, 116.8, 53.3, 42.9, 35.0, 20.5, 20.2, 12.7.

HRMS (ESI): m/z calcd. for: $C_{20}H_{20}N_2O_7Na^+$ $[M+Na]^+$: 423.1163, found: 423.1163.

(*R*)-Dimethyl-2-(3-benzoyl-5-methoxy-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3ia)



White solid; m.p.: 186.4 – 190.2 °C. 97% yield, 19.5 mg, 96% ee. $[\alpha]_D^{25}$ = -25.0 (c = 2.4, CH_2Cl_2).

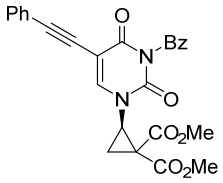
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 22.702 min, 25.395 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.89 (d, *J* = 7.6 Hz , 2H), 7.63 (t, *J* = 6.8 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 6.79 (s, 1H), 3.97 (t, *J* = 6.8 Hz, 1H), 3.76 (d, *J* = 6.8 Hz, 6H), 3.65 (s, 3H), 2.24 (t, *J* = 6.4 Hz, 1H), 1.97 (t, *J* = 7.6 Hz, 1H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 167.57, 167.55, 166.8, 158.5, 148.8, 136.3, 135.3, 131.3, 130.8, 129.2, 123.4, 58.1, 53.4, 53.3, 43.1, 35.2, 20.7.

HRMS (ESI): m/z calcd. for: $C_{19}H_{18}N_2O_8Na^+$ $[M+Na]^+$: 425.0955, found : 425.0955.

(*R*)-Dimethyl-2-(3-benzoyl-2, 4-dioxo-5-(phenylethynyl)-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3ja)



Colorless oil; 86% yield, 20.3 mg, 77% ee. $[\alpha]_D^{25}$ = -47.0 (c = 0.8, CH_2Cl_2).

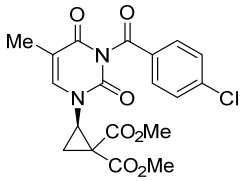
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 18.637 min, 20.815 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 7.8 Hz, 2H), 7.63 (t, *J* = 7.2 Hz, 1H), 7.58 (s, 1H), 7.48 (t, *J* = 7.2 Hz, 4H), 7.33 (s, 3H), 4.01 (t, *J* = 7.2 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.25 (t, *J* = 6.6 Hz, 1H), 2.03 (t, *J* = 7.2 Hz, 1H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.3, 167.2, 166.6, 160.2, 149.1, 144.9, 135.3, 131.7, 131.1, 130.7, 129.2, 128.9, 128.4, 122.3, 100.7, 94.7, 79.3, 53.4, 53.3, 43.0, 34.6, 20.2.

HRMS (ESI): m/z calcd. for: $C_{26}H_{20}N_2O_7Na^+$ $[M+Na]^+$: 495.1163, found: 495.1162.

(*R*)-Dimethyl-2-(3-(4-chlorobenzoyl)-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3ka)



Colorless oil; 93% yield, 19.5 mg, 92% ee. $[\alpha]_D^{25}$ = -43.6 (c = 1.7, CH_2Cl_2).

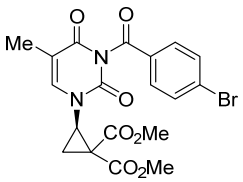
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 14.118 min, 16.072 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.83 (d, *J* = 7.8 Hz, 2H), 7.45 (s, 2H), 7.08 (s, 1H), 3.94 (t, *J* = 7.2 Hz, 1H), 3.77 (s, 3H), 3.67 (s, 3H), 2.20 (t, *J* = 6.6 Hz, 1H), 1.99 (t, *J* = 7.2 Hz, 1H), 1.95 (s, 3H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 167.6, 167.5, 166.9, 162.8, 150.2, 141.9, 139.1, 132.1, 130.1, 129.6, 111.1, 53.4, 42.8, 34.8, 20.5, 12.6.

HRMS (ESI): m/z calcd. for: $C_{19}H_{17}ClN_2O_7Na^+[M+Na]^+$: 443.0616,found: 443.0615.

(*R*)-Dimethyl-2-(3-(4-bromobenzoyl)-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3la)



Colorless oil; 83% yield, 19.3 mg, 93% ee. $[\alpha]_D^{25}$ = -68.4 (c = 1.3, CH_2Cl_2).

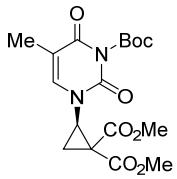
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 14.118 min, 16.072 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.74 (d, *J* = 8.4 Hz, 2H), 7.61 (d, *J* =7.8 Hz, 2H), 7.08 (s, 1H), 3.94 (t, *J* = 7.2 Hz, 1H), 3.76 (s, 3H), 3.66 (s, 3H), 2.20 (t, *J* = 6.6 Hz, 1H), 1.99 (t, *J* = 7.2 Hz, 1H), 1.94 (s, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.8, 167.6, 166.9, 162.8, 150.2, 139.1, 132.6, 132.0, 130.7, 130.6, 111.2, 53.4, 42.8, 34.8, 29.8, 20.5, 12.7.

HRMS (ESI): m/z calcd. for: $C_{19}H_{17}BrN_2O_7Na^+[M+Na]^+$:487.0111, found : 487.0111.

(*R*)-Dimethyl-2-(3-(*t*ert-butoxycarbonyl)-5-methyl-2,4-dioxo-3,4-dihyropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3ma)



Colorless oil; 96% yield, 18.3 mg, 94% ee. $[\alpha]_D^{25}$ = -22.7 (c = 1.7, CH_2Cl_2).

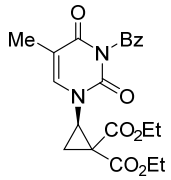
HPLC CHIRALCEL ID, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 27.175 min, 35.203 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.95 (s, 1H), 4.01 (t, *J* = 7.6 Hz, 1H), 3.79 (s, 3H), 3.71 (s, 3H), 2.27 (t, *J* = 6.4 Hz, 1H), 1.91 (s, 4H), 1.58 (s, 9H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 167.8, 166.3, 161.4, 149.3, 147.6, 138.4, 110.6, 86.9, 53.5, 53.3, 43.0, 35.2, 27.6, 20.1, 12.6.

HRMS (ESI): m/z calcd. for: $C_{17}H_{22}N_2O_8Na^+$ $[M+Na]^+$: 405.1268, found 405.1266.

(*R*)-Diethyl-2-(3-benzoyl-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclop ropane-1, 1-dicarboxylate (3ab)



Colorless oil; 84% yield, 17.4 mg, 92% ee. $[\alpha]_D^{25}$ = -56.7 (c = 1.9, CH_2Cl_2).

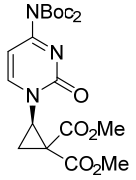
HPLC CHIRALCEL ID, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 49.228 min, 70.623 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.88 (d, *J* = 7.8 Hz, 2H), 7.61 (t, *J* = 7.2 Hz, 1H), 7.46 (t, *J* = 7.8 Hz, 2H), 7.09 (s, 1H), 4.24 – 4.15 (m, 3H), 4.04 (s, 1H), 3.97 (t, *J* = 7.2 Hz, 1H), 2.22 (t, *J* = 6.6 Hz, 1H), 1.93 (s, 3H), 1.91 (d, *J* = 7.2 Hz, 1H), 1.25 (t, *J* = 7.2 Hz, 4H), 1.16 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 168.5, 167.2, 166.2, 162.9, 150.1, 139.1, 135.1, 131.6, 130.7, 129.1, 110.8, 62.4, 62.3, 42.6, 35.2, 20.1, 14.1, 14.0, 12.6

HRMS (ESI): m/z calcd. for: $C_{21}H_{22}N_2O_7H^+$ $[M+H]^+$:415.1500, found : 415.1487.

(*R*)-Dimethyl-2-(4-(*di*-Boc-amino)-2-oxopyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (3na)



White solid; m.p.: 172.1 – 175.8 °C. 89% yield, 20.8 mg, 83% ee. $[\alpha]_D^{25}$ = 80.2 (c = 3.6, CH_2Cl_2).

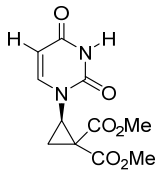
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 8.548 min, 11.892 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 (d, *J* = 7.6 Hz, 1H), 7.03 (d, *J* = 7.2 Hz, 1H), 4.21 (dd, *J* = 8.0, 6.8 Hz, 1H), 3.80 (s, 3H), 3.64 (s, 3H), 2.29 (t, *J* = 6.8 Hz, 1H), 1.97 (dd, *J* = 8.4, 6.8 Hz, 1H), 1.54 (s, 18H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 167.9, 166.3, 162.7, 155.1, 149.5, 146.3, 96.0, 85.2, 53.4, 53.3, 44.8, 35.0, 27.8, 19.6.

HRMS (ESI): m/z calcd. for: $C_{22}H_{24}N_2O_7Na^+$[M+Na]$^+$: 490.1796, found : 490.1793.

(*R*)-Dimethyl-2-(2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) cyclopropane-1,1-dicarboxylate (4ba)



White solid; m.p.: 172.1 – 175.8 °C. 81% yield, 21.7 mg, 84% ee. $[\alpha]_D^{25}$ = -14.3 (c =1.6, CH_2Cl_2).

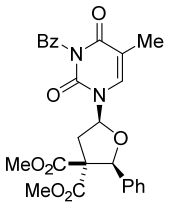
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 15.363 min, 18.775 min.

^{1}H NMR (600 MHz, DMSO-d_6) δ 11.3 (s, 1H), 7.58 (d, *J* = 8.4 Hz, 1H), 5.52 (d, *J* = 8.4 Hz, 1H), 3.97 (t, *J* = 7.2 Hz, 1H), 3.71 (s, 3H), 3.56 (s, 3H), 2.34 (t, *J* = 6.6 Hz, 1H), 1.93 (t, *J* = 7.8 Hz, 1H).

^{13}C NMR (150 MHz, DMSO-d_6) δ 168.0, 166.4, 163.8, 150.5, 144.8, 101.3, 53.3, 53.2, 34.8, 19.5.

HRMS (ESI): m/z calcd. for: $C_{22}H_{24}N_2O_7Na^+$[M+Na]$^+$: 291.0588, found : 291.0586.

(2*S*,5*S*)-Dimethyl-5-(3-benzoyl-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl)-2-phenyldihydrofuran-3,3(2*H*)-dicarboxylate (6aa)



Colorless oil; 68% yield, 33.5 mg, >20:1 dr, 50% ee. $[\alpha]_D^{25}$ = 0.72 (c = -9.1, CH_2Cl_2).

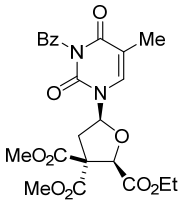
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 12.173 min, 19.650 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.07 (s, 1H), 7.95 (d, *J* = 7.8 Hz, 2H), 7.64 (t, *J* = 7.2 Hz, 1H), 7.48 (dd, *J* = 18.0, 7.2 Hz, 4H), 7.38-7.33(m, 3H), 6.36 (t, *J* = 7.2 Hz, 1H), 5.61 (s, 1H), 3.80 (s, 3H), 3.15 (s, 3H), 2.99 (dd, *J* =8.4, 7.2 Hz, 1H), 2.80 (dd, *J* = 14.4, 7.8 Hz, 1H), 2.10 (s, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 170.0, 169.9, 168.9, 136.0, 135.2, 131.7, 130.7, 129.3, 129.0, 128.3, 126.7, 112.2, 82.6, 81.7, 63.9, 53.3, 52.9, 39.3, 13.1.

HRMS (ESI): m/z calcd. for: $C_{26}H_{24}N_2O_8Na^+$ $[M+Na]^+$:515.1425, found : 515.1423.

(2*R*, 5*S*)-2-Ethyl 3,3-dimethyl-5-(3-benzoyl-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) dihydrofuran-2,3,3(2*H*)-tricarboxylate (8aa)



Colorless oil; 35% yield, 17.1 mg, 86% ee. $[\alpha]_D^{25}$ = -6.5 (c = 0.81, CH_2Cl_2).

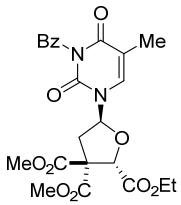
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 12.955 min, 14.542 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.13 (d, *J* = 1.2 Hz, 1H), 7.96 – 7.87 (m, 2H), 7.64 (t, *J* = 7.6 Hz, 1H), 7.49 (t, *J* = 8.4 Hz, 2H), 6.26 (dd, *J* = 8.0, 5.6 Hz, 1H), 5.18 (s, 1H), 4.32 – 4.20 (m, 2H), 3.84 (s, 3H), 3.76 (s, 3H), 2.97 (dd, *J* = 13.6, 5.6 Hz, 1H), 2.86 (dd, *J* = 13.6, 8.4 Hz, 1H), 2.01 (d, *J* = 1.3 Hz, 3H), 1.33 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 169.8, 168.9, 168.4, 167.1, 162.8, 149.6, 135.8, 135.8, 135.2, 131.7, 130.6, 129.3, 111.6, 85.4, 80.4, 63.2, 62.4, 54.2 , 53.7, 38.3, 14.2, 12.9 .

HRMS (ESI): m/z calcd. for: $C_{23}H_{24}N_2O_{10}Na^+$ $[M+Na]^+$: 511.1323, found :511.1322.

(2*S*, 5*S*)-2-Ethyl 3, 3-dimethyl-5-(3-benzoyl-5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) dihydrofuran-2,3,3(2*H*)-tricarboxylate (9aa)



Colorless oil; 37% yield, 18.1 mg, 94% ee. $[\alpha]_D^{25}$ = -8.6 (c =1.2, CH_2Cl_2).

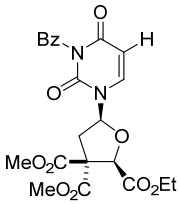
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time:16.382 min, 19.677 min.

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.92 – 7.90 (m, 2H), 7.65 (t, *J* = 7.5 Hz, 1H), 7.49 (t, *J* = 8.0 Hz, 2H), 7.29 (d, *J* = 1.2 Hz, 1H), 6.35 (dd, *J* = 6.8, 4.4 Hz, 1H), 5.44 (s, 1H), 4.27 (m, 2H), 3.82 (s, 3H), 3.76 (s, 3H), 3.32 (dd, *J* = 14.4, 7.2 Hz, 1H), 2.78 (dd, *J* = 14.4, 4.4 Hz, 1H), 1.97 (d, *J* = 1.2 Hz, 3H), 1.29 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (100 MHz, Chloroform-*d*) δ 169.3, 168.8, 168.3, 167.2, 162.8, 149.2, 135.3, 135.2, 131.6, 130.6, 129.3, 111.0, 87.7, 82.1, 62.9, 62.3, 54.1, 53.7, 39.3, 29.8, 14.2, 12.8.

HRMS (ESI): m/z calcd. for : $C_{23}H_{24}N_2O_{10}Na^+$[M+Na]$^+$: 511.1323, found : 511.1322.

(2*R*, 5*S*)-2-Ethyl 3,3-dimethyl-5-(3-benzoyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) dihydrofuran-2,3,3(2*H*)-tricarboxylate (8ba)



Colorless oil; 47% yield, 22.3 mg, 80% ee. $[\alpha]_D^{25}$ = -8.5 (c = 0.68, CH_2Cl_2).

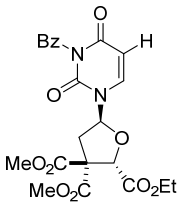
HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 16.090 min, 21.082 min.

H NMR (600 MHz, Chloroform-*d*) δ 8.31 (d, *J* = 7.8 Hz, 1H), 7.93 (d, *J* = 7.8 Hz, 2H), 7.65 (t, *J* = 7.2 Hz, 1H), 7.49 (t, *J* = 7.8 Hz, 2H), 6.21 (t, *J* = 6.6 Hz, 1H), 5.90 (d, *J* = 8.4 Hz, 1H), 5.18 (s, 1H), 4.35 – 4.17 (m, 2H), 3.83 (s, 3H), 3.76 (s, 3H), 3.00 (dd, *J* = 13.8, 5.4 Hz, 1H), 2.88 (dd, *J* = 13.8, 7.8 Hz, 1H), 1.32 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 169.7, 168.6, 168.3, 167.1, 162.0, 149.5, 140.1, 135.3, 131.5, 130.6, 129.3, 102.8, 85.9, 80.7, 63.1, 62.5, 54.2, 53.8, 38.7, 14.1.

HRMS (ESI): m/z calcd. for: $C_{22}H_{22}N_2O_{10}Na^+$ [M+Na]$^+$: 497.1167, found : 497.1167.

(2*S*, 5*S*)-2-Ethyl 3,3-dimethyl-5-(3-benzoyl-2,4-dioxo-3,4-dihydropyrimidin-1(2*H*)-yl) dihydrofuran-2,3,3(2*H*)-tricarboxylate (9ba)



Colorless oil; 24% yield, 10.0 mg, 88% ee. $[\alpha]_D^{25}$ = -7.7 (c = 0.65, CH_2Cl_2).

HPLC CHIRALCEL IA, *n*-hexane/2-propanol = 70/30, flow rate = 0.8 mL/min, λ = 254 nm, retention time: 18.915 min, 28.347 min.

^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.92 (d, *J* = 7.2 Hz, 2H), 7.66 (t, *J* = 7.2 Hz, 1H), 7.50 (t, *J* = 8.4 Hz, 3H), 6.32 (s, 1H), 5.83 (d, *J* = 8.4 Hz, 1H), 5.44 (s, 1H), 4.25-4.17 (m, 2H), 3.82 (s, 3H), 3.76 (s, 3H), 3.34 (dd, *J* = 14.4, 7.2 Hz, 1H), 2.81 (s, 1H), 1.29 (t, *J* = 7.2 Hz, 3H).

^{13}C NMR (150 MHz, Chloroform-*d*) δ 169.2, 168.5, 168.3, 167.0, 149.1, 139.4, 135.4, 131.5, 130.6, 129.4, 102.2, 88.1, 82.2, 62.7, 62.4, 54.2, 53.8, 39.4, 29.8, 14.1.

HRMS (ESI): m/z calcd. for: $C_{22}H_{22}N_2O_{10}Na^+$ $[M+Na]^+$: 497.1167, found: 497.1167.

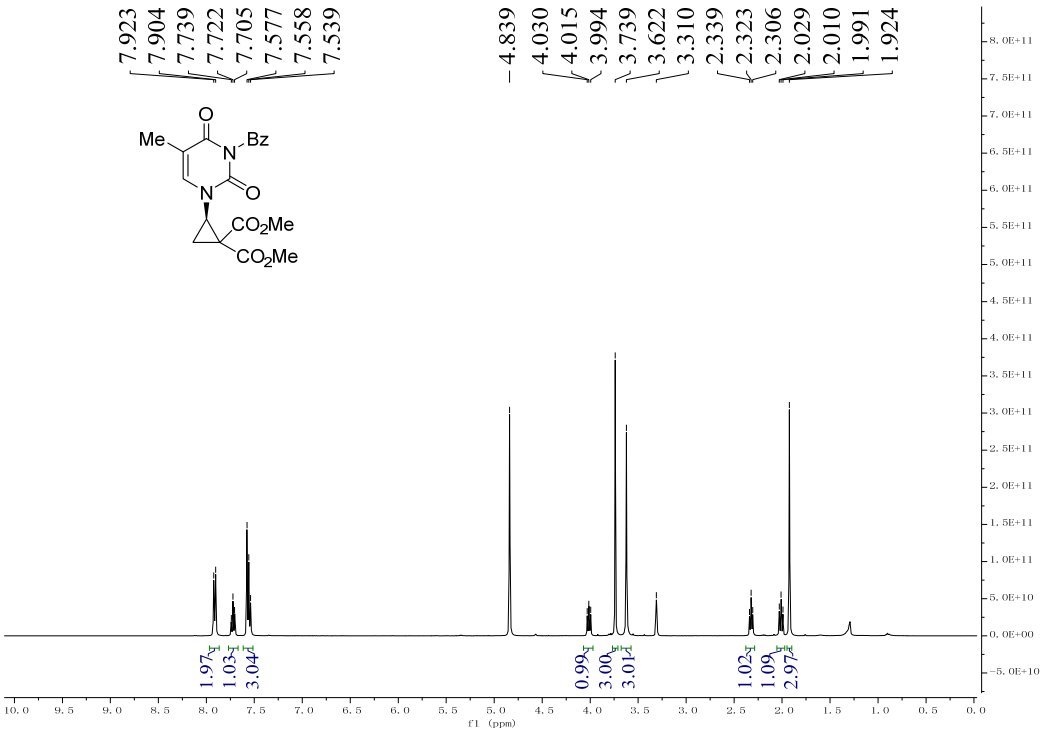
10. References

1. (a) H.-X. Wang, F.-J. Guan, M.-S. Xie, G.-R. Qu and H.-M. Guo, *Adv. Synth. Catal.*, 2018, **360**, 2233. (b) M.-S. Xie, P. Zhou, H.-Y. Niu, G.-R. Qu and H.-M. Guo, *Org. Lett.,* 2016, **18**, 4344.

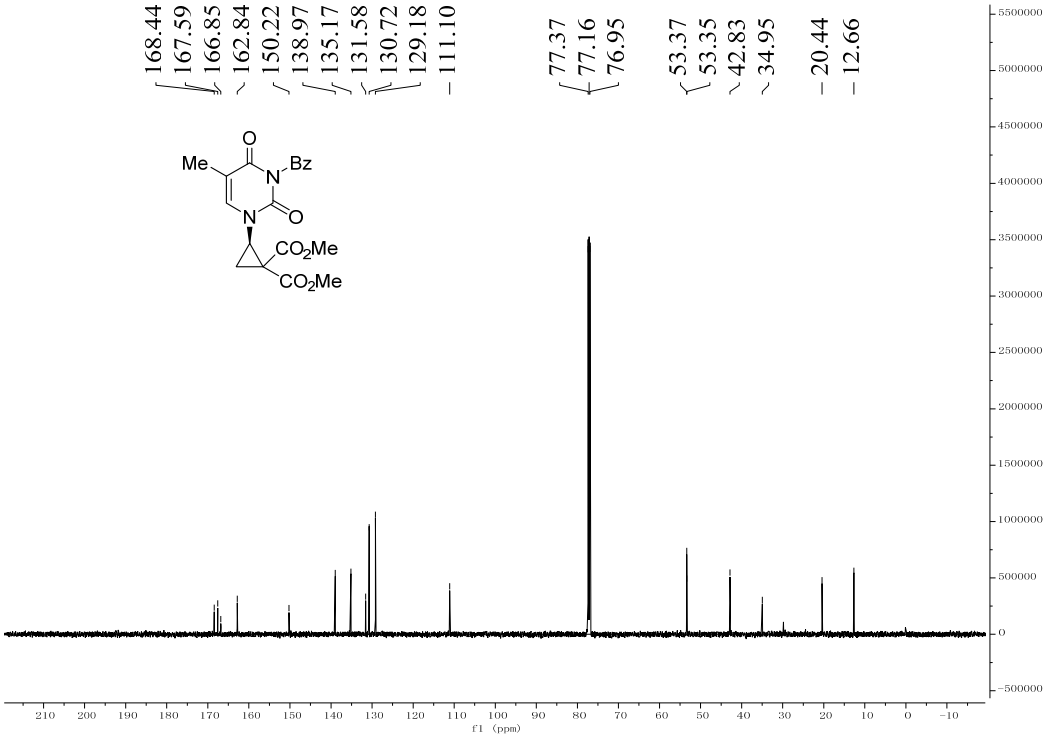
2. S. R. Goudreau, D. Marcoux and A. B. Charette, *J. Org. Chem.*, 2009, **74**, 470.

11. Copies of ^{1}H and ^{13}C NMR spectra

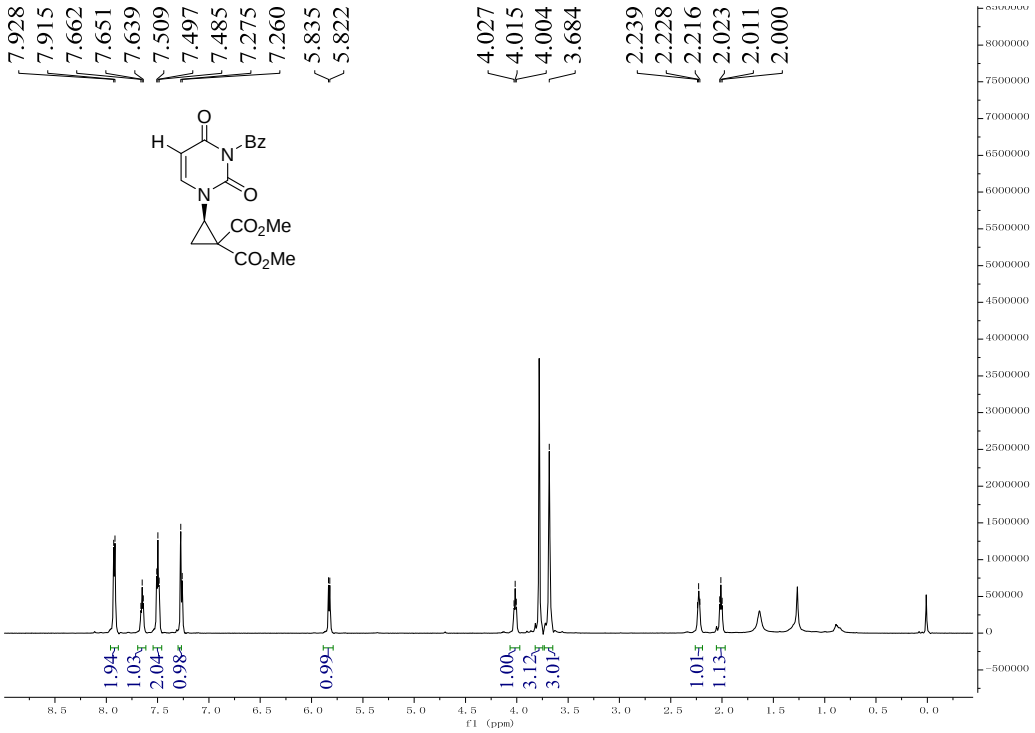
^{1}H NMR of 3aa (400 MHz, Methanol-d_4)



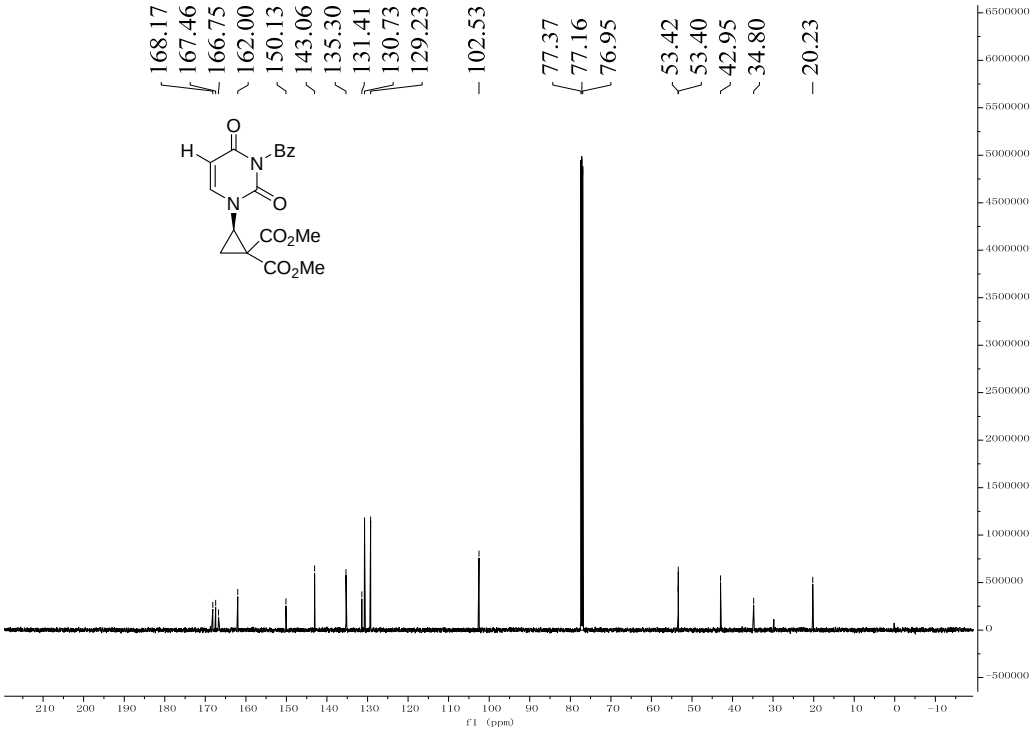
^{13}C NMR of 3aa (150 MHz, Chloroform-*d*)



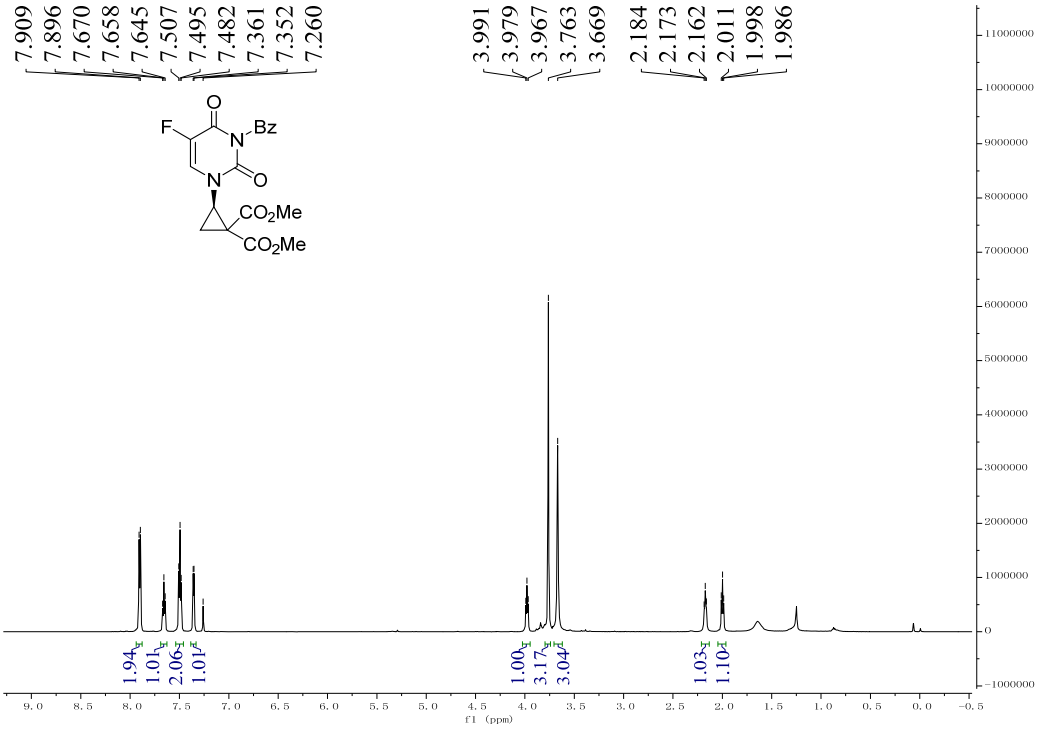
^{1}H NMR of 3ba (600 MHz, Chloroform-*d*)



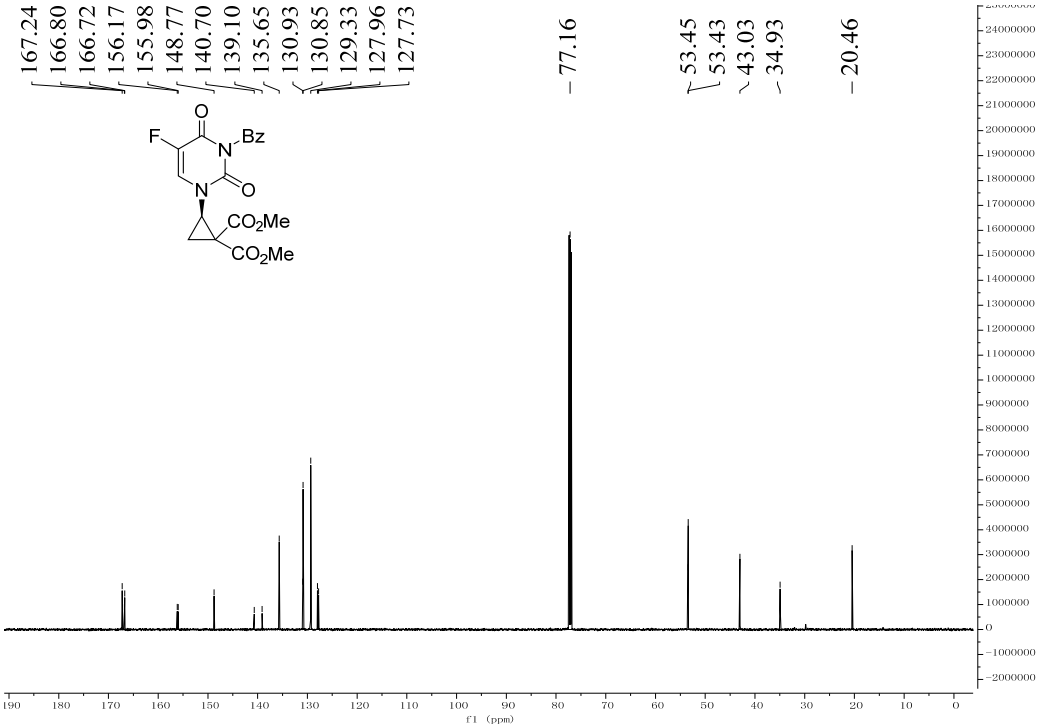
^{13}C NMR of 3ba (150 MHz, Chloroform-d)



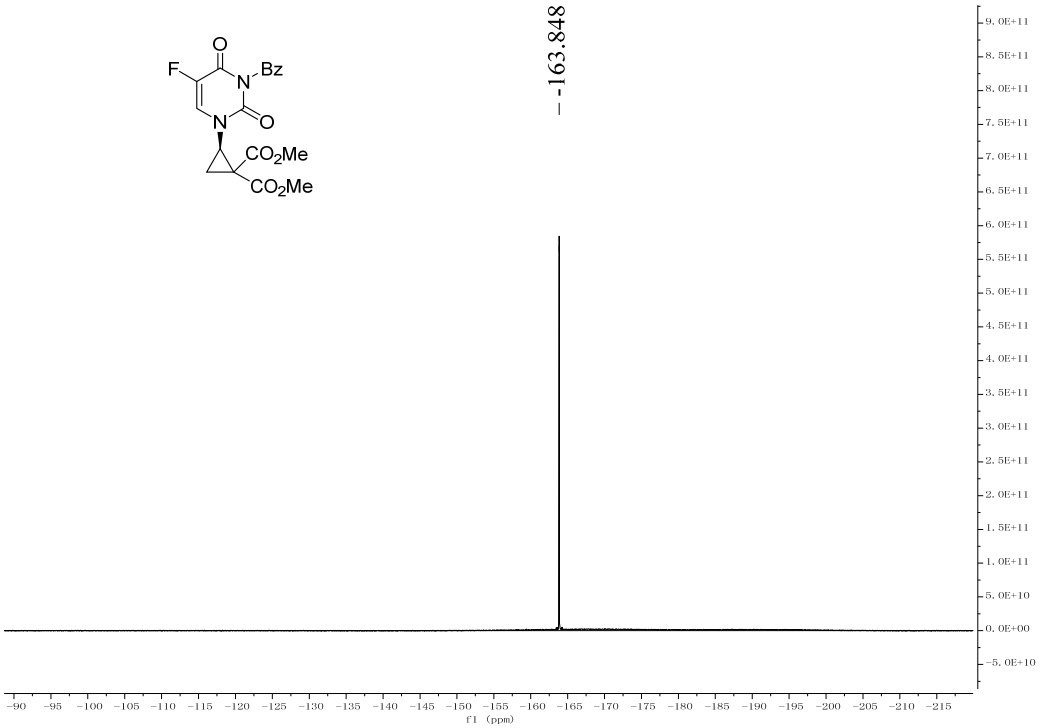
^{1}H NMR of 3ca (600 MHz, Chloroform-*d*)



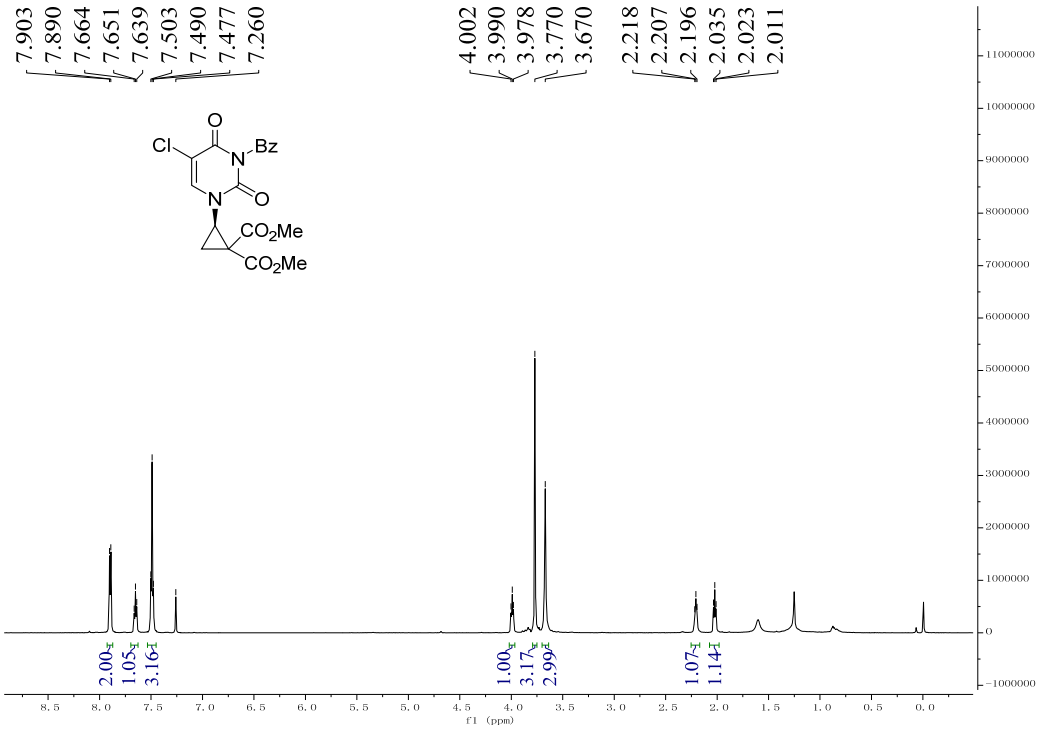
^{13}C NMR of 3ca (150 MHz, Chloroform-*d*)



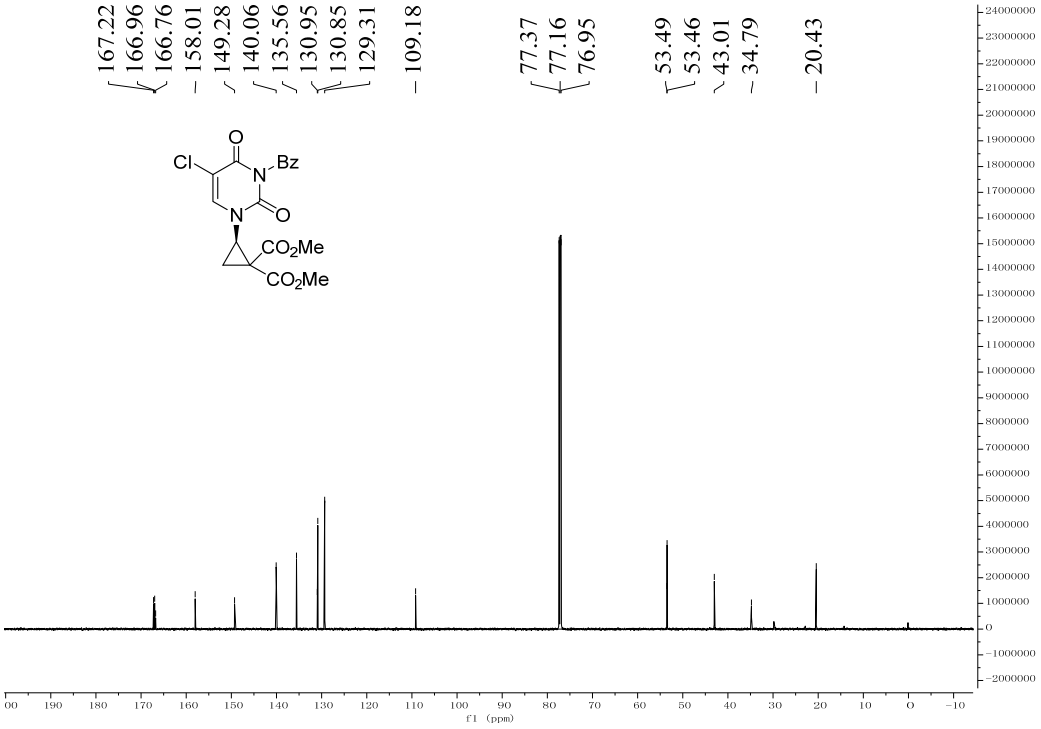
^{19}F NMR of 3ca (376 MHz, Chloroform-d)



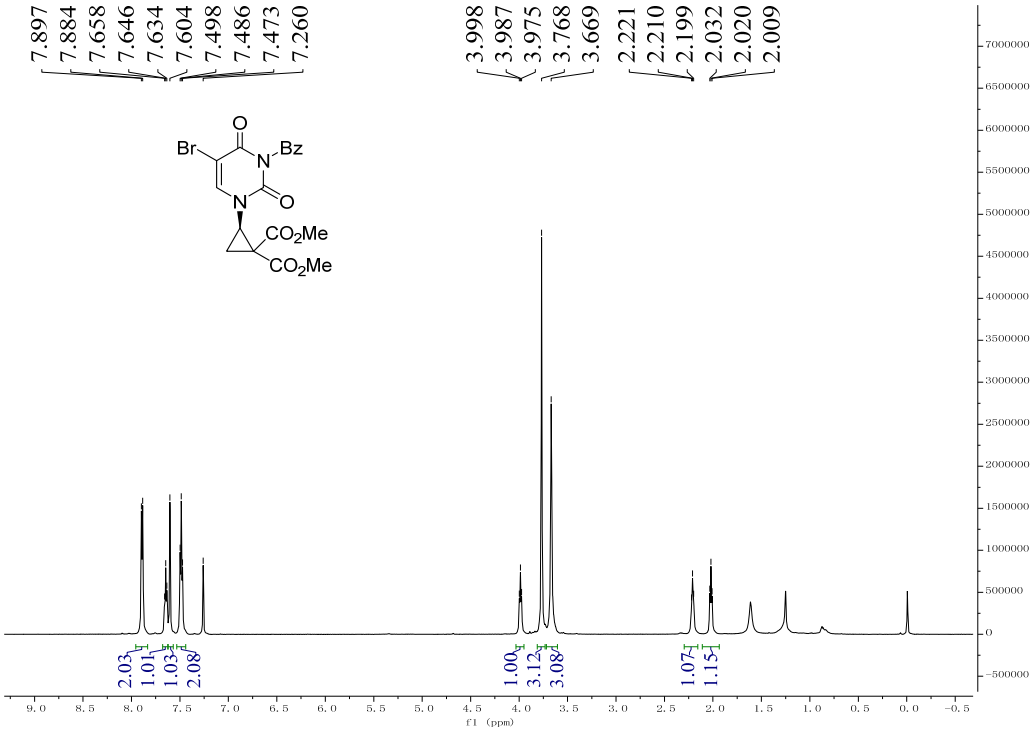
^{1}H NMR of 3da (600 MHz, Chloroform-*d*)



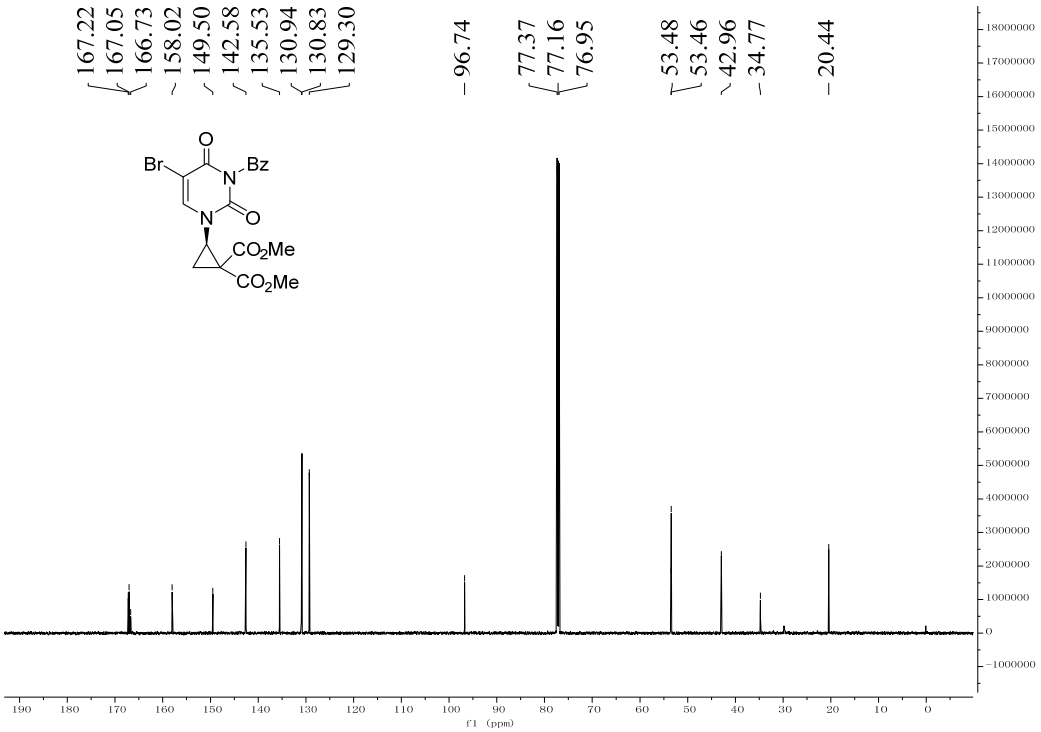
^{13}C NMR of 3da (150 MHz, Chloroform-*d*)



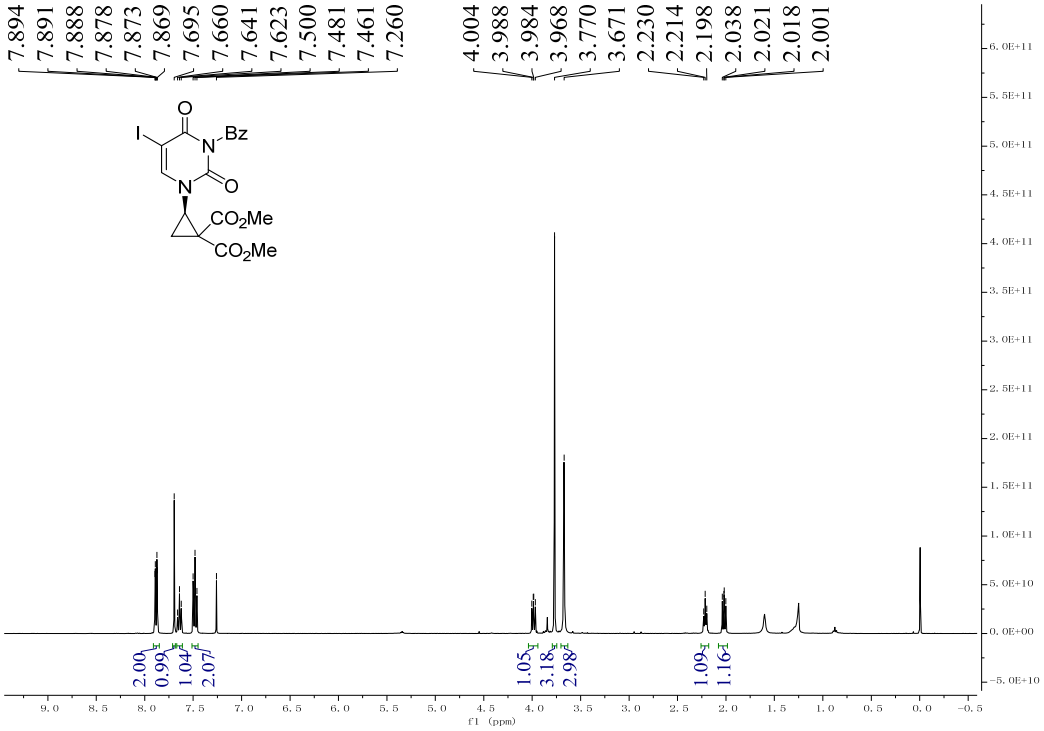
^{1}H NMR of 3ea (600 MHz, Chloroform-*d*)



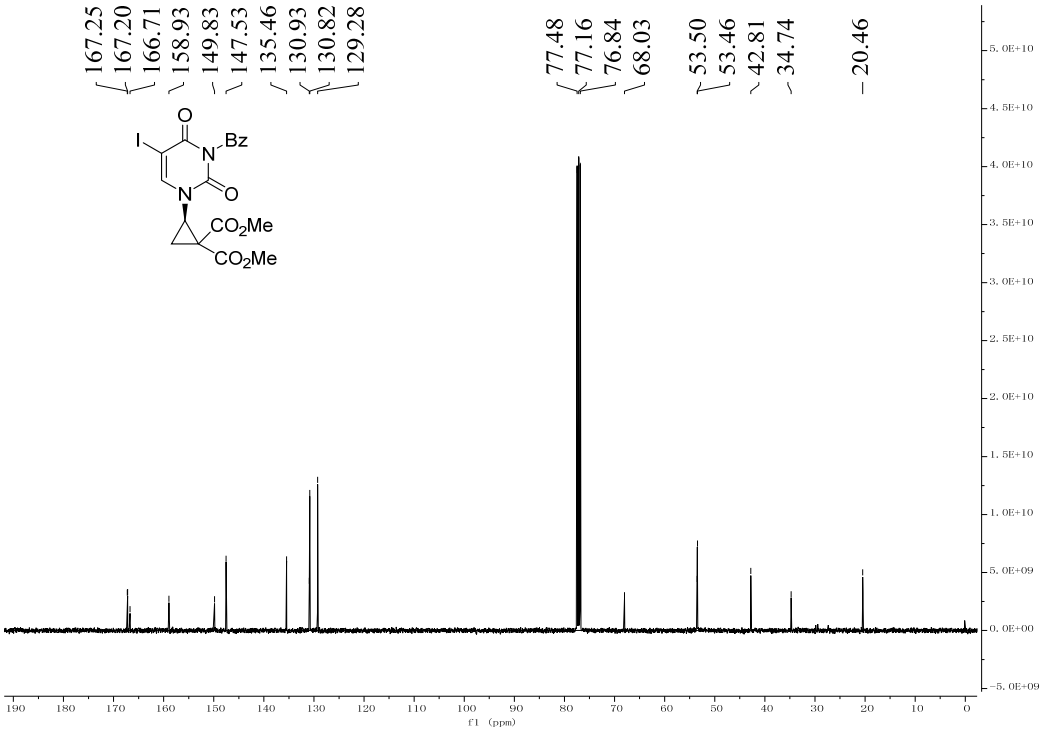
^{13}C NMR of 3ea (150MHz, Chloroform-*d*)



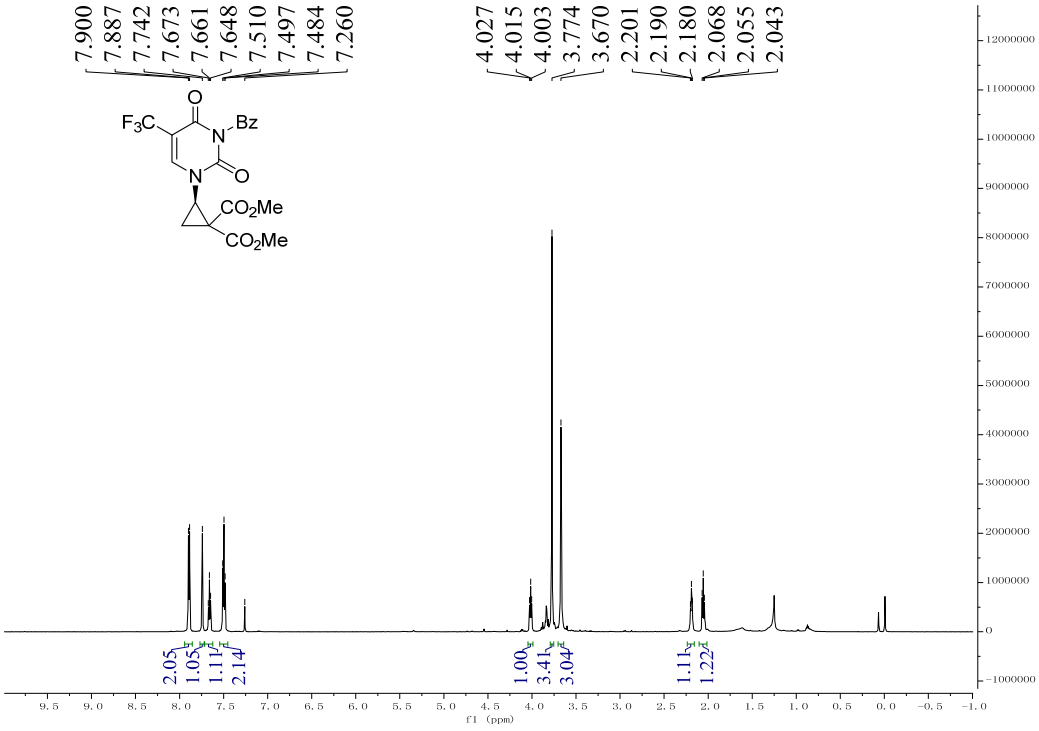
^{1}H NMR of 3fa (400 MHz, Chloroform-*d*)



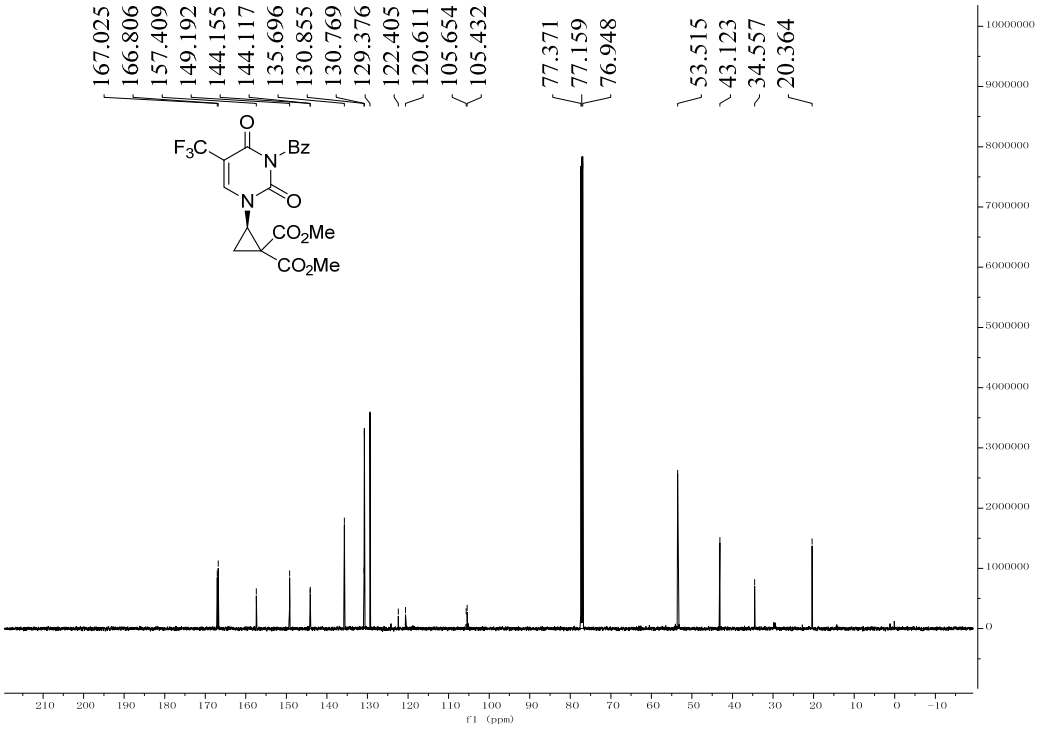
^{13}C NMR of 3fa (100 MHz, Chloroform-*d*)



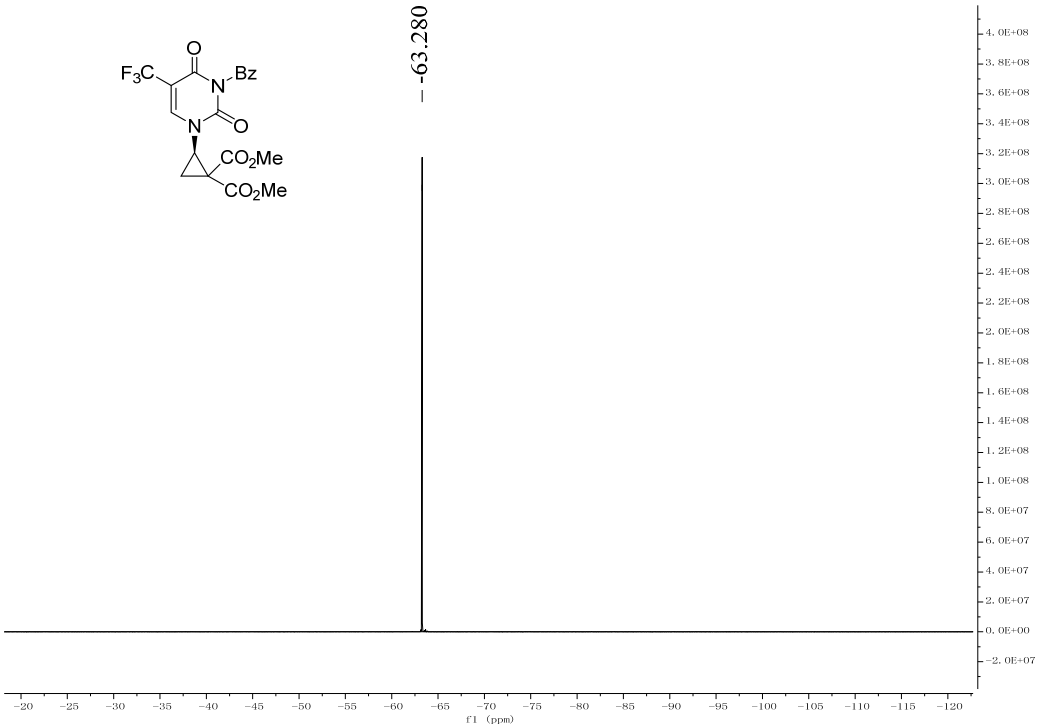
^{1}H NMR of 3ga (600 MHz, Chloroform-*d*)



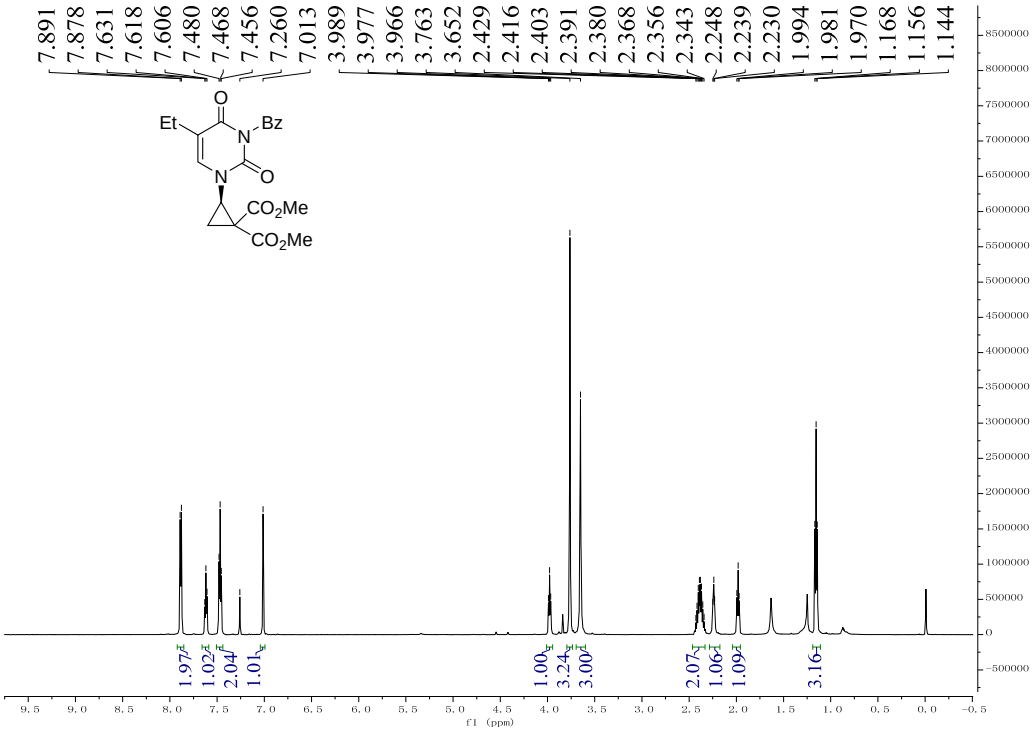
^{13}C NMR of 3ga (150 MHz, Chloroform-*d*)



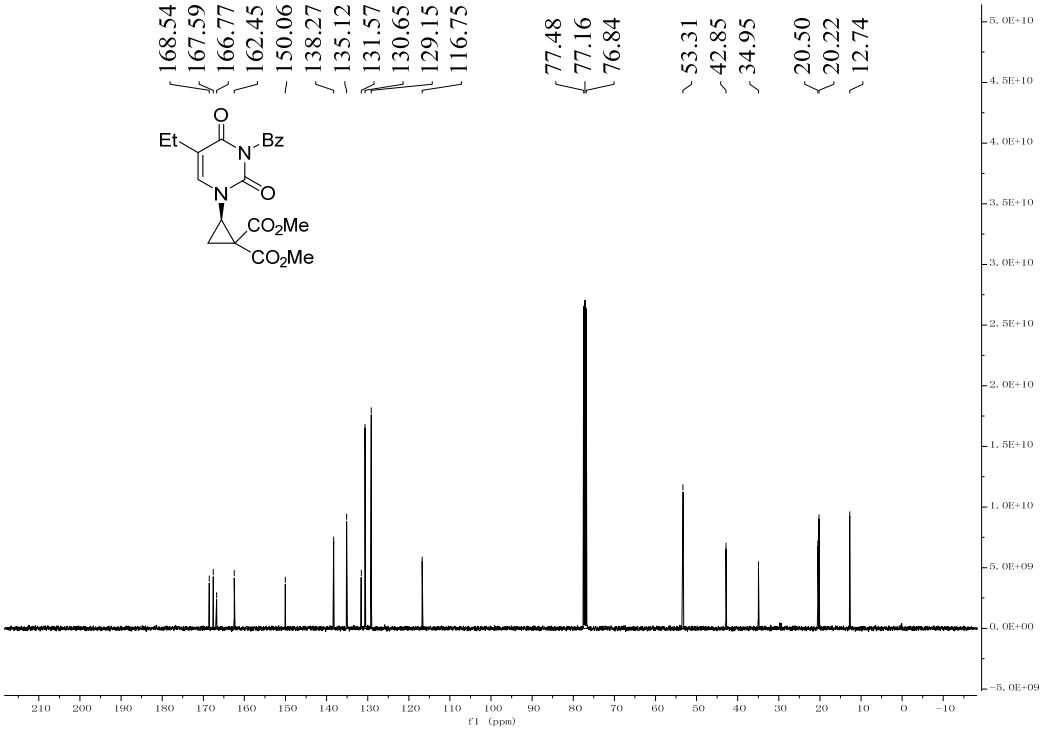
^{19}F NMR of 3ga (376 MHz, Chloroform-*d*)



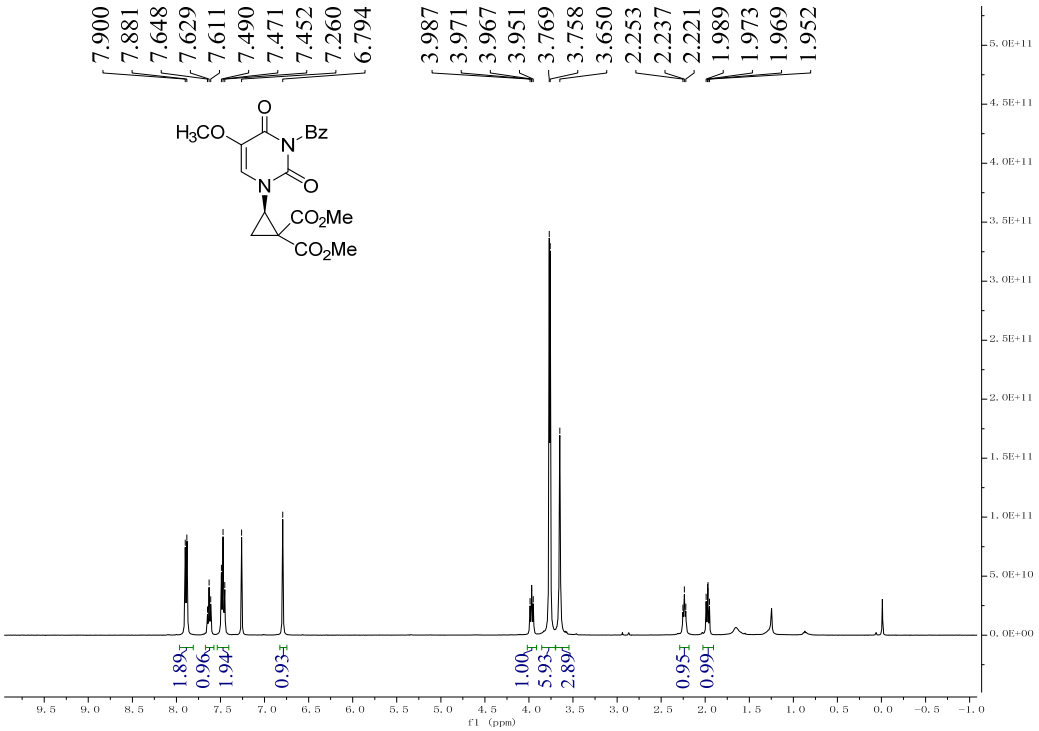
^{1}H NMR of 3ha (400 MHz, Chloroform-*d*)



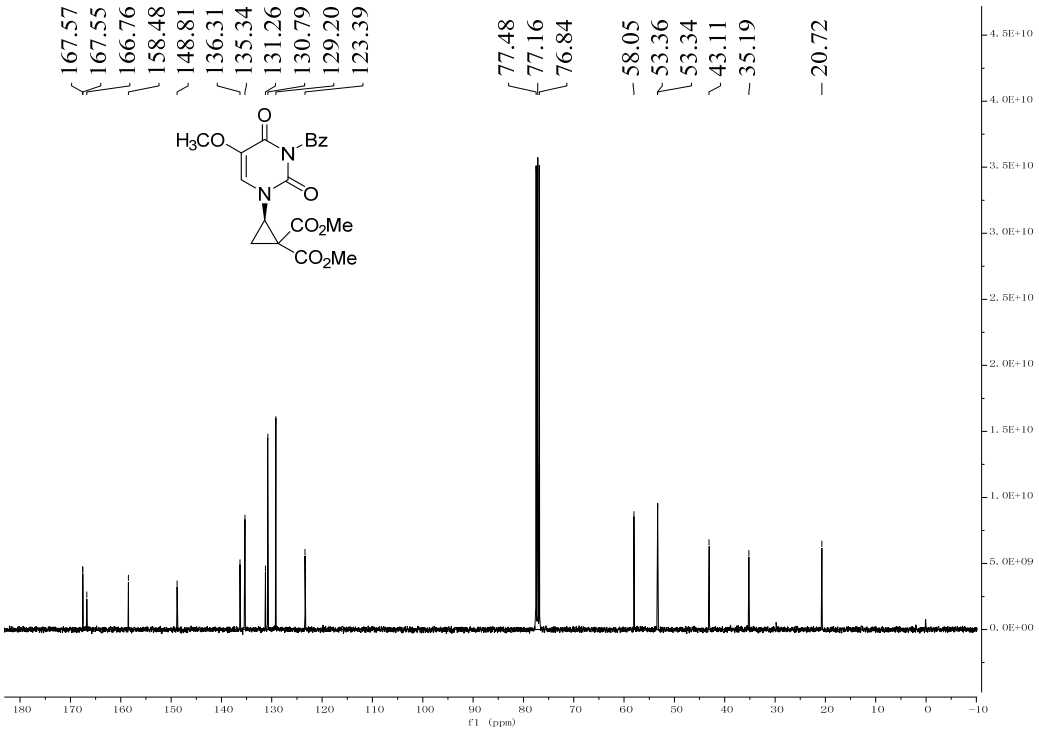
^{13}C NMR of 3ha (100 MHz, Chloroform-*d*)



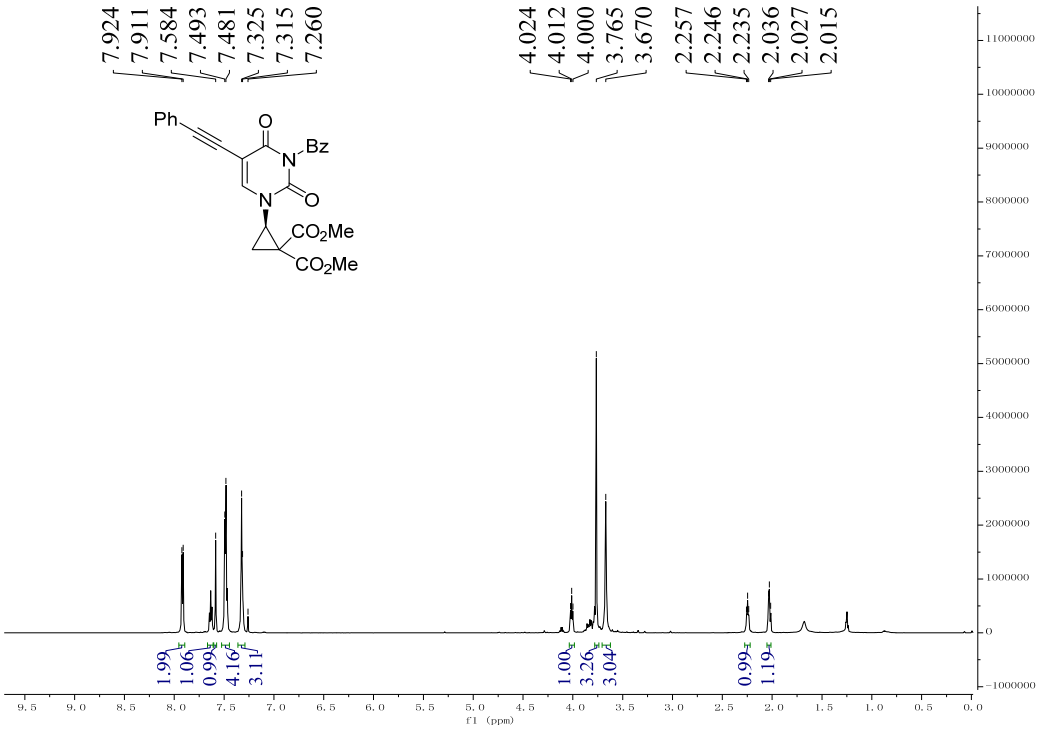
^{1}H NMR of 3ia (400 MHz, Chloroform-*d*)



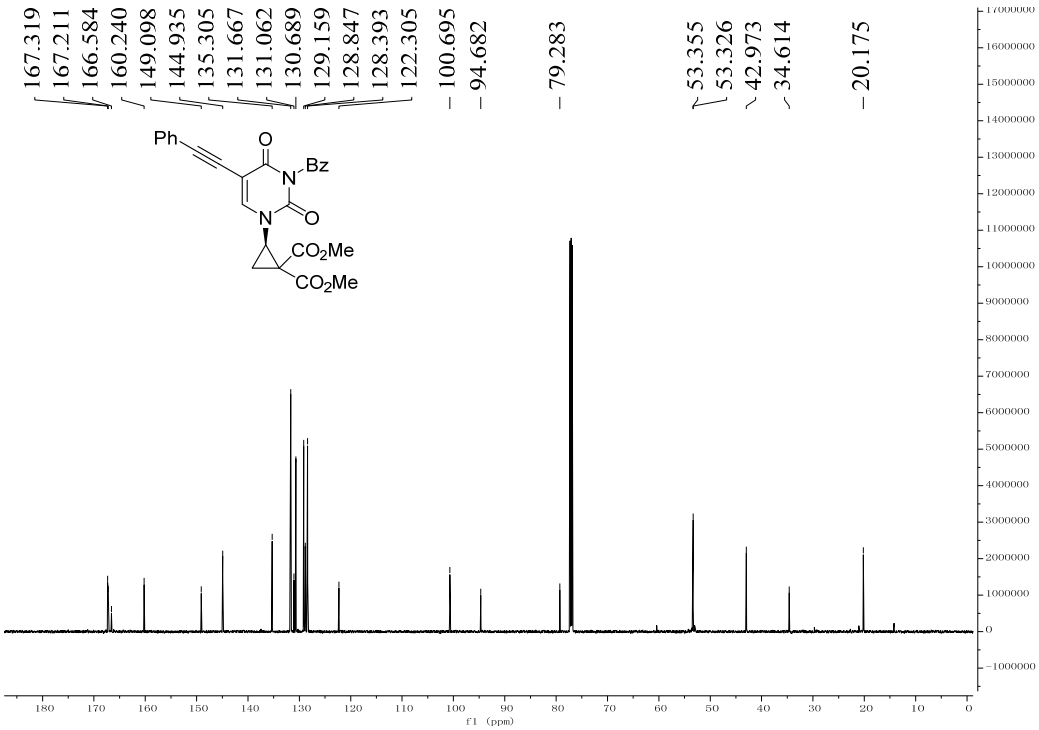
^{13}C NMR of 3ia (100 MHz, Chloroform-*d*)



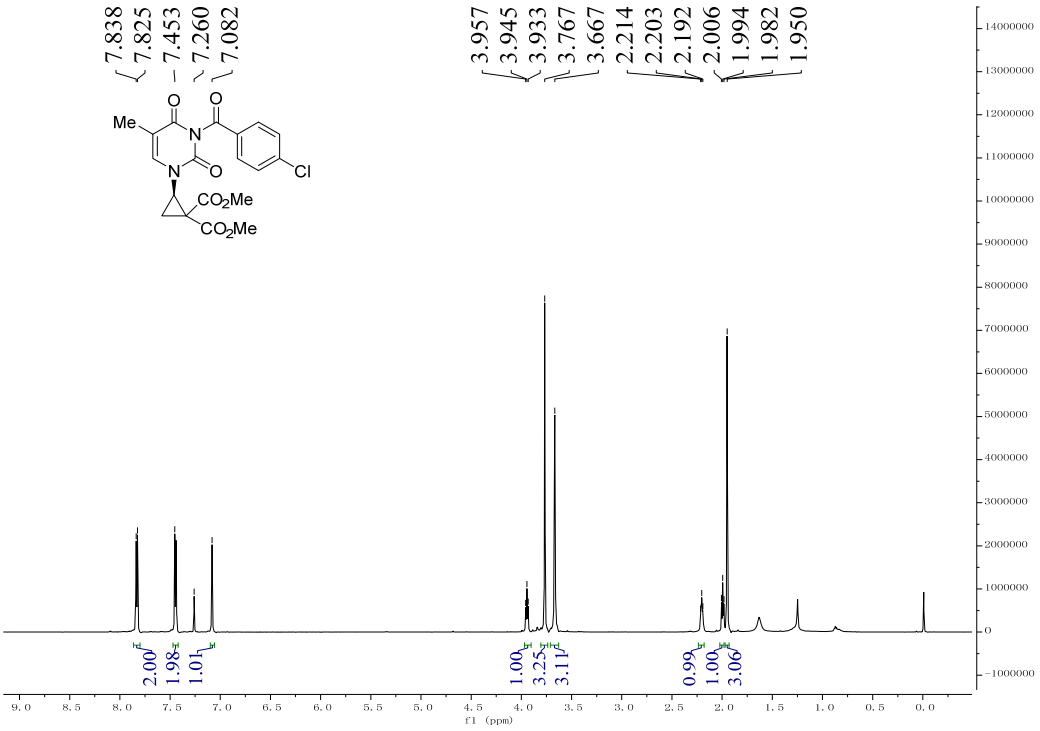
^{1}H NMR of 3ja (600 MHz, Chloroform-*d*)



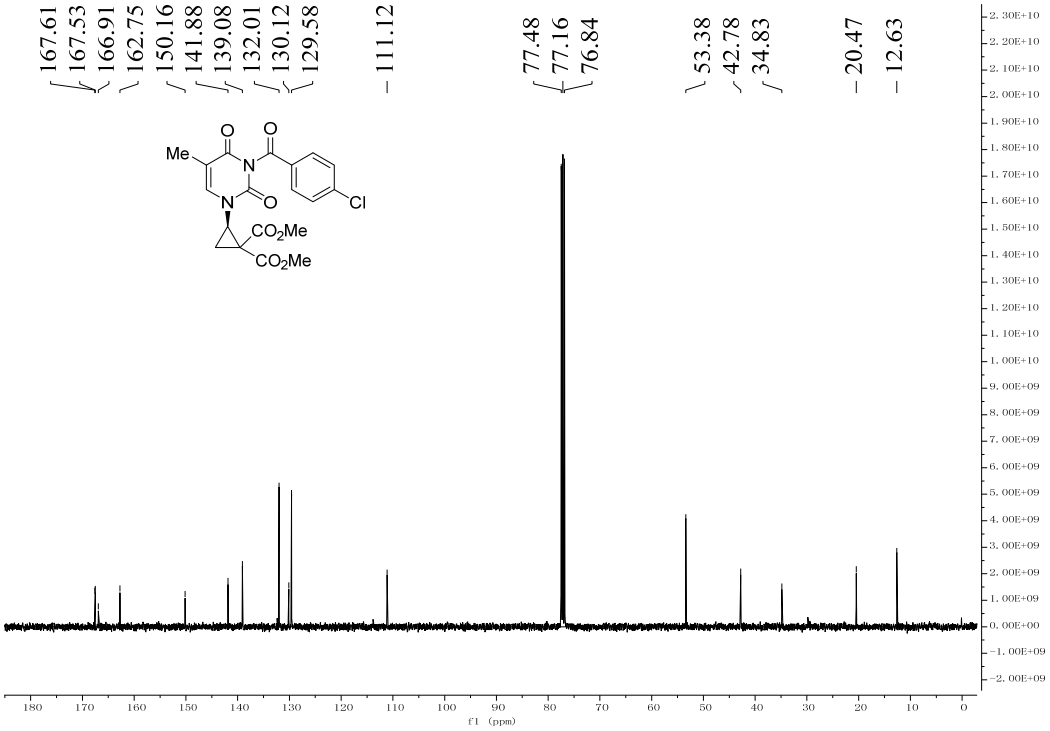
^{13}C NMR of 3ja (150 MHz, Chloroform-*d*)



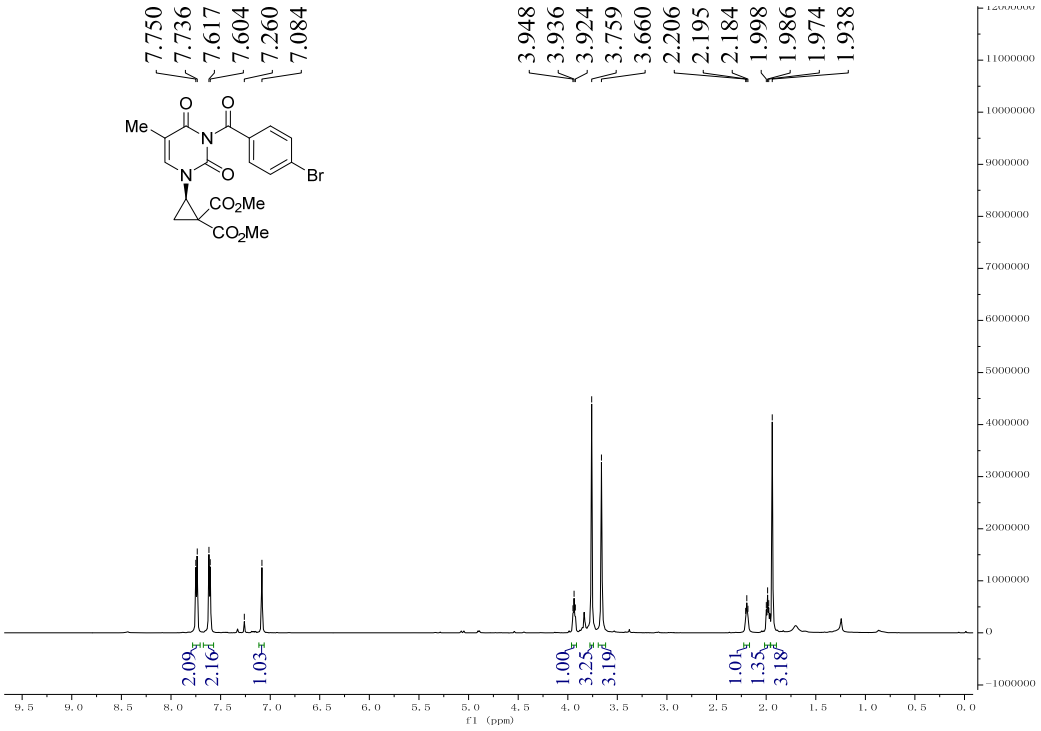
^{1}H NMR of 3ka (600 MHz, Chloroform-*d*)



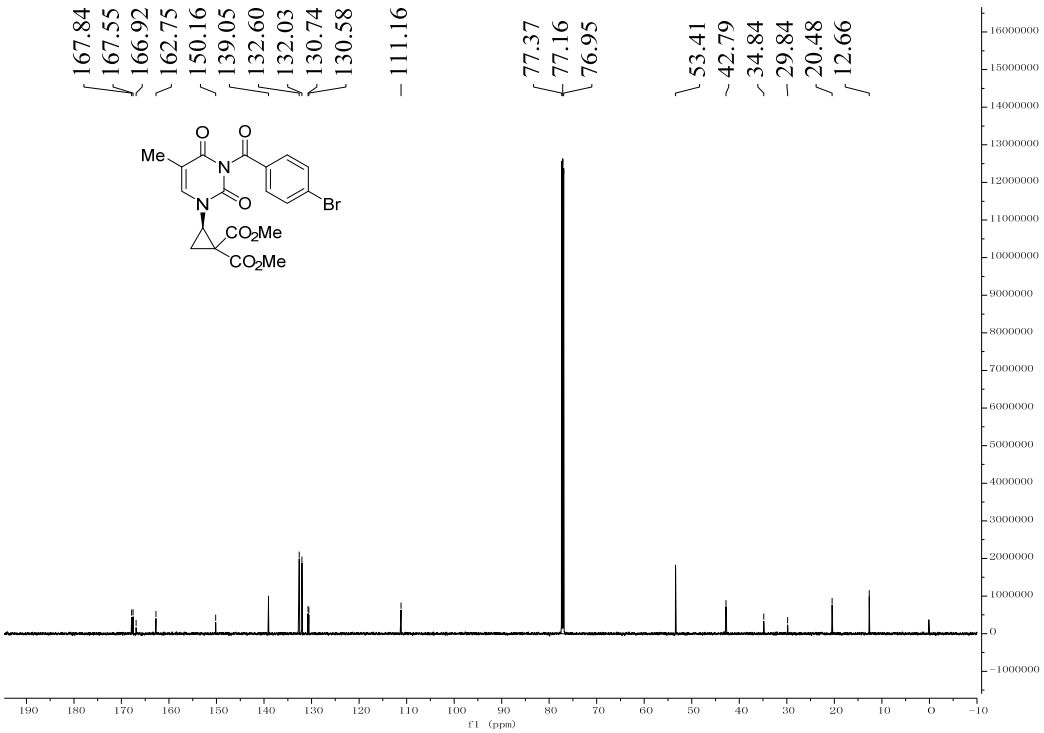
^{13}C NMR of 3ka (100 MHz, Chloroform-*d*)



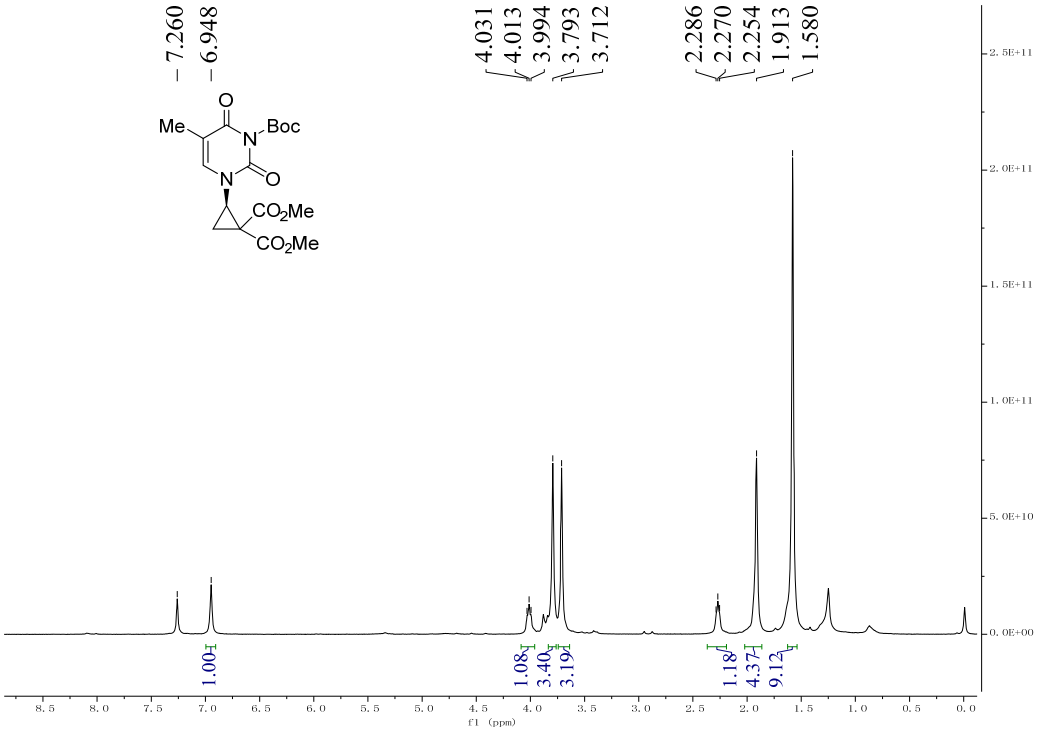
^{1}H NMR of 3la (600 MHz, Chloroform-*d*)



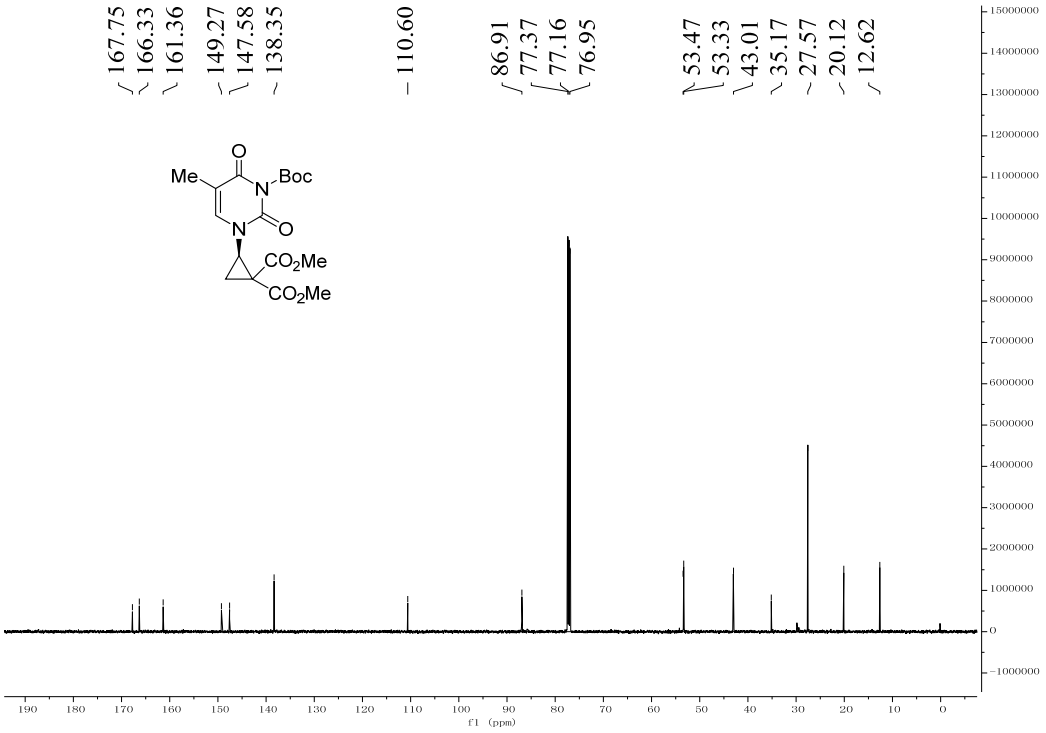
^{13}C NMR of 3la (150 MHz, Chloroform-*d*)



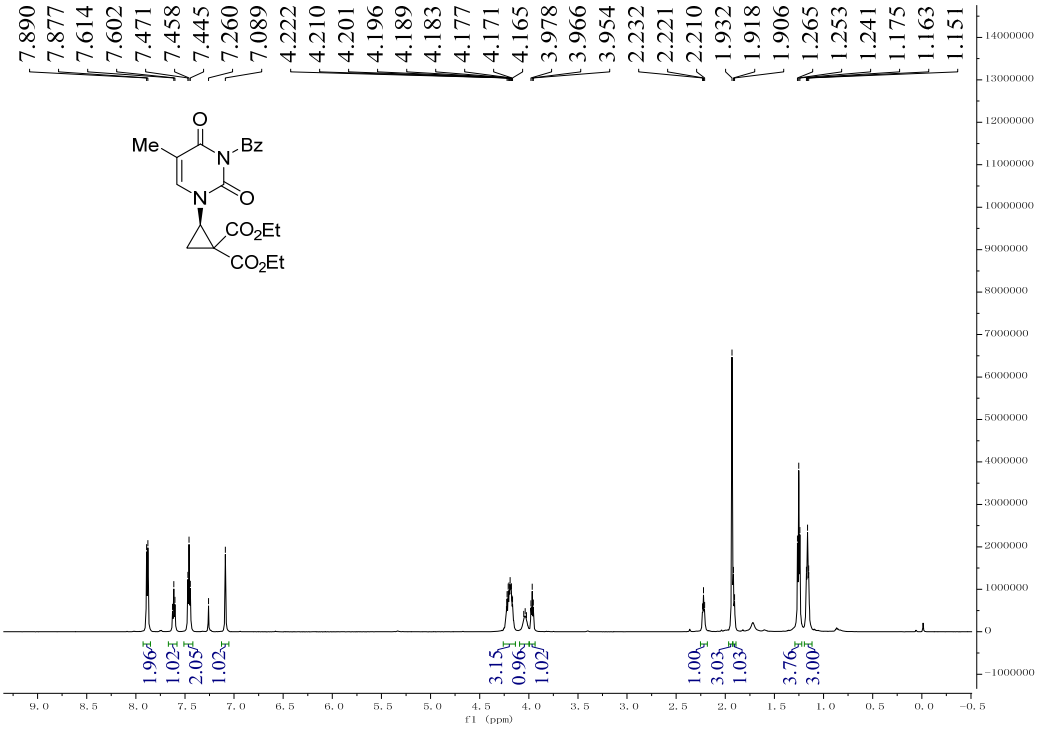
^{1}H NMR of 3ma (400 MHz, Chloroform-*d*)



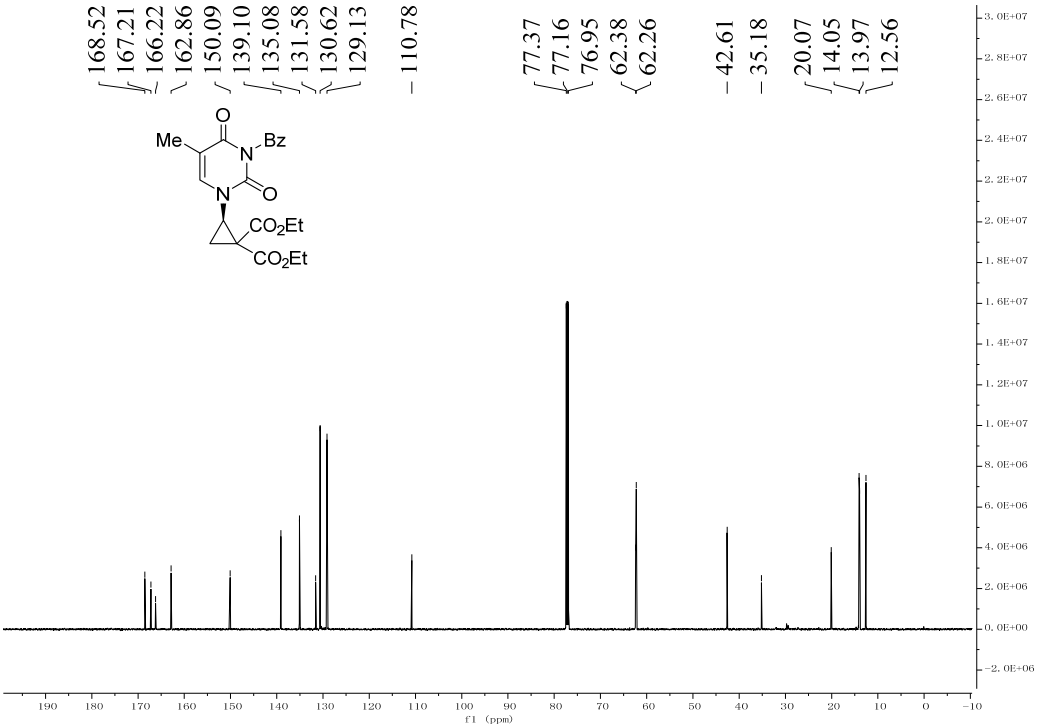
^{13}C NMR of 3ma (150 MHz, Chloroform-*d*)



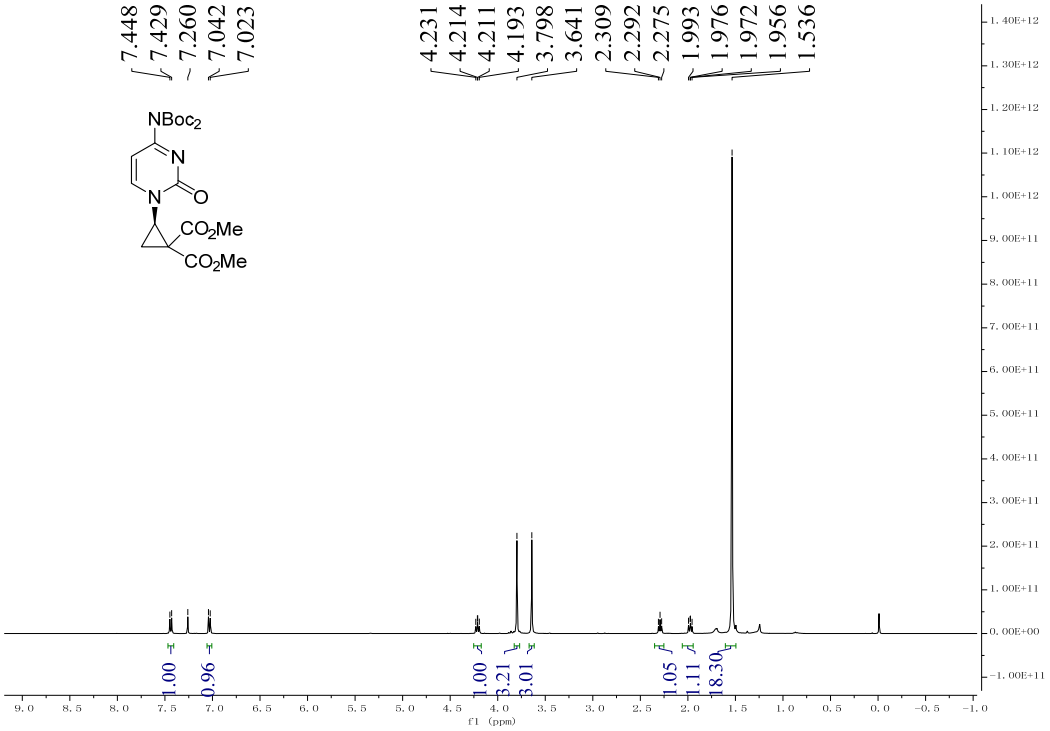
^{1}H NMR of 3ab (400 MHz, Chloroform-*d*)



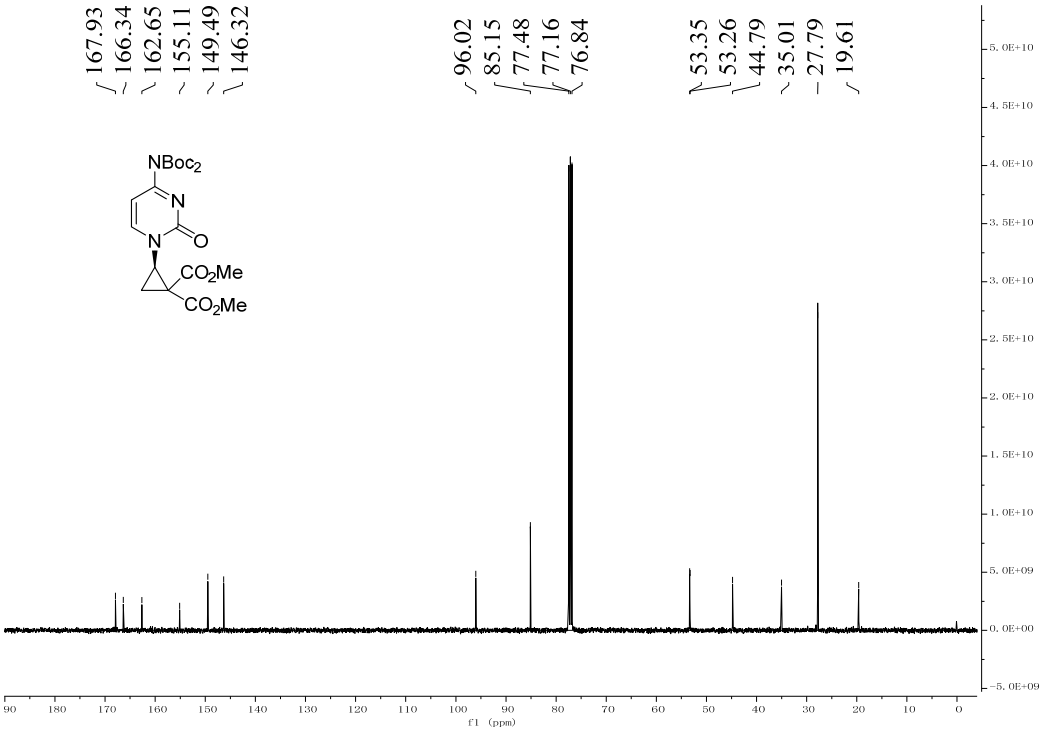
^{13}C NMR of 3ab (150 MHz, Chloroform-*d*)



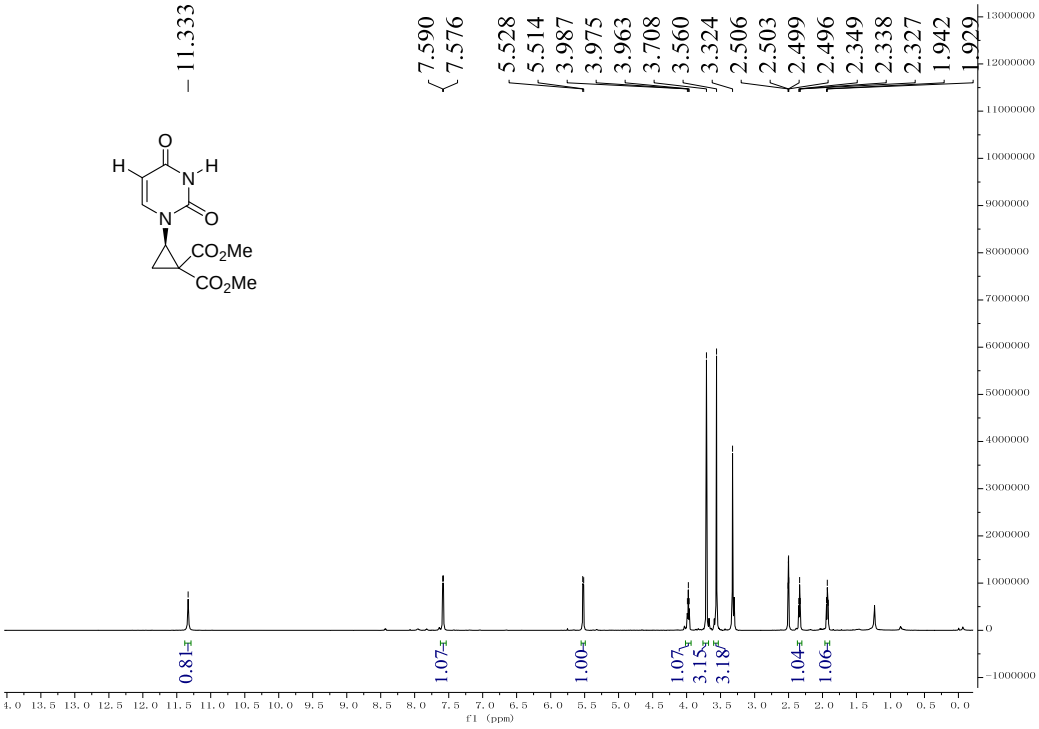
^{1}H NMR of 3na (400 MHz, Chloroform-*d*)



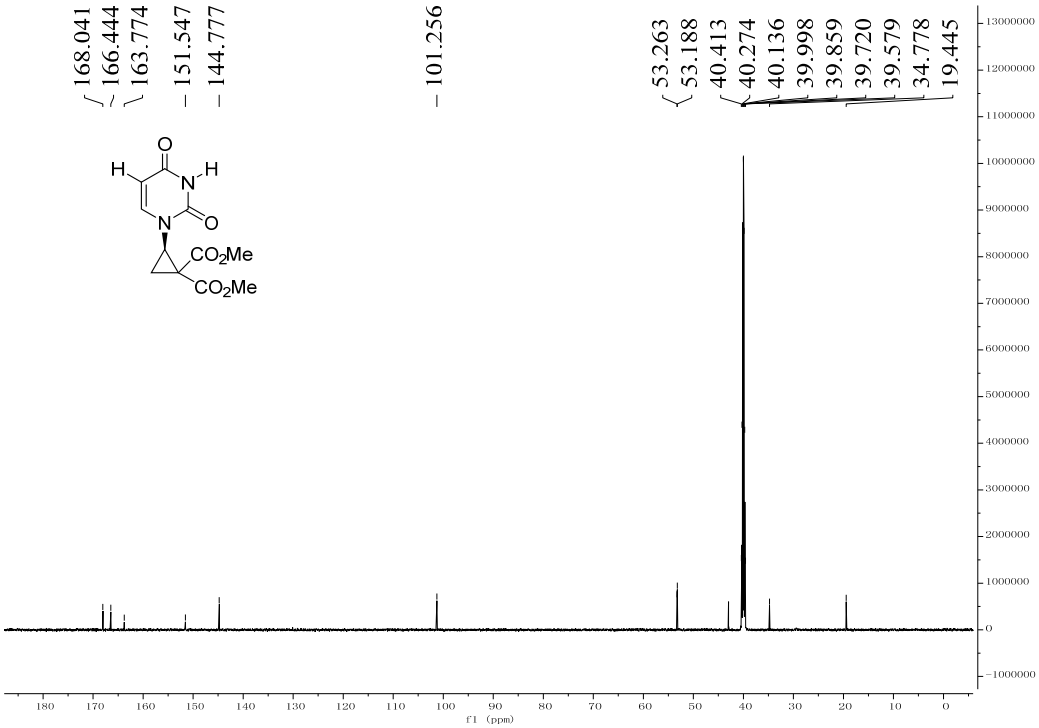
^{13}C NMR of 3na (100 MHz, Chloroform-*d*)



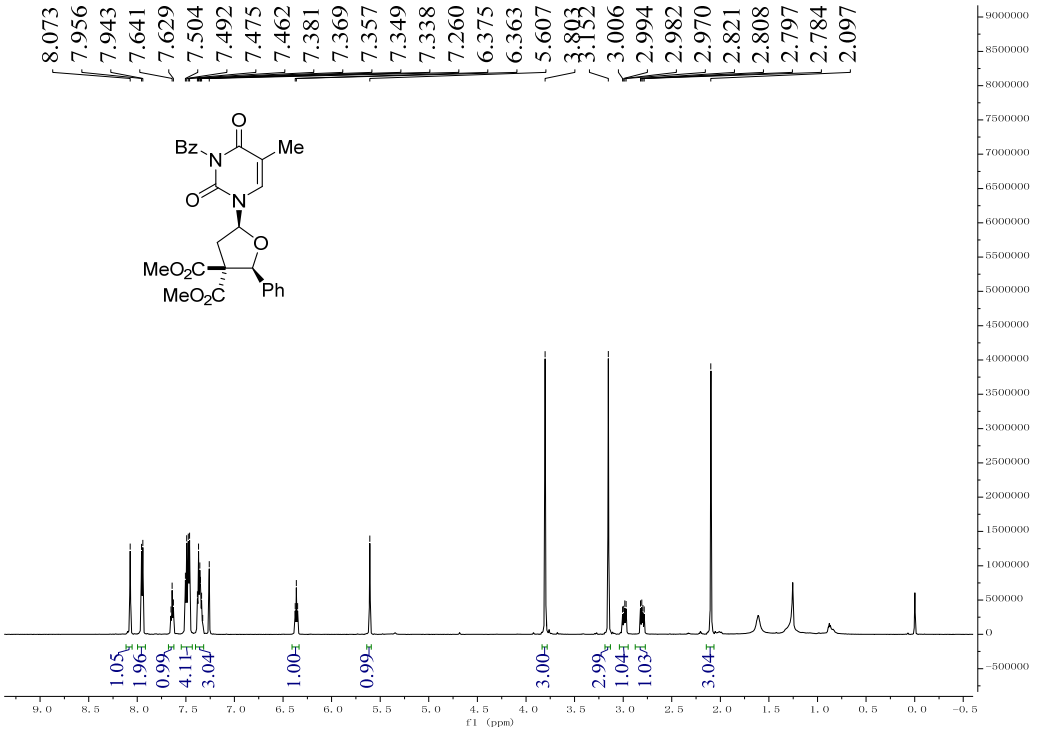
^{1}H NMR of 4ba (600 MHz, DMSO-d_6)



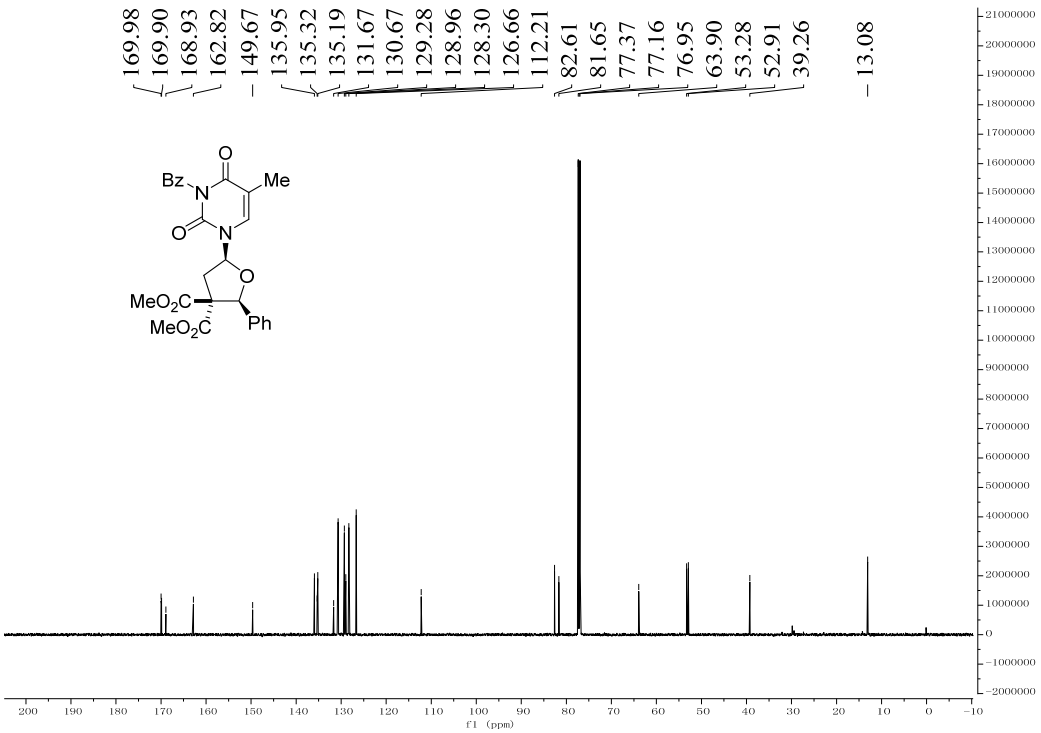
^{13}C NMR of 4ba (150 MHz, DMSO-d_6)



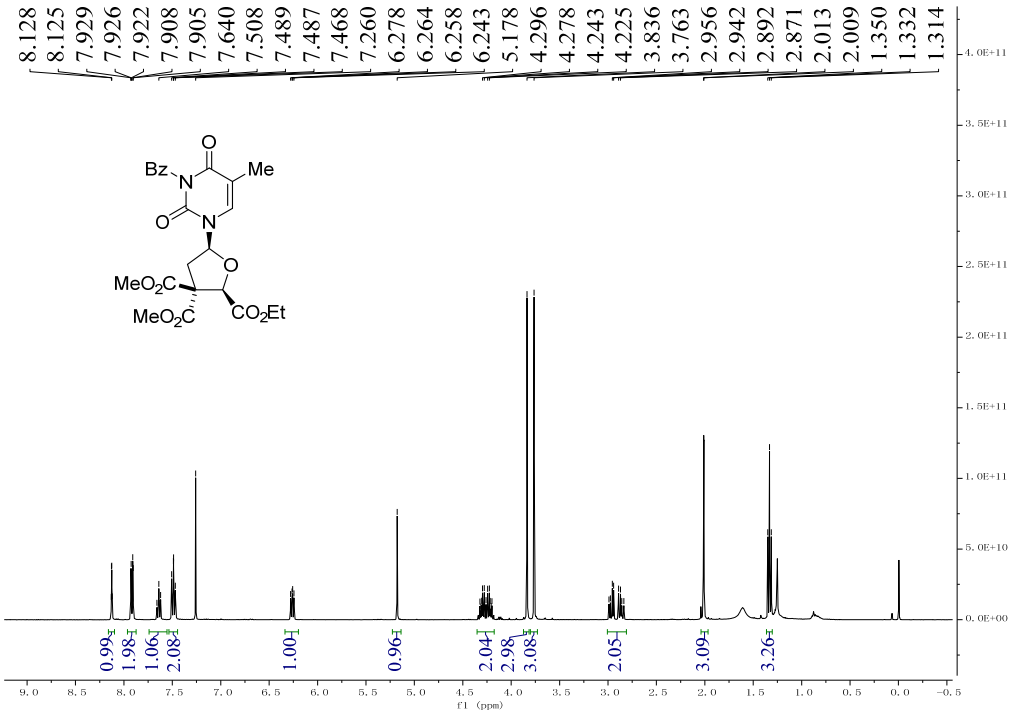
^{1}H NMR of 6aa (600 MHz, Chloroform-*d*)



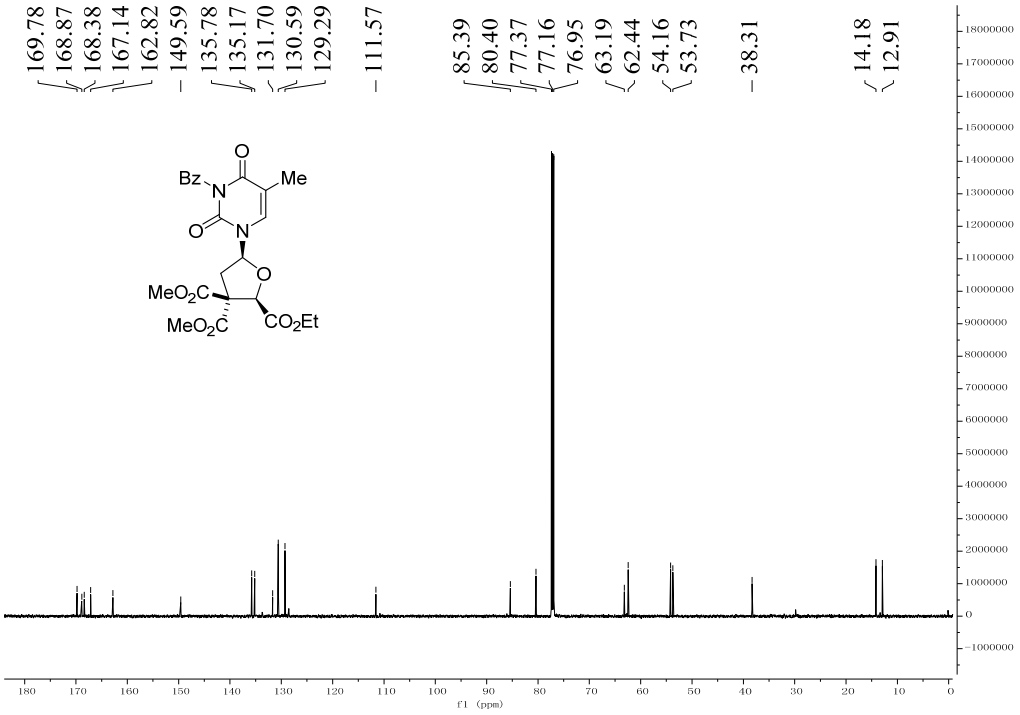
^{13}C NMR of 6aa (150 MHz, Chloroform-*d*)



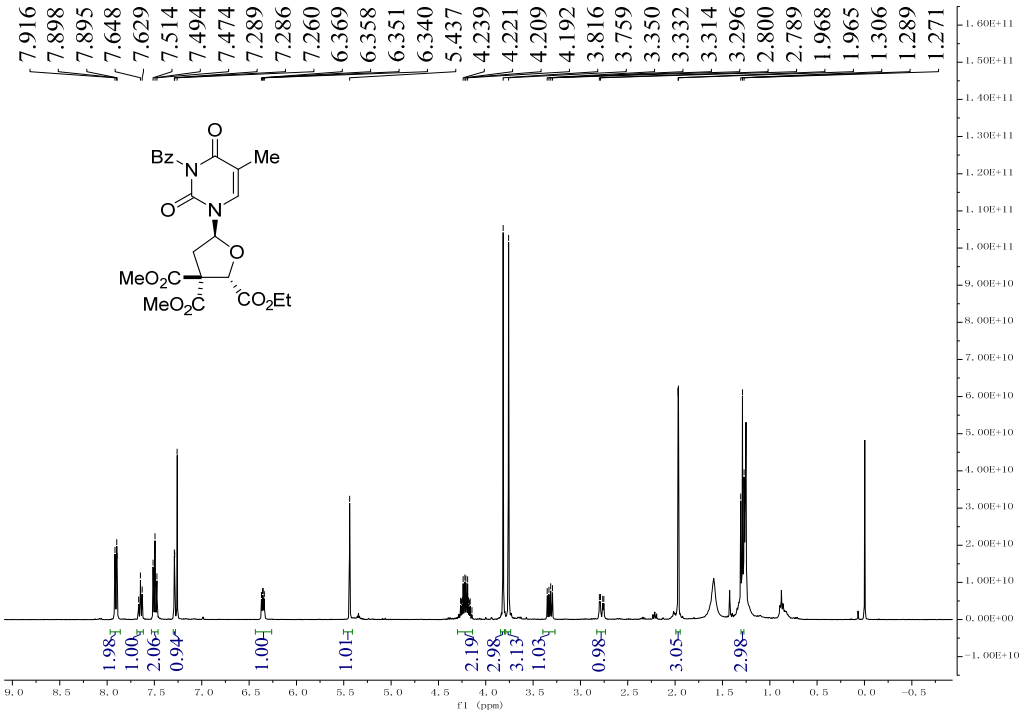
^{1}H NMR of 8aa (400 MHz, Chloroform-*d*)



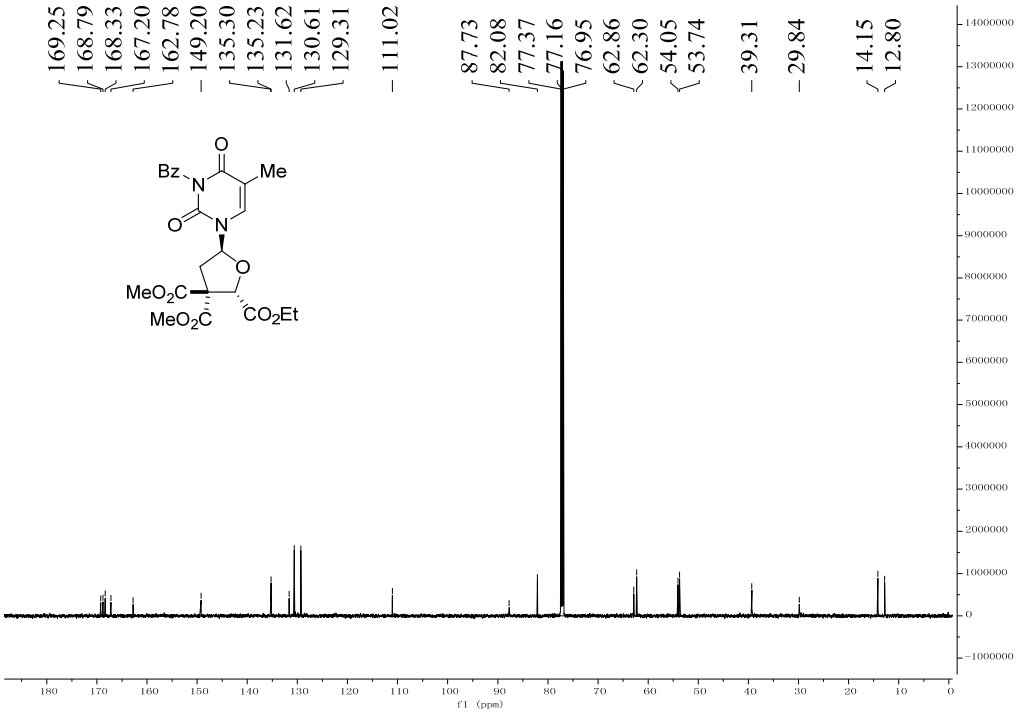
^{13}C NMR of 8aa (150 MHz, Chloroform-*d*)



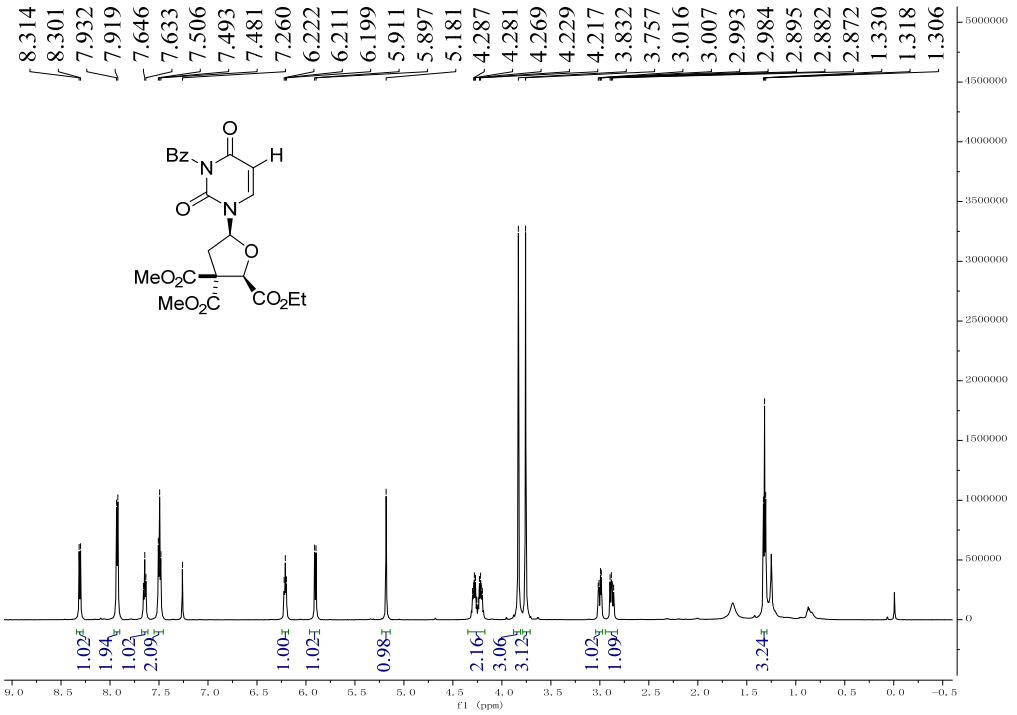
^{1}H NMR of 9aa (400 MHz, Chloroform-*d*)



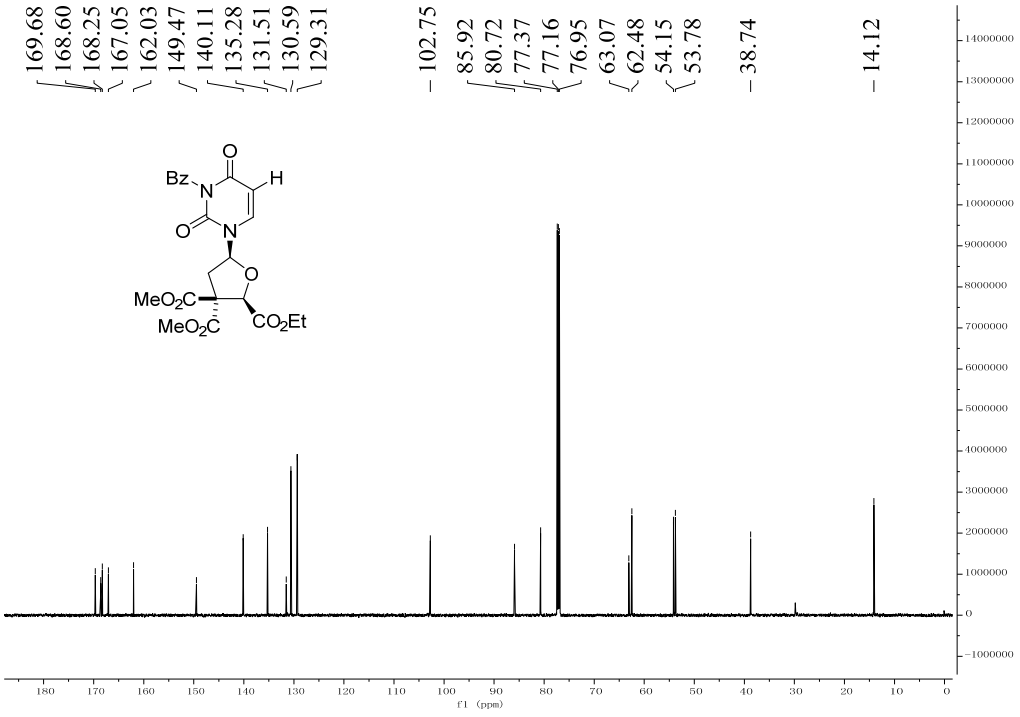
^{13}C NMR of 9aa (100 MHz, Chloroform-*d*)



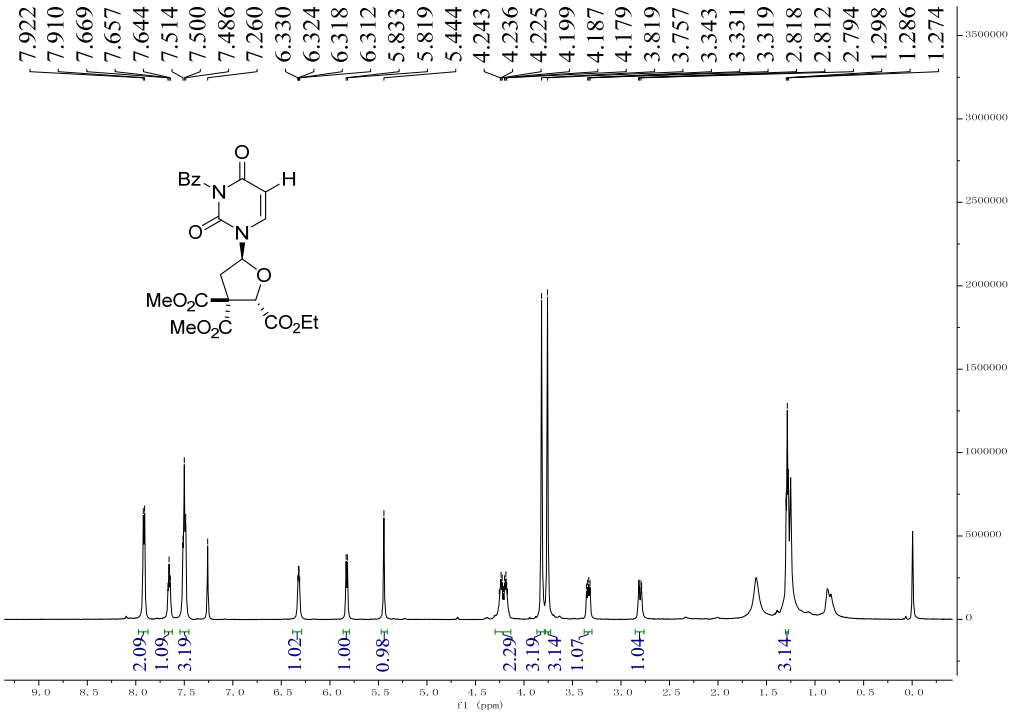
^{1}H NMR of 8ba (600 MHz, Chloroform-*d*)



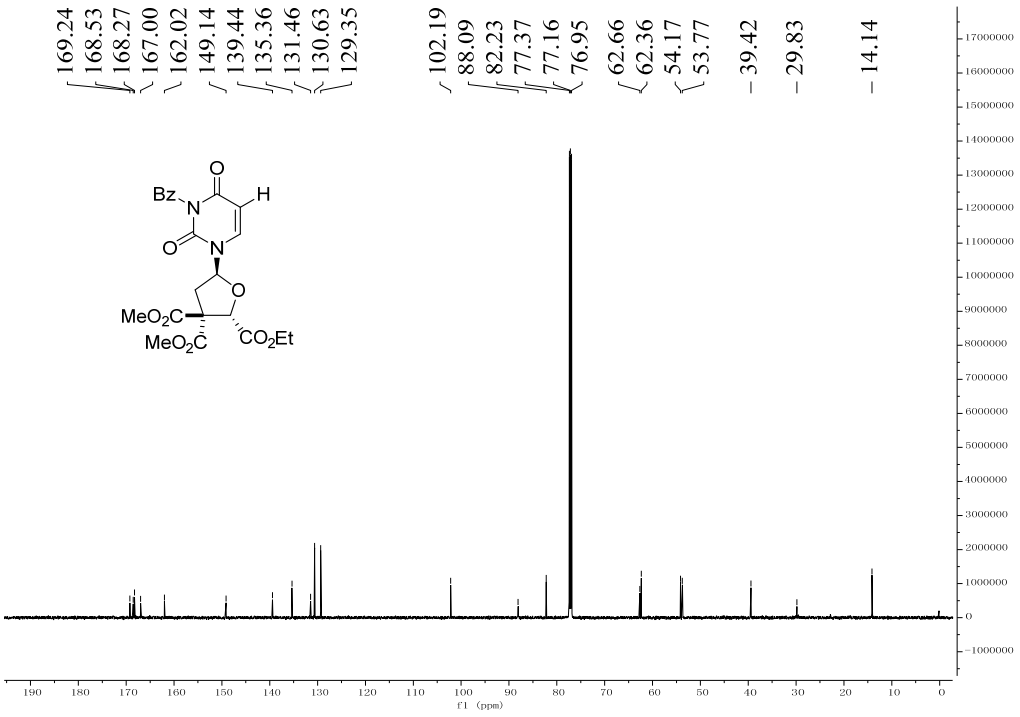
^{13}C NMR of 8ba (600 MHz, Chloroform-*d*)



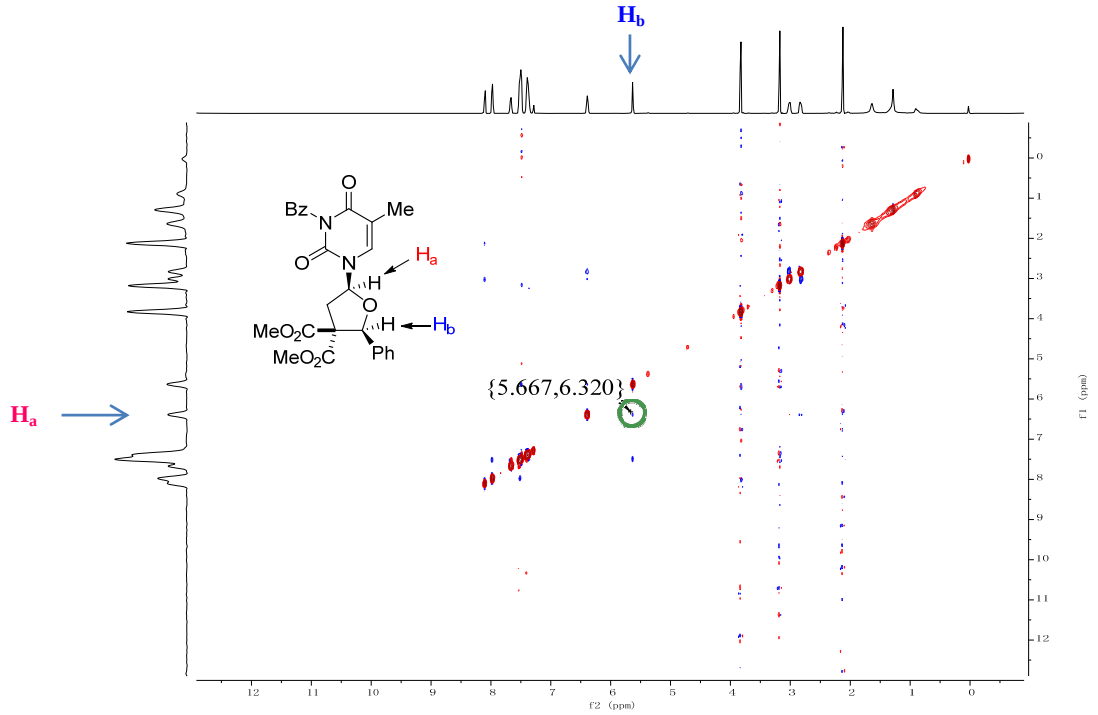
^{1}H NMR of 9ba (600 MHz, Chloroform-*d*)

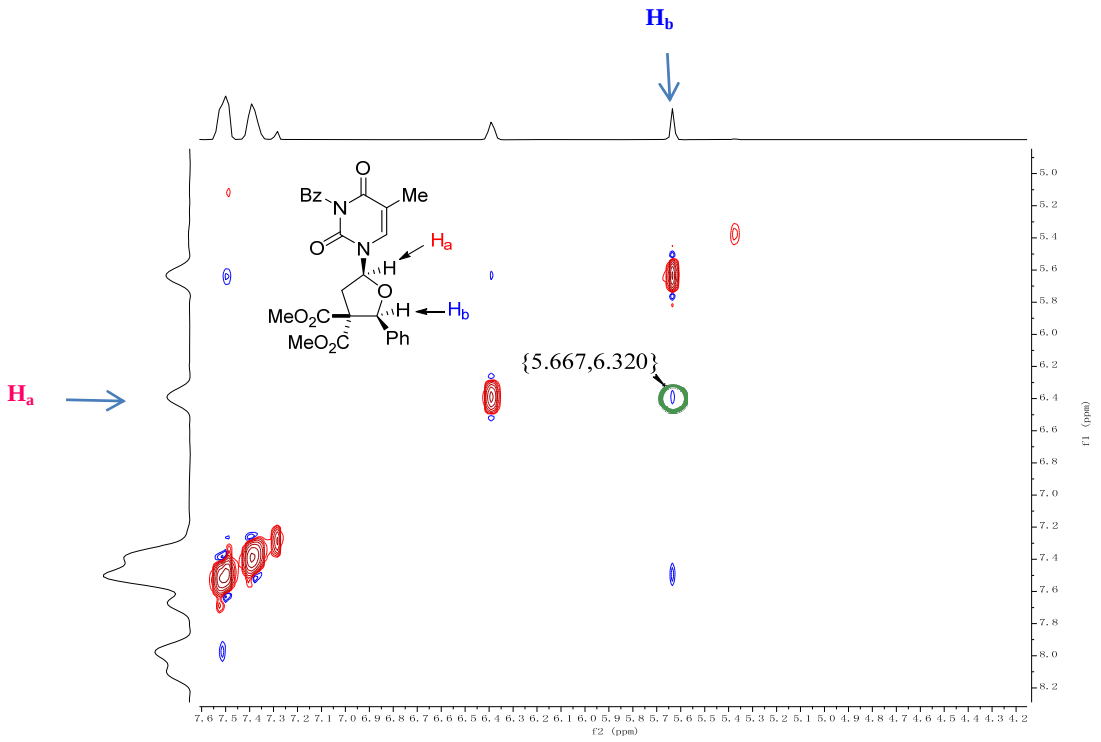


^{13}C NMR of 9ba (600 MHz, Chloroform-*d*)

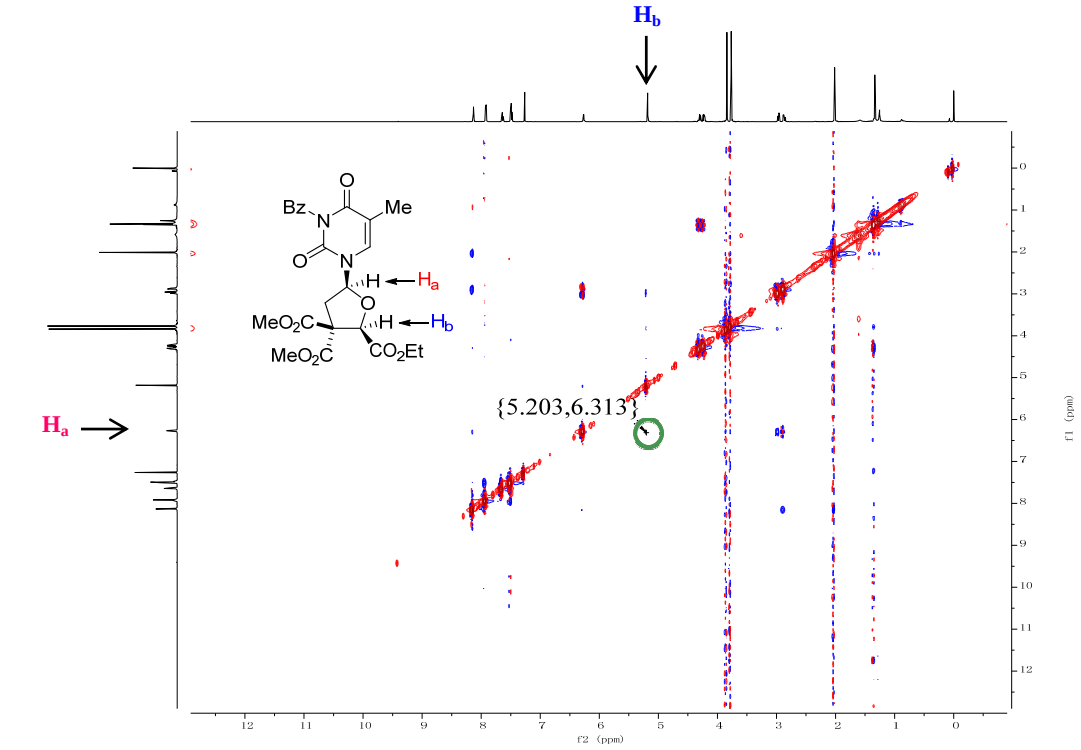


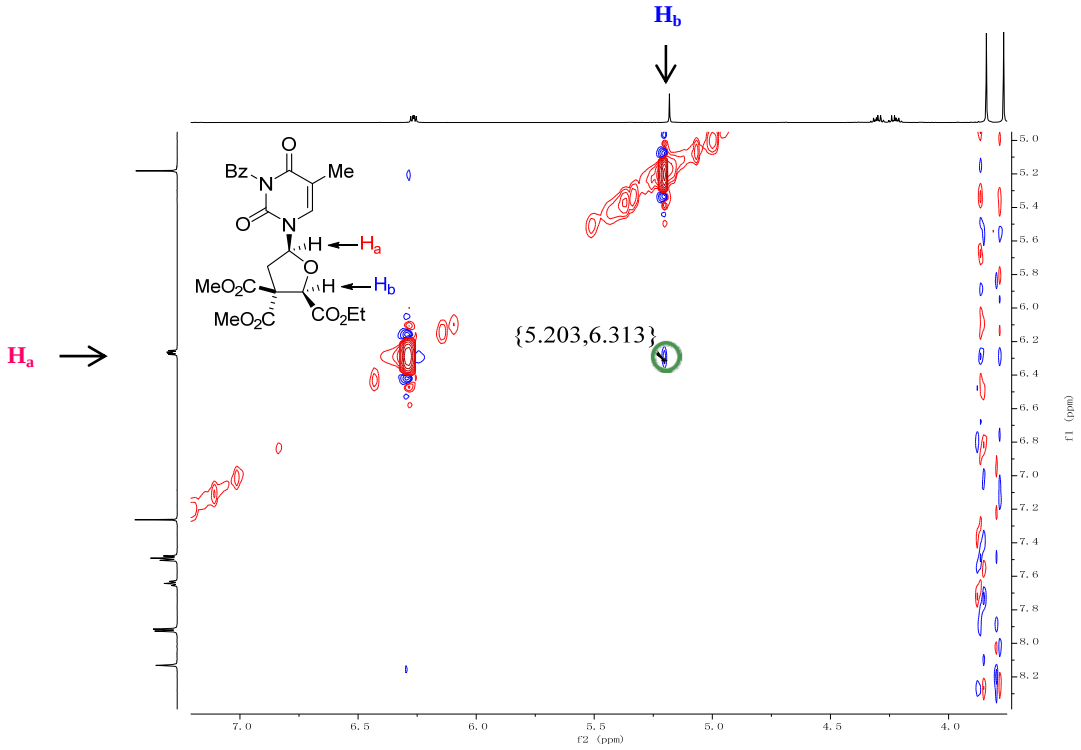
NOESY of **6aa**


Hb
Ha
Bz
Me
Ha
Hb
MeO2C
MeO2C
Ph
{5.667,6.320}
f2 (ppm)
f1 (ppm)

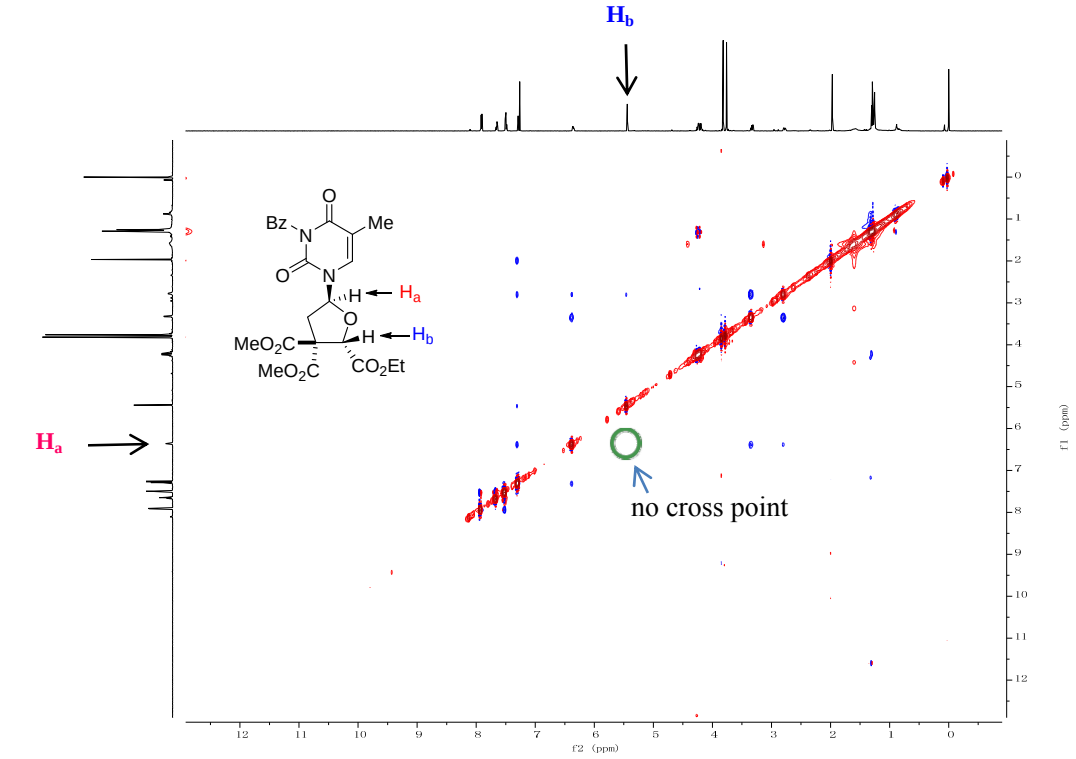

Hb
Ha
Bz
Me
Ha
Hb
MeO2C
MeO2C
Ph
{5.667,6.320}
f2 (ppm)
f1 (ppm)

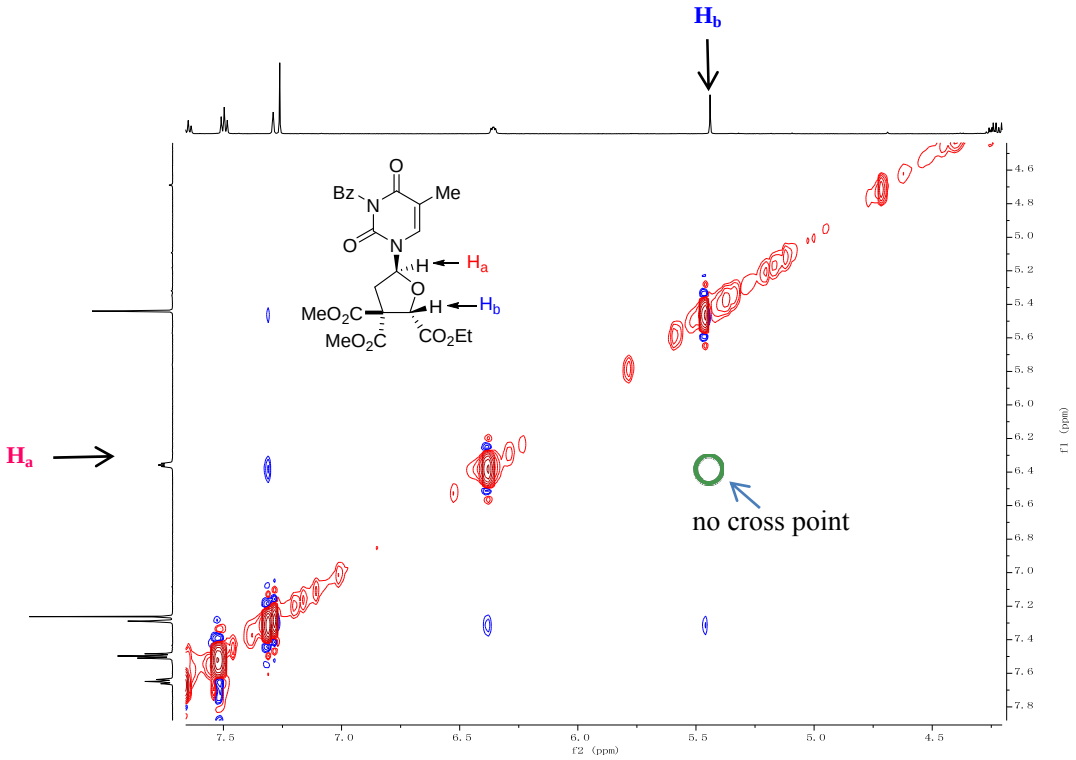
NOESY of **8aa**


Hb
Ha
Bz
Me
MeO2C
MeO2C
CO2Et
{5.203,6.313}
f2 (ppm)
f1 (ppm)

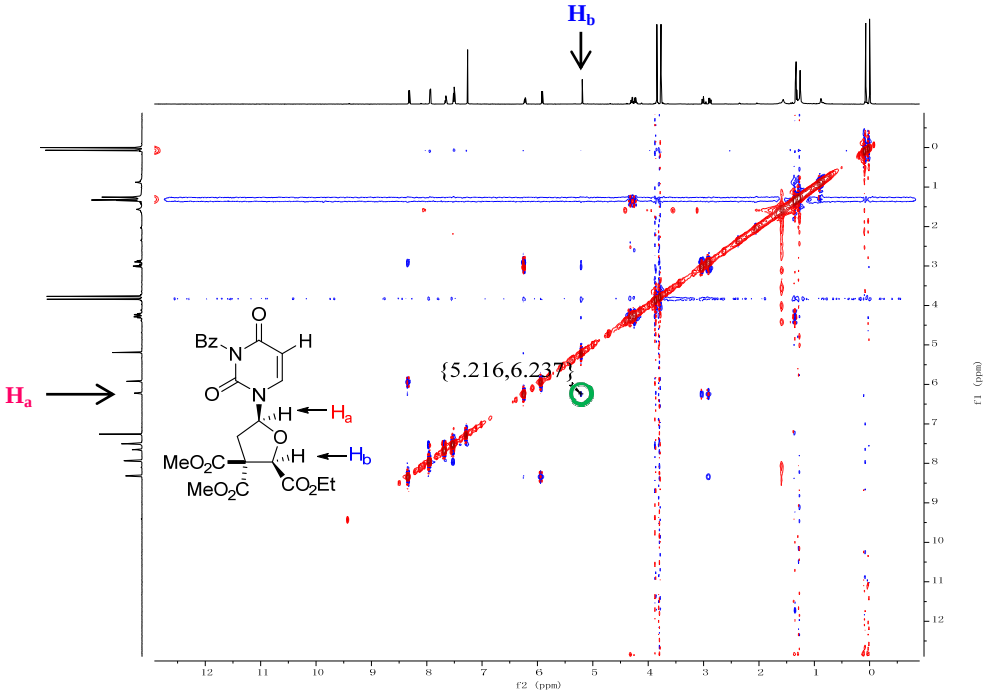

Hb
Ha
Bz
Me
MeO2C
MeO2C
CO2Et
{5.203,6.313}
f2 (ppm)
f1 (ppm)

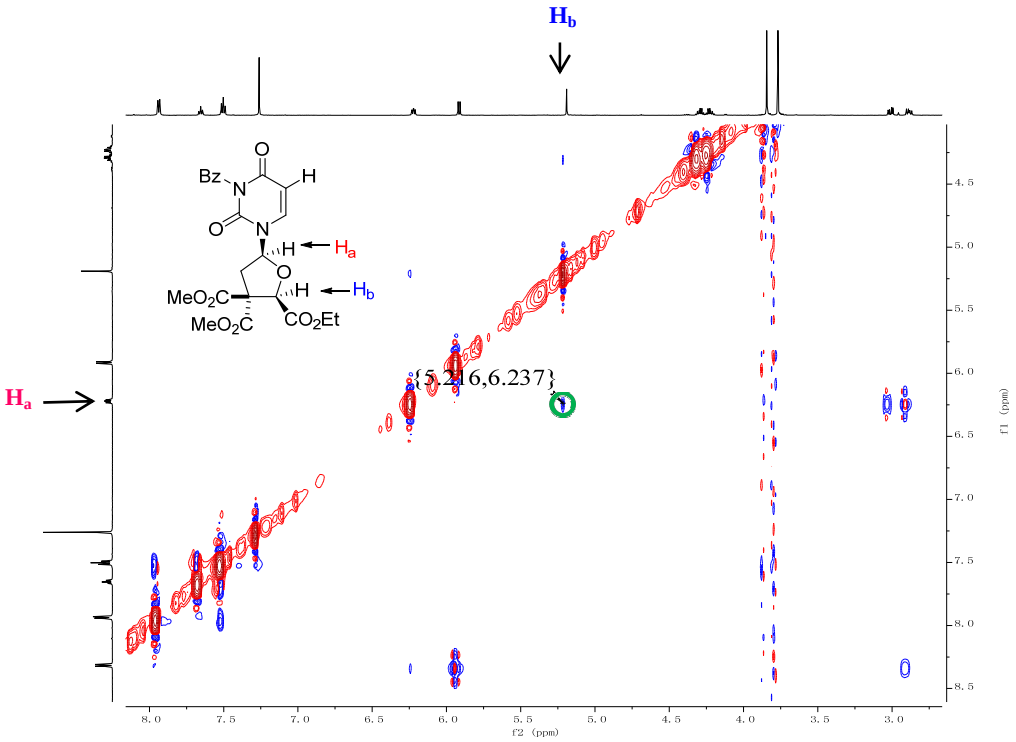
NOESY of **9aa**


Hb
Ha
Bz
Me
MeO2C
MeO2C
CO2Et
no cross point
f2 (ppm)
f1 (ppm)

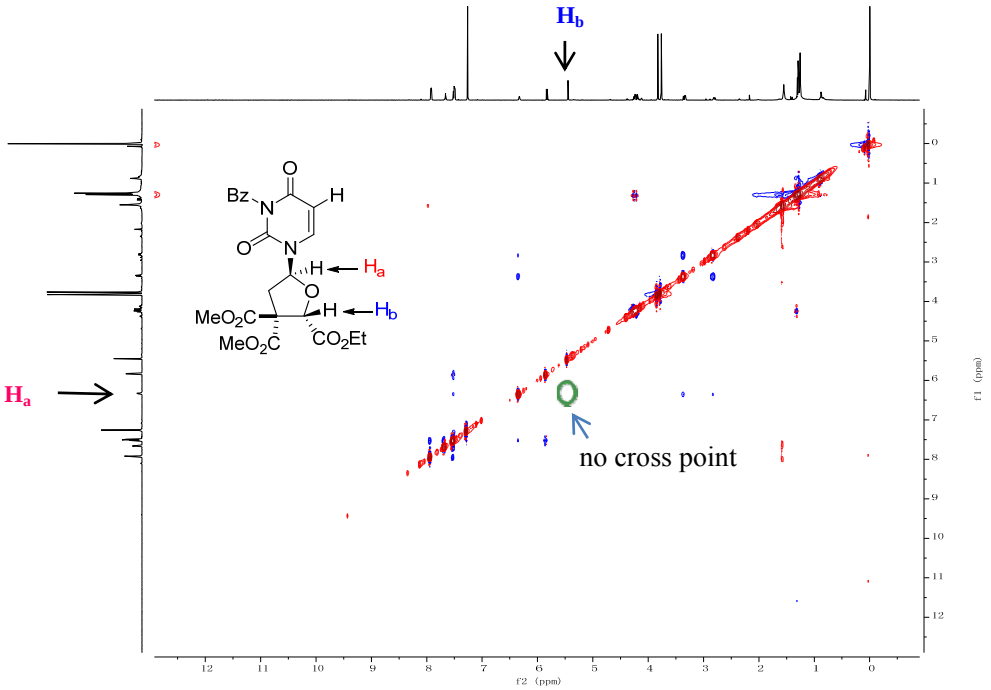

Hb
Ha
Bz
Me
MeO2C
MeO2C
CO2Et
no cross point
f2 (ppm)
f1 (ppm)

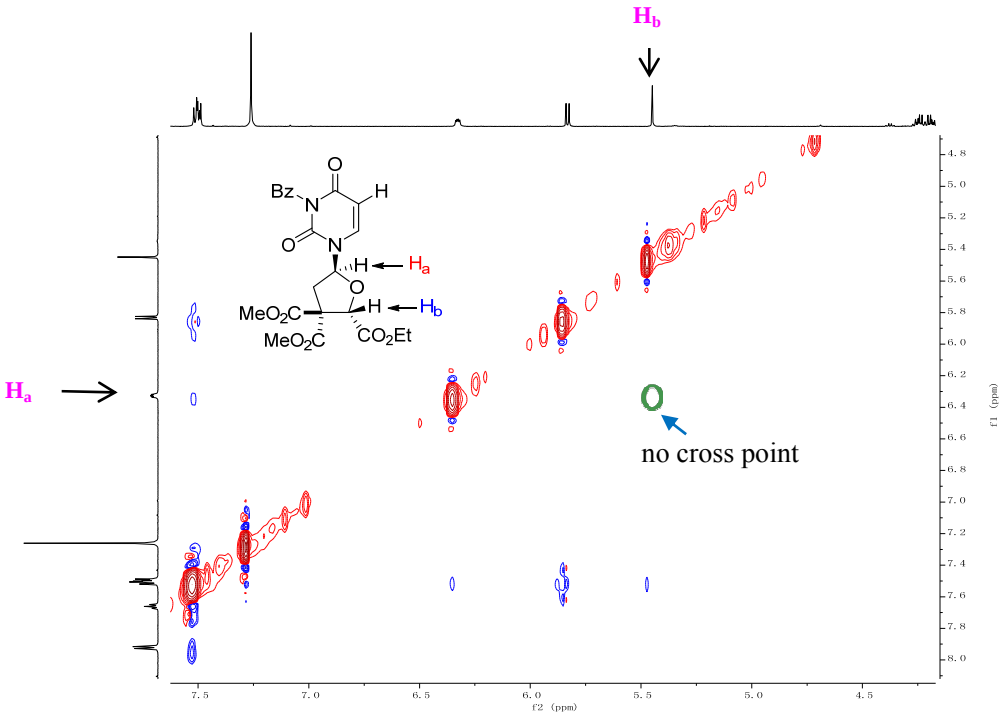
NOESY of **8ba**


Hb
Ha
{5.216,6.237}
Bz
MeO2C
MeO2C
CO2Et
f2 (ppm)
f1 (ppm)

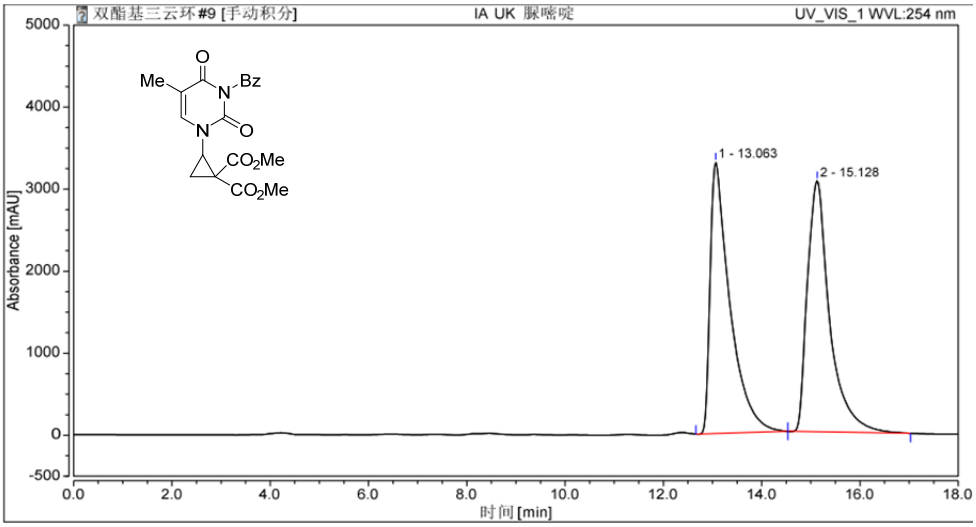

Hb
Ha
{5.216,6.237}
Bz
MeO2C
MeO2C
CO2Et
f2 (ppm)
f1 (ppm)

NOESY of **9ba**

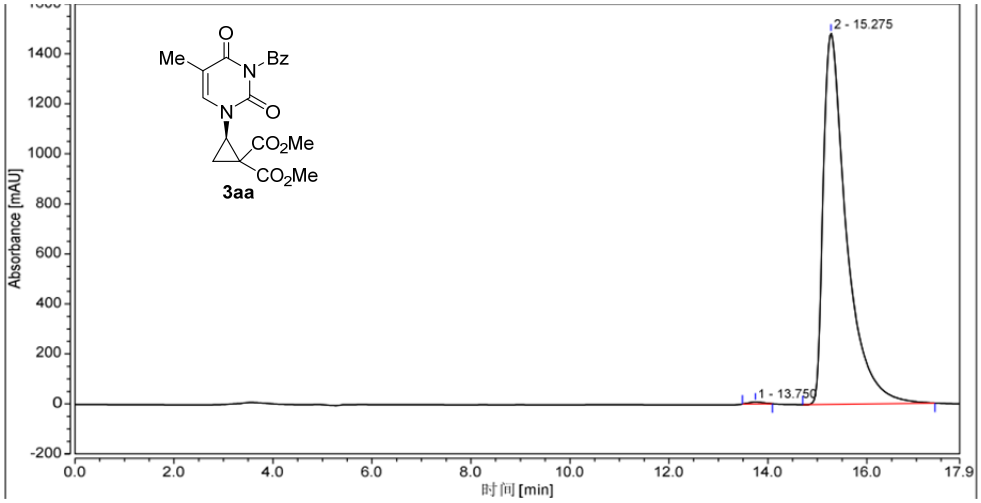

Hb
Ha
Bz
MeO2C
MeO2C
CO2Et
no cross point
f2 (ppm)
f1 (ppm)


Hb
Ha
Bz
MeO2C
MeO2C
CO2Et
no cross point
f2 (ppm)
f1 (ppm)

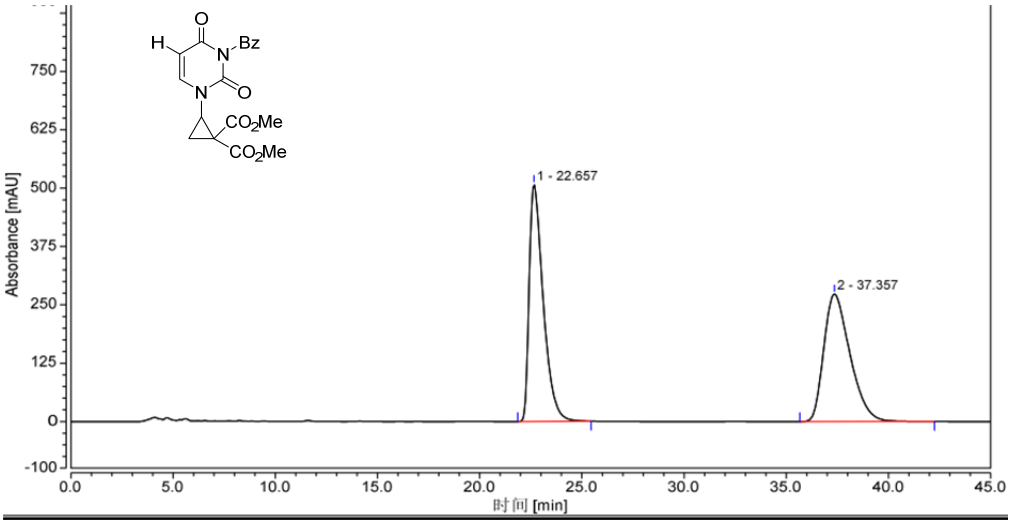
12. Copies of HPLC spectra for racemic and chiral compounds



Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	13.063	1538.139	3311.123	49.02
2	15.128	1599.614	3062.570	50.98
Total:		**3137.753**	**6373.693**	**100.00**

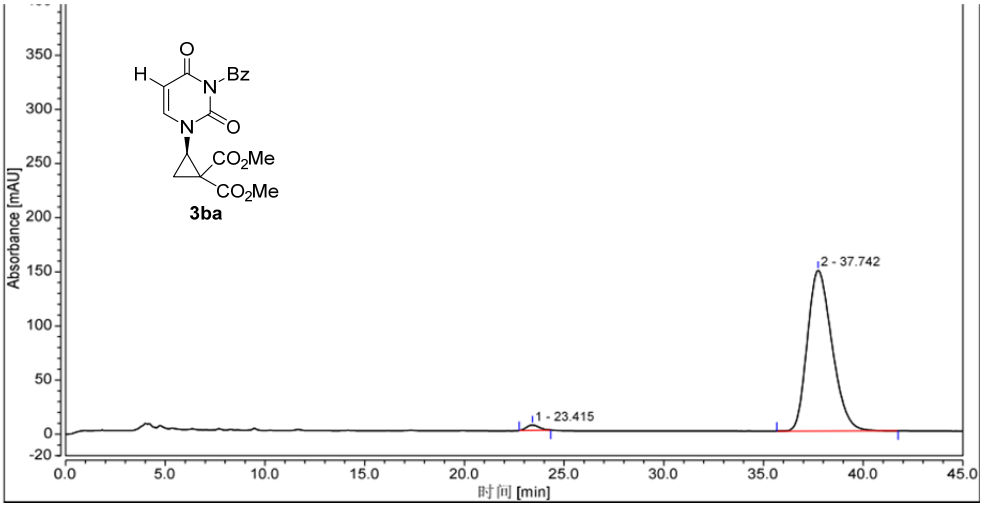


Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	13.750	2.708	7.688	0.33
2	15.275	806.982	1484.395	99.67
Total:		**809.690**	**1492.083**	**100.00**



积分结果

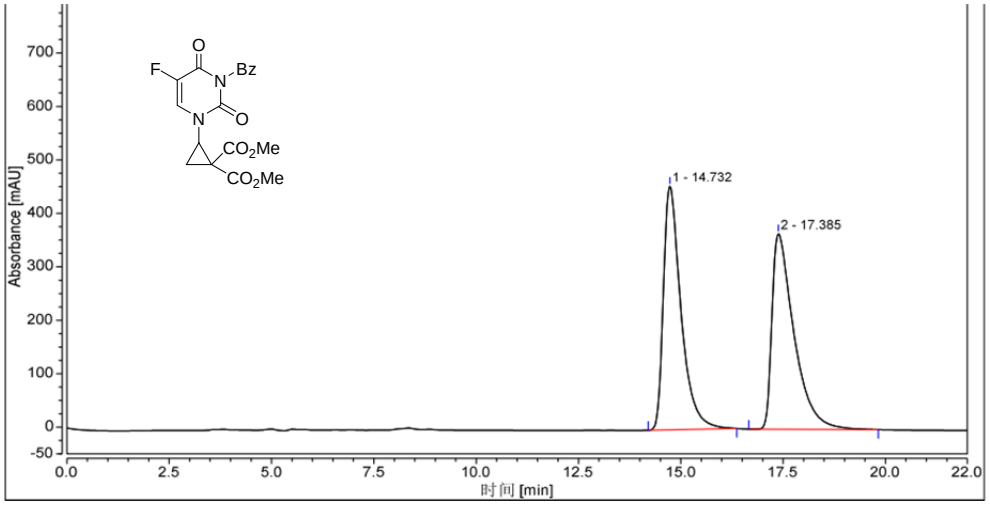
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	22.657	403.819	507.838	49.92	65.02
2	37.357	405.114	273.249	50.08	34.98
Total:		**808.932**	**781.087**	**100.00**	**100.00**



3ba

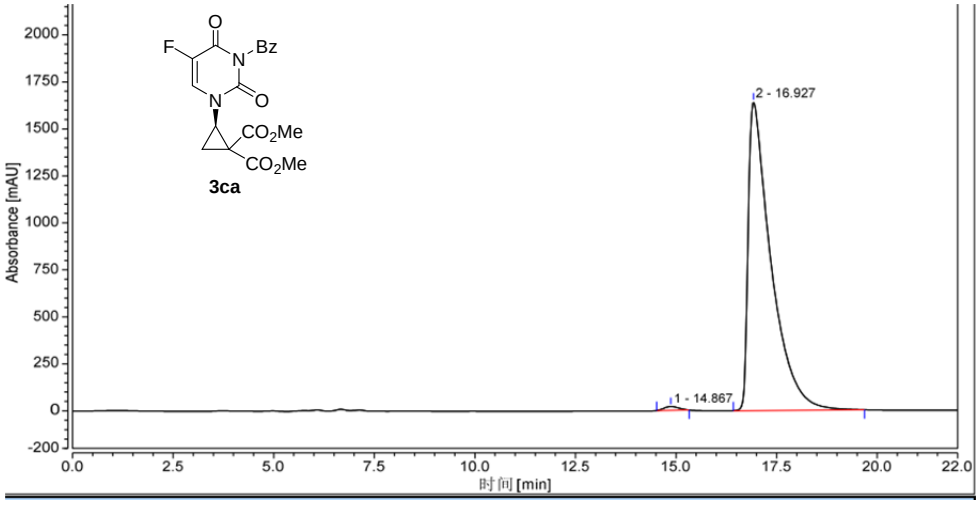
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	23.415	3.620	4.975	1.67	3.24
2	37.742	213.360	148.461	98.33	96.76
Total:		**216.980**	**153.436**	**100.00**	**100.00**



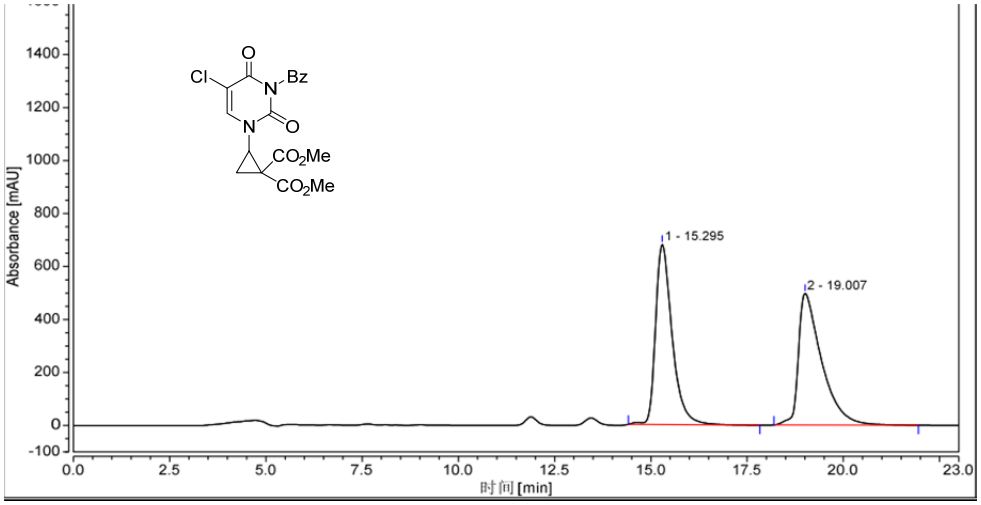
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	14.732	227.516	455.937	49.94	55.49
2	17.385	228.075	365.747	50.06	44.51
Total:		**455.591**	**821.684**	**100.00**	**100.00**



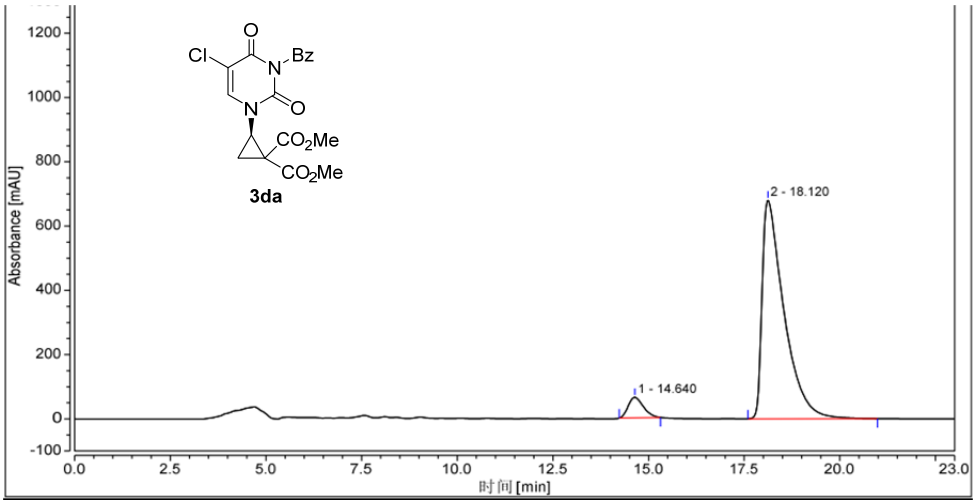
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	14.867	8.577	20.380	0.79	1.23
2	16.927	1075.603	1641.785	99.21	98.77
Total:		**1084.180**	**1662.164**	**100.00**	**100.00**



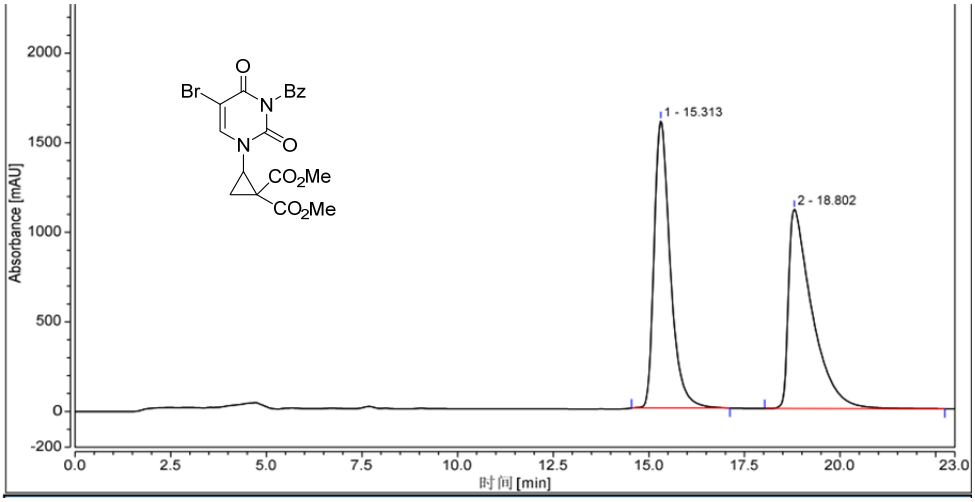
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	15.295	340.219	680.348	49.53	57.80
2	19.007	346.741	496.755	50.47	42.20
Total:		**686.960**	**1177.103**	**100.00**	**100.00**



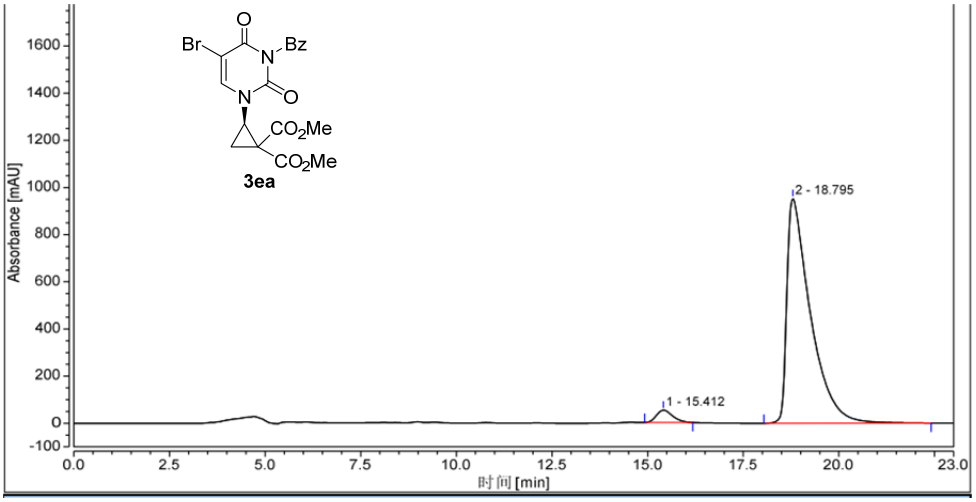
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	14.640	29.337	63.997	6.11	8.59
2	18.120	450.433	680.842	93.89	91.41
Total:		**479.770**	**744.839**	**100.00**	**100.00**



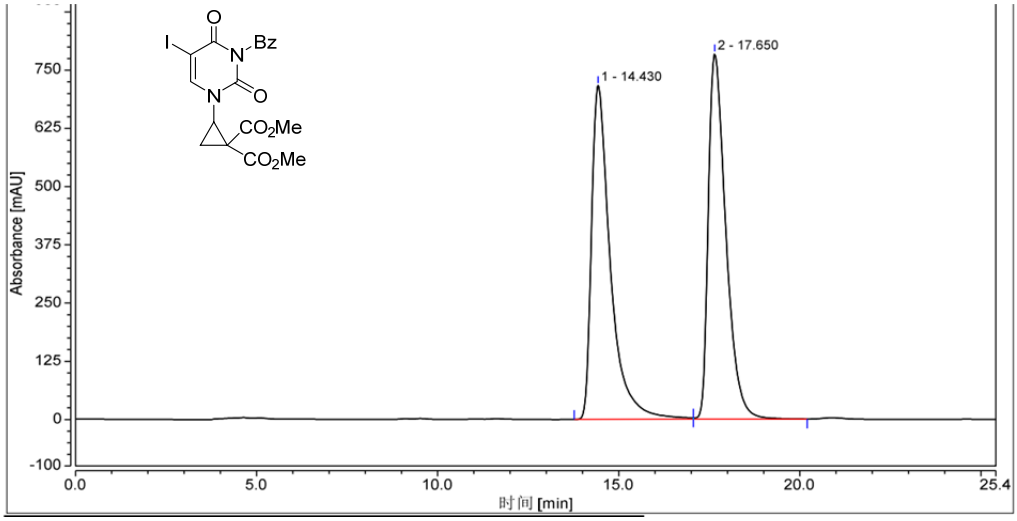
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	15.313	786.183	1604.487	49.64	59.05
2	18.802	797.450	1112.725	50.36	40.95
Total:		**1583.633**	**2717.212**	**100.00**	**100.00**

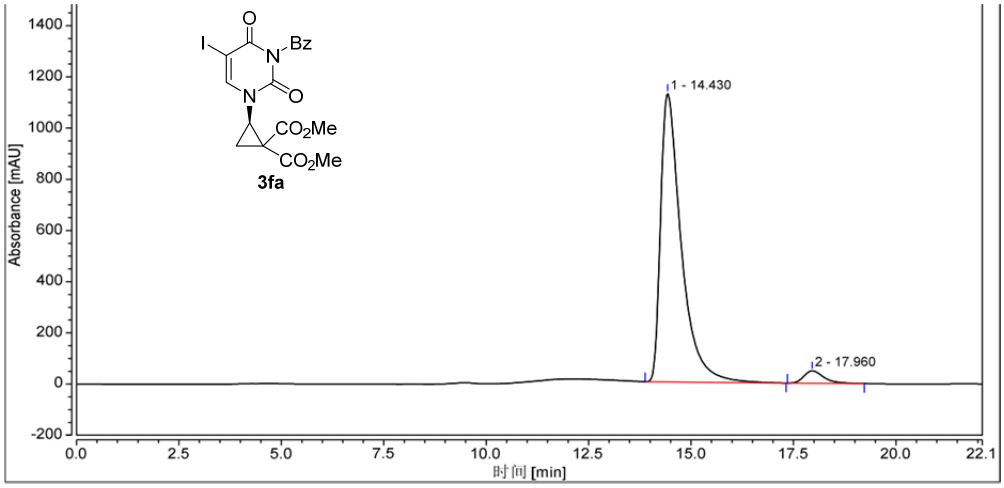


积分结果

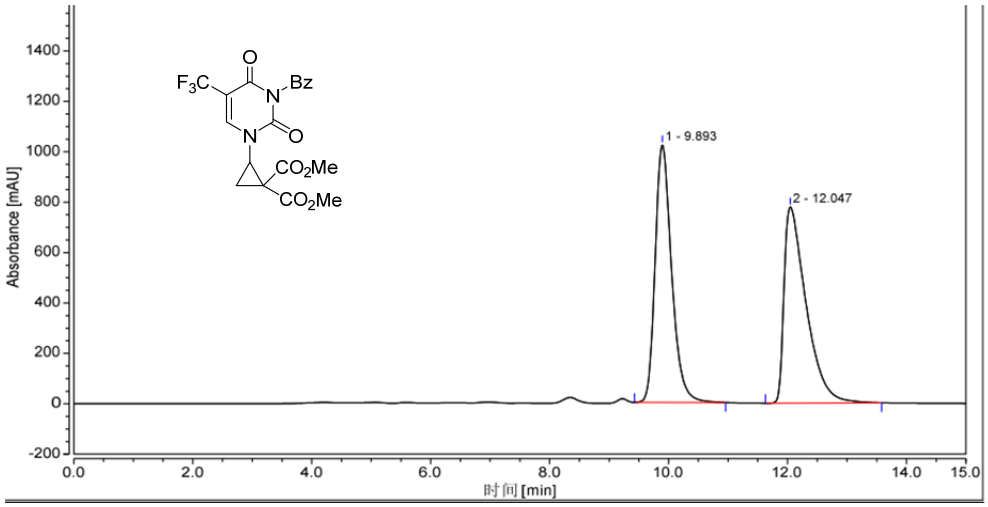
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	15.412	25.465	51.939	3.62	5.17
2	18.795	678.847	952.853	96.38	94.83
Total:		**704.313**	**1004.792**	**100.00**	**100.00**



Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	14.430	435.019	717.144	49.66
2	17.650	441.019	784.961	50.34
Total:		**876.037**	**1502.105**	**100.00**

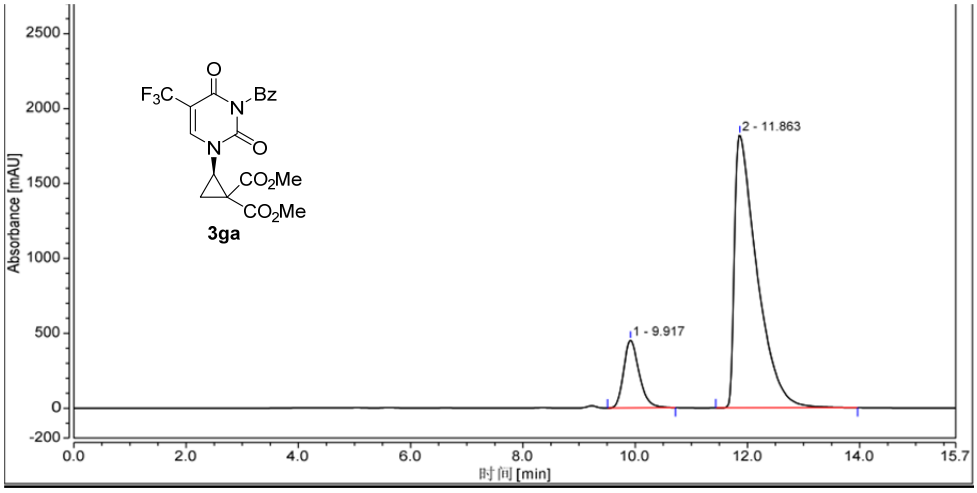


Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	14.430	659.951	1126.831	96.02
2	17.960	27.350	48.497	3.98
Total:		**687.300**	**1175.327**	**100.00**



积分结果

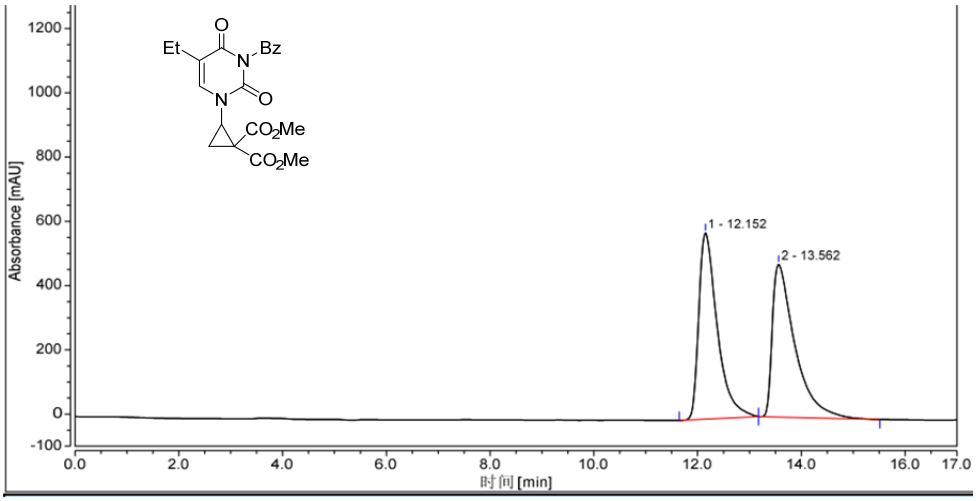
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	9.893	329.085	1024.217	49.66	56.80
2	12.047	333.599	779.099	50.34	43.20
Total:		**662.685**	**1803.316**	**100.00**	**100.00**



3ga

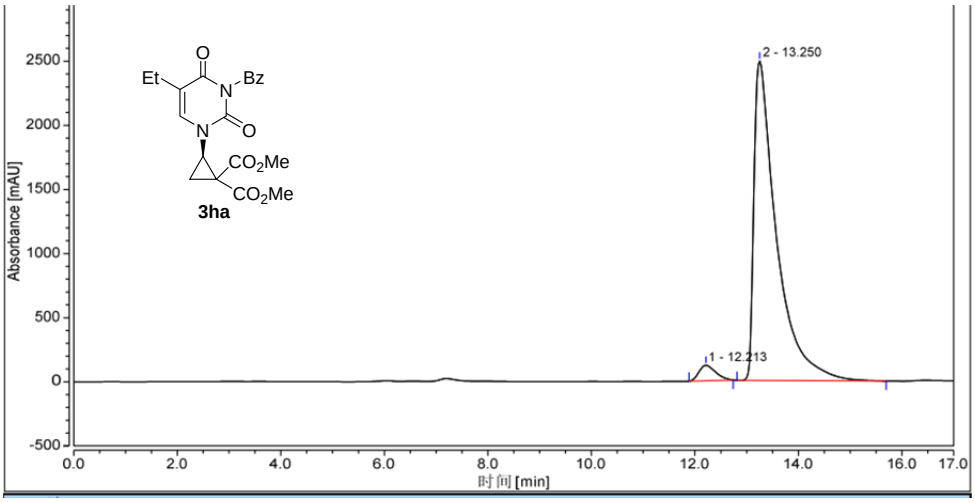
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	9.917	145.057	451.908	14.65	19.87
2	11.863	845.180	1822.261	85.35	80.13
Total:		**990.237**	**2274.169**	**100.00**	**100.00**



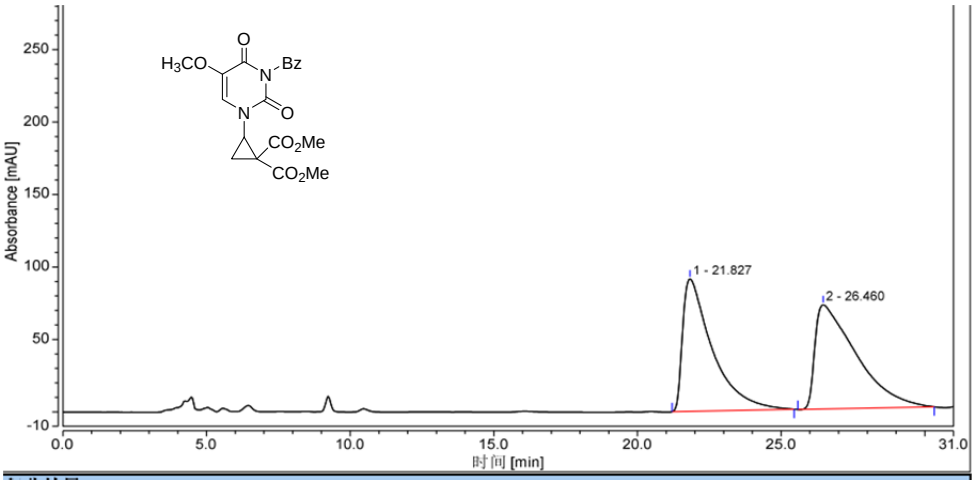
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	12.152	239.021	579.975	49.96	54.94
2	13.562	239.415	475.738	50.04	45.06
Total:		**478.435**	**1055.713**	**100.00**	**100.00**



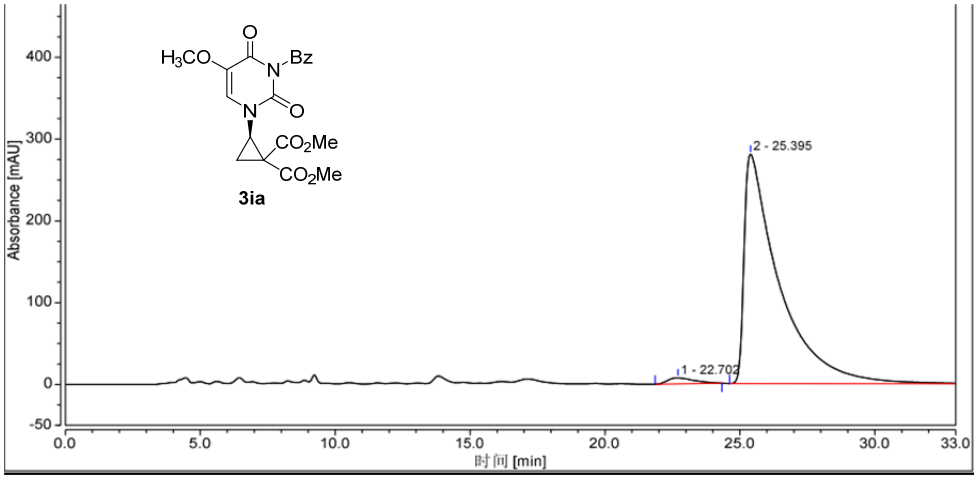
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	12.213	45.109	120.646	3.47	4.62
2	13.250	1255.451	2491.625	96.53	95.38
Total:		**1300.561**	**2612.271**	**100.00**	**100.00**



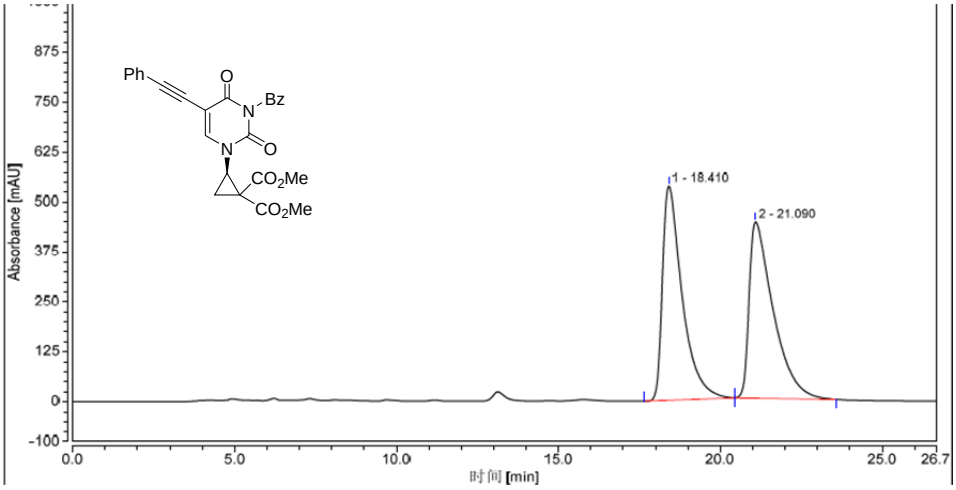
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	21.827	109.382	91.334	47.81	55.97
2	26.460	119.423	71.852	52.19	44.03
Total:		**228.805**	**163.186**	**100.00**	**100.00**

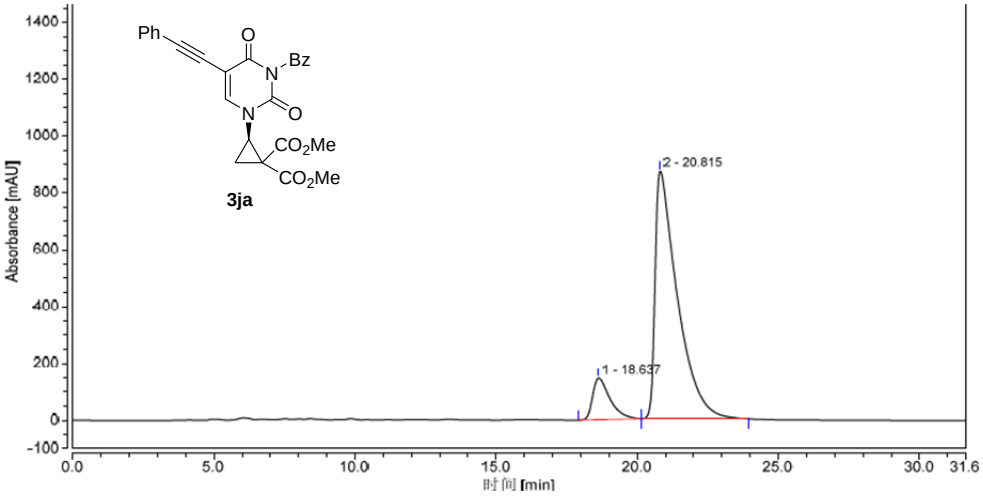


积分结果

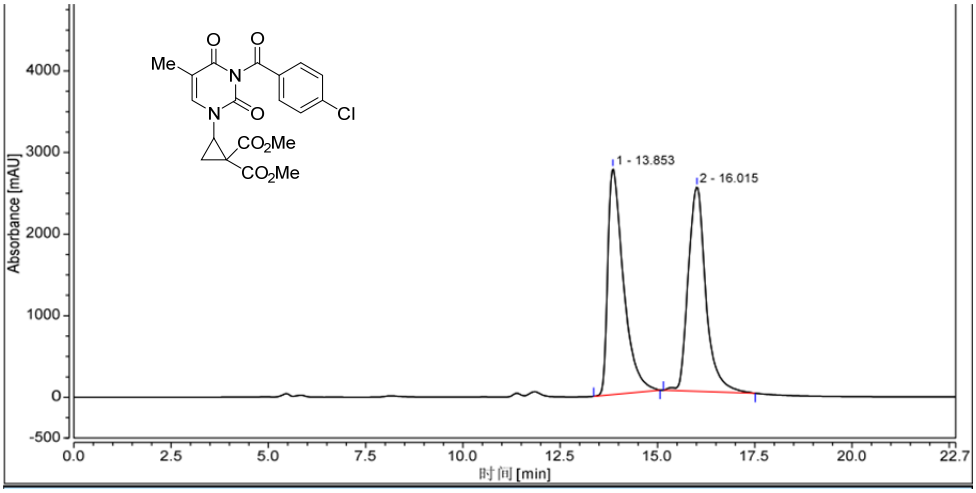
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	22.702	8.305	7.286	1.93	2.53
2	25.395	422.238	280.403	98.07	97.47
Total:		**430.543**	**287.688**	**100.00**	**100.00**



Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	18.410	378.335	536.992	49.89
2	21.090	379.987	441.841	50.11
Total:		758.321	978.832	100.00

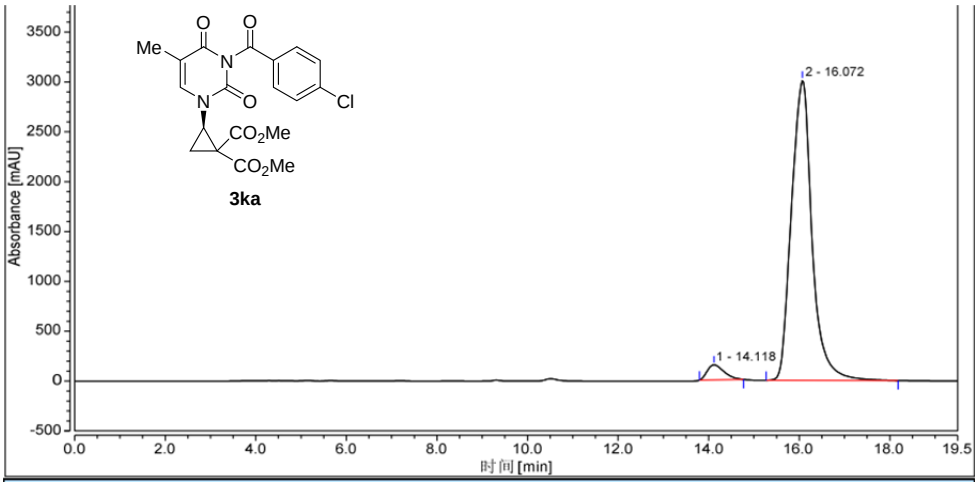


Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	18.637	104.134	146.513	11.61
2	20.815	792.921	872.726	88.39
Total:		897.055	1019.239	100.00



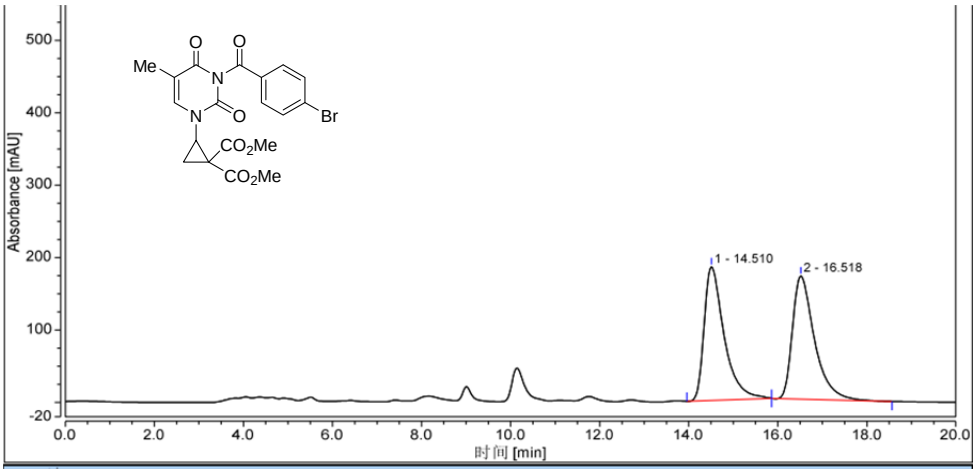
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	13.853	1297.769	2771.681	49.66	52.50
2	16.015	1315.384	2507.870	50.34	47.50
Total:		**2613.153**	**5279.550**	**100.00**	**100.00**



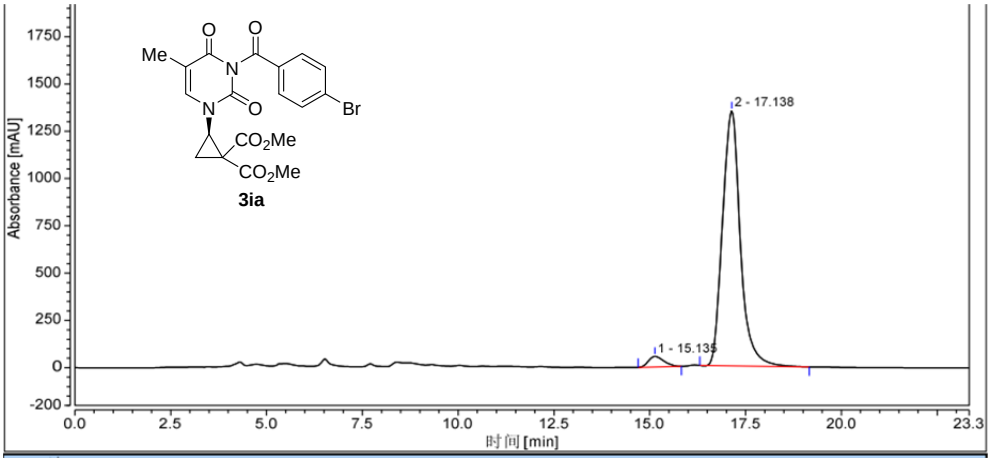
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	14.118	64.861	151.202	3.93	4.78
2	16.072	1586.573	3010.611	96.07	95.22
Total:		**1651.433**	**3161.813**	**100.00**	**100.00**



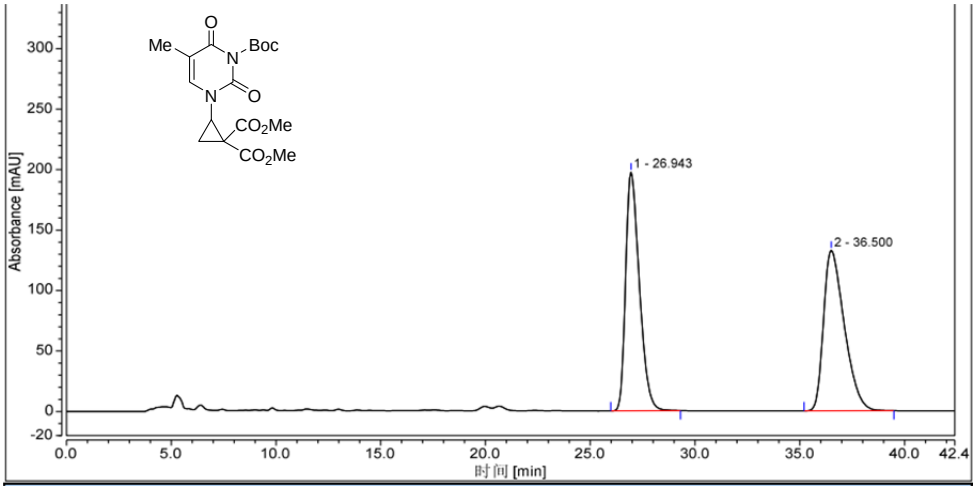
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	14.510	96.110	184.733	49.63	52.06
2	16.518	97.550	170.082	50.37	47.94
Total:		**193.660**	**354.815**	**100.00**	**100.00**

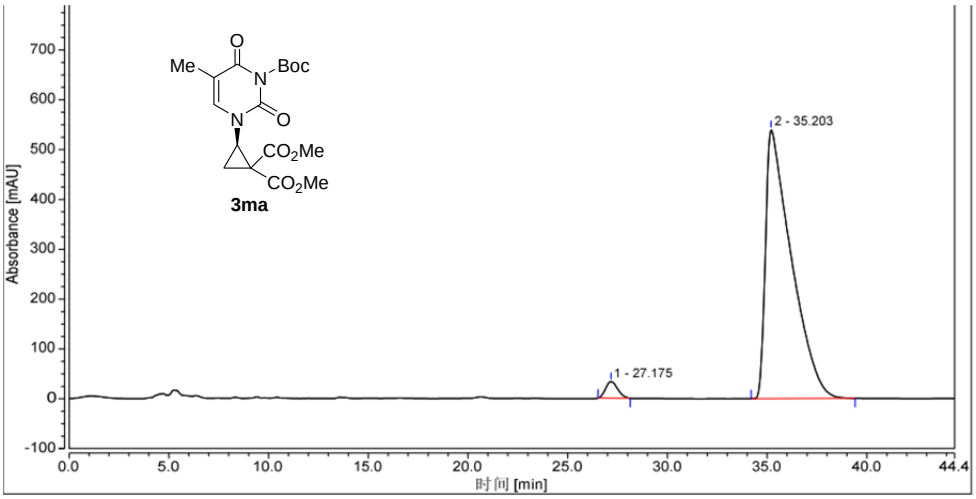


积分结果

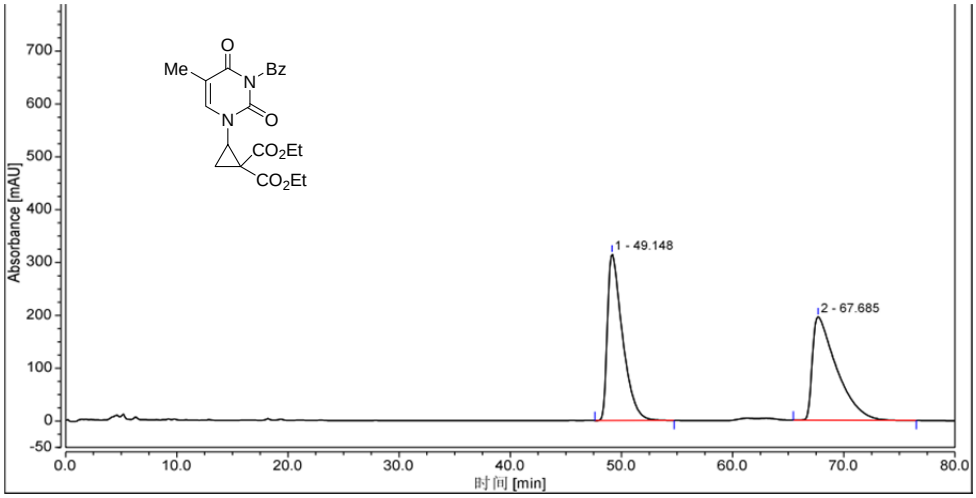
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	15.135	26.219	55.898	3.48	3.98
2	17.138	727.370	1348.598	96.52	96.02
Total:		**753.589**	**1404.496**	**100.00**	**100.00**



积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	26.943	150.197	197.396	49.61	59.78
2	36.500	152.587	132.781	50.39	40.22
Total:		**302.784**	**330.177**	**100.00**	**100.00**

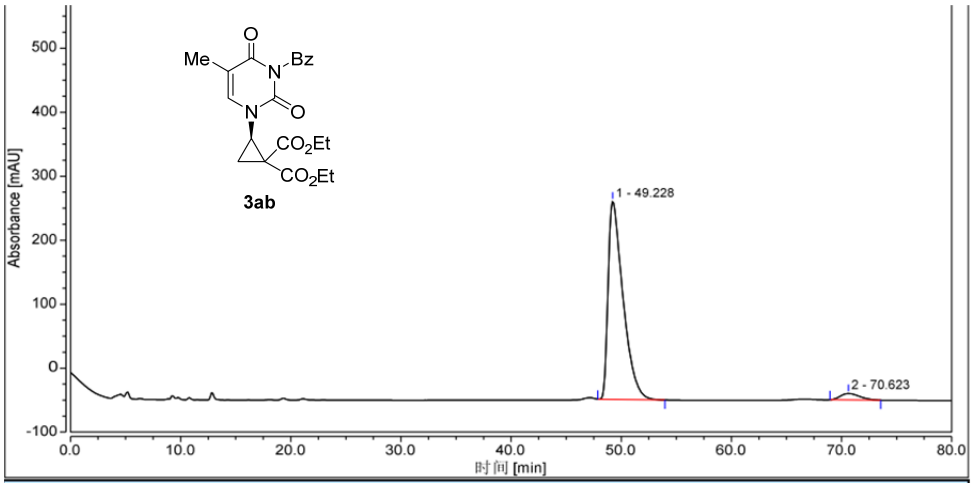


积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	27.175	23.380	33.313	2.81	5.81
2	35.203	809.520	539.615	97.19	94.19
Total:		**832.900**	**572.928**	**100.00**	**100.00**



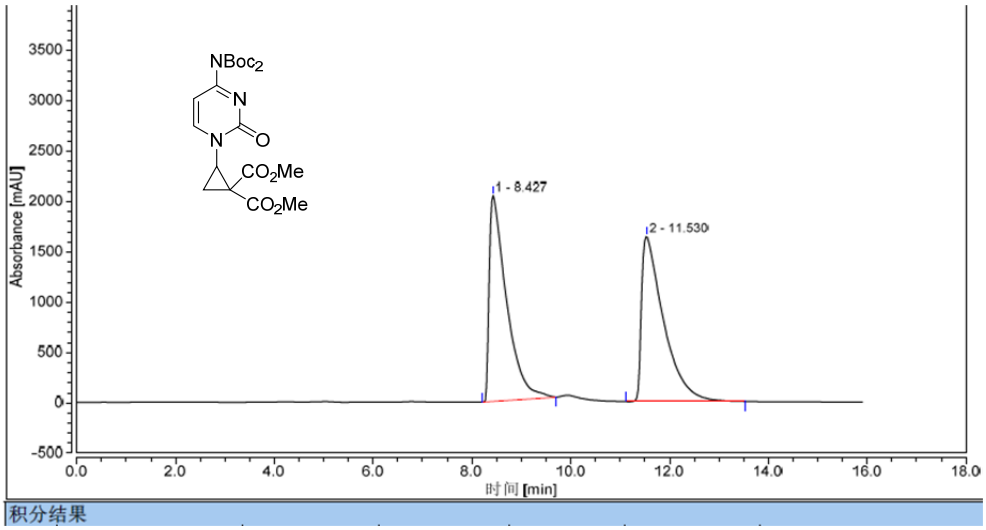
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	49.148	495.411	314.816	50.14	61.66
2	67.685	492.688	195.767	49.86	38.34
Total:		**988.099**	**510.583**	**100.00**	**100.00**



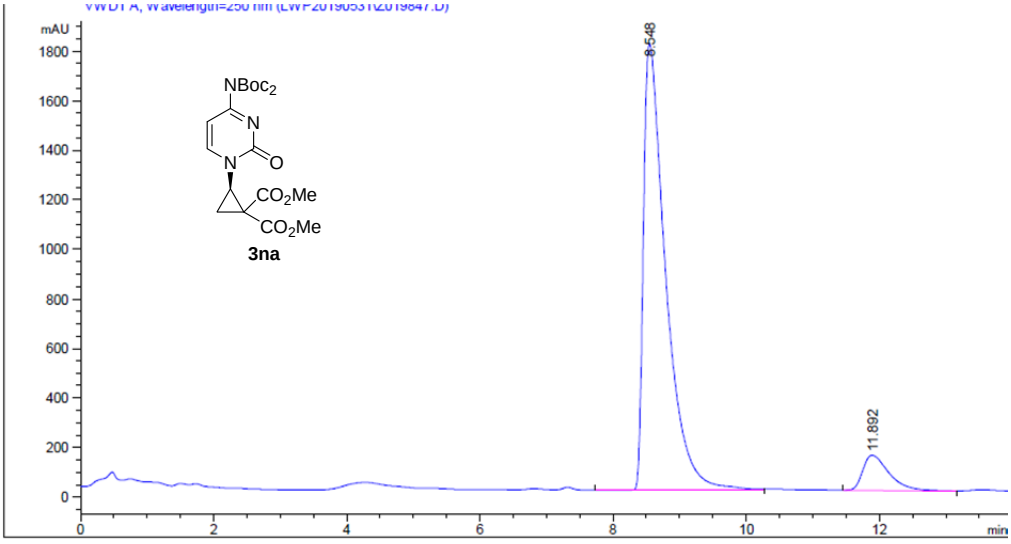
积分结果

Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	49.228	487.245	310.088	95.99	96.90
2	70.623	20.345	9.925	4.01	3.10
Total:		**507.590**	**320.013**	**100.00**	**100.00**

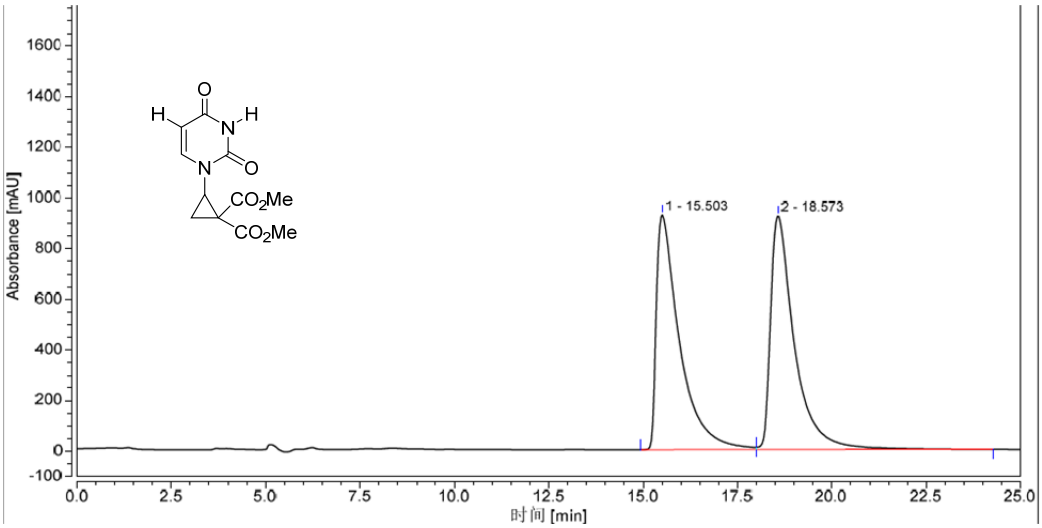


积分结果

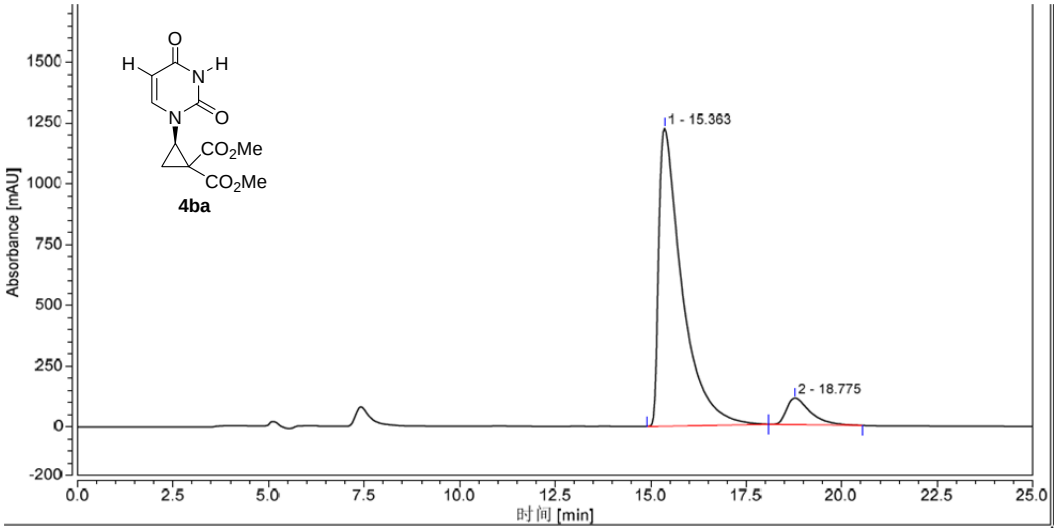
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	8.427	825.755	2046.410	49.36	55.49
2	11.530	847.337	1641.518	50.64	44.51
Total:		**1673.092**	**3687.928**	**100.00**	**100.00**



Peak #	RetTime [min]	Type	Width [min]	Area [mAU*s]	Height [mAU]	Area %
1	8.548	BV	0.3443	4.19123e4	1801.31018	91.5558
2	11.892	BB	0.4137	3865.56201	141.97562	8.4442

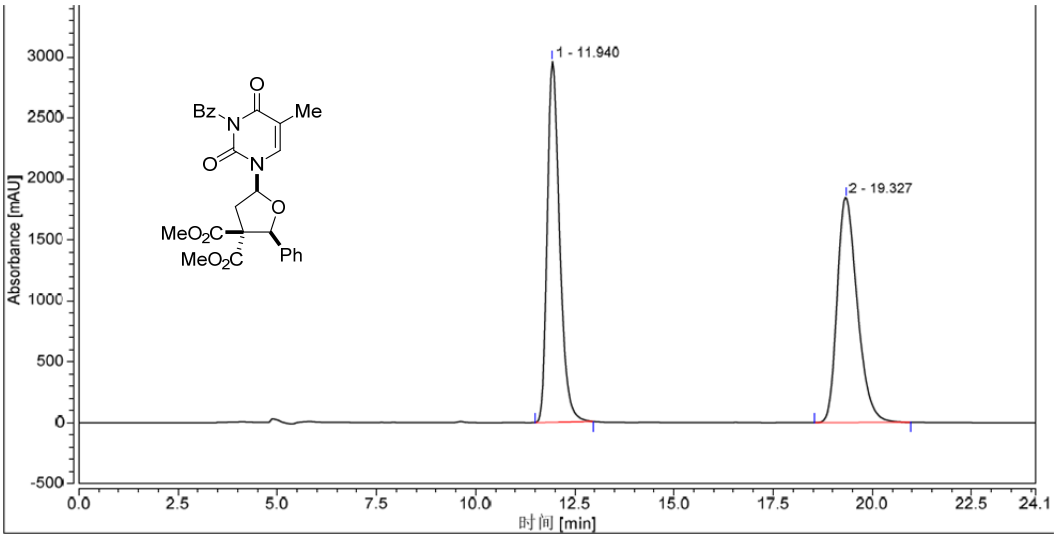


积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	15.503	659.219	927.243	49.42	50.10
2	18.573	674.726	923.509	50.58	49.90
Total:		**1333.945**	**1850.752**	**100.00**	**100.00**

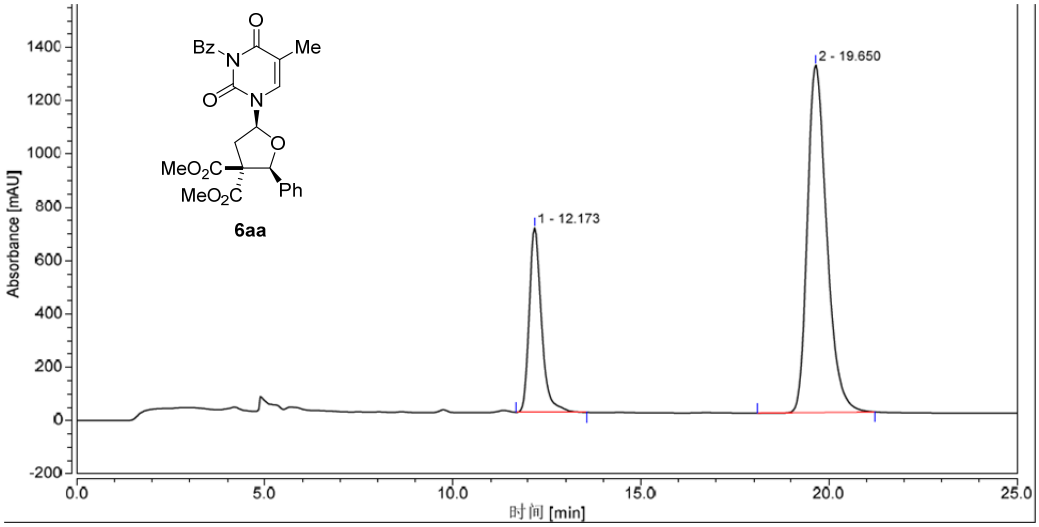


4ba

积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	15.363	865.488	1225.390	91.68	91.81
2	18.775	78.511	109.366	8.32	8.19
Total:		**943.998**	**1334.756**	**100.00**	**100.00**

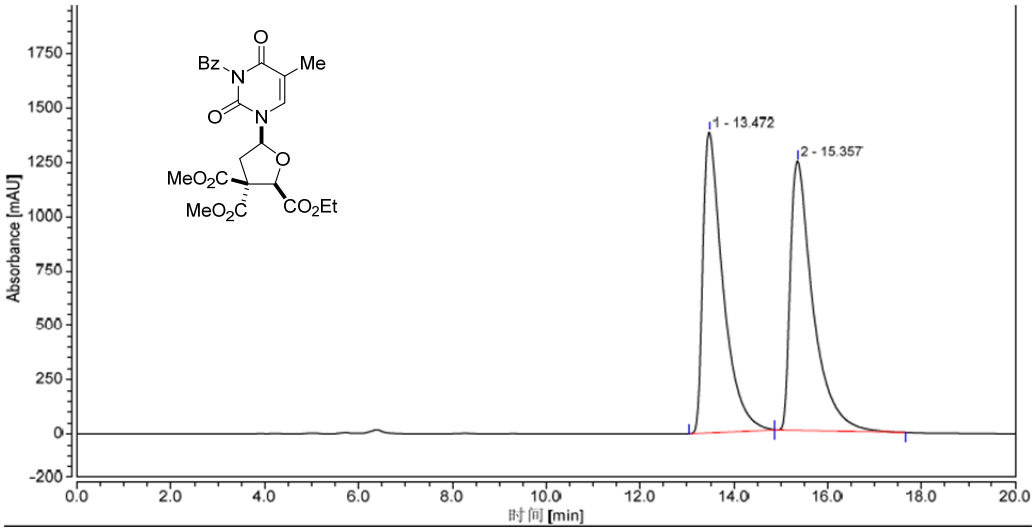


积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	11.940	1072.282	2961.281	49.61	61.57
2	19.327	1089.034	1848.484	50.39	38.43
Total:		**2161.316**	**4809.765**	**100.00**	**100.00**

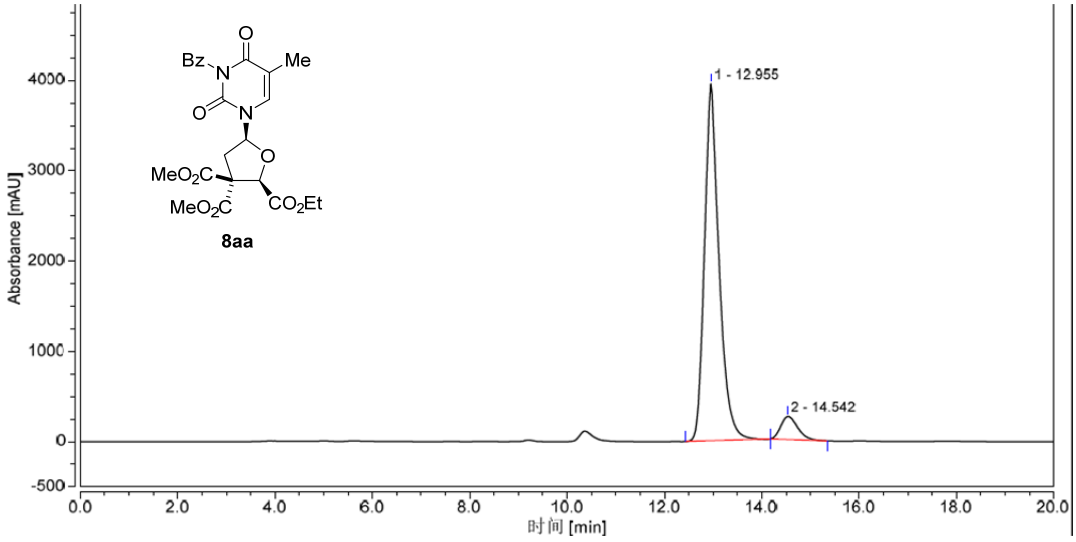


6aa

积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	12.173	262.802	692.747	25.24	34.68
2	19.650	778.402	1304.901	74.76	65.32
Total:		**1041.204**	**1997.648**	**100.00**	**100.00**

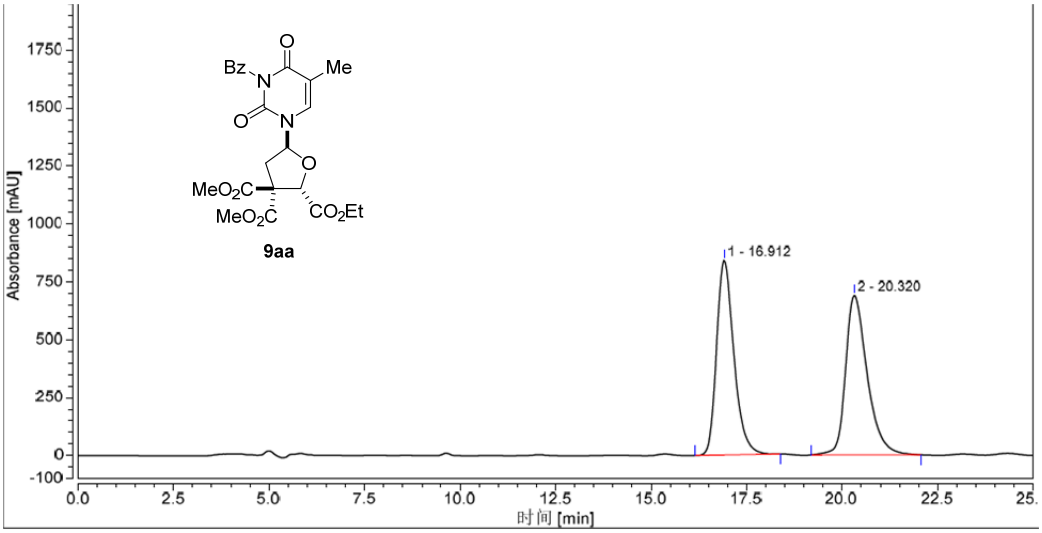


Peak	Retention Time min	Area mAU*min	Height mAU	Area %
1	13.472	690.022	1387.484	49.90
2	15.357	692.867	1241.544	50.10
Total:		**1382.889**	**2629.028**	**100.00**

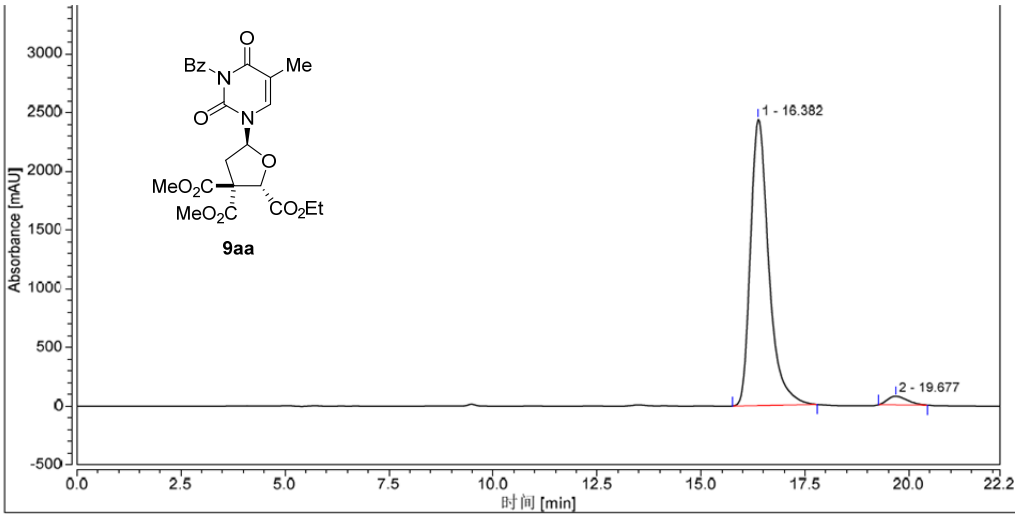


积分结果

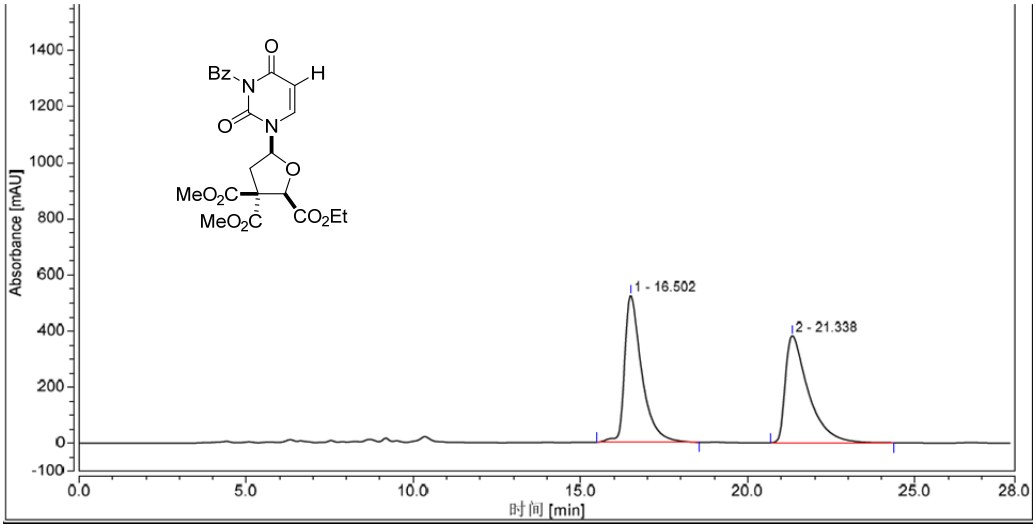
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	12.955	1364.342	3954.891	92.99	93.93
2	14.542	102.784	255.799	7.01	6.07
Total:		**1467.126**	**4210.690**	**100.00**	**100.00**



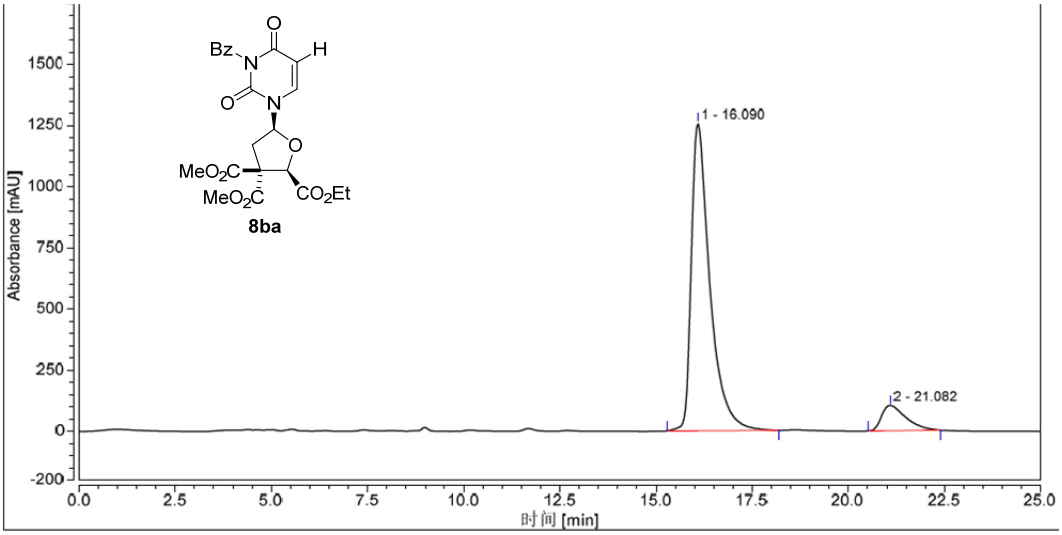
积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	16.912	441.432	840.775	49.41	54.95
2	20.320	452.041	689.362	50.59	45.05
Total:		**893.472**	**1530.137**	**100.00**	**100.00**



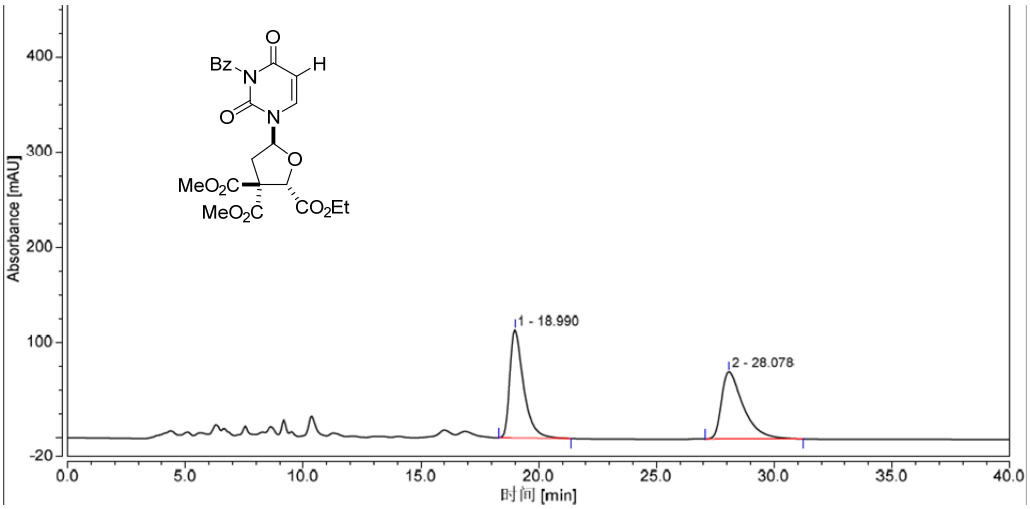
积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	16.382	1241.759	2439.181	96.82	97.05
2	19.677	40.766	74.150	3.18	2.95
Total:		**1282.524**	**2513.331**	**100.00**	**100.00**



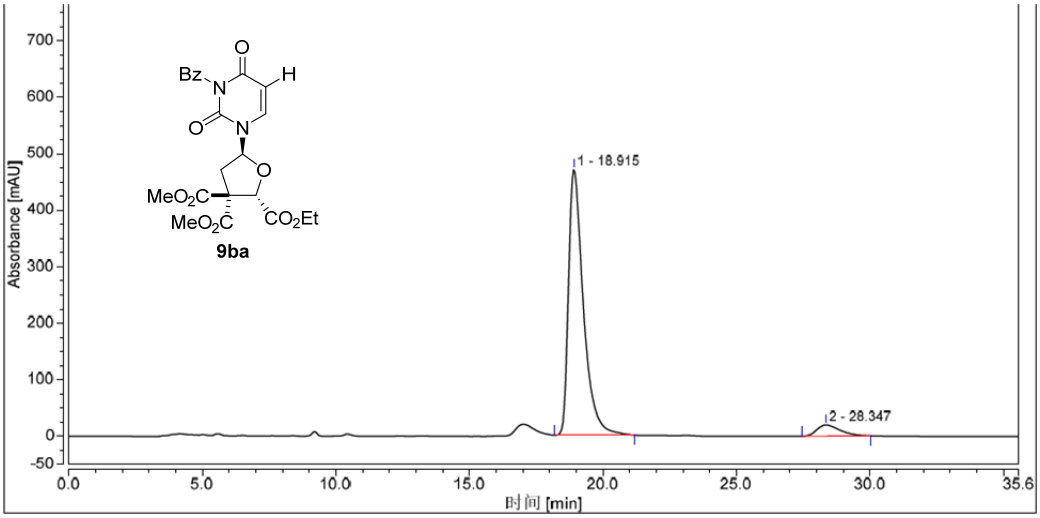
积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	16.502	312.294	523.870	50.56	57.82
2	21.338	305.379	382.208	49.44	42.18
Total:		**617.673**	**906.078**	**100.00**	**100.00**



积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	16.090	699.178	1256.002	90.27	92.39
2	21.082	75.405	103.460	9.73	7.61
Total:		**774.582**	**1359.463**	**100.00**	**100.00**



积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	18.990	77.582	113.739	50.71	61.71
2	28.078	75.402	70.582	49.29	38.29
Total:		**152.984**	**184.321**	**100.00**	**100.00**



积分结果					
Peak	Retention Time min	Area mAU*min	Height mAU	Area %	Height %
1	18.915	302.101	470.823	93.85	95.99
2	28.347	19.790	19.689	6.15	4.01
Total:		**321.892**	**490.513**	**100.00**	**100.00**